GROUNDWATER RESPONSE ACTION PLAN
LOCKHEED MARTIN MIDDLE RIVER COMPLEX

2323 Eastern Boulevard
Middle River, Maryland

LOCKHEED MARTIN

Tetra Tech
Environmental Engineers & Scientists
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Groundwater Response Action Plan
Lockheed Martin Middle River Complex
2323 Eastern Boulevard
Middle River, Maryland

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ACRONYMS

µg/L	micrograms per liter
AST	above ground storage tank
ARAR	Applicable or Relevant and Appropriate Requirement
ARD	anaerobic reductive dechlorination
ASTM	American Society for Testing and Materials International
AWQC	Ambient Water Quality Criterion
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAA	Clean Air Act
CAH	chlorinated aliphatic hydrocarbon
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	chemical of concern
COMAR	Code of Maryland Regulations
COPC	contaminant of potential concern
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
CWA	Clean Water Act
DHC	*Dehalococcoides*
DPT	direct push technology
EPA	United States Environmental Protection Agency
ESA	Environmental Site Assessment
ft/day	feet per day
g/d/ft	gallons per day per foot
GLM	Glenn L. Martin Company
gpm	gallons per minute
GRA	general response action
HHRA	human health risk assessment
K	Hydraulic conductivity
LUC	Land Use Control
MCL	Maximum Contaminant Level
MDE	Maryland Department of the Environment
MIP	membrane interface probe
MRAS	Middle River Aircraft Systems
MRC	Middle River Complex
MS2-LS&S	Maritime Systems & Sensors – Littoral Ships & Systems
MSDS	Material Safety Data Sheet
msl	mean sea level
MTBE	methyl tert-butyl ether
NAAQS	National Ambient Air Quality Standard
NCP	National Oil and Hazardous Substances Pollution Contingency Plan

ACRONYMS (Continued)

NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
OCP	Oil Control Program
OSHA	Occupational Safety and Health Administration
PCE	tetrachloroethene
POTW	Publicly Owned Treatment Works
PPE	personal protective equipment
PRG	preliminary remediation goal
RAO	response action objective
RAP	Response Action Plan
RCRA	Resource Conservation and Recovery Act
REC	Recognized Environmental Condition
RfD	Reference Dose
RME	reasonable maximum exposure
SSO	Site Safety Officer
TBC	To Be Considered
TCE	trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
TSDF	treatment, storage, and disposal facility
UIC	Underground Injection Control
USC	United States Code
UST	underground storage tank
VCP	Voluntary Cleanup Program
VOC	volatile organic compound
ZVI	zero valent iron

Section 1
Introduction

1.1 PURPOSE

On behalf of Lockheed Martin Corporation (Lockheed Martin), Tetra Tech, Inc. (Tetra Tech) has prepared this Response Action Plan (RAP) for groundwater at the Lockheed Martin Middle River Complex (MRC) located in Middle River, Maryland. The location of the MRC is shown on Figure 1-1. This RAP has been prepared in accordance with the requirements of the Maryland Department of the Environment's (MDE's) Voluntary Cleanup Program (VCP) (Section 7-508 of the Environment Article, Annotated Code of Maryland).

The purpose of the RAP is to provide the background, support, and framework for subsequent remediation of groundwater at MRC. The remedial actions and goals detailed in this RAP are conceptual and are based on current site data; they will be finalized based on the results of the additional investigations detailed in Section 3. Following this additional investigation, a RAP Addendum will be submitted. The RAP Addendum will specify cleanup goals, provide rationale for the remedial technologies chosen, and provide additional details on the application of those technologies at MRC.

A Certificate of Completion will be sought from the MDE following the satisfactory implementation and completion of the MDE-approved RAP.

1.2 SCOPE

The overall response action for MRC will address soil and groundwater with COC concentrations greater than cleanup goals. The groundwater response action presented in this RAP includes additional investigation, bench- and pilot-scale testing, and remediation of groundwater exceeding the cleanup goals established for the MRC. This Groundwater RAP is comprehensive for all tax blocks at MRC. The response actions for soil are described in separate Soil Response Action Plans provided under separate cover.

1.3 ORGANIZATION

The RAP is organized as follows:

- Section 1 – Introduction: Presents the purpose, scope and organization of the RAP.

- Section 2 – MRC Background: Presents a brief description of MRC and Site history, environmental investigations and results, nature and extent of contamination, and a summary of the proposed groundwater response action.

- Section 3 – Planned Additional Investigation: Presents a summary of additional Site investigations to be performed in support of the RAP.

- Section 4 – Exposure Assessment: Presents the current and proposed land use, media of concern, and Conceptual Site Model (CSM).

- Section 5 – Cleanup Criteria: Presents cleanup criteria, cleanup goals, and information associated with attainment of cleanup goals.

- Section 6 – Selected Technologies and Land Use Controls: Presents the screening of technologies and process options, development and analysis of alternatives, comparative analysis of alternatives, and the selected alternative to achieve cleanup of the site.

- Section 7 – Evaluation Criteria for the Selected Technology: Presents the criteria required for a Certificate of Completion.

- Section 8 – Proposed Response Actions: Presents the plan for all work necessary to perform the proposed response action.

- Section 9 – Permits, Notifications, and Contingencies: Presents local, State, and federal laws and regulations that prescribe the permits and approvals required to implement the MDE-approved RAP.

- Section 10 – Implementation Schedule: Presents the detailed schedule for all work necessary to implement the MDE-approved RAP.

- Section 11 – Administrative Requirements: Presents the administrative documents required to implement the MDE-approved RAP.

- Section 12 – References: Lists references and citations used in compiling this RAP.

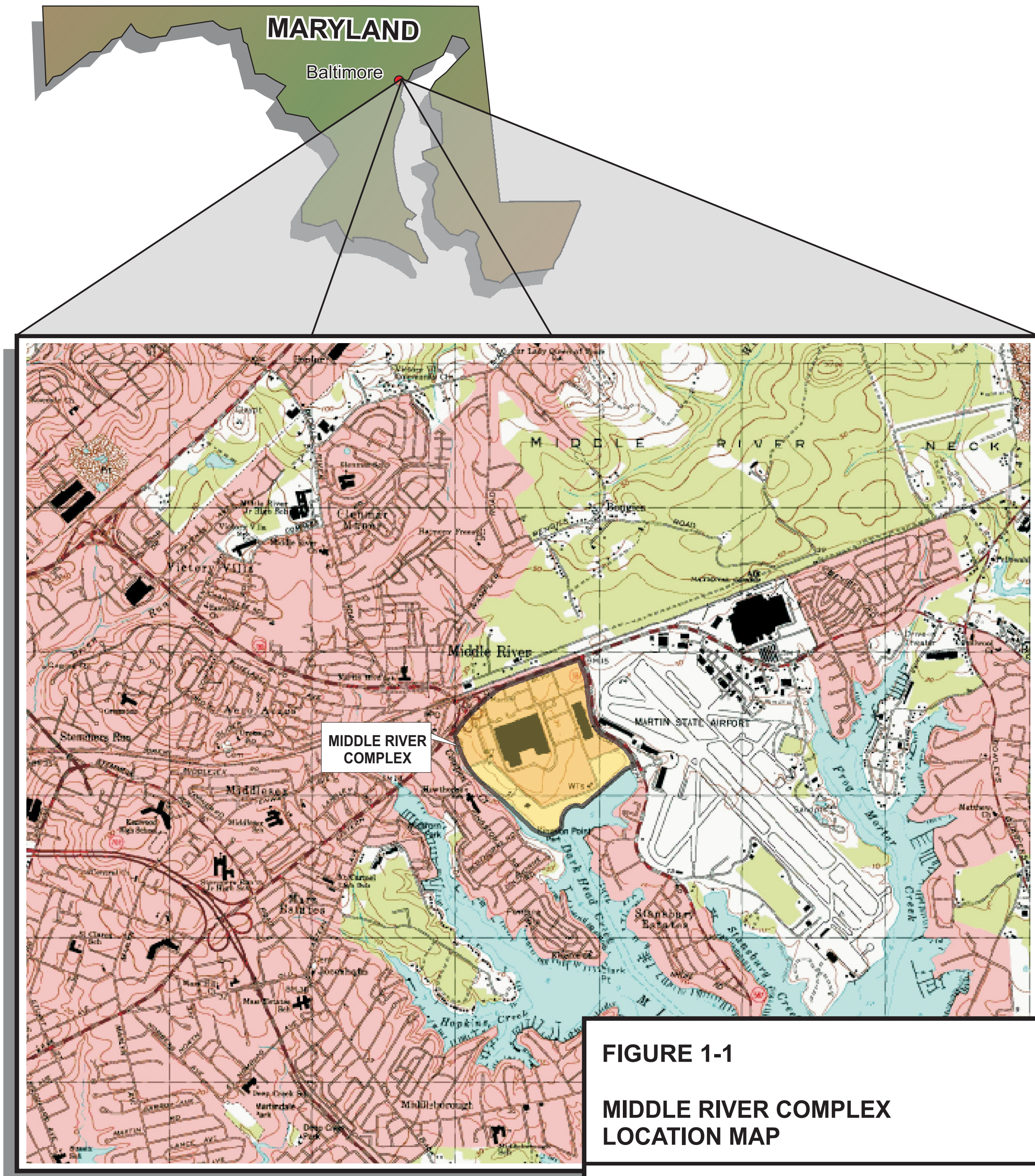

FIGURE 1-1

MIDDLE RIVER COMPLEX LOCATION MAP

Lockheed Martin Middle River Complex
Middle River, Maryland

NOT TO SCALE

N

DATE MODIFIED: 1/24/07

CREATED BY: J. F.

Tetra Tech, Inc.

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Section 2
MRC Overview

2.1 MRC BACKGROUND

The MRC, which is part of the Chesapeake Industrial Park, is located at 2323 Eastern Boulevard in Middle River, Maryland, approximately 11.5 miles northeast of downtown Baltimore. The MRC comprises approximately 161 acres including 12 main buildings, an active industrial area and yard, perimeter parking lots, an athletic field, a concrete-covered vacant lot, a trailer and parts storage lot, and numerous grass-covered green spaces along its perimeter. The MRC is bounded by Eastern Boulevard (Route 150) to the north, Dark Head Cove to the south, Cow Pen Creek to the west, and Martin State Airport to the east. The location of the MRC is shown on Figure 1-1. A MRC layout map is presented as Figure 2-1.

Currently, Lockheed Martin's primary activities at the MRC include facility and building management and maintenance. There are two main tenants at MRC: Middle River Aircraft Systems (MRAS), a subsidiary of General Electric, that conducts design, manufacturing, fabrication, testing, overhaul, repair, and maintenance of aeronautical structures, parts, and components for military and commercial applications; and Maritime Systems & Sensors – Littoral Ships & Systems (MS2-LS&S), a subsidiary of Lockheed Martin, that conducts fabrication, assembly, testing and support of vertical launch systems.

2.1.1 MRC History

In 1929, the Glenn L. Martin Company (GLM), a predecessor of Lockheed Martin, acquired a large parcel of land in Middle River, Maryland to conduct aircraft manufacturing for United States government and commercial clients. Prior to the acquisition, the MRC was reportedly undeveloped land. In the early 1960s, GLM merged with American-Marietta Company, forming

Martin Marietta Corporation. Around 1975, the adjacent western airport (Martin State Airport), totaling approximately 750 acres, was transferred to the State of Maryland. In the mid-1990s, Martin Marietta Corporation merged with Lockheed, forming Lockheed Martin Corporation, with its principal subsidiary specializing in construction and testing of new ordnance for United States Government and commercial clients. Shortly following the merger, General Electric acquired the majority of Lockheed Martin's aeronautical business in Middle River, which began to function as MRAS.

2.1.2 MRC Characteristics

2.1.2.1 Current and Surrounding Land Use

The MRC is an industrial facility, and the area surrounding the property primarily consists of commercial, industrial, and residential establishments. Six facilities, comprising the remaining portion of the Chesapeake Industrial Park, are adjacent to MRC. These facilities include Tilley Chemical Company, Inc., a food and pharmaceutical chemical distributor for personal care and industries; North American Electric, Inc., an industrial and commercial electrical contractor; Johnson and Towers, a heavy duty automotive and boat repair and maintenance company; Poly-Seal Corp., a company that produces flexible packaging; Exxon, a gasoline fill station and convenience store; and the Middle River Post Office. Residential developments are present on the opposite shores of Cow Pen Creek, Dark Head Cove, and Dark Head Creek and north of Eastern Boulevard (Route 150).

2.1.2.2 Physiography

The MRC is located within the Western Shore of the Coastal Plain Physiographic Province, which is generally characterized by low relief. The topography of the MRC is gently sloping, ranging from sea level to 32 feet above mean sea level (msl) (Cassell, July 1977). The topography slopes from Eastern Boulevard to the southwest and south towards Cow Pen Creek and Dark Head Cove.

2.1.2.3 Hydrology

The MRC is located at the junction of Cow Pen Creek and Dark Head Cove. Both surface water bodies discharge into Dark Head Creek, a tributary to Middle River, which is a tributary to Chesapeake Bay. The MRC is approximately 3.24 miles (17,100 feet) upstream of Chesapeake Bay.

No surface water bodies are present within the MRC. Excluding areas immediately adjacent to Cow Pen Creek and Dark Head Creek, surface water runoff discharges from the facility via storm drains. Lockheed Martin maintains a State of Maryland National Pollution Discharge Elimination System (NPDES) permit (State Discharge Permit No.: 00-DP-0298, NPDES No.: MD0002852), issued by MDE Industrial Discharge Permits Division, Water Management Administration. The permit covers stormwater discharge from the entire property rather than individual tenants.

2.1.2.4 Soils

Soils underlying MRC have been mapped as Mattapex-Urban Land Complex and Sassafras-Urban Land Complex by the United States Department of Agriculture Soil Conservation Service. Mattapex-Urban Land soils consist of deep, well-drained silty soils whose original texture has been disturbed, graded over, or otherwise altered. Sassafras-Urban Land soils consist of deep, well-drained sandy soils whose original texture has been disturbed, graded over, or otherwise altered. Site characterization studies indicate that fine-grained (e.g., silt and clay) soils with low permeabilities make up the majority of soils at the MRC.

2.1.2.5 Regional Geology

Based on geologic mapping of Baltimore County, the MRC is underlain by the Potomac Group, a Cretaceous-age interbedded gravel, sand, silt, and clay unit ranging in thickness from 0 to 800 feet. The Potomac Group is composed of three units: the Raritan and Patapsco Formations, the Arundel Clay, and the Patuxent Formation. The Raritan and Patapsco Formations range up to 400 feet thick and are composed of a gray, brown, and red variegated silt and clay unit with lenses of sand and few gravels. The Arundel Clay is composed of dark gray and maroon lignitic clays and ranges in thickness from 25 to 200 feet. The Patuxent Formation is described as a white or light gray to orange brown, moderately sorted sand unit with quartz gravels, silts, and clays and ranges up to 250 feet in thickness.

Lithologic logging of the soils beneath the MRC identified a very heterogeneous stratigraphy. The underlying soils are composed primarily of silty sands, fine-grained to medium-grained sands, silty clays, clayey silts, and plastic clay, with the primary lithology being clay to silty clay. Areas along the waterfront have historically been back-filled to their present elevation. Soils obtained from fill areas were similar in appearance and composition to soils considered to be native to the MRC.

2.1.2.6 Regional Hydrogeology

Sand and gravel zones within the unconsolidated surficial deposits, when present, may form an unconfined or water table aquifer system (Bennett and Meyer, 1952). The water table at MRC generally conforms to the shape of the land surface, with the highest water levels in the interior land areas and the lowest levels at approximately the surface water elevations along the shoreline.

The Patuxent Formation is the most important water-bearing formation in the Baltimore area. Industrial wells in the southeastern part of the area, specifically Curtis Bay and Sparrows Point, yield from 500 to 900 gallons per minute (gpm). Transmissivities and coefficients of storage in confined portions of the aquifer in these industrialized areas average about 50,000 gallons per day per foot (g/d/ft) and 0.00026, respectively. The Patapsco Formation is also an important water-bearing formation in industrialized Baltimore, where it is separated by clay into a lower and an upper aquifer. The lower aquifer yields as much as 500 to 750 gpm to industrial wells, and a transmissivity of 25,000 g/d/ft has been estimated. The upper aquifer yields quantities of water similar to industrial wells, and because it has a greater thickness than the lower aquifer, it likely has a higher overall transmissivity.

2.2 PREVIOUS INVESTIGATIONS

This section summarizes previous groundwater investigations at the MRC, primarily the 2005 Site-Wide Groundwater Investigation.

2.2.1 Chromium Investigation

In August 1988, a groundwater investigation was conducted to evaluate the presence of chromium immediately west of Building A (Earth Engineering and Science, Inc., 1988). A total of six borings were completed. Four of the borings (designated as B-2 and B-4 through B-6) were completed to 20 feet below ground surface (bgs), and the remaining two borings, B-1 and B-3, were completed to 35 feet and 29 feet bgs, respectively, using a mobile hollow stem auger drill rig. Groundwater was encountered at an average depth of 8 feet bgs. Three of the borings were completed only to obtain a groundwater grab sample. The remaining three borings (B-2, B-5, and B-6) were converted into groundwater monitoring wells screened from 10 to 20 feet bgs. Hexavalent chromium was detected at 160 micrograms per liter (µg/L) in boring B-2, and 10 µg/L of hexavalent chromium in borings B-5 and B-6. B-2 was located between Building A and the D.I. building. No analytical results for B-1, B-3, and B-4 were presented in the report. These wells are no longer present at the site.

2.2.2 2003 Phase I Environmental Site Assessment

A Phase I Environmental Site Assessment (ESA) was conducted on the MRC in accordance with American Society for Testing and Materials (ASTM) Standard E 1527 in February 2003. The goal of Phase I was to identify Recognized Environmental Conditions (RECs), meaning the presence or likely presence of any hazardous substances or petroleum products on a property under conditions that indicate the potential for an existing release, a past release, or a material threat of a release of any hazardous substances or petroleum products into structures on the property or into the ground, groundwater, or surface water of the property. Phase I consisted of a historical review of the MRC (i.e., a review of available facility documents, aerial photographs, and city directories), a review of federal, State, and local agency databases, interviews with site personnel, and a site visit.

The Phase I ESA identified 13 RECs associated with the MRC and recommended further investigation of the facility's historical site activities to identify other potential environmental concerns.

2.2.3 2005 Site-Wide Groundwater Investigation

This section presents the results of the site-wide groundwater investigation and groundwater human health risk assessment (HHRA) at MRC. The groundwater investigation consisted of advancing soil borings, installing shallow, intermediate, and deep wells, conducting aquifer hydraulic testing, and analyzing groundwater samples to characterize the subsurface geology, hydrogeology, and groundwater quality at the MRC. An HHRA was conducted to determine potential receptor exposure pathways, to identify contaminants of potential concern (COPCs), and to evaluate potential unacceptable risks to individuals from exposures to hazardous chemicals under hypothetical groundwater use scenarios. Also in this section, the distributions and fate and transport of the COPCs are discussed.

2.2.3.1 MRC Geology

Lithology data collected as part of the groundwater investigation were used to construct geologic cross-sections (Tetra Tech, May 2006). The locations of the groundwater monitoring wells and cross-sections are shown on Figure 2-2, and Figures 2-3 through 2-6 present longitudinal and transverse geologic cross-sections in generally north-south and east-west directions. Cross-sections A-A' and D-D' (Figures 2-3 and 2-6) are also located along the longitudinal axes of the two most significant chlorinated solvent plumes identified at the MRC. Overall, the results of the groundwater investigation indicated complex arrangements of predominantly clay, silty clay, silt, and clayey silt, with smaller, more permeable zones of silty sand and sand.

Thick sequences of low-permeability clay, silty clay, clayey silt and silt are present in the northern two-thirds of the MRC. As shown on Figure 2-3, these clayey and silty materials extend from well MW02 to the area between wells MW48 and MW27. In the northern portion of the site, clay was encountered in the first 20 feet at well MW02 and thickened to over 30 feet to the south at well MW57 near Building C. In the area between wells MW02 and MW48, clay, clayey silt, and silt extend 80 to 95 feet bgs to elevations of -50 to -70 feet above msl. A review of boring logs indicates that this thick upper, zone of clayey material terminates to the south along an east-west line roughly formed by wells MW48, MW21/MW58, and MW11. Two 10-foot-thick silty sand units were reported for MW02 at elevations of -10 feet to -40 feet above msl. However, these sandy units do not appear to be contiguous with sandy units observed farther to the south.

Interbedded sands, silty sands, sandy silts, and silts were encountered south of Buildings A, B, and C. As shown in Figure 2-3, several feet of sandy and silty materials were encountered overlying the shallow clay at wells MW05, MW37, and MW55. These sandy and silty materials thicken to the south/southeast in the area of wells MW57, MW48, MW27, and MW37. The sandy materials are approximately 15 to 70 feet thick in the area from well MW48 to well MW37 near Cow Pen Creek and overlie a lower clay confining unit present at -55 to -62 feet above msl.

Figure 2-4 is a geologic cross-section of the southwestern portion of the MRC from the former Vibration Test Building near Cow Pen Creek to Building B. As shown in the cross-section, silty sands and sandy silts were encountered in the upper several feet in the area of wells MW12 to MW56 to the northeast. Silty sand and sandy silt were also encountered southwest of MW58 at elevations ranging from +5 to -12 feet above msl and southwest of MW21 with a top surface elevation of -45 feet above msl. As shown on Figures 2-5 and 2-6, clay extends to the ground surface to the north (well MW10), and the upper sandy unit is limited to areas east of wells MW15 (Figure 2-5) and MW07 (Figure 2-6). At well MW10, the shallow sand is absent near Cow Pen Creek.

The materials described above are underlain by the Arundel Formation, a regionally extensive, thick, dense clay confining unit. It is a massive, impermeable unit that underlies the MRC and surrounding area. The Arundel Formation outcrops northwest of the MRC and dips and thickens to the southeast. The Arundel Formation has been mapped as far east as Cambridge, Maryland and has been reported to be over 600 feet thick in that area. The Arundel Formation is expected to be 50 to 125 feet thick below the MRC (Vroblesky and Fleck, 1991; Chapelle, 1985).

2.2.3.2 MRC Hydrogeology

As shown on Figures 2-3 through 2-6, groundwater was encountered at depths ranging from less than 1 foot to nearly 18 feet bgs. In the area of the site around MW21, MW55, MW57, MW58, and MW59, the groundwater may be perched. In the northern portion of the MRC, groundwater is present in silts, clays, and sand lenses in the subsurface. Low permeability clays and silty clays overlie and underlie the more permeable silty or sandy zones or lenses. In these areas, recharge from precipitation is expected to be low, and groundwater is under hydraulically confined conditions. Because the subsurface is primarily composed of silts and clays, groundwater velocity is relatively low.

To the southeast, groundwater preferentially flows to the southeast within sandy strata, which extend from MW57 to the thicker sandy material at wells MW27 and MW37. Approximately 65 to 70 feet of saturated sandy material is present above the lower confining clay in this area. Groundwater is expected to be under hydraulically unconfined or partially confined conditions because of the absence of an overlying hydraulic clay barrier in most areas. Locally where clay is at the surface, confined conditions may exist. The lower portion of the aquifer in the area of wells MW34 and MW37 is divided by silt and silty clay located at -20 to -30 feet above msl. In this area, deeper groundwater may be under hydraulically confined conditions.

To the southwest (Figure 2-4), shallow groundwater flows within the sandy and silty materials that extend from wells MW21 to MW12 and Cow Pen Creek. Approximately 13 to 18 feet of saturated sandy material is present in this area. Groundwater is expected to be under hydraulically confined conditions because of the presence of clay units above and below this unit. The upper sandy unit is separated from the lower sandy unit by approximately 35 feet of clay and clayey silt. The lower sandy unit occurs at approximately -45 feet above msl and is at least 17 feet thick in the area of well MW12. It thins to the northeast at well MW14. Groundwater in this lower sandy unit is under confined hydraulic conditions resulting from the thick, overlying clay unit and the underlying clay of the regional Arundel Formation.

Single-well permeability tests (slug tests) were conducted in 28 wells selected to represent variability across the site. The results of the slug tests are provided in Table 2-1. Slug tests were performed on 16 shallow (A) wells, five intermediate (B) wells and seven deep (C) wells.

Low average hydraulic conductivity (K) values were reported for the shallow wells and range from 0.0027 feet per day (ft/day) at MW57 to 1.25 ft/day at MW66A. The arithmetic average K for the shallow wells was 0.22 ft/day; the geometric mean K was 0.07 ft/day. These results are consistent with published permeabilities of sand and silt mixtures (Spitz and Moreno, 1996; Halford and Kuniansky, 2002), which were reported at these locations. Lower hydraulic conductivities are reported for shallow wells located to the south (MW55A through MW62A) and west (MW52A through MW54A and MW64A). The maximum K values for shallow wells (0.99 to 1.25 ft/day) were reported in the southernmost portion of the MRC at wells MW65A and MW66A where sand-rich materials are present. Excluding data from these two wells, the K values ranged from 0.0027 to 0.3 ft/day, a much narrower range.

With the exception of MW27B, the K values of the intermediate wells are more consistent than those of the shallow wells, and had an arithmetic average of 0.48 ft/day and a geometric mean of 0.22 ft/day. The B well permeabilities are consistent with published lower values for clean sand or typical values of sand and silt mixtures. With the exception of well MW37C, K values for the deep wells ranged from 0.35 to 9.16 ft/day. The average K of the deeper wells (3.82 ft/day) is approximately 10 times the average K value for the shallow and intermediate zones. The geometric mean K for deep wells was 0.89 feet/day; eliminating the low permeability at MW37C, the geometric mean K is 3.02 ft/day.

2.2.3.3 Groundwater Flow

For shallow wells, depths to groundwater ranged from approximately less than 1 foot bgs near the shoreline (MW08 through MW10, MW15, MW40, and MW47) to 14 to 18 feet bgs at the central and northern portion of the MRC (MW05, MW01, and MW02), west of Building A (MW49 and MW50), and south of Building C (MW42 and MW60). Depth to groundwater in the deepest wells ranges from less than 1 foot at MW11C to 13.50 feet at MW27C. A summary of the groundwater measurements taken at the MRC is presented in Table 2-2.

Figures 2-7 and 2-8 are groundwater elevation contour maps using data from shallow/intermediate surficial aquifer wells and deep surficial aquifer wells, respectively. Groundwater flows radially from the hydraulically upgradient northern portion of the MRC at Eastern Boulevard to the southeast, south, and southwest toward Dark Head Cove and Cow Pen Creek. The sandy zones act as preferential pathways for the transport of contaminants in groundwater, which may have their source upgradient in the clay-rich materials.

Based on the December 2005 groundwater level measurements, horizontal hydraulic gradients for shallow wells at the site ranged from 0.033 to 0.0033 feet per foot. Using the range of K values of 0.0027 to 1.25 ft/day estimated for the shallow wells, and a typical range of effective porosities for silt/sand of 0.20 to 0.30, the average linear groundwater velocity in the shallow surficial aquifer was estimated to range from 0.01 to 75 feet per year. Excluding the two outlier K values, the average linear velocity ranged from 0.01 to 18 feet per year.

2.3 GROUNDWATER HUMAN HEALTH RISK ASSESSMENT

This section presents the conclusions of the HHRA for groundwater based on data from all permanent wells installed in 2005.

2.3.1 Chemical Distribution and Analysis

This section defines the chemicals of potential concern (COPCs) in the groundwater at MRC. The contaminants of most significance in groundwater are TCE, PCE, vinyl chloride, benzene, and certain metals. The two largest groups of organic COPCs consist of chlorinated aliphatic hydrocarbons (CAHs) and petroleum-related hydrocarbons. CAHs consist of the commonly-used solvents PCE and TCE, which degrade into a variety of other VOCs. Petroleum-based fuels such as gasoline consist of numerous chemical constituents. Several of the volatile organic compounds (VOCs) associated with fuels are fairly soluble in groundwater and are mobile in the subsurface. The most common petroleum VOCs that partition to groundwater and mobilize in the subsurface are benzene, toluene, ethylbenzene, and xylenes (BTEX) and methyl tert-butyl ether (MTBE).

Concentrations of COPCs in groundwater are summarized in Table 2-3.

2.3.1.1 Organic COPCs

TCE and benzene have formed well-defined plumes, indicating migration of these analytes from the source areas. PCE was also detected frequently, but at concentrations much less than TCE with respect to the screening criteria (e.g., relative risk), and PCE is co-located with TCE in almost all cases. TCE and benzene are two of the most toxic VOCs detected. Furthermore, the CAH degradation daughter products (dichloroethenes, vinyl chloride, etc.) or petroleum isomers (benzene and toluene isomers, naphthalene, etc.) are typically co-located with these primary VOCs. Therefore, the distributions of TCE and benzene are evaluated to provide an overview of the primary VOC groundwater contamination at the MRC.

Contoured concentrations of TCE and benzene are shown on Figures 2-9 and 2-10, respectively; these concentrations are also shown in the cross-sections on Figures 2-3 through 2-6. The figures indicate several VOC plumes in groundwater throughout the central and downgradient portions of the MRC. TCE and benzene were detected in groundwater at concentrations exceeding the federal and State drinking water standard of 5 µg/L and chemical-specific risk assessment screening levels. TCE, a commonly used industrial solvent and metal degreaser, was detected in shallow groundwater in several areas with concentrations ranging from 0.5 to 2,600 µg/L. Benzene, a constituent of petroleum-based fuels, was detected in shallow groundwater in several areas with concentrations ranging from 0.4 to 1,200 µg/L. An emerging chemical of interest, 1,4-dioxane, was detected in several wells in the western TCE plume but is absent in the eastern TCE plume. Figure 2-11 shows 1,4-dioxane concentrations at the site.

<u>TCE</u>

Western TCE Plume

As shown on Figure 2-9, the highest concentrations and the second largest contiguous area of TCE groundwater contamination extends from MW21, which is located near REC #9 (Former 2,000 Gallon Waste Oil underground storage tank [UST]) to MW12, located near Cow Pen Creek.

The maximum reported concentrations of TCE were 2,600 µg/L at well MW14B in the central portion of the plume and 1,400 µg/L at well MW12A in the southernmost portion of the plume near Cow Pen Creek.

Figure 2-4 shows the concentrations of TCE in the western TCE plume on the geologic cross-section developed for this area. In this cross-section, the concentrations are plotted along the longitudinal axis and groundwater flowpath of the plume. High concentrations of TCE reported for wells MW14B and MW21B indicate that TCE has migrated to the base of the upper surficial aquifer. In these areas, residual TCE may be trapped in silt and sand lenses between the clay-rich zones and/or may be adsorbed to organic material and clays. The suspected source for the western TCE plume is a former waste oil tank (i.e., REC #9) located near well MW21A. From the suspected source area, dissolved TCE was presumably released to the groundwater and moved preferentially to the south along the more permeable sandy and silty materials present from well MW21A southward to well MW12A. The thick clay and silt below MW21B, MW14B, and MW12A is expected to hinder vertical movement of TCE in these areas as indicated by the absence of TCE in groundwater samples from deep wells MW14C and MW12C.

Eastern TCE Plume

As shown on Figure 2-9, the largest contiguous area and the second highest concentrations of TCE groundwater contamination extend southeastward from MW57, located at the southern end of Building C, to the MW37 cluster near Dark Head Cove. Maximum reported concentrations of TCE are 1,100 µg/L at well MW37A in the southeastern portion of the plume, and 710 µg/L at well MW60A south of Building C. It appears that there may be two sources of TCE contamination forming this plume; one near Building C and MW60 and one near MW37A. More investigation in these areas is planned to confirm this (Section 3).

Figure 2-3 shows the concentrations of TCE in the eastern TCE plume on the geologic cross-section developed for this area. In this cross-section, concentrations are plotted along the longitudinal axis and groundwater flowpath of the plume. Figure 2-9 shows that the maximum concentrations of TCE reported for wells MW60A and MW37A occur in the shallow portion of the surficial aquifer. The source(s) of this plume has not yet been identified, but it may be the south end of C-Basement or may be spillage or material handling in the vicinity of MW60A and/or former Building D. Near Buildings B and C residual TCE may be trapped in silt and sand lenses within the clay-rich zones and/or may be adsorbed to organic material and clays. From the source area(s), dissolved TCE was presumably released to groundwater and moves preferentially to the southeast along the more permeable sandy and silty materials present from well MW48A southeastward to well MW37A. The thick clay below MW60A and MW48A is expected to hinder the vertical movement of TCE in these areas. However, TCE may move vertically to deeper portions of the surficial aquifer in areas southeast of well MW48A where the shallow clay is not present and the more permeable sandy material thickens. The analytical results of intermediate and deep well groundwater samples for MW27B/C, MW34B, and MW37B/C indicate that TCE has migrated to deeper portions of the surficial aquifer in areas hydraulically downgradient of the source area(s).

Other TCE Areas

TCE was also detected at lower concentrations to the west in wells MW17A, MW50A, MW52A, MW53A, MW54A, and MW64A; to the southwest in wells MW07A, MW16A, MW10A; and to the south in wells MW43A and MW45A. In these wells, TCE was reported at a maximum concentration of 130 µg/L at well MW53A. Other concentrations at or above the MCL/MDE Generic Numeric Cleanup Standards in these areas were 5, 18, and 21 µg/L reported for wells MW17A, MW50A, and MW16A respectively. TCE was detected at a concentration of 2 µg/L (less than the TCE groundwater standard) at wells MW07A and MW10A located hydraulically upgradient and downgradient of MW16A, respectively.

Figures 2-5 and 2-6 indicate the presence of clay in the areas west and southwest of Building A. The presence of the lower permeability clay to the west has resulted in low groundwater velocities and has limited the movement and concentrations of the TCE to the west and southwest of the potential source areas.

Benzene

Figure 2-10 is a concentration contour map of benzene in groundwater at the MRC. Because benzene is less dense than water, the highest concentrations of benzene are expected to be encountered in shallow groundwater near source areas. Recharge (i.e., infiltrating precipitation) and downward hydraulic gradients may drive dissolved benzene downward within the aquifer as the contaminant travels further from the source areas.

Benzene was detected in groundwater at the following areas:

Building A – Northwest

Benzene was detected at a maximum concentration of 1,200 µg/L at well MW04A, located near the northwestern corner of Building A, and is associated with a former 4,000-gallon gasoline UST. Benzene was not detected in wells MW41A, MW49A, MW51A, and MW52A located downgradient of MW04A.

REC #8 (Abandoned 25,000-Gallon Fuel Oil UST)

Benzene was detected at a maximum concentration of 540 µg/L at well MW23A, located west of the Vertical Assembly Building, and is associated with a former fuel oil UST. As shown on Figures 2-3 and 2-5, low concentrations of benzene (0.5 to 0.8 µg/L) less than the MCL/Generic Numeric Cleanup Standards were detected at depths of 25 to 45 feet at wells MW25A, MW34B, and MW27B. However, benzene was not detected in the deep (C) wells, located downgradient of the source area. This plume extends to the south-southwest to wells MW24A and the MW27 cluster where it appears to co-mingle with the Eastern TCE plume.

Building A – West

Benzene was detected at a maximum concentration of 430 µg/L at well MW17A, located west of Building A, and is associated with a former 4,000-gallon gasoline UST (i.e., REC #14). Benzene was detected at a concentration less than the MCL/MDE Generic Numeric Cleanup Standards at downgradient well MW64A and was not detected in downgradient wells MW08A, MW09A, MW53A, and MW54A.

Western TCE Plume

Benzene was detected within the western TCE plume at a maximum concentration of 48 µg/L at well MW21B and is likely associated with a 2,000-gallon waste oil UST that is suspected to be the source of TCE in this area. Benzene was also detected at a concentration of 43 µg/L in well MW14B, located in REC #12 (Southern Portion of Lot 3), and wells MW12A and MW13A, located near the previously abandoned-in-place #2 and #6 fuel oil USTs. As shown on Figure 2-4, the highest concentrations of benzene were located at depths of 20 to 35 feet in the lower portion of the surficial aquifer in this area (wells MW21B and MW14B). Dissolved benzene in groundwater moves preferentially to the south along the more permeable sandy and silty materials present from well MW21A southward to well MW12A. The thick clay and silt below MW21B, MW14B, and MW12A is expected to hinder vertical movement of benzene in this area as indicated by the absence of benzene in groundwater samples from deep wells MW14C and MW12C.

Eastern TCE Plume

Benzene was detected at low concentrations ranging from 0.4 µg/L to 2 µg/L in wells within and near the eastern TCE plume. Benzene was detected in wells MW25A, MW34B, MW36A, MW37A, MW43A, MW60A, and MW62A. Wells MW36A and MW37A are in REC #3, which is the location of a former 500,000-gallon diesel fuel AST, a former 275-gallon diesel fuel UST, and an active 275-gallon AST.

Southern Areas

Benzene was detected at low concentrations ranging from 0.4 to 4 µg/L in wells MW45A and MW47A located in the southernmost portion of the property. Well MW45A is in REC #13 (Former Boat Dock Area) and is located near the Former Ramp Training School and Former Ramp Storage Building. Well MW47A is located in REC 5, which consists of seven abandoned-in-place 1,000-gallon aviation fuel USTs.

2.3.1.2 Inorganic COPCs

Metals

Concentrations of metals above MDE Generic Numeric Cleanup Standards for Groundwater and/or contributing to site risk are found throughout the MRC. The metals present at concentrations above MDE Generic Numeric Cleanup Standards include:

- Antimony – 1 location
- Beryllium – 16 locations
- Cobalt – 22 locations

- Nickel – 30 locations
- Thallium – 1 location
- Vanadium – 1 location
- Zinc – 5 locations

The highest concentrations of metals are present primarily in the northwest and center portions of the site, primarily in wells containing very low pH (see Section 5.2). However, well MW06A contains extremely high concentrations of nickel (maximum of 1,250 µg/L) and cobalt (maximum of 622 µg/L) and relatively high concentrations of beryllium (maximum of 19.6 µg/L). These concentrations are among the highest at the site; however, this well is several hundred feet upgradient of the nearest site operation and, considering the low permeability soil, would not be expected to be impacted by these operations. This well is located in Block A. Soil samples collected from this block did not exhibit elevated metals concentrations, no RECs and no potential sources were identified in Block A, the risk assessment indicated no COCs in Block A, and the block is being considered for a No Further Action Determination. Therefore, the concentrations of metals in this well may be considered as background (see Section 5.2). Additional metals leachability testing will also be used to determine if the metals observed in site groundwater are naturally occurring (see Section 3) The results of this testing will be provided and used to determine site cleanup goals in the RAP Addendum.

Concentrations of beryllium, cobalt, and nickel in groundwater (filtered and unfiltered) throughout the site are illustrated in Figures 2-12, 2-13, and 2-14, respectively. The relatively similar concentrations in the filtered and unfiltered samples at most wells indicate that the metals are dissolved in the groundwater and not the result of turbidity or suspended particulates in the samples.

2.3.2 Groundwater HHRA Conclusions

The concentrations of certain chemicals detected in groundwater, many of which exceed Maximum Contaminant Levels (MCLs) and MDE Generic Numeric Cleanup Standards for Groundwater, would preclude the use of this groundwater by any future residents in most areas of the MRC. The risk characterization for residential use of groundwater at the MRC resulted in theoretical cancer risk estimates for the reasonable maximum exposure (RME) case that exceeded the MDE's upper end threshold of 1 x 10^{-5} and also Environmental Protection Agency's (EPA's) target risk range of 1 x 10^{-6} to 1 x 10^{-4}.

Chemicals that contributed to the resident's risk in groundwater were primarily trichloroethene (TCE), vinyl chloride, tetrachloroethene (PCE), benzene, and in some locations arsenic (although arsenic concentrations do not exceed the MDE Generic Numeric Cleanup Standards for Groundwater). Potential future residential exposures to groundwater at the site resulted in theoretical noncancer hazard index estimates for the RME case that exceeded 1.0 at many locations. The main chemicals that contributed to noncancer risk in groundwater were TCE, benzene, and a number of metals.

The estimated risks for the construction worker contacting groundwater also exceeded the acceptable risk ranges, but only at a few locations. The primary concern was TCE, and the pathway of greatest risk contribution was inhalation. The risk assessment modeled the RME case for a construction worker who contacts groundwater for 4 hours per day for 250 days; to the extent that actual construction activity would reduce (or rule out) this exposure to workers, the risk estimates are overestimated. The other uncertainties associated with the construction worker's risk estimates tend to bias the results toward overestimates of actual risks. Thus, while there are concentrated portions of the plume(s) that may present a health hazard to a construction worker, it is anticipated that with foreknowledge of the conditions, risks could be mitigated by implementation of a health and safety plan.

2.4 SUMMARY OF PROPOSED RESPONSE ACTIONS

This section provides a brief description of the proposed groundwater response actions at MRC. It should be noted that the actions, as presented in this RAP, are conceptual in nature. Additional characterization and bench- and pilot-scale testing (as described in Section 3.0) will be required to confirm the efficacy of the proposed actions and to determine important parameters required for design of the response actions. Based on the additional data, changes to the proposed remedial technologies and/or to the specifics of the implementation of the proposed technologies are possible.

As stated in Section 2.3.1, there are several plumes present at the MRC. This section provides a brief overview of the response actions proposed for each.

TCE

Western TCE Plume

The western TCE plume contains the highest concentrations of TCE at the MRC, and an emerging chemical of interest, 1,4-dioxane, was detected in several wells in the area. Because in-situ technologies for the treatment of 1,4-dioxane are currently being tested and are not yet proven, it is proposed that groundwater be extracted, treated, and discharged. An estimated 12 to 15 wells will be utilized to extract groundwater from the area of the plume along Cow Pen Creek, the central and northern portions of the plume, and in isolated locations outside the primary plume which have had detections of 1,4-dioxane (MW16A and MW25A). The actual number of wells will be modified based on data to be collected during additional testing described in Section 3. In-situ chemical oxidation of the TCE and 1,4-dioxane will also be tested (in bench-scale and potentially field-scale) for potential application in this plume.

Eastern TCE Plume

The eastern TCE plume encompasses the largest area and contains the second highest concentrations of TCE in groundwater. Because there are only low levels of 1,4-dioxane in this area, groundwater extraction, as proposed for the western plume, is not considered the best alternative for this plume. The proposed treatment for areas of this plume containing greater than 100 µg/L of TCE is in-situ enhanced bioremediation, utilizing anaerobic reductive dechlorination (ARD). This will include injections of lactate, emulsified vegetable oil, pH buffering agent, and, potentially, bioaugmentation. Areas with TCE concentrations of less than 100 µg/L will not be treated via injections; however, natural attenuation is expected to be enhanced following active remediation due to the treatment of the "source" areas and the creation of anaerobic conditions downgradient of the treatment areas. The bioremediation design and the related number of injection events will be dictated by achievement of the remedial goals.

Other TCE Areas

The area surrounding MW53A will be treated via in-situ enhanced bioremediation and natural attenuation in a manner similar to that described for the eastern TCE plume. The only other well exceeding the MCL/MDE Generic Numeric Cleanup Standards for TCE is MW50A. Due to the relatively low concentrations detected at this well, monitored natural attenuation will be utilized for this area.

Benzene

Building A – Northwest and West and REC #8

Building A and REC #8 are the areas with the highest benzene concentrations at the MRC. It is proposed that they be treated via injection of a chemical oxidant into the groundwater. Areas with benzene concentrations greater than 100 µg/L will be treated in this manner (with the exception of areas located under the existing building in REC #8). Areas with concentrations less than 100 µg/L and areas under the building are expected to naturally attenuate due to the reduction of concentrations in the “source” areas and the creation of a highly oxidized environment downgradient of the treatment areas. The design and the related number of injection events will be dictated by achievement of the remedial goals. The design will also consider the desire to create reducing conditions in the nearby eastern TCE plume; care will be taken to maintain a buffer between the oxidants being injected for treatment of benzene and the electron donors being injected for treatment of the TCE.

Eastern and Western TCE Plumes

The relatively low benzene concentrations in the western plume will be treated via the groundwater extraction system summarized above. The concentrations in the eastern plume are 2 µg/L or less and will be addressed via monitored natural attenuation.

South Areas

Benzene was detected at low concentrations ranging from 0.4 to 4 µg/L in wells located in the southernmost portion of the MRC. These areas will not be directly addressed via treatment; they will be addressed via natural attenuation.

Metals

As detailed in Section 2.3.1.2, multiple areas of the site have metals concentrations in groundwater exceeding MDE Generic Numeric Cleanup Standards. Additional investigation will be conducted to determine if these metals are naturally occurring. Because these investigations have not yet been conducted and analyzed, and the ultimate management of any non-naturally occurring metals, if present, (e.g., risk management through land use/engineering controls, containment, monitored natural attenuation, and/or active treatment) has not yet been determined, treatment of metals in groundwater is not considered in this RAP.

Table 2-1

Summary of Results for Single-Well Permeability Tests (Slug Tests)
Lockheed Martin Middle River Complex, Middle River, Maryland

Well ID	K Falling-Head Test (feet/day)	K Rising-Head Test (feet/day)	K Average (feet/day) [(1)]
Shallow Wells			
MW66A	1.89	0.61	1.25
MW65A	0.75	1.23	0.99
MW50A	NT	0.30	0.30
MW60A	NT	0.22	0.22
MW54A	NT	0.17	0.17
MW56A	NT	0.10	0.10
MW53A	NT	0.10	0.10
MW52A	NT	0.10	0.10
MW63A	NT	0.06	0.06
MW62A	--	0.06	0.06
MW61A	NT	0.049	0.049
MW59A	NT	0.046	0.046
MW64A	NT	0.03	0.03
MW58A	NT	0.006	0.006
MW55A	NT	0.0049	0.0049
MW57A	NT	0.0027	0.0027
		Arithmetic Average	0.22
		Geometric Mean	0.07
Intermediate Wells			
MW34B	0.95	0.89	0.92
MW14B	0.91	0.51	0.71
MW37B	0.56	0.56	0.56
MW21B	0.28	0.18	0.23
MW27B	0.0058	--	0.006
		Arithmetic Average	0.48
		Geometric Mean	0.22
Deep Wells			
MW12C	7.73	10.58	9.16
MW27C	6.26	6.35	6.30
MW11C	5.04	5.24	5.14
MW62C	3.43	3.72	3.57
MW34C	2.16	2.27	2.22
MW14C	0.31	0.39	0.35
MW37C	0.00053	--	0.00053
		Arithmetic Average	3.82
		Geometric Mean	0.89

Notes

1 Ranked in descending order based on the arithmetic average of the two tests, if applicable.

NT = Not tested. Test could not be performed because the water table was below the top of the well screen.

-- = Test not conducted due to very slow recharge rate.

Table 2-2

Groundwater Elevations
Lockheed Martin Middle River Complex, Middle River, Maryland

Well ID	Screen Depth Bottom Feet (below grade)	Screen Elevation Bottom Feet (above msl)	Groundwater Elevation 6/5/2005 Feet (above msl)	Groundwater Elevation 10/13/2005 Feet (above msl)	Groundwater Elevation 12/6/2005 Feet (above msl)
MRC-MW01A	28	7.67	22.1	19.94	20.69
MRC-MW02A	27	3.81	22.8	20.92	21.27
MRC-MW03A	14	16.41	27.22	25.07	24.92
MRC-MW04A	14	12.33	23.75	22.65	23.10
MRC-EXT-MW04	NA	NA	18.97	35.73	35.73
MRC-MW05A	34	3.43	22.75	21.60	19.50
MRC-MW06A	33	0.85	19.11	18.46	20.16
MRC-EXT-MW06	NA	NA	NA	23.02	23.04
MRC-MW07A	22	13.32	23.87	23.63	23.19
MRC-MW08A	13	-1.34	11.46	11.46	11.46
MRC-MW09A	14	-4.24	7.17	9.37	9.37
MRC-MW10A	13	-1.50	11.31	11.31	11.31
MRC-MW11A	13	1.01	10.79	11.19	13.49
MRC-MW11C	73	-59.59	NA	NA	13.10
MRC-MW12A	14	-2.77	8.96	10.83	9.38
MRC-MW12C	75	-63.30	NA	NA	10.02
MRC-MW13A	14	-1.99	10.94	11.79	11.09
MRC-MW14A	13	5.73	14.27	14.92	15.22
MRC-MW14B	30	-12.05	NA	NA	12.80
MRC-MW14C	75	-57.16	NA	NA	10.10
MRC-MW15A	13	5.66	18.36	18.36	18.36
MRC-MW16A	13	6.42	11.24	18.89	15.14
MRC-MW17A	19	15.88	28.55	28.50	28.15
MRC-MW18A	26	8.67	17.65	27.55	22.15
MRC-MW19A	18	20.61	31.09	30.64	26.27
MRC-MW20A	25	13.34	23.99	26.94	26.40
MRC-MW21A	16	19.06	31.99	31.09	31.69
MRC-MW21B	34	0.97	NA	NA	23.93
MRC-MW22A	40	-6.19	19.26	18.04	18.66
MRC-MW23A	22	3.64	18.72	17.62	17.32
MRC-MW24A	20	3.05	14.9	NA	NA
MRC-MW25A	30	-0.99	15.53	15.48	15.23
MRC-MW26A	23	2.15	14.74	14.24	13.94
MRC-MW27A	19	4.37	13.05	NA	12.40
MRC-MW27B	50	-26.88	NA	NA	11.45
MRC-MW27C	78	-54.51	NA	NA	9.64
MRC-MW28A	19	0.68	11.89	11.34	11.01
MRC-MW29A	15	1.27	10.99	10.57	10.12
MRC-MW30A	14	-0.97	11.94	12.09	11.84
MRC-MW31A	14	-0.94	10.5	9.85	9.65
MRC-MW32A	14	-1.08	9.68	9.24	8.79

Table 2-2

Groundwater Elevations
Lockheed Martin Middle River Complex, Middle River, Maryland

Well ID	Screen Depth Bottom Feet (below grade)	Screen Elevation Bottom Feet (above msl)	Groundwater Elevation 6/5/2005 Feet (above msl)	Groundwater Elevation 10/13/2005 Feet (above msl)	Groundwater Elevation 12/6/2005 Feet (above msl)
MRC-MW33A	14	-0.97	11.08	11.10	10.95
MRC-MW34A	14	-1.04	9.37	8.92	8.42
MRC-MW34B	30	-16.99	NA	NA	8.65
MRC-MW34C	55	-42.00	NA	NA	8.69
MRC-MW35A	13	-2.23	7.89	9.01	6.84
MRC-MW36A	18.5	-6.64	5.16	4.96	4.78
MRC-MW37A	17	-4.33	5.12	4.93	4.63
MRC-MW37B	34	-24.25	NA	NA	3.55
MRC-MW37C	70	-60.41	NA	NA	3.14
MRC-MW38A	14	-4.01	4.49	4.15	4.14
MRC-MW39A	14	-7.07	6.6	6.60	3.55
MRC-MW40A	15	-8.47	6.24	6.24	6.24
MRC-MW41A	16	13.59	19.89	18.94	17.39
MRC-MW42A	19	11.22	18.65	20.50	15.12
MRC-MW43A	13.5	-0.24	11.63	11.68	11.57
MRC-MW44A	13	-0.15	11.7	11.60	11.45
MRC-MW45A	13	-6.23	NA	-3.31	-6.46
MRC-MW46A	13	-4.68	3.38	3.03	2.27
MRC-MW47A	15	-2.36	8.9	12.30	12.30
MRC-MW48A	21	5.97	18.94	17.97	17.44
MRC-MW49A	22	11.33	NA	NA	16.13
MRC-MW50A	26	6.56	NA	NA	16.42
MRC-MW51A	13	10.86	NA	NA	13.01
MRC-MW52A	13	9.33	NA	NA	15.34
MRC-MW53A	13	7.56	NA	NA	14.47
MRC-MW54A	17	1.86	NA	NA	14.88
MRC-MW55A	22	16.70	NA	NA	25.25
MRC-MW56A	12.5	25.42	NA	NA	32.68
MRC-MW57A	12	26.58	NA	NA	28.34
MRC-MW58A	18	19.33	NA	NA	32.13
MRC-MW59A	12	24.19	NA	NA	34.01
MRC-MW60A	22	18.22	NA	NA	24.62
MRC-MW61A	14	12.05	NA	NA	NA
MRC-MW62A	13	0.08	NA	NA	11.67
MRC-MW62C	65	-51.93	NA	NA	9.51
MRC-MW63A	14	4.09	NA	NA	15.14
MRC-MW64A	16	17.23	NA	NA	25.50
MRC-MW65A	18	-1.21	NA	NA	11.42
MRC-MW66A	19	-2.10	NA	NA	9.90

NA - Not available.

Table 2-3

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

Chemical	Chemical Type	MW01A Block 'A'	MW02A Block 'A'	MW06A Block 'A'	MW03A Block 'B'	MW35A Block 'D'	MW40A Block 'D'	MW30A Block 'E'	MW31A Block 'E'	MW32A Block 'E'	MW33A Block 'E'	MW34A Block 'E'	MW34B Block 'E'	MW34C Block 'E'
ANTIMONY	M	na	2.50E-05	na	na	5.80E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03
ARSENIC	M	5.70E-03	6.50E-04	6.50E-04	2.10E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	4.20E-03	1.73E-03
BARIUM	M	3.88E-02	1.32E-01	5.30E-01	1.48E-01	3.04E-02	2.95E-02	1.30E-01	1.23E-01	4.22E-02	4.17E-02	5.28E-02	1.38E-01	6.21E-02
BERYLLIUM	M	2.50E-05	5.00E-03	4.30E-03	2.50E-05	2.50E-05	3.70E-03	1.75E-04	6.20E-03	9.70E-04	1.70E-03	2.50E-05	7.10E-03	1.75E-04
CADMIUM	M	2.50E-05	3.40E-04	7.70E-04	2.50E-05	2.18E-03	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	4.70E-04	2.00E-04
COBALT	M	2.10E-03	9.60E-02	3.15E-01	1.69E-02	1.53E-03	2.33E-02	3.80E-03	6.21E-02	5.00E-03	4.17E-02	1.90E-03	1.14E-01	5.60E-04
COPPER	M	3.40E-03	7.78E-02	1.30E-02	6.60E-03	1.43E-03	5.00E-03	8.70E-04	2.55E-02	1.90E-03	8.70E-04	5.00E-05	3.24E-02	8.70E-04
LEAD	M	2.50E-05	2.50E-05	2.50E-05	2.50E-05	8.25E-04	2.50E-05	8.25E-04	8.25E-04	8.25E-04	na	8.25E-04	8.25E-04	na
NICKEL	M	8.10E-03	1.44E-01	7.76E-01	1.33E-02	5.85E-03	3.55E-02	5.70E-03	1.23E-01	9.00E-03	3.27E-02	2.00E-03	1.54E-01	na
THALLIUM	M	7.50E-05	7.50E-05	na	7.50E-05	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03
VANADIUM	M	8.60E-03	1.75E-04	1.75E-04	2.20E-03	2.44E-03	2.44E-03	6.80E-04	6.80E-04	4.60E-03	6.80E-04	1.80E-03	2.57E-02	na
ZINC	M	na	1.23E-01	5.20E-01	na	8.70E-04	7.70E-02	1.07E-02	1.25E-01	1.85E-02	1.48E-01	na	2.55E-01	na
HEXAVALENT CHROMIUM	M	6.30E-03	1.25E-02	5.70E-03	1.25E-02	1.20E-02	1.25E-02	1.25E-02	1.25E-02	1.70E-02	1.25E-02	1.25E-02	na	na
1,1-DICHLOROETHENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	4.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	6.00E-04	5.00E-04
1,2,3-TRICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,3-TRIMETHYLBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,4-TRICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	7.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,4-TRIMETHYLBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	2.00E-03
1,2-DICHLOROETHANE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,3-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	8.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,4-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	2.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,4-DIOXANE	OV	na	na	na	na	na	1.00E-03	1.00E-03	1.00E-03	1.00E-03	na	1.00E-03	1.00E-03	1.00E-03
BENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
BROMODICHLOROMETHANE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CARBON TETRACHLORIDE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	2.50E-02	5.00E-04
CHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	9.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	3.00E-04	5.00E-04
CHLORODIBROMOMETHANE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLOROETHANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
CHLOROFORM	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	7.00E-03	3.00E-03
CHLOROMETHANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	na	1.00E-03
CIS-1,2-DICHLOROETHENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	2.50E-02	2.00E-03	5.00E-04	1.00E-03	5.00E-04	2.80E-02	5.00E-04
DICHLORODIFLUOROMETHANE	OV	1.00E-03	4.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03

Table 2-3

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

	Chemical	MW01A	MW02A	MW06A	MW03A	MW35A	MW40A	MW30A	MW31A	MW32A	MW33A	MW34A	MW34B	MW34C
Chemical	**Type**	Block 'A'	Block 'A'	Block 'A'	Block 'B'	Block 'D'	Block 'D'	Block 'E'	Block 'E'	Block 'E'	Block 'E'	Block 'E'	Block 'E'	Block 'E'
ETHYLBENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
M+P-XYLENES	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
METHYL TERT-BUTYL ETHER	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	6.00E-03	*1.00E-03*	2.00E-03	*1.00E-03*	5.40E-02	*1.00E-03*
NAPHTHALENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	na	*5.00E-04*
O-XYLENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
TETRACHLOROETHENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
TOTAL 1,2-DICHLOROETHENE	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	2.60E-02	2.00E-03	*1.00E-03*	1.00E-03	*1.00E-03*	3.10E-02	*1.00E-03*
TOTAL XYLENES	OV	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*
TRICHLOROETHENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	1.50E-02	5.00E-03	7.00E-04	2.00E-03	2.50E-02	3.20E-02	*5.00E-04*
VINYL CHLORIDE	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	2.00E-03	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	7.00E-03	*1.00E-03*
GASOLINE RANGE ORGANICS	PET	2.00E-02	1.30E-02	*5.00E-03*	*5.00E-03*	na	na	2.70E-02	2.00E-02	5.20E-02	1.10E-02	1.60E-02	na	na
TOTAL PETROLEUM HYDROCARBONS	PET	2.00E-01	1.60E-01	1.30E-01	3.60E-01	na	na	na	na	na	na	na	na	na

Notes:
M = metal; OV = volatile organic; PET = gasoline/diesel range hydrocarbons
The concentration values include assumed concentrations for COPCs that were not detected in a sample; these concentrations were assumed to equal 1/2 of the COPCs sample quantitation limit and are displayed in italics
"na" = no available data in database (not analyzed for/data rejected/data gap)

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

Chemical	Chemical Type	MW36A Block 'E'	MW37A Block 'E'	MW37B Block 'E'	MW37C Block 'E'	MW43A Block 'E'	MW44A Block 'E'	MW62A Block 'E'	MW62C Block 'E'	MW38A Block 'F'	MW39A Block 'F'	MW45A Block 'F'	MW46A Block 'F'	MW47A Block 'F'	MW65A Block 'F'
ANTIMONY	M	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	1.00E-02	2.06E-03	2.06E-03
ARSENIC	M	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	7.20E-03	1.73E-03
BARIUM	M	3.24E-02	6.21E-02	8.75E-02	6.74E-02	3.03E-02	8.14E-02	3.79E-01	7.09E-02	3.64E-02	6.98E-02	7.80E-03	6.02E-02	1.10E-01	4.77E-02
BERYLLIUM	M	1.75E-04	3.50E-03	na	1.75E-04	1.75E-04	1.75E-04	3.17E-02	1.75E-04	4.20E-03	1.50E-03	1.75E-04	1.20E-03	1.75E-04	na
CADMIUM	M	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	na	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	4.80E-04	2.00E-04
COBALT	M	3.07E-02	6.40E-02	6.87E-02	2.20E-03	2.60E-02	1.30E-03	1.40E-01	1.95E-02	4.80E-02	8.30E-03	5.60E-04	3.00E-03	5.60E-03	1.26E-02
COPPER	M	8.70E-04	3.80E-03	na	na	8.70E-04	8.70E-04	na	8.70E-04	1.52E-02	2.40E-03	8.70E-04	8.30E-03	8.70E-04	na
LEAD	M	8.25E-04	1.80E-03	8.25E-04	8.25E-04	8.25E-04	8.25E-04	na	8.25E-04	8.25E-04	8.25E-04	1.20E-04	8.25E-04	8.25E-04	8.25E-04
NICKEL	M	4.58E-02	7.73E-02	5.28E-02	7.90E-03	3.68E-02	1.70E-03	7.68E-01	3.02E-02	2.44E-02	7.90E-03	7.09E-02	2.40E-02	3.80E-03	1.64E-02
THALLIUM	M	3.07E-03	na	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03
VANADIUM	M	6.80E-04	6.80E-04	2.44E-03	9.70E-03	6.80E-04	1.60E-03	2.44E-03	2.44E-03	6.80E-04	6.80E-04	2.44E-03	7.40E-03	6.80E-04	6.80E-04
ZINC	M	6.36E-02	1.18E-01	1.13E-01	6.70E-03	5.02E-02	2.61E-02	5.92E-01	3.74E-02	8.53E-02	2.48E-02	7.36E-01	2.96E-01	2.08E-01	1.17E-02
HEXAVALENT CHROMIUM	M	1.25E-02	1.25E-02	na	na	1.25E-02	1.25E-02	1.25E-02	na	1.25E-02	1.25E-02	1.25E-02	1.25E-02	1.25E-02	1.25E-02
1,1-DICHLOROETHENE	OV	5.00E-04	5.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,3-TRICHLOROBENZENE	OV	1.80E-02	5.00E-03	5.00E-04	5.00E-04	9.20E-01	5.00E-04	3.10E-01	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	5.00E-04
1,2,3-TRIMETHYLBENZENE	OV	5.00E-04	5.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	3.00E-04	5.00E-04
1,2,4-TRICHLOROBENZENE	OV	1.40E-01	5.00E-03	5.00E-04	5.00E-04	4.20E+00	5.00E-04	1.50E+00	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,4-TRIMETHYLBENZENE	OV	5.00E-04	5.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2-DICHLOROBENZENE	OV	1.00E-02	5.00E-03	5.00E-04	5.00E-04	2.90E-01	5.00E-04	6.00E-02	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2-DICHLOROETHANE	OV	5.00E-04	5.00E-03	5.00E-04	5.00E-04	9.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,3-DICHLOROBENZENE	OV	6.90E-02	5.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,4-DICHLOROBENZENE	OV	6.40E-02	5.00E-03	5.00E-04	5.00E-04	4.00E-01	4.00E-04	7.80E-02	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,4-DIOXANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	na	1.00E-03	1.00E-03	1.00E-03	na	1.05E-03	na	na	1.00E-03
BENZENE	OV	2.00E-03	5.00E-03	5.00E-04	5.00E-04	1.00E-03	5.00E-04	4.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	4.00E-03	5.00E-04
BROMODICHLOROMETHANE	OV	5.00E-04	5.00E-03	7.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CARBON TETRACHLORIDE	OV	5.00E-04	5.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLOROBENZENE	OV	5.90E-02	2.20E-02	5.00E-04	5.00E-04	5.00E-03	5.00E-04	2.00E-02	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLORODIBROMOMETHANE	OV	5.00E-04	5.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLOROETHANE	OV	1.00E-03	1.00E-02	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
CHLOROFORM	OV	5.00E-04	5.00E-03	4.00E-03	7.00E-03	5.00E-04	5.00E-04	1.80E-01	3.00E-03	5.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na
CHLOROMETHANE	OV	1.00E-03	1.00E-02	1.00E-03	4.00E-04	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
CIS-1,2-DICHLOROETHENE	OV	2.00E-03	3.80E-02	3.00E-03	6.00E-04	4.00E-04	5.00E-04	5.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
DICHLORODIFLUOROMETHANE	OV	1.00E-03	1.00E-02	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03

Table 2-3

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

Chemical	Chemical Type	MW36A Block 'E'	MW37A Block 'E'	MW37B Block 'E'	MW37C Block 'E'	MW43A Block 'E'	MW44A Block 'E'	MW62A Block 'E'	MW62C Block 'E'	MW38A Block 'F'	MW39A Block 'F'	MW45A Block 'F'	MW46A Block 'F'	MW47A Block 'F'	MW65A Block 'F'
ETHYLBENZENE	OV	*5.00E-04*	*5.00E-03*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	5.00E-04	*5.00E-04*
M+P-XYLENES	OV	*1.00E-03*	*1.00E-02*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
METHYL TERT-BUTYL ETHER	OV	*1.00E-03*	*1.00E-02*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
NAPHTHALENE	OV	*5.00E-04*	*5.00E-03*	*5.00E-04*	*5.00E-04*	6.00E-03	*5.00E-04*	6.00E-03	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
O-XYLENE	OV	*5.00E-04*	*5.00E-03*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	1.00E-03	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	1.00E-03	*5.00E-04*
TETRACHLOROETHENE	OV	*5.00E-04*	*5.00E-03*	*5.00E-04*	*5.00E-04*	8.00E-04	*5.00E-04*	1.40E-02	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
TOTAL 1,2-DICHLOROETHENE	OV	2.00E-03	3.80E-02	3.00E-03	6.00E-04	*1.00E-03*	*1.00E-03*	5.00E-03	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
TOTAL XYLENES	OV	*1.50E-03*	*1.50E-02*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	1.00E-03	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	1.00E-03	*1.50E-03*
TRICHLOROETHENE	OV	1.20E-02	1.10E+00	7.00E-03	3.00E-03	2.00E-03	*5.00E-04*	1.00E-03	*5.00E-04*	1.00E-03	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
VINYL CHLORIDE	OV	*1.00E-03*	*1.00E-02*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	1.00E-03	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
GASOLINE RANGE ORGANICS	PET	2.40E-01	2.20E-01	na	na	1.50E+00	1.20E-02	5.10E-01	na	na	na	na	*5.00E-03*	2.40E-01	2.00E-02
TOTAL PETROLEUM HYDROCARBONS	PET	2.80E-01	1.90E-01	na	na	na	na	7.30E-01	na	na	na	na	4.90E-01	4.50E-01	*3.95E-02*

Notes:
M = metal; OV = volatile organic; PET = gasoline/diesel range hydrocarbons
The concentration values include assumed concentrations for COPCs that were not detected in a sample; these concentrations were assumed to equal 1/2 of the COPCs sample quantitation limit and are displayed in italics
"na" = no available data in database (not analyzed for/data rejected/data gap)

Table 2-3

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

Chemical	Chemical Type	MW66A Block 'F'	MW09A Block 'G'	MW10A Block 'G'	MW11A Block 'G'	MW11C Block 'G'	MW12A Block 'G'	MW12C Block 'G'	MW13A Block 'G'	MW14A Block 'G'	MW14B Block 'G'	MW14C Block 'G'	MW15A Block 'G'	MW16A Block 'G'	MW54A Block 'G'
ANTIMONY	M	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	na	4.30E-03	2.06E-03
ARSENIC	M	1.73E-03	5.10E-03	3.60E-03	1.73E-03	1.73E-03	1.73E-03	4.20E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.60E-03	1.73E-03	1.73E-03
BARIUM	M	1.15E-01	8.81E-02	1.28E-01	3.51E-02	2.98E-02	8.50E-02	3.55E-02	1.56E-01	8.82E-02	8.78E-02	2.78E-01	1.03E-01	6.94E-02	2.36E-02
BERYLLIUM	M	na	1.75E-04	1.75E-04	1.75E-04	1.75E-04	1.90E-03	1.75E-04	2.50E-05	na	5.90E-04	8.90E-03	8.40E-04	1.75E-04	1.75E-04
CADMIUM	M	na	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.18E-03	2.00E-04	2.18E-03	2.18E-03	2.00E-04	2.00E-04	1.10E-04	2.00E-04	2.00E-04
COBALT	M	1.00E-01	5.60E-04	1.53E-01	2.07E-02	na	3.50E-02	7.00E-03	1.53E-03	8.80E-02	4.36E-02	4.64E-02	1.20E-01	1.60E-02	5.60E-04
COPPER	M	na	8.70E-04	2.56E-02	8.70E-04	8.70E-04	1.19E-02	8.70E-04	1.43E-03	1.43E-03	8.70E-04	8.70E-04	2.30E-03	8.70E-04	8.70E-04
LEAD	M	8.25E-04	8.25E-04	2.50E-05	8.25E-04	8.25E-04	3.30E-03	8.25E-04	8.25E-04	2.60E-03	1.80E-03	na	6.30E-04	8.25E-04	8.25E-04
NICKEL	M	4.72E-02	7.65E-04	8.16E-02	1.08E-02	na	7.16E-02	1.89E-02	5.85E-03	6.85E-02	1.10E-01	1.06E-01	3.39E-02	3.12E-02	7.65E-04
THALLIUM	M	na	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	3.07E-03	7.50E-05	3.07E-03	3.07E-03
VANADIUM	M	6.80E-04	6.80E-04	6.80E-04	2.50E-03	na	8.00E-03	2.44E-03	2.44E-03	2.44E-03	6.80E-04	8.81E-02	7.70E-04	1.39E-02	6.80E-04
ZINC	M	3.67E-02	4.60E-03	3.72E-02	1.14E+00	1.83E-02	1.75E-01	5.15E-02	8.70E-04	8.14E-02	1.82E-01	3.85E-01	4.10E-02	2.33E+00	na
HEXAVALENT CHROMIUM	M	1.25E-02	1.20E-02	5.00E-02	1.25E-02	na	1.60E-02	na	6.30E-03	1.25E-02	na	na	1.25E-02	1.25E-02	1.25E-02
1,1-DICHLOROETHENE	OV	5.00E-04	5.00E-04	9.00E-04	2.20E-02	5.00E-04	1.50E-01	5.00E-04	5.00E-04	1.00E-03	4.80E-01	5.00E-04	6.40E-02	5.80E-02	5.00E-04
1,2,3-TRICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,3-TRIMETHYLBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	2.00E-04	5.00E-04	5.00E-04	5.00E-04	3.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,4-TRICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,4-TRIMETHYLBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	3.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2-DICHLOROETHANE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	2.00E-03	5.00E-04	5.00E-04	5.00E-04	4.00E-03	5.00E-04	2.00E-03	5.00E-04	5.00E-04
1,3-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,4-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,4-DIOXANE	OV	1.00E-03	na	1.00E-03	1.80E-03	1.00E-03	7.60E-02	1.00E-03	1.00E-03	1.00E-03	1.20E-01	1.00E-03	9.90E-03	2.20E-02	na
BENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-03	5.00E-04	5.00E-04	5.00E-04	4.30E-02	5.00E-04	6.00E-04	5.00E-04	5.00E-04
BROMODICHLOROMETHANE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	2.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CARBON TETRACHLORIDE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLORODIBROMOMETHANE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLOROETHANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	4.00E-04	1.00E-03	1.00E-03	1.00E-03	1.00E-03
CHLOROFORM	OV	na	5.00E-04	5.00E-04	5.00E-04	8.00E-04	1.00E-03	6.00E-03	5.00E-04	5.00E-04	6.00E-03	2.00E-03	5.00E-04	5.00E-04	5.00E-04
CHLOROMETHANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
CIS-1,2-DICHLOROETHENE	OV	5.00E-04	5.00E-04	9.00E-04	2.00E-03	5.00E-04	1.00E-01	5.00E-04	1.00E-03	7.00E-03	1.30E-01	5.00E-04	5.00E-04	3.00E-03	5.00E-04
DICHLORODIFLUOROMETHANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03

Table 2-3

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

Chemical	Chemical Type	MW66A	MW09A	MW10A	MW11A	MW11C	MW12A	MW12C	MW13A	MW14A	MW14B	MW14C	MW15A	MW16A	MW54A
		Block 'F'	Block 'G'	Block 'G'	Block 'G'	Block 'G'	Block 'G'	Block 'G'	Block 'G'	Block 'G'	Block 'G'	Block 'G'	Block 'G'	Block 'G'	Block 'G'
ETHYLBENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
M+P-XYLENES	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
METHYL TERT-BUTYL ETHER	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
NAPHTHALENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
O-XYLENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
TETRACHLOROETHENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	1.00E-03	*5.00E-04*	*5.00E-04*	*5.00E-04*	4.00E-03	*5.00E-04*	*5.00E-04*	7.00E-03	*5.00E-04*
TOTAL 1,2-DICHLOROETHENE	OV	*1.00E-03*	*1.00E-03*	9.00E-04	2.00E-03	*1.00E-03*	1.00E-01	*1.00E-03*	1.00E-03	8.00E-03	1.30E-01	*1.00E-03*	*1.00E-03*	3.00E-03	*1.00E-03*
TOTAL XYLENES	OV	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*
TRICHLOROETHENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	7.00E-03	*5.00E-04*	1.40E+00	na	3.00E-04	6.00E-03	2.60E+00	*5.00E-04*	7.00E-04	9.00E-03	4.00E-04
VINYL CHLORIDE	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	1.00E-03	*1.00E-03*	6.00E-03	*1.00E-03*	2.00E-03	3.00E-04	1.00E-03	*1.00E-03*	1.70E-02	3.00E-03	*1.00E-03*
GASOLINE RANGE ORGANICS	PET	1.50E-02	*5.00E-03*	*5.00E-03*	5.00E-03	na	4.50E-01	na	2.90E-02	na	na	na	na	5.20E-02	*5.00E-03*
TOTAL PETROLEUM HYDROCARBONS	PET	4.50E-01	9.30E-01	5.50E-01	na	na	na	na	na	na	na	na	na	5.30E-01	1.10E-01

Notes:
M = metal; OV = volatile organic; PET = gasoline/diesel range hydrocarbons
The concentration values include assumed concentrations for COPCs that were not detected in a sample; these concentrations were assumed to equal 1/2 of the COPCs sample quantitation limit and are displayed in italics
"na" = no available data in database (not analyzed for/data rejected/data gap)

Table 2-3

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

Chemical	Chemical Type	MW63A Block 'G'	MW08A Block 'H'	MW52A Block 'H'	MW53A Block 'H'	MW01 Block 'I'	MW02 Block 'I'	MW03 Block 'I'	MW04 Block 'I'	MW04A Block 'I'	MW05 Block 'I'	MW05A Block 'I'	MW06 Block 'I'	MW07A Block 'I'	MW17A Block 'I'
ANTIMONY	M	2.06E-03	2.06E-03	2.06E-03	2.06E-03	na	na	na	na	na	na	na	2.06E-03	na	na
ARSENIC	M	1.73E-03	1.73E-03	1.73E-03	1.73E-03	na	na	6.50E-04	na	6.50E-04	na	6.50E-04	1.73E-03	6.50E-04	6.50E-04
BARIUM	M	9.17E-02	1.36E-01	1.02E+00	6.22E-01	na	na	3.38E-02	na	2.22E-01	na	4.29E-02	6.16E-02	1.03E-01	2.04E-01
BERYLLIUM	M	1.75E-04	1.50E-03	5.26E-02	5.80E-03	na	na	2.50E-05	na	6.60E-03	na	6.10E-04	na	2.00E-03	4.80E-04
CADMIUM	M	2.00E-04	2.18E-03	3.60E-03	2.00E-04	na	na	na	na	2.70E-03	na	1.40E-04	2.18E-03	9.80E-04	2.30E-04
COBALT	M	5.87E-02	1.93E-01	2.28E+00	3.09E-01	na	na	7.50E-04	na	5.48E-01	na	2.15E-02	1.53E-03	6.64E-01	1.72E-01
COPPER	M	8.70E-04	8.30E-03	6.28E-02	3.40E-03	na	na	2.00E-03	na	1.76E-02	na	1.37E-02	1.43E-03	3.73E-02	na
LEAD	M	2.60E-03	4.00E-03	1.07E-02	3.80E-03	na	na	2.80E-03	2.50E-03	1.10E-03	na	1.90E-03	8.25E-04	9.50E-03	na
NICKEL	M	9.33E-02	3.98E-01	1.70E+00	2.44E-01	na	na	1.90E-03	na	5.78E-01	na	4.00E-02	5.85E-03	4.68E-01	1.67E-01
THALLIUM	M	3.07E-03	1.20E-02	9.20E-03	3.07E-03	na	na	7.50E-05	na	7.50E-05	na	7.50E-05	3.07E-03	7.50E-05	7.50E-05
VANADIUM	M	6.80E-04	2.44E-03	6.80E-04	6.80E-04	na	na	4.80E-03	na	1.75E-04	na	4.20E-03	2.44E-03	1.75E-04	1.75E-04
ZINC	M	4.45E-02	1.89E-01	2.71E+00	3.35E-01	na	na	na	na	5.07E-01	na	7.31E-02	na	1.64E-01	1.92E-01
HEXAVALENT CHROMIUM	M	1.25E-02	1.25E-02	1.25E-02	1.25E-02	na	na	3.10E-02	na	1.25E-02	na	3.50E-02	2.00E-02	1.25E-02	1.25E-02
1,1-DICHLOROETHENE	OV	5.00E-04	5.00E-04	5.00E-04	2.00E-03	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	7.80E-02	1.10E-02	4.00E-04
1,2,3-TRICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,3-TRIMETHYLBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	2.00E-03
1,2,4-TRICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,4-TRIMETHYLBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2-DICHLOROETHANE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	3.00E-03
1,3-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,4-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,4-DIOXANE	OV	1.00E-03	na	na	na	na	na	1.00E-03	na	na	na	na	2.90E-03	4.90E-03	2.30E-03
BENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.20E-01	5.00E-04	3.30E-01	5.00E-04	5.00E-04	5.00E-04	3.10E-01
BROMODICHLOROMETHANE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CARBON TETRACHLORIDE	OV	5.00E-04	5.00E-04	5.00E-04	8.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLORODIBROMOMETHANE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLOROETHANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	na	na	1.00E-03	na	1.00E-03	na	1.00E-03	1.00E-03	1.00E-03	1.00E-03
CHLOROFORM	OV	5.00E-04	5.00E-04	5.00E-04	1.00E-03	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	8.00E-04	4.00E-03
CHLOROMETHANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	na	na	1.00E-03	na	1.00E-03	na	1.00E-03	1.00E-03	1.00E-03	1.00E-03
CIS-1,2-DICHLOROETHENE	OV	5.00E-04	5.00E-04	5.00E-04	3.00E-03	na	na	5.00E-04	na	5.00E-04	na	5.00E-04	5.00E-04	6.00E-04	4.00E-03
DICHLORODIFLUOROMETHANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	na	na	1.00E-03	na	1.00E-03	na	1.80E-01	1.00E-03	1.00E-03	1.00E-03

Table 2-3

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

Chemical	Chemical Type	MW63A Block 'G'	MW08A Block 'H'	MW52A Block 'H'	MW53A Block 'H'	MW01 Block 'I'	MW02 Block 'I'	MW03 Block 'I'	MW04 Block 'I'	MW04A Block 'I'	MW05 Block 'I'	MW05A Block 'I'	MW06 Block 'I'	MW07A Block 'I'	MW17A Block 'I'
ETHYLBENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	1.50E-01	*5.00E-04*	2.80E-01	*5.00E-04*	*5.00E-04*	*5.00E-04*	1.40E-02
M+P-XYLENES	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	na	na	*1.00E-03*	na	*1.00E-03*	na	*1.00E-03*	*1.00E-03*	*1.00E-03*	2.00E-03
METHYL TERT-BUTYL ETHER	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	na	na	*1.00E-03*	na	*1.00E-03*	na	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
NAPHTHALENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	2.00E-03	*5.00E-04*	*5.00E-04*	1.40E-01	*5.00E-04*	2.10E-02	*5.00E-04*	*5.00E-04*	*5.00E-04*	na
O-XYLENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	na	na	*5.00E-04*	na	*5.00E-04*	na	*5.00E-04*	*5.00E-04*	*5.00E-04*	4.00E-03
TETRACHLOROETHENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	na	na	*5.00E-04*	na	*5.00E-04*	na	*5.00E-04*	*5.00E-04*	3.00E-03	*5.00E-04*
TOTAL 1,2-DICHLOROETHENE	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	3.00E-03	na	na	*1.00E-03*	na	*1.00E-03*	na	*1.00E-03*	*1.00E-03*	6.00E-04	4.00E-03
TOTAL XYLENES	OV	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*5.00E-04*	*5.00E-04*	*1.50E-03*	8.90E-01	*1.50E-03*	1.00E-01	*1.50E-03*	*1.50E-03*	*1.50E-03*	5.00E-03
TRICHLOROETHENE	OV	7.00E-04	*5.00E-04*	4.00E-04	1.30E-01	na	na	*5.00E-04*	na	*5.00E-04*	na	*5.00E-04*	1.00E-03	2.00E-03	6.30E-02
VINYL CHLORIDE	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	na	na	*1.00E-03*	na	*1.00E-03*	na	*1.00E-03*	*1.00E-03*	*1.00E-03*	2.00E-03
GASOLINE RANGE ORGANICS	PET	*5.00E-03*	1.20E-02	*5.00E-03*	*5.00E-03*	na	na	*5.00E-03*	9.80E+00	2.00E-02	na	*5.00E-03*	1.40E-02	1.70E-02	8.60E-01
TOTAL PETROLEUM HYDROCARBONS	PET	1.30E-01	4.80E-01	3.60E-01	1.60E-01	na	na	3.50E-01	na	1.80E-01	na	8.50E-02	1.30E-01	*3.95E-02*	na

Notes:
M = metal; OV = volatile organic; PET = gasoline/diesel range hydrocarbons
The concentration values include assumed concentrations for COPCs that were not detected in a sample; these concentrations were assumed to equal 1/2 of the COPCs sample quantitation limit and are displayed in italics
"na" = no available data in database (not analyzed for/data rejected/data gap)

Table 2-3

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

Chemical	Chemical Type	MW18A Block 'I'	MW19A Block 'I'	MW20A Block 'I'	MW21A Block 'I'	MW21B Block 'I'	MW22A Block 'I'	MW23A Block 'I'	MW24A Block 'I'	MW25A Block 'I'	MW26A Block 'I'	MW27A Block 'I'	MW27B Block 'I'	MW27C Block 'I'	MW28A Block 'I'
ANTIMONY	M	na	na	na	na	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03
ARSENIC	M	6.50E-04	6.50E-04	6.50E-04	6.50E-04	1.73E-03	1.73E-03	5.10E-03	1.73E-03	1.73E-03	1.73E-03	6.90E-03	1.73E-03	1.73E-03	1.73E-03
BARIUM	M	3.18E-01	5.66E-02	6.14E-02	1.38E-01	9.92E-02	6.65E-02	4.82E-01	1.78E-01	2.14E-01	1.55E-01	4.23E-01	2.11E-02	2.21E-02	9.65E-02
BERYLLIUM	M	6.40E-03	1.90E-03	2.00E-04	7.40E-04	3.80E-03	1.20E-03	na	4.39E-02	2.32E-02	8.50E-03	2.60E-03	na	na	1.75E-04
CADMIUM	M	7.70E-04	1.10E-03	1.40E-04	1.90E-04	2.00E-04	2.18E-03	2.18E-03	2.18E-03	2.18E-03	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04
COBALT	M	1.58E-01	5.82E-01	3.70E-02	3.82E-02	8.33E-02	5.91E-02	2.33E-01	1.25E-01	2.64E-01	1.91E-01	5.45E-01	1.04E-01	5.30E-03	4.34E-02
COPPER	M	1.78E-02	1.54E-01	3.20E-03	1.21E-02	8.70E-04	1.43E-03	1.43E-03	3.97E-02	1.43E-03	8.70E-04	8.70E-04	3.69E-02	na	8.70E-04
LEAD	M	1.40E-03	1.70E-03	2.50E-05	1.40E-03	8.25E-04	8.25E-04	1.90E-03	5.10E-03	2.40E-03	8.25E-04	na	6.80E-03	3.00E-03	8.25E-04
NICKEL	M	2.40E-01	8.92E-01	5.87E-02	4.15E-02	1.10E-01	1.04E-01	9.58E-02	5.38E-01	3.14E-01	1.03E-01	2.53E-01	1.36E-01	1.29E-02	5.40E-03
THALLIUM	M	7.50E-05	1.25E-04	1.25E-04	7.50E-05	3.07E-03	3.07E-03	6.13E-03	6.13E-03	3.07E-03	3.07E-03	1.25E-04	3.07E-03	3.07E-03	3.07E-03
VANADIUM	M	7.00E-04	8.50E-04	na	5.00E-03	6.80E-04	2.44E-03	2.44E-03	2.44E-03	2.44E-03	6.80E-04	3.20E-03	3.30E-03	6.20E-03	6.80E-04
ZINC	M	2.76E-01	5.38E-01	na	3.46E-02	1.60E-01	9.26E-02	6.25E-02	1.00E+00	5.07E-01	1.43E-01	2.19E-01	1.95E-01	1.63E-02	2.30E-02
HEXAVALENT CHROMIUM	M	1.25E-02	7.90E-03	1.25E-02	3.10E-02	na	1.25E-02	1.25E-02	1.25E-02	1.25E-02	1.25E-02	1.60E-02	na	na	2.00E-02
1,1-DICHLOROETHENE	OV	9.00E-03	5.00E-04	4.00E-04	2.20E-02	2.90E-01	5.00E-04	5.00E-04	3.00E-03	5.00E-04	4.00E-04	5.00E-03	2.00E-03	5.00E-04	5.00E-04
1,2,3-TRICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,3-TRIMETHYLBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,4-TRICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2,4-TRIMETHYLBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,2-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	6.00E-04	5.00E-04	5.00E-04
1,2-DICHLOROETHANE	OV	5.00E-04	5.00E-04	5.00E-04	7.00E-04	4.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,3-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,4-DICHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
1,4-DIOXANE	OV	2.60E-03	2.60E-03	na	8.60E-03	3.30E-02	1.10E-03	na	1.00E-03	4.00E-03	1.00E-03	1.00E-03	2.40E-03	1.00E-03	1.00E-03
BENZENE	OV	5.00E-04	5.00E-04	5.00E-04	4.00E-04	4.80E-02	5.00E-04	1.00E-01	6.00E-03	4.00E-04	5.00E-04	4.00E-03	8.00E-04	5.00E-04	5.00E-04
BROMODICHLOROMETHANE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CARBON TETRACHLORIDE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	2.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLOROBENZENE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLORODIBROMOMETHANE	OV	5.00E-04	5.00E-04	5.00E-04	5.00E-04	1.00E-03	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04
CHLOROETHANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	2.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
CHLOROFORM	OV	1.00E-03	1.00E-03	5.00E-04	5.00E-04	1.00E-03	4.00E-04	5.00E-04	2.00E-03	5.00E-04	5.00E-04	5.00E-04	8.00E-03	7.00E-03	5.00E-04
CHLOROMETHANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	2.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
CIS-1,2-DICHLOROETHENE	OV	5.00E-04	5.00E-04	5.00E-04	2.00E-03	1.20E-02	5.00E-04	3.00E-04	9.00E-03	2.00E-03	8.00E-03	7.10E-02	3.50E-01	5.00E-04	5.00E-04
DICHLORODIFLUOROMETHANE	OV	1.00E-03	1.00E-03	1.00E-03	1.00E-03	2.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03

Table 2-3

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

Chemical	Chemical Type	MW18A Block 'I'	MW19A Block 'I'	MW20A Block 'I'	MW21A Block 'I'	MW21B Block 'I'	MW22A Block 'I'	MW23A Block 'I'	MW24A Block 'I'	MW25A Block 'I'	MW26A Block 'I'	MW27A Block 'I'	MW27B Block 'I'	MW27C Block 'I'	MW28A Block 'I'
ETHYLBENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*1.00E-03*	*5.00E-04*	3.00E-04	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
M+P-XYLENES	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*2.00E-03*	*1.00E-03*	3.00E-03	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
METHYL TERT-BUTYL ETHER	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*2.00E-03*	*1.00E-03*	2.10E-02	1.40E-01	1.00E-03	*1.00E-03*	1.50E-01	*1.00E-03*	*1.00E-03*	*1.00E-03*
NAPHTHALENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	na	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
O-XYLENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*1.00E-03*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
TETRACHLOROETHENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	3.00E-03	1.00E-02	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	6.00E-04	*5.00E-04*	*5.00E-04*	*5.00E-04*
TOTAL 1,2-DICHLOROETHENE	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	2.00E-03	1.20E-02	*1.00E-03*	*1.00E-03*	9.00E-03	2.00E-03	8.00E-03	7.70E-02	3.60E-01	*1.00E-03*	*1.00E-03*
TOTAL XYLENES	OV	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*3.00E-03*	*1.50E-03*	3.00E-03	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*
TRICHLOROETHENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	3.80E-02	8.90E-01	*5.00E-04*	4.00E-04	5.90E-02	4.50E-02	2.00E-03	2.20E-01	5.70E-01	3.00E-04	*5.00E-04*
VINYL CHLORIDE	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	2.00E-03	2.00E-03	*1.00E-03*	*1.00E-03*	4.00E-03	*1.00E-03*	1.00E-03	3.30E-02	1.80E-02	*1.00E-03*	*1.00E-03*
GASOLINE RANGE ORGANICS	PET	1.00E-02	na	2.20E-02	2.40E-02	na	1.50E-02	2.70E-01	1.70E-01	2.80E-02	1.30E-02	1.90E-01	na	na	1.20E-02
TOTAL PETROLEUM HYDROCARBONS	PET	na	na	2.50E-01	3.70E-01	na	9.00E-01	8.40E-01	1.50E-01	na	4.30E-01	3.00E-01	na	na	na

Notes:
M = metal; OV = volatile organic; PET = gasoline/diesel range hydrocarbons
The concentration values include assumed concentrations for COPCs that were not detected in a sample; these concentrations were assumed to equal 1/2 of the COPCs sample quantitation limit and are displayed in italics
"na" = no available data in database (not analyzed for/data rejected/data gap)

Table 2-3

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

Chemical	Chemical Type	MW29A Block 'I'	MW41A Block 'I'	MW42A Block 'I'	MW48A Block 'I'	MW50A Block 'I'	MW55A-2 Block 'I'	MW56A Block 'I'	MW57A Block 'I'	MW58A Block 'I'	MW59A Block 'I'	MW60S Block 'I'	MW61S Block 'I'	MW64A Block 'I'
ANTIMONY	M	*2.06E-03*	na	na	na	*2.06E-03*	*2.06E-03*	*2.06E-03*	*2.06E-03*	*2.06E-03*	*2.06E-03*	*2.06E-03*	*2.06E-03*	*2.06E-03*
ARSENIC	M	*1.73E-03*	*6.50E-04*	2.00E-03	*6.50E-04*	*1.73E-03*	*1.73E-03*	*1.73E-03*	4.80E-03	*1.73E-03*	9.30E-03	*1.73E-03*	3.90E-03	*1.73E-03*
BARIUM	M	1.70E-01	4.52E-01	9.54E-01	1.43E-01	1.48E-01	9.86E-02	9.22E-02	2.50E-01	8.36E-02	2.23E-02	1.11E-01	6.54E-01	1.19E-01
BERYLLIUM	M	4.10E-03	5.40E-03	1.03E-01	4.50E-03	1.16E-02	na	*1.75E-04*	*1.75E-04*	*1.75E-04*	*1.75E-04*	*1.75E-04*	8.60E-02	*1.75E-04*
CADMIUM	M	*2.00E-04*	1.00E-03	1.00E-03	na	8.80E-04	*2.00E-04*	*2.00E-04*	*2.00E-04*	*2.00E-04*	*2.00E-04*	*2.00E-04*	na	*2.00E-04*
COBALT	M	1.97E-01	6.17E-01	5.54E-01	1.03E-01	2.18E-01	2.34E-02	1.10E-02	2.86E-01	1.69E-02	*5.60E-04*	6.01E-02	1.35E+00	2.50E-02
COPPER	M	2.90E-03	2.80E-03	7.81E-02	8.20E-04	1.17E-01	na	*8.70E-04*	*8.70E-04*	*8.70E-04*	*8.70E-04*	*8.70E-04*	na	*8.70E-04*
LEAD	M	*8.25E-04*	*2.50E-05*	1.20E-02	*2.50E-05*	*8.25E-04*	*8.25E-04*	na	*8.25E-04*	*8.25E-04*	*8.25E-04*	*8.25E-04*	na	*8.25E-04*
NICKEL	M	1.09E-01	6.58E-01	8.77E-01	6.82E-02	2.07E-01	3.04E-02	1.91E-02	2.44E-01	4.47E-02	*7.65E-04*	6.03E-02	1.21E+00	1.19E-02
THALLIUM	M	*3.07E-03*	*1.25E-04*	*7.50E-05*	*7.50E-05*	*3.07E-03*	*3.07E-03*	*3.07E-03*	*3.07E-03*	*3.07E-03*	*3.07E-03*	*3.07E-03*	*3.07E-03*	*3.07E-03*
VANADIUM	M	*6.80E-04*	6.90E-04	2.23E-02	*1.75E-04*	*6.80E-04*	*6.80E-04*	na	*6.80E-04*	*6.80E-04*	4.84E-02	*2.44E-03*	*4.88E-03*	*6.80E-04*
ZINC	M	1.75E-01	6.28E-01	1.52E+00	6.26E-02	3.08E-01	4.50E-02	2.28E-02	3.10E-01	4.69E-02	na	2.61E-02	1.44E+00	1.02E-02
HEXAVALENT CHROMIUM	M	*1.25E-02*	1.50E-02	3.30E-02	9.60E-03	*1.25E-02*	*1.25E-02*	2.60E-02	*1.25E-02*	*1.25E-02*	1.00E-02	*1.25E-02*	*1.25E-02*	*1.25E-02*
1,1-DICHLOROETHENE	OV	5.00E-03	*5.00E-04*	*5.00E-04*	5.00E-03	*5.00E-04*	*5.00E-04*	*5.00E-04*	1.00E-03	*5.00E-04*	*5.00E-04*	2.00E-03	*5.00E-04*	*5.00E-04*
1,2,3-TRICHLOROBENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
1,2,3-TRIMETHYLBENZENE	OV	*5.00E-04*	*5.00E-04*	4.00E-04	*5.00E-04*	2.60E-02	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
1,2,4-TRICHLOROBENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	4.00E-03	*5.00E-04*	*5.00E-04*
1,2,4-TRIMETHYLBENZENE	OV	*5.00E-04*	*5.00E-04*	4.00E-04	*5.00E-04*	1.60E-02	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
1,2-DICHLOROBENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
1,2-DICHLOROETHANE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
1,3-DICHLOROBENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
1,4-DICHLOROBENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
1,4-DIOXANE	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	na	*1.05E-03*	*1.10E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	1.80E-03	*1.00E-03*	na
BENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	3.90E-01	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	6.00E-04	*5.00E-04*	4.00E-04
BROMODICHLOROMETHANE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	2.00E-03	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
CARBON TETRACHLORIDE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
CHLOROBENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
CHLORODIBROMOMETHANE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	4.00E-04	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
CHLOROETHANE	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
CHLOROFORM	OV	*5.00E-04*	*5.00E-04*	2.00E-03	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	9.00E-03	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
CHLOROMETHANE	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	na	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
CIS-1,2-DICHLOROETHENE	OV	4.00E-03	*5.00E-04*	*5.00E-04*	6.90E-02	1.00E-03	9.00E-04	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	2.80E-01	*5.00E-04*	4.00E-04
DICHLORODIFLUOROMETHANE	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*

Table 2-3

COPC Concentrations in Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

units: mg/L

Chemical	Chemical Type	MW29A	MW41A	MW42A	MW48A	MW50A	MW55A-2	MW56A	MW57A	MW58A	MW59A	MW60S	MW61S	MW64A
		Block 'I'	Block 'I'	Block 'I'	Block 'I'	Block 'I'	Block 'I'	Block 'I'	Block 'I'	Block 'I'	Block 'I'	Block 'I'	Block 'I'	Block 'I'
ETHYLBENZENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	1.30E-01	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
M+P-XYLENES	OV	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	6.60E-02	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
METHYL TERT-BUTYL ETHER	OV	5.00E-03	*1.00E-03*	*1.00E-03*	*1.00E-03*	2.80E-02	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*
NAPHTHALENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	na	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	na
O-XYLENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	8.90E-02	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*
TETRACHLOROETHENE	OV	*5.00E-04*	*5.00E-04*	*5.00E-04*	1.00E-03	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	*5.00E-04*	1.10E-02	*5.00E-04*	*5.00E-04*
TOTAL 1,2-DICHLOROETHENE	OV	4.00E-03	*1.00E-03*	*1.00E-03*	4.80E-01	1.00E-03	9.00E-04	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	2.80E-01	*1.00E-03*	*1.00E-03*
TOTAL XYLENES	OV	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	1.50E-01	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*	*1.50E-03*
TRICHLOROETHENE	OV	9.00E-03	*5.00E-04*	*5.00E-04*	2.70E-01	1.80E-02	5.00E-04	*5.00E-04*	1.30E-02	*5.00E-04*	*5.00E-04*	7.10E-01	*5.00E-04*	4.00E-04
VINYL CHLORIDE	OV	1.00E-03	*1.00E-03*	*1.00E-03*	3.80E-02	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	*1.00E-03*	1.10E-02	*1.00E-03*	4.00E-04
GASOLINE RANGE ORGANICS	PET	2.20E-02	*5.00E-03*	1.70E-02	3.00E-01	1.40E+00	3.00E-02	na	na	*5.00E-03*	na	2.60E-01	na	*5.00E-03*
TOTAL PETROLEUM HYDROCARBONS	PET	na	na	na	na	2.00E-01	8.50E-01	2.40E-01	2.90E-01	1.30E-01	5.30E-01	3.50E-01	7.50E-02	1.40E-01

Notes:
M = metal; OV = volatile organic; PET = gasoline/diesel range hydrocarbons
The concentration values include assumed concentrations for COPCs that were not detected in a sample; these concentrations were assumed to equal 1/2 of the COPCs sample quantitation limit and are displayed in italics
"na" = no available data in database (not analyzed for/data rejected/data gap)

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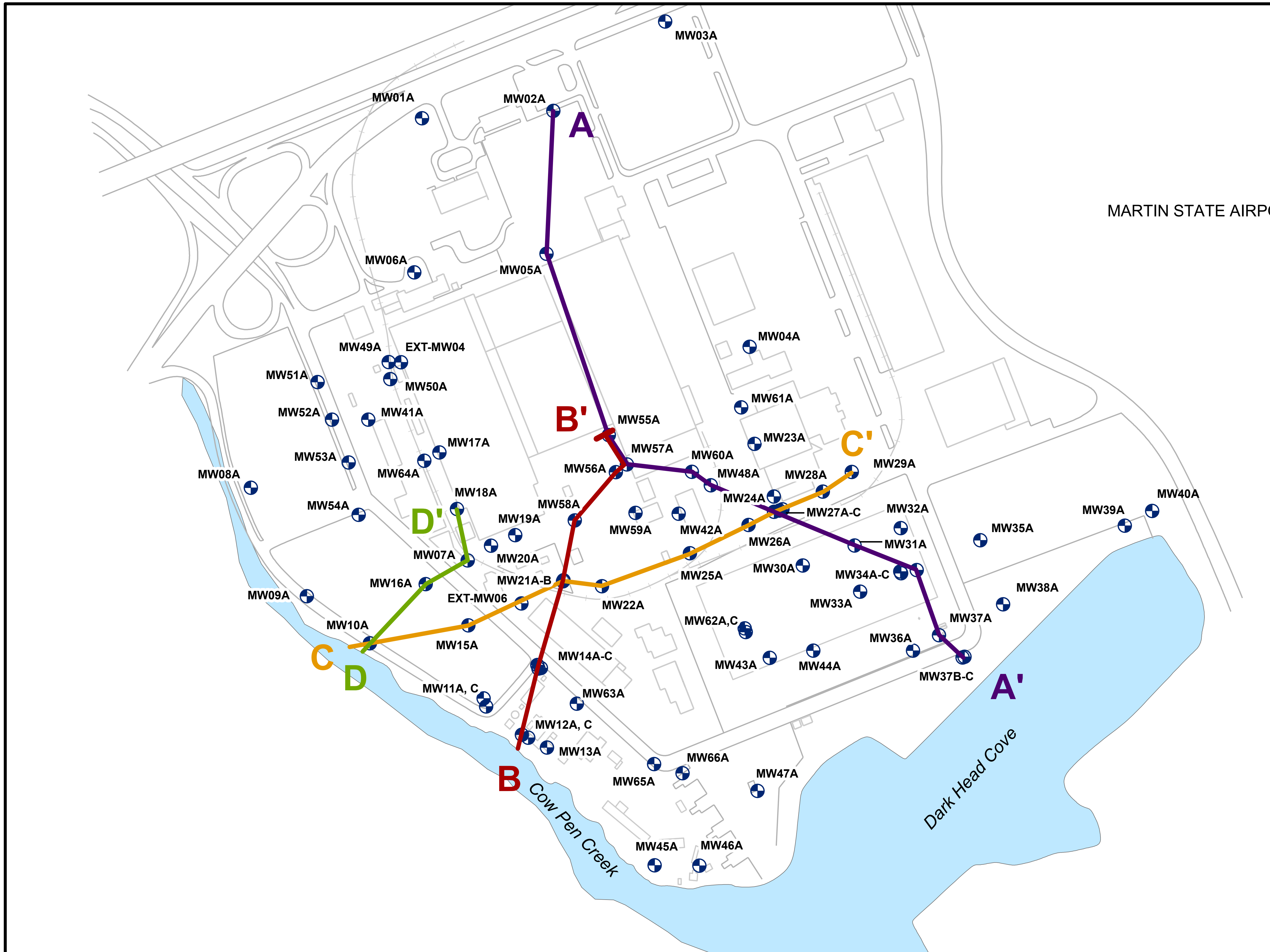

FIGURE 2-2

LOCATIONS OF GROUNDWATER MONITORING WELLS AND GEOLOGIC CROSS-SECTION

LEGEND

GROUNDWATER MONITORING WELL

WATER

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 3/27/07

CREATED BY: LR

Tetra Tech, Inc.

K:\GProject\middle_river\Maps\Middle River x-section traverse_Tabloid.mxd

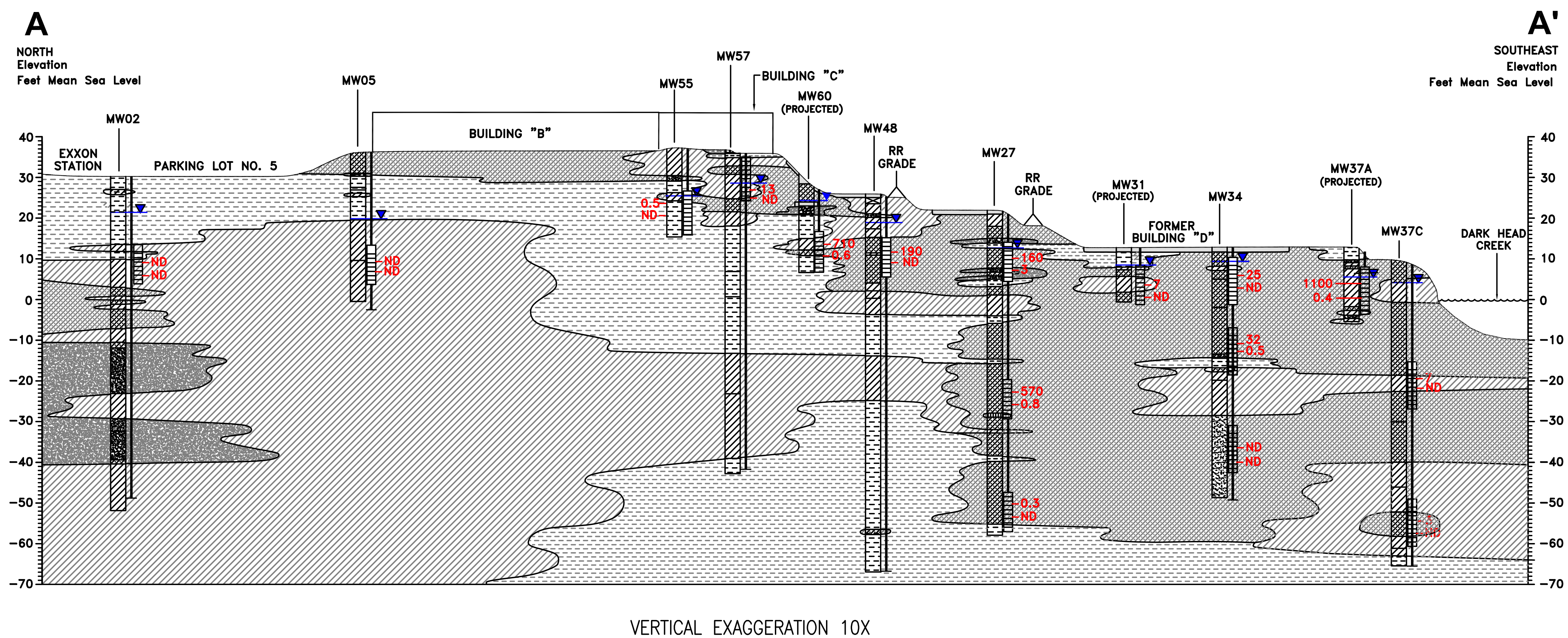

FIGURE 2-3

GEOLOGIC CROSS-SECTION A-A'

LEGEND

Lockheed Martin Middle River Complex, Middle River, Maryland

0 200 400

DATE MODIFIED 3/29/07

CREATED BY LR

Tetra Tech Inc.

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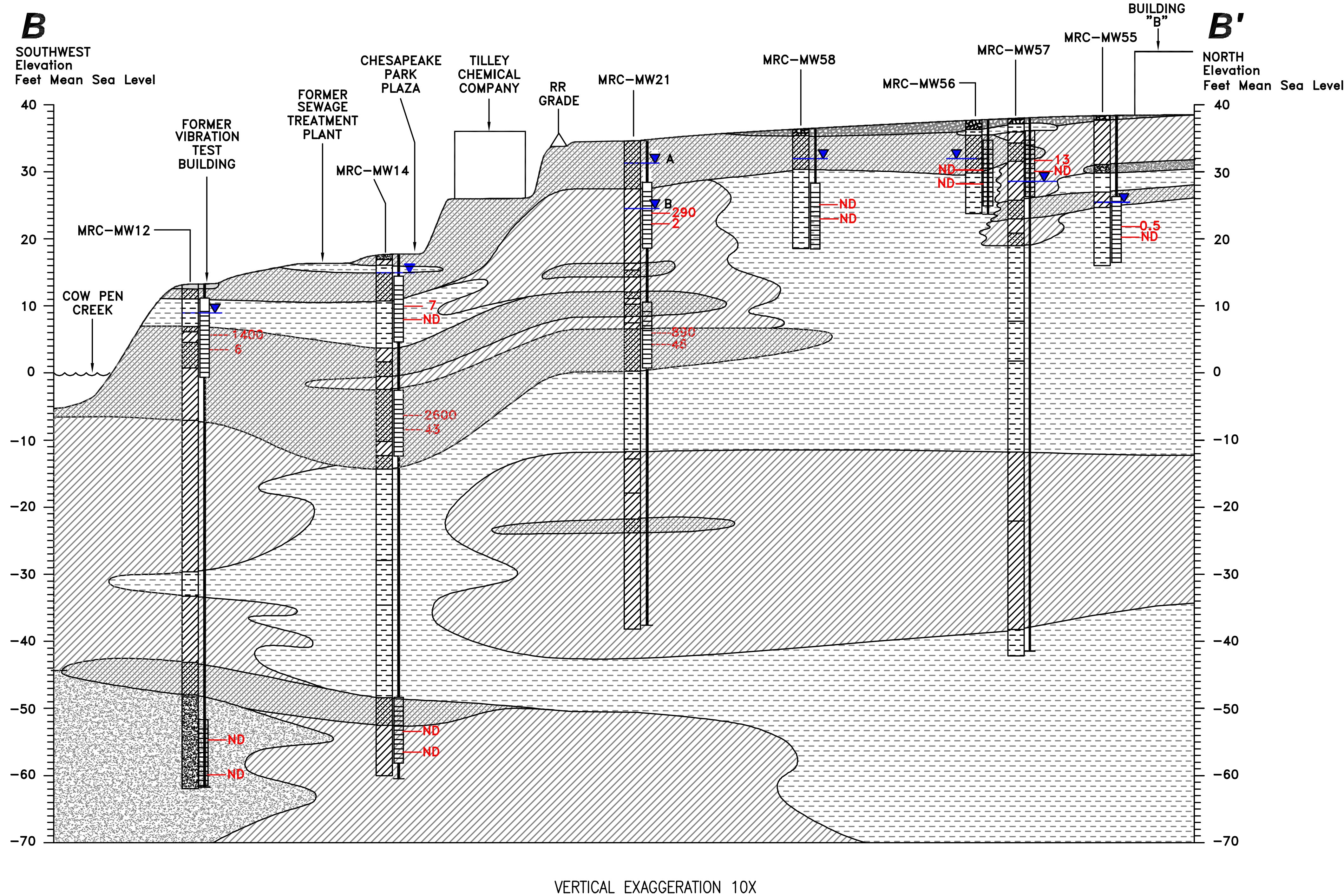

FIGURE 2-4

GEOLOGIC CROSS-SECTION B-B' WITH TCE AND BENZENE CONCENTRATIONS, JUNE - NOVEMBER 2005

LEGEND

- SAND
- SILTY SAND & SANDY SILT
- SILT & CLAYEY SILT
- CLAY & SILTY CLAY
- GRAVEL
- CONCRETE/ASPHALT
- NO SAMPLE RECOVERY
- GROUNDWATER SURFACE (12/05)
- WELL SCREEN
- TCE CONCENTRATION (ug/L)
- BENZENE CONCENTRATION (ug/L)
- SOIL BORING
- BORING TERMINUS
- ND NOT DETECTED

Lockheed Martin Middle River Complex,
Middle River, Maryland

0 100 200
SCALE IN FEET

DATE MODIFIED	CREATED BY
3/29/07	LR

Tetra Tech, Inc.

K:\GProject\middle_river\CAD\Geologic Cross Sections\0507116003A.dwg

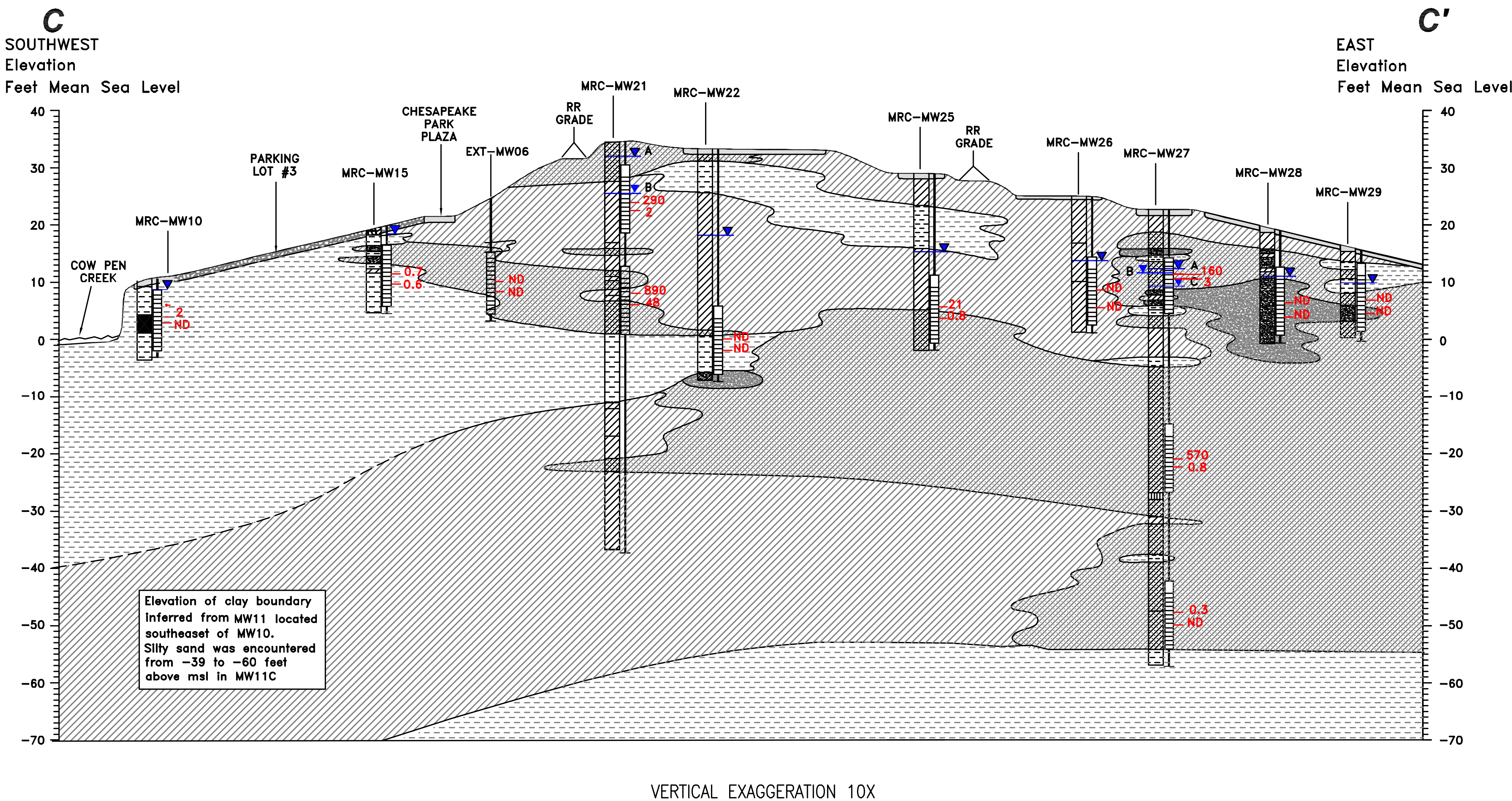

FIGURE 2-5

GEOLOGIC CROSS-SECTION C-C' WITH TCE AND BENZENE CONCENTRATIONS, JUNE - NOVEMBER 2005

LEGEND

- SAND
- SILTY SAND & SANDY SILT
- SILT & CLAYEY SILT
- CLAY & SILTY CLAY
- GRAVEL
- CONCRETE/ASPHALT
- NO SAMPLE RECOVERY
- GROUNDWATER SURFACE (12/05)
- WELL SCREEN
- TCE CONCENTRATION (ug/L) / BENZENE CONCENTRATION (ug/L)
- SOIL BORING
- BORING TERMINUS
- ND NOT DETECTED

Lockheed Martin Middle River Complex, Middle River, Maryland

0 100 200
SCALE IN FEET

DATE MODIFIED 3/29/07

CREATED BY LR

Tetra Tech, Inc.

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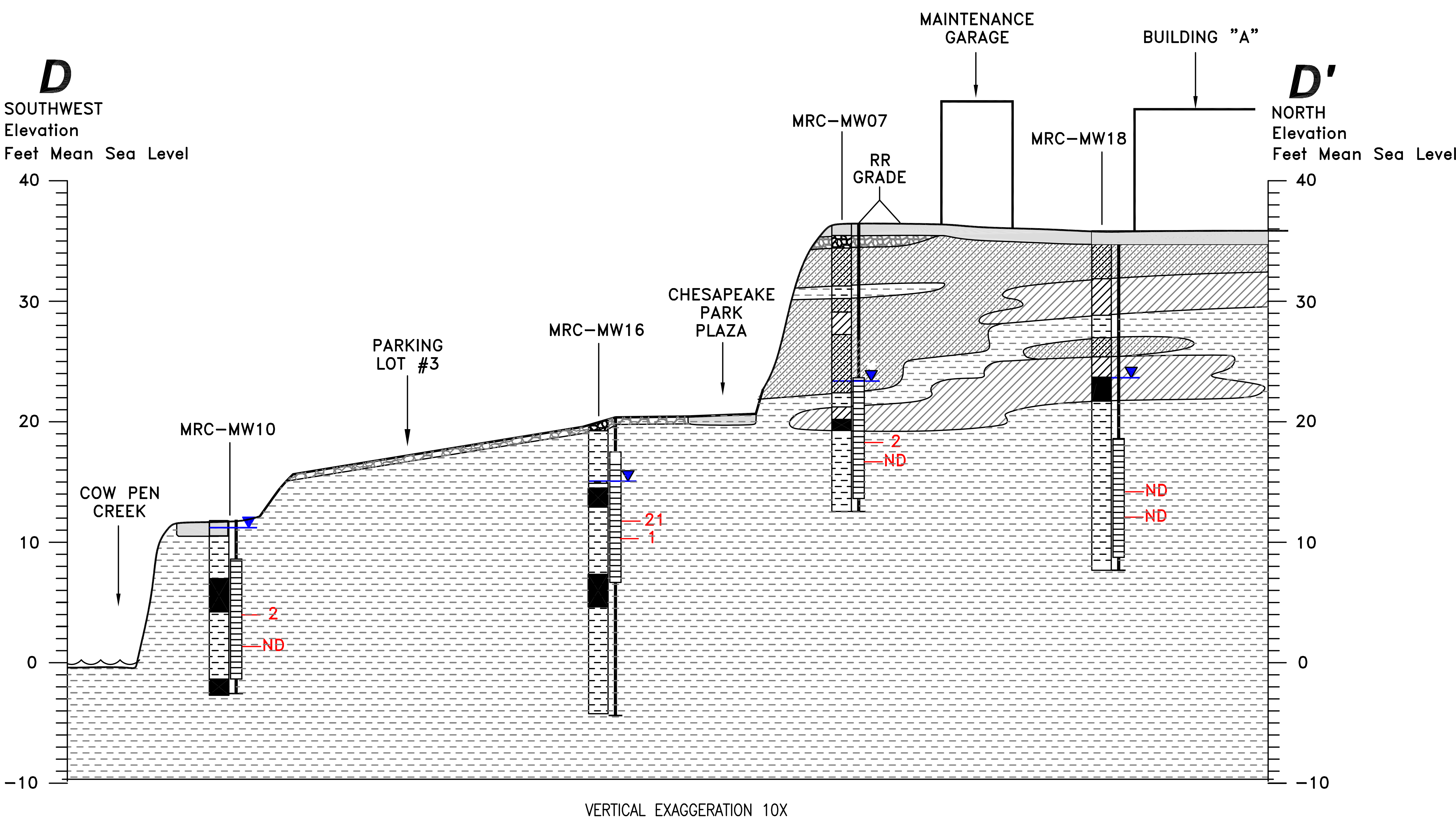


FIGURE 2-6

GEOLOGIC CROSS-SECTION D-D' WITH TCE AND BENZENE CONCENTRATIONS, JUNE - NOVEMBER 2005

LEGEND

- SAND
- SILTY SAND & SANDY SILT
- SILT & CLAYEY SILT
- CLAY & SILTY CLAY
- GRAVEL
- CONCRETE/ASPHALT
- NO SAMPLE RECOVERY
- GROUNDWATER SURFACE (12/05)
- WELL SCREEN
- TCE CONCENTRATION (ug/L)
- BENZENE CONCENTRATION (ug/L)
- SOIL BORING
- BORING TERMINUS
- ND NOT DETECTED

Lockheed Martin Middle River Complex, Middle River, Maryland

0 50 200
SCALE IN FEET

DATE MODIFIED 3/29/07

CREATED BY LR

Tetra Tech, Inc.

FIGURE 2-7

GROUNDWATER CONTOURS OF THE UPPER SURFICIAL AQUIFER, DECEMBER 2005

LEGEND

- GROUNDWATER MONITORING WELL
- WATER
- GROUNDWATER CONTOUR, FEET MSL
- INFERRED
- 15.23 WATER LEVEL, FEET MSL
- NM NOT MEASURED
- * LEVEL WAS NOT CONSISTENT WITH SURROUNDING LEVELS AND WAS NOT USED FOR CONTOURING.

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

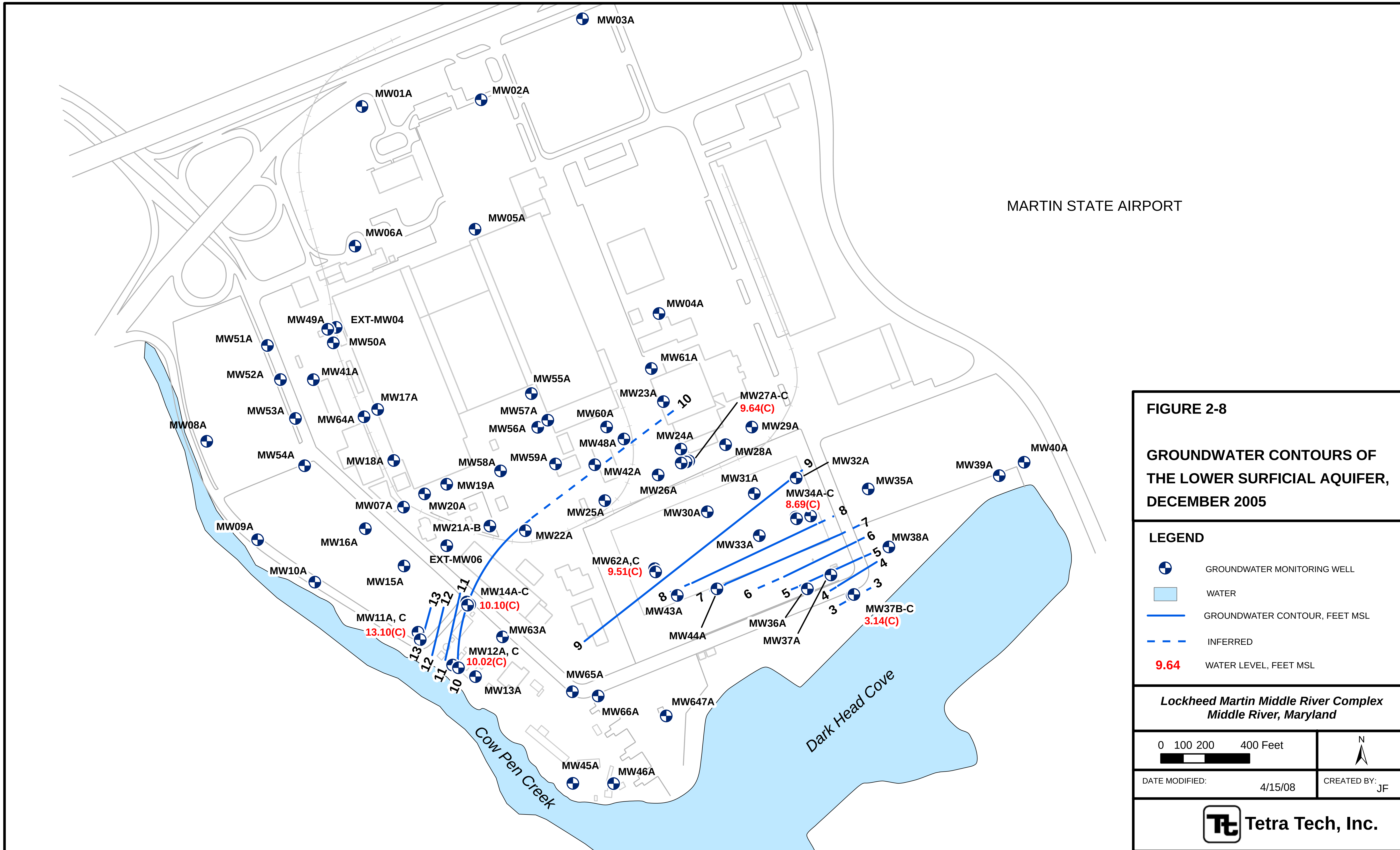
N

DATE MODIFIED: 3/27/07

CREATED BY: LR

Tetra Tech, Inc.

K:\GProject\middle_river\Maps\Middle River GW Contours of Upper Surficial Aquifer_Tabloid.mxd



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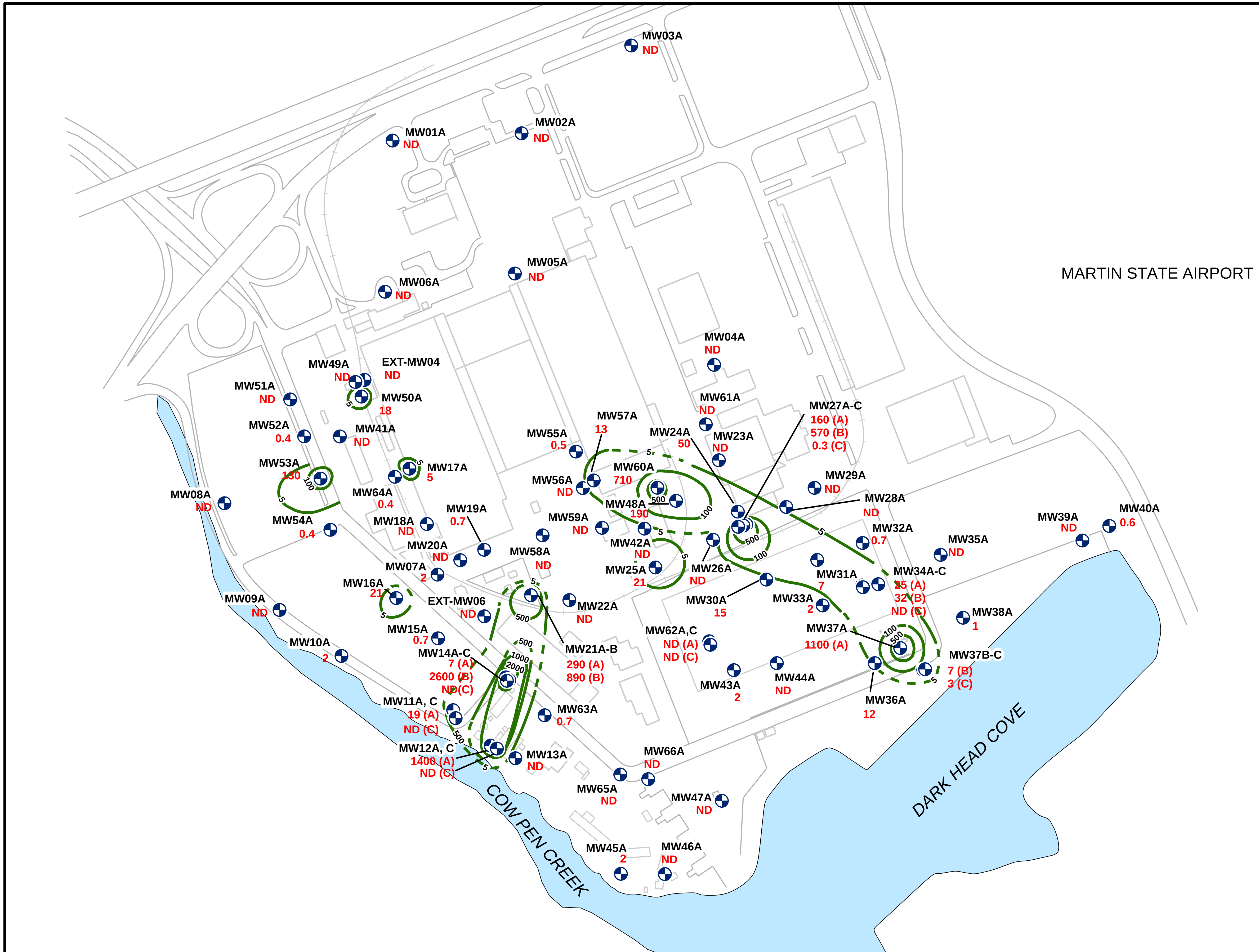


FIGURE 2-9

DISTRIBUTION OF TCE IN GROUNDWATER JUNE - NOVEMBER 2005

LEGEND

- GROUNDWATER MONITORING WELL
- WATER
- TCE ISOCONCENTRATION (ug/L)
- INFERRED
- 13 MAXIMUM TCE CONCENTRATION IN WELL (ug/L) JUNE-NOVEMBER 2005
- ND NOT DETECTED

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 4/15/08

CREATED BY: JF

Tetra Tech, Inc.

Map Document: (K:\GProject\middle_river\Maps\Middle River TCE Distribution in GW_June_Nov_2005.mxd) 4/15/2008 -- 10:09:00 AM

FIGURE 2-10

DISTRIBUTION OF BENZENE IN GROUNDWATER JUNE - NOVEMBER 2005

LEGEND

- GROUNDWATER MONITORING WELL
- WATER
- BENZENE ISOCONCENTRATION (ug/L)
- INFERRED
- 13 BENZENE CONCENTRATION IN WELL (ug/L) (JUNE-NOVEMBER 2005)
- ND NOT DETECTED

Lockheed Martin Middle River Complex Middle River, Maryland

0 100 200 400 Feet

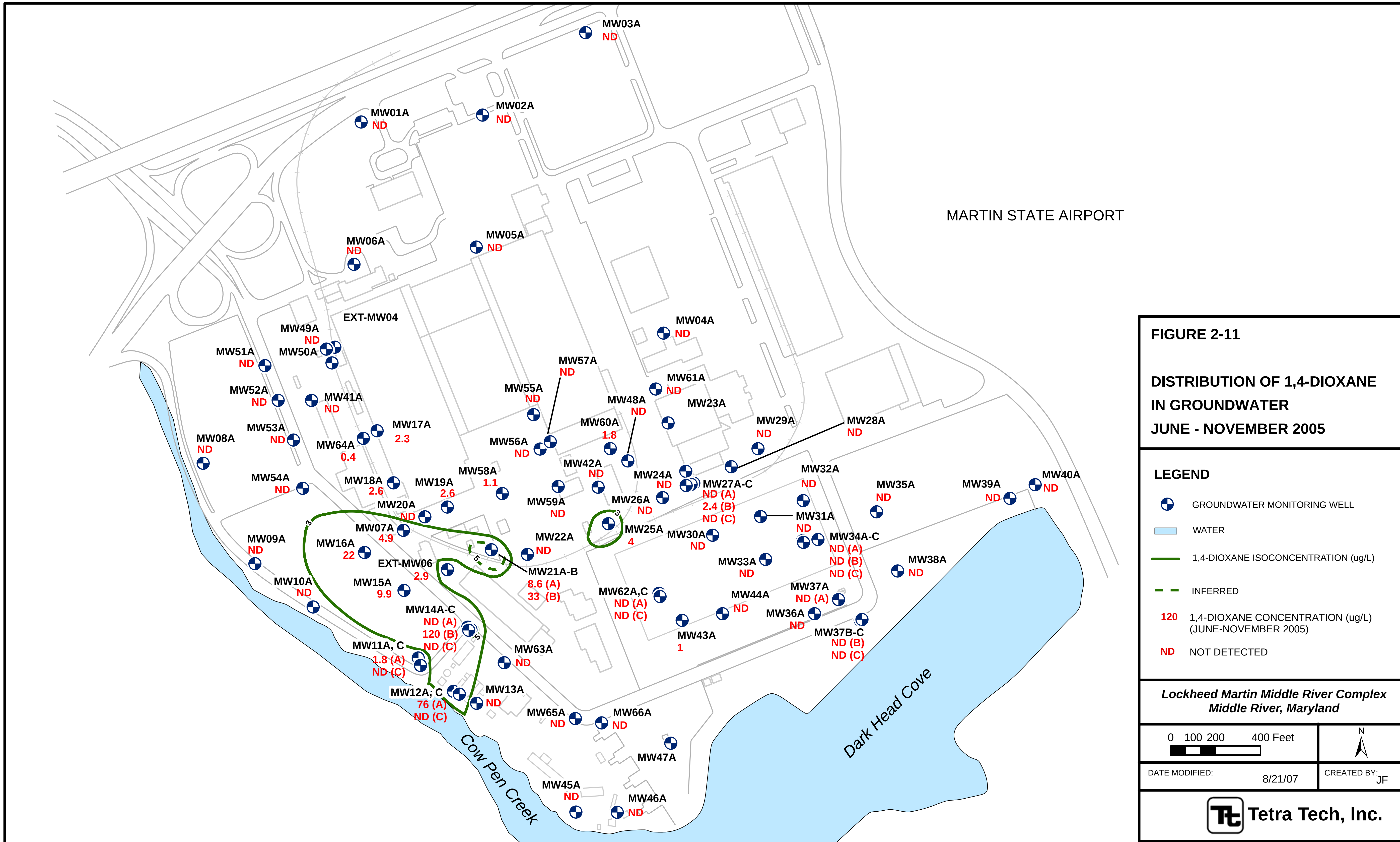
N

DATE MODIFIED: 4/15/08

CREATED BY: JF

Tetra Tech, Inc.

Map Document: (K:\GProject\middle_river\Maps\Middle River Benzene Distribution in GW_June_Nov_2005.mxd) 4/15/2008 -- 2:05:08 PM



Map Document: (K:\GProject\middle_river\Maps\Middle River Dioxane Distribution in GW_June_Nov_2005.mxd) 8/20/2007 -- 8:48:58 AM

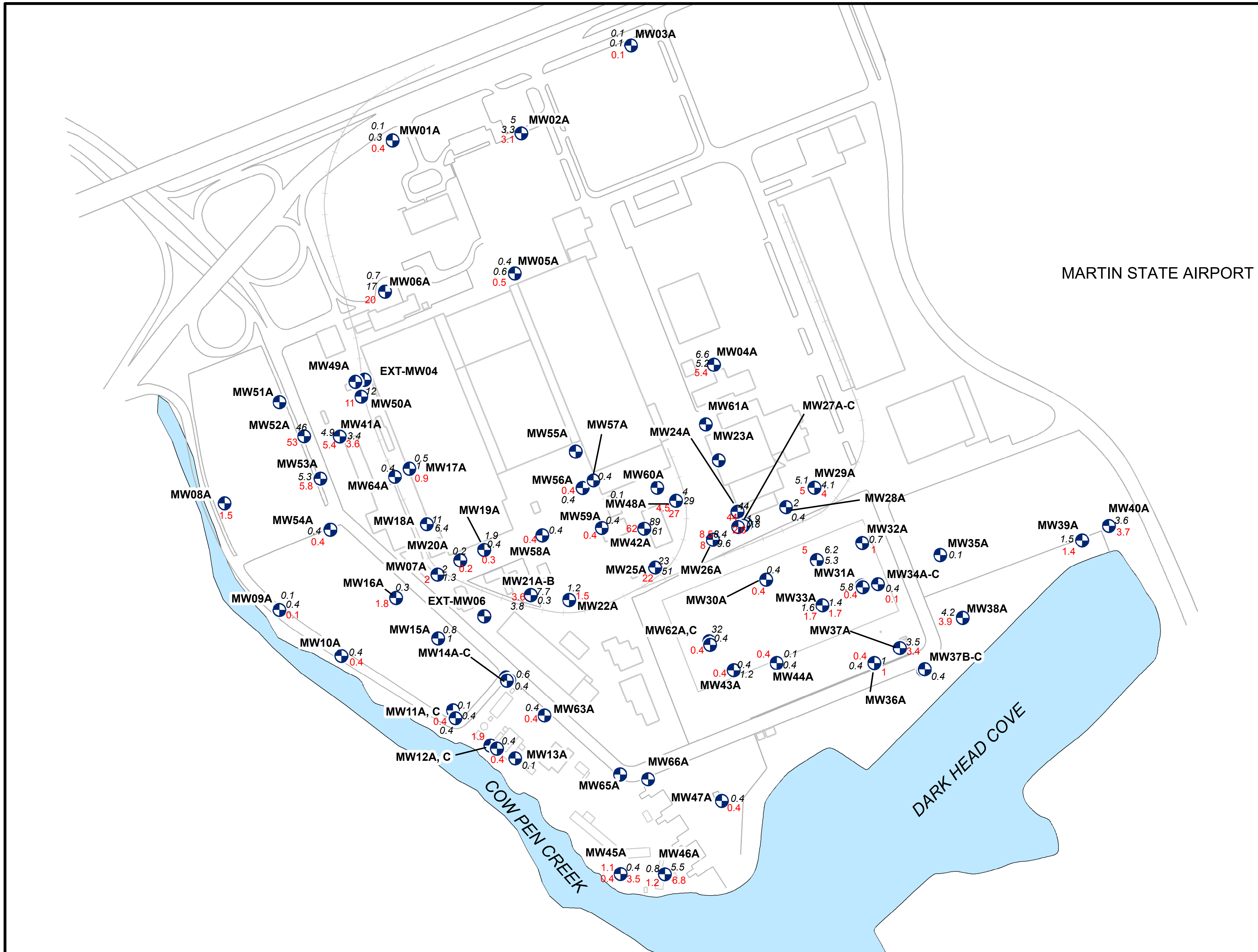


FIGURE 2-12

DISTRIBUTION OF BERYLLIUM IN GROUNDWATER
JUNE - NOVEMBER 2005

LEGEND

GROUNDWATER MONITORING WELL

WATER

13 BERYLLIUM CONCENTRATION (ug/L) UNFILTERED (RED LABELS)

13 BERYLLIUM CONCENTRATION (ug/L) FILTERED (BLACK LABELS)

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 6/5/07

CREATED BY: LR

Tetra Tech, Inc.

K:\GProject\middle_river\Maps\Middle River Beryllium Distribution in GW_June_Nov2005.mxd

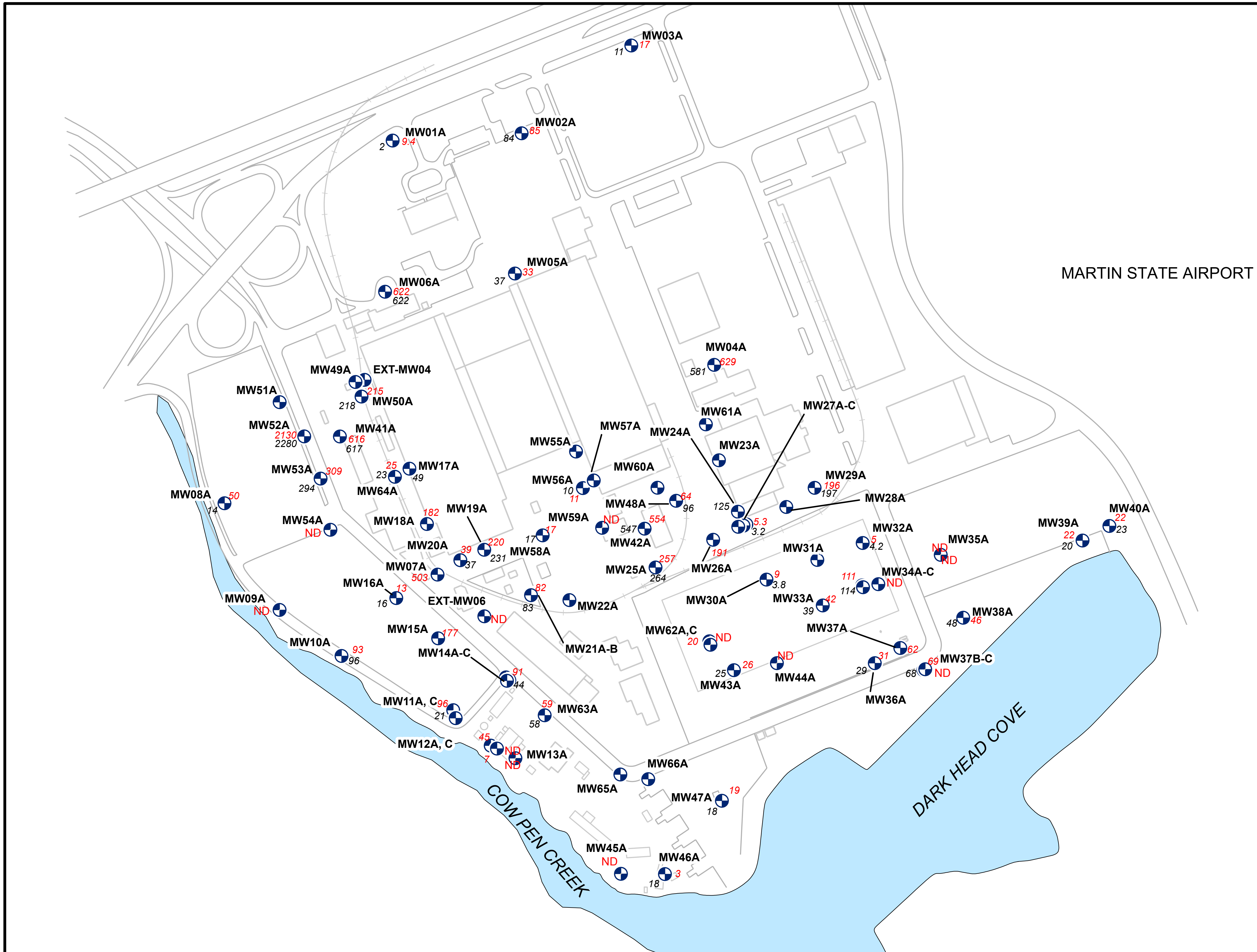


FIGURE 2-13

DISTRIBUTION OF COBALT IN GROUNDWATER JUNE - NOVEMBER 2005

LEGEND

- GROUNDWATER MONITORING WELL
- WATER
- 13 — COBALT CONCENTRATION (ug/L) UNFILTERED (RED LABELS)
- 13 — COBALT CONCENTRATION (ug/L) FILTERED (BLACK LABELS)
- ND — NON DETECTED

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 6/6/07

CREATED BY: LR

Tetra Tech, Inc.

K:\GProject\middle_river\Maps\Middle River COBALT Distribution in GW_June_Nov2005.mxd

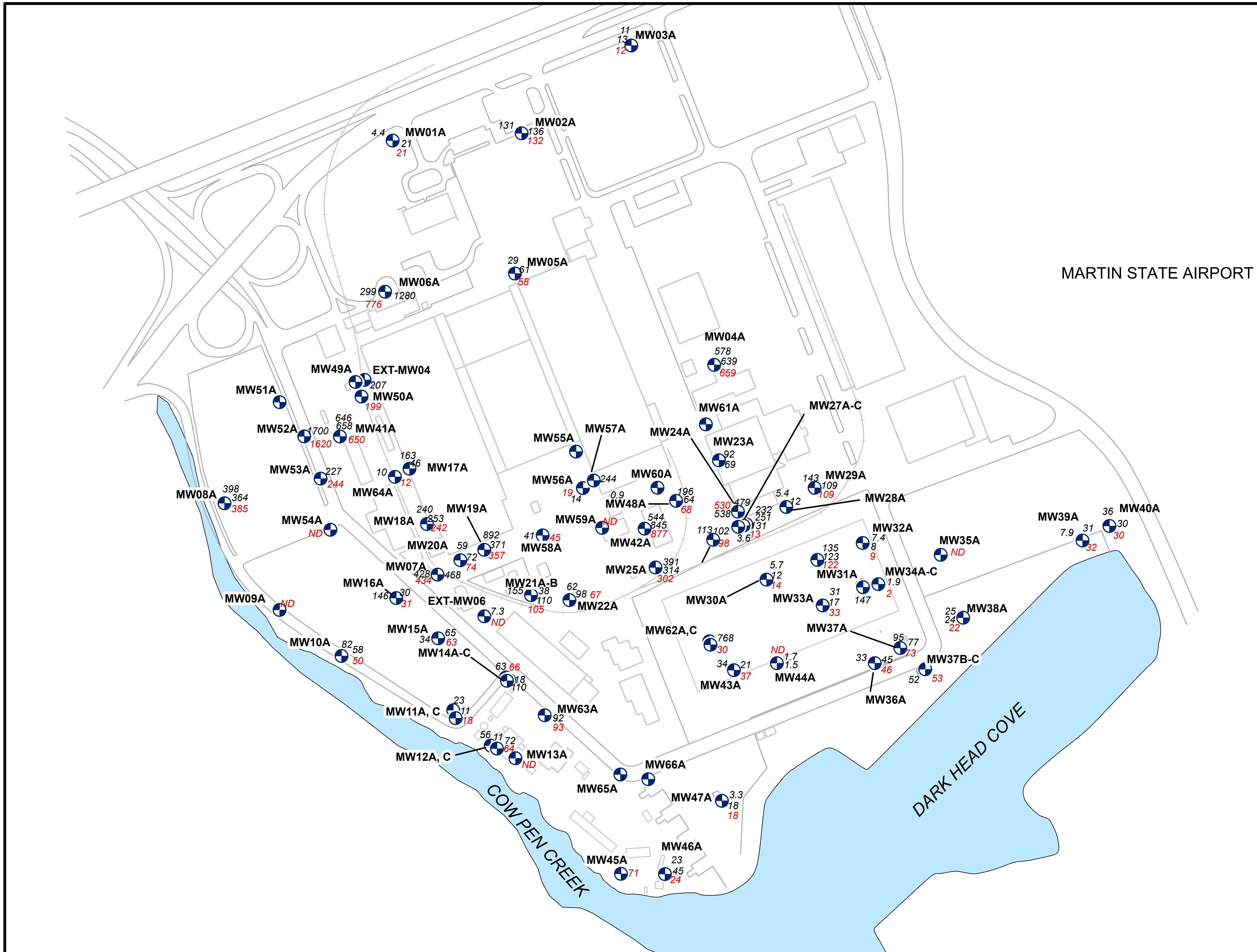


FIGURE 2-14

DISTRIBUTION OF NICKEL IN GROUNDWATER JUNE - NOVEMBER 2005

LEGEND

- GROUNDWATER MONITORING WELL
- WATER
- 13 — NICKEL CONCENTRATION (ug/L) UNFILTERED (RED LABELS)
- 13 — NICKEL CONCENTRATION (ug/L) FILTERED (BLACK LABELS)
- ND — NOT DETECTED

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 6/5/07

CREATED BY: LR

Tetra Tech, Inc.

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Section 3
Planned Additional Investigation

Additional characterization and bench- and pilot-scale testing will be required to confirm the efficacy of the proposed response actions and to determine important parameters required for design of the response actions. Testing will also be conducted to aid in determining whether metals in the site groundwater are naturally occurring. This section describes the activities proposed to complete the site investigation and to obtain sufficient hydrogeologic and engineering design information to develop and evaluate the groundwater response actions. Additional investigatory information to be obtained for soil media is detailed in the block-specific soil RAPs.

The proposed effort is designed to fill data gaps related to the known shallow TCE groundwater plumes and several isolated benzene plumes present in the surficial aquifer at the MRC, including verifying and delineating contaminant source areas and extent of the contamination; evaluating surficial aquifer groundwater flow properties (e.g., hydraulic gradients, variations in K values throughout the surficial aquifer, and the extent and magnitude of tidal influx); and evaluation of ex-situ and in-situ treatment technologies to address VOC and 1,4-dioxane concentrations greater than the screening-level cleanup goals, where present.

Prior to conducting field investigation activities, separate work plans for soil and groundwater investigations will be developed because the media are on different response action timelines. The elements of the groundwater work plan will include the proposed investigation strategy; investigation locations; sampling and analysis protocols; pump test, bench-scale test, and field pilot-scale treatability study protocols; data evaluation; reporting; and detailed project schedule and organizational chart. The initial groundwater work plan will contain a conceptual field pilot-scale treatability study protocol. After completion of the bench-scale studies, a supplemental work plan will be submitted that includes greater detail about the field pilot studies. In addition, the existing health and safety plan will be updated to address all aspects of the additional activities including site access control, emergency response, and hazard communications.

Planned field and bench-scale testing is described below. Prior to conducting these activities, work plans (one for bench-scale testing and one for pilot-scale testing) will be developed.

MIP/Geoprobe tm Investigation and Monitoring Well Installation

Monitoring wells will be installed to fill data gaps associated with the known TCE and benzene plumes. In addition, isolated areas of VOCs (at well locations MW16A and MW53A) will also be characterized. To provide a rapid real-time, cost-effective and detailed vadose and saturated zone vertical characterization and to determine permanent monitoring well locations, an initial screening step will be conducted. The screening step will employ membrane interface probe (MIP) characterization of the higher concentration areas of the TCE and benzene plumes and Geoprobetm characterization using Color-tec screening of soils and groundwater in areas of lower concentrations. These technologies will also be used to "map" the architecture of the source areas in the subsurface, particularly in the eastern TCE plume and will include both the lower and higher permeability zones. In the western plume where pump and treatment is anticipated based on the presence of 1,4-dioxane, these screening data are not as important at this time.

Following the screening-level characterization, permanent groundwater monitoring wells will be installed. The well installation program is projected to include the installation of approximately 12 "A" level wells (to approximately 20 feet bgs) and approximately 12 "B" level wells (to approximately 35 feet bgs). Drilling is assumed to be conducted by hollow stem auger drilling. Based on the MIP screening data, this number of wells may be modified. Depending on the results of this characterization, additional wells may be needed in the future to fully delineate all plumes.

Well Gauging and Sampling

One synoptic round of water levels will be collected from all new (24) and existing (80) wells coincident with well sampling. The water level data will provide information on groundwater flow characteristics and will be utilized to update groundwater contour maps. A 24-hour tidal study will be conducted during a spring tide event by monitoring water levels from a minimum of five wells and a staff gauge in adjacent surface water bodies to determine the extent and magnitude of tidal influx on the aquifer system. It is projected that the 24 new wells and the 80 existing wells will be sampled for VOCs, metals, and 1,4-dioxane. A subset of wells from each plume (20 wells in total) will also be sampled for additional geochemical parameters to assist in remedial design.

Groundwater Pump Tests

Four groundwater pump tests will be conducted, two each in the western and eastern TCE plumes, to evaluate the hydraulic conductivity of the surficial aquifers and the feasibility of groundwater pumping as a source treatment and/or containment remedy for the two major plumes. These plume areas provide the greatest density of wells for determination of capture zone.

For each of the tests, transducers will be placed in at least four nearby wells, at various depths, to collect continuous groundwater level data. A step test will then be conducted to determine the approximate sustainable flow rate. Following the step test, the pump will be operated at a constant flow rate for a period of 72 hours from a pumping well in the lower aquifer (B Zone). The second 72-hour constant flow rate test in the upper portion of the aquifer (A Zone) will be conducted as soon as possible after the completion of the first aquifer test. During this period, water level measurements will be continuously logged, groundwater flow rate will be monitored, and water samples will be collected for analysis of VOCs, 1,4-dioxane, and metals. Following shut down of the pump, recharge of the wells will be monitored for a period of 24 hours after each test.

These data will be analyzed to determine the feasibility and hydraulic design parameters (e.g., aquifer hydraulic conductivity, transmissivity, specific yield, and sustained pumping rates) of groundwater extraction at the site. These data will facilitate well design and spacing, system flow rates, and appropriate groundwater treatment technologies.

Based on capture zone analysis performed using available slug test data, it is assumed that the groundwater will be recovered at a sustainable flow rate of up to 1.0 gpm, leading to a total recovery of approximately 9,000 gallons over the course of the pumping tests.

Single-well permeability tests will also be conducted at up to 24 wells to provide hydraulic conductivity information for a variety of different soil matrices throughout MRC.

Bench-Scale Tests

To determine technologies that could treat groundwater either ex-situ or in-situ, contaminated groundwater recovered from the pump test will be tested via bench-scale testing. At this time, it is assumed that an ex-situ peroxide/ozone addition system will be tested for removal of VOCs and 1,4-dioxane. The results of the testing will be used to determine the feasibility of different treatment methods and design parameters such as residence time and chemical dosing.

Concurrently, more rigorous bench-scale testing will be conducted to determine which in-situ technologies will be applicable for the destruction of VOCs, and if these technologies are applicable for source reduction strategies. These tests will also determine the effect of these technologies on the concentrations of cobalt, nickel, and beryllium; this may effect the treatment of these metals, if proposed in the RAP Addendum, in areas proposed to be treated via ARD and outside these areas. Also, promising new technologies for in-situ 1,4-dioxane treatment (including co-metabolic biodegradation and in-situ chemical oxidation) may also be investigated. Bench-scale tests will be run on site soil and groundwater; for each technology, the tests will be designed to determine how successful the technology is in reducing soil and groundwater concentrations for the target constituents, and if successful, the dosing and residence time required for success. The following technologies are among those considered for testing:

- Chemical oxidation – via Fenton's-like reaction and/or peroxide and ozone.
- Enhanced anaerobic and/or co-metabolic biodegradation – via several potential substrates.
- Abiotic treatment utilizing zero-valent iron (ZVI) – via micro-scale and/or nanoscale ZVI.

The results of the tests will be utilized to determine if in-situ treatment is technically feasible at the MRC. If feasible, the tests will also provide the appropriate design parameters.

Additional bench-scale testing will be conducted to determine the leachability of metals from site soils at various pH levels. Testing will be conducted on soil from areas associated with site industrial operations and from "background" areas located away from these activities. The data from this testing will be used to aid in the determination as to whether the metals concentrations in the groundwater are naturally occurring. Detailed bench-scale testing methodology will be included in the Remedial Design Studies Work Plan.

In-Situ Remediation Pilot Study

The preferred technology(ies) selected from the bench-scale testing will be evaluated via in-situ remediation pilot studies in the field at MRC. The selected technology(ies) will be tested as a source reduction technology. The results of the tests will be utilized to determine if in-situ treatment is technically feasible in various areas of the site; testing may be completed in both the eastern and western TCE plumes. The tests will also provide the appropriate design parameters.

This task will include the installation of injection and monitoring wells, implementation of the technologies, performance monitoring, and reporting. The testing sites will be located in the vicinity of existing wells to: (1) utilize the historical data from those wells and (2) minimize cost. Up to six “A” level injection and monitoring wells (to depths of 20 feet bgs) and six “B” level wells (to depths of 35 feet bgs) will be installed. Liquid or gaseous amendments will be injected into the subsurface from up to six injection locations. Five rounds of groundwater sampling (one baseline and four performance monitoring rounds) over the course of one year will be performed at up to twelve total new and four existing wells in the pilot testing area (a maximum of 16 wells total per event). Groundwater from these wells will be analyzed for VOCs, 1,4-dioxane, metals, and geochemistry/natural attenuation parameters. Data obtained from the sampling will be used to determine the efficacy of the tested technology(ies) and obtain design parameters for in-situ treatment; the conclusions from the testing will be utilized to prepare the RAP Addendum.

Following completion of the tasks detailed above, a RAP Addendum will be prepared that summarizes the results of the testing, provides recommendations on any changes in the response actions proposed in this RAP, and provides the design basis for the chosen response actions.

More information on how the additional investigatory information will be used to support the response actions is presented in Section 8.0.

Section 4
Exposure Assessment

4.1 INTRODUCTION

The exposure assessment presents the current and future land use as defined by the VCP land use definitions and CSM, which includes potentially exposed populations based on future land use and potential exposure pathways.

4.2 CURRENT AND FUTURE LAND USE

The VCP requires applicants to choose a land use and restriction category based on the planned future use of the property. A No Further Requirements Determination or Certificate of Completion issued for a property is contingent on future use of the property as defined by the VCP.

Currently, the MRC is considered to be "Tier 3 Industrial." The VCP defines this land use category as follows:

> Industrial property to be used by workers over the age of 18, adult workers and construction workers, and other potential expected users. Industrial purposes allow access to the property at a frequency and duration consistent with a typical business day.

Groundwater is not currently used by any receptors.

This RAP is evaluating groundwater at the MRC in terms of what would be required to achieve a "Tier 1 Residential Unrestricted" land use and restriction category. However, the final land use/restriction category and cleanup goals for groundwater at MRC will be defined in the RAP Addendum to be submitted following the completion of the additional investigation outlined in Section 3. The VCP defines this land use and restriction category as follows:

> Property usage that allows exposure and access by all populations including infant, children, elderly, and infirmed populations. The "A (Unrestricted)" classification indicates that no LUCs are imposed on the property. Tier 1A properties typically include single-family and multi-family dwellings.

Although LUCs would not be required if the Tier 1A classification were met, the remediation of groundwater to potable use standards would require an extended period of time; therefore, LUCs would be anticipated to be required on an interim basis.

4.3 CONCEPTUAL SITE MODEL

An HHRA for groundwater at the MRC was conducted as part of the Site Characterization Report (Tetra Tech, May 2006). The HHRA postulates human activities that result in exposure to contaminants in groundwater. The CSM includes individuals who either live at (residents) or develop (construction workers) MRC and engage in activities that result in exposure via incidental ingestion of groundwater, skin contact resulting in dermal absorption of COPCs in groundwater, and inhalation of vapors from groundwater.

Section 5
Cleanup Criteria

5.1 CLEANUP CRITERIA

Development of cleanup goals must be conducted to satisfy the requirements of the VCP and be consistent with the requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Part 400.430 as implemented through the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The VCP defines a need for remedial action at sites with a cancer risk of 1 x 10^{-5} or a hazard index of 1.0. In this case, because this RAP is evaluating remedial actions based on a Tier I (Residential Unrestricted) criteria, if groundwater concentrations of target organic analytes exceed the MDE Generic Numeric Cleanup Standards for Groundwater, then groundwater remediation is considered. The final cleanup criteria for organic and inorganic compounds will be established in the RAP Addendum.

5.2 SCREENING-LEVEL CLEANUP GOALS

Organics

The screening-level cleanup goals for organics in groundwater at MRC are defined by the MDE Generic Numeric Cleanup Standards for Groundwater. Therefore, for the purposes of this RAP, the COCs for the MRC include constituents for which groundwater concentrations exceed the MDE Generic Numeric Cleanup Standards. A list of organic compounds that were detected in exceedance of the MDE Generic Numeric Cleanup Standards, and their respective cleanup standards, are presented below. Final cleanup goals will be presented in the RAP Addendum.

Organic Compound	**MDE** Generic Numeric **Groundwater Standard (µg/L)** [(1)]
TCE	5
Benzene	5
Carbon Tetrachloride	5
Chlorobenzene	11
Chloroethane	3.6
Chloroform	80
Chloromethane	2.1
cis-1,2-Dichloroethene	70
MTBE	20
Naphthalene	10
Tetrachloroethene	5
Total Petroleum Hydrocarbons – Gasoline Range Organics	47
Trans-1,2-Dichloroethene	100
Vinyl Chloride	2
1,4-Dioxane	3[(2)]

1. These standards are taken from "Cleanup Standards for Soil and Groundwater" (MDE, August 2001).
2. There is currently no MDE cleanup standard for 1,4-dioxane. For the purposes of this RAP, it is assumed that the MDE will adopt the advisory action level used by the California Department of Health Services (3 µg/L) as its groundwater standard for 1,4-dioxane.

Inorganics

As stated in Section 2.2.3.5.3, an initial screening of metals concentrations against the MDE Generic Numeric Cleanup Standards for Groundwater indicated a significant number of exceedances of beryllium, cobalt, and nickel, sporadic exceedances of zinc, and one exceedance each for antimony, thallium, and vanadium.

A brief discussion of the potential sources of these concentrations is presented below. A more complete discussion, based on additional data, will be included in the RAP Addendum. The RAP Addendum will also include cleanup goals for the inorganic compounds.

For antimony and thallium, the wells with exceedances are located on the extreme west (thallium) and south (antimony) of the site. These areas are over a 1,000 feet from any site operations with no other exceedances present at the site. Therefore, these concentrations are not believed to be derived from site operations and are considered background.

There are three primary lines of evidence to support using a background concentration as the cleanup goal for beryllium, cobalt, and nickel at this site:

- As discussed in Section 2.2.3.5.3, the concentrations present at MW06A, located a significant distance upgradient of the site operations and within Block A (which has no environmental concerns) are among the highest at the site, with only one other site well exceeding this value for nickel, three other site wells exceeding this value for cobalt, and four other site wells exceeding the value for beryllium. Wells located much closer to site operations exhibit significantly lower concentrations.

- The groundwater at MW03A, located substantially further upgradient of site operations than MW06A and upgradient of all of MRC, also contains concentrations of beryllium, nickel, and cobalt above the MDE standards. This provides additional evidence that MDE Generic Numeric Cleanup Standards for Groundwater for the metals are less than concentrations exhibited outside the influence of site operations.

- The exceedances of MDE standards are present throughout the site and are highly correlated with the presence of low groundwater pH. This indicates that the pH of the groundwater may be a more important factor than location of the well with respect to site operations when determining the location of exceedances. Because low groundwater pH is believed to be primarily a factor of natural groundwater conditions, this leads to the conclusion that a large factor in the exceedances is natural (i.e., background) conditions. The correlation of pH and exceedances of MDE standards for beryllium, cobalt, and nickel are shown in Figures 5-1, 5-2, and 5-3, respectively. These figures compare the metal concentrations versus pH for a subset of the site wells which contain high and low pH, high and low metals concentrations, and are distributed throughout the areal extent of the site. An analysis of the figures shows:

    - Beryllium - For groundwater with a pH of less than 5.5, only 2 of 14 samples (14 percent) are below the MDE standard; for groundwater with a pH greater than 5.5, 12 of 13 samples (92 percent) are below the standard.

    - Cobalt - For groundwater with a pH of less than 5.5, only 5 of 14 samples (36 percent) are below the MDE standard; for groundwater with a pH greater than 5.5, 11 of 13 samples (85 percent) are below the standard.

- For groundwater with a pH of less than 5.5, only 3 of 14 samples (21 percent) are below the MDE standard; for groundwater with a pH greater than 5.5, 11 of 13 samples (85 percent) are below the standard.

Based on a more complete analysis of existing and new data, cleanup goals for metals will be presented in the RAP Addendum.

5.3 ATTAINMENT OF CLEANUP GOALS

This RAP evaluates remedial alternatives based on achieving Tier I (Residential Unrestricted) conditions for organics in groundwater at MRC; therefore, it is considered that groundwater may be remediated to the screening-level cleanup goals presented above. Cleanup goals for inorganics have not yet been established; therefore, treatment of groundwater for inorganics to meet a cleanup goal is not addressed in this RAP.

Figure 5-1
Beryllium vs pH in MRC Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

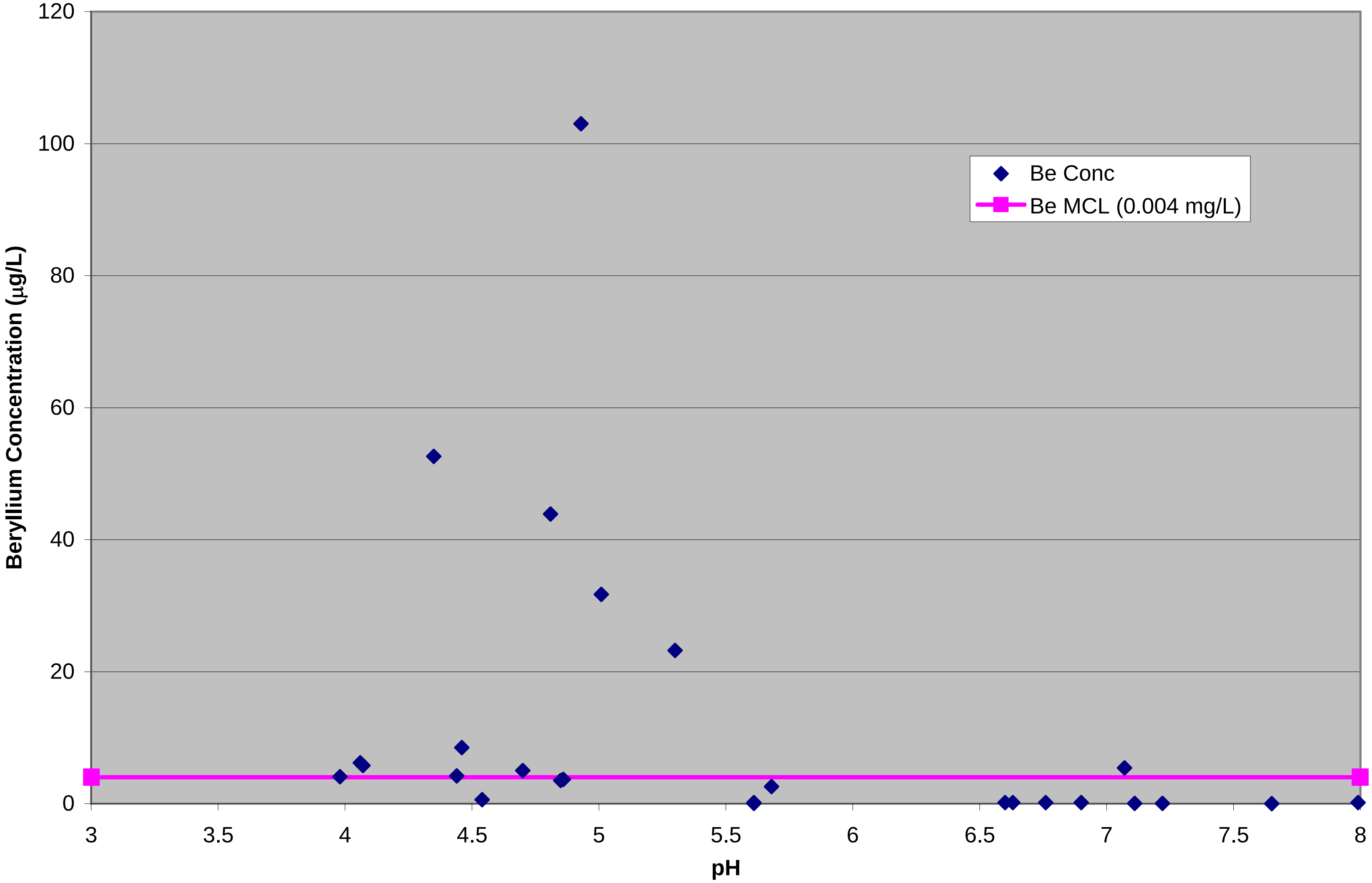


Figure 5-2
Cobalt vs pH in MRC Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland

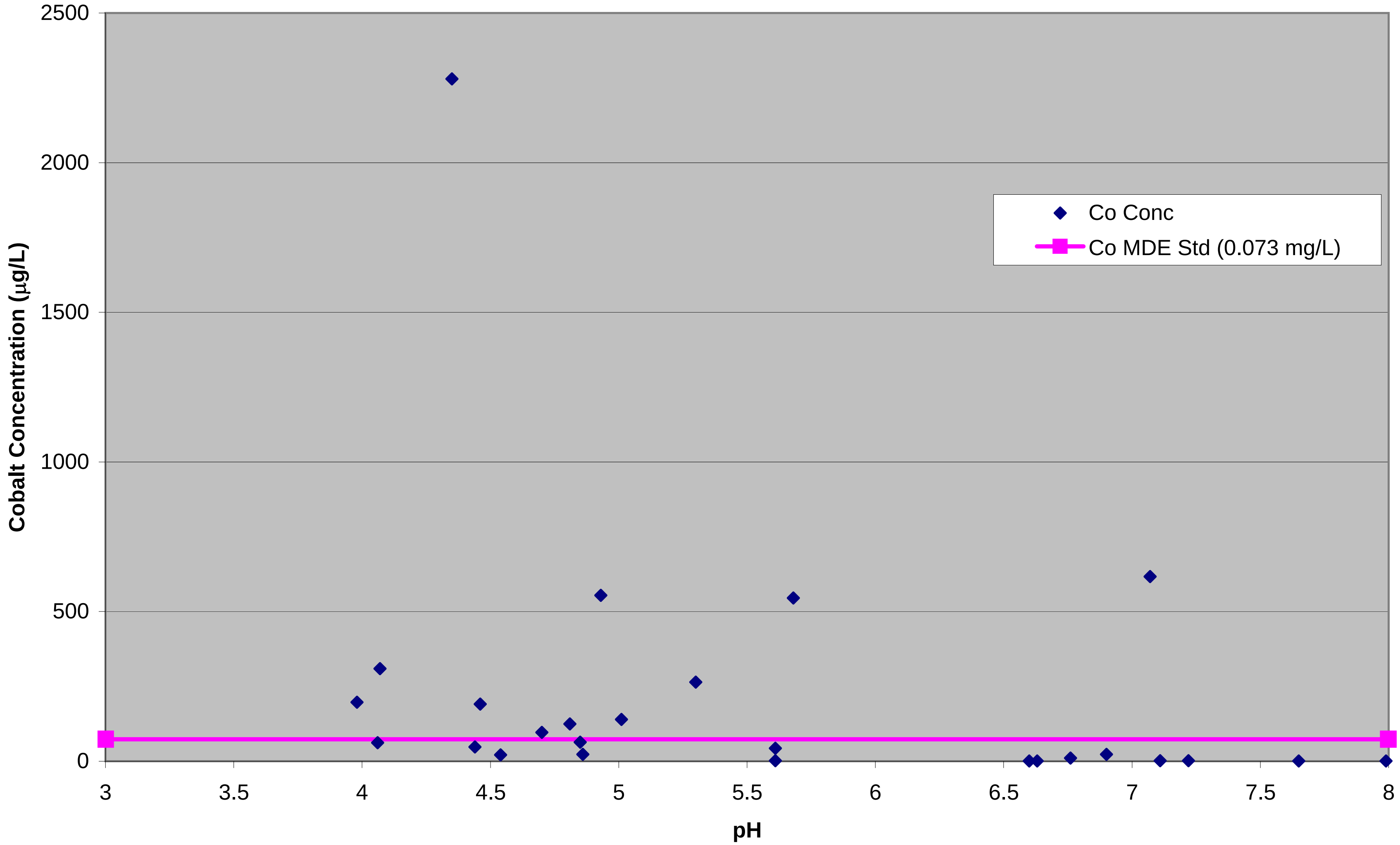
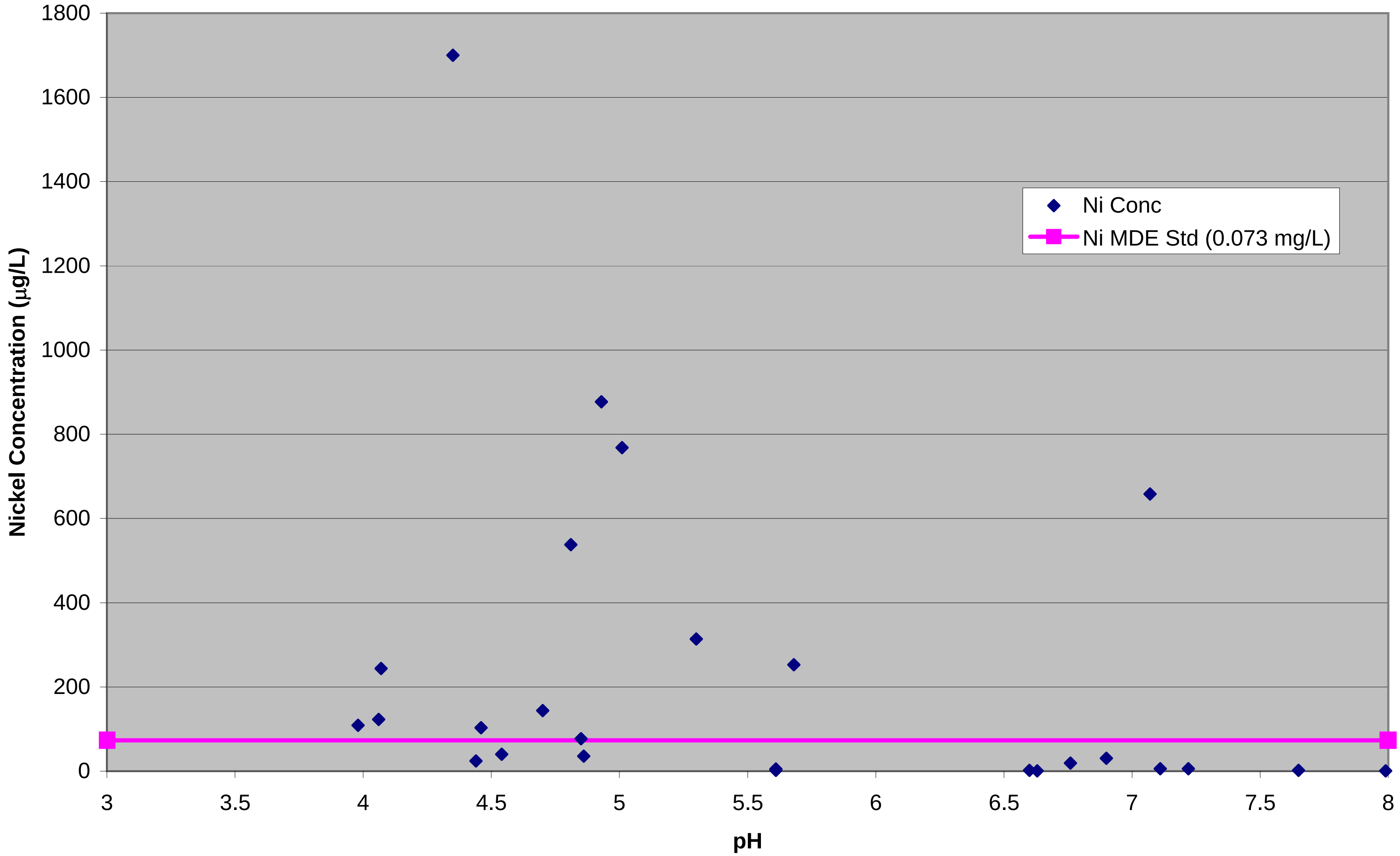


Figure 5-3
Nickel vs pH in MRC Groundwater
Lockheed Martin Middle River Complex, Middle River, Maryland



Section 6
Selected Technologies and Land Use Controls

6.1 INTRODUCTION

The selected technologies and LUCs for the proposed groundwater response actions are provided in this section as required by the VCP guidance document. The NCP, 40 CFR Part 400.430, as implemented through CERCLA, served as a guide for the process used to arrive at the selected technologies (i.e., selected alternative). This section includes the identification, screening, and evaluation of potential technologies and process options; preliminary and detailed screening of technologies and process options; selection of representative process options; development and detailed analysis of alternatives; comparative analysis of alternatives; and description of the proposed alternative.

The basis for technology identification and screening included the following:

- Development of response action objectives (RAOs)
- Identification of Applicable or Relevant and Appropriate Requirements (ARARs)
- Identification of COCs
- Development of screening-level cleanup goals
- Identification of general response actions (GRAs)
- Identification of volumes or areas of the medium of concern

6.1.1 Response Action Objectives

The purpose of this section is to develop RAOs for groundwater at the MRC. Development of RAOs is an important step in the CERCLA process. RAOs are medium-specific goals that define the objective of conducting response actions to protect human health and the environment. The

RAOs specify the COCs, potential exposure routes and receptors, and acceptable contaminant levels for the site. The development of RAOs takes into consideration ARARs and To Be Considered (TBC) criteria.

This RAP addresses groundwater contamination at the MRC. The RAOs were developed to permit consideration of a range of treatment and containment alternatives to meet the screening-level cleanup goals presented in Section 5..

The following RAO was developed for the groundwater at MRC:

- Prevent unacceptable human health risk associated with exposure to groundwater at concentrations greater than the cleanup goals.

6.1.2 Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria

The ARARs presented in this RAP are based on the screening-level cleanup goals for organic contaminants presented in Section 5 (Generic Numeric Cleanup Standards for Groundwater); modification to these ARARs based on any subsequent change in cleanup goals will be addressed in the RAP Addendum.

ARARs consist of the following:

- Any standard, requirement, criterion, or limitation under federal environmental law.
- Any promulgated standard, requirement, criterion, or limitation under a state environmental or facility-siting law that is more stringent than the associated federal standard, requirement, criterion, or limitation.

TBC criteria are nonpromulgated, nonenforceable guidelines or criteria that may be useful for developing a response action or are necessary for determining what is protective of human health and/or the environment. Examples of TBC criteria include EPA's Drinking Water Health Advisories, Reference Doses (RfDs), Cancer Slope Factors (CSFs), and certain MDE standards.

One of the primary concerns during the development of response action alternatives for hazardous waste sites is the degree of human health and environmental protection offered by a given remedy. Section 121 of CERCLA requires that primary consideration be given to response alternatives that attain or exceed ARARs. The purpose of this requirement is to make CERCLA response actions consistent with other pertinent federal and state environmental requirements.

The NCP identifies the following three categories of ARARs [40 CFR Section 300.400 (g)]:

- Chemical-Specific: Health-risk-based numerical values or methodologies that establish concentration or discharge limits for particular contaminants. Examples include MCLs and Clean Water Act (CWA) Ambient Water Quality Criteria (AWQCs). Table 6-1 presents a list of federal and State of Maryland chemical-specific ARARs and TBC criteria. These ARARs and TBC criteria provide some medium-specific guidance on "acceptable" or "permissible" concentrations of contaminants.

- Location-Specific: Restrict actions or contaminant concentrations in certain environmentally sensitive areas. Examples of these areas regulated under various federal laws include floodplains, wetlands, and locations where endangered species or historically significant cultural resources are present. Table 6-2 presents a list of federal and State of Maryland location-specific ARARs and TBC criteria. These ARARs and TBC criteria place restrictions on concentrations of contaminants or the conduct of activities solely based on the site's particular characteristics or location.

- Action-Specific: Technology- or activity-based requirements, limitations on actions, or conditions involving special substances that control or restrict response action. Examples of action-specific ARARs include wastewater discharge standards and performance or design standards, controls, or restrictions on particular types of activities. Table 6-3 presents a list of federal and State of Maryland action-specific ARARs and TBCs.

6.1.3 Chemicals Of Concern

The COCs in groundwater at the MRC are those contaminants detected at concentrations that exceed the screening-level cleanup goals. The COCs are listed in Section 5.2.

6.1.4 Cleanup Goals

Cleanup goals are chemical concentrations in environmental media that, when attained, should achieve RAOs. In general, cleanup goals are established with consideration to the following:

- Protecting human receptors from adverse health effects
- Compliance with federal and State ARARs
- Background concentrations of the COCs in groundwater

Screening-level groundwater cleanup goals were determined for the COCs in Section 5.2, and attainment of the cleanup goals was discussed in Section 5.3.

6.1.5 General Response Actions

GRAs are broadly defined response approaches that may be used (by themselves or in combination with one or more of the others) to attain RAOs. GRAs describe categories of actions that could be implemented to satisfy or address a component of an RAO for the site. Response action alternatives will then be developed using GRAs individually or in combination to meet the RAOs. The response action alternatives will be capable of achieving the RAOs for contaminated groundwater at the MRC.

The following GRAs were considered for groundwater at the MRC:

- No Action
- Limited Action: LUCs and Monitored Natural Attenuation
- Collection
- Ex-Situ Treatment
- Disposal
- In-Situ Treatment

6.1.6 Estimated Volume of Contaminated Groundwater

Preliminary areas and volumes of groundwater with contaminant concentrations greater than screening-level cleanup goals were calculated based on the most recent groundwater sampling data. The calculated areas and volumes for each groundwater plume are presented below. Note that the volumes shown in the table assume a 30 percent porosity in the soils. These areas/volumes will be refined based on the data collected as described in Section 3.0.

Plume	Approximate Area (square feet)	Approximate Thickness (feet)	Volume (cubic feet)
Building A – Northwest	8,600	14	36,120
REC #8, Vertical Assembly Building	33,000	14	138,600
Building A – West	5,000	14	21,000
Western TCE Plume	135,000	29	1,174,500
Eastern TCE Plume	325,000	14	1,365,000
Other TCE Areas	18,000	14	75,600
Total	**524,600**	--	**2,821,820**

6.2 SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

This section identifies, screens, and evaluates potential technologies and process options that may be applicable to develop response action alternatives for groundwater at the MRC. The primary objective of this phase of the RAP is to develop an appropriate range of technologies and process options that will be used for developing response action alternatives.

Technology screening evaluation is performed in this section with the completion of the following analytical steps:

- Identification and preliminary screening of technologies and process options.
- Detailed screening of technologies and process options that pass the preliminary screening step.
- Evaluation and selection of representative process options.

In this section, a variety of technologies and process options are identified under each GRA (Section 6.1.5) and screened. The selection of technologies and process options for initial screening is based on the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA, October 1988). The screening is first conducted at a preliminary level to focus on relevant technologies and process options, then the screening is conducted at a more detailed level based on certain evaluation criteria. Finally, process options are selected to represent technologies that have passed the screening and detailed evaluation.

The evaluation criteria for detailed screening of technologies and process options that have been retained after the preliminary screening are effectiveness, implementability, and cost. The following are descriptions of these evaluation criteria:

- Effectiveness
  - Protection of human health and environment; reduction in toxicity, mobility, or volume; and permanence of solution.
  - Ability of the technology to address the estimated areas or volumes of contaminated media.
  - Ability of the technology to meet the cleanup goals identified in the RAOs.
  - Technical reliability (innovative versus proven) with respect to contaminants and site conditions.

- Implementability
  - Overall technical feasibility at the site.
  - Availability of vendors, mobile units, storage and disposal services, etc.
  - Administrative feasibility.
  - Special long-term maintenance and operation requirements.

- Cost (Qualitative)
  - Capital cost.
  - Operation and maintenance (O&M) costs.

Technologies and process options will be identified for the groundwater response actions in the following sections.

Section 6.3 discusses the development of the response action alternatives developed from the process options retained in this section and provides a description of the conceptual design for these alternatives. This section also presents an evaluation of each response action alternative with respect to the criteria of the NCP of 40 CFR Part 300. These criteria and their relative importance are also discussed in this Section 6.3.

Section 6.4 compares the analyses presented for each of the response action alternatives. The criteria for comparison are identical to those used for the detailed analysis of individual alternatives.

6.2.1 Preliminary Screening of Technologies and Process Options

This section identifies and screens technologies and process options for groundwater at a preliminary stage based on implementation with respect to site conditions and COCs. Table 6-4 summarizes the preliminary screening of technologies and process options applicable to groundwater at the MRC. This table presents the GRAs, identifies the technologies and process options, and provides a brief description of each process option followed by screening comments. The technologies and process options that pass this initial screening step were retained for detailed screening in Section 6.2.2.

The technologies and process options for groundwater response actions that will be retained for detailed screening are shown below.

General Response Action	Response Action Technology	Process Option
No Action	None	Not Applicable
Limited Action	LUCs	Administrative Controls (Temporary)
	Monitoring	Groundwater Sampling
Collection	Groundwater Pumping	Pumping from Wells
Ex-Situ Treatment	Chemical Treatment	Ozone/Peroxide Addition or Other Advanced Oxidation Process.
In-Situ Treatment	Chemical	Oxidation via Hydrogen Peroxide (or Other Oxidant) or Chemical Reduction using ZVI
	Biological	Anaerobic Reductive Dechlorination and/or Cometabolic Degradation
Disposal	Discharge to Publicly Owned Treatment Works (POTW)/ Surface Water (and sludge disposal, if required)	To be Determined

6.2.2 Detailed Screening of Groundwater Treatment Technologies and Process Options

This section identifies and develops the representative process options, through a detailed screening procedure, that will be used in the formulation of response action alternatives to accomplish the RAOs and meet the screening-level cleanup goals identified for groundwater in Section 5.

6.2.2.1 No Action

No Action consists of maintaining status quo at the MRC. As required under CERCLA, the No Action alternative is carried through to provide a baseline for comparison of alternatives and their effectiveness in mitigating risks posed by site contaminants.

6.2.2.2 Limited Action

The technologies considered under this GRA are LUCs and monitoring.

Land Use Controls

During response action design, implementation, and a period of post-response action sampling, groundwater concentrations at the site would be greater than site cleanup goals. During this period, administrative LUCs would be utilized to prevent exposure to site groundwater. These LUCs would prohibit installation of wells for any purpose other than groundwater monitoring and would, if necessary, limit or specify engineering controls on the construction of buildings in areas where vapor intrusion may present unacceptable risk. These LUCs would be temporary and would be removed from individual areas of the MRC as cleanup progressed and concentrations were reduced to below the cleanup goals.

Effectiveness
LUCs would be an effective method to prevent exposure to groundwater if implemented correctly and inspected regularly.

Implementability
LUCs would be easily implemented.

Cost

Cost of implementing the LUCs would be low because it would be an administrative activity only.

Conclusion

LUCs are retained in combination with other process options for the development of response action alternatives.

Monitoring

During response action implementation, it would be necessary to establish a monitoring program to determine the effectiveness of the response action in addressing the entire areal extent and thickness of contamination, reducing COC concentrations, and creating conditions suitable for continued remediation. These data would be used to design contingent response action activities if necessary and determine when active remediation is complete. Following active remediation, monitoring would be necessary to track attenuation of the COCs.

Effectiveness

A long-term monitoring program would be effective in tracking response action efforts, determining when active remediation could be discontinued, and determining when site cleanup goals have been met.

Implementability

A monitoring program would be easily implemented.

Cost

Cost of implementing the monitoring program would be low to moderate. Cost would include sampling of a large number of wells for multiple parameters (VOCs, 1,4-dioxane, metals, and geochemical parameters) over a long period of time.

Conclusion

Monitoring is retained in combination with other process options for the development of response action alternatives.

6.2.2.3 Collection

The technology considered under this GRA is groundwater pumping. Groundwater would be pumped from a network of recovery wells located and designed to address the contaminated areas. Pump tests conducted prior to design would provide the basis for the design. The tests would determine the pumping rates and well spacing required to provide adequate capture of contaminated groundwater.

Effectiveness

Groundwater pumping would be effective in reducing groundwater migration to nearby surface water and, over the long term, in reducing groundwater COC concentrations to levels approaching the cleanup goals.

Implementability

Groundwater pumping is an established technology that has been implemented at a wide variety of sites. Therefore, it is assumed that it could be implemented with relative ease at the MRC. Complications could include designing the wells and underground piping to be compatible with future site uses and the fact that the system would need to operate for decades to meet the groundwater cleanup goals.

Cost

The cost for installation and operation of groundwater pumping would be moderate to high. The number of wells and piping lengths are relatively high, and long-term operation of the system would have significant cost.

Conclusion

Groundwater pumping is retained in combination with other process options for the development of response action alternatives.

6.2.2.4 Ex-Situ Treatment

The technology considered under this GRA is chemical treatment.

Chemical Treatment

Ex-situ chemical treatment would be used in conjunction with groundwater extraction. Chemical treatment would include injection of hydrogen peroxide and ozone into the recovered groundwater stream in a specially designed flow-through reactor. The combination of ozone and hydrogen peroxide would destroy the contaminants and produce the harmless by-products carbon dioxide and water. This proven technology has been shown to be effective for benzene, TCE, 1,4-dioxane and the other organic COCs listed in Section 5.

Additional chemical treatment such as pH adjustment, chemical precipitation, and flocculation may be necessary to treat the inorganic compounds in the groundwater. However, these technologies produce sludge requiring off-site disposal; other technologies, including Forager® sponge technology from Dynaphore, Inc., can also be tested to reduce the potential for incurring sludge disposal costs.

Effectiveness

With a proper design basis developed from data collected during future on-site testing activities (including groundwater concentrations and flow rate) and bench-scale testing, an effective chemical treatment system could be designed and installed at the MRC. This technology has been shown to reduce concentrations of these COCs to below discharge limits at sites nationwide.

Implementability

Implementing this technology would be moderately easy. The necessary data could be obtained during upcoming on-site activities. For treatment of both organics and inorganics, the product vendors could conduct bench-scale tests to determine the system design. The systems would come as an easy-to-install turn-key unit. The primary complications with implementing the technology are long-term operation, sludge handling (if necessary for metals treatment) and handling, storage, and use of hydrogen peroxide and ozone, which are potentially dangerous chemicals.

Cost

Cost of chemical treatment would be moderate. The package units are relatively inexpensive for the expected flow rates and concentrations. Long-term operation of the system, including labor, chemicals, and power, would comprise a substantial portion of the cost.

Conclusion

Ex-situ chemical treatment is retained in combination with other process options for the development of response action alternatives.

6.2.2.5 In-Situ Treatment

The technologies considered under this GRA are chemical and biological treatment.

Chemical Treatment

Several potential in-situ chemical treatment scenarios will be considered during the bench-scale testing. These include chemical oxidation via hydrogen peroxide and ozone, hydrogen peroxide, and/or activated persulfate . Although all of these options are potentially viable, for the purposes of this RAP, the in-situ chemical treatment most likely to be utilized is chemical oxidation via hydrogen peroxide for the benzene plumes.

Chemical treatment involves the injection of an oxidant into the aquifer with the intent of destroying site contaminants via chemical oxidation and producing the harmless by-products carbon dioxide and water. In this case, the target COC would be benzene and the most likely oxidant would be hydrogen peroxide. Bench- and pilot-scale testing would determine the effectiveness of hydrogen peroxide and the feasibility of injecting the liquid via direct push technology (DPT).

It is expected that multiple injection events throughout the plumes will be required to obtain the cleanup goals.

Effectiveness

In-situ chemical oxidation has been shown to be very effective in reducing contaminant concentrations at a wide variety of sites and is expected to be effective at MRC. As stated above, the effectiveness of a potential oxidant and delivery method would be confirmed prior to design of the response action. This technology would primarily be considered for areas of benzene contamination; however, bench- and pilot-scale testing for the treatment of TCE and 1,4-dioxane may show that this technology is appropriate for those COCs as well. This technology could be coupled with natural attenuation to provide effective remediation for a long period.

Implementability

The ease in implementing this technology would be largely determined during pilot-scale testing. Although it is expected to be effective, the low permeability soils at the MRC may not be suitable for direct injection of the oxidant via DPT. If direct injection does not provide an adequate radius of influence and/or contact with the contaminant, implementing the technology could be difficult. Alternative delivery systems such as pneumatic or hydraulic fracturing or groundwater recirculation may be necessary; if necessary, these processes would significantly complicate response action design and implementation.

Cost

Cost of in-situ chemical treatment would be relatively low if direct injection via DPT is feasible due to the small treatment volume as compared to the TCE plumes. If alternative forms of injection are required, the cost could increase significantly. Additionally, multiple injections would likely be required to reach the groundwater cleanup goals for benzene.

Conclusion

In-situ chemical treatment is retained in combination with other process options for the development of response action alternatives.

Biological Treatment

In this case, biological treatment would include injection of a substrate, pH buffering agent, and/or bioamendment into the subsurface to enhance natural biodegradation of the COCs. Specifically, ARD would be utilized to treat the portions of the site contaminated with only TCE and other chlorinated compounds noted in Section 5. The increased pH and reducing conditions would also lead to the precipitation of metals, thus reducing groundwater metal concentrations; this may be advantageous based on the groundwater cleanup levels for inorganics established in the RAP Addendum.

It should also be noted that aerobic co-metabolic biodegradation is being considered (and may be tested) for use in the areas containing 1,4-dioxane. The final decision on the technology to be used will be based on the testing; however, the RAP was prepared assuming that groundwater extraction will be utilized in those areas.

ARD is the primary biological degradation process by which chlorinated VOCs are transformed to innocuous compounds such as carbon dioxide, ethene, ethane, and chloride. In the presence of a suitable electron donor (e.g., hydrogen), the appropriate microbial consortia, and favorable geochemical conditions, a hydrogen atom can replace a chlorine atom on a chlorinated ethene molecule. Hydrogen is typically generated when organic carbon is fermented. In this case, the organic carbon would come from an injected carbon substrate, such as lactate or vegetable oil.

Lactate is a soluble substrate that dissolves in water and is typically used quickly by microorganisms. An advantage of soluble substrates is that delivery and distribution is more easily achieved in a heterogeneous environment, and the injection from a given point can cover a larger area than with slow-release substrates.

Vegetable oil is a slow-release substrate that slowly releases fatty acids into groundwater, which in turn are metabolized and utilized by microbes for ARD. Many of these substrates persist for months or years before being exhausted.

At the MRC, it is expected that a soluble substrate would be injected initially to quickly establish reducing conditions in the aquifer. This injection would be followed by a series of slow-release substrate injections to facilitate long-term biodegradation at the site.

As stated above, the appropriate microbial consortia are required to facilitate ARD. Baseline and performance testing of the groundwater would be conducted to determine if appropriate microbes (such as *Dehalococcoides* [DHC]) are present in sufficient quantities to provide complete ARD to harmless compounds such as ethane and ethene.

Additionally, buffering of the groundwater pH via addition of an amendment such as sodium bicarbonate may be necessary to increase the groundwater pH to a value greater than 6. At a pH of less than 6, the efficiency of ARD is suboptimal. Based on data provided in Figures 5-1 through 5-3, it is believed that an increase in pH will also lead to precipitation of metals and a decrease in groundwater metal concentrations.

Effectiveness

ARD has been shown to be very effective in reducing TCE concentrations at a wide variety of sites and is expected to be effective at the MRC. The most effective substrate, microbial innoculum, and delivery method would be determined during bench- and pilot-scale testing prior to system design. ARD has not been shown to be effective in addressing benzene or 1,4-dioxane.

Increasing the groundwater pH is expected to be effective in reducing the metals concentrations in these areas. This effectiveness will be confirmed during bench-scale testing.

Implementability

The ease of implementing this technology will be largely determined during bench- and pilot-scale- testing. Although it is expected to be effective, the low permeability soils at the site may not be suitable for direct injection of the substrate via DPT. If direct injection does not provide an adequate radius of influence and/or contact with the contaminant, implementing the technology could be difficult. Alternative delivery systems such as pneumatic or hydraulic fracturing or groundwater recirculation may be necessary; if necessary, these processes would significantly complicate response action design and implementation.

Cost

Cost of in-situ biological treatment would be relatively high due to the large treatment volume and numerous injections required. Additionally, if alternative forms of injection are required, these costs could increase significantly. However, treating plumes of this size with any technology would have a high cost.

Conclusion

In-situ biological treatment is retained in combination with other process options for the development of response action alternatives.

6.2.2.6 Disposal

The technology considered under this GRA is discharge of treated groundwater to a POTW or surface water body and sludge disposal, if required. The water being discharged would be treated effluent from the groundwater extraction system described above.

Discharge to POTW/Surface Water and Sludge Disposal at a Landfill, if Required

Treated water would be discharged to the local POTW or to a nearby surface water body. Permits would be required for both of the potential discharge options. The appropriate option would be selected based on costs of permitting (including POTW tap-in fees), discharge requirements and treatment costs to meet those requirements, and per gallon discharge fees. If sludge is generated during the metals treatment process, it would be dewatered and sent to a local landfill. It is expected that the material would be considered non-hazardous.

Effectiveness

Either option would be equally effective in disposing of treated water. Disposal of sludge at a landfill would also be effective.

Implementability

The implementability of either of the treated water disposal options is not known at this time. As design progresses, the advantages and disadvantages of each method would be considered and a final determination made. It is expected that at least one of the technologies could be implemented with relative ease. Sludge disposal would be easily implemented.

Cost

The cost of permitting would be low. If per gallon discharge fees are assessed, the overall cost throughout the entire life cycle of system operation may be significant. The cost of sludge disposal over the course of system operation may be significant.

Conclusion

Discharge to POTW/surface water and disposal of sludge at a landfill (if required) are retained in combination with other process options for the development of response action alternatives.

6.2.3 Selection of Representative Process Options

The following GRA, technologies, and process options, under the GRAs noted, are retained for the development of response action alternatives:

- No Action
- Limited Action: LUCs and Monitoring
- Collection: Groundwater Pumping
- Ex-Situ Treatment: Chemical Treatment
- In-Situ Treatment: Chemical and Biological
- Disposal: Discharge to POTW or Surface Water and Sludge Disposal at a Landfill, if Required

The next step is to select representative process options from each technology to assemble an adequate variety of alternatives and evaluate the alternatives in sufficient detail to aid in the final selection process. All process options listed above are retained for the formulation of alternatives because the processes are sufficiently varied in their functions.

6.3 DEVELOPMENT AND DETAILED ANALYSIS OF ALTERNATIVES

This section discusses the development of the groundwater response action alternatives from the process options retained above and provides a description of the conceptual designs for the alternatives. This section also presents an evaluation of each response action alternative with respect to the criteria of the NCP of 40 CFR Part 300. The criteria and the relative importance of these criteria are also discussed in this section.

6.3.1 Development of Alternatives

The technologies and process options retained in Section 6.2.3 after detailed screening were assembled into the following alternatives:

G-1. No Action:

This alternative is required by the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA, 1988) as a baseline for comparison to other alternatives.

G-2. Groundwater pumping, ex-situ treatment and discharge (and sludge disposal, if required) for areas contaminated with TCE and 1,4-dioxane and 1,4-dioxane only; in-situ biological treatment for areas contaminated with TCE only; in-situ chemical treatment for areas contaminated with benzene; temporary LUCs; and groundwater monitoring:

This alternative would treat groundwater in each of the plumes to groundwater cleanup levels. Major components of the alternative include:

- Groundwater extraction and treatment for areas containing TCE and 1,4-dioxane and 1,4-dioxane only. Although this technology requires a lengthy operational period to meet the stringent screening-level cleanup goals at the MRC, the testing required to confirm the efficacy of the in-situ method for treating 1,4-dioxane may require that an ex-situ treatment be used. This technology would be utilized in the western TCE plume and in isolated areas exhibiting 1,4-dioxane concentrations greater than the cleanup goals (near MW16A and MW25A).
- In-situ enhanced ARD would be utilized in the eastern TCE plume. Active injection would take place in areas containing TCE concentrations of 100 µg/L or greater. As TCE is removed from the areas containing relatively high concentrations and the reductive conditions established in those areas migrate to the less-contaminated areas, TCE concentrations in the less-contaminated areas would be expected to attenuate. Multiple injection events would be required to meet the screening-level groundwater

cleanup goals; results from groundwater samples collected following each injection event would be utilized to design the subsequent events. This process is also expected to reduce metals concentrations in these areas.

- In-situ chemical oxidation would be utilized in the Building A – Northwest, REC #8, and Building A – West benzene plumes. Again, injections will occur only in the areas containing benzene concentrations of 100 µg/L or greater (excluding areas under the building in REC #8). The oxygenated groundwater would then be expected to enhance biodegradation in the areas of lower concentrations. Care will be taken to avoid overlap of the area of chemical oxidation near MW23A and the organic substrate addition in the eastern TCE plume because the two processes would work to opposite effect in the subsurface and each would tend to mitigate the success of the other.

- Administrative LUCs would be utilized to prevent exposure to groundwater during response action activities and post-active response action sampling.

- Groundwater monitoring results would be utilized to track the effectiveness of the response action, to design follow-up remedial events, to determine when active response actions are complete in each portion of the MRC, and to determine when groundwater cleanup goals have been met.

It is important to note that these treatment technologies are being proposed at this time based on information currently available for the site. The individual design components and/or remedial technologies may be altered based on the results of additional investigation and bench- and pilot-scale testing detailed in Section 3. Any changes to the proposed alternatives will be documented in RAP Addendum.

6.3.2 Description and Detailed Analysis of Alternatives

This section presents a description of the conceptual design of each alternative, followed by a detailed analysis using the nine criteria of the NCP under 40 CFR Part 300. The evaluation criteria are discussed below.

6.3.2.1 Evaluation Criteria

In accordance with the NCP (40 CFR Part 300.430), the following nine criteria are used for the evaluation of response action alternatives:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs
- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, or Volume through Treatment
- Short-Term Effectiveness
- Implementability
- Cost
- State Acceptance
- Community Acceptance

<u>Overall Protection of Human Health and the Environment</u>

Alternatives must be assessed for adequate protection of human health and environment, in the short and long term, from unacceptable risks posed by hazardous substances or COCs present in MRC groundwater by eliminating, reducing, or controlling exposure to levels exceeding response action goals. Overall protection draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

<u>Compliance with ARARs</u>

Alternatives must be assessed to determine whether they attain ARARs under federal environmental laws and State environmental or facility siting laws. If one or more regulations that are applicable cannot be complied with, a waiver must be invoked. Grounds for invoking a waiver are as follows:

- The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach.

- A state requirement has not been consistently applied or the state has not demonstrated the intention to consistently apply the promulgated requirement in similar circumstances at other response actions within the state.

<u>Long-Term Effectiveness and Permanence</u>

Alternatives must be assessed for the long-term effectiveness and permanence they offer, along with a degree of certainty that the alternative will be successful. Factors that should be considered, as appropriate, include the magnitude of residual risk (e.g., risks posed by untreated waste or treatment residuals) and adequacy and reliability of controls (e.g., controls needed to manage untreated waste or treatment residuals)

Reduction of Toxicity, Mobility, or Volume through Treatment

The degree to which the alternative employs recycling or treatment that reduces the toxicity, mobility, or volume of the waste must be assessed, including how treatment is used to address the principal threats posed by the site.

Short-Term Effectiveness

The short-term impacts of the alternative must be assessed considering the following:

- Short-term risks that might be posed to the community during implementation.
- Potential impacts on workers during the response action and the effectiveness and reliability of protective measures.
- Potential environmental impacts of the response action and the effectiveness and reliability of mitigation measures during implementation.
- Time until protection is achieved.

Implementability

The ease or difficulty of implementing the alternatives must be assessed by considering technical feasibility, administrative feasibility, and availability of services and materials.

Cost

Cost estimates prepared for the purpose of evaluating alternatives are not required by the VCP and are therefore not provided herein. The relative costs of alternatives were considered on a qualitative basis only.

State Acceptance

The MDE will review the proposed RAP and will inform Lockheed Martin in writing, on or before the end of a 75-day review period, whether the RAP has been approved or rejected. If the proposed RAP is rejected, MDE will state the modifications necessary to receive approval. The 75-day MDE review period will begin after a notice of the proposed RAP is published in a local newspaper and a sign is posted at the property indicating notice of intent to conduct the RAP.

Community Acceptance

The public will be afforded the opportunity to review and provide commentary on the proposed RAP. The MDE will receive written comments from the public for 30 days after publication of the newspaper notice and posting of the sign at the property or 5 days after the public informational meeting, whichever is later. In addition, a public informational meeting will be held within 40 days after publication of the newspaper notice.

Relative Importance of Criteria

Among the nine criteria, the following are considered to be threshold criteria:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs

The threshold criteria must be satisfied for an alternative to be eligible for selection.

Among the remaining criteria, the following five are considered to be the primary balancing criteria:

- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, or Volume
- Short-Term Effectiveness
- Implementability
- Cost

The balancing criteria are used to weigh the relative merits of alternatives.

The remaining two of the nine criteria, state acceptance and community acceptance, are considered to be modifying criteria that must be considered during response action selection. These last two criteria can only be evaluated after the MDE and community have reviewed the proposed RAP. Therefore, this RAP addresses only seven of the nine criteria. The remaining two criteria will be addressed through the RAP review, comment, and approval process.

6.3.2.2 Selection of Response Action

The selection of a remedy is a two-step process. The first step consists of identification of a preferred alternative and presentation of the alternative in a proposed RAP submitted to MDE and the community for review and comment; in this case, initial proposed technologies are presented in this RAP; the final proposed technologies, based on additional data collected, will be presented in the RAP Addendum. The preferred alternative must meet the following criteria:

- Protection of human health and the environment.
- Compliance with ARARs.
- Cost effectiveness in protecting human health and environment and in complying with ARARs.
- Utilization of permanent solutions and alternate treatment technologies or resource recovery technologies to the maximum extent practicable.

The second step consists of review of comments received and consultation with the MDE to determine whether or not the preferred alternative continues to be the most appropriate response action for the site.

6.3.3 Detailed Analysis of Alternatives

6.3.3.1 Alternative G-1: No Action

Description of Alternative G-1

This alternative is a "walk-away" alternative that is required under CERCLA to establish a basis for comparison with other alternatives. Under this alternative, MRC would be released for unrestricted use.

Detailed Analysis of Alternative G-1

Overall Protection of Human Health and Environment

Alternative G-1 would not be protective of human health and the environment. Concentrations of COCs would remain in groundwater at levels that exceed the established screening-level cleanup goals. Therefore, the RAOs for MRC groundwater would not be achieved.

Compliance with ARARs

Alternative G-1 would not comply with ARARs.

Long-Term Effectiveness and Permanence

Alternative G-1 would not be effective in the long term because groundwater COCs would remain on site and pose potential human health risks. Although concentrations of COCs might gradually decrease to acceptable levels over a long period of time because of natural processes, monitoring would not be conducted to verify this.

Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative G-1 does not employ any treatment. There would most likely be some reduction in toxicity (i.e., concentrations) of COCs over time due to natural processes, but these processes would not be monitored.

Short-Term Effectiveness

There are no relevant short-term effectiveness issues under Alternative G-1 because no action would occur.

Implementability

There are no implementability concerns for Alternative G-1 because no action would be implemented.

Cost

There are no costs associated with Alternative G-1.

6.3.3.2 Alternative G-2: Groundwater Pumping, Ex-Situ Treatment and Discharge (and Sludge Disposal, if Required) for Areas Contaminated with TCE and 1,4-Dioxane and 1,4-Dioxane Only; In-Situ Biological Treatment for Areas Contaminated with TCE Only; In-Situ Chemical Treatment for Areas Contaminated with Benzene; Temporary LUCs; and Groundwater Monitoring

Description of Alternative G-2

Alternative G-2 would consist of three major components: (1) groundwater pumping and treatment, (2) in-situ biological treatment, and (3) in-situ chemical treatment. The alternative would also include temporary LUCs and groundwater monitoring. Additional details on this alternative are presented in Section 8 of this RAP.

Detailed Analysis of Alternative G-2

Overall Protection of Human Health and Environment

Alternative G-2 would be protective of human health and the environment. The removal and/or treatment of groundwater with COC concentrations greater than the screening-level cleanup goals would ensure that future use of the MRC would not pose unacceptable risk to human health. However, utilization of this technology may require decades of groundwater extraction to meet the cleanup goals. Contaminant migration to surface water would also be prevented. During the remedial process, temporary LUCs would prevent exposure to contaminated groundwater. All of the RAOs for groundwater would be achieved in the long term.

Compliance with ARARs

Alternative G-2 would achieve the screening-level cleanup goals established in Section 5. The following location-specific and action-specific ARARs would be complied with, in particular, the following:

- RCRA regulations including Identification and Listing of Hazardous Wastes and LDRs
- Occupational Health and Safety Administration (OSHA) regulations

- Maryland Hazardous Waste Management System Regulations
- Maryland Regulation of Water Supply, Sewage Disposal, and Solid Waste
- Maryland General Permit for Construction Activity
- Maryland Oil Control Program (OCP)

Long-Term Effectiveness and Permanence

Alternative G-2 would be effective in the long term because COC concentrations greater than screening-level cleanup levels would be destroyed either in situ (through chemical or biological treatment) or ex-situ (by chemical treatment). Following active treatment and post-active treatment monitoring, COCs would not be present at concentrations greater than the screening-level cleanup goals.

Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative G-2 would permanently and irreversibly reduce the mobility, toxicity, and volume of the organic contaminants in the environment by destroying them either in situ or ex situ.

Short-Term Effectiveness

The construction activities associated with this alternative would create insignificant risk to the surrounding community and on-site workers. During installation of the groundwater pumping and treatment system and during injection events, the primary threat to the community would be from inhalation of the limited amount of dust (and potential odor and organic vapor) generated during the installation of piping trenches, wells, and soil borings. This threat would be substantially eliminated by implementation of dust and vapor suppression measures. Risk from potentially dangerous substances such as hydrogen peroxide would be eliminated through proper storage and handling techniques as well as restricting access to the work zone.

Throughout system operation, samples would be collected and maintenance completed to ensure that hazardous substances are not discharged to the environment.

The groundwater treatment system could operate for more than 20 years; injection activities would take place over a period of approximately 5 years.

Implementability

Designing and implementing each of the components of Alternative G-2 would present technical and administrative challenges. However, personnel and equipment required to design and complete the actions are readily available, and time to coordinate with stakeholders and obtain necessary permits can be built into the schedule. Therefore, Alternative G-2 is implementable.

Cost

Cost estimates prepared for the purpose of evaluating alternatives are not required by the VCP and are therefore not provided herein.

6.4 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section compares the analyses presented for each of the response action alternatives in Section 6.3. The criteria for comparison are identical to those used for the detailed analysis of individual alternatives.

6.4.1 Groundwater Response Actions

The following response action alternatives for groundwater are being compared in this section:

- Alternative G-1: No Action
- Alternative G-2: Groundwater Pumping, Ex-Situ Treatment and Discharge (and Sludge Disposal, if Required) for Areas Contaminated with TCE and 1,4-Dioxane and 1,4-Dioxane Only; In-Situ Biological Treatment for Areas Contaminated with TCE Only; In-Situ Chemical Treatment for Areas Contaminated with Benzene; Temporary LUCs; and Groundwater Monitoring

6.4.1.1 <u>Overall Protection of Health and the Environment</u>

Alternative G-1 would not be protective. Alternative G-2 would be protective.

6.4.1.2 Compliance with ARARs and TBCs

Alternative G-1 would not comply with the chemical-specific TBCs and chemical- and location-specific ARARs. Action-specific ARARs do not apply to Alternative G-1. Alternative G-2 would comply with chemical-specific TBCs and chemical-, location-, and action-specific ARARs.

6.4.1.3 Long-Term Effectiveness and Permanence

Alternative G-1 would not be effective in the long term and offers no permanent solution. Alternative G-2 would be effective in the long term because it offers a remedy that removes the COCs from MRC groundwater without the need for permanent LUCs to prevent residential and commercial/industrial development and recreational use.

6.4.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives G-1 does not employ any treatment. Alternative G-2 would permanently reduce the toxicity, mobility, and volume of COCs in MRC groundwater.

6.4.1.5 Short-Term Effectiveness

Alternative G-1 would not present short-term risks to workers, the community, or the environment because no actions would be taken. Short-term risks to the community, workers, and the environment associated with Alternative G-2 could be adequately controlled.

Alternative G-1 would not achieve the groundwater RAOs. The approximate time frame for implementation and attainment of RAOs would be 20 years or more for Alternative G-2.

6.4.1.6 Implementability

There is no action to be implemented for Alternative G-1. Despite complications, Alternative G-2 would be implementable.

6.4.1.7 Cost

There are no costs associated with Alternative G-1. Cost estimates prepared for the purpose of evaluating alternatives are not required by the VCP and are therefore not provided herein.

6.4.2 Summary of Comparative Analysis of Alternatives

Table 6-5 summarizes the comparative analysis of the two groundwater response action alternatives.

6.5 PROPOSED ALTERNATIVE

The proposed alternative is Alternative G-2. This alternative would address groundwater with COC concentrations greater than screening-level cleanup goals. A detailed description of Alternative G-2 is presented in Section 8.

As stated above, it is important to note that the proposed alternative is based on information currently available for the site. The individual design components and/or remedial technologies may be altered based on additional investigation, bench- and pilot-scale testing, and final cleanup goals.

Table 6-1

Chemical-Specific ARARs and TBCs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Federal				
Safe Drinking Water Act (SWDA) Regulations, Maximum Contaminant Levels (MCLs)	40 Code of Federal Regulations (CFR) Part 141	Relevant and Appropriate	Establishes enforceable standards for potable water for specific contaminants that have been determined to adversely affect human health.	Would be used as protective levels for groundwater or surface waters that are current or potential drinking water sources.
SDWA Regulations, National Secondary Drinking Water Standards (SMCLs)	40 CFR Part 143	To Be Considered	Establishes welfare-based standards for public water systems for specific contaminants or water characteristics that may affect the aesthetic qualities of drinking water.	Would be used as protective levels for groundwater or surface waters that are current or potential drinking water sources
Cancer Slope Factors (CSFs)	NA	To Be Considered	CSFs are guidance values used to evaluate the potential carcinogenic hazard caused by exposure to contaminants.	CSFs would be considered for development of human health protection preliminary remediation goals (PRGs) for groundwater at this site.
Reference Doses (RfDs)	NA	To Be Considered	RfDs are guidance values used to evaluate the potential non-carcinogenic hazard caused by exposure to contaminants.	RfDs would be considered for development of human health protection PRGs for groundwater at this site.
State				
Cleanup Standards for Soil and Groundwater	Maryland Environmental Article 7-508/7-208	To Be Considered	This guidance document presents the approach and supporting documentation used to develop numeric cleanup standards for hazardous substances in soil and groundwater in the State of Maryland.	These standards would be used in determining cleanup goals for groundwater.

Table 6-2

Location-Specific ARARs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Federal				
Endangered Species Act Regulations	50 CFR Parts 81, 225, and 402	Potentially Applicable	This act requires federal agencies to take action to avoid jeopardizing the continued existence of federally listed endangered or threatened species.	If a site investigation or remediation could potentially affect an endangered species or its habitat, these regulations would apply (no endangered species or associated habitats have been identified at the MRC).
Historic Sites Act Regulations	36 CFR Part 62	Potentially Applicable	Requires federal agencies to consider the existence and locations of landmarks on the National Registry of Natural Landmarks to avoid undesirable impacts on such landmarks.	The existence of National Landmarks would be identified prior to remedial activities on site including remedial investigations (no National Landmarks have been identified at the MRC).

Table 6-2

Location-Specific ARARs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
State				
Nongame and Endangered Species Conservation Act	Annotated Code of Maryland 10-2A-01; Code of Maryland Regulations (COMAR) 08.03.08 and 08.02.12.	Potentially Applicable	Requires State agencies to use their authority to maintain and enhance nongame wildlife and endangered species populations.	If a site investigation or remediation could potentially affect an endangered species or its habitat, these regulations would apply (no endangered species or associated habitats have been identified at the MRC).
Division of Historical and Cultural Programs	Annotated Code of Maryland 5A	Potentially Applicable	The Maryland Historic Trust formed in 1961 to preserve, protect, and enhance districts, sites, buildings, structures, and objects significant in the prehistory, history, upland and underwater archeology, architecture, engineering, and culture of the State.	The existence of Maryland historic sites would be identified prior to remedial activities on site including remedial investigations (no historic sites have been identified at the MRC).

Table 6-3

Action-Specific ARARs and TBCs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Federal				
Resource Conservation and Recovery Act (RCRA) Regulations, Identification and Listing of Hazardous Wastes	40 Code of Federal Regulations (CFR) Part 261	Potentially Applicable	Defines the listed and characteristic hazardous wastes subject to RCRA. Appendix II contains the Toxicity Characteristic Leaching Procedure (TCLP).	These regulations would apply when determining whether or not a solid waste is hazardous, either by being listed or by exhibiting a hazardous characteristic, as described in the regulations.
Clean Air Act (CAA) Regulations, National Ambient Air Quality Standards (NAAQSs)	40 CFR Part 50	Potentially Applicable	Establishes primary (health-based) and secondary (welfare-based) air quality standards for carbon monoxide, lead, nitrogen dioxide, particulate matter, ozone, and sulfur oxides emitted from a major source of air emissions. The NAAQSs form the basis for all regulations promulgated under the CAA. However, the NAAQSs themselves are non-enforceable and are not ARARs themselves.	The principal application of these standards is during response action activities resulting in exposures through dust and vapors. In general, emissions from CERCLA activities are not expected to qualify as a major source and NAAQSs are therefore not expected to be applicable requirements. However, the requirements may be determined to be relevant and appropriate for non-major sources with significantly similar emissions.

Table 6-3

Action-Specific ARARs and TBCs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Occupational Health and Safety Administration (OSHA) Regulations, General Industry Standards	29 CFR Part 1910	Applicable	Requires establishment of programs to assure worker health and safety at hazardous waste sites, including employee training requirements	These regulations would apply to all response activities.
OSHA Regulations, Occupational Health and Safety Regulations	29 CFR Part 1910, Subpart Z	Potentially Applicable	Establishes permissible exposure limits for workplace exposure to a specific listing of chemicals.	Standards are applicable for worker exposure to OSHA hazardous chemicals during response action activities.
OSHA Regulations, Recordkeeping, Reporting, and Related Regulations	29 CFR Part 1904	Potentially Applicable	Provides recordkeeping and reporting requirements applicable to response action activities.	These requirements apply to all site contractors and subcontractors and must be followed during all site work.
OSHA Regulations, Health and Safety Standards	29 CFR Part 1926	Potentially Applicable	Specifies the type of safety training, equipment, and procedures to be used during the site investigation and response action.	All phases of the response action would be executed in compliance with this regulation.

Table 6-3

Action-Specific ARARs and TBCs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
RCRA Regulations, Contingency Plan and Emergency Procedures	40 CFR 264, Subpart D	Potentially Relevant and Appropriate	Outlines requirements for emergency procedures to be followed in case of an emergency.	The administrative requirements established in this rule would be met for response actions involving the management of hazardous waste.
RCRA Regulations, Preparedness and Prevention	40 CFR Part 264, Subpart C	Potentially Relevant and Appropriate	Outlines requirements for safety equipment and spill control for hazardous waste facilities. Facilities must be designed, maintained, constructed, and operated to minimize the possibility of an unplanned release that could threaten human health or the environment.	Safety and communication equipment would be incorporated into all aspects of the response action process, and local authorities would be familiarized with site operations.

Action-Specific ARARs and TBCs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
RCRA Regulations, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDFs).	40 CFR Part 264	Potentially Relevant and Appropriate	Establishes minimum national standards defining the acceptable management of hazardous wastes for owners and operators of facilities that treat, store, or dispose of hazardous wastes.	If response actions involve management of RCRA wastes at an off-site TSDF or if RCRA wastes are managed on site, the requirements of this rule would be followed.
RCRA Regulations, Use and Management of Containers	40 CFR Part 264, Subpart I	Potentially Relevant and Appropriate	Sets standards for the storage of containers of hazardous waste.	This requirement would apply if a response action alternative involves the storage of a hazardous waste (i.e., contaminated soil or groundwater) in containers prior to treatment or disposal.
Migratory Bird Treaty Act	16 USC 703-711	Potentially Applicable	Protects migratory birds and their nests.	Proposed response action shall not kill migratory birds or destroy their nests and eggs.

Table 6-3

Action-Specific ARARs and TBCs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
State				
Maryland Hazardous Waste Management System	Title 26, Subtitle 13 of the Code of Maryland Regulations (COMAR)	Potentially Applicable	Requires hazardous waste generators to ship their hazardous waste to a facility permitted to accept it or, with the appropriate permits, treat it themselves. Requires use of a certified hauler to ship hazardous waste off site, and shipment must be accompanied by a manifest. Requires compliance with regulations on the storage of the waste and specifies procedures to prevent the occurrence of circumstances that would threaten human health or the environment.	These regulations would apply if waste on site was deemed hazardous and needed to be stored, transported, or disposed properly.
Maryland Regulation of Water Supply, Sewage Disposal, and Solid Waste	Title 26, Subtitle 4 of the COMAR	Potentially Applicable	Sets the requirements for construction and operation for solid waste disposal facilities.	These requirements would apply if on-site waste was deemed a non-hazardous solid waste and needed to be stored, transported, or disposed properly.

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Maryland General Permit for Construction Activity	Title 26, Subtitle 17 of COMAR	Potentially Relevant and Appropriate	Establishes requirements for stormwater management and erosion and sediment control at construction sites.	Response actions involving excavation would require submittal of an erosion and sediment control plan and a stormwater management plan.

Table 6-4

Preliminary Screening of Technologies and Process Options
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

General Response Action	Response Action Technology	Process Option	Description	Screening Comment
No Action	None	Not Applicable	No activities conducted at the MRC to address contamination. Biodegradation of contaminants may occur through natural attenuation processes, but would not be verified.	Required by CERCLA. Retain for baseline comparison to other technologies.
Limited Action	Land Use Controls (LUCs)	Administrative Controls: Deed or Site Use Restrictions	Administrative action using property deeds or other land use prohibitions to restrict future site activities.	Alone, would not be suitable to meet cleanup goals in a reasonable timeframe; however, will temporarily be required as response action activities progress.
	Monitoring	Groundwater Sampling	Sampling and analysis of groundwater to evaluate the effectiveness of site treatment and the progress of natural attenuation following active remediation.	Alone, would not be suitable to meet cleanup goals in a reasonable timeframe; however, will be required during and after active remediation.

Table 6-4

Preliminary Screening of Technologies and Process Options
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

General Response Action	Response Action Technology	Process Option	Description	Screening Comment
Containment	Barrier	Groundwater Pumping	Use of pumping wells to prevent migration of groundwater to surrounding surface water bodies.	Eliminate. This technology would leave groundwater contaminants in place in the central portion of the MRC. Does not meet the remedial action objective (RAO) of unrestricted site use.
		Permeable/ Impermeable Barrier	Use of a non-permeable slurry wall or permeable reactive barrier to prevent migration of groundwater to surrounding surface water bodies.	Eliminate. Despite potential success with containment of groundwater contamination, this technology would leave groundwater contaminants in place in the central portion of the MRC. Does not meet the RAO of unrestricted site use.
Collection	Groundwater Pumping	Pumping via Wells	Extraction of groundwater via pumping wells placed within the groundwater plumes.	Retain for areas where in-situ treatment is potentially not applicable.
Ex-Situ Treatment	Physical	Air Stripping/ Carbon Adsorption	Use of air stripper and carbon adsorption to treat contaminants prior to discharge.	Eliminate. Does not address 1,4-dioxane.
	Chemical	Ozone/Peroxide Addition	Established treatment method addresses all contaminants of concern (COCs) and has been shown to be effective at the concentrations and flow rates estimated for the MRC.	Retain for areas where in-situ treatment is not applicable. This well-proven technology will address all COCs.

Table 6-4

Preliminary Screening of Technologies and Process Options
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

General Response Action	Response Action Technology	Process Option	Description	Screening Comment
In-Situ Treatment	Biological	Enhanced Anaerobic Reductive Dechlorination	Injection of substrates and/or bioamendments to create conditions suitable for reductive dechlorination.	Retain for areas containing TCE only. Not applicable for 1,4-dioxane or benzene.
	Biological	Enhanced Co-Metabolic Biodegradation	Creation of an aerobic subsurface environment and degrading 1,4-dioxane in the presence of another substrate, and not as the primary growth substrate.	This technology has been tested in bench-scale studies for 1,4-dioxane treatment. Based on data obtained from the upcoming bench-scale studies in Section 3, it may be considered to replace the groundwater extraction.
	Biological	Enhanced Biodegradation via Oxygen Addition	Inject oxygen and/or bioamendments to create conditions suitable for biodegradation of petroleum consitituents.	Eliminate. Limited effectiveness at low concentrations present at the MRC.
	Chemical	Oxidation via Oxidant Addition	Destroy contaminants via oxidation using an oxidant injected into the aquifer	Eliminated for Conceptual RAP. Testing of this technology may occur, based on continued advancement in in-situ treatment of 1,4-dioxane.

Table 6-4

Preliminary Screening of Technologies and Process Options
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

General Response Action	Response Action Technology	Process Option	Description	Screening Comment
In-Situ Treatment (Contd.)	Chemical	Oxidation via Hydrogen Peroxide Addition	Destroy contaminants via oxidation using hydrogen peroxide injected into the aquifer. Based on the results of the bench- and pilot-scale studies, other oxidants may be considered.	Retain. Applicable for benzene areas only. Not applicable for 1,4-dioxane.
	Chemical	Zero Valent Iron (ZVI) Injection	Injection of nano- or micro-scale ZVI into the areas containing TCE only or TCE and 1,4-dioxane.	This technology has been shown to be effective for TCE treatment, but has not been shown to address 1,4-dioxane. Based on data obtained from the upcoming bench-scale studies described in Section 3, it may be considered for use in these areas.
	Chemical	Peroxide/Ozone and/or Persulfate Injection	Injection of hydrogen peroxide and ozone in to the subsurface for treatment of TCE and 1,4-dioxane	This technology has been successful for treatment of these compounds ex-situ and initial pilot-scale results are encouraging for its in-situ application. Therefore, based on data obtained from the bench-scale studies in Section 3, it may be considered for use in these areas.

Table 6-4

Preliminary Screening of Technologies and Process Options
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

General Response Action	Response Action Technology	Process Option	Description	Screening Comment
Disposal	Off-Site	Hazardous/ Non-Hazardous Waste Facility	Disposal of recovered groundwater at an off-site treatment facility.	Eliminate. This option would be cost prohibitive.
	Discharge to Publicly-Owned Treatment Works (POTW)/ Surface Water	To Be Determined	Discharge of treated water under permit to either the local POTW or to nearby surface water.	Retain. Final decision on disposition will be based on relative cost.

Table 6-5

Summary of Comparative Analysis of Alternatives
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Evaluation Criterion	Alternative G-1: No Action	Alternative G-2: Groundwater Pumping, In-situ/Ex-situ Treatment, Temporary LUCs, Groundwater Monitoring
Overall Protection of Human Health and Environment	Not protective	Protective
Chemical-Specific ARARs	Would not comply	Would comply
Location-Specific ARARs	Would not comply	Would comply
Action-Specific ARARs	Not applicable	Would comply
Long-Term Effectiveness and Permanence	Not effective	Effective – will meet RAOs
Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment	None	Permanent reductions in toxicity, mobility, and volume of contaminants
Short-Term Effectiveness	No relevant issues to address	Would be effective. Minimum potential for short-term risks.
Implementability	Nothing to implement	Implementable

ARARs Applicable or Relevant and Appropriate Requirements.
RAOs Response action objective.

Section 7
Evaluation Criteria for the Selected Technology

7.1 EVALUATION CRITERIA

The proposed active groundwater treatment addresses areas of the MRC with TCE and benzene concentrations greater than 100 μg/L and 1,4-dioxane concentrations greater than 3 μg/L with active remediation. Other areas of the MRC with COCs at concentrations greater than the screening-level groundwater cleanup goals will be addressed with monitored natural attenuation. During implementation, a significant amount of sampling will be performed to evaluate the effectiveness of the response action. The evaluation criteria would include the following:

- Reduction of organic COC concentrations in the areas of active remediation, throughout the entire areal extent and thickness of contamination.
- Establishment of conditions suitable for continued remediation in these areas. This evaluation would vary for each different technology utilized.
- Reductions in organic COC concentrations outside the areas of active remediation.
- Establishment of conditions suitable for continued attenuation in these areas.
- Reductions in organic COC concentrations in areas requiring active remediation following initial injections and/or groundwater extraction.

As stated throughout this RAP, the proposed response action is conceptual in nature and the screening-level groundwater cleanup goals are preliminary; a conceptual sampling protocol to allow evaluation of the criteria stated above for the proposed response action is presented in Section 8. A complete description of the final sampling protocol will be included in RAP Addendum to be submitted following completion of the additional investigation activities detailed in Section 3. The RAP Addendum will also include more specific evaluation criteria and potential contingency measures to be implemented if these criteria are not met.

7.2 CONTINGENCY MEASURES

As stated above, the cleanup goals, response action, sampling protocol, and evaluation criteria are conceptual in nature. As part of development of the RAP Addendum, these items will be finalized. Based on this information, contingency measures will be developed and implemented if the criteria are not met.

Section 8
Proposed Response Actions

8.1 INTRODUCTION

The overall response actions for the MRC will address groundwater and soil with organic COC concentrations greater than the screening-level cleanup goals. The proposed conceptual site-specific response action for groundwater is presented in this RAP. Response actions for soil are described in the block-specific Soil RAPs provided under separate cover.

8.2 RESPONSE ACTION PLAN DESCRIPTION

The proposed groundwater response action includes treatment of the western TCE plume (containing 1,4-dioxane) and isolated areas containing 1,4-dioxane with groundwater extraction and on-site treatment, treatment of the eastern TCE plume and the area surrounding MW53A with enhanced in-situ bioremediation, and treatment of the benzene plumes at Building A – Northwest and West and REC #8 with in-situ chemical oxidation.

Although the final delineation of the plumes (horizontally and vertically), the effectiveness and final design parameters for the treatment technologies, and final cleanup goals will not be determined until completion of the additional activities described in Section 3.0, a conceptual design for the proposed response action is presented in this section. Following completion of the additional activities, results will be analyzed and an addendum to this RAP will be submitted. This RAP addendum will provide: final groundwater cleanup goals; the final design basis for the response actions; details on the areas and volumes to be treated; locations and design for the injection and extraction locations; injection materials and volumes for the initial round of in-situ chemical oxidation and enhanced biodegradation; and details on flow rates, piping locations, and unit processes for the groundwater extraction and treatment system. The addendum will also detail the remedial performance sampling protocol for each of the treatment areas.

A site plan presenting the layout of the conceptual response action design is presented in Figure 8-1.

8.2.1 Summary of Major Components

A summary of the conceptual design parameters for the proposed response action in the eastern and western TCE plumes and the benzene plumes is presented below. This proposed design may be altered based on the results of the investigation and testing outlined in Section 3.

Eastern TCE Plume and the Area Surrounding MW53A

Enhanced in-situ bioremediation is proposed for treatment of groundwater in the eastern TCE plume and the area surrounding MW53A. This response action includes injection of organic substrate and bio-amendments into the subsurface in areas with groundwater TCE concentrations greater than 100 μg/L. Natural attenuation as stimulated by the enhanced bioremediation will address the fringes of the plume where concentrations range from 5 to 100 μg/L. The injection will be accomplished via DPT if possible. Although it is believed that injection via DPT will be adequate, field testing will be required to determine if adequate contact can be achieved utilizing this method in the low permeability soils at the MRC. It appears that the areas of contamination do not coincide with areas of extremely low permeability at the MRC, increasing the likelihood that DPT injection will be effective. This conceptual model will be refined based on the data collection outlined in Section 3. If it is determined that injection via DPT is not adequate, other injection methods (such as fracturing) or groundwater extraction/recirculation will be considered.

Based on the data available at this time, the area with TCE concentrations greater than 100 μg/L and requiring injection is approximately 160,000 square feet, with portions in both the A (shallow) and B (intermediate) zones of the surficial aquifer. One potential scenario for treatment includes a total of five separate injection events in this area via DPT borings at a spacing of approximately 20 feet (10-foot radius of influence, approximately 500 injection locations). The initial injection would include lactate at a concentration of approximately 1 percent of the aquifer volume and a buffering agent, which is expected to quickly create reducing conditions in the aquifer and to raise the pH as necessary to stimulate biodegradation. This would be followed by subsequent injections in areas requiring additional active remediation to meet the cleanup goals. These injections would include emulsified vegetable oil injected with pH buffering as necessary via DPT at approximately the same spacing and dosage. The injections may also include bio-amendments, if required to provide adequate biodegradation of TCE daughter products. The vegetable oil will break down more slowly than the lactate, maintaining reducing conditions in the aquifer over a longer period. Up to four additional injections, presumably with each encompassing a progressively smaller area, may be required. Each of these injections would be conducted within 3 to 5 years. To minimize site disruption, no above-ground remediation equipment would be left on site between injection events.

Following each injection event, a site sampling protocol will be implemented to determine the effectiveness of the injections in creating an environment suitable for biodegradation and to track reductions in groundwater VOC and metals concentrations inside and outside the injection areas. These data will be used to design the subsequent injection event (areal extent, injection depth, dosage, etc.) and determine when additional active remediation is no longer required.

As stated above, the data generated by the investigations in Section 3.0 will be used as follows to determine the response action design parameters:

- Additional monitoring well installation and sampling will determine the areal extent and depth required for injection. This will be used to finalize initial injection point placement and design.

- Bench-scale testing will determine the effectiveness of in-situ enhanced biodegradation using soil and groundwater from the eastern TCE plume. Additionally, this testing will determine the appropriate organic substrates to add and the optimal injection rates. The need for injection of additional bio-amendments (microbes) will also be determined. This testing will also determine the effect of the pH buffering and changes in geochemistry in precipitating the metals and reducing their concentrations in the groundwater; if it is found that this is extremely effective in reducing metals concentrations in groundwater, injections may be expanded to isolated areas containing only metals contamination (if necessary to meet the final groundwater cleanup goals established in the RAP Addendum.

- Field testing will determine whether the substrates can be effectively injected via DPT, the effective radius of influence of the injection, and the effectiveness of the process in producing anaerobic conditions and reducing VOC and metals concentrations under field conditions.

- Pump testing in this area will provide data that can be used to determine the effectiveness of groundwater extraction in creating a barrier to prevent groundwater migration to Dark Head Cove and to determine if groundwater extraction is a viable alternative if in-situ enhanced biodegradation is not feasible.

Western TCE Plume and Isolated Areas Containing 1,4-Dioxane

At this time, in-situ treatment has not been shown to effectively treat 1,4-dioxane in groundwater. Therefore, the response action proposed for the areas of the site containing this compound includes groundwater extraction and ex-situ treatment.

It is anticipated that approximately 12 to 15 wells will be utilized for extraction in the western TCE plume and isolated 1,4-dioxane areas. These wells will be located along the southern edge of the plume to act as a barrier against groundwater migration to Cow Pen Creek, in the center and northern portions of the plume, and near the two wells containing 1,4-dioxane at concentrations greater than 3 μg/L (MW16A and MW25A). Based on data available at this time, it is expected that the flow from each well will be 1 gpm or less, for a total groundwater extraction rate of less than 15 gpm. This will be refined based upon the planned field testing discussed in Section 3.

Extracted groundwater will be transferred to a treatment area via underground piping and treated utilizing a well-established process for removal of VOCs and 1,4-dioxane. This process involves the injection of hydrogen peroxide and ozone into the recovered groundwater stream to destroy the contaminants via chemical oxidation prior to discharge. The patented HiPOX system from Applied Process Technology, or equivalent, will be utilized. As discussed in Section 3, other unit processes may be necessary for treatment of inorganic constituents, if the concentrations of these constituents exceed discharge criteria.

To meet groundwater cleanup levels, it is expected that this treatment system will operate for a minimum of 15 years and a maximum of 30 years. Throughout this operational period, system operational data and groundwater sampling data will be continuously analyzed to optimize system operation to expedite reaching cleanup goals as cost-effectively as possible.

The data generated by the investigations described in Section 3 will be used as follows to determine the design parameters:

- Additional monitoring well installation and sampling will determine the areal extent and depth required for extraction activities, which will be utilized for extraction well design and placement.

- Bench-scale testing will determine the efficacy of ex-situ groundwater treatment options. It will also determine the optimal design required to obtain the groundwater discharge limits.

- Pump testing will determine sustained pumping rates and capture zones, which will be used to determine well spacing and treatment system requirements.

- Additional bench-scale testing may provide evidence that in-situ remediation is a viable alternative for treatment of 1,4-dioxane. In that case, additional field testing may be conducted to determine the feasibility of in-situ treatment. Modifications to the proposed alternative will be required if these results suggest that in-situ remedial processes for 1,4-dioxane is feasible and cost effective.

Benzene Plumes

The proposed response action for the benzene plumes is in-situ chemical oxidation. This response action includes injection of hydrogen peroxide (or equivalent oxidizer) and catalysts, as necessary, into the subsurface in the areas of benzene concentrations greater than 100 μg/L. Areas of injection include the vicinities of wells EXT-MW04/MW50A, MW17A, and MW23A. In the area of MW23A and MW50A, the injection will occur outside the footprint of the existing building only; to compensate for the lack of injection beneath the building, the injection area will be expanded slightly outside of the 100 μg/L contour to both the north and the south. The injection will be accomplished via DPT if possible.

The areal extent of injection will be approximately 28,000 square feet, with the injections occurring mainly in the “A” zone, within 20 feet of the surface. Based on a radius of influence of 10 feet, approximately 90 injection points will be required. An estimated 250 gallons of oxidant will be injected at each location. In addition to treating the injection areas, the addition of large volumes of oxidant is expected to significantly increase dissolved oxygen concentrations in the surrounding areas. This condition is expected to increase the rate of benzene biodegradation in areas with initial concentrations less than 100 μg/L and beneath the building. Care will be taken to avoid overlap of the area of chemical oxidation near MW23A and the organic substrate addition in the eastern TCE plume because the two processes would work to opposite effect in the subsurface and each would tend to mitigate the success of the other.

It is expected that up to four rounds of injection will be required to achieve the cleanup goals. Following each injection event, a site sampling program will be implemented to determine the effectiveness of the injections in creating an oxidized subsurface environment, to confirm the injection radius of influence, and to track the reductions in groundwater benzene concentrations inside and outside the injection areas. These data will be used to design the subsequent injection event (area extent, injection depth, dosage, etc.) and determine when additional active remediation is no longer required.

The data generated by the investigations in Section 3 will be used as follows to determine the design parameters:

- Additional monitoring well installation and sampling will determine the areal extent and depth required for injection. This will be used to determine injection point placement and design.

- Bench-scale testing will determine the efficacy of in-situ chemical oxidation using soil and groundwater samples from the MRC. Additionally, the testing will determine the appropriate oxidant to add and the optimal injection rates. The need for injection of addition catalysts will also be determined.

- Field testing will determine whether the oxidant can be effectively injected via DPT, the effective radius of influence of the injection, and the effectiveness of the process in reducing benzene concentrations under field conditions.

Post-Remediation Sampling and LUCs

It is expected that active remediation will be discontinued in each area prior to reaching screening-level cleanup goals. Active remediation for each portion of the proposed response action will be discontinued when groundwater concentrations in an area have been reduced to levels where additional treatment is not cost-effective and when it is determined that cleanup goals will be achieved in a reasonable time period without additional treatment (i.e., through natural attenuation). At that time, post-remediation sampling will commence and will continue until groundwater screening-level cleanup goals are met, or it is determined that active remediation should be re-established.

Because groundwater concentrations at the MRC will exceed cleanup goals during the active remediation and post-remediation sampling, it will be necessary to establish LUCs during this period. The primary LUC will be a prohibition on use of site groundwater. This prohibition will be removed when the cleanup goals have been met.

8.2.2 Performance Criteria

The performance criteria for the RAP are presented below.

Eastern TCE Plume and the Area Surrounding MW53A

Ultimately, the performance of the in-situ enhanced biodegradation will be evaluated based on reductions in VOC concentrations in the entire plume to less than the cleanup goals. To optimize the injection process, interim performance criteria will be established, including determining if:

- Indicator parameters such as dissolved oxygen, oxidation-reduction potential, total organic carbon, hydrogen, volatile fatty acids, and pH are in the correct ranges to support anaerobic biodegradation in the injection area.

- VOC concentrations in the injection areas are being reduced at an acceptable rate, and concentrations of secondary parameters (such as methane, ethene, ethane, and chloride) indicate that reductions are due to biological processes.

- VOC concentrations in plume areas outside the injection areas (i.e., areas with TCE concentrations less than 100 μg/L) are being reduced at an acceptable rate, and concentrations of indicator parameters are in the correct ranges to support anaerobic biodegradation.

- These conditions are consistent throughout the entire areal extent and depth interval requiring treatment, indicating that an acceptable radius of influence has been established.

- A sufficient microbial community is present throughout the treatment area to support complete biodegradation (i.e., microorganisms such as DHC are present to facilitate complete reductive dechlorination).

The RAP addendum to be prepared following completion and analysis of the testing described in Section 3 will include detailed sampling protocols to facilitate these determinations. Based on the determinations, the injection protocol (locations, injection materials and quantities, etc.) will be modified between events and during events if warranted.

Western TCE Plume and Isolated Areas Containing 1,4-Dioxane

As in the eastern plume, the performance of the groundwater extraction and treatment system will be evaluated based on its ability to reduce VOC concentrations in the entire plume to less than cleanup goals. Interim performance criteria include determining if:

- Groundwater is being extracted from throughout the treatment area, including from the appropriate depth intervals.

- The cleanup goals have been met in certain areas of the MRC, allowing shut down of one or more extraction wells.

- VOC and 1,4-dioxane concentrations are being reduced at an acceptable rate in site monitoring and recovery wells.

- The treatment system is operating efficiently and effectively and is removing the VOCs, 1,4-dioxane, and metals to concentrations less than discharge limits.

The RAP Addendum will include maintenance, monitoring, and sampling protocols to allow these determinations. Based on the determinations, the extraction and treatment systems will be modified as necessary.

Benzene Plumes

Performance criteria associated with the in-situ chemical oxidation include determining if:

- Indicator parameters such as dissolved oxygen, oxidation-reduction potential, and pH throughout the injection areas indicate that the radius of influence and injected oxidant quantities are sufficient for remediation.
- VOC concentrations in the injection areas are being reduced at an acceptable rate.
- VOC concentrations outside the injection areas are being reduced at an acceptable rate, and the concentrations of the indicator parameters are in the correct ranges to support biodegradation.
- Ensure oxidant used in close proximity to ARD treatment areas does not migrate downgradient to interfere with TCE remediation.

The RAP Addendum will include detailed sampling protocols to facilitate these determinations. Based on the determinations, the injection protocol (locations, injection materials and quantities, etc.) will be modified between events and during events if warranted.

8.2.3 Sequence

The generalized sequence of the proposed response action activities is presented below. The sequence of response action activities is subject to change based on the final response action design. The years of performance are provided in parentheses:

1. Perform field investigations and bench- and pilot-scale testing as described in Section 3 (2007/2008).
2. Establish LUCs prohibiting use of groundwater (2008).
3. Complete RAP addendum and detailed response action designs (2008).

4. Complete baseline sampling to allow comparison with remedial performance sampling (2008).

5. Install the infrastructure for the groundwater extraction and treatment system and begin operation (2009).

6. Perform initial injection events for in-situ enhanced biodegradation and chemical oxidation (2009).

7. Conduct performance sampling (throughout the operational period of each response action).

8. Review data from initial events and design subsequent injection events (2009).

9. Perform continuous review of groundwater extraction and treatment system data to optimize system operation (2009 until conditions indicate that system operation can be discontinued).

10. Continue injection events and data review/injection optimization (2009 through 2011).

11. Perform post-remediation sampling as the data in each area indicates that active remediation can be discontinued.

12. After cleanup goals have been met, discontinue sampling and eliminate LUCs.

8.3 REPORTING REQUIREMENTS

Periodically throughout the response action (at an interval to be stipulated in the RAP addendum), reports will be submitted to the MDE detailing site activities to date, analytical and monitoring data, and recommendations for future site activities.

Following completion of the response action, analytical reports and documentation generated as required by the approved RAP and RAP Addendum and as necessary to achieve a Certificate of Completion will be included in the Notification of Completion Report. The Notification of Completion Report will be submitted to MDE within 90 days after completion of response action activities.

Details on the documentation to be submitted and the content of the required reports will be included in the RAP addendum.

8.3.1 Recordkeeping

Lockheed Martin will maintain complete records of the response action for a minimum of 5 years after a Certificate of Completion is received from the MDE.

FIGURE 8-1

LAYOUT OF CONCEPTUAL RESPONSE ACTION

LEGEND

- GROUNDWATER MONITORING WELL
- POTENTIAL LOCATION OF GROUNDWATER EXTRACTION WELL
- TCE ISOCONCENTRATION (100 ug/L)
- INFERRED
- 1,4 DIOXANE ISOCOCENTRATION (3 ug/L)
- BENZENE ISOCOCENTRATION (100 ug/L)
- INFERRED
- AREA OF CHEMICAL OXIDATION
- AREA OF IN-SITU ENHANCED BIOLOGICAL TREATMENT
- WATER

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 6/11/07

CREATED BY: LR

Tetra Tech, Inc.

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Section 9
Permits, Notifications, and Contingencies

9.1 INTRODUCTION

This section describes the permits required for the proposed response actions and the required notifications and contingencies if unexpected conditions are encountered during implementation of the RAP.

9.2 PERMITS

Lockheed Martin will meet all federal, State, and local permitting requirements for the proposed groundwater response action described in Section 8. Based on a review of requirements of EPA, MDE, and Baltimore County, permitting requirements for the proposed response action are related to groundwater extraction, treatment, and discharge and in-situ groundwater treatment.

9.2.1 Groundwater Extraction, Treatment, and Discharge

Well construction permits are required for groundwater extraction and monitoring wells and will be obtained by the well driller from the Baltimore County Department of Environmental Protection and Natural Resources Groundwater Management office.

There are no permitting requirements for the groundwater treatment system.

Groundwater will be discharged either to surface water (regulated by MDE and EPA) or to the local sanitary sewer system (regulated by Baltimore County).

The industrial surface water discharge permit is a combined State and federal permit under NPDES. If required, a completed application will be submitted to MDE. MDE develops discharge limits based on the information provided in the permit application and issues the permit considering public comments, if any.

A wastewater discharge permit is required to discharge industrial wastewater to the local sanitary sewer system. If required, a completed application for discharge to the Baltimore County sanitary sewer system will be submitted to the Engineering and Regulation Division of the Bureau of Utilities. There are specific limits set by the treatment plant for certain pollutants. Discharge limits for these and other pollutants may be set on a case-by-case basis. The discharge permit is issued by the Baltimore County Department of Public Works and Development Management.

9.2.2 Underground Injection Control

Injection of chemicals into groundwater is regulated by the MDE Underground Injection Control (UIC) Program. Any injection wells to be used for the proposed response action would be classified as Class V wells, which are defined as shallow wells used to place a variety of fluids below the land surface, including wells used for injection of chemicals for in-situ groundwater treatment. Information on the proposed nature and type of injection well operation(s) will be submitted to the MDE Groundwater Permits Division. MDE will then determine whether the injection wells would be authorized by rule, whether an individual permit would be required, and/or whether additional information and/or operational requirements are needed to comply with State regulations.

9.3 NOTIFICATIONS

MDE will be notified immediately of any previously undiscovered contamination, changes in the RAP schedule, and citations from regulatory entities related to health and safety practices associated with the implementation of the proposed response action.

9.4 CONTINGENCIES

As stated throughout this RAP, the response action, cleanup goals, sampling protocol, and evaluation criteria are conceptual in nature. As part of development of the response action design, these items will be finalized. Based on this information, contingency measures will be developed and implemented if the criteria are not met, or if subsurface conditions are found to be substantially different than expected.

Section 10
Implementation Schedule

A projected sequence of events for this project, including the expected year of completion of various milestones is presented in Section 8.3.2. The milestone schedule will be finalized in the RAP Addendum.

Section 11
Administrative Requirements

11.1 INTRODUCTION

MDE's VCP stipulates several administrative requirements with which the applicant must comply. The administrative requirements include a written agreement, zoning certification, performance bond or other form of security, and health and safety plan requirements. These administrative requirements are described below.

11.2 WRITTEN AGREEMENT

A written agreement is provided in Appendix A to this RAP in compliance with Section 7-508 of the Environment Article, Annotated Code of Maryland. The written agreement stipulates that if the RAP is approved, the applicant agrees, subject to the withdrawal provisions set forth in Section 7-512 of the Environment Article, to comply with the provisions of the RAP.

11.3 ZONING CERTIFICATION

A zoning certification is provided in Appendix A to this RAP in compliance with Section 7-508 of the Environment Article, Annotated Code of Maryland. Section 7-508 requires that RAPs include a certified written statement that the property meets all applicable county and municipal zoning requirements.

11.4 PERFORMANCE BOND OR OTHER SECURITY

The requirement of a performance bond for completion of groundwater remediation will be addressed in the RAP Addendum.

11.5 HEALTH AND SAFETY PLAN

A project-specific Health and Safety Plan will be prepared and submitted to the MDE prior to implementation of the MDE-approved RAP. The Health and Safety Plan will address each planned response action activity that is performed by workers engaged in hazardous waste site activities. The project-specific Health and Safety Plan will reference applicable regulations that may apply to response action activities. At a minimum, the Plan will contain the required elements specified in 29 CFR Parts 1910.120 and 1926.65, as well as other regulatory and Lockheed Martin requirements that apply to the activities to be performed. At a minimum, the project-specific Health and Safety Plan will address the following (29 CFR Part 1910 citations in parentheses):

- Health and safety personnel requirements and responsibilities [29 CFR Part 1910.120(b)(4)(iv)]
- Pertinent site information [29 CFR Part 1910.120(b)(4)(iv)]
- Scope of work [29 CFR Part 1910.120(b)(4)(iv)]
- A safety and health risk or hazard analysis for each planned site activity [29 CFR Part 1910.120(b)(4)(iv)]
- Training requirements [29 CFR Part 1910.120(e)]
- Personal protective equipment (PPE) requirements for each planned site activity [29 CFR Part 1910.120(c)(5)]
- Medical surveillance requirements [29 CFR Part 1910.120(h)(1)(i)]
- Air monitoring and sampling requirements
- Site control measures [29 CFR Part 1910.120(d)]
- Decontamination procedures [29 CFR Part 1910.120(k)(1)]
- An Emergency Response Plan [29 CFR Part 1910.120(l)(1)]
- Confined-space entry procedures (29 CFR Part 1910.146)

- Spill containment [29 CFR Part 1910.120(j)(1)(viii)]
- Recordkeeping [29 CFR Part 1910.120(f)(8)]

The Health and Safety Plan will present information to adequately address appropriate hazard recognition and evaluation and control for the potential hazards that may be anticipated for the specific planned activities.

The project-specific Health and Safety Plan is recognized as a dynamic document that is subject to review and possible revision as appropriate. Potential factors that could warrant the revision of the Plan include a change in the scope of work or as a result of evaluating data collected throughout implementation of the response action.

Implementation of the appropriate portions of the project-specific Health and Safety Plan will be accomplished by the Site Safety Officer (SSO) (with assistance from project management as appropriate) assigned to the response action. The SSO will be on site during all intrusive activities. Specific health and safety program implementation elements are summarized below.

11.5.1 Training and Medical Surveillance

All personnel who participate in on-site work where there is a potential for exposure to hazardous waste-related safety or health hazards will be current participants in health and safety training and medical surveillance programs that are in accordance with regulatory requirements. In general, the employee training and medical requirements specified in the OSHA hazardous waste regulations are regarded as minimum requirements.

At a minimum, employees who will or may participate in any on-site activities that may involve potential exposures to hazardous waste-related safety or health hazards will first have to satisfy the following health and safety training requirements:

- Forty-hour introductory hazardous waste general worker training [29 CFR Part 1910.120(e)(3)(i)].

- On their first assignment, an additional 24 hours of activity under the direction of a trained, experienced supervisor [29 CFR Part 1910.120(e)(3)(i)].

- Individuals who will be in a supervisory position must also complete an additional 8 hours of management/supervisory health and safety training [29 CFR Part 1910.120(e)(4)].

- Eight hours of annual health and safety refresher training for all general workers and supervisors [29 CFR Part 1910.120(e)(8)].

- Project-specific training prior to the start of any on-site intrusive activities.

Additional health and safety training requirements may also be specified in the project-specific Health and Safety Plan depending on the nature of the planned activities (e.g., confined space entry training, fall protection training, excavation safety training, etc.).

11.5.2 On-Site Health and Safety Functions

The SSO will be responsible for ensuring that all health and safety requirements specified in the Health and Safety Plan are adequately performed and documented. This commonly includes activities such as the following:

- Conducting and documenting on-site health and safety training.

- Implementing a project-specific hazard communication program (e.g., chemical inventory, Material Safety Data Sheets [MSDSs], chemical container labeling, etc.).

- Implementing other project-specific health and safety programs that may be relevant based on the response action scope of work and the nature of planned activities (e.g., hearing conservation program, confined-space entry program, respiratory protection program, etc.).

- Performing and documenting equipment inspections for equipment to be used on site.

- Calibration and use of air monitoring devices (e.g., organic vapor meters, particulate meters, etc.) and air sampling devices.

- Ensuring that specified PPE is appropriately used.

- Overseeing personnel and equipment decontamination activities.
- Coordinating with appropriate on- and off-site contacts and agencies and managing the Emergency Response Plan, when/as appropriate.
- Other duties as specified in the Health and Safety Plan.

Section 12
References

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7. Maryland Department of the Environment (MDE), 1994. 1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control, Maryland Department of the Environment, Water Management Administration in association with Soil Conservation Service and State Soil Conservation Committee.

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10. Spitz, K., and J. Moreno. A Practical Guide to Groundwater and Solute Transport Modeling, John Wiley and Sons, Inc., New York. 1996.

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APPENDIX A – ADMINISTRATIVE REQUIREMENTS

Written Agreement
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

WRITTEN AGREEMENT

If the Response Action Plan is approved by the Maryland Department of the Environment, Lockheed Martin Corporation agrees, subject to the withdrawal provisions of Section 7-512 of the Environment Article, to comply with the provisions of the Response Action Plan. Lockheed Martin Corporation understands that if Lockheed Martin Corporation fails to implement and complete the requirements of the approved plan and schedule, the Maryland Department of the Environment may reach an agreement with Lockheed Martin Corporation to revise the schedule of completion in the approved Response Action Plan or, if an agreement cannot be reached, the Department may withdraw approval of the plan.

Brad W. Owens
Printed Name

Director, Environmental Remediation
Title

[signature]
Signature

4/14/08
Date

Zoning Certification
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

ZONING CERTIFICATION

Lockheed Martin Corporation hereby certifies that the property meets all applicable county and municipal zoning requirements.

Lockheed Martin Corporation acknowledges that there are significant penalties for falsifying any information required by the Maryland Department of the Environment under Title 7, Subtitle 5 of the Environment Article, Annotated Code of Maryland, and that certification is required to be included in a response action plan for the Voluntary Cleanup Program pursuant to Title 7, Subtitle 5 of the Environment Article, Annotated Code of Maryland.

Brad W. Owens
Printed Name

Director, Environmental Remediation
Title

[signature]
Signature

4/14/08
Date