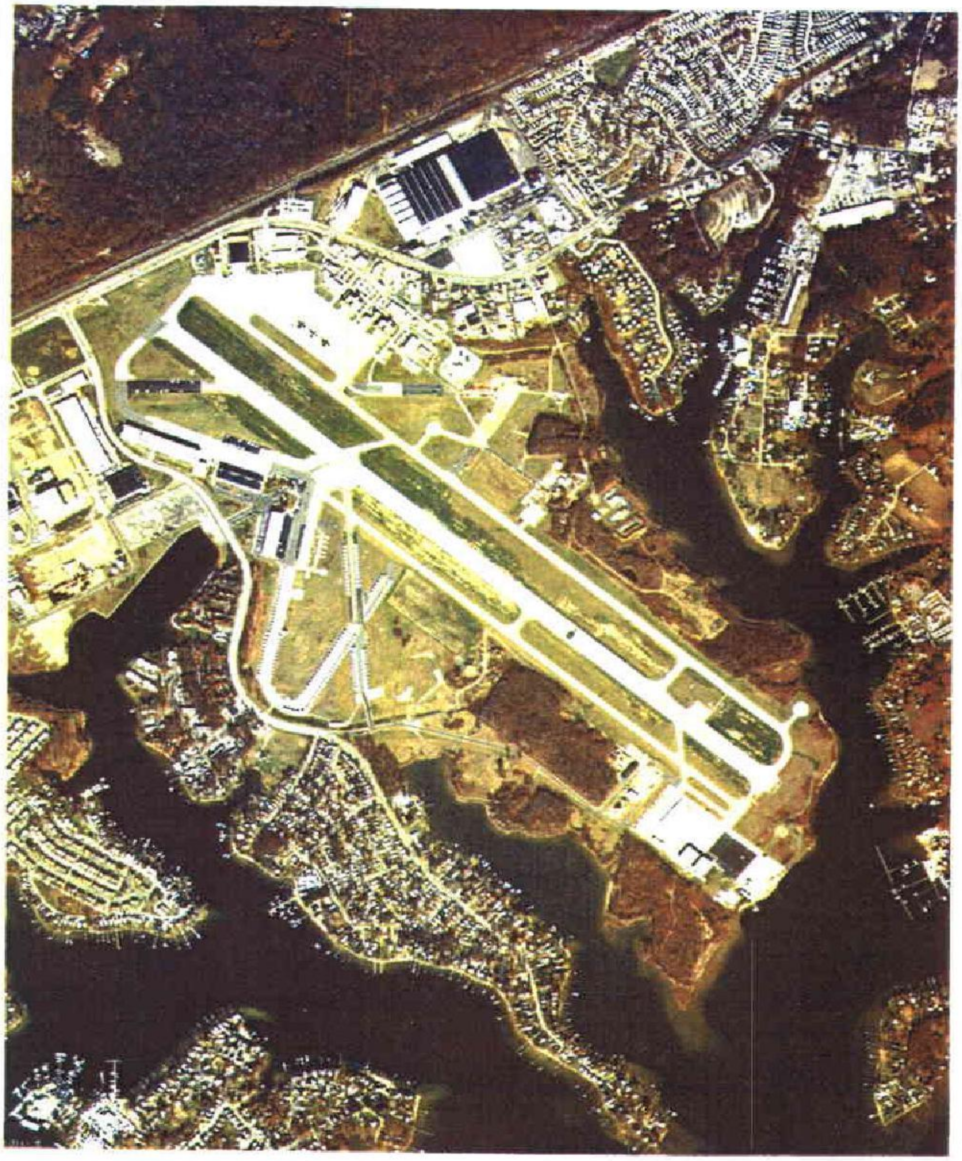
FINAL REPORT

Chemical Delineation and Groundwater Modeling Report Martin State Airport: Middle River, Maryland



LOCKHEED MARTIN

Tetra Tech

Environmental Engineers & Scientists

TC#10825-02/December 27, 2002

Final Report
Chemical Delineation and Groundwater Modeling
Martin State Airport: Middle River, Maryland

Prepared for:

Lockheed Martin Corporation

Prepared by:

Tetra Tech, Inc.

Dan Batrack
Program Manager

Nisha Bansal
Project Manager

Jia-Ling Wu, Ph.D., P.E.
Project Engineer

REGISTERED PROFESSIONAL ENGINEER
JIA LING WU
No C057033
Exp. 6/30/05
CIVIL
STATE OF CALIFORNIA

Phil Skorge
Project Geologist

TETRA TECH, INC.
3475 East Foothill Blvd.
Pasadena CA 91107
(626) 351-4664
FAX (626) 351-5291

TABLE OF CONTENTS

Page

TABLE OF CONTENTS
(continued)

LIST OF FIGURES

Page

TABLE OF CONTENTS
(continued)

LIST OF TABLES

Page

LIST OF APPENDICES

Section 1
Introduction

On behalf of Lockheed Martin Corporation, Tetra Tech has prepared the following Chemical Delineation and Groundwater Modeling Report for the southeast portion of Martin State Airport (MSA) in Middle River, Maryland. In accordance with the Maryland Department of the Environment's (MDE) requirements, subsurface soil and groundwater investigation activities were conducted to evaluate the extent of volatile organic compounds (VOC), metals, and petroleum hydrocarbons at the southeast portion of MSA. Several phases of subsurface investigation were conducted to delineate the extent of chemicals. Shallow soil samples and grab groundwater samples were collected during a delineation investigation program conducted in December 2001 and January 2002. Deep, multi-level wells were installed at two locations and sampled in May and June 2002 to evaluate the vertical distribution of chemicals. Six pre-existing shallow monitoring wells were also sampled in June 2002.

Data collected from this investigation, in conjunction with other historical site data, were used to support a groundwater modeling study for the site. Groundwater modeling was conducted to further understand groundwater flow conditions and evaluate potential migration of the existing chemical plumes. The study included development of a conceptual three-dimensional groundwater site model and numerical flow modeling to simulate the shallow groundwater flow system.

The short-term objective of the chemical delineation and groundwater modeling is to establish an appropriate long-term monitoring well network. The long-term objective is to support future feasibility study and risk assessment efforts. The recommended monitoring well locations will be outlined under a separate Technical Work Plan.

This report is organized as follows:

- Section 2 – Site Background: Presents a brief description of site history, soil and groundwater conditions, and description of the areas of investigation;
- Section 3 – Chemical Delineation Approach and Methodology: Presents the technical approach to the chemical delineation program, and a description of the field methodology employed;
- Section 4 – Investigation Results: Describes the results of the investigation, and presents the soil and groundwater data collected;
- Section 5 – Groundwater Flow Modeling: Discusses the conceptual approach to groundwater modeling and the input parameters used in the various models, and presents the modeling results;
- Section 6 – Conclusions: Provides conclusions derived from this subsurface investigation and modeling program;
- Section 7 – References: Cites references used to compile this report;
- Appendix A – Summary Data Tables: Summarizes analytical data collected during the chemical delineation program.
- Appendix B – MDE Correspondence: Includes MDE's letters approving the proposed investigation and modeling activities.

The data collected during the chemical delineation program are also outlined in two companion documents previously submitted to MDE:

- Tetra Tech's Interim Data Summary Report, dated March 15, 2002, which summarizes the shallow soil and groundwater investigation, and
- Tetra Tech's Interim Data Summary Report No. 2, dated October 4, 2002, which summarizes the installation and sampling of the monitoring wells.

The interim reports contain appendices with soil boring logs, well purging forms, and hard-copy laboratory data reports. The interim reports should be referenced for this information. To reduce the volume of information provided in this report, the appendices have not been reproduced.

Section 2
Site Background

2.1 SITE LOCATION AND DESCRIPTION

The MSA is located at 701 Wilson Point Road in Middle River, Maryland, and is bounded by Frog Mortar Creek to the east, Stansbury Creek to the west. Both creeks join into Chesapeake Bay at the south side of the airport. With surface water bodies surrounding most of MSA, the site can be considered a small peninsula. The location of MSA is shown in Figure 2-1.

Historically, MSA was owned and operated by the Glenn L. Martin Company from approximately 1929 to 1975. Glenn L. Martin Company is the predecessor to Martin Marietta; Lockheed and Martin Marietta merged in 1996 to form Lockheed Martin Corporation.

The area under investigation is located at the southeast portion of the MSA in Middle River, Maryland -- *see Figure 2-1*. In July 1991, Maryland Aviation Administration (MAA) encountered four drums adjacent to Taxiway Tango during trenching activities for the installation of an electrical cable. Based on the discovery of these buried drums, the surrounding area was investigated for potential impacts to soil and groundwater as outlined by MDE in their letters dated January 6, 1992 and January 14, 1997 to MAA. In 1998, Lockheed Martin Corporation voluntarily agreed with MAA to perform a series of four tasks to investigate the southeast portion of MSA - *see Section 2.3*.

2.2 SUBSURFACE CONDITIONS

2.2.1 Geology

Site lithology in the investigation area was interpreted based on soil borings completed during the subsurface investigations. Most soil borings were completed to depths of 25 feet or less. Two soil borings, DMW1 and DMW2, were completed to depths of approximately 100 feet below ground surface (bgs).

The uppermost 12 feet of soils consist of fill materials that were placed during construction of the airport during the 1950's. The fill materials are composed of heterogeneous layers of sands, silts and clays, with debris that includes concrete, scrap metal, brick, glass, and wood.

Beneath the surficial layer of fill materials, the uppermost native soils are interbedded sands, silts, and clays, which occur to a depth of approximately 50 feet bgs within the investigation area. Very dense, cemented sands were encountered from approximately 50 to 95 feet bgs. Fine-grained materials, consisting primarily of clayey sand and high plasticity clay, generally occur between 95 and 110 feet bgs, which is the maximum logged depth at the site. All native soils encountered to 110 feet bgs are believed to be part of the Patapsco Formation.

2.2.2 Hydrogeology

The uppermost water-bearing zone in the region is known as the Patapsco Formation. Available regional well log data indicate that the Patapsco Formation may extend to a depth of approximately 120 feet bgs beneath the site. The Patapsco Formation is underlain by the Arundel Formation, a thick red clay aquiclude. Regional lithologic information indicate that the Arundel Formation is approximately 120 feet thick and serves as the aquiclude overlying the water-bearing Patuxent Formation. Based on this information, the Arundel Formation may extend from 120 to 240 feet bgs at the MSA site.

Eight groundwater monitoring wells are located within the investigation area. Six groundwater monitoring wells were installed from 1994 to 1996 and are generally screened within the top 30 feet. Two deeper monitoring wells (screened to ~100 feet bgs) were installed in May 2002 to characterize site geology and the vertical extent of groundwater impacts. The most recent monitoring well measurements (recorded in June 2002) documented groundwater at depths ranging from approximately 7 to 22 feet bgs. Since 1994 when monitoring commenced, groundwater levels in the wells have historically ranged from 6 to 22 feet bgs. Based on groundwater elevation measurements, flow direction is to the east toward Frog Mortar Creek. Further interpretation of groundwater flow patterns is presented in Section 5.

Due to the site's proximity to Frog Mortar Creek, a standard tidal influence study was conducted on June 7, 2002. During the study, groundwater elevations fluctuated up to 0.31 feet due to tidal influence. Further discussion of the tidal study is presented in Section 5.

2.3 DESCRIPTION OF HISTORICAL AREAS OF CONCERN

From 1992 through 1996, MAA conducted several investigations at the southeast portion of Martin State Airport. Results of the investigations identified the four areas of concern. The four areas are shown in Figure 2-2, and are describes as follows:

1) *Taxiway Tango Median Anomaly Area* – After removal of four buried drums in 1991, a geophysical survey was conducted of the area adjacent to Taxiway Tango. Several anomalous zones were identified as potentially containing buried metal.

2) *Drum Area* – During a previous investigation conducted at the site in 1996, several drums were uncovered during surface vegetation clearing.

3) *Two Existing Ponds* – Based on historical records, acids may have been discharged during the 1950's and 1960's at the locations where two ponds currently exist.

4) *Petroleum Hydrocarbon Area* – During a previous investigation conducted at the site in 1996, petroleum hydrocarbons were encountered while drilling a soil boring. The petroleum hydrocarbon area is located approximately 200 feet northwest of the ponds.

2.4 SUMMARY OF PREVIOUS INVESTIGATIONS CONDUCTED BY LOCKHEED MARTIN CORPORATION

Previous sampling and investigation tasks conducted at the site by Lockheed Martin Corporation consisted of:

(1) Sampling existing groundwater monitoring wells in March 1999 (Tetra Tech, May 1999); and

(2) Source identification and assessment program at four areas of concern in March through May 2000 (Tetra Tech, September 2000).

2.4.1 Groundwater Monitoring Well Sampling

The first evaluation of the site by Lockheed Martin was performed in March 1999 and consisted of sampling existing groundwater monitoring wells to obtain updated chemical data on groundwater quality, groundwater elevation, and flow direction at the southeast portion of Martin State Airport. A total of six monitoring wells (*MW-1 through MW-6*) and one piezometer (*PZ-2*) were sampled for chemical analysis. Trichloroethene was the only volatile organic compound (VOC) detected in five of the six monitoring wells and one piezometer above the Maximum Contaminant Level (MCL) specified by the U.S. EPA's National Primary Drinking Water Regulations. Monitoring well MW-5 reported the highest concentrations of four VOCs (*cis-1,2-dichloroethene, toluene, 1,1,1-trichloroethane, and trichloroethene*) and two dissolved metals (*beryllium and cadmium*) above the MCLs. A detailed description of the groundwater sampling program is provided in the Final Groundwater Monitoring Survey and Sampling Report, dated May 18, 1999.

2.4.2 Source Identification and Assessment Program

The second investigation was identified as a Source Identification and Assessment Program and was performed from March through May 2000. Four specific areas were identified as having the potential to have released chemicals, and the investigation included a combination of excavations, localized trenching, drilling of soil borings, and sampling and laboratory analysis of soil, sediments, and groundwater. The four areas were identified as: 1) the Taxiway Tango median anomaly area, 2) a drum area, 3) two existing ponds, and 4) a petroleum hydrocarbon area. In total, eighty-three soil samples, twelve groundwater samples, and four sediment samples were collected for chemical analysis. VOCs, petroleum hydrocarbons, and metals were detected in the soil and groundwater during this investigation. Elevated concentrations of selected VOCs and metals were detected in the soil at each of the four areas, while only one VOC (*vinyl chloride*) was detected at the petroleum hydrocarbon area above the EPA Region III industrial soil risk-based concentrations used by MDE. Selected VOCs were also detected in the groundwater above their MCLs in the pond and petroleum hydrocarbon areas. Details are provided in the Final Source Identification and Assessment Report, dated September 29, 2000.

Section 3

Chemical Delineation Approach and Methodology

As presented in Section 2, chemicals (*i.e., VOCs, metals, and petroleum hydrocarbons*) were detected at elevated concentrations in soil and groundwater at the four areas of concern in the investigation area. Note that, due to the proximity of the ponds and the petroleum hydrocarbon area to each other, they are treated as one area in this section. As a result, further evaluation of the presence, concentration, and extent of chemicals in the groundwater was conducted through several phases of soil and groundwater sampling. The data were utilized in a groundwater fate and transport model to predict chemical migration patterns – *see Section 5*.

The following section describes the approach and field methodology to conduct this chemical delineation program. Investigation activities were conducted in accordance with Tetra Tech's Chemical Delineation and Modeling Work Plan, dated October 8, 2001, and revised Work Plan, dated November 28, 2001. The Work Plan was approved by MDE in a letter dated November 26, 2001 – *see Appendix B*.

3.1 PROJECT OBJECTIVES AND APPROACH

The intent of the chemical delineation program was to further assess chemicals detected in soil and groundwater at the southeast portion of MSA. The specific objectives were as follows:

1. EVALUATE LATERAL EXTENT OF CHEMICALS IN SOIL AND GROUNDWATER

Taxiway Tango Median Anomaly Area

- ✓ Determine if groundwater has been impacted by VOC and metals impacted soils.
- ✓ Evaluate if any groundwater impacts have migrated down-gradient from this area.
- ✓ Assess the lateral extent of burned material identified during the source assessment.
- ✓ Delineate the extent of VOCs and metals in soil at three excavation areas of the median.

Drum Area

- ✓ Determine if groundwater has been impacted by VOC and metals impacted soils.
- ✓ Evaluate if any groundwater impacts have migrated down-gradient from this area.
- ✓ Delineate the extent of VOCs and metals in soil at the drum area.

Pond #1 and Petroleum Hydrocarbon Area

- ✓ Determine the lateral extent of soil and groundwater impacted by VOCs, petroleum hydrocarbons, and metals.

2. DETERMINE IF IMPACTS ARE PRESENT AT PREVIOUSLY DISTURBED AREA

- ✓ At MDE's request, determine if groundwater has been impacted by potential chemicals at the previously disturbed area, located southeast of the drum area. MDE requested investigation in this area based on information provided on historical aerial photographs.

3. EVALUATE VERTICAL EXTENT OF CHEMICALS IN GROUNDWATER

- ✓ Determine if chemicals identified in the shallow perched zone have migrated to deeper portions of the aquifer.
- ✓ Characterize geology to evaluate potential lateral and vertical pathways for chemicals.
- ✓ Identify fine-grained, low-conductivity soil layers that may potentially trap VOCs and metals.

4. COLLECT DATA TO SUPPORT GROUNDWATER FLOW MODEL

- ✓ Collect geotechnical data at various locations of investigation area.
- ✓ Conduct tidal study to record daily groundwater fluctuations in monitoring wells.

To attain the above-outlined objectives, a phased investigation approach was conducted and consisted of soil sampling, groundwater grab sampling, and monitoring well installation and sampling. A detailed presentation of the sampling approach is provided in the Chemical Delineation and Modeling Work Plan, dated October 8, 2001, and revised Work Plan, dated November 28, 2001. A brief description is presented in the following sub-sections.

3.1.1 Phase 1 – Shallow Soil and Groundwater Investigation

Soil and groundwater grab samples were collected to define the extent of chemicals in the shallow subsurface around the investigation area. Groundwater samples were collected to determine the extent of chemicals in shallow groundwater (generally within 25 feet bgs). Soil sampling was conducted for both chemical and geotechnical testing to support the groundwater model. In addition, at MDE's request, visual inspection of soil cores was conducted to evaluate the extent of burned material within the Taxiway Tango median area. The investigation program was coordinated with the MAA to ensure that no sampling locations were placed near runways or other restricted areas. In addition, the presence of dense vegetation limited the availability of sampling locations near Frog Mortar Creek. All sampling locations are shown in Figure 3-1.

3.1.2 Phase 2 – Installation of Deep Monitoring Wells

In accordance with MDE's letter dated August 15, 2001, Tetra Tech installed deep, multi-level monitoring wells at two locations to characterize the site geology and vertical extent of groundwater impacts. The well locations were identified after conducting the shallow groundwater investigation presented in Section 3.2. The wells were installed at the location where the highest concentrations of TCE and vinyl chloride were detected in the shallow groundwater investigation. Deep well DMW1 was installed adjacent to groundwater sampling location PA-7, where TCE was detected at a concentration of 220,000 µg/L. Deep well DMW2 was installed adjacent to groundwater sampling location PA-15, where vinyl chloride was detected at a concentration of 27,000 µg/L. The deep well locations were approved by MDE in an e-mail dated April 8, 2002. The deep well locations are shown in Figure 3-1.

The approach to well installation was to identify thick, low-conductivity soil layers that may contain higher concentrations of VOCs or other chemicals. The goal was to install and screen the wells in those zones, in order to detect potential chemicals through groundwater sampling. Lithologic characterization and on-site screening with a Photoionization Detector (PID) was used to help make this determination.

Samples collected from the deep wells were analyzed for VOCs, total and dissolved priority pollutant metals, TPH, and SVOCs. In addition, groundwater samples were collected from the existing network of six monitoring wells as requested in MDE's letter dated August 15, 2001. The groundwater samples were analyzed for VOCs, total and dissolved priority pollutant metals, and SVOCs.

3.2 FIELD METHODOLOGY

3.2.1 Subsurface Obstruction Clearance

Prior to initiating drilling activities, utilities were identified through a site clearance program. An underground utility location center (*Miss Utility of Delmarva*) was notified to identify the locations of all utilities (*electrical, gas, water, communications, etc.*) at the site. In addition, available as-built drawings were reviewed to identify and mark utilities.

A geophysical survey was conducted to locate and mark all underground utility lines at the proposed sampling locations. A combination of electromagnetic resistivity / conductivity, line locating, and ground penetrating radar was used to assure that all proposed sampling locations are clear. Soil borings that required relocation due to subsurface obstructions were positioned as close as possible to the original location identified.

3.2.2 Direct Push Boring and Sampling Procedures

During the Phase 1 lateral chemical delineation investigation, soil borings were completed using a hydraulically-powered Geoprobe system. The Geoprobe system is a direct push drilling method in which tools penetrate the subsurface using percussion energy. A bore sampler was used for the collection of discrete interval soil samples. Advancement of the probe was halted at the desired sample depth and the bore sampler was lowered inside the probe. The sampler was then pushed into the soil for sample collection. The system generates no soil cuttings during the push drilling process.

The sampler was loaded with three clean, pre-washed stainless steel sample liners. The sample liner with the most recovery was delivered to the laboratory for chemical analysis. The other liners were used for head-space analysis and lithological logging.

Soil samples collected for chemical analysis were immediately capped and placed in a cooler with blue-ice pending delivery to the analytical laboratory. Each sample liner was covered with teflon sheets and capped with plastic end caps. A label was placed on the sample liner that includes a unique sample number, date and time that the sample was collected, name of the person handling the sample, and the specific analyses being requested from the laboratory.

3.2.3 Collection of Groundwater Grab Samples

Temporary wells were completed at each of the initial groundwater sampling locations. The temporary wells were used for a one-time groundwater sampling event, and not intended for long-term monitoring.

The wells were completed with 1-inch, Schedule 40, PVC pipe that was screened across the appropriate sampling interval. At each temporary well, a sand pack was placed in the annulus between the borehole and the PVC casing.

Groundwater was purged and sampled from the wells using a low-flow, peristaltic pump. Purged water was stored in 55-gallon steel drums. In accordance with MDE's letter dated August 15, 2001, each groundwater grab sample location was inspected for the presence of free phase product. Samples were collected in laboratory-prepared containers and placed immediately in a cooler on ice pending shipment to the laboratory.

3.2.4 Field Screening of Soil Samples

Head-space analyses were performed as a field screening technique using calibrated organic vapor detectors. Each soil sample was placed in a sealed container and filled with an approximately equal volume of clean air. After being left at ambient temperature for approximately 10 minutes, the head-space in the container was analyzed using a Photovac Microtip photoionization detector (PID). The PID registers the concentrations of total organic vapors in the head-space, which is an indication of the presence of volatile organic materials in the soil. The head-space readings were recorded on field logs. The PID was calibrated every morning and periodically during the day as needed.

3.2.5 Lithological Logging

During the drilling program, a field geologist logged all boreholes using professionally accepted techniques and procedures in accordance with ASTM Method D2488-00. Soil samples were logged to describe the color, moisture, sorting, grain size, and any other pertinent soil characteristics observed. Soil color was determined by using Munsell™ Color Charts. Textural properties of the soil were determined by using tables specified in the ASTM method. Sorting was determined by observing the grain-size distribution. Grain size was determined by comparing grains of soil to a plastic grain-size chart produced by American Stratigraphic, Inc. Grains of soil were placed on the chart, which allowed the geologist to directly compare the grains of soil to pictures of grains that range in size from very course to very fine sands. All information was documented on a boring log form.

3.2.6 Laboratory Analysis

A State of Maryland certified laboratory will analyze the soil and groundwater samples collected from the soil borings. A completed Chain-of-Custody form accompanied each shipment of samples to the laboratory to insure accountability for the samples from the time of collection to the time they are analyzed. The laboratory analyses used for the samples are summarized in Table 3-1.

Table 3-1
Laboratory Analyses

Analyte	Analytical Method
Volatile Organic Compounds (VOCs)	EPA 8260B
Priority Pollutant Metals	EPA 200.8 / 245.1A
Total Petroleum Hydrocarbons (TPH) - gasoline and diesel range	EPA 8015B
Hexavalent Chromium	EPA 7196A
SVOCs	8270C
PCBs / Pesticides	8081A / 8082

Copies of Chain-of-Custody forms and hard-copy laboratory data reports are presented in Tetra Tech's interim data reports.

3.2.7 Collection of Geotechnical Samples

Geotechnical data were collected to establish parameters for the fate and transport modeling. The geotechnical samples were collected at depths corresponding to changes in major lithologic zones and analyzed for soil porosity, bulk density, moisture content, total organic carbon, and/or permeability.

3.2.8 Equipment Decontamination

A decontamination area and a clean zone were established at the perimeter of the restricted work zone for preparation and breakdown of sampling equipment. The decontamination area was established to contain decontamination rinsate solution for subsequent disposal. The decontamination staging area included 5-gallon buckets for decontamination of equipment.

Equipment in direct contact with the soil media was decontaminated using the following process:

- ✓ Loose dirt was brushed off with a steel-bristle brush in the decontamination area;
- ✓ Equipment was washed in a non-phosphate detergent solution using plastic scrub brushes;
- ✓ Following the detergent wash, equipment was rinsed with tap water; and
- ✓ As a final step, equipment was rinsed with distilled water and allowed to air dry.
- ✓ The clean equipment was transferred to the clean zone.
- ✓ Decontamination solutions were containerized for disposal.

3.2.9 Borehole Abandonment

The primary goal when closing each borehole was to insure a pathway is not created that would facilitate the deeper spreading of any chemicals which might have been encountered in shallow soils. All borings were abandoned by backfilling with bentonite chips or a concrete-bentonite slurry.

3.2.10 Mud Rotary Drilling

Prior to drilling and well construction activities, well permits were obtained from MDE. The monitoring well borings were completed using a mud rotary drill rig fitted with 8 or 12-inch tricone bit. Environmentally-safe drilling muds were circulated through the borings to cool the bit and stabilize the borehole walls. A split-spoon sampler was used to collect samples at 5-foot intervals for on-site evaluation and lithological logging.

Two 2-inch diameter well casings were installed at different depths in the same boring. The well casings were Schedule 40 with 0.02-inch slot well screen. The well casings extended above-ground and were sealed with locking caps. The annular space around each well screen was filled with No.2 coarse-grained silica sand pack. Approximately one foot of No. 00 fine sand was placed above the coarse-grained filter pack. At lease three feet of bentonite pellets was placed above the fine sand. The remaining annular space was filled with cement grout. Each well was enclosed within a 4-foot high steel riser with locking cap. The wells were set over a 3-foot square concrete collar.

Specific construction details of the wells (well lengths, screen intervals, etc.) are described in Section 4. Well construction logs are provided in Appendix B of Tetra Tech's Interim Data Summary Report No. 2, dated October 4, 2002.

3.2.11 Well Development

After approximately 24 hours, the monitoring wells were developed. Development consisted of two steps: (1) surging; and (2) bailing. Surging was performed by forcing water into and out of the screen. The surging settled the sand pack and removed silt that had potentially entered the sand pack or screen during the installation procedure. The well was bailed and pumped to remove any suspended sediment and other materials that may have been introduced into the well during the installation and surging process. Three well volumes were removed during the well development procedure. The wells were then left to settle and reach equilibrium for a minimum of 72 hours prior to collecting groundwater samples.

3.2.12 Water Level Measurements

Water levels in the monitoring wells were measured using a water level meter consisting of a liquid sensor attached to a measuring tape that was lowered down into the well until water is encountered. Water levels were measured be reading from the tape relative to the notch in the top of the well casing. Water level measurements for each well were recorded on field data logging sheets.

3.2.13 Well Purging and Sampling

Groundwater samples were collected by first purging a minimum of 5 well volumes of groundwater and then allowing the water to recover to 80 percent of its original level. During well purging, field parameters including water temperature, pH, conductivity, dissolved oxygen, and turbidity were measured using a field water quality monitoring system. Stabilization of these parameters served as an indication of water representative of the formation, and their values were recorded on field data logging sheets. Well purging logs are presented in Appendix D of Tetra Tech's Interim Data Report No.2, dated October 4, 2002.

Groundwater samples were collected using dedicated disposable bailers (one bailer per sample per well). Prepared sample containers were provided by the laboratory prior to sampling. Water samples were collected with a clean Teflon bailer, placed in a cooler with ice and submitted to a State-Certified laboratory for analysis. The analyses performed on the soil and groundwater samples are shown in Table 3-1 – *see Section 3.2.6.*

Section 4
Investigation Results

This section describes the results of the chemical delineation program. Hard copy laboratory data reports are presented in Tetra Tech's interim data reports, dated March 15 and October 4, 2002.

4.1 RESULTS OF SHALLOW INVESTIGATION

The shallow investigation was conducted during December 2001 and January 2002. Exploratory borings were completed and soil and grab groundwater samples were collected to define the extent of chemicals and burned material in the subsurface around the investigation area.

4.1.1 Summary of Groundwater Sampling Results at Taxiway Tango Median Area

In order to determine if groundwater has been impacted beneath and down-gradient of the the Taxiway Tango median area, a total of ten groundwater samples (TT-1 through TT-10) were collected – *see Figure 3-1.* Temporary 1-inch wells were installed to depths of 13 feet to 20 feet below ground surface (bgs) for the collection of groundwater grab samples.

A total of six VOCs and two metals were detected at concentrations above their corresponding Maximum Contaminant Level (MCL) specified by EPA's national primary drinking water regulations. Five SVOCs were detected, however, no MCLs are established for these compounds. Table 4-1 identifies each chemical that was detected above its MCL. Complete summary analytical data tables are presented in Appendix A. Information regarding boring locations, soil boring logs, and laboratory data reports are presented in Tetra Tech's Interim Data Summary Report, dated March 15, 2002.

Table 4-1
Taxiway Tango Median Area
Maximum Concentrations of Chemicals Detected Above MCLs

Type of Chemical Detected	Chemical Detected	Maximum Concentration (µg/L)*	MCL (µg/L)
VOC (EPA Method 8260B)	Benzene	82	5
	Chlorobenzene	50,000	100
	Cis-1,2-Dichloroethene	1,700	70
	Toluene	1,300	1,000
	Trichloroethene	12	5
	Vinyl Chloride	7,900	2
Metal (EPA Method 200.8 / 245.1)	Cadmium	47	5
	Lead	46	15

* *Denotes the maximum concentration of the chemical detected in any of the samples collected in the Taxiway Tango Median Area*

4.1.2 Summary of Groundwater Sampling Results at Drum Area

In order to determine if groundwater has been impacted beneath and down-gradient of the drum area, a total of fourteen groundwater samples (DA-1 through DA-14) were collected – *see Figure 3-1.* Temporary 1-inch wells were installed to depths of 15 feet to 28 feet bgs for the collection of groundwater grab samples.

A total of ten VOCs and two metals were detected at concentrations above their corresponding MCL. One SVOC was detected, however, no MCL is established for this compound. Table 4-2 identifies each chemical that was detected above its MCL. Complete summary analytical data tables are presented in Appendix A. Information regarding boring locations, soil boring logs, and laboratory data reports are presented in Tetra Tech's Interim Data Summary Report, dated March 15, 2002.

Table 4-2
Drum Area
Maximum Concentrations of Chemicals Detected Above MCLs

Type of Chemical Detected	Chemical Detected	Maximum Concentration (µg/L)*	MCL (µg/L)
VOC (EPA Method 8260B)	1,2-Dichloroethane	630	5
	1,1-Dichloroethene	1,200	7
	cis-1,2-Dichloroethene	160,000	70
	trans-1,2-Dichloroethene	2,100	100
	Ethylbenzene	2,200	700
	Tetrachloroethene	110	5
	Toluene	24,000	1,000
	1,1,1-Trichloroethane	1,100	200
	Trichloroethene	130,000	5
	Vinyl Chloride	4,600	2
Metal (EPA Method 200.8 / 245.1)	Beryllium	10	4
	Cadmium	28	5

* *Denotes the maximum concentration of the chemical detected in any of the samples collected in the Drum Area*

4.1.3 Summary of Groundwater Sampling Results at Pond #1 and Petroleum Hydrocarbon Area

In order to determine the extent of chemicals in the groundwater at the Pond #1 and petroleum hydrocarbon area, a total of sixteen groundwater samples (PA-1 through PA-16) were collected – *see Figure 3-1.* Temporary 1-inch wells were installed to depths of 12 feet to 28 feet bgs for the collection of groundwater grab samples.

A total of eight VOCs and three metals were detected at concentrations above their corresponding MCL. Four SVOCs were detected, however, no MCLs are established for these compounds. Table 4-3 identifies each chemical that was detected above its MCL. Complete summary analytical data tables are presented in Appendix A. Information regarding boring locations, soil boring logs, and laboratory data reports are presented in Tetra Tech's Interim Data Summary Report, dated March 15, 2002.

Table 4-3
Pond #1 and Petroleum Hydrocarbon Area
Maximum Concentrations of Chemicals Detected Above MCLs

Type of Chemical Detected	Chemical Detected	Maximum Concentration (μg/L)*	MCL (μg/L)
VOC (EPA Method 8260B)	Benzene	120	5
	1,2-Dichloroethane	6,100	5
	cis-1,2-Dichloroethene	31,000	70
	Ethylbenzene	1,600	700
	Toluene	6,800	1,000
	Trichloroethene	220,000	5
	Vinyl Chloride	27,000	2
	Total Xylenes	35,000	10,000
Metal (EPA Method 200.8 / 245.1)	Antimony	13	6
	Arsenic	64	50
	Cadmium	94	5

* *Denotes the maximum concentration of the chemical detected in any of the samples collected at Pond #1 and Petroleum Area*

4.1.4 Summary of Groundwater Sampling Results at Previously Disturbed Area

A total of six groundwater samples were collected throughout the previously disturbed area identified by MDE – *see Figure 3-1.* Temporary 1-inch wells were installed to depths of 11 feet to 27.5 feet bgs for the collection of groundwater grab samples.

Only two metals were detected above their corresponding MCL. Table 4-4 identifies each metal that was detected above its MCL. Complete summary analytical data tables are presented in Appendix A. Information regarding boring locations, soil boring logs, and laboratory data reports are presented in Tetra Tech's Interim Data Summary Report, dated March 15, 2002.

Table 4-4
Previously Disturbed Area
Maximum Concentrations of Metals Detected Above MCLs

Metal Detected	Maximum Concentration (μg/L)*	MCL (μg/L)
Beryllium	17.8	4
Cadmium	16.6	5

* *Denotes the maximum concentration of the chemical detected in any of the samples collected in the Previously Disturbed Area*

4.1.5 Summary of Soil Sampling Results

A total of twenty soil samples were collected for laboratory analysis. All twenty soil samples were analyzed for VOCs; nineteen samples were analyzed for total priority pollutant metals using EPA Method 200.8 / 245.1 and hexavalent chromium using EPA Method 7196A; seven samples were analyzed for gasoline, diesel, and residual range organics; and six samples were analyzed for SVOCs. Three metals were detected at concentrations above their corresponding MDE August 2001 Non-Residential Soil Clean-up Standard. No other chemicals were detected above the soil clean-up standards. Table 4-5 identifies each metal that was detected above its Non-Residential Soil Clean-up Standard. Complete summary analytical data tables are presented in Appendix A. Information regarding boring locations, soil boring logs, and laboratory data reports are presented in Tetra Tech's Interim Data Summary Report, dated March 15, 2002.

Table 4-5
Summary of Soil Sampling Data
Maximum Concentrations of Chemicals Detected Above Soil Clean-up Standards

Metal Detected	Maximum Concentration (mg/kg)*	Non-Residential Soil Clean-up Standard (mg/kg)
Arsenic	6.2	3.8
Mercury	0.6	0.12
Lead	1,974	400

* Denotes the maximum concentration of the metal detected in any of the soil samples collected

4.1.6 Visual Inspection Results for Exploratory Soil Borings

As presented in the work plan and requested by MDE, a series of exploratory soil borings were completed throughout Taxiway Tango and around the perimeter of the area to delineate the lateral extent of burned material. A total of twelve exploratory borings were continuously cored to visually inspect the soil for the presence of burned material and waste disposal. Based on visual inspection of the soil, there was no signs of burned material or evidence of waste disposal.

4.1.7 Lateral Extent of Chemicals in Soil and Groundwater

As outlined in Section 4.1.5, only three compounds (arsenic, mercury, and lead) were reported above MDE's non-residential soil cleanup levels. No organic compounds (VOCs, SVOCs, or petroleum hydrocarbons) were found above the soil cleanup levels. Figure 4-1 shows the locations of the samples that exceeded the soil cleanup levels.

Based on the data collected during the shallow groundwater investigation, a total of twelve VOCs and five metals were detected in groundwater above their MCLs throughout the investigation area. The chemicals were detected primarily at depths of less than 25 feet bgs.

Chlorinated VOCs that were detected above MCLs include cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-dichloroethene (cis-1,2-DCE), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE), 1,1,1-trichloroethane (1,1,1-TCA), trichloroethene (TCE), tetrachloroethene (PCE), and vinyl chloride. Three chlorinated VOCs (TCE, cis-1,2-DCE, and vinyl chloride) were reported at concentrations exceeding 1,000 times their MCLs. Aromatic VOCs were also detected above MCLs, such as benzene, chlorobenzene, toluene, ethylbenzene, and xylenes, and were frequently found co-located with chlorinated VOCs. The highest concentration of any detected aromatic VOC was chlorobenzene at 50,000 μg/L, which is 500 times its MCL of 100 μg/L. The detected aromatic VOCs were generally found in the Petroleum Hydrocarbon Area and the northwest portion of the Taxiway Tango median area.

Antimony, arsenic, beryllium, cadmium, and lead were the only five metals detected above their respective MCLs. Cadmium was detected at the highest concentration of any metal above its MCL. Cadmium was detected at a maximum concentration of 94 μg/l, which is about 19 times higher than its MCL of 5 μg/L. Cadmium impacted groundwater was generally found in the vicinity of the Drum Area.

Overall, the primary chemicals of concern are TCE, cis-1,2-DCE, and vinyl chloride, based on detected concentrations exceeding 1,000 times their MCLs. Most other chemicals detected above MCLs were co-located with one or more of these three primary VOCs. Therefore, isoconcentration maps depicting the distribution of TCE, cis-1,2-DCE, and vinyl chloride throughout the investigation area, are presented as Figures 4-2 through 4-4. In addition, Figures 4-5 and 4-6 show sampling locations where other chemicals have been detected above their respective MCLs. Figure 4-5 shows the locations where aromatic organics exceeded MCLs, while Figure 4-6 shows the locations where metals concentrations exceeded MCLs.

As shown in Figures 4-1 through 4-3, four potential source areas are present at the site that have commingled to form one large VOC plume. Based on the lateral distribution of chemicals, the four major source areas appear to be:

1) Plume 1, originating from the Drum Area;
2) Plume 2, originating from the Petroleum Hydrocarbon Area;
3) Plume 3, originating from former Excavation 1 of the Taxiway Tango median area;
4) Plume 4, originating from former Excavation 2 of the Taxiway Tango median area.

Figures 4-2 through 4-4 show that, while the chemical plumes have been partially delineated to the north, west, and south, the plumes have not been delineated to the east toward Frog Mortar Creek. Further investigation through monitoring well installation will be required to fully evaluate the lateral extent of chemicals in groundwater.

4.2 RESULTS OF DEEP INVESTIGATION

The objective of the deep wells was to determine if chemicals (primarily VOCs) identified in shallow groundwater have migrated to deeper portions of the Patapsco aquifer. Deep well DMW1 was installed adjacent to groundwater sampling location PA-7, where TCE was detected at a concentration of 220,000 µg/L in the shallow groundwater. A second deep well, DMW2, was installed adjacent to groundwater sampling location PA-15, where vinyl chloride was detected at a concentration of 27,000 µg/L in the shallow groundwater. The drilling, well construction, and groundwater sampling program was conducted during May and June 2002.

4.2.1 Construction of Well DMW1

Drilling was conducted to a total depth of 102 feet bgs for on-site screening and lithologic characterization. Soil sampling conducted during drilling identified the following major lithologic zones:

0 – 12 feet bgs: Fill Materials

12 – 57 feet bgs: Interbedded sands, silts, and clays

57 – 85 feet bgs: Very dense, well graded sand (occasionally cemented)

85 – 102 feet bgs: Red clay

Based on soil lithology, two monitoring wells were installed in the borehole, as follows:

- DMW1-A, installed at a depth of 55 feet bgs, with a 10-foot screen interval from 45 to 55 feet bgs. The objective of the well placement was to target the top of the dense sand zone to determine if chemicals have potentially been trapped above this low-conductivity zone.

- DMW1-B, installed at a depth of 88 feet bgs, with a 5-foot screen interval from 83 to 88 feet bgs. The objective of the well placement was to target the top of the red clay zone to determine if chemicals have potentially been trapped above this low-conductivity zone.

Both wells were installed in the same borehole using 2-inch diameter, Schedule 40 PVC casing. Steel surface casing was used to seal off the uppermost 15 feet of the borehole (a 10-foot thick clay zone occurs between 12 and 22 feet bgs).

4.2.2 Construction of Well DMW2

Drilling was conducted to a total depth of 111 feet bgs for on-site screening and lithologic characterization. Soil sampling conducted during drilling identified the following major lithologic zones:

0 – 20 feet bgs: Fill Materials

20 – 60 feet bgs: Interbedded sands, silts, and clays

60 – 95 feet bgs: Very dense, well graded sand (occasionally cemented)

95 – 111 feet bgs: Sandy clay / clayey sand

Based on soil lithology, two monitoring wells were installed in the borehole, as follows:

- DMW2-A, installed at a depth of 60 feet bgs, with a 10-foot screen interval from 50 to 60 feet bgs. The objective of the well placement was to target the top of the dense sand zone to determine if chemicals have potentially been trapped above this layer.

- DMW2-B, installed at a depth of 95 feet bgs, with a 10-foot screen interval from 85 to 95 feet bgs. The objective of the well placement was to target the top of the sandy clay zone / clayey sand zone to determine if chemicals have potentially been trapped above this low-conductivity zone.

Both wells were installed in the same borehole using 2-inch diameter, Schedule 40 PVC casing.

4.2.3 Summary of Analytical Results

One soil sample was collected from the bottom of each borehole for analysis of VOCs using EPA Method 8260B. A summary of the detected VOCs is presented as follows:

DMW1-90 (collected at 90 feet bgs)

Toluene – 13 µg/kg

cis-1,2-Dichloroethene – 25µg/kg

Trichloroethene – 290 µg/kg

DMW2-110 (collected at 110 feet bgs)

MtBE – 9 µg/kg

The deep wells and the six pre-existing shallow monitoring wells were sampled for chemical analyses in June 2002. Twelve VOCs and three metals were detected at concentrations above their corresponding MCL. Table 4-6 identifies chemicals detected in the wells above MCLs. Complete summary analytical data tables are presented in Appendix A. Cross sections showing the vertical distribution of the primary VOCs detected in the groundwater are shown in Figures 4-7 and 4-8.

Table 4-6
Monitoring Well Sampling Data, Chemicals Detected Above MCLs

Monitoring Well	Chemical Detected	Concentration (µg/L)	MCL (µg/L)
DMW1-A	Benzene	46	5
	Cadmium	1,200	5
	Carbon Tetrachloride	5	5
	1,2-Dichloroethane	53	5
	1,1-Dichloroethene	34	7
	cis-1,2-Dichloroethene	6,200	70
	Chromium	150	100
	Tetrachloroethene	12	5
	Trichloroethene	9,000	5
	Vinyl Chloride	3,500	2
DMW1-B	Benzene	48	5
	Cadmium	390	5
	1,2-Dichloroethane	32	5
	1,1-Dichloroethene	15	7
	cis-1,2-Dichloroethene	4,500	70
	Trichloroethene	2,800	5
DMW2-A	Benzene	21	5
	Cadmium	5	5
	1,2-Dichloroethane	100	5
	1,1-Dichloroethene	32	7
	cis-1,2-Dichloroethene	1,800	70
	Tetrachloroethene	47	5
	1,2,4-Trichlorobenzene	540	70
	Trichloroethene	12,000	5
	Vinyl Chloride	250	2
DMW2-B	Trichloroethene	120	5
	Vinyl Chloride	3	2
MW-1	Trichloroethene	320	5
MW-2	Beryllium	6	70
	Cadmium	14	5
	Trichloroethene	19	5
MW-3	cis-1,2-Dichloroethene	510	70
	Trichloroethene	650	5
	Vinyl Chloride	36	2
MW-4	Benzene	10	5
	Vinyl Chloride	27	2
MW-5	Benzene	81	5
	Cadmium	24	5
	1,2-Dichloroethane	170	5
	1,1-Dichloroethene	690	7
	cis-1,2-Dichloroethene	110,000	70
	trans-1,2-Dichloroethene	1,100	100
	Tetrachloroethene	21	5
	Toluene	2,800	1,000
	1,1,1-Trichloroethane	520	200
	1,1,2-Trichloroethane	11	5
	Trichloroethene	20,000	5
	Vinyl Chloride	260	2
MW-6	No chemicals detected above MCLs	NA	NA

NA - Not Applicable

As shown in Table 4-6, chemicals were detected above MCLs in each of the deep well samples collected during the investigation. TCE was detected at a maximum concentration of 12,000 µg/L in DMW2-A, collected at 55 feet bgs. Vinyl chloride was detected at a maximum concentration of 3,500 µg/L in DMW1-A, collected at 50 feet bgs. The highest concentration reported for any metal was cadmium, which was detected at 1,200 µg/L in DMW1-A.

Section 5
Groundwater Flow Modeling

Groundwater flow and fate and transport modeling was conducted to predict the groundwater flow in the investigation area. The objectives of this modeling effort were to (1) improve our understanding of the shallow groundwater flow system and potential migration of the existing chemical plumes; (2) select proper locations for additional groundwater monitoring wells based on the groundwater flow model, and 3) provide a tool to organize field data which may be used in future feasibility studies and risk assessments. The objectives and approach to conducting the modeling effort is outlined in MDE's letter dated November 22, 2002 – *see Appendix B*.

5.1 MODELING APPROACH AND TOOLS

The modeling effort consisted of three primary components:

(1) Site Conceptual Model - A three-dimensional conceptual model was developed that simplifies field conditions and organizes and interprets the associated field data (e.g., chemical concentrations for delineating chemical plumes and quantifying chemical mass, groundwater elevations for determining groundwater contours, and shallow aquifer parameters, such as hydraulic conductivity, soil porosity, and bulk density).

(2) Numerical Groundwater Flow Model - Based on the site conceptual model, a three-dimensional numerical groundwater flow model was utilized to simulate the shallow groundwater flow systems. A particle tracking model was used to predict potential future plume movement.

The site conceptual model was constructed using boring logs, soil parameters, and other site-specific information. The steady-state groundwater flow numerical model was calibrated based on field measurements of groundwater levels. The calibration is to establish that the model can reproduce field-measured heads and flows. Calibration was conducted by trial-and-error adjustment of the hydraulic conductivity.

Three computer modeling programs were used in this effort – MODFLOW, Argus ONE, and MODPATH.

1) MODFLOW - Modular Finite-Difference Groundwater Flow Model (MODFLOW) was developed by the U.S. Geological Survey (USGS) to simulate common features in groundwater systems. Currently, MODFLOW is the most widely used program for simulating groundwater flow. MODFLOW 2000 (the latest version) was selected for the flow modeling. MODFLOW 2000 simulates groundwater flow in aquifer systems using the finite-difference method. A variety of features and processes such as rivers, springs, reservoirs, lakes, wells, evapo-transpiration, and recharge from precipitation and irrigation also can be simulated.
2) Argus ONE - Developed by Argus Interware, Inc., Argus ONE is a model-independent Geographical Information System (GIS) for numerical modeling. Argus ONE acts as an interface between the conceptual model and numerical model. MODFLOW GUI was developed for Argus ONE. Argus ONE is a graphical user interface for MODFLOW. The interface simplifies the process of creating model input files.
3) MODPATH - Developed by the USGS, is a post-processing program for MODFLOW to estimate flow paths in groundwater systems. MODPATH displays particle paths, and model features.

5.2 SITE CONCEPTUAL MODEL

5.2.1 Model Boundary Conditions

The lateral boundaries of the shallow groundwater flow systems are illustrated in Figure 5-1. The shallow groundwater flow systems are bounded laterally by physical boundaries, at the bottom by the impermeable clay layer, elevation of -70 feet mean sea level (msl), and at the top by the water table. Frog Mortar Creek is a physical boundary due to the presence of surface water. The southern boundary of the model coincides with the centerline of the peninsula. The centerline of the peninsula is a natural groundwater divide that forms a no-flow boundary. The boundaries along the western side of the model were defined as hydraulic boundaries, in which specified heads were selected based on knowledge of the flow system.

5.2.2 Model Layers

Based on the well boring logs, three layers of the aquifer were defined (See Table 5-1). The uppermost layer, Model Layer 1, starting from elevation 15 feet msl to -15 feet msl, has a thickness of 30 feet. Model Layer 1 was established at 15 feet msl due to the possibility of groundwater elevations at the upper-gradient near the western side boundaries being higher than 10 feet. Also, although the surface elevations in the investigation area may be below 15 feet msl, it is much easier to use a uniform layer than using a topographical map to define the thickness of the layer. This does not impact the modeling results in this application. Model Layer 2 of the aquifer was defined at elevation -15 feet msl to -40 feet msl, and has a thickness of 25 feet. The bottom layer, Model Layer 3, was defined at elevation -40 feet msl to -70 feet msl, and has a thickness of 30 feet. The impermeable layer was assumed at below elevation -70 feet msl.

5.2.3 Groundwater Elevations

Eight groundwater monitoring wells are located in the area. Six groundwater monitoring wells were installed from 1994 to 1996. Two deep monitoring wells were installed in May 2002 to characterize site geology and the vertical extent of groundwater impacts. As part of the tidal study, groundwater elevation monitoring was conducted on June 7, 2002 over a 12-hour period. The monitoring data is presented in Table 5-2. The data indicates groundwater heads fluctuate daily up to 0.31 feet due to tidal influence. Tidal influence is affected by the distance from Frog Mortar Creek to the wells and lithology surrounding the well screens.

Table 5-3 presents measured groundwater head data from wells MW-1, MW-2, MW-3, MW-4, MW-5, MW-6, PZ-2, DMW1, and DMW2. The groundwater heads measured on February 22, 1996 and March 16, 1999 have a similar range, 2.5 feet msl to 5.19 feet msl. Groundwater heads measured on February 22, 2002 are significantly lower than the previous monitoring events with a range of 1.75 feet msl to 3.25 feet msl. The differences in groundwater head monitoring results may reflect seasonal changes in which higher groundwater head reflects groundwater flow in the spring and lower groundwater head reflects groundwater flow in the summer.

Site groundwater elevation contours were estimated using linear gradients. Contour estimates were based on well locations and groundwater heads measured on June 7, 2002. The contours of groundwater head with groundwater flow direction are shown on Figure 5-2.

5.2.4 Model Aquifer Parameters

Soil samples were collected during the installation of the deep groundwater monitoring wells (DMW1 and DMW2) and the groundwater and soil investigation. Soil samples were used to determine characteristics, such as, dry bulk density, specific gravity, total porosity, and organic carbon content. The laboratory results of the soil analyses are summarized in Table 5-4. Parameters were grouped and averaged for the vertical layers of the model based on the soil characteristics.

Retardation factors for the primary VOCs of concern, (*i.e., TCE, cis-1,2 DCE and vinyl chloride*) were estimated. Equations and parameters are presented in Table 5-5.

In 1994, slug tests were conducted to estimate the hydraulic conductivity of the shallow water aquifer. Three tests were conducted at groundwater monitoring wells MW-1, MW-2 and MW-3. The results of the slug tests were 35.82 feet/day, 4.81 feet/day and 0.2 feet/day at MW-1, MW-2 and MW-3, respectively. The slug test results (which are associated with the lithology around the well screens) were used to estimate hydraulic conductivity values for the conceptual model layers.

5.3 NUMERICAL GROUNDWATER FLOW MODEL

The USGS computer model, MODFLOW -2000, was applied for simulations of ground water flow and chemical fate and transport at the MSA site. Argus ONE was also selected to organize field data, develop the conceptual model, and pre- and post-process the data for running MODFLOW.

A numerical groundwater steady-state flow model was developed based on the conceptual model presented in Section 5.3. The major steps in the modeling process include specifying boundary conditions, designing the model grid, assigning parameter values, and calibration and verification of the model.

5.3.1 Numerical Model Boundary Conditions

The head or flux must be specified along the boundaries of the system. For the natural physical boundary along Frog Mortar Creek, the specified head boundary condition was assigned to 0 feet msl. The natural groundwater divide (hydraulic boundary), located approximately at the center line of the small peninsula, is the southern, no-flow boundary of the model. Flux crossing the boundary is zero. Specified head boundaries were selected for the western boundaries of the model. Linear extensions of the groundwater contours were used to specify groundwater heads ranging from 0.5 feet msl to 10.0 feet msl. The historical groundwater monitoring data illustrated that groundwater level changes seasonally. Specified head boundaries for the western boundary of the model may not be suitable for modeling the groundwater flow in other seasons. Nevertheless, the specified head boundaries can be used to produce a steady-state flow field for calibration purposes.

Vertically, the shallow groundwater aquifer is an unconfined aquifer bounded by an impermeable clay layer (no-flow or no-leaky aquifer) at the bottom (elevation -70 feet msl) of the aquifer and the water table at the top of the aquifer.

5.3.2 Numerical Model Grids

The horizontal plane of the grid was laid out as shown on Figure 5-3. The x-axis of the model is parallel to the center line of the peninsula. It is assumed that the x-axis and y-axis are collinear with the principal directions of the hydraulic conductivity tensor (K_x K_y). This is required when using MODFLOW.

The model dimensions of the horizontal plane are 4,800 feet (0.79 miles) in length along the x-axis and 2,350 feet (0.39 miles) in width along the y-axis. The grid covers an area of 260 acres. The effective model area covered by the grid is approximately 180 acres.

The block-centered finite difference grid was used to discretize the model domain. The block size, 25 feet by 25 feet, was used to cover the two small ponds and the area where the chemical plumes were studied by applying the fate and transport model. The remaining lateral area of the model domain was covered by a grid with the block size of 50 feet by 50 feet.

The numerical model vertical grid spacing was selected based on the conceptual model layers and the variability in aquifer properties. The top, middle and bottom layers are 15 feet msl to -15 feet msl; -15 feet msl to -40 feet msl; and -40 feet msl to -70 feet msl, respectively.

5.3.3 Numerical Model Aquifer Parameters

Hydraulic conductivity is the only aquifer parameter used for the steady state groundwater flow model. The boring log data organized in Table 5-1 illustrates that the lithology varies significantly across the investigation area. The heterogeneous lithology explains the locally variable hydraulic conductivities at the site. For a field scale application, a range of hydraulic conductivity values was assigned to each vertical layer based on the aquifer lithology.

Hydraulic conductivity values ranging from 5 feet/day to 15 feet/day were assigned for the top layer. The top layer consists of a series of silt, sand, dense clay, and sand/gravel lenses. The lithology of the top layer is similar to that surrounding the well screen of MW-2. Based on slug tests, hydraulic conductivity values at MW-2 were estimated at 4.8 feet/day.

Hydraulic conductivity values ranging from 30 feet/day to 40 feet/day were assigned for the middle layer. Compared to the top layer, the middle layer is composed of less clay and silt. The middle layer's lithology is similar to that surrounding the well screen of MW-1. Based on slug tests, hydraulic conductivity values at MW-1 were estimated at 35 feet/day

Hydraulic conductivity values ranging from 50 feet/day to 70 feet/day were assigned for the bottom layer. Two boring logs, DMW1 and DMW2, show that sand dominates the bottom layer.

The aquifer layers are assumed to be isotropic media, which means $K_x = K_y = K_z$.

5.3.4 Numerical Model Calibration and Verification

Model calibrations were performed on a trial-and-error basis to produce a steady state flow characterized by the groundwater head contours presented on Figure 5-2. Hydraulic conductivity values were adjusted in sequential model runs to match calibration targets. The calibration targets were based on the groundwater heads measured from the monitoring wells. The specified head boundaries of the western side of the model were also adjusted for the steady-state flow calibrations.

Additional hydrogeologic characteristics of the site were identified for model calibration. Two small surface ponds, located in the investigation area, influence the groundwater gradient. Also, groundwater head contours with lower hydraulic gradients were twisted swiftly. This suggests the physical presence of an area with high hydraulic conductivity within the surrounding area. Third, the hydraulic conductivity (or horizontal leakages) of the aquifer along the creek is relatively low. Lastly, historical engineering plans showed that a bay previously existed in the area of one of the small ponds.

The calibration was accomplished by finding a set of hydraulic conductivity values and boundary conditions (See Figures 5-4, 5-5 and 5-6). The steady state flow model reproduced the distribution of the groundwater heads on Figure 5-7 The simulated heads at the monitoring wells are presented for a comparison to the field head measurements on June 7, 2002 in Table 5-6.

Model verification was performed using the field head measurements from March 16, 1999 and February 22, 1996. These measurements represent the early spring season. A new set of specified heads for the western side of the model boundaries was selected. Without changing the calibrated hydraulic conductivity, the steady-state flow model reproduced the distributions of the groundwater heads (See Figure 5-8). The simulated groundwater heads produced at the monitoring wells from the verification model are presented in Table 5-6.

Agreement between the simulated and field measured groundwater heads was made in the calibration process. The biggest difference determined was 0.26 feet, which is of similar scale to the daily fluctuations due to tidal influence.

In the verification process, the simulated and field measured groundwater heads were in agreement except at the location MW-3 (50 feet from PZ-2). The head at MW-3 is isolated from its vicinity aquifer due to less permeable clay deposition surrounding the well screen. The slug test confirmed the area's low hydraulic conductivity, 0.2 feet/day. Unlike other monitoring wells, the head monitoring during the 12-hour tidal study (See Table 5-2) showed no influence by tide. This suggests that the well is isolated from dynamic groundwater flow in the aquifer.

5.3.5 Dynamic Average of Groundwater Flow Conditions

In order to determine average groundwater flow conditions, it was assumed that the seasonal average of heads represents dynamic average steady-state conditions. The dynamic average of the groundwater head is 4.16 feet msl, based on MW-4 head measurement of 3.1 feet msl on September 7, 2002; 5.19 feet msl on March 16, 1999; and 5.26 feet msl on February 22, 1996. A set of specified heads for the western side boundary of the model was selected to reproduce the head at the level of 4.16 feet msl at MW-4. Figure 5-9 shows the simulated distribution of groundwater heads. These groundwater flow conditions were used to represent dynamic average steady-state groundwater flow for long term studies of chemical mass plume transport.

5.3.6 Particle Tracking Model

The MODPATH model was used predict the potential future plume movement based on particle flow prediction. Developed by the USGS, MODPATH is a post-processing program for MODFLOW to estimate flow paths in groundwater systems. The particle tracking model was conducted to evaluate potential groundwater monitoring well locations along the flow path. The results of the modeling are shown on Figure 5-10. The particle movement pathways will provide the basis for proposed monitoring wells during the next phase of groundwater investigation.

Table 5-2 Groundwater Level Monitoring in 12-hour Duration at Martin State Airport

Date: 6/7/2002

Groundwater Monitoring Wells																
	MW-1		MW-2		MW-3		MW-4		MW-5		MW-6		DMW-1		DMW-2	
	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)
	7:35	8.06	7:40	7.24	7:36	8.92	7:24	8.30	7:15	21.96	7:04	15.93	7:26	10.23	7:17	21.30
	9:12	8.08	9:11	7.25	9:13	8.92	9:09	8.32	9:06	22.00	9:04	15.96	9:10	10.26	9:08	21.31
	11:12	8.05	11:10	7.24	11:13	8.92	11:07	8.33	11:05	22.00	11:04	15.96	11:09	10.26	11:06	21.31
	13:12	8.02	13:10	7.18	13:13	8.90	13:07	8.35	13:05	21.94	13:04	15.91	13:09	10.20	13:06	21.09
	15:13	8.00	15:11	7.13	15:15	8.90	15:09	8.33	15:06	21.91	15:05	15.85	15:10	10.16	15:07	21.00
	17:14	7.98	17:12	7.13	17:16	8.90	17:09	8.28	17:06	21.82	17:05	15.85	17:11	10.15	17:08	21.02
	19:14	8.00	19:12	7.14	19:16	8.91	19:10	8.34	19:06	21.87	19:05	15.92	19:11	10.17	19:08	21.07
Average		8.03		7.19		8.91		8.32		21.93		15.91		10.20		21.16
Difference between highest and lowest		0.1		0.12		0.02		0.07		0.18		0.11		0.11		0.31

Table 5-3 Field Measurements of Groundwater Heads

		6/7/2002		3/16/1999		2/22/1996		8/15/1994	
Well I.D.	Top of PVC Elevation (feet)	Depth to Ground Water (feet)	Ground Water Elevation (feet)	Depth to Ground Water (feet)	Ground Water Elevation (feet)	Depth to Ground Water (feet)	Ground Water Elevation (feet)	Depth to Ground Water (feet)	Ground Water Elevation (feet)
MW-1	10.47	8.03	2.44			6.28	4.19	6.90	3.06
MW-2	9.28	7.19	2.09	6.21	3.07	6.51	2.77	7.07	2.21
MW-3	12.16	8.91	3.25	8.26	3.90	7.87	4.29	8.74	3.42
MW-4	11.46	8.32	3.14	6.27	5.19	6.20	5.26		
MW-5	23.68	21.93	1.75	21.05	2.63	20.85	2.83		
MW-6	17.75	15.91	1.84	14.7	3.05	14.30	3.45		
PZ-2	12.13	Not Sample	N/A	7.95	4.18				
DMW-1	11.95	10.204	1.746						
DMW-2	21.62	21.157	0.463						

Note:

The top PVC elevation of MW-1 was 9.96 feet msl before a damage was observed May, 1999.

It was used to determined the groundwater elevations measured on 8/15/1994.

Table 5-4 Soil Parameters

Site Specific Data						Average in Layer								
		Dry Density	Specific Gravity		Total Organica Carbon	Bulk Density (g/cm³)			Total Porosity			Toc (%)		
Sample ID	Description	(g/cm³)	SG (g/cm³)	Total Porosity	(%)	15' to -15'	-15' to -40'	-40' to -70'	15' to -15'	-15' to -40'	-40' to -70'	15' to -15'	-15' to -40'	-40' to -70'
DMW-1 (10-12')	Orange Brown, Sandy clay	1.381	2.65	0.479	2.5	1.38			0.48			2.50		
DMW-1 (15-17')	Gray clay	1.147	2.67	0.570	1.7	1.15			0.57			1.70		
DMW-1 (30-32')	White to yellow brown, silty sand	1.272	2.66	0.522	1.6		1.27			0.52			1.60	
DMW-1 (45-47')	white clay with sand seam	1.321	2.66	0.503	1.9		1.32			0.50			1.90	
DMW-1 (55-57')	Red-yellow brown, silty sand	1.192	2.65	0.550	0.79			1.19			0.55			0.79
DMW-1 (80-82')	White, silty, clayey sand	1.225	2.29	0.465	1			1.23			0.46			1.00
DMW-1 (100')	Red-yellow brown clay	1.329	2.68	0.504	2.6									
DMW-2 (20-22')	Dark gray clay	1.022	2.65	0.614	1.7	1.02			0.61			1.70		
DMW-2 (25-27')	White to pale brown clay	1.278	2.65	0.518	1.2	1.28			0.52			1.20		
DMW-2 (35-37')	Yellown brown sand	1.105	2.64	0.581	1.3	1.11			0.58			1.30		
DMW-2 (35-37')	Gray clay	1.221	2.67	0.543	0.94		1.22			0.54			0.94	
DMW-2 (55-57')	Orange, silty sand	1.261	2.63	0.513	2.7		1.28			0.51			2.70	
DMW-2 (95')	White, sandy clay	1.328	2.66	0.501	1.1			1.33			0.50			1.10
DMW-2 (110')	Brown clay	1.344	2.16	0.378	1.2									
PA-2-GT-SC		1.828	2.67	0.315	0.12	1.83	1.83	1.83	0.32	0.32	0.32	0.12	0.12	0.12
PA-3-GT-SC		1.720	2.65	0.350	0.1	1.72	1.72	1.72	0.35	0.35	0.35	0.10	0.10	0.10
PA-16-GT-SDC		1.333	2.56	0.480	1.32	1.33	1.33	1.33	0.48	0.48	0.48	1.32	1.32	1.32
PA-16-GT-PC		1.506	2.64	0.430	1.06	1.51	1.51	1.51	0.43	0.43	0.43	1.06	1.06	1.06
SB-7-GT-SS		1.786	2.63	0.320	1.06	1.79	1.79	1.79	0.32	0.32	0.32	1.06	1.06	1.06
Average		1.348	2.60	0.481	1.363	1.41	1.47	1.49	0.47	0.44	0.43	1.21	1.20	0.82

Table 5-5 Retardation Factor Estimates for the Mass Transport Model

$$Rd = 1 + K_d \frac{\rho_b}{n_e}$$

Parameters		Layer 1	Layer 2	Layer 3
Elevation (msl)		15' to -15'	-15' to -40'	-40' to -70'
Thickness (ft)		30	25	30
Bulk Density (ρ_b)(g/cm^3)		1.41	1.47	1.49
Effective Porosity* (n_e)		**0.32**	**0.29**	**0.28**
Toc (%)		1.21	1.2	0.82
TCE	Koc (ml/g)	166	166	166
	Kd	2.0	2.0	1.4
	Rd	**9.9**	**11.1**	**8.2**
cis-1,2-DCE	Koc (ml/g)	35.5	35.5	35.5
	Kd	0.43	0.43	0.29
	Rd	**2.89**	**3.16**	**2.55**
Vinyl Chloride	Koc (ml/g)	18.6	18.6	18.6
	Kd	0.23	0.22	0.15
	Rd	**1.99**	**2.13**	**1.81**

Note:

Effective Porosity = Total Porosity - 0.15

Kd = Koc x Toc

Section 6
Conclusions

Tetra Tech has completed a chemical delineation and initial groundwater modeling program for the southeast portion of MSA in Middle River, Maryland. Shallow soil samples and grab groundwater samples were collected during a delineation investigation program conducted in December 2001 and January 2002. Two deep, multi-level wells were installed and sampled in May and June 2002 to evaluate the vertical distribution of chemicals. Groundwater modeling was conducted using MODFLOW, MODPATH, and Argus ONE to further evaluate groundwater flow conditions and potential migration of the existing chemical plumes. Conclusions derived from the results of the delineation and modeling effort are highlighted below:

Primary Chemicals of Concern: Based on the data collected during the shallow groundwater investigation, a total of twelve VOCs and five metals were detected in groundwater above their MCLs throughout the investigation area. The chemicals include:

Volatile Organic Compounds Detected >MCLs

- cis-1,2-DCE
- trans-1,2-DCE
- 1,2-DCA
- 1,1-DCE
- 1,1,1-TCA
- TCE
- PCE
- Vinyl Chloride
- Benzene
- Chlorobenzene
- Ethylbenzene
- Toluene
- Total Xylenes

Metals Detected >MCLs

- Antimony
- Arsenic
- Beryllium
- Cadmium
- Lead

Three chlorinated VOCs (TCE, cis-1,2-DCE, and vinyl chloride) were reported at the highest concentrations of any VOCs detected during the investigation. Aromatic VOCs were also detected above MCLs, such as benzene, chlorobenzene, toluene, ethylbenzene, and xylenes, and were frequently found co-located with chlorinated VOCs. The highest concentration of any detected aromatic VOC was chlorobenzene. The detected aromatic VOCs were generally found in the Petroleum Hydrocarbon Area and the northwest portion of the Taxiway Tango median area. Cadmium was detected at the highest concentration of any metal above its MCL and was generally found in the vicinity of the Drum Area. Most samples containing metals above MCLs were co-located with the chlorinated VOCs.

During this investigation, only three compounds (arsenic, mercury, and lead) were reported above MDE's non-residential soil cleanup levels. No organic compounds (VOCs, SVOCs, or petroleum hydrocarbons) were found above the soil cleanup levels – *see Section 4 for more detailed information.*

<u>*Delineation of the Soil and Groundwater Chemical Plumes*</u>: The lateral distribution of chemical concentrations in groundwater indicate that four potential source areas are present at the site contributing to four primary groundwater plumes. These source areas and plumes are:

1) Plume 1, originating from the Drum Area;
2) Plume 2, originating from the Petroleum Hydrocarbon Area;
3) Plume 3, originating from former Excavation 1 of the Taxiway Tango median area; and
4) Plume 4, originating from former Excavation 2 of the Taxiway Tango median area.

While the four plumes potentially represent the primary source areas, the chemicals have commingled in groundwater to create a larger combined groundwater plume. The plumes appear to be migrating along the down-gradient groundwater flow path from west to east toward Frog Mortar Creek. While the extent of chemicals in groundwater have not been delineated to the east toward Frog Mortar Creek, the plumes have been partially delineated to the north, south and west of the investigation areas. For example, data collected from samples collected south of the Drum Area (MW-2, MW-6, DA-2, DA-14), indicate that the southern extent of impacted groundwater is largely delineated. In addition, samples collected from monitoring well MW-4 reported relatively low concentrations of chemicals, indicating that the northern extent of chemicals in groundwater have been partially delineated. However, samples collected from wells MW-1 and MW-3 reported TCE concentrations above 300 μg/L, which indicate that the western extent of impacted groundwater has not been fully delineated.

Groundwater Elevation Fluctuations: Groundwater elevations throughout the investigation area have fluctuated approximately 0.3 feet above mean sea level (msl). The data indicate that seasonal groundwater elevations vary more than 2 feet and have likely created an associated smear zone throughout the investigation area.

Vertical Extent of VOCs: VOCs have been detected above their MCLs to a depth of approximately 111 feet below ground surface (bgs). Two deep groundwater wells were installed at the locations where the highest concentrations of VOCs had previously been detected at the site. While the vertical extent of VOCs have not been delineated, regional well log data indicate that the Patapsco Formation consists of interbedded sands, silts, and clays from the surface to a depth of approximately 100 to 120 feet bgs. The Patapsco Formation is underlain by the Arundel Formation, a thick red clay aquiclude which begins at approximately 100 to 120 feet bgs and extends to a depth of approximately 240 feet bgs. The Arundel Formation is reportedly approximately 120 feet thick and serves as the aquiclude overlying the water-bearing Patuxent Formation.

Section 7
References

1. Maryland Department of the Environment Letter to MAA –
   Subsurface Investigations, Martin State Airport
   Arlene G. Weiner, January 6, 1992

2. Geophysical Survey Report,
   Handex Environmental Management, February 1992

3. Maryland Department of the Environment Letter to MAA –
   Martin State Airport
   Arthur O'Connell, January 24, 1997

4. Final Groundwater Monitoring Well Surveying and Sampling Report,
   Martin State Airport, Middle River, Maryland,
   Tetra Tech, May 18, 1999

5. Method D2488-00: Description and Identification of Soils (Visual-Manual Procedure),
   American Society for Testing and Materials (ASTM), 2000.

6. Munsell™ Soil Color Charts,
   GretagMacbeth, New York, 2000 revised

7. Final Source Identification and Assessment Report,
   Martin State Airport, Middle River, Maryland,
   Tetra Tech, September 29, 2000

8. Maryland Department of the Environment Comment Letter –
   Source Identification and Assessment Report
   Peggy Smith, February 16, 2001

9. Maryland Department of the Environment Comment Letter –
   Chemical Delineation and Modeling Work Plan
   Peggy Smith, August 15, 2001

10. Chemical Delineation and Modeling Work Plan,
    Martin State Airport, Middle River, Maryland,
    Tetra Tech, October 8, 2001

11. Maryland Department of the Environment Approval Letter –
Chemical Delineation and Modeling Work Plan,
Peggy Smith, November 26, 2001

12. Chemical Delineation and Modeling Work Plan, Revised
Martin State Airport, Middle River, Maryland,
Tetra Tech, November 28, 2001

13. Interim Data Summary Report
Martin State Airport, Middle River, Maryland,
Tetra Tech, March 15, 2002

14. Interim Data Summary Report No.2
Martin State Airport, Middle River, Maryland,
Tetra Tech, October 4, 2002

15. Maryland Department of the Environment Follow-up Letter –
October 28, 2002 Meeting Regarding Chemical Delineation and Modeling Work Plan,
Peggy Smith, November 22, 2002

16. Physical and Chemical Hydrogeology
Domenico, Patrick A. and F. W. Schwartz, 1990
published by John Wiley & Sons, Inc.

17. Applied Groundwater Modeling: Simulation of Flow and Advective Transport
Anderson, Mary P., and W. W. Woessner, 1992
published by Academic Press, Inc.

APPENDIX A

Table 1
Summary of Soil Analytical Results

Sample Number	Sampling Depth	Results of Chemical Analyses						
		TPH-Gas (ug/kg)	TPH-Diesel (mg/kg)	TPH-Residual (mg/kg)	VOCs (ug/kg)	Metals (mg/kg)	Hex. Cr (mg/kg)	SVOCs (ug/kg)
TT-4-1	1	NA	NA	NA	Methylene Chloride: 14*	Cr: 3.9	ND	
TT-4-5	5	NA	NA	NA	cis-1,2-Dichloroethene: 24 Methylene Chloride: 61* Vinyl Chloride: 6	As: 0.6 Cr: 25 Cu: 21 Ni: 5.2 Se: 2.8 Zn: 9.1	ND	Bis(2-ethylhexyl)phthalate: 300
TT-9-1	1	NA	NA	NA	Methylene Chloride: 13*	Cr: 8.7 Cu: 7.6 Pb: 6.8 Ni: 4.6 Zn: 14	ND	NA
TT-9-5	5	NA	NA	NA	Methylene Chloride: 14*	Cr: 16 Cu: 16 Ni: 7.6 Se: 3.8 Zn: 11	ND	NA
TT-9-10	10	NA	NA	NA	Methylene Chloride: 13*	**As: 5.1** Cr: 8.0 Cu: 29 Pb: 3.3 Se: 4.9	ND	ND
SB6-3	3	NA	NA	NA	n-Butylbenzene: 754 sec-Butylbenzene: 536 Isopropylbenzene: 652 p-Isopropyltoluene: 275 Methylene Chloride: 913* Naphthalene: 2,319 n-Propylbenzene: 986	NA	NA	NA
DA2-1	1	NA	NA	NA	Methylene Chloride: 7*	As: 3.8 Cr: 25 Cu: 16 Pb: 29 **Hg: 0.3** Ni: 10 Se: 5.7 Zn: 49	ND	NA
DA2-5	5	NA	NA	NA	Methylene Chloride: 25*	Cr: 4.0 Cu: 4.2 **Hg: 2.3**	ND	Bis(2-ethylhexyl)phthalate: 1,846

Table 1
Summary of Soil Analytical Results

Sample Number	Sampling Depth	Results of Chemical Analyses						
		TPH-Gas (ug/kg)	TPH-Diesel (mg/kg)	TPH-Residual (mg/kg)	VOCs (ug/kg)	Metals (mg/kg)	Hex. Cr (mg/kg)	SVOCs (ug/kg)
DA2-10	10	NA	NA	NA	Methylene Chloride: 6*	Cr: 3.3 Cu: 6.6 Se: 3.4 Zn: 11	ND	NA
DA-8-1	1	NA	NA	NA	Methylene Chloride: 6*	As: 1.1 Cd: 4.3 Cr: 19 Cu: 73 Pb: 53 Ni: 18 Se: 3.9 Zn: 136	ND	NA
DA-8-10	10	NA	NA	NA	1,2-Dichloroethane: 48 cis-1,2-Dichloroethene: 9 Methylene Chloride: 10* Toluene: 9 Trichloroethene: 1 Vinyl Chloride: 6 Acetone: 78	Sb: 5.4 As: 3.7 Cd: 63 Cr: 388 Cu: 6,716 **Pb: 821** **Hg: 0.6** Ni: 358 Se: 701 Ag: 60 Zn: 3,284	ND	NA
DA-8-11	11	NA	NA	NA	1,2-Dichloroethane: 14 cis-1,2-Dichloroethene: 60 trans-1,2-Dichloroethene: 27 Methylene Chloride: 16* Trichloroethene: 30 Vinyl Chloride: 39	**As: 4.1** Cr: 21 Cu: 17 Pb: 16 Ni: 17 Se: 6.1 Zn: 59	ND	*Benzo(a)pyrene: < 4950* *Chrysene: < 4950* *Dibenzo(a,h)anthracene: < 4950* *4,6-Dinitro-2-methylphenol: < 11700* *Hexachlorobutadiene: < 4950* *Hexachlorocyclopentadiene: < 4950* *N-Nitroso-di-n-propylamine: < 4950*
DA-8-15	15	NA	NA	NA	1,2-Dichloroethane: 8 cis-1,2-Dichloroethene: 607 trans-1,2-Dichloroethene: 8 Methylene Chloride: 15* Trichloroethene: 361 Vinyl Chloride: 21	**As: 6.2** Cr: 25 Cu: 16 Pb: 15 Ni: 20 Se: 11 Zn: 85	ND	NA
PA-3-1	1	ND	ND	ND	Methylene Chloride: 8*	As: 1.8 Cr: 10 Cu: 52 Pb: 31	ND	NA

Table 1
Summary of Soil Analytical Results

Sample Number	Sampling Depth	Results of Chemical Analyses						
		TPH-Gas (ug/kg)	TPH-Diesel (mg/kg)	TPH-Residual (mg/kg)	VOCs (ug/kg)	Metals (mg/kg)	Hex. Cr (mg/kg)	SVOCs (ug/kg)
						Ni: 38 Zn: 33		
PA-3-5	5	ND	ND	ND	Methylene Chloride: 13*	Cr: 7.1 Cu: 3.3 Pb: 3.7 Ni: 3.1 Zn: 15	ND	Acenaphthene: 721 Anthracene: 140 Benzo(a)anthracene: 244 Benzo(b)fluoranthene: 640 Benzo(k)fluoranthene: 151 Benzo(a)pyrene: 360 Bis(2-ethylhexyl)phthalate: 106 Chrysene: 1,163 Dibenzofuran: 279 Fluoranthene: 1,860 2-Methylnaphthalene: 45 Naphthalene: 90 Phenanthrene: 291 Pyrene: 1,000
PA-16-1	1	ND	ND	ND	Methylene Chloride: 7* Trichloroethene: 2	As: 2.6 Cr: 25 Cu: 26 Pb: 16 Hg: 0.12 Ni: 4.3 Zn: 58	ND	NA
PA-16-5	5	ND	140	89	cis-1,2-Dichloroethene: 1 Methylene Chloride: 7* Trichloroethene: 4	Sb: 3.9 As: 2.9 Cd: 38 Cr: 82 Cu: 101 **Pb: 1,974** Hg: 0.1 Ni: 49 Ag: 4.6 Zn: 1,197	ND	NA
PA-16-10	10	ND	33	42	Methylene Chloride: 42* Naphthalene: 19 Vinyl Chloride: 26	As: 2.1 Cr: 154 Cu: 17 Pb: 22 Ni: 5.5 Zn: 27	ND	Bis(2-ethylhexyl)phthalate: 104 Fluoranthene: 50 Pyrene: 60

Table 1
Summary of Soil Analytical Results

Sample Number	Sampling Depth	Results of Chemical Analyses						
		TPH-Gas (ug/kg)	TPH-Diesel (mg/kg)	TPH-Residual (mg/kg)	VOCs (ug/kg)	Metals (mg/kg)	Hex. Cr (mg/kg)	SVOCs (ug/kg)
PA-16-15	15	ND	16	ND	cis-1,2-Dichloroethene: 4 Methylene Chloride: 9* Vinyl Chloride: 12	As: 1.9 Cr: 15 Cu: 14 Pb: 17 Ni: 6.8 Se: 3.8 Zn: 35	ND	NA
PA-16-20	20	260	ND	ND	Chlorobenzene: 1 1,1-Dichloroethene: 5 cis-1,2-Dichloroethene: 233 trans-1,2-Dichloroethene: 30 Methylene Chloride: 10* Trichloroethene: 329 Vinyl Chloride: 23	As: 3.2 Cd: 6.0 Cr: 29 Cu: 49 Pb: 52 Hg: 0.1 Ni: 8.4 Se: 7.9 Zn: 288	ND	NA

*Detected in Method Blank

ND = Not Detected Above Reporting Limits

NA = Not Analyzed

Italicized Font = Chemical Was Not Detected, However the Reporting Limit Exceeded the Corresponding MDE August 2001 Non-Residential Soil Clean-up Standar

Boldface Font = Chemical Was Detected Above the Corresponding MDE August 2001 Non-Residential Soil Clean-up Standard

Standard Font (Non-Italicized and Non-Boldface) = Chemicals Detected Above Reporting Limits

Table 2
Summary of Groundwater Analytical Results for Taxiway Tango Median Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses		
		VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
TT-1	18	**Benzene: 82** *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* 1,2-Dichlorobenzene: 5 *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* *1,2-Dichloropropane: < 10* Ethylbenzene: 210 Isopropylbenzene: 24 p-Isopropyltoluene: 7 Methylene Chloride: 36* Naphthalene: 5 n-Propylbenzene: 12 *Tetrachloroethene: < 10* Toluene: 10 *1,1,2-Trichloroethane: < 10* Trichloroethene: 2 1,2,4-Trimethylbenzene: 120 1,3,5-Trimethylbenzene: 24 *Vinyl Chloride: < 10* Total Xylenes: 460	ND	NA
TT-2	20	1,2-Dichloroethane: 5 Ethylbenzene: 3 Methylene Chloride: 2* Toluene: 2 Trichloroethene: 1 Total Xylenes: 1	**Pb: 46** Ni: 88 Zn: 120	Fluorene: 2 2-Methylnaphthalene: 2 Naphthalene: 4 Phenanthrene: 2
TT-3	14.5	*Benzene: < 500* *Carbon Tetrachloride: < 500* *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500* *1,2-Dichloroethane: < 500* *1,1-Dichloroethene: < 500*	ND	NA
TT-3 (continued)		**cis-1,2-Dichloroethene: 1,700** *trans-1,2-Dichloroethene: < 500*		

Table 2
Summary of Groundwater Analytical Results for Taxiway Tango Median Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
		1,2-Dichloropropane: < 500 Methylene Chloride: 380* *Styrene: < 500* *Tetrachloroethene: < 500* **Toluene: 1,300** *1,2,4-Trichlorobenzene: < 500* *1,1,1-Trichloroethane: < 500* *1,1,2-Trichloroethane: < 500* *Trichloroethene: < 500* **Vinyl Chloride: 6,200**		
TT-4	13	*Benzene: < 500* *Carbon Tetrachloride: < 500* *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500* *1,2-Dichloroethane: < 500* *1,1-Dichloroethene: < 500* **cis-1,2-Dichloroethene: 470** *trans-1,2-Dichloroethene: < 500* *1,2-Dichloropropane: < 500* Methylene Chloride: 390* *Styrene: < 500* *Tetrachloroethene: < 500* Toluene: 360 *1,2,4-Trichlorobenzene: < 500* *1,1,1-Trichloroethane: < 500* *1,1,2-Trichloroethane: < 500* *Trichloroethene: < 500* **Vinyl Chloride: 7,900**	ND	NA
TT-5	14.5	*Benzene: < 5000* *Carbon Tetrachloride: < 5000* **Chlorobenzene: 50,000** *1,2-Dibromo-3-chloropropane: < 5000*	ND	*Atrazine: < 10* *Benzo(a)pyrene: < 10* 2-Chlorophenol: 6 *Hexachlorobenzene: < 10*

Table 2
Summary of Groundwater Analytical Results for Taxiway Tango Median Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses		
		VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
		1,2-Dichlorobenzene: < 5000 *1,4-Dichlorobenzene: < 5000* *1,2-Dichloroethane: < 5000* *1,1-Dichloroethene: < 5000* *cis-1,2-Dichloroethene: <5000* *trans-1,2-Dichloroethene: < 5000* *1,2-Dichloropropane: < 5000* *Ethylbenzene: < 5000* *Styrene: < 5000* *Tetrachloroethene: < 5000* *Toluene: < 5000* *1,2,4-Trichlorobenzene: < 5000* *1,1,1-Trichloroethane: < 5000* *1,1,2-Trichloroethane: < 5000* *Trichloroethene: < 5000* Methylene Chloride: 2,500* *Vinyl Chloride: < 5000* *Total Xylenes: < 15000*		Naphthalene: 4 *Pentachlorophenol: < 25*
TT-6	16	*Benzene: < 500* *Carbon Tetrachloride: < 500* *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500* *1,2-Dichloroethane: < 500* *1,1-Dichloroethene: < 500* **cis-1,2-Dichloroethene: 1,000** *trans-1,2-Dichloroethene: < 500* *1,2-Dichloropropane: < 500*	ND	
TT-6 (continued)		Methylene Chloride: 390* *Styrene: < 500* *Tetrachloroethene: < 500* *1,2,4-Trichlorobenzene: < 500* *1,1,1-Trichloroethane: < 500* *1,1,2-Trichloroethane: < 500*		

Table 2
Summary of Groundwater Analytical Results for Taxiway Tango Median Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses		
		VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
		Trichloroethene: < 500 **Vinyl Chloride: 1,300**		
TT-7	18	Benzene: 5 *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* **cis-1,2-Dichloroethene: 150** *1,2-Dichloropropane: < 10* Methylene Chloride: 6* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* *Trichloroethene: < 10* **Vinyl Chloride: 120**	Ni: 59 Zn: 130	NA
TT-8	18	*Benzene: < 10* *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* cis-1,2-Dichloroethene: 11 *1,2-Dichloropropane: < 10* Methylene Chloride: 6* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* *Trichloroethene: < 10* **Vinyl Chloride: 7**	**Cd: 46.5** Ni: 70 Zn: 100	NA
TT-9	14	*Benzene: < 10* *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* *1,2-Dichloropropane: < 10* **Methylene Chloride: 4*** *Tetrachloroethene: < 10*	Ni: 70 Zn: 58	*Atrazine: < 10* *Benzo(a)pyrene: < 10* *Hexachlorobenzene: < 10* *Pentachlorophenol: < 25*

Table 2
Summary of Groundwater Analytical Results for Taxiway Tango Median Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses		
		VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
		1,1,2-Trichloroethane: < 10 *Trichloroethene: < 10* **Vinyl Chloride: 10**		
TT-10	14	**Benzene: 12** *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* 1,1-Dichloroethene: 4 cis-1,2-Dichloroethene: 49 trans-1,2-Dichloroethene: 2 *1,2-Dichloropropane: < 10* Methylene Chloride: 8* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* **Trichloroethene: 12** **Vinyl Chloride: 210**	ND	NA

*Detected in Method Blank
ND = Not Detected Above Reporting Limits
NA = Not Analyzed
Italicized Font = Chemical Was Not Detected, However the Reporting Limit Exceeded the Corresponding MCL
Boldface Font = Chemical Was Detected Above the Corresponding MCL
Standard Font (Non-Italicized and Non-Boldface) = Chemicals Detected Above the Reporting Limits

Table 3
Summary of Groundwater Analytical Results for Drum Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
DA-1	26	NA	NA	NA	*Benzene: < 2500* *Carbon Tetrachloride: < 2500* *Chlorobenzene: < 2500* *1,2-Dibromo-3-chloropropane: < 2500* *1,2-Dichlorobenzene: < 2500* *1,4-Dichlorobenzene: < 2500* *1,2-Dichloroethane: < 2500* *1,1-Dichloroethene: < 2500* **cis-1,2-Dichloroethene: 4,100** *trans-1,2-Dichloroethene: < 2500* *1,2-Dichloropropane: < 2500* *Ethylbenzene: < 2500* Methylene Chloride: 1,800* *Styrene: < 2500* *Tetrachloroethene: < 2500* *Toluene: < 2500* *1,2,4-Trichlorobenzene: < 2500* *1,1,1-Trichloroethane: < 2500* *1,1,2-Trichloroethane: < 2500* **Trichloroethene: 12,000** *Vinyl Chloride: < 2500*	**Cd: 15** Ni: 140 Zn: 2,000	NA
DA-2	15	NA	NA	NA	*Benzene: < 10* *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* *1,2-Dichloropropane: < 10* Methylene Chloride: 7* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* *Trichloroethene: < 10* *Vinyl Chloride: < 10*	**Be: 10.4** **Cd: 9.7** Ni: 230 Zn: 660	NA
DA-3	22	NA	NA	NA	*Benzene: < 500* *Carbon Tetrachloride: < 500* *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500*	**Cd: 27.9** Ni: 320 Zn: 750	NA
DA-3					*1,2-Dichloroethane: < 500*		

Table 3
Summary of Groundwater Analytical Results for Drum Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
(continued)					*1,1-Dichloroethene: < 500* **cis-1,2-Dichloroethene: 6,000** *trans-1,2-Dichloroethene: < 500* *1,2-Dichloropropane: < 500* Methylene Chloride: 880* *Styrene: < 500* *Tetrachloroethene: < 500* *1,2,4-Trichlorobenzene: < 500* *1,1,1-Trichloroethane: < 500* *1,1,2-Trichloroethane: < 500* **Trichloroethene: 48,000** **Vinyl Chloride: 460**		
DA-4	20	NA	NA	NA	*Benzene: < 500* *Carbon Tetrachloride: < 500* *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500* 1,1-Dichloroethane: 550 **1,2-Dichloroethane: 630** **1,1-Dichloroethene: 1,200** **cis-1,2-Dichloroethene: 4,200** *trans-1,2-Dichloroethene: < 500* *1,2-Dichloropropane: < 500* Ethylbenzene: 110 Methylene Chloride: 1,700* *Styrene: < 500* **Tetrachloroethene: 110** *Toluene: < 500* *1,2,4-Trichlorobenzene: < 500* **1,1,1-Trichloroethane: 1,100** **Trichloroethene: 64,000** 1,2,4-Trimethylbenzene: 140 **Vinyl Chloride: 280** Total Xylenes: 220	**Cd: 13.3** Ni: 320 Zn: 480	NA
DA-5	28	59,000	5.7	ND	*Benzene: < 5000* *Carbon Tetrachloride: < 5000*	**Cd: 20.3** Cr: 42	NA

Table 3
Summary of Groundwater Analytical Results for Drum Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					Chlorobenzene: < 5000 *1,2-Dibromo-3-chloropropane: < 5000* *1,2-Dichlorobenzene: < 5000* *1,4-Dichlorobenzene: < 5000* *1,2-Dichloroethane: < 5000* *1,1-Dichloroethene: < 5000* **cis-1,2-Dichloroethene: 29,000** *trans-1,2-Dichloroethene: < 5000* *1,2-Dichloropropane: < 5000* *Ethylbenzene: < 5000* Methylene Chloride: 3,000* *Styrene: < 5000* *Tetrachloroethene: < 5000* **Toluene: 1,700** *1,2,4-Trichlorobenzene: < 5000* *1,1,1-Trichloroethane: < 5000* *1,1,2-Trichloroethane: < 5000* **Trichloroethene: 53,000** *Vinyl Chloride: < 5000* *Total Xylenes: < 15000*	Cu: 47 Ni: 220 Zn: 370	
DA-6	26	NA	NA	NA	*Benzene: < 500* tert-Butylbenzene: 130 *Carbon Tetrachloride: < 500* *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500* *1,2-Dichloroethane: < 500* *1,1-Dichloroethene: < 500* **cis-1,2-Dichloroethene: 25,000** **trans-1,2-Dichloroethene: 680** *1,2-Dichloropropane: < 500* **Ethylbenzene: 2,200** Methylene Chloride: 860* n-Propylbenzene: 110 *Styrene: < 500*	Cd: 5.0 Ni: 68 Zn: 450	NA
DA-6 (continued)					*Tetrachloroethene: < 500* **Toluene: 24,000** *1,2,4-Trichlorobenzene: < 500*		

Table 3
Summary of Groundwater Analytical Results for Drum Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					1,1,1-Trichloroethane: < 500 *1,1,2-Trichloroethane: < 500* **Trichloroethene: 33,000** 1,2,4-Trimethylbenzene: 820 1,3,5-Trimethylbenzene: 180 **Vinyl Chloride: 330** Total Xylenes: 4,800		
DA-7	26	NA	NA	NA	*Benzene: < 500* *Carbon Tetrachloride: < 500* *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500* *1,2-Dichloroethane: < 500* **1,1-Dichloroethene: 110** **cis-1,2-Dichloroethene: 45,000** **trans-1,2-Dichloroethene: 2,100** *1,2-Dichloropropane: < 500* Ethylbenzene: 140 4-Methyl-2-pentanone: 1,400 Methylene Chloride: 590* *Styrene: < 500* **Tetrachloroethene: 110** **Toluene: 1,400** *1,2,4-Trichlorobenzene: < 500* *1,1,1-Trichloroethane: < 500* *1,1,2-Trichloroethane: < 500* **Trichloroethene: 130,000** 1,2,4-Trimethylbenzene: 170 **Vinyl Chloride: 180** Total Xylenes: 280	**Cd: 8.8** Cr: 30 Ni: 110 Zn: 420	NA
DA-8	28	NA	NA	NA	*Benzene: < 500* *Carbon Tetrachloride: < 500* *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500*	**Cd: 7.0** Ni: 140 Zn: 400	*Atrazine: < 10* *Benzo(a)pyrene: < 10* *Hexachlorobenzene: < 10* Naphthalene: 5 *Pentachlorophenol: < 25*

Table 3
Summary of Groundwater Analytical Results for Drum Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					1,1-Dichloroethane: 280 *1,2-Dichloroethane: < 500* **1,1-Dichloroethene: 470** **cis-1,2-Dichloroethene: 2,100** *trans-1,2-Dichloroethene: < 500* *1,2-Dichloropropane: < 500* Methylene Chloride: 2,100* *Styrene: < 500* *Tetrachloroethene: < 500* Toluene: 400 *1,2,4-Trichlorobenzene: < 500* *1,1,1-Trichloroethane: < 500* *1,1,2-Trichloroethane: < 500* **Trichloroethene: 70,000** *Vinyl Chloride: < 500* Total Xylenes: 180		
DA-9	26	NA	NA	NA	*Benzene: < 2500* *Carbon Tetrachloride: < 2500* *Chlorobenzene: < 2500* *1,2-Dibromo-3-chloropropane: < 2500* *1,2-Dichlorobenzene: < 2500* *1,4-Dichlorobenzene: < 2500* *1,2-Dichloroethane: < 2500* *1,1-Dichloroethene: < 2500* **cis-1,2-Dichloroethene: 16,000** *trans-1,2-Dichloroethene: < 2500* *1,2-Dichloropropane: < 2500* *Ethylbenzene: < 2500* Methylene Chloride: 990* *Styrene: < 2500* *Tetrachloroethene: < 2500*	**Cd: 7.2** Ni: 120 Zn: 590	NA
DA-9 (continued)					Toluene: 590 *1,2,4-Trichlorobenzene: < 2500* *1,1,1-Trichloroethane: < 2500* *1,1,2-Trichloroethane: < 2500* **Trichloroethene: 7,300** 1,2,4-Trimethylbenzene: 1,200		

Table 3
Summary of Groundwater Analytical Results for Drum Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					Vinyl Chloride: 920		
DA-10	28	810	ND	ND	*Benzene: < 250* *Carbon Tetrachloride: < 250* *Chlorobenzene: < 250* *1,2-Dibromo-3-chloropropane: < 250* *1,4-Dichlorobenzene: < 250* *1,2-Dichloroethane: < 250* *1,1-Dichloroethene: < 250* **cis-1,2-Dichloroethene: 2,500** **trans-1,2-Dichloroethene: 400** *1,2-Dichloropropane: < 250* Methylene Chloride: 270* Naphthalene: 55 *Styrene: < 250* *Tetrachloroethene: < 250* *1,2,4-Trichlorobenzene: < 250* *1,1,1-Trichloroethane: < 250* *1,1,2-Trichloroethane: < 250* **Trichloroethene: 550** **Vinyl Chloride: 82**	**Cd: 9.0** Ni: 93 Zn: 1,900	NA
DA-11	28	7,200	ND	ND	Acetone: 1,900* *Benzene: < 500* *Carbon Tetrachloride: < 500* *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500* *1,2-Dichloroethane: < 500* *1,1-Dichloroethene: < 500* **cis-1,2-Dichloroethene: 160** *trans-1,2-Dichloroethene: < 500* *1,2-Dichloropropane: < 500* Methylene Chloride: 450*	**Cd: 15.5** Ni: 98 Zn: 2,200	NA
DA-11 (continued)					*Styrene: < 500* *Tetrachloroethene: < 500* *1,2,4-Trichlorobenzene: < 500* *1,1,1-Trichloroethane: < 500* *1,1,2-Trichloroethane: < 500* **Trichloroethene: 1,000** *Vinyl Chloride: < 500*		
DA-12	26	NA	NA	NA	*Benzene: < 2500* *Carbon Tetrachloride: < 2500*	**Cd: 21.2** Ni: 53	NA

Table 3
Summary of Groundwater Analytical Results for Drum Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					Chlorobenzene: < 2500 *1,2-Dibromo-3-chloropropane: < 2500* *1,2-Dichlorobenzene: < 2500* *1,4-Dichlorobenzene: < 2500* *1,2-Dichloroethane: < 2500* *1,1-Dichloroethene: < 2500* **cis-1,2-Dichloroethene: 160,000** *trans-1,2-Dichloroethene: < 2500* *1,2-Dichloropropane: < 2500* *Ethylbenzene: < 2500* Methylene Chloride: 1,600* *Styrene: < 2500* *Tetrachloroethene: < 2500* Toluene: 1,000 *1,2,4-Trichlorobenzene: < 2500* *1,1,1-Trichloroethane: < 2500* *1,1,2-Trichloroethane: < 2500* **Trichloroethene: 2,300** 1,2,4-Trimethylbenzene: 1,300 Total Xylenes: 1,200 *Vinyl Chloride: < 2500*	Zn: 450	
DA-13	26	NA	NA	NA	*Benzene: < 5000* *Carbon Tetrachloride: < 5000* *Chlorobenzene: < 5000* *1,2-Dibromo-3-chloropropane: < 5000* *1,2-Dichlorobenzene: < 5000* *1,4-Dichlorobenzene: < 5000* *1,2-Dichloroethane: < 5000*	**Cd: 11** Ni: 67 Zn: 52	NA
DA-13 (continued)					*1,1-Dichloroethene: < 5000* **cis-1,2-Dichloroethene: 120,000** *trans-1,2-Dichloroethene: < 5000* *1,2-Dichloropropane: < 5000* *Ethylbenzene: < 5000* Methylene Chloride: 1,400* *Styrene: < 5000* *Tetrachloroethene: < 5000* *Toluene: < 5000* *1,2,4-Trichlorobenzene: < 5000*		

Table 3
Summary of Groundwater Analytical Results for Drum Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					1,1,1-Trichloroethane: < 5000 *1,1,2-Trichloroethane: < 5000* **Trichloroethene: 1,900** **Vinyl Chloride: 4,600**		
DA-14	28	NA	NA	NA	*Benzene: < 10* *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* cis-1,2-Dichloroethene: 5 *1,2-Dichloropropane: < 10* Methylene Chloride: 7* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* Trichloroethene: 2 *Vinyl Chloride: < 10*	**Cd: 8.7** Ni: 150 Zn: 350	*Atrazine: < 10* *Benzo(a)pyrene: < 10* *Hexachlorobenzene: < 10* *Pentachlorophenol: < 25*

*Detected in Method Blank
ND = Not Detected Above Reporting Limits
NA = Not Analyzed
Italicized Font = Chemical Was Not Detected, However the Reporting Limit Exceeded the Corresponding MCL
Boldface Font = Chemical Was Detected Above the Corresponding MCL
Standard Font (Non-Italicized and Non-Boldface) = Chemicals Detected Above the Reporting Limits

Table 4
Summary of Groundwater Analytical Results for Pond#1 and Petroleum Hydrocarbon Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
PA-1	12	78,000	13	ND	**Benzene: 120** *Carbon Tetrachloride: < 500* *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500* *1,2-Dichloroethane: < 500* *1,1-Dichloroethene: < 500* **cis-1,2-Dichloroethene: 31,000** **Ethylbenzene: 1,600** *trans-1,2-Dichloroethene: < 500* *1,2-Dichloropropane: < 500* Methylene Chloride: 470* *Styrene: < 500* *Tetrachloroethene: < 500* **Toluene: 6,800** *1,2,4-Trichlorobenzene: < 500* *1,1,1-Trichloroethane: < 500* *1,1,2-Trichloroethane: < 500* **Trichloroethene: 310** 1,2,4-Trimethylbenzene: 170 1,3,5-Trimethylbenzene: 120 **Vinyl Chloride: 9,400** **Total Xylenes: 35,000**	ND	NA
PA-2	12	ND	ND	ND	**Benzene: 18** *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* trans-1,2-Dichloroethene: 8 *1,2-Dichloropropane: < 10* Methylene Chloride: 3* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* *Trichloroethene: < 10* **Vinyl Chloride: 2,400** Total Xylenes: 4	Ni: 69	*Atrazine: < 10* *Benzo(a)pyrene: < 10* *Hexachlorobenzene: < 10* *Pentachlorophenol: < 25*
PA-3	28	110	ND	ND	*Benzene: < 500*	Pb: 10	NA

Table 4
Summary of Groundwater Analytical Results for Pond#1 and Petroleum Hydrocarbon Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					Carbon Tetrachloride: < 500 *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500* *1,2-Dichloroethane: < 500* *1,1-Dichloroethene: < 500* **cis-1,2-Dichloroethene: 150** *Ethylbenzene: < 500* *trans-1,2-Dichloroethene: < 500* *1,2-Dichloropropane: < 500* Methylene Chloride: 370* Naphthalene: 100 *Styrene: < 500* *Tetrachloroethene: < 500* *1,2,4-Trichlorobenzene: < 500* *1,1,1-Trichloroethane: < 500* *1,1,2-Trichloroethane: < 500* *Trichloroethene: < 500* **Vinyl Chloride: 2,900**	Ni: 69	
PA-4	15	730	0.9	ND	Acetone: 52* **Benzene: 9** sec-Butlybenzene: 3 Chlorobenzene: 69 *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* **cis-1,2-Dichloroethene: 220** *1,2-Dichloropropane: < 10* Ethylbenzene: 18 Isopropylbenzene: 5 p-Isopropyltoluene: 3 Methylene Chloride: 10* Naphthalene: 13 n-Propylbenzene: 7 *Tetrachloroethene: < 10* Toluene: 4 *1,1,2-Trichloroethane: < 10*	**Cd: 6** Ni: 130 Ag: 11 Zn: 350	
PA-4 (continued)					**Trichloroethene: 36** 1,2,4-Trimethylbenzene: 84 1,3,5-Trimethylbenzene: 46		

Table 4
Summary of Groundwater Analytical Results for Pond#1 and Petroleum Hydrocarbon Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					Vinyl Chloride: 250 Total Xylenes: 32		
PA-5	15	ND	ND	ND	Benzene: 3 *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* cis-1,2-Dichloroethene: 7 *1,2-Dichloropropane: < 10* Methylene Chloride: 10* *Tetrachloroethene: < 10* Toluene: 8 *1,1,2-Trichloroethane: < 10* **Trichloroethene: 16** **Vinyl Chloride: 46**	Ni: 100 Zn: 230	NA
PA-6	19.5	ND	ND	ND	Acetone: 10 Carbon Disulfide: 7 *1,2-Dibromo-3-chloropropane: < 1* Toluene: 1 Total Xylenes: 2	As: 26 **Cd: 5.9** Cu: 250 Ni: 160 Zn: 1,900	*Atrazine: < 10* *Benzo(a)pyrene: < 10* *Hexachlorobenzene: < 10* *Pentachlorophenol: < 25*
PA-7	15	96,000	2.6	ND	*Benzene: < 5000* *Carbon Tetrachloride: < 5000* *Chlorobenzene: < 5000* *1,2-Dibromo-3-chloropropane: < 5000* *1,2-Dichlorobenzene: < 5000* *1,4-Dichlorobenzene: < 5000* **1,2-Dichloroethane: 6,100** *1,1-Dichloroethene: < 5000* **cis-1,2-Dichloroethene: 29,000** *trans-1,2-Dichloroethene: < 5000* *1,2-Dichloropropane: < 5000* *Ethylbenzene: < 5000* Methylene Chloride: 9,500* *Styrene: < 5000* *Tetrachloroethene: < 5000*	**Cd: 94.2** *Pb: < 20* Hg: 0.5	NA
PA-7 (continued)					**Toluene: 4,400** *1,2,4-Trichlorobenzene: < 5000* *1,1,1-Trichloroethane: < 5000* *1,1,2-Trichloroethane: < 5000*		

Table 4
Summary of Groundwater Analytical Results for Pond#1 and Petroleum Hydrocarbon Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					Trichloroethene: 220,000 **Vinyl Chloride: 3,400** Total Xylenes: 1,300		
PA-8	28	ND	ND	ND	*1,2-Dibromo-3-chloropropane: < 1* 1,2-Dichloroethane: 1 cis-1,2-Dichloroethene: 2 **Trichloroethene: 16**	**Cd: 11.6** Cu: 77 Ni: 250 Zn: 580	NA
PA-9	15	ND	ND	ND	*Benzene: < 10* *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* **cis-1,2-Dichloroethene: 160** *1,2-Dichloropropane: < 10* Methylene Chloride: 7* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* Trichloroethene: 3 **Vinyl Chloride: 32**	Ni: 130 Zn: 100	NA
PA-10	15	ND	ND	ND	*Benzene: < 10* *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* cis-1,2-Dichloroethene: 12 *1,2-Dichloropropane: < 10* Methylene Chloride: 8* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* **Trichloroethene: 6** *Vinyl Chloride: < 10*	ND	NA
PA-11	26	250	ND	ND	Benzene: 2 *1,2-Dibromo-3-chloropropane: < 5* 1,1-Dicloroethane: 1 **1,2-Dichloroethane: 11** 1,1-Dichloroethene: 6	**Cd: 7.9** Ni: 100 Zn: 2,000	*Atrazine: < 10* *Benzo(a)pyrene: < 10* Di-n-butly phthalate: 2 *Hexachlorobenzene: < 10* *Pentachlorophenol: < 25*

Table 4
Summary of Groundwater Analytical Results for Pond#1 and Petroleum Hydrocarbon Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					cis-1,2-Dichloroethene: 100 trans-1,2-Dichloroethene: 2 Methylene Chloride: 6* Tetrachloroethene: 1 Toluene: 2 1,1,1-Trichloroethane: 2 **Trichloroethene: 490** **Vinyl Chloride: 33** Total Xylenes: 15		
PA-12	28	ND	ND	ND	Benzene: 2 *1,2-Dibromo-3-chloropropane: < 5* 1,2-Dichloroethane: 4 cis-1,2-Dichloroethene: 6 Methylene Chloride: 2 **Trichloroethene: 7** **Vinyl Chloride: 6** Total Xylenes: 1	Cd: 15.1 Ni: 150 Zn: 220	NA
PA-13	28	730 ppb	0.7	ND	*Benzene: < 500* *Carbon Tetrachloride: < 500* *Chlorobenzene: < 500* *1,2-Dibromo-3-chloropropane: < 500* *1,4-Dichlorobenzene: < 500* *1,2-Dichloroethane: < 500* *1,1-Dichloroethene: < 500* **cis-1,2-Dichloroethene: 1,700** *trans-1,2-Dichloroethene: < 500* *1,2-Dichloropropane: < 500* Methylene Chloride: 450* *Styrene: < 500*	**Sb: 13.4** Ni: 120 Zn: 46	Acenaphthene: 1 *Atrazine: < 10* *Benzo(a)pyrene: < 10* *Hexachlorobenzene: < 10* *Pentachlorophenol: < 25*
PA-13 (continued)					*Tetrachloroethene: < 500* *1,2,4-Trichlorobenzene: < 500* *1,1,1-Trichloroethane: < 500* *1,1,2-Trichloroethane: < 500* *Trichloroethene: < 500* **Vinyl Chloride: 2,900**		
PA-14	25	ND	ND	ND	Acetone: 36*	**As: 64**	NA

Table 4
Summary of Groundwater Analytical Results for Pond#1 and Petroleum Hydrocarbon Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					2-Butanone: 6 Chlorobenzene: 6 *1,2-Dibromo-3-chloropropane: < 5* 1,2-Dichlorobenzene: 8 **1,2-Dichloroethane: 6** cis-1,2-Dichloroethene: 16 Ethylbenzene: 4 Methylene Chloride: 1* Toluene: 3 Trichloroethene: 3 1,2,4-Trimethylbenzene: 2 **Vinyl Chloride: 21** Total Xylenes: 2	**Cd: 5.5** Ni: 44 Zn: 28	
PA-15	22	ND	1.1	ND	*Benzene: < 2500* *Carbon Tetrachloride: < 2500* *Chlorobenzene: < 2500* *1,2-Dibromo-3-chloropropane: < 2500* *1,2-Dichlorobenzene: < 2500* *1,4-Dichlorobenzene: < 2500* *1,2-Dichloroethane: < 2500* *1,1-Dichloroethene: < 2500* **cis-1,2-Dichloroethene: 1,300** *trans-1,2-Dichloroethene: < 2500* *1,2-Dichloropropane: < 2500* *Ethylbenzene: < 2500* Methylene Chloride: 1,500* *Styrene: < 2500*	Ni: 41 Zn: 700	NA
PA-15 (continued)					*Tetrachloroethene: < 2500* Toluene: 600 *1,2,4-Trichlorobenzene: < 2500* *1,1,1-Trichloroethane: < 2500* *1,1,2-Trichloroethane: < 2500* **Trichloroethene: 1,000** **Vinyl Chloride: 27,000**		
PA-16	16	ND	ND	ND	**Benzene: 7** *Carbon Tetrachloride: < 10*	Ni: 120	Acenaphthene: 1 *Atrazine: < 10*

Table 4
Summary of Groundwater Analytical Results for Pond#1 and Petroleum Hydrocarbon Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses					
		TPH-Gas (ug/L)	TPH-Diesel (mg/L)	TPH-Residual (mg/L)	VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)
					Chlorobenzene: 7 *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* **cis-1,2-Dichloroethene: 92** trans-1,2-Dichloroethene: 23 *1,2-Dichloropropane: < 10* Methylene Chloride: 6* *Tetrachloroethene: < 10* Toluene: 4 *1,1,2-Trichloroethane: < 10* **Trichloroethene: 83** **Vinyl Chloride: 420**		*Benzo(a)pyrene: < 10* Carbazole: 3 *Hexachlorobenzene: < 10* *Pentachlorophenol: < 25* Phenanthrene: 2
SB-13	12	NA	NA	NA	**Benzene: 8** Carbon Disulfide: 22 *1,2-Dibromo-3-chloropropane: < 5* cis-1,2-Dichloroethene: 2 Trichloroethene: 2 *Vinyl Chloride: < 5*	NA	NA

*Detected in Method Blank
ND = Not Detected Above Reporting Limits
NA = Not Analyzed
Italicized Font = Chemical Was Not Detected, However the Reporting Limit Exceeded the Corresponding MCL
Boldface Font = Chemical Was Detected Above the Corresponding MCL
Standard Font (Non-Italicized and Non-Boldface) = Chemicals Detected Above the Reporting Limits

Table 5
Summary of Groundwater Analytical Results for Previously Disturbed Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses			
		VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)	PCBs / Pesticides (ug/L)
PDA-1	27.5	*Benzene: < 10* *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* *1,2-Dichloropropane: < 10* Methylene Chloride: 7* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* *Trichloroethene: < 10* *Vinyl Chloride: < 10*	Cu: 54 Ni: 130 Zn: 390	*Atrazine: < 10* *Benzo(a)pyrene: < 10* *Hexachlorobenzene: < 10* *Pentachlorophenol: < 25*	ND
PDA-2	11	*Benzene: < 10* *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* *1,2-Dichloropropane: < 10* Methylene Chloride: 6* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* *Trichloroethene: < 10* *Vinyl Chloride: < 10*	**Be: 6.3** Ni: 170 Zn: 330	NA	ND
PDA-3	12	*Benzene: < 10* *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* *1,2-Dichloropropane: < 10* Methylene Chloride: 6* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* *Trichloroethene: < 10* *Vinyl Chloride: < 10*	Ni: 180 Zn: 200	NA	ND
PDA-4	13	*Benzene: < 10* *Carbon Tetrachloride: < 10*	**Be: 17.8** **Cd: 16.6**	*Atrazine: < 20* *Benzo(a)pyrene: < 20*	ND

Table 5
Summary of Groundwater Analytical Results for Previously Disturbed Area

Sample Number	Sampling Depth (feet)	Results of Chemical Analyses			
		VOCs (ug/L)	Metals (ug/L)	SVOCs (ug/L)	PCBs / Pesticides (ug/L)
		1,2-Dibromo-3-chloropropane: < 10 *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* *1,2-Dichloropropane: < 10* Methylene Chloride: 7* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* *Trichloroethene: < 10* *Vinyl Chloride: < 10*	Cu: 90 Ni: 560 Zn: 150	*Hexachlorobenzene: < 20* *Pentachlorophenol: < 50*	
PDA-5	13	*Benzene: < 10* *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* *1,2-Dichloropropane: < 10* Methylene Chloride: 6* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* *Trichloroethene: < 10* *Vinyl Chloride: < 10*	**Be: 4.9** Ni: 70	*Atrazine: < 10* *Benzo(a)pyrene: < 10* *Hexachlorobenzene: < 10* *Pentachlorophenol: < 25*	ND
PDA-6	13	*Benzene: < 10* *Carbon Tetrachloride: < 10* *1,2-Dibromo-3-chloropropane: < 10* *1,2-Dichloroethane: < 10* *1,1-Dichloroethene: < 10* *1,2-Dichloropropane: < 10* Methylene Chloride: 7* *Tetrachloroethene: < 10* *1,1,2-Trichloroethane: < 10* *Trichloroethene: < 10* *Vinyl Chloride: < 10*	Ni: 160 Zn: 200	NA	ND

*Detected in Method Blank
ND = Not Detected Above Reporting Limits
NA = Not Analyzed
Italicized Font = Chemical Was Not Detected, However the Reporting Limit Exceeded the Corresponding MCL
Boldface Font = Chemical Was Detected Above the Corresponding MCL
Standard Font (Non-Italicized and Non-Boldface) = Chemicals Detected Above the Reporting Limits

Table 6
Summary of Groundwater Analytical Results
from Monitoring Wells

Sample Number	Screen Interval (feet)	Results of Chemical Analyses				
		TPH-Gas (ug/L)	TPH-Diesel/Residuals (mg/L)	VOCs (ug/L)	Diss. Metals (ug/L)	SVOCs (ug/L)
DMW1-A	45 to 55	NA	NA	**Benzene: 46** **Carbon Tetrachloride: 5** Chlorobenzene: 9 Choroform: 17 *1,2-Dibromo-3-chloropropane: <1* **1,2-Dichloroethane: 53** **1,1-Dichloroethene: 34** **cis-1,2-Dichloroethene: 6,200** trans-1,2-Dichloroethene: 41 **Tetrachloroethene: 12** Toluene: 380 1,2,4-Trichlorobenzene: 15 **Trichloroethene: 9,000** 1,2,4-Trimethylbenzene: 5 **Vinyl Chloride: 3,500** **Total Xylenes: 24**	**Cd: 1200** **Cr: 150** Cu: 9 Ni: 130 Zn: 350	*Atrazine: <10* *Benzo(a)pyrene: <10* *Hexachlorobenzene: <10* *Pentachlorophenol: <25*
DMW1-B	83 to 88	3,800	ND	**Benzene: 48** Chlorobenzene: 8 Choroform: 11 *1,2-Dibromo-3-chloropropane: <1* **1,2-Dichloroethane: 32** **1,1-Dichloroethene: 15** **cis-1,2-Dichloroethene: 4,500** trans-1,2-Dichloroethene: 26 Toluene: 76 **Trichloroethene: 2,800** *Vinyl Chloride: <5*	*Sb: <10* **Cd: 390** Ni: 44 Zn: 190	*Atrazine: <10* *Benzo(a)pyrene: <10* *Hexachlorobenzene: <10* *Pentachlorophenol: <25*
DMW2-A	50 to 60	NA	NA	**Benzene: 21** Chlorobenzene: 8 Chloroform: 59 *1,2-Dibromo-3-chloropropane: <1* 1,2-Dichlorobenzene: 6 1,4-Dichlorobenzene: 5 **1,2-Dichloroethane: 100** **1,1-Dichloroethene: 32** **cis-1,2-Dichloroethene: 1,800** trans-1,2-Dichloroethene: 18 Ethylbenzene: 19 Naphthalene: 10	**Cd: 5** Ni: 96 Zn: 150	*Atrazine: <10* *Benzo(a)pyrene: <10* *Hexachlorobenzene: <10* *Pentachlorophenol: <25*

Table 6
Summary of Groundwater Analytical Results
from Monitoring Wells

Sample Number	Screen Interval (feet)	Results of Chemical Analyses				
		TPH-Gas (ug/L)	TPH-Diesel/Residuals (mg/L)	VOCs (ug/L)	Diss. Metals (ug/L)	SVOCs (ug/L)
				Tetrachloroethene: 47		
				Toluene: 860 1,2,3 -Trichlorobenzene: 76 **1,2,4-Trichlorobenzene: 540** 1,1,1-Trichloroethane: 7 **Trichloroethene: 12,000** 1,2,4-Trimethylbenzene: 31 1,3,5-Trimethylbenzene: 11 **Vinyl Chloride: 250** Total Xylenes: 100		
DMW2-B	85 to 95	ND	ND	*1,2-Dibromo-3-chloropropane: <1* cis-1,2-Dichloroethene: 42 Chloroform: 6 **Trichloroethene: 120** **Vinyl Chloride: 3**	*Sb: <10* Cr: 5 Ni: 12	*Atrazine: <10* *Benzo(a)pyrene: <10* *Hexachlorobenzene: <10* *Pentachlorophenol: <25*
MW-1	36 to 46	NA	NA	*1,2-Dibromo-3-chloropropane: <1* cis-1,2-Dichloroethene: 26 1,2,4-Trichlorobenzene: 5 **Trichloroethene: 320** *Vinyl Chloride: <5*	Zn: 88	*Atrazine: <10* *Benzo(a)pyrene: <10* *Hexachlorobenzene: <10* *Pentachlorophenol: <25*
MW-2	32 to 42	NA	NA	*1,2-Dibromo-3-chloropropane: <1* cis-1,2-Dichloroethene: 13 **Trichloroethene: 19**	**Be: 6** **Cd: 14** Cr: 6 Cu: 52 Ni: 80 Zn: 440	*Atrazine: <10* *Benzo(a)pyrene: <10* *Hexachlorobenzene: <10* *Pentachlorophenol: <25*
MW-3	20 to 30	NA	NA	*1,2-Dibromo-3-chloropropane: <1* **cis-1,2-Dichloroethene: 510** 1,2,3-Trichlorobenzene: 8 1,2,4-Trichlorobenzene: 25 **Trichloroethene: 650** **Vinyl Chloride: 36**	Ni: 7 Zn: 83	*Atrazine: <10* *Benzo(a)pyrene: <10* *Hexachlorobenzene: <10* *Pentachlorophenol: <25*
MW-4	3 to 30	NA	NA	**Benzene: 10** *1,2-Dibromo-3-chloropropane: <1* 1,2-Dichloroethane: 2 **cis-1,2-Dichloroethene: 8** **Vinyl Chloride: 27**	ND	*Atrazine: <10* *Benzo(a)pyrene: <10* *Hexachlorobenzene: <10* *Pentachlorophenol: <25*
MW-5	10 to 39	NA	NA	**Benzene: 81** Chlorobenzene: 9 *1,2-Dibromo-3-chloropropane: <1* 1,1-Dichloroethane: 310	*Sb: <10* **Cd:24** Cu: 100 Ni: 130	*Atrazine: <10* *Benzo(a)pyrene: <10* *Hexachlorobenzene: <10* Naphthalene: 15

Table 6
Summary of Groundwater Analytical Results
from Monitoring Wells

Sample Number	Screen Interval (feet)	Results of Chemical Analyses				
		TPH-Gas (ug/L)	TPH-Diesel/Residuals (mg/L)	VOCs (ug/L)	Diss. Metals (ug/L)	SVOCs (ug/L)
				1,2-Dichloroethane: 170 **1,1-Dichloroethene: 690**	Se: 16 Zn: 270	*Pentachlorophenol: <25*
				cis-1,2-Dichloroethene: 110,000 **trans-1,2-Dichloroethene: 1,100** Ethylbenzene: 350 Isopropylbenzene: 11 p-Isopropyltoluene: 6 Naphthalene: 33 n-Propylbenzene:22 **Tetrachloroethene: 21** **Toluene: 2,800** **1,1,1-Trichloroethane: 520** **1,1,2-Trichloroethane: 11** **Trichloroethene: 20,000** 1,2,4-Trimethylbenzene: 160 1,3,5-Trimethylbenzene: 51 **Vinyl Chloride: 260** Total Xylenes: 380		
MW-6	14 to 34	NA	NA	*1,2-Dibromo-3-chloropropane: <1*	Cu: 8 Ni: 41 Se: 11 Zn: 390	*Atrazine: <10* *Benzo(a)pyrene: <10* *Hexachlorobenzene: <10* *Pentachlorophenol: <25*

ND = Not Detected Above Reporting Limits
NA = Not Analyzed
Italicized Font = Chemical Was Not Detected, However the Reporting Limit Exceeded the Corresponding MCl
Boldface Font = Chemical Was Detected Above the Corresponding MCL
Standard Font (Non-Italicized and Non-Boldface) = Chemicals Detected Above the Reporting Limits

APPENDIX B

MARYLAND DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard - Baltimore, Maryland 21230
410-537-3000 • 1-800-633-6101

Parris N. Glendening
Governor

Kathleen Kennedy Townsend
Lt. Governor

Richard F. Pecora
Secretary

Merrylin Zaw-Mon
Deputy Secretary

November 22, 2002

Mr. Ron Helgerson
Senior Project Manager
Lockheed Martin Corporation
6801 Rockledge Dr.
Bethesda, Maryland 20817

Dear Mr. Helgerson:

This is a follow-up letter to our October 28, 2002 meeting with you and the Maryland Aviation Administration at the Martin State Airport facility. At the meeting, you submitted a three-page summary outlining a proposed risk-based closure for the site. Based on the discussions which took place, it is our understanding that Lockheed Martin proposes to:

- Use fate and transport modeling to locate additional wells;
- Install additional wells to verify modeling results;
- Monitor groundwater to show that no off-site migration is occurring and no threat to Frog Mortar Creek exists;
- Perform a risk assessment to evaluate human exposure to chemicals;
- Request site closure and No Further Action (NFA) letter from the Maryland Department of the Environment's (MDE) State Superfund Division.

Your proposed time line for 2003 closure assumes that the above work will identify no unacceptable risks or other concerns requiring further investigation or remediation. The Department does not agree with this assumption and wants to remind you of the following points:

1) A risk-based approach will not eliminate the need for a feasibility study to be performed at the site. As stated in our February 16, 2001 letter to Jennifer Stevens of Lockheed Martin, it must be shown that all remedial alternatives have been considered before choosing a remedial action. This is especially true when choosing a no-action alternative.

2) The Department's Cleanup Standards for Soil and Groundwater states that free product must be remediated and hot spots may require removal or some other remedial action.

3) Long-term monitoring is often required at sites seeking closure to evaluate the effectiveness of the chosen remedy.

4) As stated in the February 2001 letter, the lateral and vertical extent of contamination must be fully delineated. Upgradient "shallow" well MW-1 has recently shown a concentration of 320 ppb of TCE, suggesting that delineation is not complete in this area of the site.

5) MDE views groundwater flow and transport models as a compilation of all data and interpretations derived at a site based on consistently and thoroughly observed conditions. Although models are useful for identifying data gaps or inconsistencies, they should not be used in lieu of field measurements of groundwater flow directions and geologic characteristics. When using a model to evaluate health risks or possible remedies, an understanding of the prevailing contaminant distribution and decay mechanisms are also required. Due to the complexity of reactive transport modeling, MDE recommends that an interim modeling report, outlining your conceptual site model and an explanation of site interpretation, be submitted to us for review and comment prior to initiating transport modeling.

6) A Risk Assessment should evaluate all relevant ecological and human health exposure pathways. Relevant exposure scenarios should include, but not be limited to, potential impacts to aquatic ecosystems, on-site workers, and recreational use of Frog Mortar Creek.

7) A quarterly groundwater monitoring plan should be initiated so that groundwater contaminant trends can be tracked. MDE does not consider it necessary to wait until well installations are complete before implementing regular groundwater monitoring.

8) The NFA letters issued by the State Superfund Division do not prevent the Department from taking action should future environmental concerns arise. Furthermore, this letter would only be issued once all investigation and cleanup has been accomplished and the Department is satisfied that the site no longer poses a threat to human health or the environment.

Since the above items remain to be addressed, the proposed timeline is premature, so we will reserve our comments on that matter. At the same time, the Department recognizes and appreciates Lockheed Martin's focus on moving the project ahead without delay.

If you have any questions, please contact me at (410) 537-3493.

Sincerely,

Peggy Smith

Peggy Smith, Project Manager
Site and Brownfields Assessments
State Superfund Division

PS

cc: Mr. Richard Collins
Mr. Karl Kalbacher
Mr. Arthur O'Connell
Mr. Brian Dietz
Mr. Scott Morgan
Ms. Nisha Bansal, Tetra Tech
Ms. Joanne Brooks, MAA

MARYLAND DEPARTMENT OF THE ENVIRONMENT

MDE

2500 Broening Highway • Baltimore, Maryland 21224
(410) 631-3000 • 1-800-633-6101 • http://www.mde.state.md.us

Parris N. Glendening
Governor

Jane T. Nishida
Secretary

November 26, 2001

Ms. Jennifer Stevens
Lockheed Martin CESH
7921 Southpark Plaza, Suite 210
Littleton, CO 80120

Re: *Chemical Delineation and Modeling Work Plan, Revised Final Version, Martin State Airport (MD-304)*

Dear Ms. Stevens:

The Maryland Department of the Environment (MDE), State Superfund Division has reviewed the above-referenced Work Plan, dated October 8, 2001. Based upon several e-mails and verbal correspondences with your consultant, Tetra Tech, it is our understanding that care will be taken to place borings in the high contaminant areas identified in my e-mail to Nisha Bansal of Tetra Tech on October 30, 2001. With this understanding, the MDE approves the work plan.

MDE reserves the right to request further subsurface investigation at a later date. The two wells proposed in the work plan will not adequately delineate the deep contamination and complex stratigraphy at the site. However, to prevent further delays to the implementation of this Work Plan, we suggest revisiting this issue once the proposed work has been completed and more information is available.

If you have any questions, please contact me at (410) 631-3493 or e-mail me at psmith@mde.state.md.us.

Sincerely,

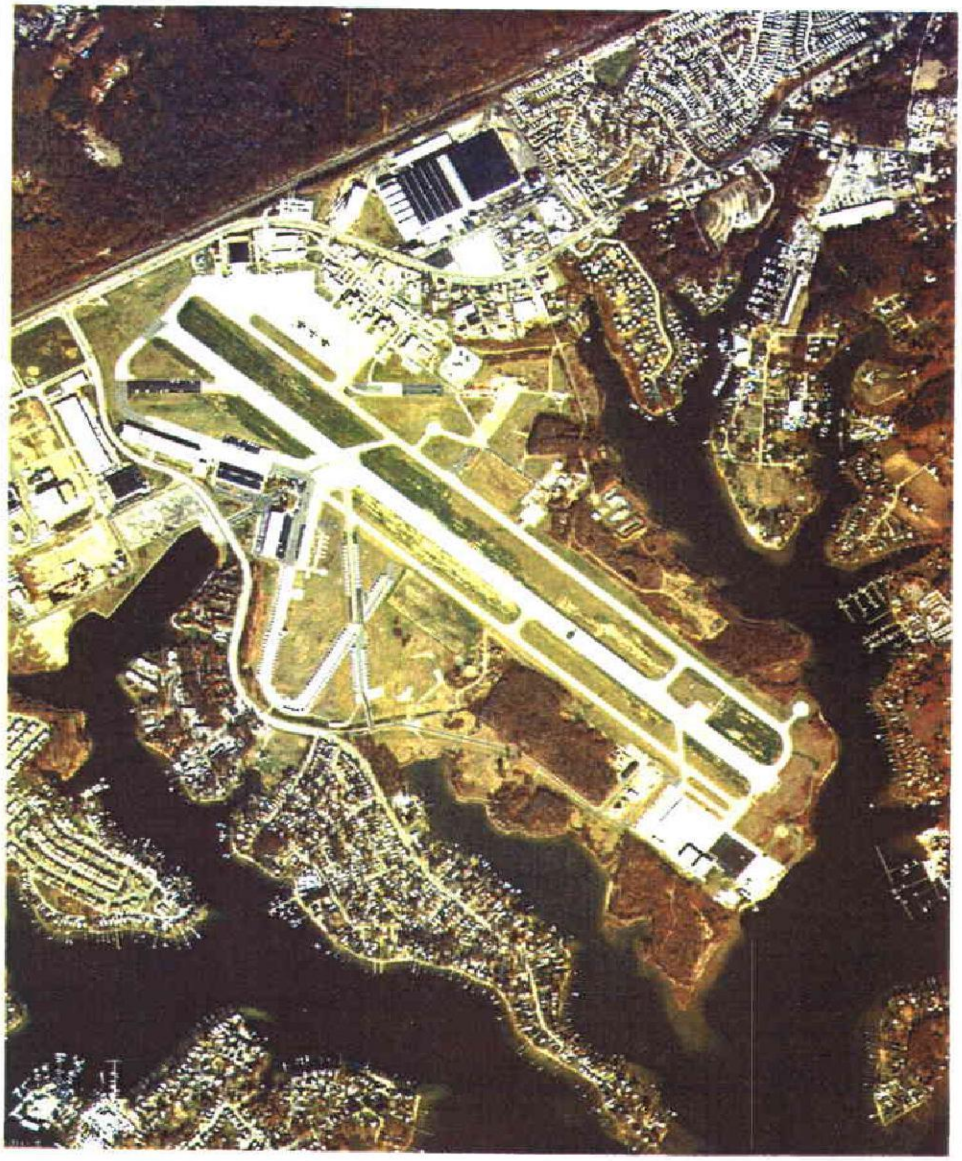
Peggy Smith

Peggy Smith, Project Manager
State and Brownfields Assessments/
State Superfund Division

PS
cc: Mr. Richard Collins
Mr. Karl Kalbacher
Mr. Art O'Connell
Ms. Nisha Bansal

FINAL REPORT

Chemical Delineation and Groundwater Modeling Report Martin State Airport: Middle River, Maryland



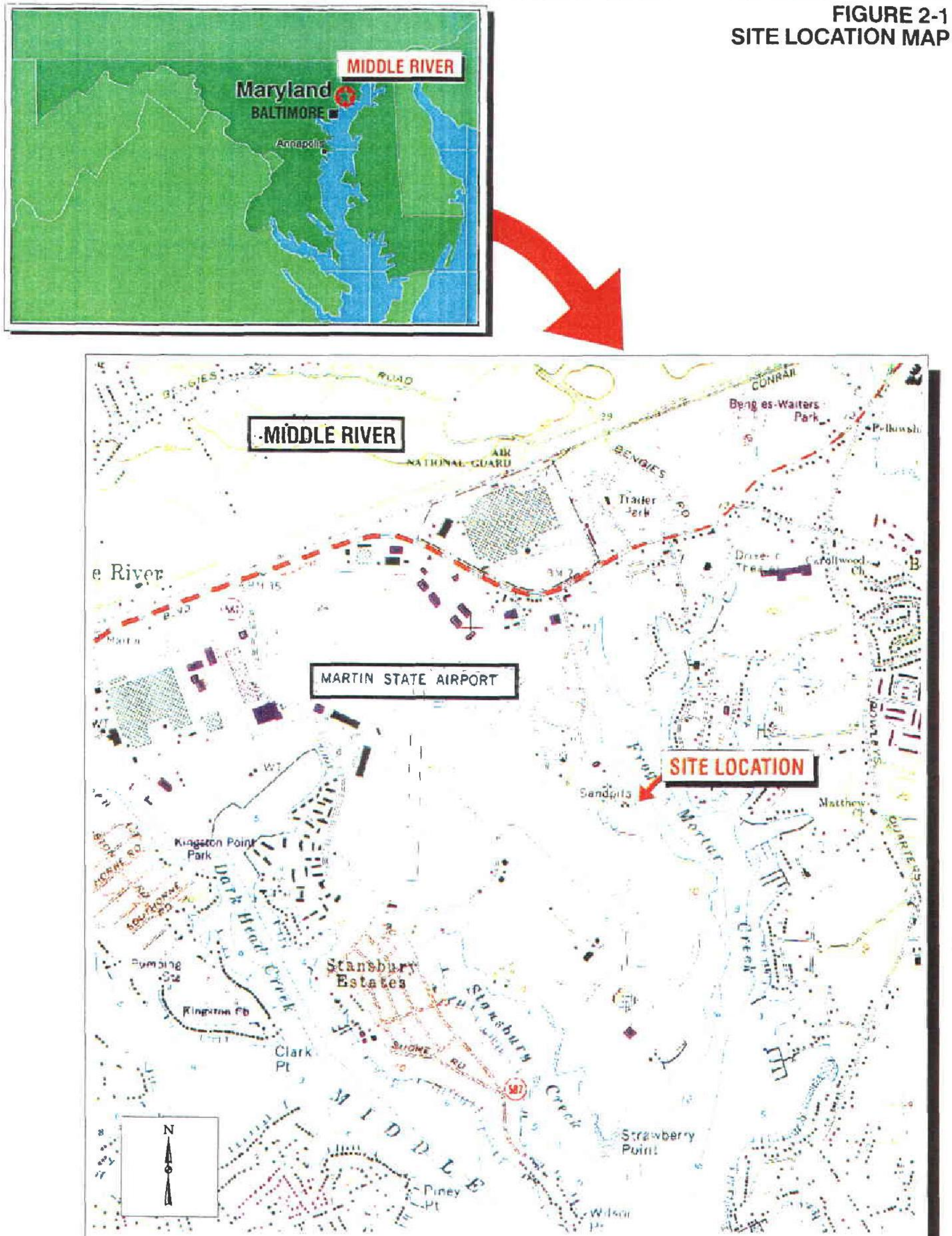
LOCKHEED MARTIN

Tetra Tech

Environmental Engineers & Scientists

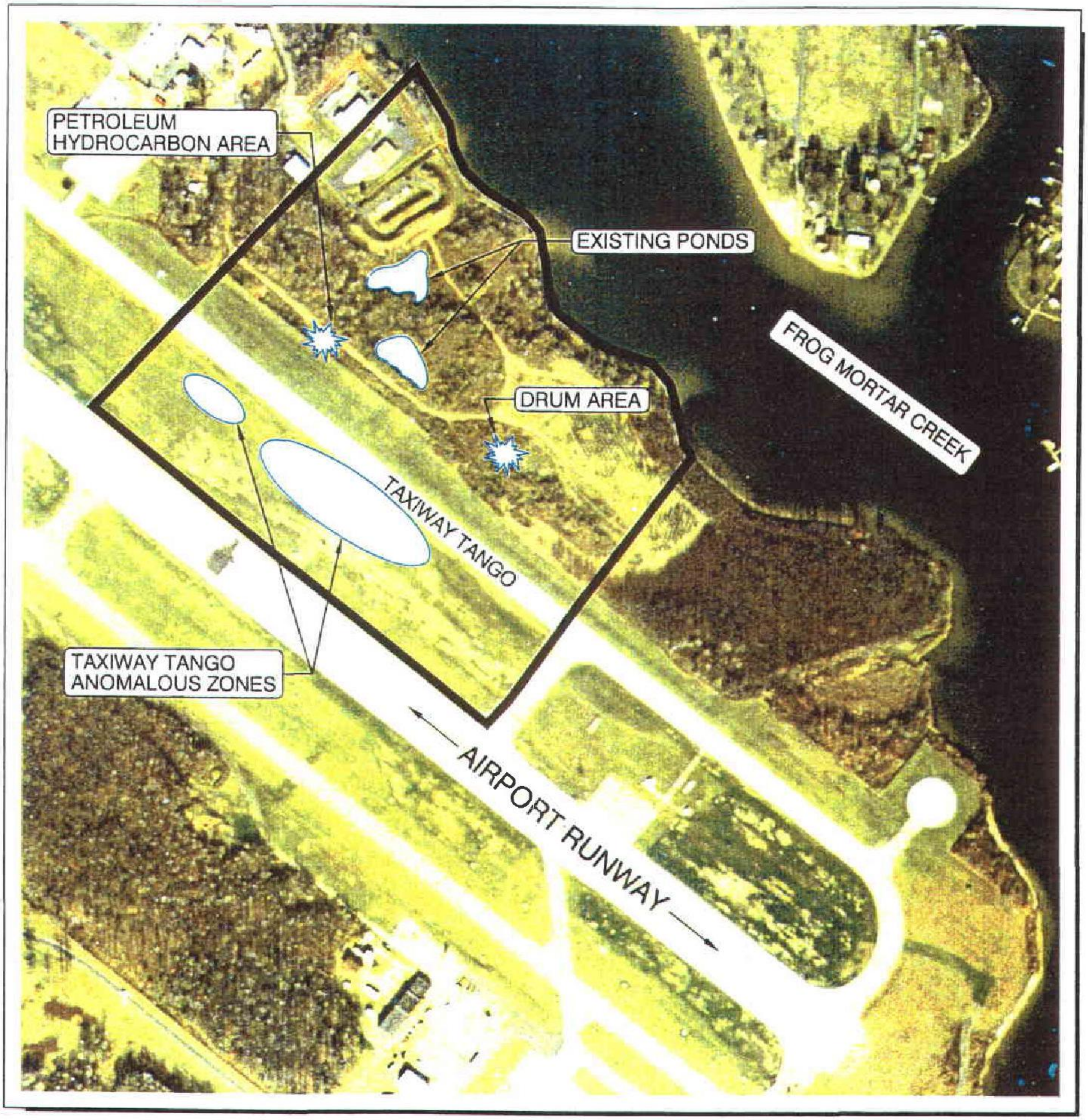
TC#10825-02/December 27, 2002

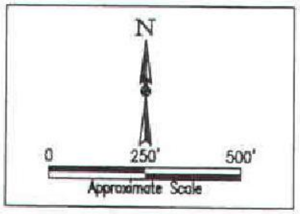
FIGURE 2-1
SITE LOCATION MAP



Cad4 Files/Projects/108025/Modeling/12-22-02/MSA_PhaseII_Fig_2-1.cdr

FIGURE 2-2
LOCATION OF AREAS OF CONCERN





Cad4Files/Projects/10825/Modeling/12-22-02/MSA_ModelingFig_2-2.dwg

FIGURE 4-1
SUMMARY OF SOIL SAMPLE DATA

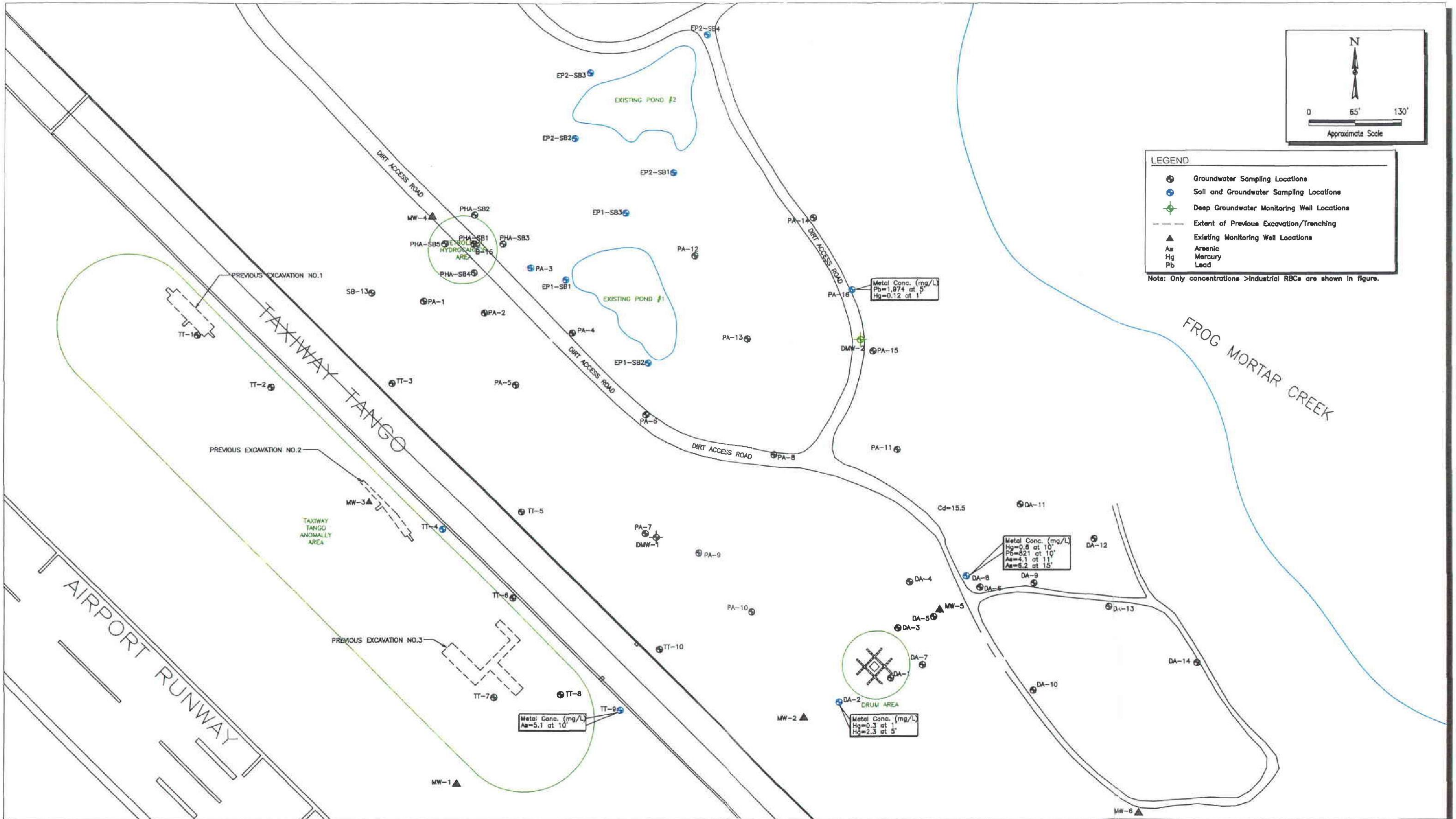
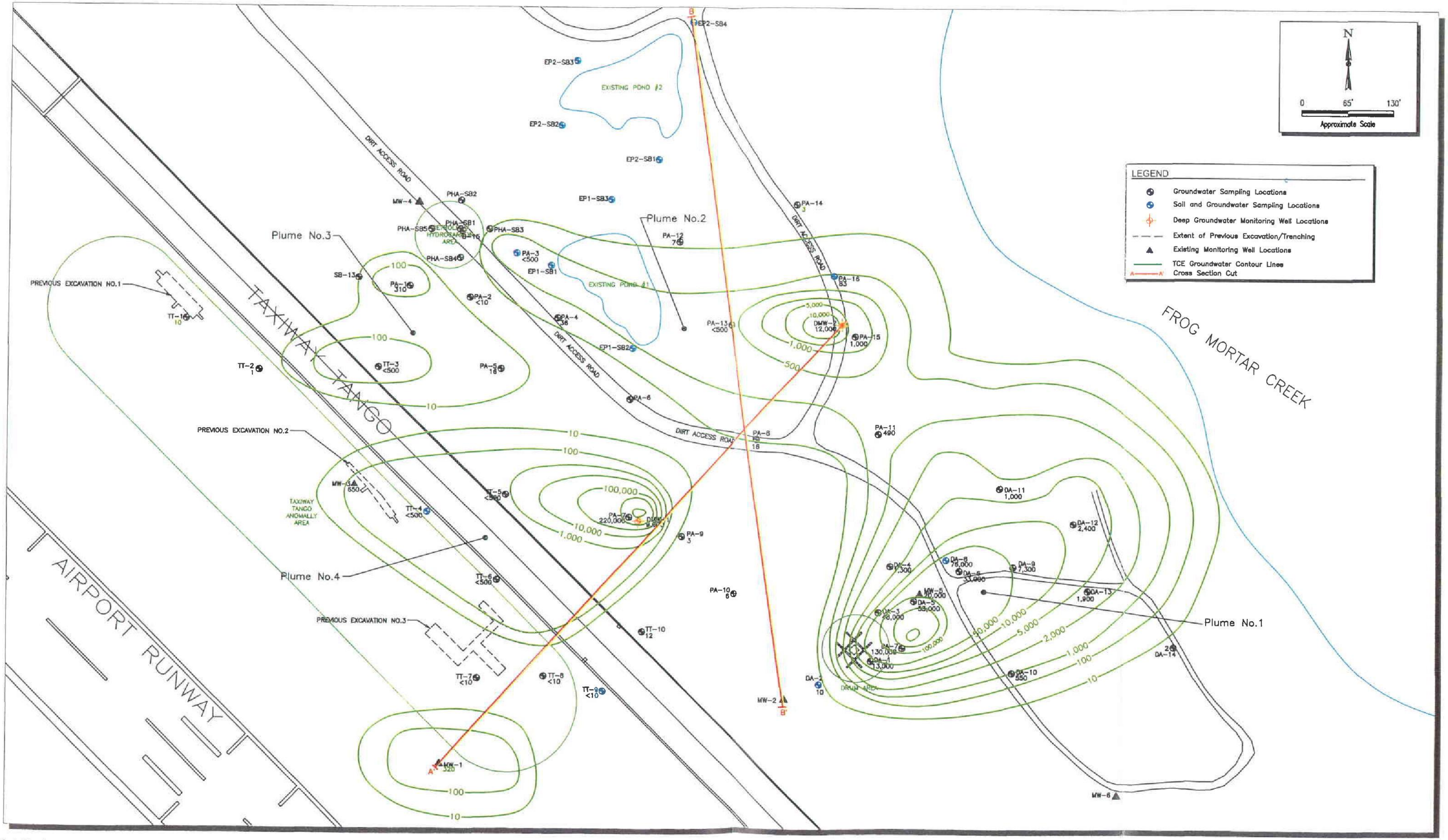
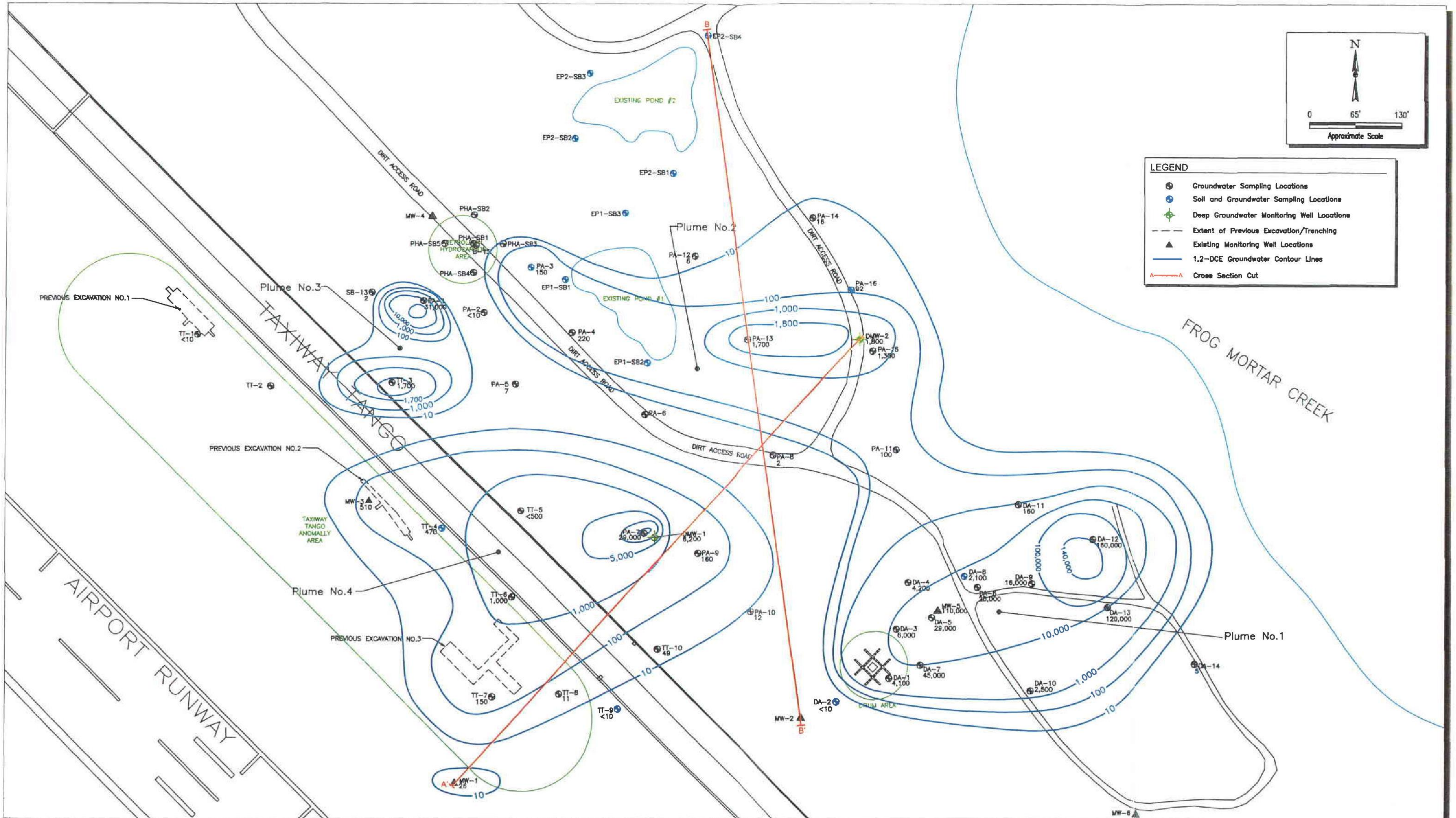


FIGURE 4-2
TCE CONCENTRATION CONTOURS OF THE PLUMES



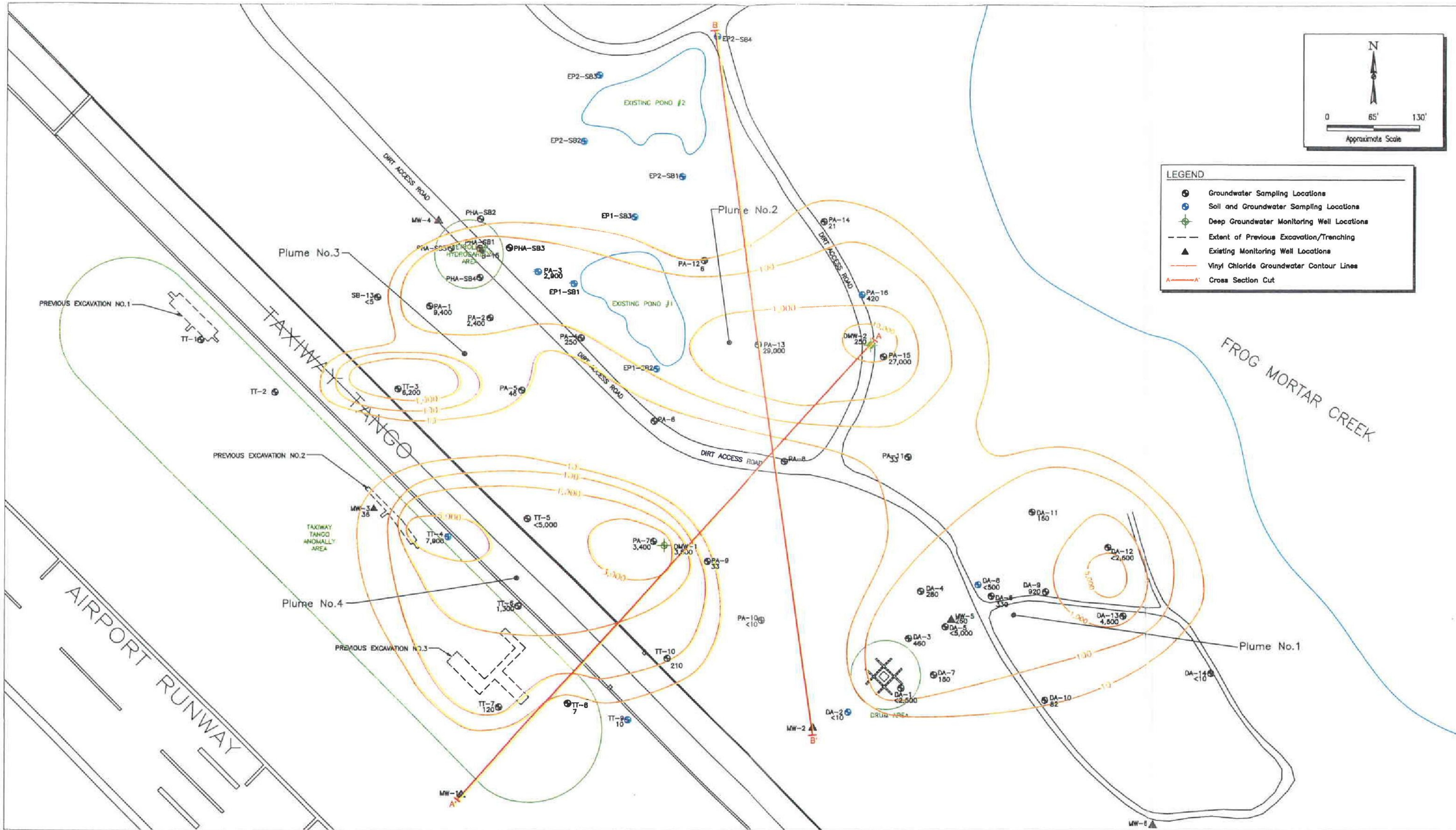
Cad4Files/Projects/10825/Modeling/12-22-02/MSA_ModelingTCE-4.1.dwg

FIGURE 4-3
cis 1,2-DCE CONCENTRATION CONTOURS OF THE PLUMES



Cad4Files/Projects/10825/Modeling/12-22-02/MSA_Modeling1-2-DCE-4-2.dwg

FIGURE 4-4
VINYL CHLORIDE CONCENTRATION CONTOURS OF THE PLUMES



Cad4Files/Projects/10825/Modeling/12-22-02/MSA_ModelingVC-4-3.dwg

FIGURE 4-5
SUMMARY OF AROMATIC ORGANICS DATA IN GROUNDWATER

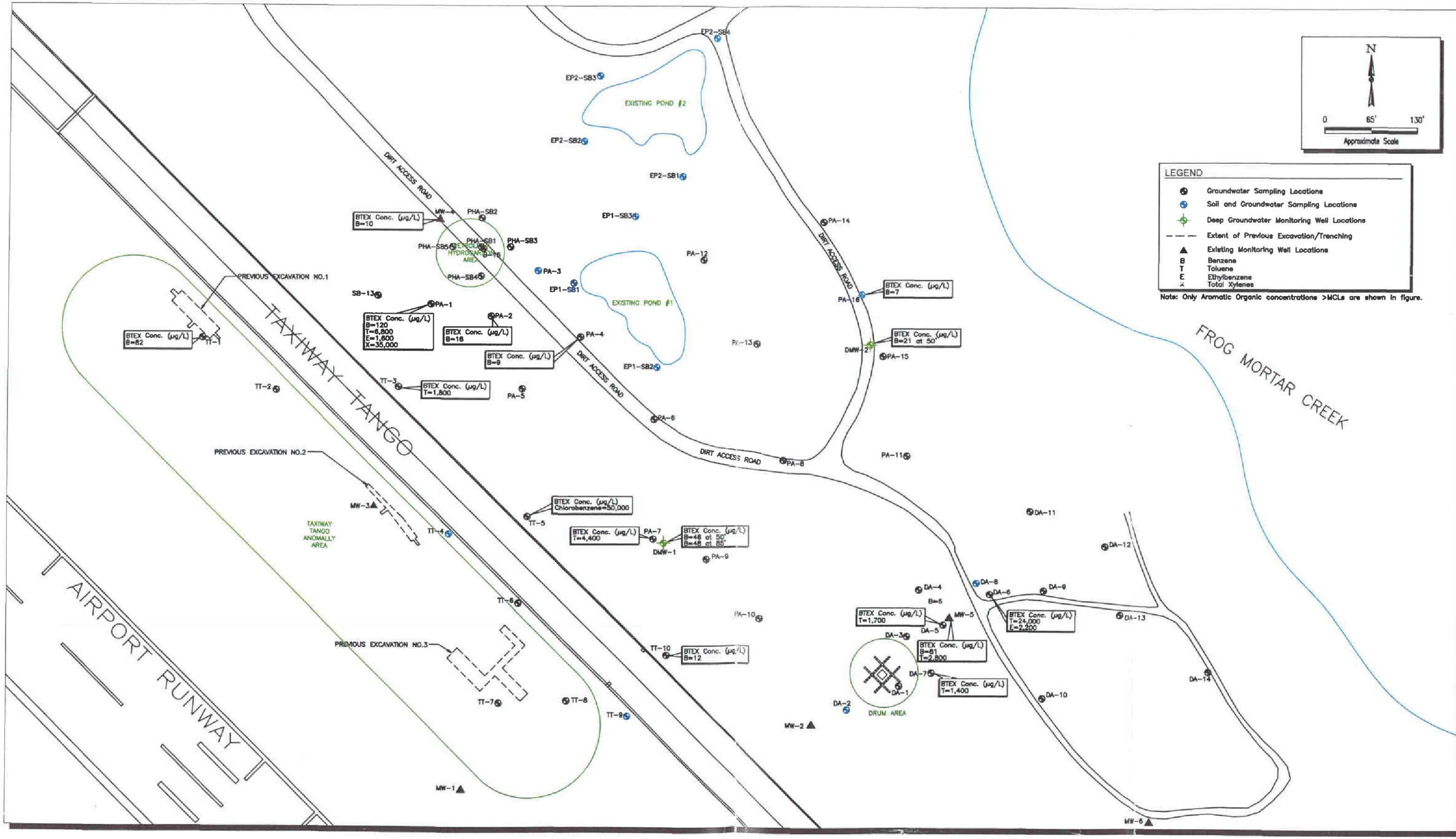
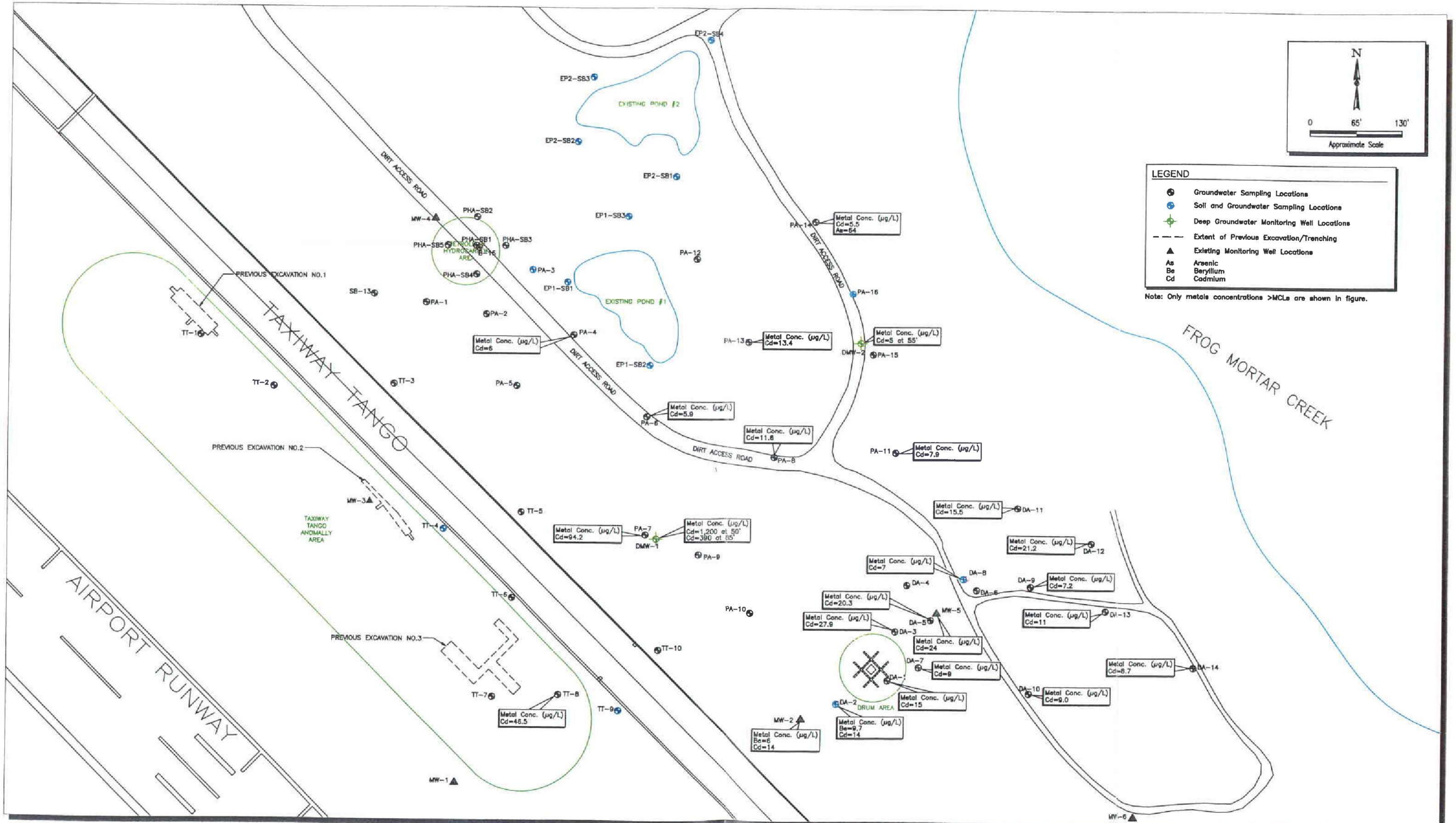


FIGURE 4-6
SUMMARY OF METALS DATA IN GROUNDWATER



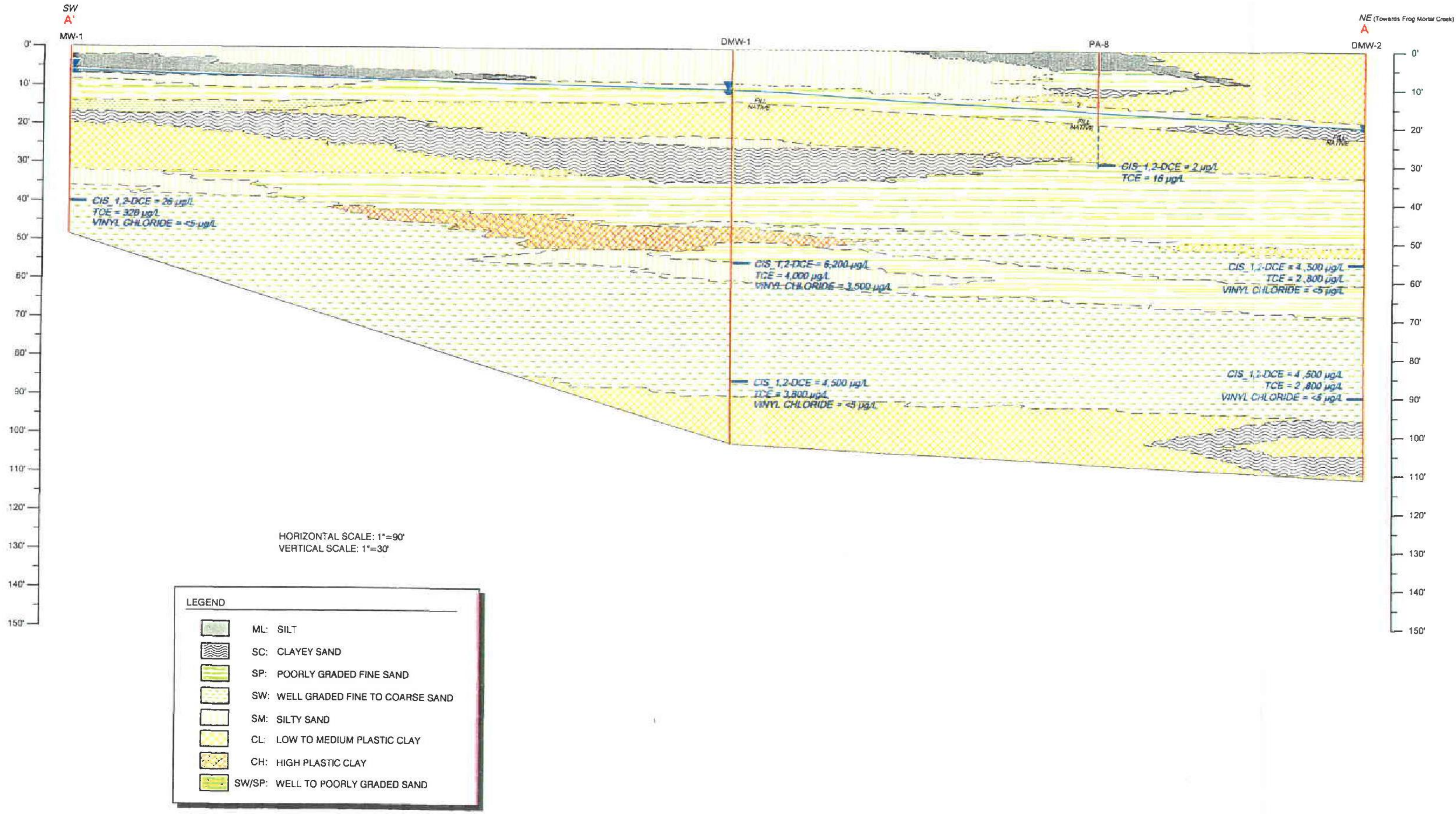

SW
A'
MW-1
DMW-1
PA-8
NE (Towards Frog Mortar Creek)
A
DMW-2
CIS_1,2-DCE = 26 µg/L
TCE = 320 µg/L
VINYL CHLORIDE = <5 µg/L
CIS_1,2-DCE = 6,200 µg/L
TCE = 4,000 µg/L
VINYL CHLORIDE = 3,500 µg/L
CIS_1,2-DCE = 4,500 µg/L
TCE = 3,800 µg/L
VINYL CHLORIDE = <5 µg/L
CIS_1,2-DCE = 2 µg/L
TCE = 16 µg/L
CIS_1,2-DCE = 4,500 µg/L
TCE = 2,800 µg/L
VINYL CHLORIDE = <5 µg/L
CIS_1,2-DCE = 4,500 µg/L
TCE = 2,800 µg/L
VINYL CHLORIDE = <5 µg/L
HORIZONTAL SCALE: 1"=90'
VERTICAL SCALE: 1"=30'
LEGEND
ML: SILT
SC: CLAYEY SAND
SP: POORLY GRADED FINE SAND
SW: WELL GRADED FINE TO COARSE SAND
SM: SILTY SAND
CL: LOW TO MEDIUM PLASTIC CLAY
CH: HIGH PLASTIC CLAY
SW/SP: WELL TO POORLY GRADED SAND

FIGURE 4-8
CROSS SECTION B-B'

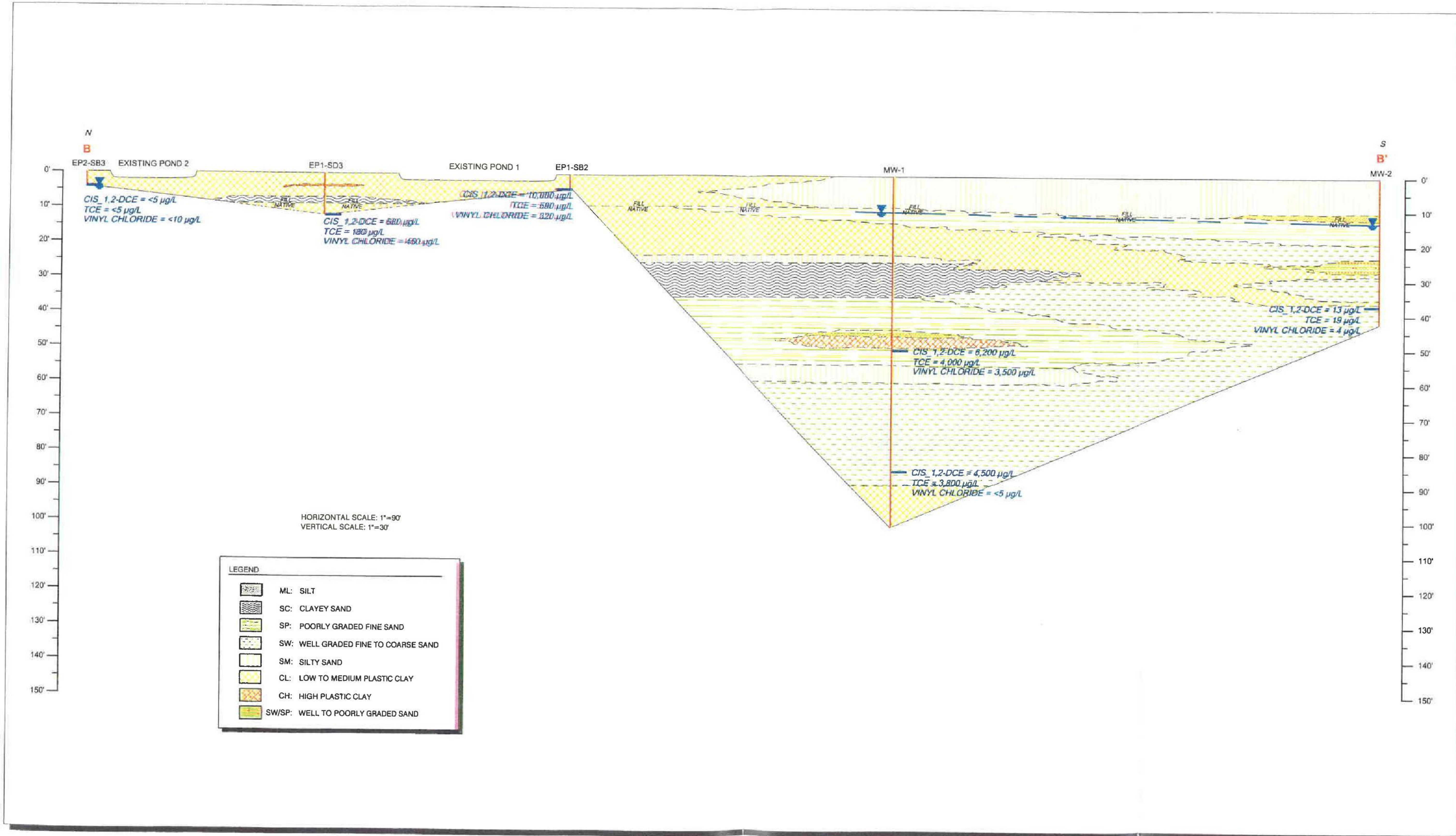


Table 5-1 Geologic Description of Conceptual Model Layers

Model Layer	Layer Thickness	Elevation (msl)	MW-4	MW-3	MW-1	DMW-2	DMW-1	MW-2	MW-5	MW-6
1	30 ft	15 to 10								
		10 to 5	clayey sand and some fine gravel		silty sand and gravel	fill material	fill material	fill material	dark gray plastic clay	gray clayey silt
		5 to 0	medium sand	gravel sand	medium sand and silt gray clay	fill material (sand)	fill material (sand)	fill material (sand)	dark gray plastic clay	gray clayey silt, duck gray clay
		0 to -5	medium to coarse sandand gravel	medium sand and some gravel	medium sand and gravel, some clay lens	silty clay	silty clay	dense gray clay, medium sand	plastic clay, clayey silt, medium sand lenses	coarse sand gravel
		-5 to -10	medium to coarse sand and gravel	silty sandy, some coarse sand and gravel	sand and gravel	sandy clay	clay and silt sand	medium sand, compacted dense clay	coarse sand and gravel	coarse sand gravel
		-10 to -15	medium to coarse sand and gravel	dense silty clay (dry-wet)	sand and gravel with gray plastic clay	sand	silty sand and clayey sand	coarse sand and gravel	coarse sand, gravel with clay lenses	coarse sand gravel
2	25 ft	-15 to -20	medium to coarse sand and gravel	gray plastic clay, sand lenses 6" (saturated)	compacted silty clay (dry)	sand	clayey sand	silty sand, dense clay	coarse sand, gravel, clay lenses	compacted medium sand
		-20 to -25	medium sand	gray dense clay and some silty and gravel	compacted silty clay	sand	sand	coarse sand and gravel with clay lens	coarse sand, gravel, clay lenses	
		-25 to -30	medium sand with lenses of gray clay	gray dense clay and some silty and gravel	coarse sand and gravel	sand	sand	coarse sand, some clay lens		
		-30 to -35		dense clay (dry)	coarse sand and gravel	sand with some silty clay	sand	coarse sand, some clay lens		
		-35 to -40		dense clay (dry)	coarse sand and gravel	sand	sand with some clay lenses			
3	30 ft	-40 to -45				sand	silty sand			
		-45 to -50				sand	sand			
		-50 to -55				sand	sand			
		-55 to -60				sand	sand			
		-60 to -60				sand	sand			
		-65 to -70				sand	sand			
Inpermeable Layer	25 ft	-70 to -75				clay sand	clay			
		-75 to -80				clay	clay			
		-80 to -85				sandy silty clay	clay			
		-85 to -90				clay	clay			
		-90 to -95					clay			

Table 5-2 Groundwater Level Monitoring in 12-hour Duration at Martin State Airport

Date: 6/7/2002

Groundwater Monitoring Wells																
	MW-1		MW-2		MW-3		MW-4		MW-5		MW-6		DMW-1		DMW-2	
	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)	Time	Depth (ft)
	7:35	8.06	7:40	7.24	7:36	8.92	7:24	8.30	7:15	21.96	7:04	15.93	7:26	10.23	7:17	21.30
	9:12	8.08	9:11	7.25	9:13	8.92	9:09	8.32	9:06	22.00	9:04	15.96	9:10	10.26	9:08	21.31
	11:12	8.05	11:10	7.24	11:13	8.92	11:07	8.33	11:05	22.00	11:04	15.96	11:09	10.26	11:06	21.31
	13:12	8.02	13:10	7.18	13:13	8.90	13:07	8.35	13:05	21.94	13:04	15.91	13:09	10.20	13:06	21.09
	15:13	8.00	15:11	7.13	15:15	8.90	15:09	8.33	15:06	21.91	15:05	15.85	15:10	10.16	15:07	21.00
	17:14	7.98	17:12	7.13	17:16	8.90	17:09	8.28	17:06	21.82	17:05	15.85	17:11	10.15	17:08	21.02
	19:14	8.00	19:12	7.14	19:16	8.91	19:10	8.34	19:06	21.87	19:05	15.92	19:11	10.17	19:08	21.07
	Average	8.03		7.19		8.91		8.32		21.93		15.91		10.20		21.16
Difference between highest and lowest		0.1		0.12		0.02		0.07		0.18		0.11		0.11		0.31

Table 5-3 Field Measurements of Groundwater Heads

		6/7/2002		3/16/1999		2/22/1996		8/15/1994	
Well I.D.	Top of PVC Elevation (feet)	Depth to Ground Water (feet)	Ground Water Elevation (feet)	Depth to Ground Water (feet)	Ground Water Elevation (feet)	Depth to Ground Water (feet)	Ground Water Elevation (feet)	Depth to Ground Water (feet)	Ground Water Elevation (feet)
MW-1	10.47	8.03	2.44			6.28	4.19	6.90	3.06
MW-2	9.28	7.19	2.09	6.21	3.07	6.51	2.77	7.07	2.21
MW-3	12.16	8.91	3.25	8.26	3.90	7.87	4.29	8.74	3.42
MW-4	11.46	8.32	3.14	6.27	5.19	6.20	5.26		
MW-5	23.68	21.93	1.75	21.05	2.63	20.85	2.83		
MW-6	17.75	15.91	1.84	14.7	3.05	14.30	3.45		
PZ-2	12.13	Not Sample	N/A	7.95	4.18				
DMW-1	11.95	10.204	1.746						
DMW-2	21.62	21.157	0.463						

Note:

The top PVC elevation of MW-1 was 9.96 feet msl before a damage was observed May, 1999.

It was used to determined the groundwater elevations measured on 8/15/1994.

Table 5-4 Soil Parameters

Site Specific Data						Average in Layer								
		Dry Density	Specific Gravity		Total Organica Carbon	Bulk Density (g/cm³)			Total Porosity			Toc (%)		
Sample ID	Description	(g/cm³)	SG (g/cm³)	Total Porosity	(%)	15' to -15'	-15' to -40'	-40' to -70'	15' to -15'	-15' to -40'	-40' to -70'	15' to -15'	-15' to -40'	-40' to -70'
DMW-1 (10-12')	Orange Brown, Sandy clay	1.361	2.65	0.479	2.5	1.36			0.48			2.50		
DMW-1 (15-17')	Gray clay	1.147	2.67	0.570	1.7	1.15			0.57			1.70		
DMW-1 (30-32')	White to yellow brown, silty sand	1.272	2.66	0.522	1.6		1.27			0.52			1.60	
DMW-1 (45-47')	white clay with sand seam	1.321	2.66	0.503	1.9		1.32			0.50			1.90	
DMW-1 (55-57')	Red-yellow brown, silty sand	1.192	2.65	0.550	0.79			1.19			0.55			0.79
DMW-1 (80-82')	White, silty, clayey sand	1.225	2.29	0.465	1			1.23			0.46			1.00
DMW-1 (100')	Red-yellow brown clay	1.329	2.68	0.504	2.6									
DMW-2 (20-22')	Dark gray clay	1.022	2.65	0.614	1.7	1.02			0.61			1.70		
DMW-2 (25-27')	White to pale brown clay	1.278	2.65	0.518	1.2	1.28			0.52			1.20		
DMW-2 (35-37')	Yellown brown sand	1.105	2.64	0.581	1.3	1.11			0.58			1.30		
DMW-2 (35-37')	Gray clay	1.221	2.67	0.543	0.94		1.22			0.54			0.94	
DMW-2 (55-57')	Orange, silty sand	1.281	2.63	0.513	2.7		1.28			0.51			2.70	
DMW-2 (95')	White, sandy clay	1.328	2.66	0.501	1.1			1.33			0.50			1.10
DMW-2 (110')	Brown clay	1.344	2.16	0.378	1.2									
PA-2-GT-SC		1.828	2.67	0.315	0.12	1.83	1.83	1.83	0.32	0.32	0.32	0.12	0.12	0.12
PA-3-GT-SC		1.720	2.65	0.350	0.1	1.72	1.72	1.72	0.35	0.35	0.35	0.10	0.10	0.10
PA-16-GT-SDC		1.333	2.56	0.480	1.32	1.33	1.33	1.33	0.48	0.48	0.48	1.32	1.32	1.32
PA-16-GT-PC		1.506	2.64	0.430	1.06	1.51	1.51	1.51	0.43	0.43	0.43	1.06	1.06	1.06
SB-7-GT-SS		1.786	2.63	0.320	1.06	1.79	1.79	1.79	0.32	0.32	0.32	1.06	1.06	1.06
Average		1.348	2.60	0.481	1.363	1.41	1.47	1.49	0.47	0.44	0.43	1.21	1.20	0.82

Table 5-5 Retardation Factor Estimates for the Mass Transport Model

$$Rd = 1 + K_d \frac{\rho_b}{n_e}$$

Parameters		Layer 1	Layer 2	Layer 3
Elevation (msl)		15' to -15'	-15' to -40'	-40' to -70'
Thickness (ft)		30	25	30
Bulk Density (ρ_b)(g/cm^3)		1.41	1.47	1.49
Effective Porosity* (n_e)		0.32	0.29	0.28
Toc (%)		1.21	1.2	0.82
TCE	Koc (ml/g)	166	166	166
	Kd	2.0	2.0	1.4
	Rd	**9.9**	**11.1**	**8.2**
cis-1,2-DCE	Koc (ml/g)	35.5	35.5	35.5
	Kd	0.43	0.43	0.29
	Rd	**2.89**	**3.16**	**2.55**
Vinyl Chloride	Koc (ml/g)	18.6	18.6	18.6
	Kd	0.23	0.22	0.15
	Rd	**1.99**	**2.13**	**1.81**

Note:

Effective Porosity = Total Porosity - 0.15

Kd = Koc x Toc

Figure 5-1 Conceptual Model Boundaries

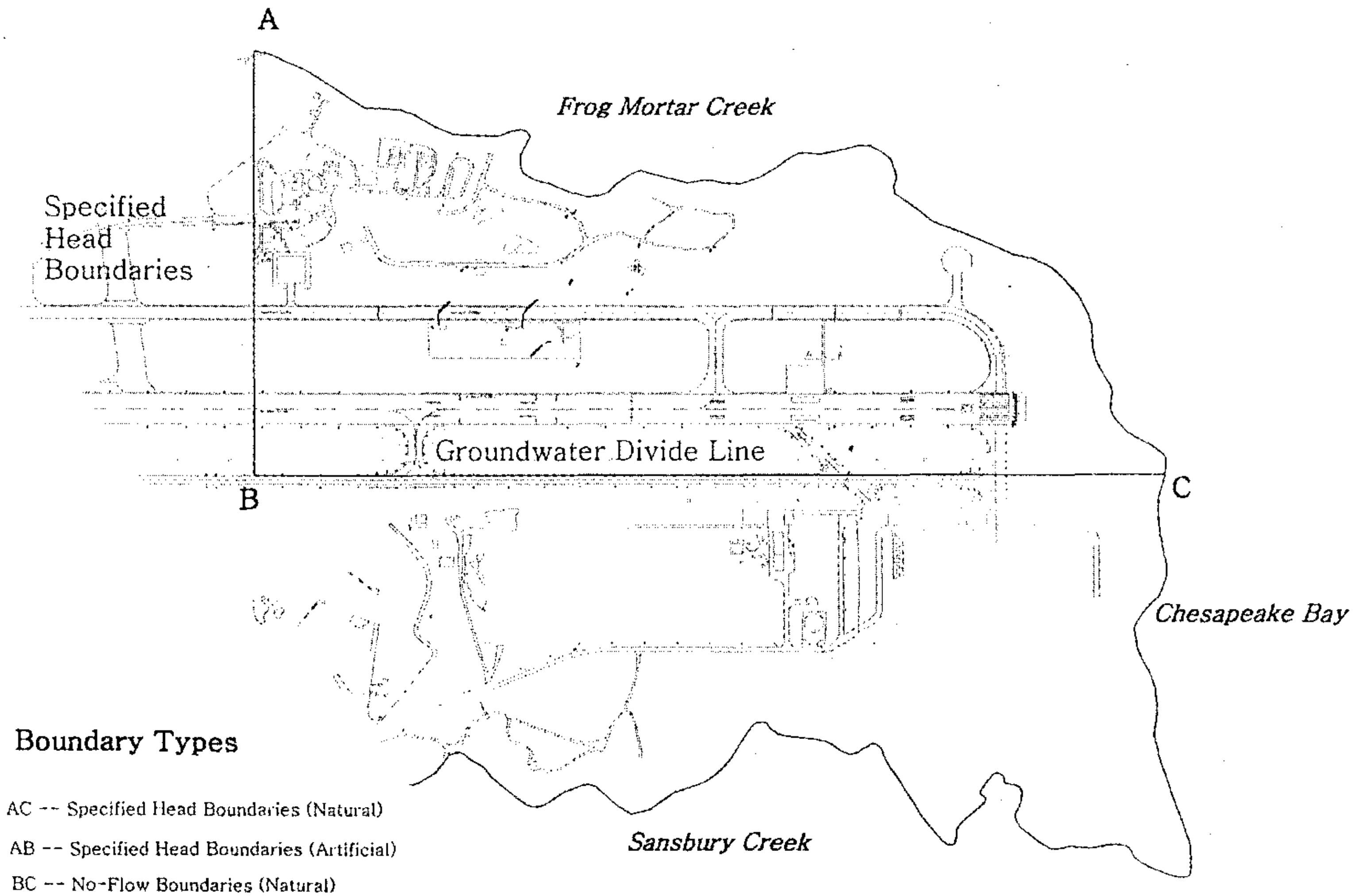


Figure 5-2 Field Measurements and Contours of Groundwater Head

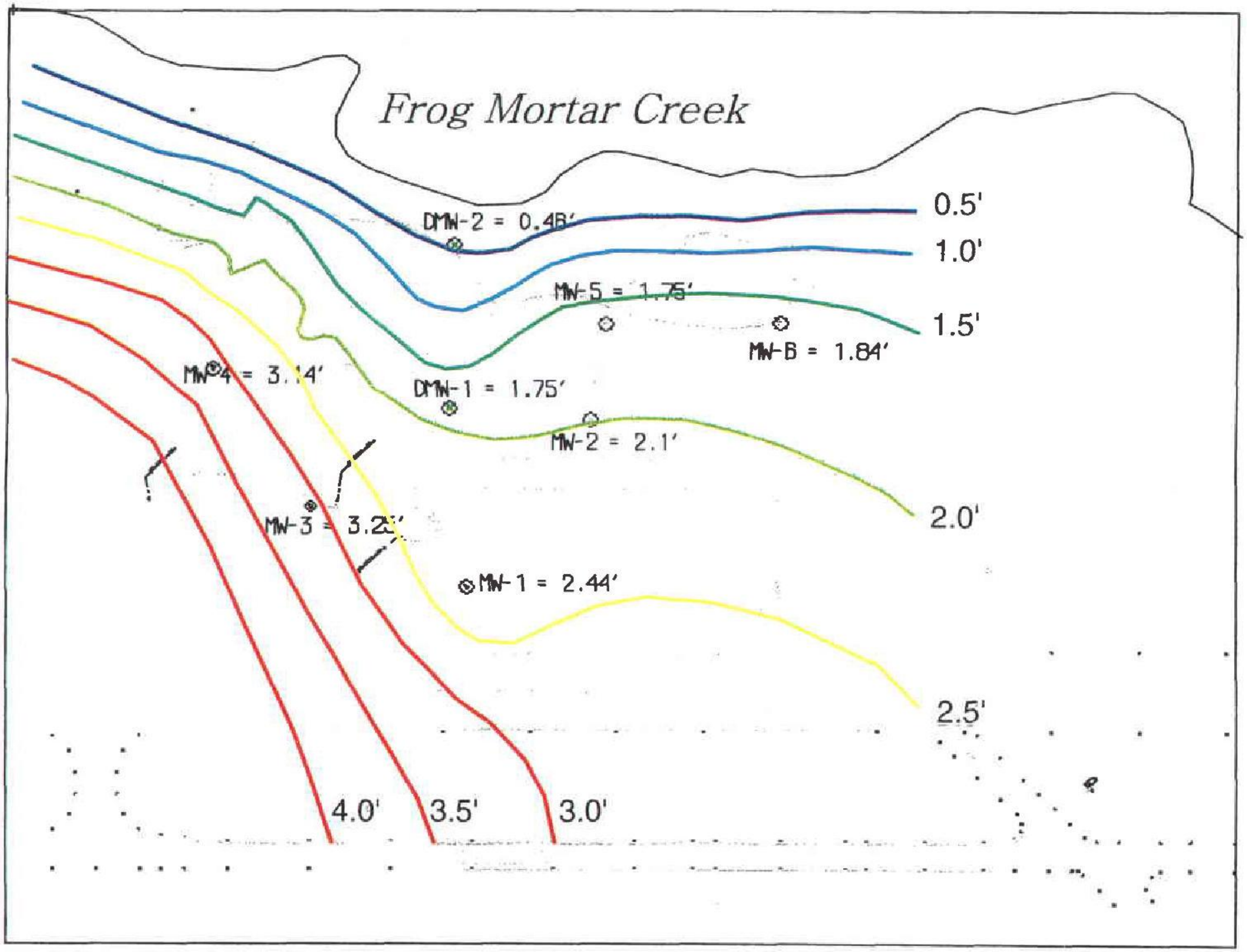


Figure 5-3 Model Domain on Horizontal Plane

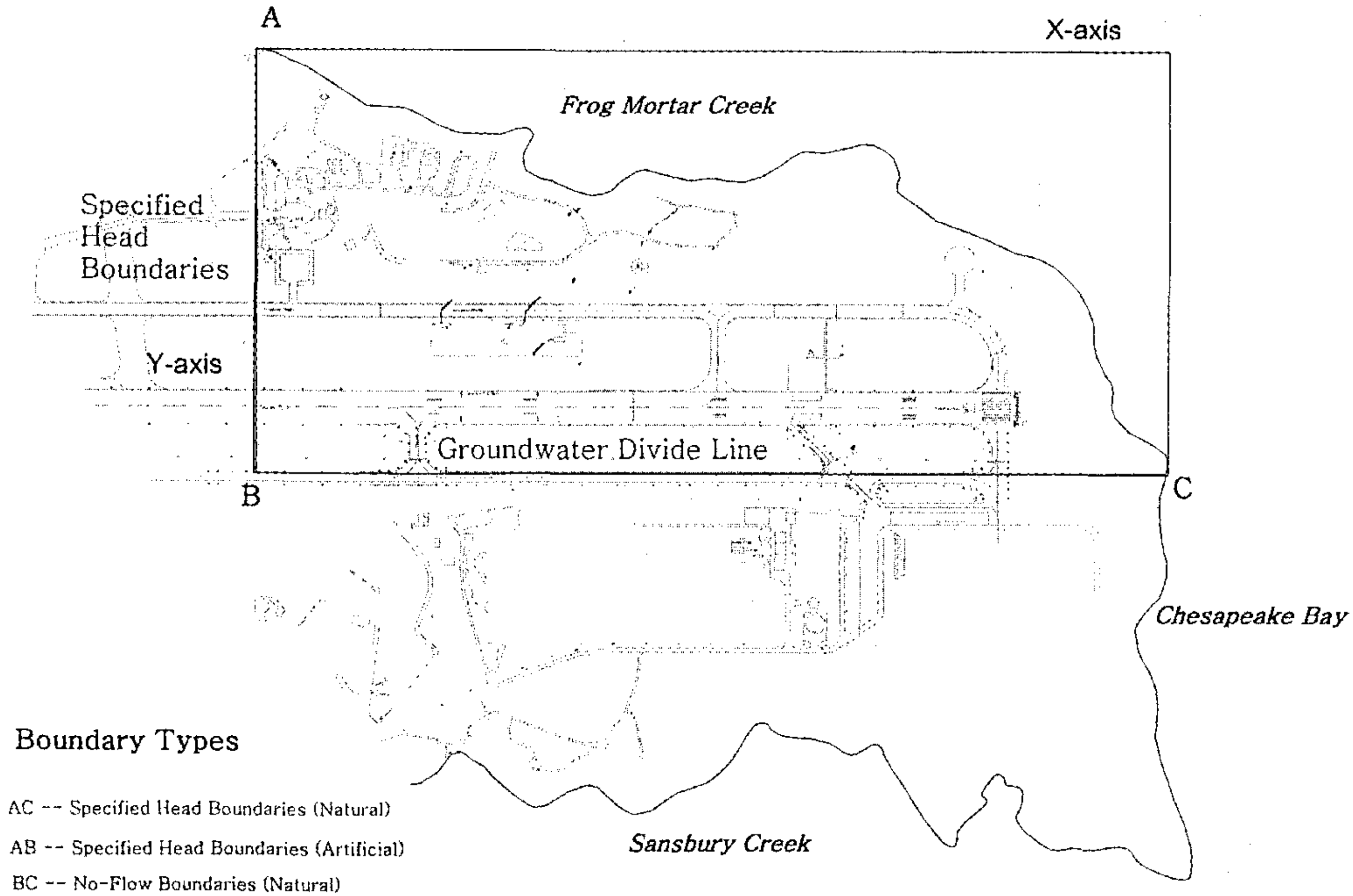


Figure 5-4 Hydraulic Conductivity Values on Layer 1

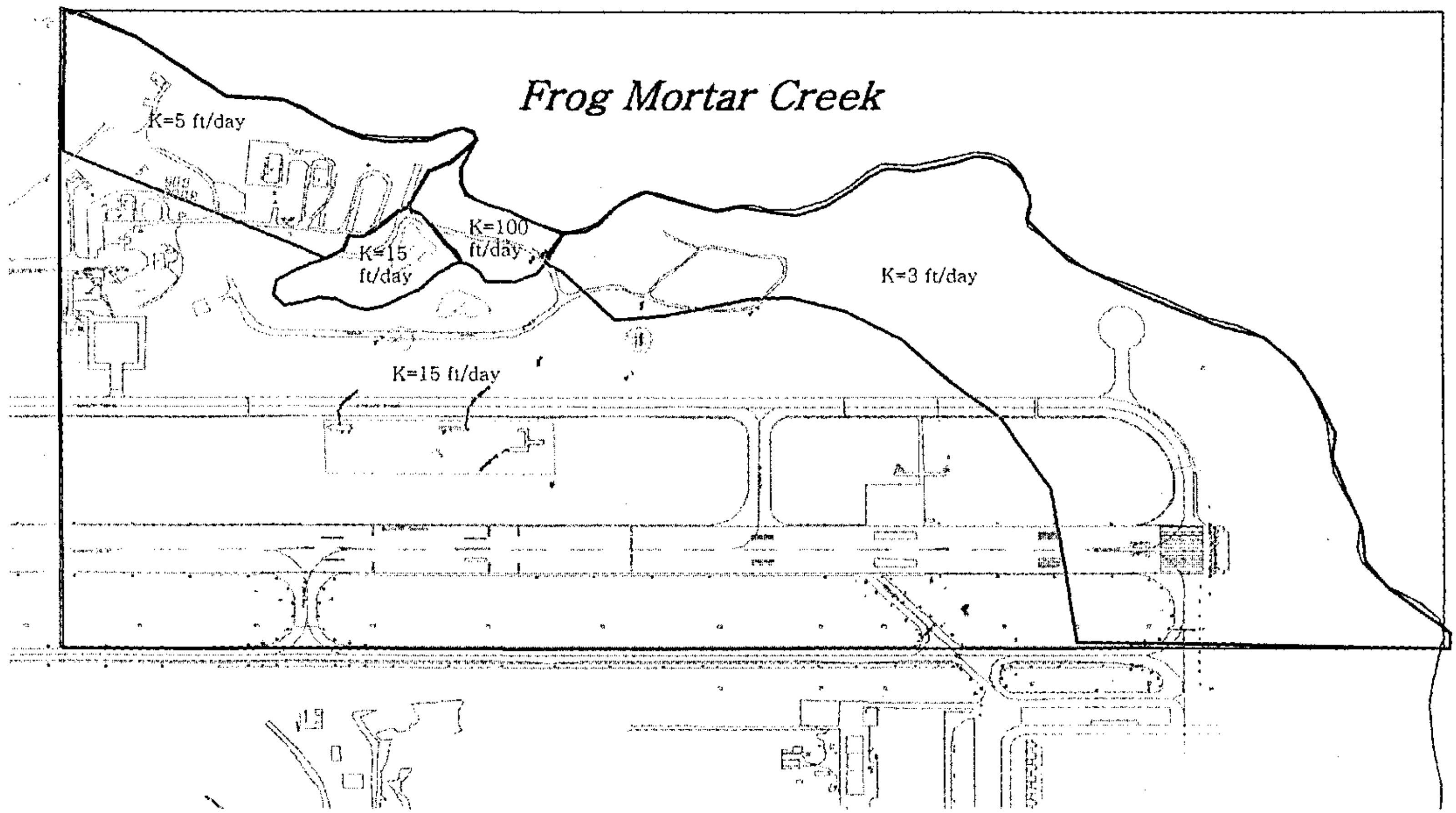


Figure 5-5 Hydraulic Conductivity Values on Layer 2

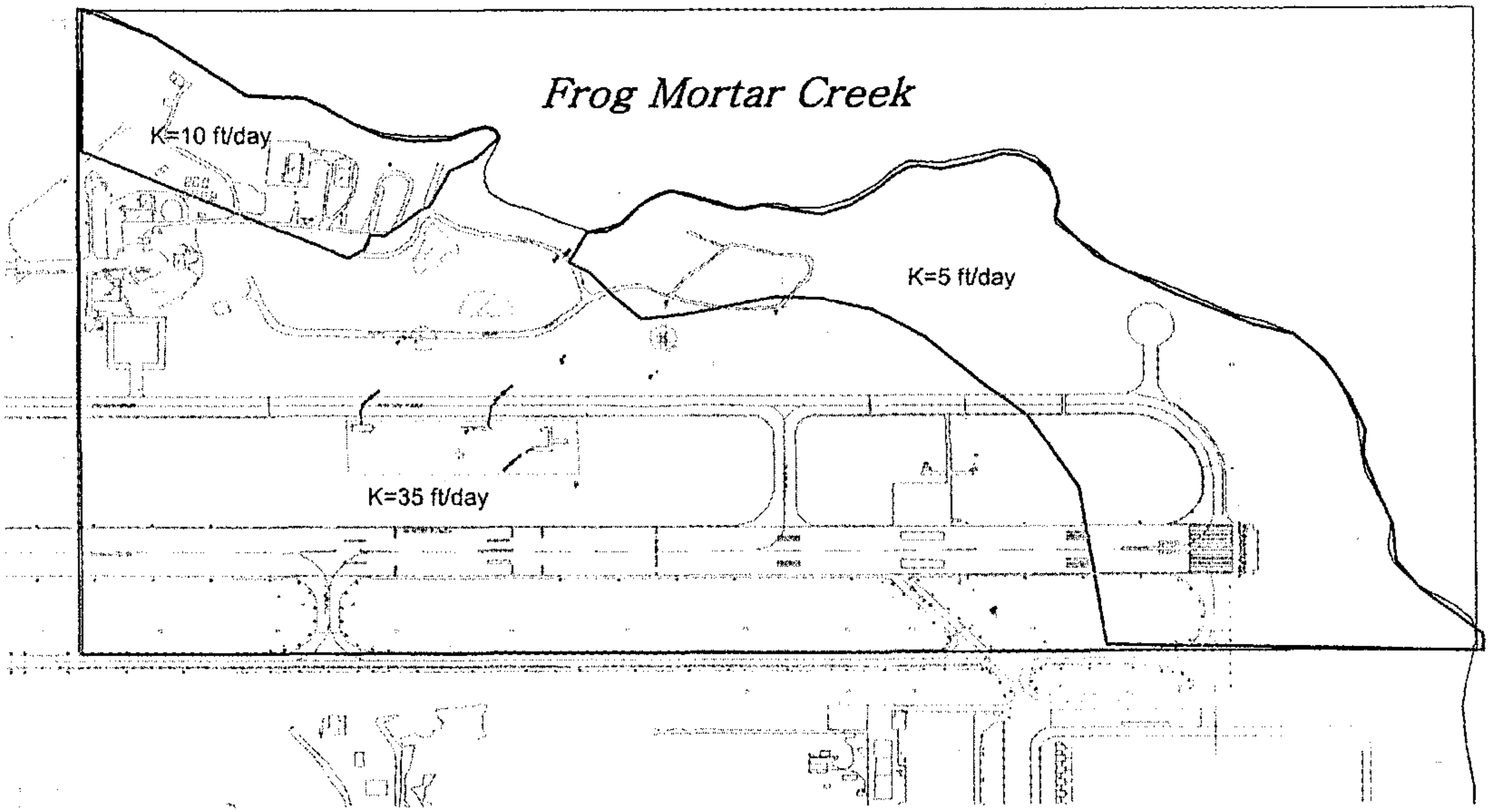


Figure 5-6 Hydraulic Conductivity Values on Layer 3

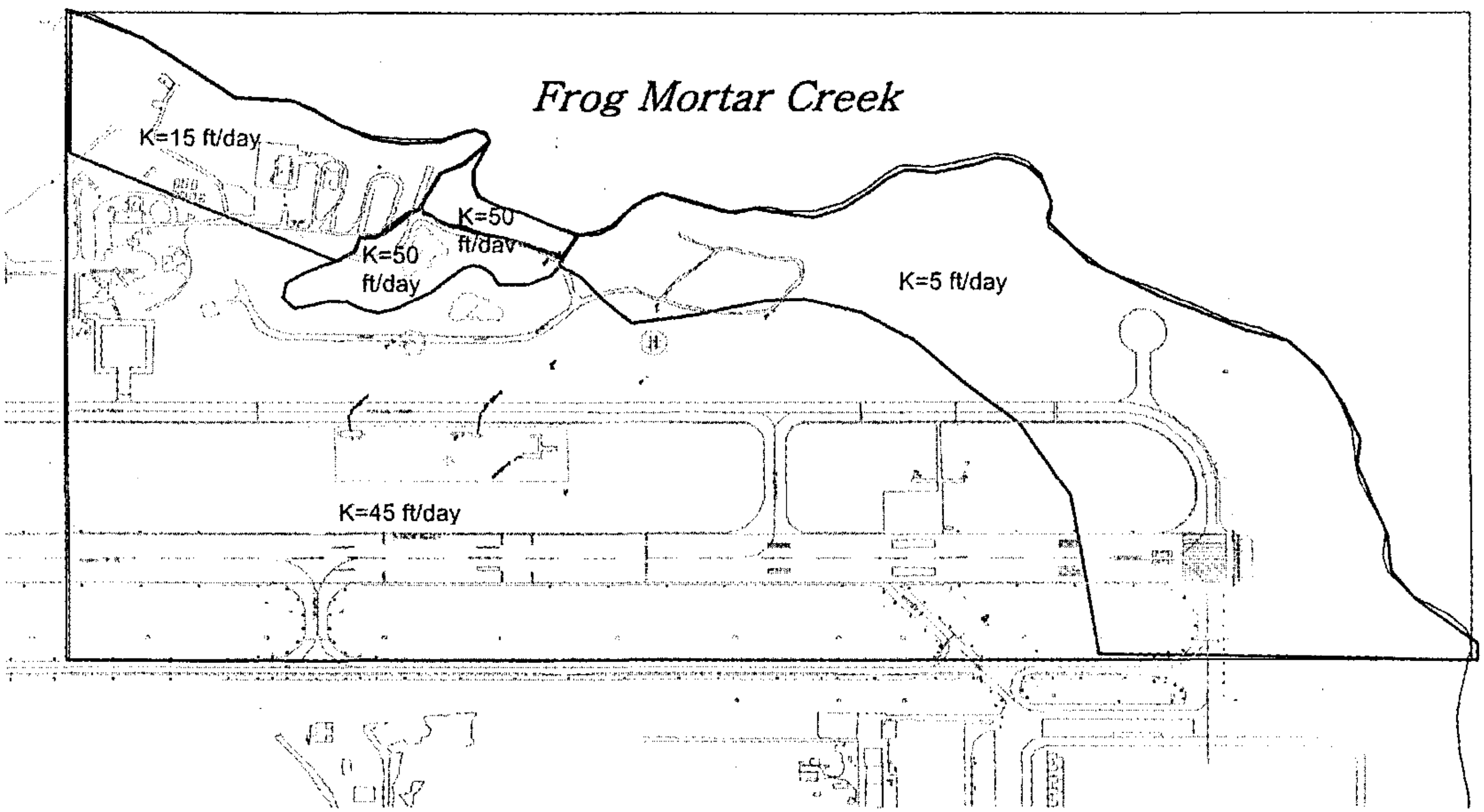


Figure 5-7 Groundwater Contours Simulated by the Calibrated Model

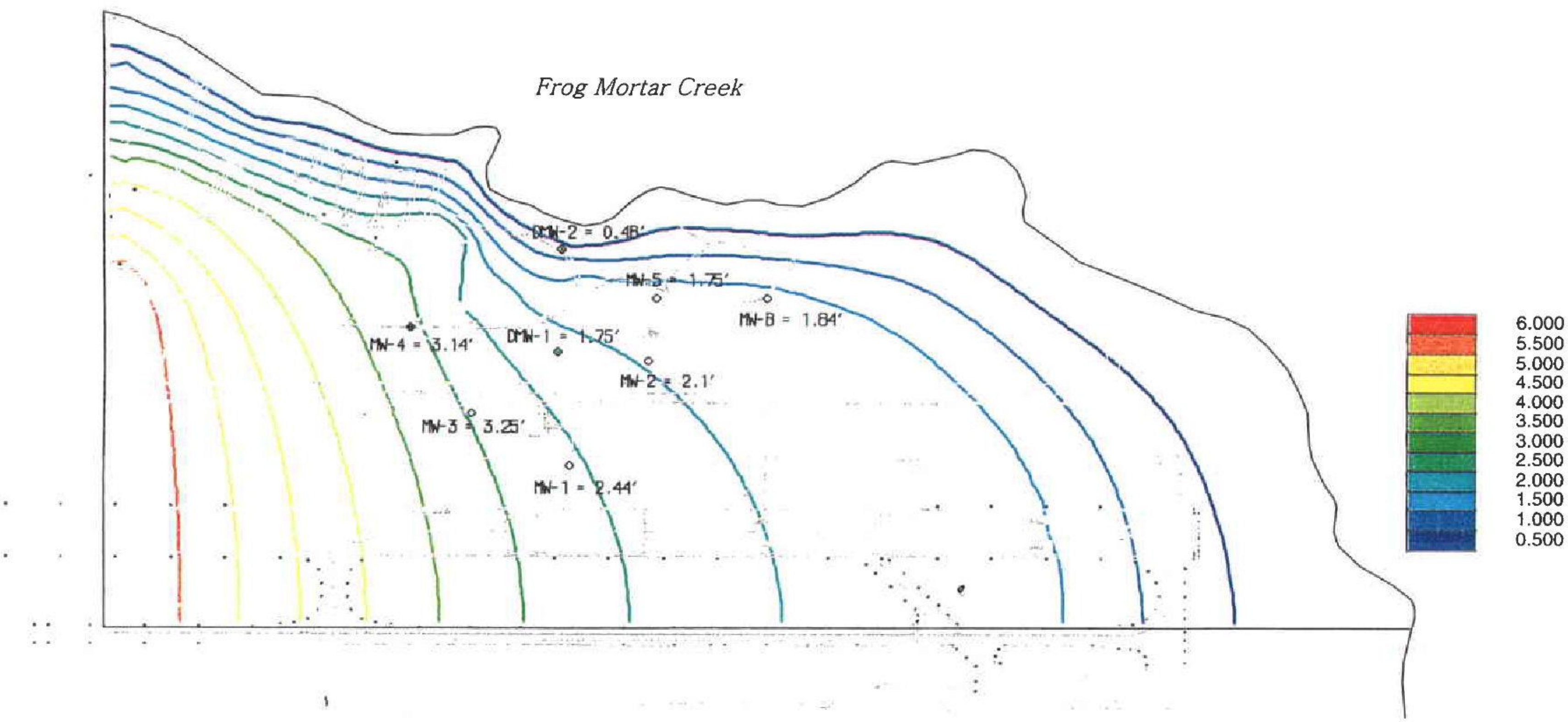


Figure 5-8 Groundwater Contours Simulated by the Calibrated Model for Verification

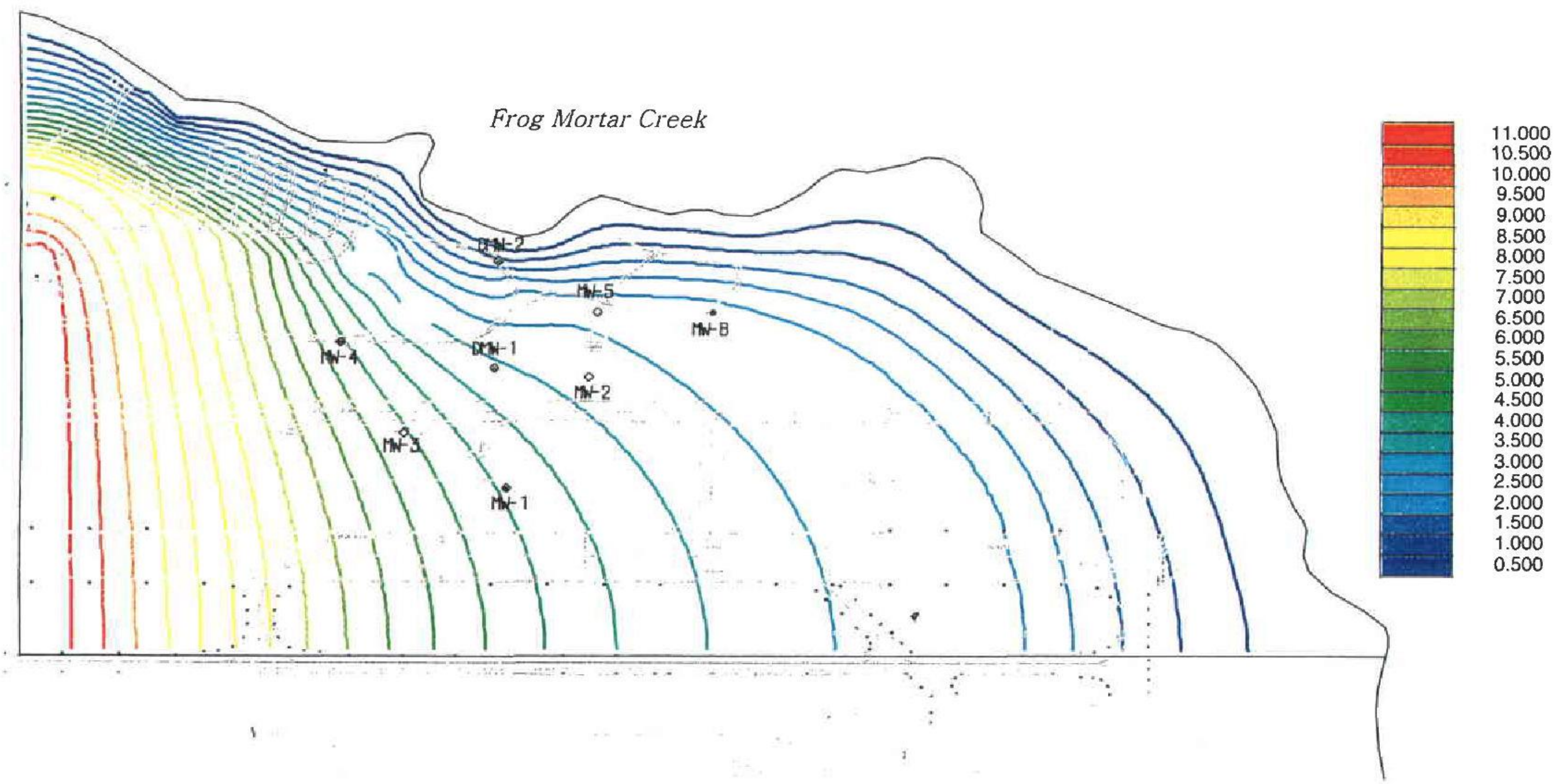
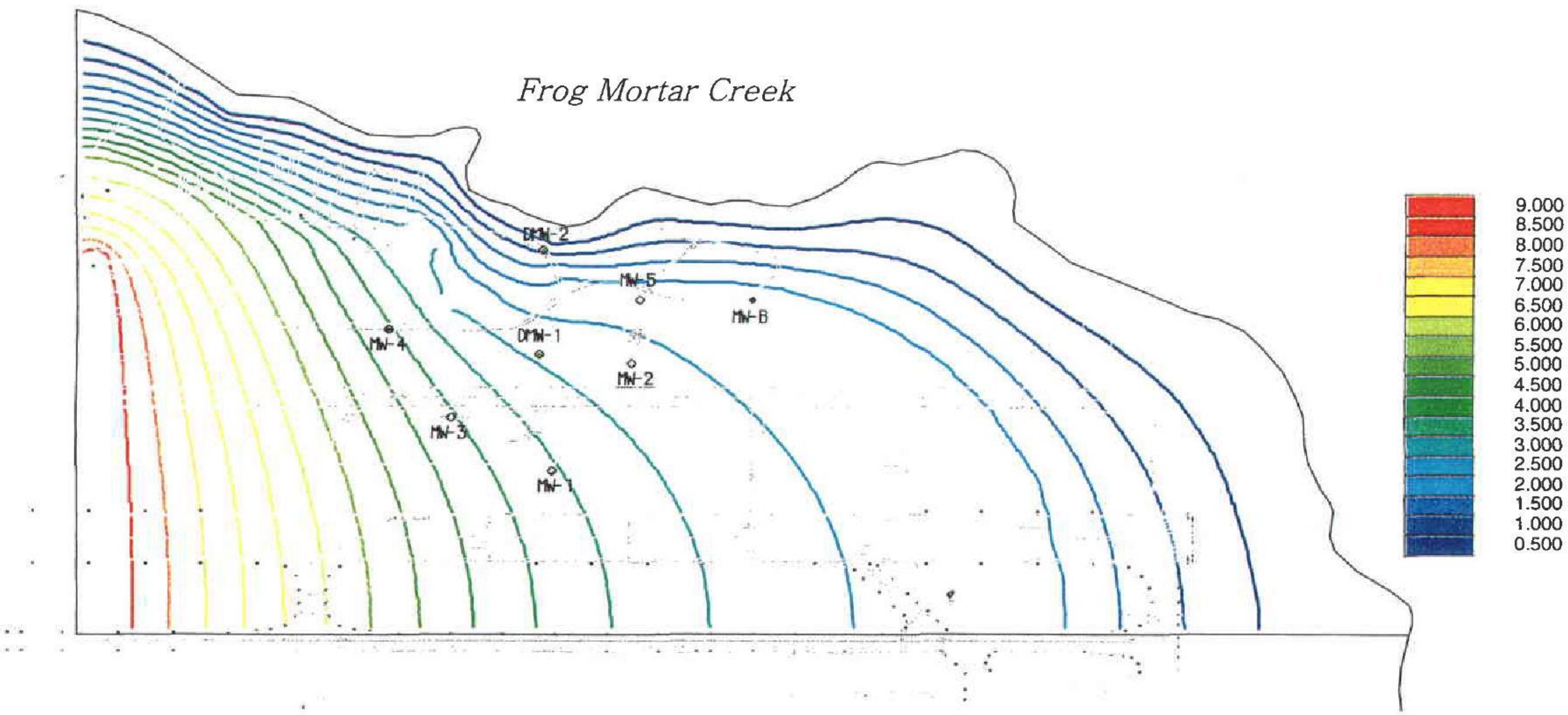


Figure 5-9 Groundwater Contours of Dynamic Average of Groundwater Flow Conditions



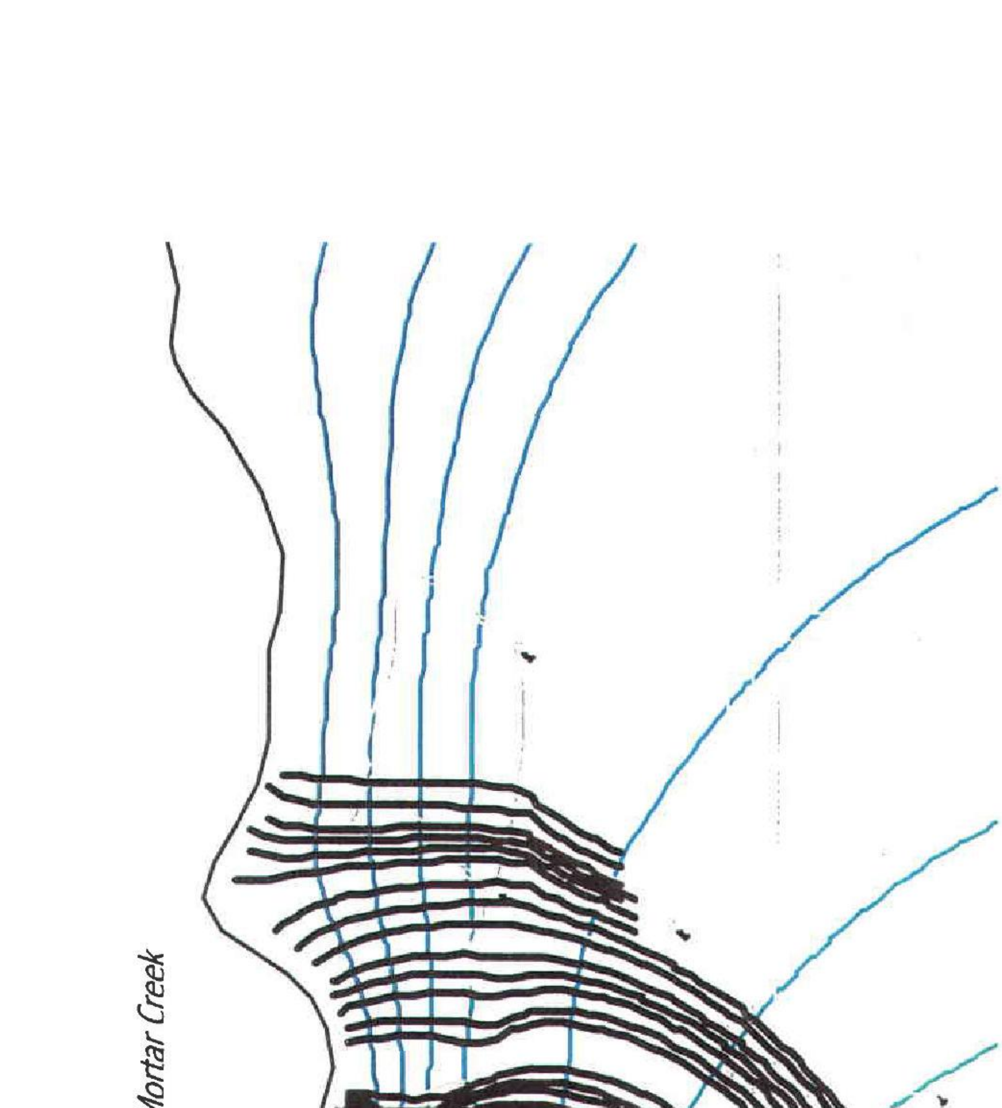


Figure 5-10 Particle Tracking for Prediction of Plume Migrations