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FINAL

REVISED

SAMPLE STRATEGY PLAN

FOCUSED/NATURAL
ATTENUATION EVALUATION
OPERABLE UNIT NO. 10, SITE 35
CAMP GEIGER AREA FUEL FARM

MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0130

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Prepared for:

DEPARTMENT OF THE NAVY
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QC Review Page

Sample Strategy Plan

OU No.10, Site No. 35

MCB Camp Lejeune

Jacksonville, North Carolina

Contract Task Order Number - 0130
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Navy CLEAN II Program

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LIST OF ACRONYMS AND ABBREVIATIONS

AFCEE Protocol	Air Force Center for Environmental Excellence Technical Protocol For Evaluating Natural Attenuation of Chlorinated Solvents In Groundwater
APG Study	Natural Attenuation of Chlorinated Volatile Organic Compounds in a Freshwater Tidal Wetland
ATV	all-terrain vehicle
bgs	below ground surface
Baker	Baker Environmental Inc.
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLP	Contract Laboratory Protocol
Draft FS	Draft Feasibility Study Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm
Draft PRAP	Draft Preliminary Remedial Action Plan Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm
EPA Protocol	Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater
f_{oc}	fractional organic carbon
Focused NAE	Focused Natural Attenuation Evaluation
FSAP	Remedial Investigation/Feasibility Study Field Sampling and Analysis Plan for Operable Unit No.10 (Site 35)
GIS	Geographic Information System
HASP	Remedial Investigation/Feasibility Study Health and Safety Plan for Operable Unit No.10 (Site 35)
HWS	North Carolina Hazardous Waste Section
IAS	in-situ air sparging
IDW	investigation derived waste
IR	Installation Restoration
IRA	Interim Remedial Action
LANTDIV	Atlantic Division, Naval Facilities Engineering Command
LDPE	Low-Density Polythylene
LNAPL	light nonaqueous phase liquid
LTM	Long Term Monitoring
MCB	Marine Corp Base
MNA	monitored natural attenuation
NAA	Natural Attenuation Assessment
NAE	Natural Attenuation Evaluation

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

NCAC 2L	15A North Carolina Administrative Code 2L Implementation Guidance
NC DOT	North Carolina Department of Transportation
OD	outside diameter
OSWER Directive	Use of Monitored Natural Attenuation Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites
OU	Operable Unit
PVC	poly vinyl chloride
RAA	remedial action alternative
RAC	Remedial Action Contractor
RCRA	Resource Conservation and Recovery Act
Region IV Protocol	Draft EPA Region 4 Suggested Practices for Evaluation of a Site for Natural Attenuation (Biological Degradation) of Chlorinated Solvents
RI	Remedial Investigation
RODs	Records of Decision
ROW	Right-of-Way
SGI	Supplemental Groundwater Investigation
SSP	Draft Sample Strategy Plan
TCE	trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
UTM	Universal Transverse Mercator
VOC	volatile organic compound
Work Plan	Remedial Investigation/Feasibility Study Work Plan for Operable Unit No. 10 (Site 35)

1.0 INTRODUCTION

This Revised Sample Strategy Plan (SSP) was prepared by Baker Environmental Inc. (Baker) to support the proposed Focused Natural Attenuation Evaluation (Focused NAE) for Operable Unit (OU) No. 10 Site 35, Marine Corp Base (MCB), Camp Lejeune, North Carolina. The SSP identifies specific field and data collection activities that must be conducted to meet the overall purpose and specific objectives of the Focused NAE, which are presented in Section 1.1. In addition, the SSP includes provisions for sediment sampling and installation of permanent well clusters as discussed at the November 2001 partnering meeting. Section 1.2 discusses how the proposed Focused NAE fits into the existing regulatory framework. Section 1.3 identifies the guidance documents that were used in the development of the SSP.

Well installation and sampling collection procedures are outlined in the Remedial Investigation/Feasibility Study Field Sampling and Analysis Plan for Operable Unit No.10 (Site 35) (FSAP) (Baker, 1993a) and the Remedial Investigation/Feasibility Study Work Plan for Operable Unit No.10 (Site 35) (Work Plan) (Baker, 1993b). Chemical hazards at the site have not changed since the 1994 Remedial Investigation (RI) was conducted. Therefore, the Remedial Investigation/Feasibility Study Health and Safety Plan for Operable Unit No.10 (Site 35) (HASP)(Baker, 1993c) that was developed to support the 1994 RI is applicable to the proposed Focused NAE field activities.

1.1 Purpose and Objectives

The methods, media, and sampling locations presented in this SSP were identified based on the purpose and specific objectives of the Focused NAE and to address other specific data gaps in site characterization. The primary purpose of the Focused NAE is to assess what extent natural attenuative processes are reducing groundwater contamination prior to discharge into Brinson Creek, and if these processes are sufficient to protect human health and the environment. The Focused NAE will be conducted in an area of the Brinson Creek wetland (see Figure 1-1) that is representative of the ecosystem along Brinson Creek. This specific area was selected because it exhibited high levels of chlorinated solvent-related contamination, and previously demonstrated evidence of contaminant biodegradation.

Another aspect of the study is to assess metals concentrations at the site. This portion of the study will establish concentrations of metals in site groundwater and in Brinson Creek from locations upstream of, adjacent to, and downstream of the site.

The third part of the study is to install permanent monitoring well clusters in the U.S. Highway 17 Bypass Right-Of-Way (ROW). These wells will allow monitoring of the contaminant plume in the area where numerous wells were abandoned to allow roadway construction.

The final part of the study is a Brinson Creek sediment-sampling task. This is designed to provide sediment quality data upstream from, adjacent to, and downstream of the site. The information will be used to assess whether the sediments are being impacted by possible releases from Site 35.

To meet the overall purpose of the Focused NAE the following specific objectives must be met:

- Assess contaminant migration from an apparent source area into Brinson Creek. This will require the following:

  - ➢ Determination of the vertical and horizontal extent of contamination in the study area.
  - ➢ Definition of major groundwater flow paths.
  - ➢ Definition of physical interactions between the water body, wetland, and aquifer.
  - ➢ Assessment of tidal impacts to groundwater/surface water system.
  - ➢ Characterization of the lithology in the subsurface environment of the wetland and Brinson Creek.

- Determine major geochemical and microbial processes affecting volatile organic compound (VOC) contamination, and assess impact of these processes.

- Evaluate significance of adsorption.

- Provide sufficient evidence that natural attenuation processes are protective of human health and the environment.

- Establish metals concentrations in site groundwater and Brinson Creek.

1.2 Regulatory Framework

The Federal Facilities Agreement and Fiscal Year 2001 Site Management Plan identified OU No. 10, Site 35, Former Camp Geiger Fuel Farm, MCB, Camp Lejeune, North Carolina as a site that required Remedial Investigation/Feasibility Study (RI/FS) activities. The Focused NAE described in this SSP is one of the required RI/FS activities.

Initial Baker RI/FS activities at Site 35 focused on site-related contamination in the vicinity of the former fuel farm and resulted in the signing of two Records of Decision (RODs). The first ROD, the Interim Record of Decision, Petroleum Hydrocarbon Contaminated Soil, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm (Baker, 1994a), identified soil removal and treatment as the selected remedy for petroleum contaminated soil. Soil removal and treatment began in 1995 and was completed in 1996. The second ROD, the Interim Record of Decision for Surficial Groundwater for a Portion of Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm (Baker, 1995) identified in-situ air sparging (IAS) as the selected remedy to treat contaminated groundwater in the vicinity of the former Camp Geiger Fuel Farm. A limited IAS system was installed in 1998 and is currently operational.

More recently, RI/FS activities at Site 35 have focused on the balance of site-related contamination located outside of the immediate area of the former fuel farm. Although site-wide RI/FS activities have been conducted to address the balance of site-related contamination, no remedial alternative has been approved by federal or state regulators.

As required by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), an individual and comparative analysis of several remedial action alternatives (RAAs) for the balance of contaminated groundwater was performed in the Draft Feasibility Study Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm (Draft FS) (Baker, 1997a). In the Draft FS, monitored natural attenuation (MNA) was considered as a stand-alone RAA for dissolved phase fuel and solvent-related groundwater contamination that reside in the upper and lower portions of the surficial aquifer. The Draft Preliminary Remedial Action Plan Operable

Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm, (Draft PRAP) (Baker, 1997b) identified MNA as the potential selected remedy for the treatment of groundwater contamination to be presented in the ROD. However, prior to signing a ROD that would address the balance of contamination, federal and state regulators required MCB Camp Lejeune to provide further evidence of the adequacy of MNA as a site-wide, stand alone, remedial alternative. This evidence was gathered in a site-wide Natural Attenuation Evaluation (NAE). The NAE also assessed the impact of IAS operations on natural attenuation processes. Although the NAE Report (Baker, 1999) is currently being reviewed, federal and state regulators have indicated that MCB, Camp Lejeune will be required to conduct a Focused NAE in an area along Brinson Creek.

The Focused NAE will gather data that will support the evaluation of MNA as a stand-alone remedial alternative for solvent-related groundwater contamination that resides in the vicinity of the Brinson Creek wetland. Federal and state regulators have also requested that the proposed Focused NAE be patterned after a study, Natural Attenuation of Chlorinated Volatile Organic Compounds in a Freshwater Tidal Wetland, conducted at Aberdeen Proving Ground, Maryland (APG Study) (Lorah, 1997). However, the Focused NAE does not address all of the remaining contamination at Site 35. Regulators have indicated that all remaining contamination that was not addressed in previous interim RODs, should be addressed in a single comprehensive ROD.

During the NAE, light nonaqueous phase liquid (LNAPL) was detected in the vicinity of building G-480. North Carolina 2L standards require delineation and removal of this contamination. (NC DENR, 1995). In accordance with current federal regulations, source areas must be addressed.

Since the development of the Draft FS (Baker, 1997a), the United States Environmental Protection Agency (USEPA) has encouraged the adoption of MNA in conjunction with source control/cut-off (USEPA, 1998). To assess the adequacy of the existing IAS trench system as a source cut-off, a groundwater tracer test was performed that indicated site groundwater did pass through the IAS trench.

Prior to the presentation of the selected remedy in a comprehensive ROD, MNA with IAS as a source cut-off would be analyzed and compared to other alternatives in the Final FS. Data gathered during the NAE, Focused NAE, and IAS tracer test will be used to perform a thorough individual and comparative analysis in the Final FS. In addition, a set of RAAs for the remediation of LNAPL located near Building G-480 will be developed and analyzed during the development of the Final FS. The comprehensive ROD will present the selected remedy identified for the removal of the LNAPL.

1.3 Regulatory Guidance

When MNA was first considered as a potential remedial alternative in the fall of 1996 for the treatment of solvent-related groundwater contamination, there were no well known accepted guidance documents that could provide strong direction for assessing and implementing MNA. Since that time, the scientific understanding of natural attenuation, especially with respect to chlorinated solvent-related contamination, has substantially evolved. Currently, the guidance documents noted below are being used by regulators and principal responsible parties to assess, select, and implement MNA as a selected remedy. All of these documents were consulted during the development of this SSP to provide either general direction or specific technical guidance.

EPA

Use of Monitored Natural Attenuation At Superfund, RCRA Corrective Action, and Underground Storage Tank Sites (OSWER Directive) (USEPA, 1999).

Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (EPA Protocol)(USEPA, 1998).

Draft EPA Region 4 Suggested Practices for Evaluation of a Site for Natural Attenuation (Biological Degradation) of Chlorinated Solvents (Region IV Protocol)(USEPA, 1997).

State of North Carolina

15A North Carolina Administrative Code 2L Implementation Guidance (NCAC 2L)(NC DENR, 1995).

Other

Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (AFCEE Protocol) (Wiedemeier, et al, 1996).

2.0 SITE BACKGROUND

This section includes a brief history of investigation and remedial activities that have occurred at Site 35 since 1994, and a brief description of the nature and extent of groundwater contamination at Site 35.

2.1 Site History

Although several investigations have been conducted at Site 35, the first site-wide RI was conducted by Baker in 1994 to assess the nature and extent of groundwater contamination associated with the former Camp Geiger Fuel Farm. The footprints of the facilities associated with the former Camp Geiger Fuel Farm are located north of the intersection of Fourth and G Streets. Extensive organic groundwater contamination was observed in both the upper and lower portion of the surficial aquifer. However, the extent of this organic contamination south of Fifth Street and north of Brinson Creek was not established during the RI. During this investigation, natural attenuation was not considered as a viable remedial alternative at this site and data supporting natural attenuation as a remedial alternative was not gathered.

The Interim Remedial Action (IRA), Remedial Investigation/Feasibility Study (Baker, 1994b) was developed from data gathered in 1993 and 1994. The IRA culminated in the signing of the Interim Record of Decision (ROD), Petroleum Hydrocarbon Contaminated Soil, Operable Unit No. 10, Site 35 (Baker, 1994a) in June of 1994 and identified soil removal and treatment as the selected remedy to treat petroleum contaminated soil.

The Interim Remedial Action Feasibility Study (IRA/FS) for Shallow Groundwater in the Vicinity of the Former Fuel Farm (Baker 1994c) was developed from the RI data gathered in 1994. This IRA/FS culminated in the signing of the Interim Record of Decision for Surficial Groundwater for a Portion of Operable Unit No. 10, Site 35 (Baker, 1995) in September of 1995 and identified IAS as the selected remedy to treat contaminated groundwater in the vicinity of the former Camp Geiger Fuel Farm.

Between the fall of 1995 and spring of 1996 petroleum contaminated soils in two source areas, identified in the Interim ROD, Petroleum Hydrocarbon Contaminated Soil, Operable Unit No.

10, Site 35, (Baker, 1994a) were remediated. These source areas were generally located northeast of Building G-480 and within the footprint of the former Camp Geiger Fuel Farm above-ground storage tank area.

During the spring of 1996, the Supplemental Groundwater Investigation (SGI) was conducted. The objectives of the SGI were to determine if groundwater contamination had migrated across Brinson Creek onto private property and to assess the nature and extent of groundwater contamination south of Fifth Street and within the Brinson Creek wetland. No contamination was detected on property across Brinson Creek. However, the SGI identified two areas with elevated levels of fuel and chlorinated sovent-related groundwater contamination in the wetland area, and delineated solvent-related groundwater contamination south of Fifth Street. The Draft FS and Draft PRAP for Site 35 were developed from the data collected during the SGI. These documents identified MNA as an appropriate technology for the remediation of contaminated groundwater located upgradient of any IAS system. However, SGI data was insufficient to fully determine if natural attenuative processes were sufficient to protect human health and the environment.

An in-situ air sparging pilot evaluation was conducted in August and July of 1996 in the wetland area of Brinson Creek. This evaluation was conducted to assess the viability of IAS as an alternative for remediating shallow groundwater contamination. The report recommended that an IAS trench be constructed on the south side of the US Highway 17 Bypass Right-of-Way (ROW).

In February of 1997, a limited groundwater investigation was performed in an area immediately south of the US 17 Bypass ROW, north of building TC 470 and east of F Street. The objective of this investigation was to verify levels of groundwater contamination and determine the optimal location of the Phase I IAS trench.

In August of 1997, the Final Remedial Action Contract (RAC) design for an IAS system was submitted by Baker. The design provided for an IAS system that was to be constructed in two phases. Construction of Phase I was completed and began operations in early 1998. This system underwent a six-month field test, which began in mid-February 1998 and ended in September 1998. The results of Phase I operations indicate the IAS trench is effectively remediating groundwater that moves through the IAS trench. Baker has preliminarily recommended that the operation and monitoring of the IAS system be continued until a groundwater tracer test could be performed to confirm the direction of groundwater in the vicinity of the IAS trench. This testing was completed and the results indicated that site groundwater did pass through the trench and did not appear to flow around the ends of the trench. Based on these results, the system continues to be operated.

To preliminarily assess natural attenuative processes in the vicinity of E and Fourth Streets, a natural attenuation screening study (Natural Attenuation Assessment [NAA]) was performed during the first six months of 1998. Groundwater samples were collected from eight shallow and nine intermediate monitoring wells and analyzed for natural attenuation parameters during three rounds of sampling that occurred in January, April, and June of 1998. The results indicated that there was evidence that biodegradation was occurring. Data gathered during these rounds was also used in the development of the site-wide NAE.

As part of the construction of the US Highway 17 Bypass, a total of 50 permanent monitoring wells were abandoned or destroyed at Site 35 in mid-June of 1998 by the North Carolina Department of Transportation (NC DOT). This restricted the ability to monitor source areas and downgradient monitoring wells located within and adjacent to the US Highway 17 Bypass ROW.

To assess natural attenuative processes site-wide and the impact of the IAS operations on natural attenuative processes, the NAE was performed in September 1998. Groundwater samples were collected from approximately 20 shallow and 30 intermediate monitoring wells, and analyzed for contaminants and natural attenuation parameters.

To fully assess plume stability and monitor for seasonal changes, approximately 19 wells have been monitored (and will continued to be monitored) quarterly (semiannually as of January 2001) since October 1998 under the Long-Term Monitoring (LTM) program. Groundwater samples collected under this program are analyzed for VOCs and natural attenuation parameters.

2.2 Summary of Nature and Extent of Contamination

The groundwater contamination associated with Site 35 is limited to the surficial aquifer. A confining unit that separates the surficial aquifer from the underlying Castle Hayne aquifer appears to prevent contamination from migrating vertically down into the Castle Hayne aquifer. The extent of groundwater contamination in the surficial aquifer at Site 35 extends over approximately 100 acres of Camp Geiger. The primary constituents of this contamination are fuel- and chlorinated solvent-related compounds. Based on the results of the RI, SGI and NAE, fuel-related contamination is prevalent in the upper portion of surficial aquifer and solvent-related contamination is prevalent in the lower portion of surficial aquifer. The NAE identified 16 potential source areas related to this contamination.

The contaminants of concern that were identified in the RI include the following:

- Benzene
- Ethyl Benzene
- Xylenes (total)
- Methl Tertiary Butyl Ether
- Trichloroethene
- cis-1,2-Dichloroethene
- trans-1,2-Dichloroethene
- Vinyl Chloride
- Tetrachloroethene
- 1,1,2,2-Tetrachlorethane

2.2.1 Upper Surficial Aquifer

Although fuel-related groundwater contamination is prevalent in the upper portion of the surficial aquifer, solvent and fuel-related contaminant plumes overlap in this portion of the aquifer. The limits of fuel- and chlorinated solvent-related contamination in the upper surficial aquifer are depicted in Figures 2-1 and 2-3. Based on the results of the NAE three fuel-related, and three chlorinated solvent-related groundwater contaminant plumes appear to reside in the upper portion of the surficial aquifer. The plume with the highest levels of fuel-related contamination in the upper surficial aquifer is located in the vicinity of the former Fuel Farm (maximum detection 1,400 ug/L at MW-16A). Two coalescing plumes with lower levels of fuel-related contamination are located in the vicinity of G-480. Maximum concentrations observed in these plumes were 711 ug/L at MW-67A and 4 ug/L at MW-10A. Approximately one half-inch of fuel-related free product was detected in MW-67A.

The plume with the highest concentration of solvent-related contamination in the upper surficial aquifer is located northwest of the IAS trench (maximum detection 1,129 ug/L at MW-14A) on the south side of the US 17 Jacksonville Bypass ROW.

Southeast of this plume on the south side of the US 17 Jacksonville Bypass ROW another solvent-related contaminant plume resides in the upper surfical aquifer. This plume appears to have a source area near building TC 470. The maximum contaminant level observed in this plume was 196 ug/L at MW-66A.

The third solvent-related plume that resides in the upper surficial aquifer is located in a wetland area between Brinson Creek and the northern ROW boundary of US 17 Jacksonville Bypass. This plume appears to have multiple source areas. The maximum levels of contamination observed in this plume were 483 ug/L at monitoring well MW-55A.

2.2.2 Lower Surficial Aquifer

Although solvent-related groundwater contamination is prevalent in the lower portion of the surficial aquifer, solvent and fuel-related contaminant plumes overlap in this portion of the aquifer. The limits of fuel- and chlorinated solvent-related contamination in the lower surficial aquifer are depicted in Figures 2-3 and 2-4. Based on the results of the NAE, four fuel-related and four chlorinated solvent-related groundwater contaminant plumes appear to reside in the lower portion of the surficial aquifer. The plume with the highest levels of fuel-related contamination in the lower surficial aquifer is located in the vicinity of the former Fuel Farm (maximum detection 122 ug/L at TW-45B). The remaining fuel-related contaminant plumes are located south of building TC 342 (maximum detection 15 ug/L at MW-37B) near barracks complex G-550-G554 (maximum detection 2 ug/L at MW-70B) and near building TC 462 (maximum detection 4 ug/L at MW-32B).

The highest concentration of solvent-related contamination in the lower portion of the surficial aquifer resides between former building TC-474 (now US 17 Jacksonville Bypass ROW and Brinson Creek). The limits of this plume were estimated using data from the NAE, SGI, and minor sampling events. The maximum detection of total chlorinated solvent-related contamination in this plume during the NAE was 2,395 ug/L at MW-55B. This area was chosen as the study area for the Focused NAE because of the high levels of solvent-related contamination; the apparent evidence that natural attenuation processes are substantially degrading solvent-related contamination; and the plumes potential impact to Brinson Creek. The apparent source of this plume has never been fully delineated and this area is currently inaccessible due to the construction of US 17 Jacksonville Bypass.

Two chlorinated solvent-related plumes potentially coalesce near the intersection of 4th and F Streets. One plume is located in the immediate vicinity of the IAS trench and the other is centered around monitoring wells MW-10B and MW-30B. Maximum detections of solvent-related contamination observed in these plumes were 1,273 ug/L at MP-06D (IAS well) and 769 ug/L at MW-10B, respectively.

A fourth plume is located near building TC-773. Maximum detections of solvent-related contamination observed in this plume was 99 ug/L at MW-42B. The full extent of this plume has not been characterized in detail.

3.0 FIELD INVESTIGATION

The field investigation will be conducted in three phases over a one-year period. Phase I will be an initial assessment and delineation of groundwater contamination, and redox zones in the wetland area. Activities that will be conducted during Phase I include a groundwater investigation, groundwater analyses, and a lithology characterization. Phase II activities will include the installation of an array of temporary monitoring well clusters and diffusion samplers. During the installation of the temporary monitoring wells a limited lithology characterization will also be performed. Phase III activities will consist of a hydrogeologic investigation (groundwater flow and tidal study) and surface water and groundwater monitoring. Initial Phase III activities will commence approximately two weeks after final well installation. Data collection and sampling activities associated with the hydrogeologic investigation and surface water/groundwater monitoring will be conducted on a quarterly basis for one year.

3.1 Phase I, Initial Assessment of Contamination and Redox Zones

The nature and extent of contaminant and redox zones in the wetland area will be characterized during this phase. This phase of the investigation will be driven by real-time analysis of groundwater samples so that the extent of contamination can be delineated during the initial mobilization.

The objectives of Phase I include:

- Initially assess the vertical and horizontal extent of contamination in the study area to support the most relevant placement of temporary well clusters.
- Identify the centerline of contaminant flow in order to locate transect C'-C.
- Assess metals concentrations in site groundwater and Brinson Creek.
- Characterize lithology.
- Preliminarily assess geochemical and microbial processes.

3.1.1 Groundwater Investigation

During Phase I, borings will be advanced in the wetlands along two planar transects, A'-A and B'-B (Figure 3-1), perpendicular to groundwater flow. Two transects are required to identify the centerline of contaminant flow as data is not currently sufficient to define the groundwater flow in the wetland area.

The borings will be advanced by a portable tripod rig or by a small all-terrain vehicle (ATV), depending on ground surface conditions. A Hydro-Punch groundwater-sampling device will be used to collect groundwater samples. A large-core Geoprobe sampler will be used to collect soil samples.

Lithology and redox heterogeneity at Camp Lejeune are generally greater in the vertical direction than in the horizontal direction. Thus, sample density will be greater in the vertical direction compared with the horizontal direction. The remainder of this section will discuss sample location distribution and rationale.

The concept of sampling locations along planar transects was taken from the <u>USEPA Seminar on Monitored Natural Attenuation for Groundwater</u>, (USEPA, 1998). The initial assumed centerline of contamination is situated between MW-55B and MW-64B. Borings will be advanced in numeric order (i.e., install IR35-IS01, then IR35-IS02, IR35-IS03, etc.). Each transect is bisected by the assumed centerline and consists of a segment northwest of the centerline and a segment southeast of the centerline. The basic sampling rational for each segment can be explained by considering transect A'-A, IS01 and IS02:

- The initial boring (IS01) will be placed at the assumed centerline of contamination.

- The second boring (IS02) will be located perpendicular to the assumed centerline at a distance twice the estimated source area width. The estimated source area width is approximately 100 feet. Thus, the second boring (IS02) is 200 feet from the first boring (IS01) along transect A'-A (USEPA, 1998).

- The third boring (IS03) will split the distance between the first boring (IS01) and the second boring (IS02).

- The fourth boring (IS04) will split the distance between the third boring (IS03) and first boring (IS01).

As noted, IR35-IS01 will be located at the assumed centerline of contamination. If the centerline of contamination is observed not to be at IR35-IS01 the transect line will be shifted. The investigation will then continue with a similar approach based on the new centerline.

Groundwater samples will be collected from each location shown on Figure 3-1. It is anticipated that groundwater samples will be collected vertically at approximate intervals of every five feet, and immediately above the Castle Hayne confining unit. The initial sample will be collected at the groundwater table, or at least one-foot below the ground surface (bgs). The estimated saturated thickness above the Castle Hayne confining unit is 30 feet. It is estimated that a maximum of seven groundwater samples will be collected per location. The Hydro-Punch sampler is capable of collecting discrete groundwater samples, over an interval of one to two feet.

A single sample from the upper surficial aquifer in each of the 14 borings will be retained for metals analysis in the fixed based laboratory. The sample obtained from the background location will also be analyzed for metals. This pattern of sampling will provide adequate characterization of metals in groundwater.

3.1.2 Groundwater Analysis

During Phase I, groundwater samples will be collected from all locations during the initial assessment phase to identify different reduction oxidation zones and determine if reductive dechlorination is occurring. Samples will be analyzed for VOCs and inorganic compounds and various indicator parameters. Specific compounds and analytical methods are summarized in Table 3-1. Analyses for additional background parameters (also summarized in Table 3-1) will be performed on a single sample collected from an interval with no readily identifiable contamination. The location of this sample will be determined in the field.

Metals analysis will include the full TAL suite. These analyses will be completed at the fixed-base laboratory.

Chemical analyses during Phase I work will be performed on-site by Baker personnel and a mobile lab subcontractor and selected samples will be sent to a fixed-base laboratory. It is currently anticipated that Baker personnel will perform all inorganic analyses with the exception of total organic carbon and metals. Total organic carbon and metals will be shipped to a fixed-base laboratory. The mobile-lab subcontractor will perform all organic analyses. A total of 10% of all samples tested by the mobile lab will be sent to a fixed-base laboratory as confirmatory samples and analyzed for the compounds noted in Table 3-1 with the exception of ferrous iron.

Equivalent methods to those identified on Table 3-1 may be substituted by the fixed-base laboratory to achieve lower detection limits or avoid interference. It should be noted that colormetric and spectrophotometric analytical methods are adequate for field screening and analysis. However, the fixed-base laboratory will avoid the use of colormetric and spectrophotometric analytical methods. Maximum detection limits of all methods used by all laboratories should be low enough to meet the requirements of the Air Force Center for Environmental Excellence (AFCEE) Protocols. During onsite analysis, turbidity may require some samples to be filtered in order to perform spectrophotometric (Hach), colormetric (Chemetrics™), and total alkalinity analyses.

All on-site analyses will be performed as soon as possible after collection and within acceptable holding times. The results of analyses performed by the fixed-base laboratory should be provided to Baker within 28 days of sample receipt.

In addition to chemical analysis, conductivity, pH, redox potential, and salinity will be monitored at each Hydro-punch™ location and temporary monitoring well. Redox potential should be measured in a flow through cell. Turbidity levels in some samples may require dissolved oxygen to be monitored with a meter and a flow through cell.

3.1.3 Subsurface Soil Investigation

During Phase I, soil samples will be collected continuously for the purpose of lithology characterization. Along transect A-A', soil samples will be collected from IR35-IS01, IR35-IS02, IR35-IS03, IR35-IS05, and IR35-IS06. Along transect B-B', soil samples will be collected from IR35-IS08, IR35-IS09, IR35-IS10, IR35-IS12, and IR35-IS13. Soil samples will be collected using either the Geoprobe large-core or macro-core sampler and described in terms of grain size, moisture content, evidence of contamination, and other significant observations.

3.2 Phase II, Monitoring System Installation

The objective of Phase II is the installation of a monitoring well system that can be used to support Phase III data and sample collection activities. A more thorough rationale for installing temporary monitoring well clusters and diffusion samplers is provided in Section 3.3.

To monitor subsurface redox conditions a total of nine monitoring well clusters will be installed at the locations shown in Figure 3-2. This system was generally patterned after the monitoring system installed to monitor groundwater flow and redox conditions during the APG Study (USGS, 1997). To monitor potential contaminant discharge into Brinson Creek three diffusion samplers will be installed in the sediments of Brinson Creek at the locations shown in Figure 3-2. Specific details of monitoring well construction are discussed in the Remedial Investigation/Feasibility Field Sampling and Analysis Plan for Operable Unit No.10 (Site 35)(Baker, 1993). In order to install temporary monitoring wells in the correct interval a limited lithology characterization will also be conducted during Phase II.

3.2.1 Temporary Well Cluster Installation

During Phase II, five temporary well clusters will be installed along transect C-C' as shown on Figure 3-2. This transect will be the established centerline of contamination flow. Each temporary well cluster will contain three to five wells. The final location of well clusters and the number of wells per cluster will be based on conditions observed during the initial assessment (Phase I). This transect of temporary well clusters is critical to determine contaminant reduction along the flow path and assess vertical groundwater flow patterns.

Figure 3-2 shows one temporary well cluster in Brinson Creek. This location is vital for assessment of contaminant distribution and redox conditions under the creek. Inferences of contaminant distribution and redox conditions under the creek and across 200 feet would be required without that location. It is unacceptable for this investigation to rely on inferences under Brinson Creek. A rig mounted on a small floating platform will be used to install this well cluster. The platform could be launched from the bank of Brinson Creek, opposite Site 35. Upon well installation completion, a wooden post will be driven into Brinson Creek adjacent to the wells. The monitoring wells will be secured to this post. A warning sign will be posted to direct all recreational boats away from/around the wells/post. State and federal permits will be required to install this well. MCB, Camp Lejeune will be required to capture all cuttings and prevent sediment transport during well installation.

Four additional temporary well clusters will flank transect C-C' as shown on Figure 3-2. These four flanking well clusters are shown to be approximately 100 feet from transect C-C'. However, the final distance of these well clusters will be determined in the field based on observed conditions. Each of these well clusters will contain three wells. These well clusters will be used primarily to characterize vertical and horizontal groundwater flow direction.

A portable tripod rig or ATV drill rig will be used to advance the temporary well borings. Engineering measures may be required to gain rig access to certain locations. These engineering measures will likely include construction of a temporary wooden plank road.

Temporary well cluster borings will be advanced using 6" diameter steel casing driven in one to two foot lifts. Cuttings will then be washed out and collected. This process will continue to depth. A maximum of three wells will be installed in each casing. More than three wells per boring will inhibit proper installation of the bentonite seal. Some locations may require two borings. Each well will be constructed of 1" outside diameter (OD) poly vinyl chloride (PVC), with a one-foot screen (0.01" slots). The annulus around each well screen will be filled with clean sand, sized appropriately for the slot size. A bentonite pellet seal of at least two feet will be placed between each screen and near the surface.

3.2.2 Permanent Well Cluster Installation

The ongoing construction of U.S. Highway 17 Bypass has resulted in the loss of 50 permanent monitoring wells in the ROW. These wells were installed at various times during the investigations performed as part of the Underground Storage Tank (UST) and Installation Restoration (IR) programs. Many of these wells had served their purpose and were no longer critical to further understanding site conditions. While this is the case, the loss of monitoring capability in the ROW leaves a data gap within the contaminant plume where there is no opportunity to collect samples to track contaminant concentrations and monitor the progress of natural attenuation. A series of permanent cluster wells will be installed in the ROW to address this gap.

Paired wells will be installed at the general locations shown on Figure 3-2. These locations are approximate; final locations will be field determined, and will be selected based on the actual alignment of the road, and the need to avoid locations in paved areas. Permanent monitoring wells will be placed within the shallow aquifer, and in the intermediate zone at each location. The two-inch monitoring wells will be installed through hollow stem augers using the same drilling, sampling, and installation procedures as those employed during previous investigations. The wells will be completed at the surface in a flush-mount vault to provide protection during road construction and later vehicular use. It should be noted that the initial installation might be required to be altered at a later date depending upon final grading and drainage features of the highway.

3.2.3 Diffusion Sampler Installation

A diffusion sampler will consist of a low-density polyethylene (LDPE), lay-flat tube, closed at both ends, and filled with carbon filtered, laboratory grade, deionized water. This bag will be inserted into a small cage constructed of wood and metal that will not restrict water flow but will provide some protection. To assist with retrieval each device will be fitted with a steel recovery cable and flotation device to mark the location.

To install the diffusion sampler, a borehole will be advanced by driving a four-inch diameter PVC screen with an end cap to a depth of two feet below the bottom of the creek. The cage will be lowered to the bottom of the screen. Three diffusion samplers will be installed at the locations shown in Figure 3-2. Installation and sample collection techniques will follow recent US Geological Survey guidance (USGS, 2001)

3.2.4 Lithology Characterization

During Phase II, soil samples will be collected continuously for the purpose of lithology characterization. Soil samples will be collected along transect C-C' from borings at Cluster 2, Cluster 4, and Cluster 5. Soil samples will be collected using either the Geoprobe large-core or macro-core sampler. Soils will be described in terms of grain size, moisture content, evidence of contamination, and other significant observations.

Lithology information obtained from this phase and Phase I will be used to develop a detailed stratigraphic model of the study area. This model will be the basis for discussion and contaminant fate and transport analysis, redox zone determination, and natural attenuation assessment.

A limited number of soil samples will be analyzed for fractional organic carbon (f_{oc}). This data will be used to estimate contaminant velocities. Samples for f_{oc} will be collected from Cluster 1 and from Cluster 3. Three vertical intervals will be sampled at each cluster: one from the upper fine sand, one from the shell material and one from wetland sediments.

3.2.5 Surface Water Sampling for Metals

Metals in surface water will be assessed as part of the Phase II efforts. Grab samples will be obtained from each of the diffusion sampling locations during the installation of the diffusion samplers. This will provide a cross section of metals concentrations across the creek. Four additional samples of surface water will be obtained:

- One will be taken from a point upstream of the diffusion sampling line that is still adjacent to Site 35;
- One will be taken from a similar point downstream of the diffusion sampling line;

- One will be taken from a suitable location, well downstream of possible site discharges; and

- One will be taken from a suitable background location upstream of Site 35.

All samples will be obtained from a point as near to the bottom of the creek as possible; however, care will be taken to ensure the bottom is not disturbed causing suspended particulates that could skew sampling results.

Analysis of the samples will be performed in a fixed-base laboratory for the full TAL suite of metals.

3.2.6 Sediment Sampling

A series of sediment samples will be collected from Brinson Creek during the Phase II investigations. The sediment-sampling program is designed to provide information related to general sediment quality in Brinson Creek, and to ascertain whether releases from Site 35 are impacting sediments. Included in the sampling strategy are samples from upstream of the site, from sediments immediately adjacent to the site, and from areas downstream of the site.

The general sediment sampling locations are shown on Figure 3-2. These are general locations based on map view; actual locations will be field selected, taking into account site constraints and access considerations. The sediment-sampling program will consist of seven samples:

- One sample will be taken from a location sufficiently upstream from the site to be unaffected by any site discharges (this sample will serve as background for comparison purposes);

- Four sampling locations will be selected from areas of the creek immediately adjacent to Site 35 evenly spaced along the site's boundary; and

- Two samples will be obtained from downstream of the site at points located approximately 200 and 500 feet from the Site 35 boundary.

This array of sampling locations will provide the information needed to establish background sediment conditions, assess whether sediments associated with Site 35 are being affected by releases from the site, and to provide an indication whether there is downstream migration of contaminants from the site.

All samples will be obtained from the top four inches of sediments. The sampling approach and equipment will be field selected based on ambient conditions. Locations will be staked on the Site 35 shore of the creek with offset to the actual sample location measured by tape. Stakes will be surveyed along with the other monitoring/sampling points.

Samples will be analyzed for the following parameters:

- Parent VOC contaminants;
- Daughter VOC contaminants; and
- TAL metals

3.3 Phase III, Data and Sample Collection

The nature and extent of groundwater contamination and redox zones will be refined during the Phase III portion of the investigation. Phase III activities will consist of a hydrogeologic investigation (groundwater flow and tidal study), and surface water and groundwater monitoring. Data collection and sampling activities associated with the hydrogeologic investigation, and surface water/groundwater monitoring will be conducted on a quarterly basis for one year.

The objectives of Phase III are as follows:

- Clearly define contaminant flow paths from the apparent source area(s) into Brinson Creek along transect C'-C.
- Clearly define major groundwater flow paths and hydrogeological parameters.
- Define physical interactions between the water body, wetland, and aquifer.
- Assess tidal and seasonal impacts to groundwater/surface water system.
- Evaluate significance of other natural attenuation processes.
- Clearly determine geochemical and microbial processes that are affecting VOC concentrations and assess impact of these processes.
- Demonstrate contaminant loss along the centerline of contaminant flow.
- Demonstrate plume stability.
- Determine a first-order degradation rate for the wetland area at Site 35.

3.3.1 Hydrogeologic Investigation

During Phase III, the hydrogeologic investigation will consist of slug testing, and a groundwater flow and tidal study. Each of these items is discussed in the paragraphs that follow.

3.3.1.1 Groundwater Flow and Tidal Study

Water levels will be measured in wells and in Brinson Creek. The purpose of such measurements is to determine a three dimensional groundwater flow field, the tidal fluctuation in Brinson Creek, and the interaction between the creek and groundwater. This will be accomplished through use of pressure transducers and data loggers, as well as manual water level measurements. Pressure transducers will be placed in the following locations:

- One in Brinson Creek
- Three in Cluster 1 (in the shallowest, middle, and the deepest well)
- Three in Cluster 3 (in the shallowest, middle, and the deepest well)
- Three in Cluster 5 (in the shallowest, middle, and the deepest well)

Data will be collected from each transducer and recorded on a data logger. The data sample interval will likely be one to two hours. Data will be collected for a period of approximately three months, between the first and second quarterly monitoring events.

During all four monitoring events, manual water levels will be collected twice daily (near high tide and near low tide). Manual water levels will be taken from the following locations:

- Cluster 2 (all wells)
- Cluster 4 (all wells)
- Cluster 6 (all wells)
- Cluster 7 (all wells)
- Cluster 8 (all wells)
- Cluster 9 (all wells)
- IR35-MW68A&B
- IR35-MW26A&B

Most, if not all, temporary well clusters will be located in a groundwater discharge area. Monitoring the static water levels of up-gradient permanent well clusters (MW68 and MW26) will provide information regarding groundwater recharge flow patterns.

The groundwater level data will be used to construct horizontal and vertical potentiometric surface maps to understand groundwater flow directions in three dimensions. The pressure transducer data will be used to identify tidal fluctuations and groundwater response to those fluctuations.

During the first quarterly monitoring event, slug tests will be performed at select locations to estimate horizontal conductivity of the surficial aquifer. During the slug test a teflon slug and pressure transducer will be lowered simultaneously into the monitoring well being tested. As the slug is lowered and water displaced the water level in the well momentarily rises above ambient levels, but begins to fall as equilibrium is approached. When equilibrium is achieved the slug is removed and the water level drops below ambient levels. The pressure tranducer monitors changes in the static water level and a data logger electronically records the readings. The results can be used to determine horizontal hydraulic conductivity. To assess the vertical hydraulic conductivity, water levels will be monitored in two adjacent monitoring wells located in the same well cluster that are screened immediately above and/or below the well being slug tested. If during the performance of the slug test, static water levels in adjacent wells fluctuate, a vertical hydraulic conductivity may be estimated. Transducers will be used to monitor water levels in adjacent monitoring wells. Slug tests will be performed at the following locations:

- Cluster 2 (one well screened in upper fine sands, one well screened in the shell layer)
- Cluster 6 (one well screened in upper fine sands, one well screened in the shell layer)
- Cluster 7 (one well screened in upper fine sands, one well screened in the shell layer)
- Cluster 8 (one well screened in upper fine sands, one well screened in the shell layer)
- Cluster 10 (one well screened in upper fine sands, one well screened in the shell layer)

Slug tests defined for Clusters 2, 6, 7, 8, and 10 identify the maximum total number of slug tests to be performed. This number may decrease if the hydraulic conductivity begins to exhibit less than expected heterogeneity. Both horizontal and vertical hydraulic conductivity will be used to estimate groundwater flow velocities, a groundwater discharge rate, and ultimately contaminant velocities.

3.3.2 Groundwater Monitoring

To determine if natural attenuative processes in the Brinson Creek wetland are degrading TCE at a rate that is sufficient to protect human health and the environment, it is necessary to develop the following lines of evidence:

- Demonstrate a reduction in contaminant loss along the centerline of the contaminant flow path downgradient of source areas.

- Demonstrate plume stability over time by showing a loss of contaminant mass over time.

- Determine geochemical and microbial processes that are occurring by identifying trends in parent and daughter compounds and geochemical indicators. Ultimately identifying the biological processes responsible for degrading contaminants.

- Determine a first order degradation rate.

The Phase III groundwater sampling activities are designed to collect the chemical and geochemical data that can be used to develop these lines of evidence. Groundwater samples will be collected from all wells located in the nine temporary groundwater monitoring well clusters and the three new permanent well clusters (in the highway ROW) on a quarterly basis. [Note: All or some of the new permanent wells installed in the ROW will be included in the LTM program for Site 35 as deemed appropriate for the needs of that program.] Samples will be collected using low-flow sampling techniques. Groundwater samples will be analyzed for parent VOC contaminants, daughter compounds, dissolved oxygen, nitrate, ferrous iron, sulfate, sulfide, methane, ethane, ethene, total organic carbon, fractional organic carbon, total alkalinity, TAL metals, and chloride. In addition, conductivity, pH, temperatures, redox, and turbidity will be monitored as the well is being purged. At the background location, (Cluster 5), groundwater will also be analyzed for total organic nitrogen, total kieldahl nitrogen, nitrite, ammonia, and orthophosphate. Analytical methods that will be used during Phase III are summarized on Table 3-2. It is anticipated that during Phase III Baker will perform the analyses for dissolved oxygen, ferrous iron, and alkalinity on-site, and a fixed base lab will perform the remaining analyses.

Hydrogen will also be collected during the second, third, and forth sampling events. Hydrogen will not be collected during the first round of sampling wells because well construction activities often temporarily result in the distortion of hydrogen levels. Sampling and analytical methods associated with hydrogen analyses have some degree of uncertainty. Considering this, hydrogen analyses may be discontinued if the results are erroneous and clearly do not provide value.

3.3.3 Groundwater Discharge Monitoring

To determine if contaminants are being transported into Brinson Creek via discharging groundwater, regulators have requested the installation of diffusion samplers. It should be noted that this sampling method is not an EPA approved method. However, this method has been found to be an effective method for monitoring the water quality of groundwater discharge into a surface water body (Vroblesky, 1997). During Phase II diffusion samplers will be placed at a total of three locations in the Brinson Creek sediments, IR35-IS15, IR35-IS16, and IR35-IS17. Construction and installation of these devices has been discussed in a previous section.

These devices will remain in place for a minimum of three weeks and then be retrieved during the first quarterly monitoring event of Phase III. Water inside of the plastic bag will be analyzed for the parameters noted in Table 3-2 with the exception of background parameters. Temperature, pH, conductivity, and turbidity will not be monitored due to limited volume. Diffusion samplers will not be reinstalled during subsequent sampling events.

3.3.4 Surface Water Monitoring

To monitor surface water quality, surface water samples will be collected from Brinson Creek on a quarterly basis during Phase III. During previous sampling events surface water samples have been collected by directly dipping bottles into Brinson Creek. However, no VOCs have ever been detected in the main channel of Brinson Creek. Because these samples are taken at the surface of the creek away from any area where groundwater is potentially discharging, contamination at the sampling point may have been diluted. To minimize the dilution potential, Baker is proposing that surface water samples be collected at three locations (IR35-SW01, SW02 and SW03, Figure 3-2) from the bottom of the creek.

A peristaltic pump will be used to collect surface water samples. The intake will be set at the bottom of the creek at the designated locations. Surface water will be monitored for pH, conductivity, salinity, dissolved oxygen, redox potential, and temperature in the field. Samples will be analyzed for the parameters noted in Table 3-2 with the exception of background parameters.

4.0 SURVEYING

The temporary wells, permanent wells clusters, Hydro-Punch borings, surface water sampling locations, staff gauge, sediment sampling, and diffusion sampler locations will be surveyed. The survey will be tied horizontally and vertically to the established site control. Northings and eastings will be reported to the nearest 0.1-foot in the North Carolina State Planer Coordinate System and the Universal Transverse Mercator (UTM) System. Elevations of temporary wells, Hydro-Punch borings, surface water sampling locations, staff gauge, and diffusion sampler locations will be reported to the nearest 0.01 foot in feet above mean sea level.

Points representing the ground surface, Brinson Creek water level, and the creek bottom along transect C-C', depicted in Figure 3.2, will be also be surveyed. Northings and Eastings will be reported to the nearest 0.1 foot in the North Carolina State Planer Coordinate System and UTM System. Elevations will be reported to the nearest 0.1 foot in feet above mean sea level.

All survey data should be submitted in a format that is compatible with Baker's Geographic Information System (GIS).

5.0 INVESTIGATION DERIVED WASTE (IDW)

Drill cuttings will be generated from borehole advancement. These cuttings will be containerized in 55-gallon drums or a roll-off box. Development and purge water will be stored in a 5,000-gallon tanker or a 1,000-gallon polyethylene tank, depending on availability.

A composite of the drill cuttings will be collected from the roll-off box and analyzed for Toxicity Characteristic Leaching Procedure (TCLP), VOCs, and Resource Conservation and Recovery Act (RCRA) Hazardous Waste Characteristics to assess disposal options. If the material is found to be non-hazardous, it will be transported to the base landfill and used as daily cover. Should the results of the TCLP testing indicate the soil is hazardous, the material will be sent to an appropriately permitted facility (to be determined once the results of laboratory analysis are available) for disposal. A single sample of groundwater will be collected from the tanker or polyethylene tank used to store IDW during the investigation. This sample will be analyzed for Contract Laboratory Protocol (CLP) VOCs. Based on the analytical results and the prior approval of Atlantic Division, Naval Facilities Engineering Command (LANTDIV) and MCB, Camp Lejeune, liquid IDW will be transported to an on-base facility for treatment and disposal.

6.0 SCHEDULE

It is anticipated that the scope of work will be performed in accordance with the schedule shown on Figure 6-1.

7.0 REFERENCES

Baker, 1993a. Remedial Investigation/Feasibility Study Field Sampling and Analysis Plan for Operable Unit No.10 (Site 35). December 1993.

Baker, 1993b. Remedial Investigation/Feasibility Study Work Plan for Operable Unit No.10 (Site 35). December 1993.

Baker, 1993c. Remedial Investigation/Feasibility Study Health and Safety Plan for Operable Unit No.10 (Site 35). December 1993.

Baker, 1994a. Interim record of Decision. Petroleum Contaminated Soil, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. Baker, 1994a.

Baker, 1994b. Interim Remedial Action, Remedial Investigation/Feasibility Study, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. Baker, 1994b.

Baker, 1994c. Interim Remedial Action Feasibility Study for Shallow Groundwater in the Vicinity of the Former Fuel Farm, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. Baker, 1994c.

Baker, 1995. Interim Record of Decision for Surficial Groundwater for a Portion of Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. Baker, 1995.

Baker, 1996. Draft Supplemental Groundwater Investigation Report, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. November 1996.

Baker, 1997a. Draft Feasibility Study, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. January 1997.

Baker, 1997b. Draft Preliminary Remedial Action Plan, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. January, 1997.

Baker, 1996. Natural Attenuation Evaluation Report, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. April 1999.

Baker, 1996. Draft Supplemental Groundwater Investigation Report, Operable Unit No. 10, Site 35 - Camp Geiger Area Fuel Farm. November 1996.

Lorah, 1997. Lorah, Michelle M., et al. Natural Attenuation of Chlorinated Volatile Organic Compounds in a Freshwater Tidal Wetland. United States Geological Survey. Baltimore, Maryland. Water-Resources Investigations Report 97-4171. 1997.

NC DENR, 1995. North Carolina Department of Environment and Natural Resources. 15A NCAC 2L Implementation Guidance. Division of Environmental Management. Raleigh, North Carolina, December 1995.

USEPA, 1997. United States Environmental Protection Agency. Draft EPA Region 4 Suggested Practices for Evaluation of a Site for Natural Attenuation (Biological Degradation) of Chlorinated Solvents. Region 4, Athens, Georgia. November 1997.

USEPA. 1998. United States Environmental Protection Agency. Seminar On Monitored Natural Attenuation for Groundwater. Philadelphia, Pennsylvania, September 1998.

USEPA. 1999. United States Environmental Protection Agency. The Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. Office of Solid Waste Management and Emergency Response. Washington, D.C. OSWER Directive 9200.4-17. April 1999.

USEPA. 1996. United States Environmental Protection Agency. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual. Region 4. Athens, Georgia. May 1996.

USGS, 2001. United States Geological Survey. Users Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells. Columbia, South Carolina, 2001.

Vroblesky, 1997. Diffusion Samplers as an Inexpensive Approach to Monitoring VOCs in Ground Water. Ground Water Monitoring and Remediation, Summer 1997.

Wiedemeier, Todd, et al. 1996. Technical Protocols for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. Air Force Center for Environmental Excellence. San Antonio, Texas. November 1996.

Wiedemeier, Todd, et al. 1999. Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface. John Wiley & Sons, Inc., New York, 1999.

TABLES

TABLE 3-1

ANALYTICAL METHODS FOR INITIAL ASSESSMENT
SITE 35, FORMER CAMP GEIGER FUEL FARM
FOCUSED NATURAL ATTENUATION EVALUATION
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

PARAMETER	MATRIX	LABORATORY	METHOD
Trichloroethene	Aqueous	Mobile	EPA Method 8260
cis-1,2 Dichloroethene	Aqueous	Mobile	EPA Method 8260
trans-1,2 Dichloroethene	Aqueous	Mobile	EPA Method 8260
1,1 Dichloroethene	Aqueous	Mobile	EPA Method 8260
Vinyl Chloride	Aqueous	Mobile	EPA Method 8260
Tetrachloroethene	Aqueous	Mobile	EPA Method 8260
1, 1, 2, 2 Tetrachloroethene	Aqueous	Mobile	EPA Method 8260
Benzene	Aqueous	Mobile	EPA Method 8260
Toluene	Aqueous	Mobile	EPA Method 8260
Ethylbenzene	Aqueous	Mobile	EPA Method 8260
Xylenes (total)	Aqueous	Mobile	EPA Method 8260
Methane	Aqueous	Mobile	RSK Method 175
Ethane	Aqueous	Mobile	RSK Method 175
Ethene	Aqueous	Mobile	RSK Method 175
Dissolved Oxygen	Aqueous	Mobile/Baker	Chemetrics ™ Method
Nitrate	Aqueous	Mobile/Baker	Hach Method 8192
Ferrous Iron	Aqueous	Mobile/Baker	Hach Method 8146
Sulfate	Aqueous	Mobile/Baker	Hach Method 8051
Sulfide	Aqueous	Mobile/Baker	Chemetrics ™ Method
Akalinity (total)	Aqueous	Mobile/Baker	Hach Method 8203
Chloride	Aqueous	Mobile	Hach Method 8113
Total Organic Carbon	Aqueous	Fixed Base	EPA Method 415.1
ADDITIONAL BACKGROUND LOCATION ANALYSES			
PARAMETER	MATRIX	LABORATORY	METHOD
Nitrite	Aqueous	Fixed Base	EPA Method 353.2
Total Kjeldahl	Aqueous	Fixed Base	EPA Method 351.2
Total Organic Nitrogen	Aqueous	Fixed Base	351.2 minus 350.2
Ammonia	Aqueous	Fixed Base	EPA Method 350.2
Othrophosphate	Aqueous	Fixed Base	EPA Method 365.1

TABLE 3-2

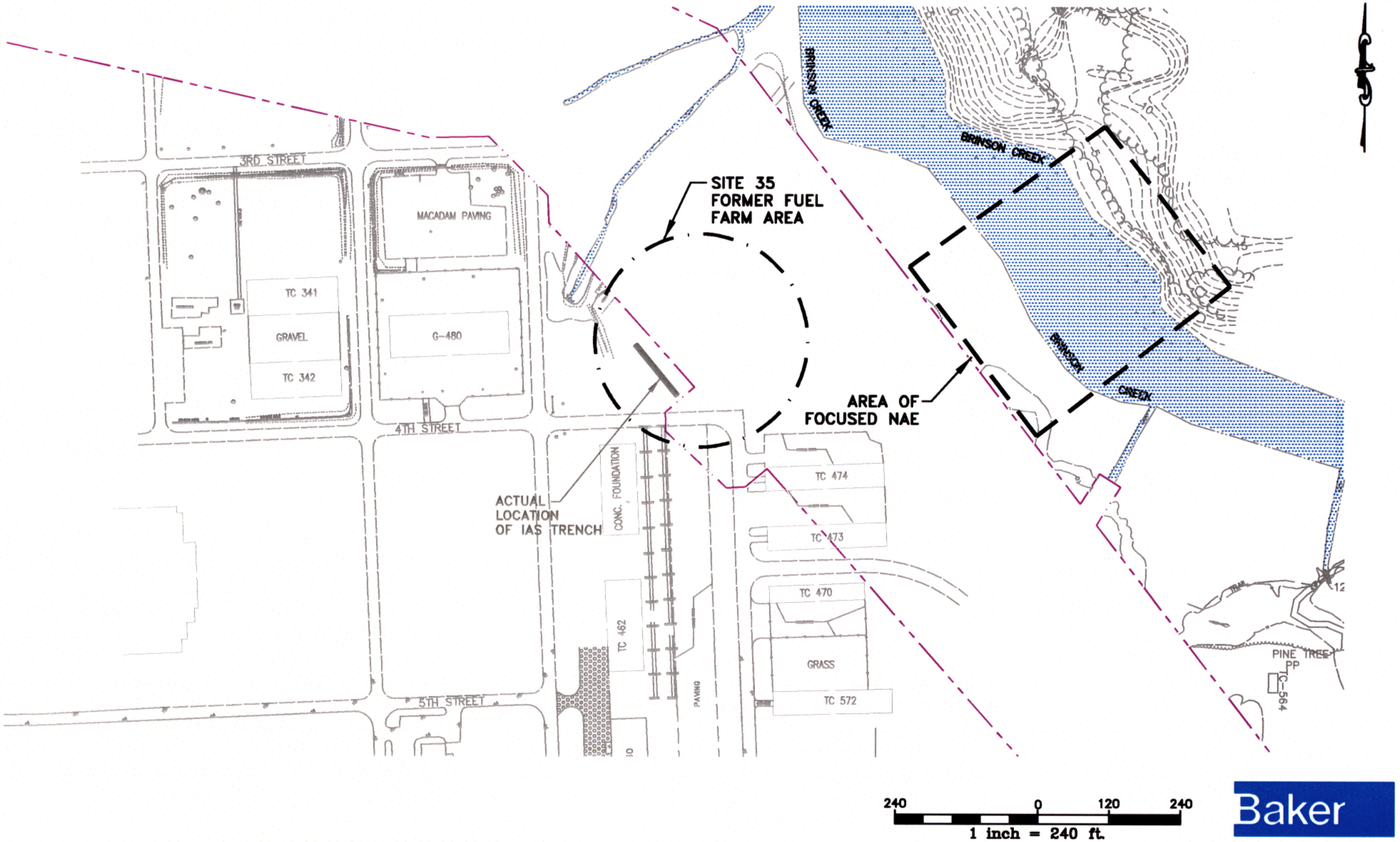
ANALYTICAL METHODS FOR PHASE II AND III
SITE 35, FORMER CAMP GEIGER FUEL FARM
FOCUSED NATURAL ATTENUATION EVALUATION
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

PARAMETER	MATRIX	LABORATORY	METHOD
Volatile Organic Compounds	Aqueous	Fixed Base	EPA Method 8260
TAL Metals	Aqueous	Fixed Base	EPA Method 7000
Methane	Aqueous	Fixed Base	RSK Method 175
Ethane	Aqueous	Fixed Base	RSK Method 175
Ethene	Aqueous	Fixed Base	RSK Method 175
Dissolved Oxygen(1)	Aqueous	Field Analysis	Chemetrics ™ Method
Nitrate	Aqueous	Fixed Base	EPA Method 300
Ferrous Iron(1)	Aqueous	Field Analysis	Hach Method 8146
Sulfate	Aqueous	Fixed Base	EPA Method 300
Sulfide(1)	Aqueous	Field Analysis	Chemetrics ™ Method
Akalinity (total) (1)	Aqueous	Field Analysis	Hach Method 8203
Chloride	Aqueous	Fixed Base	Hach Method 8113
Total Organic Carbon	Aqueous	Fixed Base	EPA Method 415.1
Fractional Organic Carbon	Solid	Fixed Base	ASA Method 29-3.5.2
ADDITIONAL BACKGROUND LOCATION ANALYSES			
PARAMETER	MATRIX	LABORATORY	METHOD
Nitrite	Aqueous	Fixed Base	EPA Method 353.2
Total Kjeldahl Nitrogen	Aqueous	Fixed Base	EPA Method 351.2
Total Organic Nitrogen	Aqueous	Fixed Base	351.2 minus 350.2
Ammonia	Aqueous	Fixed Base	EPA Method 350.2
Othrophosphate	Aqueous	Fixed Base	EPA Method 365.1

NOTES:

(1) Typically dissolved oxygen, ferrous iron, sulfide and total alkalinity analysis are performed in the field by Baker personnel.

FIGURES



Baker
Baker Environmental Inc.

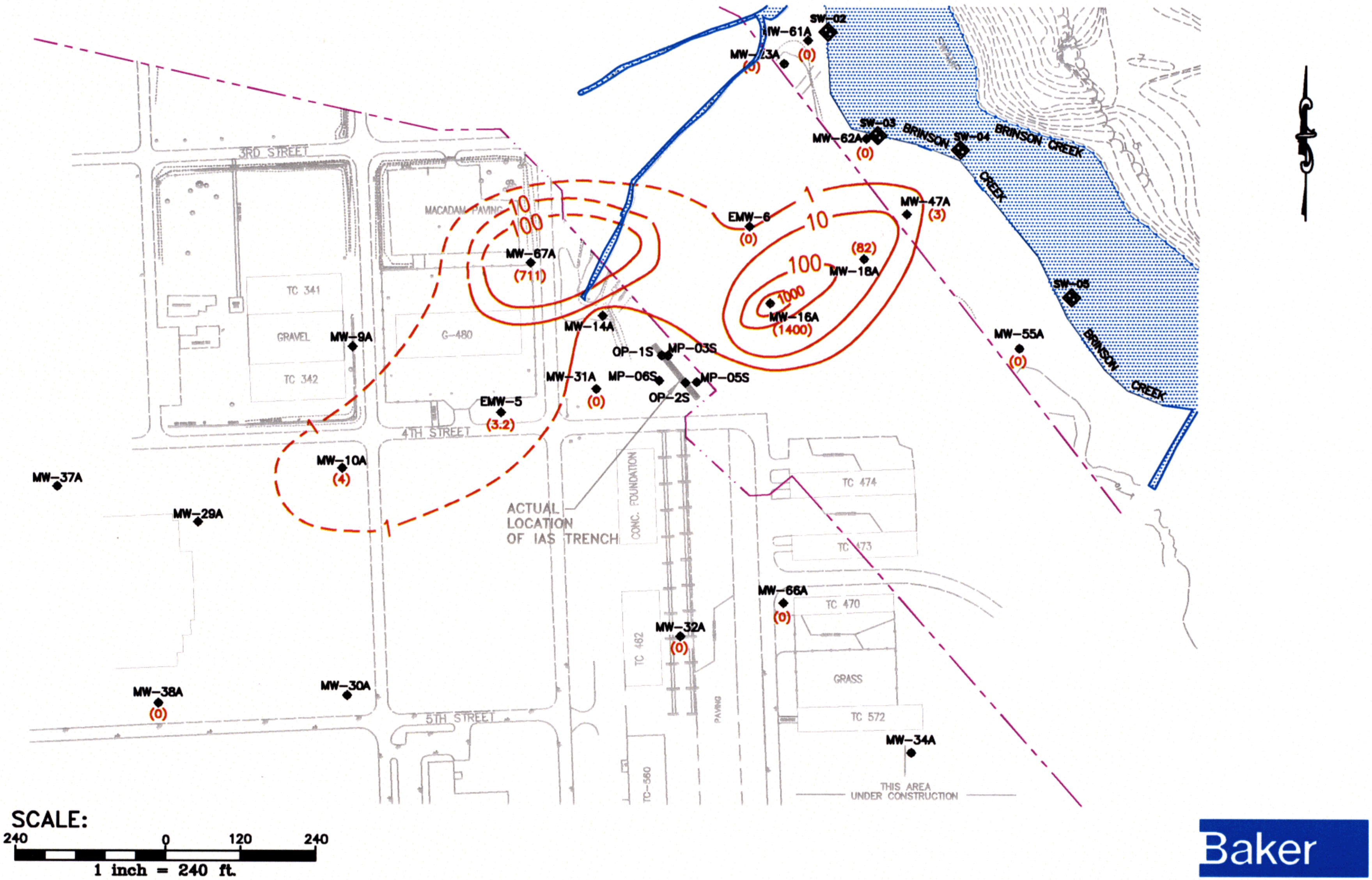
LEGEND

- AREA OF FOCUSED NAE
- FORMER CAMP GEIGER FUEL FARM
- US 17 JACKSONVILLE BYPASS RIGHT-OF-WAY LIMITS

SOURCE: LANIER AND ASSOCIATES

FIGURE 1-1
SITE PLAN
SITE 35, FORMER CAMP GEIGER FUEL FARM
FOCUSED NAE, CTO-0130
MARINE CORPS BASE, CAMP LEJEUNE,
NORTH CAROLINA

130502NA



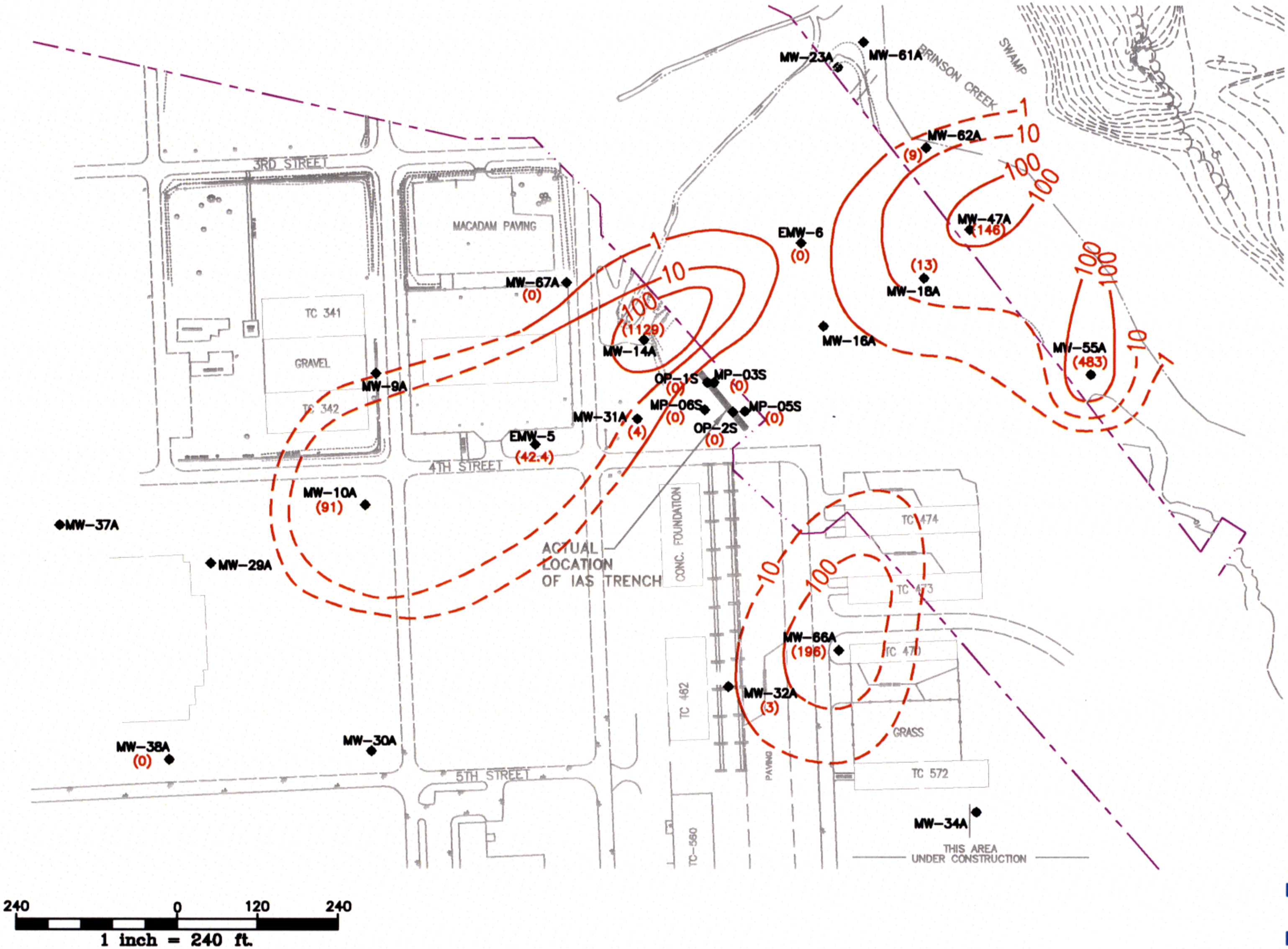
LEGEND

- ISOPLETH LINE
- ESTIMATED ISOPLETH LINE
- US 17 JACKSONVILLE BYPASS RIGHT-OF-WAY LIMITS
- MW-14A (0) MONITORING WELL WITH TOTAL BTEX CONCENTRATION IN PPB
- SURFACE WATER SAMPLE LOCATION

SOURCE: LANIER AND ASSOCIATES

FIGURE 2-1
SITE-WIDE, UPPER SURFICIAL AQUIFER
TOTAL BTEX ISOPLETH MAP
SITE 35, FORMER CAMP GEIGER FUEL FARM,
FOCUSED NAE WORK PLAN, CTO-0130
MARINE CORPS BASE, CAMP LEJEUNE,
NORTH CAROLINA

130504NA

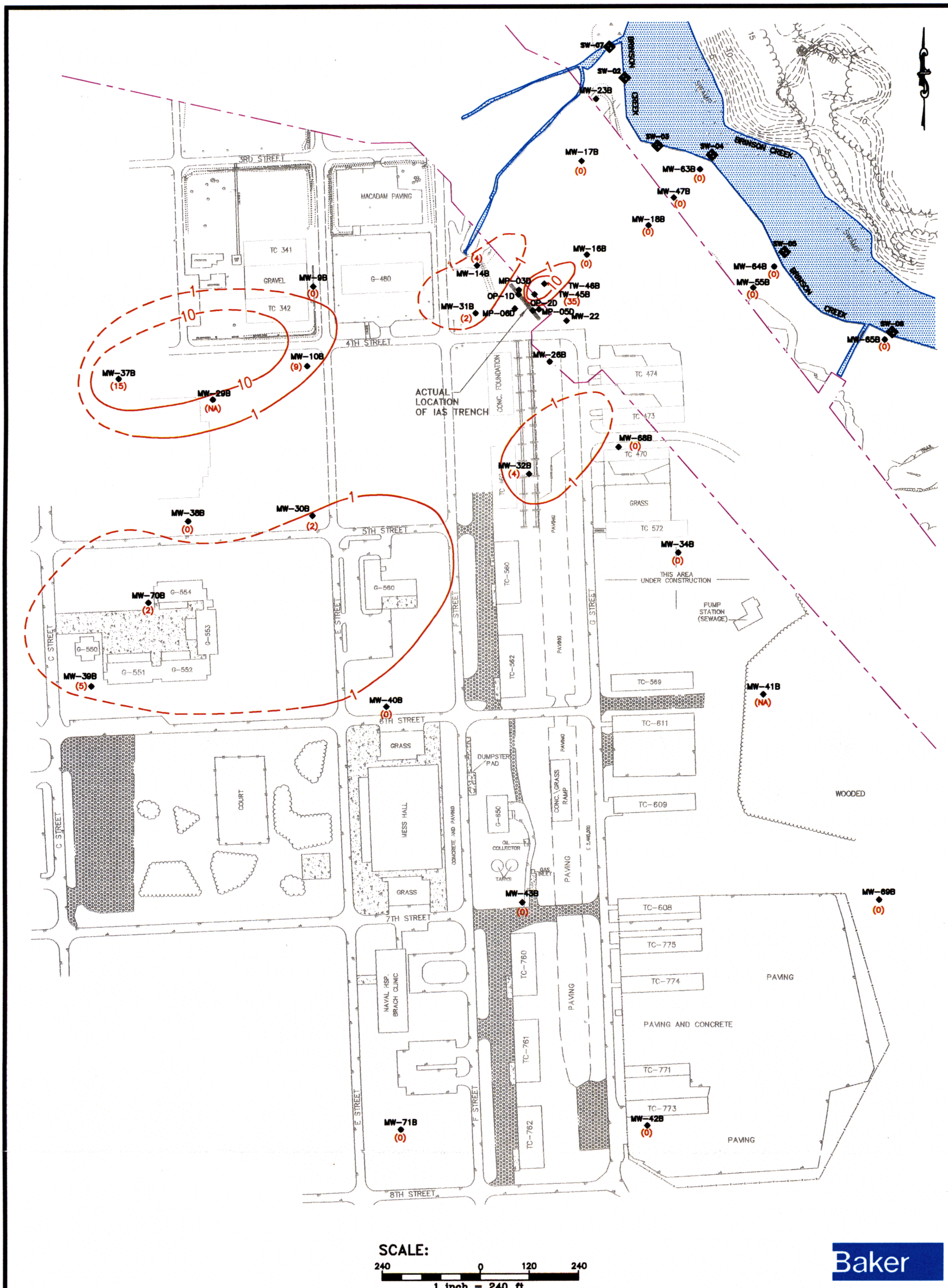


LEGEND

- ISOPLETH LINE
- ESTIMATED ISOPLETH LINE
- US 17 JACKSONVILLE BYPASS RIGHT-OF-WAY LIMITS
- US 17 JACKSONVILLE BYPASS EASEMENT LIMITS
- MW-14A (0) MONITORING WELL WITH PARAMTER CONCENTRATION IN UG/L

FIGURE 2-2
SITE-WIDE UPPER SURFICIAL AQUIFER
TOTAL CHLORINATED ISOPLETH MAP
SITE 35, CAMP GEIGER AREA FUEL FARM,
FOCUSED NAE WORK PLAN, CTO-0130
MARINE CORPS BASE, CAMP LEJEUNE,
NORTH CAROLINA

130505NA



LEGEND

ISOPLETH LINE

ESTIMATED ISOPLETH LINE

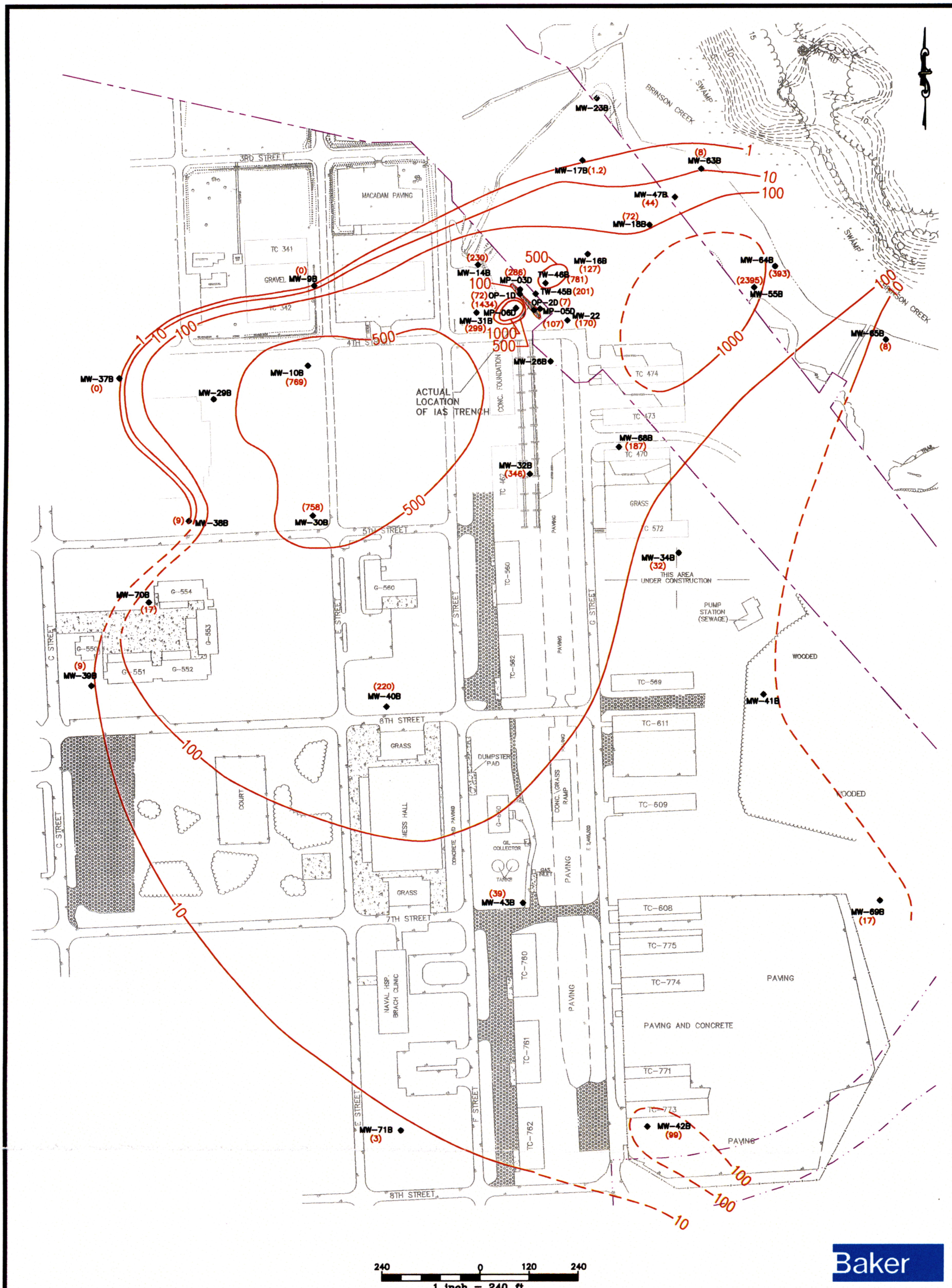
US 17 JACKSONVILLE BYPASS RIGHT-OF-WAY LIMITS

MW-14B (4) MONITORING WELL WITH TOTAL BTEX CONCENTRATION IN PPB

SURFACE WATER SAMPLE LOCATION

SOURCE: LANIER AND ASSOCIATES

FIGURE 2-3
SITE-WIDE, LOWER SURFICIAL AQUIFER
TOTAL BTEX ISOPLETH MAP
SITE 35, FORMER CAMP GEIGER FUEL FARM,
FOCUSED NAE WORK PLAN, CTO-0130
MARINE CORPS BASE, CAMP LEJEUNE,
NORTH CAROLINA



LEGEND

- SCORE LINE
- US 17 JACKSONVILLE BYPASS RIGHT-OF-WAY LIMITS
- US 17 JACKSONVILLE BYPASS EASEMENT LIMITS
- MW-14B ◆ MONITORING WELL SCORE

SOURCE: LANTDIV, OCT. 1991

FIGURE 2-4
SITE-WIDE LOWER SURFICIAL AQUIFER
TOTAL CHLORINATED ISOPLETH MAP
SITE 35, CAMP GEIGER AREA FUEL FARM,
FOCUSED NAE WORK PLAN, CTO-0130
MARINE CORPS BASE, CAMP LEJEUNE,
NORTH CAROLINA

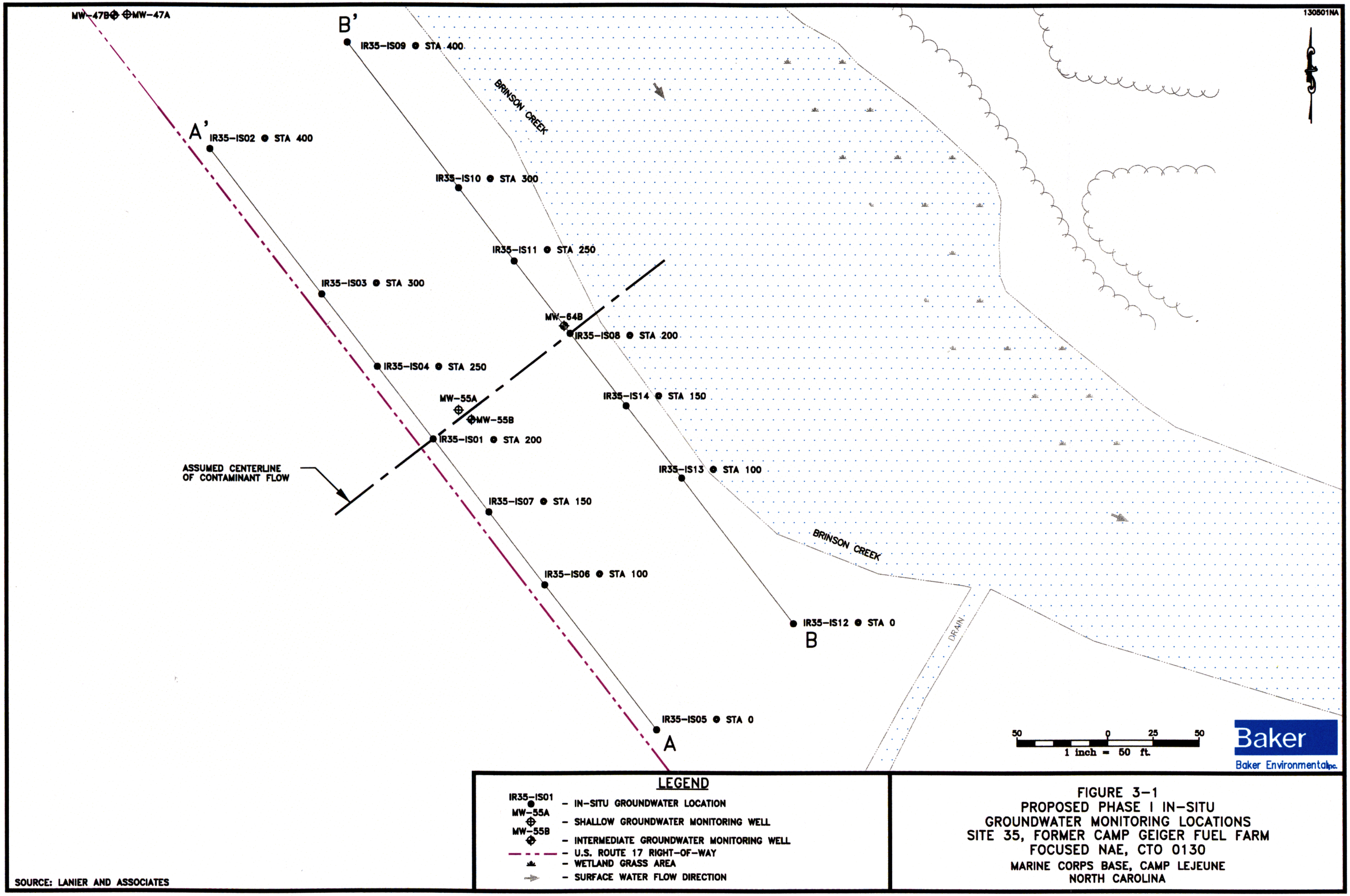
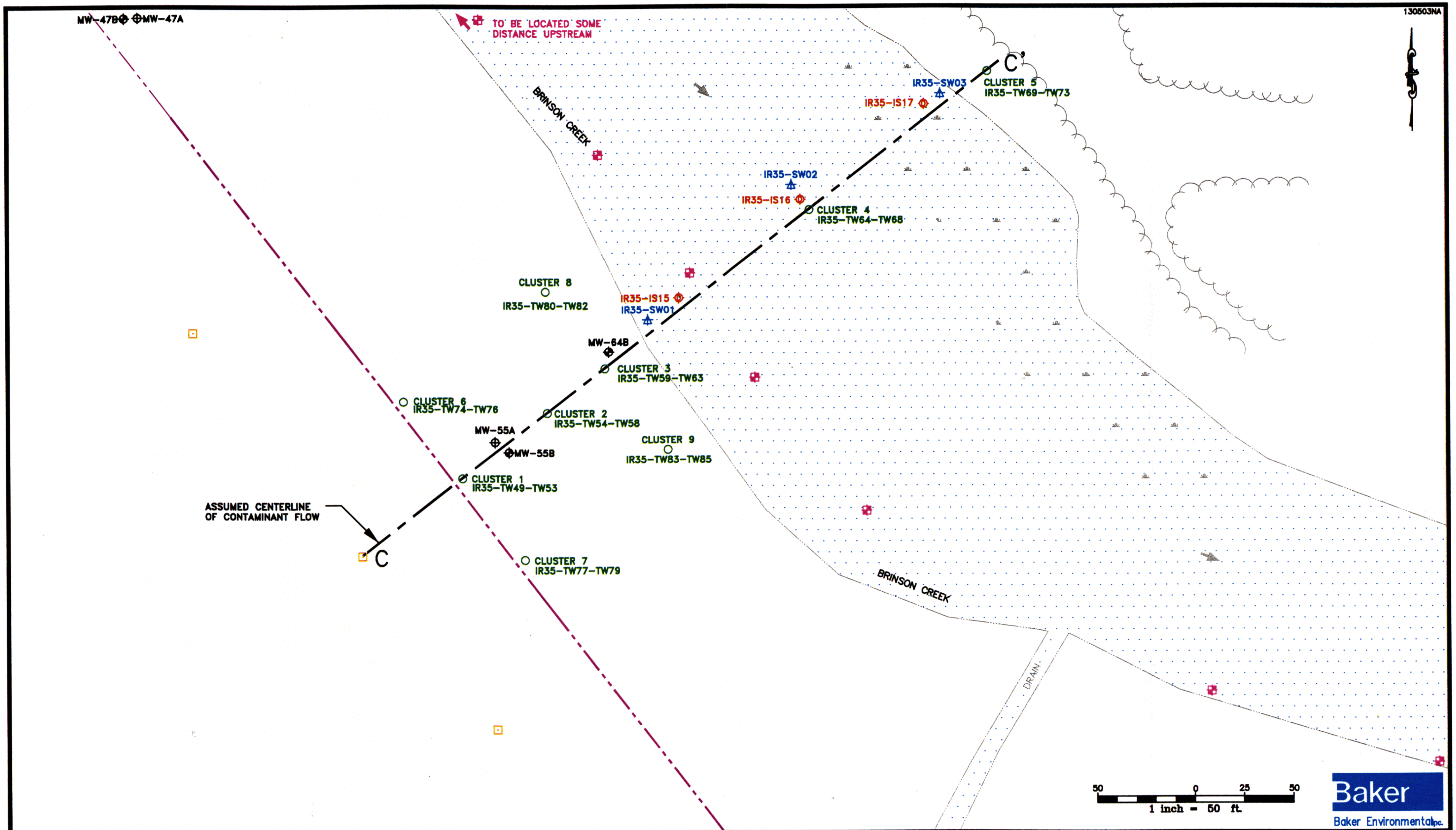


FIGURE 3-1
PROPOSED PHASE I IN-SITU GROUNDWATER MONITORING LOCATIONS
SITE 35, FORMER CAMP GEIGER FUEL FARM
FOCUSED NAE, CTO 0130
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- CLUSTER 1 – MONITORING WELL CLUSTER WITH TEMPORARY WELLS AS SHOWN
- IR35-IS15 – DIFFUSION SAMPLER LOCATIONS
- IR35-SW01 – SURFACE WATER SAMPLE LOCATIONS
- MW-55A – SHALLOW GROUNDWATER MONITORING WELL
- MW-55B – INTERMEDIATE GROUNDWATER MONITORING WELL
- U.S. ROUTE 17 RIGHT-OF-WAY
- PERMANENT WELL CLUSTER
- SEDIMENT SAMPLING LOCATION

SOURCE: LANIER AND ASSOCIATES

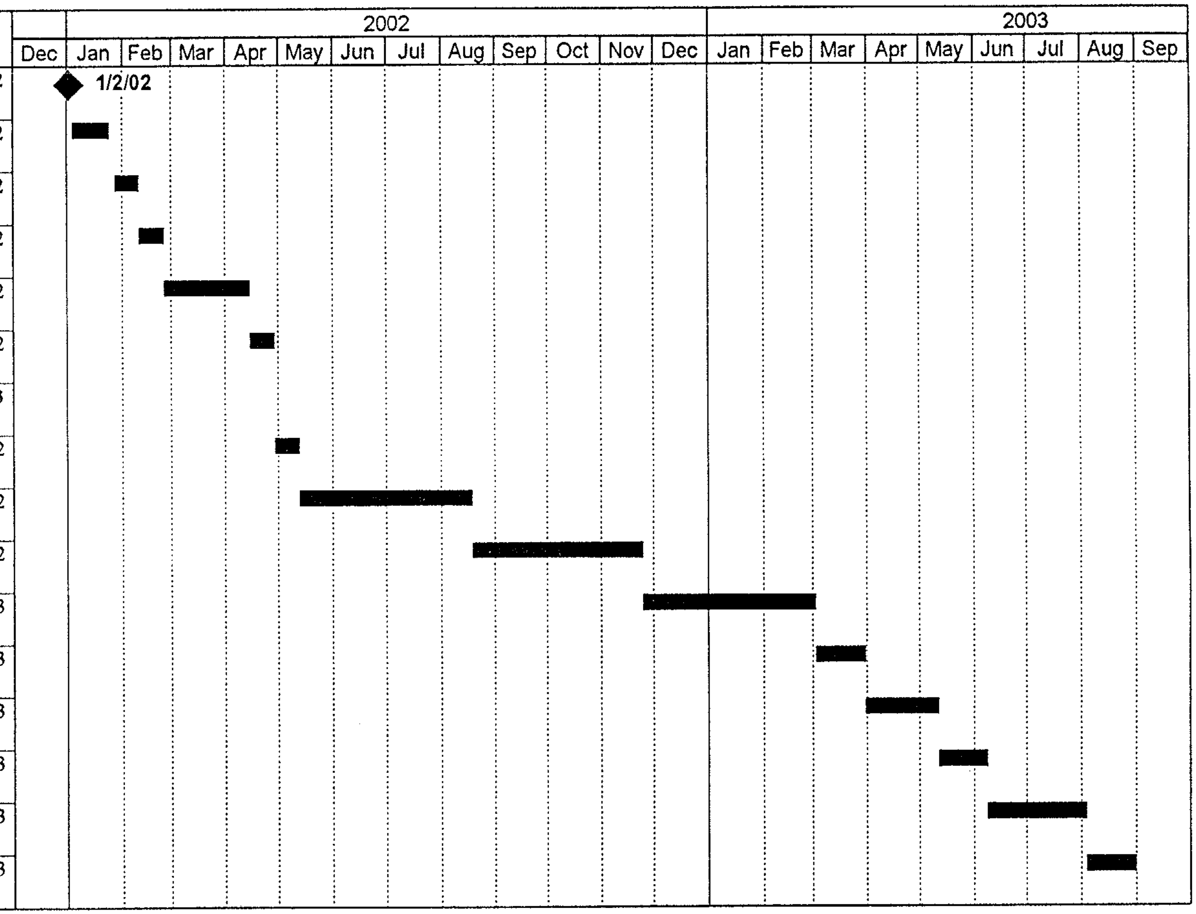
Baker
Baker Environmental Inc.

FIGURE 3-2
PROPOSED PHASE II AND III
MONITORING SYSTEM
SITE 35, FORMER CAMP GEIGER FUEL FARM
FOCUSED NAE, CTO 0130

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

FIGURE 6-1
Site 35 Wetlands Investigation
Estimated Schedule
November 2001

Task Name	Duration	Start	Finish
Notice To Proceed	1 eday	1/2/02	1/3/02
Sub Procurement/Mobilization	21 edays	1/4/02	1/25/02
Phase I	14 edays	1/28/02	2/11/02
Data Review	14 edays	2/11/02	2/25/02
Phase II	49 edays	2/25/02	4/15/02
Data Review	14 edays	4/15/02	4/29/02
Phase III	**350 days**	**4/29/02**	**9/1/03**
1st Sampling Round + Tidal Study	14 edays	4/29/02	5/13/02
2nd Sampling Round	98 edays	5/13/02	8/19/02
3rd Sampling Round	98 edays	8/19/02	11/25/02
4th Sampling Round	98 edays	11/25/02	3/3/03
Data Arives	28 edays	3/3/03	3/31/03
Data Analysis	42 edays	3/31/03	5/12/03
Draft Report	28 edays	5/12/03	6/9/03
Government Review	56 edays	6/9/03	8/4/03
Revised Report	28 edays	8/4/03	9/1/03



Project: CTO-130
Date: 11/29/01

Task ▬ Progress ▨ Milestone ◆