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FINAL

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
PROJECT PLANS

OPERABLE UNIT NO. 16 (SITES 89 AND 93)
MCB CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0344

FEBRUARY 21, 1997

Prepared for:

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION
NAVAL FACILITIES
ENGINEERING COMMAND
Norfolk, Virginia

Under:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared by:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

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LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	applicable or relevant and appropriate requirements
bgs	below ground surface
bls	below land surface
BRA	baseline risk assessment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLEJ	Camp Lejeune
CLP	Contract Laboratory Program
DOD	Department of the Defense
DoN	Department of the Navy
DQO	Data Quality Objective
EMD	Environmental Management Division (Camp Lejeune)
ESE	Environmental Science and Engineering, Inc.
°F	degrees Fahrenheit
FFA	Federal Facilities Agreement
FMF	Fleet Marine Force
FMFLANT	Fleet Marine Force Atlantic
FFSG	Force Service Support Group
ft	feet
ft/ft	foot per foot
gpm	gallons per minute
GSRA	Greater Sandy Run Area
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HPIA	Hadnot Point Industrial Area
HQ	hazard quotient
IAS	Initial Assessment Study
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
MAGTF	Marine Air Ground Task Force
MCAS	Marine Corps Air Station
MCB	Marine Corps Base
MCL	maximum contaminant level
mgd	million gallons per day
mg/L	milligram per liter
msl	mean sea level

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

NACIP	Navy Assessment and Control of Installation Pollutants
NC DEHNR	North Carolina Department of Environment, Health, and Natural Resources
NCP	National Contingency Plan
NCWQS	North Carolina Water Quality Standard
NFESC	Naval Facilities Engineering Service Center
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NREA	Natural Resources and Environmental Affairs
OU	operable unit
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
ppb	parts per billion
ppm	parts per million
PRAP	Proposed Remedial Action Plan
PRGs	Preliminary Remediation Goals
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SMCL	Secondary Maximum Contaminant Level
SQC	Sediment Quality Criteria
SSV	Sediment Screening Value
TAL	Target Analyte List
TBC	To be Considered
TCL	Target Compound List
TCLP	Toxicity Characteristics Leaching Procedure
TDS	total dissolved solids
TSS	total suspended solids
µg/L	micrograms per liter
µg/kg	micrograms per kilogram
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WOE	weight-of-evidence

1.0 INTRODUCTION

Marine Corps Base (MCB) Camp Lejeune was placed on the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) National Priorities List (NPL) effective November 4, 1989 (54 Federal Register 41015, October 4, 1989). Subsequent to this listing, the United States Environmental Protection Agency (USEPA) Region IV, the North Carolina Department of Environment, Health and Natural Resources (DEHNR), the United States Department of the Navy (DoN) and the Marine Corps entered into a Federal Facilities Agreement (FFA) for MCB Camp Lejeune. The primary purpose of the FFA was to ensure that environmental impacts associated with past and present activities at the MCB are thoroughly investigated, and that appropriate CERCLA response and Resource Conservation Recovery Act (RCRA) corrective action alternatives are developed and implemented as necessary to protect the public health and welfare, and the environment (MCB Camp Lejeune FFA, 1989).

The scope of the FFA includes the implementation of a remedial investigation/feasibility study (RI/FS) at 18 Operable Units (OUs) and 34 sites across MCB Camp Lejeune. RIs will be implemented at these OUs to determine fully the nature and extent of the threat to the public health and welfare or to the environment caused by the release and threatened release of hazardous substances, pollutants, contaminants or constituents at the site and to establish requirements for the performance of FSs. Feasibility studies will be conducted to identify, evaluate, and select alternatives for the appropriate CERCLA responses to prevent, mitigate, or abate the release or threatened release of hazardous substances, pollutants, contaminants, or constituents at the site in accordance with CERCLA/Superfund Amendments and Reauthorization Act of 1986 (SARA) and applicable State law (FFA, 1989).

This RI/FS Work Plan addresses OU No. 16 which consists of Site 89 (STC 868) and Site 93 (TC-942). The project plans for this investigation also include a Work Plan, a Field Sampling and Analysis Plan, a Quality Assurance Project Plan, and a Health and Safety Plan.

1.1 Objective of RI/FS Work

The objective of this RI/FS Work Plan is to identify the tasks required to implement the Phase II Investigation of an RI/FS for Sites 89 and 93 at MCB Camp Lejeune. The various studies or investigations required to collect appropriate data are described in this Work Plan. In addition, the Work Plan documents the scope and objectives of the individual RI/FS activities. It serves as a tool for assigning responsibilities and establishing the project schedule and cost. The preparation and contents of the RI/FS Work Plan are based on the scoping process, which is described below.

1.2 RI/FS Scoping

Scoping is the initial planning stage of the RI/FS and of site remediation. The result or outcome of the scoping process is documented in the RI/FS Work Plan. Scoping begins once the background information is reviewed and evaluated and consists of the following activities:

- Preliminary assessment of human health and environmental risks, based on existing information.

- Identifying any potential interim actions which may need to be undertaken early in the program to mitigate potential threats to the public health and environment.

- Identifying potential contaminant migration pathways.
- Identifying contaminants of potential concern.
- Identifying potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs).
- Define the optimum sequence of investigation activities.
- Identifying the sampling strategies for the collection of data.
- Determining the type, amount, and data quality objectives (DQOs) to assess human health and environmental risks, and to effectively evaluate feasible technologies/alternatives.
- Identifying potential technologies/alternatives for mitigating site problems.
- Identifying the remedial alternatives suitable to site conditions.

The background information available to this process included a number of existing environmental assessment reports, which are identified in Section 7.0 (References), and information collected during planning visits at each site.

As part of the scoping process, project meetings were conducted with the Atlantic Division, Naval Facilities Engineering Command (LANTDIV), MCB Camp Lejeune, USEPA Region IV, and the North Carolina DEHNR to discuss the proposed RI/FS scope of work for each site, and to obtain technical and administrative input from LANTDIV.

1.3 RI/FS Work Plan Format

The following elements are presented in this RI/FS Work Plan.

Section 2 - Background and Setting
Section 3 - RI/FS Data Quality and Sampling Objectives
Section 4 - RI/FS Tasks
Section 5 - Project Staffing
Section 6 - Project Schedule
Section 7 - References

Section 2 documents the evaluation of background information, along with the location and setting of the site. The purpose of this section is to define the physical and known environmental characteristics of the site. This section focuses on identifying potential and/or confirmed contaminant migration pathways, identifying potential (or known) impacts to public health and environment, listing Federal or State standards and criteria.

Section 3 defines site-specific RI/FS data quality and sampling objectives. Data or information deemed necessary to identify migration pathways, assess environmental and human health risks, or evaluate feasibility or remedial actions are presented in this section. This data may consist of chemical analyses, hydrogeologic information, or engineering analyses. The collection methods for obtaining this information are also identified and described in general terms [more detailed descriptions of the field investigation activities are documented in the Sampling and Analysis Plan (SAP)].

Section 4 identifies and describes the tasks and field investigation activities that will be implemented to complete the RI/FS at the sites in terms of meeting the site-specific objectives. These tasks generally follow the description of tasks identified in EPA's RI/FS Guidance Document (OSWER Directive 955.3-01).

Section 5 discusses project staffing for implementing the RI/FS. The RI/FS schedule is provided in Section 6. References used in developing the RI/FS Work Plan are provided in Section 7.

2.0 BACKGROUND AND SETTING

The purpose of this section is to summarize and evaluate existing information pertaining to MCB Camp Lejeune, OU 16 (Sites 89 and 93). The analysis of existing information will serve to provide an understanding of the nature and extent of contamination in order to aid in the design of RI tasks. The current understanding of the physical setting of the site, the history of the site, and the existing information related to previous environmental investigative activities are described herein.

This section specifically addresses the location and setting of the site, historical events associated with past usage or disposal activities, topography and surface drainage, regional geology and hydrogeology, site-specific geology and hydrogeology, surface water hydrology, climatology, natural resources and ecological features, and land use.

Additional background information is presented in the following documents:

- Initial Assessment Study (IAS) of Marine Corps Base Camp Lejeune, North Carolina (Water and Air Research, 1983)

- Final Site Summary Report, Marine Corps Base, Camp Lejeune (Environmental Science and Engineering, Inc. [ESE], 1990)

- Hydrogeology of Aquifers in Cretaceous and Younger Rocks in the Vicinity of Onslow and Southern Jones Counties, North Carolina (U.S. Geological Survey, 1990)

- Continuous Seismic Reflection Profiling of Hydrogeologic Features Beneath New River, Camp Lejeune, North Carolina (U.S. Geological Survey, 1990)

- Assessment of Hydrologic and Hydrogeologic Data at Camp Lejeune Marine Corps Base, North Carolina (U.S. Geological Survey, 1989)

- One Well Site Check Plus Resample Two Existing Wells Marine Corps Base, Camp Lejeune, North Carolina UST STC-868 (R.E. Wright Environmental, Inc. [REWEI], 1994)

- Five Well Site Check Marine Corps Base, Camp Lejeune, North Carolina UST TC-942 (REWEI, 1995)

- Final Remedial Investigation Report, Operable Unit No. 6 (Site 44), Marine Corps Base, Camp Lejeune, North Carolina (Baker, 1996)

- Phase I Investigation Report, Operable Unit No. 16 (Sites 98 and 93), Marine Corps Base, Camp Lejeune, North Carolina (Baker, 1996a)

2.1 MCB Camp Lejeune, North Carolina

This section provides an overview of the physical features associated with MCB Camp Lejeune, North Carolina (which also includes Camp Geiger).

2.1.1 Location and Setting

MCB Camp Lejeune is located within the Coastal Plain Physiographic Province. It is located in Onslow County, North Carolina, approximately 45 miles south of New Bern and 47 miles north of Wilmington. The facility covers approximately 236 square miles. This includes the recent acquisition of approximately 64 square miles west of the facility within the Greater Sandy Run Area of the county. The military reservation is bisected by the New River, which flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean.

The eastern border of MCB Camp Lejeune is the Atlantic shoreline. The western and northwestern boundaries are U.S. Route 17 and State Route 24, respectively. The City of Jacksonville, North Carolina, borders MCB Camp Lejeune to the north. MCB Camp Lejeune is depicted in Figure 2-1.

The Greater Sandy Run Area (GSRA) is located in the southeast portion of Onslow County, North Carolina, near the Pender-Onslow County border. The GSRA is approximately 31 miles northeast of Wilmington, North Carolina; 15 miles south of Jacksonville, North Carolina; and 5 miles northwest of the Atlantic Ocean. The GSRA is located south and west of MCB, Camp Lejeune, sharing a common boundary along Route 17 between Dixon and Verona.

There are six major Marine and two Navy commands aboard Camp Lejeune: Commander, Marine Corps Forces Atlantic; Marine Corps Base; Command Element, II Marine Expeditionary Force; Second Marine Division; Second Force Service Support Group; Marine Corps Reserve Air/Ground Task Force, Command Element, Atlantic; Naval Hospital; and the Naval Dental Center.

The Air Station and Camp Geiger are considered as a single urban area possessing two separate missions and supported by two unrelated groups of personnel. The Marine Corps Air Station (MCAS), New River encompasses 2,772 acres and is located in the northwestern section of the Complex and lies approximately five miles south of Jacksonville. The MCAS includes air support activities, troop housing and personnel support facilities, all of which immediately surround the aircraft operations and maintenance areas.

Camp Geiger, located directly north of MCAS, New River, contains a mixture of troop housing, personnel support and training uses. Currently, the area is utilized by a number of groups which have no direct relationship to one another. The majority of the land surrounding this area is comprised of buffer zones and unbuildable marshland.

The Camp Lejeune Complex contains five other areas of concentrated development, all of which are much smaller in size and population than either Hadnot Point, MCAS New River, or the Camp Geiger area. The oldest of these is the Montford Point area, which is bounded by the New River to the south and west and by Route 24 on the north. New development in Montford Point has been limited, with most of the facilities for troop housing, maintenance, supply and personnel support having been converted from their intended uses. A majority of the MCB training schools requiring classroom instruction are located here and use surrounding undeveloped areas for training operations when required. The French Creek area located directly south of Hadnot Point is occupied by the 2nd

Force Service Support Group (2nd FSSG). Its activities are directed toward providing combat service and technical support as required by Headquarters, II Marine Expeditionary Force. Expansion of the French Creek Complex is constrained by the Ordnance Storage Depot explosives safety arc on the south and by the regimental area of Hadnot Point. Onslow Beach, located along the Onslow Bay, east of the New River Inlet, presents assets for amphibious training as well as recreational use. Courthouse Bay is located on one of a series of small bays which are formed by the New River. This area is used for maintenance, storage and training associated with amphibious vehicles and heavy engineering equipment. The Engineering School, also located here, conducts training activities in the large open area located to the southeast of the Courthouse Bay. Another concentrated area of development is the Rifle Range. This area is located on the southwest side of the New River, is singular in purpose and has only a small number of assigned personnel. It was constructed in the early stages of Base development and is used solely for rifle and pistol qualification training. The small group of barracks, located at the Rifle Range, are used for two-week periods by troops assigned to range training.

2.1.2 History and Mission of Camp Lejeune

Construction of MCB Camp Lejeune began in 1941 with the objective of developing the "World's Most Complete Amphibious Training Base." Construction of the base started at Hadnot Point, where the major functions of the base are centered. Development at the Camp Lejeune Complex is primarily in five geographical locations under the jurisdiction of the Base Command. These areas include Camp Geiger, Montford Point, Courthouse Bay, Mainside, and the Rifle Range Area. Sites 89 and 93 are located in the Camp Geiger Area. Appendix A contains aerial photographs from 1956, 1960, 1964, 1970, and 1993 of the area surrounding Sites 89 and 93.

The MCB organization functions as the host command to the two Fleet Marine Force Atlantic (FMFLANT) tenant activities -- Headquarters of the II Marine Expeditionary Division and the 2nd FSSG. The MCB host organization mission is to provide housing, training facilities, logistical support and certain administrative support for tenant units and for other units assigned to MCB Camp Lejeune and to conduct specialized schools and other training maneuvers, as directed.

The mission of the 6th Marine Expeditionary Brigade is to provide the Command element for a brigade-size Marine Air Ground Task Force (MAGTF) with the primary mission of preparing to join up with LantCom MPS equipment and to conduct subsequent combat operations.

The mission of the 2nd Marine Division is to execute amphibious assault operations, and other operations as may be directed, which are supported by Marine aviation and force service support units. With the aircraft wing, the Marine division provides combined arms for service with the Fleet in the seizure or defense of advanced naval bases and for the conduct of land operations essential to the prosecution of a naval campaign.

The mission of the 2nd FSSG is to command, administer and train assigned units in order to provide combat service and technical support as required by Headquarters FMFLANT and its subordinate command in accomplishment of the overall FMFLANT mission.

2.1.3 Previous Investigations

In response to the passage of CERCLA, the DoN initiated the Navy Assessment and Control of Installation Pollutants (NACIP) program to identify, investigate, and clean up past hazardous waste disposal sites at Navy installations. The NACIP investigations were conducted by the Navy Energy and Environmental Support Activity (NEESA) and consisted of Initial Assessment Studies (IAS) and Confirmation Studies. IAS are similar to the CERCLA Preliminary Assessments/Site Investigations (PAs/SIs). Confirmation Studies are similar to CERCLA RI/FS. When the Superfund Amendment and Reauthorization Act (SARA) was passed in 1986, the DoN dissolved the NACIP in favor of the Installation Restoration Program (IRP), which adopted USEPA CERCLA terminology and procedures.

The IAS for MCB Camp Lejeune was conducted by Water and Air Research, Inc., in 1983. The IAS identified a number of sites at MCB Camp Lejeune as potential sources of contamination, Sites 89 and 93 were not included under the IAS. Based on historical records, aerial photographs, field inspections, and personnel interviews, the IAS identified 76 sites at MCB Camp Lejeune as potential sources of contamination. Of these 76 sites, 27 sites warranted further investigation to assess potential long-term impacts based on contamination characteristics, migration pathways, and pollutant receptors.

Under the MCB Camp Lejeune UST Program, R.E. Wright Environmental, Inc. conducted Well Site Checks at Sites 89 and 93. A one well site check and resampling of two existing wells was conducted at Site 89 in June 1994. In March 1995, a five well site check was conducted at Site 93. The analytical findings for these investigations identified contaminants, unrelated to the UST, in the groundwater. Subsequently, Sites 89 and 93 were brought under the IRP in order to further characterize the contamination unrelated to the former USTs.

The characterization of Sites 89 and 93 was to be conducted in two phases. The field investigation for the first phase was conducted in July and August 1996, with the report submitted in November 1996. These project plans address the second phase investigation activities.

2.1.4 Topography and Surface Drainage

The generally flat topography of MCB Camp Lejeune is typical of the seaward portions of the North Carolina Coastal Plain. Elevations on the base vary from sea level to 72 feet above mean sea level (msl); however, the elevation of most of MCB Camp Lejeune is between 20 and 40 feet above msl.

Drainage at MCB Camp Lejeune is generally toward the New River, except in areas near the coast, which drain through the Intracoastal Waterway. In developed areas, natural drainage has been altered by asphalt cover, storm sewers, and drainage ditches. Approximately 70 percent of MCB Camp Lejeune is in broad, flat interstream areas. Drainage is poor in these areas (Water and Air Research, 1983).

The U.S. Army Corps of Engineers has mapped the limits of 100-year floodplain at MCB Camp Lejeune at 7 feet above msl in the upper reaches of the New River (Water and Air Research, 1983); this increases downstream to 11 feet above msl near the coastal area (Water and Air Research, 1983).

2.1.5 Regional Geology

MCB Camp Lejeune is located in the Atlantic Coastal Plain physiographic province. The sediments of the province consist predominantly of sand, silt, and clay. Other sediments may be present, including peat, shell beds and gravel. Sediments may be of marine or continental origin (Back, 1966). These sediments lay in interfingering beds and lenses that gently dip and thicken to the southeast (ESE, 1991). These sediments range in age from early Cretaceous to Quaternary time and overlie igneous and metamorphic rocks of pre-Cretaceous age. Table 2-1 presents a generalized stratigraphic column for this area (ESE 1991).

United States Geological Survey (USGS) studies at MCB Camp Lejeune indicate that the Base is underlain by sand, silt, clay, calcareous clay and partially consolidated limestone. Aquifers that occur beneath the Base include the surficial, Castle Hayne, Beaufort, Peedee, Black Creek, and upper and lower Cape Fear aquifers. The combined thickness of these sediments beneath the base is approximately 1,500 feet. A generalized hydrogeologic cross-section illustrating the relationship between the aquifers in this area is presented in Figures 2-2 and 2-3.

2.1.6 Regional Hydrogeology

The aquifers of primary interest are the surficial aquifer and the aquifer immediately below it, the Castle Hayne. The following summary is a compilation of information, including Harned et al. (1989), and Cardinell et al. (1993).

The surficial aquifer consists of interfingering beds of sand, clay, sandy clay, and silt that contain some peat and shells. These beds are thin and discontinuous, and have limited lateral continuity. This aquifer is not used for water supply MCB at Camp Lejeune.

The thickness of the surficial aquifer ranges from 0 to 73 feet and averages nearly 25 feet over the MCB Camp Lejeune area. It is generally thickest in the interstream divide areas and presumed absent where it is cut by the New River and its tributaries.

The general lithology of the surficial aquifer and the absence of any thick, continuous clay beds are indications of good vertical conductivity within the aquifer. Data compiled by Cardinell estimate the lateral hydraulic conductivity of the surficial aquifer in the MCB Camp Lejeune area 50 feet/day, and is based on a general composition of fine sand mixed with some silt and clay. However, data from slug tests on Baker wells indicate much lower lateral hydraulic conductivity values, ranging from 0.12 to 9.00 feet/day.

Between the surficial and the Castle Hayne aquifers lies the Castle Hayne confining unit. This unit consists of clay, silt, and sandy clay beds. In general, the Castle Hayne confining unit may be characterized as a group of less permeable beds at the top of the Castle Hayne aquifer that have been partly eroded or incised in places.

The Castle Hayne confining unit is discontinuous, and has a thickness ranging from 0 to 26 feet, averaging about 9 feet where present. There is no discernable trend in the thickness of the confining unit. There is no information in the USGS literature regarding any trend of the depth of the confining unit.

The data compiled by Cardinell, et. al., indicate that the vertical hydraulic conductivity of the confining unit ranged from 0.0014 to 0.41 feet/day. Based on the moderate conductivity values and the thin, discontinuous nature of the confining unit, this unit may only be partly effective in retarding the vertical movement of groundwater between the surficial aquifer.

The Castle Hayne aquifer lies below the surficial aquifer and consists primarily of unconsolidated sand, shell fragments, and fossiliferous limestone. Clay, silt, silty and sandy clay, and indurated limestone also occur within the aquifer. The upper part of the aquifer consists primarily of calcareous sand with some continuous and discontinuous thin clay and silt beds. The calcareous sand becomes more limey with depth. The lower part of the aquifer consists of consolidated or poorly consolidated limestone and sandy limestone interbedded with clay and sand.

The Castle Hayne aquifer is about 150 to 350 feet thick in the area, and thickens eastward across the base. The top of the aquifer lies approximately 20 to 65 feet below the ground surface. The top of the aquifer dips southward, and is deepest at the Atlantic coast, east of the New River. The top of the aquifer also forms a basin in the vicinity of Paradise Point. Estimates of hydraulic conductivity indicate a wide variation in range, from 14 to 91 feet/day.

Onslow County and MCB Camp Lejeune lie in an area where the Castle Hayne aquifer generally contains freshwater. However, the proximity of saltwater in deeper layers just below the aquifer and in the New River estuary is of concern in managing water withdrawals. Over-pumping of the deeper parts of the aquifer could cause encroachment of saltwater. The aquifer generally contains water having less than 250 milligrams per kilogram (mg/L) chloride throughout the base, except for one well (USGS-8) in the southern portion of the base that is screened in the lower portion of the aquifer. Chloride was measured at 960 mg/L in a single sample collected in 1989.

Rainfall in the MCB Camp Lejeune area enters the ground in recharge areas, infiltrates the soil, and moves downward until it reaches the surficial aquifer. Recharge areas at Camp Lejeune include the interstream areas. In the aquifer, groundwater flows in the direction of lower hydraulic head until it reaches discharge points or fronts. These discharge areas include the New River and its tributaries, and the ocean. Though most of the rainfall entering the surficial aquifer discharges to local streams, a relatively small amount infiltrates to the Castle Hayne. The surficial aquifer supplies the primary recharge to the Castle Hayne aquifer. Like the surficial aquifer, the Castle Hayne naturally discharges to the New River and major tributaries. However, pumping of the Castle Hayne may locally influence discharge directions.

The potentiometric surface of the surficial aquifer varies seasonally. The potentiometric surface is determined by the water levels in monitoring wells. The surficial aquifer receives more recharge in the winter than in the summer when much of the water evaporates or is transpired by plants before it can reach the water table. Therefore, the potentiometric surface is generally highest in the winter months and lowest in the summer or early fall.

Water levels in wells in deeper aquifers, such as the Castle Hayne were also used to establish potentiometric surfaces. Because the Castle Hayne is at least partially confined from the surficial aquifer and is not influenced by rainfall as strongly as the surficial aquifer, the seasonal variations tend to be slower and smaller than in surficial aquifer.

2.1.7 Surface Water Hydrology

The following summary of surface water hydrology was originally presented in the IAS report (Water and Air Research, 1983).

The dominant surface water feature at MCB Camp Lejeune is the New River. It receives drainage from most of the base. The New River is short, with a course of approximately 50 miles on the central Coastal Plain of North Carolina. Over most of its course, the New River is confined to a relatively narrow channel entrenched in Eocene and Oligocene limestones. South of Jacksonville, the river widens dramatically as it flows across less resistant sands, clays, and marls. At MCB Camp Lejeune, the New River flows in a southerly direction into the Atlantic Ocean through the New River Inlet. Several small coastal creeks drain the area of MCB Camp Lejeune not associated with the New River and its tributaries. These creeks flow into the Intracoastal Waterway, which is connected to the Atlantic Ocean by Bear Inlet, Brown's Inlet, and the New River Inlet (WAR, 1983). The New River, the Intracoastal Waterway, and the Atlantic Ocean meet at the New River Inlet.

Water quality criteria for surface waters in North Carolina have been published under Title 15 of the North Carolina Administrative Code. At MCB Camp Lejeune, the New River falls into two classifications: SC (estuarine waters not suited for body-contact sports or commercial shellfishing) and SA (estuarine waters suited for commercial shellfishing). The SC classification applies to three areas of the New River at MCB Camp Lejeune, including the Rifle Range area; the rest of the New River at MCB Camp Lejeune falls into the SA classification (ESE, 1991).

2.1.8 Climatology

MCB Camp Lejeune experiences mild winters and hot and humid summers. The average yearly rainfall is greater than 50 inches, and the potential evapotranspiration in the region varies from 34 to 36 inches of rainfall equivalent per year. The winter and summer seasons usually receive the most precipitation. Temperature ranges are reported to be 33 to 53 degrees Fahrenheit (F) in the winter (i.e., January) and 71 to 88 F in the summer (i.e., July). Winds are generally south-southwesterly in the summer, and north-northwesterly in the winter (Water and Air Research, 1983).

2.1.9 Natural Resources and Ecological Features

The following summary of natural resources and ecological features was obtained from the IAS Report (Water and Air Research, 1983).

The MCB Camp Lejeune is predominantly tree-covered with large amounts of softwood including shortleaf, longleaf, pond, and pines (primarily loblolly), and substantial stands of hardwood species. Approximately 60,000 of the 112,000 acres of MCB Camp Lejeune are under forestry management. Timber producing areas are under even-aged management with the exception of those areas along streams and swamps. These areas are managed to provide both wildlife habitat and erosion control. Forest management provides wood production, increased wildlife populations, enhancement of natural beauty, soil protection, prevention of stream pollution, and protection of endangered species.

Upland game species including black bear, whitetail deer, gray squirrel, fox squirrel, quail, turkey, and migratory waterfowl are abundant and are considered in the wildlife management programs.

Aquatic ecosystems on MCB Camp Lejeune consist of small lakes, the New River estuary, numerous tributaries, creeks, and part of the Intracoastal Waterway. A wide variety of freshwater and saltwater fish species exist here. Freshwater ponds are under management to produce optimum yields and ensure continued harvest of desirable fish species (Water and Air Research, 1983). Freshwater fish in the streams and ponds include largemouth bass, redbreast sunfish, bluegill, chain pickerel, yellow perch, and catfish. Reptiles include alligators, turtles, and snakes, including venomous species. Both recreational and commercial fishing are practiced in the waterways of the New River and its tributaries.

Wetland ecosystems at MCB Camp Lejeune can be categorized into five habitat types: (1) pond pine or pocosin; (2) sweet gum, water oak, cypress, and tupelo; (3) sweet bay, swamp black gum, and red maple; (4) tidal marshes; and, (5) coastal beaches. Pocosins provide excellent habitat for bear and deer because these areas are seldom disturbed by humans. The presence of pocosin-type habitat at MCB Camp Lejeune is primarily responsible for the continued existence of black bear in the area. Many of the pocosins are overgrown with brush and pine species that would not be profitable to harvest. Sweet gum, water oak, cypress, and tupelo habitat is found in the rich, moist bottomlands along streams and rivers. This habitat extends to the marine shorelines. Deer, bear, turkey, and waterfowl are commonly found in this type of habitat. Sweet bay, swamp black gum, and red maple habitat exist in the floodplain areas of MCB Camp Lejeune. Fauna including waterfowl, mink, otter, raccoon, deer, bear, and gray squirrel frequent this habitat. The tidal marsh at the mouth of the New River is one of the few remaining North Carolina coastal areas relatively free from filling or other manmade changes. This habitat, which consists of marsh and aquatic plants such as algae, cattails, saltgrass, cordgrass, bulrush, and spikerush, provides wildlife with food and cover. Migratory waterfowl, alligators, raccoons, and river otter exist in this habitat. Coastal beaches along the Intracoastal Waterway and along the outer banks of MCB Camp Lejeune are used for recreation and to house a small military command unit. Basic assault training maneuvers are also conducted along these beaches. Training regulations presently restrict activities that would impact ecologically sensitive coastal barrier dunes. The coastal beaches provides habitat for many shorebirds (Water and Air Research, 1983).

The Natural Resources and Environmental Affairs (NREA) Division of MCB Camp Lejeune, the U.S. Fish and Wildlife Service, and the North Carolina Wildlife Resource Commission have entered into an agreement for the protection of endangered and threatened species that might inhabit MCB Camp Lejeune. Habitats are maintained at MCB Camp Lejeune for the preservation and protection of rare and endangered species through the Base's forest and wildlife management programs. Full protection is provided to such species, and critical habitat is designated in management plans to prevent or mitigate adverse effects of Base activities. Special emphasis is placed on habitat and sightings of alligators, osprey, bald eagles, cougars, dusky seaside sparrows, and red-cockaded woodpeckers (Water and Air Research, 1983).

Neither of the sites included in this investigation are within or in close proximity (i.e., one-half mile) to either a natural area or a protected area. Protected areas have only been established for the red-cockaded woodpecker.

Within 15 miles of MCB Camp Lejeune are three publicly owned forests: Croatan National Forest; Hofmann Forest; and Camp Davis Forest. The remaining land surrounding MCB Camp Lejeune is primarily used for agriculture. Typical crops include soybeans, small grains, and tobacco (Water and Air Research, 1983).

2.1.10 Land Use and Demographics

MCB Camp Lejeune presently covers an area of approximately 236 square miles. Military and civilian population is approximately 60,000. During World War II, MCB Camp Lejeune was used as a training area to prepare Marines for combat. This has been a continuing function of the facility during the Korean and Vietnam conflicts, and the Gulf War (i.e., Desert Storm). Toward the end of World War II, the camp was designated as a home base for the Second Marine Division. Since that time, Fleet Marine Force (FMF) units also have been stationed here as tenant commands.

The following information was extracted from the document "Master Plan, Camp Lejeune Complex, North Carolina." The existing land use patterns in the various geographic areas within the Marine Corps Base are described in this section and listed, per geographic area, on Table 2-2. The areas described below are depicted on Figure 2-1. In addition, the number of acres comprising each land use category has been estimated and provided on the table. The following is a summary of the land use areas for Sites 89 and 93.

2.1.10.1 Camp Geiger

The Camp Geiger area includes the MCAS and are considered as a single urban area possessing two separate missions and supported by two unrelated groups of personnel. The MCAS, New River encompasses 2,772 acres, is located on the northwestern section of the complex, and lies approximately 5 miles south of Jacksonville, The MCAS includes air support activities, troop housing and personnel support facilities, all of which immediately surround the aircraft operations and maintenance areas.

Camp Geiger, located directly north of the MCAS, New River contains a mixture of troop housing, personnel support and training uses. Currently, the area is used by a number of groups which have no direct relationship to one another. The majority of the land surrounding this area is comprised of buffer zones and unusable marshland. Figure 2-4 presents the location of Sites 89 and 93 in relations to other remedial investigation areas within Camp Geiger.

2.1.10.2 Base-Wide

Present military population of Camp Lejeune is approximately 40,928 active duty personnel. The military dependent community is in excess of 32,081. About 36,086 of these personnel and dependents reside in base housing units. The remaining personnel and dependents live off base. An additional 4,412 civilian employees perform facilities management and support functions. The population of Onslow County has grown from 17,739 in 1940, prior to the formation of the base, to its present population of 121,350.

2.1.11 Water Supply

MCB Camp Lejeune water is supplied entirely from groundwater. Groundwater is obtained from approximately 90 water supply wells and treated. There are five water treatment plants with a total capacity of approximately 15.8 million gallons per day (mgd). Groundwater usage is estimated at over 7 mgd (Harned, et al., 1989).

The water supply wells are all located within the boundaries of the Base. The average water supply well at the base has a depth of 162 feet, a casing diameter of eight inches, and yields 174 gpm (Harned, et al., 1989).

All of the water supply wells utilize the Castle Hayne aquifer. The Castle Hayne aquifer is a highly permeable, semiconfined aquifer that is capable of yielding several hundred to 1,000 gpm in municipal and industrial wells in the MCB Camp Lejeune Area. The water retrieved is typically a hard, calcium bicarbonate type. However, some water supply wells on Base have been closed due to contamination, etc.

Two sources were reviewed to locate water supply wells within a 1-mile radius of Sites 89 and 93. These sources were the USGS hydrogeologic assessment at Camp Lejeune (Harned, et. al., 1989) and the Wellhead Management Program Study report of 1991 (Geophex, 1991). Based on a review of these sources, there are 14 supply wells located within a one-mile radius of Sites 89 and 93.

2.2 Site 89 (STC-868)

This section addresses the setting, site topography and drainage features, site history, site geology and hydrogeology for Site 89 (STC-868).

2.2.1 Site Location and Setting

Site 89 is located near the intersection of G and Eighth Street in the Camp Geiger area. A former UST (STC-868) was located between Building STC-867, a roofed contaminated soil storage facility, and an elevated wash rack. There are two oil water separators located east of the tank excavation area. One separator is believed to be for Building STC-867 and the other appears to be associated with an inactive wash rack. A portion of the site is an asphalt paved lot used for storage of base salvage. The entire salvage storage area is fenced. The site is bordered by Seaboard Coastline Railroad and wooded areas to the east, Edwards Creek to the south, the current motor pool to the north, and Camp Geiger to the west. Figure 2-5 is a site map illustrating the general layout of the Site 89 .

2.2.2 Site Topography and Drainage

The natural topography of Site 89 is relatively flat. Ground surface elevation of approximately 13 to 15 feet above mean sea level (MSL) (REWEI, 1994). In general, the ground surface is higher in the northern portion of the site and gently slopes southeast toward the railroad and Edwards Creek. It is reported that one to two feet of water ponds in the unpaved southeastern portion of the site during periods of heavy precipitation.

Storm water runoff would tend to drain from the current motor pool area, north of the site, across the paved salvage storage area, in a southeast direction, toward Edwards Creek approximately 800 feet from the southeast corner of the site.

The NC DEHNR stream classifications for Edwards Creek are SC (aquatic life propagation and survival, fishing, wildlife, and secondary recreation), HQW (high quality water), and NSW (nutrient sensitive water).

2.2.3 Site History

The storage area at Site 89 reportedly was a swamp which was backfilled with fill from an unknown area of the base. UST STC-868 was installed in 1983 and was reportedly used until 1993 for the storage of waste oil. The tank was removed in 1993 and an initial investigation was conducted. Details of the investigation are included in Section 2.2.5. The major finding of this initial investigation at Site 89 was the detection several chlorinated solvents in the groundwater. The presence of chlorinated compounds during the initial investigation demonstrated that impact to the groundwater involved compounds not normally associated with a petroleum UST site. Historical records research of the area which is now occupied by the DRMO show that the site operated as a base motor pool from the 1940s until approximately 1988. Activities at the motor pool included daily maintenance and training on military vehicles. In 1988, the motor pool was relocated north of the storage area adjacent to the current area.

These previous findings led to the inclusion of Site 89 into MCB Camp Lejeune's Installation Restoration (IR) Program. The IR Program focuses on non UST sites and provides the framework for more complex and detailed environmental investigations at the base. The current area of Site 89 has been expanded to include more area than only the former UST site. The site presently includes the entire DRMO and additional area outside the DRMO fence, including the wooded areas to the south and east.

2.2.4 Site Geology and Hydrogeology

A fairly consistent depositional sequence was observed in the borings throughout Site 89 during the Phase I Investigation. This observed sequence is similar to the generalized North Carolina coastal plain sequence shown in Table 2-1. Table 2-1 shows that the Yorktown, Eastover, and Pungo River Formations lie between the Undifferentiated and Belgrade Formations. The Yorktown, Eastover, and Pungo River Formations, however, have not been identified at Camp Lejeune.

During the Phase I of this RI/FS, the undifferentiated and River Bend formations were encountered. The Belgrade Formation was not observed under Site 89. The undifferentiated formation is comprised primarily of loose to medium dense sands with lesser amounts of silt and clay of the Holocene and Pleistocene ages. Lenses of silt and clay are found throughout this formation. At Site 89, this formation typically extends to a depth between 20 and 25 feet below ground surface (bgs). Immediately beneath the Undifferentiated Formation lies the River Bend Formation. This formation is primarily composed of dense to very dense shell and fossil fragments interbedded with calcareous sands. Water is typically present within ten feet of the ground surface. The surficial aquifer is contained in the sediments of the undifferentiated and the upper portion of the River Bend formations to a depth of approximately 40 to 45 feet bgs.

At a depth of approximately 40 to 45 feet bgs, a green to greenish-gray fine sand layer was observed. This fine sand contains lesser amounts of silt, clay, and shell fragments that is characterized by a substantial decrease in water content and smaller grain size from the sediments above. This layer is interpreted as the Castle Hayne Confining Unit. These sediments exhibit a color, composition, and elevation consistent with sediments at other nearby sites that have been identified as the Castle Hayne Confining Unit. This unit was observed beneath, and east of Site 89. However, this unit is absent at Site 93, which is located just west of Site 89. Based on the lack of areal extent and findings of other site investigations, the Castle Hayne Confining Unit is semi-confining.

Groundwater was generally encountered from 5 to 10 bgs during the Phase I investigation. Groundwater elevation measurements indicate that groundwater flow in the surficial aquifer generally flows south and southeast, toward Edwards Creek. There is also an easterly direction to groundwater flow east of Site 89. Groundwater head differentials between the intermediate and shallow wells were evaluated to determine the presence of a vertical component of flow. The distribution of head differentials indicate a slight downward component of groundwater flow in areas away from Edwards Creek and an upward component of flow in areas proximate to Edwards Creek. This pattern indicates that groundwater recharge in the surficial aquifer occurs in interstream areas and discharge is at Edwards Creek. Furthermore, Edwards Creek is a groundwater divide in the surficial aquifer.

2.2.5 Previous Investigations

On behalf of LANTDIV, R.E. Wright Associates, Inc. performed a one well site check adjacent to former UST STC-868. One soil boring was drilled and a monitoring well subsequently installed in June 1994. Soil and groundwater samples were collected from this well (MW01) for laboratory analysis. Additional groundwater samples were collected from two previously installed monitoring wells (arbitrarily named MW02 and MW03) to further characterize hydrocarbon contamination in the subsurface. In order to accurately determine the groundwater flow direction and gradient at the site, well locations and elevations were surveyed and depth to groundwater was measured at each well. The final report was issued on October 5, 1994. A summary of the findings of the report are presented below. Previous investigation sampling locations are shown on Figure 2-6.

2.2.5.1 Soil Investigation

Continuous split-spoon soil samples were collected to a depth of 10 feet bgs. Split-spoon samples were screened in the field using a photoionization detector (PID) to quantify the presence of organic vapors. The sample that exhibited the highest PID reading was collected as a sample. One sample was analyzed for oil and grease and halogenated solvents. Analytical findings are summarized in Table 2-3.

Subsurface Soil:

- Soil sample MW01, southeast of the tank excavation area, 6-8 feet bgs, had 1,400,000 microgram per kilogram (μg/kg) oil and grease detected. Halogenated solvents were below the detection limits in this soil sample.

2.2.5.2 Groundwater Investigation

One round of groundwater samples was collected from the newly installed monitoring well (MW01) and the two existing wells (MW02 and MW03) and analyzed for volatile organic compounds (VOCs), semivolatile compounds (SVOCs), and Toxicity Characteristic Leaching Procedure (TCLP) metals. Groundwater was encountered at approximately 5 feet bgs. Monitoring well data is presented in Table 2-4. Three groundwater samples indicated concentrations of several chlorinated solvents detected at concentrations exceeding USEPAs maximum contaminant level (MCL) standards (see Table 2-5).

- Maximum concentrations of cis-1,2-dichloroethene (2,130 micrograms per liter [μg/L]), trans-1,2-dichloroethene (1,580 μg/L), 1,1,2,2-tetrachloroethane (8,600 μg/L), and trichloroethene (1,500 μg/L) were detected in sample MW02.

- Maximum concentrations of tetrachloroethane (35 μg/L) 1,1,2-tricholoroethane (29 μg/L) were detected in sample MW01.

2.2.5.3 Surface Water Investigation

As part of a remedial investigation conducted by Baker in 1995, surface water samples were collected from Edwards Creek. The detected concentrations were from locations side- and downgradient from Site 89 and downgradient from Site 93.

The following VOCs were detected at least once among the eight surface water samples obtained from Edwards Creek (the maximum concentration of each VOC is provided):

Vinyl chloride	38 µg/L
1,1-Dichloroethene	2 µg/L
1,2-Dichloroethene (total)	120 µg/L
Trichloroethene	22 µg/L
1,1,2-Trichloroethane	1 µg/L
1,1,2,2-Tetrachloroethane	42 µg/L

Trichloroethene, 1,2-dichloroethene (total), and 1,1,2,2-tetrachloroethane were detected in at least seven of the eight surface water samples obtained from Edwards Creek. Vinyl chloride and 1,1-dichloroethene were detected five and three times, respectively, among the surface water samples. Lastly, 1,1,2-trichloroethane was detected in only one Edwards Creek surface water sample.

Sampling events illustrate a reduction in total VOC concentrations from upgradient to downgradient sampling stations. Volatile analytical results from the September of 1995 sampling event were generally lower than results from the initial sampling event, conducted in May of 1995; however, the same trend of relatively higher upgradient and lower downgradient VOC concentrations was evident.

During the September 1995 sampling event an additional four sampling stations were added to the Edwards Creek surface water investigation. The analytical data from Edwards Creek suggests that a possible VOC source lies in the southeastern portion of Camp Geiger. Several former and current storage and maintenance facilities are located in this general area of Camp Geiger.

Analytical findings regarding surface water contaminant levels are summarized in Table 2-6.

2.2.6 Phase I Investigation Summary

The Phase I investigation has further delineated the extent of VOC contamination in the surface water, sediment, and groundwater in the vicinity of Site 89. Figures 2-7 through 2-13 show the distribution of contaminants in the various media. The exact source of the contamination in groundwater and surface water is unknown but are assumed to be former site operations in the area of the DRMO for the site.

2.2.6.1 <u>Surface Water</u>

VOCs are present in the portion of Edwards Creek downgradient of the DRMO facility (Figure 2-7). Six individual VOCs were detected in the surface water samples. Contaminant concentrations were relatively consistent in each of the samples obtained, showing little to no decrease in concentrations in the downstream direction. The concentrations ranged from 0.1 µg/L of PCE to 150 µg/L of TCA. TCE was the compound most frequently detected in the surface water samples.

2.2.6.2 <u>Sediment</u>

A total of five sediment sample stations were positioned within the bed of Edwards Creek . Of these, only one station (89-EC-SD03) detected VOCs. The sample detected six separate VOCs including vinyl chloride, DCE, TCA, 1,1,2-TCA, 1,1,2,2-TCA and toluene (Figure 2-8). The maximum detections of these compounds were found at depths ranging from zero to six inches below grade.

SVOCs, pesticides, and metals were also detected in the sediments of Edwards Creek (Figures 2-9, 2-10, and 2-11 respectively). The detected concentrations of the SVOCs and metals do not appear to be related to site operations and are most likely due to natural processes. Detections of pesticides are attributed to the routine application of these compounds at MCB Camp Lejeune in the past. Based upon the historical evidence of pesticide application and the detected concentrations, their presence is not attributed to any local source, but instead to general basewide application.

2.2.6.3 Groundwater

Groundwater contamination at Site 89 is present in the surficial aquifer (Figures 2-12 and 2-13). Concentrations of VOCs in the groundwater are significantly higher than allowable state and federal standards. Contaminants detected include vinyl chloride, trans-1,2-DCE, cis-1,2-DCE, 1,1,1-TCA, TCE, and PCE. The highest concentrations of VOCs occurred within the DRMO area at permanent monitoring well 89-MW02. Shallow groundwater contamination appears to be limited to the DRMO area. It appears that groundwater contamination has reached Edwards Creek based on the elevated levels of VOCs in wells 89-TW08 and 89-TW13, as well as the elevated levels of VOCs in the creek itself. The extent of groundwater contamination in the lower portion of the surficial aquifer extends at least 1,000 feet east of the site. Cis-1,2-DCE and TCE were detected above in allowable state and federal standards well 89-TW23IW.

It is apparent that the vertical and horizontal extent of groundwater contamination has not been defined east of Site 89. The extent of contamination must be confirmed through further investigative work and sampling efforts. Additionally, confirmation of the groundwater contamination boundary and plume monitoring will be performed. These tasks may be accomplished by completing the following items:

- Utilization of temporary intermediate monitoring wells and a mobile laboratory to fully define the extent of groundwater contamination. These additional temporary wells would be located north and east of the plume at Site 89.

- Installation of permanent shallow (Type II) monitoring wells in and around the perimeter of the estimated contaminant plume.

- Installation of both intermediate (Type II) and deep (Type III) wells at points within and around the estimated contaminant plume boundary. Intermediate wells will extend to approximately 40 feet bgs, while deep wells may extend another 10 to 20 feet into the aquifer.

- Collection of soil samples during monitoring well installation. In addition to environmental testing, geotechnical analyses should be conducted on these samples to assist in the preparation of groundwater migration and transport models and in the selection and design of a remedial alternative.

- Groundwater sampling from shallow, intermediate, and deep permanent monitoring wells for the contaminants of concern (i.e., VOCs) and natural attenuation parameters.

- Measurement of groundwater elevations to establish the local groundwater flow regime in the shallow aquifer and an examination of potential head differences between shallow and deeper monitoring wells. In addition, the relationship between Edwards Creek and groundwater flow must be clearly defined. Installation of staff gauges in Edwards Creek will be required to establish relationships between the hydrogeologic framework and the influence of the New River to the east.

- Completion of aquifer tests (slug tests) to establish the hydraulic conductivity of the both the surficial and Castle Hayne aquifers. A comparison of vertical and horizontal conductivity values should be made.

2.3 Site 93 (TC-942)

This section addresses the setting, site topography and drainage features, site history, site geology and hydrogeology for Site 93 (TC-942).

2.3.1 Site Location and Setting

This former UST area, which has evolved into Site 93, is located near the intersection of Ninth and E Street in the Camp Geiger area. UST 942, was located several feet from the southwest corner of Building TC-942. The site is bordered by the upper reach of Edwards Creek to the east, Curtis Road is approximately one half mile to the south, and Camp Geiger to the north and west. Edwards Creek is the nearest surface water body, located approximately 525 feet east of the former UST basin. The nearest known supply wells (TC-700 and TC-901) are located approximately 1,600 feet northwest and 1,400 feet west of the study area, respectively. Figure 2-14 is a site map illustrating the general layout of the Site 93 .

2.3.2 Site Topography and Drainage

The natural topography of Site 93 is relatively flat. Ground surface elevation of approximately 13 to 15 feet above mean sea level (MSL) (REWEI, 1994).

Storm water runoff would tend to drain from the investigation area in a southerly direction to a storm sewer system along 10th Street. The storm sewer system flows in an easterly direction and discharges to Edwards Creek approximately 500 feet from the southeast corner of the site.

The NC DEHNR stream classifications for Edwards Creek are SC (aquatic life propagation and survival, fishing, wildlife, and secondary recreation), HQW (high quality water), and NSW (nutrient sensitive water).

2.3.3 Site History

One 550-gallon UST was closed and removed in December 1993. There is no documentation available concerning the installation date or usage of the UST. Based on elevated levels of oil and grease at the time of tank removal, a release is suspected to have occurred. A subsequent investigation was conducted and five monitoring wells were installed around the UST excavation. The area previously investigated has been expanded to determine if there are any other source areas for the possible contamination. The fenced area west of Building TC-940 was reportedly used as a motor pool area from 1976 to 1986, then a chow hall. The chow hall has since been demolished. Consequently, the study area now includes areas east, west, and south of Buildings TC-940 and TC-942 and the area where the UST was excavated.

The buildings in this area were constructed during the Korean War era. Building TC-942 currently functions as a supply room for the Military Infantry School. Items such as field jackets, ponchos, and canteens area stored in the building. Other buildings in the area serve as classrooms for the school and barracks.

Two storage boxes are located between Building TC-940 and TC-942. One storage box contains spray paint cans and the other contains cleaner for canteens (calcium hypochlorite). The storage boxes have been in this location for approximately two years. There is also a steam line which is located between the two buildings. Prior to 1983, each building had one associated UST heating oil tank.

2.3.4 Site Geology and Hydrogeology

A fairly consistent depositional sequence was observed in the borings throughout Site 93 during the Phase I investigation. This observed sequence is similar to that of Site 89 with one notable exception; the Castle Hayne confining unit is absent underneath Site 93 and vicinity.

During the Phase I study, the undifferentiated and River Bend Formations were encountered. The Belgrade Formation was not observed under Site 93. The undifferentiated formation is comprised primarily of loose to medium dense sands with lesser amounts of silt and clay of the Holocene and Pleistocene ages. A substantial, shallow silt and clay layer is present immediately south of the site, and between "C" and "F" Streets. Beneath Site 93, the undifferentiated formation typically extends to a depth between 20 and 25 feet below ground surface (bgs). The River Bend Formation lies beneath the undifferentiated formation. This formation is predominantly composed of dense to very dense shell and fossil fragments interbedded with calcareous sands. The top of this formation was encountered approximately 20 to 25 feet bgs. The surficial aquifer is contained in the sediments of the undifferentiated and the upper portion of the River Bend Formations.

The green to greenish-gray fine sand Castle Hayne Confining Unit was not observed under Site 93. Based on the distribution of wells at both Sites 93 and 89, it appears that the Castle Hayne Confining Unit ends between "D" and "F" streets.

Groundwater was generally encountered from 5 to 10 bgs during the Phase I investigation. Groundwater elevation measurements indicate that groundwater flow in the surficial aquifer flows east-northeast toward Edwards Creek. Groundwater head differentials between the intermediate and shallow wells were evaluated to determine the presence of a vertical component of flow. The distribution of head differentials indicate a slight downward component of groundwater flow in areas away from Edwards Creek and an upward component of flow in areas proximate to Edwards Creek. This pattern indicates that groundwater recharge in the surficial aquifer occurs in interstream areas and discharge is at Edwards Creek. Furthermore, Edwards Creek is a groundwater divide in the surficial aquifer.

2.3.5 Previous Investigations

On behalf of LANTDIV, R.E. Wright Associates, Inc. performed a five well site check adjacent to former UST TC-942. Five soil borings were drilled and monitoring wells were subsequently installed in March 1995. Soil and groundwater samples were collected for laboratory analysis to characterize hydrocarbon contamination in the soil. Previous investigation sampling locations are shown on Figure 2-15.

2.3.5.1 Soil Investigation

Continuous split-spoon soil samples were collected to a depth of 4 (MW04 and MW05) to 6 feet bgs (MW01, MW02, and MW03). The sample that exhibited the highest PID reading from each boring was collected as a sample. Five soil borings were analyzed for oil and grease and halogenated solvents. Analytical findings are summarized in Table 2-7.

Subsurface Soil:

- Soil vapor readings were highest in the two to four foot interval, directly above the saturated soil zone. Hydrocarbon odors were detected in all the soil borings except MW04. Gasoline odors were detected in monitoring well MW05. Hydrocarbon staining was noted in soil borings MW01, MW02, and MW03.

- Oil and grease results from the soil boring samples ranged from 56,100 to 8,126,000 µg/kg, except for levels below the detection limit in MW02 and MW04 soil samples. Concentrations of oil and grease at MW01 (8,126,000 µg/kg) and MW03 (1,439,000 µg/kg) were above regulatory limits. Naphthalene and tetrachloroethene were detected in MW05 (0.049 µg/kg and 20 µg/kg, respectively). 1,2,4-Trichlorobenzene and 1,2,4-trimethylbenzene were detected in duplicate sample MW05 (2.3 µg/kg and 0.93 µg/kg, respectively). No free phase product was noted in any of the borings.

2.3.5.2 Groundwater Investigation

One round of groundwater samples was collected from the five newly installed monitoring well and analyzed for VOCs, SVOCs, and TCLP metals. Groundwater was encountered at approximately 2.9 to 3.1 feet bgs. Monitoring well data is presented in Table 2-8. Groundwater samples indicated concentrations of several chlorinated solvents detected at concentrations exceeding USEPAs maximum contaminant level (MCL) standards (see Table 2-9).

- VOCs were detected in every groundwater sample with the exception of MW03. Cis-1,2-dichloroethene (250 µg/L) and chlorobenzene (90 µg/L) detected in MW02 exceeded regulatory levels. Tetrachloroethene and trichloroethene concentrations detected in MW05 (90 µg/L and 30 µg/L, respectively) also exceeded regulatory levels.

- Several SVOCs were detected in the groundwater samples collected from MW02 and MW04. However, concentrations of these SVOCs were less than regulatory standards.

- Total cadmium concentrations in all five wells and the lead concentration in MW01 exceeded regulatory criteria.

2.3.6 Phase I Investigation Summary

The Phase I investigation has further delineated the extent of VOC contamination in the groundwater in the vicinity of Site 93. The area investigation centered around Building TC-942, with wells being placed in all four directions from the site. Figures 2-16 and 2-17 show the distribution of contaminants in the groundwater.

The groundwater investigation at Site 93 involved the collection of groundwater samples from one existing permanent monitoring well and 14 temporary monitoring wells. Each of the groundwater samples collected were analyzed according the EPA Method 8240. In addition, four samples were analyzed by the fixed based laboratory for full TCL VOAs using CLP protocols.

Five VOCs were detected in the shallow groundwater samples collected at Site 93 including trans-1,2-DCE, cis-1,2-DCE, 1,1,1-TCA, TCE, and PCE. Concentrations ranged from 0.1 µg/L of TCE and PCE to 175 µg/L of cis-1,2-DCE at temporary well TW01. The most frequently detected compound was TCE which was detected in 10 of the 20 samples collected from Site 93. Only three VOCs were detected in the intermediate wells including cis-1,2-DCE, TCE, and PCE. The concentrations of the compounds ranged from 0.1 µg/L of TCE and PCE to 4 µg/L of cis-1,2-DCE.

The majority of the groundwater contamination at Site 93 appears to be concentrated in the shallow groundwater in the area near the former UST. This is supported by the fact that the highest concentrations of VOCs were located at the permanent monitoring well 93-MW05 and directly south at temporary well TW01. Groundwater contamination was not present north or east of the former UST. In addition, the intermediate groundwater samples detected only low concentrations of VOCs. Contamination of the shallow groundwater was evident to the south and west of the site, but decreased substantially in these directions. Figure 2-16 provides an estimate of the area that has been impacted by groundwater contamination at Site 93. The estimated area of shallow groundwater contamination is local to the former UST site and extends approximately 650 feet west of the site to TW07.

Additional work required at Site 93 will be limited to the confirmation of the shallow groundwater contamination boundary and monitoring of the plume. This work will likely include:

- Installation of permanent, shallow, intermediate and deep (Type II) monitoring wells. The monitoring wells should be positioned in and around the estimated area of groundwater contamination.

- Collection of soil samples during monitoring well installation.

- Groundwater sampling from permanent monitoring wells for the contaminants of concern (i.e., VOCs) and natural attenuation parameters.

- Measurement of groundwater elevations to establish the local groundwater flow regime in the shallow aquifer and an examination of potential head differences between shallow and deeper monitoring wells. In addition, the relationship between Edwards Creek and groundwater flow must be clearly defined. Staff gauges installed in Edwards Creek as a part of the Site 89 investigation could be used to establish relationships between the hydrogeologic framework and the influence of the New River to the east.

2.4 Previous Investigation North of Sites 89 and 93

An investigation was conducted, at Site 35, north of Sites 89 and 93 which involved the installation of temporary monitoring wells and permanent monitoring wells. Temporary monitoring wells (intermediate depth) 40 to 50 feet bgs were installed in expanding horizontal locations until it could be demonstrated that contaminant levels were decreasing to levels less than state or federal regulatory levels. Temporary monitoring wells TW12B, TW13B, TW15B, and TW29B were installed in the vicinity of Sites 89 and 93. A permanent intermediate monitoring well (MW42B) also was installed adjacent to TW12B (Figure 2-12). The monitoring wells were determined to define the contaminant plume to the north of Site 89 and 93. However, a separate contaminant plume, believed to be distinctive and associated with Sites 89 and 93, was identified. This plume is believed to be distinctive due to contaminant levels, shown in Table 2-10, and the contaminant boundaries to the north of Site 89.

SECTION 2.0 TABLES

TABLE 2-1

GEOLOGIC AND HYDROGEOLOGIC UNITS IN THE COASTAL PLAIN OF NORTH CAROLINA REMEDIAL INVESTIGATION/FEASIBILITY STUDY PROJECT PLANS - CTO-0344 MCB CAMP LEJEUNE, NORTH CAROLINA

GEOLOGIC UNITS			HYDROGEOLOGIC UNITS
System	Series	Formation	Aquifer and Confining Unit
Quaternary	Holocene/Pleistocene	Undifferentiated	Surficial Aquifer
Tertiary	Pliocene	Yorktown Formation[1]	Yorktown Confining Unit
			Yorktown Aquifer
	Miocene	Eastover Formation[1]	Pungo River Confining Unit
		Pungo River Formation[1]	Pungo River Aquifer
		Belgrade Formation[2]	Castle Hayne Confining Unit
	Oligocene	River Bend Formation	Castle Hayne Aquifer
	Eocene	Castle Hayne Formation	Beaufort Confining Unit[3]
	Palocene	Beaufort Formation	Beaufort Aquifer
Cretaceous	Upper Cretaceous	Peedee Formation	Peedee Confining Unit
			Peedee Aquifer
		Black Creek and Middendorf Formations	Black Creek Confining Unit
			Black Creek Aquifer
		Cape Fear Formation	Upper Cape Fear Confining Unit
			Upper Cape Fear Aquifer
			Lower Cape Fear Confining Unit
			Lower Cape Fear Aquifer
	Lower Cretaceous[1]	Unnamed Deposits[1]	Lower Cretaceous Confining Unit
			Lower Cretaceous Aquifer[1]
Pre-Cretaceous Basement Rocks		--	--

(1) Geologic and hydrologic units probably not present beneath Camp Lejeune.
(2) Constitutes part of the surficial aquifer and Castle Hayne confining unit in the study area.
(3) Estimated to be confined to deposits of Paleocene age in the study area.
Source: USGS, 1989.

TABLE 2-2

LAND UTILIZATION: DEVELOPED AREAS LAND USE[1]
REMEDIAL INVESTIGATION/FEASIBILITY STUDY PROJECT PLANS - CTO-0344
MCB, CAMP LEJEUNE, NORTH CAROLINA

Geographic Area	Oper.	Training (Instruc.)	Maint.	Supply/ Storage	Medical	Admin.	Family Housing	Troop Housing	CM	CO	Recreat.	Utility	Total
Hadnot Point	31 (2.9)	15 (1.4)	154 (14.3)	157 (14.4)	10 (0.9)	122 (11.3)	22 (2.0)	196 (18.1)	115 (10.7)	36 (3.3)	182 (16.9)	40 (3.7)	1,080 (100)
Paradise Point	1 (0)		3 (0.4)	1 (0)			343 (34)	19 (1.9)	31 (3.1)		610 (60.4)	2 (0.2)	1,010 (100)
Berkeley Manor/ Watkins Village							406 (80)		41 (8.1)	1 (0.2)	57 (11.2)	2 (0.5)	507 (100)
Midway Park		1 (0.4)		2 (0.7)		2 (0.7)	248 (92.2)		8 (3.0)	3 (1.1)	4 (1.5)	1 (0.4)	269 (100)
Tarawa Terrace I and II			3 (0.5)			1 (0.3)	428 (77.4)		55 (9.9)	11 (2.0)	47 (8.5)	8 (1.4)	553 (100)
Knox Trailer							57 (100)						57 (100)
French Creek	8 (1.4)	1 (0.2)	74 (12.7)	266 (45.6)	3 (0.5)	7 (1.2)		122 (20.9)	22 (3.8)	6 (1.0)	74 (12.7)		583 (100)
Courthouse Bay		**73** **(28.6)**	**28** **(10.9)**	**14** **(5.5)**		**12** **(4.7)**	**12** **(4.7)**	**43** **(16.9)**	**15** **(5.9)**	**4** **(1.6)**	**43** **(16.9)**	**11** **(4.3)**	**255** **(100)**
Onslow Beach	6 (9.8)	1 (1.6)	3 (4.8)	2 (3.2)	1 (1.6)	2 (3.2)		2 (3.2)	12 (19.3)		25 (40.3)	8 (13.0)	62 (100)
Rifle Range		1 (1.3)	1 (1.3)	7 (8.8)	1 (1.3)	5 (6.3)	7 (8.8)	30 (37.5)	5 (6.3)	1 (1.3)	9 (11.3)	13 (16.3)	80 (100)
Camp Geiger	4 (1.9)	15 (6.9)	19 (8.8)	50 (23.1)		23 (10.6)		54 (25.0)	27 (12.5)	2 (1.0)	16 (7.4)	6 (2.8)	216 (100)
Montford Point	6 (2.6)	48 (20.5)	2 (0.9)	4 (1.7)	2 (0.9)	9 (3.9)		82 (35.2)	20 (8.6)	1 (0.4)	49 (21.0)	10 (4.3)	233 (100)
Base-Wide Misc.	1 (0.8)			87 (68.0)		3 (2.3)			19 (14.8)			18 (14.1)	128 (100)
TOTAL	**57** **(1.1)**	**155** **(3.1)**	**287** **(5.7)**	**590** **(11.7)**	**17** **(0.38)**	**186** **(3.7)**	**1,523** **(30.2)**	**548** **(10.8)**	**370** **(7.4)**	**65** **(1.3)**	**1,116** **(22.2)**	**119** **(2.4)**	**5,033** **(100)**

[1]Upper number is acres, lower number is percent.

TABLE 2-3

PREVIOUS SOIL INVESTIGATION ANALYTICAL RESULTS
OPERABLE UNIT NO. 16 (SITE 89)
CTO 0344
MCB CAMP LEJEUNE, NORTH CAROLINA

Analysis	MW01 (6-8 feet bgs)
Oil and Grease (µg/kg):	1,400,000
Halogenated Solvents	BDL
TCLP Volatiles	BDL
TCLP Semivolatiles	BDL
TCLP Pesticides	BDL
TCLP Inorganics	BDL

Notes:

BDL - Below Detection Limit
bgs - Below Ground Surface
TCLP - Toxicity Characteristic Leaching Procedure
Concentrations expressed in µg/kg (ppb)

Source: REWEI, 1994

TABLE 2-4

EXISTING MONITORING WELL DATA
OPERABLE UNIT NO. 16 (SITE 89)
CTO 0344
MCB CAMP LEJEUNE, NORTH CAROLINA

Sample Location	Surface Elevation (msl)	Top of Casing Elevation (msl)	Depth to Groundwater (BTOC)	Calculated Groundwater Elevation (msl)
MW01	13.7	13.32	4.94	8.38
MW02	13.7	14.81	6.58	8.23
MW03	14.2	15.38	7.12	8.26

Notes:

msl - Mean Sea Level
BTOC - Below Top of Casing

Source: REWEI, 1994

TABLE 2-5

PREVIOUS GROUNDWATER INVESTIGATION ANALYTICAL RESULTS
OPERABLE UNIT NO. 16 (SITE 89)
CTO-0344
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	NCWQS	Federal MCL	MW01	MW01 Duplicate	MW02	MW03
Volatiles (µg/L): Cis-1,2-Dichloroethene	70	70	585	550	2,130	70
Trans-1,2-Dichloroethene	70	100	390	370	1,580	60
1,1,2,2-Tetrachloroethane	--	--	4,300	3,400	8,600	240
Tetrachloroethene	0.7	5	35	38	BDL	BDL
1,1,2-Trichloroethane	--	5	29	29	BDL	BDL
Trichloroethene	2.8	5	580	580	1,500	80

Notes:

-- - No Published Standard
BDL - Below Detection Limit
NCWQS - North Carolina Water Quality Standard
MCL - Maximum Contaminant Level
Shaded areas indicate non compliant concentrations

Source: REWEI, 1994

TABLE 2-6

PREVIOUS SURFACE WATER ANALYTICAL RESULTS
OPERABLE UNIT NO. 16 (SITE 93)
CTO 0344
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Water Standard*	44-EC-SW01-02 09/28/95	44-EC-SW02-02 09/28/95	44-EC-SW03-02 09/28/95	44-EC-SW04-02 09/28/95	44-EC-SW06-01 09/28/95	44-EC-SW 7-01 09/28/95	44-EC-SW08-01 09/28/95	44-EC-SW09-01 09/28/95
Volatiles (µg/L):									
Vinyl Chloride	525	16	7J	10U	10U	25	15	38	10U
1,1-Dichloroethene	3.2	1J	10U	10U	10U	2J	10U	1J	10U
1,2-Dichloroethene (Total)	7.0	93J	51J	42J	21J	110J	68J	120J	2J
Trichloroethene	92.4	22	11	10	5J	22	4J	7J	4J
1,1,2-Trichloroethane	42.0	10U	10U	10U	10U	10U	10U	1J	10U
1,1,2,2-Tetrachloroethane	10.8	26	19	16	8J	32	32	42	10U

Notes:

µg/L = microgram per liter
J = value is estimated
U = not detected
* = Based on Edwards Creek classification

Source: Baker, 1996

TABLE 2-7

PREVIOUS SOIL INVESTIGATION ANALYTICAL RESULTS
OPERABLE UNIT NO. 16 (SITE 93)
CTO 0344
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	MW01 (2-3 Feet bgs)	MW02 (2-3 Feet bgs)	MW03 (2-3 Feet bgs)	MW03 DUP	MW04 (2-3 Feet bgs)	MW05 (3-4 Feet bgs)	MW05 DUP
Oil and Grease (µg/kg):	8,126,000	BDL	56,100	1,439,000	BDL	127,000	227,000
Halogenated Solvents (µg/kg):	BDL	BDL	BDL	BDL	BDL		
Naphthalene						0.049	BDL
1,2,4-Trichlorobenzene						BDL	2..3
1,2,4-Trimethylbenzene						BDL	0.93
TCLP Volatiles (µg/L):	BDL	NA	BDL	NA	NA	20	NA
Tetrachloroethene							
TCLP Semivolatiles (µg/L):	BDL	NA	BDL	NA	NA	BDL	NA
TCLP Inorganics (µg/L):							
Arsenic	32	NA	32	NA	NA	29	NA
Barium	3,300	NA	3,600	NA	NA	600	NA
Cadmium	16	NA	22	NA	NA	BDL	NA
Chromium	190	NA	210	NA	NA	70	NA
Lead	BDL	NA	100	NA	NA	BDL	NA
Mercury	0.6	NA	0.4	NA	NA	BDL	NA
Selenium	15	NA	12	NA	NA	BDL	NA
Silver	25	NA	BDL	NA	NA	22	NA

Notes:

BDL - Below Detection Limits
bgs - Below Ground Surface
µg/L - Micrograms per liter
µg/kg - Micrograms per kilogram
ND - Not Detected
NA - Not Analyzed
TCLP - Toxic Characteristic Leaching Procedure

Source: REWEI, 1995

TABLE 2-8

EXISTING MONITORING WELL DATA
OPERABLE UNIT NO. 16 (SITE 93)
CTO 0344
MCB CAMP LEJEUNE, NORTH CAROLINA

Sample Location	Surface Elevation (msl)	Top of Casing Elevation (msl)	Depth to Groundwater (BTOC)	Calculated Groundwater Elevation (msl)
MW-01	15.14	14.61	2.33	12.28
MW-02	15.38	15.00	2.73	12.27
MW-03	15.21	14.85	2.58	12.27
MW-04	15.25	14.96	2.66	12.30
MW-05	15.19	14.79	2.52	12.27

Notes:

msl - Mean Sea Level (in feet)
BTOC - Below Top of Casing (in feet)

Source: REWEI, 1995

TABLE 2-9

PREVIOUS GROUNDWATER INVESTIGATION ANALYTICAL RESULTS
OPERABLE UNIT NO. 16 (SITE 93)
CTO 0344
MCB CAMP LEJEUNE, NORTH CAROLINA

Analysis	NCWQS	Federal MCL	MW01	MW02	MW03	MW04	MW05
Volitiles (µg/L):							
Cis-1,2-Dichloroethene	70	70	4.3	250	BDL	9.5	23.4
Chlorobenzene	50	--	BDL	90	BDL	BDL	BDL
1,2-Dichlorobenzene	--	600	BDL	110	BDL	BDL	BDL
trans-1,2-Dichloroethene	70	100	BDL	53.0	BDL	2.4	10.3
Ethylbenzene	29	700	BDL	BDL	BDL	1.6	BDL
Naphthalene	21	--	BDL	BDL	BDL	57.3	17.0
1,2,4-Trimethylbenzene	--	--	BDL	BDL	BDL	13.9	BDL
1,3,5-Trimethylbenzene	--	--	BDL	BDL	BDL	5.8	BDL
Xylenes (total)	530	10,000	BDL	BDL	BDL	2.5	BDL
1,1,2,2-Tetrachloroethane	--	--	BDL	BDL	BDL	BDL	48.0
Tetrachloroethene	0.7	5	BDL	BDL	BDL	BDL	90.0
Trichloroethene	2.8	5	BDL	BDL	BDL	BDL	30.0
Semivolatiles (µg/L):							
1,4-Dichlorobenzene	--	75	BDL	12.3	BDL	BDL	BDL
1,2-Dichlorobenzene	--	600	BDL	94.8	BDL	BDL	BDL
1,2,4-Trichlorobenzene	--	70	BDL	4.32	BDL	BDL	BDL
Naphthalene	21	--	BDL	19.3	BDL	36.8	BDL

Notes:

-- - No Published Standard
BDL - Below Detection Limit
MCL - Maximum Contaminant Level
NCWQS - North Carolina Water Quality Standard
Shaded areas indicate non compliant concentrations, blank areas indicate non detected concentrations.

Source: REWEI, 1995

TABLE 2-9 (continued)

PREVIOUS GROUNDWATER INVESTIGATIONS ANALYTICAL RESULTS
OPERABLE UNIT NO. 16 (SITE 93)
CTO 0344
MCB CAMP LEJEUNE, NORTH CAROLINA

Analyte	NCWQS	Federal MCL	MW01	MW02	MW03	MW04	MW05
Arsenic, Total	50	50	19	14	46	11	9
Barium, Total	2,000	2,000	BDL	BDL	BDL	BDL	BDL
Cadmium, Total	5	5	42	41	47	38	39
Chromium, Total	50	100	BDL	BDL	BDL	BDL	BDL
Lead, Total	15	15*	17	7	10	4	2
Mercury, Total	1.1	2	0.3	0.2	0.2		0.2
Selenium, Total	50	50	8	7	6	7	4
Silver, Total	18	--	BDL	BDL	BDL	BDL	BDL

Notes:

-- - No Published Standard
BDL - Below Detection Limit
NCWQS - North Carolina Water Quality Standard
MCL - Maximum Contaminant Level
Concentrations reported in µg/L (ppb)
Shaded areas indicate non compliant concentrations, blank areas indicate non detected concentrations
* Action Level

Source: REWEI, 1995

TABLE 2-10

PREVIOUS GROUNDWATER INVESTIGATION ANALYTICAL RESULTS
OPERABLE UNIT NO. 16 (SITES 89 AND 93)
CTO 0344
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	NCWQS	Federal MCL	TW12B	TW13B	TW15B	TW29B
Volatiles (µg/L):						
cis-1,2-Dichloroethene	70	70	ND	ND	ND	28
Trichloroethene	2.8	5	41	ND	4	220
1,2-Dichloroethene (total)	70	70	260	ND	13	ND

Notes:

ND = Not detected
µg/L = micrograms per liter
NCWQS = North Carolina Water Quality Standard
MCL = maximum contaminant level

SECTION 2.0 FIGURES

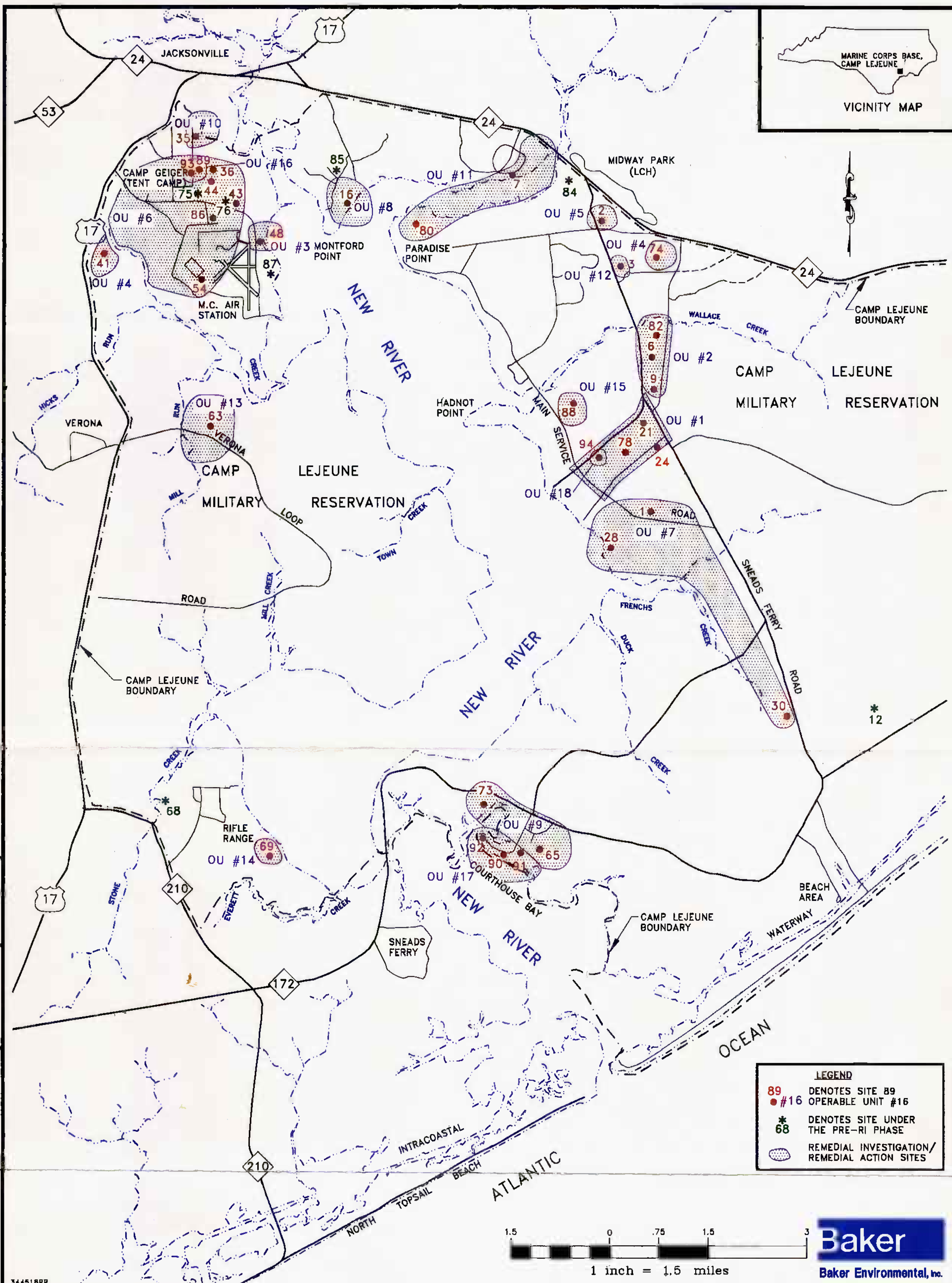
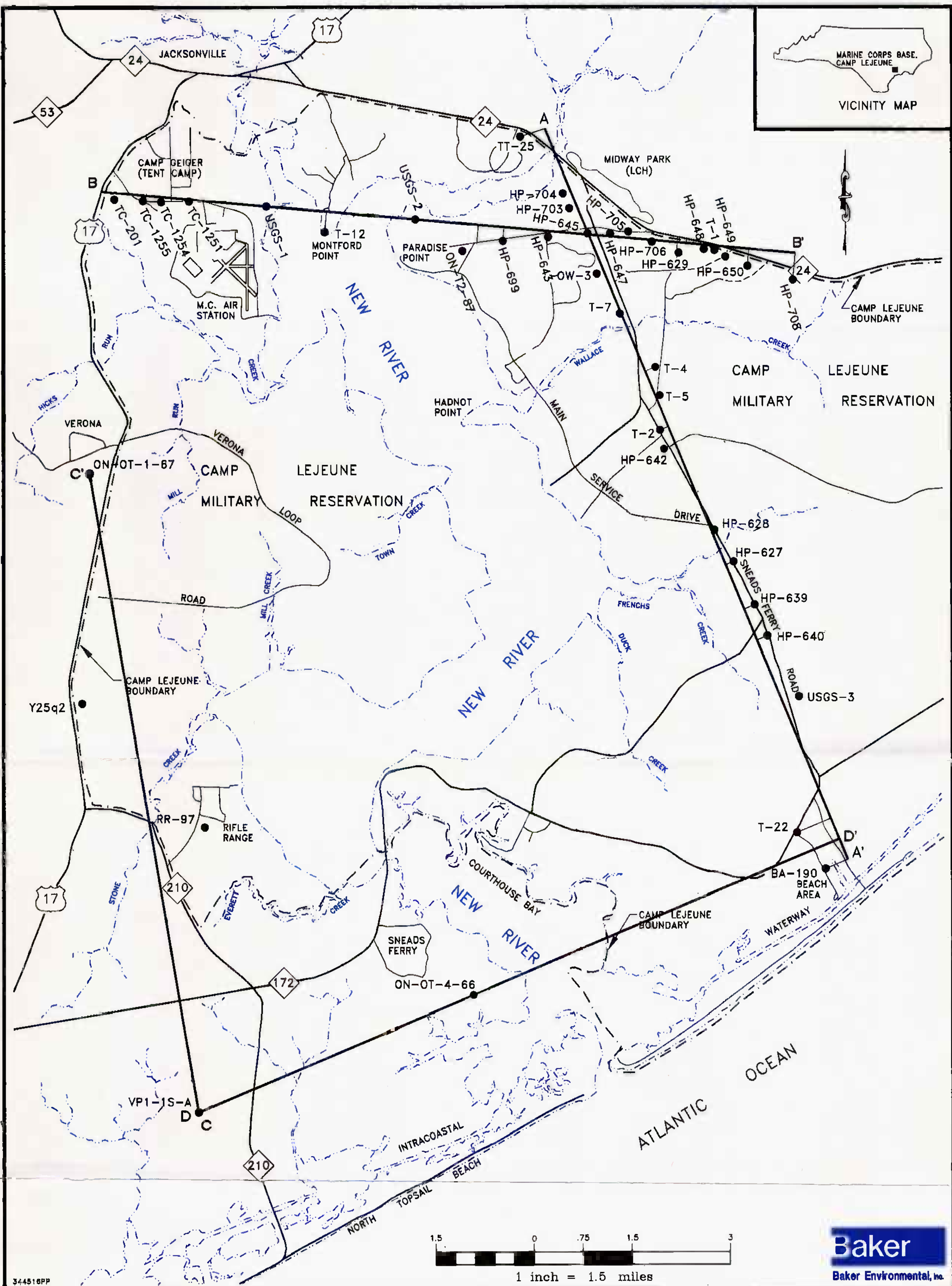


FIGURE 2-1
OPERABLE UNITS AND SITE LOCATIONS AT
MARINE CORPS BASE CAMP LEJEUNE
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01758EE B1Y

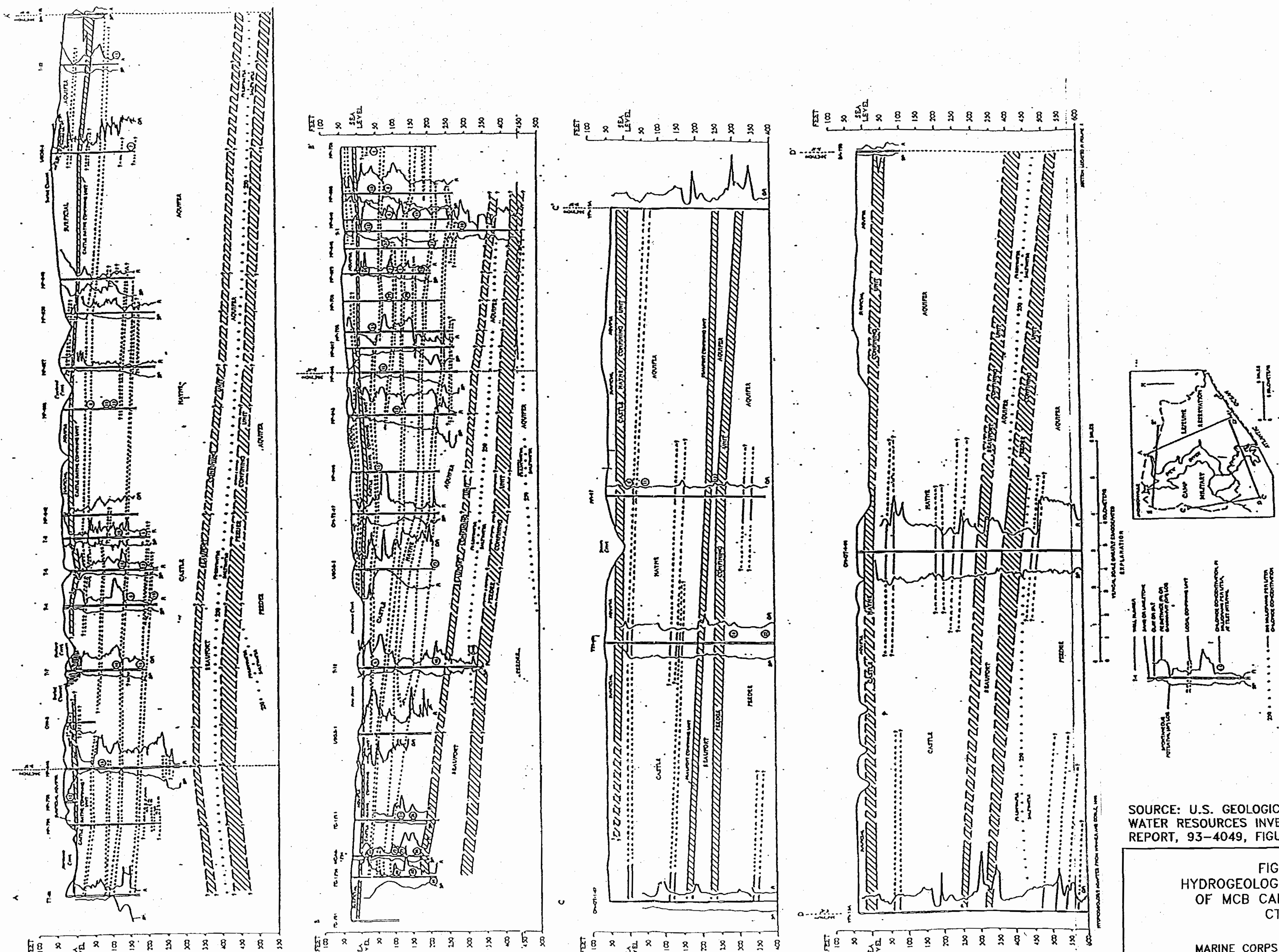


SOURCE: U.S. GEOLOGICAL SURVEY, WATER-RESOURCES INVESTIGATIONS REPORT, 93-4049, FIGURE 9

FIGURE 2-2
LOCATION OF HYDROGEOLOGIC CROSS-SECTIONS
MARINE CORPS BASE, CAMP LEJEUNE
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

344517PP

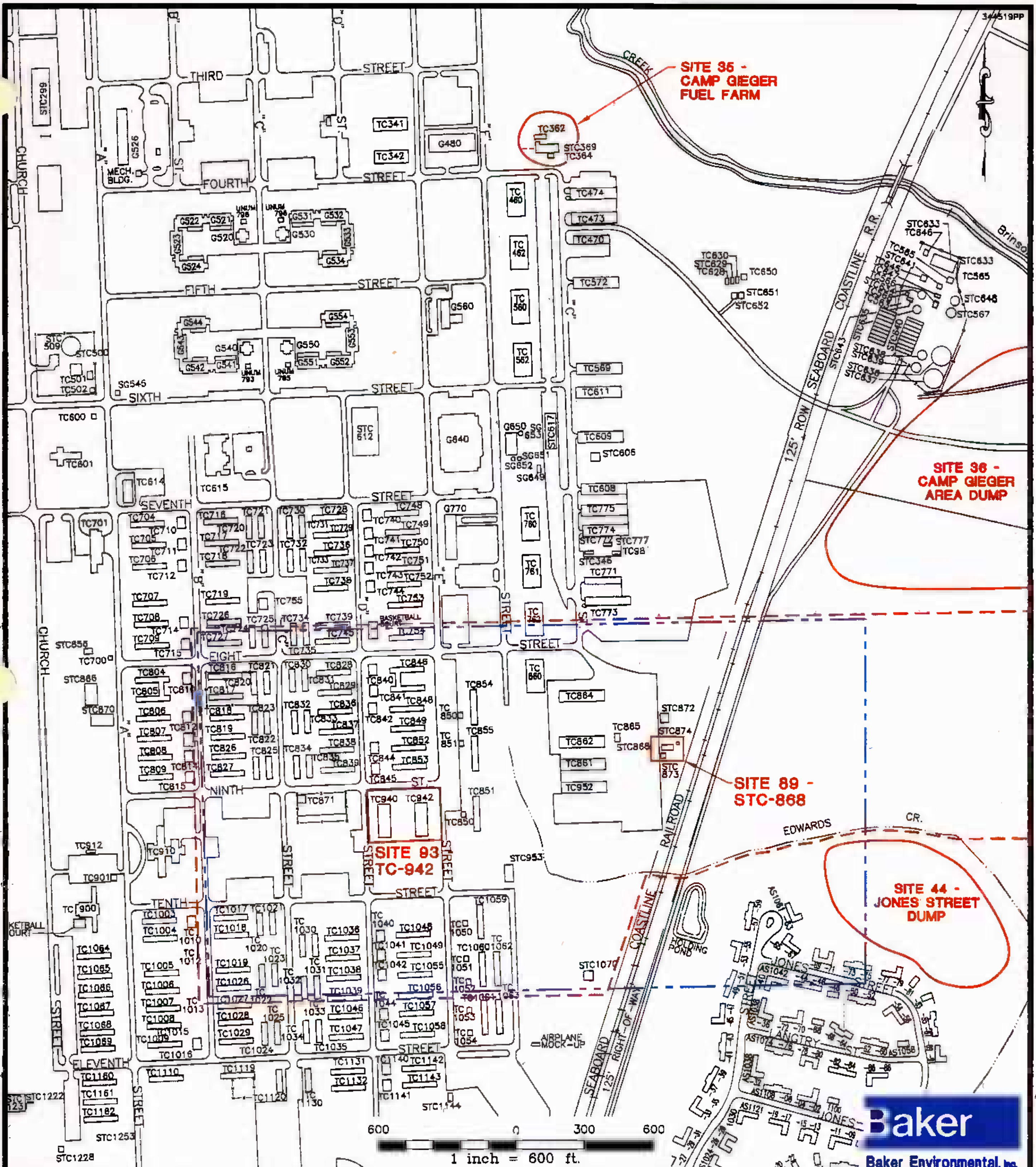


SOURCE: U.S. GEOLOGICAL SURVEY,
WATER RESOURCES INVESTIGATIONS
REPORT, 93-4049, FIGURE 9

FIGURE 2-3
HYDROGEOLOGIC CROSS-SECTIONS
OF MCB CAMP LEJEUNE AREA
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01758E012



LEGEND

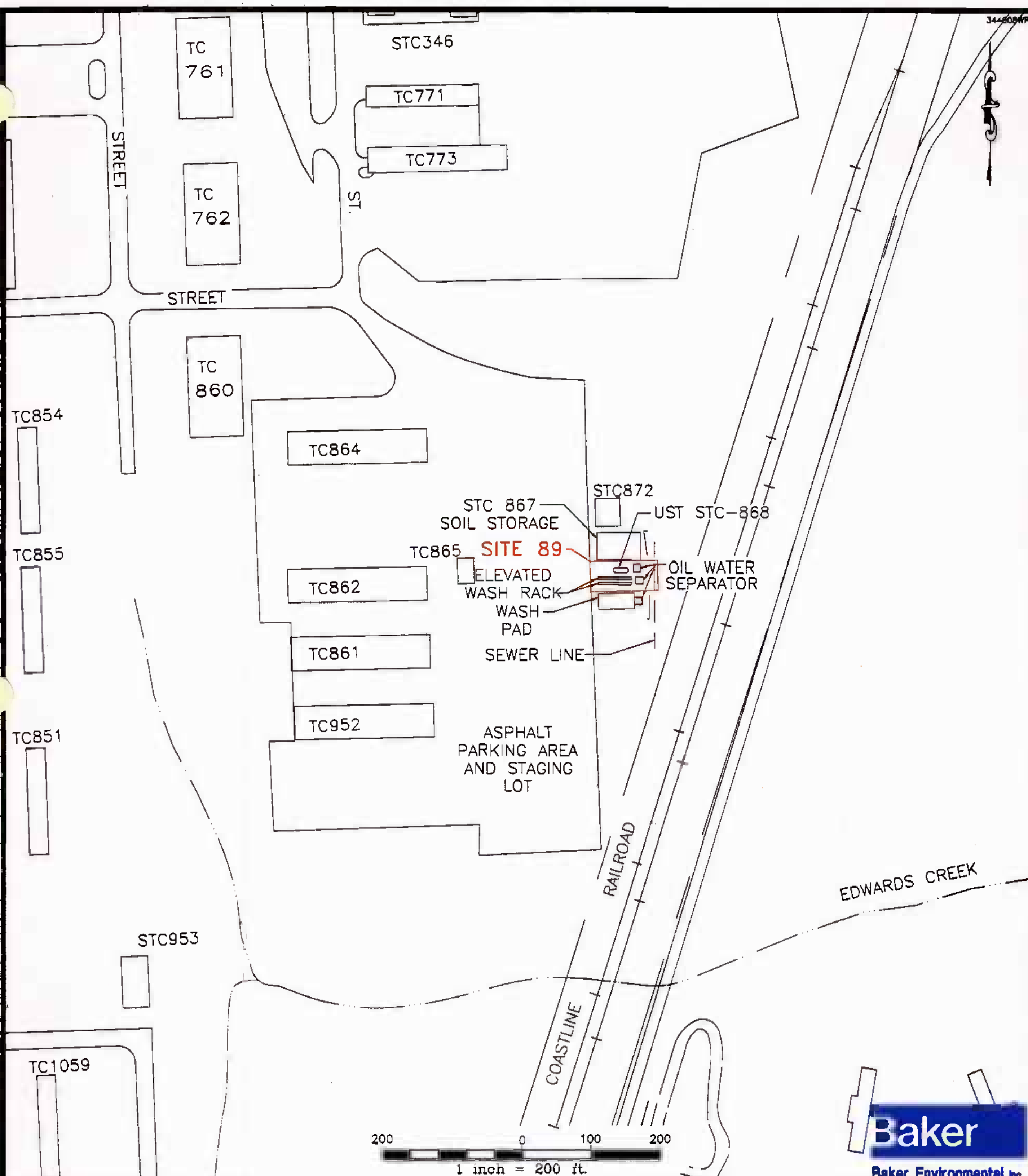
- TC1162 BUILDING
- RAILROAD TRACKS
- SITE BOUNDARY
- PHASE I INVESTIGATION AREA BOUNDARY
- PHASE II INVESTIGATION AREA BOUNDARY

SOURCE: LANTDIV, FEBRUARY 1992

FIGURE 2-4
SITES 89 AND 93 INVESTIGATION AREA
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01758EEB2Y



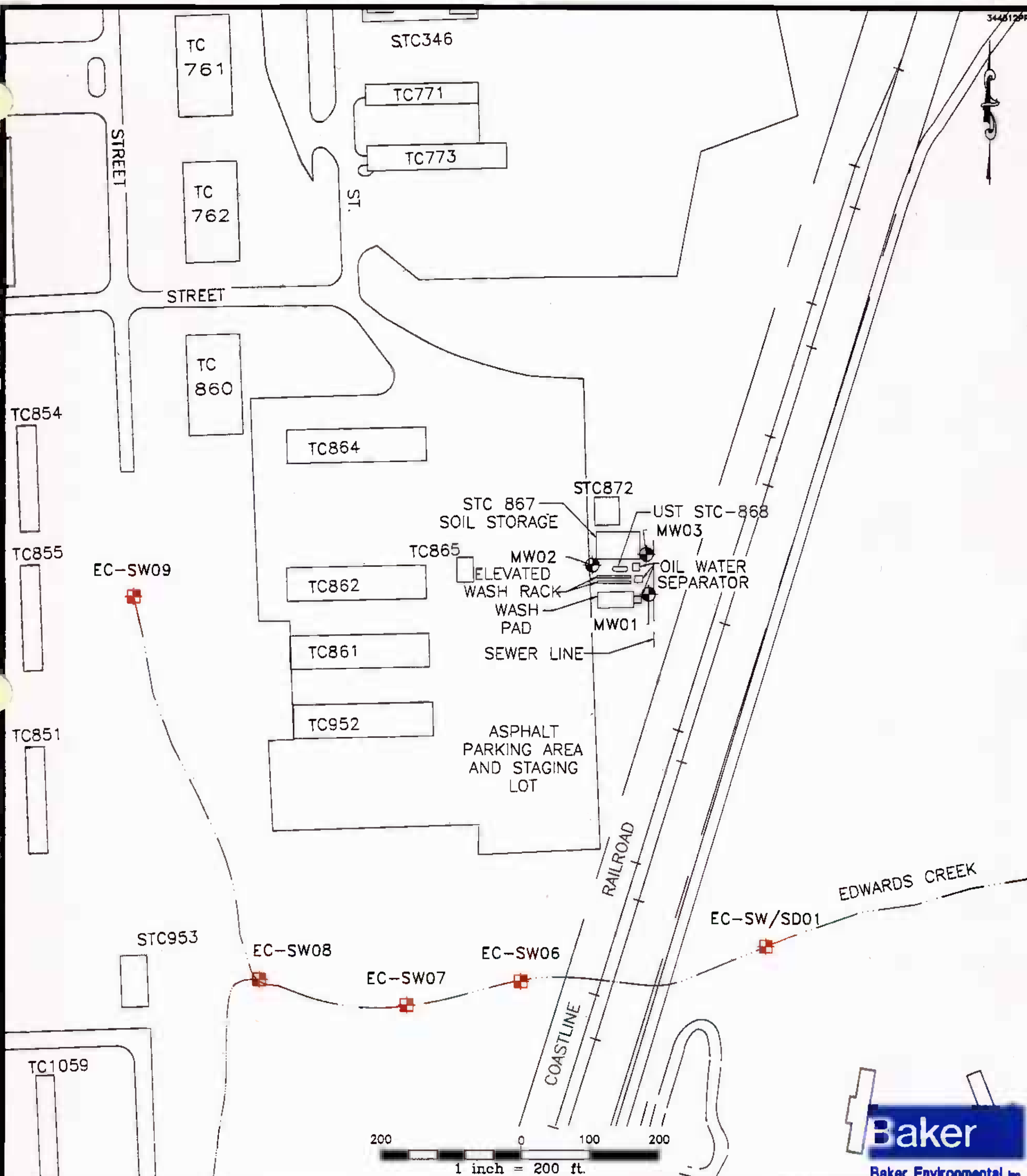
LEGEND

- BUILDING
- RAILROAD
- CREEK

SOURCE: MCB CAMP LEJEUNE REVISED BASE MAP 11/95

FIGURE 2-5
LOCATION MAP
SITE 89
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- EXISTING MONITORING WELL
- PREVIOUS SURFACE WATER SAMPLE LOCATION
- BUILDING
- RAILROAD
- CREEK

SOURCE: MCB CAMP LEJEUNE REVISED BASE MAP 11/95.

FIGURE 2-6
PREVIOUS SAMPLE LOCATIONS
SITE 89
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

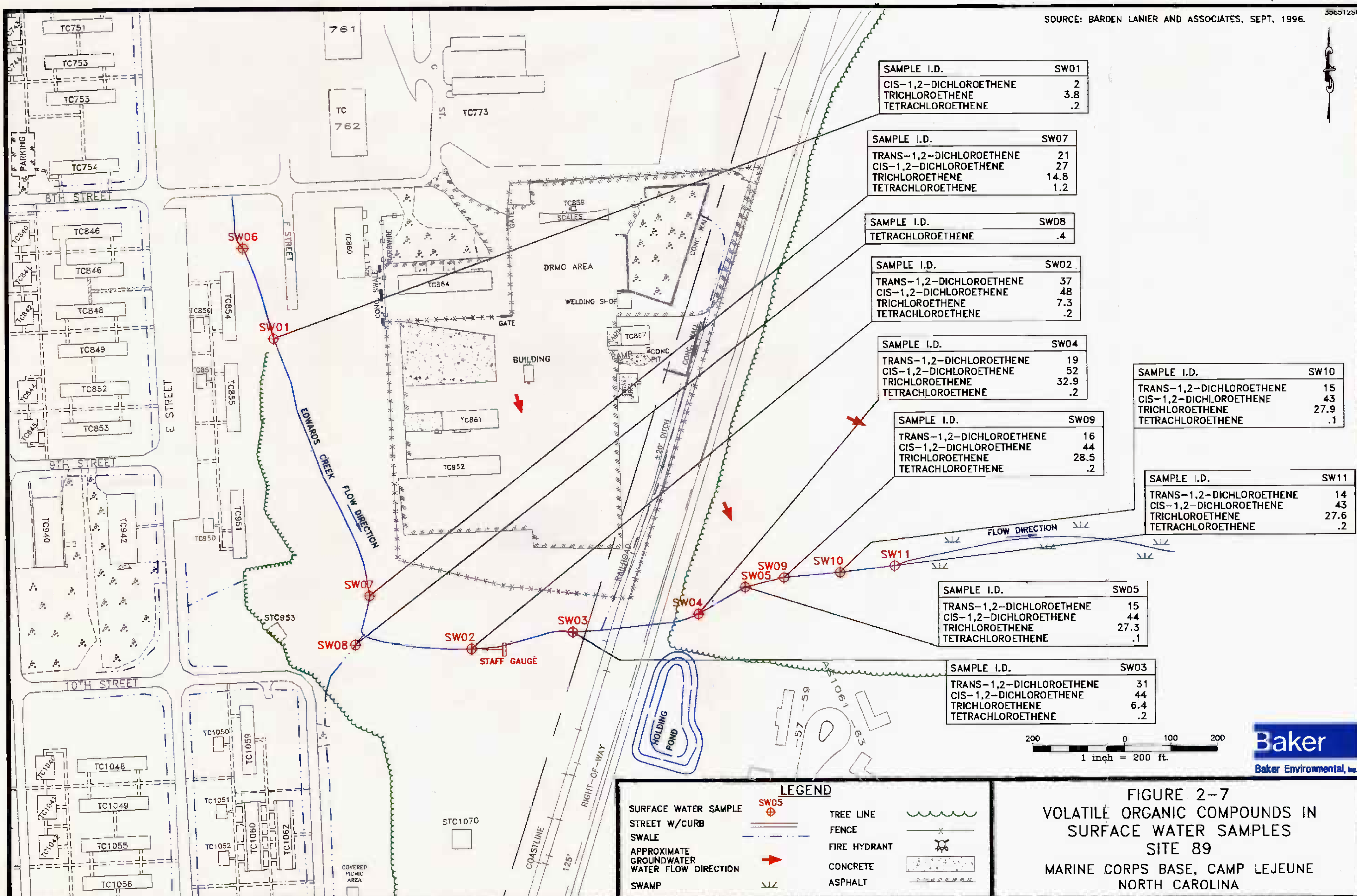
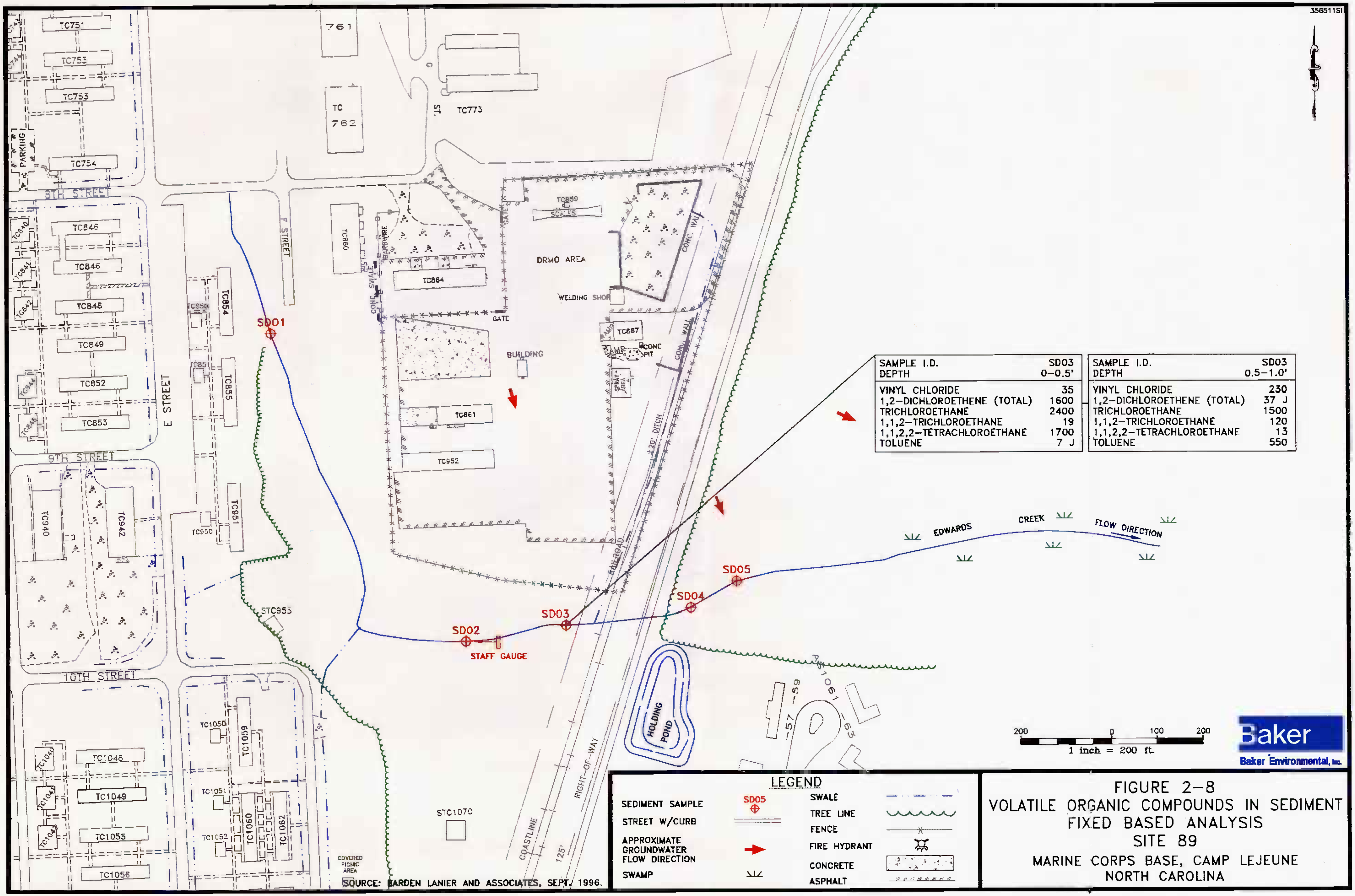


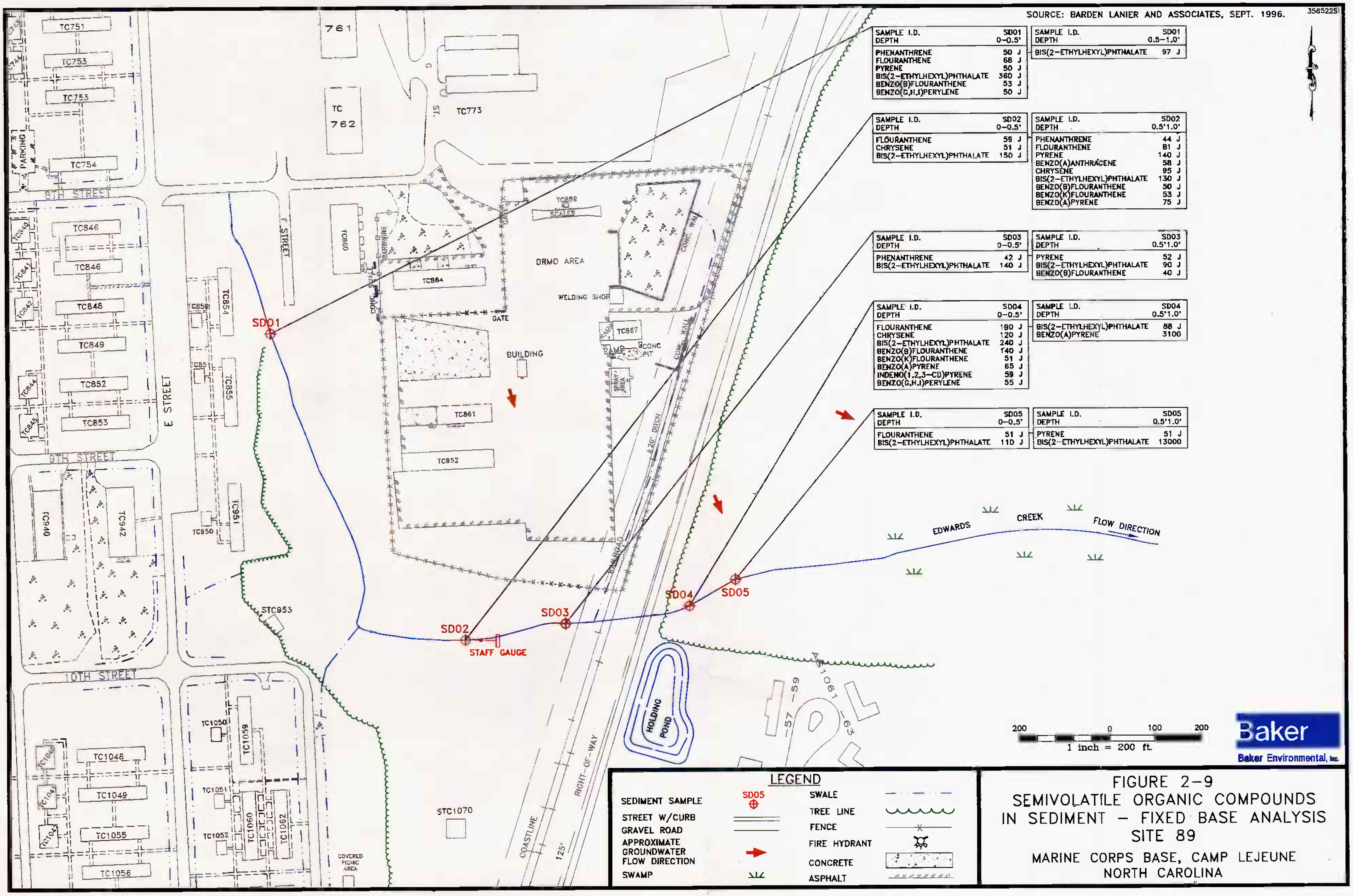
FIGURE 2-7
VOLATILE ORGANIC COMPOUNDS IN SURFACE WATER SAMPLES
SITE 89
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE I.D.	SD03
DEPTH	0–0.5'
VINYL CHLORIDE	35
1,2–DICHLOROETHENE (TOTAL)	1600
TRICHLOROETHANE	2400
1,1,2–TRICHLOROETHANE	19
1,1,2,2–TETRACHLOROETHANE	1700
TOLUENE	7 J

SAMPLE I.D.	SD03
DEPTH	0.5–1.0'
VINYL CHLORIDE	230
1,2–DICHLOROETHENE (TOTAL)	37 J
TRICHLOROETHANE	1500
1,1,2–TRICHLOROETHANE	120
1,1,2,2–TETRACHLOROETHANE	13
TOLUENE	550

FIGURE 2–8
VOLATILE ORGANIC COMPOUNDS IN SEDIMENT
FIXED BASED ANALYSIS
SITE 89
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



SAMPLE I.D.	SD01
DEPTH	0-0.5'
PHENANTHRENE	50 J
FLOURANTHENE	68 J
PYRENE	50 J
BIS(2-ETHYLHEXYL)PHTHALATE	360 J
BENZO(B)FLOURANTHENE	53 J
BENZO(G,H,I)PERYLENE	50 J

SAMPLE I.D.	SD01
DEPTH	0.5-1.0'
BIS(2-ETHYLHEXYL)PHTHALATE	97 J

SAMPLE I.D.	SD02
DEPTH	0-0.5'
FLOURANTHENE	59 J
CHRYSENE	51 J
BIS(2-ETHYLHEXYL)PHTHALATE	150 J

SAMPLE I.D.	SD02
DEPTH	0.5'1.0'
PHENANTHRENE	44 J
FLOURANTHENE	81 J
PYRENE	140 J
BENZO(A)ANTHRACENE	58 J
CHRYSENE	95 J
BIS(2-ETHYLHEXYL)PHTHALATE	130 J
BENZO(B)FLOURANTHENE	50 J
BENZO(K)FLOURANTHENE	53 J
BENZD(A)PYRENE	75 J

SAMPLE I.D.	SD03
DEPTH	0-0.5'
PHENANTHRENE	42 J
BIS(2-ETHYLHEXYL)PHTHALATE	140 J

SAMPLE I.D.	SD03
DEPTH	0.5'1.0'
PYRENE	52 J
BIS(2-ETHYLHEXYL)PHTHALATE	90 J
BENZO(B)FLOURANTHENE	40 J

SAMPLE I.D.	SD04
DEPTH	0-0.5'
FLOURANTHENE	180 J
CHRYSENE	120 J
BIS(2-ETHYLHEXYL)PHTHALATE	240 J
BENZO(B)FLOURANTHENE	140 J
BENZO(K)FLOURANTHENE	51 J
BENZO(A)PYRENE	65 J
INDENO(1,2,3-CD)PYRENE	59 J
BENZO(G,H,I)PERYLENE	55 J

SAMPLE I.D.	SD04
DEPTH	0.5'1.0'
BIS(2-ETHYLHEXYL)PHTHALATE	88 J
BENZO(A)PYRENE	3100

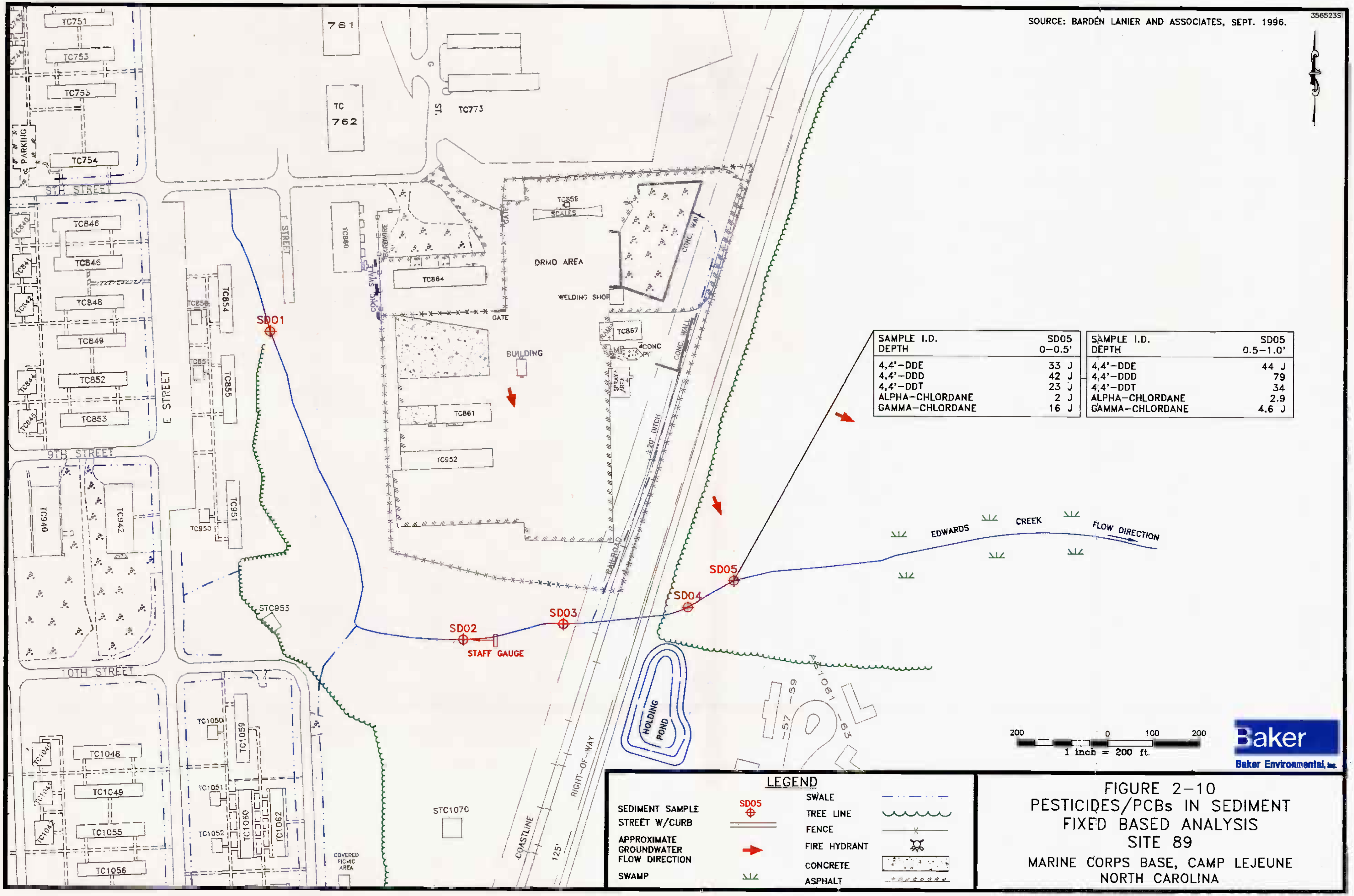
SAMPLE I.D.	SD05
DEPTH	0-0.5'
FLOURANTHENE	51 J
BIS(2-ETHYLHEXYL)PHTHALATE	110 J

SAMPLE I.D.	SD05
DEPTH	0.5'1.0'
PYRENE	51 J
BIS(2-ETHYLHEXYL)PHTHALATE	13000

LEGEND

SEDIMENT SAMPLE — SD05
STREET W/CURB
GRAVEL ROAD
APPROXIMATE GROUNDWATER FLOW DIRECTION
SWAMP
SWALE
TREE LINE
FENCE
FIRE HYDRANT
CONCRETE
ASPHALT

FIGURE 2-9
SEMIVOLATILE ORGANIC COMPOUNDS IN SEDIMENT - FIXED BASE ANALYSIS
SITE 89
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

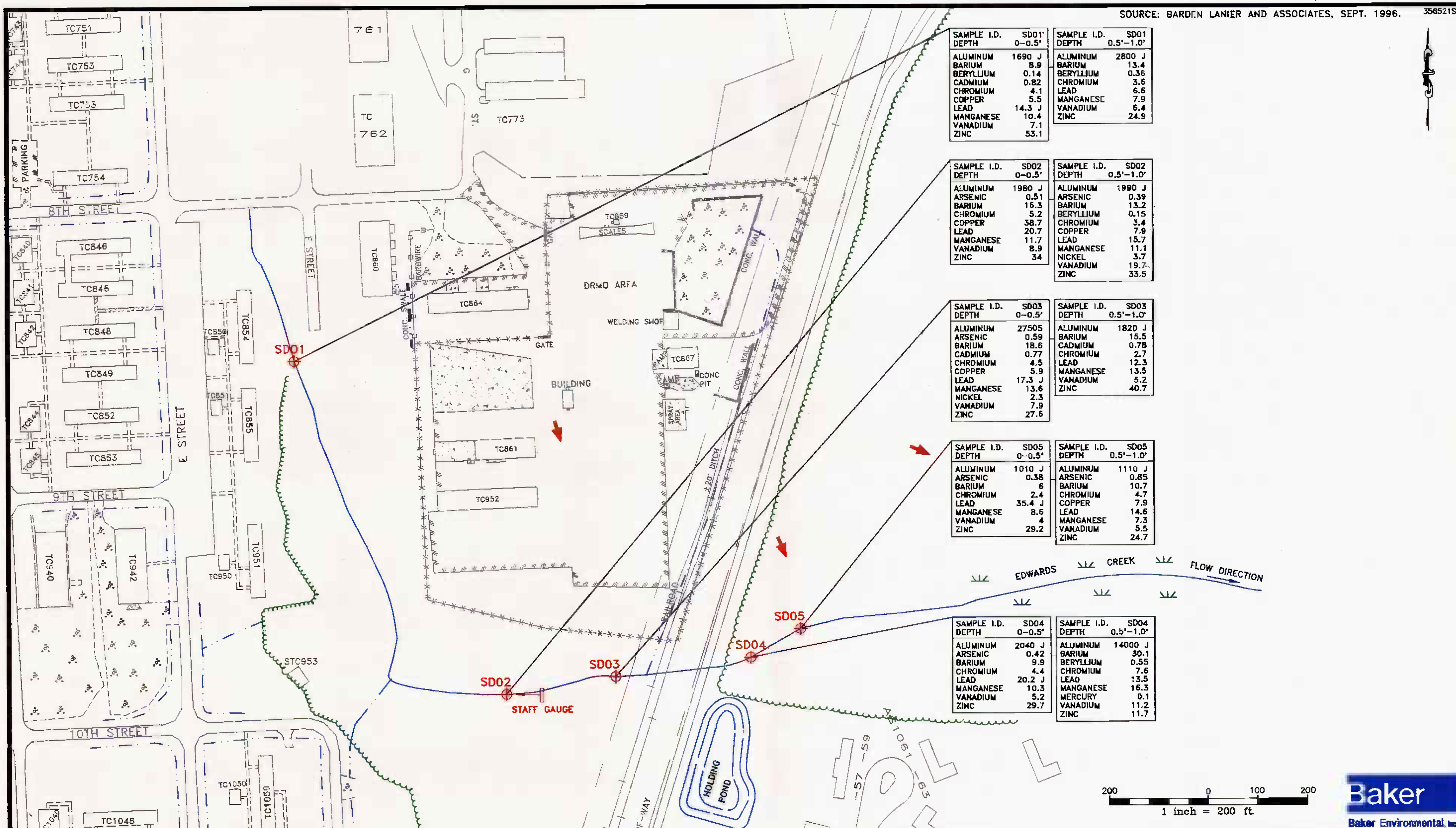


SAMPLE I.D. DEPTH	SD05 0-0.5'
4,4'-DDE	33 J
4,4'-DDD	42 J
4,4'-DDT	23 J
ALPHA-CHLORDANE	2 J
GAMMA-CHLORDANE	16 J

SAMPLE I.D. DEPTH	SD05 0.5-1.0'
4,4'-DDE	44 J
4,4'-DDD	79
4,4'-DDT	34
ALPHA-CHLORDANE	2.9
GAMMA-CHLORDANE	4.6 J

FIGURE 2-10
PESTICIDES/PCBs IN SEDIMENT
FIXED BASED ANALYSIS
SITE 89
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

SOURCE: BARDEN LANIER AND ASSOCIATES, SEPT. 1996.



SAMPLE I.D.	SD01
DEPTH	0–0.5'
ALUMINUM	1690 J
BARIUM	8.9
BERYLLIUM	0.14
CADMIUM	0.82
CHROMIUM	4.1
COPPER	5.5
LEAD	14.3 J
MANGANESE	10.4
VANADIUM	7.1
ZINC	53.1

SAMPLE I.D.	SD01
DEPTH	0.5'–1.0'
ALUMINUM	2800 J
BARIUM	13.4
BERYLLIUM	0.36
CHROMIUM	3.6
LEAD	6.6
MANGANESE	7.9
VANADIUM	6.4
ZINC	24.9

SAMPLE I.D.	SD02
DEPTH	0–0.5'
ALUMINUM	1980 J
ARSENIC	0.51
BARIUM	16.3
CHROMIUM	5.2
COPPER	38.7
LEAD	20.7
MANGANESE	11.7
VANADIUM	8.9
ZINC	34

SAMPLE I.D.	SD02
DEPTH	0.5'–1.0'
ALUMINUM	1990 J
ARSENIC	0.39
BARIUM	13.2
BERYLLIUM	0.15
CHROMIUM	3.4
COPPER	7.9
LEAD	15.7
MANGANESE	11.1
NICKEL	3.7
VANADIUM	19.7
ZINC	33.5

SAMPLE I.D.	SD03
DEPTH	0–0.5'
ALUMINUM	27505
ARSENIC	0.59
BARIUM	18.6
CADMIUM	0.77
CHROMIUM	4.5
COPPER	5.9
LEAD	17.3 J
MANGANESE	13.6
NICKEL	2.3
VANADIUM	7.9
ZINC	27.6

SAMPLE I.D.	SD03
DEPTH	0.5'–1.0'
ALUMINUM	1820 J
BARIUM	15.5
CADMIUM	0.78
CHROMIUM	2.7
LEAD	12.3
MANGANESE	13.5
VANADIUM	5.2
ZINC	40.7

SAMPLE I.D.	SD05
DEPTH	0–0.5'
ALUMINUM	1010 J
ARSENIC	0.38
BARIUM	6
CHROMIUM	2.4
LEAD	35.4 J
MANGANESE	8.6
VANADIUM	4
ZINC	29.2

SAMPLE I.D.	SD05
DEPTH	0.5'–1.0'
ALUMINUM	1110 J
ARSENIC	0.85
BARIUM	10.7
CHROMIUM	4.7
COPPER	7.9
LEAD	14.6
MANGANESE	7.3
VANADIUM	5.5
ZINC	24.7

SAMPLE I.D.	SD04
DEPTH	0–0.5'
ALUMINUM	2040 J
ARSENIC	0.42
BARIUM	9.9
CHROMIUM	4.4
LEAD	20.2 J
MANGANESE	10.3
VANADIUM	5.2
ZINC	29.7

SAMPLE I.D.	SD04
DEPTH	0.5'–1.0'
ALUMINUM	14000 J
BARIUM	30.1
BERYLLIUM	0.55
CHROMIUM	7.6
LEAD	13.5
MANGANESE	16.3
MERCURY	0.1
VANADIUM	11.2
ZINC	11.7

200 0 100 200

1 inch = 200 ft.

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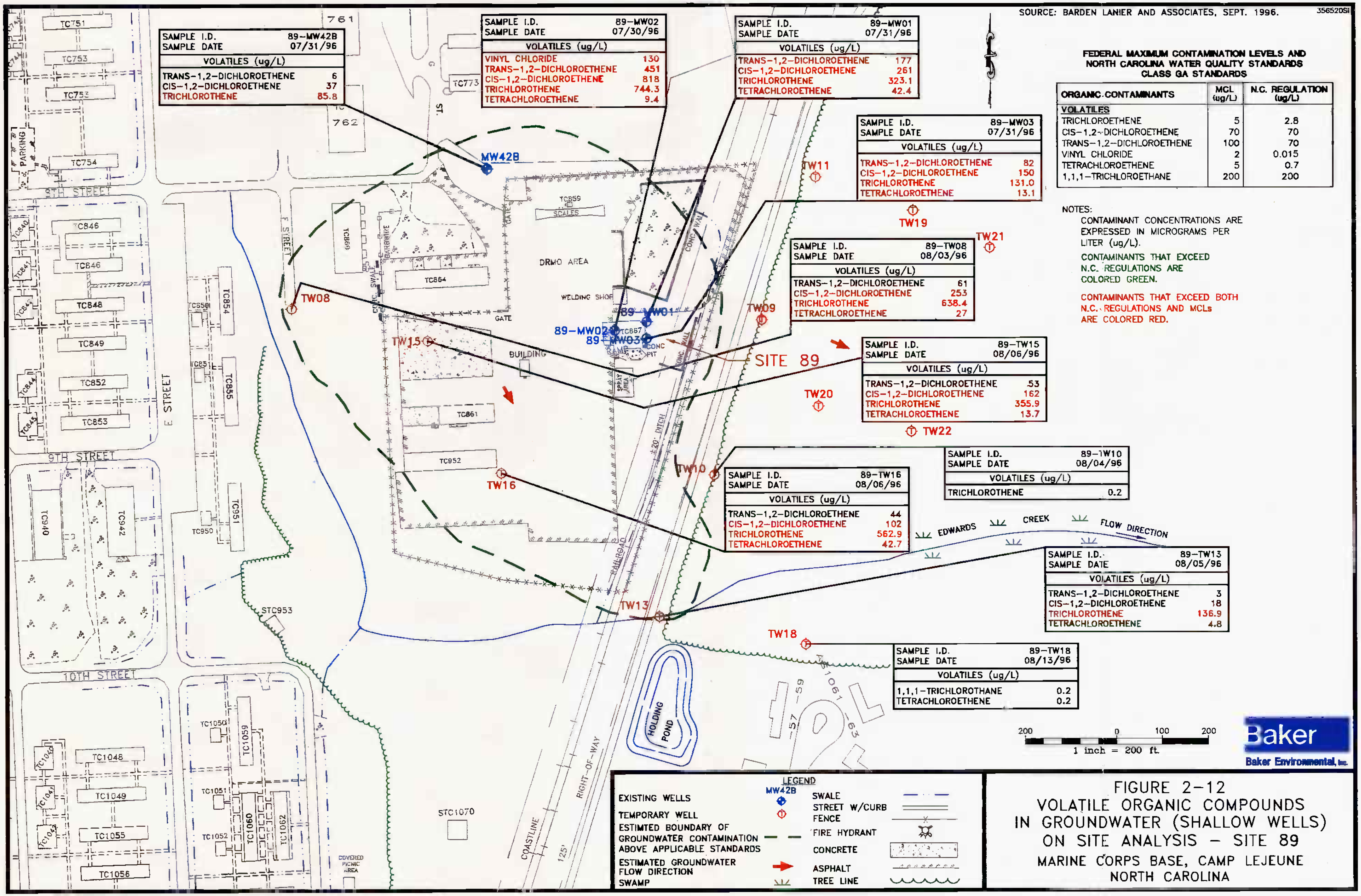
LEGEND

SEDIMENT SAMPLE (SD05)
STREET W/CURB
APPROXIMATE GROUNDWATER FLOW DIRECTION
SWAMP
SWALE
TREE LINE
FENCE
FIRE HYDRANT
CONCRETE
ASPHALT

FIGURE 2-11
METALS IN SEDIMENT
FIXED BASED ANALYSIS
SITE 89

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



FEDERAL MAXIMUM CONTAMINATION LEVELS AND NORTH CAROLINA WATER QUALITY STANDARDS CLASS GA STANDARDS

ORGANIC CONTAMINANTS	MCL (ug/L)	N.C. REGULATION (ug/L)
VOLATILES		
TRICHLOROETHENE	5	2.8
CIS-1,2-DICHLOROETHENE	70	70
TRANS-1,2-DICHLOROETHENE	100	70
VINYL CHLORIDE	2	0.015
TETRACHLOROETHENE	5	0.7
1,1,1-TRICHLOROETHANE	200	200

NOTES:

CONTAMINANT CONCENTRATIONS ARE EXPRESSED IN MICROGRAMS PER LITER (ug/L).

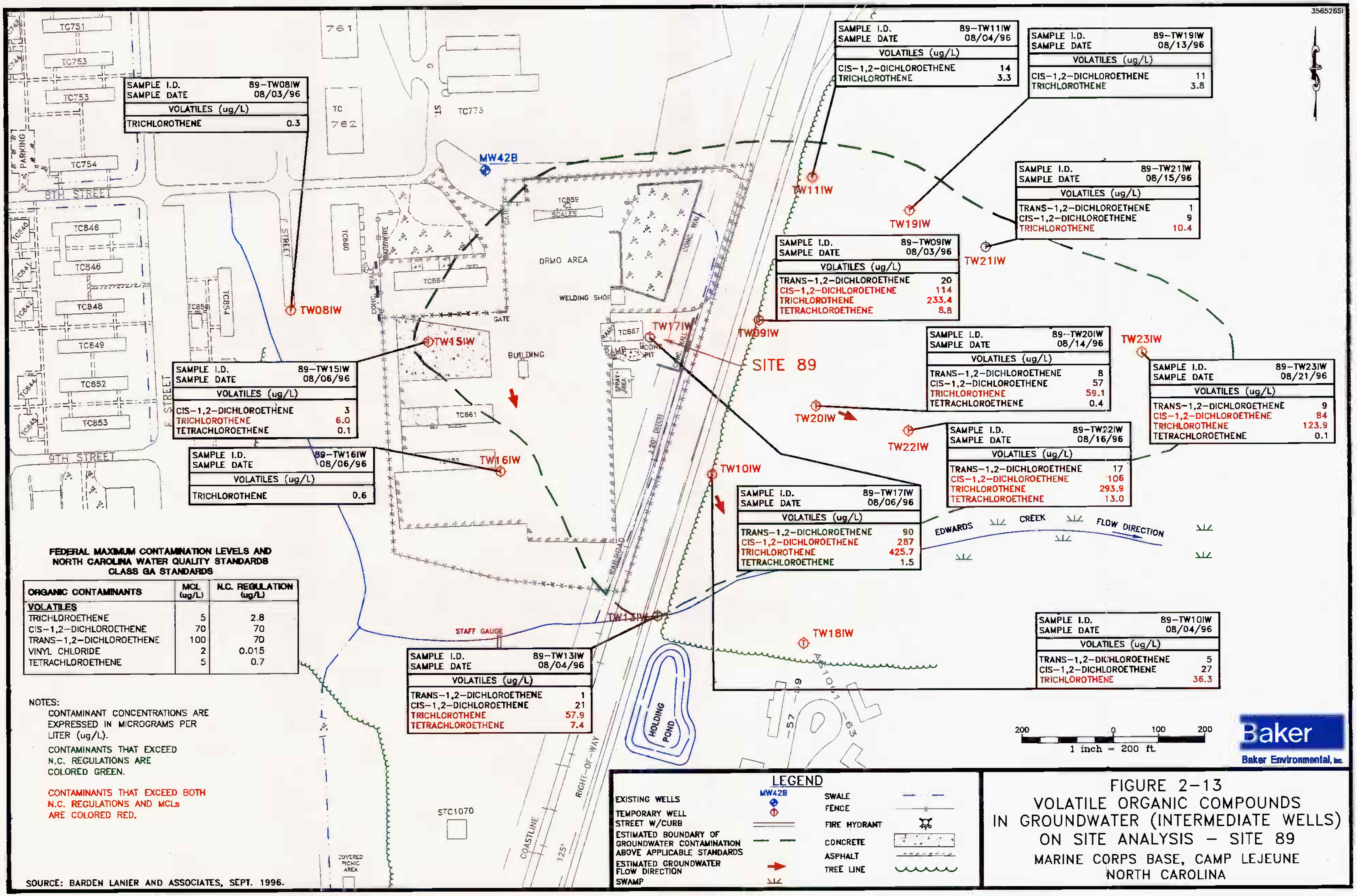
CONTAMINANTS THAT EXCEED N.C. REGULATIONS ARE COLORED GREEN.

CONTAMINANTS THAT EXCEED BOTH N.C. REGULATIONS AND MCLs ARE COLORED RED.

LEGEND

EXISTING WELLS	MW42B
TEMPORARY WELL	
ESTIMTED BOUNDARY OF GROUNDWATER CONTAMINATION ABOVE APPLICABLE STANDARDS	
ESTIMATED GROUNDWATER FLOW DIRECTION	
SWAMP	
SWALE	
STREET W/CURB	
FENCE	
FIRE HYDRANT	
CONCRETE	
ASPHALT	
TREE LINE	

FIGURE 2-12
VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER (SHALLOW WELLS) ON SITE ANALYSIS - SITE 89
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



FEDERAL MAXIMUM CONTAMINATION LEVELS AND NORTH CAROLINA WATER QUALITY STANDARDS CLASS GA STANDARDS

ORGANIC CONTAMINANTS	MCL (ug/L)	N.C. REGULATION (ug/L)
VOLATILES		
TRICHLOROETHENE	5	2.8
CIS-1,2-DICHLOROETHENE	70	70
TRANS-1,2-DICHLOROETHENE	100	70
VINYL CHLORIDE	2	0.015
TETRACHLOROETHENE	5	0.7

NOTES:
CONTAMINANT CONCENTRATIONS ARE EXPRESSED IN MICROGRAMS PER LITER (ug/L).
CONTAMINANTS THAT EXCEED N.C. REGULATIONS ARE COLORED GREEN.
CONTAMINANTS THAT EXCEED BOTH N.C. REGULATIONS AND MCLs ARE COLORED RED.

SOURCE: BARDEN LANIER AND ASSOCIATES, SEPT. 1996.

FIGURE 2-13
VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER (INTERMEDIATE WELLS) ON SITE ANALYSIS – SITE 89
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

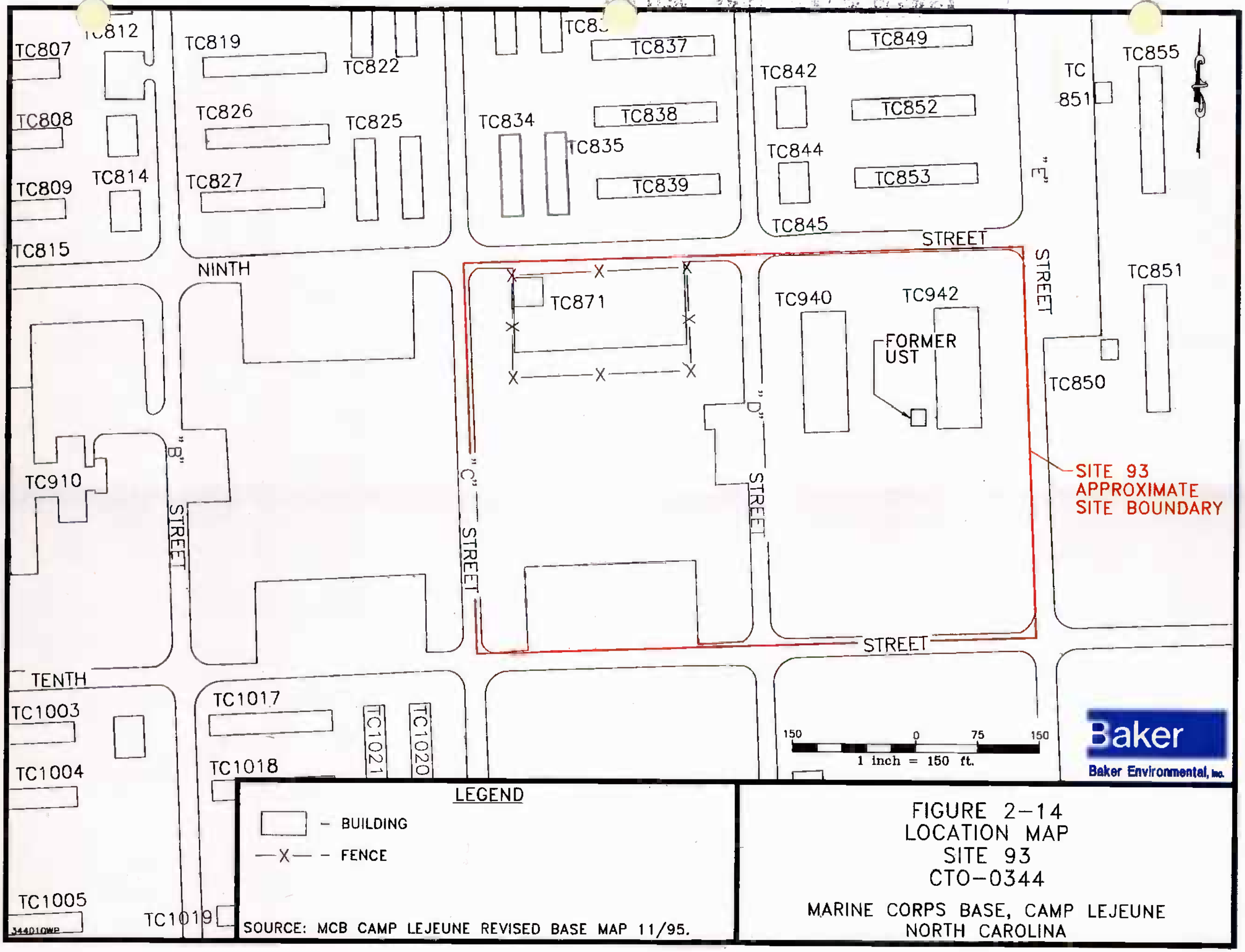


FIGURE 2-14
LOCATION MAP
SITE 93
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

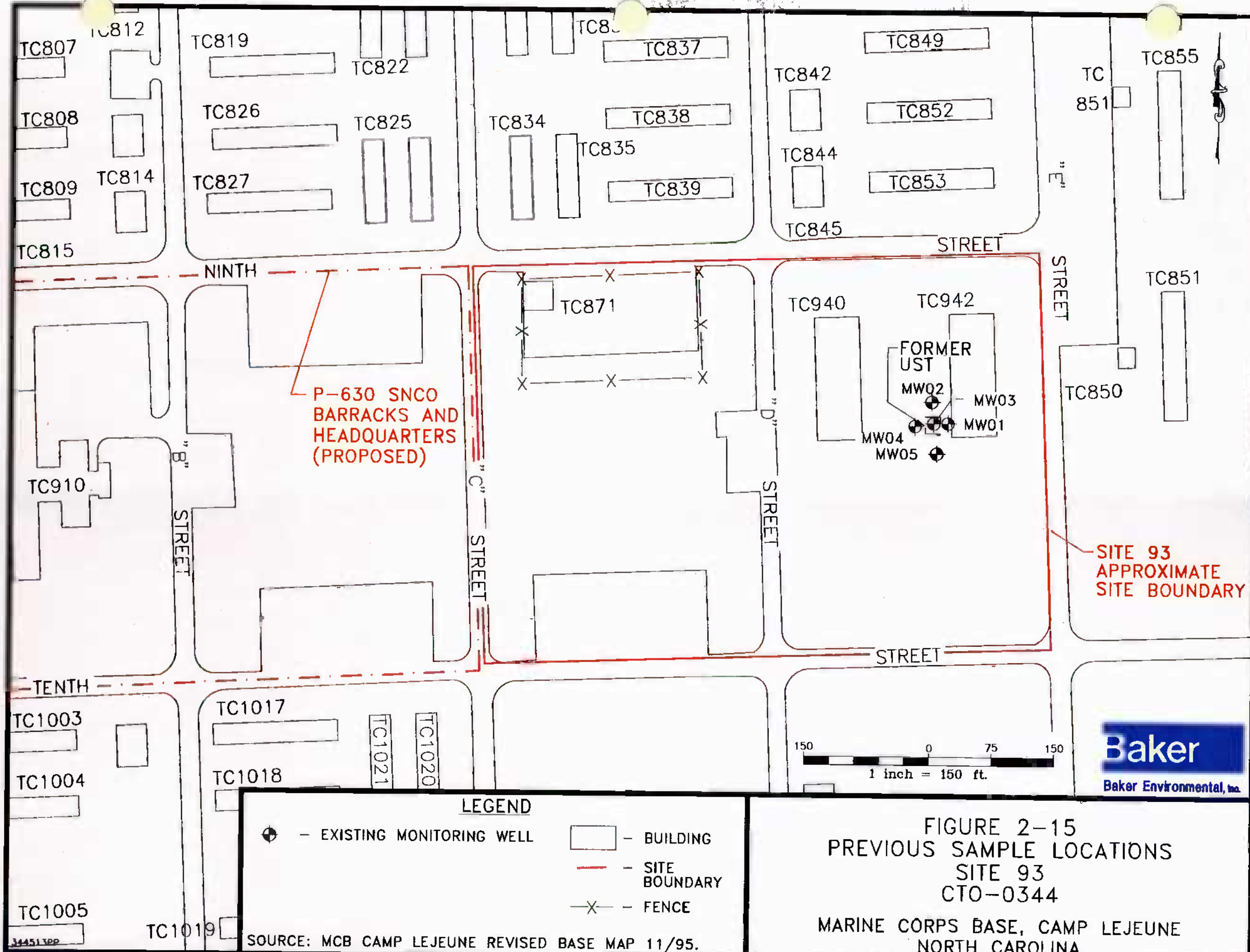


FIGURE 2-15
PREVIOUS SAMPLE LOCATIONS
SITE 93
CTO-0344

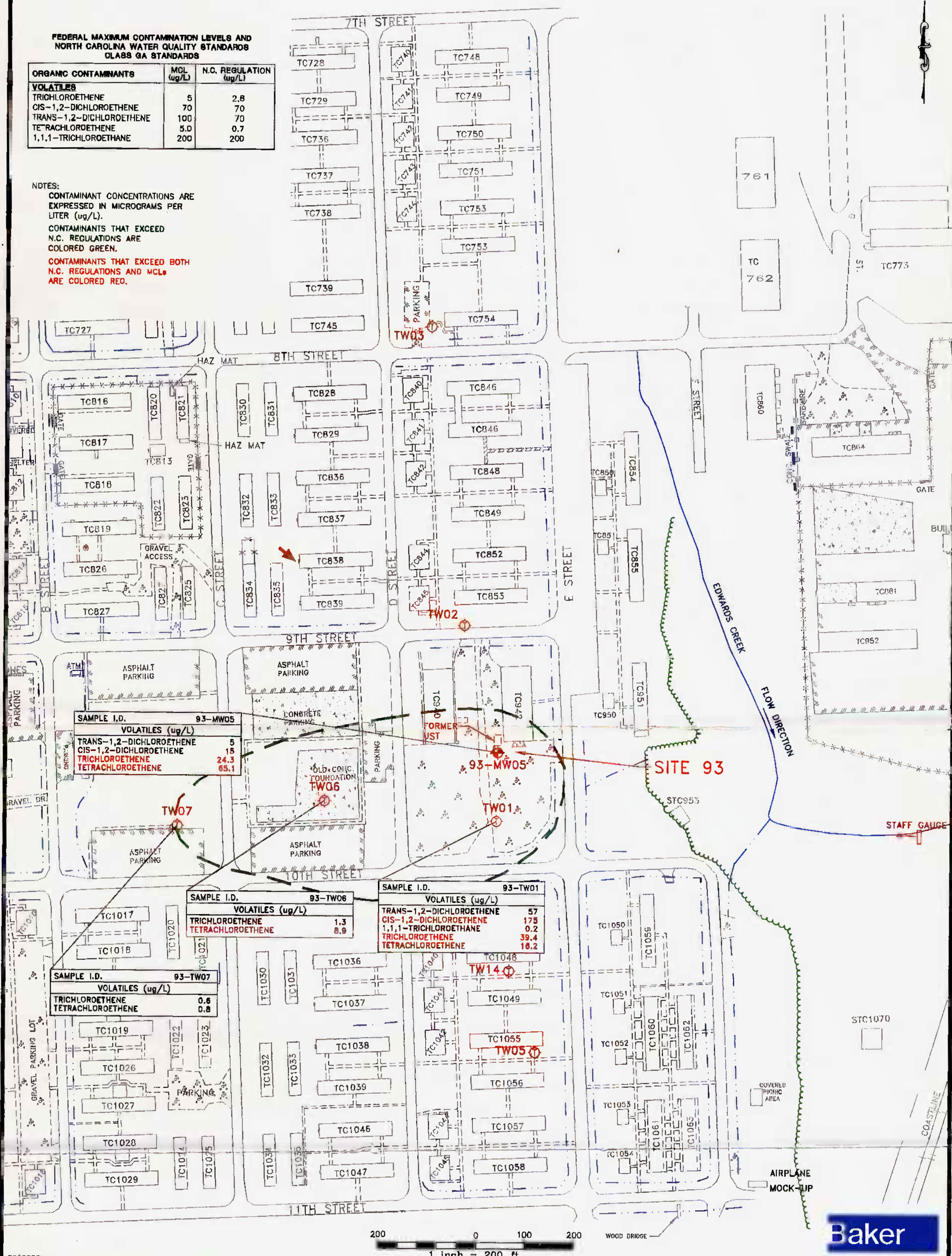
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

SOURCE: BARDEN LANIER AND ASSOCIATES, SEPT. 1996. OCT. 1991

FEDERAL MAXIMUM CONTAMINATION LEVELS AND NORTH CAROLINA WATER QUALITY STANDARDS CLASS GA STANDARDS

ORGANIC CONTAMINANTS	MCL (ug/L)	N.C. REGULATION (ug/L)
VOLATILES		
TRICHLOROETHENE	5	2.8
CIS-1,2-DICHLOROETHENE	70	70
TRANS-1,2-DICHLOROETHENE	100	70
TETRACHLOROETHENE	5.0	0.7
1,1,1-TRICHLOROETHANE	200	200

NOTES:
CONTAMINANT CONCENTRATIONS ARE EXPRESSED IN MICROGRAMS PER LITER (ug/L).
CONTAMINANTS THAT EXCEED N.C. REGULATIONS ARE COLORED GREEN.
CONTAMINANTS THAT EXCEED BOTH N.C. REGULATIONS AND MCLs ARE COLORED RED.



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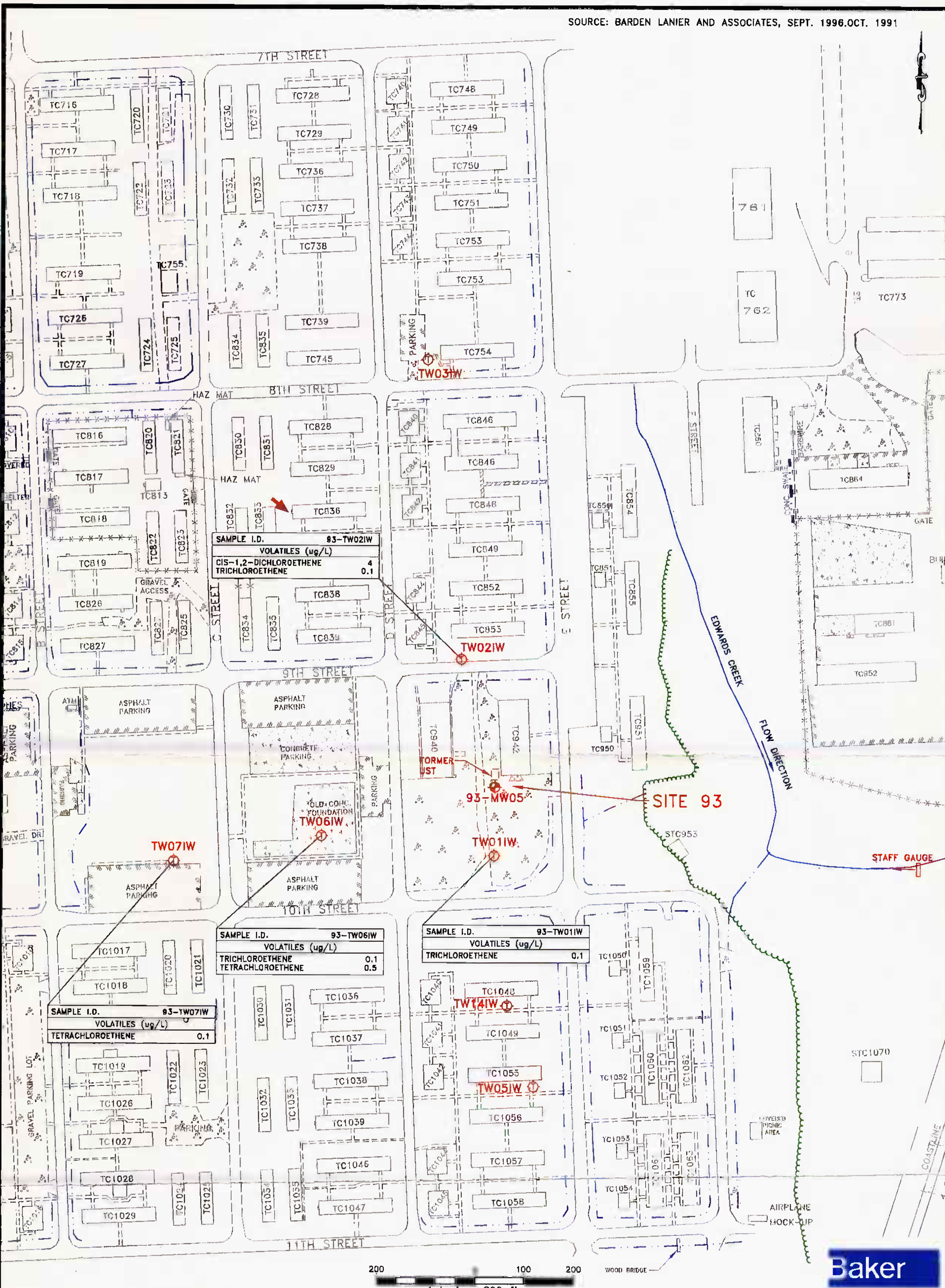
LEGEND

MONITORING WELL
TEMPORARY WELL
FORMER UST
STREET W/CURB
GRAVEL ROAD
ESTIMATED BOUNDARY OF GROUNDWATER CONTAMINATION ABOVE APPLICABLE STANDARDS
SWALE
TREE LINE
FENCE
FIRE HYDRANT
CONCRETE
ASPHALT
APPROXIMATE GROUNDWATER FLOW DIRECTION

FIGURE 2-16
VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER (SHALLOW WELLS) ON SITE ANALYSIS
SITE 93
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

MONITORING WELL		SWALE	
TEMPORARY WELL		TREE LINE	
FORMER UST		FENCE	
STREET W/CURB		FIRE HYDRANT	
GRAVEL ROAD		CONCRETE	
APPROXIMATE GROUNDWATER FLOW DIRECTION		ASPHALT	

FIGURE 2-17
VOLATILE ORGANIC COMPOUNDS
IN GROUNDWATER (INTERMEDIATE WELLS)
ON SITE ANALYSIS
SITE 93
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

3.0 DATA QUALITY AND SAMPLING OBJECTIVES

The purpose of this section is to define the site-specific RI/FS data quality and sampling objectives in order to fulfill the overall goals of characterizing the problems at each site, assessing potential impacts to the public health and environment, and identifying feasible remedial alternatives for remediating the sites, if necessary. The site-specific RI/FS objectives presented in this section have been identified based on review and evaluation of existing background information.

3.1 Data Quality Objectives

Data Quality Objectives (DQOs) are qualitative and quantitative statements that ensure data of known and appropriate quality are obtained during the RI/FS. The DQOs associated with each field sampling and analysis program are discussed and presented in this section. The DQOs were developed using the following three stages:

Stage 1- Identify decision types
Stage 2- Identify data uses/needs
Stage 3- Design data collection program

Stage 1 of the DQO process takes place during the scoping of the RI/FS. This stage involves the evaluation of existing information and the development of objectives for field data collection efforts.

Stage 2 of the DQO process involves definition of the quality and quantity of data that will be required to meet the objectives established in Stage 1.

Stage 3 involves the design of a data collection program to meet the requirements identified in Stage 2.

3.1.1 Stage 1 - Identification of Decision Types

As part of the Stage 1 DQO process, available information from previous site investigations and other sources (e.g., USGS) were reviewed in order to describe current site conditions, evaluate existing data, and assess the adequacy of the data. This was documented in Section 2.0 of this Work Plan. From this review and evaluation, RI/FS objectives have been developed to (1) assess the nature of the threat posed by the release or potential release of hazardous substances; (2) characterize the site with respect to the environmental setting; and (3) evaluating potential remedial alternatives. These objectives are presented in Section 3.2.

3.1.2 Stage 2 - Identification of Data Uses/Needs

In Stage 2 of the DQO process, the data quality and quantity required to support the RI/FS objectives developed during Stage 1 are identified. With respect to the RI/FS objectives, data will be required to address specific environmental media at each site. Data uses for each environmental media are presented in Section 3.1.2.1. Site-specific data needs are discussed in Section 3.1.2.2.

3.1.2.1 Data Uses for Environmental Media

RI/FS data uses can be described in general purpose categories. These categories include the following:

- Site Characterization - Data are used to determine the nature and extent of contamination at a site. Site characterization data are generated through the sampling and analysis of waste sources and environmental media.

- Health and Safety - Data are typically used to establish the level of protection needed for investigators or workers at a site, and if there should be an immediate concern for the population living within the site vicinity.

- Risk Assessment - Data are used to evaluate the threat posed by a site to public health and the environment. Risk assessment data are generated through the sampling and analysis of environmental and biological media, particularly where the potential for human or ecological exposure is great (e.g., sediments, surface soil, potable groundwater supplies).

- Evaluation of Alternatives - Data are used to evaluate various remedial technologies. Engineering data are collected in support of remedial alternative evaluation and to develop cost estimates for remediating the site. This may involve conducting bench or pilot-scale studies to determine the effectiveness or implementability of the technology.

- Engineering Design of Alternatives - Data collected during the RI/FS can be used for engineering purposes to develop a preliminary data base in reference to the performance of various remedial technologies. Data types collected during the RI/FS which are applicable to the RD process include waste characterization and preliminary volume estimates (these estimates can be further defined during the remedial design/remedial action via additional field verification sampling).

The above discussion of data uses was extracted from the document entitled Data Quality Objectives for Remedial Response Activities: Development Process (OSWER Directive 9355.0-7B). It has been presented in this Work Plan to provide the user with an understanding of the rationale for determining the site-specific RI/FS objectives as well as the rationale for the proposed sampling and analytical program for each site investigation.

With respect to the above data uses, an understanding of the site background, site history, and contaminant migration and exposure pathways are required in order to define the data needs (or data limitations). This "background" information was presented in Section 2.0 for each site. The site-specific data needs are presented in Section 3.1.2.2. RI/FS objectives, which have been formed to meet the data needs, are presented in Section 3.2.

3.1.2.2 Site-Specific Data Needs (Operable Unit No. 16)

The field investigation for this RI/FS has been divided into two phases, with Phase I already completed. Phase II activities are described below:

Phase II Investigation Activities

- Complete the horizontal delineation of groundwater contamination in the surficial aquifer east of Site 89. Verify the presence or absence of groundwater contamination in the Castle Hayne Aquifer.

- Verify the extent of groundwater contamination and monitor the plume with permanent monitoring wells at both sites.

- Provide hydrogeologic parameter data for the surficial aquifer and the Castle Hayne Confining Unit at Site 89.

- Determine natural groundwater flow patterns and interconnection between groundwater and surface water at both sites.

- Provide information to support the assessment of risks to human health and the environment presented by potential exposure to the groundwater, surface, and subsurface soil.

- Determine the risks to human health and the environment associated with current or future surface water (Edwards Creek) use or exposure.

- Determine the risk to human health and the environment associated with exposure to sediments in Edwards Creek.

The type and quality of data required to meet the criteria listed above are presented in Section 4.0. The data quality levels differ with respect to the end use of the data. Level IV data quality are generally required in risk assessments, characterizing the nature and extent of contamination, and to support subsequent investigations. Level III data quality is appropriate for risk assessments, site characterization, and evaluating treatment alternatives. Level II data quality is appropriate for field screening (e.g., ENSYS Screening). Level I data is appropriate for field measurements such as static water level, specific conductance, and pH. The analytical methods also differ with respect to the end use of the data. For this RI/FS, USEPA methods and Contract Laboratory Program (CLP) methods will be used when applicable.

This field investigation will employ the use of Level IV data. When applicable, the samples collected during this field investigation will be analyzed in accordance with CLP. For analyses where CLP is not applicable USEPA approved methods will be employed.

3.1.3 Stage 3 - Design Data Collection Program

The data collection program for Sites 89 and 93 has been designed to meet the objectives outlined in the following sections. Section 4.0 of the RI/FS Work Plan provides a general description of the various sampling programs for the sites. Sections 3.0 through 5.0 of the FSAP provide the specific details of these sampling programs.

The field activities will be conducted in two phases. Phase I, which has been completed, included the installation of temporary shallow and intermediate monitoring wells and surface water and sediment sampling. The Phase II activities are based on the recommendations presented in the Phase I Report. Phase II activities will begin after these project plans have been finalized.

3.2 Study Objectives

For each site-specific study objectives, the criteria necessary to meet each objective along with a general description of the study or investigation required to obtain the information in Table 3-1.

SECTION 3.0 TABLES

TABLE 3-1

REMEDIAL INVESTIGATION/FEASIBILITY STUDY OBJECTIVES FOR OPERABLE UNIT NO. 16
REMEDIAL INVESTIGATION/FEASIBILITY STUDY PROJECT PLANS - CTO-0344
MARINE CORPS BASE CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI/FS Objective	Criteria for Meeting Objective	Proposed Investigation/Study	Specific Data Needs
1. Sites 89 and 93 - Soil Phase II	1a. Assess human health and ecological risks associated with exposure to surface and subsurface soil at the site.	Evaluate contaminant levels in surface and subsurface soil at the study area and compare to federal and state standards and criteria and health-based remediation levels.	Soil Investigation Risk Assessment	VOAs SVOAs Pesticides/PCBs Metals
	1b. Determine whether contamination from soil is migrating to groundwater.	Characterize subsurface soil and leaching potential. Characterize shallow groundwater.	Soil and Groundwater Investigation	VOAs SVOAs Pesticides/PCBs Metals
	1c. Evaluate treatment alternatives.	Characterize areas of concern above action levels. Evaluate effectiveness and implementability of technologies.	Soil Investigation Feasibility Study Bench or Pilot Scale Testing	TOC Bulk density Permeability Grain size
2. Sites 89 and 93 - Groundwater Phase II	2a. Assess the extent of groundwater contamination in relationship to the Camp Geiger Area.	Determine the horizontal and vertical extent groundwater contamination.	Groundwater Investigation	VOAs
	2b. Assess health risks posed by potential future usage of groundwater.	Evaluate groundwater quality and compare to groundwater criteria or risk-based remediation levels.	Groundwater Investigation Risk Assessment	VOAs SVOAs Pesticides/PCBs Total Metals

TABLE 3-1 (Continued)

REMEDIAL INVESTIGATION/FEASIBILITY STUDY OBJECTIVES FOR OPERABLE UNIT NO. 16
REMEDIAL INVESTIGATION/FEASIBILITY STUDY PROJECT PLANS - CTO-0344
MARINE CORPS BASE CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI/FS Objective	Criteria for Meeting Objective	Proposed Investigation/Study	Specific Data Needs
2. Sites 89 and 93 - Groundwater Phase II (continued)	2c. Assess nature and extent of groundwater contamination.	Characterize groundwater quality.	Groundwater Investigation	VOAs SVOAs Pesticides/PCBs Total Metals
	2d. Define hydrogeologic characteristics for fate and transport evaluation and remedial technology evaluation, if required.	Estimate hydrogeologic characteristics of the aquifer (flow direction, transmissivity, permeability, etc.).	Groundwater Investigation	TDS/TSS BOD/COD Horizontal hydraulic conductivity estimate Vertical hydraulic conductivity estimate

SECTION 4.0 TABLES

TABLE 4-1

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
OPERABLE UNIT NO. 16 (SITES 89 AND 93)
REMEDIAL INVESTIGATION/FEASIBILITY STUDY WORK PLANS - CTO 0344
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline Number Of Samples[1]	Analysis
Sites 89 and 93 - Phase II	Groundwater	5 intermediate temporary monitoring wells	TCL VOAs - Mobile Laboratory [2]
		Expanded temporary intermediate monitoring wells	TCL VOAs - Mobile Laboratory [2]
		7 shallow monitoring wells/1 sample per well	TCL VOAs, SVOAs Pesticides/PCBs [3] TAL Total Metals Nitrate Nitrite Sulfate Sulfide Methane Chloride
		8 intermediate monitoring wells/1 sample per well	
		3 deep monitoring wells/1 sample per well	
		Additional shallow monitoring wells/1 sample per well	
		Additional intermediate monitoring wells/1 sample per well	
		Additional deep monitoring wells/1 sample per well	
		1 intermediate monitoring well/sample	TSS/TDS, BOD/COD
Sites 89 and 93 - Phase II	Soil	8 intermediate monitoring well borings/3 samples per boring	TCL VOAs, SVOAs Pesticides/PCBs [3] TAL Metals[4]
		Additional monitoring well borings/3 samples per well	
		2 monitoring well borings/1 composite per boring	TOC, Bulk density, Grain size
		2 monitoring well borings/3 samples per boring	Vertical Permeability
	Surface Water	5 stations/1 sample per station	Chloride
	Sediment	5 stations/1 sample per station	TOC, Grain size

TABLE 4-1 (continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
OPERABLE UNIT NO. 16 (SITES 89 AND 93)
REMEDIAL INVESTIGATION/FEASIBILITY STUDY WORK PLANS - CTO 0344
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline Number Of Samples[1]	Analysis
Investigation Derived Waste	Development/ Purge Water	2 (1 sample per tanker at each site)	TCL Organics TAL Metals TSS/TDS
	Soil	2 (1 sample per roll off box)	TCLP RCRA TCL PCBs

Notes:

(1) Baseline Number of samples does not include QA/QC.
(2) Ten percent of all samples also will be analyzed for TCL VOA at a fixed base analytical laboratory.
(3) Ten percent of samples collected will be analyzed for Pesticides/PCBs
(4) Target Analyte List (TAL) Metals:

Aluminum	EPA 3010/EPA 200.7	Cobalt	EPA 3010/EPA 200.7	Potassium	EPA 3010/EPA 200.7
Antimony	EPA 3010/EPA 200.7	Copper	EPA 3010/EPA 200.7	Selenium	EPA 3020/EPA 270.2
Arsenic	EPA 3020/EPA 206	Iron	EPA 3010/EPA 200.7	Silver	EPA 3010/EPA 200.7
Barium	EPA 3010/EPA 200.7	Lead	EPA 3020/EPA 239	Sodium	EPA 3010/EPA 200.7
Beryllium	EPA 3010/EPA 200.7	Magnesium	EPA 3010/EPA 200.7	Thallium	EPA 3020/EPA 279
Cadmium	EPA 3010/EPA 200.7	Manganese	EPA 3010/EPA 200.7	Vanadium	EPA 3010/EPA 200.7
Calcium	EPA 3010/EPA 200.7	Mercury	EPA 3010/EPA 245.1	Zinc	EPA 3010/EPA 200.7
Chromium	EPA 3010/EPA 200.7	Nickel	EPA 3010/EPA 200.7		

BOD - Biological Oxygen Demand
COD - Chemical Oxygen Demand
EPA - United States Environmental Protection Agency
TOC - Total Organic Carbon
TSS - Total Suspended Solids
TDS - Total Dissolved Solids
TCLP - Toxicity Characteristic Leaching Procedure (analysis of volatile organics, semivolatile organics, pesticides, herbicides, and metals on a leachate)
QA/QC - Quality Assurance/Quality Control
RCRA - Resource Conservation and Recovery Act (Corrosivity, Reactivity [reactive sulfide and cyanide], and Ignitability)

TABLE 4-2

PRELIMINARY REMEDIATION GOALS
OPERABLE UNIT NO. 16 (SITES 89 AND 93)
REMEDIAL INVESTIGATION - CTO 0344
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Medium	Contaminant of Concern	Preliminary Remediation Goal	Unit	Basis of Goal
Soil	Cis-1,2-dichloroethene	200	µg/Kg(1)	Risk(3)
	Trans-1-2-Dichloroethene	300	µg/Kg	Risk
	Tetrachloroethene	40	µg/Kg	Risk
	Trichloroethene	20	µg/Kg	Risk
Groundwater	Cis-1,2-Dichloroethane	70	µg/L(2)	NCWQS(4)
	Trans-1,2-Dichloroethene	70	µg/L	NCWQS
	Tetrachloroethane	0.7	µg/L	NCWQS
	Trichloroethene	2.8	µg/L	NCWQS
Surface Water	cis-1,2-Dichloroethane	NE(6)	--	--
	Trans-1,2-Dichloroethene	140,000	µg/L	EPA(7)
	Tetrachloroethene	8.85	µg/L	EPA
	Trichloroethene	81	µg/L	EPA
	Vinyl Chloride	525	µg/L	EPA

Notes:

(1) µg/Kg - microgram per kilogram
(2) µg/L - microgram per liter
(3) Risk - EPA Region III Soil Screening Levels - Transfers from soil to groundwater
(4) NCWQS - North Carolina Water Quality Standard
(5) MCL - Maximum Contaminant Level
(6) NE - None Established
(7) EPA - USEPA Region IV Criteria Chart, 1995 Human Health Criteria for Organism Consumption

4.0 REMEDIAL INVESTIGATION/FEASIBILITY STUDY TASKS

This section identifies the tasks and field investigations required to complete Phase II RI/FS activities at Sites 89 and 93.

4.1 Task 1 - Project Management

Project Management activities involve such activities as daily technical support and guidance, budget and schedule review and tracking, preparation and review of invoices, personnel resources planning and allocation, preparation of monthly progress reports, and communication with LANTDIV and the Activity.

4.2 Task 2 - Subcontract Procurement

Task 2 involves the procurement of services such as drilling, surveying, laboratory analysis, and data validation. Procurement of these services will be performed in accordance with the Navy Clean Contract Procurement Manual.

4.3 Task 3 - Field Investigations

The field investigations will be conducted under Task 3. An overview of the field investigation to be conducted at the site is presented in the following subsection. Specific details with respect to the sampling procedures, locations and number of samples, and analytical methods are provided in the Field Sampling and Analysis Plan (FSAP) and the Quality Assurance Project Plan (QAPP). The field investigations described below will provide data to meet the overall RI/FS objectives presented in Section 3.0 of this RI/FS Work Plan. Table 4-1 summarizes the sampling and analytical requirements. The following section outlines the activities which will encompass phase II.

4.3.1 Phase II Investigation

Additional temporary monitoring wells will be installed north and east of the Site 89 contaminant plume site using a truck-mounted drill rig. Permanent monitoring will be located in and around the contaminant plumes at both sites to verify the extent of the plumes and the presence or absence of natural attenuation processes. The number and locations of sampling locations are subject to change during the field investigation based on quick-turn analytical findings of the temporary well effort. Surface water samples will be collected to assist in the determination of tidal influences.

Surveying

All soil boring locations for temporary and permanent monitoring wells, surface water/sediment stations, and staff gauge locations will be surveyed. Other current investigation area features also will be surveyed as necessary.

Groundwater Investigation

A minimum of five additional intermediate temporary monitoring wells will be installed to fully define the vertical and horizontal extent of the contaminant plume at Site 89. These wells are anticipated to be installed to a depth of approximately 30 to 40 feet bgs. Proposed groundwater sampling locations are shown on Figure 4-1. The locations of the temporary monitoring wells are based on the currently defined plume and engineering judgement of the possible extent of the leading edge. This was accomplished through the application of a 2D groundwater flow and transport model. Additional temporary wells will be isntalled as needed to fully define the extent of the plume.

Temporary monitoring well will be installed and the investigation area boundaries will be adjusted until the contamination is found below or a pattern develops of decreasing concentration to North Carolina Water Quality Standards (NCWQS) or Federal Maximum Contaminant Levels (MCLs).

Initially, one temporary well will be installed as shown on Figure 4-1. The locations of subsequent temporary wells will be based on levels of contamination detected in the initial installation. If there is a substantial decrease in the detected contaminant concentrations (or nondetectable concentrations) between 89-TW23IW and the initial temporary well, one additional temporary well will be installed between the 89-TW23IW and initial temporary well. If contaminants are present in the initial temporary monitoring well, one additional temporary well will be installed east of the initial temporary monitoring well. When the eastern extent of the contaminant plume is established, three additional temporary wells will be installed on a north-south trending line to fully define the plume extent. One additional temporary well will be installed north of 89-TW191W and 89-TW21IW to better define the northern extent of the plume.

Local groundwater flow patterns will be established. This will be accomplished through the collection of static water levels in monitoring wells and water levels in Edwards Creek.

All groundwater samples from the temporary wells will be analyzed on-site via mobile laboratory for TCL VOAs. Ten percent of all media sampled also will be analyzed for TCL VOCs at a fixed base analytical laboratory to confirm the results of the mobile laboratory.

Upon the completion of the temporary well investigation at Site 89, permanent well clusters will be installed at both Sites 89 and 93. These well clusters will be installed in the surficial and Castle Hayne aquifers to verify the extent of groundwater contamination, and to monitor for natural attenuation processes. A total of eight well clusters are shown on Figures 4-2 and 4-3. Each of the eight clusters will include one intermediate monitoring well (Type II). Seven of eight clusters will include one shallow well (Type II). The remaining cluster will utilize an existing shallow monitoring well. The shallow monitoring wells are anticipated to be approximately 20 to 25 feet deep, while the intermediate monitoring wells are anticipated to be approximately 40 to 50 feet deep. Three of the eight clusters will also include a deep monitoring well (Type II and Type III). At Site 89, the deep monitoring wells will be placed in the first encountered groundwater below the semi-confining layer to verify the presence or absence of contamination in the upper portion of the Castle Hayne Aquifer. It is anticipated that the deep monitoring wells will be approximately 60 feet deep. At Site 93, where a semi-confining unit was not encountered, the deep monitoring well will be installed as a Type II well at a depth similar to the other deep monitoring wells at Site 89. Additional permanent well clusters will be installed at the northern and eastern edges of the contaminant plume at Site 89. The number and locations of the additional clusters will be based on the findings of the additional temporary well investigation.

Groundwater samples will be collected from all temporary wells. Samples will be analyzed for VOAs via EPA SW846 Method 8240 (Level II data quality) by an on-site mobile laboratory.

Groundwater samples will be collected from all permanent monitoring wells and analyzed for TCL VOAs, SVOAs, and TAL metals (Level IV data quality). Additional analysis will include nitrate, nitrite, sulfate, sulfide, methane, and chloride for natural attenuation assessment purposes. A sample for total dissolved solids/total suspended solids (TSS/TDS) and biological oxygen demand (BOD)/chemical oxygen demand (COD) will be collected from one intermediate well at Site 89 for feasibility study purposes. Because there is no historical use or disposal of pesticides or PCBs in this area, ten percent of groundwater samples collected will be analyzed for pesticides/PCBs. Routine analytical turnaround will be requested for all groundwater samples. Groundwater field measurements, including pH, conductivity, dissolved oxygen, reduction/oxidation potential, turbidity, and temperature (Level I quality), also will be collected.

In-situ "slug" testing will be performed in select wells which were sampled to determine horizontal hydraulic conductivity for the investigation area.

Soil Investigation

During the Phase II field activities, three soil samples will be collected from each of the eight proposed permanent intermediate monitoring well borings and submitted for chemical analysis (Figures 4-4 and 4-5). One surface soil (0- to 6- inches bgs) sample will be collected from the well borings unless the boring is located within a paved portion of the investigation area. One subsurface soil sample will be collected from just above the water table. A second subsurface soil sample will be collected from within the soil/water interface to obtain information relevant from groundwater modeling. If the depth to groundwater is greater than 10 feet below ground surface (bgs) or there is evidence of contamination, one additional subsurface soil sample (for a total of four soil samples) will be collected from a mid-depth.

All of the surface and subsurface soil samples will be analyzed for TCL VOAs, SVOAs, and TAL metals (Level IV Data Quality). Because there is no historical use or disposal of pesticides or PCBs, ten percent of the soil samples will be analyzed for TCL pesticides/PCBs. Routine analytical turnaround will be requested for all analysis. One composite sample from each of two (2) well boring locations will be analyzed for Total Organic Carbon (TOC), bulk density, and grain size. These soil sample locations will be selected during the field investigation.

Six shelby tube samples (3 samples from 2 borings) will be collected and analyzed to determine vertical hydraulic conductivity for the investigation area. Samples will be collected of sediments from the vadose zone, the surficial aquifer, and Castle Hayne confining unit.

Surface Water/Sediment Investigation

One surface water and one sediment sample will be collected from each of five stations in Edwards Creek. All surface water samples will be analyzed for chloride. All sediment samples will be analyzed for grain size and total organic carbon. All samples will be analyzed on routine analytical turnaround time.

One staff gauge will be installed in the Edwards Creek and an existing staff gauge (SG01) will be used to determine the amount of tidal influence and verify the interconnection between groundwater and surface water.

Proposed surface water and sediment sampling locations are shown on Figure 4-6. Final sampling locations will be determined in the field based on accessibility and surface water flow and depth. Surface water sampling locations are located to determine if, and what portion of Edwards creek is tidally influenced. Sediment sampling will provide data for the ecological risk assessment.

4.3.2 Investigation Derived Waste Handling

Drill cuttings or excavated soil will be collected and contained in a roll-off box if they are determined in the field to be potentially contaminated based on visual observations and HNu readings. One rigid storage tank with a capacity of 1,000 gallons will be stationed at each of the sites for containing groundwater development and purge water. A composite soil sample from the roll-off box will be collected and analyzed for full TCLP (organics and inorganics) and RCRA hazardous waste characterization (corrosivity, reactivity, and ignitability), and PCBs. One sample will be collected from each tank (two total samples) and analyzed for full TCL organics, TAL total metals, TSS and TDS. Additional details regarding IDW handling and disposal are provided in Section 6.11 of the FSAP.

4.4 Task 4 - Sample Analysis and Validation

This task involves efforts relating to the following post-field sampling activities:

- Sample Management
- Laboratory Analysis
- Data Validation

Sample management activities involve: coordination with laboratories; tracking of samples submitted for analysis; tracking of analyses received; and tracking of information related to samples submitted and received from a third party validator. Sample management also involves resolving technical or administrative problems (e.g., reanalysis, resubmission of information).

Laboratory analysis begins when the samples are shipped from the field and received by the laboratory. Validation begins when the "raw" laboratory data is received by the validator from Baker. Baker will first receive the data from the laboratory, log it into a database for tracking purposes, and then forward it to the validator. A validation report will be expected within three weeks following receipt of laboratory data packages by the validator. CLP data will be validated per the CLP criteria as outlined in the following documents:

- USEPA, Hazardous Site Control Division, Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses, 1994.

- USEPA, Hazardous Site Evaluation Division, Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses, 1994.

All other data will be validated in accordance with the method of analysis using the National Functional Guidelines as a reference.

4.5 Task 5 - Data Evaluation

This task involves efforts related to the data once it is received from the laboratory and is validated. It also involves the evaluation of any field-generated data including: water level measurements, test boring logs, and other field notes. Efforts under this task will include the tabulation of validated data and field data, generation of test boring logs and monitoring well construction logs, generation of geologic cross-section diagrams, and the generation of other diagrams associated with field notes or data received from the laboratory (e.g., sampling location maps).

4.6 Task 6 - Risk Assessment

This section of the Work Plan will serve as the guideline for the baseline risk assessments (BRAs) to be conducted for MCB Camp Lejeune during the RI.

Baseline risk assessments evaluate the potential human health and/or ecological impacts that would occur in the absence of any remedial action. The risk assessment will provide the basis for determining whether or not remedial action is necessary and the justification for performing remedial actions.

The risk assessments will be performed in accordance with USEPA guidelines. The primary documents that will be utilized include:

- Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part A), USEPA 1989.
- Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), USEPA 1991.
- Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part C, Risk Evaluation of Remedial Alternatives), USEPA 1991.
- Risk Assessment Guidance for Superfund: Volume II, Environmental Evaluation Manual, USEPA 1989.
- Supplemental Guidance to RAGS: Standard Default Values, USEPA 1991a.
- Supplemental Guidance to RAGS: Calculating the Concentration Term, USEPA 1992.
- Supplemental Guidance to RAGS: Region IV Bulletins, USEPA, 1995.
- Superfund Exposure Assessment Manual, USEPA 1988.
- Exposure Factors Handbook, USEPA 1989b.
- Guidance for Data Usability in Risk Assessment, USEPA 1990.

- Supplemental USEPA Region IV Risk Assessment Guidance, USEPA Region IV, 1991.

- Risk-Based Concentration Table, USEPA Region III.

USEPA Region IV will be consulted for Federal guidance, and the North Carolina DEHNR will be consulted for guidance in the State of North Carolina.

The technical components of the BRA are contaminant identification, exposure assessment, toxicity assessment, and risk characterization. The objectives of the risk assessment process can be accomplished by:

- Characterizing the toxicity and levels of contaminants in relevant media (e.g., groundwater, surface water, soil, sediment, and air).

- Characterizing the environmental fate and transport mechanisms within specific environmental media.

- Identifying potential current and future human and/or environmental receptors.

- Identifying potential exposure routes and the extent of the actual or expected exposure.

- Defining the extent of the expected impact or threat.

- Identifying the levels of uncertainty associated with the above items.

The BRA will utilize all available data to date that has been properly validated in accordance with USEPA guidelines plus all data to be collected from additional sampling during this RI.

4.6.1 Human Health Evaluation Process

4.6.1.1 Site Location and Characterization

A background section will be presented at the beginning of each risk assessment to provide an overview of the characteristics of each site. This section will provide a site location, a general site description, and the site-specific chemicals as discussed in past reports. The physical characteristics of the site and the geographical areas of concern will be discussed. This site description will help to characterize the exposure setting.

4.6.1.2 Data Summary

Because decisions regarding data use may influence the resultant risk assessment, careful consideration must be given to the treatment of those data. For purposes of risk evaluation, the site at MCB Camp Lejeune may be partitioned into operable units, sites, and areas of concern for which chemical concentrations will be characterized and risks will be evaluated. Sites will be grouped into operable units if they are close to one another, have similar contamination, and/or may impact the same potential receptors. In selecting data to include in the risk assessment, the objective is to characterize, as accurately as possible, the distribution and concentration of chemicals at each site.

Data summary tables will be developed for each medium sampled (e.g., surface water, sediment, groundwater, soil). Each data summary table will indicate the frequency of detection, observed range of concentrations, average background concentrations (inorganics), and the means and upper 95 percent confidence limit value for each contaminant detected in each medium. The arithmetic or geometric mean and the upper 95 percent confidence limit of that mean will be used in the summary of potential chemical data. The selection of arithmetic or geometric means will depend on whether the sample data are normally or log-normally distributed. In the calculation of the 95 percent confidence limit mean, concentrations presented as "ND" (nondetect) will be incorporated at 1/2 the analytical quantitation limit for organics and detection limit for inorganics. In cases where there is a question about the distribution of the data set, a statistical test will be used to determine the best distributional assumption for the data set.

4.6.1.3 Identifying Chemicals of Potential Concern

The criteria to be used in selecting the Contaminants of Potential Concern (COPCs) from the constituents detected during the sampling and analytical phase of the investigation are: historical information, prevalence, mobility, persistence, toxicity, established state and federal criteria and standards , comparison to blank data or base-specific naturally occurring levels (i.e., background), comparison to Region III RBCs, and comparison to anthropogenic levels. The criteria chosen to establish the COPC are derived from the USEPA's Risk Assessment Guidance for Superfund (USEPA, 1989).

All of the available sample data will undergo review upon initiation of the risk assessment. Common laboratory contaminants such as acetone, methylene chloride, phthalate esters, toluene, and methyl ethyl ketone will be addressed only if concentrations are 10 times greater than the corresponding blanks. In addition, chemicals that are not common laboratory contaminants will be evaluated if they are greater than five times the laboratory blank. The number of chemicals analyzed in the risk assessment will be a subset of the total number of chemicals detected at a site based on the elimination criteria discussed previously.

Tables will be prepared that list chemical concentrations for all media by site. Data will be further grouped according to organic and inorganic species within each table.

4.6.1.4 Exposure Assessment

The objectives of the exposure assessment at MCB Camp Lejeune will be to characterize the exposure setting, identify exposure pathways, and quantify the exposure. When characterizing the exposure setting, the potentially exposed populations will be described. The exposure pathway will identify the source and the mechanism of medium for the released chemical (e.g., groundwater), the point of potential human contact with the contaminated medium, and the exposure route(s) (e.g., ingestion). The magnitude, frequency, and duration for each exposure pathway identified will be quantified during this process.

The identification of potential exposure pathways at the site will include the activities described in the subsections that follow.

Analysis of the Probable Fate and Transport of Site- Specific Chemicals

To determine the environmental fate and transport of the chemicals of concern at the site, the physical/chemical and environmental fate properties of the chemicals will be reviewed. Some of these properties include volatility, photolysis, hydrolysis, oxidation, reduction, biodegradation, accumulation, persistence, and migration potential. This information will assist in predicting potential current and future exposures. It will help in determining those media that are currently receiving site-related chemicals or may receive site-related chemicals in the future. Sources that may be consulted in obtaining this information include computer databases (e.g., AQUIRE, ENVIROFATE), as well as the open literature.

The evaluation of fate and transport may be necessary where the potential for changes in future chemical characteristics is likely and for those media where site-specific data on the chemical distribution is lacking.

Identification of Potentially Exposed Human Populations

Human populations, that may be potentially exposed to chemicals at the MCB Camp Lejeune, include base personnel and their families, base visitors, and on-site workers and recreational fishermen. The Base Master Plan will be consulted to confirm or modify these potential exposures. Current military personnel and future residents could be exposed to chemicals as they carry out activities at the site located at MCB Camp Lejeune. The list of potential receptors and pathways to be evaluated will be refined during discussions with regulators prior to performing the BRA.

Identification of Potential Exposure Scenarios Under Current and Future Land Uses

The exposure scenarios will be finalized after consulting with the Base Master Plan, USEPA and the State of North Carolina. Generally, current and future exposure pathways will be considered preliminarily as follows:

Soil Pathway
- Direct ingestion (current military personnel and civilian worker, future residents and construction worker)
- Inhalation of dust (current military personnel and civilian worker, future residents)
- Dermal contact (current military personnel and civilian worker, future residents and construction worker)

Sediment Pathway
- Dermal contact (current military personnel, current and future residents)
- Ingestion (current military personnel, current and future residents)

Surface Water

Dermal contact (current military personnel, current and future residents)
Ingestion (current military personnel, current and future residents)

Groundwater

Direct ingestion (future residents)
Inhalation (future residents)
Dermal contact (future residents)

Exposure Point Concentrations

After the potential exposure points and potential receptors have been defined, exposure point concentrations must be calculated. The chemical concentrations at these contact points are critical in determining intake and, consequently, risk to the receptor. The data from site investigations will be used to estimate exposure point concentrations.

The upper 95 percent confidence limits of the means will be used throughout the risk assessment. In cases where maximum concentrations are exceeded by upper 95 percent confidence limit, the maximum concentrations will be used.

Exposure doses will be estimated for each exposure scenario from chemical concentrations at the point of contact by applying factors that account for contact frequency, contact duration, average body weight, and other route-specific factors such as breathing rate (e.g., inhalation). These factors will be incorporated into exposure algorithms that convert the environmental concentrations into exposure doses. Intakes will be reported in milligrams of chemical taken in by the receptor (i.e., ingested, inhaled, etc.) per kilogram body weight per day (mg/kg-day). Intakes for potentially exposed populations will be calculated separately for the appropriate exposure routes and chemicals.

4.6.1.5 Toxicity Assessment

Toxicity values (i.e., numerical values derived from dose-response toxicity data for individual compounds) will be used in conjunction with the intake determinations to characterize risk. Toxicity values may be taken or derived from the following sources (note that the most up-to-date toxicity information obtained from IRIS and/or HEAST will be used in the exposure assessments):

- Integrated Risk Information System (IRIS) - The principal toxicology database, which provides updated information from USEPA on cancer slope factors, reference doses, and other standards and criteria for numerous chemicals.

- Health Effects Assessment Summary Tables (HEAST) - A tabular summary of noncarcinogenic and carcinogenic information contained in IRIS.

For some chemicals, toxicity values (i.e., reference doses) may have to be derived if the principal references previously mentioned do not contain the required information. These derivations will be provided in the risk assessment for review by USEPA Region IV. The toxicity assessment will include a brief description of the studies on which selected toxicity values were based, the uncertainty factors used to calculate noncarcinogenic reference doses (RfDs), the USEPA weight-of-evidence (WOE) classification for carcinogens, and their respective slope factors.

4.6.1.6 Risk Characterization

Risk characterization involves the integration of exposure doses and toxicity information to quantitatively estimate the risk of adverse health effects. Quantitative risk estimates based on the reasonable maximum exposures to the site contaminants will be calculated based on available information. For each exposure scenario, the potential risk for each chemical will be based on intakes from all appropriate exposure routes. Carcinogenic risk and noncarcinogenic hazard indices are assumed to be additive across all exposure pathways and across all of the chemicals of concern for each exposure scenario. Potential carcinogenic risks will be evaluated separately from potential noncarcinogenic effects, as discussed in the following subsections.

Carcinogenic Risk

For the potential carcinogens that are present at the site, the carcinogenic slope factor (q_1*) will be used to estimate cancer risks at low dose levels. Risk will be directly related to intake at low levels of exposure. Expressed as an equation, the model for a particular exposure route is:

$$\text{Excess lifetime cancer risk} = \text{Estimated dose} \times \text{carcinogenic slope factor; or CDI} \times q_1^*$$

Where: CDI = Chronic daily intake

This equation is valid only for risk less than 10^{-2} (1 in 100) because of the assumption of low dose linearity. For sites where this model estimates carcinogenic risks of 10^{-2} or higher, an alternative model will be used to estimate cancer risks as shown in the following equation:

$$\text{Excess lifetime cancer risk} = 1 - \exp(-\text{CDI} \times q_1^*)$$

Where: exp = the exponential

For quantitative estimation of risk, it will be assumed that cancer risks from various exposure routes are additive. Since there are no mathematical models that adequately describe antagonism or synergism, these issues will be discussed in narrative fashion in the uncertainty analysis.

Noncarcinogenic Risk

To assess noncarcinogenic risk, estimated daily intakes will be compared with reference doses RfD for each chemical of concern. The potential hazard for individual chemicals will be presented as a hazard quotient (HQ). A hazard quotient for a particular chemical through a given exposure route is the ratio of the estimated daily intake and the applicable RfD, as shown in the following equation:

$$HQ = EDI/RfD$$

Where:
HQ = Hazard quotient
EDI = Estimated daily intake or exposure (mg/kg-day)
RfD = Reference dose (mg/kg-day)

To account for the additivity of noncarcinogenic risk following exposure to numerous chemicals through a variety of exposure routes, a hazard index (HI), which is the sum of all the hazard quotients, will be calculated. Ratios greater than one, or unity, indicate the potential for adverse effects to occur. Ratios less than one indicate that adverse effects are unlikely. This procedure assumes that the risks from exposure to multiple chemicals are additive, an assumption that is probably valid for compounds that have the same target organ or cause the same toxic effect. In some cases when the HI exceeds unity it may be appropriate to segregate effects (as expressed by the HI) by target organ since those effects would not be additive. As previously mentioned, where information is available about the antagonism or synergism of chemical mixtures, it will be appropriately discussed in the uncertainty analysis.

4.6.1.7 Preliminary Remediation Goals

This section discusses the Preliminary Remediation Goals (PRGs) (ARAR-based and/or risk-based) which are determined using information on media and chemicals of potential concern, the most appropriate future land use, potential exposure pathways, toxicity information, and potential ARARs. The development of PRGs will assist in the initiation of remedial alternatives and in the selection of analytical limits of detection. Risk-based PRGs established at this time are initial, and do not establish that clean up to meet these goals is warranted. Therefore, a risk-based PRG will be considered a final remediation level only after appropriate analysis in the RI/FS and ROD.

The initial step in developing PRGs is to identify media of potential concern. Important media at these sites include groundwater, soil, surface water, and sediment. Chemicals of potential concern include any chemical reasonably expected to be at the sites. These chemicals may have been previously detected at the site, may be presented based on site history, or may be present as degradation products. Identifying future land use for the site is used to determine risk-based PRGs. In general, residential land use should be used as a conservative estimation for the PRGs. Chemical-specified ARARs are evaluated as PRGs because they are often readily available and provide preliminary indication about the goals that a remedial action may have to attain. For groundwater SDWA maximum contaminant levels (MCLs), state drinking water standards, and Federal Water Quality Criteria (FWQC) are common ARARs.

FWQCs and state water quality standards (WQS) are common ARARs for surface water. Sediment Screening Values (SSVs) developed by National Oceanic and Atmospheric Administration (NOAA) can be used as ARARs for the evaluation of biological effects for aquatic organisms. In general, chemical-specific ARARs are not available for soil; however, some states have promulgated soil standards (e.g., PCB clean-up levels) that may be criteria appropriate to use as PRGs. Risk-based PRGs will be obtained from USEPA, Region III, Risk-Based Concentration Table (USEPA, 1994). The risk-based PRGs will be reviewed and modified after the completion of the baseline risk assessment. This modification will involve adding or subtracting chemicals of concern, media, pathways or revising individual chemical-specific goals. Table 4-2 provides PRGs for Sites 89 and 93, respectively.

4.6.1.8 Uncertainty Analysis

There is uncertainty associated with any risk assessment. The exposure modeling can produce very divergent results unless standardized assumptions are used and the possible variation in others are clearly understood. Similarly, toxicological assumptions, such as extrapolating from chronic animal studies to human populations, also introduce a great deal of uncertainty into the risk assessment. Uncertainty in a risk assessment may arise from many sources including:

- Environmental chemistry sampling and analysis.

- Misidentification or failure to be all-inclusive in chemical identification.

- Choice of models and input parameters in exposure assessment and fate and transport modeling.

- Choice of models or evaluation of toxicological data in dose-response quantification.

- Assumptions concerning exposure scenarios and population distributions.

The variation of any factor used in the calculation of the exposure concentration will have an impact on the total carcinogenic and noncarcinogenic risk. The uncertainty analysis will qualitatively discuss non-site and site-specific factors that may product uncertainty in the risk assessment. These factors may include key modeling assumptions, exposure factors, assumptions inherent in the development of toxicological end points, and spatio-temporal variance in sampling.

4.6.2 Ecological Risk Assessment

The overall purpose of an ecological risk assessment is to evaluate the likelihood that adverse ecological effects would occur or are occurring as a result of exposure to one or more physical or chemical stressors. This assessment will evaluate the potential effects of contaminants on sensitive or critical habitats or environments and protected species. The assessment will also employ a phased approach to determine potential adverse effects of contamination on the terrestrial and aquatic receptors (e.g., flora and fauna) on or adjacent to the site at MCB Camp Lejeune. The approach of the ecological risk assessment consists of a comparison of analytical results for soils, surface water, or sediments to available ecological standards or criteria. The approach of the ecological risk assessment will be to provide a conservative evaluation of the potential ecological effects associated with site contamination. If contaminant concentrations in environmental media exceed appropriate standards or criteria, additional phases of evaluation may be necessary to fully characterize potential ecological effects at a site.

The risk assessment methodologies will be consistent with those outlined in the Framework for Ecological Risk Assessment (USEPA, 1992b). In addition, information found in the following documents will also be consulted.

- Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (USEPA, 1989e)

- Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (USEPA, 1989a)

The following sections describe the general technical approach that will be used to evaluate the likelihood that adverse ecological effects could occur as a result of exposure to one or more physical or chemical stressors. The ecological risk assessment will consist of five components. These are: problem formulation; characterization of exposure; characterization of ecological effects; risk characterization; and uncertainty analysis.

4.6.2.1 Problem Formulation

Problem formulation is the first step of an ecological assessment and requires an understanding of site habitats, potential receptors, and potential endpoints. Problem formulation will be based on historical information and on the findings of the site visit conducted for the site. Data needs and regulatory issues will also be considered. The components of the problem formulation phase consist of stressor characteristics, ecosystems potentially at risk, ecological effects, endpoint selection, and a conceptual model.

The selection of chemical stressors or COPCs will be based on frequency of detection, background comparison, persistence of the contaminant, bioaccumulation potential, and the toxicity of the contaminant. Because of the differential toxicity of some contaminants to ecological verses human receptors, the COPCs for ecological receptors may differ from those selected for the human health risk assessment. Physical stressors including temperature and hydrologic changes and habitat alteration will also be taken into consideration.

Based on the site visit and historical information, ecological receptors will be identified, and the stressor-ecosystem-receptor relationship will be used to develop exposure scenarios in the characterization of exposure phase. Properties of the ecosystem that may be considered in the problem formulation phase include the abiotic environment (e.g., climatic conditions and soil or sediment properties), ecosystem structure (e.g., abundance and trophic level relationships), and ecosystem function (e.g., energy source, energy utilization, and nutrient processing). In addition, types and patterns of historical disturbances may be used to predict ecological receptor-stressor responses. Spatial and temporal distribution may also be used to define the natural variability in the ecosystem. The potential for indirect effects (e.g., reduction in prey availability or habitat utilization) will also be considered in the selection of ecosystem components.

Ecological effects data will be compiled for the physical and chemical stressors identified. Most of these data are available in the literature. Application of laboratory-based tests to field situations and to the interpretation of field observations that may be influenced by natural variability or non-site stressors that are not the focus of the ecological risk assessment will also be considered. The information compiled will be used to select ecological endpoints or characteristics of an ecological component that may be affected by exposure to a stressor.

A conceptual model of the site will then be developed. This conceptual model will consist of a series of working hypotheses regarding how the stressor might affect ecological components of the ecosystem potentially at risk.

4.6.2.2 Characterization of Exposure

The interaction of the stressor with the ecological component will be evaluated in the characterization of exposure. A quantitative evaluation of exposure will be developed that estimates the magnitude and spatial and temporal distributions of exposure for the various ecological components selected during the problem formulation and serve as input to the risk characterization.

4.6.2.3 Characterization of Ecological Effects

The relationship between the stressors and the assessment and measurement endpoints identified during problem formulation will be quantified and summarized in a stressor-response profile. The stressor-response profile will be used as input to the risk characterization. Scientific literature and regulatory guidelines will be reviewed for media-specific and/or species specific toxicity data. On-line databases will be accessed, such as AQUIRE and PHYTOTOX, to obtain current stressor-response data. Toxicity values will be from the most closely related species, where possible. If necessary, laboratory and in-field exposure response studies including acute and chronic toxicity tests of exposure to individual or multiple stressors may be used to supplement the available toxicological databases.

4.6.2.4 Risk Characterization

Risk characterization is the final phase of the ecological risk assessment and integrates the results of the exposure and ecological effects analyses. The likelihood of adverse effects occurring as a result of exposure to a stressor will be evaluated.

Individual endpoints may be evaluated by using single effects (e.g, media-specific and/or species specific toxicity data) and exposure values (e.g., dose units or exposure point concentrations) and comparing them using the quotient method for both media exposure and uptake exposure.

For exposure point concentrations that were monitored or modeled in the Characterization of Exposure, water criteria from either the state or from the USEPA will be compared using the quotient method to the ambient surface water concentrations. Likewise, sediment screening values from NOAA will be compared to measured sediment concentrations. These screening values will evaluate the potential for chemical constituents in both the surface water and sediments to cause adverse biological effects. Toxicity values from the literature that represent the toxicological effects on plants and/or invertebrates inhabiting soils will be compared to surface soil concentrations.

For dose unit exposure, terrestrial reference values, developed from No-Observed-Adverse-Effect-Levels (NOAELs) or Lowest-Observed-Adverse-Effect-Levels (LOAELs), will be compared to an estimate of total exposure to soils, surface water, and vegetation via calculation of a CDI. The exposure parameters used in the CDI equation will represent feeding rates, incidental soil ingestion rates, drinking water rates, body weights, and home range input for selected terrestrial receptors known to inhabit the areas of concern.

Population and community endpoints will be assessed by considering species representation by trophic group, taxa, or habitat. Site-specific field studies and biosurveys, if conducted, on and adjacent to the areas of concern may be compared to either historical population and community endpoint information or project-specific field studies and biosurveys.

The ecological significance of the risks characterized at the site will be discussed considering the types and magnitudes of the effects and their spatial and temporal patterns. Ecologically significant risks will be defined as those potential adverse risks or impacts to ecological integrity that affect populations, communities, and ecosystems, rather than individuals (i.e., measured impacts to individuals does not necessarily indicate impacts to the ecosystem).

4.6.2.5 Uncertainty Analysis

The ecological assessment is subject to a wide variety of uncertainties. Virtually every step in the risk assessment process involves numerous assumptions that contribute to the total uncertainty in the ultimate evaluation of risk. Assumptions are made in the exposure assessment regarding potential for exposure and exposure point locations. An effort is made to use assumptions that are conservative, yet realistic. The interpretation and application of ecological effects data is probably the greatest source of uncertainty in the ecological risk assessment. The uncertainty analysis will attempt to address the factors that affect the results of the ecological risk assessment.

4.6.2.6 Data Gaps

Incomplete exposure data gap pathways will be identified and recommendations for addressing same will be provided.

4.7 Task 7 - Treatability Study/Pilot Testing

This task includes the efforts to prepare and conduct bench- or pilot-scale treatability studies should they be necessary. This task begins with the development of a Treatability Study Work Plan for conducting the tests and is completed upon submittal of the Final Report. The following are typical activities:

Work plan preparation
Test facility and equipment procurement
Vendor and analytical service procurement
Testing
Sample analysis and validation
Evaluation of results
Report preparation
Project management

4.8 Task 8 - Remedial Investigation Report

This task is intended to cover all work efforts related to the preparation of the document providing the findings once the data have been evaluated under Tasks 5 and 6. The task covers the preparation of a Draft and Final RI Report. This task ends when the Final RI report is submitted.

4.9 Task 9 - Remedial Alternatives Screening

This task includes the efforts necessary to select the alternatives that appear feasible and require full evaluation. The task begins, if warranted, during data evaluation when sufficient data are available to initiate the screening of potential technologies. For reporting and tracking purposes, the task is defined as complete when a final set of alternatives is chosen for detailed evaluation.

4.10 Task 10 - Remedial Alternatives Evaluation

This task involves the detailed analysis and comparison of alternatives using the following criteria:

Threshold Criteria:

Overall Protection of Human Health and the Environment
Compliance With ARARs

Primary Balancing Criteria:

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

Modifying Criteria:

State and USEPA Acceptance
Community Acceptance

4.11 Task 11 - Feasibility Study Report

This task is comprised of reporting the findings of the Feasibility Study. The task covers the preparation of a Draft and Final FS report. This task ends when the Final FS report is submitted.

4.12 Task 12 - Post RI/FS Support

This task involves the technical and administrative support to LANTDIV to prepare a Draft and Final Responsiveness Summary, Proposed Remedial Action Plan (PRAP), and Record of Decision (ROD). This report will be prepared using applicable USEPA guidance documents.

4.13 Task 13 - Meetings

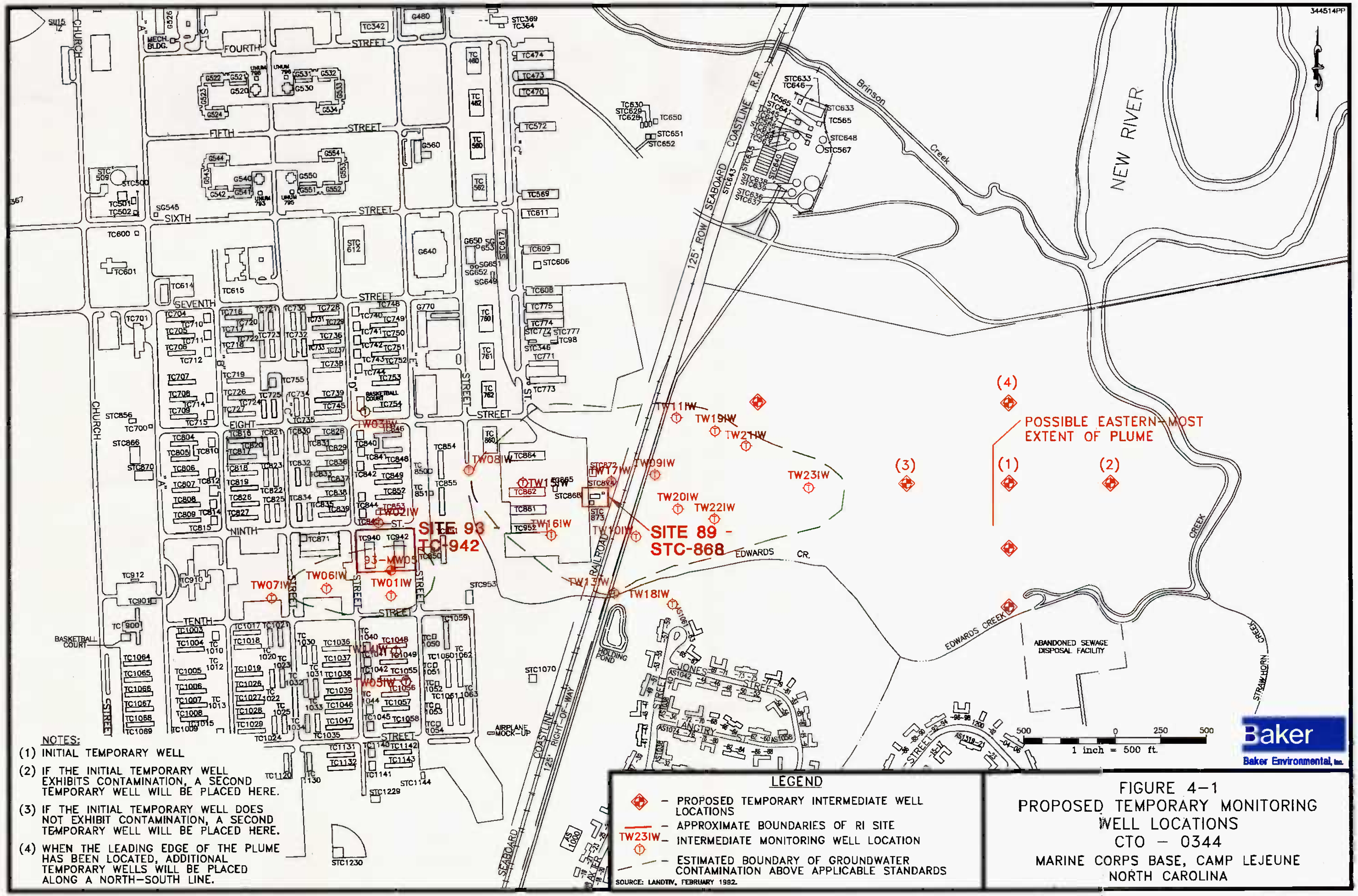
This task involves providing technical support to LANTDIV during the RI/FS. It is anticipated that the following meetings will be required:

- A remedial project management (RPM) meeting with LANTDIV/EMD, USEPA Region IV, and the North Carolina DEHNR following the submission of the Draft RI/FS report.

- A public meeting to present the findings of the RI/FS to the community at large prior to implementation of the Final ROD.

The meetings will be attended by the Baker Project Manager, and Project Engineer or Project Geologist.

SECTION 4.0 FIGURES



NOTES:

(1) INITIAL TEMPORARY WELL

(2) IF THE INITIAL TEMPORARY WELL EXHIBITS CONTAMINATION, A SECOND TEMPORARY WELL WILL BE PLACED HERE.

(3) IF THE INITIAL TEMPORARY WELL DOES NOT EXHIBIT CONTAMINATION, A SECOND TEMPORARY WELL WILL BE PLACED HERE.

(4) WHEN THE LEADING EDGE OF THE PLUME HAS BEEN LOCATED, ADDITIONAL TEMPORARY WELLS WILL BE PLACED ALONG A NORTH-SOUTH LINE.

LEGEND

- PROPOSED TEMPORARY INTERMEDIATE WELL LOCATIONS
- APPROXIMATE BOUNDARIES OF RI SITE
- TW23IW – INTERMEDIATE MONITORING WELL LOCATION
- ESTIMATED BOUNDARY OF GROUNDWATER CONTAMINATION ABOVE APPLICABLE STANDARDS

SOURCE: LANDTIV, FEBRUARY 1992.

FIGURE 4-1
PROPOSED TEMPORARY MONITORING WELL LOCATIONS
CTO – 0344
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01758EEB3Y

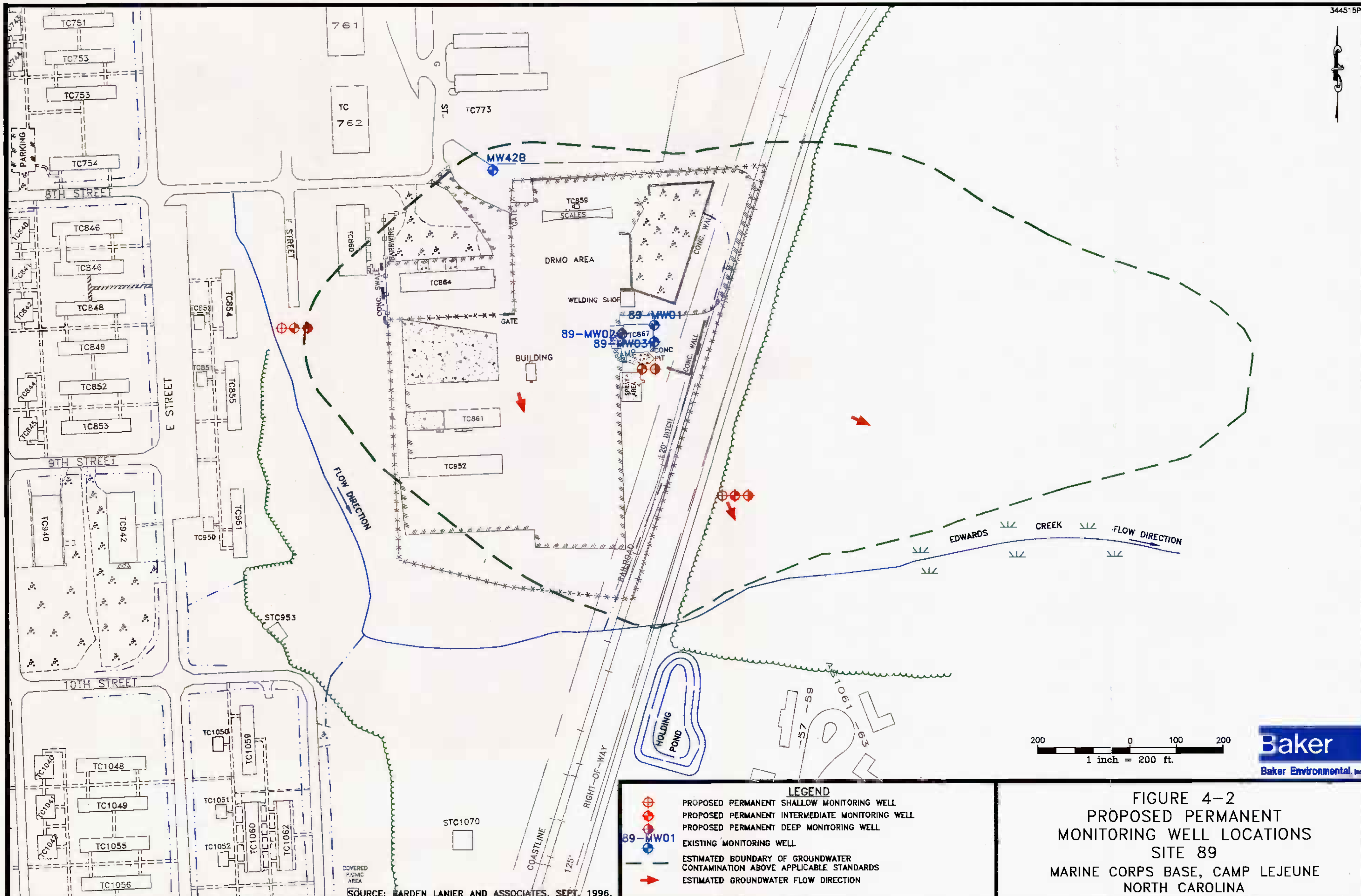
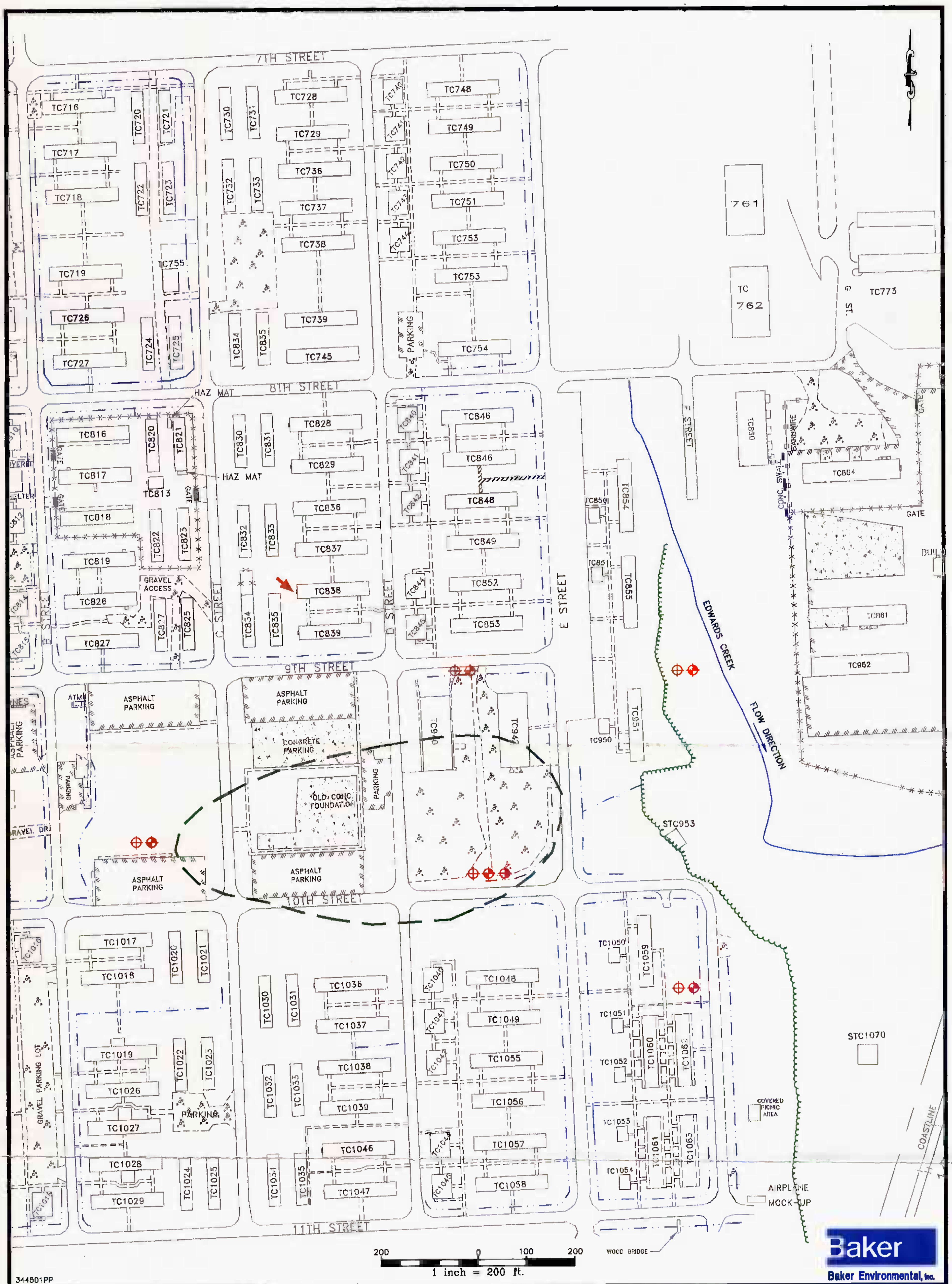


FIGURE 4-2
PROPOSED PERMANENT MONITORING WELL LOCATIONS
SITE 89
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- ⊕ PROPOSED PERMANENT SHALLOW WELL
- PROPOSED PERMANENT INTERMEDIATE WELL
- PROPOSED PERMANENT DEEP WELL
- — — ESTIMATED BOUNDARY OF GROUNDWATER CONTAMINATION ABOVE APPLICABLE STANDARDS
- ➔ APPROXIMATE GROUNDWATER FLOW DIRECTION

SOURCE: BARDEN LANIER AND ASSOCIATES, SEPT. 1996.OCT. 1991

FIGURE 4-3
PROPOSED PERMANENT MONITORING WELL LOCATIONS
SITE 93

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

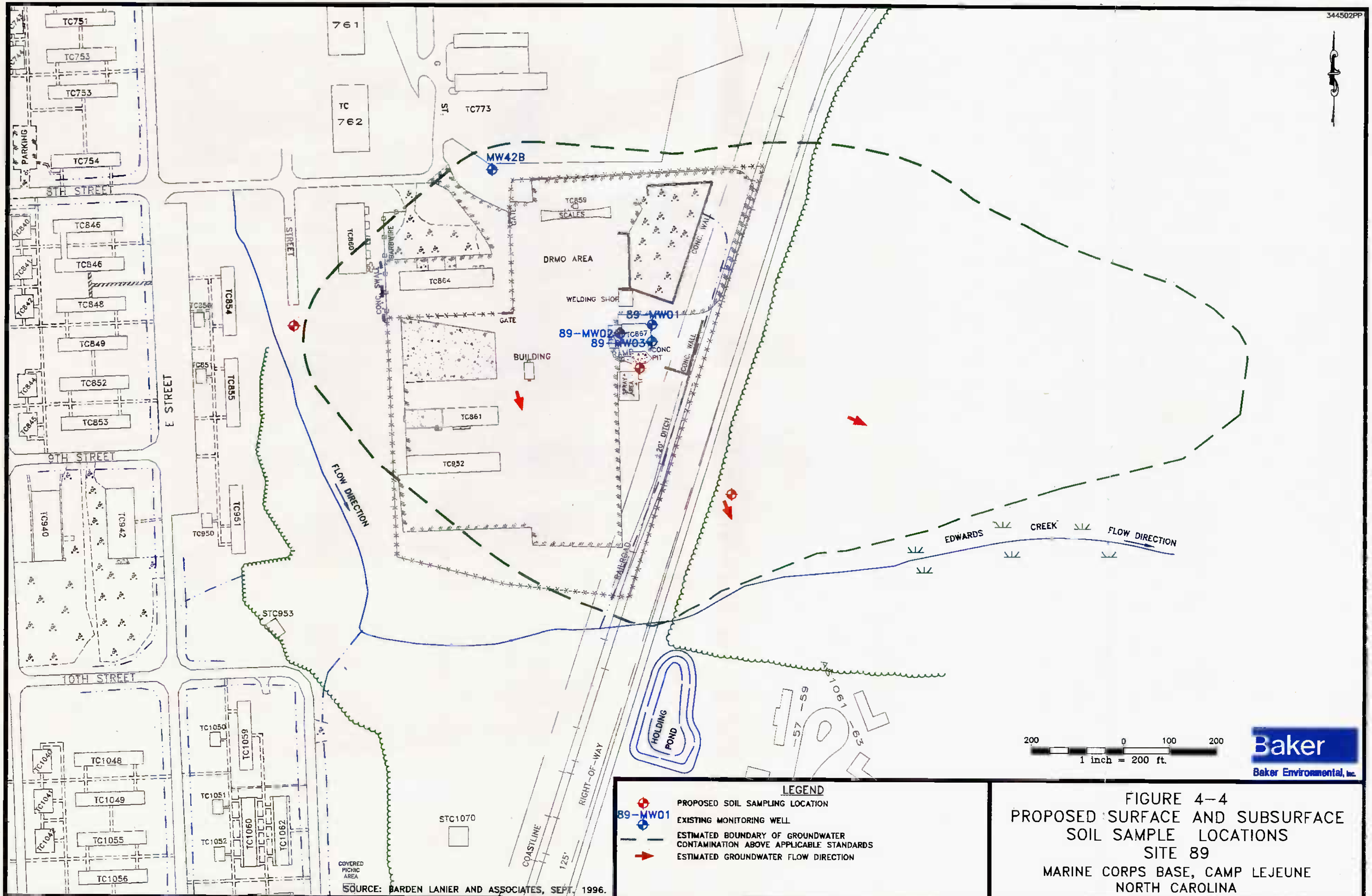
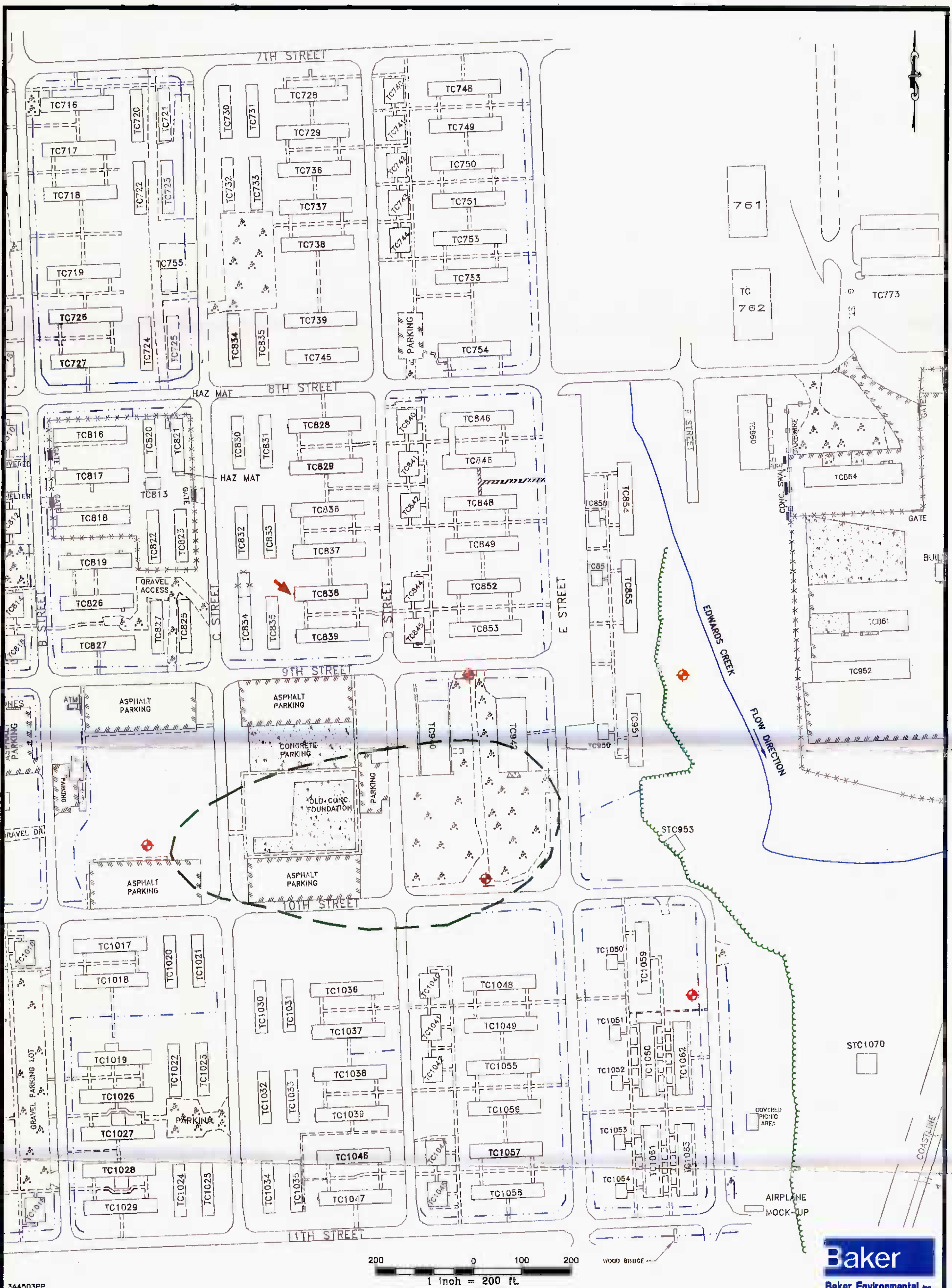


FIGURE 4-4
PROPOSED SURFACE AND SUBSURFACE SOIL SAMPLE LOCATIONS
SITE 89
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



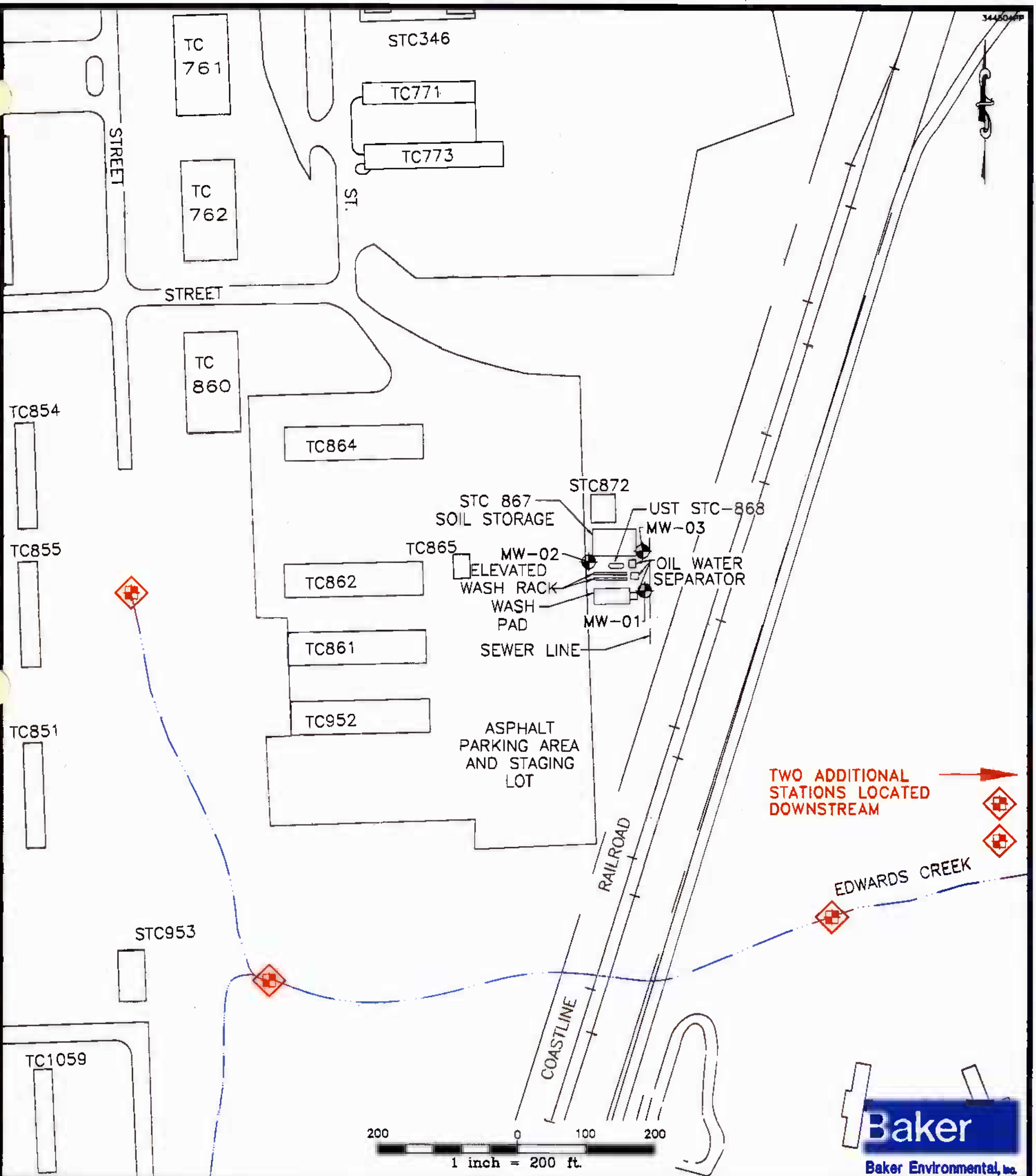
LEGEND

- PROPOSED SOIL SAMPLING LOCATION
- ESTIMATED BOUNDARY OF GROUNDWATER CONTAMINATION ABOVE APPLICABLE STANDARDS
- APPROXIMATE GROUNDWATER FLOW DIRECTION

SOURCE: BARDEN LANIER AND ASSOCIATES, SEPT. 1996,OCT. 1991

FIGURE 4-5
PROPOSED SURFACE AND SUBSURFACE SOIL SAMPLE LOCATIONS
SITE 93

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- EXISTING MONITORING WELL
- PROPOSED SURFACE WATER/SEDIMENT SAMPLE
- BUILDING
- RAILROAD
- CREEK

SOURCE: MCB CAMP LEJEUNE REVISED BASE MAP 11/95.

FIGURE 4-6
PROPOSED SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS
SITE 89
CTO-0344
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

5.0 PROJECT MANAGEMENT AND STAFFING

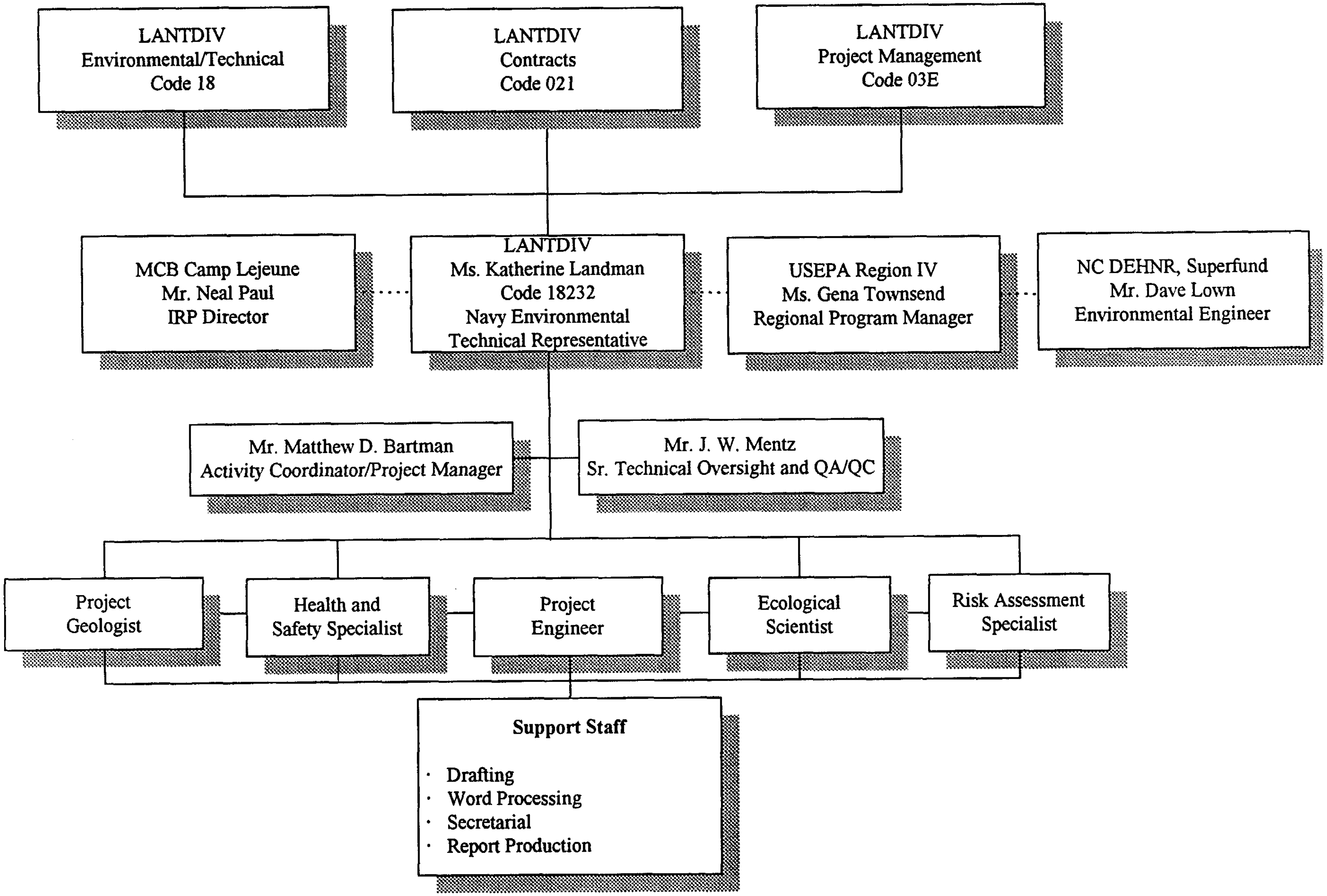
The Baker Project Team will be managed by Mr. Matthew D. Bartman. The primary responsibilities of the Project Manager will be to monitor the technical performance, cost, and schedule, and to maintain close communication with the Navy Technical Representative, Ms. Kate Landman. The Project Manager will report to Mr. John W. Mentz who will be responsible to provide program level support and overall QA/QC.

The Project Team will consist of a Risk Assessment Specialist, Project Engineer, Project Geologist, Health and Safety Specialist, Ecological Scientist, and technical support staff as shown in Figure 5-1.

SECTION 5.0 FIGURES

FIGURE 5-1

PROJECT ORGANIZATION



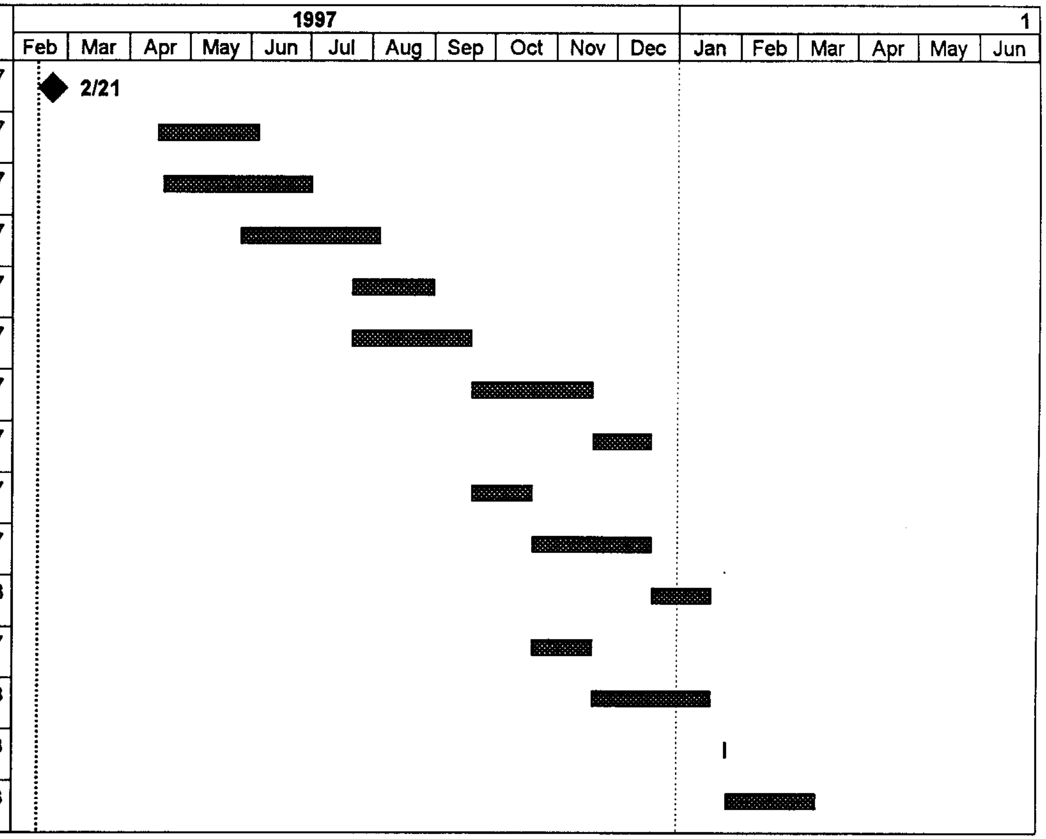
6.0 SCHEDULE

The proposed project schedule for Operable Unit No. 16 (Site 89 and 93) is presented as Figure 6-1 and is based on the availability of government funding and a notice to proceed date of April 1, 1997. The projected start up of the Phase II field program is expected to be initiated in April 1997 and completed in May 1997. The Final Report is expected to be submitted by August 1997.

SECTION 6.0 FIGURES

Figure [illegible] - 1
Phase II, Remedial Investigation/Feasibility Study Schedule
Operable Unit 16 (Sites 89 and 93), MCB Camp Lejeune, North Carolina

ID	Task Name	Duration	Start	Finish
1	Submit Final Project Plans	0ed	2/21/97	2/21/97
2	Phase II Field Investigation	51ed	4/14/97	6/4/97
3	Sample Analysis/Validation	75ed	4/17/97	7/1/97
4	Data Evaluation	70ed	5/26/97	8/4/97
5	Risk Assessment	41ed	7/21/97	8/31/97
6	Draft RI Report	60ed	7/21/97	9/19/97
7	Comment Period	60ed	9/19/97	11/18/97
8	Final RI Report	30ed	11/18/97	12/18/97
9	Draft FS/PRAP	30ed	9/19/97	10/19/97
10	Comment Period	60ed	10/19/97	12/18/97
11	Final FS/PRAP	30ed	12/18/97	1/17/98
12	Draft ROD	30ed	10/19/97	11/18/97
13	Comment Period	60ed	11/18/97	1/17/98
14	Public Meeting	1ed	1/24/98	1/25/98
15	Final ROD	45ed	1/25/98	3/11/98



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APPENDIX A
MCB CAMP LEJEUNE AERIAL PHOTOGRAPHS

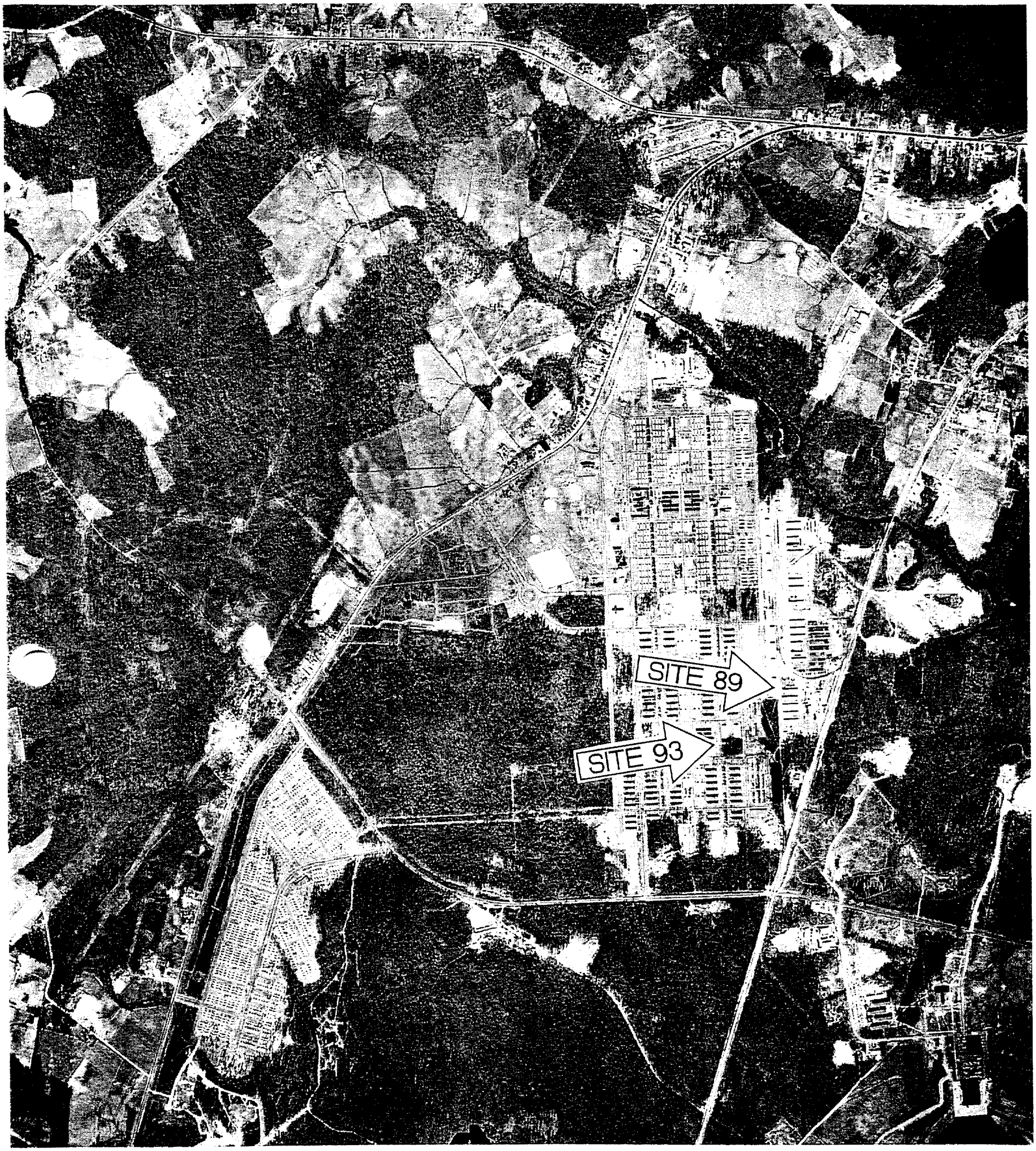

FIGURE 1
FERUARY 1, 1956
SITES 89 AND 93
MCB CAMP LEJEUNE, NORTH CAROLINA

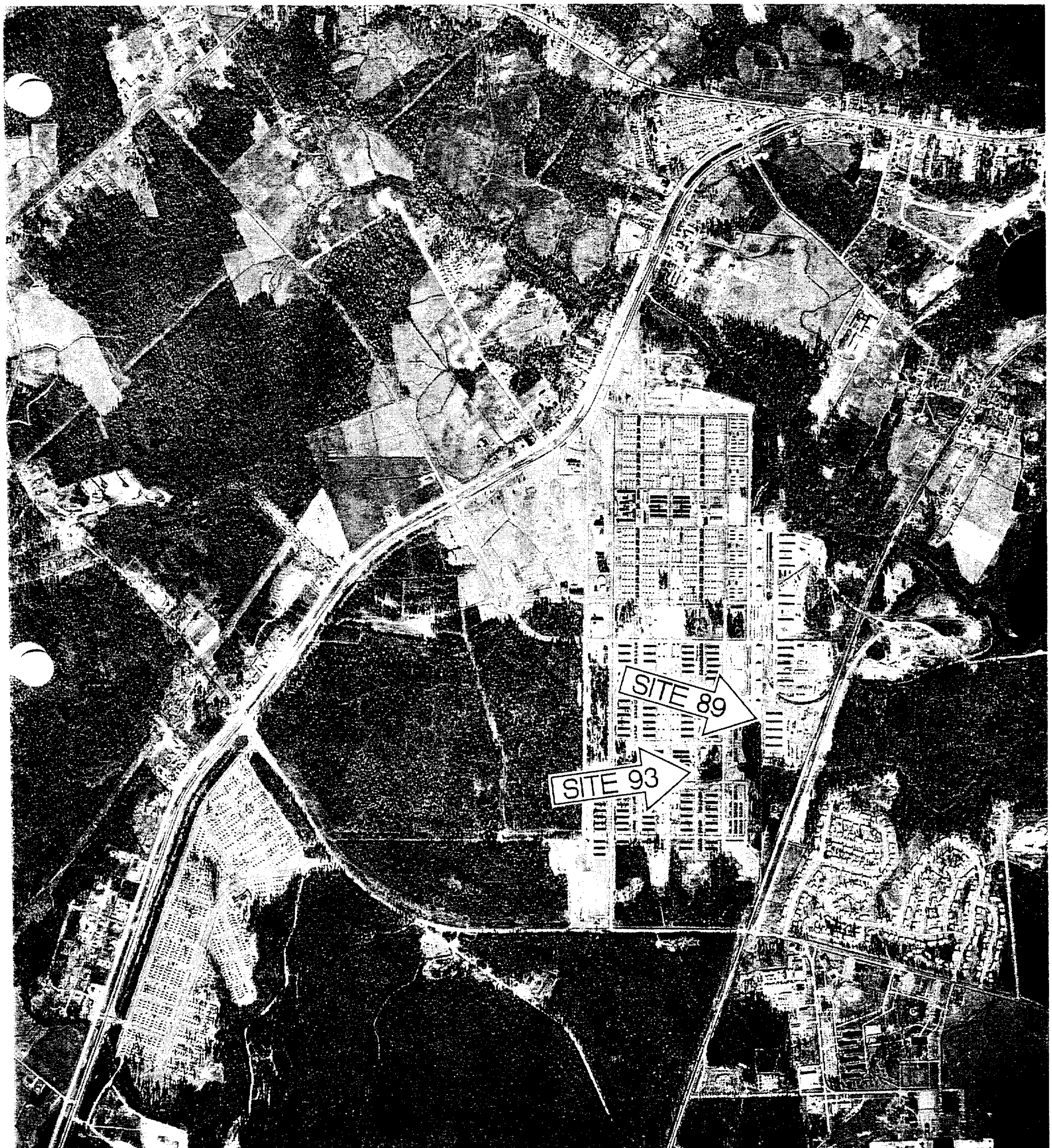

FIGURE 2
DECEMBER 17, 1960
SITES 89 AND 93
MCB CAMP LEJEUNE, NORTH CAROLINA

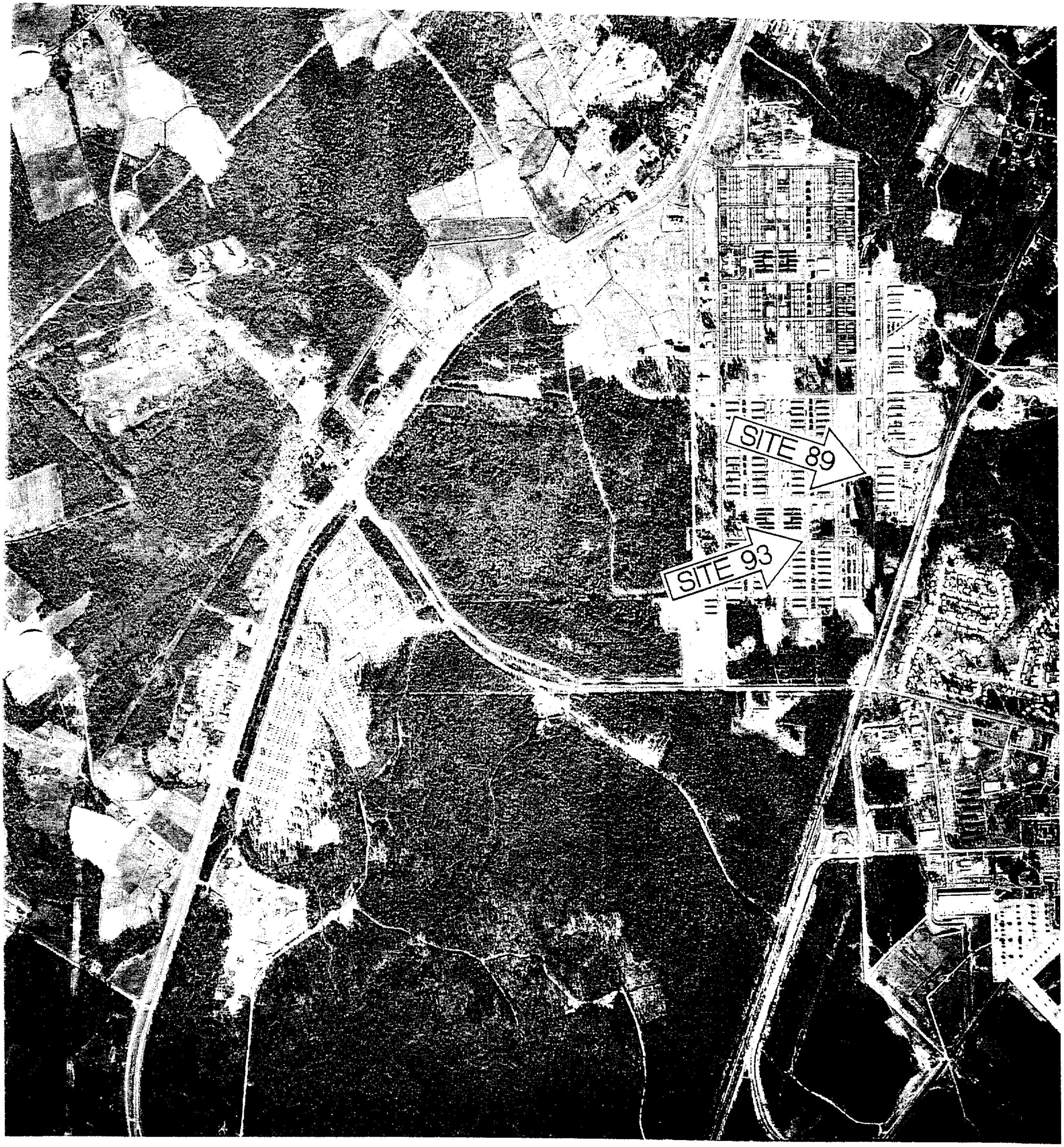

FIGURE 3
FEBRUARY 4, 1964
SITES 89 AND 93
MCB CAMP LEJEUNE, NORTH CAROLINA

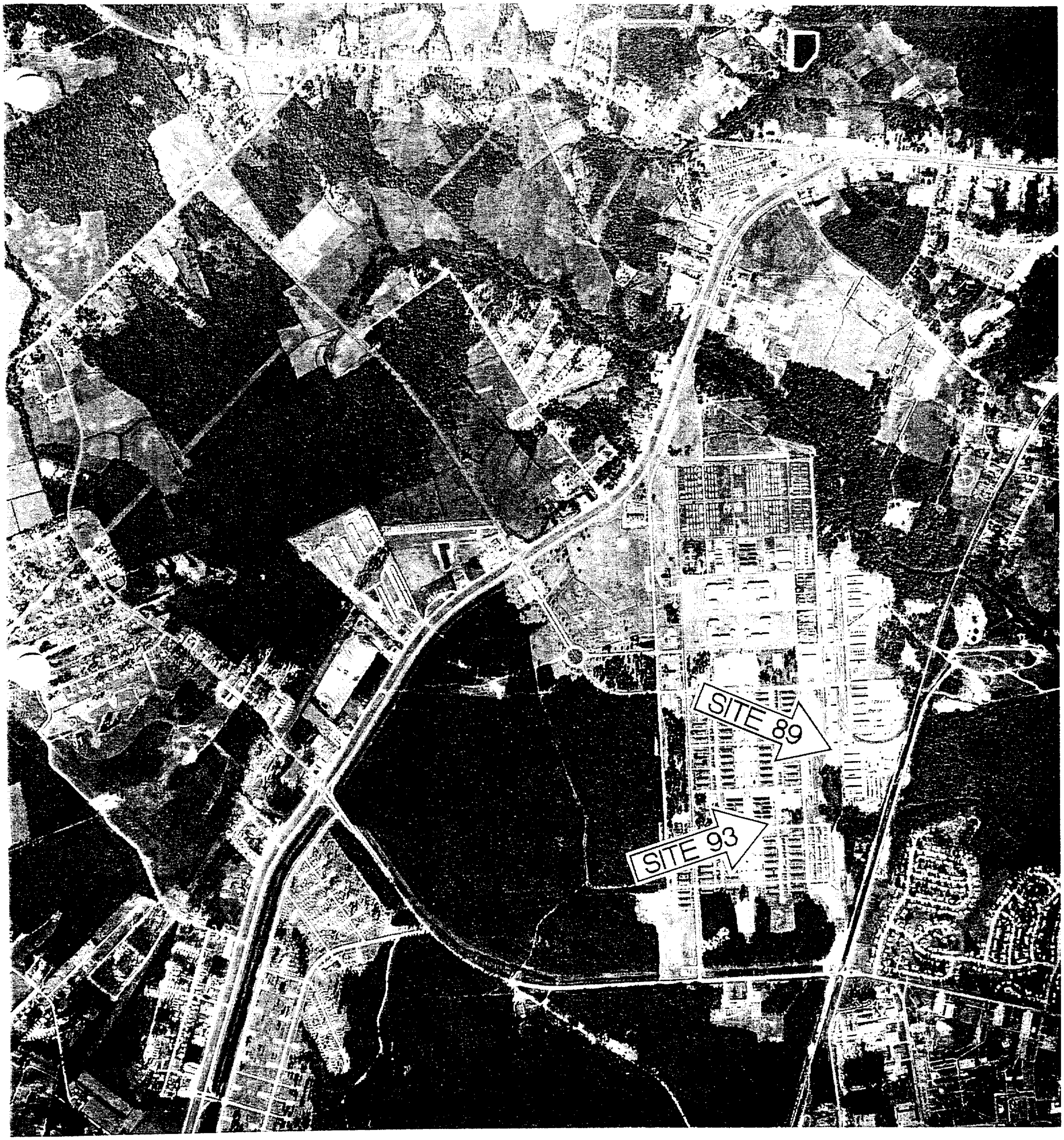

FIGURE 4
OCTOBER 4, 1970
SITES 89 AND 93
MCB CAMP LEJEUNE, NORTH CAROLINA

FIGURE 5
MARCH 6, 1993
SITES 89 AND 93
MCB CAMP LEJEUNE, NORTH CAROLINA

FINAL

REMEDIAL INVESTIGATION/ FEASIBILITY STUDY FIELD SAMPLING AND ANALYSIS PLAN

OPERABLE UNIT NO. 16 (SITES 89 AND 93) MCB CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0344

FEBRUARY 21, 1997

Prepared For:

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION
NAVAL FACILITIES
ENGINEERING COMMAND
Norfolk, Virginia

Under the:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared By:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

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ACRONYMS AND ABBREVIATIONS

AQTESOLV	Aquifer Test Solver
ASTM	American Society for Testing and Materials
Baker	Baker Environmental, Inc.
bgs	Below Ground Surface
BOD	Biological Oxygen Demand
CLP	Contract Laboratory Program
COD	Chemical Oxygen Demand
CTO	Contract Task Order
DEHNR	Department of Environment, Health, and Natural Resources
DOT	Department of Transportation
DQO	Data Quality Objective
DRMO	Defense Reutilization Management Office
ECBSOPQAM	Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual
Eh	Oxidation-Reduction Potential
EMD	Environmental Management Division
ESD	Environmental Services Division
FID	Flame Ionization Detector
FSAP	Field Sampling and Analysis Plan
HASP	Health and Safety Plan
ID	Inside Diameter
IDW	Investigation Derived Waste
L/min	Liter per Minute
LANTDIV	Atlantic Division, Naval Facilities Engineering Command
MCB	Marine Corps Base
MCL	Maximum Contaminant Level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NCWQS	North Carolina Water Quality Standard
NFESC	Naval Facilities Engineering Service Center
NTU	Nephelometric Turbidity Unit
O_2/LEL	Oxygen/Combustible Gas Meter
OD	Outside Diameter
OU	Operable Unit

ACRONYMS AND ABBREVIATIONS
(Continued)

PCB	Polychlorinated Biphynel
PID	Photoionization Detector
POL	Petroleum/Oil/Lubricant
PSI	Pounds per Square Inch
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
SOP	Standard Operating Procedure
TAL	Target Analyte List
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TDS/TSS	Total Dissolved Solids/Total Suspended Solids
TOC	Total Organic Carbon
TSDF	Treatment Storage and Disposal Facility
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
VOA	Volatile Organic Analysis
VOC	Volatile Organic Compound
WQP	Water Quality Parameter

1.0 INTRODUCTION

This Field Sampling and Analysis Plan (FSAP) presents the proposed Remedial Investigation (RI) field activities that are to be conducted at Operable Unit (OU) No. 16 (Site 89 - STC-868 and Site 93- TC-942) at Marine Corps Base (MCB), Camp Lejeune, North Carolina. The RI field activities will be conducted in two phases. Phase I, which has been completed, included the installation of temporary monitoring wells to better define the horizontal extent of contamination. Phase II will include the installation of additional temporary wells and permanent shallow, intermediate, and deep monitoring wells, and the collection of surface water, sediment, and soil samples. The FSAP is part of the Project Plans, which also contain the Work Plan, Quality Assurance Project Plan (QAPP), and Health and Safety Plan (HASP).

The primary purpose of the FSAP is to provide guidance for all project field activities by describing in detail the sampling and data collection methods to be used in implementing the various field tasks identified in the Remedial Investigation/Feasibility Study (RI/FS) Work Plan for Sites 89 and 93. This document also helps to ensure that project activities are carried out in accordance with the United States Environmental Protection Agency (USEPA) Region IV and Naval Facilities Engineering Service Center (NFESC) standard operating procedures (SOPs) so that data obtained during the field investigation are of sufficient quantity and quality to evaluate the nature and extent of contamination in various media, estimate human health and environmental risks, and to evaluate potential technologies for remediation of contaminated media.

This FSAP will provide the guidance for all the project field activities planned for the second phase of the work to be performed.

2.0 SITE BACKGROUND

A description of the history and setting of MCB, Camp Lejeune and Sites 89 and 93 is contained in Section 2.0 of the RI/FS Work Plan.

3.0 SAMPLING OBJECTIVES

The sampling and data quality objectives (DQOs) for field investigations at Sites 89 and 93 are summarized in Section 3.0 of the RI/FS Work Plan.

4.0 SAMPLING LOCATIONS AND FREQUENCY

This section of the FSAP describes the location and frequency of environmental samples to be collected during the sampling program. Support activities, sampling locations, sample matrix, constituents to be analyzed for and Quality Assurance/Quality Control (QA/QC) requirements are discussed within this section. Detailed investigation procedures, sampling handling, and analytical requirements are provided in Sections 6.0 and 7.0, respectively.

The following Phase II investigation and support activities will be conducted at Sites 89 and 93:

- Surveying
- Groundwater Investigation
- Soil Investigation
- Surface Water and Sediment Investigation
- Quality Assurance/Quality Control Samples
- Investigation Derived Waste Handling

Each activity is described in the following subsections.

4.1 Surveying

This task will involve the surveying of the newly installed temporary and permanent monitoring wells, surface water/sediment stations, and staff gauge locations. The location and elevation of a reference point on top of the polyvinyl chloride (PVC) riser and the elevation of the ground surface will be surveyed for each newly installed monitoring well. The location of each staff gauge and the corresponding elevation will be surveyed. Survey points will include a latitude and longitude coordinate, and an elevation expressed in feet above mean sea level. The vertical accuracy of the survey will be within 0.01 feet and the horizontal accuracy will be within 0.1 feet. All survey points will be correlated to the North Carolina State Plane Coordinate System.

4.2 Groundwater Investigation

A groundwater investigation will be conducted in the vicinity of Sites 89 and 93 during the Phase II field investigation for two purposes. The first purpose is to fully delineate the extent of contamination in the surficial aquifer east of Site 89. This task will be accomplished through the installation and sampling of an additional temporary wells. The second purpose is to verify the extent of the contaminant plumes to monitor for evidence of natural attenuation processes. This task will be accomplished through the installation and sampling of permanent well clusters. The following subsections provide a description of the proposed investigation.

4.2.1 Well Construction and Locations

The Phase II investigation will include the installation of temporary and permanent monitoring wells as described below:

A minimum of five additional intermediate temporary monitoring wells will be installed to fully define the horizontal extent of the contaminant plume at Site 89. The locations of the temporary monitoring wells are based on the currently defined plume and engineering judgement of the possible extent of the leading edge (Figure 4-1 of the Work Plan). Additional temporary wells will be installed as needed to fully define the extent of the plume.

Temporary monitoring well will be installed and the investigation area boundaries will be adjusted until the contamination is found below or a pattern develops of decreasing concentration to North Carolina Water Quality Standards (NCWQS) or Federal Maximum Contaminant Levels (MCLs).

Initially, one temporary well will be installed as shown on Figure 4-1. The locations of subsequent temporary wells will be based on levels of contamination detected in the initial installation. If there is a substantial decrease in the detected contaminant concentrations (or nondetectable concentrations) between 89-TW23IW and the initial temporary well, one additional temporary well will be installed between the 89-TW23IW and initial temporary well. If contaminants are present in the initial temporary monitoring well, one additional temporary well will be installed east of the initial temporary monitoring well. When the eastern extent of the contaminant plume is established, three additional temporary wells will be installed on a north-south trending line to fully define the plume extent. One additional temporary well will be installed north of 89-TW191W and 89-TW21IW to better define the northern extent of the plume.

Upon the completion of the temporary well investigation at Site 89, permanent well clusters will be installed at both Site 89 and 93 (Figures 4-2 and 4-3 of the Work Plan). These well clusters will be installed in the surficial and Castle Hayne aquifers to verify the extent of groundwater contamination, and to monitor for evidence of natural attenuation processes. Each of the eight clusters will include one intermediate monitoring well (both Type II). Seven of eight clusters will include one shallow well (Type II). The remaining cluster will utilize an existing well. Additionally, three of the eight clusters will also include a deep monitoring well (Type II and Type III). At Site 89, the deep monitoring wells will be placed in the first encountered groundwater below the semi-confining layer to verify the presence or absence of contamination in the upper portion of the Castle Hayne Aquifer. At Site 93, where a semi-confining unit was not encountered, the deep monitoring well will be installed as a Type II well at a depth similar to the other deep monitoring wells at Site 89. Additional permanent well clusters will be installed at the northern and eastern edges of the contaminant plume at Site 89. The number and locations of the clusters will be based on the findings of the additional temporary well investigation.

The temporary intermediate monitoring wells will be installed to a depth of approximately 40 to 50 feet bgs. These wells will be constructed of 1-inch inside diameter (ID) PVC pipe, with 10 feet of 0.01-inch slot well screen. The shallow permanent monitoring wells are anticipated to be installed to a depth of approximately 20 to 25 feet deep. These wells will be constructed of 2-inch ID PVC pipe, with 15 feet of 0.01-inch slot well screen. The permanent intermediate monitoring wells are anticipated to be installed to a depth of approximately 40 to 50 feet deep. These wells will be constructed of 2-inch ID PVC pipe, with 5 feet of 0.01-inch slot well screen. The permanent deep monitoring wells are anticipated to be installed to a depth of approximately 50 to 60 feet deep. These wells will be constructed of 2-inch ID PVC pipe, with 5 feet of 0.01-inch slot well screen. Section 6.2 presents specific details on procedures for temporary monitoring well installation and Appendix B contains the justification for USEPA Region IV to use PVC material.

4.2.2 Sampling and Analytical Requirements

One groundwater sample will be collected from each of the temporary monitoring wells. Upon completion of the permanent monitoring well installation, one round of groundwater sampling will be conducted. Samples will be collected using low flow purging and sampling methodology. Section 6.5 presents specific details on procedures for groundwater sampling. Groundwater measurements will be taken to confirm groundwater flow direction and tidal influence.

All groundwater samples from the temporary monitoring wells will be analyzed by an on-site laboratory for Target Compound List (TCL) volatiles by EPA SW846 Method 8240 (Level II data quality). Ten percent of all samples analyzed on-site also will be analyzed for TCL volatiles at a fixed base analytical laboratory to confirm the results of the mobile laboratory on a routine, 35-day turnaround time.

Groundwater samples collected from the permanent monitoring wells will be analyzed for TCL volatiles, semivolatiles, and Target Analyte List (TAL) total metals in accordance with contract laboratory program (CLP) methods, DQO Level IV. Ten percent of the samples will be analyzed for TCL pesticides/polychlorinated biphenyls (PCBs). Additional analysis will include nitrate, nitrite, sulfate, sulfide, methane, chloride to assess natural attenuation process. One sample for total dissolved solids/total suspended solids (TDS/TSS) and biological oxygen demand (BOD)/chemical oxygen demand (COD) will be collected from one intermediate well at Site 89 to assist the evaluation of remedial alternatives and assist in the remedial design. Routine, 35-day analytical turnaround time will be requested for all groundwater samples. Groundwater field measurements, including pH, conductivity, dissolved oxygen, reduction/oxidation potential, turbidity, and temperature (Level I quality), also will be collected. Depth-to-groundwater measurements will be taken to confirm groundwater flow direction and tidal influence.

4.2.3 Aquifer Properties Testing

In Situ slug tests will be performed on select newly installed monitoring well from the Phase II investigation. Slug tests will be performed after groundwater sampling has been conducted. The procedure for slug test performance is found in Section 6.6.

4.3 Soil Investigation

A soil investigation will be conducted in the vicinity of Site 89 and 93 during the Phase II field investigation to confirm the presence of soil contamination and to determine its horizontal and vertical extent. A utility clearance will be conducted prior to monitoring well boring installation. The following subsections provide a description of the proposed investigation.

4.3.1 Sampling Locations

During the Phase II field activities, three soil samples will be collected from each of the proposed permanent monitoring well borings and submitted for chemical analysis. One surface soil sample (0- to 6- inches bgs) will be collected from each well boring unless the boring is located within a paved portion of the investigation area. One subsurface soil sample will be collected from just above the water table. A second subsurface sample will be collected from within the aquifer to obtain information relevant for groundwater modeling. If the depth to groundwater is greater than 10 feet below ground surface (bgs) or there is evidence of contamination, one additional subsurface soil sample (for a total of four soil samples) will be collected from a mid-depth.

A total of six Shelby Tube samples will be collected from selected permanent monitoring well borings from the Phase II investigation (three samples from two wells). Shelby Tube samples will be collected from the vadose zone, from surficial aquifer, and from the Castle Hayne Confining Unit at two well boring locations.

4.3.2 Analytical Requirements

The surface and subsurface soil samples collected during Phase II of the investigation will be analyzed for TCL volatiles, semivolatiles, and TAL metals in accordance with CLP methods, DQO Level IV. Ten percent of the samples from of all permanent wells installed will be analyzed for TCL pesticides/PCBs. All soil samples will be analyzed on a routine, 35-day turnaround time. Additionally, two composited soil samples, one from Site 89 and one from Site 93, will be selected and analyzed for total organic carbon (TOC), bulk density, and grain size on a routine turnaround time. Vertical permeability will be determined from the six shelby tube samples.

4.4 Surface Water/Sediment Investigation

A surface water investigation will be conducted at Site 89 to determine if, and what portion of, Edwards creek is tidally influenced. A sediment investigation will be conducted for data input into the ecological risk assessment. The following subsections provide a description of the proposed investigation.

4.4.1 Sampling Locations

One surface water sample will be collected from five stations in Edwards Creek. The stations will be evenly distributed over the length of the creek to the point where it turns to the north (east of the railroad right-of-way). Final sampling locations will be determined in the field based on accessibility and surface water flow and depth. Sections 6.7 and 6.8 present specific details on procedures for surface water and sediment sampling, respectively.

Two staff gauge will be installed in Edwards Creek to determine the presence of tidal influences on the creek level and to assess the interconnection between groundwater and the creek. One staff gauge (SG02) will be installed in Edwards Creek, upstream from the site. One existing staff gauge (SG01), presently located downstream of the site, will be used.

4.4.2 Analytical Requirements

All surface water samples will be analyzed chloride accordance with CLP methods, DQO Level IV. All sediment samples will be analyzed for grain size and TOC. Samples will be analyzed on a routine, 35-day turnaround time.

4.5 Quality Assurance/Quality Control Samples

QA/QC requirements for this investigation are presented in the QAPP. The following QA/QC samples will be collected during field sampling activities:

Trip Blanks

Trip blanks are defined as samples which originate from the analyte-free water taken from the laboratory to the sampling site, kept with the investigative samples throughout the sampling event, and returned to the laboratory with the volatile organic analysis (VOA) samples. The blanks will only be analyzed for TCL volatile organics. The purpose of a trip blank is to determine if samples were contaminated during storage and transportation back to the laboratory. One trip blank will accompany each cooler containing samples for VOA.

Equipment Rinsates

Equipment rinsates are defined as samples which are obtained by running organic-free water over/through sample collection equipment after it has been cleaned. Equipment rinsates will be collected daily during each sampling event. One rinsate per media sampled per day will be collected. For example, if groundwater and soil samples were collected on one given day, two rinsates would be collected. Initially, samples from every other day will be analyzed. If analytes pertinent to the project are found in the rinsates, the remaining samples must be analyzed. The results from the rinsates will be used to evaluate the decontamination methods. This comparison is made during data validation and the rinsates are analyzed for the same parameters as the related samples. One equipment rinsate will be collected per media sampled per day of field sampling.

Field Blanks

Field blanks consist of the source water used in decontamination. Field blanks will be collected by pouring the water from the container directly into sample bottles. Field blanks should not be collected in dusty environments and/or from areas where volatile organic contamination is present in the atmosphere and originating from a source other than the source being sampled. One field blank will be prepared at the commencement of the project.

Field Duplicates

Field duplicates for soil samples are collected, homogenized, and split. All samples except VOAs are homogenized and split. Volatiles are not mixed, but select segments of soil are taken from the length of the core and placed in sampling jars. The duplicates for water samples should be collected simultaneously. The water samples will not be composited. Field duplicates will be collected at a frequency of 10 percent.

Matrix Spike/Matrix Spike Duplicates

Matrix Spike/Matrix Spike Duplicate (MS/MSD) samples are collected to evaluate the matrix effect of the sample upon the analytical methodology. A matrix spike and matrix spike duplicate must be performed for each group of samples of a similar matrix. MS/MSD samples will be collected at a frequency of 5 percent.

4.6 Investigation Derived Waste Handling

If generated, soil cuttings will be collected and contained in a roll-off box if it is determined in the field to be potentially contaminated based on visual observations and HNu photoionization detector (PID) readings. If visual contamination or elevated HNu PID readings are not exhibited, the cuttings will be spread out around the area. One rigid storage tank with a capacity of 1,000 gallons will be stationed at each site for containing groundwater development and purge water. A composite soil sample from the roll-off box will be collected and analyzed for full toxicity characteristic leaching procedure (TCP) (organics and inorganic) and Resource Conservation and Recovery Act (RARA) hazardous waste characterization (corrosivity, reactivity, and ignitability), and PCBs. One sample will be collected from the tank and analyzed for full TCL organics, TAL total metals, and TDS/TSS. Additional details regarding investigation derived waste (IDW) handling and disposal are provided in Section 6.11.

SECTION 4.0 FIGURES

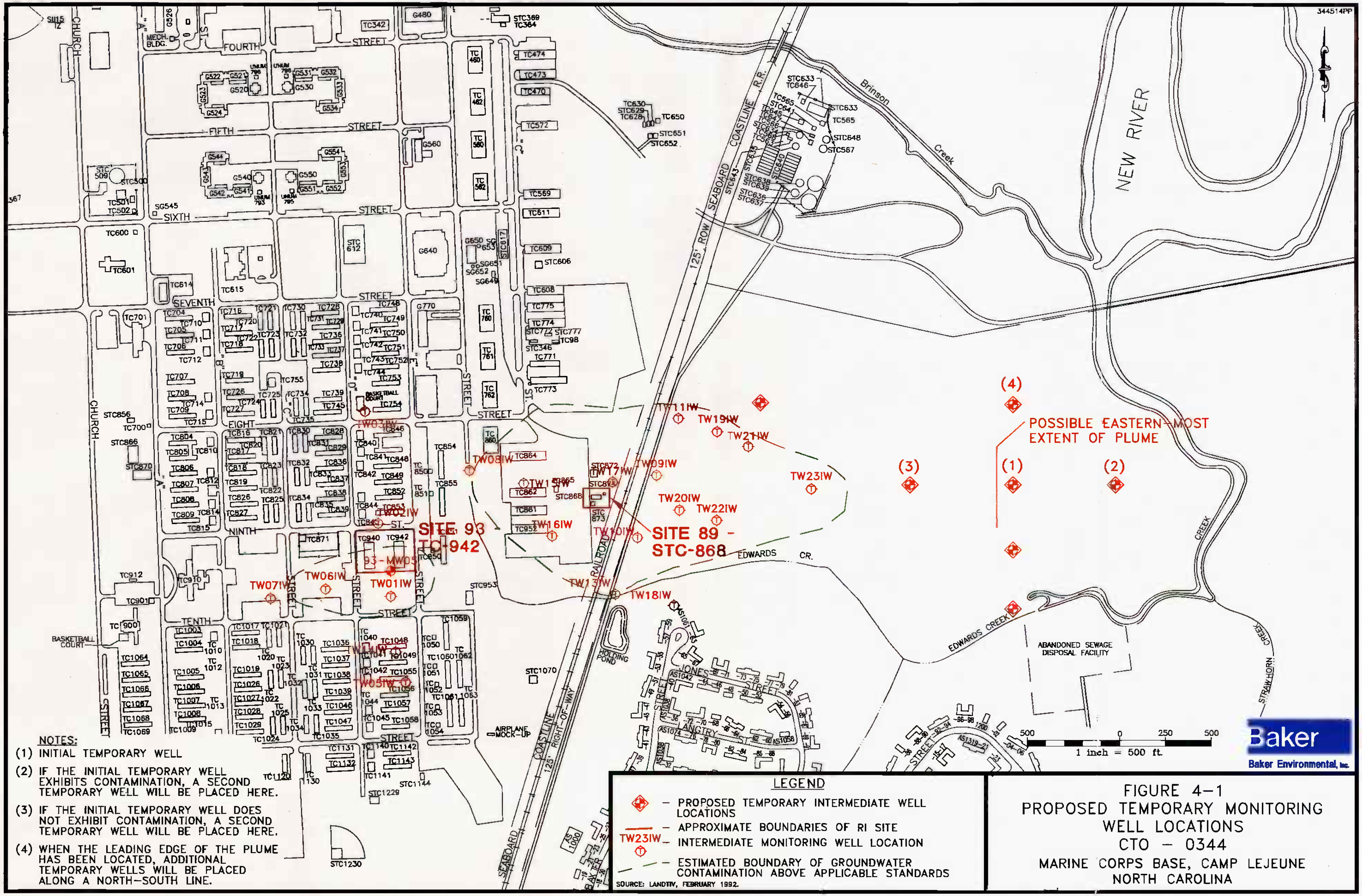


FIGURE 4-1
PROPOSED TEMPORARY MONITORING WELL LOCATIONS
CTO – 0344
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01758EEB4Y

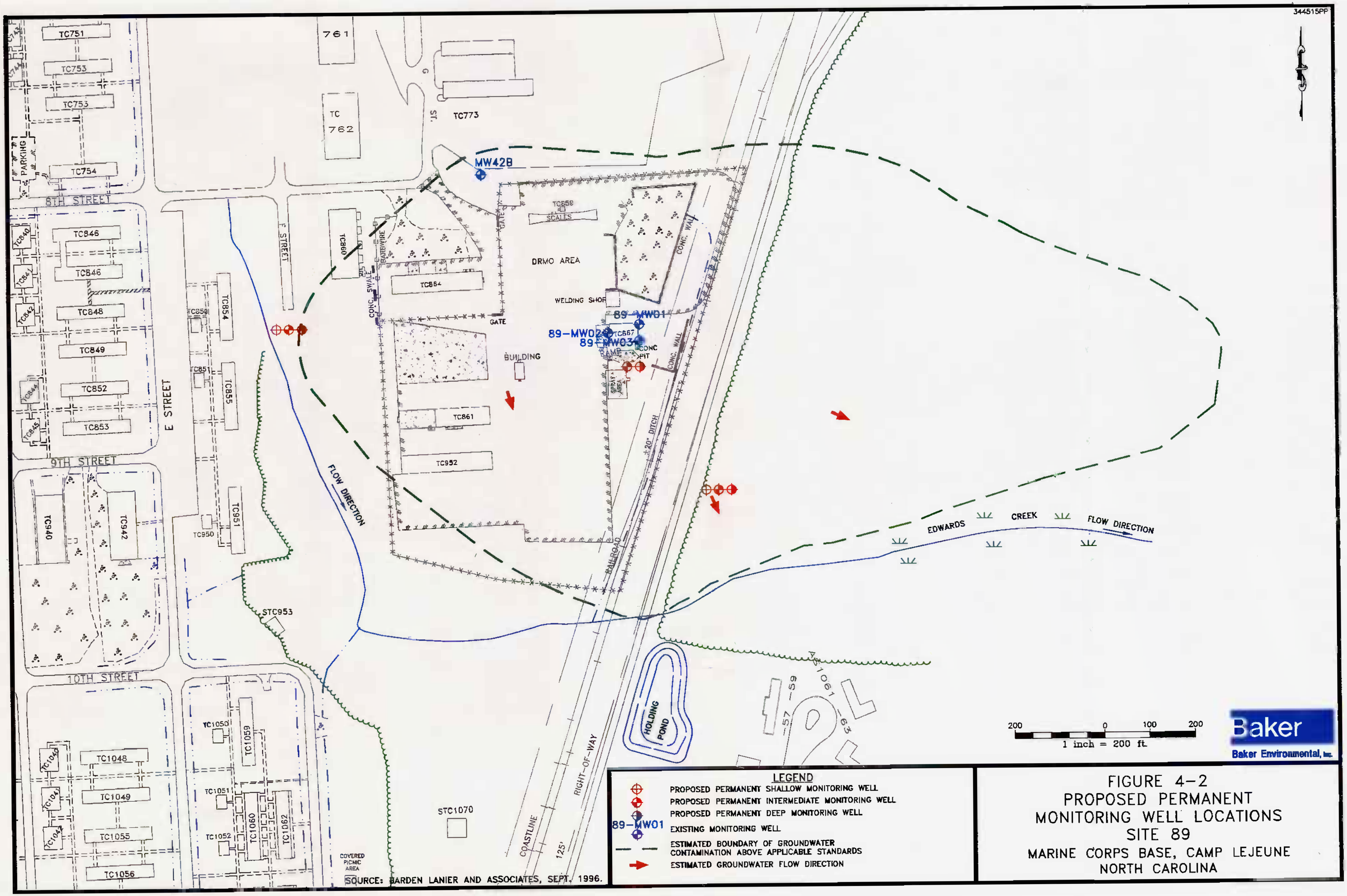
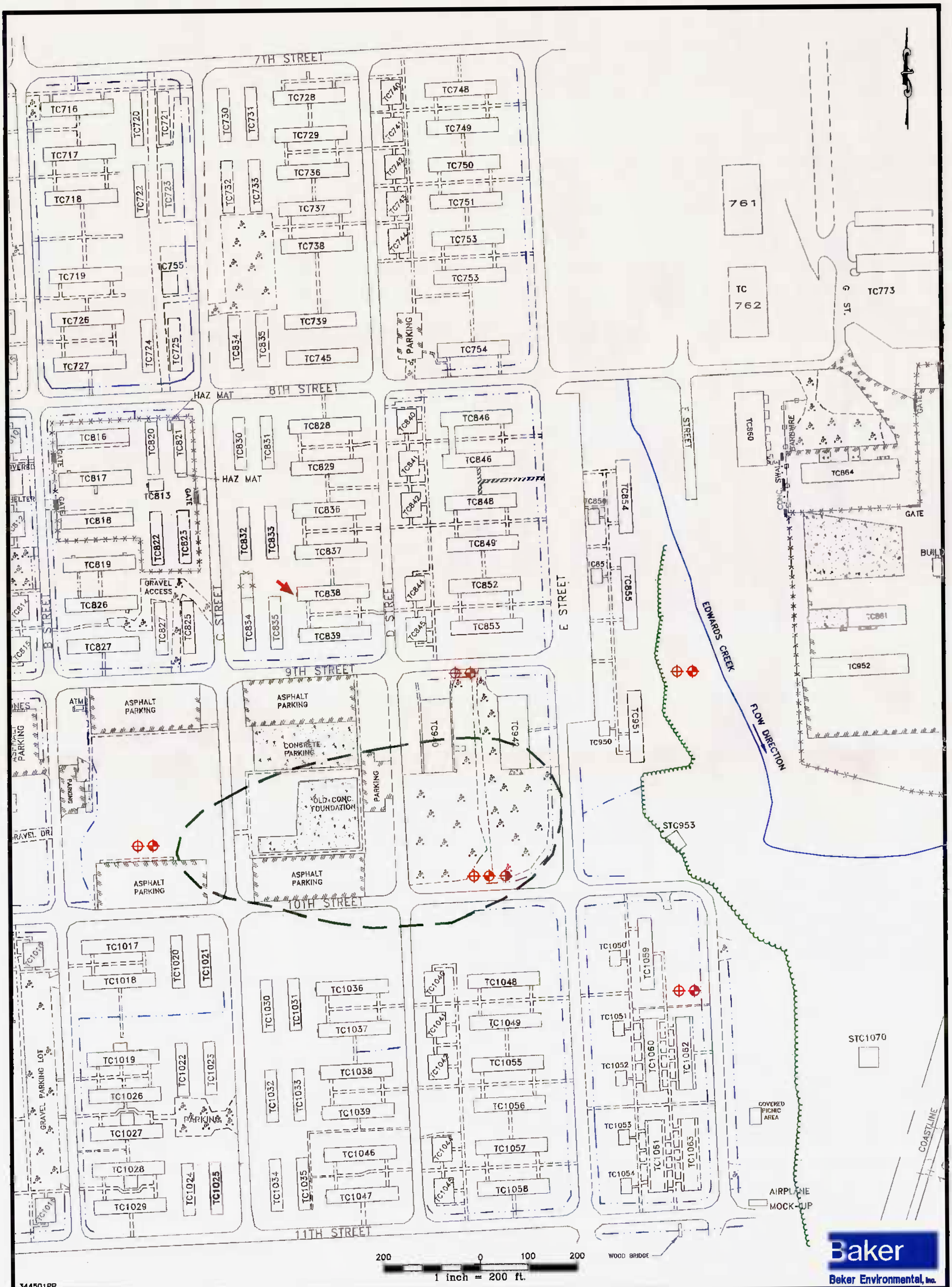


FIGURE 4-2
PROPOSED PERMANENT MONITORING WELL LOCATIONS
SITE 89
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- ⊕ PROPOSED PERMANENT SHALLOW WELL
- PROPOSED PERMANENT INTERMEDIATE WELL
- PROPOSED PERMANENT DEEP WELL
- ESTIMATED BOUNDARY OF GROUNDWATER CONTAMINATION ABOVE APPLICABLE STANDARDS
- APPROXIMATE GROUNDWATER FLOW DIRECTION

SOURCE: BARDEN LANIER AND ASSOCIATES, SEPT. 1996.OCT. 1991

FIGURE 4-3
PROPOSED PERMANENT
MONITORING WELL LOCATIONS
SITE 93

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

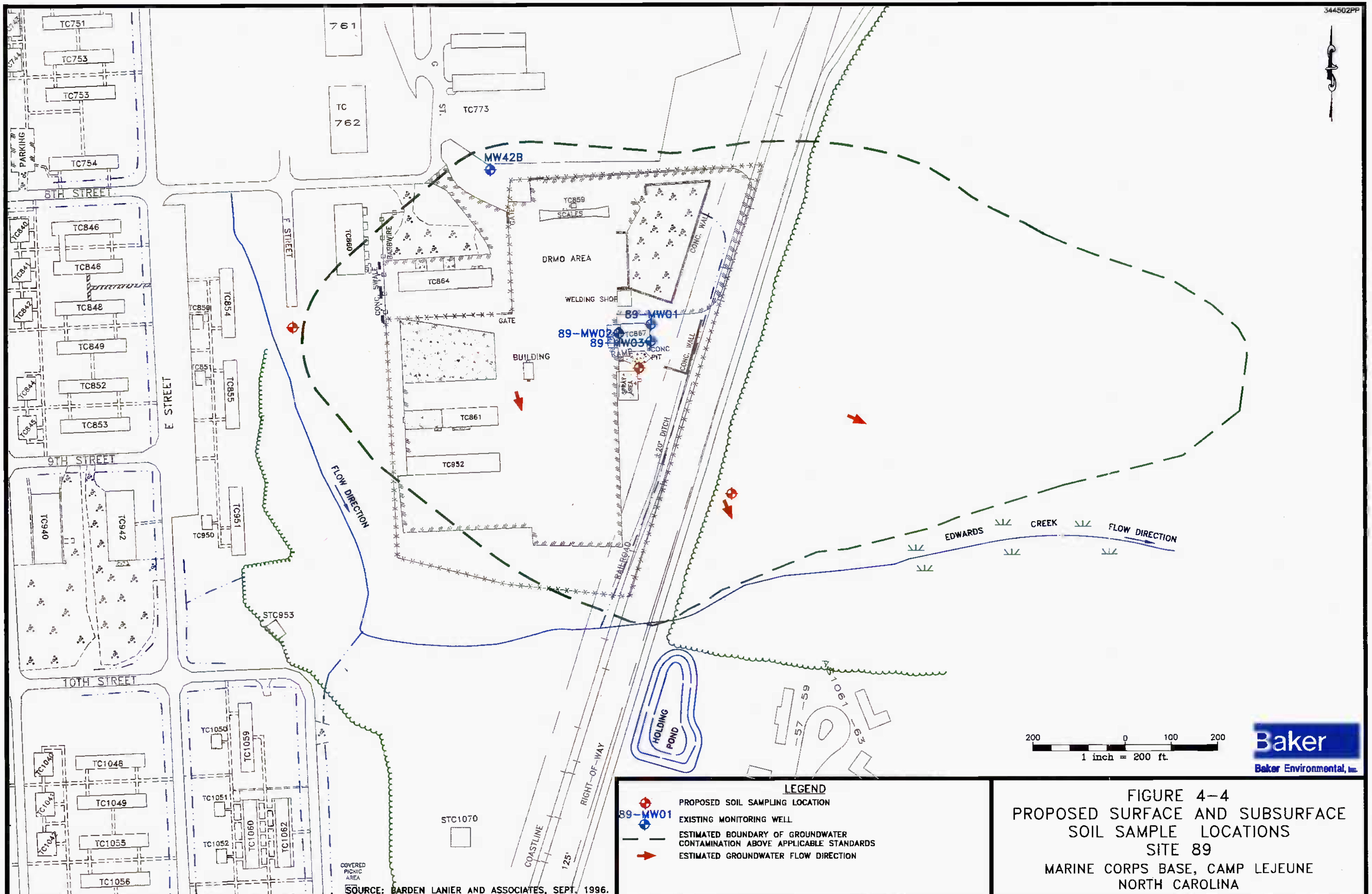
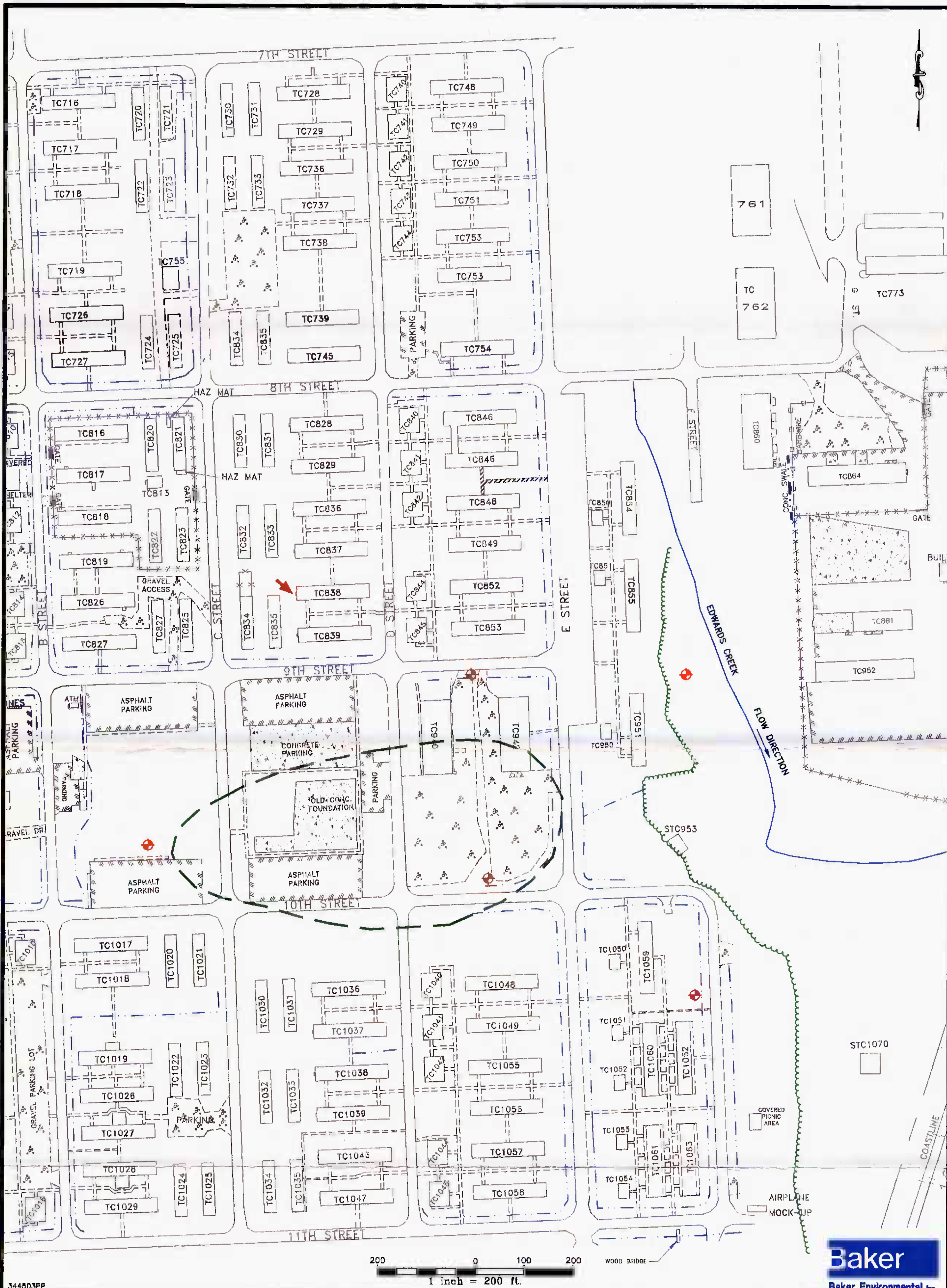


FIGURE 4-4
PROPOSED SURFACE AND SUBSURFACE SOIL SAMPLE LOCATIONS
SITE 89
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

- PROPOSED SOIL SAMPLING LOCATION
- ESTIMATED BOUNDARY OF GROUNDWATER CONTAMINATION ABOVE APPLICABLE STANDARDS
- APPROXIMATE GROUNDWATER FLOW DIRECTION

SOURCE: BARDEN LANIER AND ASSOCIATES, SEPT. 1996.OCT. 1991

FIGURE 4-5
PROPOSED SURFACE AND SUBSURFACE SOIL SAMPLE LOCATIONS
SITE 93

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

5.0 SAMPLE DESIGNATION

In order to identify and accurately track the various samples, all samples collected during this investigation, including QA/QC samples, will be designated with a unique number. The number will serve to identify the investigation, the site, the sample media, sampling location, the depth (soil) or round (groundwater) of sample, and QA/QC qualifiers.

The sample designation format is as follows:

Site#-Media/Station# or QA/QC-Depth/Round

An explanation of each of these identifiers is given below.

Site#	This investigation includes Sites 89 and 93.
Media	MW = Monitoring Well Boring GW = Groundwater SW = Surface Water SD = Sediment TW = Groundwater from a temporary well
Station#	Each soil test boring or monitoring well will be identified with a unique identification number.
QA/QC	FB = Field Blank D = Duplicate Sample (following depth/round) TB = Trip Blank ER = Equipment Rinsate MS/MSD = Matrix Spike/Matrix Spike Duplicate
Depth/Round	Depth indicators will be used for soil samples.

The number will reference the depth interval of the sample. For example:

00 = ground surface to 1 foot below ground surface
01 = 1 to 3 feet below ground surface
02 = 3 to 5 feet below ground surface
03 = 5 to 7 feet below ground surface

Round indicator will be used for groundwater samples. For example:

01 = initial round of sampling
02 = second round of sampling

Under this sample designation format, the sample number 89-GW05IW-01D refers to:

<u>89</u>-GW05IW-01D	Site 89
89-<u>GW</u>05IW-01D	Groundwater sample

89-GW05IW-01D	Monitoring well #5
89-GW05IW-01D	Intermediate monitoring well
89-GW05IW-01D	Round 1
89-GW05IW-01D	Duplicate (QA/QC) sample

The sample designation 93MW01-00D refers to:

93-MW01-00D	Site 93
93-MW01-00D	Monitoring Well Boring
93-MW01-00D	Monitoring Well #1
93-MW01-00D	Sample depth interval 0- to 12-inches
93-MW01-00D	Duplicate (QA/QC) sample

The sample designation 89-EC-SW01 refers to:

89-EC-SW01	Site 89
89-EC-SW01	Sample collected from Edwards Creek
89-EC-SW01	Surface water sample
89-EC-SW01	Sample #1

The sample designation 93-ERSD-01 refers to:

93-ERSD-01	Site 93
93-ERSD-01	Equipment Rinsate
93-ER6SD-01	Rinate taken from sediment sampling equipment
93-ERSD-01	Equipment Rinsate Sample #1

This sample designation format will be followed throughout the project. Required deviations to this format in response to field conditions will be documented.

6.0 INVESTIGATIVE PROCEDURES

The investigative procedures to be used for Sites 89 and 93 will be discussed in the following subsections. These procedures include soil sample collection, temporary and permanent monitoring well installation, well development, groundwater sample collection, in-situ slug tests, surface water sample collection, sediment sample collection, decontamination procedures and handling of site investigation derived wastes. Note that all of these procedures will comply with the field methods described in the USEPA, Region IV, Environmental Services Division (ESD), Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (ECBSOPQAM), May, 1996. Additional guidance from other sources such as American Society for Testing and Materials (ASTM) may be used, but if the ASTM and ESD methods conflict, the ESD procedure will be used. Additionally, in instances where the ESD has no SOP, other guidance sources will be used, such as manufacturer's SOP manuals. Field deviations will be recorded in the field logbook and discussed with the project manager.

6.1 Soil Sample Collection

Surface and subsurface soil samples will be collected in the vicinity of Sites 89 and 93 during the Phase II investigation. Soil samples will be collected from well borings advanced by a truck mnounted drilling rig during the installation of monitoring wells. All boring locations will receive utility clearance from the appropriate on-base personnel. Appendix A contains Baker Environmental, Inc. (Baker's) SOP for soil sample acquisition.

Soil samples from well borings will be collected using a split-spoon sampler. A split-spoon sampler is a steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. This devise can be driven into unconsolidated material using a drive weight connected to the drilling rig. A split-spoon sampler (used for performing Standard Penetration Tests) is 2-inches outer diameter (OD) and 1-3/8-inches ID. This standard spoon is available in two common lengths providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively. Split-spoons capable of obtaining 24-inch long samples will be utilized during this investigation.

The frequency of split-spoon sample collection will vary. At each temporary well boring, split-spoon samples will be collected continuously, or at five-foot intervals, as determined by the site geologist. Split-spoon samples will be collected continuously from each permanent, intermediate well boring. Split-spoon samples will be collected continuously beginning at the top of the Castle Hayne confining unit from each permanent, deep well boring. No split-spoon samples will be collected from shallow permanent well borings.

Monitoring wells will be installed at various depths. Shallow well borings will be advanced approximately 12 feet below the top of the water table. Intermediate well borings (temporary and permanent) will be advanced to a depth of approximately 40 to 50 feet bgs, based on the depth of the Castle Hayne confining unit. Deep monitoring well borings will be advanced to a depth of approximately 50 to 60 feet bgs. Again, the final depth of deep wells will be dependent on the depth of the Castle Hayne confining unit.

The physical characteristics of the samples will be described by the site geologist. The soil will be classified according to the Modified Bermeister or USCS Soil Classification System. Soil sample descriptions will be recorded in the field geologist's logbook.

Surface soil samples will not be collected using a split-spoon sampler because a sufficient quantity of sample cannot be retained from 0- to 12-inches using this sampling device. Hence, surface soil samples will be collected using a stainless-steel spoon.

Selected samples will be submitted to the laboratory for analysis. One surface soil (1-to 6-inches bgs) sample will be collected from the well boring unless the boring is located within a paved portion of the investigation area. One subsurface soil sample will be collected from just above the water table. A second subsurface soil sample will be collected from within the soil/water interface to obtain information relevant from groundwater modeling. If the depth to groundwater is greater than 10 feet below ground surface (bgs) or there is evidence of contamination, one additional subsurface soil sample (for a total of four soil samples) will be collected from a mid-depth.

6.1.1 Split-Spoon Sample Collection Procedures

The following procedure will be used for collecting soil samples:

1. The surface soil sample will be collected by a stainless steel spoon used to remove the soil from the ground. The upper inch of soil will be discarded. Soil for volatile organic analysis will be placed directly into the sample jar. Soil for all other analysis will be placed into a stainless-steel bowl, thoroughly mixed, then placed into the remaining sample jar(s).

2. The borehole will be advanced to the desired depth using hollow-stem auger or mud rotary drilling techniques. The split-spoon will be lowered into the borehole inside the boring or hollow-stem auger.

3. The subsurface soil samples will be collected by driving the split-spoon with blows from a 140-pound hammer falling 30-inches in accordance with SOP F102 Soil and Rock Sample Acquisition (Appendix A). The sampler will be driven 24-inches. Once at the desired depth, the split-spoon will be pulled from the borehole.

4. The number of blows required to effect each six inches of penetration or fraction thereof will be recorded in the field logbook. The first six inches is considered to be a seating drive. The sum of the number of blows required for the second and third six inches of penetration is termed the penetration resistance, N. If the sampler is drive less than 18-inches, the penetration resistance is the number for the last one foot of penetration. (If less than one foot is penetrated, the logs shall state the number of blows and the fraction of one foot penetrated.) In cases where samples are driven 24-inches, the sum of second and third 6-inch increments will be used to calculate the penetration resistance. (Refusal of the split-spoon will be noted at 50 blows over an interval equal to or less than 6-inches; the interval driven will be noted with the blow count.)

5. The sampler will be brought to the surface and both ends and one half of the split-spoon removed such that the soil recovered rests in the remaining half of the barrel. The Hnu PID measurements will be recorded. The recovery (length), composition, structure, consistency, color, condition, etc., of the recovered soil will be described; then put into sample jars (see below for procedures concerning submitting soil samples to the laboratory).

6. Split-spoon samplers will be decontaminated after each use and prior to the initial use at a site according to the procedures outlined in Section 6.9.

7. This operation will be repeated until the borehole has been advanced to the selected depth. Split-spoon samples will be collected continuously until groundwater is encountered.

6.1.2 Soil Sample Laboratory Submission Procedures

The following procedure will be used for submitting soil samples to the laboratory:

1. After sample collection, soil for volatile organic analysis will be placed directly into the sample jar. Small aliquots will be collected from discrete locations over the entire length of the sample interval, representative of the soil types encountered, and placed in the sample jar with minimum disturbance. The VOA sample jar will be filled completely, without headspace, to minimize volatilization. Sample bottles will be labeled prior to sample collection. Soil samples for volatile organic compounds (VOCs) should not be mixed.

2. A small, representative portion of sample will be set aside for description purposes. The remaining soil will be removed from the split-spoon sampler. Prior to filling laboratory containers, the soil sample should be mixed, in a stainless-steel bowl with stainless-steel spoons, as thoroughly as possible to ensure that the sample is as representative as possible of the sample interval.

3. All pertinent sampling information will be recorded; such as soil description, sample depth, sample number and location, and the time of sample collection in addition to the above mentioned items. Additionally, the sample bottles will be labeled as outlined in Section 7.0.

4. The sample jars will be stored in a cooler with ice until laboratory shipment.

5. The samples will be packed for shipping. Chain-of-custody seals will be attached to the shipping package. Chain-of-Custody Forms and Sample Request Forms will be properly filled out and enclosed or attached (Section 7.0).

6. The split-spoon sampler will be decontaminated as described in Section 6.9. Disposable latex gloves will be replaced between sample stations to prevent cross-contamination of the samples.

6.2 Temporary Monitoring Well Installation

Intermediate temporary monitoring wells will be installed at Site 89 during the Phase II field program. Temporary monitoring well construction should follow the procedures outlined for the installation of permanent monitoring wells outlined in Section 6.3 Permanent Monitoring Well Installation with the following exceptions:

- Temporary monitoring wells will be installed in a borehole advanced by a 3 1/4-inch ID hollow-stem augers (HSAs).

- Ten feet of 1-inch ID, schedule 40, #10 slot (0.01 inch) screen with a bottom cap will be installed. The screen will be connected to threaded, flush-joint, PVC riser. Well sock material will be placed around the well screen and riser to act as a filter pack.

- Development of the temporary monitoring wells is not required. However, the same volume of water introduced into the borehole during construction to prevent heaving sands must be removed prior to purging and sampling.

- Temporary monitoring wells will be removed manually and any remaining open boreholes will be backfilled with bentonite.

6.3 Permanent Monitoring Well Installation

During this field investigation, shallow, intermediate, and deep monitoring wells will be installed. The following subsections contain monitoring well installation procedures.

6.3.1 Shallow Monitoring Well

Shallow monitoring wells will be installed to monitor the shallow water-bearing zone (water table). It is estimated that these monitoring wells will be approximately 20 to 25 feet bgs. The procedure for the installation and construction of shallow monitoring wells is presented below (also see Figures 6-1 and 6-2):

- Activity personnel will approve all shallow monitoring well locations. These locations shall be free of underground or overhead utility lines.

- A borehole will be advanced by a drilling rig using 6-1/4 HSAs to depth.

- Upon completion of the borehole to the desired depth, shallow monitoring well construction materials will be installed (inside the hollow-stem augers).

- PVC is the material selected for shallow monitoring well construction. It was selected on the basis of its low cost, ease of use, and flexibility. USEPA Region IV requires justification of using PVC; this justification is included in Appendix B.

- Fifteen feet of 2-inch ID, Schedule 40, #10 slot (0.010 inch) screen with a bottom cap will be installed. The screen will be connected to threaded, flush-joint, PVC riser. The riser will extend 2- to 3- feet above the ground surface. A PVC slip-cap, vented to the atmosphere, will be placed at the top of the riser. The top of the well screen will be placed such that three feet of the screen (as subsurface conditions permit) extends above the water table to allow for seasonal groundwater fluctuations.

- The annular space around the screen will be backfilled with a well-graded medium to course sand (No. 1 or No. 2 Silica Sand) as the hollow-stem augers are being withdrawn from the borehole. Sand shall be placed from the bottom of the boring to approximately two feet above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the monitoring well is very shallow to allow for placement of sealing material.

- A sodium bentonite seal at least 24-inches thick will be placed above the sand pack, unless shallow groundwater conditions are encountered. The bentonite shall be allowed to hydrate for at least 4 hours before further completion of the shallow monitoring well.

- The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of either two parts sand per one part of cement and water, or three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of Portland cement.

- The depth intervals of all backfilled materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded in the field logbook.

- For shallow monitoring wells completed above the ground surface, the aboveground section of the PVC riser pipe will be protected by the installation of a 4-inch diameter, 5-foot long steel casing (with locking cap and lock) into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet bgs, as space permits. For very shallow monitoring wells, a steel casing of less than 5 feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal.

- For aboveground completion of shallow monitoring wells, the top of each monitoring well will be protected with the installation of four, 3-inch diameter, 5-foot long steel pipes which will be installed around the outside of the concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5 feet in 3,000 pounds per square inch (psi) concrete. Each pipe shall also be filled with concrete. A concrete pad shall be placed at the same time the pipes are installed. The pad will be a minimum of 4-feet by 4-feet by 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. If water table conditions prevent having a 24-inch bentonite seal and the concrete pad as specified, the concrete pad depth should be decreased. Two weep holes will be drilled into opposite sides of the protective casing just above the concrete pad. The protective casing and steel pipes will be painted with day-glo yellow paint, or equivalent.

- Some shallow monitoring wells may be completed at the ground surface or "flush-mounted" in high-traffic areas. The shallow monitoring well shall be completed at the surface using a "flush" man-hole type cover. If the monitoring well is installed through a paved surface, concrete surface, or high traffic area, the annular space shall be grouted to a depth of at least 2.5-feet and the monitoring well shall be finished with a concrete collar. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

- All monitoring wells will have a locking cap connected to the protective casing. Each monitoring well will be tagged which will contain general monitoring well construction information and marked as "Test Well - Not For Consumptive Use."

- Figure 6-1 depicts a typical Type II shallow above grade monitoring well construction diagram and Figure 6-2 depicts a typical Type II flush mounted monitoring well construction diagram.

6.3.2 Intermediate Monitoring Well

Procedures for the installation and construction of Type II intermediate monitoring wells are presented below:

- Activity personnel will approve all intermediate monitoring well locations. These locations shall be free of underground or overhead utility lines.

- A borehole will be advanced by a drilling rig using 3-1/4 inch ID hollow-stem augers. Continuous 2-foot split-spoon samples will be collected while the borehole is advanced. Samples will be collected according to the procedures outlined in Section 6.1. The boring will be completed when the Castle Hayne confining unit has been encountered (typically 40 to 50 feet bgs).

- Upon completion of the borehole to the desired depth, 6-1/4 inch ID HSAs will be used to ream the borehole to a sufficient diameter to accommodate a 2" well and annulus materials. The intermediate monitoring well construction materials will be installed inside the hollow-stem augers.

- PVC is the material selected for intermediate monitoring well construction. It was selected on the basis of its low cost, ease of use, and flexibility. USEPA Region IV requires justification of using PVC; this justification is included in Appendix B.

- Ten feet of 2-inch ID, Schedule 40, #10 slot (0.010 inch) screen with a bottom cap will be installed. The screen will be connected to threaded, flush-joint, PVC riser. The riser will extend 2- to 3-feet above the ground surface. A PVC slip-cap, vented to the atmosphere, will be placed at the top of the riser.

- The annular space around the screen will be backfilled with a well-graded medium to course sand (No. 1 or No. 2 Silica Sand) as the hollow-stem augers are being withdrawn from the borehole. Sand shall be placed from the bottom of the boring to approximately two feet above the top of the screened interval.

- A sodium bentonite seal at least 24-inches thick will be placed above the sand pack. The bentonite shall be allowed to hydrate for at least 4 hours before further completion of the intermediate monitoring well.

- The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of either two parts sand per one part of cement and water, or three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of Portland cement. The bentonite seal shall be installed using a tremie pipe, if applicable depths are anticipated (i.e., greater than 25 feet).

- The depth intervals of all backfilled materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded in the field logbook.

- For the aboveground completion of intermediate monitoring wells, the aboveground section of the PVC riser pipe will be protected by the installation of a 4-inch diameter, 5-foot long steel casing (with locking cap and lock) into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet bgs.

- For aboveground completion of intermediate monitoring wells, the top of each monitoring well will be protected with the installation of four, 3-inch diameter, 5-foot long steel pipes which will be installed around the outside of the concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5 feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete pad shall be placed at the same time the pipes are installed. The pad will be a minimum of 4-feet by 4-feet by 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. Two weep holes will be drilled into opposite sides of the protective casing just above the concrete pad. The protective casing and steel pipes will be painted with day-glo yellow paint, or equivalent.

- Some intermediate monitoring wells may be completed at the ground surface or "flush-mounted" in high-traffic areas. The monitoring well shall be completed at the surface using a "flush" man-hole type cover. If the monitoring well is installed through a paved surface, concrete surface, or high traffic area, the annular space shall be grouted to a depth of at least 2.5-feet and the monitoring well shall be finished with a concrete collar. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

- All monitoring wells will have a locking cap connected to the protective casing. Each monitoring well will be tagged which will contain general monitoring well construction information and marked as "Test Well - Not For Consumptive Use."

Figure 6-3 depicts a typical Type II intermediate above grade monitoring well construction diagram and Figure 6-4 depicts a typical Type II intermediate flush mount monitoring well construction diagram.

6.3.3 Deep Monitoring Well

Procedures for the installation and construction of Type III deep monitoring wells are presented below:

- Activity personnel will approve all deep monitoring well locations. These locations will be free of underground or overhead utility lines.

- The borehole will be advanced until completion using mud rotary drilling. Mud rotary drilling will be used for ease of casing installation and because of the greater anticipated drilling depths. A tricon drill bit with an OD of 7-7/8 inches will be used for advancing the borehole.

- Split-spoon samples will not be collected until the top of the Castle Hayne confining unit is encountered. From this point until the final depth, split-spoon samples will be collected continuously to determine the thickness of the confining unit as well as to characterize the upper portion of the Castle Hayne aquifer.

- Upon completion of the borehole to the desired depth, monitoring well construction materials will be installed.

- PVC is the material selected for monitoring well construction. It was selected on the basis of its low cost, ease of use, and flexibility. USEPA Region IV requires justification of using PVC; this justification is included in Appendix B.

- Five feet of 2-inch ID, Schedule 40, #10 slot (0.101-inch) screen with a bottom cap will be installed. The screen will be connected to a threaded, flush-joint PVC riser. The riser will extend 2- to 3-feet above the ground surface. A PVC slip-cap, vented to the atmosphere, will be placed at the top of the riser.

- The annular space around the screen will be backfilled with a well-graded medium to coarse sand (No. 1 or No. 2 Silica Sand). Sand shall be placed from the bottom of the boring to approximately two feet above the top of the screened interval.

- A sodium bentonite seal (typically bentonite pellets) at least 24-inch thick will be placed above the sand pack. The bentonite shall be allowed to hydrate for at least 4 hours before further completion of the deep monitoring well.

- The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of either two parts sand per one part of cement and water, or three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement. The bentonite seal shall be installed using a tremie pipe.

- The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded in the field logbook.

- The deep monitoring wells will be completed at the surface. The aboveground section of the PVC riser pipe will be protected by installation of a 4-inch diameter, 5-foot long steel casing (with locking cap and lock) into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet below the ground surface.

- The top of each well will be protected with the installation of four, 3-inch diameter, 5-foot long steel pipes which will be installed around the outside of the concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5 feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete pad shall be placed at the same time the pipes are installed. The pad will be a minimum of 4-feet by 4-feet by 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. Two weep holes will be drilled into opposite sides of the protective casing just above the concrete pad. The protective casing and steel pipes will be painted with day-glo yellow paint, or equivalent.

- If necessary, in high-traffic areas, the deep monitoring well shall be completed at the surface using a flush" man-hole type cover. If the well is installed through a paved surface, concrete surface, or high traffic areas, the annular space shall be grouted to a depth of at least 2.5 feet and the monitoring well shall be finished with a concrete collar. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

- All wells will have a locking cap connected to the protective casing. Each well will be tagged which will contain general well construction information and marked as Test Well - Not For Consumptive Use."

Figure 6-5 depicts a typical Type III deep above grade monitoring well construction diagram and Figure 6-6 depicts a typical Type III deep flush mount monitoring well construction diagram.

6.4 Well Development

All permanent monitoring wells which are to be sampled will be developed as specified in the ECBSOPQAM. The purpose of monitoring well development is to stabilize and increase the permeability of the filter pack around the well screen, to restore the permeability of the formation which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the monitoring well or filter pack during installation. The selection of the monitoring well development method typically is based on drilling methods, monitoring well construction and installation details, and the characteristics of the formation.

Well development shall not be initiated until a minimum of 48 hours has elapsed subsequent to monitoring well completion. This time period will allow the cement grout to set. Shallow monitoring wells typically are developed using bailers or pumps in combination with surging. Intermediate and deep monitoring wells are developed using a Wattera pump or compressed air (equipped with an air filter) in combination with surging. Selection of a development device will be dependent on conditions encountered during monitoring well installation.

All monitoring wells will be developed until well water runs clear of fine-grained materials. Note that the water in some monitoring wells does not clear with continued development. Typical limits placed on monitoring well development may include any one of the following:

- Clarity of water based on visual determination

- A maximum time period (typically one hour for shallow monitoring wells)

- Stability of pH, specific conductance, and temperature measurements (typically less than 10 percent variation between three successive measurements)

- Clarity based on turbidity measurements (typically less than 10 Nephelometric Turbidity Units [NTU])

A record of the monitoring well development will be completed to document the development process. Section 6.10 provides information on the use of monitoring and data collection equipment for water level measurements, pH, specific conductance, and temperature.

6.5 Groundwater Sample Collection

Temporary and permanent monitoring wells will be sampled via low-flow methods. Low-flow is defined as a flow rate similar to the ambient flow rate in the screened formation.

A peristaltic pump will be used to purge the monitoring wells and collect the samples. VOC loss through suction degassing is expected to be insignificant due to the very slow flow rates to be used. Baker personnel report observance of minimal bubbling in the groundwater stream during recent peristaltic pump use. The procedure for collecting groundwater samples is detailed in this section, and has been assembled from ESD SOP, recently published papers, and other documents.

6.5.1 Low-Flow Purging vs. High-Flow Purging

A number of recent studies have demonstrated that low-flow purging and sampling is a preferable to bailing or high-flow purging and sampling. High-rate pumping is described as a rate greater than, or similar to, the development rate. Some findings include:

- High-flow pumping and bailing may overdevelop a monitoring well, causing damage to the monitoring well and filter pack (USEPA, 1992).

- High-flow pumping and bailing may disturb accumulated corrosion/reaction products, or sediment (USEPA, 1992), or potentially mobilize particulate or colloidal matter from the formation (Barcelona, Wehrmann and Varljen, 1994).

- High-flow pumping may induce flow into the monitoring well from groundwater in the formation above the well screen (USEPA 1992).

- High-flow pumping and bailing may cause loss of VOCs. The velocities at which groundwater enters a bailer can actually correspond to unacceptably high purge rates (USEPA, 1992).

- Bailer use can result in composite averaging by mixing of water across the screen interval (Barcelona, Wehrmann and Varljen, 1994), resulting in unreproducible and unrepresentative data.

6.5.2 Selection of Water Quality Indicator Parameters

The water quality indicator parameters (WQP) for stabilization includes dissolved oxygen, turbidity, pH, and specific conductance. Use of these WQPs has precedence in recent studies. Dissolved oxygen and turbidity are more sensitive indicators of "fresh" groundwater than pH, specific conductance, and temperature (Puls and Powell, 1995). Barcelona, Wehrmann and Varljen, 1994, suggest that dissolved oxygen and specific conductance are good indicators of stabilization with respect to VOA sampling. Puls and Paul, 1995 used dissolved oxygen, turbidity, pH, and specific conductance as indicators of stabilization.

6.5.3 Purge Requirements

Consistent with ECBSOPQAM, a minimum of three well volumes will be purged.

6.5.4 Purging and Sampling Procedure

The following is the low-flow purge and sampling procedure that will be used at Sites 89 and 93:

1. The protective casing (for existing monitoring wells) will be unlocked, the well cap will be removed, and escaping gases will measured at the well head using a PID or flame ionization detector (FID). This will determine the need for respiratory protection.

2. The monitoring well will be allowed to equilibrate to atmospheric pressure in the event that a vent hole was not installed in the monitoring well.

3. The static water level will be measured. The total depth of the monitoring well will not be measured, as not to stir up any sediment. The total depth will be obtained from soil boring logs. The water volume in the monitoring well will then be calculated.

4. The sampling device intake (virgin, 1/4-inch ID polypropylene or polyethylene tubing) will be slowly lowered until the bottom end is 2 to 3 feet below the top of water level. Next, the water level probe will be placed into the monitoring well just above the water.

5. Purging will then begin with a peristalic pump, if possible. The discharge rate will be measured using a stopwatch and calibrated container. The flow rate will be adjusted to ambient flow conditions (i.e., no drawdown is observed in the monitoring well.) Flow rates of less than 1 liter per minute (L/min) are expected.

6. The WQPs, including turbidity, pH, and specific conductance will be measured frequently (e.g., every 2 minutes). Temperature and oxidation-reduction potential (Eh) also will be measured.

7. Purging will be complete when a minimum of three well volumes have been removed and three successive WQP readings have stabilized within 10 percent, or there is no further discernable upward or downward trend. It is Baker's experience that at low values, certain WQPs (such as turbidity) may vary by more than 10 percent, but have reached a stable plateau. Also, purging will continue until turbidity reaches 10 NTU or less. If this cannot be reasonably achieved, it will be noted in the field logbook and discussed in the RI report.

8. Upon WQP stabilization, groundwater samples will be collected from the end of the tubing into the sample bottle. The parameter sampling order shall based on volatility (with the most volatile parameters collected first). Sample bottles will be labeled prior to sample collection and filled in the same order for all monitoring wells.

9. The following information will be recorded in the field logbook:

   Project location, date, and time
   Weather
   Sample location, number, round, and identification number
   Static water level
   Calculation of amount of water to be purged
   Water quality parameters during purging
   Visual description of water (i.e., clear, cloudy, muddy, etc.)
   Names of sampling personnel
   Names of visitors on site
   Purging and sampling technique, procedure and equipment used
   Sampling remarks and observations
   QA/QC samples collected

10. The sample jars will be stored in a cooler with ice until laboratory shipment.

11. The samples will be packed for shipping. Chain-of-custody seals will be attached to the shipping package. Chain-of-Custody Forms and Sample Request Forms will be properly filled out and enclosed of attached (Section 7.0).

Sample preservation and handling procedures are outlined in Section 7.0. Appendix C presents a SOP for groundwater sampling.

6.6 In-Situ Slug Tests

Slug tests will be performed in select newly installed monitoring wells and two existing monitoring wells at Sites 89 and 93. Both falling head and rising head tests will be performed in the intermediate and deep monitoring wells. Only rising head tests will be performed in the shallow monitoring wells. An In Situ, Inc. Hermit 2000 data logger will be used for these tests. The performance of slug tests will include the following procedure:

1. The static groundwater level and depth of monitoring well will be measured. All measurements will be recorded in the field logbook.

2. The parameters for the test in the data logger will be set. The coefficients for the specific transducer being used will be entered. Entries will be double-checked. Note that the rate for recording readings should be set on the logarithmic scale. This will collect readings at the fastest rate at the start of the test when changes in the groundwater level are the most rapid and significant in the analysis of the data.

3. The data logger transducer will be set in the monitoring well, approximately one foot from the bottom of the monitoring well.

4. The slug will be prepared by securing nylon cord to the top end and marking a point on the rope which will allow the slug to be completely submerged and will place the slug a minimum of one foot above the transducer.

The following procedures are for rising head tests only (for shallow monitoring wells):

5. The slug will be lowered into the monitoring well to the mark on the cord and groundwater equilibration will be allowed to occur. The water level can be monitored through the data logger. Also, the groundwater level measurement can be taken with a water level meter to verify the fall in water level towards static. Once the groundwater has reached the static level (or at least 90 percent of static), the rising head test may begin.

6. Simultaneously, the slug will be removed and the start button will be pressed to begin the test. The water level can be monitored through the data logger or during the test, groundwater level measurements can be taken with a water level meter to verify the rise in water level to static. Once the groundwater has reached the static level (or at least 90 percent of static), the test can be terminated.

7. The transducer and cable will be removed from the monitoring well and decontaminated with liquid Alconox soap and distilled water upon the completion of each monitoring well testing.

8. The data will be downloaded from the data logger through a laptop computer onto a diskette at the end of the day and printed. A backup disk will also be made of the slug test data files.

The following procedures are for falling head and rising head tests for intermediate and deep monitoring wells:

9. Simultaneously, the slug will be lowered into the monitoring well to the mark on the cord and the start button will be pressed to begin the test. The water level can be monitored through the data logger or during the test, groundwater level measurements can be taken with a water level meter to verify the fall in water level towards static.

10. Continue the test until groundwater is within 90 percent of the static water level of the monitoring well at the start of the test. Set the data logger to begin a step (as per the instrument instructions).

11. Immediately after beginning the step, remove the slug to begin the rising head test. The water level can be monitored through the data logger or during the test, groundwater level measurements can be taken with a water level meter to verify the rise in water level to static. Once the groundwater has reached the static level (or at least 90 percent of static), the test can be terminated.

12. The transducer and cable will be removed from the monitoring well and decontaminated with liquid Alconox soap and distilled water upon the completion of each monitoring well testing.

13. The data will be entered into a field logbook while each test is ongoing. The data will also be downloaded from the data logger through a laptop computer onto a diskette at the end of the day and printed. A backup disk will also be made of the slug test data files.

The data obtained from the in-situ slug tests will be used in conjunction with Geraghty & Miller's Aquifer Test Solver (AQTESOLV™) program to calculate hydraulic conductivity values at the specific monitoring wells tested. Appendix D presents a SOP for conducting slug tests.

6.7 Surface Water Sample Collection

Five surface water stations are to be sampled as part of this investigation from Edwards Creek southwest to southeast of Site 89 and east of Site 93. Successful completion of this task will be dependent on the presence of water in the stream. Should water be present, the following procedure will be used to collect all surface water samples:

1. One surface water sample from mid-depth will be collected from each station. Surface water samples will be collected from mid-channel point.

2. In the stream, surface water samples will be collected from downstream to upstream locations to prevent potential migration of contaminants to downstream stations before sampling has been conducted. Sediment samples will be collected after the surface water samples to minimize sediment disturbance and suspension.

3. Surface samples will be collected by dipping the sample bottles directly into the water. An unpreserved, laboratory-decontaminated transfer bottle (amber sample bottle) will be used to fill preserved bottles. Additionally, a transfer bottle will be used to fill all bottles if surface water is too shallow. This transfer bottle also will be used as a sample bottle for the location sampled, or discarded. Sample bottles will be labeled prior to sample collection.

4. All sample containers not containing preservative will be rinsed at least once with the sample water prior to final sample collection. In addition, the sampling container used to transfer the surface water into the sample bottles containing preservative will be rinsed once with the sample water.

5. Temperature, pH, specific conductance, and dissolved oxygen will be measured in the field at each sampling station immediately following sample collection.

6. The sampling station will be marked by placing a wooden stake and bright colored flagging at the nearest bank or shore. The sampling station will be marked with indelible ink on the stake. In addition, the distance from the shore and the approximate location will be estimated and recorded and sketched in the field logbook. If permission is granted, photographs will be taken to document the physical and biological characteristics of the sampling station.

7. The following information will be recorded in the field logbook:

   Project location, date, and time
   Weather
   Sample location, number, and identification number
   Flow conditions (i.e., high, low, in flood, etc.)
   On site water quality measurements
   Visual description of water (i.e., clear, cloudy, muddy, etc.)
   Sketch of sampling location including boundaries of the water body, sample location (and depth), relative position with respect to the site, location of wood identifier stake
   Names of sampling personnel
   Names of visitors on site
   Sampling technique, procedure, and equipment used
   Sampling remarks and observations
   QA/QC samples collected

8. The sample jars will be stored in a cooler with ice until laboratory shipment.

9. The samples will be packed for shipping. Chain-of-custody seals will be attached to the shipping package. Chain-of-Custody Forms and Sample Request Forms will be properly filled out and enclosed or attached (Section 7.0).

Sample preservation and handling procedures are outlined on Section 7.0. Appendix E presents a SOP for surface water sampling.

6.8 Sediment Sample Collection

Five sediment stations are to be sampled as part of this investigation. The following procedure will be used to collect all sediment samples:

1. Sediment samples will be collected after the surface water sample has been collected.

2. Sediment samples will be collected from downstream to upstream locations to prevent potential migration of contaminants to downstream stations before sampling has been conducted.

3. One sediment sample will be collected from each station; from 0- to 6-inches.

4. The sediment sample interval at each station will be collected with a stainless-steel hand-held coring instrument (sediment sleeve). A disposable clear plastic liner tube, fitted with an eggshell catcher to prevent sample loss, will be used at each station.

5. The coring sleeve will be pushed into the sediment to a depth of 6-inches, or until refusal, whichever is encountered first. The sediment will be extruded from the liner with a decontaminated extruder into a stainless-steel bowl and the sample

homogenized prior to being transferred to the laboratory containers. Samples for VOC analysis will not be homogenized.

6. Sediment for volatile organic analysis will be placed directly into the sample jar. The VOA sample jar will be filled completely, without headspace, to minimize volatilization. Precautions will be taken when collecting the VOC analysis not to disturb the sample (which will promote volatilization). The remaining soil will be placed into a stainless-steel bowl and thoroughly mixed utilizing stainless-steel spoons. The sample jar(s) for all other analysis will then be filled. Sample jars will be labeled prior to sample collection.

7. The sampling station will be marked by placing a wooden stake and bright colored flagging at the nearest bank or shore. The sampling station will be marked with indelible ink on the stake. In addition, the distance from the shore and the approximate location will be estimated and recorded and sketched in the field logbook. If permission is granted, photographs will be taken to document the physical and biological characteristics of the sampling station.

8. The following information will be recorded in the field logbook:

   Project location, date, and Weather
   Sample location, number, and identification number
   Flow conditions (i.e., high, low, in flood, etc.)
   On site water quality measurements
   Visual description of water (i.e., clear, cloudy, muddy, etc.)
   Sketch of sampling location including boundaries of the water body, sample location (and depth), relative position with respect to the site, location of wood identifier stake
   Names of sampling personnel
   Sampling technique, procedure, and equipment used

9. The sample jars will be stored in a cooler with ice until laboratory shipment.

10. The samples will be packed for shipping. Chain-of-custody seals will be attached to the shipping package. Chain-of-Custody Forms and Sample Request Forms will be properly filled out and enclosed or attached (Section 7.0).

Sample preservation and handling procedures are outlined on Section 7.0. Appendix E also presents a generic SOP for sediment sampling.

6.9 Decontamination

Equipment and materials that require decontamination fall into two broad categories:

1. Field measurement, sampling, and monitoring equipment (e.g. water level meters, stainless-steel spoons, etc.)

2. Machinery, equipment, and materials (e.g. drilling rigs, backhoes, drilling equipment, monitoring well materials, etc.)

Appendices F and G detail procedures for decontaminating the two categories of equipment and materials, respectively.

6.10 Monitoring and Data Collection Equipment

Field support activities and investigations will require the use of monitoring and data collection equipment. Turbidity, dissolved oxygen, specific conductance, temperature, pH, and Eh readings will be recorded during groundwater sample collection. Dissolved oxygen, specific conductance, temperature, and pH readings will be recorded during surface water sample collection. Appendix H, On-Site Water Quality Testing, provides specific procedures for collecting conductance, temperature, and pH readings.

Additional monitoring well information may be obtained using water level meters, water-product level meters, and well depth meters. The operation and various uses of this data collection equipment is provided in Appendix I.

Health and safety monitoring and environmental media screening will be conducted using a PID and an oxygen/combustible gas meter (O_2/LEL). The operation and use of the PID is described in Appendix J. The Bacharach O_2/LEL meter will also be used during the sampling program, primarily to monitor health and safety conditions. Appendix K provides a description of the Bacharach O_2/LEL meter and operating procedures.

6.11 Investigation Derived Waste Handling

The following sections discuss the responsibilities, sources, containerization, sampling and analysis, and disposal of Investigation Derived Wastes (IDW). These wastes include soil from borings, groundwater from developing and purging of monitoring wells, decontamination fluids, and personal protection equipment.

6.11.1 Responsibilities

LANTDIV - Atlantic Division, Naval Facilities Engineering Command (LANTDIV) or the facility must ultimately be responsible for the final disposition of site wastes. As such, a LANTDIV or MCB Camp Lejeune representative will sign waste disposal manifests as the generator of the material, in the event off-site disposal is required. However, it may be the responsibility of Baker, depending on the contingency discussions during execution of the investigation, to provide assistance to LANTDIV in arranging for final disposition and preparing manifests.

Baker Project Manager - It is the responsibility of the Baker Project Manager to work with the LANTDIV-Technical Representative in determining the final disposition of site investigation wastes. The Baker Project Manager will relay the results and implications of the chemical analysis of waste or associated material, and advise on the regulatory requirements and prudent measures appropriate to the disposition of the material. The Baker Project Manager also is responsible for ensuring that field personnel involved in site investigation waste handling are familiar with the procedures to be implemented in the field, and that all required field documentation has been completed.

Baker Field Team Leader - The Baker Field Team Leader or Site Manager is responsible for the on site supervision of the waste handling procedures during the site investigations. The Baker Field

Team Leader also is responsible for ensuring that all other field personnel are familiar with these procedures.

6.11.2 Sources of Investigation Derived Wastes

Field investigation activities often result in the generation and handling of potentially contaminated materials that must be properly managed to protect the public and the environment, as well as to meet legal requirements. These wastes may be either hazardous or nonhazardous in nature. The nature of the waste (i.e., hazardous or nonhazardous) will determine how the wastes will be handled during the field investigation.

The sources of waste material depend on the site activities planned for the project. The following types of activities or sources, typical of site investigations, may result in the generation of waste material which must be properly handled:

Subsurface soil sampling and monitoring well construction (soil cuttings)
Mud rotary drilling (contaminated mud)
Monitoring well development (development water)
Groundwater sampling (purge water)
Heavy equipment decontamination (decontamination fluids)
Sampling equipment decontamination (decontamination fluids)
Personal protection equipment (health and safety disposables)

6.11.3 Designation of Potentially Hazardous and Nonhazardous Investigation Derived Wastes

Wastes generated during the field investigation can be categorized as either potentially hazardous or nonhazardous in nature. The designation of such wastes will determine how the wastes are handled. The criteria for determining the nature of the waste and the subsequent handling of the waste is described below for each type of anticipated investigative waste.

6.11.3.1 Soil Cuttings

Soil cuttings will be generated during the augering of monitoring well borings. As the borehole is augered, collected soil samples will be monitored with an HNu PID unit for organic vapors and notes made on the physical appearance of the soil. Soil cuttings that do not indicate elevated levels of organic vapors above background or have visual signs of contamination will be placed on polyethylene sheeting and backfilled into the borehole following completion of the drilling. Cuttings which, by their appearance or organic vapor readings, appear to be contaminated will be containerized in a lined roll-off box or Department of Transportation (DOT-) approved drums for analytical testing, temporary storage on site, and subsequent treatment and/or disposal.

6.11.3.2 Monitoring Well Development and Purge Water

All development and purge water shall be containerized in one 1,000 gallon tank. Groundwater development/purge water that exhibits elevated HNu PID readings should be kept separate from water that does not exhibit elevated levels for purposes of subsequent treatment and/or disposal.

6.11.3.3 Decontamination Fluids

Equipment and personal decontamination fluids shall be containerized in DOT-approved 55-gallon drums. The fluids shall be collected from the decontamination/wash pads.

6.11.3.4 Personal Protective Equipment

All personal protective equipment (i.e., tyveks, gloves, and other health and safety disposables) shall be placed in garbage bags and disposed of in trash dump boxes.

6.11.4 Investigation Derived Waste Sampling and Analysis

A composite sample shall be collected from the roll-off box or drums containing soil cuttings for the two individual sites. These samples will be analyzed for full TCP (organics and inorganic), TCL PCBs, and RARA hazardous waste characterization (corrosivity, reactivity, and ignitability). Appendix L contains procedures for collecting samples from drums.

For each container of development/purge water, a sample shall be collected for full TCL organic and TAL total metal analyses. Procedures for collecting waste water samples are presented in Appendix M.

Decontamination fluids collected during the investigation shall be sampled and analyzed for full TCL organics and TAL total metals.

6.11.5 Labeling

If DOT-approved 55-gallon drums are used to containerize soil cuttings, the containers will be numbered and labeled by the field team during the site investigation. Information shall be stenciled in paint on both the container lid and side. Container labels shall include, at a minimum:

LANTDIV Contract Task Order (CTO) (number)
Project name
Drum number
Soil boring or monitoring well number
Date
Source
Contents

If laboratory analysis reveals that containerized materials are hazardous or contain PCBs, additional labeling of containers may be required. The Project Manager will assist LANTDIV in additional labeling procedures, if necessary, after departure of the field team from the facility. These additional labeling procedures will be based upon the identification of material present; USEPA regulations applicable to labeling hazardous and PCB containing wastes are contained in 40 CFR Parts 261, 262, and 761.

6.11.6 Container Log

A container log shall be maintained in the site logbook. The container log shall contain the same information as the container label plus any additional remarks or information. Such additional information may include the identification number of a representative laboratory sample.

6.11.7 Container Storage

Containers of site investigative wastes shall be stored on site or in a specially designated secure area that is managed by the MCB Camp Lejeune Environmental Management Division (EMD) until disposition is determined. All containers shall be covered with plastic sheeting to provide protection from the weather.

If the laboratory analysis reveals that the containers contain hazardous or PCB wastes, additionally required storage security may be implemented; in the absence of the investigative team, these will be the responsibility of LANTDIV or the facility, as confirmed by the contingency discussions.

Baker will assist LANTDIV in devising the storage requirements, which may include the drums being staged on wooden pallets or other structures to prevent contact with the ground and being staged to provide easy access. Weekly inspections by facility personnel of the temporary storage area also may be required. These inspections may assess the structural integrity of the containers and proper container labeling. Also, precipitation that may accumulate in the storage area may need to be removed. These weekly inspections and whatever precipitation removal is necessary shall be recorded in the site logbook.

6.11.8 Container Disposition

The disposition of the containers of site investigation generated wastes shall be determined by LANTDIV, with the assistance of Baker, as necessary. Container disposition shall be based on quantity of materials, types of materials, and analytical results. If necessary, specific samples of contained materials may be collected to identify further characteristics which may affect disposition. Typically, container disposition will not be addressed until after receipt of applicable analytical results; these results are usually not available until long after completion of the field investigation at the facility.

6.11.9 Disposal of Contaminated Materials

Actual disposal methods for IDW will be determined following receipt of chemical analyses. The usual course will be a contractor specialist retained to conduct the disposal. However, regardless of the mechanism used, all applicable Federal, state, and local regulations shall be observed. USEPA regulations applicable to generating, storing, and transporting PCB or hazardous wastes are contained in 40 CFR Parts 262, 263, and 761.

Another consideration in selecting the method of disposal of contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of a suitable on-site disposal or treatment structure is expected, contaminated materials generated during the site investigation may be stored at the site for treatment/disposal with other site materials. In this case, the initial containment (i.e., drums or other containers) shall be evaluated for use as long-term storage. Also, other site conditions, such as drainage control, security, and soil types must be considered in order to provide proper storage.

At Site 89 and 93, any soil determined to be nonhazardous will be returned to the site. Soil determined to be hazardous will be taken to a Treatment Storage and Disposal Facility (TSDF). All water will be taken to the Site 82 treatment plant if determined not to contain petroleum/oil/lubricant (POL) constituents.

SECTION 6.0 FIGURES

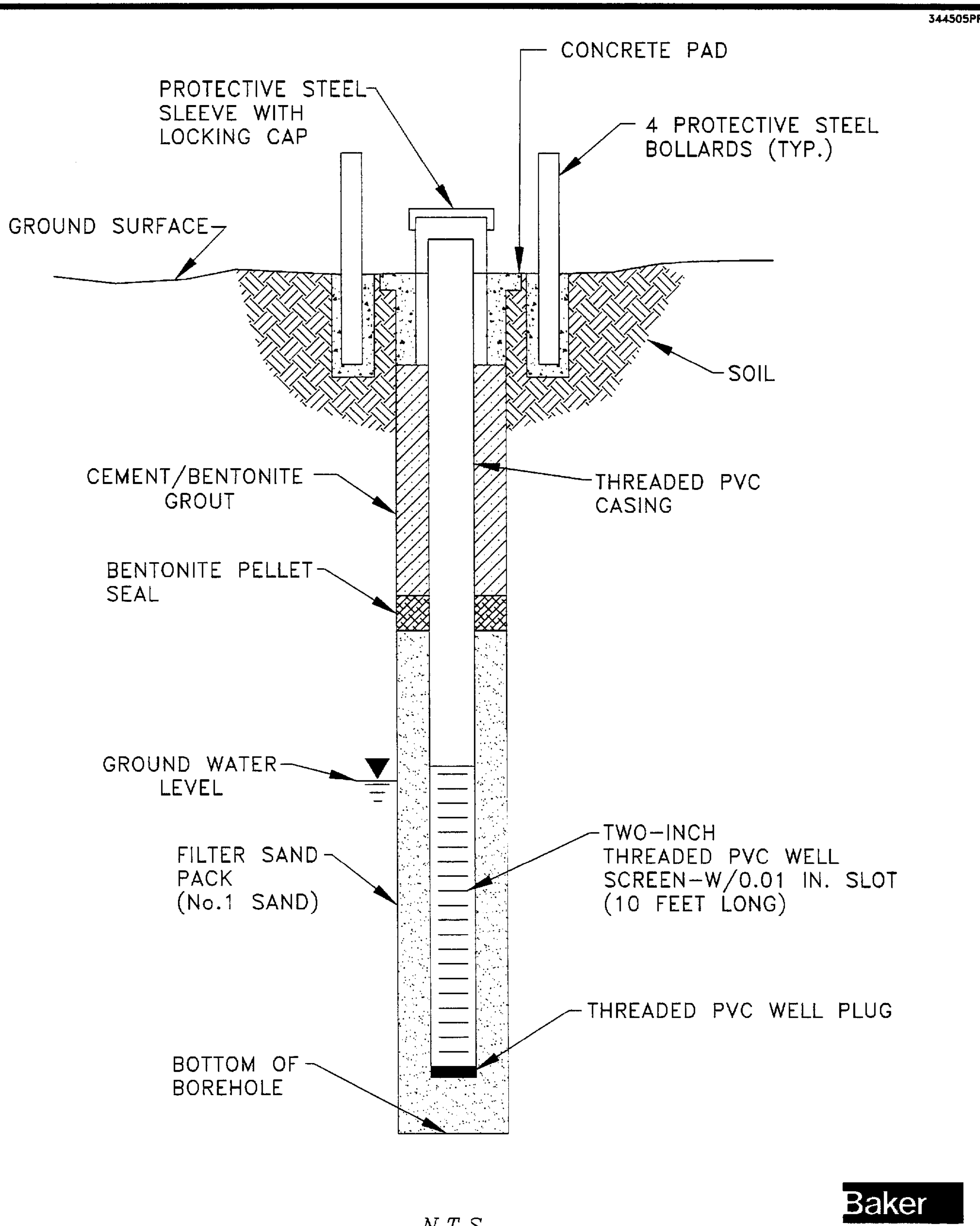
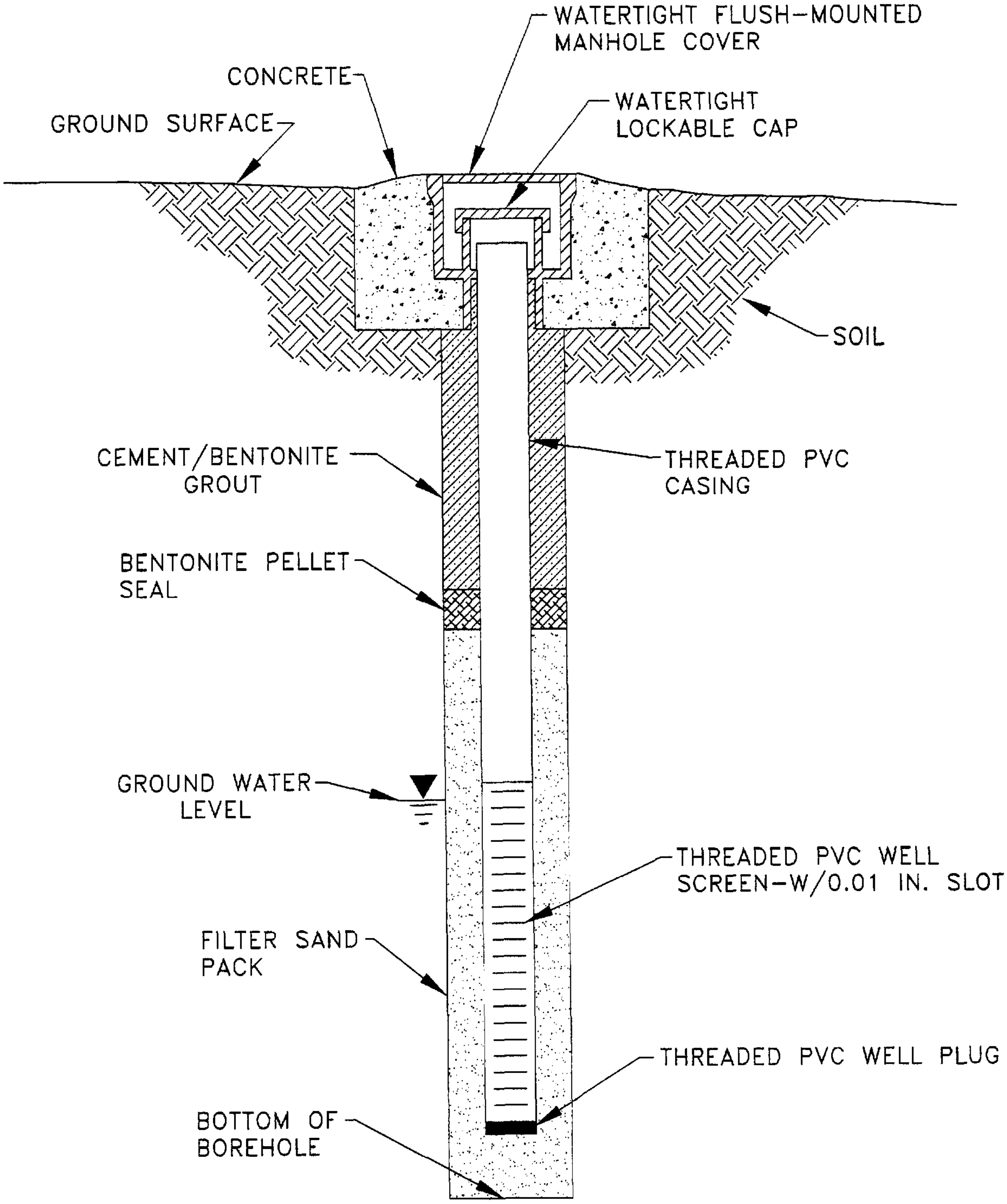


FIGURE 6-1
TYPICAL SHALLOW ABOVE GRADE GROUNDWATER MONITORING WELL CONSTRUCTION DIAGRAM
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



Baker
Baker Environmental, Inc.

FIGURE 6-2
TYPICAL SHALLOW FLUSH MOUNT GROUNDWATER MONITORING WELL CONSTRUCTION DIAGRAM
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

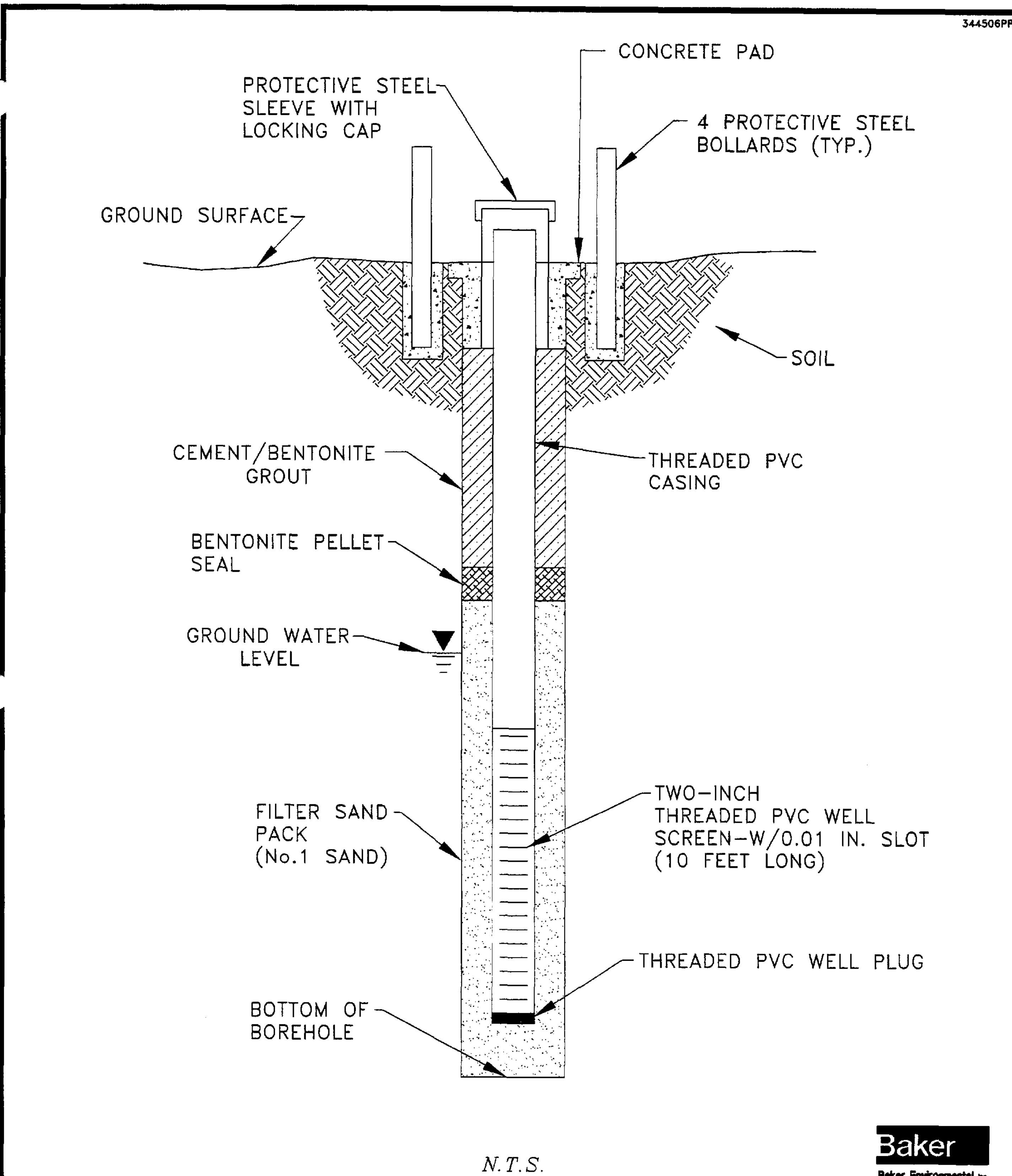
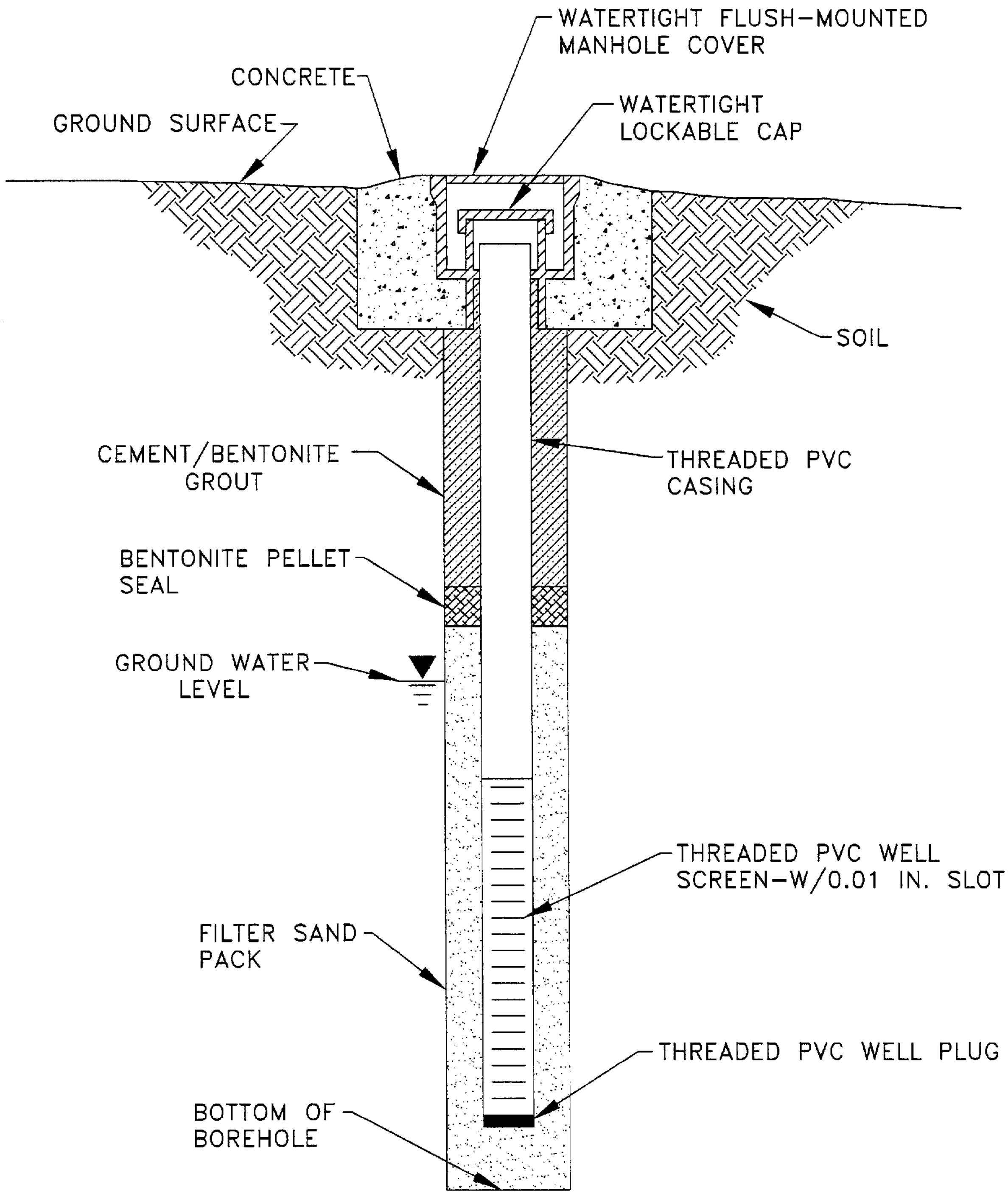


FIGURE 6-3
TYPICAL INTERMEDIATE ABOVE GRADE GROUNDWATER
MONITORING WELL CONSTRUCTION DIAGRAM
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

344508PP



N.T.S.

Baker
Baker Environmental, Inc.

FIGURE 6-4
TYPICAL INTERMEDIATE FLUSH MOUNT GROUNDWATER MONITORING WELL CONSTRUCTION DIAGRAM
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

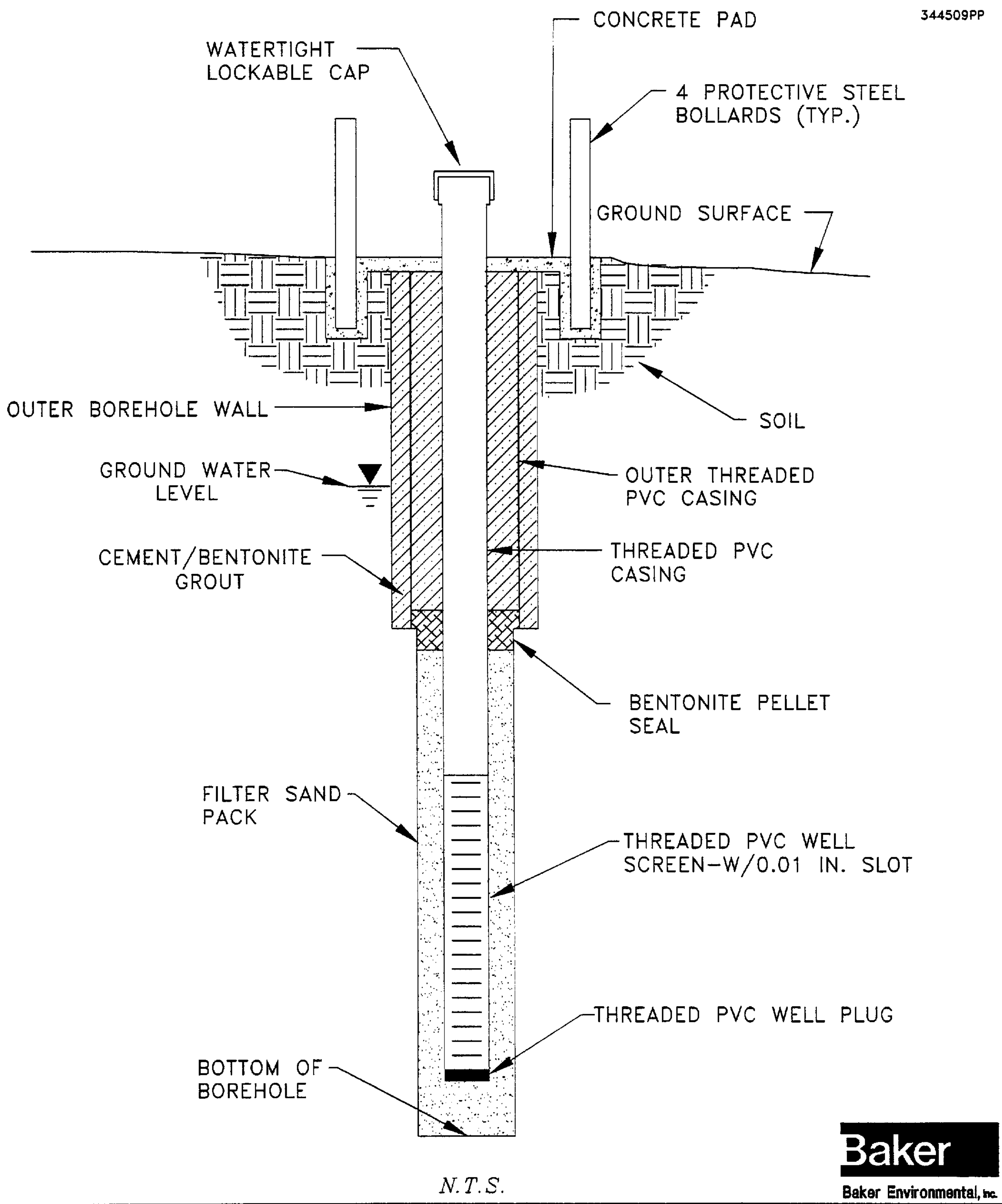
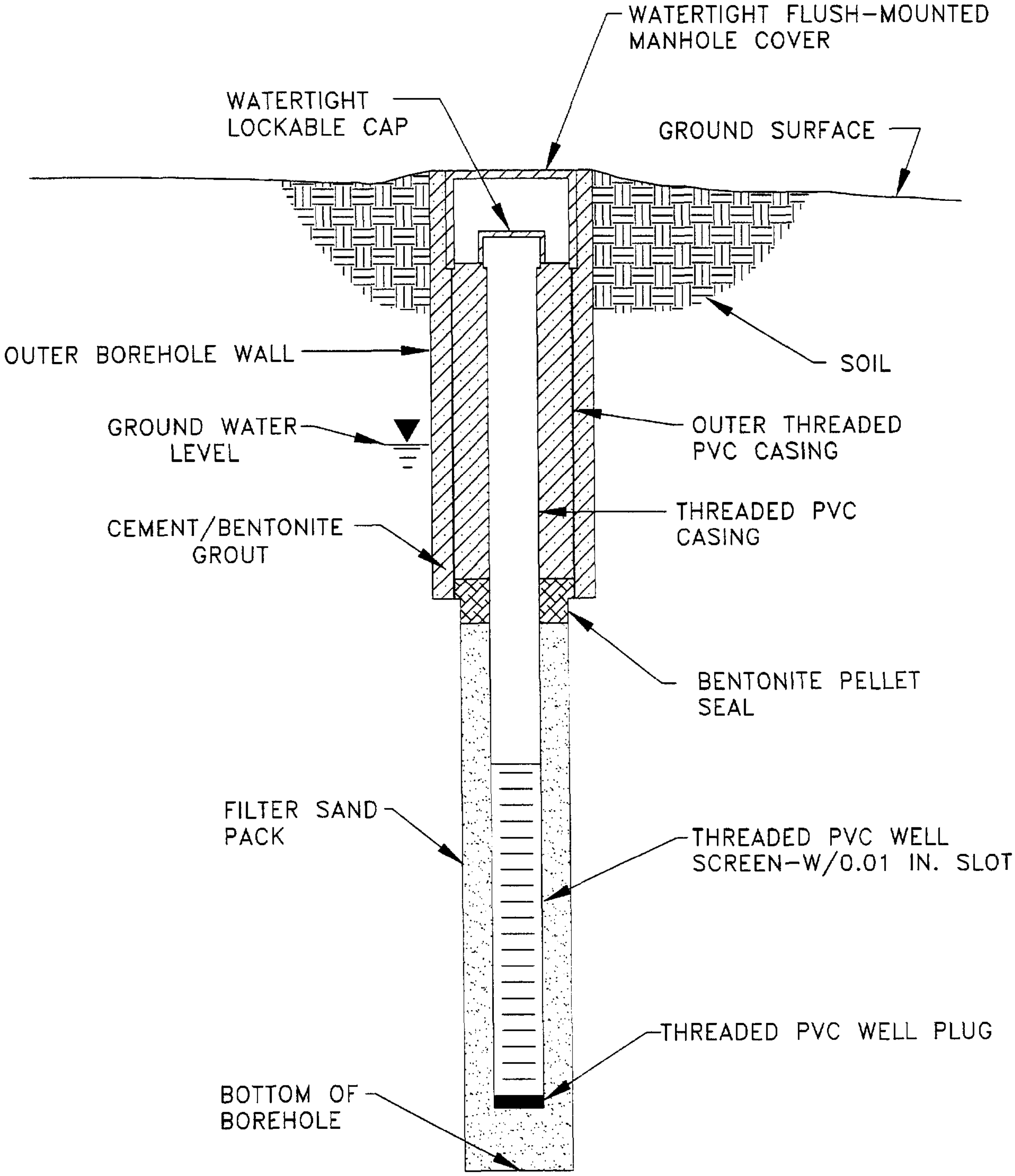


FIGURE 6-5
TYPICAL DEEP ABOVE GRADE GROUNDWATER
MONITORING WELL CONSTRUCTION DIAGRAM
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

344510PP



N.T.S.

Baker
Baker Environmental, Inc.

FIGURE 6-6
TYPICAL DEEP FLUSH MOUNT GROUNDWATER MONITORING WELL CONSTRUCTION DIAGRAM
CTO-0344

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

7.0 SAMPLE HANDLING AND ANALYSIS

Field activities will be conducted in accordance with the USEPA Region IV ESD's ECBSOPQAM (February 1, 1991). Procedures for sample preservation, labeling, handling, and maintaining a field logbook are detailed in SOPs. Because these procedures are not specific to this project, they are provided as appendices, rather than detailed herein. Major components of sample handling and analysis are discussed in the following subsections.

The number of samples, analytical methods, data quality objectives, and laboratory turnaround times are presented in Table 7-1.

7.1 Sample Preservation and Handling

Sample preservation, sample bottle packing and shipping are important components to maintaining the integrity of the samples. Preservation and handling procedures to be used in this investigation are detailed in Appendix N and Section 6.1 of the QAPP.

7.2 Chain-of-Custody

Chain-of-custody is another important component to maintaining sample integrity. Chain-of-custody procedures to be followed during this investigation are detailed in Appendix O. This SOP details sample bottle labeling and chain-of-custody procedures.

Chain-of-custody procedures ensure a documented, traceable link between measurement results and the sample or parameter they represent. These procedures are intended to provide a legally acceptable record of sample collection, identification, preparation, storage, shipping, and analysis.

7.3 Field Logbook

Field logbooks will be used to record sampling activities and information. Entries will include general and specific sampling information so that site activities may be reconstructed. In addition to the logbook, field forms, such as boring and monitoring well development logs, will be completed as support documentation for the logbook. Appendix P describes a general format for the field logbook.

Each field person will have and maintain a logbook. Logbooks will be copied daily and stored at the field trailer as back-up in case the original is lost or destroyed. Additionally, copies of completed logbooks will be filed in the project files.

SECTION 7.0 TABLE

TABLE 7-1

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
OPERABLE UNIT NO. 16 (SITES 89 AND 93)
REMEDIAL INVESTIGATION/FEASIBILITY STUDY PROJECT PLANS - CTO 0344
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline Number Of Samples[1]	Analysis	Analytical Method	Data Quality Objective	Laboratory Turnaround
Sites 89 and 93 - Phase II	Groundwater	5 intermediate temporary monitoring wells	TCL VOAs - Mobile Laboratory [2]	CLP/SOW	IV	NA
		Expanded temporary intermediate monitoring wells	TCL VOAs - Mobile Laboratory [2]	CLP/SOW	IV	NA
		7 shallow monitoring wells/1 sample per well 8 intermediate monitoring wells/1 sample per well 3 deep monitoring wells/1 sample per well Additional shallow monitoring wells/1 sample per well Additional intermediate monitoring wells/1 sample per well Additional deep monitoring wells/1 sample per well	TCL VOAs, SVOAs Pesticides/PCBs [5] TAL Total Metals Nitrate Nitrite Sulfate Sulfide Methane Chloride	CLP/SOW CLP/SOW CLP/SOW EPA 160.1/160.2 EPA 405.1/ EPA 410.1	IV IV IV IV IV	Routine Routine Routine Routine Routine
		1 intermediate monitoring well/1 sample	TSS/TDS, BOD/COD	See below	IV	Routine
	Soil	8 intermediate monitoring well borings/3 samples per boring Proposed monitoring well borings/3 samples per well	TCL VOAs, SVOAs Pesticides/PCBs [4] TAL Metals[5]	CLP/SOW CLP/SOW CLP/SOW	IV IV IV	Routine[3] Routine Routine
		2 monitoring well borings/1 composite per boring	TOC Bulk density Grain size	EPA 415.1 ASTM D 1587-14 ASTM D 1140	IV IV IV	Routine Routine Routine
		2 monitoring well borings/3 samples per well	Vertical permeability	ASTM D2434-18	IV	Routine
Site 89 - Phase II	Surface Water - Edwards Creek	5 stations/1 sample per station	Chloride	CLP/DOW	IV	Routine
	Sediments - Edwards Creek	5 stations/1 sample per station	TOC/Grain Size	CLP/SOW CLP/SOW	IV IV	Routine Routine
Investigation Derived Waste	Development/ Purge Water	2 (1 sample per site)	TCL Organics TAL Total Metals TSS/TDS	CLP/SOW CLP/SOW EPA 160.1/160.2	IV IV IV	Routine Routine Routine
	Soil	2 (1 sample per site)	TCLP RCRA TCL PCBs	SW 846 SW846 CLP/SOW	IV IV IV	Routine Routine Routine

TABLE 7-1 (continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
OPERABLE UNIT NO. 16 (SITES 89 AND 93)
REMEDIAL INVESTIGATION/FEASIBILITY STUDY PROJECT PLANS - CTO 0344
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Notes:

(1) Baseline Number of samples does not include QA/QC.
(2) Ten percent of all samples also will be analyzed for TCL VOA at a fixed base analytical laboratory.
(3) Routine analytical turnaround is 35 days following receipt of samples.
(4) Ten percent of samples collected will be analyzed for Pesticides/PCBs.
(5) Target Analyte List (TAL) Metals:

Aluminum	EPA 3010/EPA 200.7	Cobalt	EPA 3010/EPA 200.7	Potassium	EPA 3010/EPA 200.7
Antimony	EPA 3010/EPA 200.7	Copper	EPA 3010/EPA 200.7	Selenium	EPA 3020/EPA 270.2
Arsenic	EPA 3020/EPA 206	Iron	EPA 3010/EPA 200.7	Silver	EPA 3010/EPA 200.7
Barium	EPA 3010/EPA 200.7	Lead	EPA 3020/EPA 239	Sodium	EPA 3010/EPA 200.7
Beryllium	EPA 3010/EPA 200.7	Magnesium	EPA 3010/EPA 200.7	Thallium	EPA 3020/EPA 279
Cadmium	EPA 3010/EPA 200.7	Manganese	EPA 3010/EPA 200.7	Vanadium	EPA 3010/EPA 200.7
Calcium	EPA 3010/EPA 200.7	Mercury	EPA 3010/EPA 245.1	Zinc	EPA 3010/EPA 200.7
Chromium	EPA 3010/EPA 200.7	Nickel	EPA 3010/EPA 200.7		

ASTM - American Society for Testing and Materials
bgs - Below ground surface
BOD - Biological Oxygen Demand (EPA 405.1)
CLP - Contract Laboratory Program
COD - Chemical Oxygen Demand (EPA 410.1)
EPA - United States Environmental Protection Agency
TOC - Total Organic Carbon
TSS - Total Suspended Solids (EPA 160.1)
TDS - Total Dissolved Solids (EPA 160.2)
TCLP - Toxicity Characteristic Leaching Procedure (analysis of volatile organics, semivolatile organics, pesticides, herbicides, and metals on a leachate)
QA/QC - Quality Assurance/Quality Control
RCRA - Resource Conservation and Recovery Act (Corrosivity, Reactivity [reactive sulfide and cyanide], and Ignitability)
SOW - Statement of Work

8.0 SITE MANAGEMENT

This section outlines the responsibilities and reporting requirements of on-site personnel.

8.1 Field Team Responsibilities

The field investigation portion of this project will consist of one field team. All field activities will be coordinated by a Site Manager. The Site Manager will ensure that all field activities are conducted in accordance with the project plans (the Work Plan, this FSAP, the QAPP, and the Health and Safety Plan).

The Field Team will employ one drilling rig for monitoring well installation. The drilling rig will be supervised by a Baker geologist. Two sampling technicians will be assigned to the field team for groundwater, surface water, and sediment sampling. One of the sampling technicians will serve as the Site Health and Safety Officer.

8.2 Reporting Requirements

The Site Manager will report a summary of each day's field activities to the Project Manager or his/her designee. This may be done by telephone or telefax. The Site Manager will include, at a minimum, the following in his/her daily report:

- Baker personnel on site
- Other personnel on site
- Major activities of the day
- Subcontractor quantities (e.g., drilling footages)
- Samples collected
- Problems encountered
- Planned activities

The Site Manager will receive direction from the Project Manager regarding changes in scope of the investigation. All changes in scope will be discussed and agreed upon by LANTDIV, Camp Lejeune EMD, USEPA Region IV, and the North Carolina Department of Environment, Health, and Natural Resources (DEHNR).

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APPENDIX A
SOIL SAMPLE AQUISTITION

SOIL AND ROCK SAMPLE ACQUISITION
TABLE OF CONTENTS

SOIL AND ROCK SAMPLE ACQUISITION

1.0 PURPOSE

The purpose of this procedure is to describe the handling of rock cores and subsurface soil samples collected during drilling operations. Surface soil sampling also is described.

2.0 SCOPE

The methods described in this SOP are applicable for the recovery of subsurface soil and rock samples acquired by coring operations or soil sampling techniques such as split-barrel sampling and thin-walled tube sampling. Procedures for the collection of surface soil samples also are discussed. This SOP does not discuss drilling techniques or well installation procedures. ASTM procedures for "Penetration Test and Split-Barrel Sampling of Soils," "Thin-Walled Tube Sampling of Soils," and "Diamond Core Drilling for Site Investigation" have been included as Attachments A through C, respectively.

3.0 DEFINITIONS

Thin-Walled Tube Sampler - A thin-walled metal tube (also called Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outer diameter (O.D.) and 18 to 54 inches length. A stationary piston device is included in the sampler to reduce sample disturbance and increase recovery.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into unconsolidated materials using a drive weight mounted on the drilling string. A standard split-spoon sampler (used for performing Standard Penetration Tests) is two inches O.D. and 1-3/8-inches inner diameter (I.D.). This standard spoon is available in two common lengths providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively.

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes. Grab samples are associated with surface water, groundwater, wastewater, waste, contaminated surfaces, soil, and sediment sampling. Grab samples are typically used to characterize the media at a particular instant in time.

Composite Samples - A sample collected over time that typically consists of a series of discrete samples which are combined or "composited". Two types of composite samples are listed below:

- Areal Composite: A sample collected from individual grab samples collected on an areal or cross-sectional basis. Areal composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include sediment composites from quarter-point sampling of streams and soil samples from grid points.

- Vertical Composite: A sample collected from individual grab samples collected from a vertical cross section. Vertical composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include vertical profiles of soil/sediment columns, lakes and estuaries.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that, where applicable, project-specific plans are in accordance with these procedures, or that other approved procedures are developed. Furthermore, the Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Drilling Inspector – It is the responsibility of the drilling inspector to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The Drilling Inspector is responsible for the proper acquisition of rock cores and subsurface soil samples.

Sampling Personnel – It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of samples.

5.0 PROCEDURES

Subsurface soil and rock samples are used to characterize the three-dimensional subsurface stratigraphy. This characterization can indicate the potential for migration of contaminants from various sites. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of subsurface soil samples. Where the remedial activities may include in-situ treatment, or the excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Surface soil samples serve to characterize the extent of surface contamination at various sites. These samples may be collected during initial site screening to determine gross contamination levels and levels of personal protection required as part of more intensive field sampling activities, to gather more detailed site data during design, or to determine the need for, or success of, cleanup actions.

Site construction activities may require that the engineering and physical properties of soil and rock be determined. Soil types, bearing strength, compressibility, permeability, plasticity, and moisture content are some of the geotechnical characteristics that may be determined by laboratory tests of soil samples. Rock quality, strength, stratigraphy, structure, etc. often are needed to design and construct deep foundations or remedial components.

5.1 Subsurface Soil Samples

This section discusses three methods for collecting subsurface soil samples: (1) split-spoon sampling; (2) shelby tube sampling; and, (3) bucket auger sampling. All three methods yield samples suitable for laboratory analysis. Copies of the ASTM procedures for split-spoon sampling and shelby-tube sampling are provided in Attachments A and B, respectively.

5.1.1 Split-Barrel (Split-Spoon) Sampling

The following procedures are to be used for split-spoon, geotechnical soil sampling:

1. Clean out the borehole to the desired sampling depth using equipment that will ensure that the material to be sampled is not disturbed by the operation.

2. Side-discharge bits are permissible. A bottom-discharge bit should not be used. The process of jetting through the sampler and then sampling when the desired depth is reached shall not be permitted. Where casing is used, it may not be driven below the sampling elevation.

3. The two-inch O.D. split-barrel (not for geotech) sampler should be driven with blows from a 140-pound hammer falling 30 inches in accordance with ASTM D1586-84, Standard Penetration Test.

4. Repeat this operation at intervals not longer than 5 feet in homogeneous strata, or as specified in the Sampling and Analysis Plan.

5. Record on the Field Test Boring Record or field logbook the number of blows required to effect each six inches of penetration or fraction thereof. The first six inches is considered to be a seating drive. The sum of the number of blows required for the second and third six inches of penetration is termed the penetration resistance, N. If the sampler is driven less than 18 inches, the penetration resistance is that for the last one foot of penetration. (If less than one foot is penetrated, the

logs shall state the number of blows and the fraction of one foot penetrated.) In cases where samples are driven 24 inches, the sum of second and third six-inch increments will be used to calculate the penetration resistance. (Refusal of the SPT will be noted as 50 blows over an interval equal to or less than 6 inches; the interval driven will be noted with the blow count.)

6. Bring the sampler to the surface and remove both ends and one half of the split-spoon such that the soil recovered rests in the remaining half of the barrel. Describe carefully the recovery (length), composition, structure, consistency, color, condition, etc., then put into jars without ramming. Jars with samples not taken for chemical analysis should be tightly closed, to prevent evaporation of the soil moisture. Affix labels to the jar and complete Chain-of-Custody and other required sample data forms. Protect samples against extreme temperature changes and breakage by placing them in appropriate cartons stored in a protected area.

In addition to collecting soils for geotechnical purposes, split-spoon sampling can be employed to obtain samples for environmental analytical analysis. The following procedures are to be used for split-spoon, environmental soil sampling:

1. Follow sample collection procedures 1 through 6 as outlined in Section 5.2.1.

2. After sample collection, remove the soil from the split-spoon sampler. Prior to filling laboratory containers, the soil sample should be mixed thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. Soil samples for volatile organic compounds should <u>not</u> be mixed. Further, sample containers for volatile organic compounds analyses should be filled completely without head space remaining in the container to minimize volatilization.

3. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the Field Test

Boring Record or field logbook. In addition, label, tag, and number the sample bottle(s).

4. Pack the samples for shipping. Attach seal to the shipping package. Make sure that Chain-of-Custody Forms and Sample Request Forms are properly filled out and enclosed or attached.

5. Decontaminate the split-spoon sample. Replace disposable latex gloves between sample stations to prevent cross-contaminating samples.

For obtaining composite soil samples (see Definitions), a slightly modified approach is employed. Each individual discrete soil sample from the desired sample interval will be placed into a stainless-steel, decontaminated bowl (or other appropriate container) prior to filling the laboratory sample containers. Special care should be taken to cover the bowl between samples with aluminum foil to minimize volatilization. Immediately after obtaining soils from the desired sampling interval, the sample to be analyzed for Volatile Organic Compounds (VOCs) should be collected. In the event that a composite sample is required, care should be taken to obtain a representative sampling of each sample interval. The remaining soils should be thoroughly mixed. Adequate mixing can be achieved by stirring in a circular fashion and occasionally turning the soils over. Once the remaining soils have been thoroughly combined, samples for analyses other than VOCs should be placed into the appropriate sampling containers.

5.1.2 Thin-Wall (Shelby Tube) Sampling

When it is desired to take undisturbed samples of soil for physical laboratory testing, thin-walled seamless tube samplers (Shelby tubes) will be used. The following method applies:

1. Clean out the hole to the sampling elevation, being careful to minimize the chance for disturbance or contamination of the material to be sampled.

2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the hole shall not be allowed. Any side discharge bits are permitted.

3. The sampler must be of a stationary piston-type, to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler in the hole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out of the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.

4. With the sampling tube resting on the bottom of the hole and the water level in the boring at the natural groundwater level or above, push the tube into the soil by a continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed further than the length provided for the soil sample. Allow a free space in the tube for cuttings and sludge.

5. After pushing the tube, the sample should sit 5 to 15 minutes prior to removal. Immediately before removal, the sample must be sheared by rotating the rods with a pipe wrench a minimum of two revolutions.

6. Upon removal of the sampler tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of soil, from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Newspaper or other types of filler must be placed in voids at either end of the sampler prior to sealing with wax. Place plastic caps on the ends of the sampler, tape them into place and then dip the ends in wax to seal them.

7. Affix labels to the tubes and record sample number, depth, penetration, and recovery length on the label. Mark the same information and "up" direction on the tube with indelible ink, and indicate the top of the sample. Complete chain-of-custody and other required forms. Do not allow tubes to freeze, and store

the samples vertically (with the same orientation they had in the ground, i.e., top of sample is up) in a cool place out of the sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.

8. From soil removed from the ends of the tube, make a careful description of the soil.

9. When thin-wall tube samplers are used to collect soil for certain chemical analyses, it may be necessary to avoid using wax, newspaper, or other fillers. The SAP for each site should address specific materials allowed dependent on analytes being tested.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Dension or Pitcher cores can be used in conjunction with the tube samplers to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs and, therefore, their use should be weighed against the increased cost and the need for an undisturbed sample. In any case, if a sample cannot be obtained with a tube sampler, an attempt should be made with a split-spoon sampler at the same depth so that at least one sample can be obtained for classification purposes.

5.1.3 Bucket (Hand) Auger Sampling

Hand augering is the most common manual method used to collect subsurface samples. Typically, 4-inch auger buckets with cutting heads are pushed and twisted into the ground and removed as the buckets are filled. The auger holes are advanced one bucket at a time. The practical depth of investigation using a hand auger is related to the material being sampled. In sands, augering is usually easily accomplished, but the depth of investigation is controlled by the depth at which sands begin to cave. At this point, auger holes usually begin to collapse and cannot practically be advanced to lower depths, and further samples, if required, must be collected using some type of pushed or driven device. Hand augering may also become difficult in tight clays or cemented sands.

At depths approaching 20 feet, torquing of hand auger extensions becomes so severe that in resistant materials, powered methods must be used if deeper samples are required.

When a vertical sampling interval has been established, one auger bucket is used to advance the auger hole to the first desired sampling depth. If the sample at this location is to be a vertical composite of all intervals, the same bucket may be used to advance the hole, as well collect subsequent samples in the same hole. However, if discrete grab samples are to be collected to characterize each depth, a decontaminated bucket must be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of soil should be removed from the bucket to minimize the chances of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger should be decontaminated between samples.

In addition to hand augering, powered augers can be used to advance a boring for subsurface soil collection. However, this type of equipment is technically a sampling aid and not a sampling device, and 20 to 25 feet is the typical lower depth range for this equipment. It is used to advance a hole to the required sample depth, at which point a hand auger is usually used to collect the sample.

5.2 Surface Soil Samples

Surface soils are generally classified as soils between the ground surface and 6 to 12 inches below ground surface. For loosely packed surface soils, stainless steel (organic analyses) or plastic (inorganic analyses) scoops or trowels, can be used to collect representative samples. For densely packed soils or deeper soil samples, a hand or power soil auger may be used.

The following methods are to be used:

1. Use a soil auger for deep samples (greater than 12 inches) or a scoop or trowel for surface samples. Remove debris, rocks, twigs, and vegetation before collecting the sample.

2. Immediately transfer the sample to the appropriate sample container. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, chain-of-custody record, and other required forms.

3. Classify and record a description of the sample. Descriptions for surface soil samples should be recorded in the field logbook; descriptions for soil samples collected with power or hand augers shall be recorded on a Field Test Boring Record.

4. Store the sampling utensil in a plastic bag until decontamination or disposal. Use a new or freshly-decontaminated sampling utensil for each sample taken.

5. Pack and ship the samples.

6. Mark the location with a numbered stake if possible and locate sample points on a sketch of the site or on a sketch in the field logbook.

7. When a representative composited sample is to be prepared (e.g., samples taken from a gridded area or from several different depths), it is best to composite individual samples in the laboratory where they can be more precisely composited on a weight or volume basis. If this is not possible, the individual samples (all of equal volume, i.e., the sample bottles should be full) should be placed in a stainless steel bucket (or other appropriate container), mixed thoroughly using a decontaminated stainless steel spatula or trowel, and a composite sample collected. In some cases, as delineated in project-specific sampling and analysis plans, laboratory compositing of the samples may be more appropriate than field compositing. Samples to be analyzed for parameters sensitive to volatilization should be composited and placed into the appropriate sample bottles immediately upon collection.

5.3 Rock Cores

Once rock coring has been completed and the core recovered, the rock core must be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery, as well as the rock quality designation (RQD). If split-barrels are used, the core may be measured and classified in the split barrel after opening and then transferred to a core box.

Each core shall be described and classified on a Field Test Boring Record. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of hydrated formations) or oxidation of the core, the core must be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number and the footage represented in each sleeve shall be included, as well as the top and bottom of the core run.

After sampling, rock cores must be placed in the sequence of recovery in wooden or plastic core boxes provided by the drilling contractor. Rock cores from different borings shall not be placed in the same core box. The core boxes should be constructed to accommodate 10 to 20 linear feet of core and should be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened. Wood partitions shall be placed at the end of each core run and between rows. The depth from the surface of the boring to the top and bottom of the drill run and the run number shall be marked on the wooden partitions with indelible ink. The order of placing cores shall be the same in all core boxes. The top of each core obtained should be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, any empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.

The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data pertaining to the box's contents. At a minimum, the following information must be included:

- Project name
- Date
- CTO number
- Boring number
- Footage (depths)
- Run number(s)
- Recovery
- Rock Quality Designation (RQD)
- Box number (x of x)

It is also useful to draw a large diagram of the core in the box, on the inside of the box top. This provides more room for elevations, run numbers, recoveries, comments, etc., than could be entered on the upper edges of partitions or spaces in the core box.

For easy retrieval when core boxes are stacked, the sides and ends of the box should also be labeled and include CTO number, boring number, top and bottom depths of core and box number.

Due to the weight of the core, a filled core box should always be handled by two people. Core boxes stored on site should be protected from the weather. The core boxes should be removed from the site in a careful manner as soon as possible. Exposure to extreme heat or cold should be avoided whenever possible. Arrangements should be made to dispose of or return the core samples to the client for completion of the project.

6.0 QUALITY ASSURANCE RECORDS

Where applicable, Field Test Boring Records and Test Boring Records will serve as the quality assurance records for subsurface soil samples, rock cores and near surface soil samples collected with a hand or power auger. Observations shall be recorded in the Field Logbook. Chain-of-Custody records shall be completed for samples collected for laboratory analysis.

7.0 REFERENCES

1. American Society for Testing and Materials, 1987. Standard Method for Penetration Test and Split-Barrel Sampling of Soils. ASTM Method D1586-84, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

2. American Society for Testing and Materials, 1987. Standard Practice for Thin-Walled Tube Sampling of Soils. Method D1587-83, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

3. American Society for Testing and Materials, 1987. Standard Practice for Diamond Core Drilling for Site Investigation. Method D2113-83 (1987), Annual Book of Standards ASTM, Philadelphia, Pennsylvania.

4. U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

ATTACHMENT A

ASTM D1586-84
STANDARD METHOD FOR PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS

Designation: D 1586 – 84 (Reapproved 1992)[ε1]

Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils[1]

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

ε1 NOTE—Editorial changes were made throughout October 1992.

1. Scope

1.1 This test method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 2487 Test Method for Classification of Soils for Engineering Purposes[2]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

D 4633 Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems[2]

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard*

3.1.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.1.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.1.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.1.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.1.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.1.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.1.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.1.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N*-value, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.1.9 ΔN—the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.1.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by 360° (see Fig. 1).

3.1.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.1.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

4. Significance and Use

4.1 This test method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This test method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N*-value, and the engineering behavior of earthworks and foundations are available.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be

[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

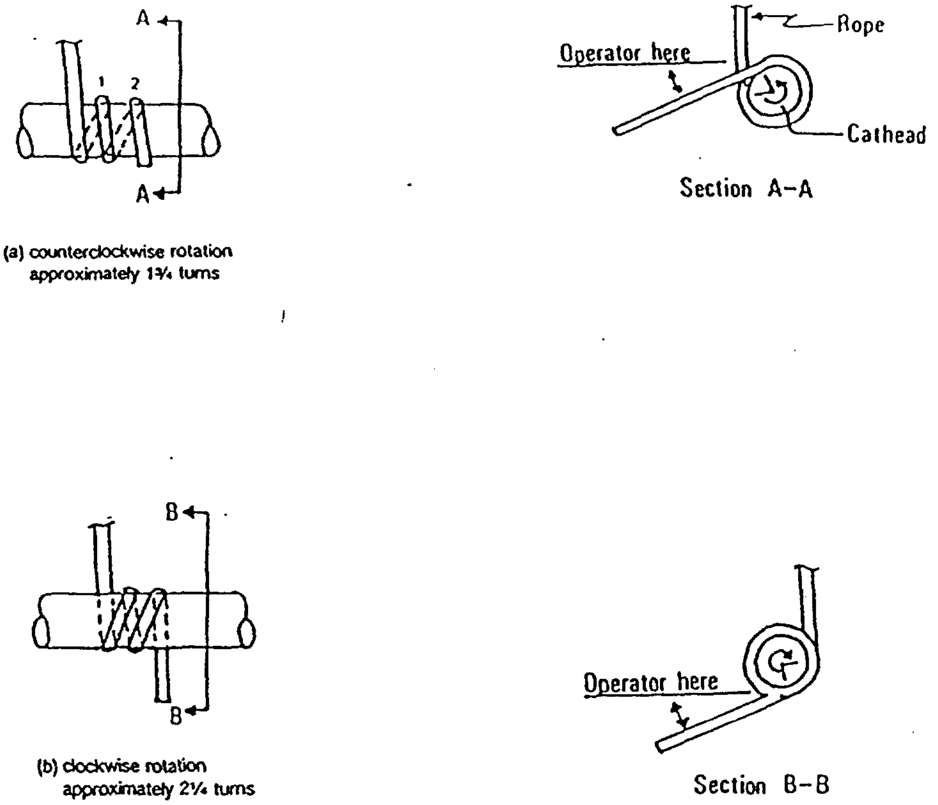


FIG. 1 Definitions of the Number of Rope Turns and the Angle for (*a*) Counterclockwise Rotation and (*b*) Clockwise Rotation of the Cathead

suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjuction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers*, with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of 1⅝ in. (41.2 mm) and an inside diameter of 1⅛ in. (28.5 mm).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the *N*-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1⅜ in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

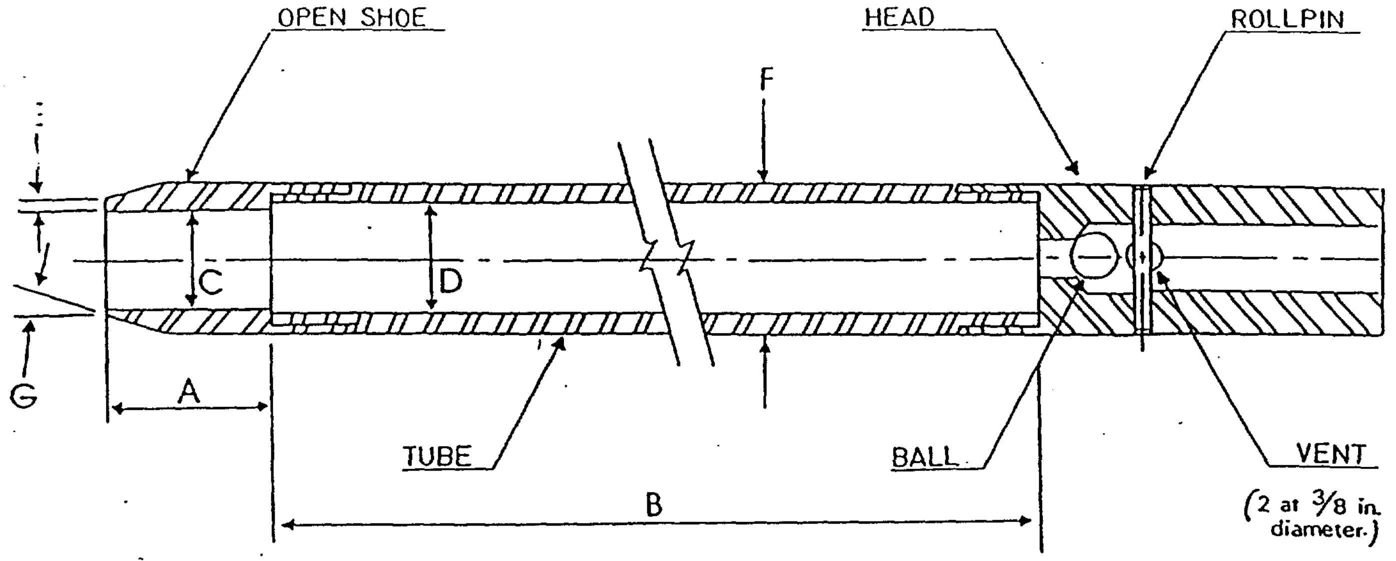
NOTE 2—Both theory and available test data suggest that *N*-values may increase between 10 to 30 % when liners are used.

5.4 *Drive-Weight Assembly:*

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 − 0.00 in. (38.1 ± 1.3 − 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 − 0.00 in. (50.8 ± 1.3 − 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 mm) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-

kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance," or the "*N*-value." If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb (63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. (0.76 m ± 25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than 2¼ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either 1¾ or 2¼ rope turns, depending upon whether or not the rope comes off the top (1¾ turns) or the bottom (2¼ turns) of the cathead. It is generally known and accepted that 2¾ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfrayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing jo designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

8.1.1 Name and location of job,

8.1.2 Names of crew,

8.1.3 Type and make of drilling machine,

8.1.4 Weather conditions,

8.1.5 Date and time of start and finish of boring,

8.1.6 Boring number and location (station and coordinates, if available and applicable),

8.1.7 Surface elevation, if available,

8.1.8 Method of advancing and cleaning the boring,

8.1.9 Method of keeping boring open,

8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,

8.1.11 Location of strata changes,

8.1.12 Size of casing, depth of cased portion of boring,

8.1.13 Equipment and method of driving sampler,

8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),

8.1.15 Size, type, and section length of the sampling rods and

8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

8.2.1 Sample depth and, if utilized, the sample number,

8.2.2 Description of soil,

8.2.3 Strata changes within sample,

8.2.4 Sampler penetration and recovery lengths, and

8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 *Precision*—A valid estimate of test precision has not been determined because it is too costly to conduct the necessary inter-laboratory (field) tests. Subcommittee D18.02 welcomes proposals to allow development of a valid precision statement.

9.2 *Bias*—Because there is no reference material for this test method, there can be no bias statement.

9.3 Variations in *N*-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.4 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

9.5 The variability in N-values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the ampler and adjusting N on the basis of comparative ıergies. A method for energy measurement and N-value adjustment is given in Test Method D 4633.

10. Keywords

10.1 blow count; in-situ test; penetration resistance; split-barrel sampling; standard penetration test

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ATTACHMENT B

ASTM D1587-83

STANDARD PRACTICE FOR THIN-WALLED TUBE SAMPLING OF SOILS

Standard Practice for Thin-Walled Tube Sampling of Soils[1]

This standard is issued under the fixed designation D 1587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This practice has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively undisturbed soil samples suitable for laboratory tests of structural properties. Thin-walled tubes used in piston, plug, or rotary-type samplers, such as the Denison or Pitcher, must comply with the portions of this practice which describe the thin-walled tubes (5.3).

NOTE 1—This practice does not apply to liners used within the above samplers.

2. Referenced Documents

2.1 *ASTM Standards:*

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

3. Summary of Practice

3.1 A relatively undisturbed sample is obtained by pressing a thin-walled metal tube into the in-situ soil, removing the soil-filled tube, and sealing the ends to prevent the soil from being disturbed or losing moisture.

4. Significance and Use

4.1 This practice, or Practice D 3550, is used when it is necessary to obtain a relatively undisturbed specimen suitable for laboratory tests of structural properties or other tests that might be influenced by soil disturbance.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment may be used that provides a reasonably clean hole; that does not disturb the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

5.2 *Sampler Insertion Equipment*, shall be adequate to provide a relatively rapid continuous penetration force. For hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

5.3 *Thin-Walled Tubes*, should be manufactured as shown in Fig. 1. They should have an outside diameter of 2 to 5 in. and be made of metal having adequate strength for use in the soil and formation intended. Tubes shall be clean and free of all surface irregularities including projecting weld seams.

5.3.1 *Length of Tubes*—See Table 1 and 6.4.

5.3.2 *Tolerances*, shall be within the limits shown in Table 2.

5.3.3 *Inside Clearance Ratio*, should be 1 % or as specified by the engineer or geologist for the soil and formation to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled. See Fig. 1 for definition of inside clearance ratio.

5.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating. Tubes which will contain samples for more than 72 h shall be coated. The type of coating to be used may vary depending upon the material to be sampled. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, and others. Type of coating must be specified by the engineer or geologist if storage will exceed 72 h. Plating of the tubes or alternate base metals may be specified by the engineer or geologist.

5.4 *Sampler Head*, serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a suitable check valve and a venting area to the outside equal to or greater than the area through the check valve. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

6. Procedure

6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

6.2 Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or hollow stem auger as carefully as

[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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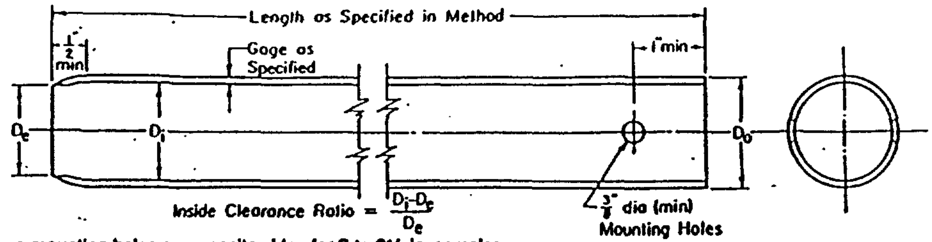

NOTE 1—Minimum of two mounting holes on opposite sides for 2 to 3½ in. sampler.
NOTE 2—Minimum of four mounting holes spaced at 90° for samplers 4 in. and larger.
NOTE 3—Tube held with hardened screws.
NOTE 4—Two-inch outside-diameter tubes are specified with an 18-gage wall thickness to comply with area ratio criteria accepted for "undisturbed samples." Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gage tubes are generally readily available.

Metric Equivalents

in.	mm
3/8	6.77
½	12.7
1	25.4
2	50.8
3½	88.9
4	101.6

FIG. 1 Thin-Walled Tube for Sampling

TABLE 1 Suitable Thin-Walled Steel Sample Tubes[A]

Outside diameter:			
in.	2	3	5
mm	50.8	76.2	127
Wall thickness:			
Bwg	18	16	11
in.	0.049	0.065	0.120
mm	1.24	1.65	3.05
Tube length:			
in.	36	36	54
m	0.91	0.91	1.45
Clearance ratio, %	1	1	1

[A] The three diameters recommended in Table 1 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

Nominal Tube Diameters from Table 1[A] Tolerances, in.			
Size Outside Diameter	2	3	5
Outside diameter	+0.007	+0.010	+0.015
	−0.000	−0.000	−0.000
Inside diameter	+0.000	+0.000	+0.000
	−0.007	−0.010	−0.015
Wall thickness	±0.007	±0.010	±0.015
Ovality	0.015	0.020	0.030
Straightness	0.030/ft	0.030/ft	0.030/ft

[A] Intermediate or larger diameters should be proportional. Tolerances shown are essentially standard commercial manufacturing tolerances for seamless steel mechanical tubing. Specify only two of the first three tolerances; that is, O.D. and I.D., or O.D. and Wall, or I.D. and Wall.

possible to avoid disturbance of the material to be sampled.

NOTE 2—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

6.3 Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler without rotation by a continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.

NOTE 3—Weight of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

6.5 When the formation is too hard for push-type insertion, the tube may be driven or Practice D 3550 may be used. Other methods, as directed by the engineer or geologist, may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a "driven sample."

6.6 In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. for sludge-end cuttings.

NOTE 4—The tube may be rotated to shear bottom of the sample after pressing is complete.

6.7 Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

7. Preparation for Shipment

7.1 Upon removal of the tube, measure the length of sample in the tube. Remove the disturbed material in the upper end of the tube and measure the length again. Seal the upper end of the tube. Remove at least 1 in. of material from the lower end of the tube. Use this material for soil description in accordance with Practice D 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube if so directed by the engineer or geologist.

NOTE 5—Field extrusion and packaging of extruded samples under the specific direction of a geotechnical engineer or geologist is permitted.

NOTE 6—Tubes sealed over the ends as opposed to those sealed with expanding packers should contain end padding in end voids in order to prevent drainage or movement of the sample within the tube.

7.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample. Assure that the markings or labels are adequate to survive transportation and storage.

8. Report

8.1 The appropriate information is required as follows:

8.1.1 Name and location of the project,

8.1.2 Boring number and precise location on project,

8.1.3 Surface elevation or reference to a datum,

8.1.4 Date and time of boring—start and finish,

8.1.5 Depth to top of sample and number of sample,

8.1.6 Description of sampler: size, type of metal, type of coating,

8.1.7 Method of sampler insertion: push or drive,

8.1.8 Method of drilling, size of hole, casing, and drilling fluid used,

8.1.9 Depth to groundwater level: date and time measured,

8.1.10 Any possible current or tidal effect on water level,

8.1.11 Soil description in accordance with Practice D 2488,

8.1.12 Length of sampler advance, and

8.1.13 Recovery: length of sample obtained.

9. Precision and Bias

9.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

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ATTACHMENT C

ASTM D2113-83 (1987)
STANDARD PRACTICE FOR DIAMOND CORE DRILLING FOR
SITE INVESTIGATION

Standard Practice for Diamond Core Drilling for Site Investigation[1]

This standard is issued under the fixed designation D 2113; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice describes equipment and procedures for diamond core drilling to secure core samples of rock and some soils that are too hard to sample by soil-sampling methods. This method is described in the context of obtaining data for foundation design and geotechnical engineering purposes rather than for mineral and mining exploration.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]

D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]

3. Significance and Use

3.1 This practice is used to obtain core specimens of superior quality that reflect the in-situ conditions of the material and structure and which are suitable for standard physical-properties tests and structural-integrity determination.

4. Apparatus

4.1 *Drilling Machine*, capable of providing rotation, feed, and retraction by hydraulic or mechanical means to the drill rods.

4.2 *Fluid Pump or Air Compressor*, capable of delivering sufficient volume and pressure for the diameter and depth of hole to be drilled.

4.3 *Core barrels*, as required:

4.3.1 *Single Tube Type, WG Design*, consisting of a hollow steel tube, with a head at one end threaded for drill rod, and a threaded connection for a reaming shell and core bit at the other end. A core lifter, or retainer located within the core bit is normal, but may be omitted at the discretion of the geologist or engineer.

4.3.2 *Double Tube, Swivel-Type, WG Design*—An assembly of two concentric steel tubes joined and supported at the upper end by means of a ball or roller-bearing swivel arranged to permit rotation of the outer tube without causing rotation of the inner tube. The upper end of the outer tube, or removable head, is threaded for drill rod. A threaded connection is provided on the lower end of the outer tube for a reaming shell and core bit. A core lifter located within the core bit is normal but may be omitted at the discretion of the geologist or engineer.

4.3.3 *Double-Tube, Swivel-Type, WT Design*, is essentially the same as the double tube, swivel-type, WG design, except that the WT design has thinner tube walls, a reduced annular area between the tubes, and takes a larger core from the same diameter bore hole. The core lifter is located within the core bit.

4.3.4 *Double Tube, Swivel Type, WM Design*, is similar to the double tube, swivel-type, WG design, except that the inner tube is threaded at its lower end to receive a core lifter case that effectively extends the inner tube well into the core bit, thus minimizing exposure of the core to the drilling fluid. A core lifter is contained within the core lifter case on the inner tube.

4.3.5 *Double Tube Swivel-Type, Large-Diameter Design*, is similar to the double tube, swivel-type, WM design, with the addition of a ball valve, to control fluid flow, in all three available sizes and the addition of a sludge barrel, to catch heavy cuttings, on the two larger sizes. The large-diameter design double tube, swivel-type, core barrels are available in three core per hole sizes as follows: 2¾ in. (69.85 mm) by 3⅞ in. (98.43 mm), 4 in. (101.6 mm) by 5½ in. (139.7 mm), and 6 in. (152.4 mm) by 7¾ in. (196.85 mm). Their use is generally reserved for very detailed investigative work or where other methods do not yield adequate recovery.

4.3.6 *Double Tube, Swivel-Type, Retrievable Inner-Tube Method*, in which the core-laden inner-tube assembly is retrieved to the surface and an empty inner-tube assembly returned to the face of the borehole through the matching large-bore drill rods without need for withdrawal and replacement of the drill rods in the borehole. The inner-tube assembly consists of an inner tube with removable core lifter case and core lifter at one end and a removable inner-tube head, swivel bearing, suspension adjustment, and latching device with release mechanism on the opposite end. The inner-tube latching device locks into a complementary recess in the wall of the outer tube such that the outer tube may be rotated without causing rotation of the inner tube and such that the latch may be actuated and the inner-tube assembly transported by appropriate surface control. The outer tube is threaded for the matching, large-bore drill rod and internally configured to receive the inner-tube latching device at one end and threaded for a reaming shell and bit, or bit only, at the other end.

4.4 *Longitudinally Split Inner Tubes*—As opposed to conventional cylindrical inner tubes, allow inspection of, and access to, the core by simply removing one of the two halves. They are not standardized but are available for most core barrels including many of the retrievable inner-tube types.

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[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved June 24, 1983. Published August 1983. Originally published as D 2113 – 62 T. Last previous edition D 2113 – 70 (1976).

[2] *Annual Book of ASTM Standards*, Vol 04.08.

4.5 *Core Bits*—Core bits shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide slugs, or strips, hard-faced with various hard surfacing materials or furnished in saw-tooth form, all as appropriate to the formation being cored and with concurrence of the geologist or engineer. Bit matrix material, crown shape, water-way type, location and number of water ways, diamond size and carat weight, and bit facing materials shall be for general purpose use unless otherwise approved by the geologist or engineer. Nominal size of some bits is shown in Table 1.

NOTE 1—Size designation (letter symbols) used throughout the text and in Tables 1, 2, and 3 are those standardized by the Diamond Core Drill Manufacturers' Assoc. (DCDMA). Inch dimensions in the tables have been rounded to the nearest hundredth of an inch.

4.6 *Reaming Shells,* shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide strips or slugs, hard faced with various types of hard surfacing materials, or furnished blank, all as appropriate to the formation being cored.

4.7 *Core Lifters*—Core lifters of the split-ring type, either plain or hard-faced, shall be furnished and maintained, along with core-lifter cases or inner-tube extensions or inner-tube shoes, in good condition. Basket or finger-type lifters, together with any necessary adapters, shall be on the job and available for use with each core barrel if so directed by the geologist or engineer.

4.8 *Casings:*

4.8.1 *Drive Pipe or Drive Casing,* shall be standard weight (schedule 40), extra-heavy (schedule 80), double extra-heavy (schedule 160) pipe or W-design flush-joint casing as required by the nature of the overburden or the placement method. Drive pipe or W-design casing shall be of sufficient diameter to pass the largest core barrel to be used, and it shall be driven to bed rock or to firm seating at an elevation below water-sensitive formation. A hardened drive shoe is to be used as a cutting edge and thread protection device on the bottom of the drive pipe or casing. The drive shoe inside diameter shall be large enough to pass the tools intended for use, and the shoe and pipe or casing shall be free from burrs or obstructions.

4.8.2 *Casing*—When necessary to case through formations already penetrated by the borehole or when no drive casing has been set, auxiliary casing shall be provided to fit inside the borehole to allow use of the next smaller core barrel. Standard sizes of telescoping casing are shown in Table 2. Casing bits have an obstruction in their interior and will not pass the next smaller casing size. Use a casing shoe if additional telescoping is anticipated.

4.8.3 *Casing Liner*—Plastic pipe or sheet-metal pipe may be used to line an existing large-diameter casing. Liners, so used, should not be driven, and care should be taken to maintain true alignment throughout the length of the liner.

4.8.4 *Hollow Stem Auger*—Hollow stem auger may be used as casing for coring.

4.9 *Drill Rods:*

4.9.1 *Drill Rods of Tubular Steel Construction* are normally used to transmit feed, rotation, and retraction forces from the drilling machine to the core barrel. Drill-rod sizes that are presently standardized are shown in Table 3.

4.9.2 Large bore drill rods used with retrievable inner-tube core barrels are not standardized. Drill rods used with retrievable inner-tube core barrels should be those manufactured by the core-barrel manufacturer specifically for the core barrel.

4.9.3 *Composite Drill Rods* are specifically constructed from two or more materials intended to provide specific properties such as light weight or electrical nonconductivity.

4.9.4 *Nonmagnetic Drill Rods* are manufactured of nonferrous materials such as aluminum or brass and are used primarily for hole survey work. Some nonmagnetic rods have left-hand threads in order to further their value in survey work. No standard exists for nonmagnetic rods.

4.10 *Auxiliary Equipment,* shall be furnished as required by the work and shall include: roller rock bits, drag bits, chopping bits, boulder busters, fishtail bits, pipe wrenches, core barrel wrenches, lubrication equipment, core boxes, and marking devices. Other recommended equipment includes:

TABLE 1 Core Bit Sizes

Size Designation	Outside Diameter		Inside Diameter	
	in.	mm	in.	mm
RWT	1.16	29.5	0.375	18.7
EWT	1.47	37.3	0.905	22.9
EWG, EWM	1.47	37.3	0.845	21.4
AWT	1.88	47.6	1.281	32.5
AWG, AWM	1.88	47.6	1.185	30.0
BWT	2.35	59.5	1.750	44.6
BWG, BWM	2.35	59.5	1.655	42.0
NWT	2.97	75.3	2.313	58.7
NWG, NWM	2.97	75.3	2.155	54.7
2¾ × 3⅞	3.84	97.5	2.69	68.3
HWT	3.89	98.8	3.187	80.9
HWG, . . .	3.89	98.8	3.000	76.2
4 × 5½	5.44	138.0	3.97	100.8
6 × 7¾	7.66	194.4	5.97	151.6

TABLE 2 Casing Sizes

Size Designation	Outside Diameter		Inside Diameter		Threads per in.	Will Fit Hole Drilled with Core Bit Size
	in.	mm	in.	mm		
RW	1.144	36.5	1.19	30.1	5	EWT, EWG, EWM
EW	1.81	46.0	1.50	38.1	4	AWT, AWG, AWM
AW	2.25	57.1	1.91	48.4	4	BWT, BWG, BWM
BW	2.88	73.0	2.38	60.3	4	NWT, NWG, NWM
NW	3.50	88.9	3.00	76.2	4	HWT, HWG
HW	4.50	114.3	4.00	101.6	4	4 × 5½
PW	5.50	139.7	5.00	127.0	3	6 × 7¾
SW	6.63	168.2	6.00	152.4	3	6 × 7¾
UW	7.63	193.6	7.00	177.8	2	. . .
ZW	8.63	219.0	8.00	203.2	2	. . .

TABLE 3 Drill Rods

Size Designation	Rod and Coupling Outside Diameter		Rod Inside Diameter		Coupling Bore, Threads		
	in.	mm	in.	mm	in.	mm	per in.
RW	1.09	27.7	0.72	18.2	0.41	10.3	4
EW	1.38	34.9	1.00	25.4	0.44	11.1	3
AW	1.72	43.6	1.34	34.1	0.63	16.8	3
BW	2.13	53.9	1.75	44.4	0.75	19.0	3
NW	2.63	66.6	2.25	57.1	1.38	34.9	3
HW	3.50	88.9	3.06	77.7	2.38	60.3	3

core splitter, rod wicking, pump-out tools or extruders, and hand sieve or strainer.

5. Transportation and Storage of Core Containers

5.1 *Core Boxes,* shall be constructed of wood or other durable material for the protection and storage of cores while enroute from the drill site to the laboratory or other processing point. All core boxes shall be provided with longitudinal separators and recovered cores shall be laid out as a book would read, from left to right and top to bottom, within the longitudinal separators. Spacer blocks or plugs shall be marked and inserted into the core column within the separators to indicate the beginning of each coring run. The beginning point of storage in each core box is the upper left-hand corner. The upper left-hand corner of a hinged core box is the left corner when the hinge is on the far side of the box and the box is right-side up. All hinged core boxes must be permanently marked on the outside to indicate the top and the bottom. All other core boxes must be permanently marked on the outside to indicate the top and the bottom and additionally, must be permanently marked internally to indicate the upper-left corner of the bottom with the letters UL or a splotch of red paint not less than 1 in.^{2} Lid or cover fitting(s) for core boxes must be of such quality as to ensure against mix up of the core in the event of impact or upsetting of the core box during transportation.

5.2 Transportation of cores from the drill site to the laboratory or other processing point shall be in durable core boxes so padded or suspended as to be isolated from shock or impact transmitted to the transporter by rough terrain or careless operation.

5.3 Storage of cores, after initial testing or inspection at the laboratory or other processing point, may be in cardboard or similar less costly boxes provided all layout and marking requirements as specified in 5.1 are followed. Additional spacer blocks or plugs shall be added if necessary at time of storage to explain missing core. Cores shall be stored for a period of time specified by the engineer but should not normally be discarded prior to completion of the project for which they were taken.

6. Procedure

6.1 Use core-drilling procedures when formations are encountered that are too hard to be sampled by soil-sampling methods. A 1-in. (25.4-mm) or less penetration for 50 blows in accordance with Method D 1586 or other criteria established by the geologist or engineer, shall indicate that soil-sampling methods are not applicable.

6.1.1 Seat the casing on bedrock or in a firm formation to prevent raveling of the borehole and to prevent loss of drilling fluid. Level the surface of the rock or hard formation at the bottom of the casing when necessary, using the appropriate bits. Casing may be omitted if the borehole will stand open without the casing.

6.1.2 Begin the core drilling using an N-size double-tube swivel-type core barrel or other size or type approved by the engineer. Continue core drilling until core blockage occurs or until the net length of the core barrel has been drilled in. Remove the core barrel from the hole and disassemble it as necessary to remove the core. Reassemble the core barrel and return it to the hole. Resume coring.

6.1.3 Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box as described in 5.1. Continue boxing core with appropriate markings, spacers, and blocks as described in 5.1. Wrap soft or friable cores or those which change materially upon drying in plastic film or seal in wax, or both, when such treatment is required by the engineer. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core which might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.

6.1.4 Stop the core drilling when soft materials are encountered that produce less than 50 % recovery. If necessary, secure samples of soft materials in accordance with the procedures described in Method D 1586, Practice D 1587, or Practice D 3550, or by any other method acceptable to the geologist or engineer. Resume diamond core drilling when refusal materials as described in 6.1 are again encountered.

6.2 Subsurface structure, including the dip of strata, the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described. Take special care to obtain and record information about these features. If conditions prevent the continued advance of the core drilling, the hole should be cemented and redrilled, or reamed and cased, or cased and advanced with the next smaller-size core barrel, as required by the geologist or engineer.

6.3 Drilling mud or grouting techniques must be approved by the geologist or engineer prior to their use in the borehole.

6.4 *Compatibility of Equipment:*

6.4.1 Whenever possible, core barrels and drill rods should be selected from the same letter-size designation to ensure maximum efficiency. See Tables 1 and 3.

6.4.2 Never use a combination of pump, drill rod, and core barrel that yields a clear-water up-hole velocity of less than 120 ft/min.

6.4.3 Never use a combination of air compressor, drill rod, and core barrel that yields a clear-air up-hole velocity of less than 3000 ft/min.

7. Boring Log

7.1 The boring log shall include the following:

7.1.1 Project identification, boring number, location, date boring began, date boring completed, and driller's name.

7.1.2 Elevation of the ground surface.

7.1.3 Elevation of or depth to ground water and raising or lowering of level including the dates and the times measured.

7.1.4 Elevations or depths at which drilling fluid return was lost.

7.1.5 Size, type, and design of core barrel used. Size, type, and set of core bit and reaming shell used. Size, type, and length of all casing used. Description of any movements of the casing.

7.1.6 Length of each core run and the length or percentage, or both, of the core recovered.

7.1.7 Geologist's or engineer's description of the formation recovered in each run.

7.1.8 Driller's description, if no engineer or geologist is present, of the formation recovered in each run.

7.1.9 Subsurface structure description, including dip of strata and jointing, cavities, fissures, and any other observations made by the geologist or engineer that could yield information regarding the formation.

7.1.10 Depth, thickness, and apparent nature of the filling of each cavity or soft seam encountered, including opinions gained from the feel or appearance of the inside of the inner tube when core is lost. Record opinions as such.

7.1.11 Any change in the character of the drilling fluid or drilling fluid return.

7.1.12 Tidal and current information when the borehole is sufficiently close to a body of water to be affected.

7.1.13 Drilling time in minutes per foot and bit pressure in pound-force per square inch gage when applicable.

7.1.14 Notations of character of drilling, that is, soft, slow, easy, smooth, etc.

8. Precision and Bias

8.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

NOTE 2—Inclusion of the following tables and use of letter symbols in the foregoing text is not intended to limit the practice to use of DCDMA tools. The table and text references are included as a convenience to the user since the vast majority of tools in use do meet DCDMA dimensional standards. Similar equipment of approximately equal size on the metric standard system is acceptable unless otherwise stipulated by the engineer or geologist.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

APPENDIX B
JUSTIFICATION CRITERIA FOR USE OF PVC WELL CASING AND SCREEN MATERIAL

The following is USEPA Region IV minimum seven point information requirements to justify the use of PVC as an alternate casing material for groundwater monitoring wells. If requested, justification of the use of PVC should be developed by addressing each of the following items:

1. **The DQOs for the groundwater samples to be collected.**

   Level IV DQOs will be used for analyses of groundwater samples collected during this project. Analytical parameters have been selected to characterize the presence or absence of contamination and to assess any associated risks to human health or the environment.

2. **The organic compound concerns.**

   There are two primary concerns regarding sample bias associated with use of PVC well casing under these conditions. One is that organic contaminants will leach from the PVC well casing. The other is that organic contaminants that may be present in the groundwater would adsorb onto the PVC. Either of these could result in biased analytical results.

3. **The anticipated residence time of the sample in the well and the aquifer's productivity.**

   It is important to note that all stagnant water from inside the well casing is purged immediately before sample collection. The time required to do this is expected to be much less than that required for groundwater sampling bias phenomena (adsorbing/leaching) to develop.

   Samples collected immediately after purging (i.e., "fresh" from the aquifer).

   Aquifer productivity: Subsurface soil samples are mostly fine sand.

   The wells should recharge (enough to sample) before any sorbing/leaching of organics can occur.

4. **The reasons for not using other casing materials.**

   Costs associated with use of stainless steel and teflon casing materials are prohibitive. PVC strength will be sufficient for this investigation. Existing groundwater quality data indicate that leaching/sorbing of organic materials from/onto the PVC will not be extensive enough to bias future groundwater analysis. PVC is lighter and more flexible than stainless steel.

5. **Literature on the adsorption characteristics of the compounds and elements of interest.**

   The following was originally presented in National Water Well Association (NWWA, 1989):

   Miller (1982) conducted a study to determine if PVC exhibited any tendency to sorb potential contaminants from solution. Trichloroethene and 1,1,2-trichloroethane did not sorb to PVC. Reynolds and Gillham (1985) found that 1,1,2,2-tetrachloroethane could sorb to PVC. The sorption was slow enough that groundwater sampling bias would not be significant if well development (purging the well of stagnant water) and sampling were to take place in the same day. No data was available for the other organic compounds listed in Item #2.

6. **Whether the wall thickness of the PVC casing would require a larger annular space when compared to other well construction materials.**

   It will not. The borehole will be of sufficient diameter for installation of the 2" PVC casing and screen.

7. **The type of PVC to be used and, if available, the manufacturers specifications, and an assurance that the PVC to be used does not leach, mask, react or otherwise interfere with the contaminants being monitored within the limits of the DQOs.**

   Baker will request the appropriate manufacturers specifications and assurances regarding this requirement. This material will be supplied to Baker by the drilling subcontractor.

References for Appendix B:

National Water Well Association, 1989, Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, Dublin, Ohio, 398 pp.

Miller, G.D., 1982, Uptake of lead, chromium and trace level volatile organics exposed to synthetic well casings. Proceedings of the Second National Symposium on Aquifer Restoration and Ground-Water Monitoring, National Water Well Association, Dublin, Ohio, pp. 236-245.

Reynolds, G.W. and Robert W. Gillham, 1985, Absorption of halogenated organic compounds by polymer materials commonly used in ground-water monitors. Proceedings of the Second Canadian/American Conference on Hydrogeology, National Water Well Association, Dublin, Ohio, pp. 125-132.

APPENDIX C
GROUNDWATER SAMPLE ACQUISITION

GROUNDWATER SAMPLE ACQUISITION
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GROUNDWATER SAMPLE ACQUISITION

1.0 PURPOSE

The purpose of this guideline is to provide general reference information on the sampling of groundwater wells. The methods and equipment described are for the collection of water samples from the saturated zone of the subsurface.

2.0 SCOPE

This guideline provides information on proper sampling equipment and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific groundwater sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and the Project Manager. The sampling personnel are responsible for the proper acquisition of groundwater samples.

5.0 PROCEDURES

To be useful and accurate, a groundwater sample must be representative of the particular zone being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of testing in order to minimize any changes in water quality parameters.

The groundwater sampling program should be developed with reference to ASTM D4448-85A, Standard Guide for Sampling Groundwater Monitoring Wells (Attachment A). This reference is not intended as a monitoring plan or procedure for a specific application, but rather is a review of methods. Specific methods shall be stated in the Sampling and Analysis Plan (SAP).

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain largely isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach should be followed during sample withdrawal:

1. All monitoring wells shall be pumped or bailed prior to withdrawing a sample. Evacuation of three to five volumes is recommended for a representative sample.

2. Wells that can be pumped or bailed to dryness with the sampling equipment being used, shall be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid and time allows, evacuation of at least three well volumes of water is preferred; otherwise, a sample will be taken when enough water is available to fill the sample containers.

Stratification of contaminants may exist in the aquifer formation. This is from concentration gradients due to dispersion and diffusion processes in a homogeneous layer, and from separation of flow streams by physical division (for example, around clay lenses) or by contrasts in permeability (for example, between a layer of silty, fine sand and a layer of medium sand).

Purging rates and volumes for non-production wells during sampling development should be moderate; pumping rates for production wells should be maintained at the rate normal for that well. Excessive pumping can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column at that point, thus result in the collection of a non-representative sample. Water produced during purging shall be collected, stored or treated and discharged as allowed. Disposition of purge water is usually site-specific and must be addressed in the Sampling and Analysis Plan.

5.1 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with EPA regulations for the appropriate contaminants and to the specific Quality Assurance Project Plan.

The following list is an example of the type of equipment that generally must be on hand when sampling groundwater wells:

1. Sample packaging and shipping equipment: Coolers for sample shipping and cooling, chemical preservatives, and appropriate packing cartons and filler, labels and chain-of-custody documents.

2. Field tools and instrumentation: PID; Thermometer; pH meter; specific conductivity meter; appropriate keys (for locked wells) or bolt-cutter; tape measure; plastic sheeting; water-level indicator; calibrated buckets and, where applicable, flow meter.

3. Pumps

   a. Shallow-well pumps: Centrifugal, Packer Pumps, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing), as applicable.

   b. Deep-well pumps: Submersible pump and electrical power generating unit, bladder pump with compressed air source, or air-lift apparatus, as applicable.

4. Tubing: Sample tubing such as teflon, polyethylene, polypropylene, or PVC. Tubing type shall be selected based on specific site requirements and must be chemically inert to the groundwater being sampled.

5. Other Sampling Equipment: Bailers, Packer Pumps, teflon-coated wire, stainless steel single strand wire, and polypropylene monofilament line (not acceptable in EPA Region I) with tripod-pulley assembly (if necessary). Bailers shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.

6. Pails: Plastic, graduated.

7. Decontamination equipment and materials: discussed in SOP F501 and F502.

Ideally, sample withdrawal equipment should be completely inert, economical, easily cleaned, sterilized, and reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well purging and sample collection.

5.2 Calculations of Well Volume for Purging

The volume of the cylinder of water in a well is given by:

Where: V =volume of standing water in well (in cubic feet)

r=well radius (in feet)
h=standing water in well (in feet)

To insure that the proper volume of water has been removed from the well prior to sampling, it is first necessary to determine the volume of standing water in the well pipe or casing. The volume can be easily calculated by the following method. Calculations shall be entered in the field logbook:

1. Obtain all available information on well construction (location, casing, screens, etc.).

2. Determine well or casing diameter (D).

3. Measure and record static water level (DW-depth to water below ground level or top of casing reference point), using one of the methods described in Section 5.1 of SOP F202.

4. Determine the depth of the well (TD) to the nearest 0.01-foot by sounding using a clean, decontaminated weighted tape measure, referenced to the top of PVC casing or ground surface.

5. Calculate number of linear feet of static water (total well depth minus the depth to static water level).

6. Calculate the volume of water in the casing:

$$V_{gal} = V_W \times 7.48 \text{ gallons/ft}^3$$

$$V_{purge} = Vgal\ (\#\ \text{Well Vol})$$

Where:

V_W	= Volume of water standing in well in cubic feet (i.e., one well volume)
π	= pi, 3.14
r	= Well radius in feet
TD	= Total depth of well in feet (below ground surface or top of casing)
DW	= Depth to water in feet (below ground surface or top of casing)
V_{gal}	= Volume of water in well in gallons
V_{purge}	= Volume of water to be purged from well in gallons
# Well Vol.=	Number of well volumes of water to be purged from the well (typically three to five)

7. Determine the minimum number of gallons to be evacuated before sampling. (Note: V_{purge} should be rounded to the next highest whole gallon. For example, 7.2 gallons should be rounded to 8 gallons.)

Table 5-1 lists gallons and cubic feet of water per standing foot of water for a variety of well diameters.

TABLE 5-1
WELL VOLUMES

Diameter of Casing or Hole (in.)	Gallons per Foot of Depth	Cubic Feet per Foot of Depth
1	0.041	0.0055
2	0.163	0.0218
4	0.653	0.0873
6	1.469	0.1963
8	2.611	0.3491
10	4.080	0.5454

5.3 Evacuation of Static Water (Purging)

The amount of purging a well should receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer.

For defining a contaminant plume, a representative sample of only a small volume of the aquifer is required. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce significant groundwater flow from a wide area. Generally, three to five well volumes are considered effective for purging a well.

An alternative method of purging a well, and one accepted in EPA Regions I and IV, is to purge a well continuously (usually using a low volume, low flow pump) while monitoring specific conductance, pH, and water temperature until the values stabilize. The well is considered properly purged when the values have stabilized.

If a well is dewatered before the required volume is purged, the sample should be collected from the well once as a sufficient volume of water has entered the well. In order to avoid stagnation, the well should not be allowed to fully recharge before the sample is collected. The field parameters (pH, conductance, and temperature) should be recorded when the well was dewatered.

The Project Manager shall define the objectives of the groundwater sampling program in the Sampling and Analysis Plan, and provide appropriate criteria and guidance to the sampling personnel on the proper methods and volumes of well purging.

5.3.1 Evacuation Devices

The following discussion is limited to those devices which are commonly used at hazardous waste sites. Note that all of these techniques involve equipment which is portable and readily available.

Bailers - Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line (e.g., Teflon-coated) is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Inexpensive.
- Minimal outgassing of volatile organics while the sample is in the bailer.
- Relatively easy to decontaminate and use.

Limitations on the use of bailers include the following:

- Limited volume of sample.
- Time consuming to remove stagnant water using a bailer.
- Collection and transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.
- Unable to collect depth-discrete sample.

Suction Pumps - There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump (generally not suitable for well purging) that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 10 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps will cause significant loss of dissolved gases, including volatile organics. In addition, the complex internal components of these pumps may be difficult to decontaminate.

Gas-Lift Samples - This group of samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Gas lift pumps are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation or loss of volatile organics. An inert gas such as nitrogen is generally used as a gas source.

Submersible Pumps - Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed air or electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for two-inch diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- Potentially low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components is difficult and time-consuming.

5.4 Sampling

The sampling approach consisting of the following, should be developed as part of the Sampling and Analysis Plan prior to the field work:

1. Background and objectives of sampling.

2. Brief description of area and waste characterization.

3. Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).

4. Sampling equipment to be used.

5. Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these should be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.

6. Sample preservation requirements.

7. Schedule.

8. List of team members.

9. Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

5.4.1 Sampling Methods

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNu or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.

2. When proper respiratory protection has been donned, measure the total depth and water level (with decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well according to Section 5.2 of this SOP.

3. Lower purging equipment or intake into the well to a distance just below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (e.g., DOT-approved 55-gallon drum).

4. Measure the rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters. Record the method of discharge measurement.

5. Observe peristaltic pump intake for degassing "bubbles" and all pump discharge lines. If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. The preferred method for collecting volatile organic samples and the accepted method by EPA Regions I through IV is with a bailer.

6. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.

7. Record measurements of specific conductance, temperature, and pH during purging to ensure that the groundwater level has stabilized. Generally, these measurements are made after the removal of three, four, and five well volumes.

8. If sampling using a pump, lower the pump intake to midscreen or the middle of the open section in uncased wells and collect the sample. If sampling with a bailer, lower the bailer to the sampling level before filling (this requires use of other than a "bucket-type" bailer). Purged water should be collected in a designated container and disposed of in an acceptable manner.

9. (For pump and packer assembly only). Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screened interval or unscreened open section volume below the packer before sampling. Packers should always be tested in a casing section above ground to determine proper inflation pressures for good sealing.

10. In the event that groundwater recovery time is very slow (e.g., 24 hours), sample collection can be delayed until the following day. However, it is preferred that such a well be bailed early in the morning so that sufficient volume of water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record in the logbook.

11. Add preservative if required. Label, tag, and number the sample bottle(s).

12. Volatile organics septum vials (40 ml) should be completely filled to prevent volatilization and extreme caution should be exercised when filling a vial to avoid turbulence which could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a "convex meniscus." The cap is then applied and some overflow is lost, but air space in the bottle is eliminated. After capping, turn the bottle over and tap it to check for bubbles; if any are present, repeat the procedure. If the second attempt still produces air bubbles, note on Chain-of-Custody form and in field notebook and submit sample to the laboratory.

    Fill the remaining sample containers in order of decreasing volatilability (semi-volatiles next, then pesticides, PCBs, inorganics, etc.).

13. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.

14. Pack the samples for shipping. Attach custody seals to the shipping container. Make sure that Chain-of-Custody forms and Sample Analysis Request forms are properly filled out and enclosed or attached.

15. Decontaminate all equipment.

5.4.2 Sample Containers

For most samples and analytical parameters, either glass or plastic containers are satisfactory. SOP F301 describes the required sampling containers for various analytes at various concentrations. Container requirements shall follow those given in NEESA 20.2 047B.

5.4.3 Preservation of Samples and Sample Volume Requirements

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. Sample volume and preservation requirements shall follow those given in NEESA 20.2-047B.

5.4.4 Field Filtration

In general, preparation and preservation of water samples for dissolved inorganics involve some form of filtration. All filtration must occur in the field immediately upon collection. The recommended method is through the use of a disposable in-line filtration module (0.45 micron filter) utilizing the pressure provided by the upstream pumping device for its operation.

In Region I, all inorganics are to be collected and preserved in the filtered form, including metals. In Region II, metals samples are to be analyzed as "total metals" and preserved unfiltered. In Regions III and IV, samples collected for metals analysis are also to be unfiltered. However, if metals analysis of groundwater is required, then both an unfiltered and filtered sample are to be collected, regardless of regulatory requirements. Filtration and preservation are to occur immediately in the field with the sample aliquot passing through a 0.45 micron filter. Samples for organic analyses shall never be filtered. Filters must be prerinsed with organic-free, deionized water.

5.4.5 Handling and Transporting Samples

After collection, samples should be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it should be double-bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged, and thus possibly become cross-contaminated. All sample containers should be enclosed in plastic bags or cans to prevent cross-contamination. Samples should be secured in the ice chest to prevent movement of sample containers and possible breakage.

5.4.6 Sample Holding Times

Holding times (i.e., allowed time between sample collection and analysis) for routine samples are given in NEESA 20.2-047B.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Sample source and source description.
- Field observations and measurements (appearance; volatile screening; field chemistry; sampling method; volume of water purged prior to sampling; number of well volumes purged).
- Sample disposition (preservatives added; lab sent to; date and time).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. Chain-of-custody forms (and sample analysis request forms) are considered quality assurance records.

7.0 REFERENCES

American Society of Testing and Materials. 1987. Standard Guide for Sampling Groundwater Monitoring Wells. Method D4448-85A, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

ATTACHMENT A

ASTM D4448-85A

STANDARD GUIDE FOR SAMPLING GROUNDWATER MONITORING WELLS

Designation: D 4448 – 85a

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Guide for Sampling Groundwater Monitoring Wells[1]

This standard is issued under the fixed designation D 4448; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers procedures for obtaining valid, representative samples from groundwater monitoring wells. The scope is limited to sampling and "in the field" preservation and does not include well location, depth, well development, design and construction, screening, or analytical procedures.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for sampling groundwater quality monitoring wells and is not intended to serve as a groundwater monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Guide

2.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to, the design and construction of the well, rate of groundwater flow, and the chemical species of interest. Sampling procedures will be different if analyzing for trace organics, volatiles, oxidizable species, or trace metals is needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well flushing, sample withdrawal, and field preparation of samples.

2.2 Monitoring wells must be flushed prior to sampling so that the groundwater is sampled, not the stagnant water in the well casing. If the well casing can be emptied, this may be done although it may be necessary to avoid oxygen contact with the groundwater. If the well cannot be emptied, procedures must be established to demonstrate that the sample represents groundwater. Monitoring an indicative parameter such as pH during flushing is desirable if such a parameter can be identified.

2.3 The types of species that are to be monitored as well as the concentration levels are prime factors for selecting sampling devices (**1, 2**).[2] The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analyte chemically in any way.

2.4 The method of sample withdrawal can vary with the parameters of interest. The ideal sampling scheme would employ a completely inert material, would not subject the sample to negative pressure and only moderate positive pressure, would not expose the sample to the atmosphere, or preferably, any other gaseous atmosphere before conveying it to the sample container or flow cell for on-site analysis.

2.5 The degree and type of effort and care that goes into a sampling program is always dependent on the chemical species of interest and the concentration levels of interest. As the concentration level of the chemical species of analytical interest decreases, the work and precautions necessary for sampling are increased. Therefore, the sampling objective must clearly be defined ahead of time. For example, to prepare equipment for sampling for mg/L (ppm) levels of Total Organic Carbon (TOC) in water is about an order of magnitude easier than preparing to sample for μg/L (ppb) levels of a trace organic like benzene. The specific precautions to be taken in preparing to sample for trace organics are different from those to be taken in sampling for trace metals. No final Environmental Protection Agency (EPA) protocol is available for sampling of trace organics. A short guidance manual, (**3**) and an EPA document (**4**) concerning monitoring well sampling, including considerations for trace organics are available.

2.6 Care must be taken not to cross contaminate samples or monitoring wells with sampling or pumping devices or materials. All samples, sampling devices, and containers must be protected from the environment when not in use. Water level measurements should be made before the well is flushed. Oxidation-reduction potential, pH, dissolved oxygen, and temperature measurements and filtration should all be performed on the sample in the field, if possible. All but temperature measurement must be done prior to any significant atmospheric exposure, if possible.

2.7 The sampling procedures must be well planned and all sample containers must be prepared and labeled prior to going to the field.

3. Significance and Use

3.1 The quality of groundwater has become an issue of national concern. Groundwater monitoring wells are one of

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[1] This guide is under the jurisdiction of ASTM Committee D-34 on Waste Disposal and is the direct responsibility of Subcommittee D34.01 on Sampling and Monitoring.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this guide.

TABLE 1 Typical Container and Preservation Requirements for a Ground-Water Monitoring Program

Sample and Measurement	Volume Required (mL)	Container P—Polyethylene G—Glass	Preservative	Maximum Holding Time
Metals As/Ba/Cd/Cr/Fe Pb/Se/ Ag/Mn/Na	1000–2000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Mercury	200–300	P/G (special acid cleaning)	high purity nitric acid to pH <2 +0.05 % $K_2Cr_2O_7$	28 days
Radioactivity alpha/beta/radium	4000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Phenolics	500–1000	G	cool, 4°C H_2SO_4 to pH <2	28 days
Miscellaneous	1000–2000	P	cool, 4°C	28 days
Fluoride	300–500	P		28 days
Chloride	50–200	P/G		28 days
Sulfate	100–500	P/G		48 hours
Nitrate	100–250	P/G		6 h
Coliform	100	P/G		on site/24 h
Conductivity	100	P/G		on site/6 h
pH	100	P/G		48 h
Turbidity	100	P/G		
Total organic carbon (TOC)	25–100	P/G	cool, 4°C or cool, 4°C HCl or H_2SO_4 to pH <2	24 h 28 days
Pesticides, herbicides and total organic halogen (TOX)	1000–4000	G/TFE-fluorocarbon lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Extractable organics	1000–2000	G/TFE-fluorocarbon-lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Organic purgeables acrolein/acrylonitrile	25–120	G/vial TFE-fluorocarbon-lined septum	cool, 4°C	14 days 3 days

the more important tools for evaluating the quality of groundwater, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

3.2 The goal in sampling groundwater monitoring wells is to obtain samples that are truly representative of the aquifer or groundwater in question. This guide discusses the advantages and disadvantages of various well flushing, sample withdrawal, and sample preservation techniques. It reviews the parameters that need to be considered in developing a valid sampling plan.

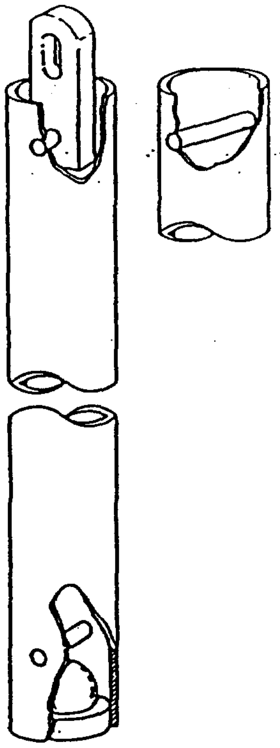
4. Well Flushing (Purging)

4.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may cause water quality alterations and even if it is unchanged from the time it entered the well, the stored water may not be representative of formation water at the time of sampling, or both. Because the representativeness of stored water is questionable, it should be excluded from samples collected from a monitoring well.

4.2 The surest way of accomplishing this objective is to remove all stored water from the casing prior to sampling. Research with a tracer in a full scale model 2 in. PVC well (5) indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stored water in the casing. The volume of the well may be calculated to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out.

4.3 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stored water (5, 6, 7). Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stored water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer will flow into the purged zone through the well's gravel/sand pack.

4.4 In low yielding wells, the only practical way to remove all standing water may be to empty the casing. Since it is not always possible to remove all water, it may be advisable to let the well recover (refill) and empty it again at least once. If introduction of oxygen into the aquifer may be of concern, it would be best not to uncover the screen when performing the above procedures. The main disadvantage of methods designed to remove all the stored water is that large volumes may need to be pumped in certain instances. The main advantage is that the potential for contamination of sample with stored water is minimized.



NOTE—Taken from Ref (15).

FIG. 1 Single Check Valve Bailer

4.5 Another approach to well flushing is to monitor one or more indicator parameters such as pH, temperature, or conductivity and consider the well to be flushed when the indicator(s) no longer change. The advantage of this method is that pumping can be done from any location within the casing and the volume of stored water present has no direct bearing on the volume of water that must be pumped. Obviously, in a low yielding well, the well may be emptied before the parameters stabilize. A disadvantage of this approach is that there is no assurance in all situations that the stabilized parameters represent formation water. If significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. Also, a suitable indicator parameter and means of continuously measuring it in the field must be available.

4.6 Gibb (4, 8) has described a time-drawdown approach using a knowledge of the well hydraulics to predict the percentage of stored water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are taken when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect in the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stored water due to effects other than drawdown (for example density differences) is not accounted for in this approach.

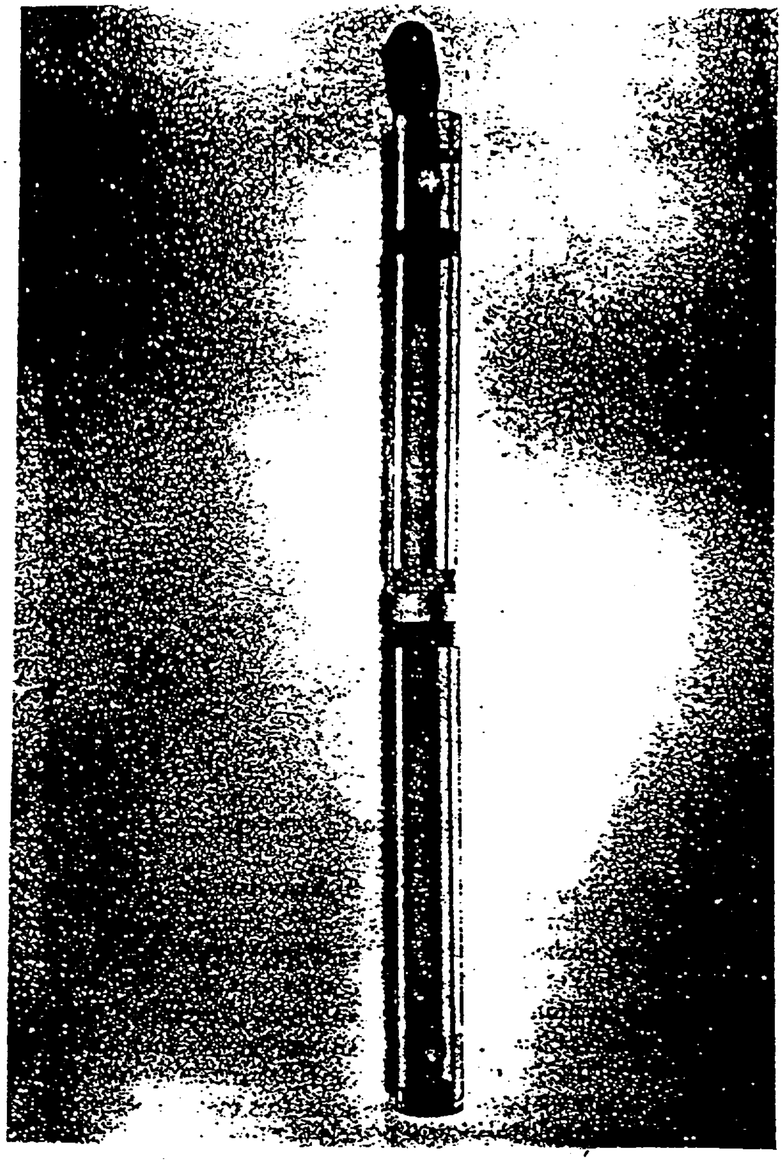
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

5. Materials and Manufacture

5.1 The choice of materials used in the construction of sampling devices should be based upon a knowledge of what compounds may be present in the sampling environment and how the sample materials may interact via leaching, adsorption, or catalysis. In some situations, PVC or some other plastic may be sufficient. In others, an all glass apparatus may be necessary.

5.2 Most analytical protocols suggest that the devices used in sampling and storing samples for trace organics analysis (μg/L levels) must be constructed of glass or TFE-fluorocarbon resin, or both. One suggestion advanced by the EPA is that the monitoring well be constructed so that only TFE-fluorocarbon tubing be used in that portion of the sampling well that extends from a few feet above the water table to the bottom of the borehole. (3, 5) Although this type of well casing is now commercially available, PVC well casings are currently the most popular. If adhesives are avoided, PVC well casings are acceptable in many cases although their use may still lead to some problems if trace organics are of concern. At present, the type of background presented by PVC and interactions occurring between PVC and groundwater are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC casing. (9)

5.3 Since the most significant problem encountered in trace organics sampling, results from the use of PVC adhesives in monitoring well construction, threaded joints might avoid the problem (3, 5). Milligram per litre (parts per million) levels of compounds such as tetrahydrofuran, methyl-ethyl-ketone, and toluene are found to leach into



NOTE—Taken from Ref (17).

FIG. 2 Acrylic Point Source Bailer

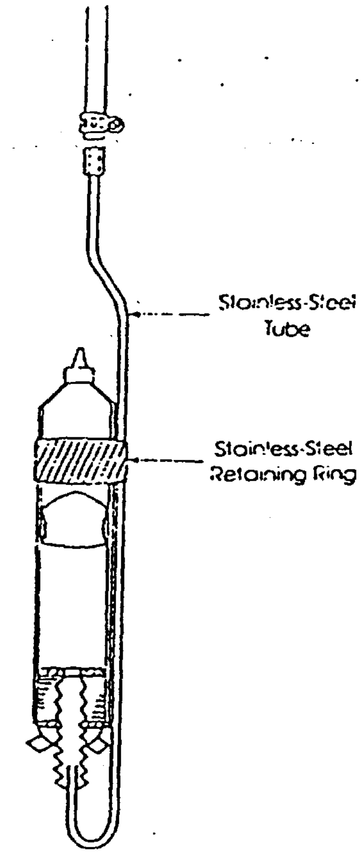
groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (8, 10) are often found in water samples at ppb levels; the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, except to say that they may be leached from plastic pipes, sampling devices, and containers.

5.4 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices and well casings. Molded parts are exposed to high temperature during fabrication which destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point.

5.5 Extruded tubing of TFE-fluorocarbon for sampling may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once removed by flushing, should not affect the sample. TFE-fluorocarbon FEP and TFE-fluorocarbon PFA resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

5.6 Louneman, et al. (11) alludes to problems caused by a lubricating oil used during TFE-fluorocarbon tubing extrusion. This reference also presents evidence that a fluorinated ethylene-propylene copolymer adsorbed acetone to a degree that later caused contamination of a gas sample.

5.7 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is probably among the best choices though it is not inconceivable it could adsorb some constituents as well as release other contaminants (for example, Na, silicate, and Fe). Of cou[illegible] glass sampling equipment must be handled carefully in [illegible] field. Stainless steel is strongly and easily machined to



NOTE—Taken from Ref (21).

FIG. 3 Schematic of the Inverted Syringe Sampler

fabricate equipment. Unfortunately, it is not totally immune to corrosion that could release metallic contaminants. Stainless steel contains various alloying metals, some of these (for example Ni) are commonly used as catalysts for various reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on groundwater quality and the constituents of interest.

5.8 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be nonplastic (unless TFE-fluorocarbon), cleanable of trace organics, and must be cleaned between each monitoring well use in order to avoid cross-contamination of wells and samples. The only way to ensure that the device is indeed "clean" and acceptable is to analyze laboratory water blanks and field water blanks that have been soaked in and passed through the sampling device to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples which represent the field background (if possible), the sampling equipment background, and the laboratory background.

5.9 Additional samples are often taken in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chemical Society's committee on environmental improvement I published guidelines for data acquisition and data evaluati which should be useful in such environmental evaluatic (10, 12).

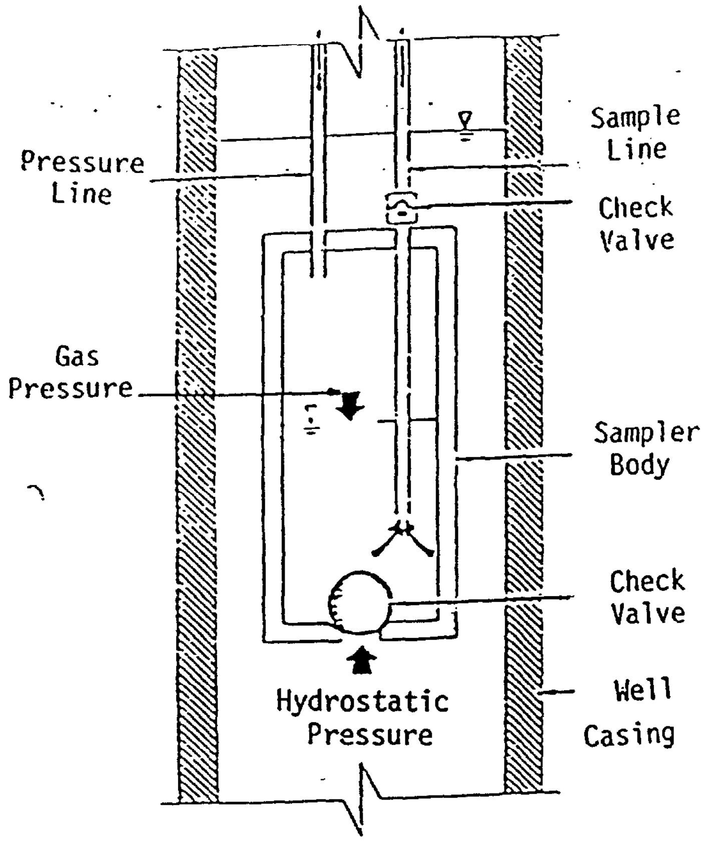
6. Sampling Equipment

6.1 There is a fairly large choice of equipment preser available for groundwater sampling from single scree wells and well clusters. The sampling devices can be cat rized into the following eight basic types.

6.1.1 *Down-Hole Collection Devices:*

6.1.1.1 Bailers, messenger bailers, or thief samplers (14) are examples of down-hole devices that probably pro valid samples once the well has been flushed. They are practical for removal of large volumes of water. T devices can be constructed in various shapes and sizes fr variety of materials. They do not subject the sampl pressure extremes.

6.1.1.2 Bailers do expose part of the sample to atmosphere during withdrawal. Bailers used for samplii volatile organic compounds should have a sample co draft valve in or near the bottom of the sampler allo withdrawal of a sample from the well below the exp surface of the water or the first few inches of the sa should be discarded. Suspension lines for bailers and samplers should be kept off the ground and free of contaminating materials that could be carried into the Down-hole devices are not very practical for use in



NOTE—Taken from Ref (5).

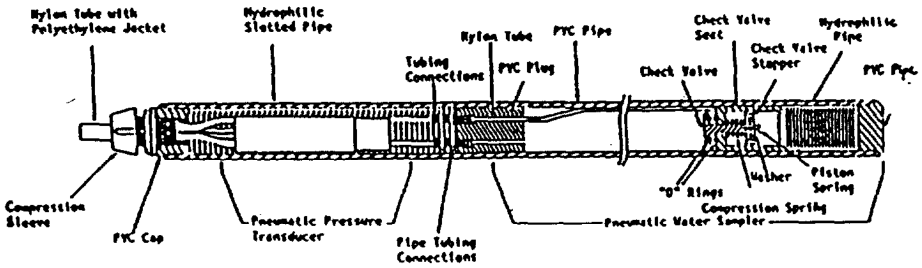
FIG. 4 The Principal of Gas Displacement Pumping

wells. However, potential sample oxidation during transfer of the sample into a collection vessel and time constraints for lowering and retrieval for deep sampling are the primary disadvantages.

6.1.1.3 Three down-hole devices are the single and double check valve bailers and thief samplers. A schematic of a single check valve unit is illustrated in Fig. 1. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to increase the sampling volume. TFE-fluorocarbon or PVC are the most common materials used for construction (15).

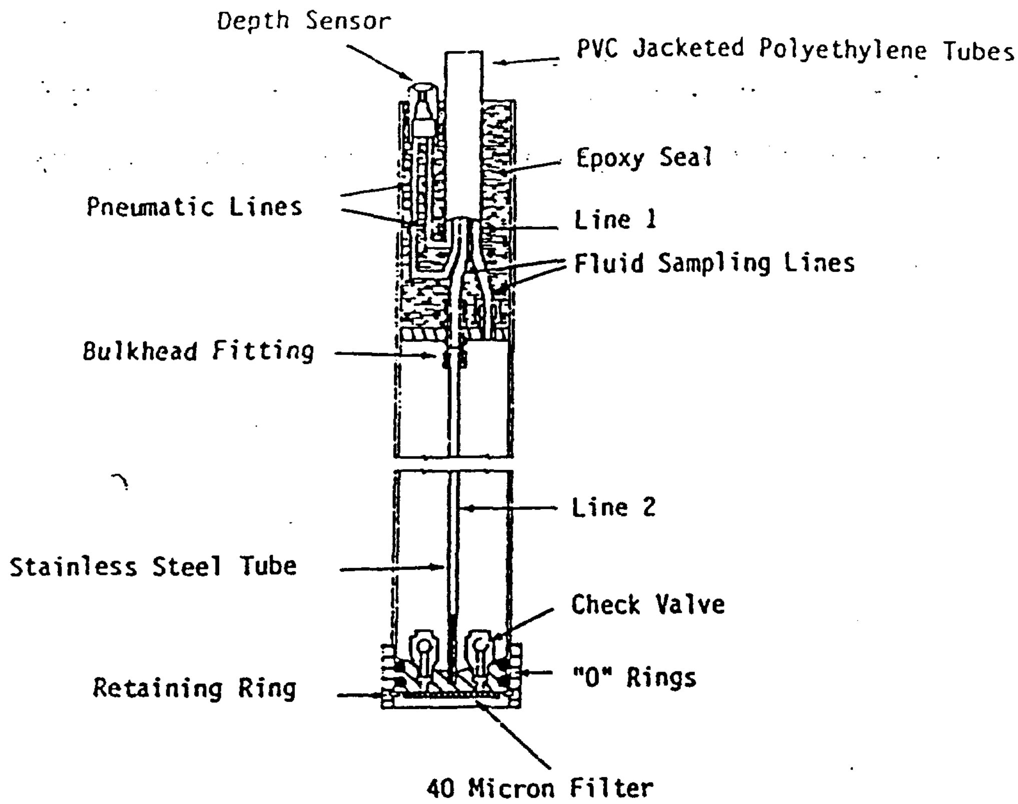
6.1.1.4 In operation, the single check valve bailer is lowered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without any samples loss through the check valve. A similar technique involves lowering a sealed sample container within a weighted bottle into the well. The stopper is then pulled from the bottle via a line and the entire assembly is retrieved upon filling of the container (14, 16).

6.1.1.5 A double check valve bailer allows point source sampling at a specific depth (15, 17). An example is shown in Fig. 2. In this double check valve design, water flows through the sample chamber as the unit is lowered. A venturi tapered inlet and outlet ensures that water passes freely through the



NOTE—Taken from Ref (41).

FIG. 5 Pneumatic Water Sampler With Internal Transducer



NOTE—Taken from Ref (42).

FIG. 6 Pneumatic Sampler With Externally Mounted Transducer

unit. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation. The acrylic model in Fig. 2 is threaded at the midsection allowing the addition of threaded casing to increase the sampling volume.

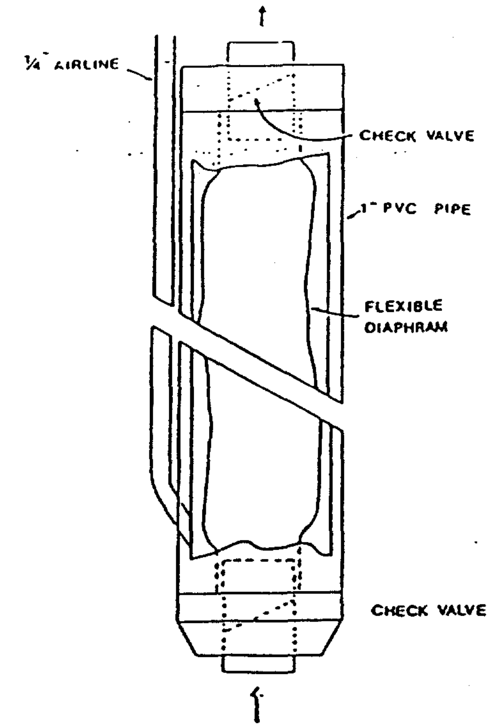
6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber **(18)**. Foerst, Kemmerer, and Bacon samplers are of this variety **(14, 17, 19)**. A simple and inexpensive pneumatic sampler was recently described by Gillham **(20)**. The device (Fig. 3) consists of a disposable 50 mL plastic syringe modified by sawing off the plunger and the finger grips. The syringe is then attached to a gas-line by means of a rubber stopper assembly. The gas-line extends to the surface, and is used to drive the stem-less plunger, and to raise and lower the syringe into the hole. When the gas-line is pressurized, the rubber plunger is held at the tip of the syringe. The sampler is then lowered into the installation, and when the desired depth is reached, the pressure in the gas-line is reduced to atmospheric (or slightly less) and water enters the syringe. The sampler is then retrieved from the installation and the syringe detached from the gas-line. After the tip is sealed, the syringe is used as a short-term storage container. A number of thief or messenger devices are available in various materials and shapes.

6.1.2 *Suction Lift Pumps:*

6.1.2.1 Three types of suction lift pumps are the direct line, centrifugal, and peristaltic. A major disadvantage of any suction pump is that it is limited in its ability to raise water by the head available from atmospheric pressure. Thus, if the surface of the water is more than about 25 ft below the pump, water may not be withdrawn. The theoretical suction limit is about 34 ft, but most suction pumps are capable of maintaining a water lift of only 25 ft or less.

6.1.2.2 Many suction pumps draw the water through some sort of volute in which impellers, pistons, or other devices operate to induce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of common materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or even cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clean between uses. Such pumps are acceptable for purging of wells, but should not generally be used for sampling.

6.1.2.3 One exception to the above statements is a peristaltic pump. A peristaltic pump is a self-priming, low volume suction pump which consists of a rotor with ball bearing rollers **(21)**. Flexible tubing is inserted around the pump rotor and squeezed by heads as they revolve in a circular pattern around the rotor. One end of the tubing is placed into the well while the other end can be connected



NOTE—Taken from Ref (4).

FIG. 7 Bladder Pump

directly to a receiving vessel. As the rotor moves, a reduced pressure is created in the well tubing and an increased pressure (<40 psi) on the tube leaving the rotor head. A drive shaft connected to the rotor head can be extended so that multiple rotor heads can be attached to a single drive shaft.

6.1.2.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may still be degassed (cavitation is unlikely) but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pumphead itself. A section of silicone tubing is commonly used within the peristaltic pumphead, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement (22) recommends using medical grade silicone tubing for organic sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Medical grade silicone tube is, however, limited to use over a restricted range of ambient temperatures. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton[3] for use with their pumps. Gibb (1, 8) found little difference between samples withdrawn by a peristaltic pump and those taken by a bailer.

6.1.2.5 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two way stopper bottle and a hand held or mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism (5, 23, 24).

6.1.2.6 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement (23, 25, 26).

6.1.2.7 Suction pump approaches offer a simple sample retrieval method for shallow monitoring. The direct line method is extremely portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 Lpm (5 to 40 gpm) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps. The withdrawal rate of peristaltic pumps can be carefully regulated by adjustment of the rotor head revolution.

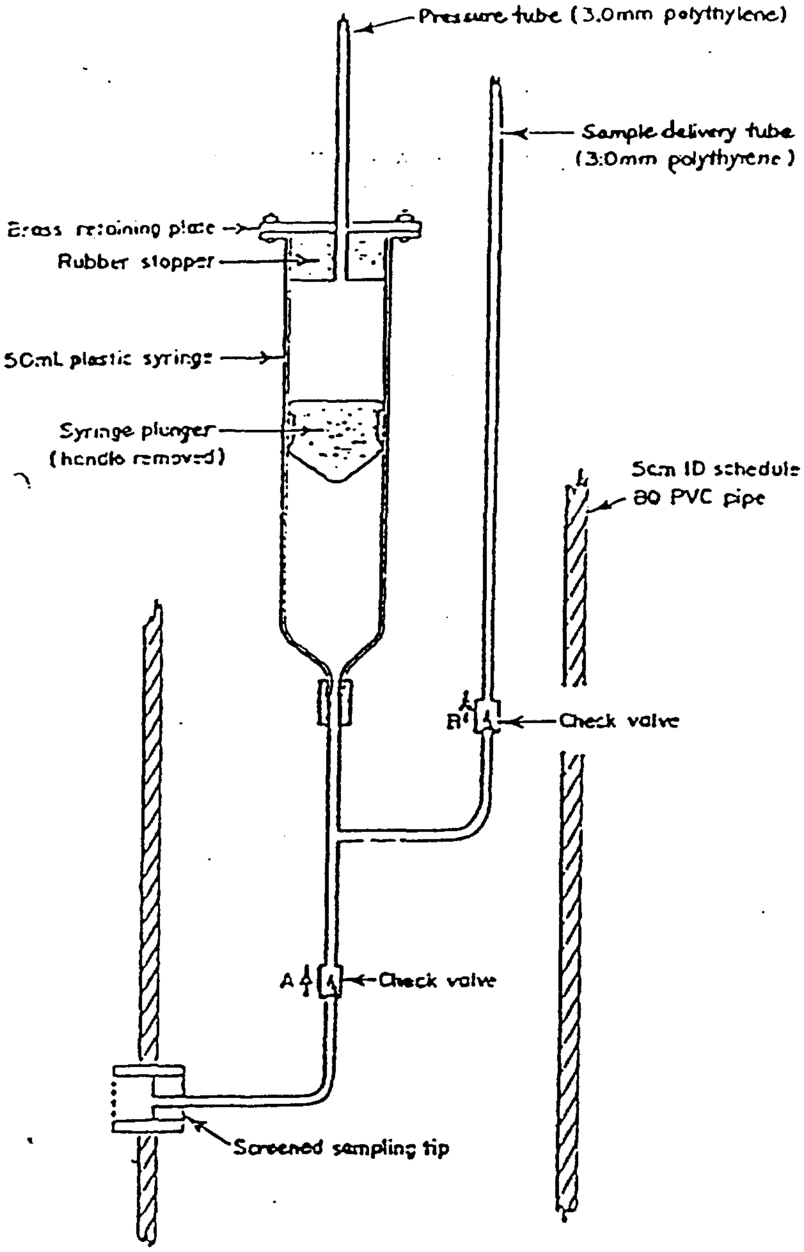
6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE flourocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

6.1.3 *Electric Submersible Pumps:*

6.1.3.1 A submersible pump consists of a sealed electric motor that powers a piston or helical single thread worm at a high rpm. Water is brought to the surface through an access tube. Such pumps have been used in the water well industry for years and many designs exist (5, 26).

6.1.3.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction

[3] Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.



NOTE—Taken from Ref (48).

FIG. 8 Positive Displacement Syringe Pump

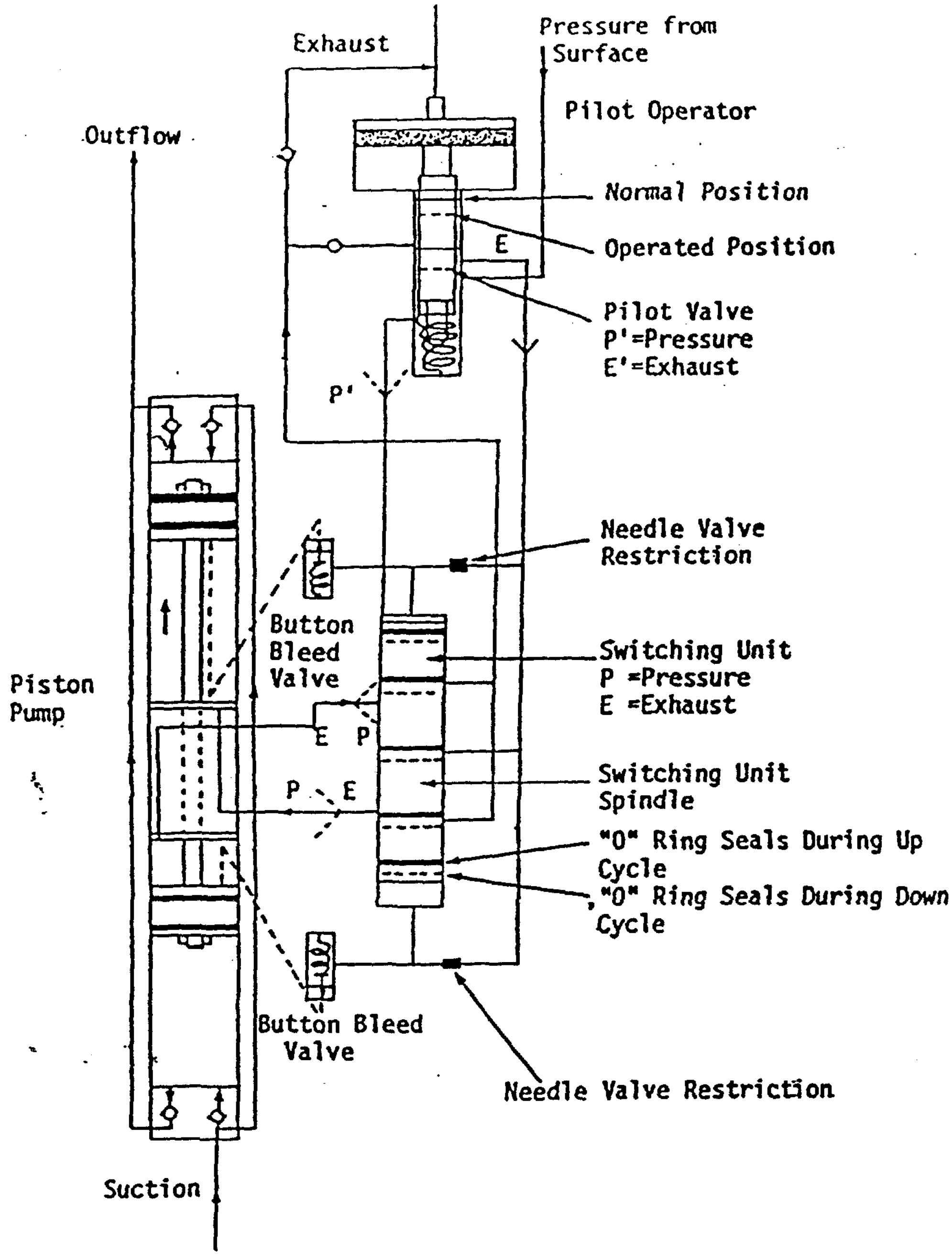
lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) depending upon the depth of the pump (28).

6.1.3.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the collection tube during transport. The possibility of introducing trace metals into the sample from pump materials also exists. Steam cleaning of the unit followed by rinsing with unchlorinated, deionized water is suggested between sampling when analysis for organics in the parts per million (ppm) or parts per billion (ppb) range is required (29).

6.1.4 *Gas-Lift Pumps:*

6.1.4.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water level (30, 31).

6.1.4.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing (32). In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping (26). A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.



NOTE—Taken from Ref (49).

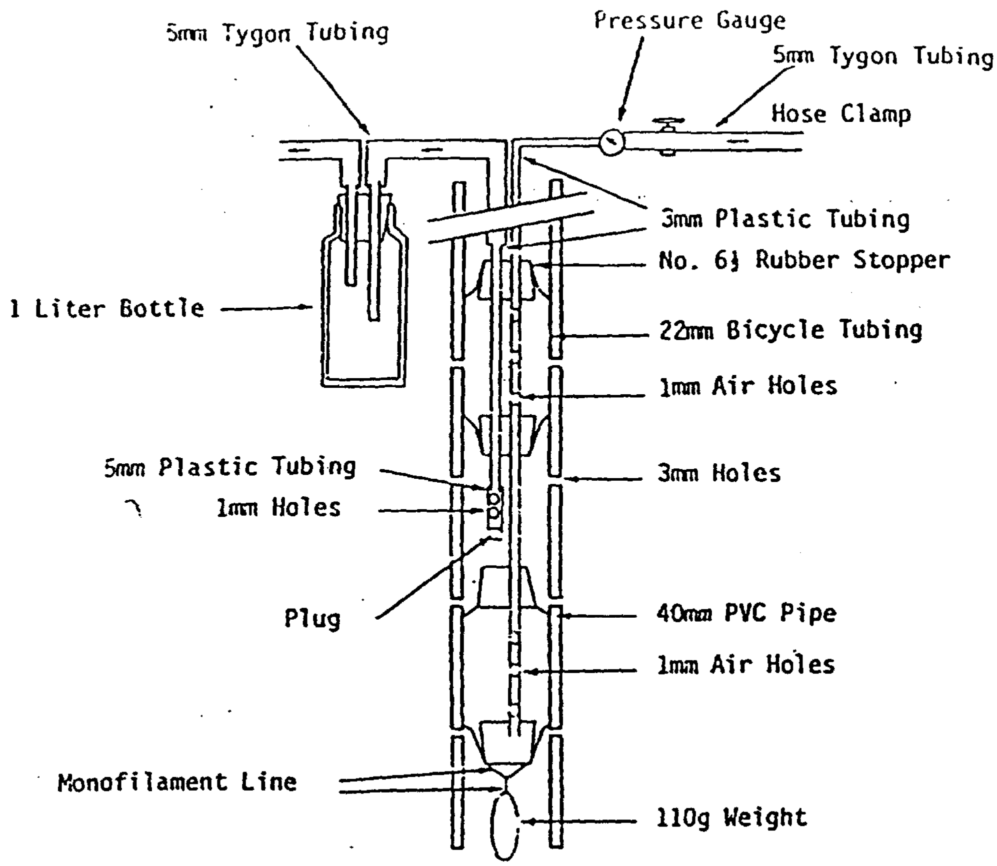
FIG. 9 Gas Driven Piston Pump

6.1.4.3 The source of compressed gas may be a hand pump for depths generally less than 7.6 m (25 ft). For greater depths, air compressors, pressurized air bottles, and air compressed from an automobile engine have been used.

6.1.4.4 As already mentioned, gas-lift methods result in considerable sample agitation and mixing within the well, and cannot be used for samples which will be tested for volatile organics. The eductor pipe or weighted plastic tubing is a potential source of sample contamination. In addition, Gibb (8) uncovered difficulties in sampling for inorganics. These difficulties were attributed to changes in redox, pH, and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

6.1.5 *Gas Displacement Pumps:*

6.1.5.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fi
Water fills the chamber. A positive pressure is applied to



NOTE—Taken from Ref (53).

FIG. 10 Packer Pump Arrangement

gas line closing the sampler check valve and forcing water up the sample line. By removing the pressure the cycle can be repeated. Vacuum can also be used in conjunction with the gas (30). The device can be permanently installed in the well (33, 34, 35) or lowered into the well (36, 37).

6.1.5.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed (38, 39). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates up to 2.3 Lpm (0.6 gpm) are possible with a 5.1 cm (2 in.) diameter unit.

6.1.5.3 Gas displacement pumps have also been developed with multiple functions. The water sample in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sample with its transducer exposed externally for piezometric measurements is illustrated in Fig. 6 (41). The sensor can activate the gas source at the surface to cause sample chamber pressurization at the predetermined depth. Another design can be used as a water sampler or as a tool for injecting brine or other tracers into a well (42).

6.1.5.4 Gas displacement pumps offer reasonable potential for preserving sample integrity because little of the driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses or contamination from the driving gas and the housing materials.

6.1.6 *Bladder Pumps:*

6.1.6.1 Bladder pumps, also referred to as gas-operated squeeze pumps, consist of a flexible membrane enclosed by a rigid housing. Water enters the membrane through a check valve in the vessel bottom; compressed gas injected into the cavity between the housing and bladder forces the sample through a check valve at the top of the membrane and into a discharge line (Fig. 7). Water is prevented from re-entering the bladder by the top check valve. The process is repeated to cycle the water to the surface. Samples taken from depths of 30.5 m (100 ft) have been reported.

6.1.6.2 A variety of design modifications and materials are available (43, 44). Bladder materials include neoprene, rubber, ethylene propylene terpolymer (E.P.T.), nitrile, and the fluorocarbon Viton.[3] A bladder made of TFE-fluorocarbon is also under development (45). Automated sampling systems have been developed to control the time between pressurization cycles (46).

6.1.6.3 Bladder pumps provide an adaptable sampling tool due primarily to the number of bladder shapes that are feasible. These devices have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas. Disadvantages include the large gas volume required, low pumping rates, and potential contamination from many of the bladder materials, the rigid housing, or both.

6.1.7 *Gas Driven Piston Pumps:*

6.1.7.1 A simple and inexpensive example of a gas driven piston pump is a syringe pump (47). The pump (Fig. 8) is constructed from a 50 mL plastic syringe with plunger stem removed. The device is connected to a gas line to the surface and the sample passes through a check valve arrangement to a sampling container at the surface. By successively applying positive and negative pressure to the gas-line, the plunger is activated driving water to the surface.

6.1.7.2 A double piston pump powered by compressed air is illustrated in Fig. 9. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston which allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke (48). Pumping rates between 9.5 and 30.3 L/hr (2.5 to 8 gal/hr) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

6.1.7.3 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

6.1.8 *Packer Pump Arrangement:*

6.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between two packers within a well. Since the hydraulic or pneumatic activated packers are wedged against the casing wall or screen, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed from some type of rubber or rubber compound (48, 49, 50, 51). A packer pump unit consisting of a vacuum sampler positioned between two packers is illustrated in Fig. 10 (52).

6.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

7. Sample Containers and Preservation

7.1 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the formost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce the volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration and freezing. For water samples, immediate refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include a recording thermometer in the sample shipment to verify the maximum and minimum temperature to which the samples were exposed. Inexpensive devices for this purpose are available.

7.2 All bottles and containers must be specially precleaned, pre-labelled, and organized in ice-chests (isolating samples and sampling equipment from the environment) before one goes into the field. Otherwise, in any comprehensive program utter chaos usually develops in the field or laboratory. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labelling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Example of detailed plans and documentation procedures have been published (14, 53).

7.3 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, and the individual laboratory protocols. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

7.4 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils (13, 14, 50, 54, 55, 56). The "Handbook for Sampling and Sample Preservation of Water and Wastewater" is an excellent reference and perhaps the most comprehensive one (14). Some of this information is summarized in Table 1.

7.5 Sample containers for trace organic samples require special cleaning and handling considerations (57). The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-flourocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples (usually about four taken from one large sample container) are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independent protected samples.

7.6 The purgeable samples must be analyzed by the laboratory within 14 days after collection, unless they are to be analyzed for acrolein or acrylonitrile (in which case they are to be analyzed within 3 days). For samples for solvent extractions (extractable organics-base neutrals, acids and pesticides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been precleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note). Samples for organic extraction must be extracted within 7 days and analyzed within 30 days after extraction. Special pre-cleaned, solvent rinsed and oven-dried stainless steel beakers (one for each monitoring well) may be used for transferring samples from the sampling device to the sample containers.

NOTE—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

7.7 For a number of groundwater parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well and parameters that sometimes can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication (5) and detailed procedures are outlined in a U.S. Geological Survey publication (58). Although a discussion of these techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made before a well is flushed or only after it has had sufficient time to recover. Parameters that can change rapidly with storage include specific conductance, pH, turbidity, redox potential, dissolved oxygen, and temperature. For some of the other parameters, the emphasis in groundwater monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45 µm membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include all metals, radioactivity parameters, total organic carbon, dissolved orthophosphate (if needed), and total dissolved phosphorous (if needed) (13, 14). If metals are to be analyzed, filter the sample prior to acid preservation. For TOC organics, the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well understood. However, if results of metal, TOC or other parameters that could be effected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.

7.8 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit. All samples for organic analysis (and many other parameters), should arrive at the laboratory within one day after it is shipped and be maintained at about 4°C with wet ice. The best way to get them to the laboratory in good condition is to send them in sturdy insulated ice chests (coolers) equipped with bottle dividers. 24-h courier service is recommended, if personal delivery service is not practical.

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APPENDIX D
IN-SITU SLUG TESTING

WELL-HEAD TESTING (SLUG-TESTS)

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**WELL-HEAD TESTING
(SLUG-TESTS)**

1.0 PURPOSE

This SOP provides a general description of the technical methods and field procedures of a representative suite of well-head testing (slug tests) to approximate part of the aquifer parameters. The well-head tests are to be considered at all times as a reconnaissance of the aquifer parameters across an area (the site under investigation); they are never reliable as definitive calculations of those parameters either at a point (an individual well) or across an area (the well-field). The descriptions herein are general in nature and do not apply to a specific well, well-field or project. Prior to designing well-head tests as part of a site investigation and during execution of the tests, the Project Manager, Site Manager and Program Geohydrologist must consult on the appropriate procedures; these procedures must then be recorded in the project documents.

2.0 SCOPE

The procedures described here apply to tests for evaluation of the aquifer parameters at sites being investigated under both the Underground Storage Tank (UST) Program and the Installation Restoration (IR) Program of Navy CLEAN. The well-head tests apply both to consolidated and unconsolidated strata; and to confined, semiconfined and phreatic conditions. The aquifer parameters subject to evaluation and approximate calculation are the Coefficient of Transmissivity and the Hydraulic Conductivity.

3.0 DEFINITIONS

The following definitions are extracted or abstracted from standard references (Section 7); further discussions are available in those references.

Hydraulic Conductivity (K) - A medium has a hydraulic conductivity (K) of unit length per unit time (for example, feet per day [ft/d]) if it will transmit in unit time a unit volume of groundwater at the prevailing viscosity through a cross-section of unit area, measured at right angles to the direction of flow, under a hydraulic gradient of unit change in head through unit length of flow (Lohman 1979).

Coefficient of Transmissivity (T) - The transmissivity (T) is the rate (for example, in gallons per day per foot of drawdown [gpd/ft]) at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient (Lohman 1979). The transmissivity is mathematically equivalent to the hydraulic conductivity multiplied by the saturated thickness: $T = Kb$.

Saturated Thickness (b) - The saturated thickness (b) is the distance (for example, in feet [ft]) from the elevation of the upper groundwater surface in either a phreatic system (the water table) or a confined or semiconfined system (the lower boundary of the upper confining or semiconfining layer, but not the potentiometric surface in a well) to the elevation of the upper boundary of the lower confining or semiconfining layer for the aquifer or water-bearing layer.

Drawdown (s) - The drawdown (s) in any well affected by a well-head test is the differential distance, usually in feet (ft), between the static (unstressed) water level in the well measured immediately prior to the test, and the (stressed) water level at the specified time during the test.

Falling-Head Test - The falling-head test is conducted where the static water level in the subject well is nearly instantaneously displaced vertically upward at the initiation of the test; the decay of this artificially impressed head is measured against time to provide data for the calculation of conductivity or transmissivity.

Rising-Head Test - The rising-head test is conducted where the static water level in the subject well is nearly instantaneously displaced vertically downward at the initiation of the test; the decay of this artificially depressed head is measured against time to provide data for the calculation of conductivity or transmissivity.

Confined Conditions - Confined conditions in a water-bearing layer are found where the groundwater is bounded vertically by opposed surfaces or layers that are impermeable to water, and where the total head of the system at the upper surface of the groundwater is greater than atmospheric pressure. For a confined system, when a well is drilled below the bottom of the upper confining layer, the water level in the well rises to an elevation (at least) within or (possibly) above the upper confining layer.

Unconfined (Phreatic) Conditions - Unconfined conditions in a water-bearing layer are found where the groundwater is bounded vertically only by a single surface or layer at the bottom of the water-bearing layer that is impermeable or semipermeable to water, and where the total head of the system at the upper surface of the groundwater is equal to atmospheric pressure. For an unconfined or phreatic or water-table system, when a well is drilled below the upper surface of the groundwater, the water level in the well does not rise to a significantly higher elevation.

Semiconfined Conditions - Semiconfined conditions in a water-bearing layer are found where the groundwater is bounded vertically by opposed surfaces or layers that are less permeable to water than the water-bearing layer itself, and where the total head of the system is greater than atmospheric pressure. For a semiconfined system, when a well is drilled below the bottom of the upper semiconfining layer, the water level in the well rises to an elevation within or above the upper semiconfining layer. However, one or both of the semiconfining layers will be, in some fashion, in hydraulic and hydrologic communication with the water-bearing layer, and may contribute water to or receive water from that layer.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation procedures which deviate from those presented herein.

Site Manager - It is the responsibility of the Site Manager to ensure that the procedures herein are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Field Geologist - Responsible for determining the need for hydrogeologic testing and has overall responsibility for the planning and implementation of the test. Evaluation and interpretation of the data is also the responsibility of the Field Geologist.

Program Geologist - Responsible for QA/QC oversight of the planning and implementation of the test, along with the evaluation of data generated by the test.

5.0 PROCEDURES

The procedures presented in this section concern the administration and execution of well-head tests; the technical content of a given test will be established by the project and program management for each instance according to experience and best professional practice.

5.1 Overview

The well-head test will conform to the objectives of the investigation and to standards of good practice common in geohydrologic investigations. Sufficient personnel, and sufficient standard and special equipment will be available for the intentions of the test. Data collection will conform to standard procedures for the collection of water levels; additionally, time will be measured and recorded no less precisely than the nearest minute or half-minute, as appropriate, while conforming to the intent of the test. Containment and disposal of discharged liquids will conform to the handling of other liquids as discussed in the FSAP.

5.2 Applications

The well-head test will usually be divided into three stages:

1. Static measurement
2. Falling-head test
3. Rising-head test

Each stage will normally be run for no more than 30 minutes. The water level in the test well should recover to between 90 and 100 percent of static conditions before beginning the next stage. Should the recovery be less than acceptable after 30 minutes from the start of the first stage, or should other field conditions conspire adversely, the second stage will not be run. Measurements of recovery during the first stage may then be extended to 60 minutes.

5.2.1 Static Measurement

This stage of the well-head test provides the data on static conditions to be used in subsequent approximation of the aquifer parameters. The static water levels are to be measured no later than immediately prior to the first stage of the test, whether falling-head or rising-head. The levels should also have been measured once daily, if possible, for two or more days preceding the test; the optimal measurement program would provide continuous measurement and recording of levels in all wells to be used for a period of several weeks preceding well-head testing.

5.2.2 Falling-Head Test

The falling-head stage of the well-head test is usually conducted before the rising-head. This stage imposes a stress on the water-bearing layer by nearly instantaneously injecting water or introducing a solid slug of impermeable material at one point (the test well). This is usually repeated at a large number of the available wells in the well-field. The measurements of the rate of recovery of the drawdown in the well provides data used in approximation of the aquifer parameters. The test should be planned to use between 50 and 75 percent of the available displacement in the well, but may use between 1 and 100 percent, at the discretion of the Site Manager. The use of a solid slug is favored by the program. The impressed head developed by this test must rise above the top of the well screen.

5.2.3 Rising-Head Test

The rising-head stage of the well-head test imposes a stress on the water-bearing layer by nearly instantaneously extracting water or removing a solid slug of impermeable material at one point (the test well). This is usually repeated at a large number of the available wells in the well-field. The measurements of the rate of recovery of the drawdown in the well provides data used in approximation of the aquifer parameters. The test should be planned to use between 50 and 75 percent of the available displacement in the well, but may use between 1 and 100 percent, at the discretion of the Site Manager. The use of a solid slug is favored by the program.

5.3 Measurements and Measurement Intervals

The measurement intervals for water levels in the test well during each stage will be modified from the following suggestions:

Time Since Start of Test (min)	Measurement Frequency (min)
0-5	0.5
5-10	1
10-20	2
20-60	5

The actual time and the test time for each reading will be recorded, with the water level measured to a precision of 0.01 ft.

The sequence of stations tested and the frequency of readings will be established by project and program management prior to the tests, and will be adjusted according to site conditions during the tests.

5.4 Calculation Methods

Calculation of the approximate values of the aquifer parameters will follow standard practice, with particular reference to the resources of Section 7, or as otherwise noted in the calculation sequence. A computer program, AQTESOLV (Duffield and Rambaugh) or similar or equivalent, may also be used; if the computer program is used, an example that has previously been verified by traditional calculation will be run as part of the data from the subject site.

6.0 QUALITY ASSURANCE RECORDS

The readings made during the well-head test may be recorded in field books or on separate forms, according to management decisions. The file for each test will include the field data, the calculations and graphs, and summaries with references for calculations by computer program.

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APPENDIX E
SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION

SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION
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SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION

1.0 PURPOSE

This procedure describes methods and equipment commonly used for collecting environmental samples of surface water and aquatic sediment either for on-site examination and chemical testing or for laboratory analysis.

2.0 SCOPE

The information presented in this SOP is generally applicable to all environmental sampling of surface waters (Section 5.2) and aquatic sediments (Section 5.3), except where the analyte(s) may interact with the sampling equipment.

Specific sampling problems may require the adaptation of existing equipment or design of new equipment. Such innovations shall be documented and presented in the Sampling and Analysis Plan.

3.0 DEFINITIONS

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes.

Composite Sample - A sample collected over time that typically consists of a series of discrete samples which are combined or composited.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation for procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific surface water and/or sediment sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of surface water and sediment samples.

5.0 PROCEDURES

Collecting a representative sample from surface water or sediments is difficult due to water movement, stratification or patchiness. To collect representative samples, one must standardize sampling bias related to site selection; sampling frequency; sample collection; sampling devices; and sample handling, preservation, and identification.

Representativeness is a qualitative description of the degree to which an individual sample accurately reflects population characteristics or parameter variations at a sampling point. It is therefore an important quality not only of assessment and quantification of environmental threats posed by the site, but also for providing information for engineering design and construction. Proper sample location, selection, and collection methods are important to ensure that a truly representative sample has been collected. Regardless of scrutiny and quality control applied during laboratory analyses, reported data are only as good as the confidence that can be placed on the representativeness of the samples.

5.1 Defining the Sampling Program

Many factors must be considered in developing a sampling program for surface water or sediments including study objectives; accessibility; site topography; flow, mixing and other physical characteristics of the water body; point and diffuse sources of contamination; and personnel and equipment available to conduct the study. For waterborne constituents, dispersion depends on the vertical and lateral mixing within the body of water. For sediments, dispersion depends on bottom current or flow characteristics, sediment characteristics (density, size) and geochemical properties (which effect adsorption/desorption). The sampling plan must therefore reflect not only the mixing characteristics of streams and lakes, but also the role of fluvial-sediment transport, deposition, and chemical sorption.

5.1.1 Sampling Program Objectives

The objective of surface water sampling is to determine the surface water quality entering, leaving or remaining within the site. The scope of the sampling program must consider the sources and potential pathways for transport of contamination to or within a surface water body. Sources may include point sources (leaky tanks, outfalls, etc.) or nonpoint sources (e.g., spills). The major pathways for surface water contamination (not including airborne deposition are: (a) overland runoff; (b) leachate influx to the waterbody; (c) direct waste disposal (solid or liquid) into the water body; and (d) groundwater flow influx to the water body. The relative importance of these pathways, and therefore the design of the sampling program, is controlled by the physiographic and hydrologic features of the site, the drainage basin(s) which encompass the site, and the history of site activities.

Physiographic and hydrologic features to be considered include slopes and runoff direction, areas of temporary flooding or pooling, tidal effects, artificial surface runoff controls such as berms or drainage ditches (when constructed relative to site operation), and locations of springs, seeps, marshes, etc. In addition, the obvious considerations such as the location of man-made discharge points to the nearest stream (intermittent or flowing), pond, lake, estuary, etc., shall be considered.

A more subtle consideration in designing the sampling program is the potential for dispersion of dissolved or sediment-associated contaminants away from the source. The dispersion could lead to a more homogeneous distribution of contamination at low or possibly nondetectable concentrations. Such dispersion does not, however, always readily occur throughout the entire body of water; the mixing may be limited to specific flow streams within the water body. For example, obtaining a representative sample of contamination from the center of a channel immediately below an outfall or a tributary is difficult because the inflow frequently follows a stream bank with little lateral mixing for some distance. Sampling alternatives to overcome this situation are: (1) move the site far enough downstream to allow for adequate mixing, or (2) collect integrated samples in a cross section. Also, nonhomogeneous distribution is a particular problem with regard to sediment-associated contaminants which may accumulate in low-energy environments while higher-energy areas (main stream channels) near the source may show no contaminant accumulation.

The distribution of particulates within a sample itself is an important consideration. Many organic compounds are only slightly water soluble and tend to adsorb on particulate matter. Nitrogen, phosphorus, and the heavy metals also may be transported by particulates. Samples will be collected with a representative amount of suspended material; transfer from the sampling device shall include transferring a proportionate amount of the suspended material.

The first step in selecting sampling locations; therefore, is to review site history, define hydrologic boundaries and features of the site, and identify the sources, pathways and potential distribution of contamination based on these considerations. The numbers, types and general locations of required samples upgradient, on site and downgradient can then be identified.

5.1.2 Location of Sampling Stations

Accessibility is the primary factor affecting sampling costs. The desirability and utility of a sample for analysis and description of site conditions must be balanced against the costs of collection as controlled by accessibility. Wading or sampling from a stream bank often is sufficient for springs, seeps, and small streams. Bridges or piers are the first choice for locating a sampling station on a larger stream or small river; they provide ready access and also permit the sampling technician to sample any point across the stream or river. A boat or pontoon (with an associated increase in cost) may be needed to sample locations on lakes and reservoirs, as well as those on larger rivers. Frequently, however, a boat will take longer to cross a water body and will hinder manipulation of the sampling equipment.

If it is necessary to wade into the water body to obtain a sample, the sampler shall be careful to minimize disturbance of bottom sediments and must enter the water body downstream of the sampling location. If necessary, the sampling technician shall wait for the sediments to settle before taking a sample. Use of boats or wading to collect samples requires the use of U. S. Coast Guard approved personal flotation devices (PFDs).

Sampling in marshes or tidal areas may require the use of an all-terrain-vehicle (ATV). The same precautions mentioned above with regard to sediment disturbance will apply.

The availability of stream flow and sediment discharge records can be an important consideration in choosing sampling sites in streams. Stream flow data in association with contaminant concentration data are essential for estimating the total contaminant load carried by the stream. If a gaging station is not conveniently located on a selected stream, obtaining stream flow data by direct or indirect methods shall be explored.

5.1.3 Frequency of Sampling

The sampling frequency and the objectives of the sampling event will be defined by the Sampling and Analysis Plan. For single-event, site- or area-characterization sampling, both bottom material and overlying water samples shall be collected at the specified sampling stations. If valid data are available on the distribution of the contaminant between the solid and aqueous phases it may be appropriate to sample only one phase, although this often is not recommended. If samples are collected primarily for monitoring purposes, consisting of repetitive, continuing measurements to define variations and trends at a given location, water samples shall be collected at established and consistent intervals, as specified in the Sampling and Analysis Plan (often monthly or quarterly), and during droughts and floods. Samples of bottom material shall be collected from fresh deposits at least yearly, and preferably during both spring and fall seasons.

The variability in available water quality data shall be evaluated before deciding on the number and collection frequency of samples required to maintain an effective monitoring program.

5.2 Surface Water Sample Collection

This section presents methods for collection of samples from various surface water bodies, as well as a description of types of surface water sampling equipment. The guidance in this section should be used to develop specific sampling procedures based on site conditions and investigation goals. A summary of sampling techniques and procedures is given in Section 5.2.5.

5.2.1 Streams, Rivers, Outfalls and Drainage Features (Ditches, Culverts)

Methods for sampling streams, rivers, outfalls and drainage features at a single point vary from the simplest of hand sampling procedures to the more sophisticated multi-point sampling techniques known as the equal-width-increment (EWI) method or the equal-discharge-increment (EDI) method.

Samples from different depths or cross-sectional locations, collected during the same sampling episode, shall be composited. However, samples collected along the length of the watercourse or at different times may reflect differing inputs or dilutions and therefore shall not be composited. Generally, the number and type of samples to be collected depend on the river's width, depth, discharge, and amount of suspended sediment. With a greater number of individual points sampled, it is more likely that the composite sample will truly represent the overall characteristics of the water.

In small streams less than about 20 feet wide, a sampling location can generally be found where the water is well mixed. In such cases, a single grab sample taken at mid-depth in the center of the channel is adequate to represent the entire cross-section.

For larger streams greater than three feet in depth, two samples at each station shall be taken from just below the surface, and just above the bottom.

5.2.2 Lakes, Ponds and Reservoirs

Lakes, ponds, and reservoirs have a much greater tendency to stratify according to physical or chemical differences than rivers and streams. The relative lack of mixing requires that more samples be obtained.

The number of water sampling locations on a lake, pond, or impoundment will vary with the size and shape of the basin. In ponds and small lakes, a single vertical composite at the deepest point may be sufficient. Similarly, the measurement of DO, pH, temperature, etc., is conducted on each aliquot of the vertical composite. In naturally-formed ponds, the deepest point may have to be determined empirically; in impoundments, the deepest point is usually near the dam.

In lakes and larger reservoirs, several vertical grab samples shall be composited to form a single sample. These vertical samples often are collected along a transect or grid. In some cases, it may be of interest to form separate composites of epilimnetic and hypolimnetic zones. In a stratified lake, the epilimnion is the thermocline which is exposed to the atmosphere. The hypolimnion is the lower, "confined" layer which is only mixed with the epilimnion and vented to the atmosphere during seasonal "overturn" (when density stratification disappears). These two zones may thus have very different concentrations of contaminants if input is only to one zone, if the contaminants are volatile (and therefore vented from the epilimnion but not the hypolimnion), or if the epilimnion only is involved in short-term flushing (i.e., inflow from or outflow to shallow streams). Normally, however, a composite sample consists of several vertical samples collected at various depths.

As it is likely that poor mixing may occur in lakes with irregular shape (with bays and coves that are protected from the wind), separate composite samples may be needed to adequately represent water quality. Similarly, additional samples are recommended where discharges, tributaries, land use characteristics, and other such factors are suspected of influencing water quality.

Many lake measurements now are made in-situ using sensors and automatic readout or recording devices. Single and multi-parameter instruments are available for measuring temperature, depth, pH, oxidation-reduction potential (ORP), specific conductance, dissolved oxygen, some cations and anions, and light penetration.

5.2.3 Estuaries

Estuarine areas are by definition among those zones where inland freshwaters (both surface and ground) mix with marine waters. Estuaries generally are categorized into three types dependent upon freshwater inflow and mixing properties. Knowledge of the estuary type is necessary to determine sampling locations:

- Mixed estuary - characterized by the absence of a vertical halocline (gradual or no marked increase in salinity in the water column) and a gradual increase in salinity seaward. Typically this type of estuary is shallow and is found in major freshwater sheetflow areas. Being well mixed, the sampling locations are not critical in this type of estuary.

- Salt wedge estuary - characterized by a sharp vertical increase in salinity and stratified freshwater flow along the surface. In these estuaries the vertical mixing forces cannot override the density differential between fresh and saline waters. In effect, a salt wedge tapering inland moves horizontally, back and forth, with the tidal phase. If contamination is being introduced into the estuary from upstream, water sampling from the salt wedge may miss it entirely.

- Oceanic estuary - characterized by salinities approaching full strength oceanic waters. Seasonally, freshwater inflow is small with the preponderance of the fresh-saline water mixing occurring near, or at, the shore line.

Sampling in estuarine areas normally is based upon the tidal phases, with samples collected on successive slack tides (i.e., when the tide turns). Estuarine sampling programs shall include vertical salinity measurements coupled with vertical dissolved oxygen and temperature profiles.

5.2.4 Surface Water Sampling Equipment

The selection of sampling equipment depends on the site conditions and sample type required. The most frequently used samplers are:

- Dip sampler
- Weighted bottle
- Kemmerer
- Depth-Integrating Sampler

The dip sampler and the weighted bottle sampler are used most often.

The criteria for selecting a sampler include:

- Disposable and/or easily decontaminated
- Inexpensive (if the item is to be disposed of)
- Ease of operation
- Nonreactive/noncontaminating - Teflon-coating, glass, stainless steel or PVC sample chambers are preferred (in that order)

Each sample (grab or each aliquot collected for compositing) shall be measured for: specific conductance; temperature; pH; and dissolved oxygen (optional) as soon as it is recovered. These analyses will provide information on water mixing/stratification and potential contamination.

5.2.4.1 Dip Sampling

Water often is sampled by filling a container, either attached to a pole or held directly, from just beneath the surface of the water (a dip or grab sample). Constituents measured in grab samples are only indicative of conditions near the surface of the water and may not be a true representation of the total concentration that is distributed throughout the water column and in the cross section. Therefore, whenever possible it is recommended to augment dip samples with samples that represent both dissolved and suspended constituents, and both vertical and horizontal distributions. Dip sampling often is the most appropriate sampling method for springs, seeps, ditches, and small streams.

5.2.4.2 Weighted Bottle Sampling

A grab sample also can be taken using a weighted holder that allows a sample to be lowered to any desired depth, opened for filling, closed, and returned to the surface. This allows discrete sampling with depth. Several of these samples can be combined to provide a vertical composite. Alternatively, an open bottle can be lowered to the bottom and raised to the surface at a uniform rate so that the bottle collects sample throughout the total depth and is just filled on reaching the surface. The resulting sample using either method will roughly approach what is known as a depth-integrated sample.

A closed weighted bottle sampler consists of a stopped glass or plastic bottle, a weight and/or holding device, and lines to open the stopper and lower or raise the bottle. The procedure for sampling is as follows:

- Gently lower the sampler to the desired depth so as not to remove the stopper prematurely (watch for bubbles).

- Pull out the stopper with a sharp jerk of the sampler line.

- Allow the bottle to fill completely, as evidenced by the absence of air bubbles.

- Raise the sampler and cap the bottle.

- Decontaminate the outside of the bottle. The bottle can be used as the sample container (as long as original bottle is an approved container).

5.2.4.3 Kemmerer

If samples are desired at a specific depth, and the parameters to be measured do not require a Teflon coated sampler, a standard Kemmerer sampler may be used. The Kemmerer sampler is a brass, stainless steel or acrylic cylinder with rubber stoppers that leave the ends open while being lowered in a vertical position to allow free passage of water through the cylinder. A "messenger" is sent down the line when the sampler is at the designated depth, to cause the stoppers to close the cylinder, which is then raised. Water is removed through a valve to fill sample bottles.

5.2.5 Surface Water Sampling Techniques

Most samples taken during site investigations are grab samples. Typically, surface water sampling involves immersing the sample container directly in the body of water. The following suggestions are applicable to sampling springs, seeps, ditches, culverts, small streams and other relatively small bodies of water, and are presented to help ensure that the samples obtained are representative of site conditions:

- The most representative samples will likely be collected from near mid-stream, the center of flow in a culvert, etc.

- Downstream samples shall be collected first, with subsequent samples taken while moving upstream. Care shall be taken to minimize sediment disturbance while collecting surface water samples. If necessary, sediment samples shall be collected after the corresponding surface water sample.

- Samples may be collected either by immersing the approved sample container or a glass or nalgene beaker into the water. Sample bottles (or beakers) which do not contain preservatives shall be rinsed at least once with the water to be sampled prior to sample collection.

- Care shall be taken to avoid excessive agitation of the water which may result in the loss of volatile constituents. Additionally, samples for volatile organic analyses shall be collected first, followed by the samples for other constituents.

- Measurements for temperature, pH, specific conductance, or other field parameters, as appropriate, shall be collected immediately following sample collection for laboratory analyses.

- The sampling location shall be marked via wooden stake placed at the nearest bank or shore. The sampling location number shall be marked with indelible ink on the stake.

- The following information shall be recorded in the field logbook:

  - Project location, date and time.
  - Weather.
  - Sample location number and sample identification number.
  - Flow conditions (i.e., high, low, in flood, etc.) and estimate of flow rate.
  - Visual description of water (i.e., clear, cloudy, muddy, etc.).
  - On-site water quality measurements.
  - Sketch of sampling location including boundaries of water body, sample location (and depth), relative position with respect to the site, location of wood identifier stake.
  - Names of sampling personnel.
  - Sampling technique, procedure, and equipment used.

General guidelines for collection of samples from larger streams, ponds or other water bodies are as follows:

- The most representative samples are obtained from mid-channel at mid- stream depth in a well-mixed stream.

- For sampling running water, it is suggested that the farthest downstream sample be obtained first and that subsequent samples be taken as one works upstream. Work may also proceed from zones suspected of low contamination to zones of high contamination.

- It is suggested that sample containers which do not contain preservative be rinsed at least once with the water to be sampled before the sample is taken.

- To sample a pond or other standing body of water, the surface area may be divided into grids. A series of samples taken from each grid is combined into one composite sample, or several grids are selected at random.

- Care should be taken to avoid excessive agitation of the water that would result in the loss of volatile constituents.

- When obtaining samples in 40 ml septum vials for volatile organics analysis, it is important to exclude any air space in the top of the bottle and to be sure that the Teflon liner faces inward. The bottle can be turned upside down to check for air bubbles after the bottle is filled and capped.

- Do not sample at the surface unless sampling specifically for a known constituent which is immiscible and on top of the water. Instead, the sample container should be inverted, lowered to the approximate depth, and held at about a 45-degree angle with the mouth of the bottle facing upstream.

- Measurements for temperature, pH, specific conductance, or other field parameters, as appropriate shall be collected immediately following sample collection for laboratory analysis.

- Items to be recorded in the field logbook are the same as those described above for small streams.

5.3 Sediment Sampling

Sediment samples usually are collected at the same locations as surface water samples. If only one sediment sample is to be collected, the sample location shall be approximately at the center of the water body. If, however, multiple samples are required, sediment samples should be collected along a cross-section to characterize the bed material. A common procedure for obtaining multiple samples is to sample at quarter points along the cross-section of flow. As with surface water samples, sediment samples should be collected from downstream to upstream.

5.3.1 Sampling Equipment and Techniques

A bottom-material sample may consist of a single scoop or core or may be a composite of several individual samples in the cross section. Sediment samples may be obtained using on-shore or off-shore techniques.

When boats are used for sampling, U. S. Coast Guard approved personal flotation devices must be provided and two individuals must undertake the sampling. An additional person shall remain on-shore in visual contact at all times.

The following samplers may be used to collect bottom materials:

- Scoop sampler
- Dredge samplers
- Bucket/hand auger
- Stainless steel spoon or trowel

5.3.1.1 Scoop Sampler

A scoop sampler consists of a pole to which a jar or scoop is attached. The pole may be made of bamboo, wood or aluminum and be either telescoping or of fixed length. The scoop or jar at the end of the pole is usually attached using a clamp.

If the water body can be sampled from the shore or if it can be waded, the easiest and "cleanest" way to collect a sediment sample is to use a scoop sampler. This reduces the potential for cross-contamination. This method is accomplished by reaching over or wading into the water body and, while facing upstream (into the current), scooping in the sample along the bottom in the upstream direction. It is very difficult not to disturb fine-grained materials of the sediment-water interface when using this method.

5.3.1.2 Dredges

Dredges are generally used to sample sediments which cannot easily be obtained using coring devices (i.e., coarse-grained or partially-cemented materials) or when large quantities of materials are required. Dredges generally consist of a clam shell arrangement of two buckets. The buckets may either close upon impact or be activated by use of a messenger. Most dredges are heavy (up to several hundred pounds) and require use of a winch and crane assembly for sample retrieval. There are three major types of dredges: Peterson, Eckman and Ponar dredges.

The Peterson dredge is used when the bottom is rocky, in very deep water, or when the flow velocity is high. The dredge shall be lowered very slowly as it approaches bottom, because it can force out and miss lighter materials if allowed to drop freely.

The Eckman dredge has only limited usefulness. It performs well where bottom material is unusually soft, as when covered with organic sludge or light mud. It is unsuitable, however, for sandy, rocky, and hard bottoms and is too light for use in streams with high flow velocities.

The Ponar dredge is a Peterson dredge modified by the addition of side plates and a screen on the top of the sample compartment. The screen over the sample compartment permits water to pass through the sampler as it descends thus reducing the "shock wave" and permits direct access to the secured sample without opening the closed jaws. The Ponar dredge is easily operated by one person in the same fashion as the Peterson dredge. The Ponar dredge is one of the most effective samplers for general use on all types of substrates. Access to the secured sample through the covering screens permits subsampling of the secured material with coring tubes or Teflon scoops, thus minimizing the chance of metal contamination from the frame of the device.

5.3.1.3 Bucket (Hand) Auger

Bucket (hand) augering is a viable method for collecting sediment samples in narrow, intermittent streams or tidal flats. Typically, a 4-inch auger bucket with a cutting head is pushed and twisted into the ground and removed as the bucket is filled. The auger hole is advanced one bucket at a time, to a depth specified in the project plans.

When a specific vertical sampling interval is required, one auger bucket is used to advance the auger hole to the first desired sampling depth. If the sample at this location is to be a vertical composite of all intervals, the same bucket may be used to advance the hole, as well collect subsequent samples in the same hole. However, if discrete grab samples are to be collected to characterize each depth, a new bucket must be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of sediment should be removed from the bucket to minimize the changes of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger should be decontaminated between samples as outlined in SOP F502.

5.3.1.4 Stainless Steel Spoon or Trowel

For loosely packed sediments, a stainless steel scoop or trowel can be used to collect a representative sample, in narrow intermittent streams or tidal flats.

Use the scoop or trowel to collect the sample from a desired depth. Remove heavy debris, rocks, and twigs before collecting the sample. Immediately transfer the sample to the appropriate sample container. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, chain-of-custody record, and other required forms.

5.3.2 Sediment Sampling Procedure

The following general procedure should be used, where applicable, for sampling sediment from springs, seeps, small streams, ditches, or other similar small bodies of water. Procedures sampling larger bodies of water (i.e., rivers, lakes, estuaries, etc.) should be developed on a project-specific basis, as needed.

- Sediment samples shall be collected only after the corresponding surface water sample has been collected, if one is to be collected.

- Sediment samples shall be collected from downstream locations to upstream locations.

- Samples shall be collected by excavating a sufficient amount of bottom material using a scoop, beaker, spoon, trowel, or auger. Samples should be collected with the sampling device facing upstream and the sample collected from downstream to upstream. Care should be taken to minimize the loss of fine-grained materials from the sample.

- The sample shall be transferred to the appropriate sample containers. Sampling personnel shall use judgment in removing large plant fragments to limit bias caused by bio-organic accumulation.

- The sampling location shall be marked via a wooden stake placed at the nearest bank or shore. The sample location number shall be marked on the stake with indelible ink.

- The following information shall be recorded in the field logbook:
  - Project location, date and time.
  - Weather.
  - Sample location number and sample identification number.
  - Flow conditions.
  - Sketch of sampling location including boundaries of water body, sample location, water depth, sample collection depth, relative position with respect to the site, location of wooden identifier stake.
  - Chemical analyses to be performed.
  - Description of sediment.

6.0 QUALITY ASSURANCE RECORDS

The description of the sampling event in the field logbook shall serve as a quality assurance record. Other records include chain-of-custody and sample analysis request forms.

7.0 REFERENCES

1. Feltz, H. R., 1980. Significance of Bottom Material Data in Evaluating Water Quality in Contaminants and Sediments. Ann Arbor, Michigan, Ann Arbor Science Publishers, Inc., V. 1, p. 271-287.

2. Kittrell, F. W., 1969. A Practical Guide to Water Quality Studies of Streams. U.S. Federal Water Pollution Control Administration, Washington, D.C., 135p.

3. U.S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, USEPA Environmental Services Division, Athens, Georgia.

4. U.S. Geological Survey, 1977. National Handbook of Recommended Methods for Water-Data Acquisition. Office of Water Data Coordination, USGS, Reston, Virginia.

APPENDIX F
DECONTAMINATION OF DRILL RIGS AND MONITORING WELL MATERIALS

DECONTAMINATION OF DRILLING RIGS AND MONITORING WELL MATERIALS

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DECONTAMINATION OF DRILLING RIGS AND MONITORING WELL MATERIALS

1.0 PURPOSE

The purpose of this SOP is to provide a general reference regarding the proper decontamination of drilling rigs and monitoring well materials used in the performance of field investigations.

2.0 SCOPE

This procedure addresses drilling equipment, test pit equipment (i.e. backhoe) and monitoring well material decontamination and should be consulted during the preparation of project-specific plans. This procedure does not pertain to personnel decontamination, or to chemical sampling or field analytical equipment decontamination.

3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants which may have accumulated on field equipment. This process ensures protection of personnel from penetrating substances, reduces or eliminates transfer of contaminants to clean areas, prevents mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that project-specific plans are in accordance with these procedures. Documentation should be developed for areas where project plans deviate from these procedures.

Field Team Leader - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field. The Field Team Leader is responsible for ensuring the field personnel overseeing decontamination activities, and personnel conducting the activities have been briefed and trained to execute these procedures.

Drilling Inspector (Site Geologist, Rig Geologist etc.) - It is the responsibility of the drilling inspector to ensure that the drilling subcontractor follows these, or other project-specific procedures as directed by the Field Team Leader.

5.0 PROCEDURE

The various drilling equipment and materials involved with test boring, test pit excavation, subsurface soil sampling, and monitoring well construction must be properly decontaminated to ensure that chemical analysis results reflect actual concentrations present at sampling locations. These procedures will minimize the potential for cross contamination between sampling locations and the transfer of contamination off site.

5.1 Equipment

All drilling equipment involved in field sampling activities shall be decontaminated prior to drilling, excavation, or sampling activities. Such equipment includes drilling rigs, backhoes, augers, downhole tools, well casings, and screens. Split-spoon soil samplers and other similar soil sampling devices shall be decontaminated according to the procedures given in SOP F502.

5.2 Decontamination Procedures

Prior to drilling, or leaving the site, large equipment not directly utilized for sampling will be decontaminated by steam-cleaning in a designated area. The decontamination procedure consists of steam-cleaning the equipment, using potable water as the steam source, to remove visible signs of soils or wastes, and allowing the equipment to air dry. If necessary, the equipment may be cleaned with a scrub brush and alconox/liquinox-water solution prior to steam cleaning to remove visible signs of contamination.

The steam cleaning area will be designed to contain decontamination wastes and waste waters, and can be a lined, excavated pit or a bermed concrete or asphalt pad. For the latter, a floor-drain must be provided which is connected to a holding tank. A shallow, above-surface tank may be used or a pumping system with discharge to a waste tank may be installed.

At certain sites, due to the type of contaminants or proximity to residences, concerns may exist about air emissions from steam cleaning operations. These concerns can be alleviated by utilizing one or more of the following practices:

- Locate the steam cleaning area on site to minimize potential impacts.
- Enclose steam cleaning operations. For example, augers and drilling rods can be steam cleaned in drums. Tarpaulins also can be placed around the steam cleaning area to control emissions.

For a given project, the location of the steam cleaning area will be identified in the Sampling and Analysis Plan.

Decontamination wastes will be collected and contained unless otherwise directed by LANTDIV. The eventual disposition of these wastes will be determined on a project-specific basis, but may include on-site treatment and/or transport off site to an approved treatment/disposal facility.

6.0 QUALITY ASSURANCE RECORDS

Rinsate samples may be collected from steam-cleaned equipment as quality assurance records. The frequency of rinsate samples from either drilling tools or well casings/screens shall be specified in the Sampling and Analysis and Quality Assurance Project Plans for a given project, as appropriate.

Documentation in the field logbook also shall serve as a quality assurance record of decontamination activities.

7.0 REFERENCES

None.

APPENDIX G
DECONTAMINATION OF DRILL RIGS AND MONITORING WELL MATERIALS

DECONTAMINATION OF DRILLING RIGS AND MONITORING WELL MATERIALS

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DECONTAMINATION OF DRILLING RIGS AND MONITORING WELL MATERIALS

1.0 PURPOSE

The purpose of this SOP is to provide a general reference regarding the proper decontamination of drilling rigs and monitoring well materials used in the performance of field investigations.

2.0 SCOPE

This procedure addresses drilling equipment, test pit equipment (i.e. backhoe) and monitoring well material decontamination and should be consulted during the preparation of project-specific plans. This procedure does not pertain to personnel decontamination, or to chemical sampling or field analytical equipment decontamination.

3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants which may have accumulated on field equipment. This process ensures protection of personnel from penetrating substances, reduces or eliminates transfer of contaminants to clean areas, prevents mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that project-specific plans are in accordance with these procedures. Documentation should be developed for areas where project plans deviate from these procedures.

Field Team Leader - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field. The Field Team Leader is responsible for ensuring the field personnel overseeing decontamination activities, and personnel conducting the activities have been briefed and trained to execute these procedures.

Drilling Inspector (Site Geologist, Rig Geologist etc.) - It is the responsibility of the drilling inspector to ensure that the drilling subcontractor follows these, or other project-specific procedures as directed by the Field Team Leader.

5.0 PROCEDURE

The various drilling equipment and materials involved with test boring, test pit excavation, subsurface soil sampling, and monitoring well construction must be properly decontaminated to ensure that chemical analysis results reflect actual concentrations present at sampling locations. These procedures will minimize the potential for cross contamination between sampling locations and the transfer of contamination off site.

5.1 Equipment

All drilling equipment involved in field sampling activities shall be decontaminated prior to drilling, excavation, or sampling activities. Such equipment includes drilling rigs, backhoes, augers, downhole tools, well casings, and screens. Split-spoon samples and other similar soil sampling devices shall be decontaminated in a different manner not discussed herein.

5.2 Decontamination Procedures

Prior to drilling, or leaving the site, large equipment not directly utilized for sampling will be decontaminated by steam-cleaning in a designated area. The decontamination procedure consists of steam-cleaning the equipment, using potable water as the steam source, to remove visible signs of soils or wastes, and allowing the equipment to air dry. If necessary, the equipment may be cleaned with a scrub brush and alconox/liquinox-water solution prior to steam cleaning to remove visible signs of contamination.

The steam cleaning area will be designed to contain decontamination wastes and waste waters, and can be a lined, excavated pit or a bermed concrete or asphalt pad. For the latter, a floor-drain must be provided which is connected to a holding tank. A shallow, above-surface tank may be used or a pumping system with discharge to a waste tank may be installed.

At certain sites, due to the type of contaminants or proximity to residences, concerns may exist about air emissions from steam cleaning operations. These concerns can be alleviated by utilizing one or more of the following practices:

- Locate the steam cleaning area on site to minimize potential impacts.
- Enclose steam cleaning operations. For example, augers and drilling rods can be steam cleaned in drums. Tarpaulins also can be placed around the steam cleaning area to control emissions.

For a given project, the location of the steam cleaning area will be identified in the Sampling and Analysis Plan.

Decontamination wastes will be collected and contained unless otherwise directed by LANTDIV. The eventual disposition of these wastes will be determined on a project-specific basis, but may include on-site treatment and/or transport off site to an approved treatment/disposal facility.

6.0 QUALITY ASSURANCE RECORDS

Rinsate samples may be collected from steam-cleaned equipment as quality assurance records. The frequency of rinsate samples from either drilling tools or well casings/screens shall be specified in the Sampling and Analysis and Quality Assurance Project Plans for a given project, as appropriate.

Documentation in the field logbook also shall serve as a quality assurance record of decontamination activities.

7.0 REFERENCES

None.

APPENDIX H
WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS AND WELL DEPTH MEASUREMENTS

WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND WELL DEPTH MEASUREMENTS

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WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND WELL DEPTH MEASUREMENTS

1.0 PURPOSE

The purpose of this procedure is to describe the method of determining various down-hole measurements: groundwater levels and product (or non-aqueous phase liquid, NAPL) levels, if present, and total depth of groundwater monitoring wells and piezometers.

2.0 SCOPE

The methods described in this SOP generally are applicable to the measurement of groundwater levels, product or NAPL levels, and well depths in monitoring wells and piezometers.

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed.

Field Team Leader - The Field Team Leader is responsible for ensuring that these procedures are implemented in the field, and for ensuring that personnel performing these activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the sampling personnel to follow these procedures or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of down-hole measurements.

5.0 PROCEDURES

Calculations of groundwater elevations and product or NAPL interface level measurements collected from a monitoring well give an indication of:

- The horizontal hydraulic gradient and the direction of groundwater flow.
- The vertical hydraulic gradient, if well nests are used (i.e., the direction of groundwater flow in the vertical plane).

- Floating or sinking product thicknesses which are also known as Light Non-Aqueous Phase Liquids (LNAPLS) and Dense Non-Aqueous Phase Liquids (DNAPLS), respectively.

This information, when combined with other site specific information such as hydraulic conductivity or transmissivity, extent of contamination, and product density, may be used to estimate the rate of contaminant movement or source areas, etc.

Well depth is one of the factors used to determine the zone that a well monitors. Well depth also is used in the calculation of purge volumes as discussed in SOP F104, Groundwater Sample Acquisition.

The following sections briefly discuss the procedures for measuring groundwater levels, product or NAPL levels, and well depth. For all of the procedures discussed, it is assumed that the measurement will be taken from the top of the PVC or stainless steel casing (though other measuring points can be used), and that horizontal and vertical control is available for each well through a site survey, such that measurements may be converted to elevations above Mean Sea Level (MSL) or some other consistent datum. A permanent notch, placed on the inner PVC or stainless steel casing by the surveyor will facilitate consistent water level measurements.

The manufacturer's instructions for all equipment referenced herein should be read by the equipment operator(s) and accompany the equipment to the field.

5.1 Water Level Measurement

Water levels in groundwater monitoring wells shall be measured from the permanent point indicated at the top of the inner casing (the surveyed elevation point, as marked by the surveyor), unless otherwise specified in the project plans, using an electronic water level measuring device (water level indicator). The point of measurement will be documented in the field logbook if different from the top of the inner casing. The reason for deviating from the measurement point should also be noted.

Water levels are measured by lowering the probe into the well until the device indicates that water has been encountered, usually with either a constant buzz, or a light, or both. The water level is recorded to the nearest foot (0.01) using the graduated markings on the water level indicator cord. This measurement, when subtracted from the measuring point elevation, yields the groundwater elevation.

Groundwater levels shall always be measured to the nearest 0.01 foot. However, reporting of water level elevations depends on the accuracy of the vertical control (typically either 0.1 or 0.01 foot).

5.2 Product or NAPL Level Measurements

The procedure for product or NAPL level measurement is nearly identical to that for groundwater elevation measurements. The only differences are the use of an interface probe that detects both NAPLs and water, and the indication signal given by the measurement device. Typically, encountering NAPLs in a monitoring well is indicated by a constant sound. When water is encountered, the signal becomes an alternating on/off beeping sound. This allows for the collection of measurements for both the top of the NAPL layer in a well and the water/NAPL interface.

The apparent water table elevation below the product level will be determined by subtracting the "depth to water" from the measuring point elevation. The corrected water table elevation will then be calculated using the following equation:

$$WTE_c = WTE_a + (\text{Free Product Thickness} \times 0.80)$$

Where:

WTE_c	=	Corrected water table elevation
WTE_a	=	Apparent water table elevation
0.80	=	Average value for the density of petroleum hydrocarbons. Site-specific data will be used where available.

5.3 Well Depth Measurements

Well depths typically are measured using a weighted measuring tape. A water level meter may also be used. The tape is lowered down the well until resistance is no longer felt, indicating that the weight has touched the bottom of the well. The weight should be moved in an up and down motion a few times so that obstructions, if present, may be bypassed. The slack in the tape then is collected until the tape is taut. The well depth measurement is read directly off of the measuring tape, at the top of the PVC or stainless steel casing, to the nearest 0.01-foot and recorded in the Field Logbook. If a water level indicator is used, add the distance from the bottom of the probe to the point where water levels are measured.

5.4 Decontamination of Measuring Devices

Water level indicators, interface probes and weighted measuring tapes that come in contact with groundwater must be decontaminated using the following steps after use in each well:

- Rinse with potable water
- Rinse with deionized water
- Rinse with Methanol or Isopropanol

- Rinse with deionized water

Portions of the water level indicators or other similar equipment that do not come into contact with groundwater, but may encounter incidental contact during use, need only undergo potable water and deionized water rinses.

6.0 QUALITY ASSURANCE RECORDS

The Field Logbook shall serve as the quality assurance record for water, product level or well depth measurements.

APPENDIX I
WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS AND WELL DEPTH MEASUREMENTS

WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND WELL DEPTH MEASUREMENTS

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WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND WELL DEPTH MEASUREMENTS

1.0 PURPOSE

The purpose of this procedure is to describe the method of determining various down-hole measurements: groundwater levels and product (or non-aqueous phase liquid, NAPL) levels, if present, and total depth of groundwater monitoring wells and piezometers.

2.0 SCOPE

The methods described in this SOP generally are applicable to the measurement of groundwater levels, product or NAPL levels, and well depths in monitoring wells and piezometers.

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed.

Field Team Leader - The Field Team Leader is responsible for ensuring that these procedures are implemented in the field, and for ensuring that personnel performing these activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the sampling personnel to follow these procedures or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of down-hole measurements.

5.0 PROCEDURES

Calculations of groundwater elevations and product or NAPL interface level measurements collected from a monitoring well give an indication of:

- The horizontal hydraulic gradient and the direction of groundwater flow.
- The vertical hydraulic gradient, if well nests are used (i.e., the direction of groundwater flow in the vertical plane).

- Floating or sinking product thicknesses which are also known as Light Non-Aqueous Phase Liquids (LNAPLS) and Dense Non-Aqueous Phase Liquids (DNAPLS), respectively.

This information, when combined with other site specific information such as hydraulic conductivity or transmissivity, extent of contamination, and product density, may be used to estimate the rate of contaminant movement or source areas, etc.

Well depth is one of the factors used to determine the zone that a well monitors. Well depth also is used in the calculation of purge volumes.

The following sections briefly discuss the procedures for measuring groundwater levels, product or NAPL levels, and well depth. For all of the procedures discussed, it is assumed that the measurement will be taken from the top of the PVC or stainless steel casing (though other measuring points can be used), and that horizontal and vertical control is available for each well through a site survey, such that measurements may be converted to elevations above Mean Sea Level (MSL) or some other consistent datum. A permanent notch, placed on the inner PVC or stainless steel casing by the surveyor will facilitate consistent water level measurements.

The manufacturer's instructions for all equipment referenced herein should be read by the equipment operator(s) and accompany the equipment to the field.

5.1 Water Level Measurement

Water levels in groundwater monitoring wells shall be measured from the permanent point indicated at the top of the inner casing (the surveyed elevation point, as marked by the surveyor), unless otherwise specified in the project plans, using an electronic water level measuring device (water level indicator). The point of measurement will be documented in the field logbook if different from the top of the inner casing. The reason for deviating from the measurement point should also be noted.

Water levels are measured by lowering the probe into the well until the device indicates that water has been encountered, usually with either a constant buzz, or a light, or both. The water level is recorded to the nearest foot (0.01) using the graduated markings on the water level indicator cord. This measurement, when subtracted from the measuring point elevation, yields the groundwater elevation.

Groundwater levels shall always be measured to the nearest 0.01 foot. However, reporting of water level elevations depends on the accuracy of the vertical control (typically either 0.1 or 0.01 foot).

5.2 Product or NAPL Level Measurements

The procedure for product or NAPL level measurement is nearly identical to that for groundwater elevation measurements. The only differences are the use of an interface probe that detects both NAPLs and water, and the indication signal given by the measurement device. Typically, encountering NAPLs in a monitoring well is indicated by a constant sound. When water is encountered, the signal becomes an alternating on/off beeping sound. This allows for the collection of measurements for both the top of the NAPL layer in a well and the water/NAPL interface.

The apparent water table elevation below the product level will be determined by subtracting the "depth to water" from the measuring point elevation. The corrected water table elevation will then be calculated using the following equation:

$$WTE_c = WTE_a + (\text{Free Product Thickness} \times 0.80)$$

Where:

WTE_c	=	Corrected water table elevation
WTE_a	=	Apparent water table elevation
0.80	=	Average value for the density of petroleum hydrocarbons. Site-specific data will be used where available.

5.3 Well Depth Measurements

Well depths typically are measured using a weighted measuring tape. A water level meter may also be used. The tape is lowered down the well until resistance is no longer felt, indicating that the weight has touched the bottom of the well. The weight should be moved in an up and down motion a few times so that obstructions, if present, may be bypassed. The slack in the tape then is collected until the tape is taut. The well depth measurement is read directly off of the measuring tape, at the top of the PVC or stainless steel casing, to the nearest 0.01-foot and recorded in the Field Logbook. If a water level indicator is used, add the distance from the bottom of the probe to the point where water levels are measured.

5.4 Decontamination of Measuring Devices

Water level indicators, interface probes and weighted measuring tapes that come in contact with groundwater must be decontaminated using the following steps after use in each well:

- Rinse with potable water
- Rinse with deionized water
- Rinse with Methanol or Isopropanol

- Rinse with deionized water

Portions of the water level indicators or other similar equipment that do not come into contact with groundwater, but may encounter incidental contact during use, need only undergo potable water and deionized water rinses.

6.0 QUALITY ASSURANCE RECORDS

The Field Logbook shall serve as the quality assurance record for water, product level or well depth measurements.

APPENDIX J
BACHARACH OXYGEN/ COMBUSTIBLE GAS METER AND PERSONAL GAS MONITOR

**BACHARACH COMBUSTIBLE GAS/
OXYGEN METER PERSONAL GAS MONITOR
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BACHARACH COMBUSTIBLE GAS/ OXYGEN METER AND PERSONAL GAS MONITOR

1.0 PURPOSE

The purpose of this SOP is to provide general reference information for using the Bacharach Sentinel 4 and Bacharach Sniffer® 503-A meters in the field. Calibration and operation, along with field maintenance, will be included in this SOP.

2.0 SCOPE

This procedure provides information into the field operation and general maintenance of the Sentinel 4 Sniffer and 503-A. Review of the information contained herein will ensure that this type of field monitoring equipment will be properly utilized. Review of the owner's instruction manuals is a necessity for more detailed descriptions.

3.0 DEFINITIONS

Carbon Monoxide Sensor - Expresses the Carbon Monoxide concentration in parts per million (ppm).

Combustible Gas - Combustible gas is expressed as a percent of the lower explosive limit (LEL).

Hydrogen Sulfide Sensor - Expresses the Hydrogen Sulfide concentration in parts per million (ppm).

Oxygen Sensor - Expresses the Oxygen concentration as a percentage.

ppm - parts per million: parts of vapor or gas per million parts of air by volume.

Sentinel 4 - Combustible Gas/Oxygen/Hydrogen Sulfide/Carbon Monoxide meter.

Sniffer 503-A - portable Combustible Gas and Oxygen Alarm instrument.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for selecting qualified individuals for the monitoring activities.

Project Health and Safety Officer (PHSO) - The Project Health and Safety Officer is responsible for developing a site-specific Health and Safety Plan (HASP) which specifies air monitoring requirements.

Field Team Leader - It is the responsibility of the Field Team Leader to implement these procedures in the field, and to ensure that the Field Investigation Personnel performing air monitoring activities, have been briefed and trained to execute these procedures before the start of site operations.

Site Health and Safety Officer (SHSO) - The SHSO is responsible for ensuring that the specified air monitoring equipment is on site, calibrated, and used correctly by the Field Personnel. The SHSO will coordinate these activities with the Field Team Leader.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project-specific procedures as directed by the Field Team Leader/Site Health and Safety Officer. The Field Investigation Personnel are responsible for documenting all air monitoring results in the Field Logbook during each field investigation.

5.0 PROCEDURES

The Sentinel 4 Personal Gas Monitor and Sniffer 503-A utilize the principle of detecting sensors. The following four paragraphs discuss theory of operation as it applies to each functional sensor.

The combustible gas sensor uses two elements that are wound with a platinum wire. One of the elements is impregnated with a catalyst to oxidize combustible gases. The other element is impregnated with material that will also oxidize combustible gases, but will respond to temperature and humidity conditions. When the meter is turned on, an electrical current is passed through the elements and wires. As a combustible gas enters the chamber the elements will oxidize the combustible gas, thus increasing the heat and resistance of the element. This change in resistance causes a system imbalance, which produces a measurable signal proportional to the combustible gas concentration.

The percent oxygen is measured utilizing an electrochemical sensor. As atmospheric oxygen enters the meter it diffuses into the sensor which converts the amount of oxygen in the sensor to a voltage signal. This voltage is directly proportional to percent oxygen in the atmosphere.

The concentration of hydrogen sulfide is measured utilizing an electrochemical sensor. As atmospheric hydrogen sulfide enters the meter it diffuses into the sensor which converts the amount of hydrogen sulfide in the sensor to a voltage signal. This voltage is directly proportional to the atmospheric hydrogen sulfide concentration.

The concentration of carbon monoxide as measured utilizing an electrochemical sensor. As atmospheric carbon monoxide enters the meter it diffuses into the sensor which converts the amount of carbon monoxide in the sensor to a voltage signal. This voltage is directly proportional to the atmospheric carbon monoxide concentration.

The Sentinel 4 Personal Gas Monitor and Sniffer 503-A are intrinsically safe for use in Class I, Division 1, Groups A, B, C and D hazard areas. One fact that needs to be expressed is that this type of monitoring equipment utilizes internal oxidation of combustibles, if the meter is placed in an oxygen deficient atmosphere, the combustible reading may be affected. Review of each of the instruction manuals will aid in determining the percentage of oxygen that affects the combustible gas readings.

The following subsections will discuss Sentinel 4 and Sniffer 503-A calibration, operation, and maintenance. These sections, however, do not take the place of the instruction manual.

5.1 Calibration

Sentinel 4

Due to the numerous steps involved in calibration, it is recommended that you follow the calibration procedures (on a daily basis) as outlined in the instruction manual from pages 5-12 to 5-20.

NOTE: A calibration kit will be provided for each Sentinel 4. This kit contains a cylinder for the combustible gas sensor, one cylinder for the hydrogen sulfide sensor, and one cylinder for the carbon monoxide sensor. The oxygen sensor can be calibrated with (uncontaminated/fresh air environment) atmospheric air and does not need cylinder gas.

Note: When a single sensor doesn't zero, none of the sensors are zeroed.

Sniffer® 503-A

Oxygen Detector

1. Check battery charge by turning function switch to "BATTERY TEST," if battery is in recharge zone instrument will need to be charged.

2. To zero the oxygen detector, turn function switch to "BATTERY TEST" position and press "TEST" switch and observe the O_2 meter indication. If indicator is zero, no further adjustment is necessary. If not, follow procedures in Section 5.4.1 of the Operations Manual.

3. To calibrate the oxygen detector, turn function switch to "BATTERY TEST" position. Unlock the "OXYGEN CALIB" knob and adjust it for an O2 meter indication of 21 or at the CAL mark. Relock "OXYGEN CALIB" knob. If using zero calibration gas, follow procedures in Section 5.4.2 of the Operator's Manual.

4. Record on Calibration Sheet.

<u>% LEL Detector</u>

1. Check battery charge by turning function switch to "BATTERY TEST," if batter is in recharge zone, instrument will need to be charged. Allow 5 minutes for the instrument to warm up.

2. Turn function switch to the % LEL position.

   Note: To eliminate the annoyance of the audible alarm, cover the alarm with a hand or duct tape during calibration. The tape must be removed, prior to operation!!

3. Connect calibration gas (typically 30% of the LEL) and allow gas to flow for 1 minute.

   Note: If calibration gas has a concentration value, not a % LEL value, the % LEL can be calculated as follows:

   % calibration gas (i.e., methane) x 20% LEL (meter alarm setting) = % LEL calibration setting

   If meter indication is within ±5% of LEL calibration gas, no further adjustment is required. If not, follow procedures in Section 5.5.4 of Operator's Manual.

<u>Sniffer® 503-A</u>

1. Connect sample probe and tubing to the instrument's sample inlet (refer to Sections 8.4 and 8.5 for the Operator's Manual for available hoses and probes.

2. Check that battery is in Operational Range.

3. Turn instrument to % LEL range and allow to warm up for 1 minute.

4. Check in a fresh air environment that % LEL reads 0% and that O_2 indicator reads 21% (calibration mark).

5. Sample air/gas from area to be tested, allow 30 seconds for readings to stabilize. When finished, allow at least 10 seconds (longer if extension line is used) to purge sample line.

6. If instrument is operating erratically, refer to "TROUBLESHOOTING" Section (Table 5-2) in Operator's Manual.

5.2 Operation

Sentinel 4

Due to the Sentinel 4 having many functions in terms of operation, it is recommended that you follow the operational procedures as outlined in the instruction manual from pages 6-1 to 6-34.

NOTE: Since the Sentinel 4 is capable of measuring four different parameters, an understanding of the alarm, error, and fault messages must be obtained. This can be done by reviewing the troubleshooting table found on pages 9-2 to 9-9.

5.3 Site Maintenance

After each use, the meters should be recharged and the outside of the instruments should be wiped clean with a soft cloth.

5.4 Scheduled Maintenance

Function	Frequency
Check alarm and settings	Monthly/before each use
Clean screens and gaskets around sensors	Monthly
Replace sensors	Biannually or when calibration is unsuccessful

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the Field Logbook.

- Identification - Site name, date, location, CTO number, activity monitored, (surface water sampling, soil sampling, etc), serial number, time, resulting concentration, comments and identity of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g., the Sentinel 4 or Sniffer 503-A had wide range fluctuations during air monitoring activities.)

  NOTE: The "Toxic Gas Meter Calibration Form" will be completed daily, prior to performing any air monitoring.

7.0 REFERENCES

Bacharach Installation, Operation, Maintenance Manual, Sentinel 4 Personal Gas Monitor, 1990.
Bacharach Installation, Operation, Maintenance Manual, Sniffer® 503-A, Rev. 3 - October, 1990.

APPENDIX K
DRUM SAMPLING

DRUM SAMPLING
TABLE OF CONTENTS

DRUM SAMPLING

1.0 PURPOSE

The purpose of this SOP is intended to provide general information for the sampling of drums by qualified individuals in the field. Due to widely varied (and potentially hazardous) conditions posed by drum sampling, specific SOPs must be determined on a case-by-case basis. This SOP provides information to assist in ensuring that safe procedures are followed as applicable to the inspection, opening, and sampling of drums in the field.

2.0 SCOPE AND APPLICATION

This SOP provides technical guidance on safe and cost-effective response actions at sites containing both known and unknown drum contents. Container contents are sampled and characterized for disposal, bulking, recycling, grouping and/or classification purposes.

3.0 DEFINITIONS

Bung - a threaded metal or plastic plug usually positioned at the top or side of a drum.

Over Pack - a metal or plastic drum-like container that is larger than the container(s) stored therein.

Lab Pack - a drum holding multiple individual containers of laboratory materials normally surrounded by cushioning absorbent material.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures where applicable, or that other approved procedures are developed. The Project Manager is responsible for selecting qualified individuals for the drum sampling activities.

Project Health and Safety Officer (PHSO) - The PHSO is responsible for developing a site-specific Health and Safety Plan (HASP) for drum sampling activities which include personal protection levels, air monitoring requirements, and safe drum sampling procedures.

Site Health and Safety Officer (SHSO) - The SHSO is responsible for ensuring that the proper respiratory and personal protective equipment for each member of the sampling team is selected in compliance with the HASP, and coordinating these efforts with the Field Team Leader.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the drum sampling techniques and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the Field Investigation personnel performing drum sampling activities have been briefed and trained to execute these procedures.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project-specific procedures as directed by the Field Team Leader and Project Manager. The Field Investigation Personnel are responsible for documenting all sampling data on the appropriate Drum Sample Characterization Sheet presented as Attachment A and in the Field Logbook.

5.0 METHOD SUMMARY

Prior to sampling, drums should be inventoried and properly staged in a secure area. An inventory entails recording visual qualities of each drum and any characteristics pertinent to the contents' classification. Staging involves the organization and sometimes consolidation of drums which have similar wastes or characteristics.

6.0 INTERFERENCES

The practice of tapping drums to determine their contents is neither safe nor effective and should not be used if the drums are visually overpressurized (bulging) or if shock-sensitive materials are suspected. Drums that have been overpressurized, to the extent that the head is swollen several inches above the chime (beveled edge of drumtop), should not be moved. A number of devices have been developed for venting critically swollen drums. One method that has proven to be effective is a tube and spear device. A light aluminum tube (3 meters long) is positioned at the vapor space of the drum. A rigid hooking device attached to the tube goes over the chime and holds the spear securely in place. The spear is inserted in the tube and positioned against the drum wall. A sharp blow on the end of the spear drives the sharpened tip through the drum and the gas vents along the grooves. The device can be inexpensively and easily designed and constructed where needed. Once the pressure has been relieved, the bung can be removed and the drum contents sampled.

7.0 EQUIPMENT APPARATUS

The following are standard materials and equipment required for drum sampling:

- Health and Safety Plan
- Air monitoring equipment
- Fire extinguishing equipment
- Personnel protective equipment
- Wide mouth glass jars with teflon cap liner, approximately 500 ml volume
- Uniquely numbered sample identification labels with corresponding data sheets
- One-gallon covered (paint) cans half-filled with absorbent (i.e. kitty litter or vermiculite)
- Chain-of-Custody forms
- Decontamination plan and materials

- Glass thieving tubes or Composite Liquid Waste Sampler (COLIWASA)
- Drum opening devices

7.1 Bung Wrench

A common method for opening drums manually is using a universal bung wrench (see Figure 1, Attachment B). These wrenches have fittings made to remove nearly all commonly encountered bungs. They are usually constructed of cast-iron, brass or a bronze-beryllium, nonsparking alloy formulated to reduce the likelihood of sparks. The use of a "NONSPARKING" wrench does not completely eliminate the possibility of a spark being produced, therefore extreme caution should be exercised.

7.2 Drum Deheader

One means by which a drum can be opened manually (when a bung is not removable with a bung wrench) is by using a drum deheader (see Figure 2, Attachment B). This tool is designed to cut the lid of a drum off (or part way off) by means of a scissors-like cutting action. This device is limited in that it can be attached only to closed head drums. Drums with removable heads must be opened by other means.

7.3 Backhoe Spike

The most common means used to open drums remotely for sampling is the use of a metal spike attached or welded to a backhoe bucket (see Figure 3 and 4, Attachment B). In addition to being very efficient, this method can greatly reduce the likelihood of personnel exposure to the potentially hazardous nature of the drum's contents.

7.4 Hydraulic Drum Opener

Another remote drum opening procedure is the utilization of remotely operated hydraulic devices. One such device uses hydraulic pressure to pierce through the wall of a drum (see Figure 5, Attachment B). The device consists of a manually operated pump which pressurizes oil through a length of hydraulic line.

7.5 Pneumatic Devices

A pneumatic bung remover consists of a compressed air supply that is controlled by a heavy-duty, two-stage regulator. A high pressure air line of desired length delivers compressed air to a pneumatic drill, which is adapted to turn a bung fitting selected to fit the bung to be removed (see Figure 6, Attachment B). It should be noted that this bung removal method does not permit the slow venting of the container, and therefore appropriate precautions must be taken to reduce personnel exposure to pressurized, potentially hazardous drum contents. It also requires the container to be upright and relatively level. Bungs that are rusted shut or are in very poor condition cannot be removed with this device.

8.0 PROCEDURES

It is anticipated that the procedures for drum sampling may include a limited degree of drum handling. Therefore, it will be necessary to inspect the drum(s) for certain conditions prior to sampling.

8.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and which equipment and supplies will be needed.

2. Obtain necessary sampling and monitoring equipment.

3. Decontaminate or preclean equipment, and ensure that the equipment is in good working order.

4. Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.

5. Perform a general site survey prior to site entry in accordance with the site-specific Health and Safety Plan.

6. Use marking devices to identify and mark all sampling locations. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions.

8.2 Inspection

Prior to sampling, drums will be visually inspected to gain as much information as possible about their contents. Items to consider during inspection include:

- Symbols, wording, labels, or other marks indicating that drum contents are hazardous, e.g., radioactive, explosive, corrosive, toxic, or flammable.

- Symbols, wording, labels, or other marks indicating that the drum contains discarded laboratory chemicals, reagents, or other potentially dangerous materials in small-volume individual containers.

- Signs of deterioration such as corrosion, rust, and leaks.

- Signs of the chemical nature of the contents, such as residue, crystal buildup, etc. at bung opening.

- Signs that the drum is under pressure such as swelling and bulging.

- Special drum types (refer to Table 1).

- Configuration of the drumhead (ringtop or bung).

- Orientation such as whether the drum is standing upright, tilted, or lying on its side.

- Accessibility of the drum.

Monitoring will be conducted around the drums using instruments such as a gamma radiation survey instrument, organic vapor monitor (OVA or HNu), colorimetric tubes (Dräger tubes), and/or a combustible gas meter. The results can be used to classify the drums into categories such as radioactive, leaking/deteriorating, bulging, explosive/shock-sensitive, or laboratory packs.

Personnel will not handle, move, open, sample or in anyway disturb a drum containing radioactive waste, explosive or shock-sensitive waste, laboratory packs, or biohazardous waste until specific direction and safe procedures are received from the Project Manager, PHSO and the Field Team Leader.

When drums exhibit the characteristics of the aforementioned categories, the following procedures will be followed:

- Radioactive Wastes - If the drum exhibits radiation levels above background, normally 0.01-0.02 mrem/hr (milliroentgen equivalent in man per hour), that are less than or equal to 2 mrem/hr, there is a possible radiation source present. Continue the investigation with caution, and inform the SHSO. If the radiation levels are greater than 2 mrem/hr there is a potential radiation hazard. Work will stop, and the Field Team Leader and Project Manager will be notified so that new procedures can be developed and implemented.

- Explosive or Shock-Sensitive Waste - If handling is necessary, exercise extreme caution, have nonessential personnel move to a safe distance, and use a grappler unit for initial handling which is constructed for explosive containment. Use nonsparking equipment and/or remote control devices.

- Bulging Drums - Do not move drums under internal pressure unless proper equipment is used, such as a grappler unit constructed for explosive containment.

- Packaged Laboratory Wastes (Lab Packs) - Lab Packs can be an ignition source for fires and sometimes contain shock-sensitive materials. Once a lab pack has been opened, a chemist or other qualified individual should inspect, classify and segregate the bottles (without opening), according to the hazards of the wastes. The objective of such a classification system is to ensure safe segregation of the lab packs' contents (refer to Table 2 for an example of a lab pack classification). If crystalline material is noted at the neck of any bottle, handle it as a shock-sensitive waste (due to the potential presence of picric acid, potassium permanganate or explosive mixtures resulting when the aqueous solution crystallizes), or other inimical (harmful) materials, and obtain advice from qualified personnel prior to handling.

Until drum contents are characterized, sampling personnel will assume that unlabeled drums contain hazardous materials. Personnel also should be aware that drums are frequently mislabeled and may not contain the material identified.

8.3 Drum Opening

Drums are to be opened and sampled in place. For opening drums manually, equipment such as a nonsparking metal (brass, bronze/manganese, aluminum, molybdenum) bung/plug wrench and a drum deheading device will be used for waste contents that are known to be nonreactive and nonexplosive, within a structurally sound drum. The drums will be grounded prior to opening either the bung or the lid

While opening drums manually with a bung wrench, the following procedures will be used:

- Drums will be positioned bung up, or, for drums with bungs on the side, laid on their sides with the bung plug up. Note that care should be taken when moving a drum into position for opening.

- Use a wrenching motion that is a slow and steady pull across the drum, using a "cheater bar" if the leverage for unscrewing the bung is poor.

- If there is evidence of incompatible chemical reactions, a sudden pressure buildup, or a release of potentially toxic fumes while the bung is being loosened, field personnel will immediately leave the area and arrange for remote drum opening equipment to be used.

- If the drum cannot be opened successfully using a nonsparking hand wrench, then other methods of drum opening (deheading or puncturing) must be considered. If deheading or puncturing a drum, it will be necessary to overpack the drum to minimize the potential for spilling the drum's contents.

- If the drum shows signs of swelling or bulging, perform all steps slowly. From a remote location, relieve excess pressure prior to drum opening using the devices listed below, if possible. If performing drum opening activities manually, place a barrier such as an explosion-resistant plastic shield between the worker and bung to deflect any gas, liquid, or solids which may be expelled as the bung is loosened.

Whenever possible, use the following remote-controlled devices for opening drums:

- A pneumatically operated impact wrench to remove drum bungs.
- A hydraulically or pneumatically operated drum piercer.
- A backhoe equipped with bronze spikes for penetrating drum tops (typical in large-scale operations).

Additional general procedures for drum opening are as follows:

- If a supplied-air respiratory protection system is used, the bank of air cylinders must be maintained outside of the work area.
- If personnel must be located near the drums being opened, place explosion-resistant plastic shields between them and the drums, in case of detonation. Locate controls for drum opening equipment, monitoring equipment, and fire suppression equipment behind the explosion-resistant plastic shield. Nonessential personnel must be positioned upwind from the drum opening and sampling operations.
- When feasible, monitor air quality continuously during drum opening, and as close as possible to the potential source of contaminants, (i.e., placing probes as close as practical without hindering drum opening operations), and hang or balance the drum opening equipment to minimize exertion.
- Do not use picks, chisels, etc. to open drums manually.
- Open exotic metal drums and polyethylene or polyvinylchloride-lined (PVC-lined) drums by removing or manually drilling the bung, while exercising extreme caution.
- Do not open or sample individual containers within laboratory packs.
- Reseal open bungs and/or drill openings as soon as possible, with new bungs or plugs to avoid explosions and/or vapor generation. If an open drum cannot be resealed, place the drum into an overpack.
- Plug any openings in pressurized drums with pressure venting caps set to a 5-psi release to allow venting of vapor pressure.
- Decontaminate and/or properly dispose of sampling equipment after each use to avoid mixing incompatible wastes and contaminating subsequent samples.

8.4 Drum Sampling

When sampling a previously sealed vessel, check for the presence of bottom sludge. Since some layering or stratification is likely in any solution left undisturbed over time, take a sample that represents the entire depth of the vessel.

The most widely used instrument for sampling is a glass tube commonly referred to as a glass thief (Figure 7, Attachment B). This tool is simple, cost effective, quick and collects a sample without having to decontaminate. Glass thieves are typically 6 mm to 16 mm I.D. and 48 inches long.

Drum sampling can be a very hazardous activity because it often involves direct contact with unidentified wastes. Prior to collecting any sample, field team personnel will become familiar with the procedures identified in the Sampling Plan and in this SOP.

Certain information can be construed from the drumhead configuration prior to sampling, such as:

- Removable "Whole" Lid = designed to contain solid material
- Bung opening = designed to contain liquids
- Drum Liner = may contain a highly corrosive or otherwise hazardous material

When manually sampling from a drum, use the following techniques:

- Keep sampling personnel at a safe distance while drums are being opened. Sample only after opening procedures are complete.

- Do not lean over or between other drums to reach the drum being sampled.

- Cover drum tops with plastic sheeting or other suitable uncontaminated materials to avoid excessive contact with the drum tops.

- Never stand on drums. Use mobile steps or another platform to achieve the height necessary to safely sample from the drums.

- After the drum has been opened, monitor headspace gases with no less than an explosimeter and an organic vapor analyzer. In most cases it is impossible to observe the contents of these sealed or partially sealed vessels.

- Obtain samples with either glass rods (thiefs) or with a vacuum pump and tubing. Do not use contaminated items such as discarded rags during sampling. Glass rods will be removed prior to pumping to minimize damage to pumps.

- Identify each drum with a sample number. Record the number on the Drum Waste Characterization Sheet and permanently on the drum (mark lid and side) using either a label, permanent marker, or spray paint. Cover drums with plastic sheeting and secure to minimize degradation of labeling from variable weather conditions.

8.4.1 Procedures for using a glass thief are as follows:

1. Remove cover from sample container.
2. Insert glass tubing almost to the bottom of the drum or until a solid layer is encountered. About one foot of tubing should extend above the drum.
3. Allow the waste in the drum to reach its natural level in the tube.
4. Cap the top of the sampling tube with a tapered stopper or thumb, ensuring liquid does not come into contact with stopper.
5. Carefully remove the capped tube from the drum and insert the uncapped end in the sample container.
6. Release stopper and allow the glass thief to drain until the container is approximately 2/3 full.
7. Remove tube from the sample container.
8. Cap the sample container tightly and place prelabeled sample container in a carrier.
9. Replace bung or lid securely on drum.
10. Break the thief into pieces inside a drum which has been designated for solid hazardous waste disposal. Previously, drum thiefs were broken and disposed inside the drum being sampled. However, this activity hinders the future disposal of liquid drum contents by introducing solid material.
11. Log all samples in the site logbook and on field data sheets.
12. Package samples and complete necessary paperwork.
13. Transport sample to decontamination zone in preparation for transport to analytical laboratory.

8.4.2 COLIWASA Sampler

The Composite Liquid Waste Sampler (COLIWASA) is designed to collect a sample from the full depth of a drum and maintain it in the transfer tube until delivery to the sample bottle. The COLIWASA (Figure 8, Attachment B) is a much cited sampler designed to permit representative sampling of multiphase wastes from drums and other containerized materials. One configuration consists of a 152 cm x 4 cm inside diameter (I.D.) section of tubing with a neoprene stopper at one end attached by a rod running the length of the tube to a locking mechanism at the other end. Manipulation of the locking mechanism opens and closes the sampler by raising and lowering the neoprene stopper.

9.0 QUALITY ASSURANCES/QUALITY CONTROL

The following quality assurance procedures apply:

- Document all data on standard chain of custody forms, field data sheets and/or within site logbooks.
- Operate all instrumentation in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the Work Plan and Sampling Plan. Equipment checkout and calibration activities must occur prior to sampling/operation, and must be documented in the field logbook.

Quality assurance records shall consist of completed Drum Waste Characterization Sheets and data entered into the Field Logbook. A sample Drum Waste Characterization Sheet is presented as Attachment A. Attachment B contains example figures of drum sampling equipment.

10.0 REFERENCES

NIOSH/OSHA/USCG/EPA, 1985. Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. Publication No. 85-115.

U.S. EPA, 1986. Drum Handling Practices at Hazardous Waste Sites. Wetzel, Furman, Wickline, and Hodge, JRB Associates, McLean, Virginia. Publication No. 86-165362.

NIOSH, 1990. NIOSH Pocket Guide to Chemical Hazards. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Cincinnati, Ohio. Publication No. 90-117.

U.S. EPA, 1991 Compendium of ERT Waste Sampling Procedures. OSWER Directive 9360.4-07. EPA/540/P-91/008

ATTACHMENT A

DRUM WASTE CHARACTERIZATION SHEET

Baker
Baker Environmental, Inc.

Drum/Sample No.

DRUM WASTE CHARACTERIZATION SHEET

Project Location ______________________ Project No. ______________

Project Manager ______________________ Telephone ______________

Logger ______________________ Sampler ______________

Weather ______________________ Date __________ Time __________

Drum Type: ☐ Fiber ☐ Steel ☐ Poly ☐ Stainless Steel ☐ Nickel
☐ Poly-Lined ☐ Ring Top ☐ Closed Top ☐ Overpacked

Drum Size: 85 ☐ 55 ☐ 42 ☐ 30 ☐ 16 ☐ 10 ☐ 5 ☐ Other __________

Drum Contents: Amount Full ☐ 3/4 ☐ 1/2 ☐ 1/4 ☐ <1/4 ☐ MT ☐

Drum Condition: Good ☐ Fair ☐ Poor ☐

	Physical State				Color	Clarity			Layer Thickness (inches)
	Liquid	Solid	Gel	Sludge	Use Std. Colors	Clear	Cloudy	Opaque	
Top									
Middle									
Bottom									

pH __________ PID __________ ppm

Rad Meter ______________ mr/hr

Other ______________________

____

MFG Name ______________________

Chemical Name ______________________

Additional Information: ______________________

____

LABORATORY COMPATIBILITY ANALYSES

	Physical State				Color	Clarity			Water Sol.	React.	pH	Hex. Sol.	Per.	Oxid.	CN	Sul.	Biel-Stein	Flash Point
	Liquid	Solid	Gel	Sludge	Use Std. Colors	Clear	Cloudy	Opaque	Sol. S or I Density	A- Air W - Water	Std. Unit	S or I	+ or -	+ or -	+ or -	+ or -	+ or -	°C or °F
Top																		
Middle																		
Bottom																		

Comments: ______________________

PCB Conc. __________ ppm Flash Point __________ °C

Data Reviewer ______________________ Compatibility Comp. Bulk No. __________

Field Reviewer ______________________

ATTACHMENT B

LIST OF FIGURES

Figure 1: Universal Bung Wrench

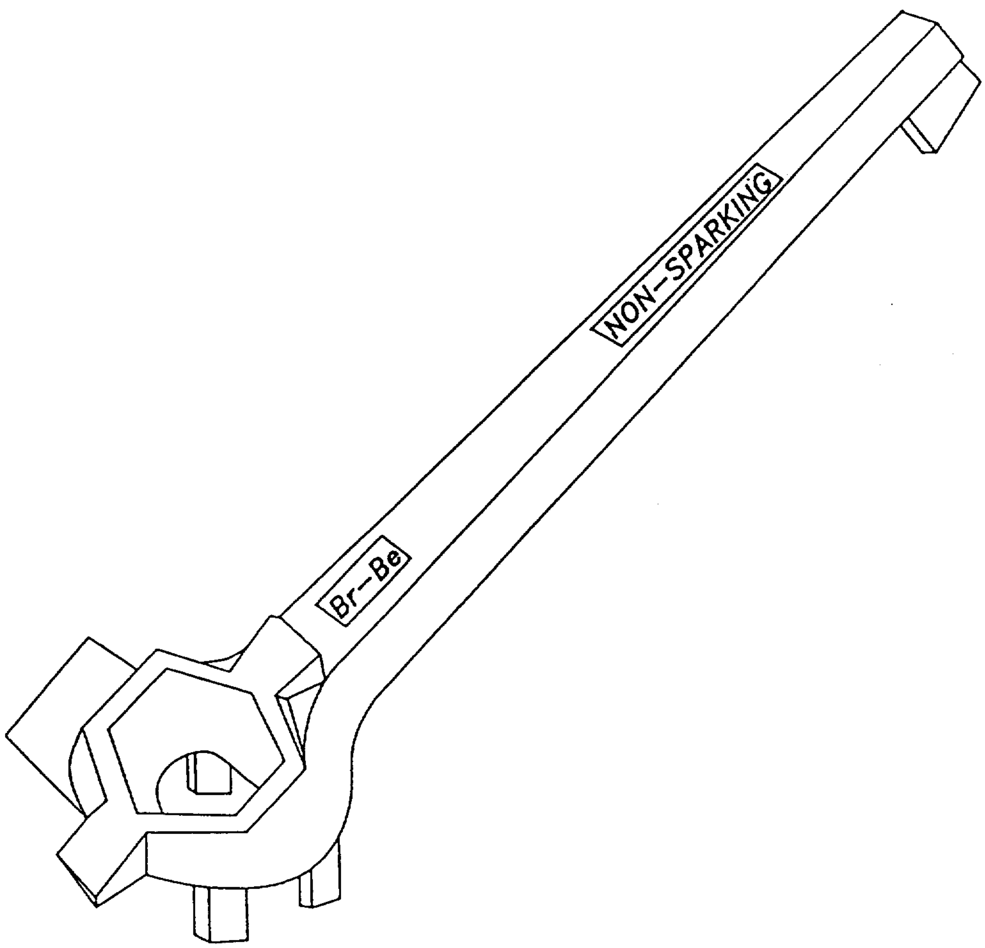


Figure 2: Drum Deheader

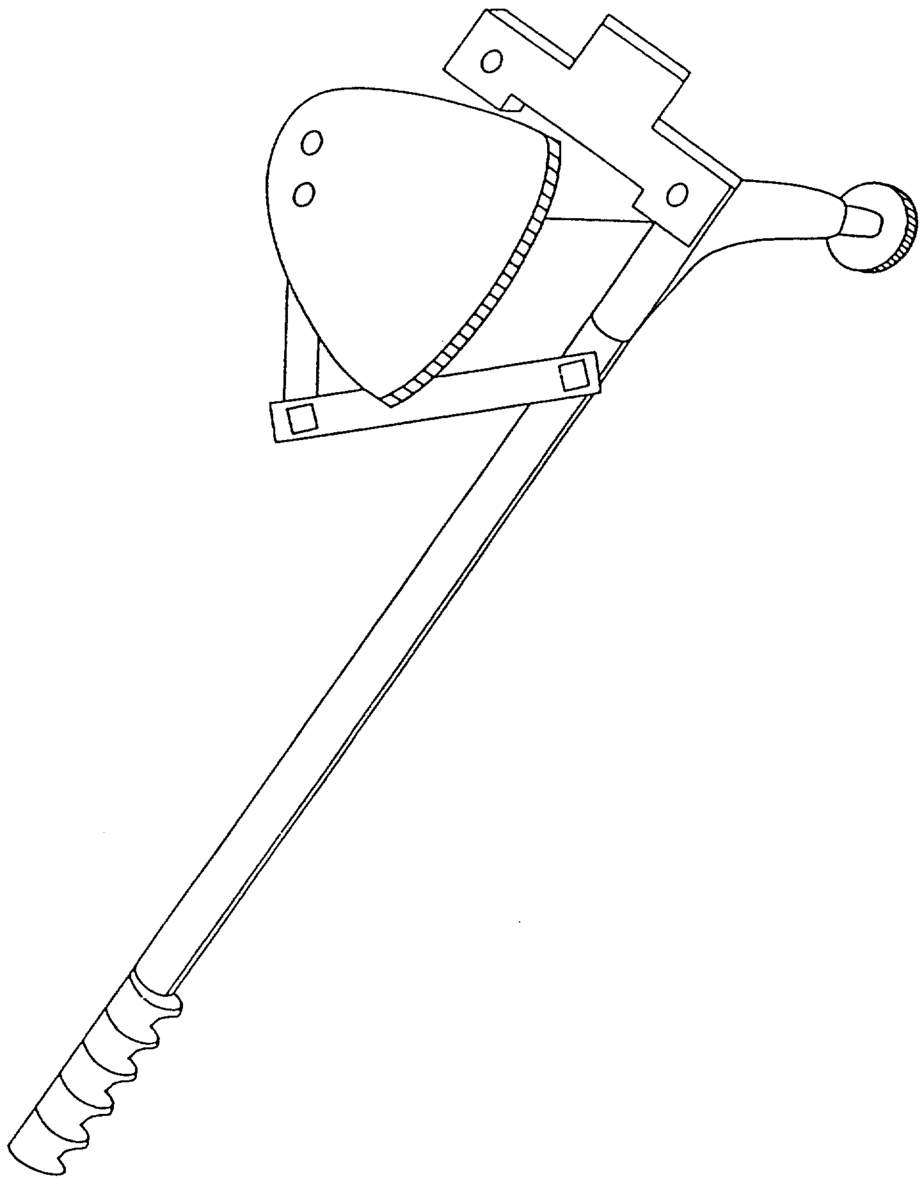


Figure 3: Hand Pick, Pickaxe, and Hand Spike

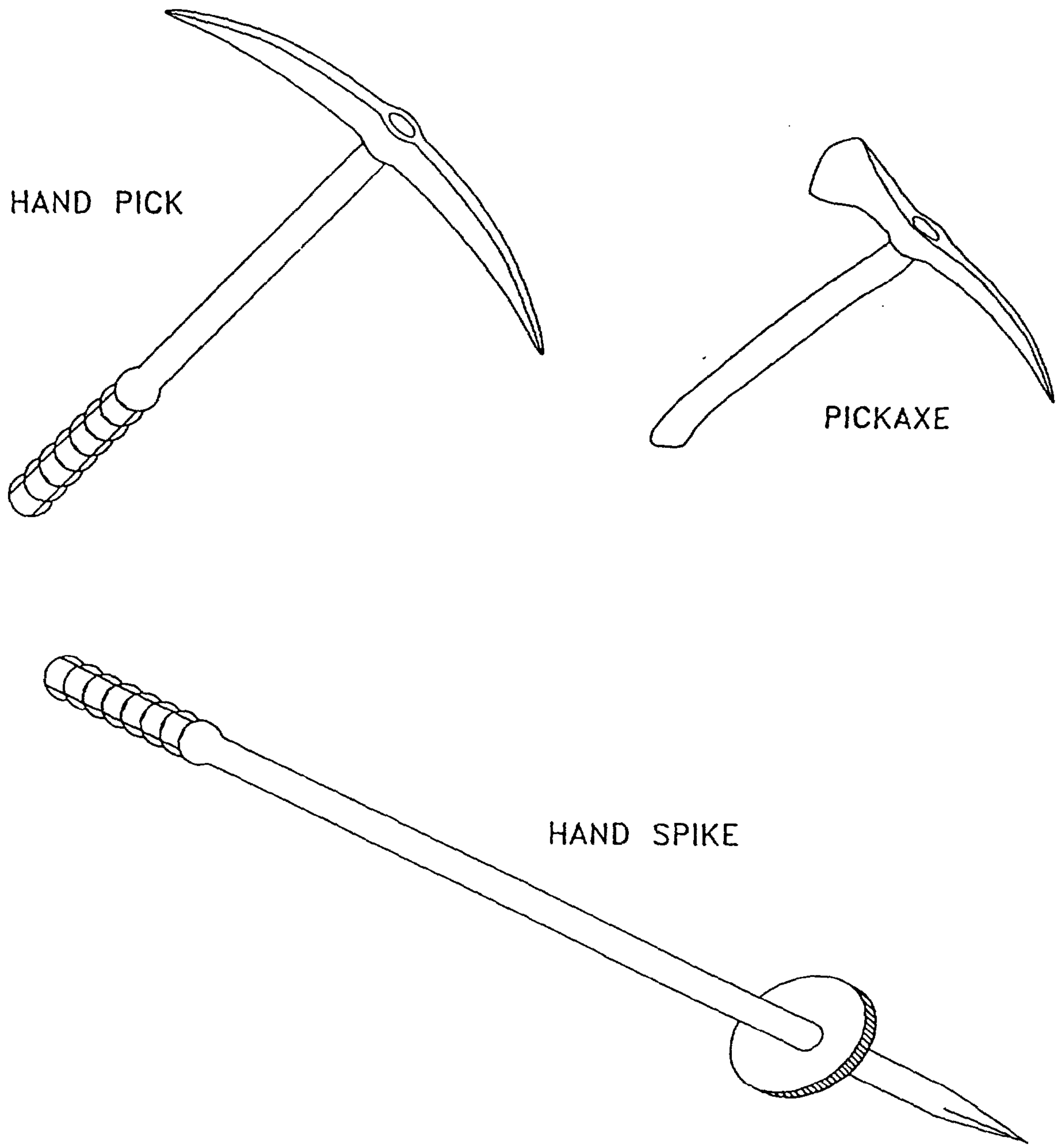


Figure 4: Backhoe Spike

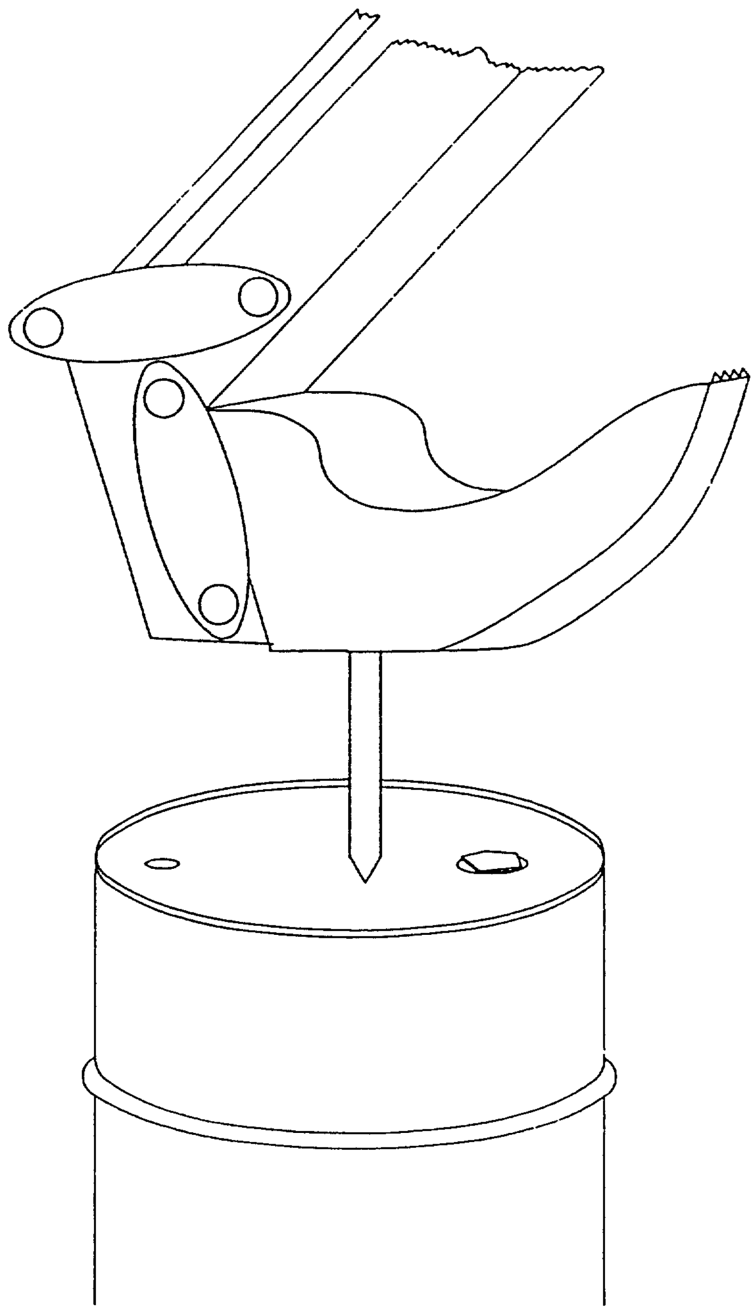


Figure 5: Hydraulic Drum Opener

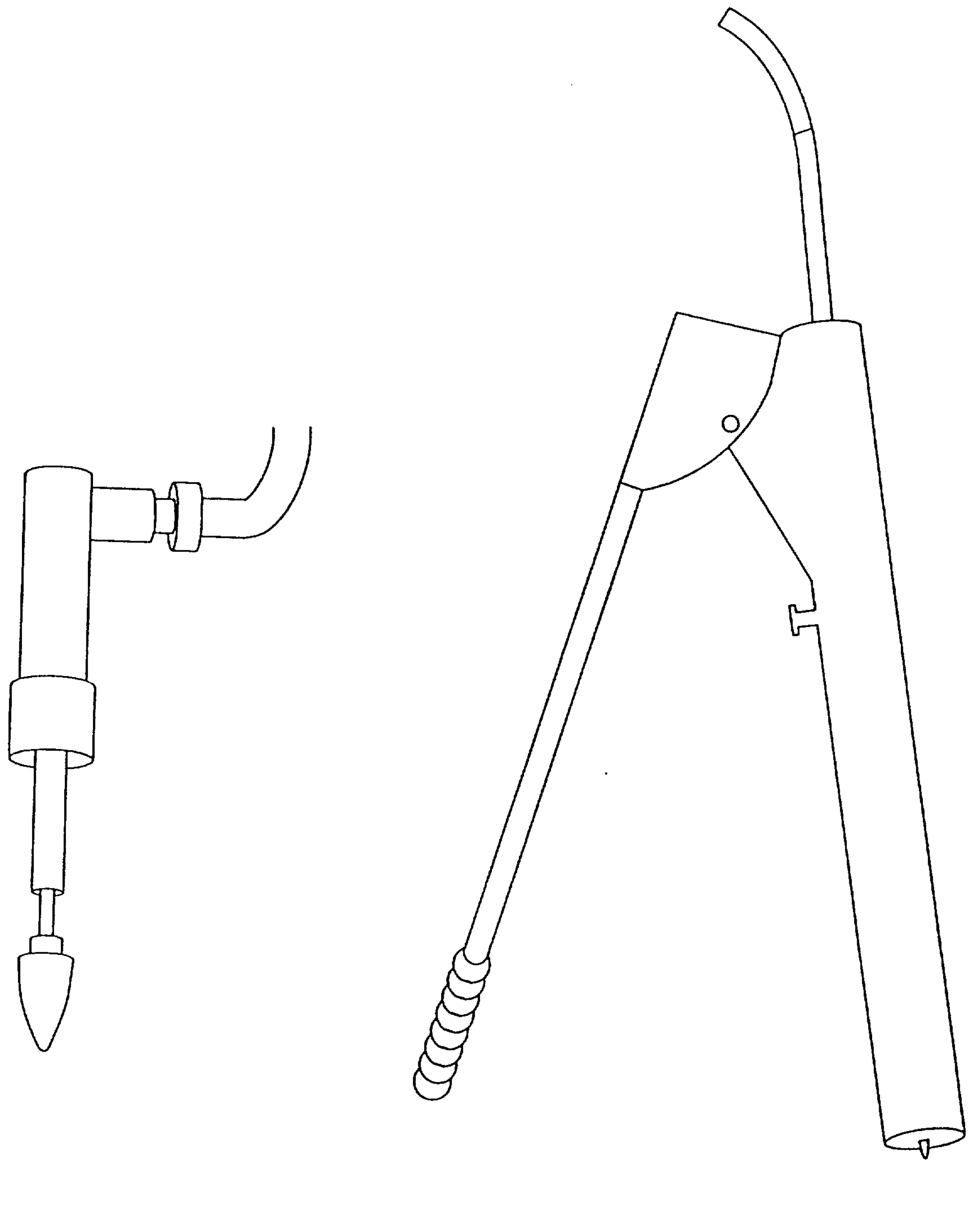


Figure 6: Pneumatic Bung Remover

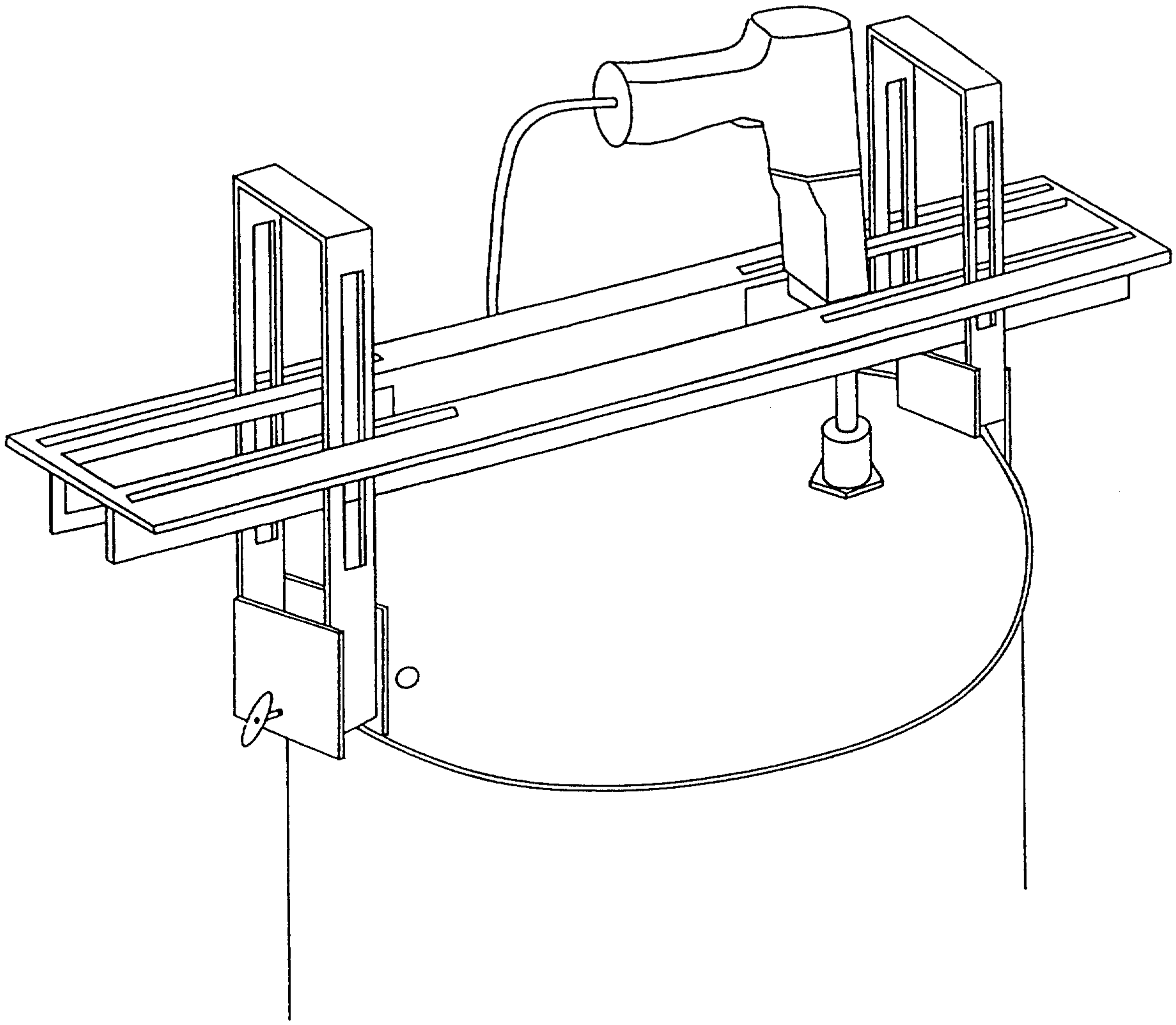
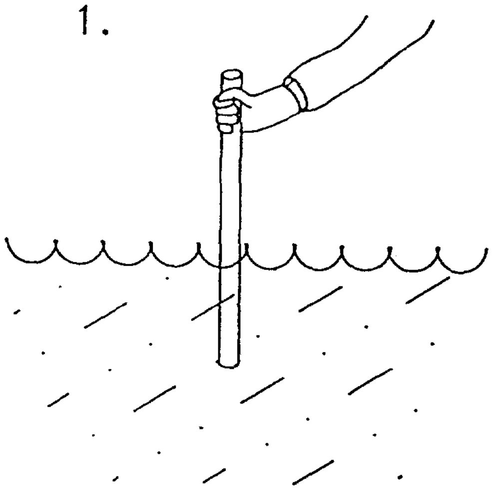


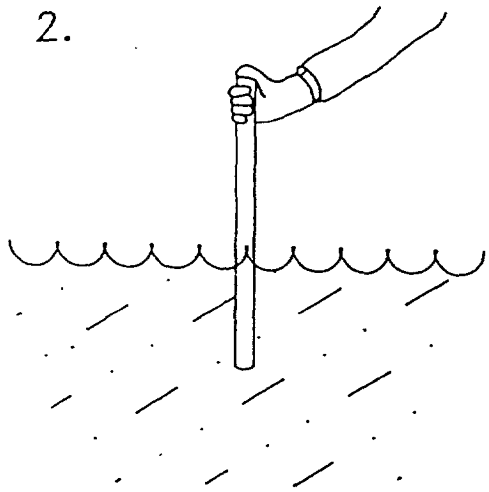
Figure 7: Glass Thief

1.



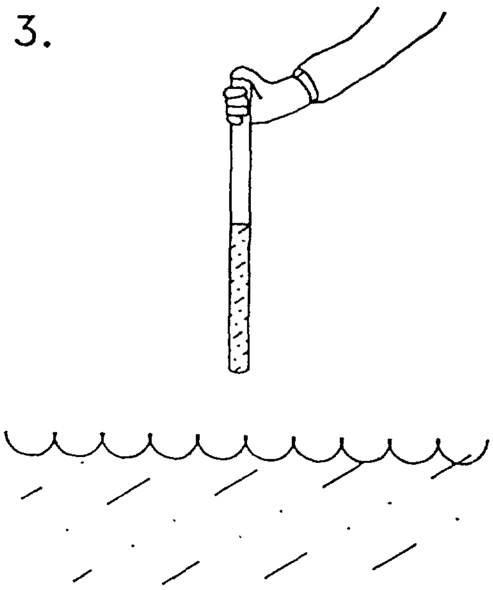
Insert open tube (thief) sampler in containerized liquid.

2.



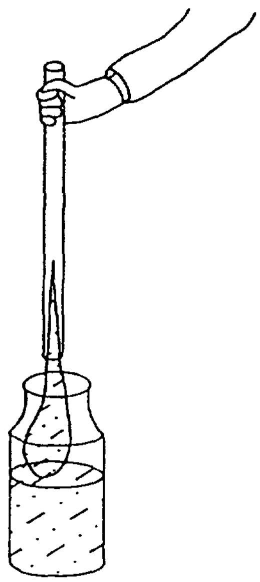
Cover top of sampler with gloved thumb.

3.



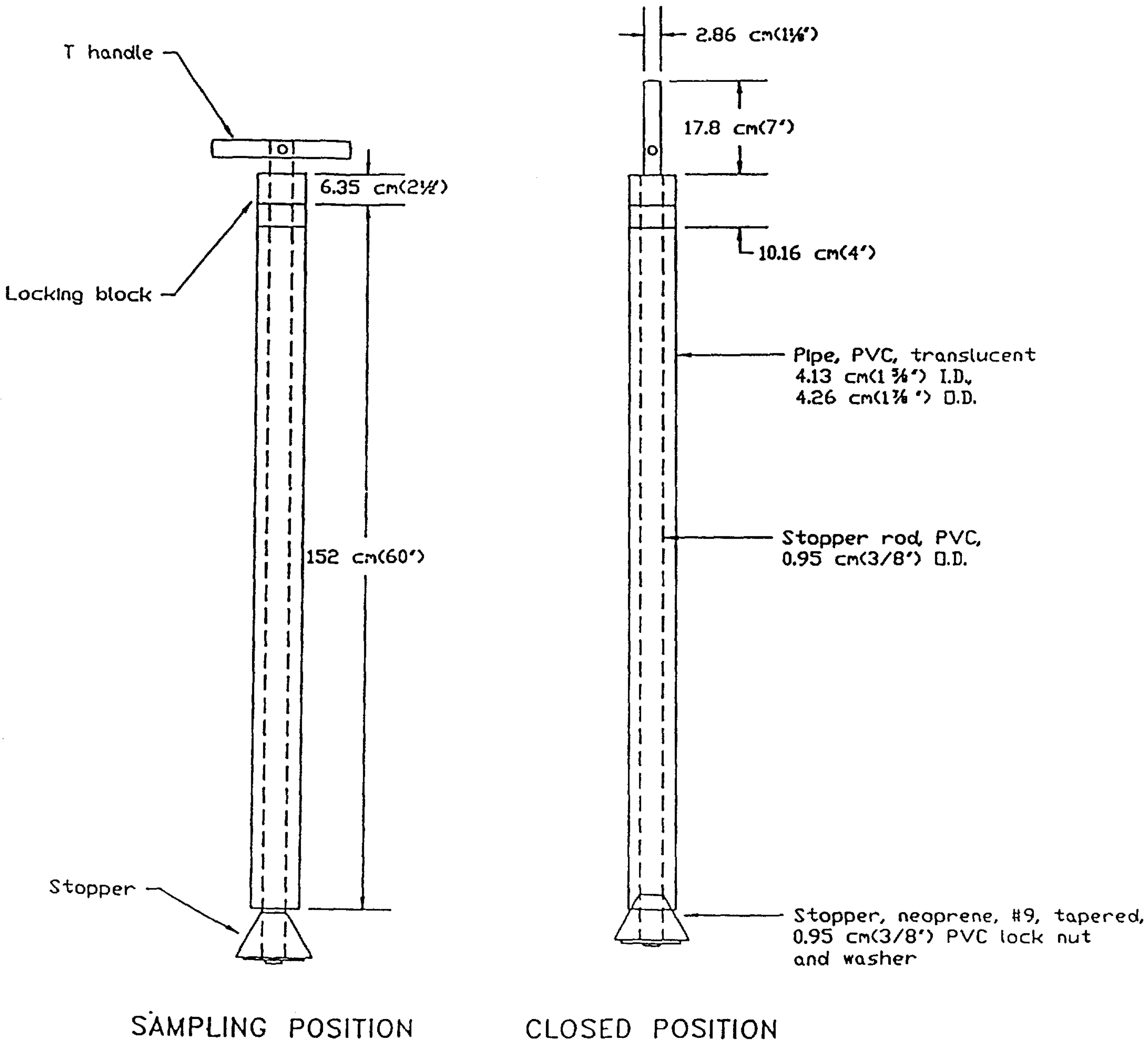
Remove open tube (thief) sampler from containerized liquid.

4.



Place open tube sampler over appropriate sample bottle and remove gloved thumb.

Figure 8: COLIWASA



APPENDIX L
WASTEWATER SAMPLE ACQUISITION

WASTEWATER SAMPLE ACQUISITION
TABLE OF CONTENTS

WASTEWATER SAMPLE ACQUISITION

1.0 PURPOSE

The purpose of this SOP is to provide general reference information for collecting wastewater samples.

2.0 SCOPE

This procedure provides information for the acquisition of waste water samples. Review of the information contained herein will ensure that sample acquisition is properly conducted.

3.0 DEFINITIONS

Sampling Plan - A "plan of action" that guides the implementation of methods that will lead to achieving the plans objective(s).

Grab Sample - An entire sample which is collected at one specific sample location at a specific point in time.

Composite Sample - A sample which is collected at several different locations and/or at different points in time.

Environmental Sample - Samples of naturally occurring materials; soil, sediment, air, water.

Waste Sample - Samples which are comprised of process wastes or other manmade waste material(s).

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project specific plans are in accordance with procedures where applicable, or that other approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the waste water sample acquisition techniques and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the Field Investigation personnel performing the sample acquisition activities have been briefed and trained to execute these procedures.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project specific procedures as outlined in the Work Plan and as directed by the Field Team Leader and Project Manager. The Field Investigation Personnel are responsible for documenting all wastewater sampling activities and ambient air monitoring results in the field log book.

5.0 PROCEDURES

This protocol outlines procedures and equipment for the collection of representative liquid samples and sediment/sludge samples from standing lakes, ponds and lagoons, and flowing streams, rivers, channels, sewers and leachate seeps.

The collection of samples from these sources presents a unique challenge. Often sampling can be quite easy and routine (e.g., collecting a surface water sample from a two foot deep stream). Other times, the nature of site specific conditions may dictate that: 1) special equipment is needed to access the sample, 2) appropriate health and safety measures are critical, 3) proper timing is essential due to waste release times or tidal fluctuations, and/or 4) wastewater flow rate is a factor for consideration.

Prior to sample collection, impoundment characteristics (size, depth, flow) should be recorded in the field log book. Sampling should proceed from downstream locations to upstream locations so that sediment disturbance (turbidity) caused by sampling does not affect sample quality. Additionally, if a sediment sample will be collected at the same location as a liquid sample, the liquid sample must be collected first to minimize sample turbidity.

If the Sampling Plan requires that samples are to be collected from the shore of an impoundment, specific health and safety considerations must be addressed. The person collecting the sample should be fitted with a safety harness and rope secured to a sturdy, immobile object on shore. Backup personnel should be available to assist in sample collection and should be prepared and able to pull the sampler to safety if unstable banks are encountered.

To more adequately characterize the content and/or quality of an impoundment, samples may be collected away from the shoreline, often at various depths. If the content of the impoundment is suspected to be highly hazardous, the risk to sampling personnel must be weighed against the need to collect the sample. If a barge or boat is used, each person on the vessel must be equipped with a life preserver and/or lifeline.

The sampling of liquids in lakes, ponds, lagoons, streams, rivers, channels, sewers and leachate seeps is generally accomplished through the use of one of the following samplers:

- Laboratory cleaned sample bottle
- Pond sampler
- Weighted bottle sampler
- Wheaton dip sampler
- Kemmerer Depth Sampler
- Bacon Bomb Sampler

The factors that will contribute to the selection of a sampler include the width, depth and flow of the location being sampled, and whether the sample will be collected from the shore or a vessel.

For flowing liquids, tidal influence on the collected sample is an additional concern and should be addressed in the Sampling Plan. At a minimum, the stage of the tide at the time of sample collection should be recorded. Consideration should be given to sampling at varied tidal stages as well as seasonally. Tidal information can be obtained from local bait shops, newspaper listings and/or local radio or television news reports.

Samplers may encounter situations where rate of flow affects their ability to collect a sample. For fast flowing rivers and steams it may be nearly impossible to collect a mid-channel sample at a specific point. Low flowing streams and leachate seeps present the opposite problem. In these cases the sampler should attempt to locate an area where flow is obstructed and a pool is created. If this is not possible, sediment may be dug with a decontaminated trowel to create a pooled area where sufficient liquid will accumulate for sampling.

5.1 On-Shore

If the banks are not sloped, sampling personnel may be able to collect the liquid directly into the sample bottle. In some instances where access is limited, a pond sampler, by virtue of its extension capabilities, may be necessary. For a stream, channel or river, collect the sample at mid-depth. For standing liquid, collect the sample from just below the surface or at mid-depth. Once the sample is obtained by sample vessel, transfer it directly into the sample bottle. If volatile organic compounds (VOCs) are to be analyzed, fill the appropriate sample containers for VOCs first, then fill sample containers for other chemical analyses. Decontaminate the sampling device following procedures outlined in the Sampling Plan and/or SOP F502 before obtaining the next sample.

5.2 Off-Shore

Collect a liquid sample using the sample bottle or decontaminated pond sampler, if necessary. If the liquid has stratified, a sample of each strata should be collected. One of the depth samplers listed above will allow collection of discrete representative liquid samples at various depths. Proper use of the chosen sampling device includes slowly lowering and careful retrieval of the sample, immediate transfer of the liquid into the appropriate sampling container, and logbook notation of the depth at which the sample was collected. After collection, the sampling device must be decontaminated prior to obtaining the next sample.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records shall consist of recording sample date and acquisition time(s), sample number, sample location(s), sample depth(s), name of the Field Investigation Personnel collecting the sample(s), and Service Order Number in the field logbook. The type of container used to hold the sample and preservative agent, if needed, also will be documented, as will the method of sampling equipment decontamination. In addition, if photographs are taken of the sample site, the photograph number and direction of view shall be recorded as well.

7.0 REFERENCES

Field Sampling Procedures Manual. Chapter 8. New Jersey Department of Environmental Protection, Trenton, New Jersey. February 1988.

Sampling and Analysis Methods. Compilation of EPA's Sampling and Analysis Methods, USEPA, Washington, D.C. 1991.

Characterization of Hazardous Waste Sites. USEPA, Washington, D. C. 1990.

APPENDIX M
WASTEWATER SAMPLE ACQUISITION

WASTEWATER SAMPLE ACQUISITION
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WASTEWATER SAMPLE ACQUISITION

1.0 PURPOSE

The purpose of this SOP is to provide general reference information for collecting wastewater samples.

2.0 SCOPE

This procedure provides information for the acquisition of waste water samples. Review of the information contained herein will ensure that sample acquisition is properly conducted.

3.0 DEFINITIONS

Sampling Plan - A "plan of action" that guides the implementation of methods that will lead to achieving the plans objective(s).

Grab Sample - An entire sample which is collected at one specific sample location at a specific point in time.

Composite Sample - A sample which is collected at several different locations and/or at different points in time.

Environmental Sample - Samples of naturally occurring materials; soil, sediment, air, water.

Waste Sample - Samples which are comprised of process wastes or other manmade waste material(s).

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project specific plans are in accordance with procedures where applicable, or that other approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the waste water sample acquisition techniques and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the Field Investigation personnel performing the sample acquisition activities have been briefed and trained to execute these procedures.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project specific procedures as outlined in the Work Plan and as directed by the Field Team Leader and Project Manager. The Field Investigation Personnel are responsible for documenting all wastewater sampling activities and ambient air monitoring results in the field log book.

5.0 PROCEDURES

This protocol outlines procedures and equipment for the collection of representative liquid samples and sediment/sludge samples from standing lakes, ponds and lagoons, and flowing streams, rivers, channels, sewers and leachate seeps.

The collection of samples from these sources presents a unique challenge. Often sampling can be quite easy and routine (e.g., collecting a surface water sample from a two foot deep stream). Other times, the nature of site specific conditions may dictate that: 1) special equipment is needed to access the sample, 2) appropriate health and safety measures are critical, 3) proper timing is essential due to waste release times or tidal fluctuations, and/or 4) wastewater flow rate is a factor for consideration.

Prior to sample collection, impoundment characteristics (size, depth, flow) should be recorded in the field log book. Sampling should proceed from downstream locations to upstream locations so that sediment disturbance (turbidity) caused by sampling does not affect sample quality. Additionally, if a sediment sample will be collected at the same location as a liquid sample, the liquid sample must be collected first to minimize sample turbidity.

If the Sampling Plan requires that samples are to be collected from the shore of an impoundment, specific health and safety considerations must be addressed. The person collecting the sample should be fitted with a safety harness and rope secured to a sturdy, immobile object on shore. Backup personnel should be available to assist in sample collection and should be prepared and able to pull the sampler to safety if unstable banks are encountered.

To more adequately characterize the content and/or quality of an impoundment, samples may be collected away from the shoreline, often at various depths. If the content of the impoundment is suspected to be highly hazardous, the risk to sampling personnel must be weighed against the need to collect the sample. If a barge or boat is used, each person on the vessel must be equipped with a life preserver and/or lifeline.

The sampling of liquids in lakes, ponds, lagoons, streams, rivers, channels, sewers and leachate seeps is generally accomplished through the use of one of the following samplers:

- Laboratory cleaned sample bottle
- Pond sampler
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- Wheaton dip sampler
- Kemmerer Depth Sampler
- Bacon Bomb Sampler

The factors that will contribute to the selection of a sampler include the width, depth and flow of the location being sampled, and whether the sample will be collected from the shore or a vessel.

For flowing liquids, tidal influence on the collected sample is an additional concern and should be addressed in the Sampling Plan. At a minimum, the stage of the tide at the time of sample collection should be recorded. Consideration should be given to sampling at varied tidal stages as well as seasonally. Tidal information can be obtained from local bait shops, newspaper listings and/or local radio or television news reports.

Samplers may encounter situations where rate of flow affects their ability to collect a sample. For fast flowing rivers and steams it may be nearly impossible to collect a mid-channel sample at a specific point. Low flowing streams and leachate seeps present the opposite problem. In these cases the sampler should attempt to locate an area where flow is obstructed and a pool is created. If this is not possible, sediment may be dug with a decontaminated trowel to create a pooled area where sufficient liquid will accumulate for sampling.

5.1 On-Shore

If the banks are not sloped, sampling personnel may be able to collect the liquid directly into the sample bottle. In some instances where access is limited, a pond sampler, by virtue of its extension capabilities, may be necessary. For a stream, channel or river, collect the sample at mid-depth. For standing liquid, collect the sample from just below the surface or at mid-depth. Once the sample is obtained by sample vessel, transfer it directly into the sample bottle. If volatile organic compounds (VOCs) are to be analyzed, fill the appropriate sample containers for VOCs first, then fill sample containers for other chemical analyses. Decontaminate the sampling device before obtaining the next sample.

5.2 Off-Shore

Collect a liquid sample using the sample bottle or decontaminated pond sampler, if necessary. If the liquid has stratified, a sample of each strata should be collected. One of the depth samplers listed above will allow collection of discrete representative liquid samples at various depths. Proper use of the chosen sampling device includes slowly lowering and careful retrieval of the sample, immediate transfer of the liquid into the appropriate sampling container, and logbook notation of the depth at which the sample was collected. After collection, the sampling device must be decontaminated prior to obtaining the next sample.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records shall consist of recording sample date and acquisition time(s), sample number, sample location(s), sample depth(s), name of the Field Investigation Personnel collecting the sample(s), and Service Order Number in the field logbook. The type of container used to hold the sample and preservative agent, if needed, also will be documented, as will the method of sampling equipment decontamination. In addition, if photographs are taken of the sample site, the photograph number and direction of view shall be recorded as well.

7.0 REFERENCES

Field Sampling Procedures Manual. Chapter 8. New Jersey Department of Environmental Protection, Trenton, New Jersey. February 1988.

Sampling and Analysis Methods. Compilation of EPA's Sampling and Analysis Methods, USEPA, Washington, D.C. 1991.

Characterization of Hazardous Waste Sites. USEPA, Washington, D. C. 1990.

APPENDIX N
CHAIN-OF-CUSTODY

CHAIN-OF-CUSTODY
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CHAIN-OF-CUSTODY

1.0 PURPOSE

The purpose of this SOP is to provide information on chain-of-custody procedures to be used to document sample handling.

2.0 SCOPE

This procedure describes the steps necessary for transferring samples through the use of Chain-of-Custody Records. A Chain-of-Custody Record is required, without exception, for the tracking and recording of samples collected for on-site or off-site analysis (chemical or geotechnical) during program activities (except wellhead samples taken for measurement of field parameters, SOP F101). Use of the Chain-of-Custody Record Form creates an accurate written record that can be used to trace the possession and handling of the sample from the moment of its collection through analysis. This procedure identifies the necessary custody records and describes their completion. This procedure does not take precedence over region-specific or site-specific requirements for chain-of-custody.

3.0 DEFINITIONS

Chain-of-Custody Record Form - A Chain-of-Custody Record Form is a printed two-part form that accompanies a sample or group of samples as custody of the sample(s) is transferred from one custodian to another custodian. One copy of the form must be retained in the project file.

Custodian - The person responsible for the custody of samples at a particular time, until custody is transferred to another person (and so documented), who then becomes custodian. A sample is under one's custody if:

- It is in one's actual possession.
- It is in one's view, after being in one's physical possession.
- It was in one's physical possession and then he/she locked it up to prevent tampering.
- It is in a designated and identified secure area.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the point and time that it was collected.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein. The Project Manager is responsible for ensuring that chain-of-custody procedures are implemented. The Project Manager also is responsible for determining that custody procedures have been met by the analytical laboratory.

Field Team Leader - The Field Team Leader is responsible for determining that chain-of-custody procedures are implemented up to and including release to the shipper or laboratory. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to initiate chain-of-custody procedures, and maintain custody of samples until they are relinquished to another custodian, the sample shipper, or to a common carrier.

5.0 PROCEDURES

The term "chain-of-custody" refers to procedures which ensure that evidence presented in a court of law is valid. The chain-of-custody procedures track the evidence from the time and place it is first obtained to the courtroom, as well as providing security for the evidence as it is moved and/or passed from the custody of one individual to another.

Chain-of-custody procedures, recordkeeping, and documentation are an important part of the management control of samples. Regulatory agencies must be able to provide the chain-of-possession and custody of any samples that are offered for evidence, or that form the basis of analytical test results introduced as evidence. Written procedures must be available and followed whenever evidence samples are collected, transferred, stored, analyzed, or destroyed.

5.1 Sample Identification

The method of identification of a sample depends on the type of measurement or analysis performed. When in-situ measurements are made, the data are recorded directly in bound logbooks or other field data records with identifying information.

Information which shall be recorded in the field logbook, when in-situ measurements or samples for laboratory analysis are collected, includes:

- Field Sampler(s)
- CTO Number
- Project Sample Number
- Sample location or sampling station number
- Date and time of sample collection and/or measurement
- Field observations
- Equipment used to collect samples and measurements
- Calibration data for equipment used

Measurements and observations shall be recorded using waterproof ink.

5.1.1 Sample Label

Samples, other than in-situ measurements, are removed and transported from the sample location to a laboratory or other location for analysis. Before removal, however, a sample is often divided into portions, depending upon the analyses to be performed. Each portion is preserved in accordance with the Sampling and Analysis Plan. Each sample container is identified by a sample label (see Attachment A). Sample labels are provided, along with sample containers, by the analytical laboratory. The information recorded on the sample label includes:

- Project or Contract Task Order (CTO) Number.
- Station Location - The unique sample number identifying this sample.
- Date - A six-digit number indicating the day, month, and year of sample collection (e.g., 12/21/85).
- Time - A four-digit number indicating the 24-hour time of collection (for example: 0954 is 9:54 am., and 1629 is 4:29 p.m.).
- Medium - Water, soil, sediment, sludge, waste, etc.
- Sample Type - Grab or composite.
- Preservation - Type and quantity of preservation added.
- Analysis - VOA, BNAs, PCBs, pesticides, metals, cyanide, other.
- Sampled By - Printed name of the sampler.
- Remarks - Any pertinent additional information.

Using only the work assignment number of the sample label maintains the anonymity of sites. This may be necessary, even to the extent of preventing the laboratory performing the analysis from knowing the identity of the site (e.g., if the laboratory is part of an organization that has performed previous work on the site).

5.2 Chain-of-Custody Procedures

After collection, separation, identification, and preservation, the sample is maintained under chain-of-custody procedures until it is in the custody of the analytical laboratory and has been stored or disposed.

5.2.1 Field Custody Procedures

- Samples are collected as described in the site Sampling and Analysis Plan. Care must be taken to record precisely the sample location and to ensure that the sample number on the label matches the Chain-of-Custody Record exactly.

- The person undertaking the actual sampling in the field is responsible for the care and custody of the samples collected until they are properly transferred or dispatched.

- When photographs are taken of the sampling as part of the documentation procedure, the name of the photographer, date, time, site location, and site description are entered sequentially in the site logbook as photos are taken. Once developed, the photographic prints shall be serially numbered, corresponding to the logbook descriptions; photographs will be stored in the project files. It is good practice to identify sample locations in photographs by including an easily read sign with the appropriate sample/location number.

- Sample labels shall be completed for each sample, using waterproof ink unless prohibited by weather conditions, e.g., a logbook notation would explain that a pencil was used to fill out the sample label if the pen would not function in freezing weather.

5.2.2 Transfer of Custody and Shipment

Samples are accompanied by a Chain-of-Custody Record Form. A Chain-of-Custody Record Form example is shown in Attachment B. When transferring the possession of samples, the individual(s) relinquishing and receiving will sign, date, and note the time on the Record. This Record documents sample custody transfer from the sampler, often through another person, to the analyst in the laboratory. The Chain-of-Custody Record is filled out as given below.

- Enter header information (CTO number, samplers, and project name).

- Enter sample specific information (sample number, media, sample analysis required and analytical method, grab or composite, number and type of sample containers, and date/time sample was collected).

- Sign, date, and enter the time under "Relinquished by" entry.

- Have the person receiving the sample sign the "Received by" entry. If shipping samples by a common carrier, print the carrier to be used in this space (i.e., Federal Express).

- If a carrier is used, enter the airbill number under "Remarks," in the bottom right corner;

- Place the original (top, signed copy) of the Chain-of-Custody Record Form in a plastic zipper-type bag or other appropriate sample shipping package. Retain the copy with field records.

- Sign and date the custody seal, a 1- by 3-inch white paper label with black lettering and an adhesive backing. Attachment C is an example of a custody seal. The custody seal is part of the chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field. Custody seals shall be provided by the analytical laboratory.

- Place the seal across the shipping container opening so that it would be broken if the container was to be opened.

- Complete other carrier-required shipping papers.

The custody record is completed using waterproof ink. Any corrections are made by drawing a line through and initialing and dating the change, then entering the correct information. Erasures are not permitted.

Common carriers will usually not accept responsibility for handling Chain-of-Custody Record Forms; this necessitates packing the record in the shipping container (enclosed with other documentation in a plastic zipper-type bag). As long as custody forms are sealed inside the shipping container and the custody seals are intact, commercial carriers are not required to sign the custody form.

The laboratory representative who accepts the incoming sample shipment signs and dates the Chain-of-Custody Record, completing the sample transfer process. It is then the laboratory's responsibility to maintain internal logbooks and custody records throughout sample preparation and analysis.

6.0 QUALITY ASSURANCE RECORDS

Once samples have been packaged and shipped, the COC copy and airbill receipt becomes part of the Quality Assurance Record.

7.0 REFERENCES

1. USEPA. User's Guide to the Contract Laboratory Program. Office of Emergency and Remedial Response, Washington, D.C. (EPA/540/P-91/002), January 1991.

ATTACHMENT A

EXAMPLE SAMPLE LABEL

ATTACHMENT A

EXAMPLE SAMPLE LABEL

Baker	Baker Environmental Inc. Airport Office Park, Bldg. 3 420 Rouser Road Coraopolis, PA 15108

Project: 19026-SRN CTO No.: 0026

Sample Description: Groundwater

Date: 09/17/92 Sampler: ABC

Time: 0944

Analysis: TAL Metals (CAP) Preservation: HNO_3

Project Sample No.: CAX-GW-04

Note: Typically, sample labels are provided by the analytical laboratory and may be used instead of the above. However, samplers should make sure all pertinent information can be affixed to the label used.

ATTACHMENT B

EXAMPLE CHAIN-OF-CUSTODY RECORD

Baker
Baker Environmental, Inc.

Baker Environmental, Inc.
Airport Office Park, Bldg. 3
420 Rouser Road
Coraopolis, PA 15108
412-269-6000
412-269-6097 (fax)

CHAIN-OF-CUSTODY RECORD

Pg. __ of __

Project Number: ____________
Project Name: ____________
Field Team: ____________
SEND RESULTS TO: ____________

Sample Number	Date	Time	Sample Location	Matrix Type (1) GB (2)	Matrix Type (1) COM. (2)	Analytical Methods / Preservatives — Type of Container(s) (3) — Number of Container(s)												General Comments — Remarks

Relinquished By: ____________ Date: ______ Time: ______
Received By: ____________ Date: ______ Time: ______
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ ____________

Relinquished By: ____________ Date: ______ Time: ______
Received By: ____________ Date: ______ Time: ______
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ ____________

Relinquished By: ____________ Date: ______ Time: ______
Received By: ____________ Date: ______ Time: ______
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ ____________

Sample Stored at 4°C: Yes ☐ No ☐
Chain-of-custody seal on cooler: Yes ☐ Number: ______ No ☐
Analysis turnaround: Priority ☐ ______ hrs. Regular ☐
See Work Order ☐
See Analysis Request Form ☐
Sample Disposal: Return to Baker ☐ Lab Disposal ☐
Archive until: ____________ (date)

NOTES:
(1) A - Air; GW - Groundwater; S - Spring; SO - Soil; SW - Surface water; W - Waste; WP - Wipe; WW - Wastewater
(2) GB - Grab; COM - Composite
(3) P - Plastic; G - Glass

White - Return with analytical results; Yellow - Laboratory Copy; Pink - Field Copy

7/94

ATTACHMENT C

EXAMPLE CUSTODY SEAL

ATTACHMENT C

EXAMPLE CUSTODY SEAL

Baker _____/_____/_____ **Date** ____________________ **Signature** **CUSTODY SEAL**	Baker _____/_____/_____ **Date** ____________________ **Signature** **CUSTODY SEAL**

APPENDIX O
CHAIN-OF-CUSTODY

CHAIN-OF-CUSTODY
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CHAIN-OF-CUSTODY

1.0 PURPOSE

The purpose of this SOP is to provide information on chain-of-custody procedures to be used to document sample handling.

2.0 SCOPE

This procedure describes the steps necessary for transferring samples through the use of Chain-of-Custody Records. A Chain-of-Custody Record is required, without exception, for the tracking and recording of samples collected for on-site or off-site analysis (chemical or geotechnical) during program activities (except wellhead samples taken for measurement of field parameters). Use of the Chain-of-Custody Record Form creates an accurate written record that can be used to trace the possession and handling of the sample from the moment of its collection through analysis. This procedure identifies the necessary custody records and describes their completion. This procedure does not take precedence over region-specific or site-specific requirements for chain-of-custody.

3.0 DEFINITIONS

Chain-of-Custody Record Form - A Chain-of-Custody Record Form is a printed two-part form that accompanies a sample or group of samples as custody of the sample(s) is transferred from one custodian to another custodian. One copy of the form must be retained in the project file.

Custodian - The person responsible for the custody of samples at a particular time, until custody is transferred to another person (and so documented), who then becomes custodian. A sample is under one's custody if:

- It is in one's actual possession.
- It is in one's view, after being in one's physical possession.
- It was in one's physical possession and then he/she locked it up to prevent tampering.
- It is in a designated and identified secure area.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the point and time that it was collected.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein. The Project Manager is responsible for ensuring that chain-of-custody procedures are implemented. The Project Manager also is responsible for determining that custody procedures have been met by the analytical laboratory.

Field Team Leader - The Field Team Leader is responsible for determining that chain-of-custody procedures are implemented up to and including release to the shipper or laboratory. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to initiate chain-of-custody procedures, and maintain custody of samples until they are relinquished to another custodian, the sample shipper, or to a common carrier.

5.0 PROCEDURES

The term "chain-of-custody" refers to procedures which ensure that evidence presented in a court of law is valid. The chain-of-custody procedures track the evidence from the time and place it is first obtained to the courtroom, as well as providing security for the evidence as it is moved and/or passed from the custody of one individual to another.

Chain-of-custody procedures, recordkeeping, and documentation are an important part of the management control of samples. Regulatory agencies must be able to provide the chain-of-possession and custody of any samples that are offered for evidence, or that form the basis of analytical test results introduced as evidence. Written procedures must be available and followed whenever evidence samples are collected, transferred, stored, analyzed, or destroyed.

5.1 Sample Identification

The method of identification of a sample depends on the type of measurement or analysis performed. When in-situ measurements are made, the data are recorded directly in bound logbooks or other field data records with identifying information.

Information which shall be recorded in the field logbook, when in-situ measurements or samples for laboratory analysis are collected, includes:

- Field Sampler(s)
- CTO Number
- Project Sample Number
- Sample location or sampling station number
- Date and time of sample collection and/or measurement
- Field observations
- Equipment used to collect samples and measurements
- Calibration data for equipment used

Measurements and observations shall be recorded using waterproof ink.

5.1.1 Sample Label

Samples, other than in-situ measurements, are removed and transported from the sample location to a laboratory or other location for analysis. Before removal, however, a sample is often divided into portions, depending upon the analyses to be performed. Each portion is preserved in accordance with the Sampling and Analysis Plan. Each sample container is identified by a sample label (see Attachment A). Sample labels are provided, along with sample containers, by the analytical laboratory. The information recorded on the sample label includes:

- Project or Contract Task Order (CTO) Number.
- Station Location - The unique sample number identifying this sample.
- Date - A six-digit number indicating the day, month, and year of sample collection (e.g., 12/21/85).
- Time - A four-digit number indicating the 24-hour time of collection (for example: 0954 is 9:54 am., and 1629 is 4:29 p.m.).
- Medium - Water, soil, sediment, sludge, waste, etc.
- Sample Type - Grab or composite.
- Preservation - Type and quantity of preservation added.
- Analysis - VOA, BNAs, PCBs, pesticides, metals, cyanide, other.
- Sampled By - Printed name of the sampler.
- Remarks - Any pertinent additional information.

Using only the work assignment number of the sample label maintains the anonymity of sites. This may be necessary, even to the extent of preventing the laboratory performing the analysis from knowing the identity of the site (e.g., if the laboratory is part of an organization that has performed previous work on the site).

5.2 Chain-of-Custody Procedures

After collection, separation, identification, and preservation, the sample is maintained under chain-of-custody procedures until it is in the custody of the analytical laboratory and has been stored or disposed.

5.2.1 Field Custody Procedures

- Samples are collected as described in the site Sampling and Analysis Plan. Care must be taken to record precisely the sample location and to ensure that the sample number on the label matches the Chain-of-Custody Record exactly.

- The person undertaking the actual sampling in the field is responsible for the care and custody of the samples collected until they are properly transferred or dispatched.

- When photographs are taken of the sampling as part of the documentation procedure, the name of the photographer, date, time, site location, and site description are entered sequentially in the site logbook as photos are taken. Once developed, the photographic prints shall be serially numbered, corresponding to the logbook descriptions; photographs will be stored in the project files. It is good practice to identify sample locations in photographs by including an easily read sign with the appropriate sample/location number.

- Sample labels shall be completed for each sample, using waterproof ink unless prohibited by weather conditions, e.g., a logbook notation would explain that a pencil was used to fill out the sample label if the pen would not function in freezing weather.

5.2.2 Transfer of Custody and Shipment

Samples are accompanied by a Chain-of-Custody Record Form. A Chain-of-Custody Record Form example is shown in Attachment B. When transferring the possession of samples, the individual(s) relinquishing and receiving will sign, date, and note the time on the Record. This Record documents sample custody transfer from the sampler, often through another person, to the analyst in the laboratory. The Chain-of-Custody Record is filled out as given below.

- Enter header information (CTO number, samplers, and project name).

- Enter sample specific information (sample number, media, sample analysis required and analytical method, grab or composite, number and type of sample containers, and date/time sample was collected).

- Sign, date, and enter the time under "Relinquished by" entry.

- Have the person receiving the sample sign the "Received by" entry. If shipping samples by a common carrier, print the carrier to be used in this space (i.e., Federal Express).

- If a carrier is used, enter the airbill number under "Remarks," in the bottom right corner;

- Place the original (top, signed copy) of the Chain-of-Custody Record Form in a plastic zipper-type bag or other appropriate sample shipping package. Retain the copy with field records.

- Sign and date the custody seal, a 1- by 3-inch white paper label with black lettering and an adhesive backing. Attachment C is an example of a custody seal. The custody seal is part of the chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field. Custody seals shall be provided by the analytical laboratory.

- Place the seal across the shipping container opening so that it would be broken if the container was to be opened.

- Complete other carrier-required shipping papers.

The custody record is completed using waterproof ink. Any corrections are made by drawing a line through and initialing and dating the change, then entering the correct information. Erasures are not permitted.

Common carriers will usually not accept responsibility for handling Chain-of-Custody Record Forms; this necessitates packing the record in the shipping container (enclosed with other documentation in a plastic zipper-type bag). As long as custody forms are sealed inside the shipping container and the custody seals are intact, commercial carriers are not required to sign the custody form.

The laboratory representative who accepts the incoming sample shipment signs and dates the Chain-of-Custody Record, completing the sample transfer process. It is then the laboratory's responsibility to maintain internal logbooks and custody records throughout sample preparation and analysis.

6.0 QUALITY ASSURANCE RECORDS

Once samples have been packaged and shipped, the COC copy and airbill receipt becomes part of the Quality Assurance Record.

7.0 REFERENCES

1. USEPA. User's Guide to the Contract Laboratory Program. Office of Emergency and Remedial Response, Washington, D.C. (EPA/540/P-91/002), January 1991.

ATTACHMENT A

EXAMPLE SAMPLE LABEL

ATTACHMENT A

EXAMPLE SAMPLE LABEL

Baker	Baker Environmental Inc. Airport Office Park, Bldg. 3 420 Rouser Road Coraopolis, PA 15108
Project: 19026-SRN	CTO No.: 0026
Sample Description: Groundwater	
Date: 09/17/92	Sampler: ABC
Time: 0944	
Analysis: TAL Metals (CAP)	Preservation: HNO_3
Project Sample No.: CAX-GW-04	

Note: Typically, sample labels are provided by the analytical laboratory and may be used instead of the above. However, samplers should make sure all pertinent information can be affixed to the label used.

ATTACHMENT B

EXAMPLE CHAIN-OF-CUSTODY RECORD

Baker Environmental, Inc.
Airport Office Park, Bldg. 3
420 Rouser Road
Coraopolis, PA 15108
412-269-6000
412-269-6097 (fax)

CHAIN-OF-CUSTODY RECORD

Project Number: ____________________
Project Name: ____________________
Field Team: ____________________
SEND RESULTS TO: ____________________

Analytical Methods / Preservatives

General Comments

Sample Number	Date	Time	Sample Location	Matrix Type (1) GB (2)	Matrix Type (1) COM. (2)	Type of Container(s) (3) / Number of Container(s)												Remarks

Relinquished By: ____________________ Date: ________ Time: ________
Received By: ____________________ Date: ________ Time: ________
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ ____________________

Relinquished By: ____________________ Date: ________ Time: ________
Received By: ____________________ Date: ________ Time: ________
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ ____________________

Relinquished By: ____________________ Date: ________ Time: ________
Received By: ____________________ Date: ________ Time: ________
Shipped by (check one): Hand ☐ Overnight ☐ Other ☐ ____________________

Sample Stored at 4°C: Yes ☐ No ☐
Chain-of-custody seal on cooler: Yes ☐ Number: ________ No ☐
Analysis turnaround: Priority ☐ ______ hrs. Regular ☐
See Work Order ☐
See Analysis Request Form ☐

Sample Disposal: Return to Baker ☐ Lab Disposal ☐
Archive until: ____________________ (date)

NOTES:

(1) A - Air; GW - Groundwater; S - Spring; SO - Soil; SW - Surface water; W - Waste; WP - Wipe; WW - Wastewater

(2) GB - Grab; COM - Composite

(3) P - Plastic; G - Glass

White - Return with analytical results; Yellow - Laboratory Copy; Pink - Field Copy

ATTACHMENT C

EXAMPLE CUSTODY SEAL

ATTACHMENT C

EXAMPLE CUSTODY SEAL

Baker _____/_____/_____ Date __________________ Signature **CUSTODY SEAL**	Baker _____/_____/_____ Date __________________ Signature **CUSTODY SEAL**

APPENDIX P
FIELD LOGBOOK

FIELD LOGBOOK
TABLE OF CONTENTS

FIELD LOGBOOK

1.0 PURPOSE

This SOP describes the process for maintaining a field logbook.

2.0 SCOPE

The field logbook is a document which records all major on-site activities conducted during a field investigation. At a minimum, the following activities/events shall be recorded in the field logbook by each member of the field crew.

- Arrival/departure of site workers and visitors
- Arrival/departure of equipment
- Sample pickup (sample numbers, carrier, time)
- Sampling activities
- Start or completion of boreholes, monitoring wells, or sampling activities
- Health and safety issues

The field logbook is initiated upon arrival at the site for the start of the first on-site activity. Entries are made every day that on-site activities take place. At least one field logbook shall be maintained per site.

The field logbook becomes part of the permanent site file. Because information contained in the field logbook may be admitted as evidence in legal proceedings, it is critical that this document is properly maintained.

3.0 DEFINITIONS

Field logbook - The field logbook is a bound notebook with consecutively numbered pages. Upon entry of data, the logbook requires the signature of the responsible data/information recorder.

4.0 RESPONSIBILITIES

The Field Team Leader is responsible for maintaining a master field logbook for the duration of on-site activities. Each member of the sampling crew is responsible for maintaining a complete and accurate record of site activities for the duration of the project.

5.0 PROCEDURES

The following sections discuss some of the information which must be recorded in the field logbook. In general, a record of all events and activities, as well as other potentially important information shall be recorded by each member of the field team.

5.1 Cover

The inside cover or title page of each field logbook shall contain the following information:

- Contract Task Order Number
- Project name and location
- Name of Field Team Leader
- Baker's address and telephone number
- Start date
- If several logbooks are required, a sequential field logbook number

It is good practice to list important phone numbers and points of contact here.

5.2 Daily Entries

Daily entries into the logbook may contain a variety of information. At the beginning of each day the following information must be recorded by each team member.

- Date
- Start time
- Weather
- All field personnel present
- All visitors present
- Other pertinent information (i.e., planned activities, schedule changes, expected visitors, and equipment changes)

During the day, an ongoing record of all site activities should be written in the logbook. The master logbook kept by the field team leader need not duplicate that recorded in other field logbooks, but should summarize the information in other books and, where appropriate, reference the page numbers of other logbooks where detailed information pertaining to a subject may be found.

Some specific information which must be recorded in the logbook includes:

- Equipment used, equipment numbers, calibration, field servicing
- Field measurements
- Sample numbers, media, bottle size, preservatives, collection methods, and time
- Test boring and monitoring well construction information, including boring/well number and location
- Sketches for each sample location including appropriate measurements if required.
- Photograph log
- Drum log
- Other pertinent information

All entries should be made in indelible ink; all pages numbered consecutively; and all pages must be signed or initialed and dated by the responsible field personnel completing the log. No erasures are permitted. If an incorrect entry is made, the entry shall be crossed out with a single line, initialed, and dated.

5.3 Photographs

If photographs are permitted at a site, the record shall be maintained in the field logbook. When movies, slides or photographs are taken of any site location, they are numbered or cross-referenced to correspond to logbook entries. The name of the photographer, date, time, site location, site description, direction of view and weather conditions are entered in the logbook as the photographs are taken. Special lenses, film, or other image-enhancement techniques also must be noted in the field logbook. Once processed, photographs shall be serially numbered and labeled corresponding to the field logbook entries. Note that it may not be permitted to take photographs at all Activities; permission must be obtained from the LANTDIV EIC and the Activity responsible individual.

6.0 QUALITY ASSURANCE RECORDS

Once on-site activities have been completed, the field logbook shall be considered a quality assurance record.

7.0 REFERENCES

None.

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