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PROJECT OPERATIONS PLAN FOR SITE INVESTIGATIONS AND REMEDIAL
INVESTIGATIONS VOLUME 1 OF 2 NTC ORLANDO FL
7/1/1994
ABB ENVIRONMENTAL

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**PROJECT OPERATIONS PLAN FOR SITE
INVESTIGATIONS AND REMEDIAL INVESTIGATIONS**

VOLUME I OF II

**NAVAL TRAINING CENTER, ORLANDO
ORLANDO, FLORIDA**

Unit Identification Code (UIC): N65928

Contract No. N62467-89-D-0317

Prepared by:

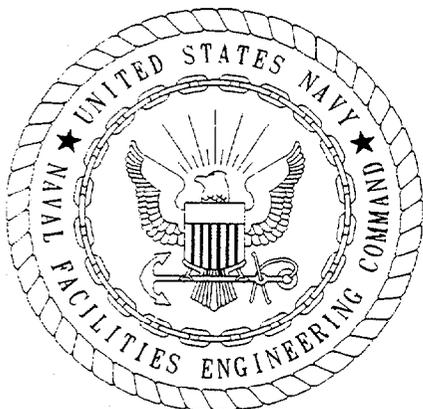
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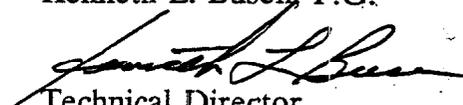
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July 1994



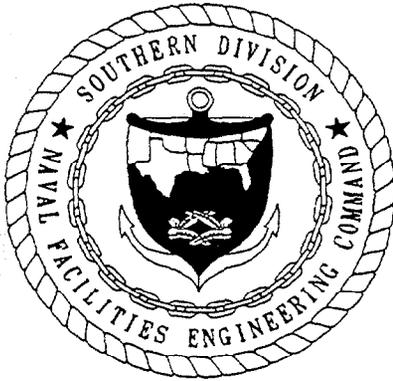
This planning document describes the Project Operations Plan (POP), Naval Training Center, Orlando and has been prepared under the direction of a Florida-Registered Professional Geologist. The work and professional opinions rendered in this report were conducted or developed in accordance with commonly accepted procedures consistent with applicable standards of practice.

Kenneth L. Busen, P.G.


Technical Director

Professional Geologist No. 191

Date: July 19, 1994



FOREWORD

The process used to determine installations for closure or realignment was identified in the Defense Base Closure and Realignment Act of 1990 (Public Law 101-510, 104 Statute 1808). Installations recommended for closure or realignment were selected based on force structure provided by the Joint Chiefs of Staff and criteria established by the Secretary of Defense. These criteria were approved by Congress and published in the Federal Register. A consolidated Department of Defense (DOD)-wide list was submitted by the Secretary of Defense to a bipartisan commission appointed by the President and confirmed by the Senate. This Commission evaluated the Secretary's recommendations and sent its finding to the President. In 1993, the Commission recommended the closure of Naval Training Center (NTC), Orlando, Florida.

Pertinent environmental legal provisions with jurisdiction at Base Realignment and Closure (BRAC) installations include the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, amended by the 1986 Superfund Amendments and Reauthorization Act (SARA), the Resource Conservation and Recovery Act (RCRA), and the 1984 Hazardous and Solid Waste Amendments. The DOD conducts an Installation Restoration (IR) program for evaluating and remediating problems related to releases and disposal of toxic and hazardous materials at DOD facilities. The Naval Assessment and Control of Installation Pollutants (NACIP) program was developed by the Navy to implement the IR program for all Naval and Marine Corps facilities. Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM) has the responsibility for administration of the Navy IR program in the southeastern United States.

This Project Operations Plan (POP) has been developed by ABB Environmental Services, Inc. (ABB-ES), to ensure proper conduct of work at NTC, Orlando. The POP has been designed to incorporate the requirements of a Quality Assurance Project Plan, Health and Safety Plan, and elements of a Field Sampling Plan (FSP) related to sampling equipment, procedures, and sample handling and analysis. Other FSP elements, including sampling objectives and sample location and frequency, will be addressed in task-specific workplans.

This POP is a dynamic document, and will be modified as necessary during the course of investigations at NTC, Orlando. A revision block has been included at the top of each page to track subsequent generations of the document. ABB-ES has

prepared this document to include specific procedures that are standards for ABB-ES and subcontractors selected for the NTC, Orlando effort.

Questions regarding this plan should be addressed to the Southern Division BRAC Environmental Coordinator (BEC) for NTC, Orlando, Mr. Wayne Hansel, at (407) 646-5294 or the Southern Division Engineer-in-Charge, Ms. Barbara Nwokike at (803) 743-0566.

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GLOSSARY

AA/ICP	atomic absorption/inductively coupled plasma
AASHTO	American Association of State Highway and Transportation Officials
ABB-ES	ABB Environmental Services, Inc.
API	American Petroleum Institute
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
BEC	BRAC Environmental Coordinator
BCP	BRAC Cleanup Plan
BCT	BRAC Cleanup Team
bls	below land surface
BOD	biological oxygen demand
BOCC	Board of County Commissioners
BRAC	Base Realignment and Closure
CAF	Corrective Action Form
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-term Environmental Action, Navy
CLP	Contract Laboratory Program
CLP-RAS	Contract Laboratory Program, Routine Analytical Services
COC	chain of custody
CompQAP	Comprehensive Quality Assurance Plan
D	duplicate
dbh	diameter at breast height
°C	degrees Celsius
°F	degrees Fahrenheit
DERP	Defense Environmental Restoration Program
DO	dissolved oxygen
DOD	Department of Defense
DON	Department of Navy
DPDO	Defense Property Disposal Office
DQOs	data quality objectives
DRMO	Defense Reutilization and Marketing Office
EBS	Environmental Baseline Survey
EC	Environmental Coordinator
ECBSOPQAM	Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual
ECD	electron capture detector
EIC	Engineer-in-Charge
EOD	explosive ordnance disposal
FDEP	Florida Department of Environmental Protection
FDER	Florida Department of Environmental Regulation
FGFWFC	Florida Game and Freshwater Fish Commission
FID	flame ionization detector

GLOSSARY (Continued)

FOL	Field Operations Leader
FSP	Field Sampling Plan
GC	gas chromatograph
GC/MS	gas chromatograph/mass spectrometer
GPR	ground-penetrating radar
HASP	Health and Safety Plan
HRS II	Hazard Ranking System II
HSA	hollow-stem auger
IAS	Initial Assessment Study
ID	identification
IDW	investigation-derived wastes
IR	Installation Restoration
ℓ/min	liters per minute
MAC	Military Airlift Command
μg/ℓ	micrograms per liter
mph	miles per hour
msl	mean sea level
MS	matrix spike
MSD	matrix spike duplicate
mV	millivolt
NACIP	Naval Assessment and Control of Installation Pollutants
NCR	Nonconformance Report
NEESA	Naval Energy and Environmental Support Activity
NGVD	National Geodetic Vertical Datum
NIST	National Institute of Standards and Technology
NPDES	National Pollution Discharge Elimination System
NSF	National Sanitary Foundation
NTC	Naval Training Center
NTUs	nephelometric turbidity units
OAFB	Orlando Air Force Base
OD	outside diameter
ORP	oxidation-reduction potential
OSHA	Occupational Safety and Health Administration
OVA	organic vapor analyzer
OVM	organic vapor meter
PARCC	precision, accuracy, representativeness, completeness, and comparability
PBS&J	Post, Buckley, Schuh, & Jernigan, Inc.
PCBs	polychlorinated biphenyls
PCE	perchloroethylene or tetrachloroethene
%D	percent difference
PID	photoionization detector
POIs	points of interest

GLOSSARY (Continued)

POP	Project Operations Plan
PPE	personal protective equipment
ppm	parts per million
psi	pounds per square inch
PTFE	polytetrafluoroethylene
PVC	polyvinyl chloride
QA	quality assurance
QAC	Quality Assurance Coordinator
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RF	response factor
RI	Remedial Investigation
RPD	relative percent difference
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SAS	Special Analytical Services
SDR	Standard Dimension Ratios
SIs	Site Investigations
SMSA	Standard Metropolitan Statistical Area
SOPs	standard operating procedures
SOUTHNAV- FACENCOM	Southern Division, Naval Facilities Engineering Command
SS	site screening
SSC	Species of Special Concern
SVOCs	semivolatile organic compounds
TAL	target analyte list
TC	terrain conductivity
TCE	trichloroethene
TCL	target compound list
TCLP	Toxicity Characteristic Leachate Procedure
TIP	total ionizables present
TOC	total organic carbon
TOM	Task Order Manager
TPH	total petroleum hydrocarbons
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USDOT	U.S. Department of Transportation
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UST	underground storage tank
UV	ultraviolet
UXO	unexploded ordnance
VOA	volatile organic analytes
VOCs	volatile organic compounds

1.0 PROJECT DESCRIPTION AND RATIONALE

1.1 PURPOSE. This Project Operations Plan (POP) has been prepared as a component of Contract Task Order 107 under Navy Contract N62467-C-0317 as guidance for the conduct of environmental investigations under Base Realignment and Closure (BRAC) 1993. The purpose of this plan is to define responsibilities and authorities for data quality, and to prescribe requirements for assuring that the field exploration activities undertaken by all consultants at Naval Training Center (NTC), Orlando, Florida, are planned and executed in a manner consistent with Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM), U.S. Environmental Protection Agency (USEPA) Region IV Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (ECBSOPQAM) (USEPA, 1991c), and Florida Department of Environmental Protection (FDEP) quality assurance (QA) program objectives. In the event of a conflict, USEPA Region IV guidelines will be followed. This POP includes specific elements of a Sampling and Analysis Plan (SAP) and Health and Safety Plan (HASP). The USEPA (1984) has prepared guidance on the preparation of a POP in *Guidance for Preparation of Combined Work/Quality Assurance Project Plans for Environmental Monitoring*. The guidance was designed to eliminate the necessity for preparation of multiple, redundant documents.

This POP provides guidance and specifications to ensure that:

- samples are obtained under controlled conditions using appropriate and documented procedures;
- samples are identified uniquely, and controlled through sample tracking systems and chain-of-custody (COC) protocols;
- field determinations and laboratory analytical results are of known quality and are valid and consistent, through the use of certified methods, preventive maintenance, calibration and analytical protocols, quality control (QC) measurements, review, correction of out-of-control situations, and audits;
- calculations and evaluations are accurate, appropriate, and consistent throughout the project;
- generated data are validated and their use in calculations is documented;
- safety is maintained by requiring that health and safety staff are included in the project organization; and
- records are retained as documentary evidence of the quality of samples, applied processes, equipment, and results.

The requirements of this POP apply to all consultant and subcontractor activities related to the collection of environmental measurements at NTC, Orlando. The POP adheres to the requirements and guidelines contained in the USEPA Region IV ECBSOPQAM and *Comprehensive Quality Assurance Plan, Florida Operations and CLEAN Operations, September 1993* (ABB Environmental Services, Inc. [ABB-ES], 1993) for collection and analysis of samples. Installation of borings and monitoring

wells, and land survey locations will be consistent with SOUTHNAVFACENGCOM *Guidelines for Groundwater Monitoring Well Installation* (Appendix A) and USEPA Region IV ECBSOPQAM guidance. In the event of a conflict, the USEPA specifications will be followed with the exception of the use of well materials (see Appendix A, Part 5).

The organizational responsibilities and interactions outlined in Chapter 2.0 extend to all quality-related controls and activities. The QC and QA elements described in each subsequent chapter are designed to prevent systematic or random deviations in quality from the prescribed protocols and to document the quality of all data.

The laboratory analytical program will be conducted by an FDEP and Naval Energy and Environmental Support Activity (NEESA)-approved Contract Laboratory Program (CLP) laboratory. Samples will be analyzed by USEPA-approved methods and will be subject to QA and QC requirements specified by USEPA.

The HASP has been prepared in conformance with Occupational Safety and Health Administration (OSHA) Regulations 29 Code of Federal Regulations (CFR), Part 1910.120, and NTC, Orlando safety requirements. The HASP references appropriate information contained in previous investigative documents from NTC, Orlando.

1.2 PROJECT DESCRIPTION. The objective of the overall project at NTC, Orlando is to perform site screening (SS) surveys, Site Investigations (SIs), and Remedial Investigations (RIs) in accordance with all relevant State and USEPA guidance. Preliminary Assessment activities are summarized in the Environmental Baseline Survey (EBS) for NTC, Orlando (ABB-ES, 1994a).

The SS/SI/RI program can include, but is not limited to, any of the following basic elements:

- monitoring well installation and groundwater sampling,
- soil boring and soil sampling,
- test pitting and soil sampling,
- geophysical surveying,
- soil gas sampling,
- surface water and sediment sampling,
- surface soil sampling,
- unexploded ordnance clearance surveying,
- water level measurement and aquifer testing,
- TerraProbeSM (direct push) soil sampling,
- field gas chromatograph (GC) and immunoassay analyses,

- geotechnical laboratory testing,
- investigation-derived waste management,
- chemical analysis,
- elevation surveying,
- site characterization, and
- public health evaluation and environmental assessment.

Samples from a variety of environmental media will be collected during the NTC, Orlando field program. Media to be sampled include surface soils, subsurface soils, surface water, sediment, and groundwater. These samples will be analyzed for a variety of inorganic and organic chemicals. Analyses may include:

- volatile organic compounds (VOCs);
- semivolatile organic compounds (SVOCs);
- total petroleum hydrocarbons (TPH);
- inorganic compounds;
- pesticides and polychlorinated biphenyls (PCBs);
- herbicides;
- radionuclides;
- explosives;
- Toxicity Characteristic Leachate Procedure (TCLP) for specific elements;
- Resource Conservation and Recovery Act (RCRA) waste characterization parameters (ignitability, reactivity, and corrosivity);
- total organic carbon (TOC);
- anions and cations such as chloride, sulfate, and non-specific nitrate plus nitrite; and
- water quality parameters such as pH, hardness, alkalinity, and total suspended solids.

1.3 FACILITY BACKGROUND. NTC, Orlando encompasses 2,072 acres in Orange County, Florida, and consists of four discrete facilities: Main Base, Area "C", Herndon Annex, and McCoy Annex (Figures 1-1 and 1-2).

1.3.1 Facility Location and Land Use The Main Base occupies 1,095 acres located approximately 3 miles east of Interstate 4 and north of State Road 50 (Figures

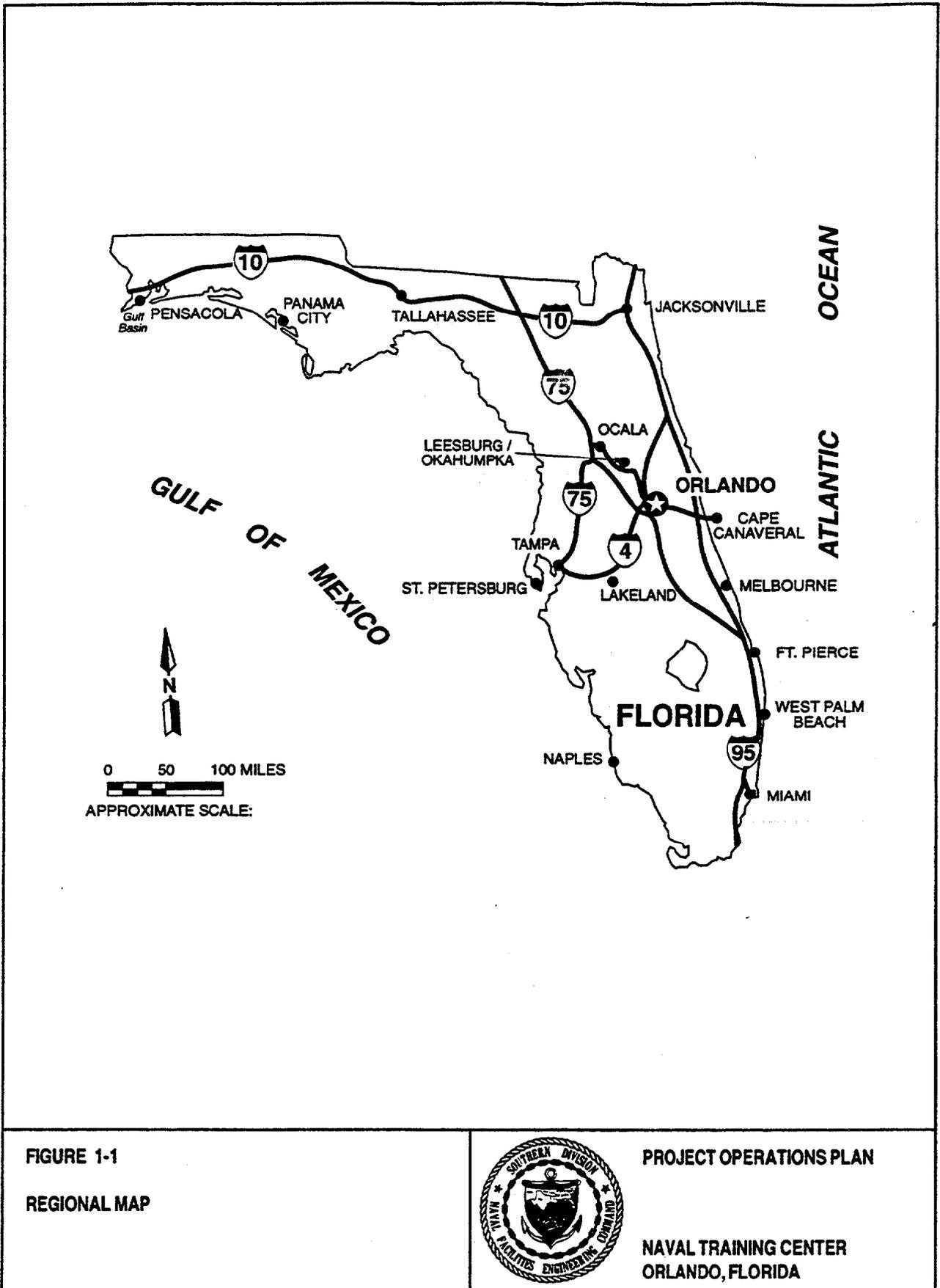


FIGURE 1-1
REGIONAL MAP



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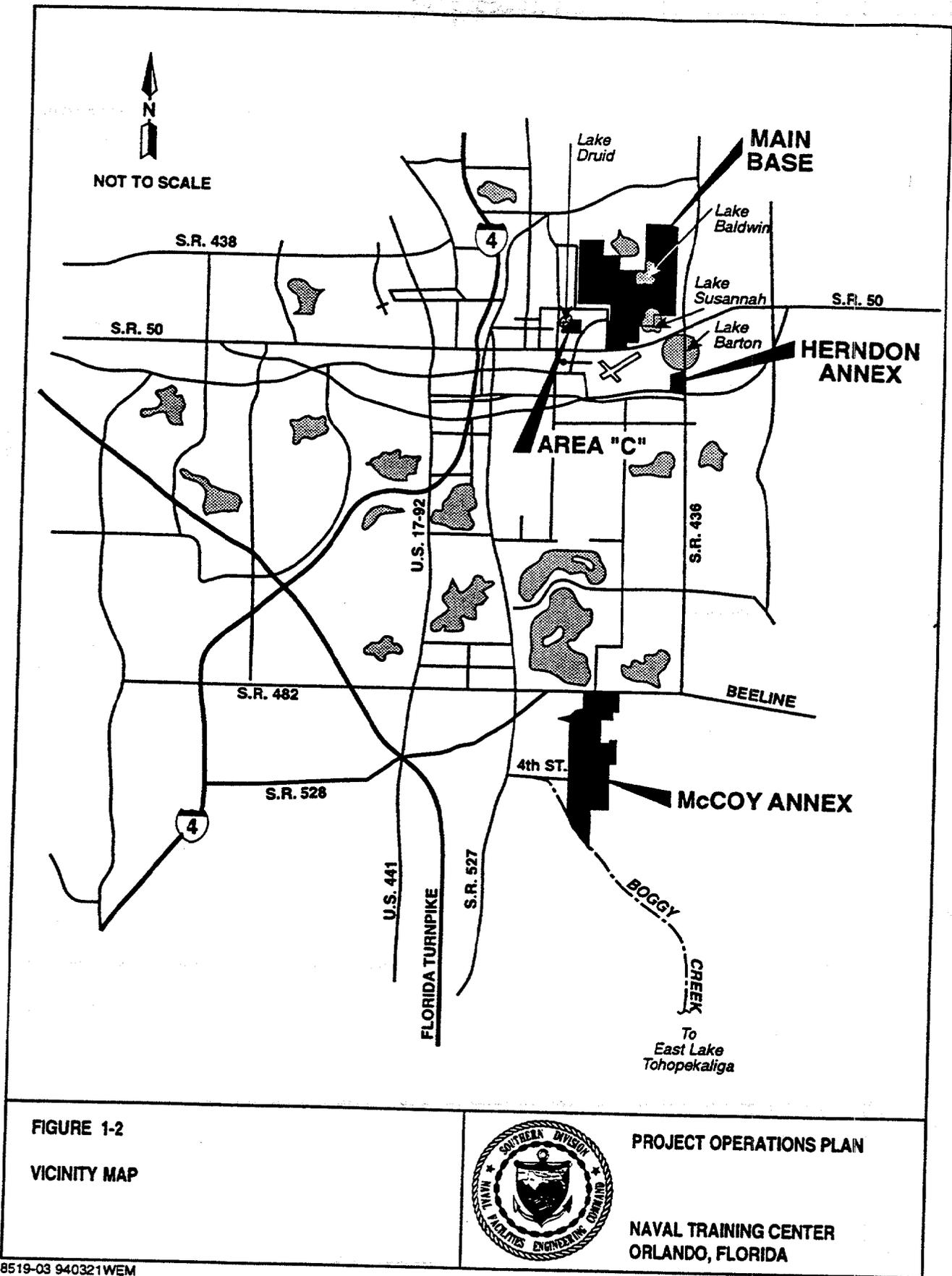


FIGURE 1-2
VICINITY MAP



PROJECT OPERATIONS PLAN

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1-2 and 1-3). The Main Base is surrounded by urban development, including single and multi-family housing, schools, and commercial buildings. Land uses directly west and northeast of the area are primarily residential. Small areas of commercial development occur to the southwest. Herndon Airport is located 1.5 miles south of the Main Base. No industrial facilities exist adjacent to the Main Base, with the exception of automotive repair facilities along Bennett Road on the southwest property line.

Area "C" occupies 46 acres and is located approximately 1 mile west of the Main Base off Maguire Boulevard (Figure 1-3). Area "C" is surrounded by urban development with multi-family residential development to the north, an office park to the east, single family residences to the west and south, and a single family residential development to the north, across Lake Druid. No industrial facilities exist adjacent to Area "C".

Herndon Annex occupies 54 acres approximately 1.5 miles south of the Main Base (Figure 1-3), within the confines of the general aviation Herndon Public Airport and on the fringe of a major residential area.

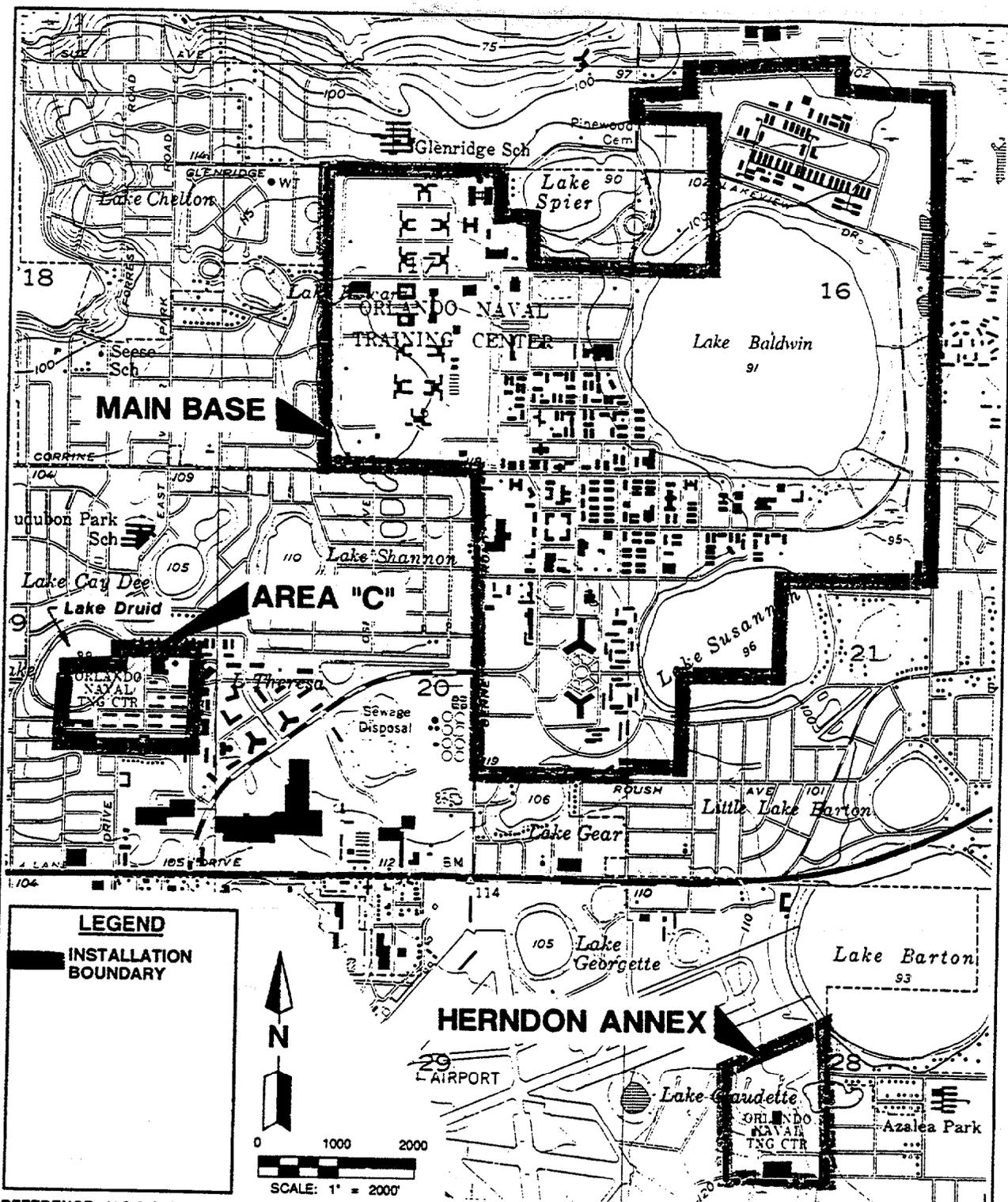
The McCoy Annex includes 877 acres and is located 12 miles south of the Main Base, west of Orlando International Airport (Figure 1-4). The western boundary of the McCoy Annex is flanked by industrially zoned property. The zoning allows heavy industry and aviation related development, although the area is not currently developed. The Beeline Expressway, a major highway running east and west through Orange County, forms the northern boundary of the Annex. The property north of the Beeline and within 0.75 mile of the McCoy Annex is used primarily by businesses directly related to the airport, such as rental agencies, hotels, and restaurants. Adjacent to the southern boundary are undeveloped woodlands (C.C. Johnson, 1985).

1.3.2 History of Operations The land use history of NTC, Orlando dates to the construction of the original Orlando Municipal Airport prior to 1940. In August 1940, the municipal airport was taken over by the Army Air Corps. Shortly thereafter, the construction program for Orlando Air Base began, culminating in its official opening on December 1, 1940. During the following 2 years, the Army Air Corps acquired additional property, and auxiliary landing fields were built in the surrounding area. The Army Air Corps conducted operations at the Main Base and Area "C" from 1940 to 1947.

In 1947, the Air Force assumed command of the facilities as the Orlando Air Force Base (OAFB). The base was deactivated on October 28, 1949, and remained on standby status until January 1, 1951, when it was reactivated as an Aviation Engineers' training site. Other Air Force units arrived, and the Military Airlift Command (MAC) assumed full jurisdiction of the base in 1953.

The Navy began moving its Training Device Center from Port Washington, New York, to OAFB on September 15, 1965, and finished the move in June 1967. In 1968, the Air Force ceased operations at OAFB, Area "C", and Herndon Annex. The property was commissioned as the Naval Training Center Orlando on July 1, 1968.

The history of McCoy Annex dates to 1941 with the construction of Orlando Municipal Airport No. 2 in Pinecastle, Florida. The new airport was needed due to the acquisition of the original municipal airport for construction of Orlando Air Base to the north. Prior to construction of the new airport, the property



REFERENCE: U.S.G.S. QUADRANGLE FOR ORLANDO EAST, FLORIDA 1953, PHOTOREVISED 1980.

FIGURE 1-3
MAIN BASE, HERNDON ANNEX, AND AREA "C"
SITE LOCATION MAP

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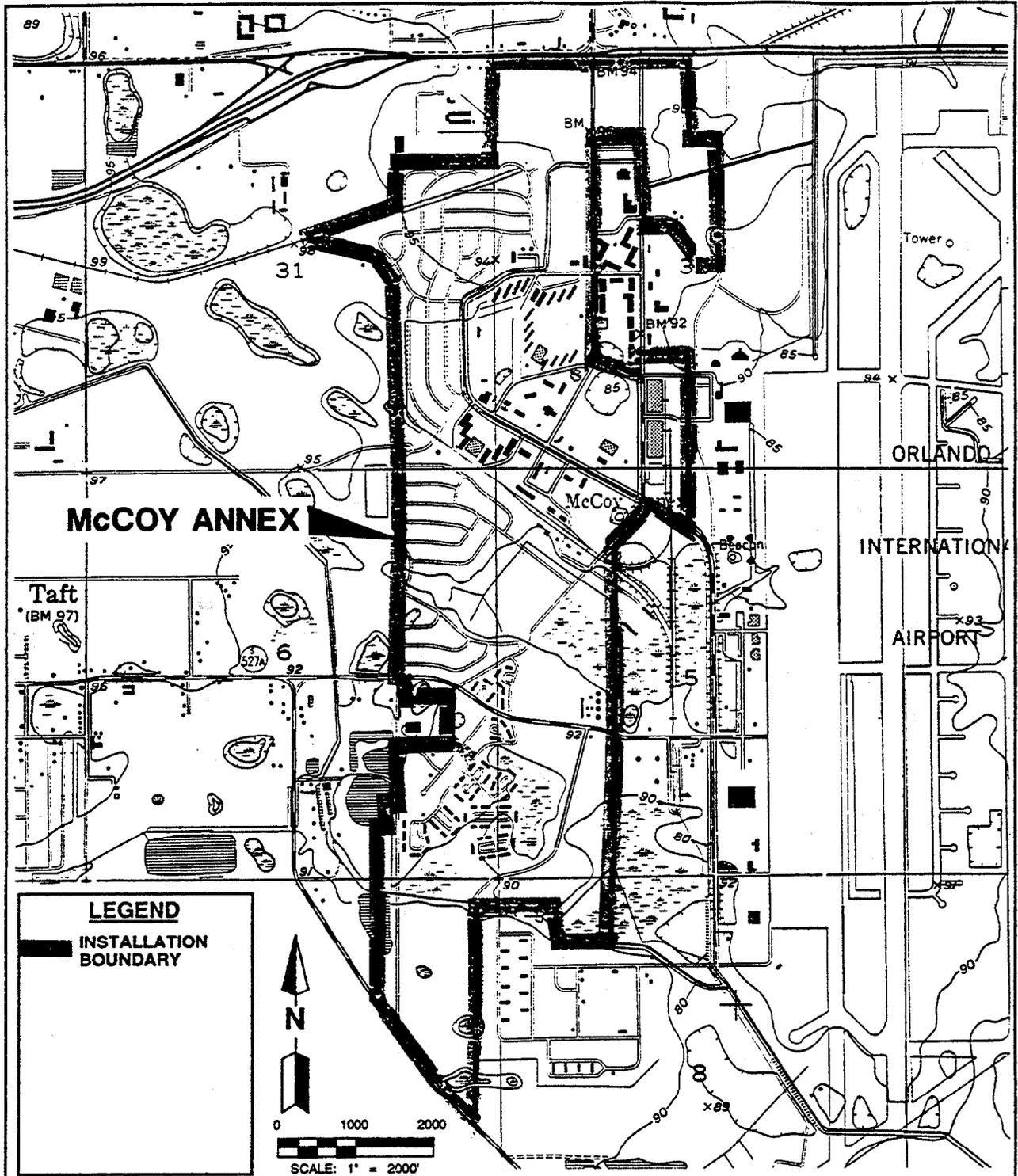


FIGURE 1-4

McCOY ANNEX
SITE LOCATION MAP



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was undeveloped swampland. In 1942, the city leased the Pinecastle property to the Army Air Corps to construct Pinecastle Army Air Field with acquired additional lands. The field was ready for operation in April 1943. At the end of World War II, the base was deactivated and the property returned to the City. The terms of the property transfer included a "reverter for reactivation" clause in case of a national emergency. This clause was exercised in 1952 during the Korean Conflict and the base was reopened as Pinecastle Air Force Base. The base was renamed McCoy Air Force Base in honor of Colonel Michael N.W. McCoy on May 7, 1958. On August 5, 1959, the Capehart Housing project, a large construction program consisting of 668 family quarters for officers and airmen, was begun. The last unit was completed in March 1961. The Air Force retained command of the base until its closure in 1973. At that time, NTC, Orlando acquired title to part of the property and changed the name to McCoy Annex. McCoy Annex was acquired to serve as a community support annex for NTC, Orlando. The majority of the property, including runways, aircraft hangars, and maintenance facilities previously used by the Air Force, was never acquired by the Navy. Currently, that property is owned and used by the Orlando International Airport (ABB-ES, 1994b).

1.3.3 Current Operations The stated mission of NTC, Orlando is to exercise command over, and coordinate the efforts of, the assigned subordinate activities in recruit training of enlisted personnel; provide initial skill, advanced, and/or specialized training for officer and enlisted personnel of the regular Navy and Naval Reserve; and to support other activities as directed by a higher authority (ABB-ES, 1994b).

The Main Base is comprised primarily of operational and training facilities. Area "C" mainly serves as a supply center for NTC, Orlando, and includes a dry cleaner and the Defense Reutilization and Marketing Office (DRMO).

The Herndon Annex provides research, design, development, testing, evaluation, procurement, fabrication, maintenance, and logistic support for naval training devices and equipment. The Herndon Annex includes a computer center, flight-training building, uniform supply warehouse, and several office buildings.

The McCoy Annex serves primarily as a housing and community support activity for NTC, Orlando (C.C. Johnson, 1985).

1.4 ENVIRONMENTAL SETTING. The four discrete land areas comprising what is now known as NTC, Orlando, located in the city of Orlando, Florida (Figures 1-3 and 1-4), have functioned as military facilities since 1940. During that time, the city has developed and surrounded NTC, Orlando. The following paragraphs describe the climate, topography, surface water, drainage, geology, hydrogeology, and potential environmental receptors associated with NTC, Orlando.

1.4.1 Climate The climate of Orange County is subtropical, with an average annual temperature of about 72 degrees Fahrenheit (°F). Orange County receives an average of 52 inches of rainfall each year. More than 50 percent of this precipitation is received from June through September, during thunderstorms that occur an average of 83 days per year (Lichtler and others, 1968).

1.4.2 Topography, Surface Water, and Drainage NTC, Orlando is situated in central Orange County, Florida, part of the Atlantic Coastal Plain physiographic

province as defined by Meinzer (1923). Most of the city of Orlando, as well as the NTC, Orlando facilities, are considered to be in the highland topographic region of the county, where elevations are generally greater than 105 feet above mean sea level (msl). The topography of this region is characterized by closed depressions and sinkhole lakes, which commonly facilitate groundwater recharge (Lichtler and others, 1968).

The topography in the Orlando area is generally flat, with elevations ranging from approximately 65 feet to 125 feet above msl. The lakes in the area are prone to flooding. Regional drainage is poorly developed, but generally flows toward the south. All surface waters in the vicinity of NTC, Orlando are classified by the State of Florida as Class III waters suitable for fish and wildlife propagation and water contact sports (Department of Navy [DON], 1992).

The area of the Main Base varies in elevation from approximately 125 feet above msl at the Recruit Training Command to approximately 91 feet above msl at Lake Baldwin. Surface water runoff from the main base flows through the storm drainage system and small intermittent streams to Lake Susannah and Lake Baldwin, and eventually to the Little Econlockhatchee River, approximately 3 miles east of the Main Base (DON, 1992; Figures 1-2 and 1-3).

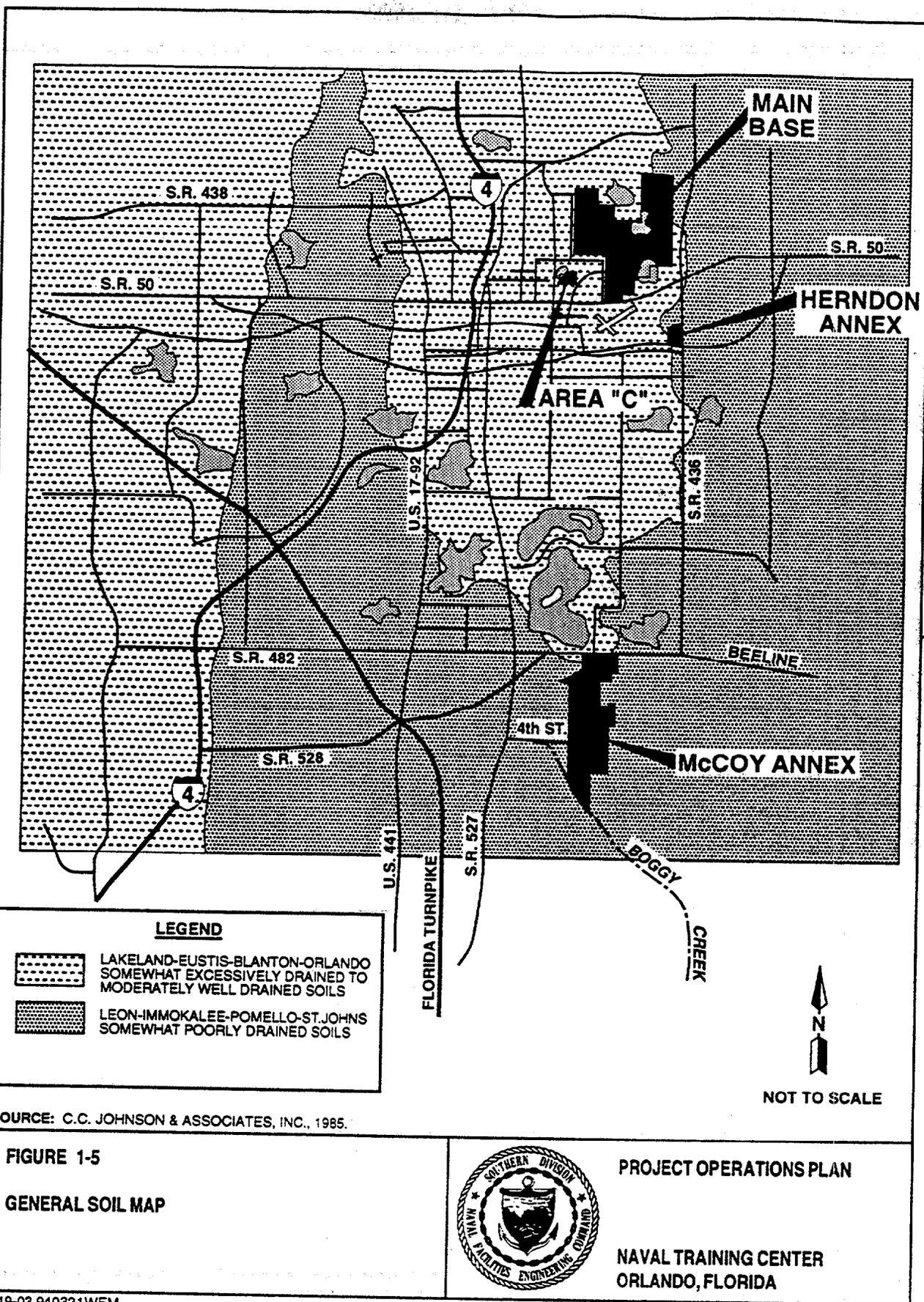
Area "C" land surface elevations range from approximately 115 feet above msl near the southeast corner of the facility to 99 feet above msl along Lake Druid, which receives most of the surface water runoff from the area (U.S. Geological Survey [USGS], 1980a).

The Herndon Annex land surface slopes from a high of approximately 120 feet above msl at the southwest corner to its low point of about 93 feet above msl at the northeast corner, adjacent to Lake Barton. Surface water runoff flows into Lake Barton or to a closed depression with a small sinkhole lake located on the east side of the area (USGS, 1980b; Figure 1-3).

The land surface at McCoy Annex is generally flat, with a very gentle slope from north to south. The land surface elevations range approximately from 85 feet to 95 feet above msl. Surface water flows south through drainage canals into Boggy Creek Drainage Basin, approximately 4 miles south of McCoy Annex. Surface water from Boggy Creek then flows into East Lake Tohopekaliga approximately 12.5 miles south of McCoy Annex (DON, 1992; Figure 1-2).

1.4.3 Regional Hydrogeology

1.4.3.1 Soils and Geology The surface and near-surface deposits in the Orlando area range from unconsolidated sands to well indurated limestones and dolomites. The soil at the Main Base and Area "C" is primarily of the Lakeland-Eustis-Blanton-Orlando type and is excessively to moderately well drained (Figure 1-5). The soil at the McCoy and Herndon Annexes is primarily of the Leon-Immokalee-Pomello-St. Johns type, which is generally poorly drained. The surface soil at NTC, Orlando consists of clayey sands with limestone deposits underneath. Soil conditions are favorable for development and do not pose any constraints to development. However, sinkholes have been known to develop in the Orlando area. No sinkholes have been found on NTC, Orlando property to date (DON, 1992).



LEGEND

-  LAKELAND-EUSTIS-BLANTON-ORLANDO
SOMEWHAT EXCESSIVELY DRAINED TO
MODERATELY WELL DRAINED SOILS
-  LEON-IMMOKALEE-POMELLO-ST. JOHNS
SOMEWHAT POORLY DRAINED SOILS

SOURCE: C.C. JOHNSON & ASSOCIATES, INC., 1985.

FIGURE 1-5
GENERAL SOIL MAP



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The geologic units of interest in the vicinity of NTC, Orlando are, in descending order: undifferentiated sediments of Recent and Pleistocene age, the Miocene-age Hawthorn Group, and the Eocene-age Ocala Group, Avon Park Limestone, and Lake City Limestone (see Figure 1-6). The Recent and Pleistocene sediments occur at a thickness of 0 to 200 feet and consist predominantly of quartz sand with varying amounts of clay and shell (Lichtler and others, 1968).

The Hawthorn Group in the study area consists of gray-green, clayey, quartz sand and silt; phosphatic sand; and buff, phosphatic limestone, mostly near the base of the unit, and may include shell or gravel beds (Lichtler and others, 1968). Included in the Hawthorn Group are, in descending order, the Peace River Formation and the Arcadia Formation (Scott, 1988). This group varies in thickness from 0 foot (not present) to 200 feet (Lichtler and others, 1968).

The Ocala Group consists of cream to tan, fine- to medium-grained, soft to hard, limestone, which is locally dolomitic. This unit varies in thickness from 0 feet (not present) to 125 feet (Lichtler and others, 1968).

The Avon Park Limestone is composed of an upper section of cream to tan, granular limestone with abundant cone-shaped foraminifera and a lower section of mostly dense, hard, brown, crystalline dolomite. In total, this unit ranges from 400 to 600 feet in thickness (Lichtler and others, 1968).

The Lake City Limestone consists of alternating layers of dark brown crystalline dolomite and chalky, fossiliferous limestone. The total thickness of this unit exceeds 700 feet (Lichtler and others, 1968).

1.4.3.2 Aquifer Systems Three aquifer systems are present in the Orlando area: the surficial aquifer system, an intermediate aquifer, and the Floridan aquifer system. The surficial aquifer system is composed of Recent, Pleistocene, and Pliocene-aged sediments. The Floridan aquifer system is composed of carbonate rocks of the Eocene Epoch (Miller, 1990). The Hawthorn Formation forms an intermediate aquifer between these two systems. The relationship between the geologic units and the hydrostratigraphic units in the area is presented schematically in Figure 1-6.

The surficial aquifer system extends to depths of 70 feet below land surface (bls) (Figure 1-6) and is composed primarily of quartz sands with varying amounts of clay and shells. The lower part of the surficial aquifer system contains predominantly marine sediments. Water is generally found at depths of 3 to 9 feet bls. Depth to water in the surficial aquifer system varies with the seasons and proximity to discharge areas. Seasonal fluctuations range from a few feet in eastern Orange County, where the topography is predominantly flat, to approximately 15 feet in the western highland areas (Board of County Commissioners [BOCC], 1991). The direction of groundwater flow in the surficial aquifer is variable (Figures 1-7 and 1-8) and generally follows topography, according to data collected from very limited areas during the previous investigations (see Section 1.5 of this document).

The Hawthorn Formation underlies the surficial aquifer system throughout most of the region. The thickness of the Hawthorn Formation varies from zero (not present) in northwest Orange County to 200 feet thick in southeast Orange County. The thickness at NTC, Orlando is approximately 85 feet (C.C. Johnson, 1985). Lithology of the Hawthorn Formation is highly variable, ranging from interfin-

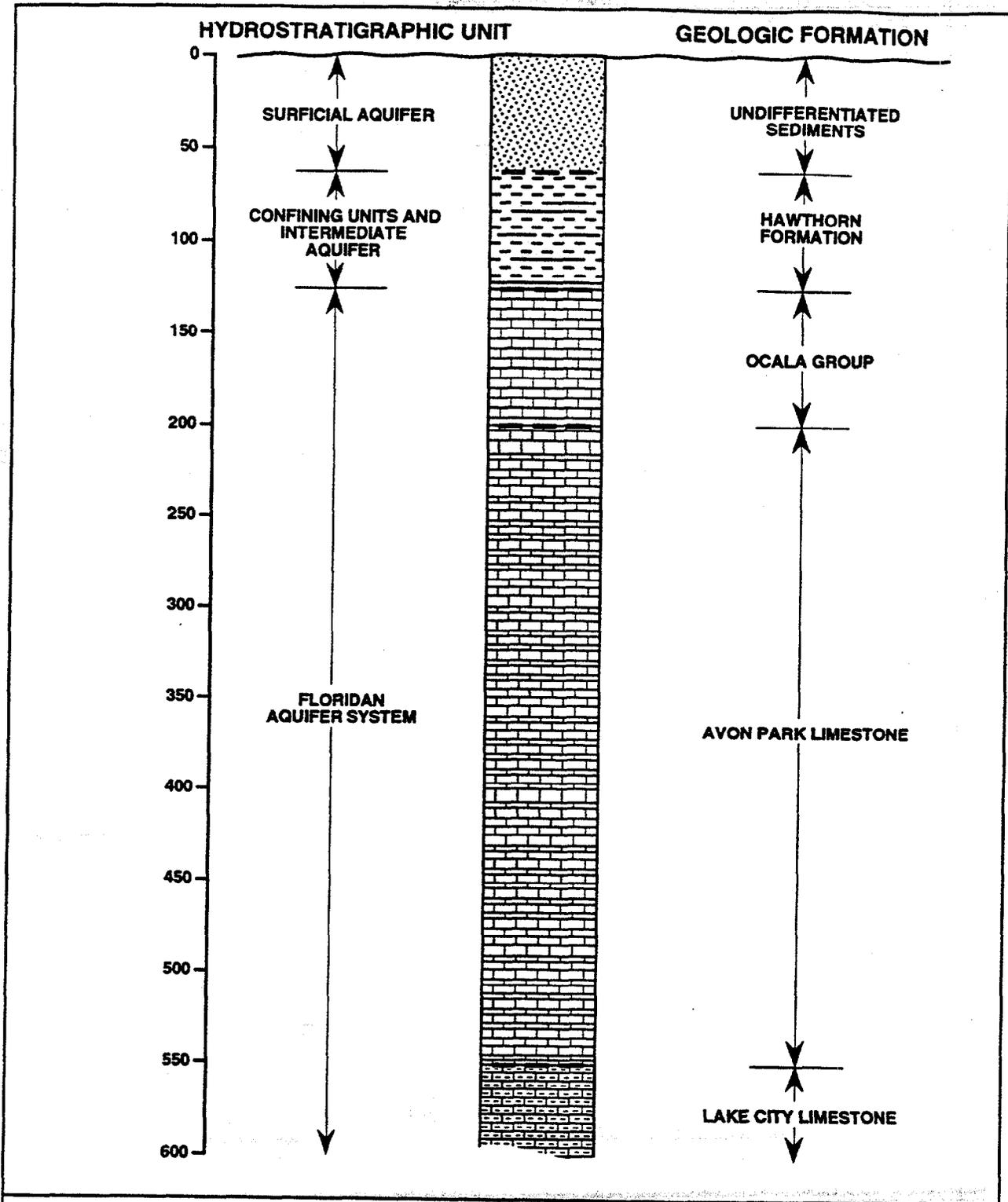


FIGURE 1-6
TYPICAL GEOLOGIC STRATIGRAPHIC COLUMN



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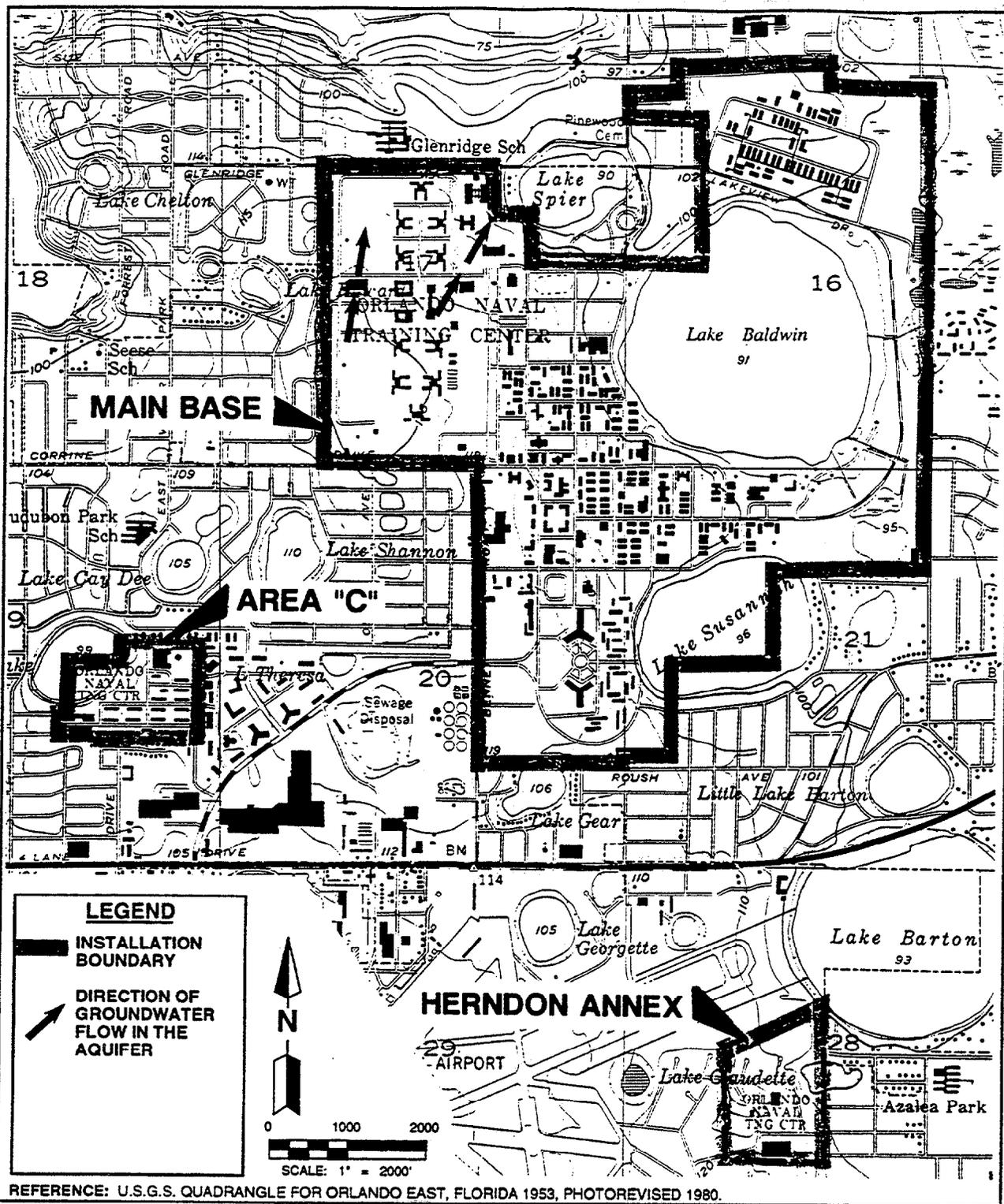


FIGURE 1-7

**MAIN BASE
 GROUNDWATER FLOW MAP,
 SURFICIAL AQUIFER SYSTEM**



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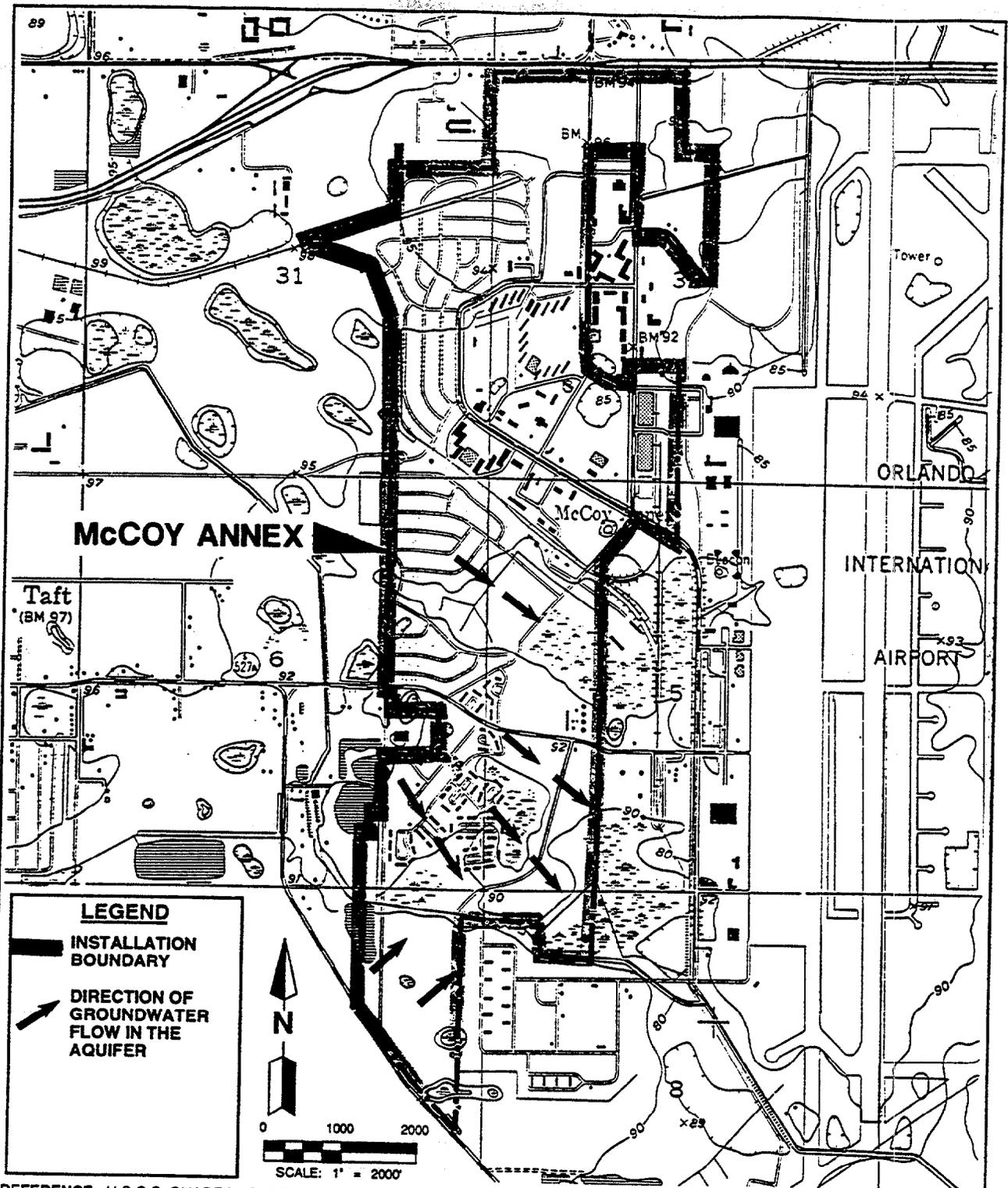


FIGURE 1-8
McCOY ANNEX
GROUNDWATER FLOW MAP,
SURFICIAL AQUIFER SYSTEM



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gered sands, clayey sands, and sandy clays in the upper parts to limestones and dolomites in the lower part of the unit. Variable amounts of clays and sands are also present with the carbonate rocks. The sandy layers comprise an intermediate artesian aquifer within the clayey confining beds. The Hawthorn Formation, where present, is also considered an upper aquitard for the Floridan aquifer system (BOCC, 1991).

The Floridan aquifer system lies below the Hawthorn Formation and is the principal water supply source for Orange County. The Floridan aquifer system is over 1,400 feet in thickness and consists primarily of limestones and dolomites. Three major rock units make up the Floridan aquifer system. These are the Ocala Group, the Avon Park Limestone, and the Lake City Limestone.

At NTC, Orlando, two major water producing zones are present in the Floridan aquifer system. The two zones correspond to the Avon Park and Lake City Limestones (Figure 1-6). The upper zone lies approximately 150 feet to 600 feet bls, and the lower zone lies approximately 1,100 to 1,500 feet bls. The lower zone is the primary water supply source in the vicinity of NTC, Orlando (BOCC, 1991).

Recharge to the Floridan aquifer system in Orange County has been divided into four areas based on the estimated amount of recharge likely to occur in 1 year. These areas have been defined as: (1) generally no recharge, (2) very low recharge (less than 2 inches per year), (3) low to moderate recharge (2 to 10 inches per year), and (4) high recharge (up to 20 inches per year). The Main Base is located in an area of high recharge and the McCoy Annex is in an area of low recharge (BOCC, 1991).

1.4.4 Potential Human Receptors NTC, Orlando is located within the Orlando Standard Metropolitan Statistical Area (SMSA), which is composed of Orange, Osceola, and Seminole Counties, and has been one of the fastest growing population centers in Florida in recent years. From 1984 to 1990, the population in the SMSA increased from 818,721 to 960,000 people. Orange County is the most populated county in the SMSA (ABB-ES, 1992).

The following subsections describe the land use, population characteristics, and potential human and ecological receptors that may be exposed to contamination at the four distinct facilities that comprise NTC, Orlando (Main Base, McCoy Annex, Herndon Annex, and Area "C"). Unless indicated otherwise, the information contained in the following subsections was obtained from the NTC, Orlando Hazard Ranking System II (HRS II) scoring document (ABB-ES, 1992).

1.4.4.1 NTC, Orlando Land Use The Main Base occupies approximately 1,095 acres within the Orlando city limits and is comprised mainly of operational and training facilities. These facilities are used for training new and recently graduated recruits, as well as enlisted and officer personnel in the nuclear engineering program. Land use at the Main Base is dominated by barracks, training facilities, administrative buildings, drill fields, and recreational areas. The population near the Main Base is transitional because of the influx of military personnel for temporary (1 to 3 years) periods of time. There are approximately 15,820 enlisted personnel onsite at the Main Base at any given time, along with an average of 4 dependents, with approximately 50 children attending the day care facility each day. There are two lakes within the Main Base property (Lakes Baldwin and Susannah) and four lakes (Spier, Forest,

Shannon, and Gear) located in the residential areas adjacent to the facility (Figure 1-3) (ABB-ES, 1992).

The McCoy Annex occupies 877 acres and is located adjacent to Orlando International Airport, approximately 12 miles south of the Main Base and outside of the Orlando city limits (Figure 1-4). There are two elementary schools located within 1 mile west of the McCoy Annex. Between 1974 and 1984, approximately 12,000 military and 2,600 civilian personnel were assigned to the McCoy Annex (C.C. Johnson, 1985). At McCoy Annex, there are approximately 676 enlisted personnel and 1,900 dependents. The golf course at the Annex is used by approximately 2,500 to 3,000 people per month (ABB-ES, 1992).

Area "C" covers approximately 46 acres and is located approximately 1 mile west of the Main Base. This region mainly serves as a supply center for the NTC, Orlando installation.

Herndon Annex, a 54-acre parcel of property, is located approximately 1.5 miles south of the Main Base, adjacent to the Herndon Public Airport. This developed parcel of property is used to provide a variety of support services for the Navy, including research, development, design, and logistics support.

1.4.4.2 Water Supply Both the Main Base and McCoy Annex facilities obtain their potable water supplies from the Orlando Utilities Commission and Winter Park Utilities. Potable water is supplied by numerous wells completed in the Floridan aquifer system. The Orlando Utilities Commission operates one of these supply wells at the southeast corner of the Main Base, obtaining water from a depth of 1,400 feet bls. There are 10 utility companies in Orange County providing potable water to residents and businesses. There are 10 irrigation wells at the Main Base and 3 at McCoy Annex. None of these wells are used for potable water and each of them draws water from a depth of 500 feet bls, within the Avon Park Limestone unit, which is the upper of the two producing zones of the Floridan aquifer system.

A wellhead protection program is being established in Orange County through the utility companies in cooperation with the South Florida and St. Johns River Water Management District offices. An interim Wellhead Protection Plan is currently being enforced by the Orange County Planning Department, but no wellhead protection areas have been delineated.

Regional drainage is poorly developed but generally flows toward the south to the canals and tributaries leading to the Kissimmee River. Surface water drainage at the Main Base is directed to Lake Susannah and Lake Baldwin, which are used for fishing and recreation. The most likely contaminant migration pathway to these lakes is through small intermittent streams and the storm drainage system at the facility. Water from each of these lakes eventually flows into the Little Econlockhatchee River and then to the St. Johns River. Both of the lakes are a source of fish and wildlife habitat, and may be habitats for endangered or threatened species.

All surface waters in the vicinity of NTC, Orlando are classified by the State of Florida as Class III waters suitable for fish and wildlife propagation and water contact sports.

1.4.4.3 Ecological Setting NTC, Orlando is within the Florida section of the Atlantic Coastal Plain; the four areas at NTC, Orlando all share similar ecological features (C.C. Johnson, 1985). Of the 2,072 acres of land at NTC, Orlando, approximately 100 acres (5 percent of the total area at NTC, Orlando) is undeveloped. Although not extensive, these undeveloped areas may provide habitat for a variety of terrestrial and aquatic ecological receptors.

Terrestrial and Wetland Vegetative Cover. In addition to a variety of ornamental plantings, three species of native flora are predominant at the Main Base: live oak (*Quercus virginiana*), slash pine (*Pinus elliottii*), and cabbage palm (*Sabal palmetto*). These native woody species are also found at Area "C", along with a non-native tree, Australian pine (*Casuarina equisetifolia*). Virtually all undeveloped land at Area "C" occurs in the areas bordering Lake Druid (Figure 1-3). The limited undeveloped areas at the McCoy Annex include uplands dominated by slash pines and live oak, as well as wetland habitat dominated by bald cypress (*Taxodium distichum*) (C.C. Johnson, 1985).

Aquatic Flora and Fauna. Lake Baldwin and Lake Susannah are both located partially within the boundaries of NTC, Orlando. Lake Baldwin is approximately 196 acres in size. Several other smaller lakes are located adjacent to the installation. Lakes Baldwin and Susannah are infested with an invasive weed, Florida elodea (*Hydrilla verticillata*) (C.C. Johnson, 1985). Fish species occurring in the lakes at NTC, Orlando include bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), golden shiner (*Notemigonus crysoleuca*), yellow bullheads (*Ictalurus natalis*), and killifish (*Fundulus* spp.). According to the NTC, Orlando Master Plan Update (SOUTHNAVFACENGCOM, 1985), grass carp (*Ctenopharyngodon idella*), an oriental species, have been introduced into several of the larger lakes at NTC, Orlando to control Florida elodea.

Fauna. Limited information is available regarding faunal ecological receptors at NTC, Orlando. It is likely that the invertebrate biomass at the installation's few undeveloped sites serves as a forage base for fish and wildlife species, including amphibians, reptiles, birds, and mammals.

Amphibians that may occur at NTC, Orlando include several species of mole salamander (*Ambystoma* spp.) that spend at least part of the year in woodlands. A number of other salamanders, frogs (including members of the genera *Hyla*, *Rana*, and *Pseudacris*), and toads (*Bufo* spp.) may also occur at NTC, Orlando. Several lizard species and various colubrid snakes may also occur in the pine forest communities at the installation (Ashton and Ashton, 1988). Turtles and other aquatic reptiles may occur in Lake Baldwin and some of the other lakes in the vicinity of NTC, Orlando.

Small mammals that may occur at the site include the cottontail rabbit (*Sylvilagus floridanus*), hispid cotton rat (*Sigmodon hispidus*), and cotton mouse (*Peromyscus gossypinus*). Predatory mammals such as the red fox (*Vulpes vulpes*) and gray fox (*Urocyon cinereoargenteus*) may feed on small mammals at NTC, Orlando. In wetland regions at the installation, mammals such as the raccoon (*Procyon lotor*) and beaver (*Castor canadensis*) may occur.

Birds of prey such as the black vulture (*Coragyps atratus*), turkey vulture (*Cathartes aura*), red-tailed hawk (*Buteo jamaicensis*), and red-shouldered hawk (*B. lineatus*) may search for prey items in the more open regions at NTC, Orlando,

and granivorous birds such as the mourning dove (*Zenaida macroura*) are likely to occur in the grassy cover type habitats at the facility. Other avifauna that may occur at NTC, Orlando include the brown-headed cowbird (*Molothrus ater*), brown thrasher (*Toxostoma rufum*), bobwhite quail (*Colinus virginianus*), mockingbird (*Mimus polyglottus*), common grackle (*Quiscalus quiscula*), killdeer (*Charadrius vociferus*), northern cardinal (*Cardinalis cardinalis*), blue jay (*Cyanocitta cristata*), rufous-sided towhee (*Pipilo erythrophthalmus*), common flicker (*Colaptes auratus*), and red-bellied woodpecker (*Centurus carolinus*). Birds that may occur in wetland regions at NTC, Orlando include swamp sparrow (*Melospiza georgiana*), Carolina wren (*Thryothorus ludovicianus*), northern cardinal, and common yellowthroat (*Geothlypis trichas*), as well as waterfowl such as the mallard duck (*Anas platyrhynchos*).

Rare and Endangered Species. Limited information is currently available regarding rare and endangered species at NTC, Orlando. Additional information will be requested from State and Federal authorities and will be included in revised versions of this POP. Based on information contained in the 1985 Master Plan Update (SOUTHNAVFACENGCOM, 1985) and in the Initial Assessment Study (IAS) (C.C. Johnson, 1985), the following rare and endangered species may currently exist (or have historically occurred) at NTC, Orlando.

Scientific Name	Common Name	Status	
		Federal	State
Florida mouse	<i>Podomys floridanus</i>	C2	SSC
Southeastern kestrel	<i>Falco s. sparverius</i>	C2	T
Short-tailed snake	<i>Stilosoma extenuatum</i>	C2	T
Eastern indigo snake	<i>Drymarchon corais couperi</i>	T	T
Gopher tortoise	<i>Gopherus polyphemus</i>	C2	SSC
American alligator	<i>Alligator mississippiensis</i>	T(S/A)	SSC

Notes: SSC = Species of Special Concern (Florida Game and Freshwater Fish Commission [FGFWFC], 1991).
 T = threatened (FGFWFC, 1991).
 C2 = Federal candidate species.
 T(S/A) = threatened, rare to similarity of appearance.

1.5 SUMMARY OF PREVIOUS INVESTIGATIONS. The Defense Environmental Restoration Program (DERP) requires the Department of Defense (DOD) to expeditiously remediate environmental contamination from hazardous substances due to past practices. The Installation Restoration (IR) program, a subcomponent of DERP, is designed to identify, investigate, and clean up contaminated sites in a manner that is consistent with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The IR program is conducted in multiple phases. To date, the IR program has identified 10 potentially contaminated sites at NTC, Orlando (Table 1-1). Investigation or remedial action has been implemented at some of these sites. In addition to the IR program sites, other sites have undergone contamination assessment and/or remedial action. Results of investigations conducted under IR and non-IR programs formed the basis for future SS/SI/RI activities to be conducted under BRAC through the IR program.

Table 1-1
Summary of Installation Restoration Program Sites

Project Operations Plan for Site Investigations
 and Remedial Investigations
 NTC, Orlando, Orlando, Florida

IAS Site No.	POI Name	Period of Operation	Expected Waste Types	Estimated Quantities	Current Use
1	North Grinder Landfill	1958 to 1967	Film, photographic chemicals, paint thinner, perchloroethene still bottoms, garbage from mess halls, cardboard boxes, biological wastes (syringes from hospital), paper, plastic, tree limbs, and construction materials.	194,000 cubic yards of waste, one-third of which was removed during dormitory construction.	Training operations, administrative functions, and housing.
2	Filled WWTP Lagoons	1977 to 1978	WWTP sludge, tree limbs, yard wastes, dirt, sand, asphalt, demolished building debris, and stainless-steel mixing tank.	Unknown	None
3	McCoy Annex Landfill	1960 to 1978	Paint, paint thinner, asbestos, transformers (possibly with transformer oil containing PCBs), hospital wastes (syringes, dressings, blood, and urine), radioactive waste, automobile batteries, steel cable, airplane parts, brick, fire hoses, parachutes, trees leaves, paper, plastic, scrap wood, scrap metal, sections of pipe, and waste oil.	> 1,000,000 cubic yards of waste	Golf course
4	Disposal Area Near the Main Base Magazine No. 123	1968 to 1969	Yard wastes (tree limbs and grass clippings).	Site was a pit 30 feet in diameter and 8 or 9 feet deep.	None
5	Old Laundry Boiler Building	? to 1972	Asbestos containing materials.	Unknown	Demolished in 1979; building was used to house boilers for the laboratory.
6	McCoy Annex DRMO	1984 to present	Used motor oil, anti-freeze, hydraulic fluid (containing PCBs), and Soilax Liquid 'S' Plus Multipurpose Cleaner (containing NaOH and 2-butoxy ethanol).	1,000-4,000 gallons estimated to have been spilled.	Drum and transformer storage.

See notes at end of table.

Table 1-1 (Continued)
Summary of Installation Restoration Program Sites

Project Operations Plan for Site Investigations
 and Remedial Investigations
 NTC, Orlando, Orlando, Florida

IAS Site No.	POI Name	Period of Operation	Expected Waste Types	Estimated Quantities	Current Use
7	Barracks Burial Area	1968	Building debris	Unknown	Barracks were demolished and bulldozed into a quarry at the southwestern end of McCoy Annex.
8	Old Pesticide Storage Area	Early 1950's to 1972	Chlordane, phenyl mercuric compounds, baygon, diazinon, anticoagulant, malathion, pyrethrum, diron, 2,4-D, monuron, dieldrin, paraquat, kepone, endothall, naled, mineral oils, arsenic, dchlorvos, hydrothol, and dimethoate.	At least 300 gallons were buried when the building was demolished; ~62,000 gallons and ~46,000 pounds of pesticides were used per year (based on 1970 data).	Grassy area on perimeter of golf course (building was demolished in 1981).
9	Lake Baldwin	Early 1950's to 1978	Drainage from building 2089 of film, photographic developers, fixers, and activators.	Unknown	Recreational fishing, boating, and swimming by Navy personnel and the public.
10	McCoy Annex WWTP	Unknown	Iron, manganese, sulfate, nitrate, arsenic, and zinc	Unknown	Demolished

Source: Hazard Ranking System II (ABB-ES, 1992) and Initial Assessment Study (IAS) (C.C. Johnson, 1985).

Notes: WWTP = wastewater treatment plant.
 PCBs = polychlorinated biphenyls.
 DRMO = Defense Reutilization and Marketing Office.
 NaOH = sodium hydroxide.
 2,4-D = 2,4-Dichlorophenoxyacetic acid.
 POI = points of interest.

1.5.1 Installation Restoration Sites The first phase of the IR program at NTC, Orlando was the IAS conducted in 1985 (C.C Johnson, 1985). This program included an archival search and site walkovers at all four parcels of NTC, Orlando. Nine potentially contaminated sites were identified. The IR program sites are all located on one of three parcels: Main Base, McCoy Annex, or Area "C". The sites included two trench and fill landfills (Sites 1 and 3), a wastewater treatment sludge lagoon (Site 2), a yard waste disposal area (Site 4), a boiler room with extensive asbestos-containing material (Site 5), the former Defense Property Disposal Office (DPDO) (now the DRMO, Site 6), a demolition debris landfill (Site 7), a pesticide storage building (Site 8), and Lake Baldwin (Site 9). A site verification study was recommended for Sites 1, 3, 6, 8, and 9. The verification study was performed in 1986 and an additional IR program site (Site 10, a wastewater treatment plant at McCoy Annex) was identified (Geraghty & Miller, 1986).

The verification study suggested that the contamination at Lake Baldwin (Site 9) did not represent a significant risk to human health or the environment, although a risk assessment was not performed (Geraghty & Miller, 1986). The study also determined that the spillage noted in the IAS at the former DPDO at McCoy Annex (Site 6) had not contaminated the soil. The former landfill at the Main Base (Site 1), the former landfill at McCoy Annex (Site 3), the pesticide storage building (Site 8), and the wastewater treatment plant at McCoy Annex (Site 10) were recommended for additional investigation. A brief workplan for the RI of these four IR program sites was prepared in 1987; however, the workplan has not been implemented (ABB-ES, 1994b).

1.5.2 Non-Installation Restoration Program Sites Non-IR program sites that have involved remedial actions include the dry cleaning facility and DRMO, both located in Area "C"; and the Rusk Memorial Chapel (Building 250) at the Main Base.

Both the DRMO and the dry cleaning facility had perchloroethylene (PCE) spills in 1989. In each case, the soils containing greater than 1 part per million (ppm) PCE were excavated. Contaminated soil from the DRMO spill was disposed at a hazardous waste disposal facility by DRMO. Contaminated soil at the dry cleaning facility was disposed at a hazardous waste landfill by the consultant responsible for the spill. Prior to May 1989, a spill of PCB-contaminated oil from an electrical transformer occurred in the uncovered (outdoor) mechanical room of Rusk Memorial Chapel. Contaminated soil was excavated, containerized, and removed by DRMO. Laboratory analyses detected approximately 68 ppm PCBs in the remaining soil. No regulatory concurrence of cleanup has been obtained (ABB-ES, 1994b).

Three other non-IR program sites involved petroleum spillage or leakage from underground storage tanks (USTs). A detailed discussion of these sites can be found in the BRAC Cleanup Plan (ABB-ES, 1994b).

1.5.3 Installation-Wide Source Discovery and Assessment Status There have been two installation-wide environmental assessments conducted after the IAS. The first survey, performed as part of the general permit application process for a National Pollution Discharge Elimination System (NPDES) stormwater discharge permit, was conducted by Post, Buckley, Schuh, & Jernigan, Inc. (PBS&J), in 1993 to identify potential illicit (i.e., non-stormwater) discharges from the stormwater discharge system at the facility. The second survey is the EBS, part

of the bottom-up program review for all BRAC installations (ABB-ES, 1994a). The field component of the EBS, which involved the inspection of more than 600 buildings, is complete. These results were used to identify points of interest (POIs), defined as base properties that are potentially contaminated and may require further investigation prior to transfer. Investigation and potential remedial actions at these POIs will be conducted in accordance with this document.

PBS&J investigated stormwater outfalls at all four parcels that comprise the installation. For the purpose of the EBS, the sources of illicit discharges to the outfalls were considered to be POIs that may require further investigation. The POIs that were identified from a review of the PBS&J report include the Fire Training Facility (Building 200), the Automotive Hobby Shop, the Pest Control Facility, and the Bulk Fuel Storage Area on the Main Base. At McCoy Annex, the Motor Pool and the fuel storage area of the Construction Battalion are suspected of discharging petroleum products to discharge ditches and swales (ABB-ES, 1994b)

Approximately 85 properties have been identified by the EBS as areas where potential environmental concerns are present. Properties surveyed in the EBS that are POIs have been assigned to a category based on the following DOD guidance for EBS:

- Category 7 (Grey), properties requiring further investigation, excluding those sites that have been assigned this category only because of the presence of an UST or an aboveground storage tank (AST);
- Category 6 (Red), properties where a release of hazardous substances has occurred excluding those sites that have been assigned this category only because of the presence of damaged friable asbestos; and
- Category 5 (Yellow), properties where storage, release, disposal, and/or migration has occurred, and action is underway, but not final.

The majority of the sites identified by the EBS as requiring additional investigation are those that have been assigned a grey classification (74). Some properties identified in the EBS are IR program sites where no restoration has occurred (e.g., Site 1, the North Grinder Landfill). Ten properties have been tentatively assigned a classification of red (release of a hazardous substance has occurred and no remedial action has been taken) (ABB-ES, 1994b). All sites identified as requiring additional investigation will be evaluated through the SS/SI/RI process.

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

This portion of the POP addresses project organization, and specifically outlines QC coordination and responsibilities. Those individuals assigned to a project or task (i.e., the project team) are responsible for conducting project work by using the resources assigned by the project management organization. In this way, resources are available to each task, but responsibility for initiating services and for ensuring acceptable results remains within the project organization. This responsibility carries with it the authority to initiate, modify, and, if necessary, stop activities as appropriate for the assurance of project quality. It is the QA Manager's (QAM) role to assist the Task Order Manager (TOM) in meeting project goals while providing an independent evaluation of product quality to the TOM.

2.1 PROJECT STAFFING AND RESPONSIBILITIES.

2.1.1 BASE REALIGNMENT AND CLOSURE (BRAC) ENVIRONMENTAL COORDINATOR. The BRAC Environmental Coordinator (BEC) for NTC, Orlando is Mr. Wayne Hansel. Mr. Hansel is the Navy representative on the BRAC Cleanup Team (BCT) and the primary project contact. He is responsible for the execution of all environmental cleanup programs related to the transfer of NTC, Orlando's real property. This responsibility includes acting as the liaison and coordinator with appropriate NTC, Orlando and SOUTHNAVFACENGCOCOM personnel, and negotiating appropriate cleanup and abatement actions with USEPA and FDEP BCT members.

2.1.2 Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOCOM) Engineer-in-Charge (EIC) The SOUTHNAVFACENGCOCOM EIC, Ms. Barbara Nwokike, is responsible for the technical and financial management of the IR program activities at NTC, Orlando. She prepares the project statement of work; manages the project scope, schedule, and budget; and provides technical review and approval of all deliverables. Ms. Nwokike will be responsible for approving changes in the IR program scope of work.

2.1.3 Consultant Task Order Manager (TOM) The consultant TOM for BRAC activities at NTC, Orlando is Mr. Jim Manning. Mr. Manning is responsible for evaluating the appropriateness and adequacy of the technical and engineering services provided. He is responsible for financial and schedule management and for ensuring that the project fulfills and remains within the contracted scope of work. Mr. Manning will be responsible for identifying necessary changes in the scope of work. Mr. Manning is also responsible for the daily conduct of work, including integration of input from supporting disciplines and subcontractors and will serve as the primary project contact.

2.1.4 Project Review Committee Mr. Ken Busen, P.G., will serve as chairman of the review committee. The function of this group of senior technical and management personnel is to provide guidance and oversight on the technical aspects of the project. This is accomplished through periodic reviews of the services provided to ensure they: represent the accumulated experience of the firm, are being produced in accordance with corporate policy, and live up to the objectives of the program as established by ABB-ES and the client.

2.1.5 Quality Assurance Manager (QAM) The TOM is supported by a QAM. The QAM, Mr. Thomas Campbell, will oversee the implementation of appropriate NEESA, USEPA, and FDEP protocols. The QAM will also work with the TOM to establish QA procedures.

2.1.6 Health and Safety Manager The Health and Safety Manager, Ms. Cynthia Sundquist, is responsible for project team compliance with corporate health and safety requirements and the NTC, Orlando project HASP. Conformance with safety protocols will be assessed through periodic site visits and daily supervision by the site leaders.

3.0 QUALITY ASSURANCE OBJECTIVES

Data quality objectives (DQOs) have been developed for the NTC, Orlando project to ensure that analytical data collected during the field investigations will be of sufficient quality to support the data's intended use. Specific objectives will be addressed in the applicable task-specific workplans. Task-specific questions such as how the data will be used and how much data are required will be considered when developing DQOs.

3.1 GENERALIZED SCOPE OF WORK. The SS, SI, and RI field efforts will involve several activities relative to the acquisition of physical and chemical data. Each investigation will involve a task-based approach that will allow the decision-making process to modify future investigative and remedial tasks. The DQOs for soil, groundwater, surface water, and sediment sample collection and analysis performed in the field will be applicable to the confirmation of the presence or absence of contamination and the nature and extent of any contamination encountered in those media. TerraProbeSM sampling and field GC, infrared, and immunoassay analyses will, in some instances, be the initial chemical data gathering task. Field analysis will not be used alone to evaluate a study area. The results of these field analyses will be used to confirm or modify the proposed sample locations from which samples will be collected for laboratory analysis.

3.2 DATA QUALITY OBJECTIVES. DQOs are qualitative or quantitative statements developed by the data user to specify the quality of data needed from a particular data activity to support specific decisions. The DQOs are the starting point in the design of the investigation. The DQO development process matches sampling and analytical capabilities to the data targeted for specific uses and ensures that the quality of the data does not underestimate project requirements. The USEPA has identified five general levels of analytical data quality as being potentially applicable to field investigations conducted at potential hazardous waste sites under the CERCLA. These levels are summarized as follows.

- (1) Level I, Field Screening. This level is characterized by the use of portable instruments that can provide real time data to assist in the optimization of sampling point locations and for health and safety support. Qualitative data can be generated regarding the presence or absence of certain contaminants (especially volatiles) at sampling locations.

Level I sampling requirements include the use of equipment and sampling containers that are clean (soap and tap water), visibly free of contamination, and free of analytes detectable by the screening method employed (USEPA, 1991c).

- (2) Level II, Field Analysis. This level is characterized by the use of portable analytical instruments that can be used onsite or in mobile laboratories stationed near a site. Depending on the types of contaminants, sample matrix, and personnel skills, qualitative and quantitative data can be obtained.

Level II sampling and equipment requirements include the use of sampling equipment constructed of material that is compatible with the parameters being analyzed (e.g., polyvinyl chloride [PVC] for inorganic parameter analyses, or chrome-plated material for organic parameter analyses) and field cleaning procedures that include a potable water and soap scrub followed by a potable water rinse (or steam cleaning or high pressure washing) (USEPA, 1991c).

- (3) Level III, Laboratory analysis. This level is characterized by the use of methods other than the CLP Routine Analytical Services (CLP-RAS). This level is used primarily in support of engineering studies using standard USEPA-approved procedures. Some procedures may be equivalent to the USEPA CLP-RAS, without the CLP requirements for documentation.

Level III field methods, decontamination procedures, and sampling equipment construction materials are as specified in the USEPA ECBSOPQAM (USEPA, 1991c). Cleaning of down-hole drilling or excavation equipment must be performed as with Level IV requirements with the exclusion of the deionized water rinse, the double rinse with pesticide grade isopropanol, and the rinse with organic-free water. All other cleaning and decontamination guidance must be followed.

When wells are constructed using materials that are not inert with respect to the contaminants being analyzed, data collected from those wells are DQO Level III or lower for those incompatible analytes, even if DQO Level IV analytical procedures are used.

Level III QA/QC sampling blank requirements include:

- a minimum of one equipment rinsate blank per week for each week sampling equipment is field cleaned;
- if samples are preserved, a preservative blank must be collected and analyzed at the beginning and end of the study; and
- a blank of the rinse water must be collected and analyzed prior to beginning the study and at the end of each week that sampling equipment is field cleaned.

A minimum of 5 percent of samples collected for DQO Level III analysis will be split for DQO Level IV analysis. These samples must be representative of all samples submitted for Level III analysis (USEPA, 1991c).

- (4) Level IV, Laboratory Analysis CLP-RAS. This level is characterized by all requirements for Level III, plus more rigorous QA/QC protocols and documentation, and provide qualitative and quantitative analytical data (USEPA, 1991c).
- (5) Level V, Non-standard methods. This level includes analyses that may require modification and/or development. CLP Special Analytical Services (SAS) are considered Level V (USEPA, 1991c).

NEESA has adopted three of these levels, C, D, and E, as QA requirements, that correspond with USEPA Levels III, IV, and V (NEESA, 1988). For the purposes of this document, the USEPA nomenclature (Levels I through V) will be used.

3.2.1 Task Specific DQOs Tasks for the SS/SI/RI at NTC, Orlando will involve data collection with DQOs expected to range from Level I through Level IV. The following discusses the typical SS/SI/RI tasks for NTC, Orlando and the associated DQO level. The tasks performed for each POI will be specified in the task-specific workplans.

- **Air Quality Monitoring, Level I:** Readings from an organic vapor analyzer (OVA) or photoionization detector (PID) and MSA Model 260 02/Explosimeter will constitute Level I field analytical data.
- **Geophysical Survey, Level I:** Terrain conductivity (TC), magnetometer, or ground-penetrating radar (GPR) surveys will be used to define potential or suspected contaminant plumes. Data generated as a result of the surveys will indicate the presence or absence of metallic objects and the relative subsurface conductivity. Data requirements are primarily qualitative.
- **Soil Sample Screening, Level I:** TerraProbeSM soil samples and split-spoon samples from discrete depths in soil borings will be screened in the field with an OVA or flame ionization detector (FID) and a PID providing Level I data concerning the presence or absence of volatile compounds. A field GC may be used to augment field screening methods.
- **Field Parameter Analysis, Level II:** More sophisticated instrumentation (such as the HNu Model 311 GC and the Mach Portable Infrared Spectrometer) used for onsite analysis of volatiles and total petroleum hydrocarbons will generate Level II analytical data. These data are supported by more extensive logbook documentation, calibration, and quality control. Immunoassay test kits may also be used for Level II analytical data. These analyses will be performed in accordance with the manufacturers' and USEPA recommendations for quality control.
- **Passive Soil Gas Survey, Level II:** Passive soil gas samples will be analyzed at an offsite laboratory. The data conform to Level II DQOs and are used to provide a preliminary survey of the presence and distribution of shallow VOC contamination.
- **Soil Headspace and Active Gas Screening, Level II:** Soil gas will be collected from TerraProbeSM soil borings (onsite) using headspace and active gas methods. The resulting data will conform to Level II DQOs.
- **Grain-Size Distribution Analysis, Level II:** Subsurface soil samples will be collected for grain-size distribution analysis. These data will conform to Level II DQOs.
- **Total Organic Carbon Analysis, Level III:** Soil and sediment samples will be collected for TOC analysis. These samples will be collected and analyzed to conform to Level III DQOs.

- Soil, Sediment, Surface Water, and Groundwater Analysis, Level III: Environmental samples obtained during site screening investigations will be collected and analyzed to conform to Level III DQOs. These data will be used to further characterize the presence and extent of contamination at each POI.
- Characterization and Confirmatory Sampling, Level IV: Groundwater and soil samples collected from monitoring wells and split-spoon soil samples will be collected and analyzed in accordance with Level IV DQOs for confirmatory investigations. Surface water and sediment samples collected during RI-stage field programs will be collected and analyzed to conform to Level IV DQOs.
- Treatability Studies, Level III: Samples collected to evaluate the effectiveness and feasibility of selected remedial alternatives will be analyzed to conform to Level III DQOs.
- Remedial Monitoring and Confirmatory Sampling, Level IV: Samples collected to monitor or confirm the input and output of treatment methods and samples collected to confirm the effectiveness of remedial actions will be analyzed to conform to Level IV DQOs.

Risk Assessment, Levels II, III, and IV: Levels II, III, and IV data may be used in preliminary risk screening evaluations. For more quantitative risk assessments, Level III and Level IV data are preferred.

The sampling approaches presented in Chapter 4.0 of this POP and the laboratory analytical procedures described in Chapter 7.0 have been selected to meet the applicable DQOs.

3.3 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) APPROACH. The approach to providing reliable data that meet the DQOs will include QA/QC requirements for each of the analytical data types generated during the field investigation. The details of field measurement QA/QC are included in Chapter 4.0 of this POP where sample collection techniques are presented. The QA/QC efforts for laboratory analyses will include collection and submittal of QC samples and the assessment and validation of data from the subcontract laboratories.

DQOs are based on the premise that different data uses require different levels of data quality. Data quality refers to a degree of uncertainty with respect to precision, accuracy, representativeness, completeness, and comparability (PARCC).

Parameters used within the data validation process to evaluate data quality include determination of PARCC. The achievable limits for these parameters vary with the DQO level of the data. The limits used for laboratory analytical data in this program will be those set by the CLP for Level IV DQOs and as specified in the USEPA methods for Level III DQOs. These parameters are defined here and methods of calculation are shown.

Precision. Precision is defined as the agreement among individual measurements of the same chemical constituent in a sample, obtained under similar conditions.

Field precision will be expressed as relative percent difference (RPD) of field duplicates using the formula:

$$RPD = \frac{|X1 - X2|}{(X1 + X2)/2} \times 100 \quad (1)$$

where

RPD = relative percent difference between duplicate results,
X1 and X2 = results of duplicate analyses, and
|X1 - X2| = absolute difference between duplicates X1 and X2.

Field duplicates take into account the level of error introduced by field sampling techniques, field conditions, and analytical variability. The RPD of field duplicates will be calculated during the data validation process to evaluate the sample precision.

Accuracy. Accuracy is defined as the degree to which the analytical measurement reflects the true concentration level present. Accuracy will be measured as percent recovery for matrix spikes as the primary criteria and for surrogate spikes as a secondary criteria.

A matrix spike is a sample (of a particular matrix) to which predetermined quantities of standard solutions of certain target analytes are added prior to sample extraction, digestion, and analysis. Samples are split into replicates, one replicate is spiked and both aliquots are analyzed.

Accuracy can also be evaluated using the recovery of surrogate spikes in the organic analyses. These spikes consist of organic compounds that are similar to the analytes of interest in chemical composition, extraction, and chromatography, but that are not normally found in environmental samples. These compounds are spiked into all blanks, standards, and samples prior to analysis.

Percent recoveries of the surrogate, blank spike, and matrix spikes will be reported by the laboratory for all analytes associated with the samples. Variations from 100 percent recovery may be due to matrix interferences, laboratory spike handling procedures, or sample heterogeneities between replicates. The percent recovery of the spikes can be calculated from the following equation:

$$\text{Percent recovery} = \left(\frac{X - B}{T} \right) \times 100 \quad (2)$$

where

X = measured amount in sample after spiking,
B = background amount in sample, and
T = amount of spike added.

Accuracy is difficult to evaluate for the entire data collection activity, especially the sampling component. Field and trip blanks will be used in addition to the matrix and surrogate spiked samples to evaluate data accuracy in the investigations.

Representativeness. Representativeness is defined as the degree to which the data accurately and precisely represents the true environmental condition

existing at each POI. Representativeness is accomplished through proper selection of sampling locations and sampling techniques and collection of a sufficient number of samples.

The sampling locations in this SS/SI/RI will be chosen in a biased approach based on previous analytical data, screening data collected in the field, and apparent and measured flow directions.

Representativeness of samples will be achieved to the greatest degree possible by adhering to the applicable task-specific workplan and the sampling procedures described in Chapter 4.0.

Completeness. Completeness is a measure of the amount of valid data obtained compared to the amount of data originally specified in the workplan. Completeness will be evaluated by carefully comparing project objectives with the proposed data acquisition and resulting potential shortfalls in needed information. The completeness goal for DQO Level III and IV has been chosen as 80 percent, which is consistent with the CLP requirement of 80 to 85 percent.

Field activities performed at DQO Levels I and II are onsite measurement techniques that provide information in real-time or after minimal delay. The completeness achieved for these methods may be more variable than those for standard analytical methods. A higher degree of completeness may be achieved because measurements can be readily repeated. However, site conditions may constrain the use of some techniques, resulting in fewer valid analyses than anticipated.

Comparability. Comparability expresses the confidence with which one set of data can be compared with another. Quantitatively, comparability can be assessed in terms of the precision and accuracy of two sets of data. Qualitatively, data subjected to strict QA/QC procedures will be deemed more reliable than data obtained without the use of these procedures. To maintain comparability, proper sampling methods, COC protocols, CLP analytical methods, and strict QA/QC procedures will provide the basis for uniformity in all data collection and analysis activities.

4.0 FIELD PROGRAM PROCEDURES AND REQUIREMENTS

4.1 FIELD SAMPLE NUMBERING. Samples, other than those collected for *in situ* measurements or analyses, will be identified by using a sample label attached to a sample container. Each sample label will be numbered to correspond with the appropriate sample(s) to be collected.

Samples collected for laboratory analysis during the field investigation will be labeled in accordance with the standard sample identification (ID) protocol described below. Specific sample numbering schemes will be included in workplans for individual tasks.

The standard sample identifier consists of four fields, each containing a code. These fields, including their length in characters, are:

1. site identifier, 2 characters (alphanumeric, characters 1 and 2);
2. sample type, 1 character (alphabetic only, character 3);
3. sample location number, 3 characters (numeric only, characters 4 through 6); and
4. sequence or qualifier indicator, 2 characters (alphanumeric, characters 7 and 8).

A data dictionary for these fields follows.

1. Site identifier: an identifier for the largest area of interest within a base; for instance, a POI number, a building number, or a study area number.
2. Type of sample being taken, including information about media, matrix, and field quality control samples. Categories and codings include:

H = groundwater, filtered	I = test pit
G = groundwater, unfiltered	F = field blank
X = surface water, filtered	T = trip blank
W = surface water, unfiltered	R = rinse blank
S = surface soil	C = blind sample
B = soil boring	N = animal tissue
D = sediment	L = sludge
A = air	U = toxicological
Q = TerraProbe, water	J = potable water source
P = TerraProbe, soil/sediment	K = tap water source blank
M = microbiological	V = soil vapor
Y = organic-free water source blank	Z = other
E = plant tissue	

3. Sample location number within the site and matrix. This number would be unique within a site and matrix, i.e., the first surface water sample taken would be 001, the fifth groundwater sample would be 005, and the first soil boring would be 001. The last available sample location number is 999.

4. Sequence or qualifier indicator: a project specific (but consistent within a project) indicator. The intended use is a sequential indicator of relative depth (or height) of a sample, relative to other samples of the same type at the same sample location, if appropriate. With this use, the sample closest to the land or water surface will be coded as 01; the sample that is ninth closest to the land or water surface will be coded as 09. Using this convention, if depth or height of sample has no meaning (plant tissue, for example), the sample may be coded as 00 (zero, zero).

Project specific coding in this field is acceptable. Any such project-specific coding must be documented in permanent records.

Duplicates, matrix spikes, and matrix spike duplicates will be indicated by appending a "D," "MS," or "MSD" (respectively) to the end of this basic sample identifier.

4.2 PREPARATION OF SAMPLE CONTAINERS. For the majority of sampling episodes, ABB-ES will obtain sample containers from a subcontract laboratory with an FDEP-approved Comprehensive Quality Assurance Plan (CompQAP). However, there may be instances when sample containers will be obtained in a pre-cleaned condition from a commercial source. The origin of sample containers for each project will be noted in the project field log. The consultant may obtain sample containers from suppliers that provide USEPA certification. Records of pre-cleaned bottles and the certification paperwork for each bottle lot will be maintained by the consultant's equipment manager.

In general, sample container selection will be based on the following standards for water:

- Teflon™ septum-sealed glass vials for volatile compounds,
- amber glass bottles with Teflon®-lined lids for organic constituents other than volatiles, and
- polyethylene bottles for inorganic analytes.

For soil and sediment samples, wide-mouth glass bottles will be used. All sample bottles will be prepared in accordance with the procedures specified in the Florida and Comprehensive Long-term Environmental Action, Navy (CLEAN) Operations CompQAP (ABB-ES, 1993).

A summary of specific containers and representative sample volumes is provided, by parameter, in Table 4-1 along with preservation and holding time requirements.

4.3 DECONTAMINATION. The following methods of decontamination will be implemented to prevent cross contamination between sampling points and exploration locations. All sampling, drilling, and excavation equipment will be decontaminated before arriving and prior to leaving the base, and between each exploration location.

Table 4-1
Sample Container and Preservation Requirements

Project Operations Plan for Site Investigations
 and Remedial Investigations
 NTC, Orlando, Orlando, Florida

Parameter	Matrix	Holding Time (from time of collection)	Container	Preservative	Minimum Sample Size ¹
Volatile organic aromatics	Water	14 days	Two 40 ml vials with Teflon™-lined caps	4 drops concentrated HCl, 4 °C	40 ml
	Soil	14 days	Glass with Teflon™-lined septum	4 °C	10 g
Volatile organic halogenated compounds 4 °C	Water	14 days	Two 40 ml vials with Teflon™-lined caps	4 drops concentrated HCl, 4 °C	40 ml
	Soil	14 days	Glass with Teflon™-lined septum	4 °C	10 g
Extractable organics	Water	7 days extraction 40 days analysis	1 l amber glass with Teflon™ liner	4 °C	1,000 ml
	Soil	14 days extraction 40 days analysis	Amber glass jar with Teflon™ liner or core tube	4 °C	50 g
Acrolein 40 days analysis	Water	14 days	Glass with Teflon™-lined septum	0.008% Na ₂ S ₂ O ₃ adjust pH to 4 to 5, 4 °C	40 ml
	Soil	14 days	Glass with Teflon™-lined septum	4 °C	enough to fill 2-40 ml vials
Organophosphorus pesticides	Water	7 days extraction 40 days analysis	1 l borosilicate glass	Adjust pH to 6.0 to 8.0 with H ₂ SO ₄ or 10 N NaOH, 4 °C	1,000 ml
	Soil	7 days extraction 30 days analysis	1 l borosilicate glass	4 °C	100 g
Chlorinated herbicides	Water	7 days extraction 30 days analysis	1 l borosilicate glass	4 °C	1,000 ml
	Soil	7 days extraction 30 days analysis	1 l borosilicate glass	4 °C	100 g
Organochlorine pesticides and PCB	Water	7 days extraction 30 days analysis	1 l borosilicate glass	4 °C	1,000 ml
	Soil	7 days extraction 30 days analysis	1 l borosilicate glass	Adjust pH to 6.0-8.0 with 1:1 H ₂ SO ₄ or NaOH, 4 °C	100 g
Metals (other than chromium VI and mercury)	Water	180 days	Polyethylene or glass	HNO ₃ to pH <2 ²	100 ml
	Soil	180 days	Polyethylene or glass	4 °C	10 g

See notes at end of table.

Table 4-1 (Continued)
Sample Container and Preservation Requirements

Project Operations Plan for Site Investigations
 and Remedial Investigations
 NTC, Orlando, Orlando, Florida

Parameter	Matrix	Holding Time (from time of collection)	Container	Preservative	Minimum Sample Size ¹
Chromium VI	Water	24 hours	Polyethylene or glass	4 °C	100 ml
	Soil	24 hours	Polyethylene or glass	4 °C	10 g
Mercury	Water	28 days	Polyethylene or glass	HNO ₃ to pH <2 ²	100 ml
	Soil	28 days	Polyethylene or glass	4 °C	10 g
Cyanide	Water	14 days	Polyethylene or glass	0.6 g ascorbic acid, NaOH to pH > 12, 4 °C	100 ml
	Soil	14 days	Polyethylene or glass	4 °C	10 g
Dioxins/furans	Water	7 days extraction 40 days analysis	Glass	4 °C	1,000 ml
	Soil/waste	14 days extraction 40 days analysis	Core tube	4 °C	50 g
Petroleum hydrocarbons as gasoline	Water	14 days	Two 40 ml vials with Teflon™ liners	4 °C, HCl to pH <2	40 ml
	Soil/waste	14 days	Core tube	4 °C	50 g
Petroleum hydrocarbons as diesel	Water	14 days extraction 40 days analytical	Glass	4 °C	500 ml
	Soil/waste	14 days extraction 40 days analytical	Core tube	4 °C	50 g
Total Petroleum hydrocarbons (TPH)	Water	28 days	Glass	4 °C, HCl to pH <2	1,000 ml
	Soil	28 days	Glass jar with Teflon™ liner or core tube	4 °C	50 g
Oil and grease	Water	28 days	Glass bottle	Adjust pH to <2.0 with H ₂ SO ₄ , 4 °C	1,000 ml
	Soil	28 days	Glass jar with Teflon™ liner	4 °C	50 g
Residue, settable	Water	48 hours	Polyethylene or glass bottle	4 °C	1,000 ml
Residue, all others (TSS, VSS, TDS)	Water	7 days	Polyethylene or glass bottle	4 °C	500 ml

See notes at end of table.

Table 4-1 (Continued)
Sample Container and Preservation Requirements

Project Operations Plan for Site Investigations
 and Remedial Investigations
 NTC, Orlando, Orlando, Florida

Parameter	Matrix	Holding Time (from time of collection)	Container	Preservative	Minimum Sample Size ¹
Biochemical oxygen demand	Water	48 hours	Polyethylene or glass bottle	4 °C	1,000 ml
Chemical oxygen demand	Water	28 days	Polyethylene or glass bottle	Adjust pH to <2.0 with H ₂ SO ₄ , 4 °C	1,000 ml
Metals (ICP)	Water	6 months	Polyethylene	HNO ₃ to pH <2	100 ml
	Soil	6 months	Core tube or glass jar	4 °C	10 g
Arsenic (GFAA)	Water	6 months	Polyethylene	HNO ₃ to pH <2	100 ml
	Soil/waste	6 months	Core tube or glass jar	4 °C	10 g
Mercury (CVAA)	Water	28 days	Polyethylene	HNO ₃ to pH <2	100 ml
	Soil/waste	28 days	Core tube or glass jar	4 °C	10 g
Selenium (GFAA)	Water	6 months	Polyethylene	HNO ₃ to pH <2	100 ml
	Soil/waste	6 months	Core tube or glass jar	4 °C	10 g
Thallium (GFAA)	Water	6 months	Polyethylene	HNO ₃ to pH <2	100 l
	Soil/waste	6 months	Core tube or glass jar	4 °C	10 g
Lead (GFAA)	Water	6 months	Polyethylene	HNO ₃ to pH <2	100 ml
	Soil/waste	6 months	Core tube or glass jar	4 °C	10 g
Chromium (VI)	Water	24 hours	Polyethylene	4 °C	100 ml
	Soil/waste	24 hours	Core tube or glass jar	4 °C	10 g
Cyanide	Water	14 days	Polyethylene or glass	0.6 g ascorbic acid, NaOH to pH ≥12, 4 °C	100 ml
	Soil/waste	14 days	Polyethylene or glass bottle	4 °C	10 g
Coliform, fecal and total	Water	6 hours	Polyethylene or glass bottle	0.08% Na ₂ S ₂ O ₃ , 4 °C	500 ml
Fecal streptococci	Water	6 hours	Polyethylene or glass bottle	0.08% Na ₂ S ₂ O ₃ , 4 °C	500 ml

See notes at end of table.

Table 4-1 (Continued)
Sample Container and Preservation Requirements

Project Operations Plan for Site Investigations
 and Remedial Investigations
 NTC, Orlando, Orlando, Florida

Parameter	Matrix	Holding Time (from time of collection)	Container	Preservative	Minimum Sample Size ¹
Nitrogen, organic and Kjeldahl	Water	28 days	Polyethylene or glass bottle	Adjust pH to <2.0 with H ₂ SO ₄ , 4 °C	500 ml
Nitrate	Water	48 hours	Polyethylene or glass bottle	4 °C	125 ml
Nitrate + nitrite	Water	28 days	Polyethylene or glass bottle	Adjust pH to <2.0 with H ₂ SO ₄	125 ml
Phosphorus, total	Water	28 days	Polyethylene or glass bottle	Adjust pH to <2.0 with H ₂ SO ₄	125 ml
Sulfate	Water	28 days	Polyethylene or glass bottle	4 °C	125 ml
Sulfide	Water	7 days	Polyethylene or glass bottle	Adjust pH to >9.0 with zinc acetate plus NaOH, 4 °C	500 ml
Surfactants	Water	48 hours	Polyethylene or glass bottle	4 °C	1,000 ml
Radiological tests: alpha, beta, radium	Water	6 months	Polyethylene or glass bottle	Adjust pH to <2.0 ²	
Total organic carbon	Soil	28 days	Polyethylene or glass bottle	Adjust pH to <2.0 4 °C	10 g
Total organic halogens	Water	28 days	Glass with Teflon™-lined cap	Adjust pH to <2.0 4 °C	40 ml

¹ Additional sample must be collected for matrix spike or matrix spike duplicate samples.

² Must be preserved in the field at time of collection.

Notes: ml = milliliter.

HCl = hydrochloric acid.

°C = degrees Celsius

g = gram.

ℓ = liter.

HNO₃ = nitric acid.

Na₂S₂O₃ = sodium thiosulfate.

NaOH = sodium hydroxide.

H₂SO₄ = sulfuric acid.

TSS = total suspended solids.

VSS = visible suspended solids.

TDS = total dissolved solids.

To assure that analytical results reflect the actual concentrations present at sampling locations, chemical sampling and field analytical equipment must be properly decontaminated prior to the field effort, during the sampling program (i.e., between sampling points), and at the conclusion of the sampling program.

This section addresses the decontamination procedures for chemical sampling and field analytical equipment as well as for drilling equipment. These cleaning procedures are based on USEPA Region IV Standard Operating Procedures (SOPs) (USEPA, 1991c). To clarify the decontamination procedures, the following definitions have been used.

Detergent will be a standard brand of phosphate-free laboratory detergent such as Alconox 41™ or Liquinox™.

Acid solution will be made from reagent-grade nitric acid and deionized water.

Tap or potable water will be treated water from any municipal water supply system.

Deionized water will be tap water that has been treated by passing through a standard deionizing resin column to remove cations and anions.

Organic-free water will be tap water that has been treated with activated carbon and deionizing units. It should contain no detectable pesticides, herbicides, extractable organic compounds, and less than 5 micrograms per liter ($\mu\text{g}/\ell$) of purgeable organic compounds as measured by a low level gas chromatograph/mass spectrometer (GC/MS) scan. This organic-free water will be used for blank preparation and for final rinse in decontamination (where applicable). The consultant may use an onsite generated source of organic-free water.

Solvent will be pesticide-grade isopropanol.

4.3.1 In-House Cleaning Procedures Prior to transport to the field, sampling equipment will be decontaminated using the procedures described below. To the extent feasible, enough sampling equipment will be made available to conduct a sampling episode without field decontamination. All decontamination procedures conducted in-house will be documented in an equipment room logbook.

The following subsections describe cleaning procedures for sampling, pumping, and measurement equipment that will be conducted "in-house" prior to transport of the equipment to the field.

4.3.1.1 Teflon™ or Glass Sampling Equipment (Trace Organics and/or Metal Analyses) In-house decontamination procedures for Teflon™ or glass sampling equipment used to collect samples for trace organic and/or metal analysis are listed below.

1. Wash and scrub equipment thoroughly with laboratory detergent and hot water.
2. Rinse thoroughly with hot tap water.
3. Rinse with at least a 10 percent nitric acid solution.

4. Rinse thoroughly with tap water.
5. Rinse thoroughly with deionized water.
6. Rinse twice with solvent (pesticide-grade isopropanol).
7. Air dry for at least 24 hours.
8. Wrap equipment in aluminum foil. Roll the edges into a "tab" to allow easy removal. Seal the foil-wrapped equipment in plastic and date.
9. After use in the field, rinse the equipment thoroughly with tap water as soon as possible, if full field decontamination procedures are not used.

4.3.1.2 Stainless-Steel or Metal Sampling Equipment (Organic and/or Metal Analyses) In-house decontamination procedures for stainless-steel or metal sampling equipment used to collect samples for trace organic and/or metal analysis are listed below.

1. Wash and scrub equipment thoroughly with laboratory detergent and hot water.
2. Rinse thoroughly with hot tap water.
3. Rinse with deionized water.
4. Rinse twice with solvent (pesticide-grade isopropanol).
5. Air dry for at least 24 hours.
6. Wrap equipment in aluminum foil. Roll the edges into a "tab" to allow easy removal. Seal the foil-wrapped equipment in plastic and date.
7. After use in the field, rinse the equipment thoroughly with tap water as soon as possible, if full field decontamination procedures are not used.

4.3.1.3 Submersible Pumps and Hoses In-house decontamination procedures for submersible pumps and hoses used for purging monitoring wells are listed below.

1. Pump a sufficient amount of soapy water through the hose to flush out any residual purge water.
2. Using a brush, scrub the exterior of the contaminated hose and pump with hot soapy water. Rinse the soap from the outside of the hose with tap water. Next rinse the hose with deionized water and recoil onto the spool.
3. Pump a sufficient amount of tap water through the hose to flush out soapy water.
4. Pump a sufficient amount of deionized water through the hose to flush out the tap water.

5. Rinse the outside of the pump housing and hose with deionized water (approximately 1/4 gallon).
6. Equipment will be placed in a polyethylene bag or wrapped with polyethylene film to prevent contamination during storage or transit.

4.3.1.4 Sampling and/or Filtering Tubing In-house decontamination procedures for Teflon™, PVC, stainless-steel, and glass tubing used for groundwater sampling and/or filtering are listed below. In-line disposable filter cartridges should be rinsed with tap water and disposed.

4.3.1.5 Teflon™ Tubing Use only new, food-grade Teflon™ tubing. This tubing is not pre-cleaned, but should be stored and transported in its original container or wrapped in polyethylene to prevent contamination. Tubing should be flushed in the field with the sample medium before sample collection to remove any residues. Tubing will not be reused.

4.3.1.6 Polyvinyl chloride (PVC) Tubing Use only new PVC tubing. PVC is not to be used for samples being submitted for organics analyses. This tubing is not pre-cleaned, but should be stored and transported in its original container or wrapped in polyethylene to prevent contamination. Tubing should be flushed in the field with the sample medium before collection to remove any manufacturing residues.

4.3.1.7 Stainless-Steel Sampling Tubing Pre-clean tubing as follows.

1. Wash and scrub equipment thoroughly with laboratory detergent and hot water.
2. Rinse thoroughly with hot tap water.
3. Rinse with deionized water.
4. Rinse twice with solvent (pesticide-grade isopropanol).
5. Air dry for at least 24 hours.
6. Wrap tubing and cap ends with aluminum foil and seal in plastic to prevent contamination during storage and transport.

4.3.1.8 Glass Tubing Use only new glass tubing, pre-cleaned as follows.

1. Wash equipment thoroughly with laboratory detergent and hot water using a brush to remove any particulate matter or surface film.
2. Rinse equipment thoroughly with hot tap water.
3. Rinse equipment thoroughly with deionized water.
4. Rinse equipment twice with solvent and allow to air dry at least 24 hours.
5. Wrap tubing and cap ends in aluminum foil and seal in plastic to prevent contamination during storage and transport.

4.3.1.9 Well Sounders and Groundwater Measurement Tapes In-house decontamination procedures for Teflon™, PVC, stainless-steel, and glass tubing used for groundwater sampling are listed below.

1. Wash with laboratory detergent and tap water.
2. Rinse with tap water.
3. Rinse with deionized water.
4. Wrap equipment in aluminum foil. Roll the edges into a "tab" to allow easy removal. Seal the foil-wrapped equipment in plastic and date.

4.3.1.10 Ice Chests and Shipping Containers In-house decontamination procedures for ice chests and shipping containers are listed below. Noticeably contaminated containers should be thoroughly cleaned and properly disposed.

1. Wash inside and out with laboratory detergent and tap water.
2. Rinse with tap water.
3. Air dry.

4.3.1.11 Field Parameter Measurement Probes Field parameter measurement probes, (e.g., pH or specific ion electrodes, geophysical probes, or thermometers) that come in direct contact with the sample will be decontaminated using the procedures listed below, unless manufacturer's instructions indicate otherwise. Probes that make no direct contact (e.g., OVA equipment) will be wiped with clean paper towels.

1. Rinse with tap water.
2. Rinse with deionized water.
3. Solvent rinse, if obvious contamination remains after rinsing and if solvent will not damage probe.
4. Rinse with deionized water.

4.3.2 Organic-Free Water Containers New containers that will be used to store and transport organic-free water will be cleaned as follows.

1. Wash containers thoroughly with hot tap water and laboratory detergent, using a bottle brush to remove particulate matter and surface film.
2. Rinse containers thoroughly with hot tap water.
3. Rinse containers with at least 10 percent nitric acid.
4. Rinse containers thoroughly with tap water.
5. Rinse containers thoroughly with deionized water.
6. Rinse twice with solvent and allow to air dry for at least 24 hours.

7. Cap with aluminum foil or Teflon™ film.
8. After using, rinse with tap water in the field, seal with aluminum foil to keep the interior of the container wet, and return to the laboratory.

Used containers will be capped with aluminum foil immediately after being used in the field. The exterior of the containers will be washed with laboratory detergent and rinsed with deionized water if necessary. The interior of the container will be rinsed twice with solvent. The interior of the container will be thoroughly rinsed with organic-free or Milli-Q™ water. The container will be filled with organic-free or Milli-Q™ water and capped with aluminum foil for storage.

4.3.3 Field Decontamination Procedures When practical, sufficient equipment should be staged in the field so that the entire study can be conducted without the need for field cleaning. However, when this is not possible, the following USEPA Region IV field decontamination procedures will be followed (USEPA, 1991c).

4.3.3.1 Sampling Equipment for Classic Water Quality Parameters Sampling equipment for classic water quality parameters (dissolved oxygen [DO], biological oxygen demand [BOD], TOC, etc.) including, but not limited to, Kemmerers, buckets, DO dunkers, and dredges, will be cleaned in the field prior to use and between sampling locations as follows.

1. Rinse and scrub with water to be sampled or tap water.
2. Rinse with deionized water.

4.3.3.2 Sampling Equipment for Organic and Metal Analysis Teflon™, stainless-steel, glass, or metal sampling equipment used to collect samples for organic and metal analysis will be cleaned between sample locations as listed below.

1. Wash and scrub equipment thoroughly with laboratory detergent and tap water.
2. Rinse thoroughly with tap water.
3. Rinse thoroughly with deionized water.
4. Rinse twice with solvent (pesticide-grade isopropanol).
5. Rinse with organic-free water and allow to air dry as long as possible.
6. If organic-free water is not available, allow equipment to air dry as long as possible. Do not rinse again with deionized or distilled water.

4.3.4 Large Equipment Decontamination Large equipment (e.g., drill rigs, backhoes, augers, drill pipe, casing, and screen) will be cleaned prior to use and between sample locations in accordance with USEPA Region IV SOPs as outlined below.

4.3.4.1 Cleaning Procedures Prior to Initiation of Field Work All equipment to be used onsite will be in good working order and free of leaks. Any part of the drill rig or backhoe that will be over the borehole or sampling location (e.g., kelly bar or mast, backhoe buckets, drilling platform, hoist or chain pulldowns, spindles, cathead, etc.) will be decontaminated prior to arriving at the site as described below.

1. Steam clean and wire brush to remove soil and rust.
2. Inspect to assure that seals and gaskets are intact and that there are no residual oils, grease, or hydraulic fluids that could drip into the sample location.
3. If necessary, use Teflon™ string to tighten drill stem.
4. Steam clean the drill rig prior to drilling each borehole.

4.3.4.2 Cleaning Procedures for Downhole Equipment Drilling, sampling, and associated equipment that will come in contact with the downhole sampling medium will be cleaned as outlined below.

1. Wash and scrub with tap water and laboratory-grade detergent.
2. Steam clean and/or high pressure wash, if necessary, to remove soils. The steam cleaner or high pressure washer should be capable of generating a pressure of at least 2,500 pounds per square inch (psi) and producing hot water and/or steam (200 degrees °F and above). If it is necessary to steam clean PVC well materials, care must be taken to control steam temperature so as to maintain the integrity of the PVC.
3. Rinse thoroughly with tap water.
4. Rinse thoroughly with deionized water.
5. Rinse twice with solvent (pesticide-grade isopropanol). Note: do not rinse PVC materials with solvent.
6. Rinse thoroughly with organic-free water and allow to air dry. Do not rinse again with deionized or distilled water.
7. If organic-free water is not available, allow equipment to air dry. Do not rinse again with deionized or distilled water.
8. Where appropriate, wrap with aluminum foil to prevent contamination during storage. Augers, drill stems, casings, and other large items can be wrapped in clean plastic if necessary.
9. If caked mud, rust, and/or paint is present that can not be removed by steam or high pressure wash, the downhole equipment will be sandblasted prior to step number 1 above, and prior to arrival onsite.
10. Printing and/or writing on well casing, screens, tremie tubing, etc., will be removed with emery cloth or sand paper prior to arrival onsite. Where possible, materials without printing or writing will be ordered.

4.3.4.3 Decontamination Staging Area and Fluid Disposal Cleaning and decontamination of all equipment will occur at a designated area at each POI or study area that is downgradient and downwind (prevailing wind direction) of the clean equipment drying and storage area. The cleaning and decontamination area will contain an excavated pit, lined with heavy duty plastic sheeting, for containment of washwater and waste. The decontamination area will be designed such that washwater will drain into the pit. Solvent rinsates will be collected in separate containers. Large portable equipment (drill rods, auger flights, well casing and screen, etc.) will be cleaned on saw horses or other supports constructed above the plastic sheeting.

The water will be pumped into 55-gallon drums and the sediment will be collected in separate drums. The plastic sheeting will be washed and the washwater will be containerized as contaminated washwater. The plastic sheeting will then be properly disposed. The pit will be backfilled with the originally excavated material.

The drums containing waste will be properly labeled, sealed, and staged for storage until laboratory analytical results are received. Drum labels will include the contents (medium), the POI or study area of origin, the investigation location ID, and the date of generation. The contaminated material will be treated as discussed in Section 4.10.

4.4 FIELD INVESTIGATION TECHNIQUES AND PROCEDURES.

4.4.1 Mobilization To streamline field tasks and minimize project delays at commencement of field activities, the following mobilization tasks will be implemented prior to initiating field investigative activities.

1. A central office facility (e.g., trailer or permanent structure) will be established to function as headquarters for field program activities. The field office will, at a minimum, have electrical power, sanitary sewage, public water, and telephone communication. Additionally, based on the size of the field program, the field office may contain a two-way radio base station, portable computer, and copy machine. The office will also serve as the location for field project files and field equipment storage.
2. Subcontractor drilling and excavation equipment and supplies are to be staged in a designated location during mobilization, prior to the initiation of subsurface exploration activities. The equipment will be decontaminated prior to arrival onsite as prescribed in Section 4.3.
3. A temporary, centrally located decontamination pad will be constructed during drilling and excavation equipment mobilization and prior to the initiation of field activities (see Section 4.3).
4. All sampling and health and safety equipment and materials will be staged in the field office.
5. Team meetings will comprise the final phase of mobilization. Meetings will focus on project health and safety requirements, installation policies and procedures to be followed (e.g., utility clearances),

field sampling procedures, site preparation and access requirements, and drilling requirements (e.g., decontamination, waste handling, and well installation).

6. During field programs, morning health and safety meetings will be held prior to commencement of the day's field activities.

4.4.2 Unexploded Ordnance Clearance Survey Unexploded ordnance (UXO) clearance surveys will be conducted by a qualified UXO consultant or Navy explosive ordnance disposal (EOD) personnel to determine the location of UXO located both within the surface and subsurface of a POI. Clearance surveys will be conducted, prior to any field exploration activities, at POIs that have been designated as potential UXO sites. The clearance survey consists of conducting records review, visual sweeps, and geophysical survey sweeps of designated areas. Results of the survey will be used to assess the need of removing UXO from any exploration location, including borehole clearance during drilling.

4.4.2.1 Records Review The UXO consultant will initially collect all pertinent data available including (1) review of base records and (2) conductance of interviews with appropriate base personnel. The information will be evaluated and combined with the actual onsite clearance data to evaluate the levels, types, and boundaries of potential UXO within designated POIs.

4.4.2.2 Visual Sweep Survey A surface, visual sweep team, consisting of a minimum of two EOD trained specialists, will conduct a visual search and clearance of the designated areas. Hazardous UXO items visually located by the sweep team will be marked with stakes. Removal of hazardous UXO items will be conducted by either the UXO consultant or EOD installation personnel. Hazardous UXO items that can be safely moved will be collected and placed at a designated ordnance holding area.

4.4.2.3 Geophysical Sweep Survey Following the visual sweep survey, the UXO consultant will perform a geophysical sweep survey of designated areas. Using marking stakes and lines, as necessary, the UXO specialist will mark the outer perimeter of each survey site. The geophysical survey team will conduct a subsurface electromagnetic search of the survey area using a military-approved ordnance locator. This hand-held unit is the most recent military-approved locator currently in use for detecting subsurface ordnance items by the U.S. Military EOD forces. An ordnance locator uses two fluxgate magnetometers that are aligned and mounted a fixed distance apart to detect changes in the earth's ambient magnetic field caused by ferrous metal or disturbances caused by soil conditions.

The EOD specialist will use the ordnance locator and move along each line of the survey grid. When a subsurface anomaly is detected, the specialist will check the ground with his hand to determine if the contact is on, or just below, the surface. If the contact is buried, the UXO consultant will mark the spot and continue until the fade out zone is established for each contact.

Any excavation deemed necessary will be completed by hand, or with hand tools, in accordance with EOD procedures. Items located by the UXO team will be marked and subsurface diagnosis will be performed by an EOD team with non-sparking tools. An EOD technician will be present to ensure safety and to verify all excavations. The items will then be recorded on the survey grid data sheets.

4.4.2.4 Borehole Clearance Prior to any drilling activities in UXO designated areas, the EOD specialist will surface sweep the access to the boring sites. The sweep will encompass a minimum access way of 25 feet and a drilling site area of approximately 70 feet in diameter and 10 feet deep at designated boring locations. Both ferrous and nonferrous locators will be used to achieve a high effectiveness of the surface sweep. At designated sites, boreholes may be cleared at the surface and every 5 feet thereafter by removing the augers and inserting the probe of the ordnance locator to the bottom of the borehole. This procedure will be followed to a minimum depth of 10 feet.

4.4.3 Surface Geophysical Survey Geophysical surveys can be used to identify buried objects or features such as utility lines or pipes, former disposal trenches or pits, buried drums, and/or waste material. Geophysical techniques commonly used as part of field investigations include GPR, magnetometry, and TC. Using more than one individual survey technique in a given area provides for correlation of anomalous features and a more comprehensive interpretation.

4.4.3.1 Magnetometry Magnetometers can be used to locate buried steel containers, define boundaries of pits or trenches filled with ferrous debris, and locate ferrous underground utility pipes and electrical conduits. Magnetometers measure the intensity of the earth's magnetic field. Buried ferrous objects can cause variations in the magnetic field, which, in turn, can be detected by the magnetometer.

Measurements can be collected at individual stations located on a grid, or continuously along traverse lines. Presentation of the data is typically limited to profile lines or contour maps showing the location of the magnetic anomaly.

The magnetic gradiometer consists of a pair of total field magnetic sensors mounted on a survey pole. The sensors are designed to measure magnetic field strength. Simultaneous readings from each sensor with the survey pole held vertically provides the gradient value by calculating the difference in total field strength between each sensor. The magnetometer thus provides both total field and magnetic gradient values at the same time. The unit is equipped with a portable data logging device to record individual gradient and total field strength readings. The particular advantage of this surveying technique is that it is fully portable and self contained. Access limitations associated with some geophysical surveying methods (e.g., cables and the need for field support vehicles) need not be considered with this form of geophysical survey.

Data will usually be collected at pre-established grid nodes within a survey area. The grid nodes will be marked in the field with flagged stakes for collecting data and locating interpreted magnetic anomalies later. Data stored in the portable data logger is down-loaded to a personal computer for processing. Processing includes establishing a uniform grid data set over the area surveyed and contouring the results. At the completion of the survey, interpretation of the contoured gradient and total field data will be conducted and anomalies marked in the field with labeled flagged stakes. Surveying limitations may occur in areas where interference from fences, railroad tracks, power lines, and surficial ferrous metal debris exist. These areas will be avoided, where possible, during the survey.

The magnetometry method requires a two-person crew consisting of one instrument operator to collect data at the designated survey nodes, and an assistant to

maintain field mapping notes on observed landmarks and surficial features that may affect magnetic readings. Field maps will be used as an integral part of the interpretation of magnetic anomalies. A magnetic base station will be established and total magnetic field data collected periodically to monitor diurnal variations in the earth's magnetic field so that corrections to the total field data from the survey can be made if necessary.

4.4.3.2 Ground Penetrating Radar GPR uses electromagnetic waves in the frequency range of 80 to 1,000 megahertz to define subsurface stratigraphy. With the GPR technique, electromagnetic energy is radiated downward into the subsurface from an antenna that is pulled slowly across the ground at speeds varying from about 0.25 to 5 miles per hour (mph), depending on the amount of detail desired and the nature of the target. The radio wave energy is reflected from surfaces where there is a contrast in the electrical properties of subsurface materials. These surfaces may be naturally occurring geologic horizons (e.g., soil layers, changes in moisture content, voids, and fractures in bedrock) or manmade (e.g., buried utilities, tanks, drums, or dunnage). The reflected energy is processed and displayed as a continuous strip chart recording of distance versus time, where time can be thought of as approximately proportional to depth. The depth of penetration of a GPR system is highly site specific, and generally depends on the soil types at the site (clean sands are best), moisture conditions (dry is best), and the frequency of the antenna (the lower the frequency, the deeper the penetration and the less the resolution).

The GPR unit will generally be operated from a utility vehicle with the remote transmitter and receiver antenna towed either manually or behind the vehicle. Reflected radar signals, transferred to a graphic strip chart recorder on the GPR unit, will be interpreted directly in the field. Interpreted reflectors will be marked at the surface with flagging or spray paint during the survey.

Several factors may adversely affect the quality, and the ability to collect interpretable data. They include: physical access limitations for both the utility vehicle and towed antenna, contrasts in electrical properties between soil and subsurface targets (clay pipe and concrete tanks are more difficult to locate than metallic objects because of the lower contrast), the size and depth of subsurface objects (deeper and smaller objects are more difficult to locate), and the clay content and degree of water saturation of soils. Wet, clay-rich soils can significantly attenuate the radar signal making interpretation difficult and sometimes impossible.

Proposed survey lines will be concentrated in areas where the targets are likely to exist for better resolution. Because of the inherent flexibility in data collection, actual GPR survey lines can be easily modified in the field based on preliminary interpretations. Survey line spacings will be increased or decreased in response to success of data collection efforts at the time of the survey. The survey will generally be conducted by a two-person crew.

4.4.3.3 Terrain Conductivity (TC) TC surveys have traditionally been used in mineral exploration for tracing conductive ore bodies (i.e., massive sulfides). More recently, TC surveys have been widely used not only for tracing conductive contaminant plumes in groundwater, but for mapping landfill boundaries and zones with high concentrations of metal, as would occur in a drum repository, and conductive soil.

Because the instrument never comes in contact with the ground, data acquisition is quite rapid. However, quantification of conductivity data to yield a layered-earth solution as is commonly done with earth resistivity techniques yields only simple solutions that should be regarded as approximate.

This instrument consists of a transmitter and receiver. When a measurement is made, the transmitter is energized by an alternating current that produces a primary magnetic field. This artificial magnetic field induces small electric currents to flow in the earth, which, in turn, produce a secondary magnetic field made up of two components: the quadrature-phase and in-phase components. The secondary magnetic field is related to the transmitter and receiver separation and to the operating frequency of the transmitter, both of which are selected by the operator. The ratio of the quadrature phase of the secondary field to the primary field is linearly proportional to the terrain conductivity. This ratio is measured by the receiver and converted into conductivity values in units of millimhos per meter.

Field measurements may be recorded on a digital data logger, which is capable of recording simultaneously both the quadrature-phase and in-phase components of the induced magnetic field. The quadrature-phase component gives the ground conductivity value in millimhos per meter. The in-phase component is significantly more sensitive to metallic objects and may be useful for rough screening for buried metal objects. Data from the in-phase component may be thought of as being equivalent to a metal detector survey. Data will be logged continuously along survey lines yielding conductivity profiles, or at selected grid nodes. In either case, data will be down-loaded from the data logger and processed into a map to provide for a comprehensive interpretation of conductivity anomalies.

Physical access is generally not a problem because of the inherent portability of TC equipment. Surficial features, such as chainlink fences, automobiles, buildings, and railroad tracks can, however, cause significant interference in TC data. Areas possessing these types of features will be avoided, to the extent practical, during surveying.

The survey method is commonly conducted by a two-person crew. One person operates the TC unit and data logger; the other logs surface landmarks and reference points on a hand-drawn map. The map is used in conjunction with processed TC data to provide a more accurate interpretation of anomalies. The map will also be used to assist in flagging areas in the field where TC anomalies have been identified.

4.4.3.4 Seismic Refraction Profiling Seismic refraction profiling is an indirect means of determining the thickness and velocity values of the various seismic layers underlying a site. There is often a direct correlation between geologic strata and the layers defined during a seismic refraction investigation.

The basis for the interpretation of data is the amount of time required for elastic waves, generated at a point source, to travel to a series of sensitive listening devices called geophones, or seismometers. Geophones are placed at known intervals along a straight line on the ground surface and connected by special multi-conductor cables to the seismograph. The cables are known as seismic spread cables and the array of geophones and cables is called a seismic spread. The seismograph is the device that records the elastic wave arrivals

from the energy source along the seismic spread, acquiring separate data for each geophone position.

The seismic waves detected in a seismic refraction survey and used for depth calculations and the identification of materials are "P" (compressional) waves. This wave travels through earth materials as a series of compressions and rarefactions. Just as sunlight bends when it passes through a glass prism (refraction), so sound waves bend as they travel deeper into the earth through the various layers of soil and rock. Because they are bent, they eventually return to the surface as refracted seismic waves. Careful measurement of the transit times between the energy source and each geophone enables interpretation of subsurface structure. The thickness and velocity values of various soil and rock layers can be computed. In the same manner, seismologists have learned about the interior of the earth by carefully measuring the arrival of seismic waves generated by distant earthquakes.

Field Procedure for Data Acquisition. Seismic spread cables, which have pre-measured shotpoint and geophone locations, are positioned along the lines of investigation. Geophones, which have a spiked base to provide good ground contact, are positioned at measured locations along the seismic spread cables. Either a weight impact (sledge hammer) or small buried charges of explosives provide the seismic energy source. If explosives are necessary, shotholes are usually prepared with a driven rod (not excavated) to ensure good ground coupling. The blaster tamps the explosives tightly and notes the depth and amount of explosives in each shothole.

Seismograms are obtained using a portable signal enhancement seismograph. This instrument records the wave arrivals from the energy source along the seismic spread, acquiring separate data for each geophone position. Timing lines across the entire recording allow direct reading of wave arrivals to an accuracy of 1 millisecond. The signal enhancement capability refers to the ability of the instrument to record the seismic waves from several impacts (or explosions), add them electronically, and retain these data in its internal digital memory for later processing and interpretation. The enhanced signal improves data quality and greatly simplifies interpretation.

Generally, the field party will obtain several recordings (seismograms) along each seismic spread. Seismograms are generated with the energy source at each end, and others may be obtained by energy generation in the middle, and at other positions along an individual seismic spread as necessary.

Continuous profiling is accomplished by having an end shotpoint of one seismic spread coincident with an end or intermediate position shotpoint of the succeeding spread. The length of each spread is determined by the required depth of penetration. Seismic spreads of varying lengths can be used in a study; the deeper the required penetration, the longer the spread must be.

Interpretation. The data are interpreted by first accurately measuring the individual transit times at each geophone position, then constructing a graph of these times versus their distance from the energy source. The geophysicist then determines by inspection of the time-distance graphs the number of subsurface seismic layers present. Straight line segments of best fit are drawn onto the graphs with each layer represented by a line of different slope. The inverse of the slope of each line is the (apparent) velocity value for each layer. The

distance, x , from the energy source to the "crossover point" between two layers is proportional to the thickness, D , of the overlying layer.

Depth calculations are made using standard critical distance formulae of the form

$$D_n = \frac{x_{n+1}}{2} \sqrt{\frac{V_{n+1} - V_n}{V_{n+1} + V_n}} + D_1 \frac{V_{n+1} \sqrt{V_n^2 - V_1^2} - V_n \sqrt{V_{n+1}^2 - V_1^2}}{V_1 \sqrt{V_{n+1}^2 - V_n^2}} + \dots \quad (3)$$

$$+ \dots + D_{n-1} \frac{V_{n+1} \sqrt{V_n^2 - V_{n-1}^2} - V_n \sqrt{V_{n+1}^2 - V_{n-1}^2}}{V_{n-1} \sqrt{V_{n+1}^2 - V_n^2}}$$

where D_n is the thickness of the n th layer, x_{n+1} , and is the critical distance for the deepest refractor, designated as the $n+1$ layer of seismic velocity value V_{n+1} .

There are several limitations, discussed below, of seismic refraction exploration that should be restated whenever such a study is planned so that expectations are reasonable.

Accuracy. The accuracy of any measurement or calculation (depth, velocity, or critical distance) is generally limited to within plus or minus 10 to 15 percent of its "true" value. For example, if a depth to a refractor (bedrock) is calculated from refraction measurements to be 50 feet, then one might reasonably expect that if one were to confirm the depth to rock through drilling, that bedrock would be encountered at a depth of 50 plus or minus 5 to 7.5 feet, or 42.5 to 57.5 feet bls.

Layer Thickness and Velocity Relationships. To be detected by seismic refraction, a target refractor must have sufficient thickness and velocity contrast with overlying layers. A general guideline that can be used is that a target refractor should have a seismic velocity value of at least 1.2 to 1.5 times the velocity of the overlying layer and a thickness of from 0.5 to 1.0 times the combined thickness of the overlying layers. The greater the contrast in velocity between the target refractor and the overlying layer, and the greater its thickness, the more accurately it can be mapped. Conversely, the smaller the contrast in velocity and the thinner the target refractor, the less likely that it will be mapped accurately. In fact, as the velocity contrast or thickness approaches smaller and smaller values, there is a point at which the layer will no longer be detected by seismic refraction.

Seismic Velocity Increases with Depth. Interpretation and data processing of all seismic refraction data make the assumption that the velocity value at which sound waves travel through subsurface materials will increase with depth. Generally, this assumption is both reasonable and valid, although there are notable exceptions. When seismic refraction measurements are made on asphalt or concrete surfaces, the asphalt or concrete "layer" is always of higher velocity than the underlying fill or soil materials. These data must be used with caution and with the knowledge that sometimes such data will not be useable. Refraction surveys in karst terrain with limestone deposits underlain by shale or weathered bedrock would also fall into this category.

Uneven Terrain and Crooked Traverses. There are many pitfalls to the successful interpretation of seismic data that are not controllable, but two common pitfalls that are controllable are avoiding uneven terrain and avoiding unnecessary bends along seismic traverses. Uneven terrain along a traverse causes otherwise flat-lying layers to behave as if they were dipping alternately in one direction, then in the other, depending on which side of a slope the observer is. If traverses can be positioned generally parallel to topographic contours, interpretation will generally be more reliable.

For crooked seismic traverses, the measured distance between geophones and the energy source will be different (shorter) from that of a straight traverse. This will shorten the arrival times between the energy source and each geophones. Traverses with significant bends will need to be time-corrected in accordance with the geometric relationships between the energy source and each geophone.

Low Velocity Effects from Organic Surface Materials. Care must be taken to position individual geophones (generally fitted with a spiked base) such that root matter and peat zones are avoided. Each foot of low velocity surface material through which seismic waves travel is equivalent to perhaps 5 to 10 times an equivalent thickness of saturated overburden materials. Not accounting properly for these time delays can lead to erroneous interpretation. The identification of various materials can be made with a knowledge of seismic velocity values based on other engineering studies, and on correlations with various test borings taken near seismic lines.

4.4.4 Test Pits Test pits may be excavated to collect subsurface soil samples and characterize shallow subsurface soil conditions. The following discussion outlines test pit excavation procedures: collection of test pit soil samples is outlined in Paragraph 4.5.1.2. Test pit excavation will be directed by the field geologist.

To expedite the sampling and record keeping efforts and to minimize periods of potential exposure during the excavation of test pits, the sampling crew will have sufficient tools and equipment to sample each pit prior to requiring decontamination. The backhoe, bucket, and boom will be decontaminated before each new test pit in accordance with procedures outlined in Subsection 4.3.4.

The actual layout of each test pit, temporary staging area, and spoils pile will depend on site conditions and wind direction at the time the test pit is made. During excavation, sampling, and logging of each test pit, the backhoe operator and all site personnel will remain upwind or crosswind of the test pit and spoils pile. Wind direction will be monitored by means of a wind sock or other banner located in a prominent position visible to all personnel.

Preselection and the use of hand and horn signals is important during completion of test pits due to noise levels around the machine. The sampling crew and backhoe operator will rehearse appropriate signals ahead of time and be thoroughly familiar with their meaning.

Test pits will be logged by the field geologist as they are excavated. Records of each test pit will be made on prepared forms or in a field book (Figure 4-1). If the log is made in a field book, it will be transcribed to prepared forms. These records include plan and profile sketches of the test pit showing all materials encountered and their depth and distribution in the test pit and sample

locations. These records will also include safety and sample screening information. This format provides a cross check with COC records and sample label counts. Photographic logs will be recorded in the field logbooks.

The actual depth of samples obtained from each test pit will be selected at the time the test pit is excavated. Additional samples of each residue phase and any fluids encountered in each test pit may also be collected.

Before the test pit is excavated, the backhoe and backhoe bucket will be decontaminated as discussed in Subsection 4.3.4. Test pits will be excavated in the following manner.

1. The sampler and subcontractor (including the backhoe operator) will plan the excavation.
2. After the area to be excavated has been cleared, the backhoe operator will excavate the test pit proceeding in increments as planned by the sampler and subcontractor.
3. After each increment, the operator will wait while the sampler inspects the test pit to decide if conditions are appropriate for sampling.
4. If conditions are suitable for sampling, discrete samples from appropriate intervals may be collected from the bottom or sides of the test pit with the backhoe bucket. Normally, test pits are not entered by any personnel for sampling. Test pits must never be entered unless the excavation conforms to OSHA requirements (see Volume II, Appendix J). Note proper depths and locations of sample collection in the field log.
5. The backhoe operator, who will have the best view of the test pit, will immediately cease digging if:
 - any fluid phase or groundwater seepage is encountered in the test pit,
 - any drums or other potential waste containers are encountered,
 - distinct changes of material are encountered, or
 - the field geologist directs the operator to cease digging.

This action is necessary to permit proper sampling of the test pit and to prevent a breach of safety protocol. For instance, should any fluids or seepage be encountered, they could, after suitable screening and monitoring, be sampled. Waste and sludge deposits could likewise be sampled before proceeding. Should uncollapsed drums be encountered, the test pit will be terminated, backfilled carefully to avoid damage from rocks, etc., flagged to identify the location of the buried drums, and redug at an adjacent location. Under no circumstances will any personnel open and/or sample any buried drums. The field investigation task leader will immediately notify the project manager and other personnel, as appropriate, so that a course of action, including health and safety considerations, may be initiated.

Test pits will be secured, when open, during the day and backfilled at the end of each day. Cleanup procedures at the conclusion of a test pit exploration include proper disposal of cuttings, decontamination of the backhoe and sampling equipment, removal of plastic sheeting, and completion of the field logbook and/or data sheets.

4.4.5 TerraProbeSM Surveys The TerraProbeSM system can be used to conduct soil vapor, soil, and groundwater surveys. These surveys provide screening information that can be used to optimize the location of soil borings and monitoring well installations and to assess VOC contamination in the vadose zone.

The TerraProbeSM system consists of a hydraulic ram unit with the capability of driving 3/4-inch diameter rods and stainless-steel sampling probes into the subsurface for sample collection. The entire system is mounted in, and operates out of, a standard cargo van. The system is unfolded from the rear of the van and the steel probe assembly is advanced to the desired depth. The closed probe point is then released using internal rods, allowing the point to recede into the probe when it is advanced further. To obtain a soil sample, the probe is then advanced another 12 inches, collecting a sample inside the tube. Water samples are collected by allowing formation water to flow into a slotted probe tip. Water within the probe is then purged and sampled using a low flow rate sampling pump or a bailer. The collection of groundwater samples via the TerraProbeSM method is dependent on sufficient saturated thickness of overburden soils and an adequate rate of inflow through the probe tip. For soil vapor, a vacuum is applied to the drive rods and a sample is collected in a syringe.

Soil gas surveys are performed by driving a probe into unsaturated soil to a designated depth (i.e., 5 feet). Probe depth depends on site-specific factors such as type of soils, depth to groundwater, location of underground utilities, and potential source and type of contamination anticipated. After the probe is in place, a soil gas sample is extracted and analyzed using an FID or PID and an electron capture detector.

As an alternative to sampling gaseous soil organic vapors, soil samples may be obtained from discrete depths in the vadose zone and GC screened. An extraction will be performed on the soil samples in the field laboratory and each sample GC screened using purge and trap techniques (see Section 4.6). The purge and trap soil screening will improve data quality while assessing the distribution of VOC contamination in the vadose zone.

Groundwater and soil samples may be field analyzed according to the field laboratory analyses outlined in Section 4.6 (see Paragraph 4.5.1.3 for TerraProbeSM sampling procedures).

4.4.6 Exploratory Drilling Soil borings will most often be drilled using hollow-stem auger (HSA) drilling and split-spoon sampling techniques where confirmatory soil and groundwater sampling is needed and where exploration depths exceed 5 feet. If conditions are encountered where the HSA method cannot be used (i.e., caving or running sands), or another method becomes advantageous, other investigative techniques, such as mud or air rotary or cased borehole methods may be used. Split-spoon samples will be collected either continuously (i.e., the 0- to 1-foot interval, then every 2 feet thereafter to the water table) or at 5-foot intervals, depending on site-specific data needs.

A qualified drilling subcontractor will supply the necessary type and number of drilling rigs capable of performing the drilling technique appropriate for the existing subsurface conditions. Prior to implementing the proposed drilling plan, the drilling subcontractor will:

- secure and comply with any required boring or well drilling permits,
- arrange drill sites (e.g., the drilling subcontractor will have containment materials on hand) to minimize the potential for the possibility of spills and leaks from the drilling operation entering the borehole,
- clean drilling equipment prior to movement to the site (see Section 4.3), and
- store well drilling equipment and well installation supplies in the staging area. At each drill location, clean equipment and supplies will be temporarily stored on sheets of disposable polyethylene sheeting to eliminate contamination from the native soils at the well location.

Soil borings will be used to obtain characterization and confirmatory samples for laboratory analyses. A geologist will be present during the drilling of borings and installation of monitoring wells. The geologist will maintain drilling logs, collect appropriate samples, and be equipped as required to perform this task appropriately. Subsurface split-spoon soil samples will be collected and logged using the Unified Soil Classification System (USCS). Typically, soil samples will be collected in accordance with Level III or IV DQOs, depending on the requirements of the task. In general, samples collected for laboratory analyses will be selected based on previous field screening results, field monitoring results (i.e., elevated PID, FID, or GC readings), visual examination, and/or at pre-designated depth intervals. Most soil boring locations will correspond with monitoring well installations. Soil borings not used for monitoring well installations will be abandoned and grouted to ground surface.

Drilling of shallow borings will be conducted using 4.25-inch inside diameter HSAs. If the site geologist determines that due to geologic conditions, augers cannot be used, borings will be advanced using an alternative method. If a boring is to be completed as a bedrock monitoring well, a surface casing will be placed through the overburden to the bedrock surface, followed by mud rotary drilling until the desired depth has been attained.

- Potable water for drilling and decontamination will be obtained from a source that has been approved by the Navy (Section 4.3).
- Drilling will be conducted by an approved drilling consultant.
- Drilling tools and rigs will be steam-cleaned prior to being delivered onsite. Drilling rigs and tools will be decontaminated in accordance with procedures outlined in Subsection 4.3.4 prior to beginning any borings, and between borings and well installations.
- Well screen and riser will be cleaned prior to installation. Well materials will be cleaned at the decontamination area in accordance

with Section 4.3, and wrapped in plastic sheeting prior to transport to the drill site. All surfaces coming into contact with decontaminated well materials will be covered with plastic sheeting.

Drill cuttings and drilling fluids will be inspected visually for discoloration or other indications of contamination and screened with a PID or FID every 5 feet drilled or at every split spoon collected, whichever is more frequent. Drilling fluids or cuttings will be contained and disposed as described in Section 4.10.

The boring methods employed at a given site are selected on the basis of subsurface conditions. The Consultant will prepare detailed drilling specifications that govern the drilling subcontractor's effort. These specifications will be modified on a site-specific basis to reflect the needs of each project.

4.4.6.1 Auger Borings With this technique, HSAs are advanced into the soil. Drill cuttings are compressed laterally and carried upwards on the auger flights. The bottom opening in the hollow stem of the auger is blocked with a plug while the auger is advanced. When the desired sampling depth is reached, the plug is removed and a sample is obtained from below the bottom of the auger. The advantages of the HSA technique include:

- simplicity of procedure,
- low risk of personnel exposure,
- can be used to obtain soil samples from a wide range of subsurface conditions,
- drilling fluids are generally not required, and
- availability of equipment.

The disadvantages of the HSA technique include:

- difficulty in penetrating excessively cobbled or bouldered soils, and
- difficulty in sampling granular soils below the water table because, without drill fluids, there are no practical means to maintain hydrostatic equilibrium in the borehole. When the plug is withdrawn, water and sediment from outside the augers may enter the borehole, potentially causing contamination and difficulty in sampling undisturbed soil below the bottom of the augers.

4.4.6.2 Water Rotary Drilling fluid is pumped down the drill rods and through a bit that is attached to the lower end of the drill rods. The fluid circulates back to the surface by moving up the annular space between the drill rods and the wall of the borehole. At the surface, the fluid discharges through a pipe and enters into a segregated or baffled sedimentation tank. The settling tank overflows into a suction tank where a pump recirculates the fluid back through the drill rods. The advantages of this drilling technique are:

- simplicity of procedure,
- low risk of personnel exposure,

- can be used to obtain soil samples from a wide range of subsurface conditions,
- can be used to obtain samples from depths greater than 100 feet, and
- availability of equipment.

The disadvantages arise from the need to use a drilling fluid. The drilling fluid used will be from an approved water source. Drilling additives will not be used unless soil pore-pressures or other down-hole conditions require a heavier drilling fluid. The drilling fluids and cuttings removed from the borehole will require collection, containerization, and transportation to a suitable onsite disposal or staging site.

In sediments such as limestone, loss of drilling fluid circulation may occur, necessitating other rotary drilling techniques, such as air rotary. This procedure is essentially identical to water rotary, except pressurized air is pumped through the drill rods and drill bit, forcing formation water and drill cuttings up the annulus to land surface.

4.4.6.3 Monitoring Well Installation Monitoring wells will be constructed of materials in accordance with National Sanitary Foundation (NSF) Standard 14 and SOUTHNAVFACENGCOCOM *Guidelines for Groundwater Monitoring Well Installation* (Appendix A), and installed in accordance with USEPA Region IV ECBSOPQAM (USEPA, 1991c) guidelines. The reader is also referred to *Statement On Use of Alternate Monitoring Well Materials* (Appendix A, Part 5). In the event of a conflict, the USEPA specifications will be followed with the exception of the use of well materials. Care will be used in steam cleaning well materials to ensure integrity is maintained.

A geologist will be present during monitoring well installation to record details of the well installation. Monitoring wells will be installed in borings unless the lithology requires abandoning the boring. Abandoned borings will be grouted in the presence of the site geologist.

For purposes of well abandonment or monitoring well installation, grout will initially be mixed to consist of 20 parts Portland Type II or V cement to one part bentonite by weight, with a maximum of 8 gallons of approved water per 94-pound bag of cement; however, these proportions may be modified to meet field conditions, with Navy approval. This grout mixture will also be used as necessary for backfilling soil borings not completed as wells. All grout materials will be combined in an above-ground rigid container or mixer and mechanically, not manually, blended onsite to produce a thick, lump-free mixture throughout the mixing vessel. The mixed grout will be recirculated through the grout pump prior to placement. Grout will be placed using a grout pump and tremie pipe. The grout pump for recirculation and placement will be a commercially available product specifically manufactured to pump cement grouts. The tremie pipe will be of rigid, not flexible, construction. Drill rods, rigid PVC, or metal pipes are acceptable tremies. Hoses and flexible PVC are unacceptable. Grout placement, via gravity and the grout head, using an elevated grout tank is expressly prohibited.

All well installations will begin immediately after boring completion. Once begun, they will continue uninterrupted, to the extent possible, until

completion. In all cases, the well screen and casing will be cleaned in accordance with procedures described in Subsection 4.3.4. All well screens will have a bottom plug.

The following materials will be used in monitoring well construction.

- Two-inch inside diameter, Schedule 40, threaded, flush-jointed, PVC screen and riser pipe will be used. No PVC solvent will be used. The well screen will be factory-slotted, with a slot width of 0.010 inch. A loose-fitting PVC cap will be used to cover the top of the well riser and to allow equilibration of the well water level with atmospheric pressure. Water table well screen lengths will typically be 10 to 15 feet in length. Monitoring well depths and screened intervals will depend on POI-specific data objectives. Whenever possible, shallow wells will be installed so that the screen will intersect the water table during all seasons.
- Clean silica sand used in the filter envelope around the well screen will be selected to be compatible with both the screen slot size and aquifer materials. The sandpack will extend a maximum of 2 feet below the bottom of the well screen to 2 feet above the top of the screen.
- A minimum of 2 feet of bentonite pellets or slurry will be used in the seal, and will be a commercially available product designed for well sealing purposes. The bentonite or slurry seal will be allowed to hydrate for the manufacturer's recommended hydration time. As an alternative, fine-grained sand may be used in place of hydrated bentonite for monitoring wells that straddle the water table. The decision to use bentonite or fine-grained sand will be made on a case-by-case basis.
- A cement-bentonite grout will be placed in the annular space above the seal layer. The cement-bentonite grout seal will extend from the top of the bentonite seal to ground surface. Grouting will be completed as a continuous operation in the presence of the field geologist. The grout will be pumped into the annular space under pressure using a tremie pipe placed at the top of the bentonite seal to ensure a continuous grout seal. The protective casing will be sealed in the grout.
- At least one sample each, 0.5 pint in volume, of the granular backfill, bentonite, mud, or other material used as part of a well installation will be taken from each shipment of materials and stored with the soil samples.
- Monitoring wells will either be flush-mounted with protective steel casing at ground surface or will have aboveground protective casings to protect the well riser. Aboveground wells in high traffic areas will be surrounded by four protective steel posts. Protective steel casings will be equipped with locking covers. The same key will be used for all padlocks that will be placed on new monitoring wells at NTC, Orlando. A concrete seal and concrete pad will be placed from the top of the grout to the ground surface around each protective casing to secure the casing, prevent surface runoff from entering the borehole,

and to direct runoff away from the casing. The concrete pad shall measure 3 foot by 4 foot by 6 inches. The aboveground parts of both the well riser and protective casing will be vented. The protective casing will have two weep holes near ground level to allow water to drain from inside the casing. A reference mark will be placed on each PVC monitoring well riser pipe for water level measurements. Wells will be permanently and properly identified as specified in SOUTHNAV-FACENGC0M guidance (Appendix A) and USEPA ECBSOPQAM guidance (USEPA, 1991c).

- A sketch of the well installation will be included with the boring log. It will show, by depth, the bottom of the boring, screen location, granular backfill, seals, grout, water level, cave-in, and height of riser above ground surface. The actual composition of the grout, seals, and granular backfill will be recorded on each sketch. Figure 4-2 illustrates a typical well installation diagram.
- Well sketches will include the protective casing detail.

Modifications to monitoring well installation requirements may be necessary if the depth to groundwater is shallow. The bentonite seal and sand-pack extension may be reduced, though it is preferred that the bentonite seal be not less than 2 feet. Modifications to installation requirements will only be implemented with prior approval from the Navy.

4.4.6.4 Monitoring Well Development The development will be performed as soon as practical after well installation, but not sooner than 24 hours after grout set time and optimally after the protective casing installation. The following data will be recorded during well development :

- well designation;
- date and time well installation completed;
- date and time of development;
- static water level before and after development, including depth to water and depth to well bottom;
- quantity of drilling fluid lost during drilling;
- quantity of standing water in well and filter pack (30-percent porosity assumed for calculation) prior to development;
- specific conductivity, temperature, turbidity, and pH measurements taken and recorded during development after removal of each well volume (calibration standards will be run prior to and after each day's operation in the field);
- screen length;
- ~~depth~~ ^{DISTANCE} from top of well casing to top of sediment inside well, before and after development;

<p>DEPARTMENT OF THE NAVY SOUTHERN DIVISION NAVAL FACILITIES ENGINEERING COMMAND CHARLESTON, SC.</p>	<p>WELL CONSTRUCTION DETAIL</p> <p>WELL NUMBER: _____</p> <p>DATE OF INSTALLATION: _____</p>
	<p>1. Height of Casing above ground: _____</p> <p>2. Depth to first Coupling: _____ Coupling Interval Depths: _____</p> <p>3. Total Length of Riser Pipe: _____</p> <p>4. Type of Riser Pipe: _____</p> <p>5. Length of Screen: _____</p> <p>6. Type of Screen: _____</p> <p>7. Length of Sump: _____</p> <p>8. Total Depth of Boring: _____</p> <p>9. Diameter of Boring: _____</p> <p>10. Depth to Bottom of Screen: _____</p> <p>11. Type of Screen Filter: _____ Quantity Used: _____ Size: _____</p> <p>12. Depth to Top of Filter: _____</p> <p>13. Type of Seat: _____ Quantity Used: _____</p> <p>14. Depth to Top of Seat: _____</p> <p>15. Type of Grout: _____ Grout Mixture: _____ Method of Placement: _____</p> <p>16. Tot. Depth of 6 in. Steel Casing: _____</p>
<p>COMMENTS ON INSTALLATION</p>	

HCT-NC

FIGURE 4-2
WELL CONSTRUCTION DETAIL

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NTC_Orl.POP
 MVL.07.94

- physical character of removed water, including changes during development in clarity, color, particulates, and odor;
- type, size, and capacity of pump and/or bailer used;
- height of well casing above ground surface; and
- quantity of water removed and time for removal.

This information will be documented on a Well Development Record (Figure 4-3) and/or in the field log book. Well development will be performed using a bailer, hand pump, air-activated surge pump, or electric-powered submersible pump. Bailers will be used to develop wells only where the recharge rate of the well is so slow that other development methods are clearly inappropriate. The pump will be periodically raised and water in the piping allowed to drain back into the hole in order to induce flow out through the well screen. A surge block may be used, in instances where field personnel expect that development may be improved by its use. Generally, neither water or air will be added to the well to aid in development. However, if deemed appropriate, water jetting and simultaneous pumping may be used if the water source is known to be free from contamination. All well development equipment will be decontaminated prior to use in the next monitoring well (see Section 4.3). Development fluids will be containerized and handled as described in Section 4.10.

A well is considered to be fully developed when all the following criteria are met:

- the well water is visually clear to the unaided eye and/or field parameters of pH, specific conductance, and temperature have stabilized to within 10 percent; and
- the total volume of water removed from the well equals five times the standing water volume in the well (including the well screen and casing plus saturated annulus, assuming 30 percent porosity) plus five times the volume of drilling fluid lost.

The well must be allowed to stabilize a minimum of 24 hours after well development before groundwater sampling.

4.4.7 Soil Gas Surveys Soil gas analysis can be performed using different methodologies, each with unique DQOs. The methods to be used will be soil headspace analysis, active soil gas collection, and passive soil gas collection. The TerraProbeSM or other push-probe technology may be used for obtaining soil gas samples at discrete intervals. Where the target soil horizon is greater than 20 feet below ground surface, a passive soil gas collection technique will be used.

Soil-gas surveys can be targeted to identify the areal extent of waste deposition and to define areas for sample collection. Soil headspace samples and soil gas samples may be collected and analyzed using an onsite GC. All soil gas analyses will be performed in accordance with Level II DQOs. Soil gas sampling points should be selected based on information about historical practices at a site and any other information that suggests where subsurface contamination might be expected.

WELL DEVELOPMENT RECORD						
Project:	Well Installation Date and Time:			Project No.		
Client:	Well Development Date and Time:	Logged by:	Checked by:			
Well/Site I.D.:	Weather:	Start Date:	Finish Date:			
Volume of Drilling Fluid Lost (gal.)	Volume of Water in Well and Filter Pack (gal.)	Start Time:	Finish Time:			
Installed Depth From Top of Well Casing to Bottom of Well:						
Initial Depth to Water (ft):			Initial Depth to Well Bottom:			
Water Level during Initial Pumping/Purging (ft):						
Depth to Water at Termination of Pumping/Purging (ft):			Depth to Well Bottom at Termination of Pumping/Purging (ft):			
BEGINNING OF WELL DEVELOPMENT						
Time	Temperature	pH	Conductivity	Turbidity	Other	Approximate Pumping Rate (gal/min.)
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
END OF WELL DEVELOPMENT						
Notes: (Include Physical character of removed water, type and size of pump, volume of water removed.)						
Well Developer's Signature _____						

FIGURE 4-3
EXAMPLE WELL DEVELOPMENT RECORD



PROJECT OPERATIONS PLAN

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Other methods for manually collecting soil gas samples include creating a ½-inch diameter hole using a manual slide-hammer sampler or other impact hammer. The hole will be opened to a predetermined depth generally between 2 and 5 feet below ground surface. Samples are collected using a hollow ½-inch diameter stainless-steel probe with perforations in the bottom 0.5 foot. The probe is placed in the hole and is pushed or driven until the end of the probe is embedded approximately 0.5 foot into undisturbed soil at the bottom of the hole. Soil gas is extracted using a portable PID or FID through a Teflon™ transfer tube attached to the sampling probe. As soil gas is extracted from the hole, total VOC concentrations are monitored on the PID or FID. When readings are observed to stabilize (i.e., measurements fluctuate by <±2 ppm), the PID or FID measurement is recorded and soil gas is collected through a septum in the transfer line, using a glass gas syringe. The sample is transferred immediately to an onsite GC for analysis.

Passive soil gas techniques involve placement of a gas collector at a prescribed depth. After a period of time (1 to 2 weeks), the collectors are retrieved and analyzed for the presence of volatiles. Several types of collectors are available. One type uses one or more adsorbents to collect VOCs. This method relies on thermal or chemical desorption of VOCs in the laboratory, followed by analysis of the desorbed vapor. A second type of collector uses a permeable membrane surrounding a glass sampling container. VOCs pass through the membrane by gaseous diffusion. Upon retrieval, the vial contents are analyzed by gas chromatography.

Sampling probes will be decontaminated before use at each sampling point by washing with approved decontamination water. Care will be taken to ensure that the perforations are clear of residual soil particles.

4.4.8 Ecological Surveys To identify potential receptors and exposure pathways, ecological communities at and in the vicinity of the POIs will be identified through literature review, consultation with known experts in the field (i.e., U.S. Fish and Wildlife Service, Florida Game and Freshwater Fish Commission (FGFWFC), Florida Natural Heritage Program, local government, and non-profit environmental organization sources), and review of relevant information sources including maps and historical records. Information previously gathered regarding ecological receptors at NTC, Orlando will be supplemented with additional data from the information source review, and from consultation with local, State, and Federal aquatic, wetlands, and terrestrial authorities. Existing information sources related to flora, fauna, and ecological communities at the installation will be reviewed and standard taxonomic sources and references will be identified.

Following the information review, a qualitative field reconnaissance program will be initiated to characterize aquatic, wetland, and terrestrial habitats at and in the vicinity of selected POIs at NTC, Orlando. This qualitative field program will involve a site walk-over by a two person team consisting of a terrestrial biologist and wetland-aquatic specialist. Ecological receptors in the vicinity of the POIs that could potentially be exposed to contaminated environmental media will be identified. Any possible site-specific exposure pathways through which ecological receptors could be exposed to contaminated media will be evaluated, and possible signs and symptoms of stress on biological receptors at the site will be observed.

If necessary, a qualitative aquatic survey will be conducted to examine the macroinvertebrate communities associated with aquatic and wetland systems at selected POIs to determine whether or not environmental contamination from the installation is resulting in any gross community level impacts. Depending on the habitats present at the site, macroinvertebrate fauna will be collected with a benthic dredge, surber sampler, aquatic dip net, and/or seine net upstream, within, and downstream of identified sites (see Subsection 4.5.4).

A terrestrial survey will identify and verify major vegetative cover types and dominant taxa at the various areas of concern at the installation. This will include a qualitative walkover survey to confirm ecological habitat types, flora, and fauna at and in the vicinity of each selected POI. Belt and/or line transect surveys of community types in the upland and wetland communities associated with the selected POIs will be conducted. Evidence of ecological stress in plant species (e.g., yellowing, wilting, or insect infestations) and animal species (e.g., disease, parasitism, death, and reduced diversity or abundance) will be noted. Any State or federally listed rare and endangered plants encountered at the installation will be documented.

When appropriate, habitat types present at the site, including wetlands, will be field mapped onto existing base maps (not-surveyed-to-scale); however, no flagging of wetlands or jurisdictional determinations regarding wetlands will be made, unless specifically required by the Navy (see Subsection 4.4.10). When appropriate, lists of flora and fauna encountered or expected at the site will be generated. Observations of plants, fish, invertebrates, amphibians, reptiles, birds, and mammals, and their sign will be noted for each habitat present and mapped.

If necessary, quantitative ecological programs (i.e., macroinvertebrate survey, biomonitoring studies, small mammal trapping) will be conducted at NTC, Orlando. Separate workplans will be prepared for any required quantitative ecological programs. Information collected in the ecological survey will be used in risk or threat evaluations at NTC, Orlando.

4.4.9 Public Health Surveys A public health survey will consist of site reconnaissance, interviews, and records search to evaluate regional land use at and in the vicinity of NTC, Orlando. Selected POIs will be studied to evaluate current and foreseeable future land uses. During the public health survey, populations that may come into contact with contamination and exposure pathways through which human receptor exposure could occur will be identified. If necessary, contacts will be made with local authorities (i.e., board of health) and relevant files of local authorities will be reviewed. Information collected in the public health survey will be used in risk or threat evaluations at NTC, Orlando.

4.4.10 Wetlands Delineation If required by the Navy, wetlands will be delineated at selected POIs at NTC, Orlando. The primary objective of this task will be to identify and delineate wetlands in the known contaminated regions at selected POIs. Wetlands at these selected POIs will be identified and delineated in accordance with applicable Federal and State guidelines, rules, and regulations.

The Florida wetlands boundary will be defined according to Chapter 17-301, Florida Administrative Code, and the FDEP (formerly Florida Department of

Environmental Regulation [FDER]) regulations on Surface Waters of the State. These regulations state that:

"The line demarcating the landward extent of surface waters, as defined by Section 403.031, F.S., shall be established for any water body, pursuant to Section 403.817, F.S., by dominant plant species. Dominance shall be determined in a plant stratum (canopy, sub-canopy, or ground cover). The canopy is composed of all woody plants with a trunk 4 inches or greater in diameter at breast height (dbh). DBH is measured at 4.5 feet above the ground. The subcanopy is composed of all woody plants with a trunk or stem and between 1 and 4 inches and a height greater than 3 feet. The ground cover includes all other plants..."

If required, the Federal wetlands boundary will be determined using criteria for hydric soils, hydrophytic vegetation, and wetland hydrology as provided in the 1987 U.S. Army Corps of Engineers (USACE) Wetlands Delineation Manual (Environmental Laboratory, 1987). This manual presents technical guidance for identifying wetlands and for distinguishing wetlands from aquatic habitats and other non-wetlands.

When required, wetland and upland boundary stations will be flagged with orange surveyor's flagging or staked with surveyor's pin flags.

4.5 SAMPLING TECHNIQUES. The procedures described in the following subsections of Section 4.5 will govern the collection of samples. Additional detail regarding sample collection methods is described in the CLEAN Operations CompQAP (ABB-ES, 1993) and USEPA Region IV ECBSOPQAM (USEPA, 1991c).

4.5.1 General Soil Sampling Methodology The soil sampling program at NTC, Orlando has been developed to define the location, nature, and concentration of contaminants in surface and subsurface soils at the site. Development of a soil sampling plan to evaluate the distribution and magnitude of contamination at a specific site requires at a minimum:

- an assessment of the site conditions, including site topography and surface drainage;
- evaluation of site waste disposal practices;
- consideration of site soil types, geology, and hydrogeology;
- evaluation of the methodology and results of any previous sampling and analysis programs that may have been completed at the site; and
- definition of the scope and objectives of the project.

A number of techniques have been developed to obtain samples from various depths below the ground surface. The techniques described herein have been selected to provide a practical and efficient means of obtaining samples in a manner consistent with safety protocols and QA/QC requirements. Additionally, they employ equipment that is normally available for use.

The selection of sampling techniques to be employed at a given site is based upon the depth from which samples must be obtained, the types of exploration, and/or the nature of the soils to be sampled. The sampling techniques are categorized by the depths or the types of explorations from which they are obtained:

- shallow soil samples, from depths of less than approximately 5 feet, usually less than 2 feet (surface soil is defined as samples from the 0- to 1-foot interval);
- test pit samples from depths up to approximately 15 feet;
- subsurface soil samples from test borings and TerraProbeSM explorations at variable depths; and
- sediment samples from depths of less than 6 inches.

Maintaining proper records is an important aspect of sample collection. All soil samples collected will be logged in the field at the time of sampling by the field geologist. Soils will be classified in accordance with the USCS. Soil samples will be described fully on the appropriate sampling logs. The descriptions for intact samples (e.g., undisturbed split spoons or test pit walls) will include the following parameters:

- general description;
- USCS symbol;
- secondary components and estimated percentages;
- color;
- plasticity;
- consistency and density;
- relative moisture content;
- texture, fabric, and bedding;
- grain angularity; and
- depositional environment or formation (unit) name, if appropriate.

If disturbed samples must be described (e.g., auger flight samples, wash samples, or backhoe bucket samples), the parameters outlined above will be used to the extent practical. In general, a substantially reduced level of detail will be appropriate for disturbed samples.

If required, soil pH will be measured in the field and will be recorded on the Sample Data Sheet. A minimum of approximately 25 grams of soil will be placed in a clean glass jar or beaker. An approximately equal volume of organic free water will be added to the soil. The mixture will be vigorously stirred or shaken and then allowed to stand for approximately 1 minute before measurement. Soil pH will be measured with a calibrated pH meter or with pH paper.

Measurements will be made within 24 hours after sample collection, and as soon after collection as practical.

4.5.1.1 Surface Soil Sampling Soil samples will be collected to determine the nature and extent of near-surface contamination. For the NTC, Orlando program, surface soil is defined as soil from the 0- to 1-foot interval. Where appropriate, surface soil samples will be based on a sampling grid established in the field. A grid system will be laid out within the POI. Grid systems will be established by staking the corners of each individual grid block and labeling the stake with the appropriate distance from the origin. Right-angle prisms may be used to facilitate grid set-up. Origin points for grids will be determined in the field, and recorded in the field notebook. A compass and 200-foot cloth tape will be used in the grid setup to ensure that stakes are located along straight lines and that the lines are perpendicular. The 200-foot cloth tape will be used to locate the stakes at the proper distances from one another. The stakes will be appropriately marked and flagged.

Surface soil samples will be collected using a decontaminated stainless-steel trowel, hand auger, tulip bulb planter, or stainless-steel spoon. Stones and vegetation will be carefully removed from the sampling location surface; these materials will also be removed from the sample prior to laboratory analysis. The soil will be mixed prior to filling sample containers, with the exception of containers for volatiles. These containers will be filled first, prior to blending, to minimize loss of volatile constituents. The soil samples will be placed in pre-labeled sample jars and sent for laboratory analysis. Appropriate sample containers are described in Section 4.2. Information regarding sample location, depth, and character will be recorded on a Surface Soil Sample Record (Figure 4-4) and/or the bound field logbook. Further data and some of the preliminary COC information will be recorded on the Surface Soil Sample Field Data Record (Figure 4-5) and/or the bound field logbook.

Surface soil samples from any ditches, swales, or trenches will typically be collected from the center line of the ditch and in sequence from the least to the most contaminated point. Surface soil samples collected from any spill or release areas will typically be collected from the outer extremities of the stained area towards the heavily contaminated area.

In the event that it is necessary to remove asphalt to collect the sample, a pickaxe or jackhammer may be used. All sampling and asphalt-removal equipment will be decontaminated between sample collections as described in Section 4.3.

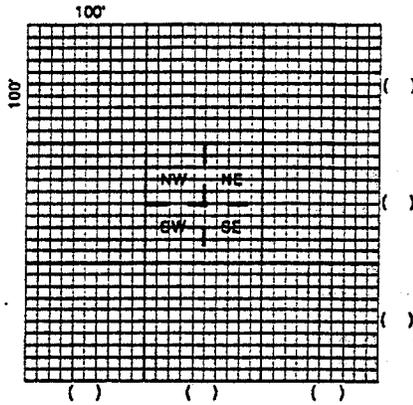
4.5.1.2 Test Pit Sampling To sample the test pit from the ground surface, two methods may be used. The method will be selected in the field at the time the test pit is sampled.

- Samples can be obtained from the backhoe bucket. The sampler or work site geologist will direct the backhoe operator to remove material from the selected depth or location within the test pit. The bucket will be brought to the surface and moved away from the pit. The sampler will approach the bucket and monitor its contents with the FID or PID and record the reading in the log. If granular or loose soils and/or uniform materials are encountered, the sample will be obtained directly from the bucket. The sample will be collected from the center of the

SURFACE SOIL SAMPLING RECORD

Point of Interest _____
 Grid Element; _____ Date; _____ Time: _____ St., _____ End. _____

Sketch Map of Grid Element



Sample Component Loss
 -Description- -Monitoring-
 -PPM-

NE Surface PPM, Spoils PPM

0		
1		
2		

NW Surface PPM, Spoils PPM

0		
1		
2		

NW Surface PPM, Spoils PPM

0		
1		
2		

SE Surface PPM, Spoils PPM

0		
1		
2		

Samples Obtained

Composite Samples

Depth (Ft)	Quadrants	Init. Ser No.	Hd. Sp. PPM
S	NE NW SE SW		
1'	NE NW SE SW		
1.5'	NE NW SE SW		
2'	NE NW SE SW		

Grab Samples

	NE NW SE SW		
	NE NW SE SW		
	NE NW SE SW		
	NE NW SE SW		

Notes: _____ Photographers Roll: _____
 _____ Exposures: _____

 _____ Reference: Field Book, Page _____

Attachments, No. _____
 Signed _____

FIGURE 4-4
EXAMPLE SURFACE SOIL SAMPLE RECORD



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SURFACE SOIL SAMPLE FIELD DATA RECORD

Project: _____ Site: _____
 Project Number: _____ Date: _____
 Sample Location ID: _____
 Time: Start: _____ End: _____ Signature of Sampler: _____

SOIL SAMPLE

DEPTH OF SAMPLE _____

EQUIPMENT USED FOR COLLECTION:

- HAND AUGER
- S.S. SPLIT SPOON
- SHOVEL
- HAND SPOON
- ALUMINUM PANS
- SS BUCKET

TYPE OF SAMPLE COLLECTED:

- DISCRETE
- COMPOSITE

SAMPLE OBSERVATIONS:

- ODOR _____
- COLOR _____

DECONTAMINATION FLUIDS USED:

- ALL USED
- ETHYL ALCOHOL
- 25% METHANOL/ 75% ASTM TYPE II WATER
- DEIONIZED WATER
- LIQUINOX SOLUTION
- HEXANE
- HNO₃ SOLUTION
- POTABLE WATER
- NONE

SOIL TYPE:

- CLAY
- SAND
- ORGANIC
- GRAVEL

FIELD GC DATA: FIELD DUPLICATE COLLECTED
 DUPLICATE ID _____

SAMPLE LOCATION SKETCH:
 YES
 NO

SAMPLES COLLECTED

✓ IF REQUIRED AT THIS LOCATION	MATRIX		✓ IF PRESERVED WITH ACID-BASE	VOLUME REQUIRED	✓ IF SAMPLE COLLECTED	SAMPLE BOTTLE IDS
	SURFACE WATER	SEDIMENT				
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	____/____/____
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	____/____/____
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	____/____/____
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	____/____/____

NOTES/SKETCH

FIGURE 4-5

EXAMPLE SURFACE SOIL SAMPLE
 FIELD DATA RECORD



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bucket and placed in sample jars using a clean trowel or spatula. Appropriate sample containers will be used as described in Section 4.2.

If cohesive soils or multiphase conditions are encountered (e.g., the bucket contains a mixture of soil and sludge) so that obtaining a sample from the bucket is not practical, the sampler may direct the backhoe operator to empty the bucket onto the ground. The sampler will then obtain the sample from the interior of soil clods or lumps of sludge using a clean trowel or spatula.

- Samples can be obtained directly from the test pit. This is necessary when soil conditions preclude obtaining suitable samples from the backhoe bucket (e.g., caving or excessive mixing of soils or wastes within the test pit) or when samples from relatively small discrete zones within the test pit are required. In these circumstances, samples will be obtained by means of extendable handle tools: scrapers, trowels, spoons, or cups. The face of the test pit will be scraped to remove the smeared zone that has contacted the backhoe bucket. The material to be sampled, if a solid, will then be removed from the test pit wall by means of long handled scoops or trowels.

4.5.1.3 Subsurface Soil Sampling Sampling procedures for obtaining subsurface soil samples for the different drilling techniques are presented in the following subsections.

Soil Test Borings. The field geologist will collect soil samples for physical and analytical testing and geologic classification at predetermined boring locations. The soil samples will be collected from pre-determined sampling intervals or whenever subsurface conditions warrant. The latter condition will be determined by the field geologist.

The samples for laboratory analysis will generally be collected using a 3-inch outside diameter (OD) by 24-inch long split spoon that is driven with a 300 pound hammer. If necessary, a thin-walled tube sampler or solid wall sampler in conjunction with direct push technology will be used for sample collection.

Samples collected for geologic classification will be collected in accordance with American Standards and Test Methods (ASTM) D-1586 Standard Penetration Testing using a 2-inch OD by 24-inch long split-spoon sampler driven with a 140 pound hammer. The collection of the samples will be in accordance with the following procedures.

- The appropriate number and type of laboratory-cleaned samples bottles will be available for use at the boring location. Refer to Section 4.2 for a summary of bottle requirements.
- Sample labels will be placed on the sample bottles prior to, or at the time of sample collection. The sample labels will be filled out using waterproof, permanent ink and will include sample identification, location, date and time, as well as the initials of the sampler and the analysis to be performed. Clear plastic tape will be placed around the sample label to ensure its integrity.

- The split spoon will be advanced ahead of the auger at the appropriate depth using the 140 pound hammer. Blow counts will be recorded by the inspecting geologist for every 6 inches the split spoon is advanced.
- The driller will remove the split spoon from the borehole and unscrew the ends, slowly and carefully opening the split spoon as the inspecting geologist monitors the sample with an ambient air monitoring device. The geologist will quickly collect and place the sample in the appropriate jars using a clean stainless-steel spatula. During this process, the geologist will note lithologic changes observed in the sample. The boring lithology will be recorded on a Soil Boring Log (Figure 4-6) and/or the bound field logbook. Soil boring logs will be transmitted to the Navy upon completion of the written report.
- The split spoons and stainless-steel sampling trowels will be decontaminated between samples using procedures outlined in Section 4.3.

TerraProbeSM Sampling. The TerraProbeSM sampling system will be used to obtain discrete soil, groundwater, or soil gas samples that can be screened with an FID or PID, onsite field GC, and/or submitted for laboratory analysis to determine the presence or absence of contaminants in unsaturated soils. The TerraProbeSM system is described in Section 4.4.5. Samples will be collected and documented, employing the procedure outlined below.

- Following removal of the assembly from the hole, the sample will be extracted and placed within the appropriate sample bottles.
- The appropriate number and type of laboratory-cleaned sample bottles will be available for use at the boring location. Refer to Section 4.2 for a summary of the bottle requirements.
- If additional soil volume is required, then the procedure will be repeated at a depth immediately beneath the previous sample.
- Sample labels will be placed on the sample bottles prior to, or at the time of sample collection. The sample labels will be filled out using waterproof, permanent ink and will include sample identification, location, date and time, initials of the sampler, and analysis to be performed. Clear plastic tape will be placed around the sample to ensure its integrity.

Immediately after the TerraProbeSM samples are collected, all labeled vials and jars will be checked for completeness and COC procedures will be initiated. TerraProbeSM explorations will be documented on the field data record (Figure 4-7) and/or in the bound field logbook. Field laboratory analyses are described in Section 4.6.

Shelby Tube Sampling. Collecting and transporting soil samples in a nearly "undisturbed" state is required for certain treatability, hydraulic, and geotechnical tests. It is recognized that this cannot be done without some degree of sample disturbance, but care will be taken to minimize disturbance.

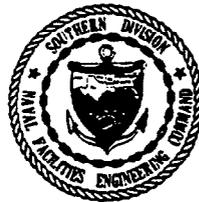
Shelby tube sampling is a common method of "undisturbed sampling." As applied herein, Shelby tube sampler refers to any open-drive sampler consisting of thin-

SOIL BORING LOG				Point of Interest: _____	
				Boring No.: _____	
Client: _____		Project No. _____		Protection: _____	
Contractor: _____		Date Started: _____		Completed: _____	
Method: _____		Casing Size: _____		PI Meter: _____	
Ground Elev.: _____		Soil Drilled: _____		Total Depth: _____	
Logged by: _____		Checked by: _____		<input checked="" type="checkbox"/> Below Ground:	
Screen: (ft.)	Riser: (ft.)	Diam: (ID)	Material:	Page	of:

DEPTH (FT)	SAMPLE NUMBER	SAMPLE DEPTH	CLIP/SCREENING	RECOVERY	PIU (ppm)	SOIL/ROCK DESCRIPTION	SOIL CLASS	BLOWS/6-IN.	WELL DATA	LITHOLOGY	ELEVATION (FT.)
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
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30											

PROPORTIONS	(-) AMOUNT (-)	ABBREVIATIONS
Trace (tr)	0-10%	f = fine gr = gray MS = Split Spoon
Little (l)	10-20%	m = medium bn = brown BW = Screened Auger
Some (so)	20-35%	c = coarse bk = black HP = Hydropunch
and	35-50%	

FIGURE 4-6
EXAMPLE SOIL BORING LOG



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8519-03 940321WEM

NTC_Orl.POP
MVL.07.94

FIELD INVESTIGATION DATA RECORD TERRAPROBE SOIL/WATER SYSTEM INFORMATION

Project _____

Point of Interest _____

Sample ID	Matrix	Date	Time	Depth	Collection Method
	<input type="checkbox"/> Water <input type="checkbox"/> Soil <input type="checkbox"/> Sediment			<input type="checkbox"/> Inches <input type="checkbox"/> Feet	<input type="checkbox"/> Soil Probe <input type="checkbox"/> Surface Soil <input type="checkbox"/> Bail for Water
Observations (Texture, Color, Odor, Etc.)				Sample Collected for: <input type="checkbox"/> Laboratory Analysis <input type="checkbox"/> Field Analysis	

Sample ID	Matrix	Date	Time	Depth	Collection Method
	<input type="checkbox"/> Water <input type="checkbox"/> Soil <input type="checkbox"/> Sediment			<input type="checkbox"/> Inches <input type="checkbox"/> Feet	<input type="checkbox"/> Soil Probe <input type="checkbox"/> Surface Soil <input type="checkbox"/> Bail for Water
Observations (Texture, Color, Odor, Etc.)				Sample Collected for: <input type="checkbox"/> Laboratory Analysis <input type="checkbox"/> Field Analysis	

Sample ID	Matrix	Date	Time	Depth	Collection Method
	<input type="checkbox"/> Water <input type="checkbox"/> Soil <input type="checkbox"/> Sediment			<input type="checkbox"/> Inches <input type="checkbox"/> Feet	<input type="checkbox"/> Soil Probe <input type="checkbox"/> Surface Soil <input type="checkbox"/> Bail for Water
Observations (Texture, Color, Odor, Etc.)				Sample Collected for: <input type="checkbox"/> Laboratory Analysis <input type="checkbox"/> Field Analysis	

Sample ID	Matrix	Date	Time	Depth	Collection Method
	<input type="checkbox"/> Water <input type="checkbox"/> Soil <input type="checkbox"/> Sediment			<input type="checkbox"/> Inches <input type="checkbox"/> Feet	<input type="checkbox"/> Soil Probe <input type="checkbox"/> Surface Soil <input type="checkbox"/> Bail for Water
Observations (Texture, Color, Odor, Etc.)				Sample Collected for: <input type="checkbox"/> Laboratory Analysis <input type="checkbox"/> Field Analysis	

Signature _____ Date ____/____/____

FIGURE 4-7

EXAMPLE TERRAPROBE FIELD DATA RECORD



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walled seamless steel tubing with a sharp and drawn-in cutting edge, that can be connected to a sampler head or adaptor containing a check valve and vents for escape of air and water. (Thin-walled refers to a wall thickness typically less than 2.5 percent of the diameter of the sampler.) Shelby tubes are disposable samplers that are used for sample collection and transportation, and typically for testing as well.

Whenever possible, the Shelby tube will be forced into the soil by rapid, uninterrupted pushing. A heavy drop hammer will be used where pushing provides insufficient penetration. In both cases, care will be taken to minimize interruptions during sampler penetration and to eliminate rotation of the sampler. Total penetration should not exceed the net length of the sampler (i.e., the sampler should not be underdriven or overdriven).

To allow full development of adhesion and friction between the sample and the sample tube, it is helpful to wait 10 to 20 minutes before beginning sample withdrawal. The drill rods should be rotated through two or three full revolutions to separate the sample from the subsoil, immediately after which the sampler should be withdrawn slowly and smoothly.

The Shelby tube will be marked with the sample ID and date and with an indication of which end of the tube is the stratigraphic top. Aluminum foil will be placed against the soil at both ends of the tube; bubble-wrap or other suitable cushioning material will be inserted between the foil and the end of the tube (if the sample does not entirely fill the tube), and plastic caps will be secured by tape over both ends of the tube. Wax seals may be used only if provisions are made to prevent contact between the wax and the soil. The samples will be kept upright at all times.

Shelby tube samples will be stored and transported in a framework that supports them in an upright position and cushions them from vibrations.

4.5.1.4 Geotechnical Testing Samples will be obtained from selected borings for geotechnical laboratory testing. The purpose of geotechnical testing will be to verify field soil classifications and to support the characterization of geologic units encountered during the field investigation. Specific tests may include, Atterberg limits, particle size analysis, and visual-manual description of soils. This section describes sample collection and standard geotechnical testing to be performed.

The test methods to be used do not require "undisturbed" samples; therefore, special drilling procedures to limit sample disturbance will not be necessary. The primary method for obtaining geotechnical test samples will be with split spoons driven in accordance with the Standard Penetration Test procedure (see Paragraph 4.5.1.3). Shallow test pit sampling and/or other sampling techniques may also be employed. Immediately after opening the split spoon, an FID or PID reading will be obtained from the sample and recorded on the boring log. Following field identification and logging of the sample, a representative portion will be selected and placed in a clean, standard 12-ounce reference jar. A minimum sample size of 8 ounces will be obtained for all three types of geotechnical tests to be performed. A label will be fixed to the side of each jar that shows plainly, the project number, the boring and sample numbers, the depth of the sample below ground surface and the number of blows for each 6 inches of penetration or fraction thereof. FID or PID readings shall be obtained

within the sample jar (head space), 1 to 2 hours after placement in the jar and recorded on the jar label and the boring log.

Soil jars will be tightly closed to minimize moisture loss and to protect from freezing. No other sample preservation requirements will be necessary. The samples will be shipped to the geotechnical laboratory with appropriate packing to prevent damage during shipment. Field boring logs will be sent to the laboratory along with the instructions for testing for each sample. Upon completion of the testing, the geotechnical laboratory will ship back to Consultant the unused or residual portions of the samples. The Consultant will dispose of the residual material within one drill cutting drum used during the field investigation.

All geotechnical testing will be performed in accordance with ASTM standard procedures. Atterberg limit tests (ASTM D4318) will generally be performed on soils exhibiting some degree of plasticity (i.e., clays and silts). Particle size analyses (ASTM D422) will generally be performed on granular soils or soils with appreciable amounts of sand and gravel material. Visual soil classification will be performed on selected samples of cohesive and granular soils. The classifications will be performed in accordance with ASTM D2488, *Standard Practice for Description and Identification of Soils, Visual Manual Procedure*. The determination of samples to be tested will be made in the field by the field geologist.

4.5.2 General Water Sampling Methodology The water sampling program at NTC, Orlando has been developed to define the location, nature, and concentration of contaminants in site surface water and groundwater. The location and distribution of contaminants at a given site are governed by many factors, including:

- site operation or waste disposal practices,
- site design,
- site closure,
- waste characteristics,
- site topography and surface drainage,
- flow rate,
- climate, and
- site hydrogeology.

Development of a water sampling plan that will effectively reveal the distribution and magnitude of contamination at a specific site requires:

- an assessment of the factors listed above,
- an evaluation of the methodology and results of any previous sampling and analysis program completed at the site, and
- a definition of the scope and objectives of the project.

4.5.2.1 Surface Water Sampling Surface water is defined as water that flows over or rests on land and is open to the atmosphere. Surface water samples may be collected from streams, ponds, lakes, and ditches at NTC, Orlando to determine the extent of contaminant migration via surface water and runoff. Sampling will begin at the location farthest downstream and proceed upstream.

Each surface water sample will be collected in the following manner.

1. The sampler will collect the sample from the surface water body by immersing a sample collection device, or sample bottle, below the surface of the water to avoid collecting floating debris. If the surface water sample is collected from a moving water body, the inverted collection container will be turned upright and pointed upstream. The sampling equipment and the individual collecting the sample should always be positioned downstream of the sampling location. For surface-water sampling from specific depths in the water column, samples will be collected using a Teflon™ bailer; a submersible pump and tubing; a specialized sampling device such as a Van Dorn, Kemmerer, or Nansen bottle; or other suitable device. Reusable samplers will be decontaminated with approved decontamination water before each successive sample is collected. The sample will be collected from a location in the water body that is, in the judgment of the sampler, well mixed and, therefore, representative of the water body. Water samples to be analyzed for dissolved inorganic compounds will be pumped through a 0.45-micron, high capacity, inline disposable filter.
2. The appropriate sample containers, as outlined in Section 4.2, will be directly filled from the sampling device if needed. Pre-preserved containers will not be used as surface water collection containers. If samples must be preserved, the preservative will be added to the container after the sample is collected. For VOC samples, free air bubbles adhering to the sides of the sample container will be removed prior to capping. If possible, VOC samples will be capped under water.
3. The sampler will measure the following parameters, if possible, in the water body, not the sample:
 - PID or FID reading, above the water;
 - temperature;
 - pH;
 - specific conductance; and
 - any other site-specific field measurements required.

If direct measurement is not possible, the sampler will measure these parameters from water remaining in the sampling device or another sample bottle. This information will be recorded on the sample data record, sample labels will be completed, and COC procedures will be initiated.

4. The sampler will complete a Surface Water and Sediment Sample Field Data Record (Figure 4-8) or record the information in the bound field logbook.

At surface-water sampling locations where surface water may not be present at the time of sampling, sumps may be dug for collecting samples of shallow groundwater. Sumps will be dug by hand to below the water table, and the sumps will be left to stabilize for at least 24 hours before sample collection. During the period before sampling, the sumps will be covered to minimize the introduction of surface soil and debris. Samples will be collected by direct immersion of sample containers. If the sump is too deep for direct immersion, stainless-steel or Teflon™ sampling equipment may be used to collect and transfer the water to the sample containers. Digging tools and sampling equipment will be decontaminated prior to each use, as described in Section 4.3.

4.5.2.2 Groundwater Sampling The groundwater sampling of all monitoring wells (or, under special circumstances, well points) will be conducted to delineate the distribution of chemicals and to quantify, to the extent possible, the chemicals in the aquifer(s) underlying the POIs. The products of monitoring well sampling are as follows:

- groundwater samples from each well;
- measurements of specific conductance, temperature, turbidity, and pH; and
- depth to static water level at each new, and designated existing, well.

The purging and sampling techniques outlined below help to ensure the collection of representative groundwater samples.

Sampling Preparation Activities. Groundwater sampling equipment will be decontaminated prior to use in accordance with the procedures outlined in Section 4.3. Calibration of the sampling equipment will be in accordance with the manufacturers' suggested procedures and will be completed prior to each day's sampling activities. Daily instrument calibration data will be recorded on a Field Instrumentation Quality Assurance Record (Figure 4-9) or in the bound field logbook.

Groundwater samples will be collected from each monitoring well using one of the procedures described in the following paragraphs. Data generated during groundwater sampling will be recorded on the Groundwater Sample Field Data Record (Figure 4-10) or in the bound field logbook. Groundwater Sample Data Records will be submitted to the Navy upon completion of the written report.

Sampling of groundwater wells will proceed from the upgradient (background) wells to the downgradient (contaminated) wells as best as can be determined, based on existing data.

Pre-purging Activities. The following activities will be performed immediately prior to purging each well. These activities will be conducted regardless of the sampling method used.

1. Check the well for proper identification and location.

SURFACE WATER AND SEDIMENT SAMPLE FIELD DATA RECORD

Project: _____ Site: _____
 Project Number: _____ Date: _____
 Sample Location ID: _____
 Time: Start: _____ End: _____ Signature of Sampler: _____

SURFACE WATER INFORMATION

TYPE OF SURFACE WATER:
 STREAM RIVER
 POND/LAKE SEEP

DECONTAMINATION FLUIDS USED:
 ALL USED
 ETHYL ALCOHOL
 25% METHANOL/ 75% ASTM TYPE II WATER
 DEIONIZED WATER
 LIQUINOX SOLUTION
 HEXANE
 HNO₃ SOLUTION
 POTABLE WATER
 NONE

WATER DEPTH AND SAMPLE LOCATION _____ (ft)

DEPTH OF SAMPLE FROM TOP OF WATER _____ (ft)

EQUIPMENT USED FOR COLLECTION:
 NONE, GRAB INTO BOTTLE
 BOMB SAMPLER
 PUMP

VELOCITY MEASUREMENTS OBTAINED? YES, SEE FLOW MEASUREMENT DATA RECORD _____

TEMPERATURE _____ Deg. C. SPEC. COND. _____ µmhos/cm pH _____ Units DISS. O₂ _____ ppm

FIELD GC DATA: FIELD DUPLICATE COLLECTED
 DPLICATE ID _____

SAMPLE LOCATION SKETCH: YES NO

METHOD USED: WINKLER PROBE

SEDIMENT INFORMATION

EQUIPMENT USED FOR COLLECTION:
 GRAVITY CORER
 S.S. SPLIT SPOON
 DREDGE
 HAND SPOON
 ALUMINUM PANS
 SS BUCKET

DECONTAMINATION FLUIDS USED:
 ALL USED
 ETHYL ALCOHOL
 25% METHANOL/ 75% ASTM TYPE II WATER
 DEIONIZED WATER
 LIQUINOX SOLUTION
 HEXANE
 HNO₃ SOLUTION
 POTABLE WATER
 NONE

DEPTH OF SEDIMENT SAMPLE _____ (ft)

TYPE OF SAMPLE COLLECTED:
 DISCRETE
 COMPOSITE

SEDIMENT TYPE:
 CLAY
 SAND
 ORGANIC
 GRAVEL

SAMPLE OBSERVATIONS:
 ODOR _____
 COLOR _____

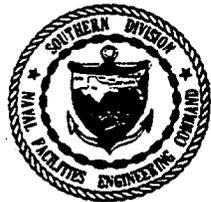
FIELD GC DATA: FIELD DUPLICATE COLLECTED
 DPLICATE ID _____

SAMPLES COLLECTED

/ IF REQUIRED AT THIS LOCATION	MATRIX		/ IF PRESERVED WITH ACID-BASE	VOLUME REQUIRED	/ IF SAMPLE COLLECTED	SAMPLE BOTTLE IDS
	SURFACE WATER	SEDIMENT				
[]	[]	[]	[]	_____	[]	____/____/____
[]	[]	[]	[]	_____	[]	____/____/____
[]	[]	[]	[]	_____	[]	____/____/____
[]	[]	[]	[]	_____	[]	____/____/____

NOTES/SKETCH

FIGURE 4-8
EXAMPLE SURFACE WATER AND SEDIMENT
SAMPLE FIELD DATA RECORD



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FIELD INSTRUMENTATION & MATERIAL QUALITY ASSURANCE RECORD

Project _____ Site _____
 Project No. _____ Sampler Signature _____
 Date _____

Field Instrumentation Calibration Data

Equipment Type/I.D.	Battery Condition	Calibration Information
_____	_____	pH 4 _____ pH 7 _____ pH 10 _____
_____	_____	pH 4 _____ pH 7 _____ pH 10 _____
_____	_____	pH 4 _____ pH 7 _____ pH 10 _____
_____	_____	Cond. Std. _____ / _____ Cond. Std. _____ / _____
_____	_____	Cond. Std. _____ / _____ Cond. Std. _____ / _____
_____	_____	Cond. Std. _____ / _____ Cond. Std. _____ / _____

Dissolved Oxygen
 _____ Avg. Winkler Value _____ ppm Meter Value _____ ppm

Redox
 _____ Zobeil Sol. Value _____ Meter Value _____

Photoionization Meter
 _____ Zero/Zero Air? Yes No Span Gas Value _____ ppm Equiv.
 _____ Meter Value _____ ppm Equiv.
 _____ Zero/Zero Air? Yes No Span Gas Value _____ ppm Equiv.
 _____ Meter Value _____ ppm Equiv.

Other

Fluids/Materials Record

Deionized Water Source: _____ ABB Staging Portable System Other
 Trip Blank Water Source: _____ ABB Lab; Lot No. _____
 _____ Other; Type _____ ID _____
 Decontamination Fluids: _____ Methyl Hydrate; Lot No. _____
 _____ Other; Type _____ ID _____
 HNO₃/DI Rinse Solution: _____ ABB Staging; Lot No. _____
 Filtration Paper ID: (In Line) Manuf/Type _____ Lot No. _____ / _____
 (Vacuum) Manuf/Type _____ Lot No. _____ / _____
 Chemicals Used: HNO₃ Lot No. _____ ZnAOC Lot No. _____
 H₂SO₄ Lot No. _____ Other Lot No. _____
 HCL Lot No. _____ Other Lot No. _____
 NaOH Lot No. _____

FIGURE 4-9
 EXAMPLE FIELD INSTRUMENTATION
 AND MATERIAL QUALITY RECORD



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 NAVAL TRAINING CENTER
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2. Measure and record the height of protective casing.
3. After unlocking the well and removing any well caps, measure and record the ambient and well-mouth organic vapor levels using the FID or PID. If the ambient air quality at breathing level reaches 5 ppm, the sampler will use the appropriate safety equipment as described in the HASP.
4. Measure and record the distance between the top of the well casing and the top of the protective casing.
5. Using the electronic water level meter, measure and record the static water level from the reference point to an accuracy of 0.01 foot. Upon removing the water level wire, rinse it with water from an approved water source.
6. Inspect the well head for any signs of forced entry which could invalidate the sampling data.

Groundwater purging and sampling may be completed using one of several methods. Two methods, referred to herein as the standard method and the low-flow method, are described below. The standard method has been widely used and accepted for many years. The low-flow method has developed out of a decade of research supported by USEPA and others (e.g., Puls and Powell, 1992), which indicates that excess disturbance of formation water during well purging and sampling potentially compromises data quality. Use of a low-flow purge and sample method is becoming increasingly commonplace and has been adopted as a standard procedure by some regulatory agencies (e.g., USEPA, 1993). Both sampling and purging methods are described below. Selection of a groundwater sampling method will be made on a case-by-case basis and specified in the appropriate workplans.

Purging and Sample Collection, Standard Method. Wells will be purged prior to sampling of groundwater to remove stagnant water so that a representative sample can be collected. The following steps outline the purging and sample collection activities using pumps and bailers.

1. The sampler will calculate the volume to be purged, assuming a total of three to five well volumes. Well volume includes the volume of standing water in the well, plus the volume of water in the filter pack (assume 30 percent porosity).
2. In all shallow water table wells, the sampler will lower a submersible pump intake to just below the top of the water column and begin purging three to five well volumes. The pump intake will not be lowered below the top of the well screen. If the well screen is dewatered, air may enter the formation, altering the chemistry of the aquifer.
3. In all deep aquifer wells, the sampler will place the pump intake at the static water level and begin purging three to five well volumes. The pump intake will not be lowered below the top of the well screen. In both water table and deep aquifer wells, low permeability formations may require the pumping rate to be reduced to allow continuous pumping. In this situation, the pumping rate will be reduced to allow the five-volume purge without depressing the water level drastically. If the

pumped flow rate drops below 1 gallon per minute, modifications to the standard purging procedures may be necessary.

4. Purging is considered complete when three to five well volumes have been purged and when the *in-situ* parameters (pH, specific conductance, turbidity, and temperature) vary by less than approximately 10 percent. For wells in low permeability locations (i.e., less than 1 gallon per minute recharge), the well will be purged of one volume and then sampled. Purging of less than five volumes, and sampling before stabilization of *in-situ* parameters, will only be done with prior approval of the ABB-ES onsite geologist or if the well purges dry.
5. The sampler will record the *in-situ* parameters (pH, specific conductance, turbidity, and temperature), once for every volume purged, on a Groundwater Sample Field Data Record (Figure 4-10) or in the bound field logbook. Redox potential may be monitored and recorded at the completion of purging activities.
6. After purging and pump removal, the sampler will lower a Teflon™, stainless-steel, or polypropylene bailer to the middle of the screened interval or midpoint of the static water level.
7. The sampler will collect the sample(s) in appropriate containers as listed in Section 4.2. Samples will be placed directly from the bailer into the appropriate containers. VOC sample containers will be filled with as little agitation as possible. Water samples to be analyzed for dissolved inorganic compounds will be pumped through a 0.45-micron, high capacity, inline disposable filter. Sample preservation methods are discussed in Section 4.2.
8. The pump assembly and bailer will be removed from the well.
9. Using the electronic water level meter, measure and record the static water level from the reference point and the depth of the well to an accuracy of 0.01 foot. Rinse the water level wire with water from an approved source.
10. The sampler will record sampling data on a Groundwater Sample Field Data Record (Figure 4-10) or the bound field logbook.
11. The well cap and lock will be secured.
12. Pumps and discharge lines used to purge the monitoring wells will be decontaminated between wells, as described in Section 4.3.

Purging and Sample Collection, Low-flow Method. Collection of groundwater samples from monitoring wells is required to characterize the nature and extent of contamination. Because of concerns about turbidity in the wells and the effects on metals sampling results, the low-flow purge and sample method may be used.

The low-flow method creates less disturbance and agitation in the well; therefore, excess turbidity is not generated during the purging and sampling process. The result is a more rapid stabilization of turbidity and other

parameters (pH, temperature, specific conductivity, dissolved oxygen, and Eh) and a sample more representative of conditions in the formation is collected.

The low-flow purge and sample method consists using a submersible or peristaltic pump to purge the well at a very low flow rate (less than 1 liter per minute [ℓ/min]). The pump intake is set approximately in the middle of the well screen, with a stagnant water column over the top of the pump. The well is purged at the low-flow rate until the field parameters (temperature, pH, specific conductance, turbidity, dissolved oxygen, and Eh) have stabilized. The sample is then collected directly from the pump discharge at a low-flow rate. The following steps outline the purging and sampling activities.

1. The sampler will attach and secure the Teflon[™]-lined polyethylene tubing to the low-flow submersible or peristaltic pump. As the pump is slowly lowered into the well, secure the safety drop cable, tubing, and electrical lines to each other using nylon stay-ties placed approximate 5 feet apart.
2. The pump should be set at approximately the middle of the screen. Be careful not to place the pump intake less than 2 feet above the bottom of the well as this may cause mobilization of any sediment present in the bottom of the well. Start pumping the well at less than 1 ℓ/min .
3. The water level in the well should be monitored during pumping and, ideally, the pump rate should equal the well recharge rate with little or no water level drawdown in the well (the water level should stabilize for the pumping rate). There should be at least 1 foot of water over the pump intake so there is no risk of the pump suction being broken or entrainment of air in the sample. Record the pumping rate adjustments and depth(s) to water in the logbook. If the recharge rate of the well is very low and the well is purged dry, then wait until the well has recharged to a sufficient level and collect the appropriate volume of sample with the pump.
4. The well should be purged at a low-flow rate (less than 1 ℓ/min). During purging, monitor the field parameters (temperature, pH, turbidity, specific conductance, dissolved oxygen, and Eh) approximately every 3 to 5 minutes (or as often as practical) until the parameters have stabilized to within 10 percent (plus or minus 5 percent) over a minimum of three readings. Turbidity and dissolved oxygen are typically the last parameters to stabilize. Note: once turbidity readings get below seven nephelometric turbidity units (NTUs), then the stabilization range can be amended to 20 percent (plus or minus 10 percent) over a minimum of three readings.
5. The sampler will record the *in-situ* parameters (pH, temperature, specific conductance, turbidity, dissolved oxygen, and Eh), along with the corresponding volume purged, on a Groundwater Sample Field Data Record (Figure 4-10) or in a bound field logbook.
6. Once the field parameters have stabilized, the sampler will collect the samples directly from the end of the tubing. The bottles should be preserved and filled according to the procedures specified in Section 4.2. All sample bottles should be filled by allowing the pump discharge to flow gently down the inside of the bottle with minimal turbulence. Cap each bottle as it is filled. Volatiles and analytes that degrade by aeration must be collected next. Volatile samples will be collected by shutting off

the pump, disconnecting the tubing, holding a thumb over the end of the tubing, and withdrawing the tubing from the well. The sample containers will be filled by removing the thumb and allowing groundwater to flow, by gravity, into the containers containing preservatives.

7. Filtered samples should be collected for approximately 10 percent of the wells sampled using the low-flow method for which metals analyses will be conducted. The remaining wells will only have unfiltered metals samples analyzed. The filtered metals samples will be collected by pumping the sample through a high-capacity, 0.45 micron, inline filter and collecting the filtrate in an appropriate sample container (Section 4.2). Document all field procedures used and any pertinent field observations.
8. Samples will be preserved, labeled, and placed immediately into a cooler and maintained at 4 degrees Celsius ($^{\circ}\text{C}$) throughout the sampling and transportation period. Samples should be labeled, recorded on the COC, and shipped according to the procedures specified elsewhere in Chapter 4.0.
9. The pump assembly should be carefully removed from the well. The TeflonTM-lined polyethylene tubing will be dedicated to each well, wherever possible. The tubing should be placed in a large plastic garbage bag, sealed, and labeled with the appropriate well identification number. The tubing will be stored onsite until the next round of sampling. The pump and discharge lines will be decontaminated between wells as described in Section 4.3.
10. The sampler will measure and record the static water level from the reference point and the total depth of the well, using an electronic water level meter. Rinse the water level wire with water from an approved source.
11. The sampler will record all sampling information on a Groundwater Sampling Record (Figure 4-10) or in a bound field logbook.
12. The sampler will secure the well cap and lock.

4.5.3 General Sediment Sampling Methodology Sediment samples will generally be collected in conjunction with surface water samples to help define partitioning of chemicals between the sediment and water. The shape, flow pattern, bathymetry, and water circulation patterns must all be considered when selecting sediment sampling sites. Sediment samples will be preferentially collected from depositional areas, rather than areas with net erosional losses. In areas with moving water, sediments will be collected from downstream locations prior to upstream locations.

All sediment sample locations will be noted on a base plan or aerial photograph and marked in the field with flagging and a 4-foot wooden stake or temporary buoy. The stake will be labeled with an identification number.

When both water and sediment samples are to be collected at a given sampling location, the water samples will be collected prior to the sediment sample. The sediment samples will be collected in the following manner.

1. The sampler will select the sample location, identify it on a site map or aerial photograph, and set the wooden stake, as close as practicable, onshore. For offshore sampling locations, temporary buoys may be set. Sediment samples will be collected from depositional areas.
2. Sampling devices include scoop samplers, core samplers, gravity corers, and dredge samplers. A gravity corer, stainless-steel spoon, or dredge will generally be used to collect river and pond samples. If the water is shallow enough, the gravity corer will be pushed directly into the substrate until approximately 1 inch (25 centimeters) or less of the core is above the sediment-water interface. If the substrate is hard or coarse, the corer will be gently rotated while it is pushed to facilitate greater penetration, and reduce core compaction. The corer or spoon will be gently removed from the sediment to avoid losing the sample, and raised to the surface so the sample may be retrieved. Dredges will generally be used when samples cannot be obtained with coring devices. Three major types of dredges may be used at NTC, Orlando: Peterson, Ekman, and Ponar dredges.
3. For collection of sediment samples beneath deep water and/or where recovery of sediment and substrate is intended, a vibratory coring system may be employed from a boat or floating platform. The system will use a high frequency vibratory drive. Sediment-substrate core will be collected in a core tube with a butyrate, acrylic, or polyethylene liner. The sediment core and liner will be removed from the core tube and will be logged by a geologist on a Sediment Core Log (Figure 4-11) or the bound field logbook.
4. Sediment sampling information will be recorded on a Surface Water and Sediment Field Data Record and COC procedures will be initiated (Figure 4-9).

A minimum of 500 grams of sediment will be collected at each location for chemical analysis. Sediment samples will be collected from the saturated zone using a stainless-steel spoon or auger. Digging tools and sampling equipment will be decontaminated prior to each use, as described in Subsection 4.3.3.

4.5.4 Aquatic Macroinvertebrate Sampling Sampling of aquatic macroinvertebrates is conducted to determine the presence or absence, population density, and taxonomic diversity of macroinvertebrate fauna; to perform statistical community analysis; to evaluate bioaccumulation and bioconcentration of contaminants; and to correlate macroinvertebrate community characteristics with concentrations of contaminants found in sediments.

To meaningfully evaluate biological conditions, sampling stations will be selected in comparable habitats (similar water depth and movement, substrate composition, and canopy coverage). Otherwise, community differences resulting from dissimilar physical habitats may be incorrectly attributed to biological degradation from chemical impact.

Typically, at each sampling station, sample(s) will be collected from vegetation (phytomacrofauna) and from sediment (benthic infauna). Samples will be collected in standardized unit areas that are clearly marked immediately prior to the commencement of sampling.

SEDIMENT CORE LOG		Point of Interest:
Client: _____		Site ID: _____
No. _____		Protection: _____
Contractor: _____	Date Started: _____	Completed: _____
Method: _____	Core Tube Size: _____	PI Meter: _____
Logged by: _____	Checked by: _____	Total Depth: _____
		Page _____ of: _____

DEPTH (FT)	REFERENCE SAMPLE NUMBER	SAMPLE DEPTH	RECOVERY	PH (ppm)	SEDIMENT DESCRIPTION	SOIL CLASS
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

FIGURE 4-11
EXAMPLE SEDIMENT CORE LOG



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Many methods are available to obtain macroinvertebrate samples. Sampling devices include hand-held corers, dip-nets, grab samplers, dredges, and artificial substrates. Phytomacrofauna will typically be collected from the water column and from submerged macrophytes with D-frame aquatic dip nets (~600 microns) by sweeping the entire marked water column both vertically and horizontally. The contents of the dip net will be washed into a number 30 USGS brass sieve. Plant matter and other debris will be discarded after removing any attached invertebrates. Material not passing through the sieve will be placed in labeled jars containing approximately 70 percent ethanol.

Benthic organisms will typically be collected, using an Eckman dredge or similar sampling device, from sampling stations with silt, muck, or sludge substrates. The dredge contents will be washed through a number 30 USGS brass sieve. Macroinvertebrates and smaller debris not passing through the sieve will be placed in labeled jars containing approximately 70 percent ethanol. If necessary, the 70 percent ethanol preservative will be replaced with fresh preservative to avoid dilution.

For each sampling station, the physical attributes of the aquatic habitat (including nature of the substrate and vegetative characteristics) and water quality parameters (dissolved oxygen, temperature, pH, and conductivity) will be recorded. When appropriate, voucher macroinvertebrates specimens will be retained for taxonomic analysis.

4.5.5 Fish Sampling Fish sampling is conducted for ecological community analysis and for pathological analysis. Fish and fish-tissue sampling is also conducted to analyze whole fish and fish fillets for specified contaminants, as a basis for determining potential ecological and human health risks. Because fish are mobile organisms and contaminants in surface water bodies usually are non-point source, fish-sampling locations should represent regions or areas, rather than fixed points. Sampling can be conducted during the day and/or at night. Target species will be selected based on the nature of the water body and the following criteria: human fishery utilization, abundance, size, ecological importance, position in food chain, metabolism, and the ability to collect sufficient, duplicate, replicate, and/or laboratory QC samples.

It is often useful to use a variety of active and passive fishing techniques to minimize sample gear bias. Available techniques include electrofishing, seining, and trawling (active techniques), and gill netting and trap netting (passive techniques). The objective of electrofishing is to stun and immobilize the fish for collection. Electrofishing consists of sweeping sampling areas with a boat-mounted electroshocking unit (e.g., Coffelt VVP-15), using moderate current densities (amperes per square centimeter) that maximize the extent of the "stun" field while minimizing the "kill" and "escape" fields. Seines nets vary considerably in length and depth. Smaller seines are typically used for biological sampling in shallow waters, whereas larger seines are often used in ponds and lakes. Entire reaches of streams and shallows of ponds and lakes can be sampled with seine nets. Trawls are bag- or funnel-shaped nets that are towed through the water by one or more boats for straining fish from the water. They vary in size and can be designed for bottom, midwater, or surface sampling. Experimental gill nets are stationary, flat nets, suspended vertically in the water, with variable meshes that entangle passing fish as they try to withdraw. Trap nets are stationary, long, tapering mesh tubes or funnels, with mesh wings

that channel and direct fish into the tube. Fish that reach the end of the tube are unable to turn around and swim out.

When appropriate, after collection, the fish will be identified to species, weighed to the nearest gram, and measured to the nearest millimeter. Fish will be checked for external pathological gross abnormalities (e.g., tumors, lesions, structural or bone defects) through an evaluation of the conditions of the lips, jaws, barbels (if and as applicable), eyes, right gill, fins, urogenital cavity, anus, body form, and body surfaces. Field processing will be minimized to avoid contamination (e.g., skinning, filleting, etc. will be performed as necessary in the laboratory).

When fish are collected for tissue analysis, after field classification and examination, fish will be placed in sealed bags, labeled, and shipped on ice to the laboratory via overnight courier. If necessary, separate workplans will be developed for fish sampling at NTC, Orlando.

4.6 FIELD LABORATORY ANALYSES. To develop screening information to aid in the placement and selection of boring, monitoring well, and sample locations, selected soil, sediment, soil vapor, and aqueous samples will be analyzed in the field to evaluate the extent of contamination. Field analyses will be conducted in accordance with the procedures and USEPA methods for field screening shown in Appendix B. The analytical method references are shown in Chapter 7.0, Analytical Procedures. Field screening analytical procedures will always be supported by sampling for laboratory analyses. An onsite field laboratory will be set up and used, as appropriate, for the analysis of VOCs, TPHs, PCBs, and inorganic analytes. VOCs from the headspace of soil and water samples will be measured in the field using a portable GC equipped with an electron capture detector and or a PID. The GC target compounds at NTC, Orlando will be: benzene; toluene; ethylbenzene; meta-, para-, and ortho-xylene; PCE; and trichloroethene (TCE). The target list of VOCs may be modified according to compounds of interest at the individual POIs. Infrared spectroscopy will be used to measure TPH concentrations in soil and water samples using a modified version of USEPA Method 418.1. PCBs will be measured in soil according to the Draft USEPA Method 4020. The method is based on the use of immunoassay test kits. X-ray fluorescence will be used to measure concentrations of selected inorganics in soil and water samples.

Results of soil and sediment field analyses will be reported in micrograms per kilogram dry weight. Liquid results will be reported in micrograms per liter.

Chemical Standards. Chemical standards will be purchased from Supelco, Inc.; Chem Service, Inc.; or an equivalent supplier. All chemical standard preparation records will be logged and coded in a project GC run logbook.

Standards Preparation. All standards will be prepared from neat solutions or prepared mixes. Stock standards will be made by diluting neat standards or prepared mixes with an appropriate solvent. For standards made from neat solutions, the compound density will be used to determine the quantity of neat compound to add to the solvent.

All calibration standards will be made by serial dilution from stock standards. The calibration standard concentrations will be determined by the expected range of contaminant concentrations.

4.6.1 Calibration Prior to analyzing samples, instrument operation conditions will be established and recorded in the instrument logbook or on an operation conditions record sheet. Standard calibration techniques will be used; a detailed description of external standard calibration is found in USEPA Method 8000 (USEPA, 1986).

Initial Calibration. At the initiation of each field program, a minimum three-point initial calibration curve will be prepared covering the desired concentration range of analyses for the site.

Quantitation of volatile organics may be calculated from a point to point calibration curve as described in USEPA Method 8000 (USEPA, 1986), but is not required. If the relative standard deviation of response factors is less than 30 percent for a given target analyte, linear regression may be used for determining the concentration detected in samples.

Continuing Calibration. Prior to sample analysis, a continuing calibration check standard will be analyzed at or near the mid-level each day. The target analytes must have percent differences (%D) of less than 30 percent when compared to the initial calibration.

Samples may be run only if no more than one compound per detector, or a total of 10 percent of the target compounds, exceed the %D criteria of 30 percent. If the above criteria are not met, a second standard will be analyzed. If the second standard is unacceptable, a new calibration curve will be prepared. Following analysis of an acceptable continuing calibration standard, samples can be analyzed for a period of 24 hours from the time of standard injection. Sample IDs for the continuing calibration standard will be entered into the instrument logbook.

Additional details and procedures concerning instrument calibration can be found in the SOPs and USEPA methods for field screening found in Appendix B.

Method Blanks. A method blank will be analyzed before samples are analyzed. Blanks will be analyzed using the same procedures as field samples. Method blanks will be deemed acceptable if no target compounds are present above the detection limits established for the instrument. Samples will not be analyzed until an acceptable method blank is run, demonstrating that the instrument is free of contamination.

Cleaning Blank. Blanks will be analyzed after any high-level sample, to ensure that carryover is not occurring. A high level sample is defined as being five times higher than the highest calibration point. Blanks may be run more often based on the judgment of the field analyst.

4.6.2 Sample Preparation Sample preparation techniques have been adapted from protocols outlined in USEPA methods and are specified in the methods found in Appendix B. Methods have been modified for the purpose of field application where appropriate. Samples will be analyzed after instrument calibration and method blank analysis has been completed.

Soil Samples. Soil samples include subsurface soils, surface soils, or sediment samples. Concentrations in soil samples will be calculated based on the dry weight. Percent moisture adjustments will be made to the raw data results. An automatic moisture balance may be used to determine percent solid as per the manufacturers' instruction.

4.6.3 Target Compound Concentrations Calculations The concentration of target compounds detected in samples will be calculated using either point-to-point comparison to the initial calibration curve, or by linear regression (if the response factor [RF] is less than 30 percent).

4.6.4 Field Documentation Procedures A log of all GC analyses will be recorded in a bound notebook with sequentially numbered pages. A separate logbook will be maintained for each GC instrument used in the field. The logbook will record the concentrations for all calibration standards injected, sample run number, sample ID, date, standard preparation code, sample volume and /or weight, and any additional information particular to the injection.

After conclusion of the field effort, data will be stored by the Consultant. Raw data includes chromatograms and calibration records from all standard, blank, and sample analyses used in the field program.

4.6.5 Quality Control Procedures In addition to instrument calibration and continuing calibration checks, duplicates and MS/MSD samples may be analyzed by field screening methods. The number and/or frequency of QA/QC samples will be determined and established on a POI specific basis dependent on the DQOs required for that particular field measurement. A minimum of 5 percent of samples collected for DQO Level II analysis (field screening) will be split for Level IV DQO confirmation.

The following procedures will be implemented by the field chemist to ensure standardization of the operating procedures.

1. All appropriate standards will be preserved by storing them in a refrigerator or cooler.
2. If a continuing calibration standard does not meet requirements, then a second standard will be analyzed. If the second standard does not meet requirements, a new initial calibration will be required.
3. The field chemist will review each sample analysis chromatogram before analyzing the next sample. Target compound retention times will be compared to calibration standards and carryover potential will be evaluated.
4. Carryover target and non-target analytes: cleaning blanks will be analyzed after samples containing high concentrations of target or non-target compounds until, in the judgment of the field analyst, carryover will not impact subsequent analytical runs.

Data from all sample analyses and relevant calibration and blank analyses will be documented in the project instrument run logbook.

4.7 SURFACE WATER HYDROLOGIC MEASUREMENTS. The following subsections describe the procedures used to obtain streamflow estimates and surface water elevation measurements.

4.7.1 Streamflow Estimates The flow of a stream or river may be calculated by measuring the water velocity and the stream channel cross-sectional area. This information is useful in evaluating site-wide surface water characteristics, and potentially, the relation of surface water hydrology to groundwater hydrology at the site. The transects used to generate velocity profiles will be selected such that no surface flow influx features or impediments (i.e., running outfalls, side channels, or bridge abutments) are located directly upstream of the profile line. The procedure for measuring streamflow and cross-sectional area follows standard USGS methods (1982) and is outlined briefly below.

1. Field personnel will select an appropriate stream reach, preferably straight-channeled, with no bars or upstream impediments or surface flow sources. The field personnel will identify marker points on opposing stream banks that can be used for an elevation and location survey.
2. A tape will be stretched across the stream width and marked into 15 to 30 equal segments that will define the subsections. Segments will be numbered consecutively, starting with 1 at the left bank. Total channel width will also be measured and recorded.
3. Channel depth will be measured at the mid-point of each section. The mid-point verticals will be the point from which velocity measurements for each subsection will be made. Total depth times 0.6 will be the depth at which velocity measurements will be taken. (Controlled field studies have shown that 0.6 times total depth is the point at which the average stream velocity occurs.) It is assumed that the velocity sample at each vertical represents the mean velocity in a rectangular subsection. The subsection area extends laterally from half the distance from the preceding observation vertical to half the distance to the next, and vertically from the water surface to the measured depth. Measurements will be recorded to the nearest 0.01 foot on data sheets. A sample streamflow measurement data sheet is presented as Figure 4-12.
4. A mechanical current meter will be lowered to the measured depth and the meter will be left in place for 60 seconds. Meter counts will be recorded on the data sheet. Flow velocity will be interpreted using the calibration curve supplied by the manufacturer and recorded on the data sheet. At least two, preferably three, flow measurements will be collected at each transect.
5. Discharge ($Q=VDW$) will be calculated for each channel section using channel subsection area and mean flow velocity normal to each subsection. Total discharge for the profile is the sum of all subsections.

$$Q = \sum_{i=1}^m q_i \quad (4)$$

where

Q = discharge ft³/min,
m = total number of segments, and
i = segment number.

The discharge for any subsection at vertical *i* is given by the equation:

$$q_i = v_i \left[\frac{b_{(i+1)} - b_{(i-1)}}{2} \right] d_i \quad (5)$$

where

q_i = discharge through subsection *i*,
v_i = measured mean velocity at vertical *i*,
b_(i-1) = distance from initial point to preceding vertical,
b_{i(i+1)} = distance from initial point to next vertical, and
d_i = depth of water at vertical.

Direct flow measurements can also be obtained using V-notch weir plates and rectangular weir plates.

4.7.2 Surface Water Elevation Measurements Surface water elevation measurements will be taken at selected locations to augment groundwater elevation data generated during water level measurement rounds. Because no permanent elevation monuments or staff gages will be erected, the following method will be used.

1. The surveyor will select a suitable surface water measurement location, (i.e., near a sampling point, easily accessible and quiet water).
2. A reference point onshore (e.g., tree, fencepost, or large boulder) will be marked and labeled by the surveying team for inclusion in the elevation survey. The reference point will be selected such that it, along with the water's edge, are readily visible from the surveyor's station.
3. The relative elevation of the reference point will be surveyed to the nearest 0.01 foot. The reference point elevation will be referenced to the National Geodetic Vertical Datum (NGVD).
4. The surface water elevation and the reference point will be shot from the same station.

4.8 AQUIFER CHARACTERIZATION. Aquifer testing will be conducted to characterize groundwater flow patterns and to assess aquifer characteristics.

4.8.1 Water Levels The depth to groundwater will be measured from a surveyor's mark on the well riser or, in the absence of such mark, from the highest point on the rim of the well casing or riser. Water level measurements at the various wells will be obtained using an electronic water level meter. The water level will be measured to the nearest 0.01 foot. The measured value will be checked by raising the probe 1 to 2 feet and remeasuring the water level to obtain a precise and accurate measurement. The probe end of the water level meter will be properly decontaminated between monitoring wells.

The water level elevations will be used to construct groundwater elevation contour maps, from which groundwater flow directions will be interpreted. Vertical hydraulic gradients can be calculated from water level data at well pairs.

4.8.2 Hydraulic Conductivity Testing Permeability testing will be conducted in (1) all new monitoring wells representative of each sampling interval and (2) specific existing wells, as requested by the Navy. Permeability tests (or slug tests) are useful for calculating estimated groundwater flow parameters, for evaluating the heterogeneity of the aquifer, for identifying high permeability zones, and for determining the viability of various remedial options. Tests will be conducted using the following procedures. A PVC slug or compressed air will be used to displace water in the well for testing. Compressed air will be used only in wells screened below the water table, and care will be taken not to lower the water table to the depth of the screen.

Slug tests can be categorized into falling head and rising head tests. Falling head tests are typically performed by introducing a solid "slug" below the water level and measuring the rate of water level decrease per time until equilibrium conditions are reached (i.e., the rate of recovery). Rising head tests are performed by withdrawing a solid "slug" and measuring the rate of recovery. The change in water level with time is measured manually with a water level tape or electronically with an In-Situ Hermit™ 1000B or 2000 Datalogger™ with 10- or 20-pound-per-square-inch transducers, or equivalent. Only rising head tests will be performed on water table wells (wells with screened zones extending above the water table). Rising and/or falling head tests will be performed on wells that are screened below the water table; however, rising head tests will be preferred.

By observing the behavior of the recovery as a function of time, an estimate of the hydraulic conductivity of aquifer materials surrounding the well can be calculated using the Hvorslev (1951) or Bouwer and Rice (1976) technique. The slug test data can also be analyzed using a method by Cooper, Bredehoeft, and Papadopoulos (1967).

An Aquifer Test Completion Checklist (Figure 4-13) will be completed for each test conducted. In addition, a Field Permeability Test Data Sheet (Figure 4-14) will be completed for each test.

Should field conditions render hydraulic conductivity tests using slugs ineffective, the following alternate method will be used. A submersible pump will be used to remove water from the well. The discharge rate will be measured and recorded. Two to three separate discharge rates will be selected to adequately stress the aquifer. Changes in water levels will be measured as a function of time during both pumping and recovery. By observing the behavior of the drawdown, discharge, and recovery as a function of time, an estimate of the hydraulic conductivity of the aquifer will be made.

4.8.3 Groundwater Pumping Tests Pumping tests are employed to measure hydraulic characteristics (transmissivity and storativity) over a large aquifer volume. They also can determine the area of influence of a pumping well and the location of hydraulic boundaries. The test typically consists of pumping water from one well at a constant rate while measuring drawdown versus time in that well and in observation wells located at various distances from the pumping well. Measurements are made both during pumping and after pumping (to observe water-

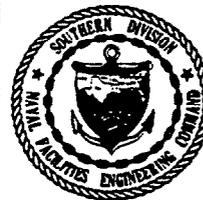
AQUIFER TEST COMPLETION CHECKLIST

AQUIFER TEST NO. _____

SETUP	DATE	BY WHOM
MONITORING WELL ID		
DATE OF TEST		
TYPE OF TEST		
HERMIT TYPE/SERIAL#		
TEST #		
DATA COLLECTION RATE		
TRANSDUCER		
SERIAL #		
PSIG		
SCALE FACTOR		
OFFSET		
INPUT CHANNEL		
TEST DATA		
INPUT MODE (TOC/SUR)		
STATIC WATER LEVEL (FT./TOC)		
WELL DEPTH (FT./TOC)		
XD DEPTH (FT./TOC)		
INITIAL XD REFERENCE		
SLUG DEPTH (FT./TOC)		
TIME OF SLUG PLACEMENT		
TIME OF WL EQUILIBRATION		
NEW XD REFERENCE		
START TIME OF TEST		
END TIME OF TEST		
NOTES:		

FIGURE 4-13

EXAMPLE AQUIFER TEST COMPLETION CHECKLIST



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level recovery). Interpretations of the time-drawdown plots will be the basis for determining the specific aquifer characteristics.

Each planned pumping test will be designed to address the specific objectives of the test and to reflect anticipated site conditions. A detailed design will be included in each task-specific workplan.

4.9 ELEVATION SURVEY. The elevation and location survey will be conducted by a Florida-registered professional land surveyor. Elevations will be referenced to the NGVD of 1929 and will be measured to an accuracy of at 0.01 foot for monitoring well casings and 0.1 foot for ground surfaces. Horizontal locations will be recorded as State Planar coordinates to the nearest 0.1 foot.

The actual surveying techniques and the required equipment to be employed, and the required accuracy and precision, are dependant upon the field conditions and the nature of the sampling stations and/or techniques to be employed. All survey observations and measurements will be properly recorded by the designated member of the survey crew in bound field books, in accordance with the requirements of these guidelines.

Any calibrations performed upon surveying equipment in connection with this work will be properly documented with regard to personnel, date, instrument number, calibration readings, procedures and standards employed, adjustments made, comments and/or observations, etc.

All analyses employed in the reduction of field data, calculations, production of maps, etc., will follow commonly accepted professional survey practices that are appropriate for the task at hand, including all appropriate procedures for QC to check and review the work. Where a computer is used to reduce data, the program employed will have first been certified to yield repeatable results within the required limits of accuracy. All office calculations, data reduction, map making, etc., will be performed in a neat, sequential, and logical order to facilitate future review.

The installed locations of all benchmarks, baselines, and monuments will be appropriately documented on a base map to indicate their relative locations. Benchmarks will be described with respect to their construction and location, on map, in addition to their grid coordinates.

If required, final maps will be submitted as an original or Mylar™, in the specified map size. If one sheet is not sufficient, the mapped area may be divided into sections, one per sheet, and appropriate references and match lines provided. Maps will be of a suitable scale to show appropriate detail clearly. Although this varies with the size of the site mapped, appropriate map scales generally range from 1 inch equals 50 feet to 1 inch equals 200 feet. The scale used will be clearly shown on the map both graphically (e.g., bar scale) and numerically (e.g., 1 inch = 50 feet). Each map will also indicate a true north meridian, preferably oriented toward the top of the page, and will be provided with appropriate borders, legends, title boxes, notes, data references, and means of identifying author, checkers, etc.

The following paragraphs summarize specific surveying requirements appropriate to various sampling locales.

4.9.1 Borings and Test Pits Horizontal locations and ground surface elevations for borings and test pits are indicated on boring and test pit logs and may be used to construct geologic sections or profiles. Horizontal locations will be staked to the nearest foot, and ground surface elevations measured to 0.1 foot. The surveyors may stake the location in advance, indicating the boring number, grid coordinates and ground-surface elevation on the stake. They will also have one or more tall witness stakes with colored flagging around the staked location to make it more readily visible. In paved areas, it is usually more convenient to spray paint the location and other information directly on the paving. A greater degree of layout accuracy may be required in confined areas, where the drilling or excavation must be performed carefully to avoid disturbance of underground facilities (i.e., utilities, tunnels, foundations, etc.).

4.9.2 Monitoring and Pumping Wells and Piezometers In general, horizontal location, well riser elevation, and ground surface elevation criteria for wells and piezometers are similar to those of test pits or borings. However, the surveyor will measure and mark the elevation of the top of the riser to 0.01 foot as this point will be used as a reference to measure precise groundwater elevations. The riser elevation will be noted, and also permanently recorded directly on the outer protective casing, if possible. The well location and ground surface elevation may be surveyed either before or after well installation, but the riser (i.e., top of casing) and outer protective casing (optional) elevations must always be surveyed afterward. For monitoring wells, pumping wells, and piezometers, a permanent mark will be made on the riser, protective casing, or other point of reference both for surveying purposes and to enable reproducible depth to water measurements.

4.9.3 Surface Water and Sediment Sampling When grab samples are obtained from the edges of surface water bodies, the samplers will install a location stake at the shoreline marked with the station number and coordinates, if appropriate. This stake may also be used as a reference point for measuring the water surface elevation (to an accuracy of the nearest 0.01 foot). In certain cases, this may not be required, because the sampler can estimate and mark the appropriate location and elevation directly on a site topographic map. Such locations do not require great locational accuracy (within several feet), because they are usually only indicated graphically on the site map.

When samples are to be taken within the surface water body away from the shoreline, better horizontal control is usually required. Sampling locations will be determined by the sampler using on-shore baselines or ranges.

4.9.4 Surface Soil and Waste Sampling Measurement and layout requirements for obtaining a single grab sample of soil or waste are comparable to those for obtaining surface water grab samples from the shoreline. Where a composited sample is to be collected from a sampling grid, the surveyors will stake out the grid and indicate the station number(s), coordinates or orientation of the grid, and ground elevation(s) on the stakes. Generally, a precision of no better than the nearest foot for location, and 0.1 foot for elevation will suffice from grab or grid surface sampling.

4.10 CONTROL AND DISPOSAL OF INVESTIGATION-DERIVED WASTE (IDW). As part of the field activities, a certain amount of IDW material will be generated in association with personal protection, sample handling, multimedia sampling, soil

boring, well installation, well development, well purging, and decontamination. Every effort will be taken to minimize the IDW generated. The majority of the material will be uncontaminated, but some material will come in contact with media suspected to be contaminated.

The IDW will be segregated by medium (i.e., solids or liquids) and by location (i.e., boring or well) into storage containers. Labels will be attached to the storage containers that describe the content of the specific container (soil or water), the POI or Study Area of origin, the specific location (boring or well), and the date of generation. The storage containers will be stored on pallets that are underlain by plastic sheeting. A tarpaulin will be used to cover the storage containers and provide protection from the elements. The tarpaulin will be anchored by sandbags or an equivalent tie-down method. The storage area will be bermed to contain any potential leakage. The storage containers will be segregated by POI of origin. The storage container pallets will be arranged so as to allow access between them for container inspection. A column and row grid numbering system will be used to facilitate the storage and inspection of the storage containers. A storage container logbook will be maintained with the previous information located in it, as well as a sketch map of the storage area showing the location of POI-specific storage containers. The IDW storage area will be designated by the Navy. To avoid transporting IDW on public roads, each discrete NTC, Orlando facility will designate at least one storage area. Quarterly inspections of the IDW storage areas will be conducted to determine that all of the above requirements are being met and that the integrity of the storage containers has not been compromised.

Liquid IDW will come from three sources: (1) groundwater generated during the sampling and purging of existing and new monitoring wells, (2) water generated during decontamination procedures, and (3) drilling fluids.

Laboratory analysis of groundwater samples from the representative monitoring wells will be used to determine if the liquid IDW is acceptable for disposal at a suitable treatment facility agreed to by the Navy, the Consultant, and State and Federal regulators. These analyses will consist of target compound list (TCL) VOCs, SVOCs, pesticides, and PCBs and target analyte list (TAL) inorganics. The analyses will be conducted in accordance with Level III or IV DQOs.

Decontamination fluids will be containerized and a composite sample representing each POI will be collected and analyzed as described above for groundwater. The fluid will be treated in the same manner as the groundwater IDW.

Solid IDW will come from three sources: (1) the advancement of soil borings, (2) the drilling of monitoring wells, and (3) personal protective equipment (PPE) and other disposable items (plastic sheeting, disposable equipment, etc.). All the solid IDW will be containerized as described above. However, heavily soiled disposable equipment and PPE waste may be rinsed, with the rinsate collected and treated as liquid IDW as described above. The rinsed disposable equipment and the PPE will be disposed in a dumpster. The remaining solids will be containerized by POI and by location of use. The results of the laboratory analyses of the samples from the same POI will be used to determine the classification of the IDW.

As described in Subsection 4.4.6, as the soil borings are advanced, split-spoon samples will be collected either continuously or at 5-foot intervals. For each

boring, a minimum of two samples will be analyzed in conformance with Level III or IV DQOs (depending on the DQO requirements established for the boring). These analyses will be used to determine if contaminants exist in the IDW generated during the advancement of the respective soil boring.

For the monitoring well locations where a soil samples will not be collected prior to the installation of the well, an analysis of the cuttings generated during the drilling of monitoring wells will be performed (in conformance with Level II DQOs) to determine if organic contaminants are present in the cuttings.

The results of the analyses from the solid samples will be used to determine the disposal option for the IDW. If the analytical results for the IDW are less than NTC, Orlando background values and less than the TCLP threshold values, the IDW will be labeled non-hazardous and the IDW will be considered clean and disposed onsite or used elsewhere on the base as clean fill. If the analytical results for the IDW are greater than NTC, Orlando background values but less than the TCLP threshold values, the IDW containers will be labeled solid waste and the IDW will be disposed at a subtitle D landfill or held for remediation with the other contaminated soils. If the analytical results for the IDW are greater than the TCLP Threshold values the IDW containers will be labelled hazardous and the IDW will be considered a hazardous waste (unless the storage containers are tested for TCLP analysis and are determined to not be a hazardous waste). The IDW will be stored at the designated storage areas. After receipt of the laboratory analytical results of the samples as described above, a determination on the characterization of the storage containers will be made. The storage containers will be labeled non-hazardous, solid waste, or hazardous based on this determination.

A copy of the laboratory analytical results will be stored on base so that comparisons of the results and IDW classification can be made. Quarterly summaries of the analytical results, the comparisons to background and TCLP threshold values, the rationale used to classify the IDW, and location maps will be provided to SOUTHNAVFACENCOM for distribution to interested parties.

5.0 SAMPLE HANDLING AND CUSTODY PROCEDURES

This chapter describes a program of sample tracking and COC that is followed during sample handling activities in both field and laboratory operations. This program, which is compatible with USEPA Region IV ECBSOPQAM (USEPA, 1991c) COC requirements, is designed to assure that each sample is accounted for at all times. To maintain this level of sample monitoring, sample container labels, shipping seal manifests, and COC forms are employed as necessary. Field data sheets and COC records are also completed by the appropriate sampling and laboratory personnel for each sample.

The objective of the sample custody identification and control system is to ensure that:

- samples are uniquely identified,
- samples are collected for all scheduled analyses,
- the correct samples are analyzed for requested analyses and are traceable to their records,
- descriptions of important sample characteristics and field observations are recorded,
- samples are protected from loss and identified if damaged,
- alteration of samples (e.g., filtration and preservation) is documented,
- a forensic record of sample custody is established,
- sample security is maintained, and
- relevant field information is recorded including location, sample number, date and time, identification of field samples, and individuals collecting the samples.

5.1 FIELD CUSTODY. The field COC record is used to record the custody of all samples or other physical evidence collected and maintained by field personnel. The COC protocol followed by the sampling crews involves the following steps:

- documenting procedures used and reagents added to samples during sample preparation and preservation;
- recording sample locations, sample site identification, field sample number, and specific sample collection procedures on the appropriate forms;
- using sample labels that contain all information necessary for effective sample tracking; and

- completing standard field data record forms and/or maintaining a bound field logbook to establish sample custody in the field before sample shipment (see Chapter 4.0).

Prior to sampling, labels are developed for each sample to be collected. Each label is numbered to correspond with the appropriate sample(s) to be collected. Samples will be identified using an 8-digit sample ID as described in Section 4.1. A summary of the labels prepared, with space for sample tracking and notations, will also be printed. This sample manifest assists sample control in the field and will eventually be retained as part of the project file. An example of a sample label and an example of a sample tracking form is shown on Figure 5-1. Additional information regarding sample tracking can be found in Section 8.5.

The COC record is used to document sample-handling information (i.e., sample location, sample identification, and number of containers corresponding to each sample number). The following information is recorded on the COC record:

- project reference;
- the site name, sample identification number, date of collection, time of collection, preservation, and sample type, number of containers, and sample matrix;
- the names of the sampler(s) and the person shipping the samples;
- serial number of custody seals and shipping cases;
- the date and time that the samples were delivered for shipping;
- analyses required; and
- the names of those responsible for receiving the samples at the laboratory.

An example of a COC is shown in Figure 5-2. Field sample data records, which also include pertinent data relative to COC procedures were presented in Chapter 4.0 (see Figures 4-5, 4-8, and 4-10). The COC is completed in triplicate. One copy accompanies the samples to the laboratory, another is kept by the sample crew chief and transferred to the Laboratory Quality Assurance Coordinator (QAC), and the last copy is maintained in the project file.

5.2 SAMPLE PACKING AND SHIPPING. Sample packaging and shipping procedures should protect the integrity of the samples and prevent detrimental effects from leakage or breakage. Regulations for packaging, marking, labeling, and shipping hazardous materials and wastes are promulgated by the U.S. Department of Transportation (USDOT) and described in the CFR Parts 171 through 177; in particular Part 172.402h, Packages Containing Samples). In general, these regulations were not intended to hamper shipment of samples collected at controlled or uncontrolled hazardous waste sites or samples collected during emergency responses. However, the USEPA has agreed through a memorandum of agreement to package, mark, label, and ship samples observing USDOT procedures. The information presented here is for general guidance.

SAMPLE ID. _____	COMMENTS
PROJECT No. _____	
DATE/TIME _____	
SAMPLE MATRIX _____	
SAMPLE SITE _____	
PRESERVATIVE _____	
FILTERED (Y/N) _____	
ANALYSIS _____	
SAMPLER _____	
ABB Environmental Services, Inc.	

FIGURE 5-1

EXAMPLE SAMPLE LABEL



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Correct packaging, storing, and shipping of environmental samples are necessary to:

- ensure samples remain sealed in original containers,
- prevent breakage,
- prevent cross-contamination of individual samples,
- ensure sample characteristics are preserved,
- prevent contamination to receiving personnel, and
- ensure samples are protected against tampering when not in sampler's possession.

Sample containers are generally packed in metal or hard plastic, insulated coolers for shipment. Bottles are packed tightly so that no motion is possible. Styrofoam, and "bubble pack" are used to protect bottles from breaking. Ziploc® bags containing ice are added to the cooler along with all paperwork. The paperwork (i.e., COC forms) is sealed in a separate Ziploc® bag. The cooler top is then taped shut and all openings are sealed with evidence tape.

The standard procedure followed for shipping environmental samples to the analytical laboratory is as follows.

- Shipping of environmental samples collected by field personnel is done daily through Federal Express or equivalent overnight delivery service. Receipts are retained as a part of the COC documentation. When samples are relinquished to a shipping company for transport, the tracking number from the shipping bill or receipt will be recorded on the COC.
- Prior to leaving for the field, the Consultant's Field Operations Leader (FOL) will notify the Laboratory/Data Management Leader of the number, type, and approximate collection and shipment dates for the samples. If the number, type, or date of shipment changes due to program changes, the FOL must notify the Project TOM and Laboratory and Data Management Leader of the changes. This notification from the field also needs to occur when sample shipments will arrive on Saturdays. The FOL will coordinate sample pick-up with the laboratory.
- If prompt shipping and laboratory receipt of the samples cannot be guaranteed (e.g., Sunday arrival), the samplers will be responsible for proper storage and custody of the samples until transportation or shipment arrangements can be made.
- The FOL will notify the appropriate laboratory when samples collected by field sampling teams are going to be shipped to the laboratory.

The Laboratory and Data Management Leader keeps the laboratory and the Project Manager informed of all field sampling activities. This communication is critical to allow the laboratory enough time to prepare for the sample shipment arrival and to keep the Project Manager current on the status of the sampling program.

During sampling, field samples will be brought to a central sample collection location. The COC will be initiated upon receipt of the samples and sample data records at the collection point. Once the COC form is initiated, when transferring possession of the samples, each transferee will sign and record the date and time on the COC record. Custody transfers, if made to a sample custodian in the field, will account for each individual sample, although samples are transferred as a group. Every person who takes custody will fill in the appropriate section of the COC record. To prevent undue proliferation of custody records, the number of custodians in the chain of possession will be kept as small as possible.

5.3 LABORATORY CUSTODY. COC procedures are also necessary in the laboratory from the time of sample receipt to the time the sample is discarded. The field samples collected by the sampling team will be submitted to a NEESA-approved laboratory. The sample custody procedure will be detailed in the laboratory's Quality Assurance Project Plan (QAPP).

6.0 EQUIPMENT CALIBRATION AND PREVENTIVE MAINTENANCE

This chapter describes calibration protocols for laboratory services and field instruments that may be used at NTC, Orlando during field activities.

6.1 CALIBRATION PROCEDURES FOR LABORATORY EQUIPMENT. The procedures used for calibration of laboratory equipment are described in the analytical methods. The laboratory will keep records on the source of all standards used, and standards will be traceable to original sources. Check standards from a second source will be used to verify the accuracy of calibration standards.

6.2 CALIBRATION PROCEDURES AND FREQUENCY FOR FIELD INSTRUMENTS. Each piece of field sampling equipment requiring calibration will be calibrated prior to each day's use or as specified in the procedures included in Appendix B. As previously discussed in Chapter 4.0, data are recorded on a form shown as Figure 4-9. The procedures described in the following subsections apply to the specific instrument noted.

6.2.1 Salinity, Conductivity, and Temperature Meters A salinity, conductivity, and temperature meter consists of a temperature probe and a specific conductance meter.

Temperature Probe:

1. Using a thermometer whose calibration can be traced to a National Bureau of Standards-approved thermometer, immerse both probes into a beaker of water and note any differences for the field probe.
2. Recalibrate as necessary.

Specific Conductance Meter:

1. Calibrate meter and probe using the calibration control and the red-line on the meter dial.
2. Turn the function switch to read conductivity times 10 and then depress the cell test button, noting the deflection. If the needle falls more than 2 percent of the reading, clean the probe and retest.
3. Using at least two solutions of different ionic strength that will most likely bracket the expected values for conductivity, note accuracy of the probe and clean probe if necessary.

6.2.2 Specific Ion Meter The Specific Ion Meter consists of an ion-specific electrode.

1. Place electrodes and buffer solutions in a water bath at the temperature of the water to be sampled. After temperature equilibrium, measure temperature and adjust the temperature compensation knob for this temperature.

2. If using refillable probes, remove electrode cap and check that filling solution is above the filling mark.
3. Immerse the probe in the pH 7 buffer solution and adjust the calibration control to read the appropriate pH. Check the pH buffer solution for correct pH value at the equilibrated temperature.
4. Remove the probe, rinse with distilled water, and immerse in either the pH 4 or pH 10 buffer solution, depending on the expected pH of the sample.
5. If the meter does not register the correct pH for that buffer solution, adjust the calibration knob on the back of the instrument to obtain the pH of the buffer.
6. After rinsing, insert the pH probe into the flow cell and allow the probe to come to equilibrium with the sample water.
7. Store the pH probe either in ambient air or a buffer solution overnight, according to the manufacturer's specifications.

6.2.3 Tripar Analyzer The Tripar Analyzer consists of a temperature sensor, a specific conductance sensor, and a pH sensor.

Temperature Calibration:

1. Temperature Zero Adjustment. Connect the temperature sensor and select temperature as the display parameter. Remove the rear access cover exposing the sensor calibration potentiometers.

Prepare an ice water slurry and place the temperature sensor in the solution. Allow the temperature sensor to stabilize for approximately 1 minute while stirring the sensor in the solution vigorously. Using the adjustment tool provided in the rear cover, adjust the temperature "zero" potentiometer for a reading of 0.00 °C on the system display.

2. Temperature Span Adjustment. Prepare a test solution to be used for temperature calibration. A beaker of water at room temperature works well as it will not be changing rapidly in temperature. Place the Tripar temperature sensor in the test solution and allow to stabilize for approximately 1 minute. Using a precision laboratory thermometer, measure the temperature of the test solution. At the Tripar rear panel, adjust the temperature "CAL" potentiometer until the Tripar display reads the value of the calibration solution.

Best results will be obtained if the temperature "ZERO" and "SPAN" calibration procedures are repeated.

Conductivity Calibration:

From time to time, the Tripar conductivity circuit will require calibration. A simple two-point calibration procedure is used by first adjusting the conductivity zero and then the span.

1. Conductivity Zero Adjustment. With the conductivity sensor clean, dry, and in air, adjust the conductivity "zero" potentiometer for a reading of 0000 on the Tripar display.
2. Conductivity Span Adjustment. Totally immerse the Tripar conductivity sensor in calibration solution of known conductance. Note that the reading displayed on the Tripar is a temperature corrected value to 25 °C. Therefore, the value of the standard solution must be calculated to 25 °C. Also, the value of the calibration solution should fall in the upper 50 percent of the ranges to be calibrated (i.e., adjustment of the 1,000 micromhos range should be accomplished with a 500 to 1,000 micromhos standard). Once the sensor has stabilized in the solution for approximately 1 minute, adjust the conductivity "CAL" potentiometer at the Tripar rear panel for a reading on the display equal to the temperature corrected value of the standard solution.

Best results will be obtained if the conductivity ZERO and SPAN procedures are repeated.

pH Calibration:

1. pH Standardization. The pH sensor should be standardized before each use after long storage. First, moisten the electrode body with tap water and carefully remove the plastic storage cap covering the tip of the electrode. Care should be taken not to bend the body of the electrode as this can result in damage to the internal element.

For first-time use after long storage, immerse the lower end of the electrode in tap water for 30 minutes. This hydrates the pH bulb and prepares the ceramic wick for contact with test solutions. If air bubbles are present in the pH bulb, shake the electrode downward to fill the bulb with solution.

Prepare a small sample of pH 7 buffer solution and measure the temperature of the buffer. Rinse the pH electrode with distilled water and immerse the pH bulb in the reference buffer. Set the compensation dial in the Tripar front panel to the temperature of the buffer, allow several minutes for the sensor to reach equilibrium, and stir the sensor slightly to dislodge any possible air bubbles from the electrode tip. Using the "Standardize" potentiometer, adjust for a reading of pH 7.00 on the Tripar display.

2. pH Slope Adjustment. Very infrequently, the pH slope adjustment may require recalibration. This adjustment is available at the Tripar readout rear panel. To accomplish this adjustment, prepare a test solution of pH 4 or 10. Measure the temperature of the solution and make the appropriate setting at the pH "Compensation" dial. Rinse the pH electrode in distilled water and immerse in the buffer solution. Allow several minutes for the sensor to equilibrate and stir the electrode slightly. Using the pH "Slope" potentiometer available at the rear panel, adjust the Tripar readout module for a reading equal to the value of the buffer solution. For best results, the pH "Standardize" and "Slope" adjustments should be repeated at least once.

Note that some interference may be seen on the pH reading if the Tripar conductivity sensor is present in the same test solution as the pH sensor.

6.2.4 Photoionization Meters A number of PID meters are available for field use, as described below.

HNu™. With the probe attached to the instrument, turn the function switch to the battery check position. The needle on the meter should read within or above the green battery area on the scale plate. If the needle is in the lower position of the battery arc, the instrument should be recharged prior to any calibration. If the red LED comes "on," the battery should be recharged. Next, turn the function switch to the "on" position. In this position, the ultraviolet (UV) light source should be on.

To zero the instrument, turn the function switch to the standby position and rotate the zero potentiometer until the meter reads zero. Clockwise rotation of the zero potentiometer produces an upscale deflection, while counter-clockwise rotation yields a downscale deflection. If the span adjustment setting is changed after zero is set, the zero should be rechecked and adjusted if necessary. Wait 15 to 20 seconds to ensure that the zero reading is stable. If necessary, readjust the zero. The instrument is now ready for calibration by switching the function switch to the proper measurement range.

Using nontoxic analyzed isobutylene gas available from the manufacturer in pressurized containers, connect the cylinder with the analyzed gas mixture to the end of the probe with a piece of tubing. Open the valve of the pressurized container until a slight flow is indicated and the instrument draws in the volume of sample required for detection. Adjust the span potentiometer so that the instrument is reading the stated value of the calibration gas.

If the instrument span setting is changed, the instrument should be turned back to the standby position and the electronic zero should be readjusted, if necessary. If the instrument does not calibrate, it may be necessary to clean the probe or the lamp connection.

Photovac™ Total Ionizables Present (TIP). The name of this instrument is derived from the fact that it measures TIP. Turn power switch on by first pulling knob out and then up. Allow the TIP to warm up for 5 minutes prior to use. Turn span knob to max (9) and zero knob to "ZERO." Attach "zero air" cylinder to TIP inlet using PVC tubing. Zero instrument using zero knob only. (TIP is very sensitive so stable reading of absolute zero is difficult and not necessary to achieve.) Next, attach isobutylene cylinder to TIP inlet. Use the span knob to adjust TIP reading to the concentration number on the isobutylene cylinder (usually 60 ppm). Remove cylinder. TIP is now calibrated and ready for use. (Calibration should be checked often because TIP has tendency to drift.) When finished, turn power off by pulling switch out and down. Recharge instrument overnight. (Battery charger must be pushed into place and then screwed into bottom of TIP.)

MicroTIP™ IS-3000. Calibration of the instrument will follow procedures in the manufacturer's operation manual. First, zero the instrument. Usually clean ambient air will be suitable as zero air. If there is any doubt, use a commercial source of zero grade air. Isobutylene at 100 ppm in air is the span

gas for calibration. To calibrate the instrument, use the calibration kit as follows.

1. Connect the supplied regulator to the span gas cylinder. Hand tighten the fittings. Observe proper handling techniques for all gases.
2. Open the valve on the gas bag by turning the valve stem fully counterclockwise.
3. Attach the nut to the regulator. Hand tighten the fittings.
4. Turn the regulator knob counterclockwise about half a turn to start the flow of gas.
5. Fill the gas bag about half full and then close the regulator fully clockwise to turn off the flow of gas.
6. Disconnect the bag from the adaptor and empty it. Flush the bag a few times with the span gas and then fill it.
7. Close the gas bag by turning the valve clockwise.
8. Press SETUP and select the desired CAL memory with the arrow keys and press ENTER. Press EXIT to return to the normal display.

Note: MicroTIP has 10 CAL memories and can be calibrated with 10 different span gases or response factors if desired. Only one cal memory can be used at a time. Each memory stores a different response factor, zero point, and sensitivity. (See instruction manual for information on programming the CAL memories).

9. Press CAL and enter the desired response factor. (Use Table 2, on page 21 of the instruction manual, to find the correct response factor for the compound of interest). If you are not looking specifically for one compound, then enter 1.00.

Note: The concentration detected by MicroTIP will be multiplied by the response factor before it is displayed and logged.

10. Expose MicroTIP to zero air. Press ENTER and MicroTIP sets its zero point.
11. The MicroTIP is then ready for the span gas concentration to be entered. Enter the known span gas concentration and then connect the span gas bag adaptor to the inlet.
12. Press ENTER to set the MicroTIP sensitivity.
13. When MicroTIP display reverts to normal, the MicroTIP is calibrated and ready for use. Remove the span gas bag from the unit.

Organic Vapor Meter (OVM). An OVM is another variety of PID that will be used during this investigation. The calibration procedure for the Thermo Electron

Instruments, Inc., Model 580B OVM is as follows. Refer to the instrument operating manual for additional details.

1. Hit ON/OFF toggle once.
2. Wait until lamp lights (screen will display "PPM = ____").
3. Hit MODE toggle.
4. Hit -/CRSR toggle until "RESET" to CALIBRATE comes up.
5. Hit RESET toggle to enter calibration mode. (Screen will display "ZERO GAS RESET WHEN READY".)
6. Hit -/CRSR toggle.
7. Connect zero gas canister via tube and gauge supplied with OVM. Open valve on gauge.
8. Hit RESET toggle. Screen will display "Model 580 Zeroing."
9. When zeroing is complete, screen will display "SPAN/PPM = 0000".
10. Span gas concentration (Isobutylene 100 ppm) is entered by hitting RESET and +/-INC toggles simultaneously to increment digit above cursor or RESET and -/CRSR simultaneously to move the cursor.
11. When correct value has been entered, hit +/-INC toggle. (Screen will display "SPAN GAS RESET WHEN READY".)
12. Connect span gas canister via tubing and gauge. Open valve on gauge.
13. Hit RESET toggle. Screen will display "Model 580 Calibrating."
14. When calibration is complete, the screen display will return to "RESET" to CALIBRATE. If calibration is acceptable, hit MODE toggle to return screen to run mode.

6.2.5 Yellow Springs Instrument Oxidation-Reduction Potential Electrode Assembly (Model 4540) The oxidation-reduction potential (ORP) device consists of an electrode assembly and cable designed for use with the YSI 3560 Water Quality Monitor System and similar ORP measuring systems.

1. Place the shorting cap on the pH input jack. Rinse the ORP electrode and a temperature sensor with deionized or distilled water and connect them to the meter. Pat dry with a laboratory tissue. Follow with a rinse of a small amount of reconstituted YSI 3682 Zobell solution.
2. Pour 3682 Zobell Solution into a sample cup (such as one from the YSI 3565 Sample Cup Pack) and immerse the ORP electrode and temperature sensor in the solution.
3. Turn on the instrument and allow the sensors to equilibrate in the solution.

4. Set the function switch to the millivolt (mV) mode. Read the temperature and calculate the correction to 25 °C by adding 1.3 mV for each degree below 25 °C, or by subtracting 1.3 mV for each degree above 25 °C; or determine the correction by use of the table provided in the Zobell Solution instrument sheet. A corrected reading within 25 mV of the value indicated assures correct electrode function.

6.2.6 Flame Ionization Detectors (FIDs) A number of FIDs are available for field use, as described below.

Century Model OVA 128 Organic Vapor Analyzer

1. Set calibrate switch to X10 and gas select control to 300.
2. Adjust meter reading to zero with the calibrate adjust knob.
3. Introduce a methane calibration gas of 95 ppm and adjust trimpot R-32 so the meter reading is 95 ppm.
4. Turn off hydrogen supply valve to put out flame.
5. Leave calibration switch on X10 position and use calibrate adjust knob to adjust meter reading to 4 ppm.
6. Place calibrate switch in X1 position and using trimpot R-31 adjust meter reading to 4 ppm.
7. Move calibrate switch to X10 position again. Use calibrate adjust (zero) knob to adjust meter to a reading of 40 ppm.
8. Move calibrate switch to X100 position and use trimpot R-33 to adjust meter reading to 400 ppm.
9. Move calibrate adjust (zero) knob to adjust meter reading to zero.
10. Unit is now balanced from range to range, calibrated to methane, and ready to be placed in normal service.
11. Note: Carbon filters are used to distinguish between methane and VOCs.
12. Note: background corrections are made for measured responses for soil borings or split-spoon samples analyzed in ambient air.

Heath PortaFID™ II OVA-FID. Calibration of the instrument will follow procedures outlined in the manufacturer's operation manual. To set up the calibration procedure, ignite and run the instrument for approximately 1 hour to stabilize. Set the instrument on a flat horizontal surface (the instrument must remain in this position throughout the calibration procedure). Now proceed as follows.

1. The meter needle should be set to zero by adjusting the zero control knob.
2. Depress the 500 ppm range switch.

3. There should be no significant drift or movement of the meter needle. The needle should remain relatively stable on zero.

Note: calibration must be conducted in a hydrocarbon-free atmosphere (clean air).
4. Attach calibration kit regulator assembly to calibration cylinder, turn calibration cylinder valve knob counterclockwise (one half to one turn). Do NOT force the knob all the way counterclockwise (open).
5. Attach calibration kit outlet connector to the hand-held unit by pushing the connector firmly into the sample inlet quick disconnect on the housing.
6. Within 30 seconds the meter needle should start moving upscale.
7. Allow the unit to run at least 30 seconds before checking the meter.
8. The meter needle should register within one division of 10 on the instrument meter scale.
9. If an adjustment is necessary to bring the meter to within one division of 10 on the 500 ppm scale, an adjusting control is supplied with the hand-held unit located inside the bottom rear of the instrument.
10. Adjust control to the proper level. Calibration is complete.
11. Repeat steps 1 through 8 to verify calibration.

7.0 ANALYTICAL PROCEDURES

Sample analyses conducted during field investigation activities at NTC, Orlando range from onsite analytical field screening analyses to CLP laboratory analyses. This section addresses the field screening and laboratory analytical methods and associated DQO levels for the media to be sampled during the NTC, Orlando project. The analytical method references are outlined in Table 7-1.

Field Screening Analytical Data. Field screening data provide real-time qualitative data and quantitative data conforming to Level II DQOs. Screening methods will be employed to attempt to define high concentration areas and to gain information concerning the horizontal and vertical extent of contamination. These analytical results will be evaluated to determine optimal locations for the collection of confirmatory soil, groundwater, surface water, and sediment samples. A minimum of 5 percent of samples collected for field screening analyses will be analyzed at Level IV DQO for confirmation.

Laboratory Analytical Data. Laboratory analytical data will be used for confirmatory sampling. These data will provide qualitative and quantitative data concerning type, concentration, and distribution of contaminants. In any level of QC and for any POI where volatiles and semivolatiles are analyzed by GC/MS, the current CLP methods will be used.

7.1 SELECTION OF PARAMETERS. Based on a review of the NTC, Orlando operational history and previous investigation, samples will be analyzed for a list of analytical parameters selected for this investigation. The lists of analytes are found in Table 7-1. Additional parameters may need to be added to the list as required on a POI-specific basis.

7.2 LABORATORY AND METHOD CERTIFICATION. Analyses will be performed by an FDEP- and NEESA-approved CLP laboratory. CLP methods are available for the analyses of VOCs, SVOCs, PCBs, and pesticides and inorganics. In the event that additional methods are needed where no CLP methods exist, USEPA-approved methods will be used whenever possible.

In addition, soil samples will be collected for geotechnical evaluation. Physical soil testing will be conducted on the soil samples using the procedures and equipment in compliance with current ASTM standards. The tests to be performed include Atterberg Limits, sieve grain size distribution, and assignment of USCS symbols equivalent to ASTM D-2.487-69. All samples will be sent, following proper COC procedures, to a geotechnical testing laboratory.

7.3 LABORATORY QUALITY CONTROL PROGRAM. The laboratory subcontractor is responsible for generation of a detailed Laboratory QA Plan. This plan will also be approved during the NEESA and FDEP certification program.

The laboratory will submit quality control reports as specified in the laboratory QA program. The Consultant will review the control charts periodically to ensure that the subcontract laboratory is performing analyses in compliance with CLP criteria.

Table 7-1
Laboratory Analytical Program

Project Operations Plan for Site Investigations
 and Remedial Investigations
 NTC, Orlando, Orlando, Florida

Media	Analytes	Method	Reference	DQO Level
Soils	TCL volatiles	Purge and trap GC/MS	CLP	III or IV
	TCL semivolatiles	GC/MS	CLP	III or IV
	TAL inorganics	AA/ICP	CLP or SW846	III or IV
	TCL pesticide and PCBs	GC/ECD	CLP or SW846 (8080)	III or IV
	TCL herbicides	GC/ECD	CLP or SW846 (8150)	III or IV
	TPH		SW846 (418.1)	III or IV
	Total organic carbon	Combustion	SW846(9060)	II
	Grain-size distribution	Sieve analysis	ASTM D 422	II
	Selected screening volatile	GC/ECD/PID	SW846-M	II
	Selected screening semivolatile	GC/ECD/PID	SW846-M	II
	Selected screening PCBs	Immunoassay Test Kit	SW846-M (4020)	II
	Selected screening inorganics	X-ray fluorescence	SW846-M	II
	Groundwater	TCL volatiles	Purge and trap GC/MS	CLP (low level)
TCL semivolatiles ¹		GC/MS	CLP	III or IV
TAL inorganics		AA/ICP	CLP or SW846	III or IV
TCL pesticides and PCBs		GC/ECD	CLP or SW846 (8080)	III or IV
TCL herbicides		GC/ECD	CLP or SW846 (8150)	III or IV
TPH			SW846 (418.1)	III or IV
Selected screening volatile		GC/ECD/PID	SW846-M	II
Selected screening semivolatile		GC/ECD/PID	SW846-M	II
Selected screening pesticides and PCBs		GC/ECD/PID	SW846-M	II
Selected screening inorganics		X-ray fluorescence	SW846-M	II
Selected radionuclides-gamma scan		Scintillation counter	(101.1)	III
Selected radionuclides-alpha or beta scan		Scintillation counter	(8310)	III
Sediments		TCL volatiles	Purge and trap GC/MS	CLP
	TCL semivolatiles	GC/MS	CLP	III or IV
	TAL inorganics	AA/ICP	CLP or SW846	III or IV
	TCL pesticides and PCBs	GC/ECD	CLP or SW846 (8080)	III or IV
	Total organic carbon	Combustion	SW846(9060)	II
Surface water	TCL volatiles	Purge and trap GC/MS	CLP	III or IV
	TCL semivolatiles	GC/MS	CLP	III or IV
	TAL inorganics	AA/ICP	CLP or SW846 (8080)	III or IV
	TCL pesticides and PCBs	GC/ECD	CLP or SW846	III or IV

¹ To achieve Florida maximum contaminant levels (MCLs) for all parameters, selective ion monitoring will be used in conjunction with standard CLP methods for detection of pentachlorophenol, hexachlorobenzene, and bis(2-ethylhexyl)phthalate. SW846 Method 8310, a high performance liquid chromatography method, will be used to detect benzo(a)pyrene at MCLs.

Notes: DQO = data quality objectives.
 TCL = target compound list.
 GC/MS = gas chromatograph/mass spectrometry.
 CLP = Contract Laboratory Program (USEPA, 1991a; 1991b).
 TAL = target analyte list.
 AA/ICP = atomic absorption/inductively coupled plasma.
 PCBs = polychlorinated biphenyls.
 GC/ECD/PID = gas chromatography/electron capture detection/photoionization detector.
 ASTM = American Society for Testing and Materials.
 M = method for field screening.
 SW846 = Test Methods for Evaluating Solid Waste.
 TPH = total petroleum hydrocarbons.

7.4 HOLDING TIMES. Analyses to be performed for this investigation will be initiated within specified time limits (i.e., sample holding times) to avoid degradation of the parameters being analyzed. When required, samples will be preserved in the field prior to shipment to the laboratory. Sample preservation and holding time requirements were presented in Section 4.2 (see Table 4-1).

8.0 DATA REDUCTION, VALIDATION, AND REPORTING

Reliable analytical field measurements of environmental samples require continuous monitoring and evaluation of the analytical processes involved. Depending on what is required of the analysis, how the results will be used, and what the expected results may be, QC requirements necessary to accomplish the objectives can and do vary substantially.

Data collected from investigative activities include survey data, field screening data, and laboratory analytical data. To represent data generated from field investigative activities in a usable form, a number of steps are required. Raw data are "reduced" for final reporting, formatting, and interpretation; "validated" when data are reviewed for accuracy; and reported when all parameters and requirements have been met.

8.1 DATA REDUCTION. Data reduction is the process of converting measurement system outputs to an expression of the parameter that is consistent with the comparability objective. Analytical results collected from both field and laboratory analytical instruments will be reduced to the concentration units specified in the analytical procedures using the equations provided in the analytical references in Chapter 7.0. Data reduction of laboratory data is conducted by the analytical laboratory. Reduction of data collected from field analytical instruments will be performed onsite by the analyst. All analysts will be trained in the required data reduction procedures required for the measurement.

Reduction of data for field measurements made by the OVA with an FID or PID will be performed according to the following formula to determine the OVA reading in ppm:

$$\begin{aligned} \text{Correct OVA Reading} = & \quad (\text{Direct Instrument Reading of Sample}) & (6) \\ & - (\text{Direct Instrument Reading of Sample Using} \\ & \quad \text{An Activated Charcoal Filter}) \end{aligned}$$

The list below identifies the field measurements read directly from the instrument in which data reduction is required.

- direct read instruments include pH meter, Model EP/pH;
- specific conductivity meter (PI Dsph-1pH); and
- water level indicator (ORS Interface Probe).

Analyses in the field will be performed by a trained field engineer or scientist. They are responsible for properly documenting and performing calculations of results that require data reduction.

Field activities and data calculations will be documented in hard-bound log books that indicate conversions of raw data to qualitative and quantitative results. Entries are made describing what samples will be taken and analyzed, the locations, raw data, and calculations. The activities will be performed by environmental scientists, field technicians, geologists, and engineers.

8.2 VALIDATION. Validation of measurements is a systematic process of reviewing a body of data to provide assurance that the data are adequate for their intended use and includes a review of PARCC parameters. Sample results are validated through comparison to QA/QC data to assure that analytical results fall within acceptable accuracy and precision confidence limits and to eliminate, correct, or flag matrix and other interference effects.

Laboratory Data. All data received from contract laboratories are validated and verified. Data validation is performed as soon as the laboratory data are received. Data validation will be conducted in accordance with NEESA document *Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program (1988)*. Other applicable guidance documents include the USEPA *Functional Guidelines for Evaluating Organic Analyses* (USEPA, 1988b) and the USEPA *Functional Guidelines for Evaluating Inorganic Analyses* (USEPA, 1988a). Validation includes a rigorous review of sample custody, holding times, sample extraction and preparation, GC/MS Spectrometry tuning, initial and daily calibration, surrogate performance, MS/MSD performance, method calibration, method, field and trip blank contamination, detection limits and detection limit standards, analytical sequences, interferences, laboratory and field duplicates, serial dilutions, laboratory control samples, post-digestion spike results, and method of standard addition results.

If data validation is performed by a subcontractor, then 10 percent of all validated data will be reviewed for accuracy, completeness, and for conformance with validation guidance documents.

During validation, the COC is reviewed for completeness and the field documentation is checked to determine at what point in the sampling sequence the equipment rinsate blank was collected, the origin of the field blank water and decontamination solvent, the source of the sample bottles, and whether the correct number of samples and blanks were collected in accordance with the workplan. During the data validation process the data are reviewed for the presence of any obvious anomalous values.

Validated data will be prepared in the following formats representing:

- laboratory data package as received from the laboratory, tabulated by media and analytical fraction; and
- annotated data resulting from the review process, tabulated in a similar format.

Field Screening Data. Field screening data provide real-time qualitative data and Level II quantitative data. This information is useful for determining strategic sampling locations. Greater variability may be expected from field screening methods and, due to time constraints, the field analytical data will not be formally validated in the same manner as laboratory data; however, the data will be carefully screened and evaluated.

Before field results are reported, they are subject to review. The field analyst has the initial responsibility for proper instrument condition and calibration, for the data meeting all acceptance criteria, and for the accuracy of all calculations. The analyst has the responsibility to correct all deficiencies at the time that they are discovered. An independent review is then conducted by a peer analyst,

receipt, and validated sample receipt, as well as various steps in the process needed to ensure the quality of the electronic data. As each milestone is achieved, the sample data manager records the achievement in a sample data management database. This database is a secure database backed-up daily on a 14-day cycle. The back-up is stored in a fire-safe vault for 2 weeks. At the conclusion of the project, the sample data manager archives the database and makes two copies to store in separate storage facilities. An example data tracking report form is presented in Figure 8-2.

Field data management procedures vary depending on the type of data collected. In all cases, two hard copies of the data exist. One copy resides in the field office, and one copy resides in the home office. Where appropriate, electronic field data also exist. The main objectives of the field data manager are to store the field data and to ensure the integrity of any reproductions of the field data. When the project is completed, the data manager ensures that two correct copies of all field data exist. The field data manager stores each copy in a separate storage facility.

9.0 INTERNAL QUALITY CONTROL

QC procedures have been established for both field activities and laboratory activities. The number and types of QC samples collected for each POI will be specified in the task specific workplans. A brief description of the types of field and laboratory QC samples and frequency of collection is presented below.

9.1 FIELD QC ACTIVITIES. Field quality control activities include the use of calibration standards and blanks for pH, specific conductance, temperature, and photoionization, and flame ionization measurements. Field QC samples to be submitted to the laboratory include trip blanks, equipment rinsate blanks, field water blanks, and field duplicates. The frequency of field QC samples is summarized in Table 9-1. Field QC samples are analyzed in the laboratory as samples, and their purpose is to assess transport, decontamination procedures, and sampling procedures as possible sources of sample contamination and to document overall sampling and analytical precision. Field staff may add blanks or duplicates if field circumstances are such that they consider normal procedures insufficient to prevent or control sample contamination, or at the direction of the Consultant's project TOM. A brief description of field QC samples for NTC, Orlando and the frequency of collection is shown below.

Table 9-1
Frequency Requirements for Field QC Samples

Project Operations Plan for Site Investigations
 and Remedial Investigations
 NTC, Orlando, Orlando, Florida

Type	Frequency
Trip Blank (volatiles only)	One per cooler containing volatile organic compound samples
Equipment Rinsate Blank	
Precognised Equipment Blank	Minimum of one, then at 5 percent of equipment sets for all parameters measured.
Field Cleaned Equipment Blank	One per day per sampling event for all parameters measured.
Field Water Blank	Two per source for all parameters measured (one at the beginning of the project and one at end).
Field Duplicates	10 percent per sample matrix for all parameters measured.
Background Samples	To be specified in the task specific workplans

9.1.1 Trip Blanks Trip blanks are required for assessing the potential for contaminating samples with VOCs during sampling, transit, and storage. The trip blank consists of a volatile organic analytes (VOA) sample container which is filled with analyte free water at the laboratory and shipped to the site with the other VOA sample containers. Preservatives or additives are added to the trip blanks during preparation, if required for that parameter group. The trip blanks are kept with the investigative samples throughout the sampling event and are

packaged and shipped with the investigative samples. A trip blank is included with each cooler of water or soil samples scheduled for VOC analysis and will be stored and analyzed with the corresponding VOC samples.

9.1.2 Equipment Rinsate Blanks An equipment rinsate is a sample of organic-free water which has been used to rinse the sampling equipment. This blank is useful in documenting adequate decontamination of sampling equipment. Two types of equipment blanks will be collected during NTC, Orlando field activities; a precleaned equipment rinsate and a field cleaned equipment rinsate.

A precleaned equipment blank is defined as an organic-free water blank of equipment rinsate performed onsite *before* sampling begins. Contaminants present within the sampling equipment are assessed by collecting a sample of organic-free water passed through the clean sampling apparatus. In addition, field cleaned equipment blanks are collected if equipment is cleaned in the field. A field cleaned equipment blank is defined as an organic-free water blank of equipment rinsate performed onsite after equipment has been cleaned in the field (i.e., between sampling points). Contaminants present within or on soil sampling apparatus where intimate contact with the sample occurs (i.e., split spoon, trowel, and Shelby tubes) are assessed by rinsing the sampling apparatus with organic-free water following decontamination. These equipment rinsate blanks are water samples collected directly into the appropriate bottle for each parameter. Preservatives or additives must be added to the equipment rinsate, where appropriate, for the parameter group.

Equipment rinsate blanks are prepared for each parameter group sampled when a particular piece of sampling equipment is employed for sample collection and subsequently decontaminated in the field for use in additional sampling. These blanks must be collected and analyzed for all matrices involved in the sampling event. Equipment rinsate blanks will not be collected during sampling activities using dedicated equipment.

9.1.3 Field Water Blanks Field water blanks include a complete set of samples collected from each water source used in the investigation. One set of samples will be collected from each water source used at the beginning of the project and one set at the completion of the project. These blanks should account for potential artifacts that could be introduced through decontamination procedures.

9.1.4 Field Duplicates Field duplicates are designed to assess the precision of the overall sampling and analytical techniques and the homogeneity of the sampling media. These samples will be submitted for analysis of all parameters specified for the media sampled. Field duplicate samples will be collected at a frequency of 10 percent per matrix. The identity of the duplicate samples will not be revealed to the laboratory.

9.1.5 Background Samples Background samples are collected from areas upgradient and away from known or suspected contaminated areas. Several background (also called upgradient) samples will be collected from each matrix. The estimated number and location of these samples at each POI will be presented in the task-specific workplans. Background samples allow identification of possible upgradient sources and/or confirm upgradient contamination. In addition, background inorganic analyses allow the estimation of concentrations for naturally occurring compounds.

9.2 LABORATORY QUALITY CONTROL (QC) ACTIVITIES. Laboratory quality controls are addressed in detail in the Laboratory QA Plan submitted as part of the laboratory approval process. The laboratory QC for chemical analyses is based on criteria developed in the CLP and in the specific analytical methods. The analysis of control samples (e.g., surrogates and method blanks) is routinely done to monitor the performance of each analytical method.

9.2.1 Matrix Spike and Matrix Spike Duplicate Samples An important element of the NTC, Orlando effort will be the collection and analysis of samples to evaluate matrix effects on target compound response. Matrix spike and matrix spike duplicate samples will be prepared in the laboratory by adding a known amount of pure compounds to an environmental sample to simulate background and interference found in actual samples. For Level IV analyses the current CLP requirements are specified. For methods not defined in the CLP, MS/MSDs will be performed for every 20 samples of similar matrix. A similar matrix is defined as soil or water from the same NTC, Orlando Facility (i.e., the Main Base, McCoy Annex, Herndon Annex, and Area "C"). For metals analysis, a laboratory duplicate and a matrix spike are required for every 20 samples of a similar matrix. For Level III analyses, a MS/MSDs and a matrix spike duplicate are required for volatiles, semivolatiles, and all GC analyses for every 20 samples of a similar matrix. For metals analyses at Level III a laboratory duplicate and matrix spike are required for every 20 samples of a similar matrix.

10.0 QUALITY ASSURANCE ACTIVITIES

Audits are performed to ensure and document that QC measures are being utilized to provide data of acceptable quality, and that subsequent calculations, interpretation, and other project outputs are checked and validated. Both scheduled and unscheduled audits are provided for in the QA program.

System and performance audits may be conducted by the QAM. The QAM may also conduct project audits of calculations, interpretations, and reports which are based on the measurement system outputs. Audits of field work and reviews of the project assessment elements may also be conducted by the QA Manger. The Laboratory QAC will perform systems, methods, and performance audits in accordance with the Laboratory QA Plan. A minimum of one internal audit will be scheduled by the QAM in coordination with the TOM during the SS/SI/RI activities. Internal audits will be performed as outlined in Section 10.3. All audit records, including audit plans, reports, written responses and corrective action forms, will be maintained with the project files. Sections 10.1 through 10.5 describe the varieties and associated requirements of audits.

In addition to routine audits, project and deliverable review systems will be implemented to assess scope compliance and overall technical quality of the contracted services.

10.1 SYSTEMS AUDIT. A systems audit is a review of a specific standard operating procedure or program. It is performed to evaluate the conformance of each activity with requirements. A systems audit may be conducted to determine that proper procedures, checks, and documentation are being completed. Systems audits may address field, office, or laboratory procedures.

The types of system audits to be performed are described in this section.

Facilities and Equipment. The audit will address whether field equipment and analytical instruments are selected and used to meet requirements specified by the project objectives stated in the POP or the task-specific workplan. Equipment and facilities provided for personnel health and safety may also be evaluated. Calibration and documentation procedures for instruments used in the field will also be reviewed.

Analytical Laboratories. Only FDEP- and NEESA-approved and CLP-certified laboratories will be contracted to provide services for NTC, Orlando. Systems audits may be performed of each laboratory

Sampling and Sample Handling Procedure. An audit of scheduled samples versus samples collected versus samples received for analysis may be performed. Field documentation may be reviewed. If deemed necessary, a site visit to NTC, Orlando will be made to ensure that designated control procedures are practiced during sampling activities.

Data Handling. During a systems audit, the QAM will review data handling procedures with the TOM. Accuracy, consistency, documentation, and appropriate selection of methodologies will be discussed.

For each field or systems audit, a checklist, described in Section 10.3, will be prepared and submitted to the Consultant's TOM.

10.2 PERFORMANCE AUDIT. These audits are intended primarily for the analytical data generation systems. The contracted analytical laboratories are CLP qualified and are pre-approved as part of the FDEP and NEESA laboratory certification programs. Periodic field performance audits are conducted to determine that instrument calibrations, QC checks, and continuing calibration verifications are being performed as specified by the appropriate SOPs. Project-specific field activities are also compared to the workplan.

The QAM is responsible for ensuring that routine performance audits are carried out as appropriate. Performance audits consist of reviews of logged calibration or standardization results and execution of measurement calibration operations, and may also consist of analysis of measurements or introduced standards or samples of known result.

10.3 AUDIT COMPONENTS

Scheduling. Audits will be scheduled by the QAM in coordination with the TOM or other responsible manager of the activity to be audited. The necessity and frequency of audits will be determined during the workplan development.

Planning.

1. The auditor will complete an audit plan that includes a checklist with the following items:

Date of Audit: Projected date and actual date.

Reason for Audit: Scheduled, Requested by, etc.

Applicable Documents: Workplan, SAP, QAPP, POP, SOPs, etc.

Scope: Activities to be monitored.

List: List of items to be checked compiled from applicable documents.

The list will address such issues as:

- organization and responsibilities,
- documentation procedures,
- sampling procedure, and
- applicable standard operating procedures.

2. The auditor will notify the TOM or Line Manager regarding the date and scope of the audit. It is the responsibility of the TOM or Line Manager to notify all affected personnel.
3. The auditor will determine if technical specialists are desirable to assist in performing the audit.

Performance.

1. The auditor(s) will meet with the TOM, or Line Manager, to explain the purpose and scope of the audit.

2. The auditor(s) will complete the audit checklist by reviewing documentation, observing activities, and interviewing field or office personnel. A draft audit report consisting of a list of findings and observations will be compiled by the auditor(s) prior to the post-audit meeting and will be submitted in writing to the leader of the activity audited. It will address these items that require corrective action.
3. At the completion of the audit, the auditor(s) will hold a post-audit meeting with the TOM and other responsible personnel to discuss the results of the audit.

The purpose of the post audit meeting is to ensure that all parties understand the draft audit observations. Any discrepancies that cannot be resolved will be noted on the draft paper.

4. Any discrepancy or observation that requires correction will be addressed either through a Corrective Action Form or, if the integrity of the program is threatened, through a Stop Work Notice.

Reporting.

1. The final audit report will be prepared by the audit team and will be reviewed and approved by the QAM.
2. A copy of the approved final audit report will be submitted to personnel as designated by the TOM:

The PM or designee will complete and submit Corrective Action Form(s) to document that the problem has been addressed. The CLEAN Task Order Manager has final responsibility for resolving any disagreements between the auditor and project personnel. All audit records, including audit plans, checklist reports, written responses, and Corrective Action Forms, will be maintained with the project files.

10.4 PROJECT REVIEWS. Project reviews are scheduled and conducted by the Consultant's TOM. The intent of a project review is to assess scope compliance and overall technical quality of the contracted services. A project review is appropriate at instances such as (1) sampling design plan finalization, (2) end of field program; and (3) determination of conclusion and recommendations. Documentation of the project review, especially identified action items and their follow-up, is essential to maximizing the utility of these reviews.

10.5 QUALITY ASSURANCE AUDIT REPORT. QA audits are conducted at the request of management or clients and occur less frequently than project reviews. A written report of a QA project audit will include the following:

- an assessment of project team status in each major project area,
- clear statements of areas requiring improvement or problems to be corrected,

- recommendations and assistance regarding proposed corrective actions or system improvements (if no action is required, the report will state that the QA audit was satisfactorily completed), and
- a timetable for any corrective action required.

Distribution of the report will be as determined by the TOM. This form will cover any field or laboratory audit checklist (internal) or external audit performed. The QAM is responsible for the coordination of such audits, the disposition of the audit records, and the monitoring of corrective actions.

10.6 QUALITY REVIEW OF STUDIES AND REPORT PREPARATION. The purpose of quality review through the course of studies, designs, and reports is to ensure that the service, designs, and documents meet currently accepted professional standards and project requirements. QA reviews will be scheduled on a routine basis for the NTC, Orlando project. The Project Review Committee will be an integral part of this process.

QA during the preparation of studies and reports relies on documentation of data utilized and peer review of conclusions drawn from the assembled data base. This allows all data base components to be traced to the primary generator and forces a review of data quality as the database is developed. Project personnel are responsible for utilization and monitoring of this process; compliance is audited by the QAM. Upon completion of the data base, data interpretation, evaluation, and report preparation commence. Data evaluation incorporates peer review to provide broad-based insight to data correlations and interactions.

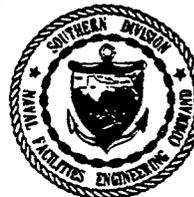
To enhance the professional quality of the company's studies and reports, the Project TOM will also (1) require that reports refer to and are consistent in scope with the project proposal and contract, and (2) require that report language and contents be chosen to foster client understanding of risks and uncertainties by distinguishing fact from opinion and identifying risks and limitations in a clear and informative manner.

Implementation of QA for reports involves the use of a review routing and sign-off form. Figure 10-1 illustrates a Deliverable Review Tracking Form. The Project TOM provides final review and release for all deliverables.

DELIVERABLE REVIEW TRACKING AND DOCUMENTATION RECORD		
Document Full Title and Facility Name: _____		
Authors: _____		
Task Order Manager: _____		Project No.: _____
Approved for Technical Review: _____		Date: _____
Task Order Manager Review	Lead Senior Technical Review	Supplementary Technical Review
Name: _____ Date: _____ Meets Statement of Work Approval: _____ Date: _____ Overall Comments: Additional Comments Attached: Yes ___ No ___	Name: _____ Date: _____ Meets <u>ALL</u> Technical Requirements Approval: _____ Date: _____ Overall Comments: Additional Comments Attached: Yes ___ No ___	Name: _____ Date: _____ Components Rev'd: _____ Approval: _____ Name: _____ Date: _____ Components Rev'd: _____ Approval: _____ Comments Attached: Yes ___ No ___
Contracts/Purchasing Review	Copy Editor	Word Processing/Drawings Release
Name: _____ Date: _____ Meets Contract Requirements Approval: _____ Date: _____ Comments Attached: Yes ___ No ___	Name: _____ Date: _____ Meets Program Editorial Standards Approval: _____ Date: _____ Comments Attached: Yes ___ No ___	Name: _____ Date: _____ Meets Navy/Applicable Format Approval: _____ Date: _____ Comments Attached: Yes ___ No ___
PROGRAM MANAGEMENT RELEASE		
DOCUMENT APPROVED FOR RELEASE		
Program Task Order Manager _____	Signature _____	Date _____
Comments Attached: Yes ___ No ___		

FIGURE 10-1

DELIVERABLE REVIEW TRACKING
AND DOCUMENTATION RECORD



PROJECT OPERATIONS PLAN

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11.0 PROBLEM PREVENTION

Problem prevention procedures attempt to control problems before they occur and before they have an adverse impact on the project. Program management and project personnel are required to plan and implement projects utilizing readiness review, project technical reviews, audits, and corrective action measures to anticipate, identify, and correct problems.

Program management and project personnel will identify events or other signals that could indicate development of problems and take early action to implement corrective measures. Proper project planning includes the development of technical workplans, field sampling and analysis plans, HASPs, and QA/QC project plans.

At the initiation of a project a review will be conducted to verify proper planning for the project. A list of potential topics for review include project organization and staff availability, project funding, subcontracts, schedules, mobilization plans, and equipment and supplies.

11.1 ANALYTICAL INSTRUMENTATION. The contracted analytical laboratories follow a well-defined program to prevent the failure of laboratory equipment or instrumentation during use. Preventive maintenance of analytical instrumentation and equipment for the contract laboratories will be performed in accordance with the CLP requirements and the individual laboratory QA/QC program.

11.2 FIELD SAMPLING INSTRUMENTS. Preventive maintenance of field sampling equipment and instrumentation, which is performed by analysts, field personnel, and sample program staging area staff, routinely precedes each sampling event; more extensive maintenance is performed by manufacturers on the basis of hours in use. Sampling crews report on the performance of the equipment after each sampling event. Critical spare parts are kept in stock. At times, it is necessary to perform routine maintenance in the field; therefore, each field instrument is provided with an operating manual.

For field analytical instrumentation, preventative maintenance will be performed by the analysts according to the procedures delineated in the manufacturer's instrument manual. For example, GC injection liners and injector septa are cleaned or replaced on a regular basis. Maintenance is performed routinely as specified or when instrument performance begins to decline as evidenced by the decrease in peak resolution, shift in calibration curves, decreased sensitivity, or failure to meet the quality control criteria.

Instrument logbooks will be maintained in the field laboratories. They contain records of usage, calibration, maintenance and repairs. Adequate supplies of spare parts for field analytical instruments such as GC columns, syringes, and septa are maintained in the laboratories so that they are available when needed.

12.0 DATA ASSESSMENT

The following items are evaluated prior to assessing POI conditions:

- quality of laboratory data
 - acceptable
 - provisional
 - unacceptable
- method limitations
 - dynamic range
 - accuracy
 - method detection limit
 - practical quantitation level
 - precision
- sampling/analysis scope and results
 - number of replicates at one location
 - number of samples for each site/media
 - background/downgradient distribution
 - consistency/trends of chemical assay data collected at site
 - agreement with existing site information
- use of data
 - chemical distribution and transport at the site (generally, order-of-magnitude comparisons)
 - compliance with standards, regulations, response objectives
 - presence or absence of chemical
 - treatability
 - disposal method for media containing chemicals
 - risk assessment

12.1 PRECISION, ACCURACY, REPRODUCIBILITY, COMPLETENESS AND COMPARABILITY (PARCC) PARAMETERS. The purpose of data quality assessment is to ensure that data generated under the NTC, Orlando project are accurate and consistent with project data quality objectives. The data assessment will be based on precision, accuracy, consistency, and completeness. Data quality assessment will be conducted in three phases:

Phase 1. Prior to data collection, sampling and analysis procedures are evaluated with regard to their ability to generate the appropriate, technically acceptable information required to achieve project objectives. The POP meets this requirement by establishing project objectives defined in terms of parameters, analytical methods, and required sampling protocols.

Phase 2. During data collection, results will be assessed to ensure that the selected procedures are efficient and effective and that the data generated provide sufficient information to achieve project objectives. The appropriateness of the precision and accuracy of selected measurement systems will also be evaluated. In general, evaluation of data will be based on performance audits, results of spiked laboratory sample analyses, and review of completeness objectives.

Phase 3. Following completion of data collection activities, an assessment of the adequacy of the data base generated with regard to completing project objectives will be undertaken by the Project TOM and QAM. Recommendations for improved QC will be developed, if appropriate. In the event that data gaps are identified, the QAM may recommend the collection of additional raw data to fully support the project's findings and recommendations.

Each phase of the assessment will be conducted in conjunction with appropriate project staff.

PARCC parameters will be assessment of precision and accuracy of analytical data, accomplished via review of multiple analyses (precision) and surrogate and/or spike recovery (accuracy), both in standard water and soil matrices. Accuracy is expressed as percent recovery. Precision is expressed as the difference between recoveries for data pairs. Documentation of substandard accuracy and precision, and corrective action if necessary, is a laboratory responsibility. A review of accuracy in the sample matrix must recognize the impact of matrix interferences. Precision must be assessed for each sample matrix because distribution of contaminants may be nonhomogeneous, especially in non-water matrices. Precision in samples must also be reviewed with knowledge of the matrix and level of analyte present.

Each certified method provides QC requirements and acceptance criteria. The QC criteria and required QC samples are specified for each analytical method and are components of the laboratory QA plan.

Another important component of Phase 3 Data Assessment is identification of laboratory contamination. Methyl ethyl ketone, acetone, toluene, phthalates, and methylene chloride are all common laboratory contaminants. Samples associated with data in which the laboratory blanks contain similar concentrations of these common laboratory contaminants will not be corrected. Data will only be corrected during validation according to procedures outlined in the USEPA Functional Guidelines for Data Review. Documentation of all data correction for nonsite-related contaminants will be provided in the project report.

12.2 CALCULATION OF DATA QUALITY INDICATORS. The equations used to calculate precision and accuracy are shown in Section 3.3.

12.3 EVALUATION OF DATA GAPS. All data will be continually assessed and POIs will be evaluated to determine: (1) if contamination is present, (2) if it presents a threat, (3) if it has been delineated, and (4) what further action is needed (i.e., delineation, interim or early remedial action, or evaluation of remedial alternatives). The goal is to eliminate lengthy interim report development and review times by allowing continual data assessment and rapid decision making.

13.0 CORRECTIVE ACTION

Corrective or preventive action is required when potential or existing conditions are identified that may adversely impact data quantity or quality. Corrective action could be immediate or long term. In general, members of the program staff who identify a condition adversely affecting quality can initiate corrective action by notifying his/her supervisor and the QAM in writing. The written communication will identify the condition and explain how it may affect data quality or quantity.

Refer to Table 13-1 for corrective action of field measurements. Inspections, tests and operating status checks may be necessary to control the use or installation of faulty, substandard, and/or nonconforming items. Controlled items may include, but are not limited to field construction and installation items, equipment, instruments, and software. The Nonconformance Report (NCR), Figure 13-1, provides a mechanism for avoiding the use of items or services that do not meet required specifications. These reports can be used to identify and correct and item, material, service, or activity that dose not comply with contract, regulatory, or other project requirements. In general, NCRs are filed for hardware or equipment problems.

Table 13-1
Summary of Corrective Action for Field Measurements

Project Operations Plan for Site Investigations
 and Remedial Investigations
 NTC, Orlando, Orlando, Florida

Analysis	Control item	Acceptance Criteria	Corrective Action
Specific conductivity at 25 °C	Check standard 0.00702 N potassium chloride	±5 percent 1000 µmhos/cm	Recalibrate with fresh potassium chloride.
pH	pH buffer 4, 7, and 10	±.2 pH	Recalibrate, adjust temperature, and check standard expiration date.
Temperature	±0.1 °C	(¹)	Calibrate against NIST thermometer.

¹ Precision and accuracy for this method have not been determined.

Notes: °C = degrees Celsius.
 µmhos/cm = micromhos per centimeter.
 NIST = National Institute of Standards and Technology.

Any person within the organization may initiate an NCR. The nonconforming item or action should be brought to the attention of the activity supervisor and the TOM. The TOM will determine if a stop work order is needed. If materials, instrumentation, or other items are determined to be out of conformance, they will be clearly labelled and, if possible, removed from the site. The TOM will consult with the QAM to determine what action is necessary to correct the nonconformance. If items are not within specification, and the deviation may impair the quality of the project, the items will be rejected and returned to the supplier or disposed. If use of the item will not impair the quality of the project, the item may be used, if justification is documented.

NONCONFORMANCE REPORT (NCR)

NCR No.: _____ Manufacturer/Vendor: _____
Date: _____ Lot No./Other ID: _____
Originator: _____
Project: _____

Specified Requirement: _____

Nonconforming Condition: _____

Recommended Disposition

Use-as-Is _____ Repair _____
Rework _____ Reject/Scrap _____

Justification (use as is and repair): _____

Disposition Approvals:

Project Manager: _____ Date: _____
QA Specialist: _____ Date: _____
Technical Representative: _____ Date: _____

Corrective Action to Prevent Recurrence Yes ___ No ___
see CAF No.

Potential Impact to Other Projects: _____

Affected Project Documents to be Modified: _____

Disposition Completion By: _____ Date: _____
Disposition Verification: By (QAM): _____ Date: _____

FIGURE 13-1

EXAMPLE NON-CONFORMANCE REPORT



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Actions, procedures, or services that are not in conformance may also be controlled through a corrective action notice, a stop work order, or a notice to the file. Documentation of the action or justification for non-action will be attached to the NCR. If the nonconformance could impact other projects, the PM or the QAM will notify responsible managers.

13.1 IMMEDIATE CORRECTIVE ACTION. Immediate corrective action is usually applied to spontaneous, nonrecurring problems (e.g., instrument malfunction). The individual who detects or suspects nonconformance to previously established criteria or protocol in equipment, instruments, data, or methods, will fix the malfunction and reperform the activity. If the measurement system will not go back into control, the individual will immediately notify his/her supervisor. The supervisor and the QAM will then investigate the extent of the problem and take the necessary corrective steps. If a large quantity of data is affected, the supervisor must prepare a Corrective Action Form (CAF) (Figure 13-2), an NCR, or a memorandum to the Project TOM and QAM. These individuals will collectively decide how to proceed. If the problem is limited in scope, the individual will decide on the corrective action measure and document the solution in the appropriate workbook or log and notify the TOM and the QAM in a memorandum. If data loss occurs as a result of the malfunction, the extent of loss will be assessed by the responsible manager, and approved by the QAM and the Florida Operations Manager or CLEAN Technical Services Manager. All other affected project managers will be informed in writing.

13.2 LONG-TERM CORRECTIVE ACTION. Long-term corrective action procedures are devised and implemented to prevent the recurrence of a potentially serious problem. The QAM will be notified of the problem and will conduct an investigation to determine the severity and extent of the problem. The QAM will then file a CAF with the Project TOM, Florida Operations Manager or CLEAN Technical Services Manager.

Corrective actions may also be initiated as a result of other activities, including (1) performance audits, (2) system audits, (3) laboratory and field comparison studies, and (4) ongoing project audits.

The QAM will be responsible for documenting all notifications, recommendations, and final decisions. The Project TOM and the QAM will be jointly responsible for notifying program staff and implementing the agreed-upon course of action. The QAM will be responsible for verifying the efficacy of the implemented actions. The development and implementation of preventive and corrective actions will be timed, to the extent possible, so as to not adversely impact either project schedules or subsequent data generation and processing activities. The QAM will also be responsible for developing and implementing FDEP and/or NEESA recommended corrective actions resulting from performance audits, system audits, validation, and data review. Finally, the QAM will also be responsible for developing and implementing routine program controls to minimize the need for corrective action.

Examples of long-term types of actions include:

- staff training in technical skills or in implementing the QA program,

CORRECTIVE ACTION FORM

Project: _____ Date: _____

Project No.: _____ Page ____ of ____

Problem Description: _____

Cause: _____

Proposed Corrective Action(s): _____

Project Manager: _____ Date: _____

QA: _____ Date: _____

Affected Organization: _____ Date: _____

Proposed Organization: _____

FIGURE 13-2
EXAMPLE CORRECTIVE ACTION FORM



PROJECT OPERATIONS PLAN

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CORRECTIVE ACTION FORM (Continued)

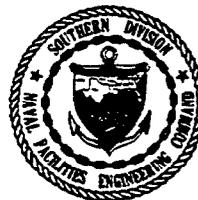
Verification Corrective Actions: _____

Comments and Recommendations: _____

Close out Signature: _____

Date: _____

FIGURE 13-2 (Cont.)
EXAMPLE CORRECTIVE ACTION FORM



PROJECT OPERATIONS PLAN

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- rescheduling of laboratory routine to ensure analysis within allowed holding times,
- identifying vendors to supply reagents of sufficient purity, and
- revision of Consultant QA system or replacement of personnel.

For either immediate or long-term corrective actions, steps comprising a closed-loop corrective action system are as follows:

- define the problem,
- assign responsibility for investigating the problem,
- investigate and determine the cause of the problem,
- determine a corrective action to eliminate the problem,
- assign and accept responsibility for implementing the corrective action,
- establish effectiveness of the corrective action and implement the correction, and
- verify that the corrective action has eliminated the problem.

Depending on the nature of the problem, the corrective action employed may be formal or informal. In either case, occurrence of the problem, corrective action employed, and verification that the problem has been eliminated will be documented.

14.0 REPORTS

14.1 QUALITY ASSURANCE AND QUALITY CONTROL REPORTS. As noted in previous chapters, reports of a variety of QA and QC activities are provided to managers at appropriate levels of the project organization. All QA and QC reports are available to SOUTHNAVFACENGCOM and FDEP.

14.2 PROJECT DELIVERABLES. Preparation of each NTC, Orlando report will begin following completion of the contamination assessment. The Draft Report will be submitted to the BCT for review. The Consultant will respond to review comments through the preparation of a Comment Response Package. Following agreement on comments, a Draft Final Report will be prepared and resubmitted to the BCT.

Preparation of the Final Report will begin when comments on the Draft Final Report are received. Comments received from the BCT on the Draft Final Report (if any) will be addressed in the Final Report. The Consultant's Task Leader will be responsible for developing the Final Report, with oversight by the TOM and the Internal Review Committee.

Report development will involve drafting of text, and compilation of data, tables, and figures for geologic, hydrogeologic, chemical, and risk assessment. Draft and Draft Final Reports will be prepared under the direction of the TOM, with review by the Internal Review Committee.

14.3 PROJECT RECORDKEEPING. Task Order-specific files will be maintained by the Consultant for the duration of the project and then turned over to SOUTHNAVFACENGCOM for long-term maintenance. Specific logs, notebooks, and forms for each element of project activity have been described as a component of the procedures in Chapter 4.0.

Summary audit reports may be prepared coincident to the completion of each task to inform task staff and management of QA status. The reports will include the following:

- periodic assessment of measurement data accuracy, precision, and completeness;
- results of performance audits and/or systems audits;
- significant QA problems and recommended solutions for future projects; and
- status of solutions to any problems previously identified.

Additionally, any incidents requiring corrective action will be fully documented. Procedurally, the QAM will prepare the reports to management. These reports will be addressed to the TOM and the Internal Review Committee. The summary of findings will be factual, concise, and complete. Any required supporting information will be appended to the report.

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APPENDIX A

**Southern Division Naval Facilities Engineering Command
Guidelines for Groundwater Monitoring Well Installation**

Rev; 4
Date: 27 MAR 89

SOUTHERN DIVISION NAVAL FACILITIES
ENGINEERING COMMAND

GUIDELINES FOR GROUNDWATER MONITORING
WELL INSTALLATION

PART 1: GENERAL

1.1 Introduction

Groundwater monitoring wells shall be located at sites approved by the Southern Division Engineer-In-Charge (EIC) and the Activity Environmental Coordinator (EC). All applicable local, state and federal regulations concerning well installations or soil borings shall be followed.

1.2 Applicable Publications

The publications listed below form a part of this guideline to the extent referenced. The publications are referred to in this text by designation only. The latest revision of the specifications shall be followed.

1.2.1 American Association of State Highway and Transportation Officials (AASHTO)

<u>Document No.</u>	<u>Title</u>
M 220	Epoxy Coatings Specifications

1.2.2 American Society of Testing and Materials (ASTM)

<u>Document No.</u>	<u>Title</u>
A 120	Pipe, Steel, Black and Hot-dipped, Zinc coated, welded and seamless
A 312	Seamless and Welded Austenitic Stainless Steel Pipe
B 209	Aluminum and Aluminum-alloy Sheet and Plate
C 150	Portland Cement
C 778	Standard Sand
D 1457	Polytetrafluoroethylene (PTFE) Molding and Extrusion Materials
D 1785	Standard Specification of Polyvinyl Chloride Pipe (PVC Pipe, Schedules 40, 80, 120)

<u>Document No.</u>	<u>Title</u>
D 1586	Method for Penetration Test and Split Barrel Sampling of Soils
D 1587	Practice for Thin Wall Tube Sampling of Soils.
D 2113	Diamond Core Drilling for Site Investigation
F 480	Thermoplastic Water Well Casing, Pipe and Couplings Made in Standard Dimension Ratios (SDR)
F 883	Padlocks

1.2.3 American Petroleum Institute (API)

<u>Document No.</u>	<u>Title</u>
13-A	Oil Well Drilling Fluid Specifications

1.3 Submittals

1.3.1 A completed "Southern Division Naval Facilities Engineering Command Groundwater Monitoring Well Installation Report" will be submitted for each well installation.

1.3.2 Certificates of Conformance: A certificate of conformance shall be provided to the EIC for any of the items below that are used in a well installation. The certificate shall describe in detail how the material meets or exceeds the required specifications for the following, as appropriate:

- | | |
|-------------------|---------------------------------|
| a) Casing | i) Well Protective Cover |
| b) Screen | j) Flush Mount Protective Cover |
| c) Grout | k) Padlock |
| d) Drilling Mud | l) Protective Post |
| e) Gravel Pack | m) Well Designation Sign |
| f) Caps and Plugs | o) Epoxy Paint |
| g) Centralizers | |
| h) Surface Casing | |

1.4 Delivery and Storage

All materials shall be delivered in undamaged condition, stored in accordance with manufacturer's recommendations (off the ground) and protected from the weather in an area designated by the EC. All defective or damaged material will be replaced with new material at no cost to the government.

PART 2: PRODUCTS

2.1 All materials shall conform to the respective specifications and other requirements as specified herein.

2.1.1 Well Casing

Material type will be approved by the EIC. The material provided will have adequate strength to resist external forces both during and after installation. The casing threads shall be compatible with the screen listed in 2.2.2. Markings, writing or paint strips are not allowable on any of the materials. The casing shall conform to the specifications listed below.

- a. PVC, flush threaded joints (schedule 40) ASTM F480 and ASTM D1785

All PVC flush threaded joints will meet or exceed the water pressure ratings (at 73 degrees Fahrenheit) for the size and schedule of PVC pipe used in the project, as listed in ASTM D1785: Table XI.2.

- b. Polytetrafluoroethylene (PT-E), flush threaded joints, ASTM D1457

Virgin materials shall be used to meet the ASTM specification. Certification of compliance and joint evaluation are required. Shall be shipped in sealed containers that are capable of preventing contact with any foreign substances. PTEF "O" rings are required to seal all joints.

- c. 316 stainless steel, flush threaded joints, ASTM A312
- d. 304 stainless steel, flush threaded joints, ASTM A312

End fittings shall be double entry flush screw threads. The casing shall be cleaned prior to delivery in the following manner: 5-minute immersion in static bath of dilute acid, pressure wash with detergent and cool water, rinse with warm water and allow to air dry.

2.1.2 Well Screen

Material type will be approved by the EIC. The material provided will have adequate strength to resist external forces both during and after installation. Water velocity through the screen openings shall not exceed 0.1 ft/sec. The opening size will be determined from an analysis of the material in geologic formation to be screened and/or the size of the filter pack material. Markings, writing or paint strips are not allowable on any of the materials. The screens shall conform to the specifications listed below.

- a. PVC, flush threaded joints (schedule 40), slotted, ASTM F480 and ASTM D1785

Two inch I.D. screens will have 3 rows of slots with a spacing of 1/8 inch between slots. Four inch I.D. screens will have six rows of slots with a spacing of 1/8 inch between slots. All PVC flush threaded joints will meet or exceed the water pressure ratings (at 73 degrees Fahrenheit) for the size and schedule of PVC pipe as listed in ASTM D1785, Table XI.2.

- b. Polytetrafluoroethylene (PTFE), flush threaded joints, slotted, ASTM D1457

Virgin materials shall be used to meet the ASTM specification. Certification of compliance and joint evaluation are required. Shall be shipped in sealed containers. PTEF "O" rings will be used to seal all joints.

- c. 316 stainless steel, wire wrapped, flush threaded joints, ASTM A312
- d. 304 stainless steel, wire wrapped, flush threaded joints, ASTM A312

The well screen shall be of a continuous slot, wire wound design. It shall be fabricated by circumferentially wrapping a triangularly shaped wire around a circular array of internal rods. The configuration must produce sharp outer edges, widening inward. PTFE "O" rings will be used to seal all joints. End fittings will be welded to the screen body.

2.1.3 End Plugs

The end plug shall be flush threaded and shall be constructed of the same type of material selected for the screen or casing above. All ASTM specifications that apply to the screen and casing materials shall apply to the end plugs. Markings, writing or paint strips are not allowable on any of the above materials.

2.1.4 Well Caps

The well cap shall be flush threaded and be constructed of the same type of material selected for the casing above. All ASTM specifications that apply to the casing materials shall apply to the well caps. Markings, writing or paint strips are not allowable on any of the above materials.

2.1.5 Adjustable Centralizers

The centralizer shall be capable of maintaining the casing and screen straight and plumb in the borehole during well installation. The material type shall be the same type of material selected for the casing/screen above. No solvents or glues will be used.

2.1.6 Annular Space Fill Materials

- a. Filter pack shall be 98% pure silica, cleaned with potable water, have a uniformity coefficient of 1-3, and a specific gravity of 2.6 - 2.7. The filter pack shall meet ASTM C 775 standard sand specifications.
- b. 1/4-inch bentonite pellets shall be 90% montmorillonite clay, with a bulk dry density 80 lbs/cu ft, a specific gravity 1.2, and a pH of 8.5-10.5.
- c. Granular bentonite shall conform to API std 13-A for bentonite. -
- d. Portland Cement shall conform to ASTM C 150 Type I.

2.1.7 Surface Casing: shall be constructed of steel meeting ASTM A 120 and shall have a wall thickness as specified below.

- a. 24 inch diameter 0.25 inch wall thickness
- b. 20 inch diameter 0.25 inch wall thickness
- c. 16 inch diameter 0.25 inch wall thickness
- d. 10.75 inch diameter 0.25 inch wall thickness
- e. 24 inch diameter 0.50 inch wall thickness
- f. 20 inch diameter 0.50 inch wall thickness
- g. 16 inch diameter 0.50 inch wall thickness
- h. 10.75 inch diameter 0.365 inch wall thickness

2.1.8 Surface Completion: all materials provided for a well surface completion shall conform to the specifications listed below.

- a. Locking 16-gauge steel protective well cover, round or square and 5-ft in length
- b. Flush mount 22-gauge steel, water resistant welded box with 3/8-inch steel lid, locking device and padlock guard
- c. Concrete pad at ground surface (3' X 4' X 6") ASTM C 150
- d. Padlock (brass, corrosion resistant, keyed alike) ASTM F 883
- e. Steel protective post (4-inch diameter, 6-ft length, 1/4-inch thickness, concrete filled) ASTM A 120.
- f. Well designation sign, sheet aluminum, ASTM B 209, 1/8 inch by 18 inch by 6 inch, anchors and fasteners compatible with sign, designation to be provided by EIC, the designation shall be stamped into the plate with 4-inch letters and numbers.
- g. High visibility yellow epoxy paint AASHTO M220.

PART 3: EXECUTION

3.1 Drilling Method

The proposed drilling method must be approved by the EIC. Hollow-stem auger methods will be given first preference, rotary methods second and any other methods will require detailed evaluation by the EIC and written approval.

3.2 Well Installation

Well depths, length of screen and sump will be determined on a site specific basis with approval of the EIC. Screen lengths will be limited to 10 feet unless longer lengths are specifically approved in writing by the EIC. Two inch well diameters will be specified for shallow well installations. Deeper well installations or wells that will be converted to recovery wells may require four inch wells. Recovery well specifications will be approved by the EIC.

Well installation shall follow commonly accepted professional drilling procedures. The borehole will be logged by a qualified geologist/hydrogeologist as drilling proceeds. Soil samples shall be collected according to one of the following methods: ASTM D 1586-Method for Penetration Test and Split Barrel Sampling of Soils or ASTM D 1587-Practice for Thin Wall Tube Sampling of Soils. Consolidated Rock will be sampled according to ASTM D2113 Diamond Core Drilling for Site Investigation.

Gravel pack, seals, and grout will be installed using tremie methods. Bentonite seals shall be allowed to hydrate the time period specified by the manufacturer. Accurate measurements shall be made to the top of the gravel pack and seals with a weighted steel tape and adjusted to reflect the top of casing.

If water is used in the drilling process, a sample shall be collected from the source and analyzed for the parameters specified in the investigation. Results will be included in the investigation report.

3.3 Well Development

Well development shall commence no sooner than 24 hours after placement of the grout. The development method shall be approved by the EIC. The selected method shall be capable of removing all drilling fluids and cuttings from inside the well, within the gravel pack and from within the formation. The development method shall not introduce any type of contamination into the aquifer. Introduction of outside water to the well shall be minimized. Any water introduced into the well shall be recovered to the maximum extent possible. A written report will be required describing the reasons why any introduced water could not be recovered.

The development process should result in wells that are sediment free. A well that produces turbid water (as defined by the Safe Drinking Water Act PL 93-523) may be rejected by the EIC.

3.4 Material Disposal

Control and disposal of investigation-derived waste (IDW) is described in Section 4.10 of this volume.

3.5 Decontamination

All down-hole drilling equipment (the drill rig, tools, etc.) will be decontaminated according to the approved Quality Control Plan prior to beginning work, between each well location and after the last well is completed. The drill rig will be placed on 10-mil polyethylene sheeting at each drilling site to contain any spillage or leaking of hydraulic fluid or fuel. All of the decontamination waste will be handled according to section 3.4 above.

3.6 Well Protection

A steel, hinged, locking protective casing will be installed within a 3-ft by 4-ft by 6-inch thick concrete pad. The pad will be set level and 4-inches below grade. The pad shall be installed so that surface runoff does not pond around the well casing and protective cover. The concrete mix shall obtain a minimum 28-day compressive strength of 3000 pounds per square inch.

If designated by the EIC, four steel protective posts will be installed 0.5 foot from the corners of the pad but not set within the pad. The post will be 6-feet in length, 4-inch in diameter and have a wall thickness of 0.25-inch. The post will be filled with concrete and set three feet below grade in a 10-inch diameter hole with concrete backfill (as above).

The protective casing and any protective post installed shall be cleaned, primed and then painted with two coats of high visibility yellow epoxy paint that meets the specifications of AASHTO M 200. The protective casing will be locked with a Type Pol (Key Operated), Option E (Corrosion Resistant) padlock that conforms to ASTM F 883. When multiple wells are installed, the padlocks for each well at an activity shall be keyed alike. The original and two copies of all keys shall be delivered to the EIC and two copies shall be delivered to the EC. All keys shall be tested to ensure performance prior to delivery.

3.7 Well Designation

A permanent well designation sign will be attached to the protective casing. The sign shall be a 18-inch by 6-inch by 1/8-inch thick sheet aluminum plate, bolted to 1/4-inch studs welded to the casing. The sign shall be stamped with 4-inch letters and numbers in accordance with the numbering system in section 4.0 of this specification.

PART 4. INSTALLATION RESTORATION PROGRAM WELL NUMBERING SYSTEM

The purpose of this well numbering system is to locate a particular well by activity, key it to the Initial Assessment Study (IAS) and sequentially number each well at each site. The EIC will provide designations for sites not included in the IAS.

Example: CEF-1-1 Cecil Field, Site 1, Well number 1
 KYW-5-8 Key West, Site 5, Well Number 8

FLORIDA

Cecil Field	CEF
Ft. Lauderdale	FLD
Key West	KYW
NavHosp Key West	KWH
Homestead	HST
Jacksonville	JAX
Mayport	MPT
Panama City	PCY
Whiting Field	WHF
Andros Island	AIS
Pensacola	PEN
Saufley	SFY
Correy Station	CRY
Orlando	OLD

GEORGIA

Albany	ALB
Atlanta	ATL
Kings Bay	KBA
Athens	ATH

SOUTH CAROLINA

Parris Island	PAI
Beaufort	BFT
NavHosp Beaufort	BFH
NWS Charleston	NWS
NS Charleston	CSY

LOUISIANA

NAS New Orleans	NOA
NSA New Orleans	NOS

MISSISSIPPI

Gulfport	GPT
NavHome Gulfport	GPH
Meridian	MRD

TENNESSEE

Memphis	MPH
Bristol	BRT

TEXAS

Corpus Christi	CCT
Chase Field	CAF
Kingsville	KVE
NAS Dallas	DNA
NWIRP Dallas	DWP
McGregor	MGR

PART 5. STATEMENT ON USE OF ALTERNATE MONITORING WELL MATERIALS

The Navy accepts the risks associated with the use of alternate materials (other than stainless steel) for groundwater monitoring. We understand that USEPA's position is that use of alternate materials may cause interference or inaccuracies in the chemical analysis of samples from such wells. However, the Navy has provided evidence that the use of stainless steel well materials may have the potential to introduce more interferences than PVC for full-suite analyses (Attachment A). Therefore, risks are associated with the use of either material.

We understand USEPA has accepted the use of PVC instead of the recommended stainless steel for investigations at Naval Training Center, Orlando, Florida.

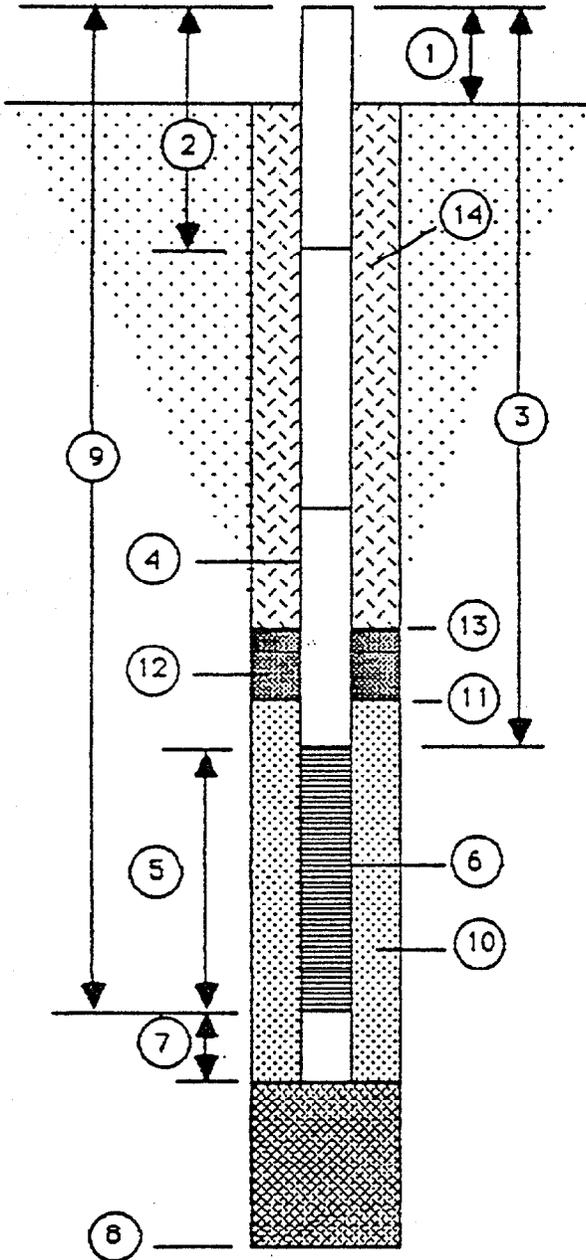
USEPA may require reassessment of the use of PVC based on POI-specific conditions. We further understand that USEPA reserves the right to refuse groundwater monitoring data generated from wells where construction materials other than those specified in the USEPA Region IV SOP are used and the groundwater data generated fails to meet the necessary DQOs.

DEPARTMENT OF THE NAVY
 SOUTHERN DIVISION
 NAVAL FACILITIES ENGINEERING COMMAND
 2155 EAGLE DR., P. O. BOX 10068
 CHARLESTON, S. C. 29411-0068

WELL CONSTRUCTION DETAILS

WELL NUMBER _____

DATE OF INSTALLATION _____



1. Height of Casing above ground _____

2. Depth to first Coupling _____

Coupling Interval Depths _____

3. Total Length of Blank Pipe _____

4. Type of Blank Pipe _____

5. Length of Screen _____

6. Type of Screen _____

7. Length of Sump _____

8. Total Depth of Boring _____ Hole Diameter _____

9. Depth To Bottom of Screen _____

10. Type of Screen Filter _____

Quantity Used _____ Size _____ U/C _____

11. Depth To Top of Filter _____

12. Type of Seal _____

Quantity Used _____

13. Depth To Top of Seal _____

14. Type of Grout _____

Grout Mixture _____

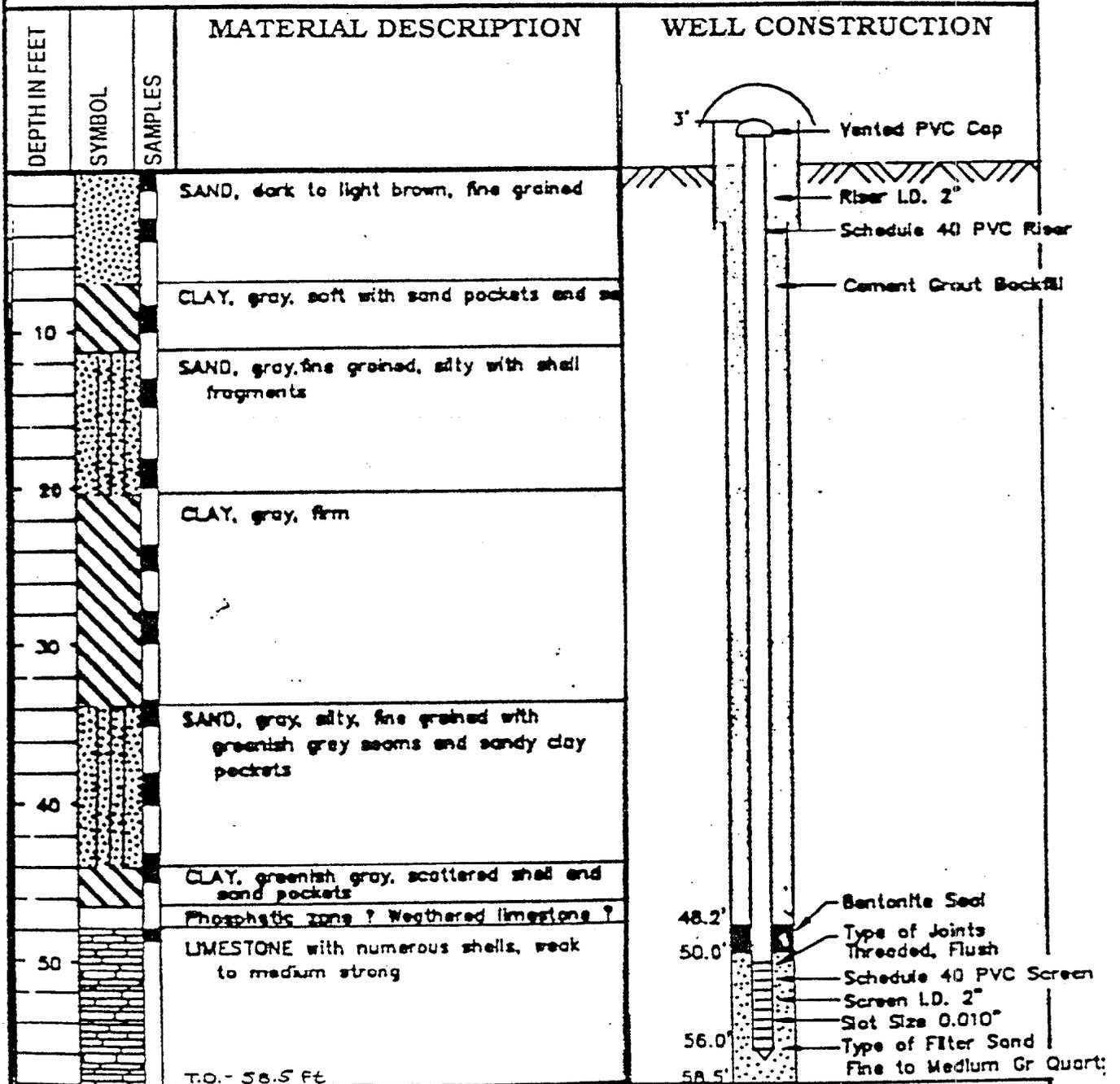
Method of Placement _____

COMMENTS ON INSTALLATION:

**SOUTHERN DIVISION NAVAL FACILITIES ENGINEERING COMMAND
GROUNDWATER MONITORING WELL INSTALLATION REPORT**

LOCATION EXAMPLE OF A COMPLETED WELL SHEET

LOG OF BORING NO. _____ LOG OF WELL NO. _____



Boring Completion Date:
Well Completion Date:
Well Development Date:
Drilling Method:
Depth to Water:

Boring Diameter:
Ground Elevation:
Top of Casing Elevation:
Driller:

ATTACHMENT A

SUPPORTING TECHNICAL LITERATURE



DEPARTMENT OF THE ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY, CORPS OF ENGINEERS
HANOVER, NEW HAMPSHIRE 03785-1290
February 25, 1991

Applied Research Branch

Ms. Peggy Lane
ABB Environmental Services
2571 Executive Center Circle, East
Suite 100
Tallahassee, Florida 32301

Dear Ms. Lane:

I have enclosed a copy of our journal article that compares the sorption of organics and metals by four well casing materials (PVC, PTFE, and stainless steel types 304 and 316). I have also included a more recent study that compares the leaching of metals from these materials; this study was conducted by Alan Hewitt. It is our opinion that since you are monitoring for both VOC's and metals that PVC is the best material to use in your monitoring wells, provided that you do not anticipate encountering an undiluted solvent of PVC. Stainless steel is not a good casing material to use when monitoring for metals. Also, stainless steel should not be placed in any environment that is corrosive. "The Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells," by Linda Aller et al. (1989, published by the National Water Well Association, Dublin, Ohio) has an excellent discussion on corrosion of steel products.

If you would like any additional questions answered, please do not hesitate to call me at 603-646-4393. Alan Hewitt can answer any questions on our metals studies. He can be reached at 603-646-4388.

29 FEB 91 2:19

I hope you find this material useful.

Sincerely,

Louise V. Parker
Research Physical Scientist
Applied Research Branch

2 enclosures

Special Report 89-32

September 1989 ...



US Army Corps
of Engineers

Cold Regions Research &
Engineering Laboratory

Leaching of metal pollutants from four well casings used for ground-water monitoring

Alan D. Hewitt

PREFACE

This report was prepared by Alan D. Hewitt, Research Chemist, Geochemical Sciences Branch, Research Division, U.S. Army Cold Regions and Research and Engineering Laboratory. This project was funded by the U.S. Army Toxic and Hazardous Materials Agency (R-90 Multi-analytical Services), Martin H. Stutz, project monitor.

The author thanks Dr. Thomas F. Jenkins and Dr. Clarence Grant for assistance in the experimental design, and Dr. Charles M. Reynolds, James H. Cragin, Dr. Jenkins, Dr. Iskandar K. Iskandar and Dr. Grant for critical reviews of the text.

The contents of this report are not to be used for advertising or promotional purposes. Citation of brand names does not constitute an official endorsement or approval of the use of such commercial products.

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Leaching of Metal Pollutants From Four Well Casings Used for Ground-water Monitoring

ALAN D. HEWITT

INTRODUCTION

Ground-water monitoring requires the installation of conduits to transfer water to the surface for collection. Four commonly used well casings are made from 2-in. (5-cm) diameter polyvinylchloride (PVC), stainless steel 304 (SS 304), stainless steel 316 (SS 316) and polytetrafluoroethylene (PTFE) pipes. Representative sampling of ground water requires that materials employed in the saturated zone do not influence the concentration of analytes of interest.

Only a few studies have reported the influence of well-casing materials on the concentrations of inorganic substances in ground water during water quality analyses. Several studies have demonstrated that these materials (stainless steel, PVC and PTFE) sorb appreciable quantities of certain ionic species (Eichholz et al. 1965, Miller 1982, Hewitt 1989). Evidence also exists showing that metals are released into ground water from stainless steel and PVC pipes (Houghton and Berger 1984, Barcelona and Helfrich 1986, Hewitt 1989). The release of metal analytes by stainless steel has been associated with its corrosion, which in some instances has been observed to produce a hydrous iron precipitate (Barcelona and Helfrich 1986, Hewitt 1989).

Recently, a laboratory experiment was conducted testing the effects of ground-water composition on the well casings cited above (Hewitt 1989). In this experiment two concentrations of metals (As, Cd, Cr and Pb), pH and total organic carbon were introduced as ground-water solution variables. Results of this experiment indicated that PTFE was inert to the variables, whereas both PVC and stainless steel well casings were affected. These two materials leached and sorbed some of the metals introduced into the ground water. In addition, several stainless steel casing sections developed

surface oxidation, which introduced a random source of variation by providing release mechanisms and active sites for sorption. PVC was a low-level source for Cd and provided sorption sites for Pb. Stainless steel 316 was a low-level source for Cd and provided sorption sites for As, Cr and Pb. Stainless steel 304 was also a low-level source for Cd and provided sorption sites for As and Pb. The extent of the sorption or release of metals was often influenced by the solution variables. This study concluded that the stainless steel casings were the least suitable for monitoring the metals studied (As, Cd, Cr and Pb) in the ground water solutions.

A concurrent study done at CRREL (Parker et al. 1989) looked at ground-water solutions spiked with organic compounds exposed to the same four well casings. In contrast to the results for metals, eight (*cis* and *trans*-1,2-dichloroethylene, *m*-nitrotoluene, trichloroethylene, chlorobenzene, *o*-, *p*- and *m*-dichlorobenzene) of the ten organic compounds studied sorbed more quickly and to a greater extent onto PTFE than PVC and did not sorb onto the stainless steels. The same results were obtained when the ground water was treated with 2.0 g NaCl/L to test for effects of ionic strength. These findings support the earlier work of Reynolds and Gillham (1985) who observed rapid sorption of tetrachloroethylene by PTFE well casing. They suggested that PTFE is the least desirable material for a well casing when organic compounds are monitored in ground water.

The results of these two recent CRREL studies (Hewitt 1989, Parker et al. 1989) and supporting evidence in the literature led to the suggestion that PVC may be the best compromise among these four well casings for monitoring ground water for both inorganic and organic analytes (Parker et al. 1986).

The objective of this study is to examine metal leaching characteristics of these four well-casing materials in ground water. Leaching studies that

compare these four well casings have not been reported in the literature. The results of this experiment will determine which casings are the most or the least susceptible to leaching the metals. The analytes analyzed included all of the metals on the Environmental Protection Agency's priority pollutant list, along with copper.

MATERIALS AND METHODS

Materials

The PVC and stainless steel well casings were obtained from Johnson Well Screen, and the PTFE was obtained from MIP, Inc. All well casings were specifically manufactured for ground-water monitoring. The casings all had approximately a 5-cm inner-wall diameter and were cut in lengths of approximately 2 cm. The exact length of the rings depended on the wall thickness and diameter of the pipe because we wanted to maintain a constant surface area of 80 cm². Cut surfaces composed 17% of the area for the PTFE and PVC well casings and 9% for the stainless steels.

Precautions were taken during pipe milling to prevent exposure to grease, dirt, oil and solvents, and to avoid excessive handling. After milling, the individual well-casing rings were rinsed with deionized water (Millipore, Type 1) and air dried before being placed into the ground-water-filled sample containers. During rinsing we made no attempt to remove surface discoloration or ink on the pipes; we used them as we had received them from the manufacturer. This limited cleaning was consistent with commonly employed field protocols.* The well-casing sections were handled with plastic gloves and nylon forceps after milling. Two sections of the SS 316 pipe were not used because excessive surface rust had formed. In general the stainless steel well casings appeared to have developed more rust during the 9-month storage period than they had when first obtained. All experimental work was performed in class 100 cleanrooms.

Polypropylene jars (69 mm od x 62 mm height, 125 mL, Model 6185-E37, Thomas Scientific) served as the sample containers. The jars were soaked in a 10% v/v concentrated, redistilled HNO₃ (G. Frederick Smith [GFS]) deionized water solution, then rinsed with and soaked for several days in deionized water prior to use. Other materials, such as the 7.5-mL sample aliquot bottles (polyethylene, Nalgel),

pipette tips (Eppendorf), and the 2-L glass bottles (reagent grade HNO₃ bottles, Baker), were cleaned similarly.

Test design

Tests for the release of metals from PVC, PTFE, SS 304 and SS 316 well casings were done in triplicate by exposing sections of each to ground water for periods of 1, 5, 20 and 40 days. Three sample containers with no well casings served as controls for each of the exposure periods. The containers with and without well casings were filled with 98 mL of ground water collected from a 76-m-deep domestic well system in Weatherfield, Vermont; 50 containers, 12 with a single section of each of the four well-casing candidates (12 x 4) and 12 controls, made up the experimental sample setup. The well-casing rings were submerged in the ground-water-filled sample containers creating a pipe-surface-area-to-aqueous-volume ratio of 0.82 cm²/cm³. This experimental design provides a surface-area-to-solution ratio similar to that of well casings in ground-water monitoring wells below the saturated zone; however, the ratio is much lower than that which exists for well screens.

Samples were prepared by transferring weighed amounts of ground water into each jar from a single 2-L glass bottle. The jars were selected randomly for the experiment because the ground water was transported in three separate 2-L glass bottles. The pH and conductivity of the ground water from all of the bottles was 7.8 and 2.40×10^{-2} mho/cm, respectively. Ground water collected from this source previously showed similar pH and conductivity levels (Hewitt 1989). While the well casings were exposed to the ground water, the jars were sealed with a cap and stored in the dark at 24°C. After the well-casing sections had been removed from the jars at the end of each time interval, 2 mL of concentrated HNO₃ (GFS) was added to the ground water to bring the pH below 1.0. Studies have shown that acidification below pH 1.5 is effective in preventing the loss of trace metals from natural waters (Subramanian et al. 1978). The acidified, ground-water-filled jars were recapped, hand-swirled for 10 seconds, then left at rest for at least 72 hours before we transferred a 5-mL aliquot to a 7.5-mL sample vial (polyethylene, Nalgel) for the subsequent determination of Ag, As, Ba, Cd, Cu, Cr, Pb and Se.

The entire experimental setup was duplicated for the analysis of Hg, except that we determined Hg immediately after the ground-water-filled jar was acidified.

In a preliminary experiment, ground water stored in the polypropylene jars was spiked with

* Personal communication with Louise V. Parker, CRREL, 1989.

Cd, Cr and Pb to see if sorption of metal ions on the jar walls would interfere with the test results. These metal ions, added to the ground water and stored for 6 days in the sample jars, were recovered upon acidification (Table 1). The desorption of metal ions from container walls has been reported by Choa et al. (1968). For this preliminary test, 5.00 µg/L of Cd, Cr and Pb was allowed to sit in ground-water-filled jars (100 mL) for 6 days. Then we added 2 mL of concentrated HNO₃ (GRS), hand swirled the solution for 10 seconds, and removed a 5-mL aliquot. A second 5-mL aliquot was removed 72 hours later, following the same procedure. The results in Table 1 show that an average of 95% of the aqueous metal was recovered immediately after acidification, and aliquots removed 3 days later showed only 2% (not significant at the 95% confidence level) additional analyte recovery. Thus the metals either remained in the laboratory ground-water solution or were desorbed from the jar walls quickly upon acidification.

Table 1. Recovery of Cd, Cr and Pb (4.90 µg/L) from ground water stored in the sample jars and allowed to equilibrate for 6 days before being acidified with 2 mL of concentrated HNO₃.

	Acidification period			
	Less than 10 minutes		72 hours	
	Amount * <i>determined</i> (µg/L)	Percent recovered	Amount * <i>determined</i> (µg/L)	Percent recovered
Cd	4.65	94.9	4.72	96.3
	4.72	96.3	4.85	99.0
Cr	4.48	91.4	4.59	93.5
	4.48	91.4	4.69	95.7
Pb	4.93	100.2	4.72	96.3
	4.72	96.3	5.01	102.2
Average recovery		95.1%		97.2%

* *determined*

Analysis

Silver, arsenic, barium, cadmium, copper, chromium and lead were determined by Graphite Furnace Atomic Absorption (GFAA) using a Perkin-Elmer (PE) model 403 Atomic Absorption Spectrophotometer (AAS) coupled with a PE model 2200 heated graphite atomizer. Instrumental procedures followed the general guidelines provided in the manufacturer's instrument manual (Perkin-Elmer 1981). Hand injections of either 20, 50 or 100 µL were employed for the analytes mentioned above.

For the determination of Se, a matrix modifier—0.015 mg Pb and 0.01 mg Mg(NO₃)₂—was added so that the charring temperature could be raised to 1200°C. Of this group, only As and Se determinations required deuterium background correction.

Mercury was determined by Cold Vapor Atomic Absorption (CVAA). We employed a 48-mL aliquot for the Hg determinations, following a modified Hatch and Ott (1968) procedure. Aliquots of 48 mL of ground water were reduced with 2 mL of 10% v/v stannous chloride and then sparged with Hg-free air. The reduced Hg vapor passed through a Mg(CO₃)₂ water vapor trap into an optical cell designed to enhance detection (Tuncel and Atoman 1983). The optical cell was positioned in the light path of the PE model 403 AAS.

Mercury was determined the same day that well casings were removed from ground-water-filled jars to limit volatilization of Hg from solution (Coyne and Collins 1972, Lo and Wai 1975) and to avoid vapor contamination associated with storage in poly containers (Cragin 1979). All of the other metals were determined within 2 weeks after the last exposure period.

Analysis procedures were designed to achieve detection limits of 1% or less of the present domestic water quality levels set by the EPA (Table 2). Selenium, determined by graphite furnace, was the only metal with a detection limit slightly above this level (Table 2). Method Detection Limits (MDLs) were established following the procedure outlined in the Federal Register (1984) for the analysis of a sample in a given solution. The MDL estimate requires that a minimum of seven replicate determinations be made of an analyte concentration that is one to five times the estimated detection level.

Table 2. EPA interim primary drinking water quality levels (1983) and the method detection limits (MDL).

Metals	EPA primary drinking water levels (µg/L)	MDL (µg/L)
As	50	0.48
Ba	1000	2.4
Cd	10	0.059
Cu	1000	4.3
Cr	50	0.16
Pb	50	0.11
Hg	20	0.010
Se	10	0.21
Ag	50	0.12

Table 3. Summary of ANOVA and LSD determinations for average analyte concentrations ($\mu\text{g/L}$). Materials with common underlining are not different at the 95% confidence level as determined by the LSD.

Days	Well casing					Days	Well casing				
a. Barium						c. Lead					
1	Control	<u>PTFE</u>	<u>PVC</u>	<u>SS304</u>	<u>SS316</u>	1	Control	<u>PTFE</u>	<u>SS316</u>	<u>SS304</u>	<u>PVC</u>
	4.3	6.0	6.6	7.1	7.7		0.16	0.35	0.90	1.14	2.46
(LSD = 1.4)						(LSD = 1.45)					
5	<u>PTFE</u>	Control	<u>PVC</u>	<u>SS304</u>	<u>SS316</u>	5	Control	<u>PTFE</u>	<u>SS316</u>	<u>SS304</u>	<u>PVC</u>
	5.3	5.8	6.6	7.8	9.9		0.21	0.27	1.07	1.36	2.23
(LSD = 2.1)						(LSD = 1.53)					
20	<u>PTFE</u>	Control	<u>PVC</u>	<u>SS304</u>	<u>SS316</u>	20	Control	<u>PTFE</u>	<u>SS316</u>	<u>PVC</u>	<u>SS304</u>
	5.5	5.9	6.1	7.4	11.3		0.14	0.35	1.00	1.04	2.56
(LSD = 2.2)						(LSD = 2.90)					
40	<u>PTFE</u>	<u>PVC</u>	Control	<u>SS304</u>	<u>SS316</u>	40	<u>PTFE</u>	Control	<u>PVC</u>	<u>SS316</u>	<u>SS304</u>
	5.2	5.6	5.9	7.0	10.1		0.21	0.33	0.73	1.26	2.06
(LSD = 2.0)						(LSD = 1.52)					
b. Chromium						d. Copper					
1	Control	<u>PTFE</u>	<u>PVC</u>	<u>SS304</u>	<u>SS316</u>	1	<u>PVC</u>	<u>SS304</u>	Control	<u>PTFE</u>	<u>SS316</u>
	0.20	0.22	1.23	1.60	6.06		9.4	10.7	11.9	12.1	35.8
(LSD = 9.76)						(LSD = 12.0)					
5	Control	<u>PTFE</u>	<u>PVC</u>	<u>SS316</u>	<u>SS304</u>	5	<u>PTFE</u>	<u>PVC</u>	Control	<u>SS304</u>	<u>SS316</u>
	0.20	0.22	1.12	1.79	3.34		7.8	9.9	10.1	11.0	42.6
(LSD = 0.37)						(LSD = 12.4)					
20	<u>PTFE</u>	Control	<u>PVC</u>	<u>SS316</u>	<u>SS304</u>	20	<u>PVC</u>	<u>PTFE</u>	Control	<u>SS304</u>	<u>SS316</u>
	0.19	0.22	1.20	3.30	4.61		6.8	8.3	10.1	24.1	51.2
(LSD = 1.17)						(LSD = 35.3)					
40	Control	<u>PTFE</u>	<u>PVC</u>	<u>SS316</u>	<u>SS304</u>	40	<u>PVC</u>	<u>PTFE</u>	<u>SS304</u>	Control	<u>SS316</u>
	0.21	0.21	1.11	2.33	3.13		4.4	5.2	11.5	14.0	52.3
(LSD = 1.04)						(LSD = 17.2)					

The MDL is obtained by multiplying the standard deviation of the replicate measurements by the appropriate one-sided *t*-statistic corresponding to *n*-1 degrees of freedom at the 99% confidence level.

Each sample aliquot with a determined analyte concentration above the MDL was analyzed at least twice. Analyte concentrations were based on the average peak heights from a strip chart recording.

Aqueous calibration standards for Ag, As, Cd, Cr, Cu, Pb, Hg and Se were prepared by diluting 1000-mg/L certified atomic absorption stock solutions (Fisher Scientific Corp.). A Ba stock standard was made by dissolving a weighed amount of Ba(NO₃)₂ (Baker, Reagent Grade) in deionized water. Working standards were prepared in deionized water acidified to 2% v/v with HNO₃ (GFS).

Calibrations were established by determining three different concentration standards in tripli-

cate. Standards were randomly introduced throughout the course of sample analysis, and all of the calibration curves were linear over the concentration range examined. To see if the intercepts were significantly different from zero, we compared the residuals for the models with an intercept and for the models with zero intercept using the *F*-ratio at the 95% confidence level. Analyte concentrations in the samples and controls were determined based on the slope and intercept only if the intercept was deemed significant. Otherwise, a zero-intercept linear model was employed.

To assess leaching of metals from the surfaces of the four well-casing materials, an analysis of variance (ANOVA) was performed on those metals (Ba, Cr, Cu and Pb) that had been consistently found above the established MDL for the four well-casing materials and the control if a significant

difference was detected by the ANOVA among the average analyte concentrations in the ground water for a given material, then a Least-Significant-Difference (LSD) analysis was performed. Both analyses (ANOVA and LSD) used the 95% confidence level. The results of these analyses established which well casings contributed particular analytes to the ground water over and above those contributed by other well casings or the control for the different exposure periods (Table 3). In addition the aqueous metal concentrations that exceed 1% of the EPA drinking water quality level were identified. This low-level warning criterion was chosen since this study did not always establish the native levels present in the ground water. Thus, the contribution of metals from the well casings could range from one or more orders of magnitude above the background concentrations.

RESULTS

Barium

The analysis of the 1-day exposure samples showed that all of the ground-water-filled vessels containing pipe sections had aqueous Ba concentrations that were significantly greater than that of the control; however, all of the values were low (Table 3a). The subsequent exposure periods do not follow this pattern but instead established that SS 316 was the only material that consistently contributed significant levels of Ba to the solution relative to the other samples and the controls (Fig. 1a). The average increase in aqueous concentration for the ground water exposed to SS 316 was about 70% compared to the control. After 3 days of exposure, ground water in contact with SS 316 developed aqueous Ba concentrations that exceeded 1% of the drinking water quality level established by the EPA. None of the other well casings tested produced aqueous Ba concentrations that exceeded 1% of the EPA drinking water quality criterion or were significantly different from the control after the initial exposure period.

Cadmium

We did not use ANOVA with Cd since the majority of concentrations determined were below the MDL (Appendix A). After 1 day of exposure, both ground-water solutions containing SS 316 and PVC had aqueous Cd that exceeded 1% of the EPA drinking water quality level.

Figure 1b shows the average Cd concentrations determined for the control and well casings. It appears that Cd is initially released from SS 316 and

PVC but becomes resorbed onto the well casing with time. Stainless steel 316 contributes approximately an order of magnitude (more than 100% of the EPA drinking water quality level in some cases) more Cd than PVC for equivalent exposure periods.

Chromium

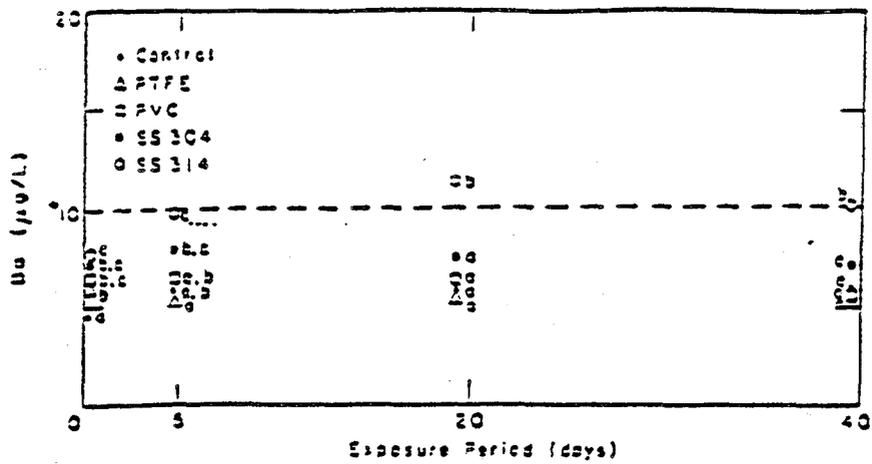
Beyond the 1-day exposure, the analysis consistently demonstrated that both stainless steel well casings contributed significantly greater quantities of Cr to the ground water than the control or the other materials tested (Table 3b). These metal well casings, along with PVC, increased Cr concentrations in the ground water above 1% of the EPA drinking water quality level (Fig. 1c). The extent of the Cr contamination coming from the PVC was three to five times less than that coming from the SS 304, which usually showed the highest average contamination for a given exposure period, the exception being the initial exposure period.

The ANOVA and LSD tests failed to distinguish any difference between the materials for the 1-day exposure because of the large variation among the three SS 316 samples. If SS 316 is removed, the analysis shows both PVC and SS 304 to contribute significantly greater quantities of Cr to the ground water than do the control and PTFE. The only material that showed a consistent trend was SS 304 (Fig. 1c), which created increasing concentrations of Cr with time. Throughout the experiment there was no significant difference for Cr between the control and the PTFE well casing.

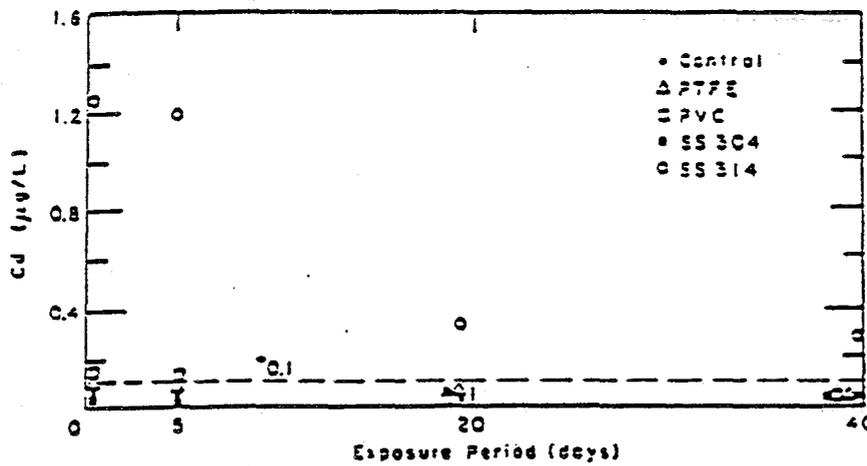
Lead

The first two exposure periods showed PVC to leach the greatest amount of Pb and to be significantly different from the control and PTFE. The two longest exposure periods showed that SS 304 leached the greatest amount of Pb to ground water; however, the levels observed in solution for SS 304 were only statistically different from the rest for the 40-day exposure period (Table 3c). The average levels obtained for both of the stainless steels and for PVC consistently exceeded 1% of the EPA drinking water quality standard (Fig. 1d).

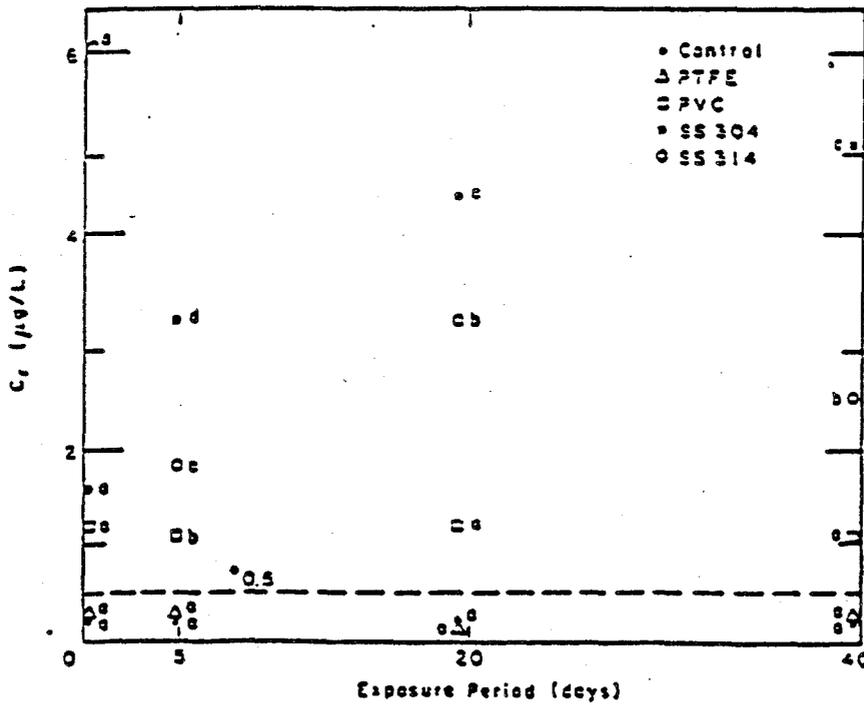
The most distinctive trend was the decrease in Pb with increasing time of exposure for PVC (Fig. 1d). Both stainless steel well casings showed slight decreases in Pb levels after aqueous concentration maxima were obtained. The Pb that was initially released was resorbed by the PVC and stainless steel well casings. Throughout the experiment, there was no significant difference among the control, SS 316 and PTFE.



a. Cu.

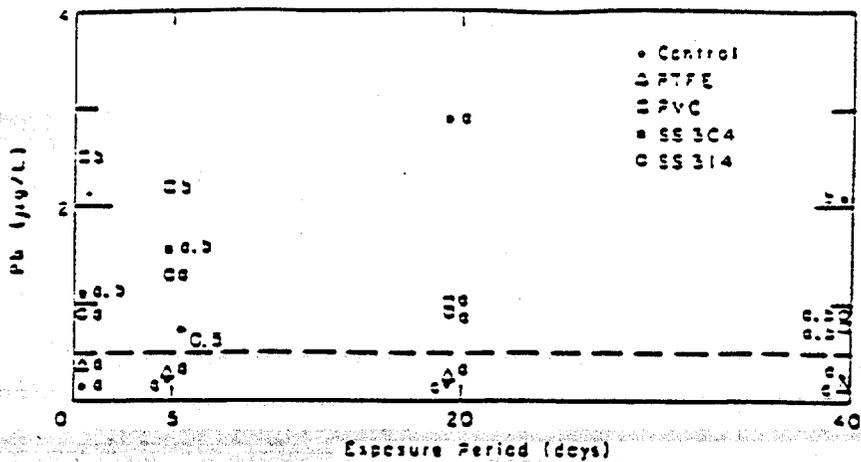


b. Cd.

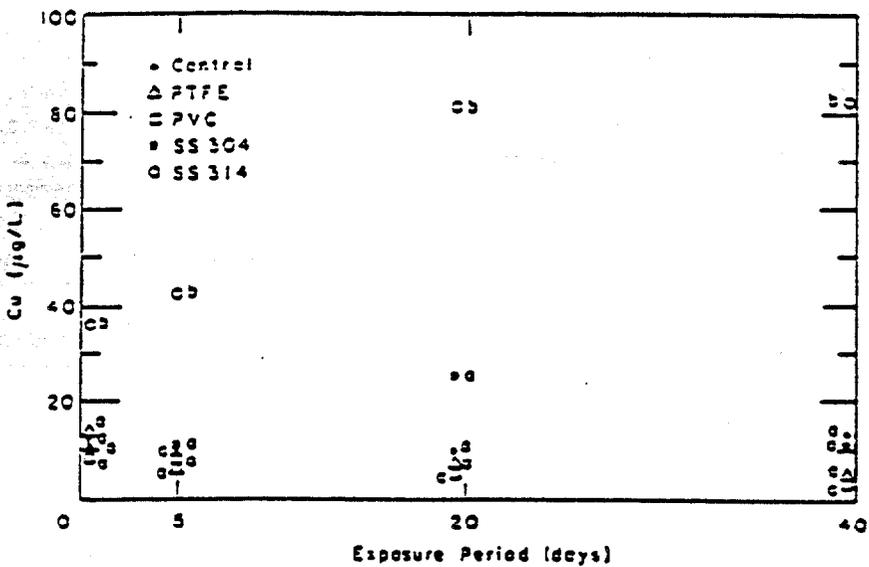


c. Cr.

Figure 1. Ground-water leaching of metals from well casings being examined. Common letters next to points denote no significant difference at the 0.05% confidence interval as determined by ANOVA and LSD.



d. Pb.



e. Cu.

Figure 1 (cont'd).

Copper

The statistical analysis distinguished SS 316 as the only material that contributed significantly more Cu when exposed to ground water than the other materials tested (Table 3d). Aqueous concentrations exceeded 80 µg/L for SS 316 versus about 10 µg/L for the other materials and the control.

Both PTFE and PVC well casing showed a general trend of decreasing Cu with increasing time of exposure and often showed concentrations below the control (Fig 1e). This trend, along with the lack of any trend with respect to the control, demonstrates that these two plastic pipes provided the substrate for sorption.

Arsenic, mercury, selenium and silver

The determinations for As, Hg, Se and Ag were not statistically analyzed because the majority of the concentrations were at or below the established MDLs. Based on the analysis methods employed, none of the well casings consistently contributed As, Hg or Ag above 1% or Se above 2% of the EPA drinking water quality level.

DISCUSSION

Ground water was collected from a domestic well system and stored in sealed 2-L glass bottles

for approximately 24 hours prior to being transferred into test jars. Ground water collected in this fashion is aerated at the faucet and exposed to an oxygen-rich environment every time the lid of the container is removed. Handling the ground water in this manner most likely changed the oxidation potential, facilitating oxidation reactions (Strumm and Morgan 1970). We made no attempt to simulate the natural ground-water redox state or to quantitatively assess the chemical equilibria that existed during the course of this experiment.

There was visible rust on 11 of 24 sections of the stainless steel pipes (Table 4). Each pipe section was carefully examined prior to submersion and after removal from the ground water. In this experiment and in a previous one (Hewitt 1989), oxidation on the stainless steel was predominantly found on the wall. If oxidation is providing sites for sorption or release mechanisms, then the freshly cut surfaces were most likely not a major factor in the behavior of these two materials. Fresh surfaces on the PVC pipe is not an experimental artifact since PVC well screen is made by slotting the pipe.

It was apparent from the values determined for the control samples that the three 2-L glass bottles used to transport the ground water had different

concentrations of aqueous Cu (Appendix A). The range of aqueous Cu concentrations most likely reflect the residence time of the ground water in the household and well plumbing. Three distinct populations of Cu concentration were determined for the controls at the 99% confidence level ($X_1 = 9.8 \pm 0.0$, $n = 4$; $X_2 = 10.3 \pm 0.22$, $n = 5$; $X_3 = 16.0 \pm 0.0$, $n = 3$). Differences between adjacent mean concentrations were established by testing against the maximum variance determined for all of populations (i.e., X_1, X_2 and X_2, X_3).

The groups established by the three Cu populations were then tested to determine if any of the other metals found above its MDL were also significantly different. Table 5 presents the averages and standard deviations for the metal groups based on the Cu populations for the controls. Only Pb shows the same increasing mean concentration trend as the Cu groupings; however, the averages for the adjacent Pb groups were not significantly different at the 95% or even the 80% confidence level when analyzed in the same manner as the Cu populations. This analysis establishes that only Cu was significantly influenced by the sample preparation procedure. Mixing the ground water from the three collection bottles would have eliminated

Table 4. Physical state of stainless steel pipes after exposure to ground water.

		Section											
		1	2	3	4	5	6	7	8	9	10	11	12
SS 304	WR	WR	—	—	WR	—	WR	WR	ER	WR	WR	WR	
SS 316	—	—	—	—	ER	—	—	—	—	—	—	—	ER

KEY: WR = rust on wall; ER = rust on edge; dash means no rust.

Table 5. Average metal concentrations for the controls based on the groups established by the Cu populations ($\mu\text{g/L}$).

Populations		Cu	Cr	Pb	As	Sr
1	Avg.	9.8*	0.22	0.11	0.55	5.2
	Sid. Dev.	0.0	0.021	0.00	0.114	0.92
2	Avg.	10.3*	0.20	0.25	0.48	5.8
	Sid. Dev.	0.19	0.032	0.154	0.00	0.29
3	Avg.	16.0*	0.22	0.23	0.48	5.6
	Sid. Dev.	0.0	0.021	0.048	0.00	0.75

* Statistically different at the 99% confidence level.

Table 6. Summary of results.

	Ba	Cd	Cr	Pb	Cu
Materials that leached >1% of the EPA drinking water quality level in ground-water solutions.	SS 316 PVC	SS 316 PVC	SS 304 SS 316 PVC	SS 304 PVC SS 316	NA*
Material that showed the highest average overall amount of analyte leached	SS 316	SS 316	SS 304	SS 304	SS 316

* Does not apply.

this artifact. The level of Cu leached from the SS 316 far exceeded the difference between the established populations.

The results of this study support our previous work (Flewin 1989) showing that PTFE is the least reactive material, whereas both PVC and stainless steel well casings influence aqueous concentrations of metals in laboratory ground-water solutions. As in the first study, the variance among the stainless steel replicates was often the greatest, indicating that this material is susceptible to producing random error. Both studies found that SS 316 and PVC leach and sorb Cd; in addition, these two materials, along with SS 304, sorb Pb. Studies in the future should be conducted under anoxic conditions to see if oxidation of the stainless steel is simply an artifact of these experiments. If corrosion of stainless steel is absent under reducing conditions, then we might expect less random variation and less of an influence on the metal analytes in ground-water solutions.

A summary of the results (Table 6) clearly shows that the stainless steels were the greatest sources of contamination under these experimental conditions. When PVC leached metals (Pb, Cr and Cd) that exceeded 1% of the EPA drinking water quality specifications into solution, there was always a trend showing a decrease in concentration with time of exposure. This would suggest that the leaching of Pb, Cr and Cd from PVC is a surface process and is small. Most likely the initial release could be decreased by more extensive cleaning before the pipes are used. The same statement does not apply to the stainless steel well casings. In the cases of leached Cu from SS 316 and leached Cr from SS 304, the concentrations of these metals continually increased with time over 40 days. It is possible that stainless steels could supply these analytes to ground water over an extended period of time, perhaps the entire life of the casing.

CONCLUSION

Among the four types of well casings tested, PTFE was the only material that did not leach any of the nine metals examined. The other materials tested in this experiment (PVC, SS 304 and SS 316) compromised laboratory ground-water samples by contributing analytes of interest (Ba, Cd, Cr, Pb and Cu). Investigations where only trace metals are of interest should use PTFE below the saturated zone. PVC would be the appropriate second choice since its influence on metal analytes appears predictable and small. In contrast, the two stainless steel materials should be avoided.

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APPENDIX A: LEVELS OF CD, PB, CR, BA AND CU DETERMINED
IN GROUND-WATER SOLUTIONS (M.L.).

mg

Pipe	Replicate	Time (days)	Number	Cd	Pb	Cr	Ba	Cu
Cnd	1	1	1	<D*	0.11	0.21	4.2	9.8
Cnd	2	1	2	<D	0.11	0.19	4.6	9.8
Cnd	3	1	3	<D	0.26	0.21	4.8	16.0
Cnd	1	5	4	<D	0.40	0.15	5.5	10.5
Cnd	2	5	5	<D	0.11	0.24	5.8	9.5
Cnd	3	5	6	<D	0.11	0.20	6.1	10.1
Cnd	1	20	7	<D	0.11	0.24	6.1	10.1
Cnd	2	20	8	<D	0.11	0.22	6.1	9.8
Cnd	3	20	9	<D	0.19	0.20	5.5	10.5
Cnd	1	40	10	<D	0.42	0.20	5.5	10.1
Cnd	2	40	11	<D	0.24	0.20	5.7	16.0
Cnd	3	40	12	<D	0.33	0.24	6.5	16.0
PIPE	1	1	1	<D	0.40	0.19	5.9	10.5
PIPE	2	1	2	<D	0.26	0.28	6.1	9.8
PIPE	3	1	3	<D	0.40	0.19	5.9	15.7
PIPE	1	5	4	0.117	0.40	0.24	4.9	9.1
PIPE	2	5	5	<D	0.30	0.21	5.5	8.4
PIPE	3	5	6	<D	0.11	0.21	5.5	5.9
PIPE	1	20	7	0.117	0.40	0.21	5.5	15.3
PIPE	2	20	8	<D	0.30	0.16	5.2	4.9
PIPE	3	20	9	<D	0.36	0.19	5.5	4.6
PIPE	1	40	10	<D	0.11	0.21	4.9	4.3
PIPE	2	40	11	<D	0.11	0.16	5.5	7.0
PIPE	3	40	12	<D	0.40	0.26	5.2	4.3
FVC	1	1	1	0.109	2.19	1.13	6.7	9.4
FVC	2	1	2	0.125	3.09	1.40	7.0	9.8
FVC	3	1	3	0.175	2.11	1.15	6.1	9.1
FVC	1	5	4	0.075	2.39	1.15	7.3	8.0
FVC	2	5	5	0.142	2.43	1.30	6.4	13.2
FVC	3	5	6	0.109	1.57	0.91	6.1	8.4
FVC	1	20	7	<D	2.11	1.30	6.4	11.9
FVC	2	20	8	<D	0.66	1.40	5.8	4.3
FVC	3	20	9	<D	0.34	0.91	6.1	4.3
FVC	1	40	10	<D	0.93	1.08	6.1	4.3
FVC	2	40	11	<D	0.75	1.03	5.2	4.3
FVC	3	40	12	<D	0.66	1.22	5.5	4.6
SS 304	1	1	1	<D	0.48	1.22	6.7	9.8
SS 304	2	1	2	<D	0.58	1.13	7.0	13.2
SS 304	3	1	3	<D	2.05	2.45	7.6	9.1
SS 304	1	5	4	<D	1.25	3.33	7.3	9.8
SS 304	2	5	5	<D	0.96	2.21	8.2	8.0
SS 304	3	5	6	<D	2.47	3.48	7.9	15.3
SS 304	1	20	7	0.092	0.80	4.36	7.3	9.1
SS 304	2	20	8	<D	2.51	3.57	7.6	49.7
SS 304	3	20	9	<D	4.95	5.59	7.3	19.6
SS 304	1	40	10	<D	2.97	5.10	6.7	9.1
SS 304	2	40	11	<D	1.47	4.56	6.4	9.4
SS 304	3	40	12	<D	1.73	5.73	7.9	15.9
SS 316	1	1	1	2.629	0.41	1.48	7.0	27.5
SS 316	2	1	2	0.209	0.60	1.29	7.3	35.5
SS 316	3	1	3	0.926	1.70	15.36	8.7	44.5
SS 316	1	5	4	0.217	0.96	1.51	8.5	37.2
SS 316	2	5	5	2.930	2.30	1.69	11.5	37.4
SS 316	3	5	6	0.451	0.55	1.66	9.6	52.9
SS 316	1	20	7	0.326	1.50	3.45	12.3	102.2
SS 316	2	20	8	0.376	0.76	2.96	9.3	56.7
SS 316	3	20	9	0.326	0.75	3.50	12.3	84.8
SS 316	1	40	10	0.267	0.67	3.18	11.5	97.3
SS 316	2	40	11	0.384	0.75	1.94	9.0	77.2
SS 316	3	40	12	0.209	2.36	2.45	9.8	72.3

* Less than MDL

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Influence of Casing Materials on Trace-Level Chemicals in Well Water

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Abstract

Four well casing materials — polyvinyl chloride (PVC), polytetrafluoroethylene (PTFE), and stainless steel 304 (SS 304) and 316 (SS 316) — were examined to determine their suitability for monitoring inorganic and organic constituents in well water.

The inorganic study used a factorial design to test the effect of concentration of mixed metals (arsenic [As], chromium [Cr], lead [Pb], and cadmium [Cd]), pH, and organic carbon. Sample times were 0.5, 4, 8, 24, and 72 hours. Except for slow loss of Pb, PTFE well casings had no significant effect on the concentration of metals in solution. For the other casings, changes in analyte concentration often exceeded 10 percent in eight hours or less and, thus, could bias analyses of samples taken from wells constructed with these materials. Specifically, PVC casings sorbed Pb and leached Cd; SS 316 casings sorbed As and Pb and leached Cd; and SS 304 casings sorbed As, Cr, and Pb and leached Cd. Both stainless steel casing materials showed markedly poorer performance than the PVC casings.

The well casings were also tested for sorption/desorption of 10 organic substances from the following classes: chlorinated alkenes, chlorinated aromatics, nitroaromatics and nitramines. Sample times were 0, 1, 8, 24, and 72 hours, seven days, and six weeks. There were no detectable losses of analytes in any of the sample solutions containing stainless steel well casings. Significant loss of some analytes was observed in sample solutions containing plastic casings, although losses were always more rapid with the PTFE casings than with PVC. Chlorinated organic substances were lost most rapidly. For samples containing PTFE casings, losses of some of these compounds were rapid enough (>10 percent in eight hours) to be of concern for ground water monitoring. Losses of hydrophobic organic constituents in samples containing PTFE casings were correlated with the compound's octanol/water partition coefficient.

Introduction

The U.S. Environmental Protection Agency's (EPA's) RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD) (U.S. EPA 1986a) states that only fluorocarbon resins or stainless steel (SS) casings should be used for monitoring volatile organics in the saturated zone. The original draft of this document (U.S. EPA 1985) suggested that Teflon® or stainless steel 304 be used for all ground water monitoring at RCRA sites. The EPA was concerned that many of the casing materials used for ground water monitoring could either affect the quality of the ground water or did not have the long-term structural characteristics required of RCRA monitoring wells. With respect to the EPA's first concern, a review of the literature published prior to 1986 did not reveal substantial evidence to support the position taken by the EPA in either edition of this document (Parker et al. 1989).

Few studies have specifically addressed the possible interactions between well casing materials and metal

be significant (Eicholz et al. 1965, Robertson 1968, Batley and Gardner 1977, and Masse et al. 1981). In one study of PVC well casings, there was negligible loss of chromium but large losses of lead from a deionized water solution (Miller 1982). Other studies with Pyrex glass and polyethylene also found that lead was the most rapidly lost analyte (Shendrikar et al. 1976). Barcelona and Helfrich (1986) compared the concentrations of several metal species in samples taken from adjacent PVC, PTFE, and SS wells. They found increased levels of iron in water samples from the non-purged SS well to be the only statistically significant difference. In a previous *in situ* study by Houghton and Berger (1984), a steel-cased well appeared to leach a number of metal species, including iron, cadmium, chromium, copper, manganese, molybdenum, selenium, and zinc, when compared with a PVC well and one constructed of acrylonitrile-butadiene-styrene (ABS).

Sorption of organic solutes by well casing materials has been reported in several publications. Miller (1982) tested PVC well casing for sorption of trace levels (2-

form, trichlorofluoromethane, trichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, and tetrachloroethylene) in aqueous solution and found slow losses of tetrachloroethylene (25-50 percent in six weeks).

Reynolds and Gillham (1986) tested both PVC and PTFE materials for sorption of trace levels (ppb) of five halogenated organics. They found rapid sorption of tetrachloroethylene by PTFE, slow sorption of 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane and hexachloroethane, and no sorption of bromoform. They also found slow sorption of all the analytes except trichloroethane by PVC. While 50 percent of the tetrachloroethylene was sorbed by the PVC in five weeks, the same amount was sorbed by PTFE in only eight hours. They attributed loss of these organics to absorption and developed a model where uptake of the compound proceeds by sorption/dissolution into the polymer surface, followed by diffusion into the polymer matrix. However, Reynolds and Gillham (1986) could not predict which organic chemicals were most susceptible to absorption.

Sykes et al. (1986) compared sorption of several organics by PVC, SS, and PTFE well casings. The casing materials were equilibrated for seven days (5 C) in analyte solution, placed in fresh analyte solution, and then tested for losses due to sorption after one and 24 hours. After 24 hours they did not find any significant losses for any of the casing materials.

While these studies indicate that sorption of some organics may be a significant problem for plastic casings over the long term, only the study by Miller (1982) examined desorption during the first two weeks. In that study, he observed some desorption (25 percent) of the tetrachloroethylene that had been previously sorbed by the PVC casings.

Casing materials may also leach a variety of organic substances. In two studies (Miller 1982, Parker and Jenkins 1986), analytical interferences in leachates from PVC well casings were sought but none were found. Curran and Tomson (1983) also examined the leachates from five plastics, including PVC and PTFE. They found that PTFE leached the fewest contaminants and that non-glued PVC was a close second. While it is possible that organic substances such as lubricants used during manufacture or inks from printing could leach from stainless or plastic casings, no information currently available in the literature confirms this.

It is interesting to note that despite the literature that is available regarding sorption of organics by PTFE, articles have recently been published that claim it is superior for sampling organic substances (e.g., Bryden and Smith 1989).

The purpose of the studies conducted by the authors was to determine the suitability of four well casing materials (PVC, PTFE, SS304, and SS316) for monitoring inorganic and organic solutes in ground water. To do this, two separate studies were conducted, one for inorganics and one for organics.

General Comments on the Inorganic and Organic Studies

Two-inch (inner) diameter well casings manufactured specifically for ground water monitoring were used in all studies. These casings were purchased specifically for the studies and were stored in a cool, dry room prior to use. Precautions were taken while the casings were being cut to prevent contamination from grease, dirt, oil, solvents, and excessive handling. The ground water used in the studies was obtained from a domestic well (249 feet [76m] deep) in Weathersfield, Vermont. No attempt was made to maintain the native dissolved oxygen level. As a general guideline for evaluating our results, we considered any change in concentration (relative to the control samples) of 10 percent in an eight-hour period to be the maximum change tolerable.

Inorganic Study

Experimental

Mixed metal solutions were prepared by spiking ground water with arsenic (As), cadmium (Cd), chromium (Cr) and lead (Pb) at two concentrations: 50 and 100 µg/L (ppb) for As, Cr, and Pb, and 10 and 2 µg/L for Cd. The higher concentrations are the current maximum concentration limits set by the EPA for drinking water (U.S. EPA 1986b). Prior to treatment, the ground water used in this study was analyzed and found to contain no detectable amounts of any of these metals at the sensitivity levels used for analysis. To simulate a wider range of ground water conditions, the tests were run at the natural pH (7.8) of the well water plus a lower pH (5.8) and at two levels of organic carbon. HCl (reagent grade) was added to lower the pH and 5 mg/L (ppm) of humic acid was added to raise the organic carbon content. A complete (2ⁿ) factorial experiment was used to test the effect of these treatments (concentration of metals, pH and organic carbon content) (Table 1).

Because the wall thicknesses varied between the plastic and the two stainless steel casings, the casings

TABLE 1
Matrix Design for Inorganic Study

Test Condition	Metal Concentrations ¹	pH	Organic Carbon Added ²
1	high	7.8	no
2	high	7.8	yes
3	high	5.8	no
4	high	5.8	yes
5	low	7.8	no
6	low	7.8	yes
7	low	5.8	no
8	low	5.8	yes

¹ High metal concentrations were 50 µg/L As, Cr, Pb, and 10 µg/L Cd. Low metal concentrations were 10 µg/L As, Cr, Pb, and 2 µg/L Cd.

were cut to different lengths so that the surface area of each was constant (80 cm²). Cut sections were rinsed with deionized water and air-dried before use. Individual well casings were then placed in 125mL polypropylene jars containing 100mL of test solution; the ratio of casing surface area to aqueous volume was 0.82 cm²/mL. Similar jars that contained the test solutions without any casings were used for control samples. The sample vessels were covered, stored at 24 C and kept from natural light. Duplicates were run for each combination of variables and each casing material.

Sample aliquots (2.5mL) were taken from each container after 0.5, 4, 8, 24, and 72 hours. The aliquots were placed in clean 7.5mL polyethylene vials and acidified to a pH of less than 1 with nitric acid to prevent sorption by the containers. Metal concentrations were obtained by graphite furnace atomic absorption spectroscopy (Perkin-Elmer, model 703 atomic absorption spectrophotometer coupled with a PE model 2200 heated graphite atomizer). The concentrations of metals given in this study were measured as total.

The metal concentrations were normalized by dividing the values obtained for sample solutions that contained well casings by the values found for equivalent

controls. This allowed the results for both concentrations to be analyzed by a single analysis of variance (ANOVA). Thus, it was possible to simultaneously test for the effect of solute concentration, pH and organic carbon at each sample time for each casing material. If a casing exerted no influence on analyte concentration, the expected value would be 1.00. An increase in the ratio indicates that the well casing released metal into the solution, while a decrease in the ratio indicates that metal was sorbed by the casing.

Results and Discussions

Approximately half of the stainless steel casings showed signs of surface rust. In some cases (SS 316 at a low pH), sufficient oxidation occurred to form a hydrous iron oxide precipitate. This precipitate was never observed in the control samples or those with PVC or PTFE casings. While the authors realize that rusting of the stainless casings is very condition-specific, the test conditions should be generally representative of shallow wells. Also, it was noticed that the casings had rusted some during storage prior to any testing.

Table 2 gives the normalized mean values and standard deviations for each analyte, well casing and time.

TABLE 2
Normalized Mean Metal Values¹ for Samples as a Function of Time

Time (hr)	Pipe	Arsenic		Cadmium		Chromium		Lead	
		Mean Value	Standard Deviation						
0.5	PVC	0.991 =	0.038	1.01 =	0.025	1.01 =	0.018	0.999 =	0.009
	PTFE	0.999 =	0.050	1.01 =	0.011	1.01 =	0.007	1.00 =	0.025
	SS304	0.997 =	0.057	1.06 =	0.036	1.01 =	0.016	1.02 =	0.008
	SS316	0.994 =	0.040	1.04 =	0.021	1.02 =	0.015	1.01 =	0.025
4.0	PVC	1.02 =	0.045	1.13 =	0.037	0.999 =	0.013	0.889 =	0.030
	PTFE	0.993 =	0.052	1.03 =	0.054	1.01 =	0.011	0.974 =	0.019
	SS304	0.978 =	0.063	1.17 =	0.15	0.957 =	0.037	0.784 =	0.035
	SS316	0.945 =	0.060	1.24 =	0.49	0.921 =	0.052	0.803 =	0.077
8.0	PVC	1.00 =	0.045	1.15 =	0.037	1.00 =	0.014	0.893 =	0.035
	PTFE	1.01 =	0.098	1.03 =	0.016	0.989 =	0.019	0.965 =	0.032
	SS304	0.962 =	0.057	1.16 =	0.14	0.972 =	0.16	0.699 =	0.031
	SS316	0.945 =	0.068	1.30 =	0.47	0.872 =	0.10	0.904 =	0.10
24.0	PVC	0.994 =	0.064	1.16 =	0.056	1.00 =	0.016	0.808 =	0.051
	PTFE	0.992 =	0.054	1.03 =	0.017	1.01 =	0.024	0.951 =	0.040
	SS304	0.894 =	0.051	1.12 =	0.12	1.03 =	0.37	0.538 =	0.042
	SS316	0.853 =	0.080	1.36 =	0.68	0.855 =	0.11	0.793 =	0.19
72.0	PVC	1.03 =	0.046	1.14 =	0.049	1.01 =	0.018	0.743 =	0.064
	PTFE	1.02 =	0.045	1.02 =	0.022	1.00 =	0.013	0.899 =	0.034
	SS304	0.891 =	0.084	1.03 =	0.14	1.03 =	0.42	0.452 =	0.061
	SS316	0.874 =	0.083	1.25 =	0.66	0.836 =	0.099	0.720 =	0.17

¹ (Concentration for samples with casing)

(Concentration for control samples)

= Normalized mean value

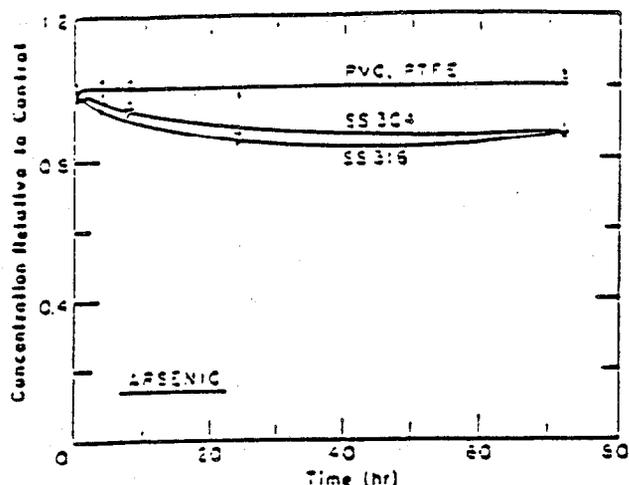


Figure 1. Trends in mean arsenic concentration for four well casing materials.

In general, there was no change in arsenic concentration for the sample solutions containing either the PVC or PTFE casings during the 72-hour test period (Figure 1), and no consistent pattern of effects was evident from the ANOVA. The reason As did not interact with these casings may be because As exists in natural waters in the anionic form (Fowler et al. 1979). Masse et al. (1981) found that anions do not strongly associate with plastic (polyethylene and PTFE) surfaces, which are known for their cation exchange capacity. The samples containing the stainless steel casings, on the other hand, showed a 10 percent decrease in aqueous arsenic concentration relative to the controls after 24 hours (Figure 1). It appears that there was no further loss of this analyte after 24 hours. Although these results cannot be used to predict exactly what losses might occur under field conditions, it is doubtful that this loss was rapid enough to impact water quality measurements (losses were less than 10 percent after eight hours).

The results for Cd are quite different. After only four hours, Cd concentrations in the samples containing PVC and stainless steel casings had increased by more than 10 percent (Figure 2), with the most leaching occurring in the samples containing the SS 316 casings. Cadmium may have been added to the PVC as a UV stabilizer (Wilson et al. 1982), and may have been added to the stainless steel to enhance resistance to chloride cracking (Sedricks 1979). The concentration of Cd in the samples containing PVC casings leveled off after eight hours. ANOVA revealed that pH had a significant effect (at the 95 percent confidence level) for this casing. Although the same amount of Cd leached in all the samples (approximately 0.5 mg/L), concentration was also significant (at the 95 percent confidence level), but only because relatively more was leached in the low-concentration samples. Concentrations in samples containing SS 304 casings decreased after eight hours and after 72 hours had returned to the same levels that were found in the control samples. Again, more Cd leached in the low pH samples. Cd was leached most rapidly in samples containing SS 316 casings. There was a large

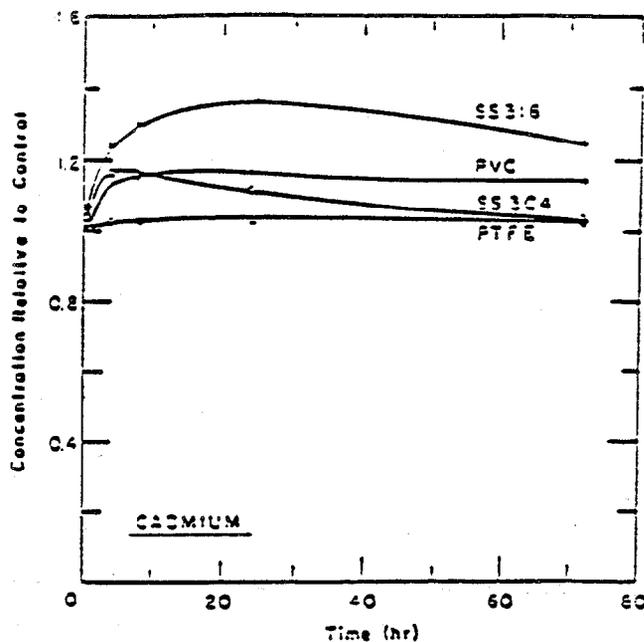


Figure 2. Trends in mean cadmium concentration for four well casing materials.

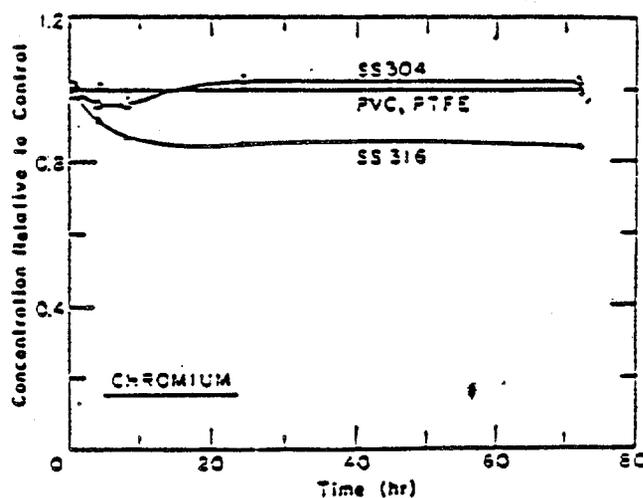


Figure 3. Trends in mean chromium concentration for four well casing materials.

plum that contained stainless steel casings. With the exception of the first set of samples ($t = 0.5$ hr), the relative standard deviations ranged from 12 to 15 percent for samples containing SS 304 and from 47 to 68 percent for those containing SS 316. In contrast, the standard deviations for samples containing PVC and PTFE casings were consistently below 6 percent. Because the variance in the samples containing SS 316 was so large, there was no consistent detectable effect of pH for these casings. However, surface oxidation appeared to be the major source of this variance. With respect to the leaching of metal stabilizers from PVC pipes, the literature indicates that loss can be a surface phenomenon that can be reduced or eliminated by either washing (with detergent) or soaking in dilute mineral acid before use (Packham 1971). It may be that the loss of Cd from PVC casings can also be reduced by a similar treatment, although we did not test this possibility.

There was no measurable sorption of chromium by

of interaction with the plastic casings may be due to chromium speciation. In solution, chromium exists predominantly as dichromate and chromate ($\text{Cr}_2\text{O}_7^{2-}$, CrO_4^{2-}) and, as mentioned previously, anions are not as likely to exchange with plastic surfaces. However, loss of chromium was rapid enough (33 percent after eight hours) for SS 316 casing material to be of concern for ground water monitoring. Losses were greater at the higher pH; Cr speciation is known to be affected by pH and may be responsible for some of these differences. Surface oxidation was greater at the lower pH, which likely contributed to the larger variability. Also, for those samples where a hydrous iron oxide precipitate was formed, co-precipitation may have contributed to the losses from solution. Again, the standard deviations were considerably greater for the samples containing the stainless steel casings. Humic acids apparently increased the stability of aqueous Cr, perhaps by acting as a complexing agent (Stumm and Morgan 1970s).

Lead was by far the most actively sorbed metal species. While all sample solutions containing casing materials showed some loss of Pb with time (Figure 4), PTFE was the least active surface and SS 304 was the most active. The losses for samples containing PTFE casings do not appear to be of concern with respect to ground water monitoring; losses were only 5 percent after 24 hours. However, losses for samples containing PVC and stainless casings are of concern: losses were 10 percent after only four hours in the samples containing PVC casings and 20 percent in those containing stainless casings. Although loss was initially rapid in samples containing SS 316 casings, it leveled off after eight hours. The standard deviation was higher for the samples containing SS 316 casings than for the other casings. For both stainless steel casings, there was less sorption of Pb at the lower pH where hydrogen ions may have competed for sorption sites. Added humic material apparently acted as a complexing agent in solution, making lead less prone to sorption. Concentration had no consistent effect.

Undoubtedly, there were shifts in the chemical equilibria of the well water solutions from the time the well water was collected until the end of the experiment. Ground water that is removed from an anoxic environment and exposed to oxygen-rich air may undergo redox and precipitation reactions (Stumm and Morgan 1970b). Also, lowering the pH shifts the carbonate equilibrium in solution from predominantly bicarbonate species toward carbon dioxide (Manahan 1972) and causes shifts in Cr speciation. Clearly, such changes would alter the trace metal species distribution. These possible changes were not monitored in this experiment.

For further details on this portion of the study, refer to Hewitt (1989).

Organic Study

Experimental

The four well casing materials were also tested for sorption/desorption of low levels of 10 organic sub-

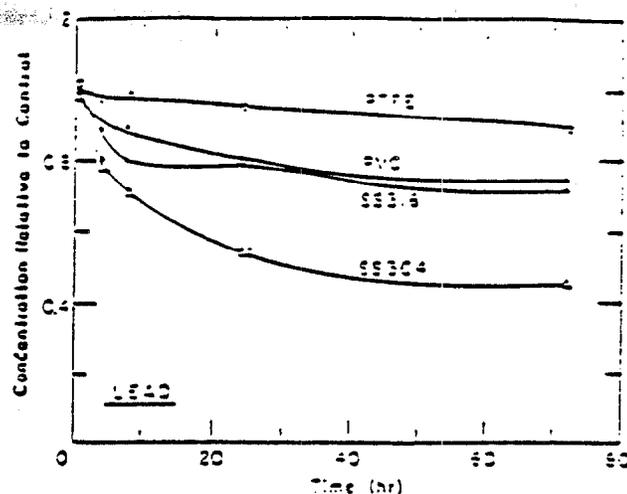


Figure 4. Trends in mean lead concentration for four well casing materials.

trinitro-1,3,5-triazine (RDX), 1,3,5-trinitrobenzene (TNB), *cis*- and *trans*-1,2-dichloroethylene (CDE and TDE), *m*-nitrotoluene (MNT), trichloroethylene (TCE), chlorobenzene (CLB), and *o*-, *p*- and *m*-dichlorobenzene (ODCB, PDCB, MDCB). The criteria used for selecting these analytes included being an EPA priority pollutant, molecular structure, solubility in water, K_{ow} value, and retention time (using reversed-phase high performance liquid chromatography [HPLC] analysis). HPLC analysis of the ground water used in these studies revealed no detectable levels of any of these substances.

For these experiments, casings were cut into 11- to 14mm-long sections, which were then cut into quarters. Again, the length was varied so that the surface area could be maintained constant. The casings were washed in solutions of detergent and deionized water, rinsed many times with deionized water, drained and left to air dry. Two pieces of each type of casing were placed in 40mL glass vials that were filled with the aqueous test solution so there was no head space, and capped with Teflon-lined plastic caps. Vials with test solution but no well casing material served as controls. These controls allowed us to eliminate any effects such as those that might be due to the vials or caps. The ratio of casing surface area to solution volume was 0.79 cm^2/mL . The ratio of solution volume to volume of casing material was approximately 10:1.

In the first experiment, the test solution was prepared by adding known amounts of each of the organic solutes directly to 2.2 L of well water in a glass-stoppered bottle, which was stirred overnight. The final concentration was approximately 2 mg/L for each organic constituent. The solution also contained 40 mg/L of HgCl_2 , which was added to prevent biodegradation of the organics. Separate vials were prepared for each sample time so that the test solution could be discarded after sampling; there were three replicate samples for each material and time. Contact times were 0 hours, one hour, eight hours, 24 hours, 72 hours (three days), 168 hours (seven days), and approximately 1000 hours (six weeks).

After an aliquot was removed for analysis from each

TABLE 3
Normalized¹ Average Concentrations of Organic Analytes for the Four Well Casings with Time

Analyte	Treatment	1 Hour	8 Hours	24 Hours	72 Hours	168 Hours	1000 Hours
RDX	PTFE	1.03	1.00	1.00	1.02	0.91	0.99
	PVC	1.01	1.00	0.98	1.00	1.02	1.00
	SS304	0.99	0.99	1.01	1.02	1.10	0.98
	SS316	1.01	0.99	1.01	1.02	1.11	1.00
TNB	PTFE	1.01	1.00	1.00	0.98	0.95	1.01
	PVC	1.01	1.00	0.98	1.02	1.01	1.02
	SS304	0.99	1.00	1.00	1.05	1.07	1.00
	SS316	1.02	0.99	1.01	1.07	1.06	1.02
Cl2DCE	PTFE	1.01	0.96*	0.96*	0.94	0.91*	0.79*
	PVC	1.00	0.99	0.95*	0.96	0.95	0.90
	SS304	0.97	1.00	1.00	0.96	1.04	0.98
	SS316	0.95	0.99	1.00	1.01	0.98	0.99
Ti2DCE	PTFE	1.00	0.92*	0.88*	0.83	0.66	0.56*
	PVC	1.00	0.98	0.93*	1.06	0.83	0.83
	SS304	0.95*	1.00	1.00	0.96	1.11	1.03
	SS316	1.00	0.99	1.00	1.12	1.03	1.00
MNT	PTFE	1.03	1.00	0.99	0.99	0.90	0.90*
	PVC	1.02	1.00	0.98	1.05	0.99	0.94
	SS304	1.00	1.00	1.01	1.00	1.08	1.07
	SS316	1.02	1.00	1.02	1.08	1.10	0.99
TCE	PTFE	1.00	0.90*	0.85*	0.78*	0.64*	0.40*
	PVC	1.01	0.98	0.94*	0.99	0.94*	0.88*
	SS304	0.96	1.00	1.01	0.96	1.04	0.99
	SS316	1.00	0.99	1.00	1.04	0.98	1.00
Cl3	PTFE	1.01	0.93*	0.90*	0.85*	0.74*	0.51*
	PVC	1.01	0.98	0.95*	0.98	0.94*	0.86*
	SS304	0.98	1.00	1.00	0.97	1.05	0.99
	SS316	0.99	0.99	1.01	1.04	0.98	0.99
ODCB	PTFE	1.01	0.91*	0.88*	0.81*	0.68*	0.43*
	PVC	1.02	0.97*	0.94*	0.98	0.93	0.86*
	SS304	0.98	0.99	1.00	0.99	1.04	1.00
	SS316	1.01	0.98*	1.01	1.03	0.98	1.00
PDCB	PTFE	0.92*	0.84*	0.77*	0.54*	0.47*	0.26*
	PVC	0.95	0.95*	0.92*	0.97	0.88*	0.80*
	SS304	0.91*	0.98	1.00	0.98	1.02	1.02
	SS316	0.94	0.97*	1.00	1.04	0.97	1.02
MDCB	PTFE	1.00	0.84*	0.78*	0.66*	0.48*	0.26*
	PVC	1.02	0.95*	0.92*	0.97	0.88*	0.80*
	SS304	0.99	0.96*	1.00	0.99	1.02	1.02
	SS316	1.03	0.96*	1.00	1.04	0.96	1.01

¹ Values are determined by dividing the mean concentration of a given analyte at a given time and for a particular well casing by the mean concentration (for the same analyte) of the control samples taken at the same time.

* Values significantly different from control values ($\alpha = 0.05$)

of the 1000-hour samples, the vials were emptied and the pieces of casing were rinsed with approximately 40 mL of fresh well water to remove any residual solution adhering to the surfaces. The casing pieces were then placed in new vials, and fresh unspiked well water was added. The vials were capped with new caps and allowed to equilibrate for three days. Aliquots were then taken from these samples and analyzed to determine if desorption had occurred.

In the second experiment 2.0 g/L of NaCl was also added to the test solution to determine the effect of increased ionic strength on the rates of sorption. Sampling times were the same except that the last samples were taken after approximately 1200 hours (seven weeks).

All analytical determinations were made by reversed-phase high performance liquid chromatography. A modular system was employed that consisted of a Spectra Physics SP 8810 isocratic pump, a Dynatech LC-241 autosampler with a 100- μ L loop injector, a Spectra-Physics SPS490 variable wavelength UV detector set at 210 nm, a Hewlett-Packard 3393A digital integrator, and a Linear model 555 strip chart recorder. Separations were obtained on a 25cm x 4.6mm (5 μ m) LC-18 column (Supelco) eluted with 1.5 mL/min of 62/38 (v/v) methanol-water. Baseline separation was achieved for all 10 analytes. Detector response was obtained from the digital integrator operating in the peak height mode. Analytical precision ranged from 0.4 to 3.98 percent, as determined by the pooled standard deviation of triplicate initial measurements.

For each analyte and sample time, a one-way analysis of variance (ANOVA) was performed to determine if the well casing material had a significant effect on analyte concentration. Where significant differences were found, Duncan's multiple range test was performed to determine which samples were significantly different from the controls.

Before the two experiments described previously were performed, a preliminary leaching study was conducted to determine if any substances that could interfere with the analytical determinations leached from the casing materials. For this study, two pieces of each type of well casing were placed in each of two vials. The vials were filled with fresh well water so that there was no headspace, capped and allowed to sit for one week. An aliquot was taken from each vial and analyzed. No detectable peaks were observed in any of the samples.

Results and Discussion

The data for the first experiment are summarized in Table 3, where the normalized concentrations for solutions containing well casings are given as a function of time. Neither type of stainless steel casing affected the concentrations of any of the analytes in solution. However, significant loss of solute did occur in the solutions that contained plastic casings. While the rate of loss differed dramatically from analyte to analyte, losses were always greater for PTFE than PVC.

For RDX and TNB there was no loss of analyte from solutions containing either plastic casing, even

after 1000 hours. There was some loss of MNT in the sample solutions that contained PTFE casings but the loss only became significant after 1000 hours (30 percent loss); there was no loss with the PVC casings. TDCE was lost much more readily in samples containing PTFE casings than was its isomer pair, ODCE (Figure 5). (The solid lines shown in this figure and Figures 6-9 were fitted manually.) Figure 6 shows the losses of TCE for the four well casings. Figure 7 shows the rate of loss of the three DCB isomers and CLB in the samples that contained PTFE casings. The order of loss was PDCB and MDCB > ODCE > CLB. While the rate of loss did not exceed 10 percent in eight hours for any of the previous solutes, it is noted that losses of PDCB and MDCB were 16 percent in eight hours and thus were rapid enough to be of concern with respect to ground

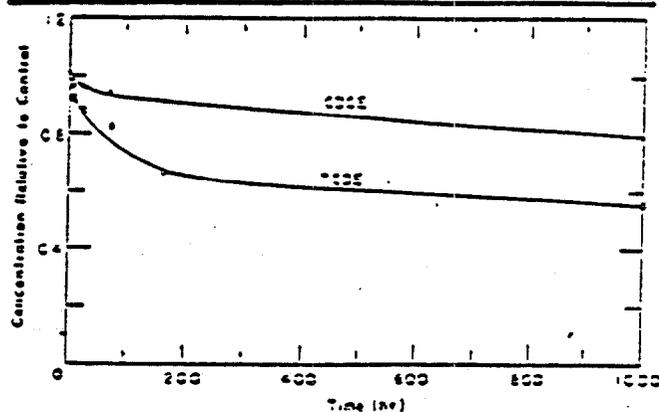


Figure 5. Sorption of ODCE and TDCE by PTFE well casings.

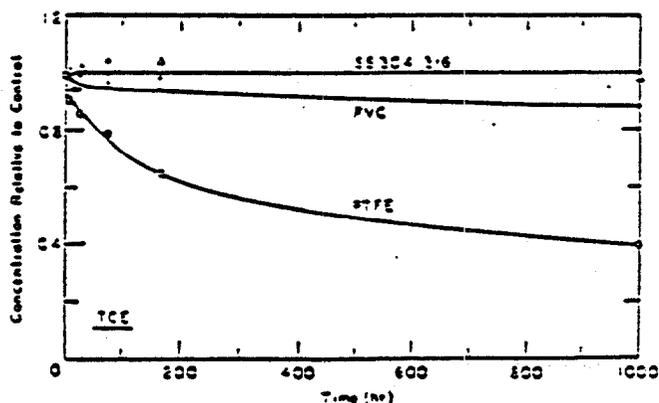


Figure 6. Sorption of TCE by the four well casing materials.

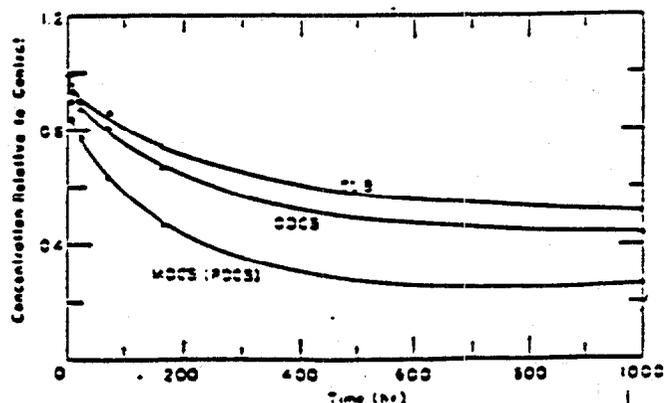


Figure 7. Sorption of CLB, ODCE, MDCB and PDCB by PTFE well casings.

TABLE 4
Results of Desorption Study

Casing Material	Concentration in mg/L after three days equilibration									
	RDX	TNB	CDCE	TDCE	MNT	TCE	CLB	ODCB	PDCB	MDCB
Teflon	ND	ND	0.20	0.43	0.075	0.47	0.23	0.33	0.50	0.35
	ND	ND	0.21	0.45	0.076	0.48	0.23	0.35	0.54	0.36
	ND	ND	.	.	0.074
PVC	ND	ND	0.079	0.15	0.046	0.14	0.10	0.15	0.17	0.13
	ND	ND	0.080	0.14	0.046	0.14	0.10	0.15	0.16	0.11
	ND	ND	0.080	0.15	0.043	0.13	0.11	0.16	0.16	0.20

* Results not presented because of additional loss of volatiles, probably resulting from a loose cap on this vial.
ND = Not detected.

water monitoring. For PVC, losses never reached 10 percent in eight hours for any of the organics tested, and thus the authors believe that PVC is clearly superior to PTFE for wells where water samples will be analyzed for organic constituents.

To determine if the loss of organic solutes was reversible, the pieces of casing that had been exposed to test solution for 1000 hours were rinsed and then exposed to fresh well water for three days. Measurable quantities of all the organics were recovered where significant losses had been observed (Table 4). Thus, loss was due to sorption and was at least partially reversible. Although this experiment did not give us information on the kinetics of desorption, the amount of analyte desorbed after three days generally paralleled the amount sorbed. However, PDCB and MDCB were sorbed to the greatest extent while TCE and TDCE were desorbed to the greatest extent. Therefore, it may be that diffusion out of the polymer is more rapid for smaller molecules.

In the second experiment NaCl was added to raise the chloride concentration above 1000 mg/L. High chloride concentrations are known to corrode 304 stainless steel. Specifically, tests were performed to determine if rusting would alter the sorptivity of the stainless steel surfaces. It is also possible that sorption on plastic materials would change with increasing ionic strength of the test solution.

While addition of NaCl caused rapid rusting of both stainless steel casings (<24 hr), it did not cause sorption of any of the organic solutes by them. In addition, the increased ionic strength had no detectable effect on the rate of sorption by either plastic casing (for example, Figures 8 and 9). These two figures also demonstrate the excellent reproducibility of the results from these two experiments.

Modeling the Sorption Process

These organic studies clearly demonstrated that the loss of organic chemicals from solutions exposed to plastic casing materials is via some reversible sorption process. However, it was uncertain whether this loss was due to sorption on the surface or whether there was

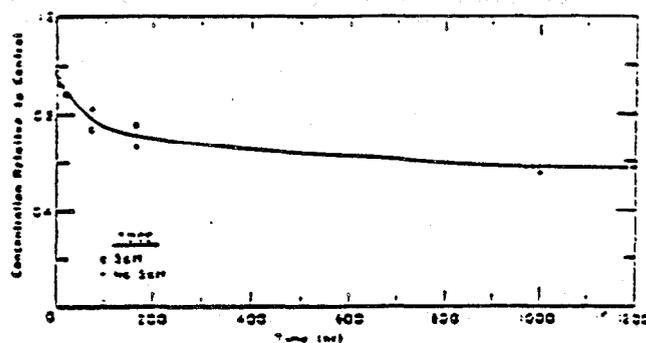


Figure 8. Sorption of TDCE by PTFE well casings in the presence and absence of salt.

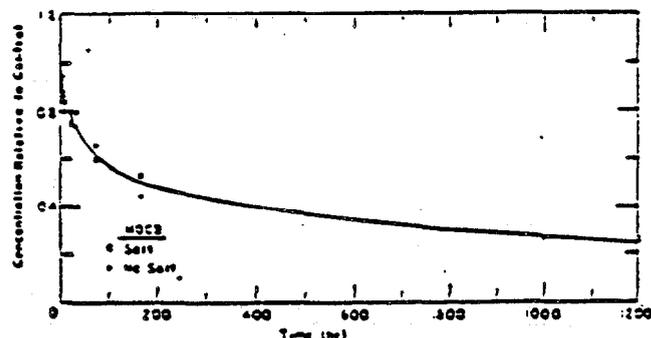


Figure 9. Sorption of MDCB by PTFE well casings in the presence and absence of salt.

penetration into the polymer matrix. The rate of sorption was found to be slow, with no established equilibrium after hundreds of hours. One explanation for this slow rate was that penetration into the polymer was occurring, with the rate controlled by slow diffusion within the bulk polymer and/or the rate of penetration into the small pores on the polymer surface. If it is assumed that this is the case, the process can be kinetically modeled by treating the plastic casing as an immiscible liquid phase in contact with water and relating the degree of partitioning for individual analytes to their octanol/water partition coefficients (K_{ow}). While there are immiscible liquids other than octanol that are better structural models for PTFE or PVC, the most extensive collection of partition coefficients is available for octanol.

If it is assumed that sorption is a reversible process,



and is first order in both directions, then the rate equation can be written as (Gouid 1959):

$$\frac{d[A_w]}{dt} = -k_1[A_w] + k_2[A_p] \quad (2)$$

where $[A_w]$ is the concentration of solute A in aqueous solution, $[A_p]$ is the concentration of solute A in the plastic casing material, and k_1 and k_2 are the first-order rate constants for sorption and desorption, respectively.

Integration of the rate equation results in a non-linear relationship for A_w as a function of time t and two constants a and b (Equation 3), where a and b are defined in Equations 4 and 5:

$$\frac{\ln(a[A_w] - b)}{a} = t \quad (3)$$

$$a = k_1 + k_2 \quad (4)$$

$$b = 10k_2[A_0] \quad (5)$$

where A_0 is the initial concentration of solute A in aqueous solution.

Optimal values for a and b were obtained for each solute exposed to PTFE by application of the Gauss-Newton method of non-linear curve fitting using the measured concentrations at 1, 8, 24, 72, 128, and 1000 hours (Parker et al. 1989). Using determined values for a and b , the authors simultaneously solved Equations 4 and 5 for each solute to obtain estimates of k_1 and k_2 . Because the process described is assumed to be reversible and first order, the ratio of the rate constants, k_1/k_2 , is the equilibrium constant, K_{eq} .

When the eight values of K_{eq} were plotted vs. $\log K_{eq}$, six of the eight points appeared to fall on a straight line, while the points for MNT and ODCB did not (Figure 10). The poor fit for MNT and the lack of significant sorption for TNB and RDX can be explained by the tendency of nitro-containing organic molecules to form strong hydrogen bonds, which keeps them in solution. While octanol can be a donor in hydrogen bonding, PTFE cannot. Thus, if the authors predict partitioning into PTFE for these molecules based on their octanol/water coefficients, the amount of sorption for these types of compounds will be overestimated.

The poor prediction for ODCB can be explained by the well-documented "ortho effect," which is a complex combination of electronic and steric interactions that often results in ortho di-substituted aromatic molecules behaving much differently than the meta- and para-isomers.

A similar model predicting the loss of analyte for PVC was not created because the percent sorbed was small when compared with the experimental error and this would produce an unacceptable degree of uncertainty in the calculated rate constants.

Therefore, it is concluded that for hydrophobic

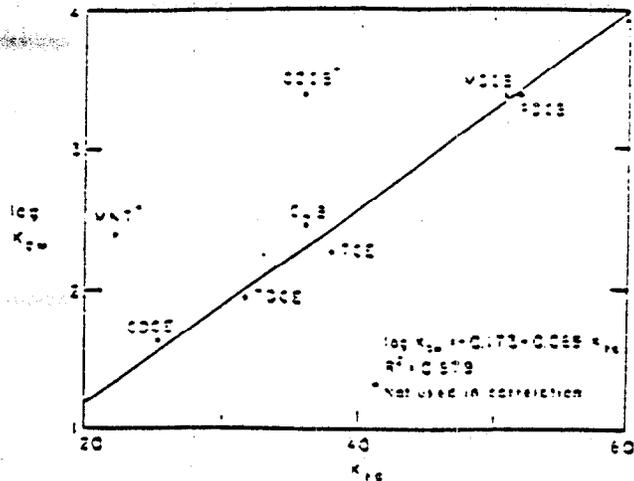


Figure 10. Correlation between $\log K_{eq}$ and K_{eq} for solutes exposed to PTFE casings.

organic molecules that are not subject to hydrogen bonding, the relationship presented in Figure 10 can be used to estimate the equilibrium partitioning of an analyte between the aqueous phase and PTFE. It is expected that losses in new wells would occur for some time until equilibrium with the water is achieved.

While K_{eq} will determine the equilibrium concentrations of each analyte in the water and plastic phases, it is the magnitude of k_1 that will determine how quickly various analytes are depleted. For small, planar molecules like TCE, the k_1 values are quite high compared to the other analytes. This may explain the rapid loss of tetrachloroethylene from solutions containing PTFE casings observed by Miller (1982) and Reynolds and Gillham (1986).

Because the rate of sorption appears to be first order, the relative concentration (concentration at a given time relative to its initial concentration) is independent of initial concentration (Castellan 1964). Thus, the percent loss at a given exposure time is expected to be independent of concentration, as was also predicted by the model of Reynolds and Gillham (1986). We did not confirm this, however, by conducting the test at several concentrations.

For further details on the organic portion of this study, refer to Parker et al. (1989).

Summary and Conclusions

In summary, the inorganic study indicated that three of the metals (As, Cr and Pb) were sorbed by one or more of the casing materials. Specifically, Cr was sorbed by SS 316 casings, As was sorbed by both 304 and 316 stainless steel casings, and Pb was sorbed by all four casings. On the other hand, Cd leached from the stainless steel and PVC casings, although subsequent sorption lowered concentrations in the samples containing stainless steel casings. While sorption of As was slow enough that it is probably not of concern for ground water monitoring, the changes in the Cr, Cd and Pb concentrations are of concern. Both SS 304 and 316 casings were subject to surface oxidation, presumably by galvanic action, which apparently provided active sites for sorption and release of major and minor constitu-

ents. Sorption and leaching of metal species was affected in some cases by the ground water composition (pH and organic carbon content). Specifically, there was more leaching of Cd and less sorption of Pb at the lower pH. Our results indicate that humic material may have acted as a complexing agent, making lead and chromium less prone to sorption. If chemical interactions are used as the only criterion, PTFE is clearly the best candidate for monitoring metal species in ground water. PVC would be a good second choice because its performance was considerably better than either SS 304 or SS 316 casing.

In contrast, the organic studies clearly indicated that PTFE was the poorest choice of the four well casing materials tested. PTFE casings sorbed all the chlorinated compounds and one nitroaromatic compound, and losses of PDCB and MDCB were rapid enough to be of concern for ground water monitoring. PVC casings also sorbed some of the same compounds, but always at rates that were considerably slower than those observed for PTFE casings. The rates of these losses on PVC were slow enough that they did not appear to be of concern for ground water monitoring. There was no loss of any of the organic solutes in the presence of either type of SS casing.

The desorption study showed that the loss of organics from aqueous solution is due to a sorption process that was reversible, or at least partially so. Desorption from contaminated casings could potentially result in falsely high concentrations of analytes if the concentrations of the analytes in the ground water were to drop.

The loss of hydrophobic organic constituents in the samples containing PTFE casings could be correlated with the substance's K_{ow} values. However, this correlation overestimates losses for hydrophilic organic substances.

There are several effects that make extrapolating these test data to a real monitoring situation difficult:

- Casings were tested and not well screens. The rate of sorption could be substantially greater in the screened portions of the well because the surface area of the screened portion would be greater.
- This experiment was conducted under static conditions. The effect of sorption under real conditions would be mitigated to some degree, depending on the rate of exchange of water between the aquifer and well casing.

Clearly, choosing one casing material for samples that will be analyzed for both trace metals and organics involves compromise. However, based on the results of the tests that the authors have performed to date, PVC appears to be the best compromise choice of the four casing materials tested.

Future studies will examine leaching of inorganic and organic solutes, the effect of low dissolved oxygen on interactions between the metals and well casings, and the suitability of other materials for ground water monitoring.

Acknowledgments

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Biographical Sketches

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difference was detected by the ANOVA among the average analyte concentrations in the ground water for a given material, then a Least-Significant-Difference (LSD) analysis was performed. Both analyses (ANOVA and LSD) used the 95% confidence level. The results of these analyses established which well casings contributed particular analytes to the ground water over and above those contributed by other well casings or the control for the different exposure periods (Table 3). In addition the aqueous metal concentrations that exceed 1% of the EPA drinking water quality level were identified. This low-level warning criterion was chosen since this study did not always establish the native levels present in the ground water. Thus, the contribution of metals from the well casings could range from one or more orders of magnitude above the background concentrations.

RESULTS

Barium

The analysis of the 1-day exposure samples showed that all of the ground-water-filled vessels containing pipe sections had aqueous Ba concentrations that were significantly greater than that of the control; however, all of the values were low (Table 3a). The subsequent exposure periods do not follow this pattern but instead established that SS 316 was the only material that consistently contributed significant levels of Ba to the solution relative to the other samples and the controls (Fig. 1a). The average increase in aqueous concentration for the ground water exposed to SS 316 was about 70% compared to the control. After 5 days of exposure, ground water in contact with SS 316 developed aqueous Ba concentrations that exceeded 1% of the drinking water quality level established by the EPA. None of the other well casings tested produced aqueous Ba concentrations that exceeded 1% of the EPA drinking water quality criterion or were significantly different from the control after the initial exposure period.

Cadmium

We did not use ANOVA with Cd since the majority of concentrations determined were below the MDL (Appendix A). After 1 day of exposure, both ground-water solutions containing SS 316 and PVC had aqueous Cd that exceeded 1% of the EPA drinking water quality level.

Figure 1b shows the average Cd concentrations determined for the control and well casings. It appears that Cd is initially released from SS 316 and

PVC but becomes resorbed onto the well casing with time. Stainless steel 316 contributes approximately an order of magnitude (more than 10% of the EPA drinking water quality level in some cases) more Cd than PVC for equivalent exposure periods.

Chromium

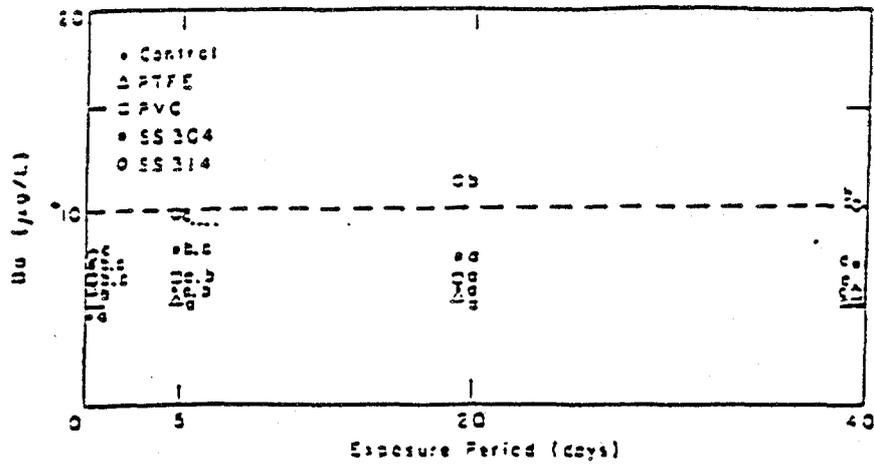
Beyond the 1-day exposure, the analysis consistently demonstrated that both stainless steel well casings contributed significantly greater quantities of Cr to the ground water than the control or the other materials tested (Table 3b). These metal well casings, along with PVC, increased Cr concentrations in the ground water above 1% of the EPA drinking water quality level (Fig. 1c). The extent of the Cr contamination coming from the PVC was three to five times less than that coming from the SS 304, which usually showed the highest average contamination for a given exposure period, the exception being the initial exposure period.

The ANOVA and LSD tests failed to distinguish any difference between the materials for the 1-day exposure because of the large variation among the three SS 316 samples. If SS 316 is removed, the analysis shows both PVC and SS 304 to contribute significantly greater quantities of Cr to the ground water than do the control and PTFE. The only material that showed a consistent trend was SS 304 (Fig. 1c), which created increasing concentrations of Cr with time. Throughout the experiment there was no significant difference for Cr between the control and the PTFE well casing.

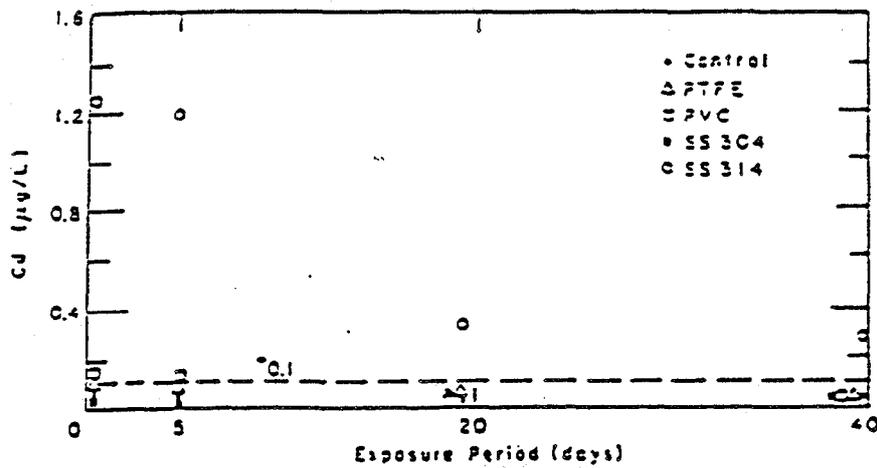
Lead

The first two exposure periods showed PVC to leach the greatest amount of Pb and to be significantly different from the control and PTFE. The two longest exposure periods showed that SS 304 leached the greatest amount of Pb to ground water; however, the levels observed in solution for SS 304 were only statistically different from the rest for the 40-day exposure period (Table 3c). The average levels obtained for both of the stainless steels and for PVC consistently exceeded 1% of the EPA drinking water quality standard (Fig. 1d).

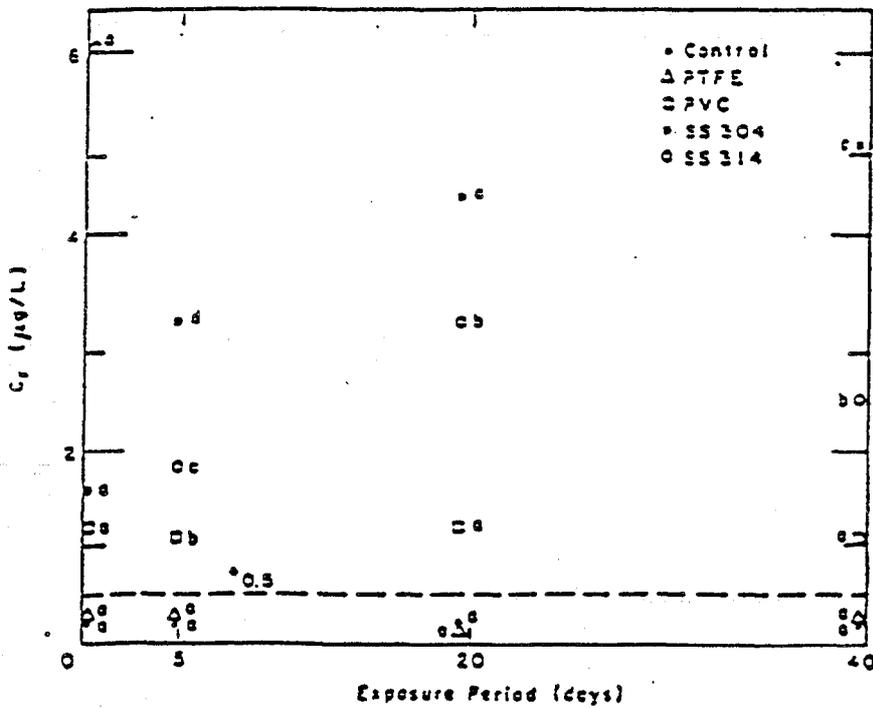
The most distinctive trend was the decrease in Pb with increasing time of exposure for PVC (Fig. 1d). Both stainless steel well casings showed slight decreases in Pb levels after aqueous concentration maxima were obtained. The Pb that was initially released was resorbed by the PVC and stainless steel well casings. Throughout the experiment, there was no significant difference among the control, SS 316 and PTFE.



a. Pb.

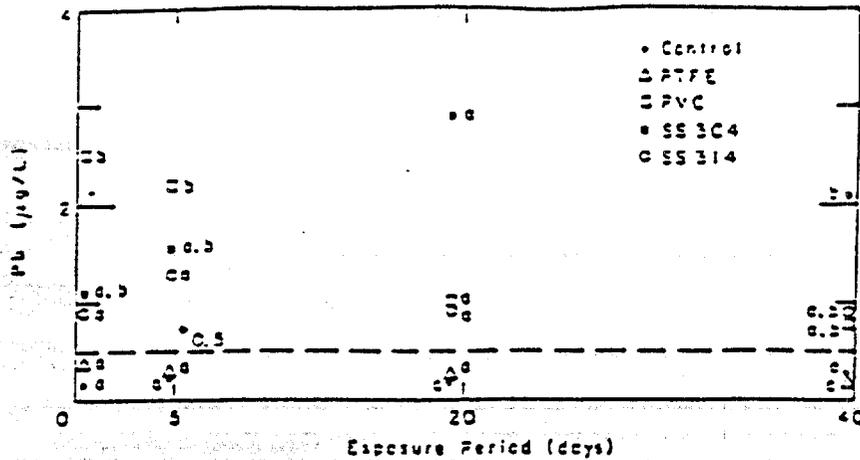


b. Cd.

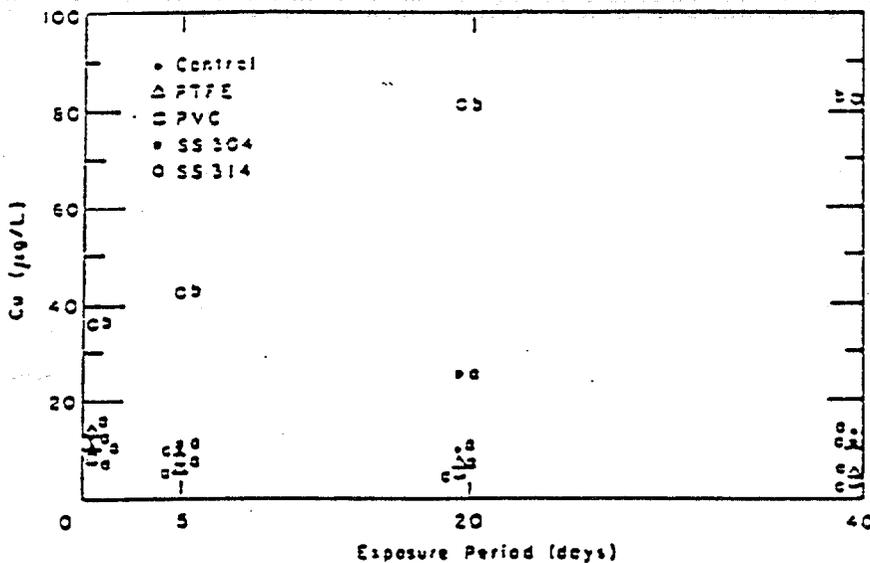


c. Cr.

Figure 1. Ground-water leaching of metals from well casings being examined. Common letters next to points denote no significant difference at the 0.05% confidence interval as determined by ANOVA and LSD.



1. Pb.



2. Cu.

Figure 1 (cont'd).

Copper

The statistical analysis distinguished SS 316 as the only material that contributed significantly more Cu when exposed to ground water than the other materials tested (Table 3d). Aqueous concentrations exceeded 80 µg/L for SS 316 versus about 10 µg/L for the other materials and the control.

Both PTFE and PVC well casing showed a general trend of decreasing Cu with increasing time of exposure and often showed concentrations below the control (Fig 1e). This trend, along with the lack of any trend with respect to the control, demonstrates that these two plastic pipes provided the substrate for sorption.

Arsenic, mercury, selenium and silver

The determinations for As, Hg, Se and Ag were not statistically analyzed because the majority of the concentrations were at or below the established MDLs. Based on the analysis methods employed, none of the well casings consistently contributed As, Hg or Ag above 1% or Se above 2% of the EPA drinking water quality level.

DISCUSSION

Ground water was collected from a domestic well system and stored in sealed 2-L glass bottles

for approximately 24 hours prior to being transferred into test jars. Ground water collected in this fashion is aerated at the faucet and exposed to an oxygen-rich environment every time the lid of the container is removed. Handling the ground water in this manner most likely changed the oxidation potential, facilitating oxidation reactions (Shumm and Morgan 1970). We made no attempt to simulate the natural ground-water redox state or to quantitatively assess the chemical equilibria that existed during the course of this experiment.

There was visible rust on 11 of 24 sections of the stainless steel pipes (Table 4). Each pipe section was carefully examined prior to submersion and after removal from the ground water. In this experiment and in a previous one (Hewitt 1989), oxidation on the stainless steel was predominantly found on the wall. If oxidation is providing sites for sorption or release mechanisms, then the freshly cut surfaces were most likely not a major factor in the behavior of these two materials. Fresh surfaces on the PVC pipe is not an experimental artifact since PVC well screen is made by slotting the pipe.

It was apparent from the values determined for the control samples that the three 2-L glass bottles used to transport the ground water had different

concentrations of aqueous Cu (Appendix A). The range of aqueous Cu concentrations most likely reflect the residence time of the ground water in the household and well plumbing. Three distinct populations of Cu concentration were determined for the controls at the 99% confidence level ($X_1 = 9.5 \pm 0.0$, $n = 4$; $X_2 = 10.3 \pm 0.22$, $n = 5$; $X_3 = 16.0 \pm 0.0$, $n = 3$). Differences between adjacent mean concentrations were established by testing against the maximum variance determined for all of populations (i.e., X_1, X_2 and X_2, X_3).

The groups established by the three Cu populations were then tested to determine if any of the other metals found above its MDL were also significantly different. Table 5 presents the averages and standard deviations for the metal groups based on the Cu populations for the controls. Only Pb shows the same increasing mean concentration trend as the Cu groupings; however, the averages for the adjacent Pb groups were not significantly different at the 95% or even the 80% confidence level when analyzed in the same manner as the Cu populations. This analysis establishes that only Cu was significantly influenced by the sample preparation procedure. Mixing the ground water from the three collection bottles would have eliminated

Table 4. Physical state of stainless steel pipes after exposure to ground water.

	Section											
	1	2	3	4	5	6	7	8	9	10	11	12
SS 304	WR	WR	—	—	WR	—	WR	WR	ER	WR	WR	WR
SS 316	—	—	—	—	ER	—	—	—	—	—	—	ER

KEY: WR = rust on wall; ER = rust on edge; dash means no rust.

Table 5. Average metal concentrations for the controls based on the groups established by the Cu populations ($\mu\text{g/L}$).

Populations		Cu	Cr	Pb	As	Sr
1	Avg.	9.5*	0.22	0.11	0.55	5.2
	Std. Dev.	0.0	0.021	0.00	0.114	0.52
2	Avg.	10.3*	0.20	0.25	0.48	5.8
	Std. Dev.	0.19	0.032	0.154	0.00	0.29
3	Avg.	16.0*	0.22	0.23	0.48	5.6
	Std. Dev.	0.0	0.021	0.048	0.00	0.75

* Statistically different at the 99% confidence level.

Table 6. Summary of results.

	Sa	Cd	Cr	Pb	Cu
Materials that leached >1% of the EPA drinking water quality level in ground-water solutions.	SS 316	SS 316	SS 304	SS 304	NA*
	PVC	PVC	SS 316	PVC	
			PVC	SS 316	
Material that showed the highest average overall amount of analyte leached	SS 316	SS 316	SS 304	SS 304	SS 316

* Does not apply.

this artifact. The level of Cu leached from the SS 316 far exceeded the difference between the established populations.

The results of this study support our previous work (Hewitt 1989) showing that PTFE is the least reactive material, whereas both PVC and stainless steel well casings influence aqueous concentrations of metals in laboratory ground-water solutions. As in the first study, the variance among the stainless steel replicates was often the greatest, indicating that this material is susceptible to producing random error. Both studies found that SS 316 and PVC leach and sorb Cd; in addition, these two materials, along with SS 304, sorb Pb. Studies in the future should be conducted under anoxic conditions to see if oxidation of the stainless steel is simply an artifact of these experiments. If corrosion of stainless steel is absent under reducing conditions, then we might expect less random variation and less of an influence on the metal analytes in ground-water solutions.

A summary of the results (Table 6) clearly shows that the stainless steels were the greatest sources of contamination under these experimental conditions. When PVC leached metals (Pb, Cr and Cd) that exceeded 1% of the EPA drinking water quality specifications into solution, there was always a trend showing a decrease in concentration with time of exposure. This would suggest that the leaching of Pb, Cr and Cd from PVC is a surface process and is small. Most likely the initial release could be decreased by more extensive cleaning before the pipes are used. The same statement does not apply to the stainless steel well casings. In the cases of leached Cu from SS 316 and leached Cr from SS 304, the concentrations of these metals continually increased with time over 40 days. It is possible that stainless steels could supply these analytes to ground water over an extended period of time, perhaps the entire life of the casing.

CONCLUSION

Among the four types of well casings tested, PTFE was the only material that did not leach any of the nine metals examined. The other materials tested in this experiment (PVC, SS 304 and SS 316) compromised laboratory ground-water samples by contributing analytes of interest (Sa, Cd, Cr, Pb and Cu). Investigations where only trace metals are of interest should use PTFE below the saturated zone. PVC would be the appropriate second choice since its influence on metal analytes appears predictable and small. In contrast, the two stainless steel materials should be avoided.

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APPENDIX A: LEVELS OF CD, PB, CR, SA AND CU DETERMINED
IN GROUND-WATER SOLUTIONS (µg/L).

ug

Pipe	Replicate	Time (days)	Number	CD	PB	CR	SA	CU
Coal	1	1	1	<D*	0.11	0.17	4.2	9.5
Coal	2	1	2	<D	0.11	0.19	4.6	9.5
Coal	3	1	3	<D	0.24	0.21	4.8	16.0
Coal	1	5	4	<D	0.40	0.15	5.5	10.5
Coal	2	5	5	<D	0.11	0.24	5.8	9.5
Coal	3	5	6	<D	0.11	0.20	6.1	10.1
Coal	1	20	7	<D	0.11	0.24	6.1	10.1
Coal	2	20	8	<D	0.11	0.22	6.1	9.5
Coal	3	20	9	<D	0.19	0.20	5.5	10.5
Coal	1	40	10	<D	0.42	0.20	5.5	10.1
Coal	2	40	11	<D	0.24	0.20	5.7	16.0
Coal	3	40	12	<D	0.35	0.24	6.3	16.0
PIPE	1	1	1	<D	0.40	0.19	5.9	10.5
PIPE	2	1	2	<D	0.24	0.28	6.1	9.8
PIPE	3	1	3	<D	0.40	0.19	5.9	15.7
PIPE	1	5	4	0.117	0.40	0.24	4.9	9.1
PIPE	2	5	5	<D	0.30	0.21	5.5	8.4
PIPE	3	5	6	<D	0.11	0.21	5.5	8.9
PIPE	1	20	7	0.117	0.40	0.21	5.5	15.3
PIPE	2	20	8	<D	0.30	0.16	5.2	4.9
PIPE	3	20	9	<D	0.36	0.19	5.5	4.6
PIPE	1	40	10	<D	0.11	0.21	4.9	4.3
PIPE	2	40	11	<D	0.11	0.16	5.5	7.0
PIPE	3	40	12	<D	0.40	0.26	5.2	4.3
FVC	1	1	1	0.109	2.19	1.13	6.7	9.4
FVC	2	1	2	0.125	2.09	1.40	7.0	9.5
FVC	3	1	3	0.175	2.11	1.15	6.1	9.1
FVC	1	5	4	0.075	2.39	1.15	7.3	8.0
FVC	2	5	5	0.142	2.43	1.30	6.4	13.2
FVC	3	5	6	0.109	1.57	0.97	6.1	8.4
FVC	1	20	7	<D	2.11	1.30	6.4	11.9
FVC	2	20	8	<D	0.66	1.40	5.8	4.3
FVC	3	20	9	<D	0.34	0.97	6.1	4.3
FVC	1	40	10	<D	0.93	1.08	6.1	4.3
FVC	2	40	11	<D	0.75	1.03	5.2	4.3
FVC	3	40	12	<D	0.66	1.22	5.5	4.6
SS 304	1	1	1	<D	0.48	1.22	6.7	9.8
SS 304	2	1	2	<D	0.58	1.13	7.0	13.2
SS 304	3	1	3	<D	2.05	2.45	7.6	9.1
SS 304	1	5	4	<D	1.25	3.33	7.3	9.5
SS 304	2	5	5	<D	0.96	2.21	8.2	8.0
SS 304	3	5	6	<D	2.47	3.48	7.9	15.3
SS 304	1	20	7	0.052	0.80	4.36	7.3	9.1
SS 304	2	20	8	<D	2.51	3.57	7.6	49.7
SS 304	3	20	9	<D	4.98	5.59	7.3	19.6
SS 304	1	40	10	<D	2.97	3.10	6.7	9.1
SS 304	2	40	11	<D	1.47	4.36	6.4	9.4
SS 304	3	40	12	<D	1.73	5.73	7.9	15.9
SS 316	1	1	1	2.629	0.41	1.48	7.0	27.5
SS 316	2	1	2	0.209	0.60	1.29	7.3	35.5
SS 316	3	1	3	0.926	1.70	15.36	8.7	44.5
SS 316	1	5	4	0.217	0.96	1.51	8.3	37.2
SS 316	2	5	5	2.930	2.30	1.69	11.5	37.4
SS 316	3	5	6	0.451	0.53	1.56	9.6	52.9
SS 316	1	20	7	0.326	1.30	3.45	12.3	102.2
SS 316	2	20	8	0.376	0.76	2.96	9.3	56.7
SS 316	3	20	9	0.326	0.75	3.50	12.3	84.3
SS 316	1	40	10	0.267	0.67	3.18	11.5	97.3
SS 316	2	40	11	0.384	0.75	1.94	9.0	77.2
SS 316	3	40	12	0.209	2.36	2.45	9.8	7.3

* Less than MDL

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Influence of Casing Materials on Trace-Level Chemicals in Well Water

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Abstract

Four well casing materials — polyvinyl chloride (PVC), polytetrafluoroethylene (PTFE), and stainless steel 304 (SS 304) and 316 (SS 316) — were examined to determine their suitability for monitoring inorganic and organic constituents in well water.

The inorganic study used a factorial design to test the effect of concentration of mixed metals (arsenic [As], chromium [Cr], lead [Pb], and cadmium [Cd]), pH, and organic carbon. Sample times were 0.5, 4, 8, 24, and 72 hours. Except for slow loss of Pb, PTFE well casings had no significant effect on the concentration of metals in solution. For the other casings, changes in analyte concentration often exceeded 10 percent in eight hours or less and, thus, could bias analyses of samples taken from wells constructed with these materials. Specifically, PVC casings sorbed Pb and leached Cd; SS 316 casings sorbed As and Pb and leached Cd; and SS 304 casings sorbed As, Cr, and Pb and leached Cd. Both stainless steel casing materials showed markedly poorer performance than the PVC casings.

The well casings were also tested for sorption/desorption of 10 organic substances from the following classes: chlorinated alkenes, chlorinated aromatics, nitroaromatics and nitramines. Sample times were 0, 1, 8, 24, and 72 hours, seven days, and six weeks. There were no detectable losses of analytes in any of the sample solutions containing stainless steel well casings. Significant loss of some analytes was observed in sample solutions containing plastic casings, although losses were always more rapid with the PTFE casings than with PVC. Chlorinated organic substances were lost most rapidly. For samples containing PTFE casings, losses of some of these compounds were rapid enough (>10 percent in eight hours) to be of concern for ground water monitoring. Losses of hydrophobic organic constituents in samples containing PTFE casings were correlated with the compound's octanol/water partition coefficient.

Introduction

The U.S. Environmental Protection Agency's (EPA's) RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD) (U.S. EPA 1986a) states that only fluorocarbon resins or stainless steel (SS) casings should be used for monitoring volatile organics in the saturated zone. The original draft of this document (U.S. EPA 1985) suggested that Teflon® or stainless steel 304 be used for all ground water monitoring at RCRA sites. The EPA was concerned that many of the casing materials used for ground water monitoring could either affect the quality of the ground water or did not have the long-term structural characteristics required of RCRA monitoring wells. With respect to the EPA's first concern, a review of the literature published prior to 1986 did not reveal substantial evidence to support the position taken by the EPA in either edition of this document (Parker et al. 1989).

Few studies have specifically addressed the possible interactions between well casing materials and metal

be significant (Eicholz et al. 1965, Robertson 1968, Batley and Gardner 1977, and Masse et al. 1981). In one study of PVC well casings, there was negligible loss of chromium but large losses of lead from a deionized water solution (Miller 1982). Other studies with Pyrex glass and polyethylene also found that lead was the most rapidly lost analyte (Shendrikar et al. 1976). Barcelona and Helfrich (1986) compared the concentrations of several metal species in samples taken from adjacent PVC, PTFE, and SS wells. They found increased levels of iron in water samples from the non-purged SS well to be the only statistically significant difference. In a previous *in situ* study by Houghton and Berger (1984), a steel-cased well appeared to leach a number of metal species, including iron, cadmium, chromium, copper, manganese, molybdenum, selenium, and zinc, when compared with a PVC well and one constructed of acrylonitrile-butadiene-styrene (ABS).

Sorption of organic solutes by well casing materials has been reported in several publications. Miller (1982) tested PVC well casing for sorption of trace levels (2-

form, trichlorofluoromethane, trichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, and tetrachloroethylene) in aqueous solution and found slow losses of tetrachloroethylene (25-50 percent in six weeks).

Reynolds and Gillham (1986) tested both PVC and PTFE materials for sorption of trace levels (ppb) of five halogenated organics. They found rapid sorption of tetrachloroethylene by PTFE, slow sorption of 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane and hexachloroethane, and no sorption of bromoform. They also found slow sorption of all the analytes except trichloroethane by PVC. While 50 percent of the tetrachloroethylene was sorbed by the PVC in five weeks, the same amount was sorbed by PTFE in only eight hours. They attributed loss of these organics to absorption and developed a model where uptake of the compound proceeds by sorption/dissolution into the polymer surface, followed by diffusion into the polymer matrix. However, Reynolds and Gillham (1986) could not predict which organic chemicals were most susceptible to absorption.

Sykes et al. (1986) compared sorption of several organics by PVC, SS, and PTFE well casings. The casing materials were equilibrated for seven days (5 C) in analyte solution, placed in fresh analyte solution, and then tested for losses due to sorption after one and 24 hours. After 24 hours they did not find any significant losses for any of the casing materials.

While these studies indicate that sorption of some organics may be a significant problem for plastic casings over the long term, only the study by Miller (1982) examined desorption during the first two weeks. In that study, he observed some desorption (25 percent) of the tetrachloroethylene that had been previously sorbed by the PVC casings.

Casing materials may also leach a variety of organic substances. In two studies (Miller 1982, Parker and Jenkins 1986), analytical interferences in leachates from PVC well casings were sought but none were found. Curran and Tomson (1983) also examined the leachates from five plastics, including PVC and PTFE. They found that PTFE leached the fewest contaminants and that non-glued PVC was a close second. While it is possible that organic substances such as lubricants used during manufacture or inks from printing could leach from stainless or plastic casings, no information currently available in the literature confirms this.

It is interesting to note that despite the literature that is available regarding sorption of organics by PTFE, articles have recently been published that claim it is superior for sampling organic substances (e.g., Bryden and Smith 1989).

The purpose of the studies conducted by the authors was to determine the suitability of four well casing materials (PVC, PTFE, SS304, and SS316) for monitoring inorganic and organic solutes in ground water. To do this, two separate studies were conducted, one for inorganics and one for organics.

General Comments on the Inorganic and Organic Studies

Two-inch (inner) diameter well casings manufactured specifically for ground water monitoring were used in all studies. These casings were purchased specifically for the studies and were stored in a cool, dry room prior to use. Precautions were taken while the casings were being cut to prevent contamination from grease, dirt, oil, solvents, and excessive handling. The ground water used in the studies was obtained from a domestic well (249 feet [76m] deep) in Weathersfield, Vermont. No attempt was made to maintain the native dissolved oxygen level. As a general guideline for evaluating our results, we considered any change in concentration (relative to the control samples) of 10 percent in an eight-hour period to be the maximum change tolerable.

Inorganic Study

Experimental

Mixed metal solutions were prepared by spiking ground water with arsenic (As), cadmium (Cd), chromium (Cr) and lead (Pb) at two concentrations: 50 and 100 µg/L (ppb) for As, Cr, and Pb, and 10 and 2 µg/L for Cd. The higher concentrations are the current maximum concentration limits set by the EPA for drinking water (U.S. EPA 1986b). Prior to treatment, the ground water used in this study was analyzed and found to contain no detectable amounts of any of these metals at the sensitivity levels used for analysis. To simulate a wider range of ground water conditions, the tests were run at the natural pH (7.8) of the well water plus a lower pH (5.8) and at two levels of organic carbon. HCl (reagent grade) was added to lower the pH and 5 mg/L (ppm) of humic acid was added to raise the organic carbon content. A complete (2ⁿ) factorial experiment was used to test the effect of these treatments (concentration of metals, pH and organic carbon content) (Table 1).

Because the wall thicknesses varied between the plastic and the two stainless steel casings, the casings

TABLE 1
Matrix Design for Inorganic Study

Test Condition	Metal Concentrations ¹	pH	Organic Carbon Added ²
1	high	7.8	no
2	high	7.8	yes
3	high	5.8	no
4	high	5.8	yes
5	low	7.8	no
6	low	7.8	yes
7	low	5.8	no
8	low	5.8	yes

¹ High metal concentrations were 50 µg/L As, Cr, Pb, and 10 µg/L Cd.
² Low metal concentrations were 10 µg/L As, Cr, Pb, and 2 µg/L Cd.

were cut to different lengths so that the surface area of each was constant (80 cm²). Cut sections were rinsed with deionized water and air-dried before use. Individual well casings were then placed in 125mL polypropylene jars containing 100mL of test solution; the ratio of casing surface area to aqueous volume was 0.82 cm²/mL. Similar jars that contained the test solutions without any casings were used for control samples. The sample vessels were covered, stored at 24 C and kept from natural light. Duplicates were run for each combination of variables and each casing material.

Sample aliquots (2.5mL) were taken from each container after 0.5, 4, 8, 24, and 72 hours. The aliquots were placed in clean 7.5mL polyethylene vials and acidified to a pH of less than 1 with nitric acid to prevent sorption by the containers. Metal concentrations were obtained by graphite furnace atomic absorption spectroscopy (Perkin-Elmer, model 703 atomic absorption spectrophotometer coupled with a PE model 2200 heated graphite atomizer). The concentrations of metals given in this study were measured as total.

The metal concentrations were normalized by dividing the values obtained for sample solutions that contained well casings by the values found for equivalent

controls. This allowed the results for both concentrations to be analyzed by a single analysis of variance (ANOVA). Thus, it was possible to simultaneously test for the effect of solute concentration, pH and organic carbon at each sample time for each casing material. If a casing exerted no influence on analyte concentration, the expected value would be 1.00. An increase in the ratio indicates that the well casing released metal into the solution, while a decrease in the ratio indicates that metal was sorbed by the casing.

Results and Discussions

Approximately half of the stainless steel casings showed signs of surface rust. In some cases (SS 316 at a low pH), sufficient oxidation occurred to form a hydrous iron oxide precipitate. This precipitate was never observed in the control samples or those with PVC or PTFE casings. While the authors realize that rusting of the stainless casings is very condition-specific, the test conditions should be generally representative of shallow wells. Also, it was noticed that the casings had rusted some during storage prior to any testing.

Table 2 gives the normalized mean values and standard deviations for each analyte, well casing and time.

TABLE 2
Normalized Mean Metal Values¹ for Samples as a Function of Time

Time (hr)	Pipe	Arsenic		Cadmium		Chromium		Lead	
		Mean Value	Standard Deviation						
0.5	PVC	0.991 =	0.038	1.01 =	0.025	1.01 =	0.018	0.999 =	0.009
	PTFE	0.999 =	0.050	1.01 =	0.011	1.01 =	0.007	1.00 =	0.026
	SS304	0.997 =	0.057	1.06 =	0.056	1.01 =	0.016	1.02 =	0.008
	SS316	0.994 =	0.040	1.04 =	0.021	1.02 =	0.015	1.01 =	0.025
4.0	PVC	1.02 =	0.045	1.13 =	0.037	0.999 =	0.013	0.889 =	0.030
	PTFE	0.993 =	0.052	1.03 =	0.054	1.01 =	0.011	0.974 =	0.019
	SS304	0.978 =	0.063	1.17 =	0.15	0.957 =	0.037	0.784 =	0.035
	SS316	0.945 =	0.060	1.24 =	0.49	0.921 =	0.052	0.803 =	0.077
8.0	PVC	1.00 =	0.045	1.15 =	0.037	1.00 =	0.014	0.893 =	0.035
	PTFE	1.01 =	0.098	1.03 =	0.016	0.989 =	0.019	0.985 =	0.032
	SS304	0.962 =	0.057	1.16 =	0.14	0.972 =	0.16	0.699 =	0.031
	SS316	0.945 =	0.068	1.30 =	0.47	0.872 =	0.10	0.804 =	0.10
24.0	PVC	0.994 =	0.064	1.16 =	0.056	1.00 =	0.016	0.808 =	0.051
	PTFE	0.992 =	0.054	1.03 =	0.017	1.01 =	0.024	0.951 =	0.040
	SS304	0.894 =	0.051	1.12 =	0.12	1.03 =	0.37	0.538 =	0.042
	SS316	0.853 =	0.080	1.36 =	0.68	0.855 =	0.11	0.793 =	0.19
72.0	PVC	1.03 =	0.046	1.14 =	0.049	1.01 =	0.018	0.743 =	0.054
	PTFE	1.02 =	0.045	1.02 =	0.022	1.00 =	0.013	0.899 =	0.034
	SS304	0.891 =	0.084	1.03 =	0.14	1.03 =	0.42	0.452 =	0.061
	SS316	0.874 =	0.083	1.25 =	0.66	0.836 =	0.099	0.720 =	0.17

¹ (Concentration for samples with casing) / (Concentration for control samples) = Normalized mean value

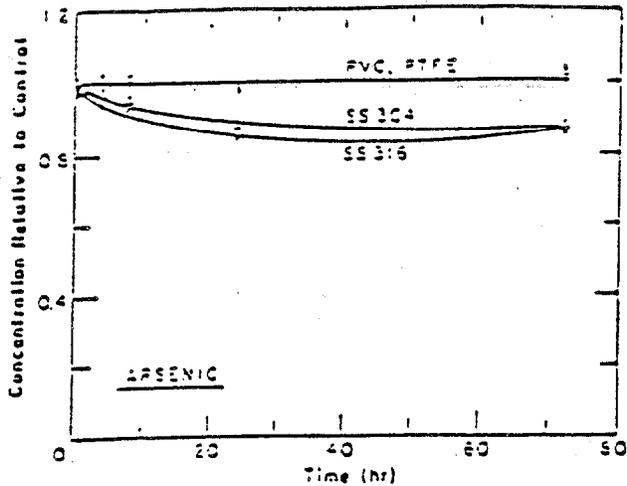


Figure 1. Trends in mean arsenic concentration for four well casing materials.

In general, there was no change in arsenic concentration for the sample solutions containing either the PVC or PTFE casings during the 72-hour test period (Figure 1), and no consistent pattern of effects was evident from the ANOVA. The reason As did not interact with these casings may be because As exists in natural waters in the anionic form (Fowler et al. 1979). Masse et al. (1981) found that anions do not strongly associate with plastic (polyethylene and PTFE) surfaces, which are known for their cation exchange capacity. The samples containing the stainless steel casings, on the other hand, showed a 10 percent decrease in aqueous arsenic concentration relative to the controls after 24 hours (Figure 1). It appears that there was no further loss of this analyte after 24 hours. Although these results cannot be used to predict exactly what losses might occur under field conditions, it is doubtful that this loss was rapid enough to impact water quality measurements (losses were less than 10 percent after eight hours).

The results for Cd are quite different. After only four hours, Cd concentrations in the samples containing PVC and stainless steel casings had increased by more than 10 percent (Figure 2), with the most leaching occurring in the samples containing the SS 316 casings. Cadmium may have been added to the PVC as a UV stabilizer (Wilson et al. 1982), and may have been added to the stainless steel to enhance resistance to chloride cracking (Sedricks 1979). The concentration of Cd in the samples containing PVC casings leveled off after eight hours. ANOVA revealed that pH had a significant effect (at the 95 percent confidence level) for this casing. Although the same amount of Cd leached in all the samples (approximately 0.5 mg/L), concentration was also significant (at the 95 percent confidence level), but only because relatively more was leached in the low-concentration samples. Concentrations in samples containing SS 304 casings decreased after eight hours and after 72 hours had returned to the same levels that were found in the control samples. Again, more Cd leached in the low pH samples. Cd was leached most rapidly in samples containing SS 316 casings. There was a large

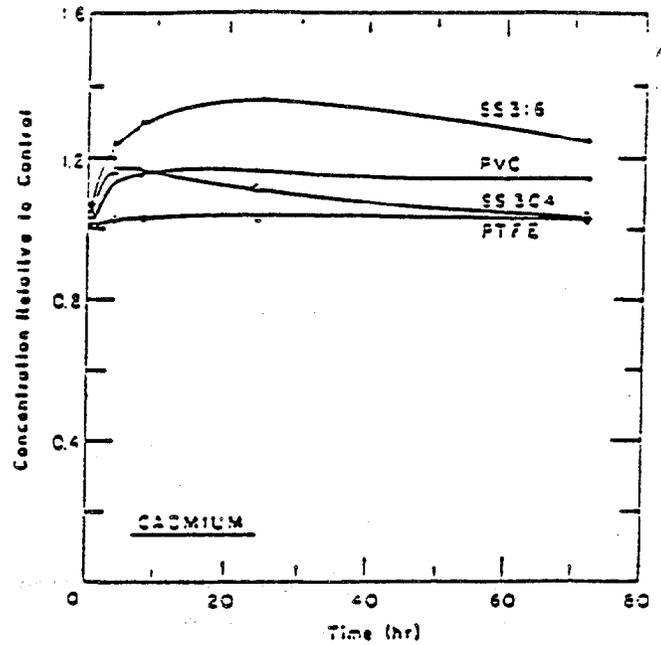


Figure 2. Trends in mean cadmium concentration for four well casing materials.

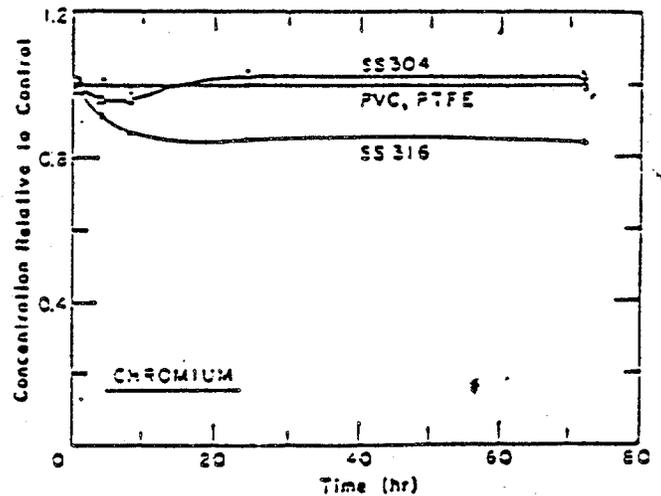


Figure 3. Trends in mean chromium concentration for four well casing materials.

samples that contained stainless steel casings. With the exception of the first set of samples ($t = 0.5$ hr), the relative standard deviations ranged from 12 to 15 percent for samples containing SS 304 and from 47 to 68 percent for those containing SS 316. In contrast, the standard deviations for samples containing PVC and PTFE casings were consistently below 6 percent. Because the variance in the samples containing SS 316 was so large, there was no consistent detectable effect of pH for these casings. However, surface oxidation appeared to be the major source of this variance. With respect to the leaching of metal stabilizers from PVC pipes, the literature indicates that loss can be a surface phenomenon that can be reduced or eliminated by either washing (with detergent) or soaking in dilute mineral acid before use (Packham 1971). It may be that the loss of Cd from PVC casings can also be reduced by a similar treatment, although we did not test this possibility.

There was no measurable sorption of chromium by

of interaction with the plastic casings may be due to chromium speciation. In solution, chromium exists predominantly as dichromate and chromate ($\text{Cr}_2\text{O}_7^{2-}$, CrO_4^{2-}) and, as mentioned previously, anions are not as likely to exchange with plastic surfaces. However, loss of chromium was rapid enough (13 percent after eight hours) for SS 316 casing material to be of concern for ground water monitoring. Losses were greater at the higher pH; Cr speciation is known to be affected by pH and may be responsible for some of these differences. Surface oxidation was greater at the lower pH, which likely contributed to the larger variability. Also, for those samples where a hydrous iron oxide precipitate was formed, co-precipitation may have contributed to the losses from solution. Again, the standard deviations were considerably greater for the samples containing the stainless steel casings. Humic acids apparently increased the stability of aqueous Cr, perhaps by acting as a complexing agent (Stumm and Morgan 1970s).

Lead was by far the most actively sorbed metal species. While all sample solutions containing casing materials showed some loss of Pb with time (Figure 4), PTFE was the least active surface and SS 304 was the most active. The losses for samples containing PTFE casings do not appear to be of concern with respect to ground water monitoring; losses were only 5 percent after 24 hours. However, losses for samples containing PVC and stainless casings are of concern: losses were 10 percent after only four hours in the samples containing PVC casings and 20 percent in those containing stainless casings. Although loss was initially rapid in samples containing SS 316 casings, it leveled off after eight hours. The standard deviation was higher for the samples containing SS 316 casings than for the other casings. For both stainless steel casings, there was less sorption of Pb at the lower pH where hydrogen ions may have competed for sorption sites. Added humic material apparently acted as a complexing agent in solution, making lead less prone to sorption. Concentration had no consistent effect.

Undoubtedly, there were shifts in the chemical equilibria of the well water solutions from the time the well water was collected until the end of the experiment. Ground water that is removed from an anoxic environment and exposed to oxygen-rich air may undergo redox and precipitation reactions (Stumm and Morgan 1970b). Also, lowering the pH shifts the carbonate equilibrium in solution from predominantly bicarbonate species toward carbon dioxide (Manahan 1972) and causes shifts in Cr speciation. Clearly, such changes would alter the trace metal species distribution. These possible changes were not monitored in this experiment.

For further details on this portion of the study, refer to Hewitt (1985).

Organic Study

Experimental

The four well casing materials were also tested for sorption/desorption of low levels of 10 organic sub-

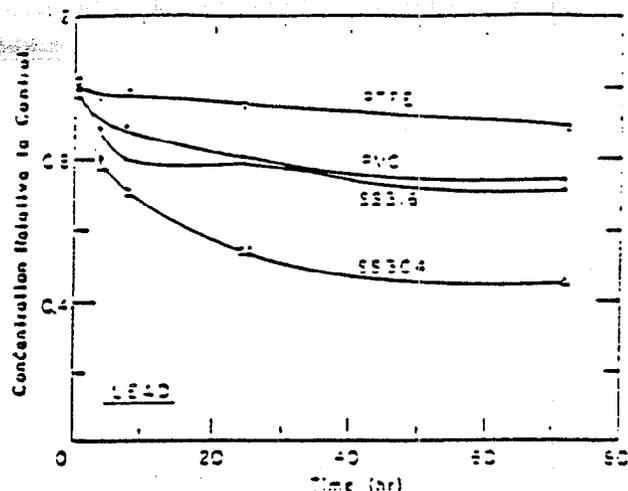


Figure 4. Trends in mean lead concentration for four well casing materials.

trinitro-1,3,5-triazine (RDX), 1,3,5-trinitrobenzene (TNB), *cis*- and *trans*-1,2-dichloroethylene (CDE and TDE), *m*-nitrotoluene (MNT), trichloroethylene (TCE), chlorobenzene (ClB), and *o*-, *p*- and *m*-dichlorobenzene (ODCB, PDCB, MDCB). The criteria used for selecting these analytes included being an EPA priority pollutant, molecular structure, solubility in water, K_{ow} value, and retention time (using reversed-phase high performance liquid chromatography [HPLC] analysis). HPLC analysis of the ground water used in these studies revealed no detectable levels of any of these substances.

For these experiments, casings were cut into 11- to 14mm-long sections, which were then cut into quarters. Again, the length was varied so that the surface area could be maintained constant. The casings were washed in solutions of detergent and deionized water, rinsed many times with deionized water, drained and left to air dry. Two pieces of each type of casing were placed in 40mL glass vials that were filled with the aqueous test solution so there was no head space, and capped with Teflon-lined plastic caps. Vials with test solution but no well casing material served as controls. These controls allowed us to eliminate any effects such as those that might be due to the vials or caps. The ratio of casing surface area to solution volume was 0.79 cm^2/mL . The ratio of solution volume to volume of casing material was approximately 10:1.

In the first experiment, the test solution was prepared by adding known amounts of each of the organic solutes directly to 2.2 L of well water in a glass-stoppered bottle, which was stirred overnight. The final concentration was approximately 2 mg/L for each organic constituent. The solution also contained 40 mg/L of HgCl_2 , which was added to prevent biodegradation of the organics. Separate vials were prepared for each sample time so that the test solution could be discarded after sampling; there were three replicate samples for each material and time. Contact times were 0 hours, one hour, eight hours, 24 hours, 72 hours (three days), 168 hours (seven days), and approximately 1000 hours (six weeks).

After an aliquot was removed for analysis from each

TABLE 3
Normalized¹ Average Concentrations of Organic Analytes for the Four Well Casings with Time

Analyte	Treatment	1 Hour	8 Hours	24 Hours	72 Hours	168 Hours	1000 Hours
RDX	PTFE	1.03	1.00	1.00	1.02	0.91	0.99
	PVC	1.01	1.00	0.98	1.00	1.02	1.00
	SS304	0.99	0.99	1.01	1.02	1.10	0.98
	SS316	1.01	0.99	1.01	1.02	1.11	1.00
TNB	PTFE	1.01	1.00	1.00	0.98	0.95	1.01
	PVC	1.01	1.00	0.98	1.02	1.01	1.02
	SS304	0.99	1.00	1.00	1.05	1.07	1.00
	SS316	1.02	0.99	1.01	1.07	1.06	1.02
CIDCE	PTFE	1.01	0.96*	0.96*	0.94	0.91*	0.79*
	PVC	1.00	0.99	0.95*	0.96	0.95	0.90
	SS304	0.97	1.00	1.00	0.96	1.04	0.98
	SS316	0.95	0.99	1.00	1.01	0.98	0.99
TIDCE	PTFE	1.00	0.92*	0.88*	0.83	0.66	0.56*
	PVC	1.00	0.98	0.93*	1.06	0.83	0.83
	SS304	0.95*	1.00	1.00	0.96	1.11	1.00
	SS316	1.00	0.99	1.00	1.12	1.03	1.00
MNT	PTFE	1.03	1.00	0.99	0.99	0.90	0.90*
	PVC	1.02	1.00	0.98	1.05	0.99	0.94
	SS304	1.00	1.00	1.01	1.00	1.08	1.07
	SS316	1.02	1.00	1.02	1.08	1.10	0.99
TCE	PTFE	1.00	0.90*	0.85*	0.78*	0.64*	0.40*
	PVC	1.01	0.98	0.94*	0.99	0.94*	0.88*
	SS304	0.96	1.00	1.01	0.96	1.04	0.99
	SS316	1.00	0.99	1.00	1.04	0.98	1.00
CLB	PTFE	1.01	0.93*	0.90*	0.85*	0.74*	0.51*
	PVC	1.01	0.98	0.95*	0.98	0.94*	0.86*
	SS304	0.98	1.00	1.00	0.97	1.05	0.99
	SS316	0.99	0.99	1.01	1.04	0.98	0.99
ODCB	PTFE	1.01	0.91*	0.88*	0.81*	0.68*	0.43*
	PVC	1.02	0.97*	0.94*	0.98	0.93	0.86*
	SS304	0.98	0.99	1.00	0.99	1.04	1.00
	SS316	1.01	0.98*	1.01	1.03	0.98	1.00
PDCB	PTFE	0.92*	0.84*	0.77*	0.64*	0.47*	0.26*
	PVC	0.95	0.95*	0.92*	0.97	0.88*	0.80*
	SS304	0.91*	0.98	1.00	0.98	1.02	1.02
	SS316	0.94	0.97*	1.00	1.04	0.97	1.02
MDCB	PTFE	1.00	0.84*	0.78*	0.66*	0.48*	0.26*
	PVC	1.02	0.95*	0.92*	0.97	0.88*	0.80*
	SS304	0.99	0.96*	1.00	0.99	1.02	1.02
	SS316	1.03	0.96*	1.00	1.04	0.96	1.01

¹ Values are determined by dividing the mean concentration of a given analyte at a given time and for a particular well casing by the mean concentration (for the same analyte) of the control samples taken at the same time.

* Values significantly different from control values ($\alpha = 0.05$)

of the 1000-hour samples, the vials were emptied and the pieces of casing were rinsed with approximately 40 mL of fresh well water to remove any residual solution adhering to the surfaces. The casing pieces were then placed in new vials, and fresh unspiked well water was added. The vials were capped with new caps and allowed to equilibrate for three days. Aliquots were then taken from these samples and analyzed to determine if desorption had occurred.

In the second experiment 2.0 g/L of NaCl was also added to the test solution to determine the effect of increased ionic strength on the rates of sorption. Sampling times were the same except that the last samples were taken after approximately 1200 hours (seven weeks).

All analytical determinations were made by reversed-phase high performance liquid chromatography. A modular system was employed that consisted of a Spectra Physics SP 8810 isocratic pump, a Dynatech LC-241 autosampler with a 100- μ L loop injector, a Spectra-Physics SPS-90 variable wavelength UV detector set at 210 nm, a Hewlett-Packard 3393A digital integrator, and a Linear model 555 strip chart recorder. Separations were obtained on a 25cm x 4.6mm (5 μ m) LC-18 column (Supelco) eluted with 1.5 mL/min of 62/38 (v/v) methanol-water. Baseline separation was achieved for all 10 analytes. Detector response was obtained from the digital integrator operating in the peak height mode. Analytical precision ranged from 0.4 to 3.98 percent, as determined by the pooled standard deviation of triplicate initial measurements.

For each analyte and sample time, a one-way analysis of variance (ANOVA) was performed to determine if the well casing material had a significant effect on analyte concentration. Where significant differences were found, Duncan's multiple range test was performed to determine which samples were significantly different from the controls.

Before the two experiments described previously were performed, a preliminary leaching study was conducted to determine if any substances that could interfere with the analytical determinations leached from the casing materials. For this study, two pieces of each type of well casing were placed in each of two vials. The vials were filled with fresh well water so that there was no headspace, capped and allowed to sit for one week. An aliquot was taken from each vial and analyzed. No detectable peaks were observed in any of the samples.

Results and Discussion

The data for the first experiment are summarized in Table 3, where the normalized concentrations for solutions containing well casings are given as a function of time. Neither type of stainless steel casing affected the concentrations of any of the analytes in solution. However, significant loss of solute did occur in the solutions that contained plastic casings. While the rate of loss differed dramatically from analyte to analyte, losses were always greater for PTFE than PVC.

For RDX and TNB there was no loss of analyte from solutions containing either plastic casing, even

after 1000 hours. There was some loss of MNT in the sample solutions that contained PTFE casings but the loss only became significant after 1000 hours (30 percent loss); there was no loss with the PVC casings. TDCE was lost much more readily in samples containing PTFE casings than was its isomer pair, ODCE (Figure 5). (The solid lines shown in this figure and Figures 6-9 were fitted manually.) Figure 6 shows the losses of TCE for the four well casings. Figure 7 shows the rate of loss of the three DCB isomers and CLB in the samples that contained PTFE casings. The order of loss was PDCB and MDCB > ODCE > CLB. While the rate of loss did not exceed 10 percent in eight hours for any of the previous solutes, it is noted that losses of PDCB and MDCB were 16 percent in eight hours and thus were rapid enough to be of concern with respect to ground

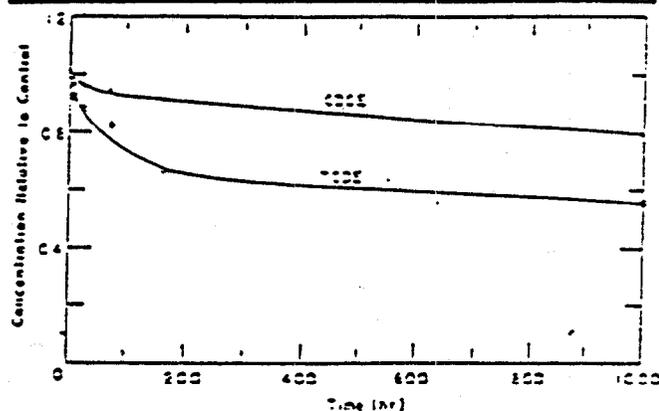


Figure 5. Sorption of ODCE and TDCE by PTFE well casings.

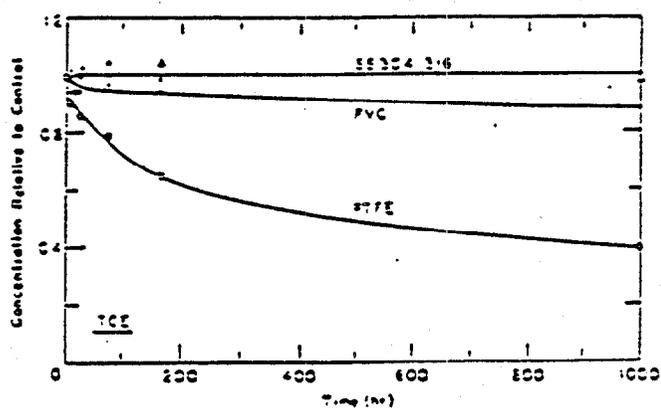


Figure 6. Sorption of TCE by the four well casing materials.

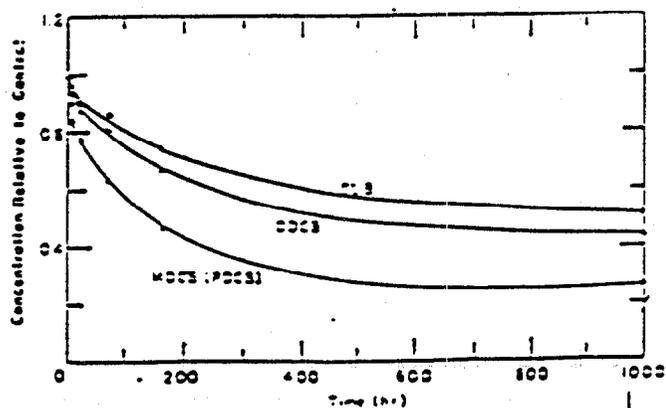


Figure 7. Sorption of CLB, ODCE, MDCB and PDCB by PTFE well casings.

TABLE 4
Results of Desorption Study

Casing Material	Concentration in mg/L after three days equilibration									
	RDX	TNB	CDCE	TDCE	MNT	TCE	CLB	ODCB	PDCB	MDCB
Teflon	ND	ND	0.20	0.43	0.075	0.47	0.23	0.33	0.30	0.35
	ND	ND	0.21	0.45	0.076	0.48	0.23	0.35	0.34	0.36
	ND	ND	"	"	0.074	"	"	"	"	"
PVC	ND	ND	0.079	0.15	0.046	0.14	0.10	0.15	0.17	0.18
	ND	ND	0.080	0.14	0.046	0.14	0.10	0.15	0.16	0.21
	ND	ND	0.080	0.15	0.043	0.13	0.11	0.16	0.16	0.20

* Results not presented because of additional loss of volatiles, probably resulting from a loose cap on this vial.
ND = Not detected.

water monitoring. For PVC, losses never reached 10 percent in eight hours for any of the organics tested, and thus the authors believe that PVC is clearly superior to PTFE for wells where water samples will be analyzed for organic constituents.

To determine if the loss of organic solutes was reversible, the pieces of casing that had been exposed to test solution for 1000 hours were rinsed and then exposed to fresh well water for three days. Measurable quantities of all the organics were recovered where significant losses had been observed (Table 4). Thus, loss was due to sorption and was at least partially reversible. Although this experiment did not give us information on the kinetics of desorption, the amount of analyte desorbed after three days generally paralleled the amount sorbed. However, PDCB and MDCB were sorbed to the greatest extent while TCE and TDCE were desorbed to the greatest extent. Therefore, it may be that diffusion out of the polymer is more rapid for smaller molecules.

In the second experiment NaCl was added to raise the chloride concentration above 1000 mg/L. High chloride concentrations are known to corrode 304 stainless steel. Specifically, tests were performed to determine if rusting would alter the sorptivity of the stainless steel surfaces. It is also possible that sorption on plastic materials would change with increasing ionic strength of the test solution.

While addition of NaCl caused rapid rusting of both stainless steel casings (<24 hr), it did not cause sorption of any of the organic solutes by them. In addition, the increased ionic strength had no detectable effect on the rate of sorption by either plastic casing (for example, Figures 8 and 9). These two figures also demonstrate the excellent reproducibility of the results from these two experiments.

Modeling the Sorption Process

These organic studies clearly demonstrated that the loss of organic chemicals from solutions exposed to plastic casing materials is via some reversible sorption process. However, it was uncertain whether this loss was due to sorption on the surface or whether there was

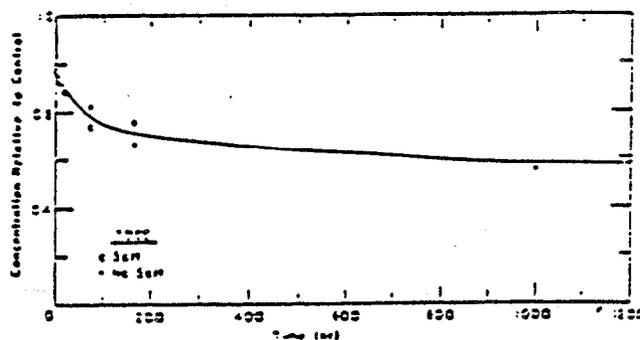


Figure 8. Sorption of TDCE by PTFE well casings in the presence and absence of salt.

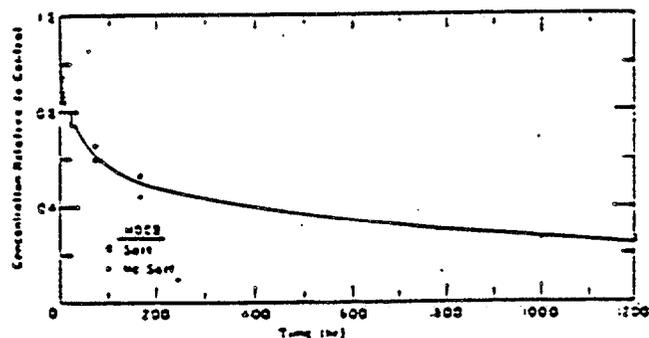


Figure 9. Sorption of MDCB by PTFE well casings in the presence and absence of salt.

penetration into the polymer matrix. The rate of sorption was found to be slow, with no established equilibrium after hundreds of hours. One explanation for this slow rate was that penetration into the polymer was occurring, with the rate controlled by slow diffusion within the bulk polymer and/or the rate of penetration into the small pores on the polymer surface. If it is assumed that this is the case, the process can be kinetically modeled by treating the plastic casing as an immiscible liquid phase in contact with water and relating the degree of partitioning for individual analytes to their octanol/water partition coefficients (K_{ow}). While there are immiscible liquids other than octanol that are better structural models for PTFE or PVC, the most extensive collection of partition coefficients is available for octanol.

If it is assumed that sorption is a reversible process,



and is first order in both directions, then the rate equation can be written as (Gould 1959):

$$\frac{d[A_w]}{dt} = -k_1[A_w] - k_2[A_p] \quad (2)$$

where $[A_w]$ is the concentration of solute A in aqueous solution, $[A_p]$ is the concentration of solute A in the plastic casing material, and k_1 and k_2 are the first-order rate constants for sorption and desorption, respectively.

Integration of the rate equation results in a non-linear relationship for A_w as a function of time t and two constants a and b (Equation 3), where a and b are defined in Equations 4 and 5:

$$\ln \frac{(a[A_w] - b)}{a} = -kt \quad (3)$$

$$a = k_1 + k_2 \quad (4)$$

$$b = 10k_2[A_0] \quad (5)$$

where A_0 is the initial concentration of solute A in aqueous solution.

Optimal values for a and b were obtained for each solute exposed to PTFE by application of the Gauss-Newton method of non-linear curve fitting using the measured concentrations at 1, 8, 24, 72, 128, and 1000 hours (Parker et al. 1989). Using determined values for a and b , the authors simultaneously solved Equations 4 and 5 for each solute to obtain estimates of k_1 and k_2 . Because the process described is assumed to be reversible and first order, the ratio of the rate constants, k_1/k_2 , is the equilibrium constant, K_{eq} .

When the eight values of K_{eq} were plotted vs. $\log K_{ow}$, six of the eight points appeared to fall on a straight line, while the points for MNT and ODCB did not (Figure 10). The poor fit for MNT and the lack of significant sorption for TNB and RDX can be explained by the tendency of nitro-containing organic molecules to form strong hydrogen bonds, which keeps them in solution. While octanol can be a donor in hydrogen bonding, PTFE cannot. Thus, if the authors predict partitioning into PTFE for these molecules based on their octanol/water coefficients, the amount of sorption for these types of compounds will be overestimated.

The poor prediction for ODCB can be explained by the well-documented "ortho effect," which is a complex combination of electronic and steric interactions that often results in ortho di-substituted aromatic molecules behaving much differently than the meta- and para-isomers.

A similar model predicting the loss of analyte for PVC was not created because the percent sorbed was small when compared with the experimental error and this would produce an unacceptable degree of uncertainty in the calculated rate constants.

Therefore, it is concluded that for hydrophobic

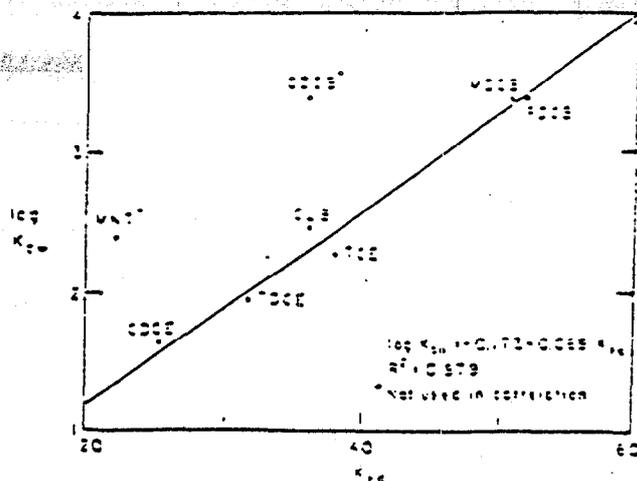


Figure 10. Correlation between $\log K_{ow}$ and K_{eq} for solutes exposed to PTFE casings.

organic molecules that are not subject to hydrogen bonding, the relationship presented in Figure 10 can be used to estimate the equilibrium partitioning of an analyte between the aqueous phase and PTFE. It is expected that losses in new wells would occur for some time until equilibrium with the water is achieved.

While K_{eq} will determine the equilibrium concentrations of each analyte in the water and plastic phases, it is the magnitude of k_1 that will determine how quickly various analytes are depleted. For small, planar molecules like TCE, the k_1 values are quite high compared to the other analytes. This may explain the rapid loss of tetrachloroethylene from solutions containing PTFE casings observed by Miller (1982) and Reynolds and Gillham (1986).

Because the rate of sorption appears to be first order, the relative concentration (concentration at a given time relative to its initial concentration) is independent of initial concentration (Castellan 1964). Thus, the percent loss at a given exposure time is expected to be independent of concentration, as was also predicted by the model of Reynolds and Gillham (1986). We did not confirm this, however, by conducting the test at several concentrations.

For further details on the organic portion of this study, refer to Parker et al. (1989).

Summary and Conclusions

In summary, the inorganic study indicated that three of the metals (As, Cr and Pb) were sorbed by one or more of the casing materials. Specifically, Cr was sorbed by SS 316 casings, As was sorbed by both 304 and 316 stainless steel casings, and Pb was sorbed by all four casings. On the other hand, Cd leached from the stainless steel and PVC casings, although subsequent sorption lowered concentrations in the samples containing stainless steel casings. While sorption of As was slow enough that it is probably not of concern for ground water monitoring, the changes in the Cr, Cd and Pb concentrations are of concern. Both SS 304 and 316 casings were subject to surface oxidation, presumably by galvanic action, which apparently provided active sites for sorption and release of major and minor constitu-

ents. Sorption and leaching of metal species was affected in some cases by the ground water composition (pH and organic carbon content). Specifically, there was more leaching of Cd and less sorption of Pb at the lower pH. Our results indicate that humic material may have acted as a complexing agent, making lead and chromium less prone to sorption. If chemical interactions are used as the only criterion, PTFE is clearly the best candidate for monitoring metal species in ground water. PVC would be a good second choice because its performance was considerably better than either SS 304 or SS 316 casing.

In contrast, the organic studies clearly indicated that PTFE was the poorest choice of the four well casing materials tested. PTFE casings sorbed all the chlorinated compounds and one nitroaromatic compound, and losses of PDCB and MDCB were rapid enough to be of concern for ground water monitoring. PVC casings also sorbed some of the same compounds, but always at rates that were considerably slower than those observed for PTFE casings. The rates of these losses on PVC were slow enough that they did not appear to be of concern for ground water monitoring. There was no loss of any of the organic solutes in the presence of either type of SS casing.

The desorption study showed that the loss of organics from aqueous solution is due to a sorption process that was reversible, or at least partially so. Desorption from contaminated casings could potentially result in falsely high concentrations of analytes if the concentrations of the analytes in the ground water were to drop.

The loss of hydrophobic organic constituents in the samples containing PTFE casings could be correlated with the substance's K_{ow} values. However, this correlation overestimates losses for hydrophilic organic substances.

There are several effects that make extrapolating these test data to a real monitoring situation difficult:

- Casings were tested and not well screens. The rate of sorption could be substantially greater in the screened portions of the well because the surface area of the screened portion would be greater.
- This experiment was conducted under static conditions. The effect of sorption under real conditions would be mitigated to some degree, depending on the rate of exchange of water between the aquifer and well casing.

Clearly, choosing one casing material for samples that will be analyzed for both trace metals and organics involves compromise. However, based on the results of the tests that the authors have performed to date, PVC appears to be the best compromise choice of the four casing materials tested.

Future studies will examine leaching of inorganic and organic solutes, the effect of low dissolved oxygen on interactions between the metals and well casings, and the suitability of other materials for ground water monitoring.

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Biographical Sketches

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APPENDIX B

FIELD METHODS AND PROCEDURES

STANDARD OPERATING PROCEDURES

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ISSUING UNIT: ABB-ES
SOP: FXRF-001-02
DATE: 12-30-91

REVIEWED BY: _____

APPROVED BY: Bob Burger

TITLE: Field Screening Analysis of Inorganic Compounds by X-ray Fluorescence.

SCOPE: These procedures describe the preparation and analysis of environmental samples for inorganic compounds using X-ray fluorescence (XRF). Elements to be analyzed using this technique are project specific and will be selected by project site chemist prior to field screening activities. This method is used when quantification of specific inorganic compounds at mid-part per million to percent level detection is required.

1.0 REQUIREMENTS: APPARATUS AND MATERIALS

INSTRUMENTATION: Field portable XRF unit (energy dispersive). Units can be equipped with a number of radioisotopic detectors sources for detection of elements across varying spectral ranges.

MATERIALS:

1. Sample cups
2. Mylar windows
3. Spatulas (plastic or teflon coated)
4. Grinding apparatus (mortar/pestle)
5. Sieve
6. Blending apparatus
7. Analytic balance
8. Weighing pans
9. Drying oven
10. Micro variable pipet (with tips)
11. 100ml volumetric flasks
12. Analytical standards

2.0 CONVENTIONS

Field screening activities will follow established guidelines for coding standards, logbook entries, calculations and quality assurance/quality control. Deviations from these guidelines will not be allowed without the issuance of a written variance or field change request. Logbook entry(s) detailing the reason(s) for the deviation(s), and a verbal discussion with the project chemist or qualified representative.

2.1 CHEMICAL STANDARDS

A. AQUEOUS: Aqueous chemical standards will be purchased through Sig Co., Aldrich Chem. Co., VWR, or an equivalent supplier.
Note: Stock aqueous standards are generally 1000ppm in concentration and are AA or ICP certified.

Documentation of standard concentrations (aqueous) should accompany the standards, along with project logbook entries entailing the following information.

1. Vendor name(s)
2. Concentration of standard(s)
3. Dilution records and calculations derived from stock standard(s) and associated concentration(s)
4. Lot number(s) of standard(s)
5. Code assigned to standards
6. Standard(s) expiration date

- B. SOLIDS: Solid reference standards will be purchased through USGS, CANMET, NES, HNU or an equivalent supplier. Site and/or matrix specific standards may be used, only when accompanied by analytical data (AA or ICP) supporting the site standards concentration and reproducibility.

2.2 STANDARDS PREPARATIONS

- A. AQUEOUS: Aqueous working/calibration standards will be prepared from single or multi-element stock solutions purchased from approved supplier. Working standards will be prepared at concentrations over the expected range of contamination on site.

Standards will be labeled, coded, and stored in appropriate containers. Standards preparation materials will be cleaned with 20% HNO₃ followed by three consecutive rinses with type II deionized water.

Standard codes and summary of standards preparation will be entered into project the logbook prior to analysis. New working standards will always be prepared whenever the quality of the standard(s) are in question.

Note: Shelf life (aqueous std's)

1. Stock standards: 2 yrs.
2. Calibration standards: 6 months

Note: Aqueous working/calibration standards should be stored in level II pre-cleaned, screw cap plastic bottles or precleaned (HNO₃/DI), snap cap volumetric lasks (short term storage). CAP AND TIGHTEN STANDARD BOTTLES IMMEDIATELY AFTER USE.

Note: 1-2% of concentrated HNO₃ or HCL (element dependant), WILL BE ADDED to the working/calibration standards during initial preparation, for standards matrix and concentration stability.

2.2 STANDARDS PREPARATION (cont.)

B. SOLIDS:

1. Purchased: Reblend every 4-6 months.
2. Site prepared:
 - a. Dry 40-50grams of sample
 - b. Disaggregate
 - c. Sieve -80mesh ..
 - d. Blend: >1hr
 - e. Split (20-30grams) off to lab (AA/ICP)
note: 4 sample min. , 3 lab runs each.

3.0 CALIBRATION

Prior to analysis, instrument operating conditions will be established and recorded in site logbook.

Calibration of XRF will be performed in two steps.

1. Energy Calibration (micro-channel/ energy alignment)
(See manufacturer's operations manual)
2. Standards Calibration: One to thirty standards can be use to calibrate the instrument. Calibration can be completed before or after the job, depending on time restraints put forth. For practical purposes a minimum of three standards will be used for instrument calibration covering the expected range of contamination on site.

4.0 QUALITY CONTROL

In addition to instrument calibration, continuing calibration checks (one per 24 hr period), duplicates, and MS/MSD may be analyzed. The number QA/QC samples will be determined and established on a site specific basis dependent upon project data quality objectives.

Energy calibration will be done at the start of the project, after servicing, or anytime conditions are in question.

5.0 METHOD DETECTION LIMITS

Method detection limits will be established on an annual basis, extrapolated from aqueous standards at or near instrument detection limits. Practical quantification limits will be established based on data generated from the MDL study.

6.0 SAMPLE PREPARATION

A. Aqueous samples

1. Pour out 2-4mls of sample into sample cup
2. Mylar and analyze (run time >200sec)

B. Solid samples

1. Dry samples at @85 degrees centigrade (>4 hrs.)
2. Grind and/or sieve samples with 30-60mesh sieve
note: sieving is mandatory on medium to coarse grained sands and nonrepresentative objects (i.e leaves, twigs, and cobbles >1-2mm in diameter).
3. Homogenize sample (blend 2-3min.)
4. Pour off 1-6grams of sample into samples cups, mylar.
5. Run times will be no less than 200 seconds.
6. Slit sample for laboratory analysis (if required).

***IMPORTANT NOTE: AQUEOUS SAMPLES WILL ONLY BE ANALYZED, IF SUFFICIENT METALS CONTAMINATION IS PRESENT. TYPICAL CONCENTRATION LEVELS IN WATERS ARE NOT DETECTABLE BY X-RAY FLUORESCENCE DUE TO INSTRUMENT DETECTION LIMITS. PROJECT CHEMIST AND TECHNICIAN SHOULD REVIEW EXISTING DATA FROM SITE BEFORE MAKING A DECISION.

7.0 FIELD DOCUMENTATION PROCEDURES

A log of all analytical runs will be recorded in a bound logbook with sequentially numbered pages. A separate logbook will be maintained for each instrument used in the field. The logbook will be used to record all standards and sample analyses, sample IDs, date of analysis and any additional information particular to the analysis (e.g. sample volume and weight, color, odor).

Individual sections in the front of the logbook will be designated for recording information on standards preparation, instrument maintenance, and instrument operating conditions.

8.0 DATA REVIEW AND DELIVERABLES

Data from all sample analysis and other relevant information will be recorded in a dedicated instrument specific logbook. The field operator will review screening data for accuracy of continuing calibration and potential matrix interferences. Data summary table may be generated as required for each project. Data will undergo periodic technical review by the project chemist assigned to the project.

METHOD 4020

SOIL SCREENING FOR POLYCHLORINATED BIPHENYLS BY IMMUNOASSAY

1.0 SCOPE AND APPLICATION

1.1 Method 4020 is a procedure for screening soils to determine when total polychlorinated biphenyls (PCBs) are present at concentrations above 5 mg/Kg. Method 4020 provides an estimate for the concentration of PCBs by comparison with a standard.

1.2 Using the test kit from which this method was developed, 95 % of samples containing 0.525 ppm or less of PCBs will produce a positive result in the 5 ppm test configuration.

1.3 In cases where the exact concentration of PCBs are required, quantitative techniques (i.e., Methods 8080/8081) should be used.

2.0 SUMMARY OF METHOD

2.1 Test kits are commercially available for this method. The manufacturer's directions should be followed. In general, the method is performed using an extract of a soil sample. Sample and an enzyme conjugate reagent are added to immobilized antibody. The enzyme conjugate "competes" with PCBs present in the sample for binding to immobilized PCB antibody. The test is interpreted by comparing the response produced by testing a sample to the response produced by testing standard(s) previously.

3.0 INTERFERENCES

3.1 Chemically similar compounds and compounds which might be expected to be found in conjunction with PCB contamination were tested to determine the concentration required to produce a positive test result. These data are shown in Table 1.

4.0 APPARATUS AND MATERIALS

4.1 PCB Test Kit (EnSys, Inc.), or equivalent. Each commercially available test kit will supply or specify the apparatus and materials necessary for successful completion of the test.

5.0 REAGENTS

5.1 Each commercially available test kit will supply or specify the reagents necessary for successful completion of the test.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 See the introductory material to this chapter, Organic Analytes, Section 4.1.

6.2 Soils samples may be contaminated, and should therefore be considered hazardous and handled accordingly.

7.0 PROCEDURE

7.1 Follow the manufacturer's instructions for the test kit being used. Those test kits used must meet or exceed the performance indicated in Tables 2-4.

8.0 QUALITY CONTROL

8.1 Follow the manufacturer's instructions for the test kit being used for quality control procedures specific to the test kit used. Additionally, guidance provided in Chapter One should be followed.

8.2 Use of replicate analyses, particularly when results indicate concentrations near the action level, is recommended to refine information gathered with the kit.

8.3 Do not use test kits past their expiration date.

8.4 Do not use tubes or reagents designated for use with other kits.

8.5 Use the test kits within the specified storage temperature and operating temperature limits.

8.6 Method 4020 is intended for field or laboratory use. The appropriate level of quality assurance should accompany the application of this method to document data quality.

9.0 METHOD PERFORMANCE

9.1 A study was conducted using fourteen standard soils and three soil samples whose PCB concentration had been established by Method 8080. Replicates were run on seven of the standard soils and on one of the soil samples for a total of 25 separate analyses. Each of two different analysts ran the 25 analyses. Results indicated that "<" assignments are accurate with almost 99% certainty at the 5 ppm level while ">" assignments can be up to about 96% accurate as the sample concentration approaches that of the testing level. Corresponding certainties at the 5 ppm level are 92% and 82% respectively. Tables 2 and 3 summarize these results.

10.0 REFERENCES

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DRAFT

Table 1
Possible Soil Interferences*

Compound	Soil Equivalent Concentration (ppm) Required to Yield a Positive Result
1-Chloronaphthalene	10,000
1,2,4-Trichlorobenzene	10,000
2,4-Dichlorophenyl-benzenesulfonate	1000
2,4-Dichloro-1-naphthol	>10,000
Bifanox	
Diesel fuel	>10,000
Pentachlorobenzene	>10,000
2,5-Dichloroaniline	>10,000
Hexachlorobenzene	>10,000
Gasoline	10,000
Dichlorofenthion	10,000
Tetradifon	125

* Ensys, Inc. publication

DRAFT

Table 2
Estimated Error Rates for 5 ppm Dilution

True Value (ppm)	0	1	2	3	4	5	6	7	8	9	10	20
Estimated Rate of False Positives (%)	1.3	13.2	39.2	65.2	82.3	-	-	-	-	-	-	-
Estimated Rate of False Negatives (%)	-	-	-	-	-	3.5	4.1	2.0	1.0	0.5	0.3	<0.1

Table 3
Estimated Error Rates for 50 ppm Dilution

True Value (ppm)	0	10	20	30	40	50	60	70	80	100
Estimated Rate of False Positives (%)	0	7.9	46.0	65.0	87.3	95.6	-	-	-	-
Estimated Rate of False Negatives (%)	-	-	-	-	-	1.7	0.7	0.3	0.2	<0.1

Table 4
 Comparison of Immunoassay¹ with GC

Sample ID	Screening Test Results	GC Results	Does screening test agree with GC/MS determination?
101	<5 ppm	<0.5 ppm	yes
284	<5 ppm	<0.5 ppm	yes
292	<5 ppm	<0.5 ppm	yes
199	<5 ppm	0.5 ppm	yes
264	<5 ppm	1 ppm	yes
257	<5 ppm	1.8 ppm	yes
259	<5 ppm	4 ppm	yes
265	<5 ppm	4.5 ppm	yes
200	<5 ppm	5 ppm	yes
170	5-50	5.8 ppm	yes
193	<5 ppm	2.2-5.8 ppm	yes
172	5-50	6.2 ppm	no
169	5-50	7.2 ppm	yes
171	5-50	7.2 ppm	yes
202	<5 ppm, 5-50	1.3-7.2 ppm	yes
163	5-50	8.1 ppm	yes
165	5-50	9 ppm	yes
168	5-50	9 ppm	yes
166	5-50	9.3 ppm	yes
164	5-50	11.9 ppm	yes
204	5-50	12.9 ppm	yes
255	5-50	13 ppm	yes
203	5-50	13.5 ppm	yes
105	5-50	15 ppm	yes
103	5-50	15-19 ppm	yes
161	5-50	15.3 ppm	yes
167	5-50	16.2 ppm	yes
247	5-50	18 ppm	yes

Table 4
Continued

Sample ID	Screening Test Results	GC Results	Does screening test agree with GC/MS determination?
148	>50	18-34 ppm	no
205	5-50	20 ppm	yes
162	5-50	20.4 ppm	yes
175	5-50	21.2 ppm	yes
176	5-50	21.6 ppm	yes
197	5-50	32 ppm	yes
243	5-50	32 ppm	yes
252	5-50	32 ppm	yes
178	5-50	43.7 ppm	yes
201	5-50	43 ppm	yes
254	5-50, >50	56 ppm	yes
238	>50	46-60 ppm	yes
248	5-50	60 ppm	yes
250	>50	68 ppm	yes
242	5-50	32-69 ppm	yes
256	>50	75 ppm	yes
249		96 ppm	yes
245	>50	102 ppm	yes
241	5-50	154 ppm	no
246		154 ppm	yes
261	>50	204 ppm	yes
260	>50	251 ppm	yes
267	>50	339 ppm	yes
	>50	460 ppm	yes
107	>50	200-3772 ppm	yes
108	>50	531-1450 ppm	yes

* for PENTACHLORISc Test Kit (EnSys, Inc.)

STANDARD OPERATING PROCEDURES

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Page 1 of 6

TITLE: Infrared Spectroscopy Analysis of Petroleum Hydrocarbons by Field Screening

SCOPE: The following procedure describes preparations and analysis for petroleum hydrocarbons by infrared spectroscopy. This method is adapted from USEPA Method 418.1, with a modified micro extraction for analysis of soils. This field analysis technique is best utilized for gross characterization of fuels such as JP4, kerosene, No. 2 fuel oil, and related hydrocarbons. Detection limits range from 50 ppm to percent levels as total petroleum hydrocarbons.

REQUIREMENTS: Apparatus and Materials

APPARATUS:

Analysis will be done using a miran fixed filter infrared detection unit, or an equivalent instrument. The instrument should have capabilities for variable wavelength adjustment, a sensitivity adjustment, range adjustment, slit adjustment and direct measurements in absorbance units and/or percent transmittance.

MATERIALS:

- cuvettes: 1 cm quartz cuvettes
- test tubes: 16 X 100, screw cap w/ teflon liner
13 X 100, screw cap w/ teflon liner
test tube rack (2)
- pipettes: 1 ml grade A volumetric
5 ml grade A volumetric

- 10 ml grade A volumetric
- 1-10 ml transfer type (4)
- 1-10 ml adjustable pipette pump
- syringes: 10 ml, 50 ml, 1 ml, (Supelco)
- additional equipment:
 - vortex
 - centrifuge
 - oven (% solid)
 - aluminum pans (% solids)
 - analytical balance (grams to 0.01g)
 - lab notebook
- reagents:
 - Freon 113 (1,1,2- trichloro-1,2,2 trifluoroethane)
 - sodium sulfate (Na_2SO_4) anhydrous, ACS grade
 - silica gel (40-140 mesh) (reagent analyzed)
 - water (deionized H_2O)
- standards:
 - n-hexadecane
 - (stock sol.) isoactane
 - chlorobenzene

CONVENTIONS: To aid in organization, all field screening activities will follow strict QA/QC guidelines for coding standards, logbook entries, calculations, and quality control. Deviations from the guidelines outlined in this

document will not be allowed without the issuance of a written field change request, a logbook entry detailing the reason(s) for any deviation(s), and a verbal discussion with the project chemist.

CHEMICAL STANDARDS:

All chemical standards will be purchased through Supelco, Inc., Chem Services, Inc. or an equivalent supplier. All chemical standards preparation(s) will be logged and coded in the project logbook E.G. FIRSTD-001-01. Minimum entries are as follows:

- a. vendor's name supplying standards
- b. concentration of standards prepared
- c. calculations performed in deriving standard(s) concentrations
- d. lot number of standards
- e. code assigned to standards (e.g. FIRO101910301 (FIR-date-page-which std on page))

STANDARD PREPARATION:

Standards may be prepared from stock solutions (neat) purchased through an approved supplier. Working standards may be made by diluting neat standards into Freon 113. Use the compound(s) density to determine quantity of neat compound to add to solvent. Calibration standards will be made by serial dilutions of the working standards. The calibration standard concentrations will be determined by the expected chemical concentrations on site. Generally, 10,50,100,500, 750 ppm concentrations are appropriate.

- all stoichiometry must be entered into logbook as well as a written description as to how calibration concentrations were made.

CALIBRATION:

INITIAL CALIBRATION

Once instrument has been zeroed, one at a time, pour to fill line on cuvette some of each of the calibration standards. For each calibration standard record the % transmittance or absorbance from the instrument. If the RSD is less than or equal to 30% for the calibration points, then

a straight line may be assumed and linear regression used. If the RSD exceeds 30%, then a calibration curve may be plotted.

CONTINUING CALIBRATION

The continuing calibration is a mid-level standard that must be analyzed and recorded before analyzing samples. If at any time the continuing calibration deviates more than 30% from the original calibration, the initial calibration standards must be reanalyzed.

METHOD BLANK

A method blank must be run before analyzing samples. The method blank should be prepared as a sample and analyzed after the instrument is zeroed.

SAMPLE EXTRACTION

ANALYZATION: EXTRACTION (SOIL)

The extraction of soils involves a two-fold process. First, weigh $2.0g \pm 0.5$ of sample into a 16 x 100 screw cap test tube and record weight. Add approximately 2 grams of anhydrous sodium sulfate (Na_2SO_4) and thoroughly mix to a dry, free-flowing constituency. Then add 10 ml of Freon 113 to sample, cap and vortex for 30 seconds. Next, decant off solvent into a 16 x 100 test tube, add approximately 2 grams of silica gel, cap, vortex for 30 seconds and centrifuge.

ANALYSIS

Pour sample extract in quartz cuvette from (3.1 extraction). Place cuvette in unit, and read. The value will be in concentration units. Multiply the concentration number by the dilution factor; in this case it is (5) (2 grams of sample into 10 mls of freon). Record value in logbook.

CALCULATIONS: $mg/kg \text{ of TPH} = \frac{(\text{conc. from IR Unit } \mu g/ml)(10 \text{ ml Freon})}{(\text{sample wt. } 2.0g)(\text{dec. } \% \text{ solids})}$

DATA REVIEW: All data will be documented in project notebook. The project field chemist will review all notebooks for accuracy, neatness, and completeness. Sample data results will be released by the field chemist to the designated field leader as requested.

REFERENCES

Petroleum Hydrocarbons, Total Recoverable. USEPA Method 418.1 (Spectrophotometric, Infrared).

Laboratory application data 001.016, miran fixed filter laboratory analyzer (Foxboro), monitoring hydrocarbons in water.

A comparison of methods for measuring total petroleum hydrocarbons in soil, Nan Thomey, David Bratbert, Applied Earth Sciences, Inc., Houston, Texas and Cathie Kalisz, Star Enterprise, Irving, Texas.

STANDARD OPERATING PROCEDURE

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Page 1 of 4

TITLE: Field Screening of Soil and Water Samples for VOCs Using Portable Gas Chromatographs

PURPOSE: To describe the procedure for GC screening of samples in the field for volatile organic compounds, in order to assure consistency of technique between operators.

SCOPE: This procedure is applicable to field projects in which fast, accurate identification of underground contaminants is necessary in order to make decisions concerning placement of soil borings and monitoring wells in the process of plume definition. This procedure is not intended to replace the GC operator's manuals.

REQUIREMENTS: Field screening for volatile organic compounds by headspace technique requires the operator to be thoroughly familiar with the instrument used and the careful handling of samples and standards. The operator should have an understanding of the principles of gas chromatography, and should read and understand the operator's manual for the instrument they are using. A new GC operator should apprentice with an experienced operator for one week of field analysis before working independently. The instrument used should be equipped with a photoionization detector (PID).

PROCEDURE: Keeping in mind a few general tips will help the field GC operator greatly in terms of saved time and money. These are listed below.

- o Always keep carrier gas flowing through the column, even when the GC is not being used. The flow rate can be decreased to conserve gas when the instrument is sitting at the office in between field jobs.
- o Never heat up the oven without carrier gas flow through the column.
- o Change the injection septum at the beginning of each analysis day. Before doing so, temporarily turn off the carrier gas flow at the supply tank, and

allow the gas to bleed through the line before opening the injection port. Try to avoid touching the injection septa with bare fingers.

- o Get the GC plugged into a power source, turned on, and warming up as soon as possible each day, as it takes some time for the instrument to stabilize.

Standards

Standards should be prepared with deionized or distilled water in 40 ml VOA vials with teflon septum caps. The liquid standards should be prepared in 1ppb, 10ppb, 100ppb, and 1000ppb (1ppm) concentrations, with a total liquid volume of 30 mls per vial. The standards should be added to each vial by dipping the end of the syringe needle below the water level and then injecting the standard mixture into the water. Cap the vial tightly and mix by inverting three times. Once a standard vial has been prepared, it should never be opened. Store vials of aqueous standards upside down on ice. Prepare fresh aqueous standards each day.

Each day, after ruling out system and equipment contamination through the analysis of blanks, the 10 ppb standard should be run. The standard vial should be allowed to come to ambient temperature by removing it from the ice and allowing it to sit out for 10 minutes, upside down. The standard vial should then be shaken vigorously for one full minute. After shaking, 200 ul of headspace should be withdrawn from the vial with a clean, 250 ul gastight syringe. The withdrawn headspace should immediately be injected onto the chromatographic column. Once all of the peaks have eluted and been integrated, response factors can be calculated by dividing the concentration of each compound by its reported response in area counts or volt-seconds. After analyzing a clean syringe blank, the analyst should analyze the 100 ppb standard in the same manner as above. If the analyst expects to encounter samples with more than 100 ppb of the target compounds, the 1 ppm standard must be analyzed, at a less sensitive gain or attenuation. All standard runs should be tabulated, reporting compounds, retention times, concentrations, response in area counts, and response factors (concentration + area counts). An example

standard reporting table is shown below.

<u>COMPOUND</u>	<u>RT (SECS)</u>	<u>CONC. (PPB)</u>	<u>AREA (V-S)</u>	<u>RF (CONC/AREA)</u>
benzene	60.2	10	1.3	7.69

Samples

All sample analyses must be quantitated against the aqueous standard, which is made to a total volume of 30 mls. If the sample cannot be analyzed immediately after collection, then it should be stored on ice until just prior to analysis. Samples should never be prepared ahead of time.

To prepare liquid samples, the operator must remove enough sample so that 30 mls total volume remains in each 40 ml sample vial. This can be easily accomplished by using a 30 ml "reference vial", a sealed 40 ml VOA vial that contains 30 mls of water. The sample vial can be held beside the reference vial, and with an indelible marker, the 30 ml water level can be marked on the sample vial. To remove the extra liquid, open the lid to the sample vial and "flick out" some of the liquid until the liquid level in the sample vial is at the mark. Quickly recap the vial. All of this must be carried out so that the sample vial is open for a minimal amount of time.

To prepare soil samples for analysis, the operator must weigh the soil on a scale that has been calibrated, and tared with an empty

40 ml VOA vial. To remove extra soil, open the cap and "flick out" the excess. Quickly recap the vial. The vial should contain 30 grams of soil plus or minus 0.5 gram. If the GC operator receives a soil sample that already contains less than 30 g., the analytical result must be adjusted to account for the dilution. This can be accomplished by dividing 30 by the number of grams of sample, and multiplying the analytical result by the number found. For example, if the sample weighs 26 g. and the calculated analytical result for

benzene is 12ppb, then:

$30 \div 26 = 1.15$; $12 \times 1.15 = 13\text{ppb}$ benzene

Using the 30 ml reference vial as a guide, mark the 30 ml water level on the outside of the soil sample vial. Open the lid to the sample vial and carefully add D.I. water until the liquid reaches the 30 ml mark. Tightly cap the sample vial. All of this should be carried out so that the sample vial is open for a minimal amount of time.

The prepared liquid or soil sample should be shaken vigorously for one full minute. If the sample contains soil, it must be rinsed from the inside of the septum before the syringe needle is inserted into the headspace, in order to avoid clogging the needle. This can usually be accomplished by "flicking" the vial so that liquid splashes onto the septum. Withdraw 200 ul of headspace from the vial with a clean 250 ul gastight syringe, and immediately inject it onto the chromatographic column. After injecting the sample onto the column, watch the beginning of the chromatographic run for the customary injection peak. If one is not seen, the needle is probably clogged and the sample will have to be rerun.

If a sample is known to be contaminated, a smaller volume can be injected. Whenever the injected sample volume is less than the injected standard volume, the calculated value of any compound seen must be multiplied by the dilution factor of the sample. For example, if 200 ul of standard was injected and 50 ul of sample was injected, all analytical results from the sample run must be multiplied by four. All sample analytical results are arrived at by multiplying the area count of the compound of interest by the response factor of the corresponding peak in the standard.

Compounds in sample runs should be quantitated against the corresponding peak from the standard run in which the peak in question is closest in size (according to area counts) to the peak which is being quantitated. Whenever possible, quantitations should only be reported for peaks which are on scale. In the event that a quantitation must be reported for a peak

which is greater than full scale, the value given must be labeled "estimate." Sample runs must always be quantitated against a standard which ran at the same gain or attenuation as the sample. All sample analysis results should be reported in table form.

Information reported should include the date, time, chromatographic conditions such as temperature, gain or attenuation, flow rate, the retention times and area counts of any reported compounds, and which standard run the sample was quantitated against.

Before any analysis can be done, the system should be checked for contamination by running a column blank. This is done by starting a chromatographic run without making any injection.

Before any syringe can be used, it should be checked for contaminants by running a syringe blank. This is done by purging the gastight syringe several times with ambient air and then making an injection of ambient air onto the column.

To rule out contamination from the water being used for dilutions, a water blank should be run. This is done by filling a VOA vial to the 30 ml mark with reagent water, capping it, and shaking vigorously for one minute. Then a volume of headspace can be withdrawn with a gastight syringe and injected onto the column.

All direct injections must be made with gastight syringes. The syringe used should be selected so that measurements are not being made in the top or bottom 20% of the graduations. For example, do not use a 100 ul syringe to make an injection of less than 20 ul or more than 80 ul.

Syringe blanks must be run after all standards, and after all samples that are not clean. Whenever possible, clean samples should be run before contaminated samples.

REFERENCES:

Fundamentals of Analytical Chemistry, Skoog &

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Management of Uncontrolled Hazardous Waste
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STANDARD OPERATING PROCEDURE

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1.0 TITLE: Gas Chromatographic (GC) Analytical Column Installation

2.0 PURPOSE: The purpose of this document is to provide the GC analyst specific procedures for analytical column installation. This document will ensure consistency of column installation between analysts and therefore standardize the quality of sample screening data using the GC.

3.0 SCOPE: The column installation procedures described in this document will be followed by all Navy CLEAN GC analysts performing soil and water screening analyses that require the use of a GC equipped with either a packed or a capillary column. Installation procedures apply only to the HNU Systems Model 311 Portable Gas Chromatograph.

4.0 REQUIREMENTS:

4.1 Knowledge of Instrument A working knowledge of the HNU Systems Model 311 GC is required prior to the installation of any chromatographic column.

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4.2 Column Specifications

Accurate identification of individual chemical compounds in a sample requires the GC analyst understand the specific column type, length, inside diameter (ID), and internal phase or packing material required for particular types of analyses.

5.0 EQUIPMENT:

- Appropriate analytical column; packed or capillary.
- Ferrules, nuts, and column fittings.
- GC kit, including wrenches and column cutting tool (necessary to install a capillary column).

6.0 PROCEDURE:

6.1 Packed Column Installation

To install a packed column in the HNU Systems Model 311 GC:

1. Turn the GC power switch off and unplug the instrument. Turn off the carrier gas flow. Allow the carrier gas pressure gauge to fall to zero to insure there is no pressure in the system. Allow unit to cool completely.
2. Open the column oven lid. If there is a column in place, remove it by loosening the ferrules holding the column in place. Simply pull out the column.
3. If no column has been installed in the unit, insure the unit is fitted with 1/8-inch injector and detector column adapters. Refer to Attachment I.
4. Slide the dead volume reducer into the column detector inlet as illustrated in Attachment I.

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5. Locate the short 1/8-inch column adaptor and feed it into the detector until it stops, then lower it approximately 1/16-inch so that it does not touch the dead volume reducer in front of it. Tighten the 1/4-inch nut slightly tighter than finger tight. **DO NOT OVERTIGHTEN.**
6. Install the nuts and ferrules onto the column.
7. Slide the long end of the column into the injector inlet until it stops. Lower the end of the column approximately 1/8-inch so that it does not touch the column adaptor in front of it. Tighten the 1/8-inch nuts as above. **DO NOT OVERTIGHTEN.**
8. Slide the short end of the column into the detector inlet until it stops. Tighten the 1/8-inch nuts as above, then with a wrench. **DO NOT OVERTIGHTEN**, as the flanges may be distorted and the resulting seal may leak.

NOTE: For 1/4-inch packed columns, the use of an adaptor is not necessary. Connect the column directly to the 1/4-inch fitting on the injection port and detector inlet.

6.2 Capillary Column Installation

The trimming of the ends of a new capillary column is an important factor in achieving good separation and a high quality chromatogram. The ends should be square, flat, and without any fractures. Cut the column ends with the cutting tool provided with the column, always after the ferrules have been positioned. With the cutting tool, it is possible to achieve a clean, flat surface at the column ends. Proceed as follows:

1. Use the sharp edge of the silicon wafer cutting tool.

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2. Holding the tool at an angle about 45° to the axis of the column, make a scratch on the surface of the column. It is possible to feel when the mark has been made successfully.

3. Hold the capillary on either side of the mark and gently pull both sides while bending slightly at the same time. The column will then break.

During column installation avoid stressing it by making small radius bends. These tend to make the column more brittle. Use proper ferrules when making connections to the column.

To install a capillary column in the GC:

1. Turn the GC power switch off and unplug the unit. Turn off the carrier gas flow. Allow the carrier gas pressure gauge to fall to zero to insure there is no pressure in the system. Allow unit to cool completely.

2. Open the column oven lid. If there is a column in place, remove it by loosening the ferrules holding the column in place. Simply pull out the column.

3. If no column has been installed in the unit, insure the unit is fitted with the proper injector and detector column adapters. Refer to Attachment II.

4. Use the same nut and ferrule arrangement as is used to secure the packed column. Slide the nut and ferrule over the adaptor and insert it into the injector. Tighten the securing nut; DO NOT OVERTIGHTEN.

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5. Slide the end of the column into the adaptor until it stops, a distance of about 8.5 cm. The column end should slide easily. If any obstructions are felt, or if the column resists, remove the injector liner to check for blockage. It is possible that a small piece of the column may obstruct the injector adapter.

6. Pull the column back very slightly, and secure the column by tightening the nut. Again, do not overtighten.

7. Repeat the above step to secure the detector end of the column.

6.3 Capillary Column Conditioning

New columns and columns that have not been recently used must be conditioned prior to use. Column conditioning procedures depend on the column packing, and should be conditioned according to the instructions shipped with the column. Most columns are conditioned as follows.

Proper column conditioning:

1. Connect the column to the injector only. DO NOT connect the column to the detector.

2. Turn on the carrier gas flow, and set the flow rate through the column. Normal packed column operation requires a flow rate of approximately 20-40 ml/min, capillary columns require approximately 10-20 ml/min.

CAUTION: MAKE SURE THERE IS FLOW THROUGH THE COLUMN BEFORE HEATING THE OVEN!

3. Turn on the GC power switch.

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4. Turn the detector(s) off at the switch.

5. Set the temperatures of the oven and the injector/detector block to those required for the column being used. The injector/detector temperature should be 10-20°C higher than the column oven.

7.0 REFERENCES:

HNU Systems, Inc. Model 311 Portable GC Operator's Manual Version 1.1; 1992.

HNU Systems, Inc. Electron Capture Detector Operator's Guide; 1991.

SUPELCO, 1991, Column Selection for Gas and Hydrocarbon Analysis, GC Bulletin 786C.

SUPELCO, 1991, SP™-1700 GC Column Provides Reproducible Hydrocarbon Analyses, GC Bulletin 802B.

8.0 ATTACHMENTS:

Attachment I - Packed Column Installation
Attachment II - Capillary Column Installation

9.0 GLOSSARY:

dead volume reducer: An adapter used when installing a packed column to reduce the amount of dead volume created as the injection passes through the column to the detector.

ferrules: Stainless steel or graphite column attachments installed above a nut to ensure proper column fit.

injector: The port in which a sample is introduced into the column.

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internal phase: The coating, either bonded or non-bonded, polar or non-polar, inside a capillary column that determines the amount of time a sample component is held in the column before passing through the detector.