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FINAL REMEDIAL INVESTIGATION FEASIBILITY STUDY WORK PLAN APPENDIX M2 FOR  
OPERABLE UNIT 3 (OU 3) NAS JACKSONVILLE FL  
3/1/1995  
ABB ENVIRONMENTAL

**APPENDIX M 2  
OF THE OPERABLE UNIT (OU) 3 REMEDIAL INVESTIGATION  
AND FEASIBILITY STUDY WORKPLAN**

**OU 3 SITE-SPECIFIC  
FIELD SAMPLING PLAN**

**FOR**

**NAVAL AIR STATION  
JACKSONVILLE, FLORIDA**

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NAS Jacksonville  
Jacksonville, Florida

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## GLOSSARY

ABB-ES	ABB Environmental Services, Inc.
ARAR	applicable or relevant and appropriate requirements
ASTM	American Society of Testing and Materials
BFSP	Basic Field Sampling Plan
bls	below land surface
CLP	Contract Laboratory Program
cm <sup>2</sup>	square centimeters
COC	chain of custody
CPCs	chemicals of potential concern
CPT	cone penetrometer test
DE	disposable equipment
DNAPL	dense non-aqueous phase liquid
DOD	Department of Defense
DPT	direct push technology
DQO	Data Quality Objective
°C	degrees Celsius
°F	degrees Fahrenheit
FDEP	Florida Department of Environmental Protection
FID	flame ionization detector
FOL	Field Operations Leader
FSP	Field Sampling Plan
GPS	Global Positioning System
HASP	Health and Safety Plan
HDPE	high density polyethylene
IDW	investigation-derived wastes
NAD	North American Datum
NADEP	Naval Aviation Depot
NAS	Naval Air Station
NEESA	Naval Energy and Environmental Support Activity
NGS	National Geodetic Survey
NGVD	National Geodetic Vertical Datum
NIRP	Navy Installation Restoration Program
OU	Operable Unit
OVA	organic vapor analyzer
PCB	polychlorinated biphenyl
PPE	personal protective equipment
PRGs	preliminary remediation goals
psi	pounds per square inch
PVC	polyvinyl chloride

## GLOSSARY (Continued)

QA/QC	quality assurance/quality control
QAPP	Quality Assurance Program Plan
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
SAV	submerged aquatic vegetation
SCT	salinity conductivity temperature
SSFP	Scoping study Field Program
SVOC	semivolatile organic compound
TAL	target analyte list
TAT	turn-around-time
TBC	to be considered
TCLP	Toxicity Characteristic Leaching Procedure
TKN	total kjeldahl nitrogen
TOC	total organic carbon
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Services
UST	underground storage tank
VOC	volatile organic compound

## 1.0 INTRODUCTION

The sampling and analysis programs for the Naval Air Station (NAS) Jacksonville Operable Unit (OU) 3 Remedial Investigation (RI) are described in this Field Sampling Plan (FSP). This FSP presents the technical approach, rationale, quantities, and locations of sampling and defines the specific sampling procedures and techniques to be used in the collection of environmental samples. It is intended as a guide for field personnel. This guidance will aid field personnel to plan and adjust the field program to assure the proper completion of the designated scopes of work.

This FSP parallels the format of the Basic Field Sampling Plan (BFSP) included as Appendix 4.4.2 of the Basic Site Workplan, Volume 4, of the NAS Jacksonville, Naval Installation Restoration Program (NIRP) plan (Geraghty & Miller, 1991).

This FSP is organized into the following chapters.

Chapter 1.0 presents the organization of the plan, the objectives of the sampling, operable unit background, and an introductory summary of the RI sampling programs.

Chapter 2.0 discusses the sampling programs and sample quantities, locations, objectives, rationale, and analysis.

Chapter 3.0 describes specific sampling procedures to be followed for the sampling programs.

Chapter 4.0 discusses the handling of investigation-derived wastes (IDW).

1.1 OBJECTIVE. The objective of the OU 3 RI field program is to fill the data gaps and fulfill data quality objectives stated in Chapter 5.0 of the OU 3 workplan. The field program will collect sufficient, high quality environmental data to complete the OU 3 conceptual model, perform risk assessment, and to scope potential remedial actions.

1.2 OPERABLE UNIT (OU) 3 BACKGROUND INFORMATION. A history of previous investigations at OU 3 is included in Section 2.2 and in Appendix B of the OU 3 RI/FS workplan. The findings of the OU 3 RI Scoping Study Field Program (SSFP), conducted in 1993, are detailed in Section 2.3 of the workplan.

1.3 GENERAL TECHNICAL APPROACH. An important factor in scoping the OU 3 RI/FS was an objective to fully characterize the OU in a single field program. All data required for characterization, risk assessment, and feasibility study evaluations are to be identified and collected during the RI. This goal is addressed with an approach that uses a mix of exploration technologies, rapid turn-around-times on chemical analyses, detailed study of results during the field program, and consultation with representatives of the OU 3 Partnering Team on an ongoing basis during the field program. The OU 3 Partnering Team consists of senior ABB Environmental Services, Inc. (ABB-ES), technical leaders and Navy, Florida Department of Environmental Protection (FDEP), and U.S. Environmental

Protection Agency (USEPA) Region IV technical staff. The framework of sampling is flexible so that the field staff can respond to unexpected circumstances. The final scope of the sampling program will generally be determined in the field. The objectives of the sampling and criteria for decisions are specified in this FSP, but sample locations, depths, and the quantity of samples will depend, in part, on physical conditions and analytical results.

The field program is designed as a series of tasks. The primary field tasks planned for the RI are outlined below, annotated to describe briefly the nature and purpose of each task. Details of the field program are presented in Chapter 2.0.

1.3.1 Piezometer Installation The OU 3 SSFP revealed complex groundwater flow patterns; additional piezometers are required to reliably map the direction of groundwater flow in some areas of OU 3, and to provide piezometric data to the U.S. Geological Survey (USGS) for their numerical modeling of NAS Jacksonville.

1.3.2 Hydraulic Fill Area Background Hand Auger Borings Soil sampling will be performed outside of OU 3 in an area of hydraulic fill to evaluate whether the fill material could be altering the quality of groundwater in OU 3. The soil samples will be analyzed for total metal concentration and these analyses will be compared to the metals data from the background reference soil samples collected during the OU 1 investigation. These data will then be factored into the data collected during the SSFP and will be used to establish preliminary remediation goals (PRG) for the chemicals of potential concern (CPCs) identified, based on Federal and State applicable or relevant and appropriate requirements (ARARs) and non-promulgated advisories to be considered (TBCs), as specified in Subsection 2.4.2 and Chapter 3.0 of the OU 3 RI/FS workplan.

1.3.3 Direct Push Technology Testing and Groundwater Sampling The objectives of direct-push technology (DPT) testing and sampling are: (1) to map the continuity of clay and sandy clay aquitards that may affect contaminant transport, and (2) to delineate the nature and extent of groundwater contaminant plumes. Six areas of OU 3 have been selected for groundwater sampling using DPT methods. Cone penetrometer tests (CPTs) and DPT groundwater sampling will be performed in each area on a regular grid pattern. Groundwater samples will be collected from multiple depths at each location to provide data on the vertical distribution of contaminants.

Groundwater samples will be submitted for offsite Naval Energy and Environmental Support Activity (NEESA)-approved laboratory analysis with 24-hour turn-around-time (TAT) on results. Analytical results returning from the laboratory each day will be used by the field team to select the next grid locations to sample. Sampling will begin in each area near those locations that showed high concentrations of CPCs during the SSFP. Sampling will radiate to other locations on the grid and progress until detected concentrations of CPCs fall below PRG concentrations that are established from Federal and State ARARs and TBCs as specified in Chapter 3.0 of the OU 3 RI/FS workplan. This approach to sampling, using temporary sample points (the DPT samplers), rapid TAT from an off-site NEESA-approved laboratory, and field review of results to place subsequent sample points, will map the geometry of groundwater contaminant plumes with a high degree of confidence.

1.3.4 Monitoring Well Installation Monitoring wells are to be installed during the RI for three purposes, described below.

1.3.4.1 Upgradient Monitoring Wells Upgradient monitoring wells will be installed to evaluate the quality of groundwater flowing into OU 3.

1.3.4.2 Monitoring Wells Adjacent to the St. Johns River To evaluate the potential discharge of contaminants via groundwater to the aquatic environment of the St Johns River, monitoring wells will be installed along the shoreline at the southern end of OU 3. These wells will supplement existing wells located along the seawall that defines the eastern side of OU 3.

1.3.4.3 Monitoring Wells to Delineate Plumes The field team, in consultation with representatives of the OU 3 Partnering Team, will select locations for and install permanent groundwater monitoring wells to monitor groundwater quality over time. Locations will be selected by using piezometric data, which indicates groundwater flow directions, in conjunction with plume maps created from DPT sampling data.

1.3.5 Hand Auger Soil Borings In addition to background soil borings conducted in the hydraulic fill area (Subsection 1.3.2), soil borings will be conducted to evaluate soil contamination in two potential source areas: PSC-14 and PSC-15. Soil borings will also be conducted to the water table during drilling at each monitoring well location.

1.3.6 Surface Soil Sampling Surface soil samples will be collected in the area of PSC-15 to evaluate the potential that soils contribute contamination to surface runoff that discharges to the St. Johns River.

1.3.7 Test Trenching Test trenches will be excavated at PSC-15 to locate and define the area of waste disposal, and to sample subsurface soils to quantify the nature and extent of soil contamination that is potentially leaching to groundwater.

1.3.8 Monitoring Well Groundwater Sampling All new monitoring wells and selected existing wells will be sampled near the end of the RI field program. Existing wells to be sampled will include the 27 piezometers installed during the SSFP, 16 other wells installed during previous investigations, and possibly additional wells to be selected during the program.

1.3.9 Surface Water and Sediment Sampling Aquatic habitats of the St. Johns River adjacent to the southern perimeter of OU 3 and of selected reference locations will be sampled to characterize the river habitat that may be exposed to potential OU 3-related contaminants. This characterization will be conducted in two steps: (1) qualitative substrate mapping of the aquatic habitats, and (2) surface water and sediment sampling for chemical and toxicity analysis.

1.3.10 Aquifer Testing Improved estimates for aquifer properties at OU 3 are required to support USGS numerical modeling. Slug tests will be performed on selected wells to obtain intermediate-scale estimates of hydraulic conductivity. Wells screened in intermediate and deep intervals will be selected to supplement existing shallow data and to represent the lateral and vertical variability of the operable unit. Single-well pumping tests will be performed at selected shallow monitoring wells to obtain large-scale estimates of transmissivity and

storativity. If the single-well tests suggest that pumping could be sustained for a standard multi-day pumping test, such a test will be planned and conducted. A standard multi-day pumping test is not currently planned.

**1.3.11 Surveying** All analytical and CPT data will be mapped in the field during the sampling programs; these maps will be the basis for selecting additional sample locations, for delineating groundwater plumes, and for deciding when sufficient data have been collected to close any data gaps. Daily location and elevation surveys of DPT groundwater sample points, surface soil sample points, test pits, and soil boring locations are required to process the above data.

Ongoing surveying of soil boring locations, DPT locations, surface soil locations, surface water and sediment locations, and test trenches will be performed by Global Positioning System (GPS) survey techniques to reduce effort and cost. Digital coordinate files will be used in mapping, contouring, and cross-section software to update the analytical and geological databases. Piezometers and monitoring wells will be surveyed by theodolite and level techniques by a Florida-licensed surveyor.

**1.4 HEALTH AND SAFETY.** Based on results of previous studies at OU 3, Level D personal protective equipment (PPE) is appropriate and will be worn by field personnel while onsite for the RI fieldwork. Working environments will be monitored by ABB-ES staff with organic vapor analyzers at all times. If conditions require upgrade to Level C or greater, work activities will be stopped until upgraded PPE is brought onsite. Use of Level C or higher PPE is not currently expected. Detailed health and safety procedures are described in the OU 3 RI Health and Safety Plan.

## 2.0 SAMPLING PROGRAMS

2.1 SCOPE AND SCHEDULE. Table 2-1 summarizes all of the field sampling tasks to be performed during the OU 3 RI field program. The sample quantities indicated are estimates. Estimates are based on assumed final totals for tasks where the sample quantities will be determined in the field. The table is intended to serve as an estimate of the field program scope. Field work will be conducted in consecutive cycles of 10-day work weeks with 4-day weekends until the designated scope of work is completed.

2.2 PIEZOMETER INSTALLATION AND GROUNDWATER CONTOURING. The OU 3 SSFP revealed complex flow patterns at OU 3. Mapping of existing piezometric datapoints suggests the presence of a groundwater mound under Building 101 and the helicopter flightline, and convergence of flow with a steep gradient near the boathouse (Building 121). Figures 2-19 and 2-20 of the OU 3 workplan present water table contour maps indicating the complexities of head distribution. Additional piezometers are required to reliably predict groundwater flow directions at OU 3. Knowledge of small-scale groundwater flow patterns will be used by the field team to guide DPT groundwater sampling and to place upgradient monitoring wells in true upgradient locations. Furthermore, the USGS requires additional piezometers in parts of OU 3 and elsewhere on NAS Jacksonville to fill data gaps identified from their numerical modeling efforts.

Piezometers will be installed at the beginning of the OU 3 RI field program, using DPT methods for installation. Installation and construction details are outlined in Subsection 3.2.1. Each piezometer location will consist of a pair of piezometers: (1) a water-table piezometer, screened to span the water table; and (2) a deep piezometer, screened in a permeable unit below the upper clay unit. A total of 32 piezometer pairs will be installed. Locations of 25 pairs are indicated on Figures 2-1a; the other 7 pairs are located to the west and north of OU 3 and are shown on Figure 2-1b. The rationale for piezometer locations is discussed in Subsection 6.1.2 of the OU 3 workplan.

In general, deep piezometers will be used to screen a hydrostratigraphic unit that exists in the northern and southern areas of OU 3: the permeable unit that underlies the shallowest clay unit. Based on cross sections prepared during the SSFP, the uppermost clay unit in the northern and southern areas of OU 3 is laterally extensive and less than 10 feet thick with its top at a depth of 10 to 20 feet below land surface (bls). The permeable unit underlying it is also laterally extensive and between 30 and 60 feet thick. It is known, for purposes of the OU 3 program, as the intermediate sand. It overlies another thin, extensive clay unit at approximately 65 to 90 feet bls. Deep piezometers located in these areas will be screened in the middle part of the intermediate sand and are expected to be approximately 30 to 50 feet deep. The intermediate sand pinches out near the center of OU 3; the upper and lower clays merge and thicken, and appear to isolate the northern and southern members of the intermediate sand. In the central area of OU 3, located approximately between existing piezometer PZ020 in the west, the river in the east, Hangar 123 in the north, and Hangar 124 and Building 125 in the south, the clay unit is up to 60 feet thick. Deep piezometers located in this area may be up to 95 feet deep, and they may screen a sand strata that underlies the intermediate sand.

**Table 2-1  
Summary of Field Program Activities**

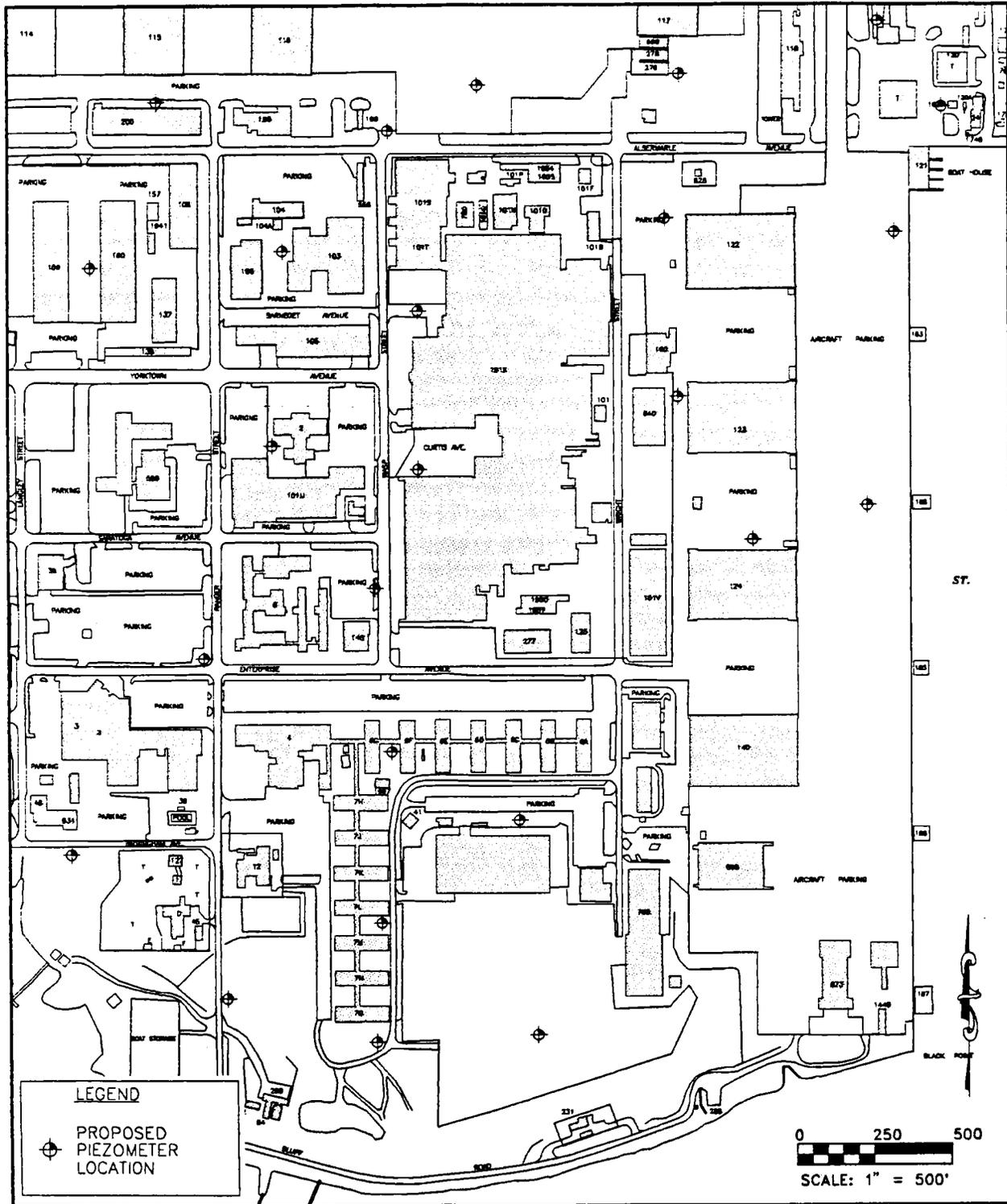
Operable Unit 3 Field Sampling Plan  
NAS Jacksonville  
Jacksonville, Florida

Activity	Description
Mobilization and Demobilization	<u>One field mobilization and demobilization</u> - General field program start-up and shut-down activities
Piezometer Installation and Water Level Measurements	<u>32 shallow and deep pairs; 64 piezometers</u> - 8 pairs (16) north and west of OU 3 - 7 pairs (14) south and southwest of OU 3 - 10 pairs (20) in areas of anomalous water levels - 7 pairs (14) outside the OU 3 area  <u>133 groundwater level measurements (after installation)</u> - 64 new piezometers - 42 existing wells - 27 existing piezometers
Background Soil Sampling	<u>Three soil borings; nine soil samples (three samples per boring)</u> - three borings in hydraulic fill area north of OU 3
Direct Push Technology (DPT) Testing and Sampling	<u>272 DPT points; 816 groundwater samples (3 samples per DPT point)</u> - 232 DPT points in sampling grids - 10 DPT points inside Building 101 - 30 DPT points surrounding isolated areas of contamination
Monitoring Well Installation	<u>51 shallow and deep pairs; 102 monitoring wells</u> - 4 pairs (8) upgradient of OU 3 - 2 pairs (4) adjacent to the St. Johns River - 36 pairs (72) to delineate contaminant plumes - 4 pairs (8) within Building 101 - 5 pairs (10) in isolated areas of contamination
Soil Borings	<u>58 soil borings; 174 soil samples (3 samples per boring)</u> - 51 borings from monitoring well locations - 3 borings in vicinity of PSC-14 - 4 borings in vicinity of PSC-15
Test Trenching and Soil Sampling	<u>2 days of test trenching at PSC-15</u> - five soil samples from test trenches
Groundwater Sampling	<u>145+ locations; 145+ groundwater samples</u> - 16+ existing monitoring wells - 27+ existing piezometers - 102 new monitoring wells
Surface Soil Sampling	<u>Eight surface soil samples</u> - eight surface soil samples from PSC-15
Aquifer Testing	<u>Selected slug tests and pumping tests</u> - Up to eight single-well 1-day pumping tests - one multi-day pumping test, if feasible - eight deep monitoring well slug tests

**Table 2-1 (Continued)  
Summary of Field Program Activities**

Operable Unit 3 Field Sampling Plan  
NAS Jacksonville  
Jacksonville, Florida

Activity	Description
Surface Water and Sediment Sampling	<u>Six transects within the St. Johns River</u> - nine samples along the southern boundary of OU 3 - two reference sample locations
Surveying	<u>Approximately 400 Global Positioning System (GPS) survey locations</u> - 272 DPT points - 61 soil boring locations (3 background; 58 OU-wide) - 6 surface soil sampling locations - delineation of PSC-15 boundary - 9 surface water and sediment sampling locations and 6 transects - 2 reference surface water and sediment sample locations  <u>166 Theodolite and level survey locations</u> - 102 new monitoring wells - 64 new piezometers
Water Level Measurements	<u>235 groundwater level measurements (at end of field program)</u> - 102 new wells - 64 new piezometers - 42 existing wells - 27 existing piezometers

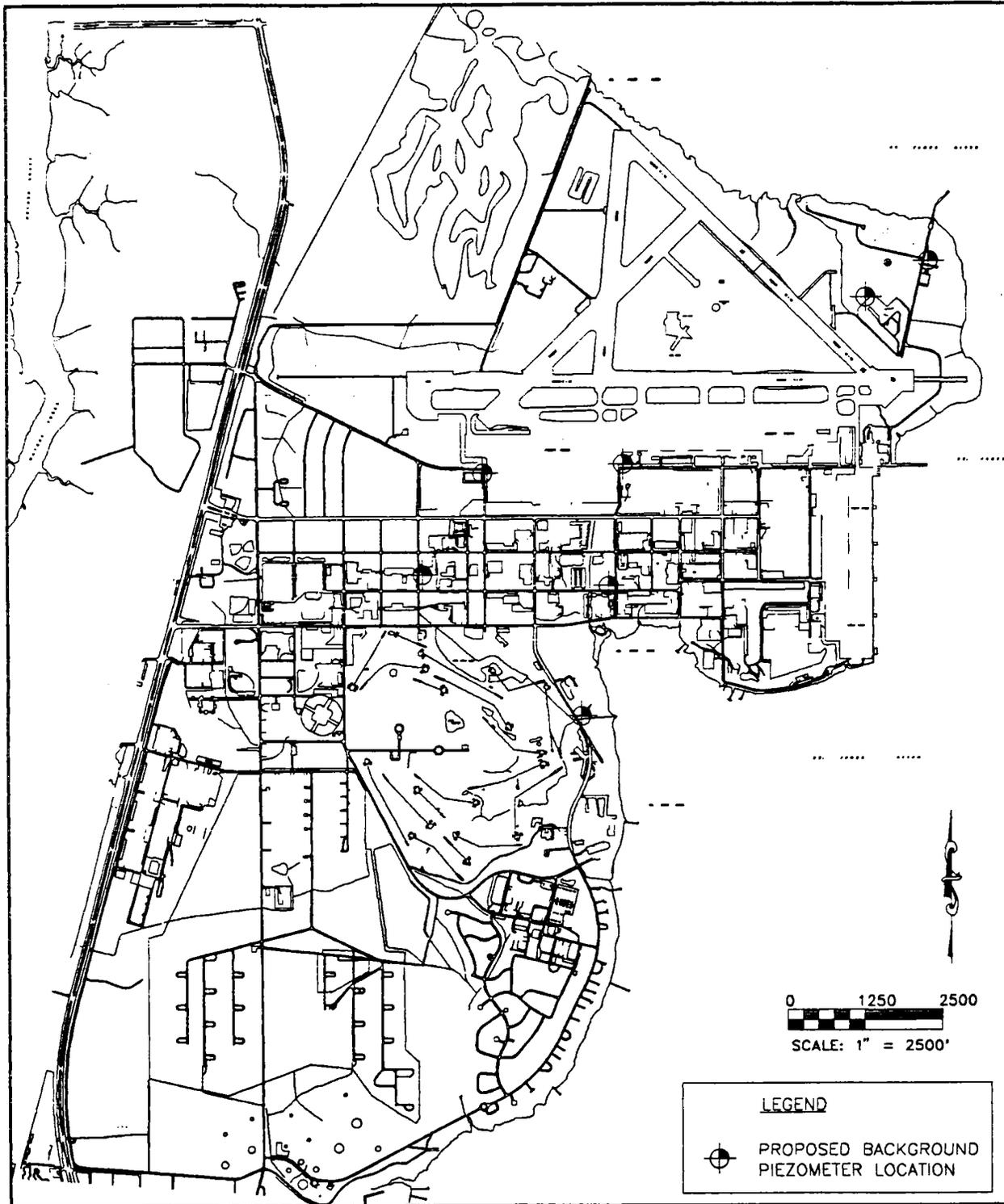


**FIGURE 2-1a**  
**PROPOSED PIEZOMETER LOCATIONS**



**FIELD SAMPLING  
 PLAN FOR OU 3**

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**FIGURE 2-1b  
PROPOSED PIEZOMETER  
LOCATIONS**



**FIELD SAMPLING  
PLAN FOR OU 3**

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Because of the complexity of the stratigraphy, the field team will have to consult the cross sections and fence diagram developed after the SSFP (Figures 2-14 through 2-18 and Appendix G of the OU 3 RI/FS workplan) to ensure that the proper sand units are screened. In areas where stratigraphic data have not yet been collected, CPTs will be performed prior to deep piezometer installation, and the logs correlated to the existing cross sections to select the piezometer screened interval. It is expected that all of the piezometer locations to the west and southwest of OU 3 will require CPT testing. The test holes will be grouted as described in Subsection 3.2.5 upon completion of the test.

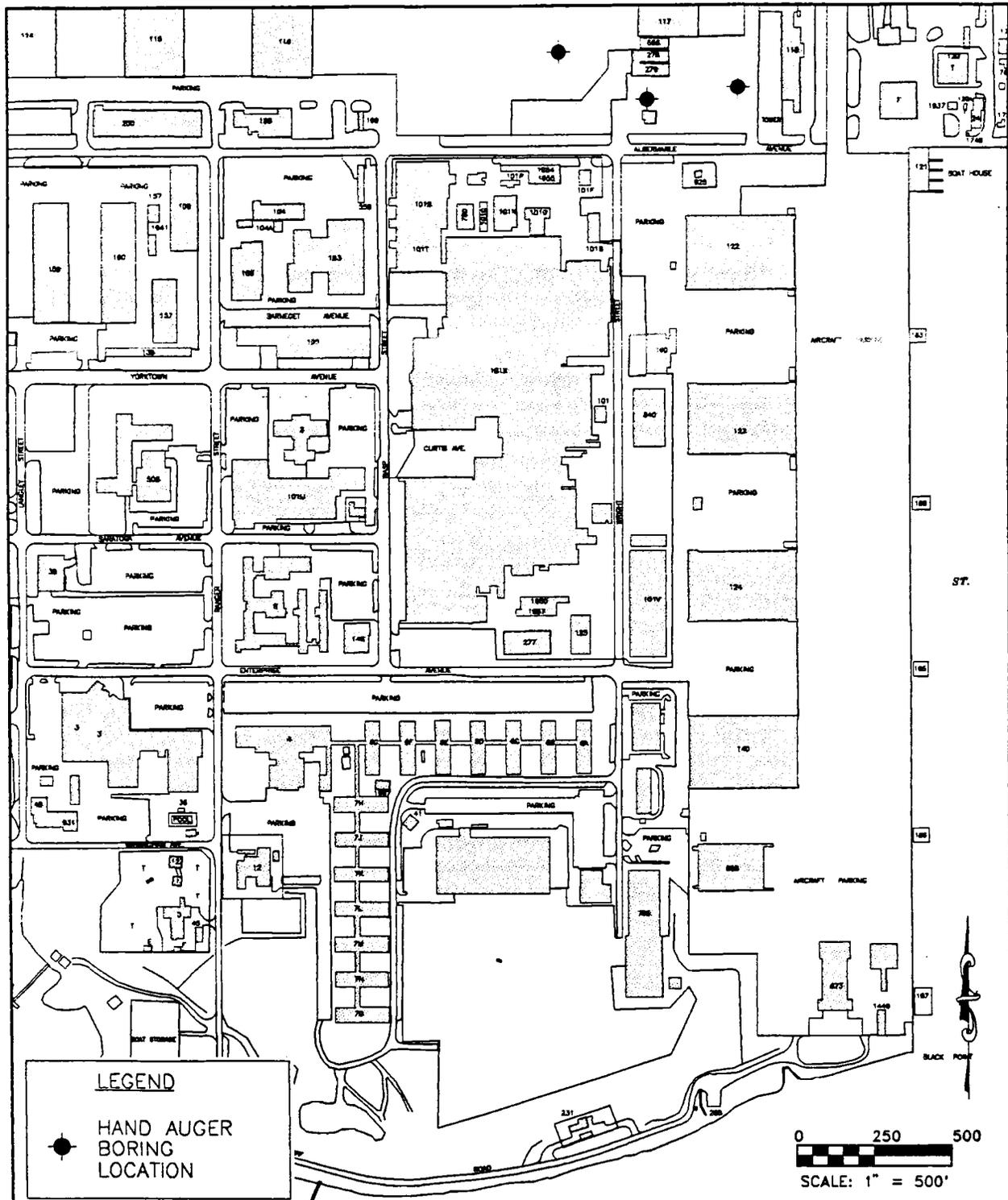
As soon as possible after piezometers are installed, their locations and elevations shall be surveyed by a Florida-licensed surveyor in accordance with the guidelines as described in Subsection 2.12.2. A round of water level measurements at all wells and piezometers at or around OU 3 (including any applicable OU 1 background wells) will be collected during a single day. The water level data will be contoured to establish detailed potentiometric surface maps for both the shallow and the deep groundwater at OU 3.

2.3 HYDRAULIC FILL AREA BACKGROUND HAND AUGER BORINGS. The potential exists that the hydraulic fill underlying most of the northern half of OU 3 has altered the quality of groundwater. The hydraulic fill originated as St. Johns River sediment, and was used to bring the flightline and NADEP area ground surface elevation to a uniform elevation of 10 feet above datum prior to World War II. The fill may be up to 20 feet thick in the region near the Air Operations radio tower at the northern perimeter of OU 3. The fill material was found to be visually indistinguishable from native soils during the OU 3 SSFP, consisting of tan to light brown, very fine-grained, clean quartz sand.

To investigate the potential that hydraulic fill may alter OU3 groundwater, unsaturated soil samples of the fill material are to be collected for chemical analyses. Samples will be collected from three randomly selected locations near the Air Operations offices (Building 118). The fill soil samples are intended to represent natural conditions; by sampling multiple locations, natural variation can be quantified and random unknown contamination, if found, can be identified.

Approximate positions for the three borings are indicated on Figure 2-2. Locations may be modified by the field team to accommodate field conditions as follows:

- avoid areas of obvious industrial activity (stored drums, vehicle or aircraft maintenance or fueling, and industrial processes),
- avoid areas of underground storage tanks (USTs),
- avoid underground utilities, and
- avoid areas where access is difficult or which unnecessarily interfere with facility operations.



**FIGURE 2-2  
PROPOSED BACKGROUND  
SOIL SAMPLING LOCATIONS,  
FILL AREA**



**FIELD SAMPLING  
PLAN FOR OU 3**

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Samples will be collected following the hand augering procedures described in Subsection 3.3.2 from the surface to the water table (estimated at 8 feet bls) at 2-foot intervals (0 to 2 feet, 2 to 4 feet, 4 to 6 feet, etc.). Samples will be submitted for offsite chemical analyses for target analyte list (TAL) metals analyses only, with NEESA Level D Data Quality Objectives (DQO), at a NEESA-approved laboratory with standard TAT on results. Each borehole will be grouted from the bottom up via a tremie pipe, and the pavement will be repaired with a like material to its original thickness and strength as described in Subsection 3.1.7.

2.4 DIRECT PUSH TECHNOLOGY TESTING AND GROUNDWATER SAMPLING. DPT groundwater sampling will be conducted in areas of OU 3 where groundwater contamination was detected during the SSFP or previous investigations. The objectives of DPT testing and sampling are: (1) to map the continuity of clay and sandy clay aquitards that may affect contaminant transport, and (2) to delineate the nature and extent of groundwater contaminant plumes. Groundwater samples are to be collected from multiple levels at each location to delineate the vertical extent of CPCs in the several permeable units underlying OU 3. Groundwater samples will be submitted for offsite chemical analyses, with NEESA Level E DQO, at a NEESA-approved laboratory with 24-hour TAT on results. Analytical results returning from the laboratory each day will be used by the field team to select additional locations to sample. So that suitable permeable strata may be identified and sampled, CPTs will be conducted prior to groundwater sampling at each location. Due to the complex and open-ended nature of the DPT sampling program, results will be discussed on a frequent and regular basis with representatives of the OU 3 Partnering Team. Field team technical leaders will discuss the data and interpretations with representatives of the OU 3 Partnering Team so that a consensus is maintained regarding the technical direction of the sampling program.

At a detailed level, the groundwater sampling program becomes very complex. It is designed to be very flexible to respond to actual field conditions in such a way as to accomplish the goal of delineating plumes. As a result, this FSP cannot identify specific DPT sample locations explicitly; they will be determined on an ongoing basis during the program. This FSP establishes the goals of the DPT program and the framework and criteria for selecting sample locations that will accomplish those goals.

In all sampling areas, DPT groundwater sampling will be performed at multiple depths at each sample location. Initially, sample depths will be selected to be similar to the sample depths of the SSFP, which were generally placed as follows:

- within 4 feet of the water table;
- in a suitable granular strata near the middle of the surficial aquifer, immediately above an aquitard separating the upper and lower zones, if found; and
- in a suitable granular strata below the lower clay unit, which is typically found at a depth of between 50 and 90 feet bls.

As data are reviewed, it may become clear that additional sampling intervals are required to delimit the vertical extent of contamination within the several

permeable units, or that the intervals should be modified to more accurately represent the distribution of contaminants. If the deepest interval sampled still shows concentrations significantly above the PRGs, a deeper sample may be required, which would require another mobilization to that location. In such situations, the following criteria will be considered by the field team to decide whether to sample to greater depth:

- whether the sample interval was underlain by a known significant thickness of sand or whether it was collected at the top of a clay aquitard, and
- whether the concentration detected was significantly above the PRG.

The suitability of a geologic unit at a given location for groundwater sampling will be determined by interpreting the data from a CPT for that location. In some cases it may not be feasible to sample groundwater from the desired depth interval because the formation will not yield water to the sampling tools. In general, silty sand or sand strata at OU 3 will yield water if they exhibit near-hydrostatic dynamic pore pressure, and a ratio of sleeve friction to tip resistance of less than 2 percent with an American Society for Testing and Materials (ASTM) standard 10 square centimeter (cm<sup>2</sup>) cone. If the desired depth interval cannot be sampled because of its soil type, the field team will sample from the suitable stratum closest in depth to the desired stratum. CPT tests will be performed at most DPT sampling locations to determine the stratigraphy at that location. However, as the set of sampling locations completed grows, the field team may become confident that sample intervals can be selected from existing stratigraphic data. Under such circumstances the Field Operations Leader (FOL) may opt to not perform the CPT sounding at any location, and perform the sampling sounding only.

In addition to its use in selecting groundwater sample depths, stratigraphic data will be used by the field team to understand the overall OU 3 stratigraphy and its influence on contaminant transport. The presence of clay units will prevent the downward migration of potential dense non-aqueous phase liquid (DNAPL) phases, and conversely, any gaps in a clay unit in an area of DNAPL contamination opens the possibility of DNAPL migration in unexpected directions. Also, clay units separate the permeable units at OU 3, causing different levels of confined aquifer conditions. Stratigraphic data will be interpreted daily and managed in a geotechnical graphics and computer database system for ease of manipulation and cross-section preparation.

The DPT groundwater sampling program is organized in three sections, discussed below: (1) sampling grids, (2) Building 101, and (3) isolated areas of contamination.

**2.4.1 Sampling Grids** DPT groundwater sampling will be conducted on a regular grid pattern in areas of OU 3 where areally extensive groundwater contamination was detected during the SSFP or historical investigations. Groundwater samples are to be collected from multiple levels at each location to delineate the vertical extent of CPCs in the several permeable units underlying OU 3. Sampling of each grid will begin near known peak contaminant and extend radially away from those areas to identify and map contaminant plumes laterally and vertically. Analytical results returning from the laboratory each day will be used by the field team to select additional grid nodes to sample. Sampling in this manner

will extend out from source areas and will progress for each plume detected until locations are sampled where organic CPC concentrations are below PRGs. The PRG concentrations are to be determined as specified in Chapter 3.0 of the OU 3 RI/FS workplan. Note that only the PRGs for organic compounds will be used to direct DPT sampling.

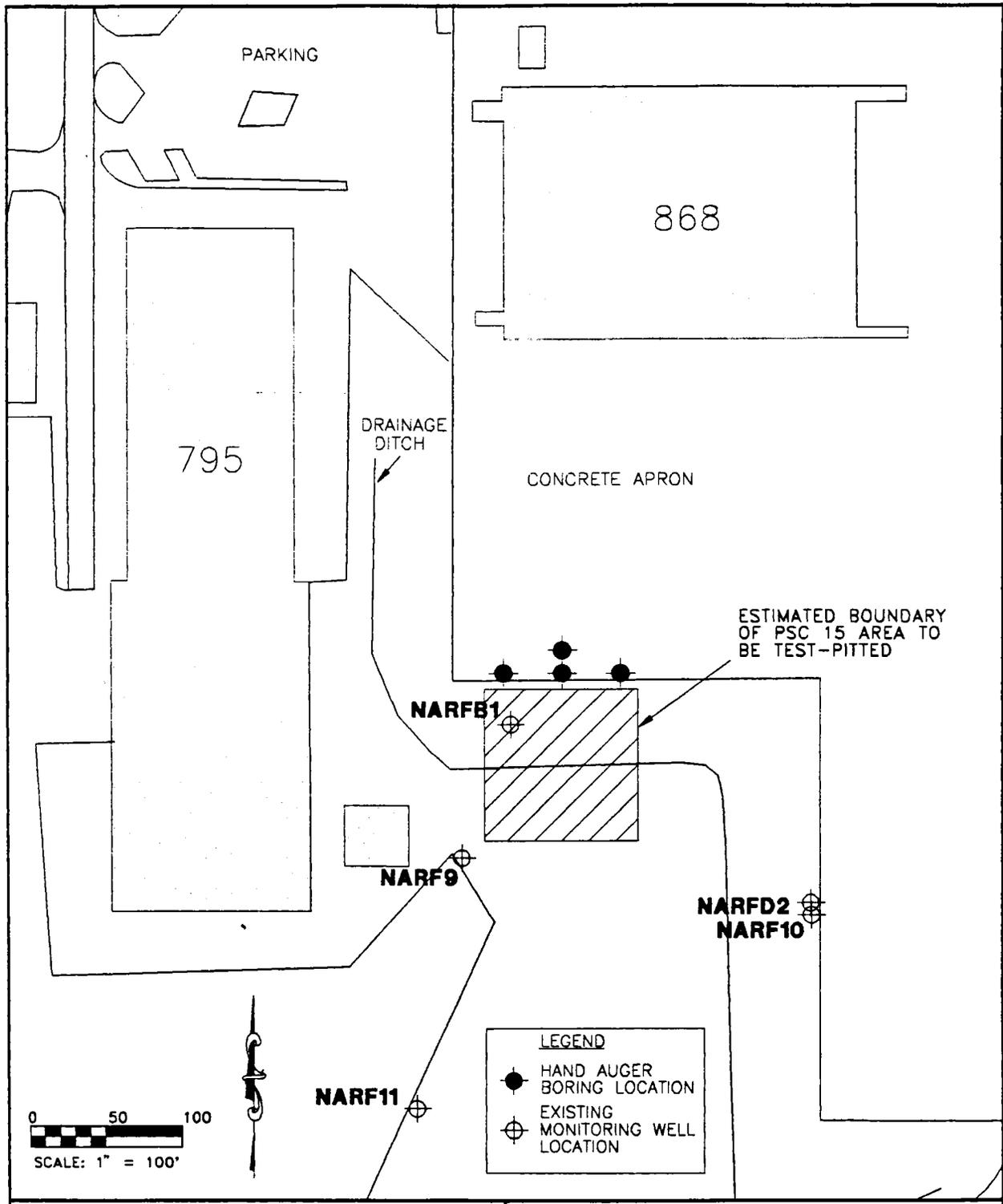
OU 3 has been divided into the following general areas of contamination for purposes of sample gridding:

- dry cleaners (Building 106),
- closed-loop recycling center (Building 780),
- Building 101 East,
- Building 101 South,
- P-615 construction area, and
- PSC-15.

The grid areas as presently defined, illustrated on Figures 2-3 through 2-7, are approximate and are only intended as guidelines for the field team. The grid size and node spacings were selected based on the extent of previously detected contamination and on the expected complexity of contaminant distribution within the gridded area. The areas ultimately gridded, and the node spacing selected, may be modified during the field program.

Sampling in each gridded area will always begin at those nodes where the highest level of contamination was detected during previous investigations. Figures 2-3 through 2-7 indicate hatchured start nodes for each of the six gridded areas. Sampling will be conducted in all of the start nodes for a given grid, at the specified node spacing, before analytical data are used to select subsequent nodes to sample. This will aid the field team in selecting subsequent nodes by familiarizing them with the size, geometry, and chemical nature of the most contaminated zones. New nodes will then be selected based on the following criteria.

- The criteria for delineating a plume is to sample groundwater from four sides surrounding the plume: upgradient, downgradient, and laterally to either side. For the edge of the plume to be considered delineated, the analytical results for the above samples should indicate CPC concentrations below the PRG thresholds.
- After the start nodes are sampled, the next nodes to be selected should be downgradient, to be followed by upgradient and lateral nodes.
- The degree to which concentrations decline with distance from a peak zone and whether the plume is large or small relative to the node spacing will be considered. The field team may wish to alter the node spacing to efficiently delineate the extent of a given plume. The required node spacing will be selected based on professional judgment. Precise volume estimation is not required, but plume edges must be sufficiently located so as to rule out the potential that the plume extends in an unknown direction for unknown distances. A general rule might be that the nodes used to define plume boundaries be no larger in area than 30 percent of the plume area.

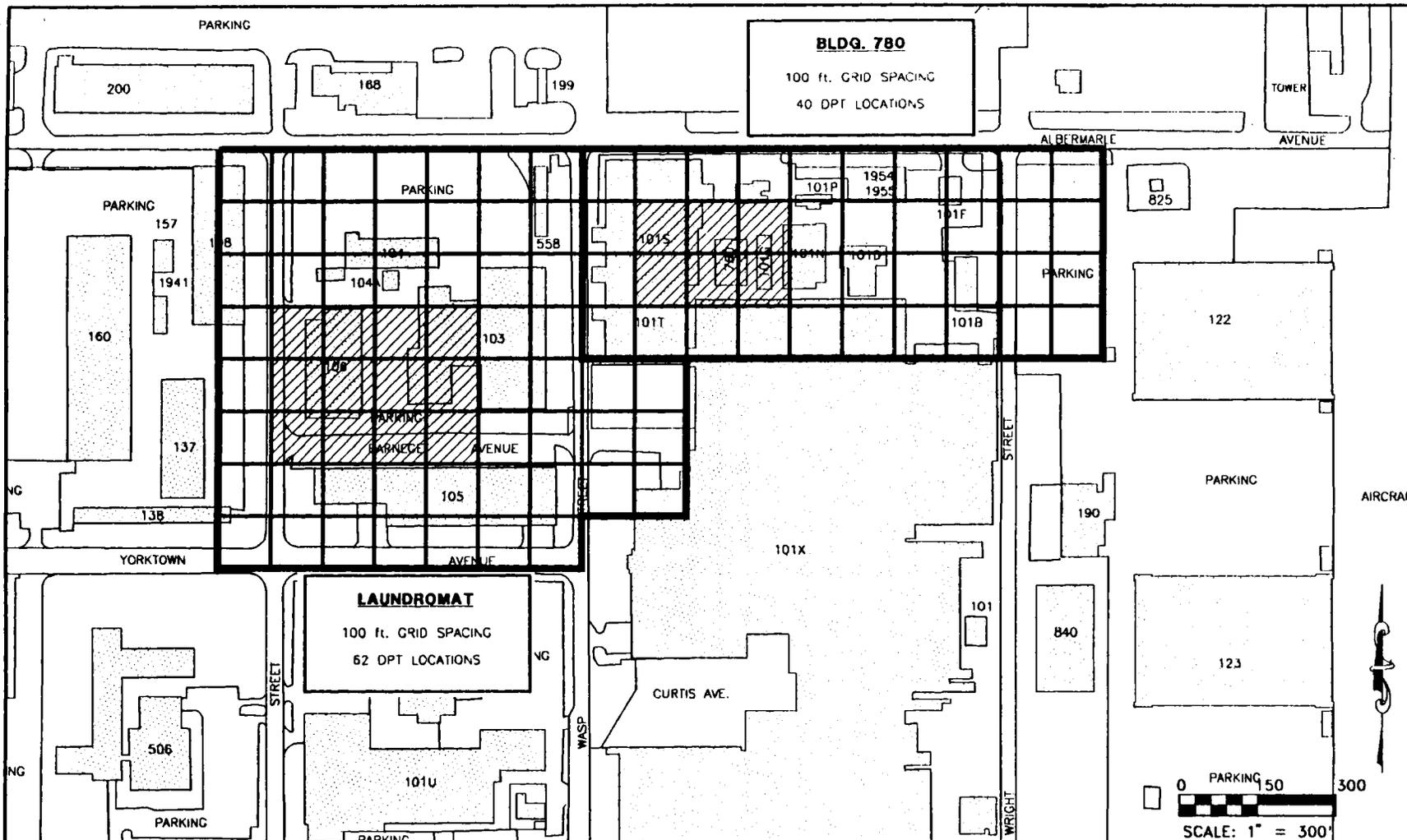


**FIGURE 2-3  
SOURCE AREA INVESTIGATION  
AT PSC 15**



**FIELD SAMPLING  
PLAN FOR OU 3**

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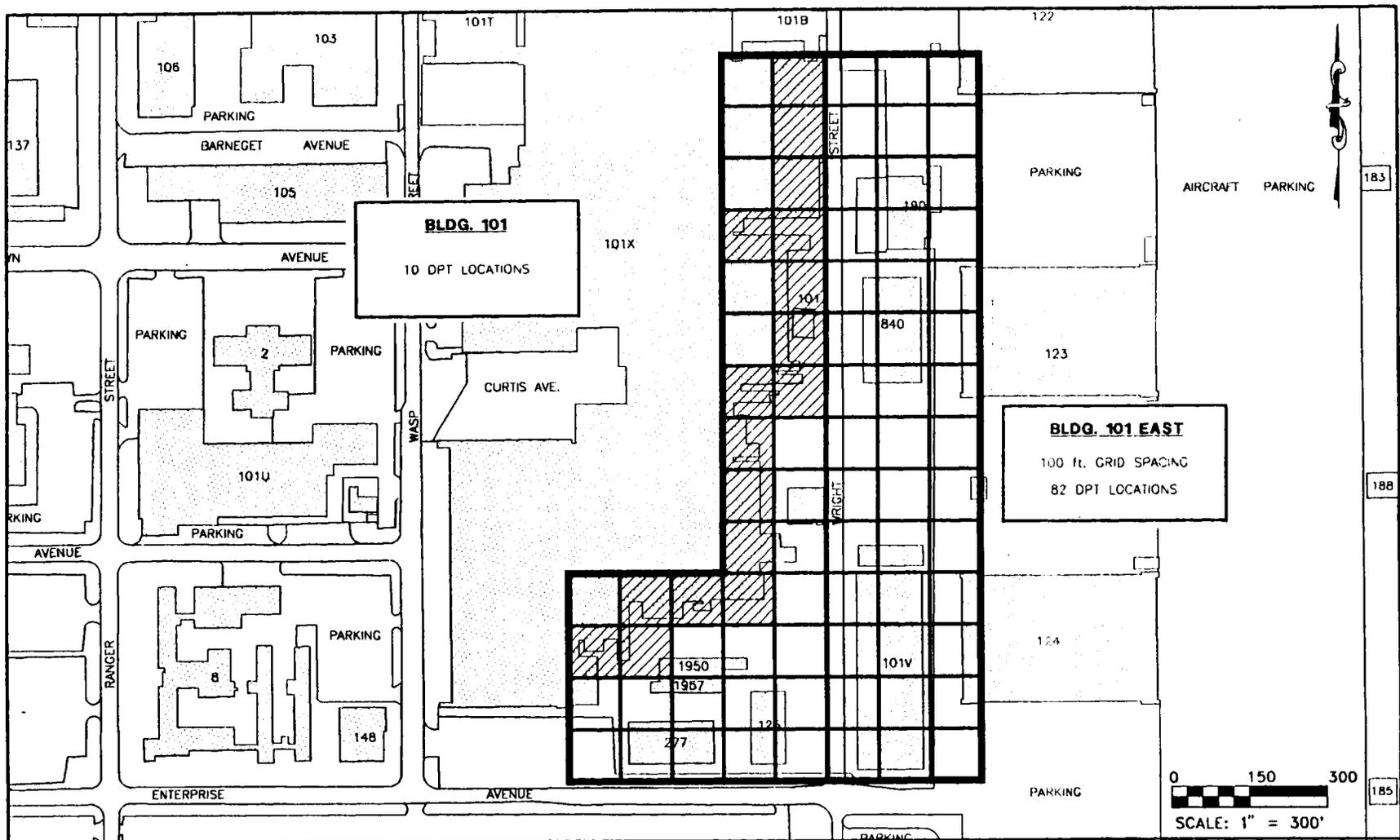


**FIGURE 2-4**  
**GRID LOCATIONS FOR**  
**DPT GROUNDWATER SAMPLING**  
**LAUNDROMAT/BUILDING 780**



**FIELD SAMPLING**  
**PLAN FOR OU 3**

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**LEGEND**

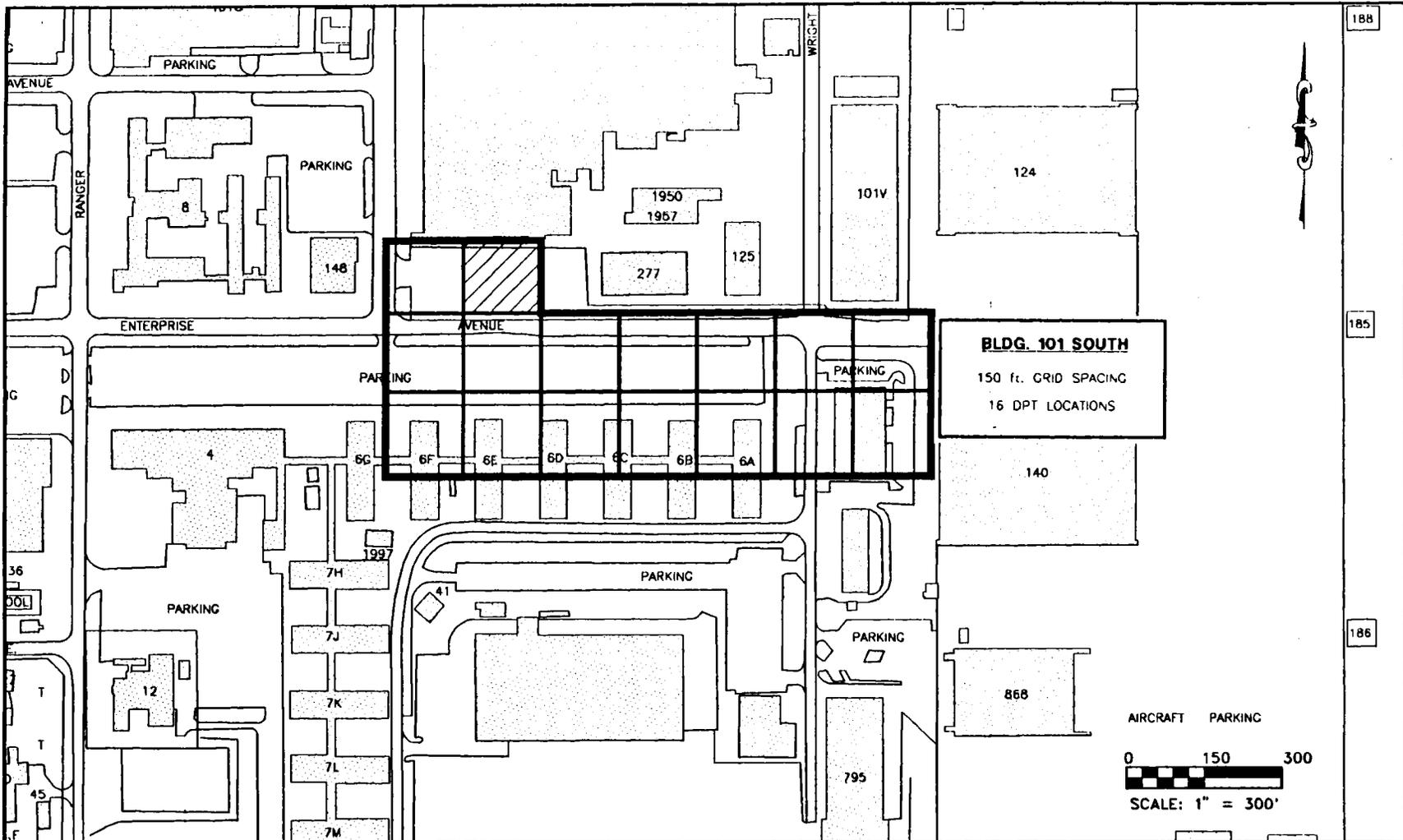
 ANTICIPATED SOURCE AREA OR "HOT SPOT" AT WHICH TO INITIATE GRID SAMPLING

**FIGURE 2-5  
GRID LOCATIONS FOR  
DPT GROUNDWATER SAMPLING,  
BLDG. 101**



**FIELD SAMPLING  
PLAN FOR OU 3**

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**LEGEND**

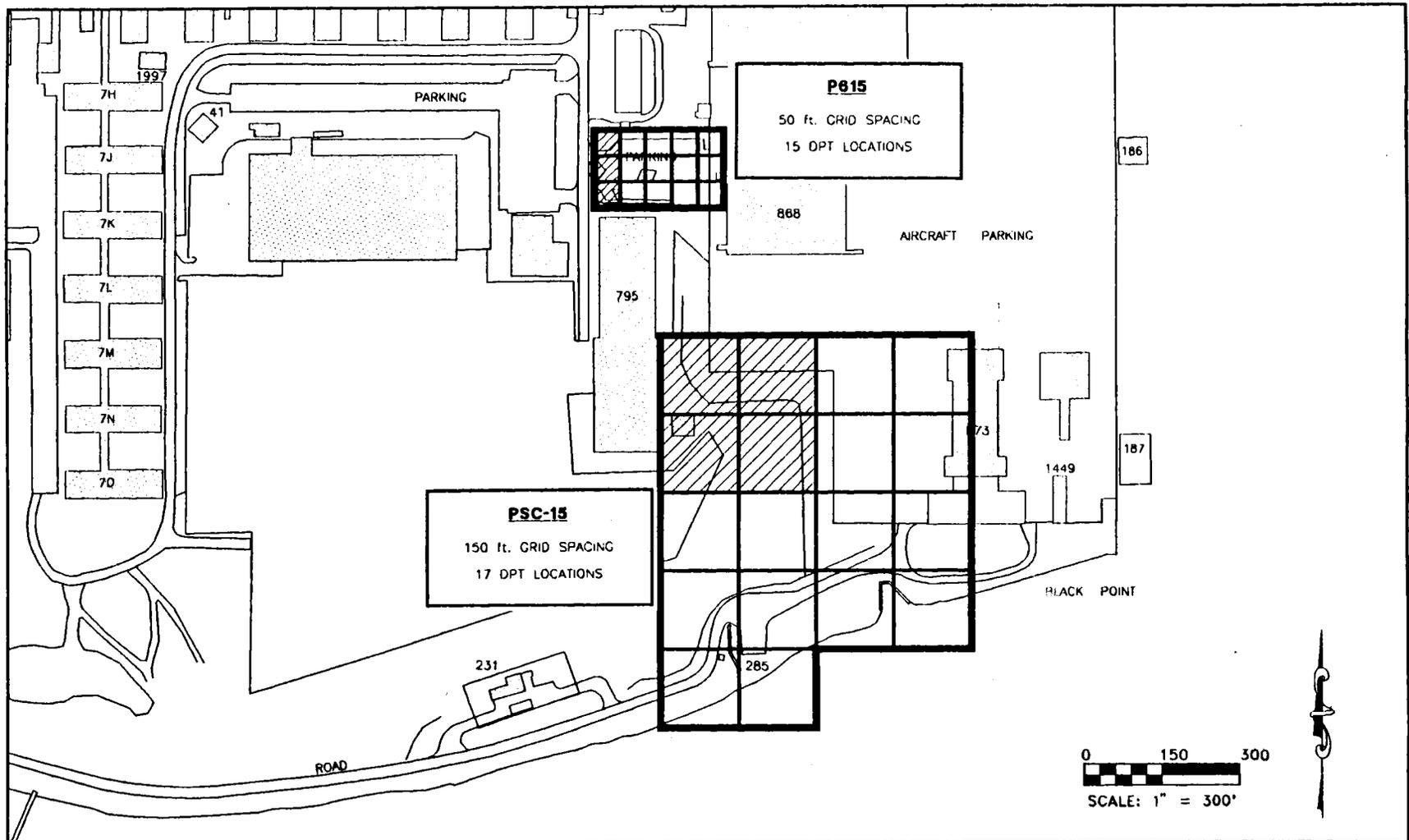
 ANTICIPATED SOURCE AREA OR "HOT SPOT" AT WHICH TO INITIATE GRID SAMPLING

**FIGURE 2-6  
GRID LOCATIONS FOR  
DPT GROUNDWATER SAMPLING,  
BLDG. 101 SOUTH**



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PLAN FOR OU 3**

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**LEGEND**

 ANTICIPATED SOURCE AREA OR "HOT SPOT" AT WHICH TO INITIATE GRID SAMPLING

**FIGURE 2-7**  
**GRID LOCATIONS FOR**  
**DPT GROUNDWATER SAMPLING,**  
**P615 AND PSC-15**



**FIELD SAMPLING**  
**PLAN FOR OU3**

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- If detected concentrations in one node are high relative to the PRGs, but below the PRGs in the adjacent node, the node spacing should be reduced in that area. An additional sample would be collected from a location equidistant between the first two.
- Sampling of the start nodes and subsequent points may reveal that parts of a gridded area are of concern, whereas other areas may be uncontaminated above the PRGs, or detected contamination may be attributed to an upgradient source beyond OU 3. It may be possible, without sampling all nodes in a gridded area, to confidently determine that contamination is limited to a part of the gridded area, making it unnecessary to sample the entire gridded area. Under such circumstances, any unsampled nodes within the uncontaminated or upgradient-contaminated area may be dropped from the grid and not sampled. In this way, the gridded areas will become focused on significant OU 3-related groundwater contamination. Some areas may not be sampled, but some areas where higher resolution is required may be sampled at a smaller node spacing. Overall, the maximum number of potential locations sampled should not change as a result of these field adjustments. However, it is uncertain at this time if all sampling locations will be required. The grids shown are anticipated to be the maximum number of points that could be required.
- The exact location of a sample within a node is flexible. The field team may place a sample anywhere within the node that is accessible; the general intent is for samples to be spaced evenly apart. Influences on location selection will be access and utilities clearance, or similar logistic issues.

2.4.2 Building 101 Ten DPT locations are within Building 101. Because access will be limited in Building 101, these locations will be selected and sampled after grid sampling surrounding the building has been completed. At that time, data from the grid sampling will indicate areas within Building 101 of particular interest, and sample locations will be selected based on those data and on the limits of DPT rig access.

2.4.3 Isolated Areas of Contamination There were five isolated DPT sample locations from the SSFP (CW02, CW10, CW16, CW19, and CW20) on the helicopter flightline that showed levels of CPCs above PRGs. DPT sampling data from surrounding locations suggest that these areas are relatively small in areal extent, so each of them will initially be investigated as an individual plume. A DPT sample point will be located approximately 25 feet downgradient of each original SSFP location to confirm the presence of contamination. Additional points will be added as necessary to delineate each plume according to the same criteria outlined above for the grid areas. The sample spacing will initially be 50 feet. If data indicate that contamination is widespread, or that the original detections are related, the field team may widen the sample spacing and investigate multiple locations as a single plume.

2.5 MONITORING WELL INSTALLATION. The groundwater monitoring well installation program is organized in five sections, each with a different purpose: (1) upgradient monitoring wells, (2) monitoring wells adjacent to the St. Johns River, (3) monitoring wells to delineate plumes, (4) monitoring wells inside Building 101, and (5) monitoring wells in isolated areas of contamination. Wells

at most locations are to be installed as pairs: a water table well and a deep well. The water table well will be constructed so that its screened interval spans the water table, and the deep well will be constructed so as to sample an interval of concern in a deeper permeable unit. A well may be installed as an individual well if an existing well at that location can serve the function of the second well. An interval of concern may be any of the following:

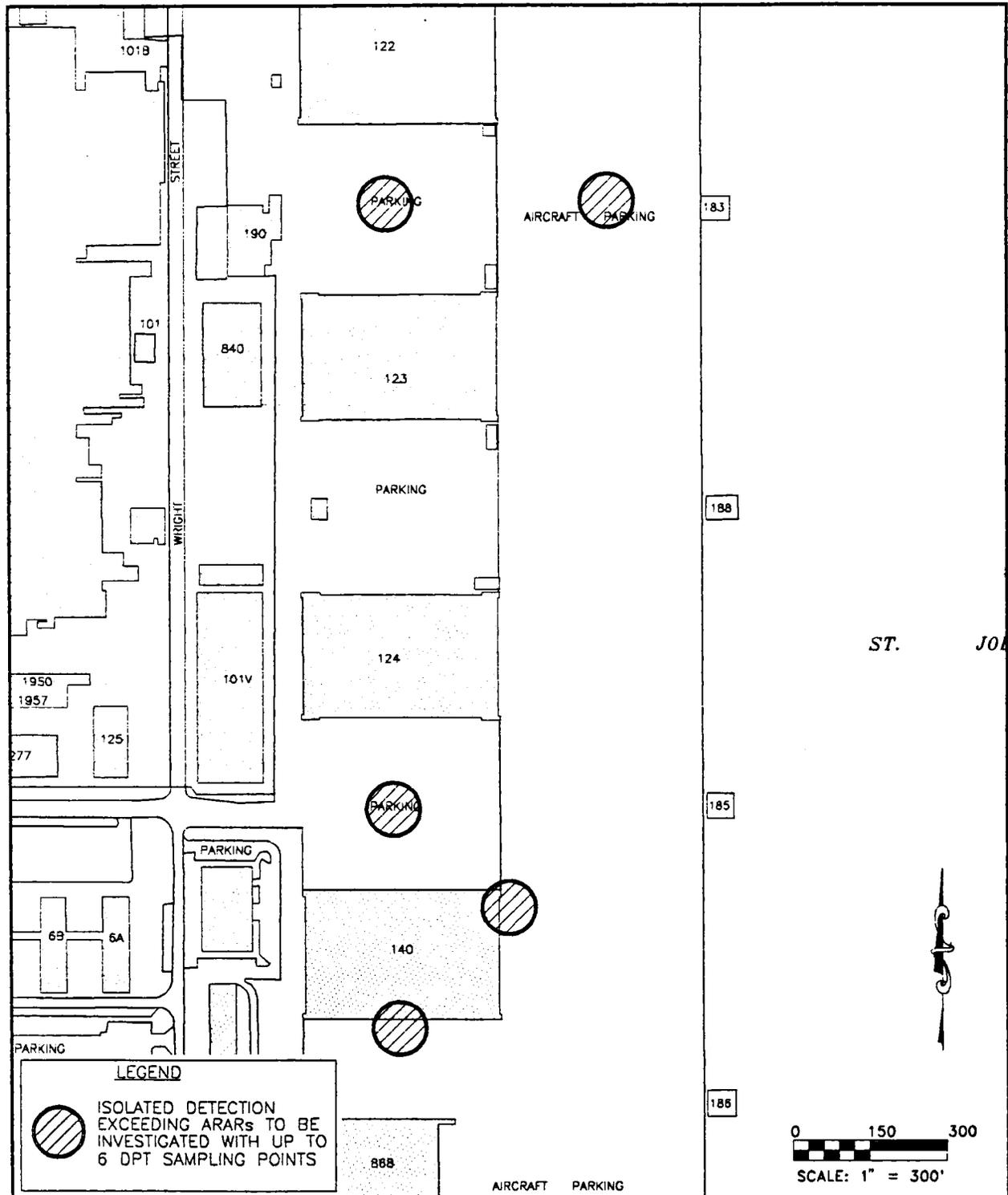
- an interval that is contaminated above the PRGs;
- an interval below all intervals contaminated above the PRGs, sampled to delineate the lower bound of contamination; and
- an interval that may, with further contaminant transport, become contaminated above the PRGs in the future.

Shallow monitoring wells will be drilled by hollow-stem auger; deep wells will be drilled with a combination of hollow-stem augering to install surface casing, and mud-rotary drilling to complete the borehole, as detailed in Subsection 3.4.2.1. During the drilling of deep monitoring wells, split-spoon sampling will be performed at 5-foot intervals for geologic reference. Also, at six monitoring well locations, a single wide-diameter split-spoon soil sample will be collected from a shallow interval for special analysis to support remedial technology evaluation (Subsection 2.6.3.1).

**2.5.1 Upgradient Monitoring Wells** After new potentiometric surface mapping indicates true upgradient locations, and DPT groundwater sampling identifies areas of groundwater contamination, four locations will be selected for upgradient monitoring well pairs. The purpose of upgradient wells is to provide permanent monitoring points that evaluate the quality of groundwater flowing into OU 3. Data from sampling of upgradient wells may be used to support risk assessment. Upgradient wells will be placed in areas upgradient of any OU 3 source of contamination. The four locations will be distributed along the western and northwestern boundary of OU 3. Tentative locations are indicated on Figure 2-8. Screened intervals for the upgradient pairs will be at the water table and at depth. Deep well screened intervals will be selected by the technical leaders during the program, based on the results of early CPTs. The screened intervals will be placed in a permeable formation that appears contiguous to deep permeable formations at OU 3, which have been shown to be contaminated.

**2.5.2 Monitoring Wells Adjacent to the St. Johns River** Two pairs of monitoring wells are to be installed at the southern end of OU 3, adjacent to the shoreline, as indicated on Figure 2-8. The purpose of these wells is to provide permanent monitoring points to evaluate the quality of groundwater as it is discharged from OU 3 to the environment of the St. Johns River. The pairs will each consist of a water table well and a deep well. The deep well will have its screened interval placed to intercept any contamination in deep permeable units, if found during DPT sampling. If no contamination above the PRG concentrations is detected at the southern end of OU 3, the deep wells will have their screened intervals placed at a depth to be selected by the field team technical leaders.

**2.5.3 Monitoring Wells to Delineate Plumes** A series of groundwater monitoring wells will be installed based on the results of DPT groundwater sampling. The purpose of these monitoring wells is twofold: (1) to document the areal extent of groundwater contaminant plumes with permanent monitoring points, and (2) to allow repeated sampling within contaminated areas to monitor changes in groundwater quality over time or during remediation.



**FIGURE 2-8  
DPT GROUNDWATER SAMPLING  
IN ISOLATED LOCATIONS**



**FIELD SAMPLING  
PLAN FOR OU 3**

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Locations of most monitoring wells will be selected based on the results of DPT groundwater sampling. Due to the complex and open-ended nature of the DPT sampling program, results will be discussed on a frequent and regular basis with representatives of the OU 3 Partnering Team. The team members will be provided with the geologic cross sections, potentiometric surface maps, and analytical data that the field team generates. Field team technical leaders will discuss the data and interpretations with the Partnering Team so that a consensus is maintained regarding the technical direction of the sampling program. Partnering Team approval of monitoring well locations will be required on an ongoing, regular basis.

To monitor the nature and extent of a given groundwater contaminant plume, a minimum of two well pairs is required: (1) located at the most contaminated point of the plume, termed the hot pair, and (2) located immediately downgradient of the leading edge of the plume, termed the downgradient pair. The term immediately downgradient is defined as either a distance between 0 and 20 feet, or a distance selected by best professional judgment. The leading edge of any plume is defined as the line of equal concentration equal to or less than the PRG for any detected CPC.

The hot pair deep well will have its screen placed within contaminated strata at depth. There will be considerable flexibility available to the field team regarding deep well placement. The specific conditions of the groundwater contamination for each plume will drive the placement for each hot pair deep well. The downgradient pair deep well will be screened at a depth suitable to intercept known deep contamination should it migrate to that location.

Well pairs over and above the two pairs per plume discussed above may be installed for some plumes. If a plume exhibits complex geometry, or is ill-defined due to a diffuse or complex source, additional wells, such as wells lateral to the axis of the plume, may be installed to better bound the plume with permanent points. Also, in selected areas where remedial actions are likely, or where risk assessment is required, additional wells may be installed within the plumes. These additional wells may be installed as individuals or as pairs. Decisions regarding the placement of wells in addition to the two pairs that define the plume's nature and extent may be made by the field team technical leaders independent of Partnering Team input.

2.5.4 Monitoring Wells in Building 101 Four pairs of monitoring wells will be installed inside Building 101 to further delineate contaminant plumes and to monitor groundwater quality close to potential sources in the building. The locations of these well pairs will be selected based on DPT sampling results. Locations may be limited to those accessible to a drilling rig. The criteria for selecting depths of deep wells is the same as for the plume delineation wells (Subsection 2.5.3).

2.5.5 Monitoring Wells in Isolated Areas of Contamination An estimated 10 pairs of monitoring wells will be installed to monitor the isolated areas of contamination on the helicopter flightline. Two pairs of wells are expected to be sufficient to document plumes in these areas, a hot pair and a downgradient pair, as discussed in Subsection 2.5.3.

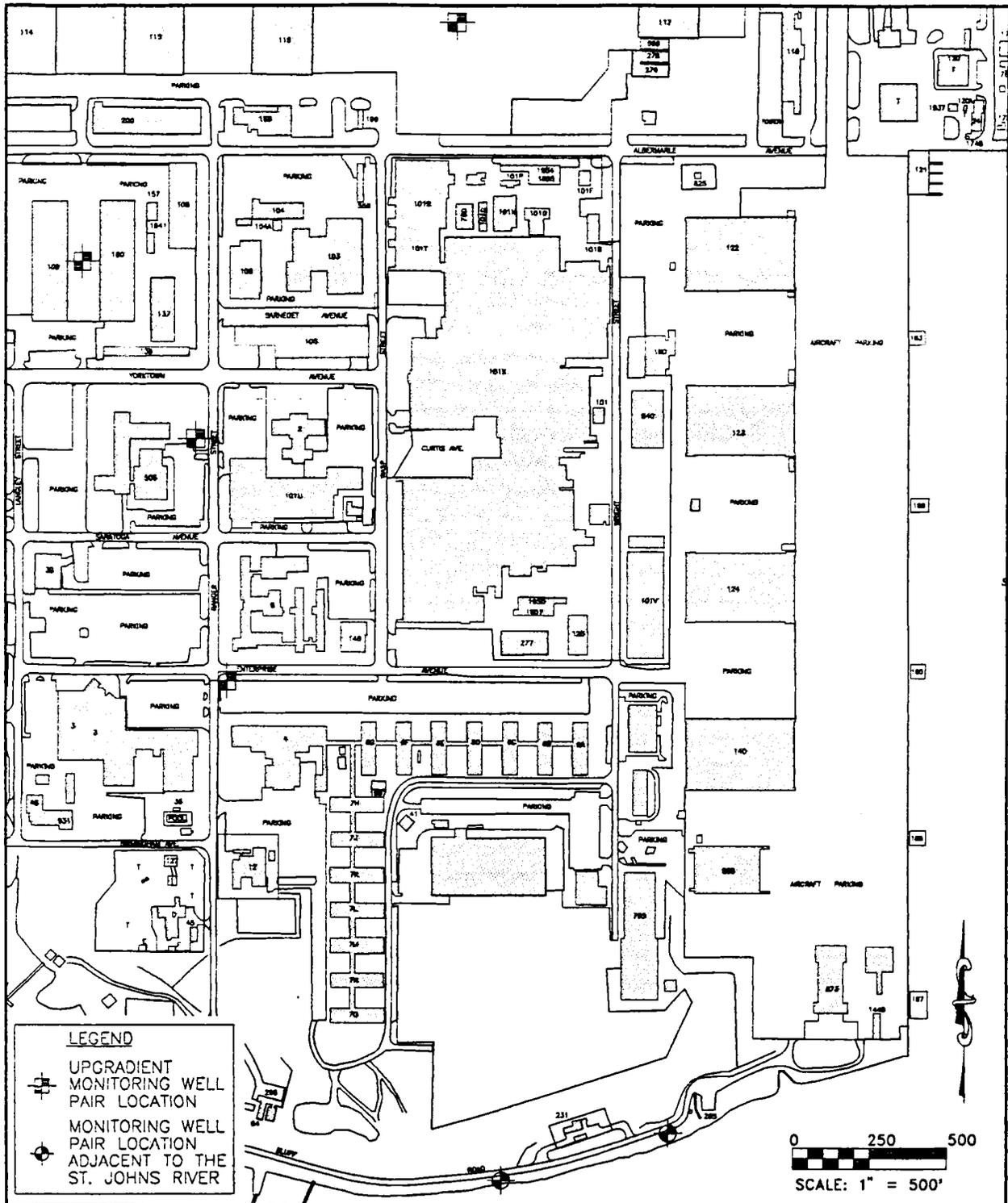
## 2.6 SOIL BORINGS.

2.6.1 Soil Borings at PSC-14 PSC-14 is a concrete-lined seepage pit located directly behind (west of) Building 125 (the Battery Shop). Waste acid from lead-acid batteries was formerly disposed in the pit. The volume estimated to be disposed is 100 gallons annually between 1959 and 1982. Three hand auger soil borings will be performed to characterize the nature of this potential source. The borings are to be located around the pit on three sides (north, west, and south), as near to the walls of the pit as possible. The borings on the north and the south sides of the pit will also be placed as near to the wall of Building 125 as possible, because east is the downgradient side of the pit. Following the hand augering procedures in Subsection 3.3.2, samples will be collected from the surface at 2-foot intervals (0 to 2 feet, 2 to 4 feet, 4 to 6 feet, etc.) to one interval below the water table (estimated at 7 feet bls). If possible, a sample will be collected from the interval just below the water table. All soil boring samples will be submitted for chemical analyses, for full CLP TCL and TAL scans with NEESA Level D DQO and standard TAT on results. Each borehole will be grouted from the bottom up via a tremie pipe, and the pavement will be repaired with a like material to its original thickness and strength as described in Subsection 3.1.7.

2.6.2 Soil Borings at PSC-15 PSC-15 is a former solvent and paint sludge disposal area. An estimated 70,000 gallons of waste were deposited in an approximate 100-foot by 100-foot area over 36 years, ending in 1978. The area of disposal is suspected to be in the unpaved area immediately south of the flightline to the south of Building 868. It is possible that solvent or paint waste contamination is also present beneath the flightline pavement near PSC-15. Soil sampling from hand auger borings will be performed through the flightline adjacent to PSC-15 to investigate that potential. Four borings will be located near the edge of the pavement between PSC-15 and Building 868, as indicated on Figure 2-9. Following the hand augering procedures in Subsection 3.3.2, samples will be collected from the surface to the water table (estimated at 6 feet bls) at 2-foot intervals (0 to 2 feet, 2 to 4 feet, 4 to 6 feet, etc.). All soil boring samples will be submitted for chemical analyses for full CLP TCL and TAL scans with NEESA Level D DQO and standard TAT on results. Each borehole will be grouted from the bottom up via a tremie pipe, and the pavement repaired with a like material to its original thickness and strength as described in Subsection 3.1.7.

2.6.3 Soil Borings at Monitoring Well Locations Wells will be installed and developed according to the procedures and specifications in Section 3.4. The first task at every well location, after pavement coring, will be to hand auger to the water table for the purpose of utilities clearance, as detailed in Subsection 3.1.6. Additionally, hand augering will be conducted to obtain samples of the vadose zone soils for chemical analyses at the following well locations: (1) at every deep well location, and (2) at shallow well locations that are not paired with a deep well. Soil samples will be collected at 2-foot intervals from the surface to the water table in accordance with the procedures outlined in Subsection 3.3.2. Analyses for these samples will be for full scan CLP TCL and TAL analytes with NEESA Level D DQO and standard TAT on results.

2.6.3.1 Special Soil Sampling for Remedial Technology Evaluation At six selected locations, the analyses and depth specifications for sampling of soil borings will be different from those discussed above. Additional parameters will



**FIGURE 2-9**  
**PROPOSED MONITORING WELL**  
**PAIRS, LOCATIONS UPGRADIENT**  
**OF OU 3 AND ADJACENT TO THE**  
**ST. JOHNS RIVER**



**FIELD SAMPLING**  
**PLAN FOR OU 3**

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be requested to support remedial technology screening. These special analyses are listed in Table 2-2. Samples will be collected for CLP TCL and TAL scans from all sampled intervals above the water table, as in other borings. Additional special analytical samples will be collected from two intervals: (1) from the interval immediately above the water table, and (2) from an interval immediately above the shallowest clay layer, as detected during CPT testing. The six locations where these special analyses are required are as follows:

- from a location at the most contaminated area of the dry cleaner (building 106),
- from the most contaminated area of building 780, and
- from four other locations to be selected in the field. These may be in other portions of the above-mentioned areas, if they prove to be extensive or heterogeneous, or they may be in new areas of high groundwater contamination, if detected, where it is likely that a remedial action would be applied. Two locations should be placed in areas of hydraulic fill. Building 780 is in an area of hydraulic fill. If two borings are selected in the area of Building 780, those two would satisfy this requirement. If only one boring is selected at Building 780, then another of the locations selected in areas of high groundwater contamination should also be an area of hydraulic fill.

**Table 2-2**  
**Special Soil Analyses for the Evaluation of Remedial Technologies**

Operable Unit 3 Field Sampling Plan  
NAS Jacksonville  
Jacksonville, Florida

Media Characteristics	Analyses
Physical and Chemical Soil Characteristics	pH Moisture content Total organic carbon Cation exchange capacity Heating value Leachable metals (Toxicity Characteristic Leaching Procedure [TCLP]) Grain size distribution
Biological Soil Characteristics	Total heterotrophic bacteria Total kjeldahl nitrogen (TKN), ammonia, and nitrite plus nitrate Orthophosphorus

Soil sampling for TCL, TAL, and special analyses will be conducted by hand auger for those intervals above the water table. The sample interval immediately above the shallowest clay unit is expected to be at approximately 15 to 25 feet depth, a depth that cannot be reached by hand augering. This interval will be sampled by split-spoon sampler when a drilling rig is mobilized for well installation. A wide-diameter, split-spoon sampler will be used in order to sample sufficient volume for all of the analyses (3-inch or greater). If a single spooned interval does not yield enough soil volume for all analyses, a second interval immediately below the first may be spooned for additional volume. For this reason, the depth interval at which the first sample is collected should

be selected so that a second interval can be sampled, if needed. The sampled intervals must both be above the contact between permeable sand and impermeable clay. Data on the depth to clay in areas of interest will be available from CPT logs.

**2.6.3.2 Lithologic Sampling at Deep Monitoring Well Locations** During drilling of every deep monitoring well location, split-spoon samples will be collected for lithologic identification at 5-foot intervals below the water table. Samples will be retained in soil jars for future geologic reference. No samples will be collected for chemical analysis.

**2.7 SURFACE SOIL SAMPLING.** Surface soil sampling will be performed at PSC-15 to investigate the potential for PSC-15 to act as a source of contamination to overland flow of surface water that ultimately discharges to the St. Johns River. Surface soil sampling will be conducted after test trenching has delineated the visible boundaries of waste disposal at PSC-15. Six samples will be located within the area determined to have been used for waste disposal. They are to be located in such a way so as to be evenly spaced apart, so that the samples are representative of the range of soil conditions in the disposal area. A location layout such as the center and points of a five-point star positioned to overlay PSC-15 is suitable. In addition to the six samples collected to characterize PSC-15, three locations will be sampled from a suitable area to represent background conditions for the soils found near PSC-15.

Surface soil samples are to be collected according to the procedures described in Subsection 3.3.1. Samples will be analyzed for CLP full scan TCL and TAL analytes with NEESA Level D DQOs and standard TAT on results.

**2.8 TEST TRENCHING.** Test trenching will be conducted with a small backhoe. Trenching will begin at the edge of the flightline near well NARF-B1, which is known to be highly contaminated. Trenches will be approximately 18 inches wide, depending on depth and soil stability, and approximately 100 feet long, and will be oriented in the north-south direction. Trench depths will initially be to the water table (estimated at 6 feet bls). If contamination is perceptible, subsequent trenches need only be deep enough to expose contamination (as detected visually, by odor, and by organic vapor analyzer [OVA]). Actual trench lengths will be sufficient to define the lengthwise extent of contamination (i.e., the edge of contamination should be visible at the ends of the trenches). Additional trenches will be dug parallel to the first at an appropriate spacing selected based on field judgment. Trenching will continue until the width of the disposal area is defined. The work will be limited to 2 days. Sampling of test trench contaminated soils is to be performed as follows. The most contaminated parts of each test trench will be selected based on visual observation and OVA readings. Three samples of the selected material will be collected from each trench. Sampling will be for full scan CLP TCL and TAL analyses with NEESA Level D DQOs and standard TAT on results, and also for geologic reference. After all trenches have been completed, five of the samples that best represent the nature and variability of the waste material will be submitted for chemical analyses.

Trenching activities are to be carried out and documented according to the procedures in Subsection 3.3.4.

**2.9 MONITORING WELL GROUNDWATER SAMPLING.** All wells installed during the RI program, all piezometers installed during the SSFP, and select wells installed during earlier investigations will be sampled near the end of the RI field program. Analyses for these wells will be full CLP TCL and TAL scans with NEESA Level D DQOs and standard TAT on results. In addition, six shallow wells located within areas where remedial action is likely will be sampled for additional special analyses required to screen potential remedial technologies. These special analyses are listed in Table 2-3.

**Table 2-3  
Special Groundwater Analyses for the Evaluation of Remedial Technologies**

Operable Unit 3 Field Sampling Plan  
NAS Jacksonville  
Jacksonville, Florida

Media Characteristics	Analyses
Field Measurements	pH Dissolved oxygen
Physical/Chemical Groundwater Characteristics	Total oil and grease Total solids Total suspended solids Total dissolved solids Redox potential
Biochemical Groundwater Characteristics	Biochemical oxygen demand Chemical oxygen demand Total heterotrophic bacteria (Standard Plate Count) Total kjeldahl nitrogen (TKN), ammonia, and nitrite plus nitrate Orthophosphorus

The six locations where these special analyses are required are the same locations as those described in Subsection 2.6.3.1 for special analyses from soil sampling. Most of the special analyses for these groundwater samples are laboratory analyses. However, during sampling, dissolved oxygen measurements will be collected in the field on the six shallow wells and also on the deep wells adjacent to them.

Selection of existing wells for groundwater sampling will be done based on the following criteria. All 27 piezometers installed during the SSFP will be sampled. Sixteen existing wells installed prior to the SSFP will also be sampled (these wells are identified on Table 2-4). In addition, any of the 26 remaining existing wells at OU 3 will be sampled if they are located within a groundwater contaminant plume as determined from DPT sampling. The monitoring well sampling program is outlined in Table 2-4.

**2.10 SURFACE WATER AND SEDIMENT SAMPLING.** Aquatic habitats of the St. Johns River adjacent to the southern perimeter of OU 3 and of selected reference locations will be sampled to characterize the river habitat that may be exposed to potential OU 3-related contaminants. This characterization will be conducted in two steps: (1) qualitative substrate mapping of the aquatic habitats, and (2) surface water and sediment sampling for chemical and toxicity analyses. Substrate mapping will be performed to establish the distribution of sediment

**Table 2-4  
Summary of Monitoring Well Groundwater Sampling**

Operable Unit 3 Field Sampling Plan  
NAS Jacksonville  
Jacksonville, Florida

Wells/Piezometers to Sample	Estimated Quantity and Description
All new monitoring wells	102
All SSFP piezometers	27
Existing wells	<p><u>To monitor discharge to river (nine total)</u></p> <ul style="list-style-type: none"> <li>• NARF-4, NARF-12, NARF-16, NARF-17, and NARF-18</li> <li>• P159MW04</li> <li>• JAX-873-1-3, JAX-873-3-2, and JAX-873-3-7</li> </ul> <p><u>To monitor known potential sources (four total)</u></p> <ul style="list-style-type: none"> <li>• NARF-9, NARF-11, and NARF-B1</li> <li>• OTC-1</li> </ul> <p><u>Wells paired with SSFP piezometers (three total)</u></p> <ul style="list-style-type: none"> <li>• B101MW01</li> <li>• P159MW01</li> <li>• JAX873-10</li> </ul> <p>Other existing wells</p> <p>Any other existing wells will be sampled if they are located within a groundwater contaminant plume, as defined by DPT sampling.</p>
<p>Notes: SSFP = Scoping Study Field Program DPT = direct push technology.</p>	

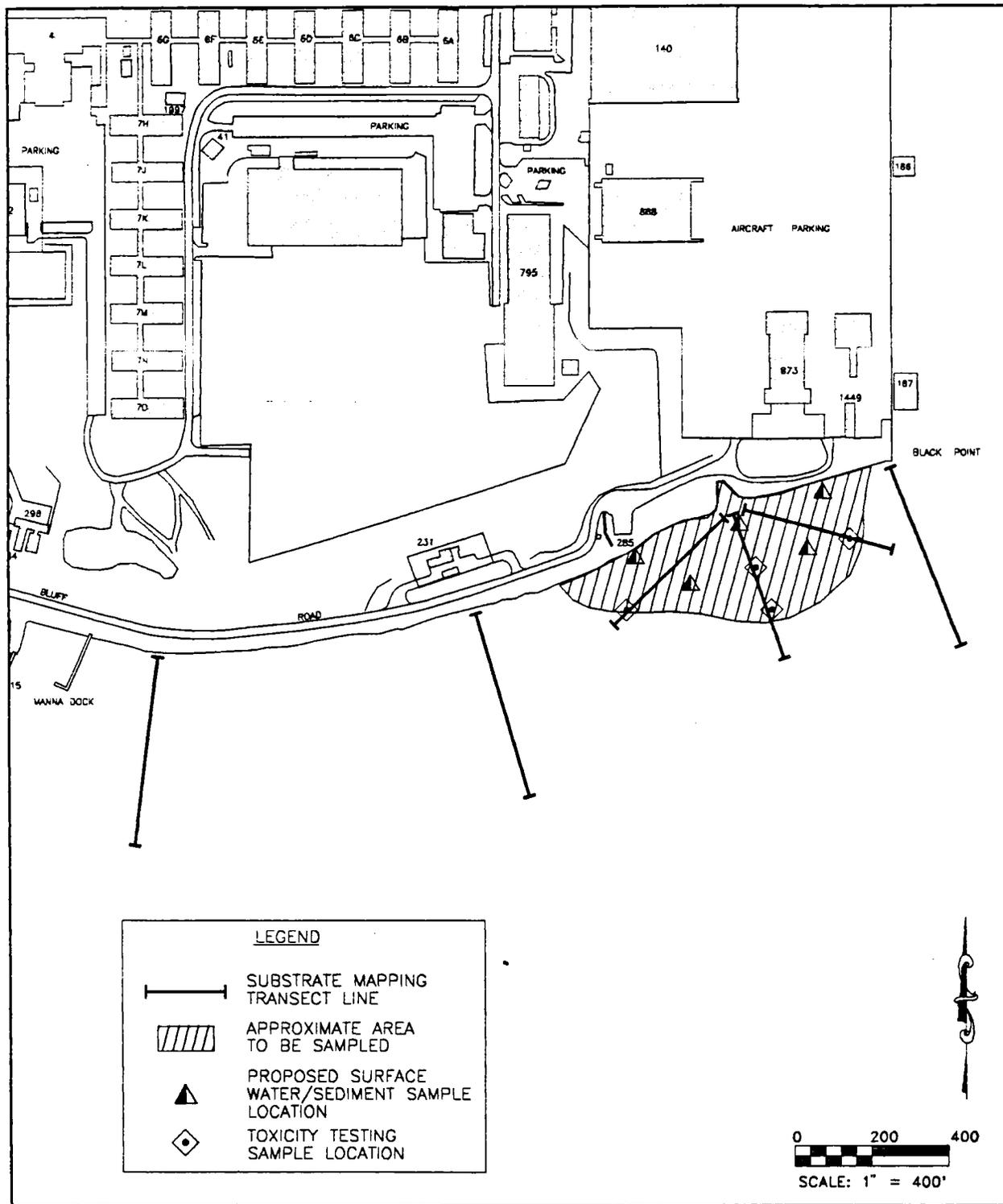
type, submerged vegetation, and water depth. These characteristics will influence the selection of surface water and sediment sample locations. All sampling proposed for the St. Johns River will be conducted from a boat to minimize disturbance to the sediment.

Six transects will be established in the St. Johns River, three of which will extend perpendicular to the shore at equidistant intervals between Black Point to the east and the marina docks to the west. The remaining three transects will extend radially from the stormwater outflow area at the southern end of OU 3 westward to Black Point and eastward to monitoring well NARF-12 (Building 285). Approximate locations of the transects are illustrated on Figure 2-10. The substrate mapping will supplement similar activities completed along the eastern perimeter of OU 3 during the SSFP.

At each interval within the six transects, a sediment corer or Ponar dredge grab sampler will be used to collect a sediment sample. The depth to the bottom will be noted, and the sediment will be qualitatively described (grain size fractions, relative amounts of organic matter, and mineral sediment). In addition, the presence, coverage, and composition of submerged aquatic macrophytes will be assessed at each location either visually or by using a Ponar dredge grab sampler. Light penetration has been reported to restrict plant growth in the river to a maximum of 1.5 to 2.0 meters depth in the submerged aquatic vegetation (SAV) zone (Brody, 1990). Secche disc measurements of light penetration will be taken at each location, as appropriate. Sampling along each transect will continue beyond the SAV zone into the deeper demersal zone. The length and interval of sampling within each transect will be variable, depending on the sediment type observed.

Once substrate mapping has been completed and areas of particular interest for sampling (i.e., areas of vegetation or fine-grained sediment deposition) have been identified, a series of surface water and sediment samples will be collected for chemical analyses and toxicity testing. Sampling will focus on the area adjacent to the stormwater outflow area where the radial transects for substrate mapping will be completed. Nine surface water and sediment samples will be collected from the approximate area indicated on Figure 2-10. Specific sample locations will be selected upon consideration of the substrate mapping data. In addition, two reference sample locations will be sampled to provide background data. Reference sample locations will be collected from an area that does not appear to be impacted by OU 3 or other known areas of contamination. Representatives of the Partnering Team will be consulted regarding the location of the surface water and sediment reference sample locations.

Surface water will be sampled at each location with a Beta bottle. Samples will be collected from approximately 6 inches above the bottom. Sediment samples will be collected with a gravity corer. If sediments cannot be obtained via the gravity corer, a Ponar dredge grab sampler will be used. Analyses for surface water samples will be full scan CLP TCL and TAL analytes with NEESA Level D DQOs and standard TAT on results including volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides and polychlorinated biphenyls (PCBs), total cyanide, and metals (unfiltered). In addition to the above analyses, the surface water samples will be analyzed for cadmium, copper, nickel, silver, and beryllium by furnace; hexavalent chromium by colorimetric; phenols by USEPA Method 8040 (USEPA, 1986); polynuclear aromatic hydrocarbons by USEPA Method 8100, and halogenated hydrocarbons by USEPA Method 8010. Hardness will



**FIGURE 2-10**  
**SURFACE WATER/SEDIMENT**  
**SAMPLE LOCATIONS SOUTH**  
**OF OU 3**



**FIELD SAMPLING**  
**PLAN FOR OU 3**

**NAS JACKSONVILLE**  
**JACKSONVILLE, FLORIDA**

also be tested. Sediment samples will be collected for full scan CLP TCL and TAL analysis, as well as for total organic carbon (TOC). Sediment samples will also be analyzed for antimony by furnace and polynuclear aromatic hydrocarbons by USEPA Method 8100. These analytical methods will achieve lower detection limits so that the data can be compared to the State of Florida Surface Water Quality Standards for Class III marine water (FDEP, 1992) and the USEPA Region IV Waste Management Division sediment screening values for hazardous waste sites (USEPA, 1992).

The ecological sampling at OU 3 will also include sediment toxicity testing. Additional sediment sample volume will be collected from four of the nine surface water and sediment locations (see Figure 2-10) and the two reference locations. The samples will be submitted to a subcontract laboratory for a 10-day survival test with a marine amphipod (*Ampelisca abdita*) (ASTM, 1992).

**2.11 AQUIFER TESTING.** Improved estimates for aquifer properties at OU 3 are required to support USGS numerical modeling. Estimates are required for hydraulic conductivity in deep permeable units at OU 3. Slug tests will be performed on selected wells to obtain estimates of hydraulic conductivity. Wells screened in intermediate and deep intervals will be selected to supplement existing shallow data and to represent the lateral and vertical variability of the operable unit. Single-well pumping tests will be performed at selected monitoring wells to obtain estimates of transmissivity that are more reliable than slug test values.

**2.11.1 Slug Tests** Estimates of hydraulic conductivity for the shallowest permeable strata underlying OU 3 have been obtained from slug tests conducted at several shallow wells. However, no slug tests have to date been conducted on wells screened in strata deeper than 25 feet. Rising-head and falling-head slug tests will be conducted at eight selected deep monitoring wells. The eight wells will be selected in the field. Slug tests will be performed after monitoring well groundwater sampling has been completed. The criteria for selecting wells for slug testing are as follows.

- Wells will be selected so that they are widely distributed across the operable unit.
- Wells will be selected whose screened intervals represent a range of lithologies. Some wells may be screened in silty sand, clayey sand, clean sand, and so on.
- Wells will be selected that screen strata in which contamination was detected.
- Wells will be selected from a variety of intermediate and deep permeable units.

**2.11.2 Single-Well Pumping Tests** To support the USGS groundwater flow and transport modeling, which will identify subsurface pathways and predict exposure levels at selected exposure points, accurate values of aquifer characteristics such as hydraulic conductivity are required. The existing data for hydraulic conductivity are available only from limited slug tests from shallow wells and,

consequently, the data reliability is not sufficient to appropriately support the numerical modeling effort.

Short duration single-well pumping tests of up to 2 or 3 hours will be conducted with careful monitoring in the pumped well of both drawdown during pumping and recovery after pump shutdown. These pumping tests will provide reliable estimates for hydraulic conductivity in the aquifer tested. The tests will be conducted using eight existing monitoring wells and piezometers. For locations with existing well pairs (shallow and deep) and well groups, the closest non-pumped wells will also be monitored to see if there is any effect due to the pumping.

This testing will proceed according to the following steps.

1. Preliminary Testing. To select wells suitable for testing and to determine the appropriate pumping rates, several of the existing wells will be surged and tested by pumping for a few minutes at various pumping rates while observing drawdown levels, then the recovery behavior will also be observed and recorded. The existing slug test data will be reviewed before selecting the wells to be tested. Using these data, eight wells across OU 3 and their appropriate pumping rates will be selected for short duration pumping tests. Five water table wells will be selected, and also three wells screened below the uppermost clay. Locations of selected wells will be distributed across the areal extent of OU 3.
2. Single-Well Tests. Each of the wells or piezometers selected in step 1 will be hydraulically tested using the determined pumping rates for a duration of 2 hours (more or less time may be spent depending upon observations made during the tests). Some of the tests may be changed to "step drawdown" tests in which the pumping rate is abruptly increased during the test. After the pumping phase of these tests, the recovery of the water level in the well will be monitored for approximately 1 hour or until 90 to 95 percent of the total drawdown has recovered.
3. Standard Pumping Test. If the single-well testing reveals that the hydraulic conductivity of the uppermost sand unit is significantly larger than indicated by the shallow well slug testing, a standard multi-day pumping test will be planned and conducted in the uppermost sand unit at a location to be selected. A multi-day pumping test is currently not planned.

2.12 SURVEYING. All analytical and CPT data will be mapped in the field during the sampling programs; these maps will be the basis for selecting additional sample locations, for delineating groundwater plumes, and for deciding when sufficient data have been collected to close any data gaps. Daily location and elevation surveys of DPT groundwater sample points, surface soil sample points, test trenches, and soil boring locations are required to process the above data. New piezometers will be surveyed immediately after installation so that they may be used to map groundwater levels to determine flow directions. New monitoring wells will be surveyed near the end of the RI field program.

2.12.1 Global Positioning System (GPS) Surveying Surveying on a day-to-day basis of soil boring locations, DPT locations, surface soil locations, surface water and sediment locations, and test trenches will be performed by GPS survey techniques to provide quick data, and to reduce effort and cost. Hundreds of points will require surveying over the course of the program. Digital coordinate files will be used in AutoCAD™ maps, GTGS™ maps and cross sections, and in other mapping, contouring, and database software to specify the locations of environmental datapoints. The locational data to collect at any exploration point will be the horizontal position and the elevation of the ground surface at the point.

A GPS system capable of sub-meter precision by differential GPS methods such as the Magellan™ GPS NAV 5000 PRO or the Trimble Prolite™ will be used. Differential GPS methods permit sub-meter precision from the Department of Defense (DOD)-scrambled GPS satellite signals, which without differential methods permit only 100-meter precision, or worse. Positional data are collected from a point of fixed, precisely known location, (a point either to be established by the field team at OU 3, or a nearby commercially operated base station) and these data are used with post-processing software on a field-based personal computer to correct locational data from points of interest at OU 3 that were collected at the same time using the same satellites. The post-processing software will produce coordinate files relative to the Transverse Mercator Projection for Florida, East Zone and the North American Datum (NAD) of 1983; and the National Geodetic Vertical Datum (NGVD) of 1929.

If the field team is using a commercial base station, one GPS receiver will be required in the field to collect locational data, but there will be the risk that the base station will not be collecting data at a given time using the same satellites as the field team (satellite choice is user selected). In that case, sub-meter precision would not be possible at that time. The field team should consult with NAS Jacksonville personnel because it is likely that the base operates a GPS base station. If the field team establishes its own base station at OU 3, sub-meter precision will always be possible, but two GPS receivers will be required: one to collect the base station data, and the second to collect simultaneous locational data at the points of interest. The field team will require a person on the team trained to collect and process GPS data.

2.12.2 Theodolite and Level Surveying Professional Florida-licensed surveyors will be required to survey the locations and elevations of piezometers and monitoring wells. Horizontal control at OU 3 has already been established temporary control points at OU 3 that are referenced to the Transverse Mercator Projection for Florida, East Zone and converted to the North American Datum of 1983. Vertical control at the same control points is referenced to the National Geodetic Survey (NGS) Station "Mulberry Camera" 1963, elevation 23.599 above NGVD. A permanent bench mark (and monument) will be established at OU 3 during the RI.

The horizontal location and vertical elevation will be established for each piezometer and monitoring well relative to the monuments at OU 3. The horizontal location for each item will be measured to the nearest 1.0 foot and referenced to the Transverse Mercator Projection for Florida, East Zone and converted to the North American Datum of 1983. The vertical elevation of each item will be established to third-order accuracy and referenced to the established monuments (NGVD of 1929). The land surface elevation of each piezometer and well location

will be measured to the nearest 0.1 foot. The reference measuring point (top of casing) of each well and piezometer will be measured to the nearest 0.01 foot.

**2.13 ANALYTICAL PROGRAM SUMMARY.** Summaries of the analytical program for OU 3 are provided in Tables 2-5 and 2-6. The table presents the estimated total number of samples and QA/QC samples to be collected by task per matrix for each analytical type.

**Table 2-5  
Analytical Program Summary, Soil and Groundwater**

Operable Unit 3 Field Sampling Plan  
NAS Jacksonville  
Jacksonville, Florida

Field Activity	NEESA DQL	Turn-around-time (TAT)	Offsite NEESA-approved Laboratory Analyses										
			TCL VOCs		TCL SVOCS		TCL Pesticides/PCBs		TAL Metals/CN		Special Analyses for Remedial Technology Evaluation <sup>1</sup>		
			Soil	Water	Soil	Water	Soil	Water	Soil	Water	Soil	Water	
Background Soil Sampling <sup>2</sup>	D	Standard									9		
DPT Groundwater Sampling <sup>3</sup>	C	24-hour		816		816		816		816			
Monitoring Well Installation Soil Borings <sup>4</sup>	D	Standard	153		153		153		153			12	
Soil Borings <sup>5</sup>	D	Standard	21		21		21		21				
Test Trench Soil Sampling	D	Standard	5		5		5		5				
Monitoring Well <sup>6</sup> Groundwater Sampling	D	Standard		145+		145+		145+		145+			6
Surface Soil Sampling	D	Standard	8		8		8		8				
QA/QC Samples													
Replicate <sup>7</sup>	D/C <sup>8</sup>	See note 7.	19	55	19	55	19	55	20	55	1		1
Matrix Spike (MS) <sup>9</sup>	D/C		10	48	10	48	10	48	10	48	1		1
MS duplicate (MD) <sup>9</sup>	D/C		10	48	10	48	10	48	10	48	1		1
Equipment blank <sup>10</sup>	D/C			40		40		40		40			1
Trip blank <sup>11</sup>	D/C			80									
Field blank <sup>12</sup>	D	Standard		8		8		8		8			1

See notes at end of table.

**Table 2-5 (Continued)  
Analytical Program Summary, Soil and Groundwater**

Operable Unit 3 Field Sampling Plan  
NAS Jacksonville  
Jacksonville, Florida

Field Activity	NEESA DQL	Turn-around-time (TAT)	Offsite NEESA-approved Laboratory Analyses										
			TCL VOCs		TCL SVOCs		TCL Pesticides/PCBs		TAL Metals/CN <sup>1</sup>		Special Analyses for Remedial Technology Evaluation <sup>1</sup>		
			Soil	Water	Soil	Water	Soil	Water	Soil	Water	Soil	Water	
Materials blank <sup>13</sup>	D	Standard											
• Bentonite powder			1		1			1		1		1	
• Bentonite chips					1			1		1		1	
• Filter sand 20/30					1			1		1		1	
• Filter sand 30/65					1			1		1		1	
• Potable decontamination water supply <sup>14</sup>						2			2		2		2
<b>Estimated Total Samples</b>			<b>230</b>	<b>1242</b>	<b>230</b>	<b>1162</b>	<b>230</b>	<b>1162</b>	<b>240</b>	<b>1162</b>	<b>15</b>	<b>11</b>	

- <sup>1</sup> Special analyses for the evaluation of remedial technologies are tabulated by sample media in Tables 2.3 and 2.4.
- <sup>2</sup> Three samples collected per each of three borings.
- <sup>3</sup> Quantity estimated; estimated 272 DPT points, average of 3 samples per point.
- <sup>4</sup> Quantity estimated; 51 locations to be sampled at 2-foot intervals from surface to water table (estimated at 6 feet depth).
- <sup>5</sup> Quantity estimated; 7 locations to be sampled at 2-foot intervals from surface to water table (estimated at 6 feet depth).
- <sup>6</sup> Quantity estimated; 102 new wells, 27 existing piezometers, 16 specified existing wells, and additional existing wells, as required (Section 2.9).
- <sup>7</sup> Quantity estimated; replicates collected at a frequency of 1 per every 10 samples for Level D QA/QC, and 1 per every 20 samples for Level C QA/QC.
- <sup>8</sup> QA/QC sample DQL and TAT will be the same as for the associated sample or activity.
- <sup>9</sup> Quantity estimated; MS/MD samples collected at a frequency of 1 per every 20 samples. MS/MDs must be taken from the same samples that are replicated.
- <sup>10</sup> Quantity estimated; equipment rinsate blanks collected at a frequency of one per sampling day for each type of sampling equipment used. However, only equipment rinsate blanks from every other day are analyzed. Other samples are held and analyzed only if evidence of contamination exists.
- <sup>11</sup> Quantity estimated; one trip blank submitted for VOC analysis for each VOC sample cooler shipped.
- <sup>12</sup> Quantity estimated; field blanks of analyte-free water supply collected at a frequency of one per work shift (10 days). Eight sampling shifts estimated.
- <sup>13</sup> Materials blanks of well drilling and construction materials are to be collected once during the field program, except where noted below. Materials blanks consist of grab samples of the dry appropriate material collected from a randomly selected bag of that material. Potable water materials blanks are to be collected from the source tap.
- <sup>14</sup> Materials blanks of potable water source(s) to be collected once at beginning of drilling field program, and again at the end of the field program.

Notes: NEESA = Naval Energy and Environmental Support Activity.  
DQL = data quality level.  
TCL = target compound list.  
VOCs = volatile organic compounds.  
SVOCs = semivolatile organic compounds.  
PCBs = polychlorinated biphenyls.  
TAL = target analyte list.

**Table 2-6  
Analytical Program Summary, Surface Water and Sediment**

Operable Unit 3 Field Sampling Plan  
NAS Jacksonville  
Jacksonville, Florida

Field Activity	TCL VOC		SVOC		Pest PCB		TAL Metals/C N <sup>1</sup>		PAH <sup>1</sup>		Hardness		TOC		Special Analysis Metals <sup>2</sup>		Cr+6 <sup>3</sup>		Phenols <sup>4</sup>		Halogenated Hydrocarbons <sup>5</sup>		Toxicity		
	SW	Sed	SW	Sed	SW	Sed	SW	Sed	SW	Sed	SW	Sed	SW	Sed	SW	Sed	SW	Sed	SW	Sed	SW	Sed	SW	Sed	
	Surface Water and Sediment Sampling	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
QA/QC Samples																									
Replicate	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Matrix spike (MS)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MS duplicate (MD)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Equipment blank	1		1		1		1		1		1		1		1		1		1		1		1		1
Trip blank	2																								
Field blank	1		1		1		1		1		1		1		1		1		1		1		1		1
Estimated Total Samples	18	14	16	14	16	14	16	14	16	14	16	14	0	14	16	14	16	0	16	0	16	0	16	0	5

<sup>1</sup> SW846 Method No. 8310.

<sup>2</sup> Surface water special analysis metals: cadmium, copper, nickel, silver, beryllium (furnace AA technique). Sediment special analysis metals: antimony (furnace AA technique).

<sup>3</sup> Colorimetric technique.

<sup>4</sup> SW846 Method No. 8040.

<sup>5</sup> SW846 Method No. 8010

Notes: TCL = target analyte list.

VOC = volatile organic compound.

SVOC = semivolatile organic compound.

PCBs = polychlorinated biphenyls.

TAL = target analyte list.

PAH = polynuclear aromatic hydrocarbon.

TOC = total organic carbon.

SW = surface water.

Sed = sediment.

### 3.0 SAMPLING PROCEDURES

This chapter provides detailed reference for field personnel on specific sampling tasks to be performed for the OU 3 RI. The following procedures are based on the USEPA Region IV *Standard Operating Procedures and Quality Assurance Manual* (SOP/QAM) dated February 1991, and on the FDEP approved ABB-ES *Comprehensive Quality Assurance Plan for Florida and Navy CLEAN Operations* (CompQAP), dated September 1993. In cases where procedures do not agree between the documents, the more stringent guidelines have been adopted. Copies of both documents will be kept onsite during the field program for easy reference, as necessary.

#### 3.1 GENERAL PROCEDURES.

3.1.1 Documentation of Field Activities This section specifically states the requirements for documenting the conditions, progress, and data collected during the RI field program. This documentation is intended to account for and specify in detail all activities performed during the course of the field program.

3.1.1.1 Field Logbook The FOL and each field team will each keep a field logbook. The field logbook is the master field investigation document. Its primary purpose is to contain within one document the actual field data or references to other field documents that contain a specific description of every activity that has occurred in the field at any given time on any given day.

#### General Notes.

- The field logbook must be a glued or sewn bound book with a hard cover. Ring binders or similar binding types are not acceptable.
- The pages will be numbered sequentially in the logbook.
- All entries will be in permanent black ink and handwriting will be completely legible.
- Errors will not to be obliterated, but crossed out with a single line, dated, and initialed. Pages will never be removed from the logbook.
- The events in the field will be listed in chronological order whenever possible.
- The logbook will be written and kept so a separate party who has never been to the site can read it and understand what, when, where, who, why, and how something took place in the field and the significance of the events.
- The logbook will contain any administrative occurrences, consultations, conditions, or activities that have affected the fieldwork for any given day or field task.
- Any deviation from the Quality Assurance Program Plan (QAPP), HASP, or project scope of work will be discussed and explained in detail in the field logbook. This will include decontamination procedures, sampling

procedures, monitoring well installation, not wearing proper safety equipment, etc.

- At the end of each day the logbook user will sign at the bottom of the last page of notes taken.
- Any blank space on any page in the logbook at the end of the day will have a single diagonal line drawn through the blank space, and will be signed and dated to prevent any notes from being added to these pages after the notes have been signed.

Site Conditions. The cover of the logbook will list the project number and name, the contract under which the investigation is being conducted, and the date(s) of use. The front of the logbook will indicate the ownership of the book as ABB-ES, with an address and phone number, should the logbook be lost. A business card taped inside the front cover works well for this purpose. The front of the logbook will also list the project number, project name, the names of the subcontracting companies and phone numbers, subcontractor personnel names and local motel phone numbers, Navy contact name and phone number, emergency phone numbers, and any other persons and personal information such as titles and phone numbers that may be needed on a day-to-day basis. Other information that should be taken on a day to day basis is as follows:

- day, date, time entered onsite, temperature, weather conditions, and names and titles of personnel present onsite;
- at the beginning of each day, a "Plan for the Day" indicating the projected scope of work for the day for the notetaking individual and associated subcontractors;
- at the end of each day, a "Summary of the Day" indicating actual accomplishments for the day, indicating quantities and billable items (i.e., feet drilled, number and nature of samples collected, decontamination time, wells installed, etc.);
- names, titles, and organization of any visitors who enter the site during the day;
- arrival and departure times of any subcontractors onsite and a general description of their chronological activities;
- a sketch of the sampling sites showing pertinent structures and items (such maps should be to scale, if possible, or at a minimum, include dimensions that unambiguously locate pertinent items relative to permanent landmarks);
- equipment used and procedures performed, such as decontamination;
- specific comments relative to any problems that occurred during the day's activities, their final resolution, and their anticipated impact of the outcome of the field investigation;
- instruments calibrated during the day, the individual who performed the calibration, results of calibrations, and reference to the page number

in the calibration log that provides more specific information on calibration procedures and results;

- a record of telephone calls (incoming or outgoing) pertaining directly to the decision-making process of the field investigation, along with the outcome of each conversations, and a reference to the telephone log to obtain more specific information on the call; and
- records of conversations (including time and whom) with superiors, Navy representatives, or subcontractor personnel in the field regarding matters that directly affect the project, and the outcome or decisions made based on these conversations.

Other field operations that require note taking include the following.

#### Drilling and Monitoring Well Installation Operations.

- The drilling beginning and ending times for each borehole will be recorded. Record the lithologic description of the drill cuttings or samples in the logbook with depth, noting also any drilling difficulties or drillers comments. Record flame ionization detector (FID) readings, blow counts, recovery, and comments. Also note any problems with the drilling equipment recording the nature of the problem and the time period of the delay. A tabular format, similar to a boring log form, is an efficient way to record these data, and facilitates later data entry into the geologic database.
- Record the construction details for monitoring wells, and the type (size, brand name, etc.) and amount of material used to complete the borehole or the monitoring well (i.e., drilling mud, well casing, well screen, bottom plug, top cap, centralizers, filter pack, bentonite pellets, cement, well cover, posts, etc.). Include the quantities of billable items (i.e., feet of mud rotary drilling with continuous split-spoon sampling 0 to 50 feet, feet of mud rotary drilling 50 to 100 feet, feet of 8.25-inch hollow stem auger drilling 0 to 25 feet, etc.). This is best done as an annotated well construction diagram.
- Record the time period for installing the boring or monitoring well. Example: 1030-1050 placed filter pack around well screen. 1050-1120 mixed grout and placed grout around MW.
- Record anything out of the ordinary that may result in a change of job scope or a cost overrun.

#### Sampling Operations.

- Record the time and date when monitoring well water level and depth were measured (to nearest 0.01 feet).
- Perform well volume calculations in the logbook and record the amount in gallons necessary to achieve the necessary purged volume required. If a pump is being used and the pumping rate is known, note that rate and record the number of minutes required for the pump to purge the well. Note any difficulties such as slow recharge, etc.

- Record the name of persons sampling and doing required paperwork and equipment being used for the sampling operation (pump, bailer, salinity conductivity temperature (SCT) meter, pH meter, etc.).
- Record water quality parameters with time each sample was collected.
- Record time samples were collected, parameters collected for, number, type of bottles, laboratory they will be sent to, quality assurance/quality control (QA/QC) samples, etc. A tabular summary updated day to day in a dedicated section of the logbook works well, and permits quick reference. Refer to chain-of-custody records for more detailed information.

#### Water Level Measurements.

- When taking water level measurements, the wells will be measured in as short a time as possible to try and achieve a snapshot picture of the water table configuration.
- Record the date, time, measurers name, well identification number, water level measurement, tape correction, and comments. This is best done in tabular form for ease and later use.

3.1.1.2 **Photographs** Keeping a record of photographs taken in the field is crucial to their validity as a representation of an existing situation. For each photograph several items will be noted in the field logbook:

- date and time photo was taken,
- photographed by (signature),
- name of site,
- general direction faced and description of the subject taken, and
- sequential number of the photograph and the roll number.

After photographs are processed, they will be bound into a photographic log. The above information will be transcribed into the photograph log to identify each photograph.

3.1.1.3 **Field Forms** In addition to the logbooks kept by each field crew, the following documents will be prepared to back up the logbooks and facilitate the transmission of information.

- Each day's portion of each field logbook will be photocopied each evening and added to a 3-ring bound replicate copy kept in the field office. These replicates are intended as backup should the fieldbooks be lost, and will also be used by office staff for database data entry.
- Separate Sample Tracking Forms will be maintained in the field office for DPT groundwater samples, soil samples, and monitoring well groundwater samples. This tracking form will be updated as samples are collected. It is intended as a summary to document progress, and as a guide for the field staff to keep up-to-date with QA/QC sampling.
- A Field Instrument Calibration/Quality Assurance Record will be completed each day for each piece of field equipment used.

- All samples sent for offsite analysis will be documented by chain-of-custody records.
- All monitoring well groundwater sampling will be documented by a Groundwater Sample Record for each well.

Daily activities and quality control procedures are to be documented on a Quality Control Report (Figure 14-1 of the OU 3 QAPP).

- Hardcopy output from cone penetrometer tests will be archived in the field office and used for field interpretation.
- Analytical data on soil and groundwater samples from the offsite laboratory will be archived in the field office and used for field interpretation.

**3.1.2 Sample and Well Tag Designation** A sample identification system has been defined for the OU 3 RI that is consistent with the system used throughout the NAS Jacksonville NIRP, found in the Basic Site Field Sampling Plan, Appendix 4.4.2 of Volume 4 (Basic Site Workplan) of the Naval IR Plan for NAS Jacksonville (Geraghty & Miller, 1991). The NAS Jacksonville sample designation system is intended to provide unique and descriptive identifications for every sample and sampling point at NAS Jacksonville. The system also satisfies database management system requirements by always providing consistent identifications with the same number of characters.

**3.1.2.1 Sample Identification System** A sample identification code will always consist of 12 characters. The code incorporates identifier codes for each of the following: site identification, sample matrix, sample location, sample sequence (depth), and QA/QC designation. The following is an example of a sample identification code:

OU3DP06501MS

where

OU3	=	site identification code,
DP	=	sample matrix code,
065	=	sample location code,
01	=	sample sequence code, and
MS	=	QA/QC code.

Each identifier code is described in the following sections.

**Site Identification Code.** This code for all samples collected at OU 3 will be the three-character alphanumeric string OU 3.

**Sample Matrix Code.** This code will be a two-character alphanumeric string that describes the type of sample matrix. The following codes will be used.

SW	=	surface water,
SD	=	sediment,
SS	=	surface soil,
SB	=	soil boring,
BW	=	background surface water,

BD = background sediment,  
BS = background surface soil,  
BB = background soil boring,  
TT = test trench,  
DP = DPT groundwater,  
MW = monitoring well groundwater, and  
PZ = piezometer (SSFP) groundwater.

All soil samples collected by hand auger, whether they be from a single purpose soil boring, or from a monitoring well installation, will be designated SB. This differs from the SSFP, during which the soil samples collected during piezometer installation were designated PZ; The difference is required because during the RI, both soil and groundwater will be collected from monitoring well locations, and the sample identification codes must differ.

Sample Location Code. This code will be a 3-digit numeric string starting with 001 and proceeding consecutively. Exceptions are as follows: begin piezometer location codes with 028 (27 piezometers were installed during the SSFP).

Sample Sequence Code. This code will be a two-digit numeric string starting with 01 and proceeding sequentially. This code is used for samples collected from locations at which multiple depths were sampled, or for multiple samples that were collected from the same location, such as test trenches. The code will apply to soil borings, DPT locations, test trenches, and monitoring well soil samples. If only one sample is collected from a location, then the default sample sequence code 01 will be used. The field logbooks will be annotated to indicate the sample depth that is assigned to each sample identification code.

QA/QC Code. This code will be a two-character alphanumeric string that identifies the sample as QA/QC data. The following codes will be used.

FB = field blank,  
EB = equipment rinsate blank,  
TB = trip blank,  
RP = field replicate,  
MS = matrix spike, and  
MD = matrix spike duplicate.

**3.1.2.2 Well Tag Identification System** A well tag identification code will always consist of eight characters. The code will be used to uniquely identify and label new piezometers and monitoring wells. It will contain codes from the sample identification code, and will be consistent with the sample identification codes for that location. A well tag identification code will consist of the following: site identification, installation code, and sample location code. The following is an example of a well identification code: OU3MW029. The site identification and sample location codes are defined exactly the same as for sample identification codes. The installation code indicates whether the location is a monitoring well or a piezometer, and will be MW and PZ, respectively.

**3.1.3 Sample Custody and Shipping** The possession of samples or other physical evidence will be traceable from the time they are obtained. This section covers chain of custody procedures as they apply to field sampling personnel.

3.1.3.1 **Sample Custody** A sample or other physical evidence is in custody if:

- it is in the sampler's or a documented transferee's actual possession; or
- it is in the sampler's or the transferee's field of view after being in her/his physical possession; or
- it was in the sampler's or a documented transferee's physical possession, and then she/he secured it to prevent tampering; or
- it is placed in a designated secure area.

Chain of Custody (COC) Record. The COC is used to record the custody of all samples collected and shipped to the offsite laboratory. All fields on the form will be filled out by the samplers in the field as they collect the samples. Fields requiring explanation are outlined below.

- All samplers and/or the sampling team leader must sign in the lower left signature block.
- The total number of sample containers for each sample must be listed in the appropriate column. In addition, sum the total number of containers at the bottom of the column. Further, list the total number of containers for each analysis at the bottom of the appropriate column.
- The sampler and subsequent transferees must document the transfer of the samples listed on the record in the blocks provided at the bottom of the form. One of the samplers documented in the sampler block or a designated and documented custodian who receives secured samples from sampling teams and maintains those samples under secure conditions must be the person to relinquish custody to a transferee. Both the person relinquishing the samples and the person receiving them must sign and date the record.

Field Custody Procedures.

- To simplify the COC, as few people as possible should handle the samples or physical evidence before they are shipped.
- All individual sample containers will be sealed with custody seals. This requirement may be waived if the sampler keeps the samples in continuous custody from the time of collection until they are delivered to the laboratory.
- Shipping coolers will be sealed with custody seals for shipment.
- Prior to packaging, each sample container should be inspected to verify correct labeling. Labels should be secured to containers with clear tape.

3.1.3.2 **Shipping** Instructions for packing and shipping are as follows.

- All breakable sample containers (glass) will be protected with packing. Bubble-pack bags or strips are acceptable.

- Sample containers will be placed in sealable plastic bags such as a Ziploc™ type.
- Multiple sample containers from one sample location and one matrix may be placed in the same sealable plastic bag.
- Sample containers from two or more locations or two or more matrixes from one location will not be placed in the same plastic bag (except for trip blanks). A cooler used to ship environmental samples should be of durable plastic material capable of resisting damage due to normal handling and dropping during shipping. Secure and tape the drain plug with fiber or duct tape. Place a layer of bubble-pack along the bottom of the shipping container extending up all sides to the top. Line the cooler with a large heavy duty plastic bag. Place the sample containers in the shipping container in an upright position. Distribute large and small containers so as to fill spaces between large containers. No direct contact between glass containers should be allowed. Place all sample containers from one sample location together or keep in the same shipping container if multiple containers are used, if possible.

Samples must be kept at 4 degrees Celsius (°C) for shipment. Place five to seven sealed 1 gallon bags of ice cubes in the cooler, distributing them among the sample containers to maintain an even temperature in the cooler, and to act as padding. The ice should be clean and double bagged. To double bag, place ice in one 1 gallon Ziploc™ bag, seal and place this bag in a second 1 gallon Ziploc™ bag, and seal.

Fill any remaining spaces between sample containers with bubble-pack. No lateral movement of the sample containers should be allowed.

Place additional layers of bubble-pack over the ice and sample containers tucking the packing down the sides of the shipping container. Add adequate layers of packing to create a tight seal when the shipping container is closed.

Place the completed COC and analysis request forms in a plastic bag and seal. Tape this bag to the inside lid of the shipping container. If multiple containers are being shipped from one sampling site, place the documents in the lead container.

Affix two COC seals to each shipping cooler. The seals are signed and dated and placed so that they span the lid and body of the cooler, on the cooler's front and back, so that the cooler cannot be opened without breaking the custody seals. The seals are taped over with fiber tape that is wrapped multiple times around the cooler to keep it shut.

**3.1.4 Field Instrument Calibration** All field instruments will be calibrated to standards according to their manufacturer's recommendations each morning. During instrument use, instrument calibrations will be checked against a standard every four hours (typically, during lunch and at the end of the day). If instrument readings differ from actual by greater than 10 percent, the instrument should be recalibrated. Instrument calibrations and any instrument maintenance will be documented in the field logbooks and on separate calibration records that remain with the instruments. Calibration standards to use are presented in Table 3.1.

**Table 3-1  
Calibration Standards**

Operable Unit 3 Field Sampling Plan  
NAS Jacksonville  
Jacksonville, Florida

Instrument	Standard Source	Standard
pH meter	Cole Palmer	Solutions of pH: 4.00 7.00 10.00
Conductivity meter	Cole Palmer	KCl solutions of: 447.1 $\mu$ mhos 3,920 $\mu$ mhos
Porta-FID™ OVA-FID	Air Products	B-size cylinder 96 ppm methane.
LEL Meters	Industrial Scientific	35 percent pentane-air mixture.

Notes: KCl = potassium chloride.  
OVA = organic vapor analyzer.  
ppm = parts per million.  
FID = flame ionization detector  
 $\mu$ mhos = micromhos.  
LEL = lower explosive limit.

**3.1.5 Field Decontamination Procedures** To prevent cross contamination between sample points and the transfer of contamination from the operable unit, chemical sampling and other field equipment must be properly decontaminated prior to the field effort, between sample points, and at the conclusion of the sampling program.

If equipment is not to be used again after being used for sampling, it will be rinsed thoroughly in potable water for decontamination at a later time. If sampling equipment is contaminated with oil, grease, or other hard to remove material, it may be necessary to rinse the equipment several times with solvent before beginning the decontamination procedures outlined below. In extreme cases it may also be necessary to steam clean the equipment before beginning.

**3.1.5.1 Definitions** For clarification, the following definitions have been used.

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

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

Solvent will be undiluted pesticide-grade isopropanol.

Potable water will be treated water from any municipal water treatment system.

Deionized water is potable water that has been treated by passing through a standard deionizing resin column.

Analyte-free is tap water that has been treated with activated carbon and deionizing units. It should contain no pesticides, herbicides, or extractable organic compounds. Analyte-free water is water in which all analytes of interest and all interferences are below method detection limits. This organic-free water will be used for blank preparation and for final rinse in decontamination (where applicable). ABB-ES uses a system with a 0.3-submicron filter, one charcoal filter, and two resin filters to produce analyte-free water. This water is normally generated onsite during field programs. Selected analytes of specific interest to projects are monitored periodically to demonstrate reliability and purity of the water source. Equipment, field, and trip blanks provide further documentation of the purity of the water source.

3.1.5.2 Decontamination Pad Cleaning and decontamination of all equipment will occur at a designated area of the operable unit, the decontamination pad. It will be located downwind and downgradient from any clean equipment drying or storage areas. The decontamination pad will consist of a shallow pit excavated with a backhoe or other heavy equipment. It will be lined with multiple layers of heavy duty plastic sheeting and graded in such a way to promote runoff and collection of wash/rinse water. If a pit cannot be excavated, a pad can be constructed with wood framing and lined with plastic as above. The pad will be constructed in such a way that the working ends of a backhoe and at least the portion of a drill rig behind the rear wheels can be positioned over the pit for decontamination.

All cleaning of large non-sampling equipment will be conducted on the decontamination pad using sawhorses or other racks. The feet of said racks should be placed on wood rails to prevent puncturing of the plastic liner. The water contained in the pit will be pumped or similarly removed from the pit as often as needed to maintain proper operation. The water will be placed in a tanker trailer for storage. As sediment accumulates in the pit, it will be removed by shoveling and contained and added to soil cuttings IDW containers. These drums will be permanently labelled with date and contents. If the liner should become damaged, it will be removed, containerized and labeled as separate IDW, and replaced with a new liner.

Decontamination of small sampling equipment (split spoons, DPT sampling tools, spoons, bowls, etc., need not take place in the decontamination pit as long as rinsates are collected for containment and storage as above. No solvent rinsates will be placed in the pit. All solvent rinsates will be collected and labeled in separate containers. The solvent rinsates will be accumulated in open tubs, which will be left out-of-doors to promote evaporation. Tub will be kept under cover in a secure area to prevent rainwater accumulation and to reduce human exposure.

Upon the completion of drilling activities, the liner will be removed and contained as above, and the pit disassembled and/or backfilled to original grade.

3.1.5.3 Analyte-free Water Containers Containers used to hold analyte-free water will be constructed of glass or Teflon<sup>™</sup>. New containers will be cleaned according to the following guidelines prior to use. Containers will be kept wet on the inside, and capped with aluminum foil or Teflon<sup>™</sup> film at all times.

3.1.5.4 Cleaning Procedure for Glass or Teflon™ Sampling Equipment The following procedure will be used on sampling equipment that comes in direct contact with samples.

- Wash thoroughly with laboratory detergent and hot potable water using a brush to remove any particulate matter or surface film.
- Rinse thoroughly with hot potable water.
- Rinse equipment with a greater than 10 percent solution of nitric acid.
- Rinse thoroughly with deionized water.
- Rinse twice with solvent.
- Rinse thoroughly with analyte-free water and air dry. If analyte-free water is not available, air dry after the solvent rinse; do not rinse with deionized or distilled water.
- Wrap equipment in aluminum foil, and seal in plastic with date for transportation.

3.1.5.5 Cleaning Procedure for Steel Sampling Equipment The cleaning procedure for steel equipment (spoons, scoops, DPT sampling tools, split spoons) is identical to the above procedure except that the acid rinse is omitted.

3.1.5.6 Cleaning Procedure for Water Level Indicators Prior to first use at the operable unit, water level indicators or interface probes will be decontaminated according to Subsection 3.1.5.5, and subsequent cleanings will be as listed in Subsection 3.4.1.

3.1.5.7 Cleaning Submersible Pumps Used to Purge Monitoring Wells Prior to first use and between wells being purged, pumps and hoses will be cleaned by the following procedures.

- Pump a sufficient volume (typically 5 to 10 gallons) of detergent solution in potable water to flush out any residual purge water in the pump and hose.
- Scrub the exterior of the pump and hoses (all hose for the first cleaning onsite, but only the wetted portion of hose between wells being purged) with detergent and hot potable water.
- Rinse the exterior of the hose with potable water.
- Rinse the exterior of the hose with deionized water and recoil onto spool.
- Pump a sufficient volume of tap water through pump and hose to flush out detergent solution.
- Pump a sufficient volume of deionized water through pump and hose to flush out the tap water, then purge hose and pump in reverse flow direction (so that pump does not have to run while dry).

- Place equipment in a polyethylene bag or wrap in polyethylene sheeting for storage or transportation.

**3.1.5.8 Cleaning Procedure for Non-sampling Equipment** Large equipment that is not directly used for sampling (drilling rig, backhoe, rods, and augers) will be decontaminated prior to use and between sample locations. Equipment must be inspected for fuel or lubricant leaks, and to confirm that all gaskets and seal are intact. Any portion of the equipment that is over the borehole or excavation (breakout table, kelly, mast, backhoe bucket, driller's stand and controls, winches, spindles, cathead, etc.) will be steam cleaned and wire brushed, if necessary, to remove rust, soil, or other material which may have come from other hazardous waste sites. Any hollow equipment (rods, augers) must be cleaned inside and out. The steam cleaner must be capable of generating at least 2,500 pounds per square inch (psi) and producing hot water and steam at temperatures of at least 200 degrees Fahrenheit (°F). Following steam cleaning, and any necessary scrubbing, all downhole equipment (rods, augers, and bits) will be decontaminated further by the following procedure.

- Rinse thoroughly with potable water.
- Rinse thoroughly with deionized water.
- Rinse twice with solvent.
- Rinse thoroughly with analyte-free water and allow to air dry. Do not rinse with potable or deionized water. If organic-free water is not available, allow the equipment to air dry.
- Wrap equipment in aluminum foil or plastic for protection during transportation to the next sample location.

Well casings and screens will preferably be supplied new, sealed in watertight factory packaging, with documentation of manufacturer's cleaning procedure. If not, it will be steam cleaned prior to use.

**3.1.6 Location Clearance** The ABB-ES FOL will coordinate exploration locations with Naval Aviation Depot (NADEP) and NAS Jacksonville personnel to prevent interference with base operations. Regular and frequent communication with base personnel will be required to keep sampling activities flowing smoothly, because new areas of DPT sampling will only be known on short notice. Locations will be cleared for underground utilities by review of as-built records by base personnel. As-built drawings are often inaccurate; also, because of the density of underground utilities in NADEP, magnetic locators may be ineffective. Thus, exploration locations must also be cleared for underground utilities by the field team by hand augering or probing to a depth of 5 feet, or by some other suitable method. No utilities are anticipated to be present below a depth of 5 feet. Sampling of hand-augered soils above the water table will be conducted at deep monitoring well locations, which will also serve as utilities clearance.

**3.1.7 Pavement Coring and Repair** At most DPT locations, most monitoring well locations, and at some piezometer locations, the ground surface is paved with asphalt or with 12-inch thick reinforced concrete. The surfacing at these locations will have to be cored or sawed out to allow exploration. Because DPT sampling locations are not known in advance, but determined by the analytical

results of previous locations, concrete coring capabilities must be ready to work on very short notice to prevent down-time for the DPT crews. Coring will be done on an ongoing basis throughout the course of the field program. During the SSFP, the experience and equipment of professional concrete corers was required to efficiently cut the extremely hard and thick flightline pavement, and to stay ahead of the sampling crews. It is anticipated that professional corers should be kept working onsite full-time for the RI program.

Pavement repair at locations after explorations will be conducted by the various subcontractors and supervised by ABB-ES staff. Repair of any surfacing material will be with a material of like type, strength and thickness as the original material. Asphalt will be repaired with an equal thickness of asphalt mix, and compacted. Small concrete coreholes for DPT locations are to be repaired by pouring an equal or greater thickness of new concrete in the corehole. Concrete pads for pierometer and well surface completions will be at least 8 inches thick in vegetated or thinly-paved areas, and will be equal in thickness to the pavement in the flightline area (12 inches). Pads will be reinforced with steel rebar. Further detail on surface completions is found in Subsection 3.4.2.1.

## 3.2 DPT PROCEDURES.

3.2.1 Piezometer Construction Thirty-two pairs of piezometers will be installed by DPT methods in and around OU 3 (Figures 2-1a and 2-1b). The piezometers will be constructed of 3/4-inch diameter polyvinyl chloride (PVC) riser and screen. The screens will be 5 feet long, and have a slot size or mesh size or attached sand pack so as to prevent very fine grained formation sand from entering and filling the piezometer. Shallow piezometers will be installed to a depth of approximately eight feet. The exact depth will vary; the piezometers should be placed at a depth so that the water table approximately bisects the screened interval. The depth to the water table may be estimated by measuring the water level in a nearby well. Hand augering will be performed at each location to a depth of at least 5 feet for utilities clearance. If desired, the DPT crew may hand auger to the water table, if deeper, to determine the piezometer depth.

In general, deep piezometers are to screen a hydrostratigraphic unit that exists in the northern and southern areas of OU 3: the permeable unit that underlies the shallowest clay unit. Deep piezometers located in these areas will be screened in the middle part of the intermediate sand and are expected to be approximately 30 to 50 feet deep. Based on cross sections prepared during the SSFP, the uppermost clay unit in the northern and southern areas of OU 3 is laterally extensive, less than 10 feet thick, and its top is at a depth of 10 to 20 feet bls. The permeable unit underlying it is also laterally extensive and between 30 and 60 feet thick. It is known, for purposes of the OU 3 program, as the intermediate sand. The intermediate sand overlies another thin, extensive clay unit at approximately 65 to 90 feet bls.

Deep piezometers, if determined to be necessary in the central area of OU 3, may be up to 95 feet deep, and may screen a sand strata that underlies the intermediate sand. The intermediate sand pinches out near the center of OU 3; the upper and lower clays merge and thicken, and appear to isolate the northern and southern members of the intermediate sand. In the central area of OU 3, located approximately between existing piezometer PZ020 in the west and the river in the east, and Hangar 123 in the north and Hangar 124 and Building 125 in the south, the clay unit is up to 60 feet thick. Piezometers penetrating this thick

clay will be installed at a depth so as to screen the first permeable sand encountered below the clay unit.

As for the shallow piezometer installation, hand augering will be performed at each deep piezometer location to a depth of at least 5 feet for utilities clearance.

Because of the complexity of the stratigraphy, the field team will have to consult the cross sections and fence diagram developed after the SSFP (Figures 2-14 through 2-18 and Appendix G of the OU 3 RI/FS workplan) to ensure that the deep piezometers screen the proper sand units. In areas where stratigraphic data have not yet been collected, cone penetration tests (CPT) will be performed prior to deep piezometer installation, and the logs correlated to the existing cross sections to select the piezometer screened interval. It is expected that all of the piezometer locations to the west and southwest of OU 3 will require CPTs. The test holes will be grouted per Section 3.2.4 upon completion of the test.

Piezometers are to be completed by installing a 6-inch thick hydrated bentonite seal above the screened interval. The remaining annulus may be backfilled.

The remaining annulus may be backfilled for the shallow piezometers. For the deep piezometers, the remaining annulus will be filled with cement or cement-bentonite (maximum 5 percent bentonite by weight) grout as the cone rods are withdrawn. The grout is to be injected under pressure to ensure a complete seal of the annular space and prevent cross flow of groundwater between permeable units. Piezometer surface completion will be flush mount. A 6-inch diameter steel flush-mount roadbox with a bolt-down lid will be placed over the piezometer and set in a reinforced concrete pad of dimensions 2 feet by 2 feet. Pad thickness will be 8 inches in unpaved or thinly paved areas, or of equal thickness (12 inches) to the surrounding original concrete for locations on the flightline. Reinforcement will be by steel rebar lain around the roadbox parallel to the sides of the pad. The rebar will be of sufficient length to cross in the corners of the pad.

The interior of the roadbox will have a bottom of concrete. A drain will be constructed of PVC pipe that will allow water accumulating on top of the concrete inside the roadbox to drain down the pipe, which is angled away to the side through the concrete and under the roadbox into native formation or backfill. The piezometer riser will be sealed with a thread-on or other suitable watertight cap.

**3.2.2 Piezometric Cone Penetration Testing** The procedures described below will be followed during subsurface sampling and sensing involving the electric cone penetrometer and DPT groundwater sampling tools.

In most cases, at DPT locations where groundwater sampling is to be performed, two soundings must actually be performed, because the same cone cannot be used for both CPT and groundwater sampling: (1) first, a CPT is performed to identify the depth intervals of suitable granular, water-bearing strata (typically those that display hydrostatic pore pressure, high tip resistance, and a ratio of sleeve friction to tip resistance of 2 percent or less); and (2) second, a sampling sounding is performed using the groundwater sampling cone. However, as the set of sampling locations completed grows, the field team may become confident that sample intervals can be selected from existing stratigraphic data.

Under such circumstances the FOL may decide not to perform the CPT sounding at any location, and perform the sampling sounding only.

The cone penetrometer system will consist of a standard electronic dutch cone penetrometer with 2 cm<sup>2</sup> cone area having the additional capability to measure pore pressure. The minimum operating procedures and data quantity and quality for the electric cone penetrometer will meet or exceed the requirements of ASTM D-3441. The electric cone penetrometer output should be relayed to a computer, which in turn will present to the operator a real time graphic display and printer output of sleeve friction, cone tip resistance, ratio of sleeve friction to tip resistance, pore pressure, and interpreted soil classification versus depth.

The DPT equipment must be a gravity vehicle with a minimum weight of 20 tons. It will exert sufficient force on the sampling and sensing tools to achieve depths of 100 feet, which is the maximum exploration depth for this project. External anchors designed to increase feed pressure cannot be used at OU 3. The DPT subcontractor will proceed with each electric cone penetrometer sounding by pushing the electric cone penetrometer into the soil at a constant rate of two centimeters per second until the final sounding depth is reached. Formation resistance may be too high to permit penetration to 100 feet in a single uninterrupted sounding. In such an event, penetration depth may be extended with the use of casing as a friction-reduction measure. A piezocone test is first performed to some arbitrary intermediate depth, and then the tools are retrieved. Casing can then be pressed down in its place. The casing inside diameter is slightly larger than the cone rod outside diameter; it supports the cone rod laterally, but allows friction-free travel of rods down the hole. The piezocone test can be continued out the bottom of the casing to the target depth. This method may also be used to extend the penetration depth of the groundwater sampling tools.

Decontamination of the DPT rig and equipment (rods and piezocone) will be required upon arrival at the operable unit, between each sounding, and prior to the subcontractor's departure from the operable unit.

**3.2.3 Orientation of DPT Locations** At locations where both a CPT sounding and a sampling sounding are to be performed, separate holes are used for the two soundings. The CPT sounding will be performed first, and then the hole will be abandoned according to Subsection 3.2.5. The groundwater sampling hole will be located approximately 3 to 6 feet in the upgradient direction from the CPT hole to prevent potential migration of grout into the zone of groundwater sampling.

**3.2.4 DPT Groundwater Sampling** This subsection details the procedures to be followed for DPT groundwater sampling.

For DPT groundwater sampling, the DPT cone rods will be fitted with a stainless steel groundwater sampling cone. The specific sampler and rods used by the subcontractor should be capable of collecting large-volume samples (greater than 2 liters) from the water table which is approximately 5 feet beneath the ground surface to an estimated maximum exploration depth of 100 feet. The cone consists of a watertight, stainless-steel cone and sleeve fitted around a retractable stainless-steel screen. At the target depth, the rods are pulled back slightly. Friction with the surrounding soil holds the sleeve in place as the screen is pulled up, thus exposing the screen to the formation.

Groundwater enters the screen and rises in the steel cone rods under hydrostatic head. Sampling is performed with a small-diameter bailer (Teflon™ or stainless steel, preferably Teflon™) for purgeable organic analyses, and by peristaltic pump with silicone tubing for other analyses.

All equipment that comes into contact with groundwater (rods, sampling cone, and bailer) will be decontaminated prior to first use and between every sample per Subsection 3.1.5.

3.2.5 Abandonment of DPT Holes After a CPT or groundwater sampling sounding is completed, the hole made through the formation by the cone rods will be grouted to surface. Grouting of cone holes will be performed under pressure, from the bottom of the hole up. The preferred method of grouting is to use tools that allow grout to be injected down the cone rods as they are pulled from the hole. If such tools are not available, the rods may be pulled and tremie pipe inserted in their place through which to inject the grout. This method carries the potential that the tremie pipe cannot be installed to the depth of completion due to borehole collapse. However, it was the experience of the SSFP that the holes remain open. The surface completion of abandoned DPT holes will be as specified in Subsection 3.1.7.

### 3.3 SOIL SAMPLING PROCEDURES.

3.3.1 Surface Soil Sampling The term surface soil refers to soil extending from the surface to a depth of no more than 1 foot below land surface.

The following describes the preparatory steps for sample collection.

- Put on the personal protective clothing and equipment as required by the site-specific HASP.
- Place plastic sheeting on a flat, level surfaces near the sampling area, if possible. Place decontamination equipment and supplies, sampling equipment, sampling containers, and insulated cooler on separate plastic sheeting. Cover all equipment and supplies with plastic sheeting when not in use.
- Record relevant information in the field logbook. Document sample location, soil description, sample number, and other pertinent information.
- Follow the sampling pattern as outlined in Section 2.7.
- Carefully remove stones, vegetation, etc., from the sampling location surface.
- Carefully remove the top 1 to 2 centimeters of exposed soil, sediment, or sludge before sample collection.

The requirements for collecting grab samples of surface soil for VOC analysis are as follows.

- Use a clean stainless-steel or Teflon™-lined scoop, trowel, shovel or hand auger bucket to collect sufficient material in one grab to fill the sample containers.
- Fill the sample containers directly from the sampling device, removing stones, twigs, grass, etc., from the sample.
- Immediately secure the Teflon™-lined caps on the sample containers.
- Rinse containers with deionized water and wipe dry.
- Label containers with the appropriate information. Place in zip-top or other plastic bag and seal the bag.
- Pack samples in cooler. Include COC forms and custody seals, as appropriate.
- Decontaminate sampling equipment after each sample location to prevent cross contamination.

The requirements for collecting samples of surface soil for analyses other than VOCs are as follows.

- Use a decontaminated stainless-steel or Teflon™-lined scoop, trowel, shovel or hand auger bucket to obtain a minimum of three sample volumes or the volume needed to fill the specified sample container.
- Empty contents of each scoop or other sampling device directly into a clean glass mixing bowl.
- Thoroughly mix the sample with a decontaminated stainless steel or Teflon™ spoon, spatula, or trowel.
- Use the spoon, spatula, or trowel to dispense the uniform mixture into the specified sample containers.
- Use the same equipment to pack the media into the containers to minimize free air space.
- Secure the appropriate cap on each container immediately after filling.
- Rinse sample containers with deionized water and wipe dry.
- Label each sample container with the appropriate information.
- Pack samples in cooler(s).
- Record all sampling information in the field logbook.
- Prepare the COC form.

**3.3.2 Hand Auger Soil Borings** The following steps describe the collection of hand augered samples.

- Determine and stake the location(s) to be sampled.

- Clear vegetation and other debris from the surface around the boring location.
- Put on personal protective clothing and equipment as required by the site-specific Health and Safety Plan (HASP).
- Prepare an area next to the sample collection location by laying plastic sheeting on the ground over the work area, as required.
- Set up the decontamination line, as required.
- Begin augering to the depth required for sampling. Contain cuttings as specified in the site-specific workplan.
- While augering, record soil descriptions in the field logbook.
- Stop augering at the top of the specified or selected sampling depth. Remove the auger from the hole and decontaminate as specified in Subsection 3.1.5. Then either use a fresh auger or the decontaminated original auger to obtain a sample.
- Discard any excessively disturbed or loose material found in the top or bottom portions of the sampler that may not be representative of the interval sampled. This material will be discarded with other boring spoils at each boring location.
- Remove the portion(s) of the sample selected for chemical analysis and place it into appropriate containers using a clean spatula. Soil intended for VOC analysis must be collected from the center (interior) portion of a sample. Exterior portions, those near or adjacent to the sampler wall must not be used for VOC analysis. The sample will be placed in containers and capped as quickly as possible. Soil intended for other types of analyses will be placed into a glass mixing bowl and thoroughly mixed using a stainless-steel spoon. Once the sample has been thoroughly mixed, sample material will then be placed in the appropriate sample containers.
- Visually examine the remainder of the sample and record its characteristics using the Unified Soil Classification System (e.g., texture, color, consistency, moisture content, layering, and other pertinent data).
- Place a representative volume of the sample interval in a soil jar for geologic reference. Place the remainder of the sample in a 16-ounce soil jar with a metal or foil cap. After several minutes, scan the soil with a photoionization detector and record the headspace reading in the field logbook.
- Properly label all containers and prepare chain-of-custody forms.
- Record sample location, description, sample numbers, and other pertinent information in the field logbook.
- Proceed with further sampling, as required.
- When all sampling is completed, dispose of cuttings.

- Decontaminate all equipment as specified in Subsection 3.1.5.
- Remove plastic sheeting and dispose.
- Complete the field logbook entry and soil boring log for the sample location. Remand custody of samples to the appropriate personnel.

3.3.3 Test Trenching The major advantages of test trench sampling are that:

- samples of any volume can be obtained, and
- the subsurface is exposed in the test trench, revealing the sample site geology and facilitating sample collection and recovery.

Test trenches will be logged (using the Unified Soil Classification System) as they are excavated. Records of each test trench will be made on prepared test trench forms and in a field logbook. These records include plan and profile sketches of the test trench showing all materials encountered, their depth and distribution in the test trench, and sample locations. These records will also include safety and sample screening information. Photographic documentation will also be performed. Photographic logs will be recorded in the field logbooks.

The following steps describe appropriate excavation and sampling methods.

- The backhoe operator can excavate the test trench in several depth increments. After each increment, the operator waits while the sample collector inspects the test trench to decide if conditions are appropriate for sampling. Practical depth increments range from 2 to 4 feet below land surface.
- The backhoe operator, who may have the best view of the test trench, will immediately cease digging if:
  - any fluid phase or groundwater seepage is encountered in the test trench, or
  - any drums or other potential waste containers are encountered, or
  - distinct changes of material are encountered.

This action is necessary to permit proper sampling of the test trench and to avoid potential hazards.

- Discrete samples from appropriate intervals may be collected from the sides of the test trench as follows.
- With a clean spatula, remove from the trench sidewall the portion(s) of the sample selected for chemical analysis and place it into the appropriate containers. Soil intended for VOC analysis will be placed in containers and capped as quickly as possible. Soil intended for other types of analyses should be placed in a glass bowl and thoroughly mixed using a stainless-steel spoon. Once the sample has been thoroughly mixed, sample material will then be placed in the appropriate sample containers. The containers will be labeled and packed in a cooler. Note the sample

identification number, depth from which sample was taken, and analyses requested in the field logbook and on the COC form.

- Proceed with further sampling, as required.
- When all sampling in a particular pit is completed, dispose of cuttings by backfilling them into the pit. Backfilling is to be performed in such a way that material is replaced at approximately the same depth interval from which it was removed.
- Decontaminate all equipment as specified in Subsection 3.1.5.
- Remove plastic sheeting and place it in the designated container.
- Complete the field logbook entry and soil boring log for the site. Remand custody of samples to the appropriate personnel.
- Under normal circumstances, test trenches are not entered for sampling.

#### 3.4 MONITORING WELL PROCEDURES.

3.4.1 Groundwater Level Measurement Groundwater level measurements will be taken using electric water level indicators. All water level indicators should be calibrated to a steel surveyor's chain to a 0.01 foot precision per 10 feet of length to establish correction factors for each instrument and ensure that measurements will be consistent between instruments. These calibrations and any instrument maintenance will be recorded in the field logbook and on separate records that remain with the instrument.

Water level indicators will be decontaminated as described in Subsection 3.1.5 prior to first use at the operable unit. Thereafter, to prevent cross contamination, they will be cleaned between wells as follows:

- wash with laboratory detergent and potable water,
- rinse with potable water,
- rinse with deionized water, and
- wrap instrument in aluminum foil, seal in polyethylene, and date.

A round of water level measurements should be taken in as short a period of time as possible to obtain a snapshot of aquifer conditions. Sufficient personnel and instruments must be available to measure all wells in a single day, and preferably faster.

Water levels are to be measured to the nearest 0.01 foot from the top of well casing mark (the north side of the well riser) to the static water level. Total well depth will be measured to the nearest 0.1 foot from top of the well casing. Well identification, date, time, water level, well depth, and instrument correction factor will be recorded in the logbook in tabular format.

#### 3.4.2 Monitoring Well Construction

3.4.2.1 Deep Monitoring Wells Deep monitoring wells are defined as all those that penetrate below the uppermost clay unit at any location.

Split-spoon Sampling. During drilling of every deep monitoring well location, split-spoon samples will be collected for lithologic identification at 5-foot intervals below the water table. Samples will be retained in soil jars for future geologic reference. Samples will not be collected for chemical analysis. Also, at six monitoring well locations, a single wide-diameter split-spoon soil sample will be collected from a shallow interval for special analysis to support remedial technology evaluation (Subsection 2.6.3.1).

Surface Casing. To prevent cross contamination during drilling of aquifer units separated by confining clay units, surface casing will be installed to isolate upper units. Using wide-diameter hollow-stem augers, the drilling contractor will drill until a dense clay unit is detected by split-spoon sampling that exceeds 4 feet in thickness. At that time, 6-inch diameter, schedule 40 PVC casing will be installed from the surface to at least one foot into the clay detected. The casing is intended to isolate the upper surficial aquifer from lower units that may not be hydraulically connected. The casing will be grouted into the borehole and a minimum of 24 hours will be allowed for the grout to set. While the grout is setting, the drilling rig may demobilize from the location to perform work at another location. The borehole will be secured with a locking cap and clearly marked with caution tape and hazard cones. When drilling resumes, mud-rotary drilling with a 5-7/8-inch, outside diameter tricone bit will be used to complete the hole and install the well.

Deep Monitoring Well Construction. Deep wells will be constructed of 2-inch diameter, flush threaded, gasketed, schedule 40 PVC. (See Appendix M 2-1 for justification for use of PVC well materials.) The well will be constructed with 5 feet of 0.010-inch slotted well screen. Graded filter sand (20/30) will be placed by tremie pipe from 2 feet below the well screen to 2 feet above the screen. Graded filter sand (35/65) will be placed by tremie for an additional foot. A dense (greater than 20 percent solids) bentonite slurry seal 5 feet thick will be placed by tremie above the filter pack, and the remaining annulus filled with a cement-bentonite grout (grout with 5 percent powder bentonite added) to the ground surface. Wells will be completed with a flush-mounted roadbox protective cover with a bolted-down lid set in a 2-foot by 2-foot reinforced concrete pad. The pad will be of equal thickness to the concrete pavement it is set in (12 inches) on the flightline, or at least 8 inches thick if set in asphalt or an unpaved location. Reinforcement will be by steel rebar lain around the roadbox parallel to the sides of the pad. The rebar will be of sufficient length to cross in the corners of the pad. The interior of the roadbox will have a bottom of concrete. A drain will be constructed of PVC pipe that will allow water accumulating on top of the concrete inside the roadbox to drain down the pipe, which is angled away to the side through the concrete and under the roadbox into native formation. The well will be secured with a locking-expanding cap with a keyed-alike brass padlock. Each well will be developed by air-lift pump after a minimum of 48 hours has elapsed for the cement grout to set. During development, the groundwater pH, temperature, turbidity, and specific conductivity will be monitored and the data recorded in the field log book along with a description of the development methods. Development will continue until these parameters have stabilized, and further development does not yield improvement in water clarity. Development water will be containerized per the IDW plan (Chapter 4.0).

3.4.2.2 Shallow Monitoring Wells A shallow surficial well will be installed with hollow-stem augers immediately adjacent to each deep surficial well. The

shallow well will be placed approximately 6 feet to the north of the deep well. The shallow wells will be constructed of 2-inch diameter, flush threaded, gasketed, schedule 40 PVC with 10 feet of 0.010-inch slotted well screen, placed to span the water table. Graded filter sand (20/30) will be placed from 2 feet below the well screen to 2 feet above the screen. A bentonite pellet seal 2 feet thick will be placed above the filter pack, hydrated, and any remaining annulus will be filled with concrete or cement grout. A thickness of cement grout of at least 18 inches is required. If the water table is too shallow to allow sandpack, seal, and grout of these thicknesses, the height of sand above the screen and the seal thickness may be reduced as needed. Surface completions will be the same as for the deep surficial wells. Well development will be performed as described above for deep wells. The development method will be such that a surging action is produced in the filter pack, inducing flow in two directions to loosen fines. Methods such as Brainard-Kilman hand positive-displacement pump or surge block are acceptable. Simply pumping with a centrifugal pump, without surging, is not acceptable. Pumping at a rate that causes the well to be pumped dry will be avoided.

**3.4.3 Monitoring Well Groundwater Sampling** Groundwater sampling from permanent monitoring wells will be conducted according to the techniques outlined below to help ensure the collection of representative samples. Important procedures are detailed after the procedures summary.

#### **3.4.3.1 Groundwater Sampling Procedures Summary**

- Wear protective clothing as specified in the HASP. Wear N-DEX nitrile gloves during purging and sampling. If other tasks are being performed simultaneously, change gloves to prevent cross contamination of samples.
- Prepare the site for sampling by covering the ground around the wellhead with plastic sheeting. No sampling equipment should be laid on bare ground.
- Open the well and note the condition of the casing and cap.
- Check for vapors in the wellhead and in ambient air with vapor analyzing equipment.
- Determine the static water level and depth of well to the nearest 0.01 foot and 0.1 foot, respectively.
- Record the information from steps 3 through 5 (above) in the field logbook and on the groundwater sample record forms.
- Determine the purge volume and purge the well according to Section 3.4.3.2.
- Record pertinent data in the field logbook and on the groundwater sample record forms.
- Arrange the labeled sample containers in order of use. The preferred order of sampling is listed below:
  1. metals,
  2. cyanide,

3. SVOCs,
4. pesticides and PCBs,
5. other organics, and
6. VOCs.

Collect the samples by peristaltic pump and closed-top Teflon™ bailer as follows.

- Teflon™ tubing is placed into the well (if it was purged by centrifugal or peristaltic pump, the same Teflon™ tubing used to purge the well is used to sample the well), and fitted to a peristaltic pump's silicone tubing. For deep monitoring wells, the tubing is inserted into the well so that its intake is located within the well's screened interval.
- Sample volumes for inorganic analysis (metals and cyanide) are collected first, and are pumped at a low flow rate (less than 1 liter per minute) through the Teflon™ tubing and the silicone tubing on the peristaltic pump head, into the sample containers.
- Sample volume for organic analyses not including VOCs are collected at a low flow rate (less than 1 liter per minute) by the peristaltic pump or vacuum jug technique, detailed in Section 3.4.3.3.
- Sample volume for VOC analysis is collected last, with a closed-top Teflon™ bailer as detailed in Section 3.4.3.3.
- Add preservative (if needed).
- Place filled containers into cooler(s) immediately and close the coolers.
- Remove sampling equipment from the well.
- Record in the field logbook the sample types and amounts collected, time and date of collection, and the names of personnel collecting samples.
- Prepare the chain-of-custody form.
- Decontaminate the sampling equipment, including Teflon™ tubing (as required).
- Dispose of the disposable sampling equipment.
- Close and lock the well cover.
- Deliver the samples to the laboratory with proper chain-of-custody documentation and seals, as required.
- Dispose of produced water as specified in the IDW plan (Chapter 4.0).

#### 3.4.3.2 Purging Procedures

General Procedure. A well will be purged before sampling to clear the well of stagnant water which is not representative of aquifer conditions. The well is then to be sampled immediately after purging.

The method is to purge three to five times the volume of water standing in the well, until field parameters (dissolved oxygen, eH, pH, specific conductivity, temperature, and turbidity) stabilize. Field parameters are measured, and recorded in the logbook, after each gallon is removed, when a well volume is less than 7 gallons, or every other gallon if a well volume exceeds 7 gallons. Purging is considered complete when any of the following is achieved:

at least three well volumes have been purged and the field parameters in two consecutive measurements differ by no more than 10 percent, and turbidity is less than 10 NTU;

five well volumes have been purged; or

the well has been pumped dry.

If possible, wells should not be pumped dry. Water levels and pumping behavior during purging can be monitored and the pumping rate adjusted to prevent wells from being pumped dry.

A well volume is calculated from the height of the standing water column in the well using the following formula (or equivalent):

$$V = \pi(d/2)^2h$$

where

V = well volume

$\pi$  = pi = 3.14159

d = inside diameter of well

h = height of standing water column (well depth minus depth to water)

Purging Methods. Shallow (water table) wells are to be purged with a peristaltic pump at a rate less than 0.5 gallons per minute. Deep wells, because of their larger well volume, are impractical to purge with a peristaltic pump. A small electric centrifugal pump or submersible pump will be used to purge deep wells, at a rate of approximately 1 gallon per minute. Because of the potential for cross-contamination with submersible pumps, vacuum lift pumps and centrifugal pumps are preferred, but submersible pumps are acceptable if no other pump is available.

Careful consideration should be given to using reuseable equipment (pumps, bailers) to bail wells that are extremely contaminated with oily compounds, because it may be difficult or impossible to adequately decontaminate severely contaminated pumps or bailers under field conditions. Alternative purging methods, such as disposable bailers, should be considered.

In the case of vacuum lift pumps or centrifugal pumps, only the intake tubing is placed into the water column; this intake tubing must be Teflon. When submersible pumps are used, pump construction must be of Teflon™ and stainless steel only, and the wetted portions of the pump and tubing are to be decontaminated according to Section 3.1.5 prior to use and prior to use at another well.

Care must be taken to prevent backflow of purged water into wells. Either the pump/pump hose is removed from the water column prior to the pump being shut off, allowing all water to be purged from the lines, or vacuum lift pumps must be equipped with a foot valve, and submersible pumps with a check valve.

Whether monitoring well purging is accomplished by peristaltic pump, centrifugal pump, or submersible pump, the tubing or pump should be lowered less than three feet into the water column, not deep into the column. This is done so that the purging will pull water from the screened interval and up the casing so that the entire water column is removed, and there is no possibility of water above the pump/intake not being removed.

3.4.3.3 Sampling Procedures Where possible, sampling of monitoring wells will proceed from the upgradient (background) wells to the downgradient (potentially contaminated) wells. Wells containing free product will not be sampled.

A low flow rate, peristaltic pump/vacuum jug procedure is the preferred sampling method for all analyses except VOCs. Sample volumes for VOC analysis are to be collected with a closed-top, Teflon™ bailer.

Inorganics Sampling. Sample volumes for inorganic analysis (metals and cyanide) are collected first, and are pumped at a low flow rate (less than 1 liter per minute) straight through the Teflon™ tubing and the silicone tubing on the peristaltic pump head, into the sample containers.

Non-VOC Organics Sampling. Sample volumes for organic analyses other than VOC analysis are collected with the aid of a vacuum jug fitted to the tubing between the peristaltic pump and the well. The vacuum jug allows groundwater to be sampled with a peristaltic pump, without the disadvantage of passing the sample through the pump's silicone tubing, which might alter the chemical quality of the groundwater sample. Teflon™ tubing from the monitoring well being sampled is fitted to an air-tight cap which is threaded to a 2-liter amber glass jug. Similarly, Teflon™ tubing is fitted from the cap to the pump's silicone tubing. When the pump is started, the vacuum it creates in the tubing and jug causes groundwater to flow through the Teflon™ tubing to fill the jug. When full, the jug is removed from the system and capped with an ordinary cap, and used as a sample container for SVOC analysis. A new jug is then placed in the system, filled as above, used to fill other sample containers, if required, and refilled a final time and recapped to become the pesticide and PCB sample volume.

Sufficient air space will be left in containers to compensate for temperature or pressure changes during shipment (approximately 10 percent of container volume).

VOC Sampling. Because of the potential for loss of VOCs due to the pressure changes a sample experiences when collected with a peristaltic pump, sample volume for VOC analysis is to be collected with a closed-top, Teflon™ bailer. New nylon twine is attached to the bailer via a Teflon-coated stainless steel wire. This wire is attached to the bailer semi-permanently and is decontaminated for reuse with the bailer. The nylon twine is cut to length and the bailer used so that only the bailer and leader wire contact the water column.

During sampling, the bailer should enter the water slowly to prevent aeration, particularly when VOC and SVOC samples are being collected. When the bailer is

retrieved to the surface, the bailer and line are not to be allowed to contact the ground, well head or personal clothing.

Samples are filled into sample vials directly from the bailer with as little agitation as possible. The sample water is to be gently poured along the inside wall of the vial. The vial is filled until the sample forms a convex meniscus above the top edge of the vial, and then carefully cap the vial. No air headspace should be in the vial. This is checked by inverting the VOC vial and tapping it to check for air bubbles. If bubbles are present, more sample is added or a new sample vial is filled.

**3.4.4 Slug Testing** Rising head and falling head slug tests are to be conducted to estimate the horizontal hydraulic conductivities of soils at OU 3. A pressure transducer and datalogger will be used to electronically acquire water level data as the aquifer recovers from a head change induced in the well by a metal or plastic slug. The field tasks to perform a slug test are as follows.

- Record the depth to water in the well to the nearest 0.01 foot.
- Place a pressure transducer into the well to a depth of approximately 8 feet below the water table, or to the depth recommended by the transducer manufacturer.
- Allow the water level to equilibrate.
- Collect 2 minutes of pre-test static water level data.
- Lower the slug into the water column and allow the water level to return to static.
- Quickly withdraw the slug from the water column at the instant that the data logger is started.
- Record data until the water level has returned to at least 80 percent of its static level.
- Perform three slug tests on each well.

The slug is to be decontaminated as described in Subsection 3.1.5 prior to use and between each well tested.

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# Influence of Casing Materials on Trace-Level Chemicals in Well Water

by Louise V. Parker, Alan D. Hewitt, and Thomas F. Jenkins

## 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 species. There is considerable evidence, however, that sorption of metals by plastic and glass containers can

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 (2-14 ppb) of six halogenated organic compounds (bromo-

were cut to different lengths so that the surface area of each was constant (80 cm<sup>2</sup>). 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 cm<sup>2</sup>/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 Values<sup>1</sup> 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 ±	0.036	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	0.985 ±	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 ±	0.064
	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

<sup>1</sup> (Concentration for samples with casing) / (Concentration for control samples) = Normalized mean value

These normalized values are the mean of all the treatments (i.e., for both pHs, organic carbon content, and concentration).

of interaction with the plastic casings may be due to chromium speciation. In solution, chromium exists predominantly as dichromate and chromate ( $\text{Cr}_2\text{O}_7^{2-}$ ,  $\text{CrO}_4^{2-}$ ) 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 (1989).

## Organic Study

### Experimental

The four well casing materials were also tested for sorption/desorption of low levels of 10 organic substances. The substances tested were hexahydro-1,3,5-

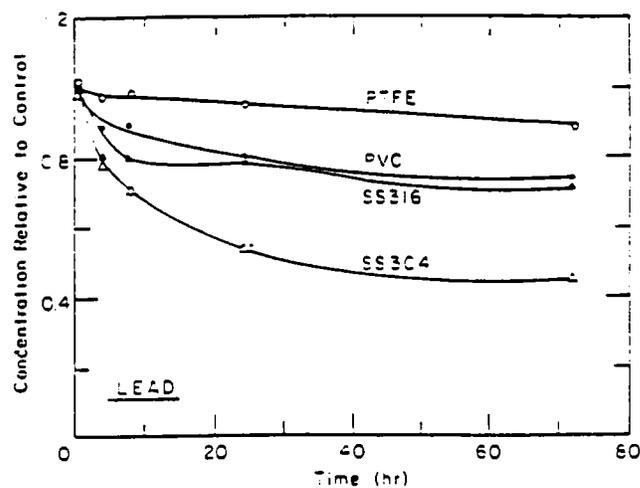


Figure 4. Trends in mean lead concentration for four well casing materials.

trinitro-1,3,5-triazine (RDX), 1,3,5-trinitrobenzene (TNB), cis- and trans-1,2-dichloroethylene (CDCE and TDCE), 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  $\text{cm}^2/\text{mL}$ . 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  $\text{HgCl}_2$ , 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

of the 1000-hour samples, the vials were emptied and the pieces of casing were rinsed with approximately 40mL 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- $\mu$ L loop injector, a Spectra-Physics SP8490 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  $\mu$ 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 (10 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, CDCE (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 > ODCB > 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

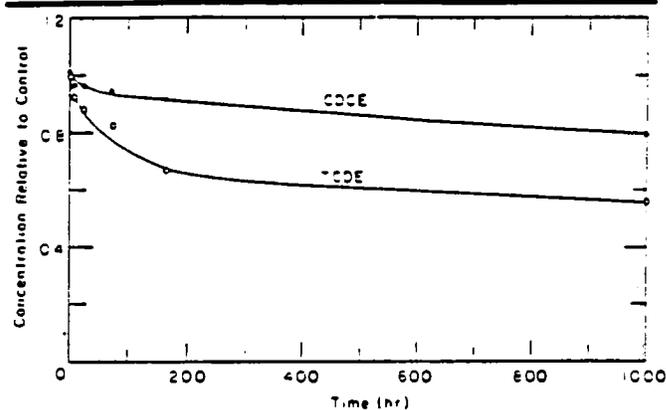


Figure 5. Sorption of CDCE and TDCE by PTFE well casings.

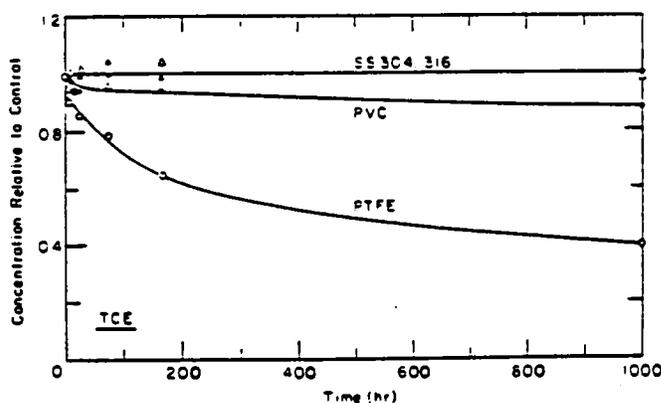


Figure 6. Sorption of TCE by the four well casing materials.

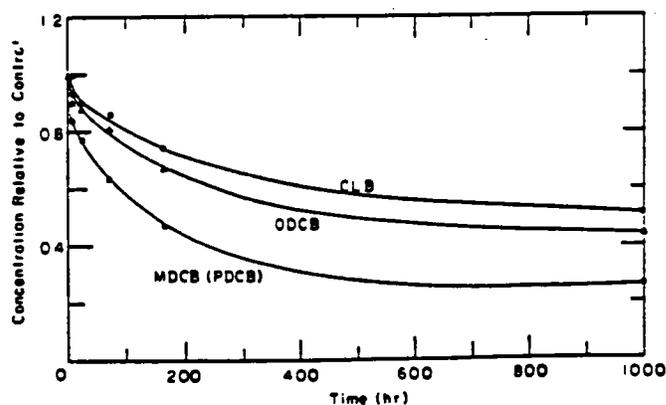


Figure 7. Sorption of CLB, ODCB, MDCB and PDCB by PTFE well casings.

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):

$$\frac{d[A_w]}{dt} = -k_1 [A_w] + k_2 [A_s] \quad (2)$$

where  $[A_w]$  is the concentration of solute A in aqueous solution,  $[A_s]$  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.  $\log K_{ow}$ , 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

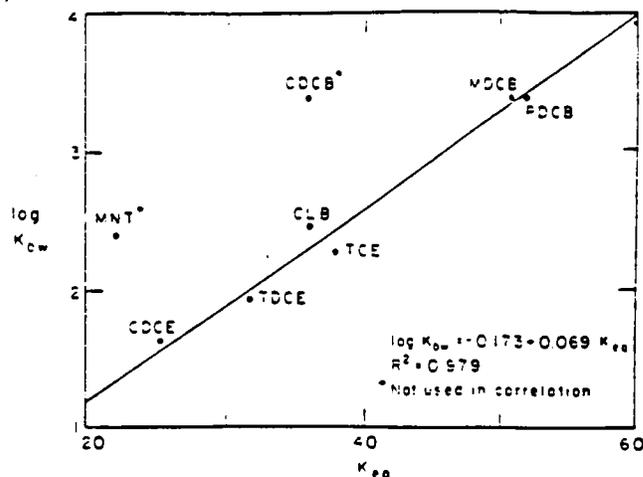


Figure 10. Correlation between  $\log K_{ow}$  and  $K_{eq}$  for solutes exposed to PTFE casings.

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-

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## Biographical Sketches

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## CONE PENETRATION TESTING

The cone penetration test (CPT) method of subsurface exploration uses a heavy, enclosed box truck to push a string of 2-inch diameter steel rods into the ground. A hydraulic press inside the truck smoothly presses the rods, and the dead weight of the truck provides a reaction force to resist the upward pressure exerted on the rods by the subsurface soils.

### THE CONE PENETROMETER INSTRUMENT.

To interpret subsurface soil types, a special cone is fitted at the leading end of the rod string. The cone is instrumented with piezoelectric pressure sensors in the cone tip and strain gauges in a friction sleeve behind the cone to measure tip resistance and sleeve friction during penetration. For an American Society for Testing and Materials (ASTM) standard cone penetrometer (ASTM standard D3441-86), the cone has an angle of 60 degrees from vertical, a cone surface area of 10 square centimeters, and a sleeve surface area of 150 square centimeters.

In addition to pressure sensors and strain gauges, a porous ceramic filter is built into or above the cone tip, with a pressure sensor just behind the filter to measure pore water pressure. A cone penetrometer instrumented in this way is often referred to as a *piezocone penetrometer*. A cone equipped with only pressure sensors in the cone tip and strain gauges in the sleeve is known as a *friction cone penetrometer*. Both types of penetrometer are illustrated in Figure 1.

### THE CONE PENETRATION TEST.

During a cone penetration test, the cone is pressed through the subsurface at a constant rate of 2 centimeters per second. The cone produces analog electronic output of cone tip resistance, sleeve friction, and dynamic pore water pressure. These data are recorded digitally on magnetic media every two centimeters. The data are processed by computer to produce a hard-copy log displaying the data versus depth and a stratigraphic column of soil type interpreted automatically from the data.

### CONE PENETRATION TEST DATA INTERPRETATION.

Soil type is interpreted from the cone data by a series of empirical relationships between the tip resistance and the ratio of sleeve friction to tip resistance which correlate to the mean diameter ( $D_{50}$ ) of the tested soil.

In general, both tip resistance and sleeve friction are high for sands, and the ratio of sleeve friction to tip resistance is less than 2 percent. For clay, both tip resistance and sleeve friction are low, and the ratio of sleeve friction to tip resistance exceeds 4 percent. Mixtures of sand and clay are more difficult to differentiate on a generalized basis. To reliably interpret such mixed soils and distinguish between them, the CPT data should be calibrated to the site of interest. This is accomplished by performing one or more CPTs at locations where conventional borings have also been performed, producing soil samples for visual inspection. CPT response for a known soil type can then be observed, allowing interpretation of similar soil types at other locations where soil samples are not collected. Such a calibration performed at NAS Jacksonville

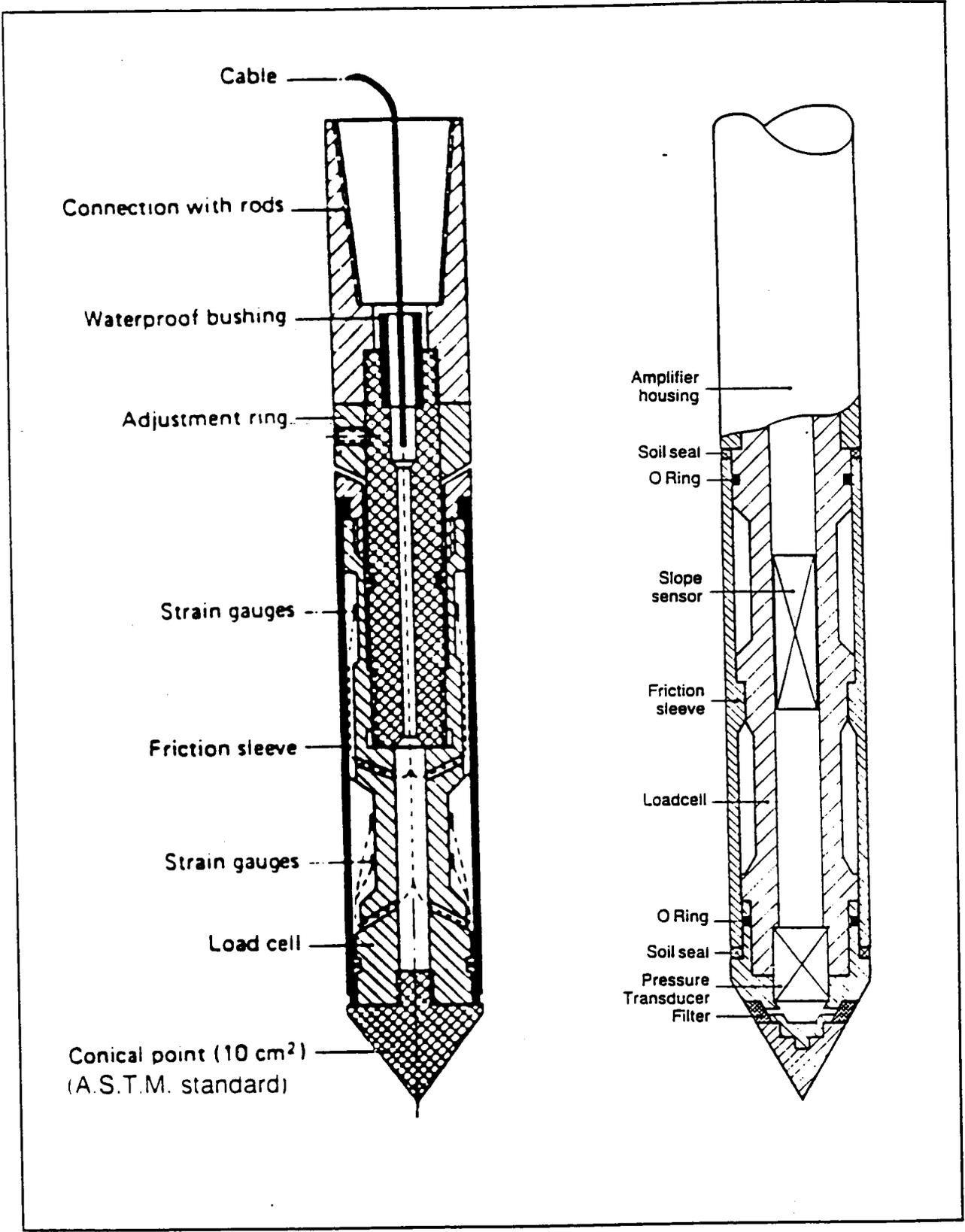


Figure 1 - Friction cone penetrometer (left) and piezocone penetrometer (right).

OU 3 during the Scoping Study field program in 1993 produced the following criteria by which sandy clay (clay with approximately 20 to 50 percent sand) and clayey sand (sand with approximately 20 to 50 percent clay) were distinguished:

- Clayey sand was found to exhibit tip resistance between 50 and 100 tons per square foot (TSF), sleeve friction of 1 to 3 TSF, and a ratio of sleeve friction to tip resistance between 2 and 4 percent.
- Sandy clay was found to exhibit tip resistance less than 50 TSF, sleeve friction less than 1 TSF, and a ratio of sleeve friction to tip resistance between 2 and 4 percent.

Further qualitative observations reinforcing these interpretations of soil type were that the readings of sleeve friction and tip resistance would oscillate dramatically within an interval of clayey sand, producing a saw-tooth plot, but these data would vary only slightly in a clay stratum, producing a nearly straight line or smooth bumps in the plot. Also, dynamic pore water pressure would jump to very high levels in soils that could not dissipate the dynamic pressures caused by the cone penetration (such as clays). In soils that instantly dissipate excess pore pressure (sands), however, the dynamic pore pressure remained hydrostatic, increasing linearly with depth.

#### HYDRAULIC CONDUCTIVITY TESTING.

Readings of pore water pressure are used qualitatively in interpretation of soil type, as described above. Pore pressure data can also be used quantitatively to calculate hydraulic conductivity in low permeability soils such as clay or sandy clay. To perform a hydraulic conductivity test, penetration is paused with the cone tip positioned in the stratum to be tested. The motion of the cone during a CPT causes a dynamic pore water pressure in excess of the natural hydrostatic pressure. When penetration is paused, this dynamic, excess pressure begins to dissipate. The decay of pore pressure is recorded, allowing computation of hydraulic conductivity by a method that exploits the theory of consolidation for clays. Each such test requires approximately thirty minutes. The test can only be done in low permeability soils because pore pressure decay must be measured over time, but excess pore pressure dissipates instantly in permeable soils such as sand.

## APPENDIX F

This page explains the data illustrated on each of the Fugro Geosciences CPT logs found in this appendix. Each log consists of a depth scale on the far left, in units of feet below land surface, three columns of cone penetrometer output, each with a horizontal units scale, and on the far right, a graphic log of soil stratigraphy.

The far left column of CPT data is the sleeve friction, in units of tons per square foot (TSF). The second column displays two measurements: the bold line is the dynamic pore water pressure and the normal-weight line is the cone tip resistance. Both are in units of tons per square foot, with the pore pressure scale ranging from zero to 12 TSF, and the tip resistance from zero to 450 TSF. The third column displays two ratios. The normal weight line is the ratio, in percent, of sleeve friction to tip resistance. The bold line was not used in interpretation.

The graphic log on the far right illustrates the interpreted soil type versus depth using the correlations of Robertson and Campanella (1984). The speckled pattern indicates sand, diagonal bars indicate clay, and vertical bars indicate an intermediate or difficult to quantify material such as silt or very fine sand.

In the depth scale on the far left has been penciled, inside small circles, the depth(s) at which DPT groundwater samples were collected at that DPT location. On the far right, the re-interpreted soil stratigraphy is penciled in. Soil stratigraphy was manually re-interpreted from the plots of sleeve friction, tip resistance, pore pressure, and ratio. This re-interpretation was done for two reasons: 1) to incorporate the results of CPT calibration which allows for the distinction of sandy clay and clayey sand; and 2) to simplify the automated interpretation into mappable stratigraphic units that were detected in multiple locations at OU 3.