RCRA RECORDS CENTER
FACILITY Pratt + Whitney
I.D. NO. CTD990672081
FILE LOC. R-9
OTHER RDMS # 100180

RDMS DocID 00100180

WORK PLAN FOR GROUNDWATER INVESTIGATION IN SUPPORT OF VCAP RISK ASSESSMENT (STEP 3)

Pratt & Whitney
400 Main Street
East Hartford, CT

Loureiro Engineering Associates, Inc.

January 27, ~~1999~~ 2000

U.S. EPA New England - Region I
Mail Code HBT
One Congress Street, Suite 1100
Boston, MA 02114-2023

Attn.: Mr. Ernest Waterman

RE: Work Plan for Groundwater Investigation (Step 3)
Pratt & Whitney, 400 Main Street, East Hartford, CT
P&W Voluntary Corrective Action Program

Dear Mr. Waterman:

Please find enclosed the Work Plan for the proposed groundwater investigation (Step 3) at the above referenced facility. The proposed investigation involves the installation of six monitoring well clusters at off-site properties in the vicinity of Willow Brook and Willow Brook Pond and three monitoring well clusters on-site in the vicinity of the ETAL area. The proposed groundwater monitoring event will cover the newly installed wells and selected existing wells. A comprehensive round of groundwater level measurements will also be performed for the shallow and top of clay aquifer zones.

Pratt & Whitney is currently negotiating access agreements with the property owners involved. The investigations will be performed as soon as the access agreements are in place. If you have any questions, please call me at (860) 747-6181.

Sincerely,

LOUREIRO ENGINEERING ASSOCIATES, INC.

Jeffrey J. Loureiro, P.E.
President

pc: Lauren Levine, Pratt & Whitney
David Ringquist, CT DEP
Manu Sharma, Gradient Corporation

100 Northwest Drive • Plainville, CT 06062 • 860.747.6181 • Fax 860.747.8822 • www.loureiro.com
An Employee Owned Company

WORK PLAN FOR GROUNDWATER INVESTIGATION IN SUPPORT OF VCAP RISK ASSESSMENT (STEP 3)

Pratt & Whitney
400 Main Street
East Hartford, CT

January 2000

Prepared for

PRATT & WHITNEY
400 Main Street
East Hartford, CT 06108

Prepared by

LOUREIRO ENGINEERING ASSOCIATES
100 Northwest Drive
Plainville, CT 06062

LEA Comm. # 600

Table of Contents

		Page
1	**INTRODUCTION**	**1**
1.1	Background	1
1.2	Objectives of Proposed Investigation	2
1.3	Facility Description	2
2	**RESULTS OF PREVIOUS INVESTIGATIONS**	**2**
2.1	Waste Treatment Area	3
2.2	ETAL Area	3
3	**PROPOSED INVESTIGATIONS**	**4**
3.1	Waste Treatment Area – Off-Site properties	4
3.2	ETAL Area	5
4	**METHODOLOGY**	**5**
4.1	Soil Boring Installation and Soil Sampling	5
4.2	Monitoring Well Installation	6
4.3	Monitoring Well Development	7
4.4	Groundwater Monitoring	7
4.5	Water-Level Measurements	8

DRAWINGS

Drawing 1 Groundwater Monitoring – Exceedances over Screening Levels

1 INTRODUCTION

1.1 Background

A groundwater investigation consisting of two steps has been performed at the Pratt & Whitney, 400 Main Street, East Hartford facility through the installation of temporary screen point and permanent wells installed throughout the plant property. This investigation has been performed in support of the voluntary corrective action program (VCAP) risk assessment with the purpose of understanding groundwater flow on-site and assessing the potential for migration of contamination off-site.

During the initial investigation, (Step 1), groundwater samples were collected from 15 existing monitoring wells and 50 temporary sampling locations on site. The temporary sampling locations were along the northern and western boundary of the site. Two groundwater samples were collected from each temporary sampling location. The first sample was collected at the water table (upper three feet of the aquifer) and the second one from approximately three feet above the surface of the clay layer. The samples collected were analyzed for metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, plus nickel and zinc), total petroleum hydrocarbons (TPH) and volatile organic compounds (VOCs).

During the subsequent investigation, (Step 2), groundwater samples were collected from existing and newly installed temporary and permanent wells throughout the plant site. The purpose of the additional investigation was three-fold. First, 9 additional screen point wells were installed to the west of the ETAL area using a Geoprobe® to allow collection of groundwater samples from across the water table and from the top of the clay layer at an approximate depth of 25 to 30 ft. These wells have been installed along the property boundary at the northwestern corner of the facility to evaluate groundwater flowing off-site at this location.

Second, 10 permanent well clusters were installed along the northern property boundary in the general vicinity of Willow Brook Pond. As in the initial investigation, each well cluster consisted of two wells, the first one intersecting the water table and the second one screened on top of the silt layer. The intent of these monitoring wells is to establish monitoring locations at areas where contamination has been identified or is suspected. In addition, soil screening samples were collected at the top-of-clay monitoring wells installed in the vicinity of Willow Brook Pond.

Third, 7 permanent well clusters were installed throughout the southwestern portion of the

property to assist in developing groundwater elevation contours for the water table wells and for the top-of-silt monitoring wells.

All newly-installed wells and a number of existing wells were sampled for volatile organic compounds (VOCs), filtered and unfiltered metals (arsenic, barium, beryllium, cadmium, copper, total chromium, hexavalent chromium, lead, mercury, nickel, selenium, silver, and zinc), cyanide, and total petroleum hydrocarbons (TPH).

1.2 Objectives of Proposed Investigation

The objectives of the proposed investigations are as follows:

- To provide supplemental information in the Waste Treatment and ETAL areas.
- To supplement the previous rounds of investigations in order to assess whether contamination is migrating off site.
- To allow the collection of groundwater samples off-site to better assess any potential impact.

1.3 Facility Description

The Pratt & Whitney Main Street facility occupies approximately 1,100 acres of land in East Hartford, Connecticut. Design, manufacturing, assembly, and testing of aircraft engines and engine components take place at the Main Street Plant. The western part of the site consists of the main factory complex, engine development and test facilities, a power house, the Centralized Waste Storage and Transfer Facility, the Concentrated Waste Treatment Plant, several office buildings, and several other auxiliary buildings. The eastern part of the facility consists of an inactive airport, an area which had been used in the past for experimental and test facilities (the Klondike, which is now demolished), and undeveloped land.

2 RESULTS OF PREVIOUS INVESTIGATIONS

The groundwater investigations performed indicated two primary areas where contamination may be migrating off site. These areas included the Waste Treatment area in the vicinity of Willow Brook and Willow Brook Pond and the area to the west of the ETAL area. The well locations are shown in Drawing No. 1. Wells with an –S suffix designate a well installed in the shallow aquifer. Well with an –I or –D suffix indicate wells advanced to the top of the clay layer. Drawing No. 1 shows only the shallow well in each cluster.

2.1 Waste Treatment Area

Chlorinated hydrocarbons such as methylene chloride, 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, cis-1,2-dichloroethylene, 1,1-dichloroethylene, 1,1-dichloroethane, vinyl chloride, and chloroform were detected in the monitoring wells installed in the vicinity of Willow Brook and Willow Brook Pond. Some of the highest VOC concentrations detected during the latest round of investigations in the area were observed in the following wells: WT-MW-05D (methylene chloride at 1,800 μg/l); WT-MW-22I (cis-1,2-dichloroethylene at 1,500 μg/l and vinyl chloride at 3,200 μg/l); and WT-MW-25I (chloroform at 200 μg/l, cis-1,2-dichloroethylene at 650 μg/l, methylene chloride at 1,100 μg/l, trichloroethylene at 350 μg/l, and vinyl chloride at 100 μg/l). The source(s) of the contamination may be associated with historic activities in the Waste Treatment area and or inside the manufacturing building. Relatively elevated concentrations of trichloroethylene (33,000 μg/l) and 1,1-dichloroethylene (1,400 μg/l) were observed in shallow and intermediate wells installed inside the facility.

Some of the highest VOC concentrations reported historically in the area were observed in the following wells: WT-MW-02 (vinyl chloride at 1,500 μg/l), WT-MW-03 (vinyl chloride at 720 μg/l), WT-MW-11D (methylene chloride at 130,000 μg/l), WT-MW-12I (methylene chloride at 110,000 μg/l), and WT-MW-13S (tetrachloroethylene at 630 μg/l).

Relatively elevated metal concentrations were also observed in the monitoring wells installed in the vicinity of Willow Brook and Willow Brook Pond. Some of the highest metal concentrations detected during the latest round of investigations in the area were observed in the following wells: WT-MW-07S (cadmium at 0.0072 mg/l); WT-MW-07D (arsenic at 0.0146 mg/l, cadmium at 0.0210 mg/l, mercury at 0.00048 mg/l, nickel at 2.27 mg/l, silver at 0.0341 mg/l, cyanide at 0.12 mg/l); WT-MW-15S (cadmium at 0.0312 mg/l, nickel at 1.98 mg/l); WT-MW-20S (cadmium at 0.0333 mg/l, chromium at 0.145 mg/l, silver at 0.153 mg/l, cyanide at 0.071 mg/l); and WT-MW-21S (cadmium at 0.0479 mg/l, chromium at 0.108 mg/l, nickel at 0.916 mg/l, cyanide at 0.38 mg/l). Some of the highest metal concentrations reported historically in the area were observed in the following wells: WT-MW-04I (cadmium 0.015 mg/l, nickel 3.00 mg/l); WT-MW-05D (arsenic: 0.036 mg/l, cobalt: 0.584 mg/l, nickel: 3.595 mg/l) and EH-RSK-GW23B (chromium at 0.13 mg/l, mercury at 0.0016 mg/l, nickel at 9.21 mg/l, zinc at 0.137 mg/l).

2.2 ETAL Area

Chlorinated hydrocarbons (trichloroethylene) were detected in the temporary piezometers in the

monitoring wells installed along the property boundary to the east of the ETAL area. The highest concentration was observed in well ET-GW-20I (trichloroethylene at 700 μg/l). Historical investigations in the area have indicated the presence of aromatic and chlorinated hydrocarbons in the area. Some of the highest VOC concentrations were observed in monitoring wells ET-MW-05S (ethylbenzene at 590 μg/l, toluene at 490 μg/l, xylenes at 3,100 μg/l); and ET-MW-10I (benzene at 3.8 μg/l, 1,1-dichloroethylene at 21 μg/l, methylene chloride at 160 μg/l, tetrachloroethylene at 170 μg/l, 1,1,1-trichloroethane at 45 μg/l, trichloroethylene at 790 μg/l, xylenes at 2.9 μg/l).

Relatively elevated metal concentrations were also detected in the following wells: ET-GW-20S (chromium at 0.197 mg/l); ET-GW-19I (chromium at 0.300 mg/l); ET-GW-20I (chromium at 0.640 mg/l); and ET-GW-22I (chromium at 0.420 mg/l). Historical data indicated the presence of elevated metal concentrations in the following well: ET-MW-05S (arsenic at 0.006 mg/l, lead at 0.018 mg/l).

3 PROPOSED INVESTIGATIONS

3.1 Waste Treatment Area – Off-Site properties

The investigations proposed in this area include the installation of off-site wells to investigate the impact, if any, of the plumes of contamination ~~observed~~ to off-site properties. In detail these investigations would entail the following:

WT-MW-29 → MW-34

- Installation of 6 permanent monitoring well clusters off-site (Drawing No. 1). Access agreements will have to be negotiated with the property owners. Two wells will be installed at each location. The Geoprobe® wells will be advanced to the upper 3 feet of the water table and to the top of the clay layer. Soil samples will be collected from each well and will be screened for the presence of VOCs using the LEA analytical laboratory. The soil samples will be also visually inspected for the presence of oil. Two soil samples will be selected from the soil boring installed at each location and will be submitted to a fixed laboratory for analysis for VOCs, SVOCs, PCBs, metals, cyanide, and TPH.

- Groundwater monitoring for all newly installed wells and 6 existing wells in the area. The existing wells in the area will represent the wells where the highest contamination has been encountered in the latest round of investigations or historically. These wells are WT-MW-11 WT-MW-20, WT-MW-21, WT-MW-22, WT-MW-24, WT-MW-25. Both shallow water table wells and top-of-clay wells will be sampled.

All groundwater samples will be analyzed for VOCs, filtered and unfiltered metals, TPH, and cyanide. The 6 permanent off-site wells will also be analyzed for PCBs and SVOCs. Groundwater elevations will be obtained from the same wells measured during Step 2 during a sitewide monitoring event.

3.2 ETAL Area

The investigations proposed in this area involve the installation of property boundary wells to assess whether any contamination is migrating off-site. Trichloroethylene and chromium have been detected in groundwater samples collected from temporary wells in the area. The proposed investigations in this area are as follows:

WT MW 18 & MW-19

- Installation of 2 permanent monitoring well clusters to the west of the ETAL area (Drawing No. 1). Two wells will be installed at each location. The wells will be flush-mounted Geoprobe® wells and will be advanced to the upper 3 feet of the water table and to the top of the clay layer. Soil samples will be collected from each well and will be screened for the presence of VOCs using the LEA analytical laboratory. Two soil samples will be selected from the soil boring installed at each location and will be submitted to a fixed laboratory for analysis for VOCs, metals, cyanide, and TPH.

- Groundwater monitoring for all newly installed wells and 4 existing wells in the area. The existing wells in the area will represent the wells where the highest contamination has been encountered historically. These wells include ET-MW-03, ET-MW-05, ET-MW-09, and ET-MW-10. Both shallow water table wells and top-of-clay wells will be sampled at the locations where well clusters exist.

  All groundwater samples will be analyzed for VOCs, filtered and unfiltered metals, TPH, and cyanide. Groundwater elevations will be obtained from the same wells measured during Step 2 during a sitewide monitoring event.

4 METHODOLOGY

4.1 Soil Boring Installation and Soil Sampling

The primary objective of the soil sampling is to provide depth profiling information on the proposed permanent well clusters. It should be noted that all soil borings will be completed as monitoring wells screened at the water table and above the top of the silt layer regardless of the depth profile of contamination.

All borings will be advanced using Geoprobe® probing and sampling methodologies, as described in LEA's Standard Operating Procedure (SOP), entitled *Geoprobe® Probing and Sampling,* (Attachment 1). The MacroCore® sampler will be used to collect soil samples. During borehole advancement, samples will be obtained continuously from below grade to the base of the boring, with soil samples collected in two-foot sampling intervals. Soils will be classified and logged as described in LEA's SOP, entitled *Geologic Logging of Unconsolidated Sedimentary Materials* (Attachment 1). All soil sampling at the site will be performed in accordance with LEA's SOP, entitled *Soil Sampling.* During soil boring advancement a portable total volatile organic compound analyzer equipped with a photoionization detector will be used to monitor for VOCs near the borehole.

The sample collection equipment will be decontaminated between sampling locations. The saturated soil samples collected will be placed in an ice-filled cooler and submitted to the Loureiro Engineering Associates Analytical Laboratory for analysis for a screening list of VOCs. This list includes 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, benzene, toluene, ethylbenzene, and xylenes.

4.2 Monitoring Well Installation

All wells will be small-diameter monitoring wells constructed using the Geoprobe® Pre-Pack monitoring well construction materials. The pre-pack construction consists of three foot-long sections of ½ inch inside diameter, 0.010-inch slotted Schedule 80 PVC screen with a 1.5-inch diameter filter pack held in place by stainless steel mesh. The pre-pack screen sections may be joined to provide screen length multiples of three feet. A ½-inch diameter Schedule 80 PVC riser connects the screen to the surface.

Screen lengths for the proposed shallow monitoring wells will be nine feet, with approximately 5 to 7 feet placed below the water table. A screen length of three feet placed on top of the clay aquitard will be used for the deeper wells. After the screen and riser is installed, one to two feet of sand will be placed above the screen to prevent the bentonite seal from leaking downward into the screened interval. A bentonite seal will be placed from the top of the sand cap to the surface. Emplacement of the sand cap and the bentonite seal will be performed while slowly retrieving the casing, allowing the native formation material to collapse around the backfill material.

All wells will be installed in general conformance with LEA's SOPs entitled, *Standard Operating Procedure for Installing and Developing Monitoring Wells and Piezometers* and *Geoprobe® Probing and Sampling.* Copies of the SOPs are provided in Attachment 1.

4.3 Monitoring Well Development

All wells installed at the site will be developed to ensure that an adequate hydraulic connection exists between the well and the aquifer. Prior to development, measurements of total depth and water level will be made at each well. Development will be conducted in general conformance with LEA's SOP entitled, *Standard Operating Procedure for Installing and Developing Monitoring Wells and Piezometers*. Development water will be placed into 55-gallon containers provided by Pratt & Whitney for off-site disposal at a licensed disposal facility.

Monitoring wells will be developed by over-pumping using a peristaltic pump to draw down the well, followed by physical surging. After surging, the well will be pumped to remove accumulated sediment. The cycle will be repeated until the well produces clean water or until the physical parameters (temperature, pH, specific conductance) stabilize. Further development by over-pumping or surging will be performed as necessary to stabilize the field parameters.

In general the water pumped from the wells should become clear by the completion of the well development process. Wells will be developed until the parameters stabilize or until the project manager approves the completion on the basis of the time spent, volume recorded, rate of recovery, or other limiting circumstances such as slow recharge.

4.4 Groundwater Monitoring

Prior to sampling each of the newly installed or the permanent monitoring wells noted above, the depth to water and total depth of each well will be recorded. From this information the total volume of water contained in each monitoring well will be calculated. The water will be purged initially and parameters such as pH, temperature, and specific conductance will be recorded. Once the initial volume of water is removed, the monitoring well will be purged a minimum of three times the standing water volume or until all standing water is evacuated. Samples will be collected using a peristaltic pump equipped with dedicated polyethylene tubing. A bailer will be used for sampling for VOCs from the existing monitoring wells. Samples for VOCs from the small diameter Geoprobe® wells will be collected with a thin tubing and a check valve. Samples collected for metals will be filtered in the field using a dedicated 0.45 micron in-line filter assembly. Unfiltered metal samples will be collected as well. The containers will be sealed, placed in a cooler, and shipped to a laboratory selected by Pratt & Whitney under chain-of-custody procedures for the analyses noted above. Total chromium and hexavalent chromium analyses will be performed by a local laboratory due to the tight holding time for hexavalent

chromium analyses.

Trip blanks, equipment blanks, and duplicate/replicate samples will be submitted for analysis for quality assurance/quality control (QA/QC) purposes as specified in the *VCAP Work Plan*. In addition two performance evaluation samples will be submitted to the laboratory.

4.5 Water-Level Measurements

Water level measurements of the newly installed wells and existing wells (measured during the recent groundwater investigation) will be performed. Both groundwater and surface water level measurements will be obtained from the river piezometers installed. All water levels will be recorded to the nearest 0.01 foot using an electronic water level indicator. Between measurements the water level indicator will be decontaminated to prevent cross-contamination. Based on the data collected from the shallow monitoring wells and piezometers, contour maps showing groundwater elevation and flow direction in the shallow (water table), and top of clay aquifer zones will be developed.

DRAWING No. 1

ATTACHMENT 1

Standard Operating Procedures

Standard Operating Procedure
for
Soil Sampling

SOP ID: 10006
Date Initiated: 2/20/90
Revision #003: 11/21/96

Approved By: _____ 11/21/96
Name 1 **Date**

Gail T. Batchelder 11/21/96
Name 2 **Date**

REVISION RECORD

Rev #	Date	Additions/Deletions/Modifications

Standard Operating Procedure for Soil Sampling

1. Statement of Purpose

This document discusses procedures for collection of soil samples for analytical analysis. Methods for collection and quality assurance/quality control requirements are covered under separate SOPs. The procedures outlined in this document are in accordance with ASTM Standard D 420 and the EPA document Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846). These procedures may vary slightly according to the needs of specific projects.

2. Equipment and Equipment Documentation

2.1. Equipment required for the collection of soil samples shall include:

- Stainless steel spatula
- Distilled water
- Hand towels
- Polyethylene plastic sheeting
- Sample collection jars
- Clean disposable gloves
- Field documentation
- Indelible marker
- Cooler, cold packs and maximum/minimum thermometer
- Custody seals and sample labels
- Polythethylene plastic sheeting (5-mil thickness)

2.2. Cleaning and Decontamination

2.2.1. Prior to collecting a soil sample, the LEA representative will ensure that all necessary sampling equipment is clean and decontaminated according to the site-specific work plan or collection method SOPs.

2.2.2. Upon completion of all sampling requirements and prior to leaving the site, all equipment used for sampling shall be cleaned and decontaminated. All generated decontamination fluids shall be

disposed of in accordance with the site-specific work plan and all municipal, state, and federal requirements.

3. Sampling Protocols

3.1. Preliminary Sampling Procedures

3.1.1. Sample Bottles

3.1.1.1. A Laboratory Request Form shall be completed and submitted to the laboratory with following information:

- Project name
- LEA commission number
- Date of submittal and date needed
- Quantity of sample locations and sample points at each location
- Type(s) of samples
- Analytes, detection limits and QA/QC needed
- Cooler(s) required
- Number of Chain-of-Custody forms requested

3.1.1.2. Check bottles against Laboratory Request Form for completeness. The bottles should also be checked for damage and cleanliness. Confirm with laboratory personnel the adequacy of the preservatives used.

3.1.1.3. Obtain preprinted labels and paperwork through the information management system.

3.1.1.4. Label all bottles prior to sampling with the information and check for accuracy. This step may also be performed in the field prior to sample collection.

3.1.1.5. The total number of sample sets shall be increased by 10% to allow for possible breakage during transport to sites or other contingencies (minimum: one additional sample bottle set per event).

3.1.1.6. A cooler with adequate ice or cold packs should be obtained from the laboratory to insure that the collected samples remain at 4°C during transport. Packing material

should also be obtained to insure against breakage during transport.

3.1.2. Site Preparation

3.1.2.1. A level table shall be placed within the exclusion zone and covered with polyethylene sheeting.

1.1.1.2. Decontaminated spatulas shall be placed on the table. Prelabeled sample bottles shall be placed in a convenient location and in order of sample collection.

3.2. Sampling Procedures

3.2.1. All personal protective equipment (PPE) should be donned and maintained in accordance with the site-specific work plan or health and safety plan during all sampling procedures. In the event that no PPE has been specified for a particular sampling event, disposable latex gloves should be donned, as a minimum, during all sampling procedures.

3.2.2. The particular soil sampling device (i.e. hand auger, split spoon, etc.) shall be retrieved from the point of collection and placed on a level table covered in polyethylene sheeting.

3.2.3. Using a decontaminated stainless steel spatula, the soil shall be transferred directly into prelabeled soil sampling containers. Care should be taken to completely fill the sample container intended for VOC analysis. Large void spaces within the container shall be minimized by packing, not agitation.

3.2.4. Wipe the rim of the sample container with a clean paper towel to remove excess solids which would prevent adequate sealing of the sample container and seal the container.

The order of sample collection shall be as follows:

- samples to be analyzed for voltile organic compounds at the LEA Analytical Laboratory
- samples to be analyzed for volatile organic compounds using appropriate EPA methodologies
- samples to be screened for total volatile organic compounds with a total volatile organic analyzer

- samples to be analyzed for other organic and inorganic constituents

3.2.5. As required, affix a custody seal, noting the date and time of collection across the cap/bottle interface and on the sample label. Place and secure sample within cooler and complete all sample collection documentation.

3.3. Post-Sampling Procedures

3.3.1. As required, upon completion of all sampling procedures for a particular site, secure the lid of the cooler using packaging tape with the Chain-Of-Custody inside.

3.3.2. Should the laboratory be local, transport the samples directly to the laboratory and present them to the sample manager. The representative of LEA should witness the verification of the Chain-Of-Custody and obtain a carbon copy for filing in the project notebook.

3.3.3. Should the laboratory be distant, arrange for transport with a reputable carrier service. The cooler and samples shall be secured for transport, and all mailing documentation secured onto the top of the cooler. Unless otherwise specified, delivery shall be overnight. A request for confirmation of acceptance should be made to the carrier at the time of pick-up.

3.4. Documentation

3.4.1. The following general information shall be recorded in the field log book and/or on the appropriate field forms:

- Project and site identification
- LEA commission number
- Field personnel
- Name of recorder
- Identification of borings
- Collection method
- Date and time of collection.
- Types of sample containers used, sample identification numbers and QA/QC sample identification
- Preservative(s) used
- Parameters requested for analysis
- Field analysis method(s)
- Field observations on sampling event

- Name of collector
- Climatic conditions, including air temperature
- Internal temperature of field and shipping (refrigerated) containers
- Chronological events of the day
- Status of total production
- Record of non-productive time
- QA/QC data

3.4.2. The following information shall be recorded on the Field Quality Review Checklist:

- Reviewer's name, date, and LEA commission number
- Review of all necessary site activities and field forms
- Statement of corrective actions for deficiencies

3.4.3. The following information shall be recorded on the chain-of-custody record:

- Client's name and location
- Boring or sampling location identification
- Date and time of collection
- Sample number
- Container type, number, size
- Preservative used
- Signature of collector
- Signatures of persons involved in the chain of possession
- Analyses to be performed
- Type and number of samples

3.4.4. The following information shall be provided on the sample label using an indelible pen:

- Sample identification number
- Date and time of collection
- Place of collection
- Parameter(s) requested (if space permits)

3.4.5. The following information shall be recorded on the sample collection data sheet:

- Client name, location and LEA commission number
- Boring or sampling location identification number

- Date and time of collection
- Sample number
- Depth sample was obtained
- Field instrumentation reading

Standard Operating Procedure
for
Installing and Developing Monitoring Wells and Piezometers

SOP ID: 10007
Date Initiated: 2/20/90
Revision #004: 7/30/97

Approved By: _____ 7/30/97
Name 1 **Date**

Gail L. Betchelder 7/30/97
Name 2 **Date**

REVISION RECORD

Rev #	Date	Additions/Deletions/Modifications

Standard Operating Procedure for Installing and Developing Monitoring Wells and Piezometers

1. Statement of Purpose

This standard operating procedure (SOP) is designed to describe the methods and procedures used to install and develop monitoring wells and piezometers in a water-table aquifer. Monitoring well and piezometer installation and development should generally follow the guidelines presented in "Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells" (US EPA, 1991), the "RCRA Ground Water Monitoring Technical Enforcement Guidance Document" (US EPA, 1986), and any state or local guidance or regulatory documents which are available.

This SOP describes general procedures and guidelines to be followed or consulted for the proper methods to be used when installing monitoring wells or piezometers in unconsolidated deposits and bedrock. Because each site is unique and the purpose of the monitoring wells may vary from installation to installation, no definitive rules can be established. Throughout this SOP reference to monitoring wells is also intended to mean piezometers unless specifically indicated otherwise.

2. Equipment and Decontamination

2.1. Equipment Supplied by the Drilling Contractor

- Drilling rig
- Monitoring well casing
- Monitoring well screen
- Bottom caps, plugs or points
- Centering guides (if they are to be used)
- Filter pack sand
- Bentonite
- Cement-bentonite grout
- Mud-scale to measure densities
- Protective casing or roadbox
- Steam-cleaning apparatus and supplies
- Suitable containers (e.g., DOT-approved 55-gallon drums with liners) for soil

cuttings, well development water, and water generated from steam cleaning.

- Metal stamps for permanently marking wells
- All necessary permits and licenses

2.2. Equipment Supplied by LEA

- Field forms
- Indelible markers
- Lock(s) and keys
- Well development equipment (pumps, surge block, bailers, etc.)
- Analytical instrumentation (Analytical instrumentation includes, but is not necessarily limited to turbidity meters, pH meters, specific conductance meters, and thermometers.)
- Calibration supplies for all analytical instrumentation, as appropriate
- Alconox®, or other non-phosphate laboratory grade detergent
- Three 5-gallon buckets
- Decontamination brushes
- Distilled, de-ionized water
- Decontamination fluids (< 10% methanol in water, 100% n-hexane, and 10% nitric acid)

2.3. Equipment Selection and Specifications

The following specifications will be followed:

Cement-Bentonite Grout: Cement-bentonite grout will be a mixture of 95 pounds of Type II Portland Cement, 4 to 6 pound of powdered sodium bentonite, and 5 gallons of potable water. The bentonite must be thoroughly mixed with the water before the cement is added. The cement bentonite grout should have a density of 14 pounds/gallon.

Filter Pack Sand: All filter pack sand will be a clean, well-rounded silica sand, in factory-sealed bags. The sand will conform to the most recent version of the American Water Works Association (AWWA) Standard AWWA/ANSI A100 for water wells. In brief, the standard states that filter pack sand will have an average specific gravity of 2.5 with not more than 1% of the material having a specific gravity less than 2.25, thin, flat or elongated particles shall not exceed 2% of the material, no more than 5% of the material shall be soluble in hydrochloric acid, and the material shall be washed and free of shale, mica, clay, dirt, loam, and organic impurities.

Bentonite: All bentonite will be pure, additive-free bentonite whether it is pellets, chips, or powder.

2.4. Equipment Decontamination

2.4.1. Equipment Decontamination for Monitoring Well Installation

All well materials and drilling equipment which are used to construct a monitoring well or piezometer must be clean and free of any potential contaminants. All well construction materials not certified as decontaminated when delivered will be decontaminated by steam cleaning before being installed. Drilling equipment must also be decontaminated, prior to beginning work, by steam cleaning.

All decontamination activities should be completed at a specially constructed decontamination pad (or a portable decontamination unit). The decontamination pad should be constructed before any drilling activity begins. The pad should be constructed of HDPE liner material, of sufficient size and strength to allow the drill rig access to the pad, and bermed to contain the generated wastewaters.

2.4.2. Equipment Decontamination for Sampling Equipment and Well Development.

All materials and equipment used to sample soil or which enter a well must be clean and free of any potential contaminants. In general, the choice of decontamination procedures should be based upon a knowledge of the site-specific contaminants and outlined in the site-specific work plan.

For sites at which the contaminants are unknown, but contamination is suspected, the decontamination procedures outlined below should be followed.

2.4.2.1. Prior to commencing any field activities, the following solutions (as appropriate for the anticipated contaminants) should be prepared and placed into 500-ml laboratory squirt bottles: <10% methanol in water; 10% nitric acid in water; 100% n-hexane; distilled, de-ionized water.

2.4.2.2. In the field, prepare approximately 2.5 gallons of a solution of Alconox® (or other suitable non-phosphate laboratory grade detergent) in tap water in a 5-gallon bucket.

2.4.2.3. Prepare a piece of 5-mil polyethylene sheeting to underlie the decontamination area. The sheeting should be of sufficient size to contain any accidental discharge of decontamination solutions. The plastic should be bermed to contain spills.

2.4.2.4. The order for decontaminating equipment is as follows:

1) Detergent scrub
2) DI water rinse
3) Hexane rinse (to be used only if separate-phase petroleum product, other than gasoline, is present)
4) DI water rinse
5) 10% nitric acid rinse (to be used only when metals are suspected as potential contaminants)
6) DI water rinse
7) Methanol rinse (<10% solution)
8) Air dry

2.4.2.5. Disposable materials such as cord should not be decontaminated and should be disposed of after use.

2.4.3. At the end of the project day, all spent decontamination fluids and materials, such as the polyethylene sheeting and personal protective equipment, shall be managed and/or disposed of in accordance with all applicable municipal, state, and federal regulations.

3. Monitoring Well and Piezometer Installation

The specific monitoring well installation methodologies are dependent upon the specific drilling method used. In general, monitoring wells will be constructed through the inside of the drill stem, once the borehole has been advanced to the desired depth.

3.1. Borehole Advancement

If the borehole has been drilled to a depth greater than that at which the well is to be set, the borehole must be backfilled with bentonite pellets, bentonite chips, or a bentonite-cement slurry to a depth of approximately one foot below the intended

well depth. Approximately one foot of clean sand must be placed on top of the backfill to return the borehole to the proper depth for the well installation.

For bedrock monitoring wells, the borehole should be advanced to approximately one foot into competent bedrock and the isolation casing grouted into place. The grout is to be allowed to cure for at least 24 hours before drilling continues. After the grout has cured, the borehole is to be advanced using the appropriate technique (e.g., coring, air rotary, mud rotary) to the desired depth. If the borehole is advanced to a depth greater than that at which the well is to be set, the borehole should be backfilled as described above.

3.2. Installation of Well Screen and Casing

The appropriate lengths of well screen (with bottom cap, or plug, or well point) and casing must be joined watertight and carefully lowered inside the drill stem to the bottom of the borehole. If centering guides are used, they must be placed at intervals around the well casing, beginning no lower than 5 feet above the top of the screen.

3.3. Design and Installation of the Filter Pack

After the well screen and casing are installed in the borehole, the filter pack should be installed. For monitoring wells in unconsolidated materials, the selection of the appropriate filter pack material should be based upon a grain-size analysis of a sample collected from the intended screen interval. The selection of the appropriate filter pack material should be based upon the methodologies presented in "Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells" (US EPA, 1991), the "RCRA Ground Water Monitoring Technical Enforcement Guidance Document" (US EPA, 1986), or any state or local guidance or regulatory documents which are available. In the absence of grain size analyses, the filter pack material should be selected based upon an experienced geologist's best judgment as to the appropriate material.

For bedrock monitoring wells, the well screen and filter pack are enplaced primarily to stabilize the borehole and are therefore not sized in the same manner as for a monitoring well in unconsolidated sediments. For typical bedrock monitoring wells, 10-slot well screen is appropriate. The selection of the appropriate filter pack material should be based upon the slot size selected for the well screen.

A filter pack of clean silica sand will be placed around the well screen. Place the filter pack into the borehole at a uniform rate in a manner that will allow even

placement of the sand. The drill stem should be raised slowly while the sand is being placed to avoid caving of the borehole walls; the drill stem should never be raised above the top of the filter pack during installation. Using a stainless steel weight on the end of a fiberglass tape, continuously sound the top of the filter pack as it is being installed. The filter pack should extend from a depth of approximately one foot below the screened interval to a minimum height of one to two feet above the top of the well screen. However, this length may be adjusted if it would create the potential for cross-contamination or in the case of shallow water tables.

A finer-grained sand cap should be installed for a minimum of one foot above the filter pack. This height may also be adjusted in the case of shallow water tables, or if it would create the potential for cross-contamination in the well.

3.4. Installation of Impermeable Seal

An impermeable seal at least two feet thick must be placed on top of the fine sand cap. The seal may be composed of either bentonite pellets or a bentonite slurry. The pellets must be placed into the borehole in a slow and continuous manner that prevents bridging. This is especially important in deeper monitoring wells where the pellets may have to be emplaced through a considerable depth of standing water in the borehole.

The bentonite slurry should be prepared by mixing 15 pounds of bentonite powder with 7 gallons of water for each one cubic foot of slurry needed. The slurry should be emplaced in the borehole via a tremie pipe. The tremie pipe must be plugged on the bottom and have openings along the sides of the bottom one foot of pipe. This will allow the slurry to be emplaced into the borehole without disturbing the fine sand cap.

Verify the position of the top of the bentonite seal using a weighted tape measure. If all or a portion of the bentonite seal must be emplaced above the water table, hydrate the bentonite with clean water. Allow 30 minutes after adding the water for the bentonite to hydrate.

The thickness of the bentonite seal may be adjusted for wells completed in aquifers with shallow water tables.

3.5. Installation of Grout Backfill

Place an annular seal of cement-bentonite grout above the bentonite seal. Install the cement-bentonite grout continuously from the bottom of the annular space to

the ground surface through a tremie pipe. The tremie pipe must be plugged on the bottom and have openings along the sides of the bottom one-foot length of pipe. This will allow the grout to be emplaced into the borehole without disturbing the bentonite seal.

3.6. Surface Completion

All monitoring wells will be finished at the surface with a concrete pad. The concrete pad should typically be two-feet square and at least four inches thick. The concrete should fill the borehole to a depth below the frost line. The pad should be constructed in one continuous pour of concrete. Note that some of the cement-bentonite grout used for the annular seal may have to be removed to install the concrete pad. A survey pin may be installed in the concrete pad before it dries, if necessary.

For monitoring wells that will be completed above-grade, a locking steel protective casing should be installed in the concrete. The protective casing should extend at least three feet into the ground and two feet above ground. For monitoring wells that will be completed flush, a steel roadbox, suitable for traffic loads, with a gasketed cover and drain should be installed.

Each well will be properly labeled on the exterior of the locking cap or protective steel casing with a metal stamp indicating the permanent well identifier.

3.7. Well Protection Bullards

Guard posts may be installed in high-traffic areas for additional protection. One to four guard posts would be installed around the protective casing, within the edges of the concrete pad. If used, guard posts will consist of concrete-filled steel tubes, at least 3 inches in diameter, painted with multiple coats of epoxy-based paint to prevent rust. The guard posts would extend at least two feet below ground and at least three feet above ground.

3.8. Monitoring Well Completion Log Forms

During the installation of a monitoring well, complete records must be kept of quantities and types of all well construction materials used.

A complete geologic log should be kept during advancement of the borehole for the well. The procedures for completing geologic logs are presented in *Standard Operating Procedure for Geologic Logging of Unconsolidated Sedimentary Materials (SOP #10015)*. However, the additional information pertinent to

monitoring well installations should be recorded on a separate form. Two Monitoring Well Completion forms are attached to this SOP – one for flush-mount well completions and one for above-grade completions. Whenever a monitoring well is installed, record all appropriate information concerning the quantity of materials used, the type and manufacturer of the materials, the mixtures of grouts or slurries, and any pertinent notes regarding the installation of each well.

After the project is completed, submit a copy of the attached Geologic Soil Boring/Well Completion Log Request Form along with copies of all Monitoring Well Completion forms for final typing. The request form provides information on the types of final logs to be produced, the scale at which to plot the final forms, and notes common to all reports.

4. Well Development

Monitoring well development may be accomplished by surging and bailing (or pumping), or overpumping. Other methods, such as air jetting, backwashing, or air-lift pumping, should be avoided because these methods introduce fluids into the formation and may have unexpected influences on groundwater quality, if only for a short period of time.

4.1. Surging and Bailing

In surging and bailing, a well is developed by alternately surging a short section of the screen with a tight-fitting surge block. Begin by lowering the surge block to the top of the screened interval and swab the well with a pumping action with a typical stroke of 2 to 3 feet. (Begin surging at the top of the well intake to avoid having loosened material from "sand-locking" the surge block.) Do not surge the well too violently to avoid damaging the well screen or the filter pack. Remove the surge block at regular intervals and bail (or pump) the fine material from the well. Proceed with surging throughout the length of the well screen, being careful to avoid hitting the bottom of the well. Check the quality of the bailed water at regular intervals, as described in Section 4.3.

In cases where a considerable volume of sediment may initially be drawn into the well, begin surging the well gently in the casing above the well screen. Proceed with surging and bailing to the bottom of the screened interval.

4.2. Overpumping

In overpumping, a well is developed by operating a pump in the well at a capacity which greatly exceeds the formation's ability to supply water. The flow velocity

into the well during overpumping usually greatly exceeds the flow velocity induced during normal sampling. This increased velocity causes movement of particles from the formation into the well.

Begin developing the well by installing a suitable pump at the bottom of the well. Alternately a surface-mounted pump with a suction hose may be used if the drawdown inside the well will not exceed the pump's available lift. The discharge from the pump should be directed to approved containers. The pump(or intake hose) must be equipped with a backflow-prevention valve to prevent introducing aerated water into the aquifer.

Start the pump and discharge water at the highest practical rate. If the well should run dry, stop the pump and allow the well to recharge. Check the quality of the discharged water at regular intervals as described in Section 4.3.

4.3. Completing Well Development

During bailing or pumping, measure and record water quality parameters to gauge the degree and effectiveness of development. Typically, pH, temperature, specific conductance, and turbidity should be checked at periodic intervals (but at least every three well-volumes) until the purge water begins to appear clear. Then measurements should be made after each well volume until the parameters stabilize. The water quality parameters may be considered stable when:

- pH, temperature, and specific conductance of consecutive measurements have relative percent differences (RPD), as defined below, of less than 10%; and,
- the turbidity is 5 NTU or less (applicable only in aquifers with low percentages of fines, and may not be achievable in all situations, but the turbidity should be less than 50 NTUs and should stabilize with an RPD of less than 10%).

However, in no case will development stop before:

- at least 3 well volumes have been removed; and/or
- the well has been surged or pumped for at least 30 minutes.

The relative percent difference (RPD) between two measurements (e.g., M1 and M2) is:

$$RPD = \frac{|M1 - M2|}{(M1 + M2)/2} \times 100\%$$

All well development equipment and supplies must be thoroughly decontaminated prior to and between each monitoring well. Place all development water into properly labeled, suitable containers; leave all filled containers in an appropriate location.

4.4. Documentation of Well Development

5. Well development activities will be documented on the appropriate field forms, and specifically on the "Field Data Record Groundwater" and "Well Development Report" forms. Information provided on those forms includes: purge method, amount of water per well volume, instrument readings after purging of each well volume

Standard Operating Procedure
for
Geoprobe® Probing and Sampling

SOP ID: 10011
Date Initiated: 11/10/94
Revision #002: 11/20/96

Approved By:

Name 1	11/20/96 **Date**
Gail T. Bachelder	11/20/96
Name 2	**Date**

REVISION RECORD

Rev #	Date	Additions/Deletions/Modifications

Standard Operating Procedure for Geoprobe® Probing and Sampling

1. Statement of Purpose

The objective of this procedure is to collect a discrete soil sample at depth using Geoprobe® probing and sampling methodologies and to recover the sample for visual inspection and/or chemical analysis. Procedures for soil sampling for chemical analysis are included in *Standard Operating Procedures for Soil Sampling*.

2. Background

2.1. Definitions

Geoprobe® *: A vehicle-mounted, hydraulically-powered, soil probing machine that utilizes static force and percussion to advance small diameter sampling tools into the subsurface for collecting soil core, soil gas, or groundwater samples.

* (Geoprobe is a registered trademark of Kejr Engineering, Inc., Salina, Kansas.)

Large Bore Sampler: A 24-inch long x 1-3/8-inch diameter piston-type soil sampler capable of recovering a discrete sample that measures up to 320 ml in volume, in the form of a 22-inch x 1-1/16-inch core contained inside a removable liner.

Liner: A 24-inch long x 1-1/8-inch diameter removable/replaceable, thin-walled tube inserted inside the Large Bore Sampler body for the purpose of containing and storing soil samples. Liner materials include brass, stainless steel, Teflon®, and clear plastic (either PETG or cellulose acetate butyrate).

2.2. Discussion

In this procedure, the assembled Large Bore Sampler is connected to the leading end of a Geoprobe® brand probe rod and driven into the subsurface using a Geoprobe® machine. Additional probe rods are connected in succession to advance the sampler to depth. The sampler remains sealed (closed) by a piston tip as it is being driven. The piston is held in place by a reverse-threaded stop-pin at the trailing end of the sampler. When the sampler tip has reached the top of the

desired sampling interval, a series of extension rods, sufficient to reach depth, are coupled together and lowered down the inside diameter of the probe rods. The extension rods are then rotated clock-wise (using a handle). The male threads on the leading end of the extension rods engage the female threads on the top end of the stop-pin, and the pin is removed. After the extension rods and stop-pin have been removed, the tool string is advanced an additional 24 inches. The piston is displaced inside the sampler body by the soil as the sample is cut. To recover the sample, the sampler is recovered from the hole and the liner containing the soil sample is removed.

3. Required Equipment

The following equipment is required to recover soil core samples using the Geoprobe® Large Bore Sampler and driving system. Sample liners for the Large Bore Sampler are available in four different materials. Liner materials should be selected based on sampling purpose, analytical parameters, and data quality objectives.

Large Bore Sampler Parts	Part Number
STD Piston Stop-pin, O-ring	AT-63, 63R
LB Cutting Shoe	AT-660
LB Drive Head	AT-661
LB Sample Tube	AT-662
LB Piston Tip	AT-663
LB Piston Rod	AT-664
LB Clear Plastic Liner	AT-665
LB Brass Liner	AT-666
LB Stainless Steel Liner	AT-667
LB Teflon® Liner	AT-668
LB Cutting Shoe Wrench	AT-669
Vinyl End Caps	AT-641
Teflon® Tape	AT-640T

Geoprobe® Tools	Part Number
Probe Rod (3 foot)	AT-10B
Probe Rod (2 foot)	AT-10B
Probe Rod (1 foot)	AT-10B
Drive Cap	AT-11B
Pull Cap	AT-12B

Extension Rod	AT-67
Extension Rod Coupler	AT-68
Extension Rod Handle	AT-69
Optional	**Part Number**
LB Manual Extruder	AT-659K
Extension Rod Jig	GS-469
LB Pre-Probe	AT-146B

Additional Tools

Vise Grips
Open Ended Wrench (3/8-inch)
1-inch or Adjustable Wrench

4. Procedures

4.1. Utilities Clearance

4.1.1. Notify the appropriate "one call" *utility notification service (e.g. Call* Before You Dig) at least three working days prior to commencing operations on a site. The locations of all proposed borings must be clearly marked in the field prior to notification.

4.1.2. Particularly upon larger private sites, consult with the owner or other person knowledgeable about the site as to locations of potential private or abandoned utilities and locate these prior to beginning work. Upon the discretion of the project manager, a pipe locator can also be used to assist in locating utilities.

4.1.3. Note that OSHA may have additional requirements for location of utilities.

4.1.4. All efforts to locate underground utilities should be properly documented in the field log book prior to onset of the work scheduled.

4.2. OSHA

The foreman or supervisor of the drilling crew shall be the Competent Person as required by OSHA for all of their work. However, this does not relieve the LEA representative from bringing to his or her attention conditions which may be unsafe or present a hazard to the drilling crew, the general public, or other workers on the site. The LEA representative is responsible for ensuring that LEA

activities are conducted in accordance with the site-specific Health and Safety Plan.

4.3. Site Preparation

4.3.1. A sufficient area shall be cordoned off to restrict access to the work area. This area shall be termed an "Exclusion Zone".

4.3.2. An equipment decontamination area shall be assembled as described in Section 4.11 within the exclusion zone.

4.3.3. The area immediately surrounding the proposed borehole and the back portion of the rig (including the tires) shall be covered with 5 mil plastic sheeting. A hole of sufficient diameter shall be cut from the center of the plastic sheeting to facilitate auger advancement.

4.3.4. All personal protective equipment shall donned.

4.4. Assembly

4.4.1. Install a new AT-63R)-ring into the O-ring groove on the AT-63 Stop-pin.

4.4.2. Seat the pre-flared end of the LB Liner (AT-665, -666, -667, or -668) over the interior end of the AT-660 Cutting Shoe. It should fit snugly.

4.4.3. Insert the liner into either end of the AT-662 Sample Tube and screw the cutting shoe and liner into place. If excessive resistance is encountered during this task, it may be necessary to use the AT-669 LB Shoe Wrench. Place the wrench on the ground and position the sampler assembly with the shoe end down so that the recessed notch on the cutting shoe aligns with the pin in the socket of the wrench. Push down on the sample tube while turning it, until the cutting shoe is threaded tightly into place.

4.4.4. Screw the AT-664 Piston Rod into the AT-663 Piston Tip. Insert the piston tip and rod into the sample tube from the end opposite the cutting shoe. Push and rotate the rod until the tip is seated completely into the cutting shoe.

4.4.5. Screw the AT-661 Drive Head onto the top end of the sample tube, aligning the piston rod through the center bore.

4.4.6. Screw the reverse-threaded AT-63 Stop-pin in the top of the drive head and turn it **counter-clockwise** with a 3/8-inch wrench until tight. Hold the drive head in place with a 1-inch or adjustable wrench while completing this task to assure that the drive head stays completely seated. The assembly is now complete.

4.5. Pilot Hole

A pilot hole is appropriate when the surface to be penetrated contains gravel, asphalt, hard sands, or rubble. Pre-probing can prevent unnecessary wear on the sampling tools. A Large Bore Pre-Probe (AT-146B) may be used for this purpose. The pilot hole should be made only to a depth above the sampling interval. Where surface pavements are present, a hole may be drilled with the Geoprobe® using a Drill Steel (AT-32, -33, -34, or -35, depending upon the thickness of the pavement), tipped with a 1.5-inch diameter Carbide Drill Bit (AT-36) prior to probing. For pavements in excess of 6 inches, the use of compressed air to remove cuttings is recommended.

4.6. Driving

4.6.1. Attach an AT-106B 1-foot Probe Rod to the assembled sampler and an AT-11B Drive Cap to the probe rod. Position the assembly for driving into the subsurface.

4.6.2. Drive the assembly into the subsurface until the drive head of the LB sample tube is just above the ground surface.

4.6.3. Remove the drive cap and the 1-foot probe rod. Secure the drive head with a 1-inch or adjustable wrench and re-tighten the stop-pin with a 3/8-inch wrench.

4.6.4. Attach an AT-105B 2-foot Probe Rod and a drive cap, and continue to drive the sampler into the ground. Attach AT-10B 3-foot Probe Rods in succession until the leading end of the sampler reaches the top of the desired sampling interval.

4.7. Preparing to Sample

4.7.1. When sampling depth has been reached, position the Geoprobe® machine away from the top of the probe rod to allow room to work.

4.7.2. Insert an AT-67 Extension Rod down the inside diameter of the probe rods. Hold onto it and place an AT-68 Extension Rod Coupler on the

top threads of the extension rod (the down-hole end of the leading extension rod should remain uncovered). Attach another extension rod to the coupler and lower the jointed rods down-hole.

4.7.3. Couple additional extension rods together in the same fashion as in Step 2. Use the same number of extension rods as there are probe rods in the ground. The leading extension rod must reach the stop-pin at the top of the sampler assembly. When coupling extension rods together, you may opt to use the GW-469 Extension Rod Jig to hold the down-hole extension rods while adding additional rods.

4.7.4. When the leading extension rod has reached the stop-pin down-hole, attach the AT-69 Extension Rod Handle to the top extension rod.

4.7.5. Turn the handle **clockwise** (right-handed) until the stop-pin detaches from the threads on the drive head. Pull up lightly on the extension rods during this procedure to check thread engagement.

4.7.6. Remove the extension rods and uncouple the sections as each joint is pulled from the hole. The Extension Rod Jig may be used to hold the rod couplers in place as the top extension rods are removed.

4.7.7. The stop-pin should be attached to the bottom of the last extension rod upon removal. Inspect it for damage. Once the stop-pin has been removed, the sampler is ready to be re-driven to collect a sample.

4.8. Sample Collection

4.8.1. Reposition the Geoprobe® machine over the probe rods, adding an additional probe rod to the tool string if necessary. Make a mark on the probe rod 24 inches above the ground surface (this is the distance the tool string will be advanced).

4.8.2. Attach a drive cap to the probe rod and drive the tool string and sampler another 24 inches. Use of the Geoprobe®'s hammer function during sample collection may increase the sample recovery in certain formations. Do not over-drive the sampler.

4.9. Retrieval

4.9.1. Remove the drive cap on the top probe rod and attach an AT-12B Pull Cap. Lower the probe shell and close the hammer latch over the pull ap.

4.9.2. With the Geoprobe® foot firmly on the ground, pull the tool string out of the hole. Stop when the top (drive head) of the sampler is about 12 inches above the ground surface.

4.9.3. Because the piston tip and rod have been displaced inside the sample tube, the piston rod now extends into the 2-foot probe rod section. In loose soils, the 2-foot probe rod and sampler may be recovered as one piece by using the foot control to lift the sampler the remaining distance out of the hole.

4.9.4. If excessive resistance is encountered while attempting to lift the sampler and probe rod out of the hole using the foot control, unscrew the drive head from the sampler and remove it with the probe rod, the piston rod. and the piston tip. Replace the drive head onto the sampler and attach a pull cap to it. Lower the probe shell and close the hammer latch over the pull cap and pull the sampler the remaining distance out of the hole with the probe machine foot firmly on the ground.

4.10. Sample Recovery

4.10.1. Detach the 2-foot probe rod if it has not been done previously.

4.10.2. Unscrew the cutting shoe using the AT-669 LB Cutting Shoe Wrench, if necessary. Pull the cutting shoe out with the liner attached. If the liner doesn't slide out readily with the cutting shoe, take off the drive head and push down on the side wall of the liner. The liner and sample should slide out easily.

4.11. Core Liner Capping

4.11.1. The ends of the liners can be capped off using the AT-641 Vinyl End Cap for further storage or transportation. A black end cap should be used at the bottom (down end) of the sample core and a red end cap at the top (up end) of the core.

4.11.2. On brass, stainless steel, and Teflon® liners, cover the end of the sample tube with AT-640T Teflon® Tape before placing the end caps on the liner. The tape should be smoothed out and pressed over the end of the soil core so as to minimize headspace. However, care should be taken not to stretch and, therefore, thin the Teflon® tape.

4.12. Sample Removal

4.12.1. Large Bore Clear Plastic and Teflon® Liners can be slit open easily with a utility knife for the samples to be analyzed or placed in appropriate containers.

4.12.2. Large Bore Brass and Stainless Steel liners separate into four 6-inch sections. The AT-659K Large Bore Manual Extruder may be used to push the soil cores out of the liner sections for analysis or for transfer to other containers.

4.12.3. The procedures for collection of soil samples for chemical analysis are described in the *Standard Operating Procedure for Soil Sampling*.

4.12.4. Soil samples collected for archive purposes shall be placed into 4-ounce clear soil jars and labeled with boring numbers, depth, and commission number.

4.13. Equipment Decontamination and Cleaning

4.13.1. Prior to conducting a boring, the LEA representative will ensure that all necessary equipment is clean and decontaminated, including the rig, all augers and probing equipment, samplers, brushes, and any other tools or equipment. Decontamination procedures may vary slightly from those presented below, dependent upon the particular types of contaminants encountered.

4.13.2. A section of 5-mil (minimum) plastic sheeting shall be cut of sufficient size to underlie the decontamination area to contain any discharge of decontamination solutions.

4.13.3. The following solutions (as appropriate for the anticipated contaminants) shall be prepared and placed in 500-ml laboratory squirt bottles: methanol solution (less than 10%); 10% nitric acid solution; 100% hexane solution; and distilled deionized (DI) water. A fifth solution of phosphate-free detergent and tap water (approximately 2.5 gallons) shall be prepared in a five-gallon bucket. Only those solutions required for site-specific conditions will be used at a given site, as specified in the site-specific work plan.

4.13.4. All loose debris shall be removed from the augers and spatulas into an empty 5-gallon bucket or plastic sheeting using a stiff bristled brush.

4.13.5. The order of decontamination solutions is as follows:

1) Detergent Scrub
2) DI Water Rinse
3) Hexane Rinse (to be used only if separate-phase petroleum product, other than gasoline, is present)
4) DI Water Rinse
5) 10% Nitric Acid Rinse (to be used only when metals are suspected as potential contaminants)
6) DI Water Rinse
7) Methanol Rinse (<10% solution)
8) Air Dry

4.13.6. Each piece of decontaminated sampling equipment will be wrapped in aluminum foil to maintain cleanliness.

4.13.7. An alternative to the procedure described above requires that the larger equipment be cleaned using a high-pressure wash and steam cleaning in an area constructed to contain spent decontamination fluid and debris (plastic sheeting bermed with timber is usually sufficient). Alternative methods of cleaning may be more appropriate for an individual piece of equipment for site conditions based upon a knowledge of site contaminants, and may be used at the discretion of the LEA representative. Section 5.4 provides additional information on management of potentially contaminated fluids and materials.

4.13.8. At the end of the project day, all used equipment shall be decontaminated. All spent decontamination solutions will be handled and disposed of in accordance with all applicable municipal, state and federal regulations.

4.14. VOC Monitoring

4.14.1. A portable volatile organic compound (VOC) analyzer shall be available on site and shall be used to screen all cuttings and fluids (if any) removed from the hole.

4.14.2. Since, in general, it cannot be presumed that there is no contamination at a given site, all cuttings and/or fluids which show a reading on the VOC analyzer that is above background shall be containerized or drummed, as appropriate, on site. Additional information on management of potentially contaminated fluids and materials is presented in Section 5.4.

5. Sample Collection and Documentation

5.1. Sample collection following removal from borehole.

5.1.1. The sample tube shall be opened by the LEA representative and immediately scanned using the VOC analyzer using the approach described in Section 5.2.

5.1.2. The LEA representative will record on the boring log at a minimum: description of the material in the sampler, depth, VOC analyzer reading, material size gradation using the Burmeister system, color, moisture, and relative density.

5.1.3. Prior to reuse, the sampler shall be decontaminated using the procedures described in Section 4.13.

5.1.4. Soil samples collected for archival purposes shall be placed into 4-ounce clear soil jars and labeled with the boring number, depth, and commission number.

5.1.5. The procedures for collection of soil samples for chemical analysis are described in the *Standard Operating Procedure for Soil Sampling*.

5.2. Field Analysis

5.2.1. The following procedure shall be used to obtain readings of the VOCs present in a soil sample:

1) Obtain an aliquot of soil (approximately 50 grams) from the split spoon and placed into a Ziploc™ plastic bag or equivalent and sealed.
2) Agitate the sample, assuring that all soil aggregates are broken, for two minutes.
3) Carefully break the seal of the bag enough to insert the VOC probe.
4) Record the maximum reading obtained on the appropriate forms, as described in Section 5.3.

5.3. Field Documentation

5.3.1. The following general information shall be recorded in the field log book and /or appropriate field forms:

- Project and site identification

- LEA commission number
- Field personnel
- Name of recorder
- Identification of borings
- Collection method
- Date and time of collection
- Types of sample containers used, sample identification numbers and QA/QC sample identification
- Field analysis method(s)
- Field observations on sampling event
- Name of collector
- Climatic conditions, including air temperature
- Chronological events of the day
- Status of total production
- Record of non-productive time
- QA/QC data
- Name of drilling firm
- Location of boring(s) on site insufficient detail to relocate boring at a future time (include sketch)

5.3.2. The following information shall be recorded on the boring log:

- Project name, location, and LEA commission number
- Borehole number, borehole diameter, boring location, drilling method, contractor, groundwater observations, logger's name and date
- Depth below grade, sample I.D. number, duplicate numbers, VOC analyzer reading, rig behavior (i.e. drilling effort, etc.)
- A complete sample description, including as a minimum: depth, material size gradation using the Burmeister system, color, moisture, and density. Should a well be constructed in a borehole, a complete well schematic shall be drawn and accurately labeled
- Use of water, including source(s) and quantity

5.3.3. The following information shall be recorded on the Field Quality Review Checklist:

- Reviewer's name, date, and LEA commission number
- Review of all necessary site activities and field forms
- Statement of corrective actions for deficiencies

5.3.4. The Field Instrument & Quality Assurance Record shall include the following information:

- Client's name, location, LEA commission number, date
- Instrument make, model, and type
- Calibration readings
- Calibration/filtration lot numbers
- Field personnel and signature

5.4. Disposal of Potentially Contaminated Materials

Potentially contaminated cuttings or fluids, as indicated by knowledge of the site, discoloration, VOC analyzer readings, or other evidence, shall be containerized on- site pending sampling and determination of hazardous waste status.

5.5. Refusal

Refusal is defined as failure to penetrate the subsurface materials to any greater depth using the maximum reasonable pressure limits of the Geoprobe® machine.

5.6. Bedrock

The term "bedrock" will not be used in a boring log or other description of subsurface materials that have been collected using the Geoprobe® machine, since a confirmational core cannot be collected.

5.7. Boring Abandonment

5.7.1. If the boring is not to be used for other purposes (i.e. monitoring well, soil vapor probe, soil vapor extraction well, etc.) it shall be abandoned.

5.7.2. The boring shall be filled and sealed with neat cement grout or high density bentonite clay grout as soon as the tools are withdrawn from the borehole.

5.7.3. Excess cuttings shall be containerized and sampled before disposal.

5.7.4. In paved areas, the upper three feet of the borehole shall be filled, up to two inches below the existing grade, with sand to allow for repairing of the pavement.

5.7.5. Pavement shall be repaired using cold patch asphalt filler or concrete.

6. Other

Depending on the specific site, other considerations may be applicable. Consult the OSHA regulations, applicable RCRA or CERGLA regulations, and the site-specific work plan for details.

7. References

Geoprobe® Systems, August 1993, "1993-04 Equipment and Tools Catalog".

Standard Operating Procedure
for
Geologic Logging of Unconsolidated Sedimentary Materials

SOP ID: 10015
Date Initiated: 12/27/94
Revision #001: 11/20/96

Approved By:

Name 1	11/20/96 **Date**
Gail T. Bartelde **Name 2**	11/20/96 **Date**

REVISION RECORD

Rev #	Date	Additions/Deletions/Modifications

Standard Operating Procedure for Geologic Logging of Unconsolidated Sedimentary Materials

1. Statement of Purpose

This document presents the methods and procedures used to describe unconsolidated sedimentary materials for geological purposes in a uniform and consistent manner. It includes procedures for properly recording the observations by providing guidelines for completing boring logs and submitting those logs for computer entry. This Standard Operating Procedure (SOP) refers only to geologic logging of soils and sediments (including artificial fill and other man-made deposits) and specifically is not intended to describe logging of soils or sediments for geotechnical or other engineering purposes. Although the SOP presents a system for describing sediments, it is not intended to be a definitive reference for classifying sedimentary materials, nor is it intended to replace experience or training. Individuals using this SOP should be trained and competent in field methodologies and geologic logging prior to commencing field activities.

2. Collection of Unconsolidated Soil/Sediment Samples

2.1. Equipment required for the geologic logging of soil/sediment samples shall include the following items:

- Tape measure or scale
- Hand lens
- Color chart
- Grain-size comparator
- Field forms
- Indelible marker(s)
- Small table
- Field Book
- Clipboard

2.2. Sample Collection

Samples of soil and unconsolidated sedimentary materials will be collected in general accordance with the SOPs for Soil Sampling (SOP #10006), Hand Auger Borings (SOP #10003), Hollow Stem Auger Soil Borings (SOP #10008), and Geoprobe® Probing and

Sampling (SOP #10011). Those SOPs include procedures for decontamination of equipment required for sample collection, as well as providing the methodologies for sample collection and documentation.

3. Descriptions of Unconsolidated Sedimentary Materials

3.1. General Sediment Description Guidelines

For the purposes of geologically logging unconsolidated soils and sedimentary materials, a Modified Burmister method of description and classification should be used. The Modified Burmister Sediment Classification System (or simply, Burmister System) is intended as a rapid field method for identifying and classifying sediments. The system is based upon visual identification of the generalized grain-size distribution and description of the physical characteristics of the sample.

A Burmister System description is comprised of three parts: a color descriptor; a grain-size descriptor; and modifier(s).

The color descriptor indicates the overall color or colors of the wet sample. The descriptor consists of a color name or names and (if possible) the color code from a standard color reference (for example, a Munsell[7] Color Chart).

The grain-size description indicates the predominant grain size in the sample, as well as the relative percentages of other grain sizes present.

Modifiers are used to further describe the geologic character of the sample. Modifiers may include descriptions of moisture content, sorting, sphericity, angularity, sedimentary structures or other pertinent information.

3.1.1. Color Description

The color of the wet sediment should be determined with reference to a standard color comparator (for example, a Munsell[7] Color Chart) for rocks or sediment. The included color descriptor should contain both the color name and, when a color comparator is used, the appropriate hue-chroma value code, for example "Reddish brown (5YR 4/4)". The color of a sample should always be gauged when the sample is wet, or it should be noted otherwise.

3.1.2. Predominant Grain-Size Description

The first step in describing a sediment sample is visually estimating the size range and percentage of the various grain sizes in the sample.

Reference should be made to standard geologic comparators for assessment of the grain size(s).

The primary grain-size descriptor indicates the predominant grain size, as judged visually, of the sample. The descriptor is always capitalized and underlined. Possible descriptors include: CLAY, SILT, SAND, GRAVEL (GRANULES, PEBBLES, COBBLES, and BOULDERS). These correspond to the standard Wentworth size-classification scheme used for describing sediments for geologic purposes. Size classifications for CLAY through GRAVEL are presented in Table 1. The descriptor should also include an indication of the relative size range of the sample within the predominant grain size (for example, "fine-to-medium sand", "coarse sand", etc.). Although Table 1 includes divisions of the silt category, this is applicable only to sediment samples analyzed by pipette or hydrometer and cannot be distinguished in the field.

The presence of other grain sizes, in addition to the predominant material is also included in the grain-size descriptor. Appropriate grain sizes are the same as for the predominant grain size of the material (clay, silt, etc.), however only the initial letter of the word is capitalized. The description should also include an indication of the relative amount of the minor components. Appropriate indicators for the relative percentages present are provided in Table 2.

It is generally not considered possible to visually distinguish between clay and silt. Estimation of the silt/clay content of a sample should be based upon the plastic properties of the sample. The plastic properties of the sample may be estimated by taking an approximately 1 cubic centimeter ball of the sediment and attempting to roll a thread of the material between the palms of the hand. The minimum size of the thread which may be rolled may be compared to the values presented in Table 3 and the plasticity estimated. A comparison of the minimum thread diameter which may be formed with the information presented in Table 3 provides an approximate silt/clay content estimate for sand-silt-clay sediments and composite clay sediments.

3.1.3. Modifiers

Various modifiers may be added to the basic sediment description to further describe the geologic character of the sample.

For sand or coarser-sized material, the relative degree of sorting, the sphericity, and angularity should also be recorded. Sorting may be visually estimated. Sphericity and angularity, however, should be made with reference to an accepted comparator. A chart illustrating various degrees of sphericity and angularity is attached as Figure 1.

The mineralogy of the sample should also be recorded. Reference should be made to the relative percentages, grain size(s), and sphericity of the mineral particles (especially where it differs significantly from that of the predominant grain-size material).

Other information which should be recorded for each sample includes an estimate of the density and cohesiveness of the sample (made from blow counts where applicable, or other specific instrumentation where appropriate), the relative moisture content of the sample, visible sedimentary structures, and any odors or staining noticeable during logging. Tables 3 and 4 present appropriate terms for describing the plasticity, density, and cohesiveness of sediment samples.

Especially important is an indication that a specific portion of the material may represent "sluff" or material collapsed from the borehole walls.

3.2. Written Sediment Descriptions

The written sediment description may be made as either an unabbreviated or an abbreviated description. Both methods should relate the same information, however the abbreviated description is better suited for field use.

In an unabbreviated description, all of the words of the description should be written out in their entirety. The descriptor should include pertinent information regarding the sample's size gradation, consistency, color, and relative grain size, as described previously. The color descriptor should precede the primary sediment component name, while additional details such as the plasticity, mineralogy, visible sedimentary structures, etc., should follow the sediment component name.

An example of an unabbreviated description is:

Red-brown (5YR 4/4), fine to coarse SAND, little fine Gravel, little Silt, moist, moderately well sorted, low

sphericity, Gravel waterworn, Sand subangular, micaceous.

Since the Burmister system is intended to provide a means for describing uniform sediments, three "special" cases should be addressed.

First, the Burmister system is intended only to describe the sediment. Where a genetic classification of the material is significant, it should be added as a separate statement at the end of the description. For example:

Olive gray (5Y 4/2), coarse to fine SAND, some fine Gravel, little Silt, moist, poorly sorted, sub-rounded to angular, dense. TILL.

A genetic classification should only be used when the origin of the material is very clear and not simply a field interpretation of possible depositional environment.

Second, in the case where the sediment sample is heterogeneous (for example, a varved silt and clay), each component should be described individually, and reference should be made to the relative percentages of each component and to the interlayering. For example:

Soft, reddish-brown (5YR 3/4), CLAY and SILT, alternately layered, medium to high overall plasticity. Layers: CLAY layers, 3/8" to 5/8" thick, comprise 60%" of sample. SILT layers, 1/8" to 3/8" thick, comprise 40%" of sample. VARVED CLAY and SILT.

Third, when one material grades uniformly into a distinct sediment type, the individual components should be described separately and the gradation noted. For example:

Soft, reddish-brown (5YR 3/4), CLAY, medium overall plasticity, grading into soft, reddish-brown (5YR 4/4), SILT, trace Clay, low overall plasticity.

In the abbreviated sediment descriptions, the sample information is presented in a manner analogous to that for the unabbreviated description substituting standard abbreviations for specific portions of the text. Abbreviations for the identifying terms in the Burmister system are presented in Tables 2, 3, and 4. Mineralogic

and geologic abbreviations may be found in standard geologic and mineralogic texts and field manuals. Except for the use of abbreviations, the abbreviated description is completely analogous to the unabbreviated description.

For the sake of consistency in describing unconsolidated sedimentary materials, the description should follow the order and general definitions presented in Table 5.

4. Recording Descriptions

4.1. Geologic Boring Logs

Attached to this SOP is a copy of LEA's standard geologic boring log form. This log should be completed for each boring that is completed. The heading information is self-explanatory. The body of the log contains space for information for each sampled interval in the boring. The following information should be recorded:

Depth Interval	The upper and lower depths from which the sample was collected.
Sample No.	The sample number, as obtained from LEA Data Management, assigned to this sample.
Recovery	The length of the recovered sample and the length of the sampler (in consistent units). The percent recovery will be calculated by the geologic logging program.
Blows/6"	The number of blow counts per 6" interval for the sample. Alternately, the downhole pressure or other pertinent information regarding the required drilling or sampling force.
Sample Description	The sample description using the guidelines and order presented in Section 3.0 and Table 5.
PID/FID	The headspace reading from a PID or FID in ppm.

The comments section of the form should be used to record general observations regarding drilling conditions, backfilling of the borehole, or other pertinent information regarding drilling the borehole.

4.2. Computer Data Entry

After a project is completed, copies of the Geologic Boring Log forms should be submitted for computer data entry. A completed copy of the Geologic Soil Boring/well Completion Log Request Form should be attached to the log forms; a copy of the request form is attached to this SOP.

TABLE I
Wentworth Size Classification System

US Standard Sieve Sizes	Millimeters	Microns	Phi (N)	Wentworth Size Classification	
Use Wire Squares	4096	4,096,000	-20	Boulder	GRAVEL
	1024	1,024,000	-10		
	256	256,000	-8		
				Cobble	
	64	64,000	-6		
				Pebble	
	16	16,000	-4		
5	4	4,000	-2		
				Granule	
6	3.36	3,360	-1.75		
7	2.83	2,830	-1.50		
8	2.38	2,380	-1.25		
10	2.0	2,000	-1.00		
				Very Coarse Sand	SAND
12	1.68	1,680	-0.75		
14	1.41	1,410	-0.50		
16	1.19	1,190	-0.25		
18	1.00	1,000	0.00		
				Coarse Sand	
20					

		0.84		840		0.25	
25		0.71		710		0.50	
30		0.59		590		0.75	
35		0.50		500		1.00	
							Medium Sand
40		0.42		420		1.25	
45		0.35		350		1.50	
50		0.30		300		1.75	
60		0.25		250		2.00	
							Fine Sand
70		0.210		210		2.25	
80		0.177		177		2.50	
100		0.149		149		2.75	
120		0.125		125		3.00	
							Very Fine Sand
140		0.105		105		3.25	
170		0.088		88		3.50	
200		0.074		74		3.75	
230		0.0625		62.5		4.00	

								Coarse Silt	MUD
270		0.053		53		4.25			
325		0.044		44		4.50			
Analyzed by Pipette or Hydrometer		0.037		37		4.75			
		0.031		31		5.0			
								Medium Silt	
		0.0156		15.6		6.0			
								Fine Silt	
		0.0078		7.8		7.0			
								Very Fine Silt	
		0.0039		3.9		8.0			
								Clay (Note: Some use 2: (or 9N) as the clay boundary.)	
		0.0020		2.0		9.0			
		0.00098		0.98		10.0			
		0.00049		0.49		11.0			
		0.00024		0.24		12.0			
		0.00012		0.12		13.0			
		0.00006		0.06		14.0			

Table 2
Modified Burmister System Descriptors

Fractions		Proportion Descriptors		
(+)	Major Fraction	Quantity	Descriptor	Abbreviation
(-)	Minor Fraction	35% - 50%	and	a
e.g., a medium to coarse SAND which is predominantly medium grained would be written as: m(+) - c SAND		20% - 35%	some	s
		10% - 20%	little	l
		1% - 10%	trace	t
		Modifiers: (+) Upper a of the range (-) Lower a of the range		

Table 3
Plasticity of Sediment Samples

Material	Symbol	Feel	Ease of Rolling Thread	Minimum Thread Diameter	Plasticity Index	Plasticity
Clayey SILT	CyM	Rough	Difficult	1/4"	1 to 5	Slight (Sl)
SILT & CLAY	M & C	Rough	Less Difficult	1/8"	5 to 10	Low (L)
CLAY & SILT	C & M	Smooth, dull	Readily	1/16"	10 to 20	Medium (M)
Silty CLAY	MyC	"Shiny"	Easy	1/32"	20 to 40	High (H)
CLAY	C	Waxy, very shiny	Easy	1/64"	40 +	Very High (VH)

Table 4
Density and Cohesiveness of Sediment Samples

Density of Cohesionless Soils		Consistency of Cohesive Soils	
Blow Counts	Relative Density	Blow Counts	Consistency
0 to 4	Very Loose	0 to 2	Very Soft
5 to 9	Loose	2 to 4	Soft
10 to 29	Medium Dense	4 to 8	Medium
30 to 49	Dense	8 to 15	Stiff
50 to 79	Very Dense	15 to 30	Very Stiff
80 or more	Extremely Dense	30 or more	Hard

Table 5
Description of Sediment Properties

Sediment Parameter	Properties
Color	The color of the sample should be described for the wet sediments. If possible the color should be referenced to a standard color chart such as a Munsell7 Color Chart.
Primary Grain Size	Primary grain size refers to the size of the predominant sedimentary size class within the material (as judged visually). The grain size divisions should conform to the standard Wentworth Scale divisions, as shown in Table 1.
Secondary Grain Size(s)	Secondary grain size(s) refer to material which, as a grain-size group, comprises less than the majority of the sediment. Aside from stating the size classification, the relative percentage of the material must be stated. The grain size divisions should conform to the standard Wentworth Scale divisions as shown in Table 1. To describe the approximate percentage of the secondary grain size(s) present, qualifiers shown in Table 2 should be used.
Moisture Content	The moisture content of the sample should be described as dry, slightly moist, moist, or wet. Gradation from one state to another should be recorded as, for example, moist to wet, or moist ÿ wet.
Sorting	The relative degree of sorting of the sediment should be indicated as poor, moderate, good, or very good. The degree of sorting is a function of the number of grain size classes present in the sample; the greater the number of classes present the poorer the sorting. In addition, for samples composed only of sand, the relative degree of sorting is a function of the number of sand-size subclasses present.
Sphericity	Sphericity is a measure of how well the individual grains, on average, approximate a sphere. The average sphericity of the sand and larger size fractions should be described as low, moderate or high. A chart illustrating various degrees of sphericity is presented in Figure 1.
Angularity	Angularity, or roundness, refers to the sharpness of the edges and corners of a grain (or the majority of the grains). Five degrees of angularity are shown in Figure 1: Angular (sharp edges and corners, little evidence of wear); Subangular (edges and corners rounded, faces untouched by wear); Subrounded (edges and corners rounded to smooth curves, original faces show some areas of wear); Rounded (edges and corners rounded to broad curves, original faces worn away); and, Well Rounded (no original edges, faces, or curves, no flat surfaces remain on grains).
Sedimentary Structures	Sedimentary structures are such things as varved layers, distinct bedding, or stratification.
Density -or- Cohesiveness	The density of cohesion of a sample (for the purposes of this application) refer to the sample's resistance to penetration by a sampling device. Density is used in reference to sediments primarily silt-size and coarser while cohesiveness is used in reference to primarily clay-sized sediments. Density or cohesiveness can be assessed from the number of blows from "standard" split-spoon sampling (i.e., 140# hammer, 30" fall, 2" X 2" (O.D., 1 3/8" I.D.)) split-spoon samplers according to the scale in Table 3.