PHILIPS DISPLAY COMPONENTS COMPANY
SENECA FALLS, NEW YORK

APPROVED WITH CONDITIONS

RCRA FACILITY ASSESSMENT
SAMPLING VISIT WORK PLAN

REVISED PAGES INSERTED

VOLUME II
SAMPLING AND ANALYSIS PLAN

Prepared for:

PHILIPS DISPLAY COMPONENTS COMPANY
SENECA FALLS, NEW YORK

Prepared by:

KEYSTONE ENVIRONMENTAL RESOURCES, INC.
3000 TECH CENTER DRIVE
MONROEVILLE, PA 15146

PROJECT NO. 288788

JUNE 1992

BUREAU OF HAZARDOUS WASTE FACILITY MANAGEMENT

___PRC______________   ___MARYANN__________
                            ___TAMMY____________

ENGINEERING GEOLOGY SECTION

✓ ECM (initials)   ___MARYANN
___WEW   ___DEBI
___DMR   ___GDC
___TR   ___PF
___LFW   ___KDJ
___LMT   ___BA

WESTERN CIVIL TECHNOLOGY SECTION

___RDM   ___KAREN
___RLA   ___RPP
___MJM   ___JD
___TID   ___KAB

EASTERN CIVIL TECHNOLOGY SECTION

✓ SJK (initials)   ___MARSHA
___SMM   ✓ VAV 7/27/92
___DCN   ___KKG
___APP   ___HJW
___VSM

Rush Review

___FILE: REGION NO. 8

FACILITY NAME Philips Display

GENERAL FILE______________

___COPIES: FOR______________

HOW MANY______________

___RETURN TO:______________

BHWFC

___JLM______

RCRA PERMIT SECTION 1

___SC______

RCRA PERMIT SECTION 2

___JWD______

BHWPD

___JEI______

PHILIPS DISPLAY COMPONENTS
SENECA FALLS, NEW YORK
SAMPLING VISIT WORK PLAN

VOLUME II
SAMPLING AND ANALYSIS PLAN

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SAMPLING VISIT WORK PLAN

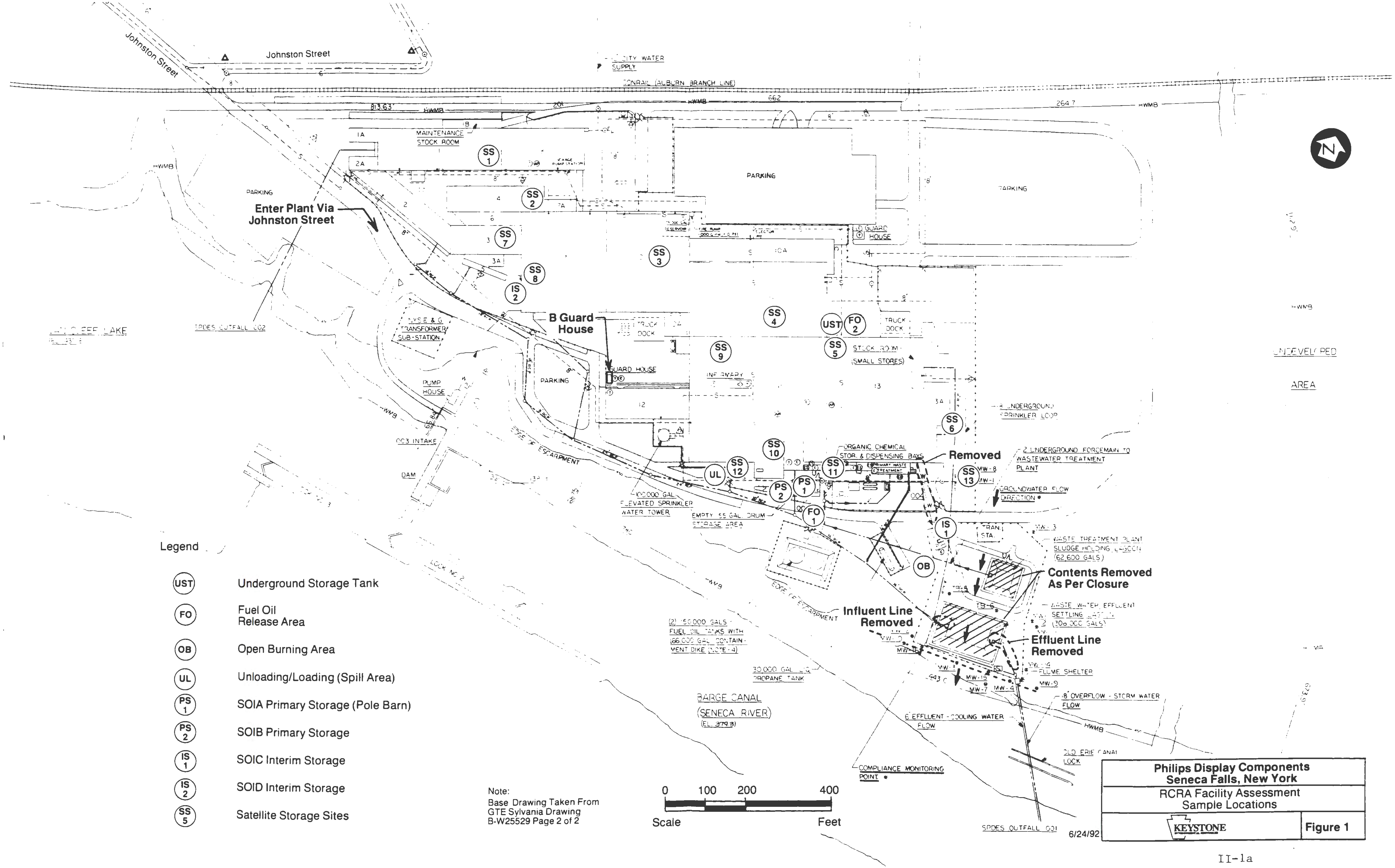
VOLUME II
SAMPLING AND ANALYSIS PLAN

1.0 INTRODUCTION

Philips Display Components Company (Philips) is presently in the RFA phase of a corrective action program established by the New York State Department of Environmental Conservation (NYSDEC). As discussed in the Management Plan (Volume I), the Sampling and Analysis Plan (Volume II) will be used in preparing for and executing the Sampling Visit at the Philips Display Components Corporation facility in Seneca Falls, New York. A schematic plan view of the facility is shown in Figure 1.

The Sampling and Analysis Plan addresses the three major phases of the Sampling Visit: pre-field or office activities, on-site sampling activities and post-sampling activities. Each phase is addressed first by briefly describing the general tasks that must be considered, and then by specifying their mode of implementation.

A portion of the material covered in the Sampling Visit Work Plan (SVWP) is also addressed in the Quality Assurance Project Plan (QAPjP). Should there be any difference(s) concerning procedure between the two documents, the QAPjP will govern.


Johnston Street
Johnston Street
CITY WATER SUPPLY
CONRAIL (AUBURN BRANCH LINE)
HWMB
MAINTENANCE STOCK ROOM
PARKING
PARKING
PARKING
Enter Plant Via Johnston Street
B Guard House
GUARD HOUSE
TRUCK DOCK
TRUCK DOCK
STOCK ROOM (SMALL STORES)
N.Y.S.E & G. TRANSFORMER SUB-STATION
PUMP HOUSE
SPDES OUTFALL 002
003 INTAKE
DAM
EDGE OF ESCARPMENT
ORGANIC CHEMICAL STOR. & DISPENSING BAYS
Removed
UNDERGROUND SPRINKLER LOOP
2 UNDERGROUND FORCEMAIN TO WASTEWATER TREATMENT PLANT
GROUNDWATER FLOW DIRECTION
100,000 GAL. ELEVATED SPRINKLER WATER TOWER
EMPTY 55 GAL. DRUM STORAGE AREA
WASTE TREATMENT PLANT SLUDGE HOLDING LAGOON (62,600 GALS.)
Contents Removed As Per Closure
WASTE WATER EFFLUENT SETTLING LAGOON
Influent Line Removed
Effluent Line Removed
FLUME SHELTER
(2) 150,000 GALS. FUEL OIL TANKS WITH 166,000 GAL. CONTAINMENT DIKE (NOTE 4)
30,000 GAL. L.P. PROPANE TANK
BARGE CANAL (SENECA RIVER) (EL. 379.3)
8" OVERFLOW - STORM WATER FLOW
6" EFFLUENT - COOLING WATER FLOW
OLD ERIE CANAL LOCK
COMPLIANCE MONITORING POINT
SPDES OUTFALL 001
UNDEVELOPED AREA
Legend
UST Underground Storage Tank
FO Fuel Oil Release Area
OB Open Burning Area
UL Unloading/Loading (Spill Area)
PS 1 SOIA Primary Storage (Pole Barn)
PS 2 SOIB Primary Storage
IS 1 SOIC Interim Storage
IS 2 SOID Interim Storage
SS 5 Satellite Storage Sites
Note:
Base Drawing Taken From GTE Sylvania Drawing B-W25529 Page 2 of 2
0 100 200 400
Scale Feet
Philips Display Components
Seneca Falls, New York
RCRA Facility Assessment
Sample Locations
KEYSTONE
Figure 1
6/24/92

2.0 PRE-FIELD OFFICE ACTIVITIES

2.1 Summary of Tasks to be Performed

Thorough preparation and pre-planning will be required in order to minimize scheduling conflicts, uncertainty as to the sampling protocol, equipment problems, and time spent during field sampling activities.

Preparation for sampling will involve four activities: 1) sampling coordination (techniques and schedule) with plant and analytical laboratory personnel so that project activities proceed without uncertainty and delay which can contribute to the loss of sample integrity: 2) equipment and form preparation; 3) personnel training in the operation of all sampling equipment and sampling procedures, including precautions to avoid sample and bottle contamination, operation of field water quality testing equipment, and record keeping procedures; and 4) review of the site Health and Safety Plan (Volume III) with all of the project personnel associated with the Sampling Visit.

The following procedure is to be initiated prior to the scheduled sampling. It is the responsibility of the person in charge of sampling (Team Leader) to certify that each task has been completed. To assure that no items have been omitted, a check list of office activities will be used as a basis for directing pre-field activities. It will be up to the Team Leader, unless otherwise specified, to initial each completed task on the punch list once all of the tasks have been addressed. The pre-field check list to be used by the Team Leader in preparing for sampling trips is presented in the QAPjP.

2.2 Procedure

At least ten days in advance of the scheduled sampling event, the Team Leader, by memo, will: 1) notify the analytical laboratory about the scheduled sampling event, 2) procure the appropriate type and number of sample containers and shipping containers, 3) brief lab personnel on the anticipated date and time that samples will be delivered, and 4) notify NYSDEC of the specific date when sampling will commence. A general list of parameters, and number of samples required at each location is provided in Table 2-1 of the QAPjP. The anticipated number of sampling sites, parameters to be measured at each site and replicate measurements required as well as the number of extra bottles needed for quality assurance testing is presented in the QAPjP and will be specified to the analytical laboratory so that the proper number of bottles and shipping containers are prepared. The analytical laboratory will use methods specified in EPA SW-846, 3rd Edition, or approved alternatives.

The Team Leader will assure that all necessary sampling equipment is assembled. A checklist to be used for assembling equipment is presented in Figure 5-5 of the QAPjP. The equipment checklist will be completed and signed by the Team Leader in preparation for the Sampling Visit.

Field meters to be used during sampling, such as the Flame Ionization Detector (FID), will be checked to ensure proper calibration and precision. A log for each meter will be maintained to document problems experienced with the meter, corrective measures taken, battery replacement dates, calibration times, when used and by whom. Appropriate new batteries will be purchased and kept with the meters to facilitate immediate replacement by field personnel when necessary.

All equipment to be utilized during the sampling will be examined to ascertain that it is in operating condition. This includes checking the manufacturer's operating manuals to ensure that all maintenance items are being observed. Field notes from previous sampling trips will be reviewed so that any prior equipment problem notations are not overlooked and to determine that all necessary repairs to equipment have been carried out.

The Team Leader will obtain a field log book and assemble all necessary forms including the Field Activities Punch List, Chain of Custody Form and Sample Analysis Request Sheet. Samples of these forms are presented in the QAPjP.

The field log will be used to record field data measurements and observations. It serves as the permanent record of all events occurring during the sampling trip. Entries onto the log will be made in waterproof ink. Information recorded at each sampling site will vary according to sitespecific facilities, procedures and conditions, but will, at a minimum, contain the following details:

- Identification of sampling location
- Sample depth
- Sample withdrawal procedure/equipment
- Date and time of sample collection
- Quality assurance/control samples
- Names of field crew present at the site
- Name of collector
- Sample identification numbers
- Types of sample containers used and preservatives (if any)
- Field observations on sampling event
- Climatic conditions including air temperature
- Parameters requested for analysis
- Sample distribution and transporter
- Internal temperature of field and shipping (refrigerated) containers
- Photographic record of sampling locations

The Field Activities Punch List is to be used to record new developments at the facilities, note observations and sampling problems and serve as an agenda for future discussions. The Field Activities Punch List form is presented in the QAPjP. A copy of this completed form is to be retained by the Team Leader and the original placed in the project files.

The Chain of Custody Form documents specific details concerning numbers and types of bottles obtained for each sample; sample preservation details; scheduling and personnel involved; and custody details. The original accompanies the samples from the time sampling occurs through completion of analysis. This original is to be immediately returned by the laboratory to the Team Leader for inclusion into the project files. A copy is retained by the Team Leader after relinquishing samples to laboratory personnel. The Sample Analysis Request Sheet is submitted to the laboratory with the Chain of Custody Form as a check against arrangements made prior to the sampling event. A copy of this form is retained by the Team Leader. Specific detection limits, if required, should be added to the Sampling Analysis Request Sheet and determine what sites are to be used for quality control during each sampling trip. It will be the Team Leader's responsibility to see that the proper bottles are assembled and quality control sampling is implemented in the field.

The arrangement of sample bottle and shipping container delivery with the analytical laboratory will be made such that sufficient time to correct errors or request additional containers can be made prior to departure for the sampling trip. Once sample bottles and shipping containers are received, it is the responsibility of the Team Leader to check that the proper number and type of containers have been supplied.

To avoid unnecessary delays in the field and serve as a check on the completeness of the sample containers, bottles are to be prelabeled by the laboratory. Sample bottle labeling will be accomplished using sticky-back labels. Prior to the sampling trip, labels will be marked and taped over with clear tape to prevent the label from peeling off due to contact with water and ice in coolers. The Chain of Custody Form will contain details of sample collection (sample type, sampler's name time and date).

One day before the scheduled sampling, the Team Leader will meet with the field sampling crew and review the sampling procedures and the requirements of this manual and of the Quality Assurance Project Plan. Prior to this meeting, the Team Leader will review previous sampling trips and identify areas of concern or techniques to be utilized at the site.

It will be the responsibility of the Team Leader to select and maintain records of quality control samples taken during the course of the sampling program. The Team Leader will randomly select samples to be collected for duplication or splitting according to the criteria set in the QAPjP.

3.0 ONSITE ACTIVITIES

3.1 Summary of Tasks to be Performed and Site Investigation Team

3.1.1 Tasks to Be Performed

Volume I of the Sampling Visit Work Plan discusses potential sources of contamination and identify which areas require sampling. The only areas discussed in this volume are those which require sampling. Volume III of the Sampling and Analysis Plan discusses potential health hazards at the site and the safety precautions which will be taken during the field investigation. The Quality Assurance Project Plan (QAPjP) summarizes and describes the quality assurance and quality control measures which will be taken for this project.

The procedures for sampling soils in primary, secondary, designated satellite storage areas, the designated underground storage tank, and other areas designated in Volume I are summarized below. All field measurements and observations will be entered into the field log book while at each sampling location.

acceptable

If there are visible signs of contamination in any sampling area, such as staining which leads to a crack in the asphalt or cement, the soil boring shall be shifted to this location. The location of all soil borings are to be agreed to by the NYSDEC prior to sampling.

3.1.2 Site Investigation Team

The site investigation team is responsible for implementation of the Sampling Plan. The site investigation team will be made up of the following personnel and subcontractors:

Keystone Environmental Resources, Inc.:

Keystone Environmental Resources, Inc. (Keystone) will act as Project Manager for this phase of the RFA. Keystone will conduct the Sampling Visit as outlined in the

Sampling Visit Work Plan, arrange for and coordinate the work of subcontractors, such as the drilling firm, carry out soil and groundwater sampling, conduct all laboratory analytical tests according to the requirements, and interpret the data and report the results of the Sampling Visit. Keystone employees and their assigned duties include:

Project Manager - Dennis Middleton

The project manager will serve as the overall focal point for decisions regarding implementation of the proposed field activities at the Philips Facility, and subsequent data interpretation and report preparation.

Team Leader /Sampling Coordinator - Mike Hursky

The team leader/sampling coordinator will supervise and coordinate all field activities and be responsible for carrying out the sampling and analysis plan. The team leader/sampling coordinator will be responsible for maintaining a field log from which the detailed narrative of the Sampling Visit can be prepared. The team leader/sampling coordinator will be responsible for the development of a photographic log of on-site activities.

Site Health and Safety Officer - James Balint

The site health and safety officer will be responsible for developing and implementing the site health and safety plan.

Sampler:

The sampler will be responsible for following standard operating procedures in collection of all soil and groundwater samples. He will be responsible for assuring that all samples collected are done so in accordance with procedures set forth in the sampling and analysis plan and in the QAPjP.

Subcontractor:

The drilling subcontractor is not known at this point, but Keystone will ensure that the subcontractor is adequate for the work, is familiar with the sampling plan, and can meet the requirements of the QAPjP.

4.0 SAMPLING PLAN FOR AREAS REQUIRING INVESTIGATION

Soil sampling will be conducted at the individual areas identified in Volume I of the SVWP to assess the extent of subsurface contamination, if any. **All soil samples collected for analysis of cadmium, chromium, lead and zinc will be analyzed using EPA Method 6010 (total metals). Analytical results from EPA Method 6010 will be used in comparison to agency established action levels.**

Soil samples collected during the MW1-RCRA Facility Investigation, will be analyzed using EPA Method 6010 and Draft EPA Method 1312. Because agency action levels are determined using Method 6010 (total metals), comparison of analytical results achieved using Draft Method 1312, rather than Method 6010 may not be appropriate when determining if action is required.

Due to the analytical requirements for the MW1-RCRA Facility Investigation, background soil samples will be analyzed using both Method 6010 and Draft Method 1312. The background samples will be collected from an area previously used for agricultural purposes. Analytical results from investigative sampling will initially be compared to action levels. However, should analytical results from background samples be above the action levels, the NYSDEC will take these background sample results into account in establishing the need for further investigation within a specific area. The background samples procedures and locations are presented in Section 4.2.7.

In the case of organic constituents of concern, concentrations greater than the detection limit will be taken as an indication of subsurface contamination.

4.1 Standard Procedures to be Followed in Areas Requiring Soil Sampling

The following procedures will be followed for all soil test borings:

1. Soil test borings will be conducted utilizing split-spoon sampling techniques followed by hollow-stem auguring as described in the Standard Operating

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4.0 SAMPLING PLAN FOR AREAS REQUIRING INVESTIGATION

Soil sampling will be conducted at the individual areas identified in Volume I of the SVWP to assess the extent of subsurface contamination, if any. Draft EPA Method 1312 will be used when analyzing soil samples for metals and the analytical results from on-site soil sampling will then be compared to agency-established action levels. Because agency action levels are determined using total metals (i.e., Method 7421 for lead, Method 6010 for chromium, cadmium and zinc), comparison of analytical results achieved using total verses Method 1312 may not be appropriate when determining if action is required.

Agency levels are conservative in nature, therefore background samples analyzed by Method 1312 for comparison to on-site soils analyzed using the same method should assure an appropriate comparison of analytical results. Thus, background soil samples will be collected from an undeveloped area southeast of the facility and analyzed using Method 1312.

Background soil samples will be collected from a portion of the facility unaffected by past operations. The background location is at the northeast corner of the facility, in an area previously used for agricultural purposes. Analytical results from investigative sampling will initially be compared to action levels. However, should analytical results from background samples be above the action levels, the NYSDEC will take these background sample results into account in establishing the need for further investigation within a specific area. The background samples procedures and locations are presented in Section 4.2.7.

In the case of organic constituents of concern, concentrations greater than the detection limit will be taken as an indication of subsurface contamination.

4.1 Standard Procedures to be Followed in Areas Requiring Soil Sampling

The following procedures will be followed for all soil test borings:

1. Soil test borings will be conducted utilizing split-spoon sampling techniques followed by hollow-stem auguring as described in the Standard Operating Procedures SOP: EXP-3 and EXP-5A, respectively (Appendix I). An acceptable alternative to the method above is hand drilling and sampling performed in accordance with Standard Operating Procedure SOP: EXP-3 (Appendix I). It is recommended that the latter Method be used in sampling areas inside plant buildings and in the PCB Capacitor Storage Area.

2. If present, concrete will be removed by coring through it, or using a jack hammer and blow torch, as required.

3. Soil test borings will be logged according to the Standard Operating Procedure SOP: EXP-4 (Appendix I).

4. Soil samples for metals analyses and for base neutral and acid-extractable organics analyses will be homogenized and placed in eight ounce glass jars as soon as they are logged. The samples will be stored in an ice-chest containing ice, prior to and during shipment to the laboratory for analysis.

5. Soil samples for volatile organics analyses will be placed immediately in 40 ml septum vials without homogenization. The samples will be stored in an ice-chest containing ice prior to and during shipment to the laboratory.

6. For soil samples which require head space analysis (see Section 4.2.7). The following procedures will be used. A portion of the split-spoon sample in the 40 ml septum vial, a second portion of the sample will be placed in a pint-size glass jar; aluminum foil will be placed on the mouth of the jar, then capped with the jar lid. The soil in the jar will be allowed to equilibrate in a warm area for 30 minutes (60° F minimum), the lid then will be removed and a head-space measurement will be taken by inserting the probe of the flame ionization detector through the aluminum foil, and collecting vapors immediately above the soil.

All soil sampling will be in accordance with the approved QAPjP and will be analyzed for the parameters presented in Table 2-1.

acceptable

If there are visible signs of contamination in the sampling area, which lead to a crack, the soil boring will be shifted to that location. The location of all borings will be verified in the field with a representative of the NYSDEC.

The test boring locations indicated in the following Section are preliminary and will require checking for buried power lines, pipes, utilities, tanks and other underground hazards, and final clearance by Philips personnel. The location of buried and overhead power lines will be scrutinized with particular care for the investigation in the PCB Capacitor Storage area.

4.2 Sampling Plans for Individual Areas

4.2.1 Interim Storage Area SO1D

Inventory controlled interim storage area SO1D (designated as SO1D in Figure 1) was used to store drums returned by outside vendors, and to store waste paint in drums. Two borings will be completed, from which four soil samples will be collected, and analyzed.

4.2.1.1 Soil Test Boring and Sample Locations

Test boring locations for area SO1D are indicated on Figure 2, and are designated SO1D-SB1 and SO1D-SB2.

For each test boring, the asphalt covering will be cored, and soil samples will be collected at depths of six and twelve inches below the base or subbase course of the asphalt.

acceptable

If there are visible signs of contamination in the sampling area, which lead to a crack, the soil boring will be shifted to that location. The location of all borings will be verified in the field with a representative of the NYSDEC.

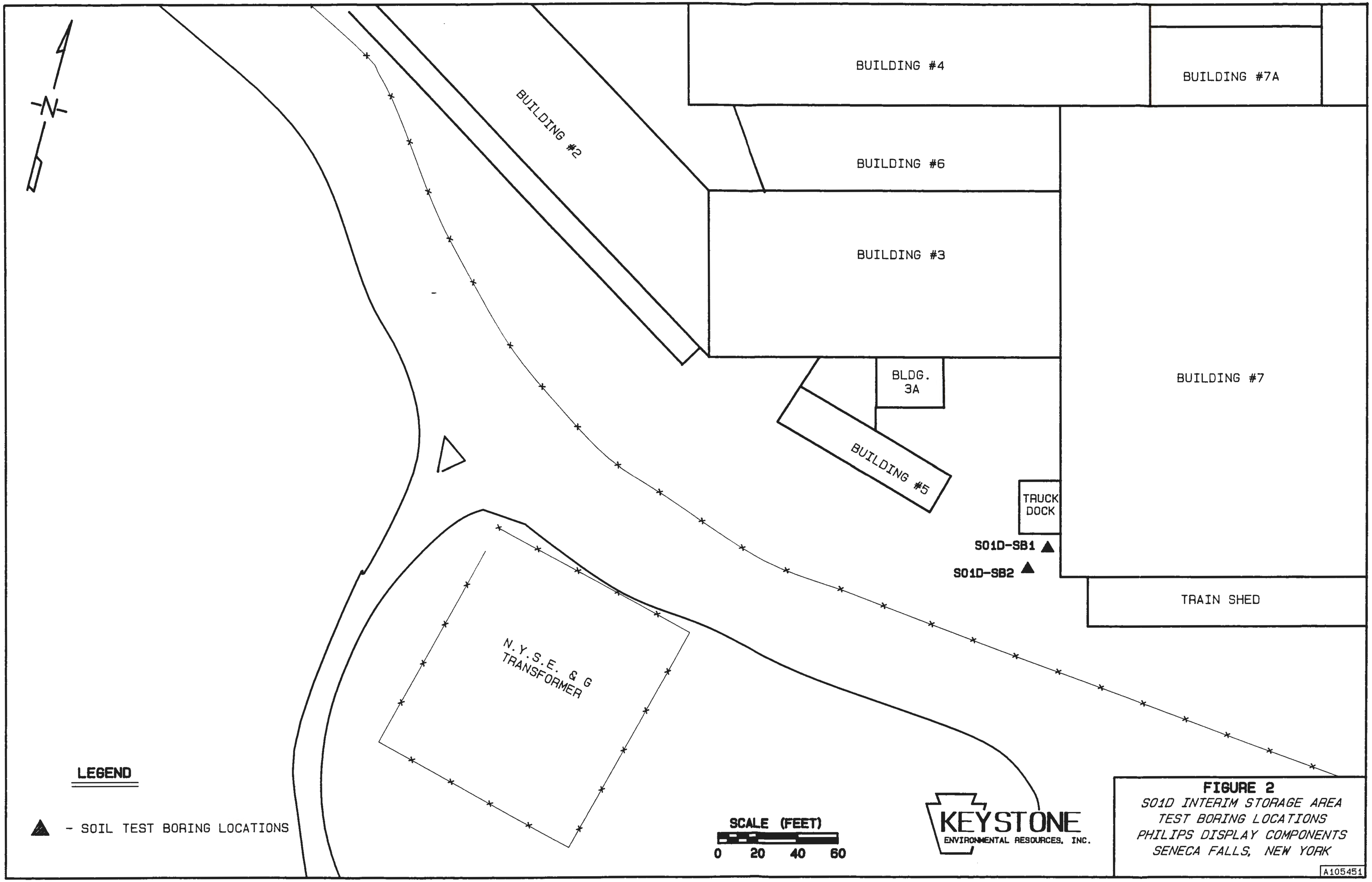

FIGURE 2
S01D INTERIM STORAGE AREA
TEST BORING LOCATIONS
PHILIPS DISPLAY COMPONENTS
SENECA FALLS, NEW YORK

4.2.1.2 Analytical Parameters

Samples will be analyzed for total chromium and lead; and for aromatic and halogenated volatile organics (using the methods presented in Table 2-1 of the QAPjP).

4.2.1.3 Decontamination Procedures

All sampling devices will be decontaminated between sampling events by sequentially following the ensuing procedure:

- scrub with water and nonphosphate detergent solution,
- rinse with distilled and analyte-free water,
- rinse with 10% nitric acid solution,
- rinse with distilled and analyte-free water,
- rinse with acetone, and
- finish with a distilled and analyte-free water rinse.

The drilling equipment will be steam-cleaned between test borings.

4.2.2 Satellite Storage Area - Loading/Unloading Dock South of Building #11

The loading/unloading dock south of Building #11 (designated as SS 12 in Figure 1) was used for temporary storage of drummed waste prior to off-site disposal. Cracks were noted in the concrete truck ramp leading to the loading dock. A Philips document to the U.S. EPA entitled "Information Regarding Potential Hazardous Waste and Hazardous Waste Constituent Releases from Solid Waste Management Units," dated April 24, 1985 includes information regarding historic spills in the loading/unloading dock area. The spilled substances were predominantly chlorinated solvents. Three test borings will be conducted to determine if there is contamination at the location of the previously reported spills.

4.2.2.1 Soil Test Boring and Sample Locations

Test boring locations in the loading/unloading dock are indicated on Figure 3, and are designated as SS12-SB1 through SS12-SB3. The test borings are sited at the locations of the previously reported spills discussed above.

For each test boring, the asphalt covering will be cored, and soil samples will be collected at depths of six and twelve inches below the base or subbase course of the concrete.

acceptable

If there are visible signs of contamination in the sampling area, which lead to a crack, the soil boring will be shifted to that location. The location of all borings will be verified in the field with a representative of the NYSDEC.

4.2.2.2 Analytical Parameters

Samples will be analyzed for total chromium and lead; and for aromatic and halogenated volatile organics (using the methods presented in Table 2-1 of the QAPjP).

4.2.2.3 Decontamination Procedures

All sampling devices will be decontaminated between sampling events by sequentially following the ensuing procedure:

- scrub with water and nonphosphate detergent solution,
- rinse with distilled and analyte-free water,
- rinse with 10% nitric acid solution,

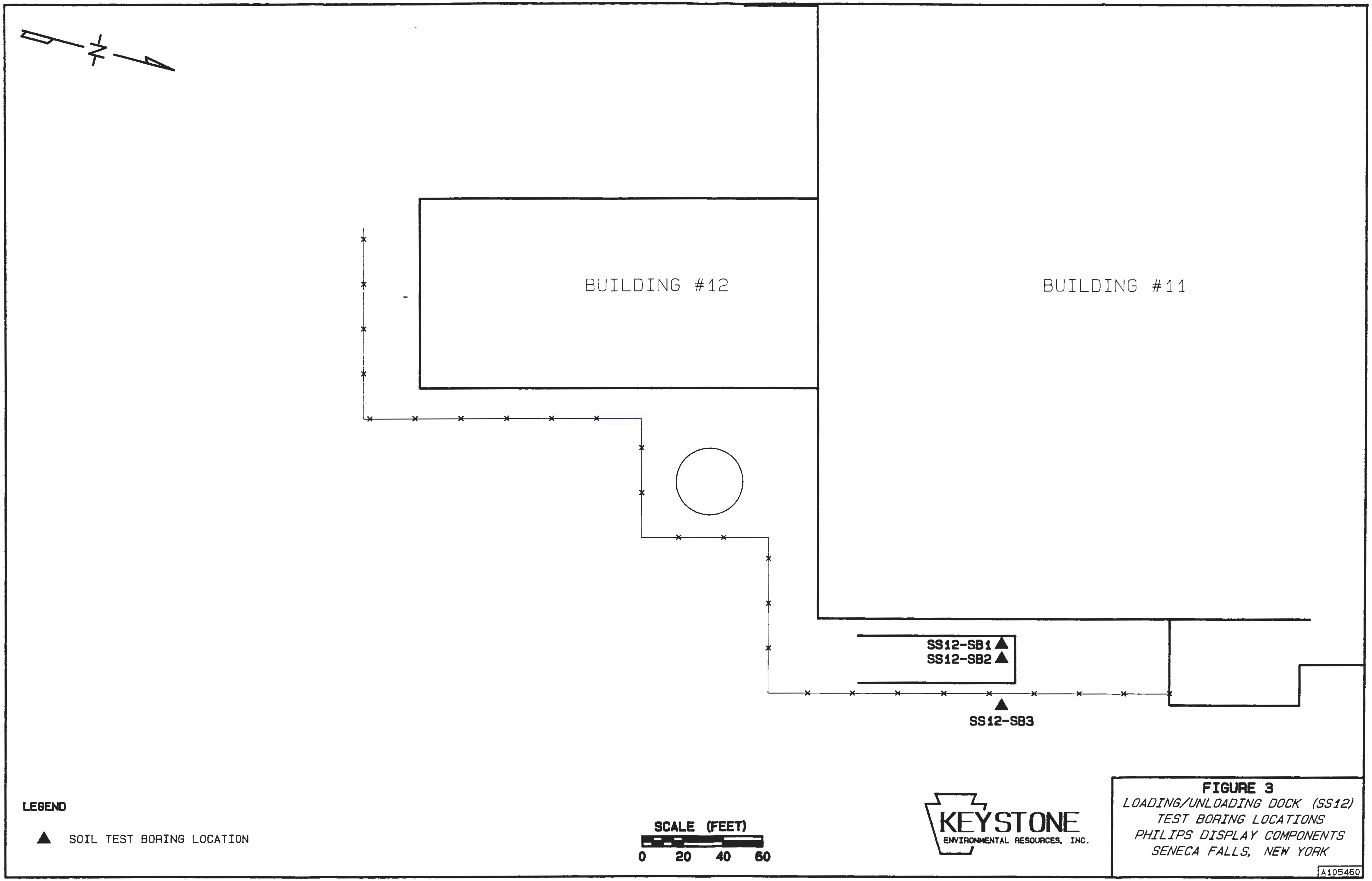

FIGURE 3
LOADING/UNLOADING DOCK (SS12)
TEST BORING LOCATIONS
PHILIPS DISPLAY COMPONENTS
SENECA FALLS, NEW YORK

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- rinse with distilled and analyte-free water,
- rinse with acetone, and
- finish with a distilled and analyte-free water rinse.

The drilling equipment will be steam-cleaned between test borings.

4.2.3 Underground Fuel Oil Tank

Oil soaked soils were previously observed during heavy truck loading and unloading in the area overlying a closed 12,000 gallon underground fuel oil tank located outside the southeastern corner of Building #10. Absorbent material was applied to all visible oil accumulations. The tank has been removed and surrounding soils have been excavated. To confirm that the removal of oil saturated soils was complete, three borings will be conducted, from which a total of six samples will be collected and analyzed for total hydrocarbons.

4.2.3.1 Soil Test Boring and Sample Locations

Test boring locations in the fuel oil tank area are indicated on Figure 4, and are designated as FOT-SB1, FOT-SB2 and FOT-SB3. The soil test borings are located near the corners of Building #10 and Building #11, such that they will be hydraulically downgradient of the location of the closed tank.

For each test boring, one soil sample will be collected six inches below ground surface; the other sample will be collected from in situ soil (assumed to be twelve feet below ground surface) below the bottom of the backfilled excavation. Selection of the "deep" soil sample will be made by field personnel and will be based on field observations.

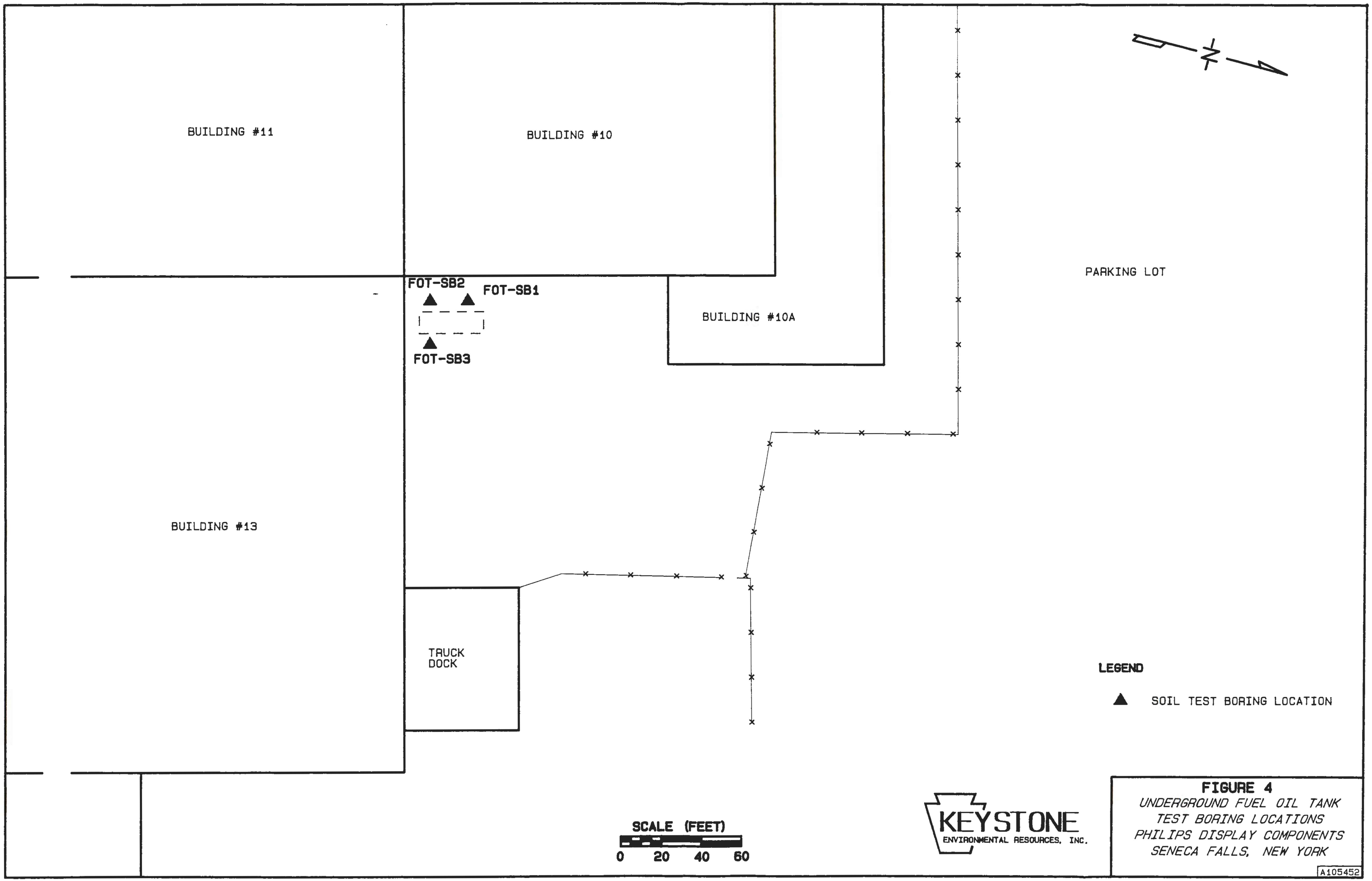

FIGURE 4
UNDERGROUND FUEL OIL TANK TEST BORING LOCATIONS PHILIPS DISPLAY COMPONENTS SENECA FALLS, NEW YORK

4.2.3.2 Analytical Parameters

Samples will be analyzed for BTEX and semi-volatile organics using the methods presented in Table 2-1 of the QAPjP.

4.2.3.3 Decontamination Procedures

All sampling devices will be decontaminated between sampling events by sequentially following the ensuing procedure:

- scrub with water and nonphosphate detergent solution,
- rinse with distilled and analyte-free water,
- rinse with acetone, and
- finish with a distilled and analyte-free water rinse.

The drilling equipment will be steam-cleaned between test borings.

4.2.4 Sumps and Drains Identified in the NYSDEC Site Visit

The NYSDEC determined that the following sumps, pits and floor drains may be sources for possible release of process waters into the ground:

- the floor drain in the southwest corner of Room 7A in Building 13
- the sump in Room 6A (Building 13)
- the waste collection pits in Room 4A (Building 13)
- the floor drains in the former degreaser area in Building 11 and the area under the TCE fill pipe outside Building 11
- the sumps and drains in the Lead Treatment Room (Building 7A)

- the trench and sump in Building 9A (adjacent to Building 9)

- the outside lift station - No. 1 sump

The outside lift station No. 1 sump will be static water leak tested in accordance with the procedures in the Sewer Evaluation Report.

A meeting was held on May 13, 1992 with the NYSDEC, Philips, GTE and Keystone. During the meeting, an agreement was reached that the present roof drains would be rerouted, that the walls of the water storage tanks inside building 9 and the filter house (southeast of building 9-A) would be sealed and that all process sewer floor drains would be sealed with cement. The proposed work would eliminate the potential infiltration/recharge of groundwater to the sediments beneath the plant building floor slabs.

The roof drains will be rerouted along the ceiling trusses, through the outside walls, and discharge to the storm water sewer system outside the building.

The walls and floors of the water storage tanks under the facility slabs will be visually inspected for cracks and then sealed to prevent leakage.

The floor drains inside the buildings will be flushed with potable water to remove sediments prior to initiating cementing operations. A flexible tremie pipe will then be placed in the sewers, and will be used to fill the floor drains to floor grade. After the cement has cured (24 hour time period) any observed settling will be filled.

At this point in time the areas beneath the floor slabs are considered an inaccessible SWMU. All potential for recharge to the materials beneath the plant buildings will be eliminated to the extent possible. Monitoring wells will be placed around the plant buildings and a regularly scheduled monitoring program will be instituted. In the event of future building demolition the NYSDEC will be notified and an investigation program will be developed in accordance with the QAPjP.

4.2.5 Other Areas - PCB Capacitor Storage Area

Between April 28, and May 5, 1980, twenty three PCB capacitors were removed from service in the Electrical Distribution Area (between Building #7 and Building #8). They were drummed with absorbant and oil contaminated clean-up materials. Disposal was coordinated via manifest through an approved secure landfill vendor. A small area of the transformer yard appeared to be discolored due to oil spillage. Four borings will be conducted, from which eight soil samples will be collected, to determine the distribution and concentration of potential contaminants of concern in this area.

4.2.5.1 Soil Test Boring and Sample Locations

Test boring locations in the PCB Capacitor Storage area are indicated on Figure 5, and are designated as PCS-SB1 through PCS-SB4. Two test borings will be conducted above soil staining, inside the fenced area, and two borings will be conducted downgradient of the storage yard, immediately outside of the fence.

For each test boring, one soil sample will be collected at ground surface, below crushed stone, and the other soil sample will be collected 12 inches below ground surface.

4.2.5.2 Analytical Parameters

Samples will be analyzed for PCB's using the methods presented in Table 2-1 of the QAPjP).

4.2.5.3 Decontamination Procedures

All sampling devices will be decontaminated between sampling events by sequentially following the ensuing procedure:

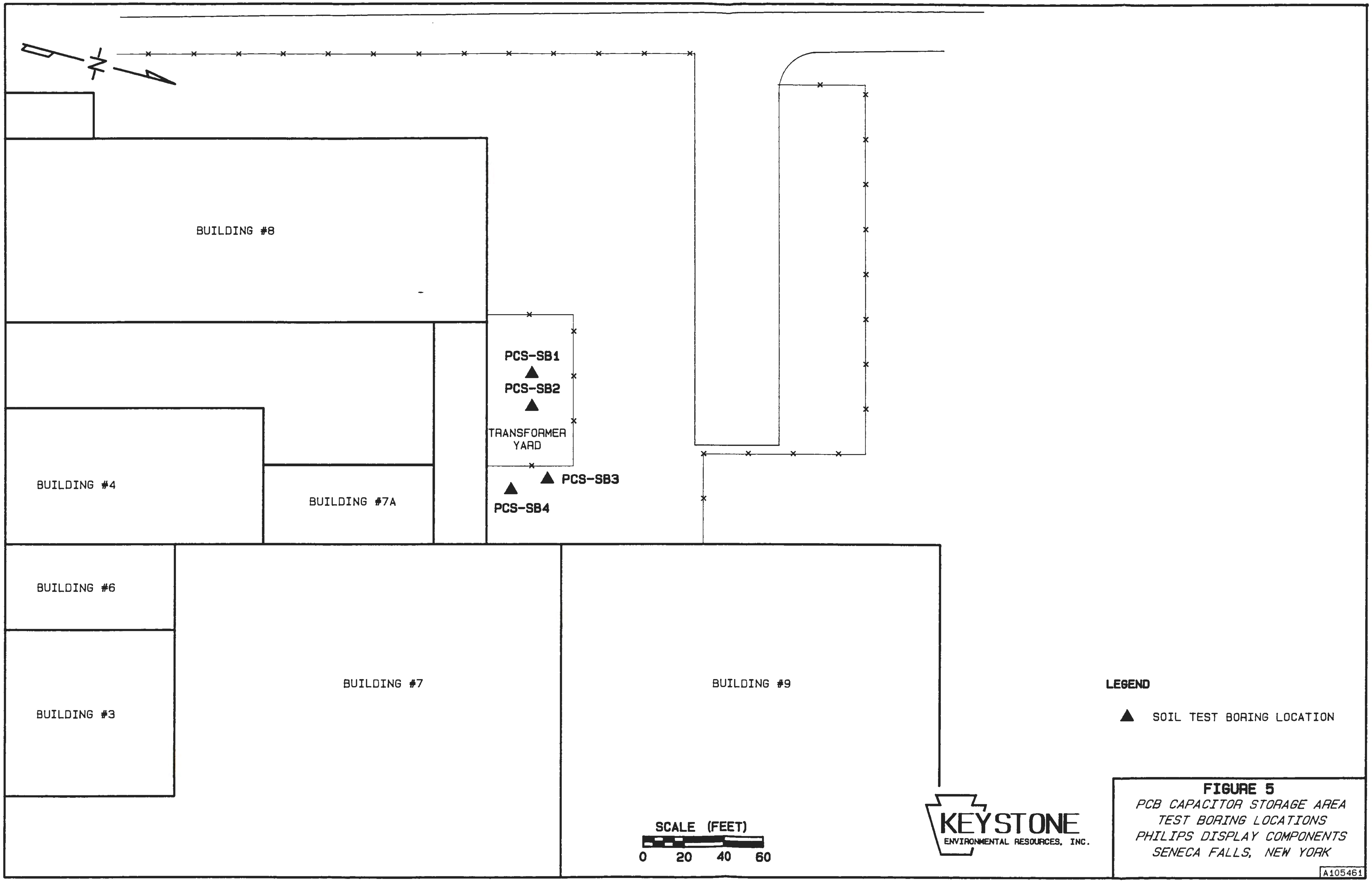

FIGURE 5
PCB CAPACITOR STORAGE AREA
TEST BORING LOCATIONS
PHILIPS DISPLAY COMPONENTS
SENECA FALLS, NEW YORK

- scrub with water and nonphosphate detergent solution,
- rinse with distilled and analyte-free water,
- rinse with acetone, and
- finish with a distilled and analyte-free water rinse.

The drilling equipment will be steam-cleaned between test borings.

4.2.6 Other Areas - Open Burning Area

Prior to the 1969 installation of the Aqueous Organic Incinerator, open burning of lacquer wastes was conducted in the area that was subsequently occupied by a 30,000 gallon liquid propane storage tank. The tank has subsequently been decommissioned and removed from the site. The area will be evaluated for possible soil contamination by conducting six soil test borings randomly located in a grid pattern designed to find the area.

4.2.6.1 Soil Test Boring and Sample Locations

The grid pattern that was used to locate the test borings in the Open Burning Area is shown in Figure 6. The grid spacing and number of test borings were selected such that the probability of detecting a 30 ft x 30 ft "hot spot" located anywhere within the area covered by the grid would be better than 50%. Six boring locations were chosen randomly from the available grid points by a lottery drawing method. The test borings are designated as OBA-SB1 through OBA-SB6 and are shown in Figure 6 along with the grid.

For each test boring, the initial 18-inch long soil samples will be collected at a depth of six inches below ground surface. The test boring will be sampled continuously to a depth of 6.5 feet below ground surface for a total of four samples per test boring. Head space measurements of all the samples will be performed with a calibrated flame ionization detector (See Section 4.1 for the headspace measurement procedure). Samples with headspace measurements 5 ppm, above background or

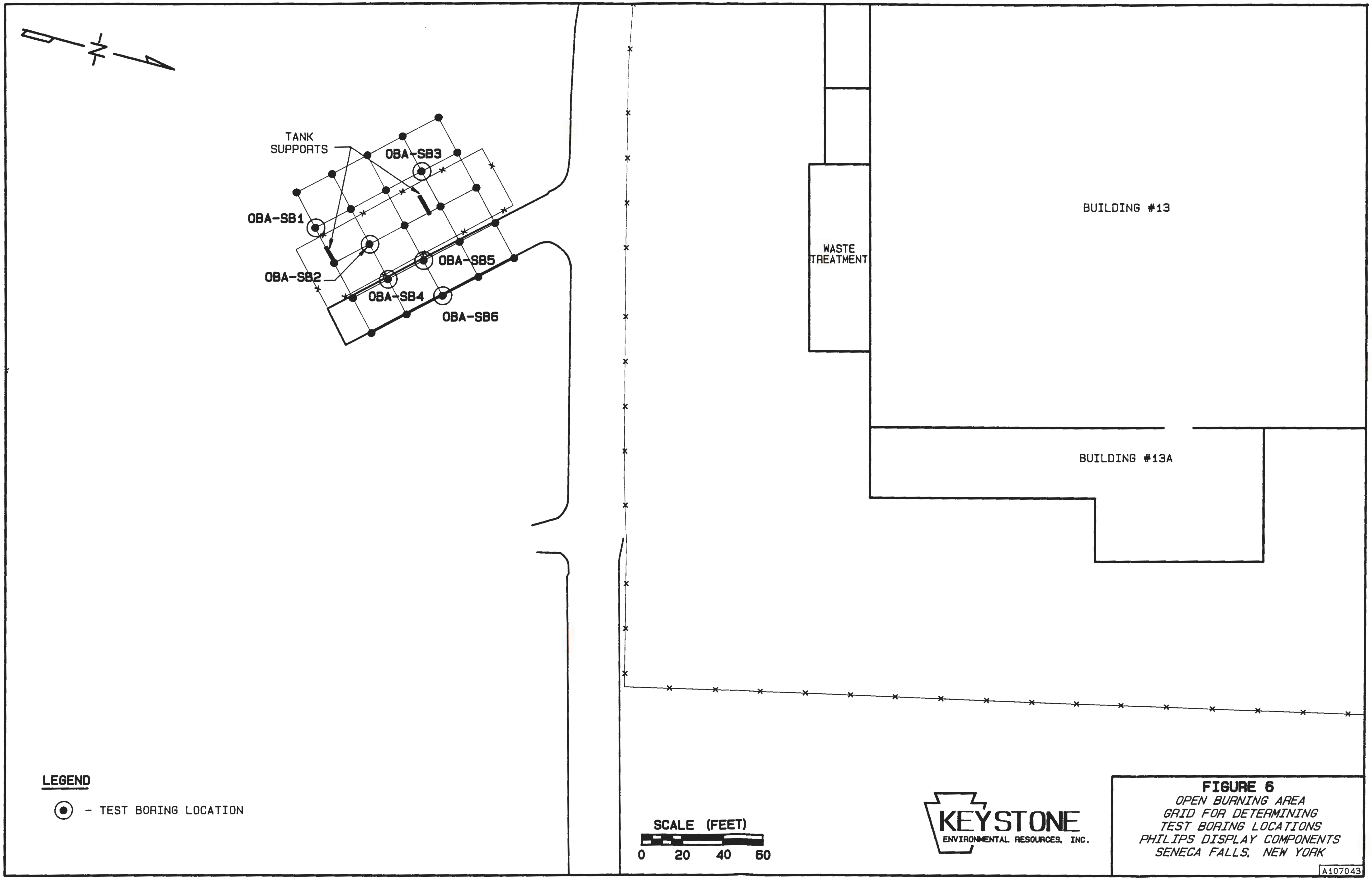

FIGURE 6
OPEN BURNING AREA
GRID FOR DETERMINING
TEST BORING LOCATIONS
PHILIPS DISPLAY COMPONENTS
SENECA FALLS, NEW YORK

more will be incorporated into the sampling set. At least one soil sample from each boring will undergo analysis at a laboratory. If no samples have a headspace reading above 5 ppm, the sample selected from each boring for analysis will be the one showing the highest reading. If nothing is detected during headspace measurement, the sample from the boring shall be chosen at random.

4.2.6.2 Analytical Parameters

Samples will be analyzed for aromatic and halogenated volatile organics using the methods presented in Table 2-1 of the QAPjP.

4.2.6.3 Decontamination Procedures

All sampling devices will be decontaminated between sampling events by sequentially following the ensuing procedure:

- scrub with water and nonphosphate detergent solution,
- rinse with distilled and analyte-free water,
- rinse with acetone, and
- finish with a distilled and analyte-free water rinse.

4.2.7 Other Areas - Background Sampling

Background soil samples will be collected in an area northeast of the facility. Based on interviews with previous plant personnel, and observations from a past site inspection, the area was previously used for agricultural purposes only, and has not been part of past plant operations.

4.2.7.1 Soil Borings and Sample Locations

Soil boring locations for the background sampling are shown on Figure 7, and are designated BS-SB1 and BS-SB2.

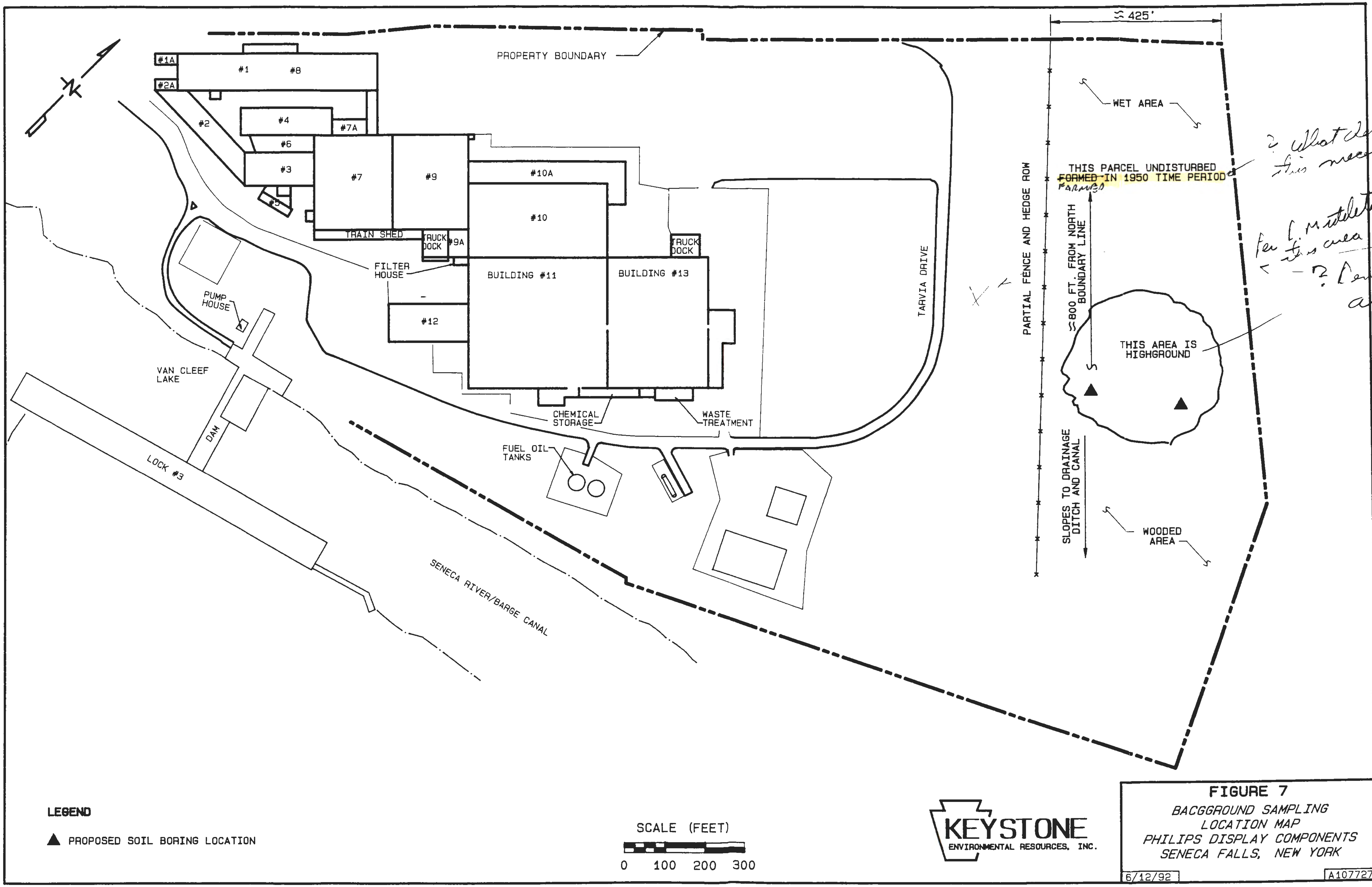

FIGURE 7

BACGGROUND SAMPLING LOCATION MAP
PHILIPS DISPLAY COMPONENTS
SENECA FALLS, NEW YORK

At each soil boring location, continuous soil samples will be collected using split barrel samplers through hollow stem augers to a depth of 16 feet. Split barrel samplers are typically 18 or 24 inches in length. Soil samples will be visually described, composited over the sampled interval placed in a clean quart jar and shipped to the laboratory for chemical analysis.

4.2.7.2 Analytical Parameters

Soil samples will be analyzed for fluoride, cadmium, chromium, lead, and zinc using Method 6010 and Draft Method 1312 as presented in the Table 2-1 of the QAPjP.

4.2.7.3 Decontamination Procedures

All sampling devices will be decontaminated between sampling events by sequentially following the ensuing procedure:

- scrub with water and nonphosphate detergent solution,
- rinse with distilled and analyte-free water,
- rinse with acetone, and
- finish with a distilled and analyte-free water rinse.

The drilling equipment will be steam-cleaned between test borings.

At each soil boring location, continuous soil samples will be collected using split barrel samplers through hollow stem augers to a depth of 16 feet. Split barrel samplers are typically 18 or 24 inches in length. Soil samples will be visually described, composited over the sampled interval placed in a clean quart jar and shipped to the laboratory for chemical analysis.

NOT NATURALLY OCCURING IN NYS

4.2.7.2 Analytical Parameters

Soil samples will be analyzed for fluoride, cadmium, chromium, lead, and zinc using the methods presented in the Table 2-1 of the QAPjP.

4.2.7.3 Decontamination Procedures

All sampling devices will be decontaminated between sampling events by sequentially following the ensuing procedure:

- scrub with water and nonphosphate detergent solution,
- rinse with distilled and analyte-free water,
- rinse with acetone, and
- finish with a distilled and analyte-free water rinse.

The drilling equipment will be steam-cleaned between test borings.

5.0 QUALITY ASSURANCE/QUALITY CONTROL

The QA/QC procedures developed for the Sampling Visit Work Plan are detailed in the Quality Assurance Project Plan (QAPjP) issued under separate cover.

6.0 RECORDS

A field logbook will be maintained to provide an accurate record of each sampling event. Photocopies of the field logbook will also be kept in the project files. A field logbook should document the following:

- Identification of sampling location
- Sample depth
- Sample withdrawal procedure/equipment
- Date and time of sample collection
- Quality assurance/control samples
- Names of field crew present at the site
- Name of collector
- Sample identification numbers
- Types of sample containers used and preservatives (if any)
- Field observations on sampling event
- Climatic conditions including air temperature
- Parameters requested for analysis
- Sample distribution and transporter
- Internal temperature of field and shipping (refrigerated) containers
- Photographic record of sampling locations

To properly account for all samples, each individual sample will be given a distinct and different sample identification number, which will consist in the test boring identification number to which a sequential two-digit number will be added (for example: OBA-SB3-02 would be the second sample obtained from test boring OBA-SB3). The sample number will be affixed to the sample container and documented on the field log and Chain of Custody Form.

A complete Chain of Custody Form will be maintained to document the possession of samples from the time the field sampling team is issued bottleware through analysis. A Sample Analysis Request Sheet and Chain of Custody Form will be placed and sealed in a large plastic bag to prevent water damage, and placed with the samples inside the cooler. The Chain of Custody Form will always be accompanied by a Sample Analysis Request Sheet.

Coolers containing samples must be sealed with a custody seal when not in the immediate possession of field personnel or secured in locked storage. Signed custody seals should be affixed to both ends of the cooler in such a manner that they must be removed or broken in order to open the cooler. This can be accomplished by affixing one custody seal to the front of the cooler, covering the space between the cooler's body and the lid. Another seal is affixed to the other side of the cooler, diagonally opposite the first seal. Fiberglass reinforced tape should then be wrapped around both ends of the cooler, slightly overlapping the custody seal. Tape should be wrapped sufficiently to afford secure closing, but not so that the seal cannot be read through the tape.

The Chain of Custody Form must be signed and dated by both the relinquisher and the receiver each time the samples change hands (as in turning samples over to the possession of the laboratory). The first entry should be signed by the sampler and subsequent entries must be signed by the person who signed the most recent "received by" entry. The original custody and analytical request forms will be kept in The Keystone Laboratory files.

The final step in the on-site activities will be to decontaminate and clean all field equipment before leaving the job site and to complete the Field Activities Check List. This is the responsibility of the Team Leader. The completed form is to be placed in the project files for future reference.

7.0 POST-SAMPLING ACTIVITIES AND REPORTING OF RESULTS

7.1 Post-Sampling Activities

The post-sampling activities center around submitting the samples to the lab for appropriate analyses and filing the necessary documentation of the sampling trip. In addition, sampling equipment and field meters must be properly cleaned, stored and any required maintenance and/or repairs performed.

Upon completing the field work, the Field Team Leader will:

1. Submit samples to the laboratory for analysis following the chain of custody procedures.

2. Provide the original of the field log and a copy for the project files.

3. File the Field Activities Check List.

4. Place copies of the chain of custody and sample analyses request records in the project files. When received from the laboratory, the originals of these forms will also be placed in the project files.

7.2 Reporting of Results

The report of results of the Sampling Visit will be presented to NYSDEC within 90 days of the receipt of final analytical results from the data validator. The report will include a summary of field activities and analytical results, and recommendations concerning areas requiring further investigation based on the results obtained.

APPENDIX I
STANDARD OPERATING PROCEDURES

KEYSTONE
ENVIRONMENTAL RESOURCES, INC.

STANDARD OPERATING PROCEDURE
SOP: EXP-3

KEYSTONE
ENVIRONMENTAL RESOURCES, INC.

SOP: EXP-3. SOIL AND ROCK BORINGS

1. SCOPE AND PURPOSE

1.1 The purpose of this guideline is to describe the methods, the sequence of operations and the equipment necessary to perform soil and rock borings.

1.2 This guideline addresses most of the accepted and standard drilling techniques, their benefits and drawbacks. It should be used generally to determine what type of drilling techniques would be most successful depending on site-specific geologic conditions and the type of samples required.

2. DEFINITIONS

Bedrock - The rock, usually solid but may be highly weathered and friable, that underlies soil, or other unconsolidated, surficial material.

Boulders - Rounded, semirounded or naturally angular particles of rock larger than 12 inches in size.

Clay - Fine grained soil or portions of soil having certain physical properties, composition and texture. Clay exhibits plastic properties within a range of water contents and exhibits considerable strength when air dried. Clay consists usually of fragments of hydrous aluminum or magnesium silicate minerals, and it consists predominantly of grains with diameters of less than 0.005 mm.

Cobbles - Rounded, semirounded or naturally angular particles of rock between 3 inches and 12 inches in size.

Gravel - Rounded or semirounded particles of rock that will pass a 3 in. sieve and be retained on a No. 4 US standard sieve (4.76 mm). Coarse gravel is larger than 3/4-inches, while fine gravel is finer than 3/4-inches.

Stone - Crushed or naturally angular particles of rock that will pass a 3 in. sieve and be retained on a No. 4 US standard sieve (4.76 mm).

Rock - Any consolidated or coherent and relatively hard, naturally formed mass of mineral matter.

Sand - Particles of rock that will pass a No. 4 US standard sieve (4.76 mm) and be retained on a No. 200 US standard sieve (0.074 mm). Coarse sand is larger than a No. 10 sieve (2.0 mm), medium sand is between the No. 40 and No. 10 sieves, and fine sand is finer than a No. 40 sieve (0.42 mm).

Silt - Material passing the No. 200 US standard sieve (0.074 mm) that is nonplastic or very slightly plastic and that exhibits little or no strength when air dried.

Soil - Sediments or other unconsolidated accumulations of solid particles that are produced by the physical and chemical disintegration of rock and that may contain organic matter.

Undisturbed Sample - A soil sample that has been obtained by methods in which every precaution has been taken to minimize disturbance to the sample. (See SOP: EXP-5B).

Water Table - A surface in an aquifer where ground water pressure is equal to atmospheric pressure.

3. RESPONSIBILITIES

Project Manager - In consultation with the Project Geologist, the Project Manager shall be responsible for evaluating the drilling requirements for the site and specifying drilling techniques that will be successful given the study objectives and geologic conditions at the site. He should also determine the disposal methods for products generated by drilling, such as drill cuttings and well development water, as well as any specialized supplies or logistical support required for the drilling operations. The Project Manager is responsible for overall supervision and scheduling of drilling activities.

Site Geologist/Rig Geologist - Responsible for insuring that standard and approved drilling procedures are followed. The Site Geologist will generate a detailed boring log for each test hole. This log shall include a description of materials, samples, method of sampling, blow counts, down pressure and other pertinent drilling and testing information that may be obtained during drilling (See SOP:EXP-4). Often this position for inspecting the drilling operations may be filled by other geotechnical personnel, such as soils and foundation engineers, civil engineers, etc. having appropriate training.

The general area in which the borings are to be located will be shown on a site map included in the project specific work plan. The boring locations shown or implied in the work plan are approximate. Determination of the exact location for borings is the responsibility of the Site Geologist. The final location for drilling must be properly documented on the boring log.

Drilling Subcontractors - Responsible for obtaining all drilling permits and clearances, and supplying all services (including labor), equipment and material required to perform the drilling, testing, and well installation program, as well as maintenance and quality control of such required equipment.

The driller must report any major technical or analytical problems encountered in the field to the Site Geologist or Project Manager within 24 hours, and must provide advance written notification for any changes in field procedures describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the Project Manager.

The Drilling Subcontractor will be responsible for following decontamination procedures specified in the Decontamination SOP:Decon-1. Upon completion of the work, the Drilling Subcontractor will be responsible for demobilizing all equipment, cleaning up specified materials deposited on site during drilling operations, and properly backfilling or abandoning any open borings.

4. GENERAL APPLICATION

4.1 The purpose of drilling test holes is:

- To determine the type, thickness, and certain physical properties of the soil and rock strata which underlie the site, and/or

- To accommodate monitoring wells.

4.2 The drilling rig, including all attachments, will be steam cleaned prior to the commencement of each boring. All drilling and sampling equipment will be cleaned using appropriate decontamination procedures between borings and samples respectively. Unless otherwise specified, it is generally advisable to drill borings at "clean" locations first, and at the most contaminated locations last, to reduce the risk of spreading contamination between locations. All borings must be logged by the rig geologist unless the project work plan specifically states that logging is not required. Situations where logging would not be required would include installation of multiple well points within a small area, or a "second attempt" boring adjacent to a boring that could not be continued through resistant material. In the latter case, the boring log can be resumed 5 feet above the depth at which the initial boring was abandoned, although the rig geologist should still confirm that the stratigraphy at the redrilled location conforms essentially with that encountered at the original location. If significant differences are seen, each hole should be logged separately.

5. DRILLING METHODS

The methods described below apply to drilling in subsurface materials, including but not limited to, sand, gravel, clay, silt, cobbles, boulders, rock and man-made fill. Drilling methods should be selected after studying the site geology and terrain, purpose of drilling, waste conditions at the site, and the overall subsurface investigation program proposed for the site. The full range of different drilling methods applicable to the proposed program should be identified with final selection based on relative cost, availability, time - constraints, and how well each method meets the sampling and testing requirements of the individual drilling program.

5.1 Continuous-Flight Hollow-Stem Auger Drilling

This method of drilling consists of screwing augers with a hollow stem into the ground. Cuttings are brought to the surface by the rotating action of the auger. This method is relatively quick and inexpensive. Additional advantages of this type of drilling include:

- Samples can be obtained without pulling the augers out of the hole by collecting samples from the auger flight returns. However, this is a poor method for obtaining samples from thin, discrete formations because of mixing of soils which occurs as the material is brought to the surface. Sampling of such formations will require the use of split-barrel (split-spoon) or thin-wall (Shelby) tube samplers advanced through the hollow core of the auger.

- No drilling fluids are required.

- A well can be installed inside the auger stem and backfilled as the augers are withdrawn.

Disadvantages and limitations of this method of drilling include:

- Augering can only be done in unconsolidated materials.

- The inside diameter of hollow stem augers used for well installation should be at least four inches greater than the well casing. Use of such large diameter hollow stem augers is more expensive than the use of smaller diameter augers in boreholes not used for well installation. Furthermore, the density of unconsolidated materials and depths becomes more of a limiting factor. More friction is produced with the larger diameter auger and subsequently greater torque is needed to advance the boring.

- The maximum effective depth for drilling is 150 feet or less, depending on site conditions, the size of augers used, and size of the drill rig.

- In augering through clean sand formations below the water table, the sand will tend to flow into the hollow stem when the plug is removed for soil sampling or well installation. This will require either drilling while maintaining a positive head of water inside the auger (to retard sand inflow) and/or washing out any sand inflow prior to proceeding with sampling or well installation.

The procedures for performing hollow stem auger soil investigation shall conform with the applicable ASTM

Standards: D1452-80 and D1586-84. The hollow stem auger may be advanced by any power operated drilling machine having sufficient torque and ram range to rotate and force the auger to the desired depth. The machine must, however, be equipped with the accessory equipment needed to perform required sampling.

When taking soil samples for chemical analysis, the hollow-stem auger shall be plugged until the desired sampling depth is reached. Samples can be taken using split-spoon or Shelby tube samplers pressed into the formation in advance of the auger. If the sample is to be taken at a relatively deep point, the auger may be advanced without a plug to within five feet of the sample depth. Then clean out the auger stem, insert a plug and continue to the sampling depth. The plug is then removed and samples taken as specified by the rig geologist. Samples should be taken according to the specifications of the sampling plan. Any required sampling shall be performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. The sequence shall be repeated for each sample desired.

The hollow stem auger may be used without the plug, when boring for geotechnical examination, for well installation, or when operating below the water table or in other water containing formations. In such cases the hollow stem auger shall be advanced to the desired sampling depth and the hole shall be cleaned out in the same manner prescribed for casing cleanout (see Section 7.0 of this guideline). Sampling will be performed as in any cased hole.

When drilling below the water table, it may be necessary to keep the hollow stem auger full of water, at least to the level of the water table, to prevent blowback and plugging of the auger. If water is added to the hole, it may be required to be sampled and analyzed to determine if it is free from contaminants prior to use. Alternately, specially designed plugs which allow passage of formation water but not solid material may be used (see Reference 1 of this guideline). This method also prevents blowback and plugging of the auger when the plug is removed for sampling. If gravelly or hard material is encountered which prevents advancing the auger, augering should be halted and either driven casing or hydraulic rotary methods should be attempted. If refusal of drilling is encountered, a five foot core run should be conducted to confirm bedrock (See Section 5.9 of this guideline).

At the option of the Project Manager and Site Geologist, when resistant materials prevent the advancement of the auger, a new boring can be attempted. The original boring must be properly backfilled and abandoned, and the new boring started a short distance away at a location determined by the site geologist. If multiple water bearing strata were encountered, the original boring must be grouted closed. In some formations it may be prudent to also grout borings which only penetrate the water table aquifer, since loose backfill in the boring would still provide a preferred pathway for surface liquids to reach the water table.

5.2 Continuous-Flight Solid-Stem Auger Drilling

This method operates in a similar manner as hollow-stem augers. Practical application of this method is severely restricted as compared with hollow stem augers. Split barrel (split-spoon) sampling cannot be done without pulling the augers which may allow the hole to collapse. The method is therefore very time consuming and is not cost effective. Also, augers would have to be withdrawn before installing a monitoring well, which again, may allow the hole to collapse. Furthermore, geologic logging by examining the soils brought to the surface is unreliable as in the case of the hollow stem auger, and depth to water may be difficult to determine while drilling.

There would be very few situations where use of a solid stem auger would be preferable to other drilling methods. The only practical applications of this method would be to drill boreholes for well installation where no lithologic information is desired and the soils are such that the borehole can be expected to remain open after the augers are withdrawn. Alternatively, the technique can be used to find depth to bedrock in an area when no other information is required from drilling.

5.3 Hydraulic Rotary Drilling

Hydraulic drilling includes air-rotary and fluid-rotary drilling.

5.3.1 Air-Rotary Drilling

Air-rotary drilling is a method of drilling where the borehole is advanced by rapid rotation of the drilling bit, which cuts, chips, and grinds the material at the bottom of the hole into small particles. The bit is cooled and the cuttings are removed by pumping air from a compressor down through the drill rods and bit and up the annulus between the borehole wall and the drill rods. Air rotary rigs are available throughout much of the United States and are well suited for many drilling applications. A variation of the air rotary method is the air hammer method, which uses a pneumatic or percussion hammer that pulverizes rock and uses air to return cuttings to the surface.

Air rotary rigs operate best in hard rock formations. Formation water is blown out of the hole along with the cuttings, so it is possible to determine when the first water-bearing zone is encountered. After filtering water blown from the hole, collection and field analysis may provide preliminary information regarding changes in water quality for some parameters. Where significant water inflow is encountered, foaming agents may be added to enhance the ability of the air stream to remove cuttings from the wellbore. Formation sampling ranges from excellent in hard, dry formations to nonexistent when circulation is lost in cavernous limestones and other formations with cavities.

Casing is required to keep the borehole open when drilling in soft, caving formations below the water table. When more than one water-bearing zone is encountered and where the hydrostatic pressures are different, flow between zones will occur between the time the drilling is done and the time the hole can be properly cased and one zone grouted off. Multiple casing strings can be used to rectify this problem, if necessary. Synthetic drilling aids are not usually used in air rotary drilling. If the air is filtered to capture compressor lubricants, contamination can be minimized more effectively than with other methods. In badly contaminated subsurface situations, air rotary drilling must be used carefully to minimize the exposure of drilling personnel to potentially hazardous materials.

Air rotary methods are conductive to drilling in hard rock and other consolidated formations where a mud or water lining is unnecessary to support the walls against caving. An important advantage of using the air rotary method is that contamination of the water zone is not a factor since no drilling fluid is used.

5.3.2 Fluid-rotary Drilling

Fluid-rotary drilling operates in a similar manner to air rotary drilling except that a drilling fluid ("mud") or clean water is used in place of air. In this case, the bit is cooled and the cuttings are removed by pumping water or drilling fluid from a sump down through the drill rods and bit and up the annulus between the borehole wall and the drill rods. The water or "mud" flows first into a settling pit and ultimately back to the main pit for recirculation. Water alone may be used when the depth is small and the soil is stable. Drilling mud is sometimes preferred, since the required flow is smaller and the mud serves to stabilize the hole; however, the mud may clog permeable soil units. A sample should be collected of any material introduced into the well (water, drilling mud, additives, etc.). The sample should be retained for future analysis if any question of contamination arises. A section of casing is used to start the hole, but the remaining part of exploratory boreholes advanced by rotary drilling is usually uncased except in soft soils.

When rotary drilling is used for exploratory borings, items such as motors, rotary driving mechanisms, winches, and pumps, are generally assembled as a unit, with a folding mast mounted on a truck or tractor. The unit also may be mounted on intermediate skids so that it can be placed on a raft or moved into places inaccessible to motor vehicles. Skid mounted drilling machines can also be used for rotary drilling.

Many types of rotary drilling bits are used, depending on the character of the material to be penetrated. Fishtail bits and two-bladed bits are used in relatively soft soils and three-to-four-bladed bits in firmer soils and soft rock. The cutting edges are surfaced with tungsten carbide alloys or are formed by special hard metal inserts. The bits used in rock have several rollers with hard-surfaced teeth. The two-cone bits are used in soft or broken formations, but the tri-cone and roller bits provide smoother operation and are more efficient in harder rocks. The number of rollers and the number and shape of the teeth are varied in accordance with the character of the rock. Relatively few and large teeth are used in soft rock, and the teeth are interfitting so that the bit will be self-cleaning. The teeth in all bits are flushed by drilling fluid flowing out of vents in the base of the bit.

Boreholes produced by rotary drilling may be cased to provide stability. The drill rod and bit can be removed from the borehole, and a sampler can be lowered through the casing to remove soil from the bottom of the boring.

Uncased boreholes are often filled with water to stabilize the hole and to remove material ground up by the boring tools. Water will exert a stabilizing effect on the parts of the hole that extend below groundwater level; however, above the water table, the water may result in a loss of soil strength and a collapse of the hole. Water alone generally prevents neither caving of borings in soft or cohesionless soils nor a gradual squeezing-in of a borehole in plastic soils. Uncased boreholes filled with the water are generally used in rock and are often used in stiff, cohesive soils.

An uncased borehole can be stabilized by filling it with a properly proportioned drilling fluid or "mud," which, when circulated, also serves to remove ground-up material from the bottom of the hole. A satisfactory drilling fluid can occasionally be obtained by mixing locally available fat clays with water, but is is usually advantageous and often necessary to add commercially prepared drilling mud additives. When suitable native clays are not available, the drilling fluid is prepared with commercial products alone. These mud-forming products consist of highly colloidal, gel-forming, thixotropic clays - primarily bentonite - with various chemicals added to control dispersion, thixotropy, viscosity, and gel strength. A sample of the drilling fluid should be analyzed to eliminate the possibility of introducing contamination into the borehole.

The stabilizing effect of the drilling fluid is caused in part by its higher specific gravity (in comparison with water alone) and in part by the formation of a relatively impervious lining or "mudcake" on the side walls of the borehole. This lining prevents sloughing of cohesionless soils and decreases the rate of swelling of cohesive materials. The drilling fluid also facilitates removal of cuttings from the hole. The required velocities and volume of circulation are smaller than for water alone, and the problem of uncontrolled erosion at the bottom of the hole is decreased. Furthermore, the drilling fluid is thixotrophic; that is, it stiffens and forms a gel when agitation is stopped, and it can be liquified again by resuming the agitation. Drilling mud is, therefore, better able than water to keep the cuttings in suspension during the time required for withdrawal and reinsertion of boring and sampling tools. It also reduces abrasion and retards corrosion of these tools.

There are a variety of fluids that can be used with this drilling method. If a drilling fluid other than water/cuttings is used, a "background" sample of the fluid should be taken for analysis of possible organic or inorganic contaminants.

The use of synthetic slurries must be avoided at any location where chemical samples are to be collected, since they contain synthetic organic compounds. However, there is also widespread concern that bentonite muds may absorb volatile organics and other potential contaminants from the groundwater. Extensive well development may therefore be required to remove this mud. One method of avoiding these concerns is to drill, with mud, to a depth of approximately 10 feet above the required groundwater sampling depth, followed by hollow stem auger drilling down to the desired depth before well placement. In this manner, a groundwater sample unaffected by the drilling fluid can be obtained.

Some synthetic drilling fluids which are designed to dissipate in the boring in several days (e.g., "REVERT") have been reported to foster the growth of bacteria in the borehole, and thus should be avoided in drilling borings where subsurface microbial and chemical data is to be collected.

Advantages to this drilling method include:

- The ability to drill in many types of formations.
- Relatively quick and inexpensive.
- Split barrel (split-spoon) or Shelby tube samples can be obtained without removing drill rods.
- In some borings casing may not be needed as the drilling fluids may keep the borehole open.
- Drill rigs are readily available in most areas.

Disadvantages to this method include:

- Formation logging is unreliable if split barrel (split-spoon) samples are not taken (i.e., the depths of materials logged from cuttings delivered to the surface are approximate).

- Drilling fluids reduce permeability of the formation adjacent to the boring to some degree, and require more extensive well development than "dry" techniques (augering, air-rotary).

- No information on depth to water is obtainable while drilling.

- Fluids are needed for drilling, and there is some question about the effects of the drilling fluids on water samples obtained. For this reason as well, extensive well development may be required.

- In very porous materials (i.e., rubble fill, boulders, coarse gravel) drilling fluids will be continuously lost into the formation. This will require either constant replenishment of the drilling fluid, or the use of casing through this formation.

- Drill rigs are large and heavy, and must be supported with supplied water.

The procedures for performing hydraulic rotary soil investigations and sampling shall conform with the applicable ASTM standards: D2113-83, D1587-83,and D1586-84.

For air or fluid-rotary drilling, the rotary drill may be advanced to the desired depth by any power operated drilling machine having sufficient torque and ram range to rotate and force the bit to the desired depth. The drilling machine must, however, be equipped with any accessory equipment needed to perform required sampling, or coring. Prior to sampling, any settled drill cuttings in the borehole must be removed.

Soil samples shall be taken as specified by the Field Sampling and Analysis Plan, or more frequently, if requested, by the rig geologist. Any required sampling shall be performed by rotation, pressing, or driving in accordance with the standard or approved governing use of the particular sampling tool.

5.4 Reverse Circulation Rotary Drilling

The common reverse circulation rig is a water or mud rotary rig with a large diameter drill pipe which circulates the drilling water down the annulus and up the inside of the drill pipe (reverse flow direction from direct mud rotary). This type of rig is used for the construction of large capacity production water wells and is not suited for small, water quality sampling wells because of the use of drilling muds and the large diameter hole which is created. A few special reverse circulation rotary rigs are made with double-wall drill pipe. The drilling water or air is circulated down the annulus between the drill pipes and up inside the inner pipe.

Advantages of the latter method include:

- o The formation water is not contaminated by the drilling water.
- o Formation samples can be obtained, from known depths.
- o When drilling with air, immediate information is available regarding the water bearing properties of formations penetrated.
- o Collapsing of the hole in unconsolidated formations is not as great a problem as when drilling with the normal air rotary rig.

Disadvantages include:

- o Double-wall, reverse circulation drill rigs are very rare and expensive to operate.

- Placing cement grout around the outside of the well casing above a well screen often is difficult, especially when the screen and casing are placed down through the inner drill pipe before the drill pipe is pulled out.

5.5 Drilling by the Driven-Casing Method

The driven-casing method consists of alternately driving casing (fitted with a sharp, hardened casing shoe) into the ground using a hammer lifted and dropped by the drill rig and cleaning out the casing using a rotary chopping bit and air or water to flush out the materials. The casing is driven down in stages (usually 5 feet per stage). A continuous record is kept of the blows per foot in driving the casing. The casing is normally advanced by a three hundred (300) pound hammer falling freely through a height of thirty (30) inches. Simultaneous washing and driving of the casing is not recommended. If this procedure is used, the elevations between which water is used in driving the casing should be recorded.

The driven casing method is used in unconsolidated formations only. When the boring is to be used later for well installation, the driven casing used should be at least four inches larger in diameter than the well casing to be installed. Advantages to this method of drilling include:

- Split barrel (split spoon) sampling can be conducted while drilling.
- Well installation is easily accomplished.
- Drill rigs used are relatively small and mobile.
- The use of casing minimizes flow into the hole from upper water bearing layers; therefore multiple aquifers can be penetrated and sampled for rough field determinations of some water quality parameters.

- The method is useful in formations which are unstable and prone to collapse, such as coarse gravels.

Some of the disadvantages include:

- This method can only be used in unconsolidated formations.
- The method is slower than other methods (average drilling progress is 30 to 50 feet per day).
- Maximum depth of the borehole varies with the size of the drill rig and casing diameter used, and the nature of the formations drilled.
- The cost per hour or per foot of drilling may be substantially higher than other drilling methods.
- It is difficult and time consuming to pull back the casing if it has been driven very deep (deeper than 50 feet in many formations).

5.6 Cable Tool Drilling

A cable tool rig uses a heavy, solid-steel, chisel-type drill bit ("tool") suspended on a steel cable, which when raised and dropped chisels or pounds a hole through the soils and rock. Drilling progress may be expedited by the use of "slip-jars" which serve as a cable-activated down hole percussion device to hammer the bit ahead.

When drilling through the unsaturated zone, some water must be added to the hole. The cuttings are suspended in the water and then bailed out periodically. When below the water table, after sufficient groundwater is entering the borehole to replace the water removed by bailing, no further water may be added.

When soft caving formations are encountered, it is necessary to drive casing as the hole is advanced to prevent collapse of the hole. Often the drilling can be only a few feet below the bottom of the casing. Because the drill bit is lowered through the casing, the hole created by the bit is smaller than the casing. Therefore, the casing (with a sharp, hardened casing shoe on the bottom) must be driven into the hole (see Section 5.5 of this guideline).

Advantages of the cable-tool method include the following:

- Information regarding water-bearing zones is readily available during the drilling. Even relative permeabilities and rough water quality data from different zones penetrated can be obtained by skilled operators.

- The cable-tool rig can operate satisfactorily in all formations, but is best suited for caving, boulder, cable or coarse gravel type formations (e.g., glacial till) or formations with large cavities above the water table (such as limestones).

- When casing is used, the casing seals formation water out of the hole, preventing down-hole contamination and allowing sampling of deeper aquifers for field-measurable water quality parameters.

- Split barrel (split spoon) or Shelby tube samples can be collected through the casing.

Disadvantages include:

- Drilling is slow compared with rotary rigs.

- The necessity of driving the casing in unconsolidated formations requires that the casing be pulled back if exposure of selected water-bearing zones is desired. This process complicates the well completion process and often increases costs. There is also a chance that the casing may become stuck in the hole.

- The relatively large diameters required (minimum of 4-inch casing) plus the cost of steel casing result in higher costs compared to rotary drilling methods where casing is not required, such as use of a hollow stem auger.

- Cable-tool rigs have largely been replaced by rotary rigs. In some parts of the U.S., availability may be difficult.

5.7 Jet Drilling (Washing)

Jet drilling consists of pumping water or drilling mud down through a small diameter (1/2 to 2-inch) standard pipe (steel or PVC). The pipe may be fitted with a chisel bit or a special jetting screen. Formation materials dislodged by the bit and jetting action of the water are brought to the surface through the annulus around the pipe. As the pipe is jetted deeper, additional lengths of pipe may be added at the surface.

Jet percussion is a variation of the jetting method, in which the casing is driven with a drive weight. Normally, this method is used to place 2-inch diameter casing in shallow, unconsolidated sand formations but has been used to install 3 to 4-inch diameter casings to 200 feet.

Jetting is acceptable in very soft formations, usually for shallow sampling, and when introduction of drilling water to the formation is acceptable. Such conditions would occur during rough stratigraphic investigation or installation of piezometers for water level measurement.

Advantages of this method include:

- Jetting is fast and inexpensive.

- Because of the small amount of equipment required, jetting can be accomplished in locations where access by a normal drilling rig would be very difficult. For example, it would be possible to jet down a well point in the center of a lagoon at a fraction of the cost of using a drill rig.

- Jetting numerous well points just into a shallow water table is an inexpensive method for determining the water table contours, hence flow direction.

Disadvantages include the following:

- A large amount of foreign water or drilling mud is introduced above and into the formation to be sampled.

- Jetting is usually done in very soft formations which are subject to caving. Because of this caving, it is often not possible to place a grout seal above the screen to assure that water in the well is only from the screened interval.

- The diameter of the casing is usually limited to two inches; therefore, samples must be obtained by methods applicable to small diameter casings.

- Jetting is only possible in very soft formations that do not contain boulders or coarse gravel, and the depth limitation is shallow (about 30 feet without jet percussion equipment).

- Large quantities of water are often needed.

5.8 Drilling with a Hand Auger

This method is applicable wherever the formation, total depth of sampling, and the site and groundwater conditions are such as to allow hand auger drilling. Hand augering can also be considered at locations where drill rig access is not possible. All hand auger borings will be performed according to ASTM D1452-80.

Samples should be taken continuously unless otherwise specified by the Site Specific Sampling Protocol. Any required sampling is performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. Typical equipment used for sampling and advancing shallow "hand auger" holes are Iwan samplers (which are rotated) or post hole diggers (which are operated like tongs). This technique is slow but effective where larger pieces of equipment do not have access and where very shallow holes are desired (less than 5 feet). Surficial soils must be composed of relatively soft and non-cemented formations to allow penetration by the auger.

5.9 Rock Drilling and Coring

When soil borings cannot be continued using augers or rotary methods due to the hardness of the soil, or when rock or large boulders are encountered, drilling and sampling can be performed using a diamond bit corer in accordance with ASTM D2113. These procedures are addressed in a separate protocol, SOP:EXP-6, Rock Core Drilling, Coring and Rock Core Handling.

5.10 Drilling & Support Vehicles

In addition to the drilling method required to accomplish the objectives of the field program, the type of vehicle carrying the drill rig and/or support equipment, and its suitability for the site terrain, will often be an additional deciding factor in planning the drilling program. The types of vehicles available are extensive, and depend upon the particular drilling subcontractor's fleet. Most large drilling subcontractors will have a wide variety of vehicle and drill types suited for most drilling assignments in their particular region, while smaller drilling subcontractors will usually have a fleet of much more limited diversity. The weight, size, and means of locomotion (tires, tracks, etc.) of the drill rig must be selected to be compatible with the site terrain, to assure adequate mobility between borehole locations. Such considerations also apply to necessary support vehicles used to transport water and/or drilling materials to the drill rigs at the borehole locations. When the drill rigs or support vehicles do not have adequate mobility to easily traverse the site, provisions must be made for assisting equipment such as bulldozers, winches, timber planking, etc., to maintain adequate progress during the drilling program.

5.11 Equipment Sizes

In planning subsurface exploration programs, care must be taken in specifying the various drilling components, so they will fit properly in the boring or well.

For drilling open boreholes using rotary drilling equipment, tri-cone drill bits are employed with air, water or drilling mud to remove cuttings and cool the bit. Tri-cone bits are slightly smaller than the holes they drill (i.e., 5 7/8" or 7 7/8" bits will nominally drill 6" and 8" holes, respectively.

For obtaining split-barrel samples of a formation, samplers are manufactured in sizes ranging from 2-inches to 4-1/2 inches in outside diameter. However, the most commonly used size is the 2-inch O.D., 1-3/8-inch I.D. split-barrel sampler. When this sampler, is used, and driven by a 140-lb hammer dropping 30-inches, the procedure is called a Standard Penetration Test, and the blows per foot required to advance the sampler into formation can be correlated to the formation's density or strength.

In planning the drilling of boreholes using hollow stem augers or casing, in which Shelby tube samples or diameter core drilling will be performed, refer to the various sizes and clearances provided in EXP-3T1 of this guideline.

5.12 Estimated Drilling Progress

To estimate the anticipated rates of drilling progress for a site the following must be considered:

- o The speed of the drilling method employed.
- o Applicable site conditions (e.g., terrain, mobility between borings, difficult drilling conditions in

bouldery soils, rubble fill or broken rock, etc.)

- Project imposed restrictions (e.g., drilling while wearing personal protective equipment, decontamination of drilling equipment, etc.).

Based on recent experience in drilling average soil conditions (no boulders) and taking samples at 5' intervals, for moderate depth (30 to 50') boreholes (not including installation or development of wells), the following daily rates of total drilling progress may be anticipated for the following drilling methods:

Drilling Method	Avg. Daily Progress (linear feet)
Hollow stem augers	75
Solid stem augers	50
Mud Rotary Drilling	100
Reverse Circulation Rotary	100
Skid Rig with Driven Casing	30
Rotary with Driven Casing	50
Cable Tool	30
Hand Auger	Varies
Continuous Rock Coring	50

This rate will vary depending upon level of personnel protective equipment required for the specific site.

6. TELESCOPING BELOW A CONFINING LAYER

A telescoping technique minimizes the potential for the migration of contaminated groundwater to lower strata below a confining layer. The telescoping technique consists of drilling to a confining layer utilizing a spun casing method with a diamond cutting or augering shoe, (a method similar to the rock coring method described in SOP:EXP-6, except that larger casing is used) or a driven casing method (see Section 5.5 of this guideline), and installing a specified diameter steel well casing. The operation consists of three separate steps. Initially, a drilling casing usually of 8" diameter is installed followed by installation of the well casing (6" diameter is common). This well casing is driven into the confining layer to insure a tight seal at the bottom of the hole. The well casing is sealed at the bottom of the hole with a bentonite-cement slurry. The remaining depth of the boring is drilled utilizing a narrower diameter spun or driven casing technique within the outer well casing. A smaller diameter well casing with an appropriate length of slotted screen on the lower end is installed to the surface.

Clean sand is placed in the annulus around and to a point about 2 ft above the screen prior to withdrawal of the drilling casing. The annular space above the screen and to a point 2 ft above the bottom of the outer well casing is sealed with a tremied cement-bentonite slurry which is pressure-grouted or displacement-grouted into the hole. The remaining casing annulus is backfilled with clean material and grouted at the surface, or it is grouted all the way to the surface.

7. CLEANOUT OF CASING PRIOR TO SAMPLING

The boring must be completely cleaned of disturbed soil, segregated coarse material and clay adhering to the inside walls of the casing. The cleaning must extend to the bottom edge of the casing and, if possible, a short distance further (1 or 2 inches) to bypass disturbed soil resulting from the advancement of the casing. Loss of wash water during cleaning should be recorded.

For disturbed samples both above and below the water table and where introduction of relatively large volumes of wash water is permissible, the cleaning operation is usually performed by washing the material out of the casing with water; however, the cleaning should never be accomplished with a strong, downward directed jet which will disturb the underlying soil. When clean out has reached the bottom of the casing or slightly below (as specified above), the string of tools should be lifted one foot off the bottom with the water still flowing, until the wash water coming out of the casing is clear of granular soil particles. In formations where the cuttings contain gravel and other larger particles, it is often useful to repeatedly raise and lower the drill rods and wash bit while washing out the hole, to force these large particles upward out of the hole. As a time saver, the drilling Contractor may be permitted to use a split barrel (split-spoon) sampler with the ball check valve removed as the clean out tool, provided the material below the spoon is not disturbed and the shoe of the spoon is not damaged. However, because the ball check valve has been removed, in some formations it may be necessary to install a flap valve or spring sample retainer in the split-spoon drive head, to prevent the sample from falling out as the sampler is withdrawn from the hole. The use of jet-type chopping bits is discouraged except where large boulders and cobbles or hard cemented soils are encountered. If water markedly softens the soils above the water table, clean out should be performed dry with an auger.

For undisturbed samples below the water table, or where wash water must be minimized, clean out is usually accomplished with an appropriate diameter clean out auger. This auger has cutting blades at the bottom to carry loose material up into the auger, and up turned water jets just above the cutting blades to carry the removed soil to the surface. In this manner there is a minimum of disturbance at the top of the material to be sampled. If any gravel material washes down into the casing and cannot be removed by the clean out auger, a split-barrel sample can be taken to remove it. Bailers and sandpumps should not be used. For undisturbed samples above the groundwater table, all operations must be performed in a dry manner.

If all of the cuttings created by drilling through the overlying formations are not cleaned from the borehole prior to sampling, some of the problems which may be encountered during sampling include:

- When sampling is attempted through the cuttings remaining in the borehole, all or part of the sampler may become filled with the cuttings. This limits the amount of sample from the underlying formation which can enter and be retained in the sampler, and also raises questions on the validity of the sample.
- If the cuttings remaining in the borehole contain coarse gravel and/or other large particles, these may block the bit of the sampler and prevent any materials from the underlying formation from entering the sampler when the sampler is advanced.
- In cased borings, should sampling be attempted through cuttings which remain in the lower

portion of the casing, these cuttings could cause the sampler to become bound into the casing, such that it becomes very difficult to either advance or retract the sampler.

- o When sampler blow counts are used to estimate the density or strength of the formation being sampled, the presence of cuttings in the borehole will usually give erroneously high sample blow counts.

To confirm that all cuttings have been removed from the borehole prior to attempting sampling, it is important that the rig geologist measure the "stickup" of the drill string. This is accomplished by measuring the assembled length of all drill rods and bits or samplers (the drill string) as they are lowered to the bottom of the hole, below some convenient reference point of the drill string; then to measure the height of this reference point above the ground surface. The difference of these measurements is the depth of the drill string (lower end of the bit or sampler) below the ground surface, which must then be compared with the depth of sampling required (installed depth of casing or depth of borehole drilled). If the length of drill string below grade is more than the drilled or casing depth, the borehole has been cleaned too deeply, and this deeper depth of sampling must be recorded on the log. If the length of drill string below grade is less than the drilled or casing depth, the difference represents the thickness of cuttings which remain in the borehole. In most cases, an inch or two of cuttings may be left in the borehole with little or no problem. However, if more than a few inches for cuttings are encountered, the borehole must be recleaned prior to attempting sampling.

8. REFERENCES

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TABLE EXP-3T1

(2 OF 2)
DRILLING EQUIPMENT SIZES

Drilling Component	Designation or Hole Size (in)	O.D. (in)	I.D. (in)	Coupling I.D. (in)
Flushed Coupled Casing	RX	1 7/16	1 3/16	1 3/16
	EX	1 13/16	1 5/8	1 1/2
	AX	2 1/4	2	1 29/32
	BX	2 7/8	2 9/16	2 3/8
	NX	3 1/2	3 3/16	3
	HX	4 1/2	4 1/8	3 15/16
Flushed Joint Casing	RW	1 7/16	1 3/16	
	EW	1 13/16	1 1/2	
	AW	2 1/4	1 29/32	
	BW	2 7/8	2 3/8	
	NW	3 1/2	3	
	HW	4 1/2	4	
	PW	5 1/2	5	
	SW	6 5/8	6	
	UW	7 5/8	7	
	ZW	8 5/8	8	
Diamond Core Barrels	EWM	1 1/2	7/8 **	
	AWM	1 7/8	1 1/8 **	
	BWM	2 3/8	1 5/8 **	
	NWM	3	2 1/8 **	
	HWG	3 7/8	3	
	2 3/4 x 3 7/8	3 7/8	2 11/16	
	4 x 5 1/2	5 1/2	3 15/16	
	6 x 7 3/4	7 3/4	5 15/16	
	AQ (wireline)	1 57/64	1 1/16	
	BQ (wireline)	2 23/64	1 7/16 **	
	NQ (wireline)	2 63/64	1 7/8	
	HQ (wireline)	3 25/32	2 1/2	

** Because of the fragile nature of the core and the difficulty to identify rock details, use of small diameter core (1 3/8") is not recommended.

TABLE EXP-3T1

(1 OF 2)
DRILLING EQUIPMENT SIZES

Drilling Component	Designation or Hole Size (in)	O.D. (in)	I.D. (in)	Coupling I.D. (in)
Hollow-Stem Augers	6 1/4	5	2 1/4	-
	6 3/4	5 3/4	2 3/4	-
	7 1/4	6 1/4	3 1/4	-
	13 1/4	12	6	-
Thin Wall Tube Samplers	-	2	1 7/8	-
	-	2 1/2	2 3/8	-
	-	3	2 7/8	-
	-	3 1/2	3 3/8	-
	-	4 1/2	4 3/8	-
	-	5	4 3/4	-
Drill Rods	RW	1 3/32	23/32	13/32
	EW	1 3/8	15/16	7/16
	AW	1 3/4	1 1/4	5/8
	BW	2 1/8	1 3/4	3/4
	NW	2 5/8	2 1/4	1 3/8
	HW	3 1/2	3 1/16	2 3/8
	E*	1 5/16	7/8	7/16
	A	1 5/8	1 1/8	9/16
	B	1 7/8	1 1/4	5/8
	N	2 3/8	2	1
				Wall Thickness (in
Driven External Coupled Extra Strong Steel* Casing	2 1/2	2.875	2.323	0.276
	3	3.50	2.90	0.3
	3 1/2	4.00	3.36	0.318
	4	4.50	3.83	0.337
	5	5.63	4.81	0.375
	6	6.625	5.76	0.432
	8	8.625	7.63	0.5
	10	10.750	9.750	0.5
	12	12.750	11.750	0.500

*Add twice the casing wall thickness to casing O.D. to obtain the approximate O.D. of the external pipe couplings.

STANDARD OPERATING PROCEDURE

SOP: EXP-4

KEYSTONE
ENVIRONMENTAL RESOURCES, INC.

SOP: EXP-4. SOIL AND ROCK BORING SAMPLE LOGGING

1. SCOPE AND PURPOSE

This SOP will provide descriptions of the standard classifications and methods for the logging of soil/rock samples and the geophysical logging of boreholes. These techniques should be used during each borehole advancement in order to obtain a uniform description of the subsurface lithology. It is particularly important that each person logging boreholes does so in a consistent fashion to insure that strata and contaminant distribution can be correlated from borehole to borehole.

Borehole logs provide information which is used in the determination of geological conditions (stratification, relative permeability, etc.) and ultimately in the assessment of contaminant distribution and in evaluations of remedial actions. Borehole logging is also performed to assure that each well is constructed according to specifications.

2. RESPONSIBILITIES

The Project or Site Geologist is responsible for overseeing all boring activities and assuring that each borehole is logged accurately and completely. If more than one rig is being used on site, he/she must ascertain that each Rig Geologist is properly trained in logging procedures and that these geologists will produce consistent logs. A brief review session to standardize classifications may be warranted when the first boring is completed. Although this guideline indicates that geologists will be performing the logging, other qualified geoscience personnel (geotechnical engineers, civil engineers) may perform this work in most cases.

3. SOIL BORING FIELD LOGS AND DOCUMENTATION

- Each boring will be fully described on a boring log (See Form EXP-4BL1) by the rig geologist as the boring is being drilled. Data which will be included in the logs, when applicable, are listed below:

- Identifying number and location of each boring will be recorded.

- Depths recorded in feet and tenths of feet.

- Soil classification in accordance with the Unified Soil Classification System (USCS), (See Section 4 and Figure EXP-4BL2 of this guideline). These classifications will be prepared in the field by the geologist and will be subject to revision based on laboratory tests or subsequent review.

- A full description of soil samples. For split-spoon, solid tube, thin wall, soil core, or otherwise intact samples, the description will include but not be limited to the USCS two-letter classification, plus a more complete verbal description following the Burmister system of color, consistency, grain size and size distribution (See Attachment EXP-4A1).

- Depth limits, type and number of each sample taken. All samples shall be numbered consecutively.

- The number of blows required for each six inch penetration of split-spoon sampler and for each twelve inch penetration of casing; hammer weight and length of fall for split-spoon or driven samplers; hydraulic pressure used to push Shelby tubes. If Shelby tubes are pushed manually, that will be indicated.

- The estimated interval for each sample.

- Depth to water as first encountered during drilling, along with the method of determination. Any distinct water-bearing zones below the first zone also will be noted.

- If drilling fluid is used the fluid losses, interval over which they occur and the quantity lost will be recorded.

- A general description of the drilling equipment used. This description, including such information as rod size, bit type, pump type, rig manufacturer, and model, may be provided in a general legend.

- Dates and times of start and completion.

- Names of Contractor, driller and rig geologist.

- Size and length of casing used in each borehole.

- HNU and/or OVA meter readings and related signs of visible contamination for each sample or from cuttings that appear contaminated.

• As the boring is drilled, the rig geologist will evaluate samples recovered, together with observation of the drill cuttings, wash water (if any), drill performance, etc., to determine appropriate stratigraphic definitions or distinctions within the soil column. Such contacts or breaks between strata must be determined by the rig geologist and indicated on the boring log. If such information is not provided, the "log" is nothing more than a listing of individual sample descriptions. In general, a stratigraphic unit contains only similar soils which can be classified within the same two-letter USCS classification category symbol. In some cases, significant differences in soil color, grain size distribution, strength, etc., would be sufficient to classify soils having the same two-letter USCS classification category symbol, into two or more distinct strata.

• After the rig geologist has indicated the appropriate stratigraphic breaks on the log, he/she should develop and record an appropriate description for each defined stratigraphic unit. Each description should contain information about the color, grain size distribution, consistency, moisture, etc., and the appropriate two-letter USCS classification category symbol. The descriptions should be entered on the log in underlined capital letters.

- Each sample collected for chemical or geotechnical analysis (See SOP:EXP-5) will be labeled according to the specific sampling SOP, Sampling Packaging and Shipment Procedures, and proper chain-of-custody procedures will be initiated. For those borings drilled employing the mud rotary method, a sample of the mud shall be taken before it is used in the boring. This sample will be used for chemical analysis of the mud.

4. CLASSIFICATION OF SOILS

All soil classification data should be written directly on the boring log and in a field notebook. The method of deriving the classification should be described, or referenced to this guideline. Handling of samples during soil classification should be coordinated with chemical sampling activities.

4.1 USCS Classification

Soils are to be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Figure EXP-4BL2. This method of classification identifies soil types on the basis of grain size and liquid limits, and categorizes them by two-letter symbols.

In the USCS system, fine-grained soils, or fines, are classified as those which will pass through a No. 200 U.S. standard sieve (0.074 mm) and are of two types: silt (M) and clay (C). Some classification systems define size ranges for these soil particles, but for field classification purposes, they are identified by their respective behaviors only. Organic material (O) is a common component of soil but has no size range, and is recognized by its composition. Highly organic fibrous materials containing a predominance of undecomposed plant or woody fiber are root mat, peat, humus and lignite.

Coarse-grained soils are divided into two types, rock fragments and sand or gravel. The terms sand and gravel not only refer to the size of the soil particles but also to their depositional history.

Gravelly soils are identified by a (G) as the first letter in the two-letter symbol, whereas sandy soils are identified with an (S). The term rock fragments should be used to indicate granular materials resulting from the breakup of rocks. These materials are normally angular, indicating little or no transport from their source. When the term "rock fragments" is used it should be followed by a size designation such as "(1/4-1/2" diameter)" or "course-sand size" either immediately after the entry or in the remarks column. The USCS classification would not be affected by this variation in terms.

The second letter in the two-letter USCS symbol provides information about the grain size distribution of granular soils, or the plasticity characteristics of fine-grained soils. These second-letter modifiers are (P) poorly graded/well sorted, (W) well graded/poorly sorted, (c) clayey, (M) silty, (L) low plasticity, or (H) high plasticity.

Well graded granular soils, within the limited definition of USCS (SW or GW), do not frequently occur in nature. Therefore, while a sample may appear to contain all of the sizes for granular soil (fine, medium and coarse), it is not likely to contain them in the proper proportions to meet the USCS definitions for well graded soil. Thus, field classifying such soils as poorly graded (SP or GP) is more likely to be correct in most cases.

4.2 Burmister Classification System

This system deals with rather precise identification of soil components and proportions. A proper identification allows construction of a grain size curve within a very narrow range. The system requires considerable laboratory and field practice before accurate identifications can be made. An accurate identification tells much about a soil's characteristics; e.g., plasticity, permeability, frost heave potential, compactibility, etc. Slight variations in the identification could indicate appreciable changes in some of the soil properties. Thus every sample is carefully identified in order to detect the potential changes. Many of the other systems of soil classification are more general and may therefore give only general impressions rather than specific impressions (See Table EXP-4BL3 and Attachment EXP-4A1).

4.3 Grain Size Classification

The names of soils, such as "silt" or "clay" are commonly assigned to different grain-size fractions. The most widely accepted size classifications are shown in graphic form in Figure EXP-4BL4. With few exceptions natural soils consist of a mixture of two or more different grain-size fractions. The designation of soils by the names of their principal constituents is facilitated by triangular diagrams where the three coordinates represent the percentage of sand, silt and clay. A mixed-grained soil is located on this diagram based on the fraction of each constituent it contains. Where this point is located determines the type to which the soil belongs (See Figure EXP-4BL5).

A classification system based on size alone can be misleading because the physical properties of the finest soil fractions depend on many factors other than grain size. Therefore, if the words "silt" or "clay" are used to express grain size it should be described in that manner, such as "clay-size particle".

4.4 Soil Descriptors

In nature, soils are comprised of particles of varying size and shape and are combinations of the various soil types. Figure EXP-4BL4 lists grain size classifications to be used in describing soils or rocks. The following terms are useful in the description of soil:

Terms Identifying Proportion of the Component	Defining Range of Percentages by Weight
trace	0-10%
little	11-20%
some	21-35%
"and"	36-50%

These descriptions are adopted from the Burmister Classification System, and are more completely described in Attachment EXP-4A1.

5. CONDITION AND STRUCTURE OF SOILS

5.1 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the geologist must first identify the soil type. Granular soils contain predominantly sands and gravels. They are noncohesive (particles do not adhere well when compressed). Finer grained soils (silts and clays) are cohesive (particles will adhere together when compressed).

- The density of noncohesive, granular soils is classified according to standard penetration resistances obtained from split barrel sampling methods detailed in SOP:EXP-5A. Those designations are:

Designation	Relative Density	Standard Penetration Resistance (blows per foot)
Very loose	0-15%	0 to 5
Loose	15-40%	6 to 10
Medium dense	40-70%	11 to 30
Dense	70-85%	31 to 50
Very dense	85-100%	Over 50

Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a 2-in. outside diameter 12 in. into the material using a 140-lb hammer falling freely through 30 in. The sampler is driven through an 18-in. or 24-in. sample interval and the number of blows is recorded for each 6-in. increment. Relative density can be rated from the standard penetration resistance in accordance with modified USBR criteria as shown on Figure EXP-4BL6 as a function of overburden pressure. It is important to note that if gravel or rock fragments are broken by the sampler or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This should be noted on the log and referenced to the sample number.

- The consistency of cohesive soils is determined by performing field tests and identifying the consistency as shown in Figure EXP-4BL7. The consistency of cohesive soils is determined either by blow counts or most accurately by a pocket penetrometer or field Torvane device. The pocket penetrometer method is conducted on a selected sample of the soil, preferably the lowest 0.5 ft of the sample in the split-barrel sampler. The sample should be broken in half and the penetrometer pushed into the end of the sample to determine the consistency. Do not determine consistency by attempting to penetrate a rock fragment. If the sample is decomposed rock, it is classified as a soft decomposed rock rather than a hard soil. Consistency should not be determined solely by blow counts. The pocket penetrometer or Torvane should be used in conjunction with blow counts.

5.2 Moisture

Moisture content is estimated in the field according to four categories: dry, moist, wet, and saturated. In dry soil, there appears to be little or no water. Saturated samples obviously have all the water they can hold. Moist and wet classifications are somewhat subjective and often are determined by the individual's judgement. A suggested parameter for judging this in a fine-grained soil would be calling a soil wet if rolling it in the hand or on a porous surface liberates water, i.e., dirties or muddies the surface. Whatever method is adopted for describing moisture, it is important that the method used by an individual remains consistent throughout an entire drilling job.

Laboratory or field tests for water content should be performed if the natural water content is important.

5.3 Color

Soil colors should be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light gray" or "blue-gray". Since color can be utilized in correlating units between sampling locations, it is important that color descriptions be kept consistent throughout the field operations.

Colors must be described while the sample is still fresh and moist. Soil samples should be broken or split vertically to describe colors. Soil sampling devices tend to smear the sample surface creating color differences between the sample interior and exterior. Adjectives such as mottled and variegated should be used where applicable.

Soil Color Charts should be used and the type of color chart used should be noted in the field notebook and boring log.

5.4 Stratification

Stratification can only be determined after the sample barrel is opened. The stratification or bedding thickness for soil is dependent on grain size and composition. The classification to be used for stratification description is shown in Figure EXP-4BL8.

5.5 Texture, Fabric and Structure

The texture, fabric, bedding, and structure of the soil should be described. Texture is described as the relative angularity of the particles (for sand-sized grains or larger): rounded, subrounded, subangular, and angular. Fabric should be noted as to whether the particles are flat or bulky and whether there is a particular relation between particles (i.e., stratified, laminated, banded, heterogeneous varved). It is important to recognize defects in a soil structure. The following are often observed: slickensides, rootholes, fissures, weathering and inclusions.

5.6 Mineral/Rock Constituent and Depositional Origin

- The type and condition of mineral and rock constituents should be noted on the boring log and/or fieldbook. Examples are quartz, shale, micaceous, feldspathic, decomposed, friable, etc.

- The depositional origin of the soils will be identified where possible. Alluvial, colluvial, glacial till, outwash and marine are a few of the environments where the soils may have been deposited.

6. TYPICAL IDENTIFICATION OF SOILS

In the description of the soil, its color shall be described first, followed by texture, composition, structure, consistency and moisture, as shown in Table EXP-4BL3. Visual contamination, if any, will be noted in the remarks column of the boring log, and located on the diagram of the lithologic column.

7. FIELD AIDS FOR IDENTIFICATION OF SOILS

In addition to visual observation of the soils recovered in sampling devices, certain field tests may be performed to assist in classifying these soils. Since many of these field tests require some additional handling of the samples, they should only be used in cases where doing so will not be hazardous. Some of these visual aids in soil identification are:

- To evaluate plasticity to distinguish between clay and silts, dry a pat of soil quickly by placing it on a hot surface (i.e., exhaust pipe of the drill rig). Attempt to crumble the fully dried pat in the hand. Clays will tend to break into fragments, with increasing strength displayed by clays of greater plasticity (CH soils). Conversely, pure silt will have virtually no internal cohesion and will very easily pulverize to a very fine powder (Dry Strength Test).

- When a pat of wet silt is held in the hand and shaken (by taping one hand against the other), free water will appear on the surface of the soil, which when touched will recede back into the pat of soil (Shaking Test).

- Clays are sticky to the touch, while silts give no such sticky feeling. Highly plastic clays (CH) will exhibit a greasy feeling.

- Organic soils are usually dark in color (dark brown or black), have an organic (earthy) odor, and often contain remnants of the vegetable matter from which they were formed. When hydrogen peroxide is applied to organic soils, it will bubble and fizz; however, this same reaction can also be caused by certain metals (e.g., iron) in the soil.

- With experience, the percentage of fines in granular soils can be judged by the degree to which handling the wet soil dirties or stains one's hand or gloves. Relatively clean (<5% fines) soils (SP, GP, SW, GW) leave little or no stain, while soils with more than 12% fines (SC, SM, GC, GM) will leave a noticeable stain when handled wet (Smear Test).

- The ability to roll a "thread" of a fine grained soil is an indication of its plasticity. In a moist state highly plastic soils (CH) can be rolled to a very thin (1/16-inch) diameter without breaking, while non-cohesive pure silt cannot be rolled to a thread without crumbling (Thread Test).

- To aid in identifying the grain size distribution of granular soils, samples of each fraction (fine, medium, coarse) can be prepared in the laboratory and used in the field for comparison against the sample. Such comparative samples can either be contained in individual vials or glued on a piece of cardboard.

8. FIELD ROCK DESCRIPTION LOG

A blank log is illustrated in Form EXP-4BL1 and will be used to provide "detailed" geologic rock classification data described in the following sections. In some cases EXP-4BL1 may be sufficient for logging general rock descriptive information. The degree of required rock descriptive information and log format will be determined by the Project Geologist and Project Manger. Each log will be completed by the rig geologist who shall also record the information listed below:

- Names of contractor, driller and rig geologist.
- Number and location of each boring.
- Date and depth of hole at start and end of working day shift.
- Depth and size of any casing at start and end of each core run.
- Depth of start and finish of each core run.
- Core diameter and changes in core size.
- Type and condition of bit.
- Time required to drill each foot of core.
- Total core recovery with information as to possible location of core losses.
- Details of delays and breakdowns.
- A general description of the drilling equipment used.
- Depth to water as first encountered during drilling, along with the method of determination. Any distinct water-bearing zones below the first zone also will be noted.
- Gain or loss of water or mud; type of cuttings.
- Standing water-level at start and end of each working period.
- Description of strata.
- Depth, type and number of each sample taken.
- Details of in-situ tests and instrumentation installed.
- HNu and/or OVA meter readings and related signs of visible contamination for each core or from cuttings that appear contaminated.
- Backfilling and grouting.

9. CLASSIFICATION OF ROCKS

Rocks are grouped into three main divisions: sedimentary, igneous, and metamorphic. Sedimentary rocks are by far the most predominant type exposed at the earth's surface. The following basic names are applied to the type of rocks found in sedimentary sequences:

- o Sandstone - Made up predominantly of granular materials ranging between 1/16 and 2 mm in diameter.
- o Siltstone - Made up of granular materials less than 1/16 mm in diameter. Fractures irregularly. Medium thick to thick bedded.
- o Claystone - Very fine grained rock made up of clay and silt-size materials. Fractures irregularly.
- o Shale - A very fine grained, fissile rock. Fractures along bedding planes.
- o Limestone - Rock made up of predominantly of calcite ($CaCO_3$). Effervesces upon the application of dilute hydrochloric acid.
- o Coal - Rock consisting mainly of organic remains.
- o Others - Numerous other rock types are present in the geologic section. Their overall abundance is dependent upon the geographic locations.

In classifying a sedimentary rock the following hierarchy should be noted: rock type, color, stratification, hardness, fracturing, weathering, and other characteristics. All classification data should be written directly on the boring log and in a field notebook. The method of deriving the classification should be described or reference to this guideline or other manuals used should be included.

9.1 Rock Type

As described above, there are numerous names for sedimentary rocks. In most cases a rock will be a combination of several rock types, therefore a modifier such as a sandy siltstone or a silty sandstone can be used. The modifier indicates that a significant portion of the rock type is composed of the modifier. Other modifiers can include carbonaceous, calcareous, siliceous, etc.

Details as to lithology, mineralogy, decomposition and sedimentary structures should be noted.

Grain diameters are used for the classification of clastic sedimentary rocks. Figure EXP-4BL9 is the Udden-Wentworth classification that will be assigned to sedimentary rocks. The individual boundaries are slightly different that the USCS subdivision for soil classification. For field determination of grain sizes, a scale can be used for the coarse grained rocks.

The division between very fine sandstone and siltstone is probably not measurable in the field. The boundary should be determined by use of a hand lens. If the grains cannot be seen with the naked eye but are distinguishable with a hand lens, the rock is a siltstone. If the grains are not distinguishable with a hand lens, the rock is a claystone.

9.2 Color

The color of a rock can be determined in the same manner as for soil samples. Rock core samples should be classified while wet, when possible, and air cored samples should be scraped clean of cuttings and wetted prior to color classification.

If Rock Color Charts are used the chart type must be recorded in the field notebook.

9.3 Stratification

The bedding thickness designations applied to soil classification will also be used for rock classification. The boring log can be used as a graphic log in which standard rock symbols are used and to indicate major stratigraphic changes. Minor changes and related details will be described in the written description.

9.4 Hardness

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness is as follows:

Soft - Weathered, considerable erosion of core, easily gouged by knife blade, scratched by fingernail. Soft rock crushes or deforms under pressure of a pressed hammer. This term is always used for the hardness of the saprolite (decomposed rock which occupies the zone between the lowest soil horizon and firm bedrock).

Medium Soft - Slight erosion of core, slightly gouged by knife blade, or breaks with crumbly edges from single hammer blow.

Medium Hard - No core erosion, easily scratched by knife blade or breaks with sharp edges from single hammer blow.

Hard - Requires several hammer blows to break and has sharp breaks. Cannot be scratched with knife blade.

Note the difference in usage here of the words "scratch" and "gouge". A scratch should be considered a slight depression in the rock (do not mistake the scraping off of rock flour from drilling with a scratch in the rock itself), while a gouge is much deeper.

9.5 Fracturing

The degree of fracturing of a rock is described by measuring the fractures or joint spacing. After eliminating drilling breaks, the average spacing is calculated and the fracturing is described by the following terms:

- o Massive: >3' (May contain hairline cracks)
- o Slightly fractured: 1'-3"
- o Moderately fractured: 0.5'-1'
- o Closely fractured: 0.1'-0.5'
- o Intensely fractured: 0.05'-0.1'
- o Crushed: <0.05' (Approx. 0.6")

The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding four inches and dividing by the total length of the coring run, to obtain a percentage:

$$RQD = (r/l) \times 100$$

where:

r = Total length of all pieces of the lithologic unit being measured, which are greater than 4 inches in length, and have resulted from natural breaks. Natural breaks include slickensides, joints, compaction slicks, bedding plane partings (not caused by drilling), friable zones, etc., and

l = Total length of the coring run.

Figure EXP-4BL10 provides qualitative descriptive terminology for rock quality (decomposition, consistency, and fracturing), relative hardness and RQD.

9.6 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and is also useful in engineering designs. The following terms can be applied to distinguish the degree of weathering.

Fresh - Rock shows little or no weathering effect. Fractures or joints have little or no staining and rock has a bright appearance.

Slight- Rock has some staining (i.e., discoloration along joints, cracks or exposed surfaces) which may penetrate several centimeters into the rock. Clay fillings of joints may occur. Feldspar grains may show some alteration.

Moderate - Most of the rock, with exception of quartz grains, is stained. Rock is weakened due to weathering and can be easily broken with hammer.

Severe - All rock, including quartz grains, is stained. Some of the rock is weathered to the extent of becoming a soil. The rock is very weak and crumbly.

Decomposed - All minerals are completely altered.

9.7 Other Characteristics

The following items should be included in the rock description:

- Description of contacts between two rock units. These can be sharp or gradational.
- Description of any filled cavities or vugs.
- Description of any joints or open fractures.
- Notation of joints with depth, approximate angle to vertical, any mineral filling or coating, and degree of weathering.
- The angle of bedding or other planar features shall be written in degrees. The preferred angular measurement is made from the perpendicular to the core axis with a protractor. Thus, a bedding feature which is horizontal in the core would be measured as a 0° angle.

Additional information should be provided, including an estimation of the degree of cementation and type of cement for granular sedimentary rocks; a description of the texture and fabric of the rock (i.e., the shape and relationship of component particles or crystals); and the structure or macroscopic features of the rock mass. Generally, rock structure is best seen in the outcrop rather than the hand specimen, but some indications of structure (e.g., horizontal or dipping beds, open joints) can be obtained from core samples.

All information shown on the field classification sheets should be neat to the point where it can be reproduced photographically for report presentation. Sections should be drawn daily by the rig geologist or site geologist. The data should be kept current to provide control of the drilling program and to indicate various areas requiring special consideration and sampling.

9.8 Additional Terms Used in the Description of Rock

The following terms are used to further identify rocks:

Seam - Thin (12 in. or less), probably continuous layer.

Some - Indicates significant (15 to 40 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (70 percent) and shale (30 percent) would be "sandstone -- some shale seams".

Few - Indicates small (0 to 15 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (90 percent) and shale (10 percent) would be "sandstone -- few shale seams".

Interbedded - Used to indicate thin or very thin alternating seams of material occurring in approximately equal amounts. For example, rock composed of seams of sandstone (50 percent and shale (50 percent) would be "interbedded sandstone and shale".

Interlayered - Used to indicate thick alternating seams of material occurring in approximately equal amounts.

10. DATA COLLECTION

Data gathered in the examination of soil and/or rock samples should include all the characteristics listed in Sections 4 through 7 for soil samples, and Sections 8 and 9 for rock samples. Actual sampling of soils or rock for chemical or geotechnical analysis is described in other technique-specific SOP's.

In addition to gathering data on the sample obtained, the geologist should gather additional data by observing the physical features of the study area. Rock outcrops can provide information on lithology, stratigraphy, structure, and degree and orientation of fracturing. Examining the geomorphological features of an area can provide additional insight into the geology of the area. Exposed soils can provide information on the origin of the soils (residual, alluvial etc.) and help in defining the area's geology.

All the above information should be obtained wherever possible and documented in field logbooks and notes. A map of the study area should be carried along on any reconnaissance and any important features found plotted on the map for reference purposes.

Form: EXP - 4BL1

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.

SITE	COORDINATES	ANGLE FROM HORIZON	BEARING

BEGAN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH (Ft.)

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH CORE RUN	SAMPLE RECOVERY CORE RECOVERY	SAMPLE BLOWS "N" % CORE RECOVERY	PENETRATION BLOWS 1st 6"	PENETRATION BLOWS 2nd 6"	PENETRATION BLOWS 3rd 6"	ELEVATION	DEPTH	UNIFIED SOIL CLASSIFICATION	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER	SITE	HOLE NO.

Unified Soil Classification

(The No 200 sieve size is about the smallest partical visible to the naked eye)

			Field Identification (Excluding particles larger than 3 inches and basing fractions on estimated weights)			Group Symbols	Typical Names
Coarse Grained Soils (More than half of material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No 4 sieve size)	Clean Gravels (Little or No fines)	Wide range of grain size and substantial amounts of all intermediate particle sizes			GW	Well graded gravels, gravel sand mixtures, little or no fines
			Predominantly one size or a range of sizes with some intermediate sizes missing			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		Gravels with fines (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below			GM	Silty gravels, poorly graded sand-gravel-clay mixture
			Plastic fines (for identification procedures see CL below			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures
	Sands (More than half of coarse fraction is smaller than No 4 sieve size)	Clean Sands (Little or fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes			SW	Well graded sands, gravelly sands, little or no fines
			Predominantly one size or a range of sizes with some intermediate sizes missing			SP	Poorly graded sands, gravelly sands, little or no fines
		Sands with Fines (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)			SM	Silty sands, poorly graded sand-silt mixtures
			Plastic fines (for identification procedures see CL below)			SC	Clayey sands, poorly graded sand-clay mixtures
	IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No. 40 SEIVE SIZE						
			Dry Strength (Crushing Characteristics)	Dilatancy (Reaction to Shaking)	Toughness (Consistency near plastic limit)		
Fine Grained Soils (More than half of material is smaller than No 200 sieve size)	Silts and Clays (Liquid limit less than 50)		None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity
			Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			Slight to medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity
	Silts and Clays (Liquid limit greater than 50)		Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
			High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays
			Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity
Highly Organic Soils			Readily identified by color, odor, spongy feel and frequently by fibrous texture			Pt	Peat and other highly organic soils

Information Required For Describing Soils

Coarse Grained Soils:

Give typical name; indicate approximate percentages of sand and gravel, max size; angularity, surface condition, and hardness of the coarse grains, local or geologic name and other pertinent descriptive information, and symbol in parentheses

For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics

Example: –

Silty sand, gravelly, about 20% hard, angular gravel particles ½-in. maxium size, rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, alluvial sand; (SM)

Fine Grained Soils:

Give typical name, indicate degree and character of plasticity, amount and maximum size of of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information; and symbol in parentheses.

For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions

Example: –

Clayey silt, brown; slightly plastic; small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML)

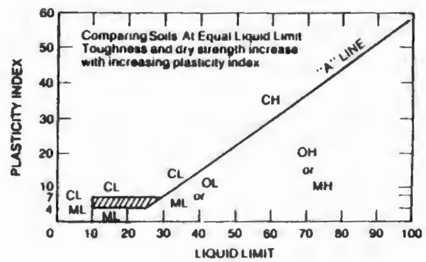
Laboratory Classification Criteria

Use grain size curve in identifying the fractions as given under field identification

Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No 200 sieve size) coarse grained soils are classified as follows:

- Less then 5%: GW, GP, SW, SP
- More than 12%: GM, GC, SM, SC
- 5% to 12%: Borderline cases requiring use of dual symbols

GW	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
GC	Atterberg limits above "A" line with PI greater than 7	
SW	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
SP	Not meeting all gradation requirements for SW	
SM	Atterberg limits below "A" line, with PI less then 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
SC	Atterberg limits above "A" line, with PI greater then 7	

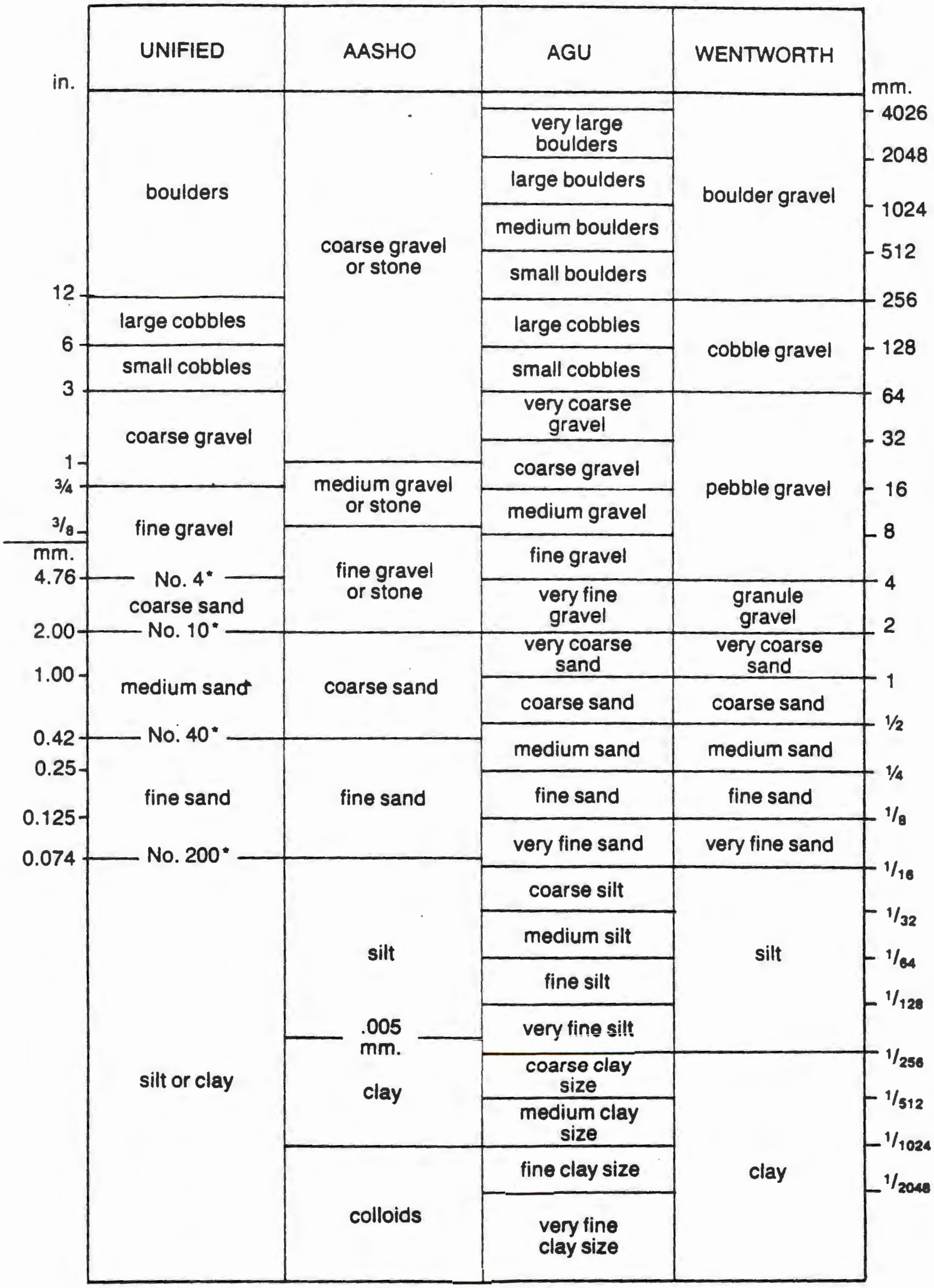


Plasticity Chart

Figure: EXP-4BL2
Unified Soil Classification System

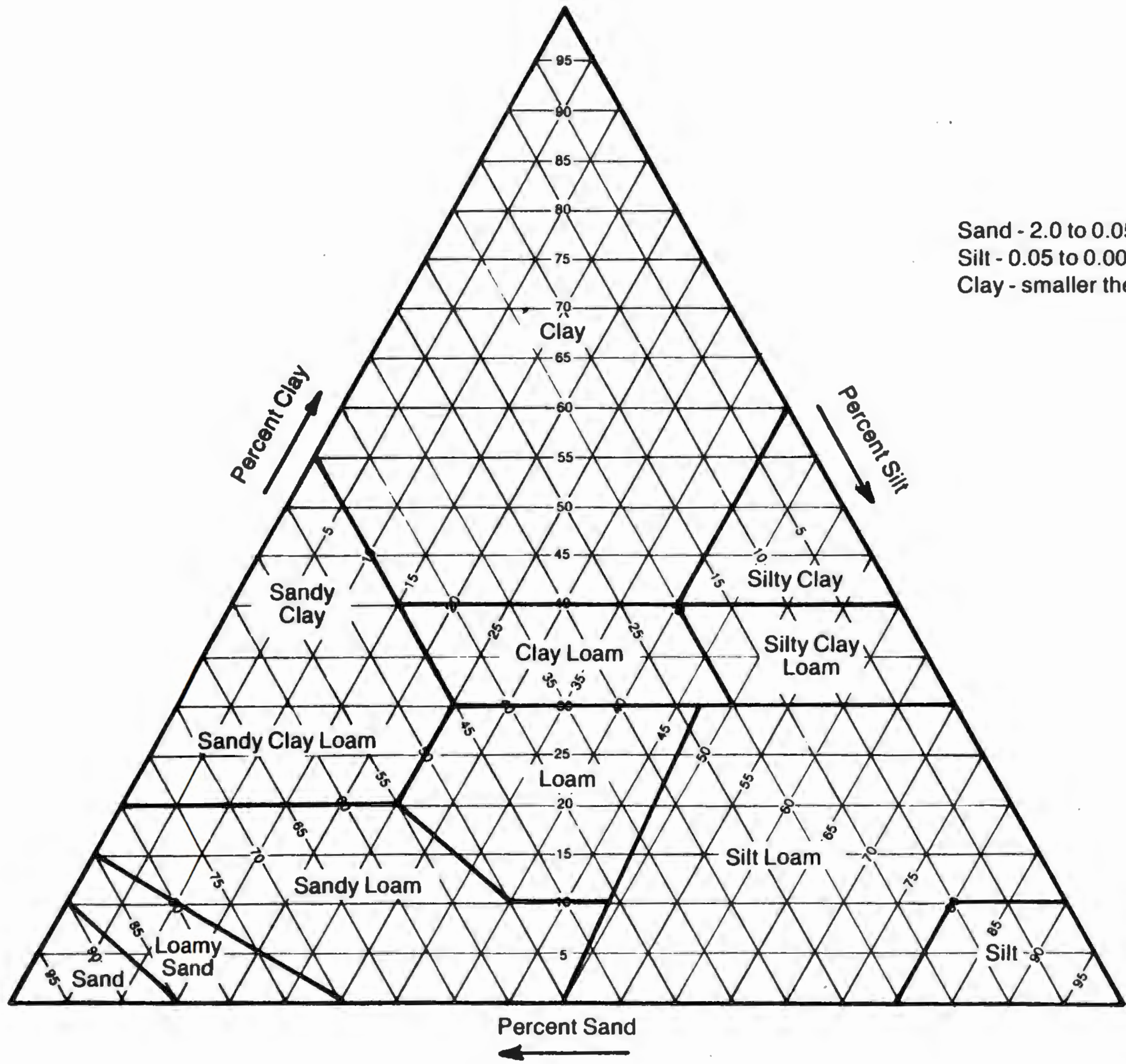
Figure: EXP-4BL2
Date: 6/88

Figure: EXP-4BL4
Comparison Of Grain-Size Classification For Soils



*U.S. Standard Sieve Number

Figure: EXP - 4BL5
Date: 6/88



Sand - 2.0 to 0.05 mm. diameter
Silt - 0.05 to 0.002 mm. diameter
Clay - smaller then 0.002 mm. diameter

Figure EXP - 4BL5
Textural Soil Classification Chart, U.S. Department of Agriculture

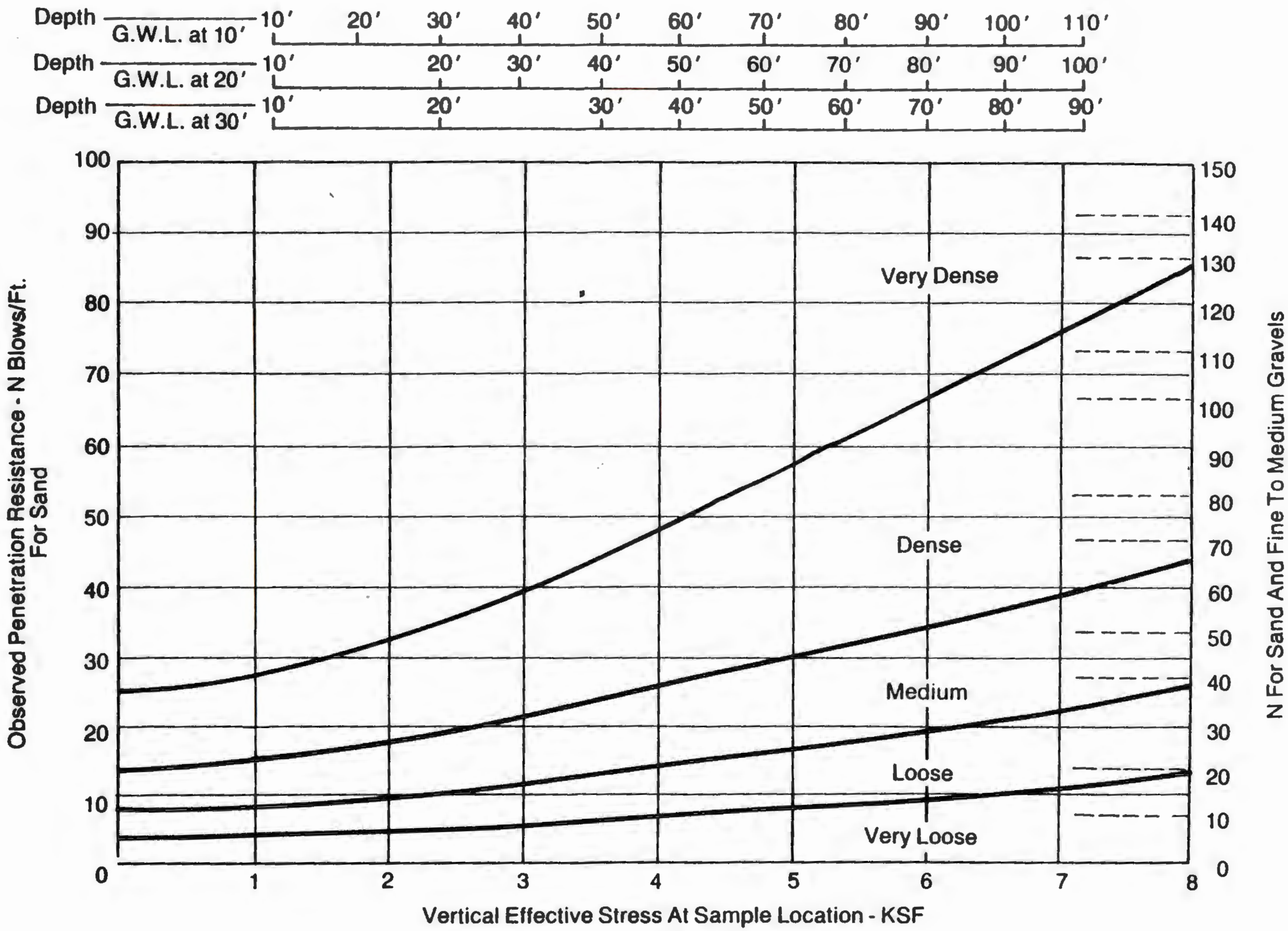


Figure: EXP-4BL6: Relative Density Of Sand From Standard Penetration Test

Figure: EXP-4BL6
Date: 6/88

Figure 2-5
Burmister System

Main Features | Modifiers

Major Component* | Minor Component (S)*

Color | Fractions | Proportion

(Minor Comp.)

Abbreviated Verson:
(Not to Be Used On Boring Logs)

Grbr m(-)f S, l(-) m G; lyr; occ lns c S''

As Identified in Field. First Letter of First Work Capitalized

Identifies Grain Size (s)
(−) = Major Fraction
(−) = Minor Fraction

Identifies Quanty, Acts as a Conjunction:
35-50% = a (and)
20-35% = s (some)
10-20% = l (little)
1-10% = t (trace)
(+) = upper third
(−) = lower third

*Abbreviation Capitalized

Unabbreviated Verson:

Gray brown medium (−) to fine SAND, little (−) medium Gravel; layered; occasional lens coarse Sand (SP).

Unified Soil Classification Adequuate for a Generalized Stratum Description

Upon Approval, The Chester Engineers May Use a Modified BURMISTER SYSTEM For Detailed Identification of Soil Components, Fractions and Proportions. The UNIFIED SOIL CLASSIFICATION,** Based Upon Field Data, Is Also Presented.

FIGURE EXP-4BL7

CONSISTENCY OF COHESIVE SOILS

Consistency	Blows per Foot	Unconfined Compressive Strength (tons per square foot by pocket penetration	Field Identification
Very Soft	0 to 3	Less than 0.25	Easily penetrated several inches by fist. Tall core will sag or slump under its own weight.
Soft	4 to 5	0.25 to 0.50	Easily penetrated several inches by thumb. Core can be pinched in two between thumb and forefinger.
Medium Stiff (Firm)	6 to 10	0.50 to 1.0	Can be penetrated several inches by thumb with moderate effort.
Stiff	11 to 15	1.0 to 2.0	Readily indented by thumb but penetrated only with great effort.
Very Stiff	16 to 30	2.0 to 4.0	Readily indented by thumb nail; penetrated very slightly by thumb.
Hard	Over 30	More than 4.0	Indented by thumb nail. Core cannot be penetrated by thumb; can be pierced with pencil.

* Note: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above, because of planes of weakness or cracks in the soil. The consistency ratings of such soils are based on penetrometer readings.

FIGURE EXP-4BL8

BEDDING THICKNESS CLASSIFICATION

Thickness (Metric)	Thickness (Approximate) Equivalent	English Classification
>1 meter	>3.3 feet	Massive
30 cm - 1 meter	1.0 ft - 3.3 ft	Thick Bedded
10 cm - 30 cm	4.0 in - 1.0 ft	Medium Bedded
3 cm - 10 cm	1.0 in - 4 in	Thin Bedded
1 cm - 3 cm	2/5 in - 1 in	Very Thin Bedded
3 mm - 1 cm	1/8 in - 2/5 in	Thickly Laminated
1 mm - 3 mm	1/32 in - 1/8 in	Thinly Laminated
< 1 mm	< 1/32 in	Micro Laminated

FIGURE EXP - 4BL 9

GRAIN CLASSIFICATION FOR ROCKS

Particle Name	Grain Size Diameter
Cobbles	> 64 mm
Pebbles	4 - 64 mm
Granules	2 - 4 mm
Very Coarse Sand	1 - 2 mm
Coarse Sand	0.5 - 1 mm
Medium Sand	0.25 - 0.5 mm
Fine Sand	0.125-0.25 mm
Very Fine Sand	0.0625-0.125 mm
Silt	0.0039-0.0625 mm
Clay	<0.0039 mm

(After Wentworth, 1922)

FIGURE EXP-4BL10

ROCK CORE DESCRIPTIVE TERMINOLOGY

GUIDE FOR ROCK DESCRIPTIONS IN FIELDLOG PREPARATION

- Rock Type - Gneiss, Basalt, etc.
- Color - Gray, pink, green, etc.
- Hardness - (See Hardness chart)
- Bedding - Stratification (See Bedding Chart), foliation, etc.
- Weathering - (See weathering chart)
- Composition - Percentage of dominant and accessory minerals
- Miscellaneous - Calcareous, vuggy, cementing material, incusions, ets.
- Discontinuities - Joints, faults, fractures, etc. with descriptions to include coatings, infilling, inclination, etc.

BEDDING

- Thinly laminated . . . . 3 mm
- Thickly laminated . . . . 3-10 mm
- Very thin bedded . . . . . . 1-3 cm
- Thin bedding . . . . 3-10 cm
- Medium bedding . . . . . . 10-30 cm
- Thick bedding . . . . 3-1 m
- Very thick bedding . . . . . > 1 m

HARDNESS

- Very Hard - Cannot be scratched with knife blade.
- Hard - Can be scratched by knife blade but only with great difficulty.
- Medium hard - Can be scratched by knife blade.
- Medium soft - Easily scratched by knife blade.
- Soft - Can be gouged 1/8" to 1/4" with knife blade.
- Very soft - Can be cut in half or nearly so with knife blade.

FRACTURING (AVERAGE SIZE OF PIECES)

- Massive - >3' (May contain hairline cracks)
- Slightly fractured - 1'-3"
- Moderately fractured - 0.5'-1'
- Closely fractured - 0.1'-0.5'
- Intensely fractured - 0.05'-0.1'
- Crushed - <0.05' (Approx. 0.6")

ROCK QUALITY DESIGNATION (R.Q.D) is based on a modified core logging procedure which, in turn, is based indirectly on the number of fractures and the amount of softening or alteration in the rock mass as observed in the rock cores. Instead of counting the fractures, an indirect measure is obtained by summing up the total length of core recovered - but counting only those pieces of core which are four inches (10 cm) in length or longer, and which are hard and sound.

This procedure obviously penalizes the rock where recovery is poor. This is appropriate, because poor core recovery usually indicates poor quality rock.

It has been found that there is a good relationship between the numerical values of the R.Q.D. and the general quality of the rock for engineering purposes. This relationship is as follows:

R.Q.D	Description of Rock Quality
0 - 25%	Very Poor
25 - 50%	Poor
50 - 75%	Fair
75 - 90%	Good
90 - 100%	Excellent

Example: Gneiss, dark green, medium soft, thin bedded, strong foliation parallel to bedding, slight weathering, fracture at 46.3' with thin clay filling. Contains 50% feldspar, 30% quartz, and 20% biotite mica, scattered garnet inclusions.

NOTE: Grain size classification for rocks will follow the Wentworth Designations.

STANDARD OPERATING PROCEDURE
SOP: EXP-5

KEYSTONE
ENVIRONMENTAL RESOURCES, INC.

SOP: EXP-5 SUBSURFACE SOIL SAMPLING

1. General Application

Subsurface soil samples are obtained for identification of soil grain-size distributions, stratigraphic correlations, and chemical analysis (if required). The characterization can indicate the potential for migration of chemical contaminants from hazardous substance sites. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of the soil samples. Subsurface soil samples are obtained in conjunction with soil boring and monitoring well installation programs and provide direct information as to the physical and chemical makeup of the subsurface environment. Where the remedial activities may include in-situ treatment or the excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

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

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

Two soil sampling methods have been addressed. These include one procedure for obtaining disturbed soil samples and soils penetration resistance information and one procedure from which one can obtain relatively undisturbed soil samples:

- o Split Barrel (Split-Spoon) Sampling
- o Thin-Wall (Shelby) Tube Sampling

SOP: EXP-5A. SUBSURFACE SOIL SAMPLING

SPLIT BARREL (SPLIT-SPOON) SAMPLING

1. Scope and Purpose

This SOP covers soil sampling by split-barrel only, as this is the means most often used for obtaining samples from unconsolidated deposits. This method provides a representative disturbed soil sample for classification purposes and a record of the soil penetration resistance. A split-barrel sampler is a steel tube, split in half lengthwise, with the halves held together by threaded collars at each end of the tube. Also called a split-spoon sampler, this device can be driven into resistant (consolidated) materials using a drive weight mounted on the drilling string.

A standard split spoon sampler (used for performing Standard Penetration Tests) is 2-inches O.D. and 1 3/8-inches I.D. This standard spoon typically is available in two common lengths providing either 20" or 26" internal longitudinal clearance for obtaining 18" or 24" long samples, respectively.

Details of the implementation of this procedure for a particular project shall be described in a project work plan which shall include a detailed description of the work to be performed and identification of field equipment to be used.

2. Responsibilities

It shall be the responsibility of the Contract Driller to provide the necessary equipment for obtaining subsurface soil samples. This includes the split-barrel sampler and sample containers (sized according to project requirements). It is the Contract Driller's responsibility to maintain a complete set of boring logs for contract purposes. Standard Penetration Tests (SPT) (ASTM: 1586-84) will be conducted by the Contract Driller if required by the project. Equipment decontamination shall also be the responsibility of the Driller.

It shall be the responsibility of the Project Geologist/Engineer to observe all activities pertaining to subsurface soil sampling to ensure that all the standard procedures are followed properly, and to record all pertinent data on a boring log, which includes but is not limited to the blow counts per every advanced six-inch increment. It is also the Geologist/Engineer's responsibility to indicate to the Contract Driller at what specific depth samples shall be collected. The Geologist/Engineer will maintain custody of all samples until they are shipped to their appropriate destination.

3. General Procedures

The sampling depth interval is typically one (1) sample every five (5) vertical feet with additional samples taken, at the discretion of the project geologist/engineer, when significant textural, visual or odor changes are encountered.

The following are the standard procedures to be used in advancing casing and obtaining soil samples.

Specific requirements described in a project's task plan may call for deviations in the standard procedures but these will be taken into account on a project by the project basis.

3.1 Standard Procedures-Advancing Casing

- Casing shall be advanced in the overburden by a series of operations which consist of driving the casing to the elevation at which the sample is to be taken, and cleaning out the hole to the bottom of the casing without disturbing the material to be sampled.

- For advancing the boring in holes requiring rock coring, casing shall be drilled or driven in 5-foot increments and seated in the top of the bedrock. For dense soils such as glacial till, the boring may be advanced by drilling the casing into the soil. In this case, the casing shoe is replaced with a casing drill bit. Hollow stem augers or solid flight augers with casings may be used to advance the hole. On borings requiring rock coring, the augers must be removed and casing firmly seated in rock prior to coring. Depending upon field conditions, drilling mud may be used in lieu of casing.

- If boulders or obstructions are encountered during the progress of the boring, the casing shall be advanced past or through the obstacles either by drilling, mechanically fracturing, or blasting.

- Casing shall consist of the flush joint or flush coupled type. With the approval of the site geologist/engineer or his delegate a heavy duty drive pipe may be used depending on the nature of the overburden or drilling method. The size of the casing shall be sufficient to allow soil sampling, rock coring, or the use of instrumentation where applicable. The casing, casing shoe, and casing bit shall be straight. The inside of the casing shall be clean and free of any obstructions.

- The casing shall generally be advanced in 5-foot intervals or to the designated sampling interval. In cohesive soils such as clay or plastic silt, where the hole remains open and clear, the boring may be advanced uncased. For such open holes, which are advanced by the use of a chopping bit, roller bit, and/or drilling mud, the casing may be advanced after drilling (for rock drilling, casing is required for the full depth of the overburden). The use of water shall not be permitted to facilitate driving of the casing except when directed by the inspecting geologist/engineer. This shall apply to dense soils in which soil sampling is not required. Such "washing and driving" of casing shall be recorded on the field boring log.

- The casing shall be cleaned out before sampling and care shall be taken to avoid sampling of material partly within the casing. Any equipment which is not specially designed for obtaining soil samples shall be considered unsatisfactory. The holes in the chopping bits used for cleaning shall be drilled so that the stream of water will not be directed downward. The amount of water shall be the minimum required to clean the casing and to raise the soil particles to the surface. When the casing cannot be cleaned by washing, augers shall be used for cleaning the drill hole preparatory to sampling. The sample spoon should not be used to remove excess material or to clean out the casing. The bottom of the boring shall be thoroughly cleaned to the required sampling depth.

- In certain borings where the hollow stem auger serves as the casing, the augers shall be advanced to the sampling depth which will normally occur at 5-foot intervals. The hollow stem auger should be equipped with a plug to prevent soil from entering into the bottom of the auger. If soil enters the auger, it shall be necessary to clean the auger out prior to sampling.

3.2 Sampling

- Drive samples of the materials encountered shall be obtained by the use of a split spoon sampler having a 2-inch O.D. and 1 3/8-inch I.D., and a clear inside length of at least 18 inches. The spoon shall be equipped with a properly fitting ball check valve and a flap valve or basket retainer shall be used when sampling in loose soils. Drill rods used for driving the sample shall have as a minimum 1 5/8-inch O.D. (AW).

- Drive samples shall be taken at every change of material or stratification and at 5-foot intervals, or as directed by the inspecting geologist/engineer.

- The inspecting geologist/engineer shall make an independent determination of depth measurements and check his determinations with those made by the drilling foreman. Any discrepancy shall be resolved in the field as soon as it is discovered. All depth measurements shall be made in feet and tenths of feet.

- The change in soil strata should be established by the inspecting geologist/engineer and the driller from sampling and observation of the wash material and driving resistance during the progress of the boring. Drive samples shall be obtained by driving the sampling spoon into the material below the bottom of the casing so as to fully fill its chamber without compressing the material. A representative sample of the material, not affected by the washing out process, shall be obtained from the sampling spoon.

- Standard penetration tests, as described below, shall be performed to facilitate the determination of the relative resistance of the various strata. The sampler shall be driven with a hammer weighing 140 pounds and falling 30 inches. The hammer shall be raised and dropped with one turn of the rope around the cathead. The use of wire or cable in driving the sampling spoon shall not be permitted. The number of blows for each six inches of penetration of the sampler shall be recorded on the boring log Form EXP-4BL1.

- The hammer weight shall be certified by an independent testing laboratory as weighing 140 pounds ±5 pounds. The 30 inches shall be so marked on the drive pipe.

- In case of poor sample recovery, a second attempt may be required by the inspecting geologist/engineer. For this attempt, the inspecting geologist/engineer may require alternate methods of obtaining samples. These methods include:

  - the use of the casing hammer to drive the split-spoon sample;

  - the use of an open-end rod driven with the casing hammer;

  - the use of an oversized spoon driven with the casing hammer;

  - the use of a core barrel which has been approved by the inspecting geologist to core the soil;

  - the use of traps or flap valves;

  - overdriving of the sample;

  - any combination of the above, or;

- other methods approved by the inspecting geologist.

- The use of any of the methods detailed in Section 3.2.7 shall be recorded on the inspector's and contractor's logs and on the sample jar or core box. Should any of these methods fail to secure a sample, the casing may be advanced to the maximum depth of the previous sample attempt and a third and final attempt may be made, at the discretion of the inspecting geologist/engineer. The third attempt, however, shall not exceed the top of the next 5-foot sampling interval.

- When sampling in fine sands below the water table, which have a tendency to flow up into the casing during various stages of the drilling operations, special precautions shall be taken. The casing shall be maintained full of water at all times. Water shall be pumped into the casing when withdrawing the wash rods after cleaning the casing. A sample of this water must be collected and analyzed prior to use in order to qualify and quantify any potential contamination of the sample. The casing shall be maintained full of water also during withdrawal of the sampler spoon to minimize the hydrostatic head in the drill rods which would tend to drive the sample out of the bottom of the spoon. A perforated section of drill rod or adapter shall be attached to the top of the sampling spoon to facilitate drainage of the drill water after sampling. The drill rods shall be withdrawn slowly to avoid losing the sample.

4. Documentation

4.1 The inspecting geologist/engineer shall prepare a field boring log of each boring (See Form EXP-4BL1). The boring log shall be kept current. All applicable portions of the log shall be filled out. In addition to the data entries noted, the inspecting geologist/engineer should be careful to observe and note any of the following:

- support of hole walls, i.e., mud, or casing;

- any unusual action of the drill rods, such as rapid drop of rods, or rods advancing under their own weight;
- the depth of casing at each soil sampling interval when casing is used during soil sampling;
- the names of the drilling crew;
- the type and make of drill rig.

4.2 The inspecting geologist/engineer shall identify the borehole by marking the identification number of the borehole on the casing.

4.3 The geologist/engineer shall complete all sample logs, chain-of-custody forms and shipping forms required for the project.

5. References

Acker, III, W.L., 1974. Basic Procedures for Soil Sampling and Core Drilling. Acker Drilling Co., Inc., Scranton, PA.

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Hvorslev, J.M., Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes. The Engineering Foundation, New York, 1949.