**Battelle**
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505 King Avenue
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February 14, 2005

Mr. Mike McCann
U.S. Nuclear Regulatory Commission
Region III
2443 Warrenville Road
Suite 210
Lisle, IL 60532-4352

Dear Mr. McCann:

Subject: Submittal of Battelle's technical basis documentation for groundwater monitoring well locations at the West Jefferson North site under the SNM-7 License.

Mike, per your request I am sending two copies each of the following documents, which in summary represent Battelle's technical basis documentation for selection of the groundwater monitoring well locations at the Battelle West Jefferson North site. These groundwater monitoring wells are also identified in our current site Environmental Monitoring Plan of which I am also sending two copies of to your attention.

1) Letter from Fred Klaer, Jr. and Associates to Battelle dated April 2, 1963
2) Quality Assurance Plan for Battelle Groundwater Monitoring dated June 18, 1990
3) Procedure for Well Installation and Well/Borehole Abandonment dated September 5, 1989
4) Site Characterization West Jefferson North Site Groundwater Monitoring Well Hydraulic Conductivity Testing and Analysis dated January 31, 1990
5) Geology and Hydrogeology of West Jefferson North Site dated September 14, 1990
6) Environmental Monitoring Plan- Columbus Closure Project dated June 2004

If you have any questions or comments please do not hesitate to call me at 614-424-4098.

Sincerely,

Joe Jacobsen
BCLDP Radiation Safety Officer

FEB 15 2005

SC-SP-004.1
Revision 1

# QUALITY ASSURANCE DOCUMENT

# PROCEDURE FOR WELL INSTALLATION AND WELL/BOREHOLE ABANDONMENT

BATTELLE
505 King Avenue
Columbus, Ohio 43201

MJS for S. Nelson
S. Nelson

September 5, 1989
Date

APPROVED BY

Michael J. Stenhouse 9/22/89
Date

APPROVED BY

9/25/89
Date

APPROVED BY

9/22/89
Date

APPROVED BY

9/29/89
Date

# DOCUMENT REVISION RECORD

Title Procedure for Well Installation and Well/Borehole Abandonment

No. SC-SP-004.1

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# PROCEDURE FOR WELL INSTALLATION AND WELL/BOREHOLE ABANDONMENT

## 1.0 Scope

This document describes the procedure for installing wells in boreholes and for abandoning wells or boreholes.

## 2.0 Purpose

The purpose of this procedure is to provide a method for performing well installations in support of drilling/coring operations. The procedure is primarily in support of soil characterization work in the Nuclear Sciences Area of Battelle's West Jefferson Site; however, it may be applied to other locations where soil characterization work is being performed. The major reason for installing wells is to obtain information from subsequent measurements relating to water levels and hydraulic conductivity. A method for abandoning wells/boreholes is also provided for restoration of the land surface and safety purposes.

## 3.0 References

3.1 Ohio Administrative Code 3745-9-10, Water Well Standards and Waivers.

## 4.0 General

### 4.1 Materials

4.1.1 Pipe casing, 2-inch Schedule 40 PVC, with suitable flush-threaded fittings. All connections will be flush-joint threaded.

4.1.2 Screen, 2-inch diameter PVC having 0.010-inch slots. The screen will be capped at the bottom.

4.1.3 Rounded sand or gravel, washed and bagged, with a grain-size distribution (U.S. Sieve Size) compatible with the screen and formation.

4.1.4 Bentonite, granulated or pelletized.

4.1.5 Cement grout; nominally 74 percent Portland Class A cement, 24 percent Pozzolan cement, and 2 percent bentonite.

## 5.0 Responsibilities

5.1 The hydrogeologist shall be responsible for the placement of wells, i.e. for determining which boreholes are to have a well installed.

5.2 The drilling subcontractor shall be suitably qualified in the installation of wells, as determined previously (during bid selection) by the hydrogeologist responsible for bid selection.

5.3 The Technical Project Manager shall determine which method to be used for each borehole.

## 6.0 Procedure

### 6.1 Well Casing Initial Installation

6.1.1 Place the screen and casing into the borehole.

NOTE: If borehole walls are found to be prone to slumping during well drilling, the hollow stem auger can be used as a temporary casing through which screens and casing can be run into the borehole.

6.1.2 Place the sand/gravel pack (Step 4.1.3) into the casing to fill the well from the bottom of the borehole to 1 foot above the top of the screen.

NOTE: If the water table is close to the land surface, the field hydrogeologist will reduce this quantity of sand/gravel pack above the screen so that no surface runoff will seep into the wells.

6.1.3 Tremie bentonite (Step 4.1.4) above the sand/gravel pack, to a minimum thickness of 3 feet.

6.1.4 Tremie-grout cement grout (Step 4.1.5) from above the bentonite seal to the land surface.

## 6.2 Completion of Well

### 6.2.1 METHOD 1

Casing Flush or Below the Land Surface (See Figure 1):

6.2.1.1 Set the casing 2 to 3 inches below land surface, using cement.

6.2.1.2 Complete the assembly with a protective steel casing, equipped with a locking lid.

6.2.1.3 Install protective housing consisting of a cast-iron valve box assembly centered in a 3-foot-diameter concrete pad sloped away from the valve box.

6.2.1.4 Maintain free drainage away from the well within the valve box.

6.2.1.5 Install a screw-type stainless steel cap with Teflon or Viton O-ring to prevent infiltration of surface water.

6.2.1.6 Maintain a minimum of 1 foot of clearance between the casing top and the bottom of the valve box lid.

### 6.2.2 METHOD 2

Above-Ground Surface Completion (See Figure 2):

6.2.2.1 Extend the well pipe approximately 2 feet above land surface.

6.2.2.2 If the well is located near a depression, lake, or creek with a history of flooding, install this extension (riser) higher than the flood stage.

6.2.2.3 Provide an aboveground stainless steel end-plug or casing cap.

6.2.2.4 Shield the above-ground pipe with a steel casing placed over the PVC pipe.

6.2.2.5 Seat all wells of this type in a 2-foot diameter by 4-inch thick concrete surface pad.

6.2.2.6 Slope the pad away from the well casing.

6.2.2.7 Install a lockable cap or lid on the steel casing.

6.2.2.8 If necessary (as determined by the Technical Project Manager), install 3-inch diameter steel guardposts for additional protection.

6.2.2.9 Install these guard posts about 5 feet high, radially from each wellhead, and recessed approximately 2 feet into the ground.

6.2.2.10 Paint the protective steel guard posts and clearly number the well on the lid exterior.

6.2.3 Provide locks for both flush and above ground well assemblies. Turn over lock keys to the Technical Project Manager following completion of the field sampling.

6.2.4 Develop all groundwater monitoring wells after installation. Prior to development, monitor water levels (to the nearest 0.01 inch) with respect to an established survey point at the top of the well casing.

6.2.5 Details of the well installation, including exact measurements, will be filled out on the Well Construction/Completion Report Sheet (DDO-125).

### 6.3 **Well/Borehole Abandonment**

6.3.1 Seal wells/boreholes according to the recommended procedure (Reference 4.3), using material impervious to migration of water in the hole or within the hole (i.e. grout).

## 7.0 Records

7.1 The QA records generated by the implementation of this procedure are completed and approved form DDO-125 and copies of quality affecting and relevant information entered in Laboratory Record Books.

## 8.0 Figures and Forms Referenced in This Procedure

### 8.1 Figures

8.1.1 Figure 1, Typical Monitoring Wall Construction - Below Ground Completion

8.1.2 Figure 2, Typical Wall Construction - Above Ground Completion

### 8.2 Forms

8.2.1 DDO-125, Well Construction/Completion Report Sheet

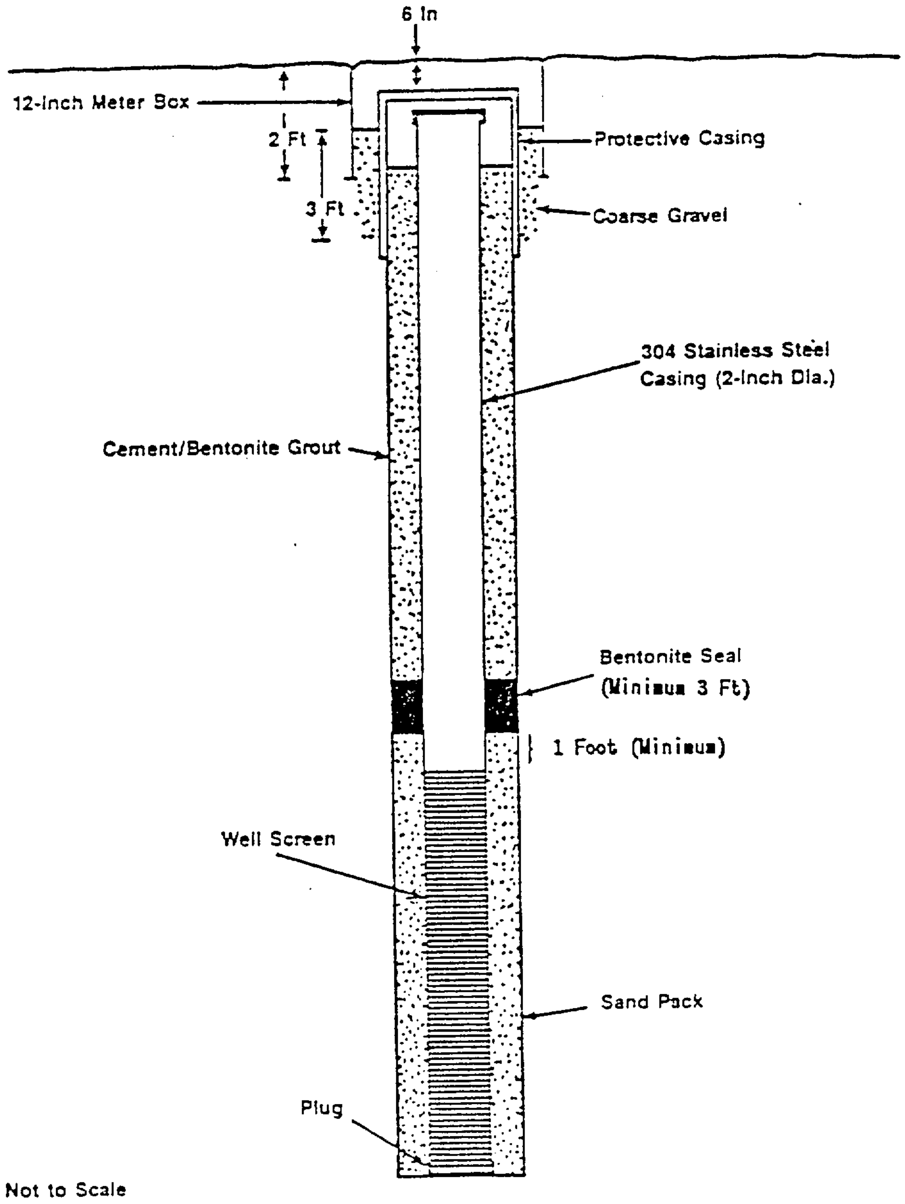

FIGURE 1. TYPICAL MONITORING WELL CONSTRUCTION - BELOW GROUND COMPLETION

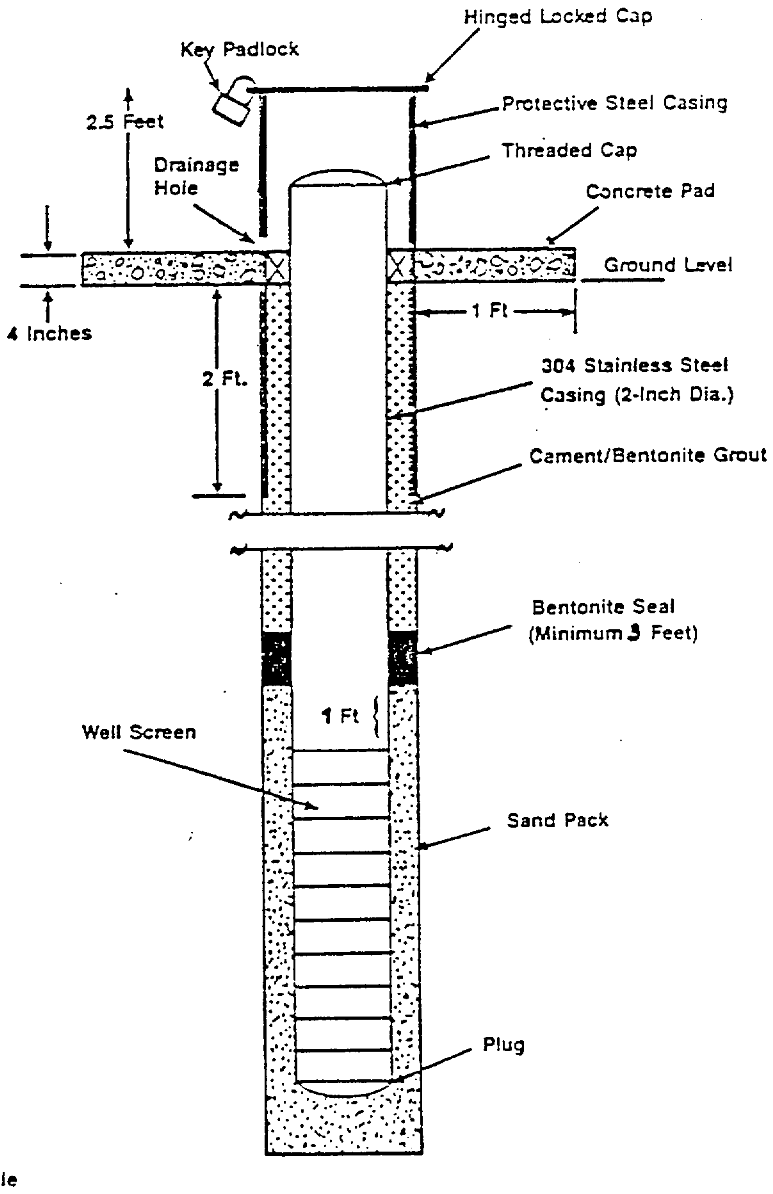

FIGURE 2. TYPICAL WELL CONSTRUCTION - ABOVE GROUND COMPLETION

# WELL CONSTRUCTION/COMPLETION REPORT SHEET

Sample Identification Code: _____-_____-_____-_____

Name of Site: ____________________

Well ID Number: ____________________

Drilling Location: ____________________
(Use Coordinates if Available)

Total Depth: ________ ft.

Drilling Contractor: ____________________

Type of Rig: ____________________

Date Installation Completed:

___ ___ ___ ___ ___ ___
(Y Y M M D D)

Observations of Monitoring Zone and Further Information:

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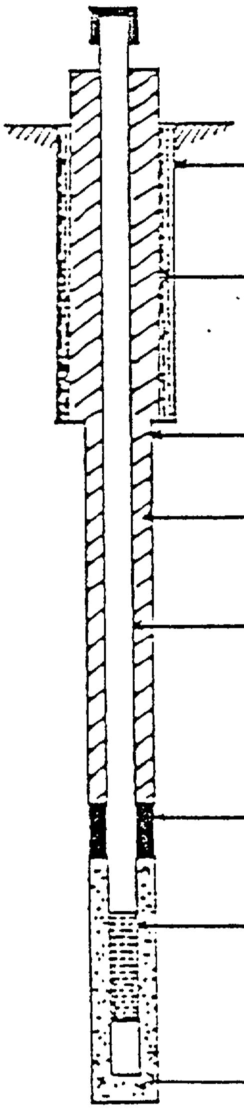

**Summary of Well Construction**

Well Cap Elevation: _____ ft.

Ground Surface Elevation: _______ ft.

Conductor Hole Dia.: ______ in.
_________ to _________ ft.

Surface Conductor
Type: ________________
ID: ______ in. OD: ______ in.
_________ to _________ ft.

Borehole Dia.: _______ in.
_________ to _________ ft.

Filler Material: ________________
_________ to _________ ft.

Casing (with screen)
Material: ________________
ID: ______ in. OD: ______ in.
_________ to _________ ft.

Seal Material: __________
_________ to _________ ft.

Screen Material: ______________
ID: ______ in. OD: ______ in.
_________ to _________ ft.
Slot Size: ______________

Pack
Type: _________ Size: _____
_________ to _________ ft.

Entered by: _____________, ________
(Signature) (Date)

Approved by: _____________, _______
(Signature) (Date)

WELL CONSTRUCTION/COMPLETION REPORT SHEET

J. Tholen

EM-QAP-2.0
Revision 0

# QUALITY ASSURANCE PLAN

for

# BATTELLE GROUNDWATER MONITORING

Battelle
505 King Avenue
Columbus, Ohio 43201

Prepared by

E.R. Swindall

June 18, 1990
Date

APPROVED BY

Louis Fadel 7/27/90
L. Fadel Date

Michael J. Stenhouse 8/2/90
M. J. Stenhouse Date

Harley L. Toy 8/2/90
H. L. Toy Date

E. Lozier 8/14/90
D. E. Lozier Date

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No. EM-QAP-2.0

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| Approval | KSR | | | | | | | | | |

# BATTELLE GROUNDWATER MONITORING

## INTRODUCTION

This plan specifically describes the quality assurance (QA) program for conducting environmental groundwater monitoring at the Battelle West Jefferson site (Figures 1 & 2) during the two phases of the Battelle Columbus Laboratories Decommissioning Project (BCLDP): surveillance and maintenance (S&M), and decontamination and decommissioning (D&D). It will be adopted as a subtier document under the Battelle Nuclear Quality Assurance (NQA) manual for the Decommissioning and Decontamination (DDO) Group. QA procedures and documents have been and will be developed and revised to provide the necessary planning, control, documentation, and safety for all activities associated with this effort.

The groundwater monitoring program is designed and will be implemented in accordance with monitoring requirements of 40 CFR Part 264, Subpart F, and 40 CFR Part 265, Subpart F. Monitoring for radionuclides shall be in accordance with DOE Orders in the 5400 series. The Task Leader of the Environmental Monitoring Group will coordinate this effort. This plan shall be reviewed annually and updated every three years until the contract expires. This plan was developed to be responsive to the requirements of DOE Order 5400.1, Chapter III, "General Environmental Protection Program", paragraph 4.a "Special Program Planning Requirements, Groundwater Protection Management Program, and the requirements of the groundwater monitoring plan pursuant to Chapter IV, paragraph 9 of DOE Order 5400.1, and all applicable DOE Orders of the 5400 series in addition to ANSI/ASME NQA-1 as listed below. Each applicable criteria is discussed in the sections that follow.

(1) Organization
(2) Quality Assurance Program
(4) Procurement Document Control
(5) Instructions, Procedures, and Drawings
(6) Document Control
(7) Control of Purchased Items and Services
(8) Identification and Control of Items
(10) Inspection
(11) Test Control
(12) Control of Measuring and Test Equipment
(13) Handling, Storage, and Shipping
(14) Inspection, Test and Operating Status
(15) Control of Nonconforming Items
(16) Corrective Action
(17) Records
(18) Audits

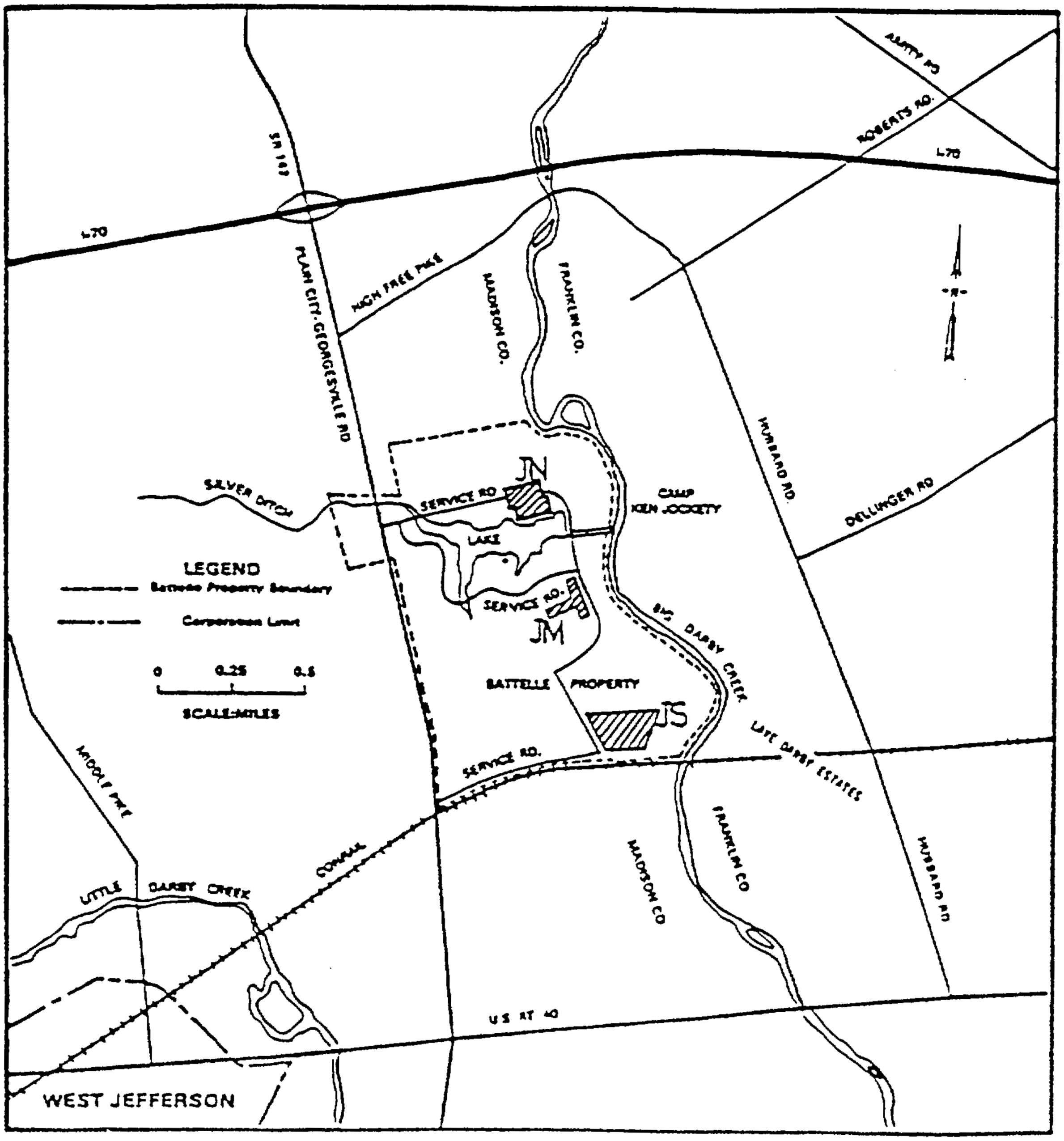


FIGURE 1. LOCAL VICINITY MAP OF WEST JEFFERSON SITE

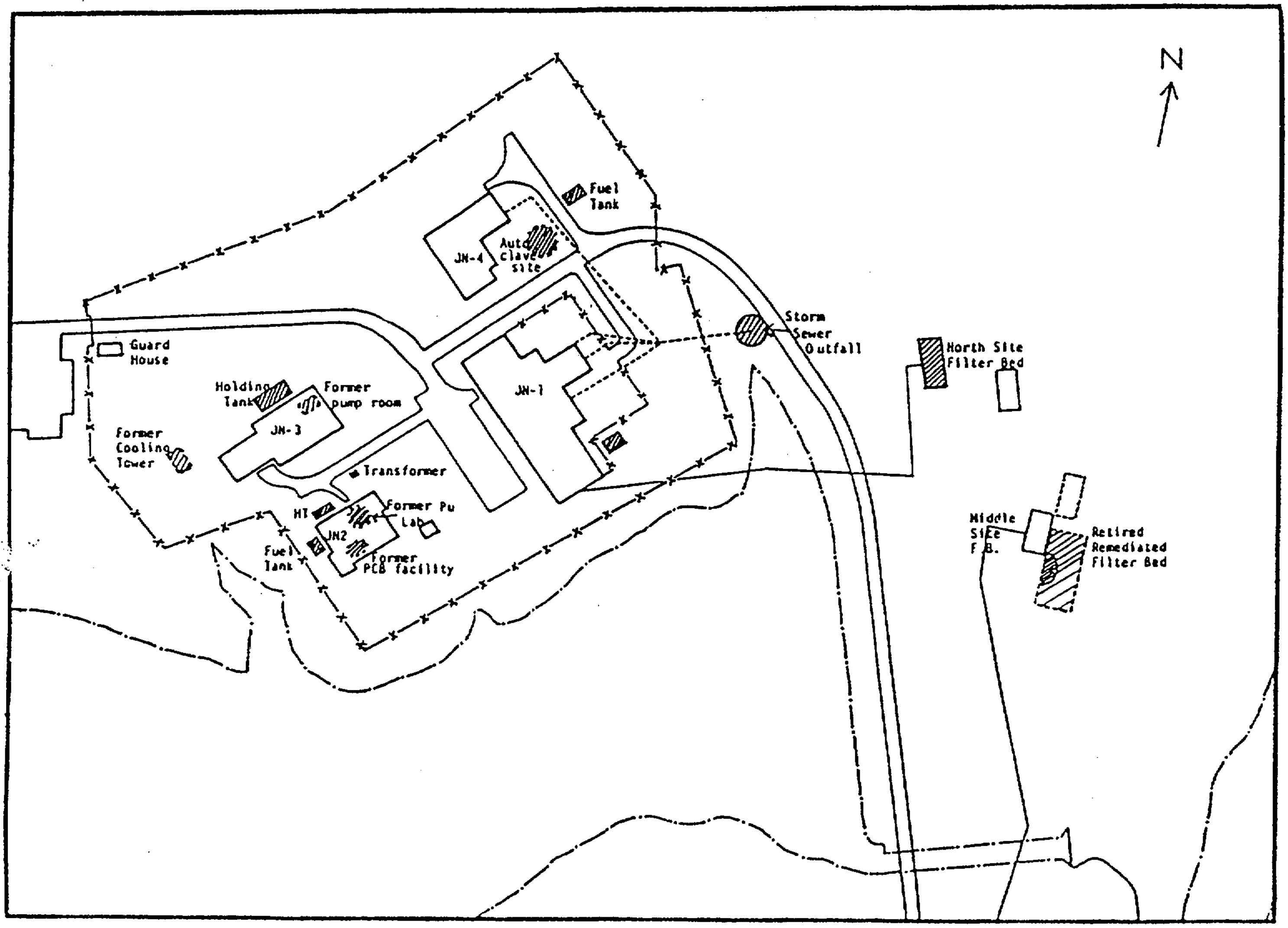


FIGURE 2. NUCLEAR SCIENCES AREA

Since no specific designs are being developed, and no special processes will be conducted during the sampling program, NQA-1 requirements (3) Design Control, and (9) Control of Processes and are not applicable to this project and are not addressed in this plan.

## 1.0 Organization

The organizational structure for Groundwater Monitoring is shown in Figure 3. The Environment, Health and Safety (ES&H) Manager, the QA Manager, and the Compliance Review Committee report directly to the BCLDP Project Manager. The Task Manager of the Radiological Environmental Monitoring Group reports directly to the ES&H Manager and is responsible for the day to day monitoring activities, equipment calibration, and review and evaluation of data generated. The Environmental Compliance Officer will assist in interpretation of data for compliance purposes.

## 2.0 Program

Battelle has done limited groundwater monitoring for radionuclides since the early 1970s. The area of concern has been an underground aquifer running in the vicinity of the nuclear fuel storage pool for the West Jefferson, JN-1 facility. Two monitoring wells were installed at the time the pool was put in. One well is a sump that collects condensate from the pool liner, while the other collects water from the aquifer on the down gradient side of the pool. Samples have been collected on a monthly basis. The samples have been analyzed for gross alpha and gross beta emitters, fission products and activation products. There has been no indication that the aquifer has become contaminated from the pool. This sampling schedule is expected to continue for at least three to six months after the pool is emptied of all water to assure that there are no leaks from the groundwater to the inside sump which would imply a leak in the pool liner that could yet allow transfer of radioactivity to the groundwater system.

Additional radiological groundwater monitoring is done at a former supply well (JN) for the West Jefferson Nuclear Sciences Area and from

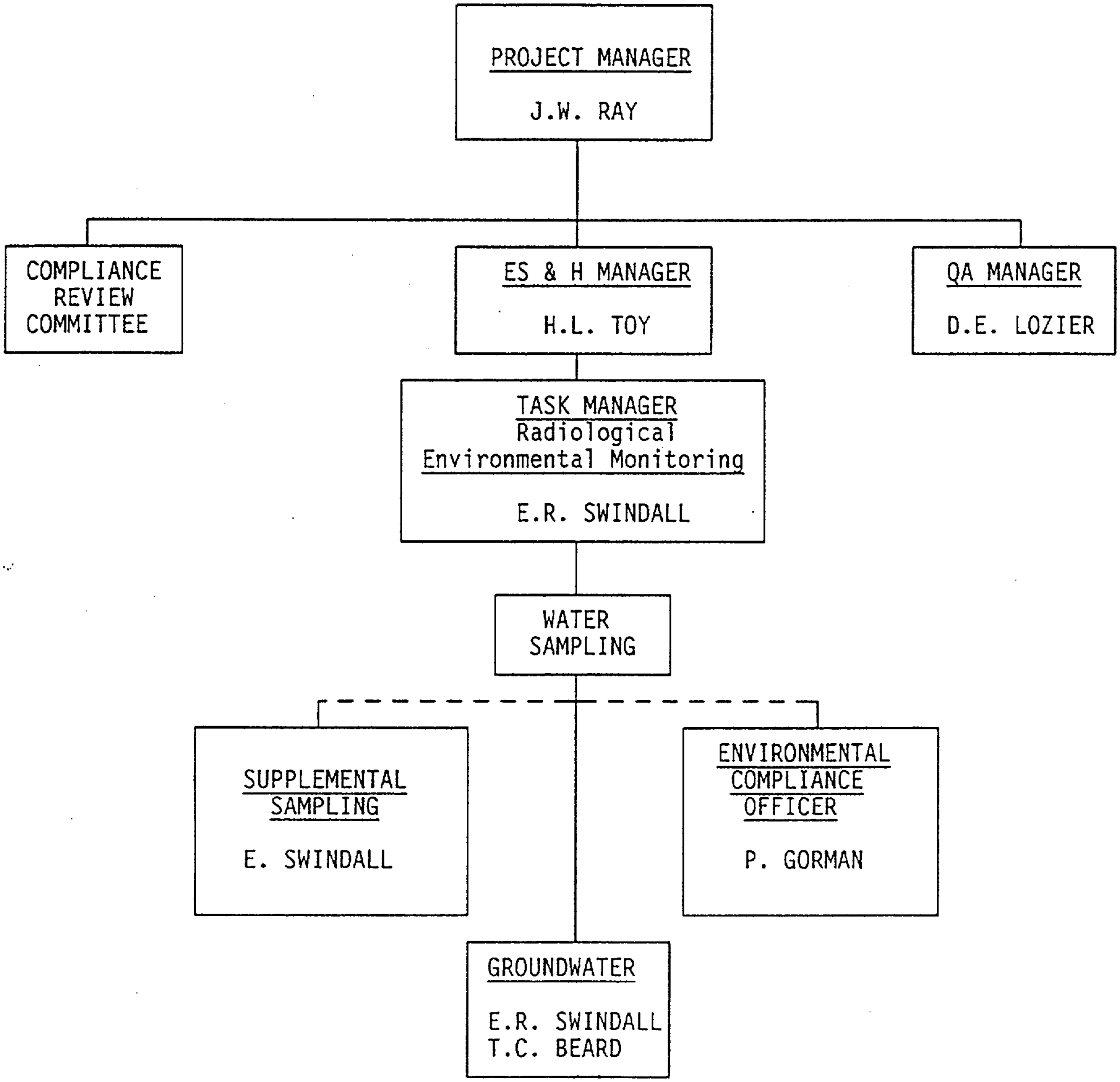


Figure 3. Organizational Structure for BCLDP Groundwater Monitoring

existing supply wells before the water is treated in any form. Samples that have been collected annually over the last five years have undergone the same analysis for gross alpha and gross beta emitters, fission products, and activation products. These wells continue to be sampled on a routine basis with additional chemical analysis of the JN well sample planned for volatile organic compounds. The Summary from the Interim Report on Site Characterization, West Jefferson North Site, Stage 1 Sampling and Analysis, Chemical Sampling Summary Report, December 22, 1989, has been modified to represent the current status of results and is presented here as the basis for the additional analysis.

## Summary

> A sampling and analysis program for chemical contaminants was performed in November 1989, at Battelle's Nuclear Sciences Area, West Jefferson Site, Ohio. A total of 32 sampling locations provided 29 soil and 3 groundwater samples for chemical analysis. During drilling operations, and the subsequent collection of soil cores, some hydrocarbon contamination of soil, assumed to be fuel oil, was observed around the three fuel storage tanks on site. Subsequent analysis of soil samples collected in these locations confirmed the presence of oil at levels of about 1300 ppm (JN-1), 1200-1500 ppm (JN-2), and 25-50 ppm (JN-4). Further characterization is underway. The EP Toxicity test for metals showed no concentrations above the RCRA limit of 1 ppm for most soil samples analyzed. PCBs were found in only one soil sample, taken close to the on-site transformer beside building JN-2, but at a ppb concentration, well below the action limit of 50 ppm. The only other contaminants, found at ppb concentrations in a few soil samples, were several volatile organic compounds, with acetone predominant. While the concentrations of these compounds are low-level, some additional sampling of soil in the storm-sewer outfall area is recommended in conjunction with the additional (Stage 2) sampling proposed for radiological purposes. No contamination was found in the groundwater samples collected.

In addition to the three chemical sampling wells, twelve shallow wells were installed around the West Jefferson North site as part of the site characterization and will be used for monitoring radionuclides. (See Figure 4.) A full hydrogeological study is expected to be completed in June, 1990, that will allow for the reduction of the number of radiological monitoring wells to six. The need for additional chemical monitoring wells in the vicinity of the fuel storage tanks is being evaluated and appropriate monitoring will be instituted.

Three of the shallow radiological monitoring wells, also installed as part of the site characterization, are located in and near two former filter beds that still shows traces of radioactive materials. The Summary mentioned above suggests the need for installing chemical wells in this area to identify any pockets of chemicals that may exist from a build up of chemicals that may have gotten into the drain over the life of the filter bed. Radiological monitoring will be performed on an annual basis using existing wells with routine chemical monitoring being added when the wells are completed.

Liquid effluents at Battelle's King Avenue site are discharged into the city sanitary sewer system. The discharge points are currently monitored under the Environmental Monitoring program. All electrical transformers are housed within the facility with secondary containment dikes. There has been no known waste disposal or treatment on site. As a result of these conditions, no groundwater sampling is planned for the King Avenue site.

The budgetary resources for this program are from the BCLDP operating funds which will have to be increased or another source found for installing additional wells and covering the cost of routine chemical sampling.

Supplemental environmental monitoring, done in support of groundwater monitoring, includes the routine sampling or monitoring of effluents from, and the collection of routine samples of surface water, soil, and biota in the environs of a facility. The data and information collected are assessed to determine the impact of the operations in the facility on the environs and persons present in the environs, and to provide guidance for adjusting the operations if the impact is inappropriate.

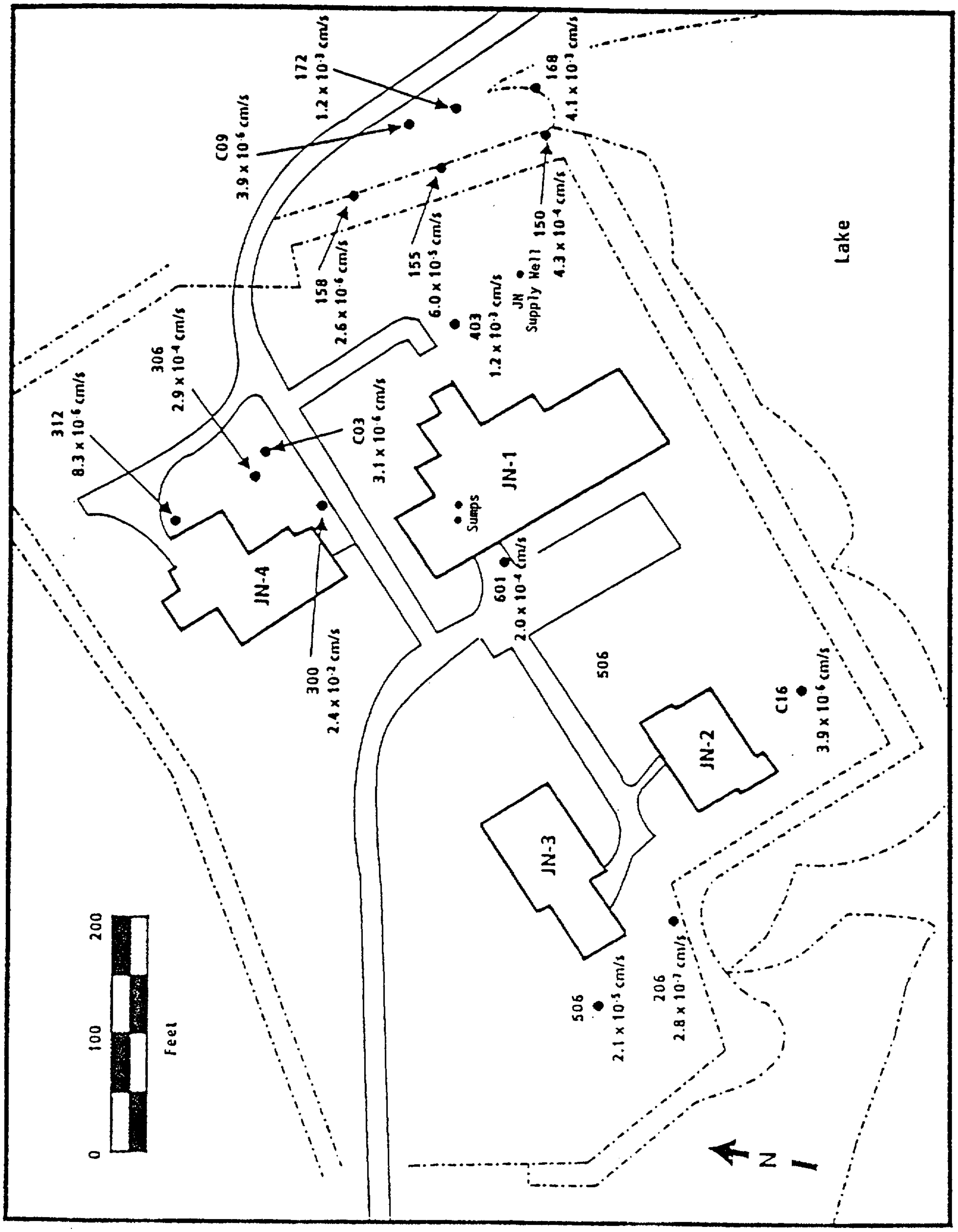


FIGURE 4. LOCATIONS OF GROUNDWATER MONITORING WELLS

**Objective:**

1. Ensure that appropriate media samples are analyzed and data correctly interpreted to determine the impact of elements, compounds and radionuclides to groundwater. The annual objective is the reporting and assessment of all data culminating in a formal report to DOE.

2. Maintain appropriate instrumentation and equipment in good repair and calibration to effectively collect and assess all sampled media.

**Work Statement:** Maintain the schedule of routine sampling, monitoring and analytical activities as provided in Appendix A and evaluate and perform additional sampling as determined necessary to adequately characterize the impact of operations on the environment.

## 4.0 Procurement

Procurement of items affecting quality of sampling shall be controlled through documents QA-AP-4.1. Procurements will be usually limited to replacement of worn or defective equipment from approved vendors.

## 5.0 Instructions, Procedures, and Drawings

Besides the application of ANSI/ASME NQA-1, the following groundwater monitoring procedure shall be used for routine monitoring, along with other procedures listed that may be used for supplemental sampling to identify potential hazards. Procedures and dates in parentheses indicate replacement procedures and the anticipated dates for completion of the replacement. Non-routine sampling shall be handled through work instruction as outlined in QA-AP-5.2.

| Procedure | Revision | Date | Title |
|---|---|---|---|
| ✓ SC-SP-012 | Rev. 0.1 | 05-30-90 | Collection of Groundwater Samples in Support of Site Groundwater Characterization |
| NS-NS-10.1<br>(EM-SP-009) | Rev. 0 | 07-07-81<br>(08-31-90) | Procedure for the Collection of Environmental Hazardous Chemical Samples |
| ✓ EM-SP-002 | Rev. 0.1 | 06-11-90 | Procedure for the Collection of Environmental Radiological Water Samples |
| NS-NS-11.1<br>(EM-SP-010) | Rev. 0 | 07-07-81<br>(08-31-90) | Procedure for the Collection of Environmental Hazardous Chemical Water Samples |
| ✓ NS-NS-12<br>(EM-SP-003) | Rev. 1 | 07-31-90<br>(08-31-90) | Procedure for the Collection of Environmental Radiological Soil Samples |
| ✓ NS-NS-13<br>(EM-SP-004) | Rev. 1 | 05-07-84<br>(08-31-90) | Procedure for the Collection of Environmental Vegetation Samples - Annual Grass |
| SC-SP-006 | Rev. 0 | 01-29-90 | Sampling of Sediment and Sludge in Ponds, Streams, Sumps and Closures |

## 6.0 Document Control

The following Project and QA program personnel or their designated alternates shall have the authority to approve quality documents:

- ES&H Manager
- Task Manager
- Health Physics Supervisor
- QA Manager
- Radiochem. Lab. Manager

All documents shall be controlled by the review, approval and issue of process document QA-AP-6.1. Document revision and operation under temporary procedure changes shall be accomplished as specified in QA-AP-6.1. Documents shall be controlled by distribution of a document index containing the current document revision, and by staff responsibility for possessing current documents.

## 7.0 Control of Purchased Items and Services

All project purchases other than routine supplies shall be reviewed by the QA Manager to determine if the purchase is a quality item based on the evaluation process described in QA-AP-4.1 and QA-AP-2.1. The QA organization personnel shall evaluate objective evidence of quality furnished by subcontractors to determine their suitability for placement on the approved suppliers list. Selection of quality-affecting subcontractors shall be made from records of past performance, incorporation on an approved suppliers list, and/or site visit evaluations, if necessary, as controlled by document QA-AP-7.1. The Project and QA organization may perform on-site surveys of the proposed subcontractor for acceptance on the approved suppliers list.

Procurements from time of order placement to receipt at Battelle shall be controlled by methods in QA-AP-7.2. The QA organization shall participate in the examination of all purchased quality items and services to determine their compliance to specifications of the purchase order. Approved inspection plans for items shall be drawn up in advance as specified in QA-AP-7.2 and QA-QP-10.1.

## 8.0 Identification and Control of Items

All specimens, samples or any items quality-related to the program shall be identified by an affixed identification designation and/or in documents traceable to the items. Routine samples shall use the appropriate sample identification found in appendix A, along with the date and time of sample collection. These samples are further identified in traceable documents and procedures. Non-routine sample identification shall be spell out in work instructions and identified in traceable documentation.

## 10.0 Inspections

Inspections for items shall be conducted in accordance with the requirements of QA-AP-10.1. The acceptance of items shall be documented and approved by the Task Manager or by higher management, as necessary and appropriate.

Spot surveillance of activities by observation by the QA Manager or his designee to assess their conformance with requirements and approved procedures. Any discrepancies noted shall be resolved with the Task Manager. Any noncompliance reports (NCRs), deficiency notices (DNs), and corrective action reports (CARs) shall be prepared, processed, and resolved in accordance with Sections 15 and 16 of this plan.

## 11.0 Test Control

Analytical testing activities will be performed to collect data from the groundwater samples. Radioanalytical activities performed at Battelle will be controlled, documented and evaluated under procedure EL-AP-1.0 and its associated testing procedures.

## 12.0 Control of Measuring and Test Equipment

**12.1** The following items of systems are quality-affecting but not directly data generating, and requiring calibration.

12.1.1 Teflon 1-1/2 inch bailer
12.1.2 Composite Water Sampling System
12.1.3 Radioanalytical Lab Counting Equipment
12.1.4 Chemical Analytical Lab
from approved vendors list

12.2 The equipment indicated in Section 12.1.3 shall be calibrated to a standard traceable to the National Institute of Standards and Technology (NIST), formerly NBS.

12.3 The re-calibration time sequence for the calibrated equipment should not exceed one year unless justification is documented.

## 13.0 Handling, Storage, and Shipping

The handling of all specimens, samples, and quality-related items shall be performed under controlled conditions predetermined to prevent damage, loss, minimize deterioration and assure safety. The storage of all specimens, samples, and quality-related items shall be implemented under controlled conditions predetermined to prevent damage, loss, minimize deterioration, and assure safety. The cleaning of all specimens, samples, and quality-related items shall be implemented under controlled conditions predetermined to prevent damage, loss, minimize deterioration, and assure safety. The packaging and shipping of all sample materials shall be implemented under controlled conditions predetermined to minimize loss, damage, and minimize deterioration.

## 14.0 Inspection, Test, and Operating Status

The status of inspection and test activities shall be documented in records traceable to the items and the items tagged or identified where possible to assure the tests or inspections are performed. All items not meeting the inspection or test specifications or allowable limits shall be marked and/or separated from the approved items to prevent their inadvertent use, transport or disposal. All samples containing contaminant radioactivity will be identified with appropriate radioactivity identification tag and segregated from uncontaminated material. All samples containing contaminant levels of chemicals will be identified with a chemical contamination tag and segregated from uncontaminated material.

## 15.0 Control of Nonconforming Items

All items or operations not meeting specifications or performed in accordance with approved procedures shall be documented on a nonconformance report. The nonconformance report shall be processed in accordance with procedure QA-AP-15.1.

## 16.0 Corrective Actions

All proposed corrective actions generated to resolve conditions adverse to quality shall be submitted to the NQA Manager for approval of the adequacy and time schedule of the action. Corrective actions shall conform to the requirements of procedure QA-AP-16.1. The cause of the adverse condition shall be determined, if possible, and corrective actions taken to preclude its recurrence. Follow-up action shall be taken by the program Technical Manager and Q.A. Manager to verify implementation and effectiveness of the corrective action.

## 17.0 Quality Assurance Records

Records which furnish documentary evidence of quality shall be specified, prepared, and maintained.

Specified records include, but are not limited to the following:

a. Maps identifying sampling locations
b. Sampler Record Book
c. Sample inventory
d. Technical procedures and data sheets
e. Calculation and analyses records
f. Reports
g. Q.A. Surveillance and Audit Records
h. Program correspondence

Records shall be made part of the BCLDP record management system and subject to all the requirements and restrictions of the system.

## 18.0 Audits

Audits shall be planned and implemented in accordance with procedure QA-AP-18.1. A pre-program audit is not required as this is a continuation of an existing program. Periodic audits will be conducted over the life of the program.

# APPENDIX A

## A-1

# ROUTINE ENVIRONMENTAL GROUNDWATER MONITORING SCHEDULE

This monitoring schedule describes the well identification, general location, sampling frequency, and the measurements to be made. Radiological measurements are to consist of gross alpha and gross beta-gamma measurements with isotopic analysis to be performed on samples that are five times the counting background.

Chemical sampling is to consist of any combination of the following parameters and analytical methods or other approved methods that will produce the same sensitivity or better.

## Analytical Methods

| | | |
|---|---|---|
| Volatile organic compounds | --- | SW-846 Method 8240 (GCMS) |
| Semi-volatile compounds | --- | SW-846 Method 8270 (GCMS) |
| Oil and grease | --- | SW-846 Method 423.1 (gravimetric) |
| Metals - EP Toxicity | --- | SW-846 Several Methods |
| PCBs | --- | SW-846 Method 8080 (GCMS) |
| pH | --- | SW-846 Method 150.1 (electrometric) |

Sample collection frequency is to be annually (A) unless otherwise specified.

A - Annually M - Monthly

A-2

# GROUNDWATER SAMPLING -WEST JEFFERSON LOCATION

## North Area West Jefferson Site

| WELL # | Location | Frequency | Measurements |
|---|---|---|---|
| 150 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| 155 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| 158 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| 168 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| 172 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| 206 | South of JN-3 | A | α, β (Diss/susp) |
| 300 | Southeast of JN-4 | A | α, β (Diss/susp) |
| 306 | East of JN-4 | A | α, β (Diss/susp) |
| 312 | Northeast of JN-4 | A | α, β (Diss/susp) |
| 403 | East of JN-1 | A | α, β (Diss/susp) |
| 506 | West of JN-3 | A | α, β (Diss/susp) |
| 601 | West of JN-1 | A | α, β (Diss/susp) |
| C03 | East of JN-4 | A | α, β (Diss/susp) |
| C09 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| C16 | Southeast of JN-2 | A | α, β (Diss/susp) |

## Remediated Filter Bed Area

| Well # | Location | Frequency | Measurements |
|---|---|---|---|
| 101 | East Side of Filter Bed | A | α, β (Diss/susp), and Chemical Sampling |
| 104 | Southeast of Filter Bed | A | α, β (Diss/susp), and Chemical Sampling |
| 110 | West Side of Filter Bed | A | α, β (Diss/susp), and Chemical Sampling |

A-3

## Supply Wells

| Well ID | Location | Frequency | Measurements |
|---|---|---|---|
| JN | Nuclear Science Area (Supply Well-Inactive) | A<br>M | $\alpha$, $\beta$ (Diss/susp), and Chemical Sampling |
| JM | West Jefferson Middle Area (Supply Well-Active) | A | $\alpha$, $\beta$ (Diss/susp) |
| JM-1 | West Jefferson Middle Area (Facility Well) | A | $\alpha$, $\beta$ (Diss/susp) |

BMI Memo

ILC Files Well WJ-1

(FORMERLY ROBERT C. SMITH & ASSOCIATES)

**FRED H. KLAER, JR. & ASSOCIATES**
CONSULTING GROUND-WATER GEOLOGISTS AND HYDROLOGISTS
16 LELAND AVENUE
COLUMBUS 14, OHIO

PHONE AMHERST 8-3316

April 2, 1963

Mr. C. T. Greenidge
Battelle Memorial Institute
505 King Avenue
Columbus 1, Ohio

Dear Mr. Greenidge:

<u>West Jefferson, Ohio.</u>

In accordance with our discussion on March 14, Mr. Don Kyser of this office met Mr. Glen Williams at the West Jefferson plant of Battelle Memorial Institute on March 15.

The non-pumping or static level in the south well (Layne No.1) was measured as 42.1' below the pump base. At the time the well was drilled in September 1954, the static level was reported by Layne as 41 feet. The apparent difference in static level is insignificant and suggests that there has been no serious regional decline in water levels during the past 9 years. It was not possible to measure the pumping level, because of the danger of flooding the basement. I believe this should be done, however, by making arrangements to waste water through several outlets within the building, if this can be worked out.

(#2)

The static water level in the north well was measured as 18.17 feet below the pump base. The static water level in April 1955, as reported by Layne was 18'5". This also shows that there has been no significant change in water levels in this area. The pumping level was measured as 39.22 feet below the pump base after 3 to 4 minutes of pumping. This is not particularly significant because of the short period of pumping.

At the present time both wells operate automatically for such short periods of time that it is impossible to get any true value for pumping level. It may be possible to make arrangements to waste water in some way, so that the pumps could operate for one-half to one hour without shutting off. This I believe should be investigated. It is obvious, however, that you are not fully utilizing the capacities of these wells.

We have plotted up the data on the south well provided to you in a letter report from Burgess and Niple, dated September 16, 1954. This indicates that the transmissibility of the limestone aquifer is about 16,500 gallons per day per foot. Assuming a coefficient of storage of 0.0001, which is reasonable for limestone aquifers, we estimate that this well could be pumped continuously at 250 gpm. for a period of a year without recharge, without lowering the pumping level below the pump intake.

Using the values assumed above, we have computed the cone of influence of the south well pumping continuously at 250 gallons per minute without recharge, a copy of which is attached. This indicates that pumping the south well continuously will lower the water level in the north well, about 3700 feet away, about 2.5 feet in 24 hrs., 6.4 feet in 10 days, 11.4 feet in 180 days and about 12.6 feet in one year. At the present time your pumping schedule is so infrequent that one well probably does not affect the other.

It is believed that the wells of West Jefferson are about 10,000 feet from the south well. The computed cone of influence graph shows that unless the pumping from the West Jefferson wells now reported as 200 - 300 gpm. increases considerably, it is unlikely that your wells will be seriously affected.

This diagram can be used to determine proper spacing for additional wells, depending on the rates and expected duration of pumping.

We will be glad to discuss this with you at your convenience.

Sincerely yours,

FRED H. KLAER, JR. & ASSOCIATES

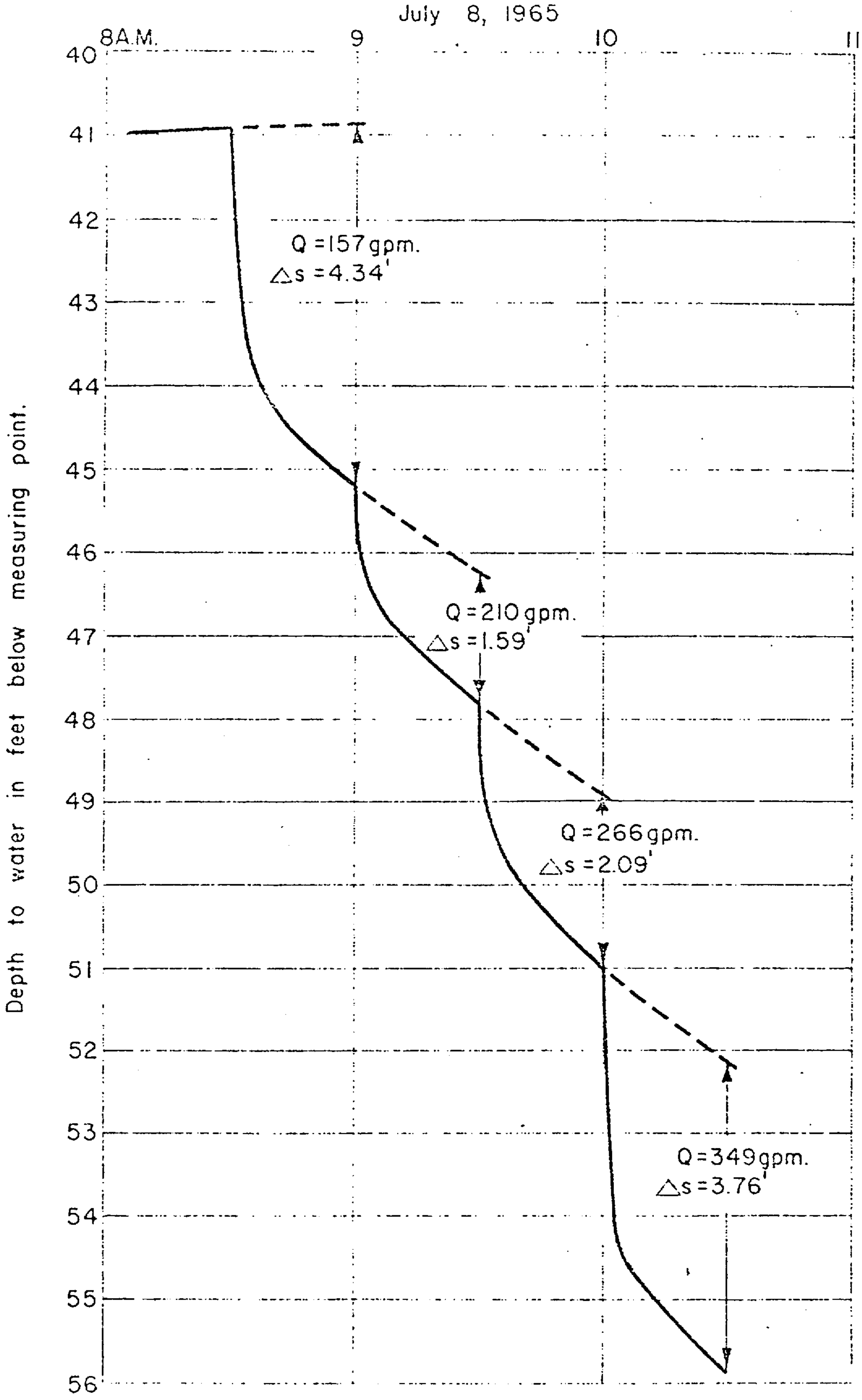
Fred H. Klaer Jr.

Fred H. Klaer, Jr.
Consulting Ground-Water Geologist
and Hydrologist.

FHKJr:eh

1-Encl.

MIDDLE WELL #3



*BATTELLE MEMORIAL INSTITUTE.*
WEST JEFFERSON, OHIO.

MULTIPLE STEP TEST OF WELL 3.

FRED H. KLAER JR & ASSOC.

(FORMERLY ROBERT C. SMITH & ASSOCIATES)

MIDDLE WELL #3

[illegible]

FRED H. KLAER, JR. & ASSOCIATES
CONSULTING GROUND-WATER GEOLOGISTS AND HYDROLOGISTS
16 LELAND AVENUE COLUMBUS, OHIO 43214
P.O. BOX 3496
PHONE AMHERST 8-3316

July 13, 1965.

Battelle Memorial Institute
505 King Avenue
Columbus, Ohio 43201

Attention: Mr. Daun Peterseim

<u>Well 3, West Jefferson, Ohio.</u>

Gentlemen,

In accordance with your instructions, we have followed closely the drilling of Well 3 near your proposed greenhouse site at your West Jefferson, Ohio, plant. The well was completed and tested during the week of July 6, 1965.

The driller's log of the well is reported as follows:

| | |
|---|---|
| 0 - 3 | topsoil |
| 3 - 5 | light brown clay |
| 5 - 48 | brown clay and gravel |
| 48 - 54 | gravel |
| 54 - 115 | light brown clay and gravel |
| 115 - 119 | gravel |
| 119 - 149 | brown lime rock |
| 149 - 152 | red clay |
| 152 - 161'9" | brown lime rock |
| 118'6" | pipe in hole |

Driller reports crevice in limestone at 141 feet.
Static water level, June 8, 1965, 40.92 feet below top of casing.

On June 8, 1965, a multiple step drawdown test was run to determine at what depths water was entering the well and to determine the well losses within the pumping well. The well was pumped at rates of 157, 210, 266, and 349 gpm. for periods of 30 minutes at each rate. Prior to the step test, the static water level was at a depth of 40.92 feet below the top of the casing. At the end of the test, the pumping level was at a depth of 55.87 feet. A hydrograph of the multiple step test is shown in an attached figure.

GROUND-WATER SUPPLIES • INVESTIGATIONS, ADVICE, REPORTS

MIDDLE WELL #3

During the step test, the pumping level at a rate of 349 gpm. was at a depth of 55.87 feet below the top of the casing. Since the casing extended to a depth of 118 feet, 6 inches, it was not possible to lower the water level below the casing to show where the water enters the well. Since the driller reported a crevice at a depth of 141 feet, we must assume that the major part of the water enters the well below a depth of 118 feet and probably at about 141 feet.

The well loss factor was computed to be 8.92 and the actual well loss at a pumping rate of 349 gpm. was 5.36 feet. This is not unreasonable for a limestone well and we believe the well is acceptable.

Some difficulty was encountered originally in developing the well to pump clear water. It was necessary to spend several days in developing. It was planned to use acid treatment to clear up the well. However, no acid was used in the well and the capacity was increased by surging and pumping. At a rate of 349 gpm. the water pumped was completely clear.

On June 9, 1965, a constant rate test was run. The well was pumped at a constant rate of 349 gpm. from 8:15 a.m. until 2:45 p.m., a total of 6-1/2 hours. The static water level at the start of the test was at a depth of 41.22 feet below the top of the casing and the pumping level at the end of the test was 62.75 feet, giving a total drawdown of 21.53 feet. The apparent specific capacity was about 16.2 gpm. per foot of drawdown.

The transmissibility of the limestone aquifer was determined as 9050 gallons per day per foot. This is somewhat lower than that computed from a pumping test on the south well of about 16,500 gpd. per ft., reported to Mr. Greenidge in our letter of April 2, 1963, based on a pumping test run by Burgess and Niple in September 1954.

Using a value of transmissibility of 9050 gpd. per ft. and a storage coefficient of 0.0001 (which is reasonable for the limestone aquifer in this area), the computed drawdown of a well pumping continuously at a rate of 500 gpm. for one year from ground water storage will be about 69.1 feet, plus 11 feet of well loss or a total of 80.1 feet. The total available drawdown will be the difference between the static water level of about 45 feet and the point where the water enters the well, say at 140 feet, giving a total drawdown of 95 feet. It is our opinion, therefore, that the safe capacity of the well is about 500 gpm. If it is necessary to pump the well at this rate the bottom of the pump intake should be set at a depth of 140 feet.

MIDDLE WELL #1

We will be glad to discuss the results of these tests you in more detail at your convenience.

Very truly yours,

FRED H. KLAER, JR. AND ASSOCIATES

Fred H. Klaer Jr.

Fred H. Klaer, Jr.
Consulting Ground-Water Geologist
and Hydrologist.

:eh

Layne-Ohio Co.

South WELL HOUSE

Jefferson Twp.
Madison Co.

# THE LAYNE OHIO COMPANY

COLUMBUS, OHIO

## LOG OF TEST WELL No. 1

For Battelle Institute City West Jefferson State Ohio

Location 3000 ft. east of Georgesville Road; north of ravine

Date Started 8-4-54 Date Finished

## FORMATIONS

| DEPTH TO TOP OF STRATUM | DEPTH TO BOTTOM OF STRATUM | THICKNESS OF STRATUM | STATIC WATER LEVEL | 1-HOUR BAILING TEST | | HOW FAR DID FORMATION HEAVE | FORMATION FOUND | REMARKS |
|---|---|---|---|---|---|---|---|---|
| | | | | AVERAGE G. P. M. | DRAWDOWN FEET | | | |
| 0' | 12' | 12' | | | | | Top soil | |
| 12 | 33 | 21 | | | | | Blue clay | |
| 33 | 38 | 5 | 24'7" | | | | Dirty gravel; a little water | |
| 38 | 60 | 22 | | | | | Blue clay | |
| 60 | 68 | 8 | 24'7" | | | | Dirty gravel | |
| 68 | 88 | 20 | | | | | Red clay | |
| 88 | 99 | 11 | | | | | Gray clay | |
| 99 | 103 | 4 | 41' | 103' of 12" pipe in hole<br>1' of 12" pipe above ground | | | Gravel | |
| 103 | 106 | 3 | 41' | Pumped 250 g.p.m. at 68'6"<br>pumping level after 12 hrs. | | | Yellow limestone | |
| 106 | 111 | 5 | | | | | Gray " | |
| 111 | 115 | 4 | | | | | Limestone; layers of clay | |
| 115 | 120 | 5 | | | | | Gray limestone | |
| 120 | 130 | 10 | 41' | | | | Limestone and clay | |
| 130 | 138 | 8 | | | | | Gray limestone | |

DRILLER Toledo Rogers

S-G P-897

(SKETCH OF LOCATION ON BACK OF THIS LOG SHEET)

# THE LAYNE OHIO COMPANY

COLUMBUS, OHIO

## LOG OF 12" ~~TEST~~ WELL No. 2

For Battelle Memorial Institute City West Jefferson State Ohio

Location

Date Started 3-16-55 Date Finished 4-8-55

## FORMATIONS

| DEPTH TO TOP OF STRATUM | DEPTH TO BOTTOM OF STRATUM | THICKNESS OF STRATUM | STATIC WATER LEVEL | 1-HOUR BAILING TEST | | HOW FAR DID FORMATION HEAVE | FORMATION FOUND | REMARKS |
|---|---|---|---|---|---|---|---|---|
| | | | | AVERAGE G. P. M. | DRAWDOWN FEET | | | |
| 0' | 6' | 6' | | | | | Yellow clay | |
| 6 | 7 | 1 | | | | | Sand and gravel | |
| 7 | 32 | 25 | | | | | Blue clay | |
| 32 | 34 | 2 | | | | | Sloppy sand | |
| 34 | 80 | 46 | | | | | Clay and gravel | |
| 80 | 98 | 18 | | | | | Brown clay | |
| 98 | 102 | 4 | 20'5" | | | | Red clay and soft rock | |
| 102 | 115 | 13 | | | | | Brown limestone | |
| 115 | 118 | 3 | | | | | Brown lime and clay | |
| 118 | 119 | 1 | | | | | Break | |
| 119 | 122 | 3 | | | | | Brown limestone | |
| 122 | 123 | 1 | 18'5" | | | | Break | |
| 123 | 128 | 5 | | | | | Brown lime | |
| 128 | 130 | 2 | | | | | Blue shale | |

DRILLER Andy Ego

MATERIAL: 107' of 12" pipe (extending 1'6" above ground)

PERMANENT LOG SHOWING WELL FORMATIONS AND CONSTRUCTION AND PUMPING EQUIPMENT WILL BE PREPARED AS SOON AS PUMPING EQUIPMENT IS INSTALLED.

(SKETCH OF LOCATION ON BACK OF THIS LOG SHEET)

S-G P-897

**ECC & E2 Closure Services, LLC**

# Environmental Monitoring Plan

## EM-AP-001

**Columbus Closure Project**
**June, 2004**

**Contract Number: DE-AC24-04OH20171**

*"A Path to Closure"*

# ECC & E2 Closure Services

## ENVIRONMENTAL MONITORING PLAN

EM-AP-001
Revision 0

## Columbus Closure Project
## Columbus, OH

**June, 2004**

| | |
|---|---|
| **Reviewed by Technical Manager** | 6-24-04<br>**Date** |
| **Approved by Project Manager** | 6/24/04<br>**Date** |
| **Approved by Site RSO** | 06/24/04<br>**Date** |
| David W. Garber<br>**Approved by QA Manager** | 6/24/04<br>**Date** |
| ✓ Keith D. Anderson<br>Signature Valid<br>Digitally signed by Keith D. Anderson<br>DN: cn=Keith D. Anderson, o=Environmental Chemical Corporation, c=US<br>Date: 2004.06.24 08:33:22 -0400<br>**Approved by Independent Oversight Manager** | 06/24/04<br>**Date** |

**Controlled Copy No:** ____

**Contract Number: DE-AC24-04OH20171**

CONTROLLED
COPY #1

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## 1.0 Purpose and Scope

### 1.1 An Environmental Monitoring Plan

The ECC & E2 Closure Services (Closure Services) Environmental Monitoring Plan (EMP) is developed to meet the requirements of Section C(4)(2)(B) of Contract DE-AC24-04OH20171 (the Contract) between Closure Services and the U.S. Department of Energy (DOE). Section C(4)(2)(B) requires Closure Services to provide an environmental monitoring program and annual report to demonstrate that all discharges and releases are in compliance with regulatory requirements. The environmental monitoring program includes collection of required samples from on-site and off-site locations to ensure that cross-contamination as a result of work activities has not occurred.

Closure Services recognizes and accepts within the boundaries of the Contract, the BMI background data, information and technical justification that formulates and describes environmental monitoring and surveillance during decontamination and decommissioning (D&D) activities at the West Jefferson North (WJN) facility in West Jefferson, Ohio. In turn, Closure Services has developed this plan to:

- Evaluate control measures for prevention of releases of radioactive materials to the environment;
- Characterize the nature and amount of any release;
- Assess the transport and fate of materials released in the environment;
- Estimate potential doses to the most probable receptors of the general public; and
- Ensure that regulatory, permit, and license conditions for the protection of the public and the environment.

BMI will periodically monitor non-radiological parameters according to the National Pollution Discharge Elimination System (NPDES), as reflected in the approval of Application No. OH0005461.

Closure Services will ensure that the number and frequency of selected sampling locations for the environmental monitoring activities effectively demonstrates compliance to the above listed parameters.

The EMP describes the direct measurement, collection, and analysis of various media by effluent monitoring and environmental surveillance. Closure Services staff perform effluent monitoring at potential points of release of radioactive materials or other regulated pollutants to the environment. Effluent monitoring includes routine monitoring of specific emission sources, general environmental surveillance of liquid and atmospheric media, and emergency response at the WJN. Section 1.2 of this plan details effluent monitoring activities.

Closure Services staff perform environmental surveillance by sampling and analyzing various media on and off the WJN facility. These include air, surface water, groundwater, grass, fish, food crop[s], sediment, and soil periodically collected and analyzed for radionuclides and chemicals of concern. Section 1.3 details environmental surveillance activities. Closure Services will report the results of the monitoring and the surveillance activities to the public in an annual Site Environmental Monitoring Report (SEMR).

The Closure Services Environmental Monitoring (EM) and Radioanalytical laboratory (RAL) administrative and operating procedures contain specific details for sampling and analytical activities.

## 1.2 Effluent Monitoring

Effluent monitoring is the collection and analysis of airborne and liquid effluents for the purpose of characterizing and quantifying contaminants, assessing the exposure of members of the public to radiation and chemical sources, providing a means to control effluents at or near the point of discharge, and demonstrating compliance with applicable government standards.

Potential liquid source terms include sprays and waste water from decontamination activities, out-flow from excavation areas, and laboratory drains. Decontamination operations will be conducted within areas constructed to control the release of decontamination liquids. Engineered controls include spray barriers and collection basins. Out-flow from excavations will be prevented by constructing barriers and pumping liquids into holding tanks. Collected liquids will be filtered, sampled, and verified as meeting the applicable NPDES limits as stated in the approved Application No. OH0005461, tested against the acceptance criteria of and transferred to a local publicly owned treatment works (POTW). Closure Services will ensure that the transfer is coordinated and communicated with the DOE and BMI.

Discharges from the RAL will be collected and transferred to the permitted BMI treatment works.

Stack air samplers will continuously monitor the exhaust stack emissions from the potential source contributors (i.e. JN-1, JN-2) to assess the effectiveness of the systems controlling airborne emissions. Once the source term is removed from the buildings, the stack monitors will be disabled and this requirement will be closed out. Dust suppression will be implemented and supplemental air monitoring will be conducted during demolition of structures.

## 1.3 Environmental Surveillance

Environmental surveillance is the collection and analysis of samples, or direct measurement, of air, water, soil, foodstuffs, biota, and other media from the sites and their environs to determine compliance with applicable standards and permit requirements and to assess the radiation and chemical exposure of members of the public and its effect, if any, on the local environment.

Closure Services will conduct continuous air monitoring to evaluate the impact of releases of radioactive and hazardous substances to the general public and the environment. A comprehensive air monitoring program is important as air is the primary exposure pathway to the general public during the D&D activities. Releases to the air may also lead to the deposition of particulates in the environment. As such, the environmental surveillance activities include other pathways that may result in contributing dose due to transfer or uptake of particulate contamination.

## 1.4 Radiation Protection and Environmental Standards, Recommendations, and Guidance

Normally, "radiation protection standards, recommendations, and guidance[1]" are defined separately from other "environmental standards, recommendations, and guidances." Radiation protection standards specify limits on exposure that are regarded as necessary for protection of public health and should be met, except in the case of accidents or emergencies, regardless of cost. As used in this document, the terms "radiation protection standards, recommendations, or guidance" refer to standards, recommendations, or guidance that are generally applicable to all sources of exposure, exclusive of natural background radiation and deliberate medical practices.

The term "environmental radiation standards or guidance" specifies limits on exposure for particular practices or sources. Most "environmental radiation standards and guidances" are judgmental and are based on the "as low as reasonably achievable" (ALARA) principle. The one exception is the U.S. Environmental Protection Agency (EPA) standard for airborne radionuclide emissions in 40 CFR Part 61, which is based on limits on lifetime risk for maximally exposed individuals and average individuals in large population groups.

Environmental monitoring standards are defined primarily by the EPA, the Occupational Safety and Health Administration, and associated state agencies. These standards are detailed in applicable sections of 40 CFR and 29 CFR pursuant to regulations promulgated under the Clean Water Act, Clean Air Act, Safe Drinking Water Act, Resource Conservation and Recovery Act, and the Occupational Safety and Health Act (see Table 1). Table 1 lists the federal and state environmental statutes and regulations that provide guidance for conducting environmental monitoring. The listed guidance does not necessarily establish the compliance basis for conducting the D&D activities.

**Table 1. Federal and State Environmental Statutes & Regulations Guidance**

| Regulator | Regulation | Description | Compliance Status |
|---|---|---|---|
| Council for Env. Quality/DOE | National Environmental Policy Act | Federal agencies must follow prescribed process to evaluate impacts on the environmental of major federal actions and alternatives. | Activities consistent with the existing BCLDP Environmental Assessment and Finding of No Significant Impact. |
| EPA | Resource Conservation & Recovery Act | Governs the generation, storage, handling and disposal of hazardous waste. | RCRA compliance is the responsibility of Closure Services Waste Management Group, large generator operating under 90-day storage limitations. |
| EPA | Clean Air Act | Regulates the release of air pollutants through the use of permits and air quality limits | Administered in Ohio by the OEPA |
| EPA | Clean Water Act | Seeks to improve the quality of surface waters by implementing a permitting program and establishing water quality standards. | Administered in Ohio by the OEPA |
| EPA | Safe Drinking Water Act | Establishes minimum drinking water standards and monitoring requirements | Administered in Ohio by the OEPA |
| EPA | Toxic Substance Control Act | Regulates the manufacture, use and distribution of all chemicals | Administered by the USEPA |
| US Fish & Wildlife Service | Endangered Species Act | Establishes threatened and endangered categories of wildlife and provides protection for critical habitats. | The State of Ohio lists 5 species of fish (including 1 federal endangered) and 8 species of mollusks (including 2 federal endangered) identified along Big Darby Creek. |
| NPS | Federal Wild & Scenic Rivers Act | Provides preservation of wild and scenic free-flow rivers in their natural condition. | The Big Darby Creek has been designated as a component of the National Wild & Scenic Rivers system. CCP activities are not subject as there is no affect the free flowing nature of the Big Darby Creek. |
| Advisory Council on Historic Preservation | National Historic Preservation Act | Identifies, evaluates, and protects historic properties eligible for listing in the National Register of Historic Places. | WJN facilities not eligible for inclusion into the national Register of Historic Places. |
| EPA | Federal Insecticide, Fungicide, & Rodenticide Act | Governs the manufacture, use, storage, and disposal of pesticides and herbicides, as well as pesticide containers and residues | This act is not applicable to CCP. Pesticides used in CCP areas are USEPA registered and purchased from a registered establishment. |
| EPA | Superfund Amendments and Reauthorization Act, Title III | Requires reporting of emergency planning information, hazardous chemical inventories, and environmental releases to federal, state and local authorities. | Closure Services reports under EPCRA 311-312: Material Safety Data Sheet/Chemical Inventory. |
| DOE | Executive Order 11990, Protection of Wetlands | Established to mitigate adverse effects to wetlands and to avoid construction in wetlands. | CCP operations should not impact any wetland areas. |

## 2.0 Environmental Monitoring Guidance

Numerous government orders, standards, guidance, and criteria influence an EMP. They determine the content and form of an EMP, and they also influence its intent. In addition, documents published by the American National Standards Institute (NSI) and the American Society of Mechanical Engineers (ASME) describe specific radiation instrument standards and support certain aspects of the EMP, specifically quality assurance.

## 2.1 Nuclear Regulatory Commission Rules and Guidance

### 2.1.1 NUREG/CR-5212, Emergency Environmental Sampling and Analysis for Radioactive Material Facilities.

NUREG/CR-5212[2] provides information that could be used in an environmental sampling and analysis program for emergency or non-routine events. Sample collection and measurement locations, sample collection procedures, and quality assurance programs are applicable to this project.

### 2.1.2 10 CFR Part 20, Subpart D, Radiation Dose Limits for Individual Members of the Public.

10 CFR Part 20, Subpart D[3,a] establishes radiation dose limits for the public.

## 2.2 American Society of Mechanical Engineers (ASME) and American National Standard Institute (ANSI

### 2.2.1 ASME NQA-1a, Quality Assurance Program Requirements for Nuclear Facilities.

The Closure Services Quality Assurance Plan is based, in part, the requirements of ASME NQA-1a[4]. This EMP has been prepared in accordance with the Closure Services Quality Assurance Plan and implementing procedures.

### 2.2.2 ANSI N42.18-1974, Specifications and Performance of Onsite Instrumentation for Continuously Monitoring Radioactivity in Effluents.

ANSI N42.18-1974[5] applies to continuous monitors that measure normal releases, detect inadvertent releases, show general trends, and annunciate radiation levels that have exceeded predetermined values.

## 2.3 Environmental Protection Agency

### 2.3.1 EPA Standards in 40 CFR Part 61, National Emission Standards for Hazardous Air Pollutants.

40 CFR Part 61[6] establishes limited on the annual effective dose equivalent for DOE facilities emitting any radionuclide, other than radon, and other pollutants, except disposal facilities.

### 2.3.2 40 CFR Part 141 EPA Standards for Community Drinking Water Systems

40 CFR Part 141[1] applies 1) to public or private water systems with at least 15 service connections or serving at least 25 persons and 2) at the tap rather than at the source.

### 2.3.3 Ohio Environmental Protection Agency

The Ohio EPA has established discharge limitations as part of its National Pollutant Discharge Elimination System (NPDES) permit for the West Jefferson facility. The discharge limitations are based on daily and monthly concentration and loading factors.

In addition, the Ohio EPA has established maximum contaminant levels for inorganic chemicals and microbiological contaminants which must be met at the West Jefferson facility. The facility operates as a non-transient, non-community water supply.

## 2.4 Legislative Acts

### 2.4.1 Endangered Species Act

Closure Services recognizes the importance of wildlife. Sampling procedures specify that care should be taken to avoid the collection of any endangered species. Any wildlife species that are inadvertently captured during sample collection along Big Darby Creek are to be released.

At the WJN Site, the following endangered species have been identified:

*Endangered Fish*

- Goldeye (Hiodan alosoides)
- Northern Brook Lamprey (Ichthyomyzon fossor)
- Northern Madtom (Noturus stigmosus)
- Scioto Madtom (Noturus trautmani) (also federal endangered)
- Spotted Darter (Etheostoma maculatum)

*Endangered Mollusks*

- Clubshell (Pleurobema clava) (also federal endangered)
- Elephant-ear (Elliptio crassiens)
- Northern riffleshell (Epioblasma torulosa rangiana) also federal endangered)
- Pocketbook (Lapsilis ovata)
- Rabbitsfoot (Quadrula cyclindrical)
- Rayed Bean (Villosa fabalis)
- Snuffbox (Epioblasma trquertra)
- Washboard (Megalonaias nervosa)

### 2.4.2 Federal Wild and Scenic Rivers Act

The Big Darby Creek was designated as a component of the National Wild and Scenic River System in 1994. At the present time, Closure Services activities are not subject to the requirements under this act, because they do not affect the free-flowing nature of the big Darby Creek. Additional state or local requirements may be implemented in the future.

## 2.5 DOE

Closure Services has considered the guidance as provided in DOE/EH-0173T, Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance, in developing the EMP.

## 2.6 EPA

The EMP will use airborne effluent monitoring and environmental surveillance sampling and analyses techniques to meet the requirements of EPA's National Emission Standards for Hazardous Air Pollutants[6], as well as NRC's 10 CFR Part 20, Appendix B.[7]

## 2.7 Non-Radiological Monitoring

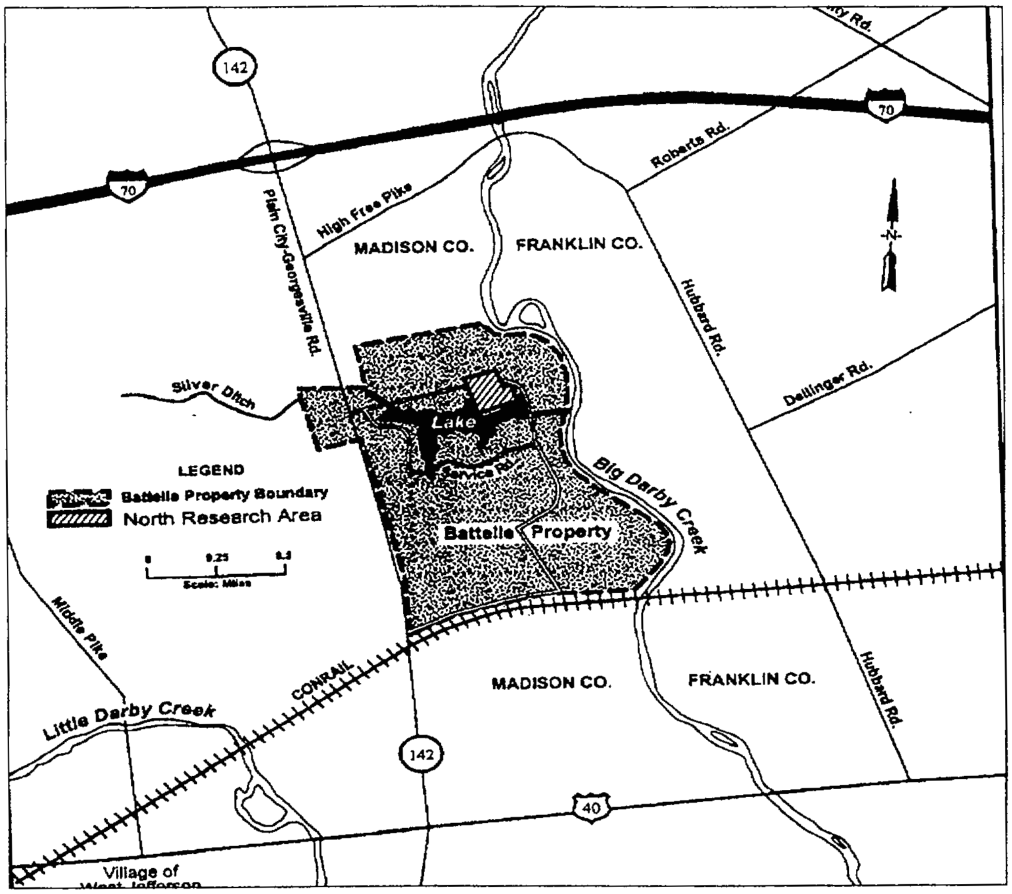
The criteria for the non-radiological monitoring are based on U.S. EPA, Ohio EPA, and DOE protocol and programs established by and conducted by BMI.

## 3.0 The Technical Basis for the Columbus Closure Project Environmental Monitoring Plan

Closure Services has reviewed the technical basis established by BMI for the environmental monitoring program. Closure Services does not intend to modify monitoring well location and frequency as each have been accepted by the regulators of concern. Perimeter air sampling location and frequency will remain as established by previous BMI activities. Closure Services will modify the external exposure monitoring locations to reflect currently planned site activities and the significant reduction in the source term at WJN. Closure Services intends to further modify locations and frequency of environmental monitoring and surveillance locations as D&D activities progress and the source term is removed from the site.

Figure 1 shows the WJN facility in relation to the surrounding vicinity. Closure Services monitoring protocol to best detect planned and unplanned releases of radionuclides and chemicals of concern, consistent with the potential for offsite impact due to planned activities and remaining source terms. The following sections detail planned activities and probable impacts to the health and safety of the general public and the environment.

Figure 1. Local Vicinity Map of North Research Area – West Jefferson Site



## 3.1 Present Decommissioning Activities

Closure Services is completing the remaining D&D activities at the WJN facility. Radioactive contamination remaining within Building JN-1, JN-2, and JN-3 consists of mixed fission products, activation products, uranium, thorium and suspect transuranics.[8] Special nuclear materials have been removed from JN-1, packaged for off-site transport, and placed onto the holding pad west of JN-4. Residual radioactive contamination in the form of dust/fragment deposits remain on the surfaces of the hot cells, hot cell equipment, and on materials stored in barrels (see Table 2). All operational materials, special nuclear materials, and stored operational wastes were removed during the phase-out of operations in the buildings.

**Table 2. Radiological Significance of West Jefferson North Buildings**

| Building | Major Survey Results |
|---|---|
| JN-1 | Interior of hot cells and storage rooms highly contaminated with fission products; fixed contamination along exterior surfaces of the mezzanine, top of HEC, other rooms, and sumps. Metal boxes and barrels of highly contaminated waste in an attached Waste Storage Building. |
| JN-2 | No significant surface contamination; a few spots of fixed contamination in the high bay and in the Radioanalytical Laboratory |
| JN-3 | No significant surface contamination; fixed contamination throughout. Currently, the only licensed activity conducted in JN-3 is for the storage of waste awaiting shipment for burial. |

### 3.1.1 Decontamination and Decommissioning Activities

The approach for decommissioning these facilities is to decontaminate and remove radioactive or contaminated (PCB or asbestos) facilities, equipment, materials, fluids and/or soil from the site to permit reuse of the property. For the facilities in question, this will generally involve dismantling and/or removing equipment, decontaminating building structures, demolishing the buildings, and removing and disposing of contaminated soil as a low-level radioactive waste.

## 3.2 Potential Source Terms

### 3.2.1 West Jefferson Site – Airborne Releases

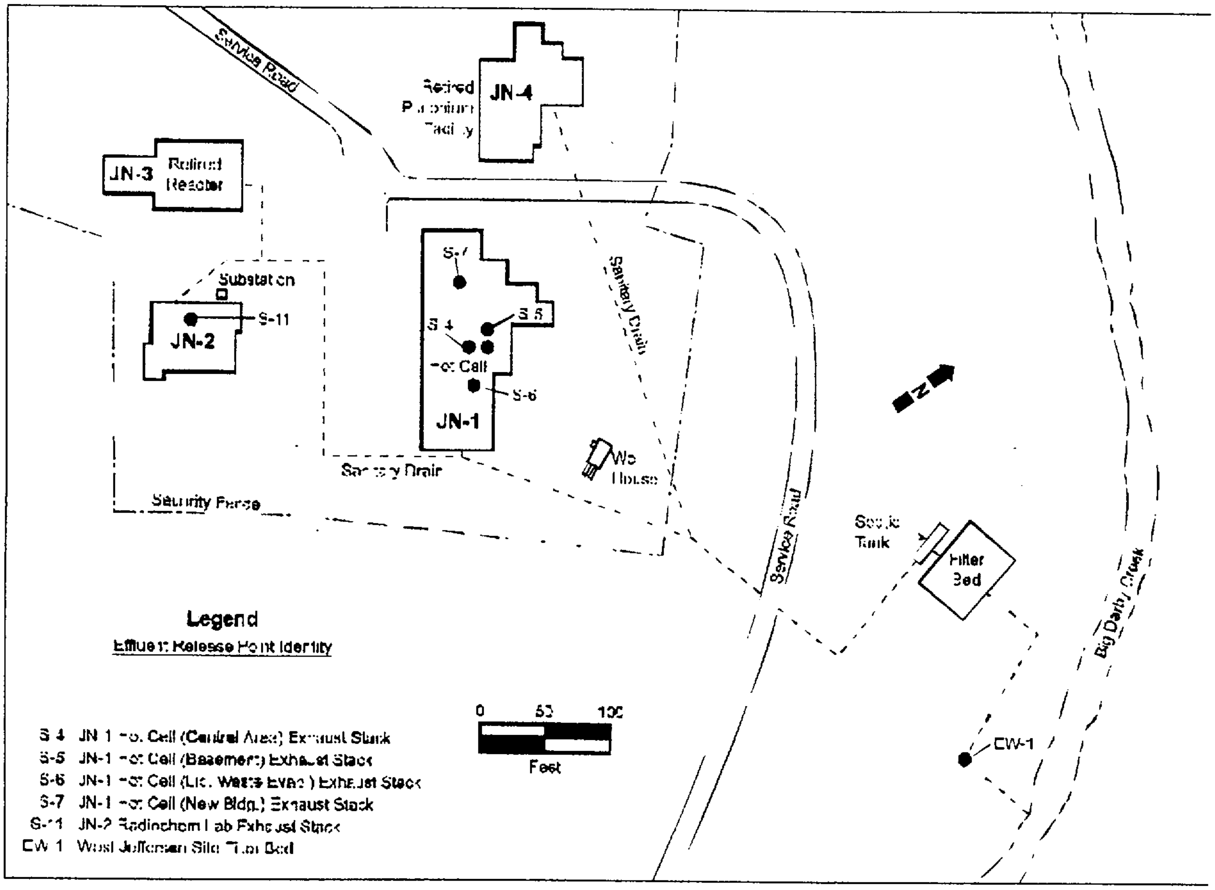
The primary potential source of airborne releases for the West Jefferson site is residual radioactive contamination from destructive and on-destructive testing conducted in several cells throughout the JN-1 Hot Cell Laboratory.[8]

### 3.2.2 West Jefferson Site – Liquid Effluent Discharges

Following treatment, all sanitary systems for the West Jefferson North and Middle sites have a common discharge point (EW-1) to Big Darby Creek. Potential liquid source terms include sprays and waste water from decontamination activities, out-flow from excavation areas, and laboratory drains. See Figure 2 for the location.

Decontamination operations will be conducted within areas constructed to control the release of decontamination liquids. Engineered controls include spray barriers and collection basins. Out-flow from excavations will be prevented by constructing barriers and pumping liquids into holding tanks. Collected liquids will be filtered, sampled, and verified as meeting the applicable NPDES limits as stated in the approved Application No. OH0005461. Discharges from the RAL will be collected and transferred to the permitted BMI treatment works.

Figure 2. North Research Area – West Jefferson North



### 3.2.3 West Jefferson Site – Soil Contamination

The WJN has several general areas of soil with elevated levels of residual radioactive contamination. One area is a storm sewer outfall (SS-JN-1-4) that collects storm water runoff from the roofs of buildings JN-1 and JN-4 and surface drains at the West Jefferson North Research Area. Outfall SS-JN-1-4 was remediated in 1994 and is routinely sampled as part of the ongoing site environmental monitoring program (see sediment sampling station ED-1 in Figure 3). This outfall remains active and will not be submitted for free release until after the demolition of JN-1.

Figure 3. Map of Site Air, Water, Sediment, and Sampling Locations

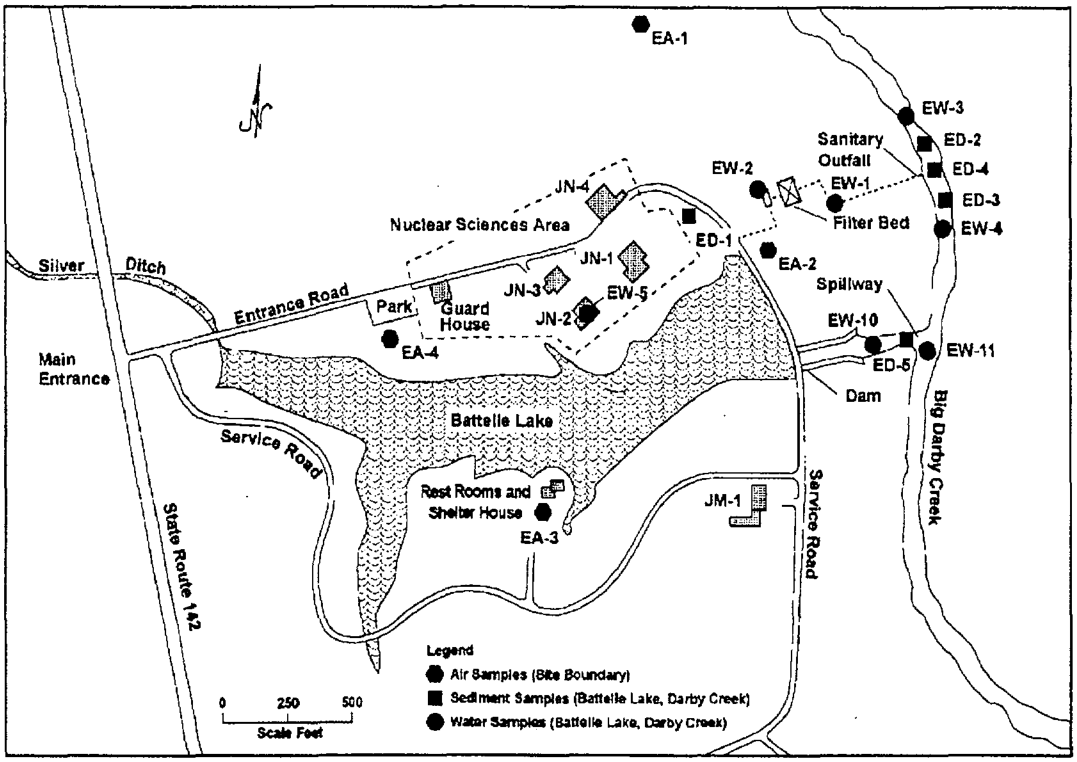


Table 3 details the concentrations of Cs-137, Co-60, and Am-241 contained in two filter beds, constructed as a secondary control to filter particulates from the wastewater effluent at the WJN facility. The 10-foot deep beds are located between the dam service road and Big Darby Creek. The total volume of soil in the filter beds is less than 2,300 m$^3$ (81,000 ft$^3$). Data from samples collected during 2000 and 2002 indicate concentrations of Cs-137 in the large bed (105 by 60 feet) range from 0.3 to 205 pCi/g, while those in the small bed (75 by 35 feet) range from 0.2 to 25 pCi/g. The maximum concentrations were measured near the surface of the filter beds. Subsequent sampling conducting after 2002 support the contamination levels at approximately the same order of magnitude as previous sampling events. The filter beds are located inside the flood plain of the Big Darby creek. Date presented in Table 3 shows that the contamination is presently immobile. Groundwater monitoring in the vicinity of the filter beds showed no release of radioactivity outside the filter beds.

An additional area of concern is subsurface contamination, located within the confines of the north site perimeter fence, about 75 feet east of JN-4.

Table 3. Radionuclides in Media of Filter Beds (Historical Data – 1988)

| Radionuclides[a] | Large Filter Bed[b] (pCi/g) | Small Filter Bed[c] (pCi/g) | Activity of Both Beds (Ci x $10^{-4}$) | CERCLA Reportable Quantity (Ci) |
|---|---|---|---|---|
| | Maximum Concentration | Maximum Concentration | | |
| Cs-137 | 223 | 32 | 5.5 | 1 |
| Co-60 | 1.3 | 0.6 | 10.1 | 10 |
| Am-241 | 7.6 | 0.5 | 10.6 | 0.01 |

[a] Filter beds, located between the service road to JN-4 and Big Darby Creek were constructed as a secondary control to filter particulates from sanitary sewer effluent water for 20 years. In 1980, portions of bed media were removed, and clean sand was backfilled and blended with remaining filter media in 1982 and covered with soil.

[b] Approximately 105 by 60 by 10 feet deep.

[c] Approximately 75 by 35 by 10 feet deep.

### 3.2.4 West Jefferson Site – Ground Water

*Ground Water Monitoring Requirements*

The ground water sampling program is designed generally in accordance with Ohio Administrative Code (OAC) 3745-54-92, *Ground Water Protection Standard.* Although the north area is not regulated by this standard at the present time, the rationale for ground water monitoring will be applied.

*Radiological Ground Water Monitoring*

Routine collection of ground water samples for radiological and chemical analysis has been conducted at the WJN facility at 18 shallow monitoring wells (generally 9 to 35 feet deep) and at three drinking water supply wells (only one of which is in the North Area) at least annually since 1989. See Figures 3 and 4 for well locations, and Table 4 for monitoring data for the North Area. The focus of the Closure Services EMP concerns groundwater monitoring within the project boundary of the WJN facility.

– Of the 18 monitoring wells, the highest activities are shown in wells 101, 103, 110, and 118 where radioactivity remains in a former filter bed. The highest combined alpha and beta activity is in well 110. This area has been recommended for further remediation in the Final *Assessment of the Radiological Status of Battelle's Nuclear Sciences Area*, dated January 1991.[9] Concentrations of radionuclides in the filter beds are summarized in Table 3. Wells C09, 168, and 172 are located to the east of the Nuclear Sciences are near the sewer outfall, where Cs-137, Co-60, Am-241, and Pu-239/240 have been measured. Wells 206 and 506 are located to the south and west of JN-3.

Figure 4. North Site Ground Water Monitoring Wells

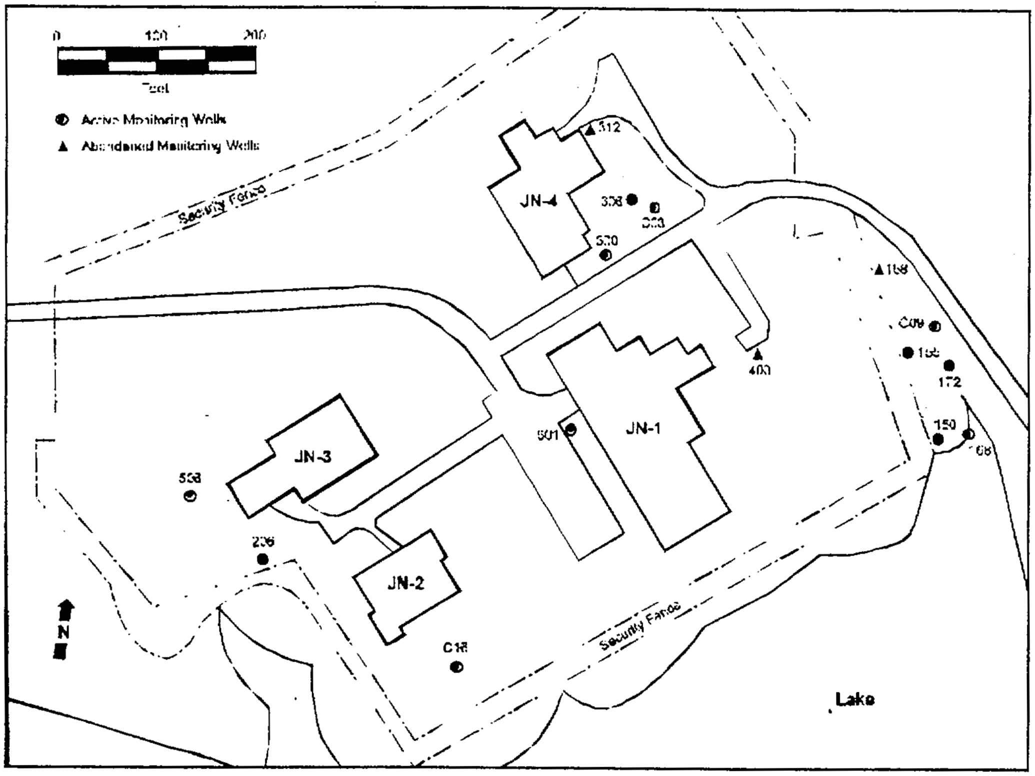


Figure 5. Filter Bed Area

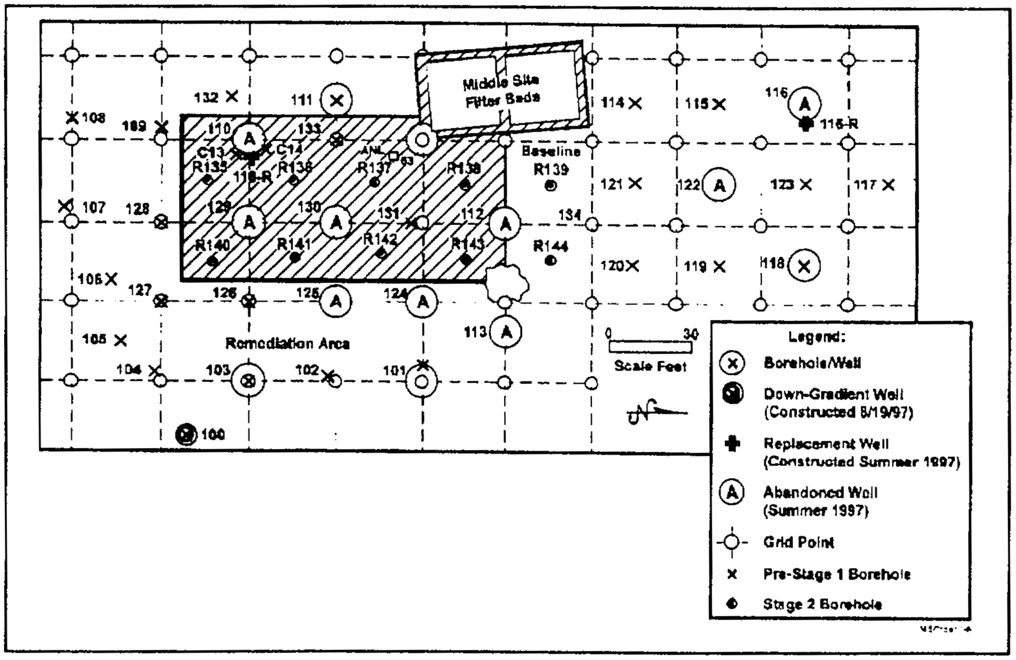


**Table 4. Radiological Analyses of Ground Water at the West Jefferson Site in 2000**

| Well Identification[a] | Location | PCi/L | |
|---|---|---|---|
| | | Gross alpha ± sigma[b] | Gross beta ± sigma[b] |
| JN-Active Supply Well | Nuclear Sciences Area: East of JN-1 | 8.93 ± 3.17 | 2.87 ± 1.35 |
| JM-Active Supply Well | West Jefferson Middle Area | 7.99 ± 3.42 | 5.00 ± 1.51 |
| JS-Active Supply Well | West Jefferson Middle South Area | 6.35 ± 3.06 | 4.93 ± 1.49 |
| CO3 | East of JN-4 | 8.39 ± 4.95 | 8.43 ± 2.38 |
| CO9 | Storm Sewer Outfall | 8.77 ± 4.76 | 30.00 ± 3.42 |
| C16 | SE of JN-2 | 7.97 ± 4.74 | 3.80 ± 2.00 |
| 100 | SE of Filter Bed | 13.30 ± 5.42 | 5.98 ± 2.13 |
| 101 | E of Filter Bed | 18.80 ± 5.12 | 14.30 ± 2.40 |
| 103 | SE of Filter Bed | 11.10 ± 5.99 | 13.30 ± 2.76 |
| 110 | W of Filter Bed | 20.90 ± 6.96 | 15.30 ± 2.73 |
| 116 | N of Filter Bed | 28.30 ± 7.67 | 16.50 ± 2.78 |
| 118 | E of Filter Bed | 26.00 ± 7.26 | 22.40 ± 3.06 |
| 150 | Storm Sewer Outfall | 7.73 ± 4.47 | 6.25 ± 2.18 |
| 155 | Storm Sewer Outfall | 6.36 ± 4.59 | 6.53 ± 2.23 |
| 168 | Storm Sewer Outfall | 9.38 ± 5.89 | 19.90 ± 3.25 |
| 172 | Storm Sewer Outfall | 14.70 ± 6.52 | 27.70 ± 3.54 |
| 206 | S of JN-3 | 8.22 ± 5.15 | 7.60 ± 2.33 |
| 300 | SE of JN-4 | 7.94 ± 23.10 | 11.70 ± 2.63 |
| 306 | E of JN-4 | 9.71 ± 4.67 | 8.76 ± 2.31 |
| 506 | W of JN-3 | 13.10 ± 6.17 | 8.95 ± 2.45 |
| 601 | W of JN-1 | 19.10 ± 5.61 | 10.40 ± 2.29 |

[a] Adapted from Battelle BCLDP, "BCLDP Site Environmental Report for Calendar Year 2000 on Radiological and Non-Radiological Parameters."

[b] Minimum Detection Limit for gross alpha is 1.0 pCi/L; for gross beta is 2.9 pCi/L.

- During the last half of CY 1995, an environmental geophysics study was conducted at the remediated filter bed area at the West Jefferson site. The study was conducted to define the hydrogeologic framework, characterize potential contamination pathways, and identify possible leakage points in buried pipelines and drainage tile. A total of six shallow piezometers were installed near the retired filter bed area during September of CY 1995. The six new well points were sampled on October 10, 1995, and received gamma spectroscopy analyses. Results from the analyses showed there were no radionuclides present. An additional sampling event of the same six well points conducted on June 5, 1996, yielded identical results. [10]

- The ground water located adjacent to the underground storage tanks located near JN-1 will be sampled annually. The samples will be tested for radiological parameters and PCBs.

Closure Services will conduct sampling and radioanalytical analysis of monitoring wells #118, #206, #306, #506, and #601 on a semi-annual basis as indicated in Table 7. Additionally, monitoring wells #118 and #306 will be sampled on an annual basis for the radioanalytical components as listed in Table 7.

*Non Radiological Liquid Effluent Monitoring*

- The drinking water system at the West Jefferson site is monitored under Ohio EPA regulations, which regulate all public water supplies. Because this is a non-transient, non-community water supply, BMI will perform various tests. Monitoring parameters include total coliform for microbiological contamination on a quarterly basis, and VOCs, SOCs, asbestos, nitrates, MCL inorganics, copper, and lead on a schedule ranging from annual to every three years. The drinking water system has consistently met water quality monitoring requirements established by the Ohio EPA.

  - The three existing supply wells (one located in each of the North, Middle, and South areas) have depths ranging from 130 to 160 feet and have been monitored annually and semi-annually for radiological and drinking water parameters since 1970. The three existing supply wells (JN-W, JM-W, and JS-W) are sampled before the water is treated and have undergone analysis for gross alpha and gross beta emitters, fission products, in addition to Ohio EPA parameters for drinking water supply evaluation. The three supply wells have consistently met water quality monitoring requirements established by the Ohio EPA. Closure Services will only sample and monitor the JN-W supply well. BMI will continue to conduct all other non-radiological effluent monitoring activities.

  - BMI performed detailed chemical monitoring with the results reported in the *Interim Report on Site Characterization, West Jefferson North Site, Stage 1 Sampling and Analysis: Chemical Sampling Summary Report*,[11] dated December 22, 1989. The results showed the groundwater samples to be free from chemical contamination.

  - Chemical sampling has been performed in three monitoring wells (C03, C09, and C16) since their installation through 2001 on an annual basis. The samples have been analyzed for eight heavy metals, 26 pesticide and PCB compounds, 36 volatile organic compounds (VOCs), 65 semi-volatile organic compounds (SOCs), oil and grease, and pH. These monitoring wells have depths ranging from 8.5 to 15 feet and have been monitored since 1989. No ground water contamination was detected in any of the wells when they were initially sampled.

  - Detailed chemical analyses have been performed annually since 1991 on ground water samples from three chemical monitoring wells (C03, C09, and C16). Samples from all three wells have been analyzed for eight heavy metals, 26 pesticides and PCB compounds, 36 VOCs, 65 SVOCs, oil and grease, and pH. The shallow wells were constructed solely for monitoring purposes. Although ground water from these shallow monitoring wells does not represent site drinking water, the results are compared to U.S. EPA

Primary Drinking Water Standards to put any observed concentrations in perspective.

- Well C03 showed traces of phenol at 17 parts per billion (ppb) (ug/L) during sampling for CY 1991. No traces of any chemical contaminant have been found in this well during sampling since 1991.
- Wells C09 and C16 have shown traces of bis (2-ethylexyl)-phthalate and 1,1,1-trichoroethane in an on-again, off-again pattern during the 1992-2000 sampling time frame. Various factors not related to the site condition, such as laboratory or shipping container contaminants, may account for the presence of these compounds at low concentrations ranging from 5 to 41 ppb (ug/L).

Closure Services will conduct sampling and chemical analysis of monitoring wells #C03, #C09, and #C16 on the frequency as listed in Table 7.

### 3.3 Estimated Radiation Doses to the Public

Estimates of doses to the public and workers are contained in "Finding of No Significant Impact (FONSI) and Environmental Assessment (EA)" June 1990. In 2001, the EA was supplemented by the addition of current conditions and information. The DOE has maintained that the FONSI is still valid for the CCP, Workers' doses are not employed in the environmental surveillance and monitoring criteria and are not evaluated in estimated radiation doses to the public.

WJN falls below an estimated effective dose equivalent of 0.1 mRem. Hence, effluent monitoring requires only periodic confirmatory measurements; calculation of dose for normal operations, assuming that the emission controls are non-operative; and a confirmatory environmental survey at least every five years. Effluent air monitoring requires total beta and total alpha as an indicator and gamma spectrometry on an annual basis.

The filter bed area estimated radiation dose is such that an annual environmental surveillance and analysis is suggested. The estimated radiation dose to a farm family living at the outfall from consumption of crops is such that routine surveillance of all pathways is recommended. Closure Services will sample farm and garden produce in the general area of the outfall to insure that an annual effective dose equivalent of 5 mRem is not exceeded.

Table 5 represents the population distributions around the West Jefferson site. The estimated annual person-rem collective EDE within 80 km (approximately 50 miles) West Jefferson site is about 7.2 person-mRem ($3.13 \times 10^{-6} \times 2.3 \times 10^{6}$).

Based on the above, the West Jefferson site requires periodic confirmation (an estimated annual collective effective dose equivalent of less than 25 person-mRem).

**Table 5. Population Within 50 Miles – West Jefferson Facility**

**Distance in Miles**

| | 0 to 1 | 1 to 2 | 2 to 3 | 3 to 4 | 4 to 5 | 5 to 10 | 10 to 20 | 20 to 30 | 30 to 40 | 40 to 50 | Total * |
|---|---|---|---|---|---|---|---|---|---|---|---|
| North | 13 | 17 | 98 | 118 | 172 | 3,565 | 5,504 | 5,365 | 9,785 | 47,453 | **72,090** |
| NNE | 8 | 34 | 147 | 116 | 192 | 2,648 | 33,177 | 32,783 | 7,950 | 19,933 | **96,988** |
| NE | 13 | 46 | 76 | 136 | 581 | 30,040 | 121,109 | 24,423 | 11,754 | 14,779 | **202,957** |
| ENE | 14 | 257 | 96 | 200 | 2,386 | 36,041 | 244,383 | 71,416 | 12,862 | 16,441 | **384,096** |
| East | 309 | 441 | 130 | 203 | 4,059 | 41,891 | 247,925 | 133,142 | 25,911 | 76,727 | **530,738** |
| ESE | 769 | 589 | 219 | 114 | 332 | 54,788 | 73,058 | 37,024 | 50,406 | 20,607 | **237,906** |
| SE | 297 | 1,046 | 43 | 65 | 419 | 5,986 | 18,009 | 15,228 | 13,430 | 9,535 | **64,058** |
| SSE | 45 | 256 | 47 | 54 | 77 | 3,349 | 11,226 | 5,499 | 14,437 | 43,088 | **78,078** |
| South | 26 | 85 | 82 | 116 | 115 | 860 | 4,671 | 3,116 | 5,026 | 12,733 | **26,830** |
| SSW | 7 | 489 | 260 | 135 | 96 | 584 | 1,220 | 3,925 | 21,493 | 7,859 | **36,068** |
| SW | 2 | 324 | 2,971 | 514 | 42 | 806 | 1,019 | 3,647 | 8,812 | 20,209 | **38,346** |
| WSW | 3 | 24 | 307 | 126 | 14 | 1,269 | 9,620 | 5,916 | 19,660 | 173,870 | **210,809** |
| West | 5 | 23 | 121 | 173 | 163 | 694 | 9,880 | 63,943 | 53,643 | 81,331 | **209,976** |
| WNW | 8 | 14 | 20 | 36 | 94 | 1,061 | 3,625 | 17,383 | 7,528 | 7,923 | **37,692** |
| NW | 14 | 15 | 29 | 88 | 83 | 439 | 1,369 | 5,833 | 22,469 | 13,509 | **43,848** |
| NNW | 17 | 4 | 45 | 495 | 87 | 676 | 14,262 | 10,010 | 4,361 | 7,133 | **37,090** |
| Total | **1,550** | **3,664** | **4,691** | **2,689** | **8,912** | **184,697** | **800,057** | **438,653** | **289,527** | **573,130** | **2,307,570** |

* Block-level data was used in the population calculations. In cases where sector lines plit blocks, the population for the block was allocated based on the proportion of the block area in that sector.
Source: 2000 Public Law 94-171, U.S. Bureau of the Census.
Prepared by: Office of Strategic Research, Ohio Department of Development. (June 2001)

## 3.4 Atmospheric Modeling

Present locations of air samplers at the West Jefferson site were determined through the use of meteorological modeling, which determined maximum ground level air concentrations.[12] This study was done for West Jefferson nuclear research operations and may not be appropriate for D&D activities. Closure Services will maintain the same air monitoring locations, enhanced monitoring during demolition activities, and close sample locations as source term is eliminated.

## 3.5 Non-Radiological Contaminant Inventory

A sampling and analysis program for chemical contaminants was performed in the past by BMI, some hydrocarbons were identified and remediated, PCBs were identified near a transformer at levels well below action levels, and very low levels of volatile and semi-volatile organics were identified in one sludge sample near the storm sewer and a few soil samples. No contamination has been found in the groundwater.

## 3.6 Implications for Effluent Monitoring and Environmental Surveillance

The number and location of effluent monitoring stations and environmental surveillance stations, the frequency of sampling, and the type and frequency of analyses are based on technical assessments that consider the following factors:

- The inventory of radioactive isotopes in each building to be decommissioned.
- The potential for release of radiation and radioactive materials from the facilities into the environment.
- The standard radiation protection measures to be undertaken during D&D operations.
- Applicable laws, regulations, criteria, and standards.
- The capabilities and reliability of available monitoring instruments.

### 3.6.1 Airborne Effluent Monitoring

Environmental monitoring data collected over several years indicate no significant releases of radionuclides. BMI conducted air sampling of aerosol concentrations and exhaust air streams of areas during decontamination tasks. Results of the sampling indicate that facility engineered systems and work control requirement are sufficient to control and quantify emissions.

To establish the basis for continued airborne effluent monitoring during reamining D&D tasks, a comparisons was made between estimated CCP emissions and applicable regulatory requirements.

Based on the results of this comparison:

- The derived dose rate to the public that may result from decontamination activities in the West Jefferson Building JN-1 is large enough to call for continuous monitoring. The details of the airborne emission monitoring plan for JN-1 are given in Section 4.2.1.

- The derived rate to the public that may result from decontamination activities in Building JN-2 is not large enough to call for continuous monitoring. The Radioanalytical Laboratory currently located in JN-2 will be transferred to the temporary facility . Because of the potential for radiological emissions from laboratory operations, airborne emissions will be monitored. The details of the airborne emission monitoring plan for JN-2 and the new portable laboratory are given in Section 4.2.2.

### 3.6.2 Liquid Effluent Monitoring

BMI will continue to perform continuous liquid effluent monitoring at the West Jefferson site at the NPDES permitted outfall into Darby Creek. Several years of environmental surveillance of liquid effluents at the West Jefferson site have detected no releases or exposures that approach regulatory limits.

### 3.6.3 General Environmental Surveillance

Closure Services will collect environmental surveillance data from numerous locations within the project site boundaries, at the WJN site boundaries, and off site. The current environmental surveillance program at West Jefferson is adequate to accomplish these objectives.

## 4.0 Location of Monitoring Stations, Type/Frequency of Sampling and Analyses

### 4.1 Effluent Monitoring Summary

The details of effluent Monitoring are listed in Table 6 and discussed in detail in Sections 4.2 and 4.3. Procedures for environmental sampling and analysis are listed by title and document number in Section 5.

### 4.2 Airborne Effluent Monitoring

Routine airborne effluent monitoring of D&D operations within the project boundaries will be carried out in accordance with Sections 4.2.1 through 4.2.3. The extent of airborne effluent monitoring for D&D operations will be based on a supplemental estimate of the potential airborne EDE that takes into account the local source term. For example, in a building's large open areas, where filtering room exhaust cannot be ensured, a short-term EDE would be calculated using the open area's radionuclide inventory, a room exhaust filtration factor of 1.00 (no filtration), and the duration of D&D in that area.

This plan will be reviewed and modified as necessary to comply with the goals of the EMP in the event of any change to the number or status of building air discharge points due to completion of D&D plans for the site.

The Environmental Technicians will change out filters at continuous monitoring locations, conduct performance tests, and calibrate and maintain the continuous air and stack monitors at the WJN Site.

Supplemental monitoring will be performed during demolition activities to verify that contamination control measures minimize the potential for releases to the general public and the environment. Monitoring will include upwind and downwind continuous air sampling and real time dust monitoring. Demolition crews will utilize dust suppression methods to reduce dust emissions. Dust suppression methods may be applied using fire hoses spraying building structures and debris during demolition and container loading. Temporary berms will be constructed or placed to collect runoff water resulting from spraying the demolition debris.

### Table 6. Effluent Monitoring Program for Columbus Closure Project

| Type of Sample | Sampling Site(s) | Sampling and Collection Frequency | Analysis Type and Frequency |
|---|---|---|---|
| Airborne Effluent at Point Sources, [a,b] | One-in-line volumetric sampler at each active fan driven exhaust vent at Buildings JN-1 and JN-2 | Continuous Sampling<br>Weekly Collection | Total Beta and Total Alpha Weekly.[c] Gamma Spectrometry Monthly Composite.[d] U Pu Isotopic and Sr-90 Analysis on Quarterly Composite.[e] |
| Liquid Effluent to NPDES Permitted Outfall[f] | Manhole immediately following chlorinators | Daily[g] | Flow Rate (24-hour total) Color Severity (observation) Odor Severity (observation) Turbidity Severity (observation) |
| | | Bi-Weekly Collection | Dissolved Oxygen (grab) Total Suspended Solids (grab) Nitrogen Ammonia (composite) Chlorine, Total Residual (grab)[h] Biochemical Oxygen Demand (composite) |
| | | Monthly | pH (grab) |
| | | Collection | Fecal Coliform (grab)[h] |
| | | | Chloroform (grab) |
| | | | Alpha Total Activity (composite) Alpha Dissolved Activity (composite) Alpha, Suspended Activity (composition) |
| | | | Beta, Total Activity (composite) Beta, Dissolved Activity (composite) Beta Suspended Activity (composite) |

[a] Inactive point sources will be tagged and sealed or otherwise isolated by approved procedures prior to the start of D&D activities.

[b] The procedure for air sampling is presented in EM-SP-001.

[c] See RL-TP-005 for details of alpha and beta analysis. For air samples, if half life is greater than 30 minutes for beta and/or greater than 2 hours for alpha, send sample for gamma spectrometric analysis immediately.

[d] RL-TP-030 describes gamma spectrometric analysis.

[e] Specific Isotopic analyses: Sr-90 RL-TP-035; Ra-226 RL-TP-025; Ra-228 RL-TP-056; Plutonium RL-TP-054; Isotopic Uranium, Am-241, and Thorium RL-TP-054; H-3 RL-TP-026; and I-129 and C-14 are analyzed off-site.

[f] NPDES-permitted outfall is for West Jefferson wastewater discharge to big Darby Creek. BMI will conduct all NPDES-outfall monitoring activities.

[g] Except days when the facility is not normally staffed. BMI will conduct all NPDES-outfall monitoring activities.

[h] summer only (May 1 through October 31).

### 4.2.1 Building JN-1

The following monitoring plan reflects the current review and status of air discharge points at Building JN-1. It is based on a comprehensive survey of the building areas conducted in 1992.

Routine: Routine airborne emission monitoring during D&D operations at Building JN-1 will include:

1) Continuous monitoring of the air discharge points (stacks), with weekly sample collection and analyses as listed in Table 6:

(S-7)002 – New Building (HEC)
(S-4)003 – Control Area (CAA)
(S-6)004 – Liquid Waste Evaporator
(S-5)013 – Basement (A/G)

The air monitoring devices will have adjustable set points and have the capability to alarm and shutdown blowers, if the set point is reached.

The locations of these discharge points are shown in Figure 2. Monitoring these air discharge points will be continued until D&D of the specific area(s) serviced by a given stack are completed and the discharge point is sealed. Inactive point sources will be sealed, locked out, disabled, or otherwise isolated to ensure that inadvertent radiological releases via unmonitored pathways during D&D are prevented.

2) Prior to the commencement of D&D activities, continuous monitoring will be required for the air discharge points that are currently not being monitored and have not been sealed or otherwise isolated. Any potential release points that remain active during D&D operations will need to be monitored continuously, sampled weekly, and analyzed as indicated in Table 6. Known potential release points in Building JN-1 include:

- Pump Room
- Boiler Room Exhaust (3)
- Restroom
- Old Stack Blowers
- Miscellaneous Air Intakes without Backdraft Control.

Supplemental monitoring will be performed during demolition activities to verify that contamination control measures minimize the potential for releases to the general public and the environment. Monitoring will include upwind and downwind continuous air sampling and real time dust monitoring. Demolition crews will utilize dust suppression methods to reduce dust emissions. Dust suppression methods may be applied using fire hoses spraying building structures and debris during demolition and container loading. Temporary berms will be constructed or placed to collect runoff water resulting from spraying the demolition debris.

Contingent: In the even that air monitors or on-site environmental surveillance equipment detects levels of airborne contamination in excess of the action levels in EM-AP-2.0, procedures will be implemented immediately to correct the situation and intensify the monitoring of the building's relevant point source(s) to the extent necessary to accurately assess the amount of contamination released. Intensified monitoring will continue until measurements show that airborne effluents are within action levels.

### 4.2.2 Building JN-2

The following monitoring plan reflects the current review and status of air discharge points at Building JN-2. It is based on a comprehensive survey of the building areas conducted in 1992 and subsequent characterization and decontamination surveys.

Routine: Routine airborne emission monitoring during D&D and RAL operations at Building JN-2 will include:

1) Continuous monitoring of the air discharge point (stack) that is currently being monitored, with weekly sample collection and analyses as listed in Table 6:

   (S-11)012 – Radioanalytical Laboratory (RAL)

   The location of this discharge point is shown in Figure 6. Inactive point sources will be sealed, locked out, disabled, or otherwise isolated to ensure that inadvertent radiological releases via unmonitored pathways during D&D are prevented.

2) Prior to the commencement of D&D activities, localized air monitoring will be required for potential release points that remain active during D&D operations. Monitoring will be continuous during D&D activities within the area, sampled weekly or at the end of work activities, and analyzed as indicated in Table 6. Known potential release points in Building JN-2 include:

   - Hood in Room 2106
   - Hood in Room 2108
   - Drying Oven Fume Hood
   - Boiler Room Exhaust (2)
   - Restroom
   - Miscellaneous Air Intakes without Backdraft Control Vaul
   - High Bay

Supplemental monitoring will be performed during demolition activities to verify that contamination control measures minimize the potential for releases to the general public and the environment. Monitoring will include upwind and downwind continuous air sampling and real time dust monitoring. Demolition crews will utilize dust suppression methods to reduce dust missions. Dust suppression may be applied using fire hoses spraying building structures and debris during demolition and container loading. Temporary berms will be constructed or placed to collect runoff water resulting from spraying the demolition debris.

Contingent: In the event that air monitors or on-site environmental surveillance equipment detects levels of airborne contamination in excess of the action levels in EM-AP-2.0, procedures will be implemented immediately to correct the situation and intensify the monitoring of the building's relevant point source(s) to the extent necessary to accurately assess the amount of contamination released. Intensified monitoring will continue until measurements show that airborne effluents are within action levels.

### 4.2.3 Building JN-3

There are presently no operational air emission monitors at Building JN-3.

Routine: Continuous airborne effluent monitoring of the point sources (vents, stacks, blowers, etc) on the exterior of Building JN-3 will not be performed. The technical basis for this determination rests on results of calculations, shown in Section 4.7.1, that show the small radionuclide inventory in the buildings, coupled with standard D&D radiation protection procedures leading to substantially less than 0.1 mrem/year EDE (the DOE criterion for continuous monitoring).

Supplemental monitoring will be performed during demolition activities to verify that contamination control measures minimize the potential for releases to the general public and the environment. Monitoring will include upwind and downwind continuous air sampling and real time dust monitoring. Demolition crews will utilize dust suppression methods to reduce dust emissions. Dust suppression methods may be applied using fire hoses spraying building structures and debris during demolition and container loading. Temporary berms will be constructed or placed to collect runoff water resulting from spraying the demolition debris.

Contingent: In the event that either recalculation of the EDE for non-standard D&D procedures exceeds 0.1 mrem/year, or in-building air monitors or on-site environmental surveillance equipment detects above-standard levels of airborne contamination, procedures will be implemented immediately to intensify monitoring of the building's relevant point source(s). Intensified monitoring will continue until measurements show that airborne effluents are below applicable regulatory standards.

## 4.3 Liquid Effluent Monitoring

BMI will conduct all liquid effluent monitoring as required under the NPDES permit conditions.

Presently, a waste water treatment system, operated under an NPDES permit in accordance with State of Ohio regulations under 41N00004*GD, handles all wastewater generated on the WJN site. Sampling of all waste water liquid effluents from the North Research Area to Big Darby Creek is performed using a continuous water sampling system located after the discharge from the UV disinfection tank. Table 5 lists the various parameters measured on daily, weekly, bi-weekly, or monthly schedules. The station, shown as EW-1 in Figure 6, will continue to be monitored during D&D operations. However, based on long-term measurements of liquid effluents from the West Jefferson site and assessments of potential liquid releases from D&D activities, no additional liquid effluent monitoring will be conducted.

Should action levels be detected in liquid samples, an immediate investigation regarding the reasons for the source terms causing the release shall be performed by BMI with the cooperation of Closure Services; and suspect operations will be suspended until corrective actions have been performed.

## 4.4 Environmental Surveillance

Table 7 lists the environmental surveillance tasks for the Columbus Closure Project. Surveillance tasks are designed to meet and/or exceed the licensing conditions for environmental surveillance.

Table 7 lists the sample collection frequency and the associated type and frequency of analyses for each sample. The table also provides reference to specific procedure documents.

Figures 3, 6, and 7, detail monitoring and sampling locations to be implemented under the EMP. Figure 3 details the current and planned sampling locations for on-site air, water, and sediment sampling, except TLDs. Figure 6 shows the locations of the 10 TLDs distributed on and around the West Jefferson site for the project area. Figure 7 shows grass, food crop, and soil sampling locations, and three off site TLD locations.

Closure Services has selected the TLD locations for the following reasons:

- Locations along the project boundary line are evenly spaced and represent the most probable receptor from the general public (i.e., BMI personnel working in JN-4). While personnel in JN-4 may be considered occupational in some regard, these individuals do not conduct activities under the NRC SNM-7 License and thus meet the standard as a member of the general public.

- Significant reduction in the source term warrants downgrading environmental TLD locations to those at the site boundary.

- Closure Services has reviewed the environmental TLD records for 2002 and 2003. The annual external dose as monitored at the current 54 locations identified in the BMI EMP all fall below background levels for external sources of radiation. Additionally, the number of dosimeters are all below background. Based upon a review of the historical environmental TLDs there is a clear indication that locations at the recreational area and at the site boundary are less than background. Thus, reducing the number of dosimeters to those at the project fence line will not adversely impact the current practice of documenting negative dose to the general public.

Table 7. Environmental Surveillance program for Columbus Closure Project

| Sampling Type | Sampling Site(s) | Collection Frequency | Analysis Type and Frequency |
|---|---|---|---|
| Airborne Particulates | Locations as described in EM-OP-002 | Continuous Sampling Weekly Collection | Total beta and alpha on weekly.[a] Gamma spectrometric analysis on monthly composition.[b] Isotope U, Pu, and Sr-90 on quarterly composite. [c] |
| Airborne Particulates | Sites as described in EM-SP-001 | Continuous Sampling | Total beta and alpha on weekly.[a] Gamma spectrometric analysis on quarterly composite.[b] Isotopic U, Pu, and Sr-90 on quarterly composite.[c] |
| Liquid Samples | Sits are described in EM-SP-002 | Weekly Sample Collection | Total beta and alpha on weekly.a Gamma spectrometric analysis on monthly composite.b U, Pu, and Sr-90 on quarterly composite.c C-14 and H-3 when appropriate. |
| Drinking Water | Onsite in building JN-2 or JN-3 | Weekly Sample Collection | Total beta and alpha on monthly composite.[a] Gamma spectrometry on quarterly composite.[b] U, Pu, Sr-90 Ra-226, Ra-228, I-129 on annual composite.[c] C-14, H-3 when appropriate. (Data used to provide site background values.) |
| Ground Water | See ground water sampling (discussed in Section 3.2) | Semi-Annual Sample Collection | Total beta and alpha,[a] gamma spectrometry[b] and U, Pu, and Sr-90 and Semi-Annual Sample.[c] C-14, H-3 when appropriate.<br>Total metals: Ag, As, BA, Cd, Cr, Hg, Pb, Se, volatile organic compounds, semi volatile compounds, pesticides and PCBs, oil and grease, and pH for selected wells on an annual basis. |
| Ground Water | See ground water sampling (discussed in Section 3.2) | Annual | Total beta and alpha, gamma spectrometric U, Pu, and Sr-90. PCBs. |
| Soil | As described in EM-SP-003 | Annual Sample Collection | Gamma spectrometry.[b] U, Pu, and Sr-90 on annual sample.[c] |
| Vegetation | As described in EM-SP-004 | Annual Sample Collection | Gamma spectrometry.[b] U, Pu, and Sr-90, on annual sample.[c] |
| Sediment | As described in EM-SP-011 | Semi-annual Sample Collection | Total beta and total alpha,[a] gamma spectrometry, [b] U, Pu, and Sr-90 on semi-annual sample |
| Fish or Mollusks | See EM-SP-007 | Annual Sample Collection | Total beta and total alpha,[a] gamma spectrometry, [b] U, Pu, and Sr-90 on annual sample.[c] |
| Field Corn and/or Soybeans | As Described EM-SP-005 | Annual Sample Collection | Gamma spectrometry.[b] U, Pu, and Sr-90 on annual sample[c]. |
| Garden Crops | See EM-SP-006 | Annual Sample at End of Growing Season | Gamma spectrometry.[b] U, Pu, and Sr-90 on annual sample.[c] |
| Beta-Gamma External (TLD) | See EM-SP-008 | Quarterly Collection | Read quarterly |

[a] See RL-TP-005 for alpha and beta analyses. For air samples, if half life is greater than 30 minutes for beta and/or greater than 2 hours for alpha, send sample for gamma spectrometric analysis immediately.

[b] RL-TP-030 describes gamma spectrometric analysis.

[c] Specific Isotopic Analyses: Sr-90: RL-TP-035; Ra-226: RL-TP-025; Ra-228: RL-TP-056; I-129: Analyzed off-site; Plutonium, Isotopic Uranium, Am-241, and Thorium: RL-TP-054; C-14 Analyzed off-site; H-3: RL-TP-026

Figure 6. Map of TLD Locations within Three-Fourth –Mile Radius of the Columbus Closure Project

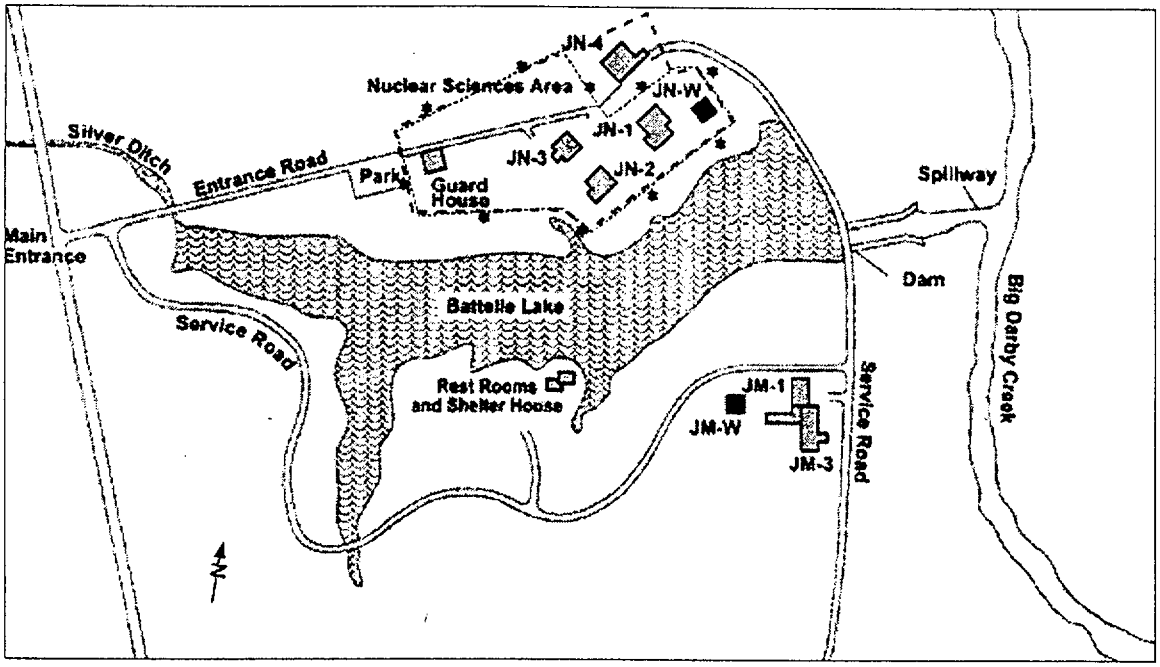
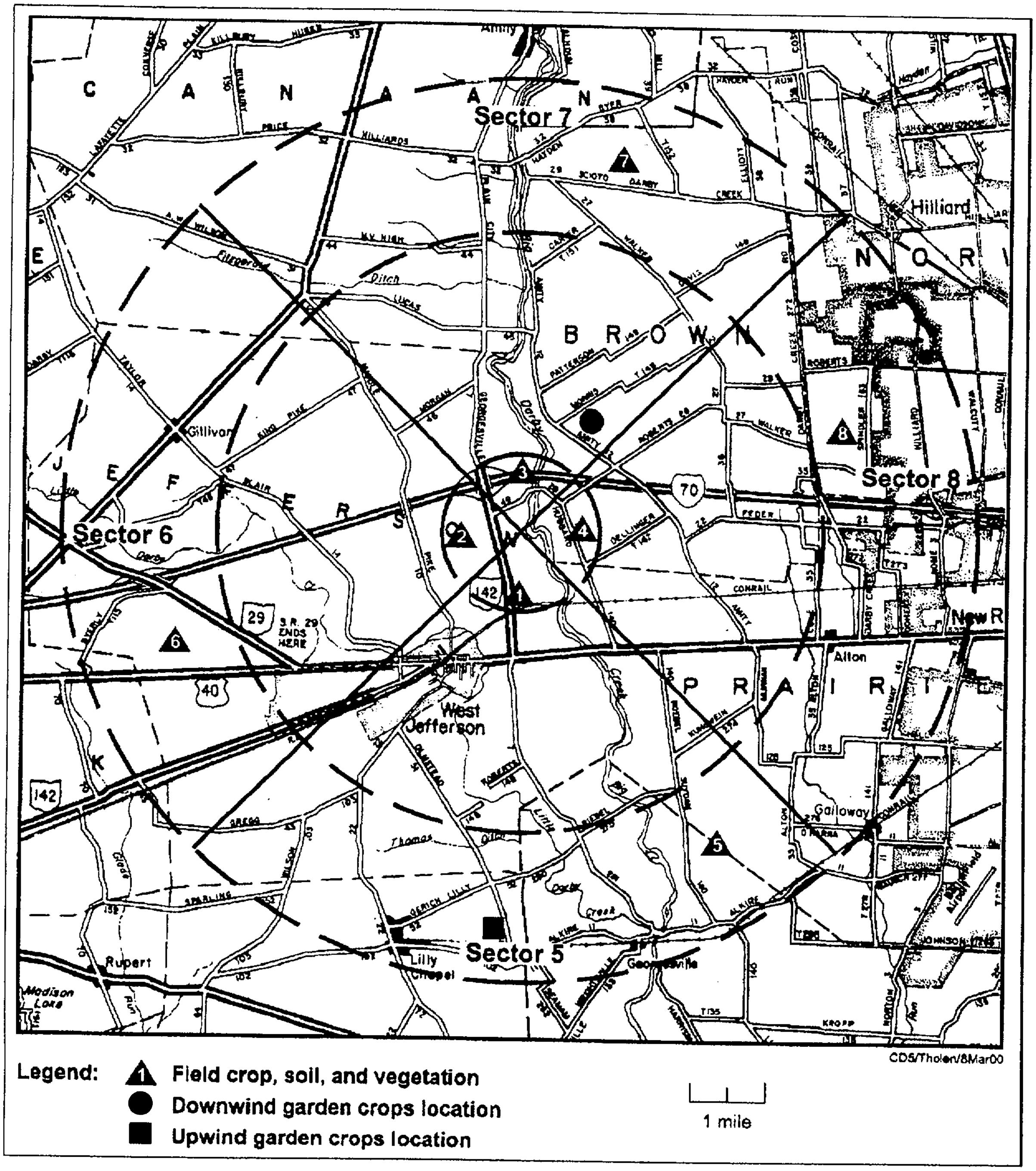


Figure 7. Map of Grass, Food Crop, and Soil Sampling Locations



## 4.5 Integration of Columbus Closure Project Emergency Management Plan into the Environmental Monitoring Program

The EMP requires flexibility to respond in the evening of a radiological accident involving the escape of radioactive materials. Conversely, the CCP emergency plan can provide backup to the EMP, particularly in terms of emergency effluent monitoring. The NRC specifically describes environmental sampling and analysis in a radiological emergency in "Emergency Environmental Sampling and Analysis for Radioactive Material Facilities."[2]

## 5.0 Sampling and Analyses Methodology and Determination of Off-Site Impact and Consequence Assessments

### 5.1 Sampling and Monitoring

The following procedures will describe sampling and monitoring activities.

| Title | Document No. |
|---|---|
| Operation and Calibration of the Eberline AMS-4 Beta Particulate Monitor | EM-OP-001 |
| Collecting and Processing Filters from Stack and Area Continuous Air Monitors | EM-OP-002 |
| Collection of Environmental Air Samples for Radiological Analysis | EM-SP-001 |
| Collection of Environmental Water and Liquid Effluent Samples for Radiological Analysis | EM-SP-002 |
| Collection of Environmental Soil Samples | EM-SP-003 |
| Collection of Perennial Vegetation Samples – Grass or Other Ground Cover, Trees and Shrubbery | EM-SP-004 |
| Collection of Annual Crop Samples | EM-SP-005 |
| Collection of Environmental Vegetation Samples – Garden Crops | EM-SP-006 |
| Collection of Environmental Fish Samples | EM-SP-007 |
| Beta-Gamma Radiation Monitoring | EM-SP-008 |
| Collection of Environmental Groundwater Samples | EM-SP-009 |
| Collection of Environmental Sediment Samples | EM-SP-011 |
| Collection of Sediment and Sludge for Chemical and Radiological Characterization | SC-SP-006 |

## 5.2 Analyses

The following procedures will describe the analyses of samples.

| Title | Document No. |
|---|---|
| Preparation of Environmental Water and Air Samples and Routine Smears for Gross Alpha and Beta Counting | RL-TP-005 |
| Gross Alpha and Gross Beta Counting of Soil/Sediment/Sludge Samples Using the Tennelec LB5100 | RL-TP-007 |
| Gross Alpha and Beta Analysis Using the Tennelec LB5100 Low Background System | RL-TP-020 |
| Analysis of Radium-226 in Environmental Water and Soil Samples | RL-TP-025 |
| Analysis of Tritiated Water and Screening for Low Beta Energy Emitters by Liquid Scintillation Counting | RL-TP-026 |
| Gamma Spectrometric Analysis of Laboratory Samples Using Canberra Procount$^{TM}$ Software | RL-TP-030 |
| Strontium-90 Analysis by Extraction Chromatogrphay | RL-TP-035 |
| Determination of Actinides in all Sample Matrices | RL-TP-054 |
| Analysis of Radium-228 in Water Using U.s. EPA Method 9320/SW-846 | RL-TP-056 |
| Gross Alpha and Gross Beta Analysis of Water Using U.S. EPA Method 9310/SW-846 | RL-TP-057 |

## 5.3 Chain-of-Custody Procedures for handling Environmental Samples

To ensure proper handling, transfer, and accountability for all samples submitted for analysis under the EMP, the chain-of-custody procedures listed in RL-AP-1.0, Administrative Operating Procedure for the Radioanalytical Laboratory, will be followed.

## 5.4 Data Analysis and Statistical Treatment of Data

Effluent monitoring and environmental measurements obtained from sampling and analysis shall be analyzed to compare them to the appropriate environmental standards (Section 2), discern spatial and temporal trends, and eliminate outliers from further statistical analysis. All environmental data obtained through monitoring shall be noted. Data values will be reported as minimum detectable activity (MDA), when activity is at or below MDA.

Comparisons of effluent monitoring and environmental surveillance data shall be made each month to indicate trends in radioactive levels. This includes analysis of all information that is capable of indicating such trends. This requirement does not negate the need of daily vigilance and inspection to determine the efficacy of effluent controls.

Determination of the less-than detectable values is the subject of numerous statistical methodologies. Given that natural background radiation is ubiquitous, and that sources other than the site may contribute to the resultant radioactivity, the criteria employed in this EMP is that detectable levels attributed to D&D activities shall be that amount equivalent to background levels of radioactivity in the environment from other sources. Sampling and analysis techniques conform to these criteria.

Most environmental data follow a normal distribution. Hence, the central tendency of the data shall be expressed as the median value and the variance as the geometric standard deviation. The range of values shall be characterized as falling between the 5th and 95th percentile.

A test of normality shall be performed on groups of ten or more data points. Plotting data on normal or log-normal probability paper is the simplest method of determining normality.

If the data is normal rather than log-normal, the mean shall be the measure of the central tendency and the standard deviation a measure of variance.

If data is sparse, different assumptions about the distribution of the data may be made and an appropriate statistical analysis employed to determine the range and uncertainty of the data.

To determine spatial and/or temporal trends, comparison of data points or groups of data is required. This type of comparison is also required in comparing monitoring results to environmental standards. Plotting the data on graph paper is often sufficient to elucidate trends over time or differences between sampling locations. Use of parametric and nonparametric statistical techniques shall be employed for groups of data to determine if significant differences exist between them.

Outliers for the purposes of this EMP shall be values more than three standard deviations from the mean (or three geometric standard deviations from the median).

The Annual SER shall summarize the results if statistical analyses become necessary for values greater than MDA.

## 5.5 Determination of Off-Site Impact and Consequence Assessments

10- CFR 20.1101, *Radiation Protection Programs*, [13] puts forth a constraint on airborne emissions of radioactive material to the environment, excluding Ra-222 and its daughters, such that an individual member of the public likely to receive a total effective dose equivalent (TEDE) in excess of 10 mRem per year from these emissions.

A constraint is a dose value above which licensees are required to report to the NRC and to take corrective actions to lower the dose below the constraint value. Enforcement action would only occur if a licensee fails to report the constraint is exceeded or fails to take appropriate and timely corrective actions.

Reg Guide 4.20, *Constraint on Releases of Airborne Radioactive Materials to the Environment for Licensees other than Power Reactors*, Section c.2.4[14] states that the computer code COMPLY is acceptable to the NRC staff for determining the dose to members of the public from exposure to airborne radioactive materials that have been released to the environment by NRC licensees other than power reactors.

Closure Services demonstrates compliance with 10 CFR 20.1101(d)[13] by using the COMPLY computer code, version 1.5d.

## Meteorological Monitoring Program

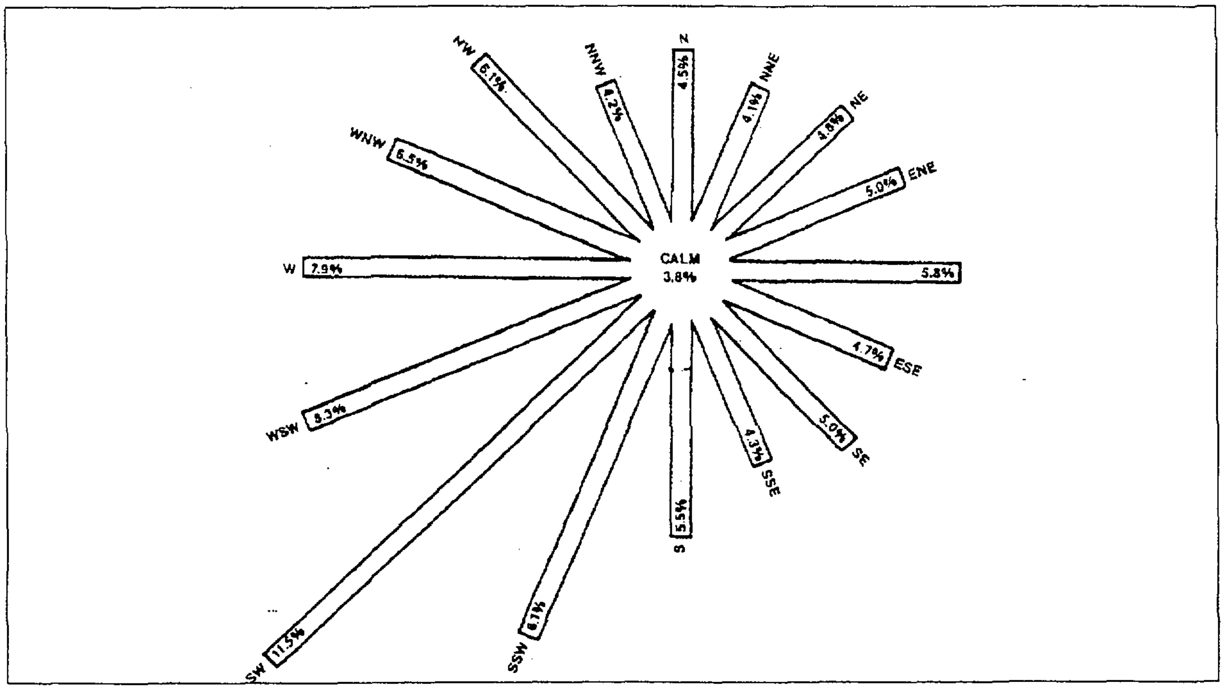
At the present time, Port Columbus International Airport meteorological data are used for the CCP.

As shown in Table 8, the predominant wind direction at the project is southwest, and the next two most frequent directions are west-southwest. Figure 10 shows the wind rose pattern for the project.

**Table 8. Average Percent Frequency of Wind Direction (Wind From) and Average Wind Speed (1990)**

| Direction | Percent | Average Speed (m/s) |
|---|---|---|
| N | 4.5 | 4.7 |
| NNE | 4.1 | 4.2 |
| NE | 4.8 | 4.0 |
| ENE | 5.0 | 4.1 |
| E | 5.8 | 4.4 |
| ESE | 4.7 | 3.8 |
| SE | 5.0 | 4.3 |
| SSE | 4.3 | 3.8 |
| S | 5.5 | 4.5 |
| SSW | 8.1 | 4.9 |
| SW | 11.5 | 5.5 |
| WSW | 8.3 | 5.3 |
| W | 7.8 | 5.1 |
| WNW | 6.5 | 4.9 |
| NW | 6.1 | 4.6 |
| NNW | 4.2 | 4.2 |
| CALM | 3.8 | ---- |
| TOTAL | 100.0 | 4.5 |

Figure 8. Wind Rose Pattern (Wind from) for West Jefferson Site



## 6.0 The Environmental Monitoring Plan's Quality Assurance Program

## 6.1 Overview

The current SER notes that a DOE quality assessment program is being administered by the DOE's Environmental Measurements Laboratory (EML).[15] The Closure Services in-house Radioanalytical Laboratory is a participant in the EML's quality assessment program. Therefore, it is appropriate that the quality assessment program (QAP) employed by the EML be a pertinent part of this Environmental Monitoring Plan.

The EMP shall be reviewed annually. Specific sampling and analytical procedures shall be reviewed and revised if necessary every two years.

The QAP, under which the RAL and EM operate, includes laboratory certification, a DOE QAP for radioactive materials, and independent data verification. This quality program does not include definitive procedures for quality assurance for non-radiological monitoring.

### 6.1.1 Laboratory Certification

Only certified laboratories will be contracted for analysis work. Sample analysis will be performed by applicable standard methods and covered under the Closure Services QAP. Before hiring a contractor to do environmental sample analysis, the Technical

Manager and the Quality Manager will ascertain that the contractor is properly accredited by such bodies as the EPA or State of Ohio.

Currently the EM Group uses both contractor laboratories and in-house facilities for both organic and inorganic chemistry and radiological work. These in-house labs are approved for analysis through adherence to accepted procedures. In-house radiological analysis is performed in the RAL. The RAL participates in the DOE EML quality assessment program and adheres to the Closure Services QAP. Outside laboratories must be approved for EPA analysis prior to being selected for chemical analysis. The RAL has performed analyses on the EML samples in the past as proof of its qualification. A contract will be negotiated with another off-site laboratory to provide back-up capabilities for both radiochemical and non-radiochemical parameters during the period of D&D activities.

### 6.1.2 DOE Laboratory quality assessment program for Radioactive Materials

Closure Services and the vendor(s) responsible for the analyses of CCP samples in support of the environmental radiological programs will participate in the DOE interlaboratory quality assessment program (coordinated by the DOE Environmental Measurements Laboratory in New York).

### 6.1.3 Independent Data Verification

Closure Services is committed to the maintenance of an effective quality assurance program. The national consensus standard of the ASME is adopted as the preferred standard for quality assurance in the nuclear industry

The Closure Services QAP discusses the written documentation of quality assurance and quality control procedures. This documentation is described in this section.

## 6.2 Definition

Three definitions related to quality assurance practices are given below.

Definitions of quality assurance, quality control and assessment/appraisal are given by DOE Order DOE 414.1A.

**Quality assurance** involves all those planned and systematic actions necessary to provide adequate confidence that a facility, structure, system, or component will perform satisfactorily and safely in service.

**Quality control**, which is included within quality assurance, comprises all those actions necessary to control and verify the features and characteristics of a material, process, product, or service to specified requirements.

**Assessment/appraisal** is a planned and documented activity performed in accordance with procedures to determine, by examination and evaluation of objective evidence, the adequacy of, and extent to which, applicable elements of the quality assurance program have been developed, documented, and effectively implemented in accordance with specified requirements.

### 6.3 Field Measurements and Sampling

The sampling procedures for field measures and sampling will incorporate quality control standards and techniques. The activities included are field sampling; preparation and storage of samples; coding and record keeping; handling, storage, and shipping; and sample archiving.

### 6.4 Radiochemical Analyses

Quality control standards and techniques for radiochemical analyses are found in RL-QAP-01.0, Radioanalytical Laboratory Quality Assurance Program Plan, and the Radioanalytical Laboratory procedures.

### 6.5 Instrumental Analyses

Instruments used by the RAL are maintained, calibrated, and stabilized by the RAL using their calibration and test procedures.

### 6.6 Data Reduction, Storage, and Reporting

The reduction, storage, and recording of analytical data from the RAL is performed through RL-AP-01.0, Administrative Operating Procedures for the Radioanalytical Laboratory and the RAL testing procedures.

### 6.7 Quality Assurance Records

Records that furnish documentary evidence of quality shall be specified, prepared, and maintained. Specified records include, but are not limited to, the following:

- Maps identifying sampling locations
- Sampler record book
- Sample inventory
- Technical procedures and data sheets
- Calculation and analyses records
- Reports
- QA surveillance and audit records

- Program correspondence

Records shall be made part of the Closure Services project record system.

## 7.0 Implementation of the Environmental Monitoring Plan

### 7.1 Environmental Monitoring Plan Implementation

The Closure Services EMP is primarily for the monitoring and surveillance of the D&D activities to be completed at the WJN facility. The plan will be reviewed annually and updated every two years until the project is completed. The annual review and biennial updates to the plan will be prepared by the Closure Services Environmental Monitoring Group and reviewed by the Quality Manager and the Radiological Technical Support Manager prior to submittal to Ohio Field Office for review.

The environmental monitoring activities have two major phases. The first phase consists of characterizing sources of pollution, including radiological and non-radiological measurements and sampling near the sources. The second phase of the plan includes analysis of pathways to the site boundary and off-site environmental sampling to substantiate the effectiveness of the control of releases. This plan includes measurements and samples taken near the surface (including air monitoring), surface water, and ground water monitoring consisting of measurements taken from a network of wells.

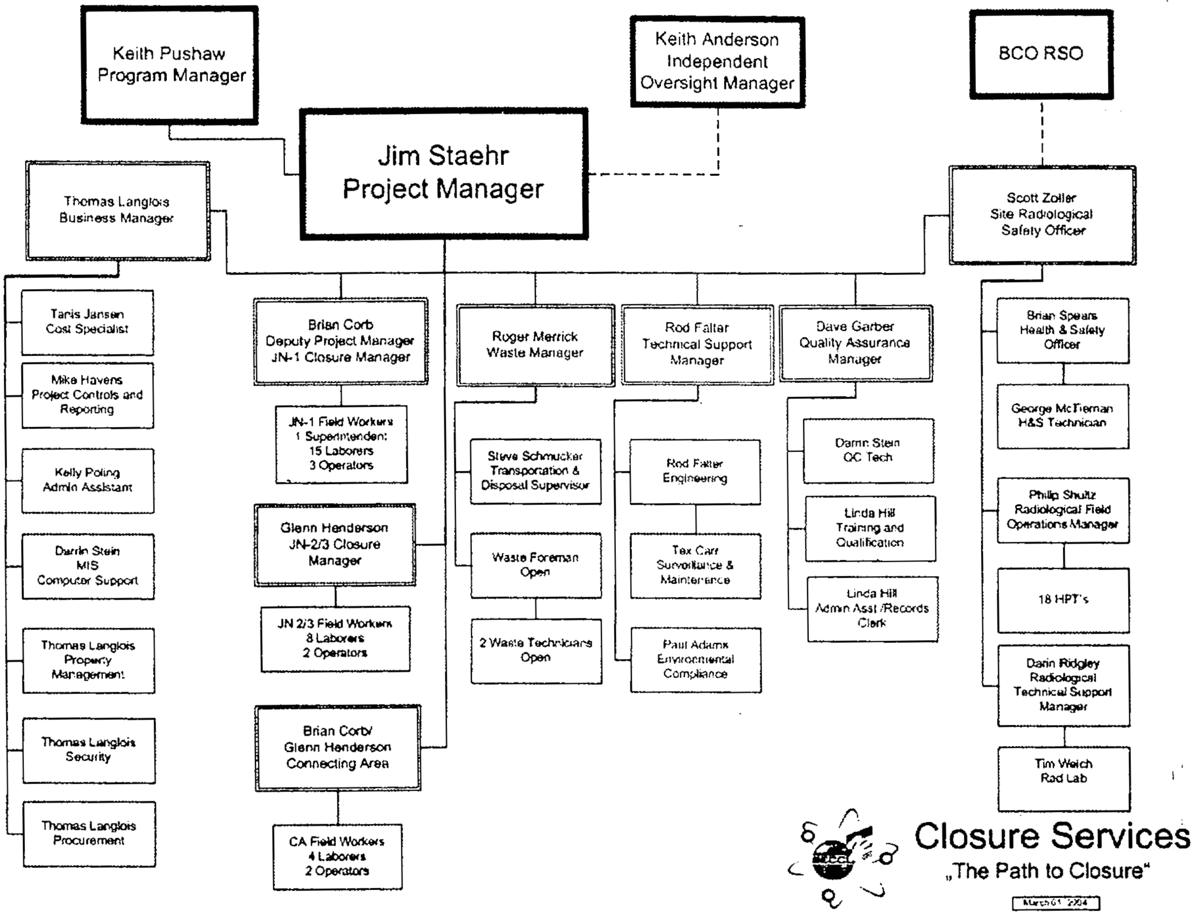
Meteorological and hydrological data are acquired as necessary to support this plan.

### 7.2 Environmental Monitoring Activities

Monitoring data are collected and analyzed to determine compliance with applicable regulations, are maintained by the Technical Support Manager and submitted appropriate to the Ohio Field Office. The Environmental Monitoring Group is responsible for implementing the EMP, doing the field work, and directing the laboratory analysis. Environmental monitoring and environmental occurrence reporting requirements (including reports for radioactive effluent, on-site discharge, and unplanned releases) are coordinated through the Technical Support Manager. This group reports the monitoring data in accordance with federal, state and local regulatory requirements. The actual reporting is done through the Technical Support Manager, with copies going to the Ohio Field Office.

The organizational structure for various tasks described in the EMP is shown in Figure 11. Each manager reports directly to the Closure Services Project Manager and is responsible for the day-to-day monitoring activities, equipment calibration, and review and evaluation of data generated.

**Figure 9. Closure Services Organizational Chart**



## 7.3 Ground Water Protection Monitoring

The Technical Manager coordinates the monitoring for radionuclides in wells around the CCP. Many of the wells used in the ground water monitoring program were designed in accordance with 40 CFR Part 264, Subpart F, or 40 CFR Part 265, Subpart F.

Ground water monitoring is done at a supply well for the West Jefferson site and from two other existing supply wells before the water is treated in any form. Eighteen (18) wells have been installed for sampling around the West Jefferson site and are randomly being selected for monitoring radionuclides; three of these wells are also monitored for chemical contamination.

## 8.0 References

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# DRAFT REPORT

on

# GEOLOGY AND HYDROGEOLOGY OF WEST JEFFERSON NORTH SITE

to

U.S. DEPARTMENT OF ENERGY

by

Thomas C. Beard and Neeraj Gupta

September 14, 1990

BATTELLE
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Columbus, Ohio 43201

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# EXECUTIVE SUMMARY

As part of the Battelle Columbus Laboratory Decommissioning Project (BCLDP) a site characterization plan was undertaken for Battelle's Nuclear Sciences Area (known as the JN site) at West Jefferson, Ohio. The site characterization program included six specific sampling areas at the JN site and the retired and remediated filterbeds located on the Big Darby Creek flood plains. This report presents the extensive geological and hydrogeological information obtained through drilling/coring operations and through a review of existing geological data. The study focuses on field evaluation of the shallow geology and groundwater flow systems within the artificial fill and shallow glacial till sediments. An attempt is made to define the location and extent of higher permeability sand and gravel lenses within the glacial sediments.

A total of 168 boreholes were drilled as part of site characterization. 116 of these were drilled during Stage 1 sampling in the summer of 1989, 20 during Stage 2 in the summer of 1990, and 32 boreholes were drilled for chemical sampling in November of 1989. Water level monitoring wells with PVC casing were installed in 25 boreholes, and stainless steel wells were installed in 3 boreholes for groundwater sampling. After drilling, boring logs for each sample point were generated and a generalized geologic fence diagram for the JN area was constructed.

In general, the shallow geology of these areas is the same as regional geology of central Ohio. That is, it is dominated by glacial till deposits. The color of till changes from brown to gray with depth. Most areas contain some artificial fill deposits. But artificial fill is most significant in area 3 and in the retired filter beds area. Sand/gravel lenses are observed in many areas but they are of limited extent. The only exception is the fine sand, silt outwash layer in area 1 which may also be connected with sand stringer found in borehole 403. Alluvial deposits are found in the retired filter beds area.

Dominant surface hydrologic controls are the lake and Big Darby Creek. A review of the water level data collected indicates that much of the shallow ground water flow from JN site discharges into the lake. Some groundwater discharge from JN site and the groundwater discharge from the

filterbeds is into the Big Darby Creek. The results of slug tests show that hydraulic conductivity falls within the range of values normally associated with the geologic materials present at each site. These materials can be categorized as the near surface brown till/fill, the confined and unconfined sandy zones, and the dense gray till. The till deposits have very low hydraulic conductivity. The sand/gravel lenses have higher permeability but appear to be discontinuous and isolated for the most part.

DRAFT REPORT

on

# GEOLOGY AND HYDROGEOLOGY OF WEST JEFFERSON NORTH SITE

to

U.S. DEPARTMENT OF ENERGY

from

BATTELLE

by

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## 1.0 INTRODUCTION

As part of the Battelle Columbus Laboratory Decommissioning Project (BCLDP), a Site Characterization Plan (SCP) was prepared for Battelle's Nuclear Sciences Area (JN). This area is situated at the north end of Battelle's West Jefferson, Ohio, site, 17 miles west of Battelle's Columbus Main Operations (Figure 1). The SCP contains a site sampling and analysis program designed to identify areas of soil which may require remedial action in order to release the site for unrestricted use.

Six areas were identified within the site for detailed sampling and analysis on the basis of existing radiological information and a knowledge of previous site activities. Those site areas have been shaded in Figure 2. An additional sampling area to be investigated was a retired and remediated filter bed (Figure 2).

### 1.1 PURPOSE

The purpose of this report is to present the extensive geological and hydrological information obtained through a review of existing geological data, in addition to extensive drilling/coring information collected as a result of this investigation. This characterization of the nature and extent

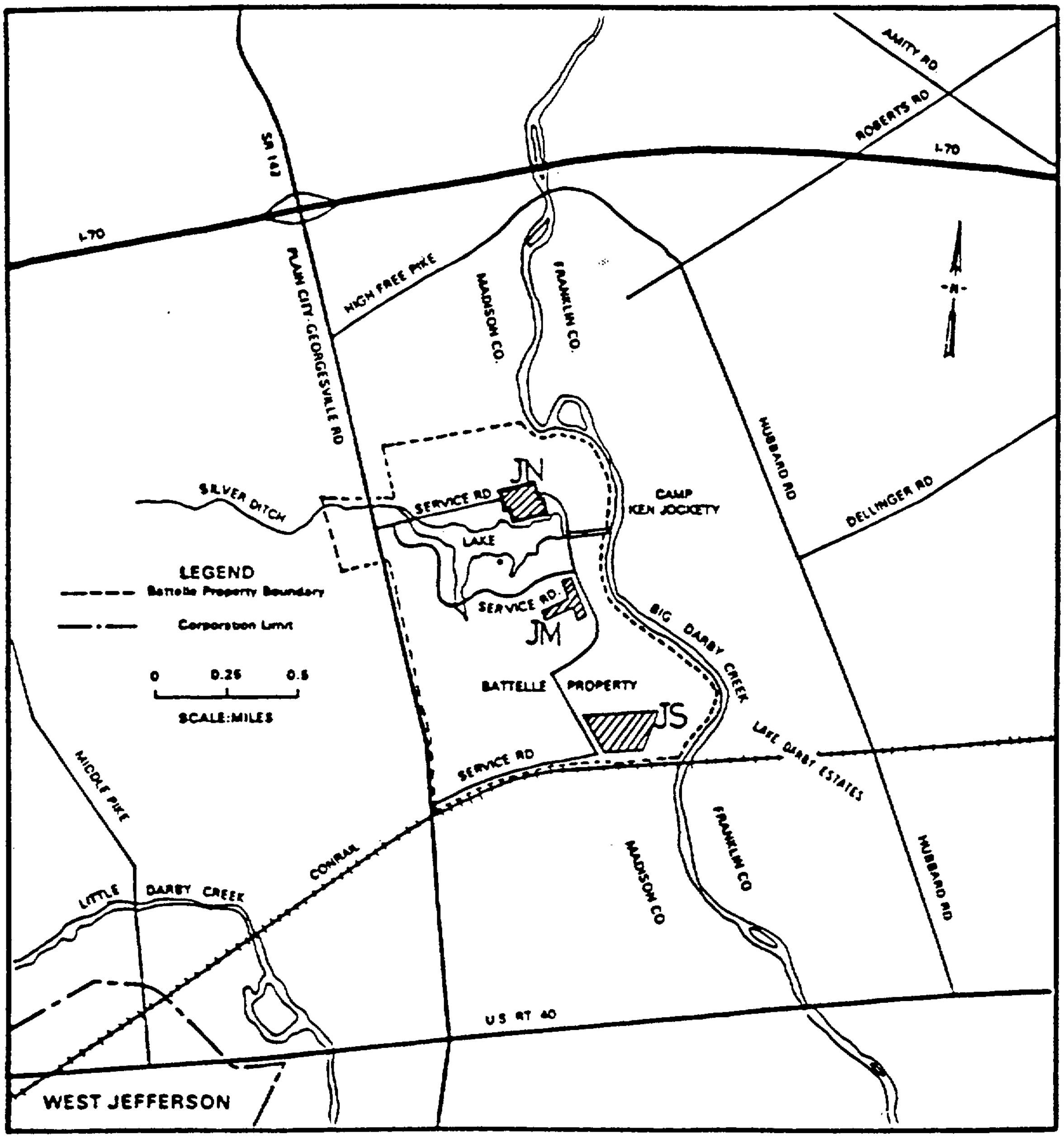

FIGURE 1. MAP OF WEST JEFFERSON SITE AND VICINITY

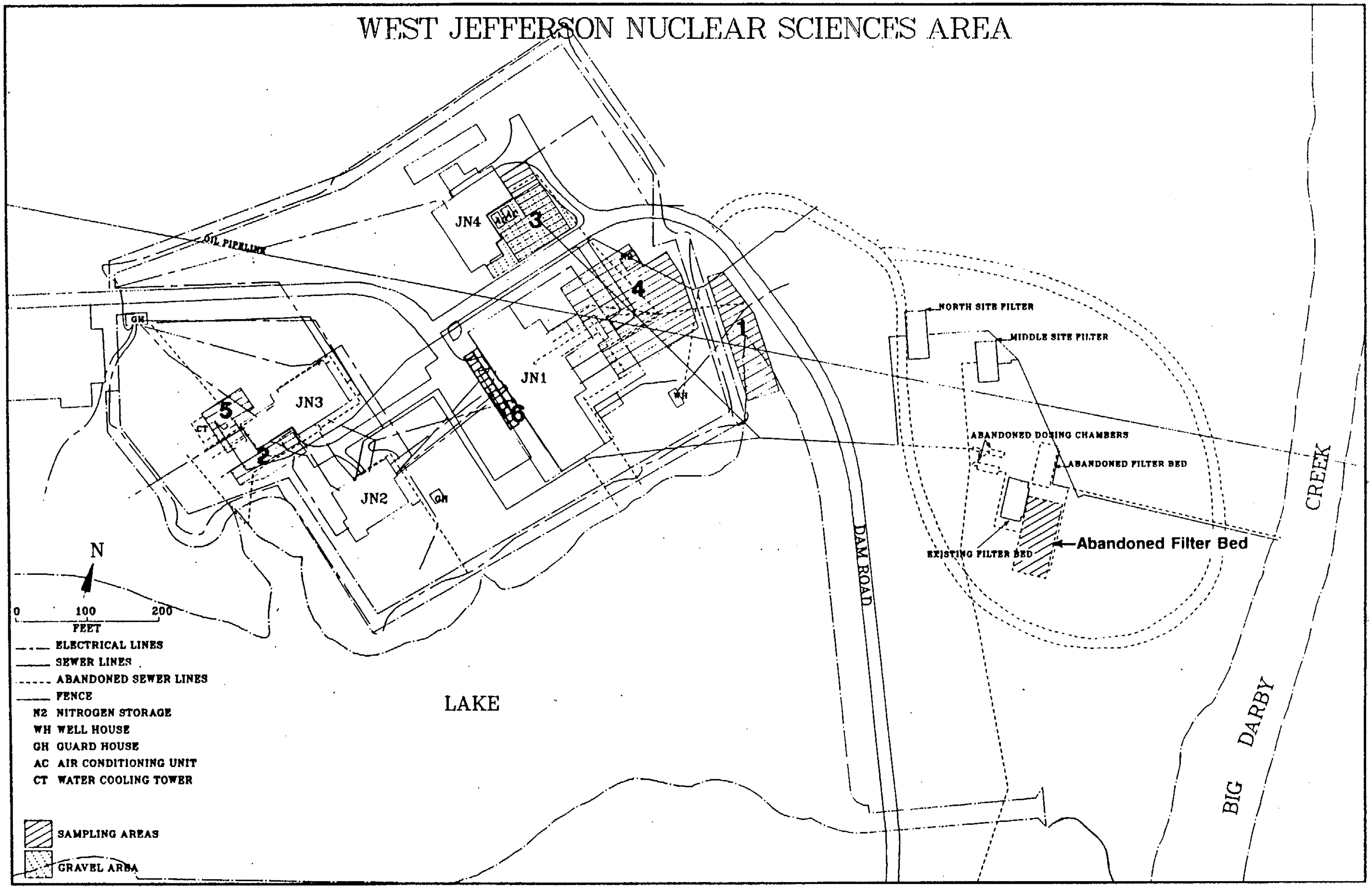

FIGURE 2. SAMPLING AREA MAP

of the subsurface environment will facilitate the decommissioning and decontamination project at West Jefferson north site.

## 1.2 SCOPE OF WORK

The West Jefferson North Area is located on the eastern border of Madison County where it meets Franklin County in Central Ohio (Figure 1). The site is bounded by Big Darby Creek to the east and the lake to the south and southwest. The Site Characterization program is limited to six specific sampling areas at the JN site and also to the retired filterbeds located on Big Darby Creek flood plain.

The study focuses on the field evaluation of the shallow geology and groundwater flow systems within the artificial fill and shallow glacial till sediments. In addition, the sand and gravel lenses within the glacial till can be significant pathway for groundwater movement due to their relatively high permeability. Therefore, an attempt is made to closely define the location and extent of these lenses within the till.

## 1.3 PREVIOUS STUDIES AND SOURCES OF DATA

While no previous site characterization studies have been performed at the site, a number of available reports provide general geological information. These include studies performed during the construction of buildings, the dam, and water wells. Boring logs are available from drillings by Burgess and Niple, Limited (1966) for the dam site, from foundation drillings below JN-1 (G. K. Jewell & Associates, 1971) and from water well drilling at JN (Klaer, Fred H. and Associates, 1963). Reports on geology, water resources, soil types, and the climate of Madison county are available with Ohio Department of Natural Resources (ODNR) and United States Geological Survey.

Information from the above sources was used along with information from drilling/coring operations, well installation, and data collection and was used for detailed site characterization of the JN facilities.

## 1.4 DESCRIPTION OF AREA

### 1.4.1 Geographic and Geologic Setting

Battelle's West Jefferson facility is located about 17 miles west of Columbus and 3 miles north-northeast of the town of West Jefferson in a rural agricultural area. It is at Madison county's eastern border along Big Darby Creek. The land surface is gently sloping except for the steep V-shaped valley of Silver Creek (now dammed and occupied by the lake) and the wide flat bottomed valley of Big Darby Creek. A topographic map of the area is shown in Figure 3.

The JN facilities lie at the northern end of the Battelle West Jefferson area, just north of the lake, approximately 500 ft west of Big Darby Creek valley. Surface elevations within the fenced area of JN are generally between 900 and 910 ft above mean sea level (MSL). The flood plain of Big Darby Creek is at elevations of about 860-870 ft MSL.

### 1.4.2 Land Use

The primary man-made structures located in this area are the dam, the lake, the JN complex of buildings, and the sanitary system filter beds. The dominant land use around the JN facilities is farmland for cultivation of corn and soybeans as shown in the aerial photo of the area (Figure 4). The flood plain of Big Darby Creek is mostly covered with trees and bushes. There are some newer residential developments on the east side of Big Darby Creek valley.

### 1.4.3 Climate

Climate of the south-central Ohio region may be described as continental-temperate. As such, the region is subject to a wide seasonal range in temperature.

Summers are quite warm with the mean temperature for the months of June, July and August being 73.3°F. Temperatures of 90°F or above are expected for about 15 days during these months. For the months of December,

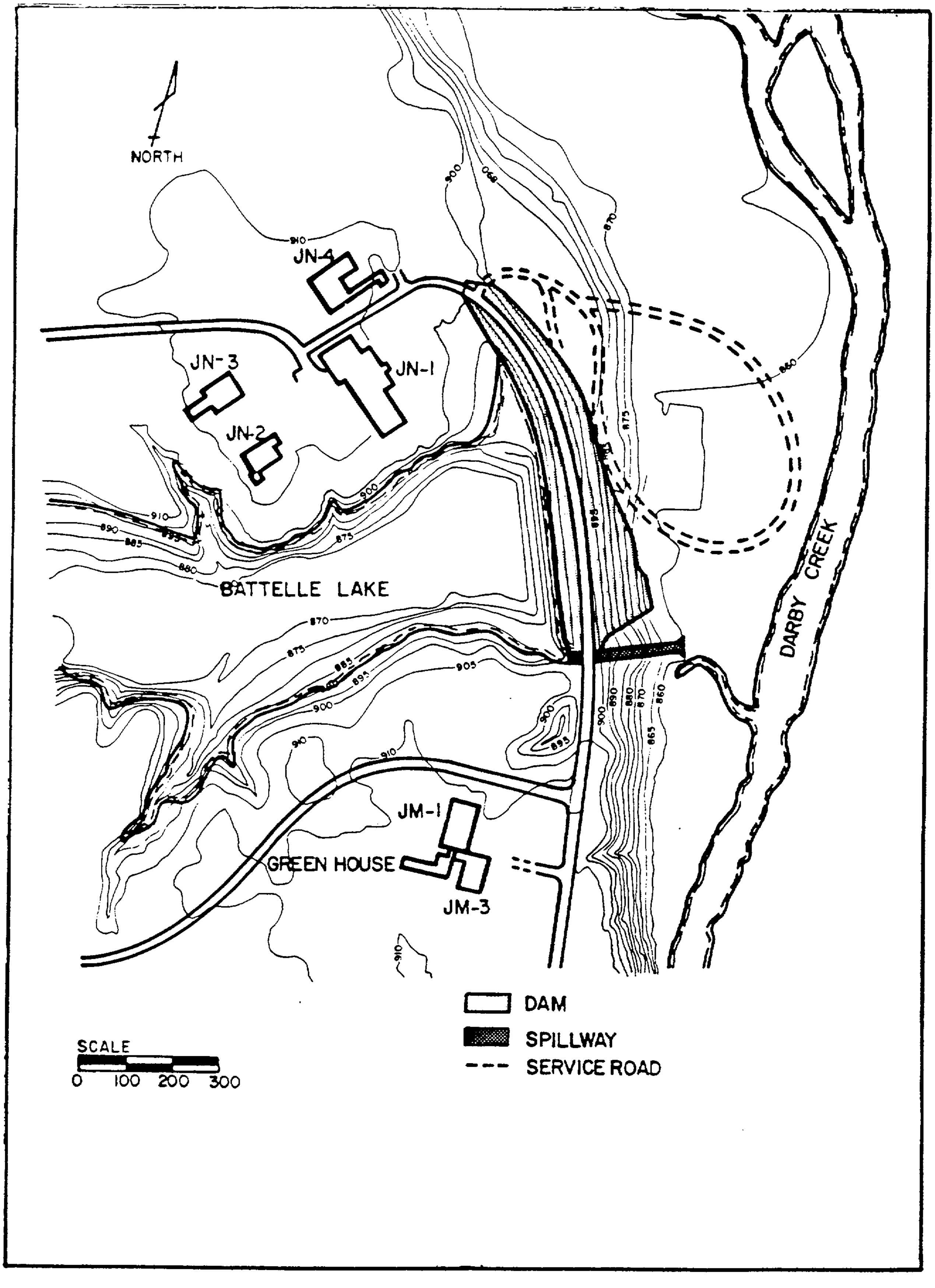

FIGURE 3. SITE TOPOGRAPHIC MAP

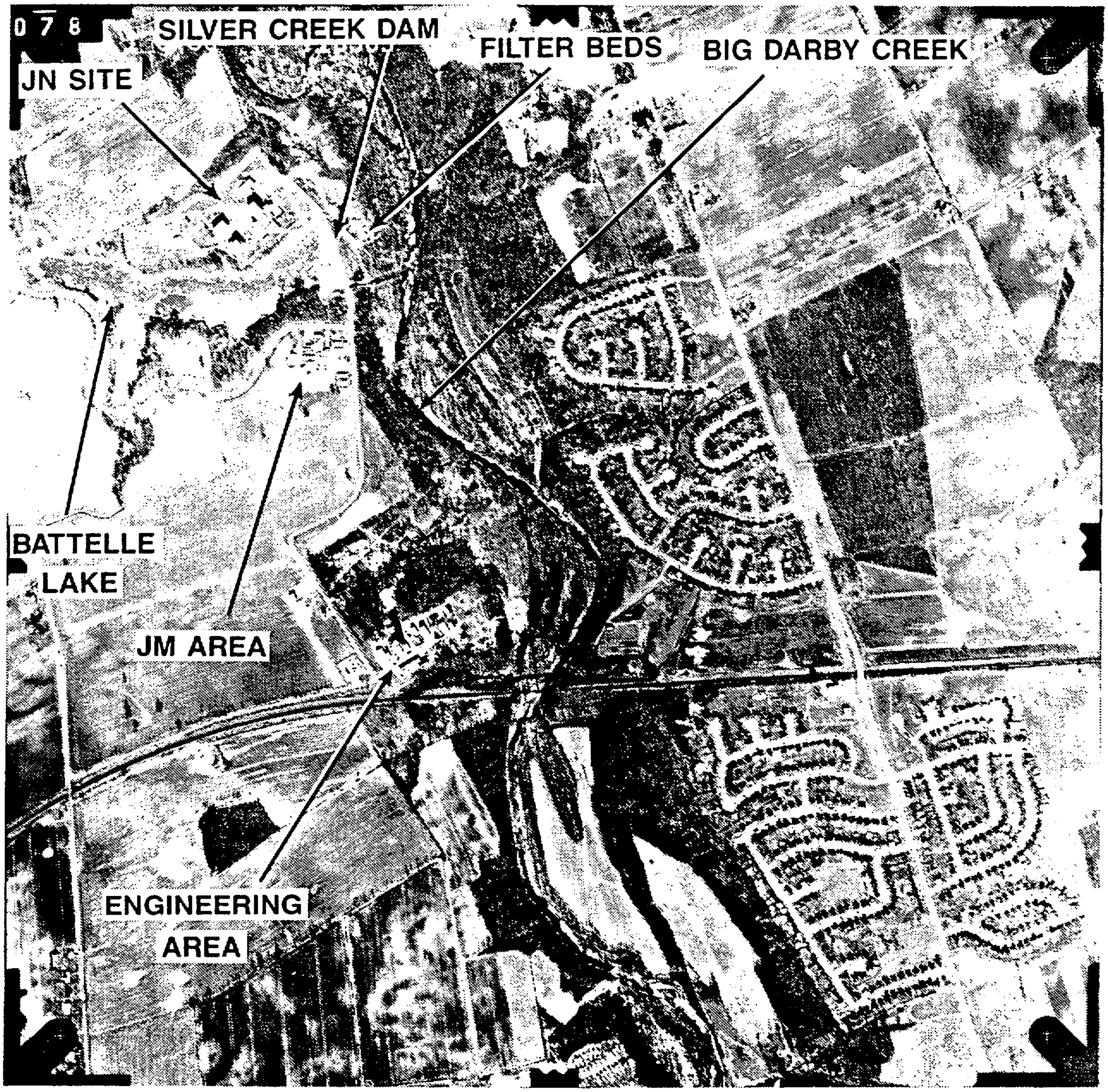

FIGURE 4. AERIAL PHOTO OF WEST JEFFERSON SITE AND VICINITY

January, and February, the mean temperature is 31.2°F, although the typical number of days per year which have temperatures below 32°F and below 0°F is 122 and 4, respectively.

Precipitation is distributed fairly uniformly during the year, although 60 percent falls during the spring and summer seasons. The annual monthly average rainfall is about 3.2 inches with the greatest recorded rainfall for any 24 hour period being 3.87 inches, in July of 1947.

# 2.0 GEOLOGY

## 2.1 INTRODUCTION

A detailed study of the geologic and hydrologic characteristics of the Nuclear Sciences Area at West Jefferson was performed as part of the Site Characterization Plan. Previously existing information in the form of boring logs was used (Figure 5) to develop correlations. In addition, extensive drilling and sampling operations were performed. This section is divided into subsections on General Site Geology and Specific Sampling Area Geology.

## 2.2 GENERAL SITE GEOLOGY

The Nuclear Science Area at the West Jefferson site is situated on glacial till deposits. The till overlies approximately 500 feet of limestone/dolomite bedrock, and, based on bedrock contours and surface elevations at the site, the maximum possible range of till thickness is estimated to be 40 to 160 feet. Soil up to 6-feet thick has developed at the top of the till. In the floodplain of Big Darby Creek the surficial material is alluvium between 10 to 15 feet deep. Fill materials are also present as a result of construction and related activities.

### 2.2.1 Soil

Four types of surficial soils are mapped at the West Jefferson JN Area (ODNR 19759, USDA 1981): Crosby-Lewisburg, Lewisburg-Celina, Medway, and Miamian (Figure 6). The Medway soil has formed on alluvium and the other types are all formed on till.

Crosby-Lewisburg soils are found in nearly level and gentle slopes. They are poorly-drained to moderately well-drained, showing seasonal wetness and temporary ponding, particularly in level areas. Permeability is slow (0.06 to 0.2 in./hr). Surface soil is slit loam about 8 in. thick. Subsoil is 14 in. thick clay loam and the parent material substratum to about 60 in. depth is glacial till. The depth to till is greater than 22 in. in some areas. In the Unified Soil Classification System (which is based on

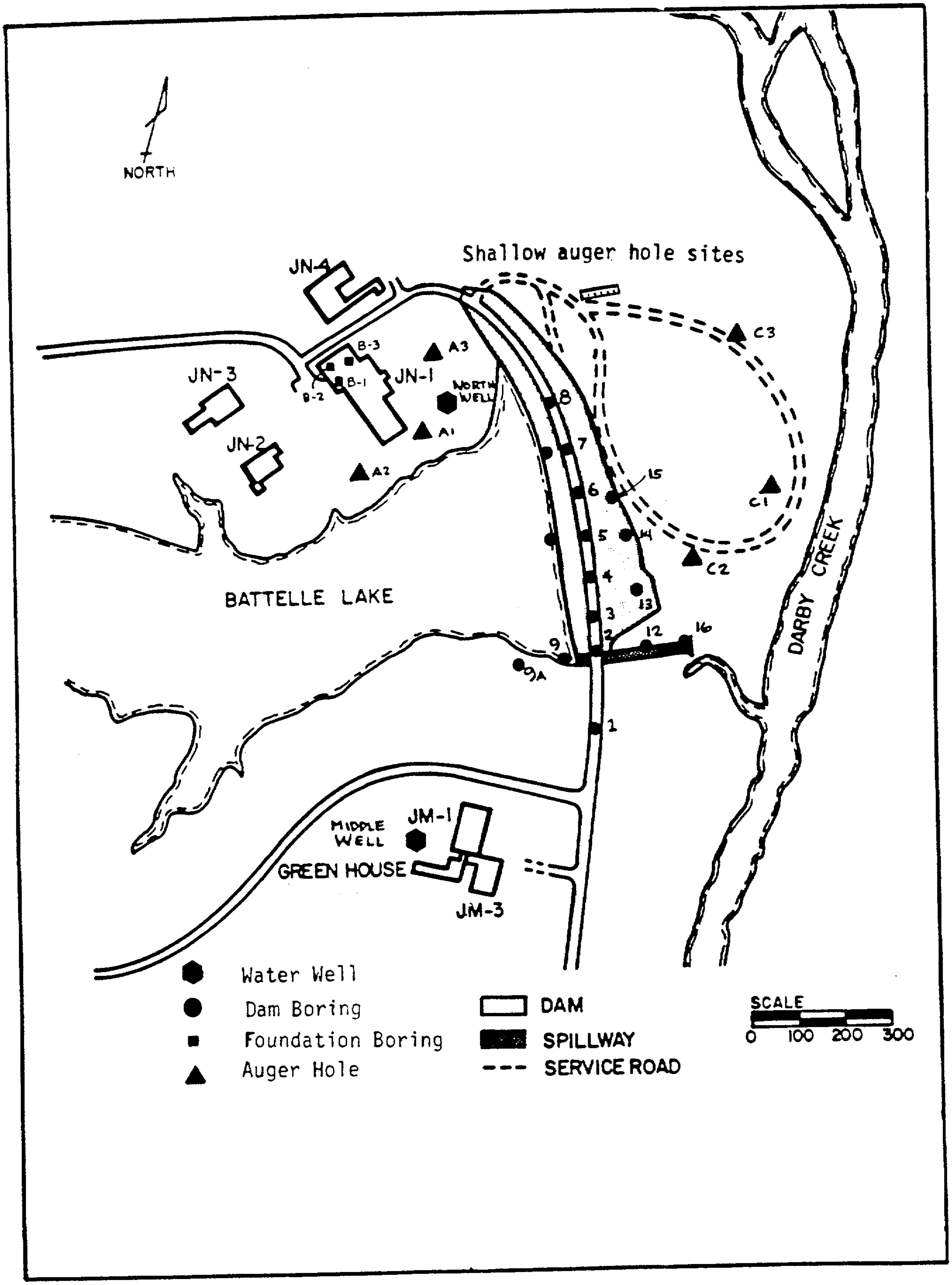

FIGURE 5. PREEXISTING BOREHOLE LOCATIONS

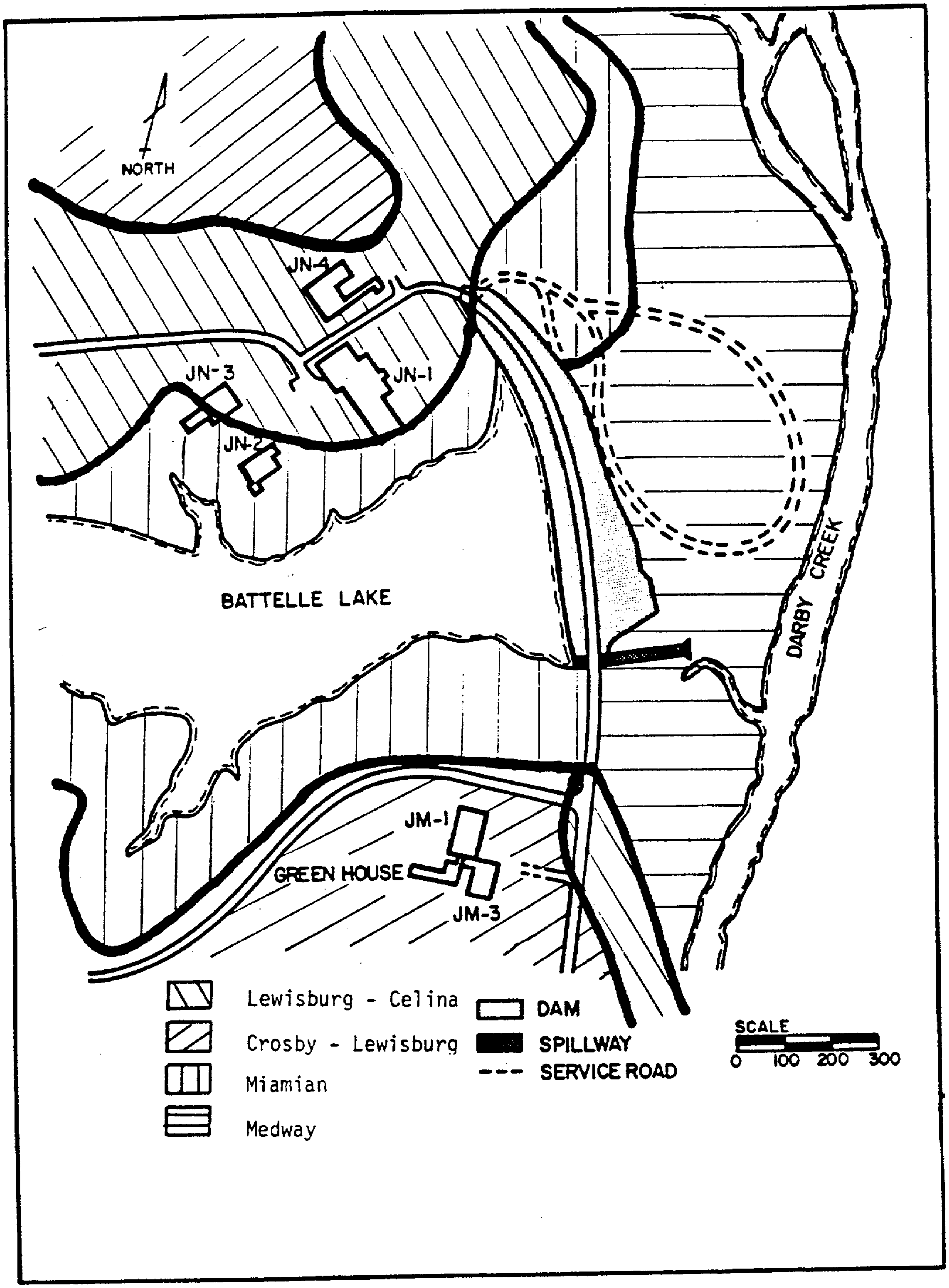

FIGURE 6. SOIL DISTRIBUTION AROUND JN FACILITIES

engineering characteristics) these soils are classified as CL/ML (CL= low-to-medium plasticity clays, including silty, sandy, and gravelly clays; ML=slightly plastic silt and very fine sand).

Lewisburg-Celina soils are found on gentle slopes and are moderately well drained. Temporary surface wetness occurs. Permeability is moderately slow (0.2 to 0.6 in/hr). The surface layer, silt loam, is about 9 in. thick. Subsoil, clay loam, is 17 in. thick and the substratum is glacial till at a depth of about 40 in. or more. The engineering classification of these soils is CL/ML.

Miamian soil is formed on gently sloping to steep topography. The surface layer, 8 in., is silt loam. The 19-in. thick subsoil is clay loam, and the substratum at approximately 27 in. is glacial till. Permeability is moderately slow (0.2 TO 0.6 in./hr). It is well drained due to the slope. The engineering classification of this soil also is CL/ML.

Medway soil occupies nearly level flood plains and forms on recent alluvium derived from upland soils. Surface soil is about 15 in. thick and is silt loam. The subsoil is 19 in. thick and is mottled silt and clay loam. The substratum is gravelly loam and may be deeper than 24 in. Permeability is moderate (0.6 to 2.0 in/hr), and it is moderately well drained. Organic material content is high. Included in areas mapped as Medway are very poorly drained loam soils in depressions, high water channels, and base of slope breaks. The engineering classification of these soils is ML/CL.

### 2.2.2 Alluvium

Alluvium consisting primarily of stratified silt, fine to medium sand, and clay is found in the flood plain of Big Darby Creek. Very thin layers of fine sand were observed in clay/silt deposits, and the alluvium is generally more well-sorted than the till. Some small gravel is sparsely interspersed in the alluvium, probably due to its abundance in the parent till.

The alluvial deposits are black, gray, red, or brown, and occasionally are mottled. Alternating wetting and drying of these materials occurs as the stream level and water table fluctuates, causing alternating oxidizing (low water) and reducing (high water) environments. Yellow and red colorations are due to oxidation of iron. The black color and a sulfur odor indicate the presence of organic material and reducing conditions.

Although sand layers within the alluvium may be continuous to some degree, they are thin and difficult to trace or correlate over distance.

The permeability of the alluvium is not known, but is estimated to be in the range of $10^1$ to $10^{-7}$ cm/sec, with clean sand at the high end and silt at the low end of the range (Freeze and Cherry, 1979).

### 2.2.3 Fill

Fill is found overlying natural soils or parent materials in areas where the West Jefferson site has been affected by construction activities. These areas include the JN building complex, roadways (paved and unpaved), the dam and spillway, spoil areas, the filter bed area, and other disturbed areas. Fill also is found where underground utilities are placed (electrical, telephone, sewer, water, gas, etc.). The depth of fill is highly variable, as are its characteristics.

The source of the fill material are excavation and borrow areas. In most instances the materials are from the site itself, although some types of fill used for specific purposes have been brought in from nearby areas because of their absence or sparsity at the site. Consequently, the gross composition of fill is usually the same as native materials; i.e., mixture of clay, silt, sand, and gravel but can be sorted or selected to consist entirely of a single constituent, such as sand or gravel.

The placement process also introduces great variability, some fill being very carefully compacted at optimal moisture content, some being compacted under less stringent specifications, some being placed and not compacted at all. This results in a range of densities and, consequently, a range of geologic and hydrologic characteristics.

Two types of fill are recognized at the site: general fill and engineered fill. General fill consists of reworked native materials that have been placed to achieve a required grade and compacted to some degree. It consists of a clayey silt with some sand and gravel. The gravel may be derived from till or may be crushed rock brought into the site. The gravel in most of the general fill tends to be larger and more abundant than in the native till. The density may vary widely from uncompacted (as in spoil piles) to compaction as great as native till, where moisture and compactive effort were optimal. Hydrologic characteristics will vary according to the methods of placement.

Engineered fill materials consist of native or imported materials that have been selected and placed to meet engineering specifications. Examples at the site include the subgrades below the foundations of various structures, subgrades of paved roads, the dam embankment, and the sanitary sewer filter beds, drains, and the backfill used for underground pipelines. The type of material is variable depending on use. Strength, moisture content, size gradation, degree of compaction, and hydrologic characteristics all depend on the design of the fill.

### 2.2.4 Till

Borings for the dam investigation and construction of two water wells show bedrock at 791 to 796.5 feet above MSL and till thickness of 63.8 feet to 119 feet. This is within 40-to 160-feet range expected based on published bedrock elevations shown in ODNR (1959) and the surface elevations. None of the borings during current Site Characterization penetrated the bedrock.

The till consists of dense, predominantly non-plastic silt and clay, with minor amounts of sand and gravel in an unstratified mixture. Boulders up to 5 feet in diameter may be present. Outwash deposits of small areal extent are also found within the till as sand and gravel lenses or stringers

The till was deposited directly by ice during two substages (episodes) of the Wisconsin glaciation, the first about 50,000 years ago and the second about 22,000 years ago. A sand and gravel deposit between the upper and lower tills is found in some areas of Madison and Franklin counties (ODNR, 1958 and 1959). These outwash deposits are reported to be as thick as 20 feet and were deposited by meltwater. Other sand and gravel layers are seen in the available logs, but are of limited lateral extent and it is difficult to correlate between borings. Some evidence of weathering (soil formation) indicates an extended ice-free interval before the upper till was deposited. A color change in till from brown to gray denotes the difference between the upper and lower tills, and this feature is used for developing correlations for Site Characterization.

The till revealed in valley walls of Silver Creek is described by Burgess and Niple (1966) as dense silt and clay with intermixed sand and gravel with "occasional erratic streaks and seams of sand." In one boring at "the Silver Creek area", whose exact location is unknown, a 6-foot thick sand layer was encountered between elevations of 882.5 and 876.5 feet. Its extent is unknown, but it is not observed in any other boreholes at the Nuclear Sciences Area. It is another example of a discontinuous outwash layer within the till.

### 2.2.5 Bedrock

The bedrock in the site area consists mainly of approximately 500 ft. thick limestone and dolomite strata of Silurian and Devonian ages (Bass Islands dolomite and Columbus Limestone, respectively). The strata lie on the east flank of the Cincinnati Arch and dip northeastward about 20 feet per mile. At the site, bedrock is at elevations of 791 to 796.5 MSL, about 113.5 to 119 feet below the surface at JN-1 (elevation about 910 feet MSL).

Prior to glaciation, the area was a relatively flat upland deeply incised by wide, steep-sided valleys. The valleys that cross this surface are the former courses of the Teays River and its tributaries. A tributary is mapped west of the Battelle site but bedrock elevations do not show it to be present at the site.

Weathering of the bedrock occurred when the rocks were exposed at the surface, resulting in open crevices. Some crevices were enlarged by solutioning to openings of 50 feet or more (ODNR, 1959). The bedrock is, therefore, very permeable, yielding up to 400 gallons per minute (ODNR, 1959). The pumping capacities of the bedrock wells at the West Jefferson site were evaluated by Klaer and Associates (1963) and are capable of 250 gpm (north well) and 500 gpm (middle well).

## 2.3 DRILLING/CORING OPERATIONS FOR SITE CHARACTERIZATION

A total of 168 boreholes were drilled as part of the site characterization plan for JN site. All drilling work was performed by John Mathes and Associates, Inc. during 1989 and 1990. The SCP calls for a two stage sampling plan. Stage 1 was the main sampling phase during which 110 boreholes were sampled in Areas 1 through 6 and in the retired filter beds in 1989 (Table 1). These borehole locations are shown in Figures 7 through 12. Stage 2 soil sampling was invoked only if the Stage 1 data do not allow a decision to be made regarding the radiological condition of any of the designated Areas. 20 boreholes were sampled in Area 3 (Figure 9) and in the retired filter beds area (Figure 12) as part of Stage 2 sampling in summer 1990 as per QA-QAP-3.0 (1990). In November 1989, 32 boreholes (Figure 13) were drilled and samples collected for chemical analysis as per quality assurance procedure SC-SP-011 (1989).

Sampling locations were identified and flagged in advance of drilling/coring operations. Procedures used for soil sample collection are described in SC-SP-004. The primary technique for extracting continuous cores was via a 5-foot long split-barrel, 3-inch OD sampler. The sampler held 2-2.5 ft long, 2 inch diameter clear plastic liners into which the core was pushed. The core usually remained intact and this system worked very well except that the core could only be viewed and not touched except on the ends. The geologic materials could be visually identified satisfactorily through the plastic. Few problems were encountered although some holes were offset either to achieve better recovery or to avoid utility liners. For sample locations which were located in asphalt or gravel covered areas, the top asphalt/gravel was removed and stored in plastic bags prior to drilling. If continuous coring did not produce greater than 50 percent recovery after three attempts then 18 inch long split-spoons were driven. The exact locations of all boreholes was later determined by a professional surveyor.

Geologic interpretation of core materials was performed as soon as core and core liners were removed from the auger. An instrument for detecting volatile organics in the boreholes was used, however, no significant organic vapors were detected except near some USTs. Continuous scanning for

TABLE 1. SUMMARY OF BOREHOLES DRILLED FOR SITE CHARACTERIZATION

| | Sampling Area | Number of Boreholes Drilled | Number of Boreholes to 10 Feet | Number of Wells Installed |
|---|---|---|---|---|
| (1) | Stormsewer outfall | 23 | 18 | 5 |
| (2) | Wash-down between JN-2 and JN-3 | 7 | 6 | 1 |
| (3) | Rear of JN-4 | | | |
| | Stage 1 | 14 | 11 | 3 |
| | Stage 2 | 10 | (30 ft. deep) | |
| (4) | Rear of JN-1 | 21 | 20 | 1 |
| (5) | Loading Zone of JN-3 | 8 | 7 | 1 |
| (6) | Loading Zone of JN-1 | 9 | 8 | 1 |
| (7) | Retired Filter Bed | | | |
| | Stage 1 | 34 | 34 | 13 |
| | Stage 2 | 10 | (10.0 - 14.5 ft. deep) | |
| (8) | Chemical Sampling Boreholes | 32 | (variable depth) | 3 |
| | Total | 168 | 104 | 28 |

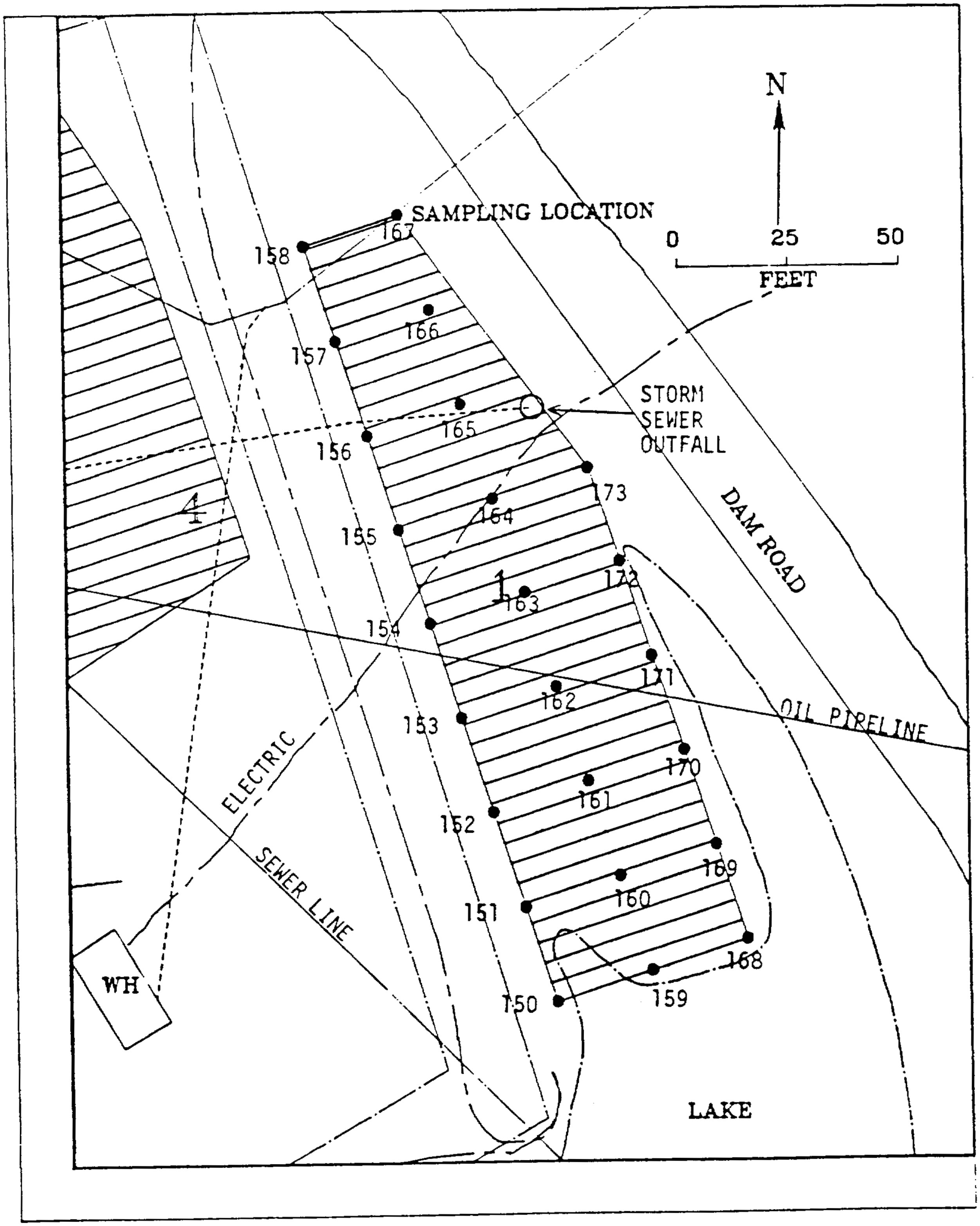

FIGURE 7. BOREHOLE LOCATIONS IN AREA 1

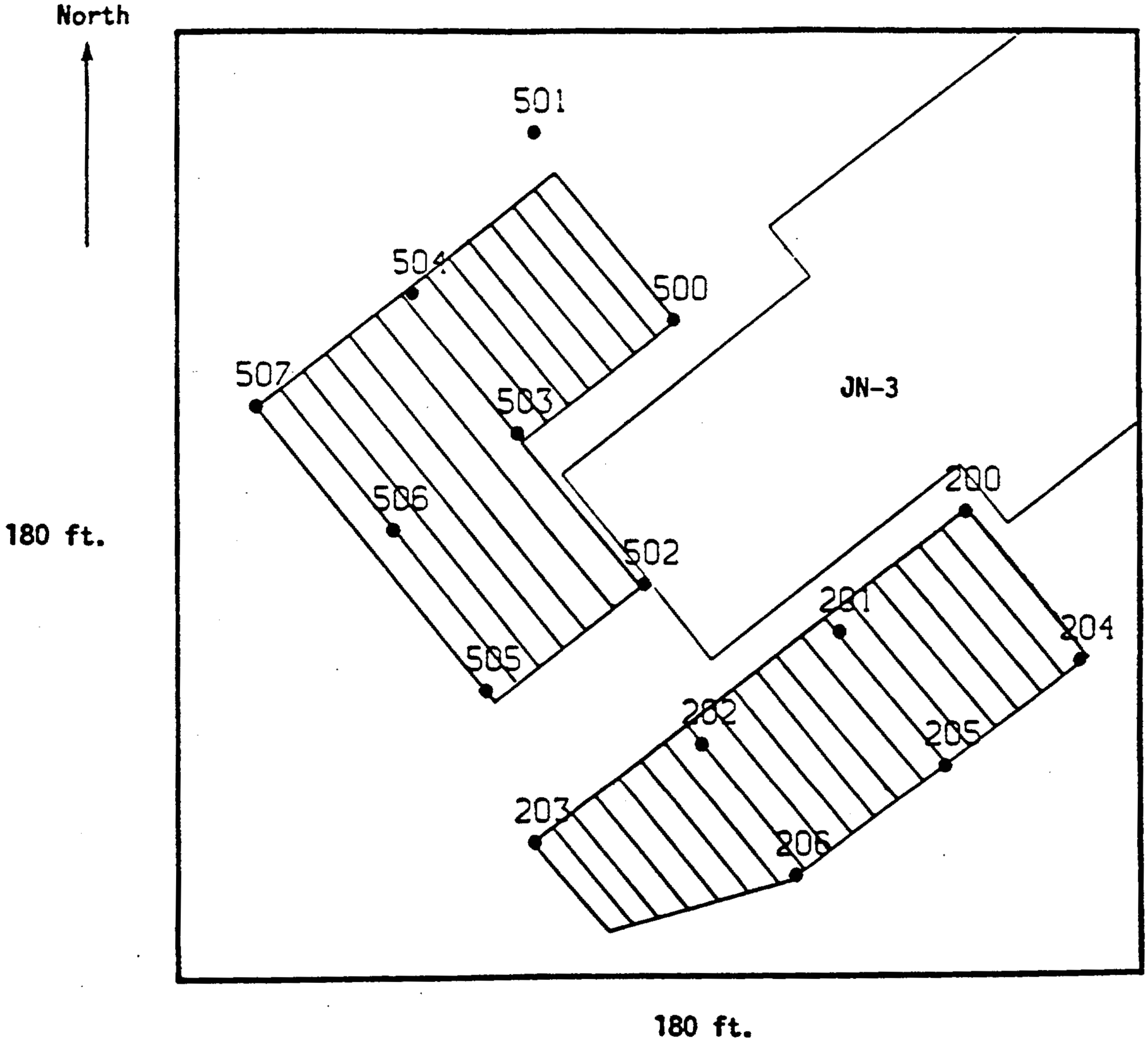

FIGURE 8. BOREHOLE LOCATIONS IN AREAS 2 AND 5

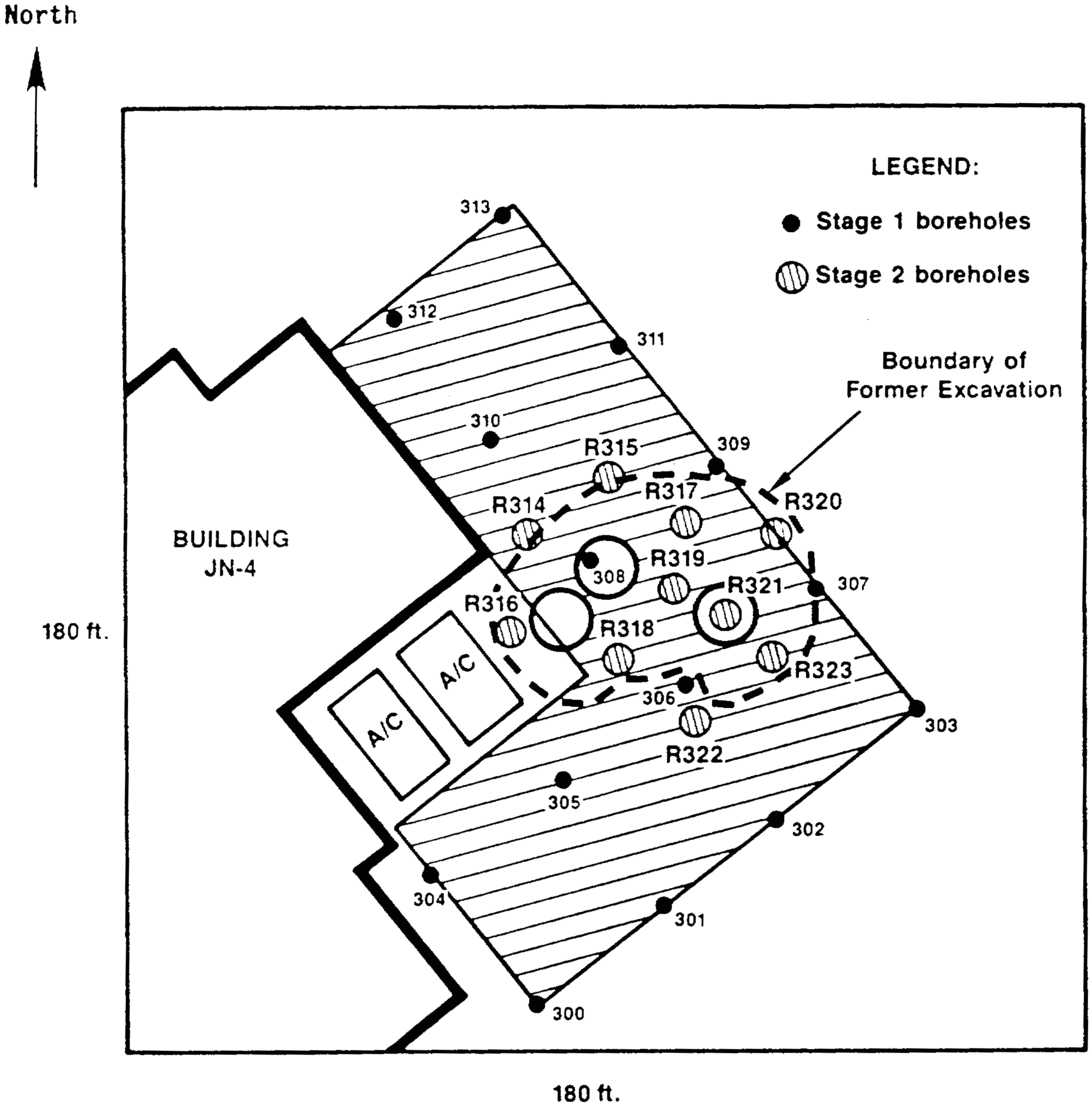

FIGURE 9. BOREHOLE LOCATIONS IN AREA 3
FOR STAGES 1 AND 2

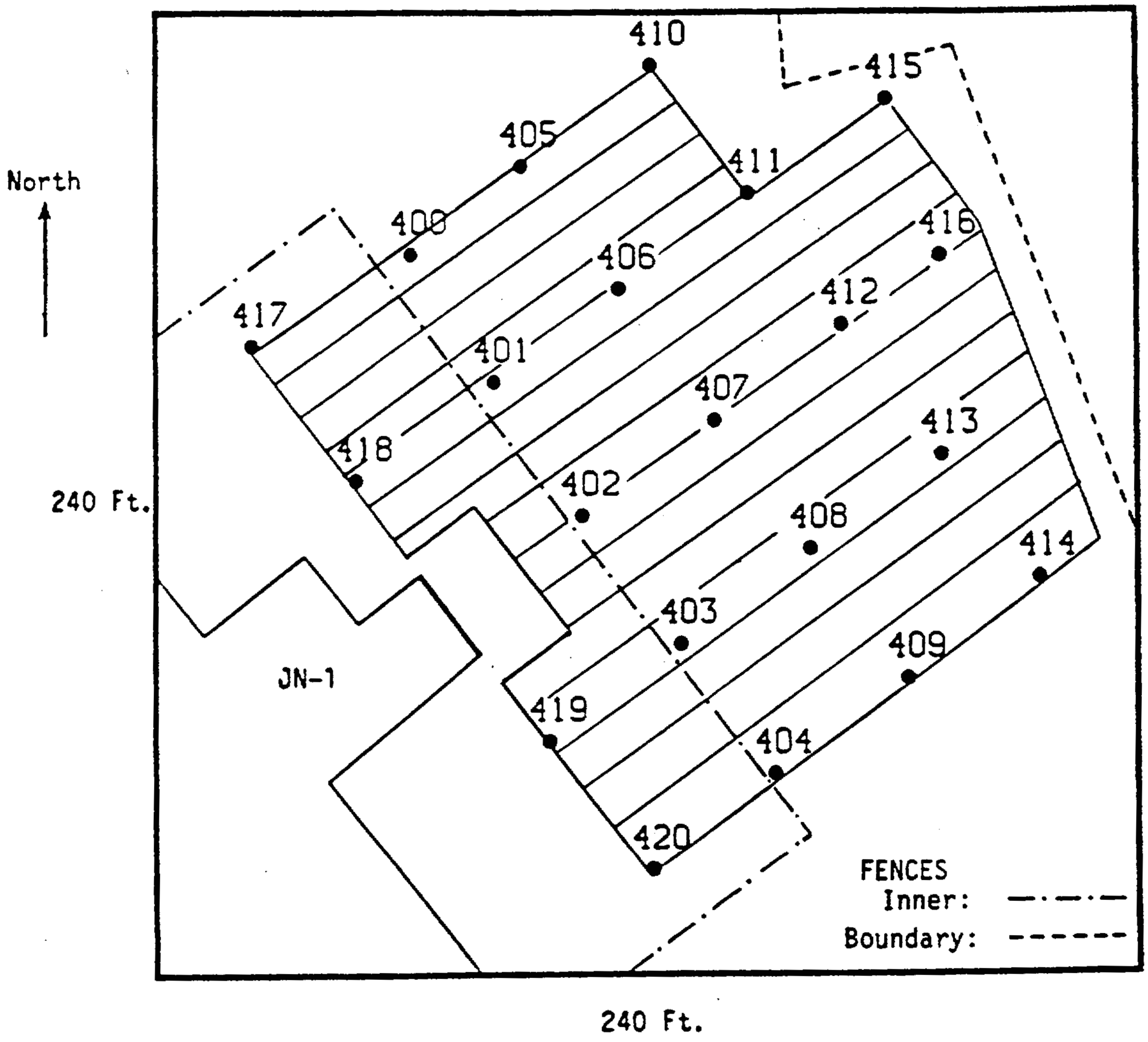

FIGURE 10. BOREHOLE LOCATIONS IN AREA 4

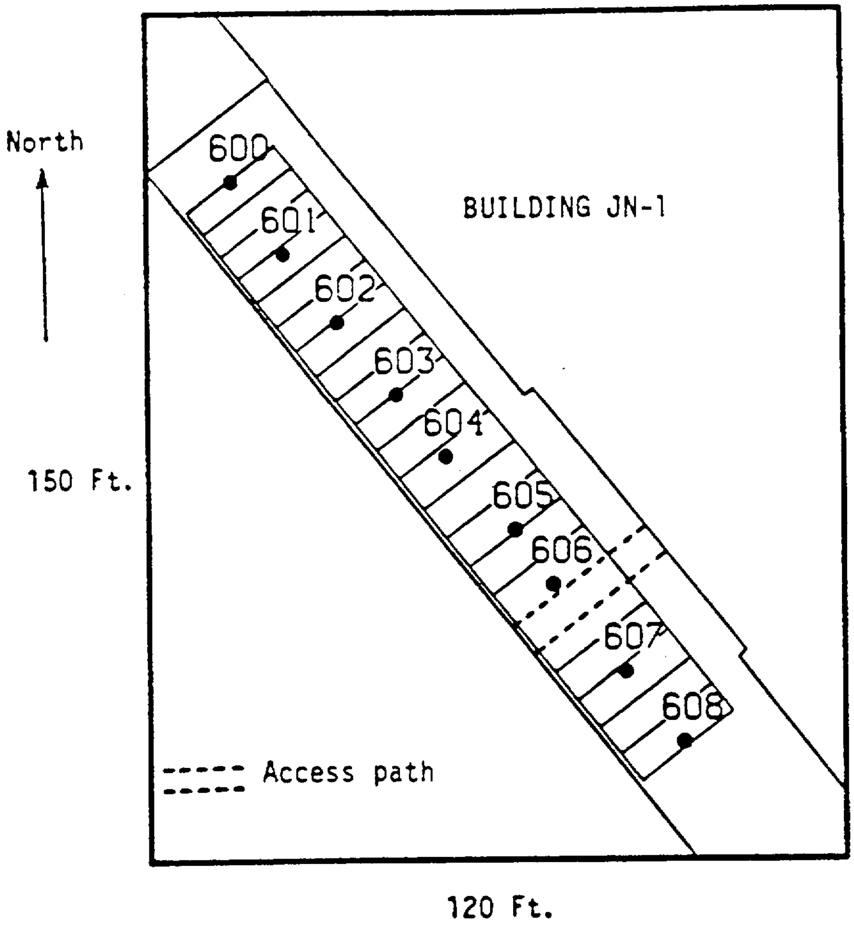

FIGURE 11. BOREHOLE LOCATIONS IN AREA 6

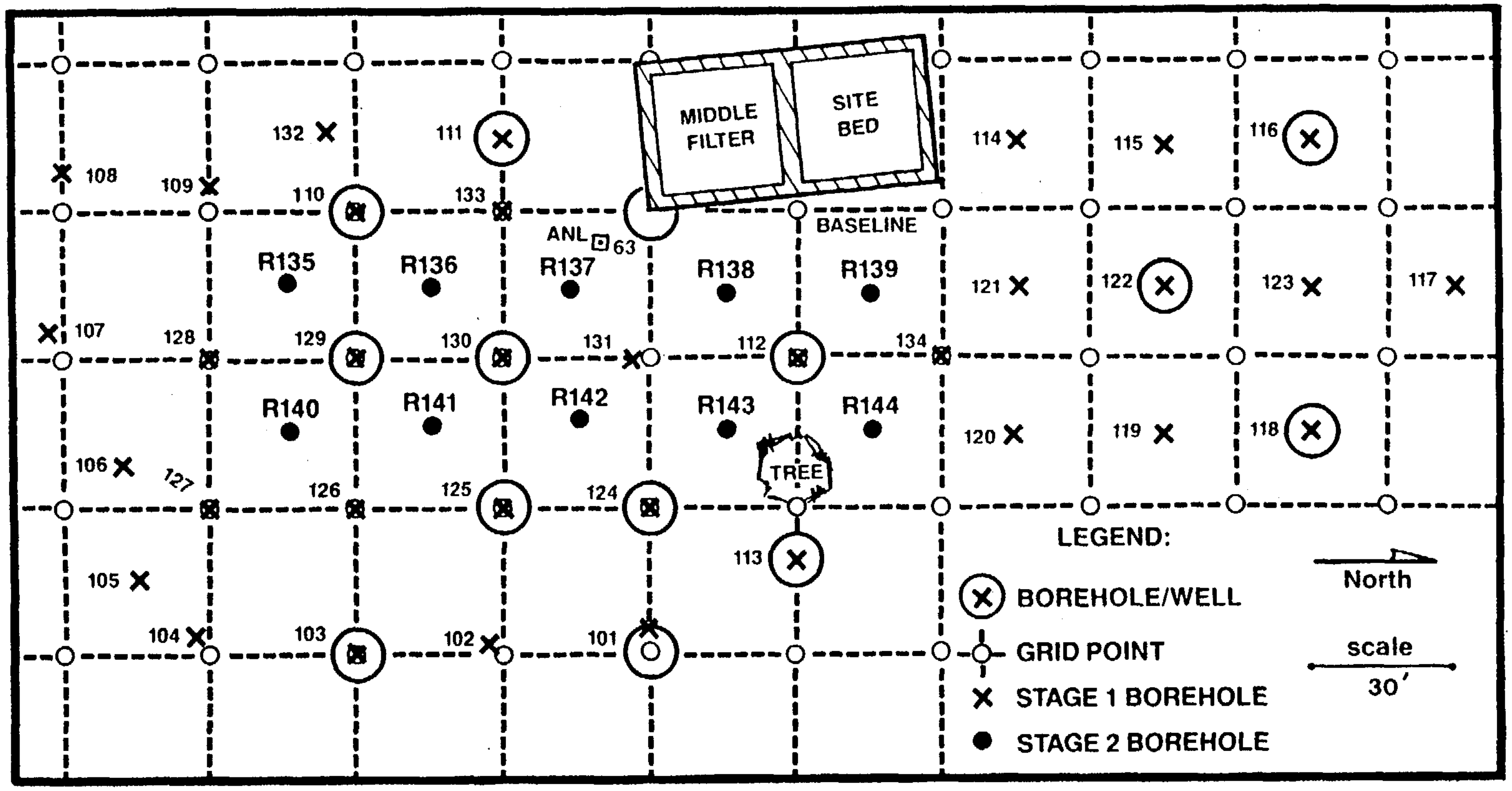

FIGURE 12. BOREHOLE LOCATIONS IN FILTER BEDS AREA

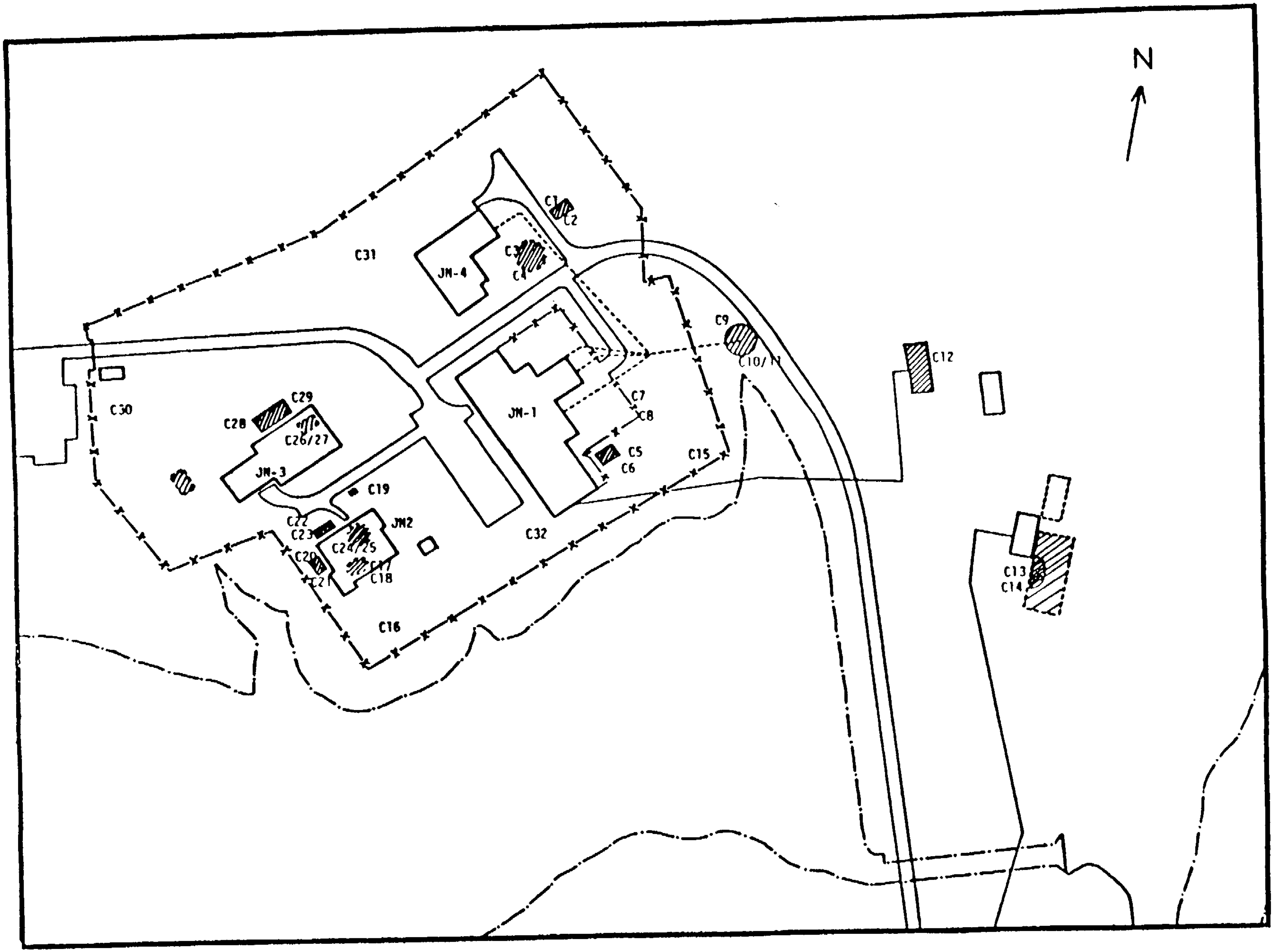

FIGURE 13. CHEMICAL SAMPLING BOREHOLE LOCATIONS

radioactivity as well as smear samples were taken on every 5 ft section for QA and safety purposes.

## 2.4 SPECIFIC SAMPLING AREA GEOLOGY

After drilling, boring logs for each sample point were generated and these are included in Appendix A. Representative core logs from each sample area were used to construct a generalized fence diagram for JN area facilities (Figure 14). In general, the shallow geology of these areas is the same as the regional geology for central Ohio. That is, it is dominated by glacial till deposits. The marker within the till for correlation purposes is where the color changes from brown to gray. Specific variations within the sampling areas are due to the presence of sand/gravel outwash deposits within the till and to artificial fill in excavations, and along utility lines. Significant observations from each sample area are discussed below.

### 2.4.1 Area 1 (Storm Sewer Outfall)

Most of the boreholes in this Area show thick deposits of silty-clay/clayey silt underlain by fine grained sand and silt deposits. These sediments are moderately well sorted and contain variable amounts of cobbles, pebbles and gravel. The general thickness of the fine sand and silt deposits increases from absent in the north (borehole 158) to more than 10 feet in the south. The sandy deposits are underlain, and sometimes intermixed, with unstratified brown till. The depth to top of gray till is between 11 to 15 feet. The sandy and silty layers are most likely of glacial outwash or alluvial origin.

### 2.4.2 Area 2 (Between JN-2 and JN-3)

The top 10 feet in this Area are dominated by poorly sorted brown fill and till. Only one stringer of clayey sand was observed at about 9.5 feet depth in hole 202. The top of gray till is at 9.5 feet depth.

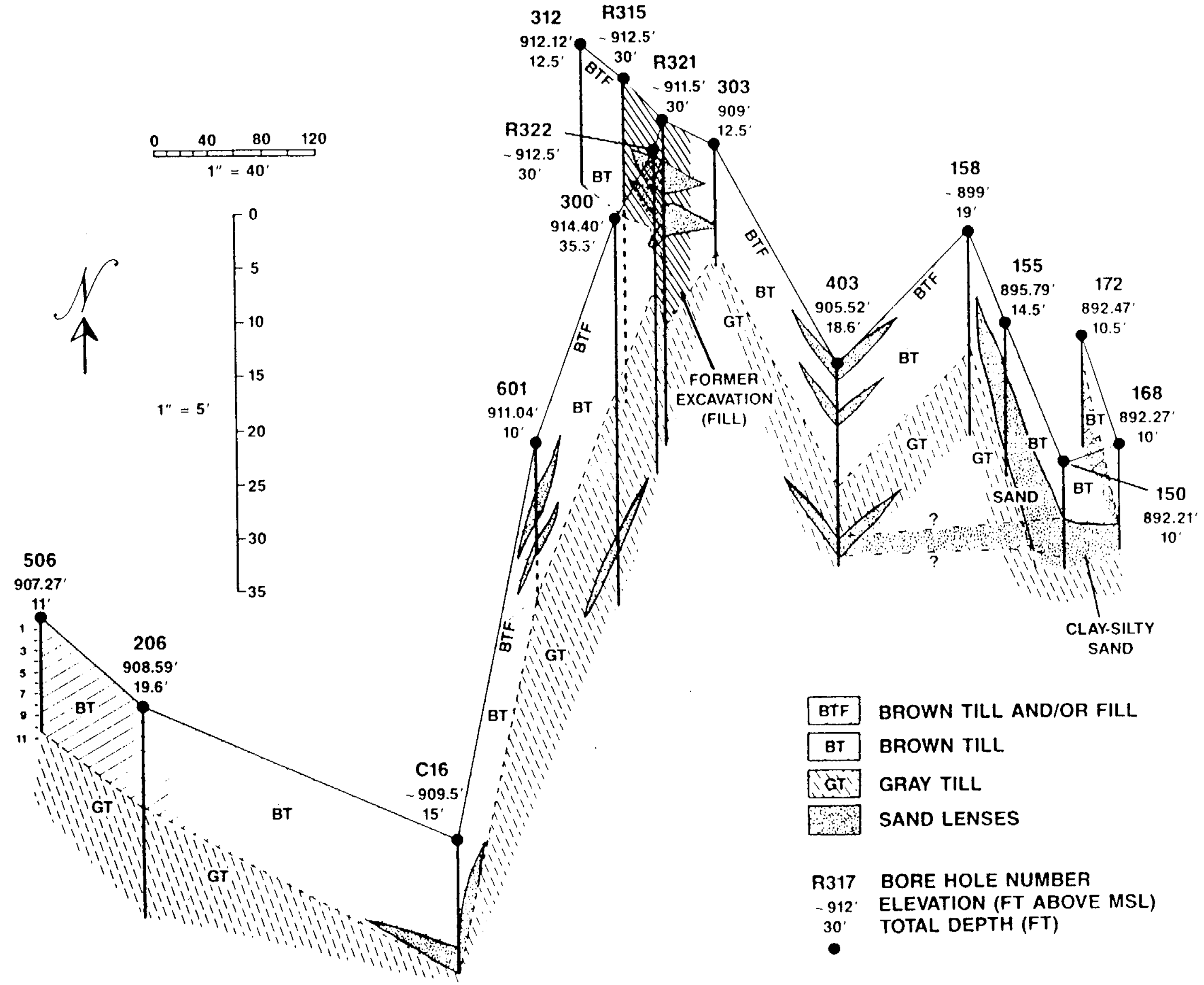

FIGURE 14. FENCE DIAGRAM FOR JN AREA

### 2.4.3 Area 3 (Rear of Building JN-4)

This Area includes the site of a former excavation pit which was later filled with loose sediments. The depth to top of gray till in areas outside the excavation is about 13 feet whereas in the deepest part of the old excavation it is as deep as 19 feet. The gray till in this Area is generally very compact with only a few thin sand and gravel lenses.

Sediments above the gray till are a mixture of soft to subcompact sand, silt, clay and gravel. This is mostly brown colored fill. Many sand and gravel rich segments were observed in the fill but they do not appear to be interconnected in all the boreholes. The general softness and medium to coarse grain size increases the possibility of rapid groundwater movement in this Area if an outlet exists.

### 2.4.4 Area 4 (Rear of JN-1)

This Area is dominated by brown fill and till, subcompact with very few sandy lenses. The gray colored dense till is seen at the bottom of some holes at about a 10 feet depth. The presence of man-made inclusions such as asphalt, crumbled steel, and metallic fines in several holes indicates widespread presence of general fill at shallow depths in this Area. Borehole 403 was drilled to 18.6 ft and encountered a fine sand stringer near the bottom of the hole. The general particle size distribution, color, and texture of this fine sand/silt was identical to the fine sand/silt deposits found in the south end of Area 1.

### 2.4.5 Area 5 (Loading Area of JN-3)

This Area is also dominated by brown subcompact till underlain by gray till at about 10 feet. These are not obvious sand lenses except the gravel from 2.5-5.0 feet in 503 which is from an abandoned drain.

### 2.4.6 Area 6 (Loading Area of JN-1)

The top 10 feet are mostly brown fill and till. There is gravel just below surface. Sand lenses are present in 601 and 604 between 5 and 10 feet deep.

## 2.5 GEOLOGY OF ABANDONED FILTER BED AREA

Characterization of the two retired, remediated filter beds was initiated in 1988, prior to Stage 1 main site characterization. 34 holes numbered 101 to 134 were drilled to a depth of 10 feet each (Figure 12). In July 1990, 10 additional boreholes were sampled as part of the Stage 2 Site Characterization. These boreholes were sampled to include all of the filter bed materials and the permeable sand and gravel layers. The total depth of the boreholes ranged between 10 and 14.5 feet.

Geologically this Area is made up of a variety of deposits including alluvial sands, sand and gravel artificial fills, and filterbed pebbles. Much of the material in the top 10 feet consists of soft, unconsolidated silty, clayey deposits intermixed with sand and gravel lenses. In the holes that penetrate the retired filter bed an unconsolidated layer of brown and black pebbles with white coatings can be seen. This varies in thickness from zero to 2.5 feet and is probably the old filterbed material. Coarse sand and gravel are widespread between 5 and 10 feet deep. These are underlain by brown and red colored till layers. The varied nature of sediments makes it difficult to correlate different layers, especially in the retired filter bed area.

# 3.0 HYDROLOGY

## 3.1 SURFACE HYDROLOGY

### 3.1.1 Surface Water and Drainage

The surface hydrologic features at the site are Big Darby Creek and the lake, which occupies the valley of a tributary to the creek.

The lake was created in 1967 following the completion of the dam. The lake surface elevation is nominally 888 feet above mean sea level, the elevation of the spillway crest. At this elevation, the lake capacity is 275 acre feet. Its maximum depth is 32 feet. JN buildings are about 100 feet north of the shore of the lake and are 20 feet or more above it.

Silver Creek is the tributary dammed to make the lake. It originates approximately 1.5 miles west of the dam and it drains a watershed of 2.1 square miles. The dam is about 400 feet from Silver Creek's junction with Big Darby Creek, and the gradient of the creek is about 75 feet in 1.6 miles.

Big Darby Creek flows from north to south about 400 feet east of the dam and 900 feet east of the JN Area. The only known stream gage on Big Darby Creek is at Darbyville, about 20 miles south of the site and downstream. Records for this gaging station are presented in yearly USGS Water Data Reports (USGS, 1988).

The average discharge over the 63 years of record is 455 cu ft/sec. However, flow ranges widely from very low, when the stream is in pool stage and the only perceptible flow is over riffles, to very high, when the stream is at flood stage. The maximum discharge was 49,000 cu ft/sec on January 22, 1959. The minimum was 1.4 cu ft/sec on September 17, 1931. The gradient of the stream at the site is very low; about 1 ft in the 1.2 mi reach from the north boundary to the southern boundary of the Battelle property (at the Engineering Area).

### 3.1.2 Precipitation, Evaporation, Infiltration

Climatological summary data were obtained from Ohio Department of Natural Resources (ODNR) for three stations surrounding the site: London, about 12 mi to the southwest; Irwin, about 19 mi to the northwest, and Columbus Airport, about 14 mi to the east. The average of the mean yearly precipitation values for the three stations is 37.96 in. per year. Published monthly precipitation records for these stations were also collected for 1983 through 1990 and can be obtained up to the current date at ODNR. In addition to above weather stations a number of private rain gages are located in the area as part of Central Ohio Rain Network (CORN). One of these, operated by Mr. David Cashell of ODNR is only 3 miles east of West Jefferson. Rain data for this station (Appendix 4) for the period June 18, 1989 to August 1990 was used for comparison with water level data from monitoring wells.

The evapotranspiration rate at the site is not known, however, the calculated evaporation loss from the lake is 18 in. per year for the record dry year (Battelle FEOD FILE). The runoff/infiltration-retention relationship for site soil is not known, but runoff appears to be fairly rapid. The calculated seepage loss from the reservoir is 6 in. per year (Battelle FEOD).

## 3.2 GROUNDWATER HYDROLOGY

### 3.2.1 General Description

A reconnaissance of available information was conducted to characterize the groundwater hydrology of the JN Area and its surroundings. This included review of soil borings and well logs available from construction of facilities and well installation and development at the site, as well as more general discussions of groundwater in Madison and Franklin counties.

The groundwater flow in the area of the JN site is controlled by lithology, stratigraphy, topography, precipitation, surface water, and construction at the site.

The hydrogeologic units at the site correspond to the five geologic units described previously: soil, alluvium, fill, till, and bedrock.

3.2.1.1 Soil. Soil hydrologic characteristics are largely the same as those of the parent materials. The soil interface with parent material is gradual, and does not constitute a permeability interface which would affect the flow of groundwater.

3.2.1.2 Alluvium. Alluvium is found on the floodplain of Big Darby Creek and on the floor of the valley occupied by the lake. Alluvium at the creek is 10 to 15 ft thick. It is characterized as relatively impermeable by ODNR. The valley floor of Silver Creek, under the lake, contained about 6 ft of alluvium and soil, the lower 2 to 3 ft of which were sand and gravel (Burgess and Niple, 1966).

The alluvium at the site is mostly fine- to very-fine-grained material derived from soils and glacial till. The permeability of alluvium is in the same range as till, with sand and gravel layers being most permeable.

At Big Darby Creek, alluvium is found a minimum of about 500 feet from JN facilities and direct contamination from them is unlikely. However, the filter beds and sewer outfall are in and on top of the alluvium. Low-conductivity silts and clays would inhibit the flow of water.

3.2.1.3 Fill. Fill, as described earlier is a highly variable material and its hydrologic characteristics are difficult to generalize. However, it is likely that the general fill is more conductive than native materials, and that engineered fills may also be more conductive than till or soil but to a lesser degree. This means that they could provide the most reasonable pathway for water to travel. Flow will follow the fill within the native materials. In order to be a significant pathway, however, the fill must first of all be located where a contaminant can reach it (e.g., fill around buried pipes, under a floor slab, etc.). Secondly, the contaminant must remain in the more conductive material. Where gravity is the dominant force affecting flow, the movement of water through the fill will be downward into less permeable materials rather than laterally (e.g., a small volume of water slowly leaking from a buried pipe surrounded by fill will quickly travel to the base of the fill and then slowly seep into till rather than being carried along the route of the pipe). If the gradient and volume of fluid are great enough, lateral flow can occur through fill, and the fill can be a significant pathway.

3.2.1.4 Till. The till is densely compacted, unsorted glacial deposits consisting of silt, clay, sand and gravel, with low to very low hydraulic conductivity. The till's general effect on the groundwater regime is that of limiting recharge to any permeable units within or below it.

Outwash deposits, and well-sorted sand and/or gravelly layers which are found interbedded within the till, are good aquifers if large enough and are often used for water supply wells in other parts of Madison County. In the site area, most outwash occurrences in the till are limited to thin beds (generally 1 to 2 ft thick), that are of limited lateral extent. Some of these beds are dry and some constitute small groundwater zones. Water levels in boreholes may be sustained at a high level as the water from these zones drains into the hole, but as they become depleted, the water levels drop. These deposits may be found anywhere in the till, at any depth.

There does appear to be a thin silty sandy bed that can be traced in the storm sewer out fall area and appears to extend through Area 4. This sandy layer may intersect the foundation of JN1 and does allow a more rapid pathway for water to move than would be possible in the till alone.

3.2.1.5 Bedrock. The limestone/dolomite bedrock is used at the site and in most of the surrounding area for a water supply. The water is obtained in the top few feet of bedrock from weathered crevices. Confined conditions exist in the aquifer because it is confined by overlying low permeability till.

Records on the north and middle well at the Battelle facilities provide site-specific information about the bedrock aquifer. At the north well, close to JN-1, the static water level reported during well construction was 18.5 feet below pump base (elevation 878.5 ft MSL). At the middle well it was 40.92 ft (elevation 869.09 ft MSL). Transmissivity of the limestone is estimated at 9,050 to 16,000 gal per day per foot (Klaer & Associates, 1963).

Although productive, the bedrock aquifer is unlikely to be a pathway due to the intervening thickness of till. By bypassing the till (e.g. by following a well or deep borehole), a significant but unlikely pathway to the bedrock aquifer could be available for groundwater to flow.

### 3.2.2 Specific Sampling Areas Hydrogeology

As part of the Stage 1 Site Characterization 12 monitoring wells with 2 inch inner diameter PVC screens were installed (Table 2) according to quality assurance procedure SC-SP-004.1 (1989). In addition, three 4 inch diameter stainless steel wells, C03, C09 and C16, were installed for chemical sampling. All of the wells were installed using a hollow-stem auger drill. Schematic well construction diagrams for all the wells are included in Appendix B. Two of the wells: #158 and #300 were later damaged by vehicular traffic and their use for data collection had to be discontinued.

3.2.2.1 Water Levels. The water level readings for monitoring wells were taken at regular intervals. These data are listed in Table 3. Well hydrographs were constructed from the water level data (Figures 15 and 16) and these give some information on the nature of flow regimes and extent of water level fluctuations at the site. The well hydrographs also show the precipitation data for the duration of study.

Wells in Area 1 show that water surface in this area is shallow (3-5 feet deep). This is consistent within the thick silt and sand deposits in this Area, but in well #158 the three available values show a deeper water surface (7.6-9 feet). This observation corresponds with the absence of silty sand lenses in well #158.

Well hydrographs in Area 1 also indicate that the dominant flow direction is from the NW to SE wells (towards the lake). This is shown by consistently higher water levels in well #155 and 172 than in well 150 and 168 which are closer to the lake.

Similarly the dominant flow from Areas 3, 4 and 6 is towards the lake. This is shown by hydrographs of the wells in these areas. These are similar to, but consistently higher than those in Area 1. The only exception to above is well 300 (now damaged) which was completed much deeper in the gray till and has a water level much lower than the surrounding wells.

# TABLE 2. MONITORING WELL DATA

| Sampling Area and Well Number | Top of Well Inner Casing Elevation (feet) | Ground Surface Elevation (feet) | Total depth (feet) | Screened Interval Depth (feet) |
|---|---|---|---|---|
| AREA 1 | | | | |
| 150 | 894.46 | 892.21 | 10.0 | 4.8-9.8 |
| 155 | 898.46 | 895.79 | 14.5 | 9.1-14.1 |
| 158* | 900.85 | DAMAGED WELL | | |
| 168 | 894.62 | 892.27 | 10.0 | 4.5-9.5 |
| 172 | 895.00 | 892.47 | 10.5 | 4.5-9.5 |
| AREA 2 | | | | |
| 206 | 910.78 | 908.59 | 19.6 | 14.4-19.5 |
| AREA 3 | | | | |
| 300* | 914.21 | 911.95 | 35.5 | 30.3-35.4 |
| 306 | 913.20 | 911.22 | 15.0 | 9.7-14.7 |
| 312 | 914.16 | 912.12 | 12.5 | 6.3-11.4 |
| AREA 4 | | | | |
| 403 | 908.37 | 905.52 | 18.6 | 13.6-18.6 |
| AREA 5 | | | | |
| 506 | 909.72 | 907.27 | 11.0 | 6.0-11.0 |
| AREA 6 | | | | |
| 601 | 913.10 | 911.04 | 10.0 | 4.0-9.0 |
| CHEMICAL SAMPLING | | | | |
| C03** | 912.15 | ≈911 | 11.4 | 5.5-11.4 |
| C09** | 895.32 | ≈892 | 8.9 | 3.0-8.9 |
| C16** | 911.95 | ≈909.5 | 13.6 | 8.0-13.6 |

* Well damaged

** 0.33 Feet Diameter Stainless Steel Well

TABLE 3. WATER LEVEL DATA

| | 6/19/89 | | 7/5-6/89 | | 10/26-27/89 | | 11/10/89 | | 12/7/89 | | 1/12/90 | | 3/28/90 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well | Depth Feet | Elevation Feet | Depth Feet | Elevation Feet | Depth Feet | Elevation Feet | Depth Feet | Elevation Feet | Depth Feet | Elevation Feet | Depth Feet | Elevation Feet | Depth Feet | Elevation Feet |
| 150 | 3.90 | 890.56 | 3.92 | 890.54 | -- | -- | 6.00 | 888.46 | 6.86 | 887.60 | 5.07 | 889.39 | 4.11 | 890.35 |
| 155 | 5.29 | 893.17 | 5.60 | 892.86 | -- | -- | 6.05 | 892.41 | 7.73 | 890.73 | 6.58 | 891.88 | 6.14 | 892.32 |
| 158 | 7.61 | 893.24 | 7.66 | 893.19 | -- | -- | 9.25 | 891.60 | -- | -- | -- | -- | -- | -- |
| 168 | 3.68 | 890.94 | 3.75 | 890.87 | -- | -- | 6.23 | 888.39 | 7.01 | 887.61 | 5.05 | 889.57 | 3.83 | 890.79 |
| 172 | 3.33 | 891.67 | 3.50 | 891.50 | -- | -- | 5.23 | 889.77 | 6.61 | 888.39 | 5.03 | 889.97 | 3.86 | 891.14 |
| 206 | -- | -- | 21.09 | 889.69 | 9.39 | 901.39 | -- | -- | 13.46 | 897.32 | 14.07 | 896.71 | 8.30 | 902.48 |
| 300 | -- | -- | 15.72 | 898.49 | -- | -- | -- | -- | 23.34 | 890.87 | 23.44 | 890.76 | 22.53 | 891.68 |
| 306 | -- | -- | 5.58 | 907.62 | 8.08 | 905.12 | -- | -- | 7.93 | 905.27 | 6.77 | 906.43 | 6.21 | 906.99 |
| 312 | -- | -- | 9.84 | 904.32 | -- | -- | -- | -- | 6.97 | 907.19 | 6.49 | 907.67 | 6.45 | 907.71 |
| 403 | -- | -- | -- | -- | 10.86 | 897.51 | 10.52 | 897.85 | 11.95 | 896.42 | 10.78 | 897.59 | 10.31 | 898.06 |
| 506 | -- | -- | -- | -- | 7.50 | 902.22 | -- | -- | 7.56 | 902.16 | 6.94 | 902.78 | 6.93 | 902.79 |
| 601 | -- | -- | -- | -- | -- | -- | -- | -- | 7.08 | 906.02 | 6.29 | 906.81 | 6.06 | 907.04 |
| C03 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6.77 | 905.38 | 5.58 | 906.57 |
| C09 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 5.43 | 889.89 | 4.27 | 891.05 |
| C16 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 8.63 | 903.32 | 8.75 | 903.20 |

TABLE 3. WATER LEVEL DATA (Continued)

| | 5/3/90 | | 5/30/90 | | 7/3/90 | | 8/13/90 | | 9/4/90 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Well | Depth Feet | Elevation Feet | Depth Feet | Elevation Feet | Depth Feet | Elevation Feet | Depth Feet | Elevation Feet | Depth Feet | Elevation Feet |
| 150 | 4.12 | 890.34 | 3.41 | 891.05 | 4.24 | 890.22 | 4.11 | 890.35 | 4.20 | 890.26 |
| 155 | 6.29 | 892.17 | 3.95 | 894.51 | 6.72 | 891.74 | 6.37 | 892.09 | 10.13 | 888.33 |
| 158 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 168 | 3.87 | 890.75 | 3.24 | 891.38 | 3.98 | 890.64 | 3.87 | 890.75 | 3.94 | 890.68 |
| 172 | 3.87 | 891.13 | 3.02 | 891.98 | 4.23 | 890.77 | 3.96 | 891.04 | 4.30 | 890.70 |
| 206 | 8.26 | 902.52 | 7.50 | 903.28 | 7.64 | 903.14 | 7.72 | 903.06 | 8.51 | 902.27 |
| 300 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 306 | 6.46 | 906.74 | 4.95 | 908.28 | 6.40 | 906.8 | 6.76 | 906.44 | 8.19 | 905.01 |
| 312 | 6.56 | 907.60 | 5.36 | 908.80 | 6.50 | 907.66 | 6.61 | 907.55 | 7.43 | 906.73 |
| 403 | 10.57 | 897.80 | 8.50 | 899.87 | 10.25 | 898.12 | 10.17 | 898.2 | 10.99 | 897.38 |
| 506 | 7.14 | 902.58 | 5.63 | 904.09 | 7.14 | 902.58 | 7.24 | 902.48 | 7.74 | 901.98 |
| 601 | 6.05 | 907.05 | 4.06 | 909.04 | 6.28 | 906.82 | 6.03 | 907.07 | 6.48 | 906.62 |
| C03 | 5.77 | 906.38 | 3.82 | 908.33 | 5.71 | 906.44 | 5.98 | 906.17 | 7.63 | 904.52 |
| C09 | 4.29 | 891.03 | 3.17 | 892.15 | 4.90 | 890.42 | 4.52 | 890.8 | 5.04 | 890.28 |
| C16 | 9.22 | 902.73 | 4.72 | 907.23 | 9.59 | 902.36 | 9.92 | 902.03 | 11.04 | 900.91 |

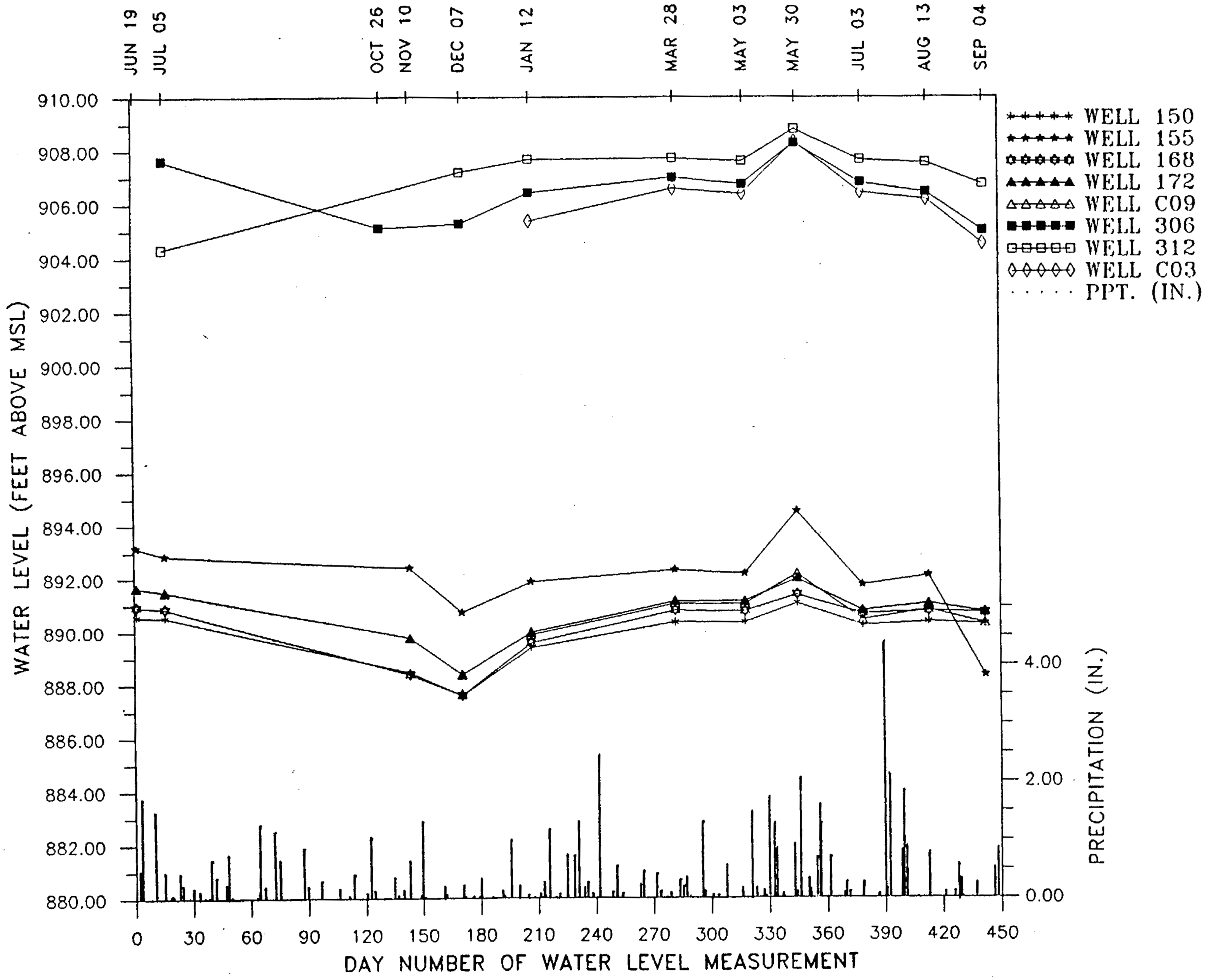

FIGURE 15. WELL HYDROGRAPHS FOR AREAS 1, AND 3

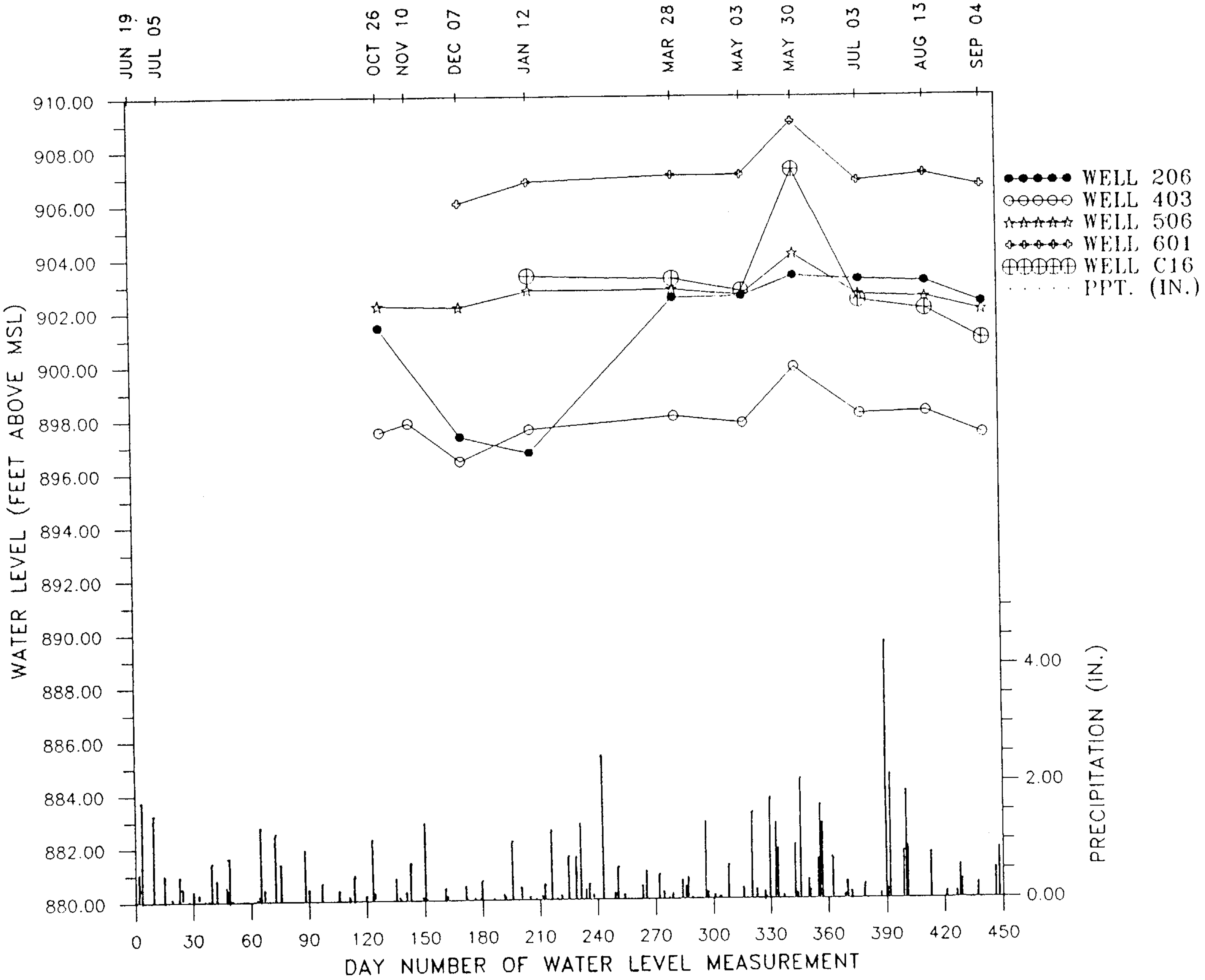

FIGURE 16. WELL HYDROGRAPHS FOR AREAS 2, 4, 5, AND 6 AND WELL C16

It appears that outwash sand layers in Areas 1, 4, and possibly 3 may form a somewhat interconnected aquifer. The sand stringer in Area 4 is found at depth and is confined by gray till, but still connected with the silty sands found in Area 1.

The water levels in shallow monitoring wells were used along with topography and the lake water-level to construct shallow water-table-surface map for JN facilities (Figure 17). This is only an approximate map and is meant to provide only a general idea of the shallow flow regime. As seen in Figure 17, the water table in the area is sloping away from the JN facility buildings. Most of the shallow groundwater flow is towards the lake. However, some of the flow from Area 3 is towards the flood plain of Big Darby Creek. The ultimate discharge for all shallow flow is into the Big Darby Creek. We can make some rough estimates of existing gradients based on the knowledge of water levels and dominant flow directions. For example, for the flow from Areas 3 and 6 towards Area 1 the approximate gradient is 0.04 ft/ft whereas, the gradient between wells 155 and 150 is about 0.016.

In Areas 2 and 5, minimum depth to water observed during drilling was about 5 feet, but only in boreholes 202, 504 and 506. For the remainder of boreholes, the water depth was greater than 10 feet (about 15 feet in borehole 206). Flow from these areas and from C16 appears to be towards the lake as shown by higher water levels in these wells compared to the lake levels.

Vertical flow gradients were determined from general observations of water levels in consecutively deeper wells near each other. The water levels were lower in deeper wells. Therefore the vertical flow gradients appear to be downward and imply that most of the area is a recharge area.

### 3.2.3 Hydraulic Conductivity Testing

This section summarizes the hydraulic conductivity determination by "slug tests" that were performed in the Stage 1 characterization of the Nuclear Sciences Area of Battelle's West Jefferson Site. The testing was done in all 15 groundwater monitoring wells as part of a comprehensive characterization and in accordance with SC-SP-009 (1989).

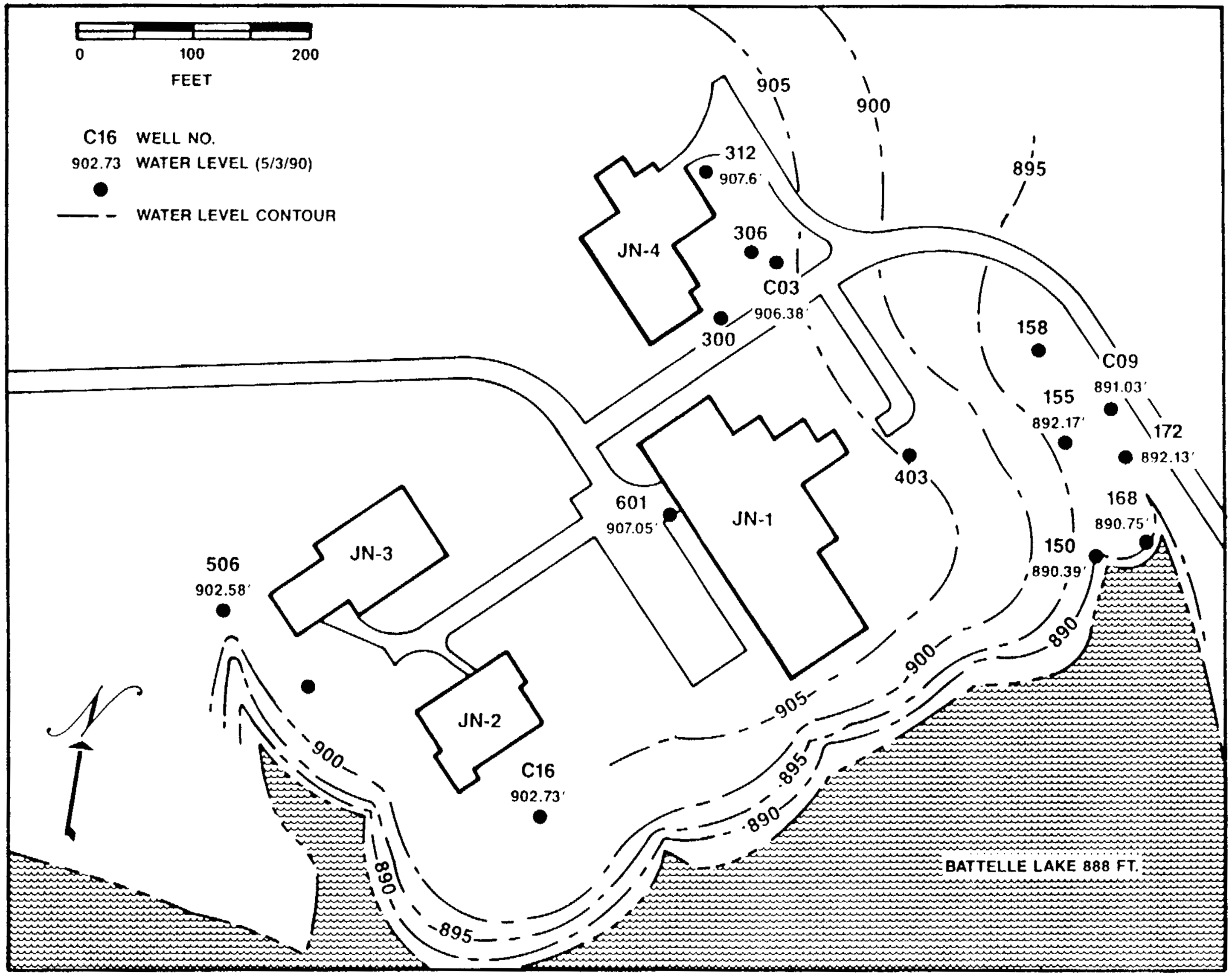

FIGURE 17. WATER TABLE SURFACE MAP FOR JN FACILITIES

The purpose of a "slug test" is to determine the hydraulic conductivity or transmissivity of an aquifer in the immediate area of a well. The test consists of causing an instantaneous change in the water level of a well by suddenly introducing or removing a known volume of water or solid cylinder, and observing the recovery of the water level with time.

3.2.3.1 Data Analysis. The time versus water-level data from the slug tests was analyzed using two standard methods. The Bouwer and Rice method (1976, 1989) was used for the data, hydrogeology, and well construction dimensions that best defined an unconfined aquifer. The other method (1967), the Copper et. al. method, was used for situations that more closely resembled a confined or semi-confined aquifer. Both methods use an analysis of semi-log plots of relative water level change versus time.

In many cases the plotted data clearly matched one method or the other, but in several instances, the data was able to be analyzed using both methods. When the data could be properly analyzed using both methods, the answers were usually within an order of magnitude of each other. The techniques of slug test evaluation can be found in the technical papers cited in SC-SP-009 and the reference section.

3.2.3.2 Results. The results of the analysis fall within the range of values normally associated with the geologic materials present at each well. The results can be grouped into four main categories by the material present, either the near surface brown till/fill material, the confined and unconfined sandy zones, and the dense grey till. Table 4 lists the results for each well by method and the best answer is indicated. The most appropriate hydraulic conductivity value for each well is shown in Figure 18.

These results as well as the boring logs both agree that in general wells 306, 312, 506, C03, and C16 were completed in the brown till with some wells extending slightly into the grey till. The hydraulic conductivity values are moderate to low, ranging from 2.6 x $10^{-4}$ cm/sec to 3.0 x $10^{-7}$ cm/sec.

Wells 150, 155, 168, 172, 300, 403, 601, and C09 were completed in the sandier materials of higher hydraulic conductivity. Wells 150 and 168 intersect a sandy deposit under unconfined conditions. Wells 155, 172, 403

TABLE 4. WEST JEFFERSON HYDRAULIC CONDUCTIVITY RESULTS

| | HYDRAULIC CONDUCTIVITY | | | |
|---|---|---|---|---|
| | Bouwer & Rice, 1976 | | Cooper et al., 1967 | |
| Well # | ft/sec | cm/sec | ft/sec | cm/sec |
| 150 | * 1.4 x $10^{-5}$ | 4.3 x $10^{-4}$ | 2.9 x $10^{-5}$ | 8.9 x $10^{-4}$ |
| 155 | 4.2 x $10^{-6}$ | 1.3 x $10^{-4}$ | * 2.0 x $10^{-6}$ | 6.0 x $10^{-5}$ |
| 158 | * 8.5 x $10^{-8}$ | 2.6 x $10^{-6}$ | 2.1 x $10^{-9}$ | 6.5 x $10^{-8}$ |
| 168 | * 1.3 x $10^{-4}$ | 4.1 x $10^{-3}$ | 2.0 x $10^{-4}$ | 6.2 x $10^{-3}$ |
| 172 | 2.8 x $10^{-5}$ | 8.5 x $10^{-4}$ | * 4.0 x $10^{-5}$ | 1.2 x $10^{-3}$ |
| 206 | * 9.1 x $10^{-9}$ | 2.8 x $10^{-7}$ | 1.4 x $10^{-10}$ | 4.2 x $10^{-9}$ |
| 300 | --- | --- | * 7.9 x $10^{-4}$ | 2.4 x $10^{-2}$ |
| 306 | 1.3 x $10^{-5}$ | 3.8 x $10^{-4}$ | * 9.4 x $10^{-6}$ | 2.9 x $10^{-4}$ |
| 312 | * 2.7 x $10^{-7}$ | 8.3 x $10^{-6}$ | 9.9 x $10^{-9}$ | 3.0 x $10^{-7}$ |
| 403 | 2.0 x $10^{-5}$ | 5.9 x $10^{-4}$ | * 4.0 x $10^{-5}$ | 1.2 x $10^{-3}$ |
| 506 | * 6.9 x $10^{-7}$ | 2.1 x $10^{-5}$ | --- | --- |
| 601 | * 6.6 x $10^{-6}$ | 2.0 x $10^{-4}$ | --- | --- |
| C03 | * 1.0 x $10^{-7}$ | 3.1 x $10^{-6}$ | --- | --- |
| C09 | * 1.3 x $10^{-7}$ | 3.9 x $10^{-6}$ | --- | --- |
| C16 | * 1.3 x $10^{-7}$ | 3.9 x $10^{-6}$ | --- | --- |

* Indicates best method (results) for the slug test data.

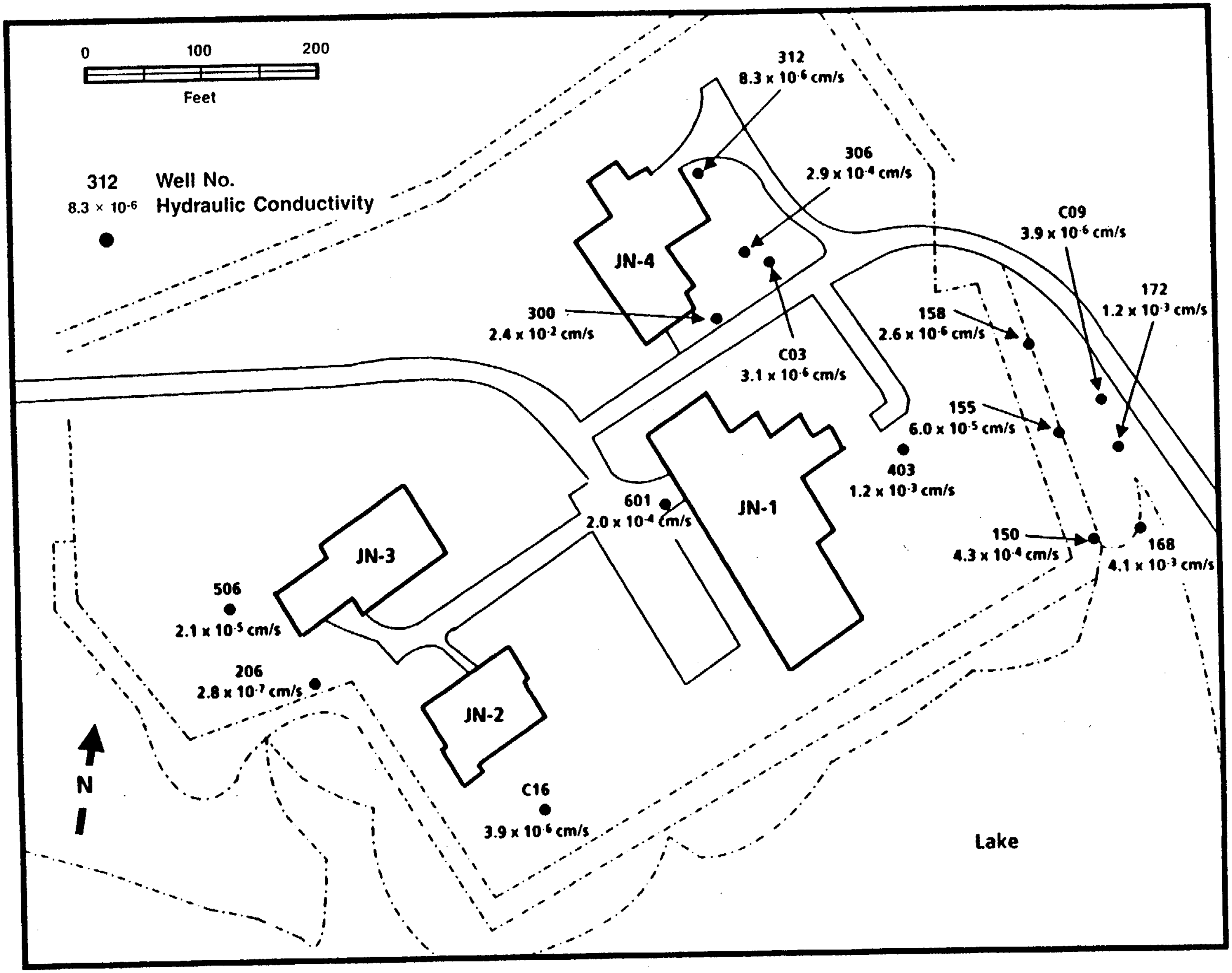

FIGURE 18. HYDRAULIC CONDUCTIVITY DISTRIBUTION

and C09 also are believed to be completed in this same sandy deposit but are under semi-confined or confined conditions, that is a lower conductivity material overlies the sand material. All of these values fall within a relatively narrow range from 1.2 x $10^{-3}$ cm/sec to 6.0 x $10^{-5}$ cm/sec. Well 300 may be completed in this same sand, but this is not certain. This well had the highest hydraulic conductivity of all wells tested at 2.4 x $10^{-2}$ cm/sec. Well 601 was completed in more conductive material but not the same continuous deposit as the others.

The remaining wells 158 and 206 were completed in dense grey till and have low hydraulic conductivities of 2.6 x $10^{-6}$ cm/sec and 2.8 x $10^{-7}$ cm/sec, respectively.

## 4.0 CONCLUSIONS

A geologic and hydrogeologic characterization of the JN Area and retired filter beds at Battelle's West Jefferson Site was performed. A total of 168 boreholes were drilled as part of site characterization.

A review of the geologic information obtained through drilling indicates that the shallow geology at the site is same as the general geology in central Ohio. Five major geologic materials present at the site are: soil, alluvial deposits, artificial fill, glacial till and limestone bedrock. The shallow geology is dominated by brown and gray colored till. Sand/gravel lenses of limited extent are present within the till. Artificial fill is dominant in Area 3 and in the retired filter beds area. Alluvial deposits are present in the filter beds area.

Hydrologically the lake and the Big Darby Creek are dominant surface features. The lake and Big Darby Creek also serve as the discharge locations for shallow groundwater flow. The hydrologic units at the site correspond to the five geologic units described previously: soil, alluvium, fill, till, and bedrock. Slug tests for permeability determination show that the till deposits have very low hydraulic conductivity, and the silty, sandy lenses within the till have moderate hydraulic conductivity.

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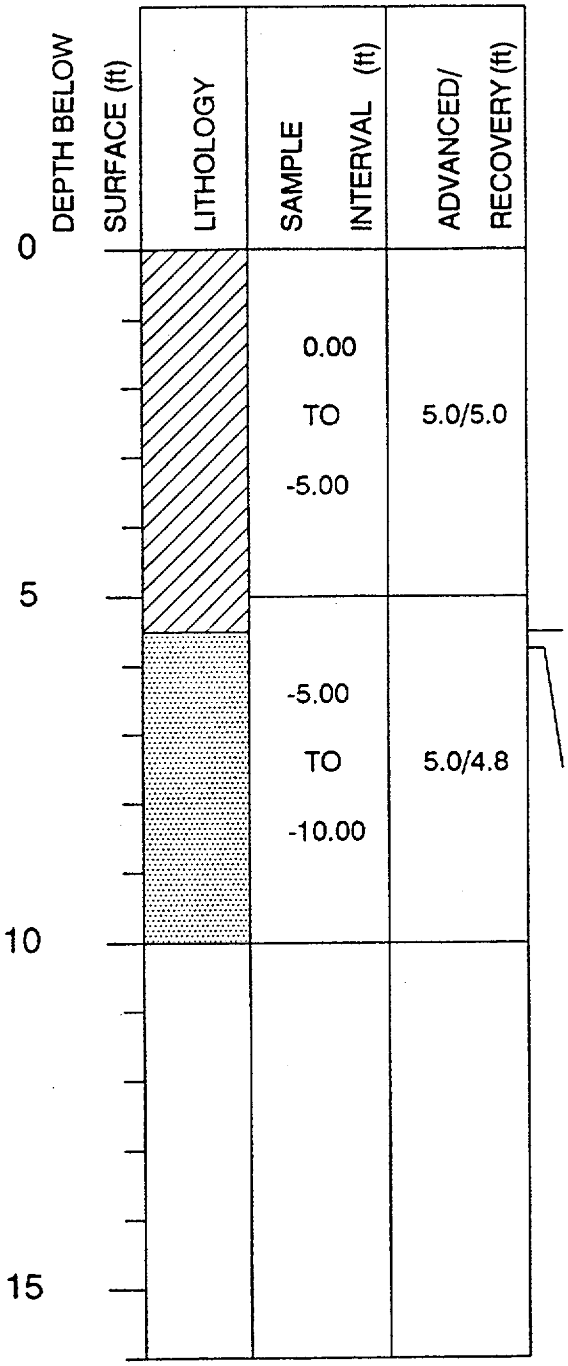
# APPENDIX 1

# BORING LOGS FOR ALL SAMPLING AREAS

BOREHOLE NUMBER: 150 LOCATION: Sample Area 1 24 APRIL 1989



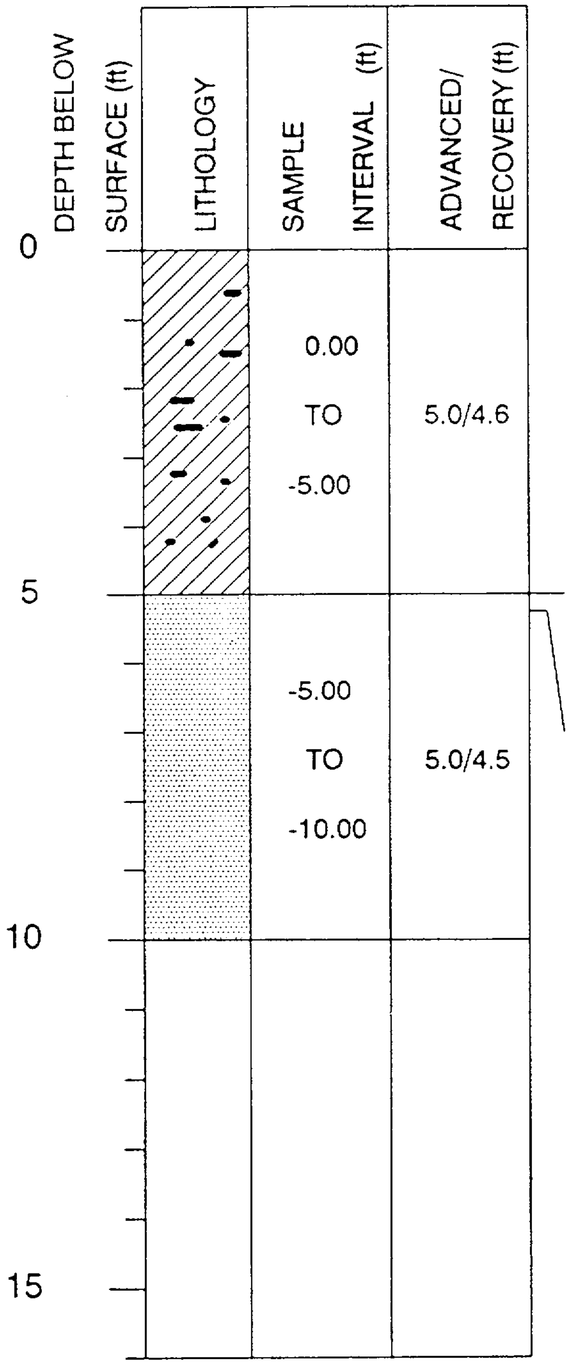
Dark brown clayey silt
changing to light brown

Brown to tan silty clayey sand
increasing sand content with depth to 10 ft
fine grained salt and pepper sand

Water encountered at 5.8 ft

T. D. 10.0 ft

BOREHOLE NUMBER: 151 LOCATION: Sample Area 1 24 APRIL 1989



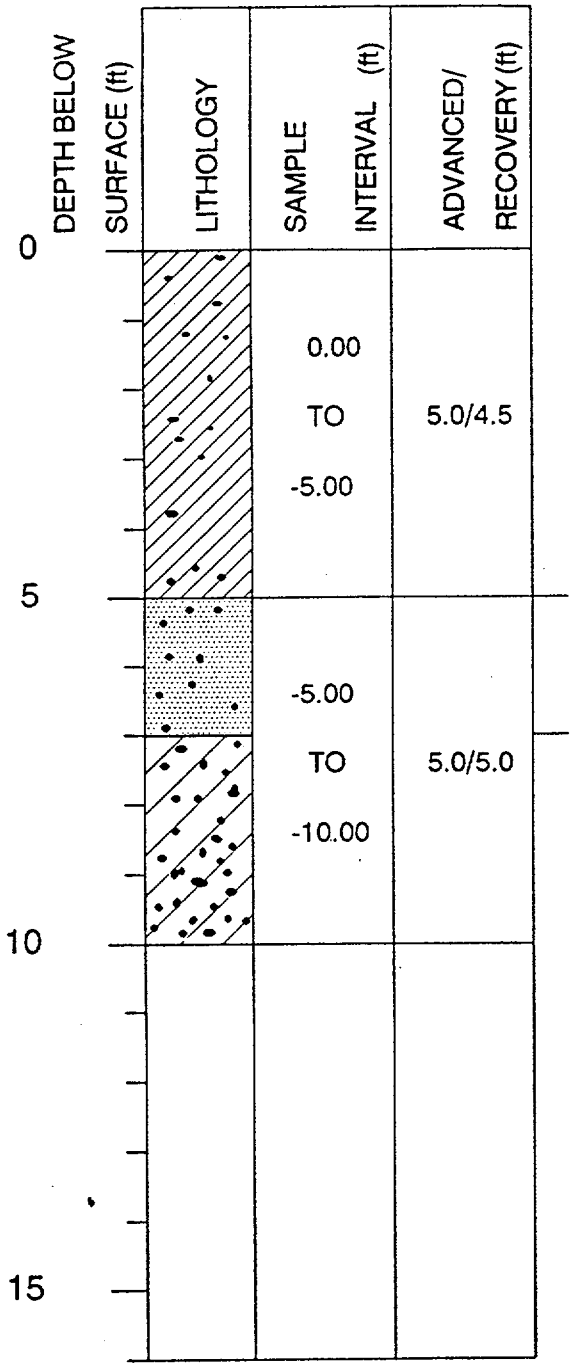
Dark brown clayey silt
occasional pebbles/gravel and some sand

Brown to tan silty clayey sand
increasing sand content with depth to 10 ft
fine grained salt and pepper sand

Water encountered at 5.3 ft

T. D. 10.0 ft

BOREHOLE NUMBER: 152 LOCATION: Sample Area 1 24 APRIL 1989



Dark brown clayey silt moist
a little sand and some pebbles

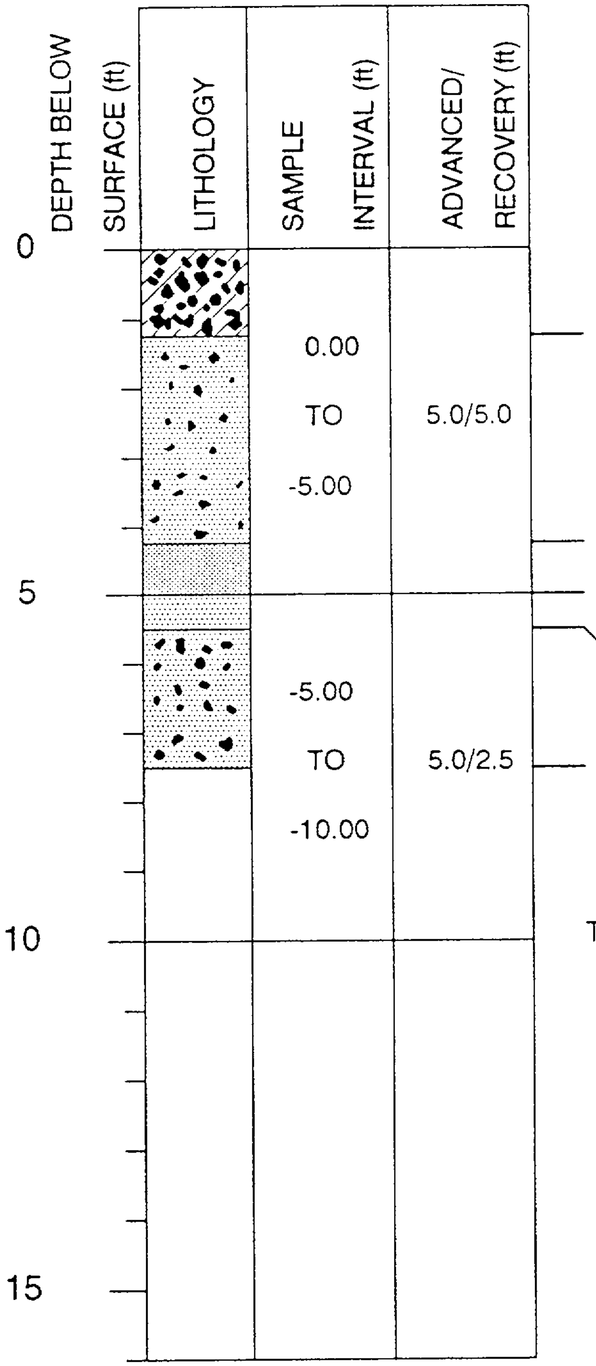
Water encountered at 5.8 ft

Light brown silty clayey sand
with pebbles and gravel wet

Abrupt change to till moist but not wet
lots of pebbles and gravel

T. D. 10.0 ft

BOREHOLE NUMBER: 153 LOCATION: Sample Area 1 26 APRIL 1989



Coarse gravel and pebbles in clayey silt

Fine grained silty clayey sands
with a few pebbles and cobbles

Abrupt change at 4.2 ft to medium to coarse
sand in silt and clay

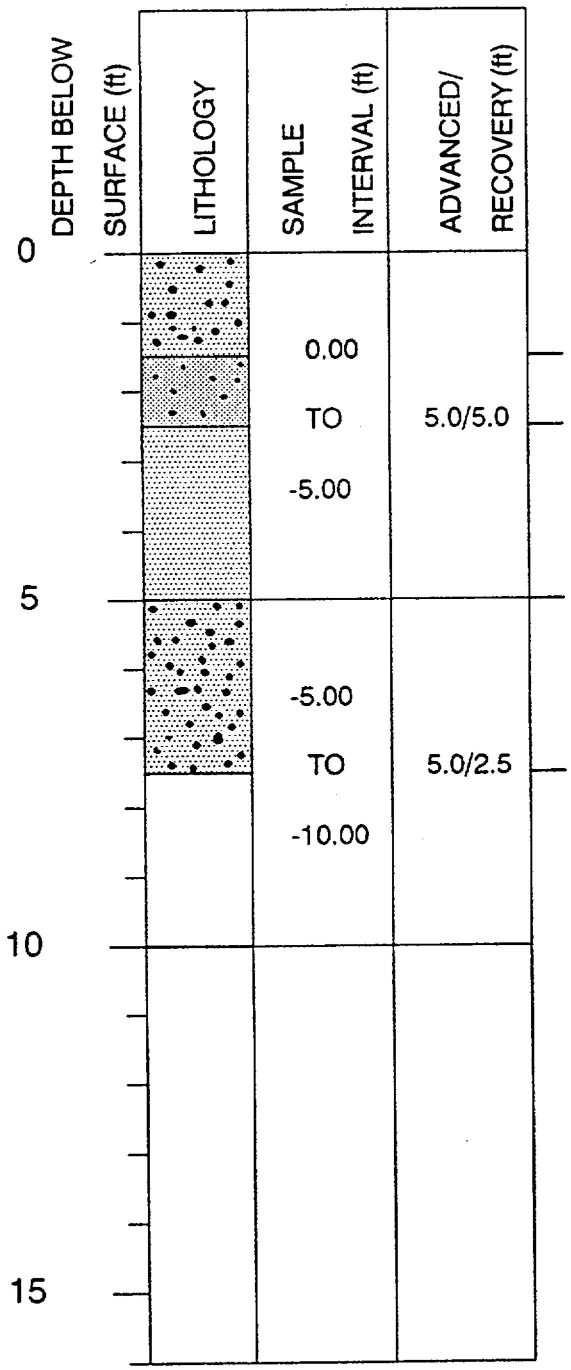
Water encountered at about 5.0 ft

Tan fine grained clayey sands wet cohesive

Bottom 2.0 ft wet silty clayey sands with
some gravel poorly sorted uncohesive

T. D. 10.0 ft

BOREHOLE NUMBER: 154 LOCATION: Sample Area 1 26 APRIL 1989



Brown silty clayey sands with gravel and pebbles. Poorly sorted

Silty sand/ sandy silt, few pebbles

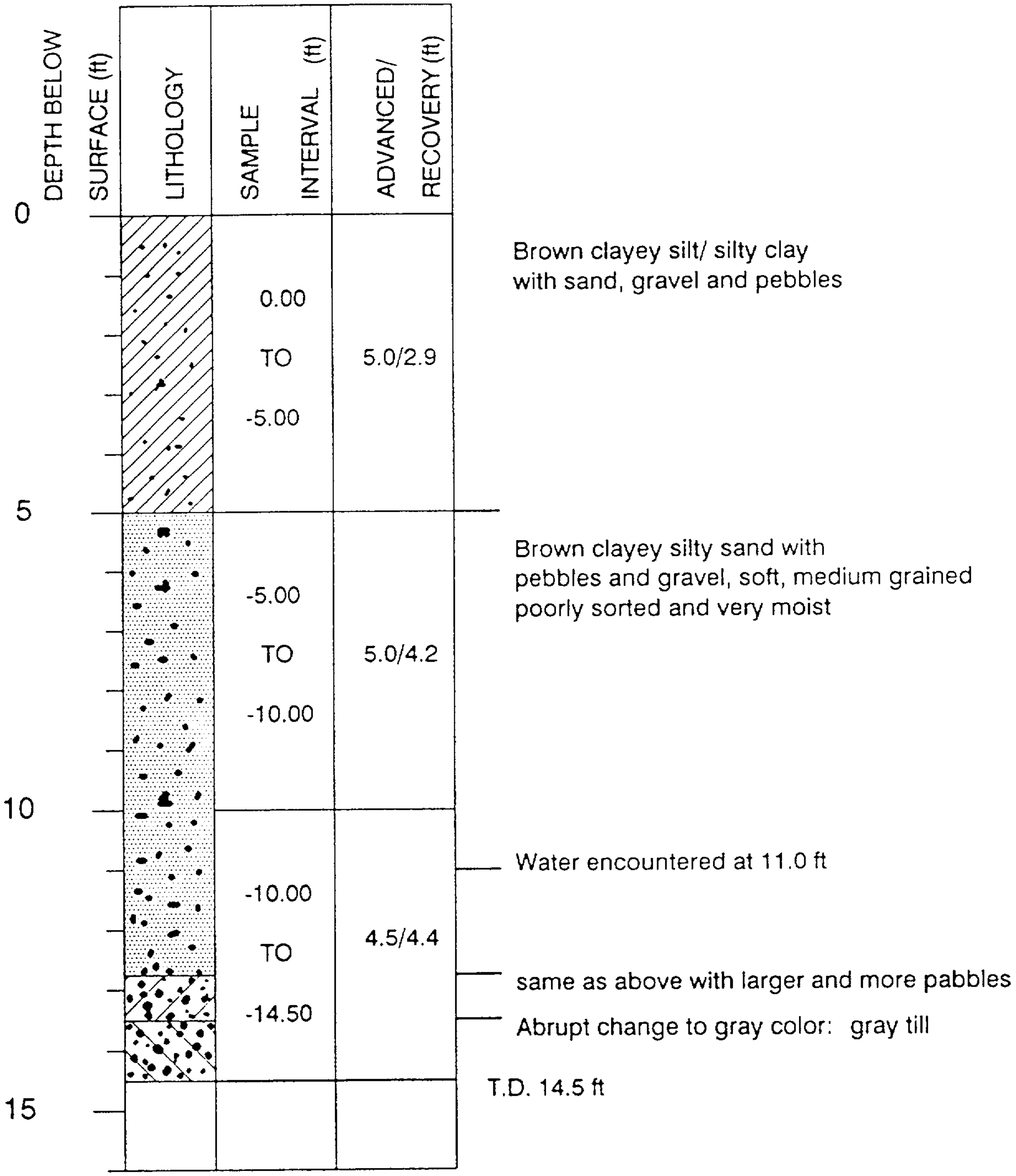
Brown and tan clayey silty sand with increasing sand content with depth

silty clayey sand with limestone pebbles and gravel

No recovery in bottom 2.5 ft

T. D. 10.0 ft

BOREHOLE NUMBER: 155 LOCATION: Sample Area 1 27 APRIL 1989



Brown clayey silt/ silty clay with sand, gravel and pebbles

Brown clayey silty sand with pebbles and gravel, soft, medium grained poorly sorted and very moist

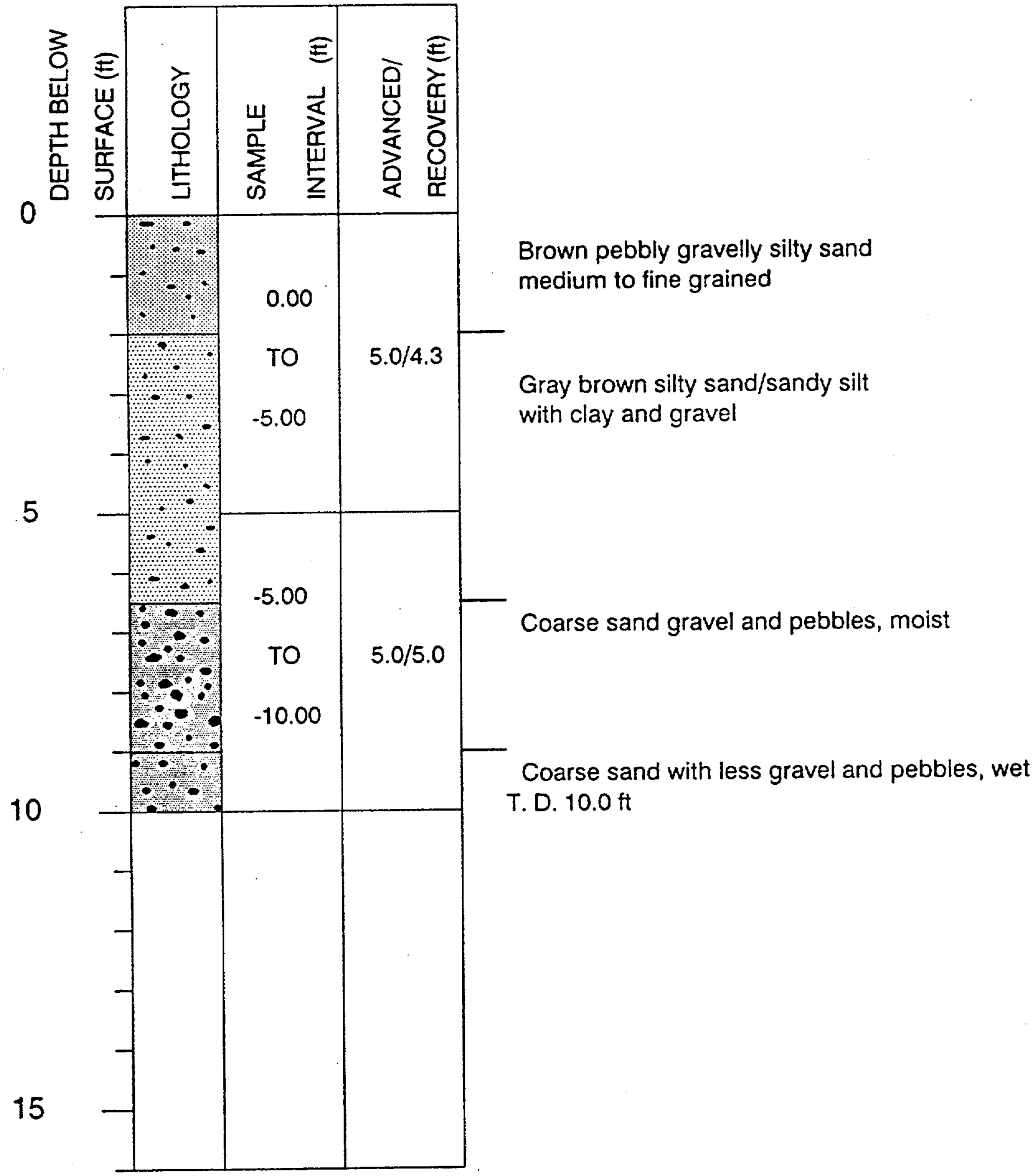
Water encountered at 11.0 ft

same as above with larger and more pabbles

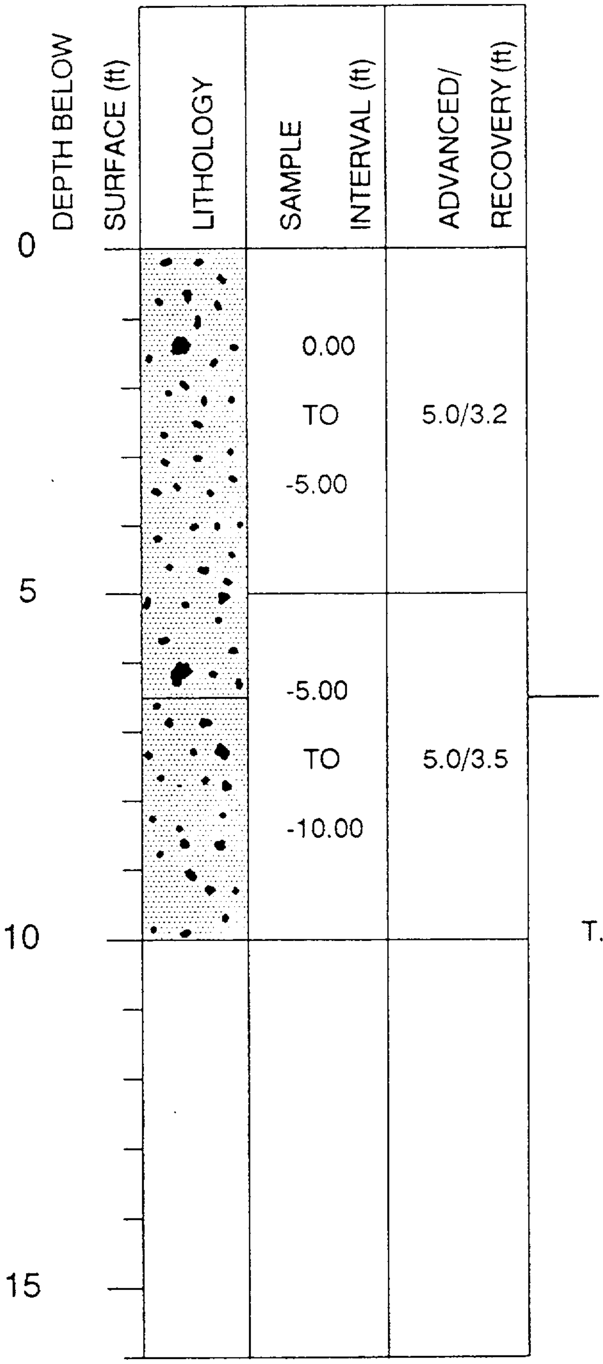
Abrupt change to gray color: gray till

T.D. 14.5 ft

BOREHOLE NUMBER: 156 LOCATION: Sample Area 1 28 APRIL 1989



BOREHOLE NUMBER: 157 LOCATION: Sample Area 1 28 APRIL 1989



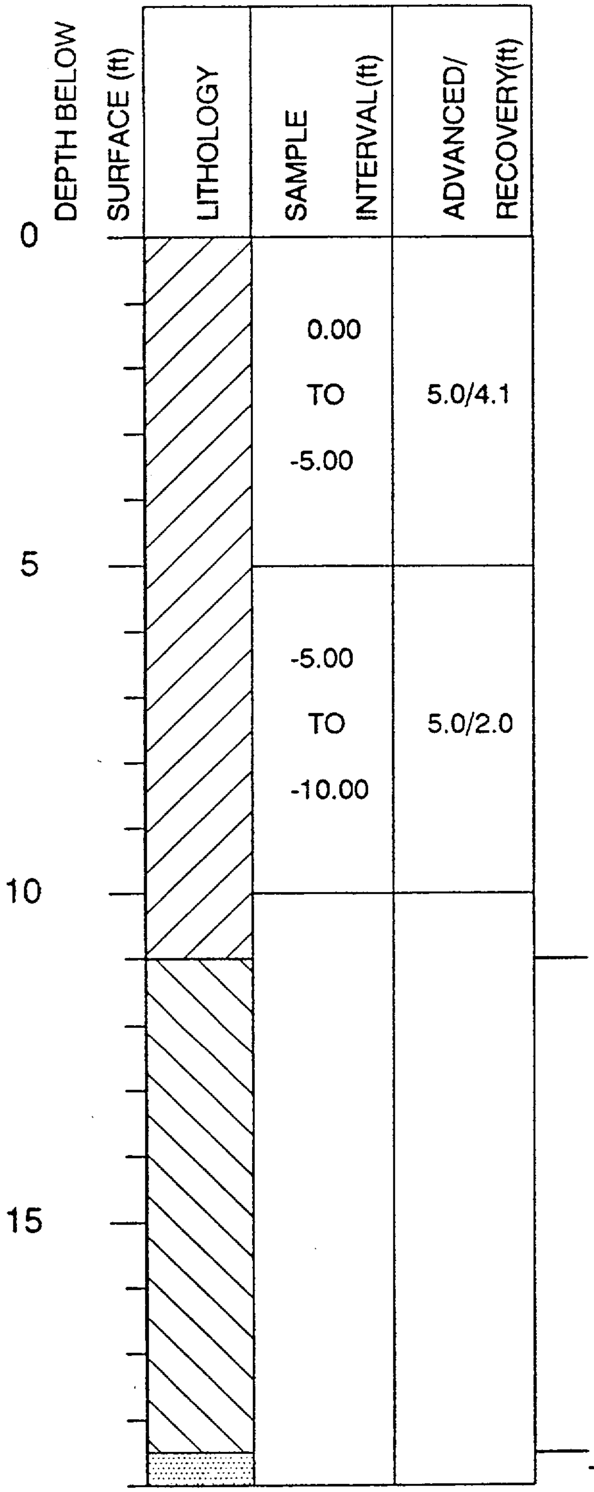
| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| 0.00 TO -5.00 | 5.0/3.2 |
| -5.00 TO -10.00 | 5.0/3.5 |

Brown gravelly pebbly silty clayey sands uncohesive dry

Silty clayey sands with finer grained sand and fewer pebbles and gravel moist

T. D. 10.0 ft

BOREHOLE NUMBER: 158 LOCATION: Sample Area 1 28 APRIL 1989



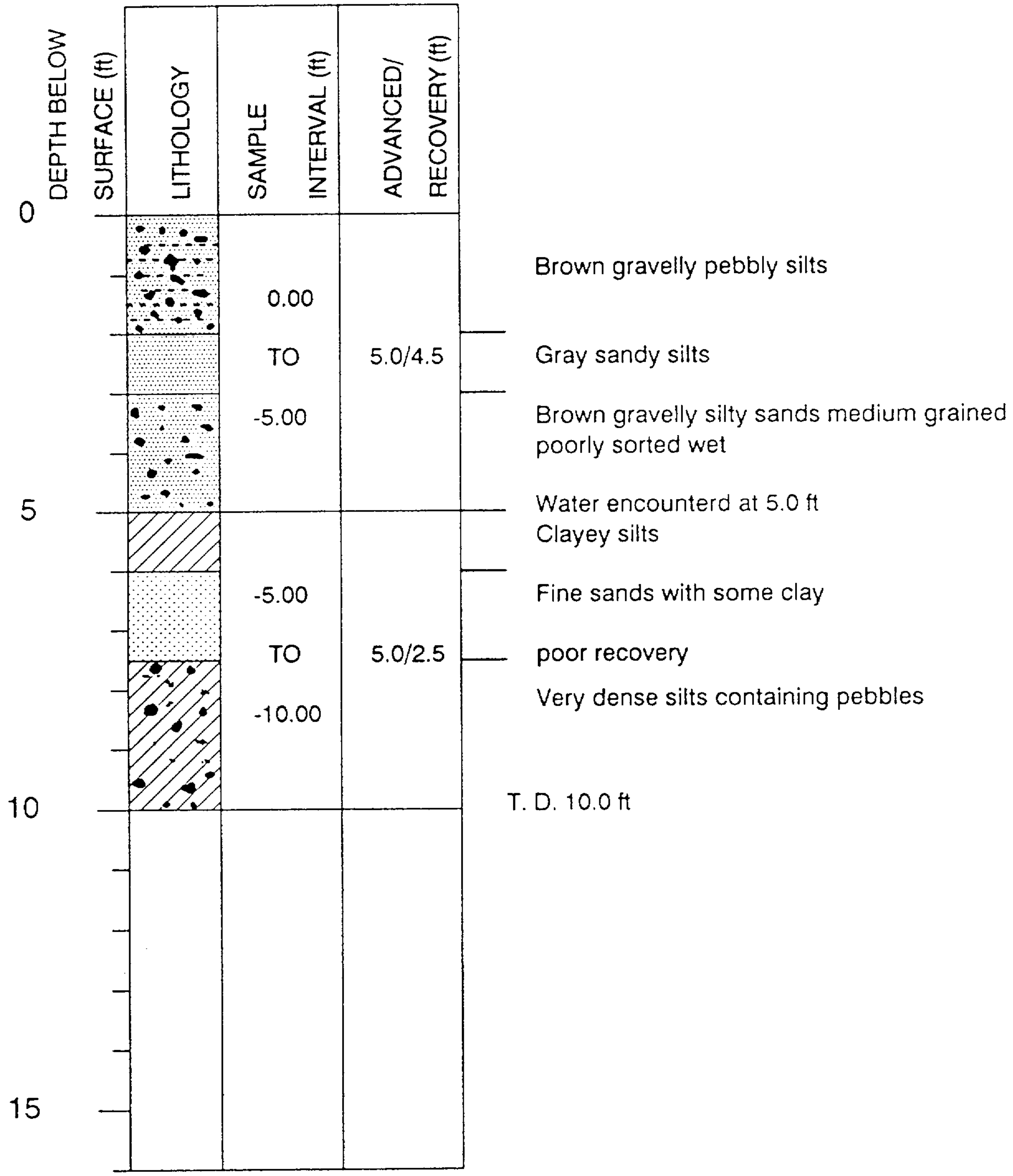
Tannish brown weathered till fractures with black organic coating

changes to tannish unweathered till with depth

Gray till

Wet clayey sands at bottom of hole
T. D. 19.0 ft

BOREHOLE NUMBER: 160 LOCATION: Sample Area 1 25 APRIL 1989



Brown gravelly pebbly silts

Gray sandy silts

Brown gravelly silty sands medium grained
poorly sorted wet

Water encounterd at 5.0 ft
Clayey silts

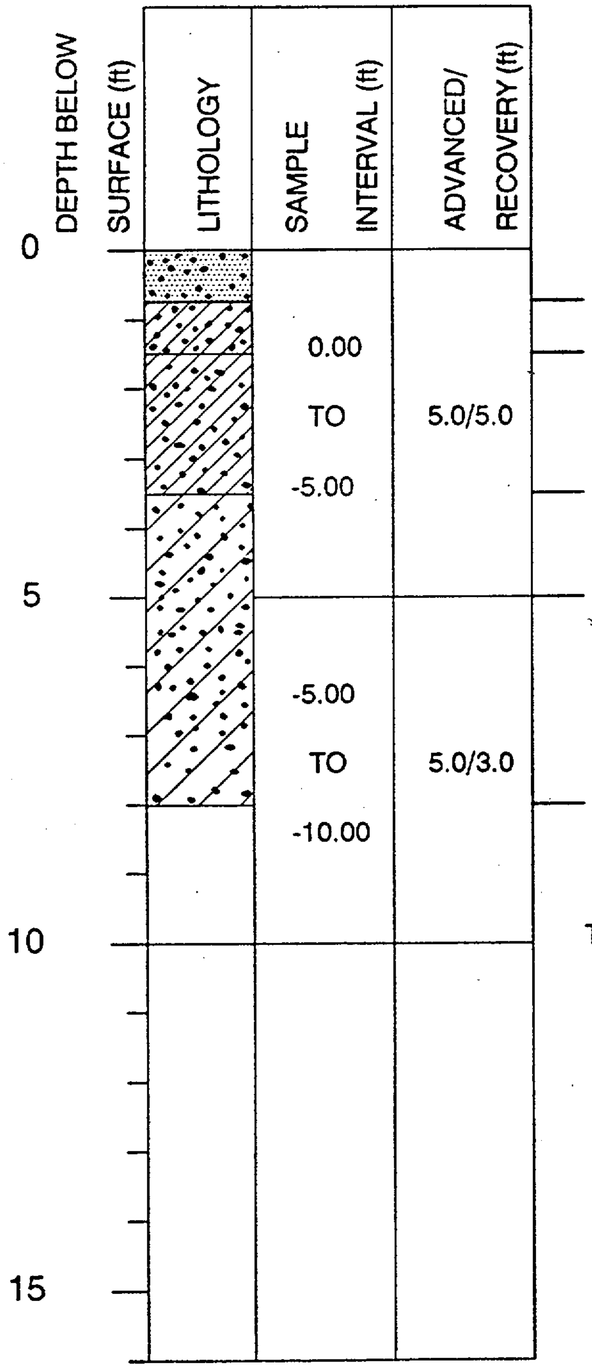
Fine sands with some clay

poor recovery

Very dense silts containing pebbles

T. D. 10.0 ft

BOREHOLE NUMBER: 161   LOCATION: Sample Area 1   26 APRIL 1989



Light brown gravel pebbles with silty sand

Brown clayey silt with gravel

Reddish brown clayey silt with gravel

Brown becoming sandier

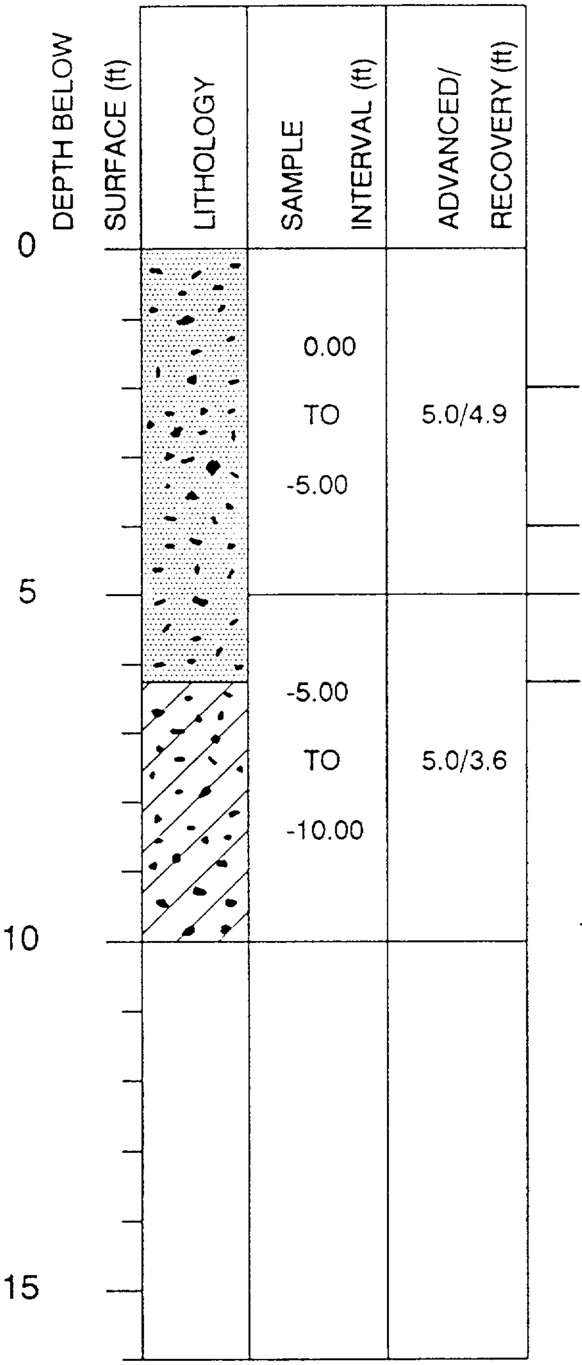
Water encountered at about 5.0 ft

Brown clayey silty sand with pebbles cobbles and gravel probably sandy till

Large limestone chunk blocked the coring device so sample is from 5.0 to 8.0 ft

T. D. 10.0 ft

BOREHOLE NUMBER: 162 LOCATION: Sample Area 1 26 APRIL 1989



Light brown gravelly pebbly silty sand
till or fill

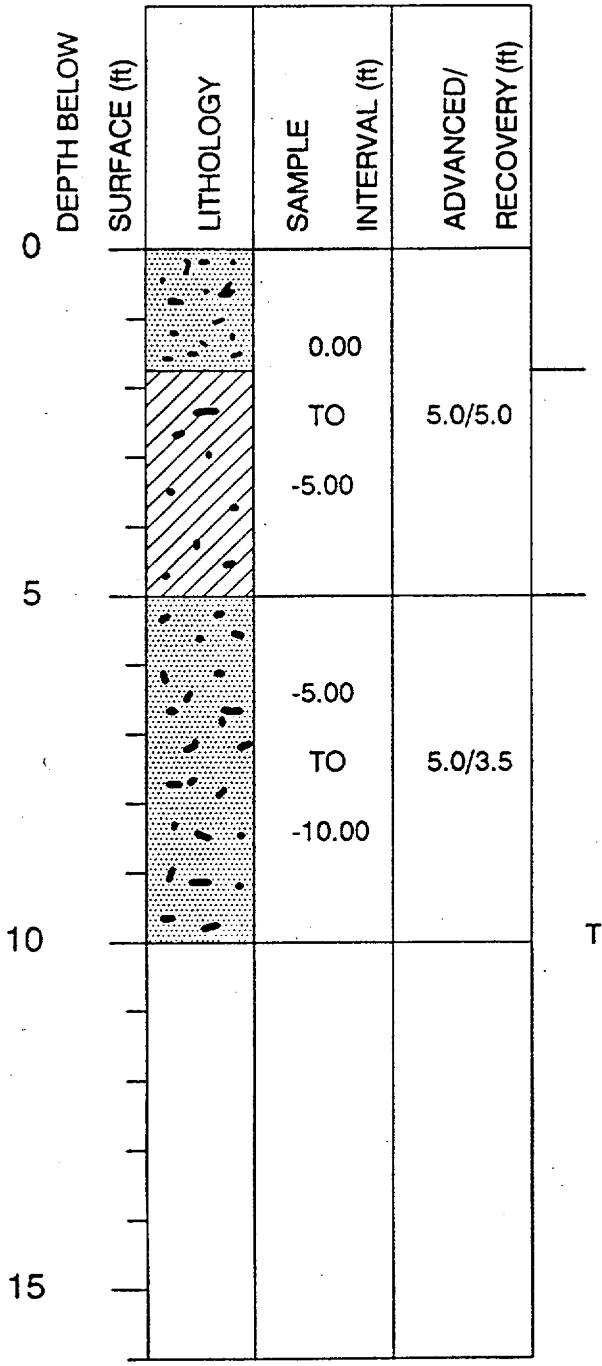
Reddish brown clayey silty sand/sandy silt
with gravel and pebbles

Brown gravelly pebbly silty sand
Water encountered at about 5.0 ft
Clayey silty pebbly sand wet unconsolidated
gradually becoming siltier and less wet

Till at bottom very dense slightly moist
consolidated lots of pebbles and gravel

T. D. 10.0 ft

BOREHOLE NUMBER: 163B LOCATION: Sample Area 1 26 APRIL 1989



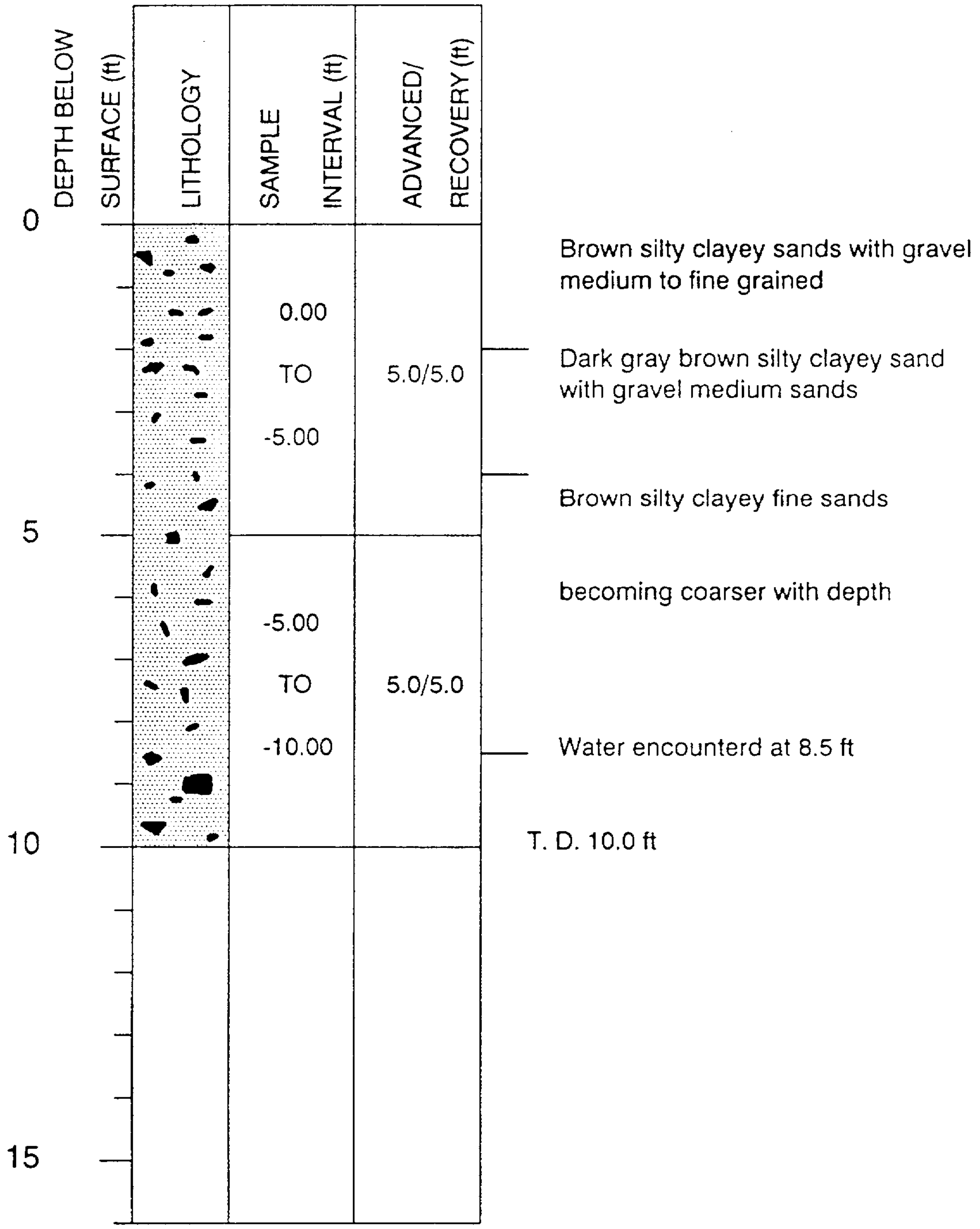
Light brown gravelly pebbly sandy silt
Lots of pebbles of 1 inch diameter

Dark brown silty clay/clayey silt
some sand and gravel sandier at bottom

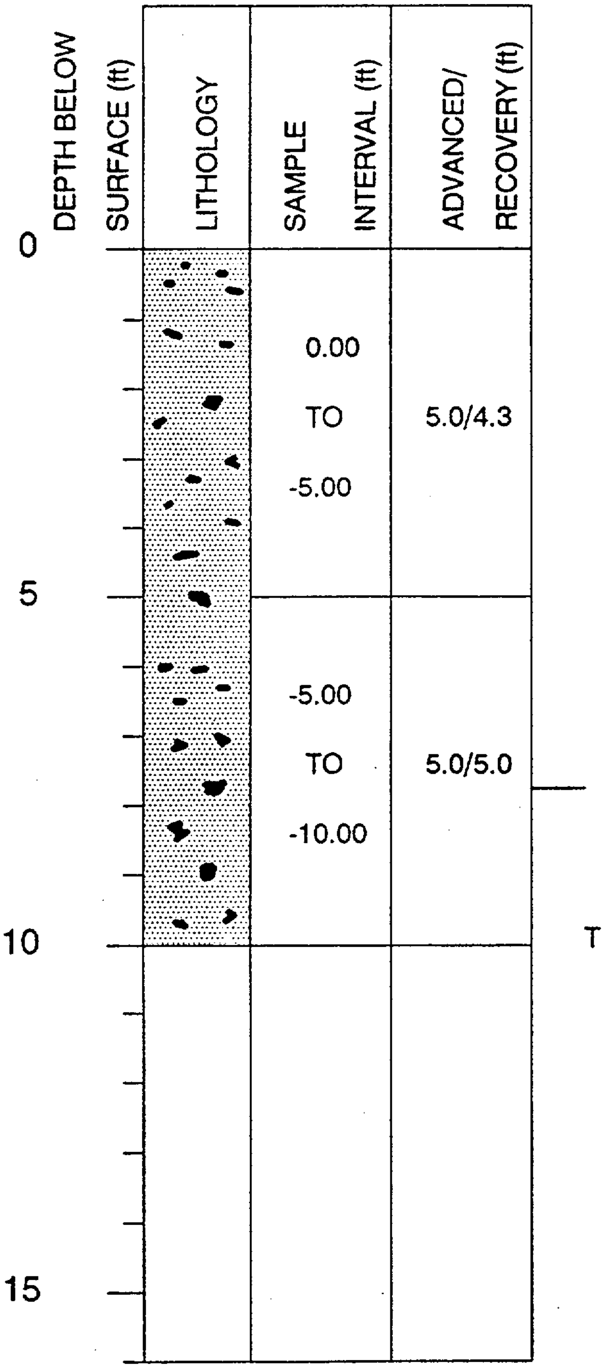
Light brown clayey silty sand
with pebbles and gravel

T. D. 10.0 ft

BOREHOLE NUMBER: 164 LOCATION: Sample Area 1 27 APRIL 1989



BOREHOLE NUMBER: 165 LOCATION: Sample Area 1 27 APRIL 1989

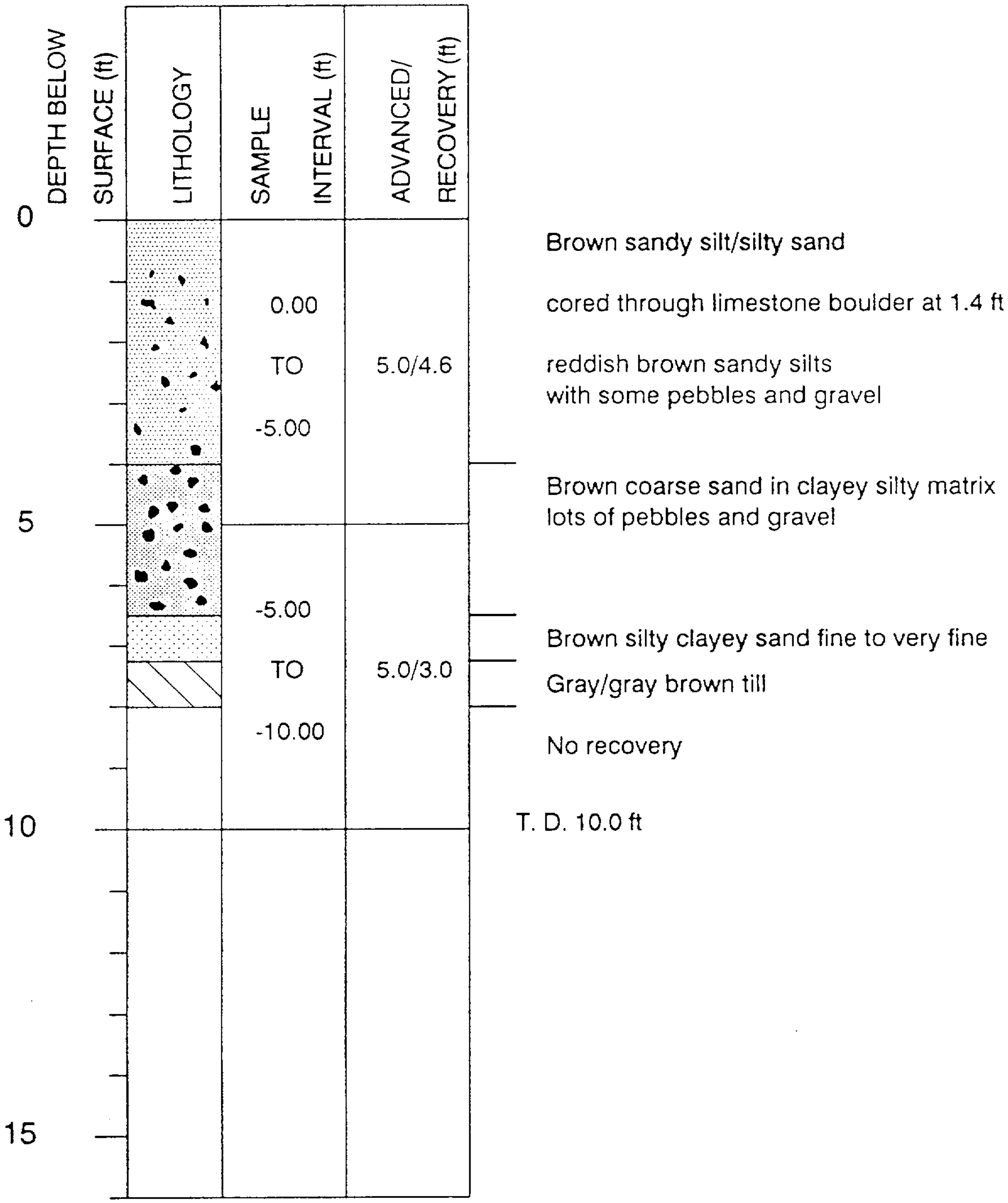


Brown silty sands with pebbles and gravel poorly sorted fine to medium sands

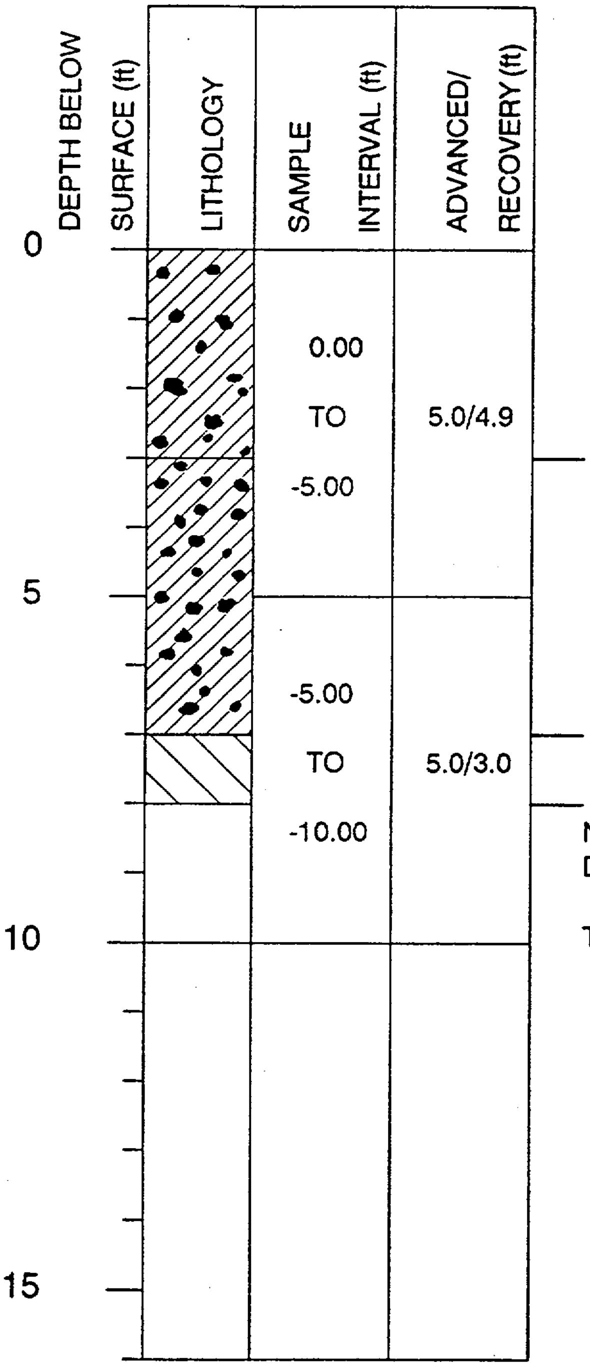
Water encountered at 7.8 ft

T. D. 10.0 ft

BOREHOLE NUMBER: 166 LOCATION: Sample Area 1 28 APRIL 1989



BOREHOLE NUMBER: 167 LOCATION: Sample Area 1 28 APRIL 1989



Brown clayey sandy silt with some gravel
bioturbation at 1.8 ft

tan color with more pebbles and gravel

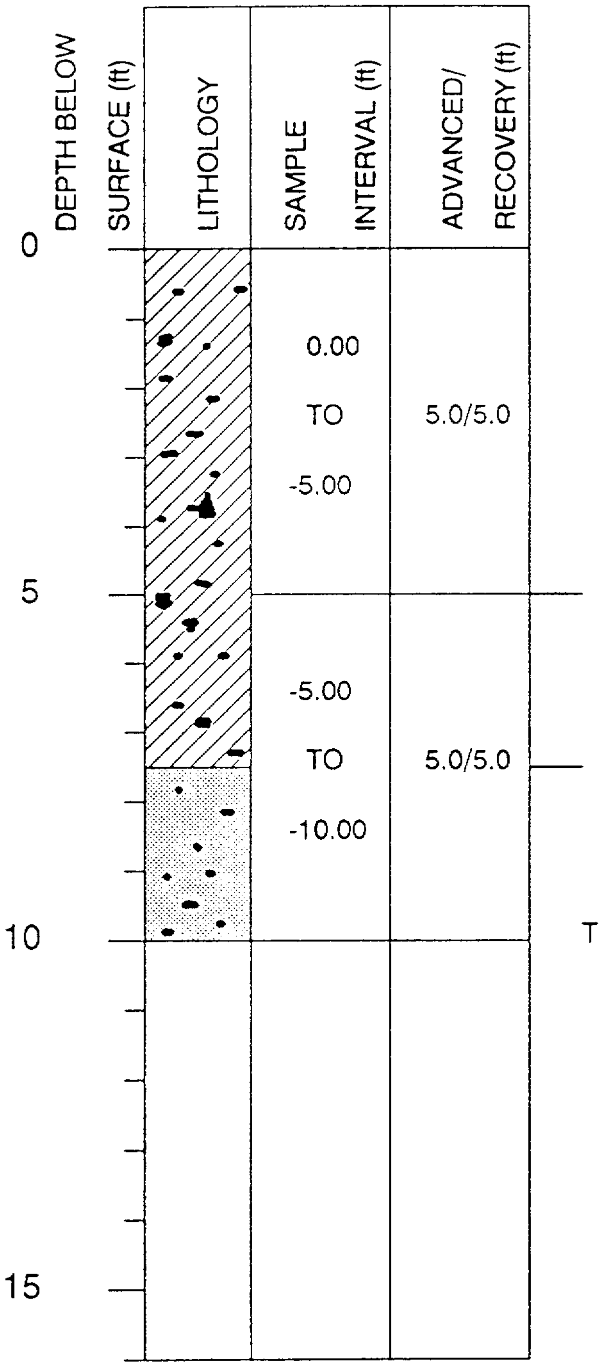
top 2.0 ft same as above

Bottom 1.0 ft grayer very compact

No recovery
Dense gray till blocking the device

T. D. 10.0 ft

BOREHOLE NUMBER: 168 LOCATION: Sample Area 1 25 APRIL 1989



Grass
Dark tan to brown soil
abrupt change to dark brown at 0.9 ft
and back to light brown at 1.5 ft
sandy clayey silt with some pebbles

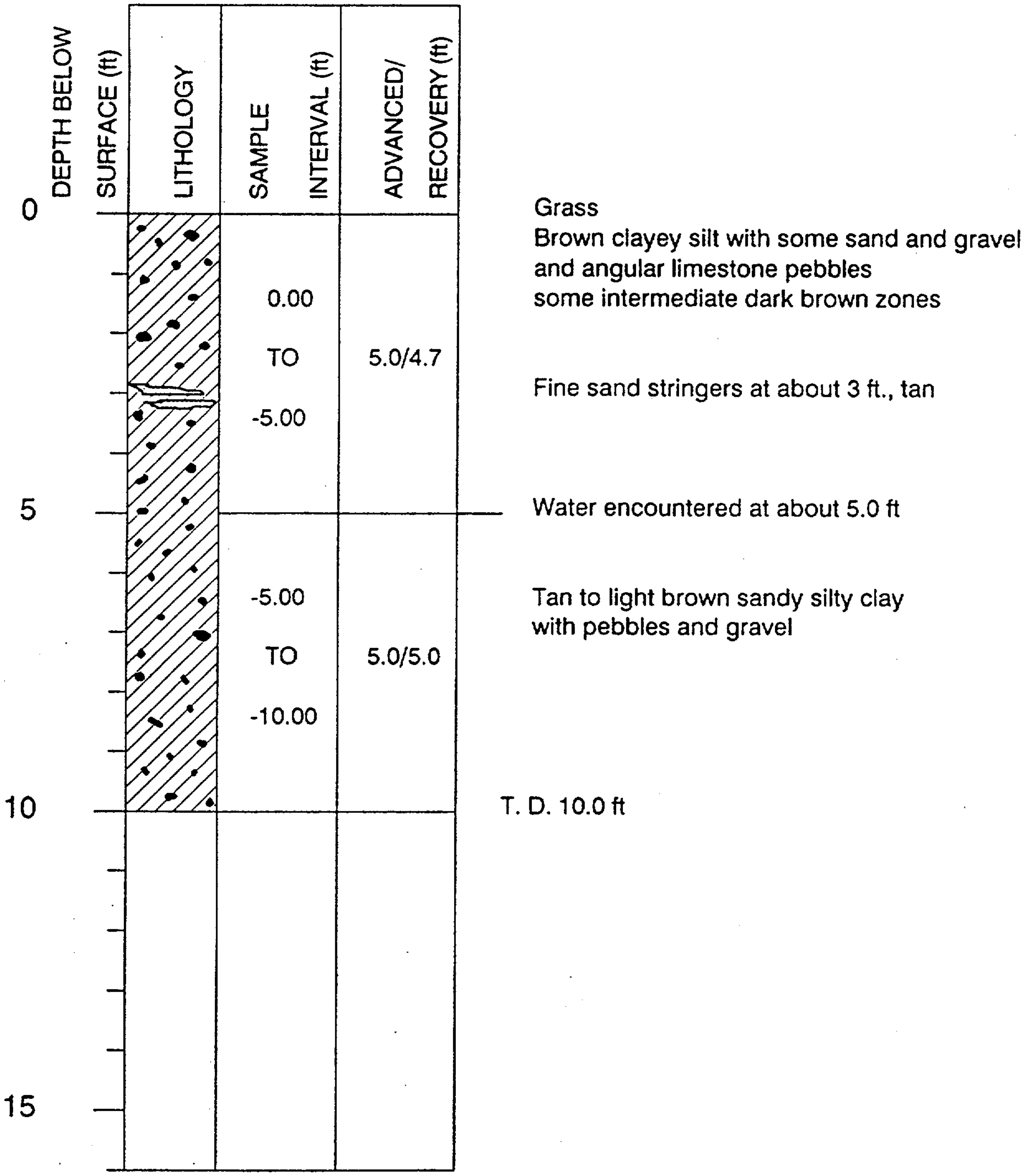
Water encountered at 5.0 ft

Brown clayey gravelly silt

Increasing sand with depth

T. D. 10.0 ft

BOREHOLE NUMBER: 169 LOCATION: Sample Area 1 25 APRIL 1989



Grass
Brown clayey silt with some sand and gravel
and angular limestone pebbles
some intermediate dark brown zones

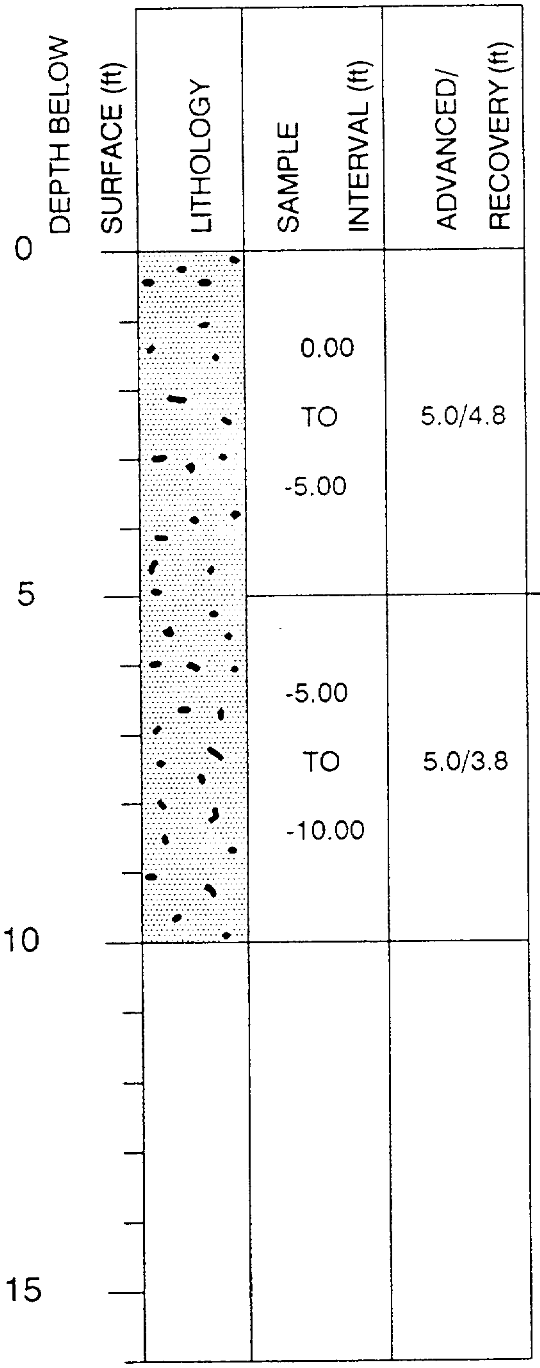
Fine sand stringers at about 3 ft., tan

Water encountered at about 5.0 ft

Tan to light brown sandy silty clay
with pebbles and gravel

T. D. 10.0 ft

BOREHOLE NUMBER: 170 LOCATION: Sample Area 1 25 APRIL 1989



Cattails on surface

Brown and tan clayey sandy silts/silty sands with lots of gravel and pebbles

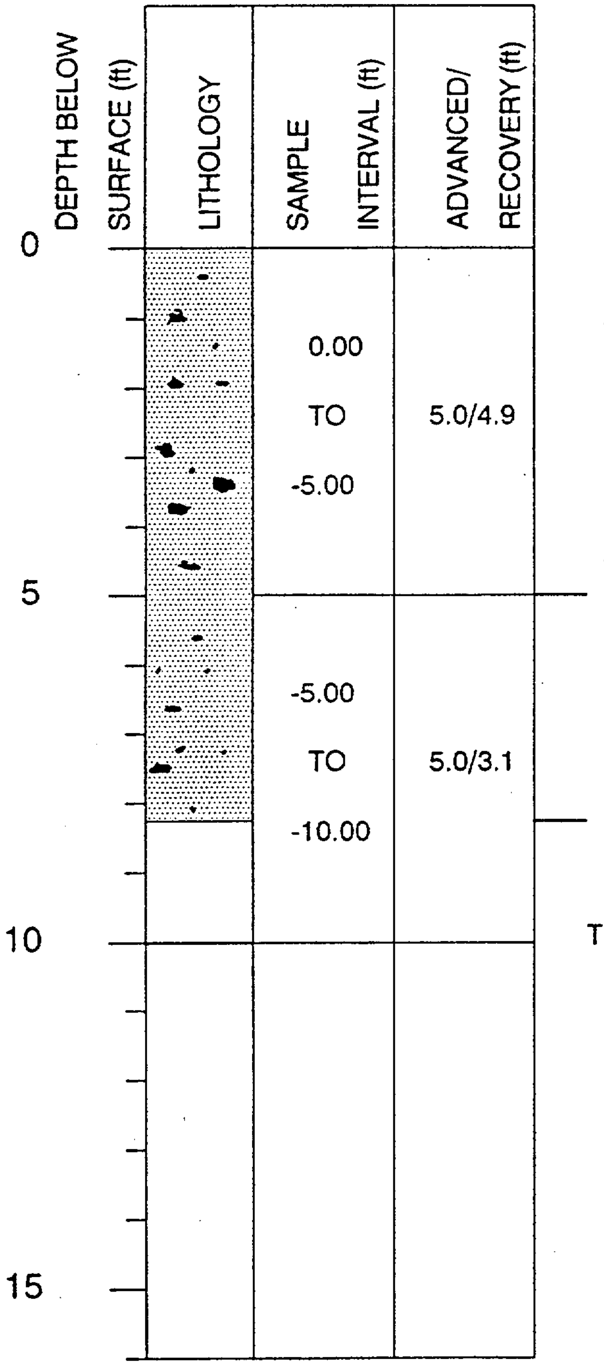
poorly sorted subrounded medium grained

Water encountered at 5.0 ft

Same as above

T. D. 10.0 ft

BOREHOLE NUMBER: 171 LOCATION: Sample Area 1 25 APRIL 1989



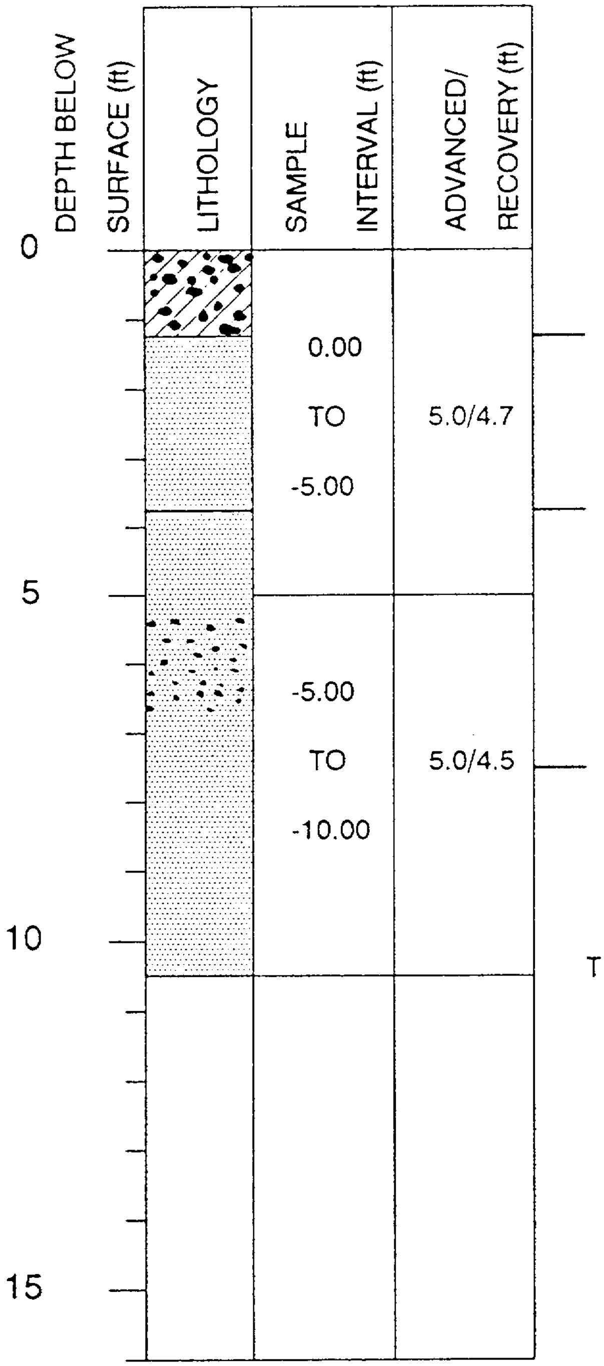
Cattails on surface
Brown clayey sands changing to grey with depth, some pebbles and gravel

Water encounterd at 4.8 ft

sampling tube blocked by rocks at about 8.1 ft

T. D. 10.0 ft

BOREHOLE NUMBER: 172 LOCATION: Sample Area 1 27 APRIL 1989



Cattails on surface
Brown sandy clayey silt, some gravel

Gradual color change to gray
in the middle 2.5 ft

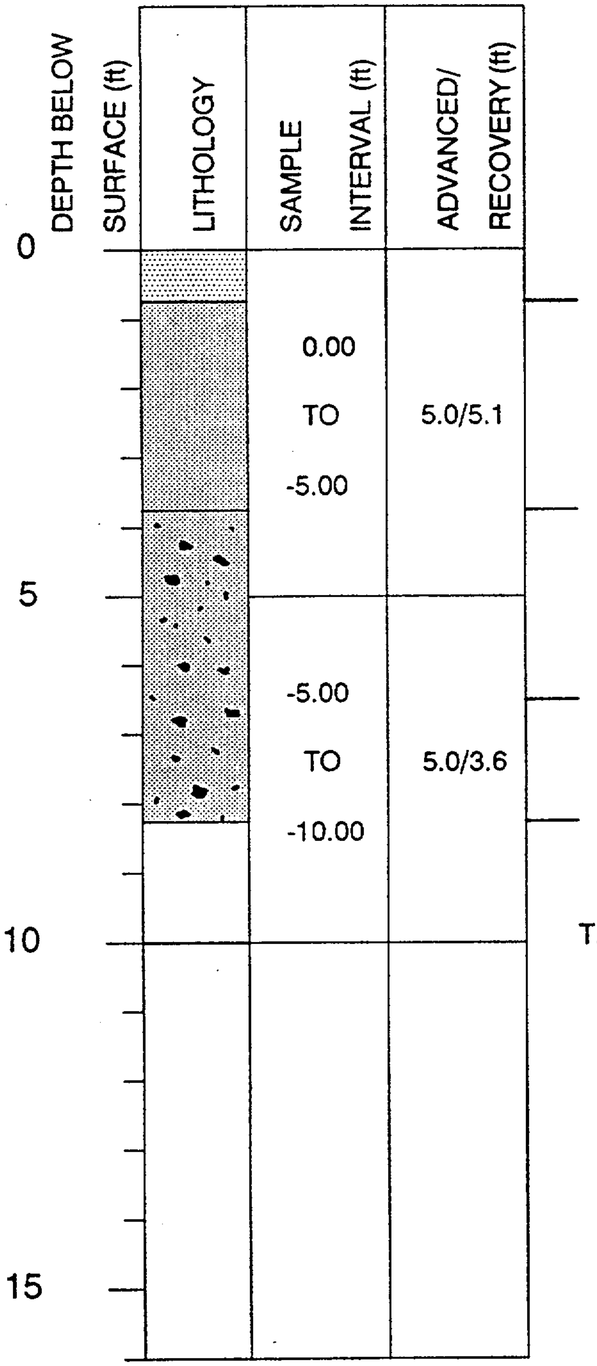
Brown silty clayey sand medium grained

lots of pebbles/gravel from 5.6 to 6.6 ft

Water encountered at 7.5 ft

moderately sorted in bottom of core
T. D. 10.5 ft

BOREHOLE NUMBER: 173 LOCATION: Sample Area 1 27 APRIL 1989



Cattails on surface
Brown fine grained silty clayey sand

Gray silty sand/ sandy silt, moist

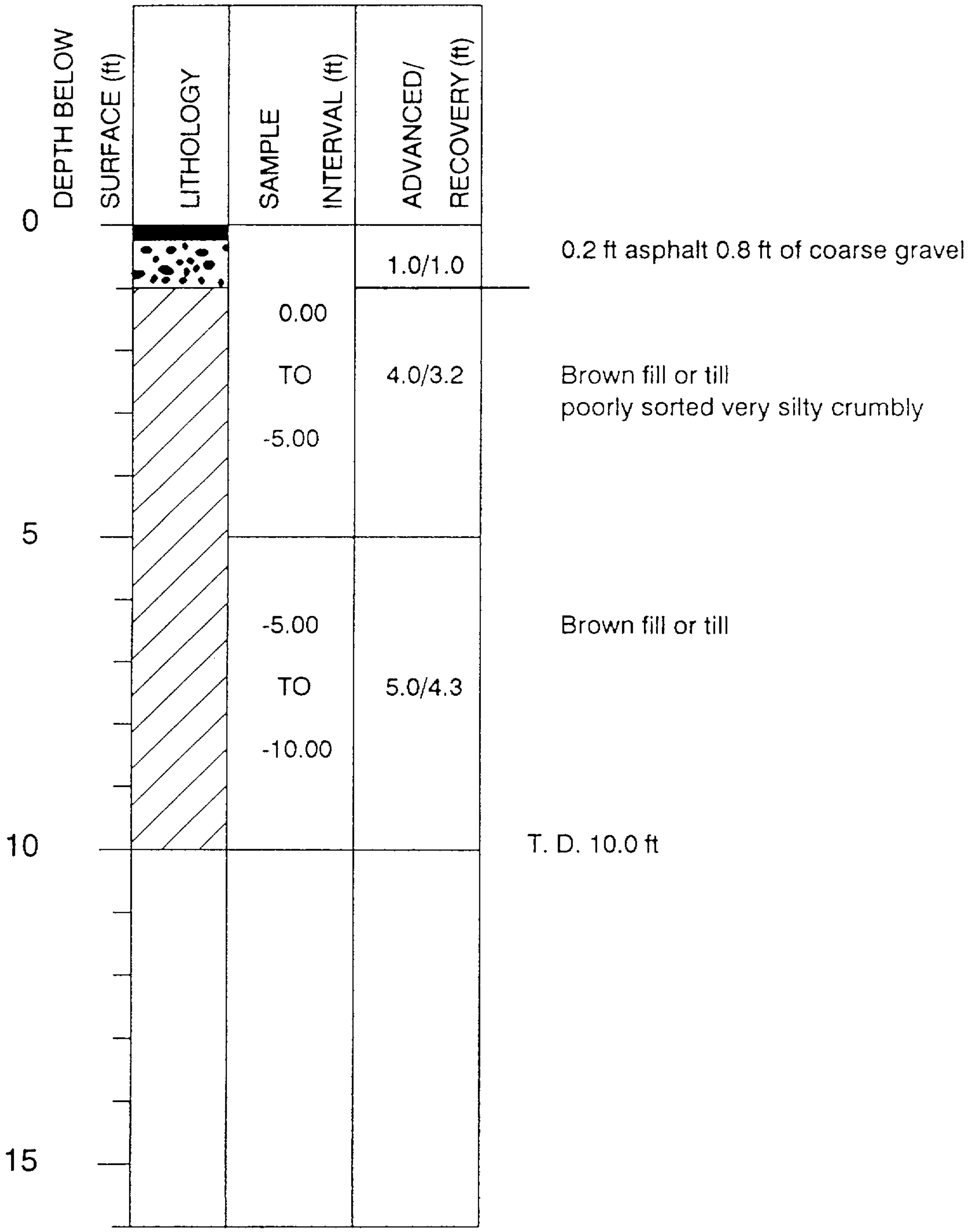
Brown silty sand/sandy silt
with clay and some gravel

Water encountered at 6.5 ft

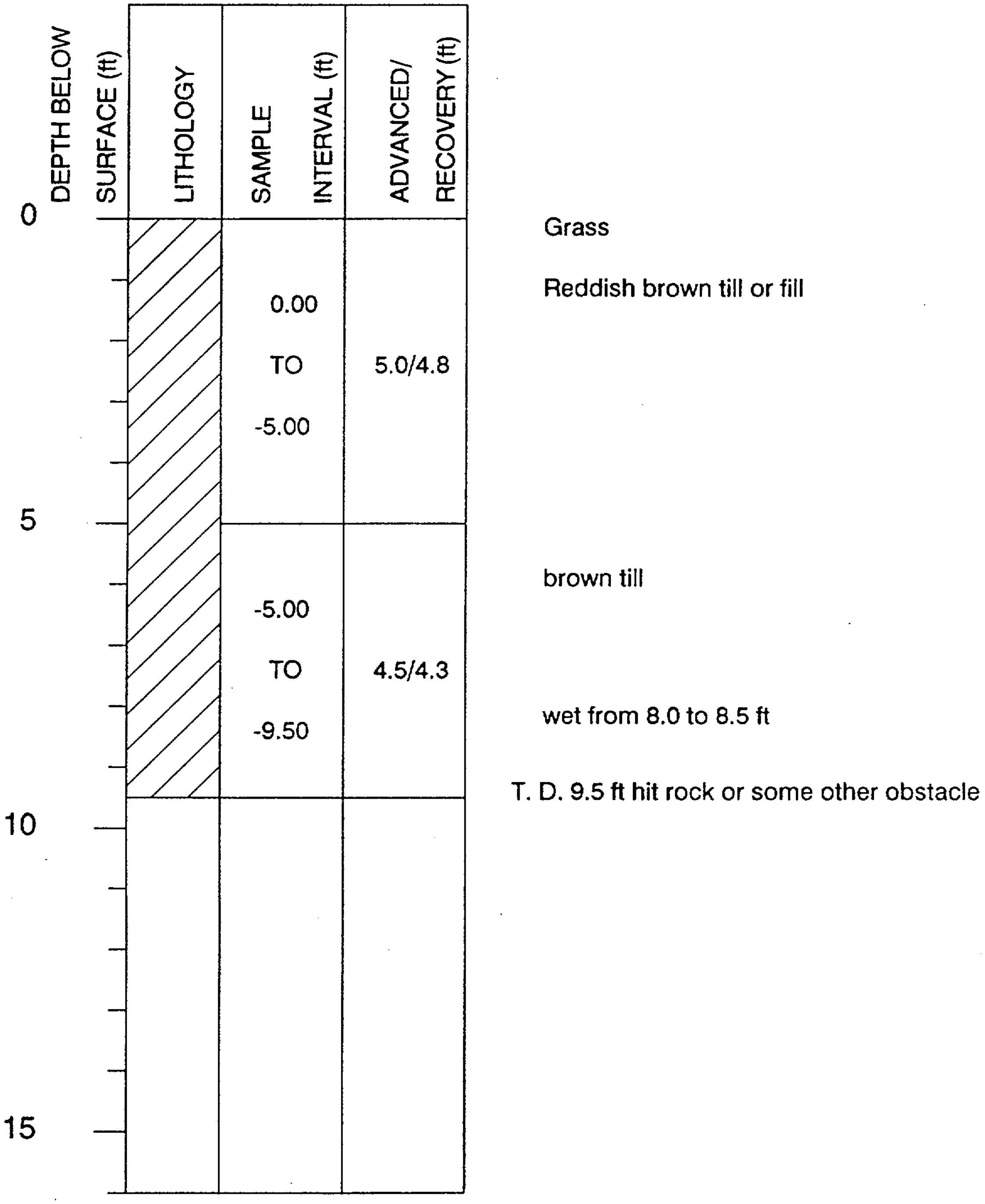
finer grained sands towards the bottom

T. D. 10.0 ft

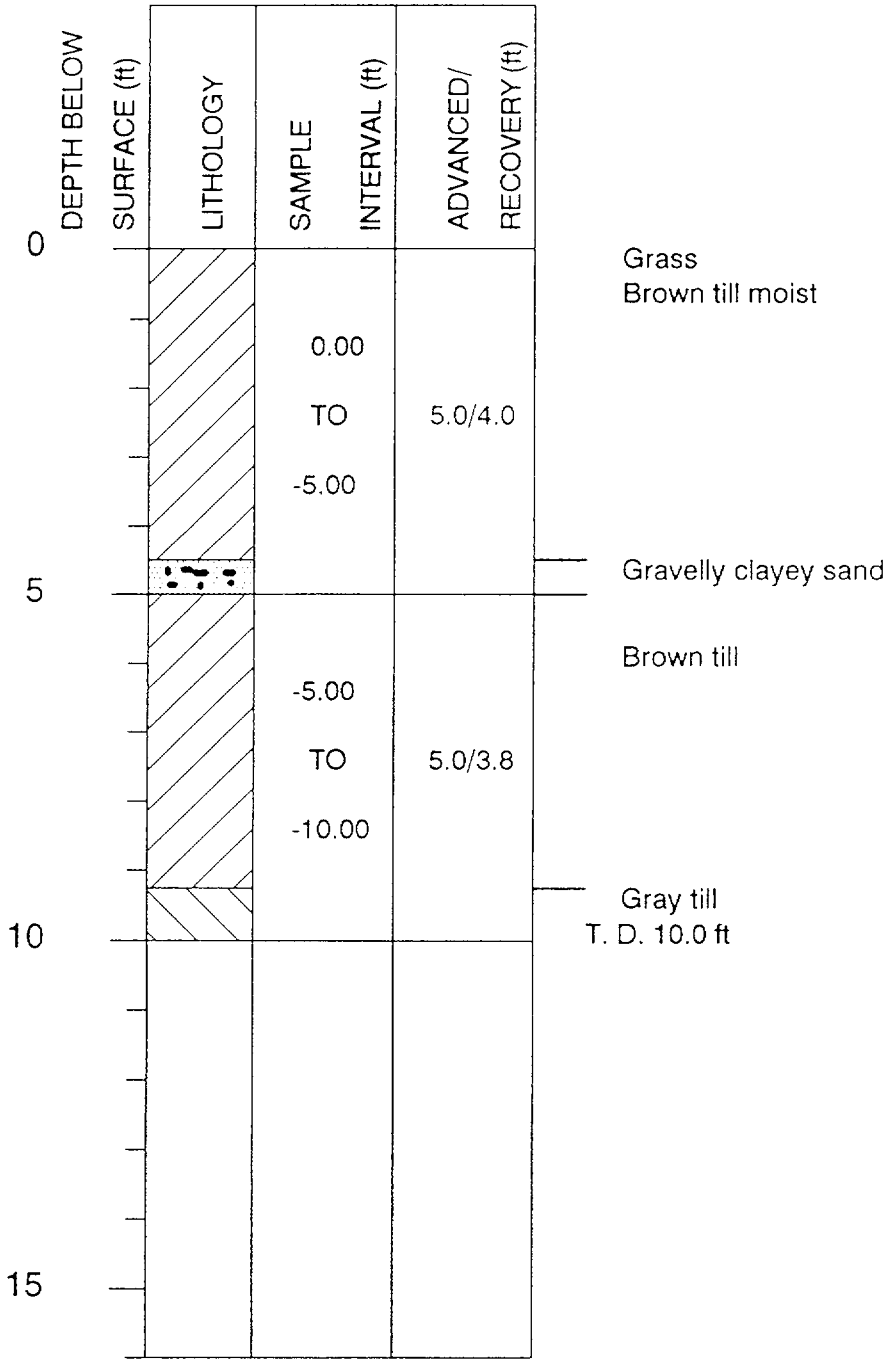
BOREHOLE NUMBER: 200 LOCATION: Sample Area 2 26 JUNE 1989



BOREHOLE NUMBER: 201 LOCATION: Sample Area 2 26 JUNE 1989



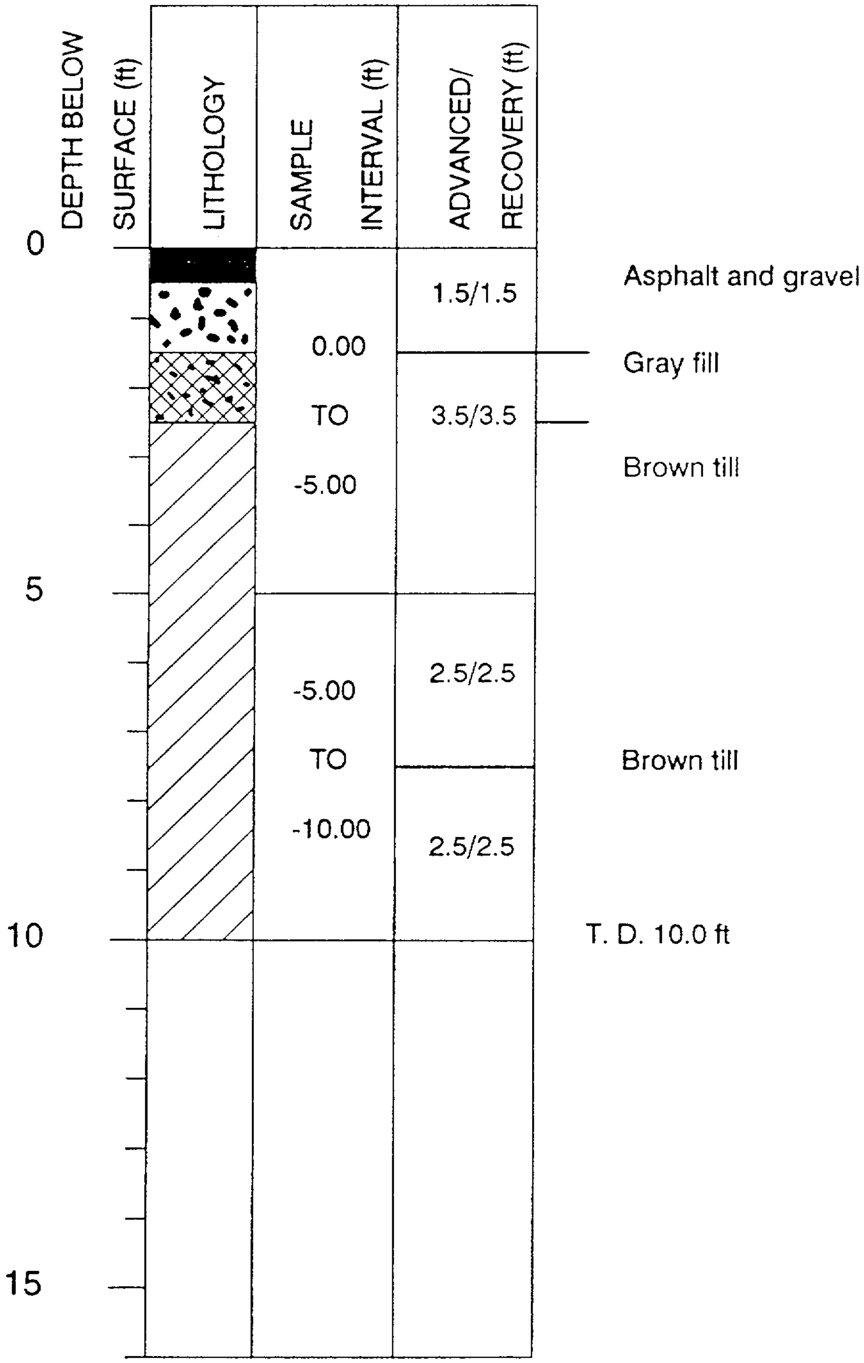
BOREHOLE NUMBER: 202 LOCATION: Sample Area 2 26 JUNE 1989



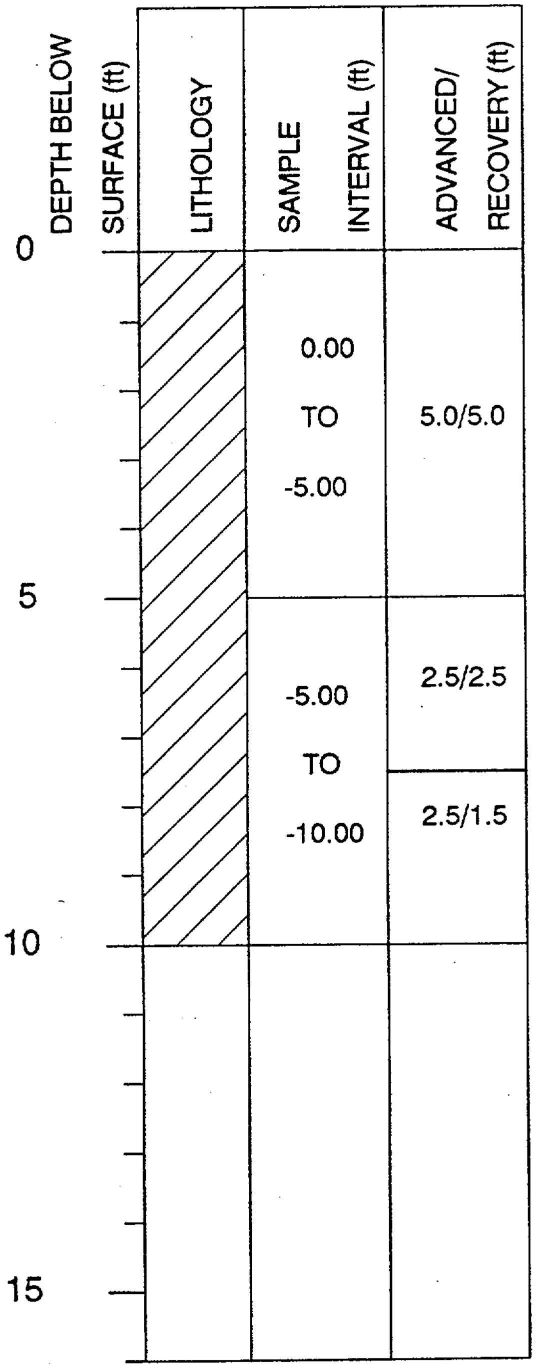
BOREHOLE NUMBER: 203 LOCATION: Sample Area 2 26 JUNE 1989

| DEPTH BELOW SURFACE (ft) | LITHOLOGY | SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) | |
|---|---|---|---|---|
| 0 | | | | Grass |
| | ▨ | 0.00<br>TO<br>-5.00 | 5.0/5.0 | Brown till or fill poorly sorted moist |
| 5 | ▨ | -5.00<br>TO<br>-10.00 | 5.0/4.8 | Brown till |
| 10 | | | | T. D. 10.0 ft |
| 15 | | | | |

BOREHOLE NUMBER: 204 LOCATION: Sample Area 2 27 JUNE 1989



BOREHOLE NUMBER: 205 LOCATION: Sample Area 2 27 JUNE 1989



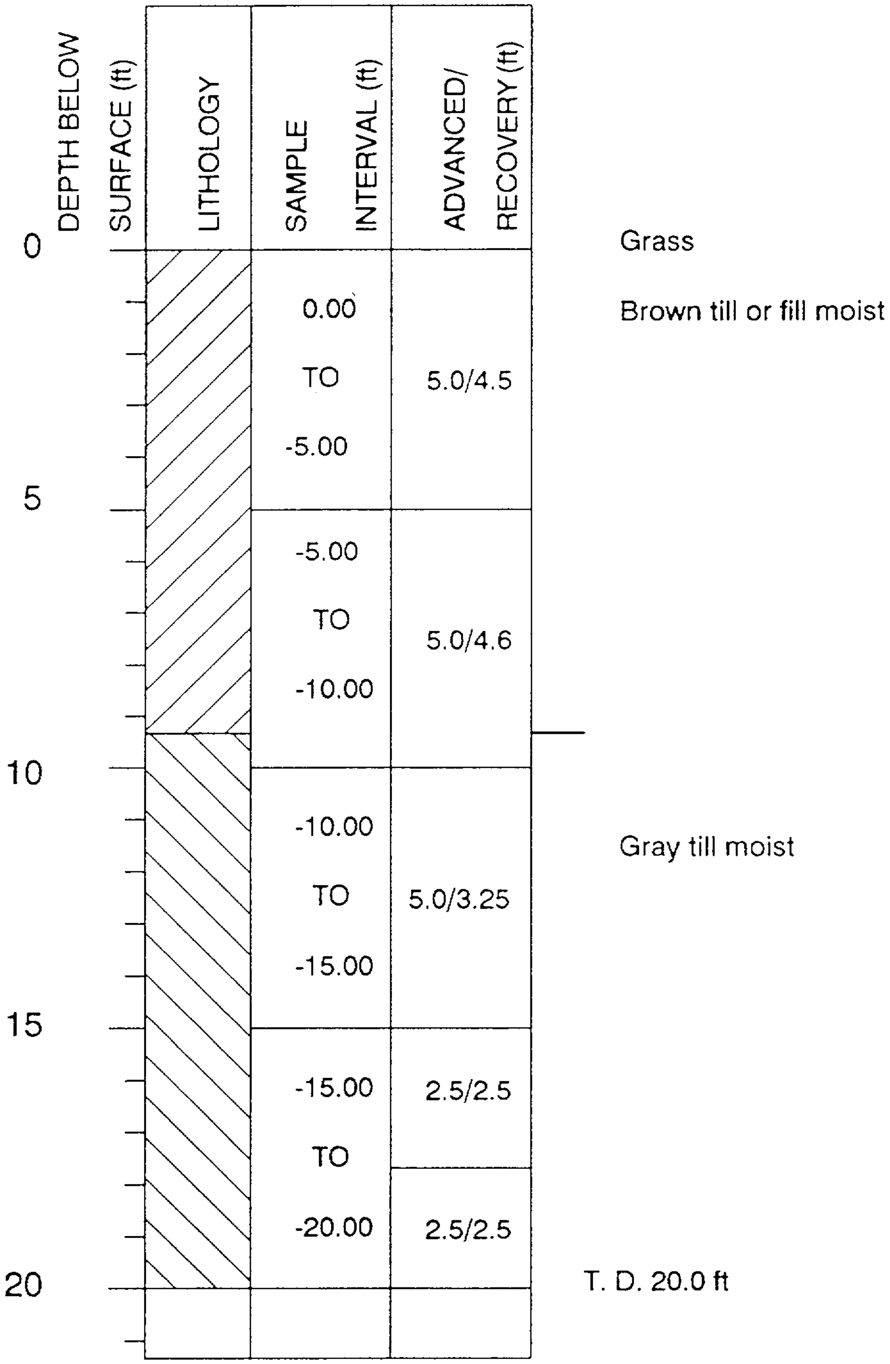
Grass

Brown till or fill

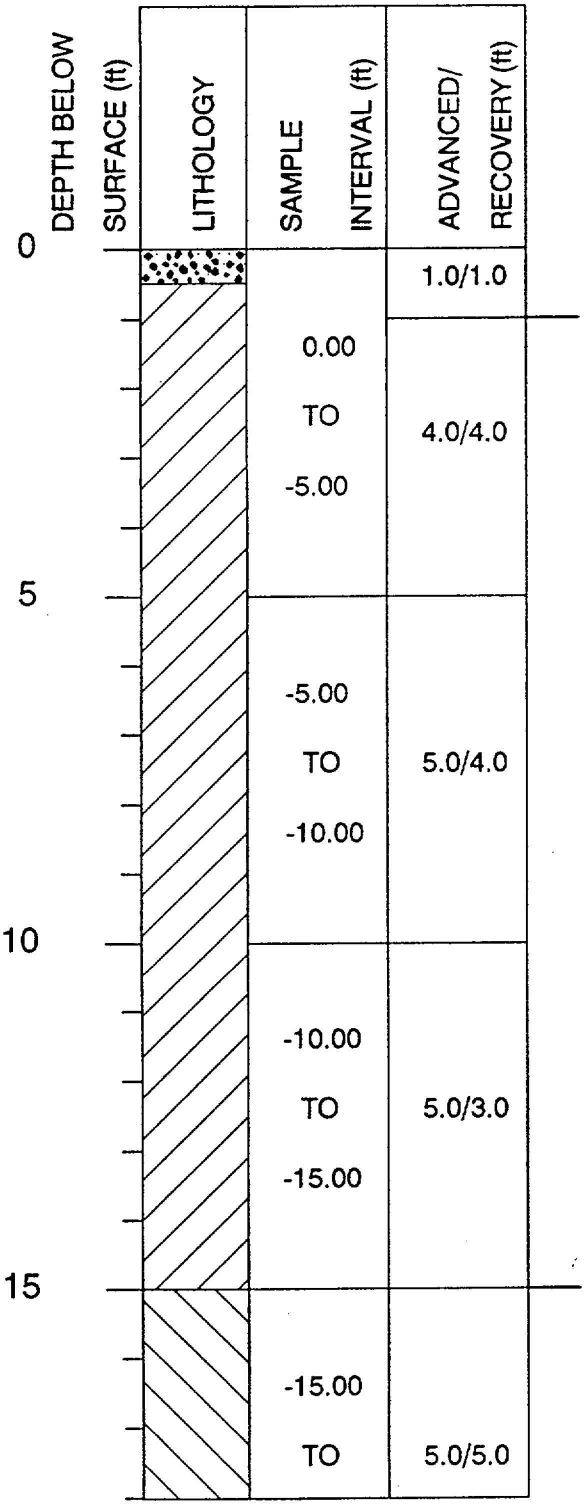
Brown till poorly sorted

T. D. 10.0 ft

BOREHOLE NUMBER: 206 LOCATION: Sample Area 2 26 JUNE 1989



BOREHOLE NUMBER: 300 LOCATION: Sample Area 3 29 JUNE 1989



Gray gravel 0.4 ft becoming finer with depth

Brown fill or till

bottom 1.0 ft dark brown till or fill

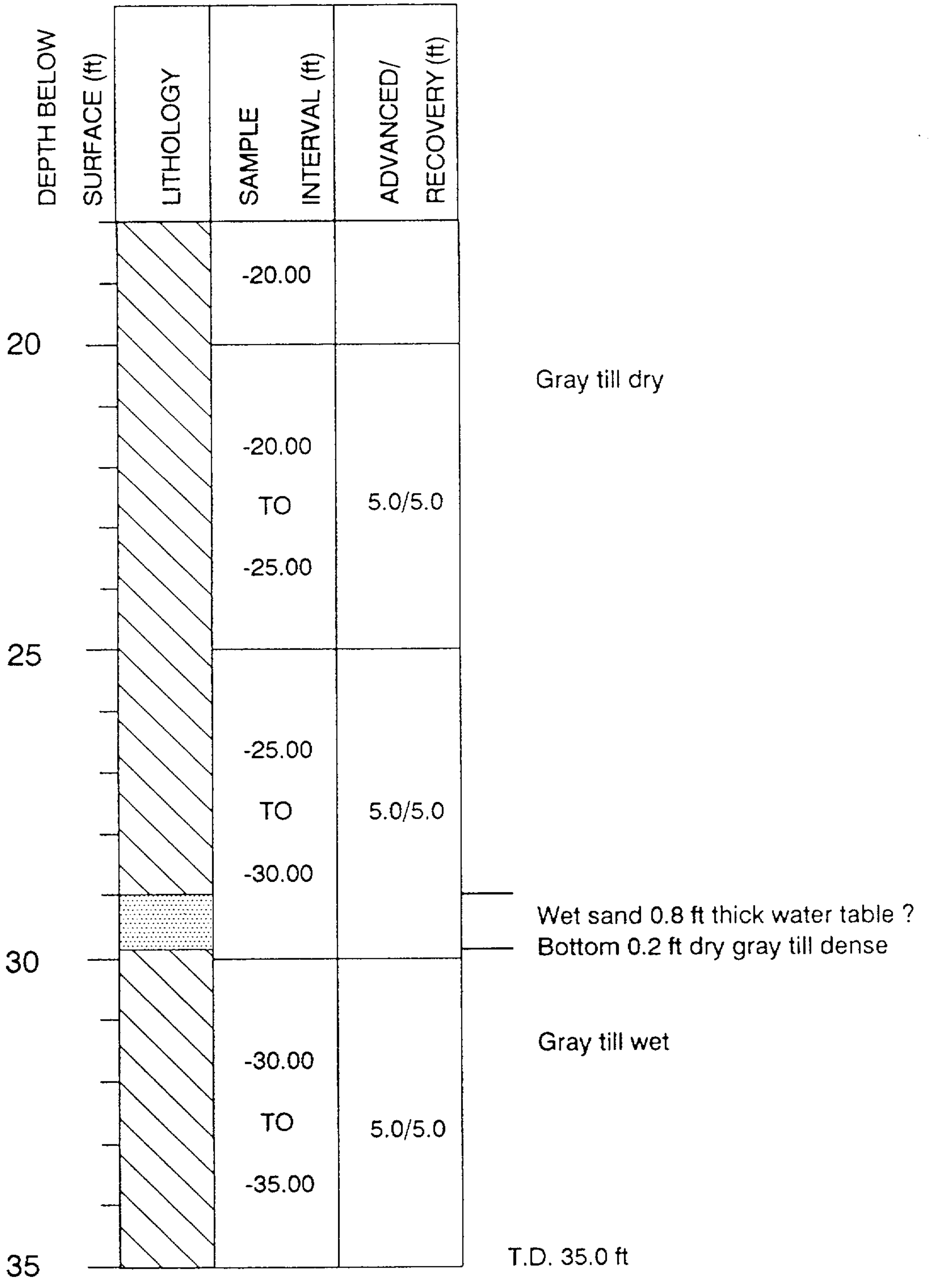
top 0.8 ft dark brown fill wet perched

bottom 3.2 ft brown till compact moist

brown till moist

Gray till dry

BOREHOLE NUMBER: 300 LOCATION: Sample Area 3 29 JUNE 1989



| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| -20.00 | |
| -20.00 TO -25.00 | 5.0/5.0 |
| -25.00 TO -30.00 | 5.0/5.0 |
| -30.00 TO -35.00 | 5.0/5.0 |

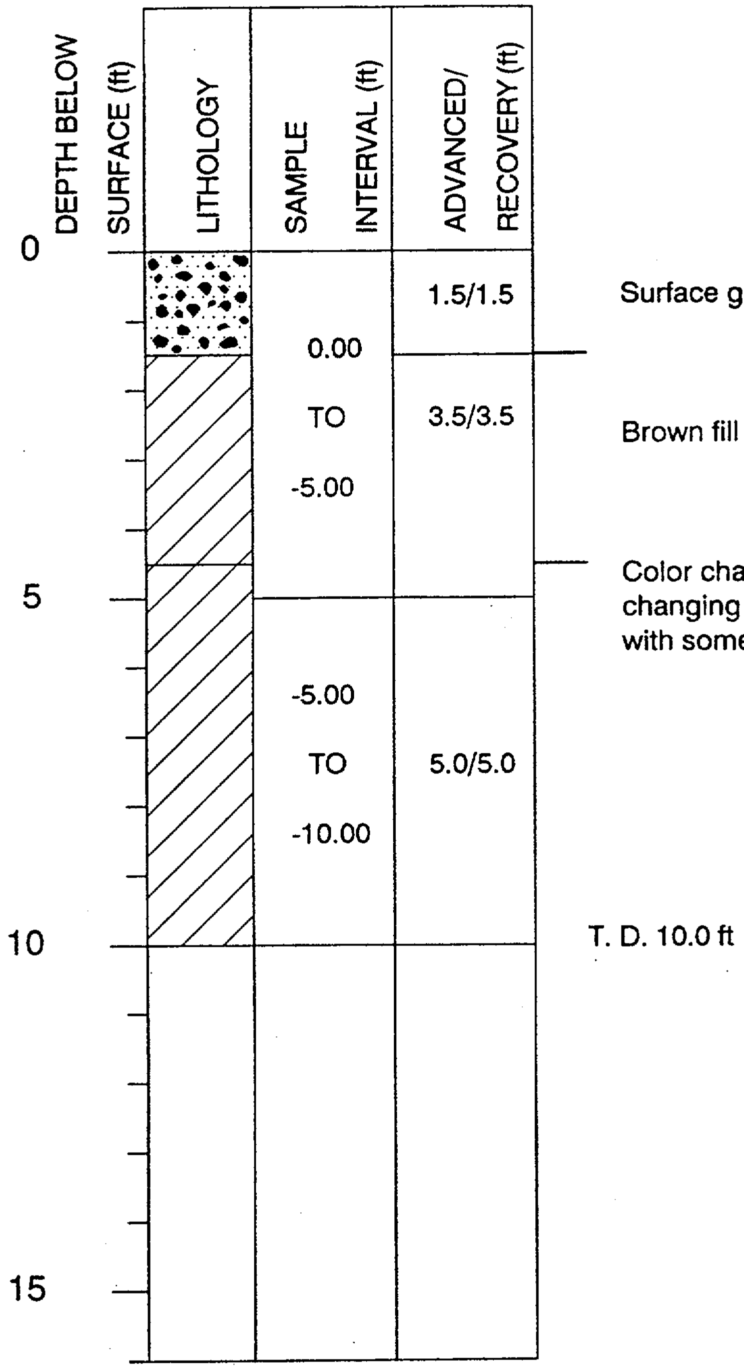
Gray till dry

Wet sand 0.8 ft thick water table ?
Bottom 0.2 ft dry gray till dense

Gray till wet

T.D. 35.0 ft

BOREHOLE NUMBER: 301 LOCATION: Sample Area 3 28 JUNE 1989



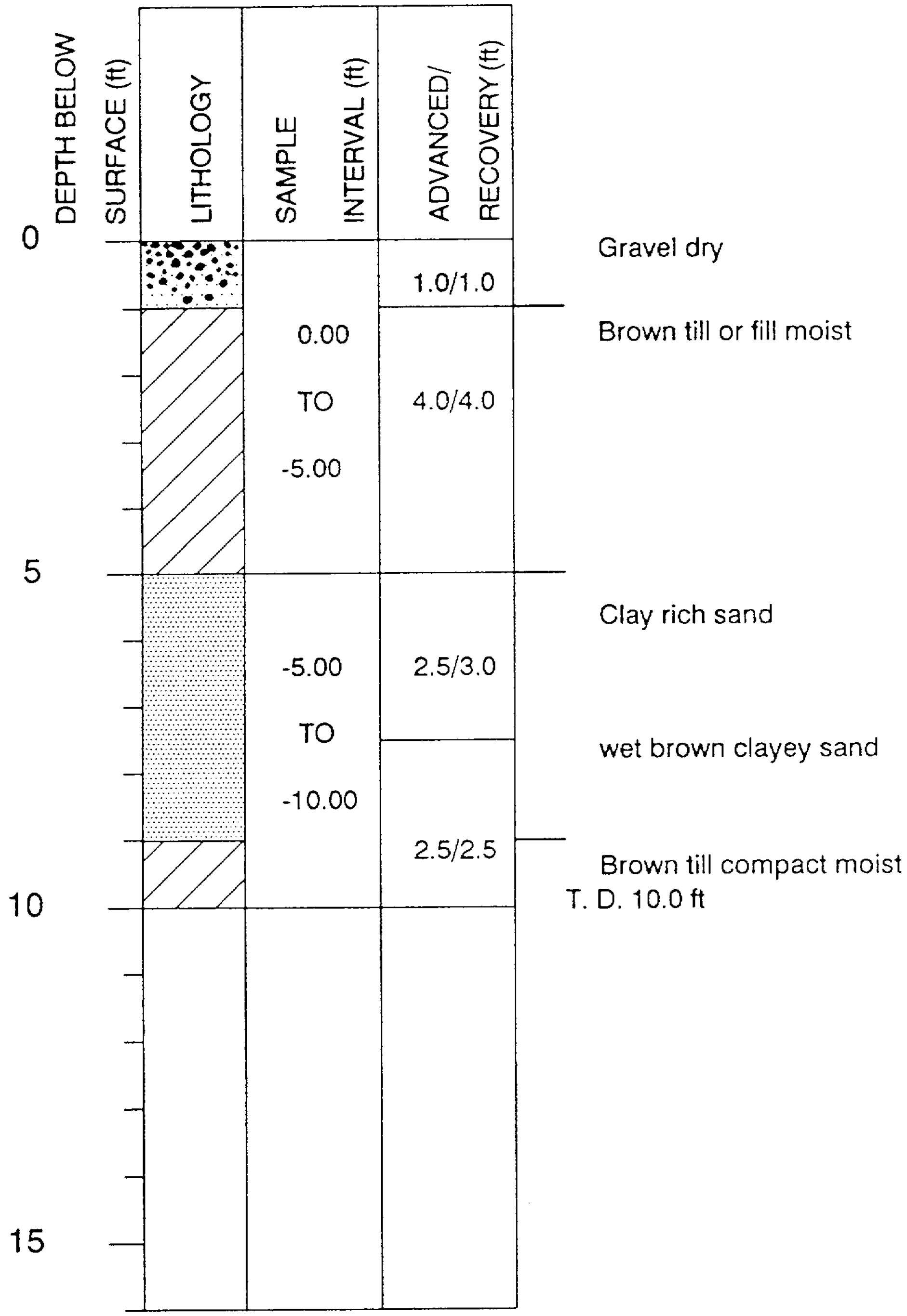
Surface gravel

Brown fill or till

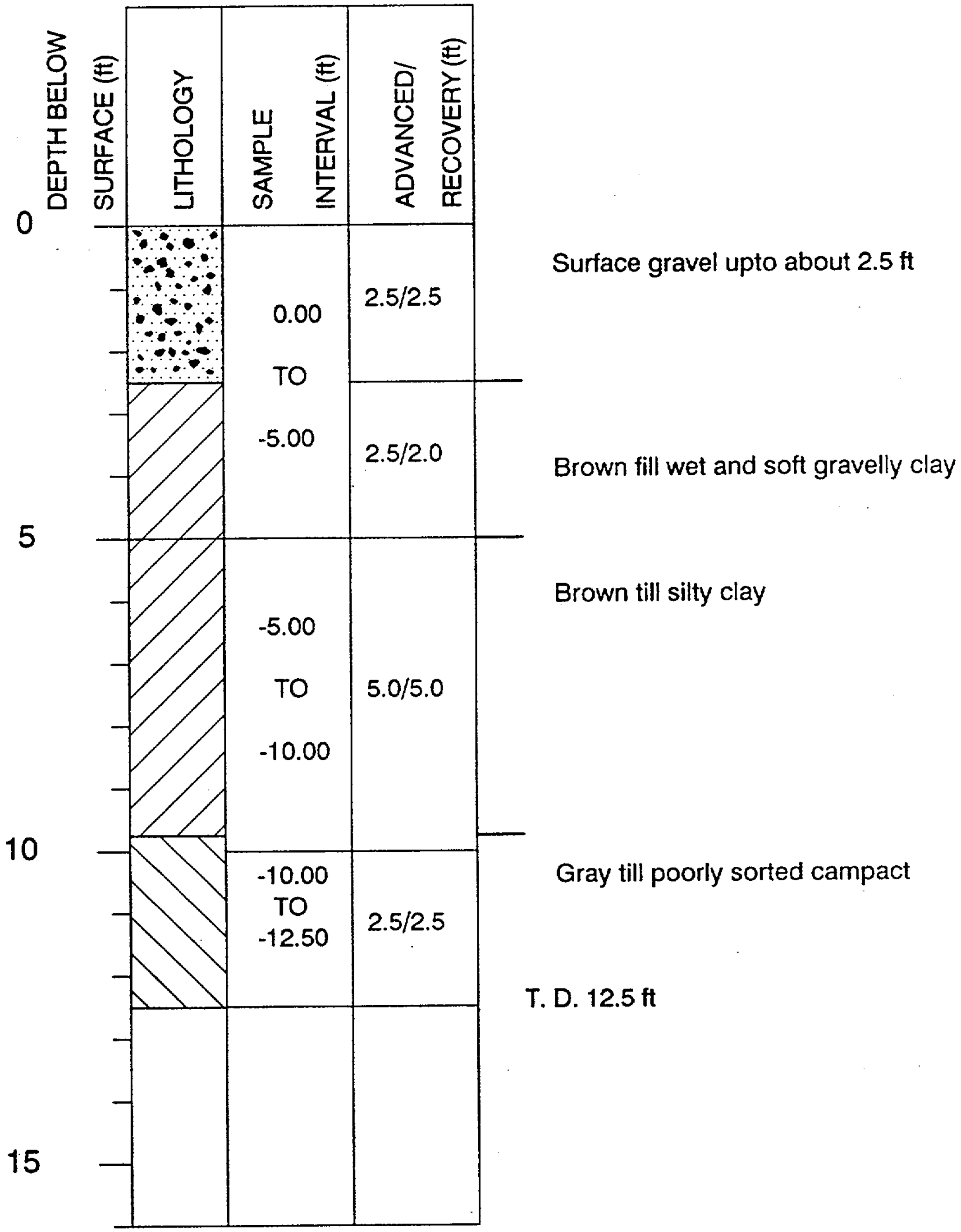
Color change to Gray/grayish brown
changing back to brown till
with some gravel very compact

T. D. 10.0 ft

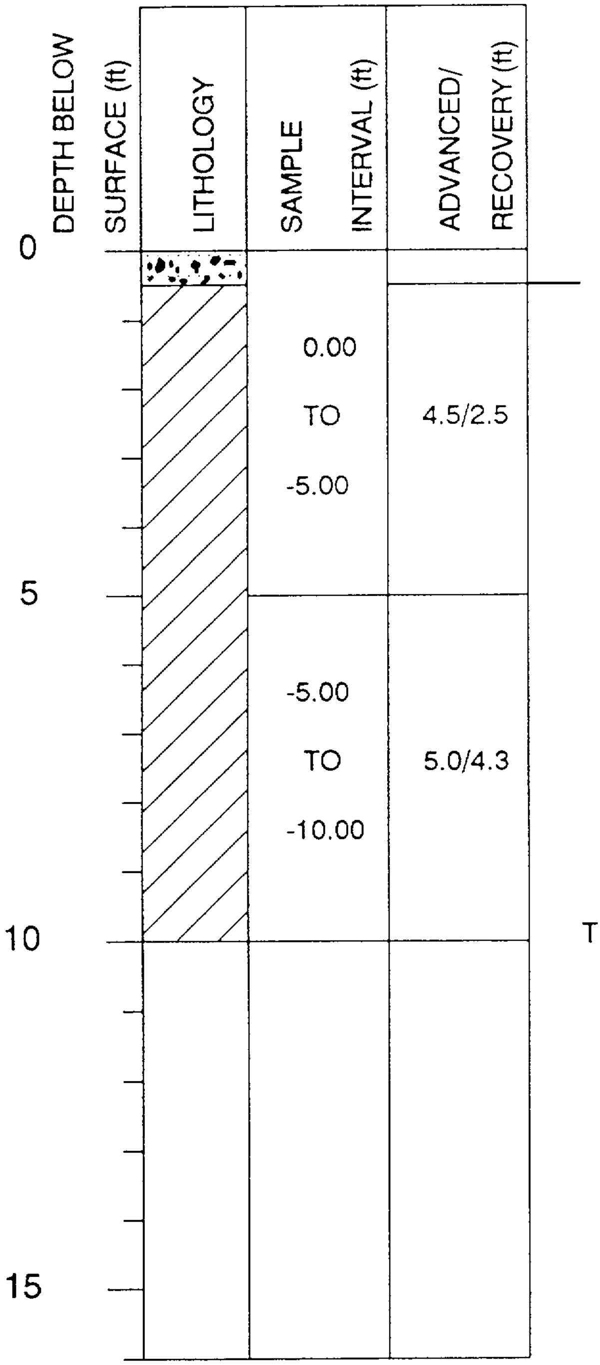
BOREHOLE NUMBER: 302 LOCATION: Sample Area 3 29 JUNE 1989



BOREHOLE NUMBER: 303 LOCATION: Sample Area 3 28 JUNE 1989



BOREHOLE NUMBER: 304 LOCATION: Sample Area 3 27 JUNE 1989

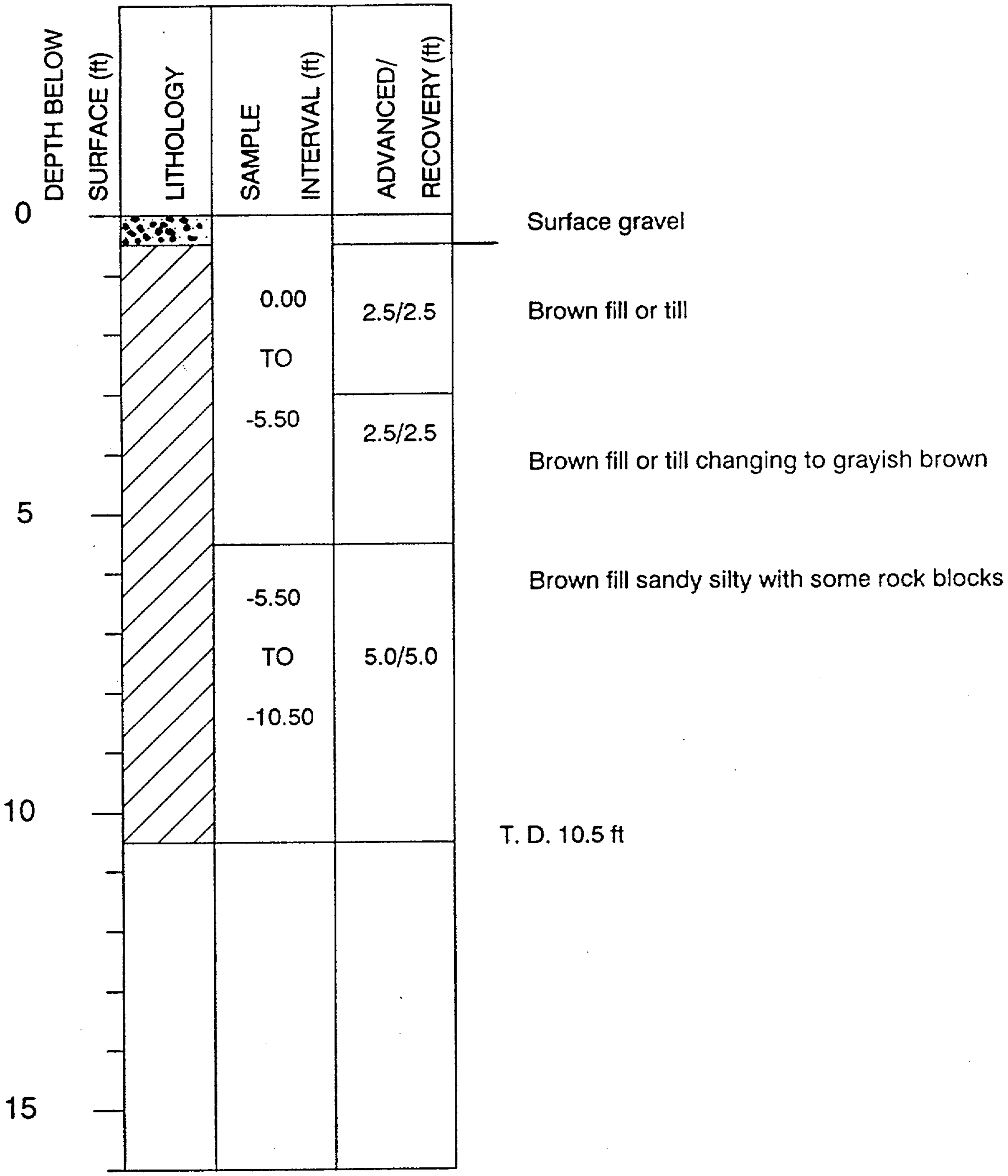


Surface gravel

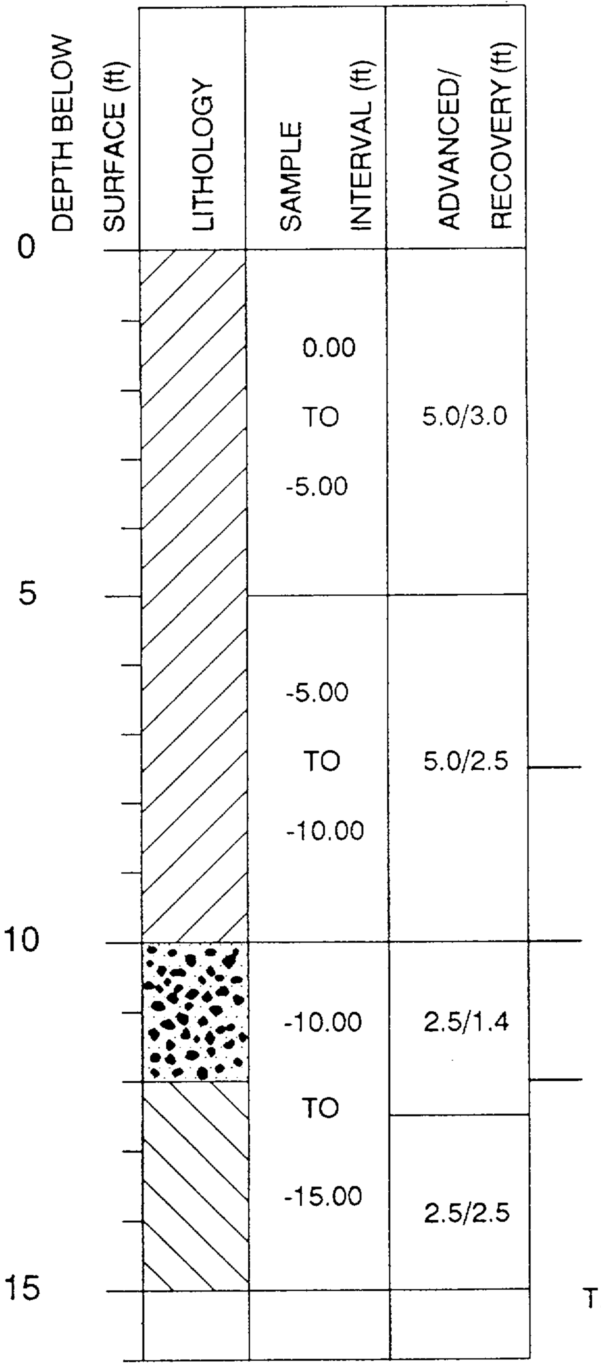
Brown silty till or fill
with some sand and gravel

T. D. 10.0 ft

BOREHOLE NUMBER: 305 LOCATION: Sample Area 3 28 JUNE 1989



BOREHOLE NUMBER: 306 LOCATION: Sample Area 3 29 JUNE 1989



Brown fill moist

bottom 0.4 ft wet

Water encountered at about 7.5 ft

brown fill wet from middle to bottom of core

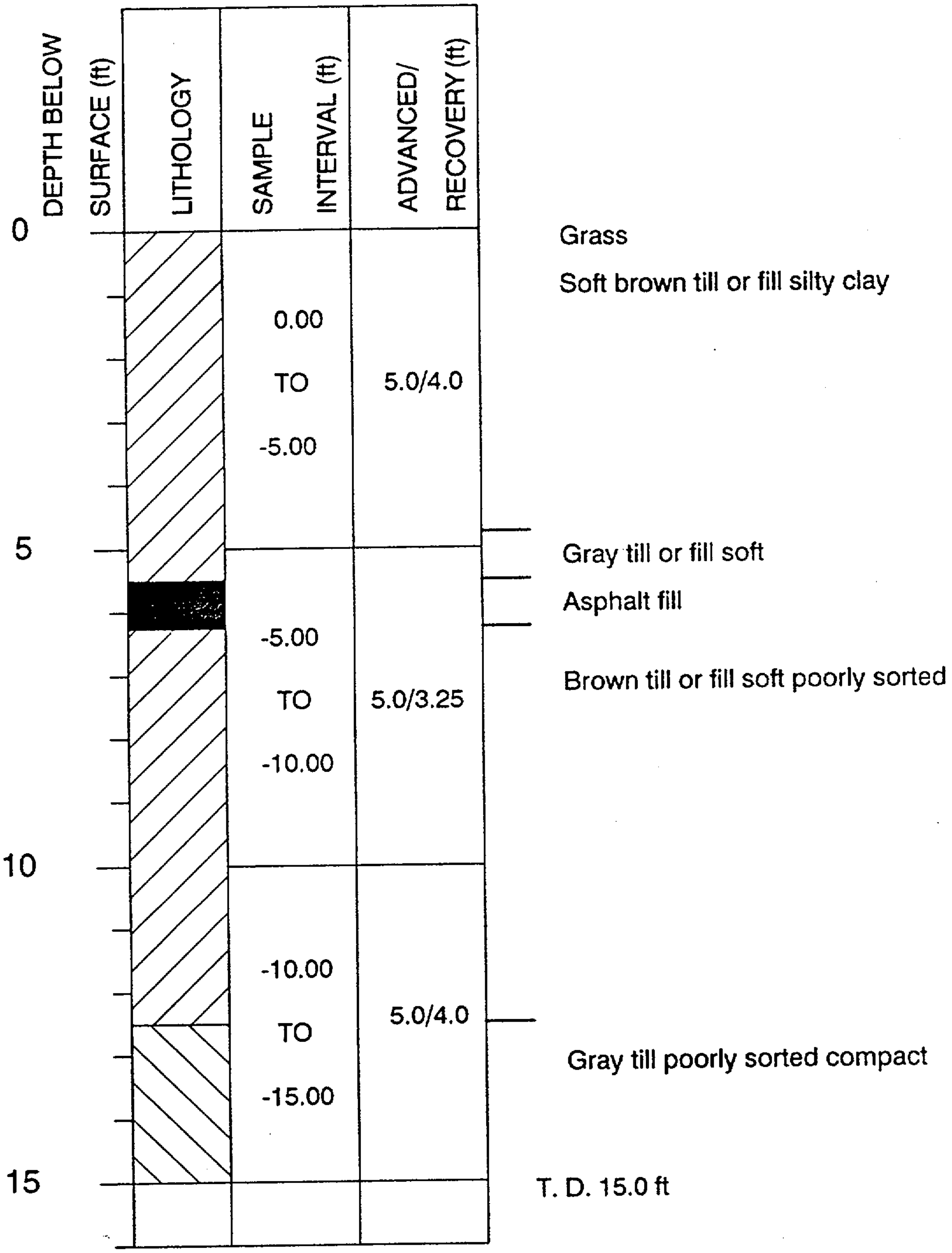
Wet gravel

Gray till wet

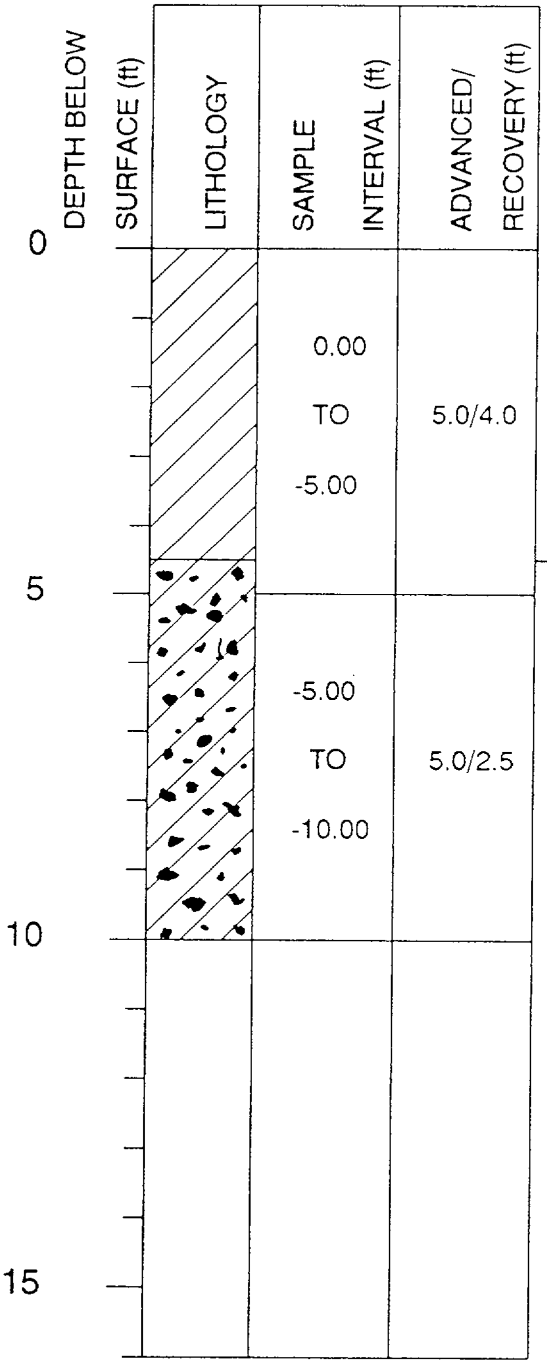
bottom 0.5 ft moist

T. D. 15.0 ft

BOREHOLE NUMBER: 307 LOCATION: Sample Area 3 28 JUNE 1989



BOREHOLE NUMBER: 308 LOCATION: Sample Area 3 29 JUNE 1989



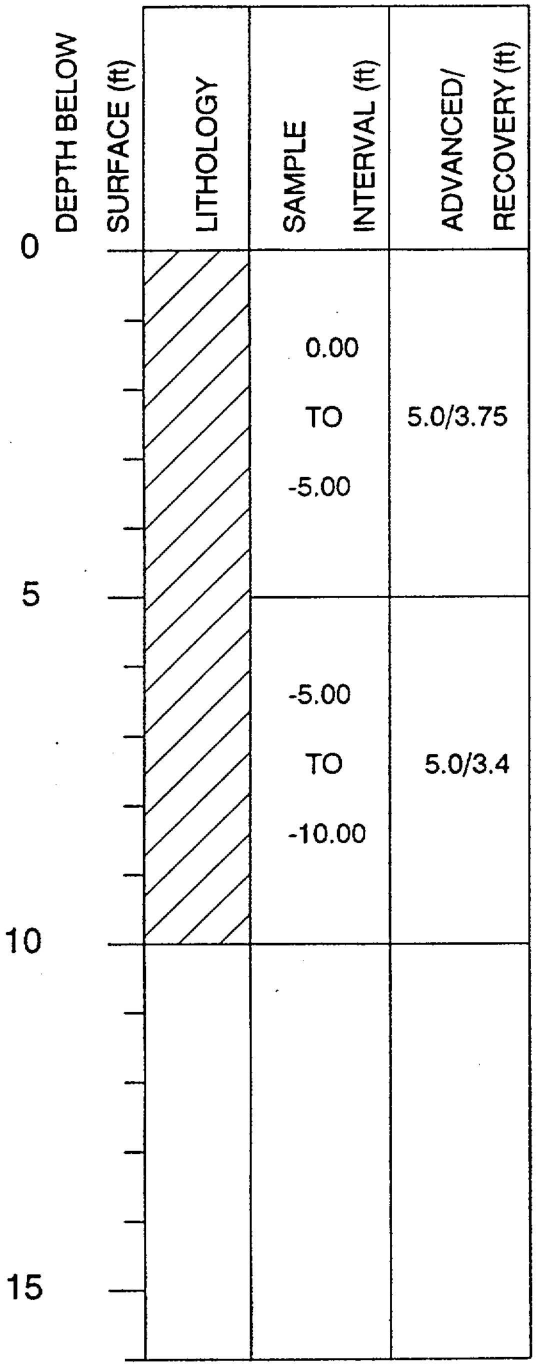
Brown fill or till moist

Water encountered at 4.5 ft
Wet clayey gravel

wet gravel with clay
too soft to get good recovery

T. D. 10.0 ft

BOREHOLE NUMBER: 309 LOCATION: Sample Area 3 28 JUNE 1989

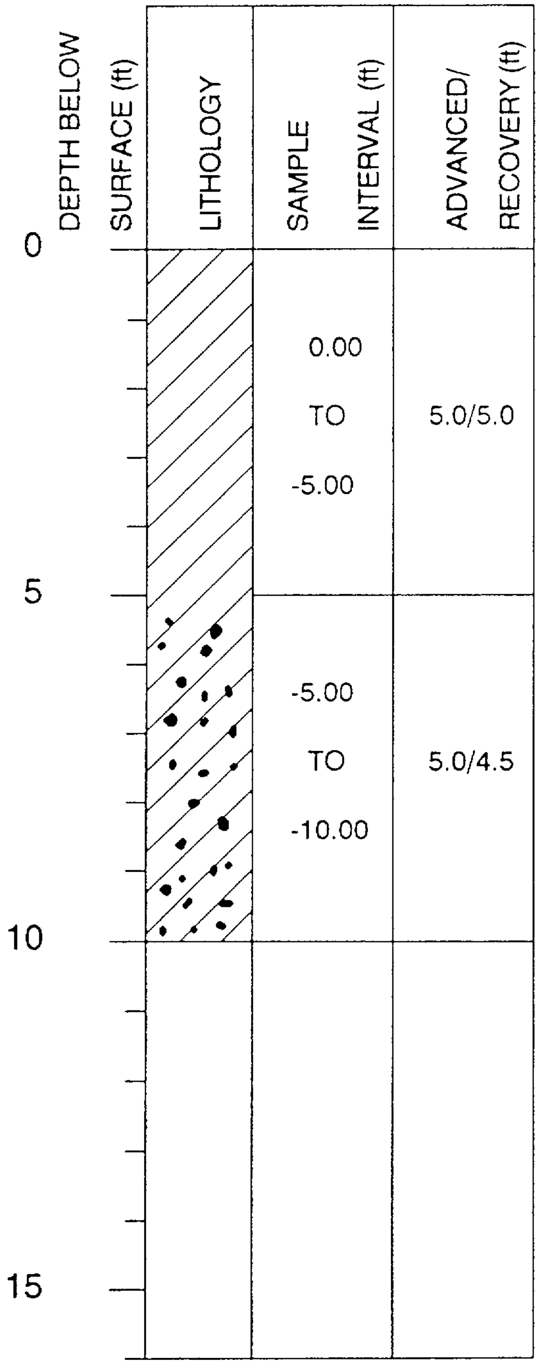


Grass

Brown fill or till silty sandy clay
very soft

T. D. 10.0 ft

BOREHOLE NUMBER: 310 LOCATION: Sample Area 3 28 JUNE 1989



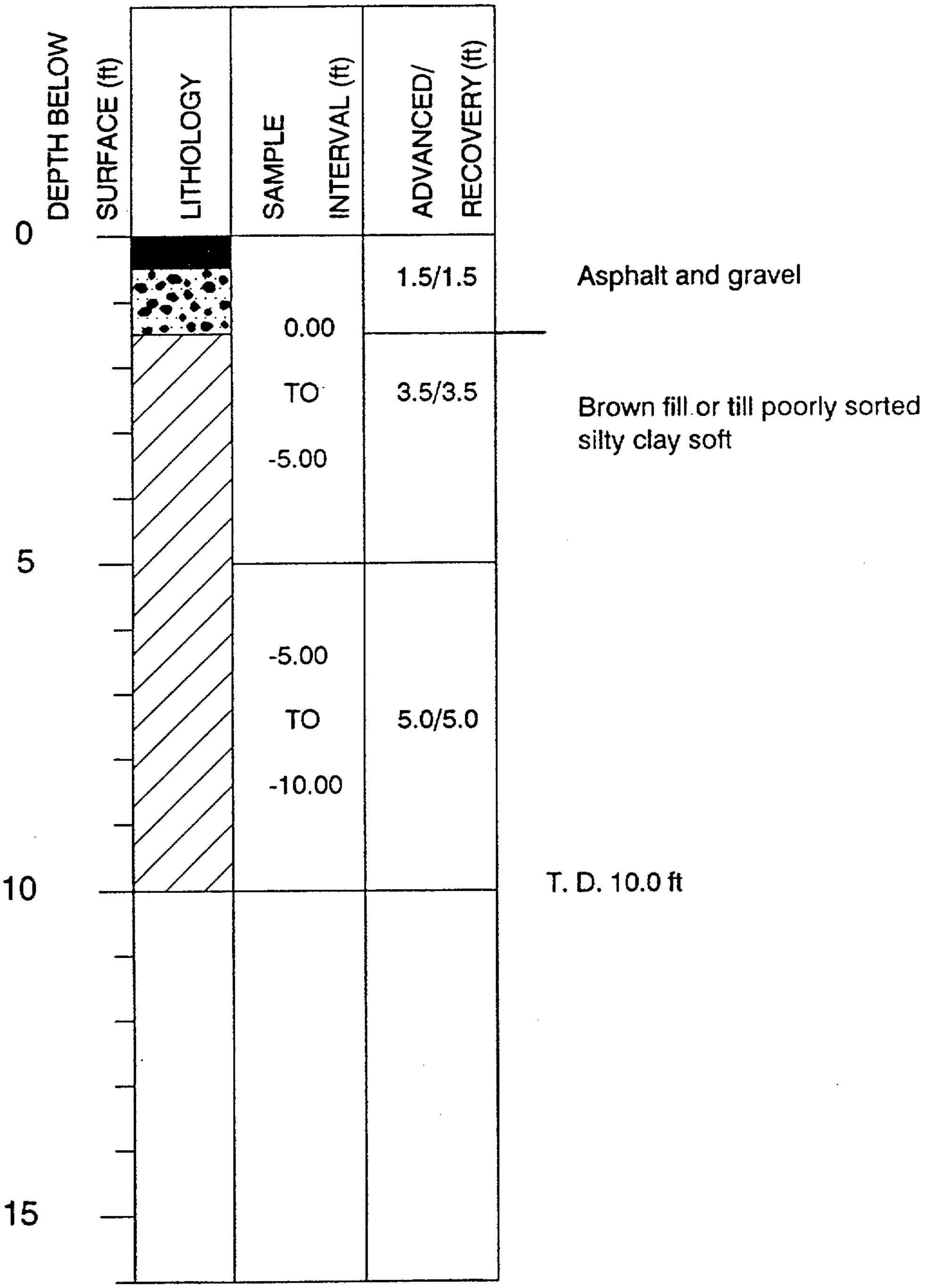
Grass and gravel
Brown fill or till soft silty clay

brown fill or till poorly sorted with
pebbles and cobbles in a silty clay matrix

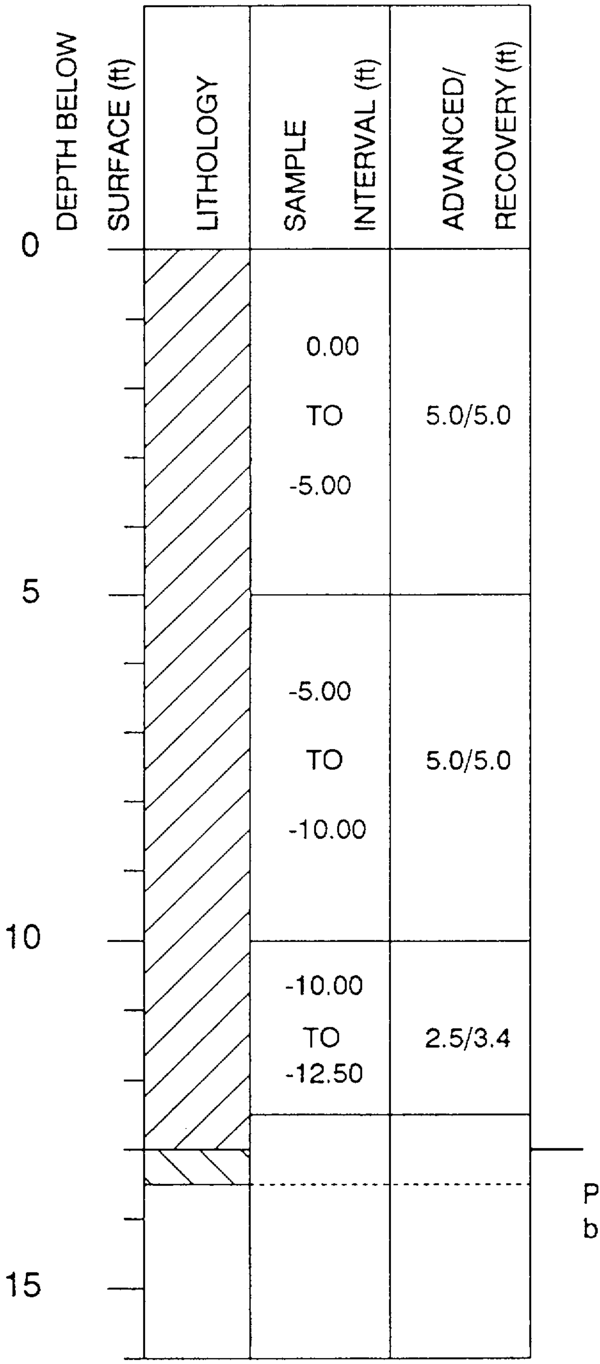
becomes very stiff at 9.0 ft

T. D. 10.0 ft

BOREHOLE NUMBER: 311 LOCATION: Sample Area 3 28 JUNE 1989



BOREHOLE NUMBER: 312 LOCATION: Sample Area 3 29 JUNE 1989

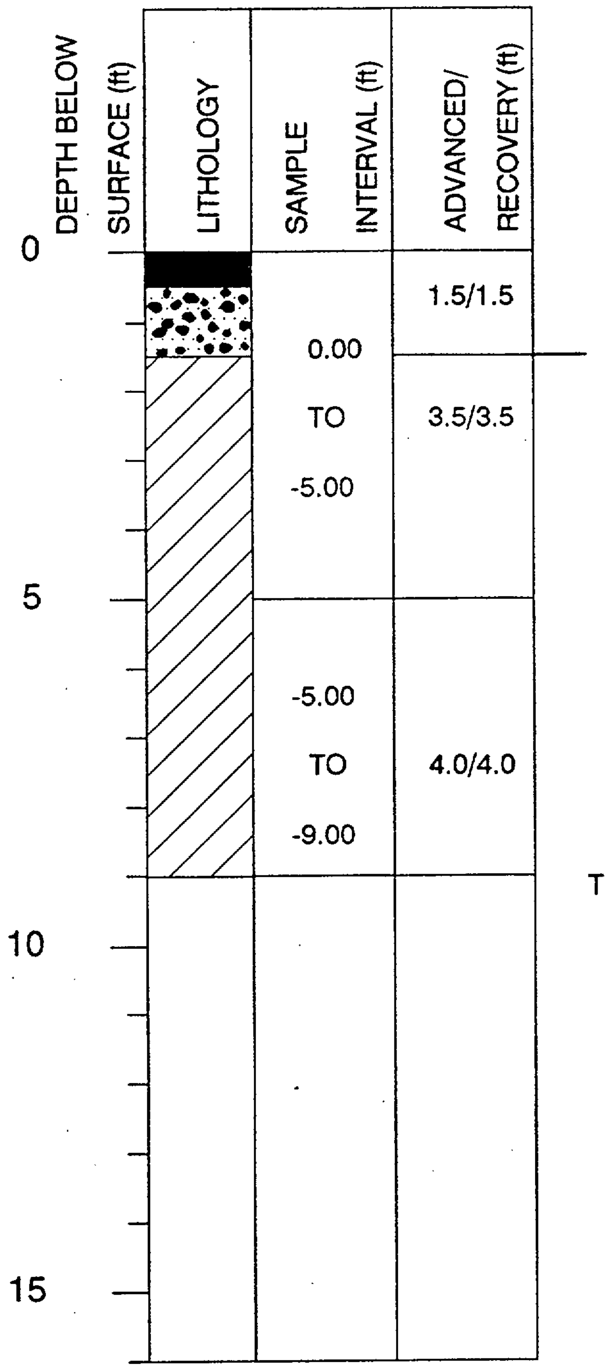


Brown till or fill moist

brown till or fill with
water in some voids

Gray till in bottom 0.4 ft of barrel
Possible T.D. 13.4 ft drilling only to 12.5 ft
but core expanded a bit

BOREHOLE NUMBER: 313 LOCATION: Sample Area 3 28 JUNE 1989



Asphalt and gravel

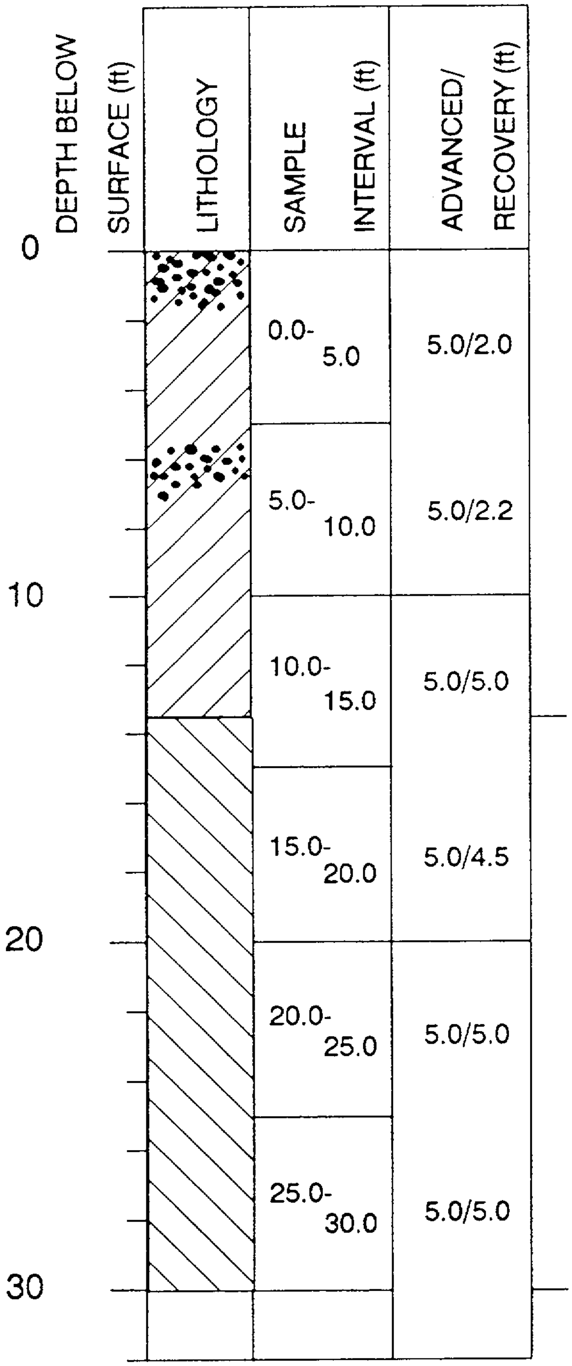
Brown fill or till poorly sorted
silty clay soft

brown till or fill with some gray sandy patches

hit something hard at 9.0 ft

T. D. 9.0 ft

BOREHOLE NUMBER: R314 LOCATION: Sample Area 3 27 JULY 1990



Grass

Brown fill with sand, silt, some gravel

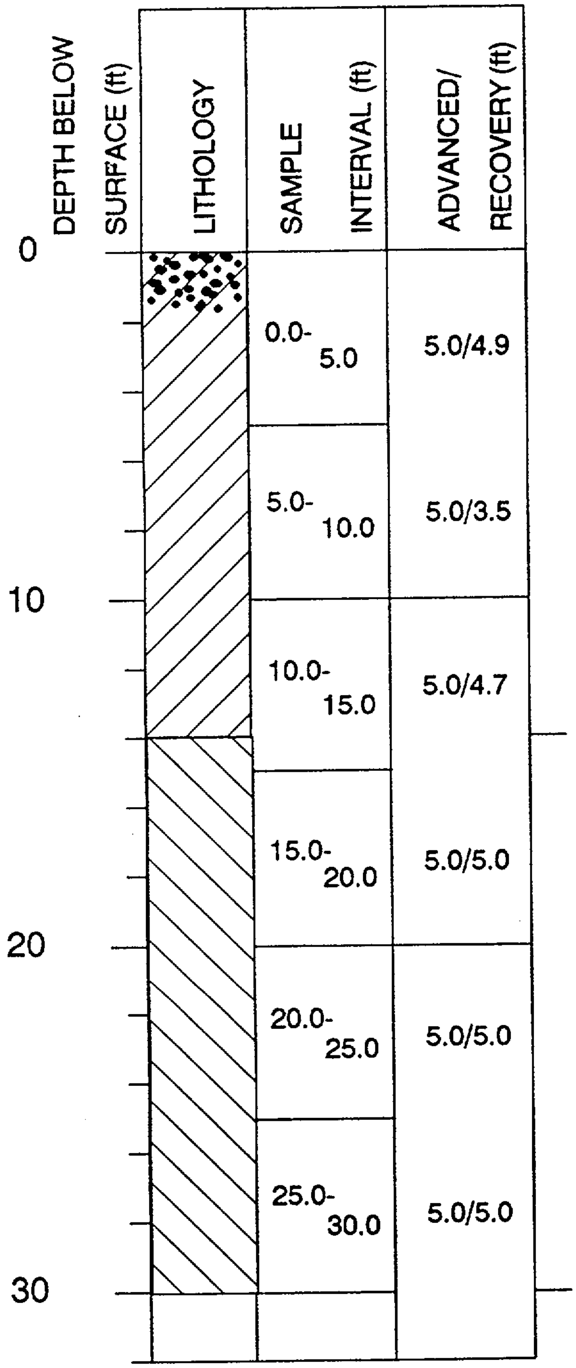
Water encountered at 5.0 ft
Brown till, with gravel and pebbles, wet

Brown till, wet

Gray till, clayey, compact, dry

T. D. 30.0 ft

BOREHOLE NUMBER: R315 LOCATION: Sample Area 3 27 JULY 1990



| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| 0.0-5.0 | 5.0/4.9 |
| 5.0-10.0 | 5.0/3.5 |
| 10.0-15.0 | 5.0/4.7 |
| 15.0-20.0 | 5.0/5.0 |
| 20.0-25.0 | 5.0/5.0 |
| 25.0-30.0 | 5.0/5.0 |

Grass

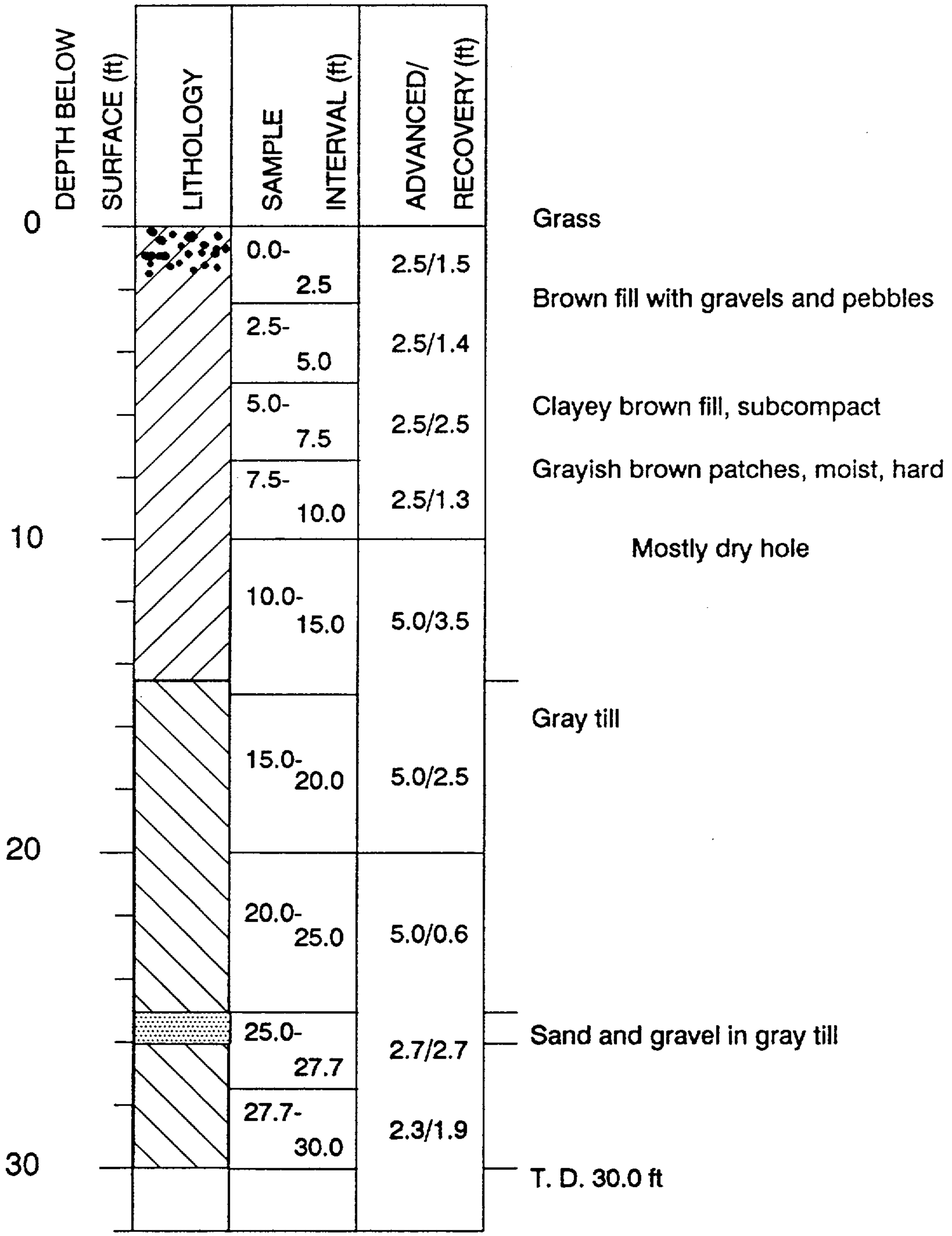
Brown fill with sand, silt, some gravel

Brown till, subcompact

Gray till, clayey, compact, dry

T. D. 30.0 ft

BOREHOLE NUMBER: R316 LOCATION: Sample Area 3 26 JULY 1990



| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| 0.0-2.5 | 2.5/1.5 |
| 2.5-5.0 | 2.5/1.4 |
| 5.0-7.5 | 2.5/2.5 |
| 7.5-10.0 | 2.5/1.3 |
| 10.0-15.0 | 5.0/3.5 |
| 15.0-20.0 | 5.0/2.5 |
| 20.0-25.0 | 5.0/0.6 |
| 25.0-27.7 | 2.7/2.7 |
| 27.7-30.0 | 2.3/1.9 |

Grass

Brown fill with gravels and pebbles

Clayey brown fill, subcompact

Grayish brown patches, moist, hard

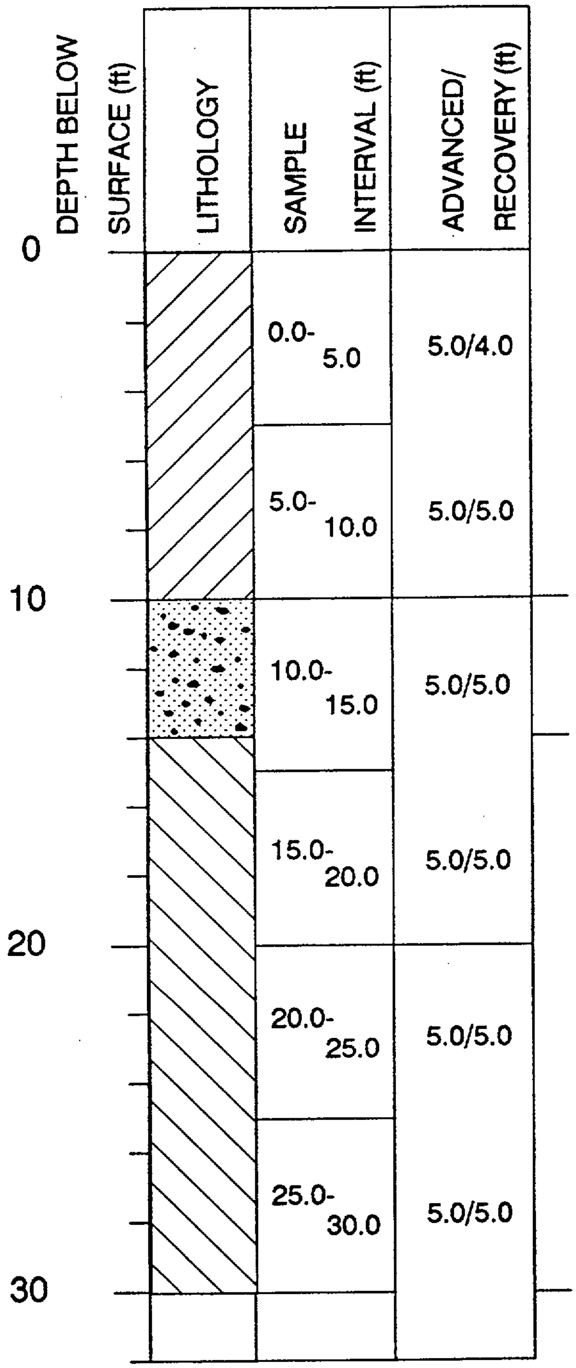
Mostly dry hole

Gray till

Sand and gravel in gray till

T. D. 30.0 ft

BOREHOLE NUMBER: R317 LOCATION: Sample Area 3 26 JULY 1990



Grass

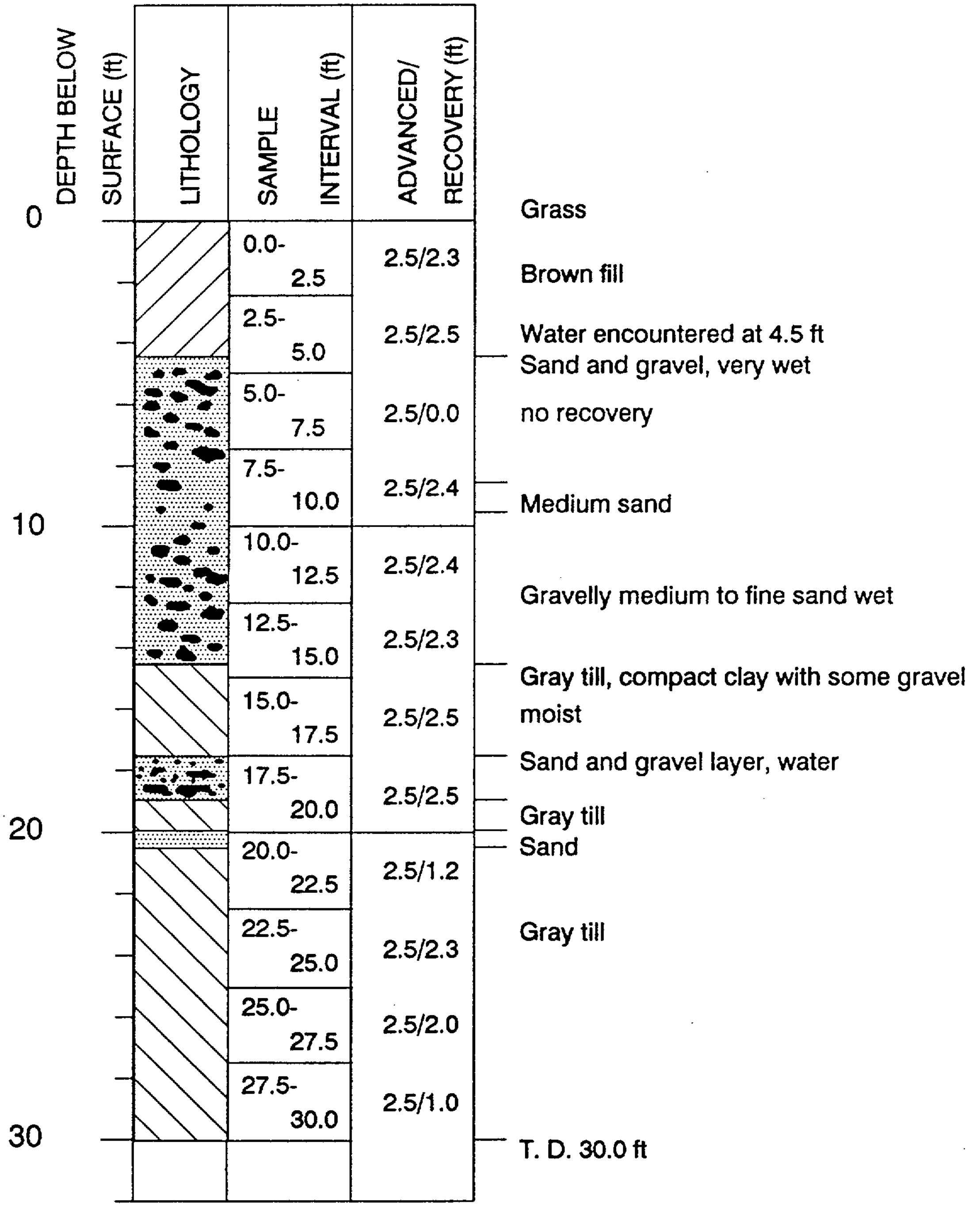
Brown fill

Water encountered at 10.0 ft
gravelly sandy brown fill

Gray till, sandy and wet

T. D. 30.0 ft

BOREHOLE NUMBER: R318 LOCATION: Sample Area 3 26 JULY 1990



| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| 0.0-2.5 | 2.5/2.3 |
| 2.5-5.0 | 2.5/2.5 |
| 5.0-7.5 | 2.5/0.0 |
| 7.5-10.0 | 2.5/2.4 |
| 10.0-12.5 | 2.5/2.4 |
| 12.5-15.0 | 2.5/2.3 |
| 15.0-17.5 | 2.5/2.5 |
| 17.5-20.0 | 2.5/2.5 |
| 20.0-22.5 | 2.5/1.2 |
| 22.5-25.0 | 2.5/2.3 |
| 25.0-27.5 | 2.5/2.0 |
| 27.5-30.0 | 2.5/1.0 |

Grass

Brown fill

Water encountered at 4.5 ft

Sand and gravel, very wet

no recovery

Medium sand

Gravelly medium to fine sand wet

Gray till, compact clay with some gravel moist

Sand and gravel layer, water

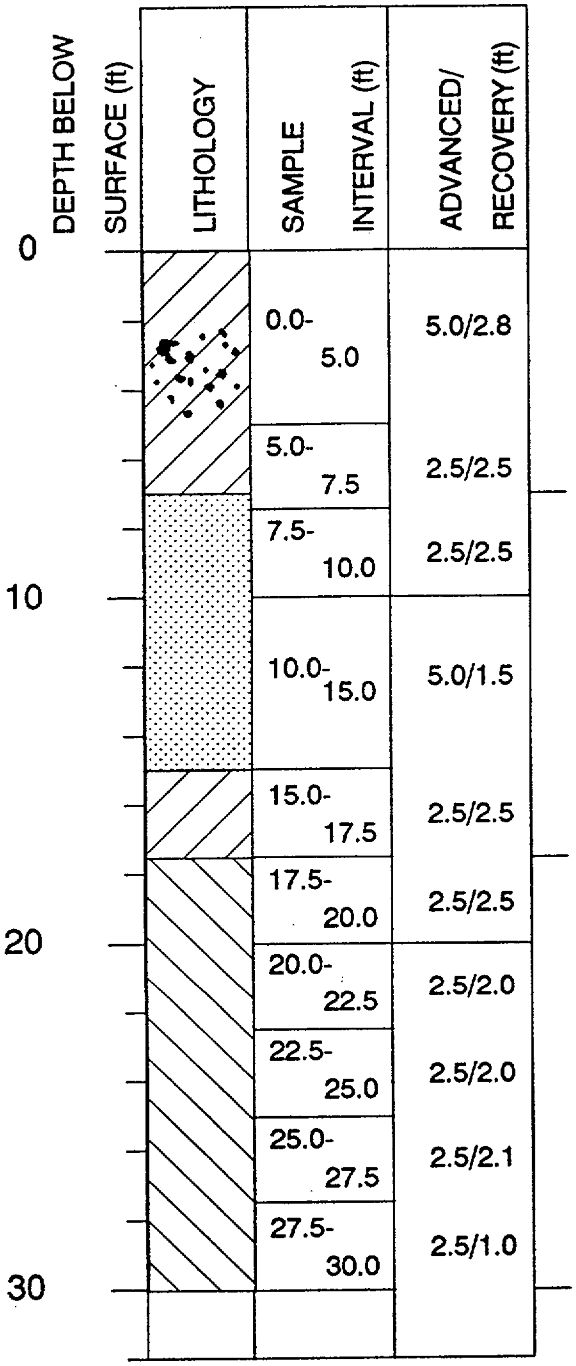
Gray till

Sand

Gray till

T. D. 30.0 ft

BOREHOLE NUMBER: R319B LOCATION: Sample Area 3 25 JULY 1990



| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| 0.0-5.0 | 5.0/2.8 |
| 5.0-7.5 | 2.5/2.5 |
| 7.5-10.0 | 2.5/2.5 |
| 10.0-15.0 | 5.0/1.5 |
| 15.0-17.5 | 2.5/2.5 |
| 17.5-20.0 | 2.5/2.5 |
| 20.0-22.5 | 2.5/2.0 |
| 22.5-25.0 | 2.5/2.0 |
| 25.0-27.5 | 2.5/2.1 |
| 27.5-30.0 | 2.5/1.0 |

Grass

Soft brown fill with gravel and asphalt chunks

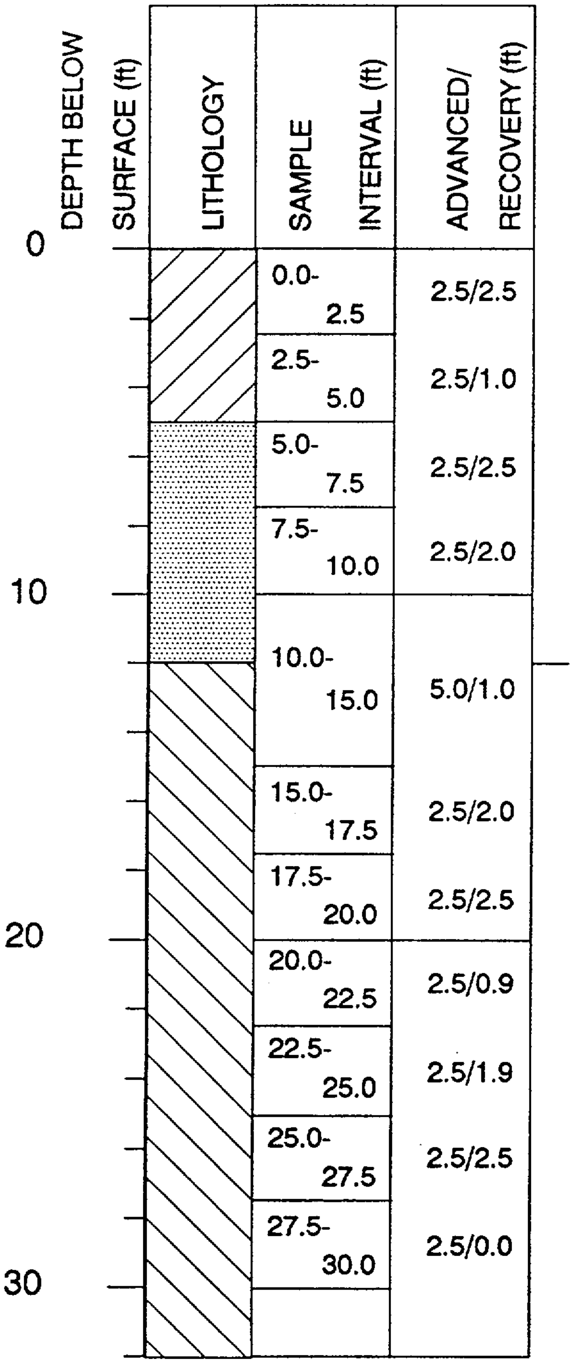
silty clayey medium sand

water encountered at 7.0 ft.

Gray till, compact

T. D. 30.0 ft

BOREHOLE NUMBER: R320 LOCATION: Sample Area 3 25 JULY 1990



| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| 0.0-2.5 | 2.5/2.5 |
| 2.5-5.0 | 2.5/1.0 |
| 5.0-7.5 | 2.5/2.5 |
| 7.5-10.0 | 2.5/2.0 |
| 10.0-15.0 | 5.0/1.0 |
| 15.0-17.5 | 2.5/2.0 |
| 17.5-20.0 | 2.5/2.5 |
| 20.0-22.5 | 2.5/0.9 |
| 22.5-25.0 | 2.5/1.9 |
| 25.0-27.5 | 2.5/2.5 |
| 27.5-30.0 | 2.5/0.0 |

Grass

Brown fill/till, poorly sorted with fine to medium sand and pebbles

Water encountered at 5.0 ft

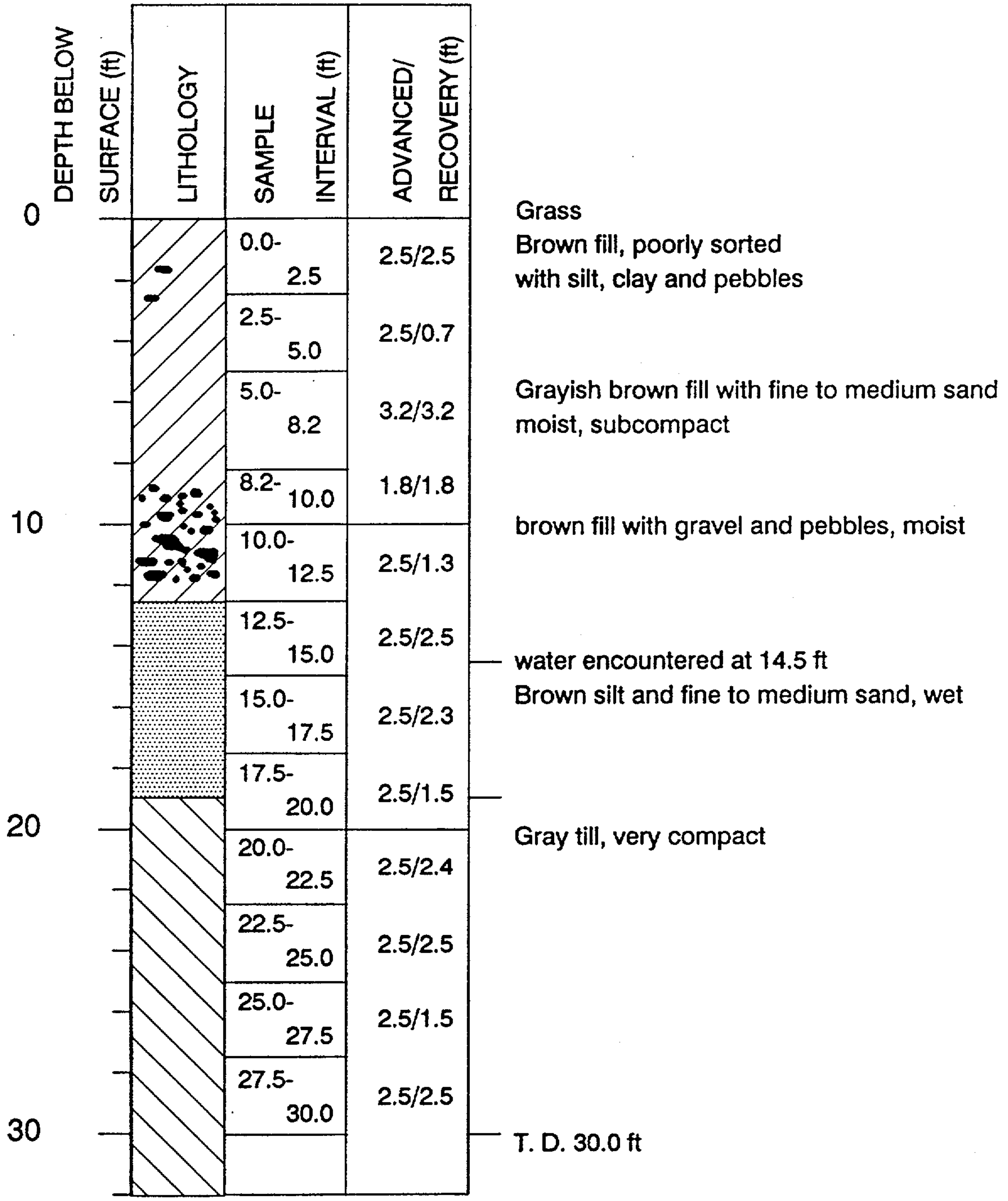
Medium to coarse sand in brown fill, wet

Gray Till, very compact

No recovery, limestone chunk in gray till

T. D. 30.0 ft

BOREHOLE NUMBER: R321 LOCATION: Sample Area 3 25 JULY 1990



| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| 0.0-2.5 | 2.5/2.5 |
| 2.5-5.0 | 2.5/0.7 |
| 5.0-8.2 | 3.2/3.2 |
| 8.2-10.0 | 1.8/1.8 |
| 10.0-12.5 | 2.5/1.3 |
| 12.5-15.0 | 2.5/2.5 |
| 15.0-17.5 | 2.5/2.3 |
| 17.5-20.0 | 2.5/1.5 |
| 20.0-22.5 | 2.5/2.4 |
| 22.5-25.0 | 2.5/2.5 |
| 25.0-27.5 | 2.5/1.5 |
| 27.5-30.0 | 2.5/2.5 |

Grass

Brown fill, poorly sorted with silt, clay and pebbles

Grayish brown fill with fine to medium sand moist, subcompact

brown fill with gravel and pebbles, moist

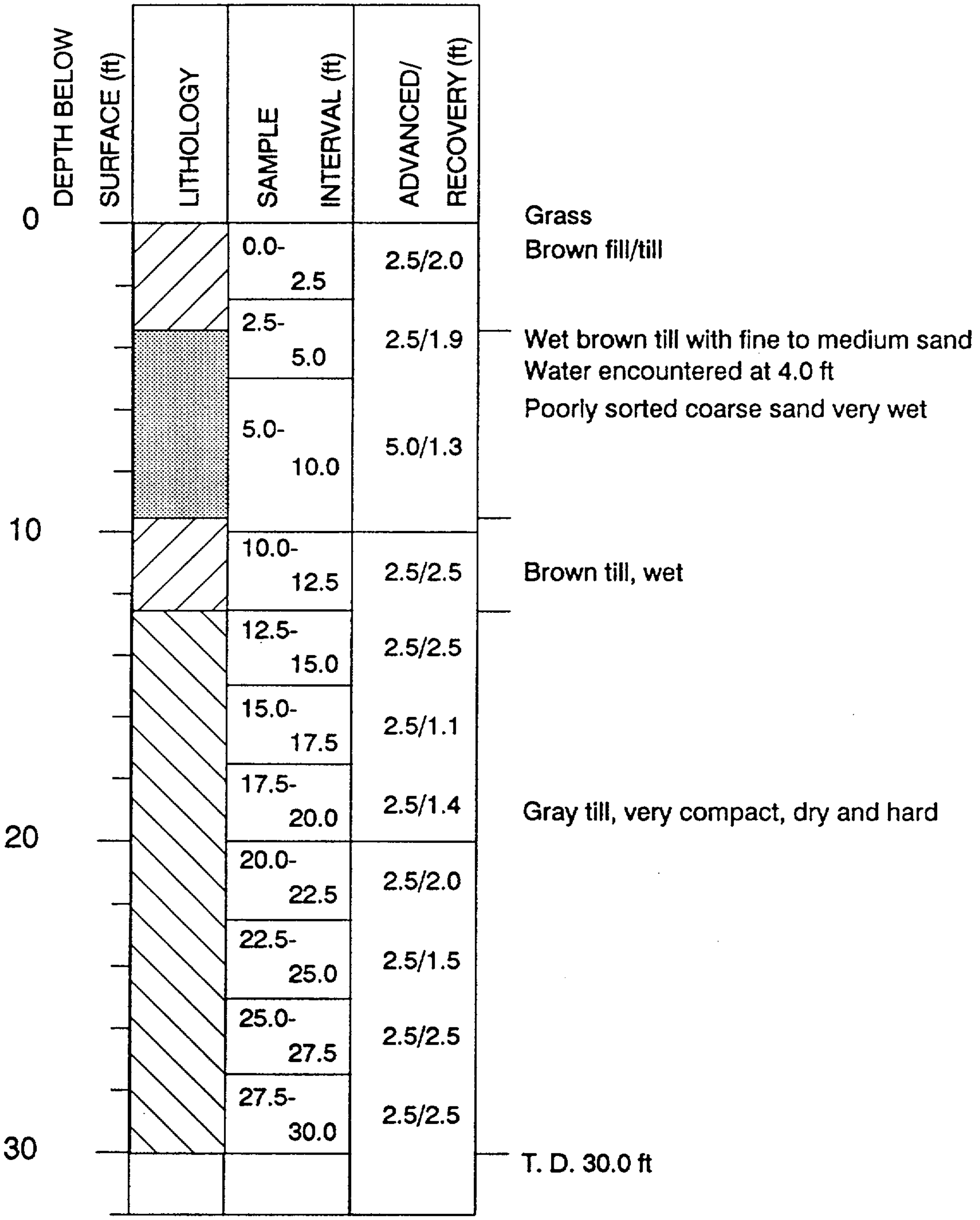
water encountered at 14.5 ft

Brown silt and fine to medium sand, wet

Gray till, very compact

T. D. 30.0 ft

BOREHOLE NUMBER: R322B LOCATION: Sample Area 3 23 JULY 1990



| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| 0.0-2.5 | 2.5/2.0 |
| 2.5-5.0 | 2.5/1.9 |
| 5.0-10.0 | 5.0/1.3 |
| 10.0-12.5 | 2.5/2.5 |
| 12.5-15.0 | 2.5/2.5 |
| 15.0-17.5 | 2.5/1.1 |
| 17.5-20.0 | 2.5/1.4 |
| 20.0-22.5 | 2.5/2.0 |
| 22.5-25.0 | 2.5/1.5 |
| 25.0-27.5 | 2.5/2.5 |
| 27.5-30.0 | 2.5/2.5 |

Grass
Brown fill/till

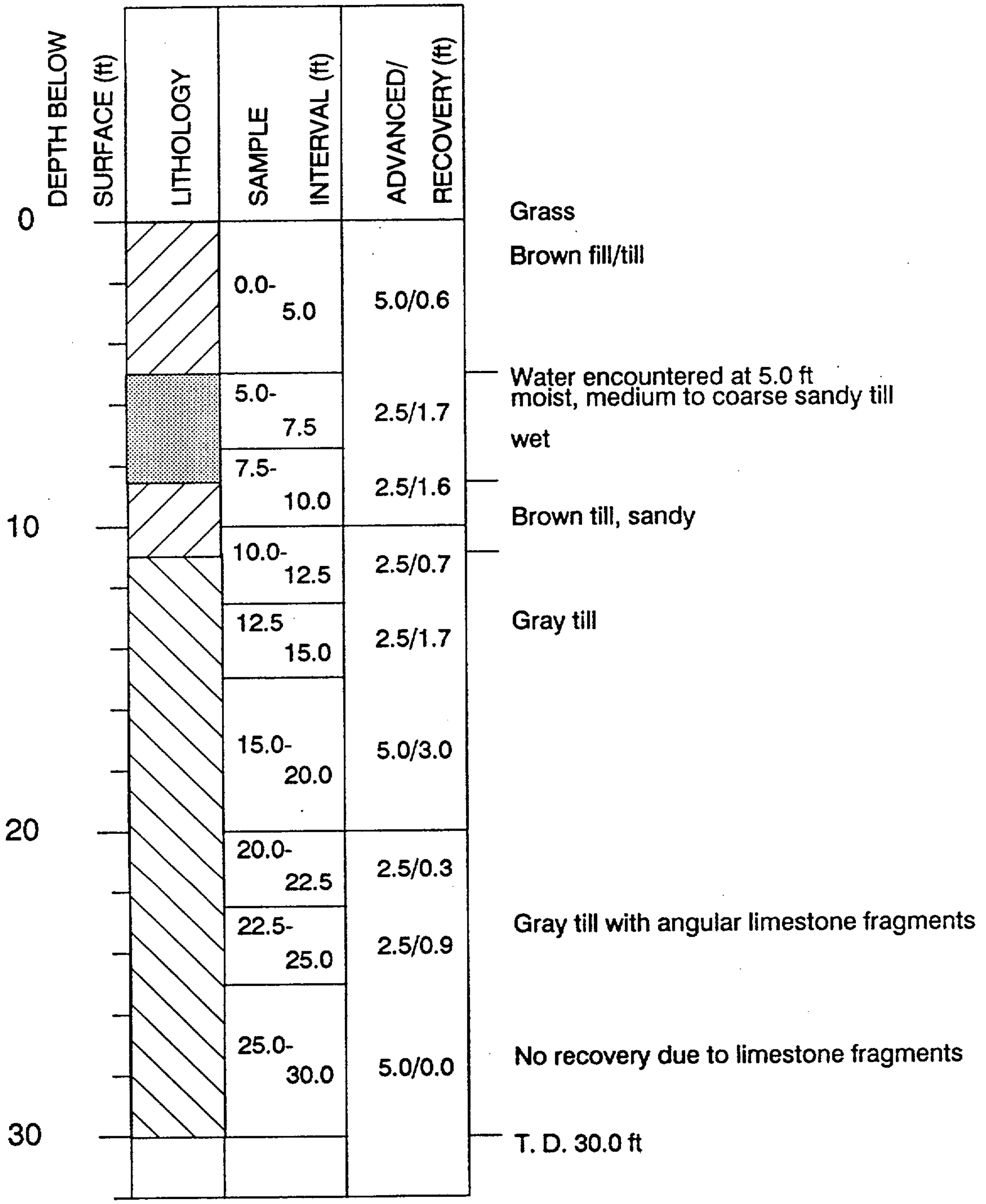
Wet brown till with fine to medium sand
Water encountered at 4.0 ft
Poorly sorted coarse sand very wet

Brown till, wet

Gray till, very compact, dry and hard

T. D. 30.0 ft

BOREHOLE NUMBER: R323B LOCATION: Sample Area 3 24 JULY 1990



| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| 0.0- 5.0 | 5.0/0.6 |
| 5.0- 7.5 | 2.5/1.7 |
| 7.5- 10.0 | 2.5/1.6 |
| 10.0- 12.5 | 2.5/0.7 |
| 12.5 15.0 | 2.5/1.7 |
| 15.0- 20.0 | 5.0/3.0 |
| 20.0- 22.5 | 2.5/0.3 |
| 22.5- 25.0 | 2.5/0.9 |
| 25.0- 30.0 | 5.0/0.0 |

Grass

Brown fill/till

Water encountered at 5.0 ft
moist, medium to coarse sandy till

wet

Brown till, sandy

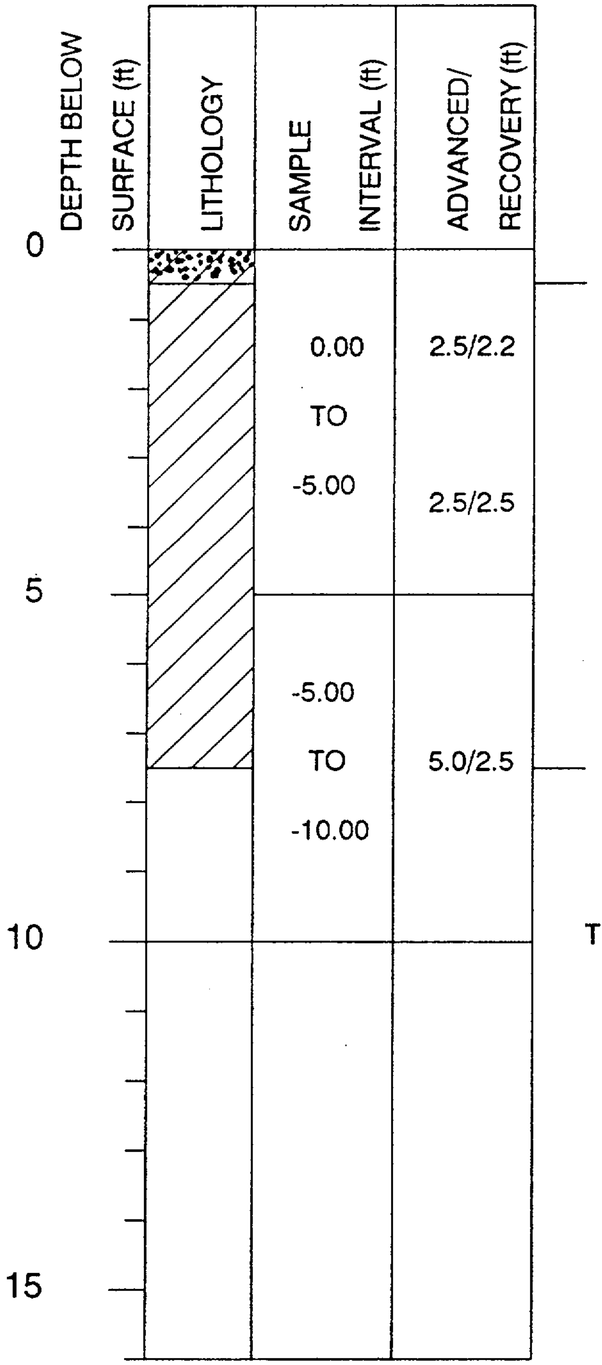
Gray till

Gray till with angular limestone fragments

No recovery due to limestone fragments

T. D. 30.0 ft

BOREHOLE NUMBER: 400 LOCATION: Sample Area 4 2 AUGUST 1989



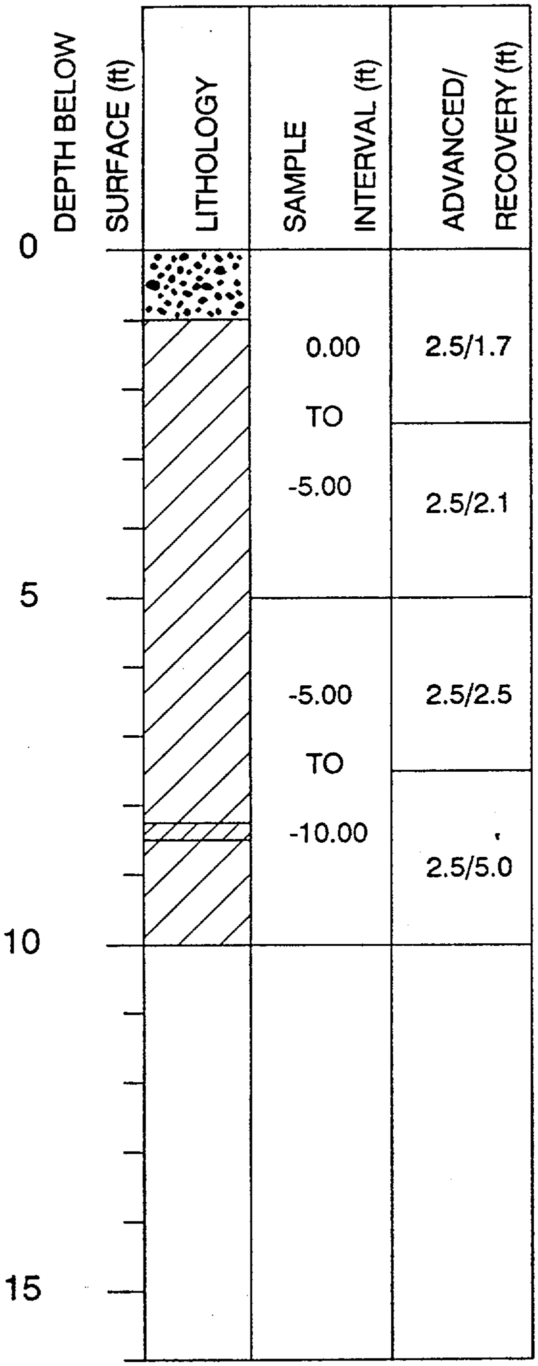
Gravel top 0.4 ft

Brown till/fill

No recovery in the bottom 2.5 ft
Gray till in the bottom of core device

T. D. 10.0 ft

BOREHOLE NUMBER: 401 LOCATION: Sample Area 4 2 AUGUST 1989



Grass
Gravel 1.0 ft

Brown till/fill moist

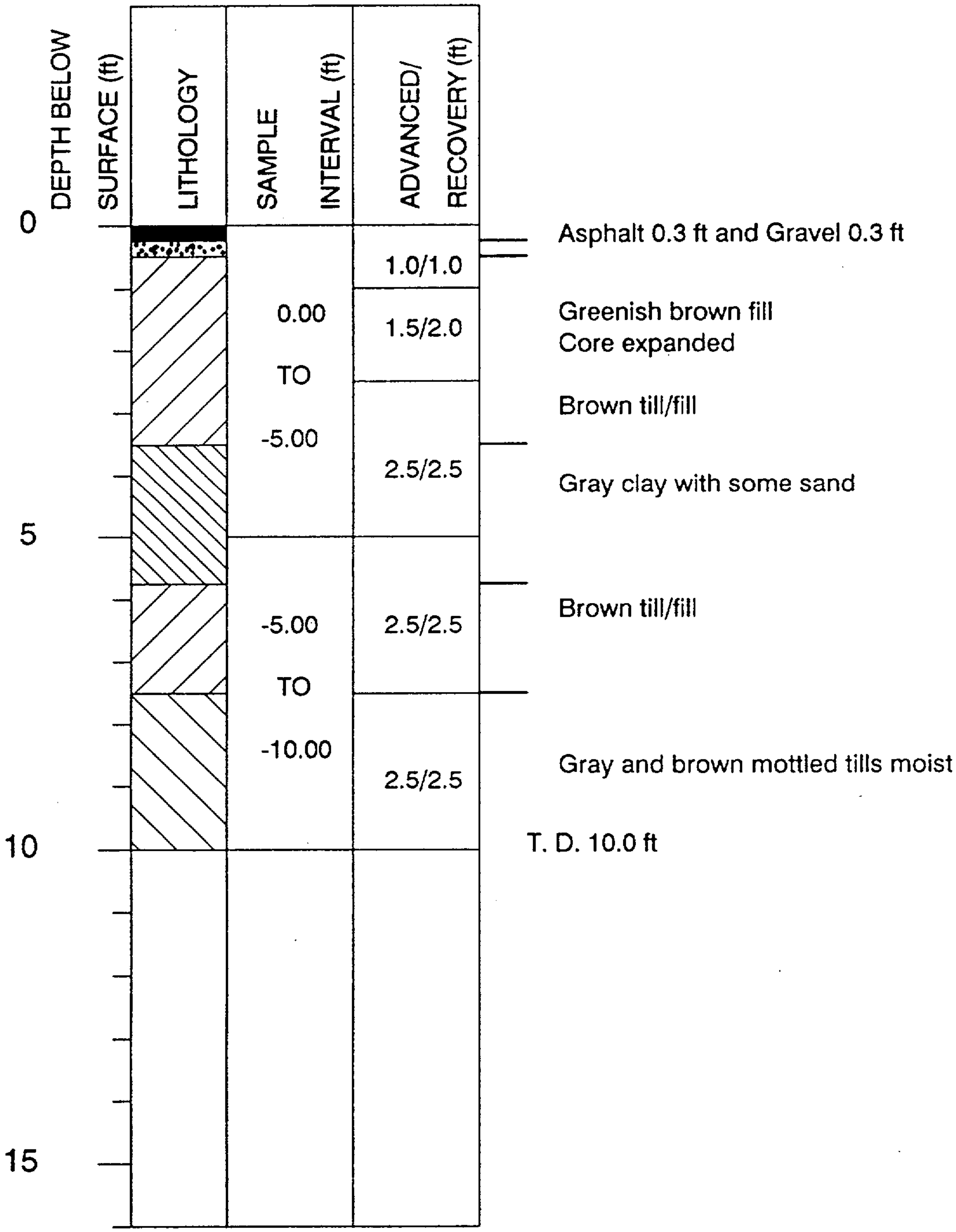
Brown till/fill

Wet clay and silt rich layer 0.3 ft thick

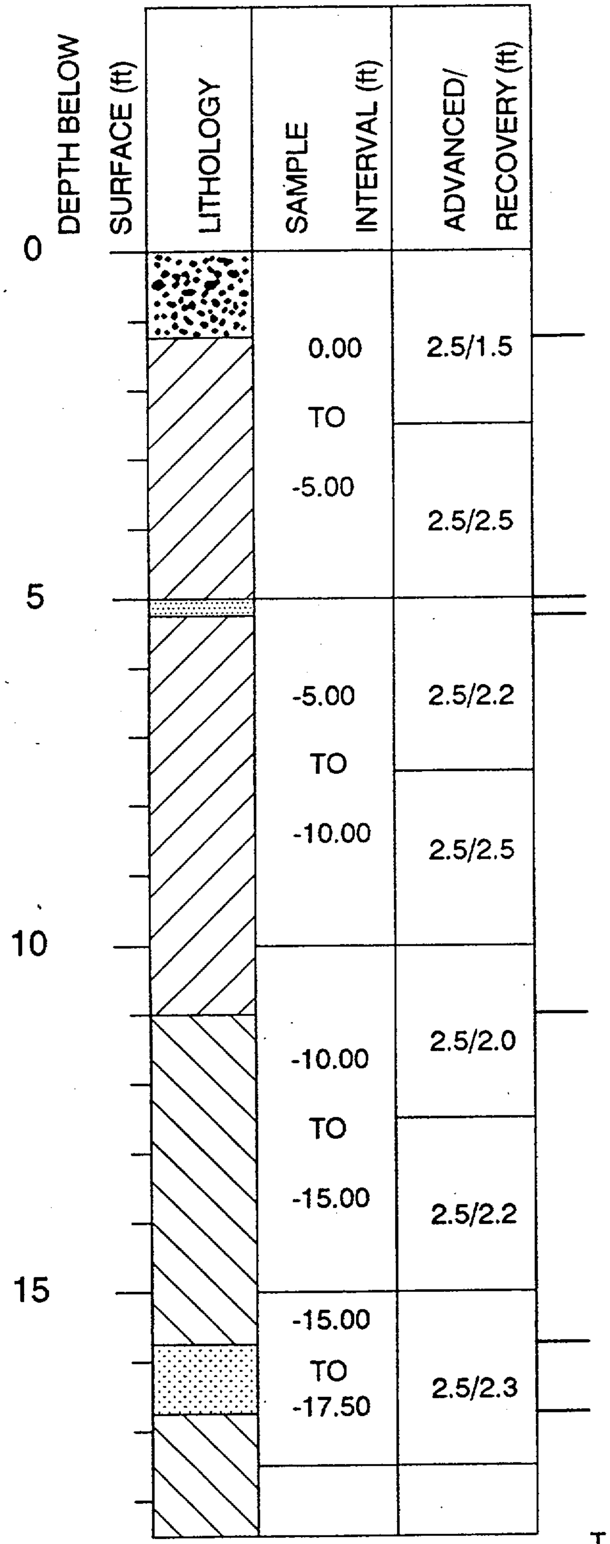
T. D. 10.0 ft

Note: 5.0 ft of core obtained on 2.5 ft
of drilling only. No explanation.
marked as 7.5 - 8.75 and 8.75 - 10.0.

BOREHOLE NUMBER: 402 LOCATION: Sample Area 4 2 AUGUST 1989



BOREHOLE NUMBER: 403 LOCATION: Sample Area 4 2 AUGUST 1989



Grass
Gravel to 1.2 ft

Brown till/fill

Clayey sand wet 0.3 ft thick

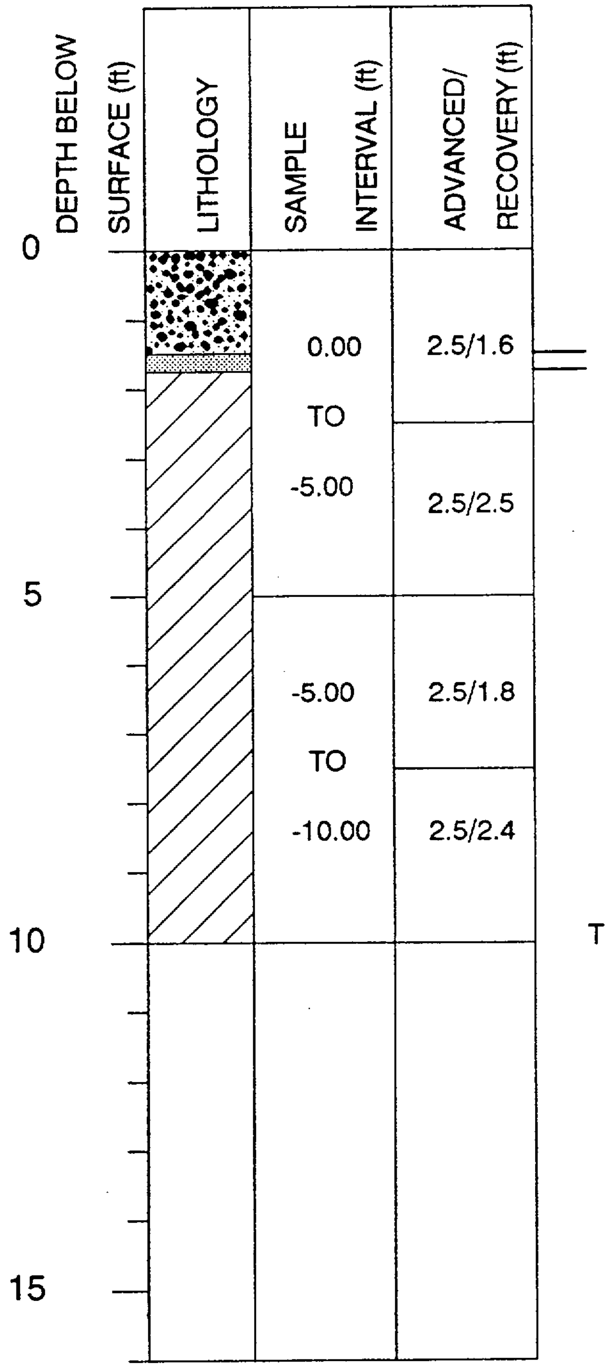
Brown till/fill

Gray till

Sand stringer wet 1 ft thick

T. D. 18.6 ft

BOREHOLE NUMBER: 404 LOCATION: Sample Area 4 2 AUGUST 1989



Gravel and cobbles top 1.5 ft

0.2 ft thick layer of metallic fines not rusted some black

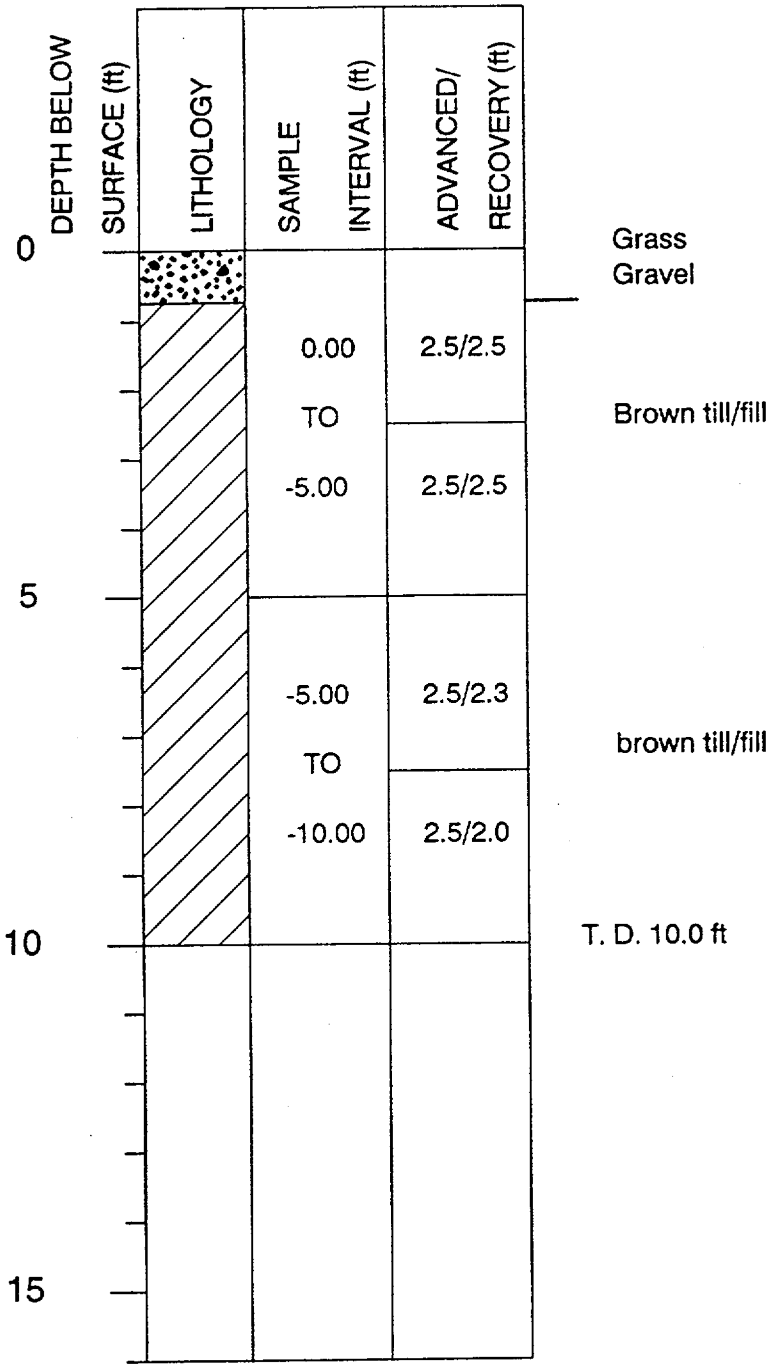
Brown till/fill

brown till/fill

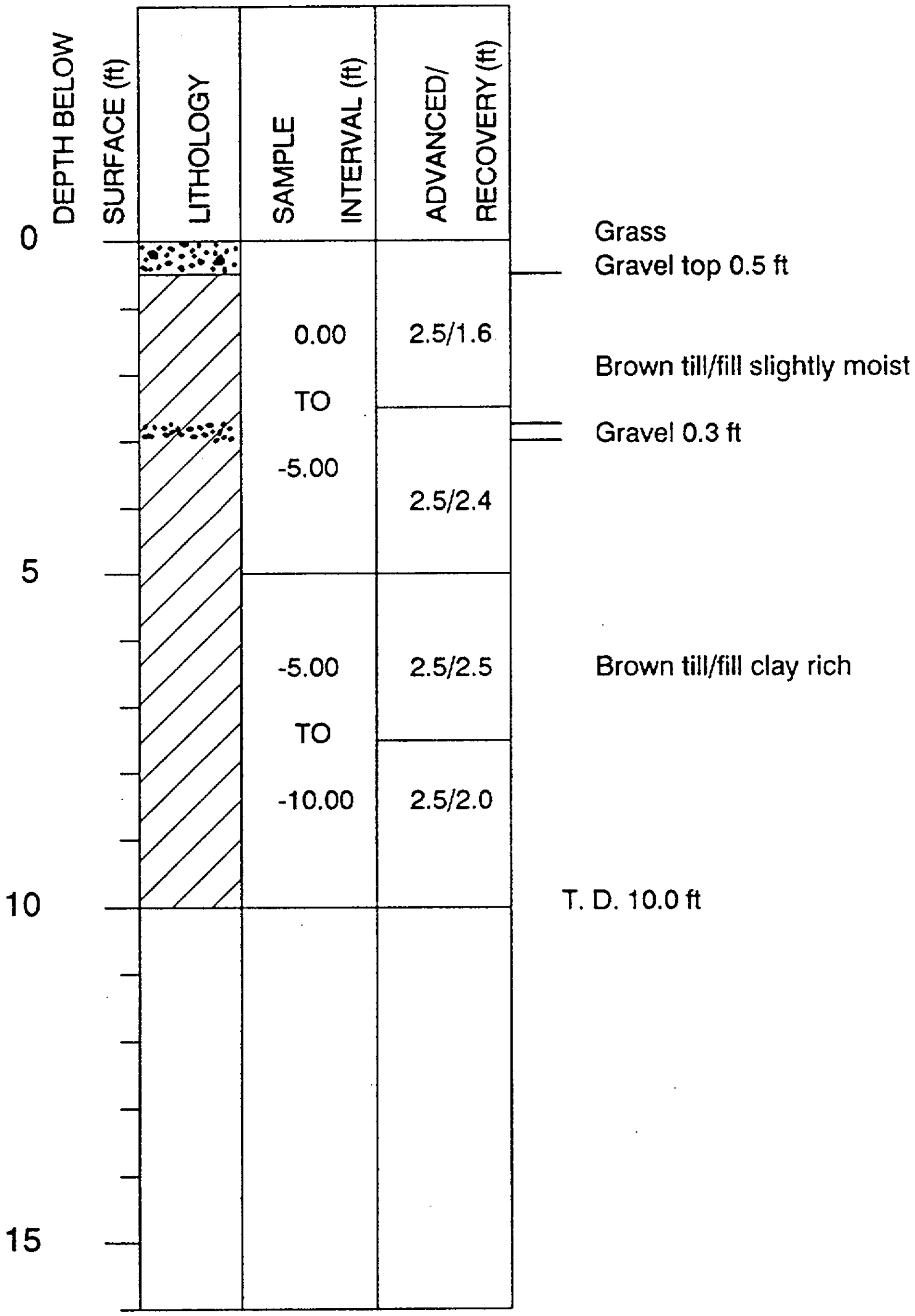
very dense slightly moist

T. D. 10.0 ft

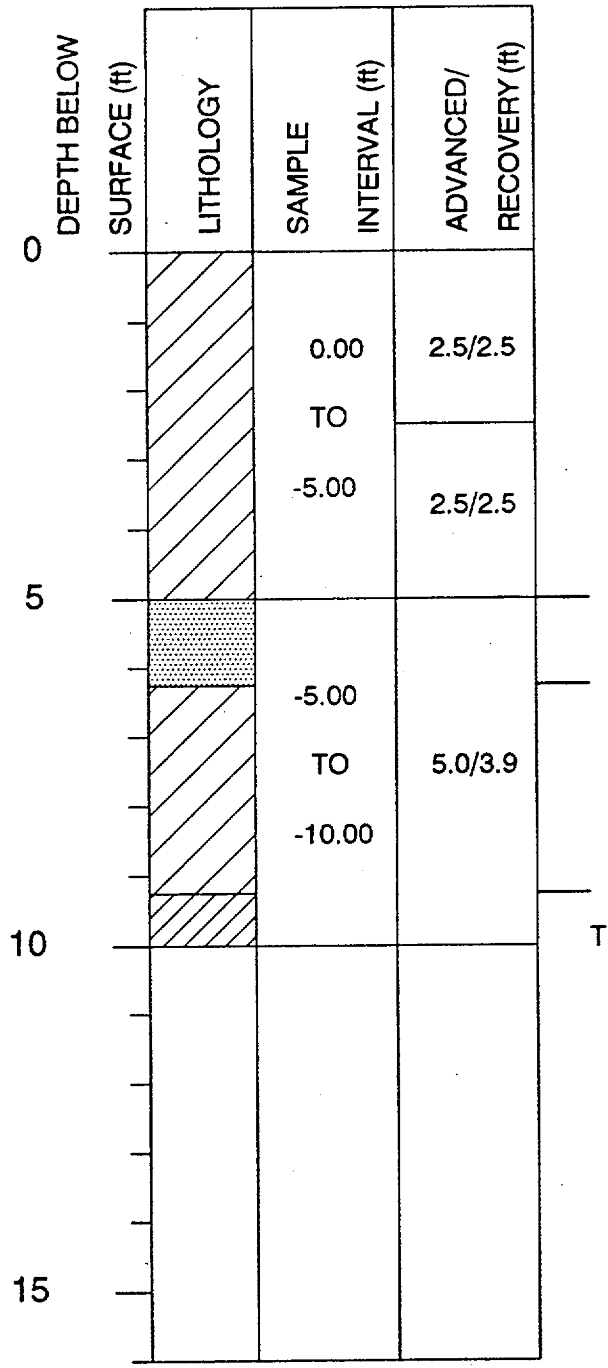
BOREHOLE NUMBER: 405 LOCATION: Sample Area 4 1 AUGUST 1989



BOREHOLE NUMBER: 406 LOCATION: Sample Area 4 1 AUGUST 1989



BOREHOLE NUMBER: 407 LOCATION: Sample Area 4 1 AUGUST 1989



Grass
Brown fill with large gravel and pebbles

moist

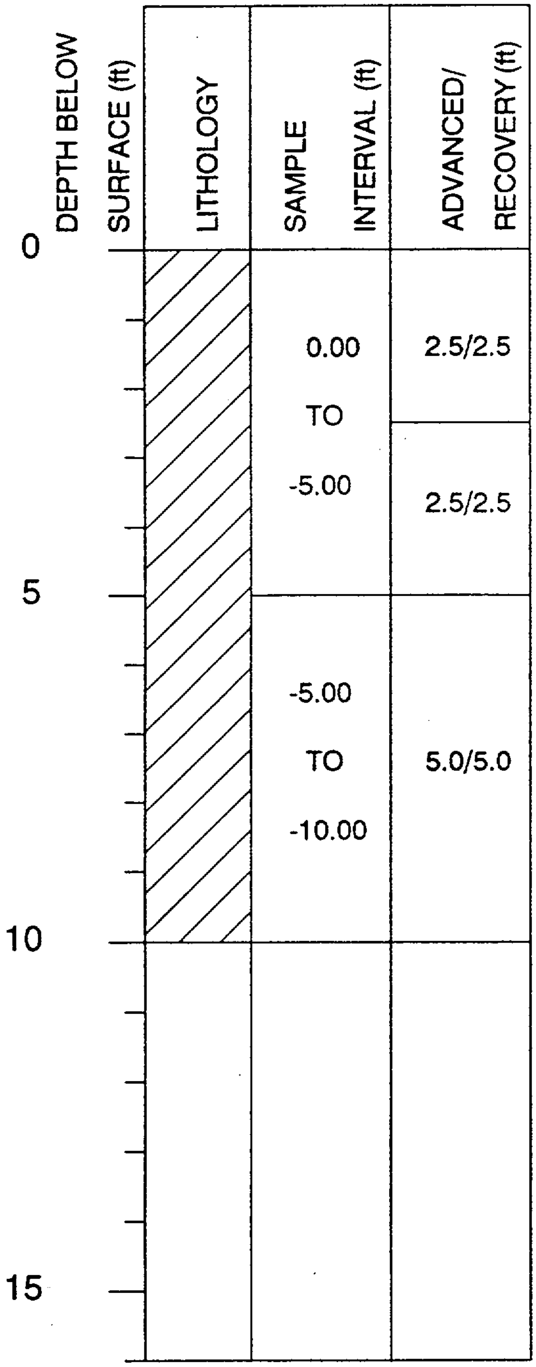
Gray clayey sand very moist

Brown clay rich till/fill very moist

Wet brown clay
T. D. 10.0 ft

Note: Copper wire stuck in end of core device from about 5 ft depth and sliced all the core from 5 to 10 ft

BOREHOLE NUMBER: 408 LOCATION: Sample Area 4 1 AUGUST 1989



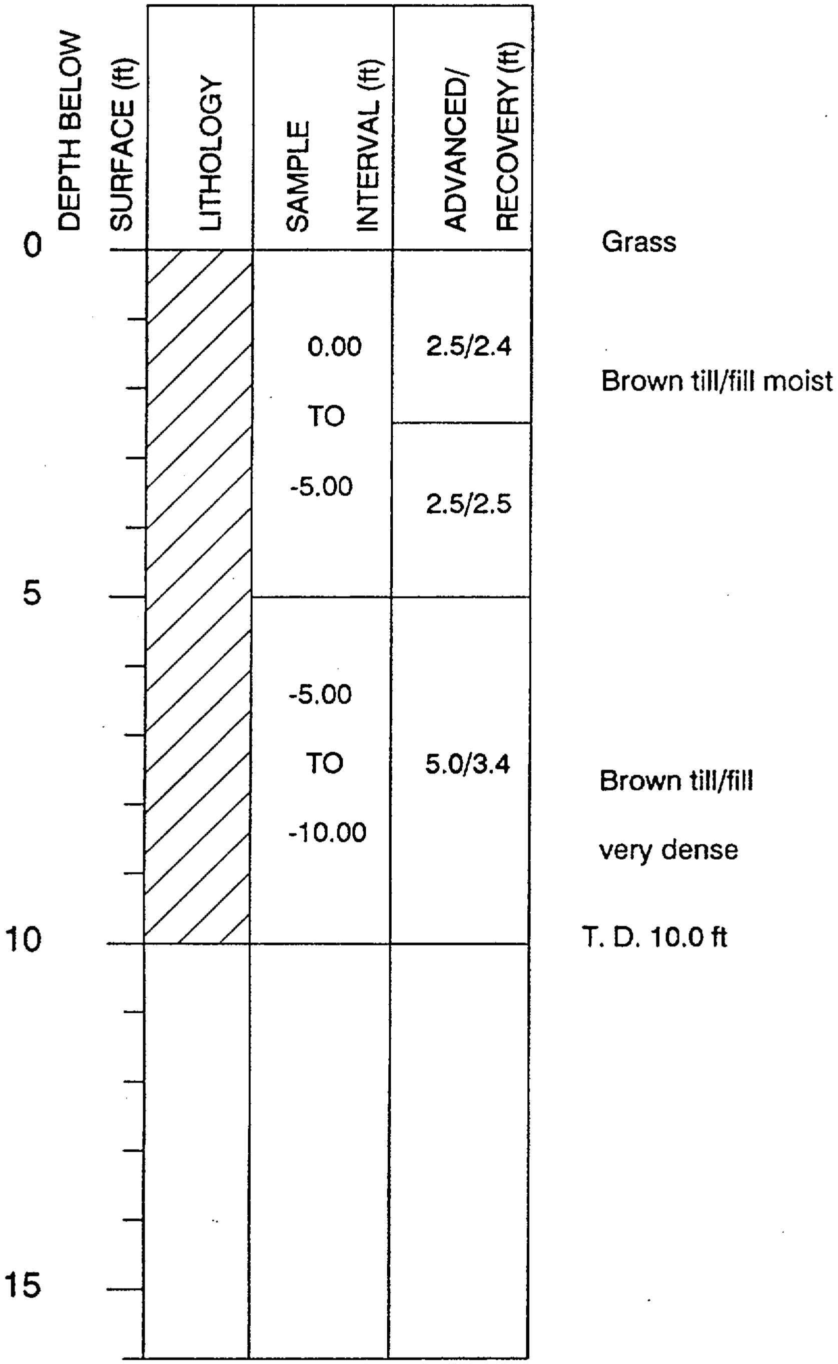
Grass

Brown till/fill very gravelly
slightly moist

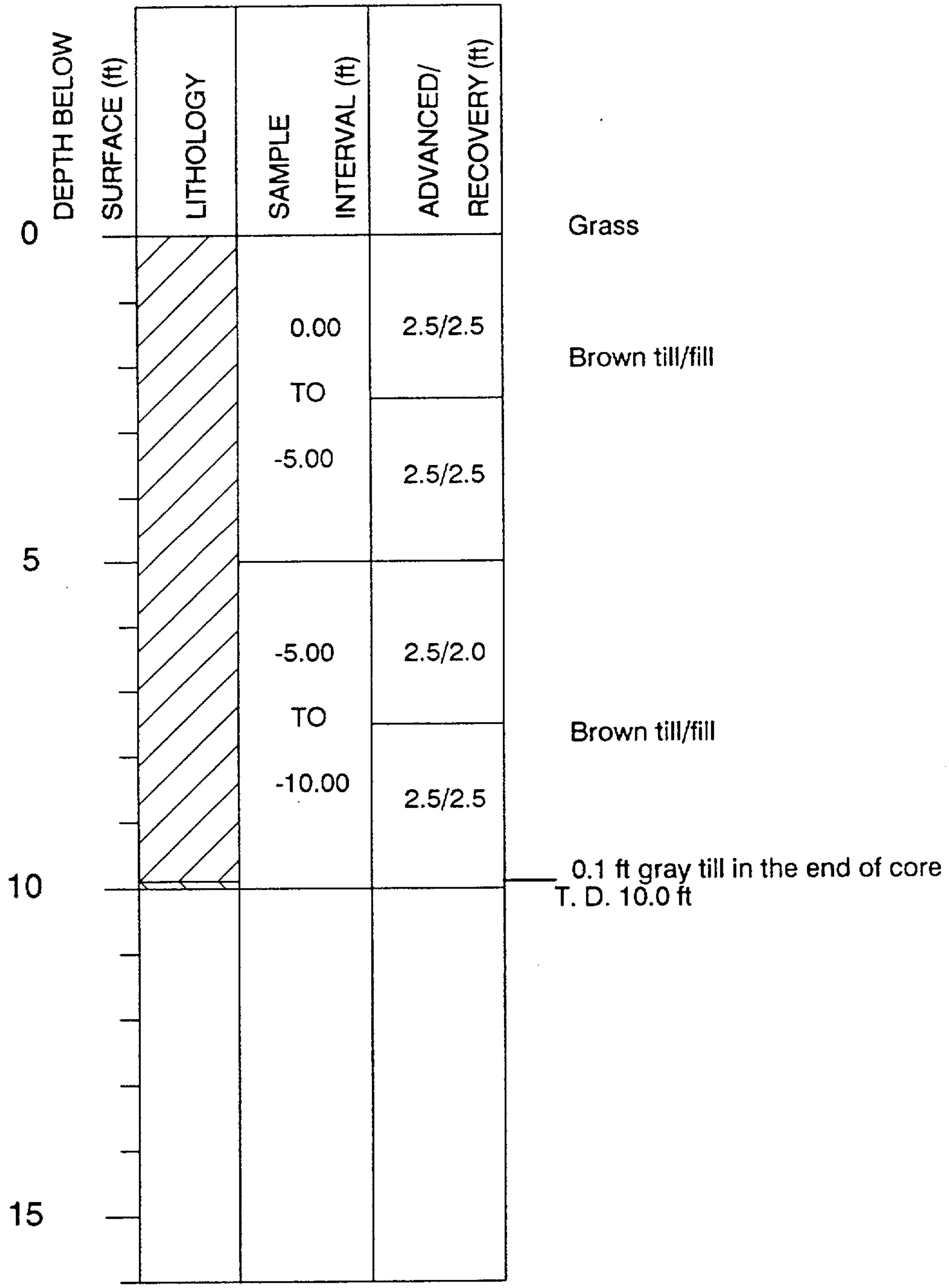
Brown till/fill slightly more moist

T. D. 10.0 ft

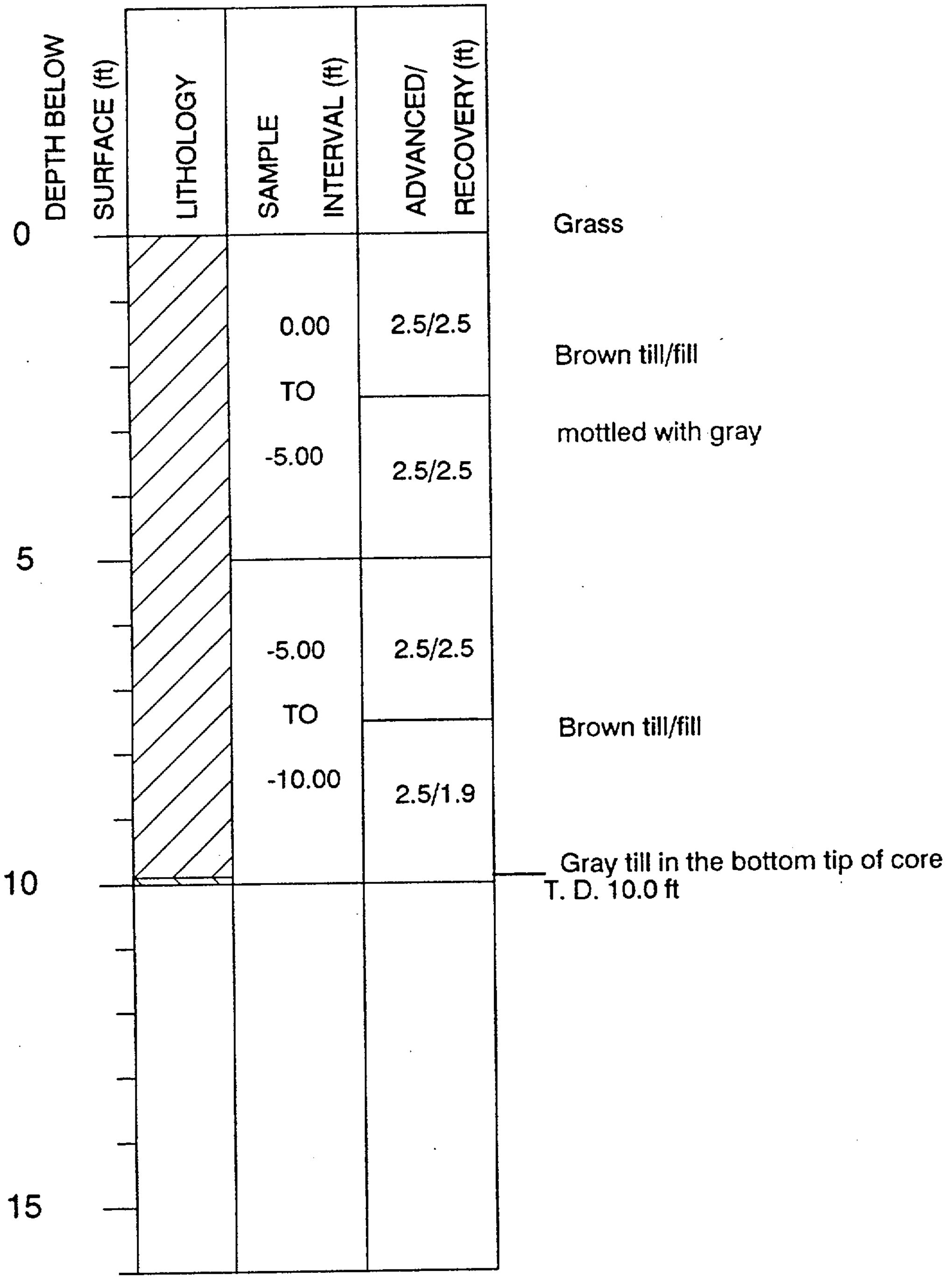
BOREHOLE NUMBER: 409 LOCATION: Sample Area 4 1 AUGUST 1989



BOREHOLE NUMBER: 410 LOCATION: Sample Area 4 1 AUGUST 1989

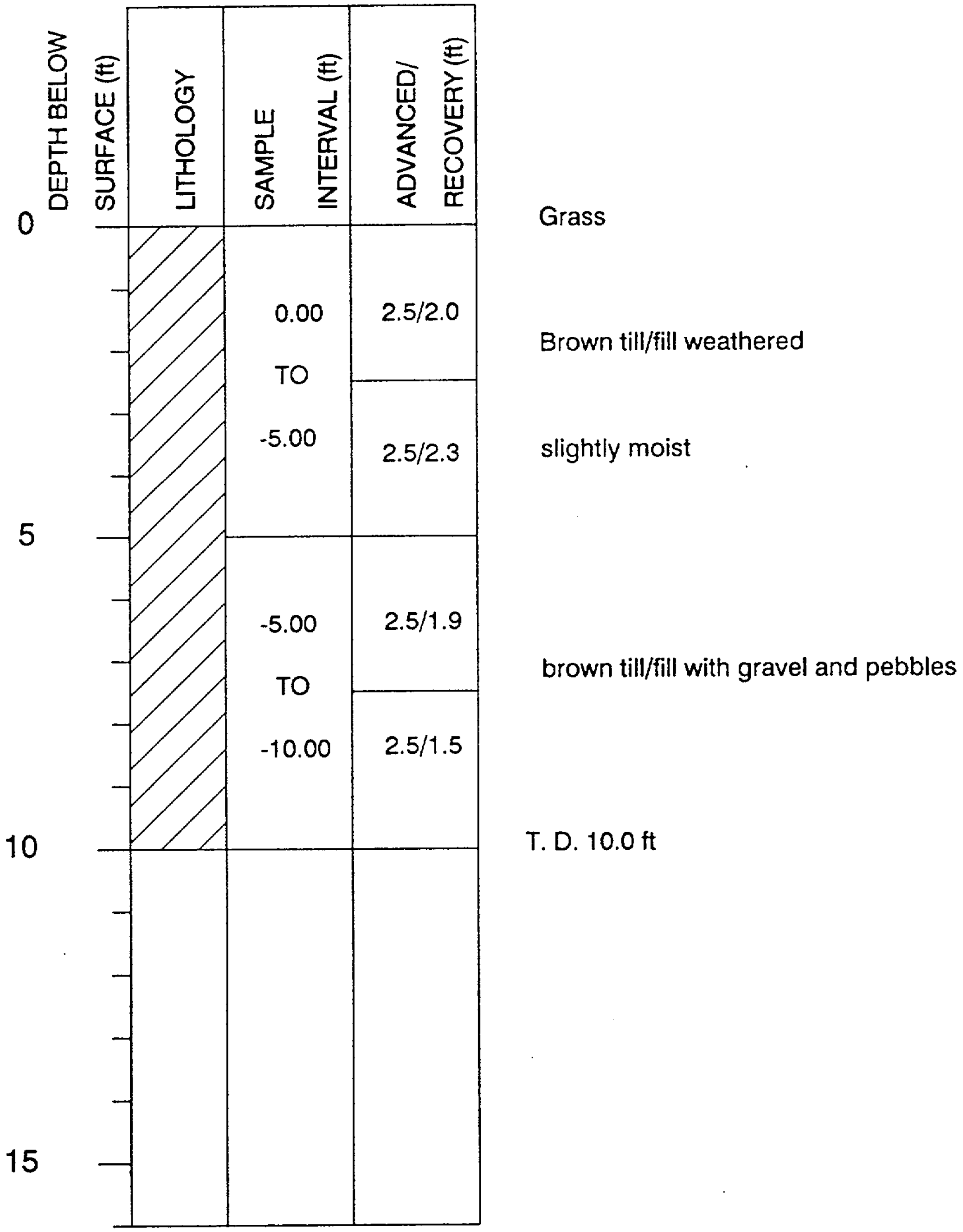


BOREHOLE NUMBER: 411 LOCATION: Sample Area 4 1 AUGUST 1989

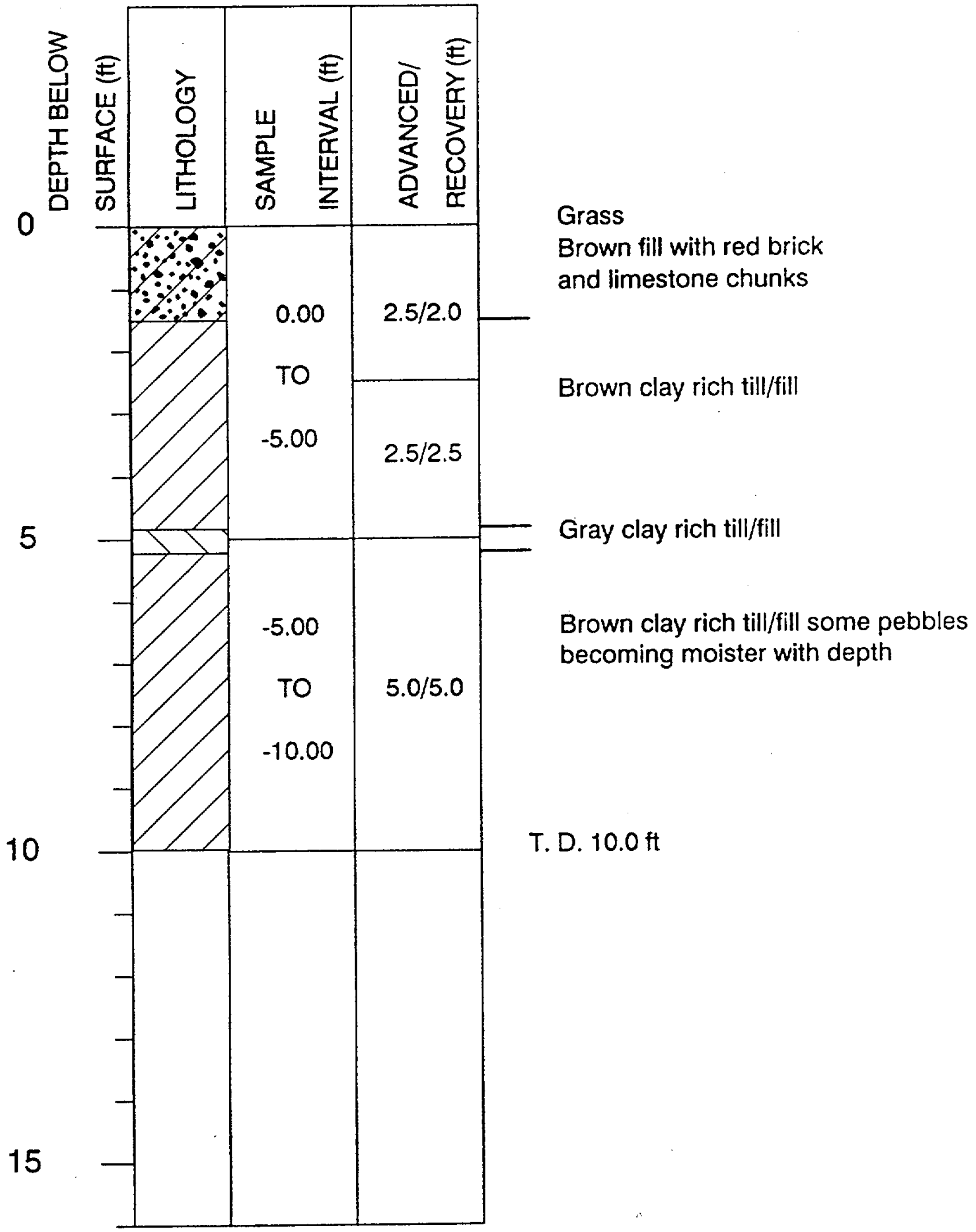


| DEPTH BELOW SURFACE (ft) | LITHOLOGY | SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) | |
|---|---|---|---|---|
| 0 | | | | Grass |
| | ▨ | 0.00 TO -5.00 | 2.5/2.5 | Brown till/fill mottled with gray |
| | ▨ | | 2.5/2.5 | |
| 5 | ▨ | -5.00 TO -10.00 | 2.5/2.5 | |
| | ▨ | | 2.5/1.9 | Brown till/fill |
| 10 | | | | Gray till in the bottom tip of core<br>T. D. 10.0 ft |
| 15 | | | | |

BOREHOLE NUMBER: 412 LOCATION: Sample Area 4 28 JULY 1989



BOREHOLE NUMBER: 413 LOCATION: Sample Area 4 28 JULY 1989



Grass

Brown fill with red brick and limestone chunks

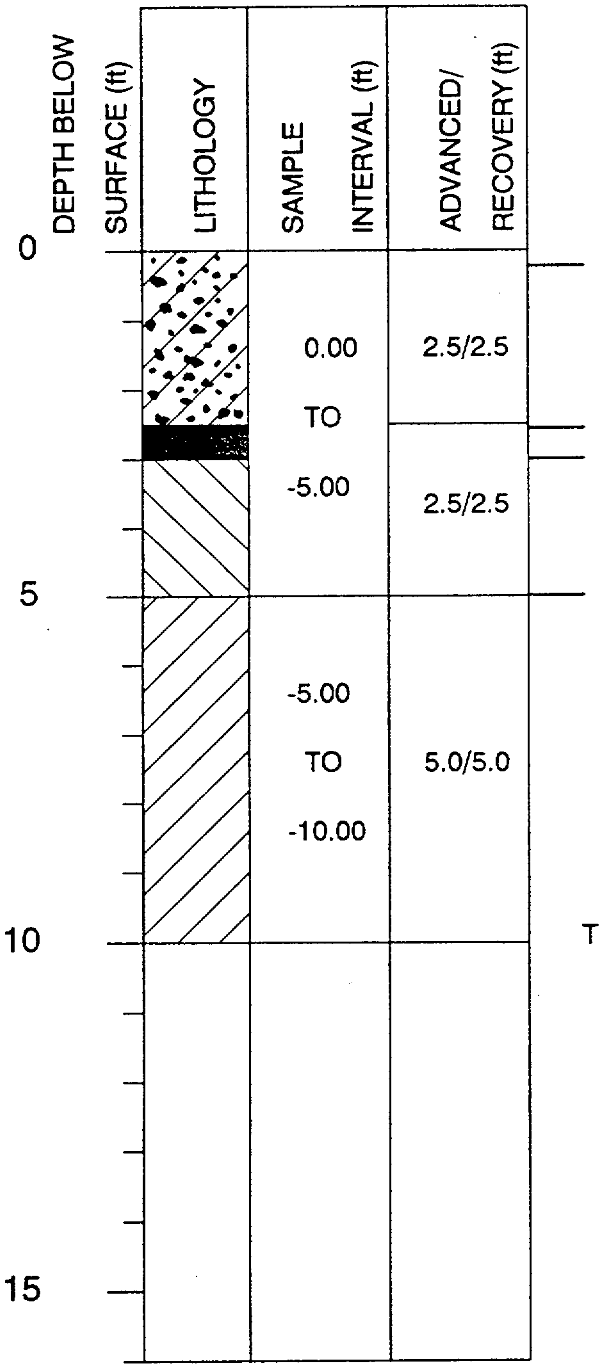
Brown clay rich till/fill

Gray clay rich till/fill

Brown clay rich till/fill some pebbles becoming moister with depth

T. D. 10.0 ft

BOREHOLE NUMBER: 414 LOCATION: Sample Area 4 28 JULY 1989



Grass
Top soil 0.2 ft

Brown fill with large limestone chunks
slightly moist

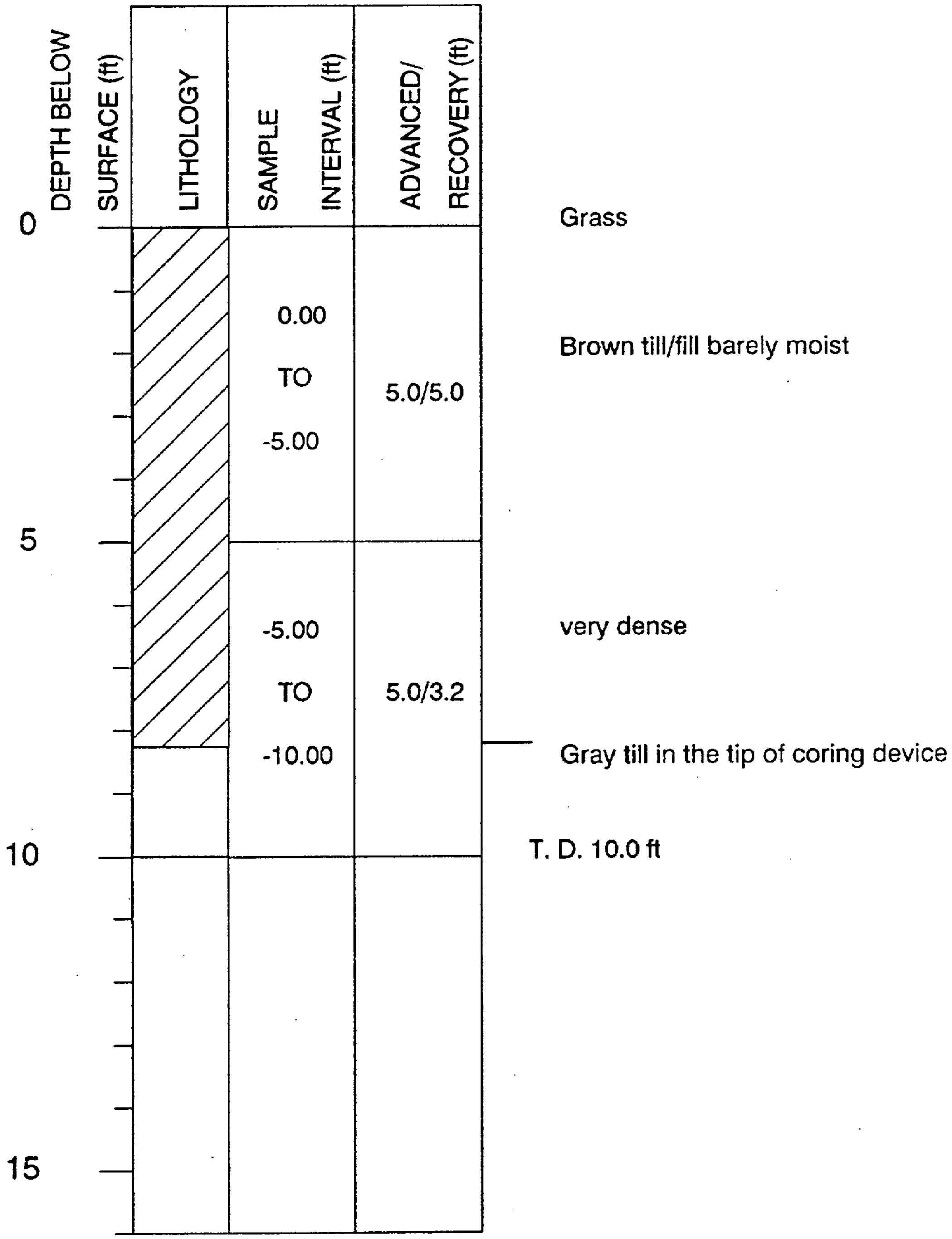
Weathered asphalt 0.4 ft
Gray clay rich till with weathering cracks
showing discoloration root holes etc.

Brown clay rich till

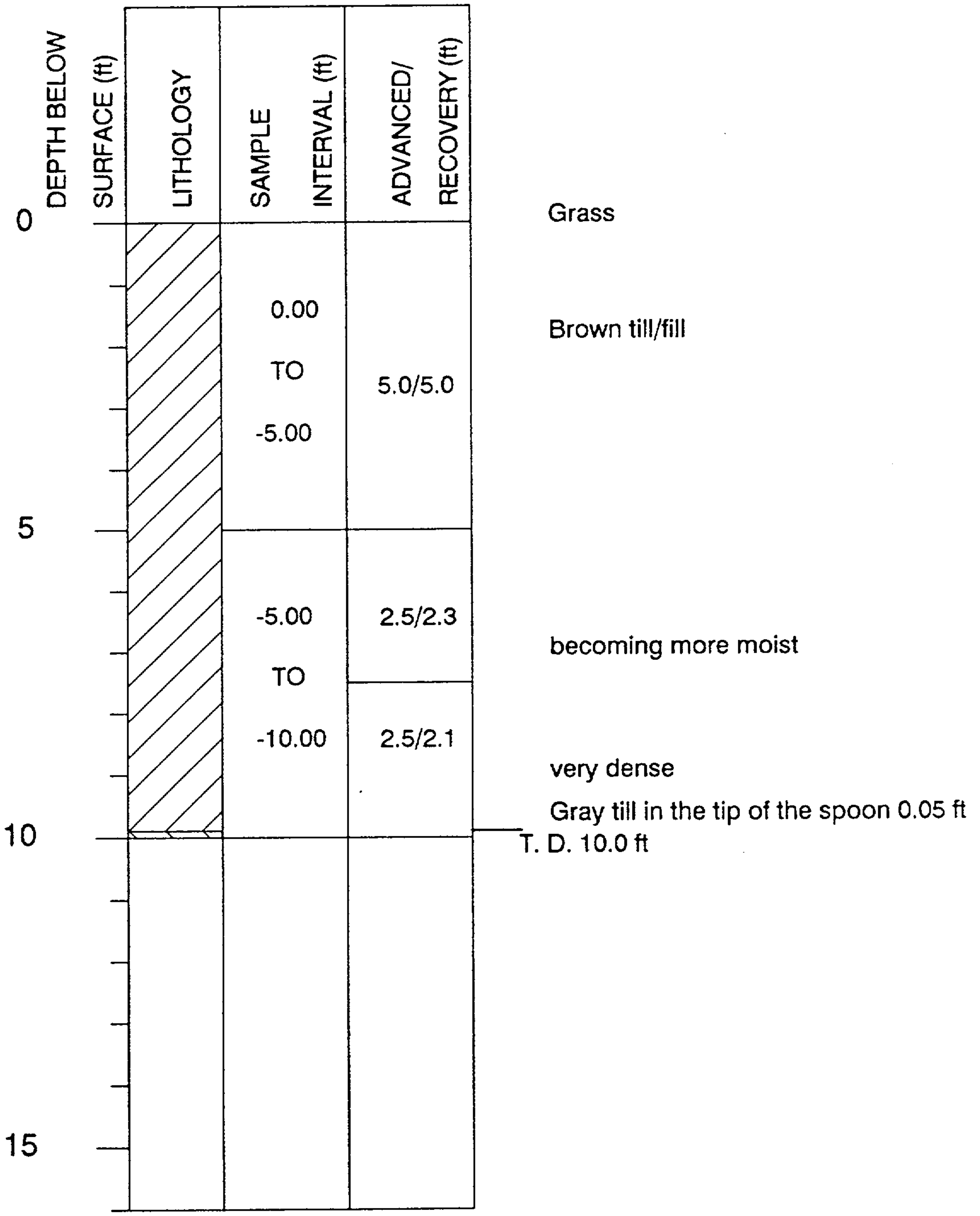
T. D. 10.0 ft

Note: Metal granules above the weathered asphalt layer possibly slag or crumbled steel not rusted

BOREHOLE NUMBER: 415 LOCATION: Sample Area 4 1 AUGUST 1989

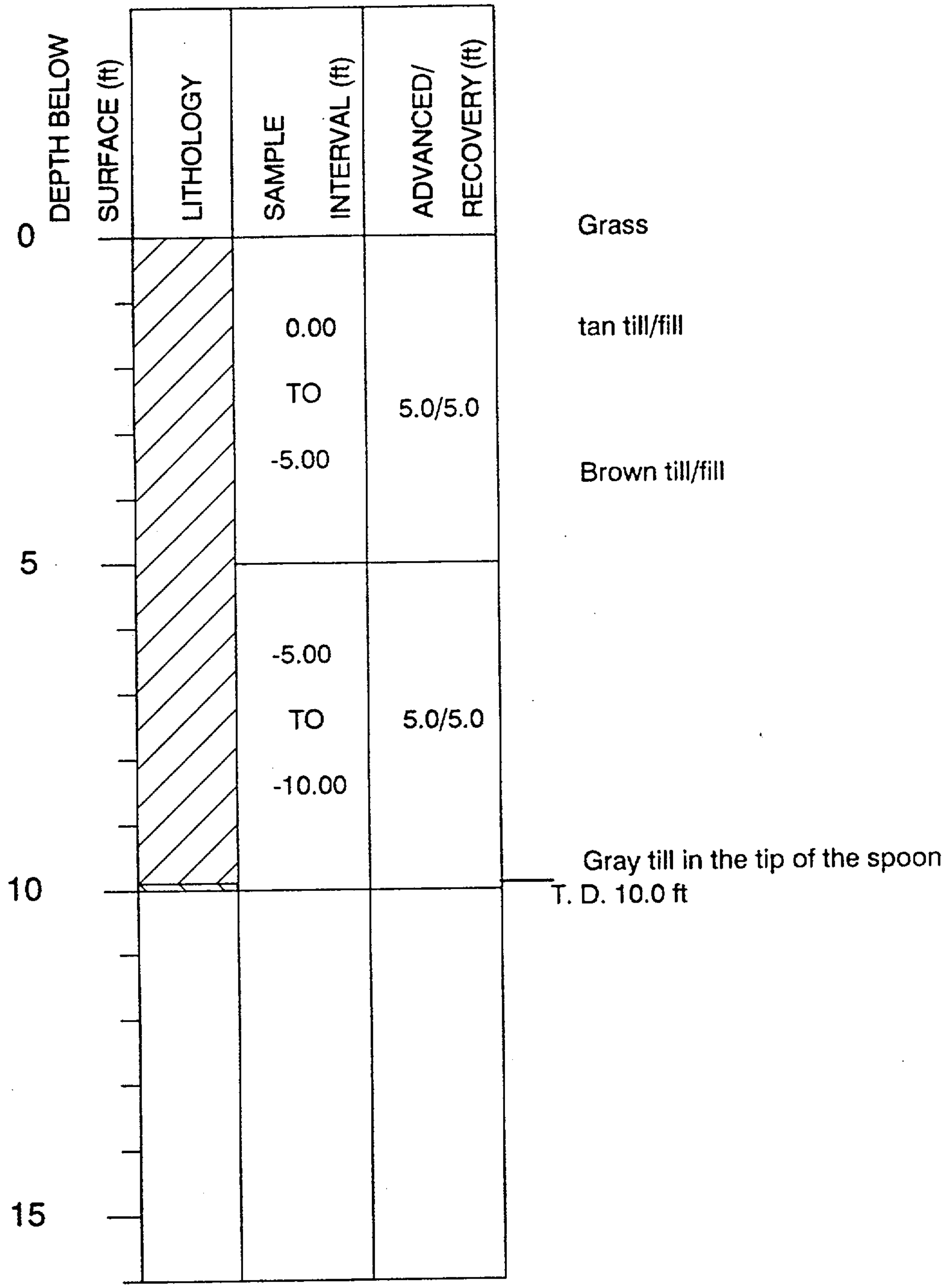


BOREHOLE NUMBER: 416 LOCATION: Sample Area 4 1 AUGUST 1989

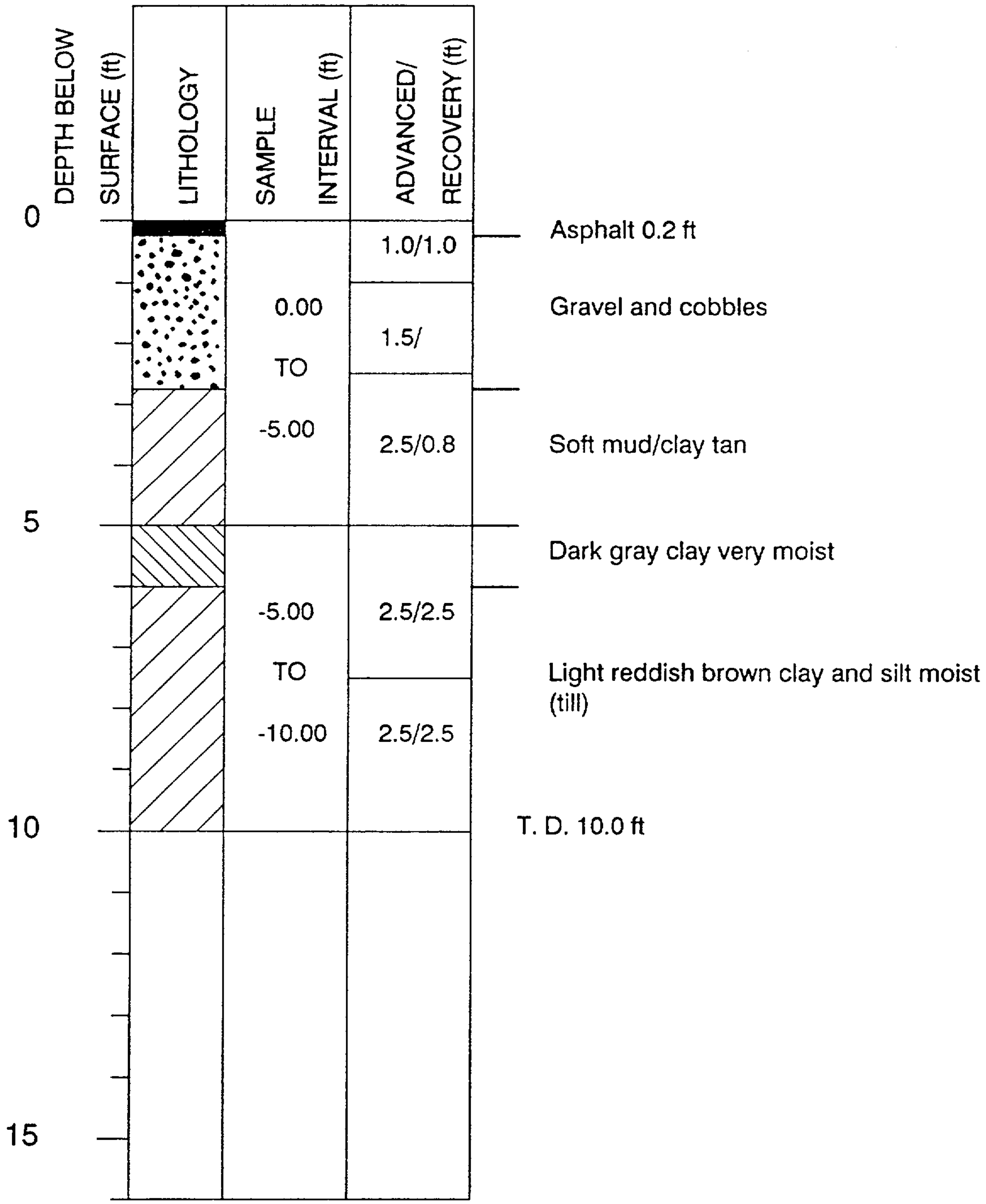


| DEPTH BELOW SURFACE (ft) | LITHOLOGY | SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) | |
|---|---|---|---|---|
| 0 | | | | Grass |
| | | 0.00 TO -5.00 | 5.0/5.0 | Brown till/fill |
| 5 | | -5.00 TO -10.00 | 2.5/2.3 | becoming more moist |
| | | | 2.5/2.1 | very dense<br>Gray till in the tip of the spoon 0.05 ft |
| 10 | | | | T. D. 10.0 ft |
| 15 | | | | |

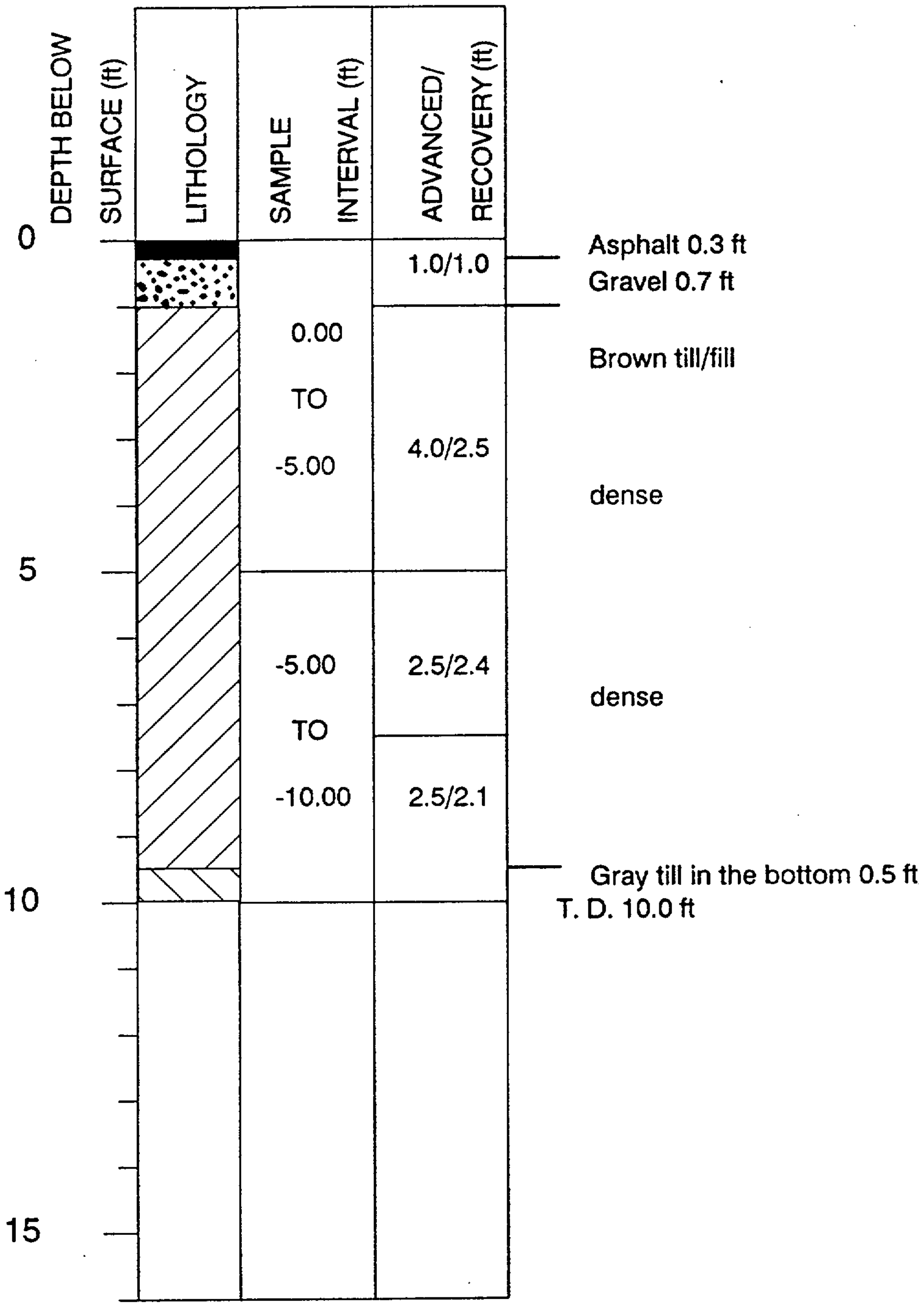
BOREHOLE NUMBER: 417 LOCATION: Sample Area 4 2 AUGUST 1989



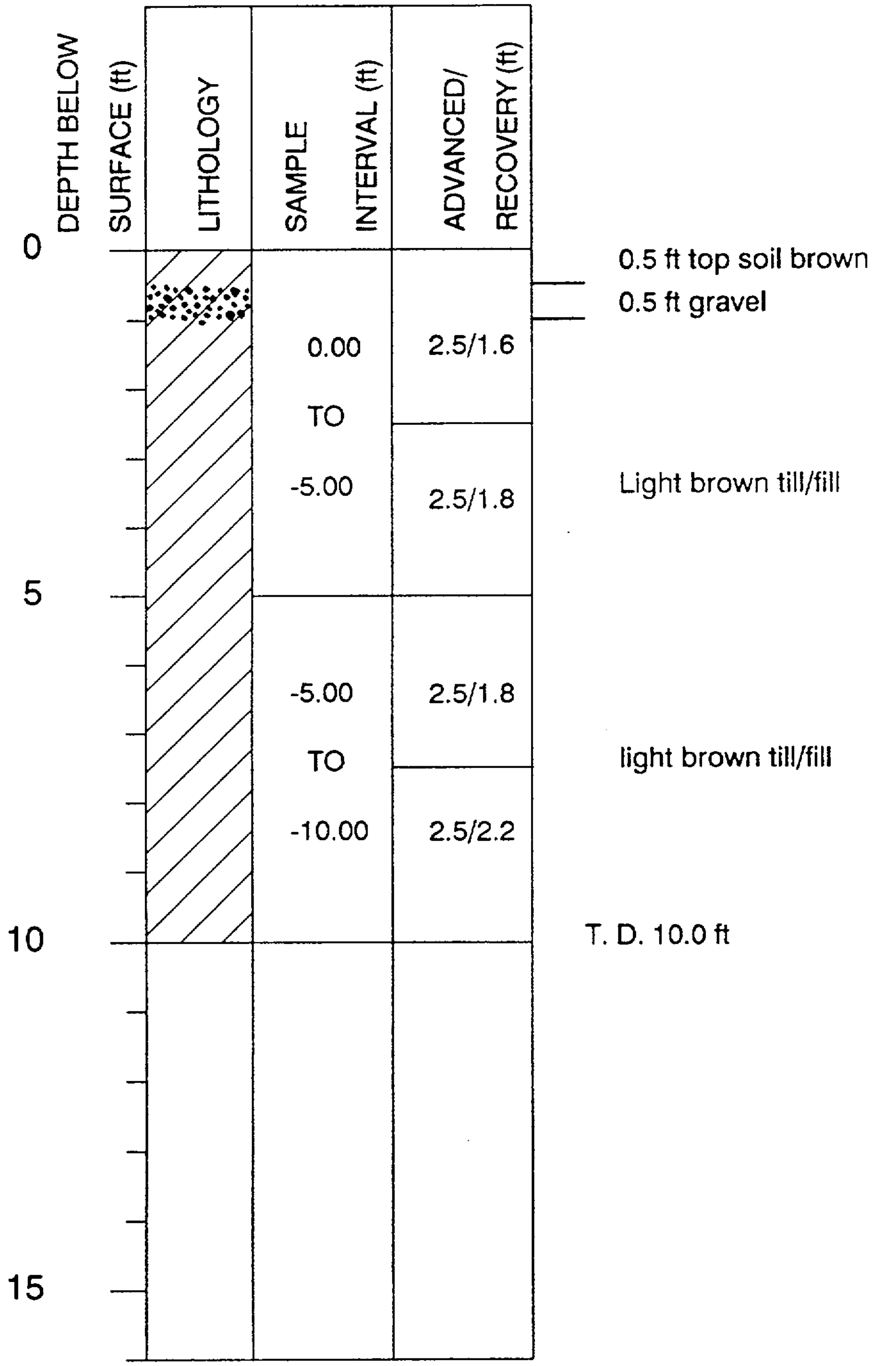
BOREHOLE NUMBER: 418 LOCATION: Sample Area 4 2 AUGUST 1989



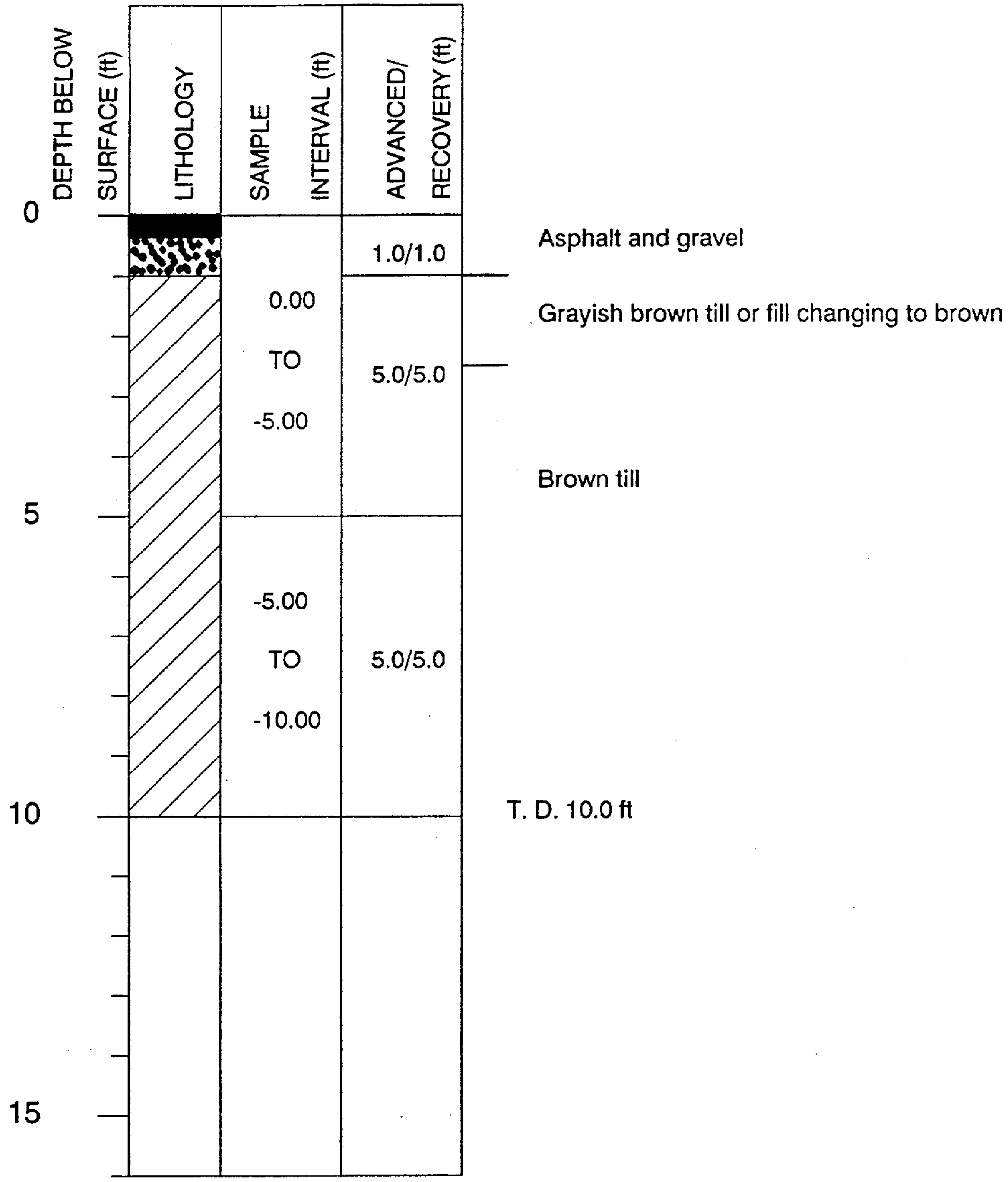
BOREHOLE NUMBER: 419 LOCATION: Sample Area 4 2 AUGUST 1989



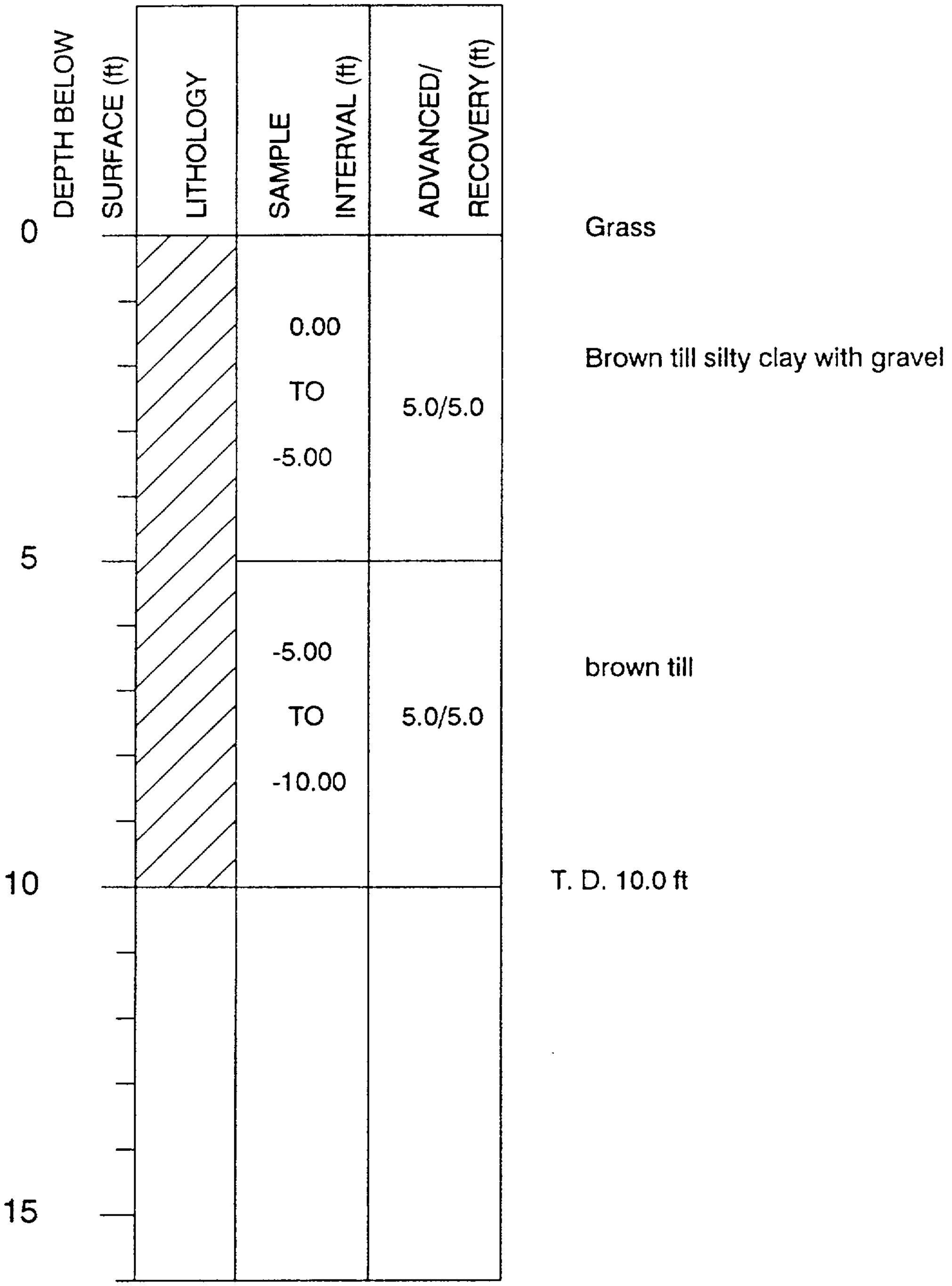
BOREHOLE NUMBER: 420  LOCATION: Sample Area 4  2 AUGUST 1989



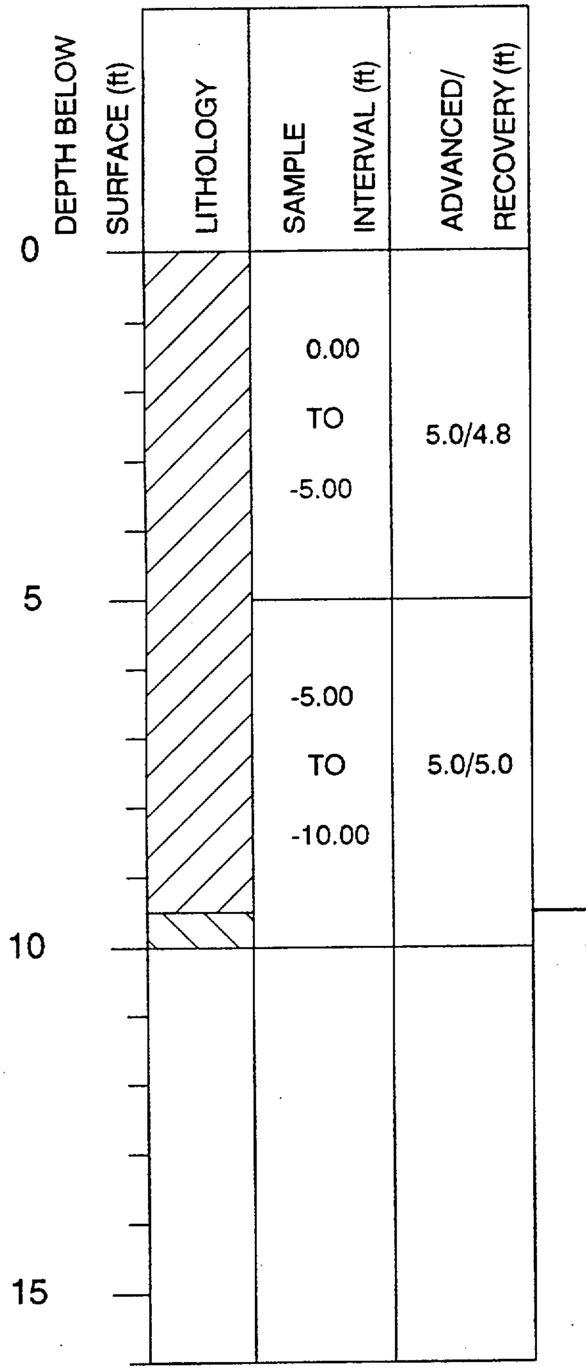
BOREHOLE NUMBER: 500 LOCATION: Sample Area 5 24 JULY 1989



BOREHOLE NUMBER: 501 LOCATION: Sample Area 5 25 JULY 1989



BOREHOLE NUMBER: 502 LOCATION: Sample Area 5 24 JULY 1989



Grass

Brown till silty clay with gravel moist

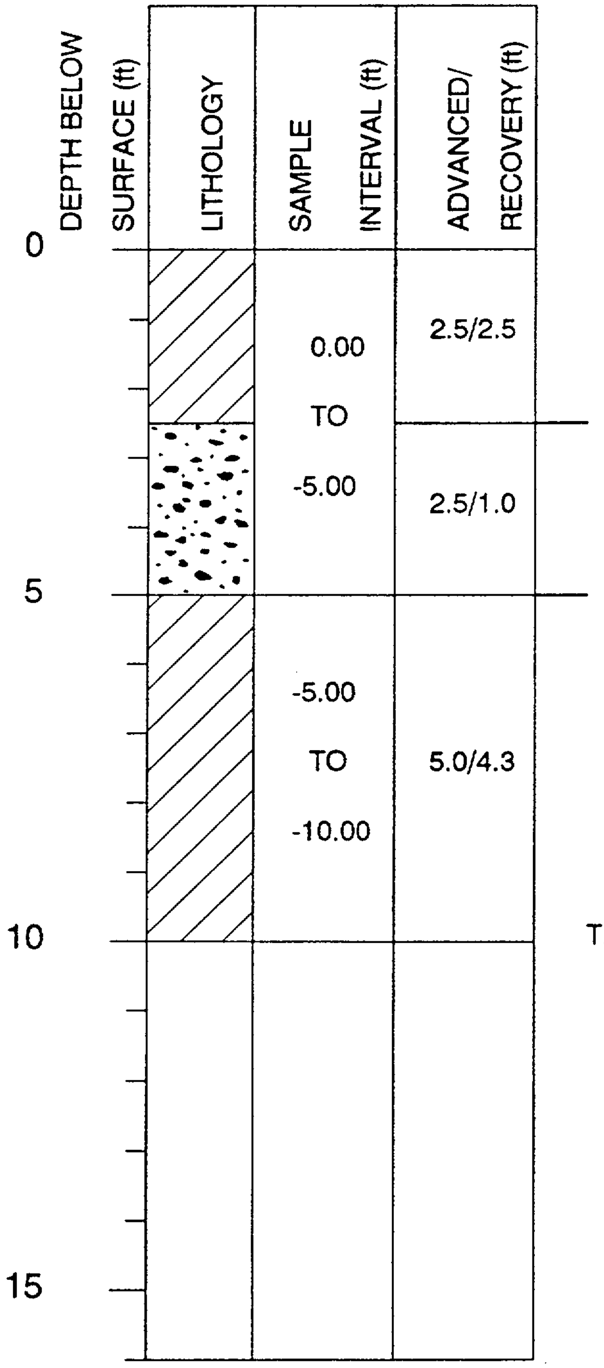
bottom 1.0 ft brown sandy silt with gravel wet

brown till moist

Bottom 0.6 ft Gray till stiff

T. D. 10.0 ft

BOREHOLE NUMBER: 503 LOCATION: Sample Area 5 24 JULY 1989



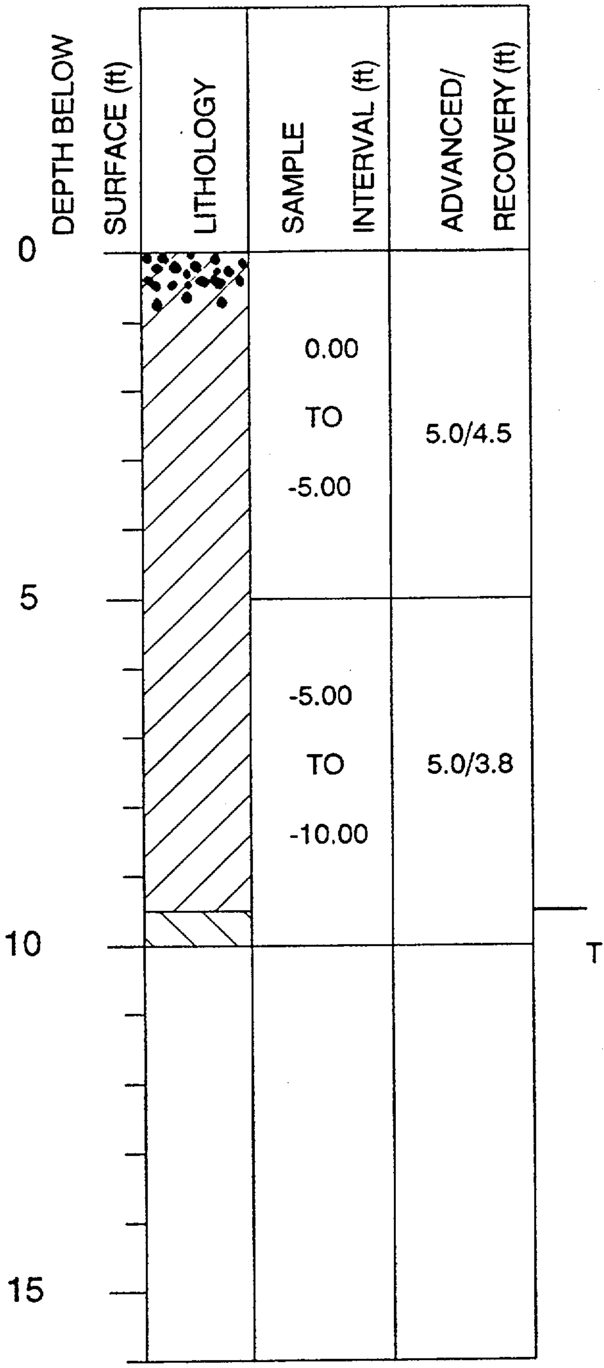
Grass
Brown fill

Gravel probably from abandoned drain tiles
poor recovery

Brown till

bottom 1.0 ft wet
T. D. 10.0 ft

BOREHOLE NUMBER: 504  LOCATION: Sample Area 5  24 JULY 1989



Grass
some gravel in top 1 ft

Brown till

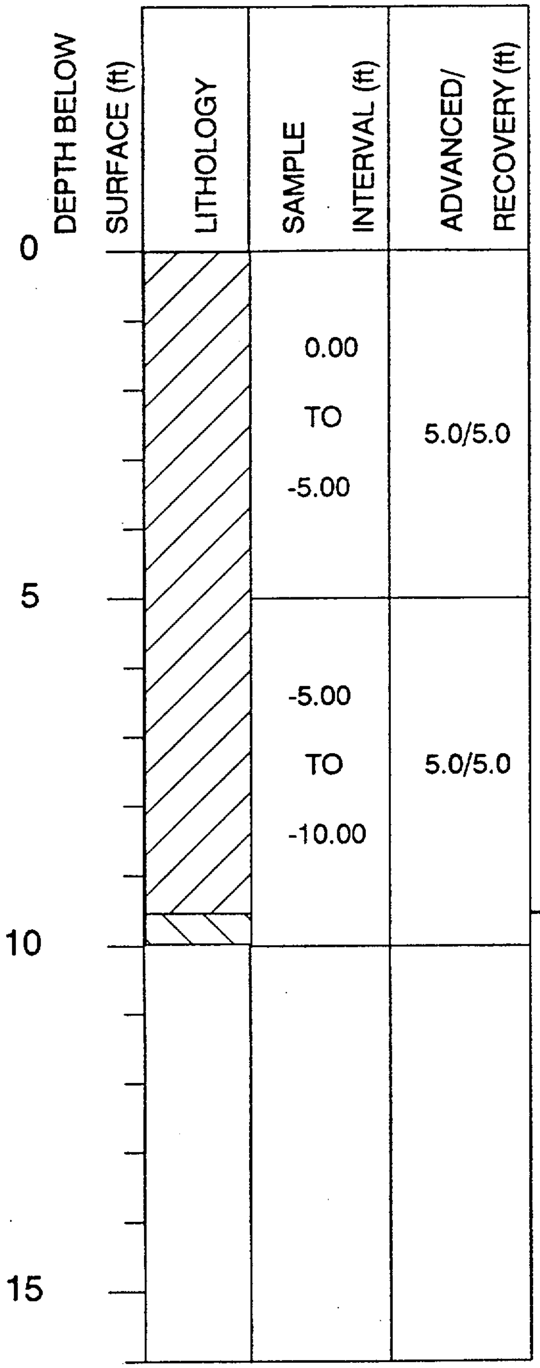
brown till

Gray till in bottom 0.5 ft
T. D. 10.0 ft

BOREHOLE NUMBER: 505    LOCATION: Sample Area 5    24 JULY 1989

| DEPTH BELOW SURFACE (ft) | LITHOLOGY | SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) | |
|---|---|---|---|---|
| 0 | | | | Grass |
| | ▨ | 0.00<br>TO<br>-5.00 | 5.0/4.5 | Brown till silty clay with some gravel moist some gray patches |
| 5 | ▨ | -5.00<br>TO<br>-10.00 | 5.0/5.0 | brown till wet in top 0.5 ft then moist<br>sandy silt with gravel at the bottom |
| 10 | | | | T. D. 10.0 ft |
| 15 | | | | |

BOREHOLE NUMBER: 506 LOCATION: Sample Area 5 24 JULY 1989

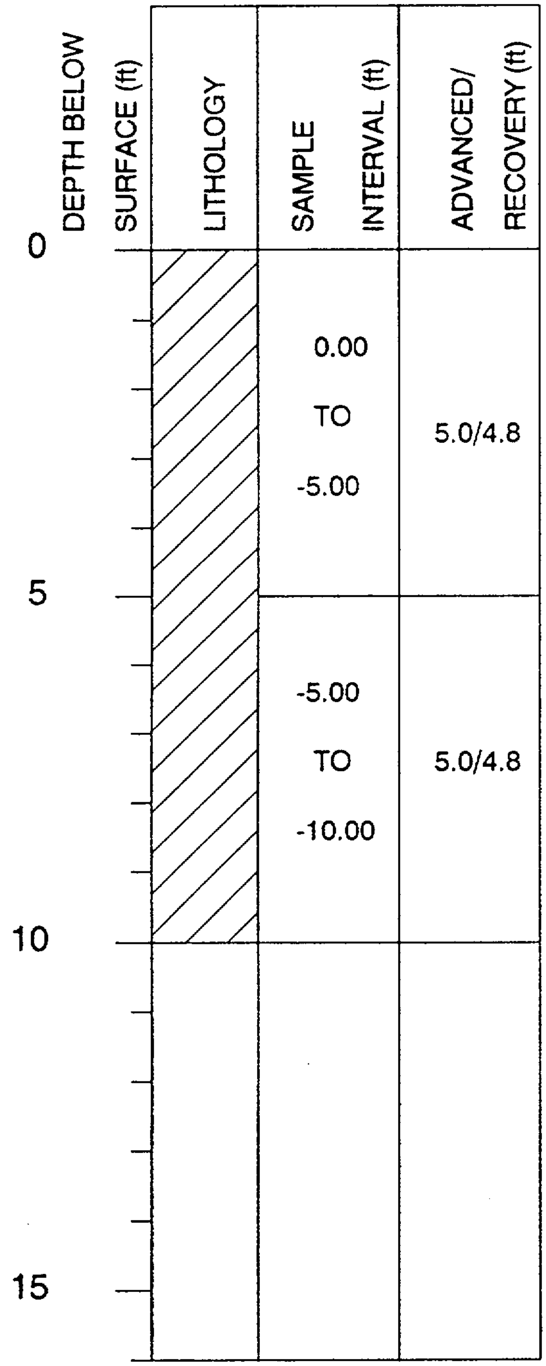


Grass
Brown till silty clay with gravel moist

brown till

Gray till bottom 0.4 ft silty clay with gravel
T. D. 10.0 ft

BOREHOLE NUMBER: 507 LOCATION: Sample Area 5 25 JULY 1989



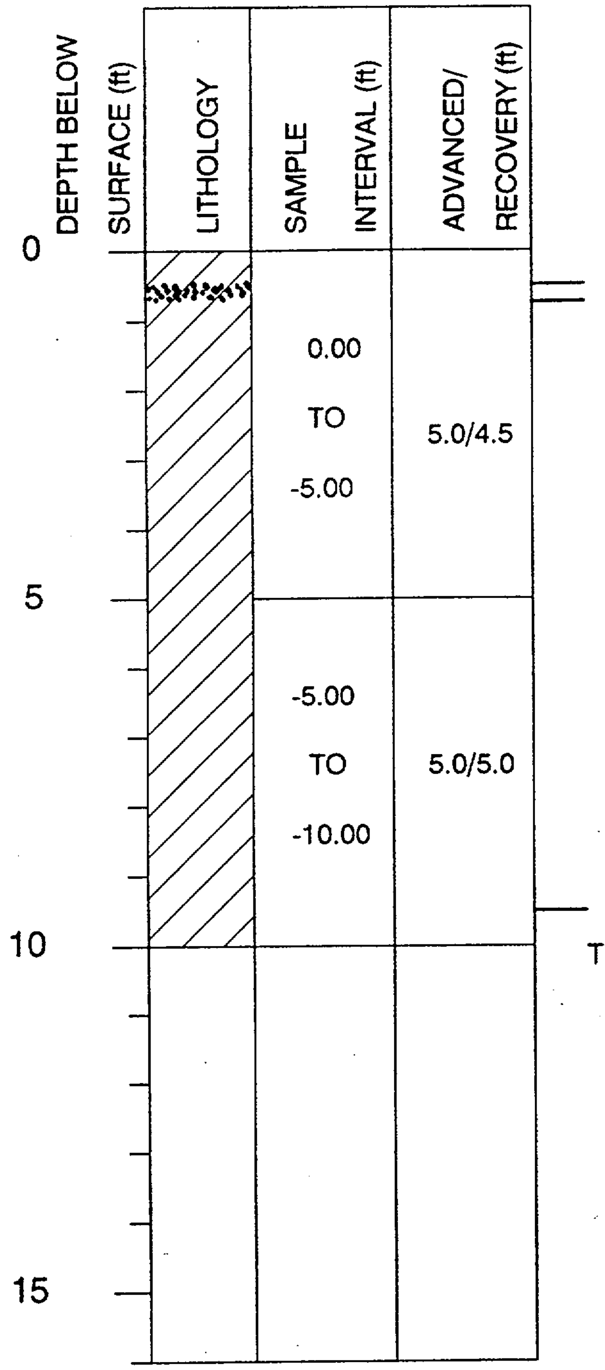
Grass
Brown till soft clayey silt

brown till stiff moist

becoming grayish brown at the bottom

T. D. 10.0 ft

BOREHOLE NUMBER: 600 LOCATION: Sample Area 6 26 JULY 1989



Grass
Dark brown top soil 0.5 ft
Limestone gravel 0.2 ft

Dark brown till or fill becoming lighter brown with depth

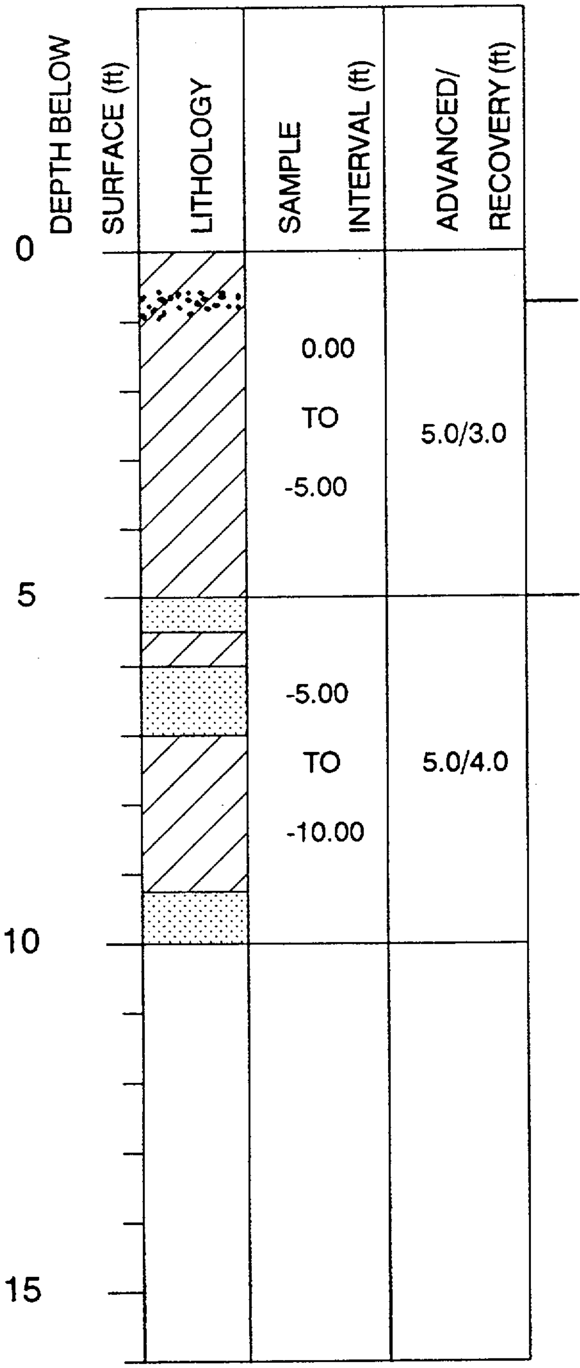
brown till or fill

moist

Groundwater encountered at 9.5 ft

T. D. 10.0 ft

BOREHOLE NUMBER: 601 LOCATION: Sample Area 6 26 JULY 1989



Grass
Dark brown top soil 0.5 ft
Gravel 0.3 ft

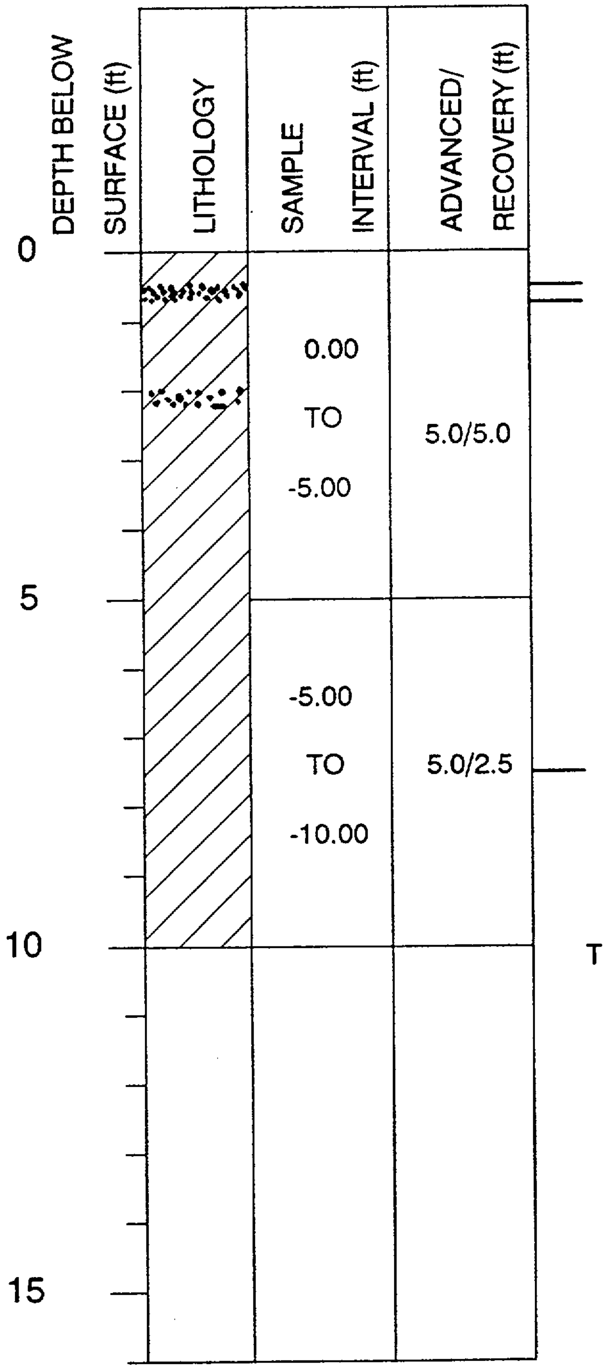
Brown till/fill

Ground water encountered at 5.0 ft

Interbedded pebbly sands and clay
very wet

T. D. 10.0 ft

BOREHOLE NUMBER: 602 LOCATION: Sample Area 6 26 JULY 1989



Grass
Dark brown top soil 0.5 ft
Limestone gravel 0.2 ft

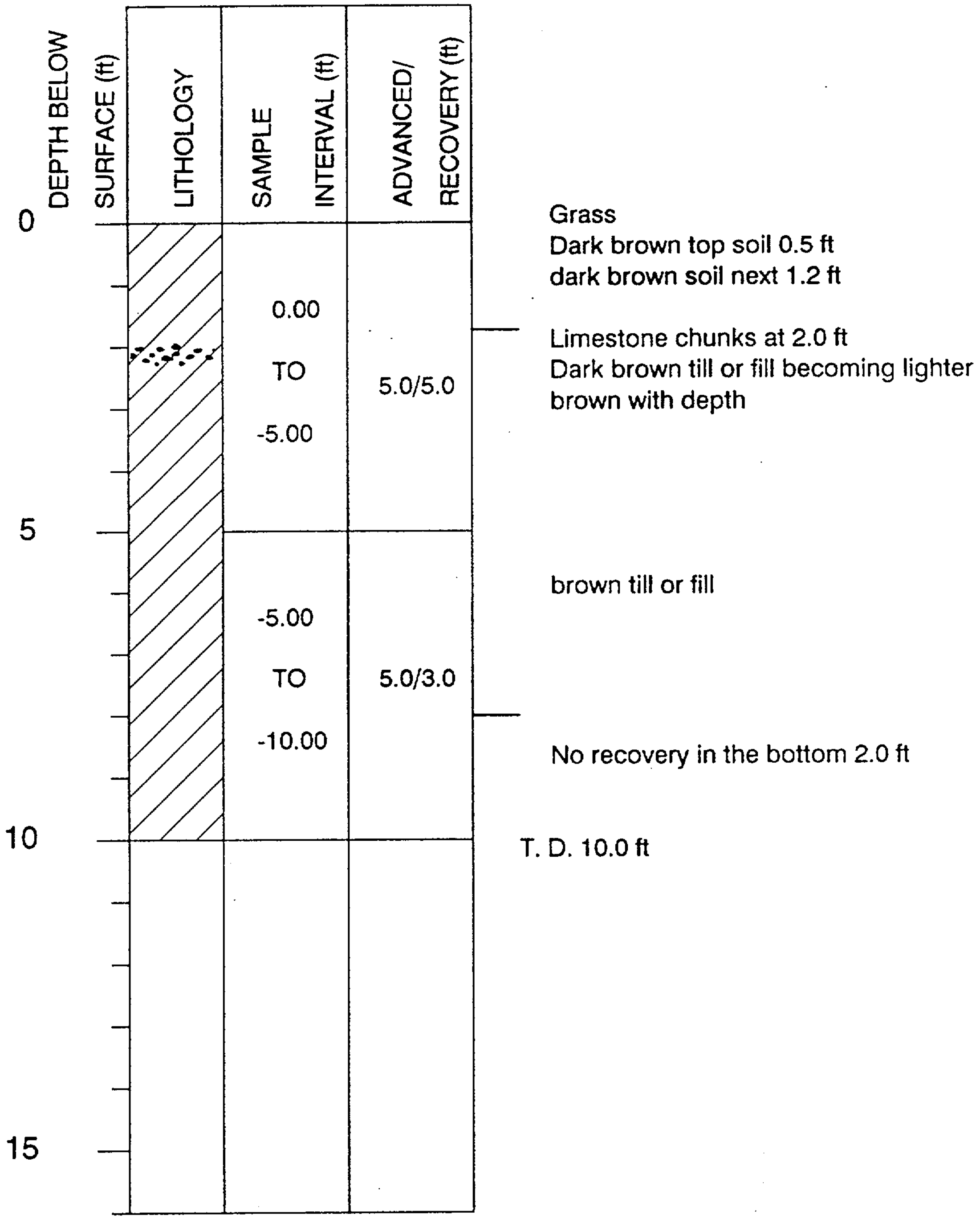
Dark brown till or fill becoming lighter brown with depth

brown till or fill

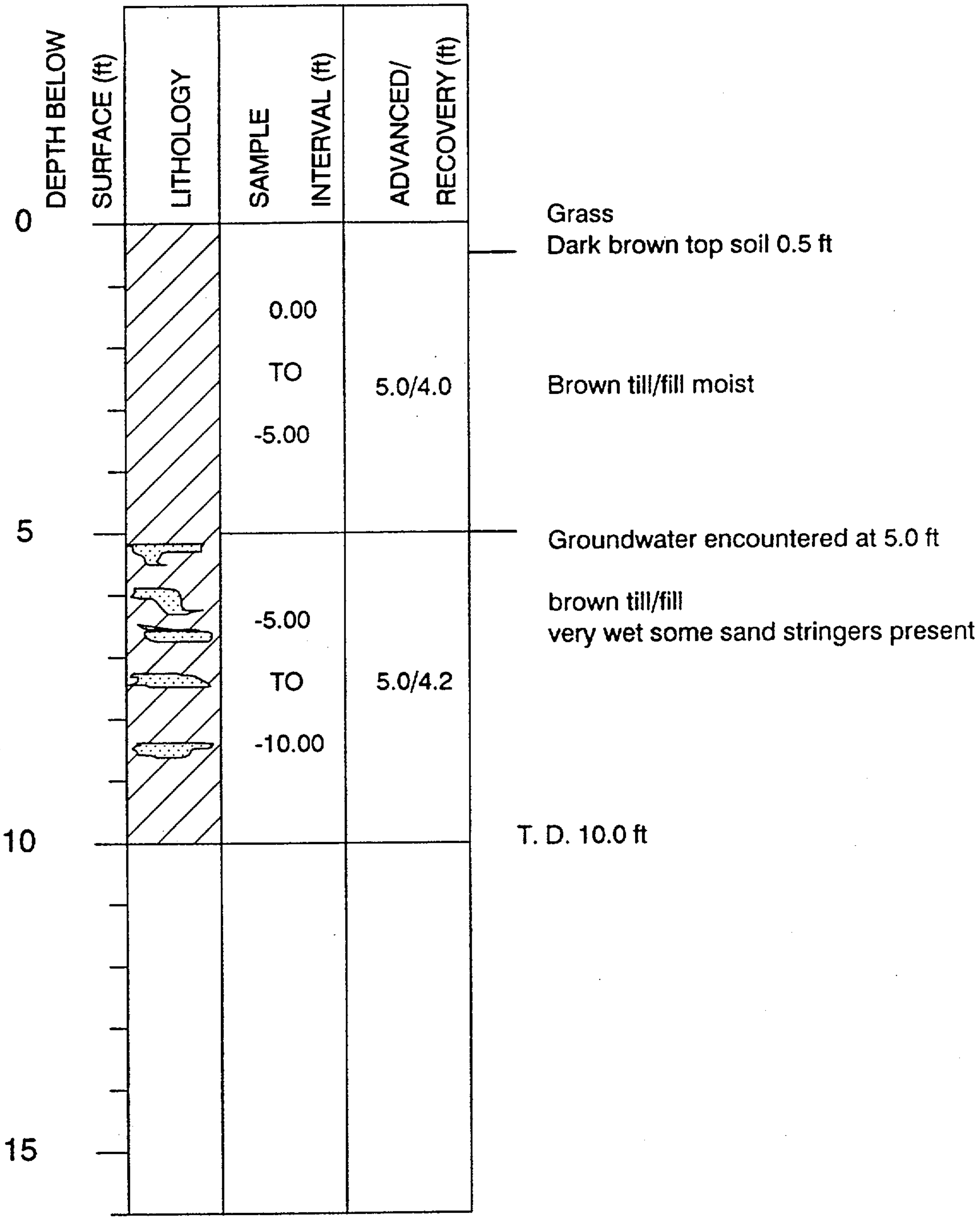
mottled and hard spoon blocked

T. D. 10.0 ft

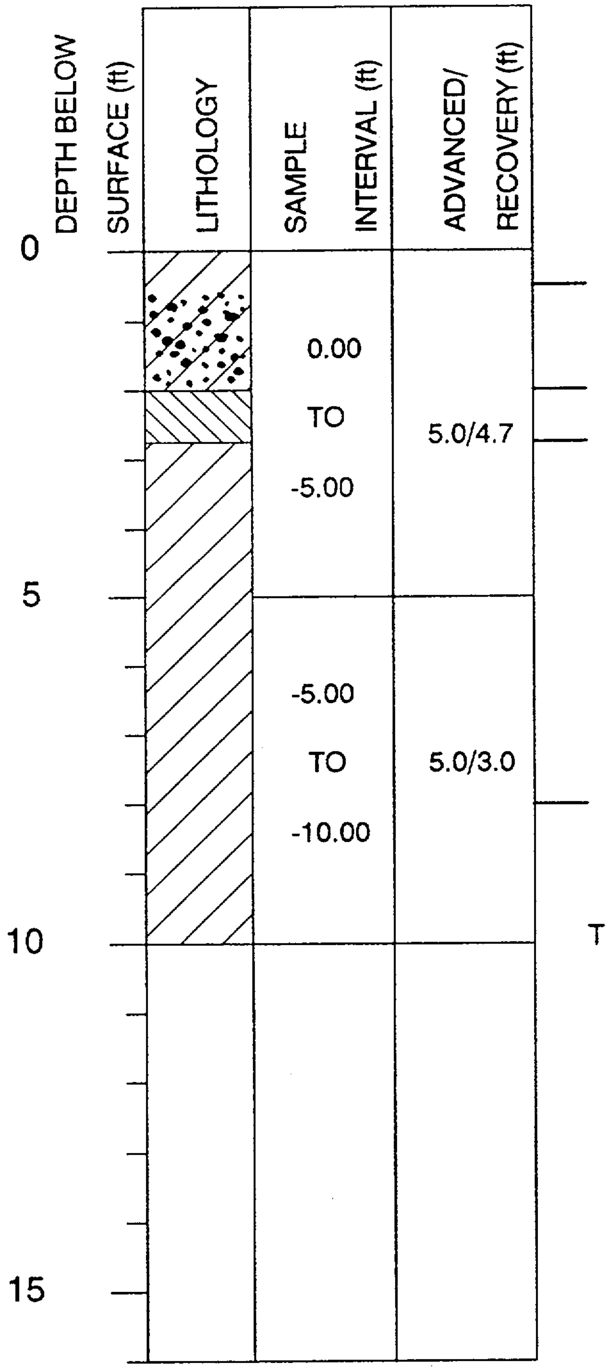
BOREHOLE NUMBER: 603 LOCATION: Sample Area 6 26 JULY 1989



BOREHOLE NUMBER: 604 LOCATION: Sample Area 6 26 JULY 1989



BOREHOLE NUMBER: 605 LOCATION: Sample Area 6 26 JULY 1989



Grass

Dark brown top soil 0.5 ft

Brown till/fill with limestone chunks 1.7 ft

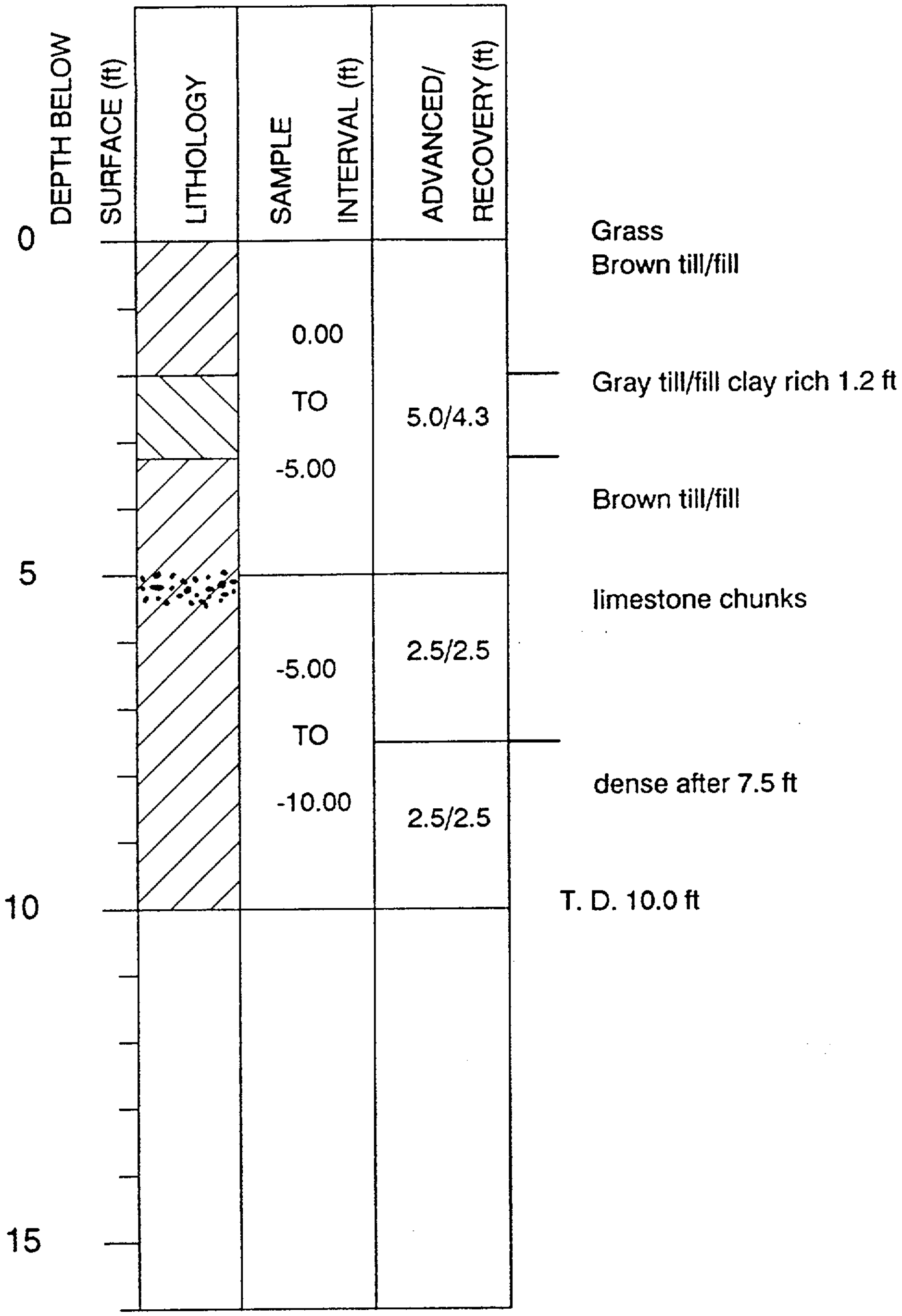
Gray clay 0.8 ft

Brown till fill moist

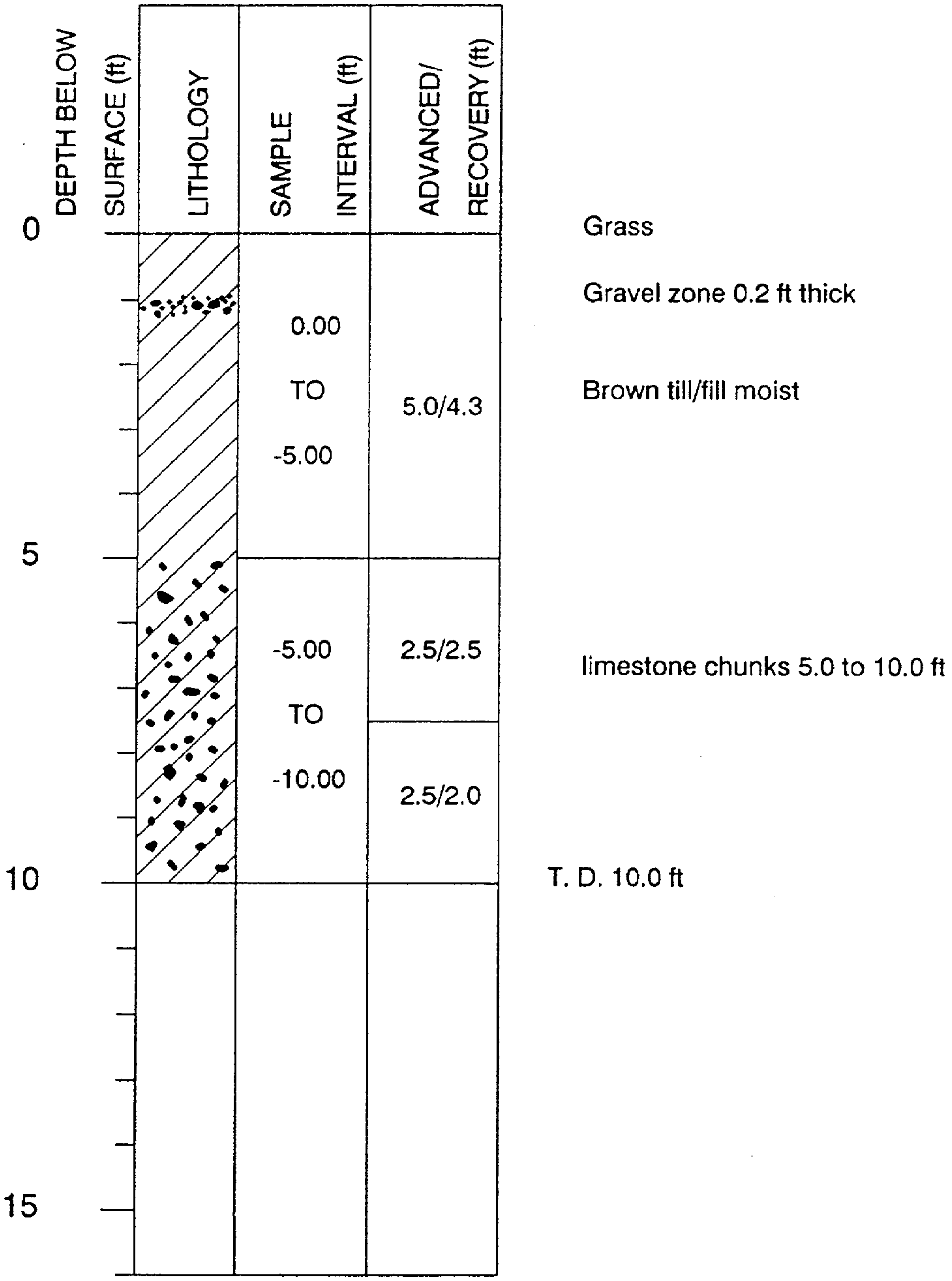
Dense after about 7 to 8 ft no recovery

T. D. 10.0 ft

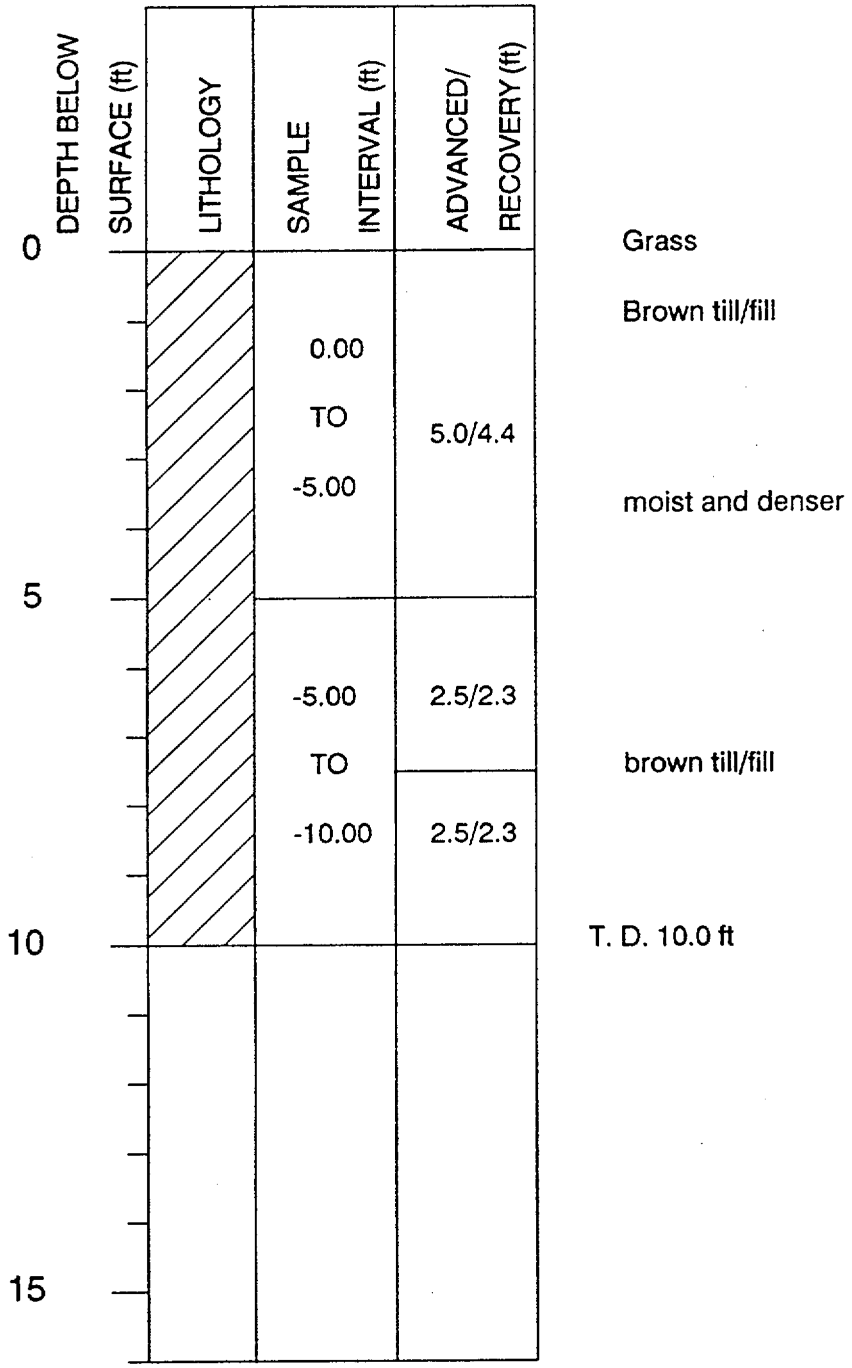
BOREHOLE NUMBER: 606 LOCATION: Sample Area 6 27 JULY 1989



BOREHOLE NUMBER: 607 LOCATION: Sample Area 6 27 JULY 1989

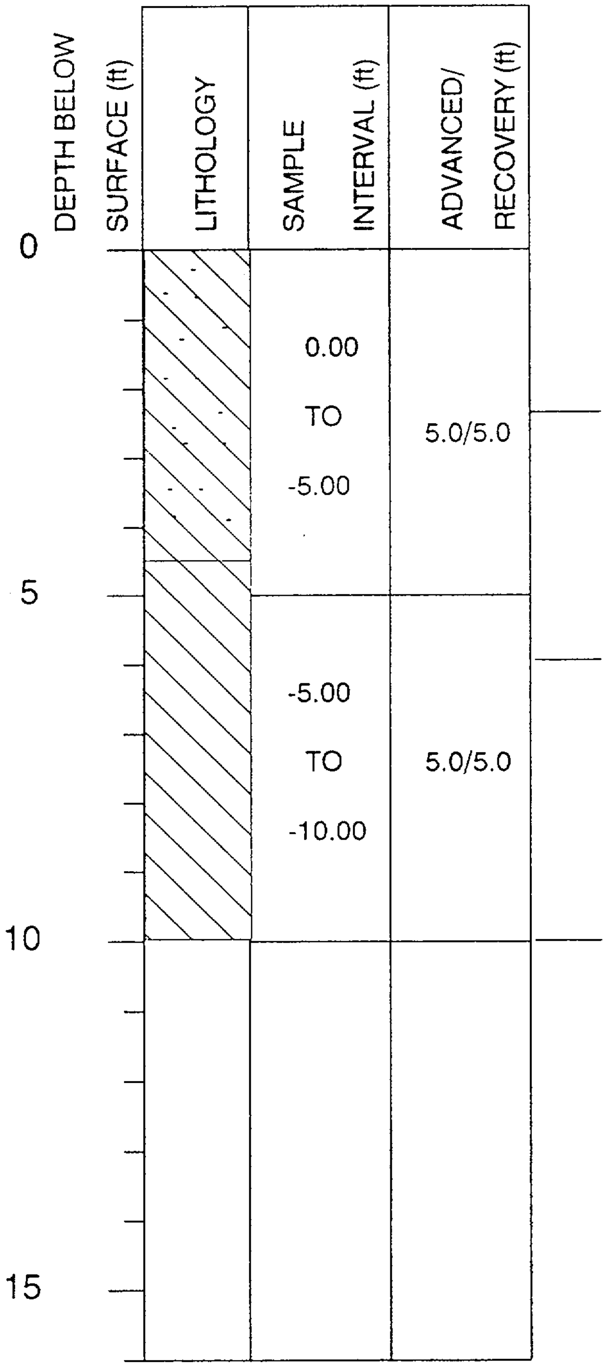


BOREHOLE NUMBER: 608 LOCATION: Sample Area 6 27 JULY 1989



BOREHOLE NUMBER: C-01

14 November 1989



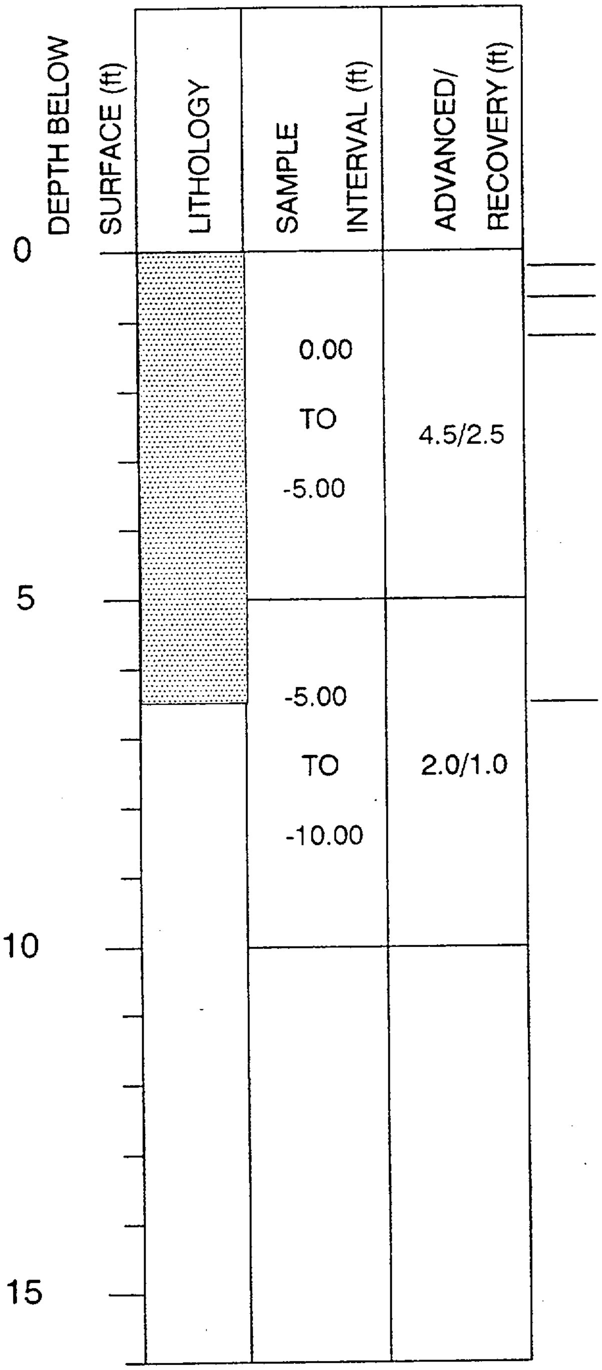
**Brown fill with pea gravel**

**Water encountered at 6.0 ft**

**T.D. 10.0 ft**

BOREHOLE NUMBER: C-02

**14 November 1989**



**0.2 ft brown/grey top soil**

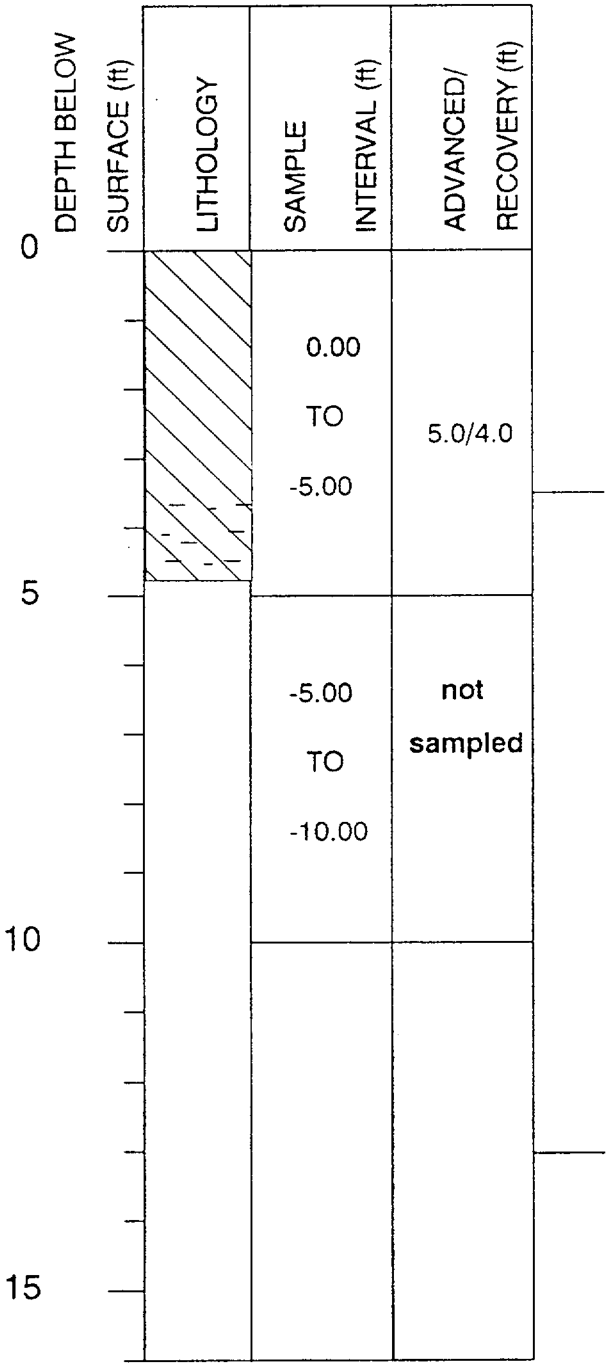
**0.5 ft brown fill**

**1.0 ft brown till with pea gravel**

**T.D. 6.5 ft**

BOREHOLE NUMBER: C-03

17 November 1989



| DEPTH BELOW SURFACE (ft) | LITHOLOGY | SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|---|---|
| 0 | ▨ | 0.00<br>TO<br>-5.00 | 5.0/4.0 |
| 5 | | -5.00<br>TO<br>-10.00 | not sampled |
| 10 | | | |
| 15 | | | |

**Brown fill soft**
**Very moist & soft**

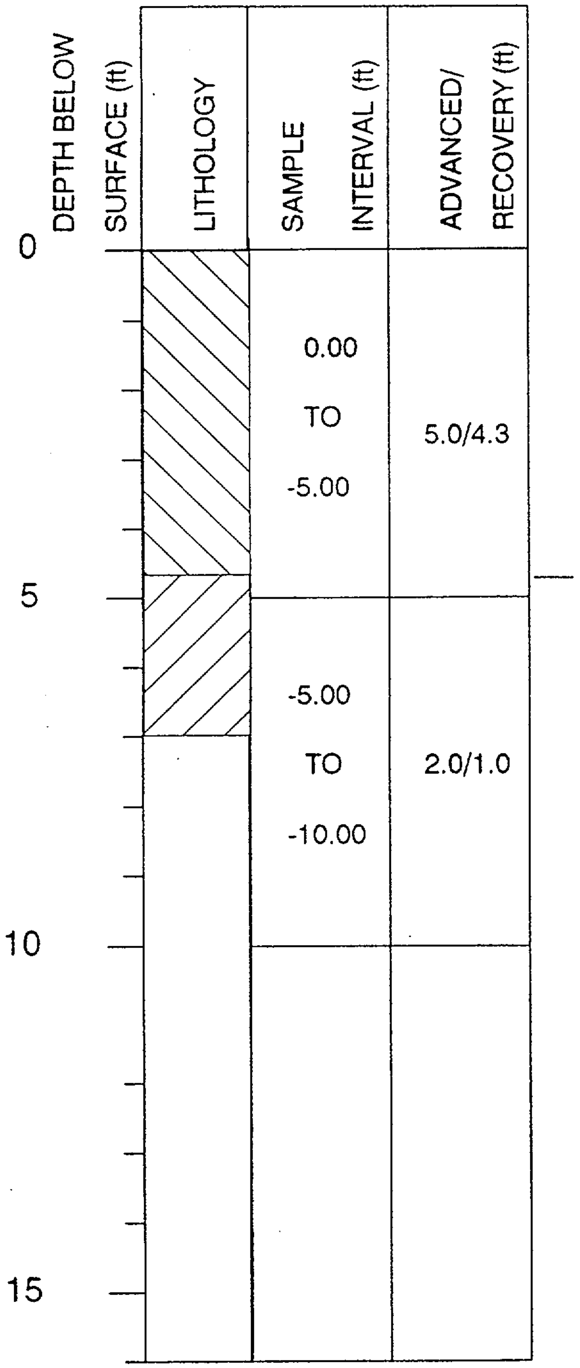
**Water encountered 4.5 ft**

**Drier fill more dense**
**More gravel & pebbles**

**T.D. 12.0 ft**

BOREHOLLE NUMBER: C-04

**14 November 1989**

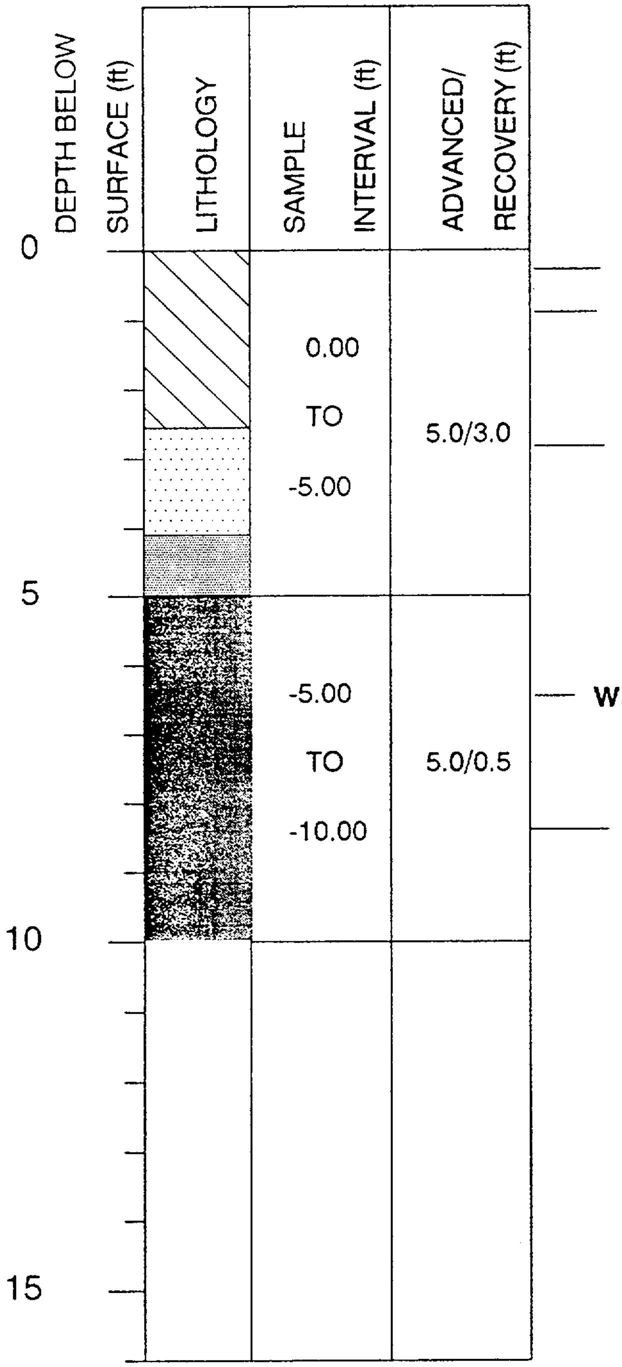


**Brown fill**

**Grey fill/till moist & soft**
**Not enough volume**

BOREHOLE NUMBER: C-05

**14 November 1989**



**Grass**

**1.8 Brown soil with fill**

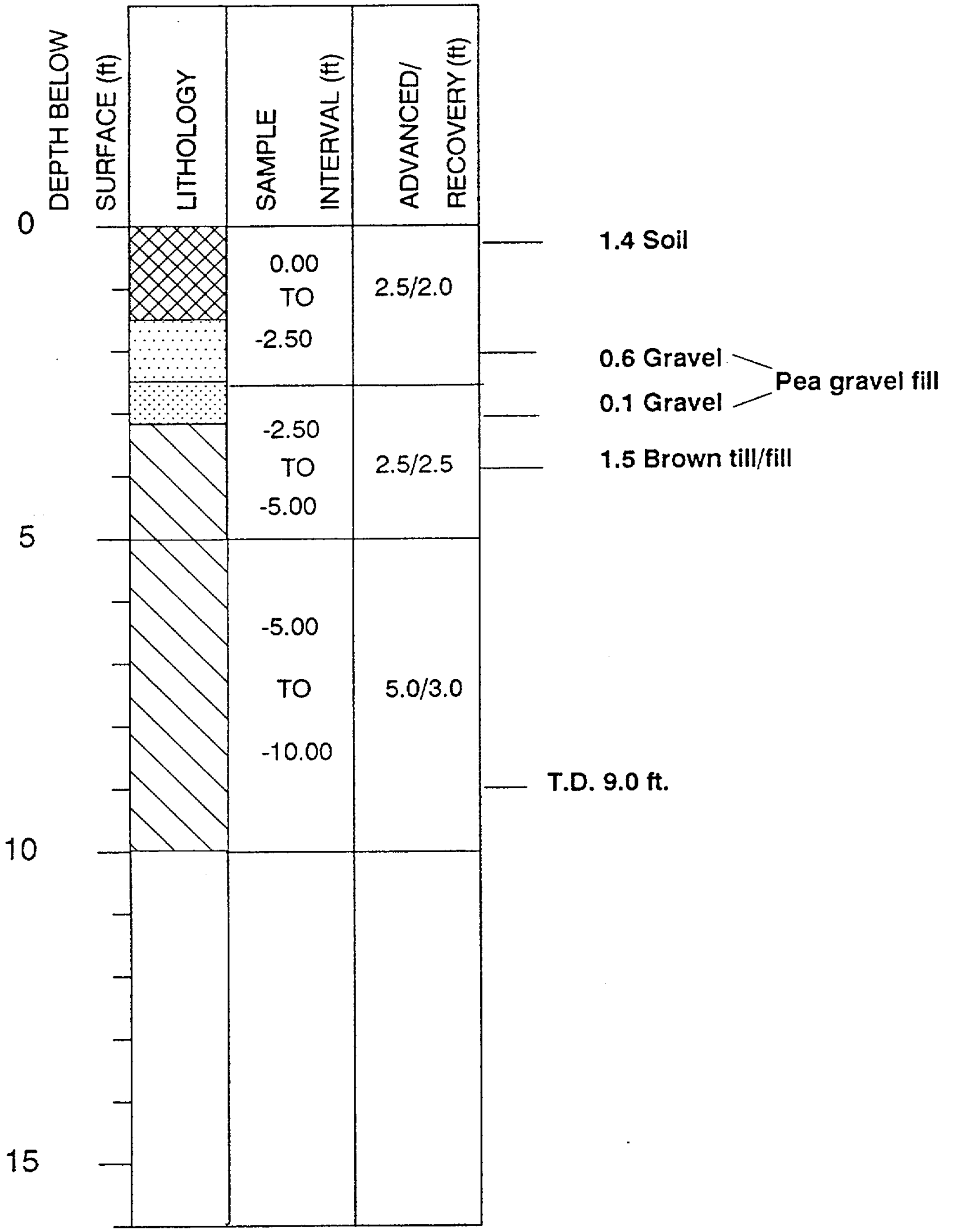
**1.2 Pea gravel with some grey/yellow clay bottom 0.3 ft.**

**Water encountered at 6.5 ft.**

**Pea gravel with oil smear**

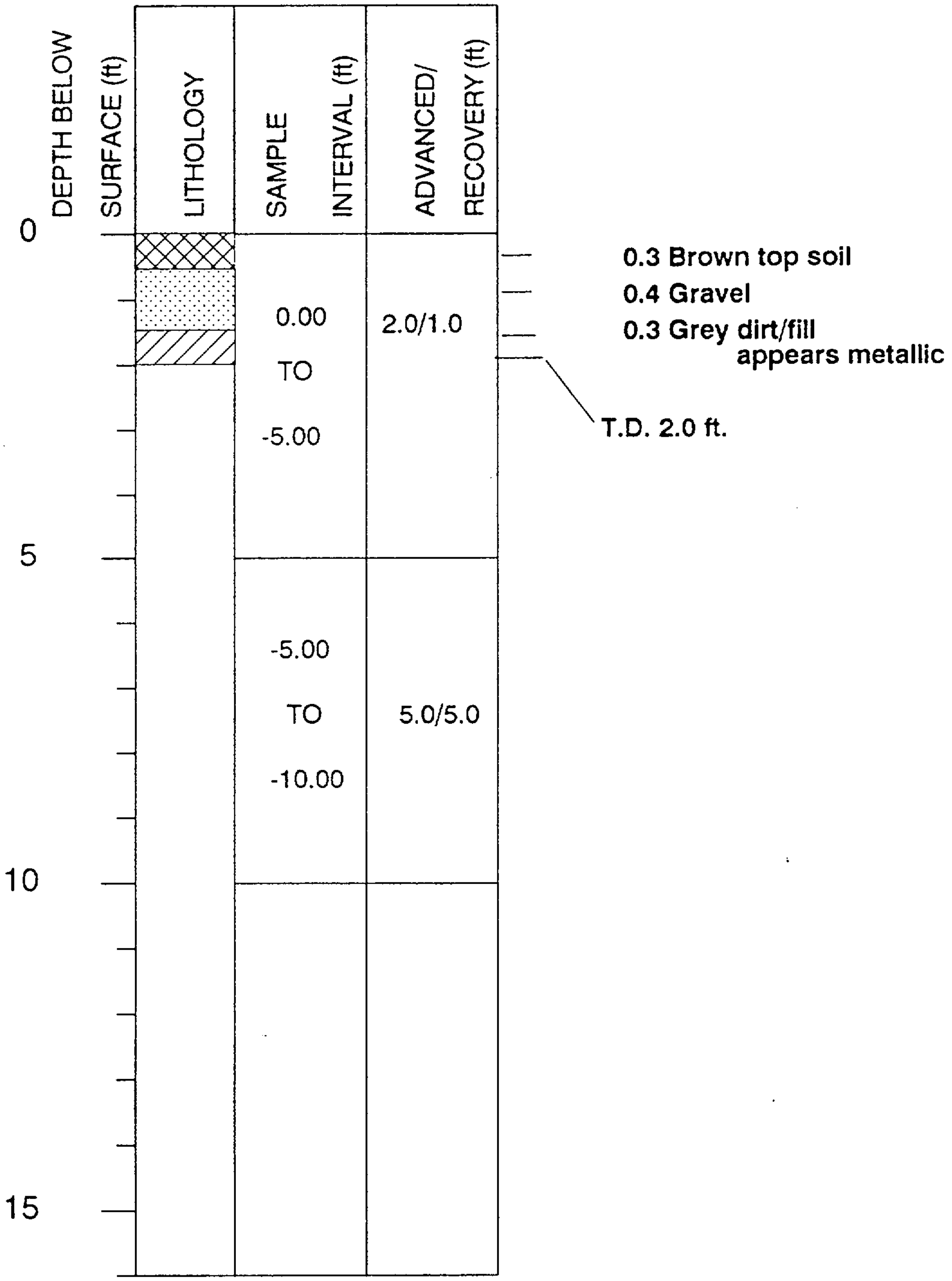
BOREHOLE NUMBER: C-06

14 November 1989



BOREHOLE NUMBER: C-07

**14 November 1989**

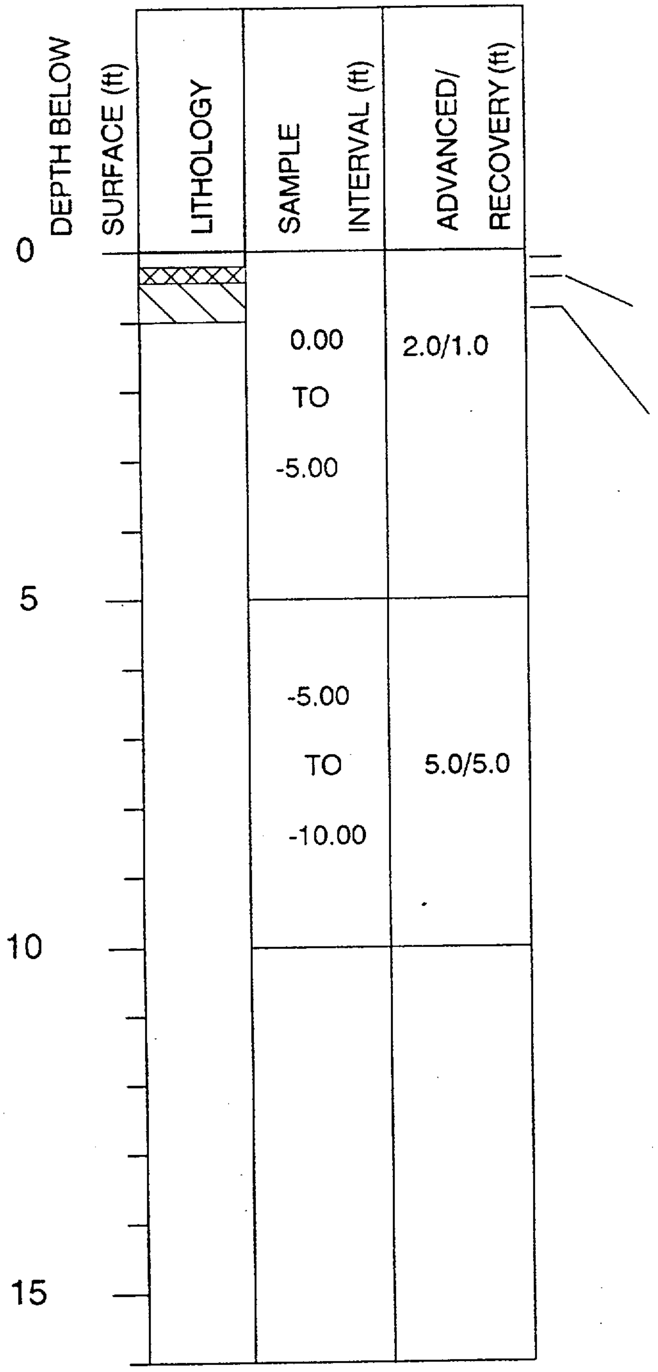


**0.3 Brown top soil**
**0.4 Gravel**
**0.3 Grey dirt/fill appears metallic**

**T.D. 2.0 ft.**

BOREHOLE NUMBER: C-08

14 November 1989



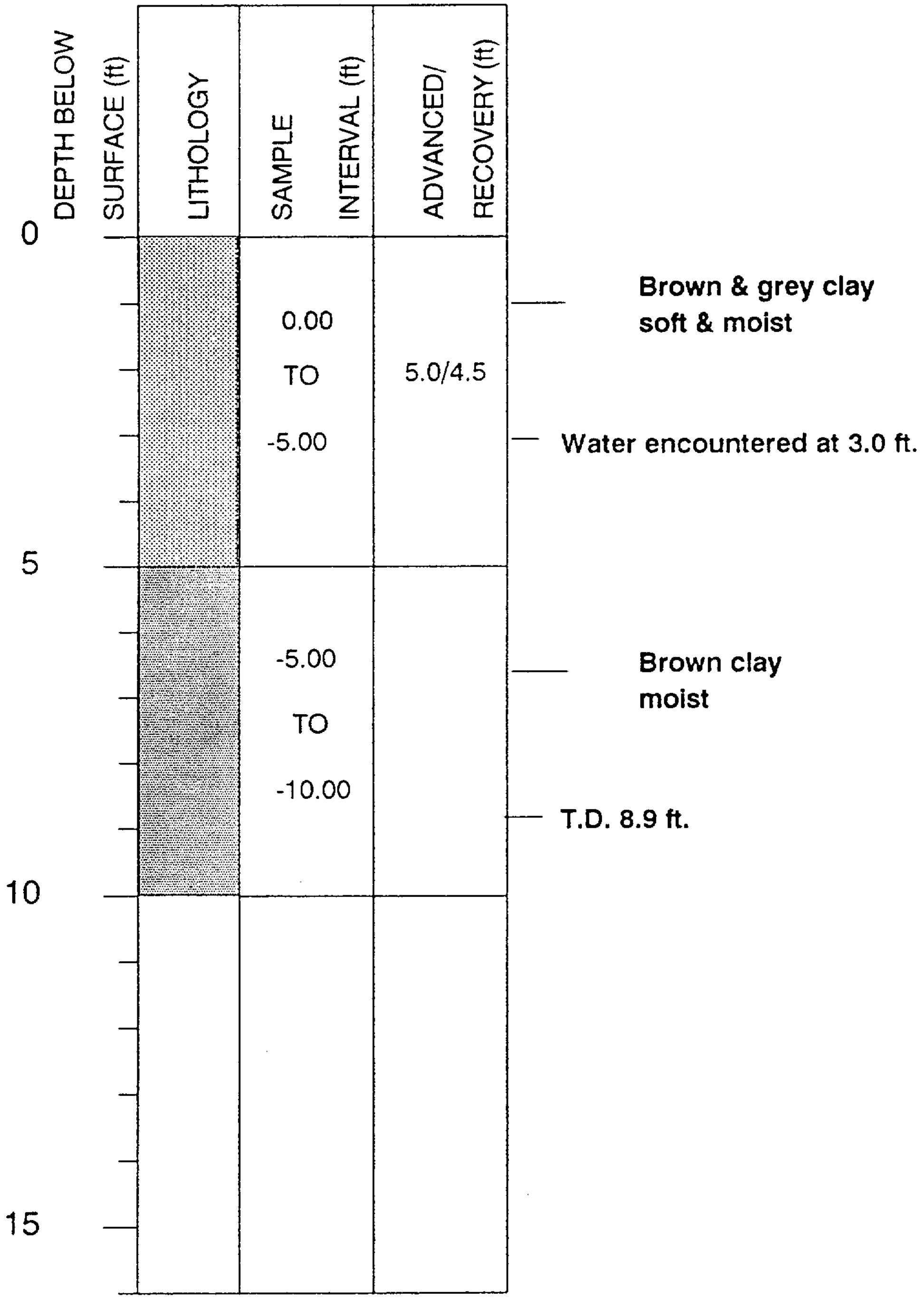
**0.2 Grass**

**0.2 Brown soil**
**white chemical or solid**
**substance in middle**

**0.6 Brown till/fill**

BOREHOLE NUMBER: C-09

**17 November 1989**



| DEPTH BELOW SURFACE (ft) | LITHOLOGY | SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|---|---|
| 0 | ▒ | 0.00 TO -5.00 | 5.0/4.5 |
| 5 | ▒ | -5.00 TO -10.00 | |
| 10 | | | |
| 15 | | | |

**Brown & grey clay**
**soft & moist**

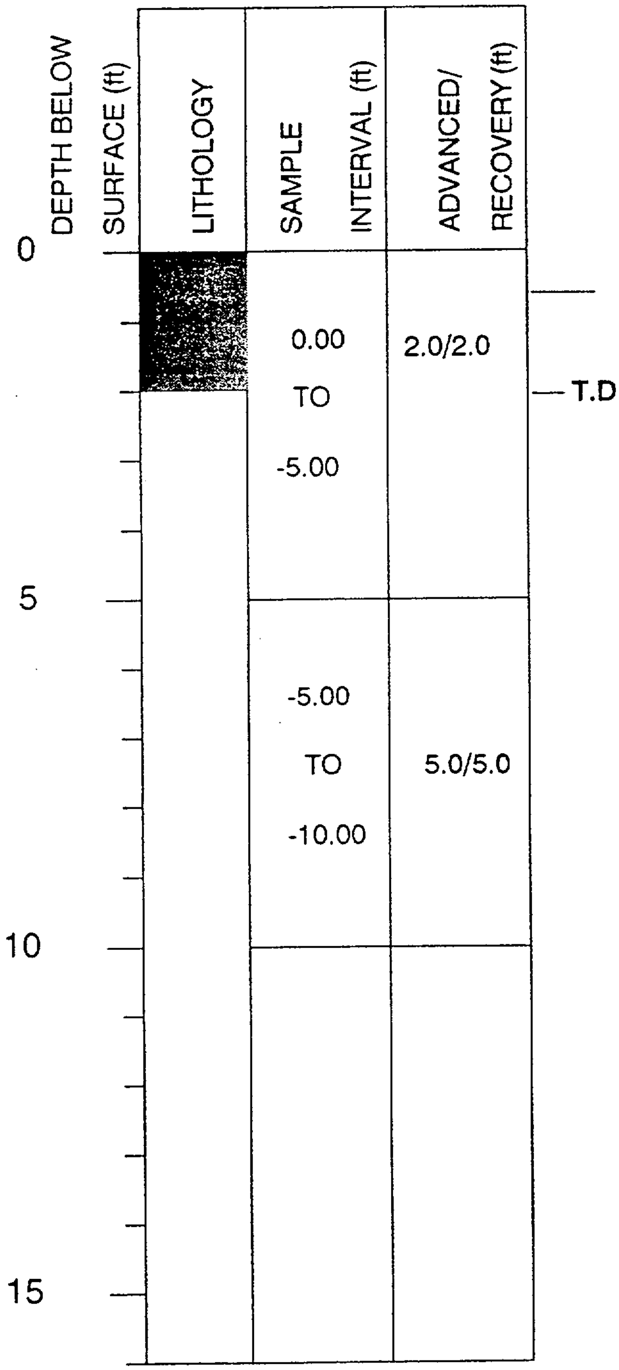
**Water encountered at 3.0 ft.**

**Brown clay**
**moist**

**T.D. 8.9 ft.**

BOREHOLE NUMBER: C-10

**15 November 1989**

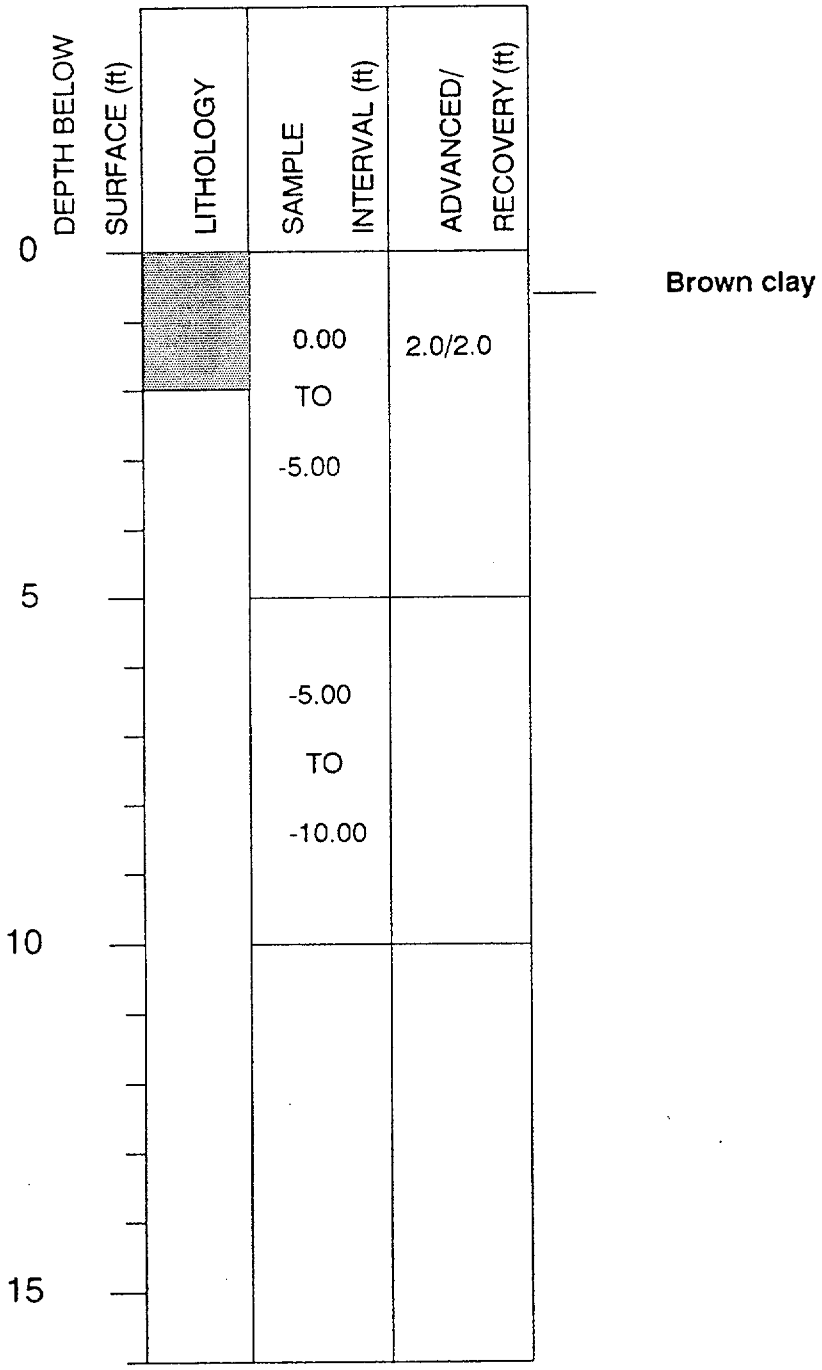


**Soft grey & black clay with organic matter some roots**

**T.D. 2.0 ft.**

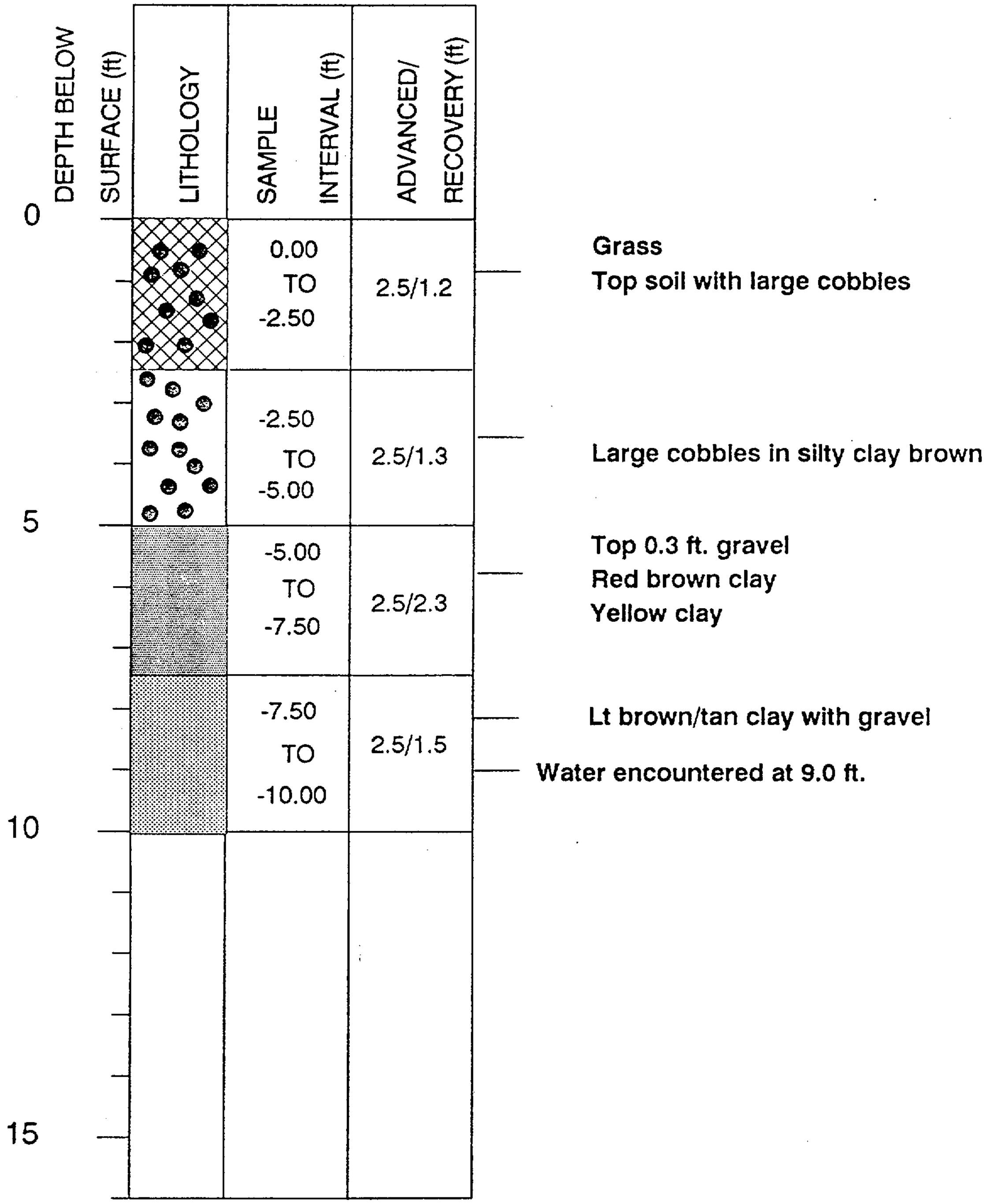
BOREHOLE NUMBER: C-11

**15 November 1989**



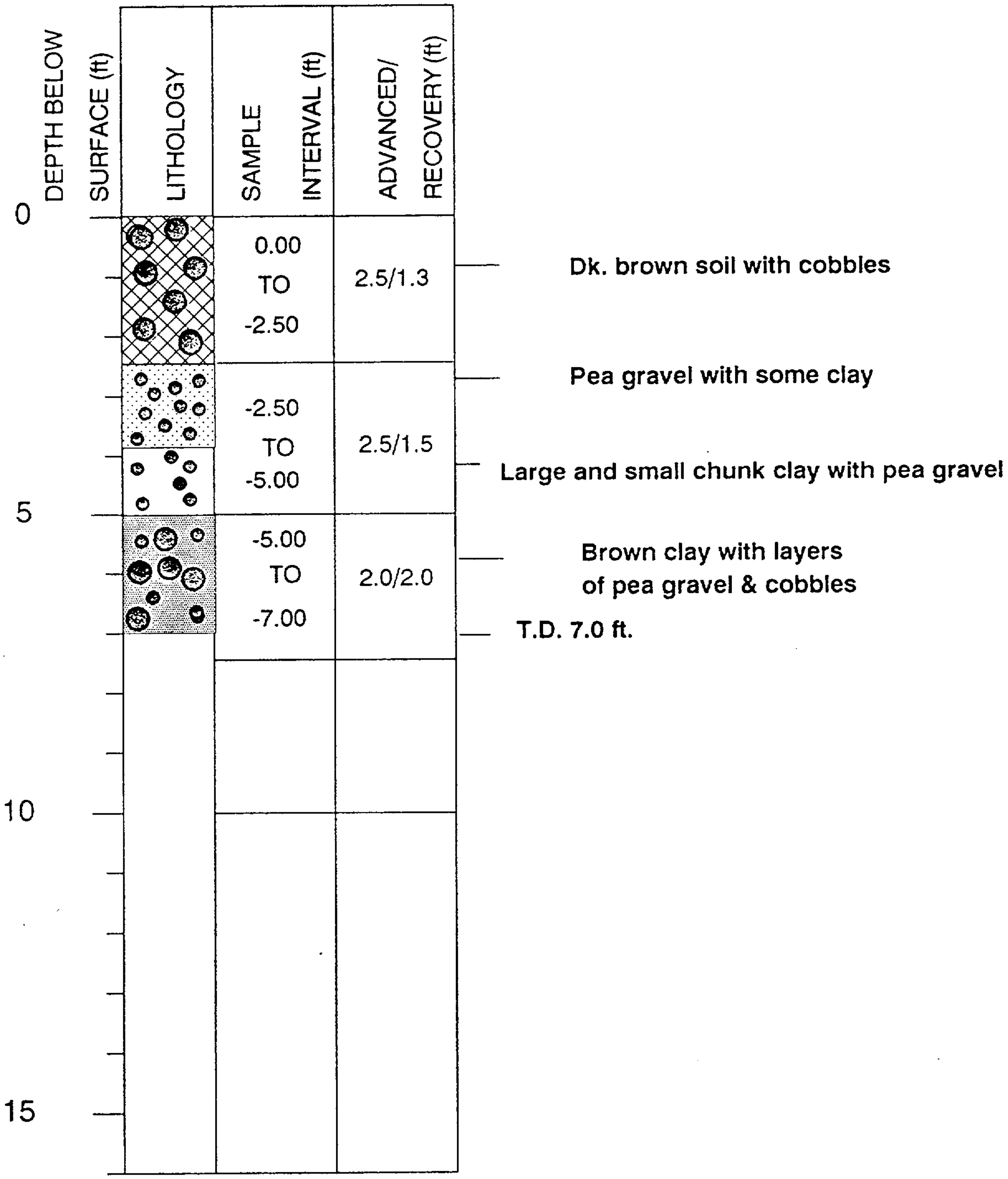
BOREHOLE NUMBER: C-13

15 November 1989



BOREHOLE NUMBER: C-14

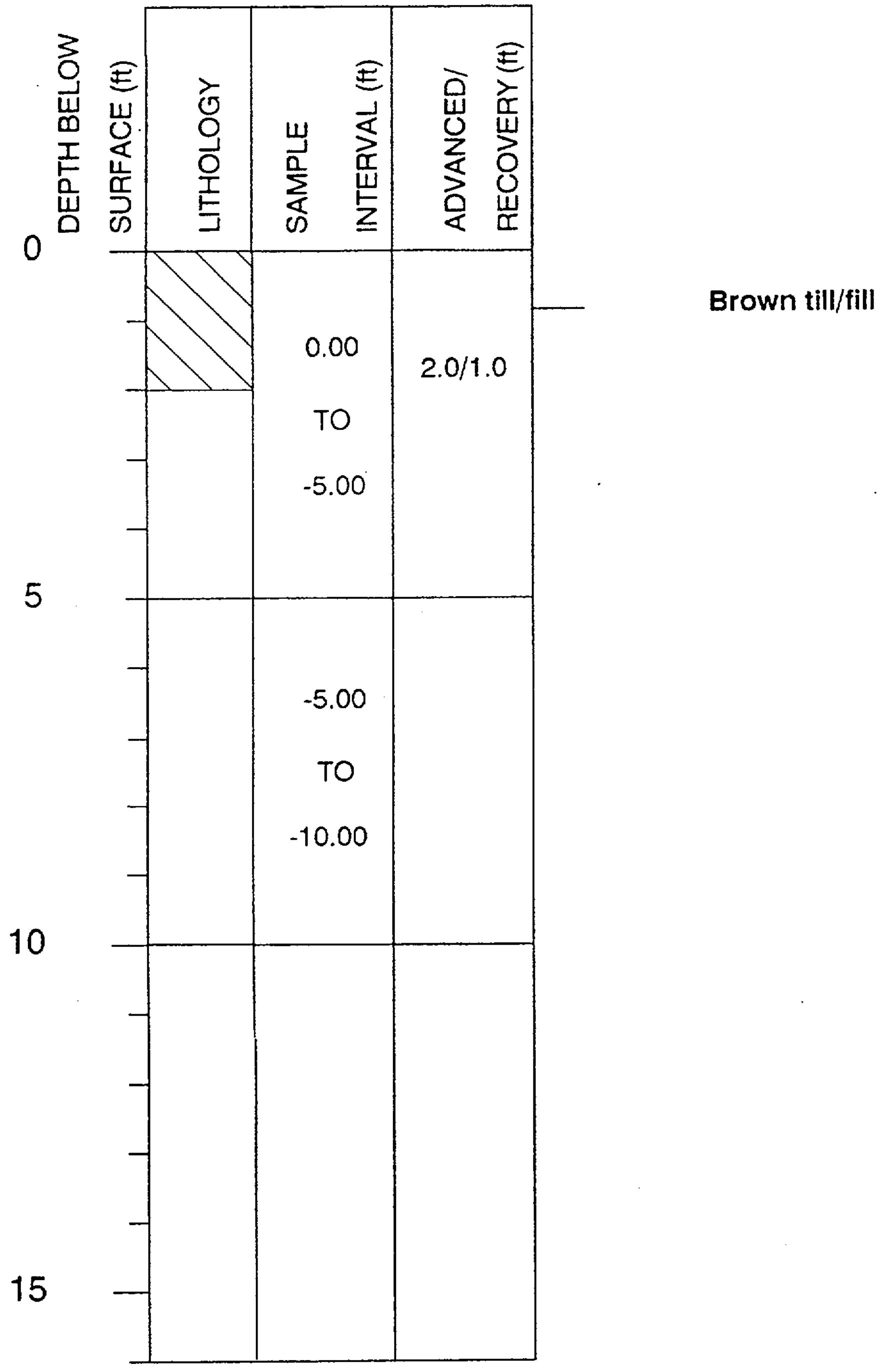
15 November 1989



| DEPTH BELOW SURFACE (ft) | LITHOLOGY | SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) | |
|---|---|---|---|---|
| 0 | | 0.00 TO -2.50 | 2.5/1.3 | Dk. brown soil with cobbles |
| | | -2.50 TO -5.00 | 2.5/1.5 | Pea gravel with some clay<br>Large and small chunk clay with pea gravel |
| 5 | | -5.00 TO -7.00 | 2.0/2.0 | Brown clay with layers of pea gravel & cobbles<br>T.D. 7.0 ft. |
| 10 | | | | |
| 15 | | | | |

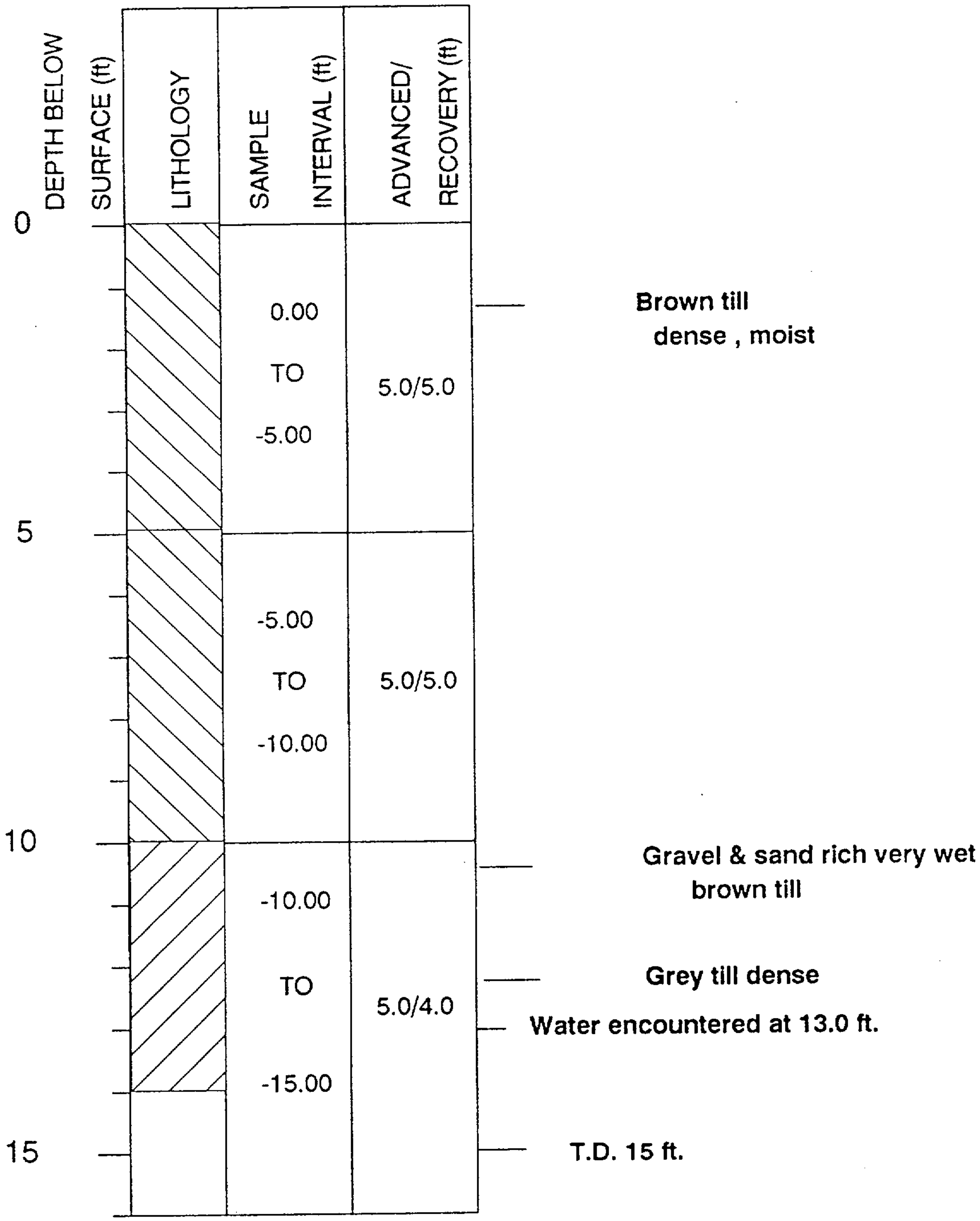
BOREHOLE NUMBER: C-15

**15 November 1989**



BOREHOLE NUMBER: C-16

15 November 1989



**Brown till**
**dense , moist**

**Gravel & sand rich very wet**
**brown till**

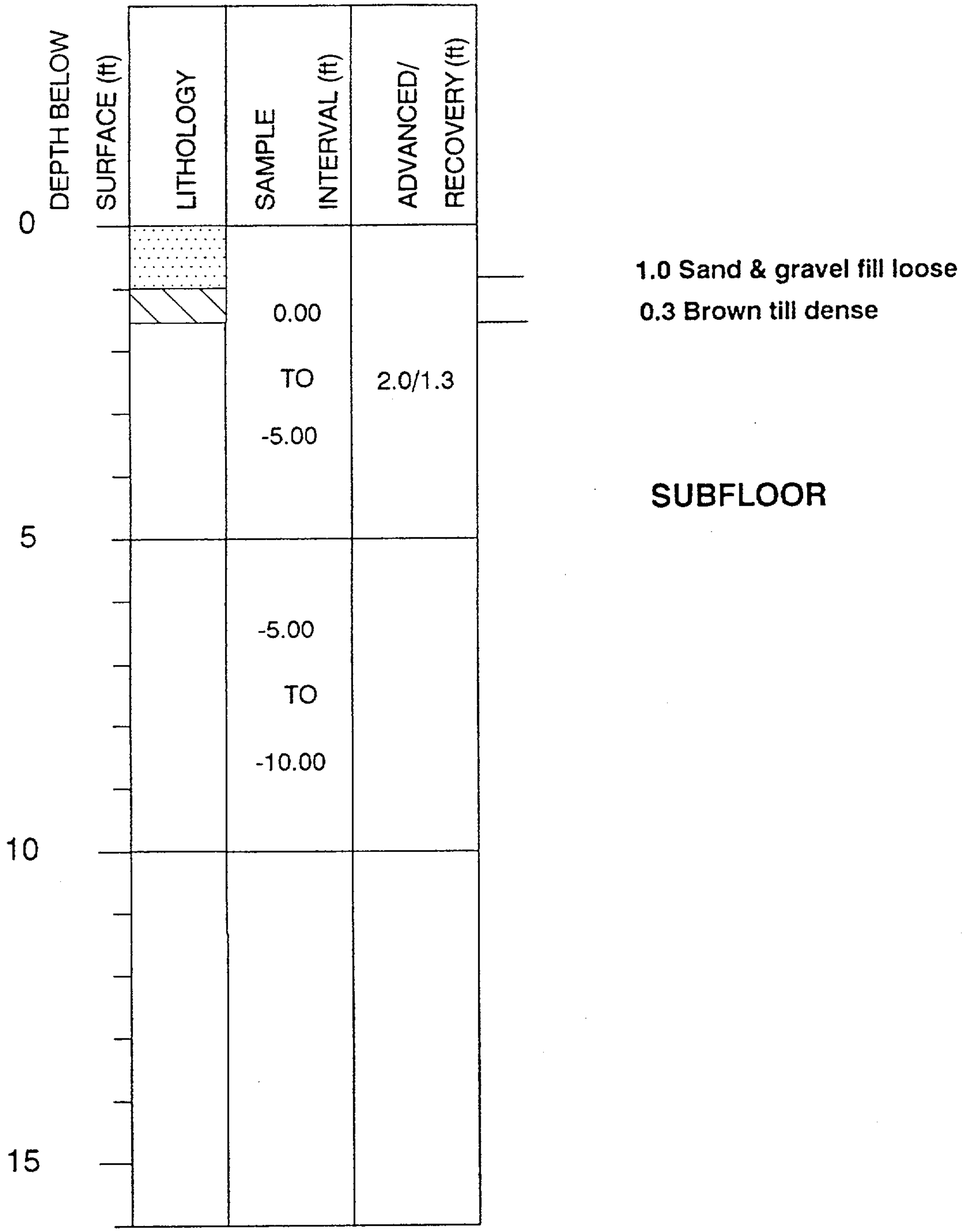
**Grey till dense**

**Water encountered at 13.0 ft.**

**T.D. 15 ft.**

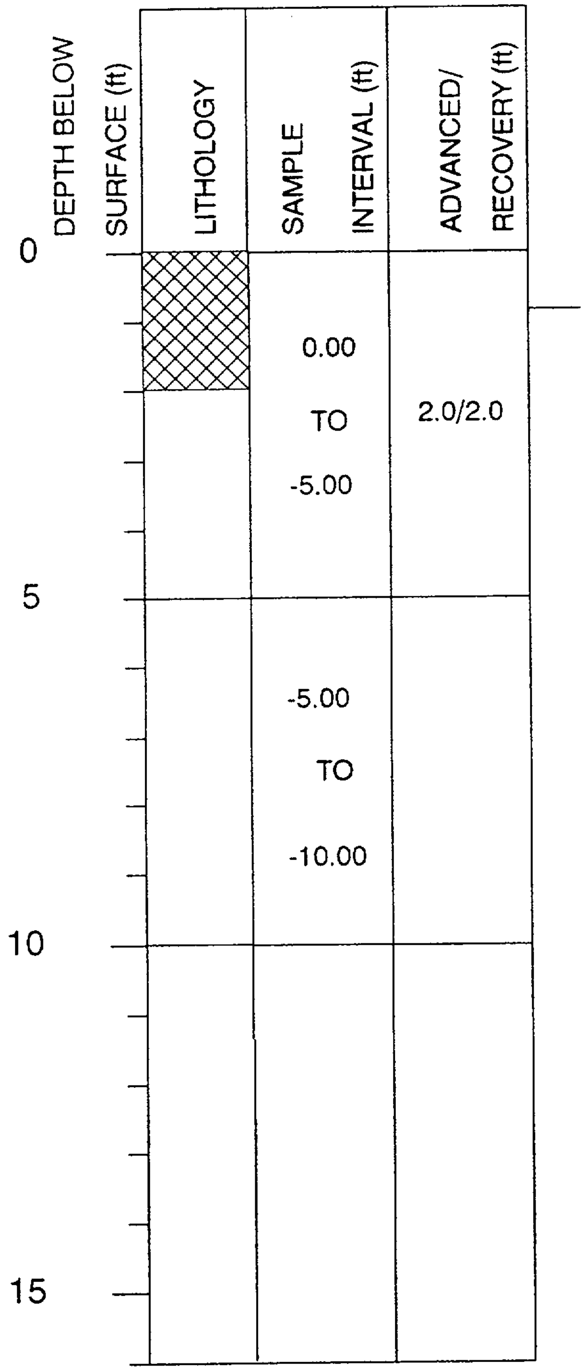
BOREHOLE NUMBER: C-17

27 November 1989



BOREHOLE NUMBER: C-18

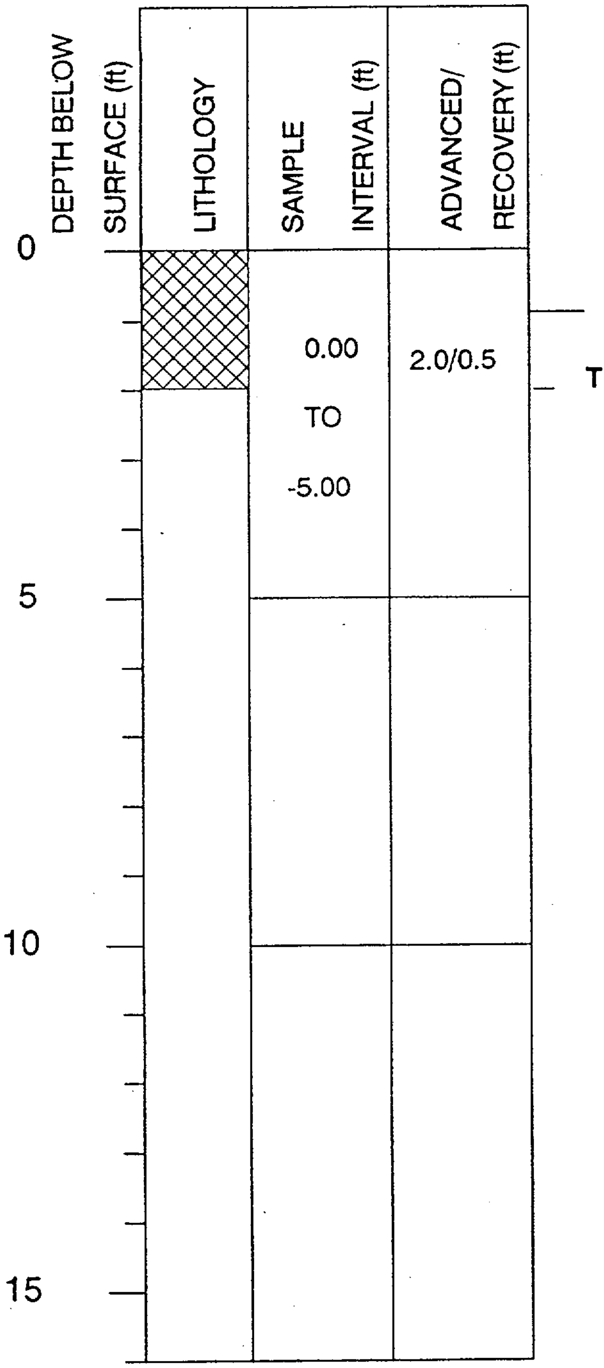
15 November 1989



**Brown soil**

BOREHOLE NUMBER: C-19

15 November 1989

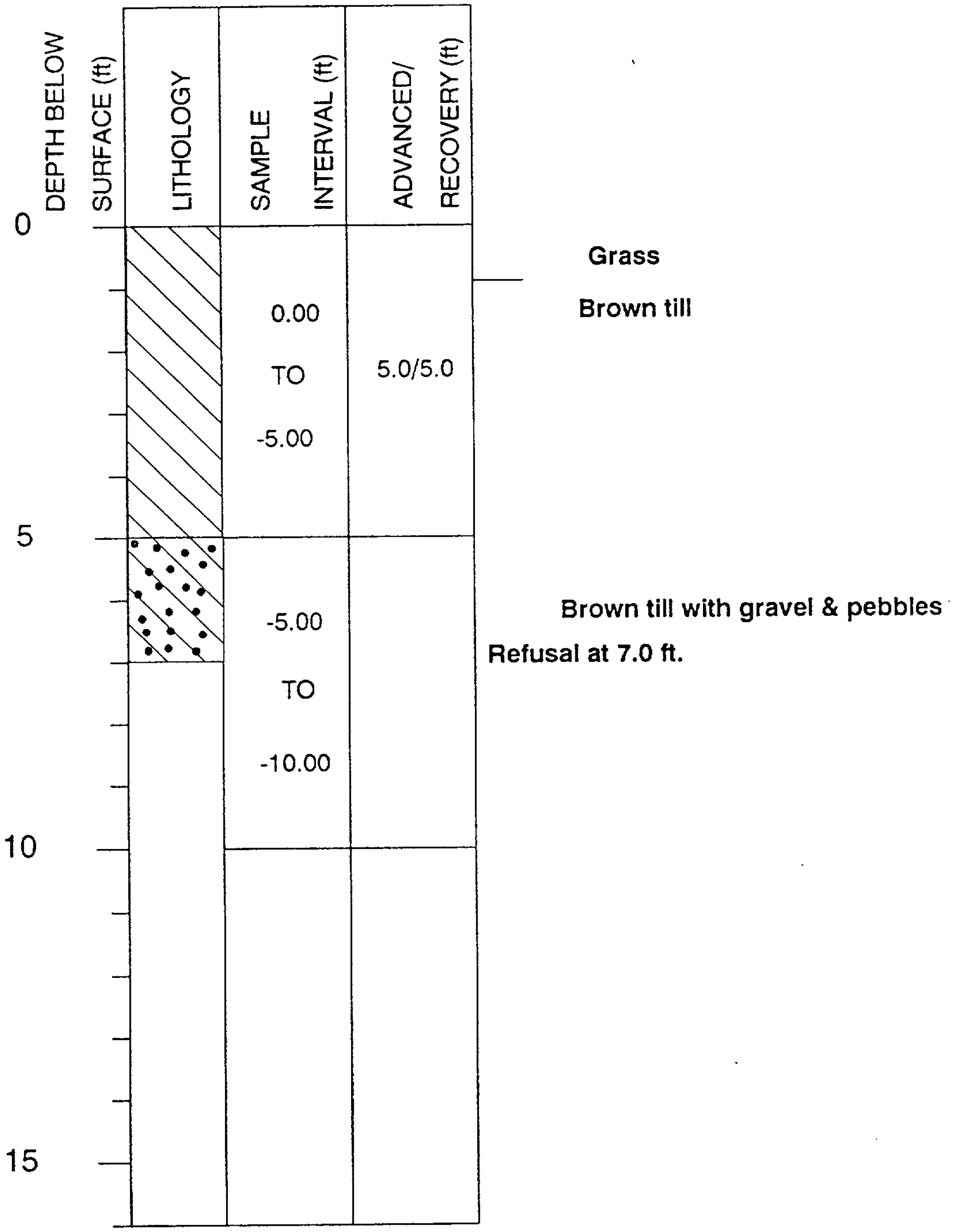


**Brown soil with worms & grubs**

**T.D. 2.0 ft.**

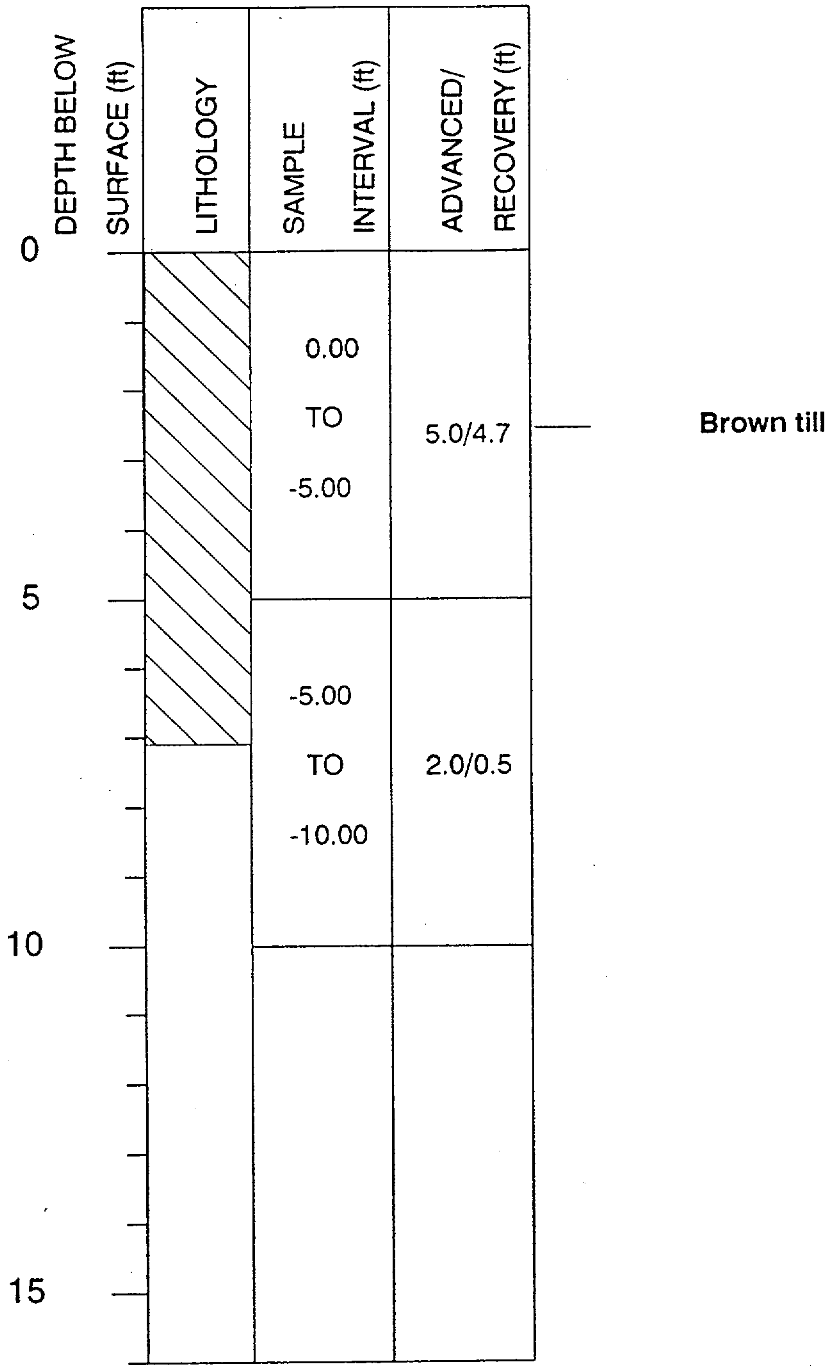
BOREHOLE NUMBER: C-20

**15 November 1989**



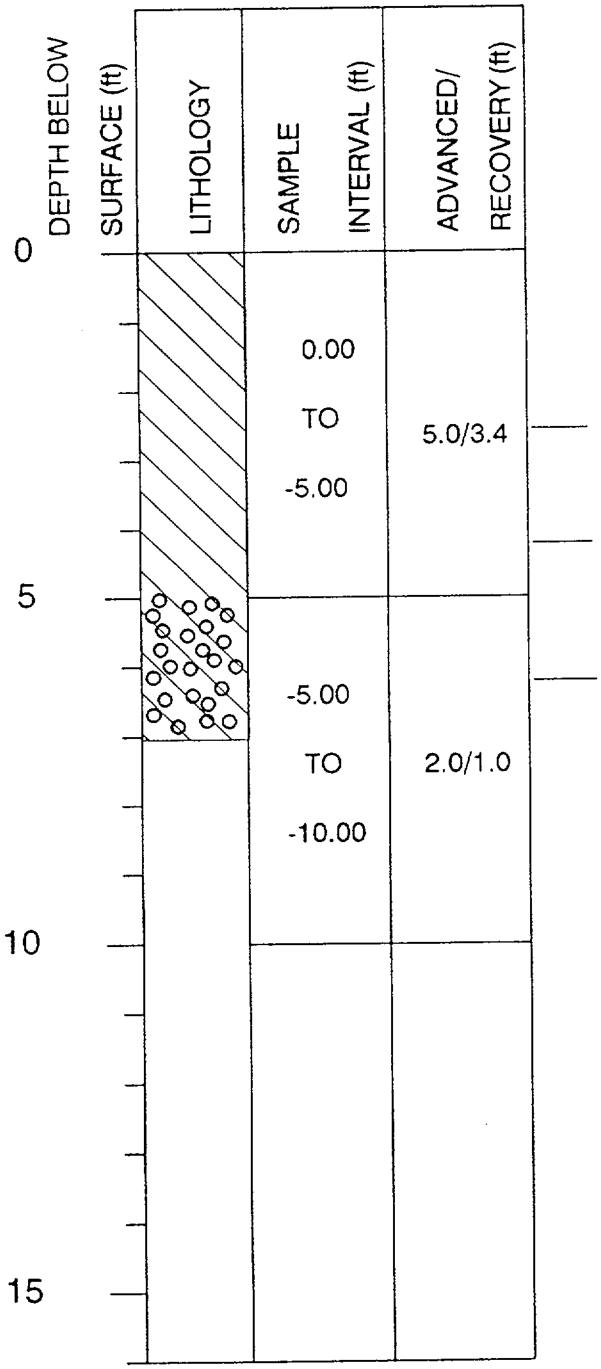
BOREHOLE NUMBER: C-21

15 November 1989



BOREHOLE NUMBER: C-22

15 November 1989



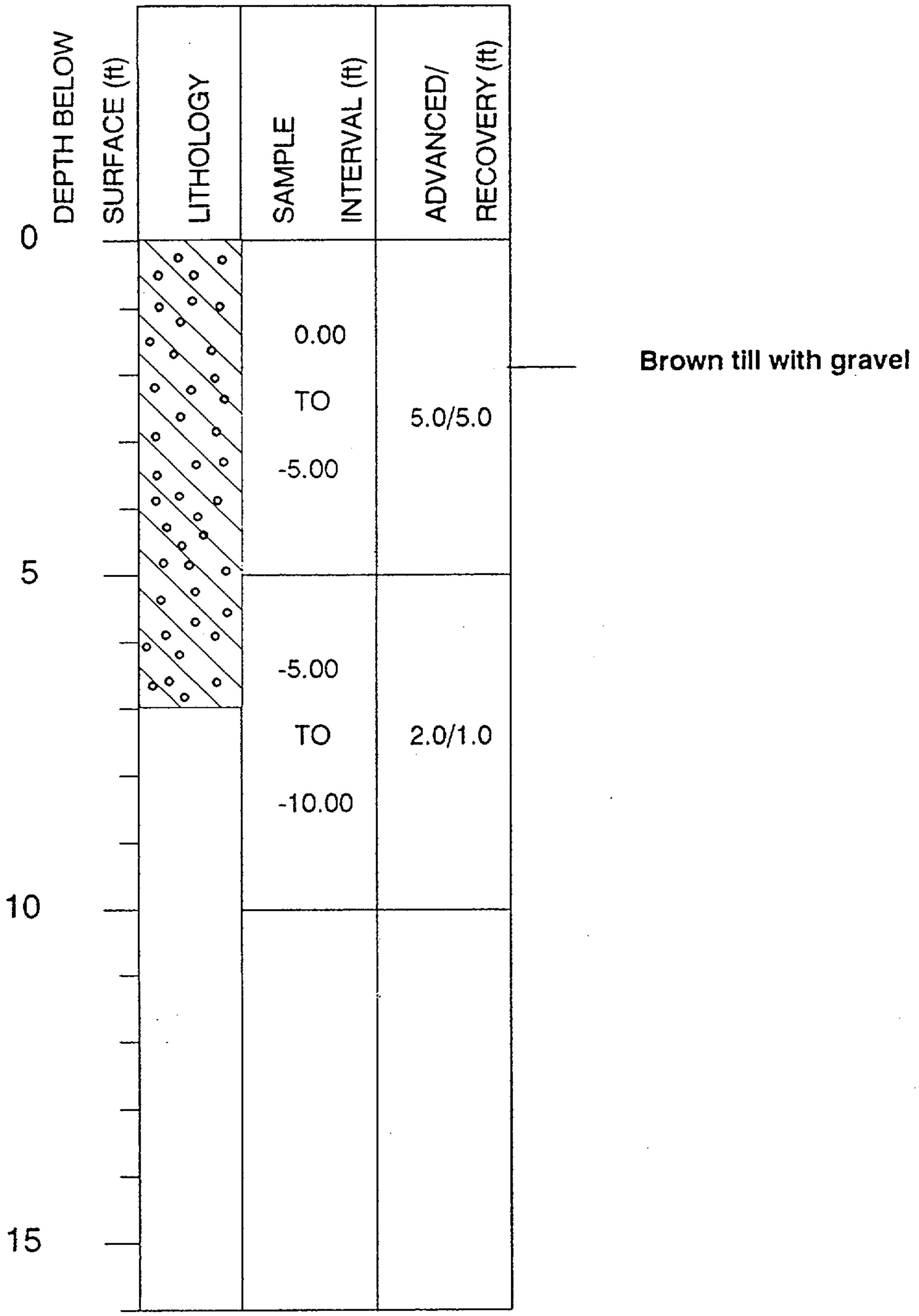
**Brown till fill**

**Gravelly in bottom 0.5 ft.**

**Brown till with gravel**

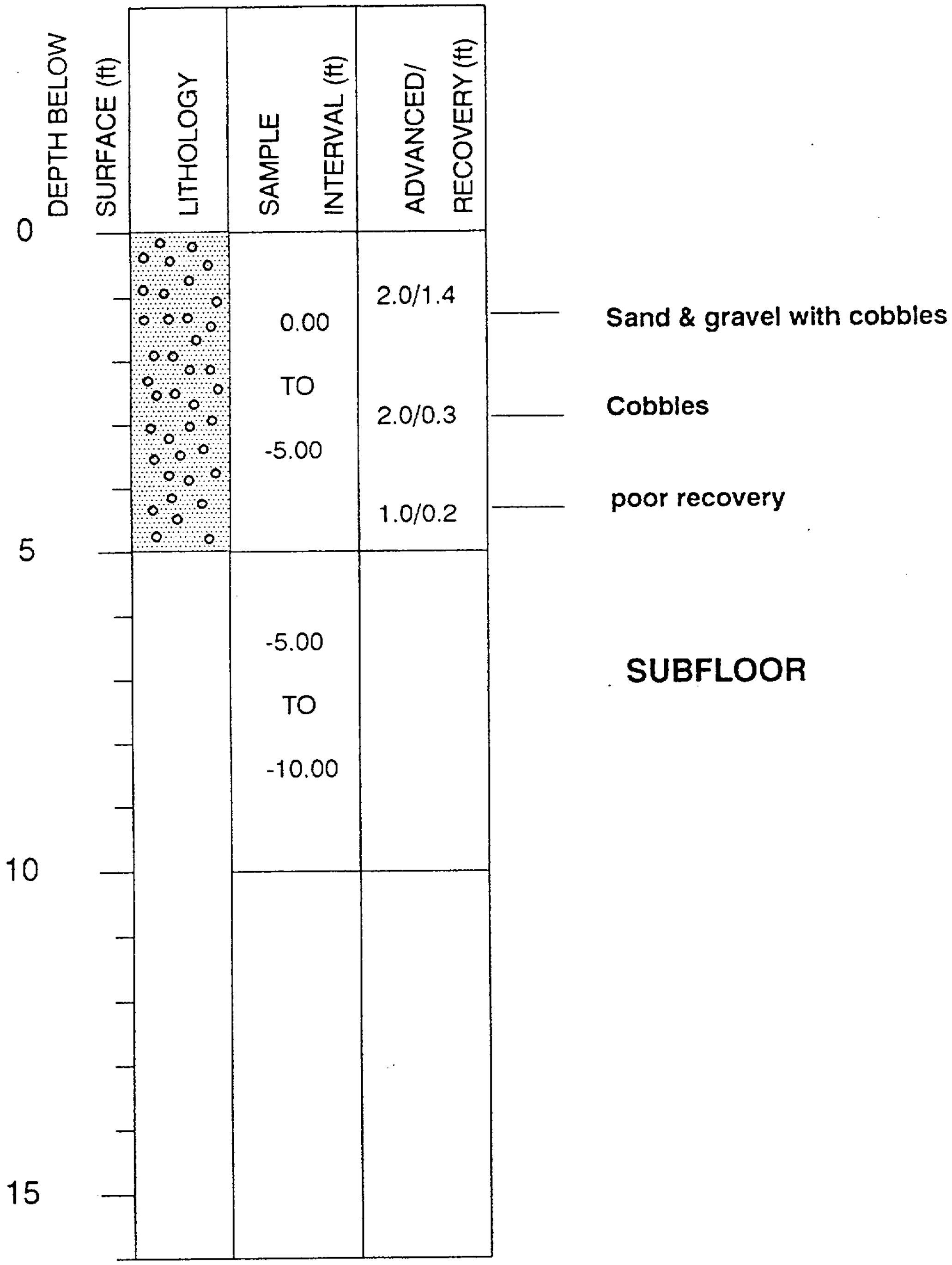
BOREHOLE NUMBER: C-23

**15 November 1989**

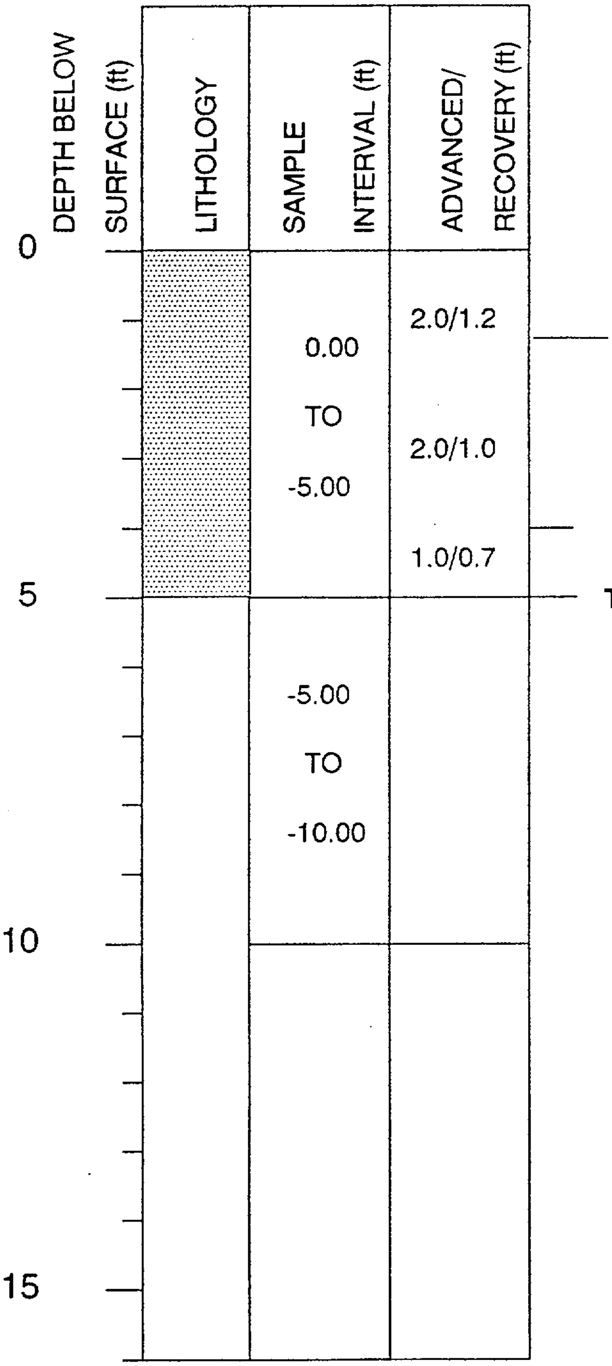


BOREHOLE NUMBER: C-24

**27 November 1989**



BOREHOLE NUMBER: C-25 27 November 1989



**Sand & gravel fill**
**tile drain in sample**

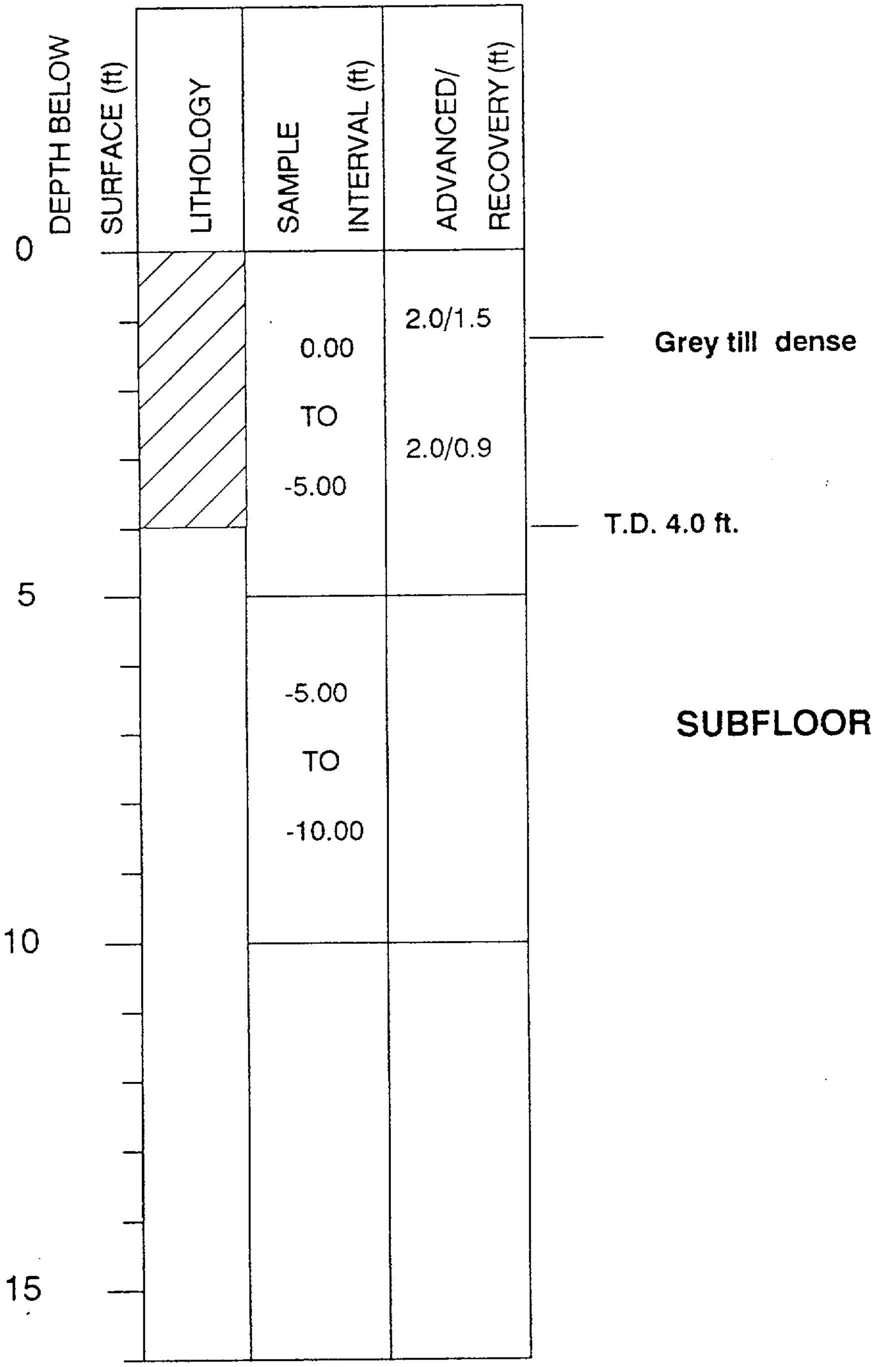
**Water encountered at 4.0 ft.**

**T.D. 5.0 ft.**

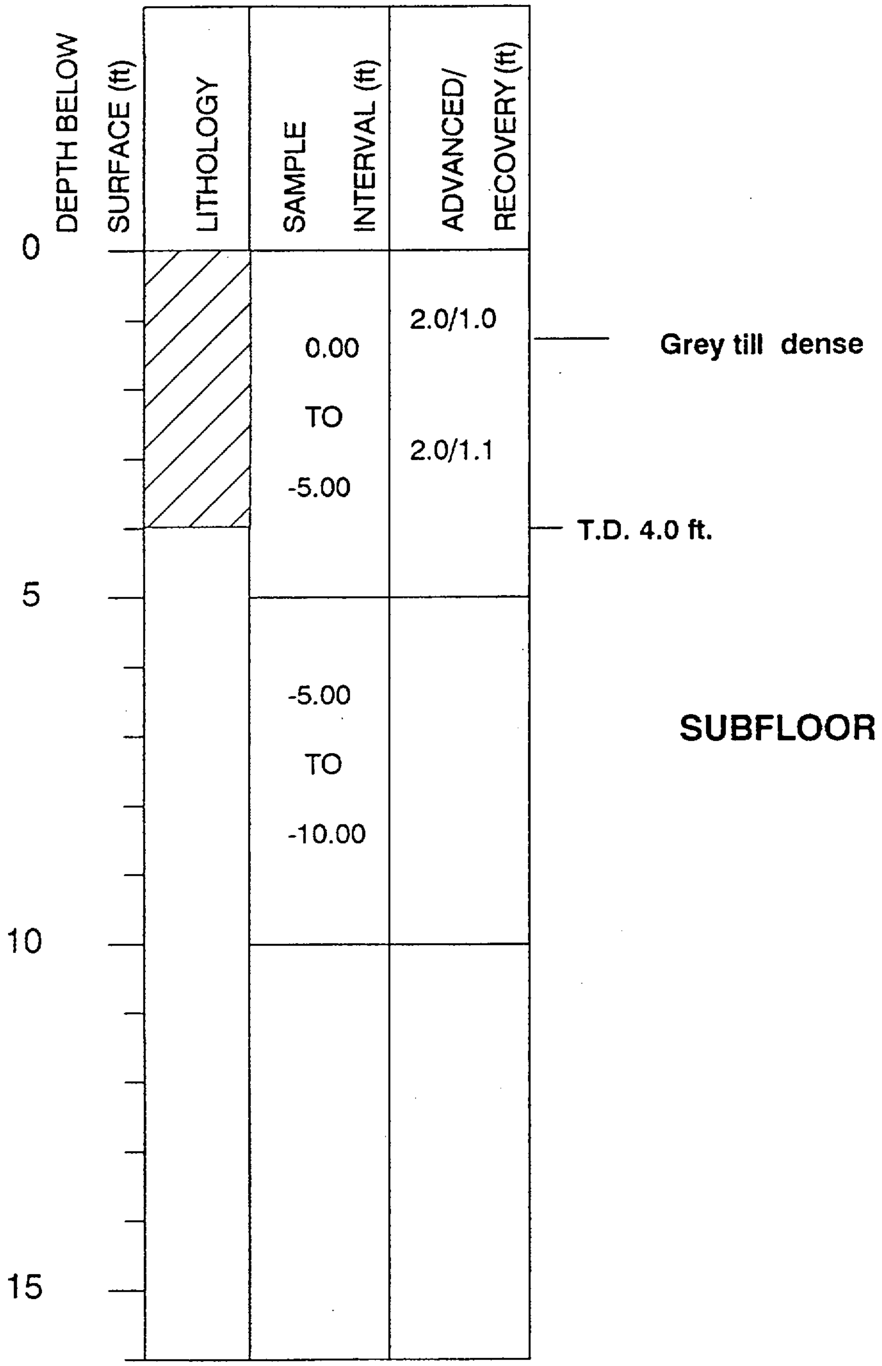
**SUBFLOOR**

BOREHOLE NUMBER: C-26

27 November 1989

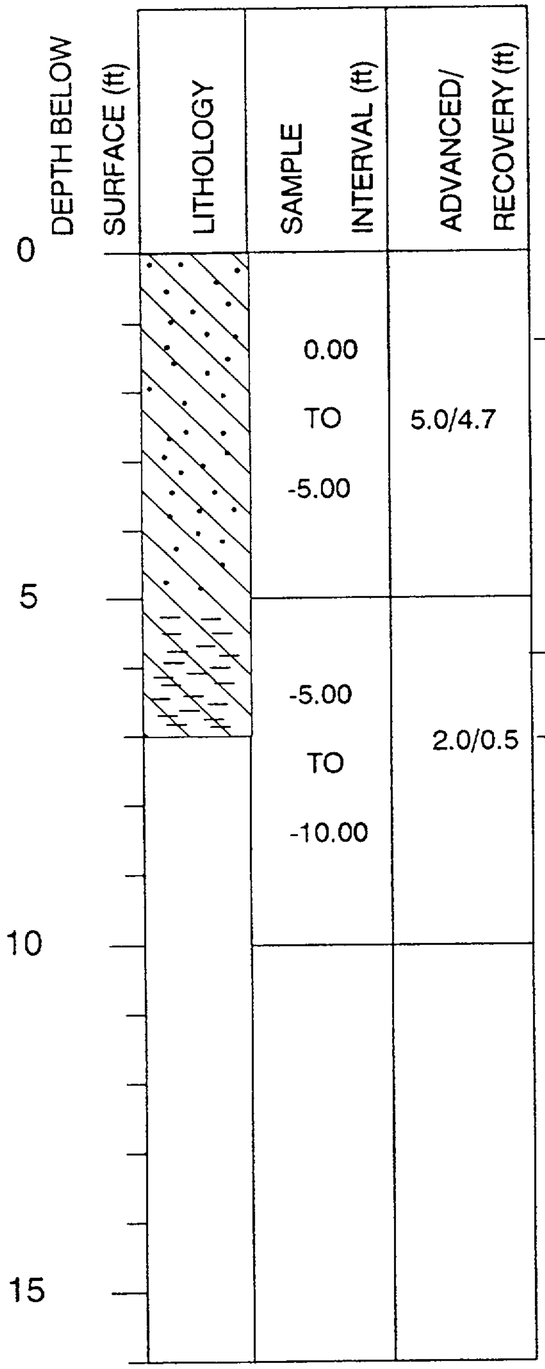


BOREHOLE NUMBER: C-27 27 November 1989



BOREHOLE NUMBER: C-28

**16 November 1989**



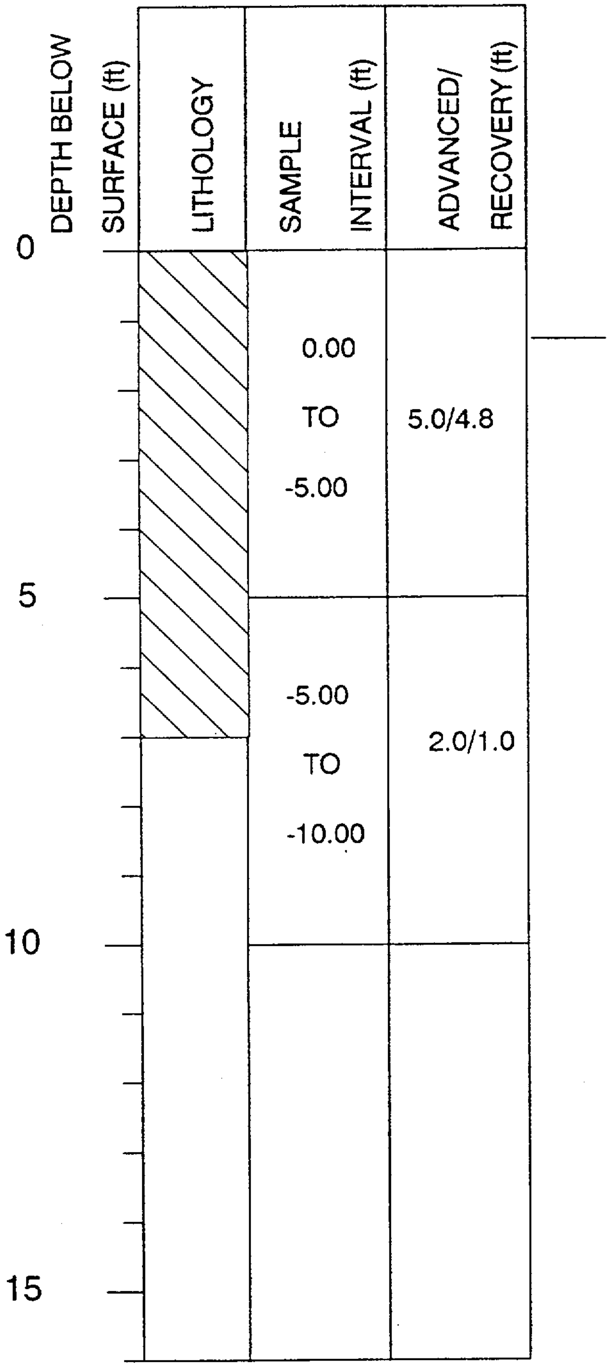
**Brown fill/till with gravel**

**Clay rich**

**T.D. 7.0 ft.**

BOREHOLE NUMBER: C-29

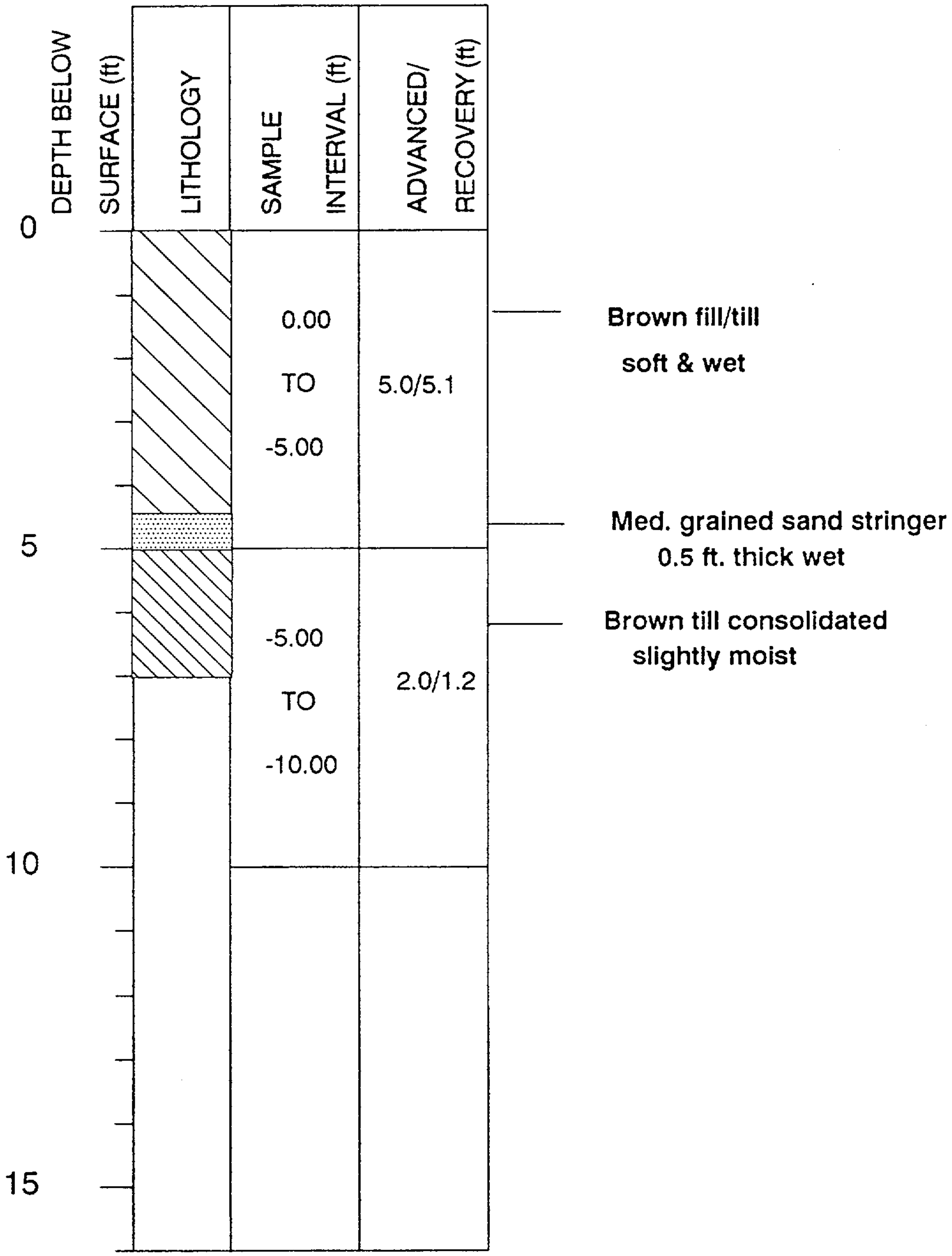
**16 November 1989**



**Brown fill/till**

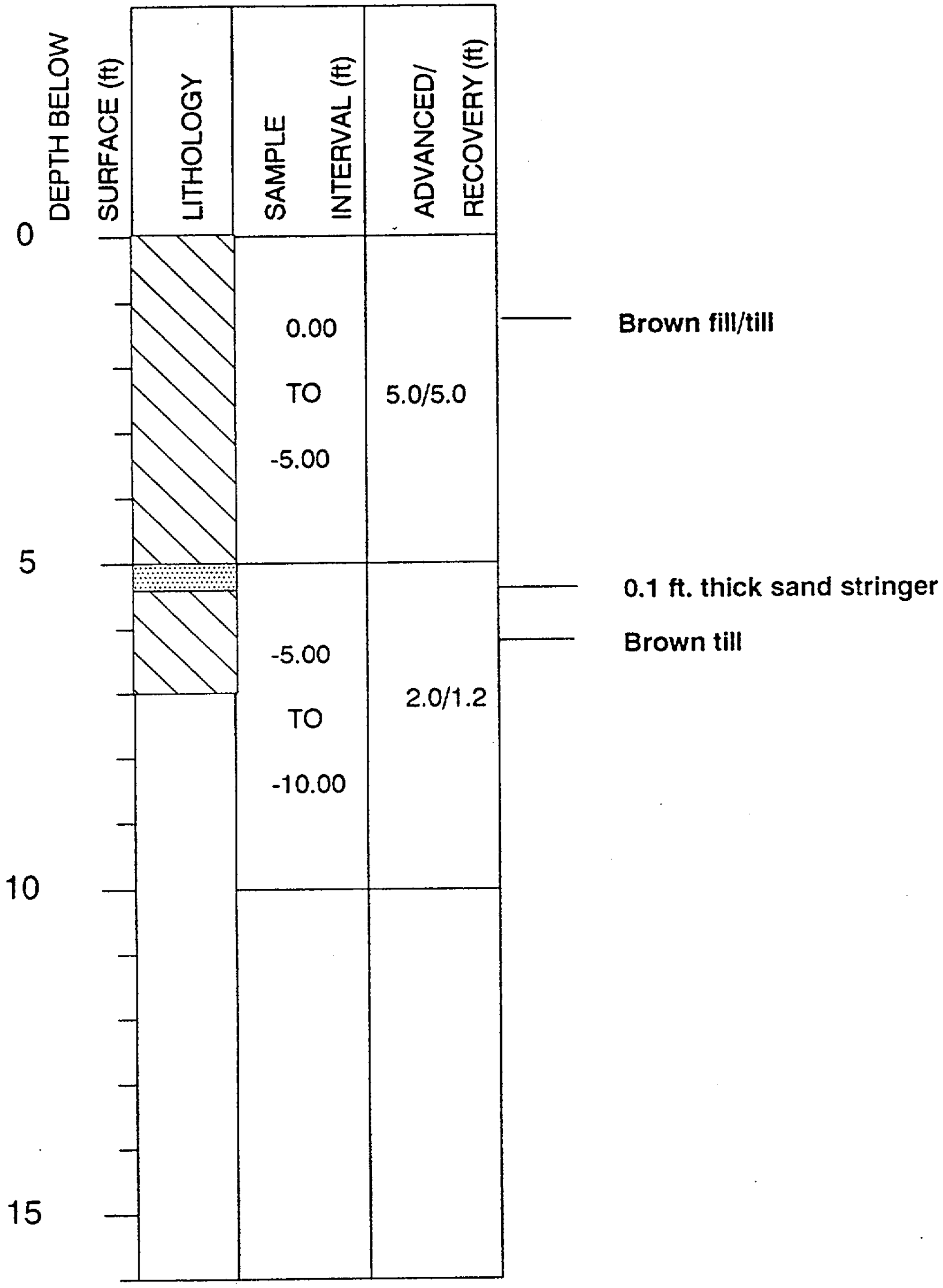
BOREHOLE NUMBER: C-30

16 November 1989



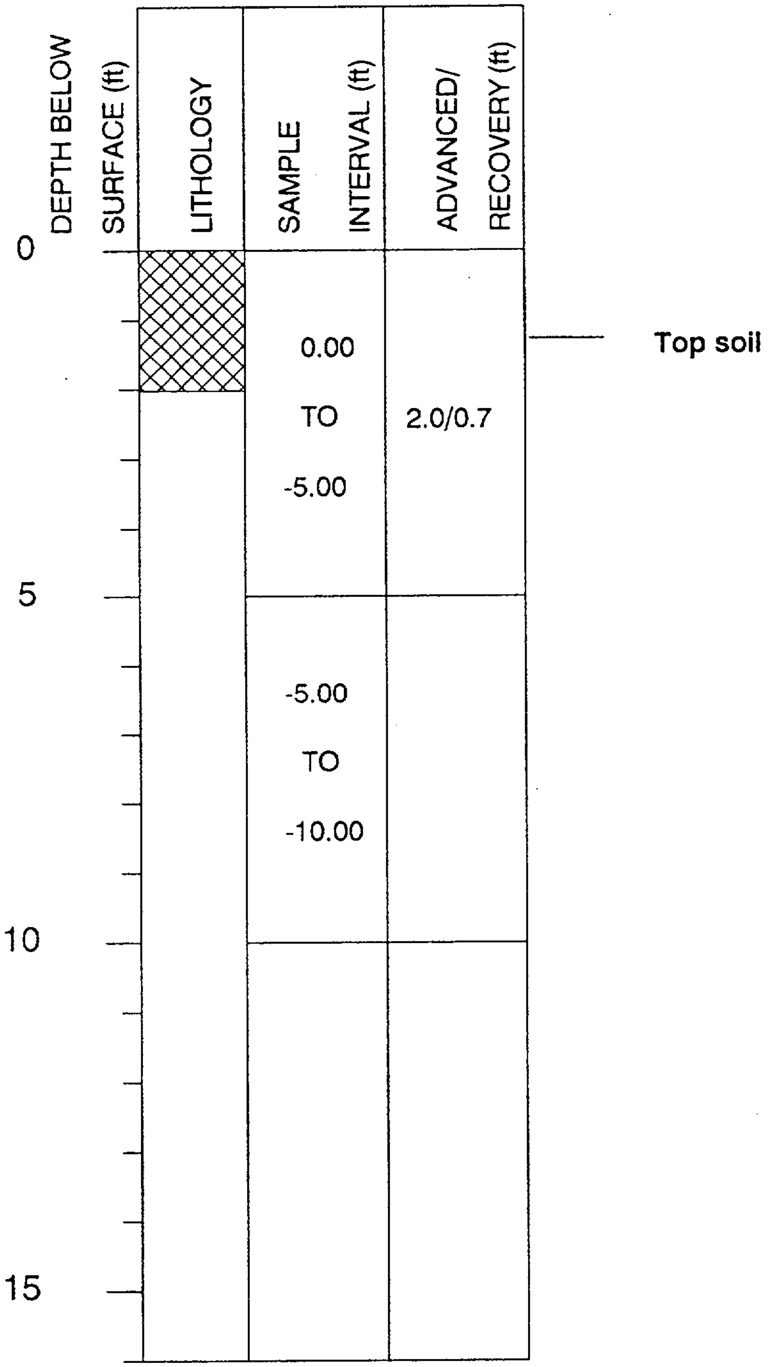
BOREHOLE NUMBER: C-31

16 November 1989



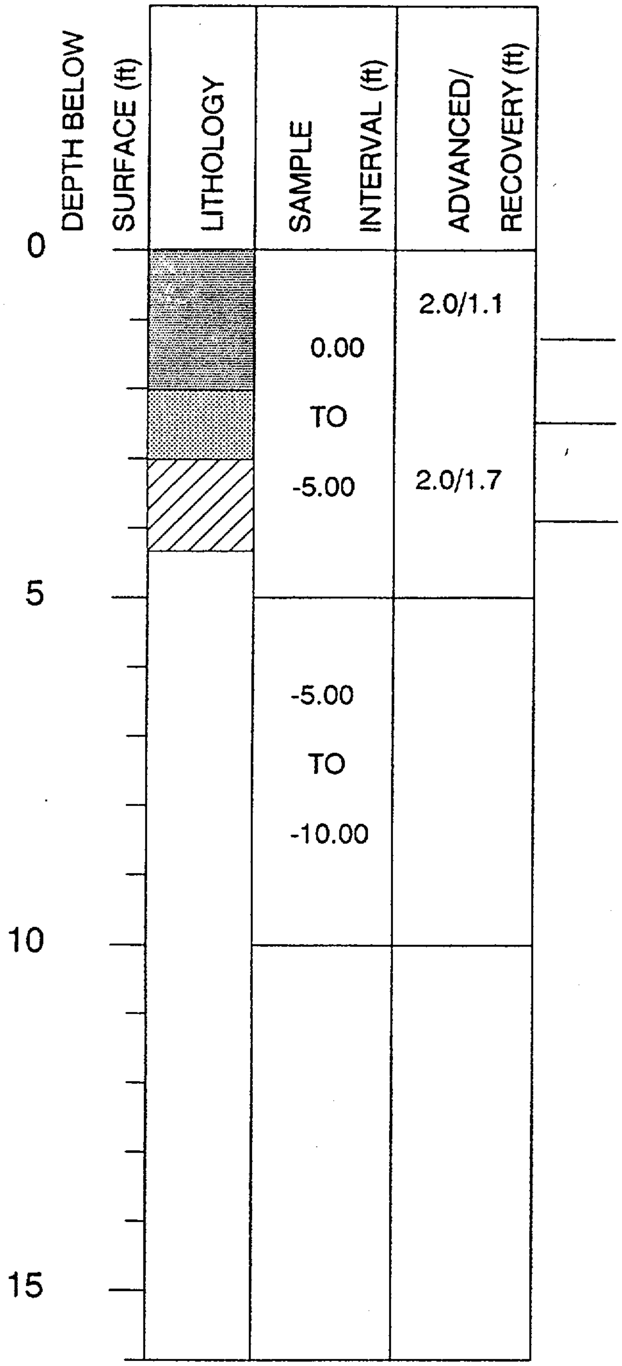
BOREHOLE NUMBER: C-32

**16 November 1989**



BOREHOLE NUMBER: R-1

28 November 1989



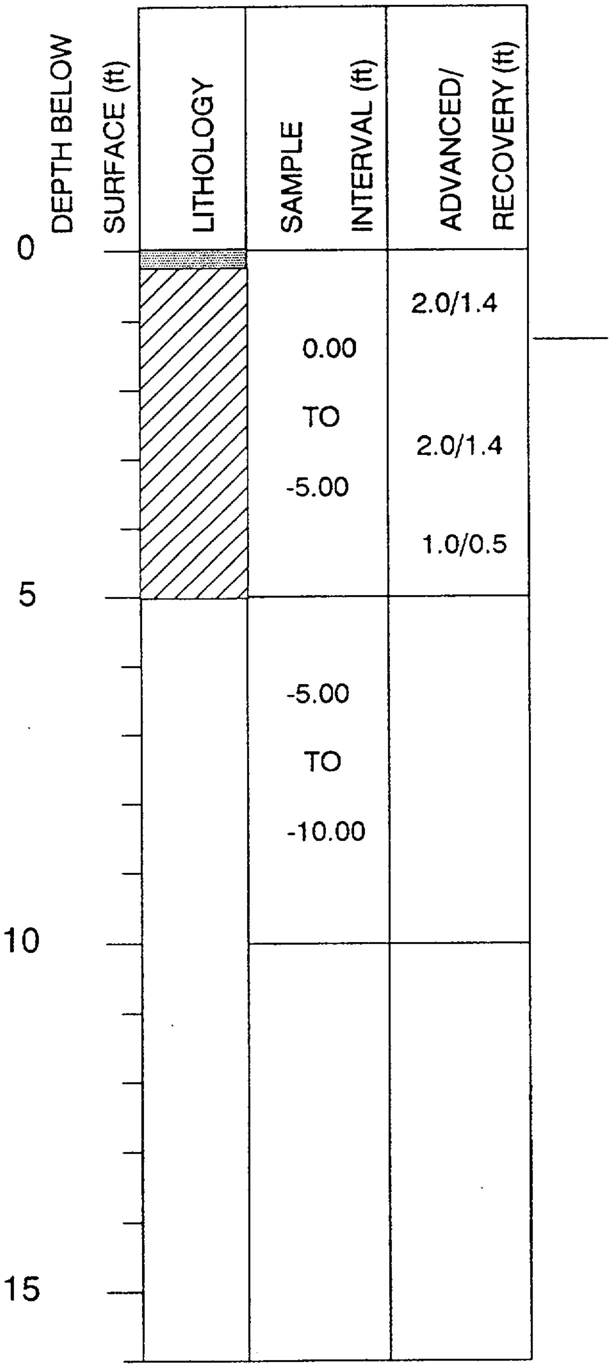
0.1 sand
1.0 soft grey mud

0.7 soft grey mud
0.15 sand wet coarse

0.85 dense grey till moist

BOREHOLE NUMBER: R-2

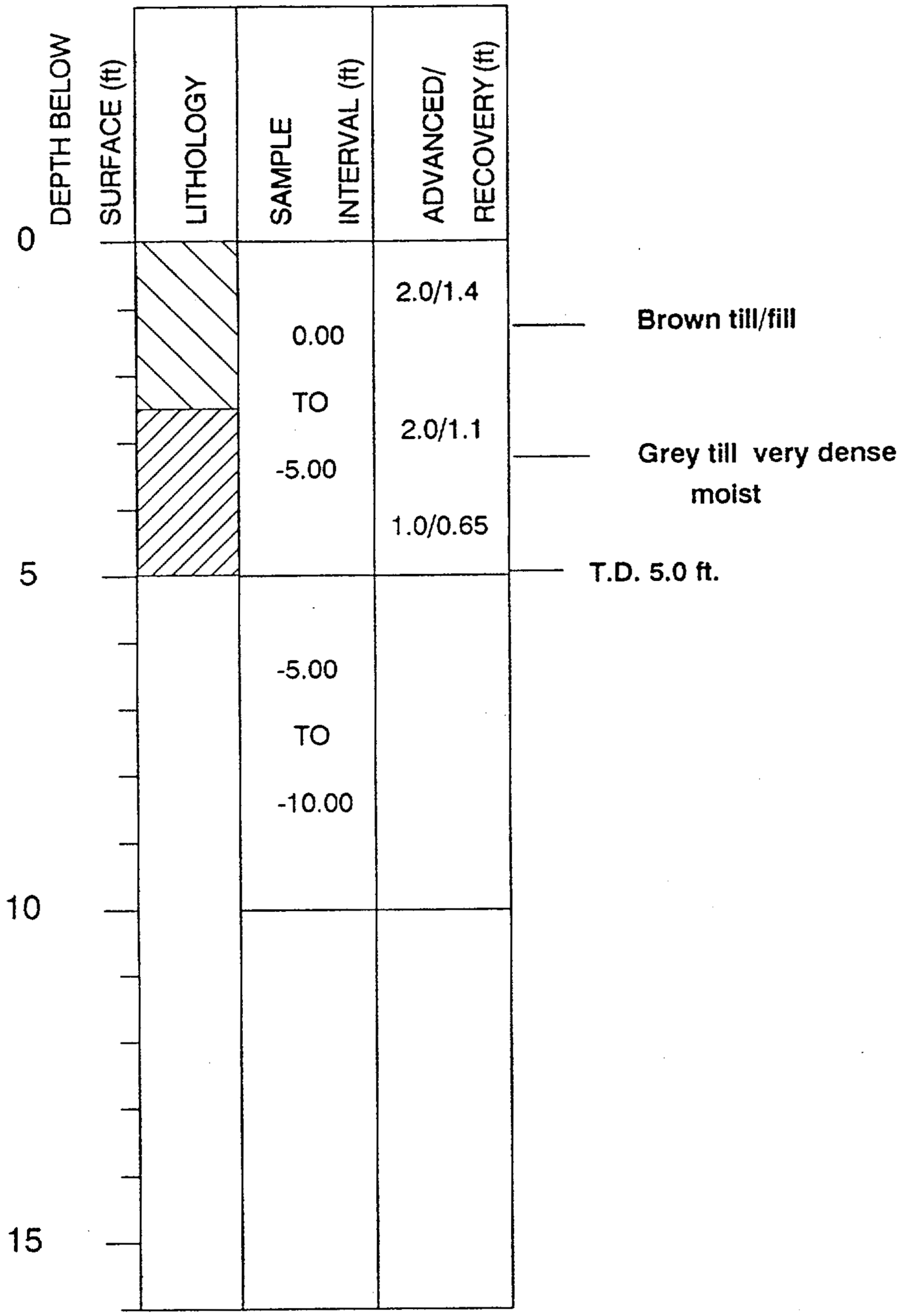
**27 November 1989**



**0.1 sand**
**Grey till very dense**

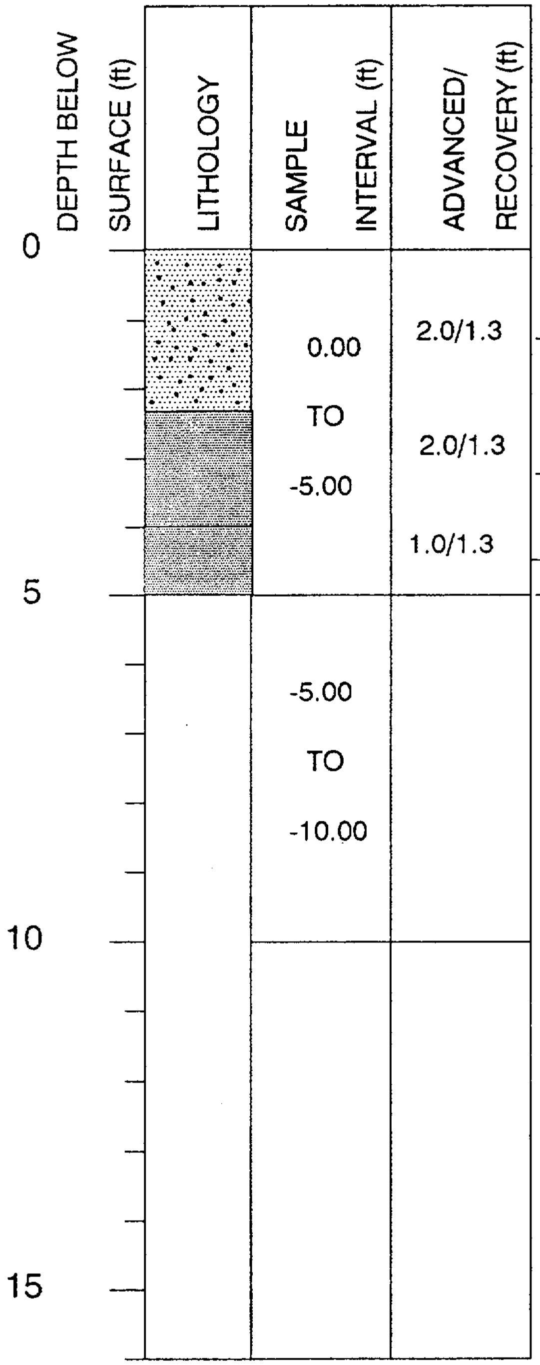
BOREHOLE NUMBER: R-3

27 November 1989



BOREHOLE NUMBER: R-4

27 November 1989



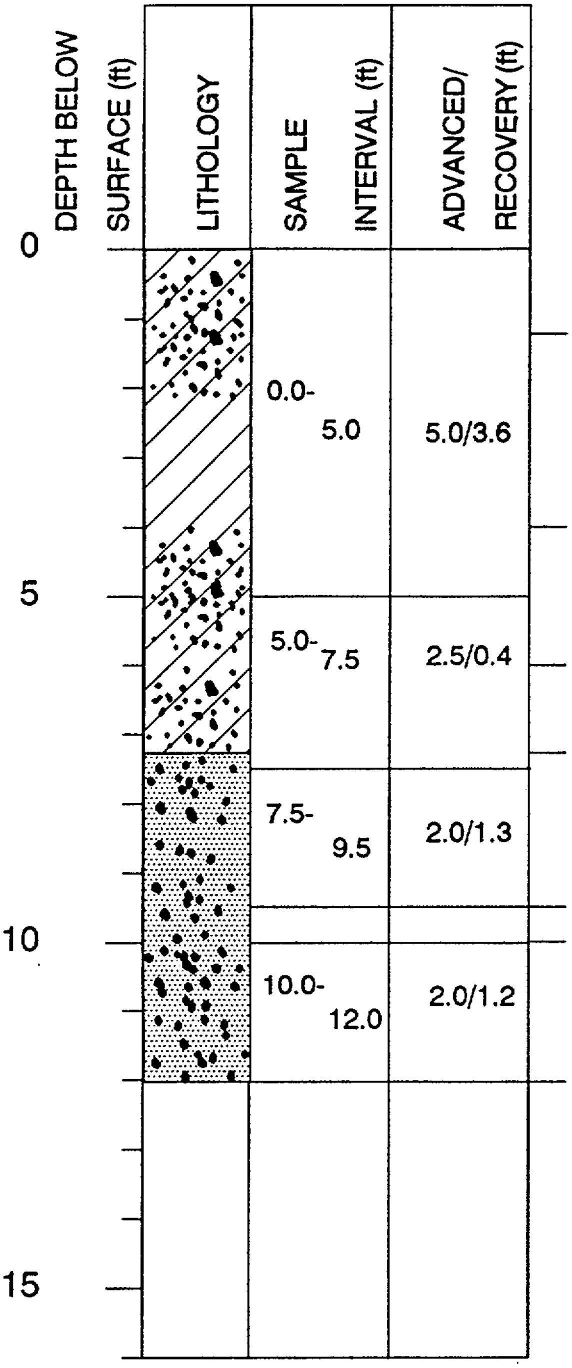
Sand & gravel

1.1 bottom Grey clay moist
cohesive but soft

Grey clay

T.D. 5.0 ft.

BOREHOLE NUMBER: R135 LOCATION: Filter Beds 31 JULY 1990



Weeds

Gravel in brown fill, upto 1 in. diameter

Brown fill, silty clay with some gravel

dark brown pebbly fill with white coatings

Water encountered at 6.0 ft

Sand, gravel, wet

Split spoon sample

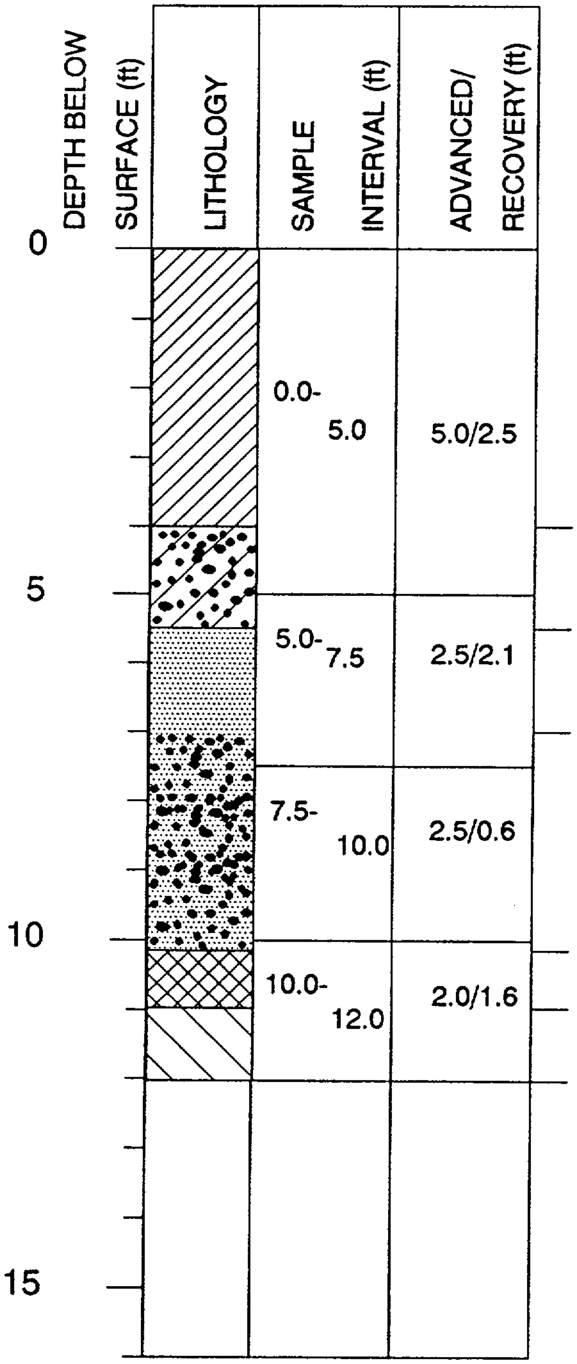
No sample

Sand and gravel, very wet and loose

Split spoon sample

T. D. 12.0 ft

BOREHOLE NUMBER: R136 LOCATION: Filter Beds 31 JULY 1990



Weeds

Brown fill, silty clayey sand

dark brown pebbly fill with white coatings

Silty sand

Water encountered at 7.0 ft

Sand and gravel, very wet and loose

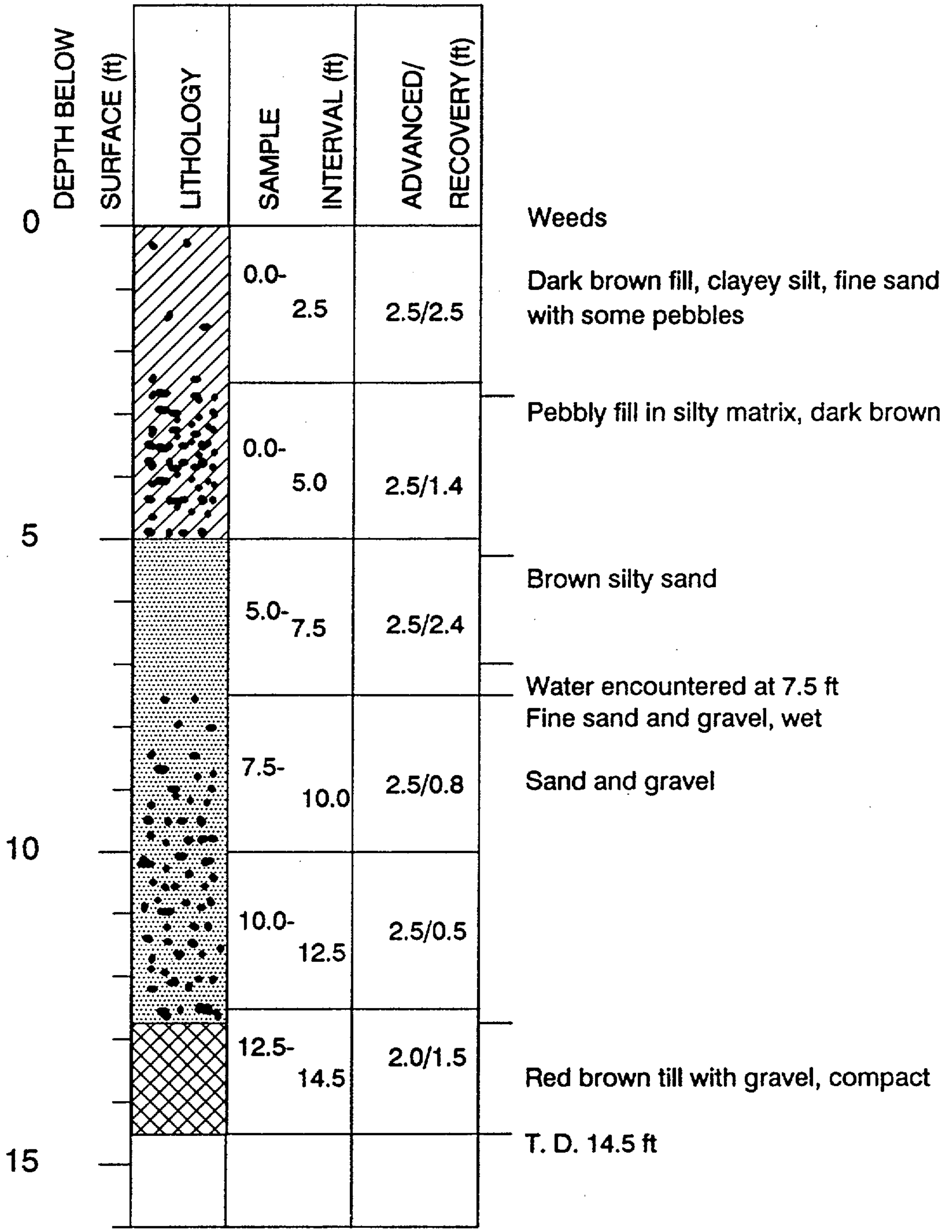
Reddish brown till

Gray till, silty, compact

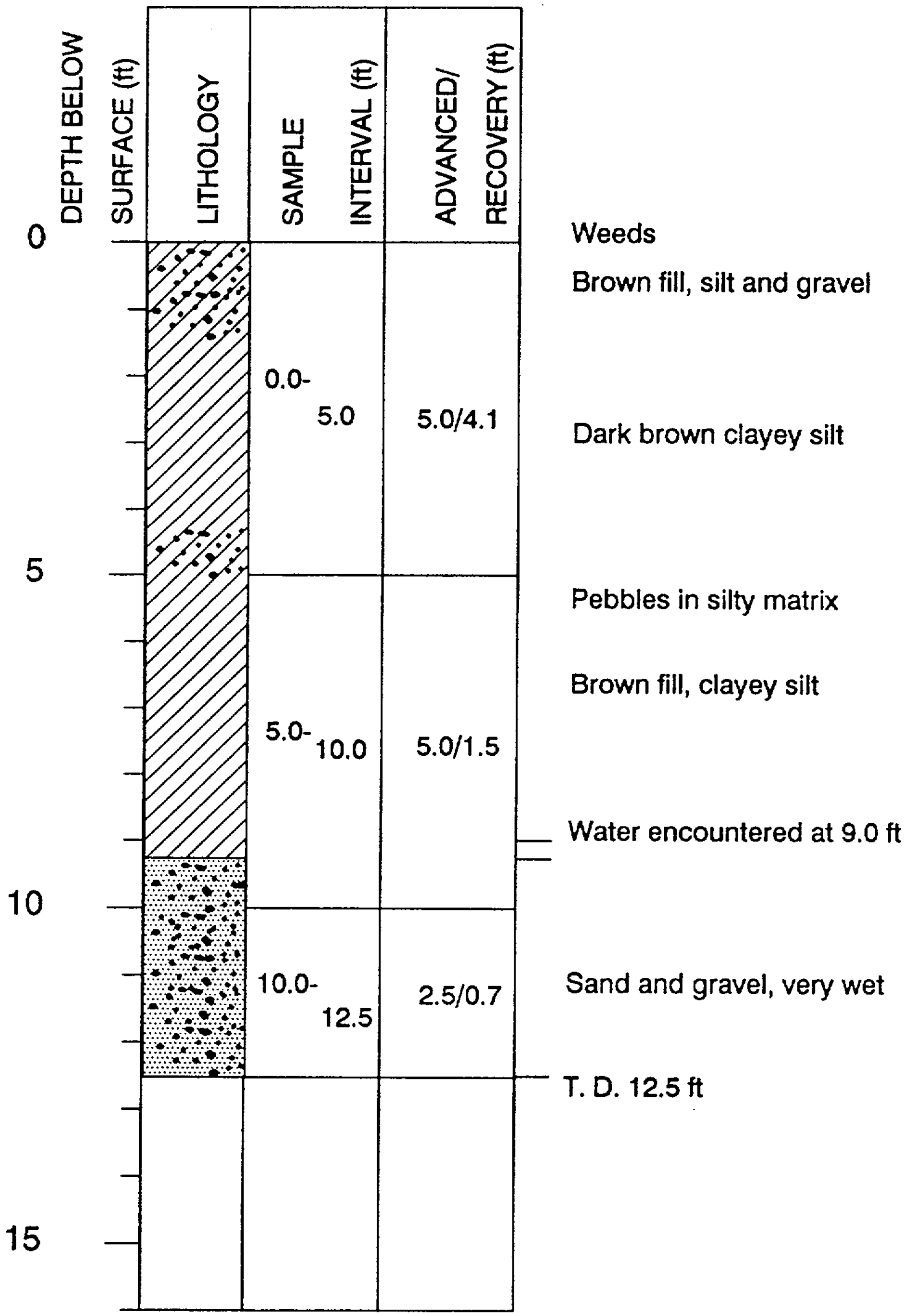
Split spoon sample

T. D. 12.0 ft

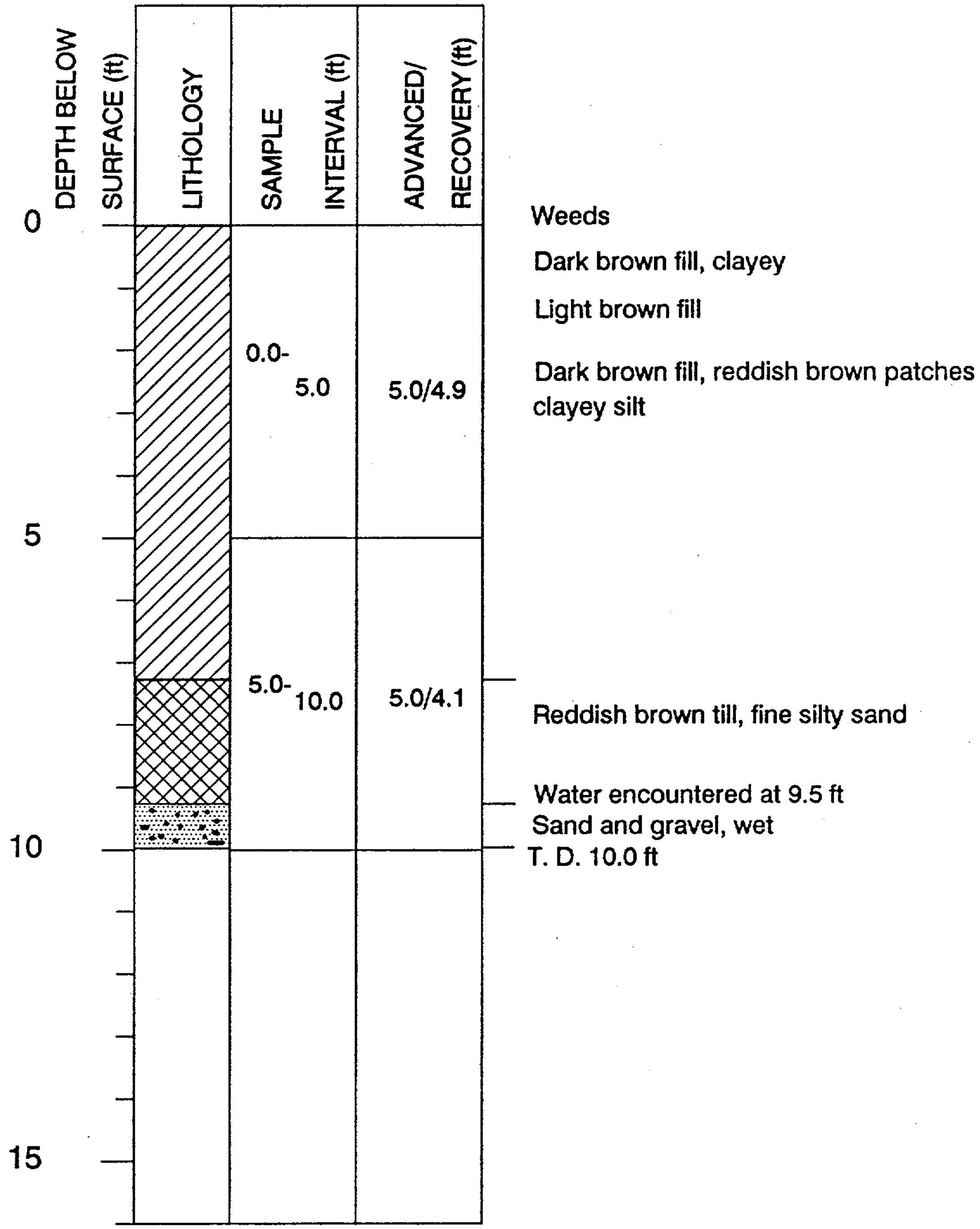
BOREHOLE NUMBER: R137 LOCATION: Filter Beds 31 JULY 1990



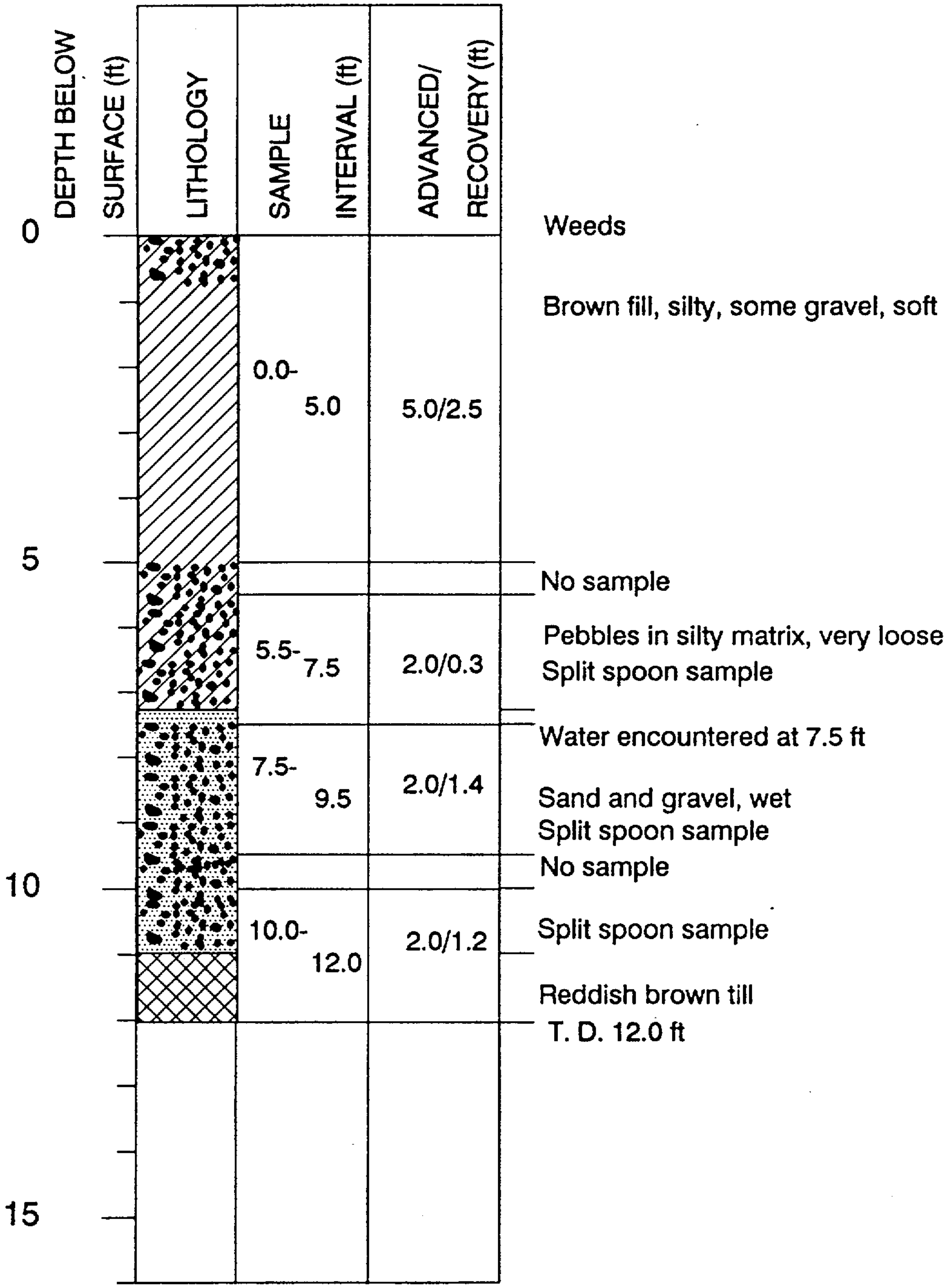
BOREHOLE NUMBER: R138 LOCATION: Filter Beds 30 JULY 1990



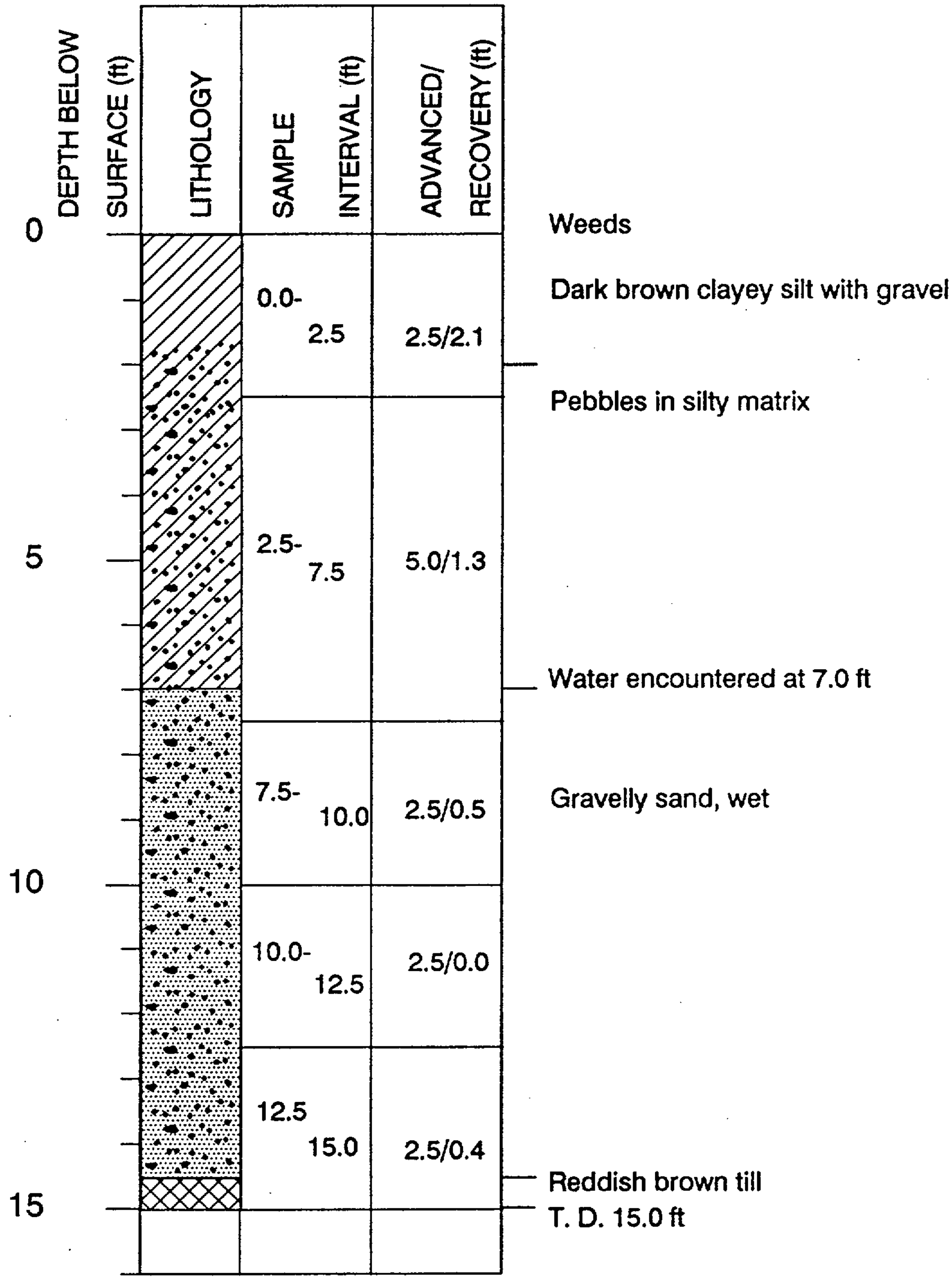
BOREHOLE NUMBER: R139 LOCATION: Filter Beds 30 JULY 1990



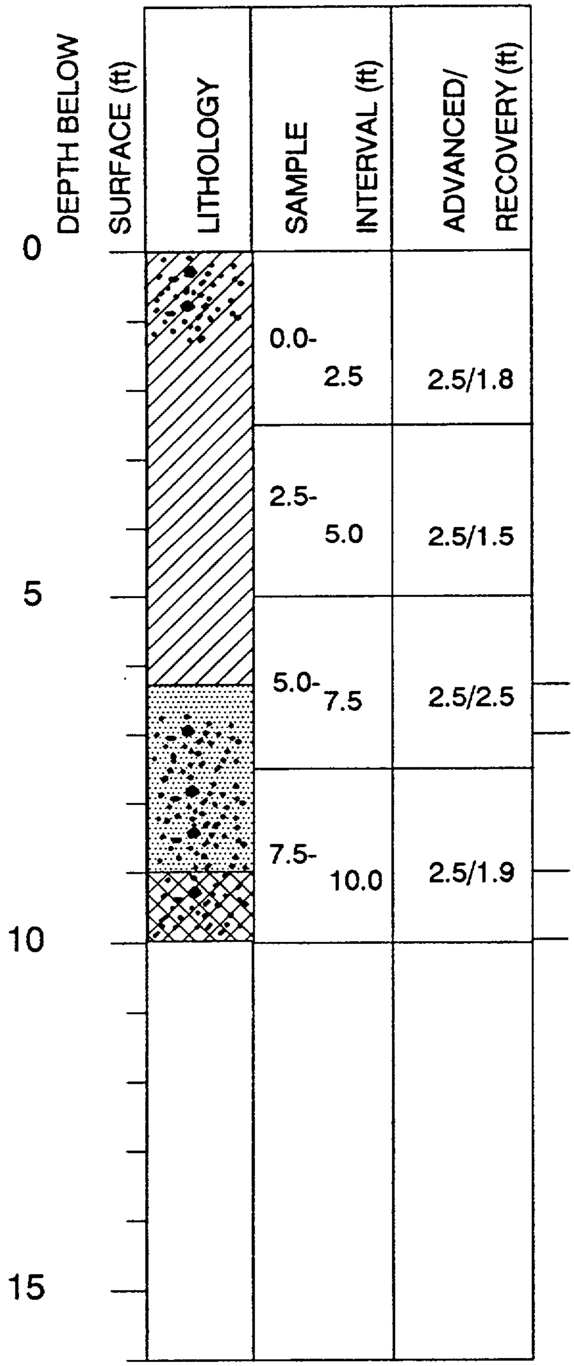
BOREHOLE NUMBER: R140B LOCATION: Filter Beds 31 JULY 1990



BOREHOLE NUMBER: R141 LOCATION: Filter Beds 30 JULY 1990



BOREHOLE NUMBER: R142 LOCATION: Filter Beds 30 JULY 1990



Weeds

Dark brown silty fill, gravel

becoming compact and moist with depth

Light brown silty sand

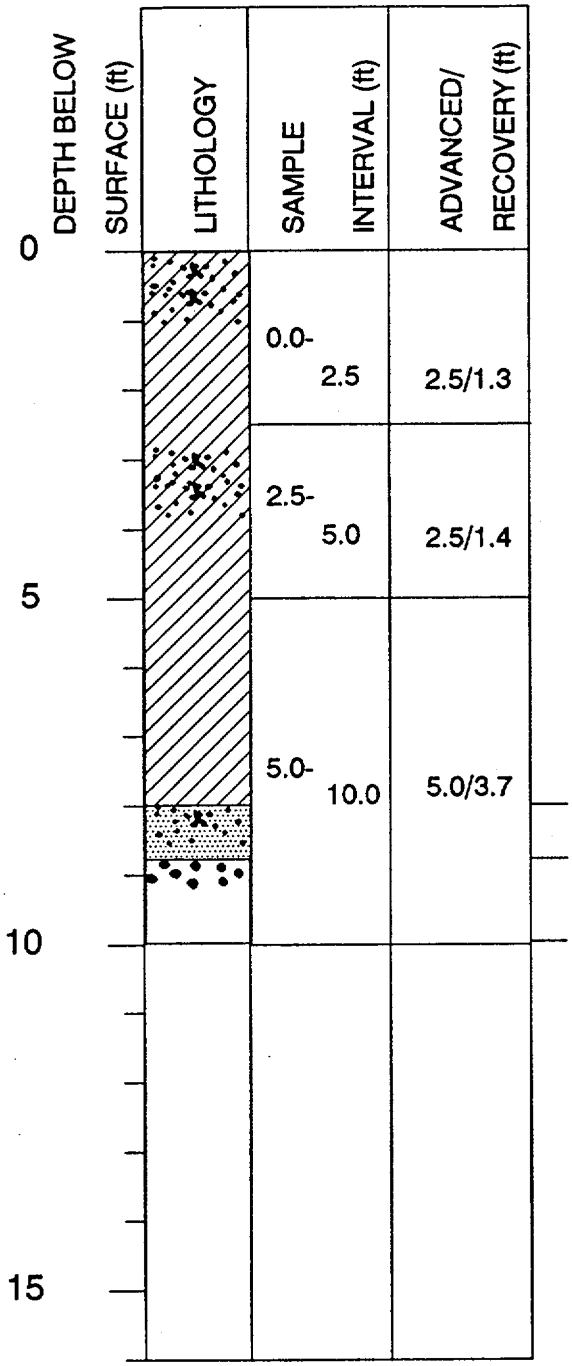
Water encountered at 7.0 ft

Very coarse sand and gravel, wet

Compact reddish brown till with gravel

T. D. 10.0 ft

BOREHOLE NUMBER: R143 LOCATION: Filter Beds 30 JULY 1990



| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| 0.0-2.5 | 2.5/1.3 |
| 2.5-5.0 | 2.5/1.4 |
| 5.0-10.0 | 5.0/3.7 |

Weeds

Dark brown clayey silt, gravel

loose material

Light brown clayey silt

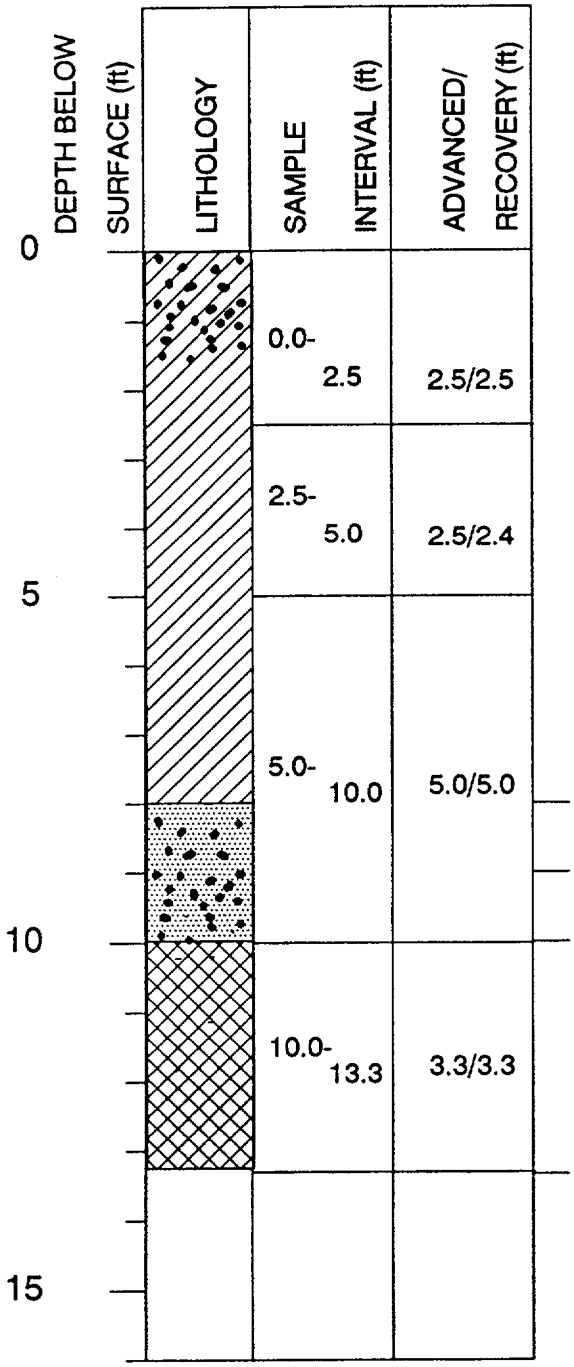
water encountered at 8.0 ft

Sand and gravel, wet

Gravel, upto 1.5 in. diameter, no recovery

T. D. 10.0 ft

BOREHOLE NUMBER: R144 LOCATION: Filter Beds 30 JULY 1990



Weeds

Dark brown to brown sandy silt, pebbles
High organic content

moist

Light brown silty sand, fine, large pabbles

Water encountered at 9.0 ft

Reddish brown till with pebbles, cobbles and gravel, compact

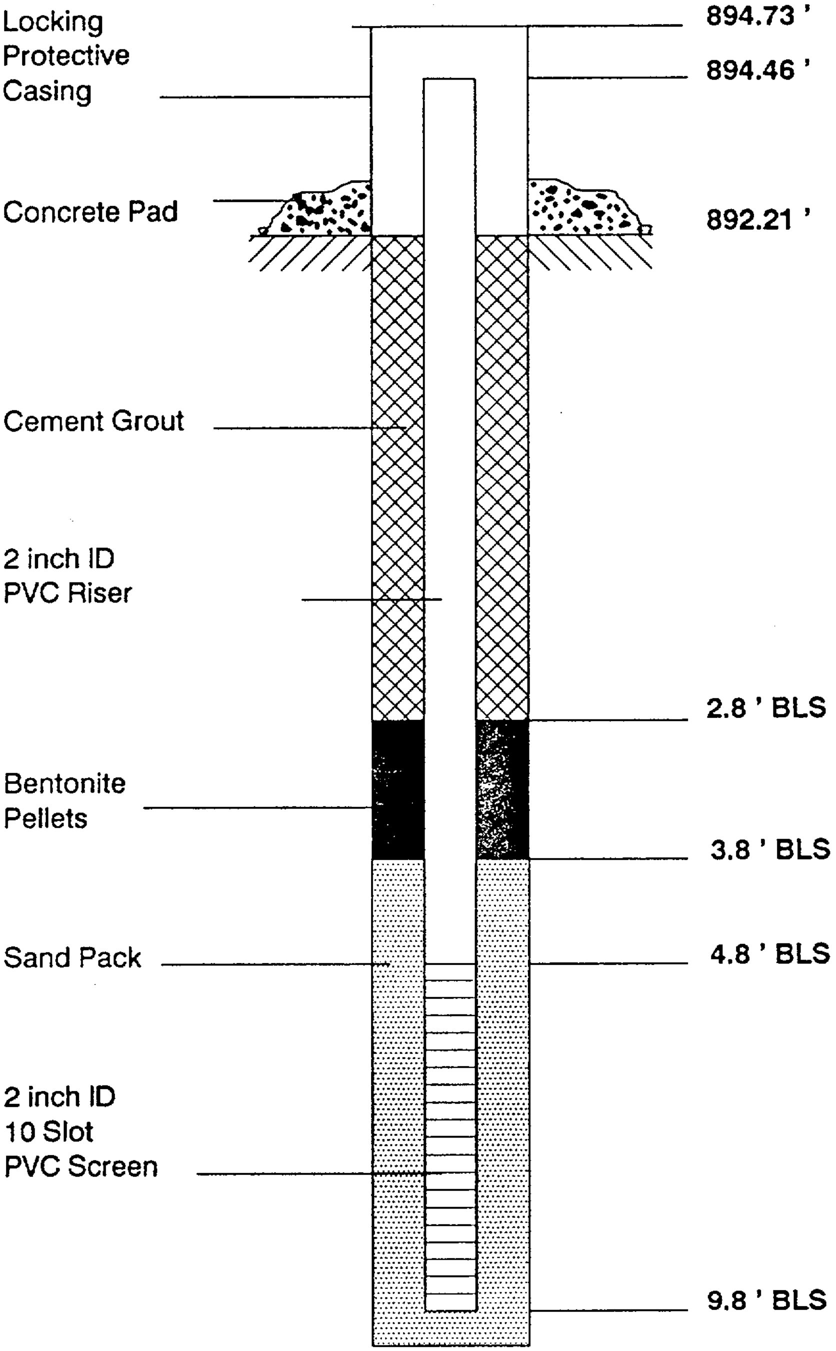
T. D. 13.3 ft

# APPENDIX 2

## MONITORING WELLS CONSTRUCTION DIAGRAMS

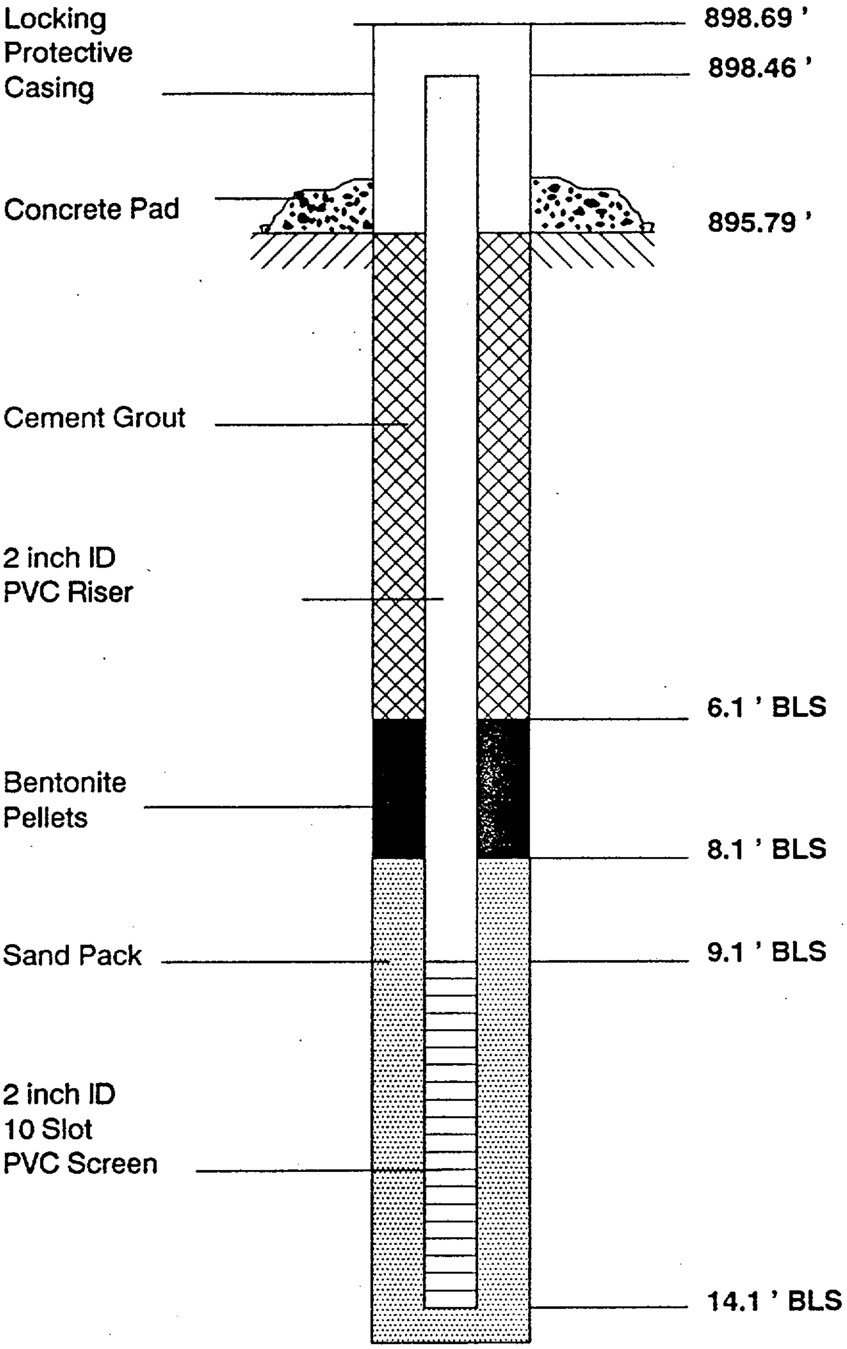
**BOREHOLE NUMBER: 150 LOCATION: Sample Area 1 25 April 1989**

Total Depth **10.0 '** Borehole Diameter **0.7 '**



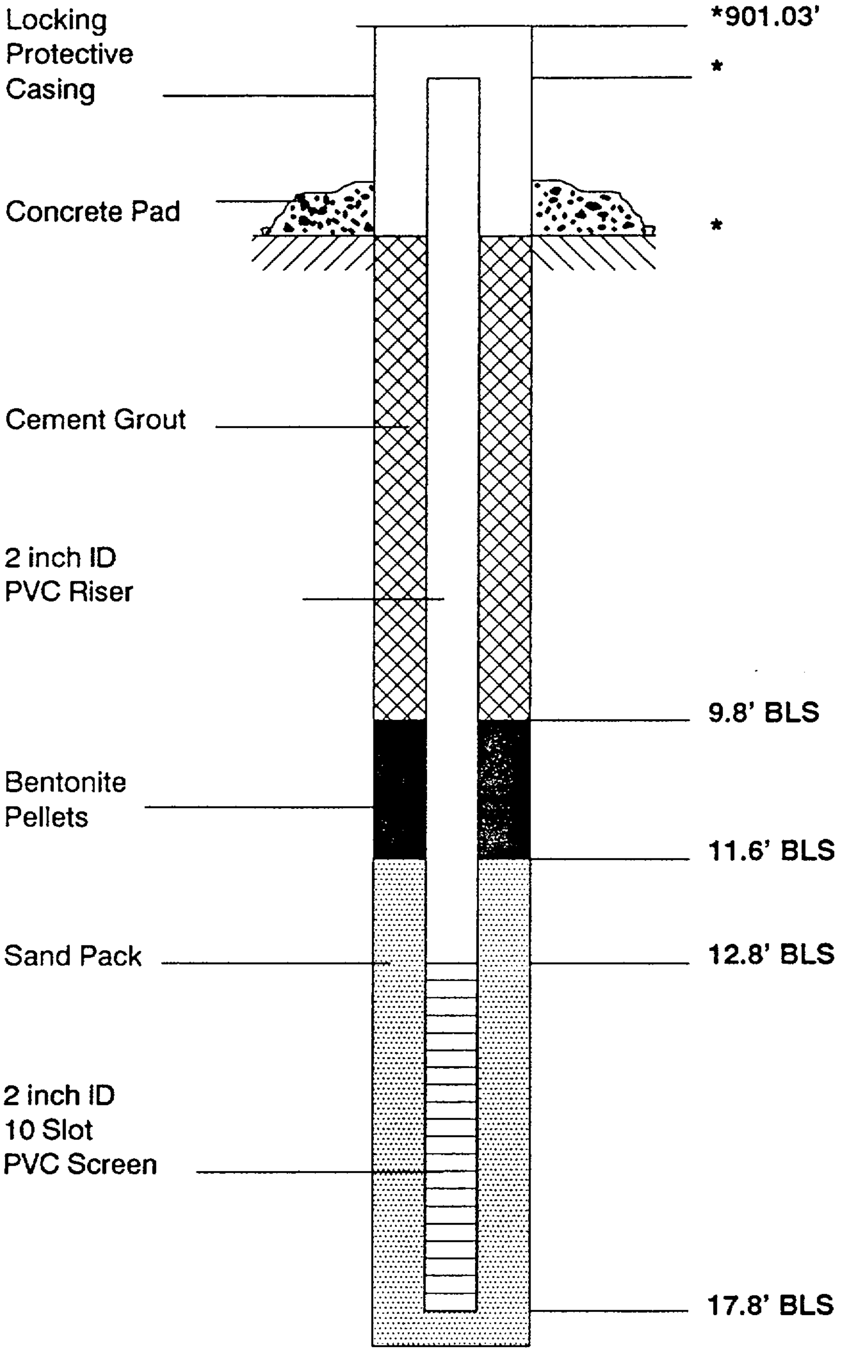
**BOREHOLE NUMBER: 155 LOCATION: Sample Area 1 27 April 1989**

Total Depth **14.5 '** Borehole Diameter **0.7 '**



BOREHOLE NUMBER: 158  LOCATION:Sample Area 1   28 April 1989

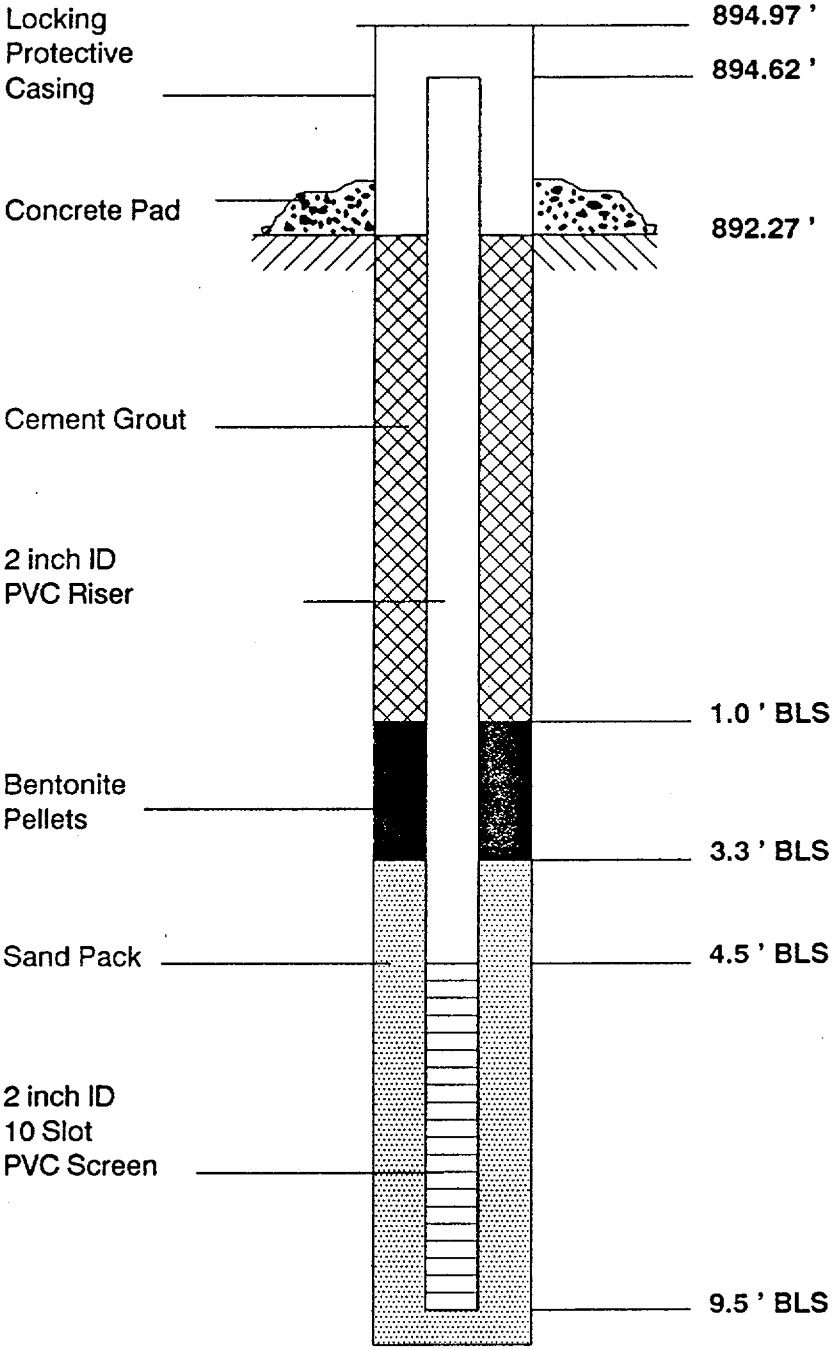
Total Depth  19.0'     Borehole Diameter  0.7'



* The well has been damaged, and the elevations are approximate.

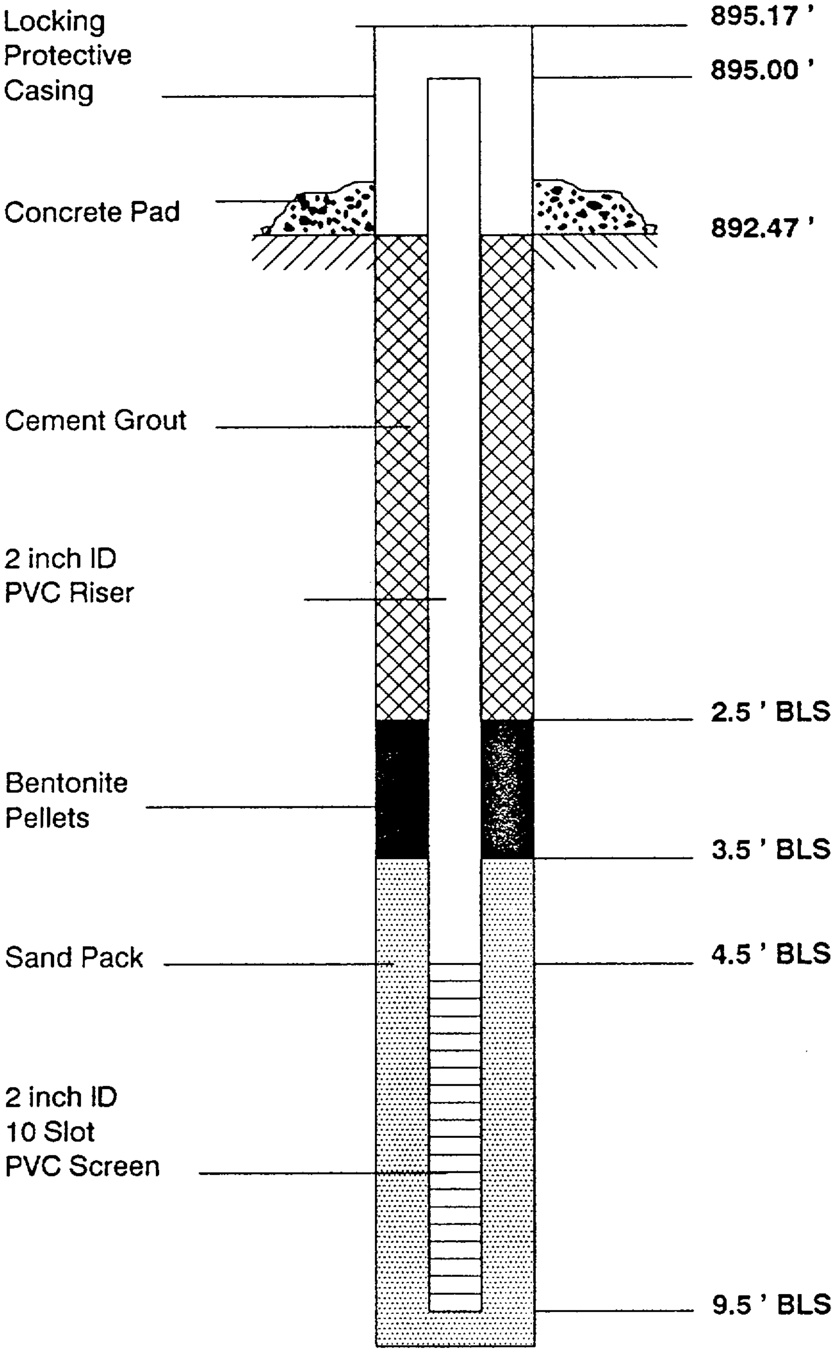
**BOREHOLE NUMBER: 168    LOCATION: Sample Area 1    25 April 1989**

Total Depth 10.0 '    Borehole Diameter 0.7 '



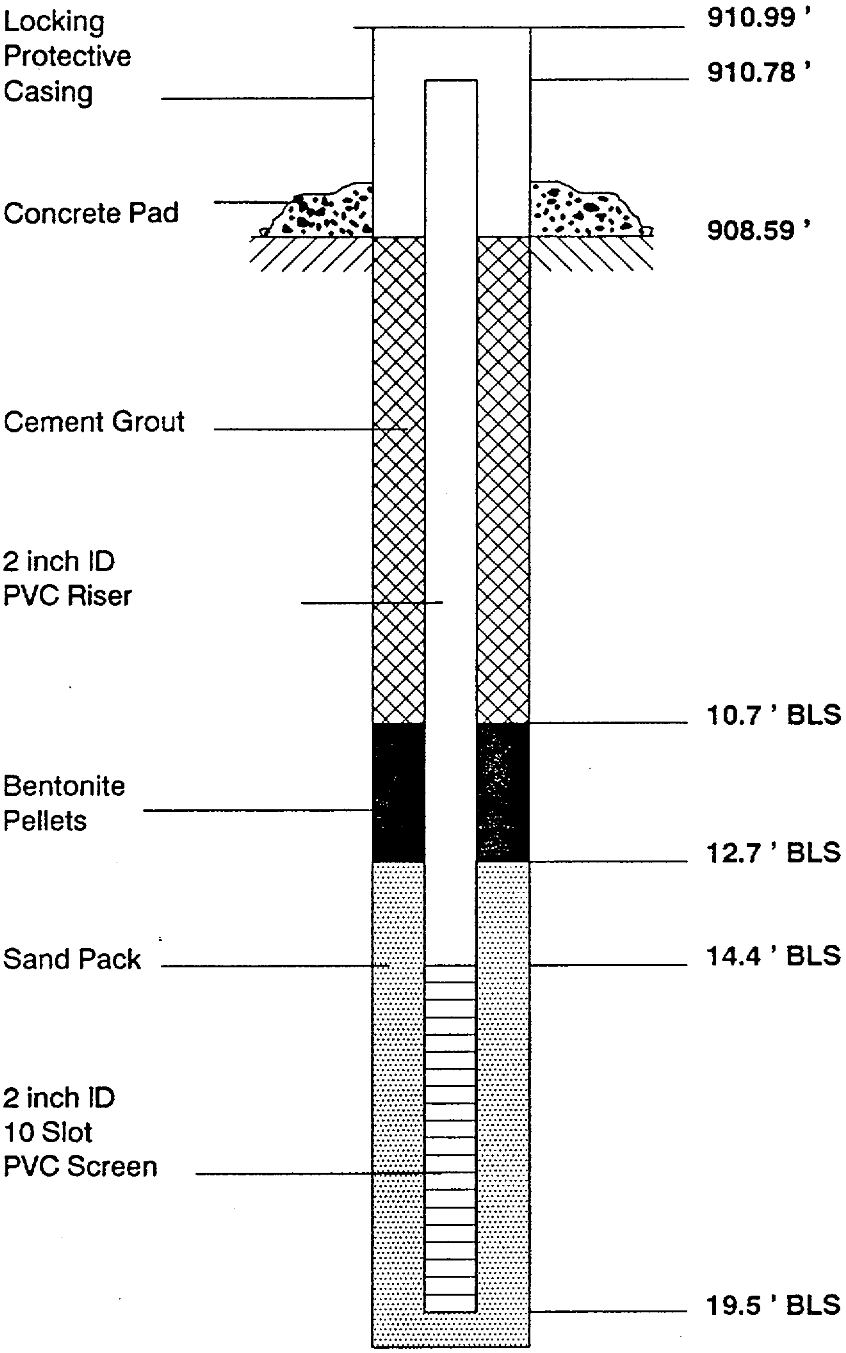
**BOREHOLE NUMBER: 172   LOCATION: Sample Area 1   27 April 1989**

Total Depth **10.5 '**   Borehole Diameter **0.7 '**



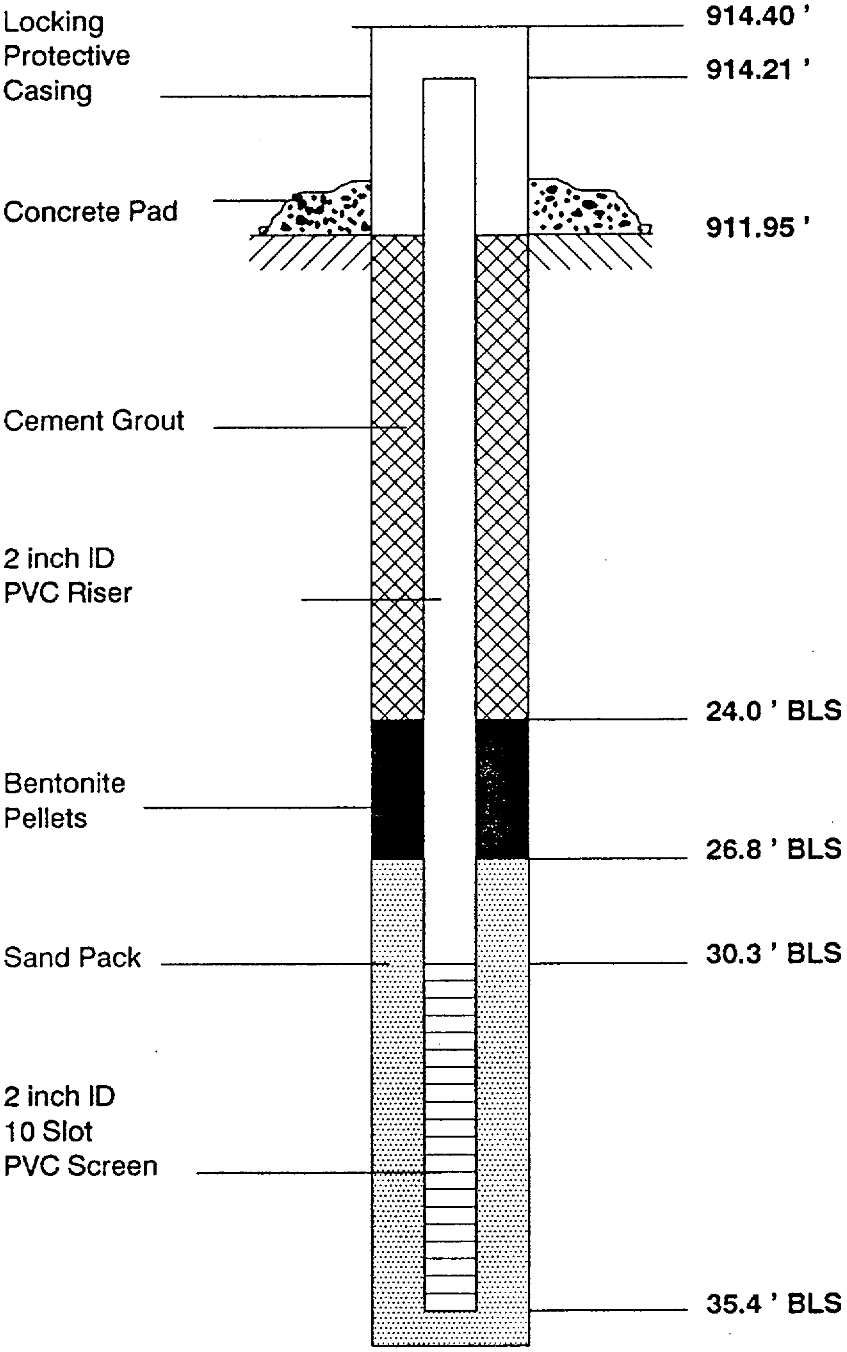
**BOREHOLE NUMBER: 206 LOCATION: Sample Area 2 27 June 1989**

Total Depth **19.6 '** Borehole Diameter **0.7 '**



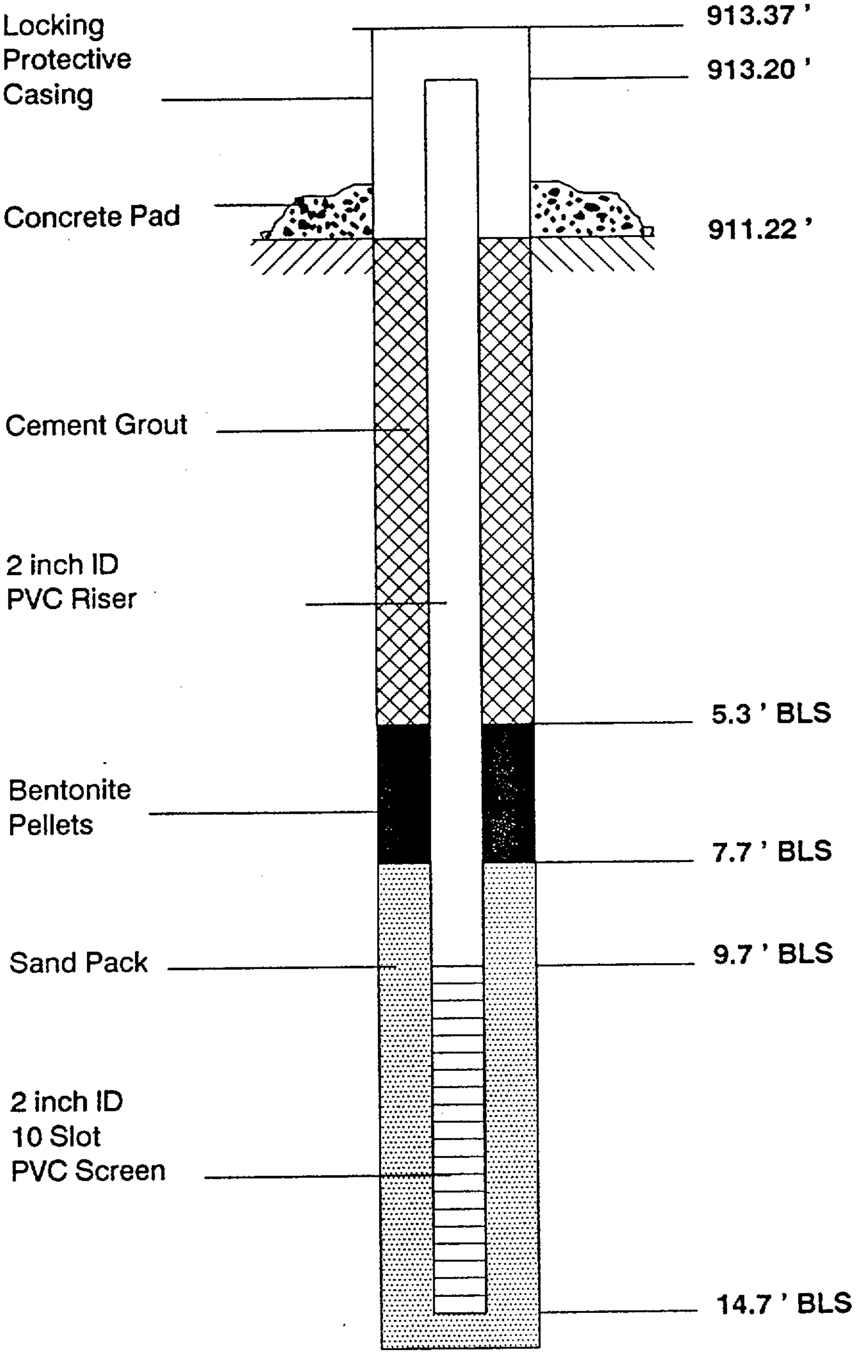
**BOREHOLE NUMBER: 300 LOCATION: Sample Area 3 30 June 1989**

Total Depth **35.5 '** Borehole Diameter **0.7 '**



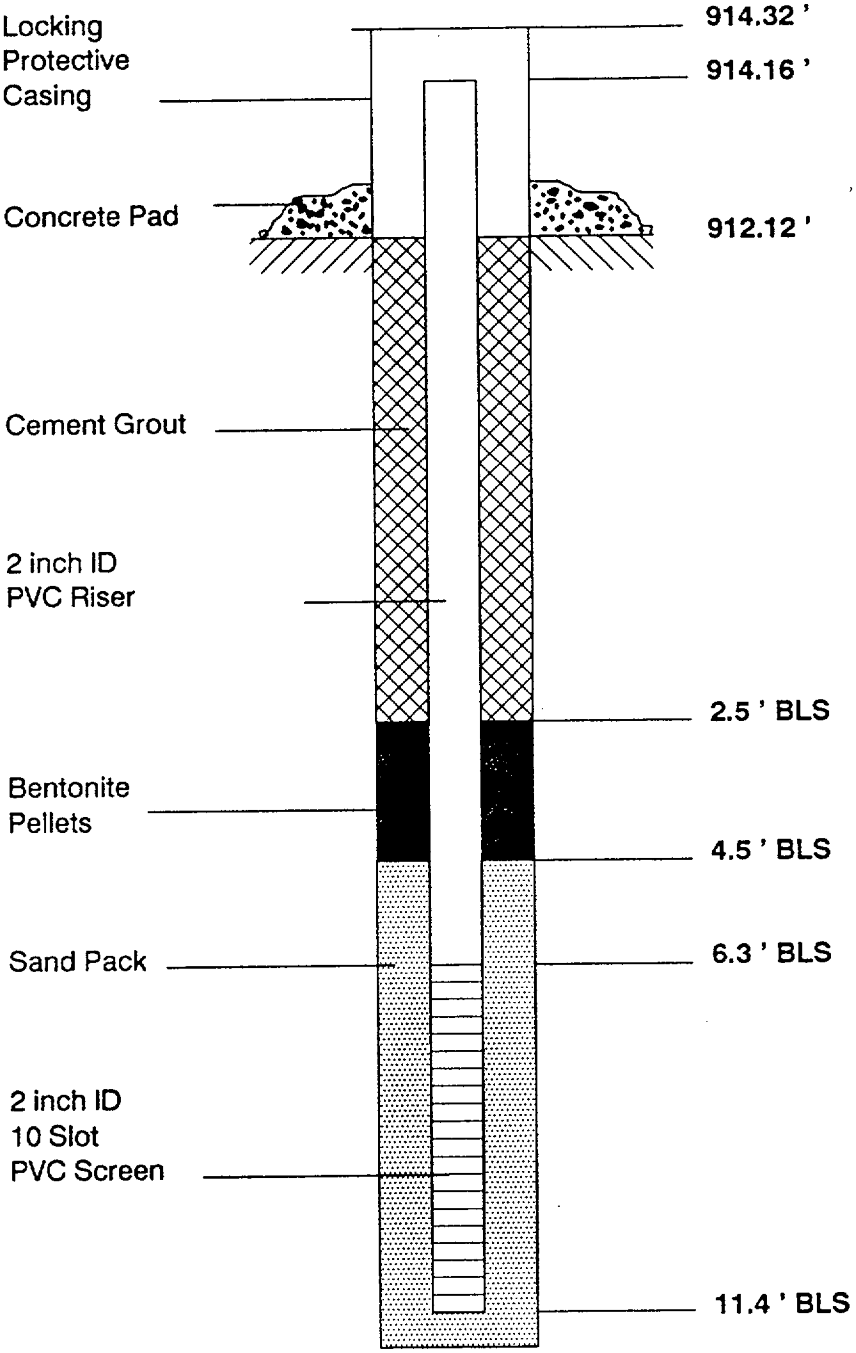
**BOREHOLE NUMBER: 306** **LOCATION: Sample Area 3** **29 June 1989**

Total Depth **15.0 '** Borehole Diameter **0.6 '**



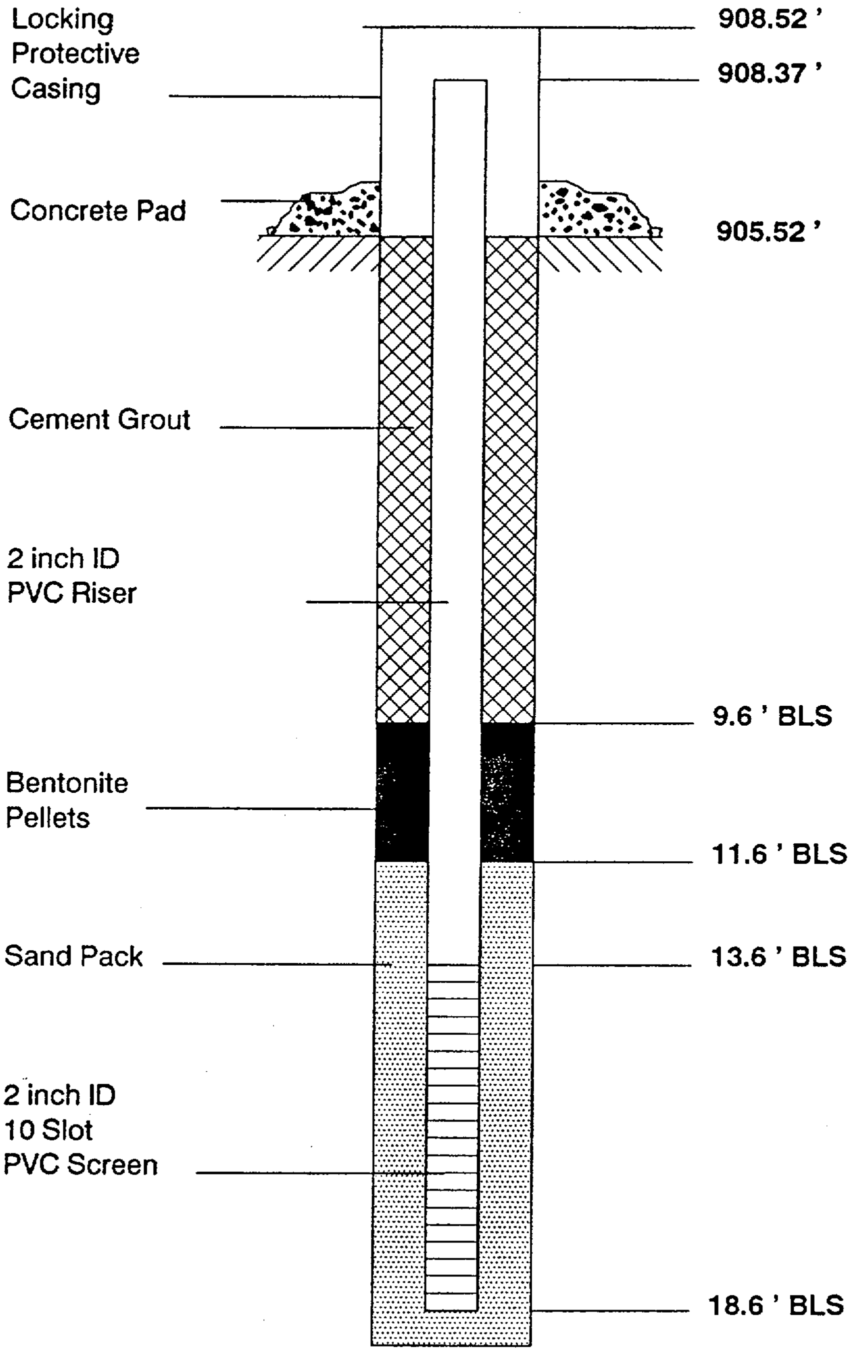
**BOREHOLE NUMBER 312　LOCATION: Sample Area 3　29 June 1989**

Total Depth **12.5 '**　　Borehole Diameter **0.6 '**



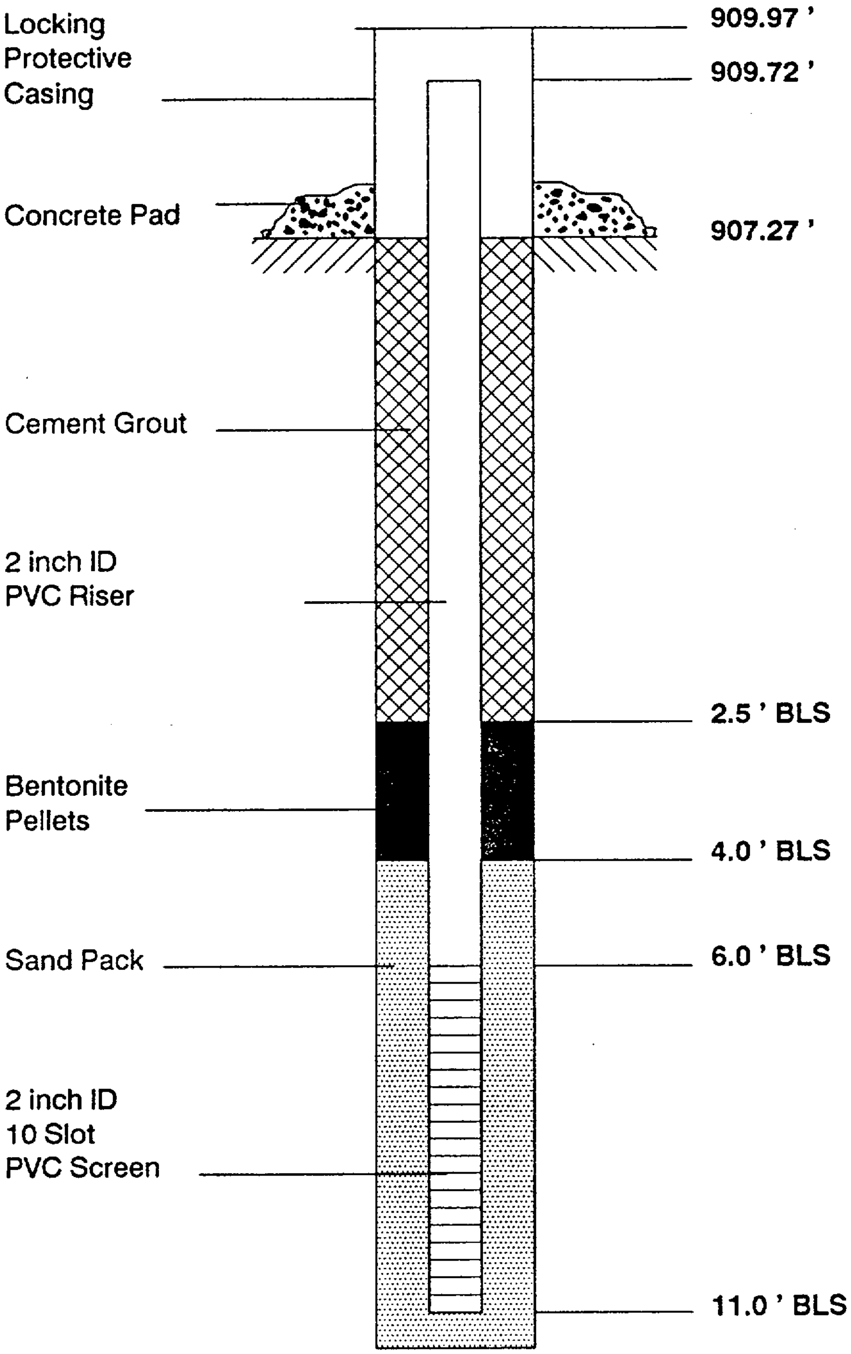
**BOREHOLE NUMBER: 403   LOCATION: Sample Area 4   03 August 1989**

Total Depth **18.6 '**   Borehole Diameter **0.8 '**



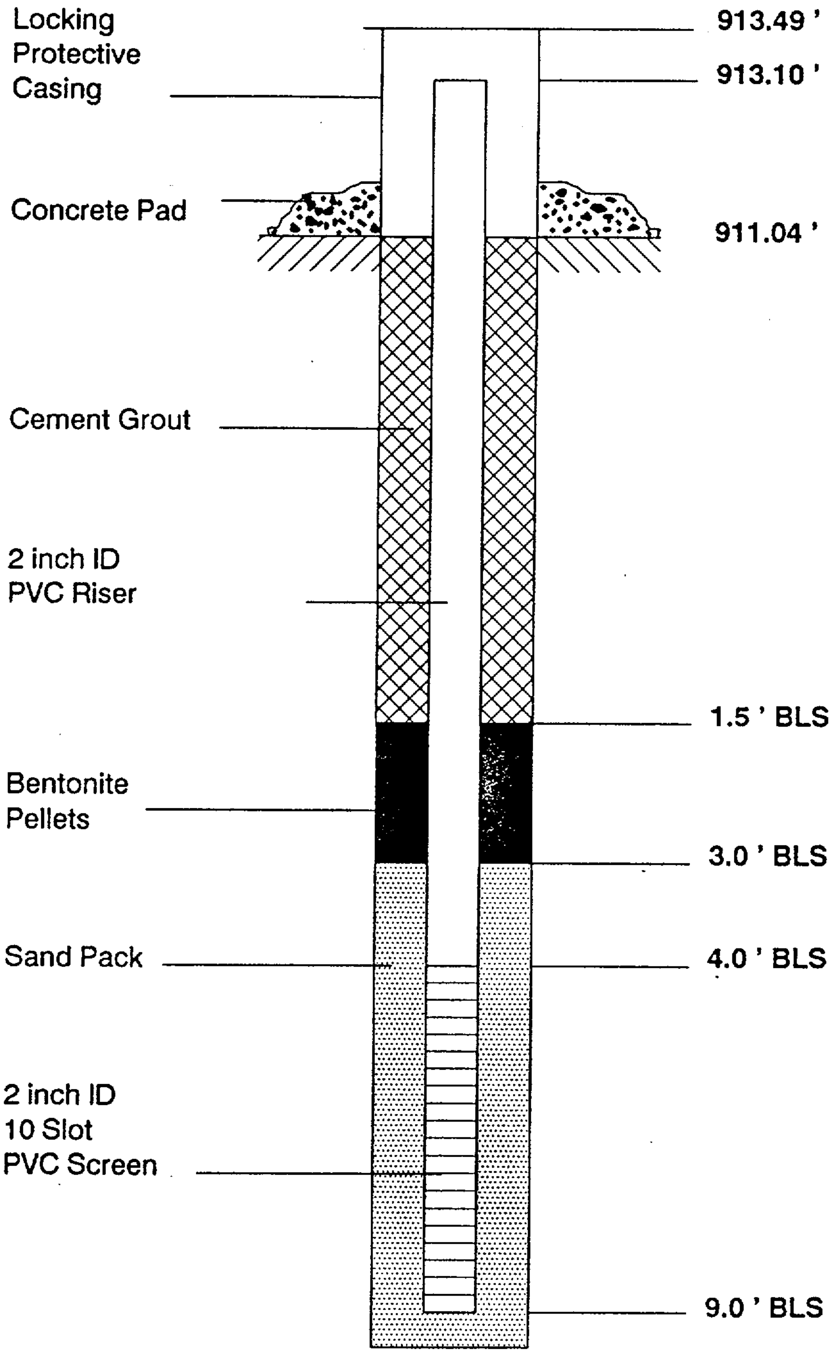
**BOLEHOLE NUMBER: 506 LOCATION: Sample Area 5 03 August 1989**

Total Depth **11.0 '** Borehole Diameter **0.8 '**



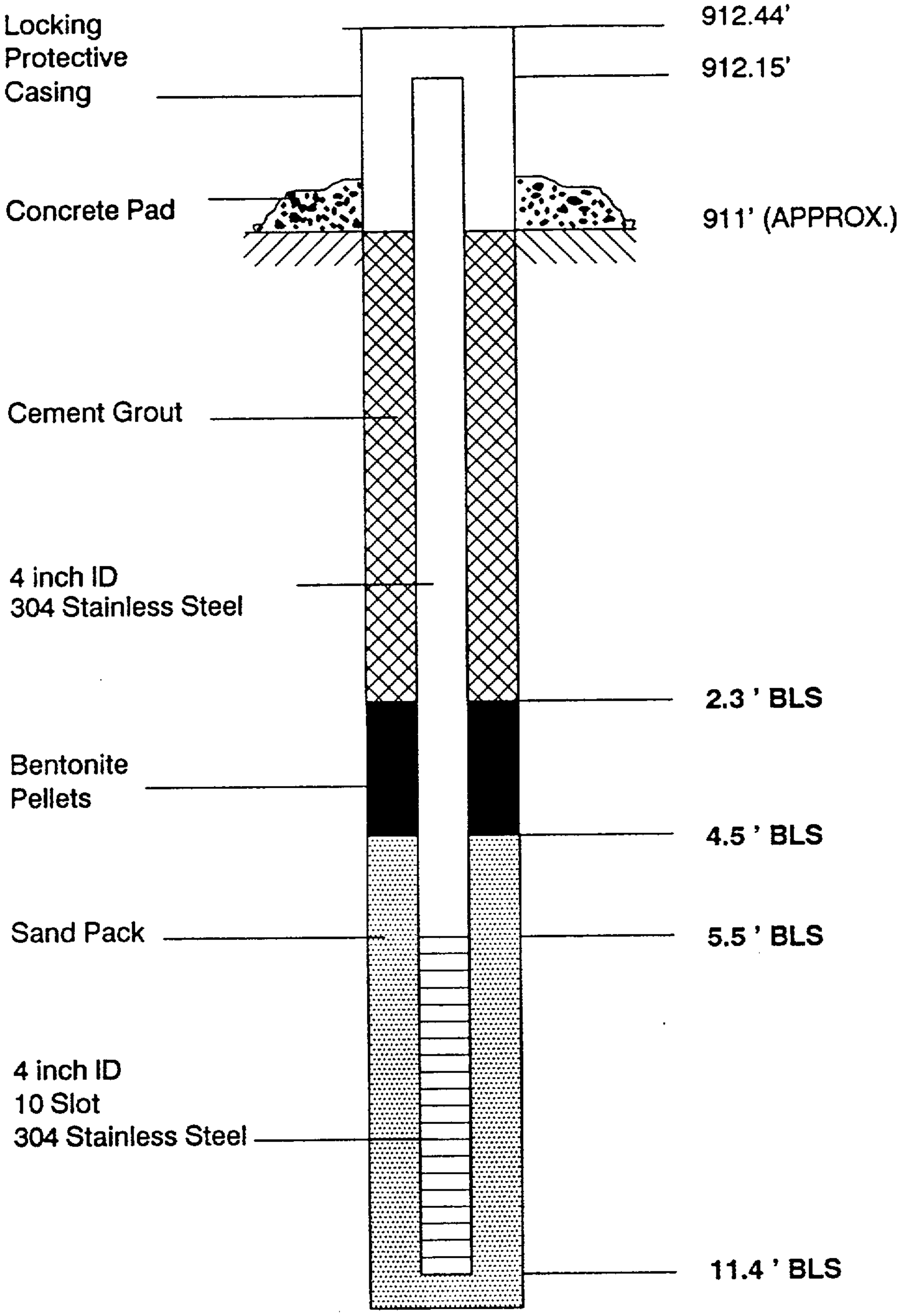
**BOREHOLE NUMBER:** 601 **LOCATION:** Sample Area 6 25 July 1989

Total Depth **10.0 '** Borehole Diameter **0.8 '**



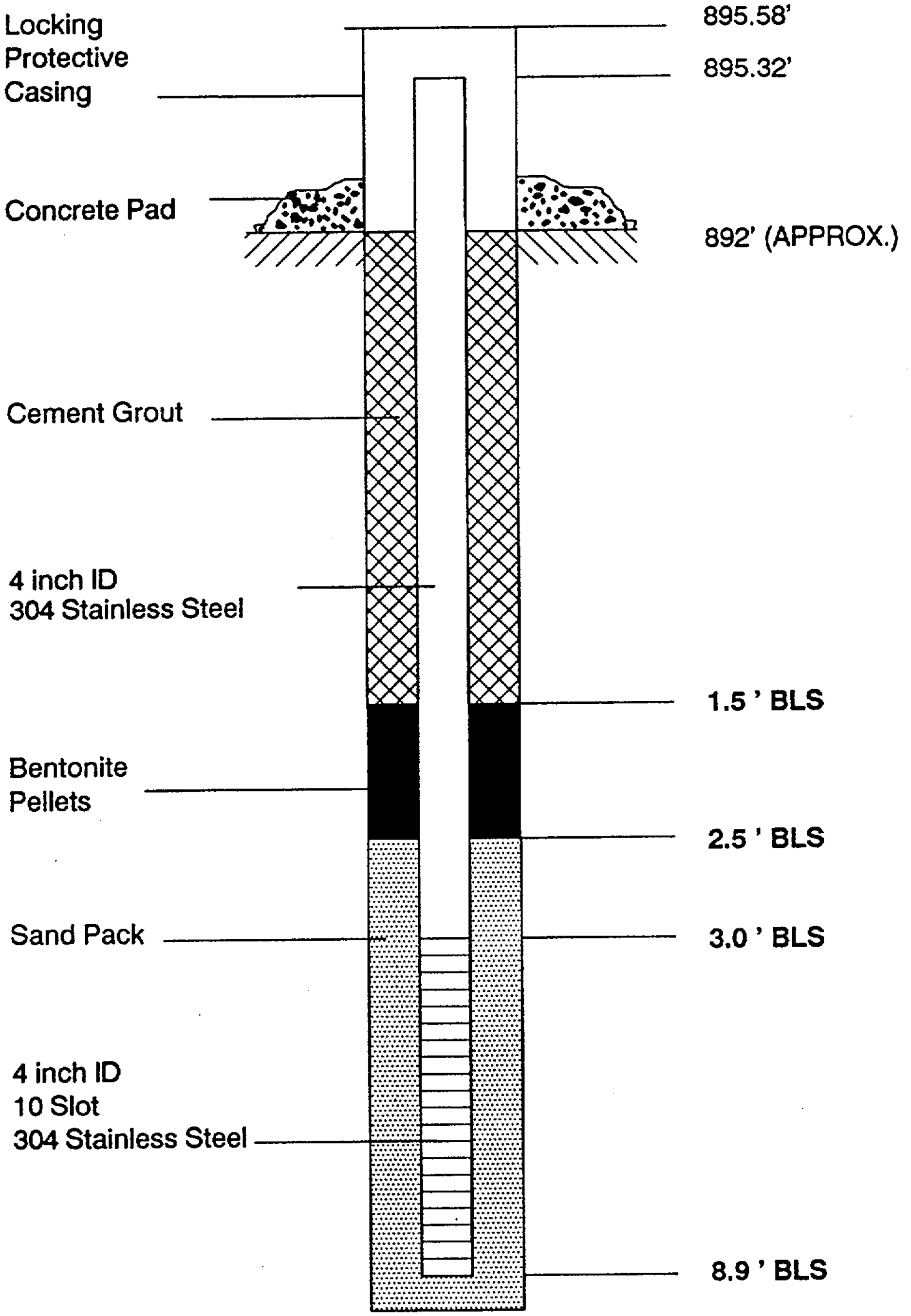
**BOREHOLE NUMBER: C-03 LOCATION: Behind JN-4 17 November 1989**

Total Depth **11.4 '** Borehole Diameter **0.8 '**



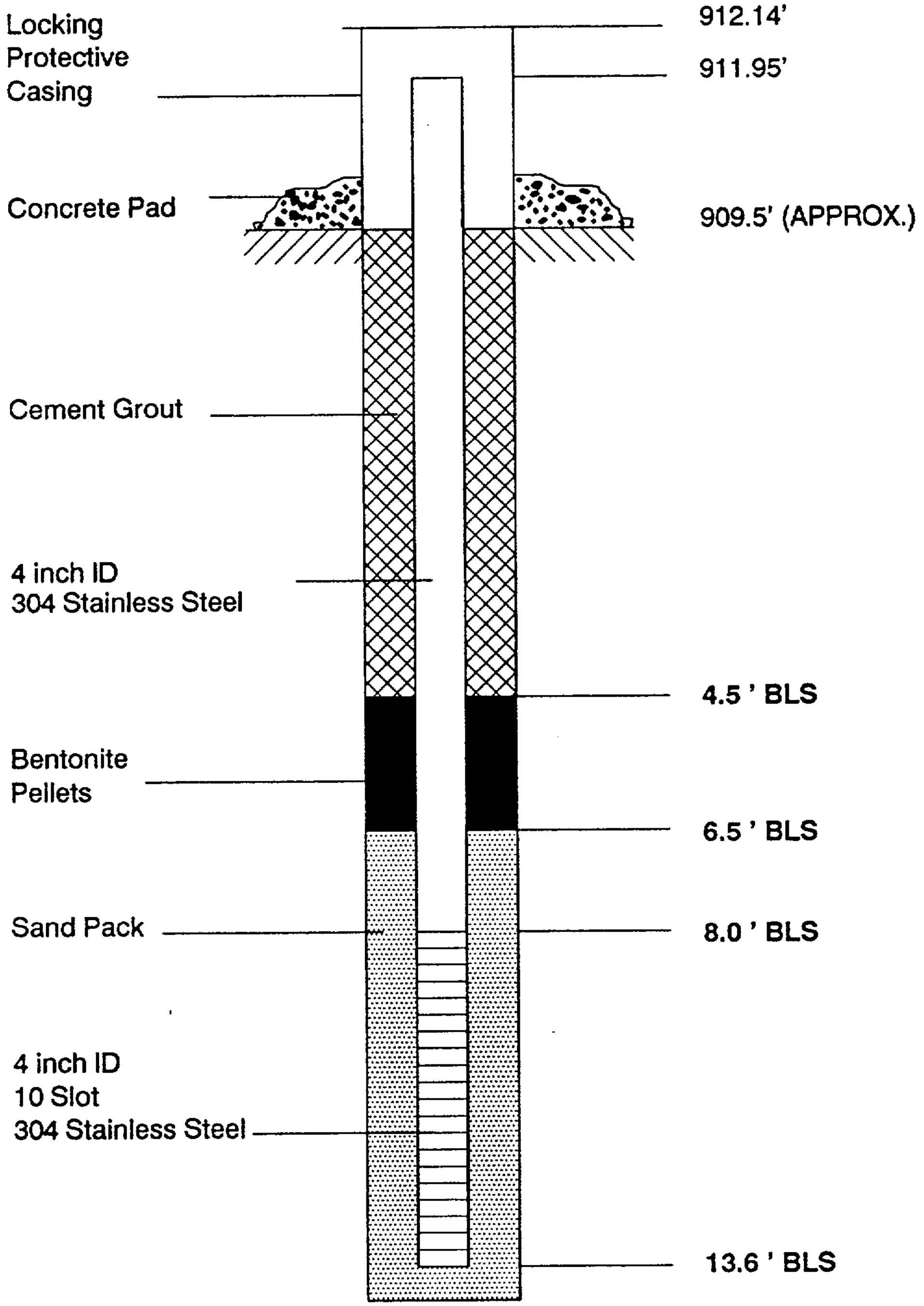
**BOREHOLE NUMBER: C-09 LOCATION: Sewer Outfall 17 November 1989**

Total Depth **8.9 '** Borehole Diameter **0.8 '**



BOREHOLE NUMBER: C-16 LOCATION: South of JN-2 17 November 1989

Total Depth 13.6 ' Borehole Diameter 0.65 '



# APPENDIX 3

# SLUG TEST DATA

# HERMIT DATA FOR WELL 150 SLUG TEST

```
        SE1000B
  Environmental Logger
     11/10  18:33

  Unit# 00476  Test# 0

INPUT 1:  Level (F) TOC

Reference         0.00
Scale factor     29.98
Offset            0.04

Step# 0   11/10  09:40

Elapsed Time    Value                   Elapsed Time    Value
------------  ---------                 ------------  ---------
   0.0000         0.07                     0.9167         0.83
   0.0033         0.81                     1.0000         0.78
   0.0066         6.19                     1.0833         0.72
   0.0099     -   0.00                     1.1667         0.69
   0.0133         1.69                     1.2500         0.64
   0.0166         2.03                     1.3333         0.60
   0.0200         1.68                     1.4166         0.56
   0.0233         1.73                     1.5000         0.53
   0.0266         1.80                     1.5833         0.51
   0.0300         1.77                     1.6667         0.47
   0.0333         1.74                     1.7500         0.44
   0.0500         1.71                     1.8333         0.42
   0.0666         1.66                     1.9167         0.39
   0.0833         1.62                     2.0000         0.36
   0.1000         1.57                     2.5000         0.26
   0.1166         1.54                     3.0000         0.18
   0.1333         1.50                     3.5000         0.14
   0.1500         1.46                     4.0000         0.10
   0.1666         1.43                     4.5000         0.08
   0.1833         1.39                     5.0000         0.06
   0.2000         1.37                     5.5000         0.04
   0.2166         1.35                     6.0000         0.04
   0.2333         1.32                     6.5000         0.03
   0.2500         1.29                     7.0000         0.03
   0.2666         1.27                     7.5000         0.02
   0.2833         1.25                     8.0000         0.02
   0.3000         1.23                     8.5000         0.01
   0.3166         1.21                     9.0000         0.01
   0.3333         1.20                     9.5000         0.01
   0.4167         1.14                    10.0000         0.01
   0.5000         1.09                  END
   0.5833         1.05
   0.6667         1.02
   0.7500         0.95
   0.8333         0.88
```

# HERMIT DATA FOR WELL 155 SLUG TEST

```
         SE1000B
   Environmental Logger
       11/10  18:38

   Unit# 00476  Test# 3

 INPUT 1:  Level (F) TOC

 Reference          0.00            Elapsed Time    Value
 Scale factor      29.98            ------------  ---------
 Offset             0.04               0.9167        1.52
                                       1.0000        1.50
 Step# 0   11/10  11:17                1.0833        1.46
                                       1.1667        1.43
 Elapsed Time    Value                 1.2500        1.40
 ------------  ---------               1.3333        1.38
    0.0000         8.15                1.4166        1.36
    0.0033         7.65                1.5000        1.33
    0.0066     -   0.99                1.5833        1.31
    0.0099         3.96                1.6667        1.28
    0.0133         1.13                1.7500        1.26
    0.0166         2.54                1.8333        1.23
    0.0200         1.87                1.9167        1.21
    0.0233         2.17                2.0000        1.20
    0.0266         2.05                2.5000        1.09
    0.0300         2.04                3.0000        0.99
    0.0333         2.04                3.5000        0.90
    0.0500         2.01                4.0000        0.84
    0.0666         1.99                4.5000        0.77
    0.0833         1.97                5.0000        0.70
    0.1000         1.95                5.5000        0.66
    0.1166         1.94                6.0000        0.61
    0.1333         1.92                6.5000        0.57
    0.1500         1.91                7.0000        0.53
    0.1666         1.90                7.5000        0.50
    0.1833         1.89                8.0000        0.47
    0.2000         1.87                8.5000        0.44
    0.2166         1.86                9.0000        0.41
    0.2333         1.85                9.5000        0.39
    0.2500         1.84               10.0000        0.36
    0.2666         1.83               12.0000        0.29
    0.2833         1.82               14.0000        0.25
    0.3000         1.80               16.0000        0.21
    0.3166         1.79               18.0000        0.18
    0.3333         1.79               20.0000        0.17
    0.4167         1.73               22.0000        0.15
    0.5000         1.70               24.0000        0.13
    0.5833         1.66               26.0000        0.12
    0.6667         1.62               28.0000        0.12
    0.7500         1.58               30.0000        0.12
    0.8333         1.55              END
```

# HERMIT DATA FOR WELL 158 SLUG TEST

```
        SE1000B
  Environmental Logger
     11/10  18:39

  Unit# 00476  Test# 4

INPUT 1:  Level (F) TOC

Reference          0.00
Scale factor      29.98
Offset             0.04

Step# 0   11/10  12:14

Elapsed Time     Value
------------   ---------
    0.0000         3.14
    0.0033         3.83
    0.0066         3.56
    0.0099         1.36
    0.0133         0.72
    0.0166         1.78
    0.0200         2.61
    0.0233         2.49
    0.0266         1.92
    0.0300         1.70
    0.0333         1.93
    0.0500         1.99
    0.0666         2.00
    0.0833         2.01
    0.1000         2.00
    0.1166         1.99
    0.1333         1.99
    0.1500         1.98
    0.1666         1.98
    0.1833         1.98
    0.2000         1.98
    0.2166         1.97
    0.2333         1.97
    0.2500         1.97
    0.2666         1.97
    0.2833         1.97
    0.3000         1.97
    0.3166         1.97
    0.3333         1.96
    0.4167         1.96
    0.5000         1.96
    0.5833         1.95
    0.6667         1.95
    0.7500         1.95
    0.8333         1.95

Elapsed Time     Value
------------   ---------
    0.9167         1.94
    1.0000         1.94
    1.0833         1.94
    1.1667         1.94
    1.2500         1.93
    1.3333         1.93
    1.4166         1.93
    1.5000         1.93
    1.5833         1.93
    1.6667         1.92
    1.7500         1.92
    1.8333         1.92
    1.9167         1.92
    2.0000         1.92
    2.5000         1.90
    3.0000         1.90
    3.5000         1.90
    4.0000         1.89
    4.5000         1.88
    5.0000         1.88
    5.5000         1.87
    6.0000         1.86
    6.5000         1.85
    7.0000         1.84
    7.5000         1.84
    8.0000         1.83
    8.5000         1.82
    9.0000         1.82
    9.5000         1.81
   10.0000         1.81
   12.0000         1.78
   14.0000         1.76
   16.0000         1.74
   18.0000         1.73
   20.0000         1.71
   22.0000         1.69
   24.0000         1.67
   26.0000         1.65
   28.0000         1.64
   30.0000         1.62
   32.0000         1.61
   34.0000         1.60
   36.0000         1.59
   38.0000         1.57
   40.0000         1.55
   42.0000         1.55
   44.0000         1.53
```

```
HERMIT DATA FOR WELL 158 (Continued)

 Elapsed Time     Value
------------   ---------
   46.0000        1.53
   48.0000        1.51
   50.0000        1.49
   52.0000        1.48
   54.0000        1.47
   56.0000        1.45
   58.0000        1.44
   60.0000        1.43
   62.0000        1.42
   64.0000        1.41
   66.0000        1.40
   68.0000        1.39
   70.0000        1.38
   72.0000        1.38
   74.0000        1.37
   76.0000        1.36
   78.0000        1.35
   80.0000        1.34
   82.0000        1.33
   84.0000        1.32
   86.0000        1.32
   88.0000        1.31
   90.0000        1.30
   92.0000        1.29
   94.0000        1.28
   96.0000        1.27
   98.0000        1.27
   100.000        1.26
   110.000        1.21
   120.000        1.19
   130.000        1.15
   140.000        1.11
   150.000        1.09
END
```

HERMIT DATA FOR WELL 168 SLUG TEST

```
        SE1000B
  Environmental Logger
      11/10  18:34

  Unit# 00476  Test# 1

INPUT 1:  Level (F) TOC

Reference          0.00
Scale factor      29.98
Offset             0.04

Step# 0   11/10   10:03

Elapsed Time     Value              Elapsed Time     Value
------------   ---------            ------------   ---------
    0.0000         4.89                 0.9167         0.07
    0.0033         0.94                 1.0000         0.06
    0.0066         1.67                 1.0833         0.05
    0.0099         1.69                 1.1667         0.05
    0.0133         1.63                 1.2500         0.04
    0.0166         1.52                 1.3333         0.04
    0.0200         1.45                 1.4166         0.04
    0.0233         1.38                 1.5000         0.04
    0.0266         1.33                 1.5833         0.03
    0.0300         1.27                 1.6667         0.03
    0.0333         1.22                 1.7500         0.03
    0.0500         1.03                 1.8333         0.03
    0.0666         0.90                 1.9167         0.03
    0.0833         0.79                 2.0000         0.03
    0.1000         0.69                 2.5000         0.02
    0.1166         0.63                 3.0000         0.01
    0.1333         0.56                 3.5000         0.01
    0.1500         0.51                 4.0000         0.01
    0.1666         0.46                 4.5000         0.01
    0.1833         0.42                 5.0000         0.00
    0.2000         0.38                 5.5000         0.00
    0.2166         0.35                 6.0000         0.00
    0.2333         0.33                 6.5000         0.00
    0.2500         0.31                 7.0000         0.01
    0.2666         0.29                 7.5000         0.01
    0.2833         0.27                 8.0000         0.01
    0.3000         0.25                 8.5000         0.01
    0.3166         0.23                 9.0000         0.01
    0.3333         0.22                 9.5000         0.01
    0.4167         0.17                10.0000         0.01
    0.5000         0.14             END
    0.5833         0.12
    0.6667         0.10
    0.7500         0.08
    0.8333         0.07
```

# HERMIT DATA FOR WELL 172 SLUG TEST

```
        SE1000B
  Environmental Logger
      11/10  18:36

  Unit# 00476  Test# 2

INPUT 1:  Level (F) TOC

Reference          0.00
Scale factor      29.98
Offset             0.04

Step# 0   11/10  10:28

Elapsed Time     Value
------------   ---------
   0.0000         6.95
   0.0033     -   0.04
   0.0066         1.67
   0.0099         1.72
   0.0133         1.72
   0.0166         1.71
   0.0200         1.65
   0.0233         1.62
   0.0266         1.60
   0.0300         1.58
   0.0333         1.55
   0.0500         1.49
   0.0666         1.42
   0.0833         1.38
   0.1000         1.33
   0.1166         1.28
   0.1333         1.23
   0.1500         1.20
   0.1666         1.16
   0.1833         1.12
   0.2000         1.08
   0.2166         1.05
   0.2333         1.03
   0.2500         1.00
   0.2666         0.96
   0.2833         0.93
   0.3000         0.91
   0.3166         0.88
   0.3333         0.86
   0.4167         0.75
   0.5000         0.66
   0.5833         0.58
   0.6667         0.51
   0.7500         0.46
   0.8333         0.41

Elapsed Time     Value
------------   ---------
   0.9167         0.37
   1.0000         0.34
   1.0833         0.30
   1.1667         0.27
   1.2500         0.25
   1.3333         0.23
   1.4166         0.21
   1.5000         0.19
   1.5833         0.17
   1.6667         0.17
   1.7500         0.15
   1.8333         0.15
   1.9167         0.13
   2.0000         0.12
   2.5000         0.08
   3.0000         0.06
   3.5000         0.05
   4.0000         0.03
   4.5000         0.03
   5.0000         0.02
   5.5000         0.02
   6.0000         0.01
   6.5000         0.01
   7.0000         0.00
   7.5000         0.00
   8.0000         0.00
   8.5000         0.00
   9.0000         0.00
   9.5000         0.00
  10.0000         0.00
END
```

# HERMIT DATA FOR WELL 206 SLUG TEST

```
        SE1000B
  Environmental Logger
     12/19  17:28

  Unit# 00476  Test# 6

INPUT 1:  Level (F) TOC

Reference         0.00
Scale factor     29.98
Offset            0.04

Step# 0   12/19  11:32

Elapsed Time    Value
------------  ---------
   0.0000         0.99
   0.0033         4.49
   0.0066         4.74
   0.0099         0.34
   0.0133      -  0.32
   0.0166         2.60
   0.0200         3.14
   0.0233         1.22
   0.0266         0.56
   0.0300         1.92
   0.0333         2.45
   0.0500         1.85
   0.0666         1.60
   0.0833         1.55
   0.1000         1.56
   0.1166         1.58
   0.1333         1.60
   0.1500         1.60
   0.1666         1.60
   0.1833         1.59
   0.2000         1.59
   0.2166         1.59
   0.2333         1.59
   0.2500         1.58
   0.2666         1.58
   0.2833         1.58
   0.3000         1.58
   0.3166         1.58
   0.3333         1.58
   0.4167         1.57
   0.5000         1.57
   0.5833         1.57
   0.6667         1.57
   0.7500         1.57
   0.8333         1.57
```

```
Elapsed Time    Value
------------  ---------
   0.9167        1.56
   1.0000        1.56
   1.0833        1.56
   1.1667        1.56
   1.2500        1.56
   1.3333        1.56
   1.4166        1.56
   1.5000        1.56
   1.5833        1.56
   1.6667        1.56
   1.7500        1.56
   1.8333        1.56
   1.9167        1.56
   2.0000        1.56
   2.5000        1.56
   3.0000        1.55
   3.5000        1.55
   4.0000        1.55
   4.5000        1.55
   5.0000        1.55
   5.5000        1.55
   6.0000        1.55
   6.5000        1.55
   7.0000        1.55
   7.5000        1.55
   8.0000        1.55
   8.5000        1.55
   9.0000        1.55
   9.5000        1.55
  10.0000        1.55
  12.0000        1.55
  14.0000        1.55
  16.0000        1.55
  18.0000        1.55
  20.0000        1.55
  22.0000        1.55
  24.0000        1.54
  26.0000        1.54
  28.0000        1.54
  30.0000        1.54
  32.0000        1.54
  34.0000        1.54
  36.0000        1.53
  38.0000        1.53
  40.0000        1.53
  42.0000        1.53
  44.0000        1.53
```

## HERMIT DATA FOR WELL 206 (Continued)

```
 Elapsed Time     Value
 ------------  ---------
   46.0000          1.53
   48.0000          1.53
   50.0000          1.53
   52.0000          1.53
   54.0000          1.53
   56.0000          1.53
   58.0000          1.53
   60.0000          1.53
   62.0000          1.52
   64.0000          1.52
   66.0000          1.52
   68.0000          1.52
   70.0000          1.52
   72.0000          1.52
   74.0000          1.52
   76.0000          1.52
   78.0000          1.52
   80.0000          1.52
   82.0000          1.52
   84.0000          1.52
   86.0000          1.51
   88.0000          1.51
   90.0000          1.51
   92.0000          1.51
   94.0000          1.51
   96.0000          1.51
   98.0000          1.51
   100.000          1.51
   110.000          1.50
   120.000          1.50
   130.000          1.50
   140.000          1.49
 END
```

# HERMIT DATA FOR WELL 300 SLUG TEST

```
        SE1000B
  Environmental Logger
     12/19  17:31                       Elapsed Time     Value
                                        ------------   ---------
  Unit# 00476  Test# 7                     0.9167         0.41
                                           1.0000         0.40
INPUT 1:  Level (F) TOC                    1.0833         0.38
                                           1.1667         0.37
Reference          0.00                    1.2500         0.37
Scale factor      29.98                    1.3333         0.35
Offset             0.04                    1.4166         0.35
                                           1.5000         0.34
Step# 0   12/19  15:10                     1.5833         0.34
                                           1.6667         0.34
Elapsed Time     Value                     1.7500         0.33
------------   ---------                   1.8333         0.33
   0.0000          0.86                    1.9167         0.33
   0.0033          5.37                    2.0000         0.32
   0.0066          3.43                    2.5000         0.31
   0.0099          2.59                    3.0000         0.30
   0.0133          4.06                    3.5000         0.28
   0.0166          1.41                    4.0000         0.28
   0.0200          1.42                    4.5000         0.28
   0.0233          1.82                    5.0000         0.28
   0.0266          1.50                    5.5000         0.27
   0.0300          1.54                    6.0000         0.27
   0.0333          1.51                    6.5000         0.27
   0.0500          1.36                    7.0000         0.27
   0.0666          1.24                    7.5000         0.27
   0.0833          1.15                    8.0000         0.26
   0.1000          1.06                    8.5000         0.26
   0.1166          1.00                    9.0000         0.26
   0.1333          0.94                    9.5000         0.27
   0.1500          0.89                   10.0000         0.26
   0.1666          0.85                   12.0000         0.26
   0.1833          0.81                   14.0000         0.26
   0.2000          0.77                   16.0000         0.25
   0.2166          0.74                   18.0000         0.26
   0.2333          0.71                   20.0000         0.25
   0.2500          0.69                   22.0000         0.25
   0.2666          0.68                   24.0000         0.25
   0.2833          0.66                   26.0000         0.25
   0.3000          0.64                   28.0000         0.25
   0.3166          0.62                   30.0000         0.25
   0.3333          0.61                   32.0000         0.25
   0.4167          0.55                   34.0000         0.25
   0.5000          0.51                   36.0000         0.25
   0.5833          0.49                   38.0000         0.25
   0.6667          0.46                   40.0000         0.25
   0.7500          0.44                   42.0000         0.25
   0.8333          0.43                   44.0000         0.25
```

```
HERMIT DATA FOR WELL 300 (Continued)

 Elapsed Time    Value
 ------------  ---------
   46.0000        0.25
   48.0000        0.25
   50.0000        0.24
   52.0000        0.24
   54.0000        0.25
   56.0000        0.24
   58.0000        0.25
   60.0000        0.25
   62.0000        0.25
   64.0000        0.24
   66.0000        0.25
   68.0000        0.25
   70.0000        0.25
   72.0000        0.25
   74.0000        0.25
   76.0000        0.25
   78.0000        0.25
   80.0000        0.25
   82.0000        0.25
   84.0000        0.25
   86.0000        0.25
END
```

# HERMIT DATA FOR WELL 306 SLUG TEST

SE1000B
Environmental Logger
11/10 18:45

Unit# 00476 Test# 5

INPUT 1: Level (F) TOC

Reference 0.00
Scale factor 29.98
Offset 0.04

Step# 0 11/10 16:01

| Elapsed Time | Value |
|---|---|
| 0.0000 | 0.01 |
| 0.0033 | 2.50 |
| 0.0066 | 6.28 |
| 0.0099 | 2.26 |
| 0.0133 | 0.53 |
| 0.0166 | 3.71 |
| 0.0200 | 0.86 |
| 0.0233 | 1.84 |
| 0.0266 | 2.44 |
| 0.0300 | 1.15 |
| 0.0333 | 2.18 |
| 0.0500 | 2.46 |
| 0.0666 | 2.32 |
| 0.0833 | 2.38 |
| 0.1000 | 1.53 |
| 0.1166 | 1.55 |
| 0.1333 | 1.55 |
| 0.1500 | 1.53 |
| 0.1666 | 1.50 |
| 0.1833 | 1.47 |
| 0.2000 | 1.45 |
| 0.2166 | 1.42 |
| 0.2333 | 1.40 |
| 0.2500 | 1.38 |
| 0.2666 | 1.36 |
| 0.2833 | 1.34 |
| 0.3000 | 1.32 |
| 0.3166 | 1.30 |
| 0.3333 | 1.28 |
| 0.4167 | 1.21 |
| 0.5000 | 1.14 |
| 0.5833 | 1.07 |
| 0.6667 | 1.03 |
| 0.7500 | 0.98 |
| 0.8333 | 0.94 |
| 0.9167 | 0.89 |
| 1.0000 | 0.86 |
| 1.0833 | 0.83 |
| 1.1667 | 0.79 |
| 1.2500 | 0.76 |
| 1.3333 | 0.72 |
| 1.4166 | 0.69 |
| 1.5000 | 0.68 |
| 1.5833 | 0.65 |
| 1.6667 | 0.62 |
| 1.7500 | 0.60 |
| 1.8333 | 0.58 |
| 1.9167 | 0.56 |
| 2.0000 | 0.54 |
| 2.5000 | 0.45 |
| 3.0000 | 0.38 |
| 3.5000 | 0.34 |
| 4.0000 | 0.31 |
| 4.5000 | 0.28 |
| 5.0000 | 0.26 |
| 5.5000 | 0.24 |
| 6.0000 | 0.23 |
| 6.5000 | 0.22 |
| 7.0000 | 0.21 |
| 7.5000 | 0.20 |
| 8.0000 | 0.18 |
| 8.5000 | 0.18 |
| 9.0000 | 0.17 |
| 9.5000 | 0.17 |
| 10.0000 | 0.16 |
| 12.0000 | 0.15 |
| 14.0000 | 0.13 |
| 16.0000 | 0.12 |
| 18.0000 | 0.11 |
| 20.0000 | 0.11 |
| 22.0000 | 0.10 |
| 24.0000 | 0.11 |
| 26.0000 | 0.10 |
| 28.0000 | 0.10 |
| 30.0000 | 0.10 |
| 32.0000 | 0.13 |
| 34.0000 | 0.11 |
| 36.0000 | 0.11 |
| 38.0000 | 0.08 |
| 40.0000 | 0.08 |
| 42.0000 | 0.07 |
| 44.0000 | 0.08 |

## HERMIT DATA FOR WELL 306 (Continued)

```
Elapsed Time     Value
------------   ---------
  46.0000          0.09
  48.0000          0.08
  50.0000          0.08
  52.0000          0.09
  54.0000          0.08
  56.0000          0.08
  58.0000          0.09
  60.0000          0.08
  62.0000          0.08
  64.0000          0.08
  66.0000          0.08
  68.0000          0.08
  70.0000          0.08
  72.0000          0.08
  74.0000          0.09
  76.0000          0.08
  78.0000          0.08
  80.0000          0.08
END
```

# HERMIT DATA FOR WELL 312 SLUG TEST

```
        SE1000B
  Environmental Logger
      12/19  17:33                         Elapsed Time    Value
                                           ------------  ---------
  Unit# 00476  Test# 7                         0.9167         1.57
                                               1.0000         1.57
INPUT 2:  Level (F) TOC                        1.0833         1.56
                                               1.1667         1.56
Reference          0.00                        1.2500         1.56
Scale factor      19.98                        1.3333         1.56
Offset             0.09                        1.4166         1.56
                                               1.5000         1.56
Step# 0   12/19  15:10                         1.5833         1.56
                                               1.6667         1.56
Elapsed Time     Value                         1.7500         1.56
------------   ---------                       1.8333         1.56
   0.0000       -  0.02                        1.9167         1.56
   0.0033          1.98                        2.0000         1.55
   0.0066          5.07                        2.5000         1.55
   0.0099          2.09                        3.0000         1.55
   0.0133          1.53                        3.5000         1.54
   0.0166          1.87                        4.0000         1.54
   0.0200          1.49                        4.5000         1.54
   0.0233          1.81                        5.0000         1.54
   0.0266          1.56                        5.5000         1.54
   0.0300          1.69                        6.0000         1.53
   0.0333          1.61                        6.5000         1.53
   0.0500          1.62                        7.0000         1.53
   0.0666          1.63                        7.5000         1.53
   0.0833          1.62                        8.0000         1.53
   0.1000          1.60                        8.5000         1.53
   0.1166          1.60                        9.0000         1.54
   0.1333          1.60                        9.5000         1.54
   0.1500          1.60                       10.0000         1.56
   0.1666          1.60                       12.0000         1.56
   0.1833          1.60                       14.0000         1.59
   0.2000          1.60                       16.0000         1.60
   0.2166          1.59                       18.0000         1.59
   0.2333          1.59                       20.0000         1.60
   0.2500          1.59                       22.0000         1.60
   0.2666          1.59                       24.0000         1.59
   0.2833          1.58                       26.0000         1.59
   0.3000          1.58                       28.0000         1.58
   0.3166          1.58                       30.0000         1.55
   0.3333          1.58                       32.0000         1.56
   0.4167          1.58                       34.0000         1.55
   0.5000          1.58                       36.0000         1.55
   0.5833          1.58                       38.0000         1.56
   0.6667          1.58                       40.0000         1.56
   0.7500          1.58                       42.0000         1.57
   0.8333          1.57                       44.0000         1.57
```

HERMIT DATA FOR WELL 312 (Continued)

```
 Elapsed Time    Value
 ------------  ---------
    46.0000        1.57
    48.0000        1.59
    50.0000        1.57
    52.0000        1.55
    54.0000        1.54
    56.0000        1.54
    58.0000        1.55
    60.0000        1.56
    62.0000        1.56
    64.0000        1.56
    66.0000        1.55
    68.0000        1.56
    70.0000        1.56
    72.0000        1.56
    74.0000        1.54
    76.0000        1.53
    78.0000        1.53
    80.0000        1.52
    82.0000        1.52
    84.0000        1.53
    86.0000        1.52
END
```

# HERMIT DATA FOR WELL 403 SLUG TEST

```
       SE1000B
 Environmental Logger
    11/10  18:47                        Elapsed Time    Value
                                        ------------  ---------
 Unit# 00476  Test# 5                      0.9167        1.60
                                           1.0000        1.57
INPUT 2:  Level (F) TOC                    1.0833        1.55
                                           1.1667        1.53
Reference          0.00                    1.2500        1.50
Scale factor      19.98                    1.3333        1.48
Offset             0.09                    1.4166        1.46
                                           1.5000        1.44
Step# 0   11/10  16:01                     1.5833        1.42
                                           1.6667        1.40
Elapsed Time    Value                      1.7500        1.38
------------  ---------                    1.8333        1.36
   0.0000        0.00                      1.9167        1.34
   0.0033        2.70                      2.0000        1.32
   0.0066        7.04                      2.5000        1.23
   0.0099        7.37                      3.0000        1.15
   0.0133        5.96                      3.5000        1.08
   0.0166        4.37                      4.0000        1.01
   0.0200     -  0.75                      4.5000        0.95
   0.0233        3.45                      5.0000        0.89
   0.0266        2.14                      5.5000        0.85
   0.0300        1.14                      6.0000        0.80
   0.0333        2.69                      6.5000        0.77
   0.0500        1.91                      7.0000        0.74
   0.0666        1.96                      7.5000        0.72
   0.0833        1.95                      8.0000        0.70
   0.1000        1.94                      8.5000        0.68
   0.1166        1.92                      9.0000        0.66
   0.1333        1.92                      9.5000        0.65
   0.1500        1.90                     10.0000        0.64
   0.1666        1.89                     12.0000        0.59
   0.1833        1.89                     14.0000        0.55
   0.2000        1.87                     16.0000        0.52
   0.2166        1.87                     18.0000        0.51
   0.2333        1.86                     20.0000        0.50
   0.2500        1.85                     22.0000        0.49
   0.2666        1.84                     24.0000        0.49
   0.2833        1.83                     26.0000        0.49
   0.3000        1.82                     28.0000        0.50
   0.3166        1.82                     30.0000        0.49
   0.3333        1.81                     32.0000        0.50
   0.4167        1.77                     34.0000        0.51
   0.5000        1.74                     36.0000        0.52
   0.5833        1.71                     38.0000        0.49
   0.6667        1.68                     40.0000        0.42
   0.7500        1.65                     42.0000        0.40
   0.8333        1.62                     44.0000        0.37
```

```
HERMIT DATA FOR WELL 403 (Continued)

 Elapsed Time     Value
 ------------   ---------
   46.0000         0.37
   48.0000         0.35
   50.0000         0.35
   52.0000         0.35
   54.0000         0.34
   56.0000         0.34
   58.0000         0.35
   60.0000         0.35
   62.0000         0.35
   64.0000         0.35
   66.0000         0.35
   68.0000         0.35
   70.0000         0.36
   72.0000         0.37
   74.0000         0.37
   76.0000         0.37
   78.0000         0.37
   80.0000         0.37
END
```

# HERMIT DATA FOR WELL 506 SLUG TEST

```
        SE1000B
   Environmental Logger
      12/19  17:30

   Unit# 00476  Test# 6

 INPUT 2:  Level (F) TOC

 Reference         0.00
 Scale factor     19.98
 Offset            0.09

 Step# 0   12/19  11:32

 Elapsed Time    Value
 ------------  ---------
    0.0000         5.65
    0.0033         4.34
    0.0066         1.58
    0.0099         1.49
    0.0133         2.10
    0.0166         1.42
    0.0200         1.80
    0.0233         1.61
    0.0266         1.61
    0.0300         1.61
    0.0333         1.55
    0.0500         1.47
    0.0666         1.39
    0.0833         1.31
    0.1000         1.25
    0.1166         1.20
    0.1333         1.15
    0.1500         1.12
    0.1666         1.09
    0.1833         1.07
    0.2000         1.06
    0.2166         1.05
    0.2333         1.03
    0.2500         1.03
    0.2666         1.02
    0.2833         1.02
    0.3000         1.01
    0.3166         1.00
    0.3333         1.00
    0.4167         0.98
    0.5000         0.97
    0.5833         0.97
    0.6667         0.96
    0.7500         0.95
    0.8333         0.95

 Elapsed Time    Value
 ------------  ---------
    0.9167         0.95
    1.0000         0.95
    1.0833         0.94
    1.1667         0.94
    1.2500         0.93
    1.3333         0.93
    1.4166         0.93
    1.5000         0.93
    1.5833         0.93
    1.6667         0.92
    1.7500         0.92
    1.8333         0.92
    1.9167         0.92
    2.0000         0.91
    2.5000         0.91
    3.0000         0.90
    3.5000         0.89
    4.0000         0.88
    4.5000         0.88
    5.0000         0.87
    5.5000         0.86
    6.0000         0.85
    6.5000         0.85
    7.0000         0.84
    7.5000         0.83
    8.0000         0.83
    8.5000         0.82
    9.0000         0.82
    9.5000         0.81
   10.0000         0.80
   12.0000         0.75
   14.0000         0.69
   16.0000         0.64
   18.0000         0.59
   20.0000         0.56
   22.0000         0.51
   24.0000         0.48
   26.0000         0.44
   28.0000         0.41
   30.0000         0.38
   32.0000         0.36
   34.0000         0.34
   36.0000         0.32
   38.0000         0.30
   40.0000         0.27
   42.0000         0.27
   44.0000         0.26
```

```
HERMIT DATA FOR WELL 506 (Continued)

 Elapsed Time    Value
 ------------  ---------
   46.0000        0.24
   48.0000        0.23
   50.0000        0.23
   52.0000        0.23
   54.0000        0.22
   56.0000        0.21
   58.0000        0.20
   60.0000        0.19
   62.0000        0.17
   64.0000        0.15
   66.0000        0.14
   68.0000        0.13
   70.0000        0.13
   72.0000        0.13
   74.0000        0.13
   76.0000        0.11
   78.0000        0.11
   80.0000        0.11
   82.0000        0.12
   84.0000        0.11
   86.0000        0.11
   88.0000        0.09
   90.0000        0.09
   92.0000        0.08
   94.0000        0.08
   96.0000        0.09
   98.0000        0.10
   100.000        0.10
   110.000        0.07
   120.000        0.07
   130.000        0.06
   140.000        0.03
END
```

# HERMIT DATA FOR WELL 601 SLUG TEST

```
        SE1000B
  Environmental Logger
      01/12  11:15

  Unit# 00476  Test# 9

INPUT 1:  Level (F) TOC

Reference         0.00
Scale factor     29.98
Offset            0.04

Step# 0   01/12  10:50

Elapsed Time    Value                 Elapsed Time    Value
------------  ---------               ------------  ---------
   0.0000        1.02                    0.9167        0.30
   0.0033        0.49                    1.0000        0.30
   0.0066        1.43                    1.0833        0.29
   0.0099        0.17                    1.1667        0.28
   0.0133        1.66                    1.2500        0.28
   0.0166        0.91                    1.3333        0.27
   0.0200        1.27                    1.4166        0.27
   0.0233        1.38                    1.5000        0.26
   0.0266        1.32                    1.5833        0.25
   0.0300        1.26                    1.6667        0.24
   0.0333        1.21                    1.7500        0.22
   0.0500        1.01                    1.8333        0.21
   0.0666        0.84                    1.9167        0.20
   0.0833        0.70                    2.0000        0.20
   0.1000        0.60                    2.5000        0.17
   0.1166        0.53                    3.0000        0.15
   0.1333        0.49                    3.5000        0.14
   0.1500        0.46                    4.0000        0.12
   0.1666        0.43                    4.5000        0.12
   0.1833        0.42                    5.0000        0.11
   0.2000        0.39                    5.5000        0.10
   0.2166        0.38                    6.0000        0.10
   0.2333        0.37                    6.5000        0.09
   0.2500        0.37                    7.0000        0.09
   0.2666        0.36                    7.5000        0.08
   0.2833        0.35                    8.0000        0.08
   0.3000        0.35                    8.5000        0.07
   0.3166        0.35                    9.0000        0.07
   0.3333        0.34                    9.5000        0.08
   0.4167        0.34                   10.0000        0.07
   0.5000        0.33                   12.0000        0.06
   0.5833        0.32                   14.0000        0.06
   0.6667        0.31                   16.0000        0.06
   0.7500        0.30                   18.0000        0.06
   0.8333        0.31                   20.0000        0.05
                                      END
```

# HERMIT DATA FOR WELL C03 SLUG TEST

SE1000B
Environmental Logger
01/16 18:03

Unit# 00476 Test# 0

INPUT 1: Level (F) TOC

Reference 0.00
Scale factor 29.98
Offset 0.04

Step# 0 01/12 14:04

| Elapsed Time | Value |
|---|---|
| 0.0000 | - 0.02 |
| 0.0033 | 0.01 |
| 0.0066 | - 0.04 |
| 0.0099 | 0.83 |
| 0.0133 | 1.95 |
| 0.0166 | 0.94 |
| 0.0200 | 1.90 |
| 0.0233 | 2.04 |
| 0.0266 | 1.95 |
| 0.0300 | 1.90 |
| 0.0333 | 1.85 |
| 0.0500 | 1.73 |
| 0.0666 | 1.63 |
| 0.0833 | 1.55 |
| 0.1000 | 1.46 |
| 0.1166 | 1.37 |
| 0.1333 | 1.29 |
| 0.1500 | 1.23 |
| 0.1666 | 1.16 |
| 0.1833 | 1.11 |
| 0.2000 | 1.08 |
| 0.2166 | 1.04 |
| 0.2333 | 1.03 |
| 0.2500 | 1.00 |
| 0.2666 | 0.98 |
| 0.2833 | 0.98 |
| 0.3000 | 0.99 |
| 0.3166 | 0.96 |
| 0.3333 | 0.95 |
| 0.4167 | 0.92 |
| 0.5000 | 0.89 |
| 0.5833 | 0.86 |
| 0.6667 | 0.86 |
| 0.7500 | 0.86 |
| 0.8333 | 0.85 |
| 0.9167 | 0.84 |
| 1.0000 | 0.84 |
| 1.0833 | 0.83 |
| 1.1667 | 0.82 |
| 1.2500 | 0.82 |
| 1.3333 | 0.82 |
| 1.4166 | 0.83 |
| 1.5000 | 0.81 |
| 1.5833 | 0.82 |
| 1.6667 | 0.80 |
| 1.7500 | 0.81 |
| 1.8333 | 0.81 |
| 1.9167 | 0.81 |
| 2.0000 | 0.79 |
| 2.5000 | 0.79 |
| 3.0000 | 0.78 |
| 3.5000 | 0.77 |
| 4.0000 | 0.77 |
| 4.5000 | 0.77 |
| 5.0000 | 0.76 |
| 5.5000 | 0.73 |
| 6.0000 | 0.75 |
| 6.5000 | 0.75 |
| 7.0000 | 0.75 |
| 7.5000 | 0.75 |
| 8.0000 | 0.75 |
| 8.5000 | 0.74 |
| 9.0000 | 0.74 |
| 9.5000 | 0.74 |
| 10.0000 | 0.74 |
| 12.0000 | 0.73 |
| 14.0000 | 0.74 |
| 16.0000 | 0.75 |
| 18.0000 | 0.73 |
| 20.0000 | 0.74 |
| 22.0000 | 0.72 |
| 24.0000 | 0.72 |
| 26.0000 | 0.72 |
| 28.0000 | 0.71 |
| 30.0000 | 0.72 |
| 32.0000 | 0.71 |
| 34.0000 | 0.71 |
| 36.0000 | 0.70 |
| 38.0000 | 0.70 |
| 40.0000 | 0.70 |
| 42.0000 | 0.69 |
| 44.0000 | 0.70 |

```
HERMIT DATA FOR WELL C03 (Continued)

 Elapsed Time    Value
 ------------  ---------
   46.0000        0.69
   48.0000        0.70
   50.0000        0.70
   52.0000        0.69
   54.0000        0.69
   56.0000        0.69
   58.0000        0.69
   60.0000        0.69
   62.0000        0.69
   64.0000        0.69
   66.0000        0.69
   68.0000        0.69
   70.0000        0.69
   72.0000        0.69
   74.0000        0.69
   76.0000        0.69
   78.0000        0.68
   80.0000        0.69
   82.0000        0.68
   84.0000        0.67
   86.0000        0.67
   88.0000        0.67
   90.0000        0.67
   92.0000        0.67
   94.0000        0.66
   96.0000        0.68
   98.0000        0.67
   100.000        0.67
   110.000        0.65
   120.000        0.65
   130.000        0.66
   140.000        0.64
   150.000        0.64
   160.000        0.64
   170.000        0.63
   180.000        0.62
END
```

# HERMIT DATA FOR WELL C09 SLUG TEST

```
         SE1000B
   Environmental Logger
      01/16  17:53

   Unit# 00476  Test# 2

 INPUT 1:  Level (F) TOC

 Reference          0.00
 Scale factor      29.98
 Offset             0.04

 Step# 0   01/16  16:33

 Elapsed Time     Value
 ------------   ---------
    0.0000         0.00
    0.0033         0.01
    0.0066         0.00
    0.0099         0.39
    0.0133         1.26
    0.0166         1.22
    0.0200      -  0.49
    0.0233         0.14
    0.0266         1.19
    0.0300         1.70
    0.0333         2.03
    0.0500         1.72
    0.0666         1.67
    0.0833         1.56
    0.1000         1.47
    0.1166         1.37
    0.1333         1.28
    0.1500         1.21
    0.1666         1.14
    0.1833         1.10
    0.2000         1.06
    0.2166         1.03
    0.2333         1.02
    0.2500         1.00
    0.2666         0.98
    0.2833         0.97
    0.3000         0.96
    0.3166         0.95
    0.3333         0.94
    0.4167         0.91
    0.5000         0.89
    0.5833         0.87
    0.6667         0.86
    0.7500         0.86
    0.8333         0.85
```

```
 Elapsed Time     Value
 ------------   ---------
    0.9167         0.84
    1.0000         0.84
    1.0833         0.83
    1.1667         0.82
    1.2500         0.82
    1.3333         0.81
    1.4166         0.81
    1.5000         0.80
    1.5833         0.80
    1.6667         0.79
    1.7500         0.79
    1.8333         0.79
    1.9167         0.79
    2.0000         0.79
    2.5000         0.77
    3.0000         0.75
    3.5000         0.74
    4.0000         0.73
    4.5000         0.72
    5.0000         0.71
    5.5000         0.70
    6.0000         0.69
    6.5000         0.69
    7.0000         0.69
    7.5000         0.68
    8.0000         0.67
    8.5000         0.67
    9.0000         0.66
    9.5000         0.65
   10.0000         0.65
   12.0000         0.62
   14.0000         0.60
   16.0000         0.58
   18.0000         0.56
   20.0000         0.54
   22.0000         0.52
   24.0000         0.51
   26.0000         0.49
   28.0000         0.48
   30.0000         0.46
   32.0000         0.45
   34.0000         0.43
   36.0000         0.42
   38.0000         0.41
   40.0000         0.39
   42.0000         0.38
   44.0000         0.37
```

```
HERMIT DATA FOR WELL C09 (Continued)

  Elapsed Time    Value
  ------------  ---------
    46.0000        0.36
    48.0000        0.35
    50.0000        0.34
    52.0000        0.34
    54.0000        0.33
    56.0000        0.32
    58.0000        0.31
    60.0000        0.31
    62.0000        0.30
    64.0000        0.29
    66.0000        0.28
    68.0000        0.27
    70.0000        0.262
END
```

## HERMIT DATA FOR WELL C16 (Continued)

```
 Elapsed Time     Value
------------    ---------
   46.0000         1.73
   48.0000         1.73
   50.0000         1.72
   52.0000         1.72
   54.0000         1.71
   56.0000         1.70
   58.0000         1.70
   60.0000         1.70
   62.0000         1.70
   64.0000         1.70
   66.0000         1.69
   68.0000         1.69
   70.0000         1.68
   72.0000         1.68
   74.0000         1.68
   76.0000         1.67
   78.0000         1.67
   80.0000         1.67
   82.0000         1.68
   84.0000         1.67
   86.0000         1.67
   88.0000         1.66
   90.0000         1.65
   92.0000         1.65
   94.0000         1.65
   96.0000         1.64
   98.0000         1.64
   100.000         1.65
   110.000         1.62
   120.000         1.59
   130.000         1.57
   140.000         1.56
   150.000         1.55
   160.000         1.53
   170.000         1.52
   180.000         1.50
   190.000         1.50
   200.000         1.48
   210.000         1.46
   220.000         1.47
   230.000         1.45
   240.000         1.43
   250.000         1.42
   260.000         1.41
   270.000         1.40
   280.000         1.39
   290.000         1.38
END
```

# APPENDIX 4

# PRECIPITATION RECORD

# HERMIT DATA FOR WELL C16 SLUG TEST

SE1000B
Environmental Logger
01/11 16:57

Unit# 00476 Test# 8

INPUT 1: Level (F) TOC

Reference 0.00
Scale factor 29.98
Offset 0.04

Step# 0 01/11 11:52

| Elapsed Time | Value |
|---|---|
| 0.0000 | - 0.01 |
| 0.0033 | 1.86 |
| 0.0066 | 1.62 |
| 0.0099 | 1.70 |
| 0.0133 | - 0.28 |
| 0.0166 | 0.89 |
| 0.0200 | 1.93 |
| 0.0233 | 1.91 |
| 0.0266 | 1.89 |
| 0.0300 | 1.89 |
| 0.0333 | 1.86 |
| 0.0500 | 1.90 |
| 0.0666 | 1.88 |
| 0.0833 | 1.88 |
| 0.1000 | 1.87 |
| 0.1166 | 1.86 |
| 0.1333 | 1.87 |
| 0.1500 | 1.87 |
| 0.1666 | 1.88 |
| 0.1833 | 1.86 |
| 0.2000 | 1.87 |
| 0.2166 | 1.87 |
| 0.2333 | 1.86 |
| 0.2500 | 1.87 |
| 0.2666 | 1.86 |
| 0.2833 | 1.86 |
| 0.3000 | 1.86 |
| 0.3166 | 1.86 |
| 0.3333 | 1.87 |
| 0.4167 | 1.85 |
| 0.5000 | 1.85 |
| 0.5833 | 1.85 |
| 0.6667 | 1.83 |
| 0.7500 | 1.83 |
| 0.8333 | 1.83 |
| 0.9167 | 1.83 |
| 1.0000 | 1.83 |
| 1.0833 | 1.83 |
| 1.1667 | 1.82 |
| 1.2500 | 1.82 |
| 1.3333 | 1.82 |
| 1.4166 | 1.82 |
| 1.5000 | 1.82 |
| 1.5833 | 1.82 |
| 1.6667 | 1.82 |
| 1.7500 | 1.82 |
| 1.8333 | 1.82 |
| 1.9167 | 1.82 |
| 2.0000 | 1.82 |
| 2.5000 | 1.82 |
| 3.0000 | 1.81 |
| 3.5000 | 1.82 |
| 4.0000 | 1.81 |
| 4.5000 | 1.81 |
| 5.0000 | 1.81 |
| 5.5000 | 1.81 |
| 6.0000 | 1.81 |
| 6.5000 | 1.80 |
| 7.0000 | 1.80 |
| 7.5000 | 1.80 |
| 8.0000 | 1.81 |
| 8.5000 | 1.80 |
| 9.0000 | 1.80 |
| 9.5000 | 1.80 |
| 10.0000 | 1.81 |
| 12.0000 | 1.80 |
| 14.0000 | 1.79 |
| 16.0000 | 1.79 |
| 18.0000 | 1.78 |
| 20.0000 | 1.77 |
| 22.0000 | 1.78 |
| 24.0000 | 1.77 |
| 26.0000 | 1.77 |
| 28.0000 | 1.77 |
| 30.0000 | 1.76 |
| 32.0000 | 1.76 |
| 34.0000 | 1.75 |
| 36.0000 | 1.75 |
| 38.0000 | 1.74 |
| 40.0000 | 1.73 |
| 42.0000 | 1.74 |
| 44.0000 | 1.73 |

## PRECIPITATION RECORD

| Date | Day No. | Rainfall Inches | Date | Day No. | Rainfall Inches |
|---|---|---|---|---|---|
| June 18, 1989 | 0 | 0.02 | Nov. 2, 1989 | 137 | 0.05 |
| | | | 5 | 140 | 0.13 |
| June 20, 1989 | 2 | 0.48 | 8 | 143 | 0.64 |
| 21 | 3 | 1.71 | 14 | 149 | 0.05 |
| 28 | 10 | 1.49 | 15 | 150 | 1.32 |
| | | | 16 | 151 | 0.02 |
| July 3, 1989 | 15 | 0.45 | 26 | 161 | 0.20 |
| 7 | 19 | 0.05 | 27 | 162 | 0.06 |
| 11 | 23 | 0.43 | | | |
| 12 | 24 | 0.23 | Dec. 6, 1989 | 171 | 0.22 |
| 16 | 28 | 0.01 | 7 | 172 | 0.02 |
| 18 | 30 | 0.18 | 11 | 176 | 0.03 |
| 21 | 33 | 0.12 | 14 | 179 | 0.02 |
| 24 | 36 | 0.01 | 15 | 180 | 0.33 |
| 26 | 38 | 0.01 | 21 | 186 | 0.02 |
| 28 | 40 | 0.66 | 26 | 191 | 0.09 |
| 30 | 42 | 0.36 | 27 | 192 | 0.04 |
| | | | 31 | 196 | 1.00 |
| Aug. 4, 1989 | 47 | 0.24 | | | |
| 5 | 48 | 0.74 | Jan. 4, 1990 | 200 | 0.21 |
| 7 | 50 | 0.02 | 9 | 205 | 0.05 |
| 20 | 63 | 0.03 | 12 | 208 | 0.01 |
| 21 | 64 | 0.08 | 15 | 211 | 0.06 |
| 22 | 65 | 1.27 | 16 | 212 | 0.01 |
| 24 | 67 | 0.18 | 17 | 213 | 0.25 |
| 30 | 73 | 1.16 | 20 | 216 | 1.18 |
| | | | 23 | 219 | 0.02 |
| Sept. 1, 1989 | 75 | 0.63 | 25 | 221 | 0.07 |
| 14 | 88 | 0.87 | 29 | 225 | 0.74 |
| 16 | 90 | 0.19 | | | |
| 23 | 97 | 0.30 | Feb. 2, 1990 | 229 | 0.73 |
| | | | 4 | 231 | 1.30 |
| Oct. 2, 1989 | 106 | 0.17 | 7 | 234 | 0.17 |
| 7 | 111 | 0.04 | 9 | 236 | 0.27 |
| 10 | 114 | 0.41 | 11 | 238 | 0.08 |
| 16 | 120 | 0.09 | 15 | 242 | 2.45 |
| 19 | 123 | 1.05 | 22 | 249 | 0.10 |
| 20 | 124 | 0.12 | 24 | 251 | 0.55 |
| 31 | 135 | 0.36 | 27 | 254 | 0.08 |

# PRECIPITATION RECORD

| Date | Day No. | Rainfall Inches | Date | Day No. | Rainfall Inches |
|---|---|---|---|---|---|
| March 8, 1990 | 263 | 0.23 | July 1, 1990 | 379 | 0.25 |
| 10 | 265 | 0.46 | 9 | 387 | 0.06 |
| 17 | 272 | 0.41 | 12 | 390 | 4.39 |
| 19 | 274 | 0.12 | 13 | 391 | 0.15 |
| 22 | 277 | 0.01 | 14 | 392 | 2.11 |
| 24 | 279 | 0.08 | 21 | 399 | 0.81 |
| 29 | 284 | 0.31 | 22 | 400 | 1.83 |
| 31 | 286 | 0.20 | 23 | 401 | 0.88 |
| April 1, 1990 | 287 | 0.34 | Aug. 5, 1990 | 414 | 0.78 |
| 3 | 289 | 0.02 | 13 | 422 | 0.1 |
| 10 | 296 | 1.30 | 18 | 427 | 0.11 |
| 11 | 297 | 0.11 | 20 | 429 | 0.56 |
| 14 | 301 | 0.05 | 21 | 430 | 0.32 |
| 17 | 304 | 0.04 | 22 | 431 | 0.01 |
| 21 | 308 | 0.56 | 29 | 438 | 0.25 |
| 29 | 316 | 0.17 | | | |
| | | | Sept. 7, 1990 | 447 | 0.51 |
| May 4, 1990 | 321 | 1.48 | 9 | 449 | 0.85 |
| 6 | 323 | 0.15 | | | |
| 10 | 327 | 0.11 | | | |
| 11 | 328 | 0.03 | | | |
| 13 | 330 | 1.73 | | | |
| 16 | 333 | 1.29 | | | |
| 17 | 334 | 0.85 | | | |
| 20 | 337 | 0.05 | | | |
| 26 | 343 | 0.92 | | | |
| 27 | 344 | 0.09 | | | |
| 29 | 346 | 2.05 | | | |
| June 2, 1990 | 350 | 0.32 | | | |
| 3 | 351 | 0.14 | | | |
| 7 | 355 | 0.68 | | | |
| 8 | 356 | 1.60 | | | |
| 9 | 357 | 1.28 | | | |
| 14 | 362 | 0.70 | | | |
| 21 | 369 | 0.07 | | | |
| 23 | 371 | 0.27 | | | |
| 24 | 372 | 0.10 | | | |

142-90-48

# REPORT

# SITE CHARACTERIZATION
# WEST JEFFERSON
# NORTH SITE
# GROUNDWATER
# MONITORING WELL
# HYDRAULIC
# CONDUCTIVITY TESTING
# AND ANALYSIS

JANUARY 31, 1990

WJN

Site Characte

~~Groundwater~~

Hydraulic Cond Test

Battelle
. . . *Putting Technology To Work*

# REPORT

on

# SITE CHARACTERIZATION WEST JEFFERSON NORTH SITE GROUNDWATER MONITORING WELL HYDRAULIC CONDUCTIVITY TESTING AND ANALYSIS

January 31, 1990

BATTELLE
505 King Avenue
Columbus, Ohio 43201-2693

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# REPORT

on

# SITE CHARACTERIZATION
# WEST JEFFERSON NORTH SITE
# GROUNDWATER MONITORING WELL
# HYDRAULIC CONDUCTIVITY
# TESTING AND ANALYSIS

January 31, 1990

## 1.0 INTRODUCTION

This report summarizes the hydraulic conductivity testing that was performed in the Stage 1 characterization of the Nuclear Sciences Area of Battelle's West Jefferson Site. The testing was done in 15 groundwater monitoring wells that were installed in the summer and fall of 1989 as part of a comprehensive characterization to identify areas of soil which might require remediation in order to release the site for unrestricted use. Figure 1-1 shows the West Jefferson North Site area with the buildings designated "JN". In addition, the well locations are also shown. The results of this work can be used in conjunction with additional information regarding groundwater flow directions and gradients as input to permit accurate pathways analysis of radionuclide transport in the subsurface.

## 2.0 DESCRIPTION OF THE AREA

The land surface in the area generally is gently sloping except for the V-shaped valley of Silver Ditch south of the facility which is now dammed and occupied by a lake. The surface elevations within the fenced area are for the most part between 900 and 910 feet MSL, with the area to the east of the facility sloping downward to the Big Darby Creek flood plain.

The Nuclear Science Area at the West Jefferson Site is situated on glacial till deposits. The till overlies limestone/dolomite bedrock, and, based on bedrock contours and surface elevations at this site, the maximum range of till thickness is estimated to be 40 to 160 feet. The depth to bedrock in the immediate area is estimated to be 100 feet. Soil up to 6-feet thick has developed on the top of the till.

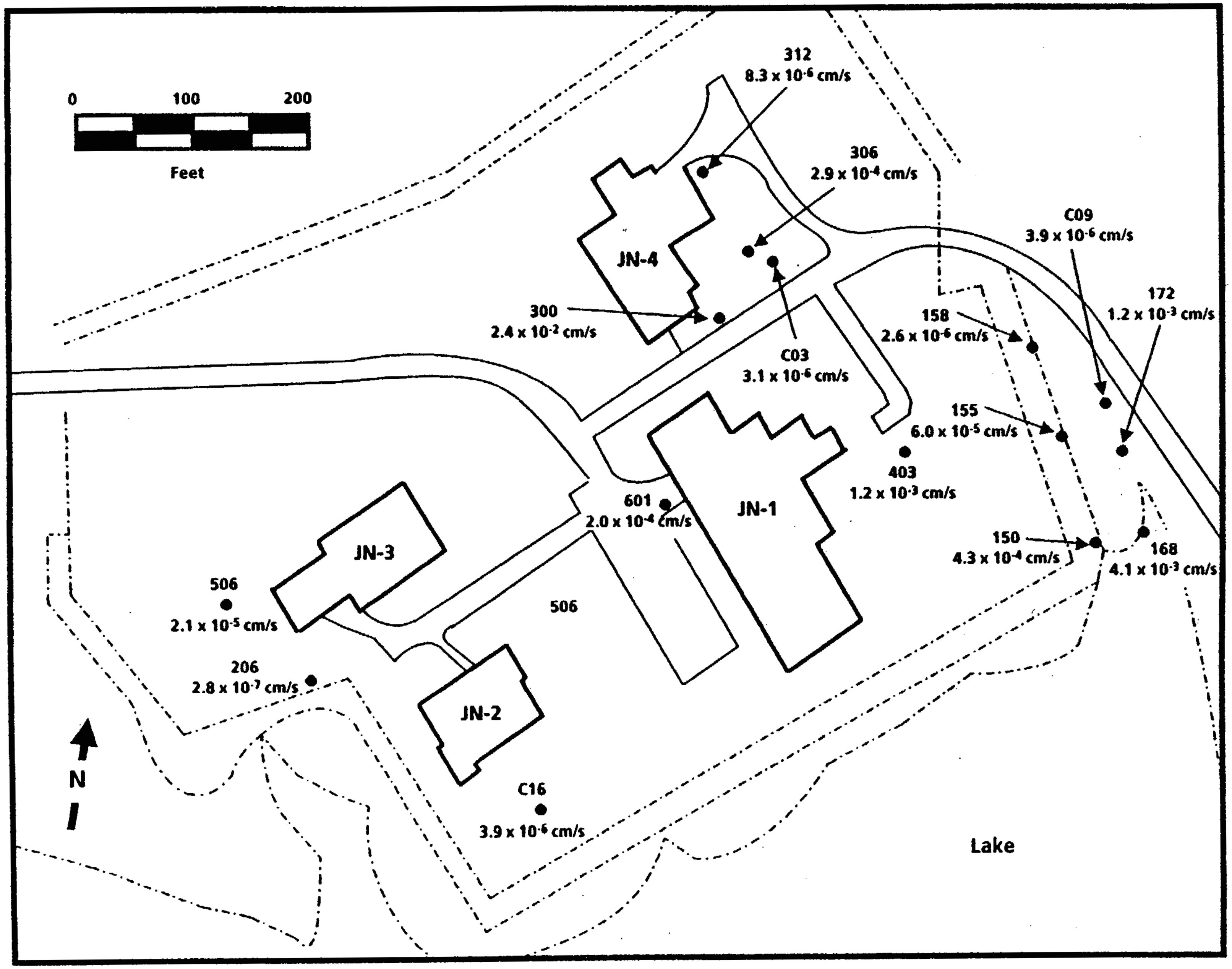


FIGURE 1.1: LOCATIONS OF THE GROUNDWATER MONITORING WELLS

It is in the till deposits that the borings and well installations were performed. The till consists of dense, predominantly non-plastic silt and clay, with minor amounts of sand and gravel in an unstratified mixture. Larger cobbles and boulders have been found in the till. Outwash deposits of small areal extent are also found within the till as sand and gravel lenses or stringers. The till has been subdivided in the boring logs (Appendix 1) by color into a brown till that is generally from 8 to 15-feet thick which overlies a grey till that is believed to extend to bedrock.

## 3.0 HYDRAULIC CONDUCTIVITY FIELD TESTING

In the fall and winter of 1989, hydraulic conductivity tests, also called slug tests, were performed in 15 monitoring wells at the West Jefferson North Site. Twelve of the wells were constructed of 2-inch diameter PVC with [redacted] and three of the wells were 4-inch diameter stainless steel wells [redacted] The detailed well construction diagrams are located in Appendix 2.

The wells were slug tested according to Site Characterization Procedure SC-SP-009 using a Hermit 1000 B data logger and pressure transducer. The results of the slug testing are located in Appendix 3.

## 4.0 DATA ANALYSIS

The time versus water-level data from the slug tests was analyzed using two standard methods. The Bouwer and Rice method was used for the data, hydrogeology, and well construction dimensions that best defined an unconfined aquifer. The other method, the Cooper et. al. method, was used for situations that more closely resembled a confined or semi-confined aquifer. Both methods use an analysis of semi-log plots of relative water level change versus time.

In many cases the plotted data clearly matched one method or the other, but in several instances, the data was able to be analyzed using both methods. When the data could be properly analyzed using both methods, the answers were usually within an order of magnitude of each other. The techniques of slug test evaluation can be found in the technical papers cited in SC-SP-009 and the reference section.

## 5.0 RESULTS

The results of the analysis fall within the range of values normally associated with the geologic materials present at each well. The results can be grouped into four main categories by the material present, either the near surface brown till/fill material, the confined and unconfined sandy zones, and the dense grey till. Table 5-1 lists the results for each well by method and the best answer is indicated. The most appropriate hydraulic conductivity value for each well is shown in Figure 1-1.

These results as well as the boring logs both agree that in general wells 306, 312, 506, C03, and C16 were completed in the brown till with some wells extending slightly into the grey till. The hydraulic conductivity values are moderate to low, ranging from 2.6 x $10^{-4}$ cm/sec to 3.0 x $10^{-7}$ cm/sec.

Wells 150, 155, 168, 172, 300, 403, 601, and C09 were completed in the sandier materials of higher hydraulic conductivity. Wells 150 and 168 intersect a sandy deposit under unconfined conditions. Wells 155, 172, 403 and C09 also are believed to be completed in this same sandy deposit but are under confined conditions, that is a lower conductivity material overlies the sandy material. All of these val~~y~~ues fall within a relatively narrow range from 1.2 x $10^{-3}$ cm/sec to 6.0 x $10^{-5}$ cm/sec. Well 300 may be completed in this same sand, but this is not certain. This well had the highest hydraulic conductivity of all wells tested at 2.4 x $10^{-2}$ cm/sec. Well 601 was completed in sandier material but not the same continuous deposit as the others.

The remaining wells 158 and 206 were completed in dense grey till and have low hydraulic conductivities of 2.6 x $10^{-6}$ cm/sec and 2.8 x $10^{-7}$ cm/sec, respectively.

TABLE 5.1. WEST JEFFERSON HYDRAULIC CONDUCTIVITY RESULTS

| | | HYDRAULIC CONDUCTIVITY | | | |
|---|---|---|---|---|---|
| | | Bouwer & Rice, 1976 | | Cooper et al., 1967 | |
| | Well # | ft/sec | cm/sec | ft/sec | cm/sec |
| 135 | 150 | * 1.4 x $10^{-5}$ | 4.3 x $10^{-4}$ | 2.9 x $10^{-5}$ | 8.9 x $10^{-4}$ |
| 20 | 155 | 4.2 x $10^{-6}$ | 1.3 x $10^{-4}$ | 19 * 2.0 x $10^{-6}$ | 6.0 x $10^{-5}$ |
| 1 | 158 | * 8.5 x $10^{-8}$ | 2.6 x $10^{-6}$ | 2.1 x $10^{-9}$ | 6.5 x $10^{-8}$ |
| 1260 | 168 | * 1.3 x $10^{-4}$ | 4.1 x $10^{-3}$ | 2.0 x $10^{-4}$ | 6.2 x $10^{-3}$ |
| 400 | 172 | 2.8 x $10^{-5}$ | 8.5 x $10^{-4}$ | * 4.0 x $10^{-5}$ | 1.2 x $10^{-3}$ |
| 8.1 | 206 | * 9.1 x $10^{-9}$ | 2.8 x $10^{-7}$ | 1.4 x $10^{-10}$ | 4.2 x $10^{-9}$ |
| 7666 | 300 | --- | --- | * 7.9 x $10^{-4}$ | 2.4 x $10^{-2}$ |
| 91 | 306 | 1.3 x $10^{-5}$ | 3.8 x $10^{-4}$ | * 9.4 x $10^{-6}$ | 2.9 x $10^{-4}$ |
| 3 | 312 | * 2.7 x $10^{-7}$ | 8.3 x $10^{-6}$ | 9.9 x $10^{-9}$ | 3.0 x $10^{-7}$ |
| 400 | 403 | 2.0 x $10^{-5}$ | 5.9 x $10^{-4}$ | 400 * 4.0 x $10^{-5}$ | 1.2 x $10^{-3}$ |
| 7 | 506 | * 6.9 x $10^{-7}$ | 2.1 x $10^{-5}$ | --- | --- |
| 60 | 601 | * 6.6 x $10^{-6}$ | 2.0 x $10^{-4}$ | --- | --- |
| 1 | C03 | * 1.0 x $10^{-7}$ | 3.1 x $10^{-6}$ | --- | --- |
| 1.3 | C09 | * 1.3 x $10^{-7}$ | 3.9 x $10^{-6}$ | --- | --- |
| 1.3 | C16 | * 1.3 x $10^{-7}$ | 3.9 x $10^{-6}$ | --- | --- |

* Indicates best method (results) for the slug test data.

## 6.0 REFERENCES

Bouwer, H., 1989. "The Bouwer and Rice Slug Test - An Update", Groundwater, 27 (3), pp. 304-309.

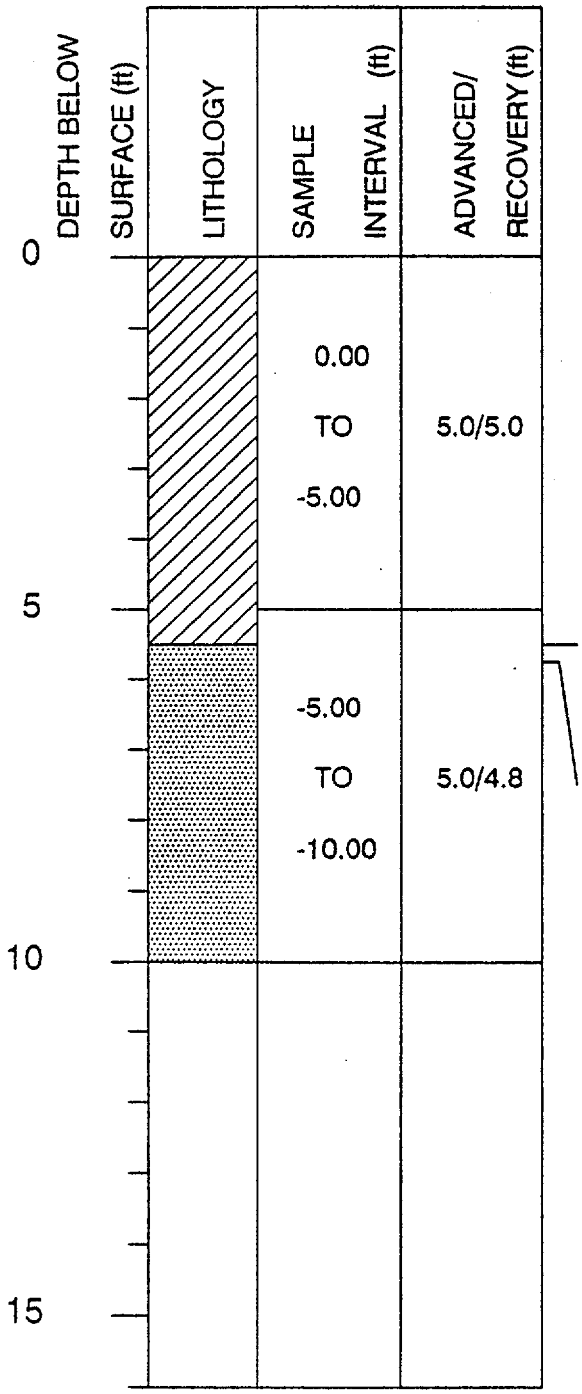
Bouwer, H., and Rice, R. C., 1976. "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells", Water Resources Research, 12, pp. 423-428.

Cooper, H. H. Jr., Bredehoeft, J. D., and Papadopulos, I. S., 1967. "Response of a Finite Diameter Well to an Instantaneous Charge of Water", Water Resources Research, 3, pp. 263-269.

# APPENDIX 1

# BORING LOGS FOR MONITORING WELLS

BOREHOLE NUMBER: 150 LOCATION: Sample Area 1 24 APRIL 1989



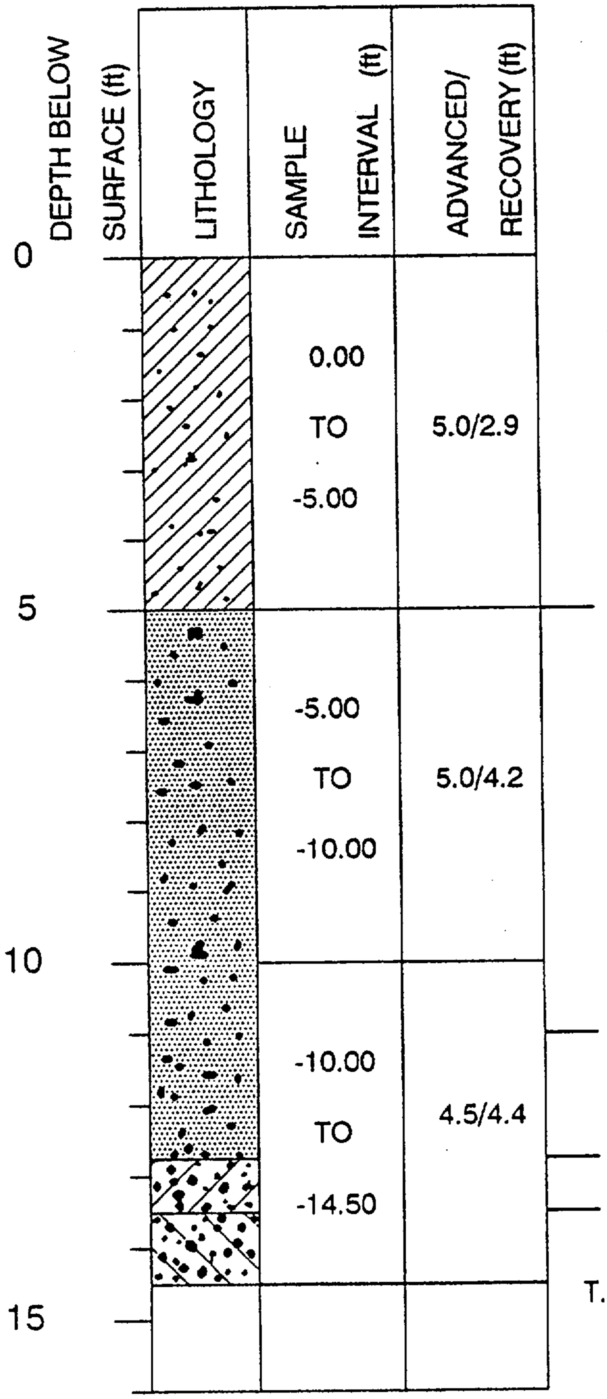
Dark brown clayey silt
changing to light brown

Brown to tan silty clayey sand
increasing sand content with depth to 10 ft
fine grained salt and pepper sand

Water encountered at 5.8 ft

T. D. 10.0 ft

BOREHOLE NUMBER: 155 LOCATION: Sample Area 1 27 APRIL 1989



Brown clayey silt/ silty clay with sand, gravel and pebbles

Brown clayey silty sand with pebbles and gravel, soft, medium grained poorly sorted and very moist

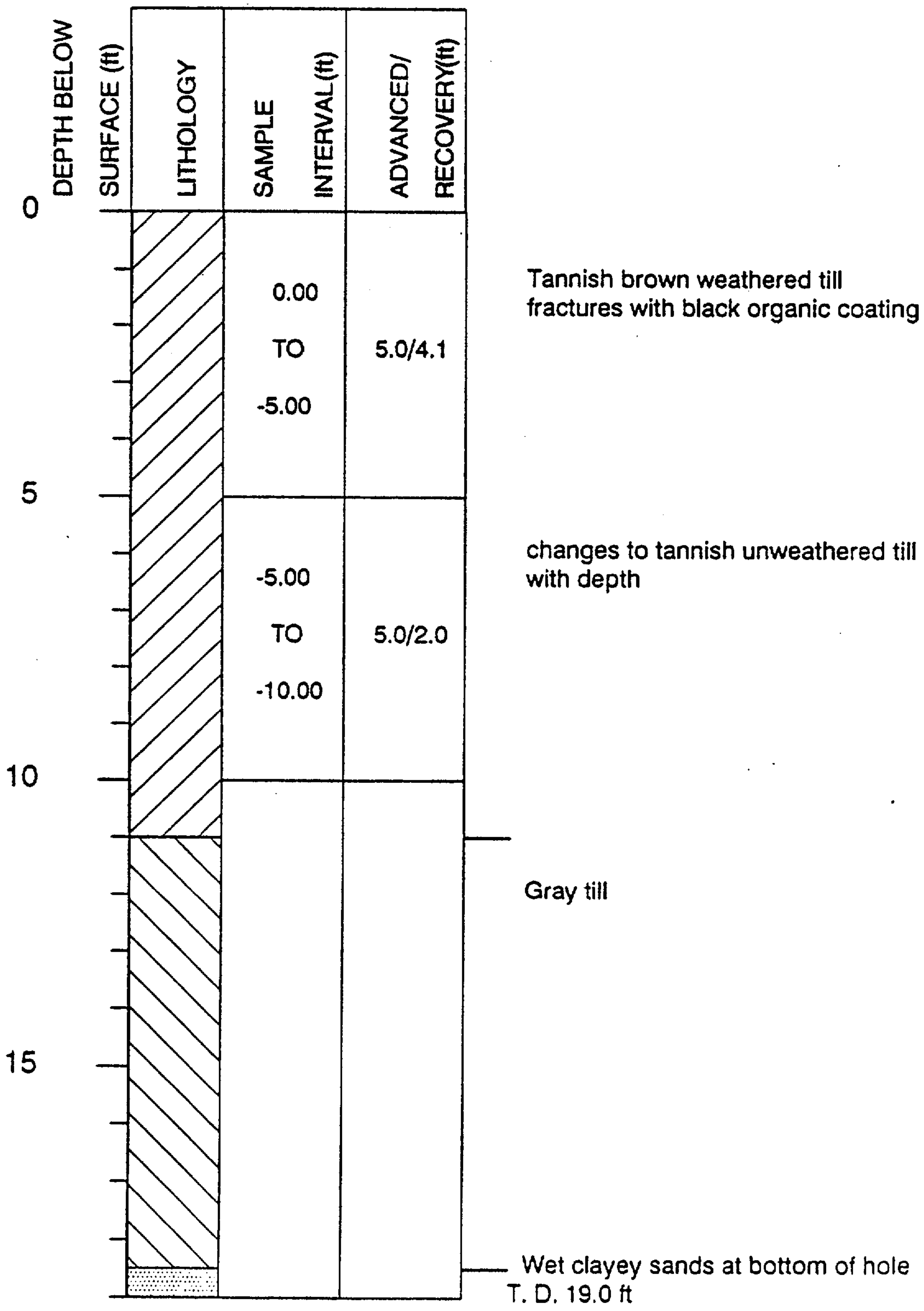
Water encountered at 11.0 ft

same as above with larger and more pabbles

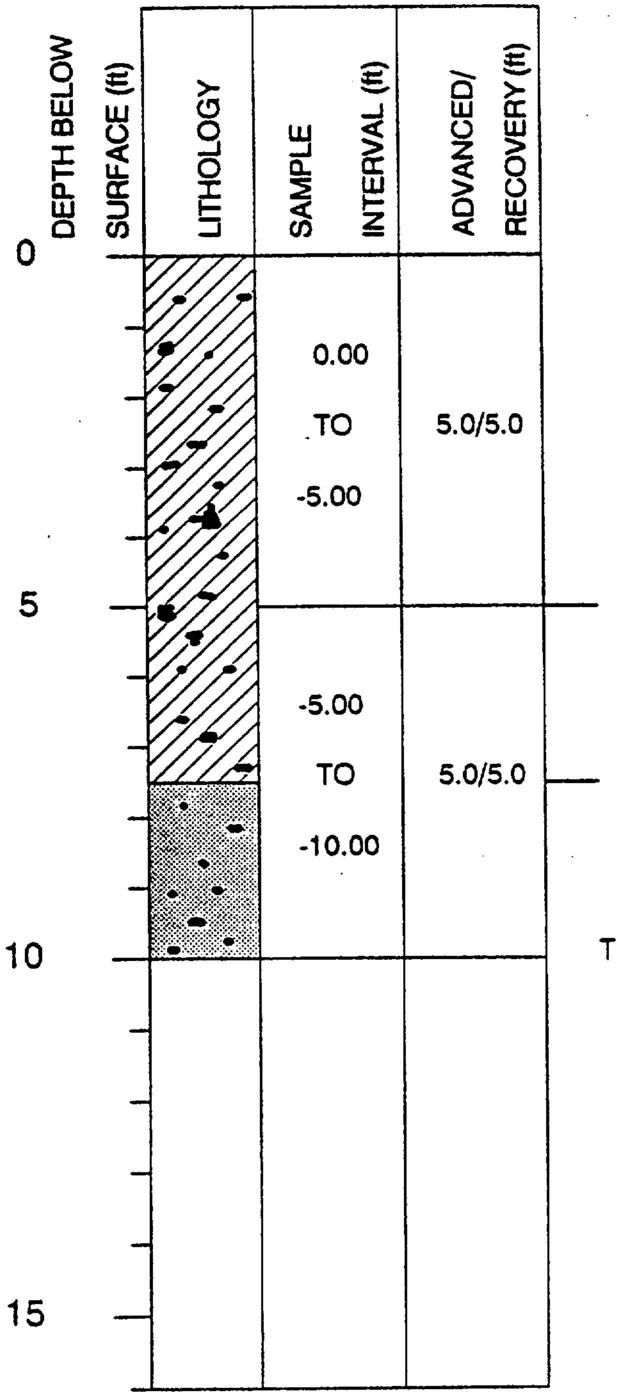
Abrupt change to gray color: gray till

T.D. 14.5 ft

BOREHOLE NUMBER: 158 LOCATION: Sample Area 1 28 APRIL 1989



BOREHOLE NUMBER: 168 LOCATION: Sample Area 1 25 APRIL 1989



Grass
Dark tan to brown soil
abrupt change to dark brown at 0.9 ft
and back to light brown at 1.5 ft
sandy clayey silt with some pebbles

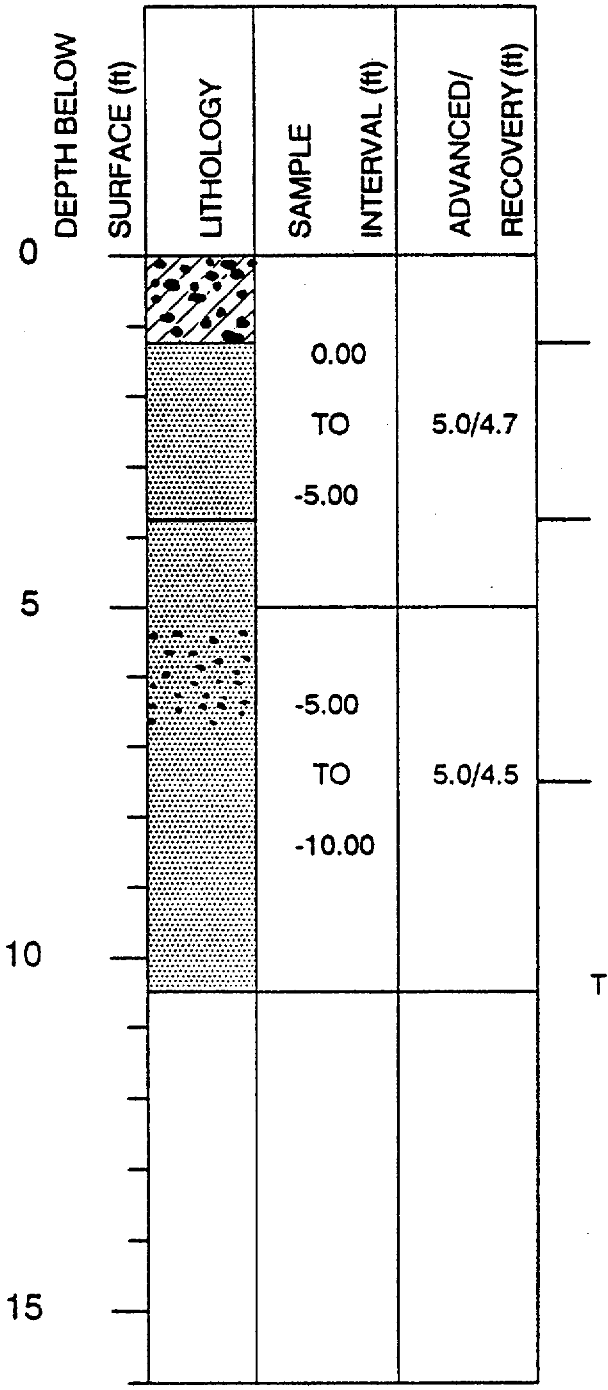
Water encountered at 5.0 ft

Brown clayey gravelly silt

Increasing sand with depth

T. D. 10.0 ft

BOREHOLE NUMBER: 172 LOCATION: Sample Area 1 27 APRIL 1989



Cattails on surface
Brown sandy clayey silt, some gravel

Gradual color change to gray
in the middle 2.5 ft

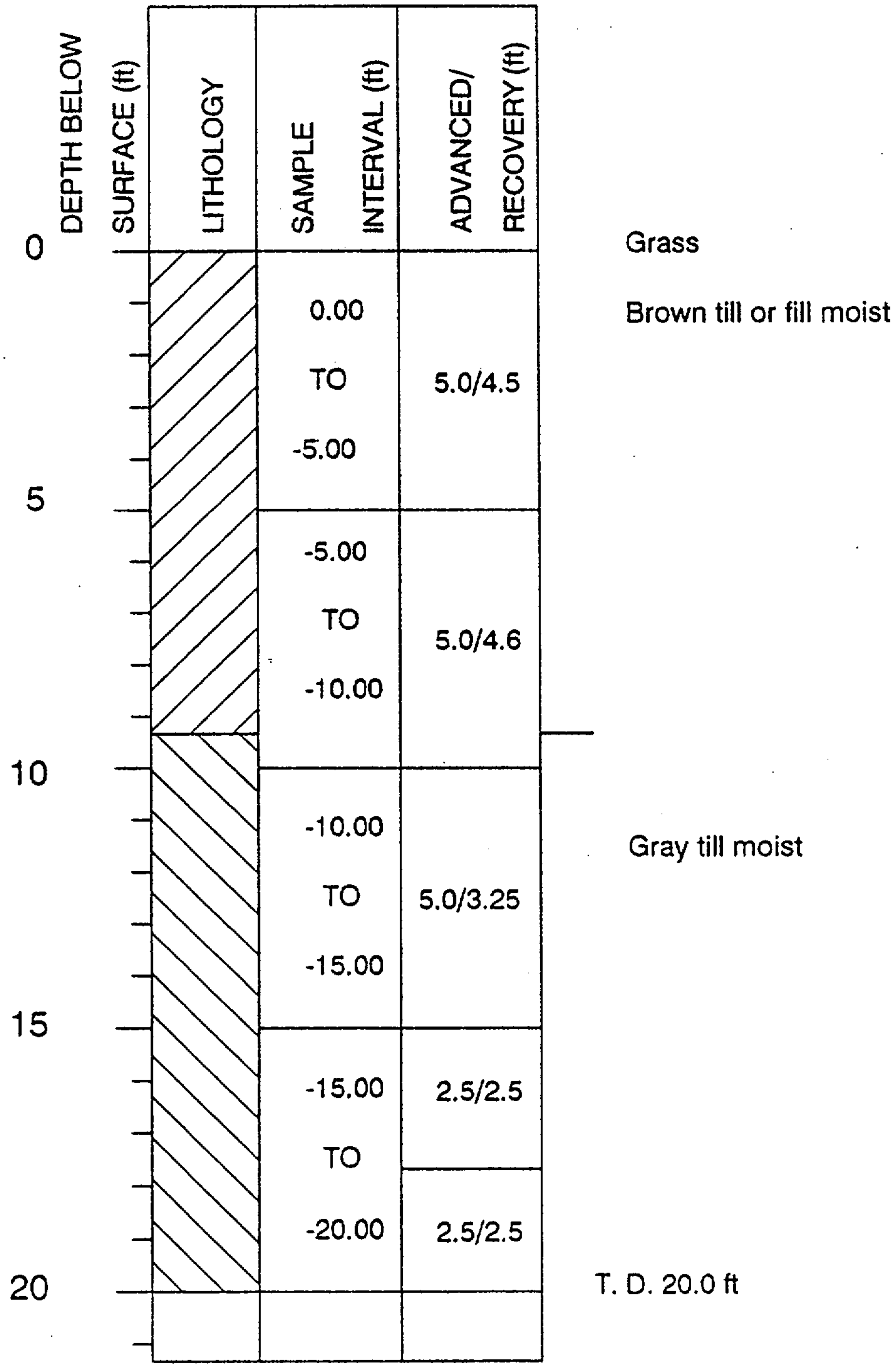
Brown silty clayey sand medium grained

lots of pebbles/gravel from 5.6 to 6.6 ft

Water encountered at 7.5 ft

moderately sorted in bottom of core
T. D. 10.5 ft

BOREHOLE NUMBER: 206 LOCATION: Sample Area 2 26 JUNE 1989

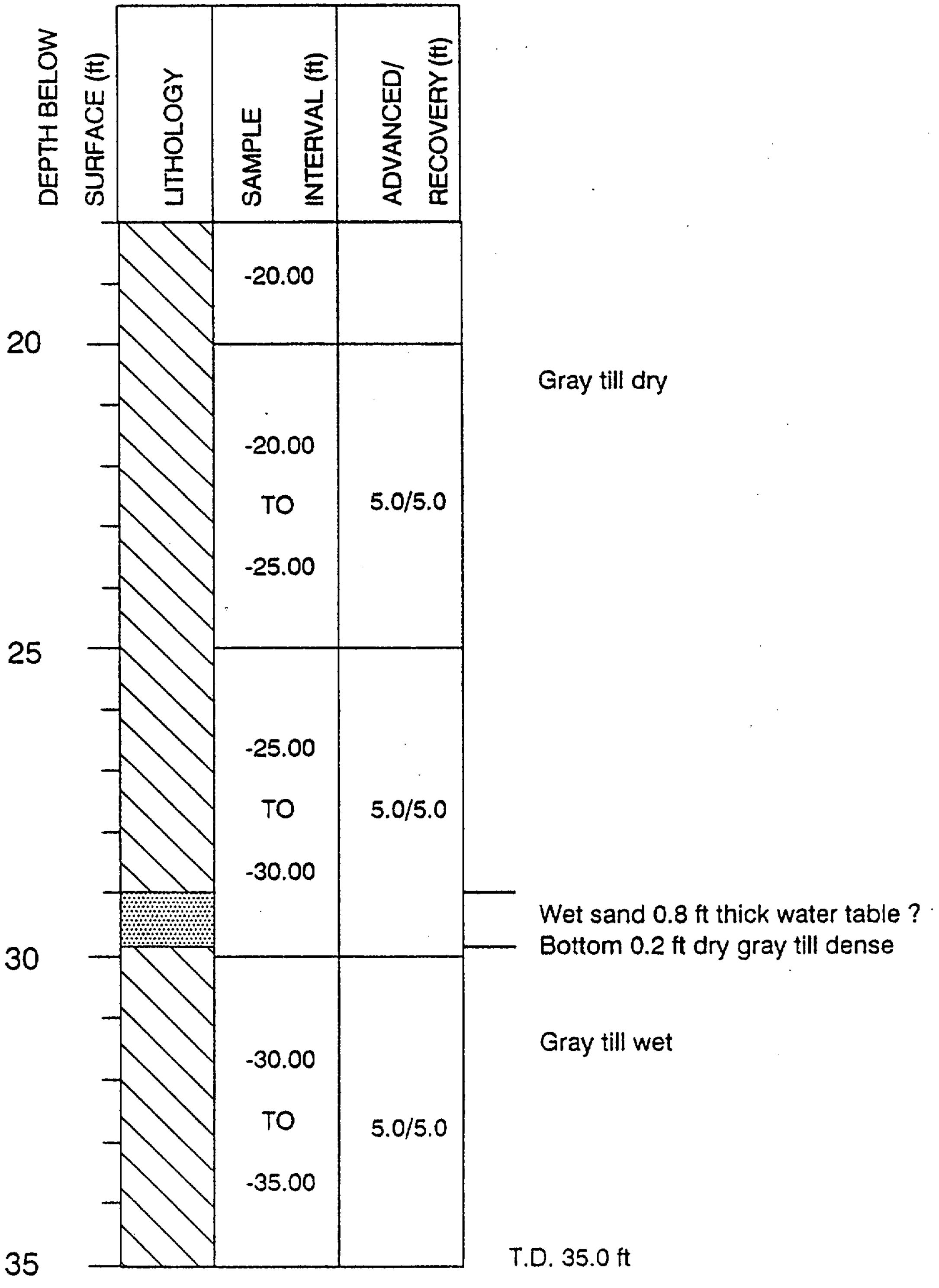


BOREHOLE NUMBER: 300 LOCATION: Sample Area 3 29 JUNE 1989

| DEPTH BELOW SURFACE (ft) | LITHOLOGY | SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) | |
|---|---|---|---|---|
| 0 | | 0.00<br>TO<br>-5.00 | 1.0/1.0 | Gray gravel 0.4 ft becoming finer with depth |
| | | | 4.0/4.0 | Brown fill or till<br>bottom 1.0 ft dark brown till or fill |
| 5 | | -5.00<br>TO<br>-10.00 | 5.0/4.0 | top 0.8 ft dark brown fill wet perched<br>bottom 3.2 ft brown till compact moist |
| 10 | | -10.00<br>TO<br>-15.00 | 5.0/3.0 | brown till moist |
| 15 | | -15.00<br>TO | 5.0/5.0 | Gray till dry |

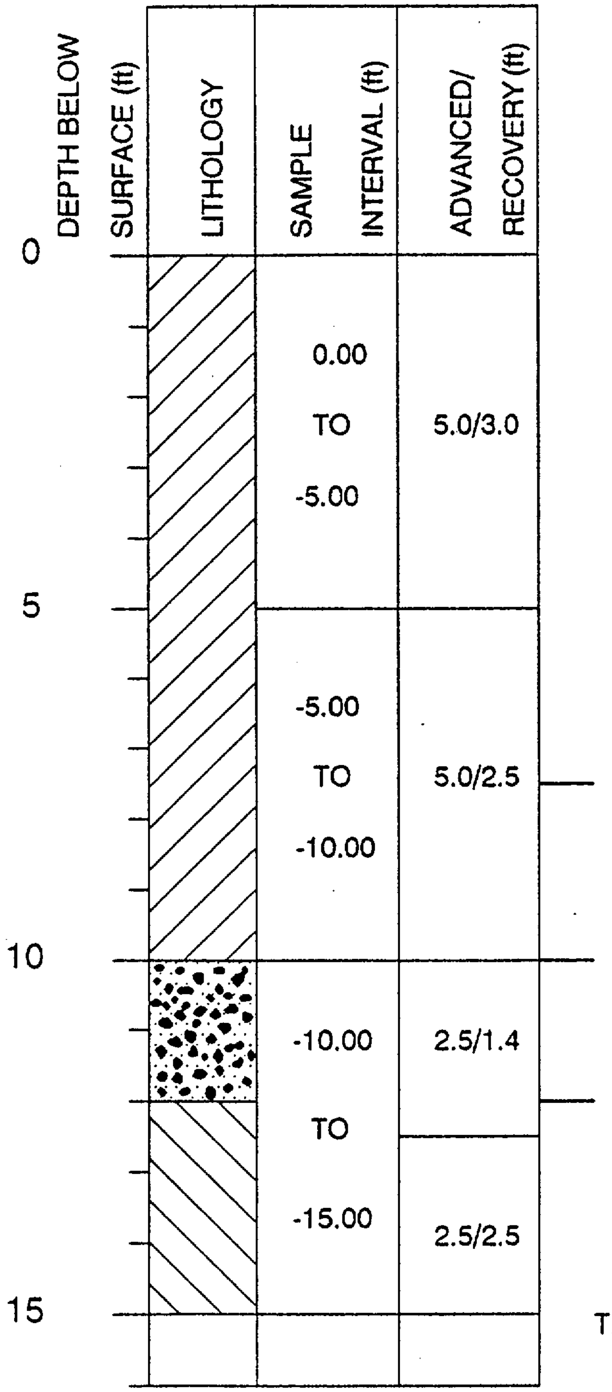
PAGE 2 OF 2

BOREHOLE NUMBER: 300 LOCATION: Sample Area 3 29 JUNE 1989



| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| -20.00 | |
| -20.00 TO -25.00 | 5.0/5.0 |
| -25.00 TO -30.00 | 5.0/5.0 |
| -30.00 TO -35.00 | 5.0/5.0 |

BOREHOLE NUMBER: 306 LOCATION: Sample Area 3 29 JUNE 1989



Brown fill moist

bottom 0.4 ft wet

Water encountered at about 7.5 ft

brown fill wet from middle to bottom of core

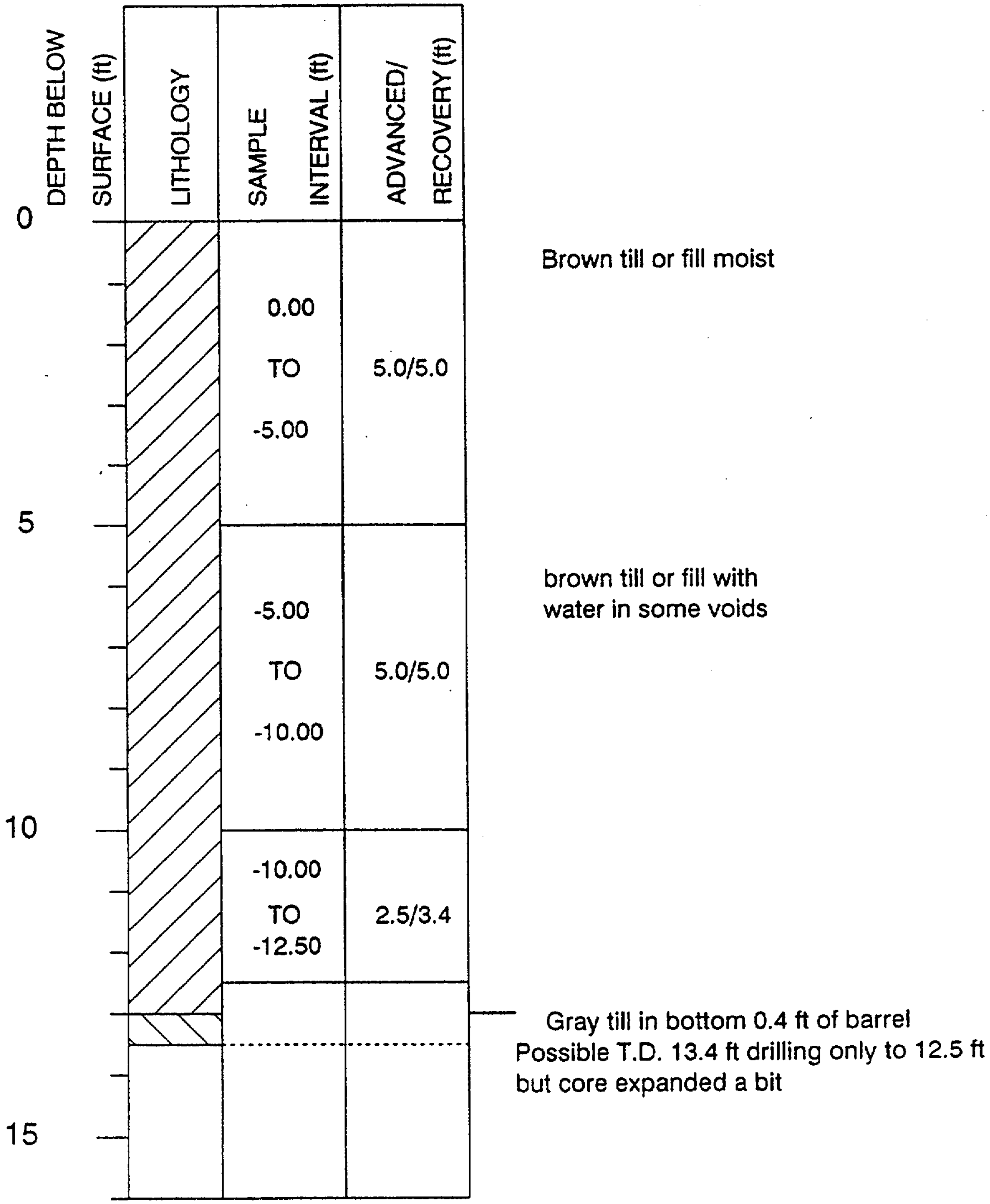
Wet gravel

Gray till wet

bottom 0.5 ft moist

T. D. 15.0 ft

BOREHOLE NUMBER: 312 LOCATION: Sample Area 3 29 JUNE 1989



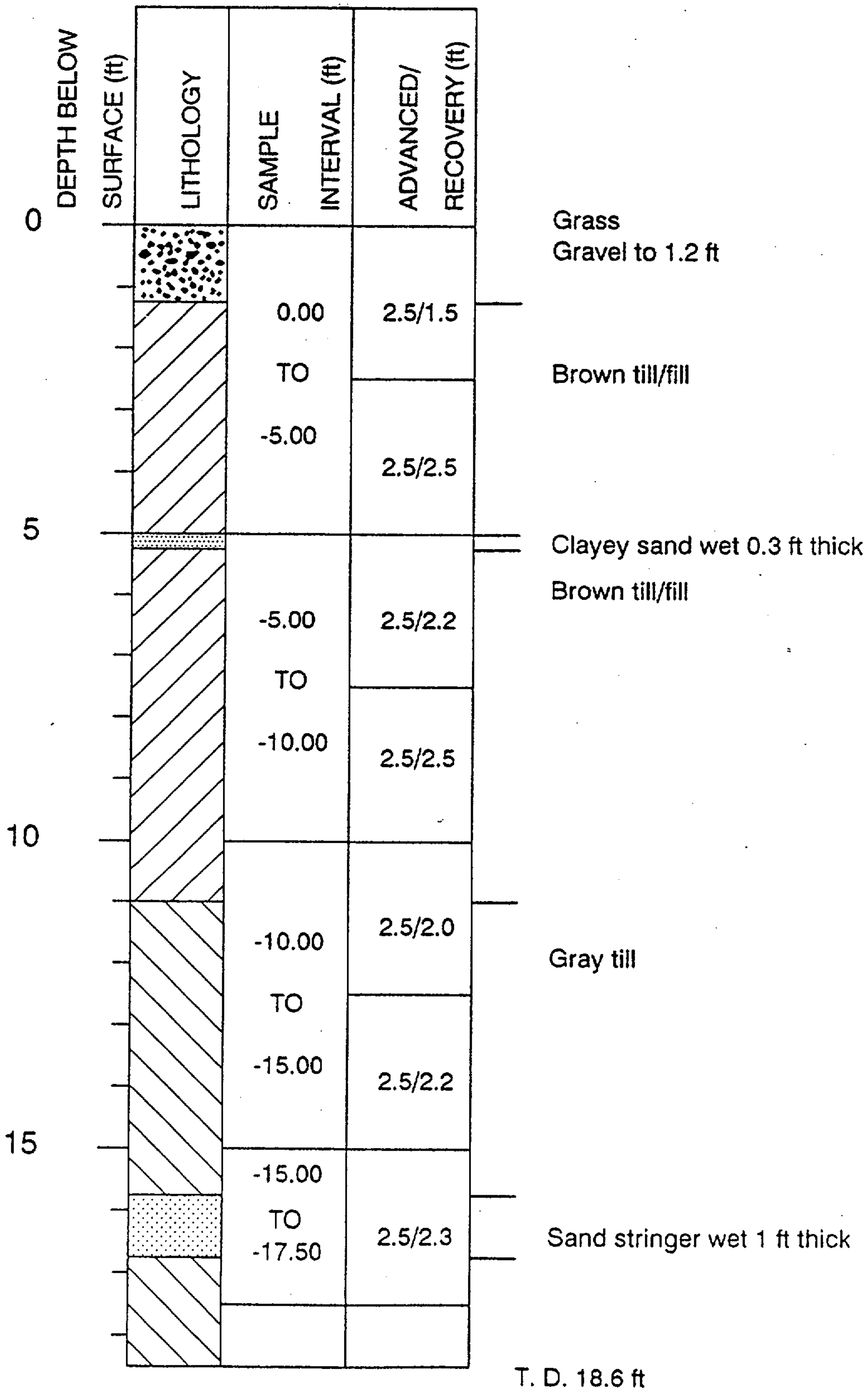
| SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) |
|---|---|
| 0.00 TO -5.00 | 5.0/5.0 |
| -5.00 TO -10.00 | 5.0/5.0 |
| -10.00 TO -12.50 | 2.5/3.4 |

Brown till or fill moist

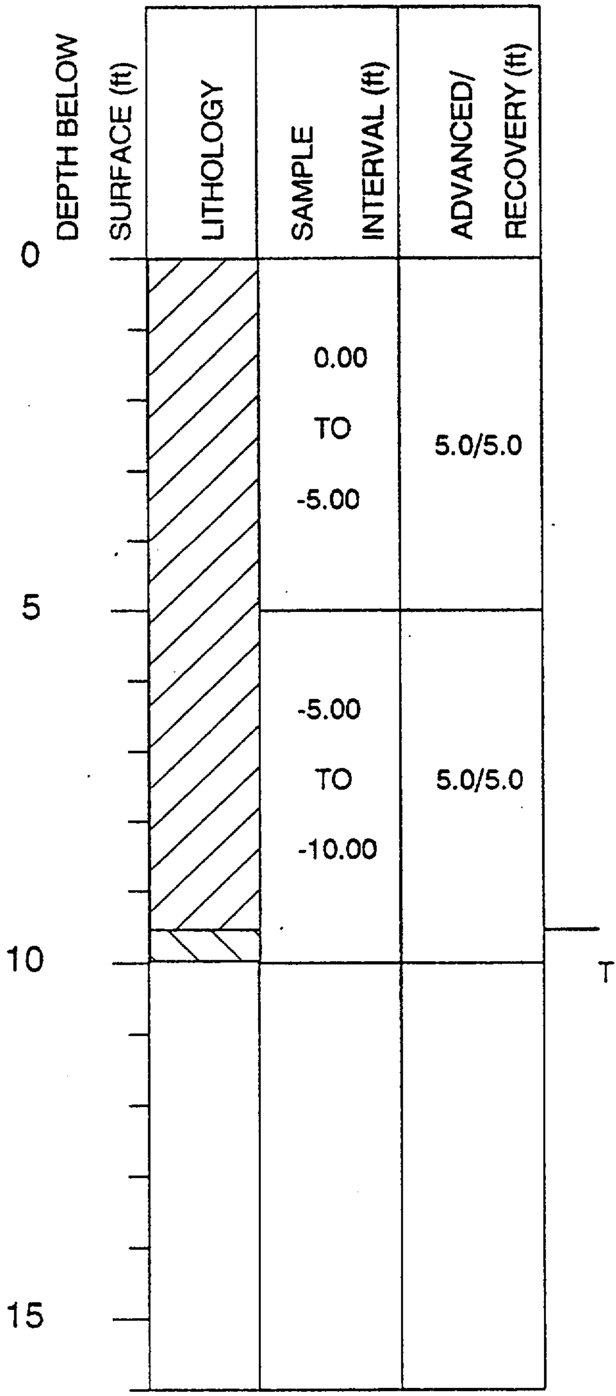
brown till or fill with water in some voids

Gray till in bottom 0.4 ft of barrel
Possible T.D. 13.4 ft drilling only to 12.5 ft but core expanded a bit

BOREHOLE NUMBER: 403 LOCATION: Sample Area 4 2 AUGUST 1989



BOREHOLE NUMBER: 506  LOCATION: Sample Area 5  24 JULY 1989

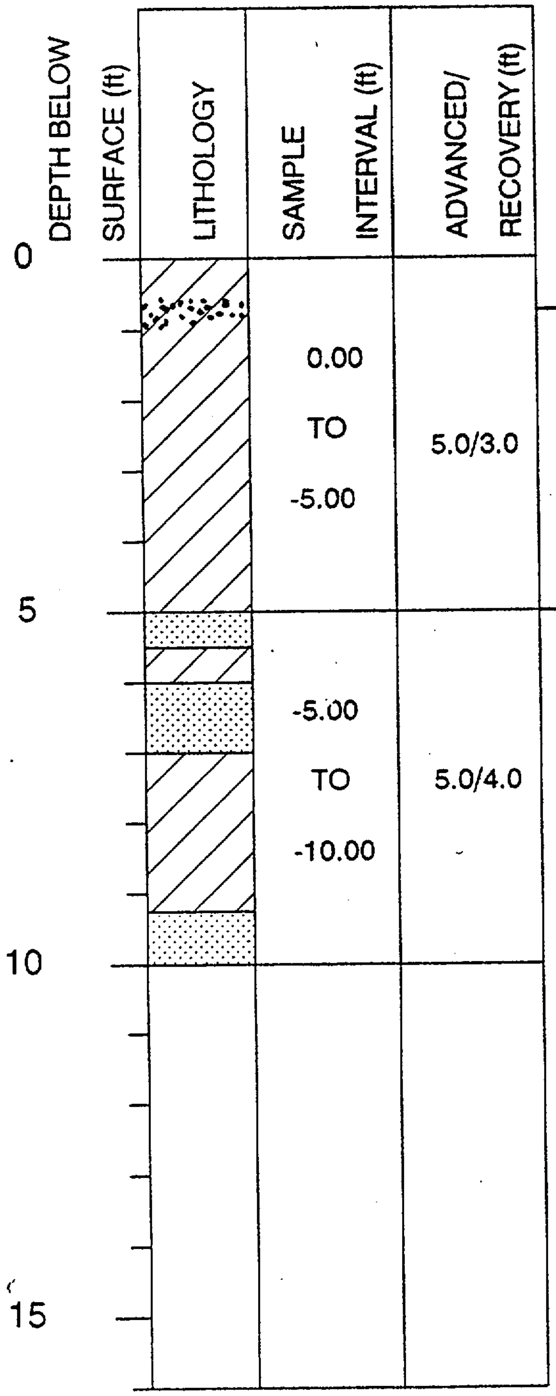


Grass
Brown till silty clay with gravel moist

brown till

Gray till bottom 0.4 ft silty clay with gravel
T. D. 10.0 ft

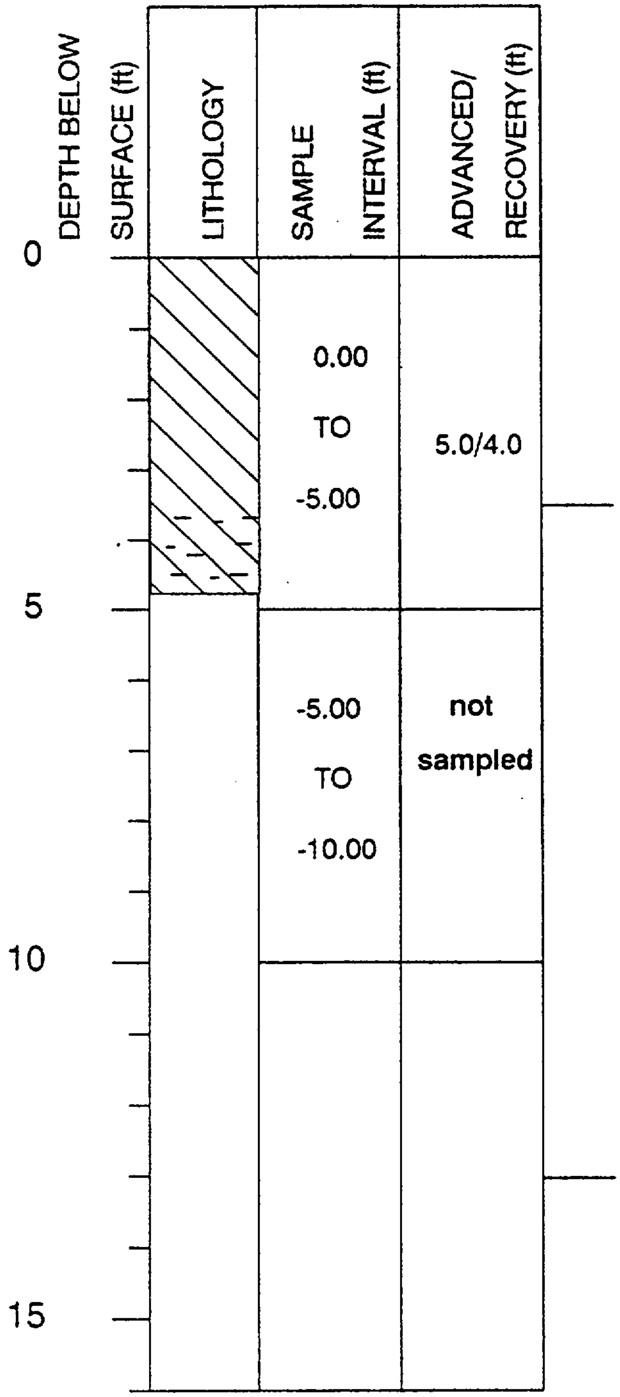
BOREHOLE NUMBER: 601 LOCATION: Sample Area 6 26 JULY 1989



| DEPTH BELOW SURFACE (ft) | LITHOLOGY | SAMPLE INTERVAL (ft) | ADVANCED/ RECOVERY (ft) | |
|---|---|---|---|---|
| 0 | | | | Grass<br>Dark brown top soil 0.5 ft<br>Gravel 0.3 ft |
| | | 0.00<br>TO<br>-5.00 | 5.0/3.0 | Brown till/fill |
| 5 | | | | Ground water encountered at 5.0 ft |
| | | -5.00<br>TO<br>-10.00 | 5.0/4.0 | Interbedded pebbly sands and clay<br>very wet |
| 10 | | | | T. D. 10.0 ft |
| 15 | | | | |

BOREHOLE NUMBER: C-03

17 November 1989



**Brown fill soft**
**Very moist & soft**

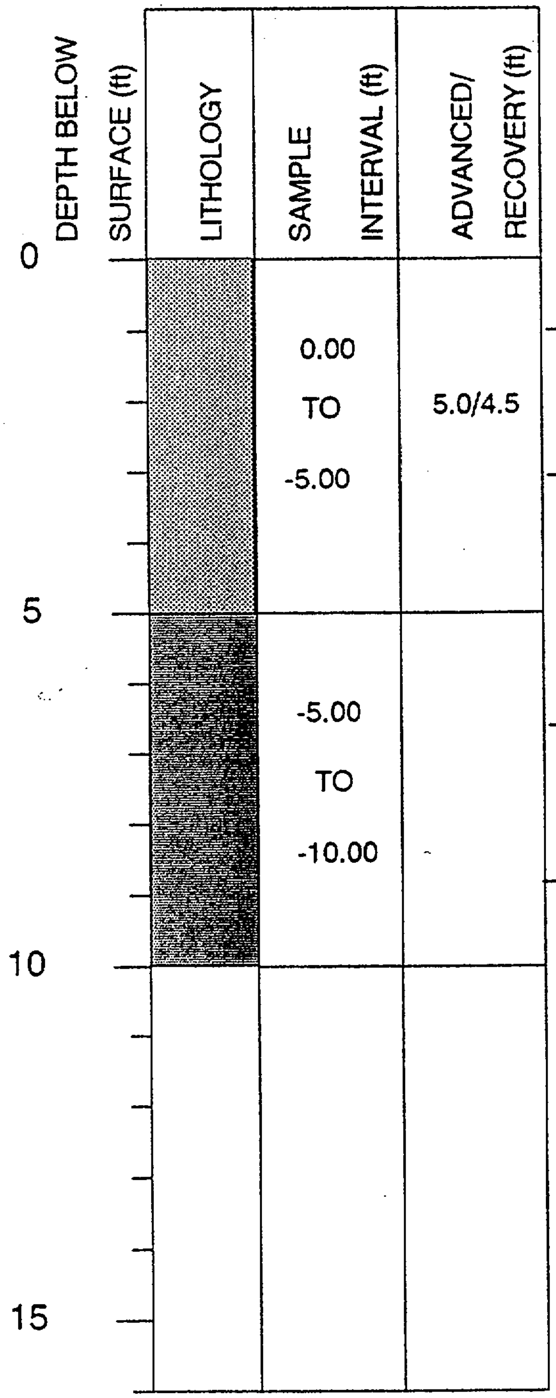
**Water encountered 4.5 ft**

**Drier fill more dense**
**More gravel & pebbles**

**T.D. 12.0 ft**

BOREHOLE NUMBER: C-09

17 November 1989



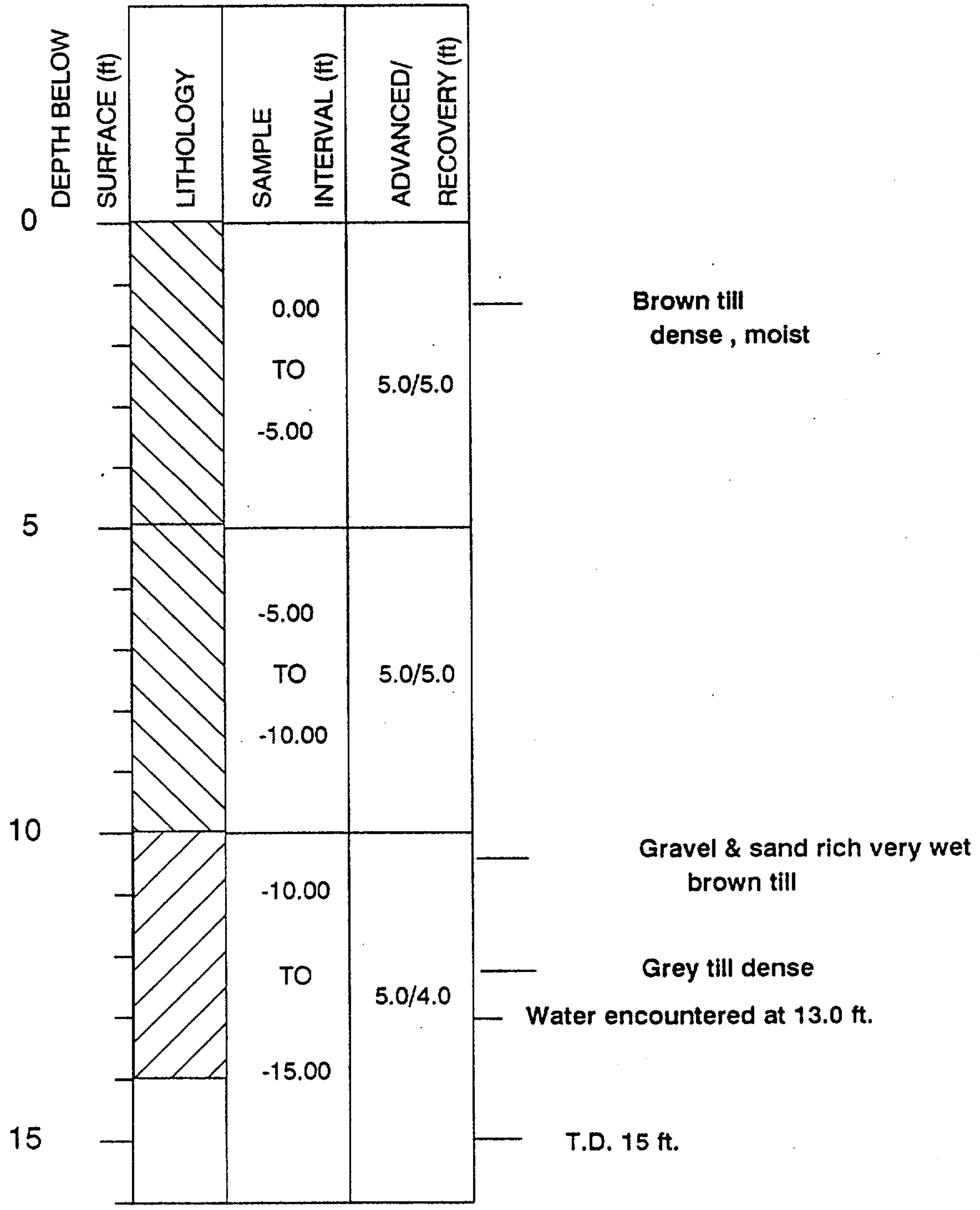
Brown & grey clay
soft & moist

Water encountered at 3.0 ft.

Brown clay
moist

T.D. 8.9 ft.

BOREHOLE NUMBER: C-16 15 November 1989

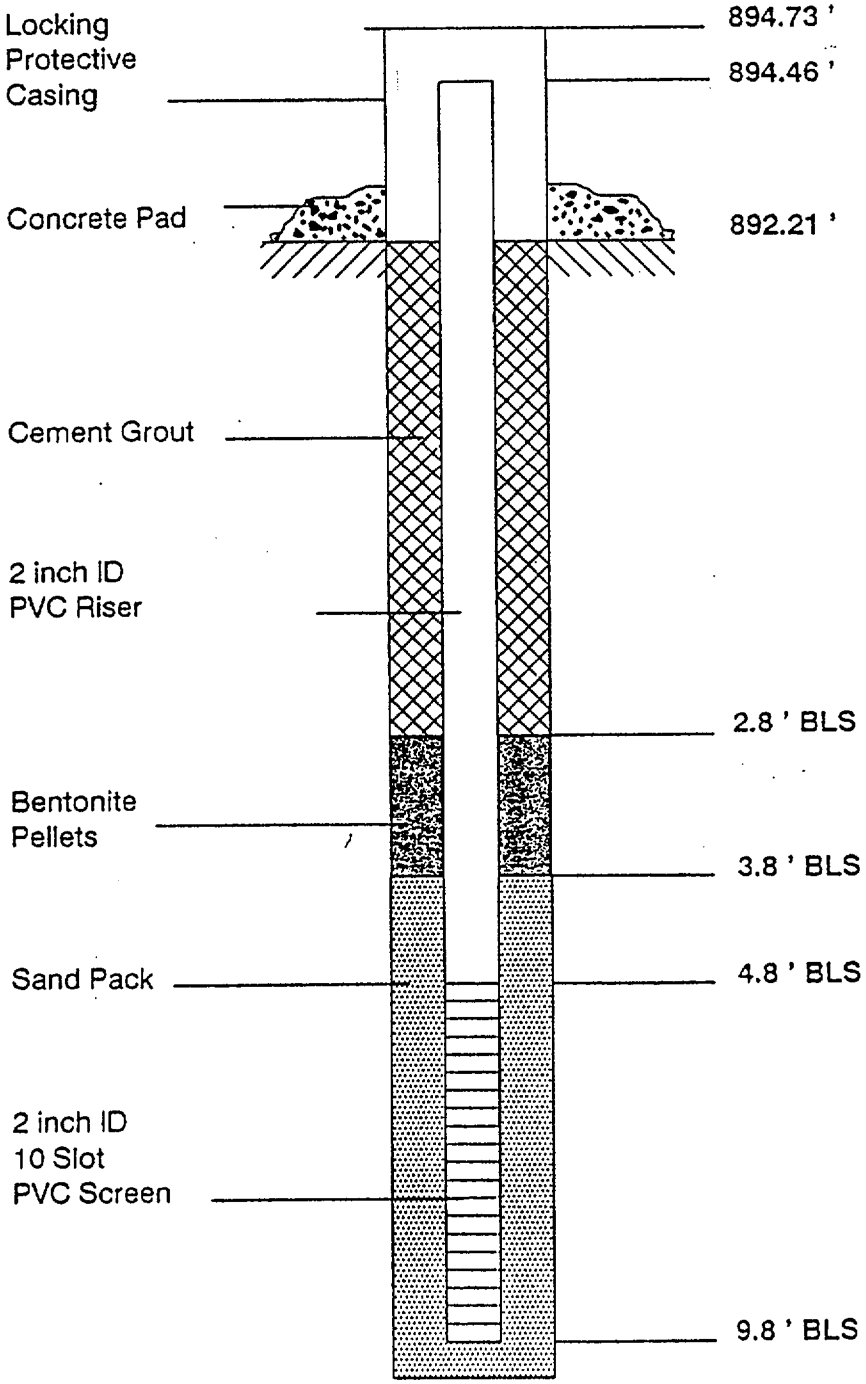


# APPENDIX 2

# MONITORING WELL CONSTRUCTION DIAGRAMS

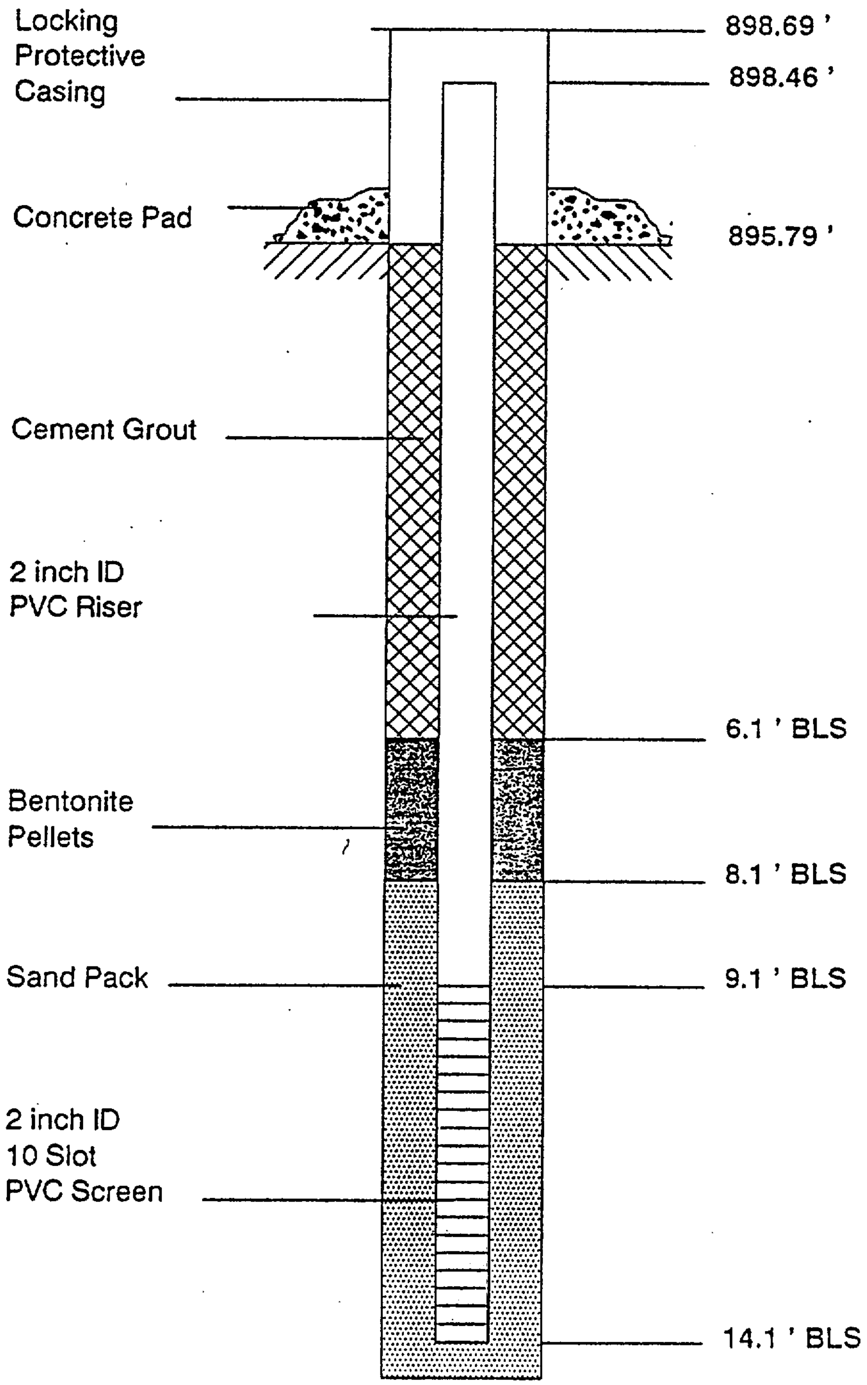
BOREHOLE NUMBER: 150 LOCATION: Sample Area 1 25 April 1989

Total Depth 10.0 ' Borehole Diameter 0.7 '



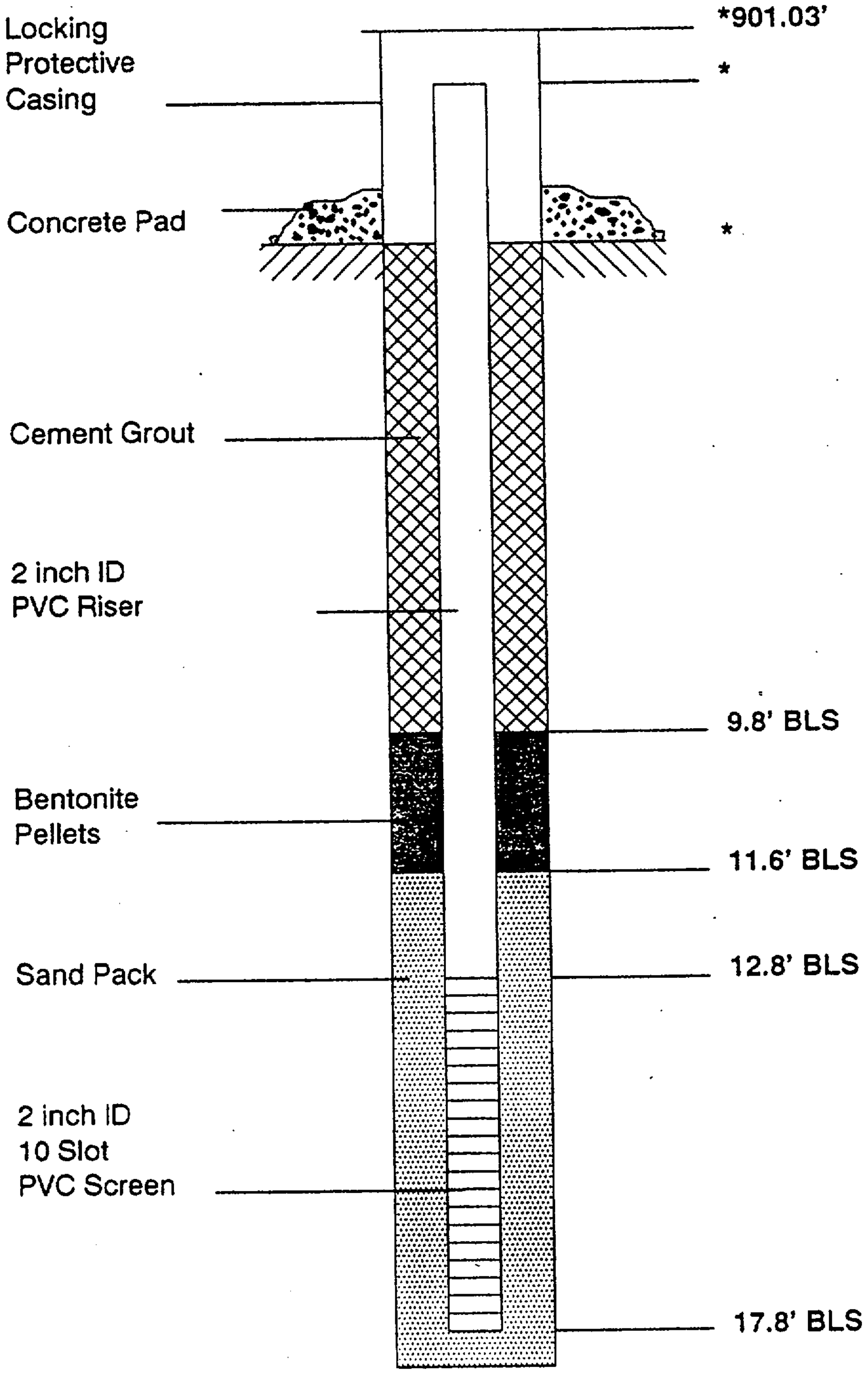
BOREHOLE NUMBER: 155 LOCATION: Sample Area 1 27 April 1989

Total Depth 14.5 ' Borehole Diameter 0.7 '



BOREHOLE NUMBER: 158 LOCATION:Sample Area 1 28 April 1989

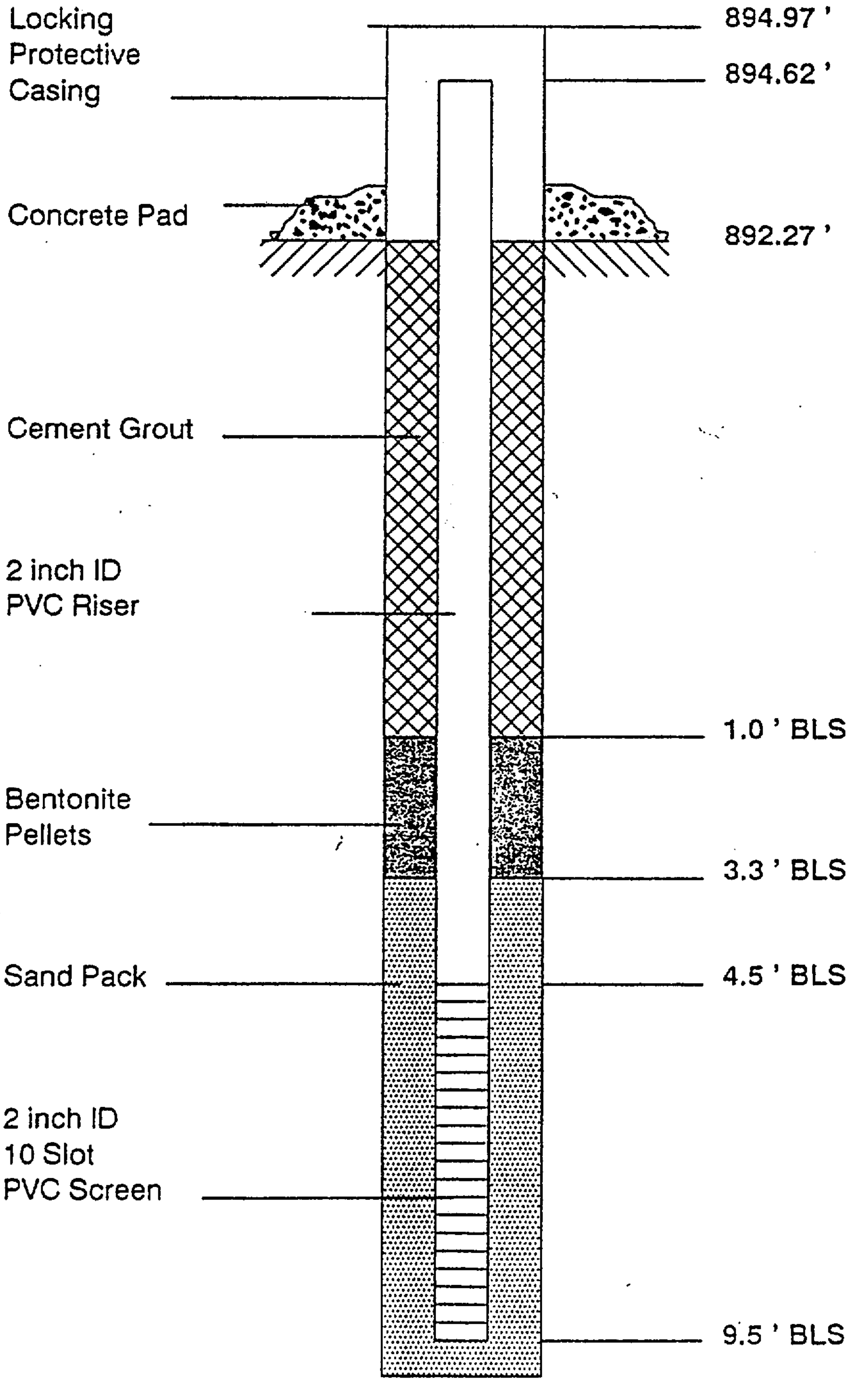
Total Depth 19.0' Borehole Diameter 0.7'



* The well has been damaged, and the elevations are approximate.

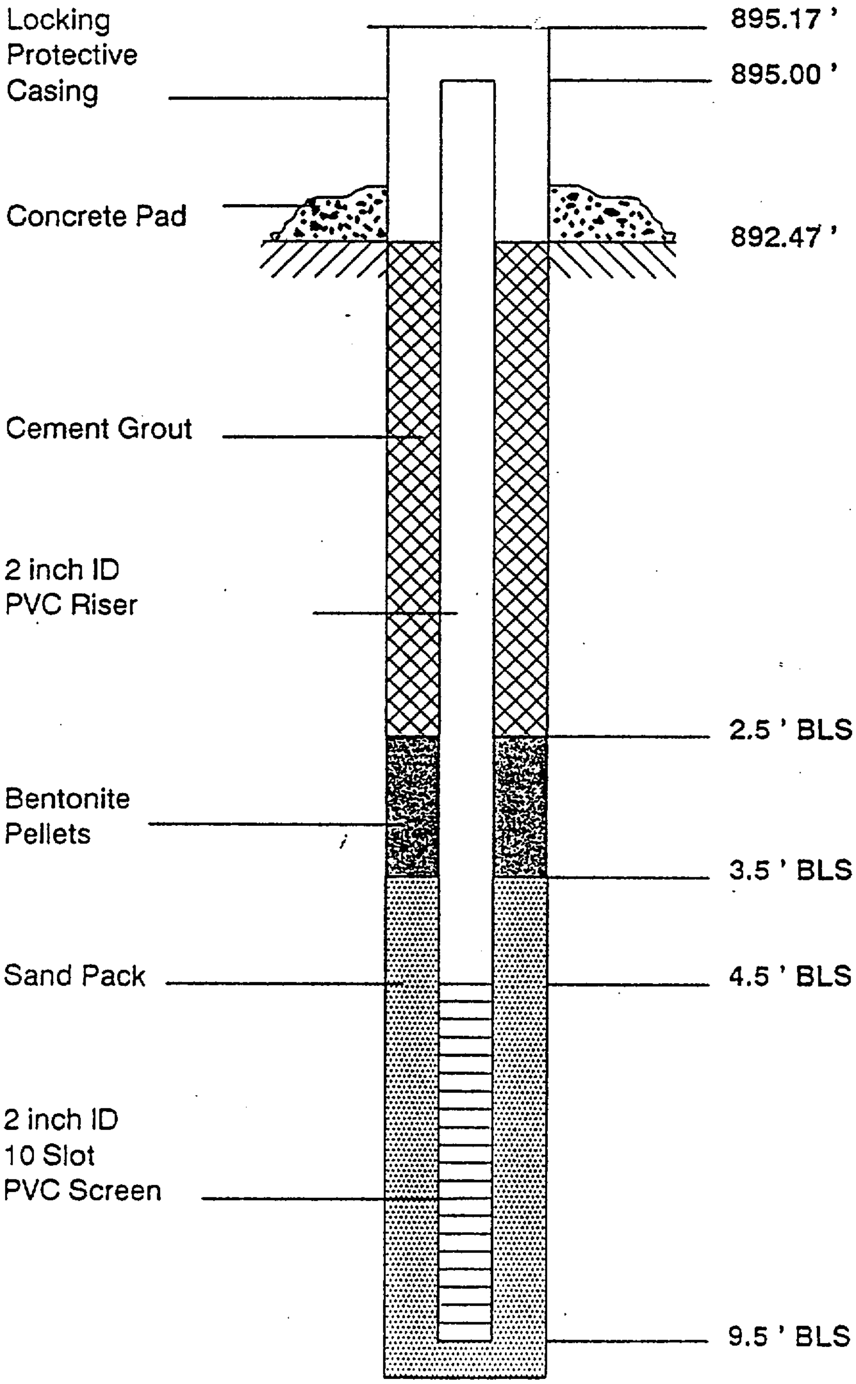
BOREHOLE NUMBER: 168    LOCATION: Sample Area 1    25 April 1989

Total Depth 10.0 '    Borehole Diameter 0.7 '



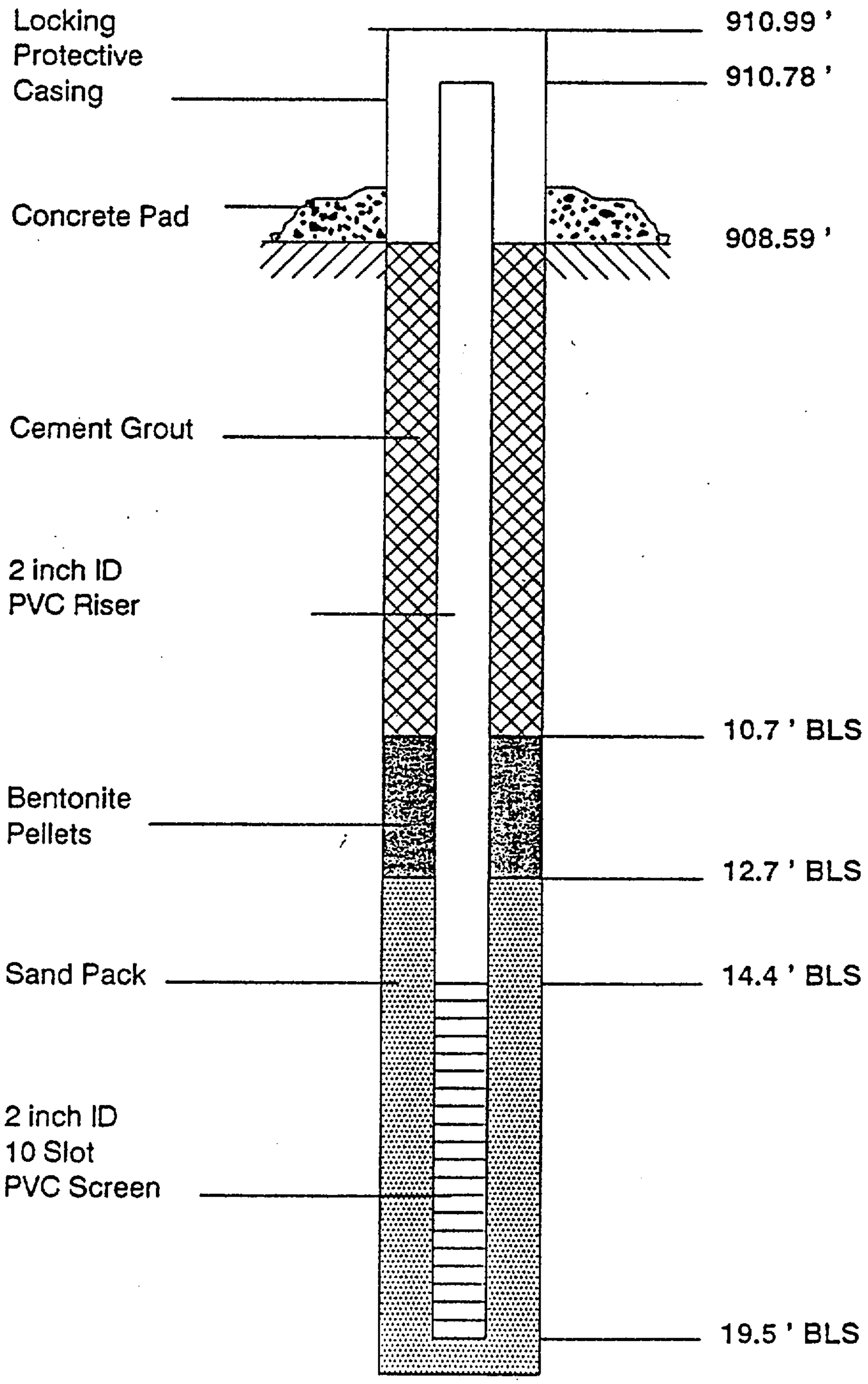
BOREHOLE NUMBER: 172 LOCATION: Sample Area 1 27 April 1989

Total Depth 10.5 ' Borehole Diameter 0.7 '



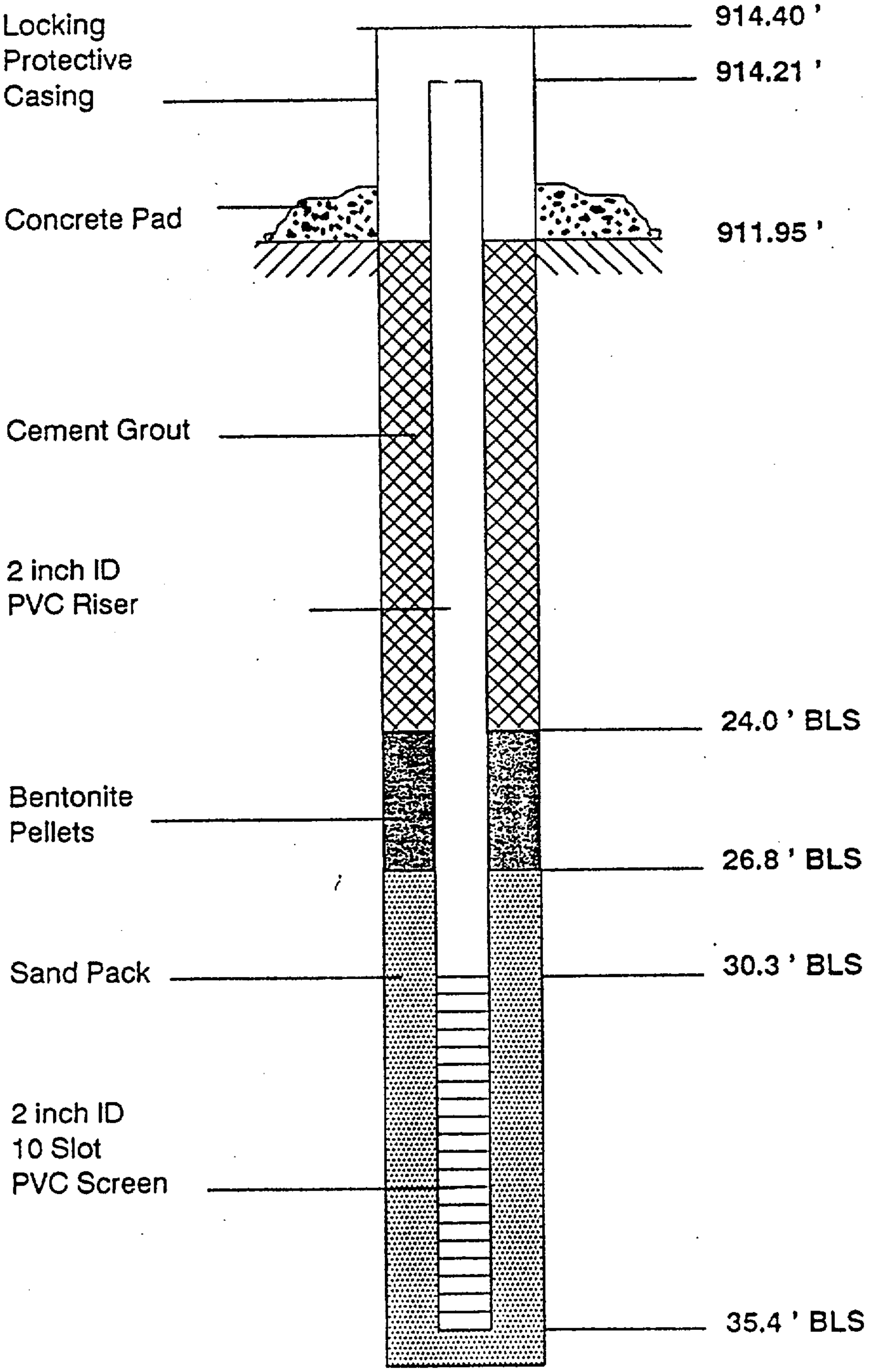
BOREHOLE NUMBER: 206    LOCATION: Sample Area 2    27 June 1989

Total Depth 19.6 '    Borehole Diameter 0.7 '



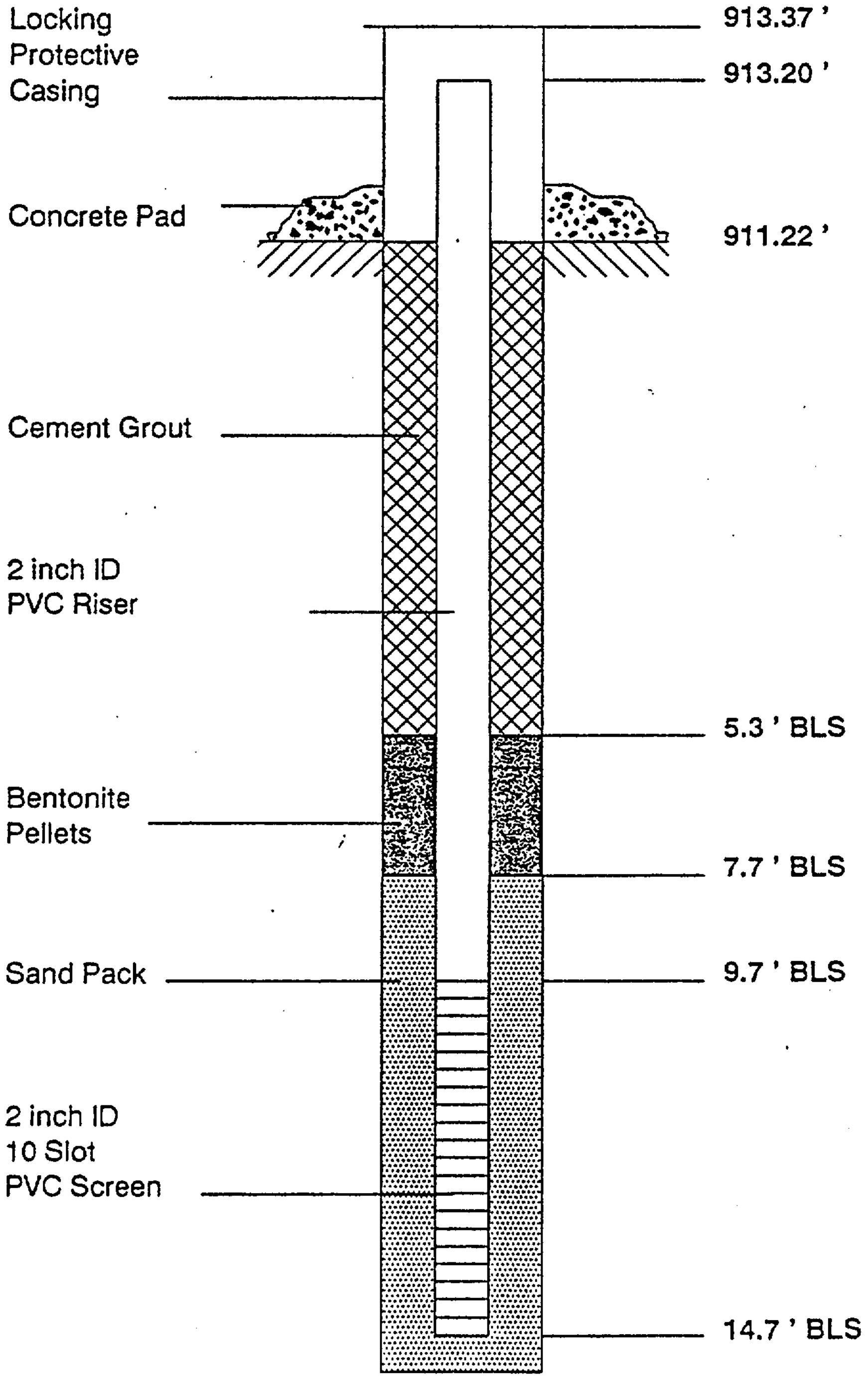
BOREHOLE NUMBER: 300 LOCATION: Sample Area 3 30 June 1989

Total Depth 35.5 ' Borehole Diameter 0.7 '



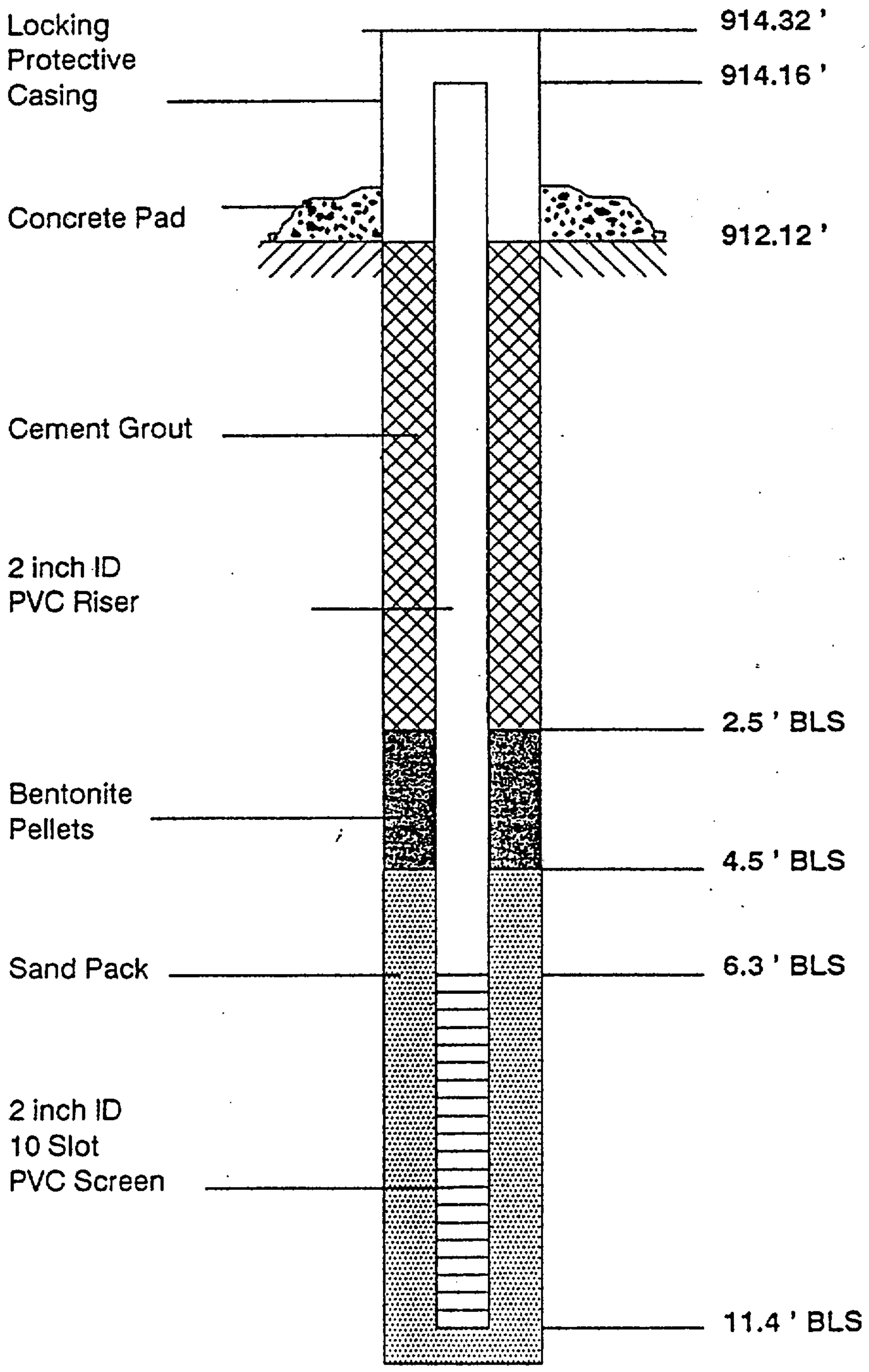
BOREHOLE NUMBER: 306   LOCATION: Sample Area 3   29 June 1989

Total Depth 15.0 '   Borehole Diameter 0.6 '



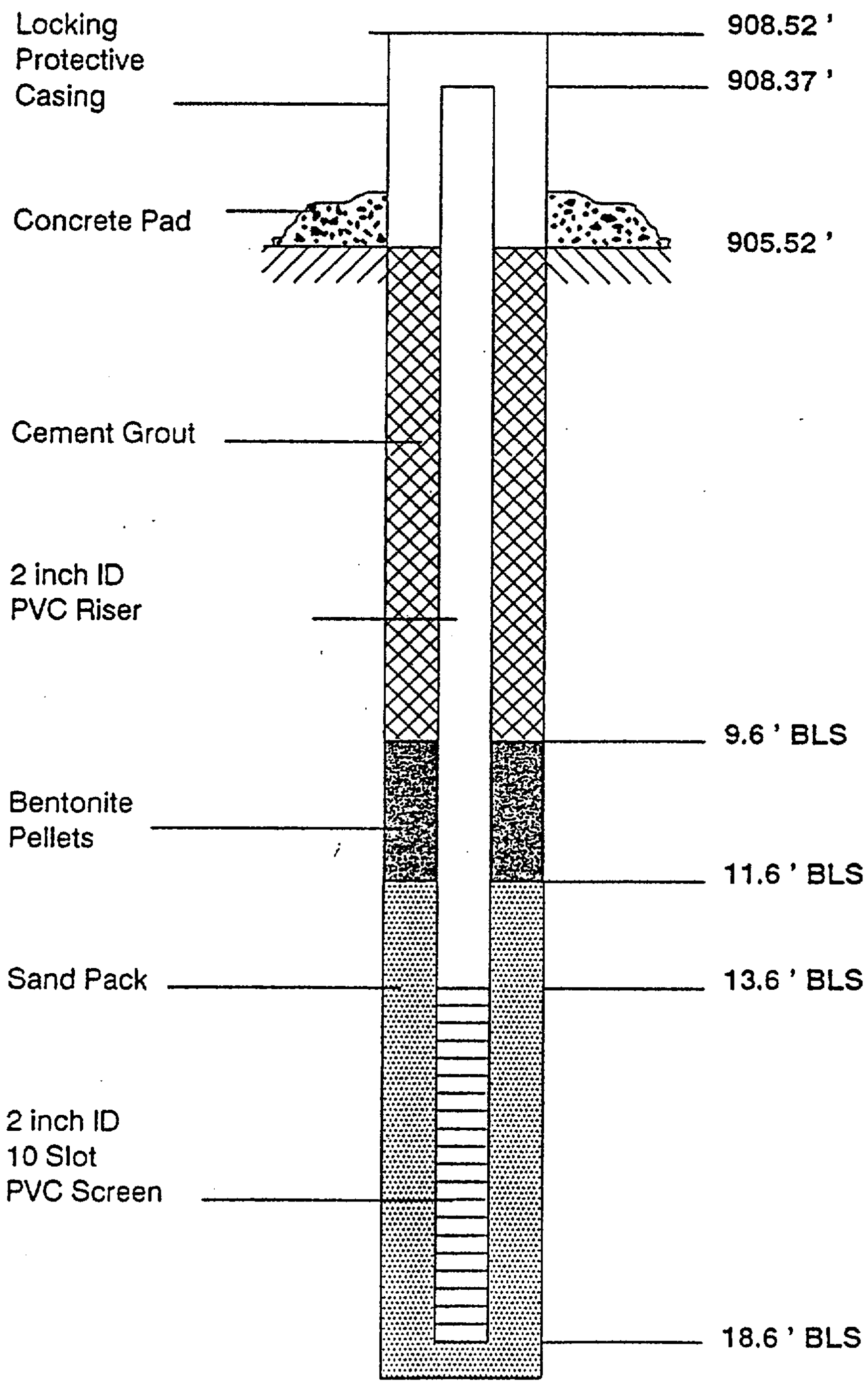
BOREHOLE NUMBER 312 LOCATION: Sample Area 3 29 June 1989

Total Depth 12.5 ' Borehole Diameter 0.6 '



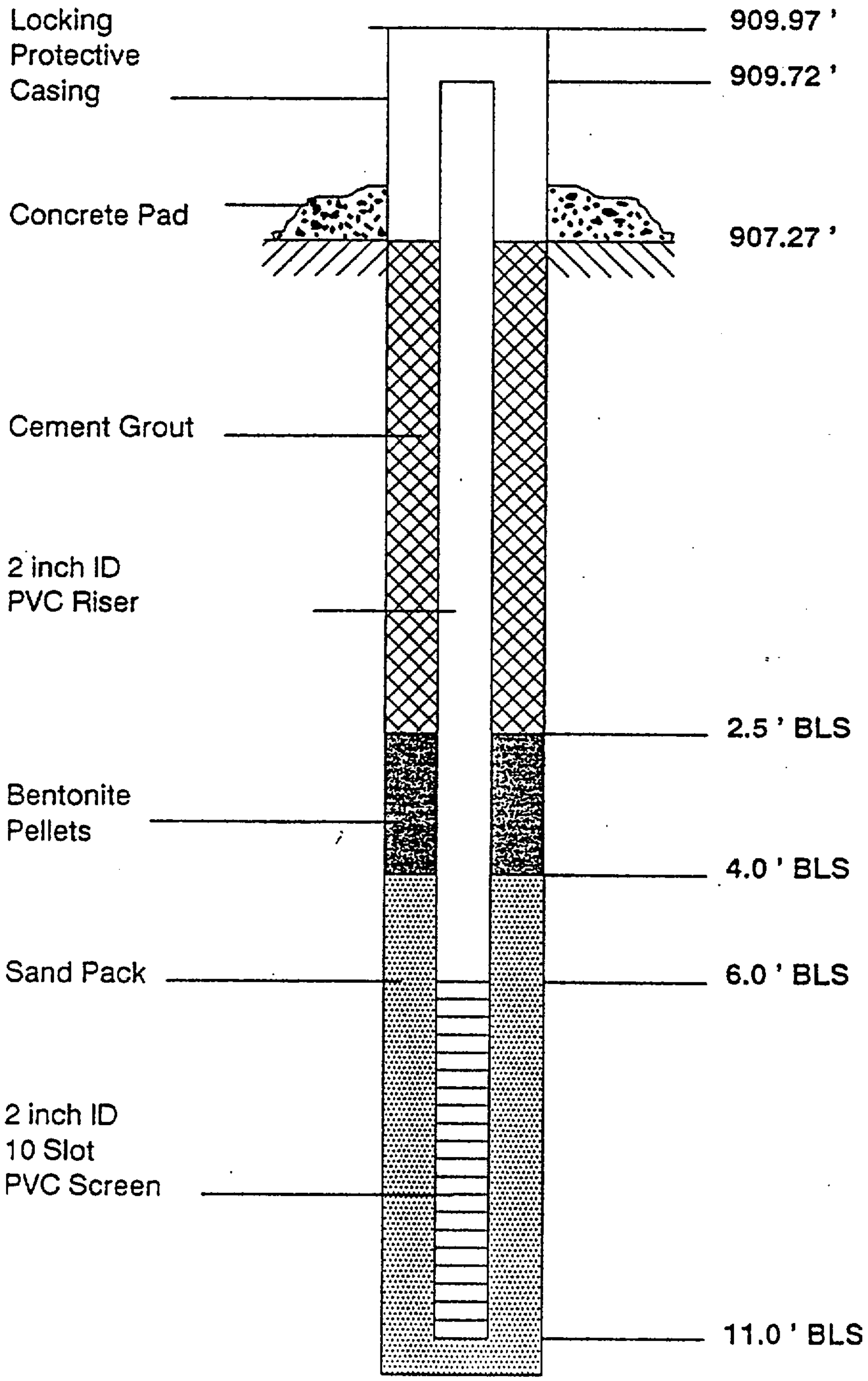
BOREHOLE NUMBER: 403 LOCATION: Sample Area 4 03 August 1989

Total Depth 18.6 ' Borehole Diameter 0.8 '



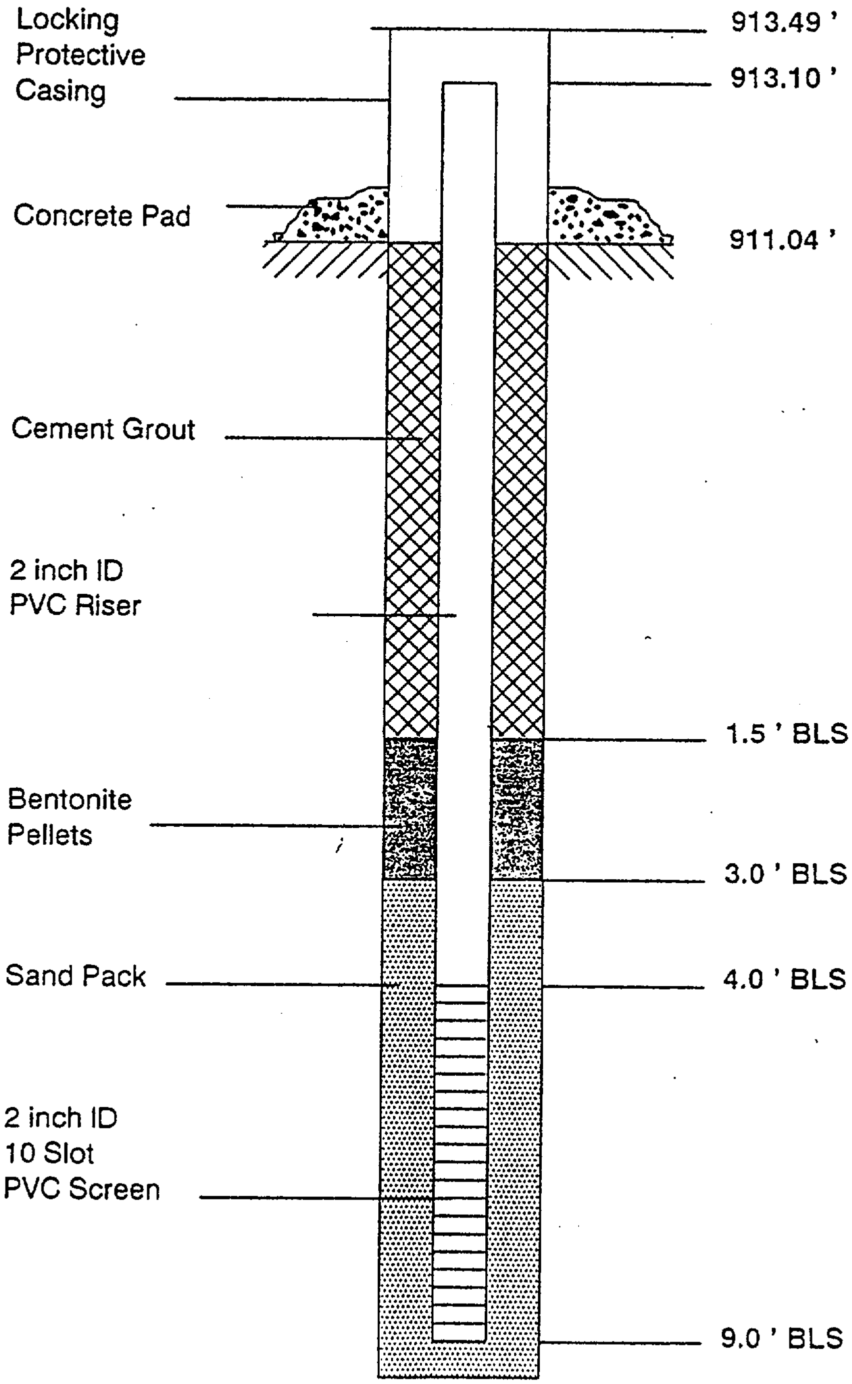
BOLEHOLE NUMBER: 506 LOCATION: Sample Area 5 03 August 1989

Total Depth 11.0 ' Borehole Diameter 0.8 '



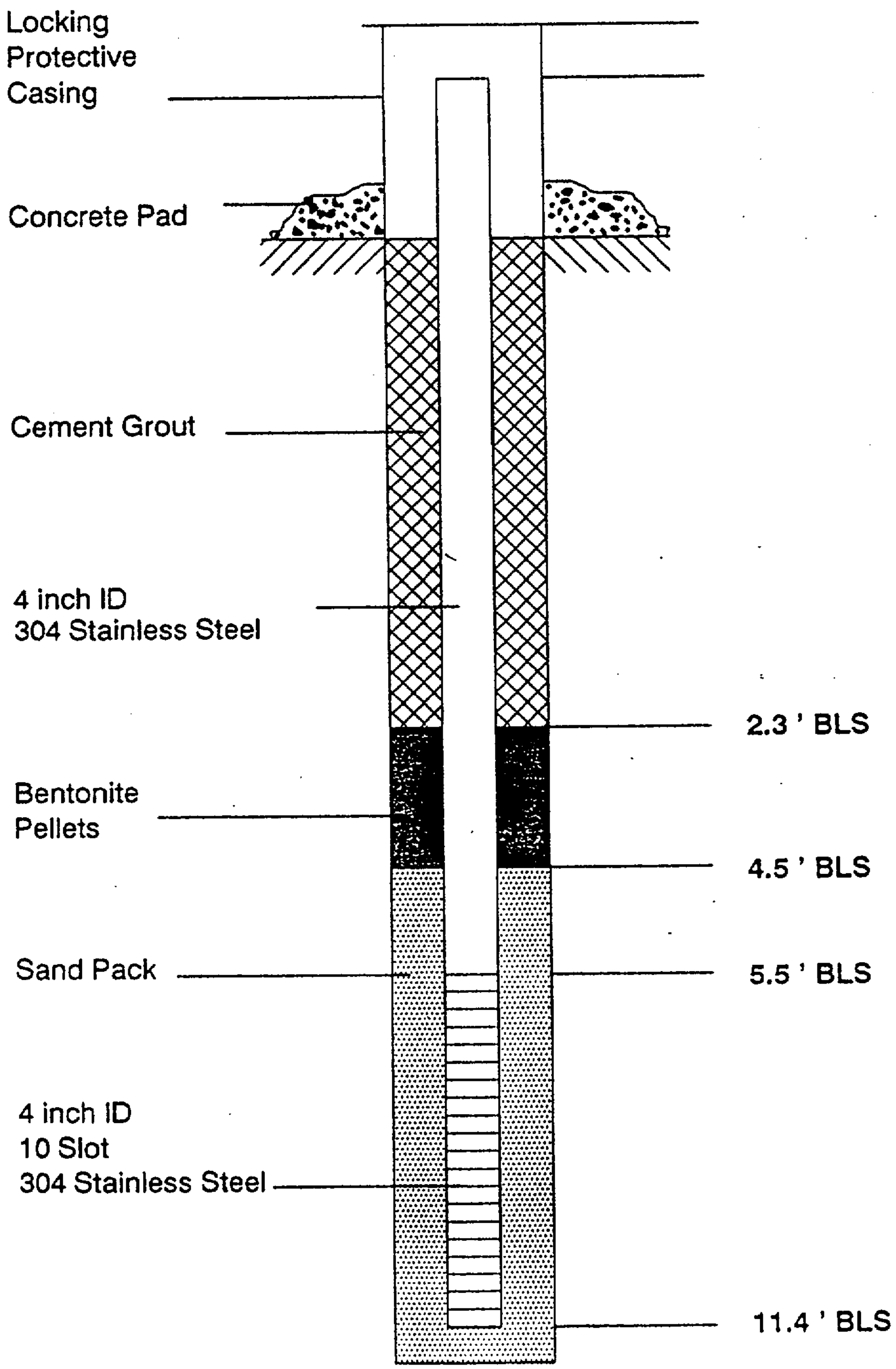
BOREHOLE NUMBER: 601 LOCATION: Sample Area 6 25 July 1989

Total Depth 10.0 ' Borehole Diameter 0.8 '



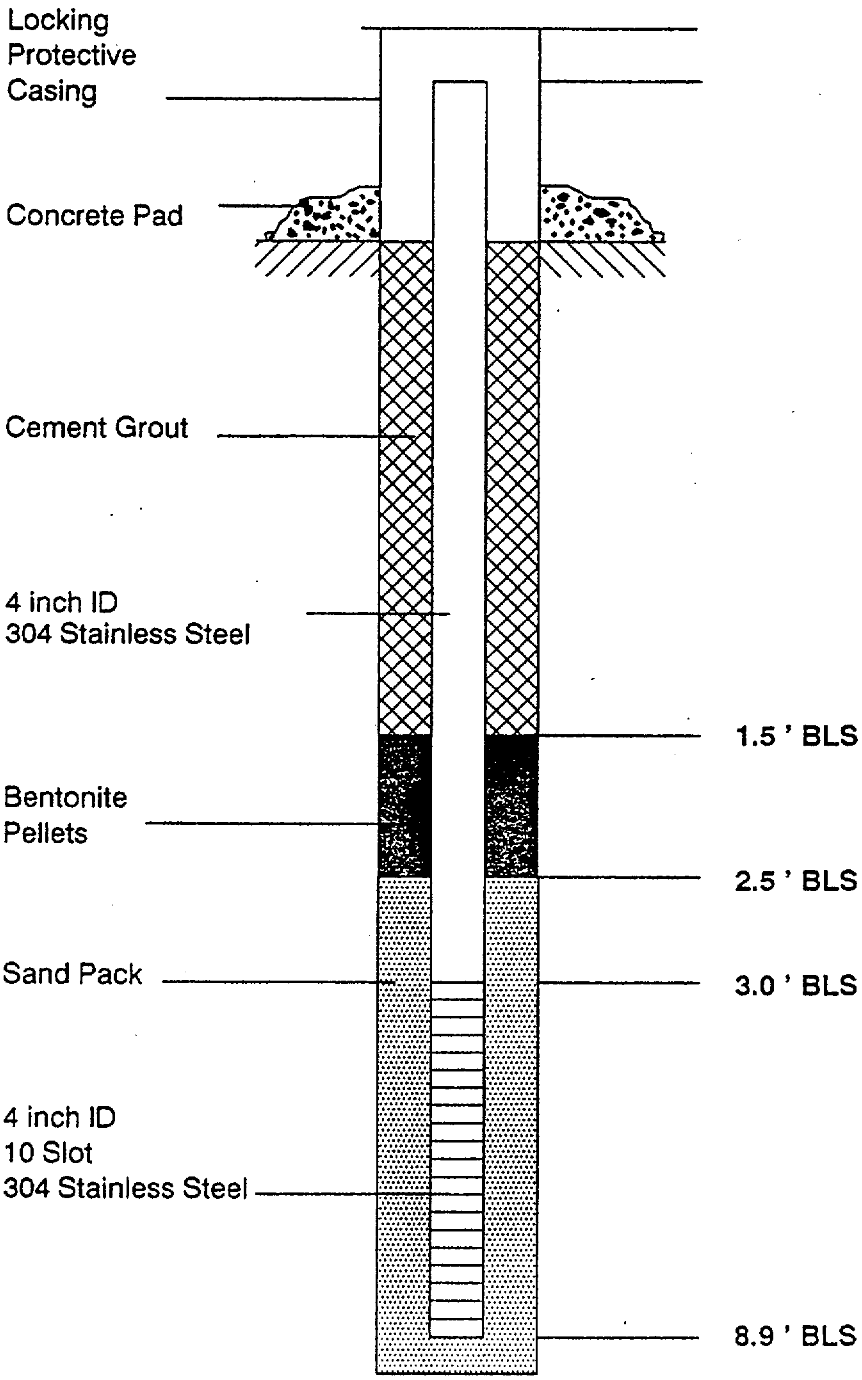
**BOREHOLE NUMBER: C-03  LOCATION: Behind JN-4  17 November 1989**

Total Depth **11.4 '**  Borehole Diameter **0.8 '**



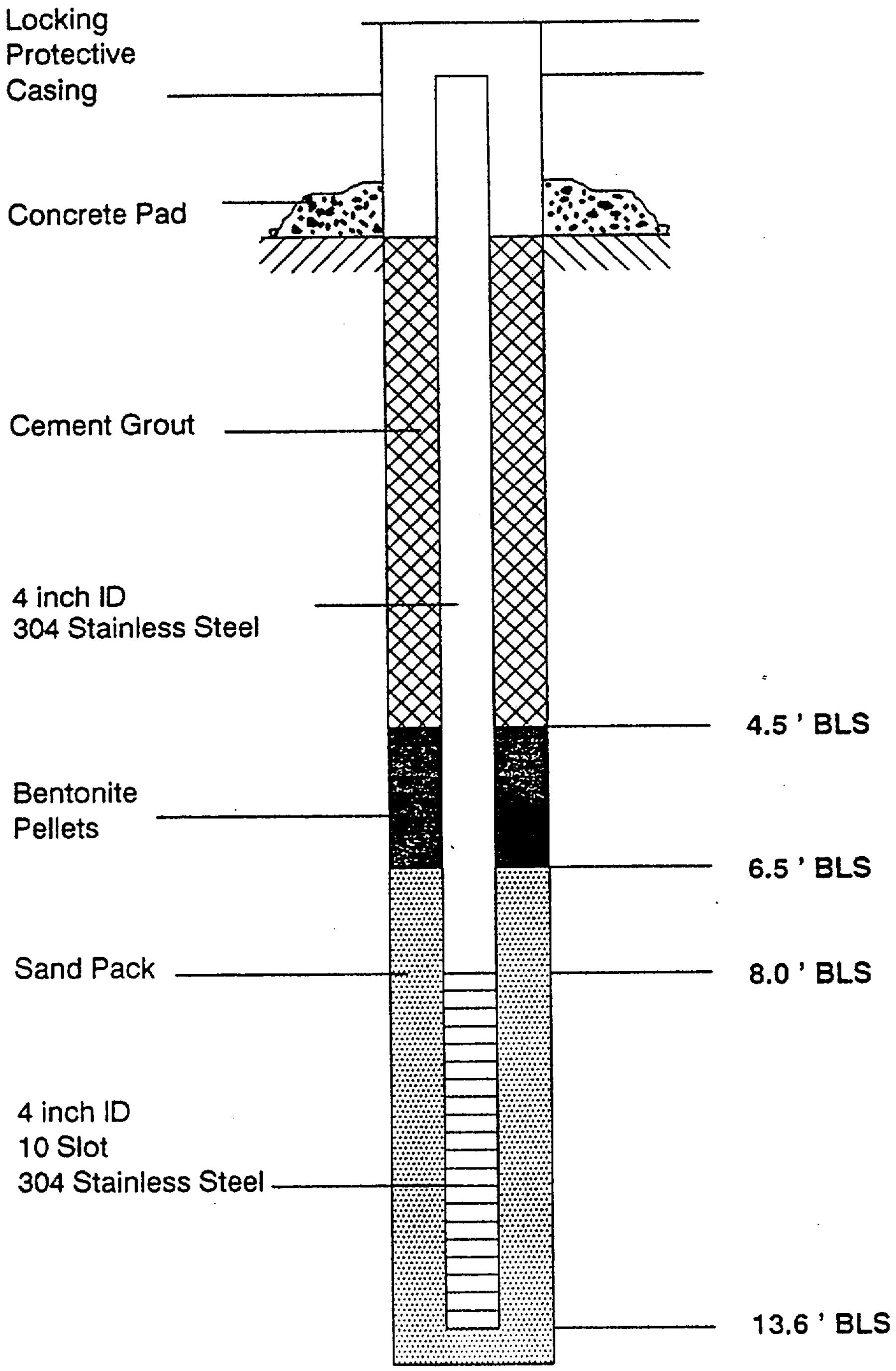
BOREHOLE NUMBER: C-09   LOCATION: Sewer Outfall   17 November 1989

Total Depth   8.9 '   Borehole Diameter   0.8 '



BOREHOLE NUMBER: C-16 LOCATION: South of JN-2 17 November 1989

Total Depth 13.6 ' Borehole Diameter 0.65 '



# APPENDIX 3

# SLUG TEST DATA

# HERMIT DATA FOR WELL 150 SLUG TEST

SE1000B
Environmental Logger
11/10 18:33

Unit# 00476 Test# 0

INPUT 1: Level (F) TOC

Reference 0.00
Scale factor 29.98
Offset 0.04

Step# 0 11/10 09:40

| Elapsed Time | Value |
|---|---|
| 0.0000 | 0.07 |
| 0.0033 | 0.81 |
| 0.0066 | 6.19 |
| 0.0099 | - 0.00 |
| 0.0133 | 1.69 |
| 0.0166 | 2.03 |
| 0.0200 | 1.68 |
| 0.0233 | 1.73 |
| 0.0266 | 1.80 |
| 0.0300 | 1.77 |
| 0.0333 | 1.74 |
| 0.0500 | 1.71 |
| 0.0666 | 1.66 |
| 0.0833 | 1.62 |
| 0.1000 | 1.57 |
| 0.1166 | 1.54 |
| 0.1333 | 1.50 |
| 0.1500 | 1.46 |
| 0.1666 | 1.43 |
| 0.1833 | 1.39 |
| 0.2000 | 1.37 |
| 0.2166 | 1.35 |
| 0.2333 | 1.32 |
| 0.2500 | 1.29 |
| 0.2666 | 1.27 |
| 0.2833 | 1.25 |
| 0.3000 | 1.23 |
| 0.3166 | 1.21 |
| 0.3333 | 1.20 |
| 0.4167 | 1.14 |
| 0.5000 | 1.09 |
| 0.5833 | 1.05 |
| 0.6667 | 1.02 |
| 0.7500 | 0.95 |
| 0.8333 | 0.88 |
| 0.9167 | 0.83 |
| 1.0000 | 0.78 |
| 1.0833 | 0.72 |
| 1.1667 | 0.69 |
| 1.2500 | 0.64 |
| 1.3333 | 0.60 |
| 1.4166 | 0.56 |
| 1.5000 | 0.53 |
| 1.5833 | 0.51 |
| 1.6667 | 0.47 |
| 1.7500 | 0.44 |
| 1.8333 | 0.42 |
| 1.9167 | 0.39 |
| 2.0000 | 0.36 |
| 2.5000 | 0.26 |
| 3.0000 | 0.18 |
| 3.5000 | 0.14 |
| 4.0000 | 0.10 |
| 4.5000 | 0.08 |
| 5.0000 | 0.06 |
| 5.5000 | 0.04 |
| 6.0000 | 0.04 |
| 6.5000 | 0.03 |
| 7.0000 | 0.03 |
| 7.5000 | 0.02 |
| 8.0000 | 0.02 |
| 8.5000 | 0.01 |
| 9.0000 | 0.01 |
| 9.5000 | 0.01 |
| 10.0000 | 0.01 |

END

# HERMIT DATA FOR WELL 155 SLUG TEST

```
         SE1000B
   Environmental Logger
       11/10  18:38

  Unit# 00476  Test# 3

INPUT 1:  Level (F) TOC

Reference          0.00
Scale factor      29.98
Offset             0.04

Step# 0   11/10  11:17

Elapsed Time    Value
------------  ---------
   0.0000         8.15
   0.0033         7.65
   0.0066       - 0.99
   0.0099         3.96
   0.0133         1.13
   0.0166         2.54
   0.0200         1.87
   0.0233         2.17
   0.0266         2.05
   0.0300         2.04
   0.0333         2.04
   0.0500         2.01
   0.0666         1.99
   0.0833         1.97
   0.1000         1.95
   0.1166         1.94
   0.1333         1.92
   0.1500         1.91
   0.1666         1.90
   0.1833         1.89
   0.2000         1.87
   0.2166         1.86
   0.2333         1.85
   0.2500         1.84
   0.2666         1.83
   0.2833         1.82
   0.3000         1.80
   0.3166         1.79
   0.3333         1.79
   0.4167         1.73
   0.5000         1.70
   0.5833         1.66
   0.6667         1.62
   0.7500         1.58
   0.8333         1.55

Elapsed Time    Value
------------  ---------
   0.9167         1.52
   1.0000         1.50
   1.0833         1.46
   1.1667         1.43
   1.2500         1.40
   1.3333         1.38
   1.4166         1.36
   1.5000         1.33
   1.5833         1.31
   1.6667         1.28
   1.7500         1.26
   1.8333         1.23
   1.9167         1.21
   2.0000         1.20
   2.5000         1.09
   3.0000         0.99
   3.5000         0.90
   4.0000         0.84
   4.5000         0.77
   5.0000         0.70
   5.5000         0.66
   6.0000         0.61
   6.5000         0.57
   7.0000         0.53
   7.5000         0.50
   8.0000         0.47
   8.5000         0.44
   9.0000         0.41
   9.5000         0.39
  10.0000         0.36
  12.0000         0.29
  14.0000         0.25
  16.0000         0.21
  18.0000         0.18
  20.0000         0.17
  22.0000         0.15
  24.0000         0.13
  26.0000         0.12
  28.0000         0.12
  30.0000         0.12
 END
```

# HERMIT DATA FOR WELL 158 SLUG TEST

SE1000B
Environmental Logger
11/10 18:39

Unit# 00476 Test# 4

INPUT 1: Level (F) TOC

| | |
|---|---|
| Reference | 0.00 |
| Scale factor | 29.98 |
| Offset | 0.04 |

Step# 0 11/10 12:14

| Elapsed Time | Value |
|---|---|
| 0.0000 | 3.14 |
| 0.0033 | 3.83 |
| 0.0066 | 3.56 |
| 0.0099 | 1.36 |
| 0.0133 | 0.72 |
| 0.0166 | 1.78 |
| 0.0200 | 2.61 |
| 0.0233 | 2.49 |
| 0.0266 | 1.92 |
| 0.0300 | 1.70 |
| 0.0333 | 1.93 |
| 0.0500 | 1.99 |
| 0.0666 | 2.00 |
| 0.0833 | 2.01 |
| 0.1000 | 2.00 |
| 0.1166 | 1.99 |
| 0.1333 | 1.99 |
| 0.1500 | 1.98 |
| 0.1666 | 1.98 |
| 0.1833 | 1.98 |
| 0.2000 | 1.98 |
| 0.2166 | 1.97 |
| 0.2333 | 1.97 |
| 0.2500 | 1.97 |
| 0.2666 | 1.97 |
| 0.2833 | 1.97 |
| 0.3000 | 1.97 |
| 0.3166 | 1.97 |
| 0.3333 | 1.96 |
| 0.4167 | 1.96 |
| 0.5000 | 1.96 |
| 0.5833 | 1.95 |
| 0.6667 | 1.95 |
| 0.7500 | 1.95 |
| 0.8333 | 1.95 |
| 0.9167 | 1.94 |
| 1.0000 | 1.94 |
| 1.0833 | 1.94 |
| 1.1667 | 1.94 |
| 1.2500 | 1.93 |
| 1.3333 | 1.93 |
| 1.4166 | 1.93 |
| 1.5000 | 1.93 |
| 1.5833 | 1.93 |
| 1.6667 | 1.92 |
| 1.7500 | 1.92 |
| 1.8333 | 1.92 |
| 1.9167 | 1.92 |
| 2.0000 | 1.92 |
| 2.5000 | 1.90 |
| 3.0000 | 1.90 |
| 3.5000 | 1.90 |
| 4.0000 | 1.89 |
| 4.5000 | 1.88 |
| 5.0000 | 1.88 |
| 5.5000 | 1.87 |
| 6.0000 | 1.86 |
| 6.5000 | 1.85 |
| 7.0000 | 1.84 |
| 7.5000 | 1.84 |
| 8.0000 | 1.83 |
| 8.5000 | 1.82 |
| 9.0000 | 1.82 |
| 9.5000 | 1.81 |
| 10.0000 | 1.81 |
| 12.0000 | 1.78 |
| 14.0000 | 1.76 |
| 16.0000 | 1.74 |
| 18.0000 | 1.73 |
| 20.0000 | 1.71 |
| 22.0000 | 1.69 |
| 24.0000 | 1.67 |
| 26.0000 | 1.65 |
| 28.0000 | 1.64 |
| 30.0000 | 1.62 |
| 32.0000 | 1.61 |
| 34.0000 | 1.60 |
| 36.0000 | 1.59 |
| 38.0000 | 1.57 |
| 40.0000 | 1.55 |
| 42.0000 | 1.55 |
| 44.0000 | 1.53 |

```
HERMIT DATA FOR WELL 158 (Continued)

 Elapsed Time    Value
 ------------  ---------
   46.0000        1.53
   48.0000        1.51
   50.0000        1.49
   52.0000        1.48
   54.0000        1.47
   56.0000        1.45
   58.0000        1.44
   60.0000        1.43
   62.0000        1.42
   64.0000        1.41
   66.0000        1.40
   68.0000        1.39
   70.0000        1.38
   72.0000        1.38
   74.0000        1.37
   76.0000        1.36
   78.0000        1.35
   80.0000        1.34
   82.0000        1.33
   84.0000        1.32
   86.0000        1.32
   88.0000        1.31
   90.0000        1.30
   92.0000        1.29
   94.0000        1.28
   96.0000        1.27
   98.0000        1.27
   100.000        1.26
   110.000        1.21
   120.000        1.19
   130.000        1.15
   140.000        1.11
   150.000        1.09
END
```

# HERMIT DATA FOR WELL 168 SLUG TEST

```
         SE1000B
  Environmental Logger
      11/10  18:34

  Unit# 00476  Test# 1

INPUT 1:  Level (F) TOC

Reference          0.00
Scale factor      29.98
Offset             0.04

Step# 0    11/10  10:03

Elapsed Time     Value
------------   ---------
   0.0000        4.89
   0.0033        0.94
   0.0066        1.67
   0.0099        1.69
   0.0133        1.63
   0.0166        1.52
   0.0200        1.45
   0.0233        1.38
   0.0266        1.33
   0.0300        1.27
   0.0333        1.22
   0.0500        1.03
   0.0666        0.90
   0.0833        0.79
   0.1000        0.69
   0.1166        0.63
   0.1333        0.56
   0.1500        0.51
   0.1666        0.46
   0.1833        0.42
   0.2000        0.38
   0.2166        0.35
   0.2333        0.33
   0.2500        0.31
   0.2666        0.29
   0.2833        0.27
   0.3000        0.25
   0.3166        0.23
   0.3333        0.22
   0.4167        0.17
   0.5000        0.14
   0.5833        0.12
   0.6667        0.10
   0.7500        0.08
   0.8333        0.07

Elapsed Time     Value
------------   ---------
   0.9167        0.07
   1.0000        0.06
   1.0833        0.05
   1.1667        0.05
   1.2500        0.04
   1.3333        0.04
   1.4166        0.04
   1.5000        0.04
   1.5833        0.03
   1.6667        0.03
   1.7500        0.03
   1.8333        0.03
   1.9167        0.03
   2.0000        0.03
   2.5000        0.02
   3.0000        0.01
   3.5000        0.01
   4.0000        0.01
   4.5000        0.01
   5.0000        0.00
   5.5000        0.00
   6.0000        0.00
   6.5000        0.00
   7.0000        0.01
   7.5000        0.01
   8.0000        0.01
   8.5000        0.01
   9.0000        0.01
   9.5000        0.01
  10.0000        0.01
END
```

# HERMIT DATA FOR WELL 172 SLUG TEST

```
      SE1000B
  Environmental Logger
     11/10  18:36

  Unit# 00476  Test# 2

INPUT 1:  Level (F) TOC

Reference         0.00
Scale factor     29.98
Offset            0.04

Step# 0   11/10  10:28

Elapsed Time     Value
------------   ---------
   0.0000         6.95
   0.0033       - 0.04
   0.0066         1.67
   0.0099         1.72
   0.0133         1.72
   0.0166         1.71
   0.0200         1.65
   0.0233         1.62
   0.0266         1.60
   0.0300         1.58
   0.0333         1.55
   0.0500         1.49
   0.0666         1.42
   0.0833         1.38
   0.1000         1.33
   0.1166         1.28
   0.1333         1.23
   0.1500         1.20
   0.1666         1.16
   0.1833         1.12
   0.2000         1.08
   0.2166         1.05
   0.2333         1.03
   0.2500         1.00
   0.2666         0.96
   0.2833         0.93
   0.3000         0.91
   0.3166         0.88
   0.3333         0.86
   0.4167         0.75
   0.5000         0.66
   0.5833         0.58
   0.6667         0.51
   0.7500         0.46
   0.8333         0.41

Elapsed Time     Value
------------   ---------
   0.9167         0.37
   1.0000         0.34
   1.0833         0.30
   1.1667         0.27
   1.2500         0.25
   1.3333         0.23
   1.4166         0.21
   1.5000         0.19
   1.5833         0.17
   1.6667         0.17
   1.7500         0.15
   1.8333         0.15
   1.9167         0.13
   2.0000         0.12
   2.5000         0.08
   3.0000         0.06
   3.5000         0.05
   4.0000         0.03
   4.5000         0.03
   5.0000         0.02
   5.5000         0.02
   6.0000         0.01
   6.5000         0.01
   7.0000         0.00
   7.5000         0.00
   8.0000         0.00
   8.5000         0.00
   9.0000         0.00
   9.5000         0.00
  10.0000         0.00
END
```

# HERMIT DATA FOR WELL 206 SLUG TEST

SE1000B
Environmental Logger
12/19 17:28

Unit# 00476 Test# 6

INPUT 1: Level (F) TOC

| | |
|---|---|
| Reference | 0.00 |
| Scale factor | 29.98 |
| Offset | 0.04 |

Step# 0 12/19 11:32

| Elapsed Time | Value |
|---|---|
| 0.0000 | 0.99 |
| 0.0033 | 4.49 |
| 0.0066 | 4.74 |
| 0.0099 | 0.34 |
| 0.0133 | - 0.32 |
| 0.0166 | 2.60 |
| 0.0200 | 3.14 |
| 0.0233 | 1.22 |
| 0.0266 | 0.56 |
| 0.0300 | 1.92 |
| 0.0333 | 2.45 |
| 0.0500 | 1.85 |
| 0.0666 | 1.60 |
| 0.0833 | 1.55 |
| 0.1000 | 1.56 |
| 0.1166 | 1.58 |
| 0.1333 | 1.60 |
| 0.1500 | 1.60 |
| 0.1666 | 1.60 |
| 0.1833 | 1.59 |
| 0.2000 | 1.59 |
| 0.2166 | 1.59 |
| 0.2333 | 1.59 |
| 0.2500 | 1.58 |
| 0.2666 | 1.58 |
| 0.2833 | 1.58 |
| 0.3000 | 1.58 |
| 0.3166 | 1.58 |
| 0.3333 | 1.58 |
| 0.4167 | 1.57 |
| 0.5000 | 1.57 |
| 0.5833 | 1.57 |
| 0.6667 | 1.57 |
| 0.7500 | 1.57 |
| 0.8333 | 1.57 |
| 0.9167 | 1.56 |
| 1.0000 | 1.56 |
| 1.0833 | 1.56 |
| 1.1667 | 1.56 |
| 1.2500 | 1.56 |
| 1.3333 | 1.56 |
| 1.4166 | 1.56 |
| 1.5000 | 1.56 |
| 1.5833 | 1.56 |
| 1.6667 | 1.56 |
| 1.7500 | 1.56 |
| 1.8333 | 1.56 |
| 1.9167 | 1.56 |
| 2.0000 | 1.56 |
| 2.5000 | 1.56 |
| 3.0000 | 1.55 |
| 3.5000 | 1.55 |
| 4.0000 | 1.55 |
| 4.5000 | 1.55 |
| 5.0000 | 1.55 |
| 5.5000 | 1.55 |
| 6.0000 | 1.55 |
| 6.5000 | 1.55 |
| 7.0000 | 1.55 |
| 7.5000 | 1.55 |
| 8.0000 | 1.55 |
| 8.5000 | 1.55 |
| 9.0000 | 1.55 |
| 9.5000 | 1.55 |
| 10.0000 | 1.55 |
| 12.0000 | 1.55 |
| 14.0000 | 1.55 |
| 16.0000 | 1.55 |
| 18.0000 | 1.55 |
| 20.0000 | 1.55 |
| 22.0000 | 1.55 |
| 24.0000 | 1.54 |
| 26.0000 | 1.54 |
| 28.0000 | 1.54 |
| 30.0000 | 1.54 |
| 32.0000 | 1.54 |
| 34.0000 | 1.54 |
| 36.0000 | 1.53 |
| 38.0000 | 1.53 |
| 40.0000 | 1.53 |
| 42.0000 | 1.53 |
| 44.0000 | 1.53 |

```
HERMIT DATA FOR WELL 206 (Continued)

 Elapsed Time    Value
 ------------  ---------
   46.0000         1.53
   48.0000         1.53
   50.0000         1.53
   52.0000         1.53
   54.0000         1.53
   56.0000         1.53
   58.0000         1.53
   60.0000         1.53
   62.0000         1.52
   64.0000         1.52
   66.0000         1.52
   68.0000         1.52
   70.0000         1.52
   72.0000         1.52
   74.0000         1.52
   76.0000         1.52
   78.0000         1.52
   80.0000         1.52
   82.0000         1.52
   84.0000         1.52
   86.0000         1.51
   88.0000         1.51
   90.0000         1.51
   92.0000         1.51
   94.0000         1.51
   96.0000         1.51
   98.0000         1.51
   100.000         1.51
   110.000         1.50
   120.000         1.50
   130.000         1.50
   140.000         1.49
 END
```

# HERMIT DATA FOR WELL 300 SLUG TEST

SE1000B
Environmental Logger
12/19 17:31

Unit# 00476 Test# 7

INPUT 1: Level (F) TOC

Reference 0.00
Scale factor 29.98
Offset 0.04

Step# 0 12/19 15:10

| Elapsed Time | Value |
|---|---|
| 0.0000 | 0.86 |
| 0.0033 | 5.37 |
| 0.0066 | 3.43 |
| 0.0099 | 2.59 |
| 0.0133 | 4.06 |
| 0.0166 | 1.41 |
| 0.0200 | 1.42 |
| 0.0233 | 1.82 |
| 0.0266 | 1.50 |
| 0.0300 | 1.54 |
| 0.0333 | 1.51 |
| 0.0500 | 1.36 |
| 0.0666 | 1.24 |
| 0.0833 | 1.15 |
| 0.1000 | 1.06 |
| 0.1166 | 1.00 |
| 0.1333 | 0.94 |
| 0.1500 | 0.89 |
| 0.1666 | 0.85 |
| 0.1833 | 0.81 |
| 0.2000 | 0.77 |
| 0.2166 | 0.74 |
| 0.2333 | 0.71 |
| 0.2500 | 0.69 |
| 0.2666 | 0.68 |
| 0.2833 | 0.66 |
| 0.3000 | 0.64 |
| 0.3166 | 0.62 |
| 0.3333 | 0.61 |
| 0.4167 | 0.55 |
| 0.5000 | 0.51 |
| 0.5833 | 0.49 |
| 0.6667 | 0.46 |
| 0.7500 | 0.44 |
| 0.8333 | 0.43 |
| 0.9167 | 0.41 |
| 1.0000 | 0.40 |
| 1.0833 | 0.38 |
| 1.1667 | 0.37 |
| 1.2500 | 0.37 |
| 1.3333 | 0.35 |
| 1.4166 | 0.35 |
| 1.5000 | 0.34 |
| 1.5833 | 0.34 |
| 1.6667 | 0.34 |
| 1.7500 | 0.33 |
| 1.8333 | 0.33 |
| 1.9167 | 0.33 |
| 2.0000 | 0.32 |
| 2.5000 | 0.31 |
| 3.0000 | 0.30 |
| 3.5000 | 0.28 |
| 4.0000 | 0.28 |
| 4.5000 | 0.28 |
| 5.0000 | 0.28 |
| 5.5000 | 0.27 |
| 6.0000 | 0.27 |
| 6.5000 | 0.27 |
| 7.0000 | 0.27 |
| 7.5000 | 0.27 |
| 8.0000 | 0.26 |
| 8.5000 | 0.26 |
| 9.0000 | 0.26 |
| 9.5000 | 0.27 |
| 10.0000 | 0.26 |
| 12.0000 | 0.26 |
| 14.0000 | 0.26 |
| 16.0000 | 0.25 |
| 18.0000 | 0.26 |
| 20.0000 | 0.25 |
| 22.0000 | 0.25 |
| 24.0000 | 0.25 |
| 26.0000 | 0.25 |
| 28.0000 | 0.25 |
| 30.0000 | 0.25 |
| 32.0000 | 0.25 |
| 34.0000 | 0.25 |
| 36.0000 | 0.25 |
| 38.0000 | 0.25 |
| 40.0000 | 0.25 |
| 42.0000 | 0.25 |
| 44.0000 | 0.25 |

## HERMIT DATA FOR WELL 300 (Continued)

```
 Elapsed Time    Value
 ------------  ---------
   46.0000        0.25
   48.0000        0.25
   50.0000        0.24
   52.0000        0.24
   54.0000        0.25
   56.0000        0.24
   58.0000        0.25
   60.0000        0.25
   62.0000        0.25
   64.0000        0.24
   66.0000        0.25
   68.0000        0.25
   70.0000        0.25
   72.0000        0.25
   74.0000        0.25
   76.0000        0.25
   78.0000        0.25
   80.0000        0.25
   82.0000        0.25
   84.0000        0.25
   86.0000        0.25
 END
```

# HERMIT DATA FOR WELL 306 SLUG TEST

SE1000B
Environmental Logger
11/10 18:45

Unit# 00476 Test# 5

INPUT 1: Level (F) TOC

| | |
|---|---|
| Reference | 0.00 |
| Scale factor | 29.98 |
| Offset | 0.04 |

Step# 0 11/10 16:01

| Elapsed Time | Value |
|---|---|
| 0.0000 | 0.01 |
| 0.0033 | 2.50 |
| 0.0066 | 6.28 |
| 0.0099 | 2.26 |
| 0.0133 | 0.53 |
| 0.0166 | 3.71 |
| 0.0200 | 0.86 |
| 0.0233 | 1.84 |
| 0.0266 | 2.44 |
| 0.0300 | 1.15 |
| 0.0333 | 2.18 |
| 0.0500 | 2.46 |
| 0.0666 | 2.32 |
| 0.0833 | 2.38 |
| 0.1000 | 1.53 |
| 0.1166 | 1.55 |
| 0.1333 | 1.55 |
| 0.1500 | 1.53 |
| 0.1666 | 1.50 |
| 0.1833 | 1.47 |
| 0.2000 | 1.45 |
| 0.2166 | 1.42 |
| 0.2333 | 1.40 |
| 0.2500 | 1.38 |
| 0.2666 | 1.36 |
| 0.2833 | 1.34 |
| 0.3000 | 1.32 |
| 0.3166 | 1.30 |
| 0.3333 | 1.28 |
| 0.4167 | 1.21 |
| 0.5000 | 1.14 |
| 0.5833 | 1.07 |
| 0.6667 | 1.03 |
| 0.7500 | 0.98 |
| 0.8333 | 0.94 |
| 0.9167 | 0.89 |
| 1.0000 | 0.86 |
| 1.0833 | 0.83 |
| 1.1667 | 0.79 |
| 1.2500 | 0.76 |
| 1.3333 | 0.72 |
| 1.4166 | 0.69 |
| 1.5000 | 0.68 |
| 1.5833 | 0.65 |
| 1.6667 | 0.62 |
| 1.7500 | 0.60 |
| 1.8333 | 0.58 |
| 1.9167 | 0.56 |
| 2.0000 | 0.54 |
| 2.5000 | 0.45 |
| 3.0000 | 0.38 |
| 3.5000 | 0.34 |
| 4.0000 | 0.31 |
| 4.5000 | 0.28 |
| 5.0000 | 0.26 |
| 5.5000 | 0.24 |
| 6.0000 | 0.23 |
| 6.5000 | 0.22 |
| 7.0000 | 0.21 |
| 7.5000 | 0.20 |
| 8.0000 | 0.18 |
| 8.5000 | 0.18 |
| 9.0000 | 0.17 |
| 9.5000 | 0.17 |
| 10.0000 | 0.16 |
| 12.0000 | 0.15 |
| 14.0000 | 0.13 |
| 16.0000 | 0.12 |
| 18.0000 | 0.11 |
| 20.0000 | 0.11 |
| 22.0000 | 0.10 |
| 24.0000 | 0.11 |
| 26.0000 | 0.10 |
| 28.0000 | 0.10 |
| 30.0000 | 0.10 |
| 32.0000 | 0.13 |
| 34.0000 | 0.11 |
| 36.0000 | 0.11 |
| 38.0000 | 0.08 |
| 40.0000 | 0.08 |
| 42.0000 | 0.07 |
| 44.0000 | 0.08 |

## HERMIT DATA FOR WELL 306 (Continued)

```
Elapsed Time    Value
------------  ---------
  46.0000         0.09
  48.0000         0.08
  50.0000         0.08
  52.0000         0.09
  54.0000         0.08
  56.0000         0.08
  58.0000         0.09
  60.0000         0.08
  62.0000         0.08
  64.0000         0.08
  66.0000         0.08
  68.0000         0.08
  70.0000         0.08
  72.0000         0.08
  74.0000         0.09
  76.0000         0.08
  78.0000         0.08
  80.0000         0.08
END
```

# HERMIT DATA FOR WELL 312 SLUG TEST

```
        SE1000B
  Environmental Logger
     12/19  17:33                       Elapsed Time    Value
                                        ------------  ---------
  Unit# 00476   Test# 7                    0.9167         1.57
                                           1.0000         1.57
INPUT 2:  Level (F) TOC                    1.0833         1.56
                                           1.1667         1.56
Reference          0.00                    1.2500         1.56
Scale factor      19.98                    1.3333         1.56
Offset             0.09                    1.4166         1.56
                                           1.5000         1.56
Step# 0   12/19  15:10                     1.5833         1.56
                                           1.6667         1.56
Elapsed Time    Value                      1.7500         1.56
------------  ---------                    1.8333         1.56
    0.0000     -  0.02                     1.9167         1.56
    0.0033        1.98                     2.0000         1.55
    0.0066        5.07                     2.5000         1.55
    0.0099        2.09                     3.0000         1.55
    0.0133        1.53                     3.5000         1.54
    0.0166        1.87                     4.0000         1.54
    0.0200        1.49                     4.5000         1.54
    0.0233        1.81                     5.0000         1.54
    0.0266        1.56                     5.5000         1.54
    0.0300        1.69                     6.0000         1.53
    0.0333        1.61                     6.5000         1.53
    0.0500        1.62                     7.0000         1.53
    0.0666        1.63                     7.5000         1.53
    0.0833        1.62                     8.0000         1.53
    0.1000        1.60                     8.5000         1.53
    0.1166        1.60                     9.0000         1.54
    0.1333        1.60                     9.5000         1.54
    0.1500        1.60                    10.0000         1.56
    0.1666        1.60                    12.0000         1.56
    0.1833        1.60                    14.0000         1.59
    0.2000        1.60                    16.0000         1.60
    0.2166        1.59                    18.0000         1.59
    0.2333        1.59                    20.0000         1.60
    0.2500        1.59                    22.0000         1.60
    0.2666        1.59                    24.0000         1.59
    0.2833        1.58                    26.0000         1.59
    0.3000        1.58                    28.0000         1.58
    0.3166        1.58                    30.0000         1.55
    0.3333        1.58                    32.0000         1.56
    0.4167        1.58                    34.0000         1.55
    0.5000        1.58                    36.0000         1.55
    0.5833        1.58                    38.0000         1.56
    0.6667        1.58                    40.0000         1.56
    0.7500        1.58                    42.0000         1.57
    0.8333        1.57                    44.0000         1.57
```

```
HERMIT DATA FOR WELL 312 (Continued)

 Elapsed Time    Value
 ------------  ---------
    46.0000        1.57
    48.0000        1.59
    50.0000        1.57
    52.0000        1.55
    54.0000        1.54
    56.0000        1.54
    58.0000        1.55
    60.0000        1.56
    62.0000        1.56
    64.0000        1.56
    66.0000        1.55
    68.0000        1.56
    70.0000        1.56
    72.0000        1.56
    74.0000        1.54
    76.0000        1.53
    78.0000        1.53
    80.0000        1.52
    82.0000        1.52
    84.0000        1.53
    86.0000        1.52
 END
```

# HERMIT DATA FOR WELL 403 SLUG TEST

SE1000B
Environmental Logger
11/10 18:47

Unit# 00476 Test# 5

INPUT 2: Level (F) TOC

Reference 0.00
Scale factor 19.98
Offset 0.09

Step# 0 11/10 16:01

| Elapsed Time | Value |
|---|---|
| 0.0000 | 0.00 |
| 0.0033 | 2.70 |
| 0.0066 | 7.04 |
| 0.0099 | 7.37 |
| 0.0133 | 5.96 |
| 0.0166 | 4.37 |
| 0.0200 | - 0.75 |
| 0.0233 | 3.45 |
| 0.0266 | 2.14 |
| 0.0300 | 1.14 |
| 0.0333 | 2.69 |
| 0.0500 | 1.91 |
| 0.0666 | 1.96 |
| 0.0833 | 1.95 |
| 0.1000 | 1.94 |
| 0.1166 | 1.92 |
| 0.1333 | 1.92 |
| 0.1500 | 1.90 |
| 0.1666 | 1.89 |
| 0.1833 | 1.89 |
| 0.2000 | 1.87 |
| 0.2166 | 1.87 |
| 0.2333 | 1.86 |
| 0.2500 | 1.85 |
| 0.2666 | 1.84 |
| 0.2833 | 1.83 |
| 0.3000 | 1.82 |
| 0.3166 | 1.82 |
| 0.3333 | 1.81 |
| 0.4167 | 1.77 |
| 0.5000 | 1.74 |
| 0.5833 | 1.71 |
| 0.6667 | 1.68 |
| 0.7500 | 1.65 |
| 0.8333 | 1.62 |
| 0.9167 | 1.60 |
| 1.0000 | 1.57 |
| 1.0833 | 1.55 |
| 1.1667 | 1.53 |
| 1.2500 | 1.50 |
| 1.3333 | 1.48 |
| 1.4166 | 1.46 |
| 1.5000 | 1.44 |
| 1.5833 | 1.42 |
| 1.6667 | 1.40 |
| 1.7500 | 1.38 |
| 1.8333 | 1.36 |
| 1.9167 | 1.34 |
| 2.0000 | 1.32 |
| 2.5000 | 1.23 |
| 3.0000 | 1.15 |
| 3.5000 | 1.08 |
| 4.0000 | 1.01 |
| 4.5000 | 0.95 |
| 5.0000 | 0.89 |
| 5.5000 | 0.85 |
| 6.0000 | 0.80 |
| 6.5000 | 0.77 |
| 7.0000 | 0.74 |
| 7.5000 | 0.72 |
| 8.0000 | 0.70 |
| 8.5000 | 0.68 |
| 9.0000 | 0.66 |
| 9.5000 | 0.65 |
| 10.0000 | 0.64 |
| 12.0000 | 0.59 |
| 14.0000 | 0.55 |
| 16.0000 | 0.52 |
| 18.0000 | 0.51 |
| 20.0000 | 0.50 |
| 22.0000 | 0.49 |
| 24.0000 | 0.49 |
| 26.0000 | 0.49 |
| 28.0000 | 0.50 |
| 30.0000 | 0.49 |
| 32.0000 | 0.50 |
| 34.0000 | 0.51 |
| 36.0000 | 0.52 |
| 38.0000 | 0.49 |
| 40.0000 | 0.42 |
| 42.0000 | 0.40 |
| 44.0000 | 0.37 |

```
HERMIT DATA FOR WELL 403 (Continued)

 Elapsed Time    Value
 ------------  ---------
   46.0000        0.37
   48.0000        0.35
   50.0000        0.35
   52.0000        0.35
   54.0000        0.34
   56.0000        0.34
   58.0000        0.35
   60.0000        0.35
   62.0000        0.35
   64.0000        0.35
   66.0000        0.35
   68.0000        0.35
   70.0000        0.36
   72.0000        0.37
   74.0000        0.37
   76.0000        0.37
   78.0000        0.37
   80.0000        0.37
 END
```

# HERMIT DATA FOR WELL 506 SLUG TEST

```
        SE1000B
   Environmental Logger
      12/19  17:30

   Unit# 00476  Test# 6

 INPUT 2:  Level (F) TOC

 Reference          0.00
 Scale factor      19.98
 Offset             0.09

 Step# 0   12/19  11:32

 Elapsed Time    Value
 ------------  ---------
    0.0000          5.65
    0.0033          4.34
    0.0066          1.58
    0.0099          1.49
    0.0133          2.10
    0.0166          1.42
    0.0200          1.80
    0.0233          1.61
    0.0266          1.61
    0.0300          1.61
    0.0333          1.55
    0.0500          1.47
    0.0666          1.39
    0.0833          1.31
    0.1000          1.25
    0.1166          1.20
    0.1333          1.15
    0.1500          1.12
    0.1666          1.09
    0.1833          1.07
    0.2000          1.06
    0.2166          1.05
    0.2333          1.03
    0.2500          1.03
    0.2666          1.02
    0.2833          1.02
    0.3000          1.01
    0.3166          1.00
    0.3333          1.00
    0.4167          0.98
    0.5000          0.97
    0.5833          0.97
    0.6667          0.96
    0.7500          0.95
    0.8333          0.95
```

```
 Elapsed Time    Value
 ------------  ---------
    0.9167          0.95
    1.0000          0.95
    1.0833          0.94
    1.1667          0.94
    1.2500          0.93
    1.3333          0.93
    1.4166          0.93
    1.5000          0.93
    1.5833          0.93
    1.6667          0.92
    1.7500          0.92
    1.8333          0.92
    1.9167          0.92
    2.0000          0.91
    2.5000          0.91
    3.0000          0.90
    3.5000          0.89
    4.0000          0.88
    4.5000          0.88
    5.0000          0.87
    5.5000          0.86
    6.0000          0.85
    6.5000          0.85
    7.0000          0.84
    7.5000          0.83
    8.0000          0.83
    8.5000          0.82
    9.0000          0.82
    9.5000          0.81
   10.0000          0.80
   12.0000          0.75
   14.0000          0.69
   16.0000          0.64
   18.0000          0.59
   20.0000          0.56
   22.0000          0.51
   24.0000          0.48
   26.0000          0.44
   28.0000          0.41
   30.0000          0.38
   32.0000          0.36
   34.0000          0.34
   36.0000          0.32
   38.0000          0.30
   40.0000          0.27
   42.0000          0.27
   44.0000          0.26
```

```
HERMIT DATA FOR WELL 506 (Continued)

 Elapsed Time     Value
 ------------   ---------
   46.0000         0.24
   48.0000         0.23
   50.0000         0.23
   52.0000         0.23
   54.0000         0.22
   56.0000         0.21
   58.0000         0.20
   60.0000         0.19
   62.0000         0.17
   64.0000         0.15
   66.0000         0.14
   68.0000         0.13
   70.0000         0.13
   72.0000         0.13
   74.0000         0.13
   76.0000         0.11
   78.0000         0.11
   80.0000         0.11
   82.0000         0.12
   84.0000         0.11
   86.0000         0.11
   88.0000         0.09
   90.0000         0.09
   92.0000         0.08
   94.0000         0.08
   96.0000         0.09
   98.0000         0.10
   100.000         0.10
   110.000         0.07
   120.000         0.07
   130.000         0.06
   140.000         0.03
END
```

# HERMIT DATA FOR WELL 601 SLUG TEST

```
        SE1000B
  Environmental Logger
      01/12  11:15

  Unit# 00476  Test# 9

INPUT 1:  Level (F) TOC

Reference        0.00
Scale factor    29.98
Offset           0.04

Step# 0   01/12  10:50

Elapsed Time     Value                   Elapsed Time     Value
------------   ---------                 ------------   ---------
   0.0000         1.02                      0.9167         0.30
   0.0033         0.49                      1.0000         0.30
   0.0066         1.43                      1.0833         0.29
   0.0099         0.17                      1.1667         0.28
   0.0133         1.66                      1.2500         0.28
   0.0166         0.91                      1.3333         0.27
   0.0200         1.27                      1.4166         0.27
   0.0233         1.38                      1.5000         0.26
   0.0266         1.32                      1.5833         0.25
   0.0300         1.26                      1.6667         0.24
   0.0333         1.21                      1.7500         0.22
   0.0500         1.01                      1.8333         0.21
   0.0666         0.84                      1.9167         0.20
   0.0833         0.70                      2.0000         0.20
   0.1000         0.60                      2.5000         0.17
   0.1166         0.53                      3.0000         0.15
   0.1333         0.49                      3.5000         0.14
   0.1500         0.46                      4.0000         0.12
   0.1666         0.43                      4.5000         0.12
   0.1833         0.42                      5.0000         0.11
   0.2000         0.39                      5.5000         0.10
   0.2166         0.38                      6.0000         0.10
   0.2333         0.37                      6.5000         0.09
   0.2500         0.37                      7.0000         0.09
   0.2666         0.36                      7.5000         0.08
   0.2833         0.35                      8.0000         0.08
   0.3000         0.35                      8.5000         0.07
   0.3166         0.35                      9.0000         0.07
   0.3333         0.34                      9.5000         0.08
   0.4167         0.34                     10.0000         0.07
   0.5000         0.33                     12.0000         0.06
   0.5833         0.32                     14.0000         0.06
   0.6667         0.31                     16.0000         0.06
   0.7500         0.30                     18.0000         0.06
   0.8333         0.31                     20.0000         0.05
                                         END
```

# HERMIT DATA FOR WELL C03 SLUG TEST

SE1000B
Environmental Logger
01/16 18:03

Unit# 00476 Test# 0

INPUT 1: Level (F) TOC

Reference 0.00
Scale factor 29.98
Offset 0.04

Step# 0 01/12 14:04

| Elapsed Time | Value |
|---|---|
| 0.0000 | - 0.02 |
| 0.0033 | 0.01 |
| 0.0066 | - 0.04 |
| 0.0099 | 0.83 |
| 0.0133 | 1.95 |
| 0.0166 | 0.94 |
| 0.0200 | 1.90 |
| 0.0233 | 2.04 |
| 0.0266 | 1.95 |
| 0.0300 | 1.90 |
| 0.0333 | 1.85 |
| 0.0500 | 1.73 |
| 0.0666 | 1.63 |
| 0.0833 | 1.55 |
| 0.1000 | 1.46 |
| 0.1166 | 1.37 |
| 0.1333 | 1.29 |
| 0.1500 | 1.23 |
| 0.1666 | 1.16 |
| 0.1833 | 1.11 |
| 0.2000 | 1.08 |
| 0.2166 | 1.04 |
| 0.2333 | 1.03 |
| 0.2500 | 1.00 |
| 0.2666 | 0.98 |
| 0.2833 | 0.98 |
| 0.3000 | 0.99 |
| 0.3166 | 0.96 |
| 0.3333 | 0.95 |
| 0.4167 | 0.92 |
| 0.5000 | 0.89 |
| 0.5833 | 0.86 |
| 0.6667 | 0.86 |
| 0.7500 | 0.86 |
| 0.8333 | 0.85 |
| 0.9167 | 0.84 |
| 1.0000 | 0.84 |
| 1.0833 | 0.83 |
| 1.1667 | 0.82 |
| 1.2500 | 0.82 |
| 1.3333 | 0.82 |
| 1.4166 | 0.83 |
| 1.5000 | 0.81 |
| 1.5833 | 0.82 |
| 1.6667 | 0.80 |
| 1.7500 | 0.81 |
| 1.8333 | 0.81 |
| 1.9167 | 0.81 |
| 2.0000 | 0.79 |
| 2.5000 | 0.79 |
| 3.0000 | 0.78 |
| 3.5000 | 0.77 |
| 4.0000 | 0.77 |
| 4.5000 | 0.77 |
| 5.0000 | 0.76 |
| 5.5000 | 0.73 |
| 6.0000 | 0.75 |
| 6.5000 | 0.75 |
| 7.0000 | 0.75 |
| 7.5000 | 0.75 |
| 8.0000 | 0.75 |
| 8.5000 | 0.74 |
| 9.0000 | 0.74 |
| 9.5000 | 0.74 |
| 10.0000 | 0.74 |
| 12.0000 | 0.73 |
| 14.0000 | 0.74 |
| 16.0000 | 0.75 |
| 18.0000 | 0.73 |
| 20.0000 | 0.74 |
| 22.0000 | 0.72 |
| 24.0000 | 0.72 |
| 26.0000 | 0.72 |
| 28.0000 | 0.71 |
| 30.0000 | 0.72 |
| 32.0000 | 0.71 |
| 34.0000 | 0.71 |
| 36.0000 | 0.70 |
| 38.0000 | 0.70 |
| 40.0000 | 0.70 |
| 42.0000 | 0.69 |
| 44.0000 | 0.70 |

## HERMIT DATA FOR WELL C03 (Continued)

```
 Elapsed Time    Value
 ------------  ---------
    46.0000        0.69
    48.0000        0.70
    50.0000        0.70
    52.0000        0.69
    54.0000        0.69
    56.0000        0.69
    58.0000        0.69
    60.0000        0.69
    62.0000        0.69
    64.0000        0.69
    66.0000        0.69
    68.0000        0.69
    70.0000        0.69
    72.0000        0.69
    74.0000        0.69
    76.0000        0.69
    78.0000        0.68
    80.0000        0.69
    82.0000        0.68
    84.0000        0.67
    86.0000        0.67
    88.0000        0.67
    90.0000        0.67
    92.0000        0.67
    94.0000        0.66
    96.0000        0.68
    98.0000        0.67
    100.000        0.67
    110.000        0.65
    120.000        0.65
    130.000        0.66
    140.000        0.64
    150.000        0.64
    160.000        0.64
    170.000        0.63
    180.000        0.62
END
```

# HERMIT DATA FOR WELL C09 SLUG TEST

```
       SE1000B
 Environmental Logger
     01/16  17:53

 Unit# 00476  Test# 2

INPUT 1:  Level (F) TOC

Reference          0.00
Scale factor      29.98
Offset             0.04

Step# 0   01/16  16:33

Elapsed Time     Value
------------  ---------
   0.0000         0.00
   0.0033         0.01
   0.0066         0.00
   0.0099         0.39
   0.0133         1.26
   0.0166         1.22
   0.0200      -  0.49
   0.0233         0.14
   0.0266         1.19
   0.0300         1.70
   0.0333         2.03
   0.0500         1.72
   0.0666         1.67
   0.0833         1.56
   0.1000         1.47
   0.1166         1.37
   0.1333         1.28
   0.1500         1.21
   0.1666         1.14
   0.1833         1.10
   0.2000         1.06
   0.2166         1.03
   0.2333         1.02
   0.2500         1.00
   0.2666         0.98
   0.2833         0.97
   0.3000         0.96
   0.3166         0.95
   0.3333         0.94
   0.4167         0.91
   0.5000         0.89
   0.5833         0.87
   0.6667         0.86
   0.7500         0.86
   0.8333         0.85
```

```
Elapsed Time     Value
------------  ---------
   0.9167         0.84
   1.0000         0.84
   1.0833         0.83
   1.1667         0.82
   1.2500         0.82
   1.3333         0.81
   1.4166         0.81
   1.5000         0.80
   1.5833         0.80
   1.6667         0.79
   1.7500         0.79
   1.8333         0.79
   1.9167         0.79
   2.0000         0.79
   2.5000         0.77
   3.0000         0.75
   3.5000         0.74
   4.0000         0.73
   4.5000         0.72
   5.0000         0.71
   5.5000         0.70
   6.0000         0.69
   6.5000         0.69
   7.0000         0.69
   7.5000         0.68
   8.0000         0.67
   8.5000         0.67
   9.0000         0.66
   9.5000         0.65
  10.0000         0.65
  12.0000         0.62
  14.0000         0.60
  16.0000         0.58
  18.0000         0.56
  20.0000         0.54
  22.0000         0.52
  24.0000         0.51
  26.0000         0.49
  28.0000         0.48
  30.0000         0.46
  32.0000         0.45
  34.0000         0.43
  36.0000         0.42
  38.0000         0.41
  40.0000         0.39
  42.0000         0.38
  44.0000         0.37
```

## HERMIT DATA FOR WELL C09 (Continued)

```
 Elapsed Time    Value
 ------------  ---------
   46.0000        0.36
   48.0000        0.35
   50.0000        0.34
   52.0000        0.34
   54.0000        0.33
   56.0000        0.32
   58.0000        0.31
   60.0000        0.31
   62.0000        0.30
   64.0000        0.29
   66.0000        0.28
   68.0000        0.27
   70.0000        0.262
END
```

# HERMIT DATA FOR WELL C16 SLUG TEST

SE1000B
Environmental Logger
01/11 16:57

Unit# 00476 Test# 8

INPUT 1: Level (F) TOC

| | |
|---|---|
| Reference | 0.00 |
| Scale factor | 29.98 |
| Offset | 0.04 |

Step# 0 01/11 11:52

| Elapsed Time | Value |
|---|---|
| 0.0000 | - 0.01 |
| 0.0033 | 1.86 |
| 0.0066 | 1.62 |
| 0.0099 | 1.70 |
| 0.0133 | - 0.28 |
| 0.0166 | 0.89 |
| 0.0200 | 1.93 |
| 0.0233 | 1.91 |
| 0.0266 | 1.89 |
| 0.0300 | 1.89 |
| 0.0333 | 1.86 |
| 0.0500 | 1.90 |
| 0.0666 | 1.88 |
| 0.0833 | 1.88 |
| 0.1000 | 1.87 |
| 0.1166 | 1.86 |
| 0.1333 | 1.87 |
| 0.1500 | 1.87 |
| 0.1666 | 1.88 |
| 0.1833 | 1.86 |
| 0.2000 | 1.87 |
| 0.2166 | 1.87 |
| 0.2333 | 1.86 |
| 0.2500 | 1.87 |
| 0.2666 | 1.86 |
| 0.2833 | 1.86 |
| 0.3000 | 1.86 |
| 0.3166 | 1.86 |
| 0.3333 | 1.87 |
| 0.4167 | 1.85 |
| 0.5000 | 1.85 |
| 0.5833 | 1.85 |
| 0.6667 | 1.83 |
| 0.7500 | 1.83 |
| 0.8333 | 1.83 |
| 0.9167 | 1.83 |
| 1.0000 | 1.83 |
| 1.0833 | 1.83 |
| 1.1667 | 1.82 |
| 1.2500 | 1.82 |
| 1.3333 | 1.82 |
| 1.4166 | 1.82 |
| 1.5000 | 1.82 |
| 1.5833 | 1.82 |
| 1.6667 | 1.82 |
| 1.7500 | 1.82 |
| 1.8333 | 1.82 |
| 1.9167 | 1.82 |
| 2.0000 | 1.82 |
| 2.5000 | 1.82 |
| 3.0000 | 1.81 |
| 3.5000 | 1.82 |
| 4.0000 | 1.81 |
| 4.5000 | 1.81 |
| 5.0000 | 1.81 |
| 5.5000 | 1.81 |
| 6.0000 | 1.81 |
| 6.5000 | 1.80 |
| 7.0000 | 1.80 |
| 7.5000 | 1.80 |
| 8.0000 | 1.81 |
| 8.5000 | 1.80 |
| 9.0000 | 1.80 |
| 9.5000 | 1.80 |
| 10.0000 | 1.81 |
| 12.0000 | 1.80 |
| 14.0000 | 1.79 |
| 16.0000 | 1.79 |
| 18.0000 | 1.78 |
| 20.0000 | 1.77 |
| 22.0000 | 1.78 |
| 24.0000 | 1.77 |
| 26.0000 | 1.77 |
| 28.0000 | 1.77 |
| 30.0000 | 1.76 |
| 32.0000 | 1.76 |
| 34.0000 | 1.75 |
| 36.0000 | 1.75 |
| 38.0000 | 1.74 |
| 40.0000 | 1.73 |
| 42.0000 | 1.74 |
| 44.0000 | 1.73 |

## HERMIT DATA FOR WELL C16 (Continued)

```
 Elapsed Time    Value
 ------------  ---------
    46.0000       1.73
    48.0000       1.73
    50.0000       1.72
    52.0000       1.72
    54.0000       1.71
    56.0000       1.70
    58.0000       1.70
    60.0000       1.70
    62.0000       1.70
    64.0000       1.70
    66.0000       1.69
    68.0000       1.69
    70.0000       1.68
    72.0000       1.68
    74.0000       1.68
    76.0000       1.67
    78.0000       1.67
    80.0000       1.67
    82.0000       1.68
    84.0000       1.67
    86.0000       1.67
    88.0000       1.66
    90.0000       1.65
    92.0000       1.65
    94.0000       1.65
    96.0000       1.64
    98.0000       1.64
    100.000       1.65
    110.000       1.62
    120.000       1.59
    130.000       1.57
    140.000       1.56
    150.000       1.55
    160.000       1.53
    170.000       1.52
    180.000       1.50
    190.000       1.50
    200.000       1.48
    210.000       1.46
    220.000       1.47
    230.000       1.45
    240.000       1.43
    250.000       1.42
    260.000       1.41
    270.000       1.40
    280.000       1.39
    290.000       1.38
END
```

SC-SP-004.1
Revision 1

# QUALITY ASSURANCE DOCUMENT

# PROCEDURE FOR WELL INSTALLATION AND WELL/BOREHOLE ABANDONMENT

BATTELLE
505 King Avenue
Columbus, Ohio 43201

MJS for S. Nelson
S. Nelson

September 5, 1989
Date

APPROVED BY

Michael J. Stenhouse 9/22/89
Date

APPROVED BY

9/25/89
Date

APPROVED BY

9/22/89
Date

APPROVED BY

9/29/89
Date

SC-SP-004.1
Revision 1
September 29, 1989
Page i of i

# DOCUMENT REVISION RECORD

Title Procedure for Well Installation and Well/Borehole Abandonment

No. SC-SP-004.1

Page i of i

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## REVISION RECORD

| Rev. No. | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | | 9/29/7 | | | | | | | | |
| Approval | | | | | | | | | | |

# PROCEDURE FOR WELL INSTALLATION AND WELL/BOREHOLE ABANDONMENT

## 1.0 Scope

This document describes the procedure for installing wells in boreholes and for abandoning wells or boreholes.

## 2.0 Purpose

The purpose of this procedure is to provide a method for performing well installations in support of drilling/coring operations. The procedure is primarily in support of soil characterization work in the Nuclear Sciences Area of Battelle's West Jefferson Site; however, it may be applied to other locations where soil characterization work is being performed. The major reason for installing wells is to obtain information from subsequent measurements relating to water levels and hydraulic conductivity. A method for abandoning wells/boreholes is also provided for restoration of the land surface and safety purposes.

## 3.0 References

3.1 Ohio Administrative Code 3745-9-10, Water Well Standards and Waivers.

## 4.0 General

### 4.1 Materials

4.1.1 Pipe casing, 2-inch Schedule 40 PVC, with suitable flush-threaded fittings. All connections will be flush-joint threaded.

4.1.2 Screen, 2-inch diameter PVC having 0.010-inch slots. The screen will be capped at the bottom.

4.1.3 Rounded sand or gravel, washed and bagged, with a grain-size distribution (U.S. Sieve Size) compatible with the screen and formation.

4.1.4 Bentonite, granulated or pelletized.

4.1.5 Cement grout; nominally 74 percent Portland Class A cement, 24 percent Pozzolan cement, and 2 percent bentonite.

## 5.0 Responsibilities

5.1 The hydrogeologist shall be responsible for the placement of wells, i.e. for determining which boreholes are to have a well installed.

5.2 The drilling subcontractor shall be suitably qualified in the installation of wells, as determined previously (during bid selection) by the hydrogeologist responsible for bid selection.

5.3 The Technical Project Manager shall determine which method to be used for each borehole.

## 6.0 Procedure

### 6.1 Well Casing Initial Installation

6.1.1 Place the screen and casing into the borehole.

NOTE: If borehole walls are found to be prone to slumping during well drilling, the hollow stem auger can be used as a temporary casing through which screens and casing can be run into the borehole.

6.1.2 Place the sand/gravel pack (Step 4.1.3) into the casing to fill the well from the bottom of the borehole to 1 foot above the top of the screen.

NOTE: If the water table is close to the land surface, the field hydrogeologist will reduce this quantity of sand/gravel pack above the screen so that no surface runoff will seep into the wells.

6.1.3 Tremie bentonite (Step 4.1.4) above the sand/gravel pack, to a minimum thickness of 3 feet.

6.1.4 Tremie-grout cement grout (Step 4.1.5) from above the bentonite seal to the land surface.

## 6.2 Completion of Well

### 6.2.1 METHOD 1

Casing Flush or Below the Land Surface (See Figure 1):

6.2.1.1 Set the casing 2 to 3 inches below land surface, using cement.

6.2.1.2 Complete the assembly with a protective steel casing, equipped with a locking lid.

6.2.1.3 Install protective housing consisting of a cast-iron valve box assembly centered in a 3-foot-diameter concrete pad sloped away from the valve box.

6.2.1.4 Maintain free drainage away from the well within the valve box.

6.2.1.5 Install a screw-type stainless steel cap with Teflon or Viton O-ring to prevent infiltration of surface water.

6.2.1.6 Maintain a minimum of 1 foot of clearance between the casing top and the bottom of the valve box lid.

### 6.2.2 METHOD 2

Above-Ground Surface Completion (See Figure 2):

6.2.2.1 Extend the well pipe approximately 2 feet above land surface.

6.2.2.2 If the well is located near a depression, lake, or creek with a history of flooding, install this extension (riser) higher than the flood stage.

6.2.2.3 Provide an aboveground stainless steel end-plug or casing cap.

6.2.2.4 Shield the above-ground pipe with a steel casing placed over the PVC pipe.

6.2.2.5 Seat all wells of this type in a 2-foot diameter by 4-inch thick concrete surface pad.

6.2.2.6 Slope the pad away from the well casing.

6.2.2.7 Install a lockable cap or lid on the steel casing.

6.2.2.8 If necessary (as determined by the Technical Project Manager), install 3-inch diameter steel guardposts for additional protection.

6.2.2.9 Install these guard posts about 5 feet high, radially from each wellhead, and recessed approximately 2 feet into the ground.

6.2.2.10 Paint the protective steel guard posts and clearly number the well on the lid exterior.

6.2.3 Provide locks for both flush and above ground well assemblies. Turn over lock keys to the Technical Project Manager following completion of the field sampling.

6.2.4 Develop all groundwater monitoring wells after installation. Prior to development, monitor water levels (to the nearest 0.01 inch) with respect to an established survey point at the top of the well casing.

6.2.5 Details of the well installation, including exact measurements, will be filled out on the Well Construction/Completion Report Sheet (DDO-125).

### 6.3 Well/Borehole Abandonment

6.3.1 Seal wells/boreholes according to the recommended procedure (Reference 4.3), using material impervious to migration of water in the hole or within the hole (i.e. grout).

## 7.0 Records

7.1 The QA records generated by the implementation of this procedure are completed and approved form DDO-125 and copies of quality affecting and relevant information entered in Laboratory Record Books.

## 8.0 Figures and Forms Referenced in This Procedure

### 8.1 Figures

- 8.1.1 Figure 1, Typical Monitoring Wall Construction - Below Ground Completion
- 8.1.2 Figure 2, Typical Wall Construction - Above Ground Completion

### 8.2 Forms

- 8.2.1 DDO-125, Well Construction/Completion Report Sheet

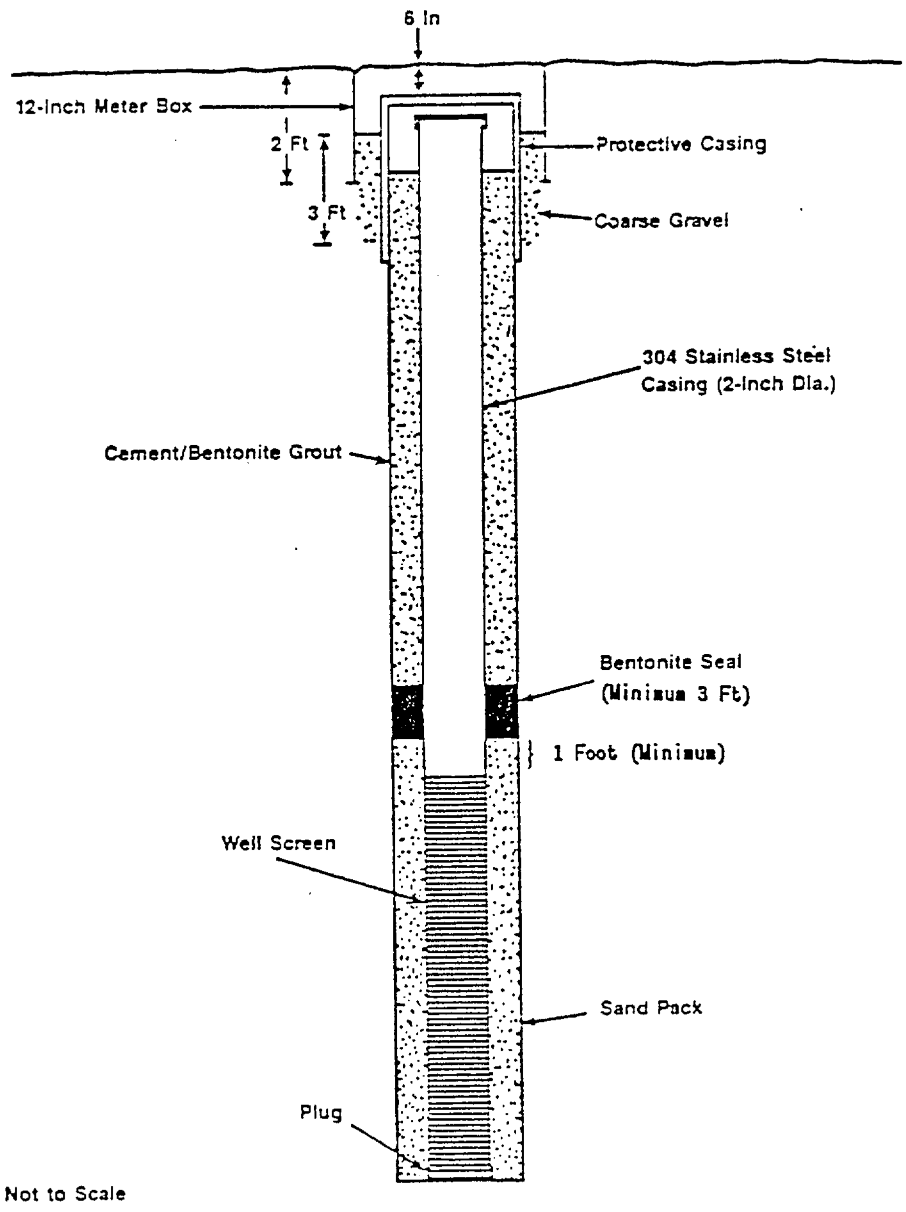


FIGURE 1. TYPICAL MONITORING WELL CONSTRUCTION - BELOW GROUND COMPLETION

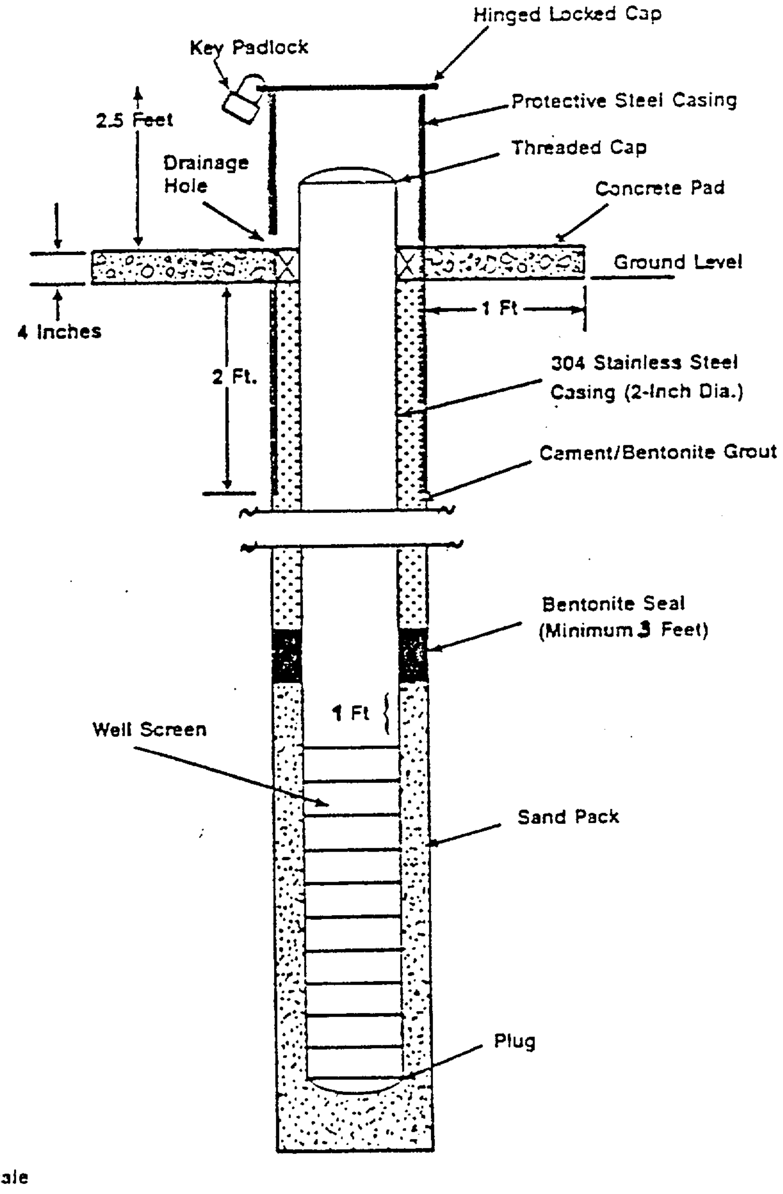


FIGURE 2. TYPICAL WELL CONSTRUCTION - ABOVE GROUND COMPLETION

## WELL CONSTRUCTION/COMPLETION REPORT SHEET

Sample Identification Code: _____-_____-_____-_____

Name of Site: ____________________

Well ID Number: ____________________

Drilling Location: ____________________
(Use Coordinates if Available)

Total Depth: ________ ft.

Drilling Contractor: ____________________

Type of Rig: ____________________

Date Installation Completed:

___ ___ ___ ___ ___ ___
(Y Y M M D D)

Observations of Monitoring Zone and Further Information:

______________________________

______________________________

______________________________

______________________________

______________________________

______________________________

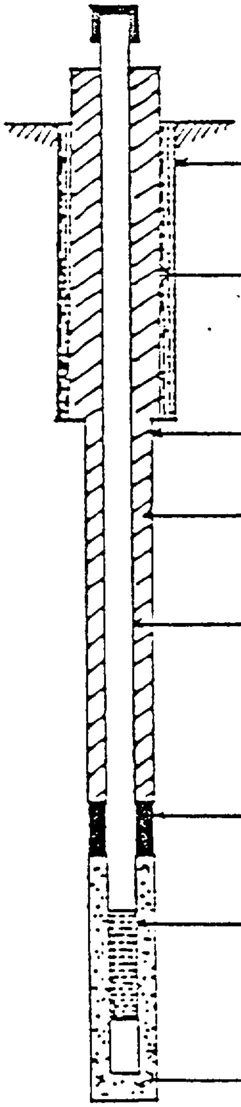
______________________________

______________________________

______________________________

______________________________

______________________________



Summary of Well Construction

Well Cap Elevation: _____ ft.

Ground Surface Elevation: _______ ft.

Conductor Hole Dia.: ______ in.
__________ to __________ ft.

Surface Conductor
Type: ________________
ID: ______ in. OD: ______ in.
__________ to __________ ft.

Borehole Dia.: _______ in.
__________ to __________ ft.

Filler Material: ________________
__________ to __________ ft.

Casing (with screen)
Material: ________________
ID: ______ in. OD: ______ in.
__________ to __________ ft.

Seal Material: __________
__________ to __________ ft.

Screen
Material: ____________
ID: ______ in. OD: ______ in.
__________ to __________ ft.
Slot Size: ______________

Pack
Type: _________ Size: _____
__________ to __________ ft.

Entered by: ______________, ________
(Signature) (Date)

Approved by: ______________, ________
(Signature) (Date)

WELL CONSTRUCTION/COMPLETION REPORT SHEET

J. Tholen

EM-QAP-2.0
Revision 0

# QUALITY ASSURANCE PLAN

for

# BATTELLE GROUNDWATER MONITORING

Battelle
505 King Avenue
Columbus, Ohio 43201

Prepared by

E.R. Swindall ers

June 18, 1990
Date

APPROVED BY

Louis Fadel 7/27/90
L. Fadel Date

Michael J. Stenhouse 8/2/90
M. J. Stenhouse Date

Harley L. Toy 8/2/90
H. L. Toy Date

D. E. Lozier 8/14/90
D. E. Lozier Date

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## DOCUMENT REVISION RECORD

Title Quality Assurance Plan for Battelle Groundwater Monitoring

No. EM-QAP-2.0

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### REVISION RECORD

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| Date | 8-17-90 | | | | | | | | | |
| Approval | KSR | | | | | | | | | |

# BATTELLE GROUNDWATER MONITORING

## INTRODUCTION

This plan specifically describes the quality assurance (QA) program for conducting environmental groundwater monitoring at the Battelle West Jefferson site (Figures 1 & 2) during the two phases of the Battelle Columbus Laboratories Decommissioning Project (BCLDP): surveillance and maintenance (S&M), and decontamination and decommissioning (D&D). It will be adopted as a subtier document under the Battelle Nuclear Quality Assurance (NQA) manual for the Decommissioning and Decontamination (DDO) Group. QA procedures and documents have been and will be developed and revised to provide the necessary planning, control, documentation, and safety for all activities associated with this effort.

The groundwater monitoring program is designed and will be implemented in accordance with monitoring requirements of 40 CFR Part 264, Subpart F, and 40 CFR Part 265, Subpart F. Monitoring for radionuclides shall be in accordance with DOE Orders in the 5400 series. The Task Leader of the Environmental Monitoring Group will coordinate this effort. This plan shall be reviewed annually and updated every three years until the contract expires. This plan was developed to be responsive to the requirements of DOE Order 5400.1, Chapter III, "General Environmental Protection Program", paragraph 4.a "Special Program Planning Requirements, Groundwater Protection Management Program, and the requirements of the groundwater monitoring plan pursuant to Chapter IV, paragraph 9 of DOE Order 5400.1, and all applicable DOE Orders of the 5400 series in addition to ANSI/ASME NQA-1 as listed below. Each applicable criteria is discussed in the sections that follow.

(1) Organization
(2) Quality Assurance Program
(4) Procurement Document Control
(5) Instructions, Procedures, and Drawings
(6) Document Control
(7) Control of Purchased Items and Services
(8) Identification and Control of Items
(10) Inspection
(11) Test Control
(12) Control of Measuring and Test Equipment
(13) Handling, Storage, and Shipping
(14) Inspection, Test and Operating Status
(15) Control of Nonconforming Items
(16) Corrective Action
(17) Records
(18) Audits

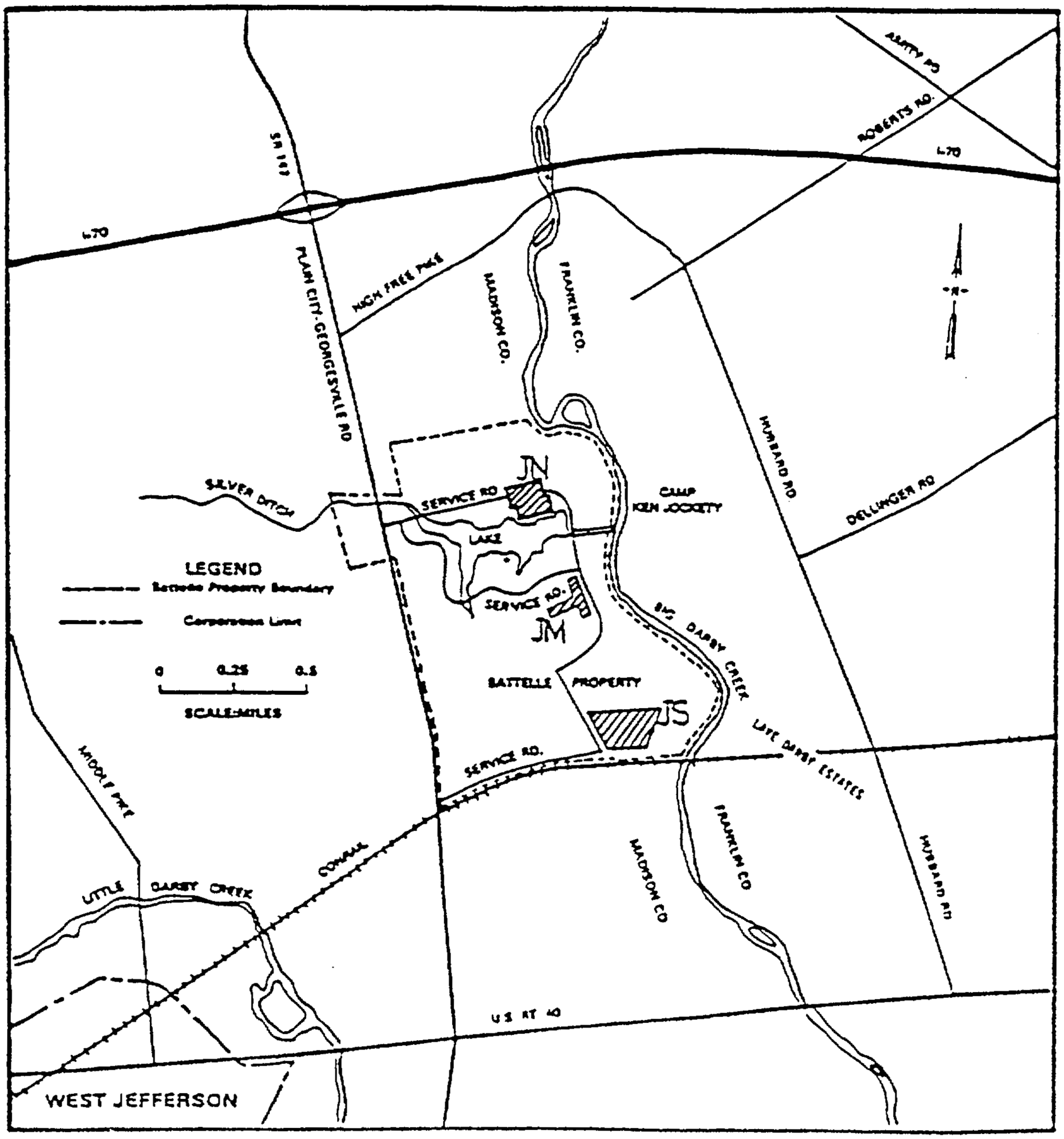


FIGURE 1. LOCAL VICINITY MAP OF WEST JEFFERSON SITE

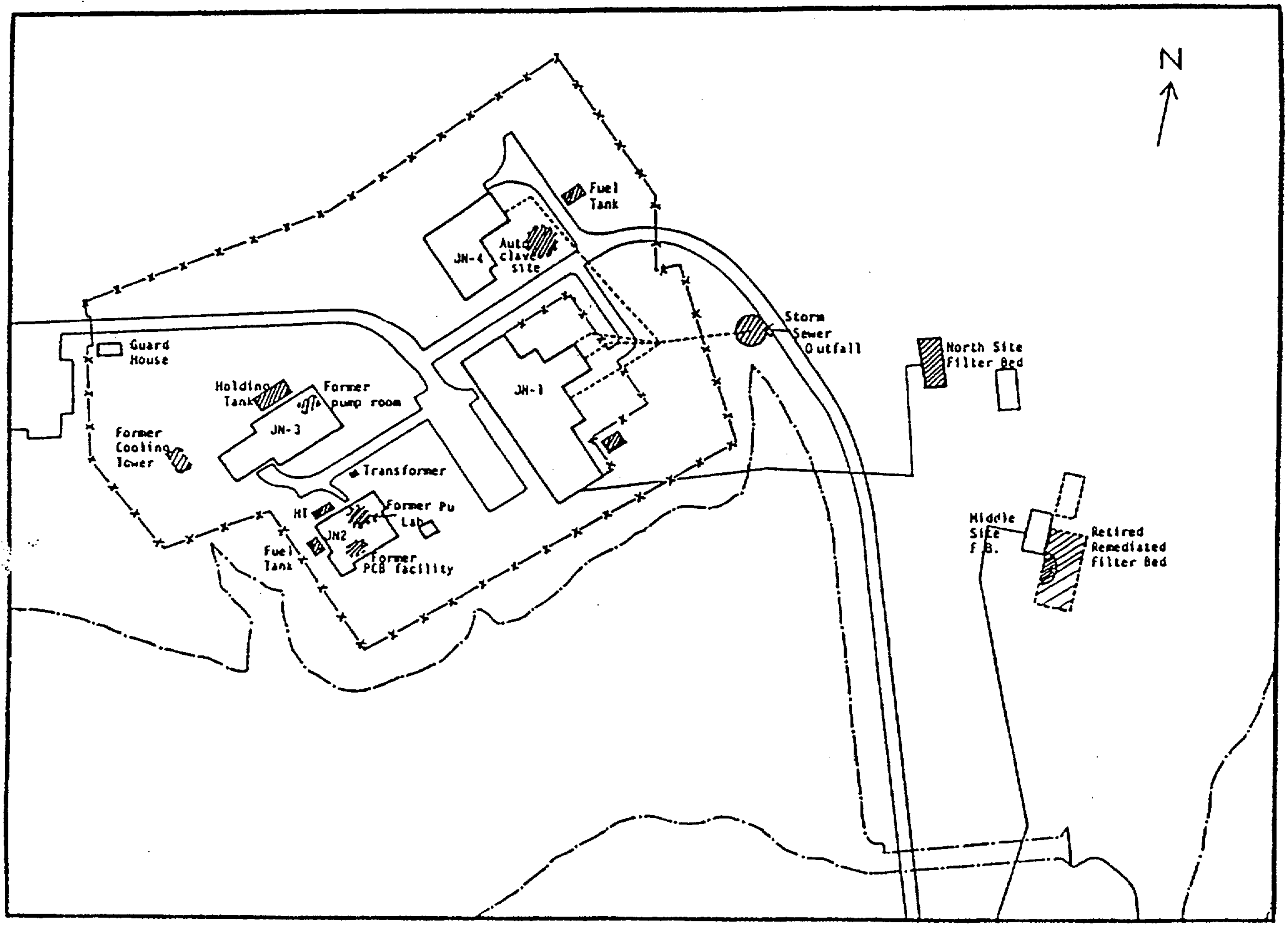


FIGURE 2. NUCLEAR SCIENCES AREA

Since no specific designs are being developed, and no special processes will be conducted during the sampling program, NQA-1 requirements (3) Design Control, and (9) Control of Processes and are not applicable to this project and are not addressed in this plan.

## 1.0 Organization

The organizational structure for Groundwater Monitoring is shown in Figure 3. The Environment, Health and Safety (ES&H) Manager, the QA Manager, and the Compliance Review Committee report directly to the BCLDP Project Manager. The Task Manager of the Radiological Environmental Monitoring Group reports directly to the ES&H Manager and is responsible for the day to day monitoring activities, equipment calibration, and review and evaluation of data generated. The Environmental Compliance Officer will assist in interpretation of data for compliance purposes.

## 2.0 Program

Battelle has done limited groundwater monitoring for radionuclides since the early 1970s. The area of concern has been an underground aquifer running in the vicinity of the nuclear fuel storage pool for the West Jefferson, JN-1 facility. Two monitoring wells were installed at the time the pool was put in. One well is a sump that collects condensate from the pool liner, while the other collects water from the aquifer on the down gradient side of the pool. Samples have been collected on a monthly basis. The samples have been analyzed for gross alpha and gross beta emitters, fission products and activation products. There has been no indication that the aquifer has become contaminated from the pool. This sampling schedule is expected to continue for at least three to six months after the pool is emptied of all water to assure that there are no leaks from the groundwater to the inside sump which would imply a leak in the pool liner that could yet allow transfer of radioactivity to the groundwater system.

Additional radiological groundwater monitoring is done at a former supply well (JN) for the West Jefferson Nuclear Sciences Area and from

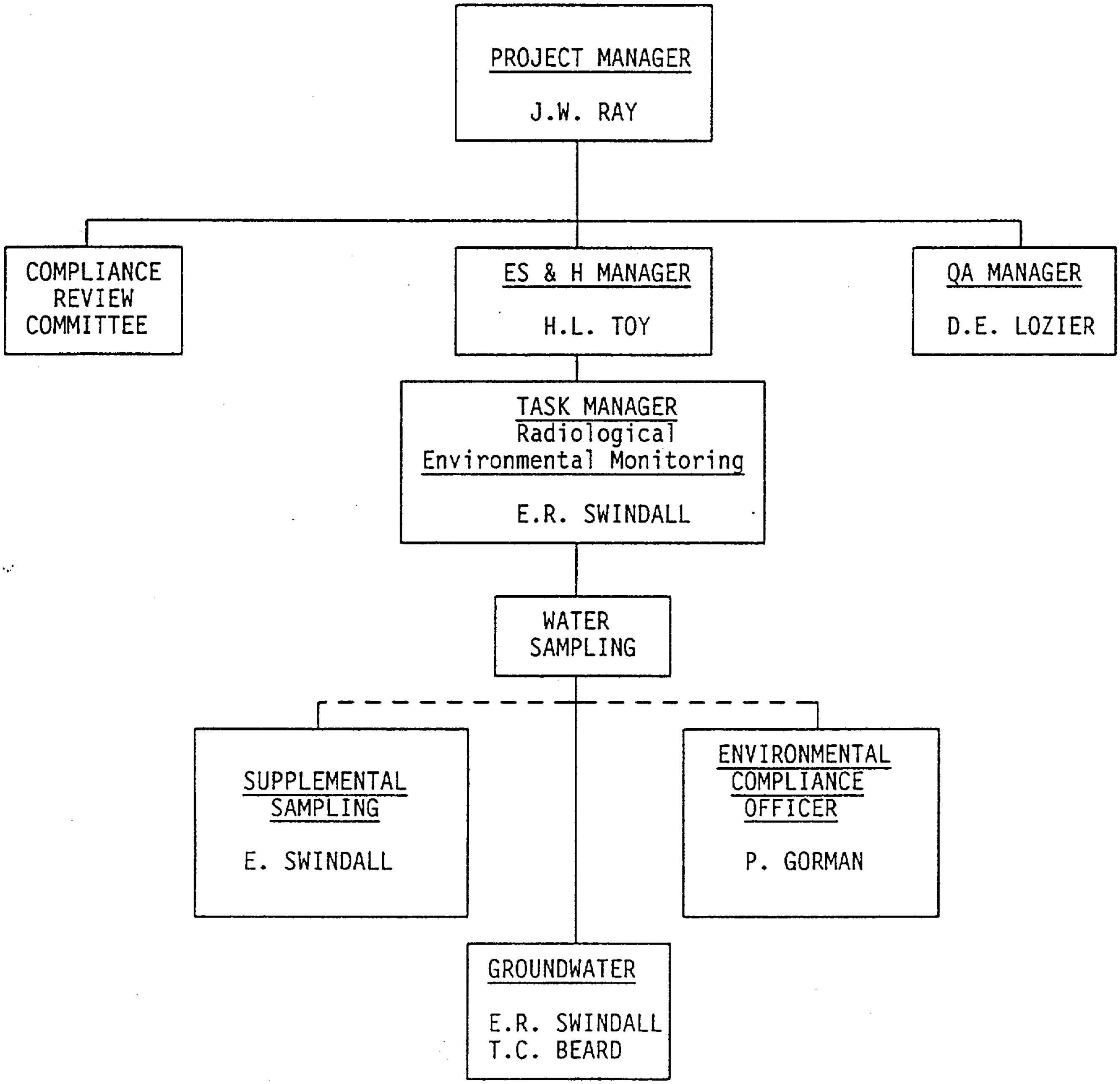


Figure 3. Organizational Structure for BCLDP Groundwater Monitoring

existing supply wells before the water is treated in any form. Samples that have been collected annually over the last five years have undergone the same analysis for gross alpha and gross beta emitters, fission products, and activation products. These wells continue to be sampled on a routine basis with additional chemical analysis of the JN well sample planned for volatile organic compounds. The Summary from the Interim Report on Site Characterization, West Jefferson North Site, Stage 1 Sampling and Analysis, Chemical Sampling Summary Report, December 22, 1989, has been modified to represent the current status of results and is presented here as the basis for the additional analysis.

## Summary

> A sampling and analysis program for chemical contaminants was performed in November 1989, at Battelle's Nuclear Sciences Area, West Jefferson Site, Ohio. A total of 32 sampling locations provided 29 soil and 3 groundwater samples for chemical analysis. During drilling operations, and the subsequent collection of soil cores, some hydrocarbon contamination of soil, assumed to be fuel oil, was observed around the three fuel storage tanks on site. Subsequent analysis of soil samples collected in these locations confirmed the presence of oil at levels of about 1300 ppm (JN-1), 1200-1500 ppm (JN-2), and 25-50 ppm (JN-4). Further characterization is underway. The EP Toxicity test for metals showed no concentrations above the RCRA limit of 1 ppm for most soil samples analyzed. PCBs were found in only one soil sample, taken close to the on-site transformer beside building JN-2, but at a ppb concentration, well below the action limit of 50 ppm. The only other contaminants, found at ppb concentrations in a few soil samples, were several volatile organic compounds, with acetone predominant. While the concentrations of these compounds are low-level, some additional sampling of soil in the storm-sewer outfall area is recommended in conjunction with the additional (Stage 2) sampling proposed for radiological purposes. No contamination was found in the groundwater samples collected.

In addition to the three chemical sampling wells, twelve shallow wells were installed around the West Jefferson North site as part of the site characterization and will be used for monitoring radionuclides. (See Figure 4.) A full hydrogeological study is expected to be completed in June, 1990, that will allow for the reduction of the number of radiological monitoring wells to six. The need for additional chemical monitoring wells in the vicinity of the fuel storage tanks is being evaluated and appropriate monitoring will be instituted.

Three of the shallow radiological monitoring wells, also installed as part of the site characterization, are located in and near two former filter beds that still shows traces of radioactive materials. The Summary mentioned above suggests the need for installing chemical wells in this area to identify any pockets of chemicals that may exist from a build up of chemicals that may have gotten into the drain over the life of the filter bed. Radiological monitoring will be performed on an annual basis using existing wells with routine chemical monitoring being added when the wells are completed.

Liquid effluents at Battelle's King Avenue site are discharged into the city sanitary sewer system. The discharge points are currently monitored under the Environmental Monitoring program. All electrical transformers are housed within the facility with secondary containment dikes. There has been no known waste disposal or treatment on site. As a result of these conditions, no groundwater sampling is planned for the King Avenue site.

The budgetary resources for this program are from the BCLDP operating funds which will have to be increased or another source found for installing additional wells and covering the cost of routine chemical sampling.

Supplemental environmental monitoring, done in support of groundwater monitoring, includes the routine sampling or monitoring of effluents from, and the collection of routine samples of surface water, soil, and biota in the environs of a facility. The data and information collected are assessed to determine the impact of the operations in the facility on the environs and persons present in the environs, and to provide guidance for adjusting the operations if the impact is inappropriate.

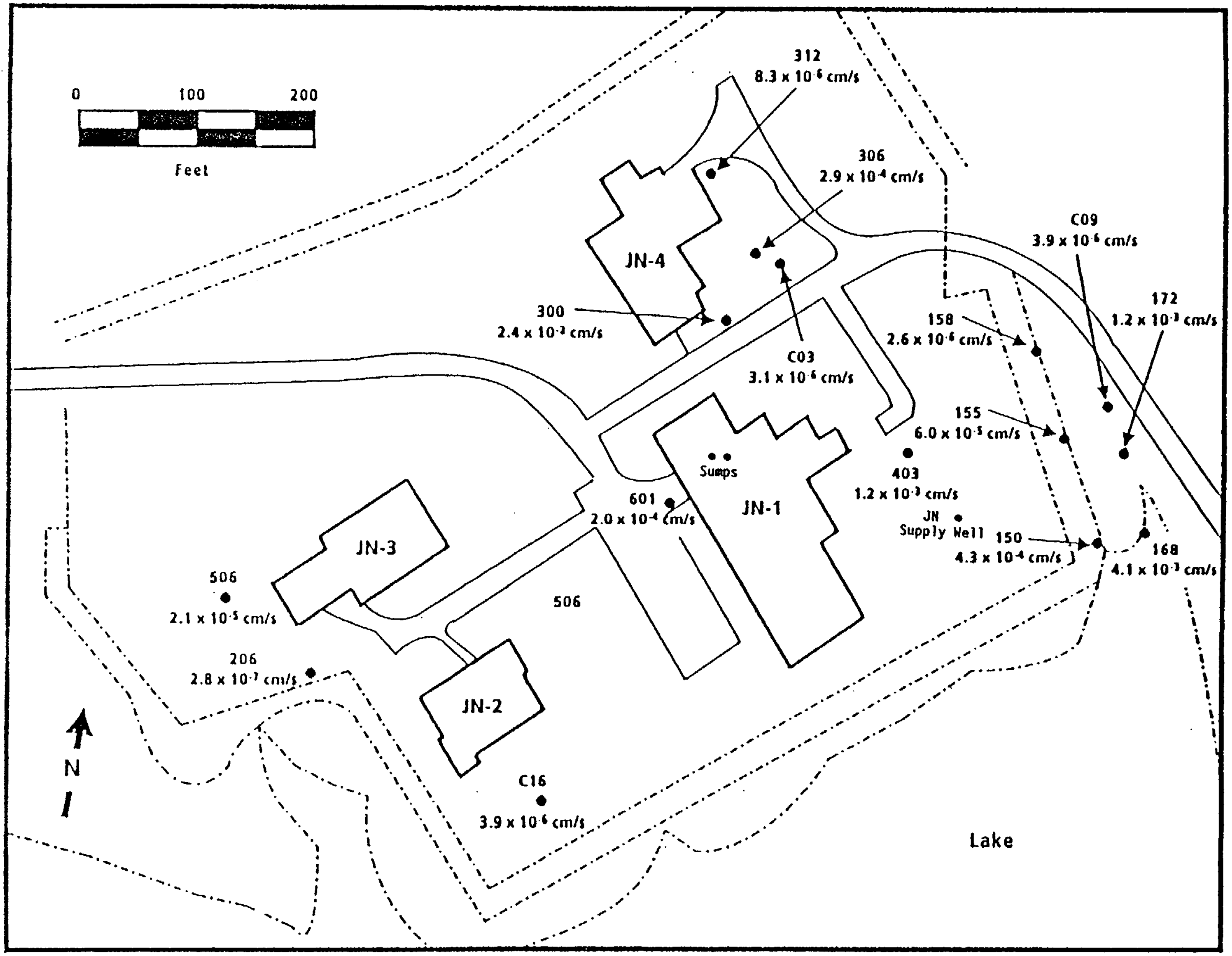


FIGURE 4. LOCATIONS OF GROUNDWATER MONITORING WELLS

Objective:

1. Ensure that appropriate media samples are analyzed and data correctly interpreted to determine the impact of elements, compounds and radionuclides to groundwater. The annual objective is the reporting and assessment of all data culminating in a formal report to DOE.

2. Maintain appropriate instrumentation and equipment in good repair and calibration to effectively collect and assess all sampled media.

Work Statement: Maintain the schedule of routine sampling, monitoring and analytical activities as provided in Appendix A and evaluate and perform additional sampling as determined necessary to adequately characterize the impact of operations on the environment.

## 4.0 Procurement

Procurement of items affecting quality of sampling shall be controlled through documents QA-AP-4.1. Procurements will be usually limited to replacement of worn or defective equipment from approved vendors.

## 5.0 Instructions, Procedures, and Drawings

Besides the application of ANSI/ASME NQA-1, the following groundwater monitoring procedure shall be used for routine monitoring, along with other procedures listed that may be used for supplemental sampling to identify potential hazards. Procedures and dates in parentheses indicate replacement procedures and the anticipated dates for completion of the replacement. Non-routine sampling shall be handled through work instruction as outlined in QA-AP-5.2.

| Procedure | Revision | Date | Title |
|---|---|---|---|
| ✓ SC-SP-012 | Rev. 0.1 | 05-30-90 | Collection of Groundwater Samples in Support of Site Groundwater Characterization |
| NS-NS-10.1<br>(EM-SP-009) | Rev. 0 | 07-07-81<br>(08-31-90) | Procedure for the Collection of Environmental Hazardous Chemical Samples |
| ✓ EM-SP-002 | Rev. 0.1 | 06-11-90 | Procedure for the Collection of Environmental Radiological Water Samples |
| NS-NS-11.1<br>(EM-SP-010) | Rev. 0 | 07-07-81<br>(08-31-90) | Procedure for the Collection of Environmental Hazardous Chemical Water Samples |
| ✓ NS-NS-12<br>(EM-SP-003) | Rev. 1 | 07-31-90<br>(08-31-90) | Procedure for the Collection of Environmental Radiological Soil Samples |
| ✓ NS-NS-13<br>(EM-SP-004) | Rev. 1 | 05-07-84<br>(08-31-90) | Procedure for the Collection of Environmental Vegetation Samples - Annual Grass |
| SC-SP-006 | Rev. 0 | 01-29-90 | Sampling of Sediment and Sludge in Ponds, Streams, Sumps and Closures |

## 6.0 Document Control

The following Project and QA program personnel or their designated alternates shall have the authority to approve quality documents:

- ES&H Manager
- Task Manager
- Health Physics Supervisor
- QA Manager
- Radiochem. Lab. Manager

All documents shall be controlled by the review, approval and issue of process document QA-AP-6.1. Document revision and operation under temporary procedure changes shall be accomplished as specified in QA-AP-6.1. Documents shall be controlled by distribution of a document index containing the current document revision, and by staff responsibility for possessing current documents.

## 7.0 Control of Purchased Items and Services

All project purchases other than routine supplies shall be reviewed by the QA Manager to determine if the purchase is a quality item based on the evaluation process described in QA-AP-4.1 and QA-AP-2.1. The QA organization personnel shall evaluate objective evidence of quality furnished by subcontractors to determine their suitability for placement on the approved suppliers list. Selection of quality-affecting subcontractors shall be made from records of past performance, incorporation on an approved suppliers list, and/or site visit evaluations, if necessary, as controlled by document QA-AP-7.1. The Project and QA organization may perform on-site surveys of the proposed subcontractor for acceptance on the approved suppliers list.

Procurements from time of order placement to receipt at Battelle shall be controlled by methods in QA-AP-7.2. The QA organization shall participate in the examination of all purchased quality items and services to determine their compliance to specifications of the purchase order. Approved inspection plans for items shall be drawn up in advance as specified in QA-AP-7.2 and QA-QP-10.1.

## 8.0 Identification and Control of Items

All specimens, samples or any items quality-related to the program shall be identified by an affixed identification designation and/or in documents traceable to the items. Routine samples shall use the appropriate sample identification found in appendix A, along with the date and time of sample collection. These samples are further identified in traceable documents and procedures. Non-routine sample identification shall be spell out in work instructions and identified in traceable documentation.

## 10.0 Inspections

Inspections for items shall be conducted in accordance with the requirements of QA-AP-10.1. The acceptance of items shall be documented and approved by the Task Manager or by higher management, as necessary and appropriate.

Spot surveillance of activities by observation by the QA Manager or his designee to assess their conformance with requirements and approved procedures. Any discrepancies noted shall be resolved with the Task Manager. Any noncompliance reports (NCRs), deficiency notices (DNs), and corrective action reports (CARs) shall be prepared, processed, and resolved in accordance with Sections 15 and 16 of this plan.

## 11.0 Test Control

Analytical testing activities will be performed to collect data from the groundwater samples. Radioanalytical activities performed at Battelle will be controlled, documented and evaluated under procedure EL-AP-1.0 and its associated testing procedures.

## 12.0 Control of Measuring and Test Equipment

12.1 The following items of systems are quality-affecting but not directly data generating, and requiring calibration.

- 12.1.1 Teflon 1-1/2 inch bailer
- 12.1.2 Composite Water Sampling System
- 12.1.3 Radioanalytical Lab Counting Equipment
- 12.1.4 Chemical Analytical Lab
  from approved vendors list

12.2 The equipment indicated in Section 12.1.3 shall be calibrated to a standard traceable to the National Institute of Standards and Technology (NIST), formerly NBS.

12.3 The re-calibration time sequence for the calibrated equipment should not exceed one year unless justification is documented.

## 13.0 Handling, Storage, and Shipping

The handling of all specimens, samples, and quality-related items shall be performed under controlled conditions predetermined to prevent damage, loss, minimize deterioration and assure safety. The storage of all specimens, samples, and quality-related items shall be implemented under controlled conditions predetermined to prevent damage, loss, minimize deterioration, and assure safety. The cleaning of all specimens, samples, and quality-related items shall be implemented under controlled conditions predetermined to prevent damage, loss, minimize deterioration, and assure safety. The packaging and shipping of all sample materials shall be implemented under controlled conditions predetermined to minimize loss, damage, and minimize deterioration.

## 14.0 Inspection, Test, and Operating Status

The status of inspection and test activities shall be documented in records traceable to the items and the items tagged or identified where possible to assure the tests or inspections are performed. All items not meeting the inspection or test specifications or allowable limits shall be marked and/or separated from the approved items to prevent their inadvertent use, transport or disposal. All samples containing contaminant radioactivity will be identified with appropriate radioactivity identification tag and segregated from uncontaminated material. All samples containing contaminant levels of chemicals will be identified with a chemical contamination tag and segregated from uncontaminated material.

## 15.0 Control of Nonconforming Items

All items or operations not meeting specifications or performed in accordance with approved procedures shall be documented on a nonconformance report. The nonconformance report shall be processed in accordance with procedure QA-AP-15.1.

## 16.0 Corrective Actions

All proposed corrective actions generated to resolve conditions adverse to quality shall be submitted to the NQA Manager for approval of the adequacy and time schedule of the action. Corrective actions shall conform to the requirements of procedure QA-AP-16.1. The cause of the adverse condition shall be determined, if possible, and corrective actions taken to preclude its recurrence. Follow-up action shall be taken by the program Technical Manager and Q.A. Manager to verify implementation and effectiveness of the corrective action.

## 17.0 Quality Assurance Records

Records which furnish documentary evidence of quality shall be specified, prepared, and maintained.

Specified records include, but are not limited to the following:

a. Maps identifying sampling locations
b. Sampler Record Book
c. Sample inventory
d. Technical procedures and data sheets
e. Calculation and analyses records
f. Reports
g. Q.A. Surveillance and Audit Records
h. Program correspondence

Records shall be made part of the BCLDP record management system and subject to all the requirements and restrictions of the system.

## 18.0 Audits

Audits shall be planned and implemented in accordance with procedure QA-AP-18.1. A pre-program audit is not required as this is a continuation of an existing program. Periodic audits will be conducted over the life of the program.

# APPENDIX A

A-1

# ROUTINE ENVIRONMENTAL GROUNDWATER MONITORING SCHEDULE

This monitoring schedule describes the well identification, general location, sampling frequency, and the measurements to be made. Radiological measurements are to consist of gross alpha and gross beta-gamma measurements with isotopic analysis to be performed on samples that are five times the counting background.

Chemical sampling is to consist of any combination of the following parameters and analytical methods or other approved methods that will produce the same sensitivity or better.

## Analytical Methods

| | | |
|---|---|---|
| Volatile organic compounds | --- | SW-846 Method 8240 (GCMS) |
| Semi-volatile compounds | --- | SW-846 Method 8270 (GCMS) |
| Oil and grease | --- | SW-846 Method 423.1 (gravimetric) |
| Metals - EP Toxicity | --- | SW-846 Several Methods |
| PCBs | --- | SW-846 Method 8080 (GCMS) |
| pH | --- | SW-846 Method 150.1 (electrometric) |

Sample collection frequency is to be annually (A) unless otherwise specified.

A - Annually M - Monthly

A-2

# GROUNDWATER SAMPLING -WEST JEFFERSON LOCATION

## North Area West Jefferson Site

| WELL # | Location | Frequency | Measurements |
|---|---|---|---|
| 150 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| 155 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| 158 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| 168 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| 172 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| 206 | South of JN-3 | A | α, β (Diss/susp) |
| 300 | Southeast of JN-4 | A | α, β (Diss/susp) |
| 306 | East of JN-4 | A | α, β (Diss/susp) |
| 312 | Northeast of JN-4 | A | α, β (Diss/susp) |
| 403 | East of JN-1 | A | α, β (Diss/susp) |
| 506 | West of JN-3 | A | α, β (Diss/susp) |
| 601 | West of JN-1 | A | α, β (Diss/susp) |
| C03 | East of JN-4 | A | α, β (Diss/susp) |
| C09 | Storm Sewer Outfall | A | α, β (Diss/susp) |
| C16 | Southeast of JN-2 | A | α, β (Diss/susp) |

## Remediated Filter Bed Area

| Well # | Location | Frequency | Measurements |
|---|---|---|---|
| 101 | East Side of Filter Bed | A | α, β (Diss/susp), and Chemical Sampling |
| 104 | Southeast of Filter Bed | A | α, β (Diss/susp), and Chemical Sampling |
| 110 | West Side of Filter Bed | A | α, β (Diss/susp), and Chemical Sampling |

## Supply Wells

| Well ID | Location | Frequency | Measurements |
|---|---|---|---|
| JN | Nuclear Science Area (Supply Well-Inactive) | A<br>M | α, β (Diss/susp), and Chemical Sampling |
| JM | West Jefferson Middle Area (Supply Well-Active) | A | α, β (Diss/susp) |
| JM-1 | West Jefferson Middle Area (Facility Well) | A | α, β (Diss/susp) |

BMI Memo

ILC Files Well W-1

(FORMERLY ROBERT C. SMITH & ASSOCIATES)

**FRED H. KLAER, JR. & ASSOCIATES**
CONSULTING GROUND-WATER GEOLOGISTS AND HYDROLOGISTS
16 LELAND AVENUE
COLUMBUS 14, OHIO

PHONE AMHERST 8-3316

[illegible]

April 2, 1963

Mr. C. T. Greenidge
Battelle Memorial Institute
505 King Avenue
Columbus 1, Ohio

Dear Mr. Greenidge:

West Jefferson, Ohio.

In accordance with our discussion on March 14, Mr. Don Kyser of this office met Mr. Glen Williams at the West Jefferson plant of Battelle Memorial Institute on March 15.

The non-pumping or static level in the south well (Layne No.1) was measured as 42.1' below the pump base. At the time the well was drilled in September 1954, the static level was reported by Layne as 41 feet. The apparent difference in static level is insignificant and suggests that there has been no serious regional decline in water levels during the past 9 years. It was not possible to measure the pumping level, because of the danger of flooding the basement. I believe this should be done, however, by making arrangements to waste water through several outlets within the building, if this can be worked out.

(well #2)

The static water level in the north well was measured as 18.17 feet below the pump base. The static water level in April 1955, as reported by Layne was 18'5". This also shows that there has been no significant change in water levels in this area. The pumping level was measured as 39.22 feet below the pump base after 3 to 4 minutes of pumping. This is not particularly significant because of the short period of pumping.

At the present time both wells operate automatically for such short periods of time that it is impossible to get any true value for pumping level. It may be possible to make arrangements to waste water in some way, so that the pumps could operate for one-half to one hour without shutting off. This I believe should be investigated. It is obvious, however, that you are not fully utilizing the capacities of these wells.

We have plotted up the data on the south well provided to you in a letter report from Burgess and Niple, dated September 16, 1954. This indicates that the transmissibility of the limestone aquifer is about 16,500 gallons per day per foot. Assuming a coefficient of storage of 0.0001, which is reasonable for limestone aquifers, we estimate that this well could be pumped continuously at 250 gpm. for a period of a year without recharge, without lowering the pumping level below the pump intake.

Using the values assumed above, we have computed the cone of influence of the south well pumping continuously at 250 gallons per minute without recharge, a copy of which is attached. This indicates that pumping the south well continuously will lower the water level in the north well, about 3700 feet away, about 2.5 feet in 24 hrs., 6.4 feet in 10 days, 11.4 feet in 180 days and about 12.6 feet in one year. At the present time your pumping schedule is so infrequent that one well probably does not affect the other.

It is believed that the wells of West Jefferson are about 10,000 feet from the south well. The computed cone of influence graph shows that unless the pumping from the West Jefferson wells now reported as 200 - 300 gpm. increases considerably, it is unlikely that your wells will be seriously affected.

This diagram can be used to determine proper spacing for additional wells, depending on the rates and expected duration of pumping.

We will be glad to discuss this with you at your convenience.

Sincerely yours,

FRED H. KLAER, JR. & ASSOCIATES

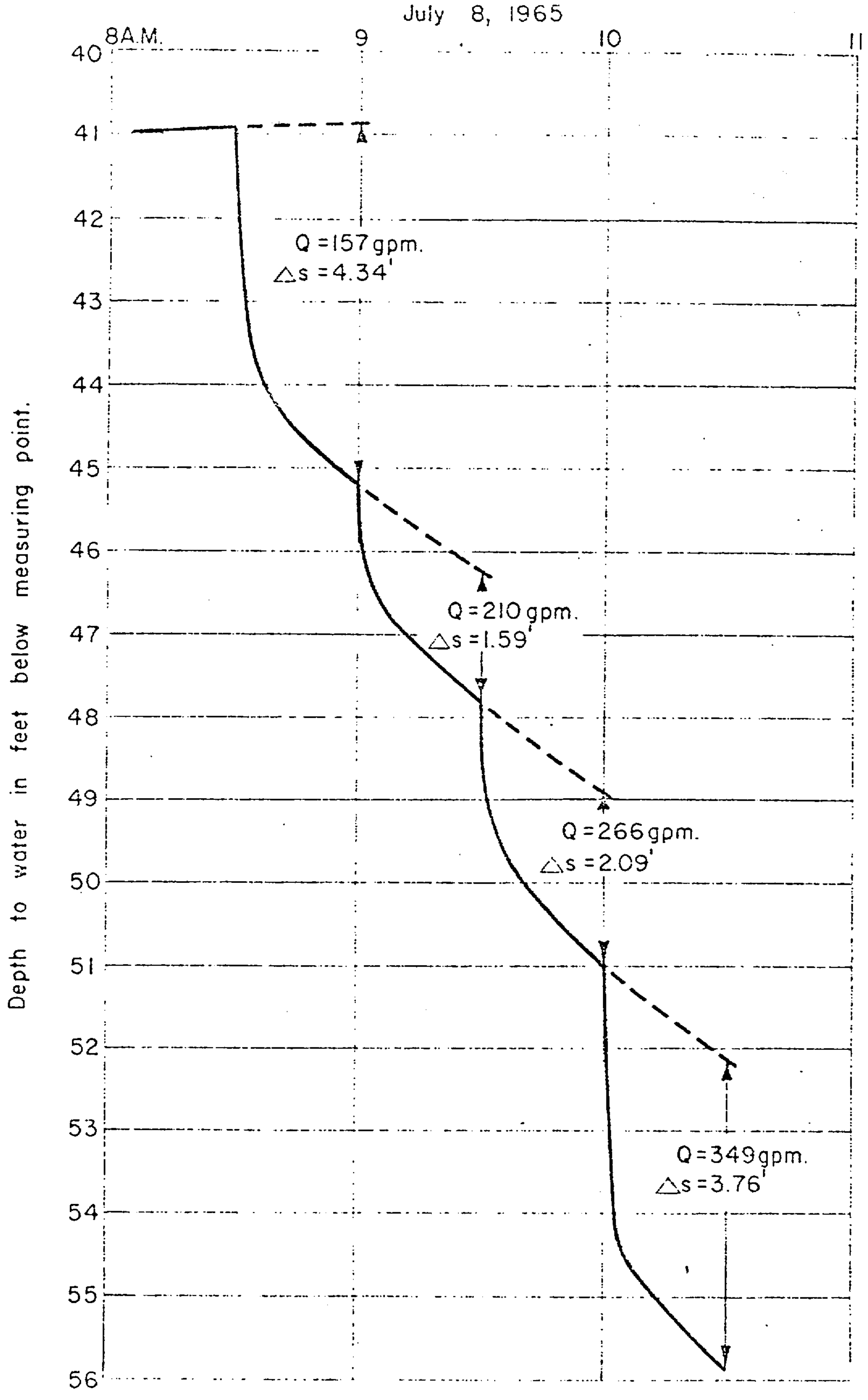
Fred H. Klaer Jr.

Fred H. Klaer, Jr.
Consulting Ground-Water Geologist
and Hydrologist.

FHKJr:eh

1-Encl.

MIDDLE WELL #3



*BATTELLE MEMORIAL INSTITUTE.*
WEST JEFFERSON, OHIO.

MULTIPLE STEP TEST OF WELL 3.

FRED H. KLAER JR & ASSOC.

MIDDLE WELL #3

(FORMERLY ROBERT C. SMITH & ASSOCIATES)

FRED H. KLAER, JR. & ASSOCIATES
CONSULTING GROUND-WATER GEOLOGISTS AND HYDROLOGISTS
16 LELAND AVENUE COLUMBUS, OHIO 43214
P.O. BOX 3496
PHONE AMHERST 8-3316

July 13, 1965.

Battelle Memorial Institute
505 King Avenue
Columbus, Ohio 43201

Attention: Mr. Daun Peterseim

Well 3, West Jefferson, Ohio.

Gentlemen,

In accordance with your instructions, we have followed closely the drilling of Well 3 near your proposed greenhouse site at your West Jefferson, Ohio, plant. The well was completed and tested during the week of July 6, 1965.

The driller's log of the well is reported as follows:

| | |
|---|---|
| 0 - 3 | topsoil |
| 3 - 5 | light brown clay |
| 5 - 48 | brown clay and gravel |
| 48 - 54 | gravel |
| 54 - 115 | light brown clay and gravel |
| 115 - 119 | gravel |
| 119 - 149 | brown lime rock |
| 149 - 152 | red clay |
| 152 - 161'9" | brown lime rock |
| 118'6" | pipe in hole |

Driller reports crevice in limestone at 141 feet.
Static water level, June 8, 1965, 40.92 feet below top of casing.

On June 8, 1965, a multiple step drawdown test was run to determine at what depths water was entering the well and to determine the well losses within the pumping well. The well was pumped at rates of 157, 210, 266, and 349 gpm. for periods of 30 minutes at each rate. Prior to the step test, the static water level was at a depth of 40.92 feet below the top of the casing. At the end of the test, the pumping level was at a depth of 55.87 feet. A hydrograph of the multiple step test is shown in an attached figure.

MIDDLE WELL #3

During the step test, the pumping level at a rate of 349 gpm. was at a depth of 55.87 feet below the top of the casing. Since the casing extended to a depth of 118 feet, 6 inches, it was not possible to lower the water level below the casing to show where the water enters the well. Since the driller reported a crevice at a depth of 141 feet, we must assume that the major part of the water enters the well below a depth of 118 feet and probably at about 141 feet.

The well loss factor was computed to be 8.92 and the actual well loss at a pumping rate of 349 gpm. was 5.36 feet. This is not unreasonable for a limestone well and we believe the well is acceptable.

Some difficulty was encountered originally in developing the well to pump clear water. It was necessary to spend several days in developing. It was planned to use acid treatment to clear up the well. However, no acid was used in the well and the capacity was increased by surging and pumping. At a rate of 349 gpm. the water pumped was completely clear.

On June 9, 1965, a constant rate test was run. The well was pumped at a constant rate of 349 gpm. from 8:15 a.m. until 2:45 p.m., a total of 6-1/2 hours. The static water level at the start of the test was at a depth of 41.22 feet below the top of the casing and the pumping level at the end of the test was 62.75 feet, giving a total drawdown of 21.53 feet. The apparent specific capacity was about 16.2 gpm. per foot of drawdown.

The transmissibility of the limestone aquifer was determined as 9050 gallons per day per foot. This is somewhat lower than that computed from a pumping test on the south well of about 16,500 gpd. per ft., reported to Mr. Greenidge in our letter of April 2, 1963, based on a pumping test run by Burgess and Niple in September 1954.

Using a value of transmissibility of 9050 gpd. per ft. and a storage coefficient of 0.0001 (which is reasonable for the limestone aquifer in this area), the computed drawdown of a well pumping continuously at a rate of 500 gpm. for one year from ground water storage will be about 69.1 feet, plus 11 feet of well loss or a total of 80.1 feet. The total available drawdown will be the difference between the static water level of about 45 feet and the point where the water enters the well, say at 140 feet, giving a total drawdown of 95 feet. It is our opinion, therefore, that the safe capacity of the well is about 500 gpm. If it is necessary to pump the well at this rate the bottom of the pump intake should be set at a depth of 140 feet.

MIDDLE WELL #1

We will be glad to discuss the results of these tests you in more detail at your convenience.

Very truly yours,

FRED H. KLAER, JR. AND ASSOCIATES

Fred H. Klaer Jr.

Fred H. Klaer, Jr.
Consulting Ground-Water Geologist
and Hydrologist.

[illegible]:eh

[illegible]: Layne-Ohio Co.

South WELL HOUSE

Jefferson Twp.
Madison Co.

# THE LAYNE OHIO COMPANY

COLUMBUS, OHIO

## LOG OF TEST WELL No. 1

For Battelle Institute City West Jefferson State Ohio

Location 3000 ft. east of Georgesville Road; north of ravine

Date Started 8-4-54 Date Finished

## FORMATIONS

| DEPTH TO TOP OF STRATUM | DEPTH TO BOTTOM OF STRATUM | THICKNESS OF STRATUM | STATIC WATER LEVEL | 1-HOUR BAILING TEST | | HOW FAR DID FORMATION HEAVE | FORMATION FOUND | REMARKS |
|---|---|---|---|---|---|---|---|---|
| | | | | AVERAGE G. P. M. | DRAWDOWN FEET | | | |
| 0' | 12' | 12' | | | | | Top soil | |
| 12 | 33 | 21 | | | | | Blue clay | |
| 33 | 38 | 5 | 24'7" | | | | Dirty gravel; a little water | |
| 38 | 60 | 22 | | | | | Blue clay | |
| 60 | 68 | 8 | 24'7" | | | | Dirty gravel | |
| 68 | 88 | 20 | | | | | Red clay | |
| 88 | 99 | 11 | | | | | Gray clay | |
| 99 | 103 | 4 | 41' | 103' of 12" pipe in hole<br>1' of 12" pipe above ground | | | Gravel | |
| 103 | 106 | 3 | 41' | Pumped 250 g.p.m. at 68'6"<br>pumping level after 12 hrs. | | | Yellow limestone | |
| 106 | 111 | 5 | | | | | Gray " | |
| 111 | 115 | 4 | | | | | Limestone; layers of clay | |
| 115 | 120 | 5 | | | | | Gray limestone | |
| 120 | 130 | 10 | 41' | | | | Limestone and clay | |
| 130 | 138 | 8 | | | | | Gray limestone | |

DRILLER Toledo Rogers

S-G P-897

(SKETCH OF LOCATION ON BACK OF THIS LOG SHEET)

# THE LAYNE OHIO COMPANY

COLUMBUS, OHIO

## LOG OF ~~TEST~~ 12" WELL No. 2

For Battelle Memorial Institute City West Jefferson State Ohio

Location

Date Started 3-16-55 Date Finished 4-8-55

## FORMATIONS

| DEPTH TO TOP OF STRATUM | DEPTH TO BOTTOM OF STRATUM | THICKNESS OF STRATUM | STATIC WATER LEVEL | 1-HOUR BAILING TEST | | HOW FAR DID FORMATION HEAVE | FORMATION FOUND | REMARKS |
|---|---|---|---|---|---|---|---|---|
| | | | | AVERAGE G. P. M. | DRAWDOWN FEET | | | |
| 0' | 6' | 6' | | | | | Yellow clay | |
| 6 | 7 | 1 | | | | | Sand and gravel | |
| 7 | 32 | 25 | | | | | Blue clay | |
| 32 | 34 | 2 | | | | | Sloppy sand | |
| 34 | 80 | 46 | | | | | Clay and gravel | |
| 80 | 98 | 18 | | | | | Brown clay | |
| 98 | 102 | 4 | 20'5" | | | | Red clay and soft rock | |
| 102 | 115 | 13 | | | | | Brown limestone | |
| 115 | 118 | 3 | | | | | Brown lime and clay | |
| 118 | 119 | 1 | | | | | Break | |
| 119 | 122 | 3 | | | | | Brown limestone | |
| 122 | 123 | 1 | 18'5" | | | | Break | |
| 123 | 128 | 5 | | | | | Brown lime | |
| 128 | 130 | 2 | | | | | Blue shale | |

DRILLER Andy Ego

MATERIAL: 107' of 12" pipe (extending 1'6" above ground)

PERMANENT LOG SHOWING WELL FORMATIONS AND CONSTRUCTION AND PUMPING EQUIPMENT WILL BE PREPARED AS SOON AS PUMPING EQUIPMENT IS INSTALLED.

(SKETCH OF LOCATION ON BACK OF THIS LOG SHEET)

S-G P-897

**Customer: Seal only when using a FedEx Ship or interNetShip document.**

39

100

**FedEx** Express *US Airbill*

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8488001296 73 FedEx Tracking Number

Date Feb 14,05

Sender's Name [illegible] Phone [illegible]14 [illegible]79-6941

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Address [illegible] Dept/Floor/Suite/Room

City [illegible] JEFFERSON State [illegible] ZIP 4 162

**2 Your Internal Billing Reference** BMI Individual Basis

**3 To**

Recipient's Name Dr. Mike M[illegible] Phone

Company U.S. NRC Region III

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☐ FedEx Express Saver Third business day*
FedEx Envelope rate not available. Minimum charge: One-pound rate

*Packages over 150 lbs.*

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☐ FedEx 2Day Freight Second business day**
☐ FedEx 3Day Freight Third business day**
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* Declared value limit $500

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☑ FedEx Pak* Includes FedEx Small Pak, FedEx Large Pak, and FedEx Sturdy Pak
FedEx Box
☐ FedEx Tube
☐ Other

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☐ HOLD Saturday at FedEx Location Available ONLY for FedEx Priority Overnight and FedEx 2Day to select locations

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☐ Yes As per attached Shipper's Declaration
☐ Yes Shipper's Declaration not required
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Cargo Aircraft Only

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☒ Sender Acct. No. in Section 1 will be billed
☐ Recipient
Third Party
Credit Card
☐ Cash/Check

[redacted]

Total Packages Total Weight Total Charges

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Credit Card Auth.

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