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SITE CHARACTERIZATION OF THE WASTE STORAGE AREAS
PART 2, VOLUME 1: SUPPORT DOCUMENTATION
AUGUST 1986

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Department of Energy Feed Materials Production Center

Fernald, Ohio

Site Characterization Of The Waste Storage Areas

Part 2, Volume 1:
Support Documentation

For: Westinghouse
Materials Company
Of Ohio

Prepared By:
Roy F. Weston, Inc.

August 1986

Section 1

SITE CHARACTERIZATION OF THE WASTE STORAGE AREAS

PART 2, VOLUME I: SUPPORT DOCUMENTATION

DEPARTMENT OF ENERGY
FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO

FOR: WESTINGHOUSE MATERIALS COMPANY OF OHIO

Prepared by:

ROY F. WESTON, INC.

August 1986

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INTRODUCTION

Westinghouse Materials Company of Ohio (WMCO) operating under its prime contract with the United States Department of Energy (DOE), coordinates activities, including waste management, at the Feed Materials Production Center (FMPC), Fernald, Ohio. WMCO is administratively responsible to the Oak Ridge Operations Office of the DOE. Waste management activities are funded and directed by the DOE Office of Defense Waste and By-Product Management.

As part of the comprehensive waste management and environmental program for the FMPC, specific alternatives are being developed and evaluated for the final disposition of low-level radioactive waste inventory currently stored at the site. The Waste Storage Areas under evaluation in this program consist of six storage pits, the clear well, the burn pit, three concrete silos, two fly-ash piles, and adjoining areas.

This program is being implemented in two phases. Phase I will include site characterization, consisting of assessment of existing data and reports, development of a detailed work plan, performance of field investigations, data interpretation and analysis and final reporting. Phase II will include the development of remedial alternatives, initial screening of alternatives, detailed analysis of options, ranking of alternatives, and final reporting.

Part 2, Support Documentation, contains nine sections which in their entirety form the planning basis for site characterization activities at the Waste Storage Area. (A separate volume will contain the plans for sampling the K-65 silos). Their intent is to fully document the why, what, where, and how of the investigations to be performed at FMPC. Sections 2 through 5 comprise the environmental sampling plans which present the rationale and procedures to be used in the field. The chemical and radiological characteristics of the wastes will be defined, as well as any contamination which may have migrated into the various environmental pathways. Section 6 presents the Health and Safety Plan, the implementation of which will ensure that the studies will be conducted in a manner which will ensure worker and public protection. The QA/QC Plan, contained in Section 7.0 is intended to assure and control the proper collection of data. Section 8.0 presents the series of activities and methods which will be used to keep the public informed as these studies progress. The Data Management Plan, in Section 9.0, describes how the data is to be reviewed, collected, stored, analyzed, and reported.

Section 2

SECTION 2

RADIOLOGICAL AND CHEMICAL SAMPLING PLAN FOR THE CHARACTERIZATION OF THE WASTE STORAGE AREA AT THE FEED MATERIALS PRODUCTION CENTER

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RADIOLOGICAL AND CHEMICAL SAMPLING PLAN
FOR THE CHARACTERIZATION OF THE WASTE STORAGE AREA
AT THE FEED MATERIALS PRODUCTION CENTER

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SECTION 2

2.0 RADIOLOGICAL AND CHEMICAL SAMPLING PLAN

2.1 BACKGROUND

The FMPC is located in a rural area of southwestern Ohio approximately ten miles northwest of Cincinnati and eight miles southwest of Hamilton. The site occupies 1,050 acres and is bounded by highway 126 to the north, a transmission line to the east, Willey Road to the south, and Paddy's Run Road and the Ohio and Chesapeake Railroad to the west (Figure 2.1).

The primary work at the FMPC was the production of metallic uranium fuel elements, target cores and other uranium compounds for use at DOE facilities. The initial processing began with ore concentrates, recycled uranium or miscellaneous other uranium compounds. The mill concentrates were digested with nitric acid and this solution was then extracted with tributyl phosphate in a kerosine carrier. This organic extract of uranyl nitrate was stripped with water. The purified aqueous solution was further concentrated by evaporation and was finally denitrated by heating to produce uranium trioxide, UO_3. Conversion of this product to the green salt, UF_4, was accomplished by hydrogen reduction to produce UO_2, followed by hydrofluorination with anhydrous HF. Uranium metals were produced from UF_4 by direct reduction with magnesium.

This process generated a variety of waste types. These included depleted MgF_2 slag, slag leach filter cake, various raffinate solutions, depleted sump cake, general sump sludges, and dust collector residues. Since 1952 when the production operations were initiated, these low-level radioactive wastes have been stored at a designated storage area west of the FMPC Production Area.

The FMPC Waste Storage Area utilized two types of facilities for the long-term storage of these low-level radioactive wastes. These included four above ground silos and six in-ground waste storage pits. Other waste storage areas on site include a burn pit, the clear well and two fly ash disposal areas. All of these facilities are presented in Figure 2.1.

The six in-ground waste pits were constructed principally for disposal of depleted magnesium fluoride slag, slag leach filter cake, neutralized raffinate, depleted sump cake, sump sludges,

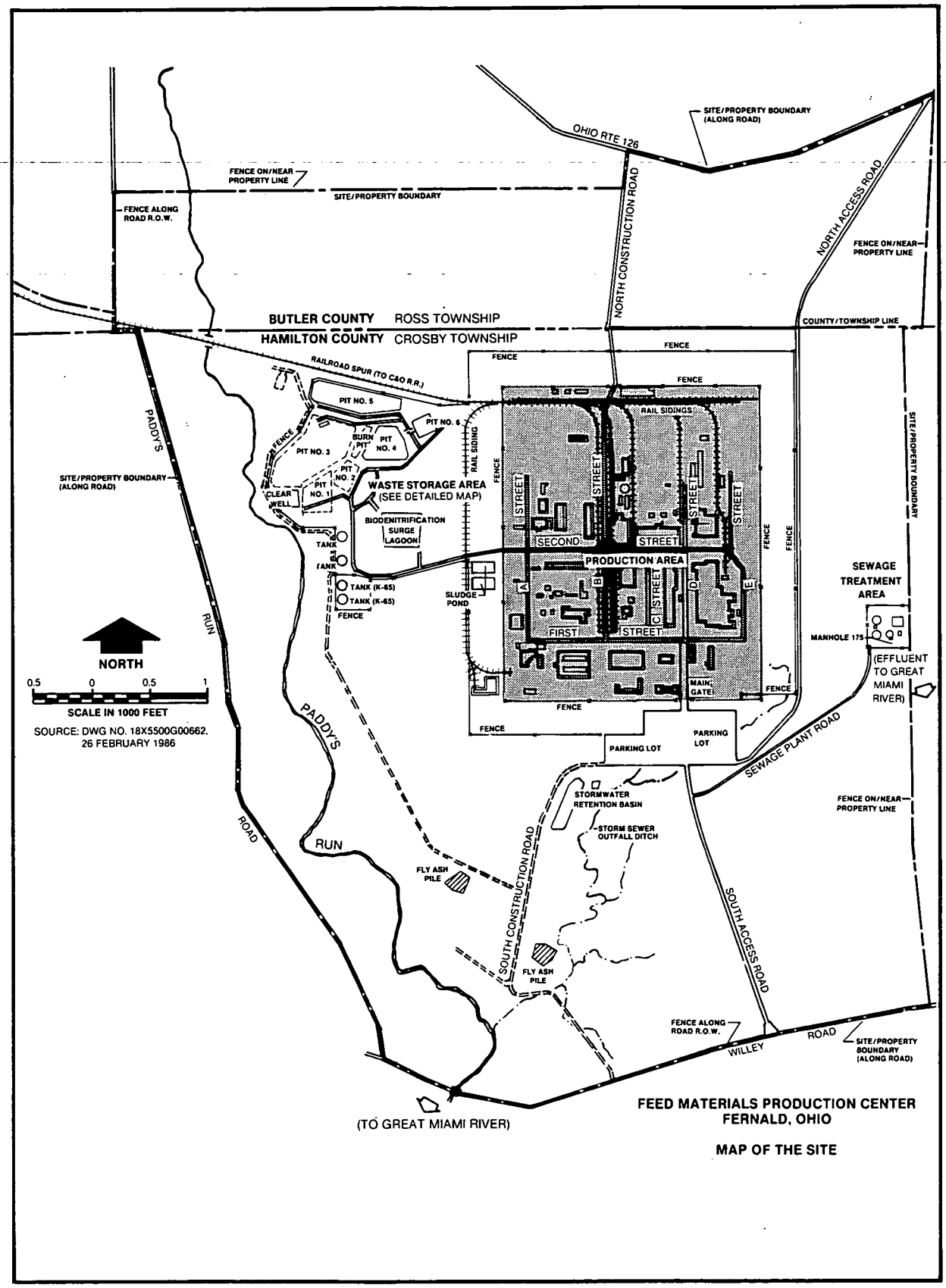

FIGURE 2-1 MAP OF THE SITE
FEED MATERIALS PRODUCTION CENTER, FERNALD, OHIO

and dust collection residues. In addition, miscellaneous construction wastes (brick, graphite, concrete, asbestos, etc.) were disposed of into Pits 2 and 4.

The four concrete waste storage silos were constructed in 1952. Silos 1 and 2 were utilized to dispose of K-65, an acronym describing the radium bearing raffinate wastes produced from the processing of pitchblende. Silo 3 was used to dispose of dry residues from the dewatering of waste raffinate slurries.

The burn pit was constructed in 1957 and was used to incinerate laboratory chemicals and various other wastes. Although actual contents are unknown, items burned include pyrophoric and reactive chemicals, oils, and contaminated combustibles. The burn pit apparently was backfilled and is now overgrown with native grasses.

The clear well was built in 1959 primarily to collect clear process supernate from the waste pits. Surface runoff from the waste pits also collects in the clear well. Its purpose is to provide final settling prior to transport to the on-site sewage treatment plant.

The fly ash disposal areas are located south of the production facility. Fly ash from the FMPC coal fired power plant continues to be deposited into the lower fly ash area. Dumping into the upper fly ash pile has been discontinued.

The sanitary landfill was used to dispose of uncontaminated nonburnable material. This included such waste as cafeteria scrap, asbestos, and miscellaneous construction rubble. Dumping into the landfill has been discontinued.

The lime sludge ponds received residue from the waste water treatment facility. The southern pond is completely full with no standing water present. The northern pond is filled with water.

2.2 OBJECTIVES

A site characterization of the Feed Materials Production Center's (FMPC) Waste Storage Area and associated drainage paths is being conducted to characterize the nature and extent of radiological and chemical components in soils, waste, ground water and surface water and its threat to human health and the environment. The information collected during the characterization will be used to identify, evaluate and select the most environmentally acceptable disposal alternative.

The work objectives of this Plan are designed to:

- Characterize the type and quantity of potentially hazardous radioactive and chemical waste materials in the FMPC Waste storage area.
- Estimate radiological and chemical constituent migration in order to support risk assessment studies.
- Determine the present lateral and vertical extent of radiological and chemical constituents.
- Provide input for the development and validation of site modeling.

The Sampling Plan for the FMPC Waste Storage Area and surrounding locations presents sampling procedures and analytical requirements needed for performing the remedial investigation. The following field activities are addressed in this plan:

- Logistics
- Field Radiation Measurements
- Surface Soil Sampling Protocol
- Subsurface Soil Sampling Protocol
- Surface Sediment Sampling Protocol
- Surface Water Sampling Protocol
- Radon Flux Measurements
- Air Quality Sampling Protocol
- Flora and Fauna Sampling Protocol

A separate sampling plan will be developed for obtaining samples from the three silos in the Waste Storage Area. Obtaining samples from the silos will require considerable engineering effort to maintain adequate health and safety precautions for the workers.

For each field activity listed above, this plan will address the following topics:

- Sampling Frequency
- Sampling Locations
- Sampling Methodology
- Sample Containers and Preservatives
- Sample Identification and Numbering
- Field Laboratory Analyses
- Outside Laboratory Analyses

2.3 LOGISTICS

During the course of the radiological and chemical field operations, major emphasis will be placed on the Waste Storage Area and drainage paths that discharge into Paddy's Run and the Great Miami River. Access to these areas for personnel and equipment will be coordinated with Westinghouse Operations Staff. WESTON'S Project Manager will provide logistical information to Westinghouse on a weekly basis or more frequently as circumstances warrant.

A location near the Waste Storage Area has been identified for placement of a logistics support facility. The Logistics Support Map (Figure 2.2) shows the locations of three trailers to be used for field support. The trailer housing the field office (trailer-1) is located adjacent to the gate on the west perimeter security fence. This trailer will be utilized as a staging area for access control and storage of sampling equipment and containers, radiation survey instruments, and chemical screening instruments. This trailer will also contain a showering facility for the unlikely event of personnel decontamination. The effluent from this shower will be contained for proper disposal.

A second trailer (trailer-2) will be located in an elevated level area about 125 feet west of the field office. This will be utilized as the field laboratory. At this location, soil and sediment samples will be dried, prepared and analyzed for specific radionuclides. In addition, the field laboratory will be used for preliminary processing and preparation of soil, sediment and water samples for off-site shipment.

A third trailer (trailer-3) will be located immediately south of trailer-2. This will be utilized for additional field offices, a lunchroom and as a conference/work-staging area.

These locations were chosen for logistics support operations because of their proximity to the access gate and the Waste Storage Area, the near background exposure rates, the parking space, and the availability of electrical power.

A mutually agreeable location in the logistics support area will be identified for the placement of portable toilets for use by the field staff. These shall be implemented per 29 CFR 1926.51

Northeast of Pit 4 is a concrete pad that has an adjacent all weather fire hydrant. This area will be used to decontaminate equipment such as auger bits, split spoon samplers, drill rigs, and other sampling apparatus. Water from this operation will be managed as directed by Westinghouse.

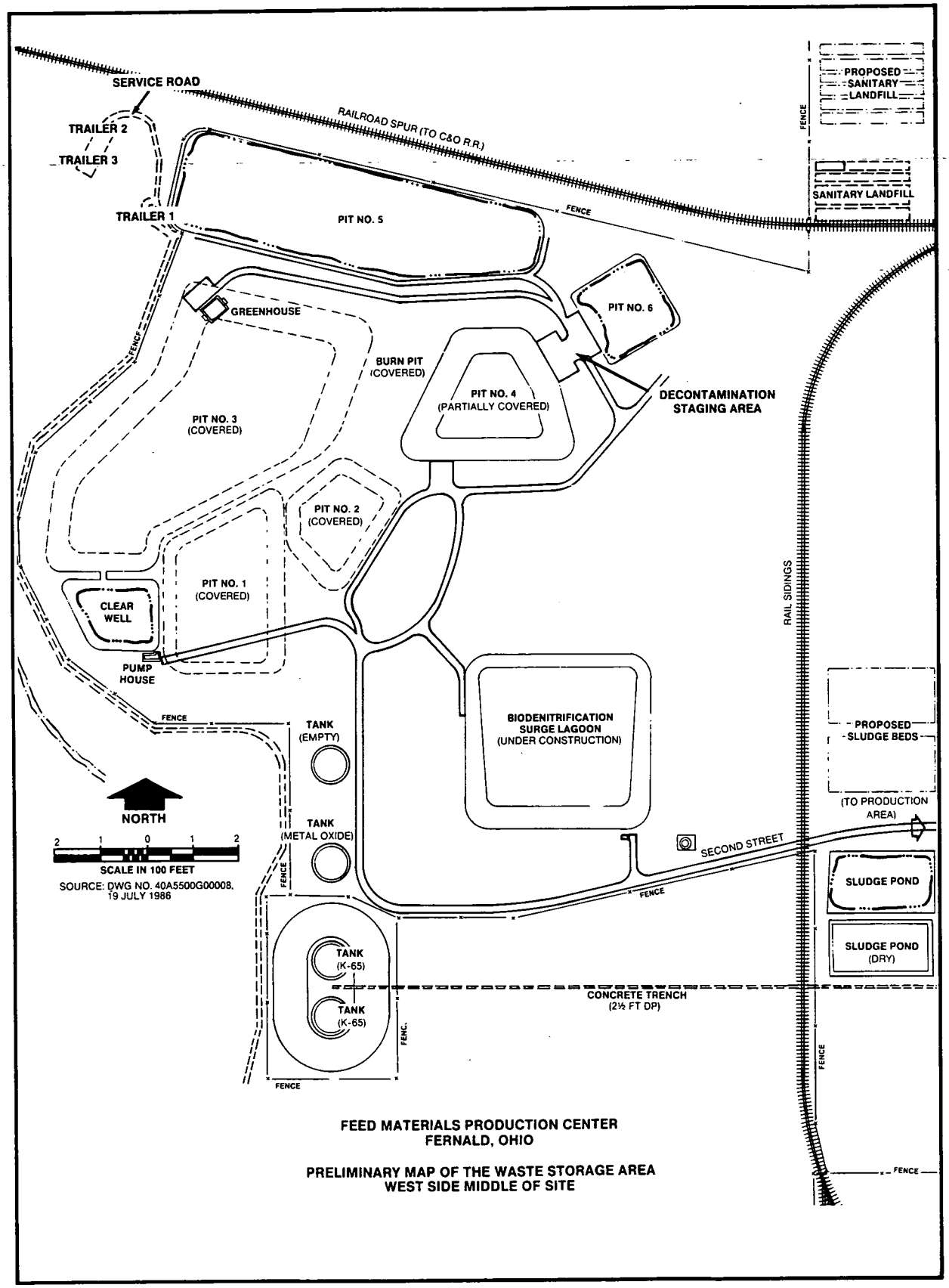

FIGURE 2-2 LOGISTICS SUPPORT MAP

2.4 SAMPLE IDENTIFICATION/NUMBERING

For each sample taken during the course of the field investigation, a coding system will be used to identify various information concerning each sample. This identification includes:

- Project identification - FMP will be used to designate the Feed Materials Production Center.

- Sample or measurement type and location - a two letter designation following the project identification code.

The sample types and corresponding codes for this investigation consist of the following:

SS - Surface Soil Samples

SW - Surface Water Samples

SD - Surface Sediment Samples

SL - Subsurface Samples

GW - Groundwater Observation Well Samples

AR - Air Samples

MW - Existing Monitoring Wells

RF - Radon Flux Measurements

RM - Radiation Measurement

A two digit designation indicating the sample location will be used following the sample type code. These two digit designations are presented in Table 2.1.

- Sample number - a three digit code will be used to consecutively number samples taken for each sample type.

For example FMP-SW02-001 designates the Feed Materials Production Center, the first surface water sample taken from Pit 2.

All information pertinent to field activities including sampling must be recorded on various forms (e.g., logbooks, sample tags, photographs). Each field worker must keep detailed records of inspections, investigations, photographs taken, and thoroughly review all notes before leaving the site. Appendix A details sample document control and provides appropriate labeling techniques.

Table 2.1 Two Digit Designations for Identifying Sample/Measurement Locations

Sample/Measurement Location	Two Digit Code No.
Pit-1	01
Pit-2	02
Pit-3	03
Pit-4	04
Pit-5	05
Pit-6	06
Burn Pit	07
Clear Well	08
Periphery of Pit-1	09
Periphery of Pit-2	10
Periphery of Pit-3	11
Periphery of Pit-4	12
Periphery of Pit-5	13
Periphery of Pit-6	14
Berm of Silo-1	15
Berm of Silo-2	16
Berm of Silo-3	17
Periphery of Silos (a)	18
Storm Sewer Outfall	19
Paddy's Run	20
Drainage Swale N. of Pit 5	21
Wetlands W. of Waste Storage Area	22
Slurry Line to K-65 Silos	23
Upper Fly Ash Pile	24
Lower Fly Ash Pile	25
Drainage Swales S.E. of Waste Storage Area	(b)
Pipes (Drainage Swales) Exiting W. of Waste Storage Area	(b)
Drainage Swales in Waste Storage Area	(b)

(a) Sampling contingent upon previous sampling at each location. If contamination is found in initial sampling, the peripheral sampling will be required to assess migration.

(b) Two digit number will be identified for each drainage swale when identified in the field.

2.5 RADIATION AND EXPOSURE RATE MEASUREMENTS

This section describes the radiation measurement protocol that will be carried out at numerous locations around the FMPC Waste Storage Area and associated drainages.

2.5.1 Radiation Measurement Objectives

The objective of performing the various radiation measurements in the Waste Storage Area and surrounding drainages is to provide a graphic contour of the lateral extent of above background surface radiation levels. During the course of taking the measurements, surface soil samples will be taken and analyzed for radionuclides likely to be contributing to instrument readings correlating to uranium concentrations at or above 35 pCi/g. The data generated from the surface soil analyses will be used to identify the lateral extent of surface soil radionuclide concentrations. This information will also provide WESTON with locations where subsurface or vertical profiles of radionuclide concentrations need to be evaluated. In addition, the surface radiation measurements will provide an initial data base for the evaluation of potential surface migration of radionuclides away from the various storage areas.

2.5.2 Radiation Measurement Frequency

Characterizing the beta and gamma radiation levels will be the first field activity to be carried out during the WESTON scope of work. As data are generated and analyzed, it may be necessary to expand the planned measurement protocol in order to better define the boundary of above background radiation levels.

2.5.3 Measurement Location

Tentative locations for making radiation measurements are depicted on Figure 2.3. The locations where this field work will be conducted are discussed below.

1) Waste Storage Area

A grid system comprised of mutually perpendicular lines spaced at 100 foot intervals will be surveyed and staked across and adjacent to the Waste Storage Area. Measurements using a Field Instrument for Detecting Low Energy Radiation (FIDLER) and a portable Geiger Meuller (GM) detection system will be performed at 50 foot intervals within the grid system. A gamma-ray scan of each grid block (with the FIDLER) will be performed in order to identify uranium

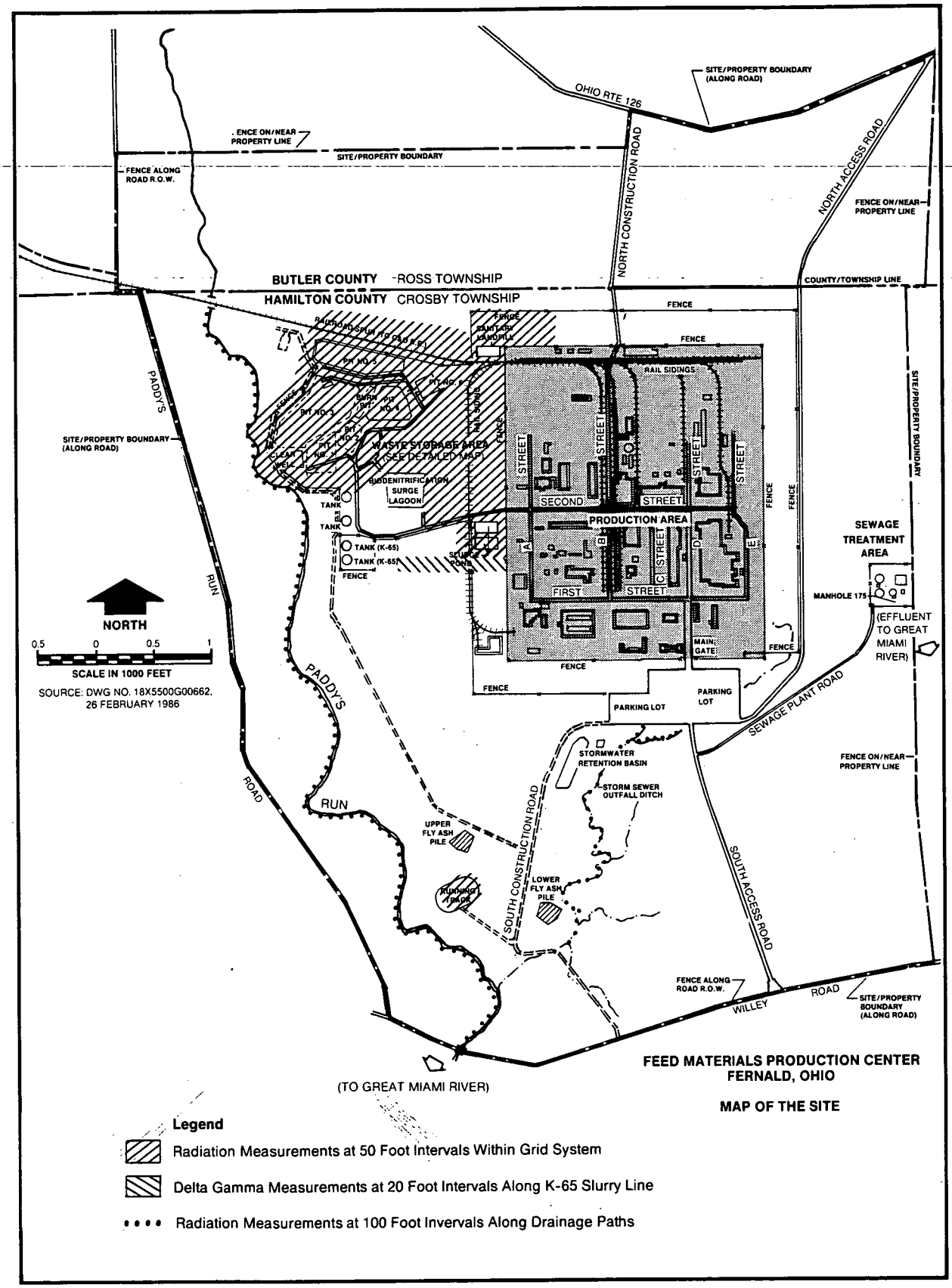

FIGURE 2-3 RADIATION MEASUREMENT LOCATIONS

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concentrations at or above 35 pCi/g. If found, additional measurements using the FIDLER and the portable Geiger Meuller (GM) detector will be taken in order to define the lateral extent of the beta and gamma radiation levels. Surface soil samples (described in Section 2.6) will be taken for field laboratory analysis to identify the types and concentrations of contributing radionuclides. Each area will be mapped and surveyed. It is estimated that measurements will be taken at 900 locations.

Twenty-five gamma ray exposure rate measurements will be taken using a Pressurized Ion Chamber (PIC) in and around the Waste Storage Area. Each measurement will be made at a location chosen by the Field Coordinator. At each of these locations, measurements with a gamma-ray survey meter will be made in order to develop area specific correlations (based on PIC measurements) required to evaluate the exposure rate form the meter reading on the survey instrument. These correlations must be made on an area specific basis due to the energy dependent nature of the instrument. An additional 100 measurements will be taken at various locations in and around the Waste Storage Area using this portable survey meter. The data generated from these exposure rate measurements will provide WESTON Health and Safety personnel the information required to evaluate and plan work activities in order to keep exposure to a minimum.

2) Sanitary Landfill

The grid system described above will be extended to encompass the inactive sanitary landfill. Beta and gamma- ray measurements will be performed at 50 foot intervals within the grid system. It is estimated that measurements will be taken at 100 locations. A FIDLER scan of each grid block will be performed in order to identify uranium concentration at or above 35 pCi/g. If such areas are observed, they will be further evaluated as described in 1) above.

3) Lime Sludge Ponds

The grid system will be extended to the southeast in order to encompass the peripheral area around the northern Lime Sludge Pond and the surface of the southern Lime Sludge Pond. Beta and gamma-ray measurements will be performed at 50 foot intervals within the grid system. It is estimated that measurements will be taken at 70 locations. A FIDLER scan of each grid block will be performed in order to identify uranium concentrations at or above 35 pCi/g. If such areas are observed, they will be further evaluated as discussed in 1) above.

4) Storm Sewer Outfall

An identifying landmark located at the storm sewer outfall release point shall be identified, surveyed into the work grid system, and staked. From this landmark, the field survey team will measure and stake the storm sewer at 100 foot intervals. At each 100 foot interval, FIDLER and GM measurements will be made on alternate sides of the streambed. It is estimated that measurements shall be recorded at 33 locations. Between each measurement interval along the storm sewer, a scan using the FIDLER will be carried out in order to detect uranium concentrations at or above 35 pCi/g. If such areas are observed, they will be further evaluated as discussed in 1) above.

5) Paddy's Run

An upstream background location shall be identified in the field. This shall be staked for future reference. FIDLER and GM measurements will be performed at this location.

An identifying landmark directly upstream of the Waste Storage Area shall be surveyed into the existing grid system and staked for future reference. Downstream to the site boundary at Willey Road, the field site team shall measure and stake at 100 foot intervals. At each 100 foot interval, FIDLER and GM measurements will be made on alternate sides of the flowing stream. It is estimated that measurements will be taken at 82 locations. Between each measurement interval along Paddy's Run, a gamma-ray scan using the FIDLER will be carried out in areas not covered by water in order to detect uranium concentrations at or above 35 pCi/g. If such areas are observed, they will be further evaluated as discussed in 1) above.

6) Two Drainage Paths Southwest of Waste Storage Area

Two drainage paths, southwest of the Waste Storage Area, each flowing into Paddy's Run, have been identified. At both drainages, an identifying landmark near the Production Center shall be identified, surveyed into the work grid system, and staked. From these landmarks, the sampling team shall measure and stake 100 foot intervals. At each 100 foot interval, FIDLER and GM measurements shall be recorded. It is estimated that measurements will be recorded at 30 locations. Gamma-ray scans using the FIDLER will be performed between measurement locations, and characterization of locations having instrument readings correlating to uranium levels at or above 35 pCi/g shall be performed as discussed in 1) above.

7) Pipes Exiting West Perimeter of Waste Storage Area/Wetlands

These drainage points were observed during the site visit. One is located in a storm drain below the clear well, the other exits west of Pit 3, and is located near the gate below the evaporation greenhouse. These drainages flow a short distance into a low lying area called the wetlands. FIDLER and GM measurements will be taken at the discharge points out of the Waste Storage Area and will continue every twenty feet into the wetlands. Each measurement location will be surveyed and staked. In the wetlands area, a 50-foot grid will be established. FIDLER and GM measurements will be taken at each grid point. It is estimated that 75 measurements will be taken at these locations. A FIDLER scan of individual grid blocks and drainage areas will be performed in order to identify uranium concentrations at or above 35 pCi/g. If found, these areas shall be characterized as discussed in 1) above.

8) Drainages North of Pit 5

These drainages flow east to west and lie just north of Pit 5. One flows between the berm of the railroad and the berm of Pit 5, the other flows just north of the railroad track. An identifying landmark upstream of each drainage will be identified, surveyed into the grid system and marked. From this landmark, the sampling team will measure 100 foot intervals. At each 100 foot interval, FIDLER and GM measurements shall be recorded. It is estimated that measurements will be recorded at 40 locations. Gamma-ray scans using the FIDLER will be performed between measurement locations, and characterization of locations having uranium concentrations at or above 35 pCi/g will be performed as discussed in 1) above.

9) Drainages and Seeps in Waste Storage Area

The field team shall identify all drainages and seeps in the Waste Storage Area. The team coordinator will identify an initial starting point at each drainage in which to start taking radiation measurements. These locations shall be surveyed into the work grid system and staked for future reference. From each starting point, the Field team will measure 50 foot intervals along each drainage path. At each interval, FIDLER and GM measurements will be made on alternate sides of the stream. It is estimated that measurements will be made at 40 locations. Between each measurement interval, a gamma-ray scan using the FIDLER will be carried out in areas not covered with water in order to detect

uranium concentrations at or above 35 pCi/g. If such areas are observed, they will be further evaluated as discussed in 1) above.

10) Fly Ash Piles

The upper and lower fly ash piles will be surveyed and mapped to ascertain the lateral extent of material. A 50 foot grid will be established within the observed boundary of each pile, and radiation measurements using the FIDLER and GM will be recorded at each grid point. It is estimated that 30 measurements will be taken on the upper fly ash pile and 45 measurements will be taken on the lower fly ash pile. FIDLER scans of individual grid blocks will be carried out to detect surface uranium concentrations at or above 35 pCi/g. If found these areas will be characterized as discussed in 1) above.

During the site visit, it was observed that there is significant migration of fly ash material from runoff downslope of both piles. Measurements will be taken in these runoff areas as determined by the Field Coordinator. Concentrations at or above 35 pCi/g will be mapped and further evaluated as described in 1) above.

11) Running Track

The running track and adjacent areas will be surveyed and a 50 foot grid will be established within this low-lying area. FIDLER and GM measurements will be recorded at each grid point. It is estimated that 75 measurements will be taken in this area. FIDLER scans of each grid block will be carried out to identify uranium concentrations at or above 35 pCi/g. If such areas are observed, they will be characterized as described in 1) above.

12) Slurry Line to K-65 Silos

This line was installed in a concrete trench leading from the production area to the silos. It will be surveyed and staked at 20 foot intervals starting at the Production Area fence and extending to the berm surrounding the silos. Delta-Gamma measurements will be taken at each of the estimated 25 locations. These measurements will be taken because the gamma radiation level along this slurry line can be expected to increase significantly as one approaches Silos 1 and 2, thus preventing bare probe measurements to be taken.

13) Background Locations

Locations in which to evaluate background radiation levels using the instrumentation proposed in this characterization will be chosen based on data presented in the EG&G aerial survey. This EG&G data provides the gamma-ray exposure rate contours developed from aerial gamma-ray measurement techniques. WESTON and its subcontractors will choose background locations at distances where there is no influence from FMPC operations.

2.5.4 Radiation Measurement Methodology

The radiation measurement protocol for the characterization effort will include:

- Near-surface delta measurements of gamma rays at uniformly spaced points along the slurry line to the K-65 silos.
- Surface measurements of low energy photons (from uranium deposits) using a Field Instrument for Detecting Low Energy Radiation (FIDLER) at uniformly spaced points on the site grid and at measurement intervals along each drainage swale.
- Scan for low energy photons using the FIDLER within major site grid blocks and between measurement intervals on each drainage swale.
- Surface measurements of beta-gamma dose rates using a portable Geiger-Mueller (GM) detector at uniformily-spaced points on the grid and at locations identified as having uranium concentrations at or above 35 pCi/g.
- Gamma-ray exposure rate measurements using a Pressurized Ion Chamber (PIC) and a portable scintillometer.

A general description of each of these measurement procedures to be used during the FMPC characterization are presented below. Specific details of these measurement techniques as well as procedures for documenting field readings are presented in Appendix B.

1) Gamma-Ray Measurements For In-Situ Gamma Radionuclide Analysis

At locations where air scattered gamma radiation from the storage silos prevents bare probe readings to be taken, the measurement of gamma-ray emitting radionuclides in soils

will be made using an Eberline SPA-3 scintillation detector and a differential measurement technique, herein referred to as a delta-gamma measurement. Two readings will be taken for each measurement, one without a filter and one with a half-inch lead filter between the detector and the soil surface. The difference between the two readings is proportional to the gamma radiation emitted from a sample volume directly beneath the detector. In this way, interference from adjacent sources of radiation is minimized.

2) Field Instrument for Detecting Low Energy Radiation (FIDLER)

Measurements with a FIDLER will be used at all grid intersections and measurement intervals discussed in Section 2.5.3 to estimate uranium concentrations from the sample location. The FIDLER probe will be coupled to a portable ratemeter/scaler (Eberline PRS-1 or ESP-1). Counts will be accumulated at each grid intersection for one minute with the probe at the ground surface.

The FIDLER will also be used to scan all individual grid blocks and to scan between measurement intervals on all drainage swales. This technique will be used to identify the lateral extent of areas having uranium concentrations at or above 35 pCi/g.

3) Thin Window GM Detector

Measurements of the beta-gamma dose rate will be made at all grid intersections and measurement intervals discussed in Section 2.5.3. These measurements will be taken at the ground surface using an Eberline HP-210T probe coupled to a portable ratemeter/scaler (Eberline PRS-1 or ESP-1). Counts will be accumulated for one minute with the probe at the ground surface. While these measurements provide no direct correlation to radionuclide concentrations in soil, they will provide supplemental radiation data to verify the presence of anomalous radiation as determined during the low-energy photon surveys using the FIDLER.

4) Pressurized Ionization Chamber (PIC) and Scintillation Measurements

These measurements will be used to determine the gamma-ray exposure rate at various areas across the site. The PIC shall be placed at specific grid points one meter above the surface and set for a 90 second evaluation time. The average exposure rate for that time interval shall be displayed in microR/hr.

The PIC is not a portable instrument due to its size and weight. In order to provide a lighter, more portable method of assessing exposure rates, various PIC measurements will be correlated with measurements at the same location using an Eberline SPA-3 scintillation detector. The resulting area specific correlations will permit the estimation of exposure rates using these portable instruments.

2.5.5 Instrumentation for Investigation

Table 2.2 lists each instrument type and associated readout. Also listed are the measurement type, calibration frequency, and response check frequency. Site-specific calibrations will be conducted by taking soil samples and performing regression analysis to develop a correlation between instrument reading and uranium soil concentrations.

Table 2.2 Instrumentation for Radiological Investigation

Type Detector	Type Readout	Type Measurement	Calibration Frequency	Response Check Frequency[1]
Thin window G-M probe, Eberline HP-210T	Portable rate-meter/scaler, Eberline PRS-1 or ESP-1	Beta-gamma dose rate at surface	Quarterly	Start of day and at hourly intervals
NaI probe (2 in. x 2 in.) Eberline SPA-3	Portable rate-meter/scaler, Eberline PRS-1 or ESP-1	Near-surface del ta gamma radia-tion measurements and gamma-ray exposure rate	Quarterly	Start of day and at hourly intervals
Thin NaI probe, 5 in. diameter, FIDLER	Portable rate-meter/scaler, Eberline PRS-1 or ESP-1	Surface measure-ments of uranium concentration and sample screening	Quarterly	Start of day and at hourly intervals
Pressurized ionization chamber (PIC), Reuter-Stokes RSS-III	Retuer Stokes electrometer	Gamma-ray expos-sure rate (also used to correlate SPA-3 NaI probe on-site)	Annual at manufac-turer's plant	Start of day and at hourly intervals

1) Using sealed radioactive check source

2.5.6 Measurement Identification and Numbering

All measurement locations and associated measurement numbers shall be identified using the code described in Section 2.4.

2.5.7 Deliverables

The following deliverables will be provided by WESTON:

- Results of field analyses
- Contours developed by a computer graphics package.
- Memorandum describing field activities including documentation of measurements taken.

2.6 SURFACE SOIL SAMPLING

This section describes the surface soil sampling protocol that will be carried out in conjunction with taking radiation measurements. This sampling will be carried out at numerous locations within and around the various FMPC Waste Storage Areas. Surface sediment sampling of the drainages and various runoff areas is presented in Section 2.8.

2.6.1 Surface Soil Sampling Objectives

The objective of sampling surface soils during the radiation measurement protocol is to identify the radionuclides contributing to above background radiation levels. The analysis of surface soils will provide additional data for the evaluation of potential surface migration of radionuclides away from the various storage areas. These data will be used in demarcating the geographic boundaries of radioactive materials, and locating areas where uranium concentrations are at or above 35 pCi/g. Such information is necessary for developing engineering plans for cleanup.

The objective of sampling surface soils for chemical analyses is to determine the presence and vertical extent of chemical species migrating from the soil covers on Pits 1, 2, 3 and 4, and the Burn Pit. The sampling will occur in two stages. The first stage will be to sample at various areas over a pit cover. These are considered the most likely areas for identifying chemical constituents that may be leaching out of the pit to the ground surface. If laboratory analyses are positive for any of these samples, then additional sampling will be performed off of the pit cover in areas of likely migration. The analyses for this second stage of sampling will be performed in order to identify any of the constituents found in the initial sampling.

2.6.2 Sampling Frequency

Because of the age of the Waste Storage Area and the absence of construction or remedial activities, it should not be necessary to collect multiple or periodic samples of surface soil.

2.6.3 Sampling Locations

Surface soil samples will be collected at each grid intersection within the Waste Storage Area, wetlands, fly-ash piles and running track area where radiation levels correlate to uranium concentrations at or above 35 pCi/g. Additional surface soil samples will be taken at locations having uranium concentrations

at or above 35 pCi/g as identified during the FIDLER scan. It is estimated that 500 surface soil samples will be taken from these areas.

Surface soil samples for analysis of chemical constituents will be collected at various grid intersections located on the covers of Pits 1, 2, 4 and the Burn Pit. It is estimated that 40 samples (10 per pit) will be collected on Pits 1, 2, 4 and the Burn Pit, and 20 samples will be collected on Pit 3. Sample locations will be spread out to encompass the entire surface of the Pit. Any anomalous area (i.e. loss of vegetation, seeps, or stained soil where obvious leaching is occurring) shall be sampled, surveyed and staked.

Particular attention will be placed on delta-gamma measurements during the survey of the slurry line from the production center to the K-65 silos. Surface delta-gamma measurements above background plus three standard deviations will require taking a surface soil sample. It is estimated that 9 surface soil samples will be taken.

Ten surface soil samples will be taken from background locations identified from EG&G aerial survey data. These samples will be used to develop a baseline for comparison of samples to background, and to evaluate the background gross alpha count rate for use in screening samples for alpha emitting radionuclides as described in Appendix C.

2.6.4. Sampling Methodology

The surface soil sampling for radionuclide analysis will initially require taking a surface to 6 inch soil sample. Each sample will be taken using methods described in GJ/TMC-13 UC-70, Procedures For Sampling Radium-Contaminated Soils, 1985. Care will be taken to obtain an even cross-section of the entire depth being sampled. These shall be transferred to the field laboratory for screening of radiological parameters. If radionuclide concentrations are high (i.e. uranium greater than 35 pCi/g) as assessed during the screening, additional sampling at that location in deeper increments will be required as directed by the WESTON Site Manager. This will require the field team to take the appropriate instrument (the delta-gamma instrument for the K-65 slurry line or the FIDLER at all other locations) and take measurements in the initial six inch sample hole. After these are recorded, a six to twelve inch soil sample will be taken. Radiation measurements will be taken at this twelve-inch depth and recorded. If radiation levels correlating to uranium concentrations at or above 35 pCi/g are detected, then a twelve to eighteen inch soil sample will be taken. Radiation measurements will then be taken

eighteen inches, if similar radiation levels are detected, boreholes shall be drilled, sampled and downhole gamma spectral measurements shall be taken in order to determine the depth and concentrations of contributing radionuclides.

The surface soil sampling for chemical analysis will require taking a surface to 6-inch soil sample. Each sample will be taken using methods described in SW-846, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, U.S. Environmental Protection Agency, 1982, 2nd Ed. Care will be taken to obtain an even cross section of the entire depth being sampled.

Field equipment will be decontaminated after each use in accordance with the procedures outlined in Appendix H. Spent decontamination solution and rinse waters will be containerized and managed as directed by Westinghouse.

2.6.5 Sample Containers and Preservatives for Off-site Shipping and Storage

Table 2.3 lists the appropriate containers to be used for sample storage and shipment to off-site laboratories.

Table 2.3 Soil Sample Containers and Preservatives

Specified Analysis	Sample Container	Sample Size	Preservation	Holding Time Days	Reporting Units
HSL Volatile	Vial w/Teflon lined silicon rubber septum	40 ml	cool, 4°C	14	ug/L
HSL Base/ Neutral/Acid	Amber glass	100 g	cool, 4°C	7/40[2]	ug/Kg
HSL Pesticide/PCB	Amber glass	100 g	cool, 4°C	7/40[2]	ug/Kg
HSL Inorganic [1]	Amber glass	100 g	cool, 4°C	7/40[2]	ug/Kg
Radiological	Wide mouth plastic bottle	3207 g	None	6 mos.	Variable

[1] Does not include tin

[2] Extract within 7 days; analysis within 40 days of extraction

Packaging, marking and shipping of samples is addressed in Appendix D. Chain of Custody should accompany the samples at all times to document sample transfer from field to the laboratory. Laboratory personnel must then implement procedures sufficient to maintain that the samples remain secure until analytical tests are conducted. Chain of Custody procedures are detailed in Appendix A.

2.6.6 Field Analyses and Preparation

The following procedures will be utilized for field analyses and sample preparation:

- To protect sampling and laboratory personnel from potential exposure to possible hazardous or radioactive contaminants, all samples will be decontaminated prior to packaging. After each sample is collected, sample containers will be washed on the exterior with a detergent, rinsed with tap water, and dried with paper towels. Decontamination solutions and rinse waters will be containerized and stored with the equipment decontamination solutions. These solutions will be disposed of as directed by Westinghouse.

- Identify radionuclides of interest (e.g. U238, Th232, Ra226, Cs137) using gamma spectroscopy. Procedures for the multichannel analyzer and detection system are presented in Appendix E.

- Screen the sample for low level gamma radiation using the FIDLER. The procedures for this technique are presented in Appendix F.

- Dry, homogenize, and sieve samples as required.

- Screen for gross alpha radiation using a ZnS probe coupled to a portable ratemeter/scaler. Procedures for the alpha screening technique are presented in Appendix C. Samples that show significant alpha activity in the absence of low level gamma activity as screened using the FIDLER, and absent of various higher energy gamma-ray emitters as screened using gamma spectrometry will be included for outside laboratory analysis.

- Place samples in proper storage containers.

- Package and label those samples to be shipped to an off-site laboratory for analysis. Packaging, labeling and shipping requirements are presented in Appendix D.

- Remaining samples shall be archived at a designated storage facility. All samples shall be appropriately labeled and sealed prior to transfer to this facility, and a complete inventory of archived samples will be prepared.

2.6.7 Outside Laboratory Analysis

It is estimated that 150 samples will be sent to TMA/Eberline for radioactive analyses. These samples will be chosen based on field laboratory results. An additional 60 samples will be sent to WESTON Analytical Laboratory for analysis of chemical constituents. These samples will be analyzed for Hazardous Substance List (HSL)-Inorganics, HSL-Volatiles, HSL-Semivolatiles, and HSL-Pesticide/PCB's, with an additional library search to identify targeted non-HSL constituents (listed below) and any additional non-targeted non-HSL constituents. The HSL constituents and analytical methods are presented in Appendix Q. The targeted, non-HSL constituents identified by Westinghouse include:

Dichlorodifluoromethane
Tributylphosphate
Acrolien
Acrylonitrile
bis (chloromethyl) ether
1,2 Dichloropropylene
Methyl chloride
Methyl bromide
Trichlorofluoromethane
cis 1,2 Dichloroethylene

TMA/Eberline radionuclide analyses will include:

Isotopic uranium
Isotopic thorium
Isotopic plutonium
Technetium99
Cesium137
Strontium90
Ruthenium106
Neptunium237
Gamma Spectral Analysis

An additional 15 blind duplicate samples will be sent to TMA/Eberline and six blind duplicate samples will be sent to WESTON for external quality control purposes.

2.6.8 Sample Identification and Numbering

A preprinted form label with an adhesive backing will be attached to each sample container. (See Figure 1 in Appendix A). All sampling locations and associated sample numbers shall be identified using the code described in Section 2.4. This information will be documented on the sample container label.

2.6.9 Deliverables

The following deliverables will be submitted by WESTON:

- Results of field analyses
- Results of laboratory analyses
- Copies of Field Coordinators field notes
- Completed Chain of Custody Forms

2.6.10 Contingency

Should extensive or severe radionuclide or chemical concentrations be found during the surface soil sampling protocol, additional soil samples may need to be obtained and analyzed for detailed characterization of the area.

2.7 SUBSURFACE SOIL SAMPLING

This section describes the subsurface sampling protocol that will be carried out at numerous locations with the Waste Storage Area. Subsurface sediment sampling of the various drainages is presented in Section 2.8

2.7.1 Subsurface Soil Sampling Objectives

The objective of subsurface sampling during characterization at FMPC is to obtain material from known depths in order to evaluate site characteristics, detect the presence of radionuclides and chemicals, and to evaluate the potential for vertical migration. Such information is necessary for developing engineering plans for cleanup.

2.7.2 Subsurface Sampling Locations

The following locations in the Waste Storage Area (Figure 2.4) have been tentatively defined for subsurface soil sampling. Additional subsurface samples will be obtained from the fly ash piles and along the K-65 slurry line. These may be modified based upon geophysical survey results, previous geotechnical or soil analytical data, and/or where the presence of permanent structures or underground utilities impede boring. A total of 144 boreholes are tentatively scheduled to be drilled and sampled. If not located over water, these boreholes are to be staked by the surveyor with horizontal coordinates reported within 0.5 foot, and elevation reported within 0.1 foot.

1) Waste Pits 1, 2 and 3

Pits 1, 2 and 3 were constructed similarly in that they are lined with clay to form an impenetrable barrier to protect against contaminant migration. The sampling operations will not come into contact with the clay liners. Based on background information, the maximum depths of Pits 1, 2 and 3 are 17 feet, 13 feet and 27 feet, respectively. Each of these pits were covered with an unknown volume of fill dirt and are presently overgrown with native grasses.

Five boreholes will be advanced into Pit 1, four boreholes will be advanced into Pit 2, and six boreholes will be advanced into Pit 3. In addition, two slant-drilled boreholes will be advanced under each pit in order to assess vertical migration of chemical and radiological constituents below the clay lining these pits. It is estimated that 22 peripheral boreholes will be advanced in order to characterize the lateral migration of these constituents. All borehole locations are presented on Figure 2-4.

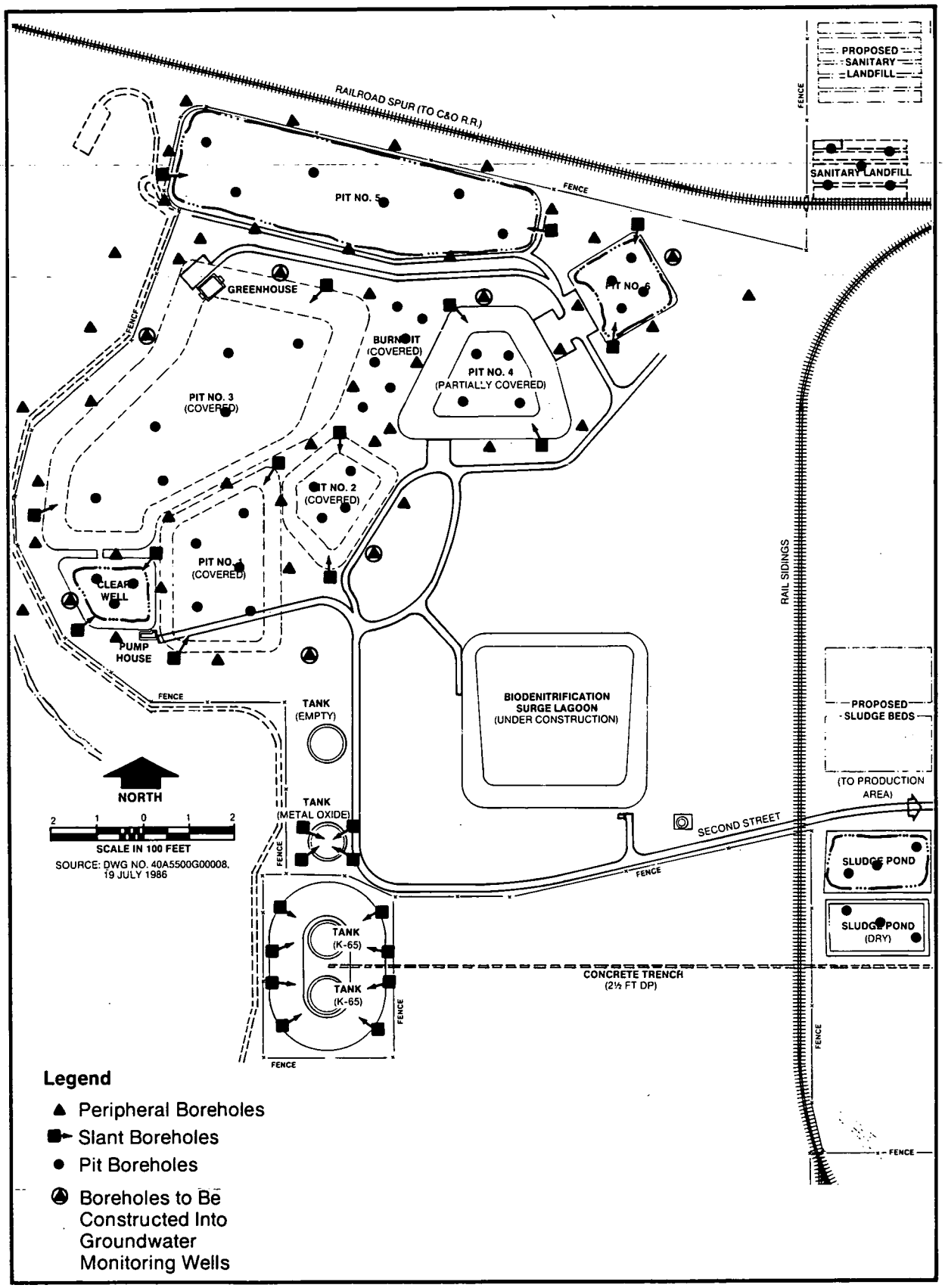

FIGURE 2-4 SUBSURFACE SOIL SAMPLING LOCATIONS IN WASTE STORAGE AREA

2) Pit 4

Observations made of Pit 4 during the site visit show that there are considerable quantities of construction rubble overlying miscellaneous waste. In addition, there is standing water located on the southwest corner of the Pit. The maximum depth of Pit 4 is 24 feet. This pit has recently been backfilled with an unknown volume of fill dirt.

Four boreholes will be drilled into Pit 4. Six boreholes will be advanced around the perimeter of this pit to evaluate for lateral migration of radiological and chemical constituents from the clay liner. In order to evaluate for vertical migration of these constituents, two slant-drilled boreholes will be advanced under the pit. All borehole locations are presented in Figure 2-4.

3) Pit 5

Pit 5 is no longer used for settling solids, but clear process effluent still flows across the pit. The pit is lined with 60 mil Royal Seal EPDM Elastometric Membrane. Limited observations made during the site visit show that the lining is in relatively good condition. The maximum depth of Pit 5 is 30 feet.

Continuous residue samples will be obtained from below the liquid/solid interface at six locations. Eleven boreholes will be advanced around the perimeter of Pit 5 to evaluate for lateral migration of radiological and chemical constituents from the liner. In order to evaluate for vertical migration of these constituents, two slant-drilled boreholes will be advanced under the pit. All borehole locations are presented on Figure 2-4.

4) Pit 6

Pit 6 is not currently being used for the dumping of solid wastes. The Pit is lined with a 60 mil EPDM Hydroseal liner. Observations made during the site visit show that the pit is filled with water. Some uncovered solid residues are present on the west side of the pit. These solid residues are not consolidated and will not support significant weight. The maximum depth of Pit 6 is 24 feet.

Continuous residue samples will be obtained from below the liquid/solid interface at four locations. Five boreholes will be advanced around the perimeter of Pit 6 to evaluate for lateral migration of radiological and chemical constituents from the liner. In order to evaluate for

vertical migration of these constituents, two slant-drilled boreholes will be advanced under the pit. All borehole locations are presented on Figure 2-4.

5) Burn Pit

Limited background information is available for the burnpit. During the site visit it was noted that this area is relatively level and has a shallow trench extending north and south through the middle. There is some water seepage in this trench. Apparently fill dirt was put over the burned material. The area is now covered with native grasses.

Six boreholes will be advanced in the burn pit to determine the presence and vertical limits of radiological and chemical constituents.

6) Sanitary Landfill

Five boreholes will be advanced into the Sanitary Landfill. These boreholes will be used to determine the presence and limits of contamination. If elevated concentrations of radionuclides or chemicals are detected, then a series of boreholes around the periphery of the landfill will be advanced to detect migration of these constituents.

7) Lime Sludge Ponds

Six core samples of the material in the Lime Sludge Ponds (three from each pond) will be obtained to determine the presence and limits of radionuclides or chemical constituents. If elevated concentrations are detected, a series of boreholes around the periphery of the ponds will be advanced to detect the lateral extent of these constituents.

8) Clear Well

Three samples of sludge from the bottom of the clear well will be obtained to determine the presence and limits of radionuclides or chemical constituents. Four boreholes will be advanced around the clear well to evaluate for lateral migration of these constituents. In order to evaluate for vertical migration, two slant-drilled boreholes will be advanced under the clear well. These borehole locations are presented in Figure 2-4.

9) Fly Ash Piles

Fly ash from the steam plant has been piled in two distinct areas. These will be identified as the upper and lower fly ash piles as depicted on Figure 2.1.

Five boreholes will be advanced into the lower fly ash pile and five boreholes will be advanced into the upper pile. These boreholes will be used to determine the presence of any radiological and chemical constituents.

10) Silos 1, 2 and 3

Four boreholes will be slant drilled beneath each silo to document the presence and limits of radiological constituents. If detected, additional borings will need to be advanced in order to determine the lateral extent of this material.

11) Slurry Line to K65 Silos

Ten boreholes will be advanced along the slurry line at anomalous locations found during the radiation measurement/surface soil sampling protocol These will be used to assess the presence and vertical limits of radiological constituents.

12) Storm Sewer Outfall Discharge

One borehole will be advanced into the sediment immediately downstream of where the storm sewer outfall discharges into Paddy' Run. This borehole will be used to determine the presence and vertical extent of radiological and chemical constituents.

13) Paddy's Run

One borehole will be advanced just upstream of Pit 3. A second borehole will be advanced immediately downstream of the clear well. These boreholes will be used to identify the presence and vertical extent of radiological and chemical constituents migrating from the Waste Storage Area.

2.7.3 Subsurface Sampling Methodology

The following items must be accounted for during the subsurface sampling scope of work.

- Prior to drilling, techniques that screen for submersed objects below the drilling location shall be initiated.

- During the waste pits drilling/sampling program, the auger lead space in all boreholes will be monitored with a portable Organic Vapor Analyzer (OVA).

- During the drilling contract work, work area air sampling for radon, radioactive particles, asbestos and chemical contaminants will be performed. Section 2.13 details the procedures for work area air sampling.

- All boreholes drilled into a solid matrix shall have downhole gamma spectral measurements taken in order to evaluate the depth and identities of gamma-ray contributing radionuclides. These measurements will be made as a function of depth as described in Appendix G.

- Field equipment shall be decontaminated between borings in accordance with the procedures outlined in Appendix H. All decontamination washwaters and nonsample material will be managed as directed by Westinghouse.

The sampling methods will follow the criteria discussed below.

1) <u>Pits 1, 2, 3 and 4</u>

The specified subsurface soil sample locations into Pits 1, 2 and 3 will be investigated using various drill rigs and sampling with split spoon samplers. The procedures for subsurface sampling are presented in the Appendix I. Prior to placing heavy equipment on each pile, a preliminary assessment of the consolidation and integrity of the cover of each Pit will be performed by Bowser Morner personnel. After this investigation, the appropriate equipment shall be strategically placed at the proper sampling locations.

The boreholes for Pits 1, 2, 3 and 4 are to be advanced to depths of 12 feet, 10 feet, 20 feet and 20 feet below the surface, respectively. The drilling operation must not come into contact with the clay lining these pits. The borehole samples will be collected in 24 inch increments beginning at the surface. A three inch outer diameter 24 inch long split spoon sampler shall be used to collect samples, and standard penetration tests (ASTM-1586) shall be done on these samples by determining blow counts at six inch intervals. Lithological logs shall be completed according to procedures presented in Section 3.3.4.3. If water is encountered in any

borehole, the water level shall be recorded and a sample will be collected in accordance with procedures presented in Section 3.3.5.1.

After drilling and sampling to the nominal depths, each borehole will have downhole gamma spectral measurements taken in order to evaluate the depth and identities of gamma-ray contributing radionuclides. These measurements shall be recorded as a function of depth in each borehole. All boreholes shall be grouted back to the surface with non-shrink bentonite-cement as the auger is withdrawn from the hole.

2) Pit 5 and 6

The collection of residue samples from pits 5 and 6 represents a difficult operations problem since most of the residues are covered with water. The following are two methods that are being considered for obtaining samples from these pits. The sampling depths for Pits 5 and 6 will be from the liquid surface to 20 and 18 feet, respectively.

A sampling platform with low-density foam flotation will be used to position the field sampling team at each sampling location. Through a hole in this platform, a one inch diameter stainless steel sampling tube will be inserted into the residue in order to obtain a continuous sample beneath the water/residue interface. Attached to the base of the sampling tube will be an eggshell core catcher, which will allow the sample to enter the tube unobstructed and folds shut when the tube is raised. Upon full insertion of the tube, free water in the tube will be withdrawn and a rubber stopper will be inserted as a seal. As the tube is withdrawn from the pit, the outer surface will be wiped dry with absorbent wipes to remove loose material. Upon withdrawal, a seal will be placed in the bottom end. The sampling tube will then be labeled in accordance with the sample identity for that location. The tube will be deposited on shore prior to advancing to the next sampling location.

A crane will be utilized to support a sampling platform over the appropriate location. Through a hole in the platform, the stainless steel sampling tube will be inserted into the

residue in order to obtain a continuous sample beneath the water/residue interface. If the sampling tube cannot be manually inserted, the cathead on the crane will be used to hoist a 140 pound hammer which will be used to drive the tube to the desired sampling depth.

3) Sanitary Landfill

The specified subsurface sample locations in the Sanitary Landfill will be investigated as described for Pits 1, 2 and 3. The boreholes are to be advanced to two feet below the waste/soil interface. If downhole gamma spectral measurements or chemical screening of the sample at this depth show that radiological or chemical constituents are present, the drilling, sampling and downhole spectral measurement protocol will continue until the depth of material can be determined. Samples will be fractioned into 24-inch increments. Penetration tests will be performed during this operation by determining blow counts at six inch intervals. Lithologic logs will be maintained, and boreholes will be grouted back to the surface with non-shrink bentonite cement.

4) Lime Sludge Ponds

The lime sludge ponds will be investigated using the techniques described for sampling Pits 5 and 6. The sampling tubes are to be advanced to twenty feet below the water/residue interface or until the friction of the solid within the tube prevents additional residue from entering the sample tube.

5) Clear Well

Sediment on the bottom of the clear well will be obtained from a flotation sampling platform. Samples will be pulled up using a Ponar-type stainless steel grab dredge lowered with a cable. Sediment samples will be collected from the upper one-half foot of bottom sediment. Standard operations for sediment sampling are presented in Appendix J.

6) Burn Pit

The protocol for subsurface sampling in the Burn Pit will follow that described for Pits 1, 2 and 3. The boreholes are to be advanced to two feet below the waste/soil interface. Samples will be fractioned into 24 inch increments. If downhole spectral measurements and chemical screening of samples from this depth show radiological and chemical constituents are present, then the drilling, sampling and

downhole measurement protocol will continue until the depth of such material can be determined. All boreholes will be grouted back to the surface with non-shrink bentonite-cement as the auger is withdrawn from the hole.

7) Fly Ash Piles

The boreholes into the fly ash pile will be advanced with the drill rig to a depth two feet below the soil/fly ash interface. Samples will be obtained using a split spoon sampler. Samples will be fractioned into 24 inch increments. If downhole gamma spectral measurements at these depths show the soil to have significant radionuclide concentrations, then the drilling, sampling and downhole gamma spectral measurement protocol will continue until the depth of radioactive material can be determined. Penetration tests will be done during this operation by determining blow counts at six inch intervals. Lithologic logs will be completed and water levels recorded. All boreholes will be grouted back to the surface with non-shrink bentonite cement.

8) Silos 1, 2 and 3

Figure 2.5 depicts the slant drilling scheme to be used for subsurface sampling under Silos 1, 2 and 3. The boreholes are to be advanced 80 feet for Silos 1 and 2, and 20 feet for the holes drilled under Silo 3. Samples are to be collected using a split spoon sampler. Samples shall be fractioned into 24 inch increments. Lithologic logs will be completed and all water levels recorded. The boreholes will be grouted back to the surface using non-shrink bentonite-cement. If downhole gamma spectral measurements at these depths show the soil to have significant radionuclide concentrations, then additional peripheral boreholes will need to be drilled, sampled and gamma spectral measurements taken in order to assess the vertical extent of radioactive material migrating from beneath the silos.

9) Periphery of Pits

Forty eight boreholes are to be advanced at various locations around the Pits. These locations are depicted on Figure 2.4. Each borehole will be advanced to a depth of thirty feet. All holes will be drilled using either a hollow stem auger or cable tool method. Samples will be collected using a split spoon sampler and fractioned into 24-inch increments. If downhole gamma spectral measurements and chemical screening techniques show significant radionuclide and chemical concentrations at these depths, the drilling, sampling and downhole spectral measurement protocol will continue until the depth of material can be determined. Standard penetration tests will be performed

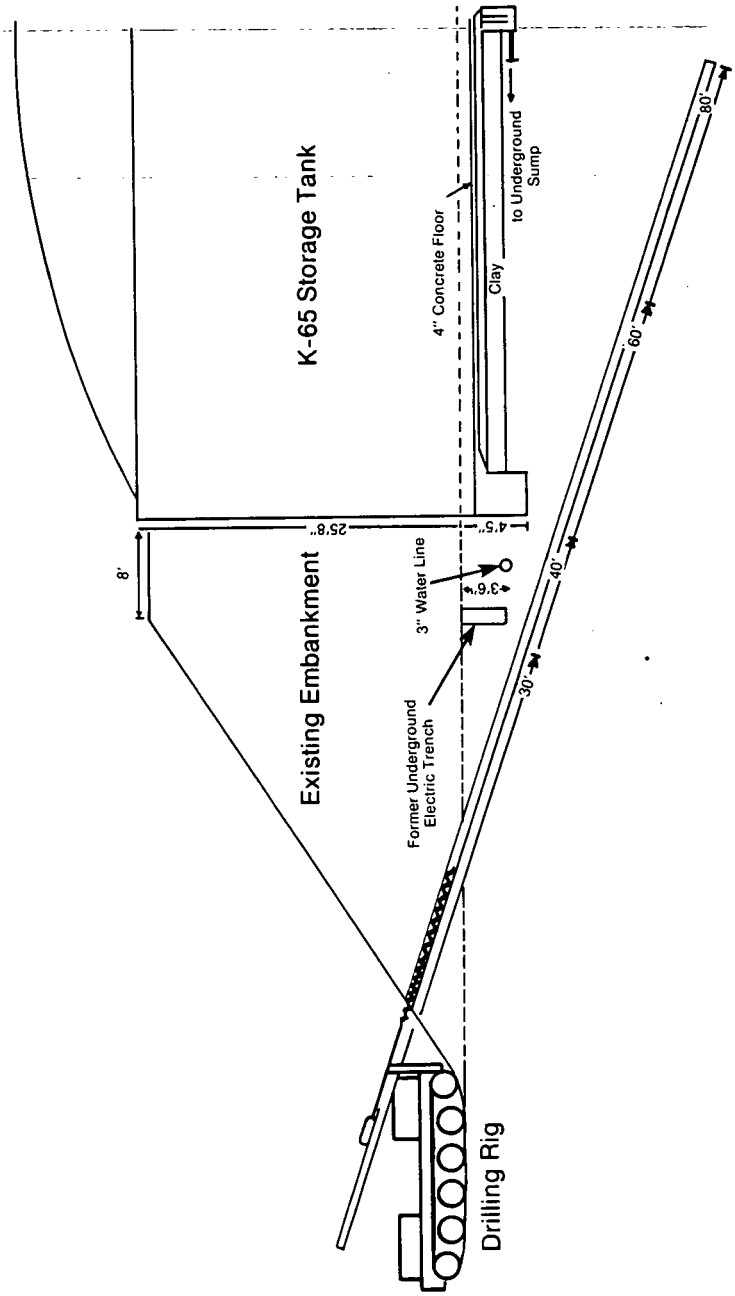

FIGURE 2-5 SURFACE DRILLING BENEATH SILOS

during the operation by determining blow counts at six inch intervals. Lithologic logs will be completed and all water levels recorded. All boreholes will be grouted back to the surface using non-shrink bentonite cement.

10) Slant-Drilling Below Pits 1-6 and Clear Well

The slant-drilled boreholes below the pits and clear well are to be advanced to depths of ten feet below the estimated pit depths and ten feet in a horizontal direction under the bottom of the pit. It is estimated that the drilling depths will be 40 feet for Pit 1, 35 feet for Pit 2, 40 feet for Pit 3, 50 feet for Pit 4, 70 feet for Pit 5, 50 feet for Pit 6, and 35 feet for the Clear Well (assuming the clear well is approximately twenty feet deep). These depths were conservatively calculated on the assumption that each pit wall was vertical, forming a 90 degree angle with the pit bottom. Samples are to be collected using a split spoon sampler. Samples will be fractioned into 24-inch increments. Lithologic logs will be completed and all water levels recorded. If downhole gamma spectral measurements and chemical screening techniques show significant radionuclides and chemical concentrations at these depths, the drilling, sampling, and downhole measurement protocol will continue until the depth of those constituents can be determined. All boreholes will be grouted back to the surface with non-shrink bentonite cement.

11) Slurry Line to K-65 Silos

Ten boreholes will be advanced using a drill rig at various locations along the slurry line to the K-65 Silos. These locations will be identified during the radiation measurement/surface soil sampling protocol. Samples will be obtained using a split spoon sampler. It is estimated that the depth of these holes will be ten feet. If downhole gamma spectral measurements show significant radionuclide concentrations at this depth, the drilling, sampling and spectral measurement protocol will continue until the depth of radioactive material can be determined. Penetration tests will be performed during the operation. Lithologic logs will be completed and all water levels recorded.

12) Storm Sewer Outfall and Paddy's Run

The protocol for subsurface sediment sampling in the drainages will follow that discussed for Pits 1, 2 and 3. The boreholes are to be advanced ten feet. Samples will be fractioned into 24-inch increments.

13) Subsurface Background

Background gamma spectral measurements and subsurface background soil will be obtained at WESTON's upgradient monitoring well locations. samples of auger turnings will be collected as the borehole is drilled and will be used throughout the project for subsurface soil and sample blanks. Prior to installation of the well casing, the boreholes will have downhole gamma spectral measurements taken in accordance with procedures presented in Appendix G.

2.7.4 Sample Containers and Preservatives for Off-site Shipping and Storage

Table 2-3, in Section 2.6.5 lists the appropriate container and preservative to be used for sample storage and shipment to off-site laboratories. In addition, samples sent for RCRA characteristic analysis shall be placed in amber glass containers. The sample size will be 100 grams and preservation will include cooling to 4°C.

Subsurface soil samples collected at locations described in Section 2.7.2 will be collected in 3-inch diameter, 24-inch long split spoon samplers. This material will be removed from the split spoons and placed in containers as discussed in Attachment 1 of Appendix I.

Packaging, marking and shipping of samples is addressed in Appendix D. Chain-of-custody forms will accompany the samples at all times to document sample transfer from field to the laboratory. Laboratory personnel must then implement procedures sufficient to maintain that the samples remain secure until analytical tests are conducted. Chain-of-custody procedures are detailed in appendix A.

2.7.5 Field Analyses and Preparation

The following procedures will be utilized for field analyses and sample preparation:

- To protect sampling and laboratory personnel from potential exposure to possible hazardous or radioactive contaminants, all samples will be decontaminated prior to packaging. After each sample is collected, sample containers will be washed on the exterior with a detergent, rinsed with tap water, and dried with paper towels. Decontamination solutions and rinse waters will be containerized and stored with the equipment

decontamination solutions. These solutions will be disposed of as directed by Westinghouse.

- Identify radionuclides of interest (i.e. U-238, Th-232, Ra-226, Cs-137) using gamma spectroscopy. Procedures for the multichannel analyzer and detection system are presented in Appendix E.

- Screen the sample for low level gamma radiation using the FIDLER. The procedures for this technique are presented in Appendix F.

- Dry, homogenize and sieve samples as required.

- Screen samples for gross alpha radiation using a ZnS probe coupled to a portable ratemeter/scaler. Procedures for the screening of samples are presented in Appendix C. Samples that show significant alpha activity in the absence of low level gamma activity as screened using the FIDLER, and absent of higher energy gamma radiation as screened using gamma spectrometry will be included for outside laboratory analysis.

- An ongoing laboratory test program is being developed to determine the physical properties of the subsurface pit samples. (This laboratory will also be used for K-65 samples). The laboratory tests will follow the procedures outlined in Section 4.

- All samples will be screened visually, with the olfactory senses, and with OVA and HNu field instruments

- Package and label those samples to be shipped to an off-site laboratory for analysis. Packaging and shipping requirements are presented in Appendix D.

- Remaining samples will be archived at a designated storage facility. Arrangements for archival will be made between WESTON and Westinghouse. All samples shall be appropriately labeled and sealed prior to transfer to this facility and a complete inventory of samples will be prepared.

2.7.6 Outside Laboratory Analysis

It is estimated that 351 samples will be sent to TMA/Eberline for radionuclide analysis, and 317 samples will be sent to WESTON Analytical Services for chemical analysis. The samples chosen for off-site analyses will be based on field laboratory screening results. In addition, 35 blind duplicate samples will be taken and sent to TMA/Eberline laboratory and 32 samples will be taken and sent to WESTON Analytical Services for external quality control purposes. A summary of sample location, number of samples, and number and kind of analyses to be performed by the off-site laboratories are presented on Table 2.4. Suggested analytical methods are presented in Appendix Q.

2.7.7 Sample Identification and Numbering

All sampling locations and associated sample numbers shall be identified using the code described in Section 2.4.

2.7.8 Deliverables

The following deliverables will be submitted by WESTON:

- Borehole logs
- Results of field analyses
- Results of laboratory analyses
- Results of geotechnical analyses
- Copies of field notes from the supervising geologist or engineer.

2.7.9 Contingency

Should extensive or severe contamination be found during the waste area subsurface sampling protocol, additional soil sampling and laboratory analyses may be required.

Table 2.4 Subsurface Sampling Locations and Analyses

Sample Location	No. of Holes	Drilling Feet	No. of Samples Obtained	Est. # of Samples Analyzed	Analyses
Pit 1	5	12	5[a]	5 5 5	LCGT HSL R
Pit 2	4	10	4[a]	4 4 4	LCGT HSL R
Pit 3	6	20	6[a]	6 6 6	LCGT HSL R
Pit 4	4	20	4[a]	4 4 4	LCGT HSL R
Pit 5	6	20	6[a]	6 6 6	LCGT HSL R
Pit 6	4	18	4[a]	4 4 4	LCGT HSL R
Burn Pit	6	18[b]	36	7 7 5	LCGT HSL R
Clear Well	3	N/A	3	3 3 3	LCGT HST R
Silo 1	4	80	160	32	LCG
Silo 2	4	80	160	32	LCG
Silo 3	4	20	40	8	LCG
Periphery of Pits	48	30[b]	720	144 144	LCGT HSL
Slurry Pipe to Silos	10	10[b]	50	10	LCG

See Key at end of this Table.

Table 2.4 Subsurface Sampling Locations and Analyses (cont.)

Sample Location	No. of Holes	Drilling Feet	No. of Samples Obtained	Est. # of Samples Analyzed	Analyses
Drainages	3	10[b]	15	3	LCGT
				3	HSL
Lime Sludge Ponds	6	20[b]	6[a]	6	LCGT
				6	HSL
				6	R
Sanitary Landfill	5	20[b]	5[a]	5	LCGT
				5	HSL
				5	R
Pit 1 (Slant Drill)	2	40	40	8	LCGT
				8	HSL
Pit 2 (Slant Drill)	2	35	35	7	LCGT
				7	HSL
Pit 3 (Slant Drill)	2	40	40	8	LCGT
				8	HSL
Pit 4 (Slant Drill)	2	50	25	5	LCGT
				5	HSL
Pit 5 (Slant Drill)	2	70	70	14	LCGT
				14	HSL
Pit 6 (Slant Drill)	2	50	25	5	LCGT
				5	HSL
Clear Well (Slant Drill)	2	35	35	7	LCGT
				7	HSL
Fly Ash Pits	8	20[c]	80	15	LCG
				15	HSL
					Inorganic
					Pesticide/PCB
Blind Duplicates	-	-	35	35	Radiological
			32	32	Chemical

See Key at the end of this Table

Key

(a) Each sample will consist of a composite of an entire length of core from the borehole.

(b) These are the estimated depths of drilling. If downhole gamma spectral measurements and chemical screening shows radiological and chemical constituents at these depths, the drilling, sampling, and measurement protocol will continue until the depth of material has been determined.

(c) These pits need to be drilled to two feet below the fly ash/soil interface.

L - Pb-210

C - Isotopic thorium and uranium

G - Gamma Spectral Analysis

T - Tc-99, Sr-90, Ru-106, Np-237, isotope plutonium

R - The samples from these matrices will be analyzed for the following RCRA characteristics:

Toxic Characteristic Leachate Procedure (TCLP) - this procedure will be defined per regulations at the time of analysis.

Reactivity
Corrosivity
Ignitability

HSL - The samples from these matrices will be analyzed for HSL-Inorganics, HSL-volatiles, HSL- Semivolatiles and HSL-Pesticides/PCBs. The HSL constituents and analytical methods are presented in Appendix Q. Non-targeted, non-HSL constituents and targeted non-HSL constituents that may appear in the pit samples will be identified using a comprehensive library search. The targeted non-HSL constituents identified by Westinghouse include:

Dichlorodifluoromethane	1,2 Dichloropropylene
Tributylphosphate	Methylbromide
Acrolien	Methylchloride
bis (chloromethyl) ether	Trichlorofluoromethane
Acrylonitrile	cis 1,2 Dichloroethylene

2.8 SURFACE WATER SAMPLING

This section describes the surface water sampling protocol that will be carried out at numerous locations in the Waste Storage Area. Additional sampling will be performed in various drainages on the FMPC site.

2.8.1 Objectives

The objective of sampling surface waters is to obtain information on the quality of surface water in the Waste Storage Area and surface water runoff leaving the FMPC site. The sampling strategy has been designed to identify sources of chemical and radiological constituents entering the various drainages on the site.

2.8.2 Sampling Frequency

Surface water will be sampled once during the field investigation. Additional samples will be collected after a heavy rainfall in locations that were previously dry. All surface water samples must be free of sediments.

2.8.3 Sample Locations

Tentative locations for sampling surface water will consist of the following:

1) Clear Well

Three samples will be taken near the inlet pipe at the northwest corner of the clear well. These will consist of a single sample from the lower, middle and upper depths in order to evaluate the vertical stratification of radiological and chemical constituents.

Three samples will be taken from a single point at the end of the walkway on the southwest corner of the clear well. These will consist of a single sample from the upper, middle and lower depths.

2) Pit 4

Obtain a single grab sample from middle depth of the standing water in the southeast corner of the Pit.

3) Pit 5

Around the inlet pipe at the east end of Pit 5, there is a small volume of liquid. Obtain a single grab sample at this location.

Three samples will be taken at the center of the Pit. These will be collected at a single location from the lower, middle and upper depths of the liquid.

Three samples will be taken from the end of the walkway on the southwest corner of the pit. These will be collected from the lower, middle and upper depths of the liquid.

4) Pit 6

Obtain a single grab sample from mid-depth a few feet out from each of the four corners of the pit.

5) Storm Sewer Outfall

During periods of heavy runoff, excess water in the storm sewer system overflows into a natural drainage northwest of the site. If water is flowing in this drainage, five samples will be taken at selected points established by site hydrology personnel. Each location shall be staked for future sampling activities.

6) Paddy's Run

A sample will be obtained at the background location selected during the radiological measurement protocol.

Two sampling locations, one upstream and one downstream from Pit 3, shall be identified and sampled.

A sampling location immediately downstream from all drainage discharge points shall be identified and sampled. During the site visit, three were identified.

Two sampling locations one upstream and one downstream from the storm sewer outfall shall be identified and sampled.

Two additional samples will be taken downstream from the Waste Storage Area at locations established by site hydrology personnel.

7) Two Drainage Paths Southwest of Waste Storage Area

During the site visit, two drainages flowing southwest of the Waste Storage Area were identified. Water was flowing in one of these, the other contained standing water. Both discharged into Paddy's Run. If standing or flowing water is present during the field work (i.e., after significant rainfall), two samples from each drainage will be collected at specified locations identified by site hydrology

personnel. These locations shall be staked for future sampling activities.

8) Pipes Exiting West Perimeter Waste Storage Area/ Wetlands

These areas were dry during the site visit. If standing or flowing water is present during the field work (i.e. after significant rainfall), three locations shall be identified by site hydrology personnel and sampled. Each location shall be staked for future sampling activities.

9) Drainages North of Pit-5

This drainage was dry during the site visit. If standing or flowing water is present during the field work, four samples will be taken. These will include a sample immediately downstream from the Sanitary Landfill, one immediately upstream of Pit 5, one immediately downstream of Pit 5, and one immediately above the discharge into Paddy's Run.

10) Drainage North of Railroad Tracks

This drainage flows north of the Sanitary Landfill and follows the railroad towards Paddy's Run. Samples will be taken above and immediately below the Sanitary Landfill. Two additional sampling locations shall be identified by site hydrology personnel during the field work.

11) Drainages in the Waste Storage Area

Three samples will be taken from the drainage that flows south of Pit 1 and the clear well. These will include a sample taken as far upstream as possible from the clear well (and Pit 1), a sample immediately downstream from the clear well, and a sample immediately above the culvert below the maintenance road west of the clear well. All samples locations will be marked for future sampling activities.

Two samples will be taken from the drainage flowing just north of the maintenance road near the new Biodenitrification Surge Lagoon. These will include a sample upstream from the Biodentrification facility, and a sample immediately east of the metal oxide sites. All of the locations will be marked for future sampling activities.

Three samples will be taken from the drainage flowing south the maintenance road next to Pits 4 and 6. These will include a sample as far upstream as possible from Pit 6, one immediately downstream from Pit 6, and one immediately downstream from Pit 4.

A single sample will be obtained from the seep at the northwest corner of Pit 3 near the evaporation greenhouse.

Additional drainages and seeps will be identified during the field work. If standing or flowing water is present during the characterization, six additional samples will be collected and the locations marked for future sampling activities.

12) South Lime Sludge Pond

A single grab sample shall be obtained near the inlet pipe on the southeast corner. This sample shall be taken at mid-depth. A single grab sample shall also be obtained at mid-depth from the northwest corner.

2.8.4 Sampling Methodology

The existing drainages and seeps in and around the Waste Storage Area are quite small with little flow. These areas shall be sampled by hand using a pond or dip sampler. Samples shall be transferred to the appropriate container as listed in Table 2.6. Paddy's Run and existing drainages shall be sampled at mid-depth in the mid-section or deepest flow channel. Samples will be collected directly into the sample container if the water is deep enough. The pits shall be sampled either with the dip sampler attached to the end of a telescopic pole or samples taken from various depth increments will be obtained using a Kemmerer water sampler.

All sampling equipment will be cleaned prior to use. If wading into the water is necessary, the sampling technician shall be careful not to disturb bottom sediments and to wait until sediments settle prior to obtaining the sample. Procedures for obtaining these samples are presented in Appendix K.

2.8.5 Surface Water Sample Containers and Preservatives for Off-site Shipping and Storage

Table 2.5 lists the appropriate container and preservative to be used for sample storage and shipment to off-site laboratories.

Table 2.5 Surface Water Containers and Preservatives

Specified Analysis	Sample Container	Sample Size	Preservation	Holding Time Days	Reporting Units
HSL Volatile	40 ml vial w/ Teflon-lined silicon rubber septum	40 mL	cool, 4°C	14	ug/L
HSL Base/ Neutral/Acid	Amber glass	1 L	cool, 4°C	7/40[2]	ug/L
HSL Pesticide/PCB	Amber glass	1 L	cool, 4°C	7/40	ug/L
HSL Inorganic [1]	Polyethylene or glass	1 L	pH <2, HNO_3	180	ug/L
Radiological	Cubitaner	4 L	pH <2, HNO_3	6 mos.	Variable

[1] Does not include tin

[2] Extract within 7 days, analysis within 40 days of extraction

Packaging, labeling and shipping of samples is addressed in Appendix C. Chain of custody forms and procedures are presented in Appendix A. These must accompany the sample at all times to document sample transfer from the field to the laboratory.

2.8.6 Field Analyses and Preparation

The following field and analyses shall be performed. Appendix L details the Standard Operating Procedures for each analysis.

Analysis	EPA Method No.
PH	150.1
Temperature	170.1
Conductivity	120.1
Dissolved Oxygen	360.1/360.2
Flow	Pygmy, Marsh - McBirney, or equivalent

Site hydrology personnel shall select a single sample from each location sampled (estimate 15 samples) to be split so that one fraction can be filtered for HSL Inorganic analysis and the other analyzed unfiltered. This technique will provide WESTON with additional data for understanding constituent migration. Those

assessments require that a distinction be made between soluble species and suspended matter. Water samples requiring filtration will be filtered in the field, immediately following collection.

To protect sampling and laboratory personnel from potential exposure to possible hazardous or radioactive contaminants, all samples will be decontaminated prior to packaging. After each sample is collected, sample containers will be washed on the exterior with a detergent, rinsed with tap water, and dried with paper towels. Decontamination solutions and rinse waters will be containerized and stored with the equipment decontamination solutions. These solutions will be disposed of as described by Westinghouse.

2.8.7 Off-site Laboratory Analyses

It is estimated that sixty-two samples will be taken during the surface water sampling protocol. These will be sent off-site for analysis of all specified parameters. The fifteen split samples that were filtered will be analyzed for HSL Inorganics. In addition, six blind duplicates and six field blanks will be sent to each laboratory for external quality control. The sixty-two samples and external quality control samples will be analyzed for the following parameters:

Chemical Analysis

Indicators - Total dissolved solids
Total suspended solids

Biological - Coliform Bacteria

Metals - Hazardous Substance List Inorganics, cyanide

Anions - Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate
Phosphate
Fluoride
Sodium

Organics - Hazardous Substance List Volatiles
Hazardous Substance List Semi-volatiles
Hazardous Substance List Pesticides/PCB's

These constituents and analytical methods are presented in Appendix Q. Additional constituents that may appear in the surface water samples that are not included on the HSL list will be identified using a comprehensive library search. These

include ten targeted, non-HSL constituents and non-targeted, non-HSL constituents. The targeted non-HSL chemicals identified by Westinghouse include:

Dichlorodiflouromethane
Tributylphosphate
Acrolein
Acrylonitrile
bis (chloromethyl) ether
Methylbromide
Methylchloride
Trichlorofluoromethane
cis 1,2 Dichloroethylene
1,2 Dichloropropylene

Radiological Analyses

Ra-226, Ra-228
Isotopic uranium
Isotopic thorium
Isotopic plutonium
Cs-137
Sr-90
Ru-106
Np-237
Tc-99

2.8.8 Sample Identification and Numbering

All surface water sampling locations and associated sample numbers numbers shall be identified using the code described in Section 2.4.

2.8.9 Deliverables

The following deliverables shall be submitted by WESTON:

- Results of Field Laboratory Analysis
- Results of Outside Laboratory Analyses
- Completed Chain of Custody Forms
- Memorandum describing field activities including documentation of sample collection and handling techniques.

2.8.10 Contingency

If significant concentrations of radionuclides and/or chemicals are detected in any of the off-site drainages, additional sampling may be required.

2.9 SURFACE SEDIMENT SAMPLING

This section describes the surface sediment sampling protocol that will be carried out in the drainage courses and low lying wetland areas on and adjacent to the FMPC Waste Storage Area.

2.9.1 Sediment Sampling Objectives

The objectives of sampling surface and subsurface sediments are 1) to evaluate the transport of suspended constituents by surface water, 2) to evaluate the attenuation of of constituents dissolved in surface waters by the sediments, and 3) to assess the potential for leaching of constituents from the sediments into either surface or groundwater.

2.9.2 Sampling Frequency

Surface sediments will be sampled once during the field investigation.

2.9.3 Sampling Locations

Tentative surface sampling locations consist of the following:

1. Storm Sewer Outfall

   Sediment samples shall be obtained at each location measured and staked during the surface water sampling protocol. It is estimated that approximately five samples will be obtained. Additional samples will be taken during the FIDLER scan when radiation levels correlate to uranium concentrations at or above 35 pCi/g.

2. Paddy's Run

   A background location shall be identified and sampled.

   Sediment samples shall be obtained at each location measured and staked during the surface water sampling protocol. It is estimated that ten samples will be obtained. Additional samples will be taken during the FIDLER scan when radiation levels correlate to uranium concentrations at or above 35 pCi/g.

3. Two Drainage Paths Southwest of Waste Storage Area

   Sediment samples will be obtained at each location measured and staked during the surface water sampling protocol. It

is estimated that four samples, two from each drainage, will be collected. Additional samples will be taken during the FIDLER scan when radiation levels correlate to uranium concentrations at or above 35 pCi/g.

4. Pipes Existing West of Waste Storage Area/Wetlands

Three sediment samples will be taken from locations measured and staked during the surface water sampling protocol.

5. Drainage North of Pit-5

Sediment samples will be collected at each location measured and staked during the surface water sampling protocol. It is estimated that four samples will be collected. Additional samples will be taken during the FIDLER scan when radiation levels correlate to uranium concentrations at or above 35 pCi/g.

6. Drainage North of Railroad Tracks

Sediment samples will be collected at the four locations measured and staked during the surface water sampling protocol. Additional samples will be taken during the FIDLER scan when radiation levels correlate to uranium concentrations at or above 35 pCi/g.

7. Drainages From Upper Fly Ash Pile

During the site visit, it was noted that significant runoff has washed fly ash into a gully where the running track is located. If any sediments exist in these drainages, five samples will be taken. These locations will be identified by WESTON hydrology personnel in the field.

8. Drainages in the Waste Storage Area

The drainage ditch south of the maintenance road next to Pits 4 and 6 will have three sediment samples taken at locations measured and staked during the surface water sampling protocol. Sediment samples will also be taken during the FIDLER scan when radiation instrument readings correlate to uranium concentrations at or above 35 pCi/g.

The drainage south of the Pit 1 and the clear well will have three sediment samples taken at locations measured and staked during the surface water sampling protocol. Sediment

samples will also be taken during the FIDLER scan when radiation instrument readings correlate to uranium concentrations at or above 35 pCi/g.

The drainage north of the maintenance road near the new Biodenitrification Surge Lagoon will have three sediment samples taken at locations measured and staked during the surface water sampling protocol. Sediment samples will also be taken during the FIDLER scan when radiation instrument readings correlate to uranium concentrations at or above 35 pCi/g.

A single sediment sample will be collected from the seep at the northwest corner of Pit 3, near the evaporation greenhouse. This will be taken at the location identified and staked during the surface water sampling protocol.

Any additional drainages or seeps within the Waste Storage Area that are identified and staked during the surface water sampling will have sediment samples taken at several measurement intervals. It is estimated that six additional samples will be collected.

2.9.4 Sampling Methodology

The Standard Operating Procedures and all sample documentation procedures for stream sediment sampling are presented in Appendix J. Special care must be taken to ensure that samples are not contaminated due to poor cleanup of sampling equipment.

Sediment samples from flowing streams will be collected below the water surface at quarterpoints across the stream channel. The samples shall be obtained using a stainless steel scoop. If pebbles and particles larger than 2mm are present, they shall be removed by shaking the sample through a 2mm mesh sieve into a stainless steel container. Excess water shall be poured out of the container, and the sample shall be placed into a cloth bag which allows excess water to filter through. The cloth bag shall be placed into a plastic bag and transferred to the field laboratory.

Surface sediment samples from dry streams shall be collected by using the scoop to scrape away the upper inch of stream sediment. Five scoopfuls of sediment shall be collected at quarterpoints across the stream channel. Each sample shall be sieved, placed into a plastic bag, and transferred to the field laboratory.

2.9.5 Sample Containers and Preservatives for Off-site Shipping and Storage

Table 2.6 lists the appropriate container and preservative to be used for sample storage and shipment to off-site laboratories.

Table 2.6 Sediment Sample Containers and Preservatives

Specified Analysis	Sample Container	Sample Size	Preservation	Holding Time Days	Reporting Units
HSL Volatile	Vial w/Teflon lined silicon septum	40 ml	cool, 4°C	14	ug/L
HSL Base/ Neutral/Acid	Amber glass	100 g	cool, 4°C	7/40[2]	ug/Kg
HSL Pesticide/PCB	Amber glass	100 g	cool, 4°C	7/40	ug/Kg
HSL Inorganic [1]	Amber glass	100 g	cool, 4°C	7/40	ug/Kg
Radiological	Wide mouth plastic bottle	3207 g	None	6 mos.	Variable

[1] Does not include tin

[2] Extract within 7 days; analysis within 40 days of extraction

Packaging, labeling and shipping of samples is addressed in Appendix D. Chain of custody forms and procedures are presented in Appendix A and will accompany the samples at all times to document sample transfer from the field to the laboratory.

2.9.6 Field Analyses and Preparation

The following procedures will be utilized for field analyses and sample preparation:

- To protect sampling and laboratory personnel from potential exposure to possible hazardous or radioactive contaminants, all samples will be decontaminated prior to packaging. After each sample is collected, sample containers will be washed on the exterior with a detergent, rinsed with tap water, and dried with paper

towels. Decontamination solutions and rinse waters will be containerized and stored with the equipment decontamination solutions. These solutions will be disposed of as directed by Westinghouse.

- Identify radionuclides of interest (e.g. U-238, Th-232, Ra-226, Cs-137) using gamma spectroscopy. Procedures are presented in Appendix E.

- Dry, homogenize and sieve samples as required.

- Screen the sample for low level gamma radiation using the FIDLER. Procedures for this screening technique are presented in Appendix F.

- Screen for gross alpha radiation using a ZnS probe coupled to a portable ratemeter/scaler. Procedure for this screening technique is presented in Appendix C. Samples that show significant alpha activity in the absence of low level gamma activity as screened using the FIDLER, and absent of higher energy gamma radiation as screened using gamma spectrometry, will be included for outside laboratory analysis.

- Place samples in storage containers and add appropriate preservative as listed in Table 2.5.

- Package and label these samples for shipment to an off-site laboratory. Packaging and shipping requirements are presented in Appendix D.

- Remaining samples shall be archived at a designated storage facility. All samples shall be appropriately labeled and sealed prior to transfer to this facility, and a complete inventory of archived samples will be prepared.

2.9.7 Off-Site Laboratory Analyses

Each of the forty-seven samples taken will immediately be sent to the WESTON Analytical Laboratory for chemical analyses. The samples taken for radionuclide analysis will be screened in the field laboratory. Based on these results, it is estimated that twenty samples will be sent to the TMA/Eberline laboratory for further radionuclide characterization.

It is estimated that an additional thirty sediment samples will be obtained at locations identified during the FIDLER scan. Each of these samples will be screened for radioactivity in the field

laboratory, and twenty will be selected for off-site analysis of radionuclides at TMA/Eberline.

Two sets of five blind duplicate samples will be collected during the course of the sampling. One set will be sent to WESTON and the other will be sent to TMA/Eberline. These samples will be analyzed and used for external quality control purposes.

The radiological and chemical parameters that will be assessed by the off-site laboratories are presented below. Individual constituents and analytical methods are presented in Appendix Q.

Chemical Analysis

HSL Inorganics
HSL Volatile
HSL Semi-Volatile
HSL Pesticides/PCB's

These constituents and analytical methods are presented in Appendix Q. Additional constituents that may appear in the sediment samples that are not included on the HSL list will be identified using a comprehensive library search. These include ten targeted non-HSL constituents, and non-targeted, non-HSL constituents. The targeted non-HSL chemicals identified by Westinghouse include:

Dichlorodifluoromethane
Tributylphosphate
Acrolien
Acrylonitrite
bis (chloromethyl) ether
1,2 Dichloropropylene
Methylbromide
Methylchloride
Trichlorofluoromethane
cis 1,2 Dichloroethylene

Radiological Analyses

Gamma Spectral Analysis
Isotopic uranium
Isotopic thorium
Isotopic plutonium
Tc-99
Sr-90
Ru-106
Np-237
Pb-210

2.9.8 Sample Identification and Numbering

All sampling locations and associated sample numbers shall be identified using the code described in Section 2.4.

2.9.9 Deliverables

The following deliverables shall be submitted by WESTON:

- Results of field analyses
- Results of laboratory analyses
  Completed chain of custody forms
- Memorandum describing field activities including documentation of sample collection and handling techniques

2.9.10 Contingency

Should extensive or severe levels of contamination be found in the surface sediments on or adjacent to the Waste Storage Area, additional sampling and laboratory analyses may be required for adequate characterization.

2.10 RADON FLUX MEASUREMENTS

This section describes the radon flux measurement protocol that will be carried out at numerous locations in the Waste Storage Area.

2.10.1 Radon Flux Measurement Objectives

The primary objective for making radon flux measurements is to detect radon emanating from significant subsurface concentrations of radium-226. This data will provide additional information as to the presence of radium in each pit.

2.10.2 Sampling Frequency

Prior to the radon flux monitoring effort, canisters shall be displayed at different areas around the site for several different periods of time, and subsequently measured on the gamma spectrometer. Based on prior calibration of the canisters at the MOUND facility, each canister will be evaluated for radon uptake. This value, corrected for radioactive decay, will then be plotted as a function of exposure time. From these data, a site average time can be developed in which to deploy the radon flux canisters during the field measurements.

2.10.3 Sampling Locations

Tentative locations for placement of charcoal canisters are depicted on Figure 2.6 and consist of the following:

1) Six canisters on Pit 1
2) Six canisters on Pit 2
3) Ten canisters on Pit 3
4) Six canisters on Pit 4
5) Four canisters on the burn pit
6) Two canisters in close proximity to Pit 6
7) Two canisters on the east berm of Pit 5
8) Two canisters on each Fly Ash Pile
9) Two canisters in assumed background location
10) Two sample blanks

2.10.4 Sampling Methodology

The procedure for applying the charcoal canister method of determining radon flux will involve the placement of the canister on the emanating source of radon for the time period established. A procedure for Radon Flux measurements is presented in Appendix M.

The Rn-222 absorbed on charcoal in the canister will be analyzed using a calibrated 4"x4" NaI(Tl) scintillation spectrometer

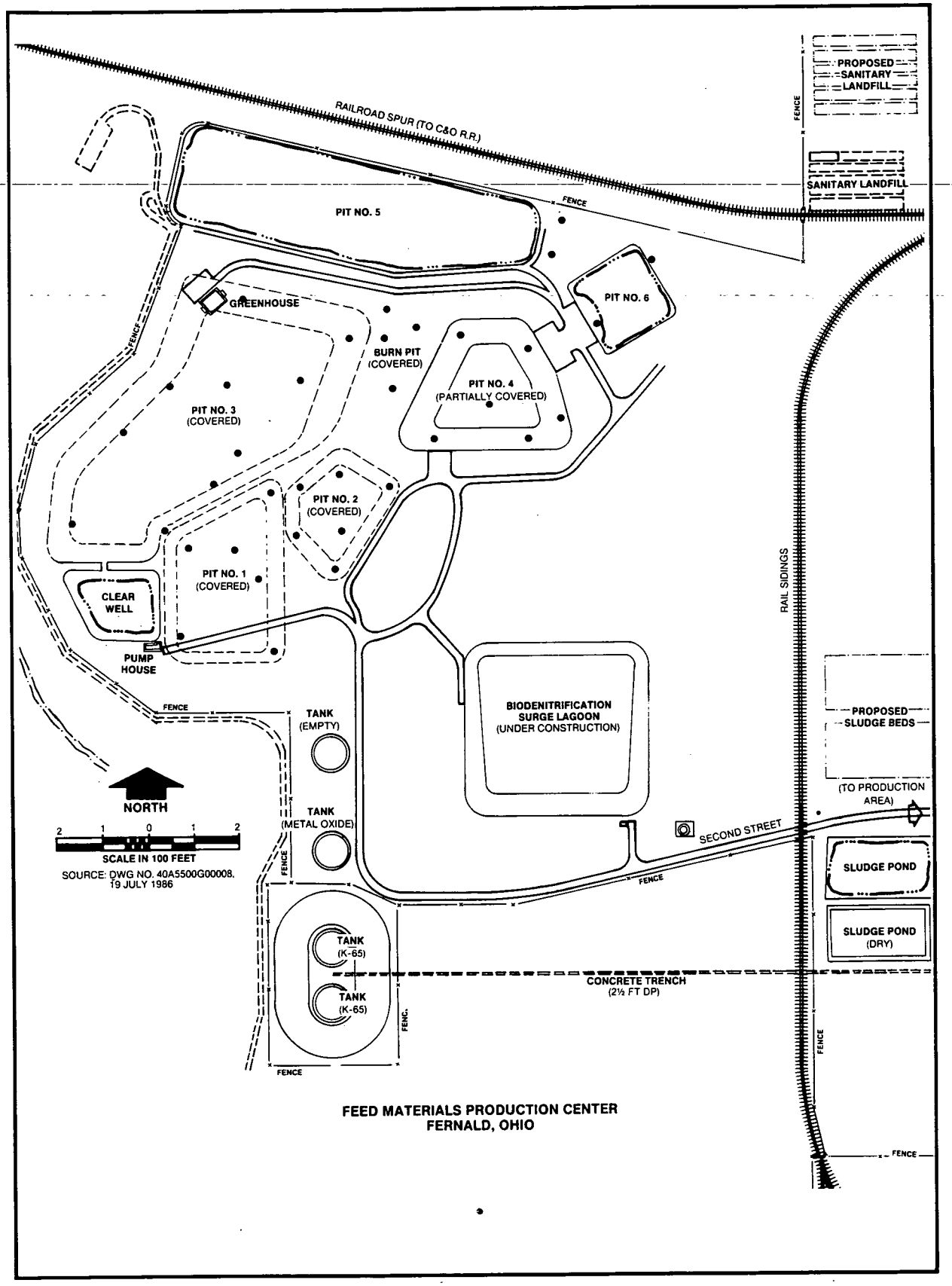

FIGURE 2-6 RADON FLUX MEASUREMENTS ON WASTE STORAGE AREA

system in the field laboratory. The integration region on the multi-channel analyzer will be set to includes the 0.294 MeV, and 0.352 MeV photons from Pb-214 and the 0.609 MeV, 1.12 MeV, and 1.76 MeV photons from Bi-214. Each analysis will be decay, geometry, and efficiency corrected to obtain the average radon flux during the time of collection. Care will be taken to avoid saturation of the charcoal. It will be assumed that the radon is emanating from a planer source, and results will be documented in $pCi/m^2/sec$.

2.10.5 Field Laboratory Analysis

Table 2.7 summarizes all sampling locations and analysis to be made during the radon flux sampling protocol.

Table 2.7 Radon Flux Sampling Locations and Analysis

Sampling Location	No. of Samples	Analysis
Pit 1	6	G
Pit 2	6	G
Pit 3	10	G
Pit 4	6	G
Berm of Pit 5	2	G
Solids on Pit 6	2	G
Fly Ash Piles	4	G
Burn Pit	4	G
Background	2	G

G - Gamma Spectral Analysis

2.10.6 Sample Identification and Numbering

All sampling locations and associated sample numbers will be identified using the code described in Section 2.4

2.10.7 Deliverables

The following deliverables shall be submitted by WESTON:

- Results of Field Laboratory Analysis
- Memorandum describing field activities including documentation of sample collection and handling techniques.

2.11 RADON MEASUREMENTS USING FILM DETECTOR METHODS

This section describes the ambient radon measurement protocol using track-etch film detectors. This sampling will be carried out at various locations around the Waste Storage Area.

2.11.1 Objectives

The principal objective of this radon monitoring is to provide a time integrated measurement of radon concentration. This data will be compared to radon flux measurement results and inferences can be made as to the source of radon emanation in the Waste Storage Area (i.e. is the radon emanating directly from the Pit areas or is it migrating to these areas from the K65 silos). The data from the track-etch detection methods will also be used to evaluate occupational exposures (with respect to accepted standards) when workers are performing routine (non-soil boring) characterization efforts within the Waste Storage Area.

Thoron (Rn-220) from the Th-232 series may be present in above background concentrations in the Waste Storage Area. Because of the short half-life (55 seconds), it is unlikely that it can emanate from significant depths in the moist soil covering the pits. However, WESTON shall evaluate whether the Rn-220 concentrations are significant enough to warrant a time integrated characterization (0.5 pCi/g or greater).

2.11.2 Sampling Frequency

Each radon monitoring detector shall remain in place for a period no less than three months.

Grab sampling will be performed during the initial stages of field work in order to detect the presence and limits of Rn-220 in the Waste Storage Area.

2.11.3 Sampling Locations

Twenty locations around the Waste Storage Area will be chosen during the initial stages of field work for the placement of track-etch film detectors. A minimum of two detectors shall be placed at each location. In addition, three background locations shall be identified and film detectors shall be installed. Isopleths developed during the Mound (1985) study shall be utilized to identify potential background locations.

During the initial stages of field work, air samples using the two-filter method for thoron will be taken at several locations directly above Pits 1 through 4, and at several locations

adjacent to pits 5 and 6. The operating procedures for this technique are included as Attachment-1 of Appendix N.

2.11.4 Measurement Methodology

Track-etch film detectors (and canisters) shall be placed so that the filter face of the detector is at least four inches from any obstruction. The protective canister and film detector shall be placed at a height of one meter. Appendix N details the procedures for implementing track-etch detection methods. Track-etch detectors will be shipped to the Terradex Corporation for evaluation.

The two filter technique for measuring Rn-220 is performed by drawing air through a metal tube equipped with a high-efficiency glass filter at each end. The inlet filter removes all Rn-220 daughters, admitting only Rn-220 together with the sample air into the tube. The Rn-220 partially decays in transit, producing Th-A (Po-216) and Th-B (Pb-212), most of which is collected on the exit filter, the remainder depositing on the tube wall. After sampling, the exit filter is removed and analyzed after a delay of 180 minutes in an alpha counter. Rn-220 concentrations will be calculated by an equation that accounts for the tube dimensions, sample flow rate, sampling and counting intervals, and the fraction of Th-A and Th-B that reaches the exit filter. If Rn-220 concentrations in excess of 0.5 PCi/l are detected, additional two-filter measurements or time integrated track-etch measurements will be taken.

2.11.5 Off-site Shipping and Storage

When all detectors have been retrieved from the field and visually inspected, they shall be packed in an aluminum bag (ten cups per bag). The aluminum bag shall be sealed and all pertinent information should be transferred from the field data sheet (Appendix N) to the vendor's data sheet. The detectors are assembled with the central group detectors. The entire shipment, along with properly filled out data sheets and chain-of-custody paperwork (Appendix A) are shipped to the vendor (Terradex Corporation) for analysis.

2.11.6 Outside Laboratory Analysis

Terradex Corporation will provide the analysis of all film detectors. WESTON will send all film detectors including two unexposed field blanks, and two film detectors that have been exposed to known concentrations. Analysis consists of visually

counting tracks produced by the alpha radiation in the film, and correlating this data to known standards. Results shall be recorded in pCi/l and in either tracks/mm^2 or total tracks.

2.11.7 Measurement Identification and Numbering

All measurement locations and associated measurement numbers shall be identified using the code described in Section 2.4. Enter the date the bag was opened, the date installed, sample number, the serial number of the film detector cup, and location on the field data sheet.

2.11.8 Deliverables

The following deliverables will be admitted by WESTON.

- Results of Terradex Corporation's analysis
- Copies of Field Coordinator's field notes
- Completed chain of custody forms.

2.11.9 Contingency

If initial investigations of Rn-220 using the two-filter technique show that significant concentrations are present, WESTON will implement a Rn-220 measurement program. This will be carried out using Terradex track-etch detection methods or additional two-filter analyses.

2.12 CONTINUOUS AIR SAMPLING FOR RADIOACTIVE PARTICULATES

This section describes the continuous air sampling protocol that will be on-going throughout the WESTON characterization activities.

2.12.1 Continuous Air Sampling Objectives

Continuous air monitoring for radioactive particulates will be performed throughout the characterization efforts in order to identify any work activities that increase the ambient levels of atmospheric long-lived radioactive particulates. Filters will be pulled and analyzed weekly. This data will provide additional information regarding the effectiveness of our dust control measures.

2.12.2 Continuous Air Sampling Frequency

Continuous air sampling will be performed throughout the characterization effort. Filters will be changed every week and counted in the field laboratory. Various filters will be sent to TMA/Eberline for analysis.

2.12.3 Continuous Air Sampling Locations

A location shall be identified for taking background radioactive particulate measurements. This data will serve as a baseline by which to compare all sampling locations.

Four sampling locations in which to implement continuous air monitoring techniques shall be chosen during the initiation of work on the FMPC site. These locations shall be chosen based on the availability of power. Depending upon such availability, WESTON will implement continuous air monitoring at each boundary of the Waste Storage Area.

2.12.4 Continuous Air Sampling Methodology

Air will be pulled through a 47-mm, 0.45-micron Gelman (#61631) glass fiber filter, using an Eberlin RAS-1. Normally, a total flow of 40 to 60 liters per minute is adequate. Each week, the filters shall be changed and taken to the field laboratory for gross alpha counting. If, after 72 hours, gross alpha activity exceeds 2E-3 pCi/l (equivalent to the MPC for Th-230, the most limiting isotope), the filter will be sent to TMA/Eberline for radionuclide analysis. Procedures for air particulate sampling are presented in Appendix O.

2.12.5 Sample Containers for Off-site Shipping

Filters will be placed in glassine envelopes and packaged individually. Packaging, labeling and shipping of samples is addressed in Appendix C. Chain-of-custody forms and procedures are presented in Appendix A. These must accompany the sample at all times to document sample transfer from field to laboratory.

2.12.6 Outside Laboratory Analysis

Filters will be sent to TMA/Eberline for analysis of radioactive particulates. These analyses will include total uranium, Th-230, Ra-226 and Pb-210. It is estimated that two filters will be sent in each week for twelve weeks. Thus, twenty-four separate analyses will be performed for these radionuclides.

2.12.7 Sample Identification and Numbering

All continuous air sampling locations and associated sample numbers shall be identified using the code described in Section 2.4. All pertinent data shall be recorded in the field data sheet.

2.12.8 Deliverables

The following deliverables shall be submitted by WESTON;

- Results of field laboratory analysis
- Results of outside laboratory analysis
- Completed Chain-of-Custody forms
- Memorandum describing field activities, including documentation of filter collection and handling techniques

2.13 WORK AREA AIR QUALITY INVESTIGATION

This section describes various work area air monitoring that will be performed during the drilling and subsurface sampling protocol.

2.13.1 Work Area Air Monitoring Objectives

The primary objective for evaluating the air quality during the drilling and subsurface sampling program is to provide WESTON with adequate health and safety coverage for the workers on site. The data from these analyses will be used by Health and Safety personnel for assessing levels of protection and providing data for calculating radiation dose. These data are required for ALARA considerations.

2.13.2 Work Area Air Monitoring Frequency

Work area air quality sampling will be conducted during all drilling and subsurface sampling work on the various waste storage locations. Health and Safety personnel will call out any additional sampling locations where these analyses need to be incorporated.

2.13.3 Work Area Air Monitoring Locations

Locations for work area air monitoring will be identified by WESTON Health and Safety personnel. Great care will be taken to sample air analagous to that in the various workers' breathing zone. This may require placing air sampling equipment at several locations around the drilling and sampling operation. If detectable winds are blowing, sampling will be performed both upwind and downwind of the work area. It is anticipated that these measurements will be taken during the drilling and subsurface sampling on Pits 2-4, the Burn Pit along with the K-65 Slurry Line, and on the Fly-Ash-piles.

2.13.4 Work Area Air Monitoring Procedures

1) Radioactive Particulates

Air particulate samples will be collected in the immediate vicinity of all drilling and subsurface sampling operations. Procedures for radioactive particulate measurements and analyses are presented in Appendix O. For sampling particulates, air will be drawn through an open face 47mm, 0.45 micron Gelman (#61631) glass fiber filter with an AC powered sampling pump (Eberline RAS 1 or Stapler Hi-Vol.). Filters shall be counted immediately in the field laboratory with an

alpha counter/scaler (Eberline SAC 4). If after 72 hours the gross alpha activity exceeds 2E-3 pCi/l (MPC for Th-230, the most limiting isotope), the filter will be sent to TMA/-Eberline for analyses.

After following the established counting protocol, identified filters shall be packaged and shipped off-site for analysis of total uranium, Th-230, Ra-226, and Pb-210. It is estimated that 30 filters will be shipped to TMA/Eberline's Analytical Laboratory for these analyses.

2) Radon and Radon Daughter Measurements in Work Area

During drilling operations in the Waste Storage Area, air will be sampled continuously using a pulse pump and Tedlar bag. The samples will be analyzed for radon in accordance with procedures presented in Appendix P. On an as needed basis (i.e. areas where Ra-226 is suspected), radon daughter concentrations will be determined by sampling at least 10 liters of air through a membrane filter (five minute sample) and performing a modified Kuznets analysis (Attachment-1 of Appendix P). For sampling radon daughters, air will be pulled through a membrane filter paper (0.45-micron, 25 mm for MSA pump, 47 mm for RAS-2 pump). The modified Kuznets method was chosen so as to minimize the time spent by laboratory personnel on making working level (WL) measurements. This analysis requires taking a single count after a 40 to 90 minute decay period.

3) Asbestos Measurements in Work Area

Field decisions by WESTON Health and Safety personnel will be made as to the need for air sampling of asbestos fibers when drilling and subsurface sampling into Pits 2, 4 and 6. These pits are posted and have been identified as having various asbestos-containing materials. These decisions shall be made based on moisture content of the materials and respiratory safety measures being implemented. If the pit material is saturated with water and Level B protection is being used, sampling for asbestos will not provide useful information. If Health and Safety personnel identify that asbestos sampling is required, the sampling will be performed as provided in NIOSH Sampling Method 7400 R-4.

Asbestos analysis shall be performed by TMA/Cleveland. Analysis will include the characterization of the type of asbestos fiber (chrysotile, amosite, crocidolite, anthophyllite, actinolite and tremolite) and concentration of fibers through the known sample volume.

4) Chemical Screening in Work Area

Screening for organics will be performed on all subsurface samples using both a flame ionization detector and a photo-ionizing detector. These will provide an instantaneous measurement of hydrocarbon content in the material. Additional screening with these instruments will be performed around each auger head space.

Acidic fumes shall be detected around each auger head space by sampling the air using a piston/bellows pump and colorimetric tubes. These will provide an initial screen as to acidic conditions but will not provide a descriptive identification of the acids present. This information will allow WESTON Health and Safety personnel to determine whether adequate protective clothing is being worn.

2.14 Flora and Fauna Sampling

The sampling of flora and fauna will be contingent upon the results of the subsequent materials sampled. If significant contamination is found in the soils and sediments of the various drainage paths adjacent to the Waste Storage Area, then plants and animals most likely to enter the human food chain shall be sampled and analyzed. If subsequent sampling shows that these areas are not contaminated, the results from past FMPC Annual Environmental Monitoring Reports will be adequate to assess off-site risk estimates for the "no-action" alternative. These documents provide uranium concentrations in various vegetation, farm produce, milk and fish.

APPENDIX A

SAMPLE CONTROL AND DOCUMENTATION

1.0 SAMPLE CONTROL AND DOCUMENTATION

The purpose of document control is to assure that all documents for the FMPC project will be accounted for when the project is completed. Accountable documents will include items such as logbooks, filed data records, correspondence, sample tags, chain of custody reports, and analytical records. Each document will bear a serial number and should be listed, with the number, in a project document inventory assembled at the project's completion. Waterproof ink must be used in recording all data in documents bearing serial numbers.

A documentation coordinator will number all logbooks, sample tags, and chain of custody records. In a logbook, he shall record transfer of other logbooks to individuals who have been designated to perform specific tasks on the project. All project logbooks are to be turned over to the coordinator at the completion of each work period, and to a central file at the completion of the field activity.

Field Logbook - All information pertinent to a field activity must be entered in a bound book with consecutively numbered pages. Entries in the logbook must include at least the following:

Date and time of entry

Purpose of sampling

Name and address of field contact (Federal, state, local representative)

Producer of waste and address (if known)

Type of process producing waste (if known)

Type of waste (sludge, wastewater, etc.)

Description of sample

Waste components and concentrations (if known)

Number and size of sample taken

Description of sampling point

Date and time of collection of sample

Collector's sample identification number(s) and/or name

References such as maps or photographs of the sampling site

Field observations

Any field measurements made

Because sampling situations vary widely, notes should be as descriptive and inclusive as possible. Someone reading the entries should be able to reconstruct the sampling situation from the recorded information. Language must be objective, factual, and free of personal feelings or any other inappropriate terminology. If anyone other than the person to whom the logbook was assigned makes an entry, he must date and sign it.

1.1 Sample Labels

Each sample must be sealed immediately after it is collected and labeled using waterproof ink. Label tags may be filled out prior to collection to minimize handling of the sampling containers. Figure A-1 provides an example of the common sample label to be used on FMPC samples.

Occasionally, sample containers will be marked in the field using an etching tool rather than immediately applying a sample label or tag. This avoids possible label contamination problems and subsequent decontamination difficulties. In this case, the data intended for the sample label will be written into a sampling logbook and transcribed onto the label after the sample containers have been decontaminated.

Labels must be firmly affixed to the sample containers. The container must be dry enough for a gummed label to be securely attached.

FIGURE A-1
EXAMPLE OF OFFICIAL SAMPLE LABEL

SOIL SAMPLE IDENTIFICATION TAG

SITE ID _____ LOCATION ID _____
SAMPLE ID _____ LOG DATE _____
LABORATORY _____
DEPTH INTERVAL OF SAMPLE:
BEGINNING DEPTH (FT. FROM DATUM) _____
ENDING DEPTH (FT. FROM DATUM) _____
SAMPLER (S) _____
COMMENTS _____
_____

WATER SAMPLE IDENTIFICATION TAG

SITE ID _____ LOCATION ID _____
SAMPLE ID _____ _____
BOTTLE ID _____ _____
PRESERVATION METHOD _____
LOG DATE _____ LOG TIME _____
SAMPLER(S) _____
COMMENTS: _____
_____

1.2 Sample Collection and Identification

The number of persons involved in collecting and handling samples will be kept at a minimum. Guidelines established in this manual for sample collection, preservation, and handling should be used. Field records will be completed at the time the sample is collected and will be signed or initialed, including the date and time, by the sample collector(s). Field records will contain the following information:

Unique sampling or log number as discussed in Section 2.4 of the Radiological and Chemical Sampling Plan

Date and time

Source of sample (including name, location, and sample type)

Preservative used (if any)

Analysis required

Name of collector(s)

Pertinent field data

One member of the sampling team is to be appointed field custodian -- the documentation coordinator is a good choice. Samples will be turned over to the field custodian by team members who collect the samples. The field custodian will document each transaction and the sample will remain in his custody until it is shipped to the laboratory.

1.3 Chain of Custody Procedures

As in any other activity that may be used to support litigations, regulatory agencies must be able to provide the chain of possession and custody of any samples which are offered for evidence or which form the basis of analytical test results introduced as evidence. Written procedures must be available and followed whenever evidence samples are collected, transferred, stored, analyzed or destroyed. The primary objective of these procedures is to create an accurate written record which can be used to trace the possession and handling of the sample from the moment of its collection through analysis and its introduction as evidence.

A sample is in someone's "custody" if:

It is in one's actual possession, or

It is in one's view, after being in one's physical possession, or

It is in one's physical possession and then locked up so that no one can tamper with it, or

It is kept in a secured area, restricted to authorized personnel only.

When transferring the samples, the transferee must sign and record the date and time on the chain of custody record (Figure A-2). Custody transfers made to a sample custodian in the field should account for each sample, although samples may be transferred as a group. Every person who takes custody must fill in the appropriate section of the chain of custody record. To minimize custody records, the number of custodians in the chain of possession will be minimized.

The field custodian is responsible for properly packaging and dispatching samples to the appropriate laboratory. This responsibility includes filling out, dating, and signing the appropriate portion of the chain of custody record.

All packages sent to the laboratory will be accompanied by the chain of custody record and other pertinent forms. A copy of these forms will be retained by the originating office (either carbon or photocopy). Mailed packages will be registered with return receipt requested. For packages sent by common carrier, receipts will be retained as part of the permanent chain of custody documentation. Samples to be shipped must be packed so as not to break and the package sealed or locked so that any tampering can be readily detected.

FIGURE A-2 CHAIN-OF-CUSTODY RECORD

WESTON DESIGNERS CONSULTANTS

Custody Transfer Record/Lab Work Request

Received By _____ Client _____ RFW Contact _____

Date _____ Client Contact _____ Date Due _____

Assigned to _____ Phone _____ Project Number _____

776

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SAMPLE IDENTIFICATION **ANALYSES REQUESTED**

Sample No.	Client ID No.	Description	Matrix	Date Collected	Container/Preservative								

Matrix:

S- Soil **DS-** Drum Solids
W- Water **DL-** Drum Liquids
O- Oil **X-** Other

Special Instructions:

Items/Reason	Relinquished By	Received By	Date	Time	Items/Reason	Relinquished By	Received By	Date	Time

RFW 21-[illegible]01/A-3/86

2A-6

APPENDIX B

RADIATION MEASUREMENT TECHNIQUES

- Near Surface Gamma Radiation Survey Using the Field Instrument for Detection of Low Energy Radiation (FIDLER)
- In-situ Gamma Ray Measurements Using a Shielded Delta-Gamma Procedure
- Beta-Gamma Radiation Measurements
- Exposure Rate Measurements Using a Pressurized Ion Chamber
- Procedure for Correlating a Sodium Iodide Detector to the Pressurized Ion Chamber

NEAR SURFACE GAMMA RADIATION SURVEY USING THE FIELD INSTRUMENT FOR DETECTION OF LOW ENERGY RADIATION (FIDLER)

1.0 PURPOSE

This procedure describes the methods by which a Field Instrument for the Detection of Low Energy Radiation (FIDLER) is used to monitor ground surface deposits of uranium.

2.0 SCOPE

Included in this procedure are instructions for: 1) initial instrument set up (voltage plateau), 2) daily response standardization using a sealed "check source", 3) determination of the instrument's response to terrestrial background radiation, 4) establishment of field calibration factors, 5) use of the instrument to scan ground surface areas, and 6) use of the instrument to estimate the concentration of uranium in surface soil.

3.0 REFERENCE

3.1 TMA/Eberline Standard Operating Procedure EA3.4 - Operation of the Eberline Digital Ratemeter Scale (PRS-1).

3.2 UMTRA Procedure 10.17.3 - In-Situ Ra-226 Measurement Using the Shielded Delta Procedure.

3.3 Initial performance data sheet from TMA/Eberline Instrument Calibration Group.

3.4 Tinney, J.F. and Koch, J.J., An X-Ray Screening Meter for Plutonium Contamination, UCRL-5000-67-3, 1967.

4.0 DISCUSSION

The Field Instrument for the detection of low energy radiation (FIDLER) was developed in the 1960's as a portable instrument to monitor ground surfaces contaminated with plutonium. A five-inch diameter thin sodium iodide (NaI) crystal serves as the detector. It is optically coupled to a quartz light pipe and installed in a standard five-inch probe housing, which has an entrance window of beryllium. The principal use of this detector is for photons with energies less than about 75 KeV. Uranium is an alpha emitter, however the radiation from its daughter products include low energy photons, principally L x-rays from thorium. In the case of U-238, by far the predominant uranium isotope at

FMPC, there are two low energy photons from Th-234 which can be detected by the FIDLER. These are 63 KeV (3.5 percent abundant) and 93 KeV (4 percent abundant). If significant concentrations of natural thorium are present, radiation from Ac-228 will create interference in detecting the 93 KeV photon from Th-234. For this reason the instrument will be adjusted for maximum response from the 63 KeV photon from Th-234.

5.0 EQUIPMENT

5.1 Eberline digital ratemeter/scaler (PRS-1)

5.2 Bicron Corporation - FIDLER

5.3 AM-241 check source

5.4 Cables

6.0 INSTRUCTIONS

6.1 High Voltage Plateau

Before this instrument can be used to monitor low energy radiation in the field, it is necessary to determine the correct operating voltage. This is done by determining the plateau for background radiation, and for radiation from a source of Am-241 (60 KeV) whose intensity is several times greater than background radiation levels.

6.1.1 Inspect the FIDLER, PRS-1, and interconnecting cable for obvious damage. If no damage is observed, and before connecting the FIDLER and PRS-1, adjust the High Voltage to 900 volts or less, then turn PRS-1 selector switch to off.

6.1.2 Connect FIDLER to PRS-1 in an area which, from previous measurements, is known to exhibit background radiation. Turn PRS-1 selector switch to the H.V. setting and adjust the high voltage to 900 volts.

6.1.3 Place the FIDLER in a position so that a series of 0.5 minute counts can be made at various high voltage settings.

6.1.4 With the high voltage set at 900 volts, make three 0.5 minute readings and record in columns. When these three readings have been completed, adjust the high voltage upward 50 volts and repeat the three readings. Continue this procedure until three recordings have been made at a high voltage setting of 1400 volts.

6.1.5 Place a source of Am-241 approximately one inch from the beryllium entrance window near the center of the probe, and repeat the series of 0.5 minute readings for high voltage settings between 900 and 1400 volts. Example count rates for TWO FIDLER probes (No. 1 to be used at FMPC) are presented in Table B-1. Response for FIDLER 1 to Am-241 is given along with the response of FIDLER 2 to background and to U-238.

6.1.6 On x - y coordinate paper, plot the FIDLER response as a function of high voltage. Notice that between 1100 and 1300 volts there is little change in the detector's response. This represents the operating plateau. Set the PRS-1 High Voltage at the mid-point of the plateau (typically 1200 volts) for field operation. Minor fluctuations in the high voltage due to environmental conditions or battery drain will not affect the count rate. A typical plateau is shown in Figure B-1.

6.2 Daily Source Check

Following completion of 6.1.6, establish a fixed source-detector geometry such that the source-to-detector distance is a matter of record and reproducible from one day to the next.

6.2.1 Make five one minute counts with the Am-241 source in its check position. Record each count in the instrument log book.

6.2.2 Determine the standard deviation of the five one minute counts from 6.2.1. Record this value (σ) and three times the value (3σ) in the instrument log book.

6.2.3 A control chart will be prepared using information from the previous two steps. This chart will be prepared at the beginning of the site characterization, and will be used each day to record the FIDLER's response to the Am-241 source. On a piece of linear graph paper, place consecutive calendar dates on the x-axis. Define

a range along the y-axis which includes the average FIDLER source count ± 3 times the standard deviation. Draw three horizontal lines which intersect the y-axis at these three points.

6.2.4 On a daily basis, repeat step 6.2.1 before the FIDLER is used for field measurements.

6.2.5 Determine the average count rate and plot this value on the control chart for that day. If the average count rate falls within the boundary as defined in the step 6.2.3, the FIDLER may be used for field measurements. However, if the average count rate is not within the boundary, corrective action must be taken. Follow the instructions 6.2.6 through 6.2.11 if this is the case.

6.2.6 Check the PRS-1 calibration due date.

6.2.7 Check to see that the PRS-1 high voltage is not set at the plateau mid-point.

6.2.8 Turn off PRS-1 and disconnect cable to FIDLER. Clean the cable and chassis connectors with ethyl alcohol and let dry.

6.2.9 Re-connect cable, turn on PRS-1, check voltage setting.

6.2.10 Check source-to-detector distance and make necessary corrections.

6.2.11 Repeat steps 6.2.1 and 6.2.5. If FIDLER response is within average count rate ± 3 σ , the unit may be used. If the average count rate is still outside the control boundary, turn off the PRS-1 and use a substitute PRS-1. Repeat steps 6.2.1 and 6.2.5. If problems still exist, repeat instruction 6.1. Repeated failures will require attention by the manufacturer.

6.3 <u>Determine FIDLER Response to Background</u>

As part of the site characterization, several background locations will be selected in the vicinity of FMPC. The FIDLER response to radioactivity in the soil at each of these background locations will be determined.

6.3.1 At each background station, establish an area where measurements can be made with the FIDLER probe in

contact with the surface. Mark the location so that additional (or repeat) measurements can be made at later dates.

6.3.2 In a field logbook, describe the area chosen for background measurements and list specific features (soil is sandy, rocky, damp, wet, etc.). Also record climatic conditions at the time measurements are made.

6.3.3 Make five one minute counts and record in the field logbook.

6.3.4 When all background location measurements have been completed, compare the average count rate at each station with the concentration of uranium in soil samples collected at that point.

6.3.5 Prepare a table representing data from step 6.3.4.

6.4 Establish Field Calibration Factors for the FIDLER

The response of a FIDLER to radioactivity in soil is site specific and is governed by several parameters, such as the presence of radioactivity other than uranium, a layer of clean soil between a subsurface deposit or uranium and the ground surface, nearby radioactive sources such as radon in the air or a waste storage pit. Therefore, the field calibration factors determined in this instruction can only be considered an estimate. The use of this calibration serves as an indicator for the need to perform soil sample analyses.

6.4.1 Several areas within the waste management area where surface radioactivity is evident will be chosen as test areas. These should range from near background radiation levels to at least 10 times the background radiation level.

6.4.2 Perform five one minute measurements with the FIDLER in contact with the ground surface and record the count rate in a field logbook.

6.4.2 Collect a sample of surface soil (0-6 inch) and submit it to the field laboratory for a gamma-ray spectral analysis.

6.4.4 Following completion of the analysis of soil samples, compare the data from 6.4.2 to the soil concentration of uranium and prepare a table of values. An example of this type information is given in Table B-2 for data from a site contaminated with uranium.

6.4.5 Based on information from 6.4.4, establish a field calibration factor which represents an estimate or uranium concentration. Record this factor in the instrument logbook.

6.5 Use of a FIDLER to Scan Ground Surfaces

Surface scanning (whether on the ground, on equipment, or on building surfaces) with portable radiation detectors is normally carried out to determine: 1) the location of anomalous areas (radiation levels in excess of guideline values) within a measurement grid block or 2) the average radiation level within a measurement grid block. The scan of ground surfaces at FMPC will be carried out to determine the average estimated soil concentration of uranium within small areas which have been staked by a licensed civil surveyor. This will be accomplished by moving the FIDLER probe in a serpentine pattern over the area to be surveyed. During this scan, the detector will be held approximately 2 inches above the surface (although the beryllium window is protected by a thin layer of low density foam, care must be taken to protect the window during this operation).

6.5.1 Materials needed include:

1. FIDLER/PRS-1 detection system with headphones.

2. Plan view (site map) of the area to be surveyed, which includes grid system coordinates.

3. Calibrated measurement tape or chain.

4. Surface Measurements Field Logbook Forms

6.5.2 Determine that the FIDLER/PRS-1 system has been checked and is ready for field measurements.

6.5.3 Receive instructions from the WESTON Field Sampling Coordinator. These instructions should be specific as to: 1) area to be scanned, 2) the number of people

required (one technical to monitor and one to record data), 3) time requirements, and 4) special instructions.

6.5.4 Areas to be scanned could be level regular ground surfaces which have been subdivided into square grid blocks, or they could be located in a drainage path.

6.5.5 Grid block squares should be further subdivided into square grid blocks, the total area of which can be scanned in one-half or one-minute intervals. Areas 12.5 feet by 12.5 feet can be scanned in one-half minute. This task will be done using a calibrated measurement tape.

6.5.6 Drainage paths will have been staked at 100 foot intervals. Scanning these areas with a FIDLER can only be done if the area is free of standing or flowing water. If the area is dry, place a grid stake at 25 foot intervals between the 100 foot stakes.

6.5.7 Attach a Surface Measurements Field Logbook Form to a clipboard or other suitable writing surface, and mark the grid block coordinates in the boxes along the left and top margins (See Figure B-2 for an example of the logbook form with coordinate locations for scanning.)

6.5.8 Scan measurements will be recorded as integral counts over the area to be scanned. That is, pulses from the FIDLER will be summed for one-half minute or for one minute. Only grid blocks with 12.5 foot dimensions will be scanned in one-half minute periods. Turn the main selector switch of the PRS-1 to either 0.5 or 1 minute.

6.5.9 Scans will begin at one corner of a grid block and will progress in a serpentine pattern over the entire block, ending at the diagonally opposite corner of the block. Push the PRS-1 reset button as the scan begins. With practice, the timed count will end upon reaching the opposite corner. During the scan, the technician must listen to the audible signal from headphones. Although scanning speed should not be slowed when increased audible signals are heard, the presence of apparent "hot spots" should be noted when the integrated count for the scan is recorded.

6.5.10 Upon completion of the scan for an individual grid block, record the integrated count in its respective position on the Surface Measurements Field Logbook Form. Place a check mark above the recorded count to signify that anomalous or "hot spot" areas may exist on the basis of audible signals for that grid block.

6.5.11 When all grid blocks for each assignment have been completed, return signed Surface Measurement Logbook Forms to the Field Sample Coordinator and return the FIDLER/PRS-1 system to its storage area for end of day check out and preparation for the next day.

6.6 Use of the FIDLER to Estimate Soil Concentrations of Uranium

Based on the field calibration factor developed in Instruction 6.4, estimates of the concentration of uranium in soil may be made on the basis of in-situ measurements with the FIDLER resting on the ground surface for fixed periods of time. One must remember, however, that such an estimate is not exact and will be influenced by the presence of other gamma emitting radionuclides either in the soil or from nearby radiation sources. Accurate estimates of uranium in soil can only be made through the application of gamma-ray spectral or radiochemical techniques.

There are two situations where the FIDLER would be used to estimate the concentrations of uranium in soils: 1) at regular intervals on the overall site grid (i.e. intersections of mutually perpendicular grid lines spaced at 100 foot intervals), and 2) specific anomalous areas which were identified during the scan of subdivided grid block areas.

6.6.1 Materials needed include:

1. FIDLER/PRS-1 detection system with headphones.

2. Plan view (site map) of the area to be surveyed which includes grid system coordinates.

3. Calibrated measurement tape or chain.

4. Surface Measurements Field Logbook Forms.

6.6.2 Determine that the FIDLER/PRS-1 system has been checked and is ready for field measurements.

6.6.3 Receive measurement instructions from the WESTON Field Sampling Coordinator. These instructions should be specific as to: 1) the area(s) and total number of grid point measurements to be made, 2) a list of subdivided grid blocks from previous scan surveys which require further investigations to pinpoint anomalous areas, determine their boundaries, and estimate the concentrations of uranium, 3) the number of people required for the survey, 4) time requirements, and 5) special instructions.

6.6.4 Organize areas to be monitored so that measurements can proceed with a minimum of back tracking.

6.6.5 Attach a Surface Measurements Field Logbook Form to a clipboard or other suitable writing surface and mark the grid point coordinates in the boxes along the left and top margins (see Figure B-3 for an example of the logbook form with coordinate locations for grid point measurements).

6.6.6 Grid point measurements will be recorded as a single 0.5 minute count in the upper half of the square for a given grid point coordinate.

6.6.7 Proceed to the first grid point location and place the FIDLER probe on the surface.

6.6.8 Turn the main selector switch of the PRS-1 to 0.5 minute. Push the reset button to begin the count.

6.6.9 When the 0.5 minute count has ended, record the total count in the appropriate place on the surface Measurements Logbook Form.

6.6.10 After completion of 100 measurements (a full form), use a random number generator and repeat measurements at 10 percent of the grid points. Using the 10 block by 10 block matrix on the form, the top row represents positions 1 - 10, the second row 11 - 20, and so on. the random number generator is to be based on a total number of 100 location numbers.

6.6.11 The repeat measurements are for quality control purposes and these 0.5 minute counts will be recorded in the lower half of the square for a given grid point coordinate.

6.6.12 Organize individual subdivided grid blocks which, during the scanning survey, appeared to have anomalous radiation levels, into an efficient measurement sequence.

6.6.13 Use a single Surface Measurements Logbook Form to record measurements for an individual subdivided grid block. On this form, label the coordinates of the northwest corner of the grid block in the upper left and left top block reserved for grid coordinates as shown in Figure B-4.

6.6.14 Measurements are to be made using the PRS-1 in its microprocessor controlled counting mode. Turn the PRS-1 selector switch to the "C" position. This will adjust the PRS-1 to integrate a total of 1000 counts and, after a delay of 3 seconds, display the result in counts per minute. Record a total of nine "C" scale measurements in each grid block; at the corners, at mid-points along each side of the grid block, and in the center of the block (see Figure B-4 for an example).

6.6.15 When all measurements have been completed, return completed and signed Surface Measurement Logbook Forms to the Field Sampling Coordinator, and return the FIDLER/PRS-1 system to its storage area for end-of-day check out and preparation for the next day.

TABLE B-1

RESPONSE OF FIDLER DETECTORS

COUNT RATE AS A FUNCTION OF HIGH VOLTAGE

HIGH VOLTAGE	COUNTS PER MINUTE FIDLER 1 Am-241	FIDLER 2 BKG	FIDLER 2 U-238
400	7		
450	36		
500	100		
550	300		
600	502		
650	1030		
700	3300		
750	7370		
800	68800		
850	79800		
900	92000	5194	110312
950	115000	4790	124978
1000	125000	6010	130472
1050	128000	6222	133822
1100	129000	6198	135652
1150	130000	6370	138056
1200	131000	6356	139094
1250	132000	6326	139446
1300	134000	6300	139366
1350		6488	137990
1400		6570	136696

TABLE B-2

CALIBRATION OF FIDLER PROBE FROM FIELD MEASUREMENTS
AND LABORATORY ANALYSIS OF SOIL SAMPLES

SAMPLE ID	FIDLER (CPM)	LABORATORY (pCi/g)*
16	24872	170
17	13894	36
18	31688	73
19	41776	410
20	11799	32
21	14279	65
22	13545	61
23	17274	100
24	11466	44
25	10170	17

LINEAR REGRESSION: $Y = aX + b$

ARBITRARY DECISION - ELIMINATE SAMPLE 18 ON BASIS OF OTHER DETERMINATIONS (GROSS ALPHA, AND FIELD LABORATORY ANALYSIS)

$$Y = 80.6X + 9297$$

$R^2 = 0.99$
Y = FIDLER CPM
X = URANIUM pCi/g

FOR 35 pCi/g, Y = 12,118 CPM

INTERCEPT, b = 9297 REPRESENTS APPROXIMATE BACKGROUNG

* GAMMA-RAY SPECTROMETRY

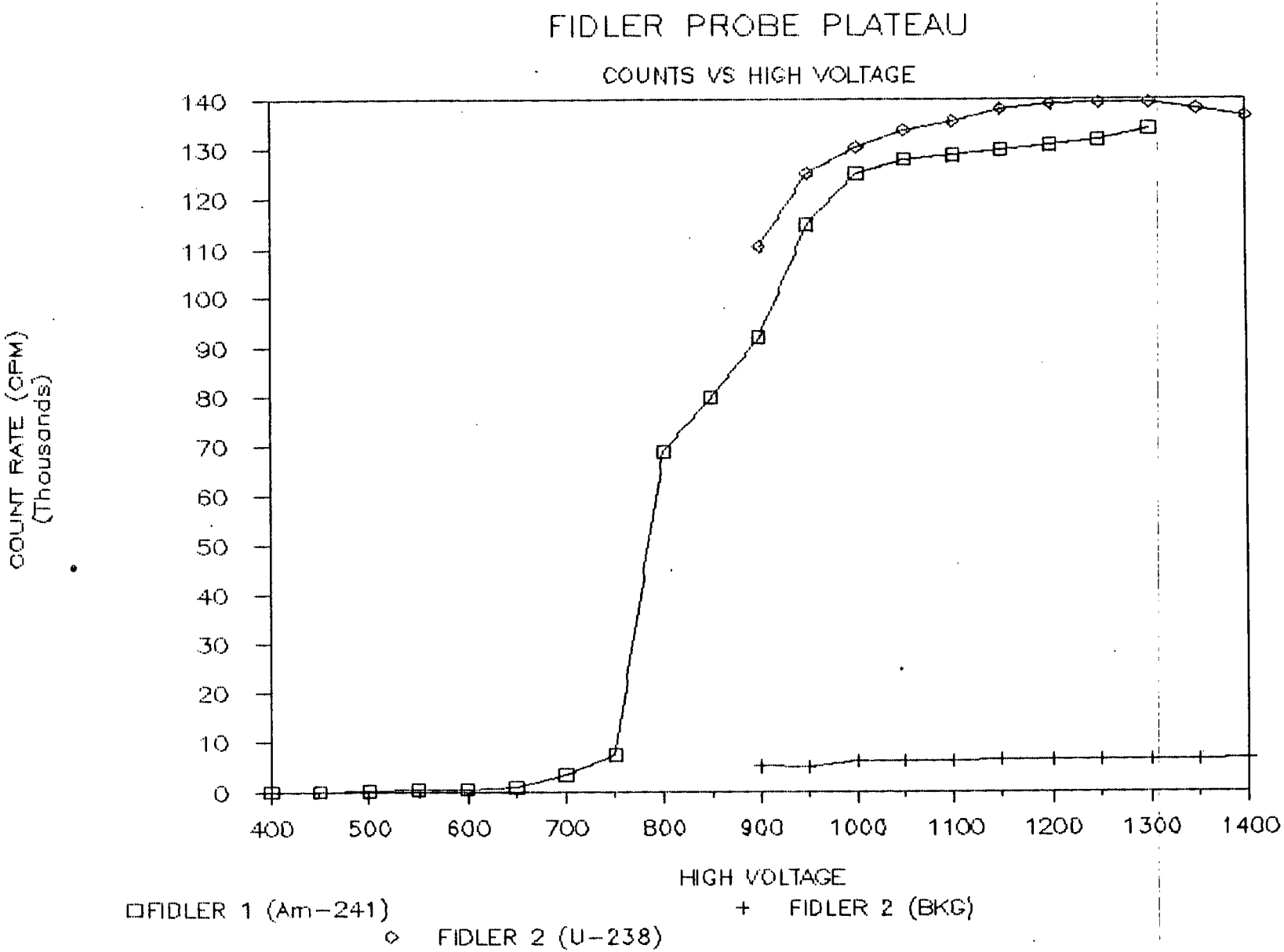
FIDLER PROBE PLATEAU
COUNTS VS HIGH VOLTAGE
COUNT RATE (CPM)
(Thousands)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
400
500
600
700
800
900
1000
1100
1200
1300
1400
HIGH VOLTAGE
FIDLER 1 (Am-241)
FIDLER 2 (U-238)
FIDLER 2 (BKG)

FIGURE B-1

SURFACE MEASUREMENTS FIELD LOGBOOK NO. 1 Page XX

Site: FMPC Surveyors: John Doe, Jane Doe

Area: Waste Management Recorder: John Doe

Legend: FIDLER SCAN Count Time: 0.5 MIN Bkg: FIDLER 9000 CPM

Date: 9-15-86 CPM

(-X)W ← COORDINATES → E(+X)

(-Y)S ↓ COORDINATES ↑ N(+Y)

	0	12.5	25	37.5	50	62.5	75	87.5	100	112.5
612.5										
600										
587.5										
575										
562.5										
550										
537.5										
525										
512.5										
500										

Comments: COUNTS RECORDED ABOVE REPRESENT THE INTEGRATED COUNT FOR A SCAN OF 12.5 X 12.5 FT. GRID BLOCKS LYING SOUTHEAST OF THE INDICATED GRID LOCATION

MET. CONDITIONS - CLOWDY, COLD, DAMP, WIND SW 0-5 MPH

Scaler Model PRS-1 Serial No. 26

Probe Model FIDLER Serial No. A617D

Scaler Model _____ Serial No. _____

Probe Model _____ Serial No. _____

PIC Serial No. _____

Notes: Comments must be made for specific grid location. Give coordinates of the location to which each comment applies.

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Figure B-2

Eberline SERVICES DIVISION

SURFACE MEASUREMENTS FIELD LOGBOOK NO. 2 Page XX

Site: FMPC Surveyors: John Doe, Jane Doe

Area: WASTE MANAGEMENT Recorder: Jane Doe

Legend: FIDLER GRID POINT / FIDLER GRID POINT (QC) Count Time: 0.5 MIN Date: 9-20-86 Bkg.: FIDLER- 9000 CPM / CPM

(-X)W ← COORDINATES → E(+X)

(-Y)S ↓ COORDINATES ↑ N(+Y)

	100	200	300	400	500	600	700	800	900	1000
1000	—	—	—	—	—	—	—	—	—	—
900	—	—	—	—	—	—	—	—	—	—
800	—	—	—	—	—	—	—	—	—	—
700	—	—	—	—	—	—	—	—	—	—
600	—	—	—	—	—	—	—	—	—	—
500	—	—	—	—	—	—	—	—	—	—
400	—	—	—	—	—	—	—	—	—	—
300	—	—	—	—	—	—	—	—	—	—
200	—	—	—	—	—	—	—	—	—	—
100	—	—	—	—	—	—	—	—	—	—

Comments: COUNTS RECORDED ABOVE REPRESENT 0.5 MIN COUNTS WITH FIDLER PLACED ON SURFACE AT INDICATED GRID POINT

MET. CONDITIONS - CLEAR, WARM, LIGHT WIND, DRY

Scaler Model PRS-1 Serial No. 26
Probe Model FIDLER Serial No. A617D
Scaler Model _____ Serial No. _____
Probe Model _____ Serial No. _____
PIC Serial No. _____

Notes: Comments must be made for specific grid location. Give coordinates of the location to which each comment applies.

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Figure B-3

Eberline SERVICES DIVISION

SURFACE MEASUREMENTS FIELD LOGBOOK NO. 2 Page ~~XX~~ 776

Site: FMPC Surveyors: John Doe, Jane Doe

Area: Waste Management Recorder: Jane Doe

Legend: FIDLER ON SURFACE Count Time: "C" scale Bkg: FIDLER 9000 CPM

Date: 9-30-86 CPM

NORTHWEST CORNER

(-X)W ← COORDINATES → E(+X)

(-Y)S ← COORDINATES → N(+Y)

	100									
587.5	COUNT				COUNT				COUNT	
	COUNT				COUNT				COUNT	
	COUNT				COUNT				COUNT	

Comments: PRS-1 SET ON "C" SCALE

	100		1125
587.5	X	X	X
	X	X	X
575	X	X	X

MET. CONDITIONS - CLEAR, NOT, DRY, CALM

Scaler Model PRS-1 Serial No. 26

Probe Model FIDLER Serial No. A617D

Scaler Model _____ Serial No. _____

Probe Model _____ Serial No. _____

PIC Serial No. _____

Notes: Comments must be made for specific grid location. Give coordinates of the location to which each comment applies.

Figure B-4

Eberline SERVICES DIVISION

IN-SITU GAMMA RAY MEASUREMENTS USING A SHIELDED DELTA-GAMMA PROCEDURE

IN-SITU GAMMA RAY MEASUREMENTS USING THE DELTA-GAMMA TECHNIQUE

1.0 PURPOSE

The purpose of this procedure is to provide guidance for the in-situ measurement of gamma-rays emitted from surface soil, and to provide a technique for screening potentially contaminated soils in the presence of adjacent sources of air scattered gamma radiation.

2.0 SCOPE

These procedures were developed for the Uranium Mill Tailings Remedial Action (UMTRA) Program for measuring in-situ Ra-226 concentrations in soil where adjacent sources of radiation influence have probe measurements. This procedure will be based on the above procedures and will be used to screen for anomalous gamma radiation levels in areas where adjacent sources of radiation influence the use of an unshielded probe.

3.0 REFERENCES

3.1 UMTRA Calibration Data Sheet - Delta Instrument

IN-SITU RA-226 MEASUREMENT USING THE SHIELDED DELTA PROCEDURE, UMTRA PROCEDURE 10.17.3

4.0 EQUIPMENT

4.1 Shielded Delta Housing Built by WESTON, Inc.
4.2 Eberline PRS-1 Portable Ratemeter/Scalers
4.3 Eberline SPA-3 NaI Detector
4.4 Am-241 Check Source

5.0 DISCUSSION

Screening of soils in areas of elevated gamma-ray intensity will be based on the results of the delta-gamma technique described below. This survey technique will provide a basis for detecting anomalous conditions in the soil below the measurement location.

To provide a statistical basis for evaluating gamma-ray measurements of potentially contaminated locations as a function of site background levels, twenty background delta measurements will be taken. The average background delta count and its standard deviation will be determined. Measurements subsequently taken

during the field work that have a delta count greater than the average background plus three standard deviations of the background will be marked, and the area will be further characterized by taking additional delta-gamma measurements and following the surface soil sampling protocol.

Figure B-5 presents a field data sheet to be used in the laboratory for documenting background delta-gamma results, and to calculate the average and standard deviation of the background data. Figure B-6 provides a field data sheet to be used for documenting field delta-gamma measurements.

The delta-gamma calibration will be peformed at the UMTRA Project Laboratory. The calibration factor will account for Th-232 and K-40 concentrations. It will initially be developed for estimating in-situ Ra-226 concentations. Site specific calibration constants can be developed by performing delta counts at various locations having a uniform increase in surface radiation levels. At each location, a surface soil sample will be obtained and analyzed for gamma emitting radionuclides. From this data, a correlation of delta count rate to gamma-ray contributing radionuclide concentrations can be established.

6.0 INSTRUCTIONS

6.1 Daily before each sampling exercise, check the high voltage (as stated on detector probe), threshold setting (100), window setting (gross mode) and battery conditions (BAT indicator off) on the Eberline PRS-1 ratemeter/scaler.

6.2 The measurement of in-situ gamma radiation is performed by making "up" (shield out) and down (shield in) counts over the area to be characterized.

6.3 With the shield out, make and record 3 up counts with the PRS-1 set to integrate 1000 counts ("c" scale). When 1000 counts have been registered, the PRS-1 will calculate the count rate (CPM) and display the value. Record each value on the field data sheet. With the shield in, make and record 3 down counts in the same fashion. Record each value on the field data sheet.

6.4 Compare the sample delta to the average background delta plus three standard deviations of the background delta. If the former is greater than the latter, the location will be staked and the areal extent of material further characterized by making additional delta-gamma measurements, and by obtaining surface soil samples.

FIGURE B-5

SHIELDED DELTA - GAMMA IN-SITU MEASUREMENT
FMPC BACKGROUND ASSESSMENT

Job No.:_____ Recorded By:_____
Date:_____ Time:_____
Delta Housing No.:_____ Daily Check Results:
Probe No.:_____ HV_____(1000V) Threshold_____(100)
PRS-1 No.:_____ BAT_____(OK) WINDOW _____(OUT)

Check Source No.:_____ Check Location:_____

Up	C_{1*}_____	C2_____	C_3 _____	Avg. Up _____
Down	C_{1*}_____	C2_____	C_3 _____	Avg. Down _____
Delta	1 _____	2_____	3_____	Avg. Delta_____

Bkg. Meas.	Location	UP C_1*	UP C_2	UP C_3	DOWN C_1*	DOWN C_2	DOWN C_3	Delta
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Average _____
Std Dev. _____
Average + 3 Std. Dev._____

*Each count represents the counts per minute based on integration of 1000 cts on the "C" scale of an Eberline PRS-1 ratemeter/scaler.

FIGURE B-6

SHIELDED DELTA-GAMMA IN-SITU MEASUREMENTS
FMPC FIELD RADIATION MEASUREMENTS

Job. No._____ Recorded by:_____

Delta Housing No. _____ Calibration factor:_____

Probe No.:_____ Comments:_____

PRS-1 No.:_____ _____

FIELD MEASUREMENTS

Measurement Location		Up Counts (CPM)			Down Counts (CPM)			Average Delta	Location for Further Consideration	
N	E	C_1	C_2	C_3	C_1	C_2	C_3	KCPM	Y	N

BETA-GAMMA EXPOSURE RATE SURVEY

Attachment 1 OPERATION OF THE EBERLINE DIGITAL RATEMETER SCALER, PRS-1

Attachment 2 OPERATION OF THE EBERLINE HP-210 OR HP-260 PANCAKE-GEOMETRY GEIGER DETECTOR

1.0 PURPOSE

The purpose of this procedure is to ensure beta-gamma surface exposure rates are determined in a reproducible manner.

2.0 SCOPE

This procedure describes the methodology for determining surface exposure rates due to beta-gamma radiation to levels approaching natural background (above 0.01 mrad/hr.)

3.0 REFERENCES

3.1 EA2.1, General Area Decontamination Monitoring.

3.2 EA3.4, Operation of the Eberline PRS-1, Digital Ratemeter Scaler.

3.3 EA3.6, Use of the Eberline HP-210, Pancake Geometry Geiger Detector.

4.0 EQUIPMENT AND MATERIALS

4.1 Thin Window GM Probe (Eberline HP-210 or Equivalent).

4.2 Ratemeter Scaler (Eberline PRS-1 or Equivalent).

4.3 Beta-Gamma Exposure Rate Survey (Form Figure B-7).

5.0 INSTRUCTIONS

5.1 Insure proper instrument operation per instruction EA3.4 and EA3.6 (attached).

5.2 Beta-Gamma exposure rates shall be measured at grid intersections.

NOTE: Beta-gamma exposure rates may be measured at other locations within the area if deemed appropriate, for example, at points identified as hot spots.

5.3 Place the HP-210 probe on the surface at the grid point.

CAUTION: The thin window of the HP-210 probe may be easily punctured. Care should be taken to protect the window from sharp objects on the surface.

5.4 Take a count of predetermined duration (0.5 to 2 minutes).

5.5 Multiply the count by the calibration factor to determine dose rate in mrad/hr and record in Figure B-7.

5.6 Complete the information on top of Figure B-7 before initiating the survey.

FIGURE B-7

BETA - GAMMA EXPOSURE RATE SURVEY

Site _____ Location _____

Date _____ Survey No. _____ Surveyor _____

Instrument and Probe

Scaler model _____

Serial No. _____

Probe model _____

Serial No. _____

Background

_____ cpm

Calibration Factor

_____ mrad/hr/cpm

Count Time

_____ min.

Efficiency

_____ cpm/dpm

GRID POINT	CPM	mrad/hr	GRID POINT	CPM	mrad/hr

OPERATION OF THE EBERLINE DIGITAL RATEMETER SCALER PRS-1 (EA3.4)

1.0 PURPOSE

The purpose of this instruction is to describe the use and operation of the PRS-1 Digital Ratemeter Scaler

2.0 SCOPE

This instruction describes the operation of the Eberline digital Ratemeter Scaler (PRS-1). Repairs to equipment will be accomplished at Eberline Analytical Corporation, Albuquerque, New Mexico.

3.0 REFERENCES

Eberline Technical Manual, PRS-1

4.0 EQUIPMENT AND MATERIALS

4.1 Eberline PRS-1 (Digital Ratemeter Scaler).

4.2 Eberline HP-210 Pancake GM Probe.

4.3 Eberline AC-3 Alpha Scintillation Probe.

5.0 DESCRIPTION

The PRS-1, sometimes called the "RASCAL", is a portable digital display instrument with selectable ratemeter or scaler functions. The instrument is rugged and splashproof with its own internal battery power supply. Incorporated into the PRS-1 are the following features:

5.1 Variably high voltage power supply (500 to 1500 volts).

5.2 Pulse height amplifier for single channel pulse height analyses.

5.3 Six decade liquid crystal display.

5.4 Crystal controlled time base.

5.5 Built-in speaker and earphone jack.

5.6 Pack "D" cell battery.

5.7 Internal multiplier or divider calibration functions which provide a means of converting counts to detector units (mr/hr, uR/hr, mRad/hr, etc.) and for correction of probe efficiency.

6.0 INSTRUCTIONS

Operational checks shall be performed daily prior to use of equipment as follows:

6.1 Visually check for external dirt, corrosion and damage. Clean the instrument or return for repair as required.

6.1.1 Battery Check:

A. Turn function switch to the rate mode.

B. Turn speaker on.

C. Reduce threshold to zero for maximum speaker noise.

D Turn light on.

E. If the ERROR legend comes on or the "Batt. OK" legend is OFF, have the batteries replaced by a qualified technician.

6.1.2 Check reset function.

6.1.3 Check time base on one scaler mode preset time.

6.1.4 High Voltage Check:

A. Put function switch in H.V. position.

B. Vary the H.V. potentiometer setting.

C. The high voltage should vary from 400 to 1400 volts.

D. Turn the functional switch to OFF.

6.2 Detector Probe Operational Check:

6.2.1 Visually check the detector probe, probe cable and cable connection for dirt, corrosion or damage.

6.2.2 Check for noisy cable by flexing cable with PRS-1 in an operational mode. Repair or replace as needed.

OPERATION OF THE EBERLINE HP-210 OR HP-260 PANCAKE-GEOMETRY GEIGER COUNTER (EA3.6)

1.0 PURPOSE

This instruction describes the operation of the HP-210 or HP-260 probes coupled to the Eberline PRS-1 Ratemeter Scaler.

2.0 SCOPE

The HP-210 or HP-260 probes are rugged, pancake-geometry geiger tubes designed for detecting beta radiation. The HP-210 or HP-260 probes are capable of detecting gamma radiation and high energy alpha radiation. However, the gamma detecton efficiency is low and the detection efficiency for alpha particles is a function of the window thickness and the alpha energy.

3.0 REFEENCES

3.1 Eberline Technical Manual, HP-210 or HP-260 Probe.

3.2 EA-3,4 Opeation of the Eberline digital Ratemeter Scaler, PRS-1.

4.0 EQUIPMENT AND MATERIALS

4.1 Eberline HP-210 or HP-260 Probe.

4.2 Eberline PRS-1 Survey Instrument.

4.3 SrY-90 Sources (standard and check sources).

4.4 Field Source Check Form (Form EA3.5-1).

4.5 Instrument Log Book.

5.0 DESCRIPTION

The Model HP-210 or HP-260 probes are rugged, sensitive detectors for monitoring beta and gamma radiation with a limited efficiency for alpha radiation. The HP-210 or HP-260 utilizes a thin window G-M tube with a large open area protected by a sturdy wire screen which allows detection of beta particles for energies greater than 40 KeV. The HP-210 and HP-260 specfications are:

5.1 Active probe face area 15.5 cm^2.

5.2 Mica window thickness of 1.4 to 2.0 mg/cm.

5.3 Operating voltage: 900 $\pm$ 50V.

5.4 Connector: BVC series coaxial.

5.5 Size: 6-1/2 inches long x 3-1/2 inches wide x 3-7/8 inches high and wighs 4.25 pounds.

5.6 Sensitivity through window:

5.6.1 Gamma: approximately 3600 cpm/mr/hr using Cs-137.

5.6.2 Beta: approximately 20% of 4 pi emission for SrY-90 rate.

5.6.3 Beta: approximately 15% of 4 pi emission for TC-99 rate.

5.6.4 Alpha: approximately 5% of 4 pi emission rate.

5.6.5 Alpha: approximaely 2.5% for Th-230.

5.7 Removal of screen will increase efficiencies approximately 40% for alpha and beta's.

5.8 Plateau length: 100V.

5.9 Plateau slope: 0.1% per volt.

5.10 Operating temperature range: -30° to $+75^{\circ}$C.

6.0 DAILY FIELD RESPONSE CHECKS

Beginning of each shift or use period:

6.1 Take a 1 to 3 minute background count to insure probe is not contaminated. If count rate is greater than 50 cpm, decontaminate or repair the probe.

6.2 Take a 1 to 3 minute beta source count using a SrY-90 check source. If the beta sensitivity varies by $\pm$20% from the source value, the detector shall be recalibrated or repaired.

6.3 All results of routine daily field checks shall be entered on the field Source Check Form (Form EA3.5-1) or Instrument Log Book.

7.0 OPERATION

7.1 The HP-210 or HP-260 probe is capable of detecting alpha, beta and gamma radiation.

7.2 The HP-210 or HP-260 may be used as a hand probe for direct surface readings or as a single counter when used with Model Sh-4A sample holder.

7.2.1 When using the HP-210 or HP-260 probe to measure low level direct contamination, calibration should be made with the probe setting direction on the SrY-90 (or other suitable) source.

7.2.2 When using HP-210 or HP-260 with the SH-4A, the source should be placed in the sample drawer and counted. Use the same method as described in Step 6.2 for determing counter efficiency, etc.

NOTE; Always subtract background from observed readings unless relative high (>20 times bkg) measurements are being made.

Form EA-3.5-1

FIELD SOURCE CHECK FORM

Date _____

Site _____ Area _____

Data Recorded by _____

Scaler Model No. _____ Serial No. _____ H.V. Set _____

Probe Model No. _____ Serial No. _____ Efficiency _____

Scaler Model No. _____ Serial No. _____ H.V. Set _____

Probe Model No. _____ Serial No. _____ Efficiency _____

Count Time _____

Time	Location	AC-3 Th-230			HP-210 SrY-90			
		Gross Count	Gross Bkg	Net Count	Gross Count	Gross Bkg	Net Count	

AC-3 Tolerance _____ To _____

HP-210 Tolerance _____ To _____

Was HV checked this morning? Yes ____ No ____

Th-230 Source: Serial No. _____ DPM _____

SrY-90 Source: Serial No. _____ DPM _____

EXPOSURE RATE MEASUREMENTS USING A PRESSURIZED ION CHAMBER

1.0 PURPOSE

The purpose of this instruction is to ensure uniform measurement techniques when using a secondary standard instrument, the pressurized ion chamber, for determining external gamma exposure rate at a height of one meter above the soil or facility surfaces.

2.0 SCOPE

One of the most accurate methods for measuring the gamma radiation exposure rate in the field is with a secondary standard instrument such as the Reuter-Stokes pressurized ion chamber (PIC). The PIC will be used to "field calibrate" or standardize other exposure rate measuring instruments such as the SPA-3 or hand-held scintillation instruments.

3.0 REFERENCES

3.1 Reuter-Stokes PIC Operational Manual.

3.2 EA-2.1, General Area Decontamination Monitoring.

4.0 EQUIPMENT AND MATERIALS

4.1 Reuter-Stokes Pressurized Ion Chamber.

4.2 Stop Watch.

4.3 Gamma-Ray Exposure Rate Survey (Figure B-8).

5.0 INSTRUCTIONS

5.1 Ensure proper operation of the PIC per operational manual.

5.2 Place the PIC in the center of the survey grid block per instruction EA-2.1.

5.3 Instrument Setup

5.3.1 Attach sensor head to tripod.

5.3.2 Adjust height of the chamber to one meter from the surface to be measured.

CAUTION: Ensure electrometer and mode switches are both in the OFF position.

5.3.3 Connect cable to read-out housing.

5.3.4 Turn DISPLAY/RECORDER switch to ON.

A. Turn ELECTROMETER switch to zero.

B. Turn MODE switch to BATT position

C. Simultaneously depress the PUSH-TO-READ switch (located below digital display device) and the switch designated 300 V.

D. If the digital display shows less than 85 (as a percent of charge) replace 300 V battery per procedure EA-3.22.

5.3.5 Check the charge on the -14V, +14V and 12V lead-acid batteries by depressing switch immediately below the voltmeters for each battery. If the needle is on or near the shaded area of the meter, recharge these batteries before proceeding.

5.3.6 Place the MODE switch in the DC position.

5.3.7 Place the ELECTROMETER switch in the ZERO position, wait 60 seconds.

5.3.8 Place the ELECTROMETER switch in the READ position.

5.3.9 Turn the recorder ON.

5.3.10 Reset the mechanical counter and start the stopwatch simultaneously.

5.3.11 After 10 minutes, or until the counter integrates 1.0 uR, record elapsed time and exposure.

5.3.12 Determine exposure rate in microR/hr (uR/hr) using the following formula:

$$\frac{\text{60 minutes/hr.}}{\text{count time minutes}} \times \text{exposure recorded by PIC}$$

The resulting value is in uR/hr.

5.3.13 Record the exposure rate in Figure B-8.

GAMMA-RAY EXPOSURE RATE SURVEY

Site _____ Location _____

Date _____ Survey No. _____ Surveyor _____

Instrument and Probe

Scaler model _____

Serial No. _____

Probe model _____

Serial No. _____

Background

_____ cpm

Calibration Factor

_____ μR/hr/cpm

Count Time

_____ min.

Comments: _____

GRID POINT	μR/hr	GRID POINT	μR/hr	GRID POINT	μR/hr	GRID POINT	μR/hr

Figure B-8

PROCEDURE FOR CORRELATING A SODIUM IODIDE DETECTOR TO THE PRESSURIZED IONIZATION CHAMBER

PROCEDURE FOR CORRELATING A SODIUM IODIDE DETECTOR TO THE PRESSURIZED IONIZATION CHAMBER (PIC)

1.0 PURPOSE

By correlating scintillation-detector measurements with accurate PIC measurements on a site-specific basis, correction factors can be determined and applied to the scintillation detector measurements to evaluate gamma exposure rates. This procedure permits the use of less expensive portable instruments to obtain exposure rate survey data.

2.0 SCOPE

This procedure describes the methodology for correlating counts obtained using an Eberline SPA-3 coupled to a ratemeter/scaler to the exposure rate measurements taken with the PIC.

3.0 REFERENCES

3.1 Reuter-Stokes PIC Operational Manual

3.2 EA 2.8 Operation of the Eberline SPA-3, Gamma Scintillation Probe

3.3 EA3.4 Use of the PRS-1 Digital Ratemeter Scaler

4.0 EQUIPMENT AND MATERIALS

4.1 SPA-3, Gamma Scintillation Probe
4.2 PRS-1, Pulse Ratemeter Scales
4.3 Reuter-Stokes Pressurized Ion Chamber

5.0 INSTRUCTIONS

5.1 The correlation is performed using 5 to 20 locations ranging in activity from normal background to about 100 microR/hr. There will be several areas at the FMPC where these correlations will be performed. They will be chosen as to subdivide the Waste Storage Area into regions where, within the region, there should not be a varied photon spectrum. The measurement locations should be chosen so that the exposure rate does not vary with slight differences in positioning of the two detectors. Measurements will be

taken alternately at each location with both instruments at approximately three feet off the the ground. Results will be recorded on the Site-Specific Exposure Rate Correlation Form (Figure B-9).

5.2 After performing measurements at a sufficient number of locations, the readings from both instruments will be correlated using a least square regression. The regression equation will have the form

$$E = a(Em) + b$$

where:

E is the PIC reading in micro R/hr.

a is the slope of the line

Em is the scintillation reading in counts per time interval,

b is the Y-axis intercept.

EXPOSURE RATE CORRELATION DATA
ENTRY FORM - SITE-SPECIFIC

Site _____ Location _____

Date _____ Survey No. _____ Surveyor _____

Location		PIC # _____		Inst # ___	Inst # ____
North	East	Sec	MR/hr	CPM	CPM
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					

FIGURE B-9 EXPOSURE RATE CORRELATION DATA FORM

APPENDIX C

PROCEDURES FOR SCREENING SOIL SAMPLES FOR ALPHA EMITTING RADIONUCLIDES

1.0 PURPOSE

The purpose of this procedure is to provide a method of screening for alpha contributing radionuclides in soil samples.

2.0 SCOPE

This guidance describes the methodology for screening of various alpha emitting radionuclides in soil samples. It provides a statistical analysis to determine if a particular sample is contaminated with levels above background concentrations.

3.0 REFERENCES

3.1 Ludlum Model 43-1 Operations Manual.
3.2 Ludlam Model 2220 Portable Scales Operations Manual.
3.3 WESTON Procedure 20.14.1 Alpha Detector Efficiency Calibrations.

4.0 EQUIPMENT

4.1 Ludlam Model 43-1 Alpha Scintillation Probe
4.2 Ludlam Model 2220 Portable Scaler
4.3 Bottom half of Plastic Petri Dish (1.5 cm high, 10 cm diameter, volume of 117 cm^3)
4.4 Myler Film having Thickness of 100 ug/cm^2
4.5 Thick Plastic Sandwich Bags
4.6 Heat Lamp
4.7 Small Trowel
4.8 Paper Towels
4.9 Th-230 Check Source

5.0 DISCUSSION

Screening for alpha emitting radionuclides (i.e., Th-230) in soil samples will be based on the results of the procedures detailed below. Samples that show significant alpha activity in the absence of low level gamma radiation as screened using the FIDLER, and absent of higher energy gamma radiation as screened using gamma spectrometry will be included for outside laboratory analysis.

To provide a statistical basis for evaluating sample alpha count data as a function of background alpha count data, ten background soil samples will be taken, prepared and counted as discussed below. The average and standard deviation of the background alpha count will be determined. Samples subsequently counted that have a ten minute count greater than the average background

plus three standard deviations of the background will be included for outside laboratory analysis.

Figure C-1 provides a Field data sheet to be used in the laboratory for documenting background results and calculating the average and standard deviation of the background count rate dates. Figure C-2 provides a field data sheet to be used by the laboratory to document sample analysis.

6.0 INSTRUCTIONS

6.1 Switch the instrument on. Check the batteries for adequate power, and perform a field check of the instrument. Maintain that the instrument is within calibration due-date.

6.2 A small aliquot of the sample shall be taken and placed into two overlapping plastic sandwich bags using the small trowel. Seal the bags and thoroughly mix the material by hand, being sure to break up any large clods.

6.3 When the sample is uniformly mixed, transfer it into the bottom of a clean petri dish and place it under the heat lamp. Make sure there is enough sample so that when dry, it will mound over the flange of the petri dish.

6.4 When the sample is dry, use the lid of the petri dish to press down on the top of the sample and smooth out the surface until it is flush with the top of the container. Discard the petri dish used for smoothing the sample into a depository for potentially contaminated waste.

6.5 Put a single layer of the mylar film over the sample, and place the detector so that it is centered over the sample.

6.6 Count the sample for ten minutes. Record the accumulated counts on the Gross Alpha Counting Data Sheet (Figures C-1 and C-2)

6.7 Compare the sample counts to the average background count plus three standard deviations of the background count as described on Figure 2.0. If the former count data is greater than the latter, then the sample shall be included for outside laboratory analysis.

6.8 Transfer the sample in the petri dish back into the original sample container and mark the entire sample as includable for outside laboratory analysis. If not includable, place it back into archive.

FIGURE C-1 GROSS ALPHA SCREENING FIELD LOG - BACKGROUND EVALUATION

Site _____ Job No. _____ Lab Technician _____

Date _____

Instrument No. _____

Probe No. _____

Calibration Due _____

Source Check _____

Sample	Location	10 Minute Count
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Average _____

Standard Deviation _____

FIGURE C-2

GROSS ALPHA SCREENING FIELD LOG

Site _____ Job No. _____ Lab Technician _____

Sample Location _____ Grid No. _____

Date _____ Instrument No. _____

Comments _____ Probe No. _____

_____ Calibration Due _____

_____ Source Check _____

_____

10 Minute Count _____

Background + 3 (Standard Deviations) _____

Sample Included For Outside Laboratory Analysis - Yes/No (circle one).

APPENDIX D

GUIDE TO THE HANDLING PACKAGING AND SHIPPING OF FMPC SAMPLES

ATTACHMENT 1 - ASSIGNMENTS OF A_1 AND A_2 QUANTITIES FOR LEAD 214, BISMUTH-214, AND POLONIUM-214

1.0 SAMPLE HANDLING, TRANSPORT AND STORAGE

Samples collected during site characterization operations will have to be transported to laboratories in New Mexico and Pennsylvania for analysis. The transportation of samples must be accomplished not only in a manner designed to protect the integrity of the sample, but also to prevent any detrimental effects from the potentially hazardous nature of the samples. Regulations for packaging, marking, labeling and shipping of hazardous material, hazardous substances and hazardous wastes are promulgated by the U.S. Department of Transportation (DOT) and described in the Code of Federal Regulations (49 CFR 171 through 177, in particular, 172.402h, Packages Containing Samples). In general, these regulations were not intended to cover the shipment of samples collected at hazardous waste sites. However, the U.S. EPA has deemed it prudent to package, mark, label, and ship samples observing these DOT procedures. The information contained in this appendix is for general guidance and, although factual, should not be misconstrued as identical to DOT regulations for transportation of hazardous materials.

Samples collected at the FMPC site shall be classified as either environmental or hazardous substances (or wastes) samples. In general, environmental samples are collected off-site such as water samples from the various drainages and are not expected to be grossly contaminated with high levels of toxic substances. Samples of soil or water from certain locations in the Waste Storage Area will be considered hazardous substances. A distinction between the two types of samples, environmental and hazardous, must be made for two major reasons: one, to determine the appropriate procedures for the transportation of the samples; secondly, to protect the health and safety of the laboratory personnel receiving the samples. Special precautions, procedures and secondary containment areas within laboratories will used when samples other than environmental samples are received. If there is any doubt as to the classification of a sample, it will be considered a hazardous sample and shipped accordingly.

1.1 Environmental Samples

Samples judged to be environmental are not considered hazardous material; however, environmental samples will be packaged and shipped according to the following procedures.

1.1.1 Packing

Environmental samples can be packaged following the procedures for samples classified as "flammable liquids" or "flammable

solids. Marking, labeling,, and shipping papers do not apply. Environmental samples can also be packaged without being placed inside metal cans as required for "flammable liquids". Sample containers properly identified and with a sealed lid, in sealed polyethylene bags, can be packed in fiberboard containers or metal picnic cooler-type containers. Sufficient incombustible, absorbent cushioning material will be used to minimize the possibility of sample container breakage.

1.1.2 Marking and Labeling

Sample containers must have a completed sample identification tag. The outside container should be marked "Environmental Sample." No DOT marking and labeling is required.

1.1.3 Shipping Papers

No DOT shipping papers are required.

1.1.4 Transportation

There are no DOT restrictions on mode of transportation.

1.2 HAZARDOUS SUBSTANCE SAMPLES

FMPC samples not determined to be environmental samples or samples known or expected to contain hazardous material must be considered hazardous substance samples and transported according to the following requirements. If the material in the sample is known or can be identified, then it should be packaged, marked, labeled and shipped according to the specific instructions for that material (if listed) found in the DOT Hazardous Materials Table, 49 CFR 172.101. For those samples of hazardous substances where the contents are unknown, the selection of the appropriate transportation category will be based upon the DOT Hazardous Material Classification, a prioritized system of transportation categories. This system is presented in Table D.1

Eliminating other substances as flammable liquids requires flashpoint testing which is impractical and possibly dangerous at a site.

Unless it is demonstrated that the sample consists of material listed below flammable liquid on the table, it is to be considered a flammable liquid (or solid) and shipped as such.

TABLE D.1

DOT HAZARDOUS MATERIALS CLASSIFICATION

1. Radioactive Material
2. Poison "A"
3. Flammable Gas
4. Non-Flammable Gas
5. Flammable Liquid
6. Oxidizer
7. Flammable Solid
8. Corrosive Materials (liquid)
9. Poison B
10. Corrosive Material (solid)
11. Irritating Materials
12. ORM-E
13. Combustible liquid (in containers having capacity exceeding 110 gallons)
14. ORM-B
15. ORM-A
16. Combustible liquids (in containers having capacity of 100 gallons or less)

The selection of the correct category for an unknown sample is through the process of elimination utilizing the DOT classification system. Unless known or demonstrated otherwise (through the use of radiation survey instruments), the sample will be considered radioactive and appropriate shipping regulations for radioactive material will be followed. If radioactive material is eliminated the sample will be considered to contain Poison "A" materials, the next material on the list. Poison "A" is defined by DOT as extremely dangerous poisonous gases or liquids of such a nature that a very small amount of gas, or vapor of the liquid, mixed with air is dangerous to life. The class "A" poisons listed in 49 CFR 172.101 and their physical state at normal temperatures are presented in Table D.2.

TABLE D.2

CLASS "A" POISONS AND THEIR PHYSICAL STATE AT ROOM TEMPERATURES

Compound	Physical State
arsine	gas
bromoacetone	liquid
chloropicrin & methyl chloride mixture	gas
chloropicrin & non-flammable, non-liquified compressed gas mixture	gas
cyanogen chloride	gas at temperature greater than 13.1oC
cyanogen gas	gas
gas identification set	---
gelatin dynamite (H.E. Germaine)	---
grenade (with poison "A" gas charge)	---
hexaethyl tetraphosphate & compressed gas mixture	gas
hydrocyanic acid (prussic solution)	liquid
hydrocyanic acid, liquified	gas
insecticide liquified gas, containing poison "A" or poison "B" materials	gas
methyldichloroarsine	liquid
nitric acid	gas
nitrogen peroxide	gas
nitrogen tetroxide	gas
nitrogen dioxide, liquid	gas
parathion & compressed gas mixture	gas
phosgene (diphosgene)	liquid

If poison "A" is eliminated as a shipment category, the next two classifications are "flammable" and "non-flammable" gases. Since few gas samples are collected, flammable liquids would be the next category. The elimination of the classification of radioactive, Poison "A", flammable gas, and non-flammable gas which require more stringent shipping procedures, then permits the sample to be classified as flammable liquid (or solid) and shipped accordingly. The shipping requirements for flammable liquids would also suffice for shipping any other samples classified below flammable liquids on the DOT classification schedule. For samples containing unknown materials, other categories listed below flammable liquids/solids on the table, are generally not considered because:

1.2.1 Samples Classified as Radioactive (TMC, GJ/TMC-13 U-70A)

The Federal regulations governing the transport of radioactive sample material are extremely complex and reflect overlapping jurisdiction from many Federal agencies. The important features of the Department of Transportation regulations (49 CFR 173, dated 1 November 1983) are summarized with their application to samples contaminated with uranium and associated daughter radionuclides.

In general, most samples collected at the FMPC will not be classified radioactive for transport purposes and will therefore require no special attention to be considered in compliance. On the other hand, certain samples may fall into categories for which special packaging and shipping restrictions are mandated. Guidelines for determining the category to which a particular sample shipment belongs and for selecting a suitable mode of shipment and appropriate packaging are described below:

1.0 DEFINITIONS

The following definitions are summarized from those presented in 49 CFR 173.403:

Natural Thorium - Thorium characterized by the naturally occurring distribution of thorium isotopes (essentially 100 weight-percent thorium-232).

Natural Uranium - Uranium characterized by the naturally occurring distribution of uranium isotopes (approximately 0.711 weight-percent uranium-235 and the remainder essentially uranium-238).

Specific Activity - In reference to a radionuclide, the activity of the nuclide per unit mass of the nuclide. The specific activity of a material in which a radionuclide is uniformly distributed is expressed as the activity per unit mass of the material.

Radioactive Material - Any material having a specific activity greater than 0.002 microcurie per gram.

Special Form Radioactive Material - Radioactive material that is either a single, solid piece or is obtained in a sealed capsule.

Normal Form Radioactive Material - Radioactive material that is not Special Form Radioactive Material.

Transport Index - The dimensionless number (rounded up to the first decimal place) marked on the label of a package to designate the degree of control to be exercised by the carrier during transport. Generally, the transport index is the number expressing the maximum radiation level, in millirem per hour, occurring at distance of 1 meter (3.3 feet) from the external surface of the package. Other considerations may apply to certain fissile materials.

2.0 QUANTITIES OF RADIOACTIVITY IN PACKAGES

The regulations impose limits on the total activity (i.e., specific activity times the weight of the package) contained within a package of radioactive material. With respect to Type A packages, the limits are expressed as two quantities, A_1 and A_2, which refer to the maximum permissible activity for radionuclides in Special Form and Normal Form radioactive materials, respectively. Since the samples from FMPC fall into the latter category, the A_2 value sets the activity limits for packages of such samples. In those cases where contaminated material shipments are designated Low Specific Activity or Limited Quantity, some fraction of the A_2 value will normally apply (for further discussion, see Section 3.0).

Table D.3 lists the A_1 and A_2 values cited in 49 CFR 173.435 for radionuclides of the uranium decay series. Values for radionuclides not listed in the regulations (e.g., lead214, bismuth-214, and polonium-214) have been assigned in accord with the specifications set forth in Section 173.433(a)(2); details of the calculations are presented in Attachment A of this Appendix.

Determination of permissible quantities for samples that are contaminated with FMPC waste is more complicated than simple reference to the A_2 values, since such material contains a mixture of radionuclides. For such mixtures, two rules apply. A mixture of radionuclides from a single decay chain is considered to be a single radionuclide if the following criteria are met: 1) the parent and daughters are present in their naturally occurring proportions (for example, in secular equilibrium), 2) no daughter

TABLE D.3

A_1 AND A_2 QUANTITIES FOR RADIONUCLIDES OF THE URANIUM DECAY SERIES

Isotope	Atomic Number	Decay	Half-Life[a]	Quantity in Curies A_1	Quantity in Curies A_2
U-238	92	Alpha	4.5×10^9 y	Unlimited	Unlimited
Th-234	90	Beta	24 d	10	10
Pa-234	91	Beta	18 m	--	--
U-234	92	Alpha	2.5×10^5 y	100	0.1
Th-230	90	Alpha	7.5×10^4 y	3	0.003
Ra-226	88	Alpha	1622 y	10	0.05
Rn-222	86	Alpha	3.8 d	10	2.0
Po-218	84	Alpha	3.05 m	2	0.002
Pb-214	82	Beta	26.8 m	0.09[b]	0.002[b]
Bi-214	83	Beta	19.7 m	0.09[b]	0.002[b]
Po-214	84	Alpha	10^{-4} s	2[b]	0.002[b]
Pb-210	82	Beta	22 y	100	0.2
Bi-210	83	Beta	5 d	100	4.0
Po-210	84	Alpha	138 d	200	0.2

[a]Abbreviations: y = years; d = days; m = minutes; s = seconds
[b]Not listed in 49 CFR 173.435; calculation shown in Attachment 1

has a half-life longer than 10 days, and 3) no daughter has a half-life longer than the parent radionuclide. For such a mixture, the A_2 quantity to be applied is that of the parent radionuclide (Section 173.433(b)(2)). For those mixtures in which the identity and activity of radionuclides is known, the permissible quantity for each radionuclide must be such that the following equation is true:

$$F_1 + F_2 + \ldots + F_k \ldots F_n \leq 1$$

where F_k is the ratio of the total activity of the kth radionuclide to its A_1 or A_2 quantity [Section 173.433 (b) (3)].

3.0 SHIPPING CATEGORIES

Certain categories permit shipping of radioactive materials in other than specification packaging (i.e., Type A and Type B). These are of special interest since they may provide more latitude in the handling of field samples.

Low Specific Activity Materials

Low Specific Activity (LSA) materials include uranium and thorium ores, physical and chemical concentrates of these ores (e.g., yellow cake), unradiated natural or depleted uranium or thorium, nonradioactive material externally contaminated with radioactivity that is not readily dispersible, and material in which the radioactivity is essentially uniformly distributed and does not exceed certain prescribed concentration limits. These limits for radionuclides of the uranium decay series, beginning with thorium-230, are listed in Table D-4. In general, these concentrations will not be exceeded in FMPC samples.

TABLE D.4

LSA CONCENTRATION LIMITS FOR RADIONUCLIDES OF THE URANIUM DECAY SERIES FROM [FROM CFR 173.403(N)(4)]

Nuclide	A_2 Value (Curies)	Estimated Average Concentration Microcuries/Gram	Curies/Kilogram
Th-230	0.003	0.1	0.0001
Ra-226	0.05	0.1	0.0001
Rn-222	2.0	300	0.3
Po-218	0.002	0.1	0.0001
Pb-214	0.002	0.1	0.0001
Bi-214	0.002	0.1	0.0001
Po-214	0.002	0.1	0.0001
Pb-210	0.2	5.0	0.005
Bi-210	4.0	300	0.3
Po-210	0.2	5.0	0.005

Details for shipping LSA materials are described in 49 CFR 173.425. The chief advantage of shipping under the LSA category arises when the shipment is consigned "Exclusive Use," that is, under the supervision or direction of a single consignor from point of origin to final destination [Section 173.403(i)]. When packaged shipments of LSA materials are consigned as Exclusive

Use, the shipment is exempt from specification packaging, labeling and marking. Requirements that must be met include the following [Section 173.425(b)]:

1. The shipment must be consigned Exclusive Use, unloaded from the conveyance in which it was originally loaded, and accompanied by written instructions for the maintenance of Exclusive Use shipping controls. LSA materials can not be shipped by air.

2. The material must be packaged in strong, tight packages that will not leak under normal conditions of transport, and each package must be marked "Radioactive - LSA."

3. The package does not exceed the limits for removable radioactive contamination and radiation level (see Section 4.0 of this report).

4. The transport vehicle must be appropriately placarded, unless the shipment consists solely of unconcentrated uranium and thorium ores.

Limited Quantities of Radioactive Material

Limited Quantity shipments of radioactive material must meet the requirements specified in 49 CFR 173.421 and 173.423. If the activity per package does not exceed 10^{-3} A_2 quantity of the radionuclide, then it is exempt from specification packaging and from the associated shipping-paper, marking, and labeling requirements. Instead, the package need only comply with the following requirements:

1. The material must be packaged in strong, tight packages that will not leak under normal conditions of transport. The outside of the inner packaging, or the outside of the packaging itself when there is no inner packaging, must be marked "Radioactive."

2. The package does not exceed the limits for removable radioactive contamination and radiation level (see Section 4.0 of this report).

3. The package must be certified as being acceptable for transport by having a notice enclosed in or attached to the package, stating the name of the consignor and including the statement:

This package conforms to conditions and limitations specified in 49 CFR 173.421 for excepted radioactive material, limited quantity, n.o.s., UN2910.

One advantage of Limited Quantity shipments is that there are no restrictions on air transport. [Guidelines specified in the International Civil Aviation Organization (ICAO) regulations should be consulted for air shipments of radioactive materials.] The major disadvantage is the low concentrations and quantity weights permissible for mixtures of different radionuclides.

4.0 RADIATION AND CONTAMINATION CONTROL

Measurements of radiation level (dose rate) and of nonfixed (removable) radioactive contamination are conducted on radioactive-material shipments to control exposure to radioactivity. Inspectors of such shipments can readily determine whether the packages comply with the regulations summarized below.

Radiation Level

Radiation level is the radiation dose-equivalent rate expressed in millirem per hour (mrem/h) [Section 173.403(v)]1. Permissible radiation levels for various shipping categories are described below:

Limited Quantity Packages - The radiation level at any point on the external surface of the package may not exceed 0.5 mrem/h [Section 173.421(b)].

LSA Packages - The radiation level of the LSA packages transported as Exclusive Use shipments shall not at any time during transport exceed any of the following limits [Section 173.441(b)]:

-- 200 mrem/h on the accessible external surface of the package; or 1000 mrem/h if the following criteria are met: the shipment is made in a closed transport vehicle, the package is secured so that its position remains fixed during transport, and no unloading/loading operations occur between the beginning and end of transport.

-- 10 mrem/h at any point on the outer surface of the transport vehicle.

-- 10 mrem/h at any point 2 meters (6.6 feet) from the outer surfaces of the transport vehicle.

-- 2 mrem/h at any normally occupied position in the transport vehicle. This provision does not apply to private motor carriers when personnel operate under a radiation protection program.

Other packages - The radiation level must not exceed 200 mrem/h at any point on the external surface of the package, and the transport index must not exceed 10.

Contamination Control

Nonfixed (removable) radioactive contamination is defined as radioactive contamination that is easily removed from the surface by wiping with an absorbent material [Section 173.403(r)]. The maximum permissible limits for removable radioactive contamination, as set forth in 49 CFR 173.443(a), Table 10, are summarized below; these limits apply to any area of 300 square centimeters.

- 10^{-5} micro Ci/cm^2 or 22 disintegrations per minute (dpm)/cm^2, for beta/gamma-emitting radionuclides, all radionuclides with half-lives less than 10 days, natural uranium, natural thorium, uranium-235, uranium-238, thorium-232, and thorium-228 and thorium-230 when contained in ore and physical concentrates.
- 10^{-6} micro Ci/cm^2 or 2.2 dpm/cm^2, for all other alpha-emitting radionuclides.

Exclusive Use consignments of radioactive material may not exceed these limits at the beginning of transport, and may not exceed 10 times the limits at any time during transport (Section 173.443).

1.2.2 Samples Classified as Poison "A" Procedures

Packaging-

Collect samples in a polyethylene or glass container which is of an outer diameter narrower than the valve hole in a DOT Spec. #3A1800 or #3A1800 metal cylinder. Fill sample container allowing sufficient ullage (approximately 10% by volume) so it will not be liquid-full at 130°F. Seal sample container.

Attach a properly completed identification tag to sample container.

With a string or flexible wire attached to the neck of the sample container, lower it into a metal cylinder which has been partially filled with incombustible, absorbent loose packaging material (vermiculite or earth). Allow sufficient absorbing material between the bottom and sides of the container and the metal cylinder to prevent breakage and absorb leakage. After the cylinder is filled with cushioning material, drop the ends of the string or wire into the cylinder valve hole. Only one sample may be placed in a metal cylinder.

Replace valve, torque to 250 feet/pound (for 1 inch opening) and replace valve protector on metal cylinder, using teflon tape.

One or more cylinders may be placed in a DOT approved outside container.

Marking and Labeling

Use abbreviations only where specified. Place the following information on the side of the cylinder, or on a tag wired to the cylinder valve protector, either hand printed or in label form.

"Poisonous Liquid, n.o.s." or "Poisonous Gas, n.o.s. NA9035", laboratory name and address, and place the following DOT label on the cylinder - "Poisonous Gas" (even if the sample is liquid).

If the metal cylinders are placed in an outside container, both the container and cylinders inside must have the same markings and labels as above. In addition, "Laboratory Sample" and "Inside Packages Comply with the Prescribed Specifications" should be marked on the top and/or front side of the outside container. "THIS SIDE UP" marking must be placed on the topside of the container, and upward pointing arrows on all 4 sides.

Shipping Papers

Complete the shipper provided bill of lading and sign the certification statement (if the carrier does not provide, use standard industry form) with the following information in the order listed. One form may be used for more than one exterior container. Use abbreviations only as specified.

"Poisonous Liquid, n.o.s. NA9035, "Limited Quantity" or "Ltd. Qty.", net weight or net volume. The net weight or net volume must be placed just before or just after the "Poisonous Liquid, n.o.s." marking.

A chain-of-custody record form should also be properly executed and included in the container or with the cylinder, if legal use of samples is required or anticipated.

Unless samples are driven to the laboratory, a WESTON employee will accompany shipping container to the transport carrier and, if required, open outside container for freight inspection.

Using the word "poisonous" does not convey the certain knowledge that a sample is in fact poisonous, or how poisonous, but is intended to describe the class of packaging in order to comply with DOT regulations.

Transportation

Poison "A" categorized packages may not be transported by Federal Express Corporation (air cargo) or other common carrier aircraft, or by rental, non-government aircraft. Samples may be shipped by ground transport or government owned aircraft.

1.2.3 Samples Classified as Flammable Liquids or Flammable Solids Procedures

Packaging:

Collect sample in a glass container with non-metallic, teflon lined screw cap. Allow sufficient ullage (approximately 10% by volume) so that the container is not liquid full at 130°F. If an air space in the inner most container cannot be tolerated in order to maintain sample integrity, place it within a second container to provide the required ullage.

Attach properly completed sample identification tag to sample container.

Seal sample container closure and place in 2-mil thick (or thicker) polyethylene bag, one sample per bag. The sample identification tags should be positioned to enable it to be read through the bag.

Place sealed bag inside an appropriate sized metal can with enough incombustible, absorbent, cushioning matter (e.g., vermiculite or diatomaceous earth) to prevent breakage and absorb liquid; one bag per can. Pressure close the can and use clips, tape, or other positive means to hold the lid securely, tightly, and effectively.

Place one or more metal cans (or single 1-gallon bottle) surrounded with incombustible, absorbing packaging material for stability during transport into a strong outside container, such as a cooler or inside an approved fiberboard box.

Marking and Labeling

Use abbreviations only where specified. Place the following information on the metal can (or 1 gallon bottle), either hand printed or in label form: laboratory name and address, "Flammable Liquid n.o.s. UN1993" or "Flammable Solid n.o.s. UN1325". Not otherwise specified (n.o.s.) is not used if the flammable liquid or solid is identified. In that case, the name of the specific material is used and listed before the category (e.g., "Flammable Liquid")

Place the following DOT labels on the outside of the can (or bottle): "Flammable Liquid" or "Flammable Solid." The "Dangerous When Wet" label must be used with the "Flammable Solid" label if the material meets the definition of a water reactive material. The "Cargo Aircraft Only" label must be used if the net quantity of the sample in each package is greater than one quart (for "Flammable Liquid", n.o.s.) or 25 lbs. (for "Flammable Solid" n.o.s.). (172.402, 172.101).

If the cans are placed in an exterior container, both that container and inside can (or bottle) must have the same markings and labels as above.

The words "This End Up" or "This Side Up" must be clearly printed on the top of the outer package. Upward pointing arrows should be placed on the sides of the package. The words: "Laboratory Samples" should also be printed on the top of the package.

Shipping Papers

Use abbreviations only where specified below. Complete the carrier provided bill of lading and sign the certification

statement (if the carrier does not provide, use standard industry form) with the following information in the order listed. One form may be used for more than one exterior container.

"Flammable Liquid n.o.s. UN1993" or flammable Solid n.o.s. UN1324"; Limited quantity (or Ltd. Qty); net weight or net volume (abbreviations of weight or volume are acceptable). Further descriptions such as "Laboratory Samples" or "Cargo Aircraft Only" (if applicable) are allowed if they do not contradict the required information.

The net weight or net volume must be placed just before or just after the "Flammable Liquid, n.o.s." or "Flammable Solid, n.o.s." description.

A chain-of-custody record, properly executed, must be included in the exterior container.

Transportation

Unknown hazardous substances classified as flammable liquids may be transported by rented or common carrier truck, bus, railroad, or by Federal Express Corporation, but they should not be transported by any other common carrier air transport, even "cargo only" aircraft. (DOT regulations permit "cargo only" aircraft such as TWA, United, etc.; however, difficulties with regular airlines transportation suggests avoiding these types of transportation.)

These procedures are designed to enable air cargo shipment by entities like Federal Express; however, they should not be construed as an endorsement of a particular commercial carrier.

If samples are transported by any type of government owned vehicle, including aircraft, DOT regulations are not applicable. However, personnel will use the packaging procedures described, except the bill of lading with a certification, does not have to be executed.

Other Considerations

The size of the sample to be collected should be ascertained by the analytical laboratory.

Use of sample preservatives or packaging in ice should be determined by the analytical laboratory.

Using "flammable" not does convey the certain knowledge that a sample is in fact flammable, or how flammable, but is intended to prescribe the class of packaging in order to follow DOT regulations.

WESTON or Eberline employees will accompany shipping containers to the transport carrier and if required, open outside container(s) for inspection.

For overnight shipments, weight restrictions should be determined. Federal Express, for instance is 70 pounds or less.

ATTACHMENT 1

ASSIGNMENTS OF A_1 AND A_2 QUANTITIES FOR LEAD-214, BISMUTH-214, AND POLONIUM-214

SUMMARY OF THE REGULATIONS FOR CALCULATING ASSIGNMENTS

For radionuclides of known identity for which A_1 and A_2 quantities are not specified with 49 CFR 173.435, the quantities must be calculated in accord with the guidelines set forth in Section 173.433(a)(2). These guidelines are summarized below.

DETERMINATION OF A_1 QUANTITY

According to the requirements of 49 CFR 173.433(a)(2)(i), the A_1 quantity for a radionuclide that emits only one kind of radiation (gamma, X, beta, or alpha) is determined in accord with rules A, B, C, or D, respectively (see below). For those radionuclides that emit more than one kind of radiation, A is taken to be the most restrictive (smallest) quantity of those determined for each kind of radiation emitted. If the radionuclide decays to a shorter lived daughter with a half-life less than 10 days, A_1 must be calculated for the parent and the daughter, and the more restrictive of the two assigned to the parent. In any case, A shall not exceed 1000 curies.

Rule A - Gamma-Ray Emitters

A_1 = 9/gamma

where gamma is the gamma ray constant in roentgen-meters per hour-curie, approximately equal to 0.5N [E_{gamma}(average)] where N is the number of gamma quanta per disintegration and E_{gamma}(average) is the average gamma energy in MeV (U.S. Department of Health, Education, and Welfare, 1970, p. 33).

Rule B - X-ray Emitters

For $Z < 55$, A_1 = 1000 curies
For $Z > 55$, A_1 = 200 curies

where Z is the atomic number of the radionuclide.

Rule C - Beta-Ray Emitters

A_1 is determined by the maximum beta energy, E_{max}, according to the following specifications:

Maximum Beta Energy (MeV)	A_1 Quantity (curies)
$E_{max} < 0.5$	1000
$0.5 \leq E_{max} < 1.0$	300
$1.0 \leq E_{max} < 1.5$	100
$1.5 \leq E_{max} < 2.0$	30
$E_{max} \geq 2.0$	10

Rule D- Alpha-Ray Emitters

$A_1 = 1000\ (A_3)$

where A_3 is determined from the relationships detailed below, based on the atomic number of the radionuclide, Z, and the half-life, $T_{1/2}$.

For $Z \leq 81$,

Range of Half-Life	A_1 Quantity (curies)
$T_{1/2} < 10^3$ days	3
10^3 days $\leq T_{1/2} \leq 10^4$ years	0.050
$T_{1/2} > 10^4$ years	3

For $Z \geq 82$,

Range of Half-Life	A_1 Quantity (curies)
$T_{1/2} < 10^3$ days	0.002
10^3 days $\leq T_{1/2} \leq 10^4$ years	0.002
$T_{1/2} > 10^4$ years	3

DETERMINATION OF A_2 QUANTITY

Pursuant to 49 CFR 173.433 (A)(2)(ii), the A_2 quantity is the more restrictive of the following:

- The corresponding A_1 value.
- The value of A_3 as determined from Rule D above.

ASSIGNMENTS OF A_1 AND A_2 QUANTITIES FOR

LEAD-214, BISMUTH-214, AND POLONIUM-214

DATA REQUIRED FOR CALCULATING A_1 QUANTITIES

Lead-214

- Emissions: Beta Rays, Gamma Rays, X Rays
- $T_{1/2}$: 26.8 minutes
- Feeds: Bi-214 ($T_{1/2}$ = 19.9 minutes)
- Z: 82
- E_{9max} (beta): 0.980 MeV (U.S. Department of Health, Education, and Welfare, 1970, p. 94)
- N_{gamma}: 22 (Kocher, 1981)
- E_{gamma} (average): 0.2807 MeV (Kocher, 1981)

Bismuth-214

- Emissions: Beta Rays, Gamma Rays, X Rays
- $T_{1/2}$: 19.9 Minutes
- Feeds: Po-214 ($T_{1/2}$ = 1.6×10^{-4} second)
- Z: 83
- E_{max} (beta): 3.20 MeV (Kocher, 1981)
- N_{gamma}: 182 (Kocher, 1981)
- E_{gamma} (average): 1.158 MeV (Kocher, 1981)

Polonium-214

- Emissions: Alpha Rays, Gamma Rays
- $T_{1/2}$: 1.6×10^{-4} second
- Feeds: Pb-210 ($T_{1/2}$ = 22.26 years)
- Z: 84
- N_{gamma} 3 (Lederer and Shirley, 1978)
- E_{gamma} (average): 0.797 MeV (Kocher, 1981)

A_1 AND A_2 ASSIGNMENTS

The assignments of A_1 and A_2 quantities for lead-214, bismuth-214, and polonium-214 are presented in Tables D.5 and D.6, respectively.

TABLE D.5
A_1 QUANTITIES FOR Pb-214, Bi-214, and Po-214

Isotope	Calculate A_1 Quantity (curies)				Assigned A_1
	Gamma	X	Beta	Alpha	Quantity (curies)
Pb-214	1.5	200	300	NA	0.09
Bi-214	0.09	200	10	NA	0.09
Po-214	10.8	NA	NA	2	2

TABLE D.6
A_2 QUANTITIES FOR Pb-214, Bi-214, and Po-214

Isotope	A_2 Quantity (curies)
Pb-214	0.002
Bi-214	0.002
Po-214	0.002

APPENDIX E

PROCEDURES FOR USE OF THE MULTICHANNEL ANALYZER AS A SCREEN FOR GAMMA-RAY EMITTING RADIONUCLIDES IN FMPC SAMPLES

CALIBRATION AND OPERATION OF THE PULSE HEIGHT ANALYSIS SYSTEM (CANBERRA SERIES 10) WITH INTRINSIC GERMANIUM AND SODIUM IODIDE DETECTORS

1.0 PURPOSE

To guide the user in the calibration and operation of the pulse height analysis system.

2.0 SCOPE

This procedure applies to the use of a gamma-ray spectrometry system to count soil samples and charcoal canisters during field investigations at the Feed Materials Production Center.

3.0 REFERENCES

Canberra Series 10 Operator's Manual, revised January 10, 1983.

4.0 EQUIPMENT

4.1 Canberra 10 multi-channel analyzer

4.2 Reverse electrode high purity germanium detector

4.3 Sodium iodide (4-in. diameter by 4-in. long detector)

4.4 Associated electronics (H.V. power supplies, amplifiers, test equipment, etc.)

4.5 Lead counting shields

4.6 High speed oscilloscope

4.7 Digital voltmeter

4.8 Check sources: Am-241, Cs-137, Y-88

4.9 Counting standards: uranium ore standard (0.025%) in jar and petri dish geometry; thorium ore standard (15 pCi/g) in jar and petri dish geometry

5.0 INSTRUCTION

5.1 BATTERY CHARGING

The system can be operated up to 8 hours on a fully charged battery. To charge battery, connect charger connector to J105 on rear panel and charger power cord to a 115 volt 60 hz AC outlet.

5.1.1 For fast charge the power switch must be in the RST or STBY position. Charging will take approximately 16 hours.

5.1.2 The batteries will charge if the system is ON but will take approximately 1.5 days to charge.

5.2 AC OPERATION

The Series 10 (s10) can be operated indefinitely from an 115V 60 hz power source if the charger is connected as per above.

5.3 EXTERNAL AUTO DC POWER

A car battery can be used to operate the S10 by using the cigarette lighter plug adaptor cable connected to J105 on the rear panel.

6.0 OPERATION

Primary Column: The sequential steps for setting parameters and operations.

Secondary Column: Pressing the designated key at the appropriate place in procedure will bypass that area if no change is necessary.

Status Check (any time while turned on).

Pressing "Menu" a second time will exit out of Menu from anywhere in the procedure.

Power Switch: (rear panel)

Rests the S10 to Factory Prom settings.

Applies power to memory only to retain user parameters.

System power in ON, but high voltage is disabled.

System power in ON and high voltage is enabled.

6.1 SETTING PARAMETERS

6.1.1 Turn power switch to H.V. ON.

6.1.2 Memory selection:

A. Memory mode.
B. Select memory size.
C. Select section of memory.
D. Enter selection.

6.2 SETUP MODE

6.3 AMPLIFIER (choice):

6.3.1 Positive input.

6.3.2 Negative input.

6.3.3 Fast shaping.

6.3.4 Slow shaping.

6.3.5 Gain:

A. To change number.
B. Clear number.
C. Enter desired number.
D. Check entry.
E. Load entry.

6.4 E-2 To increase number.
E-3 To decrease number.
E-4 Exit gain.
E-5 Exit amplifier.

6.5 SCA

6.5.1 Lower level discriminator

A. To change number (option)

1. Clear number
2. Enter desired number
3. Check entry
4. Load entry

B. To increment number

C. To decrement number

D. Exit LLD

6.5.2 Upper level discriminator

A. To change number (option)

1. Clear number
2. Enter desired number
3. Check entry
4. Load entry

B. To increment number

C. To decrement number

D. Exit ULD

6.5.3 Exit SCA

6.6 ADC

6.6.1 Zero

A. Clear number
B. Enter desired number
C. Check entry
D. Load entry

6.6.2 Offset

A. Clear number
B. Enter desired number

C. Check entry
D. Load entry

6.6.3 Gain (gain should match the size of memory)

A. Select gain
B. Load selection

6.6.4 PHA (2 options)

A. Add
B. Subtract

6.6.5 Exit ADC

6.7 Entering Second String of Setup Mode

6.8 High Voltage Power Supply

6.8.1 Set HV

A. Clear number
B. Enter desired number
C. Check entry
D. Load entry

6.8.2 HV ON

6.8.3 HV OFF

6.8.4 Stabilizer (2 options)

A. ON
B. OFF

6.8.5 Exit HVPS

6.9 EIA

6.9.1 Band rate (4 options)

A. Select rate
B. Load selection

6.9.2 Word length (2 options)

A. Select length
B. Load selection

6.9.3 Parity (3 options)

A. Select: off, even, or odd
B. Load selection

6.9.4 Exit EIA

6.10 CLOCK

6.10.1 Time

A. Enter hours (0-23)
B. Load hours
C. Enter minutes (0-59)
D. Load minutes
E. Load time

6.10.2 Date

A. Enter day (1-31)
B. Load day
C. Enter month 91-12)
D. Load month
E. Enter year
F. Load year
G. Load date

6.10.3 Exit clock

7.0 DEFAULT

NOTE: Default automatically resets all parameters to the factory prompt settings - same as power switch RST.

7.1 Exit SETUP mode

7.2 Preset collection time interval

7.2.1 <u>To change preset time (5 options)</u>

A. Live time

1. Clear number
2. Enter desired number
3. Check entry
4. Load entry

B. True time

1. Clear number
2. Enter desired number
3. Check entry
4. Load entry

C. Area

1. Clear number
2. Enter desired number
3. Load number
4. Enter desired ROI number (1-50)
5. Check entry
6. Load entry

D. Integral

1. Clear number
2. Enter desired number
3. Load number
4. Enter desired ROI number (1-50)
5. Check entry
6. Load entry

E. Count

1. Clear number
2. Enter desired number
3. Load number
4. Clear channel number
5. Select channel number

   a. Cursor:
      1 Move cursor to desired channel
      2 Select cursor
      3 Load entry

b. Number:
1 Check channel number
2 Check entry
3 Load entry

8.0 COLLECT DATA (3 OPTIONS)

8.1 START, STOP, CONTINUE

8.1.1 Recycle (optional, see note below)

A. Clear number
B. Enter number of times for recycling
C. Load entry

8.1.2 Start collection

NOTE: Recycle is used to count a sample several times and automatically dump data after each run.

9.0 READ INPUT/OUTPUT

9.1 INPUT (2 options)

9.1.1 EIA

9.1.2 Tape

9.2 OUTPUT (4 options)

9.2.1 EIA (3 options)

A. ALL, ROIS, BRIEF

1. Clear tag number
2. Enter new tag number
3. Check entry

B. Start outputting

9.2.2 Terminal (3 options)

A. ALL, ROIS, BRIEF

1. Clear tag number
2. Enter new tag number
3. check entry

B. Start outputting

9.2.3 TAPE (2 options)

A. ALL ROIS

1. Clear tag number
2. Enter new tag number
3. Check entry

B. Start outputting

9.2.4 Computer (2 options)

A. ALL ROIS

1. Clear tag number
2. Enter new tag number
3. Check entry

B. Start outputting

9.3 STOP

10.0 CHANGE ROIS

Region of interest

10.1 Create ROI

10.1.1 Enter ROI number
Load number

10.1.2 Cursor (optional)

A. Move cursor to low channel of region of interest
B. Load channel number
C. Move cursor to upper channel of region of interest
D. Load channel number
E. Load ROI

10.1.3 Channel Number (optional)

A. Enter lower channel number of region of interest
B. Load number
C. Enter upper channel number of region of interest
D. Load number
E. Load ROI

10.2 Delete ROIS (2 options)

10.2.1 ALL

10.2.2 ROI number

A. Enter ROI number to be deleted
B. Check entry
C. Execute entry

10.3 To exit change ROI

11.0 CALIBRATION

11.1 Detector and Preamp Connections:

11.1.1 Connect preamp power connector to J108 on rear panel

11.1.2 Connect high voltage SHV connector to J107 on rear panel

11.1.3 Connect signal BNC connector to J101 on rear panel

11.1.4 Turn rear switch to H.V. On

11.2 PRELIMINARY SETUP PARAMETERS

11.2.1 Memory

A. Quarter

1. First quarter
2. Load entry

11.2.2 Preset collection time

A. To change preset

B. Live time

1. Clear number
2. Enter new number
3. Clear entry
4. Load entry

11.2.3 Setup mode

A. Amplifier

1. Positive - load entry
2. FAST - load entry
3. Exit AMP

B. SCA

1. LLD 0%
2. ULD 110%
3. Exit SCA

C. ADC

1. Zero 0%

   a. Clear number
   b. Enter number
   c. Check entry
   d. Load entry

2. Offset 0

   a. Clear number
   b. Enter new number
   c. Check entry
   d. Load entry

3. Gain 1024

   a. 1024
   b. Load entry

4. PHA

   a. ADD
   b. Load entry

5. Exit ADC

D. High voltage power supply

1. Set 1000V

a. Clear number
b. Enter new number
c. Check entry
d. Load entry

2. Stabilizer off

a. Off
b. Load entry

3. HVPS ON

Load entry

4. Exit HVPS

E. Exit Menu

11.3 POLE ZERO ADJUST

11.3.1 Expose detector to a source

11.3.2 Connect oscilloscope to ADC in on rear panel

Adjust horizontal and vertical on scope for a good representation of signal and base line.

11.3.3 Adjust P/Z on rear panel for the flattest base line.

11.4 SPECTRUM CALIBRATION

11.4.1 For 3 KeV per channel (NaI), 3072 KeV full scale

A. Upper end, Y-88 1836 KeV peak on channel 612
B. Lower end, Am-241 60 KeV peak on channel 20

11.4.2 For 1.5 KeV per channel (HPGE), 1536 KeV full scale

A. Upper end, Cs-137 662 KeV peak on channel 441
B. Lower end, Am-2341 60 KeV peak on channel 40

11.4.3 Repeated collections will be necessary

11.4.4. Move cursor to upper end channel

NOTE: You may have to expand the display to get on the channel you desire.

Adjust AMP gain to put the upper end energy peak at the cursor position.

A. Change number for coarse changes
B. For fine changes move up down arrows
C. Exit Menu

11.4.5 Move cursor to lower end channel

A. If the Am-241 60 KeV peak is not on the desired channel, adjust AMP gain (as above) to bring the upper and lower energy peaks to an equal distance from their respective channels.

B. If the peaks are above their channels, count the number of channels they are off and enter this number into the ADC Offset.

C. If the peaks are below their channels, count the number of channels they are off and enter this number into the ADC Zero, with a negative sign.,

11.5 ECAL

11.5.1 Collect a spectrum using both sources used in spectrum calibration.

11.5.2 Go into ECAL mode

A. If there is an equation, clear it

B. If channel numbers are known, enter them and their respective energies

1. Repeat for each peak
2. Exit

C. <u>If channel numbers are not known</u>

1. Move cursor to desired peak

   a. Enter channel number
   b. Load channel number

2. Enter energy of peak

   a. Check entry
   b. Load entry

3. Exit

D. Set energy value KEV

E. Exit ECAL

11.6 <u>COMPUTE</u>

11.6.1 <u>For compute mode you must assign regions of interest</u>

A. Enter ROI number

B. Move cursor to lower end of region of interest; enter channel number

C. Move cursor to upper end of region of interest; enter channel number

D. Repeat for each region of interest, giving each a different designator number

E. Exit

11.6.2 <u>Compute mode</u>

A. <u>Area</u>

1. Select 3 channels of background for subtraction
2. Press index to compute each area of interest

B. <u>Integral</u>

1. Press index for each area of interest

C. Time gives total live time, total true time, start time of collection, and the date of collection

D. OFF exits compute mode

11.7 USE OF COUNTING STANDARDS

Two counting standards are to be used to establish calibration factors. These are uranium and thorium ore standards of 86 pCi/g and 15 pCi/g respectively. The uranium ore standard will be used as a comparison standard to determine the concentration of U-238 and Ra-226 in soil and sediment samples. The thorium ore standard will be used to determine the concentration of Th-232 in soil and sediment samples. Certain photo peaks in the spectrum of each counting standard will be used for calibration purposes. For U-238 in soil a petri dish geometry will be used. For Ra-226 and Th-232, a cylindrical plastic jar (16 oz) will be used. Weights of these standards will be marked on each container.

11.7.1 Place the uranium ore (petri dish) on the detector and count for 10 minutes. Using 11.6.1, establish a Region of Interest (ROI) for the 63.3 KeV and 92.6 KeV photons from Th-234. Using 11.6.2, determine net counts for each ROI by using the 3 channel background subtractions. Record the net count rate for each ROI.

11.7.2 Place the uranium ore (jar) on the detector and count for 10 minutes. Using 11.6.1, establish Regions of Interest for the following photons: 295 KeV, 352 KeV, 609 KeV and 1120 KeV. Using 11.6.2, determine the net counts for each ROI by using the 3 channel background subtractions. Record the net count rate for each ROI.

11.7.3 Place the thorium ore (jar) on the detector and count for 10 minutes. Using 11.6.1, establish regions of interest for the following photons: 33.85 KeV, 463 KeV, 911 KeV, and 968.9 KeV. Using 11.6.2, determine the net counts for each ROI by using the 3 channel background subtraction. Record the net count rate for each ROI.

11.7.4 Following completion of 5 repetitions of 11.7.1 through 11.7.3, prepare a calibration table for each photon for each geometry and record the average calibration factor for each photon in units of pCi/ct-g. This value is to be used for purposes of calculating the concentrations

of U-238, Ra-226, and Th-232 in soil and sediment samples.

11.7.5 Daily, before counting samples, each counting standard will be counted and results of the net count for each ROI will be recorded in the Laboratory Notebook. The counting standard will also be counted after each 10 sample count.

11.8 SAMPLE ANALYSIS

11.8.1 Place a pre-numbered label on each sample container.

11.8.2 On a tared analytical balance, weigh each sample and record the weight on a sticky tag and attach to the sample container.

11.8.3 Based on the type of analysis desired, count each sample for 10 minutes. Using 11.6.2, determine the net count rate for each ROI and record in the Laboratory notebook.

11.9 SOIL AND SEDIMENT CONCENTRATIONS

From the calibration table developed in 11.7, determine the concentration of radionuclides in soil and sediment samples as follows:

Example: Soil in petri dish - U-238

U_1 = U-238 pCi/g = $CF_{63.3}$(pCi/gt-g) x Net $ROI_{63.3}$ (cts) x mass(g)

U_2 = U-238 pCi/g = $CF_{92.6}$(pCi/gt-g) x Net $ROI_{92.6}$ (cts) x mass(g)

$$\text{Average U-238 PCi/g} = \frac{U_1 + U_2}{2}$$

11.10 DOCUMENTATION

Each sample analysis which is determined in the field laboratory will be recorded in the Laboratory Notebook and on data collection forms. These data will be entered in a computer data base for purposes of determining isotopes and for reporting.

11.11 QUALITY CONTROL

The principal differences between established and field laboratories are few. In general, an established laboratory contains ample floor space for its various activities, and is equipped with adequate facilities such as electrical power, hot and cold water, waste collection, etc. In spite of these differences, gamma-ray spectrometers have been used successfully in field laboratories for a number of years. Quality control measures are essentially the same in both cases.

11.11.1 Samples from field collection activities will be received at the laboratory on a daily basis. Each group of 10 or more samples will constitute a batch. Except for special requests for analysis, each batch of samples will be processed and analyzed in the order of arrival at the field laboratory.

11.11.2 Each sample which is received in the field laboratory will be tagged with a pre-numbered adhesive backed sticker, and will be listed in a laboratory notebook which will serve as an official record of sample handling and analysis activity.

11.11.3 For purposes of assuring sample identity, information contained in the laboratory notebook will be matched with sample information contained on the Field Sample Collection Form. This will be done for each batch of samples, and entries in the laboratory notebook will bear the initials of both the laboratory manager and the field sampling coordinator.

11.11.4 Each day prior to counting samples, each counting standard (U and Th ore) will be counted for 10 minutes. The net counts for each region of interest will be recorded in the laboratory notebook and the calculated concentration of U-238, Ra-226, and Th-232 will be plotted on a chart for each day of laboratory operation.

11.11.5 Each day prior to counting samples, a blank or background sample will be counted for 10 minutes. As in 11.11.4, the results of calculations will be recorded in the laboratory notebook and plotted on a chart.

11.11.6 Following the completion of each sample count, net counts from each region of interest will be recorded in the laboratory notebook. Calculations of radionuclide concentrations will be performed using these data.

11.11.7 Once these notebook entries have been made, the photon spectrum of each sample will be recorded on a magnetic tape cassette. Spectra for any given sample can be recalled for additional or duplicate analysis as needed.

11.11.8 One in every ten samples of each batch will be counted a second time following the analysis of the tenth sample and a re-count of the counting standard.

11.11.9 At the close of daily laboratory activities, all analyses will be reviewed by the laboratory manager and the field sampling coordinator.

APPENDIX F

SCREENING SOIL SAMPLES FOR LOW-LEVEL GAMMA RADIATION USING THE FIDLER

1.0 USE OF FIDLER TO SCAN INDIVIDUAL SOIL SAMPLES FOR LOW ENERGY RADIATION

The FIDLER Probe may be used to scan individual samples for low energy photons. Data from these measurements represent gross counts and serve only as an indicator. The combination of this information with gross alpha counts of the same sample will be used only to assist in decisions regarding the samples to be sent to the TMA/Eberline laboratory for specific analyses. It is assumed that the presence of high gross alpha counts and a low FIDLER count may indicate the presence of Th-230, an alpha emitter with very low abundance low energy photons.

2.0 EQUIPMENT

2.1 FIDLER/PRS-1 detector system

2.2 Lead shield

2.3 Sample counting logbook

3.0 PROCEDURE

3.1 Place the FIDLER probe in a counting jig inside the lead shield so that it is positioned above the center of a sample container holder and adjust the height so that the FIDLER is one inch above the sample container.

3.2 Retrieve the sample to be counted and record the identification number in the sample counting logbook.

3.3 Place the soil sample container in the counting shield and close the door.

3.4 Turn the PRS-1 selector switch to manual, push the reset button to start, and count for 10 minutes.

3.4 Record the count in the sample counting log next to the sample identification number.

3.6 Remove the sample container, store in sample archive, and repeat 3.2 - 3.5.

APPENDIX G

SUBSURFACE GAMMA SPECTRAL MEASUREMENTS

THIS PROCEDURE IS BEING DEVELOPED AND WILL BECOME AVAILABLE PRIOR TO THE INITIATION OF CHARACTERIZATION ACTIVITIES.

APPENDIX H

DECONTAMINATION OF FIELD EQUIPMENT

DECONTAMINATION PROCEDURES

1.0 GENERAL APPLICABILITY

This procedure describes the methods to be used for the decontamination of all field equipment which becomes potentially contaminated during a sample collection task. The equipment may include split spoons, bailers, trowels, shovels, hand augers, or any other type of equipment used during field activities.

Decontamination is performed as a quality assurance measure and a safety precaution. It prevents cross-contamination between samples and also helps to maintain a clean working environment for the safety of all field personnel involved, including the environment.

Decontamination is mainly achieved by rinsing with liquids which include: soap and/or detergent solutions, tap water, deionized water, and methanol. Equipment will be allowed to air dry after being cleaned or may be wiped dry with chemical free cloths or paper towels if immediate re-use is needed. Steam cleaning shall be used whenever possible.

The frequency of equipment use dictates that most decontamination be accomplished at each sampling between collection points. Waste products produced by the decontamination procedures such as waste liquids, solids, rags, gloves, etc. will be collected and disposed of properly as directed by Westinghouse.

2.0 RESPONSIBILITIES

It is the primary responsibility of the site operations manager to assure that the proper decontamination procedures are followed and that all waste materials produced by decontamination are properly stored and disposed of.

It is the responsibility of the project safety officer to draft and enforce safety measures which provide the best protection for all persons involved directly with sampling and/or decontamination.

It is the responsibility of any subcontractors (i.e., drilling contractors) to follow the proper, designated decontamination procedures that are stated in their contracts and outlined in the Project Health and Safety Plan.

It is the responsibility of all personnel involved with sample collection or decontamination to maintain a clean working environment and to ensure that any contaminants are not negligently introduced to the environment.

3.0 SUPPORTING MATERIALS

Cleaning liquids: soap and/or detergent solutions, tap water, deionized water, methanol

Personal safety gear (defined in Project Health and Safety Plan)

Chemical-free paper towels

Disposable gloves

Waste storage containers: drums boxes, plastic bags

Cleaning containers: plastic buckets, galvanized steel pans

Cleaning brushes

4.0 METHODS OR PROTOCOL FOR DECONTAMINATION

4.1 General Procedures

The extent of known contamination will determine what extent the equipment needs to be decontaminated. If the extent of contamination cannot be readily determined, cleaning should be done according to the assumption that the equipment is highly contaminated until enough data are available to allow assessment of the actual level of contamination.

Adequate supplies of all materials must be kept on hand. This includes all rinsing liquids and other materials listed in Section 3.0.

The standard procedures listed in the following section can be considered the procedure for full field decontamination. If different or more elaborate procedures are required for a specific project, they will be spelled out in the project work plan. Such variations in decontamination may include the following, just part, or an expanded scope of the decontamination procedure stated herein.

4.2 Standard Procedures

Remove any solid particles from the equipment or material by brushing and then rinsing with available tap water. This initial step is performed to remove gross contamination. For drilling equipment only, steam cleaning will be necessary.

Wash equipment sampler with the soap or detergent solution.

Rinse with tap water.

Rinse with deionized water.

Rinse with methanol

Repeat entire procedure or any parts of the procedure if necessary.

Allow the equipment or material to air dry.

Surface swipes of 100 cm^2 shall be taken and analyzed for gross alpha contamination.

Dispose of any soiled materials in the designated disposal container.

Northeast of Pit 4 is a concrete pad that has an adjacent all weather fire hydrant. This area will be used to decontaminate equipment such as auger bits, split spoon samplers, drill rigs, and other sampling apparatus. Water from this operation will be managed as directed by Westinghouse.

APPENDIX I

SUBSURFACE SOIL SAMPLING PROCEDURES

SUBSURFACE SOIL SAMPLING PROCEDURES

1.0 PURPOSE

These procedures describe the methods to be used in obtaining subsurface soil samples to be used for radiological and chemical analysis. Subsurface soil samples will be obtained in conjunction with soil boring and monitoring-well installation programs. Additional samples will be taken to provide direct information as to the physical, chemical, and radiological make-up of the subsurface environment. This procedure covers subsurface soil sampling by split-spoon sampler. (refer to Attachment I for the removal of material from the split spoon sampler.)

2.0 RESPONSIBILITIES

2.1

It shall be the responsibility of the contract driller to provide the necessary materials for obtaining subsurface soil samples. This includes the use of drill rig(s), portable augers as well as split spoon samplers. Standard Penetration Tests (ASTM: 1586-67) will be conducted by the contract driller if required by the project. Equipment decontamination shall be the responsibility of both the driller and field technicians on site. Decontamination shall follow the procedures described in Appendix H.

2.2

It shall be the responsibility of the project geologist/engineer to observe all activities pertaining to subsurface soil sampling to ensure that all the standard procedures are followed properly, and to record all pertinent field data on boring logs. It is the geologist/engineers responsibility to indicate to the contract driller at what specific depth samples will be collected. The geologist/engineer will maintain custody of all samples until they are shipped to their appropriate destination.

2.3

It shall be the responsibility of the Field Health and Safety Coordinator to maintain and ensure that all adequate safety precaution are enforced. Work shall be stopped until compliance with health and safety is adequate.

3.0 EQUIPMENT AND MATERIALS

In addition to those materials provided by the contract driller, the geologist/engineer will provide:

- Analytical sample containers and sample labels
- Boring Logs
- Field notebook
- Chain-of-custody forms

4.0 INSTRUCTIONS

4.1 GENERAL PROCEDURES

The sampling depth interval is typically (1) sample per every two vertical feet (24 inches), with additional samples taken at the discretion of the project geologist/engineer, when significant textural, visual or odorous changes are encountered.

ASTM details the procedures that are to be used in advancing casing. Specific requirements described in the Sample Plan may call for deviations in the procedures. These will be taken into account on a project-by-project basis. Any deviations from specified procedures will be recorded on the boring log.

4.2 PROCEDURES FOR SUBSURFACE SOIL SAMPLING

4.2.1

Subsurface soil samples shall be obtained using a split-tube type sampler (split-spoon) having a 3-inch O.D. with a corresponding 2.5 inch I.D. and a 24 inch long sample capacity. It shall be equipped with a ball check valve and will require a flap valve or basket-type retainer for loose-soil sampling. Sample frequency will be as stated in Section 4.1, or as specified in the project task plan.

4.2.2

Sampling depth shall be independently determined by the inspecting geologist, and any discrepancies shall be resolved prior to obtaining the sample.

4.2.3

Samples shall be obtained using the standard Penetration Test which allows for determination of resistance within the deposits. The sampler shall be driven using a 140 pound hammer with a vertical drop of 30 inches using 1 to 2 turns of the rope on a cathead. A certificate indication exact weight may be required for documentation purposes. The number of hammer blows required for 6 inches of penetration shall be recorded on the boring log.

4.2.4

The sampler shall be immediately opened upon removal from the casing. If the recovery is inadequate, another attempt shall be made before drilling progresses. Adequate recovery should be no less than 12 inches, not including any residual waste material brought up with the sample.

4.2.5

The sample shall be removed from the sampler as detailed in Attachment I. The sample shall be split as necessary, placed in the appropriate container and labeled. The boring log sample label, and field log book should contain the following information on each sample: site name, boring location, blow counts, recovery, sample number, collection date, name of geologist/engineer. The type of material shall be indicated in the boring logs and will be described using the Unified Soil Classification System (ASTM: D2487-69 and D2488-69).

4.2.6

The sampler shall be cleaned between attempts in order to prevent cross-contamination. Appendix H details decontamination procedures.

4.2.7

Samples shall be transferred to the Field Laboratory for analysis. Proper chain-of-custody forms shall be initiated. Once analyzed, proper procedures for delivery to the designated laboratory shall be initiated. This includes packaging, shipping with copies of sample logs, analysis request forms, and chain-of-custody forms. Any additional samples shall be archived as requested.

ATTACHMENT 1

PROCEDURES FOR HANDLING SUBSURFACE SOIL SAMPLES

1.0 PURPOSE

This procedure is presented as a guide for handling subsurface soil samples. It was developed for use by the field sampling team.

2.0 SCOPE

Instructions in this procedure cover the activities associated with the removal of soil cores from split spoon samples, the splitting of soil cores for both radiological and chemical analyses, and the packing of soil in sample containers.

3.0 REFERENCES

1. U.S. Environmental Protection Agency, Test Methods for Evaluating Solid Waste (Physical/Chemical Methods), SW846, Second Edition (Revised), Washington, D.C., 1984.

4.0 EQUIPMENT AND MATERIALS

1. Supply of sample containers (approved for sample types included in project for which this procedure is implemented) in sealed packages.

2. Decontamination supplies (water, methanol, wipes, bags, etc.)

3. Plastic sheets approximately 4 ft. x 6 ft. (quantity to be based on the number of samples handled).

4. Stainless steel spatula with 1-in. wick by 8-in, long blade.

5. Portable volatile organic analyzer.

6. Labels for sample containers.

7. Marking pens

8. Gummed paper sample seals

9. Field log book

10. Chain of custody forms

11. Sample analysis request forms

5.0 INSTRUCTIONS

Once a split spoon sampler has been advanced in a borehole, it should be opened as soon as possible so that the sampled material can be transferred to sample containers. Only those personnel who have received training in the handling of split spoon samples will perform his work.

1. In the field log book, record all pertinent data for each split spoon sample as it is handled. Information to be included for each sample will correspond to those items listed in Section 1.3.3. Field Log Book of Reference 1.

2. Wipe the outer surface of the split spoon sampler with damp wipes to remove all visible solid and liquid material, and place the sampler on a clean plastic sheet.

3. Disassemble the split spoon sampler for access to sampled media.

4. Measure and record the length of material sampled.

5. Using a portable volatile organic analyzer hold the probe close to the sampled material and record readings (in ppm) at a minimum of four locations (take care not to touch sample). A reading of 0 to 5 units above ambient background will be interpreted as the positive presence of volatile organics.

6. Using the stainless steel spatula cut the sampled material at the midpoint of its length. Record sample identity for each fraction.

7. Wipe visible material from the spatula using a wipe dampened with methanol.

8. Using the spatula, slice one portion into two halves. From the inner face of each half, use the spatula tip to collect small aliquots of soil along the length and transfer this material to a 40 ml VOA vial. Close the vial, and place a sample seal across the cap-vial interface. Record sample identity on the sample label and in the field log book. Place VOA vial in a cooled ice chest for preservation. This ample portion will be reserved for analysis of HSL-volatiles.

9. Place one half of the sliced portion in a wide mouth glass jar (3202), place a sample seal across the lid-jar interface, record sample identify on sample label and in field log book and place glass jar in the cooled ice chest. This portion will be reserved for, additional HSL constituents analyses.

10. Place the remaining half of the sliced portion into a wide mouth plastic jar (1602), place a sample seal across the lid-jar interface, record sample identity on sample label, complete log book entries, and place jar in a box for delivery to the field laboratory. This portion will be analyzed for radionuclides.

11. Repeat steps 5.7 through 5.10 for the second half of the split spoon sample from step 5.6.

12. Wipe all visible material from all surfaces of the split spoon.

13. Wash the split spoon with water and detergent and rinse with methanol. After the sampler parts have air-dried, reassemble the split spoon and return to the driller.

14. Place all plastic sheet, wipes, trash, etc. in a rad waste container.

APPENDIX J

LAKE, POND, AND STREAM-BOTTOM SEDIMENT SAMPLING

LAKE, POND AND STREAM-BOTTOM SEDIMENT SAMPLING

1.0 PURPOSE

Sediment samples are obtained in order to provide information on the transport of contaminants. This procedure describes the methods to be used to obtain representative samples from lake, pond and stream-bottom sediments. Sediment sampling is performed in order to define the radiological, chemical and in some cases, the physical or biological composition of the sediment.

Sediments may be obtained directly from small streams using trowels or small shovels. If subsurface core sediments are to be obtained, a thin-walled coring device can be used to obtain undisturbed sediment profiles. Sediments from ponds or lakes will be obtained using dredge/clam shell-type samplers

2.0 REFERENCES

National Handbook of Recommended Methods of Water Data Acquisition (USGS, 1984).

EPA Handbook for Sampling and Sample Preservation of Water and Wastewater, EPA - 600/4-82-029, September, 1982.

3.0 RESPONSIBILITIES

It will be the responsibility of the site operations/field work coordinator to provide that all sediment samples are collected in accordance with these procedures and the site specific sampling protocol.

4.0 EQUIPMENT

- Project Sampling Plan
- Sediment Sampling Log
- Deionized water dispenser rinse bottles
- Methanol dispenser rinse bottles
- Chemical free paper towels
- Sample logs
- Sample containers and sample labels
- 100 foot tape measure
- Wader-type rubber boots (shallow streams)
- Floatation sampling platform (ponds)
- Logbooks
- Plastic spoons
- Plastic or galvinized steel basin
- 2mm mesh sieve
- Cloth bags
- Plastic sandwich bags

5.0 INSTRUCTIONS

5.1 GENERAL PROCEDURE - STREAM SEDIMENT SAMPLING

5.1.1 Samples from small streams will be collected either from the bank or by wading into the stream. Samples shall be collected from quarter points across the stream channel and then composited. The sampling plan will provide the depths for sampling

5.1.2 Sampling equipment shall be decontaminated after every sample aliquot is taken. Decontamination procedures are presented in Appendix H.

5.1.3 If pebbles and particles larger than 2mm are present, they shall be removed by shaking through a 2mm mesh seive into a plastic container.

5.1.4 Excess water shall be poured out of the container and the sample shall be placed into a clean cloth bag to filter out the excess water. The sample shall then be placed into a plastic bag and put into an appropriate labeled sample container

5.1.5. All field observations shall be maintained in the field notebook. In addition, a Sediment Sample Log (Figure J-1) will be completed for each location. Chain of custody forms shall be completed.

5.1.6 The sample shall be transferred to the field laboratory for sample analysis and preparation for off-site laboratory shipment.

5.2 GENERAL PROCEDURE - Pond - Lake Sediment Sampling using Ponar clamshell-type scoop.

5.2.1 Measure the depth of water and attach Ponar to the required length of sample line.

5.2.2 Secure free end of line to the safety railing on the floatation sampling platform to prevent accidental loss of samples.

5.2.3 Open the sampler jaws until they are latched. Support the sampler by its lift line or the sampler will be tripped and the jaws will close.

5.2.4 Slowly lower the sampler to the bottom and allow the sample line to slack. When tension is released on the sample line, the latch releases, allowing the clamshell to close when the sampler is retrieved.

5.2.5 Slowly raise the sampler clear of the surface and open the clamshell into a plastic sample tray. Follow the procedures discussed above in Section 5.1.4

5.2.6 Thoroughly decontaminate the sampler per Appendix H between every sample collection.

5.2.7 The sample shall be placed into a plastic bag and put into an appropriately labeled sample container.

5.2.8 All field observations shall be maintained in the field notebook. In addition, a Sediment Sample Log (Figure J-1) will be completed for each location. Chain-of-custody forms shall be completed.

5.2.9 The sample shall be transferred to the field laboratory for sample analysis and preparation for off-site laboratory shipment.

FIGURE J-1

SEDIMENT SAMPLE LOG

PROJECT NO._____ PROJECT LOCATION_____

SAMPLE POINT NO._____

DATE _____

SAMPLE POINT DESCRIPTION/DESIGNATION

_____

_____

TYPE OF SURFACE WATER SOURCE_____

DEPTH OF SURFACE WATER AT SAMPLE POINT_____

DESCRIPTION OF SEDIMENT SAMPLE(include: estimation of organic/inorganic fraction, presence of humic material, colour, oil film, odor, etc.)

_____

_____

_____

_____

_____

REMARKS_____

_____

_____

_____

INSPECTOR'S NAME_____

APPENDIX K

SURFACE WATER SAMPLING TECHNIQUES

SURFACE WATER SAMPLING TECHNIQUES

1.0 SCOPE AND APPLICATION

This Standard Operating Procedure describes the basic techniques and considerations to be followed for the collection of water samples from streams, lakes, and ponds using a dipper. The specific details of sample collection are dependent upon local site conditions as well as the purpose of the water quality study.

2.0 APPARATUS

The dipper consists of a glass or plastic beaker clamped to the end of a 2- or 3-piece telescoping aluminum or fiberglass pole which serves as the handle. A dipper samples liquids and free-flowing streams. Dippers are not commercially available and must be fabricated to conform to the specifications detailed in Figure 3, of Reference 1 (EPA). The following lists the parts required to fabricate a dipper:

Quantity	Item	Supplier
1	Adjustable clamp, 6.4 to 8.9 cm (2-1/2 to 3-1/2 in.) for 250-60-ml beakers. Heavy duty aluminum	Laboratory supply houses
1	Tube 2.5 to 4.5 m long with joint cam locking arm mechanism. 2.54 cm I.D. and 3.18 cm I.D.	Swimming pool supply Diameter houses
1	Polypropylene or glass beaker, 250 ml to 600 ml	Laboratory supply houses
4	Bolts 2-1/4 in. x 1/4 in., NC	Hardware stores
4	Nuts, 1/4 in., NC	Hardware stores

3.0 GENERAL COMMENTS AND PRECAUTIONS

- Do not use a nonfluorocarbon plastic containing organic materials.
- Do not use a glass beaker to sample wastes of high pH or wastes that contain hydrofluoric acid.
- Paint aluminum pole and clamp with a 2-part epoxy or other chemical resistant paint when sampling either alkaline or acidic wastes.

4.0 MATERIALS

- Sample Plan - surface waste sampling protocol
- Site area maps
- Sample containers and preservatives
- Insulated containers (e.g., coolers) for sample storage and large quantities of ice.
- Field equipment for analyses specified in the sampling program. Include calibration standard for any field measurements.
- Dipper
- Weighted tape measure or ridged gage
- Field data sheets and/or log book
- First aid kit

5.0 PROCEDURES

5.1 Sample Location Selection

The selection of sampling locations where mixing is incomplete should be avoided if an average composition is required. Use of a field conductivity meter is recommended for determining the uniformity of the water composition across the width and depth of the water body. Once the sampling point is selected, it must be fixed by detailed description, maps, or with the aid of stakes or other landmarks so that the sampling can be repeated if needed.

5.2 Stream Sampling

5.2.1 In shallow streams (those that can be transversed safely on foot) the sample container can be filled directly with the flowing water. Unless otherwise specified, the sample shall be collected at mid-depth in the mid-section or deepest flow channel of the stream.

5.2.2 In deep rivers, use of a floatation sampling platform may be required to obtain a representative sample. Samples should be obtained at mid-depth in the mid-channel unless otherwise specified. Stream depth can be determined using the weighted measuring tape or ridged gage.

5.3 Pond and Lake Sampling

5.3.1 Water - Ponds and lakes are generally poorly mixed and thermal stratification is frequently observed. Single samples only represent the spot from which they were obtained. In some studies, samples taken at the inlet(s) and/or outlet of the pond or lake are of most importance. In other studies, a grid can be established over the water and samples can be collected at various intersections.

5.4 Sampling Using a Dipper

1. Clean beaker, clamp and handle per decon instructions (Appendix H).

2. Turn dipper so the mouth of the beaker faces down and insert into water. Turn beaker right side up when dipper is at the desired depth. Allow beaker to fill completely as shown by the cessation of air bubbles.

3. Raise dipper and transfer sample to container.

6.0 SAMPLE HANDLING AND PRESERVATION

6.1 In general, the shorter the time lapse between sample collection and analysis, the more reliable the results will be. Certain water-quality parameters, including pH, temperature and dissolved oxygen, are closely related to the environment of the water and meaningful results can only be obtained by in-situ field measurements.

6.2 The EPA has developed a list of recommended sample containers, preservatives and maximum holding times for water quality measurements (Federal Register 44:69464). Unless specified in the sampling plan, this list should be followed. Preservatives can be added directly to the sample containers in the field after filling, or the containers can be pre-preserved. All samples should be placed on ice immediately after collection and should remain on ice until delivery to the analytical laboratory.

7.0 DESCRIPTION

Records must be kept of every sample collected and each bottle must be marked with a waterproof label. A field-data sheet for water quality is provided in Figure K-1. The field record must provide sample identification as well as the name of the sample collector, the date, time and exact locations of the collection

point, and results of all field water quality measurements. Other information such as weather and stream flow conditions should also be noted. All documentation shall be retained in the appropriate project files.

8.0 REFERENCES

USEPA, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Office of Waste and Emergency Response, SW846, 2nd Ed., 1982.

FIGURE K-1

WATER QUALITY FIELD DATA SHEET

Title Date Time Project No. Proposal No.

Location _____

Station No. _____ Station Name _____

Observers _____

Comments _____

Location Within Transect* _____

Total Depth _____ Secchi Disc Depth _____

FIELD MEASUREMENTS

Depth (meters)	Temp (°C)	DO (mg/l)	DO Sat. (%)	Conductivity (umhos/cm)	pH (units)	Depth (meters)	Velocity (ft/sec)

*Left bank and right bank are determined facing downstream.

APPENDIX L

METHODS FOR ANALYSES OF WASTE WATER

Temperature
pH
Conductance
Dissolved Oxygen

TEMPERATURE

METHOD 170.1 (THERMOMETRIC)

STORET NO. 00010

1. SCOPE AND APPLICATION

1.1 This method is applicable to drinking, surface, and saline waters, domestic and industrial wastes.

2. SUMMARY OF METHOD

2.1 Temperature measurements may be made with any good grade of mercury-filled or dial type centrigrade thermometer, or a thermistor.

3. COMMENTS

3.1 Measurement device should be routinely checked against a precision thermometer certified by the National Bureau of Standards.

4. PRECISION AND ACCURACY

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

5. REFERENCE

5.1 The procedure to be used for this determination is found in: Standard Methods for the Examination of Water and Wastewater, 14th Edition, p 125, Method 212(1975).

pH

METHOD 150.1 (ELECTROMETRIC)

STORET NO.
Determined on site 00400
Laboratory 00403

1.0 SCOPE AND APPLICATION

1.1 This method is applicable to drinking, surface, and saline waters, domestic and industrial wastes and acid rain (atmospheric deposition).

2.0 SUMMARY OF METHOD

2.1 The pH of a sample is determined electrometrically using either a glass electrode in combination with a reference potential or a combination electrode.

3.0 SAMPLE HANDLING AND PRESERVATION

3.1 Samples should be analyzed as soon as possible preferably in the field at the time of sampling.

3.2 High-purity waters and waters not at equilibrium with the atmosphere are subject to changes when exposed to the atmosphere, therefore the sample containers should be filled completely and kept sealed prior to analysis.

4.0 INTERFERENCES

4.1 The glass electrode, in general, is not subject to solution interferences from color, turbidity, colloidal matter, oxidants, reductants or high salinity.

4.2 Sodium error at pH levels greater than 10 can be reduced or eliminated by using a "low sodium error" electrode.

4.3 Coatings of oily material or particulate matter can impair electrode response. These coatings can usually be removed by gentle wiping or detergent washing, followed by distilled water rinsing. An additional treatment with hydrochloric acid (1 + 9) may be necessary to remove any remaining film.

4.4 Temperature effects on the electrometric measurement of pH arise from two sources. The first is caused by the change in electrode output at various temperatures. This interference can be controlled with instruments having temperature compensation or by calibrating the electrode-instrument system at the temperature of the samples. The second source is the change of pH inherent in the sample at various temperatures. This error is sample dependent and cannot be controlled. It should therefore be noted by reporting both the pH and temperature at the time of analysis.

5.0 APPARATUS

5.1 pH Meter Laboratory or field model. A wide variety of instruments are commercially available with various specifications and optional equipment.

5.2 Glass electrode.

5.3 Reference electrode - a calomel, silver-silver chloride or other reference electrode of constant potential may be used.

NOTE I: Combination electrodes incorporating both measuring and reference functions are convenient to use and are available with solid, gel type filling materials that require minimal maintenance.

5.4 Magnetic stirrer and Teflon-coated stirring bar.

5.5 Thermometer or temperature sensor for automatic compensation.

6.0 REAGENTS

6.1 Primary standard buffer salts are available from the National Bureau of Standards and should be used in situations where extreme accuracy is necessary.

6.1.1 Preparation of reference solutions from these salts requires some special precautions and handling([1]) such as low conductivity dilution water, drying ovens, and carbon dioxide free purge gas. These solutions should be replaced at least once each month.

6.2 Secondary standard buffers may be prepared from NBS salts or purchased as a solution from commercial vendors. Use of these commercially available solutions, that have been validated by comparison to NBS standards, are recommended for routine use.

---

[1]National Bureau of Standards Special Publication 20.

7.0 CALIBRATION

7.1 Because of the wide variety of pH meters and accessories, detailed operating procedures cannot be incorporated into this method. Each analyst must be acquainted with the operation of each system and familiar with all instrument functions. Special attention to care of the electrodes is recommended.

7.2 Each instrument/electrode system must be calibrated at a minimum of two points that bracket the expected pH of the samples and are approximately three pH units or more apart.

7.2.1 Various instrument designs may involve use of a "balance" or "standardize" dial and/or slope adjustment as outlined in the manufacturer's instructions. Repeat adjustments on successive portions of the two buffer solutions as outlined in procedure 8.2 until readings are within 0.05 pH units of the buffer solution value.

8.0 PROCEDURE

8.1 Standardize the meter and electrode system as outlined in Section 7.

8.2 Place the sample or buffer solution in a clean glass beaker using a sufficient volume to cover the sensing elements of the electrodes and to give adequate clearance for the magnetic stirring bar.

8.2.1 If field measurements are being made the electrodes may be immersed directly in the sample stream to an adequate depth and moved in a manner to insure sufficient sample movement across the electrode sensing element as indicated by drift free (<0.1 pH) readings.

8.3 If the sample temperature differs by more than 2°C from the buffer solution, the measured pH values must be corrected. Instruments are equipped with automatic or manual compensators that electronically adjust for temperature differences. Refer to manufacturer's instructions.

8.4 After rinsing and gently wiping the electrodes, if necessary,immerse them into the sample beaker or sample stream and stir at a constant rate to provide homogeneity and suspension of solids. Rate of stirring should minimize the air transfer rate at the air water interface of the sample.

Note and record sample pH and temperature. Repeat measurement on successive volumes of sample until values differ by less than 0.1 pH units. Two or three volume changes are usually sufficient.

8.5 For acid rain samples it is most important the the magnetic stirrer is not used. Instead, swirl the sample gently for a few seconds after the introduction of the electrode(s). Allow the electrode(s) to equilibrate. The air-water interface should not be disturbed while measurement is being made. If the sample is not in equilibrium with the atmosphere, pH values will change as the dissolved gases are either absorbed or desorbed. Record sample pH and temperature.

9.0 CALCULATION

9.1 pH meters read directly in pH units. Report pH to the nearest 0.1 unit and temperature to the nearest ^{o}C.

10.0 PRECISION AND ACCURACY

10.1 Forty-four analysts in twenty laboratories analyzed six synthetic water samples containing exact increments of hydrogen-hydroxylions, with the following results:

pH Units	Standard Deviation pH Units	Accuracy As Bias %	Bias, pH Units
3.5	0.10	-0.29	-0.01
3.5	0.11	-0.00	
7.1	0.20	+1.01	+0.07
7.2	0.18	-0.03	-0.002
8.0	0.13	-0.12	-0.01
8.0	0.12	+0.16	+0.01

(FWPCA Method Study 1, Mineral and Physical Analyses)

10.2 In a single laboratory (EMSL), using surface water samples at an average pH of 7.7, the standard deviation was ±0.1.

BIBLIOGRAPHY

1. Standard Methods for the Examination of Water and Wastewater, 14th Edition, p. 460(1975)

2. Annual Book of ASTM Standards, Part 31, "Water", Standard D1293-65, p. 178(1976).

3. Peden, M.E. and Skowron, L.M. Ionic Stability of Precipitation Samples. Atmospheric Environment, Vol. 12, pp. 2323-2349, 1978.

CONDUCTANCE

METHOD 120.1, (SPECIFIC CONDUCTANCE, UMHOS AT 25°c)

STORET NO. 00095

1.0 SCOPE AND APPLICATION

1.1 This method is applicable to drinking, surface and saline waters, domestic and industrial wastes and acid rain (atmospheric deposition).

2.0 SUMMARY OF METHOD

2.1 The specific conductance of a sample is measured by use of a self-contained conductivity meter, Wheatstone bridge-type or equivalent.

2.2 Samples are preferable analyzed at 25°C. If not, temperature corrections are made and results reported at 25°C.

3.0 COMMENTS

3.1 Instrument must be standardized with KCI solution before daily use.

3.2 Conductivity cell must be kept clean.

3.3 Field measurements with comparable instruments are reliable.

3.4 Temperature variations and corrections represent the largest source of potential error.

4.0 SAMPLE HANDLING AND PRESERVATION

4.1 Analyses can be performed either in the field or laboratory.

4.2 If analysis is not completed within 24 hours of sample collection, sample should be filtered through a 0.45 micron filter and stored at 4°C. Filter and apparatus must be washed with high quality distilled water and pre-rinsed with sample before use.

5.0 APPARATUS

5.1 Conductivity bridge, range 1 to 1000 umho per centimeter.

5.2 Conductivity cell, cell constant 1.0 or micro dipping type cell with 1.0 constant. YSI #3403 or equivalent.

5.3 Thermometer

6.0 REAGENTS

6.1 Standard potassium chloride solutions, 0.01 M: Dissolve 0.7456 gm of pre-dried (2 hour at 105°FC) KCL in distilled water and dilute to 1 liter at 25°C.

7.0 CELL CALIBRATION

7.1 The analyst should use the standard potassium chloride solution (6.1) and the table below to check the accuracy of the cell constant and conductivity bridge.

Conductivity 0.01 m KCL

°C	Micromhos/cm
21	1305
22	1332
23	1359
24	1386
25	1413
26	1441
27	1468
28	1496

8.0 PROCEDURE

8.1 Follow the direction of the manufacturer for the operation of the instrument.

8.2 Allow samples to come to room temperature (23 to 27°C), if possible.

8.3 Determine the temperature of samples within 0.5°C. If the temperature of the samples is not 25°C, make temperature correction in accordance with the instruction in Section 9 to convert reading to 25°C.

9.0 CALCULATION

9.1 These temperature corrections are based on the standard KCl solution.

9.1.1 If the temperature of the sample is below 25°C, add 2% of the reading per degree.

9.1.2 If the temperature is above 25°C. subtract 2% of the reading per degree.

9.2 Report results as Specific Conductance umhos/cm at 25°.

10.0 PRECISION AND ACCURACY

10.1 Forty-one analysts in 17 laboratories analyzed six synthetic water samples containing increments of inorganic salts, with the following results:

Increment As Specific Conductance	Precision As Standard Deviation	Accuracy As Bias, %	Accuracy As Bias, umhos/cm
100	7.55	-2.02	-2.0
106	8.14	-0.76	-0.8
808	66.1	-3.63	-29.3
848	79.6	-4.54	-38.5
1640	106	-5.36	-87.9
1710	119	-5.08	-86.9

10.2 In a single laboratory (EMSL) using surface water samples with an average conductivity of 536 umhos/cm at 25°C, the standard deviation was ±6.

OXYGEN, DISSOLVED

METHOD 360.1 (MEMBRANE ELECTRODE)

STORET NO. 00299

1.0 SCOPE AND APPLICATION

1.1 The probe method for dissolved oxygen is recommended for those samples containing materials which interfere with the modified Winkler procedure such as sulfite, thiosulfate, polythionate, mercaptans, free chlorine or hypochlorite, organic substances readily hydrolyzed in alkaline solutions, free iodine, intense color or turbidity and biological flocs.

1.2 The probe method is recommended as a substitute for the modified Winkler procedure in monitoring streams, lakes, outfalls, etc., where it is desired to obtain a continuous record of the dissolved oxygen content of the water under observation.

1.3 The probe method may be used as a substitute for the modified Winkler procedure in BOD determinations where it is desired to perform nondestructive DO measurements on a sample.

1.4 The probe method may be used under any circumstances as a substitute for the modified Winkler procedure provided that the probe itself is standardized against the Winkler method on samples free of interfering materials.

1.5 The electronic readout meter for the output from dissolved oxygen probes is normally calibrated in convenient scale (0 to 10, 0 to 15, 0 to 20 mg/l for example) with a sensitivity of approximately 0.05 mg/liter.

2.0 SUMMARY OF METHOD

2.1 The most common instrumental probes for determination of dissolved oxygen in water are dependent upon electrochemical reactions. Under steady-state conditions, the current or potential can be correlated with DO concentrations. Interfacial dynamics at the probe-sample interface are a factor in probe response and a significant degree of interfacial turbulence is necessary. For precision performance, turbulence should be constant.

3.0 SAMPLE HANDLING AND PRESERVATION

3.1 See 4.1, 4.2, 4.3, 4.4 under Modified Winkler Method (360.2)

4.0 INTERFERENCES

4.1 Dissolved organic materials are not known to interfere in the output from dissolved oxygen probes.

4.2 Dissolved inorganic sales are a factor in the performance of dissolved oxygen probe.

4.2.1 Probes with membrane respond to partial pressure of oxygen which, in turn, is a function of dissolved inorganic salts. Conversion factors for seawater and brackish waters may be calculated from dissolved oxygen saturation versus salinity data. Conversion factors for specific inorganic sale may be developed experimentally. Broad variations in kinds and concentrations of salts in samples can make the use of a membrane probe difficult.

4.3 Reactive compounds can interfere with the output or the performance of dissolved oxygen probes.

4.3.1 Reactive gases which pass through the membrane probes may interfere. For example, chlorine will depolarize the cathode and cause a high probe-output. Long-term exposures to chlorine will coat the anode with the chloride of the anode metal and eventually desensitize the probe. Alkaline samples in which free chlorine does not exist will not interfere. Hydrogen sulfide will interfere with membrane probes if the applied potential is greater than the half-wave potential of the sulfide ion. If the applied potential is less than the half-wave potential, an interfering reaction will not occur, but coating of the anode with the sulfide of the anode metal can take place.

4.4 Dissolved oxygen probes are temperature sensitive, and temperature compensation is normally provided by the manufacturer. Membrane probes have a temperature coefficient of 4 to 6 percent/^{o}C dependent upon the membrane employed.

5.0 APPARATUS

5.1 No specific probe or accessory is especially recommended as superior. However, probes which have been evaluated or are in use and found to be reliable are the WESTON & Stack DO Analyzer Model 30, the Yellow Springs Instrument (YSI) Model 54, and the Beckman Fieldlab Oxygen Analyzer.

6.0 CALIBRATION

Follow manufacturer instructions.

7.0 PROCEDURE

Follow manufacturer instructions.

8.0 CALCULATION

Follow manufacturer instructions.

9.0 PRECISION AND ACCURACY

Manufacturer's specification claim 0.1 mg/l repeatability with ± 1% accuracy.

Bibliography

1. Standard methods for the Examination of Water and Wastewater, 14th Edition, p 450, Method 422F(1975).

APPENDIX M

PROCEDURES FOR MAKING RADON FLUX MEASUREMENT

1.0 PURPOSE

The purpose of this procedure is to present a series of instructions for the determination of radon flux from surfaces.

2.0 SCOPE

This procedure provides instructions for the determination of radon flux from ground surfaces. It is limited to the use of charcoal canisters placed in contact with the ground, and the evaluation of these canisters using gamma ray spectrometry techniques. Further, this procedure is limited to work to be performed at the Feed Materials Production Center, Fernald, Ohio.

3.0 REFERENCES

W.A. Goldsmith, et al., Radon Flux Measurements, RASCA Procedures Manual, Procedure No. 13.11, Rev. 8, ORNL-6000, September, 1982.

4.0 MATERIALS AND SUPPLIES

4.1 One lot-charcoal canisters used for radon flux determinations - 24 each.

4.2 Plastic bags (12" x 12" x .003" thick).

4.3 Masking tape - 1 roll.

4.4 Sample container labels - 50 each.

4.5 Waterproof ink pens.

4.6 Field Log Book.

47. Sample Collection Forms.

4.8 Time piece (clock, stop watch, etc.).

4.9 Low temperature oven.

5.0 PROCEDURES

NOTE: Radon which emanates across a soil/air interface will vary as ambient weather conditions change. Flux is a function of Ra-226 in subsurface soil, but is affected by soil porosity, soil moisture, and ambient pressure

and temperature. While determinations of radon flux are not exact, a series of canisters placed at various points in an area where ambient conditions are the same, should provide information about the relative magnitude of the radon source.

6.1 SAMPLE PREPARATION

Before a charcoal canister may be used for estimation of radon flux, it must be conditioned. This is done by placing each canister in an over for 24 hours (T=100°C). After the canisters have cooled, they are placed individually in a plastic bag and sealed. Also prior to use in the field, a background count must be made and recorded.

6.2 SAMPLE LOCATION

The location for radon flux measurements will be marked on a mpa of the FMPC Waste Storage Area by the Field Sampling Coordinator.

6.3 SAMPLE PLACEMENT

Each charcoal canister will be placed on a smooth ground surface after grass has been removed. Remove one canister from its plastic bag and twist the canister's thin wall cylinder about 0.5 cm into the ground. Soil should be packed around the canister as a seal. Record the location and time of emplacement in the Field Log Book. Place the remaining canisters as indicated on the sample map.

6.4 SAMPLE DURATION

The appropriate period of exposure time for canisters is a function of the local radon fux. To determine this approximate period, it will be necessary to deploy several canisters at selected sites in order to establish an exposure time. This will be done by placing canisters in an area believed to represent near background conditions, and one which is believed to represent a near maximum radon flux. At each location, 4 canisters will be placed on the ground and sealed as described in 6.3. One canister will be removed from each location following exposures of 2, 6, 24 and 32 hours. As each canister is removed, it will be sealed in a clean plastic bag and transported to the laboratory trailer. Following a period of at least four hours, the canister will be counted using gamma-ray spectrometry techniques. An evaluation of data from this exercise will be used to establish optimum exposure periods.

6.5 SAMPLE RETRIEVAL

Following exposure for the established optimum period, canisters will be retrieved. When the canister is removed from the ground, a clean rag or paper wipe will be used to remove loose soil, mud, etc., from the canister rim in contact with the ground.

6.6

Place each canister in an individual plastic bag, complete all information blanks on a sample container label and attach the label to the plastic bag. Record sample identification on the Chain-of-Custody record and in the Field Log Book.

6.7

Transport Samples to the field laboratory trailer and store for a minimum of four hours to permit equilibration of radon daughters.

6.8 SAMPLE COUNTING

Charcoal canisters will be counted with gamma-ray spectrometry equipment in a manner similar to that used to analyze soil samples.

6.8.1

For charcoal samples exposed at the FMPC, counting will be performed using a sodium iodide crystal or a reverse electro high purity germanium crystal coupled to a manual multi-channel analyzer. Calibration factors for the determination of radon flux from ground surfaces will be determined through a series of calibration tests performed at Mound Laboratory or the Environmental Measurements Laboratory (DOE Laboratories). This work will be completed before field work begins.

6.8.2

With the canister in its plastic bag, place the canister in the counting position on top of the detector crystal and close the shield door.

6.8.3

Reset the multi-channel analyzer and count the sample for 20 minutes (this counting period may be varied as needed to obtain optimum counting statistics).

6.8.4

When the counting period has ended, record the net area (number of counts in a Region of Interest (ROI) minus the background in the ROI due to Compton Scattering in the detectors) for the following photo-peaks: 0.295 MeV and 0.352 MeV from Pb-214, and 0.609 MeV and 1.12 MeV from Bi-214. This information will be used to obtain four individual estimates of the concentration of radon in each canister and hence the estimated radon flux. For a given location, the radon flux estimate will be represented by the average of the four radon flux estimates.

6.9 CALCULATIONS

Radon flux for the ith photon will be determined by the following relation:

$$\text{flux}_i = \frac{C_i \cdot a_i}{E_i \times A\,(1-e^{-\lambda t})\,(e^{-\lambda t_1}-e^{-\lambda t_2})} \quad \text{pCi/m}^2\text{ - sec}$$

where:

C_{i*} = Net Count for ith photon (0.295, 0.352, etc.)

a_i = Constant for ith photon

E_i = Efficiency factor which incorporates canister efficiency, photon abundance, counting time, and exposure time for ith photon

A = Area of canister in M^2

λ = $7.55 \times 10^{-3}\ h^{-1}$

t = exposure time in hours

t_1 = time between end of exposure and start of count in hours

t_2 = time between end of exposure and end of counting in hours

*The actual C_i is the net count determined by the MCA minus previously determined canister background for the ith ROI.

An estimate of the radon flux for a given location maybe determined from the following relationship:

$$\text{Flux} = \sum_{i=1}^{n} [(\text{flux}_i) \quad (Wi)]$$

where:

Flux_i is the flux estimate for the ith photon.

i = 1 is the flux for the .295 MeV photon.
i = 2 is the flux estimate for the .352 MeV photon.
i = 3 is the flux estimate for the .609 MeV photon.
i = 4 is the flux estimate for the 1.12 MeV photon.

Wi is a weighting factor associated with the relative abundance (Ai) of the 4 photons.

$$Wi = \frac{Ai}{\sum_{i=1}^{n} Ai}$$

6.10 CHARCOAL CANISTER REGENERATION

After counting, collect the used canisters and place them in an oven (100°C) for a period of 24 hours to purge radon from the canisters and reactivate the charcoal.

6.11 CHARCOAL CANISTERS BACKGROUND

Before he canister is used for subsequent radon flux measurements, it must be recounted to determine the background for each Region of Interest.

APPENDIX N

THE DETERMINATION OF RADON 222 IN AIR USING THE RADON FILM DETECTOR METHOD

ATTACHMENT 1 - TWO-FILTER METHOD FOR THORON (Rn-220)

OUTDOOR LONG-TERM RADON-222 MEASUREMENTS PROCEDURE USING TRACK ETCH DETECTORS

1.0 PURPOSE:

To provide detailed procedures and overall guidance for making long-term average Rn-222 measurements using Track Etch detectors. This procedure only applies to outdoor measurements.

2.0 SCOPE:

As radon and radon progeny decay, the resultant alphas particles produce radiation-damage tracks in thin plastic films exposed to the air. The film detector is mounted inside the bottom of a plastic shield. A special filter installed over the mouth of the cup filters out radon daughters, as well as dust and dirt, such that only radon gas enters the cup. The detectors are chemically treated after exposure to make the tracks visible. The number of tracks in a specified area is directly proportional to the integrated alpha exposure from the decay of the radon to which the detector was exposed. The detection range is from 0.2 to 20,000 pCi/l-months for outdoor measurements.

3.0 REFERENCES:

"Passive Integrating Radon monitor for Environmental Monitoring," H. Ward Alter and Robert L. Fleisher, Health Physics, Vol. 40, p.693 (1981).

"Instructions for Track-Etch[R] Type F Radon Detectors," Terradex Corporation, 460 N. Wiget Lane, Walnut Creek, California. 94598.

4.0 PROCEDURE SUMMARY

Film detectors and shields are ordered from Terradex on an as-needed basis in advance of installation. The number of detectors ordered include enough to install a minimum of two detectors at each location and a number for quality assurance exposures. All detectors that are to be utilized for a specific exposure period should come from the same batch (master sheet) of film detectors. The film detectors are received from the vendor in aluminum bags of ten detectors each; however, a smaller number may be enclosed in a bag. Installation is handled by opening one bag of detectors in the field at a time. Assembly of the detector cups is also handled at the monitoring location, as the detector cups are installed. The serial number, date opened, date installed, site number, and location are entered on the field data sheet for each detector. After initial installation, the film detector cups are changed on a quarterly basis. Upon

retrieval of the detector cups, the filter is removed and checked for pinholes and a visual inspection of the film is made. The date removed is then entered on the field data sheet along with comments. When all detectors have been retrieved, they are packed in an aluminum bag, ten cups per bag. The aluminum bag is sealed and information transferred from field data sheets to the vendor's data sheets. The detectors are assembled with the control group detectors consisting of blanks (unexposed detectors) and detectors exposed at known concentrations (optional). The entire shipment, along with properly filled out data sheets, are shipped to the vendor for analysis.

5.0 EQUIPMENT:

- Radon film detector cups, type F, Terradex Corporation.
- Filters, Terradex Corporation.
- Yellow plastic separator sheets, Terradex Corporation.
- Red retaining rings, Terradex Corporation.
- Outdoor field canisters (shields), Terradex Corporation.
- Data sheets - field recording, (Figure N-1).
- Data sheets - vendor, Terradex Corporation.
- Aluminum storage bags.
- Tape (strapping).

6.0 INSTRUCTIONS:

6.1 PROCUREMENT:

- Prior to the planned installation of the film detectors, submit a purchase order for the purchase and readout of the detectors.

- Specify the delivery date with two weeks prior to installation.

- Specify the quantity of detectors desired. This should include enough to install a minimum of two detectors per location and at least ten detectors (optional) for known exposures and background determinations.

- Request that the detectors in this order be from the same batch of film. The detectors must all be of the type F configuration.

- Specify maximum readout area for outdoor monitoring. For Terradex film detectors, this is 19.3 mm^2

- Specify that results should be reported in pCi/l and in either tracks/mm^2 or total tracks.

- Inspect the shipment of film detector cups when they arrive from Terradex.

- Check the aluminum bags for holes or tears.

- Check the contents of each bag by feeling along the entire length of the aluminum bag for crushed cups. DO NOT open bag.

IMPORTANT: DO NOT open the sealed aluminum bags until they are to be installed at the monitoring location.

6.2 INSTALLATION OF PROTECTIVE CANISTERS FOR OUTDOOR MONITORING

- Attach the protective canister (shield) to a post or other suitable location at a height of two to three meters. The shield should be firmly mounted with no obstructions to the free flow of air past the detector. In general, canisters should be mounted on the northern sides of the mounting post. Building walls, highway structures, or large signs should be avoided.

- Alternatively, the detector (with insulation canister) surrounding the plastic (cup) may be placed inside a larger stand-alone shelter. Canisters should be installed so that the entire detector is at least 6 inches from any obstruction. Install the canister with the open mouth facing down. The stand-alone shelter should be open and allow the free flow of air through it. The detectors must be mounted firmly to avoid movement within the shelter.

6.3 ASSEMBLY AND INSTALLATION OF RADON FILM DETECTORS (FIELD PERSONNEL):

- At the monitoring location, open one aluminum bag and remove sufficient film detector cups to enable installation of the appropriate number of replicates, making sure to close the bag after removing the set.

- Visually inspect the film detector to assure that it is securely fastened to the bottom of the cup. If the film is not secured to the bottom of the cup, secure it. Extreme care should be taken not to touch the film.

- If the film is touched, use a different cup and detector. On the field data sheet, write down the serial

number of the breached cup and indicate what happened in the comments section.

- Take one filter and cover the mouth of the cup. The shiny side of the filter should be facing out.

- Take one red cover ring and, holding the filter taut, firmly push the cover ring over the two sets of ribs of the cup.

- Assure that the cover is fully seated around the cup rim. Inspect the fully assembled detector to assure that the filter covers the entire mouth of the cup, there are no large wrinkles in the filter, and that the filter has not been torn or punctured by assembly.

- Install the film detector cup at the monitoring location inside the protective canister.

- Enter the serial number of the film detector cup, the date the bag was opened, the date installed, site number, and location on the field data sheet.

- Schedule the installation of the film detector cups such that when a bag is opened, all cups can be installed immediately. Do not use film detector cups that have been stored in an opened bag overnight. The aluminum bags should be saved for use when the film detector cups are retrieved.

6.4 RETRIEVAL OF RADON FILM DETECTORS (FIELD PERSONNEL):

- Remove the film detector cup from the canister and wipe off any dust or dirt from the outside of the cup. Remove the red cover ring and filter from the mouth of the cup.

- Inspect the filter by holding it up to the light. Note any damage to the filter in the comments section of the data sheet (e.g., pinholes, scratches, tears, etc.).

- Visually inspect the film on the bottom of the cup. Note any discoloration or damage to the film in the comments section of the data sheet.

- Enter the date removed for the correct serial number on the field data sheet, and place the film detector cup in the aluminum bag.

- Stack the exposed cups. Close aluminized bag and proceed to install new cups, if necessary. After an aluminized bag is filled (10 cups, maximum), insert the empty cup provided into the last film detector cup with a yellow plastic separator sheet. If an end cup is not provided, place a yellow plastic separator sheet over the mouth of the last film detector cup and secure it with one of the red cover rings.

- Fold the open end of the aluminum bag and seal using tape. Remember, do not exceed 10 cups per bag.

6.5 SHIPPING GUIDELINES (FIELD PERSONNEL):

- When all exposed detectors have been retrieved, proof-read the field data sheets to assure that all applicable information is recorded in the proper column and that all comments are legible. (Detector serial number, date opened, date installed, date removed, site number, location).

- Assure that all aluminum bags containing exposed detectors are sealed and have no pinholes or tears.

- Transcribe all data from the field data sheets to the vendor's data sheets.

- Complete the vendor's preshipping checklist. Specify the readout sensitivity with any special handling instructions and include with the data sheets and detectors.

- Ship detectors to the vendor for readout.

FIGURE N-1

TRACK ETCH DETECTOR FIELD DATA SHEET

Site: _____ Page_____of_____

Detector serial number	Date opened	Date installed	Installed by	Date Removed	Removed by	Location or I.D.	Comments

Additional Comments:

ATTACHMENT 1

TWO-FILTER METHOD FOR THORON (Rn-220)

TWO-FILTER METHOD FOR THORON

1.0 PURPOSE

The purpose of this procedure is to describe a method to be used for screening thoron in areas having elevated Th-232 concentrations.

2.0 SCOPE

Air is drawn thorough a metal tube equipped with a high efficiency filter at each end. The inlet filter removes all thoron daughters, admitting only thoron together with the sample air into the tube. The thoron partially decays in transit, producing Th-A and Th-B atoms, most of which are collected on the exit filter, the remainder depositing on the tube wall. After sampling, the exit filter is removed and analyzed in an Eberline SAC-4 alpha counter. Thoron is calculated by an equation that accounts for the dimensions, sample flow rate, sampling and counting intervals, and the fraction of Th-A and Th-B that reaches the exit filter.

3.0 REFERENCES

3.1 Operation of the Eberline SAC-4 Scintillation Alpha Counter.

3.2 Operation of RAS-1, Portable Air Sampler.

3.3 Jess W. Thomas, Thoron Determination by the Two-Filter Method, Health and Safety Laboratory, USAEC, NY; January 1971.

4.0 EQUIPMENT

4.1 A stainless steel cylinder of 50 cm in length, and 5 cm in diameter, having a filter assembly at each and having a connection from the exit filter to an air pump. The diameter of the filters should equal that of the tube. The exit filter should be amenable to rapid disassembly so that the filter may be removed promptly.

4.2 A portable RAS-1 low volume air sampler.

4.3 Particulate Filters.

4.4 Timing device.

4.5 Envelopes for filter samples.

4.6 SAC-4 alpha scintillation counter.

4.7 Field data sheet.

5.0 PROCEDURES

5.1 Place filters in sample heads. Always mark the new filter to indicate direction of air flow.

5.2 Start air sampler, adjust flow to 10 liters/minute, record flow rate, date, time, and sample number and/or location on prestamped envelopes for new sample.

5.3 A ten-minute sample will be collected with the two filter tube.

5.4 After sampling, the exit filter will be removed, and placed in an envelope. Record location, date, time, flow rate, and initials of HP Technician.

5.5 Thoron concentration is calculated using the following equation:

$$C_{th} = \frac{0.45x}{E\ Z\ V\ F_f}$$

where:

C_{th} = thoron concentration in pCi/l
X = number of alpha counts - BKG
E = counting efficiency (Attachment 1 of Appendix O)
Z = factor, function of sampling and counting times; Z = 0.843 for a 10-minute sample and 100-minute count, begun 180 minutes after sampling.
V = tube volume in liters
F_f = fraction of thoron decay atoms found in the tube that deposits on the exit filter. These are presented on Figure N-2.

Other combinations of sampling and counting periods other than those specified above may be used with consequent differences in sensitivity, in accordance with the table on Figure N-3. The same inlet filter may be used on successive measurements but it should be replaced when its resistance becomes great enough to interfere with the nominal sampling flow rate.

6.0 PRECAUTIONS

6.1 The calibration of the air flow meter must take into account a compensation for the combined resistance of the two filters in series. This can be done experimentally in the field laboratory with a reliable standard volumetric flow meter.

6.2 Timing of the sampling interval is critical. The use of a stop-water is advisable.

Figure N-2

FACTORS FOR USE IN THE TWO-FILTER METHOD

The following tables give factors for use in the two-filter method for measuring radon and thoron concentration (see Sections 6.1.2 and 6.1.3).

TABLE AIII-1. VALUES OF F_f FOR USE IN THE TWO-FILTER METHOD FOR MEASURING RADON AND THORON

μ	F_f	μ	F_f
0.005	0.877	0.25	0.420
0.008	0.849	0.30	0.384
0.01	0.834	0.35	0.349
0.02	0.778	0.40	0.324
0.03	0.737	0.45	0.302
0.04	0.705	0.50	0.282
0.05	0.678	0.60	0.248
0.06	0.654	0.70	0.220
0.07	0.633	0.80	0.197
0.08	0.614	0.90	0.178
0.09	0.596	1.00	0.162
0.10	0.580	1.50	0.110
0.12	0.551	2.00	0.083
0.14	0.525	2.50	0.067
0.16	0.502	3.00	0.056
0.18	0.481	4.00	0.042
0.20	0.462	5.00	0.033

$$\mu = \pi DL/q$$

F_f = fraction of atoms formed in the tube and arriving at exit filter

π = 3.1416

D = diffusion constant, 0.085 cm^2/s for RaA, 0.06 cm^2/s for ThA

L = tube length (cm)

q = flow rate (cm^3/s)

FIGURE N-3

~~TABLE AIII-3.~~ VALUES OF Z FOR USE IN THE TWO-FILTER METHOD FOR MEASURING THORON

t	T_1	T_2	Z
10	1	11	0.01262
10	60	70	0.05724
10	10	110	0.51591
10	10	1010	6.31420
30	1	11	0.06713
30	60	70	0.18498
30	10	110	1.69989
30	10	1010	18.98648
120	1	11	0.60925
120	60	70	0.88502
120	10	110	8.48933
120	10	1010	75.32111

Z = decay correction factor (min)

t = sampling time (min)

T_1 = start of counting period (min)

T_2 = end of counting period (min)

(T = 0 at end of sampling)

FIGURE N-4

Rn-220 SAMPLING LOG

776

Sampler Type: _____ Job Site: _____

Sampler S/N: _____ Sample ID No.: _____

Sample Location: _____

Initials: _____

	Date/Time	Flowmeter Reading (lpm)	Vacuum	Elapsed Time
Start Sample				
End Sample				

Sample Duration (min): _____ X _____ : Average Flowrate (lpm)

Description of Site Activities: _____

During Sample Collection: _____

==========

Counter Type: _____

Counter S/N: _____

	Date/Time of Start Count	Count	Duration (minutes)
First Background			
Sample			
Second Background			

Average Background: _____ (cpm)

Daily Detector Eff. (dpm/cpm): _____

Sample Activity: _____ (pCi/l)

APPENDIX O

AIR PARTICULATE SAMPLING PROCEDURE

ATTACHMENT 1 - OPERATION OF THE EBERLINE SAC-4 SCINTILLATION ALPHA COUNTER (EA 320)

1.0 PURPOSE

This procedure provides guidance in collecting samples of airborne particulates in ambient air using portable and stationary air samplers.

2.0 SCOPE

For implementation of the radiation protection program, it is necessary to know the location and concentration of airborne radioactivity in order to limit personnel exposure and characterize potential off-site exposure. Sampling locations of interest are often where there are no fixed air monitors available, such as operation sites involving loose contamination. Air samples are taken with portable instruments in such instances to determine the particulate airborne radioactivity and document that permissible concentrations have not been exceeded.

3.0 REFERENCES

3.1 NCRP report 57.

4.0 EQUIPMENT AND MATERIALS

4.1 Portable Air sampler (RAS-1 or Staplex Hi-Vol.).

4.2 For remote areas, the air sampling trailer containing a gasoline powered generator will be necessary.

4.3 Particulate Filters.

4.4 Timing Device.

4.5 Envelopes for Filter Samples.

5.0 INSTRUCTIONS

5.1 PREREQUISITES AND LIMITATIONS

5.1.1

For continuous air particulate monitoring, the air volume passed through the filter or cartridge must be sufficient to enable the detection of air activity using the procedures in EA3.2.

Normally, a total flow of 40-50 liters per minute is adequate.

The RAS-1 will be used for low volume, long collection time samples. For specific step by step operations of the RAS-1, refer to EA3.2

5.1.2

Grab sampling (short duration high volume sampling) is accomplished through the use of a Staplex High-Volume Sampler.

The Staplex High-Volume Sampler has a flow rate of approximately 20 cubic feet per minute (FMP). For specific step by step operation of the Staplex sampler, refer to EA3.3.

5.1.3

The locations chosen for sampling are based upon evaluation of the operation to be performed. General area sampling should be performed at approximately 3-5 feet above the surface. Special samples may require other locations.

Caution: Avoid sampling locations that will cause particles to be drawn into the sampler from contaminated surfaces and thus provide erroneous data. Also avoid setting sampler on the ground.

5.2 PROCEDURE FOR CHANGING FILTER SAMPLES

5.2.1

Always mark the new filter to indicate direction of air flow.

5.2.2

Record flow rate on the filter envelope (prestamped), turn off sampler and remove filter.

5.2.3

Place filter in envelope, record location, date, time, flow rate, and initials of Health Physics technician.

5.2.4

Place new filter in the sample head.

5.2.5

Start air sampler, adjust flow if necessary, record flow rate, date, time, and sample number and/or location on prestamped envelopes for the new sample.

5.2.6

Send sample envelopes to field laboratory for counting.

5.2.7

After waiting at least 3 hours from the end of sample collection, make a count using the Eberline SAC-4 (Operational Procedures are presented in Attachment 1) of the background. This should be done without a filter present for at least 10 minutes. Record this data on the Air Particulate Sampling Log (Figure O-1).

5.2.8

Place the sample in the detector and make a count of at least 50 minutes. Record the start time and result. After counting the sample, repeat the background determination in Step 5.2.7.

5.2.9

Use the following formula to calculate the long-lived alpha activity of the sample:

$$A = \frac{S-B}{E \times F \times ST \times CT \times 2.2}$$

where:

S = Sample alpha count
B = Background count (over the sample count interval)
E = Daily detector efficiency (cpm/dpm)
F = Average flow rate from flow meter readings (lpm)
ST = Sample collection duration (min)
CT = Counting time duration (min)

5.2.10

If the determination in Step 5.2.9 exceeds 2.0×10^{-3} pCi/l, then the sample must be stored for at least 72 hours and Step 6 repeated. This is to allow any radon or thoron daughters collected on the filter to decay.

5.2.11

If the subsequent count exceeds 2.0×10^{-3} pCi/l, then the filter will be packaged and sent to TMA/Eberline for analysis of radionuclides detailed in the work plan.

ATTACHMENT 1

OPERATION OF THE EBERLINE SAC-4 SCINTILLATION
ALPHA COUNTER (EA 3.20)

1.0 PURPOSE

This instruction provides a general description, pertinent characteristics, and describes the operation of the SAC-4 Alpha Scintillation Counter.

2.0 SCOPE

The SAC-4 is an Alpha Scintillation Counter and is intended for use in counting particulate air sample filters and smears taken on surfaces.

3.0 REFERENCES

Eberline Technical Manual - SAC-4.

4.0 EQUIPMENT AND MATERIALS

4.1 SAC-4 Scintillation Alpha Counter.

4.2 Th-230 Alpha Check Source.

4.3 Air Particulate Sample Reporting Log (Form EA 3.20-1).

5.0 DESCRIPTION

The SAC-4 is a complete alpha counting system consisting of the following major components:

5.1 A ZnS(Ag) power scintillation phosphor on a plastic light pipe.

5.2 A two-inch diameter photomultiplier tube, ten stage and window.

5.3 Preset electronic timer with range of 0.1 to 50 minutes.

5.4 Digital readout in accumulated counts per unit time (six decade readout).

5.5 Sample tray can accommodate a two-inch diameter sample.

5.6 Reset buttons for scaler and timer.

6.0 CHARACTERISTICS

6.1 Efficiency is 40% of 4 pi minimum from a one-inch diameter Pu-239 alpha source.

6.2 Background is less than 0.3 counts per minute.

6.3 Plateau is at least 200 volts long with a slope of less than 1% per 100 volts.

6.4 Resolution time of approximately 7 microseconds.

6.5 Discriminator is internally biased at 1.25V which gives an overall sensitivity from 0.125 to 1.25 pCi depending on gain setting.

6.6 Power is obtained from 115/230 ± 10% VAC.

6.7 Instrument size is 11.5 inches high x 6.0 inches wide and 14.0 inches deep and weighs 16.75 lbs.

6.8 Operational high voltage, 1500V, is adjustable by a rear panel control.

6.9 Temperature: 0° to $+60^{\circ}$C.

6.10 Weight: 16-3/4 pounds.

7.0 CALIBRATION

7.1 Power to instrument should be allowed to stabilize for one hour prior to calibration.

7.2 Check high voltage and adjust to 1500V.

7.3 Reset time and scaler to zero.

7.4 Set lower time on the 2 position and the time multiplier on x10 position and start counter for twenty minute background count. Determine counts per minute (cpm) background. Background should be less than 1.0 cpm. If cpm is greater than 1.0 cpm, remove sample try and decontaminate. Repeat these steps until background is less than 1.0 cpm. Desired background is less than 0.7 cpm.

7.5 Insert Th-230 alpha source in sample tray (source should have a strength of 200-1,000 dpm).

7.6 Obtain four 5.0 minute counts with Th-230 alpha source. Calculate each cpm and average the four cpm results.

7.7 Calculate efficiency as follows:

$$\text{Efficiency} = \frac{\text{obtained count rate (cpm)} - \text{Bkg. (cpm)}}{\text{source strength (dpm)}}$$

= efficiency as decimal, typical values are 0.3 - 0.45 cpm/dpm

APPENDIX P

WORK AREA RADON MEASUREMENTS IN AIR

ATTACHMENT 1 - OPERATION OF THE EBERLINE SAC-R5 SCINTILLATION CELL COUNTER (EA-3.19)

ATTACHMENT 2 - RADON DAUGHTER WORKING LEVEL MEASUREMENTS (MODIFIED KUZNETS METHOD EA-2.10)

ATTACHMENT 3 - OPERATION OF THE LOW VOLUME AIR SAMPLER RAS-1 (EA-3.2)

ATTACHMENT 4 - OPERATION OF THE RADON PULSE PUMP III

1.0 PURPOSE

The purpose of this procedure is to describe the methods used to collect samples of ambient air and soil gas, and the subsequent analysis of those samples for radon gas concentration.

2.0 SCOPE

Two basic types of sampling are used in radon measurements, gas bag samples and soil gas samples (radon flux). Gas bags provide integrated samples of ambient radon in air while soil gas accumulators provide samples of radon in emanated soil gas. Instantaneous air samples may be collected using an evacuated SC-6 scintillation cell.

3.0 REFERENCES

3.1 DOE Order 5480.1.

3.2 10 CFR 20.

3.3 EPA Standards 40 CFR 192.

4.0 EQUIPMENT AND MATERIALS

4.1 Radon Gas Bag and Pulse-pump (Section EA-3.1)

4.2 55-gal. Drum End-Section with Valving

4.3 Stop Watch

4.4 50 cc Syringe

4.5 SC-6 Alpha Scintillation Cells (1.4 liter)

4.6 Tygon Tubing with an In-line 0.45 Micron Filter

5.0 INSTRUCTIONS

5.1 Gas Bag Sampling (24, 48, or 72 hour integrated sample) of ambient air

5.1.1 Place radon gas bag at sampling location and turn on pulse pump. Record date and time of startup in logbook and on the gas bag. To fill 44 liter bag use the following pump cycles:

Sample Time (Hours)	Pump Interval (Seconds)
24	5
48	12
72	15

Secure and protect sampling equipment from inclement weather conditions and vandalism.

5.1.2 After completion of sampling period, turn off pulse pump and record date and ending time in logbook and on the gas bag.

5.1.3 Take the gas bag to the counting room for transfer of air sample to a SC-6 scintillation cell.

5.1.4 Using a small piece of tygon tubing attach an evacuated SC-6 cell to the valve on the gas bag in series with a 0.45 micron filter and transfer the air into cell by opening the valves. Pass at least three cell volumes to ensure a representative sample has been collected in the cell. Record date and time of sample transfer on label of SC-6 cell and in logbook.

5.1.5 Place the SC-6 cell in the sample holding area for counting in a SAC-R5 alpha counter. Results of the count will be used to determine the radon gas concentration expressed in pCi/l in the integrated sample. See instruction EA-3.19 for calibration and counting procedures for the use of the SAC-R5 and SC-6 scintillation cell radon counting system.

5.2 RADON FLUX

5.2.1 Position the special 55-gallon drum section over the sampling point and, with a downward twisting motion, countersink the barrel one to two inches into the soil, or otherwise seal the drum to the ground.

5.2.2 Attach the 50-cc syringe to the valve assembly, open the valve, and rapidly pump the syringe ten times.

5.2.3 Close the valve, remove the syringe, and attach an evacuated SC-6 cell by means of a piece of tygon tubing with in line 0.45 micron filter.

5.2.4 Open the valve on the drum, then open the valve on the SC-6, and fill the SC-6 cell. Close the valve on the

SC-6 cell, and close the valve on the barrel. Record the time and the date for the sample. Also record the cross sectional area of the sum as the sample area.

Note: A 55-gallon drum with a diameter of 22.5 inches has an area equivalent to 0.256 m^2.

5.2.5 After 45 minutes, repeat steps 5.2.2 through 5.2.4 using a second evacuated SC-6 cell.

Note: The first sample is considered to be a background sample and the second sample represents the radon buildup over the 45-minute sampling time

5.2.6 Submit the samples to the counting lab for counting. The radon concentration will be determined by counting in a SAC-R5 alpha counter. Results will be used to determine the radon flux ratio expressed in pCi/m^2-sec.

5.3 INSTANTANEOUS AIR SAMPLES

5.3.1 Instantaneous or "spot" air samples are collected using an evacuated SC-6 scintillation cell.

5.3.2 At the desired sampling location collect a sample by opening the valve on a SC-6 cell which has an in-line 0.45 micron filter connected to the valve by means of a small piece of tygon tubing. Record the location, date, and time of collection on the SC-6 cell label.

5.3.3 Transfer the filled SC-6 cell to the counting lab for counting in a SAC-R5 alpha counter. Results in pCi/l will be used to determine the concentration of radon in the sample.

ATTACHMENT 1

OPERATION OF THE EBERLINE SAC-R5
SCINTILLATION CELL COUNTER (EA-3.19)

1.0 PURPOSE

The purpose of this instruction is to describe the use of the SAC-R5, SC-6 cell and the MS-2 scaler in measuring Rn-222 concentrations in ambient air.

2.0 SCOPE

This instruction will describe each of the scintillation cell counting system components, give their characteristics, and step-by-step operational instructions.

3.0 REFERENCES

3.1 Eberline Technical Manual for Alpha Scintillation Counter Model SAC-R5 and Scintillation Cell Model SC-6.

3.2 Eberline MS-2 Instrument Manual.

4.0 EQUIPMENT AND MATERIALS

4.1 SC-6 Scintillation Cells.

4.2 SAC-R5 Photomultiplier Tube and Assembly.

4.3 MS-2 Mini Scaler/Ratemeter.

4.4 Power Supply.

4.5 Radiological Survey Air Sampling Radon Gas (Form EA3.19-1).

5.0 DESCRIPTION

The scintillation cell counting system for radon concentration measurement consists of an MS-2 scaler with the SAC-R5 detector assembly and SC-6 scintillation cell detectors.

5.1 Specifications - MS-2 Scaler

See instruction EA-3.14, Operation of the Eberline MS-2 Mini Scaler/Ratemeter.

5.2 Specifications - SAC-R5 Detector Assembly

The SAC-R5 provides an enclosed space in which scintillation events can be detected. It consists of a five-inch photomultiplier tube, mounted with the window up, and a

light tight enclosure, which is designed to contain the scintillation cell to be counted.

5.2.1 Maximum sample size: Approximately 4-7/8 inches diameter x 8-3/4 inches high (12.4 cm diameter x 2.22 cm high).

5.2.2 Photomultiplier tube: Nominal five inch diameter, 10 stage end window with 4.7 inch (12 cm) diameter photocathode.

5.2.3 Background count: One count per minute maximum when set to operate properly on the alpha plateau and with the counting chamber empty.

5.2.4 Electrical connection: Single coaxial, MHV tube connector. Positive high voltage, 2500V maximum. Approximate input resistance is 120 megaohms, requiring 10 microamps at 1200V.

5.2.5 Operating voltage: Dependent upon photomultiplier gain, cable length, input sensitivity of counter used, and type of scintillator or scintillation cell being counted.

5.2.6 Size: Large (base) diameter, 6.5 inches (16.5 cm). Overall height, 17.7 inches (45 cm).

5.2.7 Weight: 8.5 lbs (3.9 kg).

5.3 Specifications - SC-6 Scintillation Cell

The SC-6 scintillation cell is used to collect gaseous samples containing Rn-222 and to subsequently detect alphas emitted from the gas and from daughter products of the gas. The cell is made of transparent plastic and the inner walls are lined with ZnS(Ag) scintillator. Two valves are provided on top so that gas can flow through the cell when collecting the sample or purging the cells. The cell is also designed to hold a vacuum so that it may be evacuated and subsequently filled with the sample. The bottom of the SC-6 cell is left transparent, not coated with scintillation materials. This improves the light collection from the larger cell.

5.3.1 Volume: 1.4 liters. 10.2 cm diameter x 17.3 cm high (85.5 cu. in., 4 in. diameter x 6.8 in. high).

5.3.2 Sensitivity to Rn-222: Nominal count rate at equilibrium is 3.9 counts per minute per picocurie (of Rn-222 in the cell), or 5.5 counts per minute per picocurie (of Rn-222) per liter.

5.3.3 Overall size: Approximately 22 cm high x 11.5 cm diameter (8.7 in. high x 4.5 in. diameter).

5.3.4 Weight: Approximately 680 g (1.5 lbs).

5.3.5 Pressure limits: From vacuum to approximately ambient. Do not pressurize.

5.3.6 Scintillator: ZnS(Ag) phosphor on adhesive coating.

5.3.7 Hose fittings: For 5/6 in. ID hose (.79 cm).

6.0 OPERATION

6.1 Inspection:

6.1.1 SAC-R5 Detector Assembly

Check for SAC-R5 for any obvious damage. The cover should fit all the way down on the mating surface to make a light tight seal. Check that the phototube is unbroken and that it is down in its socket. Be gentle with the phototube. It is very fragile and can be damaged by shock even though the glass is not broken. Turn it upside down and listen for rattles. If any are heard, refer to the Maintenance Section for disassembly.

6.1.1 SC-6 Scintillation Cell

Check the SC-6 cell for any obvious damage. Slight cracking or crazing of the plastic will not impair performance.

CAUTION: Do not remove the SAC-R5 cover when high voltage is applied to the phototube. The bright light may cause excessive tube currents and the tube may be temporarily or permanently damaged. When using the SAC-R5 with most Eberline counting instruments, it is unlikely that permanent damage will result due to the limited high voltage supply

current available and also due to the high resistance in the photomultiplier tube voltage divider. The tube dark current may temporarily increase and appear as a high background count for a while. Turn off the high voltage or disconnect the detector before removing the SAC-R5 cover.

6.2 System Preparation:

6.2.1 SAC-R5

Connect the SAC-R5 to the counting instrument using coaxial cable. The connector on the SAC-R5 is an MHV type. The counting instrument must supply high voltage to the SAC-R5 and also detect the pulse signal on the high voltage line. The counting circuitry should detect pulses of 100 millivolts or smaller, preferably below 30 millivolts. For initial setup, see the Maintenance Section on how to set the high voltage.

6.2.2 Scintillation Cells

The Rn-222 sample should normally be drawn through a particulate filter to keep the cell free of dirt and to make sure no long life radioactive particulates are drawn into the cell. Once in the cell, there is no way to purge particulate matter. Also, if the daughters of Rn-222 are excluded from the sample taken, a coarse indication of the radon concentration can be obtained early (using Figure 1) and this may indicate that further counting is unnecessary. (If the sample is drawn from an area of very high humidity, it should also be drawn through a desiccant to keep water from condensing in the cell.) If a sample must be taken when a particulate filter is not available, it will be usable if counting is delayed until equilibrium is obtained between Rn-222 and its daughters. The time of day and date should always be recorded when a sample is taken.

The sample can be drawn by the flow method or the vacuum method. If the sample source is large, such as in environmental or area monitoring, the cell can be purged and filled at the same time by flowing the sample through the cell until the old

gas is essentially replaced. For smaller sample sources, for quantitative transfer of small volumes of gas, or for quicker collecting, the cell may be evacuated by using a vacuum pump and the valve subsequently opened to draw in the new sample. When used in this manner, each cell should be checked to verify the vacuum leaks are small enough to not interfere with the sample transfer for the accuracy required for the measurement.

After the cells are counted and the sample is no longer needed, the cell should be flushed with filtered air or other gas that has low radon content. This is especially important if the radon concentration was high. If the cells are not flushed, a gradual buildup of alpha background will result from the long life daughters of Rn-222. Although a new sample may be drawn any time after flushing, a 3-hour waiting period should be allowed for the radon daughters products of the previous sample to decay.

6.3 Counting Samples

Turn off the high voltage or disconnect the detector and remove the SAC-R5 cover. Place the SC-6 cell, to be counted, on the phototube. Place the cover back on the SAC-R5 making sure it is all the way down and connect the detector. Turn on the high voltage. Allow at least 5 minutes for the cell to dark adapt before counting, and start the counter. After counting, turn off the high voltage or disconnect detector before removing the SC-6 cell.

NOTE: Cells that are exposed to bright light may take several minutes for light-induced response to subside. This wait can be avoided by keeping the cells covered or in subdued light immediately prior to counting. The precaution is especially important when measuring "near background" environmental concentrations of Rn-222.

7.0 INTERPRETATION OF RESULTS

Use form P-1 to record and calculate gas concentration and error term. Form EA3.19-1 (Table B) shows the change in alpha count rate in a cell as a function of time after the Rn-222 sample was taken, provided the sample was filtered to

eliminate the intake of radon daughter products. There are three alpha emitters involved and at equilibrium; all contribute to the alpha count rate. One of the emitters is the Rn-222 gas and its contribution is immediate and constant. Note that the curve starts at about 40%, not at zero. The first daughter of Rn-222 gas, Po-218 (historically radium A), is an alpha emitter and has a 3-minute half life. It contributes alpha particles quickly and is essentially in equilibrium with the radon after 20 minutes. Note in Table B, Form EA3.19-1 that, after 20 minutes, about two-thirds of the final reading is obtained. The third alpha emitter, Po-214 (historically radium C), has two radionuclides between it and Po-218 which give it an apparent half life of about 30 minutes. It is essentially in equilibrium with the radon after three hours. Although the curve doesn't extend far enough to show it, immediately after equilibrium is reached, the count rate begins to decrease with the 3.8 day half life of the Rn-222. If the radon is not flushed out, it will essentially all decay into an alpha emitter with an apparent 21 year half life. This will have the effect of gradually increasing the alpha background. The background of any cell may be checked any time by flushing the cell, waiting three hours (or longer if the previous sample concentrations was high) and counting it.

If the Rn-222 sample is counted before equilibrium is reached, use Table B to find the proper (fractional buildup) correction factor. Divide the number shown on the counting instrument by the number from the graph to obtain the equivalent equilibrium count. Divide this number by the number of minutes counted to obtain the count rate in counts per minute (cpm). Subtract the background cpm for that cell to obtain net cpm.

To find the amount of Rn-222 introduced into the cell, divide the net cpm number obtained in the preceding paragraph by the counts per minute per picocurie calibration factor posted on the SC-6 cell. To find the Rn-222 concentrations of the sample, divide the net cpm number obtained in the above paragraph by the cpm/pCi per liter. Since the SC-6 cell volume is 1.4 liters, the concentration per liter should be 1.4 times less than the concentration of the entire SC-6 sample.

EXAMPLE: A Rn-222 sample was drawn (through a filter) into an SC-6 and counted for 10 minutes about 60 minutes after the sample was taken. At the end of the count period, the counter read 125 and the background count of the cell in use was known to be about 1.3 counts per minute. What was the total amount of radon drawn into the cell and what was the concentration level of the area from which the sample was taken? Cell calibration factor is 4.3 cpm/pCi.

125 - (1.3 x 10 min) = 112 counts in 10 minutes from radon sample, less background.

$\frac{112}{.82}$ (from curve for 60 minutes) = 136.6 equivalent equilibrium number.

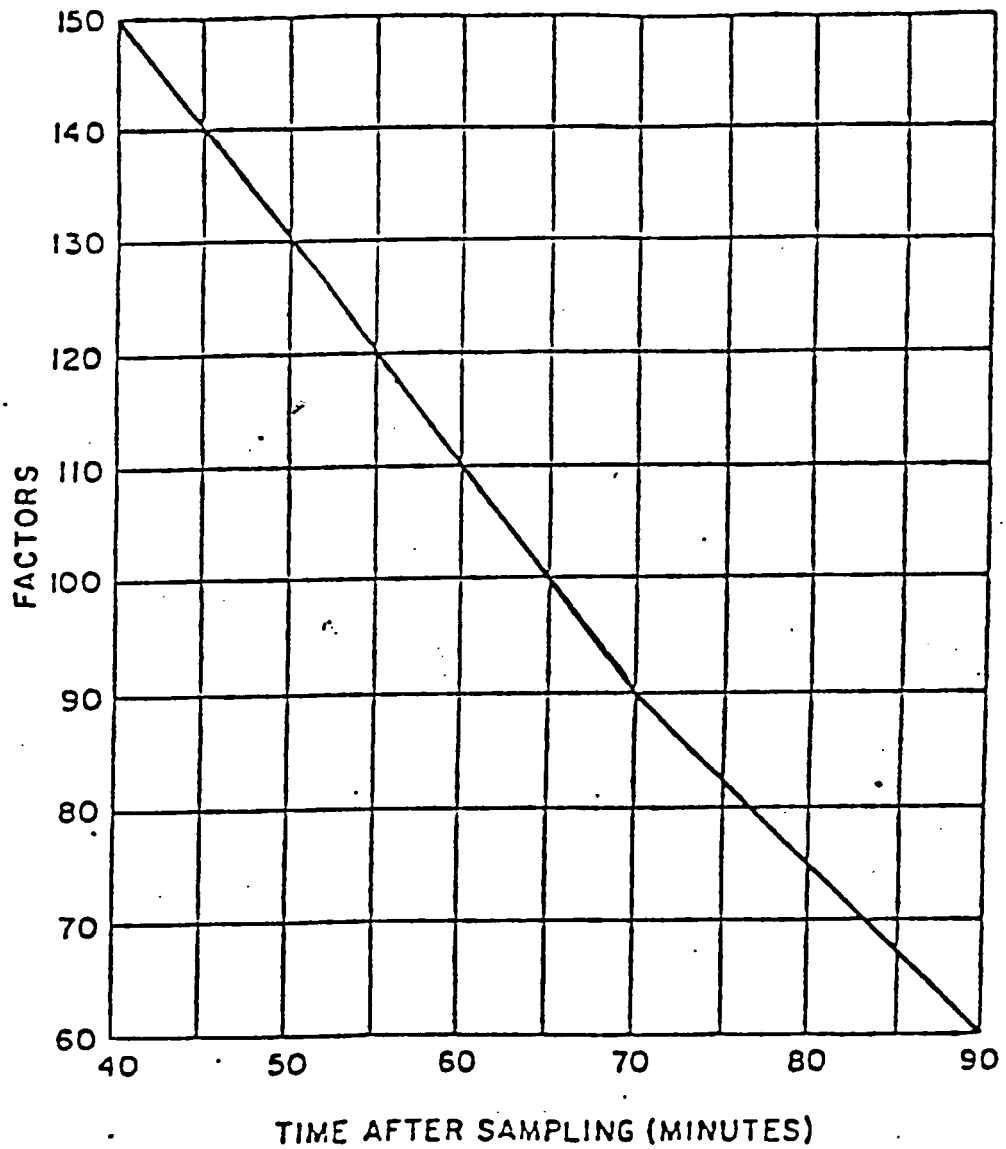
$\frac{136.6}{10}$ = 13.66 counts per minute equilibrium number.

$\frac{13.66}{4.3}$ cpm/pCi = 3.18 picocuries of Rn-222 in sample.

$\frac{13.66}{6.0}$ cpm/pCi/l = 2.28 picocuries of Rn-222 per liter in area sample was taken

The statistical uncertainty of the count may be calculated using normal counting statistics. The overall uncertainty of the measurement should also consider the reliability of completeness of sample transfer to the counting cell.

Figure 1.



Factors for Determining Multiple of Working Level of Radon Daughter Products in the Atmosphere

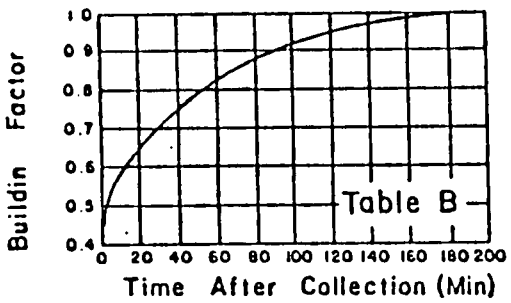
RADIOLOGICAL SURVEY
AIR SAMPLING
RADON GAS

Form EA3.19-1

Location:
Date:
Surveyor:

LOCATION	Time of Collection	Count Time From	Count Time To	Total CT. Time (Min)	Chamber Background (CPM)	Gross Counts	CPM	Corrected Counts (CPM-Bkg)	BF	DF	pCi/liter	uCi/m pCi/liter x

☐ Routine ☐ Special (If special, indicate reason for survey below.) ☐ Corrective Action Taken



$$pCi/liter = \frac{\left(\frac{C_{s+b}}{T_{s+b}} - \frac{C_b}{T_b}\right)}{(Cell\ vol)(CF)(BF)(DF)} \pm 2\sigma$$

$$2\sigma = 2\,\frac{\sqrt{\frac{C_{s+b}}{T^2_{s+b}} + \frac{C_b}{T^2_b}}}{K}$$

Where:

K = (Cell vol)(CF)(BF)(DF)

$$DF = e^{-\left(\frac{0.693}{t_{1/2}}\Delta t\right)}$$

Δt - Lapsed Time (mid-time of collection to mid-time of count.)

$t_{1/2}$ - Half Life of ^{222}Radon (3.825 days or 91.80 hrs.)

BF = Buildin Factor of daughters
DF = Decay Factor of ^{222}Radon
CF = Cell Factor CPM/pCi/Liter
C_{s+b} = Counts, Sample + Background
T_{s+b} = Time, Sample + Background
C_b = Counts, Background
T_b = Time, Background

Typical Cell Factor

Cell Type	SC-5	SC-6
Vol (liters)	0.5	1.4
Cell Factor (CF)	2.3	6.0

Instrument Check

Standard I.D. No. _____

Standard DPM _____

Gross Counts, CPM _____

Efficiency = $\frac{CPM}{DPM}$ _____ = _____

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ATTACHMENT 2

RADON DAUGHTER WORKING LEVEL MEASUREMENTS
(EA2.10)

1.0 PURPOSE

The purpose of this procedure is to describe the methodology for measuring radon daughters concentration in working levels.

2.0 SCOPE

The buildup of radon daughters on an air particulate filter can be used to determine the working level (WL) concentration of radon daughters. This is accomplished by drawing a known volume of air through a filter paper and counting the alpha activity at a measured time after sampling. The method calculates the WL using the Modified Kusnetz Method. The WL may be calculated using the HP-41C Calculator or by using the equations on Form EA-2.10-1.

3.0 REFERENCES

3.1 EA-1.11, Sampling for Airborne Particulates.

3.2 EA-3.2, Low Volume Air Sampler (RAS-1).

3.3 EA-3.21, Use of the MSA Monitaire MDL-5 Lapel Air Sampler.

3.4 American National Standard Institute N13.8 1973 or MSA Monitaire Sampler Model 5.

4.0 EQUIPMENT AND MATERIALS

4.1 RAS-1 Low Volume Air Sampler.

4.2 HP-41C Hewlett Packard Calculator.

4.3 SAC-4 Alpha Scintillation Counter.

4.4 Radiological Survey Air Sampling Radon Daughters (Form EA2.10-1).

4.5 Membrane filter Paper 0.45 micron 25 mm for MSA pump or 47 mm for RAS-1 pump.

5.0 INSTRUCTIONS

5.1 Ensure proper operation and calibration of the RAS-1 per instruction EA-3.2 or MSA for EA-3.21.

5.2 Draw a sample through a filter paper per in EA-1.11 using:

5.2.1 Flow rate: Minimum 2 liters/minute using MSA or set RAS-1 for 1 liter/minute.

5.2.2 Sampling time: 5 minutes.

5.2.3 The filter paper should be Gelmen Metricel Membrane Filter, Type GN-6 or equivalent.

5.3 The air filter shall be counted after a 40 to 90 minute decay period. Record the time the count begins.

5.4 The air filter shall be counted for 10 minutes using a SAC-4 alpha counter or equivalent.

5.5 Record the counting time, background count rate, sample count and detector efficiency on Form EA-2.10-1.

6.0 ANALYSIS OF WORKING LEVELS

The Modified Kusnetz Method is used to calculate WL using either the HP-41C calculator (6.1) or the graphic method presented in Section 6.2.

6.1 Working Level Program (HP-41C Calculator)

6.1.1 Using an HP-41C calculate the working levels per the following instructions.

Working Level Program (Modified Kusnetz Method)

STEP	KEY STROKE	DISPLAY
1. Turn calculator on	ON	---
2. Call program	User, Shift, ½+]	0-CT,1-WL,2-RN
3. W/L Program	1, R/S	Eff or Cf
4. Enter Ctr Eff (CPM/DPM)	.3*, R/S	Counts: Bkg?
5. Enter Ctr Bkg, C_b	2500, R/S 2500*	Time: Bkg?
6. Enter Bkg Ctg Time, T_b	50, R/S 50*	Counts: Sample
7. Enter Sample Cts, C_{s+b}	2500, R/S 2500*	Time: Sample
8. Enter Sample Ct Time, t_s	10, R/S 10*	Key: Vol
9. Enter Sample Volume Flow (lpm) x Time (Min)	1, R/S 1*	Time A/S =

10. Enter time between end of sample collection and start of counting (t_{as}) Displays WL's	90, R/S	90*	A W/L = 11.11
11. Working Level error loop to start of program to analyze second set of	R/S		E W/L = 0.567
12. Data at Step 7	R/S		
13. To change Eff, Cf or Bkg data	[A]		Eff or Cf

*Values to be entered to test HP-41C Calculator.

6.1.2 If HP-41C is not preprogrammed enter program as given in Appendix A.

6.2 Working Level Calculations (Graphic Method)

6.2.1 Count the sample 40-90 minutes after collection.

6.2.2 Calculate total volume sampled (sampling time x sampling flow rate).

6.2.3 Calculate alpha activity as follows:

$$\frac{\text{Sample count rate (cpm)} - \text{bkgd (cpm)}}{\text{Counter efficiency (eff.)}} = \text{alpha activity (dpm)}$$

6.2.4 Calculate air concentration as follows:

$$\frac{\text{Alpha activity (dpm)}}{\text{Total Sample Volume (liters)}} = \text{dpm/liter}$$

6.2.5 From Figure 1 select the appropriate factor based on elapsed time between collection and counting.

6.2.6 Divide the air concentration by the factor selected in 6.2.5 to determine WL.

6.3 Example of Graphic Method Calculations of Working Level

6.3.1 An air sample was taken for 5 minutes at a flow rate of 2 liters/minute. The filter paper was alpha counted 50 minutes after sampling and the counter read 1500 counts in 10 minutes. The

background for the counter is 0.3 cpm with an alpha efficiency of 42%. What is the air concentration of radon daughters?

$$\text{Total volume sampled} = 2 \text{ liters/min} \times 5 \text{ min} = 10 \text{ liters}$$

$$\text{Total alpha activity} = \frac{150 \text{ cpm} - 0.3 \text{ cpm}}{0.42 \text{ cpm/dpm}} = 356 \text{ dpm}$$

$$\text{Air concentration} = \frac{356 \text{ dpm}}{10 \text{ liters}} = 35.6 \text{ dpm/liter}$$

$$\text{Fraction of working level} = \frac{35.6 \text{ dpm/liter}}{130} = 0.3 \text{ WL}$$

6.4 Record WL on Form EA-2.10-1 and in Survey Log Book as per instruction EA-2.1.

APPENDIX A.

HP-41C Counting Program

```
PRF -COUNT-

01 LBL "COUNT"
02 LBL E
03 CLA
04 CLRG
05 FIX 3
06 SF 27
07 CF 00
08 CF 01
09 CF 02
10 0.0
11 "0-CT,1-W,L2-RN"
12 PROMPT
13 SF IND X
14 GTO 12
15 LBL A
16 "EFF. OR C.F"
17 PROMPT
18 STO 00
19 "COUNTS:ENG?"
20 PROMPT
21 STO 01
22 "TIME:ENG"
23 PROMPT
24 ST/ 01
25 RCL 01
26 X<>Y
27 /
28 STO 02
29 GTO IND 12
30 LBL B
31 LBL 00
32 "COUNTS:SAMPLE"
33 PROMPT
34 STO 03
35 FS? 02
36 GTO 18
37 "TIME:SAMPLE?"
38 PROMPT
39 LBL 16
40 ST/ 03
41 RCL 03
42 X<>Y
43 /
44 STO 04
45 RCL 02
46 RCL 04
47 *
48 SQRT
49 2
50 *
51 STO 05
52 RCL 03
53 RCL 01
54 -
55 STO 06
56 RCL 02
57 SQRT
58 3
59 *
60 X>Y?
61 XEQ 10
62 RCL 06
63 "KEY VOL?"
64 PROMPT
65 STO 07
66 RCL 00
67 *
68 STO 08
69 ST/ 05
70 /
71 STO 09
72 FS? 02
73 RTN
74 FS? 01
75 RTN
76 "AD/V="
77 XEQ 11
78 RCL 05
79 "ED/V="
80 XEQ 11
81 2.22
82 ST/ 09
83 /
84 RCL 09
85 "AP/V="
86 XEQ 11
87 "EP/V="
88 ARCL Y
89 XEQ 03
90 GTO B
91 LBL C
92 LBL 01
93 XEQ 00
94 "TIME A/S="
95 PROMPT
96 STO 10
97 70
98 X<>Y
99 X>Y?
100 GTO 04
101 -2
102 *
103 230
104 +
105 GTO 05
106 LBL 04
107 RCL 10
108 -3
109 2
110 /
111 *
112 195
113 +
114 LBL 05
115 STO 11
116 RCL 09
117 X<>Y
118 /
119 "A W/L="
120 XEQ 11
121 RCL 05
122 RCL 11
123 /
124 "E W/L="
125 XEQ 11
126 GTO C
127 LBL 10
128 "LESS:CS/ENG"
129 GTO 03
130 LBL 11
131 ARCL X
132 LBL 03
133 AVIEW
134 STOP
135 RTN
136 LBL D
137 LBL 02
138 CF 06
139 CF 07
140 "6-CELL,7-EAS"
141 PROMPT
142 STO 13
143 SF IND X
144 GTO IND 13
145 LBL 07
146 "ST.BAS,DDD.HHH"
147 PROMPT
148 XEQ 15
149 STO 14
150 "FN.BAS,DDD.HHH"
151 PROMPT
152 XEQ 15
153 STO 15
154 RCL 14
155 ENTER↑
156 ENTER↑
157 RCL 15
158 X<>Y
159 -
160 2
161 /
162 +
163 STO 19
164 LBL 06
165 "TO.CELL,DDD.HHH"
166 PROMPT
167 XEQ 15
168 STO 16
169 "CT.CELL,DDD.HHH"
170 PROMPT
171 XEQ 15
172 STO 17
173 "CELL.CT.TIME,HH"
174 PROMPT
175 STO 18
176 1
177 STO 23
178 RCL 17
179 RCL 16
180 -
181 60
182 *
183 STO 22
184 180
185 X<>Y
186 X>Y?
187 GTO 08
188 .21653
189 Y↑X
190 .32698
191 *
192 STO 23
193 LBL 08
194 RCL 17
195 RCL 18
196 120
197 /
198 +
199 STO 20
200 LBL 13
201 FS? 06
202 GTO 09
203 RCL 20
204 RCL 19
205 -
206 STO 21
207 GTO 12
208 LBL 09
209 RCL 20
210 RCL 16
211 -
212 STO 21
213 LBL 12
214 .493
215 CHS
216 91.8
217 /
218 RCL 21
219 *
220 E↑X
221 STO 24
222 LBL 14
223 XEQ 00
224 RCL 23
225 RCL 24
226 *
227 ST/ 05
228 /
229 STO 09
230 "AP/L="
231 XEQ 11
232 RCL 05
233 "EP/L="
234 XEQ 11
235 GTO IND 13
236 LBL 18
237 RCL 18
238 GTO 16
239 LBL 15
240 ENTER
241 INT
242 24
243 *
244 X<>Y
245 FRC
246 1 E2
247 *
248 +
249 HR
250 RTN
251 "END"
252 END
```

EA2.10
Rev: 0
Date: 10 Dec 85

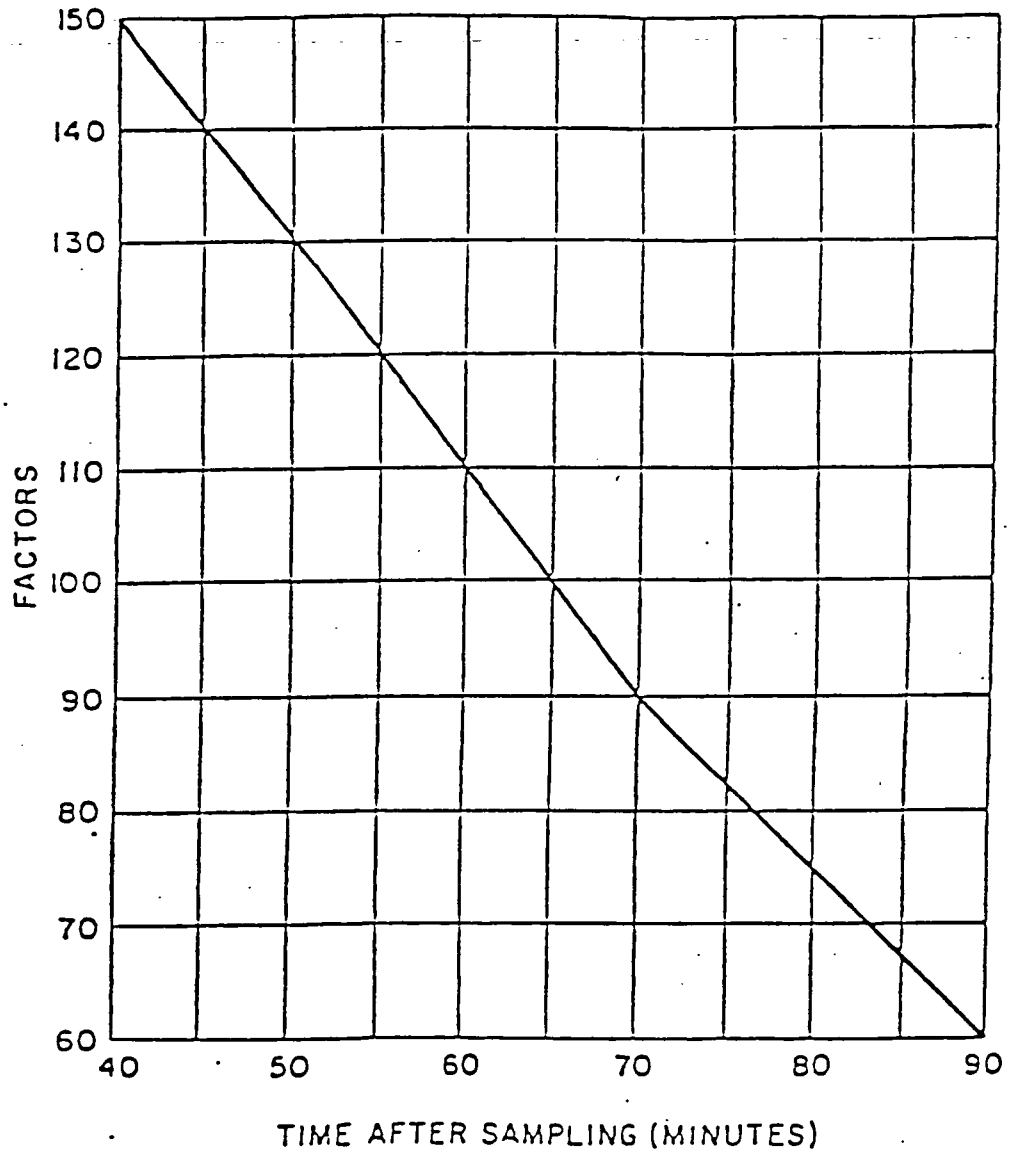


Figure 1.

Factors for Determining Multiple of Working Level of Radon Daughter Products in the Atmosphere

FORM NO. VIII

Form EA-2.10-1

RADIOLOGICAL SURVEY
AIR SAMPLING
RADON DAUGHTERS

EBERLINE INSTRUMENT CORPORATION

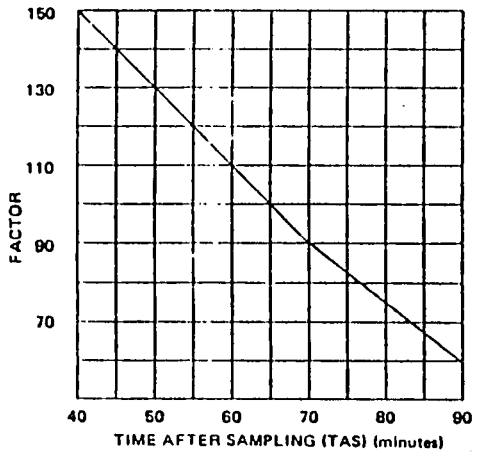
Location: _____
Date: _____
Surveyor: _____

LOCATION	COLLECTION						ANALYSIS									
	Time		Total Time (min)	Flow Rate (LPM)		Total Volume (liter)	Sample		Background		Net Count	Eff. CPM/DPM	DPM/liter	TAS	Table Factor	Working Level
	Start	Stop		Start	Stop		Gross Count C_{s+b}	Count Time T_{s+b}	Gross Count C_b	Count Time T_b						

☐ ROUTINE ☐ SPECIAL (If special, indicate reason for initiation of survey below). ☐ CORRECTIVE ACTION TAKEN

_____

_____



Pump I.D. No. _____

Cal Date _____

Cal Corr _____

$$W.L. \pm 2\sigma = \frac{\left(\frac{C_{s+b}}{T_{s+b}} - \frac{C_b}{T_b}\right)}{\left(Eff. \frac{CPM}{DPM}\right)(Vol, liters)(Table\ Factor)} \pm 2\sigma$$

$$2\sigma = 2\sqrt{\frac{\frac{C_{s+b}}{T^2_{s+b}} + \frac{C_b}{T^2_b}}{K}}$$

K = (Eff) (Vol) (Table Factor)
C_{s+b} = Counts, Sample + Background
T_{s+b} = Time, Sample + Background
C_s = Counts, Sample
T_b = Time, Background

1. Air sample collection exactly five minutes through .45μ membrane filter at a flow rate of 2 - 10 LPM.
2. Analysis minimum of 40 minutes after collection. Count for one minute.
3. Calibration Check
   Thorium 230
   Standard I.D. No. _____

   Thorium Standard DPM _____

   Gross Counts, CPM _____

   $\frac{CPM}{DPM}$ = Efficiency _____

ATTACHMENT 3

OPERATION OF THE LOW VOLUME AIR SAMPLER (RAS-1)
(EA3.2)

1.0 PURPOSE

The purpose of this instruction is to provide adequate information to personnel using the RAS-1 (regulated air sampler) to ensure its proper calibration and use.

2.0 SCOPE

This instruction provides a description of the RAS-1, its operational characteristics and instructions for proper operation.

3.0 REFERENCES

3.1 Eberline Technical Manual, RAS-1.

3.2 EA-1.11, Sampling for Airborne Particulates.

4.0 EQUIPMENT AND MATERIALS

4.1 RAS-1 Air Sampler.

4.2 Air Particulate Sampling: Glass Fiber Filter, 47mm, 0.45 micron Gelman No. 61631.

4.3 Radon Daughter Sampling: Membrane filter, 47mm, 0.45 micron Gelman GN-6.

5.0 DESCRIPTION AND SPECIFICATIONS

The Model RAS-1 is an oil-less vacuum pump with regulated flowrate for use where a nearly constant air flow is desirable. The regulator maintains a constant pressure drop across and in-line orifice by varying a bypass valve into the pump. This system allows the pump to work at a minimum differential pressure so it runs cooler thereby extending its lifetime.

As the pressure varies, the flow through an orifice varies approximately as the square root of the ratio of the absolute pressure. Thus, if paper loading causes a pressure drop to one-half of the original pressure, the flow, referenced to atmospheric pressure, will decrease to 0.7 of the original flow. The orifice size is adjustable, allowing flowrate adjustment from near zero up to the maximum capacity of the pump.

5.1 Specifications

5.1.1 Power supply: 115V, 60Hz at 5A.

5.1.2 Sample size: 47 mm.

5.1.3 RAS-1 size: 17.5 inches long x 7 inches wide 10 inches high.

5.1.4 Weight: 30 pounds.

5.1.5 Pump type: oil-less carbon vane.

5.1.6 Maximum capacity: 4 CFM at zero pressure drop

5.1.7 Ultimate vacuum: 26 inches Hg at sea level.

5.1.8 Typical operating flow rates: 5-75 LPM.

5.1.9 Flow meter: 0-100 LPM scale.

5.1.10 Thermal protector: built-in motor.

6.0 OPERATION

6.1 Ensure the RAS-1 has a valid calibration.

6.2 Selection of sample location is described in EA-1.11.

6.3 Provide 110-115 VAC power to the RAS-1 from area power grid, if available, or use power supplied from portable electric generators as an alternate power supply.

6.4 Place filter paper in filter holder as described in EA-1.11.

6.5 Start pump motor and check flow meter. The regulator is normally set to provide a flowrate of approximately 50 LPM. Check calibration tag on pump handle for proper flow meter setting for a 50 LPM flowrate.

6.6 If flowrate is not adjusted to the predetermined rate adjust the flowrate by turning the brass screw on the side of the regulator housing. (An arrow on top of the regulator indicates its location.) Turn brass screw clockwise to decrease and counterclockwise to increase the flowrate. Do not set flowrate greater than 60 LPM

as regulator will not operate properly with older pumps.

CAUTION: Do not attempt to control air flow with an external valve or close off the air bypass line

6.7 During the extended sampling periods check the RAS-1 motor and pump for proper operation and overheating when air sample filters are changed.

ATTACHMENT 4

OPERATION OF THE RADON PULSE PUMP III
(EA 3.1)

1.0 PURPOSE

The purpose of this instruction is to describe the operations and calibration of the pulse pump, Environmental Measurements Model PP-III, to be used for collecting air samples for radon gas analysis.

2.0 SCOPE

DOE Order 5480.1 prescribes maximum permissible radon levels in air that must be complied with. In order to achieve the sensitivity required to document those levels and to provide a time integrated sample volume, a pulse pump is employed to collect a volume of air over a large time span.

3.0 REFERENCES

3.1 EA-2.9, Radon Measurements.

3.2 Environmental Measurements, Inc., Pulse Pump III Operational Manual.

4.0 EQUIPMENT AND MATERIALS

4.1 Stop Watch.

4.2 2.5 cm Filter Head.

4.3 2.5 cm Glass Fiber Filter.

4.4 Check Valve.

4.5 1/4" I.D. Tubing.

4.6 Mylar Gas bag (44 liters).

4.7 Calibrated Pulse Pump (PP-III).

4.8 50 cc Syringe.

4.9 24-hour Clock Timer.

5.0 DESCRIPTION

The Pulse Pump III uses a reliable positive displacement dry type piston pump complete with an electronic controller and battery pack in a rugged personal size case.

The pump offers dual mode operation: (1) it can be used as a vacuum pump for filter sampling or a pressure pump for filling gas sampling bags; (2) the unit has an adjustable low flow rate variable from 1 to 20 liters per hour. There is also a fixed high flow setting of 1.5 liters per minute.

The pump is suitable for long and short term, time-integrated studies or for taking quick grab samples.

Up to 100 hours of operation at the low flow setting may be obtained from one set of batteries.

The pump is available with either rechargeable or disposable batteries.

5.1 Specifications - Pulse Pump Model PP-III

5.1.1 Type: Personal sampling pump.

5.1.2 Size: 4.0 x 7.3 x 10.2 cm (1.6 x 2.9 x 4.0 inches).

5.1.3 Weight: 255 grams (9 ounces) with batteries.

5.1.4 Controls: ON-OFF switch, flow mode switch, an flow adjustment potentiometer.

5.1.5 Sample Ports: Positive pressure (bag filling) 4 mm; negative pressure (vacuum) 6 mm.

5.1.6 Power: One each 1.5 "C" cell, 9 volt "NEDA 1604 cell" both field replaceable.

5.1.7 Battery Life: 15 to 20 hours in High Flow continuous mode (alkaline cell), 75 to 100 hours in Low Flow Pulsating mode (alkaline cell).

5.1.8 Operation Cycle:

Low Flow:	Liters per hour:				
Flow rate	20	10	5	2	1
On time (m.sec)	200	200	200	200	200
Off time (sec)	0.5	1	2	5	10
Pulse per hour	7200	3600	1800	900	450

High Flow:	Liters per minute:
Bag filter	1.5
Membrane filter	1.1
Charcoal filter	0.7

Materials: Pump and motor: stainless steel, mild steel, aluminum and nylon case: high impact plastic.

6.0 OPERATION

NOTE: Unlike particulate air samplers, the actual volume of air collected is not critical to gas bag sample. The calibration of the pulse pump only involves adjusting the pulse interval to assure that sample collection is not too rapid or slow.

6.1 Adjust the time interval to approximately 1.0 pulse per second and set timer for 24-hour turnoff.

Sample Time (Hours)	Pulse Interval (Seconds)
24	5
48	12
72	15

6.2 Connect the air sampler head to the inlet side of the pump and place a glass fiber filter in the sampler head.

6.3 Connect the gas bag to the check valve.

6.4 Connect the check valve to the pressure side of the pump.

NOTE: Be sure that the check valve is oriented so that the air flow is from the pump to the bag.

6.5 Install at the sampling location and turn on power.

6.6 After about 24 hours, stop the sampling and return the bag with the sample location, collection time, dates, etc., to the lab for analysis as per instruction EA-2.9.

6.7 Replace all batteries (1-9 volt and 1-"C" cell Alkaline type) before installing in sample location to avoid loss of sample due to pump failure.

APPENDIX Q

ANALYTICAL PROCEDURES TO BE USED FOR FMPC SAMPLE ANALYSES

1.0 INTRODUCTION

This analysis plan describes the methods which will be used for analysis of samples from various waste storage areas and drainages at the Feed Materials Production Center in Fernald, Ohio. The sample matrices are anticipated to include ground and surface water, various solid residues as taken from waste storage pits, surface and subsurface soils, and fly ash.

The objective of the analytical program for the characterization activities at the Feed Materials Production Center is to provide high quality data that meets the needs of DOE, and is legally defensible. Operating practices for this project have been developed to meet the specialized requirements of the Environmental Protection Agency's Contract Laboratory Program (EPA-CLP).

2.0 ANALYTICAL METHODS

2.1 Hazardous Substance List (HSL) Analysis

Background data is limited as to the information of what constituents are present in the waste Storage Area. Since the Pits received material from several process operations, the majority of samples will be analyzed for all organic and inorganic HSL compounds. In addition, a library search will be performed to identify targeted and untargeted non-HSL constituents. The target analyses are those constituents not on the HSL list that were compiled by Westinghouse and Dames and Moore during the course of RCRA ground water monitoring of Pit 4 (1985). These include:

Dichlorodifluoromethane
Tributylphosphate
Acrolein
Acrylonitride
bis (chloromethyl) ether
Methylbromide
Methylchloride
Trichlorfluormethane
cis 1,2 Dichloroethylene
1,2 Dichloropropylene

The methods and target detection limits are listed on Tables Q.1 and Q.2. These methods are described in References 1 and 2.

2.2 Radiochemical Analyses

The radiochemical analyses of the FMPC samples will include all or some of the following:

Solid Matrix	Liquid Matrix
Isotopic uranium	Isotopic uranium
Isotopic thorium	Isotopic thorium
Isotopic plutonium	Isotopic plutonium
Gamma Spectral Analysis	Co-137, Ra-226, Ra-228
Sr-90, Ru-106, Np-237, Tc-99	Sr-90, Ru-106, Np-237, Tc-99

The procedures used will be outlined in the Health and Safety Laboratory Procedures Manual (HASL 300) contained in the EML Procedures Manual (DOE, 1982).

3.0 DETECTION LIMITS

The target detection limits for inorganic and organic HSL compounds are listed in Tables Q.1 and Q.2. Achieving these detection limits depends on the sample matrix. Highly contaminated samples requiring dilution will have detection limits higher than those listed.

TABLE Q.1

Hazardous Substance List (HSL) and
Contract Required Detection Limits (CRDL)**

Volatiles	CAS Number	Detection Limits* Low Water[a] ug/L	Low Soil/Sediment[b] ug/Kg
1. Chloromethane	74-87-3	10	10
2. Bromomethane	74-83-9	10	10
3. Vinyl Chloride	75-01-4	10	10
4. Chloroethane	75-00-3	10	10
5. Methylene Chloride	75-09-2	5	5
6. Acetone	67-64-1	10	10
7. Carbon Disulfide	75-15-0	5	5
8. 1,1-Dichloroethene	75-34-4	5	5
9. 1,1-Dichloroethane	75-35-3	5	5
10. trans-1,2-Dichloroethene	156-60-5	5	5
11. Chloroform	67-66-3	5	5
12. 1,2-Dichloroethane	107-06-2	5	5
13. 2-Butane	78-93-3	10	10
14. 1,1,1-Trichloroethane	71-55-6	5	5
15. Carbon Tetrachloride	56-23-5	5	5
16. Vinyl Acetate	108-05-4	10	10
17. Bromodichloromethane	75-27-4	5	5
18. 1,1,2,2-Tetrachloroethane	79-34-5	5	5
19. 1,2-Dichloropropane	78-87-5	5	5
20. trans-1,3-Dichloropropene	10061-02-6	5	5
21. Trichloroethene	79-01-6	5	5
22. Dibromochloromethane	124-48-1	5	5
23. 1,1,2-Trichloroethane	79-00-5	5	5
24. Benzene	71-43-2	5	5
25. cis-1,3-Dichloropropene	10061-01-5	5	5

TABLE Q.1 (continued)

Hazardous Substance List (HSL) and
Contract Required Detection Limits (CRDL)**

Volatiles	CAS Number	Detection Limits* Low Water[a] ug/L	Low Soil/Sediment[b] ug/Kg
26. 2-Chloroethyl Vinyl Ether	110-75-8	10	10
27. Bromoform	75-25-2	5	5
28. 2-Hexanone	591-78-6	10	10
29. 4-Methyl-2-pentanone	108-10-1	10	10
30. Tetrachloroethene	127-18-4	5	5
31. Toluene	108-88-3	5	5
32. Chlorobenzene	108-90-7	5	5
33. Ethyl Benzene	100-41-4	5	5
34. Styrene	100-42-5	5	5
35. Total Xylenes		5	5

a Medium Water Contract Required Detection Limits (CRDL) for Volatile HSL Compounds are 100 times the individual Low Water CRDL.

b Medium Soil/Sediment Contract Required Detection Limits (CRDL) for Volatile HSL Compounds are 100 times the individual Low Soil/Sediment CRDL.

TABLE Q.1 (continued)

Hazardous Substance List (HSL) and
Contract Required Detection Limits (CRDL)**

Semi-Volatiles	CAS Number	Detection Limits* Low Water[c] ug/L	Detection Limits* Low Soil/Sediment[d] ug/Kg
36. N-Nitrosodimethylamine	62-75-9	10	330
37. Pbenol	108-95-2	10	330
38. Aniline	62-53-3	10	330
39. bis(2-Chloroethyl) ether	111-44-4	10	330
40. 2-Chlorophenol	95-57-8	10	330
41. 1,3-Dichlorobenzene	541-73-1	10	330
42. 1,4-Dichlorobenzene	106-46-7	10	330
43. Benzyl Alcohol	100-51-6	10	330
44. 1,2-Dichlorobenzene	95-50-1	10	330
45. 2-Methylphenol	95-48-7	10	330
46. bis(2-Chloroisopropyl) ether	39638-32-9	10	330
47. 4-Methylphenol	106-44-5	10	330
48. N-Nitroso-Dipropylamine	621-64-7	10	330
49. Hexachloroethane	67-72-1	10	330
50. Nitrobenzene	98-95-3	10	330
51. Isophorone	78-59-1	10	330
52. 2-Nitrophenol	88-75-5	10	330
53. 2,4-Dimethylphenol	105-67-9	10	330
54. Benzoic Acid	65-85-0	50	1600
55. bis(2-Chloroethoxy) methane	111-91-1	10	330
56. 2,4-Dichlorophenol	120-83-2	10	330
57. 1,2,4-Trichlorobenzene	120-82-1	10	330
58. Naphthalene	91-20-3	10	330
59. 4-Chloroaniline	106-47-8	10	330
60. Hexachlorobutadiene	87-68-3	10	330
61. 4-Chloro-3-methylphenol (para-chloro-meta-cresol)	59-50-7	10	330
62. 2-Methylnaphthalene	91-57-6	10	330
63. Hexachlorocyclopentadiene	77-47-4	10	330
64. 2,4,6-Trichlorophenol	88-06-2	10	330
65. 2,4,5-Trichlorophenol	95-95-4	50	1600

TABLE Q.1 (continued)

Hazardous Substance List (HSL) and
Contract Required Detection Limits (CRDL)**

Semi-Volatiles	CAS Number	Detection Limits* Low Water[c] ug/L	Low Soil/Sediment[d] ug/Kg
66. 2-Chloronaphthalene	91-58-7	10	330
67. 2-Nitroaniline	88-74-4	50	1600
68. Dimethyl Phthalate	131-11-3	10	330
69. Acenaphthylene	208-96-8	10	330
70. 3-Nitroaniline	99-09-2	50	1600
71. Acenaphthene	83-32-9	10	330
72. 2,4-Dinitrophenol	51-28-5	50	1600
73. 4-Nitrophenol	100-02-7	50	1600
74. Dibenzofuran	132-64-9	10	330
75. 2,4-Dinitrotoluene	121-14-2	10	330
76. 2,6-Dinitrotoluene	606-20-2	10	330
77. Diethylphthalate	84-66-2	10	330
78. 4-Chlorophenyl Phenyl ether	7005-72-3	10	330
79. Fluorene	86-73-7	10	330
80. 4-Nitroaniline	100-01-6	50	1600
81. 4,6-Dinitro-2-methylphenol	534-52-1	50	1600
82. N-nitrosodiphenylamine	86-30-6	10	330
83. 4-Bromophenyl Phenyl ether	101-55-3	10	330
84. Hexachlorobenzene	118-74-1	10	330
85. Pentachlorophenol	87-86-5	50	1600
86. Phenanthrene	85-01-8	10	330
87. Anthracene	120-12-7	10	330
88. Di-n-butylphthalate	84-74-2	10	330
89. Fluoranthene	206-44-0	10	330
90. Benzidine	92-87-5	50	1600
91. Pyrene	129-00-0	10	330
92. Butyl Benzyl Phthalate	85-68-7	10	330
93. 3,3-Dichlorobenzidine	91-94-1	20	660
94. Benzo(a)anthracene	56-55-3	10	330
95. bis(2-ethylhexyl)phthalate	117-81-7	10	330

TABLE Q.1 (continued)

Hazardous Substance List (HSL) and
Contract Required Detection Limits (CRDL)**

Semi-Volatiles	CAS Number	Detection Limits* Low Water[c] ug/L	Low Soil/Sediment[d] ug/Kg
96. Chrysene	218-01-9	10	330
97. Di-n-octyl Phthalate	117-84-0	10	330
98. Benzo(b)fluoranthene	205-99-2	10	330
99. Benzo(k)fluoranthene	207-08-9	10	330
100. Benzo(a)pyrene	50-32-8	10	330
101. Indeno(1,2,3-cd)pyrene	193-39-5	10	330
102. Dibenz(a,h)anthracene	53-70-3	10	330
103. Benzo(g,h,i)perylene	191-24-2	10	330

[c]Medium Water Contract Required Detection Limits (CRDL) for Semi-Volatile BSL Compounds are 100 times the individual Low Water CRDL.

[d]Medium Soil/Sediment Contract Required Detection Limits (CRDL) for Simi-Volatile RSL Compounds are 60 times the individual Low Soil/Sediment CRDL.

TABLE Q.1 (continued)

Hazardous Substance List (HSL) and Contract Required Detection Limits (CRDL)**

Pesticides	CAS Number	Detection Limits* Low Water[e] ug/L	Low Soil/Sediment[f] ug/Kg
104. alpha-BHC	319-84-6	0.05	8.0
105. beta-BHC	319-85-7	0.05	8.0
106. delta-BHC	319-86-8	0.05	8.0
107. gamma-BHC (Lindane)	58-89-9	0.05	8.0
108. Heptachlor	76-44-8	0.05	8.0
109. Aldrin	309-00-2	0.05	8.0
110. Heptachlor Epoxide	1024-57-3	0.05	8.0
111. Endosulfan I	959-98-8	0.05	8.0
112. Dieldrin	60-57-1	0.10	16.0
113. 4,4'-DDE	72-55-9	0.10	16.0
114. Endrin	72-20-8	0.10	16.0
115. Endosulfan II	33213-65-9	0.10	16.0
116. 4,4'-DDD	72-54-8	0.10	16.0
117. Endrin Aldehyde	7421-93-4	0.10	16.0
118. Endosulfan Sulfate	1031-07-8	0.10	16.0
119. 4,4'-DDT	50-29-3	0.10	16.0
120. Endrin Ketone	53494-70-5	0.10	16.0
121. Methoxychlor	72-43-5	0.5	80.0
122. Chlordane	57-74-9	0.5	80.0
123. Toxaphene	8001-35-2	1.0	160.0
124. AROCLOR-1016	12674-11-2	0.5	80.0
125. AROCLOR-1221	11104-28-2	0.5	80.0
126. AROCLOR-1232	11141-16-5	0.5	80.0
127. AROCLOR-1242	53469-21-9	0.5	80.0
128. AROCLOR-1248	12672-29-6	0.5	80.0
129. AROCLOR-1254	11097-69-1	1.0	160.0
130. AROCLOR-1260	11096-82-5	1.0	160.0

[e]Medium Water Contract Required Detection Limits (CRDL) for Pesticide HSL Compounds are 100 times the individual Low Water CRDL.

[f]Medium Soil/Sediment Contract Required Detection Limits (CRDL) for Pesticide HSL compounds are 60 times the individual Low Soil/Sediment CRDL.

*Detection limits listed for soil/sediment are based on wet weight. The detection limits calculated by the laboratory for soil/sediment, calculated on dry weight basis, as required by the contract, will be higher.

**Specific detection limits are highly matrix dependent. The detection limits listed here in are provide for guidance and may not always be achievable.

TABLE Q.2

Elements Determined by Inductively Coupled Plasma Emission or Atomic Absorption Spectroscopy

Element	Contract Required Detection Level[1,2] (ug/L)
Aluminum	200
Antimony	60
Arsenic	10
Barium	200
Beryllium	5
Cadmium	5
Calcium	5000
Chromium	10
Cobalt	50
Copper	25
Iron	100
Lead	5
Magnesium	5000
Manganese	15
Mercury	0.2
Nickel	40
Potassium	5000
Selenium	5
Silver	10
Sodium	5000
Thallium	10
Tin	40
Vanadium	50
Zinc	20

Element	Contract Required Detection Level[1, 2] (ug/L)
Cyanide	10

1: Any analytical method specified in SOW Exhibit D may be utilized as long as the documented instrument or method detection limits meet the Contract Required Detection Level (CRDL) requirements. Higher detection levels may only be used in the following circumstance:

If the sample concentration exceeds two times the detection limit of the instrument or method in use, the value may be reported even though the instrument or method detection limit may not equal the contract required detection level. This is illustrated in the example below:

For lead:
Method in use = ICP
Instrument Detection Limit (IDL) = 40
Sample concentration = 85
Contract Required Detection Level (CRDL) = 5

The value of 85 may be reported even though instrument detection limit is greater than required detection level. The instrument or method detection limit must be documented as described in Exhibit E.

2: These CRDL are the instrument detection limits obtained in pure water that must be met using the procedure in Exhibit E. The detection limits for samples may be considerably higher depending on the sample matrix.

Method References

1. U.S.E.P.A. Statement of Work, "Organic Analysis Multi-Media, Multi-Concentration," 7/85.

2. U.S.E.P.A. Statement of Work "Inorganic Analyses Multi-Media, Multi-Concentration" SOW 785, July 1985.

3. "Test Methods for Evaluating Solid Waste, "Office of Solid Waste and Emergency Response, Washington D.C. 20460, Revised April, 1984.

Section 3

SECTION 3

HYDROGEOLOGICAL SAMPLING PLAN FOR THE CHARACTERIZATION OF THE WASTE STORAGE AREAS AT THE FEED MATERIALS PRODUCTION CENTER

SECTION 3

HYDROGEOLOGIC SAMPLING PLAN FOR THE CHARACTERIZATION OF THE WASTE STORAGE AREAS AT THE FEED MATERIALS PRODUCTION CENTER

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SECTION 3

HYDROGEOLOGICAL SAMPLING PLAN

3.1 PROGRAM OBJECTIVES

The hydrogeological field program will focus on determining the effect that stored wastes may have had on the groundwater at the FMPC site.

Specifically, the objectives of the hydrogeological investigation are to:

- Determine if subsurface water bearing zones at FMPC have been impacted by the past waste storage activities.
- Analyze the chemical nature of this impact should it exist.
- Determine the concentrations of radiological and chemical constituents onsite and identify their source or sources.
- Determine the nature of the subsurface geology at the site, and determine which units have been affected by waste materials.
- Determine the horizontal and vertical extent of the plume or plumes within each hydrogeologic unit.
- Define the subsurface migration pathways for radiological and chemical constituents.
- Identify discharge areas and other locations most likely at risk from groundwater having above background levels of radiological and chemical constituents.
- Provide data needed to evaluate the actual and potential risk to public health and the environment from the current and future uses of the groundwater.
- Provide data needed to evaluate remedial action alternatives for groundwater remediation.

3.2 PREVIOUS STUDIES AND CONCLUSIONS

The recent studies that are most relevant to the hydrogeological investigations are:

- 'Groundwater Study, Task C Report' by Dames and Moore, July 1985.
- 'Results of RCRA Sampling, Feed Materials Production Center, Fernald, Ohio, Pit #4' by Dames and Moore, August 1985.
- 'Results of RCRA Sampling, Feed Materials Production Center, Fernald, Ohio Sand and Gravel Aquifer' by Dames and Moore, August 1985.

The most recent information available is from the RCRA sampling at Pit #4 which included sampling of wells surrounding Pit #4. (Figure 3-1). The downgradient wells (MW TP-19, MW TP-21, and MW TP-22) are located east, south, and west of Pit #4 respectively. (See Figures 3-1 and 3-2). A well, hydraulically upgradient of the pit (based on water level measurements), MW-12, was sampled in order to provide background water quality for comparison. These wells are screened in the uppermost geologic unit which is a glacially deposited clay (till).

Analyses for 95 compounds were performed, including metals, volatile organics, pesticides, and radionuclides (See Appendix A). The report presents data from one round of sampling in August, 1985. These data indicate above background concentrations of radionuclides, especially radium 228 (75 pCi/L) and cesium 137 (115 pCi/L) in Well TP-22. Other radionuclides detected include potassium 40, thorium 232, strontium 90, ruthenium 106, and neptunium 237. Actual levels of natural uranium, radium 226, and the plutonium isotopes reportedly could not be determined because of interference from other compounds.

Other compounds identified at above background concentrations in wells include arsenic, barium, calcium, nickel, zinc, total organic carbon and total organic halogens. Well TP-19 exhibited concentrations of calcium (372 mg/L), and total organic halogen (80.25 mg/L) above values in MW-12. The values for barium (0.863 mg/L), calcium (415 mg/L), nickel (0.137 mg/L), and zinc (0.240 mg/L) were above background levels in Well TP-21. Results from Well TP-22 also indicate above background concentrations of calcium (154 mg/L), and TOC (6.5 mg/L). In addition the background well contained concentrations of sodium (268 mg/L),

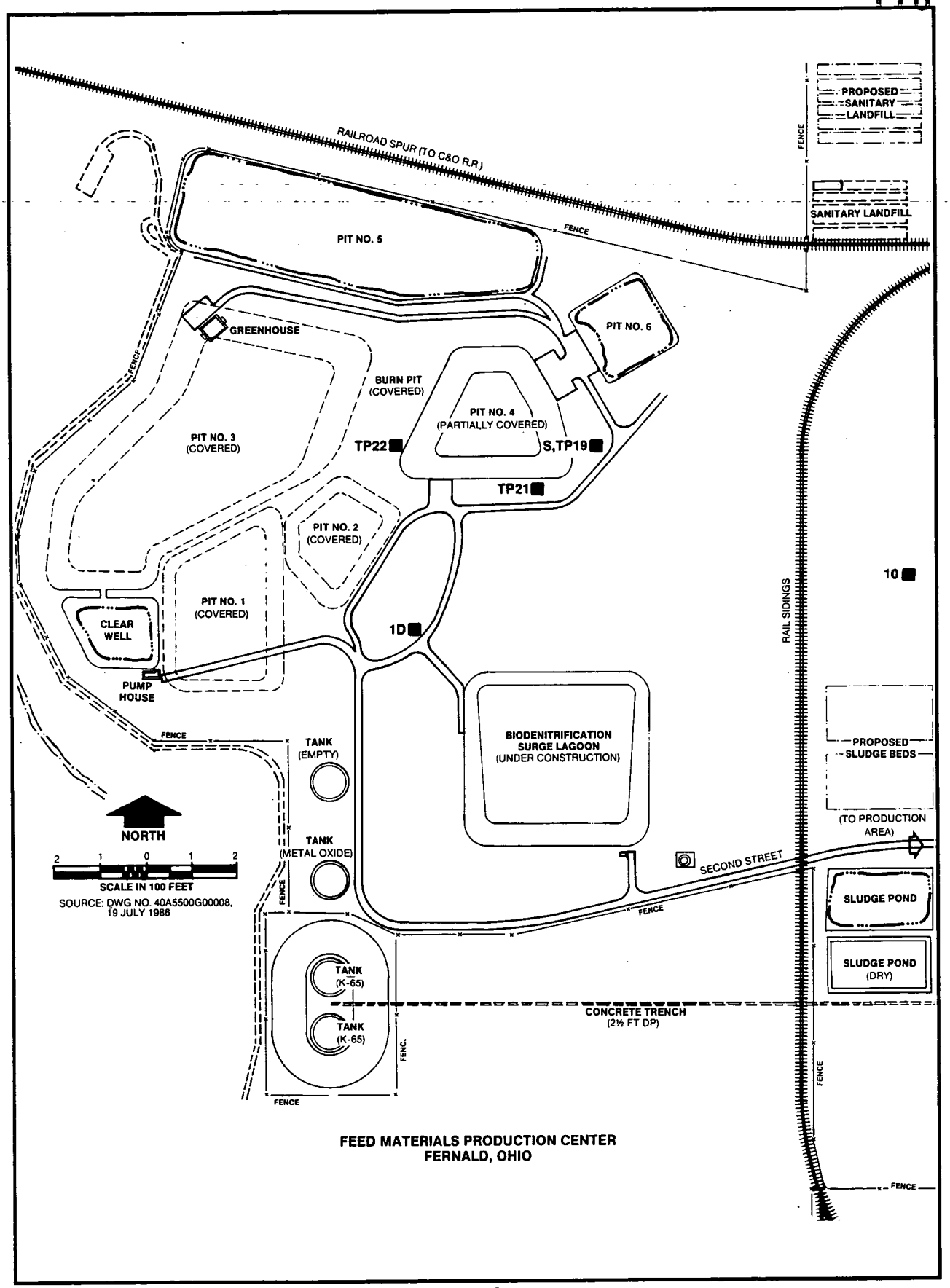


FIGURE 3-1 DAMES AND MOORE RCRA SAMPLING LOCATIONS

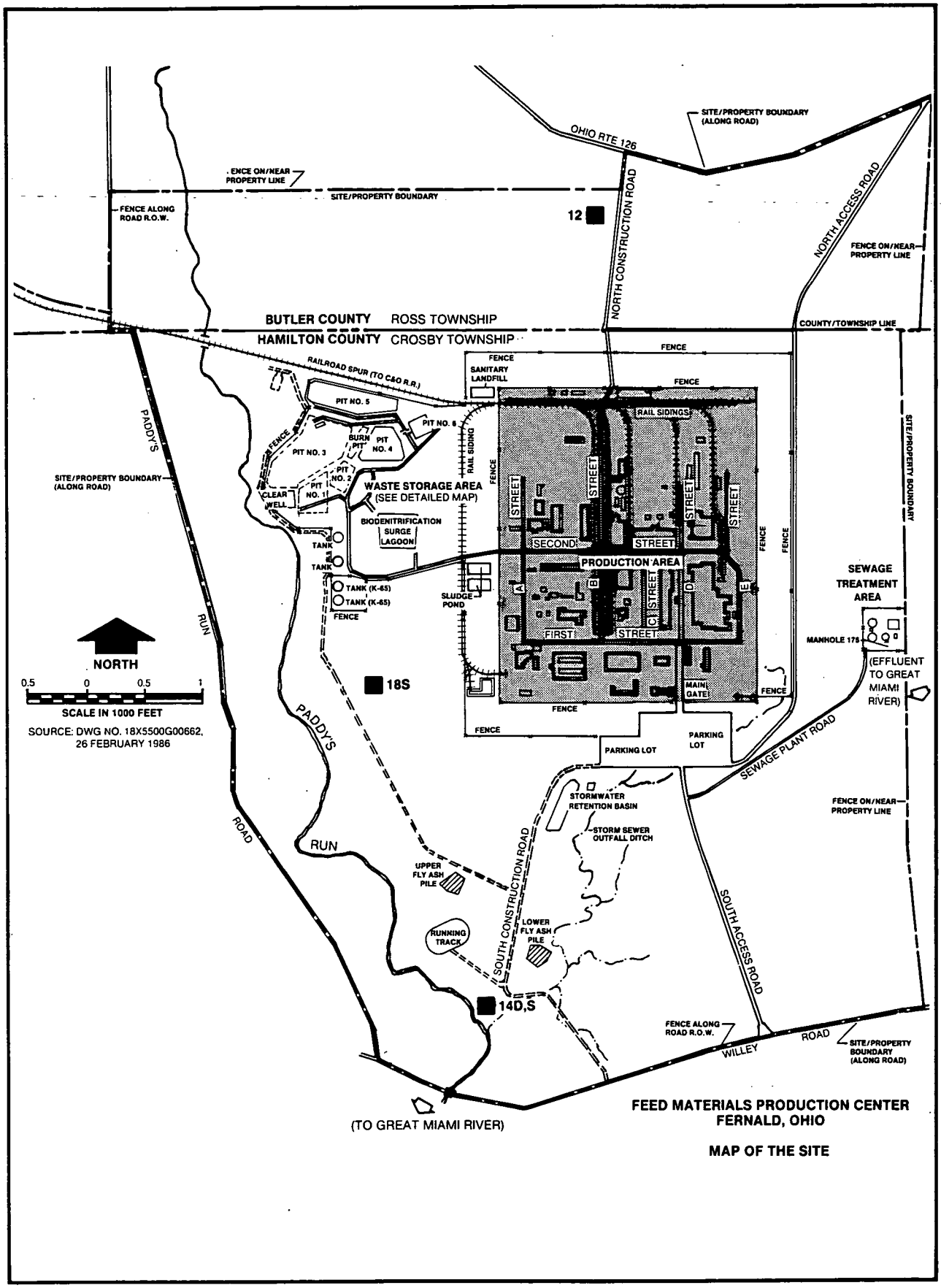


FIGURE 3-2 DAMES AND MOORE RCRA SAMPLING LOCATIONS

fluoride (2.00 mg/L), and lead (0.32 mg/L) which are above those found in the on-site wells.

Finally, the volatile organic compound and pesticide analysis indicated the presence of only 1.1 dichloroethane (3.4 ug/L) in well TP-19 on-site. The background well, number 12, apparently contains benzene (14.8 ug/L) and xylenes (11.8 ug/L).

The RCRA sampling in the sand and gravel aquifer included well numbers SW-1, MW-1D, MW-10, MW-14D, MW-14S, MW-18S, and MW-19S (See Figure 3-2). These wells are sequenced at various deviations in the sand and gravel aquifer which is beneath the glacial till. Samples were collected from these wells and analyzed for the compounds shown in Appendix A. The report presents one set of analyses data for samples collected in August, 1985. Several radionuclides were detected at apparently elevated levels in well MW-19S. Gross Beta (1,250 pCi/L), Thorium 232 (80 pCi/L), Cesium 137 (110 pCi/L), and Ruthenium 106 (75 pCi/L) appear to be unusually high in well MW-19S.

Other compounds detected in the on-site wells include iron, manganese, sodium sulfate, calcium, total chromium, copper, nickel, nitrate, lead, zinc, total coliform and 1,1,1 Trichloroethane. The values reported for these compounds are shown in Table 3-1. There is some indication of unusually high concentrations of at least one parameter in all of the on-site wells.

A significant difficulty in interpreting this data is the inconsistency in well screen settings. The wells chosen are not all screened at the same elevation in the sand and gravel aquifer. In addition it is difficult to base any conclusions on data from one round of sampling.

Dames and Moore concluded that the radionuclides present in MW-TPP22 on the west side of Pit #4 indicate westward migration of shallow groundwater from the pit area towards Paddy Run. In addition, a berm on the west side of Pit #4, constructed of potentially contaminated onsite soils, may also be contributing to the elevated radionuclide level. The report also concludes that radionuclide contamination in well 19S may be attributable to leachate from the waste pit area.

Based on these previous investigations, WESTON has developed a conceptual understanding of the geologic and hydrogeologic systems. This understanding is illustrated in Figure 3-3 and has been used to guide the design of this investigation. The local groundwater system is known to be composed of several water bearing zones, (see Figure 3-3). Most of the site is capped with glacial till - a clay-rich layer of heterogeneous material up to

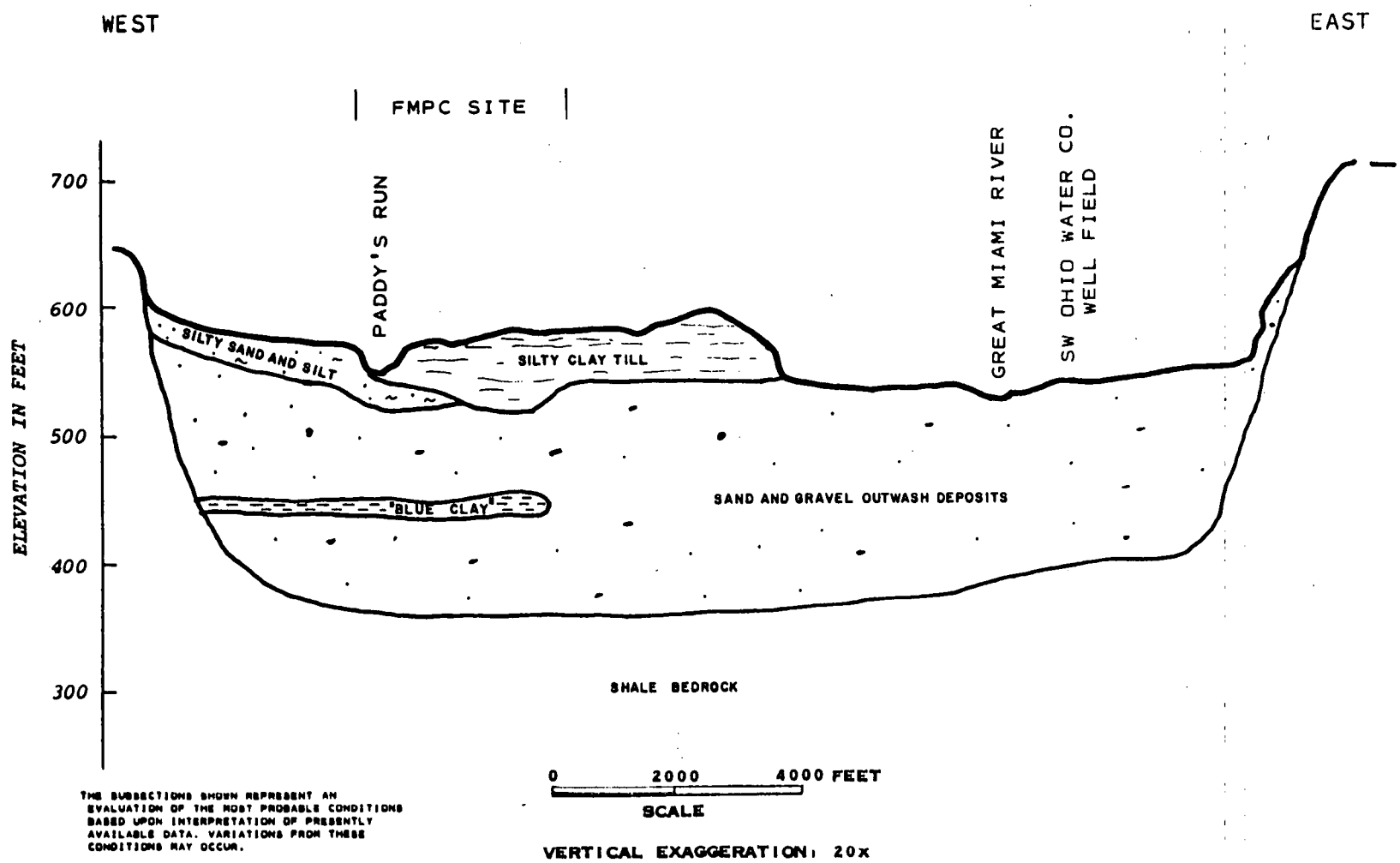
Table 3-1

Concentrations Reported in the Sand and Gravel Aquifer

Compound	SW-1	MW-1d	MW-10	MW-14d	MW-14s	MW-18s
Iron (ppm)	<.05	61.8	18.9	0.123	37.2	18.3
Manganese (ppm)	0.125	0.649	5.5	2.02	0.451	0.818
Sodium (ppm)	15	29.7	162	12.7	10.4	8.6 18
Sulfate (ppm)	60	40	470	70	70	50 13
Calcium (ppm)	94.4	80.7	1232	89	241	165 36
Total Chromium (ppm)	<.005	0.019	0.014	<.005	0.159	0.147
Copper (ppm)	<.025	0.146	<.025	<.025	0.289	0.179
Nickel (ppm)	<.005	0.012	0.039	0.01	0.027	0.022
Nitrate (ppm)	2.06	<.02	155.6	1.2	0.89	0.72 2
Lead (ppm)	<.005	0.028	<.005	0.011	0.1	0.047
Zinc (ppm)	0.025	0.141	0.056	0.0250	0.166	0.109
Total Coliform	18	190,000	140,000	110	2,200	3,500 19
1,1,1 Trichloroethane (ppb)	ND	ND	ND	ND	ND	ND

Note: Nd = not detected

All data from: Results of RCRA Sampling, Feed Materials Production Cen
and Gravel Aquifer, August 1985.



Reference: Dames and Moore, 1985

FIGURE 3-3 | GENERALIZED GEOLOGIC CROSS SECTION OF NEW HAVEN TROUGH

50 feet thick. The till is variable in texture and includes lenses of sandy and gravelly materials. The saturated zone(s) in the till may represent either a water table aquifer, or isolated perched zones, or both. Underlying the till, and exposed at the surface where the till has been eroded away, is an outwash sand and gravel unit which is the regional aquifer. A layer of clay ("blue clay") at a depth of about 125 feet below ground separates this unit into an upper sand and gravel and a lower sand and gravel. For purposes of this study, and groundwater above the blue clay, a possible local confining layer, will be termed the upper water bearing zones. The upper water bearing zone includes the local groundwater zones in the till, plus the upper sand and gravel aquifer.

3.3 SAMPLING PROGRAM

3.3.1 Objectives

The scope of the hydrogeologic investigation has been developed to address the following specific objectives:

1. Provide more details on the subsurface materials in the areas of known radiological and chemical materials storage (i.e. waste pit areas);

2. Characterize the three-dimensional ground water flow pattern within each separate hydrologic unit;

3. Gather data to better define the groundwater plume that the Dames and Moore Study identified; and

4. Define subsurface migration pathways for radiological and chemical constituents and identify areas most likely at risk from these ground water anomolies.

In order to achieve these objectives, a phased approach to field activities is planned. The first major phase of work will concentrate on investigating the geologic and hydrogeologic systems above the "blue clay" confining layer. Once this zone is adequately understood, an investigation of deeper zones will be designed. The next section discusses the approach to the first phase of this investigation.

3.3.2 Approach

The intent of the proposed field program is to systematically collect data regarding the nature and extent of subsurface

concentrations of radionuclides and chemical constituents, and to correctly characterize the geologic and hydrogeologic environments. In order to achieve this goal, two general tools will be applied at this site. These tools are geophysical surveys, and monitor well network installation. Used in conjunction with one another, they will provide the means to efficiently achieve the goals of this field program. The approach of this investigation is to execute distinct steps in the field program which will enhance the quality of each successive effort.

Initially, non-intrusive, geophysical techniques will be applied to all known and/or suspected waste or contaminated areas. These techniques include magnetometer, ground penetrating radar (GPR), and electromagnetic conductivity (EM). Data provided by surveys performed using these instruments will be used to finalize the proposed shallow (100 series) monitor well locations. Once the locations are finalized the shallow wells will be installed. Following installations the wells will be sampled for chemical analysis. The geologic data obtained during the drilling will be evaluated along with the chemical analyses results for the shallow (100 series) wells. This evaluation will help refine and finalize the locations for the proposed intermediate (200 series) and deep (300 series) wells. Once the locations are selected the 200 and 300 series wells will be installed. Following installation of the 200 and 300 series wells all wells will be sampled for chemical analysis. The results of the chemical analysis, geologic data and geophysical survey data will be thoroughly evaluated to prepare a work plan for investigation of the deeper portion of the sand and gravel aquifer. This approach is designed to provide the maximum understanding of the radiological and chemical constituent distribution and hydrology of each hydrogeologic zone before proceeding to the next. The result will be the most cost effective and environmentally sound placement of monitor wells possible. Figure 3-4 illustrates the general approach of this investigation and the specific steps in phase I are described in more detail in following sections.

3.3.3 Geophysical Survey

Geophysical surveys are used to provide information regarding relatively shallow subsurface conditions at a site. This information is collected for large areas in a relatively small amount of time, provides a general understanding of shallow stratigraphy and potential waste concentrations, and may detect ground water constituent plumes in shallow aquifers. An additional benefit of geophysical survey data is to allow placement of borings and monitor wells in locations that will yield the maximum amount of

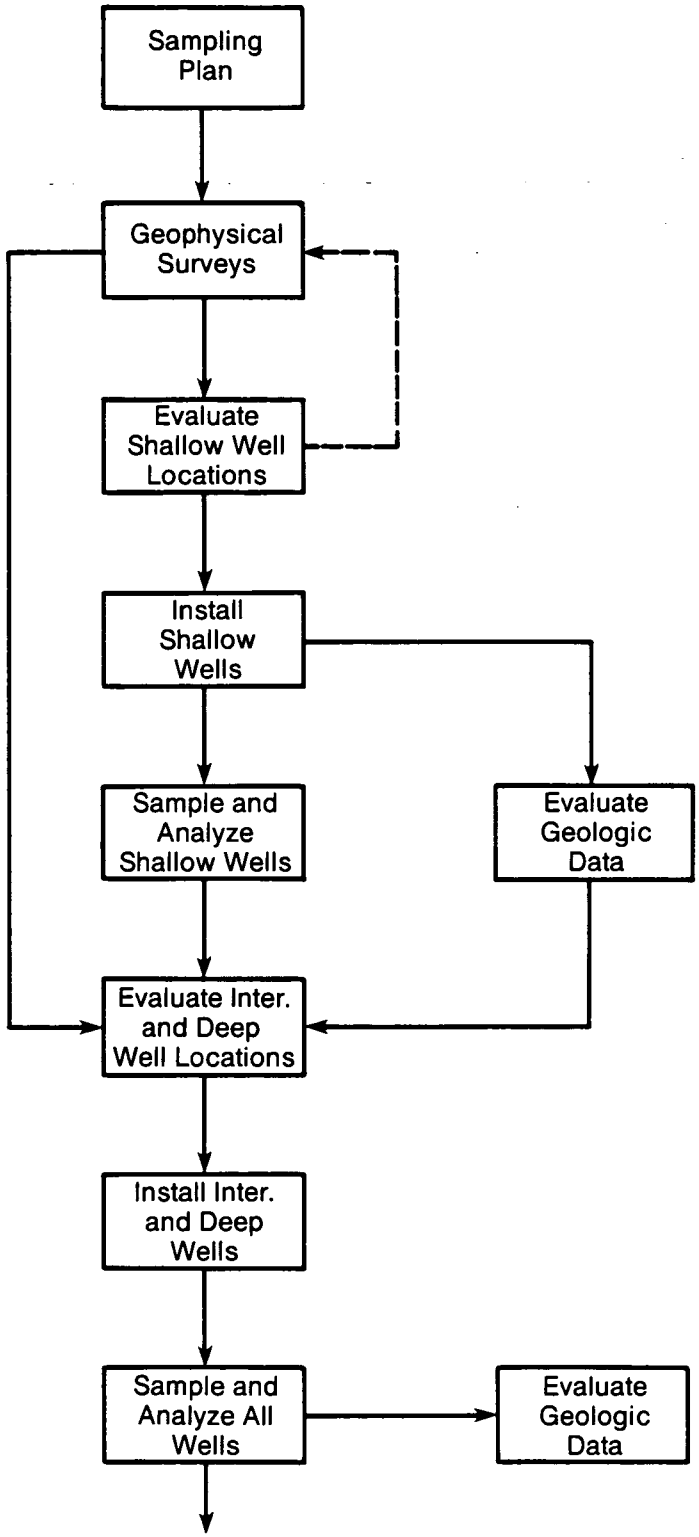

Sampling Plan
Geophysical Surveys
Evaluate Shallow Well Locations
Install Shallow Wells
Sample and Analyze Shallow Wells
Evaluate Geologic Data
Evaluate Inter. and Deep Well Locations
Install Inter. and Deep Wells
Sample and Analyze All Wells
Evaluate Geologic Data

FIGURE 3-4

useful data. The early use of the disposal pits was reportedly uncontrolled and many different types of wastes, including metal objects, may be in them. The potential presence of drums is important in that drums present a safety hazard during drilling. At a preliminary site inspection performed by WESTON in May 1986, many rusted drums were observed partially buried in Pit #4. For these reasons another goal of the geophysical survey will be to identify any potentially hazardous drilling locations.

The following three techniques have been selected for use at various sections of the site:

- Magnetometer - to locate areas in which buried metals occur.
- GPR (Ground Penetrating Radar) - to define the boundaries of the now covered waste pits (i.e. Pits 1, 2, 3 & 4) and to verify indications of buried metals (i.e. drums, etc.) from the magnetometer survey.
- EM (Electromagnetic Terrain Conductivity) - to detect anomalously high conductivity in groundwater.

A more detailed description of the goals of each survey, and areas where they will be applied, is provided in the following sections. The area of each survey is also shown on Figures 3.5 and 3.6. Detailed descriptions of each method can be found in "Geophysical Techniques for Sensing Buried Waster and Waste Migration", 1984, (EPA-600/7-84-064).

3.3.3.1 Magnetometer

A magnetometer is an instrument which is capable of very precise measurements of the earths magnetic field. Variations in the magnetic field can be caused either by the presence of naturally occurring ferromagnetic minerals or the presence of buried ferromagnetic metal objects. This capability of detecting changes induced by some buried metal objects makes the magnetometer a useful tool for subsurface investigations at waste sites. Magnetometer surveys can be used to successfully locate buried drums or tanks and are especially effective at locating large deposits of drums or other metal objects. Typically, single drums can be detected to a depth of 20 feet while large collections of drums may be detected up to 66 feet below the surface.

The magnetometer survey will be done using the Scientrex MF2-100 magnetometer which is a vertical field flux gate type, sensitive to the vertical component of the natural geomagnetic field. This dramatically reduces the potential that interferences from other extraneous metal objects such as cars, fences, or buildings will affect the measurements. The magnetometer survey is conducted on a grid, with measurements taken typically at 25 foot intervals. A grid will be established by survey crews and will be used for this task as well as others requiring accurate position on site. The data from the magnetometer are corrected for diurnal fluctuations and contoured by computer to highlight any magnetic anomalies detected. This technique will be applied to Pit numbers 1,2,3,4, and the burn pit (See Figure 3-5).

3.3.3.2 Ground Penetrating Radar

Ground penetrating radar (GPR) is a state-of-the-art technology routinely used to conduct subsurface site investigations. GPR is used to map depth, thickness, and lateral variations in soils and rock layers. GPR is also used to detect buried pipes, karst caverns, buried drums, abandoned shallow mine rooms, and confining clay layers. GPR can also be used in over-water surveys to map the same interfaces as on land, to measure ice thickness, and to profile the bottoms of rivers and lakes.

GPR responds to changes in electrical properties, which are a function of soil and rock type and moisture content. WESTON's GSSI System 8 equipment is pulled by hand or by vehicle, and is capable of continuous measurements along a profile line. The depth of penetration is site-specific, and may be as great as 100 feet; however, typical depth penetration is less than thirty feet.

In the waste disposal area some of the individual pits have been graded and covered with vegetation,such that their boundaries are indefinite (Pits 1,2 and Burn Pit). The GPR (ground penetrating radar) will be used to locate the edges of these disposal pits, and also be able to define the depth to and configuration of the pit bottom. A grid of survey stakes placed prior to the geophysical survey task will be used to provide location data to field equipment operators. GPR measurements will be made at 25 foot intervals referenced to the control grid (See Figure 3-5).

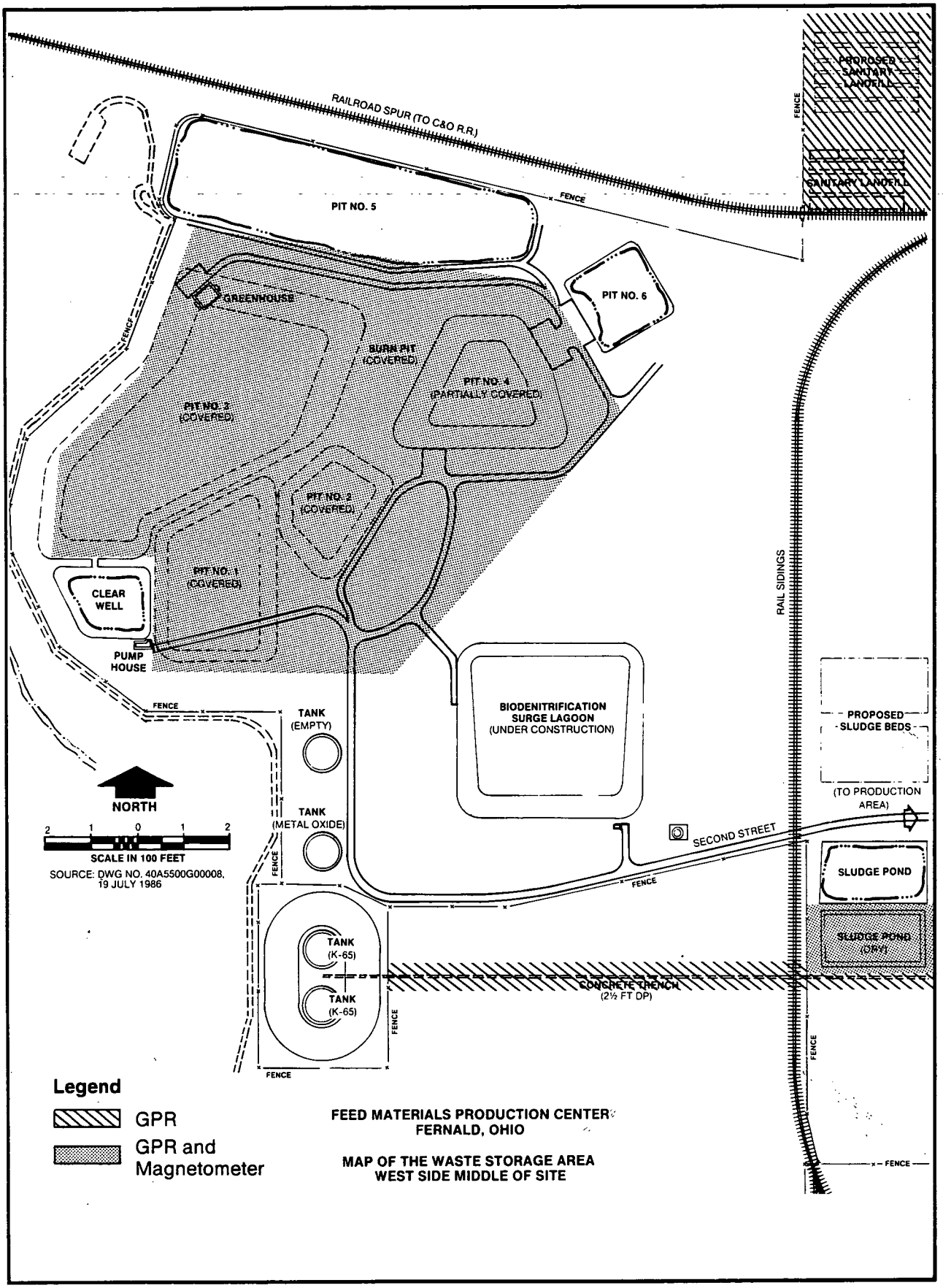


FIGURE 3-5 PROPOSED GEOPHYSICAL SURVEY LOCATIONS

3.3.3.3 Electromagnetic Conductivity

Electromagnetic terrain conductivity (EM) techniques provide non-intrusive methods for measuring the electrical conductivity of subsurface materials. The conductivity of a material is dependant upon its mineral content, porosity, permeability, degree of saturation and nature of the fluid in pore spaces. Pore fluids, however, usually contribute the dominant variable factor contributing to the conductivity of a soil or rock. Any of several natural variations in the physical characteristics of a subsurface environment can result in a corresponding change in conductivity. In addition, EM techniques can be successfully applied to locating man-made changes in the subsurface environment. Features such as buried drums, trenches, waste pits and utility lines, can be successfully located using EM techniques. Since EM methods are particularly sensitive to pore fluid characteristics, they can also be very useful in locating constituent plumes in shallow groundwater systems. Groundwater with an abnormally high free ion concentration increases the conductivity of the material it is moving through.

An EM survey is proposed for both the waste pit/silo area and the ash disposal area. In the waste pit/silo area an initial, large grid survey will be performed to provide additional data on the boundaries of Pits 2,3,4, and the Burn Pit. An additional, smaller scale survey will also be performed in selected areas around the perimeter of the waste pit/silo area. This survey is expected to provide valuable information on the location and extent of groundwater plumes in the glacial till. In the area of the ash disposal piles, a small scale EM survey will be performed to identify the constituent plume in either the glacial till or the shallow sand and gravel aquifer (See Figure 3.6).

Two instruments will be used to complete these surveys. They are the EM 31 and the EM 34, both manufactured by Geonics. The EM 31 will be used for the small scale grid survey and the EM 34 for the large scale grid surveys. EM measurements will be made every 50 feet for the fine grid survey and every 100 feet for the coarse grid survey.

3.3.3.4 Survey Location Control

As discussed above, all of the surveys will be tied to a base grid established in the field by the engineering survey crew. This grid will be established at both the waste pit/site area and the ash disposal area and will be marked with stakes at regular

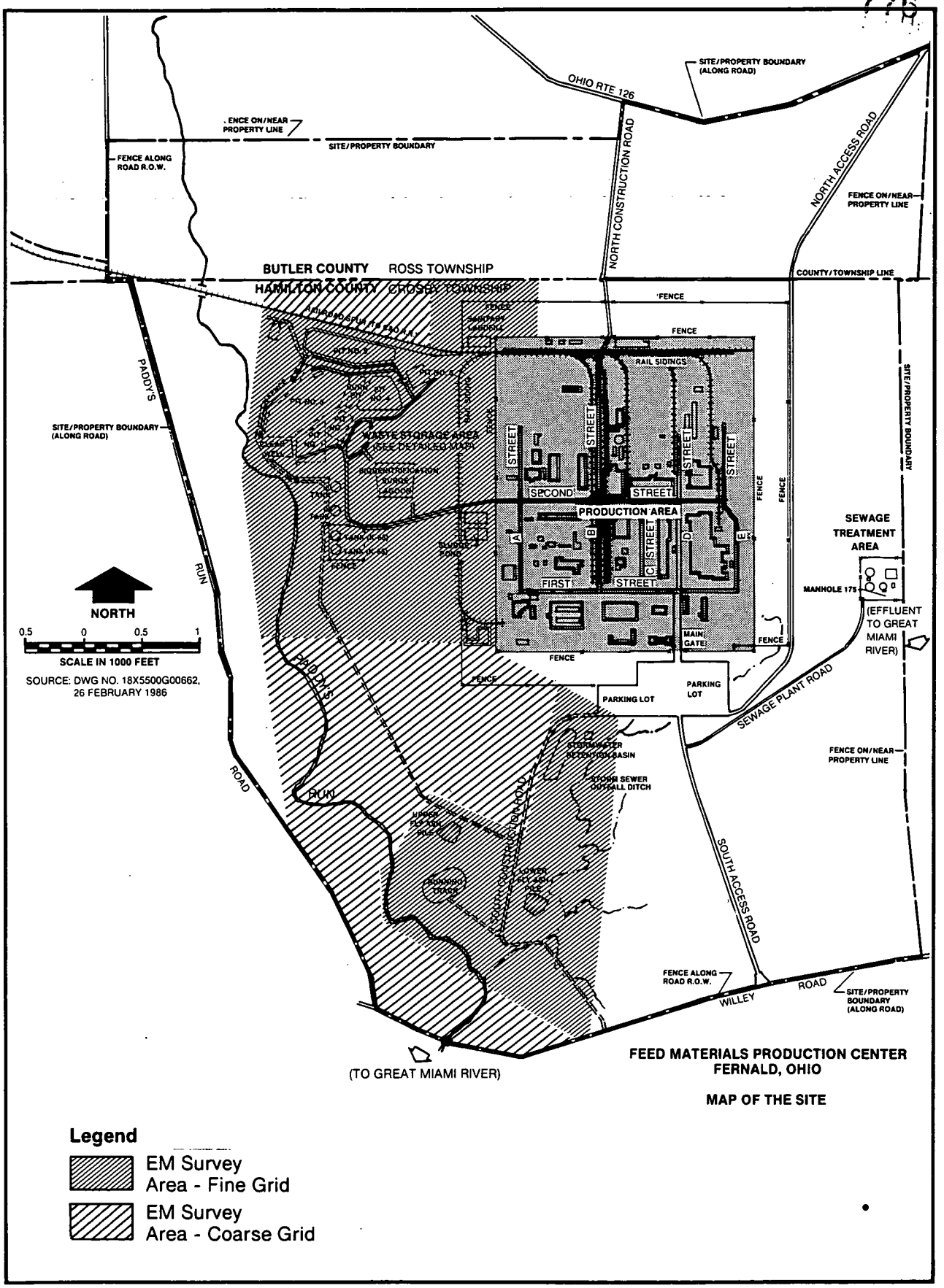


FIGURE 3-6 PROPOSED GEOPHYSICAL SURVEY LOCATIONS

intervals. Each grid will also be tied into other applicable engineering survey control so that it can be accurately located on the site map. In this manner, geophysical survey locations can be preserved for mapping and data interpretation purposes.

3.3.4 Monitor Well Location

The purpose of the monitor well network is to complete the exploration and groundwater sampling coverage of the waste pit/silo area, the ash disposal area, and the east perimeter. Because of the variability of the geologic setting and the relative complexity of the ground water flow system, the number of existing well points at the site is not sufficient to adequately define the flow system in either the till or in the upper sand and gravel aquifer. In order to characterize the 3-dimensional flow patterns in each zone, clusters of wells (penetrating the till and the top and bottom of the upper sand and gravel aquifer) will be installed. These proposed wells will make it possible to define the flow system in and between each zone. This understanding is critical because the migration pathways for compounds through the aquifer will determine the range of options to be considered for future remedial activities. Well locations were selected based on data needs identified in the horizontal distribution of existing wells, and well depths at each location were selected to provide necessary additional vertical information. The existing well locations were used to the maximum extent possible in establishing the monitoring network for this investigation.

The proposed well numbering system is a two part system. Each well number is made up of a location number and a series number which designates well screen depth. For example, the glacial till wells are series 100, so the till well at location 24 is well number 124. Similarly, the upper sand and gravel aquifer well (series 200) at location 24 is well 224. This system will also be used to renumber the existing wells.

3.3.4.1 Well Locations

Each of the well locations and depths was selected to achieve a specific goal. Table 3-2 summarizes the existing monitor wells, and lists the additional wells planned at both existing and new locations. Three different water-bearing zones will be intercepted by these monitor wells. The shallowest wells (100 series) will be seated in the till and will screen either the water table or isolated perched water. Based on stratigraphic logs from existing borings on site, it is estimated that the till wells will be up to 35 feet deep. The intermediate depth wells (200

TABLE 3.2
SUMMARY OF PLANNED AND EXISTING MONITOR WELL LOCATIONS

Well Location No.	Existing Wells (1)				Additional Well(s) Planned			Geotechnical Sampling (X)	Geochemical Sampling (X)
1		201		401					
3		203			103			X	
4		204			104		304	X	X
5									
8			308	408	108	208		X	
9			309		109	209			
10			310		110	210			
11		211			111		311	X	
12	112					212	312		
13		213	313		-				
14		214	314		-				
15		215		415			315		
16		216	316		-				
17		217	317		-				
18		218	318		118			X	
19	119	219	319		-				
20	120	220	320		-				
21	121	221			-				
22	122	222			-				
23		-			123	223		X	
24		-			124	224	324	X	
25		-			125			X	X
26		-			126			X	X
27		-			127	227		X	X
28		-			128			X	X
29		-			129			X	X
30		-			130	230			
31		-			131	231			X
32		-			132				
33		-			133			X	
34		-			134	234	334	X	
35		-			135			X	
36		-			136			X	
37		-			137			X	

TABLE 3.2 (continued)
SUMMARY OF PLANNED AND EXISTING MONITOR WELL LOCATIONS

Well Location No.	Existing Wells (1)	Additional Well(s) Planned			Geotechnical Sampling (X)	Geochemical Sampling (X)
38	-	138	238	338		
39		139			X	
40	-	140			X	
41	-	141				
42	-	142	242			
43	-		243	343		
44	-		244	344		
45	-	145			X	
46	-	146			X	
47	-	147			X	
48	-	148			X	
49			249			
50			250			
51			251			

NOTES:

(1) Existing wells now renumber as follows:
till wells = 100 series i.e. - well no. TP-12 now = 112
top of upper sand = 200 series i.e. - well no. 14s now = 214
bottom of upper sand = 300 series i.e. - well no. 14d now = 314

series, approximately 70 feet deep), and will screen the upper portion of the upper sand and gravel aquifer; the deep wells (300 series) will be approximately 120 feet deep, and will screen the lower portion of the upper sand and gravel aquifer. No new wells will be installed at this time below the blue clay reported to underlie the upper sand and gravel aquifer. the locations of the new monitor wells are shown in Figures 3-7, 3-8. 3-9, and 3-10. Most clusters are located around the main storage area (the waste pits). Several additional upgradient locations (wells no. 12, 23, 23) are included.

3.3.4.1.1 Till Wells (100 Series)

In order to examine the extent of potential impact in the overlying till it will be necessary to place grouping of shallow wells immediately around the waste storage zones. because stratigraphy within tills is particularly variable, subsurface interpretations in the till cannot be extended across large areas, and only local interpretations are justifiable.

The till material is the unit most likely to be affected by direct contact with wastes (pits 106) and by infiltration through soils. Previous sampling onsite has demonstrated that groundwater in the till near the waste pit area has been impacted (2.1 mg/l uranium in MW TP-22). In order to better understand the constituent distribution in the till, WESTON will install 31 shallow monitor wells to intercept groundwater in the till. These shallow wells will permit interpretation of the flow system within this near surface unit. Figures 3-7 and 3-8 present the locations of the proposed wells. The final locations of these wells will be refined on the basis of the results of the geophysical surveys as discussed in Section 3.3.3. Current evidence suggest that groundwater in the till is not directly connected to groundwater in the next sand and gravel unit. Water levels in the two units are different, and the top of the sand and gravel unit is not saturated. Therefore, until the constituent distribution in the till is more clearly defined, the approach is to drill and sample all the shallow till wells before advancing deeper holes into the sand and gravel aquifer below. this will avoid the inadvertent spread of constituents by drilling through potentially high concentrations of compounds.

3.3.4.1.2 Sand and Gravel Aquifer Wells (200 and 300 Series)

The sand and gravel outwash materially which underlies the glacial till is less complex than the till. It is also more extensive and represents a regional scale aquifer which is being

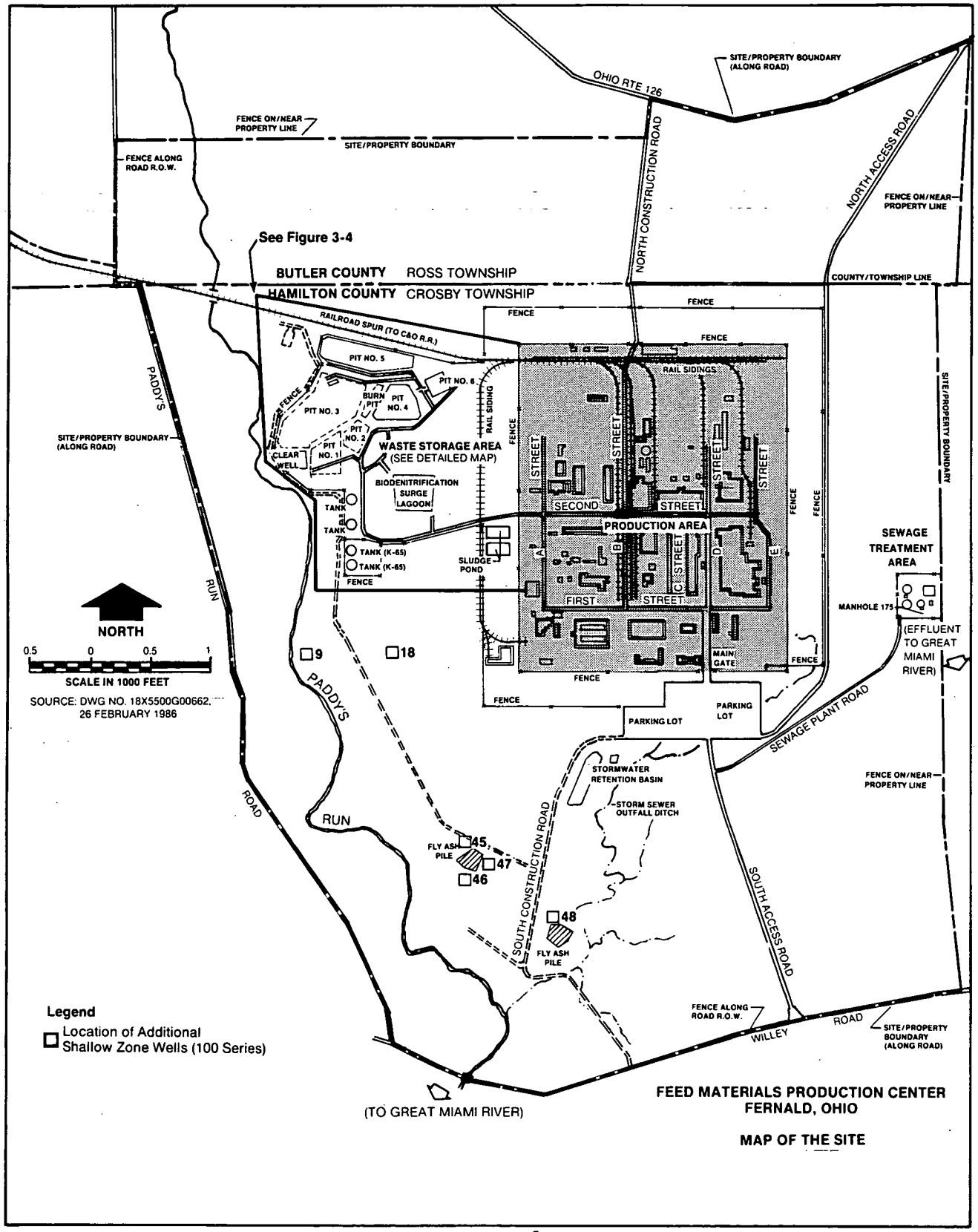


FIGURE 3-7 PROPOSED LOCATION OF ADDITIONAL SHALLOW ZONE WELLS

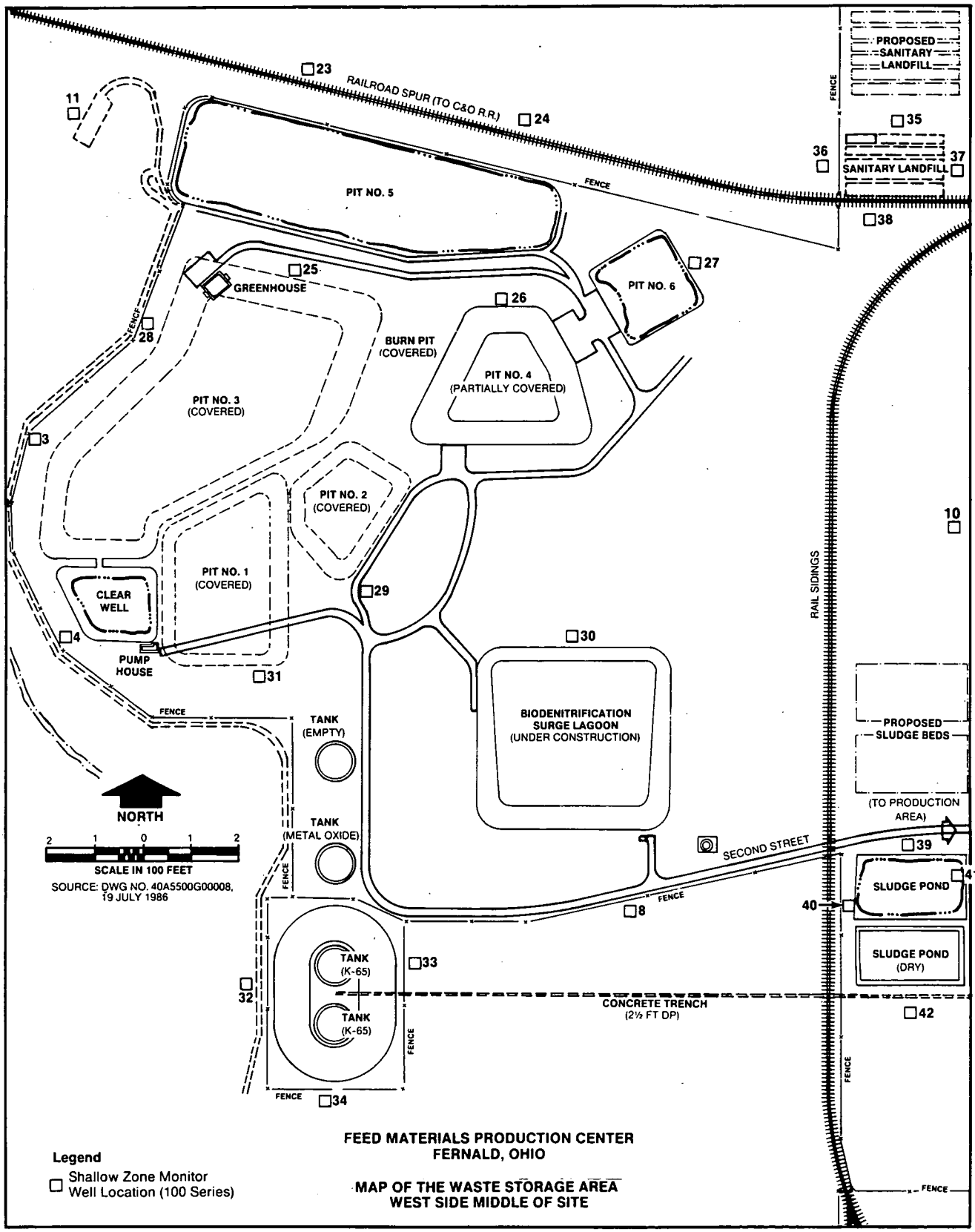


FIGURE 3-8 PROPOSED LOCATION OF ADDITIONAL SHALLOW ZONE MONITOR WELLS

extensive and represents a regional scale aquifer which is being used for water supply purposes. Previous sampling of existing wells indicates the presence of constituents in this aquifer in the area immediately downgradient of the waste pit area (see Section 3.2). The nature and extent (vertical and/or horizontal) of this impact can't be adequately defined using the existing monitor well network. In addition the vertical and horizontal components of groundwater flow must be more completely defined. Based on consideration of the existing well locations and depths additional wells are proposed for the sand and gravel aquifer. Those proposed wells include wells in the upper portion of the aquifer (200 series) and wells in the portion immediately above the "blue clay" layer (300 series). The locations for both series of wells are shown in Figures 3.9 and 3.10. A total of 17,200 series wells and 9,300 series wells are proposed. Data collected from these wells along with existing wells will be used to guide the placement of several wells in the zone below the "blue clay" layer. This will provide maximum assurance against inadvertent introduction of compounds into the deeper aquifer from drilling activities.

3.3.4.2 Well Location Rationale

Based on general rationale for placement of the proposed monitor wells can be placed in one of several groups. These groups are based primarily on the various goals of groundwater monitoring in different areas within the site. Table 3.3 summarizes the specific rationale for each proposed well while the following is a brief description of each group and the wells involved.

- Waste Pit Area
  The proposed wells included in this group include; 103, 104, 111, 123, 124, 125, 126, 127, 128, 129, 131, 223, 224, 227, 231, 304, and 324. Generally the goal of this group is to define the extent of impact in the immediate area of the waste storage pits. In addition the 200 and 300 series wells will help to measure the vertical component of groundwater flow. All wells in this group will contribute to the understanding of groundwater flow in the various hydrologic zones.

- K-65 Tank Area
  The proposed wells in this group are numbers 132, 133, 134, 234, and 334. The primary concern here is to determine the extent of the effects resulting from the materials stored in the K-65 silos. All of these wells will also contribute to the overall understanding of groundwater flow and constituent distribution.

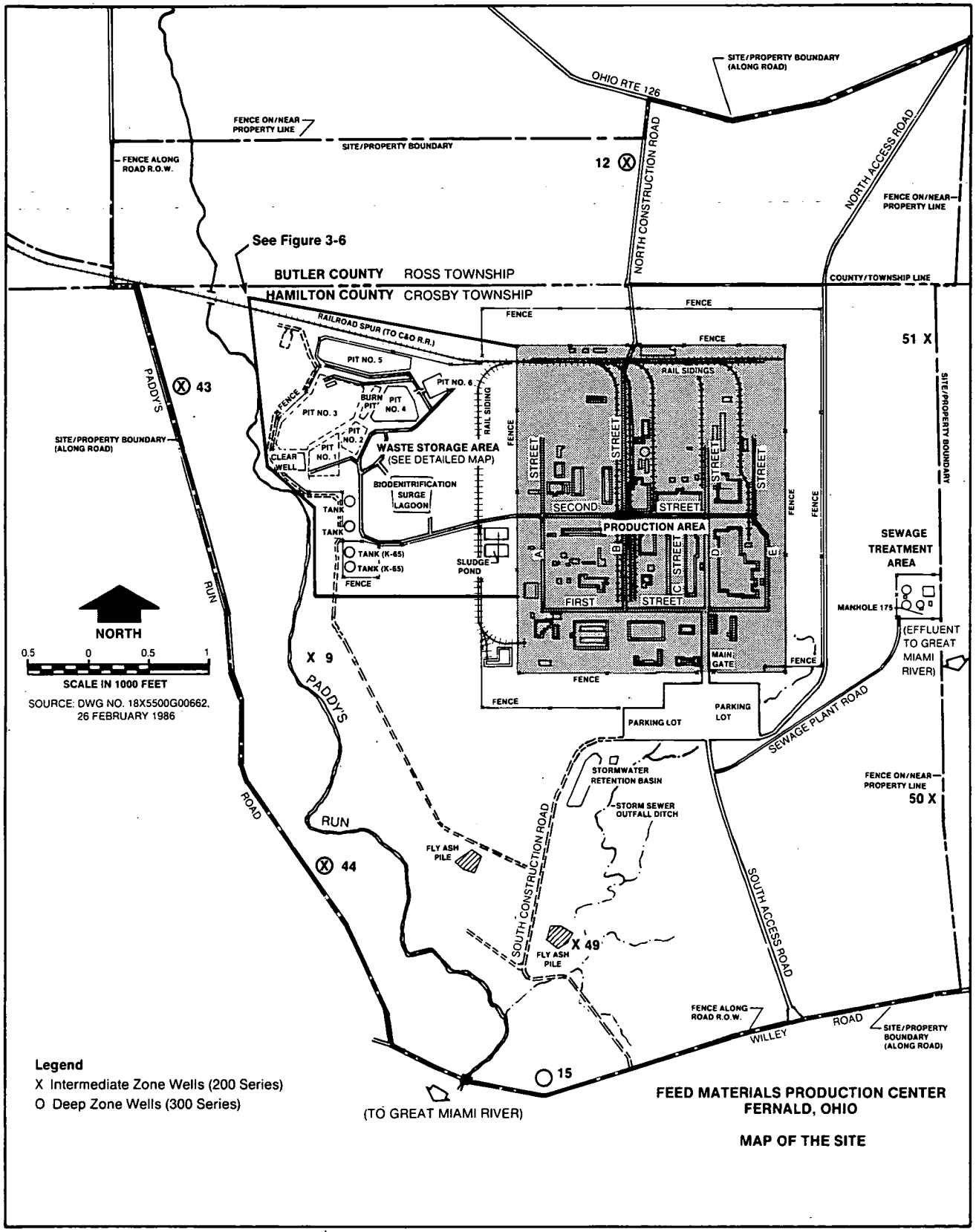


FIGURE 3-9 PROPOSED LOCATION OF ADDITIONAL INTERMEDIATE AND DEEP ZONE WELLS

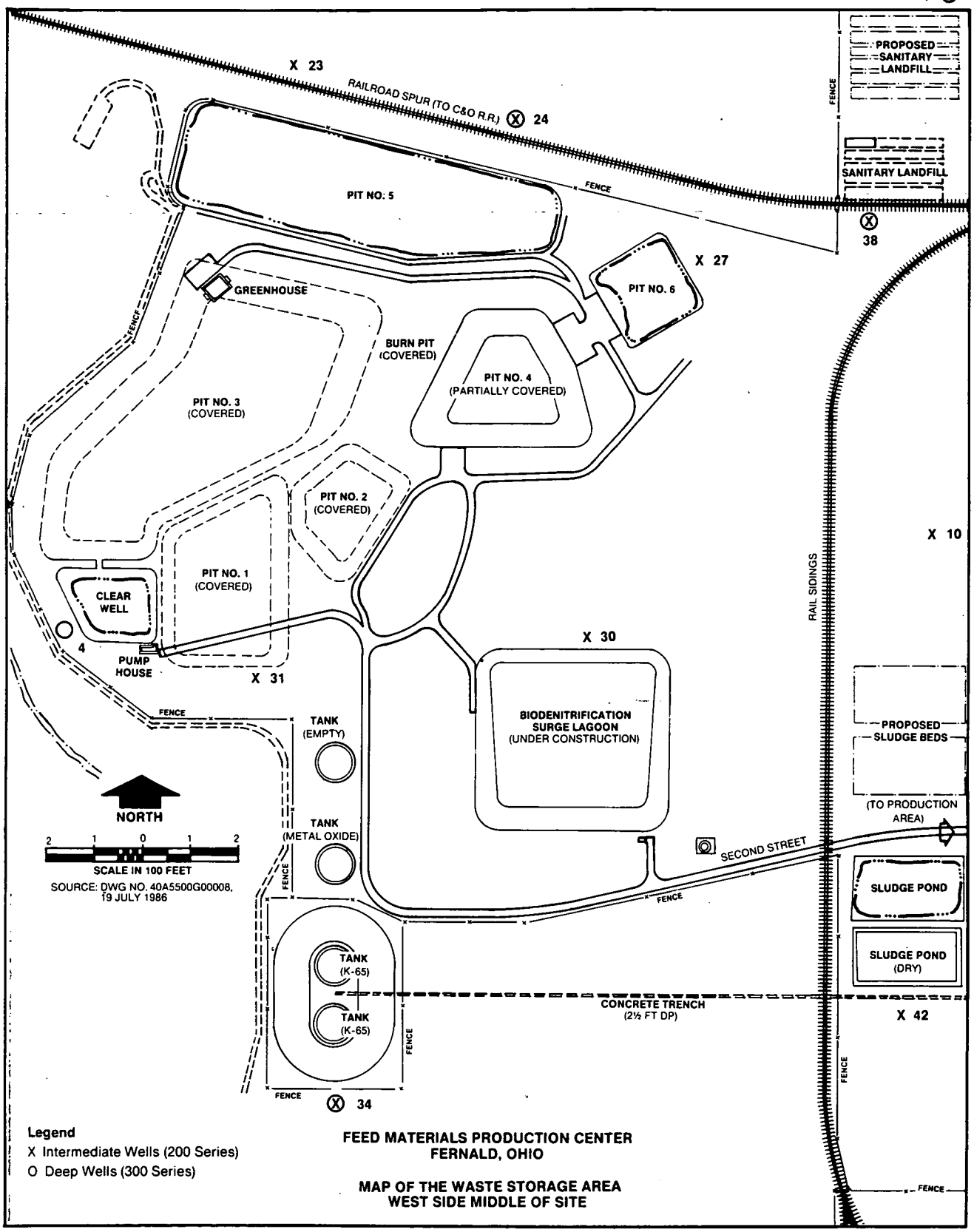


FIGURE 3-10 PROPOSED LOCATION OF ADDITIONAL INTERMEDIATE AND DEEP ZONE WELLS

Table 3.3

Siting Rationale for Planned Locations of
New Monitor Wells Feed Materials Production Center

New Well No.	Siting Rationale
101	a,b,c
103	b,c
104, 304	a,b,c,d
108, 208	a,b,c,d,f
109, 209	a,d,e,i
110, 210	a,b,c,d,f
111, 311	a,c
212, 312	a,d,f,i
315	d,f,h,l,k
118	a,h,i
123, 223	b,c,d,i
124, 224, 324	a,b,c,d,i
125	b,c
126	b,c
127, 227	b,c,d,f
128	b,c
129	b,c
130, 230	b,c,d,f
131, 231	b,c,d
132	b,c
133	b,c
134, 234, 334	b,c,d,f
135	b,c,i
136	b,c
137	b,c
138, 238, 338	c,d,f
139	c,i
140	c
141	c
142, 242	c,d,f
243, 343	d,e
244, 344	d,e
145	c,h,l
146	c,h,l
147	c,h,l
148	c,h,k,l
249	c,d,h,k
250	d,g,j
251	d,g,j

Table 3.3 (continued)

Siting Rationale for Planned Locations of
New Monitor Wells Feed Materials Production Center

NOTES:

(a) Complete a 3 well cluster (till top of upper sand, bottom sand)

(b) Intercept shallow groundwater in till in immediate vicinity of waste storage area

(c) Provide a ring of monitoring points around probable source area

(d) Examine flow regime in upper sand aquifer

(e) Examine shallow groundwater across Paddys Run, a possible groundwater divide

(f) Examine water quality of deeper groundwater (top of upper sand) in area where shallow groundwater (till) may be contaminated

(g) Characterize groundwater status on east side of production area

(h) Examine effect of waste fly ash piles on groundwater

(i) Proposed upgradient control point

(j) Examine potential groundwater divide and eastward flowing groundwater on the east side of facility

(k) To examine effect of storm sewer outfall ditch

(l) Provide additional extent of southward flowing plume

- Sludge Pond Area
  Five new wells are proposed for this area. Four are completed in the till zone (137, 140, 141, 142) and one in the upper zone of the sand and gravel aquifer (242). Again the foremost concern is to identify the impacts on groundwater quality, if any, resulting from the sludge ponds. These wells, especially 242 will be used to better understand the regional flow system.

- Sanitary Landfill Area
  The six wells proposed in this area include; 135, 136, 137, 138, 238, and 338. The identification of groundwater quality near the sanitary landfill is the primary reason for these wells. Well numbers 238 and 338 will also provide valuable upgradient information with regard to flow in the sand and gravel aquifer.

- Ash Pile Area
  There are 5 additional wells proposed for the ash pile area. Included are 4 till zone wells (145, 146, 147, and 148) and one upper sand and gravel aquifer well (249). The concerns here are to identify any potential constituent plume and to define the groundwater flow directions. Since well number 249 is to the south of the majority of the other 200 series wells it will also be valuable in defining regional flow directions in the sand and gravel aquifer.

  The remaining wells are placed to maintain continuity between one specific area and the next, provide data at a site boundary, or at an upgradient background location. Table 3.3 provides more specific rationale for each proposed well.

3.3.4.3 Monitor Well Network

The proposed wells discussed in the preceding sections will combine with existing wells to create the initial monitor well network. This network is shown in Figures 3-11 and 3-12. There are two groups of existing wells which are included in the network. One is a group designated as test wells and numbered 1 through 11. No data has been located regarding construction details of these wells other than steel casing and screen and

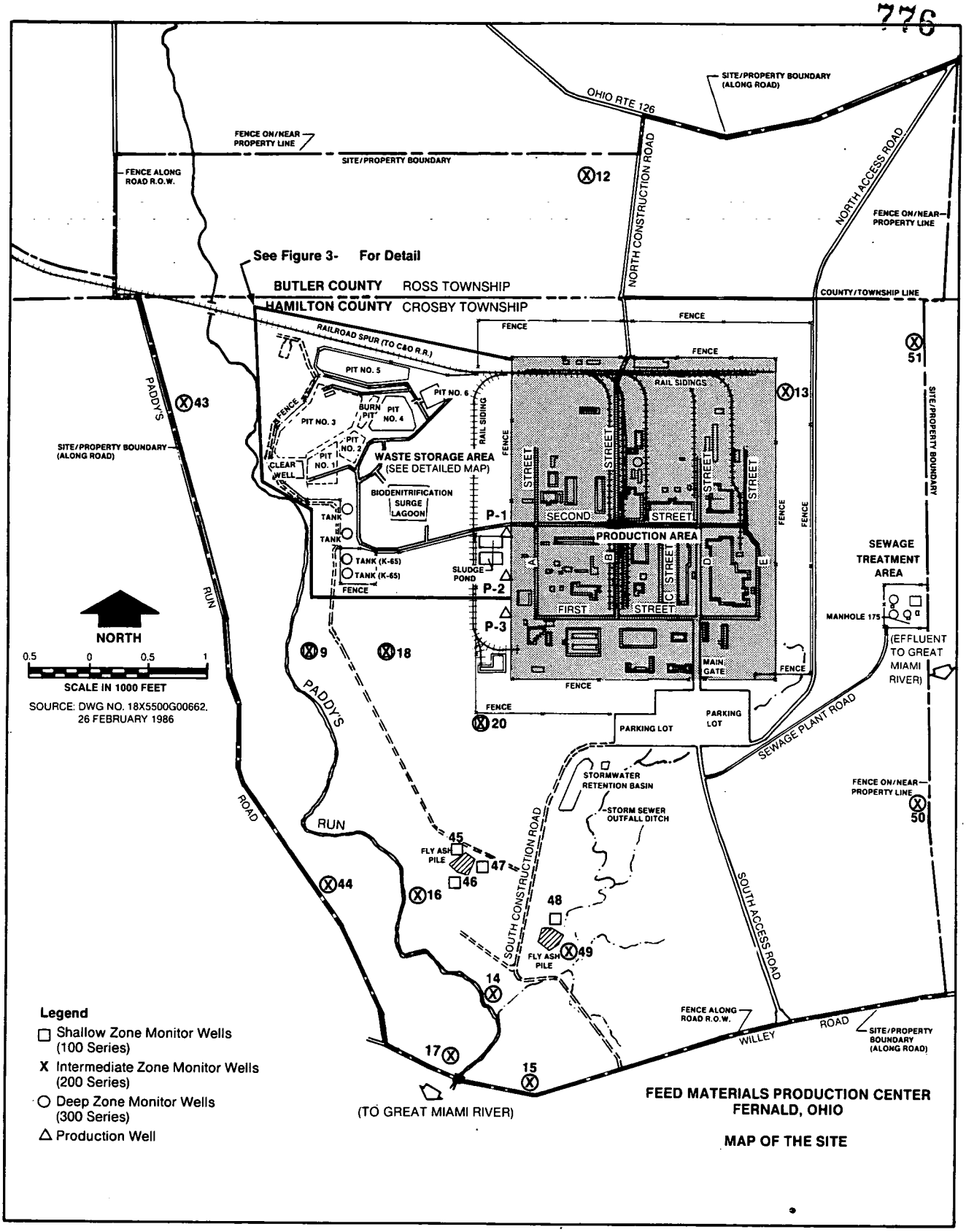


FIGURE 3-11 PROPOSED GROUNDWATER SAMPLING LOCATIONS

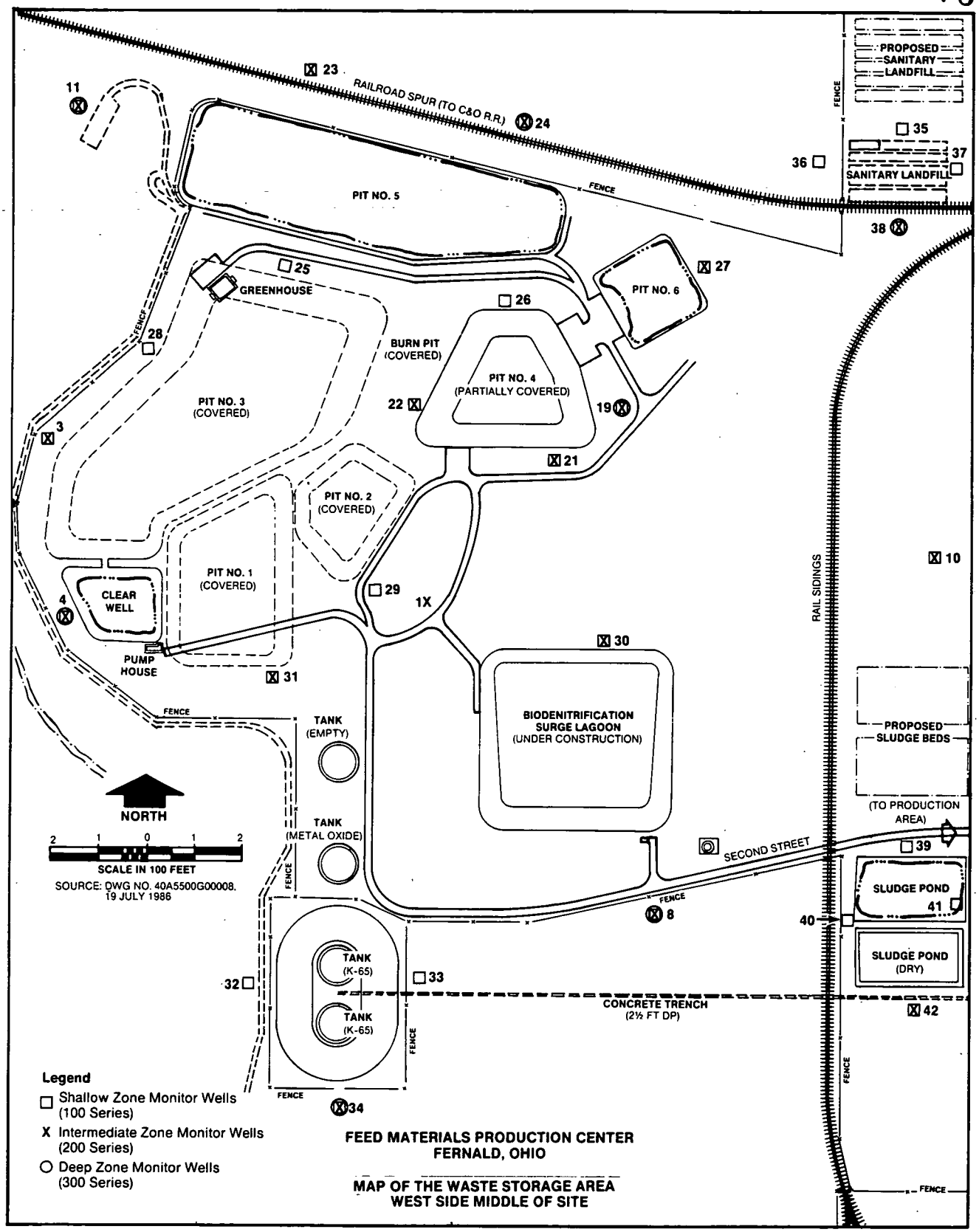


FIGURE 3-12 PROPOSED GROUNDWATER SAMPLING LOCATIONS

diameters ranging from 4 to 8 inches. The second group were installed under direction of Dames and Moore and are numbered 12 through 22. Logs and construction details are available for these wells which are all 4 inch diameter PVC casing and screen. In order to confirm that these wells are suitable for inclusion in the monitor well network two types of tests are proposed.

The first step is to construct a new well adjacent to and at the same depth as an existing well. Once this is complete the water levels in both wells will be compared. This will provide an indication of the integrity of the existing well. Based on the well logs provided by Dames and Moore (Task C Report) the backfill material may not be sufficient to adequately seal the well annulus and backfill methods for the test wells are unknown. If there is a significant difference in water levels between the existing well and the new well a poorly sealed annulus is indicated. This procedure will be performed at 3 existing well locations, for each group of wells. The well location selected for the test wells are 9, 10, and 11. Locations 16, 19, and 20 have been selected for the Dames and Moore wells.

In addition a groundwater quality comparison will be performed on the six pairs of wells selected above. The existing wells are constructed of either PVC or steel and the new wells will be 316 stainless steel. There is some concern that the well screen material may interfere with water quality by either removing components through some adsorption mechanism or contributing a compound through leaching or desorption. In order to use groundwater quality results from wells constructed of different materials the magnitude of these interferences must be investigated. Samples will be obtained from the matched well pairs discussed above using identical procedures. The analysis results from these pairs of samples will be compared in order to address the potential for interference.

Providing that the tests outlined above do not indicate any problems with the existing wells they all will be included in the groundwater monitoring network as shown on Figures 3-10 and 3-11. If the comparison tests indicate uncertainties regarding the use of the other group of existing wells they will not be included in the monitor well network. It will be necessary then to replace most of the deleted group with new, properly constructed monitor wells.

3.3.5 Monitor Well Construction

3.3.5.1 Schedule

As discussed in Section 3.2 the drilling and well construction will proceed in phases. No drilling will be initiated until the geophysical data has been reviewed in sufficient detail to allow confirmation of all initial drilling location. The first phase of the well installation will involve drilling and construction of 31 wells in the till zone (35 feet). These wells will be sampled, and the data evaluated prior to initiating the second phase. The data from phase I will be used to finalize the well locations and construction techniques for the deeper, sand and gravel aquifer wells. An effort will be made to avoid drilling through highly contaminated areas in the till when constructing the deeper wells. If it is absolutely necessary to drill through a significantly impacted area special well construction techniques will be used to minimize the potential for cross contamination.

The second phase includes the installation of 17, 200 series wells (70 feet deep) and 9 300 series (120 feet deep). Again the 200 series wells will be screened in the upper portion of the sand and gravel aquifer and the 300 series wells in the lower portion immediately above the "blue clay" layer.

3.3.5.2 Drilling

All boreholes will be drilled using cable tool drilling methods and will follow the general procedures presented in Appendix B. A temporary steel casing will be driven or pushed as the borehole is advanced so that the casing is never more than one foot above the bottom of the hole. The temporary casing will be nominal 8 inch diameter to allow for construction of the monitor well. Cuttings will be removed from the borehole using a sand pump, or dart valve bailer, whichever proves most effective. Samples will be taken at the bottom of the borehole following bailing with a split spoon sampler using the procedure outlined in 3.3.5.3 below. Following completion of the borehole to the desired depth the well is constructed according to 3.3.5.4 and 3.3.5.5. and the temporary casing is removed. The drilling tools, temporary casing and drilling will be thoroughly decontaminated prior to moving to the next well location.

The cable tool drilling method offers several advantages to this investigation. First no drilling fluids, other than possibly a small amount of water are needed. This means that there is no

fugitive drilling mud to remove during development and which could potentially interfere with groundwater chemistry. A well constructed with cable tool methods will develop more quickly and there is no possibly of any component of the technique interfering with the groundwater chemistry. This method also minimizes physical impacts on the geologic materials at the borehole wall. Auger drilling, for example, can severely smear the wall of a borehole and significantly reduce hydraulic conductivity of the formation at the well interface. This is a particular concern in materials which have a significant clay content (glacial till) and a relatively low hydraulic conductivity naturally. Although driving and removing a temporary casing can cause some smearing it is not as severe as that caused by auger drilling. These advantages along with the complex nature of the geology and hydrogeology at this site warrant the use of cable tool drilling techniques.

3.3.5.3 Logging and Sampling

During the process of drilling monitoring wells relatively undistributed soil samples will be collected with a split-spoon sampler using the Standard Penetration Test (ASTM-1586). the samples will be collected through temporary casing at 2 feet intervals from two to ten feet then five foot intervals and at every change in lithology as drilling progresses to 20 feet below the water table, whichever is encountered first. Beyond this depth,split spoon sampling conducted every 10 feet and at each change in lithology.

All samples will be examined and described by the project geologist. The geologist will describe and classify all samples based on their color (Munsell Soil Colour Charts), texture (Unified Soil Classification System), estimated water content, and depth from land surface (see Appendix G).

Representative soil samples from each split-spoon will be placed in half-pint glass jars with self-sealing screen type lids, and stored in individual compartments of sectioned cardboard boxes. Each sample container will be labeled to identify: sample location, sample internal data and time of collection, sampling personnel, and special comments. Samples collected will be secured in a sample storage chest following chain-of-custody procedures and will be stored to prevent freezing. All such pertinent field data will also be recorded in the field log of the geologist. Detailed descriptions of logging boreholes and test pits are included in Appendix G.

3.3.5.4 Well Design and Materials

Each well will be designed specifically for the conditions encountered in each borehole. This will be done by the field geologist and will provide the most effective and appropriate design for each well. These designs will be based on standard practice (see Appendix C) and Figure 3-13 is a summary of the well design.

3.3.5.5 Well Installation

Shallow wells (100 series) will be completed in the water table or in localized perched water zones, in the till which overlies the upper portion of the regional sand and gravel aquifer. Drilling techniques will consist of cable tool plus sampling ahead of the boring with split spoons.

The intermediate wells (200 series) will be completed at the top of the sand and gravel aquifer so that the screen top is 5 feet above the water table and the screen bottom is 15 feet below the water table. If the aquifer is confined the screen will be set at the top of the sand and gravel material.

The deep wells (300 series) will be completed at the top of a clay layer referred as the blue clay. In the event that the blue clay is not encountered the well will be completed at an elevation which corresponds to the top of the blue clay where encountered.

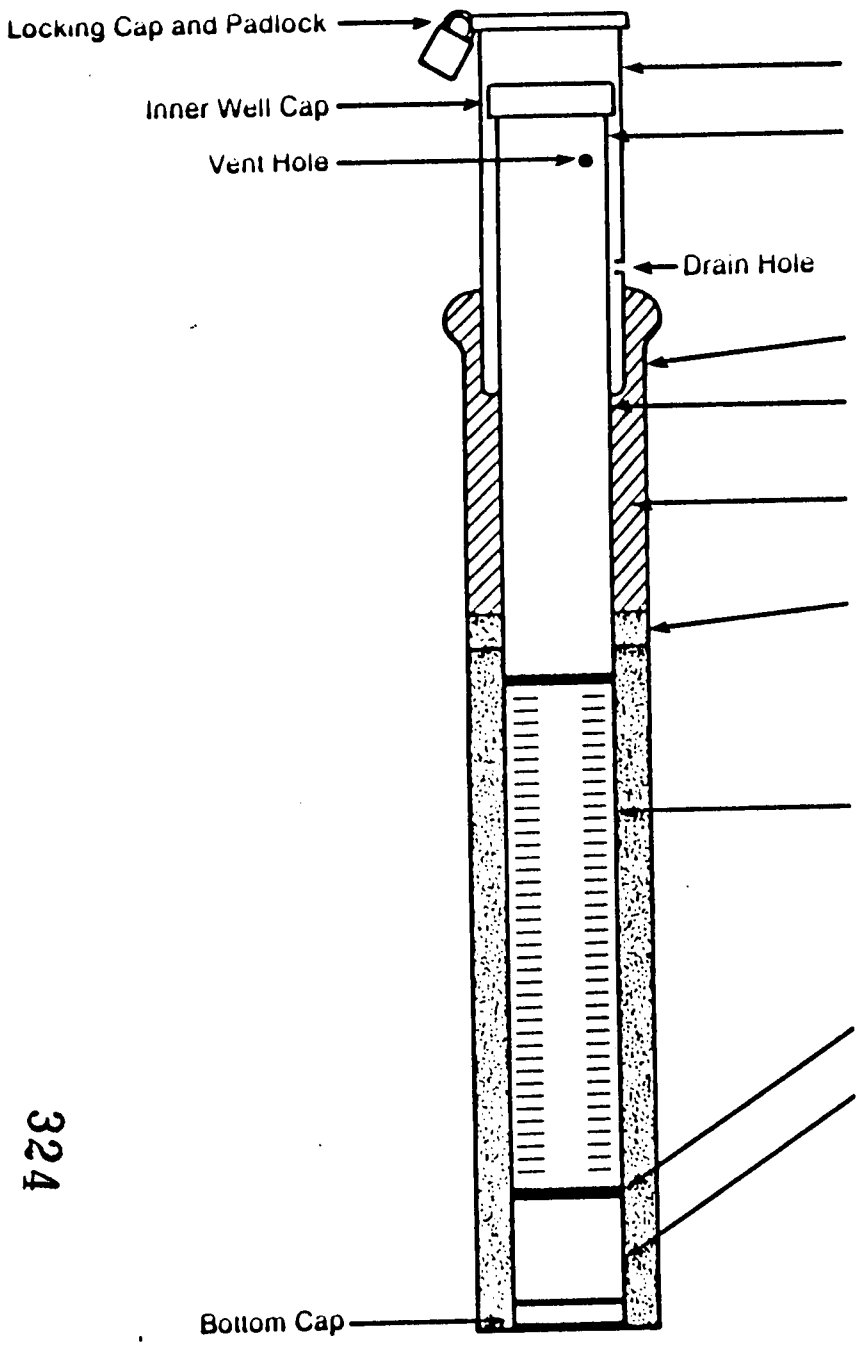
The details of well installation are presented in Appendix C.

3.3.5.6 Well Development

All wells will be developed according to guidelines in Appendix D. Development will be after grout has set (at least 48 hours after completion of grouting).

3.3.5.7 Well Security

The well risers will be permanently marked to indicate the well number using the numbering system described above. As shown in Figure 3.13, the riser will be protected by an outer black iron pipe (minimum thickness - 5/16 inch) implanted in the cement/ bentonite grout cap and fitted with a hinged steel cap consisting of a circular top and welded two inch sleeve (minimum thickness - 3/16 inch).



Protective Casing 5-foot long, 6-inch ID; steel

Stickup 2.5 feet above land surface; 2 inches below protective casing

Traffic Pad Not Required

Well Development Pumping and surging; may require adding water

Borehole Diameter 8 inches

Casing Diameter 4 inches

Material 316 Stainless Steel

Grout: Material/Mixture 1 to 2 Mix of sodium bentonite powder and portland cement

Setting Top of plug to Top of Borehole

Plug: Material Sodium Bentonite Pellets

Setting Top of sandpack to 2 feet above sandpack

Sandpack: Material Quartz sand

Gradation Well-sorted medium sand

Setting Bottom of borehole to 2 feet above screen

Screen: Material 316 Stainless Steel (4 inch ID)

Length 20 feet

Type wrapped or wound

Opening Size 0.010 inch (10 slot)

Setting based on well depth

Coupling Flush couple, screw in type

Sump Length none

FIGURE 3-13 SUMMARY OF SPECIFICATIONS FOR WELL COMPLETION

Each steel cap will be painted fluorescent orange to permit easy identification. Additional descriptions of well security are included in Appendix C, Attachments C-3, and C-4.

3.3.5.8 Well Survey

All the wells will be surveyed to establish the location of each well according to UTM coordinates, and to determine the elevations to the top of the measuring point on the well casing in feet and meters above mean sea level (msl). Horizontal coordinates will be accurate to 0.5 feet; elevation will be accurate to 0.01 foot.

In addition, the existing wells which are to be included in the monitoring network will be resurveyed to ensure accuracy.

3.3.5.9 Geophysical Well Logging

Down-hole natural gamma logging will be performed on completed wells according to procedures in Appendix E. FPMC monitor wells that have been descriptively logged will be logged as references. All new wells will be logged so that the logs can be referenced to recovered spoon samples and radiological waste characteristics.

3.3.6 Hydrologic Data Collection

3.3.6.1 Water Level Measurements

One week after the completion of monitoring well installation, static water levels will be measured in all wells, (see form F-5, Appendix F), including those from the previous surveys. The purpose of these readings is to map the water table and piezometric levels in the aquifer at a single point in time. Measurements will be completed within a 2-day period. At the completion of the last well measurement on the second day, the first five wells measured (the previous day) will be remeasured to determine if a range of water-level fluctuations exists and can be measured.

Water level measurements will be measured to the nearest 0.01 foot with an electrical probe, referenced to the top of the measuring point on the well casing. All data will be recorded in a field log book.

In addition, an In-situ Model SE-1000B electronic data logger (Hermit) with two transducers will be installed at location 8. One recorder on each of two wells, 108 and 208. Also, a Hermit will be installed at location 14. Wells 114 and 214 will each be fitted with a transducer. Data from these recorders will be used to detect patterns in water level changes.

3.3.6.2 Aquifer Testing

Two types of aquifer testing are proposed. Long term pumping tests and short term slug tests. Pumping tests are specifically suited to determining transmissivity and strativity in water valve, leaky, or confined aquifers. These tests provide measurements over a relatively large volume of the aquifer and are useful in identifying recharge/discards zones and/or barrier boundaries. Slug test are suited to measurements of hydraulic conductivity in the material immediately adjacent to the well screen.

A 96 hour pumping test will be performed at each of the three locations. One location is in the area of the waste pits and involves pumping well 308 at a maximum sustainable rate. This rate will be determined based on the results of a 4 hour step drawdown test. The well will be allowed to rest at least 24 hours between the end of the step test and the beginning of the long term pump test. Water level data will be collected at the pumping well and at least 9 observation wells in the sand and gravel aquifer. In the event that the sand and gravel aquifer is determined to be confined or semi-confined additional observation wells will be added in the till zone. All data acquisition will be done by automatic electronic equipment such as the In-site Inc. SE-200 and/or SE-1000B "Hermit"

The second test location will be at the southern end of the property. Well 31 will pumped at the maximum sustainable rate as determined from a 4 hour step test. The well will be allowed to recover for a minimum of 24 hours following the step test before the pumping test is started. Water level data will be collected from the pumping well and at least 6 observation wells. The data acquisition will be done by the same automatic equipment referenced above.

The third proposed pumping test will involve one of the FMPC productions wells as the pumping well. Water levels will be measured in the pumping well if possible, as well as at least 6 observation wells. Data acquisition will again be accomplished

with automatic equipment. Observation wells from this pump test will be located both in the same zone below the "blue clay", as the production well and in the sand and gravel immediately above the "blue clay." This test will provide data for evaluation of the leakage through the "blue clay" as well as the properties of the deeper sand and gravel deposits.

In all cases the discharge water from the pumping well will be routed away from the area of interest far enough so that it does not interfere with test results. Where practical the FMPC sewer system will be used for this purpose. Groundwater quality data will also be evaluated prior to initiation of the pump tests in case the quality of discard water requires special precautions. A more detailed description of test procedures is contained in Appendix F.

3.3.7 Groundwater Sample Collection

3.3.7.1 Well Purging

New wells will be developed by pumping after completion and allowed equilibrate before sampling. Immediately prior to sampling, all wells (new plus existing wells) will be purged of approximately 3 to 5 well volumes, as per standard EPA sampling methods.

The primary consideration is to obtain a representative sample of the ground-water body by guarding against mixing the sample with stagnant (standing) water in the well casing. In non-pumping wells, there will be little or no vertical mixing of the water and stratification will occur. The well water in the screened section will mix the ground water due to normal flow patterns, but the well water above the screened section will remain isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following guidelines and techniques are adhered to during sample withdrawal:

- All monitoring wells will be pumped prior to withdrawing a sample. Three to five volumes of the well casing is recommended for a representative sample.

- For wells that can be pumped or bailed to dryness with the sampling equipment being used, the well will be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid, evacuation of more than one volume of water is preferred.

3.3.7.2 Groundwater Sampling

All wells included in the monitor well network will be sampled according to Appendix H.

The following is a list of equipment which is needed for sampling:

- Documentation forms
- Waterproof markers
- Sample bottles
- Preservatives
- Filtering apparatus
- Metal shipping coolers
- Vermiculite or bubble-pack
- Decontamination supplies

All groundwater samples will be analyzed according to Section 2, Appendix Q for the following parameters:

- HSL volatile organic compounds
- HSL semi-volatile organic compounds
- HSL PCS and pesticide
- HSL inorganics
- Radionuclides including:
  - isotopic thorium
  - isotopic uranium
  - isotopic plutonium
  - technetium - 99
  - strontium - 90
  - ruthenium - 106
  - neptunium - 237
  - radium - 226
  - radium - 228

APPENDIX A

LIST OF RCRA ANALYSIS PARAMETERS

(III) Parameters Analyzed : RCRA Sampling Pit #4 , August 1985 (Dames and Moore)

A. For General Water Quality

1. Chloride
2. Iron
3. Manganese
4. Phenols (total)
5. Sodium
6. Sulfate

B. For Indicators of Contamination (Quadruplicate Analysis)

1. pH
2. Specific Conductance
3. Total Organic Carbon (TOC)
4. Total Organic Halogen (TOX)

C. For Drinking Water Suitability

1. Arsenic
2. Barium
3. Cadmium
4. Chromium-Hexavalent
   -Total
5. Fluoride
6. Lead
7. Mercury
8. Nitrate
9. Selenium
10. Silver
11. Gross alpha
12. Gross beta
13. Radium
14. Endrin
15. Lindane
16. Methoxychlor
17. Toxaphene
18. 2,4-D
19. 2,4,5-TP Silvex
20. Coliform Bacteria

D. Other Metals, Organics, and Site Specific Parameters

1. Nickel
2. Cyanide
3. Copper
4. Zinc
5. Magnesium
6. Calcium
7. Phosphorus
8. Chlorobenzene
9. Chlorodibromomethane
10. Chloroethane
11. 2-chloroethlvinyl Ether
12. Chloroform
13. Dichlorobromomethane
14. Dichlorodifluromethane
15. Total Dissolved Solids (TDS)
16. Total Potassium
17. Biochemical Oxygen Demand (COD)
18. per Chloroethylene
19. cis 1,2,Dichloroethyl
20. Tributylphosphate
21. Acrolein
22. Acrylonotrille
23. Benzene
24. bis (chloromethyl) Et
25. Bromoform
26. Bromodichloromethane
27. Bromoethane
28. Carbontetrachloride
29. Chloromethane
30. 1.2 Dichlorobenzene
31. 1,3 Dichlorobenzene
32. 1,4 Dichlorobenzene
33. 1,1 Dichloroethane
34. 1,2 Dichloroethane
35. 1,1 Dichloroethylene
36. 1,2 Dichloropropane

D. Other Metals, Organics, and Site Specific Parameters (continued

37. 1,2 Dichloropropylene
38. Ethylbenzene
39. Methylbromide
40. Methylchloride
41. trans-1,2 Dichloroethylene
42. 1,3 Dichloropropane
43. 1,1,2,2 Tetrachloroethane
44. Tetrachloroethylene
45. Toulene
46. 1,1,1 Trichloroethane
47. 1,1,2 Trichloroethane
48. Trichloroethylene
49. Trichlorofluoromethane
50. Vinyl Chloride

E. Radionuclides

1. Potassium 137
2. Total Uranium
3. Radium 226
4. Radium 228
5. Technetium 99
6. Thorium 228
7. Thorium 230
8. Thorium 232
9. Cessium 137
10. Strontium 90
11. Ruthenium 106
12. Neptunium 237
13. Plutonium 238
14. Plutonium 239
15. Plutonium 240

F.Schedule - Quarterly for one (1) year; semiannual thereafter necessary according to regulations.

APPENDIX B

DRILLING PROCEDURES

APPENDIX B
DRILLING PROCEDURES

1.0 PURPOSE

To define the procedures to be followed while conducting hydrogeologic and geotechnical drilling programs.

2.0 SCOPE

The following procedures will be implemented before, during, and after the drilling program.

3.0 PROCEDURES

3.1

Only clear potable water, air, or commercially available inorganic sodium bentonite drilling mud, such as "Volclay" or equal, shall be acceptable as a drilling media.

3.2

The source(s) of any water to be used in drilling, grouting, well and/or lysimeter installation must be approved prior to field operations.

3.3

The abandonment of any borings and wells will be approved prior to any casing removal or sealing/backfilling. Once approved, these borings and/or wells shall be sealed by grouting from the bottom of the boring or well to ground surface. This shall be done by placing a grout pipe to the bottom of the boring or well and pumping grout through this until undiluted grout flows from the boring or well at ground surface. The grout shall consist of a neat cement with 7 pounds of commercial bentonite and approximately 7-1/2 gallons of water added per 94-pound bag of cement. After the grout has set (about 72 hours) the contractor shall check the abandoned site for grout settlement. Any depression in the grout shall then be filled with a grout mix as described above. Methods other than those set forth herein may be implemented as dictated by appropriate state and/or local agencies.

3.4

No grout additives shall be used.

3.5

The use of dug sumps (lined) is not allowed. The use of portable recirculation tanks is required.

3.6

No dyes, tracers, or other substances shall be used or otherwise introduced into borings, wells, lysimeters, grout, backfill, ground water, or surface water unless specifically required by the contract.

3.7

Each operating drill rig shall have a geologist or engineer responsible for logging the samples, preparing the boring logs and well sketches, and well installation of that rig. No geologist or engineer will be responsible for more than one operating rig per project site or installation involving soil sampling, rock coring or monitor well installation functions.

3.8

Air systems shall not be used for drilling, well installation, well development, or sampling without prior approval. When used, air systems shall include an air line oil filter, frequently replaced, to remove essentially all oil residue from the air compressor. The usage of any air system shall be fully described in the drillers log to include equipment description, manufacturer(s), model(s), air pressures used, frequency of oil filter change and evaluation of air line filtering.

3.9

Representative disturbed soil samples shall be placed in small plastic "olive sized" screw lid containers provided by the drilling subcontractor. A labeling sample tag indicating borehole number, sample depth and site designation shall be placed on the outside of each jar. Thin wall (Shelby) samples shall be sealed in the tube and the sample shall be kept from freezing.

3.10

Rock cores shall be stored in cardboard core boxes in such a manner as to preserve their relative position by depth. Intervals of lost core shall be noted in the core sequence. Boxes shall be marked to provide contract number, boring number, cored interval, and box number in cases of multiple boxes. The weight of each fully loaded box shall not exceed 75 pounds. No data shall appear on or within the box that is not specified on the Boring Log.

3.11

During gear bit-rotary wash drilling, several items should be recorded as follows:

a. Rate of drilling.
b. Percent drilling fluid recovery.
c. Changes in drilling fluid, water color.
d. Lithologic description.

The most convenient method to determine lithology during rotary wash drilling is to utilize a kitchen screen to separate rock particles from the return waters. Careful hand lense inspection of the cuttings will enable the geologist or field engineer to estimate rock types encountered. Small plastic or glass sample jars should be used instead of the normal double plastic bags.

3.12

The contractor shall be responsible for securing any and all boring or well drilling permits required by state or local authorities and for complying with any and all state or local regulations with regard to the submission of well logs, samples, etc.

3.13

The contractor shall be responsible for complying with any and all (to include placement) regulations with regard to drilling safety and underground utility detection.

3.14

Unless otherwise specified in the scope of work or contract, soil samples shall be taken and retained every 2 feet from 2 to 10

feet then every 5 feet or each major change of material, to 20 feet below the water table then every 10 feet or at every change in material. These samples are to be obtained with a driven (split spoon) or pushed (thin wall) type sampler or both. Auger flight or wash samples will not suffice to satisfy this requirement.

WESTON

DAILY FIELD ACTIVITY REPORT

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SITE ID: _____ WEEK OF: _____

FTR: _____ DRILLING CONTR.: _____

BILLABLE WORK	MON	TUES	WED	THURS	FRI	SAT	SUN
MOBILIZATION	____EA	____EA	____EA	____EA	____EA	____EA	____EA
DRILLING							
4 INCHES	____	____	____	____	____	____	____
6 INCHES	____	____	____	____	____	____	____
8 INCHES	____	____	____	____	____	____	____
SAMPLING							
CONTINUOUS	____	____	____	____	____	____	____
5 FT INT	____	____	____	____	____	____	____
10 FT INT	____	____	____	____	____	____	____
STEEL CASING DIA ___IN	____FT	____FT	____FT	____FT	____FT	____FT	____FT
PVC PIPES							
DIA ___IN	____FT	____FT	____FT	____FT	____FT	____FT	____FT
DIA ___IN	____FT	____FT	____FT	____FT	____FT	____FT	____FT
PVC SCREEN							
DIA ___IN	____FT	____FT	____FT	____FT	____FT	____FT	____FT
DIA ___IN	____FT	____FT	____FT	____FT	____FT	____FT	____FT
WELL DEVT.	____HR	____HR	____HR	____HR	____HR	____HR	____HR
RIG SET-UP	____EA	____EA	____EA	____EA	____EA	____EA	____EA
ROCK CORING TYPE _____	____FT	____FT	____FT	____FT	____FT	____FT	____FT
PRESSURE TESTING	____HR	____HR	____HR	____HR	____HR	____HR	____HR
PUMP TESTING	____HR	____HR	____HR	____HR	____HR	____HR	____HR
TEST PIT WORK	____HR	____HR	____HR	____HR	____HR	____HR	____HR
STANDBY TIME	____HR	____HR	____HR	____HR	____HR	____HR	____HR
SHELBY TUBES	____EA	____EA	____EA	____EA	____EA	____EA	____EA
BRASS LINERS	____EA	____EA	____EA	____EA	____EA	____EA	____EA
OTHER:						337	
FTR (INITIAL)							
SUBCONTR (INIT)							

APPENDIX C

MONITORING WELL DESIGN AND INSTALLATION

APPENDIX C
MONITORING WELL DESIGN AND INSTALLATION

1.0 PURPOSE

To assure quality control on monitor well design and installation the following standard operating procedures have been set forth, along with the applicable forms, to successfully complete a field drilling investigation oriented towards obtaining geohydrological and future water-quality information.

2.0 SCOPE

Outlined herein are the minimum requirements for monitoring well design and installation. As attachments to this section are the applicable forms:

C-1, Well Completion Reward
C-2, Borehole/Well Construction Log

Also included are:

C-3, Summary of Specifications for Well Completion.
C-4, Post Placement Around Wells.

All field measurements and comments will be recorded on the appropriate forms. As per data reporting format and protocols, all lines on the forms will be completed. The letter designation "NA" for not applicable or "NK" for not known will be used in all blank spaces. If some steps or procedures were not performed as described, the reason must be stated as is practicable on the appropriate form or submitted as an attachment thereto.

3.0 PROCEDURES

3.1

All monitor wells will use the following design and materials:

- Well casing will be 4-inch inside diameter, 316 stainless steel with screw-fit joints.
- Twenty-foot sections of commercial 0.01-inch-slot screens will be used (minimum 3 sq. in. open area per foot of screen).

- Screen gravel pack material will be a well sorted medium quartz sand. A representative sample will be retained by WESTON.

- Sodium bentonite pellets and commercial sodium bentonite powder will be used in backfill. The cement used will be commercial Portland cement. Samples of all grouts and cement will be retained by WESTON characterization.

- All wells will be backfilled as shown in Figure 3-9 with sand pack to a height of 2 feet above the screen, then 5 feet of bentonite pellets above the sand pack, and then grouted to the surface with a pumpable cement:bentonite mixture.

- Annular space grout seals will be composed of 2:1 cement:bentonite mixture by weight, made up with only enough potable water from the approved source to make a pumpable mixture.

- All gravel pack, bentonite plug, and grout material will be placed using pumps and tremie line methods.

- A 5-foot length (minimum thickness 5/16 inch) of 8-inch inside diameter black iron pipe will be used as a security oversleeve. Each oversleeve will be fitted with a hinged cap hasp, and lock. A drain hole will be placed in the oversleeve 1 foot above the ground surface.

- A mixture of 1:2 cement:sand and approved water will be placed between the well riser and the outer security oversleeve to a height of about 6 inches above the land surface.

- The top of the inside casing will be finished with a vented stainless steel cap or an airtight cap and a vent hole not more than 6 inches from the top of the casing.

- All wells and well points will be identified with a stamped metal tag, and all protective casings will be sprayed-painted fluorescent orange.

- A measuring point notch will be filed on the inner casing of each well and will be identified on the notes and well sketches.

- All disturbed drilling areas will be regraded.

3.2

A one-quart (one liter) representative sample of each type of proposed granual backfill shall be submitted by the contractor for approval prior to use. Each sample shall be described in terms of lithology, grain size distribution, and source (both company from whom purchased and pit or quarry of origin). This material shall be clean, inert, and siliceous. Typically, graded sand meeting the requirements of ASTM C-33 for fine aggregate (concrete sand) is sufficient.

3.3

A sketch of any well installation, including lysimeters, shall be recorded on the Well Completion Record Log and shall show, by depth from surface grade, the bottom of the boring, screen location, coupling design and location, granular backfill, seals, grout, cave-in, centralizers, and height of riser above ground surface. The actual composition of the grout, seals, and granular backfill shall also be recorded on each Well Completion Record Log. Also include the screen slot size (in inches), slot configuration, total open area per foot of screen, and screen manufacturer. Any use of PVC solvents, glues, or cleaners is prohibited.

3.4

Attachments C-3 depicts typical well construction. However, specific contract requirements may alter some of the components and/or values shown. Furthermore, when installed as a piezometer or well point (for water levels only), the well configuration may significantly vary from these figures. Because of these potential variations, references to water levels in these figures have been purposely omitted.

3.5

Well sketches shall also include the protective casing detail.

3.6

Protective casing shall be installed around all monitor wells. Exceptions will be on a case-by-case basis, as determined. Minimum elements in the protection design include:

a. A 5-foot minimum length of black iron pipe or galvanized pipe extending 2.5 feet above the ground surface and set in cement grout (see Attachments C-3 and C-4).

b. A 6" pipe diameter for 4" wells and 4" diameter for 2" wells.

c. A locking cover (as in Attachments C-3 and C-4) shall be provided and secured to the top of each protective casing.

   Location ID shall be painted on the inside of the cover with enamel type paint. Location ID shall conform with format and shall be designated by the site manager.

d. The cover must keep precipitation out of the protective casing and shall be secured to that casing by means of a padlock.

e. All padlocks at a given site shall be opened by the same key.

f. Protective casing to be painted fluorescent orange (optional).

g. As shown in Attachment C-5, 3" diameter steel posts, 3 each radially located 4 feet around each well, placed 2 feet below ground surface, having 4 feet minimally above ground surface. Each post will be cemented in-place.

3.8

Once the boring has been advanced to the desired depth, the well will be constructed by the following procedure:

- Place the desired length of screen and casing inside the temporary casing.
- Place the sand pack in the annular space between the screen/casing and temporary casing.
- Withdraw the temporary casing slowly while placing gravel pack material.
- After placing the sand pack to a level of at least 2 feet above the top of the screen, a five-foot thick bentonite pellet layer is placed above the sand pack as the temporary casing continues to be withdrawn slowly.
- The remaining annual space will be filled to the surface using the cement:bentonite mixture described above.
- The temporary casing will be removed gradually as the backfill materials are placed.
- The steel security oversleeve case will be installed and cemented in place.

This same procedure will be used for well construction in boring advanced for purposes of soil chemical quality analysis or geotechnical sampling.

WESTON

WELL COMPLETION RECORD

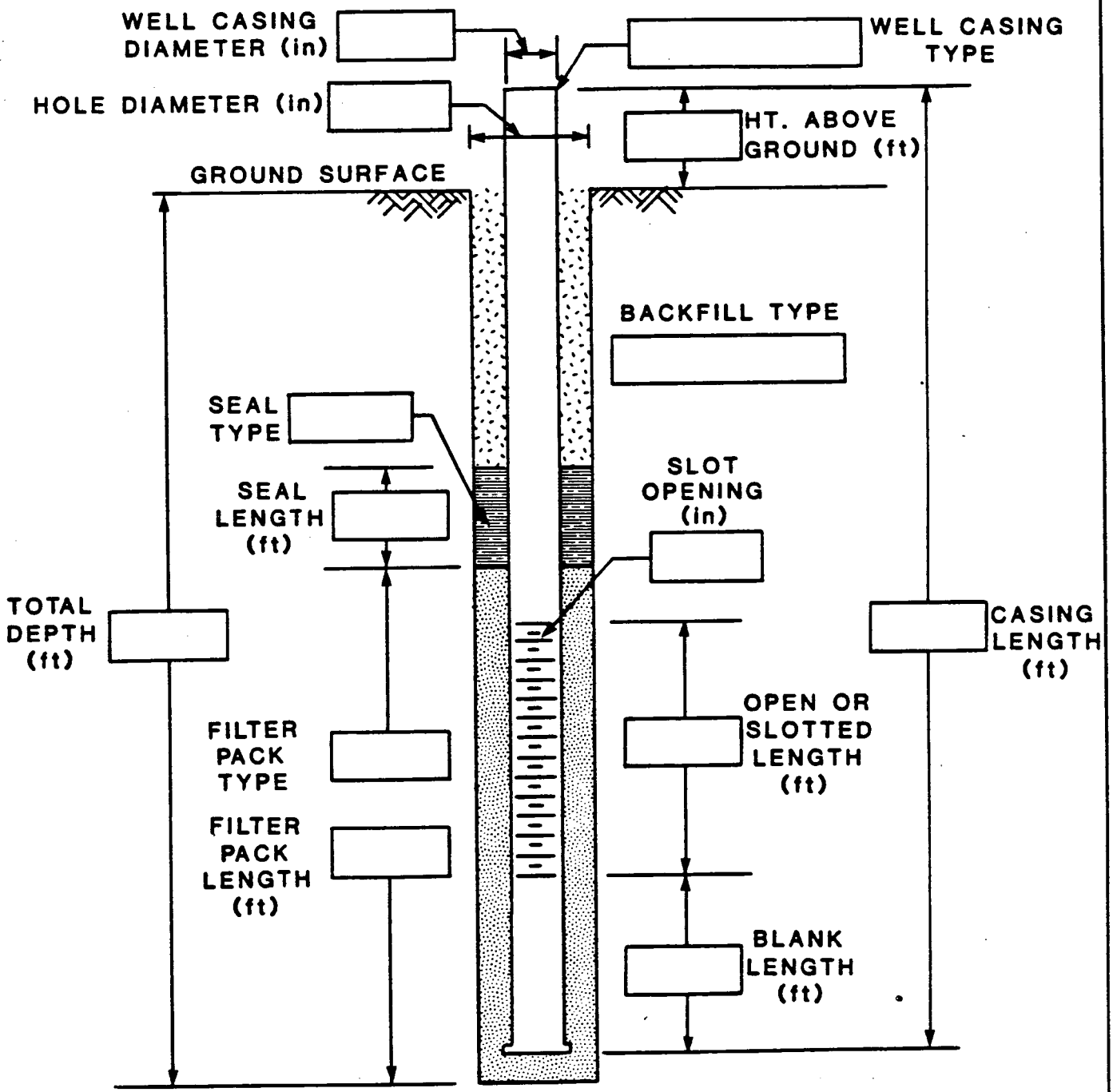
SITE ID: _____ LOCATION ID: _____ DATE INSTALLED: _____

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: _____

FIELD REP.: _____ DRILLER: _____



COMMENTS: _____

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WESTON DESIGNERS CONSULTANTS 776

BOREHOLE/WELL CONSTRUCTION LOG

SITE ID: _____ LOCATION ID: _____ FIELD REP: _____

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: _____

BOREHOLE SUMMARY

DRILLER: _____

RIG TYPE: _____

BIT TYPE	HOLE DIA. (in.)	END ● DEPTH (ft.)	FLUID TYPE

CASING SUMMARY

CASING TYPE*	DESCRIPTION	DIA. (in.)	END✚ DEPTH (ft.)

* P-Protective S-Screen B-Blank O-Open N-None

✚ Depth from Top of Casing

CONSTRUCTION TIME LOG

ACTIVITY	START		END TIME
	DATE	TIME	
DRILLING			
CASING			
FILTER PACK			
SEAL			
BACKFILL			
DEVELOPMENT			
OTHER			

WELL CONSTRUCTION

TYPE CODE*	DESCRIPTION	END ● DEPTH (ft.)

● B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

WELL DEVELOPMENT

COMMENTS: _____

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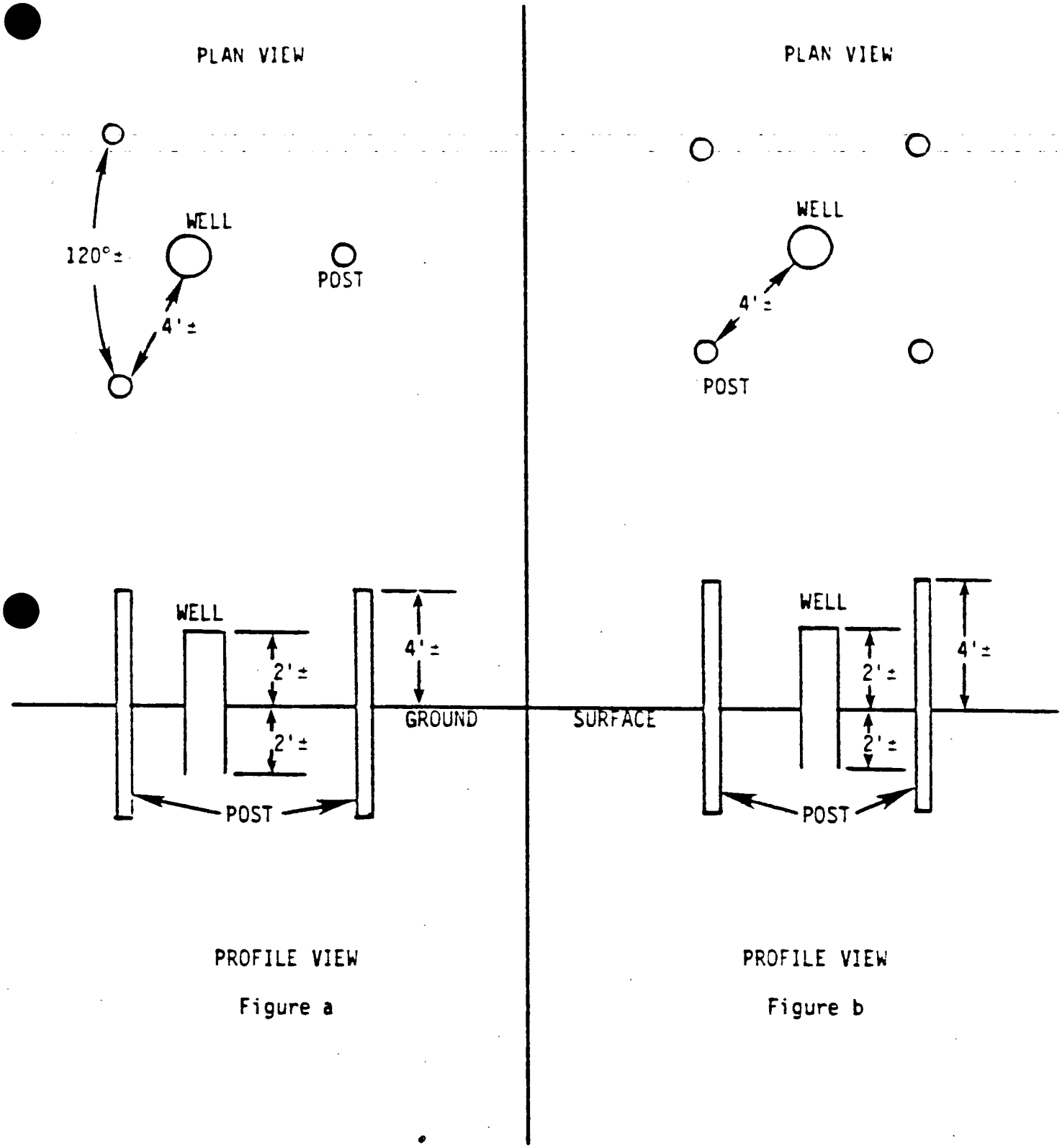
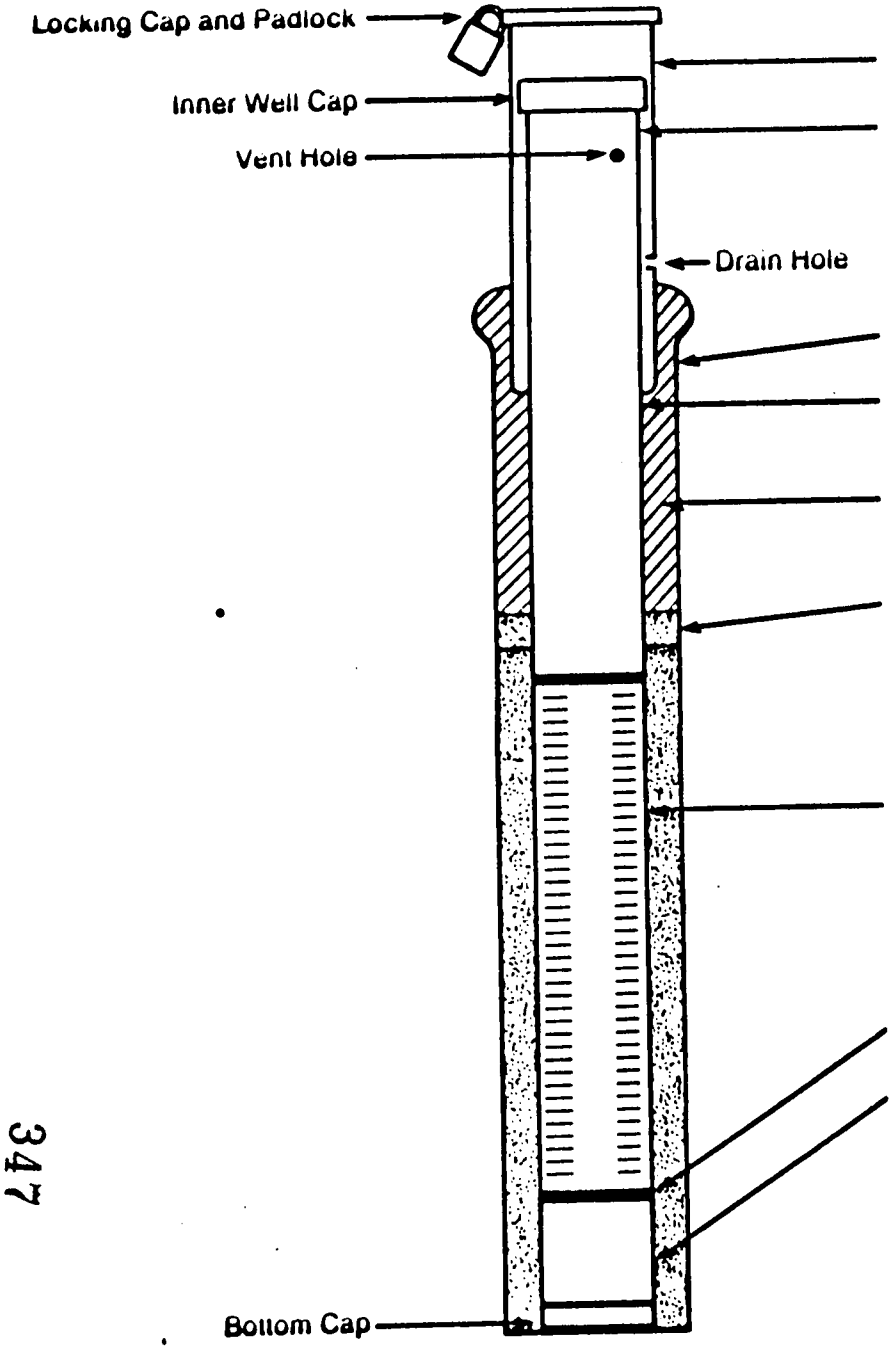


POST PLACEMENT AROUND WELL



Protective Casing 5-foot long, 6-inch ID; steel

Stickup 2.5 feet above land surface; 2 inches below protective casing

Traffic Pad Not Required

Well Development Pumping and surging; may require adding water

Borehole Diameter 8 inches

Casing Diameter 4 inches

Material 316 Stainless Steel

Grout: Material/Mixture 1 to 2 Mix of sodium bentonite powder and portland cement

Setting Top of plug to Top of Borehole

Plug: Material Sodium Bentonite Pellets

Setting Top of sandpack to 2 feet above sandpack

Sandpack: Material Quartz sand

Gradation Well-sorted medium sand

Setting Bottom of borehole to 2 feet above screen

Screen: Material 316 Stainless Steel (4 inch ID)

Length 20 feet

Type wrapped or wound

Opening Size 0.010 inch (10 slot)

Setting based on well depth

Coupling Flush couple, screw in type

Sump Length none

SUMMARY OF SPECIFICATIONS FOR WELL COMPLETION

APPENDIX D

WELL DEVELOPMENT

APPENDIX D
WELL DEVELOPMENT

1.0 PURPOSE

To define the procedures to be followed while developing a well in order to obtain water samples for future water-quality testing.

2.0 SCOPE

The following procedures will be implemented after the installation of an observation monitoring well.

As attachments to this section are the applicable forms:

Borehole/Well Construction Log.

All field measurements and comments will be recorded on the appropriate forms as per data reporting forms and protocols. All lines on the forms will be completed. The letter designation "NA" for not applicable or "NK" for not known will be used in all blank spaces. If some steps or procedures were not performed as described, the reason must be stated as is practicable on the appropriate form or submitted as an attachment thereto.

3.0 PROCEDURES

3.1

The development shall be performed as soon as practical after well installation, but no sooner than 48 hours after grouting is completed.

3.2

Development shall be accomplished with a pump and/or bottom discharge bailer, possibly supplemented with a surge block, until the well water is clear and sediment within the well is removed to the fullest extent practical. As a minimum:

1. For those wells where the boring was made without the use of drilling fluid (mud and/or water); remove five (5) times the standing water volume in the well (well screen and casing plus saturated annulus). Should recharge be so slow that five volumes could not be

removed in one day; or the water remain discolored or contain greater than 1 percent particulates after this five volume removal, the office will direct an alternate procedure based on the subjective judgement of the lead geotechnical engineer.

2. For those wells where the boring was made or enlarged with the use of drilling fluid (mud and/or water): remove five times the measured amount of total fluids lost while drilling plus five times the standing water volume as above (in 1). The same procedure also applies here as in 1 for cases of slow recharge, discolored, or particulate-laden water.

3.3

No water shall be added to the well to assist development without prior approval. No dispersing agents, acids, or disinfectants shall be used.

3.4

During development, the effort shall be made to remove the standing water from points near the bottom of the well screen as well as the top of the water column.

3.5

A one-pint sample of the last water to be removed during development shall be obtained and kept on-site for visual inspection.

3.6

If problems are encountered during development, the project team shall be notified by telephone within 1 hour after problem detection.

3.8

The following data shall be recorded on the Borehole/Well Construction Log or an attachment there of as part of development:

1. Well designation (location ID).

2. Date(s) of well installation.

3. Date(s) and time of well development.

4. Static water level before and after development.

5. Quantity of water removed and time of removal.

6. Depth of open hole inside well before and after development.

7. Physical character of removed water, to include changes during development in clarity, color, particulates, and odor.

8. Physical character of removed sediments, to include lithology and grain size.

9. Type and size/capacity of pump and/or bailer used.

10. Description of surge techniques, if used.

WESTON

BOREHOLE/WELL CONSTRUCTION LOG

SITE ID: _____ LOCATION ID: _____ FIELD REP: _____

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: _____

BOREHOLE SUMMARY

DRILLER: _____

RIG TYPE: _____

BIT TYPE	HOLE DIA. (in.)	END ● DEPTH (ft.)	FLUID TYPE

CASING SUMMARY

CASING TYPE*	DESCRIPTION	DIA. (in.)	END✚ DEPTH (ft.)

* P-Protective S-Screen B-Blank O-Open N-None

✚ Depth from Top of Casing

WELL CONSTRUCTION

TYPE CODE*	DESCRIPTION	END● DEPTH (ft.)

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

CONSTRUCTION TIME LOG

ACTIVITY	START		END TIME
	DATE	TIME	
DRILLING			
CASING			
FILTER PACK			
SEAL			
BACKFILL			
DEVELOPMENT			
OTHER			

WELL DEVELOPMENT

COMMENTS: _____

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APPENDIX E

BOREHOLE GEOPHYSICAL LOGGING

APPENDIX E
BOREHOLE GEOPHYSICAL LOGGING

1.0 PURPOSE

To acquire subsurface geophysical data that aids in hydrogeological investigations. This procedure provides a means of consistently performing and documenting the geophysical logging activities.

2.0 SCOPE

The following procedure shall be followed by the Task Leader (TL) or designated Field Team Leader (FTL) and the subcontractor's Logging Engineer (LE) under TL or FTL direction.

3.0 PROCEDURE

3.1

Prior to any geophysical logging operation, the TL or designated FTL will contact the representative of the subcontractor logging service company to review the logging program and supply the information necessary to: 1) transport all applicable equipment to the drill site when required; and 2) provide an acceptable logging operation.

3.2

The geophysical logging company will calibrate all logging equipment and provide documentation of all before survey, and after survey calibrations to the FTL. The FTL will forward copies of all calibrations and log runs to the TL. The TL shall ensure that all logs are appropriately filed.

3.3

When the logging service company arrives at the drill site, the FTL will review the logging program with the LE, and provide information necessary for completing the log heading of the Field Log Quality Control Check List (FLQCCL) (Attachment 1). Field prints of all logging activities shall be provided to the FTL, including calibration steps. The FTL will monitor and record the progress of logging activities.

3.4

Prior to releasing the logging subcontractor, the FTL will check the FLQCCL (Attachment 1) for completeness. Any unchecked items will be discussed and recorded in the "remarks" section. When the FTL is satisfied with the performance of the logging operation, he/she and the Logging Engineer will both sign and date the FLQCCL.

3.5

At the conclusion of logging operations, copies of all data generated will be transferred to the TL for distribution, analysis, and archiving. The logging company will secure all original log data. Magnetic recordings, if generated during the course of downhole logging, will be transmitted to the main office. This will be done at the convenience of and in a recording format specified by the project manager.

WESTON

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FIELD BOREHOLE GEOPHYSICAL LOG QUALITY CONTROL CHECK LIST

SITE ID _____ LOGGING COMPANY _____

LOCATION ID _____ LOG DATE _____

BOREHOLE DEPTH, AS MEASURED FROM LAND SURFACE
- DRILLER _____ FEET
- LOGGER _____ FEET

LOG RUNS

- ☐ NATURAL GAMMA
- ☐ NEUTRON POROSITY
- ☐ SPONTANEOUS POTENTIAL
- ☐ SHORT-NORMAL RESISTIVITY
- ☐ CALIPER
- ☐ TEMPERATURE
- ☐ GAMMA-GAMMA DENSITY
- ☐ SPECTRAL GAMMA-RAY
- ☐ INDUCED POLARIZATION
- ☐ INDUCTION
- ☐ THERMAL NEUTRON
- ☐ LONG-NORMAL RESISTIVITY

LOGGING ENGINEER SHALL CHECK ALL ITEMS 1 THROUGH 63 APPLICABLE TO THE LOGGING OPERATION. ITEMS UNCHECKED SHALL BE DISCUSSED AND RECORDED IN THE "REMARKS" SECTION. ITEMS NOT APPLICABLE SHALL BE DESIGNATED "N/A". LOGGING ENGINEER AND FTR SHALL SIGN AND DATE THE CHECKLIST UPON COMPLETION OF THE LOGGING OPERATION AND THIS CHECKLIST.

NO.	✓	GENERAL
1		LOGGING ENGINEER HAS COPIES OF NEARBY DRILL HOLES FOR COMPARISON
2		LOGGING ENGINEER HAS COPIES OF PREVIOUS LOG RUNS OF THIS DRILL HOLE
3		LOG HEADINGS COMPLETELY FILLED OUT
4		APPROPRIATE LOGGING SCALES CHOSEN AND RECORDED FOR ALL LOGS
5		DEPTHS AT WHICH ANY MAJOR CHANGES IN MUD PROPERTIES OCCURED ARE INCLUDED IN REMARKS SECTION OF LOG HEADING
6		DEPTHS AT WHICH ANY HOLE OR CASING SIZE CHANGES OCCUR ARE INCLUDED IN REMARKS SECTION OF LOG HEADING
7		DEPTHS AT WHICH ANY UNUSUAL HOLE CONDITIONS WERE ENCOUNTERED ARE INCLUDED IN REMARKS SECTION OF LOG HEADING
8		MUD SAMPLE TAKEN FROM FLOW LINE IMMEDIATELY AFTER CIRCULATING BOTTOMS UP AND BEFORE COMING OUT OF THE HOLE
9		Rm, Rmf, Rmc AND CORRESPONDING TEMPERATURES MEASURED AND RECORDED
10		CASING I.D. SIZE, BIT SIZE AND HOLE SIZE RECORDED
11		LOGGING SPEEDS RECORDED AND CONFORM TO CLIENT'S REQUEST OR SERVICE COMPANY SPECIFICATION
12		ALL SCALE CHANGES NOTED ON LOG AT CORRESPONDING DEPTHS
13		DEPTHS TO RECOGNIZABLE MARKER BEDS AGREE ON ALL LOGS
14		TOOL DESCRIPTION AND DESIGNATION INCLUDED IN LOG HEADING
15		DATE OF LAST SHOP CALIBRATION RECORDED
16		BASE OF CASING DETECTED AND LABELED ON ALL LOGS
17		CALIBRATION BEFORE AND AFTER EACH SURVEY
18		ALL CURVES LABELED

GAMMA RAY LOG

19		BACKGROUND GAMMA RAY RECORDED
20		CALIBRATION SENSITIVITY RECORDED
21		LOGGING SPEED LESS THAN 20 FEET/MINUTE

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FIELD BOREHOLE GEOPHYSICAL LOG QUALITY CONTROL CHECK LIST

SITE CODE _____ LOCATION I.D. _____

DATE _____

DEPTH { DRILLER _____ LOGGING COMPANY _____ LOGGER _____

NO.	✓	NEUTRON LOG
22		CALIPER RECORDED
23		BACKGROUND GAMMA RAY RECORDED
24		LOGGING SPEED LESS THAN 20 FEET/MINUTE
25		POROSITY (%) AND RATIO CURVES RECORDED
26		NEUTRON MATRIX LABELED

SPONTANEOUS POTENTIAL

27		GROUND ELECTRODE IN A STABLE POSITION
28		ADEQUATE SCALE FOR SP SENSITIVITY APPROXIMATELY 5 DIVISIONS DEFLECTIONS FROM SHALE LINE TO CLEAN SAND LINE
29		SP BASELINE SHIFTS GREATER THAN ONE DIVISION CORRECTED ABRUPTLY AND LABELED
30		IF SP ABNORMAL RE-RUN WITH SURVEY CURRENT OFF AND GROUND ELECTRODE CHECKED
31		WHILE ON BOTTOM PRIOR TO LOGGING SP RECORDED AND LABELED WITH CURRENT ON AND OFF
32		WHILE ON BOTTOM PRIOR TO LOGGING SP CALIBRATION SIGNAL RECORDED AND LABELED
33		WHILE STOPPED IN HOLE PRIOR TO LOGGING SP GALVANOMETER CHECKED FOR DRIFT OR CALIBRATION
34		LOGGING SPEED LESS THAN 20 FEET/MINUTE

RESISTIVITY LOGS

35		RESISTIVITY CURVES DO NOT READ LESS THAN ZERO
36		LOGGING SPEED LESS THAN 20 FEET/MINUTE
37		LATEROLOG HAS SYMMETRICAL CURVE SHAPE
38		BACKGROUND GAMMA RAY RECORDED

CALIPER LOG

39		CHANGES OF 1/8 INCH CAPABLE OF BEING DISTINGUISHED ON SELECTED SCALE
40		RECORDING MADE IN CASING AS A CHECK OF CALIBRATION
41		LOGGING SPEED LESS THAN 20 FEET/MINUTE

TEMPERATURE LOG

42		LOG RECORDED WHILE GOING IN HOLE AT LESS THAN 20 FEET/MINUTE
43		FLOW LINE, MUD PIT AND AIR TEMPATURE MEASURED AND RECORDED

GAMMA-GAMMA DENSITY LOG

44		CALIPER RECORDED
45		BACKGROUND GAMMA RAY RECORDED
46		LOGGING SPEED LESS THAN 20 FEET/MINUTE
47		BULK DENSITY (G/cc) AND POROSITY (%) CURVES RECORDED
48		MATRIX DENSITY AND FLUID DENSITY LABELED
49		CORRECTION CURVES (G/cc) RECORDED

SPECTRAL GAMMA RAY LOG

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50		LOGGING SPEED LESS THAN 20 FEET/MINUTE
51		K, U, AND T CURVES LABELED
52		BACKGROUND GAMMA RAY RECORDED

FIELD BOREHOLE GEOPHYSICAL LOG
QUALITY CONTROL CHECK LIST

SITE CODE _____ LOCATION I.D. _____

DATE _____

DEPTH { DRILLER _____ LOGGING COMPANY _____ LOGGER _____

NO.	✓	INDUCED POLARIZATION
53		LOGGING SPEED LESS THAN 20 FEET/MINUTE

INDUCTION LOG

54		RESISTIVITY CURVES DO NOT READ LESS THAN ZERO
55		LOGGING SPEED LESS THAN 20 FEET/MINUTE
56		INDUCTION LOG AND SHORT NORMAL HAVE SYMMETRICAL SHAPE
57		INDUCTION RESISTIVITY CURVE CHECKS CONDUCTIVITY CURVE
58		AMPLIFIED SHORT NORMAL RECORDED
59		SHORT NORMAL DOES NOT READ LESS THAN ZERO
60		CONDUCTIVITY DOES NOT READ LESS THAN ZERO

THERMAL NEUTRON

61		LOGGING SPEED LESS THAN 20 FEET/MINUTE
62		BACKGROUND GAMMA RAY RECORDED

GENERAL

			HOUR	DATE
63		WHEN SERVICE COMPANY NOTIFIED		
64		WHEN SERVICE COMPANY REQUESTED		
65		WHEN SERVICE COMPANY ARRIVED		
66		WHEN HOLE READY		
67		WHEN LOGGING STARED		
68		WHEN LOGGING COMPLETED		
69		WHEN SERVICE COMPANY RELEASED		

OPERALTIONAL EFFICIENCY CHECK: ITEMS 63 THROUGH 69 SHALL BE FILLED OUT BY THE FTR

LOG TYPE	DEPTH (FT.)		TIME (HOUR)	
	FROM	TO	ELAPSED	LOST

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NOTE ELAPSED TIME INCLUDES LOST TIME

FIELD BOREHOLE GEOPHYSICAL LOG
QUALITY CONTROL CHECK LIST

SITE CODE _____ LOCATION I.D. _____

DATE _____

DEPTH { DRILLER _____
LOGGING COMPANY _____
LOGGER _____ }

REMARKS

NO.	

_____ DATE

_____ (SIGNATURE OF FTR)

_____ DATE

_____ (SIGNATURE OF SERVICE COMPANY REPRESENTATIVE AND COMPANY)

APPENDIX F

AQUIFER PUMP TESTING

APPENDIX F
AQUIFER PUMP TESTING

1.0 PURPOSE

To define the procedures to be followed by hydrologists in conducting pumping tests of aquifers for characterization of hydrogeologic units on the Project.

2.0 SCOPE

The pumping test will be performed to estimate the hydrologic characteristics of the hydrogeologic interval. The equipment used in the test will depend on the rate of flow of fluid encountered and drill hole stability conditions. Because of the great variety of hydrogeologic conditions that are likely to be encountered during drilling and testing, several different test tool arrangements are planned in order to be able to perform the pumping test.

3.0 PROCEDURE

3.1

The test methods used will follow the guidelines for well testing in Technical Memorandum No. 1 (Attachment F-1). The data obtained during any pump test, regardless of method or equipment, shall include:

a. Static water level.

b. Water discharge rate.

c. Pressure versus time data for each gauge.

d. Water temperature and specific conductivity.

e. Depth of water intake.

f. Whether or not a flowmeter/traced ejector survey was performed.

3.2

An aquifer test data form (Attachment F-2) shall be completed for each test in order to document the test results. This form shall

be the lead page of the data records of the test. The complete, original test data records shall be sent to the project office, to the attention of the site hydrologist, after each test. Additionally, a copy of these records shall be retained by the field representative in charge of the test.

3.3

A diagram of the equipment actually used in each pumping test shall be prepared by the site hydrologist or received from the subcontractor responsible for the testing. The diagram will show the tubing dimensions, the depth of water intake, and the location of gauges and packers. This diagram shall become part of the data records of each test.

3.4

All gauges and flowmeters used in the pump-out testing procedures shall be calibrated before arrival on site. Copies of the documentation of instrument calibration shall be obtained from the instrument or testing service company by the site hydrologist. The calibration records shall consist of laboratory measurements and, if performed, any on-site zero adjustment and/or calibration.

3.5

Water pumped from the well during the pumping test shall be disposed of in such a manner so that no adverse impacts are created on surface water quality or on the quality of the drawdown data from observation wells.

3.6

In cases where a weir or an orifice are used to measure flow volumes or rates, these devices will be checked on-site using a bucket of known volume and stopwatch and their accuracy documented before testing proceeds.

3.7

All equipment shall be installed and demonstrated to the technical representative that the system is in proper working order and performing to specifications at least 24 hours before the proposed start of the pumping test.

3.8

For air-lift pumping tests, water samples will be collected by wireline sampler which shall be put down the hole after the pumping has stopped. The actual depth of the interval which is producing the fluid and the depth at which the sample was collected shall be recorded.

3.9

For pumping tests which employ mechanical pumps, samples will be collected above ground level from the discharge line.

3.10

After collection, the water sample will be treated in accordance with water sampling/preserving/shipping and testing procedures (Appendix G) and will be analyzed for HSL inorganic compounds and radionuclides according to Section 2, Appendix Q.

4.0 REFERENCES

Thackston, J., 1985, Technical Memorandum No. 1, "Bore Hole Hydraulic Testing for Aquifer Characterization."

ATTACHMENT F-1
TECHNICAL MEMORANDUM NO. 1
BORE HOLE HYDRAULIC TESTING FOR
AQUIFER CHARACTERIZATION

1.0 INTRODUCTION

This technical memorandum provides guidelines and procedures for determining the hydraulic parameters of aquifers using slug tests and pumping tests. The hydraulic conductivity (K) of an aquifer is a measure of the aquifer's ability to conduct water. The greater the value of hydraulic conductivity, the more rapidly the aquifer conducts water. Figure 1 illustrates the typical range of hydraulic conductivity values associated with a variety of earth materials. The transmissivity (T) of an aquifer is defined as the ability of the aquifer to transmit water through its entire thickness and is equal to the hydraulic conductivity (K) times the saturated thickness of the aquifer (b); this can be stated as $T = Kb$, for cases in which K is constant with depth. Otherwise, transmissivity is equal to the integration of hydraulic conductivity over depth, $T = K(Z)dz$.

Specific yield of an aquifer is the ratio of the volume of water drained by gravity from a unit volume of aquifer material. The storage coefficient of an aquifer is the volume of water in storage released from a column of aquifer with unit cross section under a unit decline of head.

1.1 SLUG TEST

1.1.1 Purpose

The purpose of this section is to outline procedures for the conduction and evaluation of slug tests which are a quick and inexpensive method of estimating the hydraulic conductivity or transmissivity of many aquifer systems.

A slug test will generally work in aquifers where K is less than or equal to 10^{-2} cm/sec. In aquifers of greater hydraulic conductivity the water level may return to static level before a sufficient number of water level readings can be made. In aquifers of low K (10^{-4} to 10^{-7} cm/sec), slug tests are generally a reliable field method of determining hydraulic conductivity or transmissivity near the screened zone of the well.

The advantages of using slug tests to estimate hydraulic conductivities are:

1. Estimates can be made in situ and errors incurred in laboratory testing of disturbed samples are avoided.

2. Tests can be performed quickly at relatively low cost because a pumping well and observation wells are not required.

3. The hydraulic conductivity of small discrete portions of an aquifer can be made, for example, such as sand layers in a clay.

There are disadvantages in using slug tests which must be evaluated before the test is conducted. These include:

1. Only the hydraulic conductivity of the area immediately surrounding the well is estimated. These results may not be representative of the average hydraulic conductivity of the area.

2. Often only a range of hydraulic conductivity values rather than an average value can be deduced from test results.

3. Certain assumptions are made in the analysis process. If the assumptions made are inappropriate for the geologic conditions at the site, the results may be erroneous.

4. The storage coefficient, S, usually cannot be determined.

5. Data sufficient for analysis may not be collected if the hydraulic conductivity is relatively high.

This technical memorandum explains procedures and equipment commonly used in conducting most slug tests and a list of analysis techniques used under different geologic conditions and for different bore hole or well systems. Also included are example calculations of typical slug tests (Appendices 1-1 and 1-2).

1.1.2 Design, Drilling and Construction of Slug Test Well

Several factors enter into the design of a well for the performance of slug testing. These include depth and diameter of the test well, length of screened interval and size of screen openings. Some of these factors can be chosen as drilling proceeds or be predetermined from previous borings. Well design is generally determined from a combination of drill cuttings, corings, and geophysical logging.

The depth and screened interval of the hole are determined by the location of the zone of interest. The diameter of the hole and casing to be inserted in the hole should be large enough in order that the volume of the slug does not overflow the top of casing. This may be a problem when the water level in the bore hole is relatively close to the ground surface. The screened interval should consist of screen with a percentage of open intervals large enough so as not to excessively restrict water flowing from the bore hole to the subsurface materials tested. Wells with screened intervals which require a gravel pack should be packed with material of a grain size distribution that would result in approximately an order of magnitude of higher hydraulic conductivity than the subsurface materials being tested.

A variety of drilling techniques can be used in completing the test well. These may include mud-rotary, air-rotary, coring and auger techniques. The type of drilling method used depends on the behavior of the material being drilled and the specific objectives of the project. Drilling without drilling fluids is preferred because this prevents further contamination of the subsurface. Mud-rotary techniques are sometimes required in order to lubricate the bit and hold up the bore hole walls when relatively thick, coarse, unconsolidated materials are encountered. Augering is normally performed without the use of drilling fluids and used in the drilling of relatively shallow holes with relatively cohesive materials.

The construction of the test well is relatively simple and involves the assembly of the appropriate diameter casing (usually PVC because of lower cost) for insertion into the bore hole. A pre-slotted screened section is prepared and attached to the casing string, normally with a cap on the bottom (to prevent material from entering the bottom of the screen), and the whole assembly is lowered into the hole. If a gravel pack is necessary as a filter due to the aquifer containing very fine unconsolidated sand, then it should be placed opposite the screened interval

using a tremie pipe. The annulus is then grouted from the top of the gravel pack up to the ground surface in order to allow hydraulic connection only between the test well and the zone to be tested. The hole should be flushed or bailed before grouting if drilling fluid remains in the hole. If the ground water in the hole is highly contaminated, special safety precautions should be taken to control the discharge water before test well development.

1.1.3 Equipment

Equipment necessary to conduct a slug test include:

- Well or bore hole.
- Water level measuring device.
- Known solid volume of particular shape (slug) that will easily fit into the well or bore hole or container to add or remove a known volume of water.
- Watch with second hand.
- Semi-log graph paper.
- Indelible pen or pencil and paper.

A number of water level measuring devices can be used for measuring the depth to water in a well. An excellent device for measuring the depth to water during a slug test is the pressure transducer. An example strip chart data record is shown in Appendix 1-2. Accurate readings may also be obtained with electric water level indicators or weighted tapes with ploppers. Water level measurement by the wetted-tape method should be avoided as it may be difficult to obtain a sufficient number of readings for analysis of the test if the water level recovers quickly in a short amount of time.

1.1.4 Procedure

Before beginning the slug test, the following information should be recorded:

- Site ID and well or bore hold location.
- Location and elevation of reference point from which water depth measurements are made.

- Elevation of ground water with respect to the reference point.
- Date and time of test.
- Well depth, screen length, riser pipe radius, well screen radius, and radius of the gravel pack plus the well screen or bore hole depth and radius.
- Aquifer or ground water zone being tested.
- Volume of water added or withdrawn or volume of solid cylinder (slug).
- Type of measuring device used.
- Names of personnel conducting test.

The following procedures will apply to most slug tests. The field procedures required fora particular slug test may be slightly different, however, and the procedures should be modified to that test as necessary.

- Determine the static water level in the well by measuring the depth to water periodically for several minutes and taking the average of the readings.
- "Instantaneously" introduce or remove a known volume of water to the well. Another method is to introduce a solid cylinder of known volume to displace and raise the water level, allow the water level to restabilize and remove the cylinder. It is important to remove or add the volumes as quickly as possible because the analysis assumes an "instantaneous" change in volume is created in the well.
- With the moment of volume addition or removal assigned time zero, measure and record the depth to water and the time at each reading. Depths should be measured to the nearest 0.01 foot. The number of depth-time measurements necessary to complete the test are variable. It is critical to make as many measurements as possible in the early part of the test.
- Continue measuring and recording depth-time measurements until the water level returns to equilibrium

conditions or a sufficient number of readings have been made to clearly show a trend on a semi-log plot of time versus depth.

The time required for a slug test to be completed is a function of the volume of the "slug," the hydraulic conductivity of the formation and the type of well completion. The slug volume should be large enough that a sufficient number of water level measurements can be made before the water level returns to equilibrium conditions. The length of the test may range from less than a minute to several hours.

If the well is to be used as a monitoring well, precautions should be taken that the wells are not contaminated by material introduced into the well. If water is added to the monitoring well, it should be from an uncontaminated source and transported in a clean container. Bailers or measuring devices should be cleaned prior to the test. If tests are performed on more than one monitoring well, care must be taken to avoid cross contamination of the wells.

1.1.5 Data Analysis

The analysis of slug test data is based on the modification of well-known ground water flow equations (either the Theim equation, the Theis equation, or subsequent modification). Several authors have presented analytical solutions for the analysis of slug test data. Most solutions require a semi-logarithmic plot of the data collected: dimensionless head (logarithmic scale) or residual head (logarithmic scale) versus time (arithmetic scale).

Hvorslev (1951) was one of the first researchers to publish techniques of analysis of either constant or slug (falling head) tests in near-surface saturated soils. His analysis for slug tests involves a semi-logarithmic plot of the falling head (or water level) divided by the initial head against time. Basic algebraic equations are presented for different configurations of the soil relative to the test hole. In general, the permeability is proportional to a "shape factor" and inversely proportional to a "time lag." The "shape factor" is determined from the test well characteristics or dimensions. "Time lag" is determined from the semi-logarithmic plot.

Cooper et al. (1967) and Papadopulos et al. (1973) developed a set of type curves for analyzing slug test data, particularly for tests run in materials which are confined (under artesian

pressure). The field data are plotted as dimensionless head (arithmetic scale) versus time (logarithmic scale) and matched to a set of type curves. The match point values are substituted into simple algebraic formulated to obtain a value for K (Appendix 1-1).

Bower and Rice (1976) and Bower (1978) developed a technique for analyzing slug test data collected from completely or partially penetrating wells in unconfined aquifers. Their analysis involves a plot of residual head (logarithmic scale) versus time (arithmetic scale). A straight line is applied to the early-time data and used to calculate a value for K. An example of the use of this technique is presented in Appendix 1-2. A plot of the data and calculations are included.

Pressurized slug test methods have been developed for testing extremely low conductivity (10^{-8} cm/sec or lower) materials (Bredehoeft and Papadopulos, 1980). Basically, the pressurized slug technique is a modification of the conventional slug test discussed previously. The advantage of the pressurized slug technique is the reduction of time required to perform a test in tight formations. This method involves creating an instantaneous pressure surcharge on drawdown in the test zone, then closing a valve to shut in the well. Based on the rate of decay of the pressure slug and the geometry of the test zone, the transmissivity, hydraulic conductivity, and storativity may be calculated.

1.2 AQUIFER PUMPING TEST

1.2.1 Purpose

The purpose of this section is to briefly describe the use of aquifer pumping tests to evaluate aquifer characteristics. Aquifer pumping tests, commonly referred to as pump tests, are used to determine hydraulic characteristics and properties of water-bearing zones. Pumping tests provide results that are often more representative of the aquifer's characteristics than do slug tests.

Aquifer characteristics which may be obtained from pumping tests include hydraulic conductivity (K), transmissivity (T)k, and specific yield (S_y) for unconfined aquifers and storage coefficient (S) for confined aquifers.

Equipment, personnel and time commitments needed to conduct pumping tests are greater than those required for slug tests. Briefly, a pumping test consists of pumping one well and recording the drawdown in the pumping well and in other nearby observation wells.

Advantages of pumping test:

- A greater portion of the aquifer is tested and the results obtained may be more reliable and representative of the aquifer characteristics.
- Coefficient of storage and specific yield values can be determined.

Disadvantages of pumping test:

- In low permeability aquifers long-term pumping may be required to complete the test and obtain reliable aquifer characteristics.
- Disposal of discharged water may require special provisions if the ground water is contaminated.
- Test may be very expensive when compared to slug tests.

There are several types of pumping tests. The most common type is the constant rate discharge test (Todd, 1980). Variable rate tests are also employed under some conditions. Although the analysis is more complicated, any sort of temporal variations in flow rate can be accounted for by assuming the law of superimposition holds. Usually this is a good assumption. The most widely used variable rate tests are the step-drawdown test, the constant head test, and the air-lift pump test (Kruseman and DeRidder, 1976).

Another useful technique is injection testing. Injection tests, both constant rate and variable rate, are analytically identical to pumping tests except for considering the flow rate a surcharge on the aquifer rather than a withdrawal. the data quality is also similar. Although injection tests are commonly used in the petroleum industry (Earlougher, 1977), numerous applications exist in hazardous waste practice. Obviously, water sampling for hydrochemical characterization of the aquifer must be conducted prior to injection (or considered unimportant) in application of this technique. The injection fluid should be free of suspended

solids and should by of equal or higher quality than the ground water at the test site.

One major advantage of this type of test is that contaminated ground water is not removed from the formation and, thus, is not a disposal problem. a potential disadvantage of the injection test is that in certain cases the injection well would have to be able to withstand some induced hydraulic pressure. Cases where the injection rate is large enough to elevate the water level above the well casing would require a sealed well head configuration and proper well construction so that there would be no leakage of injected fluid on the ground surface. these requirements may be relatively expensive and difficult to operate in the field with out the necessary precautions. Once an injection system is working at a constant rate of flow, the data collected are analyzed in much the same way as those from an aquifer pumping test, except that water level buildup is used in the analysis instead of drawdown.

This memo briefly describes equipment, procedures and other factors which must be considered for constant-rate pumping tests. References which provide additional information are presented in the list of references. Ground Water Wells (Johnson, 1966) is a field guide with many suggestions on how to perform the test. Ground Water Hydrology (Todd, 1980) and other references, such as Kruseman and Deridder (1976), provide analytical techniques and example problems of pumping tests conducted under different geologic conditions.

1.2.2 Equipment

The amount of equipment necessary to perform a constant-rate pumping test is greater than that used in a slug test. This is part of the reason why the aquifer pumping test is considerably more expensive. Equipment needed for a pumping test includes:

- Pumping well and pump. Pumps are commonly of the submersible or turbine type. The pumping well should be properly developed prior to testing.

- One or more observation wells hydraulically connected to the pumped aquifer and completed to the proper specifications for the particular test.

- An orifice, weir, flow meter, container or other type of water measuring device to accurately measure and monitor the discharge from the pumping well .
- Sufficient pipe to transport the discharge from the pumping well away from the area to prevent infiltration in the area of influence of the pumped zone.
- Gate valve on the discharge pipe to control the pumping rate.
- Outlet near well head for water quality determinations and sampling.
- Depth-to-water measuring devices for each observation well and the pumping well (this may include steel tapes, electric sounding probes, Stevens recorders, or pressure transducers).
- A thermometer and other water quality equipment necessary.
- Watches capable of reading to the nearest second for all observers or a stopwatch.
- 3-cycle by 5-cycle log and 5-cycle semi-log graph paper.
- Indelible pens or pencils and forms for recording times and drawdown measurements at each well.
- Appropriate references and calculator for determinations in the field.
- A barometer or recording barograph (for tests conducted in confined aquifers).

1.2.3 Pump Well Design

Design of the pump well is an important consideration in aquifer testing. In some cases an existing well will be used for pumping. When sufficient funds and conditions permit, a pumping well can be designed and constructed specifically for the test. The pumping well should be screened throughout the thickness of the aquifer to be tested with standard well screen. The well should be gravel packed, if necessary, to minimize sand production in unconsolidated fine-grained aquifers. standard well construction techniques are discussed in Johnson (1966). the well should be correctly sealed from overlying and underlying units that are not

to be directly pumped and so that leakage down the well annulus cannot occur which may interfere with the interpretation of the test. The completed pumping well should be developed by the appropriate methods to remove drilling fluid from the surrounding aquifer materials. Proper development of the well may prevent an unexpected variation in the pumping rate during the constant discharge test which, if the variation occurred, could lead to inconsistent drawdown data from the pumping well.

1.2.4 Observation Well Siting

The location and number of observation wells depends on several factors:

- Whether the aquifer tested is confined or unconfined.
- The thickness of the aquifer.
- The anisotropy of the aquifer.
- Location of the screened interval of the pumping well relative to the total aquifer thickness.
- Location of aquifer boundaries, whether positive (lake or stream) or negative (impermeable boundaries).
- Practical and economic considerations.

Any number of observation wells may considered. Often, four wells are desirable, three on a line passing through the center of the pumped well and one on a line normal to that line and also passing through the pumping well. A number of guidelines for location of observation wells are presented in the Ground Water Manual prepared by the U.S. Department of Interior and Kruseman and DeRidder (1976).

as a general rule for tests performed in both confined and unconfined aquifers, the observation wells should be screened or completed in a substantial portion of the aquifer thickness in approximately the median depth of the test zone. In some cases, special tests require that observation wells be selectively completed in several depth zones in order to accurately determine aquifer characteristics such as anisotropy and vertical hydraulic conductivity.

The location of the observation well from the pumping well is in part controlled by the aquifer conditions: whether they are confined or unconfined. The location of observation wells generally depends on four aquifer conditions:

- most aquifers with fully penetrating pumping wells: observation wells should by located at a distance estimated by using the Theis formulation (Theis, 1935). Use of this formulation is described by Walton (1970). Assumed aquifer parameters are used to determine a location which will give the amount of drawdown required for proper analysis.

- Thin aquifers with fully penetrating wells: for confined aquifers the nearest observation well should be located at least 25 feet from the pumping well. For unconfined aquifers, observation wells should generally be located 15 to 100 feet from the pumping well.

- Thick, isotropic aquifers with a partially penetrating pumping well: observation wells should be located one and one-half to two times the aquifer thickness from the pumping well.

- Thick anisotropic aquifers with partially penetrating well: observation wells should be located at a minimum distance from the pumping well equal to twice the thickness of the aquifer times the square root of the ratio of the horizontal to the vertical hydraulic conductivity.

1.2.5 Procedures

The field procedures to conduct pumping tests are similar. The basic procedure consists of monitoring the water level over time in the pumping well and each observation well as the pumping well is discharged at a constant rate.

The following data must be recorded accurately at the time the test is performed:

- Well identification number or location of pumping well and each observation well.

- Location and elevation of each well.

- Location and elevation of reference point from which water depth measurements are made and elevation of ground with respect to the reference point.
- Date and time of test.
- Well depth, pump depth, screen length, well radius and radius of gravel pack plus well screen for each well.

All gauges, transducers, flow meters, etc. used in conducting pumping tests shall be calibrated before use at the site. Copies of the documentation of instrumentation calibration should be obtained by the hydrogeologist and later filed with the test data records. The calibration records will consist of laboratory measurements and, if performed, any on-site zero adjustment and/or calibration. In cases where a weir or an orifice is used to measure flow rates, the device will be checked on site using a container of measured volume and stopwatch. Accuracy of the meters must be verified before testing proceeds.

If funds are available, it is normally advised to monitor pretest water levels at the test site for about one week prior to performance of the test. This can be accomplished by using a continuous-recording device such as a Stevens Recorder. This information allows the determination of the barometric efficiency of the aquifer when barametric records are available. It also helps determine if the aquifer is experiencing an increase or decrease in head with time due to recharge or pumping in the nearby area, or dirunal effects of evapotranspiration. Changes in barometric pressure are recorded during the test (preferably with an on-site baragraph) in order to correct water levels for any possible fluctuations which may occur due to changing atmospheric conditions. Pre-test water level trends are projected for the duration of the test. These trends and/or barometric changes are used to "correct" water levels during the test so that they are representative of the hydraulic response of the aquifer due to pumping of the test well.

During an aquifer test, water levels should be measured to give at least ten observations of drawdown within each log cycle of time. During the early part of the test, sufficient personnel should be available to have at least one person at each observation well and at the pumping well. After the first two hours, two people are usually sufficient to continue the test. It is not necessary that readings at the wells be taken simultaneously. It is very important that depth to water readings be measured

accurately and readings recorded at the exact time measured. A typical aquifer pump test data form is shown as Attachment 1.

The duration of the test is determined by the needs of the project and the aquifer properties. One simple test for determining adequacy of data is when the log-time versus drawdown for the most distant observation well begins to plot as a straight line on the semi-log graph paper. There are several exceptions to this simple rule of thumb; therefore, it should be considered a minimum criteria. Different hydrogeologic conditions can produce straight line trends on log-time versus drawdown plots. In general, longer tests produce more definitive results. If budget permits, a duration of one to several days is desirable, followed by a similar period of monitoring the recovery of the water level. Unconfined aquifers and partially penetrating wells may have shorter test durations. a knowledge of the local hydrology, combined with a clear understanding of the overall objectives of the project, is necessary in interpreting just how long the test should be conducted. There is no need to continue the test if the water level becomes constant with time. This normally indicates that a hydrogeologic source has been intercepted and that additional useful information will not be collected by continuing the pumping portion of the test.

Measurement of recovering water levels after pumping is concluded is often done to verify results obtained from the pumping portion of the test. The recovering water levels in the pumping well and the observation wells are measured for a period immediately following cessation of pumping. Monitoring of the recovery period should, by rule of thumb, be at least one-half the length of the pumping portion of the aquifer test. This length of time usually allows the collection of useful data for additional analysis.

1.2.6 Data Analysis

Numerous techniques of analysis have been developed by researchers to evaluate water level data collected from constant discharge aquifer pumping tests. Many of the analyses use the graphical "curve matching" technique which involves the matching of theoretical "type" curves to plots of log-drawdown versus log-time from the observation wells. Other analyses rely on other graphical techniques such as application of a straight line to plots of drawdown versus log-time.

Theis (1935) developed a theoretical formulation which related the lowering of the potentiometric level in an aquifer due to the constant withdrawal of water from the aquifer. This classic formulation has been widely used to predict water level response in aquifers due to specified pumping stresses. Several authors have described the use of this formulation in estimating transmissivity and storativity from aquifer test data: Lohman (1972), Walton (1970), Todd (1980), and Freeze and Cherry (1979). in brief, the method involves superimposing the theis solution (or "type" curve) on a log-log plot of drawdown versus time data from a test well. The coordinate axis of the type curve must be kept parallel to the field data plot axes. Data from the "match point" is used to solve two algebraic equations which give the value of transmissivity (T) and storativity (S) (or storage coefficient). Hydraulic conductivity (K) may be computed by dividing T by the aquifer thickness (b). An example of the application of this technique is presented in Appendix 1-3.

The same aquifer parameters can also be determined from a semi-log plot of drawdown versus time for either the pump well or observation wells. Cooper and Jacob (1946) showed that after a relatively short time after pumping begins and analysis of the data, plotted as described above, provided essentially the same T, S, and K values as the Theis technique.

Hydrogeologic judgement should be used in applying straight line (Cooper-Jacob method) fits to these plots because different hydrogeologic conditions can produce similar trends in the data plot. For example, bounded aquifers produce straight line trends that may yield apparent transmissivity values that are too low. knowledge of the hydrogeology of the area and the type of aquifer conditions is essential for correct analysis of test data.

Since the development of the Theis equation, several other formulations have been published which attempt to describe the response of certain aquifers to a constant pumping stress. Hantush (1955, 1956) developed formulations and a corresponding set of type curves for an aquifer which is overlain and/or underlain by a confining bed which has significant storage and experiences vertical flow when the adjacent aquifer is pumped. The same curve matching procedure is used here as with the Theis type curve except that several type curves are available for matching to the data depending on the degree of leakage into the pumped aquifer. Hydraulic characteristics of the confining unit can be calculated using the set of Hantush type curves.

Another commonly used set of "type" curves was developed by Boulton (1954, 1963) and is used when the aquifer tested is unconfined and may exhibit a phenomenon known as delayed yield. Delayed yield is a result of retardation of drainage due to such a force as capillary tension. Boulton's type curves include a set of early-time type curves and late-time type curves. The early-time data and late-time data are respectively matched to the early-time and late-time type curves to give values for transmissivity, storage coefficient, and specific yield. The particular curve used in the set of "type" curves yields additional information concerning how the unconfined aquifer responds to pumping. Newman (1972, 1974, 1975) also developed a set of type curves for the response of unconfined aquifers to pumping but used different assumptions concerning the physical processes in effect. In practice, Neuman and Boulton curves have been shown to give similar results.

Other less common analytical techniques have been described in detail by the authors mentioned above. A publication by Kruseman and DeRidder (1976) is one of the most complete works on the analysis and evaluation of pumping test data. Methods described (with practical examples) include treatment of aquifers from confined to unconfined under both non-steady and steady-state pumping conditions. Methods of correcting drawdown data from tests in which partially penetrating wells exist is also discussed by Kruseman and DeRidder (1976). In addition, the analyses of data from aquifers which have a non-ideal shape or are bounded in some fashion by different hydrogeologic units are presented. Techniques for analysis of recovery data collected after the completion of pumping are presented. Analyses for various types of variable discharge rat tests, such as the Aron-Scott method, are also presented in Kruseman and DeRidder (1976).

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APPENDIX 1-1

EXAMPLE OF ANALYSIS OF SLUG TEST

APPENDIX 1-1

EXAMPLE OF ANALYSIS OF SLUG TEST
AFTER COOPER, BREDEHOEFT AND PAPADOPULOS (1967)

SLUG TEST MW-20

From Recorder Chart

Time (sec)	mv x 0.556 =	Head (ft)	H/Ho
30	2.7	1.50	0.94
60	2.5	1.39	0.87
120	2.2	1.22	0.76
180	1.9	1.06	0.66
330	1.4	0.78	0.49
480	1.0	0.56	0.35
630	0.7	0.39	0.24

From 2-Cycle Semi-Log Plot

$H_o = 1.60$ ft

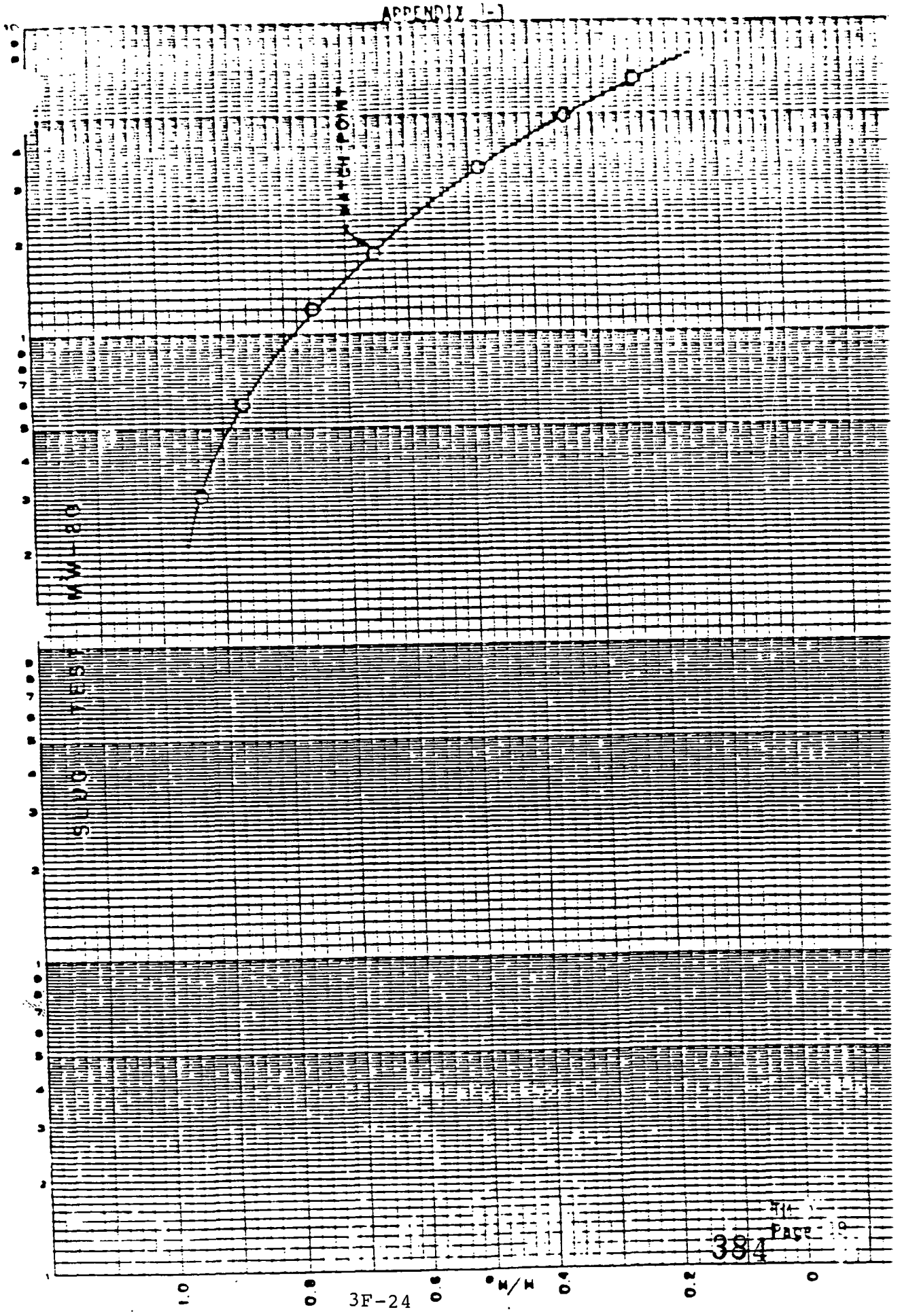
From 4-Cycle Semi-Log Plot at Match Point ($\alpha = 10^{-5}$ Curve)

$\frac{Tt}{r_c^2} = 1.23 \quad H/H_o = 0.66 \quad t = 180$ sec

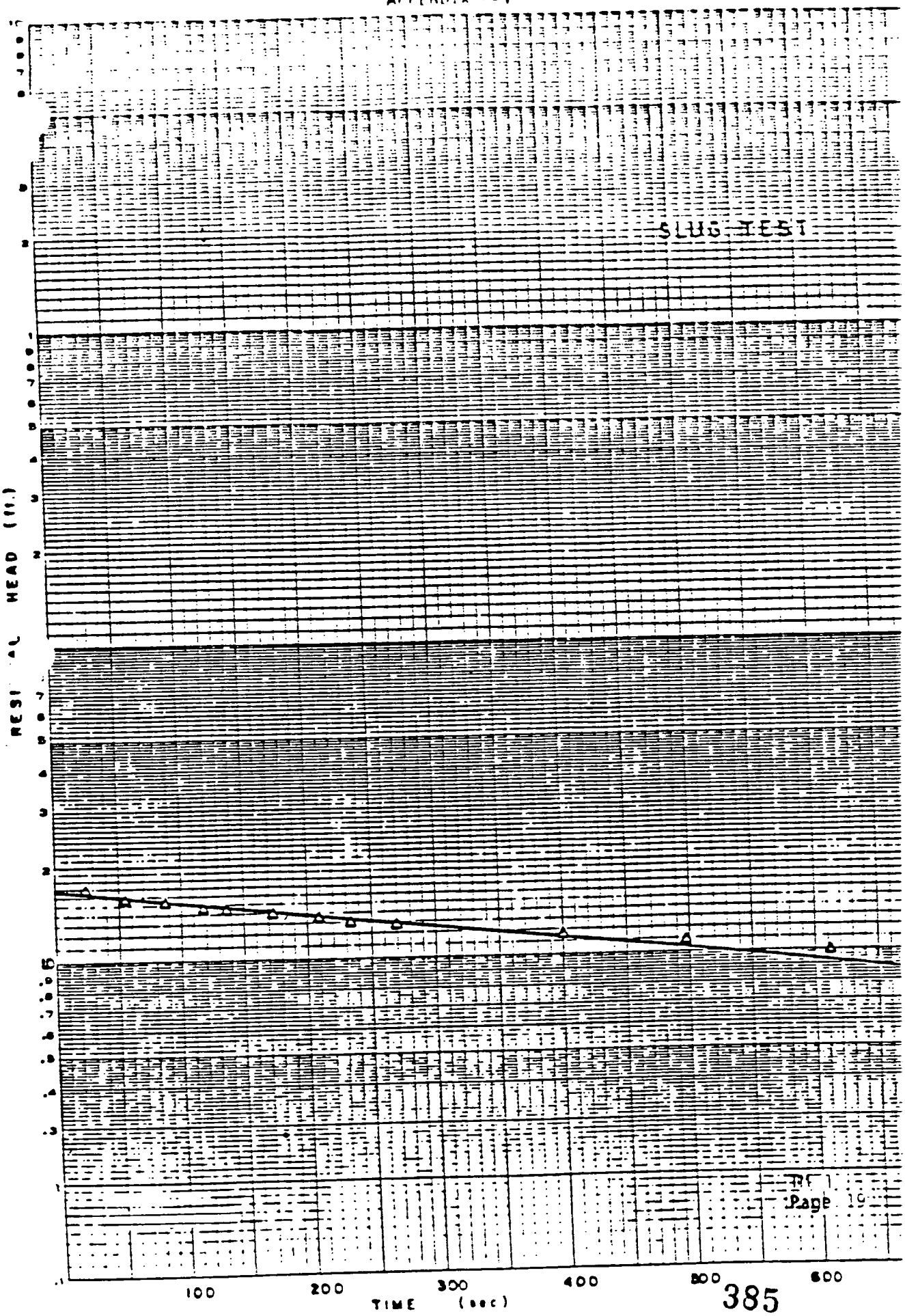
$$T = \frac{1.23(0.125)^2}{180} = 1.07 \times 10^{-4} \text{ ft}^2/\text{sec}$$

$$K = \frac{T}{4.00}(30.48) = 8.14 \times 10^{-4} \text{ cm/sec}$$ (using screen length)

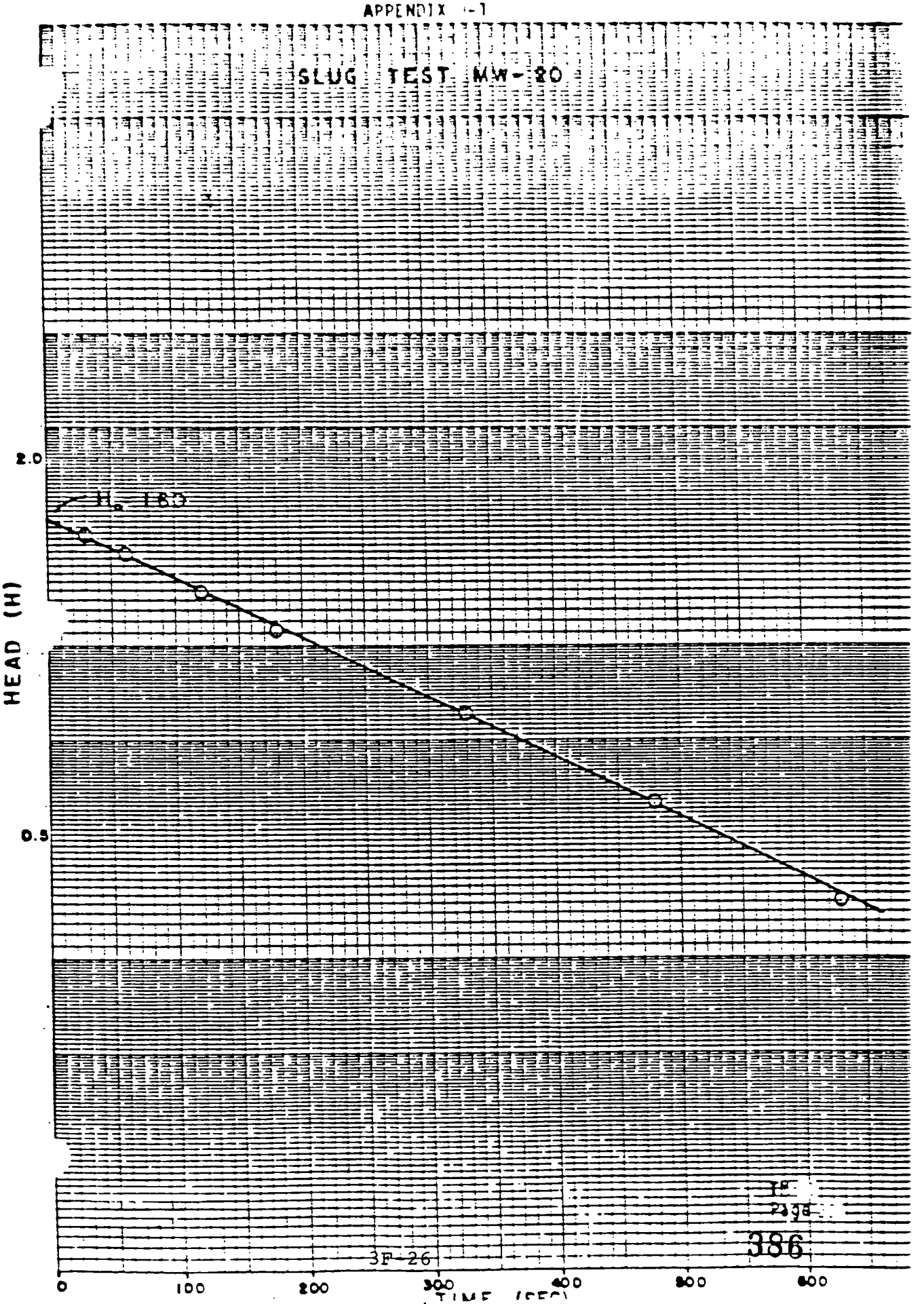
APPENDIX 1-1

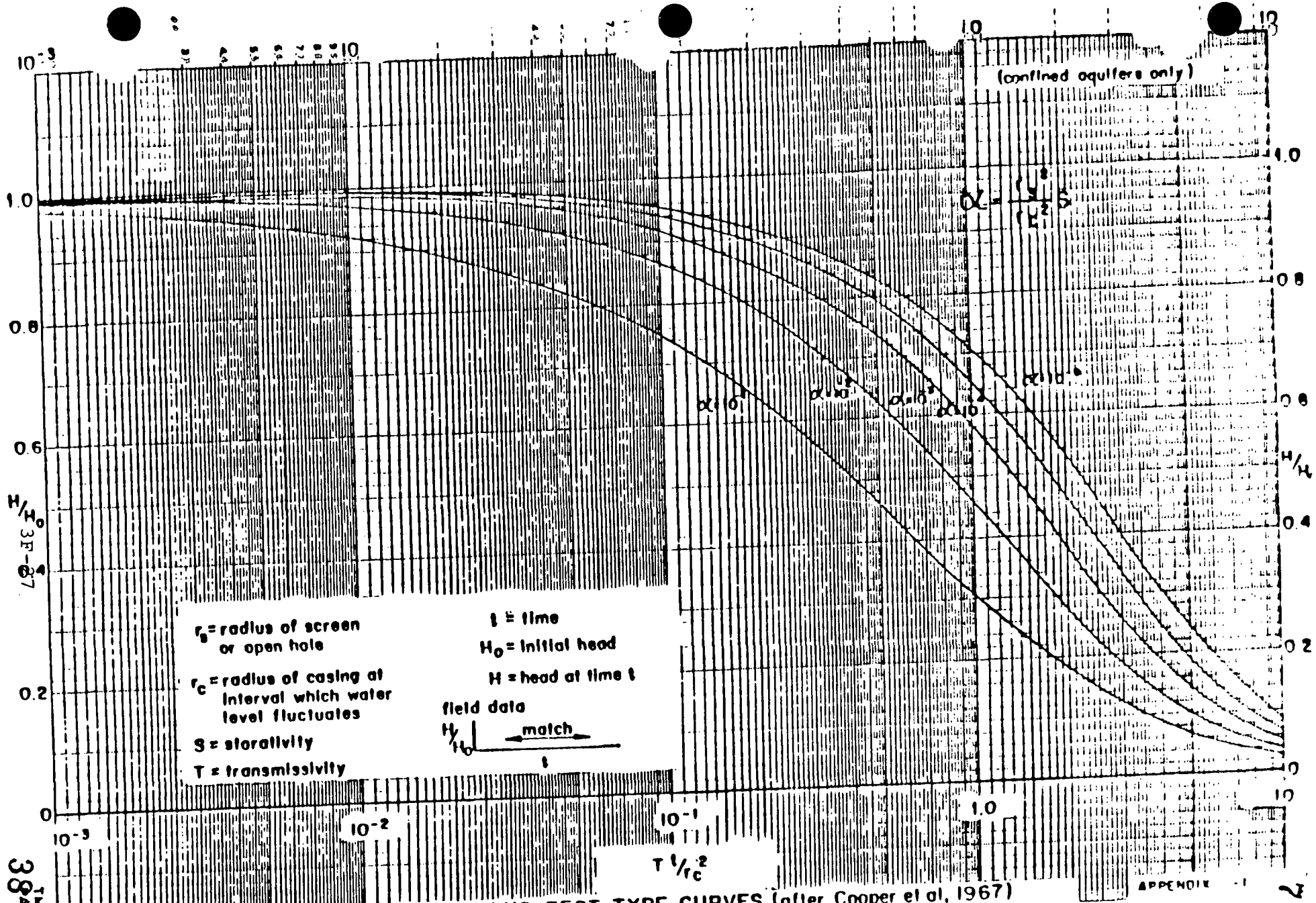


APPENDIX F-1


SLUG TEST
RESIDUAL HEAD (ft.)
TIME (sec)
100
200
300
400
500
600
Page 19

APPENDIX C-1


SLUG TEST MW-20
2.0
0.5
HEAD (H)
H_o 180
0
100
200
300
400
500
600
TIME (SEC)

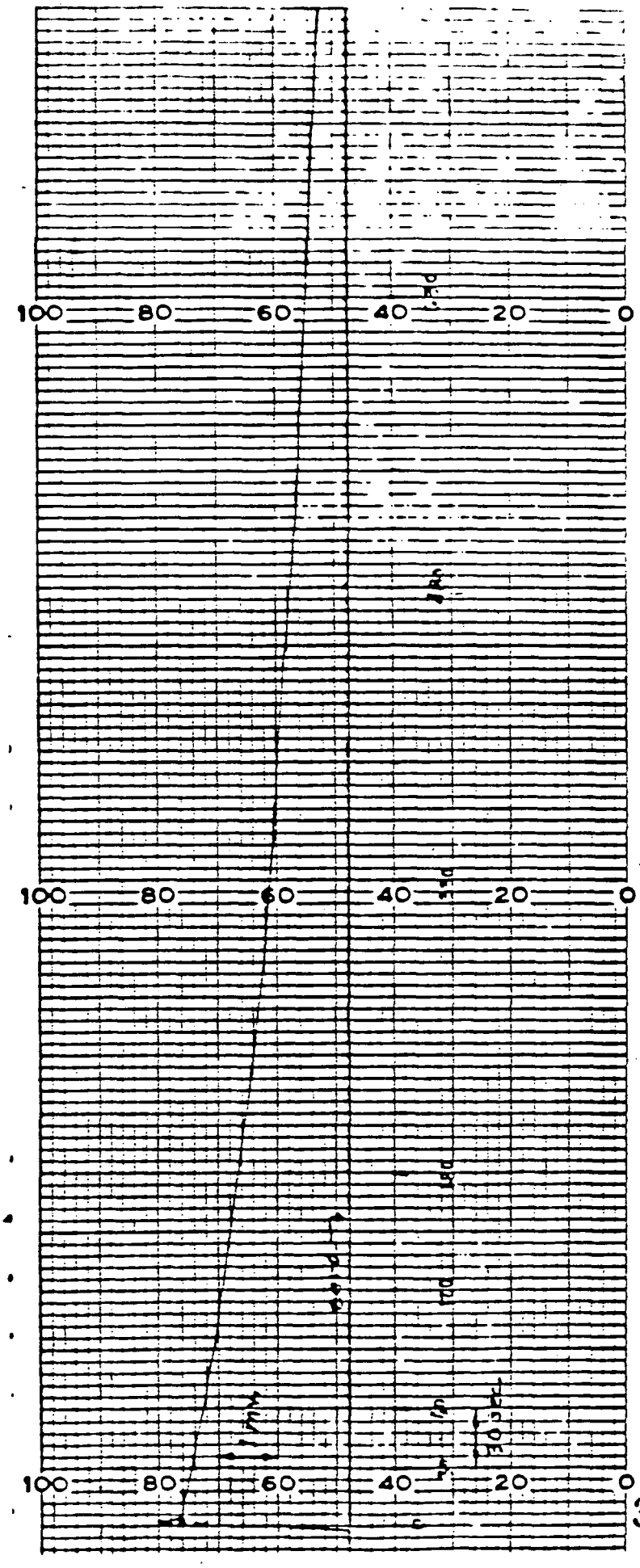


SLUG TEST TYPE CURVES (after Cooper et al, 1967)

APPENDIX 1-2

EXAMPLE OF PRESSURE TRANSDUCER CHART RECORD AND ANALYSIS OF SLUG TEST

APPENDIX 3-2



PRESSURE TRANSDUCER DATA, SLUG TEST

APPENDIX 1-2

EXAMPLE OF ANALYSIS OF SLUG TEST DATA ANALYSIS
FOR AN UNCONFINED AQUIFER
After Bouwer and Rice (1976)

1) Slug Test Data for Example Well

r_w = 0.333 ft
r_c = 0.167 ft
L = 10.0 ft
D = 27.8 ft
H = 11.8 ft

y_t = 1.21 ft at t = 300 sec
y_o = 1.67 feet

2) Evaluate Coefficients A and B or C as required (Figure 3 of Bouwer and Rice, 1976)

$$L/r_w = \frac{10 \text{ ft}}{.333 \text{ ft}} = 30.03$$

A = 2.5 B = 0.38 C = ____ (C is not determined because D ≠ H)

3) Evaluate $\ln (R_e/r_w)$ where R_e is the effective radius over which the heads are dissipated.

$\ln [(D-H)/r_w] = 3.84$: $\left(\text{if } \ln \left[\frac{D-H}{r_w}\right] > 6, \text{ then } = 6\right)$

$$\ln\left(\frac{R_e}{r_w}\right) = \left[\frac{1.1}{\ln(H/r_w)} + \frac{A + B \ln [(D-H)/r_w]}{(L/r_w)}\right]^{-1} \text{ (where } D \neq H)$$

Or,

$$\ln\left(\frac{R_e}{r_w}\right) = \left[\frac{1.1}{\ln(H/r_w)} + \frac{C}{(L/r_w)}\right]^{-1} \text{ (where } D = H)$$

Using the slug test data,

$$\ln\left(\frac{R_e}{r_w}\right) = \left[\frac{1.1}{\ln\left(\frac{11.8}{.333}\right)} + \frac{2.5 + (0.38 \times 3.87)}{30.03}\right]^{-1}$$

$$= 2.27$$

APPENDIX 1-2 (continued)

EXAMPLE OF ANALYSIS OF SLUG TEST DATA ANALYSIS
FOR AN UNCONFINED AQUIFER
After Bouwer and Rice (1976)

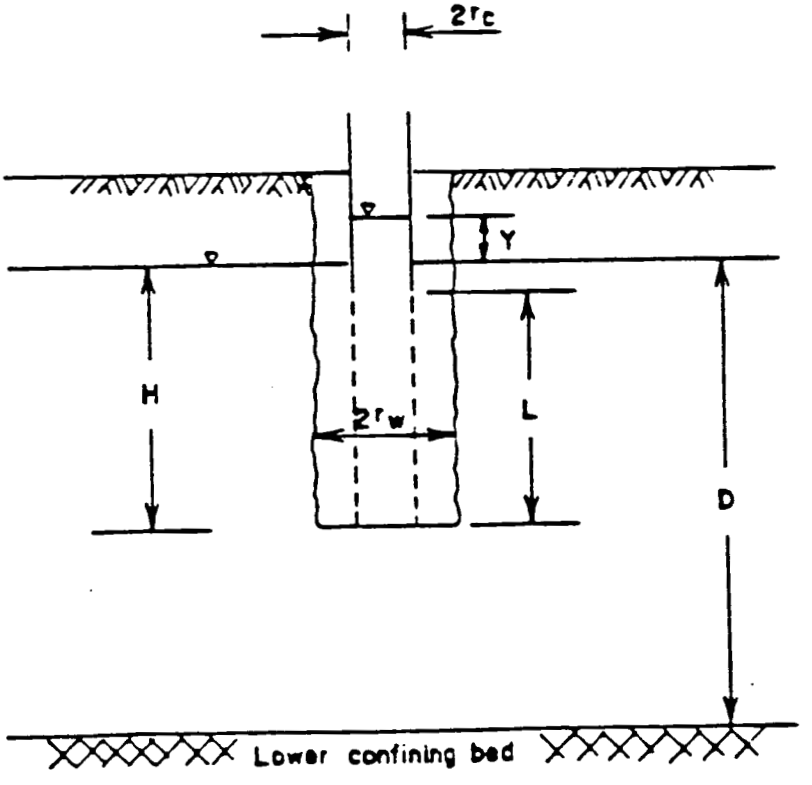
4) Evaluate the Hydraulic Conductivity, K

$$K = \frac{r_c^2 \ln\left(\frac{r_e}{r_w}\right)}{2 L t} \ln \frac{y_o}{y_t}$$

$$= 3.4 \times 10^{-6} \text{ ft/sec} = 1.0 \times 10^{-4} \text{ cm/sec} = 2.2 \text{ gpd/ft}^2$$

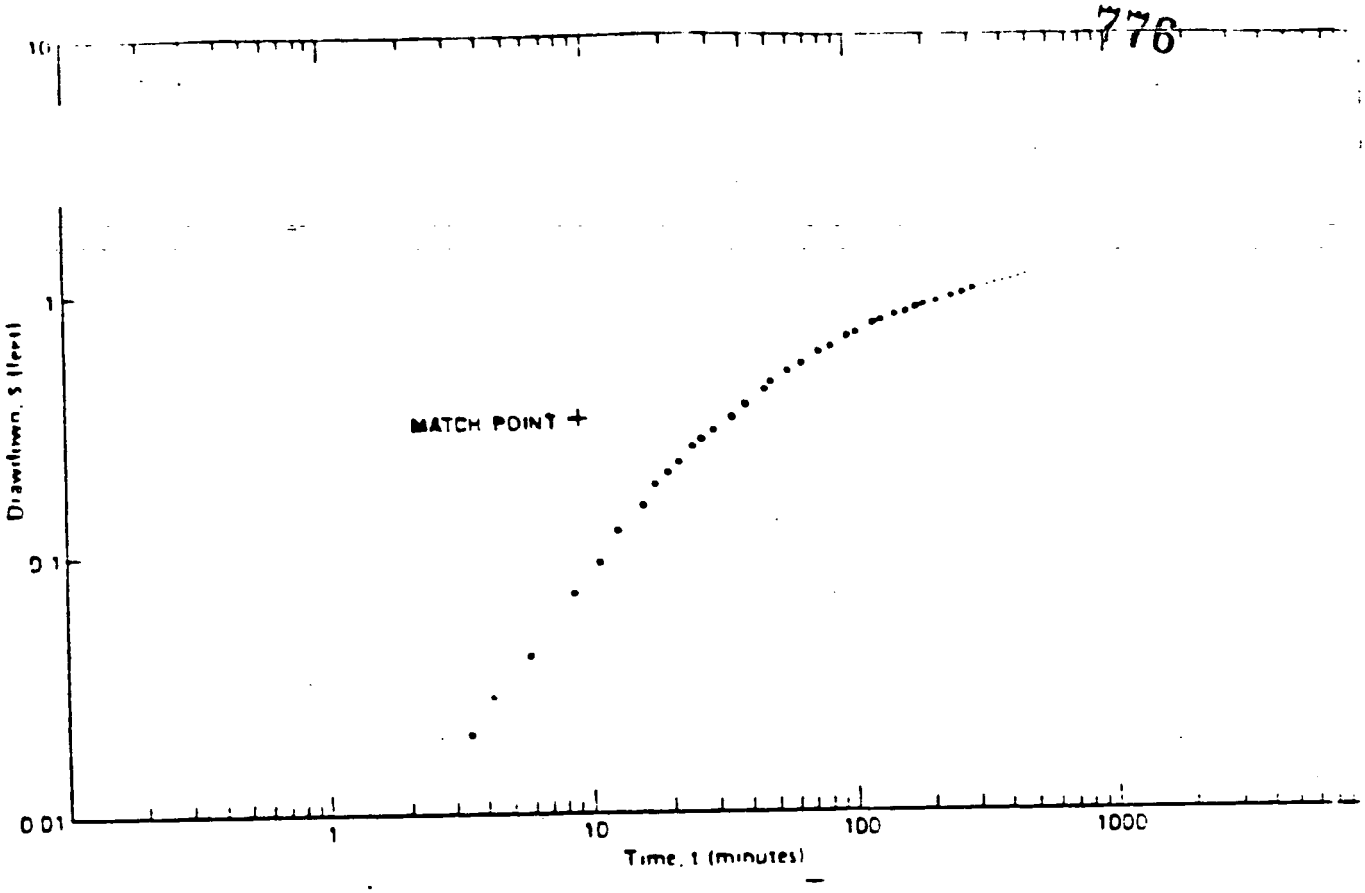
5) Evaluate the Transmissivity, T

T = KxD = 61 gpd/ft



APPENDIX 1-3

EXAMPLE OF ANALYSIS OF AQUIFER TEST DATA



$$T = \frac{114.60}{s} W(u)$$

$$= \frac{114.6\ (21.6)}{0.345}\ (1)$$

$$T = 7200\ \text{gpd/ft}$$

$$S = \frac{Tut}{1.87\ r^2}$$

$$= \frac{(7200)\ (1)\ (6.8 \times 10^{-3})}{1.87\ (60.4)^2}$$

$$S = 0.007$$

$Q = 21.6$ gpm
$r = 60.4$ ft
$b = 53$ ft

$$K = \frac{T}{b} = \frac{7200}{53} = 140\ \text{gpd/ft}^2$$

<u>Theis Match Point</u>

$$\left.\begin{array}{l} W(u) = 1 \\ u = 1 \\ s = 0.345\ \text{ft} \\ t = 9.8\ \text{min} \end{array}\right\} +$$

APPENDIX 1-3: EXAMPLE OF ANALYSIS OF AQUIFER TEST DATA

AQUIFER TEST

SITE ID: _____ LOCATION ID: _____
START TEST: DATE _____ END TEST: DATE _____
TIME _____ TIME _____
DATUM ELEV. (FT. MSL): _____ AVG. PUMPING RATE (GAL/MIN): _____
STATIC WATER LEVEL (FT. MSL): MEASUREMENT METHOD: _____
INITIAL (AT t_0) _____ WELL DEPTH (FT.): _____
FINAL _____ CASING DIAMETER (IN.): _____

WATER LEVEL MEASUREMENT METHOD: _____
DISTANCE FROM PUMPED WELL, r (FT.): _____
DATA ADJUSTED FOR REGIONAL WATER LEVEL CHANGES? _____
FIELD REP(S): _____
COMMENTS: _____

PUMP TEST			RECOVERY TEST	
ELAPSED TIME (MIN.)	DEPTH TO WATER * (FT.)	PUMPING RATE (GAL/MIN)	ELAPSED TIME (MIN.)	DEPTH TO WATER * (FT.)

* BELOW DATUM

WESTON

AQUIFER TEST

PUMP TEST			RECOVERY TEST	
ELAPSED TIME (MIN.)	DEPTH TO WATER * (FT.)	PUMPING RATE (GAL/MIN)	ELAPSED TIME (MIN.)	DEPTH TO WATER * (FT.)

* BELOW DATUM

776

SLUG TEST DATA

SITE ID: _____ LOCATION ID: _____

SLUG VOLUME (ft.^{3}): _____

INITIAL WATER LEVEL (AT t_o):

DATE: _____

TIME: _____

DEPTH (ft FROM TOC): _____

STATIC WATER LEVEL:

DATE: _____ TIME: _____

DEPTH (ft): _____

OPEN INTERVAL (ft.) _____ to _____

TOTAL DEPTH OF WELL (ft): _____

WELL DIAM. (ft): _____

FIELD REP: _____

ELAPSED TIME (MIN. from to)	GROUNDWATER (ft. from TOC)	RESIDUAL DDN (ft.)	$1/t_m$	H/H_o or $\frac{H-h}{H-H_o}$

COMMENTS: _____

396

776

STATIC GROUNDWATER LEVEL RECORD

Page__of __

SITE ID: _____ FIELD REP.: _____

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER DEPTH (FT. FROM DATUM) *

COMMENTS: _____

* Borehole - Top of Ground

Well - Top of Casing

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APPENDIX G

SOIL AND ROCK CORE BOREHOLE AND TEST PIT LOGGING

APPENDIX G
SOIL AND ROCK CORE BOREHOLE AND TEST PIT LOGGING

1.0 PURPOSE

The following standard operating procedure directs the Field Team Leader (FTL) and/or the Task Leader (TL) in the appropriate manner of completing those forms applicable to the description of soil or rock encountered during drilling and test pit excavating programs.

2.0 SCOPE

Outlined herein are the minimum requirements for borehole (soil and rock) and test pit logging. As attachments to this section are the applicable forms used by the FTL for soil and rock borehole logging and test pit logging.

Attachment G-1, Borehole Log (Soil)
Attachment G-2, Borehole Log (Rock)
Attachment G-3, Test Pit Log

As shown by the examples set forth in the following procedures, all field measurements and comments will be recorded on the appropriate forms as per data reporting formats and protocols. All lines on the forms will be completed. The letter designation "NA" for not applicable or "NK" for not known will be used in all blank spaces.

For the convenience of the FTL and to assure standardization of form completeness, completed examples pertaining to specific blank spaces are given herein.

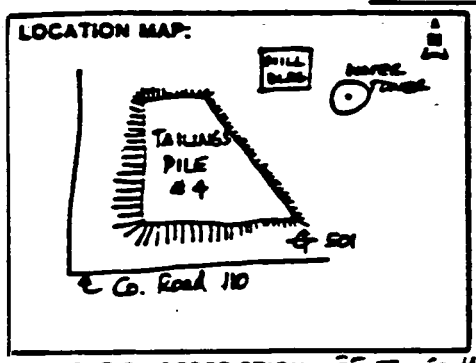
3.0 PROCEDURES

3.1

This section details the procedure and required information for completing the Borehole Log (Soil) form. The TL/FTL is referred to the ASTM Designation: D 2487-83 Standard Test Method for Classification of Soils for Engineering Purposes and ASTM Designation D 2488-69 Standard Recommended Practice for Description of Soils (Visual-Manual Procedure).

BOREHOLE LOG (SOIL) Page 1 of 1

LOCATION MAP:



SITE ID: LEV 01 LOCATION ID: SC1
SITE COORDINATES (ft.):
N NK E NK
GROUND ELEVATION (ft. MSL): NK
DRILLING METHOD: 6 3/4 in. HSA
DRILLING CONTR.: GEOTECH M. Byers
DATE STARTED: 7-14-84
DATE COMPLETED: 7-14-84
FIELD REP.: PC Zell

GROUNDWATER LEVELS		
DATE	TIME	DEPTH (ft.)
7-14-84	10:35 am	7.5
7-14-84	1:00 pm	7.2
7-16-84	7:45 am	7.1

LOCATION DESCRIPTION 25' SW of SE corner T.P. #4.
SITE CONDITION Flat areas covered.

3.1.1 Site ID and Location ID

The Site ID and location ID must conform to the system previously designated for this site and borehole sequence.

3.1.2 Site Coordinates and Ground Elevation

The site coordinates refers tot he horizontal location of the borehole and along with the ground elevation will probably not be known by the TL/FTL at the time of drilling. In this case, NA or NK should be placed in each of these three (3) spaces. If approximate site coordinates for a borehole are known, provide these in the appropriate northing and easting spaces. Regardless of the situation, this information is provided when the survey data comes in after the drilling program has been completed.

3.1.3 Drilling Method

The drilling method could be, but is not limited to, hollow stem auger (HSA) drilling, conventional auger drilling, rotary drilling, percussion - churn drilling, wash boring or displacement borings.

3.1.4 Drilling Contractor

The drilling contractor is the company name of the subcontracting drilling firm and the name of the driller.

3.1.5 Date Started and Date Completed

This should include the month, day and year that drilling started and was completed on a hole to hole basis.

3.1.6 Field Rep.

This is the person's name who is filling out the Borehole Log (Soil).

3.1.7 Groundwater Levels

Water levels in boreholes should be recorded when water is first encountered during the drilling and then at least one, if not more, water level measurements after drilling has been completed and the borehole left open or a piezometer and/or monitoring well has been installed.

3.1.8 Location Description

This is the written description of the approximate borehole location in respect to some permanent, topographic or geographic location nearby.

3.1.9 Location Map

This is the graphic description of the approximate borehole location in respect to some permanent, topographic or geographic location nearby.

3.1.10 Site Condition

This is a brief statement about the topography, vegetative cover, etc., that is at the borehole location.

3.1.11 Depth Column

This is a numerical designation and generally depicts lithologic soil boundaries. Each space is usually designated as being equal to 1.0 feet of depth below ground surface. The Borehole Log (Soil) represents 30.0 feet of borehole. Depths shall be recorded on the Borehole Log (Soil) in feet and fractions thereof (tenths). Note that computer entries for depths are only accepted in feet and tenths of feet, not inches.

CONVERSION TABLE
INCHES TO TENTHS OF FEET

Inches	Tenths of Feet
1	.08
2	.17
3	.25
4	.33
5	.42
6	.50
7	.58
8	.67
9	.75
10	.83
11	.92
12	1.00

3.1.12 Sample Interval

This is the designated starting and ending depth of the appropriate sampling technique. The following table summarizes common sample length intervals.

Sampling Device	Sample Interval (Feet)
SPT	1.5 or 2.0
Large diameter ring sample	1.0, 1.5 or 2.0
Shelby tube	2.0

It should be noted that if the designated sample is 1.5 feet (SPT) but in actuality the SPT only penetrates 0.5 feet (or some length less than the sample interval) in 50 blows per 6 inches or less (refusal below count) the graphical representation for the sample interval is still 1.5 feet.

3.1.13 Sample Recovery

This is the numerical representation of the actual sample recovered by the respective sampling method.

3.1.14 Sample Retained

This is the numerical representation of actual sample retained for future laboratory testing or sample storage. This number cannot be larger than what the sample recovery number is. If no sample is retained place "NR," for not retained, in the space provided.

3.1.15 Type

This refers to what sampling method was employed to retain a subsurface soil sample. Sample types are listed below and for the TR/FTR's convenience, the box in the lower right hand corner of the Borehole Log (Soil) lists sample types.

Sample Types

A - Auger cuttings
S - 2 in. O.D. 1.38 in. I.D. drive sample
U - 3 in. O.D. 2.42 in. I.D. tube sample
T - 3 in. O.D. thin-walled Shelby tube

3.1.16 ID

This is always a two-digit number with a range of 01 through 99 assigned to ensure that data collected retains uniqueness from other data collected when ambiguity is possible especially when multiple soil samples are taken in the same borehole. Each borehole sampled will have the same ID start with 01. If no sample is recovered a two-digit number, used in the established sequence, shall still be used to indicate an SPT was taken.

3.1.17 Blows Per 6 Inch

Count and record number of blows required for each 6 inches of the 18 (or 24 inch) SPT.

3.1.18 "N" Value

This is the sum of the number of blows in the last two, 6 inch intervals of the SPT.

3.1.19 USCS

The Unified Soil Classification System (USCS) provides a method of grouping unconsolidated earth materials according to their engineering properties. It is based on soil behavior, which is a reflection of the physical properties of the soils and its constituents. For the purpose of classifications, the system established 16 soil groups, each having distinctive engineering properties. Boundary classifications are provided for soils which have characteristics of two groups.

3.1.20 Visual Classification

Soil descriptions shall be in accordance with ASTM Designation: D 2488-69 Standard Recommended Practice for Description of Soils (Visual-Manual Procedure). When describing coarse-grained soils Table 2 should be used with the partial omission of the use of the Munsell notation, No. 78 and omit No. 6 entirely. When describing fine-grained soils Table 4 should be used omitting No's 4, 5 and 6 entirely and partially omitting No. 8; do not use the Munsell notation. These descriptions will be prepared in the field by the geologist and shall be subject to change based upon laboratory tests or subsequent review. To assist the TL/FTL, the following sections are designed as an aid in pointing out some of the parameters used in describing the soil.

USCS	VISUAL CLASSIFICATION
CL	Sandy Clay, low plastic, fine, moist, rootlets, dark yellowish brown. TOPSOIL
SP	Sand, fine w/trace fine gravel, moist, light brown. River alluvium
SM	Silty Sand, fine w/some silt, wet, brown. River alluvium

3.1.21 Soil and Rock Shorthand for Description

Consistency

Ls	Loose
Fm	Firm
Ds	Dense
VDs	Very Dense
VSo	Very Soft
So	Soft
ST	Stiff
Hd	Hard

Color

Gr	Gray
Br	Brown
Tn	Tan
Yel	Yellow
R	Red
Blk	Black
Grn	Green
W	White
O	Orange
Ma	Maroon
Ol	Olive

Soil Texture - Composition

CB	Cobbles	Ang	Angular	Lt	Light
Bd	Boulder	Rnd	Rounded	Cem	Cemented
Gv	Gravel	Cly	Clayey	S	Some
Sa	Sand	Sny	Sandy	Tr	Trace
Si	Silt	Sty	Silty	M	Moderately
Cl	Clay	L	Low	Pr	Predominantly
OL	Organic	M	Medium	NP	Non-Plastic
PT	Peat	H	High	Occ	Occasional
Cal	Calcarenous	Pl	Plastic	T	Thick
Shl	Shells	N	Non	Bd	Bedded
Lat	Lateritic	V	Very	Hd	Hard
Cs	Coarse	Dk	Dark	TN	Thin
Fi	Fine				

Rock		Details	
Ss	Sandstone	Slc	Slickensides
Sh	Shale	Sm	Seam
St	Siltstone	Lns	Lens
Ct	Claystone	Por	Porous
Lg	Lignite	WT	Water Table
Cg	Conglomerate	W	Weathered
Ls	Limestone	Jt	Jointed
Do	Dolomite	Dec	Decomposed
Gy	Gypsum	Cav	Cavity
Gr	Granite	Rt	Roots
Ba	Basalt	Con	Concretions
Sa	Salt	Mod	Modular
Di	Diorite	Mot	Mottled
Tf	Tuff	Vv	Varved
Ry	Rhyolite	Ban	Banded
Gn	Gneiss	Stg	Stringers
Qt	Quartzite	Smo	Smooth
Sl	Slate	Cln	Clean
		Rh	Rough
		Sl	Slight

3.1.22 Grain Size Identification

Name	Symbol	Size Limits	Familiar Example
Boulder	Bd	12 in. (305 mm) to 36 in. (914 mm)	Larger than basketball
Cobbles	Cb	3 in. (76 mm) to 12 in. (305 mm)	Grapefruit
Coarse gravel	CsGv	3/4 in. (19 mm) to 3 in. (76 mm)	Orange or lemon
Fine gravel	FiGv	4.76 mm (No. 4 Sieve) to 3/4 in. (19 mm)	Grape or pea
Coarse sand	CsSa	2 mm (No. 10 Sieve) to 4.76 mm (No. 4 Sieve)	Rocksalt
Medium sand	MSa	0.42 mm (No. 40 Sieve) to 2mm No. 10 Sieve)	Sugar, table salt

3.1.22 Grain Size Identification (Cont'd)

Name	Symbol	Size Limits	Familiar Example
Fine sand*	FiSa	0.074 mm (No. 200 Sieve) to 0.42 mm (No. 40 Sieve)	Powdered sugar
Fines		Less than 0.074 mm (No. 200 Sieve)	

*Particles finer than fine sand cannot be discerned with the naked eye at a distance of 8 in. (20 cm).

3.1.23 Plasticity

Term	Symbol	PI	Dry Strength	Field Test (Dry Cubes)
Nonplastic	NP	0-3	Very low	Falls apart easily
Slightly plastic	SlPl	4-15	Slight	Easily crushed with fingers
Medium plastic	MPl	15-30	Medium	Difficult to crush
Highly plastic	HPl	31 or higher	High	Impossible to crush more with fingers

3.1.24

If greater than 50 percent by weight of the soil to be classified passes the No. 200 sieve, then the following modifiers are applicable:

Modifiers for Granular Portion		Examples
Trace (Tr)	0-15%	silty clay with trace fine sand - CL
Some (S)	15-30%	clayey silt with some coarse gravel - ML
Use Modifier	30-40%	fine to coarse sandy silt - ML
Use Dual Callout for 40%-60% Granular and/or Fine Grained (passing #200 Portion		fine to coarse sand and silt - SM/ML

3.1.25

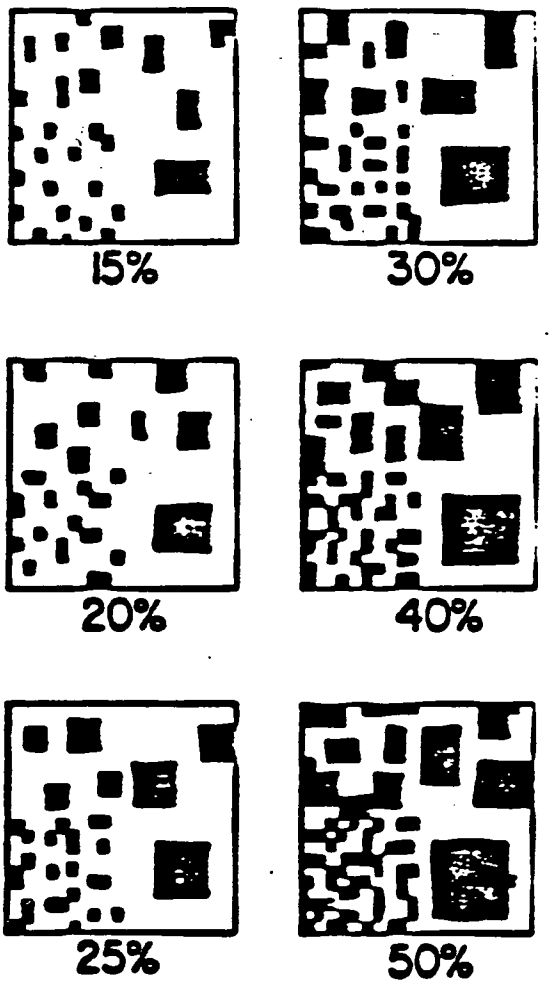
If greater than 50 percent by weight of the soil to be classified is retained on the #200 sieve, then the following modifiers are applicable:

Modifiers for Fine Grained (Passing #200) Portion		Example
Trace (Tr)	0-5%	fine sand with trace clay - SP

Modifiers for Fine Grained (Passing #200) Portion		Example
Some (S)	5-12%	fine sand with some silt - SM/SP
Use Modifier	12-40%	silty fine sand - SM

Modifiers for Coarse Grained Portion		Example
Trace (Tr)	0-15%	silty fine & coarse gravel with trace fine sand - GM
Some (S)	15-30%	coarse gravel with some fine sand - GP
Use Modifier	30-40%	coarse gravelly fine to coarse sand - SW

The following diagram illustrates percentages of material and what the appropriate estimation of those percentages are. These charts are particularly useful for estimating oversized materials in the sidewalls of a test pit.



Each fourth of any one square has the same amount of black

3.1.26 Describing Soil Structures

The structure of the soil must be determined by careful observation. The following descriptive terms may be used:

Homogeneous (uniform properties)
Stratified (alternate layers of different soils)
Laminated (repeating alternate layers less than 1/8" thick)
Banded (alternate layers in residual soils)

It is important to recognize defects in a soil structure. The following are often observed:

Slickensides (former failure planes)
Rootholes
Fissures (cracks, from shrinkage, frost)
Weathering (irregular discoloration)

3.1.27 Cohesive and Cohesionless Soils

A. Cohesive Soils

Term	Symbol	Field Identification	q_u (T.S.F.)	SPT Penetration "N" Values Blows/Foot
Very soft	VSO	Easily penetrated several inches by fist	<0.25	< 2
Soft	SO	Easily penetrated several inches by thumb	0.25 - 0.5	2 - 4
Med. stiff	Mst	Can be penetrated several inches by thumb with moderate effort	0.5 - 1.0	4 - 8
Stiff	St	Readily indented with thumb, but penetrated only with great effort	1.0 - 2.0	8 - 15
Very stiff	VSt	Readily indented by thumbnail	2.0 - 4.0	15 - 30
Hard	Hd	Indented with difficulty by thumbnail	>4.0	>30

A. Cohesionless Soils

Term	Symbol	Field Identification	q_u (T.S.F.)	SPT Penetration "N" Values Blows/Foot
Very loose	VLS	Easily penetrated with ½-inch re-bar pushed by hand	0 - 20	0 - 4
Loose	LS	Same as above	20 - 40	5 - 10
Med. dense	MDS	Easily penetrated with ½-inch re-bar driven with 5 lb. hammer	40 - 70	11 - 30
Dense	DS	Penetrated 1 foot with a ½-inch re-bar driven with 5 lb. hammer	70 - 90	31 - 50
Very dense	VDS	Penetrated only a few inches with a ½-inch re-bar driven with 5 lb. hammer	90 - 100	> 50

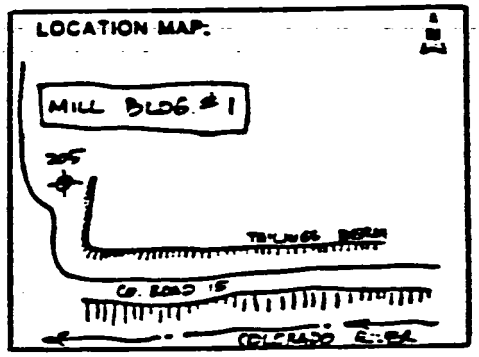
3.2

This section details the procedures and required information for completing the Borehole Log (Rock) form.

The TL/FTL is referred to the ASTM Designation: D 2113-83 Standard Practice for Diamond Core Drilling for Site Investigation which accompanies this manual at the end of this section.

BOREHOLE LOG (ROCK) Page 1 of 1

LOCATION MAP:



SITE ID: GRJ 01 LOCATION ID: 205
SITE COORDINATES (ft.):
N NK E NK
GROUND ELEVATION (ft. MSL): NK
DRILLING METHOD: ROTARY - AIR
DRILLING CONTR.: WESTERN STATE J. NICKS
DATE STARTED: 2-5-83
DATE COMPLETED: 2-5-83
FIELD REP.: P.S. DARR

GROUNDWATER LEVELS		
DATE	TIME	DEPTH (ft.)
2-5-83	1:30 pm	63.2
2-6-83	7:30 am	63.0
2-6-83	6:15 pm	50.0

LOCATION DESCRIPTION NW corner of tailings berm — 150 FT SE of mill building.
SITE CONDITION Flat - barren rocky surface.

3.2.1 Site ID and Location ID

The site ID and location ID must conform to the Coded Data Definitions previously designated for this site and borehole sequence.

3.2.2 Site Coordinates and Ground Elevation

The site coordinates refers to the horizontal location of the borehole and along with the ground elevation will probably not be known by the TL/FTL at the time of drilling. In this case, NA or NK should be placed in each of these three (3) spaces. If appropriate site coordinates for a borehole are known, provide these in the appropriate northing and easting spaces. Regardless of the situation, this information is provided when the survey data comes in after the drilling program has been completed.

3.2.3 Drilling Method

The drilling method will most likely be NX size rock coring. NQ size rock coring may also be utilized.

3.2.4 Drilling Contractor

The drilling contractor is the company name of the subcontracting drilling firm and the name of the driller.

3.2.5 Date Started and Date Completed

This should include the month, day and year that drilling started and was completed on a hole to hole basis.

3.2.6 Field Representative

This is the person's name who is filling out the Borehole Log (Rock).

3.2.7 Groundwater Levels

Water levels in boreholes should be recorded when water is first encountered during the drilling and then at least one, if not more, water level measurements after drilling has been completed and the borehole left open or a piezometer and/or monitoring well has been installed.

3.2.8 Location Description

This is the written description of the approximate borehole location in respect to some permanent, topographic or geographic location nearby.

3.2.9 Location Map

This is the graphical description of the approximate borehole location in respect to some permanent, topographic or geographic location nearby.

3.2.10 Site Condition

This is a brief statement about the topography, vegetative cover, etc., that is at the borehole location.

3.2.11 Depth Column

This is a numerical designation and generally depicts lithologic rock boundaries. Each space is usually designated as being equal to 1.0 feet of depth below ground surface. The Borehole Log (Rock) represents 25 feet of borehole. Depths shall be recorded on the Borehole Log (Rock) in feet and fractions thereof (tenths). Note that computer entries for depths are only accepted in feet and tenths of feet, not inches.

CONVERSION TABLE
INCHES TO TENTHS OF FEET

Inches	Tenths of Feet
1	.08
2	.17
3	.25
4	.33
5	.42
6	.50
7	.58
8	.67
9	.75
10	.83
11	.92
12	1.00

3.2.12 Boring Operation

The boring operation could be, but is not limited to, hollow stem auger (HSA) drilling, conventional flight auger, gear bit, NX rock coring and/or NQ wireline rock coring. For the TL/FTL's convenience, the box in the lower right hand corner of the Borehole Log (Rock) lists boring operation.

Boring Operations

H - 6 1/2 in. Hollow Stem Auger
C - 4 1/2 in. Continuous Flight Auger
GB - Gearbit (Specify diameter)
NX - NX Rock Coring
NQ - NQ Wireline Rock Coring

3.2.13 Percent Core Recovery

Once the Core is presented to the TL/FTL, preferably while still in the core barrel if it is a split core barrel, the total length recovered can be measured and, when divided by the length of run, a percent recovery can be obtained. Sometimes it is possible to determine where in the run core loss occurred. The following clues are sometimes present: (1) plugging off during drilling, (2) intense fracturing in certain sections of core, possibly can be correlated with rough, high vibrations during drilling, and (3) when excessive core loss is experienced, you will find rolled and recut pieces of core. Record recovery of core to the nearest 5 percent.

3.2.14 Rock Quality Designation (RQD)

The Rock Quality Designation (RQD) is only for NX size core samples and is computed by summing the lengths of all pieces of core equal to or longer than 4 inches and dividing by the total length of the coring run. One call per run. The result is multiplied by 10 to get RQD in percent.

$$RQD = \frac{\text{Length} > 4''}{\text{Core Run}} \times 100$$

It is necessary to distinguish between natural fractures and those caused by the drilling or recovery operations. The fresh, irregular breaks should be indicated and the pieces counted as intact lengths. Depending on the engineering requirements of the project, breaks induced along high anisotropic planes, such as foliation or bedding, may be counted as natural fractures.

By definition, rock which falls in the soft to slightly hard categories has no RQD. Rocks of this category are usually soft, wet claystones, siltstones, and fine-grained, weakly-cemented sandstones. Lengths which contain strong and recemented fractures should be measured in total. Record to nearest 5 percent.

RQD %	Rock Mass Quality
90 - 100	Excellent
75 - 90	Good
50 - 75	Fair
25 - 50	Poor
0 - 25	Very Poor

3.2.15 Percent Drilling Fluid Recovery

Record on the Borehole Log (Rock) fluid losses and the interval over which they occur, giving some idea as to the quantity lost; e.g., "no fluid loss" to mean that no fluid was apparently lost other than through spillage and filling the hole; "partial fluid loss" meaning though a return was achieved, the amount of return was significantly less than the amount being pumped; and "complete water loss" meaning that no fluid returned to the surface during pumping operation. A combination of the TL/FTL and the driller's opinions on this matter will result in the best estimate. A crude but relatively effective estimate can be made by placing a calibrated stick in the mud pit, followed by estimating the return flow, and an estimate as to the volume of the pit at 1/2 to 1 foot interval on the stick. The pumping rate can be obtained by measuring elapsed time to withdraw a specific volume from the pit without return. After estimating the return flow, a percentage can be obtained. Return flow can sometimes be crudely measured with a 5-gallon bucket.

A change in the fluid recovery rates must be recorded. If the recovery is essentially the same for an entire core run, only one call per change is necessary. Record to the nearest 10 percent.

3.2.16 Packer Test

This is a graphical representation which requires a line be placed in the column provided denoting the bottom of the top packer and the top of the bottom packer.

3.2.17 Spacing

Describe spacing of discontinuities as close, wide, etc., in accordance with the following:

Spacing	Description for Structural Features: Bedding, Foliation, or Flow Banding	Symbol	Description for Joints, Faults or Other	Symbol
(1) More than 6 feet	Very thickly (bedded, foliated, or banded)	VT	Very widely (fractured or jointed)	(VW)
(2) 2 - 6 feet	Thickly	T	Widely	(W)
(3) 8 - 24 inches	Medium	M	Medium	(M)
(4) 2½ - 8 inches	Thinly	TN	Closely	(C)
(5) 3/4 - 2½ inches	Very thinly	VTN	Very closely	(VC)

Not common, but when encountered, the following should be noted in the remarks column. In describing structure features, describe rock mass as thickly bedded or thinly bedded in accordance with the above criteria. Depending on the project requirements, identify he form of joint (stepped, smooth, undulating, planar, etc.), its dip (in degrees), its surface (rough, smooth, slickensided), its opening (giving width), and its filling (none, sand, clay, breccia, etc.).

3.2.19 Condition

This refers to the roughness and amount of in filling in the fractures. Examples of condition description are: Smooth, clean, rough, stained, etc. Use abbreviations detailed in Section 3.1.21.

3.2.20 Weathering

Describe as fresh, slightly weathered, etc., in accordance with the following:

Grade	Symbol	Diagnostic Features
Fresh	F	No visible sign of decomposition or discoloration. Rings under hammer impact.
Slightly	SlW	Slight discoloration inwards from open fractures, otherwise similar to F.
Moderately Weathered	MW	Discoloration throughout. Weaker minerals such as feldspar decomposed. Strength somewhat less than fresh rock but cores cannot be broken by hand or scraped by knife. Texture preserved.
Highly Weathered	HW	Most minerals somewhat decomposed. Specimens can be broken by hand with effort or shaved with knife. Core stones present in rock mass. Texture becoming indistinct but fabric preserved.
Completely Weathered	CW	Minerals decomposed to soil but fabric and structure preserved (Saprolite). Specimens easily crumbled or penetrated.
Residual Soil	RS	Advanced state of decomposition resulting in plastic soils. Rock fabric and structure completely destroyed. Large volume change.

CAUTION: Soft rock is not necessarily weathered. Look for signs of alteration, etc., which indicates true weathering.

BORING OPERATION	% CORE RECOVERY	% ROCK QUALITY DESIGNATION (RQD)	% DRILLING FLUID RECOVERY	PACKER TEST INTERVAL	SPACING	ORIENTATION	CONDITION	WEATHERING
NX	92	78	90		T	10	Cln	Slw
					M			F
	↓	↓	↓					
NX	83	64	90		TN	10	Cln	
					VTN			
					TN			
						75	Rh	
						10	Cln	
	↓	↓	↓					

3.2.21 Lithology

Geological Classification. Identify the rock by geologic name and local (if any). A simplified classification is given herein. Identify subordinate constituents in rock sample such as seams or bands or other type of minerals, e.g., dolomitic limestone, calcareous sandstone, sandy limestone, mica schist. Example of typical description: Sandstone, coarse, shaly, fresh, moderately close fractured, gray.

The following outlines diagnostic lithologic classifications for determining common igneous, sedimentary and metamorphic rocks. The rock shorthand description in Section 3.1.21 should be used in Lithology column.

Common Igneous Rocks					
Color	Light		Intermediate	Dark	
Principle Mineral	Quartz & Feldspar Other Minerals Minor	Feldspar	Feldspar & Hornblende	Augite and Feldspar	Augite Hornblen Olivine
Texture					
Coarse, Irregular, Crystalline	Pegmatite	Syenite pegma-tite	Diorite pegma-tite	Gabbro pegma-tite	
Coarse and Medium Crystalline	Granite	Syenite	Diorite	Gabbro	Peridoti
			Dolerite		
Fine Crystalline	Aplite			Diabase	
Aphanitic	Felsite			Basalt	
Glassy	Volcanic glass			Obsidian	
Porous (Gas Openings)	Pumice		Scoria or vesicular basalt		
Fragmental	Tuff (fine), breccia (coarse), cinders (variable)				

Common Sedimentary Rocks				
Group	Grain Size	Composition		Name
Clastic	Mostly Coarse Grains	Rounded pebbles in medium-grained matrix		Conglomerate
		Angular coarse rock fragments, often quite variable		Beccia
	More than 50% of medium grains	Medium quartz grains	Less than 10% of other minerals	Siliceous sandstone
			Appreciable quantity of clay minerals	Argillaceous sandstone
			Appreciable quantity of calcite	Calcareous sandstone
			Over 25% feldspar	Arkose
			25-50% feldspar and darker minerals	Graywacke
	More than 50% fine grain size	Fine to very fine quartz grains with clay minerals		Siltstone (if laminated, shale
		Micro-scopic clay minerals	10% other minerals	Shale
			Appreciable calcite	Calcareous shale
			Appreciable carbon-aceous material	Carbonaceous sha
			Appreciable iron oxide cement	Ferruginous shal

Common Sedimentary Rocks			
Group	Grain Size	Composition	Name
Organic	Variable	Calcite and fossils	Fossiliferous limestone
	Medium to microscopic	Calcite and appreciable dolomite	Dolomite limestone or dolomite
	Variable	Carbonaceous material	Bituminous coal
Chemical	Microscopic	Calcite	Limestone
		Dolomite	Dolomite
		Quartz	Chert, Flint, etc.
		Iron compounds with quartz	Iron formation
		Halite	Rock salt
		Gypsum	Rock gypsum

Common Metamorphic Rocks			
Texture	Structure		
	Foliated		Massive
Coarse Crystalline	Gneiss		Metaquartzite
Medium Crystalline	Schist	(Sericite) (Mica) (Talc) (Chlorite) (etc.)	Marble Quartzite Serpentine Soapstone
Fine to Microscopic	Phyllite Slate		Hornfels Anthracite coal

LITHOLOGY	ROCK TYPE & REMARKS
Ss	Sandstone, very fine, moist, hard, gray. MENEFEE FM.
Sh	Shale, trace very fine sand, dry, soft, dark gray. MENEFEE FM.
Lg	Lignite, wet, very soft, black.
Sh	Shale, dry, soft, dark gray. MENEFEE FM
Ss	Sandstone, fine, moist, hard, grayish brown.

3.2.22 Color and Grain Size

Describe with respect to the basic color of the rock. Use the following term to describe grain size:

1. For Igneous and Metamorphic Rocks:

   coarse-grained - grain diameter >5 mm
   medium-grained - grain diameter 1 - 5 mm
   fine-grained - grain diameter <1 mm
   aphanitic - grain size is too small to be perceived by unaided eye
   glassy - no grain form can be distinguished

2. For Sedimentary Rocks

   coarse-grained - grain diameter >2 mm
   medium-grained - grain diameter = 0.06 - 2 mm
   fine-grained - grain diameter = 0.002 - 0.06 mm
   very fine-grained - grain diameter <0.002 mm

3. Use 10X hand lens if necessary to examine rock sample.

3.3.23 Hardness Classification

Describe as very soft, soft, etc., in accordance with the following:

Class	Hardness	Symbol	Field Test
I	Extremely hard	EM	Many blows with geologic hammer required to break intact specimen.
II	Very hard	VH	Hand held specimen breaks with hammer end of pick under more than one blow.
III	Hard	H	Cannot be scraped or peeled with knife, hand held specimen can be broken with single moderate blow with pick.
IV	Soft	SO	Can just be scraped or peeled with knife. Indentations 1 mm to 3 mm show in specimen with moderate blow with pick.
V	Very soft	VSO	Material crumbles under moderate blow with sharp end of pick and can be peeled with a knife, but is too hard to hand-trim or triaxial test specimen.

3.2.24 Boxing the Core

The cores should be clean from all drilling fluid before being placed into the core box. The core should be placed in the core box as illustrated below. The label spaces provided on the core box should be filled out completely. If no label space is present the following information should be placed in the outside of the core box:

Project name
Site identification
Starting depth
Ending depth
Date sampled
Field representative
Box __ of __

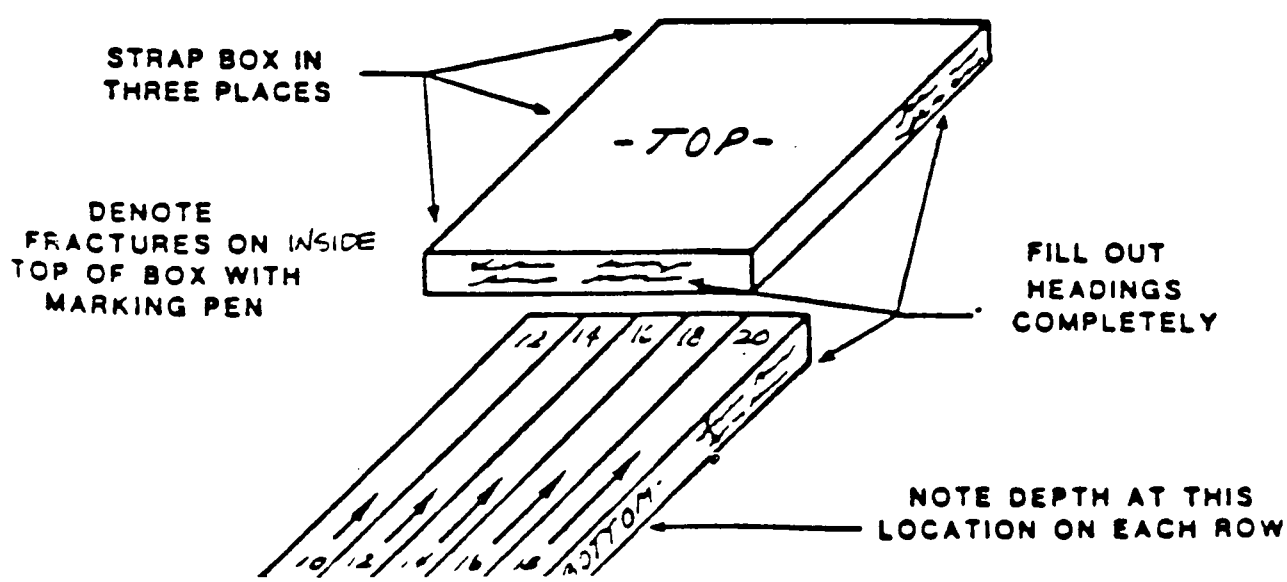
Also on the inside top of the core box indicate natural breaks (fractures and joints) where they occur in the boxed core. This will help the person editing the core in the laboratory to identify between natural breaks and those breaks related to boxing and shipping of the core.

If core is susceptible to air slacking, the core must be sealed in tubular plastic bags.

Use 2-by-2-inch wood blocks to designate major core loss.

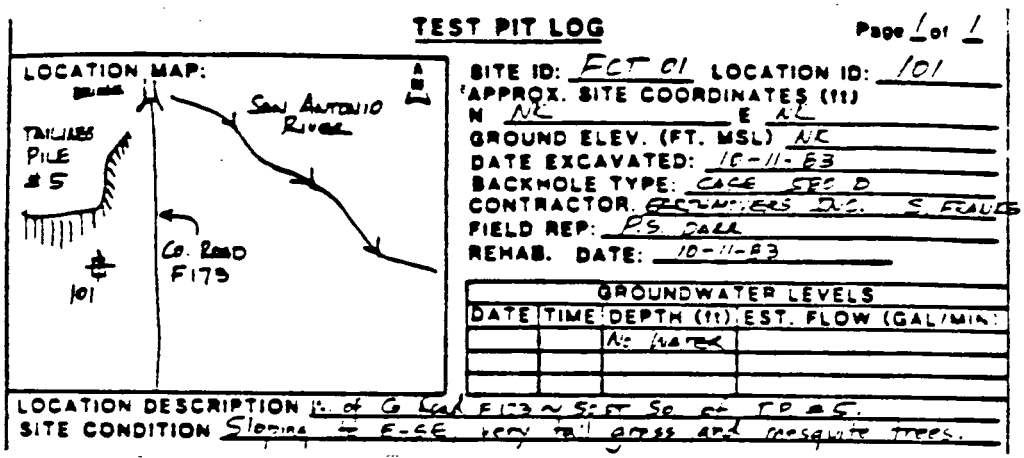
Use indelible pen on boxes.

Seal core box with three strips of strapping tape.



3.3

This section details the procedure and required information for completing the Test Pit Log form. The TL/FTL is referred to the ASTM Designation: D 2487-83 Standard Test Method for Classification of Soils for Engineering Purposes and ASTM Designation D 2488-69 Standard Recommended Practice for Description of Soils (Visual-Manual Procedure) which accompanies this manual at the end of this section.


TEST PIT LOG

Page 1 of 1

LOCATION MAP:

SITE ID: FCT 01 LOCATION ID: 101

APPROX. SITE COORDINATES (ft)

N NK E NK

GROUND ELEV. (FT. MSL) NK

DATE EXCAVATED: 10-11-83

BACKHOLE TYPE: CASE SES D

CONTRACTOR: ECTIMERS D.C. S. FRANCS

FIELD REP: P.S. CALL

REHAB. DATE: 10-11-83

GROUNDWATER LEVELS			
DATE	TIME	DEPTH (ft)	EST. FLOW (GAL/MIN)
		No Water	

LOCATION DESCRIPTION

SITE CONDITION

3.3.1 Site ID and Location ID

The site ID and location ID must conform to the coded Data Definitions previously designated for this site and borehole sequence. The TL/FTL should look at Section 3 of the Project's Field Task Leader Manual for further clarification of the Coded Data Definitions.

3.3.2 Site Coordinates and Ground Elevation

The site coordinates refers to the horizontal location of the borehole and along with the ground elevation will probably not be known by the TL/FTL at the time of drilling. In this case, NA or NK should be placed in each of these three (3) spaces. If approximate site coordinates for a borehole are known, provide these in the appropriate northing and easting spaces. Regardless of the situation, this information is provided when the survey data comes in after the test pit excavation program has been completed.

3.3.3 Date Excavated

This should include the month, day and year the test pit was excavated.

3.3.4 Backhoe Type

This should include the manufacturer's name and model number of the backhoe.

3.3.5 Contractor

The backhoe contractor is the name of the subcontracting backhoe firm and the backhoe operator's name.

3.3.6 Field Representative

This is the person's name who is filling out the Test Pit Log.

3.3.7 Rehabilitation Date

This refers to the date at which time the excavated pit was backfilled and the appropriate grass seed mixture spread across the disturbed land surface.

3.3.8 Groundwater Levels

In an open excavated test pit water, when encountered, will most likely be seeping from one or more sidewalls of the test pit. Note the depth at which the seep originates and estimate the flow rate, in gallons per minute (gpm), of water the seep is producing.

3.3.9 Location Description

This is the written description of the approximate test pit location in respect to some permanent, topographic or geographic location nearby.

3.3.10 Location Map

This the graphic description of the approximate test pit location in respect to some permanent, topographic or geographic location nearby.

3.3.11 Site Condition

This is a brief statement about the topography, vegetative cover, etc., that is at the test pit location.

3.3.12 Depth Column

This is a numerical designation and generally depicts lithologic soil boundaries. Each space is usually designated as being equal to 1.0 feet of depth below ground surface. The Test Pit Log represents 30.0 feet of excavation. Depths shall be recorded on the Test Pit Log in feet and fractions thereof (tenths). Note that computer entries for depths are only accepted in feet and tenths of feet, not inches.

CONVERSION TABLE
INCHES TO TENTHS OF FEET

Inches	Tenths of Feet
1	.08
2	.17
3	.25
4	.33
5	.42
6	.50
7	.58
8	.67
9	.75
10	.83
11	.92
12	1.00

3.3.13 Sample Interval

This is a graphical representation depicting the interval from which the sample was collected from.

3.3.14 Type

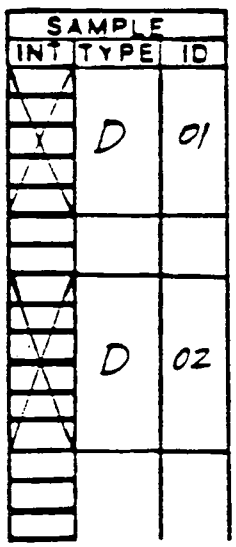
This refers to the type of sample taken. for the TR/FTR's convenience, the box in the lower right hand corner of the Test Pit Log lists the two sample types.

SAMPLE TYPE

B - Undisturbed Block Sample
D - Disturbed Bulk Sample

3.3.15 ID

This is always a two-digit number with a range of 01 through 99 assigned to ensure that data collected retains uniqueness from other data collected when ambiguity is possible especially when multiple soil samples are taken in the same test pit. Each test pit sampled will have the sample ID start with 01.



UNIFIED SOIL CLASS.	VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC.
CL	Sandy Clay, low plastic, fine, moist to wet, dark yellowish brown.
SM	Silty Sand, fine w/ some silt, moist, yellowish brown

3.3.16 Unified Soil Classification System

The Unified Soil Classification System (USCS) provides a method of grouping unconsolidated earth materials according to their engineering properties. It is based on soil behavior, which is a reflection of the physical properties of the soil and its constituents. For the purpose of classifications, the system established 15 soil groups, each having distinctive engineering properties. Boundary classifications are provided for soils which have characteristics of two groups.

3.3.17 Visual Classification

Soil descriptions shall be in accordance with ASTM Designation: D 2488-69 Standard Recommended Practice for Description of Soils (Visual-Manual Procedure). When describing coarse-grained soils Table 2 should be used with the partial omission of the use of the Munsell notation No. 7, and omit No. 6 entirely. When describing fine-grained soils Table 4 should be used omitting No's 4, 5, and 6 entirely and partially omitting the use of the Munsell notation, No. 8. These descriptions will be prepared in the field by the geologist and shall be subject to change based upon laboratory tests or subsequent review. To assist the TR/FTR, sections 3.1.21 through 3.1.27 are designed as an aid in pointing out some of the parameters used in describing the soil.

3.3.18

Basically, three methods of sampling a test pit can be used.

1. Strip sampling of the pit involves the vertical cutting of a representative sample from each distinctive lithologic unit of the test pit wall.

2. Undisturbed block sampling can also be performed within a test pit. Normally, the block sample size is approximately 1 foot square. Microcrystalline wax sealing and proper storage and shipment is essential for block samples to avoid drying and breakage.

3. Another method sometimes employed when the test pit is inaccessible or ground water is infiltrating the excavation consists of having the backhoe operator selectively dig in certain lithologic units.

WESTON

BOREHOLE LOG (SOIL)

LOCATION MAP: N

SITE ID: _____ LOCATION ID: _____
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: _____
DRILLING CONTR.: _____
DATE STARTED: _____
DATE COMPLETED: _____
FIELD REP.: _____

GROUNDWATER LEVELS		
DATE	TIME	DEPTH (ft.)

LOCATION DESCRIPTION _____
SITE CONDITION _____

DEPTH	SAMPLE INTERVAL	SAMPLE RECOVERY	SAMPLE RETAINED	TYPE	ID	BLOWS PER 6 in.	N VALUE	USCS	VISUAL CLASSIFICATION

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COMMENTS: _____

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

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BOREHOLE LOG (ROCK)

Page ___ of ___

LOCATION MAP:

SITE ID: _____ LOCATION ID: _____
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: _____
DRILLING CONTR.: _____
DATE STARTED: _____
DATE COMPLETED: _____
FIELD REP.: _____

GROUNDWATER LEVELS		
DATE	TIME	DEPTH (ft.)

LOCATION DESCRIPTION _____
SITE CONDITION _____

DEPTH (FT.)	BORING OPERATION	% CORE RECOVERY	% ROCK QUALITY DESIGNATION (RQD)	% DRILLING FLUID RECOVERY	PACKER TEST INTERVAL	SPACING	ORIENTATION	CONDITION	WEATHERING	LITHOLOGY	ROCK TYPE & REMARKS

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COMMENTS: _____

BORING OPERATION
H - 6 1/2 HOLLOW STEM-AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NQ - NQ WIRELINE ROCK CORING

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BOREHOLE AND TEST PIT SUMMARY

SITE ID: _____
LOCATION ID: _____
LOCATION COORDINATES:
N _____
E _____
GROUND ELEVATION (FT. MSL): _____

BH-BOREHOLE/TP-TEST PIT: _____
DRILLER/EXCAVATOR: _____
COMPLETION DATE: _____
BOREHOLE DIAMETER (IN): _____
TOTAL DEPTH (FT.): _____

WELL SUMMARY

WELL OWNER: _____
INSTALLER: _____
INSTALLATION DATE: _____
CASING ELEV. (FT. MSL): _____
CASING LENGTH (FT.): _____
CASING DIA. (IN.): _____
SEAL (END) DEPTH (FT.): _____

FILTER PACK LENGTH (FT.): _____
FORMATION OF COMPLETION: _____
STRATIGRAPHIC ORDER: _____
OPEN/SCREEN DEPTH (FT.): _____
OPEN/SCREEN LENGTH (FT.): _____
OPEN/SCREEN AREA ($IN.^2/FT.$): _____
*FLOW RELATIONSHIP: _____

LITHOLOGICAL SUMMARY

SOIL/ROCK PROFILE				STD. PENETRATION TEST			
DEPTH (FT.)	UNIFIED SOIL/ROCK CLASS	STRAT. ORDER	VISUAL DESCRIPTION	SAMPLE ID	DEPTH INTERVAL (FT.)	SAMPLE METHOD	N VALUE

436

FLOW RELATIONSHIP:
U-Upgradient
D-Downgradient
C-Cross Gradient
O-On Site
N-Not Known

SAMPLE METHODS:
A-Auger Cuttings
S-2"O.D. 1.38"I.D. drive sample
U-3"O.D. 2.42"I.D. tube sample
T-3" O.D. thin-walled Shelby tube
H-6 1/2 Hollow Stem Auger
C-4 1/2 Continous Flight Auger
GB-Gear Bit
NX-NX Rock Coring
NQ-NQ Wireline Rock Coring
B-Undisturbed Block Sample
D-Disturbed Bulk Sample

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LITHOLOGICAL SUMMARY

PAGE ____ OF ____

SOIL/ROCK PROFILE				STD. PENETRATION TEST			
DEPTH (FT)	UNIFIED SOIL/ ROCK CLASS	STRAT. ORDER	VISUAL DESCRIPTION	SAMPLE ID	DEPTH INTERVAL (FT)	SAMPLE METHOD	N VALUE
						437	

SAMPLE METHODS

A - AUGER CUTTINGS
S - 2" O.D. 1.38" I.D. DRIVE SAMPLE
U - 3" O.D. 2.42" I.D. TUBE SAMPLE
T - 3" O.D. THIN-WALLED SHELBY TUBE
H - 6 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NQ - NQ WIRELINE ROCK CORING
B - UNDISTURBED BLOCK SAMPLE
D - DISTURBED BULK SAMPLE

UNIFIED SOIL CLASSIFICATION SYSTEM

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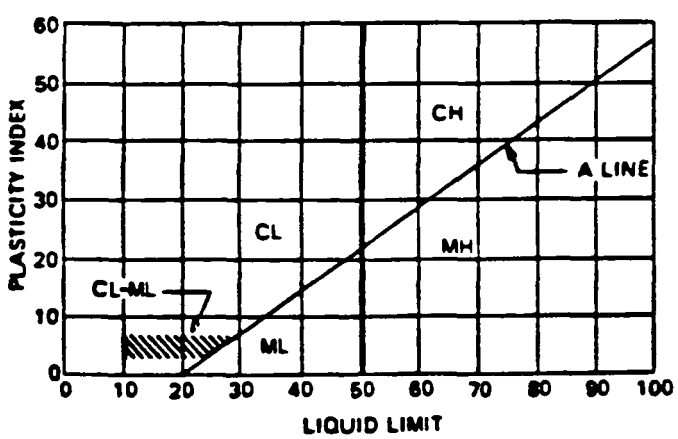
Soils are visually classified by the Unified Soil Classification system on the boring logs presented in this report. Grain-size analysis and Atterberg Limits Tests are often performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. For a more detailed description of the system, see "The Unified Soil Classification System" Corp of Engineers, US Army Technical Memorandum No. 3-357 (Revised April 1960) or ASTM Designation: D2487-66T.

MAJOR DIVISIONS				GRAPHIC SYMBOL	GROUP SYMBOL	TYPICAL NAMES
COARSE-GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (50% or less of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)			GW	Well graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures.
					GP	Poorly graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures.
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		GM	Silty gravels, gravel-sand-silt mixtures.
			Limits plot above "A" line & hatched zone on plasticity chart		GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS (More than 50% of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 seive)			SW	Well graded sands, gravelly sands.
					SP	Poorly graded sands, gravelly sands.
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		SM	Silty sands, sand-silt mixtures.
			Limits plot above "A" line & hatched zone on plasticity chart		SC	Clayey sands, sand-clay mixtures.
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)	SILTS (Limits plot below "A" line & hatched zone on plasticity chart)	SILTS OF LOW PLASTICITY (Liquid Limit Less Than 50)			ML	Inorganic silts, clayey silts with slight plasticity.
		SILTS OF HIGH PLASTICITY (Liquid Limit More Than 50)			MH	Inorganic silts, micaceous or diatomaceous silty soils, elastic silts.
	CLAYS (Limits plot above "A" line & hatched zone on plasticity chart)	CLAYS OF LOW PLASTICITY (Liquid Limit Less Than 50)			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		CLAYS OF HIGH PLASTICITY (Liquid Limit More Than 50)			CH	Inorganic clays of high plasticity, fat clays, sandy clays of high plasticity.

NOTE: Coarse grained soils with between 5% & 12% passing the No. 200 sieve and fine grained soils with limits plotting in the hatched zone on the plasticity chart to have double symbol.

PLASTICITY CHART



DEFINITIONS OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
Cobbles	Above 3 in.
Gravel	3 in. to No. 4 sieve
Coarse gravel	3 in. to ¾ in.
Fine gravel	¾ in. to No. 4 sieve
Sand	No. 4 to No. 200
Coarse	No. 4 to No. 10
Medium	No. 10 to No. 40
Fine	No. 40 to No. 200
Fines (silt or clay)	Below No. 200 sieve

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WESTON

SOIL SAMPLE INVENTORY SUMMARY

SITE ID: _____ DATE: _____

FIELD REP.: _____

LOCATION ID	SAMPLE ID	SAMPLE TYPE	MATERIAL TYPE	SAMPLE DEPTH	BOREHOLE/ TEST PIT	SHIPPED TO	COMMENTS
							439

SAMPLE TYPE: LD-LARGE DISTURBED, SD-SMALL DISTURBED, SPT-STANDARD PENETRATION TEST, R-RING, T-SHELBY TUBE, C-DRILL CUTTINGS

APPENDIX H

WATER SAMPLING/PRESERVING/SHIPPING AND TESTING

APPENDIX H
WATER SAMPLING/PRESERVING/SHIPPING AND TESTING

1.0 PURPOSE

To ensure that field programs for the collection of ground water quality samples are conducted and documented properly.

2.0 SCOPE

This procedure addresses all ground water samples which will be collected.

3.0 PROCEDURES

Sampling consists of several steps, including:

a. Preparing for the collection trip.
b. Collecting the sample.
c. Preserving and shipping the sample.
d. Making field measurements of the ambient water.

3.1 PREPARATION FOR SAMPLING

The following steps will be taken no later than three weeks before sampling is to begin.

Sample locations will be determined by the Site Hydrogeologist and approved by the Task Manager.

The analytical laboratory will be told:

- Approximately how many samples it will be receiving.
- Approximately when it will receive them.
- The set of analytes.
- See (Attachment 1 and 2) for more details regarding required communication with support labs.

Also, all equipment will be checked to ensure that it is working properly. Supplies of bottles, reagents, solutions, filters, etc., will be checked to ensure there are enough on hand. The

type of bottles and preservatives used will be consistent with recommendations in EPA-60014-79-020, 1983.

These steps also will be documented on the pre-field checklist.

3.2 GROUNDWATER SAMPLE COLLECTION

3.2.1 General Procedures

To prevent cross-contamination, sample wells which are unlikely to be contaminated before those that may be contaminated. When sampling domestic wells, ask for information regarding depth, completion interval, use, diameter, etc. Take water from domestic wells as close to the well head as is practicable and downhole if possible. Do not take samples downstream of any device which alters water quality, such as water softeners. Put the location of domestic wells on a map.

Make a note of any odors, colors, etc., that are noticed during pumping. Make a note of any deviations from (or modifications to these general procedures, and document the rationale for these changes.

3.2.2 Monitoring Well Sampling

The following outlines the procedures used in sampling monitor wells. The procedures are to be used after the well has been purged.

1. Lay out plastic sheeting and arrange sampling equipment, bottles and logging information.

2. Remove and inspect sample containers, sampling forms and chain-of-custody forms, check for consistency with well number.

3. Review Table H-1 regarding required preservation, bottle types, and documentation.

4. Wear proper sampling gear (see Safety Plan).

5. Decontaminate the bailer with an Alconox solution, final rinse with distilled water. Similarly, decontaminate the 0.45-micron filter, flask, and lines.

Table H-1

REQUIRED SAMPLE CONTAINERS, PRESERVATIVES, AND DOCUMENTATION

Sample Type	Level	Required Containers	Fixative	Fill Level	Documentation
Organic (AQ)	Low	2, 40-ml glass vials AND	Cool	100%	
		4, 1-L amber glass bottles	Cool	90%	Chain of Custody (per laboratory) Custody Seals (per container) Air bills (per laboratory)
		OR 2, 1-Liter glass bottles			
Inorganic (AQ)	Low	2, 1-Liter polyethylene bottles	metals*** HNO_3 to pH<2, cool NaOH to pH>12, cool	90%	Same as Organic (AQ)
Organic(S)	Low	2, 120-ml glass vials AND	Cool	75-90%	Same as Organic (AQ)
Inorganics	Low	2, 8-oz glass jars OR 4, 4-oz glass jars	Cool	75-90%	

AQ - aqueous
S - solid
L - liter

* Two (2) VOA vials require only one (1) tag.
** Hazardous samples require only one High Hazard Form.
*** Filter monitoring well samples before fixing.

6. Slowly lower the cleaned bailer into the well and allow water to fill the bailer.

7. When the bailer is full, carefully retrieve the bailer land, as required, filter only dissolved metals samples through a 0.45 micron filter and fill sample containers.

8. Use only bottle which have previously been prepared by the laboratory.

9. Preserve samples with specific fixatives (see Table H-1).

10. Field label each bottle using the predetermined location coding.

11. Decontaminate the sampling equipment and bottles by rinsing them with Alconox and tap water, taking care not to wash off the field labels.

12. Take a grab sample for immediate field measurement of field parameters (pH and specific conductivity) and record the results in the field log.

13. Enclose the sample containers in clear plastic bags through which the sample tags and labels are visible.

14. Carefully pack the samples in waterproof, <u>metal</u> ice chests or coolers packed with noncombustible, absorbent material (vermiculite) so that the sample containers will not make contact during shipment.

15. Complete the Custody Transfer Record for the sample (Attachment H-2).

16. Ship the bottom two of the Chain of Custody Form (Figure 3-10) with the appropriate samples to the laboratory. Enclose the Chain-of-Custody Records in a waterproof plastic bag and tape them to the underside of the cooler lid.

17. Seal the coolers with custody seals (see Figure 5-7) in such a manner that the custody seal would be broken if the cooler were opened.

18. Add clearly visible return address labels on the outside and "This End Up" labels on all four sides of the cooler.

19. Ship samples the same day they are collected. Alert the shipping service of the restricted articles prior to pick-up.

20. If needed fill out one air bill (Attachment H-3) for all shipments with the same destination.

3.2.3 Sampling for Organics

When sampling for analysis of organic parameters (such as TOC, TOX, pesticides, and EPA priority pollutant organics), special procedures and equipment may be required. Many plastics such as PVC and polyethylene absorb organic contaminants and also bleed other trace compounds from their surfaces. For this reason, only glass or Teflon containers are to be used for sample collection. Also, all sample tubing and pump parts should be made of either Teflon or approved silicon. Samples should be refrigerated at the time of collection, and should contain no trapped air bubbles. Sample container caps must be Teflon-lined. Grab samples to be analyzed for volatile organics (VOA samples) are best obtained by means of a Teflon bailer (Pettyjohn et al., 1981). Certain organic compounds, such as polynuclear aromatics, are light-sensitive and should be collected in opaque bottles land stored in the dark. Special preservatives and relatively short holding times may be specified for many organic samples. Specific needs for organic sampling should be determined in consultation with the support laboratory. See Pettyjohn and others (1981) and Korte and Kearl (1984) for additional guidance in sampling for organics.

3.3 FIELD MEASUREMENTS

3.3.1 General

All field measurements and comments will be recorded on the water quality field form (Attachment H-1). All lines on the field form will be completed by the field team leader. If some steps were not taken or not applicable, so indicate in the appropriate space. The forms are to be completed with non-water soluble black ink, not felt tip type pens or pencils. If any procedures are not performed as prescribed, the reason must be stated on the field form.

When practical, final field measurements are to be taken after at least three bore volumes have been pumped from the well and as close to the time of sampling as is practicable.

3.3.2 pH

1. Connect the probe to the meter and immerse it in a flow through cell soon after pumping has begun. This will reduce or eliminate drift.

2. Bring the standard solutions to the temperature of the water in a flow through bath. If the meter has a temperature adjustment, set it to the temperature of the water.

3. Standardize the meter immediately before taking the measurement. The calibrating solutions must bracket the sample: either pH=7.0 and pH=4.0, or pH=7.0 and pH=10.0.

4. Standardize the meter as follows:

   - Put the probe in the pH=7.0, or the pH=4.0 solution if the pH is less than 4.0, and adjust the standardization know to achieve a reading of 7.0 or 4.0.

   - Put the probe in the other solution and adjust the slope to achieve a reading of 4.00, or 10.00 as appropriate.

   - Repeat the above steps until adjustment is no longer required.

5. Clean the probe with distilled water and clean tissues.

6. Put the probe in a flow-through cell. Record measurement within five minutes or after drift has ceased, whichever is sooner.

7. Immediately rinse and dry the probe and put it in each calibrating solution for about 30 seconds. Record the readings.

NOTES:

- During storage and between measurements, keep the probe immersed in pH=4.0 solution.

- Rinse the probe in distilled water and pat dry with a clean tissue completely before putting it in a calibrating solution. Rubbing the probe may cause a static charge which will disrupt measurements.

- Keep hoses leading to the flow-through bath or cell out of direct sunlight as the water can heat up quickly at low discharge rates.

3.3.3 Temperature

Measure temperature in a small flow-through cell. Record measurements periodically throughout the time of pumping.

NOTES:

- The field thermometer must be calibrated against a lab grade thermometer. Do this before going to the field.

- Place the flow-through cell close to the well head. Keep the cell and discharge hose out of direct sunlight.

3.3.4 Electrical Conductivity

The conductivity meter will be calibrated with at least three standard KCl solutions, the extremes of which bracket the samples. This will be done at least two times during the field program: before sampling; and after sampling is completed. A record of each calibration will be kept and the temperature of each calibrating solution will be recorded.

1. Clean probe and cable with distilled water and clean tissues.

2. Measure conductivity in a flow-through cell. Record conductivity periodically throughout the time of pumping. Record the position of each setting on the meter.

NOTES:

- Rinse the probe in distilled water and dry it completely before putting it in a calibration solution.

- Most conductivity probes produce an electrical field which may be disturbed if the probe is near a solid object. Therefore, keep the probe at least two inches away from cell

walls. Keep lead weights at least six inches above the probe. This does not apply to the Martek X probe.

3.4 SAMPLE PREPARATION

3.4.1 Filtering

Sample preparation is initiated by pumping raw sample through an in-line filter. The procedure is as follows:

1. Drain pump hoses to ensure all old sample water is expelled.

2. Pump approximately two liters of distilled water through the hoses. Continue pumping until all distilled water is expelled.

3. Clean outside of hoses and downhole pumps with detergent distilled water and tissues before putting them down the hole, connecting them to another pump, or putting them into a car boy. Set the intakes a few feet above the top of the screened interval.

4. Disassemble the filter apparatus and discard the old filter. Thoroughly rinse all surfaces which come in contact with the sample in distilled water.

5. With clean hands, install a new filter, touching it only along its perimeter. Allow no dirt or dust to blow onto the cleaned apparatus or filter. Re-assemble the apparatus.

6. Before taking any samples, run a few hundred ml of sample water through the filter.

7. Fill the sample bottles. Allow no dirt or dust to blow into bottles or bottle caps.

8. Add appropriate preservatives immediately after filling bottles. Note the amount and type. See Attachment 1.

9. Rinse inside of bottle caps with filtered water and screw onto bottle. Shake the bottle to mix the preservative.

10. Pour a few drops of preserved samples onto litmus paper to check the pH. If the pH is too high or too low, add acid or base as appropriate and note the amount added.

11. Rinse inside of bottle caps with filtered sample and screw caps on tightly. Seal bottles with electrical tape or parafilm.

NOTES:

- While filling, and once the sample is in the bottle, do not allow it to touch anything but the bottle walls. Never stick anything into the sample.
- Do not smoke near open sample bottles.
- Keep samples out of direct sunlight.
- If the filter becomes clogged, replace it as above, repeating steps 4 through 6. Do not clean it, back flush it, etc.

3.4.2 Labeling and Transport

1. Bottles will be labeled with the pre-printed labels. Fill in all appropriate information in blank spaces.

2. Immediately put the samples requiring refrigeration into an insulated container with ice or "blue ice." Put all others into a box, away from direct sunlight.

3. Put the address and telephone number of the Project Office and the name of a contact in the insulated container. Include a list giving the number of samples and sample I.D.'s in each container. This sample list will be completed by the laboratory and set to the Contracts Department so records will be kept on the list of samples received. This list can be compared to a duplicate sample list which is retained with the water sampling data to assure that no samples were lost or misplaced during shipment.

4. Tape the container with strapping tape for shipping. When possible, ship the samples so they arrive at the lab no later than 72 hours after they were taken. Tell the lab when they will be arriving.

5. Schedule sampling so that samples do not arrive at the lab after 4 p.m. on a Friday, or on a Saturday or Sunday.

3.4.3 Split Samples Using Split Jug

1. Thoroughly rinse the split jug with about one gallon of distilled water. Drain through both the inlet and outlet tubes.

2. Pump approximately 10 liters of filtered sample water into the split jug. Rinse thoroughly and drain through both the inlet and outlet tubes.

3. When possible, pump more than enough filtered water into the split jug to fill all sample sets. As a minimum, pump more than enough filtered water to fill all bottles used for identical analyses. Swirl the jug to thoroughly mix the water.

4. Dispense sample types consecutively. That is, fill one lab's anion bottle immediately after the other's, one lab's metals bottle immediately after the other's, etc.

3.4.4 Sample Splits, Known Solutions, and Archived Samples

Field samples shall be grouped into lots for shipment to the support laboratory. A lot will consist of no more than nine field samples, plus four splits of one of the field samples, plus at least one known solution. Every field sample and known solution will also be split into a sample for analysis and an archived sample.

3.5 POST-COLLECTION

1. Clean field equipment.

2. Replace expended items, filters, reagents, etc.

3. Report and repair broken equipment.

4. Examine electrical conductivity and temperature calibrations. Adjust data as indicated and note on field forms.

5. Make copies of field forms and place the originals in the appropriate file. Copies of all field forms associated with a given lot of samples shall be distributed by the sampling team to the Site Hydrologist and Site Manager within two weeks of collection of the lot. Give final field values to data base administrator for inclusion in technical data base.

4.0 REFERENCES

N. Korte and P. Kearl, 1984, "Procedures for the Collection and Preservation of Ground-water and Surface Water Samples and for the Installation of Monitoring Wells," U.S. Department of Energy, Grand Junction, Colorado.

Pettyjohn, Wayne A., W.J. Dunlap, R. Cosby, and J.W. Keeley, 1981. "Sampling Ground Water for Organic Contaminants." Ground Water, 19(2):180-189.

USEPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020.

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WATER QUALITY SAMPLING RECORD

SITE ID: _____

LOCATION ID: _____

SAMPLE ID: _____

STATIC WATER LEVEL (FT) _____

SAMPLE DEPTH (FT) _____

SAMPLING DATE _____

SAMPLING TIME:

START _____

COMPLETE _____

FINAL FIELD VALUES:	SURFACE	DOWN-HOLE
pH (S.U.):		
Ec (µmhos/cm)		
Eh (millivolts)		
TEMP. (°C):		
ALKALINITY (mg/l $CaCO_3$):		

LOCATION DESCRIPTION _____

	CONTAINER SIZE	NONACIDIFIED	ACIDIFIED	VOL. ACID (ml)
NUMBER OF CONTAINERS COLLECTED:	ONE-LITER			
	150 ml			
	50 ml			
SPECIFY OTHERS:				

COMMENTS: _____

FIELD REP (S): _____

DATE	TIME	TOTAL VOLUME WITHDRAWN (Gals)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	Ec (µmhos/cm)	TEMP. (°C)	COMMENTS
		0.0	0.0	-	-	-	START PUMPING

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WATER QUALITY SAMPLING RECORD

DATE	TIME	TOTAL VOLUME WITHDRAWN (Gals)	TOTAL VOLUME WITHDRAWN (Bore Volumes)	pH	Ec (µmhos/cm)	TEMP. (°C)	COMMENTS
						453

WATER QUALITY SAMPLING RECORD

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

SAMPLING INFORMATION

DEPTH TO WATER (h_2) (FT.) _____
DEPTH OF WELL (h_1)(FT.) _____
WELL DIA (FT.) _____
BORE VOL. $(FT.)^3$ _____
DEPTH TO SCREEN (FT.) _____

WITHDRAWAL METHOD _____
SAMPLING METHOD _____
FILTER SIZE _____
THERMOMETER ID _____
Ec METER ID _____
pH METER ID _____
PUMP ID _____

CALIBRATION INFORMATION

DATE/TIME OF LAST Ec CALIBRATION _____
TIME OF pH CALIBRATION _____
pH AFTER MEASUREMENT _____ FOR STANDARD pH _____
pH AFTER MEASUREMENT _____ FOR STANDARD SOLUTION pH _____
Eh OF CALIBRATING SOLUTION _____
Eh READING IN CALIBRATING SOLN. AFTER MEASUREMENT _____
TEMP. OF CALIBRATION SOLN. (°C) _____

SHIPPING INFORMATION

LAB(S) SHIPPED TO: _____ _____ _____
DATE(S) SHIPPED: _____ _____ _____
METHOD OF SHIPMENT: _____ _____ _____

NOTES:

WESTON

Custody Transfer Record/Lab Work Request

Received By _____ Client _____ RFW Contact _____

Date _____ Client Contact _____ Date Due _____

Assigned to _____ Phone _____ Project Number _____

SAMPLE IDENTIFICATION — ANALYSES REQUESTED

Sample No.	Client ID No.	Description	Matrix	Date Collected	Container/Preservative								

Matrix:

S- Soil DS- Drum Solids

W- Water DL- Drum Liquids

O- Oil X- Other

Special Instructions:

Items/Reason	Relinquished By	Received By	Date	Time	Items/Reason	Relinquished By	Received By	Date	Time

776

456

3H-16

217 OF 1000

PRESS HARD 5 COPIES

PLEASE PRINT OR TYPE

FEDERAL EXPRESS

PLEASE COMPLETE ALL INFORMATION IN THE 5 BLOCKS OUTLINED IN ORANGE
SEE BACK OF FORM SET FOR COMPLETE PREPARATION INSTRUCTIONS

AIRBILL NUMBER 001794472

194

YOUR FEDERAL EXPRESS ACCOUNT NUMBER: 0191-1273-0

DATE

FROM (Your Name)

COMPANY: ROY F WESTON INC

DEPARTMENT/FLOOR NO

STREET ADDRESS: WESTON WAY

CITY: WEST CHESTER

STATE: PA

TO (Recipient's Name)

If Hold For Pick Up or Saturday Delivery Recipient's Phone Number

COMPANY

DEPARTMENT/FLOOR NO

STREET ADDRESS (P.O. BOX NUMBERS ARE NOT DELIVERABLE)

CITY

STATE

AIRBILL NO. 001794472

ZIP ACCURATE ZIP CODE REQUIRED FOR CORRECT INVOICING: 1 9 3 8 0

IN TENDERING THIS SHIPMENT SHIPPER AGREES THAT F.E.C. SHALL NOT BE LIABLE FOR SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING FROM CARRIAGE HEREOF. F.E.C. DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED WITH RESPECT TO THIS SHIPMENT. THIS IS A NON NEGOTIABLE AIRBILL SUBJECT TO CONDITIONS OF CONTRACT SET FORTH ON REVERSE OF SHIPPER'S COPY. UNLESS YOU DECLARE A HIGHER VALUE, THE LIABILITY OF FEDERAL EXPRESS CORPORATION IS LIMITED TO $100.00. FEDERAL EXPRESS DOES NOT CARRY CASH OR CASH EQUIVALENT (FOREIGN).

ZIP ACCURATE ZIP CODE REQUIRED FOR OVERNIGHT DELIVERY

YOUR NOTES/REFERENCE NUMBERS (FIRST 12 CHARACTERS WILL ALSO APPEAR ON INVOICE)

PAYMENT ☐ Bill Shipper ☐ Bill Recipient's F.E.C. Acct ☐ Bill 3rd Party F.E.C. Acct ☐ Bill Credit Card

☐ Cash in Advance Account Number/Credit Card Number

SERVICES
CHECK ONLY ONE BOX

PRIORITY 1
1 ☐ Overnight Packages (up to 70 lbs.)
COURIER PAK
2 ☐ Overnight Envelope (up to 2 lbs.)
3 ☐ Overnight Box (up to 5 lbs.)
4 ☐ Overnight Tube (up to 5 lbs.)

STANDARD AIR
5 ☐ Delivery 2nd Business Day Following Pick Up (up to 70 lbs.)

OVERNIGHT LETTER
6 ☐ (up to 2 oz.)
7 ☐
8 ☐
9 ☐

OVERNIGHT IS NEXT BUSINESS DAY (MONDAY THROUGH FRIDAY). TWO DAYS FROM ALASKA/HAWAII. SATURDAY DELIVERY AVAILABLE IN CONTINENTAL U.S. SEE "SPECIAL HANDLING"

DELIVERY AND SPECIAL HANDLING
CHECK SERVICES REQUIRED

1 ☐ Hold For Pick Up at FEDERAL EXPRESS Location (Recipient's Phone Number Required)
2 ☐ Deliver
3 ☐ Saturday Service Required (See Reverse (Extra charge applies for delivery))
4 ☐ Restricted Articles Service (P-1 and Standard Air Packages only, extra charge)
5 ☐ SSS (Signature Security Service) (required, extra charge applies)
6 ☐ Dry Ice _____ lbs.
7 ☐ Other Special Service _____
8 ☐ _____
9 ☐

PACKAGES	WEIGHT	DECLARED VALUE	O/S
TOTAL	TOTAL	TOTAL	

RECEIVED AT
SHIPPER'S DOOR
☐ REGULAR STOP
☐ ON CALL STOP
☐ F.E.C. TOC

Federal Express Corporation Employee No

DATE/TIME For Federal Express Use

AGT/PRO

AGT/PRO

FEDERAL EXPRESS USE

FREIGHT CHARGES

DECLARED VALUE CHARGE

ADVANCE ORIGIN

ADVANCE DESTINATION

OTHER

TOTAL CHARGES

PART# 2041730751
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Section 4

SECTION 4

GEOTECHNICAL SAMPLING PLAN FOR THE CHARACTERIZATION OF THE WASTE STORAGE AREAS AT THE FEED MATERIALS PRODUCTION CENTER

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SECTION 4
GEOTECHNICAL SAMPLING PLAN

4.1 INTRODUCTION

4.1.1 Objectives

Geotechnical information is essential for developing an accurate understanding of subsurface conditions, necessary for evaluating the feasibility of remediation alternatives such as in-site stabilization and stabilization on-site. It also provides crutial data for the evaluation of alternative disposal areas on-site and the suitability of local soils for cover material.

The geotechnical investigation is designed to gather the following information:

1) Define the subsurface stratigraphy in the site area.

2) Characterize the physical properties of the soils.

3) Provide data on the engineering behavior of the soils (i.e. compressibility, permeability, shear strength, etc.).

4.1.2 Background

The most recent and applicable of previous reports is the Department of Energy FMPC Groundwater Study, Task C Report by Dames and Moore, July 1985. A review of this report indicates that there is some information already available. For example, a significant number of borings have been completed in the waste pit/silo area. Unfortunately, the field logging data is incomplete because the blow counts were not recorded, and there is no data on standard penetration tests. The blow counts and standard penetration test data are needed in order to evaluate the onsite soils for use as possible construction materials. In addition, there is no data reported for any laboratory analysis of either physical or engineering properties of site soils.

4.1.3 Scope

The two areas where the highest density of data is required are the waste pit/silo area and the ash disposal area. In these areas the largest number of borings per unit area is proposed. This will provide the most information possible on subsurface stratigraphy in the areas where contaminants are most likely to

contact the subsurface environment. A total of 13 borings are proposed in the waste pit/silo area and six borings in the ash disposal area. (See Figure 4.1) In addition to these borings, twelve borings have been placed at other locations throughout the site. These borings will provide stratigraphy data on a more regional basis as well as data on physical and engineering characteristics of on site soils. Boring depths will be selected to provide the most information regarding the shallow environment (less than 50 feet). There will be, however, at least one boring advanced to bedrock.

Because of the anticipated complexity of the subsurface environment and the uncertainties surrounding the extent of the contaminant plume, the borings will be completed in successive layers starting with the uppermost layer and working downward. All of the initial borings will be advanced only to the bottom of the glacial till layer. This will eliminate the potential for introducing contaminants from the till into the underlying sand and gravel aquifer. Once the location and strength of any potential contaminant plume is defined, the borings to be installed to greater depths can be planned. Initially, borings at the locations shown will be shallow (30'). Locations for the deeper borings will be selected when the initial data is evaluated.

4.2 FIELD PROGRAM

4.2.1 Approach

The purpose of the planned field program is to collect data from subsurface borings which will help achieve the goals of this investigation. In order to achieve these goals in the most cost effective manner, the geotechnical testing and sampling will be performed concurrent with borings for monitor well construction whenever possible. This will eliminate unnecessary duplication of effort where monitor well locations correspond with geotechnical boring locations. Table 4.1 summarizes those locations where combined borings are proposed. Also, as discussed above, the shallow borings will be completed first and the deeper borings will not begin until their locations and depths have been refined based upon results of the groundwater sampling and the shallow wells.

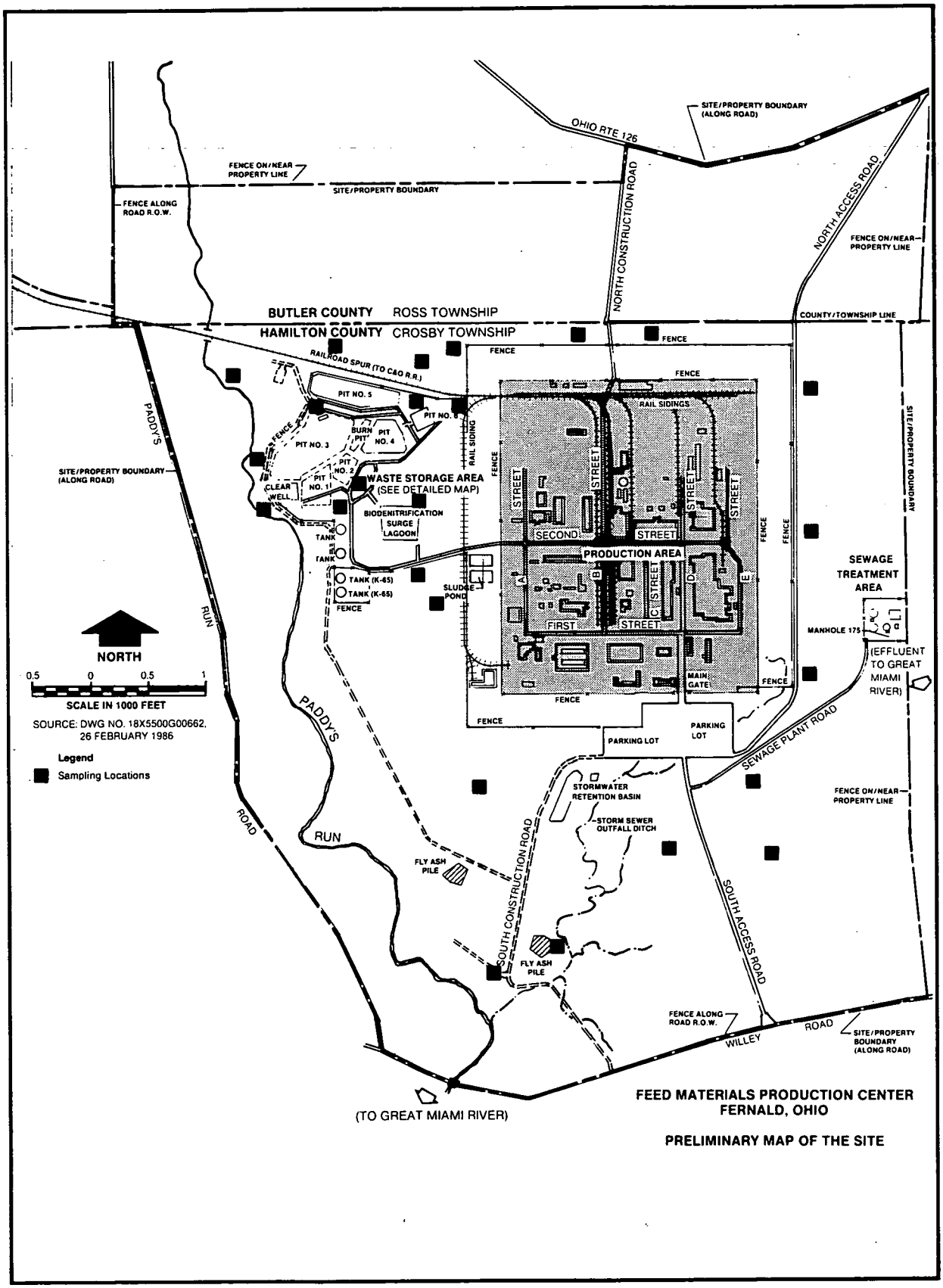

FIGURE 4-1 GEOTECHNICAL SAMPLING

TABLE 4.1
SUMMARY OF PLANNED AND EXISTING MONITOR WELL LOCATIONS

Well Location No.	Existing Wells (1)			Additional Wells Planned			Geotechnical Sampling (X)	Chemical Sampling (X)
1	201	301		101			X	X
3	203			103			X	X
4	204			104			X	X
5								
8		308	408	108	208		X	X
9		309		109	209		X	X
10		310		110	210		X	X
11	211			111		311	X	X
12	112				-			
13		213	313	113				
14		214	314	-				
15		215				315		
16		216	316	-				
17		217	317	-				
18		218	318	118			X	
19	119	219	319	-				
20	120	220	320	-				
21	121	221		-				
22	122	222		-				
23		-		123	223		X	
24		-		124	224	224	X	
25		-		125	225		X	X
26		-		126	226		X	X
27		-		127	227		X	X
28		-		128	228		X	X
29		-		129			X	
30		-		130	230			
31		-			231			
32		-			232			
33		-		133			X	X
34		-		134			X	X
35		-		135	235		X	
36		-		136	236		X	
37		-		137	237		X	

Notes: (1) Existing wells now renumbered as follows:
till wells = 100 series i.e. - well no. 12tp now = 112
top of upper sand = 200 series i.e. - well no. 14s now = 214
bottom of upper sand = 300 series i.e. - well no. 14d now = 31.

4.2.2 Drilling and Sampling

Test borings will be drilled using a hollow stem auger to advance the holes. Sampling will be done with an 18" drive split spoon sampler using ASTM Method D 1586-84, penetration tests and split barrel sampling of soils. Soils will be sampled at intervals of 2, 5, 8, and 10 feet below ground, and at 5 foot intervals thereafter. All field observations will be recorded in the standard forms provided in Appendix A.

Representative samples from each spoon will be stored in glass jars with tight fitting screw-on lids. Recorded on the jar cap will be the following information: boring number, sample number, depth of sample interval and blow counts. These samples will be stored onsite until needed for laboratory analysis. In addition, undisturbed samples will be collected at a rate of one or two per hole. Conventional 30", Shelby tubes will be used if subsurface conditions permit. The tubes will be pushed in advance of the bottom of the hole and properly trimmed, waxed, capped, and taped. These samples will be recorded on the field log and tubes will be marked with the boring number, Shelby tube number, depth of sample, and indicator of top and bottom. Shelby tubes will be stored onsite in an upright position until sent out for analysis.

Existing boring logs do not include blow counts, therefore it is not possible to estimate whether the fine grained soils are too dense to sample with conventional Shelby tubes. If soil conditions onsite make it impossible to use Shelby tubes, a more sophisticated sampler, such as a pitcher-type device, or Dennison sampler, or equivalent, will be used to collect "undisturbed" samples.

4.2.3 ANALYSIS PARAMETERS

4.2.3.1 Physical properties of the soils will be determined using the following laboratory tests:

- Grain size distribution (USCS classification) by sieve hydrometer.
- Atterburg Limits (including liquid limit, plastic limit and shrinkage limit)

  Specific gravity

  Natural moisture content

In a few select borings, a complete moisture profile will be obtained by testing moisture content of samples form the surface down to the bottom of the boring.

4.2.3.2 The analysis of engineering properties will include the following tests:

- Modified Proctor Compaction Test (ASTM D1557)
- Vertical permeability
- Unconfined compression
- Triaxial shear test (consolidated isotropically undrained, C.I.U with pore pressure)
- Vertical consolidation (dial reading/log time technique)

The compaction tests will be performed on grab samples collected in areas of potential future borrow material. All remaining tests will be performed on the undisturbed samples.

Results of the geotechnical investigation will include all the raw data generated in the field and in the lab, the classification of soils based on physical properties, and the use of accepted engineering classification to describe the engineering properties of the soils onsite. Laboratory results will be reported on the standard forms provided in Appendix A.

APPENDIX A
STANDARD FORMS

WESTON

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BOREHOLE LOG (SOIL)

LOCATION MAP:

SITE ID: _____ LOCATION ID: _____
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: _____
DRILLING CONTR.: _____
DATE STARTED: _____
DATE COMPLETED: _____
FIELD REP.: _____

GROUNDWATER LEVELS		
DATE	TIME	DEPTH (ft.)

LOCATION DESCRIPTION _____
SITE CONDITION _____

DEPTH	SAMPLE INTERVAL	SAMPLE RECOVERY	SAMPLE RETAINED	TYPE	ID	BLOWS PER 6 in.	N VALUE	USCS	VISUAL CLASSIFICATION

467

COMMENTS: _____

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

WESTON

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BOREHOLE LOG (ROCK)

Page __ of __

LOCATION MAP:

SITE ID: _____ LOCATION ID: _____
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: _____
DRILLING CONTR.: _____
DATE STARTED: _____
DATE COMPLETED: _____
FIELD REP.: _____

GROUNDWATER LEVELS		
DATE	TIME	DEPTH (ft.)

LOCATION DESCRIPTION _____
SITE CONDITION _____

DEPTH (FT.)	BORING OPERATION	% CORE RECOVERY	% ROCK QUALITY DESIGNATION (RQD)	% DRILLING FLUID RECOVERY	PACKER TEST INTERVAL	SPACING	ORIENTATION	CONDITION	WEATHERING	LITHOLOGY	ROCK TYPE & REMARKS

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COMMENTS: _____

BORING OPERATION
H - 6 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NQ - NQ WIRELINE ROCK CORING

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TEST PIT LOG

Page __ of __

LOCATION MAP:

SITE ID: _____ LOCATION ID: _____
APPROX. SITE COORDINATES (ft)
N _____ E _____
GROUND ELEV. (FT. MSL) _____
DATE EXCAVATED: _____
BACKHOLE TYPE: _____
CONTRACTOR: _____
FIELD REP: _____
REHAB. DATE: _____

GROUNDWATER LEVELS			
DATE	TIME	DEPTH (ft)	EST. FLOW (GAL/MIN)

LOCATION DESCRIPTION _____
SITE CONDITION _____

DEPTH (ft.)	SAMPLE INT	SAMPLE TYPE	SAMPLE ID	UNIFIED SOIL CLASS.	VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC.

469

COMMENTS: _____

SAMPLE TYPE
B - Undisturbed Block Sample
D - Disturbed Bulk Sample

WESTON

BOREHOLE AND TEST PIT SUMMARY

SITE ID: _____ BH-BOREHOLE/TP-TEST PIT: _____
LOCATION ID: _____ DRILLER/EXCAVATOR: _____
LOCATION COORDINATES: COMPLETION DATE: _____
N _____ BOREHOLE DIAMETER (IN): _____
E _____ TOTAL DEPTH (FT.): _____
GROUND ELEVATION (FT. MSL): _____

WELL SUMMARY

WELL OWNER: _____ FILTER PACK LENGTH (FT.): _____
INSTALLER: _____ FORMATION OF COMPLETION: _____
INSTALLATION DATE: _____ STRATIGRAPHIC ORDER: _____
CASING ELEV. (FT. MSL): _____ OPEN/SCREEN DEPTH (FT.): _____
CASING LENGTH (FT.): _____ OPEN/SCREEN LENGTH (FT.): _____
CASING DIA. (IN.): _____ OPEN/SCREEN AREA ($IN.^2$/FT.): _____
SEAL (END) DEPTH (FT.): _____ *FLOW RELATIONSHIP: _____

LITHOLOGICAL SUMMARY

SOIL/ROCK PROFILE				STD. PENETRATION TEST			
DEPTH (FT.)	UNIFIED SOIL/ROCK CLASS	STRAT. ORDER	VISUAL DESCRIPTION	SAMPLE ID	DEPTH INTERVAL (FT.)	SAMPLE METHOD	N VALUE

FLOW RELATIONSHIP:
U-Upgradient
D-Downgradient
C-Cross Gradient
O-On Site
N-Not Known

SAMPLE METHODS:
A-Auger Cuttings
S-2"O.D. 1.38"I.D. drive sample
U-3"O.D. 2.42"I.D. tube sample
T-3" O.D. thin-walled Shelby tube
H-6 1/2 Hollow Stem Auger
C-4 1/2 Continous Flight Auger
GB-Gear Bit
NX-NX Rock Coring
NQ-NQ Wireline Rock Coring
B-Undisturbed Block Sample
D-Disturbed Bulk Sample

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WESTON

PHYSICAL PROPERTY TEST RESULTS

SITE ID: _____ LOCATION ID: _____

DATE: _____ CHECKED BY: LAB _____

LAB NAME: _____ TAC _____

SAMPLE ID	DEPTH INTERVAL (FT)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	SPECIFIC GRAVITY
					471

WESTON

MECHANICAL SIEVE TEST RESULTS

SITE ID: _____ LOCATION ID: _____

DATE: _____ CHECKED BY: LAB _____

LAB NAME: _____ TAC _____

SAMPLE ID	DEPTH INTERVAL (FT)	% PASSING STANDARD SIEVE NUMBERS *										
		3"	1 1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200

472

*ENTER ONLY VALUES LESS THAN 100%.

776

HYDROMETER ANALYSIS TEST RESULTS

SITE ID: _____ LOCATION ID: _____

DATE: _____ CHECKED BY: LAB _____

LAB NAME: _____ TAC _____

SAMPLE ID	DEPTH INTERVAL (FT)	% FINER THAN (mm) *							
		.074 mm	.05 mm	.037 mm	.019 mm	.009 mm	.005 mm	.002 mm	.001 mm

473

* ENTER ONLY VALUE LESS THAN 100%

776

SOIL EROSION PROPERTIES TEST RESULTS

SITE ID: _____ LOCATION ID: _____

DATE: _____ CHECKED BY: LAB _____

LAB NAME: _____ TAC _____

SAMPLE ID	DEPTH INTERVAL (FT)	CRUMB TEST (D or ND)	DOUBLE HYDROMETER (% DISPERSION)	PINHOLE TEST (D OR ND)

D- DISPERSIVE ND - NON-DISPERSIVE

474

NOTE: DOUBLE HYDROMETER TO BE TABULATED ON JACOBS' 'HYDROMETER ANALYSIS TEST RESULTS' FORMS.

776

ROCKY MATERIAL PROPERTY TEST RESULTS

SITE ID: _____ LOCATION ID: _____

DATE: _____ CHECKED BY: LAB _____

TAC _____

LAB NAME: _____

SAMPLE ID	DEPTH INTERVAL (FT)	LA ABRASION (%)		SPECIFIC GRAVITY		ABSORPTION %	SLAKE DURABILITY (%)	SULFATE AGGREGATE SOUNDNESS (% LOSS)
		TOTAL LOSS	LOSS 100/500 CYCLE	APPAR-ENT	BULK			
								475

776

IN-SITU MOISTURE AND DENSITY DETERMINATION

SITE ID: _____ CHECKED BY: LAB _____

DATE: _____ TAC _____

LAB NAME: _____

LOCATION ID	SAMPLE ID	DEPTH INTERVAL (FT)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)

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WESTON

PERMEABILITY TEST RESULTS

SITE ID: _____ CHECKED BY: LAB _____

DATE: _____ TAC _____

LAB NAME: _____

LOCATION ID	SAMPLE ID	DEPTH INTERVAL (FT)	TEST METH.	COMPACTION (%)	MOISTURE CONTENT (%)		DRY DENSITY (PCF)		SATURATION (%)		TOTAL PRESSURE HEAD (FT)	PERMEABILITY (CM/SEC)
					INIT.	FINAL	INIT.	FINAL	INIT.	FINAL		

TEST METHODS: CH - CONSTANT HEAD FH - FALLING HEAD TX - TRIAXIAL BACKPRESSURE FALLING HEAD

776

CAPILLARY - MOISTURE RELATIONSHIP

SITE ID: _____ LOCATION ID: _____

DATE: _____ CHECKED BY: LAB _____

LAB NAME: _____ TAC _____

SAMPLE ID	DEPTH INTERVAL (FT)	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	COMPACTION (%)	TEST RESULTS	
					TENSION (BARS)	MOISTURE CONTENT (%)

478

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MOISTURE DENSITY RELATIONSHIP

SITE ID: _____ LOCATION ID: _____

DATE: _____ CHECKED BY LAB: _____

LAB NAME: _____ TAC: _____

SAMPLE ID	DEPTH INTERVAL (FT)	TEST METHOD	MAXIMUM DRY DENSITY (PCF)	OPTIMUM MOISTURE CONTENT (%)	TEST NO.
					1
					2

TEST RESULTS #1	
DRY DENSITY (PCF)	MOISTURE CONTENT (%)

TEST RESULTS #2	
DRY DENSITY (PCF)	MOISTURE CONTENT (%)

479

TEST METHOD: SP- STANDARD PROCTOR (ASTM-D698) MP-MODIFIED PROCTOR (ASTM-D1557)

776

CONSOLIDATION TEST RESULTS

SITE ID: _____ LOCATION ID: _____

DATE: _____ CHECKED BY LAB: _____

LAB NAME: _____ TAC: _____

SAMPLE ID	DEPTH INTERVAL (FT)	BEGINNING SUBMERGED STRESS (PSF)	COMPACTION (%)

INITIAL CONDITIONS			
DRY DENSITY (PCF)	MOISTURE CONTENT (%)	DEGREE OF SATURATION (%)	VOID RATIO e

FINAL CONDITIONS			
DRY DENSITY (PCF)	MOISTURE CONTENT (%)	DEGREE OF SATURATION (%)	VOID RATIO e

TEST RESULTS		
AXIAL STRESS (PSF)	VOID RATIO e	COEFFICIENT OF CONSOLIDATION (cm3/sec)

480

NOTE: INDIVIDUAL TIME-RATE INCREMENTS TO BE ATTACHED ON LABORATORY SUBCONTRACTOR FORMS

WESTON

DIRECT SHEAR TEST RESULTS

SITE ID: _____

LOCATION ID: _____

DATE: _____

LAB NAME: _____

CHECKED BY: LAB _____

TAC _____

SAMPLE ID	DEPTH INTERVAL (FT)	STRAIN RATE (IN/IN)	COMPACTION %	APPLIED NORMAL STRESS (PSF)

INITIAL CONDITIONS

DRY DENSITY (PCF)	MOISTURE CONTENT (%)	DEGREE OF SATURATION (%)	VOID RATIO e

FINAL CONDITIONS

DRY DENSITY (PCF)	MOISTURE CONTENT (%)	DEGREE OF SATURATION (%)	VOID RATIO e

TEST RESULTS

HORIZ. DISPL. (IN)	VERT. DISPL. (IN)	SHEAR STRESS (PSF)	HORIZ. DISPL. (IN)	VERT. DISPL. (IN)	SHEAR STRESS (PSF)

NOTE: CONSOLIDATION DATA TO BE ATTACHED ON LABORATORY SUBCONTRACTORS FORMS

WESTON

UNCONFINED COMPRESSION TEST

SITE ID: _____

LOCATION ID: _____

DATE: _____

LAB NAME: _____

CHECKED BY: LAB _____

TAC _____

SAMPLE ID	DEPTH INTERVAL (FT)	STRAIN RATE (IN/IN)	COMPACTION (%)

INITIAL CONDITIONS

DRY DENSITY (PCF)	MOISTURE CONTENT (%)	DEGREE OF SATURATION (%)	VOID RATIO e

FINAL CONDITIONS

DRY DENSITY (PCF)	MOISTURE CONTENT (%)	DEGREE OF SATURATION (%)	VOID RATIO e

TEST RESULTS

AXIAL STRESS (PSF)	AXIAL STRAIN (%)	AXIAL STRESS (PSF)	AXIAL STRAIN (%)

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4A-16

WESTON

UNCONSOLIDATED - UNDRAINED TRIAXIAL "Q" TEST

SITE ID: _____

LOCATION ID: _____

DATE: _____

LAB NAME: _____

CHECKED BY: LAB _____

TAC _____

SAMPLE ID	DEPTH INTERVAL (FT)	COMPACTION (%)	CELL CONFINING PRESSURE (PSF)

INITIAL CONDITIONS

DRY DENSITY (PCF)	MOISTURE CONTENT (%)	DEGREE OF SATURATION (%)	VOID RATIO e

FINAL CONDITIONS

DRY DENSITY (PCF)	MOISTURE CONTENT (%)	DEGREE OF SATURATION (%)	VOID RATIO e

TEST RESULTS

AXIAL STRESS (PSF)	AXIAL STRAIN (%)	AXIAL STRESS (PSF)	AXIAL STRAIN (%)	AXIAL STRESS (PSF)	AXIAL STRAIN (%)

WESTON DESIGNERS CONSULTANTS

CONSOLIDATED - UNDRAINED TRIAXIAL "R" TEST WITH PORE PRESSURE MEASUREMENT

SITE ID: _____

LOCATION ID: _____

DATE: _____

LAB NAME: _____

CHECKED BY: LAB _____

TAC _____

SAMPLE ID	DEPTH INTERVAL (FT)	COMPACTION %	CELL CONFINING PRESSURE (PSF)

INITIAL CONDITIONS

DRY DENSITY (PCF)	MOISTURE CONTENT (%)	DEGREE OF SATURA-TION (%)	VOID RATIO e	B PARAM.

FINAL CONDITIONS

DRY DENSITY (PCF)	MOISTURE CONTENT (%)	DEGREE OF SATURATION (%)	VOID RATIO e

TEST RESULTS

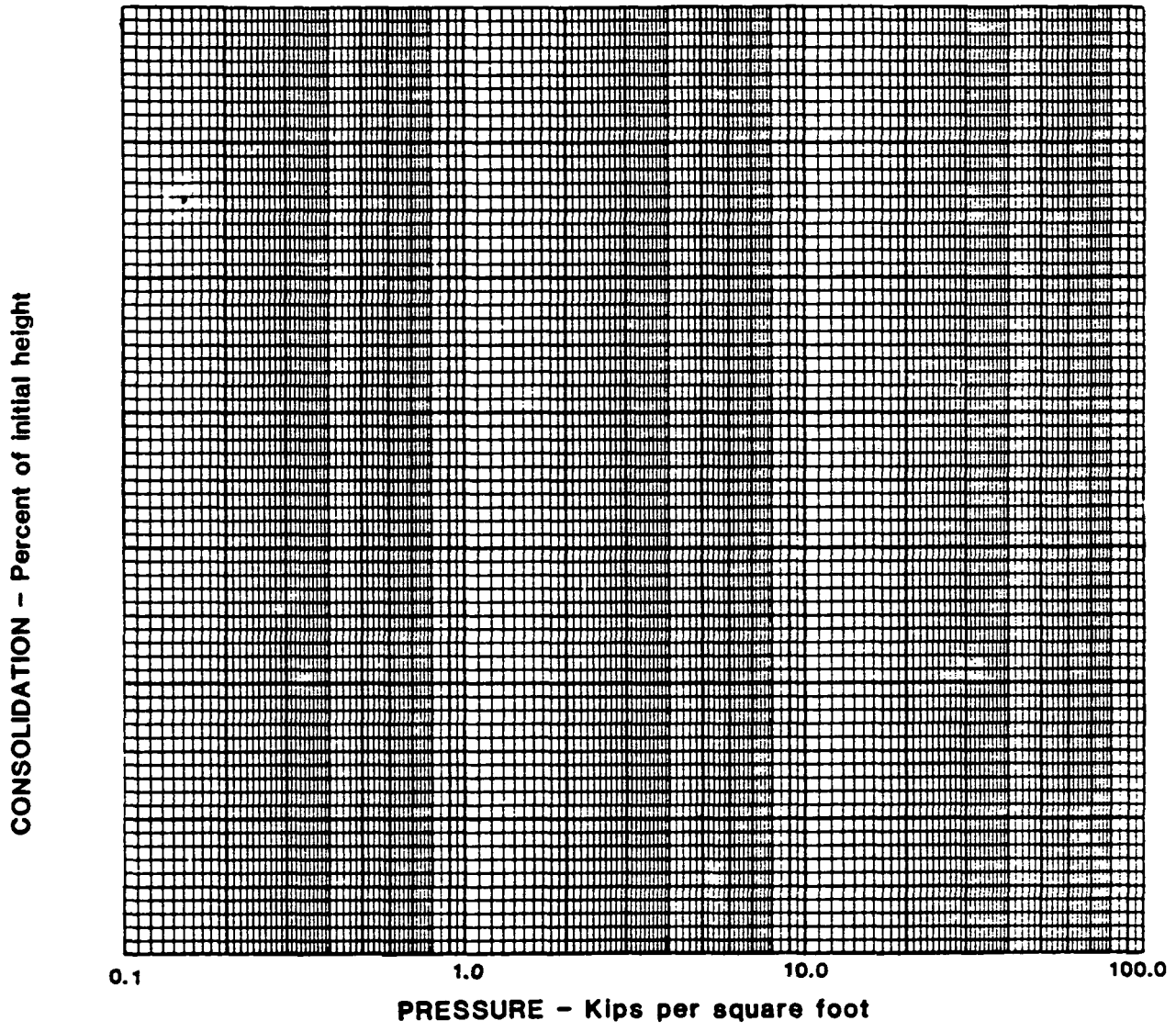
AXIAL STRAIN (%)	MAJOR PRINC. STRESS (PSF)	PORE PRESS. (PSF)	AXIAL STRAIN (%)	MAJOR PRINC. STRESS (PSF)	PORE PRESS. (PSF)

NOTE: CONSOLIDATION DATA TO BE ATTACHED ON LABORATORY SUBCONTRACTOR FORMS.
USE ONE FORM PER PHASE OF MULTI-PHASE TRIAXIAL TESTS.

SUMMARY OF CONSOLIDATION TESTS

SITE ID: _____ LOCATION ID: _____ DATE: _____

LAB NAME: _____



CURVE ID CODE *	SAMPLE ID	DEPTH INTERVAL (ft)	DRY DENSITY PCF LBS./CU. FT.		MOISTURE CONTENT (%)		UNIFIED SOIL CLASSIFICATION
			INITIAL	FINAL	INITIAL	FINAL	

* TEST MOISTURE CONDITION

I - IN SITU — — — — — S - SUBMERGED ————

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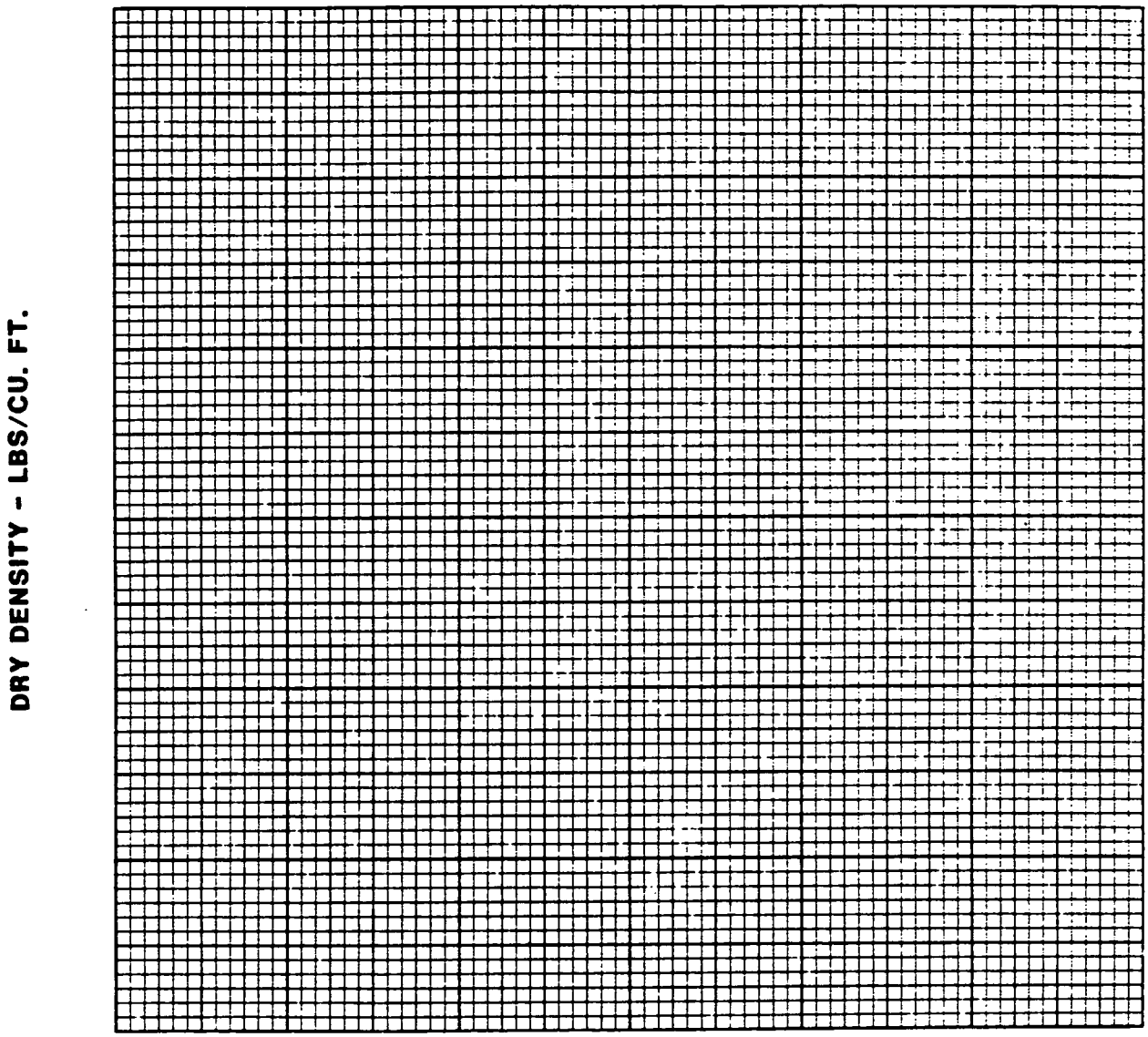
SUMMARY OF MOISTURE-DENSITY RELATIONSHIP TESTS

SITE ID:_____ LOCATION ID:_____ DATE:_____

LAB NAME:_____



CURVE ID	SAMPLE ID	DEPTH INTERVAL (ft)	OPTIMUM MOISTURE CONTENT (%)	MAXIMUM DRY DENSITY LBS/CU. FT.	ASTM TEST	
					DESIGNATION	METHOD

PLOT ZERO AIR-VOIDS CURVE FOR SPECIFIC GRAVITY OF 2.70.

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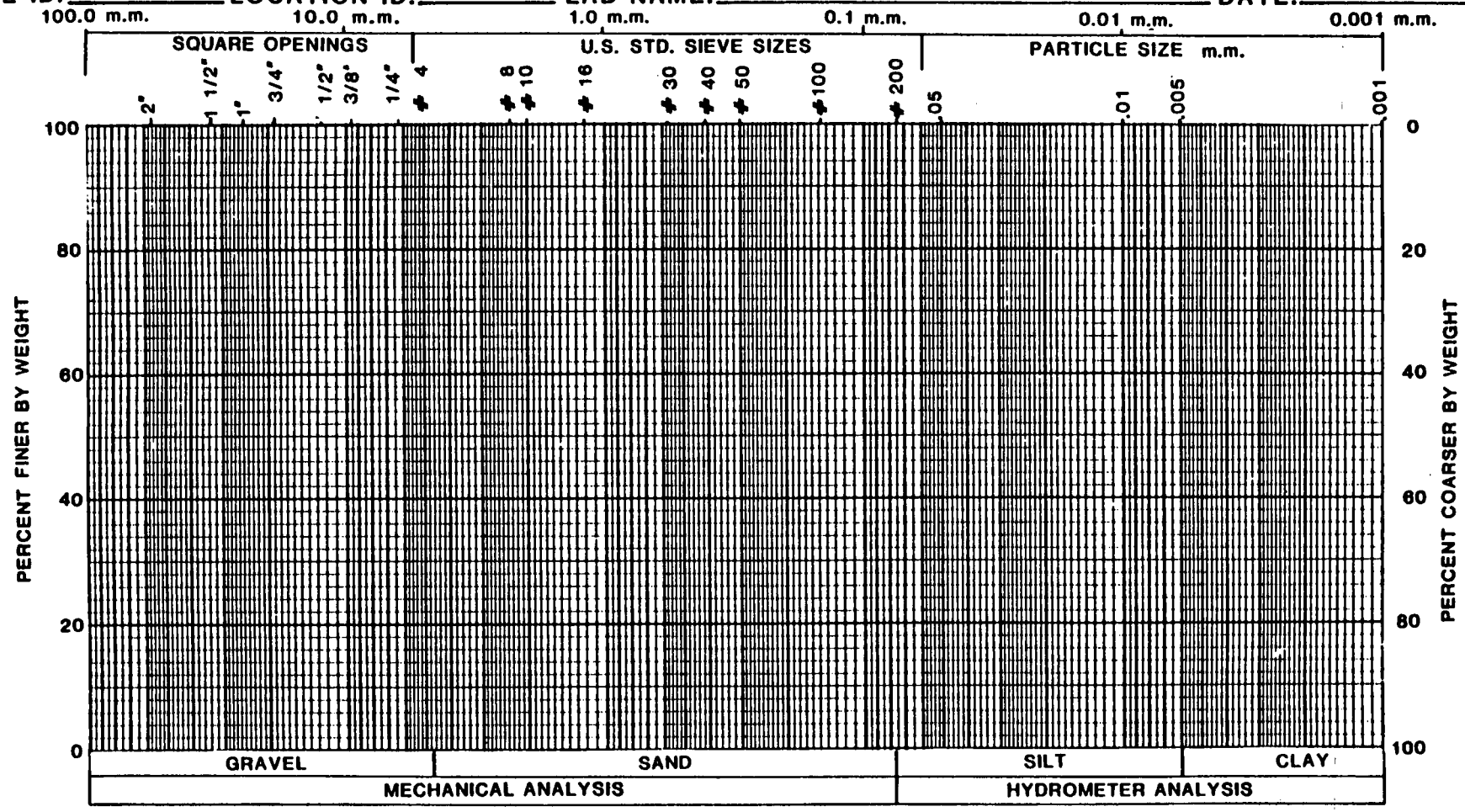
PARTICLE SIZE DISTRIBUTION CURVE

SITE ID:_____ LOCATION ID:_____ LAB NAME:_____ DATE:_____



CURVE ID	SAMPLE ID	DEPTH INTERVAL (ft)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	ACTIVITY	UNIFIED SOIL CLASSIFICATION
I						

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LITHOLOGICAL SUMMARY

PAGE ____ OF ____

SOIL/ROCK PROFILE				STD. PENETRATION TEST			
DEPTH (FT)	UNIFIED SOIL/ ROCK CLASS	STRAT. ORDER	VISUAL DESCRIPTION	SAMPLE ID	DEPTH INTERVAL (FT)	SAMPLE METHOD	N VALUE

SAMPLE METHODS

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A - AUGER CUTTINGS
S - 2" O.D. 1.38" I.D. DRIVE SAMPLE
U - 3" O.D. 2.42" I.D. TUBE SAMPLE
T - 3" O.D. THIN-WALLED SHELBY TUBE

H - 6 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT

NX - NX ROCK CORING
NQ - NQ WIRELINE ROCK CORING
B - UNDISTURBED BLOCK SAMPLE
D - DISTURBED BULK SAMPLE

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SOIL SAMPLE INVENTORY SUMMARY

SITE ID: _____ DATE: _____

FIELD REP.: _____

LOCATION ID	SAMPLE ID	SAMPLE TYPE	MATERIAL TYPE	SAMPLE DEPTH	BOREHOLE/ TEST PIT	SHIPPED TO	COMMENTS

SAMPLE TYPE: LD-LARGE DISTURBED, SD-SMALL DISTURBED, SPT-STANDARD PENETRATION TEST, R-RING, T-SHELBY TUBE, C-DRILL CUTTINGS

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UNIFIED SOIL CLASSIFICATION SYSTEM

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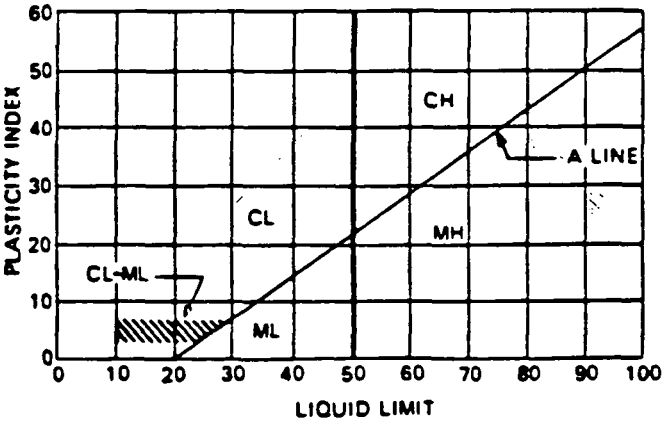
Soils are visually classified by the Unified Soil Classification system on the boring logs presented in this report. Grain-size analysis and Atterberg Limits Tests are often performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. For a more detailed description of the system, see "The Unified Soil Classification System" Corp of Engineers, US Army Technical Memorandum No. 3-357 (Revised April 1960) or ASTM Designation: D2487-66T.

MAJOR DIVISIONS				GRAPHIC SYMBOL	GROUP SYMBOL	TYPICAL NAMES
COARSE-GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (50% or less of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)			GW	Well graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures.
					GP	Poorly graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures.
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		GM	Silty gravels, gravel-sand-silt mixtures.
			Limits plot above "A" line & hatched zone on plasticity chart		GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS (More than 50% of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 seive)			SW	Well graded sands, gravelly sands.
					SP	Poorly graded sands, gravelly sands.
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		SM	Silty sands, sand-silt mixtures.
			Limits plot above "A" line & hatched zone on plasticity chart		SC	Clayey sands, sand-clay mixtures.
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)	SILTS (Limits plot below "A" line & hatched zone on plasticity chart)	SILTS OF LOW PLASTICITY (Liquid Limit Less Than 50)			ML	Inorganic silts, clayey silts with slight plasticity.
		SILTS OF HIGH PLASTICITY (Liquid Limit More Than 50)			MH	Inorganic silts, micaceous or diatomaceous silty soils, elastic silts.
	CLAYS (Limits plot above "A" line & hatched zone on plasticity chart)	CLAYS OF LOW PLASTICITY (Liquid Limit Less Than 50)			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		CLAYS OF HIGH PLASTICITY (Liquid Limit More Than 50)			CH	Inorganic clays of high plasticity, fat clays, sandy clays of high plasticity.

NOTE: Coarse grained soils with between 5% & 12% passing the No. 200 sieve and fine grained soils with limits plotting in the hatched zone on the plasticity chart to have double symbol.

PLASTICITY CHART



DEFINITIONS OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
Cobbles	Above 3 in.
Gravel	3 in. to No. 4 sieve
Coarse gravel	3 in. to ¾ in.
Fine gravel	¾ in. to No. 4 sieve
Sand	No. 4 to No. 200
Coarse	No. 4 to No. 10
Medium	No. 10 to No. 40
Fine	No. 40 to No. 200
Fines (silt or clay)	Below No. 200 sieve

490

Section 5

SECTION 5

ECOLOGICAL SAMPLING PLAN FOR THE CHARACTERIZATION OF THE WASTE STORAGE AREAS AT THE FEED MATERIALS PRODUCTION CENTER

ECOLOGICAL SAMPLING PLAN FOR THE CHARACTERIZATION OF THE WASTE STORAGE AREAS AT THE FEED MATERIALS PRODUCTION CENTER

SECTION 5

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REFERENCES

SECTION 5

ECOLOGICAL SAMPLING PLAN

5.1 OBJECTIVES

Ecological information is necessary to identify potential pathways by which humans may be exposed to contaminants. In addition, ecological sampling will identify the presence of threatened or endangered species and then suitable habitat.

Specifically, sampling of flora will:

- identify wetlands, ponds, and other depressions that act as collectors of contaminants from surface runoff.
- identify threatened or endangered species, if present, and their suitable habitat.
- identify and map various communities.

5.2 PREVIOUS STUDIES

5.2.1 Aquatic Fauna

Paddy's Run is the only aquatic habitat on or immediately adjacent to the FMPC. Paddy's Run, which is part of the Great Miami watershed, joins with the Great Miami River about 1.5 miles south of the FMPC. Its upstream drainage area (including the FMPC) is approximately 17 square miles.

Paddy's Run is an intermittent stream that generally flows only from January through May (Dames and Moore, no date). In April, 1986, although flowing at its upper reaches, flow had ceased immediately upstream of Willey Road (southern boundary of the FMPC) leaving standing pools in the deeper stream bends (Lechel, 1986). Average flows are estimated to be less than 0.4 cfs (Dames and Moore, no date). However, as evidenced by the clean cobble substrate, stream bank undercutting, and live trees that had washed into the run in late 1985 - early 1986, heavy rains on the watershed cause flash floods and much higher flows for a few hours or days duration (Lechel, 1986).

Paddy's Run fishes and benthic macroinvertebrates were sampled and identified in 1972-1973 and again in 1977 (Battelle, 1977; Bauer et. al., 1978). Locations sampled extended from about 2 air miles north of the northwest corner of the FMPC south to the confluence with the Great Miami River (Table 5.1).

TABLE 5.1

LOCATIONS OF PADDY'S RUN SAMPLING STATIONS

Number	Location	Fauna Sampled
1.	About 1.5 mi. north of Shandon, at crossing of State Highway 748, Butler County	Fishes
2.	About 0.1 mi. east of Shandon, at crossing of Hamilton New London Rd., Butler County	Fishes
3.	About 1.5 mi. southeast of Shandon below crossing of State Highway 126, Butler County	Fishes
4.	About 0.1 mi. upstream of the railroad crossing near the northeast boundary of the FMPC, Hamilton County.	Fishes, Macroinvertebrates
5.	Private drive off of Paddy's Run Rd. approximately 0.4 mi. north of Fernald, Hamilton County	Fishes
6.	Crossing of New Haven Rd. approximately 0.5 mi. west of Fernald, Hamilton County	Fishes
7.	Mouth of Paddy's Run at entrance into Great Miami River about 0.2 mi. below State Highway 128, Hamilton County	Fishes

Ref. Battelle, 1977; Bauer, et. al., 1978.

Benthic Macroinvertebrates

Macroinvertebrates were collected at sampling station 4, and 19 species were collected (Table 5.2) (Battelle, 1977). Species diversity was relatively low due principally to the intermittent flow along Paddy's Run.

Fishes

Twenty three species of fish were collected in Paddy's Run (Battelle, 1977; Bauer et al., 1978) (Table 5.3). Seven of the nine species reported by Battelle (1977) were previously collected by Bauer, et al (1978). Both reports indicated that minnows were the dominant species. Because of the intermittent nature of Paddy's Run, it is apparent that resident fish populations are low; transients may move from the Great Miami River during times of high flow.

Sampling of aquatic fauna to verify species composition and relative abundance, and to ascertain the contaminant (radionuclides, metals) concentrations present is not anticipated. Because of the intermittent nature of Paddy's Run, the limited resident fish population, and lack of sport or commercial species, the risk of human exposure to contaminants from the waste storage area through this pathway is exceedingly low.

5.2.2 Terrestrial Flora and Fauna

Terrestrial ecological sampling was conducted at the FMPC by Battelle (1977). This sampling program was designed solely to provide a generalized description and broad-scale map of the major plant communities, and species composition. No effort was expended to identify wetlands, surface depressions, or ponds that act as collector sinks for contaminants borne by surface runoff from the waste storage area. In addition, although the species lists are relatively complete (particularly for vegetation), insufficient data are available regarding the extent (acres) and exact locations (in relation to the waste storage area) of plant communities, wetlands and ponds, and other floral and faunal information necessary to form a comprehensive baseline description from which to assess the real and potential impacts of various remedial alternatives.

A brief reconnaisance survey in April, 1986, resulted in the observation of numerous wet depressions, wet meadows, several ponds, and other wetland types. The wet depressions and small ponds over the years will have acted to concentrate radionuclides and other contaminants because of surface water runoff from the

TABLE 5.2

BENTHIC MACROINVERTEBRATES (NUMBER/FT^2)
COLLECTED FROM PADDY'S RUN IN THE VICINTIY
OF THE FMPC, JULY, 1977

	1	2	3
DIPTERA			
Chironomidae			
Micropsectra sp.	7	2	2
Microtendipes sp.	3	3	8
Polypedilum sp.	6	3	8
Cricotopus sp.	3	1	4
Pentaneura sp.	-	1	2
Chironomus (*Dicrotendipes*) sp.	-	-	2
Tipulidae			
Hexatoma sp.	2	2	8
Empididae			
Unknown sp.	3	3	-
EPHEMEROPTERA			
Baetidae			
Baetis sp.	5	8	8
TRICHOPTERA			
Hydropsychidae			
Hydropsyche sp.	88	91	80
Cheumatopsyche sp.	260	135	320
Helicopsychidae			
Helicopsyche sp.	4	4	14
Hydroptilidae			
Agraylea sp.	-	3	6
Philoptamidae			
Cimarra sp.	14	17	74
COLEOPTERA			
Elimdae			
Stenelmis sp.	12	8	30
Psephenidae			
Psephenus herricki	1	-	-

TABLE 5.2 (Cont')

BENTHIC MACROINVERTEBRATES (NUMBER/FT^2)
COLLECTED FROM PADDY'S RUN IN THE VICINTIY
OF THE FMPC, JULY, 1977

	1	2	3
HEMIPTERA			
Veliidae			
Microvelia sp.	-	-	2
PELECYPODA			
Sphaeriidae			
Sphaerium sp.	1	-	-
DECAPODA			
Astacidae			
Orconectes sp.	1	-	2
Total Number of Individuals	410	281	570
Total Number of Species	15	14	16
Species Diversity	1.80	2.10	2.21

(Ref. Battelle, 1977)

TABLE 5.3

FISHES OF PADDY'S RUN

Scientific Name	Common Name
Dorosoma cepedianum	Gizzard shad
Campostoma anomalum	Stoneroller
Ericymba buccata	Silverjaw minnow
Notropis ardens	Rosefin shiner
N. atherinoides	Emerald shiner
N. boops	Bigeye shiner
N. chrysocephalus	Striped shiner
N. cornutus	Common shiner
N. spilopterus	Spotfin shiner
N. stramineus	Sand shiner
Semotilus atromaculatus	Creek chub
Phoxinus erythrogaster	Southern redbelly dace
Pimephales notatus	Bluntnose minnow
P. promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
Catostomus commersoni	White sucker
Lepomis cyanellus	Green sunfish
L. macrochirus	Bluegill
L. megalotis	Longear sunfish
L. cyanellus *L. macrochirus*	Bluegill/longear sunfish
Micropterus salmoides	Smallmouth bass
Etheostoma nigrum	Johnny darter
E. spectabile	Orangethroat darter
E. flabellare	Fantail darter

(Ref. Battelle, 1977; Bauer et al., 1978)

waste storage areas and the likely exposure to near-surface contaminated ground water. The degree of concentration also would depend on such things as the source term, topography, substrate, and nutrients (Whicker and Schultz, 1982).

Analyses of the vegetation is also important because:

- Mapping and habitat analyses will assist in the assessment of T and E species.
- Mapping will determine the location and extent of other sensitive (i.e., ecologically and regulatory) plant communities.
- Mapping will support analyses of remedial alternatives during the feasibility study particularily if alternate sites are considered.

5.3 SAMPLING PROGRAM

Because of deficiencies in the baseline characterization, and a complete lack of information regarding wetlands and wetlands types, a terrestrial ecological sampling program will be undertaken. Sampling will focus on the vegetation that occurs at the FMPC. Ancillary to the botanical study, qualitative information will be gathered regarding the faunal components of the various plant communities. In addition, the status of threatened and endangered (T and E) species, if any, that may occur on-site will be addressed.

Specifically, a field survey will be conducted to develop a detailed map of on-site vegetation, with special emphasis on wetlands, and other ponds or depressions. All such areas will be delineated, mapped, and their species composition recorded. In addition, baseline conditions will be expanded from Battelle (1977) and will be discussed to the extent necessary to conduct impacts analysis.

5.3.1 Sampling Frequency

Vegetation will be mapped and fauna recorded during field surveys to be conducted in June or July, 1986. A preliminary field survey was conducted on April 29 and 30, 1986 to aid in the development of this sampling plan.

5.3.2 Sampling Location

Vegetation within the FMPC, excluding the production area, will be mapped.

5.3.3 Sampling Methods

- Vegetation: The plant communities will be mapped with the aid of air photos. Blue line prints of a recent aerial survey of the site will serve as field maps. The plant communities (e.g., wetlands, ponds, forests) will be mapped at great detail on these maps. The plant species which occur in each type will be listed. This includes woody trees, shrubs, and vine species along with the common herbacous species. Land use (i.e., grazed vs. ungrazed) and man made features which occur in each mapped unit also will be noted.

- Fauna: During the course of vegetation mapping, all wildlife heard or observed will be noted for each habitat mapped. The data generated from these observations will be qualitative and will expand upon the baseline faunal information provided in Battelle (1977).

- T and E species: Much additional information regarding T and E species in Ohio has been generated since Battelle's (1977) work. This includes a state maintained computerized T and E species data bank, additional listed species, and additional information on the ecology and distribution of T and E species in Ohio. For these reasons, a new analysis of the possible occurrence of T and E species at the FMPC is proposed as part of this sampling plan.

  A phased approach to the analysis of T and E species will be undertaken:

  - Phase I: Federal and State agencies will be consulted to determine which T and E species occur in the region of the FMPC.

  - Phase II: Literature describing the ecology of the T and E species which occur in the region of the FMPC will be reviewed. In addition, biologists familiar with these species will be contacted.

  - Phase III: If it is determined that habitat suitable for a T and E species occurs on the FMPC, additional effort will be made to assess these habitats during the vegetation field survey.

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