43176

WORK PLAN

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
DU PONT - NEWPORT SITE
NEWPORT, DELAWARE

VOLUME III

ATTACHMENT A -
Quality Assurance Project Plan (QAPP)

ATTACHMENT B -
Health and Safety Plan (HASP)

Prepared for:

E.I. DU PONT DE NEMOURS AND COMPANY

Wilmington, Delaware

Prepared by:

WOODWARD-CLYDE CONSULTANTS

Plymouth Meeting, Pennsylvania

April 7, 1988

Attachment A
Quality Assurance Project Plan
(QAPP)

REVISION 1

QUALITY ASSURANCE PROJECT PLAN (QAPP)

FOR

REMEDIAL INVESTIGATION/FEASIBILITY STUDY
DU PONT NEWPORT SITE
Newport, Delaware

For

E.I. DU PONT DE NEMOURS AND COMPANY, INC.
Wilmington, Delaware

By

WOODWARD-CLYDE CONSULTANTS
Plymouth Meeting, Pennsylvania

88C2076-1
7 April 1988

QUALITY ASSURANCE PROJECT PLAN
FOR
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
DU PONT NEWPORT LANDFILL
Newport, Delaware

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1.0 INTRODUCTION

This Quality Assurance Project Plan (QAPP) presents the organization, objectives, functional activities and specific Quality Assurance (QA) and quality control (QC) activities associated with the Remedial Investigation/Feasibility Study (RI/FS) at the Du Pont Landfill in Newport, Delaware. The QAPP is designed to achieve the specific data goals of the RI/FS by describing minimum procedures to assure that the precision, accuracy, sensitivity, completeness and representativeness of the collected data are known and documented.

This QAPP has been prepared in accordance with "USEPA, December 29, 1980, Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans, QAMS-005/80 (Ref. 1)."

Other documents which have been prepared for the Du Pont Newport RI/FS and are referenced in this QAPP (Refs. 2 through 12) include:

- Administrative Order by Consent (Consent Order) - (Ref. 2)
- Work Plan - (Ref. 3)
- Health and Safety Plan. (HSP) - (Ref. 4)

2.0 TABLE OF CONTENTS

		Page Number
1.0	TITLE PAGE	3
	INTRODUCTION	
2.0	TABLE OF CONTENTS	5
3.0	PROJECT DESCRIPTION	17
	3.1 OVERVIEW	
	3.2 BACKGROUND	
	3.3 START, MILESTONES AND COMPLETION	
	3.4 OBJECTIVES AND USE OF DATA	
	3.5 DATA COLLECTION SUMMARY	
4.0	PROJECT ORGANIZATION AND RESPONSIBILITIES	8
	4.1 LABORATORY TESTING ASSIGNMENTS	
	4.2 LABORATORY QA/QC RESPONSIBILITIES	
	4.3 PERFORMANCE AND SYSTEM AUDITS	
5.0	QA OBJECTIVES FOR MEASUREMENT DATA	24
	5.1 LEVEL OF QC EFFORT	
	5.2 ACCURACY, PRECISION AND SENSITIVITY OF ANALYSIS	
	5.3 COMPLETENESS, REPRESENTATIVENESS AND COMPARABILITY	
	5.4 FIELD MEASUREMENTS	
6.0	SAMPLING AND FIELD OPERATION PROCEDURES	14
7.0	SAMPLE AND DOCUMENT CUSTODY PROCEDURES	9
	7.1 SAMPLE HANDLING, SHIPPING AND CUSTODY	
	7.2 FIELD DOCUMENTATION	
	7.3 PROJECT FILE	
8.0	CALIBRATION CONTROL	2
9.0	ANALYTICAL PROCEDURES	5

TABLE OF CONTENTS (Continued)

		Page Number
10.0	DATA REDUCTION, VALIDATION AND REPORTING	3
11.0	INTERNAL QC CHECKS	2
12.0	PERFORMANCE AND SYSTEM AUDITS	1
13.0	PREVENTIVE MAINTENANCE	1
14.0	DATA MEASUREMENT ASSESSMENT PROCEDURES	1
15.0	CORRECTIVE ACTION	1
16.0	QUALITY ASSURANCE REPORTS TO MANAGEMENT	1
17.0	REFERENCES	1

LIST OF APPENDICES

WCC HAZARDOUS WASTE MANAGEMENT TECHNICAL MEMORANDA

NO. 3 - GROUNDWATER MONITORING WELL AND PIEZOMETER INSTALLATION PROCEDURES

NO. 4 - AIR QUALITY MONITORING AND SAMPLING

NO. 5 - WATER SAMPLING

NO. 6 - SOIL, SEDIMENT ROCK SAMPLING

NO. 8 - BOREHOLE HYDRAULIC TESTING FOR AQUIFER CHARACTERIZATION

NO. 12 - SOIL GAS SAMPLING AND ANALYSIS

LIST OF TABLES

		Page Number
3-1	WASTE DISPOSAL INVENTORY	Sec. 3, 10-11
3-2	PLANNED SAMPLING AND ANALYSIS EFFORT	Sec. 3, 12
3-3	TARGET COMPOUND LIST (TCL) PARAMETERS	Sec. 3, 13-15
5-1	QC LEVEL OF EFFORT FOR ANALYTICAL TESTING	Sec. 5, 5
5-2	ACCURACY AND PRECISION CRITERIA FOR ANALYTICAL TESTING	Sec. 5, 6
5-3	MATRIX AND SURROGATE SPIKE CONTROL LIMITS FOR ORGANIC ANALYSIS	Sec. 5, 7
5-4	MATRIX SPIKE CHEMICALS AND CONTROL LIMITS FOR INORGANIC ANALYSIS	Sec. 5, 8
5-5	METHOD DETECTION LIMITS FOR ORGANIC ANALYSIS	Sec. 5, 9-13
5-6	METHOD DETECTION LIMITS FOR INORGANIC ANALYSIS	Sec. 5, 14
5-7	ACCURACY AND PRECISION CRITERIA FOR ORGANICS FOR DRINKING WATER PROTOCOL	Sec. 5, 15-16
5-8	ACCURACY AND PRECISION CRITERIA FOR ICP METALS FOR DRINKING WATER PROTOCOL	Sec. 5, 17-18
5-9	ACCURACY AND PRECISION CRITERIA FOR FURNACE METALS INORGANICS FOR DRINKING WATER PROTOCOL	Sec. 5, 19
5-10	METHOD DETECTION LIMITS FOR ORGANICS FOR DRINKING WATER PROTOCOL	Sec. 5, 20-23
5-11	METHOD DETECTION LIMITS FOR INORGANICS FOR DRINKING WATER PROTOCOL	Sec. 5, 24

LIST OF TABLES (Continued)

		Page Number
7-1	SAMPLE CONTAINERS, PRESERVATION AND HOLDING TIMES	Sec. 7, 5
7-2	SAMPLE CONTAINER PREPARATION SUMMARY	Sec. 7, 6
7-3	SAMPLE CONTAINER PREPARATION PROTOCOLS	Sec. 7, 7
9-1	ANALYTICAL METHODS	Sec. 9, 2-3
9-2	ANALYTICAL METHODS FOR INORGANICS ANALYSIS FOR DRINKING WATER	Sec. 9, 4
9-3	ANALYTICAL METHODS FOR ORGANIC ANALYSIS FOR DRINKING WATER	Sec. 9, 5

LIST OF FIGURES

		Page Number
3-1	REGIONAL LOCATION MAP, HOLLY RUN PLANT SITE	Sec. 3, 16
3-2	HOLLY RUN PLANT SITE	Sec. 3, 17
4-1	PROJECT ORGANIZATION CHART	Sec. 4, 8
7-1	SAMPLE LABELS	Sec. 7, 8
7-2	CHAIN-OF-CUSTODY RECORD	Sec. 7, 9

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LIST OF ACRONYMS

CLP	Contract Laboratory Program
DMP	Data Management Plan
Du Pont	E.I. du Pont de Nemours and Company, Inc.
DR	Data Reviewer
ETC	ETC Corporation Laboratories
FM	Field Manager
FRC	Field Record Custodian
FS	Feasibility Study
HSP	Health and Safety Plan
IFB	Invitation for Bid
IR	Internal Reviewer
LIM	Laboratory Information Management
MP	Method Procedures
NEIC	National Enforcement Investigations Center (USEPA)
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
OVA	Organic Vapor Analyzer
PM	Project Manager
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
QAU	Quality Assurance Unit (ETC Corporation)
EAS	Routine Analytical Services (CLP)
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
SIPM	Site Investigation Procedures Manual
SHSO	Site Health and Safety Officer
STL	Sampling Team Leader
STM	Sampling Team Member(s)
SOW	Statement of Work
SOP	Standard Operating Procedure
TCL	U.S. EPA Target Compound List
TM	Task Manager
USEPA	U.S. Environmental Protection Agency
VOA	Volatile Organic Analysis
WA	Work Assignment
WCC	Woodward-Clyde Consultants

3.0 PROJECT DESCRIPTION

3.1 OVERVIEW

In 1986, the Mitre Corporation, under contract to the USEPA, conducted a site evaluation at the Holly Run Plant site and generated a Hazard Ranking System (HRS) score for the North Disposal site, in accordance with provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund"). An overall HRS score for the site of 51.91 was developed, based upon observed groundwater contamination and the potential (not observed) impact on regional water supply wells. Surface water and airborne exposure routes were considered insignificant in the HRS scoring. Based upon the HRS score, the USEPA has proposed inclusion of the site on the Superfund National Priority List (NPL), which would require remedial investigations, feasibility studies,and possible remedial actions under the terms of CERCLA.

Under the terms of an Administrative Order by Consent with the USEPA (Consent Order) (Ref. 2) dated February 18, 1980, Du Pont has agreed to conduct an RI/FS at the Holly Run Plant Site. The RI/FS will be performed in accordance with the terms and conditions of the Consent Order. Details of the scope of services and schedule for implementation of the tasks necessary to conduct a RI/FS for the Site are contained within the Work Plan (Ref. 3).

3.2 BACKGROUND

The Du Pont Newport landfill is located at the site of the Holly Run (or Newport) Plant of the E.I. du Pont de Nemours and Company in Newport, Delaware (Figure 3.1). The landfill consists of two separate areas separated by the Christina River which flows through New Castle County, Delaware. The portion of the landfill which is located north of the Christina River is a seven acre parcel bounded on its southeast side by the Christina River. The southern part of the land is fifteen acre parcel bounded by the Christina

River on the northwest. The former is referred to herein as the North Disposal Site, and the latter is referred as the South Disposal Site.

The Newport Plant is a pigment manufacturing plant now owned by Ciba-Geigy located at James and Water Street in Newport, Delaware. The site was originally owned and operated (from 1902 to 1929) by Henrik J. Krebs for the manufacture of Lithopone, a white inorganic pigment. In 1929, Du Pont purchased the site, which has since been used to manufacture Lithopone and other materials, including organic and inorganic pigments. The pigment manufacturing operations were purchased by Ciba-Geigy in 1984 while chromium dioxide recording tape operations have been retained by Du Pont.

During plant operations, areas of the site bordering the Christina River were landfilled as a means of waste disposal until 1974, when Du Pont terminated such on-site landfill activities (Figure 3.2). The South Disposal Site operated from approximately 1902 to 1953 and covers approximately 15 acres. Materials disposed in this landfill consisted of primarily insoluble residues of zinc and barites ores, which were pumped through a pipeline under the Christina River. Some dikes and berms were constructed to contain the material. This material hardened to a sandstone consistency, according to Du Pont's records. In 1973, the State of Delaware, Department of Highways, deposited approximately 130,000 cubic yards of soil from highway construction at this location, covering the South Disposal site with approximately 3 feet of soil.

The North Disposal site (see Figure 3.2) was used for disposal of general refuse and process wastes from the early 1900's until 1974. The North Disposal site covers approximately 7 acres. Table 3-1 presents a summary of materials known or suspected to have been disposed in the North and South Disposal sites.

The major waste materials containing potentially hazardous constituents, based upon available information, are discussed below:

Lithopone Wastes The lithopone process produced a white pigment composed of barium sulfide and zinc sulfate. Some lithopone pigments (off-quality) and lithopone wastes may have been disposed in the North Disposal site. Several thousand tons of fill dirt containing zinc and barites ore were also placed in the North Disposal site.

Wastes from the lithopone process consisted of insoluble ore residues. Zinc ore was treated with sulfuric acid to dissolve zinc. Insoluble residues were precipitated with ferric hydroxide, resulting in a "red mud" which was disposed. The zinc process also produced a byproduct filter cake which was sold for cadmium recovery.

The barium sulfate ore was roasted in kilns to reduce the sulfate to barium sulfide, which was dissolved in hot water. The insoluble ore residues formed a "black mud", which was disposed. The waste muds were generated in an estimated ratio of 1 part red mud to 3 parts black mud. Best estimates indicate disposal of approximately 25,000 tons of this mixture over approximately 15 acres in the South Disposal site. After 1953, any remaining ore residue wastes were disposed in the North Disposal site. According to the available records, after disposal, the muds solidified to a "sandstone consistency". Potential contaminants from lithopone wastes and ore residues include barium, zinc, and cadmium.

Copper Phthalocyanine Wastes Copper phthalocyanine, a stable blue-green pigment has been manufactured at the plant since 1947. In general, byproducts have been discharged to municipal waste treatment facilities. Some off-quality pigments were disposed at the North Disposal site. According to data provided by Du Pont, copper phthalocyanine is essentially non-toxic by the oral route. It has been approved by the U.S. Food and Drug Administration (DFA) for use as a pigment in polymers used in food packaging. According to Merck (1983), this compound is also approved by FDA for use in polypropylene sutures.

Quinacridone Wastes Quinacridone, a stable red organic pigment, has been manufactured at the plant since 1958. Byproducts of the process have generally been discharged to municipal wastewater treatment facilities, with the exception of an insoluble

tarry solid, which was disposed in the North Disposal site until 1974. Primary constituents of this tar are biphenyl, diphenyl ether, and alpha-methyl naphthalene. The quinacridone process also used tetrachloroethylene and it is possible that some quinacridone wastes may have become contaminated with tetrachloroethylene or Dowtherm constituents. Off-quality quinacridone pigments were also disposed in the North Disposal site. Soluble components of quinacridone wastes, including tetrachloroethylene if present, represent potential groundwater contaminants from this material. According to data supplied by Du Pont, quinacridone itself is essentially non-toxic by the oral route, and has been approved by FDA as a colorant for polyolefins used in food packaging.

"Afflair" Pigment Wastes Afflair, a stable white pigment, consists of mica coated with titanium dioxide. Some scrap mica (a natural mineral), was disposed at the North Disposal site. This material is unlikely to represent a significant source of contamination.

Metal Production Wastes From 1950 to 1960, several metals and metal alloys were manufactured at the plant. These included titanium, zirconium, and silicon, which are relatively inert substances. Unknown, small quantities of off-grade materials were disposed in the North Disposal site.

For about 2 years during this period, thoriated nickel (nickel containing 2-5 percent of ThO_2) was produced. Approximately 20 tons of process wastes (primarily off-grade thoriated nickel) were disposed in the North Disposal site under NRC guidelines. Thorium is a radioactive substance.

Since the metals produced are essentially insoluble in their metallic forms, there is little potential for leaching of the disposed ThO_2 and its daughters.

Chromium Dioxide Wastes Chromium dioxide has been manufactured at the plant since 1966, some of which is used in production of magnetic recording tape (mylar coated with chromium dioxide). Approximately 10 tons of off-quality chromium dioxide (in drums)

and mylar recording tape (in bags) were disposed at the North Disposal site. The primary potential groundwater contaminant from this material is the heavy metal, chromium, which has not been found in groundwater in measurable concentrations.

Miscellaneous Wastes As shown on Table 3-1 a variety of other wastes including low volume process wastes, lab packs, and garbage were disposed in the North Disposal site. A variety of low level contaminants could be present in these materials.

3.3 START, MILESTONES AND COMPLETION

The RI/FS activities will be implemented according to the deliverables schedule set forth in Article VI of the Consent Order (Ref. 2). A summary of the project schedule is presented in Section 9 of the Work Plan (Ref. 3).

3.4 OBJECTIVES AND USE OF DATA

The overall objectives of this RI/FS are to:

- determine the nature and extent of contamination at the Du Pont site (Remedial Investigation, RI),
- determine if the site poses a threat to public health and environment (Endangerment Assessment, EA), and
- develop, screen and evaluate remedial action alternatives to prevent, mitigate or otherwise respond to or remedy the release of hazardous substances (if any) from the Newport site.

The RI/FS includes the following 7 general tasks, each having several subtasks:

Task 1 Description of Current Situation
Task 2 Site Investigation
Task 3 Site Investigation Analysis
Task 4 Remedial Investigation (RI) Report
Task 5 Remedial Alternatives Screening
Task 6 Remedial Alternatives Evaluation
Task 7 Feasibility Study (FS) Report

The environmental monitoring and measurement efforts covered by this QAPP are limited to subtasks within Task 2, Site Investigation. The Site Investigation will be performed to gather sufficient data to accomplish the RI/FS objectives. The Site Investigation is designed to more fully characterize the current on-site conditions and the environmental pathways by which the site may be impacting the surrounding areas. The subtasks include:

Subtask 2a	Waste Characterization
Subtask 2b	Radiological Investigation
Subtask 2c	Hydrogeologic Investigation
Subtask 2d	Production/Residential Well Investigation
Subtask 2e	Soil and Sediment Investigation
Subtask 2f	Cap Integrity Study
Subtask 2g	Surface Water Investigation

The specific objectives of the Site Investigation subtasks are as follows:

2a Waste Characterization

- o Determine boundaries of the waste disposal area at the site through a surface geophysics survey,
- o Determine the potential on-site location and extent of distribution of volatile organic compounds through a soil-gas survey,
- o Assess the on-site waste characterization by sampling disposed materials from test pits and borings, and
- o Define naturally occurring background concentrations for U.S. EPA Target Compound List (TCL) parameters in the ground water within the immediate site vicinity so that comparisons with on-site liquids can be evaluated.

2b Radiological Investigation

- o Determine the presence or absence of radioactive material in the waste by radon gas sampling and defining surfical extent of any gamma radiation emission from the site surface above ambient background levels for health and safety of on-site personnel.

2c Hydrogeologic Investigation

- o Assess the current ground water quality of the water bearing formation(s) beneath the site with respect to occurence and contaminant mobility,
- o Define the vertical and horizontal nature and extent of contamination (if any) within the local ground water,

- Characterize the ground water flow pathways near the site by evaluating physical data relating to regional aquifer(s), local flow directions and the attenuation capacity and mechanisms of the soils, and

- Define naturally occuring background concentrations for TCL parameters in ground water in the immediate site vicinity so that comparisons with down-gradient concentrations can be evaluated.

2d Residential/Production Well Investigation

- Assess the current and potential impact of site related contamination (if any) on the water quality of nearby residential, commercial and industrial production wells, and

- Define naturally occurring background concentrations for TCL parameters in production wells in the immediate site vicinity so that comparisons with down-gradient concentrations can be evaluated.

2e Surface Soil and Sediment Investigation

- Assess the horizontal distribution of TCL parameter contamination in cover materials surface soils and sediments from on-site areas, at the site perimeters, and in close proximity to the site,

- Define naturally occurring background concentrations for TCL parameters in surface soil and sediment samples in the immediate site vicinity so that comparisons with on-site and down-gradient concentrations can be evaluated.

2f Cap Integrity Investigation

- Assess the physical integrity of the current cover material on the site to determine its physical characteristics, and
- Evaluate the surface runoff/infiltration potential of this material.

2g Surface Water Investigation

- Identify the site drainage patterns, the flow characteristics and the general physical nature of the adjacent surface water systems,
- Assess the impact of surface water runoff from the site in its current condition on the quality of adjacent ditches, streams and ponds,
- Determine levels of TCL parameters in the water of these surface water bodies that may have been impacted by previous or current site conditions, and
- Define naturally occurring background concentrations for TCL parameters in surface water bodies in the immediate site vicinity so that comparisons with down-gradient concentrations can be evaluated.

3.5 DATA COLLECTION SUMMARY

A complete descriptions of the Site Investigation subtasks are provided in the Work Plan (Ref. 3, Section 2). A summary of the sampling and analysis effort is presented in Table 3-2. The parameters which will be analyzed in the various site media are indicated in Table 3-3.

TABLE 3-1

WASTE DISPOSAL INVENTORY
DU PONT NEWPORT SITE

NORTH DISPOSAL SITE

Material	Estimated Quantity
o Garbage	several tons
o Trash (glass, wood, paper, cardboard)	100 tons
o Steel drums	several hundred tons
o Lever Packs	several hundred tons
o Sand and dirt	several hundred tons
o Concrete	
o Steel work	
o Asbestos	5 tons
o Light ballasts - PCB's/PBB's	2 tons
o Rubber - gasket material, tires from garage	a few tons
o Nylon shutters	2 tons
o Artificial marble - "Corian"	4 tons
o Acrylates and latex emulsions	several hundred pounds
o Quinacridone tars	1,000 tons
o Bad quality copper phthalocyanine pigment	100 tons
o Bad quality quinacridone pigment	
o Bad quality "Afflair" pigment	estimated 10,000 - 15,000 lbs
o Bad quality Chromium Dioxide coated "Mylar" recording tape	6 tons
o "Afflair" fines (30% mica) plus (70% tiO_2)	estimated 100,000 lbs
o Bad quality Chromium Dioxide floor sweepings and bags	2 tons
o Thoriated nickel	20 tons of combined waste
o Dirt contaminated with zinc ore	several hundred tons
o Raw materials left in bag liners and drums and leaks from drums	several hundred tons
- Quinacridone	a few tons
- Copper phthalocyanine	a few tons
- "Afflair"	a few tons
- Magnetic Products	a few tons

TABLE 3-1 (Continued)

Material	Estimated Quantity
o Labortaory waste including resins from Quinacridone, copper phthalocyanine, "Afflair", and Magnetic Products	a few tons
o Zinc and Barite ores	several thousand tons

o Scrap amounts of the following materials (maximum several tons).

- Graphite (thick pieces-carbon 3' x 1-1/2' rock) + shavings + powder
- Titanium - metal
- Sodium (burned or exploded)
- "Baxtron: (tungsten carbide cobalt)
- "Tiper-sul" (potassium titanate (PKT)
- "Fibex" (TiO_2)
- "Erifon"
- Silica
- Silicon
- Zirconium
- Columbium
- Titanium bisteric - synthetic oil - antifreeze
- Tetra-isopropyltitanate

SOUTH DISPOSAL SITE

o Lithopone Waste Slurry zinc and barium ore residues including barium sulfide	estimated 25,000 tons

TABLE 3-2

PLANNED SAMPLING AND ANALYSIS EFFORT (PHASE II)

Matrix	No. of Stations	Freq.	No. of Samples	Field(4) Dup.	Field Blanks	Matrix Spike	Total(1) Samples	Test Parameters
Groundwater (res/prod wells)	14	1	14	2	2	1	19	Field(2) Total TCL(3)
River Water (Christina River)	6	1	6	1	1	1	9	Field(2) Total TCL(3)
River Sediment (Christina River)	6	1	6	1	--	1	8	Total TCL(3)
Surface Soil (background)	4	1	4	1	--	1	6	Total TCL(3) except volatiles
Wetlands Biota	5	1	5	1	--	1	7	TCL Semi-volatiles(3) and metals
Subsurface Soil(5) (cover soils)	13	1	13	--	--	--	13	Soil identifica geotechnical testir

Notes:

(1) A trip blank will be included in each shipment containing water samples for Volatile Organic Compound Analysis. Trip blanks are not included in the total number of samples indicated.
(2) Field test for pH, Specific Conductivity and Temperature will be performed at the time of sampling each monitor well, residential well and surface water.
(3) TCL parameters are shown in Table 3-3 of QAPP.
(4) Field duplicates will be based on 10 percent of all samples.
(5) Samples will be obtained with split-spoon samplers for soil identification purpose. No chemical testing will be done.

TABLE 3-3

TARGET COMPOUND LIST (TCL) PARAMETERS

Volatile Organic Compound Analysis

	CAS #		CAS #
Chloromethane	74-87-3	1,2-Dichloropropane	78-87-5
Bromoethane	74-83-9	trans-1,3-Dichloropropene	10061-02-6
Vinyl Chloride	75-01-4	Trichloroethene	79-01-6
Chloroethane	75-00-3	Diboromochloromethane	124-48-1
Methylene Chloride	75-09-2	1,1,2-Trichloroethane	79-00-5
Acetone	67-64-1	Benzene	71-43-2
Carbon Disulfide	75-15-0	cis-1,3-Dichloropropene	10061-01-5
1,1-Dichloroethene	75-35-4	2-Chloroethyl Vinyl Ether	110-75-8
1,1-Dichloroethane	75-35-3	Bromoform	75-25-2
trans-1,2-Dichloroethene	156-60-5	2-Hexanone	591-78-6
Chloroform	67-66-3	4-Methyl-2-pentanone	108-10-1
1,1-Dichloroethane	107-06-2	Tetrachloroethene	127-18-4
Carbon Tetrachloride	56-23-5	Toluene	108-88-3
Vinyl Acetate	108-05-4	Chlorobenzene	108-90-7
Bromodichloromethane	75-27-4	Ethyl Benzene	100-41-4
1,1,2,2-Tetrachloroethane	79-34-5	Styrene	100-42-5
		Total Xylenes	

Extractables Organic Compound Analysis (semi-volatiles)

	CAS #		CAS #
Phenol	108-95-2	Acenaphthene	83-23-9
bis(2-Chloroethyl)ether	111-44-4	2,4-Dinitrophenol	51-28-5
2-Chlorophenol	95-57-8	4-Nitrophenol	100-02-7
1,3-Dichlorobenzene	541-73-1	Dibenzofuran	132-64-9
1,4-Dichlorobenzene	106-46-7	2,4-Dinitrotoluene	121-14-2
Benzyl Alcohol	100-51-6	2,6-Dinitrotoluene	606-20-2
1,2-Dichlorobenzene	95-50-1	Diethylphthalate	84-66-2
2-Methylphenol	95-48-7	4-Chlorophenyl Phenyl ether	7005-72-3
bis(2-Chloroisopropyl)ether	39638-32-9	Fluorene	86-73-7
4-Methylphenol	106-44-5	4-Nitroaniline	100-01-6
N-Nitroso-Dipropylamine	621-64-7	4,6-Dinitro-2-methylphenol	534-52-1
Hexachloroethane	67-72-1	N-nitrosodiphenylamine	86-30-6
Nitrobenzene	98-95-3	4-Bromophenyl Phenyl ether	101-55-3

TABLE 3-3 (Continued)

Isophorone	78-59-1	Hexachlorobenzene	118-74-1
2-Nitrophenol	88-75-5	Pentachlorophenol	87-86-5
2,4-Dimethylphenol	105-67-9	Phenanthrene	85-01-8

Extractable Organic Compound Analysis (semi-volatiles)

	CAS #		CAS #
Benzoic Acid	65-85-0	Anthracene	120-12-7
bis(2-Chlorethoxy)methane	111-91-1	Di-n-butylphthalate	84-74-2
2,4-Dichlorophenol	120-83-2	Fluoranthene	206-44-0
1,2,4-Trichlorobenzene	120-82-1	Pyrene	129-00-0
Naphthalene	91-20-3	Butyl Benzyl Phthalate	85-68-7
4-Chloroaniline	106-47-8	3,3'-Dichlorobenzidine	91-94-1
Hexachlorobutadiene	87-68-3	Benzo(a)anthracene	56-55-3
4-Chloro-3-methylphenol		bis(2-ethylhexyl)phthalate	117-81-7
(para-chloro-meta-cresol)	59-50-7	Chrysene	218-01-9
2-Methylnapthalene	91-57-6	Di-n-octyl Phthalate	117-84-0
Hexachlorocyclopentadiene	77-47-4	Benzo(b)fluoranthene	205-99-2
2,4,6-Trichlorophenol	88-06-2	Benzo(k)fluoranthene	207-08-9
2,4,5-Trichlorophenol	95-95-4	Benzo(a)pyrene	50-32-8
2-Chloronapthalene	91-58-7	Indeno(1,2,3-cd)pyrene	193-39-5
2-Nitroaniline	88-74-4	Dibenz(a,h)anthracene	53-70-3
Dimethyl Phthalate	131-11-3	Benzo(g,h,i)perylene	191-24-2
Acenaphthylene	208-96-8		
3-Nitroaniline	99-09-2		

Pesticide and PCB Analysis

	Cas #		CAS #
alpha-BHC	319-84-6	Endosulfan Sulfate	1031-07-8
beta-BHC	319-85-7	4,4'-DDT	50-29-3
delta-BHC	319-86-8	Endrin Ketone	53494-70-5
gamma-BHC (Lindane)	58-89-9	Methoxychlor	72-43-5
Heptachlor	76-44-8	Chlordane	57-74-9
Aldrin	309-00-2	Toxaphene	8001-35-2
Heptachlor Epoxide	1024-57-3	AROCLOR-1016	12674-11-2
Endosulfan 1	959-98-8	AROCLOR-1221	11104-28-2
Dieldrin	60-57-1	AROCLOR-1232	11141-16-5

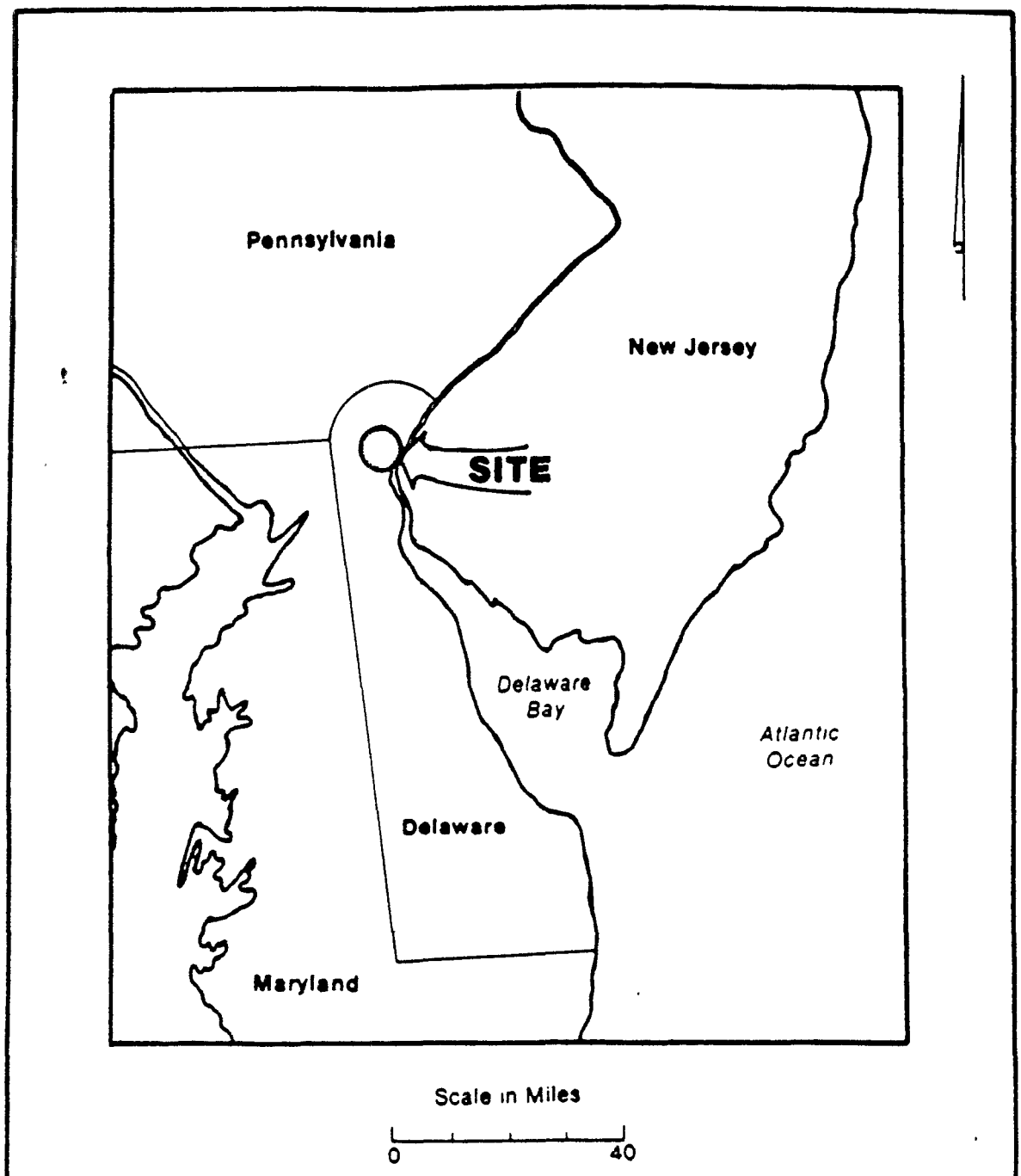
TABLE 3-2 (Continued)

4,4'-DDE	72-55-9	AROCLOR-1242	53469-21-9
Endrin	72-20-8	AROCLOR-1248	12672-29-6
Endosulfan 11	33213-65-9	AROCLOR-1254	11097-69-1
		AROCLOR-1260	11096-82-5

Metals Analysis

	CAS#		CAS#
Aluminum	7429-90-5	Lead	7439-92-1
Antimony	7440-36-0	Magnesium	7439-95-4
Arsenic	7429-38-2	Manganese	7439-96-5
Barium	7440-39-3	Mercury	7439-97-6
Beryllium	7440-41-7	Nickel	7440-02-0
Cadmium	7440-43-9	Potassium	7440-09-7
Calcium	7440-70-2	Selenium	7782-49-2
Chromium	7440-47-3	Silver	7440-22-4
Cobalt	7440-48-4	Sodium	7440-23-5
Copper	7440-50-8	Thallium	7440-28-0
Cyanide	74-90-8	Tin	7440-31-5
Iron	7439-89-6	Vanadium	7440-62-2
		Zinc	7440-66-6

VICINITY MAP



REGIONAL LOCATION MAP
HOLLY RUN PLANT SITE
NEWPORT, DELAWARE

Woodward-Clyde Consultants

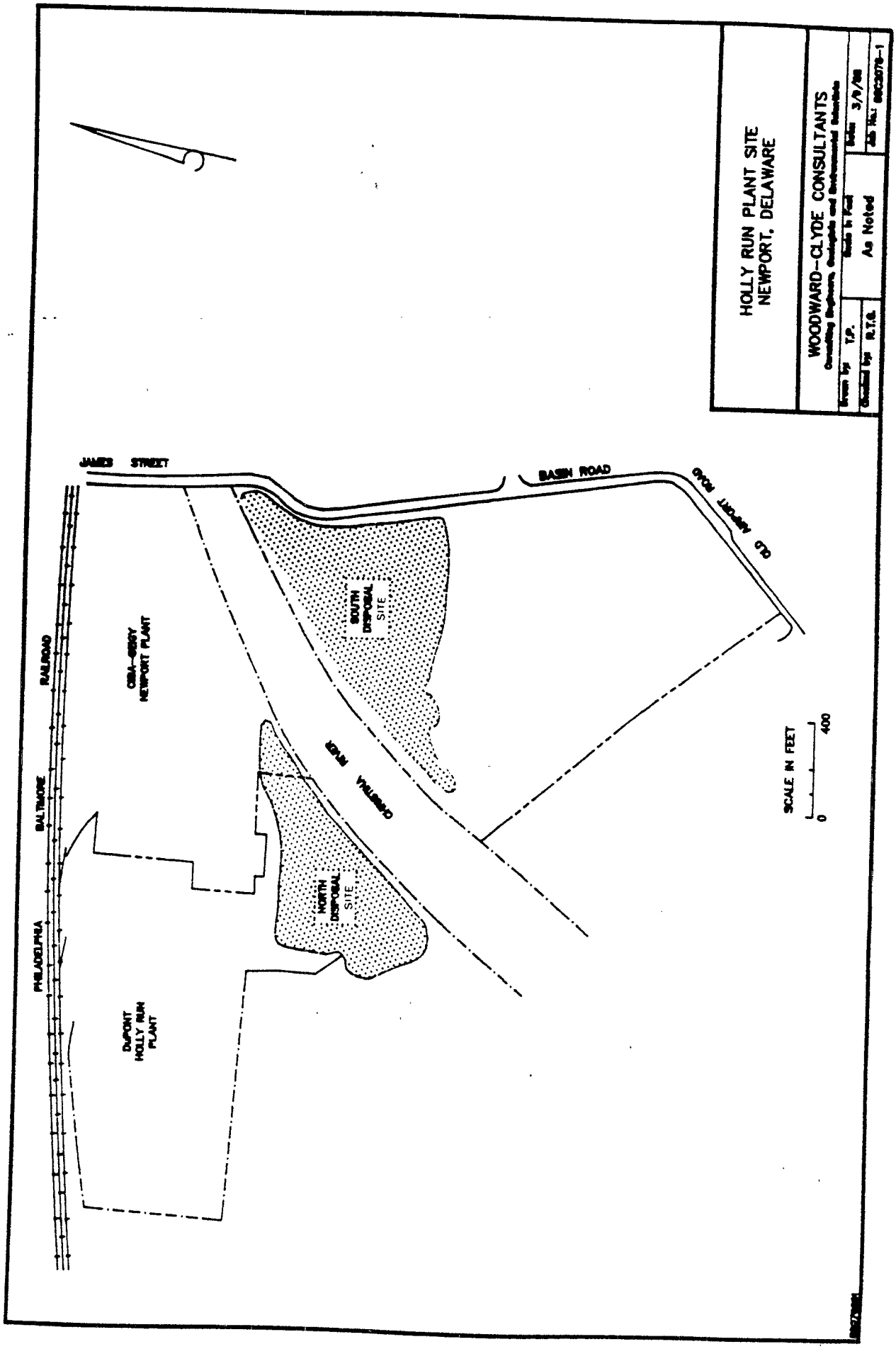

HOLLY RUN PLANT SITE
NEWPORT, DELAWARE
WOODWARD-CLYDE CONSULTANTS
Drawn by T.P.
Checked by R.T.G.
Scale As Noted
Date 3/9/88
Job No.: 88C2076-1
JAMES STREET
BASIN ROAD
OLD NEWPORT ROAD
RAILROAD
BALTIMORE
PHILADELPHIA
CONRAIL
CIBA-GEIGY NEWPORT PLANT
DuPONT HOLLY RUN PLANT
SOUTH DISPOSAL SITE
NORTH DISPOSAL SITE
HOLLY RUN
SCALE IN FEET
0
400

FIGURE 3-2

4.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

The Du Pont Newport Site RI/FS will be performed by Woodward-Clyde Consultants (WCC), Plymouth Meeting, Pennsylvania. The project organizational structure is shown on Figure 4-1. The following are the definitions of responsibilities of the WCC positions shown:

- Project Manager (PM) - Alfred Hirsch, Ph.D. will be responsible for adherence to project schedules; reviewing and assessing the adequacy of the performance of technical staff assigned to the project, the drilling contractor and the laboratory; maintaining full and orderly project documentation; interaction with the Du Pont, USEPA Region III during the progress of the project; and preparing monthly progress reports and the RI/FS technical reports.

- Field Manager (FM) - Mr. Roger Gresh will be responsible for coordinating the activities of field personnel and those of the drilling contractor; adherence of the field work to the project plans; and documentation of field work.

- Sampling Team Leader (STL) - will be responsible for coordinating the activities of the Sampling Team Members with respect to installing and calibrating the field instrumentation, conducting the sampling program, assuring the availability and maintenance of all sampling equipment, materials and decon, providing for shipping and packaging materials, and supervising the accurate completion of all sampling paper work that includes but is not limited to chain-of-custody records and field log books.

- Sampling Team Member (STM) - will be responsible for inspecting field operations such as boring and well installation, performing geophysical survey, and collecting appropriate environmental samples from the various media

under study - all in accordance with the requirements and procedures stipulated in the Health and Safety Plan and the Sampling and Analysis Plan.

- Field Record Custodian (FRC) - will be responsible for accurate completion of pre-sampling and sampling records, chain-of-custody records, shipping and handling of samples, and management of analytical records from field activities.

- Site Health and Safety Officer (SHSO) - will be responsible for implementing the site-specific health and safety directives in the Health and Safety Plan.

- Data Reviewer (DR) - will be responsible for review of field and laboratory data for compliance with QA objectives (precision, accuracy, sensitivity and completeness); and notification to the Project Manager of any QC deficiencies.

- Internal Reviewer (IR) - will be independent of the project team and responsible for providing review of project documents and reports with respect to conformance to the scope of work and technical adequacy.

- Task Leader (TL) - will be responsible for coordinating technical activities of an assigned task under the direction of the Project Manager.

Analytical testing of samples will be performed by ETC Corporation, Edison, New Jersey. The functional organization and responsibilities of ETC Corporation staff for this project are summarized below:

ETC Program/Project Manager - (Marilyn C. Bracken, Ph.D.)

- Provide liaison with client's program needs and laboratory staff.

- Assign duties of the laboratory staff and orientation of the staff to the QA needs and requirements of the project.
- Ensure all approved laboratory-specific procedures and internally prepared plans, and reports meet QA requirements.
- Serve as liaison (with QA official) between the Project Staff and other internal/external organizations or organization sub-units.
- Ensure laboratory's performance meets the requirements of the contract.

ETC Project Services Coordinator (Diane Komar)

- Provide all field/laboratory coordination activities including those of any subcontractors.
- Ensure proper labeling, handling, storage and shipping requirements have been met.
- Ensure all appropriate chain-of-custody procedures have been followed.
- Assist the QA Official in implementing any audits.
- Provide coordination of any requests for information on sample status, invoice questions or general project status.
- Serve as the "collection point" for Project Staff reporting of nonconformances and changes in QA project documents and activities.
- Keep Program Manager abreast of all laboratory performance problems, quality action reports for changes in protocol added program.

ETC Laboraory Director (Kenneth G. Hebeo)

- Provide general supervision of laboratories.
- Collaborate with Project Manager/Program Management office in establishing quality sampling and testing programs.
- Schedule and execution of testing program.
- Serve as liaison between the laboratory staffs and other groups.

- Serve as the "collection point" for laboratory staff reporting of nonconformances and changes in laboratory activities.
- Notify laboratory and quality control groups of specific laboratory nonconformances and changes.
- Release technical reports and data management reports.

ETC Laboratory Sample Custodian (William Deckelman)

- Receive and inspect samples and shipping containers.
- Record the conditions of sample and shipping containers.
- Sign appropriate documents shipped with the samples.
- Verify and record correctness of sample documentation (i.e., sample tags, chain-of-custody records, billings, etc).
- Initiate transfer of samples to appropriate lab sections with proper documentation (i.e., lab notebollk, assignment sheets, inventory sheets, lab ID number, etc.).
- Place samples, sample/extracts, and spent samples into appropriate storage and secure areas.
- Control and monitor access an dstorage of samples/extracts.

ETC QA Director (Karen Kotz)

- Serve as the official organizational contact for all QA matters for the project. For example, QA project plan implementation, sampling and analytical methodologies, Data Quality Objectives (DQO's), field and laboratory audits, management and data quality audits, PE and QC studies, etc.

- Identify and response to QA needs, resolve problems, and answer requests for guidance or assistance. For example, field sampling problems (limited supplies of sample containers), transportation problems (holding time conflicts), etc.

- Review, evaluate and approve QA project plans prior to EPA review, evaluations and approval/nonapproval.

- Provide guidance in the development of QA project plans to each respective organization's program offices, management offices and program/program managers or officers.

- Ensure that management, data quality, field and laboratory audits are performed on QA Project Plans.

- Track the progress of all QA tasks in Project Plans (from preplanning to data assessments) and consult periodically with program/project managers.

- Prepare and submit all internal QA reports (with recommendations and comments) to the appropriate line managers in their organization and to EPA officials when properly coordinated with program/project management.

- Assure that appropriate corrective actions are taken on all QA tasks when, where and however needed.

- Ensure that data of known quality and integrity are available for each planning (DQO's) and report phase (valid data).

4.1 LABORATORY TESTING ASSIGNMENTS

Various types of samples from different matrices will be sent to different laboratories as described below:

- ETC Corporation will provide the analytical services for the RI/FS. ETC Corporation will analyze the samples in their Edison, New Jersey facility for all of the required parameters.

- Teledyne Isotopes, Inc., Westwood, New Jersey will conduct analyses of alpha, beta and gamma radioactivity on soil and rock and analysis of radon gas concentrations from soil gas samples.

- Earth Technology Corporation, geotechnical laboratory, will conduct classification and testing of contaminated soils and subsurface soil samples. Testing of uncontaminated soils will be conducted by WCC.

- The drilling services for the RI/FS will be provided by a qualified local driller.

4.2 LABORATORY QA/QC RESPONSIBILITIES

4.2.1 ETC CORPORATION

- Internal QC to be provided by commercial analytical laboratory.
- QA overview of data by WCC QA Officer.

4.2.2 TELEDYNE ISOTOPES, INC.

- Internal QC to be provided by H.W. Jeter.
- QA overview of data by H.G. King, Quality Assurance Manager.

4.2.3 EARTH TECHNOLOGY CORPORATION

- Internal QC provided by Thierry R. Sanglerat, the geotechnical laboratory.
- QA overview of data by WCC QA Officer.

4.3 PERFORMANCE AND SYSTEM AUDITS

The performance of various elements and systems participating in these studies may be audited by the indicated audit agency.

- Field Operations - Du Pont QA Officer.
- ETC Corporation - ETC QA Officer or USEPA Region III QA Officer.
- Evidence Audit - USEPA Region III QA Office or USEPA NEIC.
- Earth Technology Corporation - USEPA Region III QA Office.

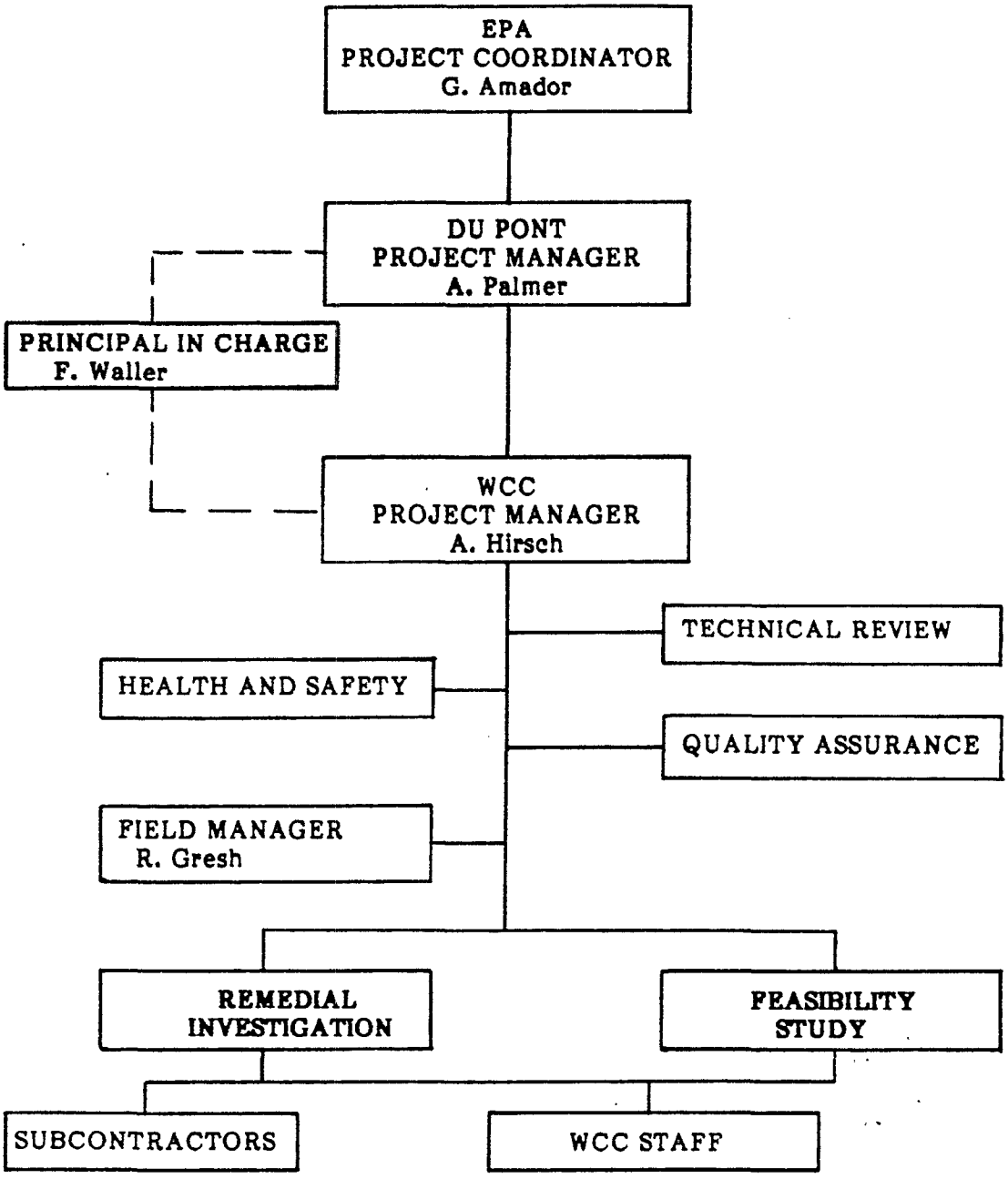


Figure 4-1 PROJECT ORGANIZATION CHART

5.0 QA OBJECTIVES FOR MEASUREMENT DATA

The overall QA objective is to develop and implement procedures for sampling, laboratory analyses, field measurements and reporting that will provide data to a degree of quality consistent with its intended use. This section defines the goals for levels of QC effort; and the accuracy, precision, sensitivity, completeness, representativeness and comparability of laboratory analyses.

5.1 LEVEL OF QC EFFORT

Field duplicates and field blanks will be taken and submitted to the analytical laboratory to provide means to assess the quality of the data resulting from the field sampling program. Field duplicate samples will be analyzed to check for sampling and analytical reproducibility. Field blank samples will be analyzed to check for procedural contamination of samples. The general level of this QC effort will be one field duplicate and one field blank for every 10 investigative liquid samples. One field duplicate sample of soil and sediment will be collected for every 10 investigative samples, but field blanks of soil and sediment are not required. Duplicate and blank samples will also be collected for air samples at the rate of one for each 10 investigative samples per media/analysis. The specific level of field QC effort for the Du Pont Landfill RI/FS is summarized by sample matrix in Table 3-2.

ETC Corporation is a participant in the USEPA Contract Laboratory Program (CLP) for organics and inorganics testing and has been routinely audited and approved by the USEPA. The level of QC effort provided by ETC Corporation will be equivalent to the level of QC effort specified under the CLP program for the Routine Analytical Services (RAS) parameters to be tested. The level of QC effort for testing of inorganics (Metals and Cyanide) will conform to the protocols in SOW-785 (Ref. 5) or SOW-787, if applicable. The level of QC effort for testing of Target Compound List (TCL) organics (Volatiles, Semi-volatiles and Pesticides/PCB's) will conform to the protocols in SOW-785. The level of QC effort for testing of TCL organics (Volatiles Semi-volatiles and Pesticides/PCB's) for drinking water

criteria will conform to protocols in 40 CFR Part 136, October 26, 1984, entitled "Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; Final Rule and Interim Final Rule and Proposed Rule" (Ref. 6). The level of QC effort for the specific parameters to be tested under the Du Pont Newport Site RI/FS is summarized on Table 5-1.

The QC level of effort for the field measurement of pH consists of pre-measurement calibration and a post-measurement verification using two standard reference solutions each time as appropriate to the sample pH. This procedure will be performed for each sample tested. The QC effort for field conductivity measurements will include daily calibration of the instrument using standard solutions of known conductivity.

5.2 ACCURACY, PRECISION AND SENSITIVITY OF ANALYSIS

The QA objective with respect to accuracy, precision, and sensitivity of laboratory analytical data is to achieve the QC acceptance criteria of the analytical protocols. In general, the accuracy, precision and sensitivity criteria and methods are those stipulated by the SOW-785 and the CRL SOP for organic and inorganic analyses (Refs. 5 and 6).

The accuracy and precision of laboratory analyses will be determined by testing of laboratory blanks, duplicates and spiked samples in accordance with the frequencies shown in Table 5-1. Accuracy and precision criteria for the parameters to be tested are shown in Table 5-2 5-7, 5-8 and 5-9. Compounds that will be used as matrix and surrogate spikes for organic analyses, and their control limits, are shown in Table 5-3. Chemicals that will be used as spikes for inorganic analyses are shown in Table 5-4; inorganic spike recovery control limits are 75-125%.

The sensitivities for the analytical testing are the detection limits shown in Tables 5-5, 5-6, 5-10, and 5-11. It is anticipated that these detection limits will be achieved

for the majority of samples. Higher detection limits may be obtained in oily samples and samples containing high concentrations of contaminants.

The accuracy of field measurements of pH will be assessed through pre-measurement calibrations and post-measurements verifications using at least two standard buffer solutions. The two measurements must each be within + 0.05 standard unit of buffer solution values. Precision will be assessed through replicate measurements. (The electrode will be withdrawn, rinsed with deionized water, and re-immersed between each replicate). The instrument used will be capable of providing measurements to 0.1 standard unit.

5.3 COMPLETENESS, REPRESENTATIVENESS AND COMPARABILITY

It is expected that ETC Corporation will provide data meeting QC accept-ance criteria for 95 percent or more of all samples tested. Completely valid data (ie, all QC parameters within control limits) are required for samples designated as "background" samples.

The sampling program was established to provide data representative of site conditions. During development of this network, consideration was given to past site operations and practices, existing analytical data, physical setting and processes. The extent to which existing and planned analytical data will be comparable depends on the similarity of sampling and analytical methods. The procedures used to obtain the planned analytical data, as documented in this QAPP, are expected to provide comparable data. These new analytical data, however, may not be directly comparable to existing data because of differences in procedures.

5.4 FIELD MEASUREMENTS

Measurement data will be generated in many field activities that are incidental to collecting samples for analytical testing or unrelated to sampling. These activities include, but are not limited to, the following:

- Documenting time and weather conditions,
- Locating and determining the elevation of sampling stations,
- Determining depths in a borehole or well and static water levels,
- Standard penetration testing,
- Slug testing and grain size analysis,
- Calculating pumping rates, and
- Verifying well development and pre-sampling purge volumes.

The general QA objective for such measurement data is to obtain reproducible and comparable measurements to a degree of accuracy consistent with the intended use of such data through the documented use of standard procedures.

TABLE 5-1

QC LEVEL OF EFFORT FOR ANALYTICAL TESTING

Parameters	Audit	Frequency(1)
Metals	Calibration Blank (ICP and AA)	Each calibration, beginning and end of each run, 10% frequency
	Initial Calibration Verification (ICP and AA)	Daily and each instrument setup
	Continuing Calibration Verification (ICP and AA)	Beginning and end of each run; 10% frequency or every 2 hrs
	Preparation Blank (ICP and AA)	One per batch or one per 20 samples received
	Matrix Spike Analysis (ICP and AA)	One per case or one per 20 samples received
	Duplicate Sample Analysis (ICP and AA)	One per case or one per 20 samples received
	Laboratory QC Sample Analysis (ICP and AA)	One per batch or one per 20 samples received
	Duplicate Injections (AA-Furnace)	Each sample (at least a single analytical spike will we be performed to determine if the method of standard addition is required for quantitation)
	Interference Check Sample (ICP)	Beginning and end of each run or one per 4-hr shift
	Serial Dilution Analysis (ICP)	One per case or one per 20 samples received
Cyanide	Calibration Blank	One per analytical run or at least one per set-up
	Matrix Spike Analysis	One per analytical run or at least one per set-up
	Duplicate Sample Analysis	One per analytical run or at least one per set-up
	Laboratory QC Sample Analysis	One per analytical run or at least one per set-up
Organics (GC/MS) VOC, Semi-Volatile, Pesticide/ PCB's	Laboratory Blank	One per case or one per 20 samples received
	Matrix Spike Analysis	One per case or one per 20 samples received
	Matrix Spike Duplicate Analysis	One per case or one per 20 samples received
	Surrogate Spike	Each sample

NOTE:

(1) QC audits are to be performed at most frequent interval specified.

TABLE 5-2

ACCURACY AND PRECISION CRITERIA FOR ANALYTICAL TESTING

Parameters	Audit	Control Limits
Metals		
AA-Furnace	Calibration Blank	± D.L.
	Initial Calibration Verification	90-110%
	Continuing Calibration Verification	90-110%
	Preparation Blank	± D.L.
	Matrix Spike Analysis	75-125%
	Duplicate Sample Analysis	± D.L. or 20% RPD
	Laboratory QC Sample Analysis	85-115%
	Duplicate Injections	± 20% RPD
ICP	Calibration Blank	± D.L.
	Initial Calibration Verification	90-110%
	Continuing Calibration Verification	90-110%
	Preparation Blank	± D.L.
	Interference Check Sample	± 20%
	Serial Dilution Analysis	± 10%
	Matrix Spike Analysis	75-125%
	Duplicate Sample Analysis	± D.L. or 20% RPD
	Laboratory QC Sample Analysis	85-115%
Mercury	Calibration Blank	± D.L.
	Initial Calibration Verification	80-120%
	Continuing Calibration Verification	80-120%
	Preparation Blank	± D.L.
	Matrix Spike Analysis	75-125%
	Duplicate Sample Analysis	± D.L. or 20% RPD
	Laboratory QC Sample Analysis	80-120%
Cyanide	Calibration Blank	± D.L.
	Initial Calibration Verification	85-115%
	Continuing Calibration Verification	85-115%
	Preparation Blank	± D.L.
	Matrix Spike Analysis	75-125%
	Matrix Duplicate Analysis	± D.L. or 20% RPD
	Laboratory QC Sample Analysis	80-120%
Volatile and Extractable Organic Compounds	Laboratory Blank	± D.L.
	Laboratory Duplicate	± 35% RPD
	Matrix Spike Analysis	(1)
	Surrogate Spike	(1)

Notes:

(1) Matrix and Surrogate Spike recovery limits are shown in Table 5-3.

AA = Atomic Absorption
D.L. = Detection Limit
ICP = Inductively Coupled Plasma
LTE = Less than or equal to
RPD = Relative Percent Difference

TABLE 5-3

MATRIX AND SURROGATE SPIKE(1) CONTROL LIMITS FOR ORGANICS ANALYSIS

MATRIX SPIKE/MATRIX SPIKE DUPLICATE

Fraction	Compound	Water (%)(2) Recovery Limits	Water (%)(2) RPD	Soil/Sediment (%)(2) Recovery Limits	Soil/Sediment (%)(2) RPD
VOA	1,1-Dichloroethane	61-145	14	59-172	22
VOA	Trichlorethane	71-120	14	62-137	24
VOA	Chlorobenzene	75-130	13	60-133	21
VOA	Toluene	76-125	13	59-139	21
VOA	Benzene	76-127	11	66-142	21
BN	1,2,4-Trichlorobenzene	39-98	28	38-107	23
BN	Acenaphthane	46-118	31	31-137	19
BN	2,4-Dinitrotoluene	24-96	38	28-89	47
BN	Pyrene	26-127	31	35-142	36
BN	N-Nitroso-di-n-propylamine	41-116	38	41-126	38
BN	1,4-Dichlorobenzene	36-97	28	28-104	27
Acid	Pentachlorophenol	9-103	50	17-109	47
Acid	Phenol	12-89	42	26-90	35
Acid	2-Chlorophenol	27-123	40	25-102	50
Acid	4-Chloro-3-methylphenol	23-97	42	26-103	33
Acid	4-Nitrophenol	10-80	50	11-114	50
Pest.	Lindane	56-123	15	46-127	50
Pest.	Heptachlor	40-131	20	35-130	31
Pest.	Aldrin	40-120	22	34-132	43
Pest.	Dieldrin	52-126	18	31-134	38
Pest.	Endrin	56-121	21	42-139	45
Pest.	4,4'-DDT	38-127	27	23-134	50
PNA's(3)	Napthalene	29-122	40		
PNA's(3)	Fluoranthene	46-123	30		
PNA's(3)	Benzo(a)anthracene	26-135	40		
PNA's(3)	Indeno(1,2,3-cd)pyrene	39-116	30		

SURROGATE SPIKE

Fraction	Compound	Recovery Limits(%) Water	Recovery Limits(%) Soil/Sediment
VOA	Toluene-d_8	88-110	81-117
VOA	4-Bromfluorobenzene	86-115	74-121
VOA	1,2-Dichloroethane-d_4	76-114	70-121
BN	Nitrobenzene-d_5	35-114	23-120
BN	2-Fluorobiphenyl	43-116	30-115
BN	p-Terphenyl-d_{14}	33-141	18-137
Acid	Phenol-d_5	10-94	24-113
Acid	2-Fluorophenol	21-100	25-121
Acid	2,4,6-Tribromophenol	10-123	19-122
Pest.	Dibutylchlorendate	24-154(2)	20-150(2)

NOTES:

(1) Spike levels will be in accordance with SOW-787

(2) These limits for matrix spike and pesticide surrogate spike analyses are for advisory purposes only and will not be used to determine if a sample should be reanalyzed.

(3) These limits are also applicable to laboratory control spikes for PNA's.

TABLE 5-4

MATRIX SPIKE CHEMICALS(1) AND
CONTROL LIMITS (2) FOR INORGANIC ANALYSIS

Chemical	ICP/AA Water	ICP/AA Soil/Sediment	Furnace AA Water	Furnace AA Soil/Sediment	Other
Aluminum	X(3)	*(4)	X	X	
Antimony	X	X	X	X	
Arsenic	X	X	X	X	
Barium	X	X			
Beryllium	X	X	X	X	
Cadmium	X	X	X	X	
Calcium	*	*			
Chromium	X	X	X	X	
Cobalt	X	X			
Copper	X	X			
Iron	X	*			
Lead		X	X	X	
Magnesium	*	*			
Manganese	X	X			
Mercury					X
Nickel	X	X			
Potassium	*	*			
Selenium	X	X	X	X	
Silver	X	X	X	X	
Sodium	*	*			
Thallium	X	X	X	X	
Vanadium	X	X			
Zinc	X	X			
Cyanide					X

(1) Matrix spike levels will be in accordance with SOW-785 or SOW-787, if applicable.
(2) Control limits for spike recovery shall be 75-125% for all chemicals.
(3) X = spike required
(4) * = spike not required

TABLE 5-5

METHOD DETECTION LIMITS FOR ORGANIC ANALYSIS

Volatiles	CAS Number	Detection Limits(1) Low Water(2) ug/l	Detection Limits(1) Low Soil(3) Sediment ug/kg
Chloromethane	74-87-3	10	10
Bromomethane	74-83-9	10	10
Vinyl Chloride	75-01-4	10	10
Chloroethane	75-00-3	10	10
Methylene Chloride	75-09-2	5	5
Acetone	67-64-1	10	10
Carbon Disulfide	75-15-0	5	5
1,1-Dichloroethane	75-35-4	5	5
1,1-Dichloroethane	75-35-3	5	5
trans-1,2-Dichloroethane	156-60-5	5	5
Chloroform	67-66-3	5	5
2-Butanone	78-93-3	10	10
1,1,1-Trichloroethane	71-55-6	5	5
Carbon Tetrachloride	56-23-5	5	5
Vinyl Acetate	108-05-4	10	10
Bromodichloromethane	75-27-4	5	5
1,1,2,2-Tetrachloroethane	79-34-5	5	5
1,2-Dichloropropane	78-87-5	5	5
trans-1,3-Dichloropropene	10061-02-6	5	5
Trichloroethane	79-01-6	5	5
Dibromocloromethane	124-48-1	5	5
Benzene	71-43-2	5	5
cis-1,3-Dichloropropene	10061-01-5	5	5
2-Chloroethyl Vinyl Ether	110-75-8	10	10
Bromoform	75-25-2	5	5
2-Hexanone	591-78-6	10	10
4-Methyl-2-Pentanone	108-10-1	10	10
Tetrachloroethane	127-18-4	5	5
Toluene	108-88-3	5	5
Cholorobenzene	108-90-7	5	5

TABLE 5-5 (Continued)

Semi-Volatiles	CAS Number	Detection Limits(1) Low Water(2) ug/l	Low Soil(3) Sediment ug/kg
Ethyl Benzene	100-41-4	5	5
Styrene	100-42-5	5	5
Total Xylenes		5	5
N-nitrosodimethylamine	62-75-9	10	330
Phenol	108-95-2	10	330
Aniline	62-53-3	10	330
bis(2-Chloroethyl)ether	111-44-4	10	330
2-Chlorophenol	95-57-8	10	330
1,3-Dichlorobenzene	541-73-1	10	330
1,4-Dichlorobenzene	106-46-7	10	330
Benzyl Alcohol	100-51-6	10	330
1,2-Dichlorobenzene	95-50-1	10	330
2-Methylphenol	95-48-7	10	330
bis(2-Chloroisopropyl)ether	39638-32-9	10	330
4-Methylphenol	106-44-5	10	330
N-Nitroso-Dipropylamine	621-64-7	10	330
Hexachloroethane	67-72-1	10	330
Nitrobenzene	98-95-3	10	330
Isophorone	78-59-1	10	330
2-Nitrophenol	88-75-5	10	330
2,4-Dimethylphenol	105-67-9	10	330
Benzoic Acid	65-85-0	50	1600
bis(2-Chloroethosy)methane	111-91-1	10	330
2,4-Dichlorophenol	120-83-2	10	330
1,2,4-Trichlorobenzene	120-82-1	10	330
Naphthalene	91-20-3	10	330
4-Chloroaniline	106-47-8	10	330
Hexachlorobutadiene	87-68-3	10	330
4-Chloro-3-methylphenol (para-chloro-meta-cresol)	59-50-7	10	330
2-Methylnaphthalene	91-57-6	10	330

TABLE 5-5 (Continued)

Semi-Volatiles	CAS Number	Detection Limits(1) Low Water(2) ug/l	Detection Limits(1) Low Soil(3) Sediment ug/kg
Hexachlorocyclopentadiene	77-47-4	10	330
2,4,6-Trichlorophenol	88-06-2	10	330
2,4,5-Trichlorophenol	95-95-2	50	1600
2-Chloronaphthalene	91-58-7	10	330
2-Nitroaniline	88-74-4	50	1600
Dimethyl Phthalate	131-11-3	10	330
Acenaphthylene	208-96-8	10	330
3-Nitroaniline	99-09-2	50	1600
Acenaphthene	83-32-9	10	330
2,4-Dinitrophenol	51-28-5	50	1600
4-Nitrophenol	100-02-7	50	1600
Dibenzofuran	132-64-9	10	330
2,4-Dinitrotoluene	121-14-2	10	330
2,6-Dinitrotoluene	606-20-2	10	330
Diethylphthalate	84-66-2	10	330
4-Chlorophenyl Phenyl ether	7005-72-3	10	330
Fluorene	86-73-7	10	330
4-Nitroaniline	100-01-6	50	1600
4,6-Dinitro-2-methylphenol	534-52-1	50	1600
N-nitrosodiphenylamine	86-30-6	10	330
4-Bromophenyl Phenyl ether	101-55-3	10	330
Hexachlorobenzene	118-74-1	10	330
Pentachlorophenol	87-86-5	50	1600
Phenanthrene	85-01-8	10	330
Anthracene	120-12-7	10	330
Di-n-butylphthalate	84-74-2	10	330
Fluoranthene	206-44-0	10	330
Benzidine	92-87-5	100	1600
Pyrene	129-00-0	10	330
Butyl Benzyl Phthalate	85-68-7	10	330

TABLE 5-5 (Continued)

Semi-Volatiles	CAS Number	Detection Limits(1) Low Water(2) ug/l	Detection Limits(1) Low Soil(3) Sediment ug/kg
3,3'-Dichlorobenzidine	91-94-1	20	660
Benzo(a)anthracene	56-55-3	10	330
bis(2-ethylhexyl)phthalate	17-81-7	10	330
Chrysene	218-01-9	10	330
Di-n-octyl Phthalate	17-84-0	10	330
Benzo(b)Fluoranthene	205-99-2	10	330
Benzo(k)fluoranthene	207-08-9	10	330
Benzo(a)pyrene	50-32-8	10	330
Ident(1,2,3-cd)prene	193-39-5	10	330
Dibenz(a,h)anthracene	53-70-3	10	330
Benzo(g,h,i)perylene	191-24-2	10	330

Pesticides(6)	CAS Number	ug/l	ug/kg
alpha-BHC	319-84-6	0.05	2.0
beta-BHC	319-85-7	0.05	2.0
delta-BHC	319-86-8	0.05	2.0
gamma-BHC (Lindane)	58-89-9	0.05	2.0
Heptachlor	76-44-8	0.05	2.0
Aldrin	309-00-2	0.05	2.0
Heptachlor Epoxide	1024-57-3	0.05	2.0
Endosulfan 1	959-98-8	0.05	2.0
Dieldrin	60-57-1	0.10	4.0
4,4'-DDE	72-55-9	0.10	4.0
Endrin	72-20-8	0.10	4.0
Endosulfan 11	33213-65-9	0.10	4.0
4,4'-DDD	72-54-8	0.10	4.0
Endrin Aldehyde	7421-93-4	0.10	4.0
Endosulfan Sulfate	1-07-8	0.10	4.0
4,4'-DDT	50-29-3	0.10	4.0
Endrin Ketone	53494-70-5	0.10	4.0

TABLE 5-5 (Continued)

Pesticides(6)	CAS Number	ug/1	ug/kg
Methoxychlor	72-43-5	0.5	20.0
Chlordane	57-74-9	0.5	20.0
Toxaphene	8001-35-2	1.0	40.0
AROCLOR-1016	12674-11-2	0.5	20.0
AROCLOR-1221	11104-28-2	0.5	20.0
AROCLOR-1232	11141-16-5	0.5	20.0
AROCLOR-1242	53469-21-9	0.5	20.0
AROCLOR-1248	12672-29-6	0.5	20.0
AROCLOR-1254	11097-69-1	1.0	40.0
AROCLOR-1260	11096-82-5	1.0	40.0

NOTES:

(1) 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.

(2) Medium Water Contract Required Detection Limits (CRDL) for Volatile Hazardous Substances List (HSL) Compounds are 100 times the individual Low Water CRDL.

(3) Medium Soil/Sediment CRDL for Volatile HSL Compounds are 100 times the individual Low Soil/Sediment CRDL.

(4) Medium Water CRDL for Semi-Volatile HSL Compounds are 100 times the individual Low Water CRDL.

(5) Medium Soil/Sediment CRDL for Semi-Volatile HSL Compounds are 60 times the individual Low Soil/Sediment CRDL.

(6) Specific detection limits for pesticides are highly matrix dependent. The detection limits listed herein are provided for guidance and may not always be achievable.

(7) Medium Water CRDL for Pesticide HSL Compounds are 100 times the individual Low Water CRDL.

(8) Medium Soil/Sediment CRDL for Pesticide HSL Compounds are 60 times the individual Low Soil/Sediment CRDL.

TABLE 5-6

METHOD DETECTION LIMITS FOR INORGANICS ANALYSIS

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
Cyanide	10

NOTES

(1) Any analytical method specified in SOW-785 may be utilized as long as the documented instrument or method detection limits meet the 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 CRDL.

(2) These CRDLs are the instrument detection limits obtained in pure water thatmust be met using the procedure in SOW-785. The detection limits for samples may be considerably higher depending on the sample matrix.

TABLE 5-7

ACCURACY AND PRECISION CRITERIA FOR ORGANICS FOR DRINKING WATER PROTOCOL

All units are Micrograms/Liter

Parameter	Audit	Compounds	Spike Level (ug/l)	Control Limits*
VOLATILES	Lab Blank	--	--	< Detection Limit except for: Methylene Chloride Toluene Acetone 5 x D.L.
	Matrix Spike Duplicate Precision	--	--	<22 percent
	Surrogate Spike Recovery	1,2-Dichloroethane-D_4	10	8-12 (ug/l)
		Benzene-D6	10	8-12 (ug/l)
		Toluene-D8	10	8-12 (ug/l)
	Control Standard Spiked with a Rotating Mixture of 10 to 12 Standards	See Method Detection Limit Table for Volatile Compounds		Will vary for each set of samples
ACID/BASE/ NEUTRAL COMPOUNDS	Method Blank	--	--	< 2 times Detection Limit
	Matrix Spike Duplicate Precision	—	—	<38 Percent RPD
	Surrogate Spike Recovery	2-Fluorophenol	100	43 - 166 percent
		Phenol-D_5	100	10 - 94 percent
		Nitrobenzene-D_5	100	35 - 114 percent
		2-Fluorobiphenyl	100	43 - 116 percent
		2,4,6-Tribromophenol	100	10 - 123 percent
		p-Terphenyl-D_{14}	100	33 - 141 percent

TABLE 5-7 (Continued)

Parameter	Audit	Compounds	Spike Level (ug/l)	Control Limits*
ACID/BASE/ NEUTRAL COMPOUNDS	Matrix Spike Recovery	Phenol	100	10 - 100 percent FOR ALL COMPOUNDS
		2-Chlorophenol	100	
		1,3-Dichlorobenzene	100	
		1,4-Dichlorobenzene	100	
		Benzyl Alcohol	100	
		n-Nitrosodipropylamine	100	
		1,2,4-Trichlorobenzene	100	
		4-Chloroaniline	100	
		4-Chloro-3-ethylphenol	100	
		2,6-Dinitrotoluene	100	
		Acenaphthene	100	
		Dibenzofuran	100	
		2,4-Dinitrotoluene	100	
		4-Nitrophenol	100	
		Pentachlorophenol	100	
		Di-n-Butyl-phthalate	100	
		Pyrene	100	
PCBs-Pesticides	Lab Blank	--	--	< Detection Limit
	Lab Duplicate	--	--	< 35 percent RPD
	Surrogate Spike Recovery	Dibutyl Chlorendate	0.7	75 - 125 percent
	Matrix Spike Recovery	Aldrin	5	3-6 (ug/l)
		Lindane	2	1-4 (ug/l)
		4,4'-DDT	15	10-18 (ug/l)
		Dieldrin	5	3-6 (ug/l)
		Endosulfan I	6	4-7 (ug/l)
		Endrin	10	6-12 (ug/l)
		Heptachlor	2	1-4 (ug/l)
		4,4'-Methoxychlor	20	15-28 (ug/l)
		Archlor 1242	2	2-6 (ug/l)

* In Reagent water

TABLE 5-8

ACCURACY AND PRECISION CRITERIA FOR ICP METALS FOR DRINKING WATER PROTOCOL

An undigested control standard will be analyzed at the beginning and end of each run to evaluate instrument performance. A digested acidified reagent water laboratory blank will be analyzed with each run to check the system for contaminants and interferences. The control limits for these audits for each parameter are presented below:

Parameter	Control Limits for Control Standards	Control Standard Concentration	Control Standards for Laboratory Blank
Aluminum	± 400 ug/l of true ≤ 800 ug/l difference	4,000 ug/l	0 ± 80 ug/l
Barium	± 20 ug/l of true ≤ 40 ug/l difference	200 ug/l	0 ± 5 ug/l
Beryllium	± 20 ug/l of true ≤ 40 ug/l difference	200 ug/l	0 ± 1 ug/l
Cadmium	± 20 ug/l of true ≤ 40 ug/l difference	200 ug/l	0 ± 2 ug/l
Calcium	± 10,000 ug/l of true ≤ 20,000 ug/l difference	100 ug/l	0 ± 500 ug/l
Chromium	± 70 ug/l of true ≤ 140 ug/l difference	700 ug/l	0 ± 8 ug/l
Cobalt	± 20 ug/l of true ≤ 40 ug/l difference	200 ug/l	0 ± 2 ug/l
Copper	± 70 ug/l of true ≤ 140 ug/l difference	700 ug/l	0 ± 6 ug/l
Iron	± 1,400 ug/l of true ≤ 2,800 ug/l difference	14,000 ug/l	0 ± 80 ug/l

TABLE 5-8 (Continued)

Parameter	Control Limits for Control Standards	Control Standard Concentration	Control Standards for Laboratory Blank
Magnesium	± 500 ug/l of true ≤ 1,000 ug/l difference	5,000 ug/l	0 ± 100 ug/l
Manganese	± 35 ug/l of true ≤ 70 ug/l difference	350 ug/l	0 ± 5 ug/l
Nickel	± 120 ug/l of true ≤ 240 ug/ difference	1,200 ug/l	0 ± 15 ug/l
Potassium	± 2,000 ug/l of true ≤ 4,000 ug/l difference	10,000 ug/l	0 ± 2,000 ug/l
Silver	± 10 ug/l of true ≤ 20 ug/l difference	100 ug/l	0 ± 3 ug/l
Sodium	± 2,000 ug/l of true ≤ 4,000 ug/l difference	20,000 ug/l	0 ± 1,000 ug/l
Tin	± 20 ug/l of true ≤ 40 ug/l difference	200 ug/l	0 ± 40 ug/l
Vanadium	± 25 ug/l of true ≤ 50 ug/l difference	250 ug/l	0 ± 5 ug/l
Zinc	± 300 ug/l of true ≤ 600 ug/l difference	3,000 ug/l	0 ± 40 ug/l

TABLE 5-9

ACCURACY AND PRECISION CRITERIA FOR FURNACE METALS INORGANICS FOR DRINKING WATER PROTOCOL

Parameter	Audit	Frequency	Control Limits	Control Standard Concentration
Mercury	Mercuric Chloride Control Standard (1)	Once per run	± .2 ug/l of true value	1.5 ug/l
	Methyl Mercury Control Standard (2)	Beginning and end of run	± .2 ug/l of true value ≤ .3 ug/l difference	1.5 ug/l
	Laboratory Blank	Once per run	0.0 ± 0.1 ug/l	
Cyanide	Undistilled Standard	Beginning and end of run	± 15 ug/l of true ≤ 30 ug/l difference	100 ug/l
	Distilled Standard	Beginning and <30 ug/l difference	± 15 ug/l of true	100 ug/l
	Distilled Blank	Once per run	0 ± 8 ug/l	
Antimony, Selenium, and Thallium	Control Standard Undigested	Beginning and end of run	± 1 ug/l of true ≤ 2 ug/l difference	10 ug/l
	Laboratory Blank Undigested	Once per run	0 ± 2 ug/l	
	Laboratory Blank Digested*	Once Per run	0 ± 2 ug/l	
Lead and Arsenic	Control Standard Undigested	Beginning and end of run	± 2 ug/l of true ≤ 4 ug/l difference	20 ug/l
	Laboratory Blank Undigested	Once per run	0 ± 2 ug/l	
	Laboratory Blank Digested*	Once per run	0 ± 2 ug/l	

TABLE 5-10

METHOD DETECTION LIMITS FOR ORGANICS
FOR DRINKING WATER PROTOCOL

VOLATILE COMPOUNDS

PARAMETER	CAS #	METHOD* DETECTION LIMIT (ug/l)	SPIKE LEVEL IN REAGENT WATER (ug/l)	CONTROL* LIMITS (ug/l)
BENZENE	71-43-2	1.5	10	8-12
BROMODICHLOROMETHANE	75-27-4	1.5	10	8-12
BROMOFORM	75-25-2	1.5	10	8-12
BROMOMETHANE	74-83-9	10.0	10	1-20
CARBON TETRACHLORIDE	56-23-5	1.5	10	8-12
CHLOROBENZENE	108-90-7	1.5	10	8-12
CHLOROETHANE	75-00-3	1.5	10	8-12
2-CHLOROETHYL VINYL ETHER	110-75-8	1.5	10	8-12
CHLOROFORM	67-66-3	1.5	10	8-12
CHLOROMETHANE	74-87-3	10.0	10	1-20
DIBROMOCHLOROMETHANE	124-48-1	1.5	10	8-12
1,1-DICHLOROETHANE	75-34-3	1.5	10	8-12
1,2-DICHLOROETHANE	107-06-2	1.5	10	8-12
1,1-DICHLOROETHENE	75-34-4	1.5	10	8-12
trans-1,2-DICHLOROETHENE	156-60-5	1.5	10	8-12
1,2-DICHLOROPROPANE	78-87-5	1.5	10	8-12
cis-1,3-DICHLOPROPROPENE	10061-01-5	2.0	10	8-12
trans-1,3-DICHLOROPROPENE	10061-02-6	1.0	10	8-12
ETHYL BENZENE	100-41-4	1.5	10	8-12
METHYLENE CHLORIDE (1)	75-09-2	1.0	10	8-12
1,1,2,2-TETRACHLOROETHANE	79-34-5	1.5	10	8-12
TETRACHLOROETHENE	127-18-4	1.5	10	8-12
TOLUENE (1)	108-88-3	1.5	10	8-12
1,1,1-TRICHLOROETHANE	71-55-6	1.5	10	8-12
1,1,2-TRICHLOROETHANE	79-00-5	1.5	10	8-12
TRICHLOROETHENE	79-01-6	1.5	10	8-12
VINYL CHLORIDE	75-01-4	10.0	10	1-20
ACROLEIN	107-02-8	100.0	300	200-400
ACETONE (1)	67-64-1	75.0	300	225-375
ACRYLONITRILE	107-13-1	50.0	300	250-350
CARBON DISULFIDE	75-15-0	3.0	10	7-13
2-BUTANONE	78-93-3	(50)	100	50-150
VINYL ACETATE	108-05-4	15.0	15	1-30
4-METHYL-2-PENTANONE	108-10-1	(3)	20	16-24
2-HEXANONE	519-78-6	(50)	150	100-200
STYRENE	100-42-5	1.0	10	8-12
m-XYLENE	108-38-3	2.0	10	8-12
o-XYLENE (2)	95-47-6			
p-XYLENE (2)	106-42-3	2.5	20	7-13

* IN REAGENT WATER
(1) COMMON LABORATORY SOLVENT - BLANK LIMIT IS 5x METHOD DETECTION LIMIT
(2) THE o-XYLENE AND p-XYLENE ARE REPORTED AS A TOTAL OF THE TWO

TABLE 5-10 (Continued)

BASE/NEUTRAL AND ACID EXTRACTABLE COMPOUNDS

PARAMETER	CAS #	METHOD* DETECTION LIMIT (ug/l)
ANILINE	62-53-3	1.5
BIS (2-CHLOROETHYL) ETHER	111-44-4	1.5
PHENOL	108-95-2	2.0
2-CHLOROPHENOL	95-57-8	2.0
1,3-DICHLOROBENZENE	541-73-1	2.0
1,4-DICHLOROBENZENE	106-46-7	2.0
1,2-DICHLOROBENZENE	95-50-1	2.5
BENZYL ALCOHOL	100-51-6	2.0
BIS (2-CHLOROLSOPROPYL) ETHER	118-60-1	2.5
2-METHYLPHENOL	95-48-7	1.0
HEXACHLOROETHANE	67-72-1	2.0
N-NITROSODIPROPYLAMINE	621-64-1	1.5
NITROBENZENE	98-85-3	2.5
4-METHYLPHENOL	108-39-4	1.0
ISOPHORONE	78-59-1	2.5
2-NITROPHENOL	88-75-5	2.0
2,4-DIMETHYLPHENOL	105-67-9	2.0
BIS (2-CHLOROETHOXY) METHANE	111-91-1	2.5
2,4-DICHLOROPHENOL	120-83-2	2.0
1,2,4-TRICHLOROBENZENE	120-82-1	2.0
NAPHTHALENE	91-20-3	2.0
4-CHLOROANILINE	106-47-8	2.0
HEXACHLOROBUTADIENE	87-68-3	2.5
BENZOIC ACID	65-85-0	(30)
2-METHYLNAPHTHALENE	91-57-6	2.0
4-CHLORO-3-METHYLPHENOL	59-50-7	1.5
HEXACHLOROCYCLOPENTADIENE	77-47-4	2.0
2,4,5-TRICHLOROPHENOL	95-95-4	1.5
2,4,6-TRICHLOROPHENOL	88-06-2	1.5
2-CHLORONAPHTHALENE	91-58-7	1.5
ACENAPHTHYLENE	208-96-8	1.5
DIMETHYL PHTHALATE	131-111-3	1.5
2,6-DINITROTOLUENE	606-20-2	1.0
ACENAPHTHENE	83-32-9	1.5
3-NITROANILINE	99-09-2	2.5

* In Reagent Water

NOTE: Method Blank Limit in Reagent Water is 2x Detection Limit
Values in Parenthesis are estimated.

TABLE 5-10 (Continued)

BASE/NEUTRAL AND ACID EXTRACTABLE COMPOUNDS (Continued)

PARAMETER	CAS #	METHOD* DETECTION LIMIT (ug/l)
DIBENZOFURAN	132-64-9	1.0
2,4-DINITROPHENOL	51-28-5	(15)
2,4-DINITROTOLUENE	121-14-2	1.0
FLUORENE	86-73-7	1.0
4-NITROPHENOL	100-02-7	1.5
4-CHLOROPHENYL PHENYL ETHER	7005-72-3	1.0
DIETHYL PHTHALATE	84-66-2	1.0
4,6-DINITRO-2-METHYLPHENOL	534-52-1	(15)
1,2-DIPHENYLHYDRAZINE (AZOBENZENE)	122-66-7	1.0
N-NITROSODIPHENYLAMINE AND DIPHENYLAMINE	100-01-6	3.0
4-NITROANILINE	100-01-6	3.0
4-BROMOPHENYL PHENYL ETHER	101-55-3	1.5
HEXACHLOROBENZENE	118-74-1	1.5
PENTACHLOROPHENOL	87-86-5	2.0
PHENANTHRENE	85-01-8	1.0
ANTHRACENE	120-12-7	2.5
DI-n-BUTYL PHTHALATE	84-74-2	2.0
FLUORANTHENE	206-44-0	1.5
PYRENE	129-00-0	1.5
BUTYL BENZYL PHTHALATE	85-68-7	3.5
CHRYSENE**	218-01-9	
BENZO (a) ANTHRACENE**	56-55-3	1.5
BIS (2-ETHYLHEXYL) PHTHALATE	117-81-7	1.0
DI-n-OCTYL PHTHALATE	117-84-0	1.5
BENZO (b) FLUORANTHENE***	205-99-2	
BENZO (k) FLUORANTHENE***	207-08-9	1.5
BENZO (a) PYRENE	193-39-5	2.0
INDENO (1,2,3-cd) PYRENE	193-39-5	3.5
DIBENZO (a,h) ANTHRACENE	53-70-3	2.5
BENZO (ghi) PERYLENE	191-24-2	4.0
2-NITROANILINE	88-74-4	1.0

* In Reagent Water
** These two parameters reported as a total
*** These two parameters reported as a total

Note: Values in parentheses are estimated

Table 5-10 (Continued)

PESTICIDES AND PCBS

PARAMETER	CAS #	METHOD* DETECTION LIMIT ug/l
ALDRIN	309-00-2	0.005
alpha BHC	319-84-6	(0.010)
beta BHC	319-85-7	(0.005)
delta BHC	319-86-8	(0.005)
gama BHC (LINDANE)	58-89-9	0.005
CHLORADANE	57-74-9	(0.020)
4,4'-DDD	72-54-8	(0.020)
4,4'DDE	72-55-9	(0.005)
4,4'-DDT	50-29-3	0.020
DIELDRIN	60-57-1	0.010
ENDOSULFAN I	959-98-8	0.010
ENDOSULFAN II	33213-65-9	0.010
ENDOSULFAN SULFATE	1031-07-8	(0.10)
ENDRIN	72-20-8	0.010
ENDRIN ALDEHYDE	7421-93-4	(0.030)
ENDRIN KETONE	53494-70-5	(0.030)
HEPTACHLOR	76-44-8	0.030
HEPTACHLOR EPOXIDE	1024-57-3	0.005
4,4'-METHOXYCHLOR	72-43-5	0.020
TOXAPHENE	8001-35-2	(0.25)
PCB-1242	53469-21-9	(0.10)
PCB-1248	12672-29-6	(0.10)
PCB-1254	11097-69-1	(0.10)
PCB-1260	11096-82-5	(0.10)

* In Reagent Water

Note: Values in parentheses are estimated.

TABLE 5-11

METHOD DETECTION LIMITS FOR INORGANICS FOR DRINKING WATER PROTOCOL

Parameter	Method Detection Limit* (ug/l)	Upper Limit of Working Range Without Dilution*
Aluminum	80	1×10^6
Chromium	8	2×10^4
Barium	5	2×10^4
Beryllium	1	2×10^4
Cobalt	6	2×10^4
Copper	6	2×10^4
Iron	80	1×10^6
Nickel	15	2×10^4
Manganese	5	2×10^4
Zinc	40	1×10^6
Vanadium	5	2×10^4
Silver	3	1×10^4
Arsenic	2	30
Antimony	2	30
Selenium	2	30
Thallium	2	30
Mercury	0.1	20
Tin	40	2×10^4
Calcium	500	1×10^6
Potassium	2000	1×10^{-6}
Magnesium	100	2×10^5
Sodium	1000	1×10^6
Cadmium	2	2×10^4
Lead	2	30 (AA), 2×10^4 (ICP)
Cyanide	5	200

* In Reagent water.

6.0 SAMPLING AND FIELD OPERATION PROCEDURES

The scope of field investigations for sampling air, water and soil at the Du Pont Newport Site are described in the Work Plan (Ref. 3).

Sampling and field operation procedures presented below are consistent with the Standard Operating Procedures (SOP) in the USEPA REM II Site Investigation Procedure Manual (Ref. 7) and WCC Site Investigation Baseline Procedures (Ref. 8). Specialized sampling procedures are described in this section of the QAPP. These specialized procedures take precedence over the SOPs. The procedures applicable to Remedial Investigations at the Du Pont Newport Site are summarized below:

PROCEDURE TITLE	PROCEDURE REFERENCE
Monitoring and Site Surveys	
o Monitoring Well and Piezometer Installation	WCC Technical Memorandum No. 3*
o Borehole Geophysics Survey	Sec. 6, pg. 3-4
o Soil Gas Sampling and Analysis	WCC Technical Memorandum No. 12*
o Radiometric Survey	Sec. 6, pg. 5-6
o Air Quality Monitoring and Sampling	WCC Technical Memorandum No. 4*
o Terrain Conductivity Survey	Geonics EM31 Manual
Sampling Procedures	
o Water Sampling	WCC Technical Memorandum No. 5*
o Soil, Sediment and Rock Sampling	WCC Technical Memorandum No. 6*
o River Sediment Sampling	Sec. 6, pg. 7-9
o Radon Gas Sampling	Sec. 6, pg. 10
o Determination of Ra-226 in Water	Sec. 6, pg. 11-14

PROCEDURE TITLE	PROCEDURE REFERENCE
Subsurface Investigation	
o Split Spoon Sampling	ASTM D 1586
o Soil Logging	ASTM D 2488
o Soil Grain Size Analysis	ASTM D 421 & 422
o Aquifer Testing	WCC Technical Memorandum No. 8*

* Referred WCC, Hazardous Waste Management Practice, Technical Memoranda are presented in the Appendix to QAPP.

PROCEDURE FOR PERFORMING BOREHOLE GEOPHYSICS SURVEY

General

Borehole geophysics will be conducted utilizing the Neltronics 1000K portable logging unit (or equivalent). Borehole geophysics will be conducted in the deepest monitor wells.

The geophysical logging tools will be decontaminated between each boring. Decontamination will include the tool itself and any cable which went down the boring. Decontamination will consist of a detergent/water wash and potable water rinse.

Borehole Logging Procedure

Borehole geophysics will be conducted with the Neltronics 1000K (or equivalent) portable logging unit. After each borehole is advanced to its final depth, the logger is positioned near the borehole. A geophysical tool is attached to the logging cable and centered at the top of the borehole. The tool is lowered into the borehole to the final depth of drilling and then pulled up through the borehole while an analog plotter graphs the response generated by the tool. Tools to be utilized on this project include resistance, spontaneous potential, and natural gamma ray. A brief discussion of each of these is included below.

Resistance

The resistance tool consists of a ground surface electrode and an electrode lowered into the borehole. An electrical current is passed between the electrodes. The total resistance between the two electrodes is then measured and plotted versus depth.

Natural Gamma Ray

The natural gamma ray borehole logging tool consists of a sensing device which measures the natural gamma ray emissions of the soils surrounding the sensor in the borehole. As the tool is pulled up from the hole bottom, the sensor readings are plotted versus depth for all strata encountered. The most common source of radioactivity in soils is adsorbed ions of mineralized waters on clay particles. Therefore in soils, the gamma log can be indicative of clay content.

Spontaneous Potential

Spontaneous potential is a record of the naturally occurring potentials in a borehole as a function of depth. A reference electrode is located at the ground surface and the sensing electrode is in the tool which is lowered into the borehole. Variations in spontaneous potential indicate that there are currents flowing between the formation and the fluid in the borehole. These currents are primarily electrochemical in nature.

Borehole Geophysics Results

Borehole geophysics field results will be used to aid in identifying and correlating significant stratigraphic units and selecting screen depths for subsequent shallow monitor wells.

PROCEDURE FOR PERFORMING RADIOMETRIC SURVEY

Objectives

This survey has two objectives; 1) to identify areas where thorium dioxide has been buried in the northern disposal area, and 2) to evaluate whether gamma radiation related to the buried thorium is penetrating the landfill cover. The survey is designed to identify anomalous areas and not to quantify the concentration of buried thorium dioxide in the landfill.

Procedure

A Scintrex GAD-6 four channel gamma ray spectrometer, utilizing a GSP-3 sensor with a sodium iodide crystal (or equivalent), will be used to perform the survey. An instruction manual is provided with the equipment and should be read by the operator prior to performing the survey. The steps outlined below summarize the field procedure and highlight certain aspects of operating the equipment. They are not intended as a replacement for the instruction manual.

The instruction manual recommends that the instrument be "laboratory energy calibrated" on a weekly basis. This is particularly true if a quantitative survey is to be performed. The supplier of the equipment has indicated that the GAD-6 will be shipped "laboratory calibrated" and recommends that only the daily "field energy calibration" be performed. If survey results show high variability, the operator should assume that the instrument is out of calibration or that it has malfunctioned, and the supplier should be contacted for additional information.

The field energy calibration procedure is described on page 24 of the Scintrex GAD-6 instruction manual. Before attempting the field calibration the operator should inspect the equipment to insure that all cables and batteries are properly installed and connected, and that the barium (Ba) stabilizer source is installed in the sensor. The Ba source is located in a well in the sensor end of the detector (the end that does not have the cable attachment). A

screw head, located in the center of the sensor holds the Ba source in place. The operator must unthread the screw and make sure that the Ba source is present. The Ba source is required for proper operation of the equipment and must be installed during the field calibration procedure and during normal operation.

After field calibration is complete, data collection can begin. The outcome of a gamma ray survey can be affected by two major variables, the distance the detector is held above subsurface radioactive material and the count time. During data collection the detector will be held vertically with the sensor in contact with the ground. The northern disposal site is relatively flat, and complications due to variations in relief are not anticipated. The sensor will be held at arms length, i.e., about 2 feet above the ground surface. The count time will be fixed at 300 seconds (5 minutes). However, prior to actually collecting data in the disposal area, natural background radiation levels should be established. Background measurements will be taken in an area north and west of the northern disposal area, in several locations underlain by native materials. While establishing background levels, the instrument will be operated with the display switch set on automatic. At each background station, readings will be taken at count times of 100, 300 and 1,000 seconds, to evaluate the consistency of readings at different count times. During the background survey, readings for each channel (total count, K, U and Th) will be logged).

The survey across the northern disposal area will be performed with the instrument operating in the automatic mode and with the mode selection switch set to "differential non-stripped". Data collection will be performed along a grid system that has been surveyed at the site. The survey lines are at right angles to one another and spaced 100 feet apart. Readings will be taken at 25 foot intervals along each line. After the count is completed at each station the data will be logged by the operator on a data form. During the survey, occasional repeat readings will be obtained at both the background stations, and at stations along the traverse lines to check for possible instrument drift with time.

RIVER SEDIMENT SAMPLING PROCEDURES

Objective of river sediment sampling and analysis is to provide an indication of whether river sediments have been contaminated by materials landfilled in the North and South Disposal Sites by collection and analyses of samples from three areas along the section of the Christina River which separates the two Disposal Sites.

To maximize the geographic coverage, sampling areas were proposed upstream of the South Disposal Site boundary, downstream of the North Disposal Site boundary, and directly between the North and South Disposal Sites. In each sampling area, two sample stations will be established approximately 50-feet apart on opposite sides of the river centerline. At each sample station, sediments will be sampled to a depth of 5-feet below the sediment surface, will be sectioned into discrete depth intervals, and will be submitted for chemical analysis.

SAMPLING METHODOLOGY

Samples will be collected utilizing the WCC vibration drive sediment sampler (VDSS) operating from a floating barge constructed for that purpose. Samples will be collected from two stations in each of the three sampling areas.

Sediment sampling stations will be selected in accessible areas upstream, adjacent to, and downstream of the North and South Disposal Sites. Sample station locations will be determined in the field by use of a marine sextant. Once the sampling barge had been anchored over a sample station, from that reference point the angles between three visible landmarks will be measured and recorded. These landmarks had been located on the site map previously. The sample stations will be located by plotting these measurements. Water depth will be measured at each sample station by sounding, and will be recorded along with the date and time of measurement. Elevations of all sample stations will be back-calculated from

concurrent continuous measurement of tidal fluctuations recorded at the James Street bridge monitoring station.

The sediment sampler assembly consists of a steel sampler tube 5-feet in length with a 3.5-inch O.D. and a 2.75-inch I.D. The sampler tube is equipped with a cutting shoe at its leading edge, and a trailing-end cap compatible with an AW drill rod connection. It is lined with a replaceable 2.75-inch O.D., 2.5-inch I.D. polybutyrate sleeve for sample collection. The interior of the liner sleeve is fitted with a 2.5-inch diameter o-ring sealed piston which provides necessary vacuum assistance in sediment sample recovery. The entire sampler assembly is attached via AW drill rod connection to a vibrating drive head operated by compressed air.

The sediment sampler assembly is lowered on an elevator mast to the sediment surface. Penetration of sediments is achieved by liquefaction of saturated sediments due to vibration, and gravity advancement of the sampler assembly. Sediments slide into the interior of the sampler assembly liner assisted vacuum provided by the o-ring sealed piston. The piston is locked at a stationary position at the sediment surface. On recovery, the liner containing sampled sediments is removed from the sampler assembly, capped, and sectioned into appropriate depth intervals.

Equipment which came into contact with sample material will be disassembled and decontaminated after use. Decontamination will be performed by washing with a mixture of Alconox and potable water, followed by thorough steam cleaning. Decontaminated sampling equipment will then be reassembled, and wrapped in a protective layer of clean plastic or tin foil until needed. A clean unused polybutyrate liner will be used at each sample station.

Sampler liners containing recovered sediment material will be sectioned, by cutting in the field, into three discrete depth segments whenever recovery will be sufficient to do so. Typically, the recovered sample from a single sample station will be sectioned into a 0.0 to 1.0-ft. depth interval, a 1.0 to 2.5-ft. depth interval, and a 2.5- to end-of-recovery

depth interval. The depth intervals selected will be so selected to accommodate the analytical sample volume requirements. Table 1 provides sample format for recording of sampling depths, sample recoveries, section logs, location and laboratory identifiers.

Following sectioning into discrete depth intervals, recovered sediment materials within each liner segment will be individually extruded, bisected along the long axis if the material was cohesive, and representative portions will be placed in laboratory cleaned containers. If the material recovered is not cohesive, an effort will be made to collect a representative composite. Samples in laboratory cleaned containers will be preserved by cooling, were packed in laboratory provided shuttles, and will be shipped on the date of collection in most cases.

PROCEDURE FOR RADON GAS SAMPLE COLLECTION

The following procedure describes the method used for collection of radon gas samples for anlaysis by Teledyne Isotopes, Inc., of Westwood, New Jersey. The radon gas samples will be collected in conjunction with soil gas sampling for analysis of volatile organic compounds. The sample containers are provided by Teledyne Isotopes.

Before a sample is taken, a vacuum pump is used to evacuate the soil gas probe for a period of five minutes at the rate of 1 liter per minute. The pump is then disconnected and the radon sampling cylinder attached to the probe head vacuum port. The sampling cylinder is attached to the vacuum port with duct tape because both ports are approximately the same size, and both consist of threaded pipe instead of graded gas outlet pipe. Therefore, duct tape provides a better seal than plastic tubing.

When in place against the vacuum port and sealed, the sample cylinder inlet opened. The release of the vacuum in the sampling cylinder draws soil gas in through the probe. The vacuum release valve is slowly opened allowing approximately 4 to 8 liters per minute to be drawn into the container.

When the container is full, the valve is closed and the end resealed. Each cylinder is tagged showing the date of sampling, sampler, analysis requested (radon), sample identification, and the Woodward-Clyde contact and address.

All samples are to be shipped to Teledyne the day of sampling.

DETERMINATION OF RA-226 IN WATER

1.0 INTRODUCTION

The procedure describes the method of determining Ra-226 in water samples by the emanation technique. Radon-222 is equilibrated with the parent radionuclide, Ra-226, and then transferred through a closed system to an evacuated one-liter alpha chamber. The Rn-222 and daughters activities are measured in successive counting periods for an eighteen hour period.

2.0 DETECTION CAPABILITY

The minimum detectable level (MDL) for water samples is nominally 0.1 pCi/ℓ for Ra-226 at the 4.66 sigma confidence level. This figure is based upon a sample volume of 0.5ℓ, a counting time of 1000 minutes, and upon representative values of counting efficiency (for Rn-222 and two alpha emitting daughters) and background of 2.45 and 2.3 cpm, respectively. 11/05/

3.0 SAMPLE SELECTION PROCEDURE

(a) Using the Sample Receipt Form with the Teledyne Isotopes sample number, locate the sample (or sample group) in the Sample Receiving and Storage Room. Transport the sample(s) to the Gas Analysis Laboratory.

(b) Begin filling out the Calculation Sheet -- Ra-226 Gas Counting form, entering the customer name, the sample number, sample collection date, the sample preparation date and the initials of the analyst.

4.0 SAMPLE PREPARATION PROCEDURES

(a) Transfer 0.5ℓ of water to a labeled emanation flask and close the flask from the atmosphere through the tapered, ground seal. Different volumes of sample may be used in order to 11/05/8

Issue or Revision	Pages	Prepared By	Effective Date	Technical Approval	Approved By Manager Quality Assurance
Issue	(See original for 1976-1983 signatures)				
Rev. 3	4		11/05/86		
		J. D. Martin		H. W. Jeter	H. G. King

obtain different minimum detection levels and depending on the availability of sample volume. 11/06/86

(b) Connect flask to helium supply and pass helium for ten minutes through the frited disk. The bubbling from the frit purges radon from the sample.

(c) Close the two stopcocks on the emanation flask.

(d) Set flask aside for two weeks to permit the Rn-222 activity to equilibrate with the Ra-226, if any, in the water.

5.0 DETECTOR LOADING

After two weeks, proceed with following steps.

(a) Attach the flask to an evacuated 1ℓ volume alpha counting chamber through the gas handling system.

(b) Open the stopcock on the flask which will permit Rn-222 and other gases ~~(and any residual He)~~ to pass into the 1ℓ counting chamber.

(c) After two ~~ten~~ minutes (d) ~~attach the He supply to the other stopcock and open stopcock and flow He through the frit,~~ water sample and into the 1ℓ counting ~~chamber~~ until a pressure of one atmosphere is ~~reached on the~~ vacuum gauge. This step and step (b) ~~transfers~~ Rn-222 from the water sample to the counting ~~chamber~~.

(d) Close the vacuum valve attached to the 1ℓ counting chamber.
(e) Record the pressure.

6.0 SAMPLE COUNTING

(a) Turn on high voltage power supply and adjust voltage to predetermined counting voltage.

(b) After two minutes, erase any counts on the scaler and push the start accumulation button. Record the start time. 11/05/86

(c) Record Count at 60 minute intervals until ingrowth of Rn-222 daughters is complete as indicated by a maximum count. If activity is indicated by the count, recount the following day for 60 minutes to verify the presence of Rn-222 by the decay.

7.0 STANDARDS AND CONTROL OF COUNTERS

(a) A Ra-226 standard which is NBS traceable, is counted in the same manner as described above once per month. The efficiency of the combined radon extraction from the sample and the nuclear counting is determined with the standard. Record the results on a chart.

8.0 CALCULATION OF Ra-226 ACTIVITY

The Ra-226 activity is determined from the Rn-222 activity as follows:

$$\frac{\text{Net pCi}}{\text{unit volume}} = \underbrace{\frac{\left(\frac{N}{\Delta t} - \beta\right)e^{\lambda t_2}}{2.22(v)\,(\epsilon)\,\cancel{(1-e^{-\lambda t_1})}}}_{\text{net activity}} \pm \underbrace{\frac{2\left(\sqrt{\frac{\frac{N}{\Delta t}+\beta}{\Delta t}}\right)e^{\lambda t_2}}{2.22(v)\,(\epsilon)\,\cancel{(1-e^{-\lambda t_1})}}}_{\text{counting error}}$$

10/04

where: N = total counts from sample (counts)

Δt = counting time for sample (min)

β = background rate of counter (cpm)

$2.22 = \frac{\text{dpm}}{\text{pCi}}$

v = volume of sample analyzed

ϵ = efficiency of the counter

~~$(1-e^{-\lambda t_1})$ = determines the "ingrowth" of Rn 222 from Ra 226 during the time lapse of t_1~~

~~t_1 = the time lapse of the first helium purge to the second helium purge~~

λ = the decay constant for Rn-222

$e^{\lambda t_2}$ = the correction for Rn-222 decay from the mid count time to the time it was transferred to the counting chamber

t_2 = the time lapse from transfer to chamber to mid count time

Establishing and reporting activities that are equal to or less than the detection limit:

If the net activity is equal to or is less than a specified multiple of the background counting error, the activity is below the limits of detection and is called "less than" (L.T.) or "minimum detectable level" (MDL).

The L.T. value can be specified by stating only the counting error at a predetermined multiple (σm) of the one sigma statistics. A sigma multiple (σm) of 4.66 is used for calculation of the L.T. values unless the customer requests another value such as 2.83. 10/04/

$$\text{thus L.T.} = \frac{\sigma m \sqrt{\frac{B}{\Delta t}} \left(e^{\lambda t_2} \right)}{2.22(v)(c)\cancel{(1 - e^{-\lambda t_1})}}$$

7.0 SAMPLE AND DOCUMENT CUSTODY PROCEDURES

7.1 SAMPLE HANDLING, SHIPPING AND CUSTODY

The samples will be collected into pre-washed and quality controled containers with preservatives provided by ETC Corporation. Sample containers, preservation techniques and maximum holding times prior to extraction and/or analysis are specified in Table 7-1.

Sample containers will be prepared and labeled as summarized in Table 7-2 using the preparation protocols in Table 7-3. Examples of sample labels identified in Table 7-2 are shown on Figure 7-1. Sample containers for certain analyses will be pre-preserved at the laboratory using the chemicals and concentrations summarized in Table 7-3. ETC Corporation will maintain documentation of the manufactures, grade, lot number and/or other identifying information regarding preservatives added to sample containers.

One groundwater sample will be collected from each monitoring well during each scheduled groundwater sampling event. The filtrate will be filtered into an appropriate pre-preserved and pre-labeled sample bottle to be submitted to the laboratory for dissolved metal analysis. These samples will be filtered in the field using a 0.45 micron filter. Filtering of the sample may not be possible if the specimen contains amounts of oil and grease that would clog the filter. In this case, the oil and grease will be decanted from the top phase in such a manner as to permit filtering of the water phase. In addition, one round of ground water samples will be collected from the background monitoring wells that will not be filtered. These samples will be analysed for total metal concentrations and will be used to determine the background conditions of waste liquids collected on-site.

Following sampling, the outside of the sample containers will be decontaminated at the Contamination Reduction Zone (see Ref. 4) by immersing the container up to the neck (or slightly below the bottom of the cap) in a soap (Alconox or equivalent) and water solution, followed by a potable and two distilled water rinses. Pertinent sample

identification data will be recorded on the sample label, and the sample containers will be placed in sample shuttles provided by ETC Corporation for overnight shipment. The Chain-of-Custody Form will be signed by each sampling participant and will be placed in the sample shuttles.

Water and soil samples will be shipped the same day collected. Upon arrival in the laboratory, samples will be checked in by the ETC Corporation. The Sample Custodian will:

- Verify that the number of samples received in the shipment agrees with the number listed on the Chain-of-Custody Form.
- Verify that the label information on each bottle agrees with the information documented on the Chain-of-Custody Form.
- Document on the Chain-of-Custody Form, the integrity/condition (bottle intact, temperature, etc) of all received samples.

In the event of any discrepancy or problems associated with the sample shipment, the Sample Custodian will immediately notify the WCC Project Manager. A unique labora-tory sample number will be assigned to each sample. Pertinent information from the Chain-of-Custody Form and/or sample label (WCC sample number, sampling location, sampling date and time, sample description, and requested analyses) together with the date of sample receipt, will be entered into ETC Corporation's computerized laboratory information management system which will be used to record the status of samples, their storage locations and the analytical results (see Section 10).

The laboratory will retain the soil samples for 30 days after analysis report is delivered to WCC.

Sample handling and chain-of-custody procedures will be in accordance with those guidelines described in USEPA "User's Guide to the Contract Laboratory Program" (Ref.

9) and the NEIC "Policies and Procedures" (Ref. 10). A Chain-of-Custody Form (Figure 7-2) will be maintained for each sample collected. The Chain-of-Custody Form will provide an accurate written record which can be used to trace the possession and holding of samples from the time of collection through data analysis and reporting. The following information will be specified for each sample on the Chain-of-Custody Form: 1) sequential sample number, 2) sample date, 3) sample time, 4) sample location (and depth where appropriate), and 5) analyses to be performed.

7.2 FIELD DOCUMENTATION

Field log books will provide the means of recording data collection activities performed. As such, entries will be described in as much detail as possible so that persons going to the site could reconstruct a particular situation without reliance on memory.

Field log books will be bound, field survey notebooks. Log books will be assigned to field personnel, but will be stored in the field project file when not in use. Each log book will be identified by a project-specific number. The title page of each notebook will contain: 1) person or organization to whom the book is assigned, 2) book number, 3) project name, 4) start and end dates.

Entries into the log book will contain a variety of information. At the beginning of each entry, the date, start time, weather, names of all sampling andor investigative personnel present, level of personal protection being used, and the signature of the person making the entry will be entered. The names of visitors to the site and the purpose of their visit will be recorded in the field log book.

Measurements made and samples collected will be recorded. All entries will be made in ink and no erasures will be made. If an incorrect entry is made, the information will be crossed out with a single strike mark. Wherever a sample is collected or a measurement is made, a detailed description of the location of the station, which includes

compass and distance measurements, will be recorded. The number of photographs taken of the station will also be documented. All equipment used to make measurements will be identified, along with the date of calibration.

The equipment used to collect samples will be noted, along with the time of collection, sample description, depth from which sample was collected, volume and number of containers. Sample identification numbers will be assigned prior to sample collection. Duplicates, which will receive a separate sample number, will be noted under sample description.

Representative photographs of sampling stations with respect to surrounding areas and relative to objects used to locate the station may be taken. If taken, the picture number and roll number will be logged in the field log book to identify which sampling site is depicted in the photograph. The film roll number will be identified by taking a photograph of an informational sign on the first frame of the roll. The project and film roll numbers and date should be shown on this sign.

7.3 PROJECT FILE

Project documentation will be maintained in general accordance with guidelines in NEIC "Policies and Procedures" (Ref. 10). A project file will be maintained by the Project Manager which will contain complete project documentation. This file will include: project plans and specifications; field logbooks and data records; photographs, maps and drawings; sample identification documents; chain-of-custody records; the entire analytical data package provided by the laboratory including QC documentation; data review notes; references and literature; report notes and calculations; progress and technical reports; correspondence and other pertinent information.

TABLE 7-1

SAMPLE CONTAINERS, PRESERVATION AND HOLDING TIMES

Matrix	Test Parameters	Sample Containers(1) and Volumes	Preservation Requirements(2)	Holding Times
Water Samples	Volatile Organics	2 40-ml VOA vials; no headspace	Iced to 4°C	(3)
	Extractable Organics	2 1-L amber glass bottles; fill to neck	Iced to 4°C	(3)
	Total Metals	1 1-L plastic bottle; fill to neck	HNO_3 to pH LTE 2, Iced to 4°C	6 months/26 days for Hg
	Cyanide (Total)	1 500-ml plastic bottle, fill to neck	NaOH to pH GTE 12, Iced to 4°C	14 days
Soil and Sediment Samples	Total Organic Carbon, Extractable Organics, Metals	2 8-ounce glass bottles; 3/4 full	Iced to 4°C	(4)
	Volatile Organics	2 120-ml glass bottles; no headspace	Iced to 4°C	(4)
Air	All	Glass sorbant tubes packed with XAD-2, XAD-7 or charcoal	Iced to 4°C	(4)

Notes:

(1) Containers will be prepared and labeled as summarized in Table 7-2 and will have teflon-lined caps.

(2) Sample bottles will be supplied containing the required preservatives by **ETC Corporation** who will maintain documentation regarding the manufacturer, grade and lot number of such preservatives. Amounts of preservatives added are listed in Table 7-3.

(3) It is essential that extraction and analysis for volatile organics will be performed in 7 days and semi-volatiles will be extracted within 5 days and will be analyzed within 40 days of extraction.

(4) It is essential that samples selected for initial analysis will be extracted within 10 days and analyzed within 40 days of extraction for extractable organic compounds and will be analyzed within 10 days for volatile organic compounds. The time between air sample collection and extraction will not exceed 72 hours; the time between extraction and analysis will not exceed 21 days.

LTE = Less than or equal to
GTE = Greater than or equal to

TABLE 7-2

SAMPLE CONTAINER PREPARATION SUMMARY

Matrix	Parameter	Preparation Protocol(1)	Label(2)
Water	Volatile Organics	B	Organics
	Extractable Organics	A	Organics
	Metals	C	Metals
	Cyanide	C	Cyanide
Soil	Volatile Organics	B	Organics
	Extractble Organics	A	Organics
	Metals	C	Metals
	Volatile Organics	B	Organics
Air	Volatile Organics	B	Organics
	Extractable Organics	A	Organics

Notes:

(1) Preparation protocols are listed in Table 7-3
(2) Examples of labels shown on Figure 7-1.
(3) Containers for air sampling are provided directly from the factory.

TABLE 7-3

SAMPLE CONTAINER PREPARATION PROTOCOLS

PROTOCOL A

1. Wash containers, closures and teflon liners in hot tap water with laboratory grade non-phosphate detergent.
2. Rinse three times with tap water.
3. Rinse with 1:1 nitric acid.
4. Rinse three times with ASTM Type 1 deionized water.
5. Rinse with pesticide grade methylene chloride.
6. Oven dry.
7. Remove containers, closures, and teflon liners from oven.
8. Place teflon liners in closures and place closures on container. Attendant to wear gloves and containers to no be removed from preparation room until sealed.

PROTOCOL B

1. Wash containers, septa, and closures in hot water with laboratory grade non-phosphate detergent.
2. Rinse three times with tap water.
3. Rinse three times with ASTM Type 1 deionized water.
4. Oven dry containers, septa and closures.
5. Remove containers, septa, and closures from oven.
6. Place liners in closures, teflon side down, and place on containers. Attendant to wear gloves and containers to n be removed from preparation room until sealed.

PROTOCOL C

1. Wash containers, closures, and teflon liners with hot tap water with laboratory grade non-phosphate detergent.
2. Rinse three times with tap water.
3. Rinse with 1:1 nitric acid
4. Rinse three times with ASTM Type 1 deionized water.
5. Air dry in contaminant-free-environment.
6. Place liners in closures and place closures on containers. Attendant to wear gloves and containers to not be remove from preparation room until sealed.

PRESERVATION SCHEDULE FOR WATER SAMPLES

Parameter	Preservative	Container Size (ml)	Amount Preservative Added (ml)	Concentration in Sample (ml/l)
Metals	Conc. HNO_3	1000	2.0	2
Cyanide	10 N NaOH	500	1.0	2

Sample Number	Bottle Type	#	Analysis
808933	VOA		Volatiles

Preparer	Date	Facility	Preservative

ETC Corp. provides computer-printed adhesive labels (with indelible ink) on all sample bottles. The following information appears on the label:

Sample Number, Bottle Type, Analysis, Preparer, Date, Facility, Preservative.

FIGURE 7-1

SAMPLE LABELS

ENVIRONMENTAL TESTING and CERTIFICATION

CHAIN OF CUSTODY FORM (CC1) ORIGINAL

Seal No. _____ ETC Job # _____

Date Sealed _____ By: _____

Company: _____ Attn.: _____

Facility/Site: _____ Phone: _____

Address: _____

SAMPLE IDENTIFICATION

Facility: _____ (Facility/Site Code) _____ (Optional Sample Point Description)

Sample Point: _____ (Source Code (from below)) _____ (Your Sample Point ID (left justify)) _____ (Start Date (YYMMDD)) _____ (Start Time (24HR hr. clock)) _____ (Elapsed Hours (optional))

Source Codes:

Well	(W)	Outfall	(O)	Bottom Sediment	(B)	Surface Impoundment	(I)	Leachate Collection Sys.	(C)	Other	(X)
Soil	(S)	River/Stream	(R)	Generation Point	(G)	Treatment Facility	(T)	Lake/Ocean	(L)	Specify _____	

SHUTTLE CONTENTS

BOTTLE				ANALYSIS	SAMPLER		LAB
No.	Type	Size	Preserv.		Filt. (Y/N)	Observations	Observations

CHAIN OF CUSTODY CHRONICLE

1. Shuttle Opened By: (print) _____ Date: _____ Time: _____
   Signature: _____ Seal #: _____ Intact: _____

2. I have received these materials in good condition from the above person.
   Name: _____ Signature: _____
   Date: _____ Time: _____ Remarks: _____

3. I have received these materials in good condition from the above person.
   Name: _____ Signature: _____
   Date: _____ Time: _____ Remarks: _____

4. Shuttle Sealed By (print) _____ Date: _____ Time: _____
   Signature: _____ Seal #: _____ Intact: _____

LAB USE ONLY Opened By: _____ Date: _____ Time: _____

SHUTTLE # _____ TEMP. °C _____ SEAL # _____ COND. _____

FIGURE 7-2

CHAIN-OF-CUSTODY RECORD

8.0 CALIBRATION CONTROL

All field and laboratory instruments will be calibrated prior to use. The calibration procedures will follow standard manufacturer's instructions to assure that the equipment is functioning within tolerances established by the manufacturer and analytical requirements.

Laboratory calibration procedures for testing of TCL parameters will be performed in accordance with the CLP Statements of Work and the CRL Standard Operating Procedures. Calibration of instrumentation used in the analyses of inorganics (Metals and Cyanide) will conform to the procedures in SOW-785 (Ref. 5) or SOW-787 when applicable and CRL SOP (Ref. 6). Calibration of instrumentation used in the analyses of HSL organics (Volatiles, Semi-volatiles and Pesticides/PCB's) will conform to the procedures in SOW-787 (Ref. 5) and CRL SOP (Ref. 6).

Field calibration procedures will be performed on field instrumentation as follows:

- o <u>pH Meter</u> - premeasurement calibration and post-measurement verification using at least two standard buffer solutions for each sample tested. The buffer solutions should bracket the sample pH. The two measurements must be within+ 0.05 standard unit of buffer solution values.

- o <u>Conductivity Meter</u> - daily calibration using potassium chloride (KCl) standard solution. The meter measurement must read within 10 percent of the standard to be considered in control.

- o <u>Temperature</u> - temperature is measured using a thermostat built into the Conductivity Meter. The readings will be checked at least once at the start of the field use of the instrument using a quality grade thermometer.

- Air Sampling Pumps - before and after each field sample is collected, a calibration of the pump will be conducted with a representative XAD-2, XAD-7, or charcoal tube in line to assure proper flow rates are maintained. A soap-film bubble column v,'ill be attached to the inlet of the sample calibration tube, and the volume of air displaced and elapsed time will be recorded on calibration sheets as verification of the flow rate.

- OVA - Calibration will be accomplished using a single known sample of methane in the range of 90 to 100 ppm. The calibration procedure will be performed daily.

- HNu P1101 - Calibration will conform to Procedure 6607001 of Reference 7.

9.0 ANALYTICAL PROCEDURES

The analytical methods that will be used to test each parameter in water, sediment, soil, and air are listed in Tables 9-1, 9-2 and 9-3. The analytical procedures for testing the TCL parameters will be in accordance with those specified in the SOW-785 or SOW-787 when applicable, and 40 CFR Part 136 (Refs. 5 and 6).

TABLE 9-1

ANALYTICAL METHODS

Parameter	Method	Type
Metals (1,2,3)	EPA Method 200.7 CLP-M	ICP, AA-Fla, or AA-Furnace
Mercury (1,2) (Water)	EPA Method 245.1(.2) CLP-M Vapor	Manual (Automatic) Cold
Mercury (1,2,3) (Soil, Sediment)	EPA Method 245.5 CLP-M	Manual Cold Vapor
Cyanide (1)	EPA Method 335.2 CLP-M	Titrimetric; Manual Spectrophotometric
Volatile Organics (5)	EPA Method 624 CLP-M	GC/MS
Semi-Volatile Organics (5)	EPA Method 625 CLP-M	GC/MS
Pesticides/PCB's(5)	EPA Method 608 CLP-M	GC/EC
Air Volatile Organics	NIOSH Method 1501 (6)	GC, FID

NOTES:

(1) Testing for Metals and Cyanide will conform to the procedures in SOW-785 for Inorganic Analysis, (Ref. 5).

(2) Preparation of samples for metals testing will conform with the following procedures in SOW-785:

Furnace Digestion Procedure for Waters
ICP/Flame AA Digestion Procedure for Waters
Sample Preparation of Sediments, Sludges and Soils

TABLE 9-1 (Continued)

NOTES: (cont'd)

(3) A separate determination of percent solids will be performed according to Sample Preparation of Sediments, Sludges and Soils and concentrations determined inthe digest will be reported on a dry weight basis.

(4) Any analytical method listed in SOW-785 may be used as long as the documented instrument or method detection limits meet the detection limit requirement shown in Table 5-5. Analytical methods with higher detection limits may be used only if the sample concentration exceeds twice the documented detection limit of the instrument or method.

(5) Testing for Volatile Organics, Semi-Volatile Organics and Pesticides/PCB's will conform to the procedures in SOW-785 for Organics Analysis (Ref. 5). These procedures will be modified by adding Appendix 11 Analyses that are not included in the CLP protocols (see Table 3-3).

(6) Test Methods from NIOSH Manual of Analytical Methods (Ref. 12).

AA	Atomic Absorption
CLP-M	Modified for Contract Laboratory Program
EC	Electron Capture
FID	Flame Ionization Detector
GC	Gas Chromatography
ICP	Inductively Coupled Plasma
MS	Mass Spectrascopy

TABLE 9-2

ANALYTICAL METHODS FOR INORGANICS ANALYSIS FOR DRINKING WATER

Parameter	Method Number	Method Designation	Date
Antimony	204.1	Atomic Absorption, AA Furnace[1] Technique, Standard Addition	In effect
Arsenic	206.2	Atomic Absorption, AA Furnace[1] Technique, Standard Addition	In effect
Lead	239.2	Atomic Absorption, AA Furnace[1] Technique, Standard Addition	In effect
Selenium	270.2	Atomic Absorption, AA Furnace[1] Technique, Standard Addition	In effect
Thallium	279.2	Atomic Absorption, AA Furnace[1] Technique, Standard Addition	In effect
Alluminum, Barium, Beryllium, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Nickel, Potassium, Silver, Sodium, Tin, Vanadium, Zinc	200.7	Inductively Coupled Plasma, Digested	In effect
Mercury	245.2	Total Mercury (automated persulfate digestion, cold-vapor AA determination)	In effect
Cyanide	335.3 335.2	Screen by Method 335.3 S and confirm positive values using Method 335.2S for total cyanide (manual distillation, automated spectrophotometric determination	In effect

(1) Samples containing suspended or settled particulates will be digested prior to analysis.

TABLE 9-3

ANALYTICAL METHODS FOR ORGANICS ANALYSIS FOR DRINKING WATER

Parameter	Method Number	Method Designation	Effective Date
Base/Neutral/Acid Compounds	625	GC/MS/DS analysis of nonvolatile organic compounds	In effect
Volatiles	524.1	Analysis of volatile organic compounds in drinking water samples using GC/MS	In effect
Pesticides and PCBs	608	Organochlorine pesticides and PCBs	In effect

10.0 DATA REDUCTION, VALIDATION AND REPORTING

ETC Corporation will perform in-house analytical data reduction and validation under the direction of the Laboratory QA Officer. The Laboratory QA Officer is responsible for assessing data quality and advising of any data which were rated "preliminary" or "unacceptable" or other notations which would caution the data user of possible unreliability. Data reduction, validation, and reporting by ETC Corporation will be conducted as follows:

- Raw data produced by the analyst is turned over to the respective area supervisor.
- The area supervisor reviews the data for attainment of quality control criteria as outlined in CLP protocols and/or established EPA methods and for overall reasonableness.
- Upon acceptance of the raw data by the area supervisor, a computerizedreport is generated and sent to the Laboratory QA Officer.
- The Laboratory QA Officer will complete a thorough audit of reports at a frequency of one in ten, and an audit of every report for consistency.
- The QA Officer and area supervisor will decide whether any sample re-analysis is required.
- Upon acceptance of the preliminary reports by the QA Officer, final reports will be generated and signed by the Laboratory Project Manager. The laboratory package shall be presented in the same order in which the samples were analyzed.

Data reduction and reporting procedures will be those specified in the CLP SOW-785 or SOW-787, when applicable, for inorganic and organic analyses.

ETC Corporation will prepare and retain full analytical and QC documentation similar to that required by the Contract Laboratory Program. Such retained documentation

need not be hard (paper) copy, but may be in other storage media(e.g., magnetic tape). As needed, ETC Corporation will supply hard copy of the retained information.

ETC Corporation will report the data in the same chronological order in which it is analysed along with QC data. ETC Corporation will provide the following information to WCC in each analytical data package submitted:

1. Cover sheet listing the samples included in the report and narrative com-ments describing problems encountered in analysis.
2. Tabulated results of inorganic and organic compounds identified and quantified.
3. Analytical results for QC sample spikes, sample duplicates, initial and a continuous calibration verifications of standards and blanks, standard procedural blanks, laboratory control samples and ICP interference check samples.
4. Tabulation of instrument detection limits determined in pure water.
5. Raw data system printouts (or legible photocopies) identifying date of analyses analyst, parameters determined, calibration curve, calibration verifications, method blanks, sample and any dilutions, sample duplicates, spikes and control samples.

For organic analyses, data packages must include matrix spikes, matrix spike duplicates, surrogate spike recoveries, chromatograms, GC/MS spectra and computer printouts.

In addition to the analytical data package described above, WCC and ETC Corporation will establish a telecommunications data link so that analytical test results in ETC Corporation's system can be electronically transferred to WCC computers.

WCC assessment will be accomplished by the joint efforts of the Data Reviewer and Project Manager. The data assessment by the Project Manager will be based on the criteria that the sample was properly collected and handled according to Section 7.0 of this QAPP.

The WCC Data Reviewer will conduct a systematic review of the data for compliance with the established QC criteria based on the spike, duplicate and blank results provided by the laboratory. An evaluation of data accuracy, precision, sensitivity and completeness, based on criteria in Section 5.0, will be performed and presented in the RI report.

The Data Reviewer will identify any out-of-control data points and data omissions and interact with the laboratory to correct data deficiencies. Decisions to repeat sample collection and analyses may be made by the Project Manager based on the extent of the deficiencies and their importance in the overall context of the project.

All data generated for the Du Pont Newport Site RI/FS will be computerized in a format organized to facilitate data review and evaluation. The computerized data set will include the data flags provided by ETC Corporation (in accordance with the SOW-785 (Ref. 5) or SOW-787, if applicable, as well as additional comments of the Data Reviewer. The laboratory-provided data flags will include such items as: 1) concentration below required detection limit, 2) estimated concentration due to poor spike recovery, and 3) concentration of chemical also found in laboratory blank. The Data Reviewer comments will indicate that the data are: 1) useable as a quantitative concentration, 2) useable with caution as an estimated concentration, or 3) unuseable due to out-of-control QC results.

The Du Pont Newport Site RI/FS data set will be available for controlled access by the Project Manager, and authorized personnel using a site-specific code. The complete data set will be incorporated into the RI report.

Further details concerning the management of the Du Pont Newport Site RI/FS data set and files are addressed in the Work Plan (Ref. 3).

11.0 INTERNAL QC CHECKS

There are two types of quality assurance used by ETC Corporation to ensure the production of analytical data of known and documented useable quality: program quality assurance and analytical method quality control.

ETC Corporation has a written Quality Assurance/Quality Control program which provides rules and guidelines to ensure the reliability and validity of work conducted at the laboratory (Ref. 11). Compliance with the QA/QC program is coordinated and monitored by ETC Corporation's Quality Assurance Unit (QAU), which is independent of the operating departments.

The stated objectives of the ETC Corporation QA/QC Program are to:

- Ensure that all procedures are documented, including any changes in administrative and/or technical procedures.
- Ensure that all analytical procedures are conducted according to sound scientific principles and have been validated.
- Monitor the performance of the laboratory by a systematic inspection program and provide for corrective action as necessary.
- Collaborate with other laboratories in establishing quality levels, as appropriate.
- Ensure that all data are properly recorded and archived.

All laboratory procedures are documented in writing as either Standard Operating Procedures (SOP) or Method Procedures (MP) which are edited and controlled by the QAU. Internal quality control procedures for analytical services will be conducted by ETC Corporation in accordance with their standard operating procedures and the individual method requirements in a manner consistent with appropriate SOW-785 or SOW-787, if applicable, and 40 CFR Part 136. These specifications include the types of audits required (sample spikes,

surrogate spikes, reference samples, controls, blanks), the frequency of each audit, the compounds to be used for sample spikes and surrogate spikes, and the quality control acceptance criteria for these audits.

The internal quality control procedures associated with testing of the Du Pont Newport Site RI/FS parameters have been described in Section 5.0, and are summarized in Tables 5-1 through 5-11.

ETC Corporation will document, in each data package provided, that both initial and ongoing instrument and analytical QC functions have been met. Any samples analyzed in non-conformance with the QC criteria will be reanalyzed by the laboratory if sufficient sample volume is available. It is expected that sufficient volume of samples will be collected for reanalysis.

12.0 PERFORMANCE AND SYSTEM AUDITS

System audits will be performed on a semi-continuous basis as appropriate throughout the duration of the project. The Field Team Leader is responsible for super-vising and checking that samples are collected and handled in accordance with the approved project plans and that documentation of field work is adequate and complete. The Project Manager is responsible for overseeing that the Du Pont Newport Site RI/FS performance satisfies the QA objectives, as set out in this QAPP. Reports and technical correspondence will be reviewed by an assigned qualified individual, otherwise external to the project, before being finalized.

ETC Corporation participates in the USEPA Contract Laboratory Program. Performance audits of laboratories participating in the Contract Laboratory Program (CLP) are performed in accordance with the procedures and frequencies established for the CLP by USEPA. ETC Corporation is routinely been audited by CLP auditors. The analyses for the Du Pont Newport Site RI/FS analytical testing program will be audited at least once during the conduct of the program by ETC Corporation Quality Assurance Unit.

The USEPA may elect to conduct separate performance audits of the ETC Corporation in relation to ETC Corporation's involvement in the Du Pont Newport Site RI/FS.

13.0 PREVENTIVE MAINTENANCE

As part of their QA/QC Program, a routine preventive maintenance program is conducted by ETC Corporation to minimize the occurrence of instrument failure and other system malfunctions. ETC Corporation has an internal metrology group to perform routine scheduled maintenance, and to repair or coordinate with the vendor the repair of all instruments. ETC Corporation has multiple instruments which will serve as backup to those instruments dedicated to this project. Field instruments will be checked and calibrated prior to their use on-site and batteries will be charged daily, where applicable.

14.0 DATA MEASUREMENT ASSESSMENT PROCEDURES

Specific procedures to access precision, accuracy, sensitivity and completeness will be in accordance with the requirements of the SOW-785 or SOW-787, if applicable, and the 40 CFR Part 136 for inorganic and organic analyses (Refs. 5 and 6). Data assessment and review will be accomplished by the joint efforts of the Data Reviewer and Project Manager. The Data Reviewer will review the analytical results for compliance with the established QC criteria as described in Section 10.0. The data assessment by the Project Manager will be based on the criteria that the samples were properly collected and handled according to the Work Plan (Ref. 3) and Section 7.0 of this QAPP. Any problems arising during sample collection, packing, shipping or analysis will be taken into consideration.

15.0 CORRECTIVE ACTION

Quality control limits for acceptance of data are defined in the SOW-785 or SOW-787, if applicable, and the 40 CFR Part 136 for inorganic and organic analyses (Refs. 5 and 6) and have been summarized in Section 5.0. Nonconformance with the established quality control procedures will be identified and controlled. No additional work which is dependent on the non-conforming activity will be performed until the non-conformance is corrected. Corrective actions will be defined and documented by the Project Manager as appropriate.

Corrective action indicated by audit results or detection of unacceptable data will be determined by the WCC Project Manager. Corrective action may include, but is not limited to:

- reanalyzing the samples, if holding time criteria and sample volume permit,
- resampling and analyzing,
- evaluating and amending sampling and analytical procedures,
- accepting data with an acknowledged level of uncertainty, and/or
- discarding the data.

16.0 QUALITY ASSURANCE REPORTS TO MANAGEMENT

ETC Corporation will provide WCC with QA reports of their audits by CLP and of internal audits by their QA Unit. The WCC Data Reviewer will submit a QA Report to the WCC Project Manager after each round of sampling and analyses which describes the accuracy, precision and completeness of data collected during that round.

The complete and correct implementation of this QAPP will be reviewed by the Project Manager and an assessment of adherence to sample collection procedures and data quality will be presented in the Du Pont Newport Site RI Report.

Meetings to discuss the progress of the project will be held, as requested by Du Pont or USEPA Region III. Concerns which arise during the course of the work that might require significant changes to the scope of work or departures from the protocols specified in the approved project plans will be discussed at these meetings. Proposed adjustments will be submitted to USEPA, and approved in writing, before they are implemented.

17.0 REFERENCES

1. USEPA, 1983, "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans", QAMS-005/80, EPA-600/4-83-004, December.

2. USEPA, Region III, (1988), Administrative Order by Consent, Re: RI/FS, Du Pont Newport Site (under negotiations, to be signed).

3. WCC, 1988, "Work Plan for RI/FS at Du Pont Newport Site, Newport, Delaware (Volume 1 and 2).

4. WCC, 1988, "Health and Safety Plan for RI/FS at Du Pont Newport Site, Newport, Delaware (Volume 3, Attachment B of Work Plan for RI/FS at Du Pont Newport Site Newport, Delaware, WCC, 1988).

5. USEPA, 1985, "Contract Laboratory Program, "Statement of Work for Inorganic and Organics Analysis, Multi-Media, Multi-Concentration", SOW-785.

6. Federal Register, 40 CFR Part 136, October 26, 1984, EPA Part VIII, Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act.

7. USEPA, 1985, "Site Investigation Procedures Manual", Vol. 1, 2, 3 and 4, October (prepared by REM II Contractor, CDM).

8. WCC, 1987, "Hazardous Waste Management Practice Site Investigation Baseline Procedures Technical Memoranda" (Appendices to this QAPP).

9. USEPA, 1984, "User's Guide to the EPA Contract Laboratory Program," Sample Management Office, October.

10. USEPA, 1983, "NEIC Policies and Procedures," National Enforcement Investigations Center, EPA-330/9-78-001-R, May 1978, Revised February 1983.

11. ETC Corporation, 1987, "Laboratory Quality Assurance Project Plan, Newport Landfill Site," 6 July (Volume 2, Appendix D of Proposed Work Plan, Du Pont Newport-North Disposal site, July 20, 1987).

12. NIOSH, "Manual of Analytical Methods," U.S. Department of Health and Human Services.

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OIL, SEDIMENT AND ROCK SAMPLING

NO. 8 - BOREHOLE HYDRAULIC TESTING FOR AQUIFER CHARACTERIZATION

NO. 12 - SOIL GAS SAMPLING AND ANALYSIS

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NO. 7 - SOIL, SEDIMENT AND ROCK SAMPLING

NO. 8 - BOREHOLE HYDRAULIC TESTING FOR AQUIFER CHARACTERIZATION

NO. 12 - SOIL GAS SAMPLING AND ANALYSIS

300157

NO. 3

GROUNDWATER MONITORING WELL

AND PIEZOMETER INSTALLATION PROCEDURES

WOODWARD-CLYDE CONSULTANTS
HAZARDOUS WASTE MANAGEMENT PRACTICE
TECHNICAL MEMORANDUM NO. 3

GROUNDWATER MONITORING WELL AND PIEZOMETER INSTALLATION PROCEDURES

REVISION 1

January 1987

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TABLE OF CONTENTS

TECHNICAL MEMORANDUM NO. 3
GROUNDWATER MONITORING WELL AND PIEZOMETER INSTALLATION PROCEDURES

Section		Page
3.1	Monitoring Well Installation	1
3.1.1	Purpose	1
3.1.2	General Considerations	1
3.1.3	Well Installation Materials	2
3.1.4	Monitoring Well Design	3
3.1.4.1	Type A Wells	6
3.1.4.2	Type B Wells	6
3.1.4.3	Clustered Wells	7
3.1.4.4	Nested Wells	7
3.2	Piezometer Installation	7
3.2.1	Purpose	7
3.2.2	General Considerations	7
3.2.3	Design and Installation of Piezometers	8
3.2.3.1	Standpipe Piezometers	8
3.2.3.2	Closed-System Piezometers	9
3.3	Well Development	9
3.3.1	Purpose	9
3.3.2	Methods of Developing Wells	9
3.3.2.1	Surge Block	9
3.3.2.2	Air Lift	10
3.3.2.3	Bailer and Pumping	10
3.4	Methods and Equipment Used for Advancing Borings	10
3.4.1	Purpose	10
3.4.2	General Considerations	11
3.4.3	Auger Drilling	12
3.4.3.1	Solid-stem Auger	12
3.4.3.2	Hollow-stem Augers	13
3.4.4	Rotary Drilling Methods	13
3.4.4.1	Water-based Rotary Methods	13
3.4.4.2	Air-based Rotary Methods	15
List of References		16
Table 3-1 Factors Affecting Choice of Drilling Methods		17
Figure 3-1 - Typical Type A Monitoring Well		19
Figure 3-2 - Typical Type B Monitoring Well		20
Figure 3-3 - Clustered Monitoring Wells (Nested)		21
Figure 3-4 - Typical Standpipe Piezometer		22

HAZARDOUS WASTE MANAGEMENT PRACTICE

TECHNICAL MEMORANDUM NO. 3
GROUNDWATER MONITORING WELL AND PIEZOMETER INSTALLATION PROCEDURES

3.1 Monitoring Well Installation

3.1.1 Purpose

Monitoring wells must be installed in a manner such that representative groundwater samples can be readily obtained. Contamination of the water-bearing zone by drilling equipment or cross contamination of wells during the drilling process must be avoided. (Decontamination procedures are described in Technical Memorandum No. 11.) Vertical seepage of surface water to the monitoring well groundwater intake zone must also be minimized.

This section describes designs, procedures and materials that can be used to construct a monitoring well that may be capable of producing representative groundwater samples. An accuracy in the parts per billion range is required at many hazardous waste sites. A variation of the technical approach from that contained in this section may be acceptable, provided the quality and accuracy of the end product is not compromised and the variation is approved by the Project Manager.

3.1.2 General Considerations

Many government agencies have well specifications which differ from the design specifications presented in this section. In addition, licensing and/or certification of the driller may be required. Well construction procedures should meet regulatory agency requirements. Examples of state agencies which may promulgate regulations applying to monitoring wells include: Department of Natural Resources, Department of Health, Department of Water Resources, Environmental Protection Agency and Geological Survey.

To maintain quality control and obtain accurate log information, a WCC engineer or geologist should be on site during well installation to log subsurface conditions and well construction details for each well.

Factors which are considered in determining the method of well installation include:

1. The expected nature of the materials to be encountered.
2. Site accessibility.
3. Availability of drilling water.
4. Diameter and depth of well desired.

Factors which apply to selection of an appropriate well design include:

1. Expected transmissivity and storage coefficient of the aquifer.
2. Water level conditions and trends.
3. Water quality and type and characteristics of contaminants.
4. Economic, budget, and time constraints.
5. Length of time the well will be in service.

Factors which influence the location of monitoring wells include:

1. Objectives of the monitoring program.
2. Location of facilities to be monitored.
3. Groundwater gradient.
4. Location of above-ground and underground utilities and man-made features.
5. Accessibility to desired areas.

3.1.3 Well Installation Materials

Materials used in the construction of monitoring wells must remain essentially chemically inert with respect to the contaminants in the groundwater for the duration of the well monitoring program.

The most commonly used well construction materials are PVC and stainless steel. PVC is the least expensive and easiest material to use. It is generally believed that PVC does not decompose in contact with groundwater containing low concentrations of organics. High concentrations of organic contaminants have been shown to react with PVC and cause decomposition of the casing over a period of time. Stainless steel provides greater structural strength and its use may be advantageous for large diameter wells. Teflon casing is manufactured and is chemically inert but is very expensive. Well casing and screen are available in threaded and unthreaded sections and typically in lengths of 5, 10 and 20 feet. Threaded pipe joints should be wrapped with Teflon tape to facilitate joining and to improve the seal. Sections of casing and screen should be assembled on site to allow inspection immediately before installation.

Well materials should be cleaned prior to well installation. Two methods are acceptable, namely, high pressure hot water or steam, and detergent wash and distilled rinse. The former is preferred because it is easier and faster.

Screen

The purpose of the well screen is to allow water to enter the well easily while preventing entry of large amounts of sediment. The slot size of the well screen is usually determined based on selection of the filter pack material. Both are commonly related to the grain size analysis of the formation material. Methods of determining appropriate screen slot size are listed in the EPA Manual of Water Well Construction Practices, 1975 (EPA Publication 570/9-75-001).

Seal

Typically a seal of bentonite pellets with a thickness of at least 2 feet is installed above the filter pack to more effectively seal the collection zone of the well and to prevent the intrusion of overlying cement or cement bentonite grout material into the filter pack. Depending on the type of seal used, it may be placed by tremie pipe, pumping, gravity, or mechanical means. If bentonite pellets are used and the top of the filter pack is above the top of the groundwater, the pellets should be crushed or broken and distilled water should be poured in to allow the bentonite to hydrate and swell before backfilling with grout. The breaking-up of the pellets allows hydration to occur more rapidly. If available, granulated bentonite is preferred over pellets or balls because the granulated can produce a tighter seal and more rapidly. Granulated bentonite is more expensive and commonly difficult to obtain.

Annulus Backfill

The annular space above the filter pack and seal is grouted with a bentonite, bentonite/cement or cement grout with shrinkage reducer. The primary purpose of grouting is to minimize the vertical migration of water to the groundwater intake zone. Another purpose is to increase the integrity of the well casing.

The EPA recommends that a cement grout consist of no more than six gallons of potable water per 94-pound bag of Portland cement.

If sand aggregate is used, the recommended mixture is two parts of aggregate by weight to one part cement with no more than six gallons of potable water per 94-pound bag of Portland cement. (Refer to EPA Manual of Water Well Construction Practices.)

Certain groundwater quality may further require special grout materials.

Grouting Technique

To avoid the possibility of breaching or well casing damage, extreme care must be used when heavy grout materials, such as concrete, are poured. Grout may be placed by a variety of methods including pouring, bailer dumping, tremie pipe, and pumping. Pouring the grout down the annular space is not generally recommended, especially if the depth is greater than approximately 20 feet or if water is standing in the annular space. If the annular space is wide enough to permit the entry of a dumping bailer or tremie pipe, grout may be placed by either of these methods. The grout should be added near the bottom of the remaining annular space and the placement device slowly raised as the grout is placed. Pumping the grout is generally the best method of grouting if the distance to placement is great or water is standing in the annular space. If grout is pumped through a rotary drill rig pump, care must be taken to adequately clean the pump after grouting is completed.

Cement or concrete are often placed over a bentonite grout in the upper few feet of annulus to allow setting of a protective casing. If a cement or concrete grout has been used, grouting may continue to ground surface and the protective casing installed directly into the grout. A drain hole should be drilled through the protective casing nominally 6 inches below the top of the casing (but below the level of the vented cap of the stick-up portion of the well). The casing is set over the well, such that the embedded part is greater than or equal to one-half the protective casing length, if possible. Grout is then added inside the casing to the level of the drain hole. The protective casing should be marked with identifying decals and surveyed into the existing grade to allow the determination of the groundwater elevation in the well. A locking device should be installed to prevent unauthorized entry or vandalism of the well.

Well Types

Four typical monitoring well types are discussed in subsequent sections: (1) wells screened over a single interval (Type A), (2) telescoping wells (Type B), (3) clustered wells, and (4) nested wells. Of these four designs, three designs (Types A, B, and clustered wells) are recommended for general use and are easily constructed. Design of nested wells calls for multiple sampling zones within a single borehole, has limited use, and is very difficult to construct. Each well design is discussed and its principal advantages and disadvantages addressed. Selection of well type should be based upon formation and contamination characteristics.

Monitoring wells must be developed before samples are obtained. Section 3.3 addresses well development procedures.

3.1.4.1 Type A Wells

Wells screened over a single vertical interval are the most common type of monitoring well. A typical detail for a Type A well is shown in Figure 3-1. The design of the well consists of a section of slotted well casing or well screen connected to a riser pipe that extends above the ground surface. Typically, a filter pack is placed in the annulus between the screen and the borehole. (A filter pack may not be possible under certain conditions such as heaving or running sand.) The remaining height of annulus is sealed and/or grouted to the surface with a bentonite, cement, or bentonite/cement grout. Lockable protective casing is constructed over the stick-up portion of the well.

The diameter of the borehole and the inside diameter of any drill casing or hollow stem auger should be at least 4 inches greater than the outside diameter of the well casing and screen. This annular clearance facilitates the placement of the filter pack and grout around the outside of the well screen and casing.

The advantages of a Type A well are that it is quick, simple, and relatively inexpensive to install. The major disadvantage is that, by itself, it is not possible to determine the vertical distribution of contaminants in the groundwater.

Commonly, Type A well screens are installed at the level of the water table, typically 10-feet long to permit recording seasonal fluctuation of the water table.

3.1.4.2 Type B Wells

Telescoping wells are installed when the groundwater zone to be sampled must be sealed off from overlying groundwater zones. This is necessary to minimize cross-contamination of the lower zone, especially if analyses in the parts per billion range are to be performed. An example of a typical telescoping well is shown in Figure 3-2.

A large diameter boring, often 6 to 12 inches or more in diameter, is drilled to an elevation above the groundwater zone to be sampled and below the zone to be sealed off. A minimum 2-foot-thick cement/bentonite grout plug is pumped or tremied into the bottom of the boring. A casing with an outside diameter 2 to 4 inches less than the borehole is centered and set into the grout before it sets to provide an effective bottom seal. A bentonite or cement/bentonite grout is placed in the annular space to ground surface. After the grout has set, the borehole is advanced through the cement/bentonite plug to the desired depth in the underlying groundwater zone by drilling or coring inside the installed casing with a bit smaller in diameter than the casing.

The remainder of the installation process is similar to that used to install Type A wells. An interior well casing with screen, approximately 4 inches less in diameter than the exterior casing, is placed in the boring. The riser pipe extends approximately 2 feet above ground surface. A filter pack is placed in the annular space around the well screen to a minimum of 2 feet above the top of the screen. A minimum 2-foot-thick, bentonite or cement/bentonite seal is placed above the filter pack. The remaining height of the annular space between the inner well casing and outer casing is grouted to the ground surface.

3.1.4.3 Clustered Wells

Well clusters consist of two or more wells, which may be a combination of Type A or Type B wells, installed in proximity to one another but screened at different depths. Telescoping wells may also be clustered. Well cluster systems allow sampling of groundwater from different aquifers or from different zones within the same aquifer. An example of a clustered well system is shown in Figure 3-3. Installation procedures for each component of a well cluster are the same as for Type A wells or Type B wells. Screened sections of deep wells of clusters are commonly shorter than for shallow wells (e.g. 2 to 5-foot versus 10-foot sections).

3.1.4.4 Nested Wells

Nested wells consist of multiple sampling point wells with several well casings installed in a single borehole. They allow sampling groundwater from two or more different zones or aquifers using one borehole. Each well is screened at a different depth and seals are attempted above and below each well screen. This technique significantly increases the potential for cross contamination and seal leakage. Nested wells are not recommended for use.

3.2 Piezometer Installation

3.2.1 Purpose

Piezometers are generally small diameter pipes and/or tubing that are designed to allow measurement of piezometric pressures. The purpose of this section is to describe typical piezometers which may be used at hazardous waste sites.

3.2.2 General Considerations

State or other governmental agencies may require piezometer installations to meet certain specifications other than those provided below and they may require installation by drillers who are licensed and/or certified. These agencies should be contacted in advance of piezometer installation to ensure that proper piezometer materials are obtained and piezometer installation procedures meet the specifications.

To ensure quality control and obtain necessary information, a WCC geologist or engineer should be on site during the drilling process to log subsurface conditions, obtain samples, and other information for each piezometer. Determinations of the depth of the piezometer, depth and length of the screened portion and areas to be sealed off are dependent in part upon geologic and hydrogeologic conditions at the site.

3.2.3 Design and Installation of Piezometers

3.2.3.1 Standpipe Piezometers

A standpipe piezometer design is very similar to that of a Type A monitoring well. A typical standpipe piezometer design is illustrated in Figure 3-4. Typically piezometers are smaller in diameter than monitoring wells (commonly 1 to 2 inches) and because no samples are collected, less rigid quality assurance specifications are required for materials and procedures. A common procedure is to backfill a portion of the the boring annulus with cuttings, instead of grouting, at a substantial savings in cost.

Standpipe piezometers are commonly constructed with PVC pipe but galvanized or stainless steel pipe can also be used. The size of the piezometer may commonly vary from 1/2 to 4 inches in diameter. The screened section of the piezometer consists of commercial screen or, more commonly, slotted well casing. The piezometer riser pipe consists of non-slotted well casing which extends approximately 2 feet above the ground surface. As with monitoring wells, piezometers should be assembled on site so that a thorough inspection of joints and materials can be made immediately prior to installation.

A sand and/or gravel filter pack is placed in the annulus around the slotted section of pipe and should extend at least 2 feet above the top of the slotted section. A seal is placed above the filter pack and the annulus grouted or backfilled with tamped clay or auger cuttings. A surface seal of cement or cement/bentonite grout should be installed in the upper 5 feet of annular space to limit surface water infiltration into the piezometer. Design criteria and installation methods for the filter pack, seal and grouting are the same as those for Type A wells. The elevation of the top of the standpipe piezometer should be surveyed and recorded to allow determination of the groundwater elevation.

Development of the piezometer may be necessary if a bentonite drilling mud was used or if large amounts of fines entered the well at the completion of drilling. Refer to Section 3.3 for a description of development procedures.

3.2.3.2 Closed-System Piezometers

Closed-system or low displacement piezometers may be fabricated or are available prefabricated to be installed in a water-bearing unit to determine the piezometric pressure at that point. Many types and designs of closed-system piezometers are available. The units should be carefully selected to be compatible with their intended use.

3.3 Well Development

3.3.1 Purpose

The purpose of this section is to provide procedures for developing monitoring wells. During the drilling process the side of the borehole may become smeared with clays or other fine sediments. This plugging action substantially reduces the permeability of the aquifer in the zone of the boring and retards the movement of water into the well. In addition, sediment may enter the filter pack or clog the well screen slots during installation of the well materials.

Well development is the process of flushing the aquifer interface with the well and cleaning the filter pack and the well or piezometer screen slots to permit groundwater to flow into the monitoring well. Development is required: (1) to restore the natural permeability of the formation adjacent to the borehole, (2) to remove clay, silt and other fines from the filter pack and well screen so that subsequent water samples will not be abnormally turbid or contain undue suspended matter, and (3) to remove remnant drilling fluids from the well, filter pack and aquifer and contaminants introduced during the time of drilling.

3.3.2 Methods of Developing Wells

The development process is best accomplished by causing the natural formation water collected inside the well screen to be moved vigorously in and out through the screen in order to agitate the clay and silt and move these fines into the well where they can be removed. Use of water other than the natural formation water is not recommended due to the possibility of contributing contaminant or atypical water quality to the groundwater. Any equipment used for well development must be thoroughly cleaned before use to prevent possible contamination of the well. The following procedures are available for developing monitoring wells.

3.3.2.1 Surge Block

A surge block is a round plunger with pliable edges (constructed of a material such as rubber belting) that will not catch on the well screen. Moving the surge block forcefully up and down inside the well screen causes the water to surge in and out through the screen accomplishing the desired

cleaning action. Close monitoring of the amount of pressure generated must be made to prevent cracking of the well casing or screen.

3.3.2.2 Air Lift

The air lift method involves pumping compressed air down a pipe placed inside the well casing. Due to its inert characteristic, nitrogen is the preferred gas for air lifting. The use of standard air for well development may affect groundwater quality. Pressure applied intermittently and for short periods causes the water to surge up and down inside the casing. Once the desired washing is accomplished, continuously applied air pressure is used to blow water and suspended sediments upward out of the well.

Considerable care must be exercised to avoid injecting air directly through the well screen. Air can become trapped in the formation outside the well screen and affect subsequent chemical analyses of water samples and hydraulic conductivity measurements. The bottom of the air pipe should not be placed below the top of the screened section of casing.

Another restriction on the use of air is the submergence factor. Submergence is defined as the height of the water column above the bottom of the air pipe (in feet) divided by the total length of the air pipe. To result in efficient air lift operation, the submergence should be at least 20 percent. This may be difficult to achieve in shallow monitoring wells or wells which contain small volumes of water.

3.3.2.3 Bailer and Pumping

A bailer which is heavy enough to sink rapidly through the water can be raised and lowered through the water column to produce an agitating action that is similar to that caused by a surge block. The bailer, however, has the added capability of removing turbid water and fines each time it is brought to the surface. Bailers can be custom-made and can be hand operated in shallow wells. As with surge blocks, it is possible to produce pressure great enough to crack PVC casing. Bailers are the simplest and least costly method of developing a well. (Refer to Technical Memorandum No. 5 for information about well bailer design.)

Pumping can be used effectively in wells where recharge is rapid. The type and size of the pump used is contingent upon the well design.

3.4 Methods and Equipment Used for Advancing Borings

3.4.1 Purpose

Most borings utilized in hazardous waste remedial investigations are advanced by only a few of the wide range of drilling methods available for standard water resources and geotechnical projects. There are two main

reasons for this. First, it is important to maintain control of the borehole verticality and stability. Second, and most important, it is necessary to prevent spreading contamination or altering subsurface conditions during the drilling process.

The purpose of this section is to review the drilling methods and equipment which are routinely used in hazardous waste remedial investigations for collecting subsurface soil samples and installing monitoring wells for groundwater sampling and flow assessment. The methods discussed below consist of two main types: those which use a drilling fluid (e.g. mud or or compressed air) to remove cuttings, and those which use none.

Of the former type, some methods such as the cable tool method and jet or wash drilling are not discussed because these are not currently used during remedial investigations at uncontrolled hazardous waste sites. Of the latter type, only power-augering methods are discussed. Hand augers may be used to reach subsurface material for sampling in waste piles inaccessible to large power drilling machinery. Refer to Technical Memorandum No. 7 for further information about methods of sampling hazardous waste. The use of borings and the methods employed for sampling soil and rock from the subsurface are discussed in Technical Memorandum No. 6.

A list of references is provided with this memorandum which describes the methods presented herein, and many others, in more detail. The reader is urged to review them if a step-by-step description is desired.

3.4.2 General Considerations

Drilling boreholes in the subsurface is an integral part of most remedial investigations of soil and groundwater contamination. Information from boreholes is generally used to: (1) provide geological data on subsurface conditions; namely, stratigraphy, occurrence of groundwater, and depth to bedrock, (2) obtain representative disturbed or undisturbed samples for identification and laboratory testing, (3) provide holes for geophysical logging and downhole hydraulic testing, and (4) install piezometers and monitoring wells. Because the cost of drilling holes for remedial investigations is higher than normal due to the need to decontaminate the equipment as well as the potential risks to health and safety associated with contaminants, the objectives and design of each boring should be carefully planned in advance. If drill holes can successfully achieve multiple objectives without reducing the quality of the desired formation, then drilling should be designed for a specific purpose, and it's rare for one design to meet multiple objectives. The objectives/planning/design part is critical and should be emphasized here.

Before drilling can begin, several steps must be taken. These steps usually are contained in an approved Field Sampling Plan (Technical Memorandum No. 1) depending on project requirements. First, permits must be obtained

from the appropriate State agency or agencies. There is a fee for permits, and drilling subcontractors usually include this as part of their fee. Second, the appropriate State (and sometimes Federal) authorities, must be notified (verbally or in writing) in advance of the date that drilling is scheduled to begin. Third, the property owners must provide right-of-entry access. This permission should be documented in writing. Fourth, buried utilities must be checked at all planned drilling locations. For reasons of safety and liability, no drill hole should be advanced if this step has not been completed. Fifth, an approved Health and Safety Plan must be in effect and its provisions adhered to for protection of the field crew. Sixth, provisions for disposal of all cuttings and discharge water must be made in accordance with regulations. Permits may be required. Lastly, a boring inspector; namely, a qualified field geologist or engineer, must be present (on-site) during drilling.

It should be recognized that many factors must be considered when deciding which drilling methods are most appropriate at a site under specific conditions. The factors which are related to remedial investigation concerns for the drilling methods described below are summarized in Table 3-1. Advantages and disadvantages of each technique are identified below.

3.4.3 Auger Drilling

3.4.3.1 Solid-stem Auger

Auger flights consist of spiral flanges welded to a pipe with cutting teeth on the bottom end. A solid-stem auger may consist of either a single flight or multiple sections known as continuous flights; hence, the term continuous-flight auger (CFA). Single-flight augers are commonly of large diameter (14 to 24 inches). CFA's produce smaller hole diameters (see Table 3-1), because they are designed to drill to greater depth in stable overburden formations than a single-flight auger. Drill rigs turn the auger sections using a rotary drive head mounted on a hydraulic-feed mechanism that pushes the auger flight string down or pulls it back. As the borehole is advanced, the cuttings are brought to the top of the hole by the flights which act as a screw conveyor. Large obstructions (boulders or buried debris) and bedrock typically result in "refusal", i.e., an end to borehole advancement using augers.

There are several advantages of CFA boreholes. First, the auger method is rapid in most unconsolidated, fine- to medium-grained geologic materials. Second, drilling fluids are not used to remove cuttings and, therefore, the in-situ chemical conditions of the borehole are not degraded further either by diluting contaminants with added water or contributing suspended solids from drilling muds used to stabilize the borehole walls in soft ground. Third, auger flights are easily cleaned and decontaminated (see Technical Memorandum No. 11). Also, although cuttings may be subject to disposal regulations, the volume of cuttings is much less than other methods.

There are also some significant disadvantages. First, casing is not used to stabilize the hole. Thus, there is a significant potential for borehole cave-in when the flights are removed for sampling, especially below the water table. Even without cave-in occurrences, withdrawal of the flights leaves an open hole which may result in sample and formation cross-contamination. Drilling may also cause an increase of hazardous particulates and/or vapors in the air near the borehole. Air quality monitoring may be required during drilling, and dermal and respiratory protection may be needed.

3.4.3.2 Hollow-stem Auger

The flanges of a hollow-stem auger (HSA) are welded onto a larger diameter pipe than the CFA. The flights are linked together such that the stem is hollow throughout the drill string. The cutting bit has a center plug which prevents loose soil from entering the stem. Thus, with the plug removed, a split-spoon sampling device may be lowered inside the drill string and driven ahead of the cutting bit for an in-situ sample as required. The HSA string, therefore, serves as a form of casing because it does not have to be withdrawn each time a sample is collected. Table 3-1 summarizes important factors to consider when planning to use the HSA.

Some of the advantages of using the CFA apply to HSA also, such as drilling without a fluid to remove cuttings, rapid drill rate, and ease of cleaning. Additional advantages include the characteristic of auger flights serving as casing. This means that piezometers and monitoring wells can be constructed by raising the flights as needed. One can obtain more accurate samples because the flights do not have to be removed. Drilling rate is even better than CFA because the drill string remains in the hole until it's completed.

Cleaning and decontamination require more time than the CFA due to the interior surfaces present. But this consideration is minor. Drilling below the water table, especially in fluid soils such as supersaturated or "running" sands, may be difficult if the head in the stem is less than the head in the formation. The result is the inflow of groundwater and sediment around the cutting bit and center plug. If water is used in the stem to equalize the pressure, it must be potable. It may be necessary to have the drilling water analyzed to assure its quality.

3.4.4 Rotary Drilling Methods

3.4.4.1 Water-based Rotary Methods

Boreholes drilled by the direct rotary method use a drill rig that rotates a bit, while continuously circulating a drilling fluid down through the drill stem and out through ports in the bit to remove cuttings as the bit penetrates the formation. The cuttings flow upward between the drill stem

and the borehole wall (or casing) into a settling tub from which clean fluid (minus cuttings) is re-circulated for drilling. Different types of bits are used depending on the strength and resistance of materials being drilled. Stabilizers, i.e. sleeves with guides fixed to the drill string, keep the assembly centered in the hole as drilling progresses. They are especially necessary for relatively deep (long) boreholes. Tabel 3-1 summarizes factors to be considered for use of this method.

When drilling deep holes in loose, unconsolidated geological formations, the rotary method using water and/or drilling mud may be more effective technically and economically than using a hollow-stem auger. Penetration rates are relatively high. Minimal casing is required during the drilling operation. In shallow overburden, casing may be set and clean water used as the drilling fluid. In deeper overburden, a special-purpose mud mixture or water with clay additive (bentonite slurry) is used. The drilling mud helps to remove cuttings; supports and stabilizes the borehole wall to prevent caving; cools, cleans and lubricates the drill bit, drill string, and mud pump system; and seals the borehole wall to reduce loss of drilling fluid. The latter characteristic together with the chemical nature of the fluid is a primary complicating factor in evaluating the chemical analysis results of soils and groundwater samples and evaluating in-situ aquifer tests results (see Technical Memorandum No. 8). (It should also be noted that certain drilling grease or "dope" used to lubricate threaded joints should <u>not</u> be used because it contains organic compounds that invalidate chemical analysis of groundwater samples.)

When it is necessary to drill into the bedrock, rotary drilling using clean water is standard. Samples may be collected as rock cores or as cuttings depending on the bit used to advance the hole. Procedures for coring are discussed in Technical Memorandum No. 6. The principal concern is, again, prevention of cross-contamination between the shallow overburden groundwater, if present, and deeper water bearing zones or layers in the bedrock. Drilling an open hole increases the chances of intraformational cross-contamination. Commonly, it is helpful, and sometimes required, that prior to penetrating the bedrock, a large-diameter hole must be drilled to the bedrock surface, and casing must be grouted into the upper 1 to 2 feet of rock to seal the shallow groundwater system from the bedrock system during drilling. When the boring in the bedrock is terminated, individual water-bearing zones or layers (aquifers) may be monitored using the techniques of bedrock monitoring well installation described in Technical Memorandum No. 3.

The source of drilling water must be clean, and may need to be analyzed in advance. Discharge water and disposal of cuttings may be subject to permitting and disposal regulation. Dermal and respiratory protection may be required during drilling, and the field crew should be prepared accordingly. Mud is advantageous in that it reduces the respiratory hazard compared to augering. Decontamination of interior surfaces of the drill stem,

bit and mud system may be difficult and will require extra time for adequate decontamination.

3.4.4.2 Air-based Rotary Methods

With the air rotary drilling method, borehole advancement is accomplished by rotating a tricone bit. Drill cuttings are removed by injecting compressed air through the rotating drilling rods which forces the cuttings through jets or ports on the drill bit at the bottom of the hole. The air forces the cuttings and any water yielded by the formation, up the annular space between the rods and the borehole wall (or casing) to the surface. Adding small amounts of water to air creates an air-mist system. Misting helps reduce dust and breaks down mud collars forming on the drill rods. Air drilling is extremely effective in drilling hard, stable formations such as crystalline rock and certain coarse-grained and bouldery deposits such as glacial till, outwash, and alluvium. Air reduces lost circulation in fractured and highly porous rock. The principal problem encountered is usually insufficient air supply to attain a velocity that will remove cuttings from the hole. This is essentially related to the depth of the hole, but may be related to erosion of the borehole wall. Also, if a small quantity of formation water seeps into the hole, mud cakes or collars can form which affect the air pressure in the hole. Additional problems are related to the risk of health and safety of the field crew. It will be necessary to direct the air/water/soil cuttings stream away from the drill hole collar area. This may require certain specialized modifications to standard equipment that is commercially available.

Factors to consider for air-based rotary methods are summarized in Table 3-1. The air rotary method provides a relatively good drilling rate. Well completion with this method allows good quality control of gravel pack and seal placement. It is relatively cost effective, and can be employed for deep wells. Also, no foreign liquids are introduced into the hydrologic system.

There are, however, several key disadvantages of this method for remedial investigations. The air flow may dilute or evaporate volatile organic compounds in the groundwater, thus invalidating the sample analysis. Also, the air filtration method of the air compressor may compromise groundwater quality if oil is used in the compression mechanism. It is difficult to produce accurate boring logs from the cuttings. Because of the high volume of air, fines are washed away before samples can be collected. Zones which yield small amounts of water are often missed, whereas leakage from more highly productive zones around the casing shoe due to air pressure can lead one to identify a water-bearing zone where there is none. Casing sizes are also limited.

The use of foam (air/water/surfactants) is not possible as part of remedial investigations due to the chemical nature of the foam.

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TABLE 3-1
FACTORS AFFECTING CHOICE OF DRILLING METHODS

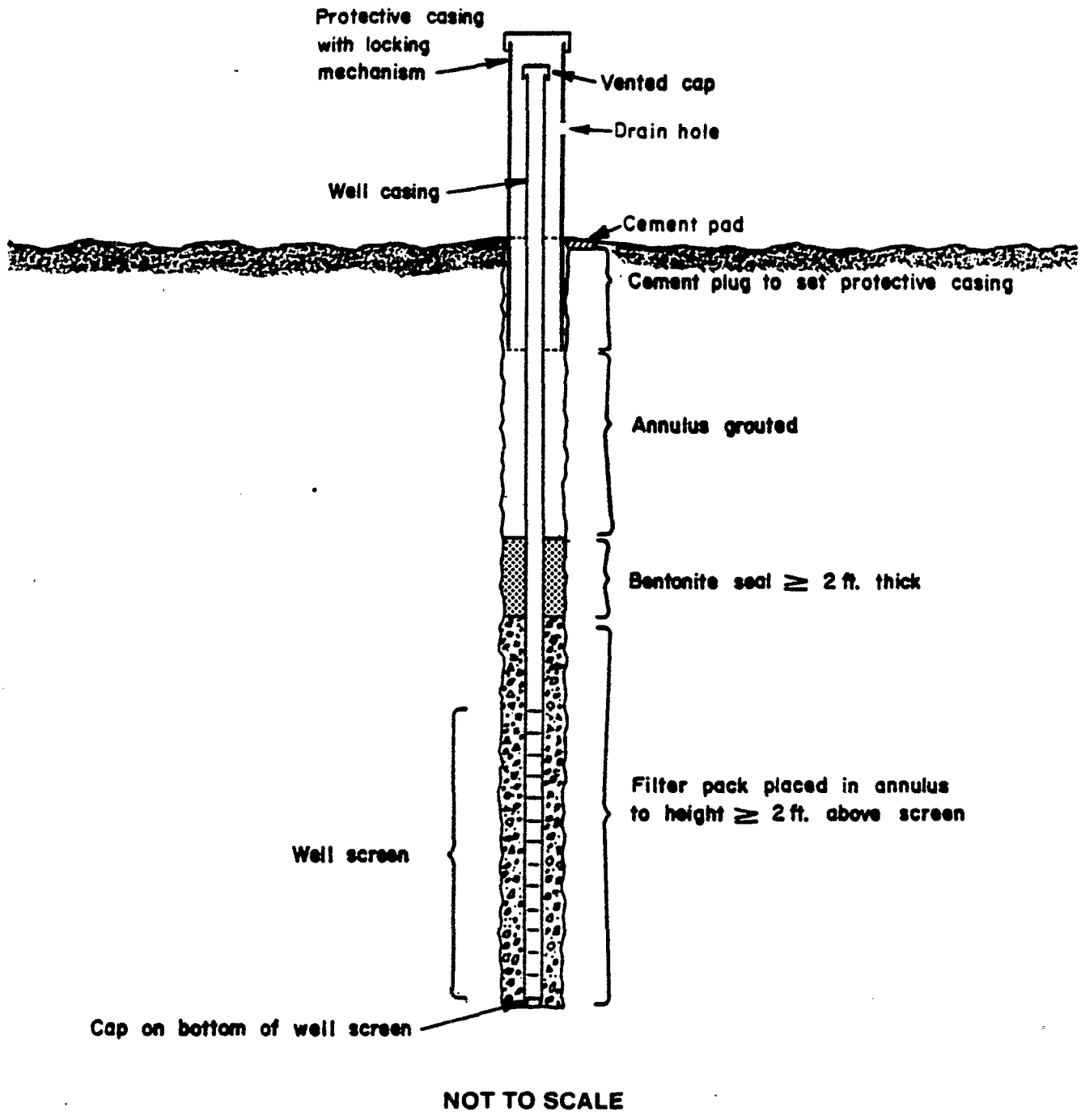
Method	Common Hole Diameter (inches)	Common Effective Operating Depth (feet)	Considerations Specific to Hazardous Waste Site Investigations
Continuous-Flight Auger	3 - 10	to 150	No drilling fluids commonly used which may affect groundwater quality. Potential for high concentrations of airborne contaminants near drilling personnel from borehole opening and cuttings pile. Relatively easy to clean and decontaminate equipment. User is in close proximity to the hazardous waste. Disposal of cuttings may be subject to regulation. Potential for borehole cave-in without casing, especially below water table.
Hollow-Stem Auger	5 - 12	to 100	No drilling fluids commonly used which may affect groundwater quality. Well installation possible inside HSA. Potential for high concentrations of airborne contaminants from borehole and cuttings. Below groundwater table, hydrostatic pressure must be maintained inside stem; water could affect groundwater quality. Difficult to clean and decontaminate inside surfaces of auger flights. Disposal of cuttings may be subject to regulation.
Water-based Rotary	3 - 24	Very deep	Water or drilling muds used may affect groundwater quality. Disposal of water and cuttings may be subject to regulations. Difficult to clean and decontaminate inside surfaces of drill stem.

300176

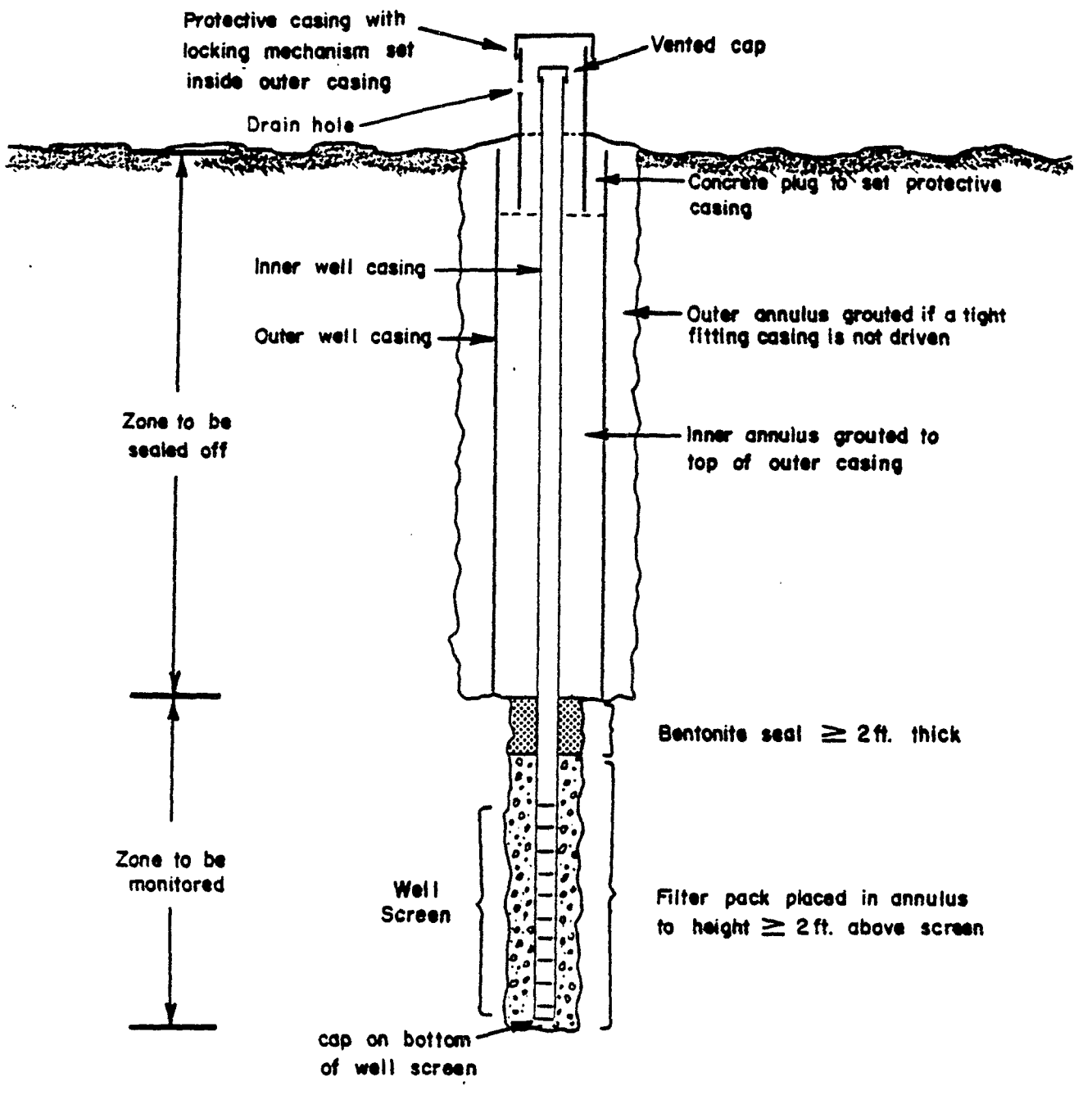
TABLE 3-1
FACTORS AFFECTING CHOICE OF DRILLING METHODS

Method	Common Hole Diameter (inches)	Common Effective Operating Depth (feet)	Hazardous Waste Site Investigations
Air-based Rotary	3 - 24	Very deep	Air flow may dilute contaminants and can be directed away from drilling personnel. May not require liquid drilling fluid, so groundwater quality would not be affected. Depending on soil characteristics and hole depth, water or foam may be required in small volumes - groundwater quality may be affected in these cases. Some air compressors use oil which may contaminate hole. Difficult to clean and decontaminate inside surfaces of drill stem and bit.

300177



TYPICAL TYPE A MONITORING WELL
TECHNICAL MEMORANDUM NO. 3



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TYPICAL TYPE B MONITORING WELL
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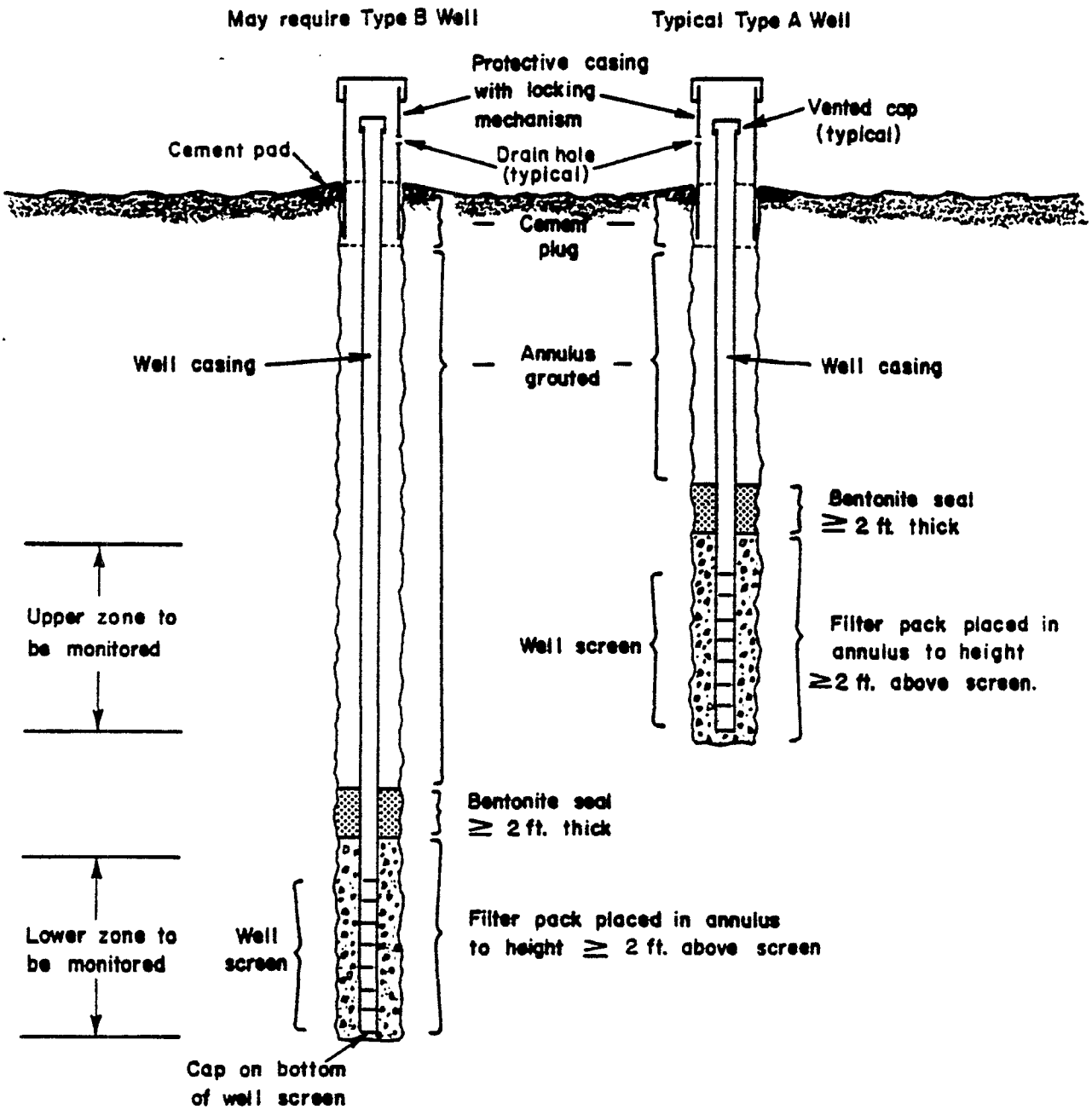

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CLUSTERED MONITORING WELLS
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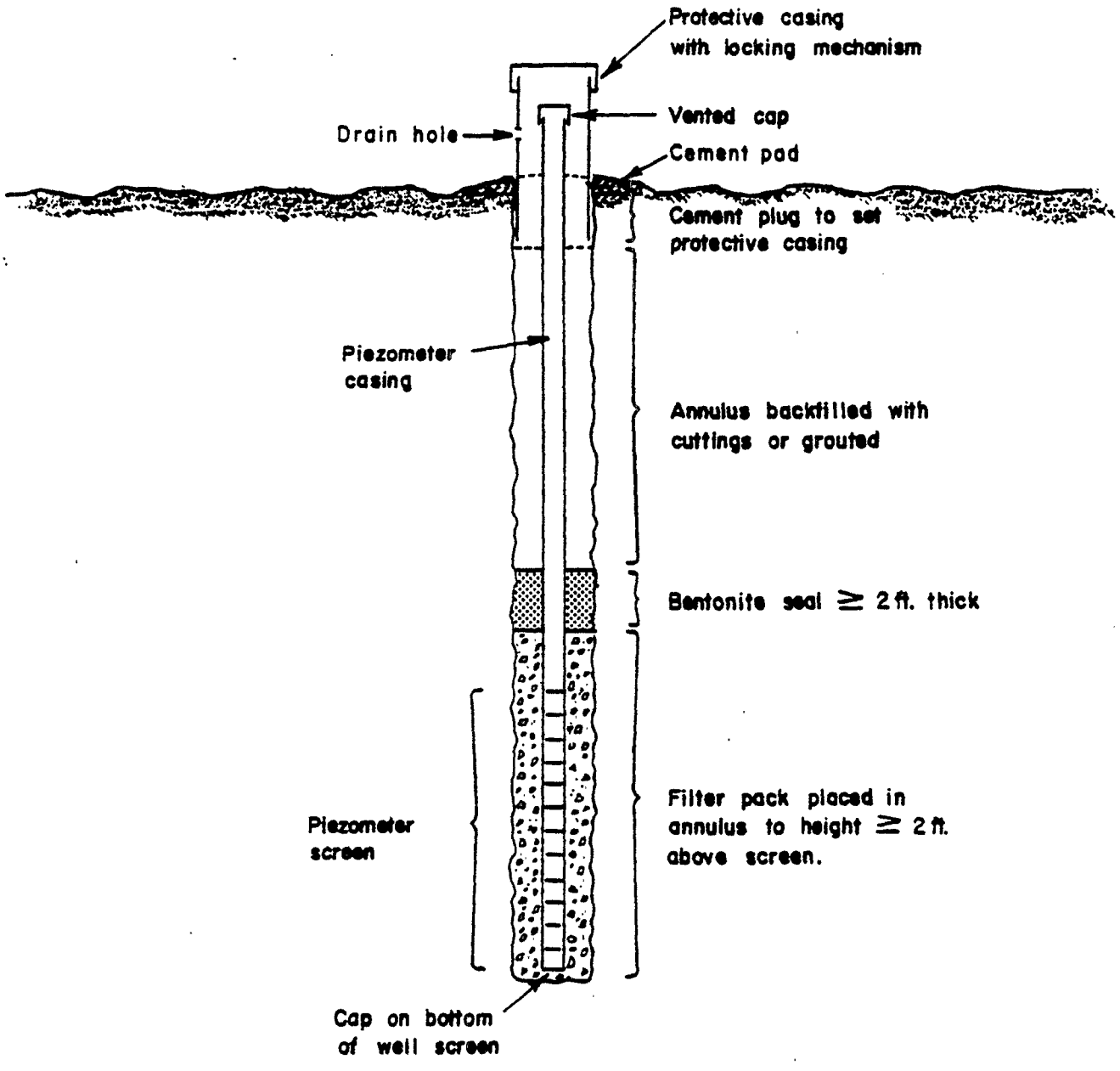

NOT TO SCALE

TYPICAL STANDPIPE PIEZOMETER
TECHNICAL MEMORANDUM NO. 3

NO. 4

AIR QUALITY MONITORING AND SAMPLING

300182

WOODWARD-CLYDE CONSULTANTS
HAZARDOUS WASTE MANAGEMENT PRACTICE
TECHNICAL MEMORANDUM NO. 4

AIR QUALITY MONITORING AND SAMPLING

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300183

TABLE OF CONTENTS

TECHNICAL MEMORANDUM NO. 4
AIR QUALITY MONITORING AND SAMPLING

Section		Page
4.0	Purpose	1
4.1	Measuring Methods and Equipment	1
4.1.1	Methods	1
4.1.2	Equipment	2
4.1.2.1	Direct Measurement	2
4.1.2.2	Indirect Measurements	4
4.2	Procedures	6
4.2.1	Site Surveys	6
4.2.2	Air Sampling	6
4.2.3	Occupational Monitoring	7
4.2.3.1	Identification of Hazardous Conditions	7
4.2.3.2	Worker Exposure	7
4.2.4	OVA Monitoring	8
4.2.4.1	Air Rotary Rigs	8
4.2.4.2	Auger Rigs	9
4.2.4.3	Data Interpretation	9
4.3	Personnel Training	10
List of References		12
Figure 4-1 - Checklist of Equipment		13
Figure 4-2 - Checklist of Procedures		15
Appendix A - Instruments for Dynamic Air Quality Measurements		A-1
Appendix B - Instruments for Passive Air Quality Measurements		B-1
Appendix C - Colorimetric Detector Tubes		C-1
Appendix D - Instrument Suppliers		D-1

HAZARDOUS WASTE MANAGEMENT PRACTICE

TECHNICAL MEMORANDUM NO. 4
AIR QUALITY MONITORING AND SAMPLING

4.0 Purpose

The purpose of this document is to provide guidance on equipment and methods for identifying air quality conditions that may be detrimental to: (1) the health of personnel engaged in investigations of chemical waste disposal sites and spills, and (2) to the public. Guidance provided in this document supplements that provided in WCC's Health and Safety Manual and is intended for use by individuals with at least a basic knowledge of methods for air quality sampling and analysis. The fundamentals of gas flow and volume measurement and pressure/temperature corrections are essential.

A wide variety of methods and equipment have been developed for sampling and analyzing air to determine its hazard to health. This document focuses on methods and equipment that either have wide application or are currently used by WCC. As the need arises to use other methods and equipment, this document may be expanded.

During investigations of chemical waste disposal sites or spills, air quality measurements should be performed whenever there is a possibility of encountering health threatening air quality conditions. In most cases, the need to measure air quality will be prompted by suspicion of the presence of hazardous airborne chemicals. In some cases, the need will be prompted by the possibility that oxygen deficient conditions exist.

If there are any questions and/or a peer review of program plans is desired, you are encouraged to contact one of the WCC offices listed in Appendix D.

4.1 Measuring Methods and Equipment

4.1.1 Methods

Measuring air quality entails identifying and quantifying chemical substances in air. A variety of methods have been developed to measure air quality. Basically, these methods can be classified as direct and indirect.

Direct methods analyze air without sample pretreatment and provide information almost immediately. They should be used whenever rapid assessments are needed. They are especially useful for determining the presence of hazardous airborne chemicals during field and laboratory operations. These

operations include work near spill or disposal sites where volatile chemicals are exposed to the atmosphere, installing observation/sampling wells and other borings, excavations, inspection and sampling of drums and other relatively small containers, confined space entry, opening of sealed sample containers, and laboratory testing of samples. Direct methods are also useful in conducting preliminary on-site air quality surveys for the purpose of designing and fine-tuning health and safety programs and more detailed air quality monitoring programs.

A variety of electronic instruments and other devices have been developed for direct measurement of air quality. All are designed for the on-the-spot measurements. Some are highly sophisticated; however, compared with instruments used in well-equipped analytical chemistry laboratories, direct measuring instruments and devices are usually less sensitive, have poorer resolving power, and are limited in the number and kinds of chemicals that they can detect.

Direct measuring equipment is available for both chemical detection without quantification, and for detection, identification and quantification. All are best used for detecting and/or quantifying known or suspected chemical substances. Although portable gas chromatographs, infrared spectrophotometers, and other instruments with chemical identifying capabilities can be used for identifying unknown chemicals, use of such instruments in the field for identification purposes is difficult and not generally recommended.

The indirect methods entail collecting air samples for subsequent laboratory analysis. They should be used whenever accurate identification and quantification of airborne chemicals are desired. In most cases, the samples do not comprise air per se, but sorbents or filters that remove and concentrate air contaminants upon exposure to air. Because considerable time can be involved in collecting samples and considerable time is always involved in analysis of the samples, indirect methods are best used where immediate knowledge of air quality conditions is not critical.

Indirect methods are recommended for determining air quality at chemical disposal or spill sites prior to commencement of field work, especially where there is a question about the kinds of airborne chemicals present. Samples collected should be analyzed to identify the chemicals they contain and the concentration of each chemical. The method is also recommended for obtaining information on personnel and public exposure after work commences.

4.1.2 Equipment

4.1.2.1 Direct Measurement

Appendices A and B list many of the instruments available for purchase or rent to perform direct air quality measurements. Information on the kinds

of chemicals the instruments are capable of measuring, ranges of detection, principle of operation, and manufacturer are also provided.

Two general kinds of instruments are listed. Dynamic measuring instruments are equipped with pumps that pull air through the detector mechanism. Results are derived from meter readings and/or strip chart recordings. Passive measuring instruments rely on air diffusing into the detector mechanism. Both types of instruments usually require calibration before use. Individuals responsible for operating any of these instruments should read the operating instruction manuals and become thoroughly familiar with the operation of the instruments through training and practice before using them in the field or laboratory.

Portable direct measurement instruments (DMI's) are very useful for detecting and quantifying airborne organic vapors and gases. Chemical analysis is usually via flame ionization, photoionization or thermal conductivity.

The OVA manufactured by Foxboro is one such DMI. The OVA can be operated in the total vapor mode or in the gas chromatographic mode. In the total vapor mode, the OVA can be used to determine total concentration of organic compounds in air or the concentrations of specific organic compounds. Concentrations are expressed in parts per million. When the instrument is used in the total vapor mode to determine the concentration of a specific compound, the instrument should be calibrated with the compound of concern. For general applications, methane is used for calibrations, resulting in readings in units of ppm (methane equivalent). A strip chart recorder, which can be purchased with the OVA can be very useful for documenting measurements.

In the gas chromatographic mode, the OVA with a flame ionization detector can be used to identify, as well as approximately quantify, organic vapors and gases when found in relatively high concentrations. A chromatographic column and a strip chart recorder, as well as an operator who has experience with gas chromatography, are required. For each detectable organic compound in an air sample, a peak is produced on the chart if the proper column is used. Identification of the compounds that produced the peaks requires using the instrument to analyze known amounts of each compound suspected of producing the peaks. These reference compounds must be of high purity. Identification of the compounds associated with each peak is accomplished by matching retention times (i.e., time to peak formation) of the reference compounds with those of the peaks produced by the sample. Quantification is achieved by comparing peak heights or areas of matched peaks. Unless one has a fairly good idea of the chemicals present in the samples, identification and quantification can be extremely difficult. The chromatographic column-equipped OVA is a crude chromatographic device. It can be very useful in certain situations, but has significant limitations that should be considered during sampling program design.

Portable DMI's such as those manufactured by HNU Systems, Inc. use photoionization to determine the total concentration of organic and inorganic compounds in air, or the concentrations of specific compounds with the exception of methane. Methane cannot be detected by the HNU instrument. Concentrations are expressed in parts per million in benzene equivalents. As in flame ionization, when the instrument is used to determine the concentration of a specific compound, the instrument should be calibrated with the compound of concern. If methane is of concern at a given site, an additional instrument, such as a combusion meter, is required to measure the Lower Explosive Limit (LEL).

There are other instruments on the market, such as the Bacharak TLV, that can be used as a DMI at hazardous waste facilities. There is no one instrument that covers all situations. Application of any of these DMI's should be evaluated by the Site Safety Officer in consultation with the Business Unit Health and Safety Officer to make sure that the appropriate instrument is used.

It is important to understand that each DMI's sensitivity varies for different compounds. One compound may be able to produce readings 1,000 times higher than the same concentration of a different compound. This is why it is imperative that DMI's be calibrated with the compound of concern before use.

A direct measuring device not listed in Appendices A or B is the colorimetric detector tube. A colorimetric detector tube contains a chemical that changes color when it comes in contact with another chemical. Color development along the length of the tube increases as the concentration of the chemical being measured increases. The concentration of the chemical being measured is determined using a calibration that is provided when the tube is purchased. These devices are useful only in the temperature ranges specified by the manufacturers. At low temperatures a device may be ineffective.

Colorimetric detector tube kits are available from several manufacturers. The basic kit comprises a hand-operated pump and an instruction manual. Detector tubes are available as separate items and are selected according to the chemical to be measured. Results can be obtained in a few minutes; however, they may not be reliable if the concentration of the chemical being measured is low. Colorimetric detector tubes are useful in situations where relatively high chemical concentrations are expected and the chemicals have been identified. Appendix C lists detector tubes available from four manufacturers for detecting specific compounds.

4.1.2.2 Indirect Measurements

This section addresses sampling equipment only. Sampling methods and equipment should always be discussed and agreed upon with the laboratory to obtain best results.

Air samples may be collected by collecting a known volume of air per se or by passing a known volume of air through a suitable sorbent or filter that will remove the chemical substances of interest from the air.

Samples of air per se are considered grab samples. Such samples may be collected by pumping air into specially designed bags of known volume, by drawing air into a gas-tight syringe or evacuated container. Because the volume of air that can be practically collected is relatively small, grab sampling is best used when high air contaminant levels are expected, such as in waste drums and containers. The vessel material, whether bag, syringe or container must be carefully chosen and cleaned so as not to introduce interference. Negative interferences can include reaction with the vessel surface, and adsorption or permeation into or through the vessel walls. Positive interferences can be caused by reactions, vessel contamination during prior use, or during manufacture.

Sampling by sorption or filtration is performed dynamically (with a pump) or passively (without a pump). The dynamic technique entails drawing air through a sorbing/filtering material at a known rate for a known period of time. The passive technique relies on diffusion. Dynamic sampling has an advantage over grab sampling in that the volume of air that can be sampled is limited only by the sorbing/filtering capacity of the sorbent/filter used. The dynamic sampling technique can be used for area as well as personnel monitoring.

In dynamic sorption sampling, care must be exercised in choosing a sorbent appropriate to the materials of interest. A wide variety of sorbents are available. Two general purpose solid sorbents are activated carbon and silica gel. Both are relatively effective sorbents for organic vapors and gases and are widely used. Both sorbents can be purchased packed in ready to use tubes or containers. It is especially important to consult with the laboratory selected for analysis before deciding on the sorbent. Often the laboratory can provide sorbent tubes. Widely used filter materials include cellulose ester, glass fiber, polyvinyl chloride, and silver membrane. Filters are generally used to sample chemicals in particulate form and chemicals sorbed to particulate matter. Certain filters will sorb non-particulates. Filters are used to collect particulate matter (e.g. asbestos and PCB's). The filter material must be selected to be compatible with the sampling apparatus and the analytical technique to be used. A wide variety of filters is available.

A variety of hand and electrically operated pumps are available on the market for dynamic sampling. Electrically operated pumps are powered by battery or regular house current, and some are equipped with flow meters and/or timers that automatically shut the pump off at a time set by the operator. Pumps that draw air through the filter or sorbent are almost always preferred because pumps themselves can interfer with sample collection when placed upstream of the collection medium. This is unavoidable

with most grab sampling methods involving bags; care should be taken when selecting a pump for such applications.

There are a variety of passive samplers with different principles of operation and application. One type, which is used for personnel monitoring is called a personnel monitoring badge, designed to be attached to a person's clothing. The badge comprises a disc coated with finely ground activated carbon enclosed in a specially designed protective casing. Organic chemicals in the air are sorbed on the carbon by diffusion. When badges from several manufacturers were evaluated by an independent firm, the results indicated that the carbon used in the badges was contaminated with various organic compounds. Therefore, an unused badge should be included in each group of badges submitted for chemical analysis.

4.2 Procedures

4.2.1 Site Surveys

An air quality survey may be conducted prior to the initiation of activities at a site. Site surveys may employ the use of a meteorological station, OVA total vapor concentration scan, oxygen or combustible gas meters, sorbent tube sampling, and other equipment which may be identified in the site safety or sampling plans. Examples for a checklist of equipment and a checklist of procedures are presented in Figures 4-1 and 4-2, respectively.

The OVA is commonly used to perform a site screening in which total organic vapor concentration of the air is measured during a walk-around of the site. Measurements are recorded on a site map. Enclosed areas might also be monitored using combustible gas meters or oxygen meters.

For accurate identification and quantification of airborne chemicals, air samples should be collected using appropriate sample collecting systems at carefully selected locations on a site. Short-term (a few hours) and long-term (8 to 24 hours) sampling times should be considered (see Section 4.2.2).

Air quality surveys may be conducted periodically if the site is substantially disturbed during the field investigation or remedial work; a final air quality survey may be performed following completion of site work to detect any change in ambient air quality resulting from the investigation procedures or remedial work.

4.2.2 Air Sampling

Locations for obtaining air samples should be selected based upon data collected during the site survey; places where elevated OVA readings or combustible gases are detected are logical points for air sampling. In the

absence of any detectable concentrations of vapors or gases, samples should be taken in a manner that will adequately cover the areas where potential air quality problems may arise. Locations downwind and adjacent to storage tanks or ponds, lagoons, pits or other waste facilities are prime targets for air quality sampling. Of course, sensitive receptors (e.g. nearby homes, offices, schools) are also candidates for sampling sites when local population exposure is of concern. Upwind samples are also useful as controls to measure background concentrations.

If weather conditions are likely to affect contaminant volatilization (such as heavy rainfall or very hot or cold temperatures), additional air samples may be taken to ascertain the magnitude of weather effect on air quality.

Air sampling is accomplished primarily by using sorbent tubes and sampling pumps; monitor badges are an alternative. The OVA equipped with a GC, strip chart option, may be used to obtain hard copy plots for analysis of compounds. Technical training and experience are required to interpret these graphs accurately; such an effort is likely to be time consuming if more than a few compounds are being sought. Laboratories can often provide turn around times of a few days on sorbent tube samples.

4.2.3 Occupational Monitoring

4.2.3.1 Identification of Hazardous Conditions

Air samples should be collected or air quality monitoring performed at any site activity that disturbs the environment or brings personnel into proximity with potential contaminant sources (drilling and sampling procedures are examples). The frequency of air monitoring and sampling and the procedures to be used should be specified in the site safety plan.

4.2.3.2 Worker Exposure

Worker exposure is most easily monitored by the use of monitor badges (described in a preceding section); personnel sampling pumps and sorbent tubes and/or particulate filters may alternately be used. Personnel sampling pumps are equipped with a clip so that the unit can be worn on a worker's belt. An intake tube with a sorbent is placed in-line to the pump and fastened to the clothing with the intake opening placed near the worker's face. These pumps are capable of operating continuously for about six to eight hours and their batteries may be recharged with the charging unit provided. Sorbent tubes or badges may be submitted for immediate analysis or refrigerated for later analysis. Generally, the quantity of samples collected during personnel monitoring will prohibit analysis of the entire set due to budget constraints. Randomly selected samples may be analyzed as a safety precaution. Additional samples may need to be analyzed if randomly selected samples indicate high concentrations. Badges or tubes worn at times when high DMI readings were detected (or odors

reported) should be analyzed to evaluate personnel exposure to potentially high levels of inorganic or organic vapors. Other samples should be held until the conclusion of the project in case a worker experiences an illness or some other situation prompts the need for analysis of a particular sample.

4.2.4 DMI Monitoring

The DMI may be used to obtain direct readings of total inorganic and organic vapor concentrations. Measurements may be made in the general work area at the potential source of contaminants (such as borehole openings) and both downwind and upwind of the activity.

Prior to the initiation of drilling, the wind direction and approximate wind speed should be determined at the drilling location. This determination can typically be made by securing lengths of surveyor's plastic ribbon to the drill rig boom or by attaching lengths of surveyor's plastic ribbon to a separate pole. Based on the determination of wind direction, the drill rig should be appropriately located to allow the majority of work to be conducted upwind of the drilling location. In addition, the wind direction indicators should be checked during the drilling process. If the wind direction does change substantially during the drilling process, additional efforts may be necessary to monitor the concentration of inorganic and organic vapors in the ambient air in the work space, if work would then be conducted downwind of the drilling location.

The operation of the DMI during drilling is dependent upon the type of drilling being conducted. Different procedures will be utilized for air quality monitoring in the area of the air rotary rig and the auger rigs.

4.2.4.1 Air Rotary Rigs

Recommended procedures for air monitoring in the area of the air rotary drilling rigs are as follows. DMI readings should be obtained from the air discharge of the air rotary rig as the drill bit advances each 10 feet. Caution should be exercised to prevent sampling too close to the discharge area to prevent the lodging of soil particles or water droplets into the entrance port of the DMI. The entrance port may be oriented downwind from the discharge. The DMI may be damaged if particles are allowed to enter into the combustion chamber. In addition, care should be exercised to limit DMI readings in the air discharge due to high concentrations of water vapor in the discharge stream. This excessive moisture may accumulate in the air sample collection tube and in the internal portions of the DMI resulting in freezing during cold weather conditions. If increased organic vapor concentrations are detected in the air discharge stream of the air rotary rig, DMI readings should be obtained for the ambient air of the general working area. DMI readings may be obtained from the open borehole

and/or drill cuttings when the drill rig is shut down or off location. Additionally, the ambient background concentration of vapors should be confirmed to ensure that a positive electronic drift in the instrument is not occurring and that the increased vapor concentration is not resulting from work being conducted upwind of the drilling location. If any individual detects the presence of an organic vapor, DMI readings should also be taken in the ambient air of the work space and at potential source locations.

After use, the pneumatic lines of the DMI should be inspected for contamination and cleaned, if necessary.

4.2.4.2 Auger Rigs

The operation of the DMI in the area of the auger drilling rig is slightly different from the air rotary rig since the auger drilling rig does not produce large volumes of air during the drilling process. It is anticipated that vapors which arise from the drilling process will result from volatilization of compounds contained in the auger cuttings or from an open borehole when drilling is completed. For this reason, DMI readings should be obtained in the cuttings spoil area at least once for every 20 feet of drilling. To assess whether auger cuttings have the potential to produce substantial vapor concentrations, auger cuttings may be collected and sealed in a plastic bag, box, or glass jar to allow volatile compounds to accumulate in the entrapped air. A DMI reading can then be taken from this entrapped air. Additional DMI readings should also be taken in the ambient air as described in the air monitoring procedures provided above for the Air Rotary Drilling Rigs if an organic vapor source is detected in the bore-hole, auger cuttings, or identified by field personnel. Concentrations thus obtained will be higher than those present in the ambient air. A dilution factor of 100 or more is generally applicable to such readings in open spaces, e.g., if auger cuttings in the sealed box produce a reading of 400 parts per million (ppm), the ambient air concentration of vapors produced by these cuttings may be in the order of 4 ppm or less. This "rule of thumb" is intended to be conservative. In most cases, dilution will be greater, but is highly dependent on release rate, distance, and weather. Dilution can be less in enclosed areas, where this approach is not applicable.

4.2.4.3 Data Interpretation

Depending upon the types of compounds detected during the site survey sampling, upper limits of vapor concentrations for worker exposure may be established. If a compound is present that has been assigned a NIOSH Threshhold Limit Value (TLV - the maximum concentration to which a worker can be continuously exposed over an eight-hour workday), that concentration may be used as the limit of exposure above which respiratory protection is mandated. In the absence of a TLV, a provisional maximum exposure limit concentration must be chosen. The limit should be based on available data

on the toxicity of the compound in question and chosen by the Business Unit Health and Safety Officer or the Corporate Health and Safety Administrator. In either case, the maximum exposure value is measured at ambient conditions in the work area.

If the predetermined maximum allowable ambient level for vapors is exceeded, all work should be stopped, and personnel should be provided the appropriate level of protection. If the ambient concentrations do not change, personnel will continue to implement the appropriate safety equipment. The site safety plan should be reevaulated under these conditions by the Site Safety Officer and the Business Unit Health and Safety Officer should be notified.

The DMI operator must use caution while monitoring the air quality because of the necessity to closely approach potential sources of contamination; levels near the source may be higher than ambient. Proper interpretation of the results of DMI monitoring is essential. Wind direction, effect of exhaust from nearby vehicles or drilling rigs and changes in upwind ambient conditions all must be considered when making air quality judgments. Also, an elevated reading at the borehole opening or from auger cuttings does not necessarily imply that the ambient air quality has deteriorated to the point at which additional safety precautions must be taken. Continued monitoring of ambient air quality is of prime importance. Specific action levels under prescribed conditions should be included in the site health and safety plan, if possible.

A detailed log should be maintained for the use of the DMI at each drilling location. This air monitoring log should include the name of the operator, date, time of reading, depth of boring, wind direction and approximate speed, general climatic conditions, all DMI readings, detections of odors by personnel, and a summary of any other pertinent information such as specific locations of measurements taken. This DMI log will serve as the documentation of air quality during the drilling process and should be maintained as completely as possible. Use of the OSHA form in Appendix D is preferred over personal logbooks.

Other types of meters may also be used if oxygen levels or the presence of combustible gases are of concern, primarily for sampling in closed areas.

4.3 Personnel Training

Project managers are encouraged to seek peer review of air quality monitoring program plans by a professional with at least five years experience in air and gas sampling and monitoring. Staff assigned to collect air and soil gas samples using techniques described in this Technical Memorandum must have appropriate training in the use and calibration of air sampling and analytical (chemical) instrumentation. Such staff must be under the supervision of and/or must have had appropriate prior training in air and

soil gas sampling and analysis from an experienced professional. Assistance with plan peer reviews and training can be obtained by calling the manager of air quality or analytical chemistry services in any of the following Woodward-Clyde Offices: Denver, Santa Barbara, Walnut Creek, and Wayne.

LIST OF REFERENCES

Information and procedures described in this memorandum have been compiled from procedures used at various hazardous waste sites and from consultation with personnel in Woodward-Clyde Consultants Environmental Systems Division, San Francisco.

Linch, A. L., Evaluation of Ambient Air Quality by Personnel Monitoring, Volume 1, Gases and Vapors, Second Edition, CRC Press, Boca Raton, 363 pp., 1981.

NIOSH Manual of Analytical Methods, Volume I, Monitoring Methods, Second Edition, USHEW, PHS, CDC, NIOSH, 1977.

Occupational Health Guidelines for Chemical Hazards, Volumes 1 and 2, F. W. Mackison, R. S. Stricoff, and L. J. Partridge, Jr. Eds., DHHS/NIOSH Publication No. 81-123, 1981.

Patty's Industrial Hygiene and Toxicology, Third Edition, Volume I -General Principle (1978), Volume 2A - Toxicology (1981), Volume 2B - Toxicology (1981), Volume 3 - Theory and Rationale of Industrial Hygiene Practice (1979), G. D. Clayton and F. E. Clayton, Ed. John Wiley & Sons, New York.

Air Sampling Instruments for Evaluation of Atmospheric Contaminants, 5th Edition, American Conf. Governmental Industry Hygiene, 1978.

ASTM, Annual Book of ASTM Standards, Atmospheric Analysis, 1985.

AR300196

FIGURE 4-1

CHECKLIST OF EQUIPMENT

A. Equipment required for monitoring

1. Meteorological monitoring station (or source of weather data)
   Suppliers:

2. OVA
   Suppliers:

3. Combustible gas meter
   Suppliers:

4. Oxygen meter
   Suppliers:

5. CH_4, H_2S or CO meters
   Suppliers:

B. Equipment required for air sampling

1. Gas detector tubes/sampling pumps

   Compounds:

   Suppliers:

2. OVA
   Suppliers:

3. Charcoal sorbent tubes/sampling pumps
   Suppliers:

4. Organic vapor badges
   Suppliers:

5. Particulate filters and sampling apparatus
   Suppliers:

FIGURE 4-2

CHECKLIST OF PROCEDURES

A. Procedures initiated prior to sampling/monitoring

1. Develop a site health and safety plan.

2. Determine the kinds of monitoring and/or sampling required.

3. Arrange for rental or purchase of necessary equipment.

4. Arrange for laboratory to analyze badges and/or sorbent tubes.

B. Procedures initiated at least one week prior to sampling/monitoring

1. Conduct training sessions on operation of equipment.

2. Make arrangements for shipment of equipment to the field.

C. Sampling/monitoring procedures

1. Conduct a site survey with the OVA to determine ambient air quality.

2. Select stations for sorbent devices for air sampling.

3. Conduct air sampling and ship samples for analyses.

4. Establish maximum allowable contaminant levels for ambient air.

5. Conduct occupational monitoring with the OVA at the site of drilling or sampling activities.

6. Assign personnel exposure monitoring devices to drill rig personnel.

7. Store personnel monitoring samples properly and establish criteria for selecting samples for analyses.

8. Maintain accurate, complete records of all OVA (or other) monitoring, air sampling and personnel exposure equipment use. Records should include meteorological conditions (wind speed, wind direction, termperature, pressure), equipment condition, equipment calibration procedures and results.

APPENDIX A

INSTRUMENTS FOR DYNAMIC AIR QUALITY MEASUREMENTS

Manufacturer or vendor	Model number	Dimensions L × W × D cm	Weight Kg	Gases of vapors detected	Range ppm	Principle of operation
Bacharach-J.W.[a]	MV-2	28.9 × 12.1 × 11.1	2.7	Mercury	0—0.2, 0—1.0 mgm[3]	UV absorption at 253.7 nm
	H[b]	14.6 × 7.6 × 11.1	2.5	Combustible	0—100% gas	Cat. combustion
	G[b]	14.6 × 7.6 × 11.1	1.8	Combustible	—	Cat. combustion
	L[b]	14.6 × 7.6 × 11.1	1.8	Combustible	0—100% LEL	Cat. combustion
	TLV[b,d]	2.2 × 9.5 × 16.8	2.6	Hydrocarbons	0—10,000	Cat. combustion
	K	14.6 × 7.6 × 11.1	1.1	Oxygen	0—25%	Electrolytic
	GPK	10.3 × 14 × 19	2.6	Combustible + O_2	0—25% O_2	Combination electrolytic and cat. combustion
	Sentox 2[e]	26.7 × 17.2 × 16.5	3.4	Combustible + O_2	0—100% LEL	Combination electrolytic and cat. combustion
Biomarine[f]	500[b]	21.9 × 11.8 × 12.4	1.6	CO	0—100, 0—500	Electrochemical oxid.
	501[b]	21.9 × 11.8 × 12.4	1.6	CO	0—100, 0—500	Pulsed operation
	701	21.9 × 11.8 × 12.4	1.5	H_2S	0—20, 0—100	Electrochemical oxid. diffusion membrane
	911	21.9 × 11.8 × 12.4	1.5	Combustible	0—100% LEL	Pt ceramic bead
	901	21.9 × 11.8 × 12.4	1.6	Combustible	0—100% LEL	Pt ceramic bead
	900	21.9 × 11.8 × 12.4	1.6	Combustible + O_2	0—100% LEL 0—40% O_2	Electrochemical
Bendix[f]	GA-1C	14.6 × 11.4 × 13.4	—	Combustible	% LEL	Cat oxid. Pt filament
Century[a]	OVA	21.9 × 29.5 × 10.8	5.0	Organic	1—100,000	Gas chromatography
	88 and 98	21.9 × 29.5 × 10.8	5.0	Vapors	1—10,000	Flame ionization
Energetics Science[a]	Ecolyzer 2100—2800	18.7 × 33.0 × 18.7	4.1	CO	0—50, 0—4000	Electrochemical
	Hipster 6000 series[d,f]	—	1.6	CO	0—100, 0—500	3 Electrode electrochemical
	Hipster 6000 series[d,f]	—	1.6	H_2S	0—320	Oxid.
Enmet[a]	[f]	—	—	Combustible + O_2	1—100% LEL 0—25% O_2	Hand operated squeeze bulb
Gas Tech[a]	1177—1314[f]	—	—	Combustible + O_2	0—100% LEL 0—25% O_2	Cat. oxid. Pt filament
	GV-3[b,f]	—	—	Combustible + O_2	0—100% LEL 0—25% O_2	Electrochemical O_2
	GP-204[b]	—	—	Combustible	0—100% LEL	Cat. oxid. Pt filament
	XP-204[b]	—	—	O_2	0—25%	Electrochemical
	1238[b]	30.5 × 9.5 × 14.0	2.7	Hydrocarbons	0—500 as toluene	Cat. combustion 0—100% LEL
Interscan Corp.[a]	1140—1148	15.2 × 17.8 × 25.4	3.2	CO	0—600	Electrochemical oxid.
	1240—1249	15.2 × 17.8 × 25.4	3.2	SO_2	0—20	Electrochemical oxid.
	1170—1175[c,d]	15.2 × 17.8 × 25.4	3.2	H_2S	0—50	Electrochemical oxid.
IST[a]	[f]	—	—	Combustible oxygen	0—100% LEL, 0—25%	Hand operated squeeze bulb, cat. oxid.
MSA[a]	2A[f,g]	9.5 × 13.6 × 14.0	1.8	Explosimeter	0—100% LEL	Pt filament, cat. oxid.
	3[f]	9.5 × 13.6 × 14.0	1.8	H_2 + O_2 mixture	0—100% LEL	Pt filament, cat. oxid.
	4[f]	9.5 × 13.6 × 14.0	1.8	Acetylene	0—100% LEL	Pt filament, cat. oxid.
	5[f]	9.5 × 13.6 × 14.0	1.8	Leaded gasoline	0—100% LEL	Pt filament, cat. oxid.
	20—40[f]	9.5 × 13.6 × 14.0	1.8	5 Gases	0—100% LEL	Pt filament, cat. oxid.
	Gascope[f] natural gas	15.2 × 10.2 × 14.6	2.9	%/Volume combustible	0—100%	Thermal conductivity
	100[c,f]	25.4 × 17.8 × 9.5	3.2	Combustible	0—100% LEL	Pt filament, cat. oxid.
	250	19.1 × 13.7 × 8.6	—	Combustible + O_2	0—100% LEL	Pt filament, cat. oxid.
	77600[a]	17.2 × 10.5 × 14.6	2.6	O_2	0—25%	Electrolytic
	87762[a]	17.2 × 10.5 × 14.6	2.6	O_2	5—40%	Electrolytic
Neutronics[a]	BZ/3007-AA[f]	—	—	Combustible	—	Conversion kit battery operated pump

300200

Notes: Dimensions = LxWxD = Length × Width × Depth (wide); Kg = kilograms; ppm = parts per million as volume per volume (V/V); LEL = lower explosive limit; Pt = platinum; MOS = metallic oxide semiconductor; UV = ultraviolet light; HC = hydrocarbons (aliphatic and aromatic); CO = carbon monoxide; Cat. = catalytic; Oxid. = oxidation.

- Bacharach Instrument Co., Division of AMBC Industries, Inc., 625 Alpha Dr., Pittsburgh, Pa.
- Also available in the passive mode.
- Built-in alarm.
- Chart recorder available.
- Biomarine Industries, Inc., 45 Great Valley Center, Malverne, Pa.
- The Bendix Corp., Environmental and Process Instruments Division, Lewisburg, W. Va.
- Century Systems, *
- "Ecolyzer", Energetics Science, Inc., 85 Executive Blvd., Elmsford, N.Y.
- Personnel monitor type.
- Calibration kits (gas) available.
- Enmet, 2308 Industrial Hwy., Ann Arbor, Mich.
- Conversion kit for passive instruments.
- Gas Tech, Inc., Johnston Instrument Division, 331 Fairchild Dr., Mountain View, Calif.
- Interscan Corp., 9614 Cozycroft Ave., Chatsworth, Calif., U.S. Patent No. 4,017,373.
- International Sensor Technology, 3201 S. Halladay St., Santa Ana, Calif.
- "MSA", Mine Safety Appliances Co., 400 Penn Center Bldg., Pittsburgh, Pa.
- All MSA models hand squeeze bulb operated except models 100 and 2.
- Four models available for five specific gases: pentane, octane, xylene, and combustible vapors.
- Neutronics, Inc., 450 Drew Ct., King of Prussia, Pa.
- Battery operated pump for conversion to dynamic sampling mode for passive instruments.

7690	Nitrogen dioxide
7814	Nitrogen dioxide refill
7969	Phenol
7970	Phenol refill
7067	Silica
6627	Silica refill
7671	Sulfide (H_2S)
7815	Sulfide refill
7691	Sulfur dioxide
7816	Sulfur dioxide refill
7702	TDI
7818	TDI refill

- Kit consists of absorbing solution, reagents, instructions, and color comparator. Approximately 25 tests per kit.

*now manufactured by Foxboro, Burlington, MA.

APPENDIX B

INSTRUMENTS FOR PASSIVE AIR QUALITY MEASUREMENTS

Manufacturer or vendor	Model number	Dimensions L × W × D (cm)	Weight kg	Gas or vapor detected	Range (ppm)	Principal of operation
Bacharach[a]	51—7026[b,j]	11.4 × 8.4 × 4.1	0.54	Combustible	0—100% LEL	Hot Pt filament
	Sentox 2[b,d,j]	5.1 × 6.4 × 12.7	0.41	Oxygen	0—40%	Galvanic cell
	Sentox[d,j]	26.6 × 17.1 × 16.5	3.2	H_2S	3—50	MOS-conductor
	51-702[b,j]	11.4 × 8.4 × 4.1	0.54	H_2S	—	MOS-conductor
Biomarine[a]	911[b,j]	8.3 × 14.6 × 5	0.54	Combustible 0—4% CH_4	0—100% LEL	Pt-ceramic bead
	OA222R[b,c,e]	5.1 × 6.4 × 12.7	0.41	Oxygen	0—40%	Galvanic cell
	OM322	5.1 × 6.4 × 12.7	0.41	Oxygen	0—40%	Galvanic cell
	900, 922[b,j]	8.3 × 17.8 × 5	0.68	Oxygen Combustible		Galvanic cell Pt ceramic bead
	500	8.2 × 17.8 × 5	0.68	CO	0—500	
	700	8.3 × 17.8 × 5	0.68	H_2S		?
Chemtrix[i]	30	—	1.37	Oxygen	0—15 ppm	Galvanic cell
Draeger[j]	25D[d,e]	—	—	Oxygen	0—25%	Galvanic cell
Dynamation Combo[a]	75-300[b,j,l]	20.4 × 10.2 × 7	0.85	Oxygen	Alarm—19.5%	Galvanic cell
				Combustible	Alarm—20% LEL	MOS-conductor
				H_2S	Alarm—10	MOS-conductor
	H_2S—8[d,j]	15.1 × 8.2 × 5.1	0.68	H_2S	0—50	MOS-conductor
	CO—8[d,j,l]	15.1 × 8.2 × 5.1	0.68	CO	0—300	MOS-conductor
Dictaphone life-guard[m]	H_2S	7.6 × 15.2 × 3.1	0.40	H_2S	1—100	Electrochemical
	Detector[d]					
Enmet[a]	CGS-8[b,j]	12 × 9.5 × 6.3	0,62	Combustible CO	0—100% LEL 50—500/TLV	MOS-conductor
Enmet[a]	CGS-10[d,j]	12 × 9.5 × 6.3	0.77	Oxygen Combustible	18—19.5% 0—100% LEL	Galvanic cell MOS-conductor
Enmet-Cont[a]	OMA-10	12 × 9.5 × 6.3	0.56	Oxygen CO	0—25% 50—100	Galvanic cell
Tritector[a]	CGS-10[b,j,l]	12 × 9.5 × 6.3	0.77	H_2S	10—100	MOS-conductor
Edmont[a]	60-620 to 60-626	8 × 13 × 13	0.45	xygen	0—25%	Galvanic cell (polarographic)
MDA[a]	60-400[d,j]	30.5 (diameter) × 7.6	3.6	Combustible Oxygen	0—100% LEL 0—25%	Galvanic Hot Pt filament
Gas-Pro Lumidor[a]	LP-BGA-g[d,e]	76 × 51 × 151	0.46	Combustible CO	0—100% LEL 100	MOS-conductor
Gas Tech[i]	1177	30 × 9.5 × 14	2.27	Combustible	0—100% LEL	Hot Pt filament
	Protector[b,d,j]	9.7 × 6.4 × 20	0.97	Combustible	0—100% LEL	Hot Pt filament
	Gastechtor[b,d,j]	30 × 9.5 × 14	2.27	Oxygen Combustible	0—25% 0—100% LEL	Galvanic cell Hot Pt filament
Gen Elect.[i]	Area dosimeter	12.7 × 10.2 × 5.1	0.64	CO	0—250	Meter readout TWA coulometer
IST[a]	2500[b,d]	10.3, 13.5, 18.9	2.5	Chlorine	0—10, 20, 50	MOS-conductor
	2900-NH[b,d,e]	10.3 × 13.5 × 18.9	2.5	Ammonia	0—200	MOS-conductor
	3400[b,d,e]	10.3 × 13.5 × 18.9	2.5	SO_2	0—5, 0—25	MOS-conductor
	2100[b,d,e]	10.3 × 13.5 × 18.9	2.5	H_2S	0—500, 0—100	MOS-conductor
	2800[b,d]	10.3 × 13.5 × 18.9	2.5	Acrylonitrile	0—200	MOS-conductor
	AG5100	7.6 × 5.1 × 5.2	0.8	Hydrogen	0—100	MOS-conductor
	AG6000[d,e]	7.6 × 5.1 × 5.2	0.8	Combustible H_2S	0—100 % LEL 0—200	MOS-conductor + semi-permeable membrane
Kitagawa[a]		11 × 6 × 3	0.34	Hexane	500—1000	Hot Pt filament
Sipin[a]	FPA40-D			Isobutane	800	
MDA[a] Dosimeter	777[d,e,f]	12.1 × 7.0 × 3.5	0.28	CO	100, 200	Electrochem. oxid.
MSA[a]	100[b,d,j]	25.4 × 17.9 × 9.5	3.2	Combustible	0—100% LEL	Hot Pt filament
	250[b,j]	19 × 13.9 × 8.1	—	Combustible	0—100% LEL	Hot Pt filament

Biomarine[a]				Oxygen	0—25%	Galvanic cell
Biomarine[a]	244, 244R	5.1 × 6.4 × 12.7	0.31	Oxygen	0—25%	Galvanic cell
NEI-Bendix[i]	Micro-Methano Meter-800	800 3.6 × 6 × 4.7	0.26	Methane	0—5%	?
	Guardian[d,i] 2450 series	14.6 × 5.7 × 10.8	—	Combustible	1/3 LEL	Hot Pt filament
National Mine Safety[m]	COMonitor[d,i]	5.1 × 2.5 × 12.7	0.34	CO	100, 200, 300	MOS-semiselect cat. combustion
Neutronics[n]	Otox-90-91[c,d]	17.8 × 21.6 × 5.1	1.36	Oxygen	0.1—35%	Galvanic cell
	H_2S dosimeter	7.6 × 20.3 × 5.1	1.36	H_2S	10—150	Colorimetrictape
	Otox-80[d,i]					IR sensor
	AGM Series[d,i]	7.6 × 20.3 × 5.1	1.36	Combustible gases	below LEL	Catalytic
Photo-ionization[o]	PHOI	24 × 21 × 13	4.1	See table in the reference/calib-benzene	0.1—600	UV ionization
	PI-101[d,e,h,i]	24 × 21 × 13	4.1	See table in the reference	0.1—600	UV ionization
Texas Analytical Controls[ee]	701[d,i]	12 × 8.9 × 5.7	0.68	H_2S	0—100, 0—50, 0—25	MOS-conductor
IST[a]	AG 6000[c,d,e,i]	7.6 × 5.1 × 5.2	0.8	Combustible	0—100% LEL	MOS-conductor
				H_2S	0—200	+ semipermeable
	AG 5100	7.6 × 5.1 × 5.2	0.8	Hydrogen	0—100	membrane
				CO		
				Hydrocarbons	0—1000	
				Ammonia	0—400	
				Chlorine	0—50	

Note: Dimensions = L × W × D = Length × Width × Depth (Wide); kg = kilograms; ppm = parts per million as volume per volume (V/V); LEL = lower explosive limit; Pt = Platinum; MOS = metallic oxide semi-conductor; UV = ultraviolet light

- [a] Bacharach Instrument Co., Division of AMBAC Industries, Inc., 625 Alpha Drive, Pittsburgh, Pa.
- [b] Also available in the dynamic mode-squeeze bulb.
- [c] Also available in the dynamic mode-battery operated pump.
- [d] Built-in alarm.
- [e] Personnel monitor type.
- [f] Calibration gas kit available.
- [g] Biomarine Industries, Inc., 45 Great Valley Center, Malvern, Pa.
- [h] Chart recorder available.
- [i] Chemtrix, Inc., Giangarlo Scientific Co., 3237 Dawson Street, Pittsburgh, Pa.
- [j] Schinkman, M., Some aspects of measuring the oxygen concentration in gas mixtures — using fuel cell sensors, *Draeger Rev.*, 39, 34, 1977; see also National Draeger, Inc., Parkway View Dr., Pittsburgh, Pa.
- [k] Dynamation Gas Detection Instruments, P.O. Box 225, Ann Arbor, Mich.
- [l] Also available for other toxic gases on the TLV list.
- [m] Gas Detection Products, Dictaphone, Audio/Electronics Division, 475 Ellis Street, Mountain View, Calif.
- [n] Enmet, 2308 Industrial Highway, Ann Arbor, Mich.
- [o] Edmont-Wilson, Division of Becton, Dickinson and Co., Cochocton, Ohio, U.S. Patent No. 3,666,650.
- [p] MDA Scientific, Inc., 808 Busse Highway, Park Ridge, Ill.
- [q] Lumidor Products Corp., Safety Division, 5364 N. W. 167th St., Miami, Fla.
- [r] Calibrated with methane (CH_4).
- [s] Gas Tech, Inc., Johnston Instrument Division, 331 Fairchild Dr., Mountain View, Calif.
- [t] Carbon Monoxide Detectors, General Electric, Aircraft Equipment Division, 50 Fordham Rd., Wilmington, Mass.
- [u] International Sensor Technology, 3201 South Halladay St., Santa Ana, Calif.
- [v] Formerly E. D. Bullard Company (1977).
- [w] "Sipin", Anatole J. Sipin Co., Inc., 425 Park Ave. S., New York, N.Y.
- [x] Gas dosimeter cell records and accumulated Time Weighted Average (TWA).
- [y] Mine Safety Appliances Co., Inc., 400 Penn Center Blvd., Pittsburgh, Pa.
- [z] Micro-Methanometer, Model 800, Bendix Environmental and Process Instruments Division, Lewisberg, W. Va.
- [aa] National Mine Service Company, 3000 Koppers Bldg., Pittsburgh, Pa.
- [bb] Oxygen, Hydrogen Sulfide and Flammable Vapor Analyzers, Neutronics, Inc., 450 Drew Ct., King of Prussia, Pa.
- [cc] HNU Systems, Inc., 383 Elliot St., Newton Upper Falls, Ma; Representative: Giangarlo Scientific Co., 3237 Dawson Street, Pittsburgh, Pa.
- [dd] Texas Analytical Controls, 7707 Bissonnet, P.O. Box 42183, Houston, Tx. 77042-Phone (713) 777-4062

APPENDIX C

COLORIMETRIC DETECTOR TUBES

Compound	Detector tube identification, tube number, and detection range			
	Bendix-Gastec	Dräger	Matheson-Kitagawa	MSA
Acetaldehyde	—	6726665 (100—1000 ppm)	8014-133 (0.004—1.6 %)	93963 (25—1000 ppm)
Acetic acid	81 (1—80 ppm)	6722101 (5—80 ppm)	—	92623 (5—400 ppm)
Acetic anhydride	81 (0.5—40 ppm)	—	—	—
Acetone	151 (0.01—2%)	CH 22901 (100—1200 ppm)	8104-102A (0.05—5.0%) 8104-102C (0.01—4.0%)	—
Acetonitrile	—	—	—	91624 (10—200 ppm)
Acetylene	171 (0.1—4%)	CH 26101 (500—3000 ppm)	8104-101 (50—1000 ppm)	82802 (3—600 ppm)
Acrilet	—	—	—	91624 (8—70 ppm)
Acrolein	—	—	8014-136 (0.005—2.5%)	—
Acrylonitrile	191 (10—500 ppm)	CH 26901 (5—30 ppm)	8014-128A (0.1—3.5%) 8014-128B (10—500 ppm)	91624 (5—150 ppm)
Alcohol	—	CH 29701 (100—3000 ppm)	—	—
Ammonia	3L (1—60 ppm) 3H (0.2—32%) 3M (10—1000 ppm)	CH 25501 (25—700 ppm) CH 31901 (0.5—10%) (0.05—1%) CH 20501 (5—70 ppm) (50—700 ppm)	8104-105B (20—700 ppm) 8014-105A (1—25%)	92115 (10—1500 ppm)
n-Amyl alcohol	—	—	—	95097 (25—2000 ppm)
Iso-Amyl alcohol	—	—	—	95097 (50—1000 ppm)
sec-Amyl alcohol	—	—	—	95097 (25—2000 ppm)
tert-Amyl alcohol	—	—	—	95097 (25—2000 ppm)
n-Amyl mercaptan (1-pentanethiol)	—	—	—	454206 (0.5—100 ppm)
Aniline	181 (1.25—60 ppm)	CH 20401 (1—20 ppm)	—	—
Arsine	—	CH 25001 (0.05—3 ppm) (1—60 ppm)	804-140 (5—160 ppm)	—
Benzene	121 (5—120 ppm)	67 18801 (5—40 ppm) CH 24801 (15—420 ppm) (0.05—1.4 mg/L)	8014-118A (2—70 ppm) 8014-118A (10—310 ppm) 8014-118B (25—345 ppm)	93074 (5—200 ppm)
Benzyl bromide	136 (25—850 ppm)	CH 24401 (qual)	—	—
Benzyl chloride	132L (0.5—25 ppm)	67 28031 (1—10 ppm) (5—50 ppm)	—	—
Bromine	9L (2—23 ppm)	CH 24301 (0.2—3 ppm) (2—30 ppm)	8014—114 (1—50 ppm)	82399 (5—75 ppm) 87042 (5—200 ppm)
Bromobenzene (mono)	—	—		93074 (10—800 ppm)
Bromoform	136 (0.5—50 ppm)	CH 24401 (qual)	—	—
Butadiene	174 (50—800 ppm)	CH 31201 (0.01—0.12%)	8014-168A (0.03—2.6%) 8014-168B (30—600 ppm)	93962 (100—4000 ppm)
Butane	104 (50—1400 ppm)	CH 26101 (0.1—1%)	—	—
Butyl acetate	142 (0.01—0.8%)	—	8014-138 (0.01—1%)	—
2-Butoxy ethanol (butyl cellosolve)	—	—	—	95097 (30—900 ppm)
n-Butyl alcohol	112 (100—1500 ppm)	CH 29701 (100—3000 ppm)	—	95097 (50—4000 ppm)
Iso-Butyl alcohol	—	—	—	95097 (50—4000 ppm)
sec-Butyl alcohol	—	CH 29701 (100—3000 ppm)	—	95097 (50—4000 ppm)
tert-Butyl alcohol	—	—	—	95097 (100—1000 ppm)
		—	—	92115 (2—100 ppm)
n-Butyl mercaptan (1-butane thiol)	—	— —	454206	(0.5—100 ppm)
tert-Butyl mercaptan (2-methyl-2-propanethiol)	—	—	—	454206 (0.5—100 ppm)
Butylene-(1)	—	CH 31201 (1—50 mg/l)	—	—
Carbon dioxide	2LL (0.03—0.5%) 2L (0.13—8%) 2H (1—20%	CH 30801 (0.01—0.3%) CH 23501 (0.1—1.2%) (0.5—6.5%) CH 25101 (1—20%)	8014-126B (100—7,000 ppm)	85976 (0.1—10%)

300204

		CH 31401 (0.5—10%) CH 20301 (5—60%)		
Carbon disulfide	13 (5—50)	CH 26001 (13—228 ppm) (0.04—0.9 mg/L) CH 23201 (0.1—10 mg/L) (32—3200 ppm)	8014-141 (10—200 ppm)	95297 (5—500 ppm)
Carbon monoxide	1LL (5—50 ppm) 1La (8—1000 ppm) 1L (50—2000 ppm) 1M (0.1—4%) 1H (0.2—10%)	CH 28900 (10—300 ppm) (100—3000 ppm) CH 19701 (8—150 ppm) CH 25601 (5—150 ppm) (100—700 ppm) CH 20601 (10—300 ppm) (100—3000 ppm) CH 29601 (0.1—1.2%) CH 24901 (0.3—4%) CH 29901 (0.5—7%)	8014-100 (20—1000 ppm) 8014-106A (10—6000 ppm) 8014-106B (10—6000 ppm) 8014-106C (10—6000 ppm)	91229 (10—3000 ppm) 47134 (0.01—0.1 %)
CO200/a + CO_2 (simultaneous tube)	—	67 18301 (200—2500 ppm CO) (2—12% CO_2)	—	—
CO (supplementary part for the respiratory test)	—	CH 270	—	—
Carbon tetrachloride	134 (1—60 ppm)	CH 27401 (10—100 ppm)	8014-147 (5—300 ppm)	88536 (10—200 ppm)
Chlorine	8LA (0.3—16 ppm)	CH 20701 (50—500 ppm) CH 24301 (0.2—3 ppm) (2—30 ppm)	8014-109 (1—40 ppm)	87042 (3—100 ppm) 82399 (0.5—20 ppm)
Chlorine dioxide	8LA (0.3—16 ppm)	CH 24301 (0.1—1.5 ppm)	8014-116 (1—40 ppm)	82399 (0.05—16 ppm)
Chlorobenzene	121 (5—350 ppm)	—	—	85834 (10—200 ppm) 93074 (10—800 ppm)
Chlorobromomethane	136 (8—80 ppm) 135 (40—350 ppm)	—	—	85833 (50—500 ppm) 88536 (25—500ppm)
Chloroform (trichloromethane)	—	CH 27301 (5—50 ppm)	8014-152 (75—600 ppm)	88536 (25—400 ppm)
Chloropicrin	134 (1—60 ppm)	—	—	—
1-Chloro-1,1-difluoroethane (Genetron 1428)	—	—	—	88536 (100—2500 ppm) 92030 (100—400 ppm)
Chlorodifluoromethane (Freon® 22)	—	—	—	88536 (200—2000 ppm)
1-Chloro-1-nitropropane	—	—	—	91624 (2—75 ppm)
Chloropentafluoroethane (Freon® 115)	—	—	—	88536 (200—2000 ppm)
Chloroprene	—	67 18901 (5—60 ppm) (7.5—90 ppm)	8014-169 (5—800 ppm)	—
Chlorotrifluoromethane (Freon® 13)	—	—	—	88536 (250—2500 ppm) 92030 (200—3500 ppm)
Cumene	122 (5—2400 ppm)	CH 27801 (0.1—7 mg/L) (25—1860 ppm)	—	—
Cyanogen	—	—	—	91624 (2—100 ppm)
Cyanogen chloride	—	CH 19801 (0.25—5 ppm)	—	—
Cyclohexane	102H (0.015—1.2%)	67 25201 (100—1500 ppm)	8014-115 (0.01—0.6%)	—
Cyclohexanol	—	—	—	95097 (25—1000 ppm)
Cyclohexylamine	—	—	—	92115 (2—100 ppm)
Diborane	—	67 18101 (0.05—3 ppm)	—	—
1,1-Dibromoethane	136 (7—70 ppm)	—	—	—
1,2-Dibromoethane	136 (6—80 ppm)	CH 24401 (qual)	—	88536 (10—200 ppm) 85834 (5—100 ppm)
o-Dichlorobenzene	121 (10—700 ppm)	—	—	85834 (10—200 ppm)

Dichlorodifluoromethane (Freon® 12)	—		—		—	88536	(25—3000 ppm)
1,1-Dichloroethane	—		—		—	85833	(25—500 ppm)
1,2-Dichloroethylene	132H	(10—450 ppm)	—		8014-145	85833	(cis) (10—300 ppm)
						88536	(cis) (100—500 ppm)
						85833	(trans) (25—400 ppm)
						92030	(trans) (25—1000 ppm)
1,2-Dichloroethane (ethylene dichloride)	—		CH 27301	(5—50 ppm)	—	85834	(25—400 ppm)
						92030	(25—450 ppm)
Dichloroethyl ether	—		—		—	85834	(5—75 ppm)
1,1 Dichloro-1-nitroethane	—		—		—	91624	(2—75 ppm)
Dichlorotetrafluoroethane (Freon® 114)	—		—		—	88536	(200—2000 ppm)
Diethyl benzene	122	(25—2400 ppm)	CH 27801	(0.1—7 mg/L) (25—1860 ppm)	—		—
Diethylamine	3L	(1.6—48 ppm)	67 18401	(5—60 ppm)	—	92115	(5—200 ppm)
Diethyl ether	161	(0.04—1.0%)	67 30501	(100—4000 ppm)	8014-107		(0.04—1.4%) —
Dimethyl aniline	181	(2.5—45 ppm)		—	—		—
Dimethyl sulfate		—		—	—	95300	(5—50 ppm)
Dimethyl acetamide		—	67 28011	(10—40 ppm)	—	91624	(5—80 ppm)
Dimethylamine	3L	(2—30 ppm)	67 18401	(5—60 ppm)	—	92115	(5—200 ppm)
Dimethyl ether	161	(0.03—0.9%)		—	8014-123		(0.01—1.2%) —
Dimethylformamide			67 18501	(10—40 ppm)	—	91624	(5—150 ppm)
1,1-Dimethyl hydrazine		—	CH 31801	(0.25—3 ppm)	—		—
Dioxane	163	(0.5—5.6%)		—	8014-154		(0.01—2.5%) —
Dimethyl sulfate (ester)		—	67 18701	(0.2—5 ppm)	—	95300	(1—50 ppm)
			67 18901	(5—60 ppm)			
Dimethyl sulfoxide		—		—	—	95739	(10—250 ppm)
Di-N-propylamine		—		—	—	92115	(2—70 ppm)
Ethyl acetate	141	(0.04—1.5%)	CH 20201	(200—3000 ppm)	8014-111		(0.01—5.0%) —
2-Ethoxyethanol (Cellosolve)		—		—	—	95097	(50—1000 ppm)
Ethyl alcohol (ethanol)	112	(0.05—5%)	CH 29701	(100—3000 ppm)	8014-104A	95097	(0.04—5.0%) (200—10,000 ppm)
Ethylamine		—	67 18401	(5—60 ppm)	—	92115	(10—500 ppm)
Ethyl benzene	122	(7—700 ppm)	CH 27801	(0.1—7 mg/L) (25—1860 ppm)	—		—
Ethyl bromide		—		—	—	85833	(25—400 ppm)
Ethyl chloride		—		—	—	85833	(100—2000 ppm)
						92030	(100—2000 ppm)
Ethylene (ethene)	172	(50—800 ppm)	CH 26101	(0.5—2%)	—		—
Ethylene	172L	(0.2—50 ppm)	67 28051	(50—2500 ppm)	8014-108B	82802	(0.01—100 ppm) (0.5—100 ppm)
Ethylenediamine	3L	(4—120 ppm)		—	—		—
Ethyl mercaptan	72	(5—120 ppm)	CH 20801	(2—100 ppm)	8014-165	454206	(1—160 ppm) (0.5—100 ppm)
Ethylene dibromide	136	(6—80 ppm)		—	8014-166		(1—100 ppm) —
Ethylene imine		—	CH 31801	(0.25—3 ppm)	—	92115	(2—100 ppm)
Ethylene oxide	163	(0.1—3.0%)	CH 26101	(1.5—5%)	8014-122		(0.01—3.5%) —
n-Ethyl morpholine		—		—	—	92115	(2—100 ppm)
Fluorotrichloromethane (Freon® 11)		—	CH 27401	(5—50 ppm)	—	88536	(250—2000 ppm)
						92030	(250—2000 ppm)
Formaldehyde	91	(2—20 ppm)	CH 26401	(2—40 ppm) (0.002—0.05 mg/L)	8014-171	93963	(1—35 ppm) (1—100 ppm)
Formic acid	81	(1—80 ppm)	67 22701	(1—15 ppm)	—		—
Fumi-1-Gate		—		—	—	91624	(10—200 ppm)
Furan (furfuran)		—		—	8014-161		(0.05—1.6%) —
Furfuryl alcohol		—		—	—	95097	(25—500 ppm)

Gasoline	101	(0.015—1.2%)		—		—		—
n-Heptane	101	(0.015—1.2%)		—		—		—
n-Hexane	102H	(0.015—1.2%)	67 25201	(100—1500 ppm)	8014-113	(0.01—0.6%)		—
	102L	(50—1200 ppm)						
Hydrazine	3L	(0.5—35 ppm)	CH 31801	(0.25—3 ppm)		—		—
Hydrocarbon		—	CH 26101	(0.1—1 vol.%)		—		—
		—	CH 25401	(2—25 mg/L)		—		—
Hydrochloric acid	14L	(0.2—40 ppm)	CH 29501	(1—10 ppm)		—	91636	(2—500 ppm)
				(2—20 ppm)				
Hydrocyanic acid	12H	(0.05—2%)	CH 25701	(2—30 ppm)	8014-112A	(0.01—3.0%)	93262	(1—65 ppm)
	12L	(2.5—60 ppm)		(10—150 ppm)	8014-112B	(1—100 ppm)		
Hydrogen (special tube)		—	CH 30901	(0.5—3 vol.%)		—		—
Hydrogen fluoride	17	(0.5—20 ppm)	CH 30301	(0.5—15 ppm)		—		
Hydrogen selenide		—		—	8014-167	(1—600 ppm)		—
Hydrogen sulfide	4HH	(0.1—4%)	CH 28101	(0.2—7 vol.%)	8014-120H	(0.02—0.3%)		—
	4H	(100—3200 ppm)	CH 29101	(100—2000 ppm)	8014-120A	(0.01—0.17%)		
	4LL	(0.5—60 ppm)	67 19001	(1—20 ppm)	87414	(1—800 ppm)		
	4L	(10—240 ppm)		(10—200 ppm)				
			CH29801	(5—60 ppm)				
				(50—600 ppm)				
Hydrogen sulfide + sulfur dioxide		—	CH 28201	(0.2—7 vol.%)	8014-120C	(0.005—0.16%)		—
				(0.02—0.7 vol.%)				
Insect-O-Fume		—		—		—	91624	(8—70 ppm)
Isobutyl acetate	142	(0.005—66%)		—	8014-153	(0.01—1.4%)		—
Isobutyl alcohol	112	(100—3000 ppm)		—		—		—
Iso-octane	101	(0.015—1.2%)		—		—		—
Isopropyl acetate	151	(0.05—0.75%)		—	8014-149	(0.01—1.2%)		—
Isopropyl alcohol	113	(0.02—5%)	CH 29701	(100—3000 ppm)	8014-150	(0.01—2%)		—
Isopropylamine		—		—		—	92115	(2—100 ppm)
Kerosene		—	CH 25401	(2—35 mg/L)		—		—
LP gas	100A	(0.02—0.8%)		—		—		—
Mercaptan		—	CH 20801	(2—100 ppm)		—		—
Mercury vapor		—	CH 23101	(0.1—2 mg/m³)	8014-142	(0.1—2.0 mg/m³)	83089	(0.05—2.0 mg/m³)
Methyl acetate		—		—	8014-148	(0.01—3.0%)		—
Methacrylonitrile		—	67 30101	(1—10 ppm)		—	91624	(10—80 ppm)
Methyl alcohol (methanol)	111	(0.01—3%)	CH 29701	(100—3000 ppm)	8014-119	(0.01—6.0%)	95097	(100—1000 ppm)
Methyl amine		—	67 18401	(5—60 ppm)		—	92115	(10—500 ppm)
Methyl bromide	136	(10—200 ppm)	CH 27301	(5—50 ppm)	8014-157	(10—500 ppm)	85834	(10—100 ppm)
							88536	(10—100 ppm)
Methyl chloride		—		—		—	92030	(25—1000 ppm)
Methyl chloroform 1,1,1-trichloroethane	135	(100—500 ppm)	CH 24401	(10—500 ppm)	8014-160	(50—800 ppm)	88536	(100—700 ppm)
Methyl chloroformate		—	67 18601	(0.2—100 ppm)		—		—
Methylene chloride		—	67 24601	(100—2000 ppm)		—	88536	(100—1000 ppm)
							85834	(100—2000 ppm)
							92030	(50—2000 ppm)
2-Methyl isobutyl carbinol (methyl amyl alcohol)		—		—		—	95097	(25—1000 ppm)
Methyl diethylamine		—	67 18401	(5—60 ppm)		—		—
Methyl ethyl ketone	152	(0.02—0.6%)	CH 2290	(100—2000 ppm)	8014-139B	(0.01—1.4%)		—
Methyl isobutyl ketone	153	(0.01—0.6%)	CH 22901	(100—12,000 ppm)	8014-155	(0.005—1.0%)		—
Methyl mercaptan	71	(0.5—70 ppm)		—	8014-164	(1—20 ppm)	454206	(0.5—100 ppm)
Monoethylamine	3L	(2—30 ppm)		—		—	92115	(10—500 ppm)
Monomethyl aniline	181	(2.5—45 ppm)		—		—		—
Monostyrene	124	(10—1000 ppm)	67 23301	(10—200 ppm)	8014-158	(1—300 ppm)		—
			CH 27601	(50—400 ppm)		—	93962	(10—900 ppm)
Natural gas (Drager test)		—	CH 20001			—		—
Nickel tetracarbonyl		—	CH 19501	(0.1—1 ppm)	8014-129	(20—700 ppm)		—
Nitric acid	15L	(0.2—40 ppm)		—		—		—

Nitric oxide	10	(NO:2—200 ppm) (NO$_2$:5—200 ppm)	—		—		—	
Nitroethane		—	—		—		91624	(10—300 ppm)
Nitrogen dioxide	9L	(0.2—100 ppm)	CH 30001	(0.5—10 ppm)	8014-117	(1—1000 ppm)	83099	(0.1—50 ppm)
	10	(5—200 ppm)	67 19101	(2—50 ppm) (5—100 ppm)				
Nitrous fumes		—	CH 29401	(0.5—10 ppm)	—		—	
			CH 31001	(2—50 ppm) (5—100 ppm)				
			67 24001	(20—500 ppm)				
			CH 27701	(100-1000 ppm) (500—5000 ppm)				
Nitroglycerine		—	67 18201	(5—100 ppm)	—		—	
Nitroglycol		—	67 18201	(5—100 ppm)	—		—	
Nitromethane		—	—		—		91624	(5—300 ppm)
1-Nitropropane		—	—		—		91624	(2—100 ppm)
2-Nitropropane		—	—		—		91624	(5—150 ppm)
Octane	101	(0.015—1.2%)	—		—		—	
Olefine 0.05		—	CH 31201	(1—50 mg/L)	—		—	
Oxygen		—	CH 31601	(5—21 vol.%)	8014-159	(2—30%)	—	
Ozone	18L	(0.05—3 ppm)	CH 31301	(0.05—1.4 ppm) (0.5—14 ppm)	—		93865	(0.05—5.0 ppm)
		—	CH 21001	(10—300 ppm)	—		—	
n-Pentane		—	67 24701	(100—1500 ppm)	8014-170	(0.01—0.5%)	—	
Perchloroethylene (tetrachloroethylene)	133	(5—200 ppm)	CH 30701	(10—400 ppm)	8014-135	(10—400 ppm)	85833	(10—400 ppm)
							88536	(25—400 ppm)
Phenol		—	CH 31501	(5 ppm)	—		—	
Phosgene		—	CH 19401	(0.05—1.2 ppm)	—		—	
Phosgene (carbonyl chloride)	16	(0.1—90 ppm)	CH 28301	(0.25—15 ppm) (1,2—75 ppm)	8014-146	(0.05—50 ppm)	89890	(0.1—10 ppm)
Phosphine	7	(5—200 ppm)	CH 31101	(0.1—4 ppm) (1—40 ppm)	8014-121B	(5—90 ppm)	—	
			CH 21201	(50—1000 ppm) (15—300 ppm) (150—3000 ppm)	8014-121A 8014-121C 8014-121D	(20—800 ppm) (50—700 ppm) (2—160 ppm)		
Propane		—	CH 26101	(0.1—1.3 vol.%)	—		—	
n-Propyl acetate	151	(0.06—0.9%)	CH 20201	(200—3000 ppm)	8014-151	(0.01—1.4%)	—	
n-Propyl alcohol	112	(0.02—0.8%)	CH 29701	(100—3000 ppm)	—		95097	(10—10,000 ppm)
iso-Propyl alcohol		—	CH 29701	(100—3000 ppm)	—		95097	(100—10,000 ppm)
n-Propyl mercaptan (1-oropanethiol)		—	CH 20801	(2—100 ppm)	—		454206	(0.5—100 ppm)
n-Propyl nitrate	—		—		—		91624	(10—100 ppm)
Propylene	100A	(0.02—0.8%)	CH 31201	(1—50 mg/L)	—		82802	(1—400 ppm)
Propylene dichloride (1,2-dichloropropane)	—		CH 27301	(5—50 ppm)	—		85834	(25—250 ppm)
							92030	(25—500 ppm)
Propylene imine	—		—		—		92115	(2—300 ppm)
Propylene oxide	163	(0.3—3.6%)	—		8014-163	(0.1—4.0%)	—	
Pyridine	—		—		—		91624	(2—50 ppm)
Sulfur dioxide	5L	(5—200 ppm)	CH 24201	(20—200 ppm)	8014-103C	(5—300 ppm)	92623	(1—400 ppm)
	5M	(100—3600 ppm)		(200—2000 ppm)	8014-103A	(0.1—4.0%)		
	5LA	(1—90 ppm)	67 27101	(0.1—3 ppm)	8014-103B	(0.02—0.3%)		
	5H	(0.25—8%)	CH 31701	(1—20 ppm)	8014-103BF	(0.02—0.3%)		
Xystox (tetrahydrotheophene)	—		CH 27501	(0.5 mg/m^3)	—		—	
Termi-Gas	—		—		—		91624	(10—200 ppm)
Termi-Nate	—		—		—		91624	(8—70 ppm)
1,1,2,2-Tetrabromoethane	—		—		—		85834	(2—50 ppm)

1,1,2,2-Tetrachloroethane	—	—	—	85834 (2—50 ppm)
1,1,3,3-Tetrachloropropane	—	—	—	85834 (5—100 ppm)
Tetrahydrofuran	161 (100—2500 ppm)	CH 29701 (30—400 ppm)	8014-162 (0.1—5.0%)	—
Toluene	122 (10—600 ppm)	CH 23001 (5—400ppm) CH 27801 (0.1—7 mg/L) (25—1860 ppm)	8014-124 and 124B (1—1000 ppm)	93074 (10—800 ppm)
Toluylene diisocyanate	—	67 24501 (0.02—0.2 ppm)	—	—
o-Toluidine	181 (2.5—35 ppm)	—	—	—
Trichlorethane	—	CH 21101 (50—350 ppm) (100—700 ppm)	—	85834 (25—700 ppm) 88536 (50—500 ppm)
Trichlorethylene	132L (2—50 ppm) 132H (20—560 ppm)	CH 24401 (10—400 ppm)	8014-134 (10—400 ppm)	85833 (25—600 ppm) 88536 (25—400 ppm)
1,2,3-Trichloropropane	—	—	—	85833 (10—500 ppm)
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon® 113)	—	—	—	88538 (100—2000 ppm) 92030 (100—4000 ppm)
Triethylamine	3M (3.5—140 ppm)	67 18401 (5—60 ppm)	—	92115 (2—100 ppm)
Trifluoromonobromomethane (Freon® 1381)	—	—	—	88536 (100—4000 ppm)
Trimethylamine	3M (2.5—100 ppm)	—	—	92115 (5—250 ppm)
Vinyl acetate	141 (0.01—1.0%)	—	—	—
Vinyl chloride (chloroethylene)	131L (0.5—28 ppm)	CH 19601 (100—3000 ppm)	8014-132 (0.05—1.0%) 8014-132B (1—500 ppm)	85833 (100—1250 ppm) 92030 (100—2000 ppm)
Vinylidene chloride	131L (0.3—17 ppm)	—	—	—
Vinyl pyridine	—	—	—	91624 (1—100 ppm)
Water vapor	6 (0.5—32 mg/L)	CH 23401 (0.1—40 mg/L)	—	—
Xylene	123 (10—500 ppm)	CH 27801 (0.7—7 mg/L)	8014-143 and 143B (50—5000 ppm)	93074 (10—800 ppm)

Courtesy of Bendix Corporation, Environmental and Process Instruments Division, Lewisburg, W. Va. National Drager, Inc., Parkway View Dr., Pittsburgh, Pa.; Matheson, P.O. Box 85, 932 Paterson Plank Rd., E. Rutherford, N.J.; Kitagawa Precision Laboratories 1-8-24, Chu-Cho, Meguro, Tokyo, 152, Japan; Toxic Gas Detectors, Mine Safety Appliances Co. (MSA), 400 Penn Center Building, Pittsburgh, Pa.

Source of Appendix A,B, & C: Linch, A. L., 1981. Evaluation of Ambient Air Quality By Personnel Monitoring. Volume 1. Gases and Vapors. Second Edition. CRC Press, Inc. Boca Raton, FL

APPENDIX D

INSTRUMENT SUPPIERS

DMI SUPPLIERS

Foxboro Analytical
151 Woodward Avenue
South Norwalk, CT 06856
(203) 853-1616

HNU Systems, Inc.
160 Charlemont Street
Newton Highlands, MA 02161
(617) 9646690

COMBUSTIBLE GAS METER SUPPLIERS

Gas Tech, Inc.
8445 Central Avenue
Newark, CA 94560
(415) 794-6200

OXYGEN METER SUPPLIERS

Gas Tech, Inc.
8445 Central Avenue
Newark, CA 94560
(415) 794-6200

SAMPLING PUMPS

SKC West, Inc.
P.O. Box 2805
2021-G West Commonwealth
Fullerton, CA 92633-0805
(714) 992-2780

NO. 5

WATER SAMPLING

300211

WOODWARD-CLYDE CONSULTANTS
HAZARDOUS WASTE MANAGEMENT PRACTICE
TECHNICAL MEMORANDUM NO. 5

WATER SAMPLING

REVISION 1

January 1987

300212

TABLE OF CONTENTS

TECHNICAL MEMORANDUM NO. 5
WATER SAMPLING

Section		Page
5.1	Purpose and Scope	1
5.2	Field Procedures	2
5.2.1	Scope and Purpose	2
5.2.2	Sample Collection	2
5.2.2.1	General Requirements	2
5.2.2.2	Sample Filtration	2
5.2.3	Field Measurements	4
5.3	Surface Water Sampling	5
5.3.1	Purpose	5
5.3.2	Sampling Plan and Quality Assurance	5
5.3.2.1	Standing Water	6
5.3.2.2	Running Water	7
5.3.2.3	Open Water	8
5.3.3	Sampling Equipment	8
5.3.4	Sampling Methods	9
5.4	Groundwater Sampling Procedures	11
5.4.1	Scope	11
5.4.2	Sampling Plan and Quality Assurance	11
5.4.3	Sampling Equipment	12
5.4.4	Sampling Methods	14
5.4.4.1	Field Measurements	14
5.4.4.2	Well Purging and Evacuation Procedures	16
5.4.4.3	Sampling Procedure for Bottom-fill Check Valve Bailer	17
5.4.4.4	Sampling Procedure for Suction Lift Pumps/Centrifugal Pumps	18
5.4.4.5	Sampling Procedure for Portable Submersible Pumps	18
5.4.4.6	Sampling Procedure for Air Lift Pumps	19
5.4.4.7	Sampling Procedure for Bladder Pumps (Gas Squeeze Pumps)	19
5.4.4.8	Sampling Procedure for Gas Displacement Pumps	19
5.4.4.9	Sampling Procedure for Gas Piston Pump	20
5.4.4.10	Sampling Procedure for Packer Pumps	20
5.4.4.11	Sampling Procedure for Bacon Bomb Sampler	20
5.4.4.12	Kemmerer Depth Sampler	20
5.4.4.13	Potable Well Sampling Procedure	21

TABLE OF CONTENTS (continued)
TM 5 - WATER SAMPLING

Section	Page
List of References	22
Figure 5-1 - Checklist for Surface Water Sampling Procedures	23
Figure 5-2 - Checklist for Groundwater Sampling Equipment	24

HAZARDOUS WASTE MANAGEMENT PRACTICE

TECHNICAL MEMORANDUM NO. 5
WATER SAMPLING

5.1 Purpose and Scope

This memorandum outlines procedures and equipment for the collection of water samples including non-aqueous phases. In general, these procedures are different for surface water (section 5.2) and groundwater (section 5.3). Also discussed in section 5.2 are procedures and guidelines for sample collection, filtration, trip and field blank collection, and measuring physical chemical water properties in the field.

Prevention and remediation of water contamination is the primary goal of most hazardous waste investigations. The greater the number of water samples which are collected and analyzed, the more accurately the extent of contamination is known. Because of the considerable cost involved with laboratory analysis, and water pollution mitigation technology, extreme care should be exercised to insure that baseline data is accurate. Laboratory work, no matter how sophisticated, is only as good as the quality of the sample supplied to the analyst. Field procedures are relatively crude when compared to the technology of modern analytical chemistry. There are many aspects of sampling to which special attention should be paid to assure analysis of a sample which is truly representative of its environment.

Some of these aspects are covered in other technical memoranda: sample preservation, packaging, and shipment are discussed in Technical Memorandum No. 2; equipment decontamination is discussed in Technical Memorandum No. 11; and procedures associated with well drilling and construction materials are included in Technical Memorandum No. 3.

Of course correct procedures are only useful when the data collected is integrated into an overall plan for investigation of a site. Since hazardous waste sites vary, no one procedure for creating a site investigation/sampling plan can suffice. General guidelines are included in Technical Memorandum No. 1. Also included in Technical Memorandum No. 1 are general guidelines for preparation of site safety plans.

Included in this technical memorandum are some special health and safety considerations for water sampling and methods, and materials for the most commonly encountered types of water sampling. This memorandum is intended for general use in preparation of a site sampling plan and reference of field sampling personnel. Actual procedures for water sampling should be contained in a site-specific sampling plan which has the approval of the review agency. Specific U.S. EPA (guidance under RCRA and CERCLA and state

specific guidance should be consulted prior to finalizing sampling procedures. Procedures required by the reviewing agency should be followed if they are different from the procedures specified in this memorandum.

5.2 Field Procedures

5.2.1 Scope and Purpose

In addition to equipment and specific sampling techniques involved with surface and groundwater sampling are some general field procedures which should be followed when collecting any water sample.

Some general procedures which should be followed involve sample collection and filtration and procedures for taking field measurements.

5.2.2 Sample Collection

5.2.2.1 General Requirements

All sampling instruments should be cleaned as specified in the site sampling plan. General guidelines for decontamination of equipment are included in Technical Memorandum No. 11.

Sample collection bottles should always be at the site of water sampling. Sample bottle size, preservation techniques, quantity, and other specifics should be clearly explained in the site sampling plan. Sample bottles are discussed in general in Technical Memorandum No. 2.

In general, if field measurements cannot be made in situ, the first quantity of water obtained should be used for field measurements. Field measurements are discussed in detail in section 5.2.3. of this technical memorandum.

The first water sample collected should be that for volatile organic analysis. The vials intended for this analysis should be filled with as little agitation of the water as possible as it passes from the sampling device to the sample bottle. There should be no air bubbles present in a volatile organic sample vial. Other sample bottles can then be filled and preserved as specified in the site sampling plan.

Trip blanks should be supplied by the laboratory along with the sample bottles. Field blanks should be collected as specified in the site sampling plan and are discussed in general in Technical Memorandum No. 2.

5.2.2.2 Sample Filtration

Because suspended particles are not generally transported by groundwater, it is important to filter groundwater samples designated for metals analyses so that an accurate determination of dissolved metal concentrations

may be obtained. If infiltration is required, it should be performed in the field, prior to addition of preservatives, for the portion of the sample to be analyzed for metals. Surface water samples typically are not filtered prior to sample collection for metal analysis.

The procedures outlined below have been formulated based on practical experience and consideration of chain-of-custody and other requirements.

Prior to sample filtration, all equipment used in the procedure should be cleaned according to procedures described in Technical Memorandum No. 11. Samples for filtration are collected in pre-filtration sample bottles included in the set of bottles for each sampling station. A temporary sample label should be affixed to the pre-filtration bottle. Following sample collection the pre-filtration sample containers are placed on ice in a separate cooler and transported to the location where the filtration will be performed.

Many types of filtration apparatus are marketed and several may be satisfactory for use. A filtering apparatus can be assembled with the equipment and procedures described below:

1. Vacuum pump (electric pump or water faucet eductor)
2. Vacuum tubing with stop-cocks, t-connectors
3. Buchner funnels (one per sample)
4. 0.45-micron membrane filters
5. Glass fiber prefilters
6. One-hole rubber stoppers, reamed to facilitate funnel insertion (one per sample)
7. 1000-ml Erlenmyer side-arm filter flasks (one per sample)
8. Acid-preserved sample bottles (one per sample)
9. Filter apparatus box (to support several flasks and tubing network)

A funnel and flask should be set up for each sample collected. Several samples may be filtered simultaneously using a branched vacuum tubing network with appropriate t-connectors and in-line stop-cocks. The side-arm of the flask is connected to the vacuum tubing which in turn is connected to the vacuum pump. A 0.45-micron membrane filter is placed into the Buchner funnel using the glassine paper spacers to pick up and insert the filter. Avoid bending, folding, or touching these membranes. The glass fiber prefilters are then placed over the 0.45-micron filters. The pre-filter serves to remove large solids and greatly reduces filtering time. When all filters are in place, the vacuum pump is started. The stop-cock to the filter flask is opened slowly to seat the membrane. Approximately ¼ to ½ inch of sample water is poured into the funnel and checked to see that the filter membrane is seated properly. If no cracks or air bubbles are observed and the membrane is tight against the funnel strainer, additional sample is added. If the membrane is ruptured or does not seat properly,

the filtering process should be stopped and repeated with a new membrane. Sample water that has passed the ruptured membrane should be refiltered.

When all of the sample has been filtered, the stop-cock is slowly closed and the funnel is removed from the flask. The filtrate from the Erlenmyer flask is poured into the appropriately labeled and preserved sample bottle. The bottle is then placed into the cooler with the other samples and the logbook and chain-of-custody forms are filled out. The used filter should be discarded and the used funnel and flask placed into a plastic bag for storage until they can be cleaned.

As an alternative to this technique, a disposable filtering system may be used. The principles of operation are the same as those described above. To eliminate the need to clean the contaminated equipment, these systems provide an inexpensive, disposable filter cup and strainer with a 0.45-micron filter and a glass fiber pre-filter in place, attached to a disposable filtrate container. This unit attaches directly to the vacuum pump.

5.2.3 Field Measurements

Field measurements are vital to integrating the results of sample analysis with water behavior of a site.

Physical characteristics of water samples should be recorded in field logbooks and include color, general turbidity, ordor, viscosity, and any other impressions. These can also include water elevations in wells or depth of a body of water. The required physical measurements should be specified in the site sampling plan.

Some chemical parameters can be analyzed in the field and provide valuable data in interpreting water characteristics on the site as a whole. Parameters which can be measured fairly quickly and easily include:

- temperature
- conductivity/salinity
- pH
- dissolved oxygen
- alkalinity

These procedures should be done, if at all possible, in every body of water, well, or location sampled.

In the case of wells, measurements such as conductivity and pH can be used to determine that the purging process in completed and uniform water representative of the aquifer is present in the well. Due to the nature of most field measurement devices, it is difficult or impossible to decontaminate them thoroughly and so they should not enter the well directly. Therefore, field measurements should be taken from a point in line of pump purging or a sample should be withdrawn for field measurements.

Taking field measurements from a surface water body should be done in situ if contamination of the surface water will not result (such as a moving stream or large pond). Care should be taken not to contaminate the field measurement equipment with material that cannot be safely rinsed off.

If it is impossible to take field measurements in situ, then a sample of water should be taken in accordance with the site-specific sample plan and tested for field test parameters.

Field measurements obtained in this form are only as reliable as the instruments themselves. Proper and frequent calibration both before and during sampling are essential.

Calibrations should be documented as to: specific device, date, reference standard, adjustments which were made, and any repairs which should be made.

Field personnel should be familiar with calibration procedures for each piece of equipment and proper reference standards to be used. Calibrations should be made as often as practical during sampling but, as a minimum, done before and after sampling with differences noted in the field logbook.

5.3 Surface Water Sampling

5.3.1 Purpose

The purpose of this memorandum is to provide procedures which may be used to obtain representative samples of surface water. A checklist for surface water sampling procedures is presented in Figure 5-1.

5.3.2 Sampling Plan and Quality Assurance

Samples will be collected from locations which are selected based upon knowledge of site conditions and associated parameters. Parameters which should be examined include geologic conditions such as natural drainage systems, identified environmentally sensitive areas such as wetlands or wildlife habitats, and the proximity of the site to human activities likely to bring people in contact with contaminants. These activities include, but are not limited to, drinking water intakes on rivers or springs, swimming areas, and fishing areas. Areas of standing or running water on

site or leaving the site will be sampled near the site as well as at locations some distance from the site.

Sample collection materials and methods are discussed in Sections 5.3.2 and 5.3.3. In general, sampling techniques are simple and involve the use of plastic or glass containers or scoops for collection of the samples. More complicated tools are available which provide the capability of sampling from specific depths or collecting multiple phase contaminants that may be present in water.

If a multiple phase contaminant (for example, immiscible organic liquids) or stratified water layers are suspected, a sampler may be used to obtain composite water samples in the vertical profile. This sampler is generally some type of tube with a stopper at the bottom connected through the tube to a locking handle at the top. The stopper is locked into its open position before the sampler is lowered through the water. As the sampler is slowly lowered into the water the layers of contaminants or other fluids encountered will enter the tube. After the sampler reaches bottom (or the desired depth), the stopper is pulled upward and locked into a seal with the bottom of the tube. The sampler is removed from the water and its contents transferred to a sample bottle or multiple bottles if samples of the stratified layers are desired.

5.3.2.1 Standing Water

Standing Water includes lakes, ponds, lagoons, and inundated areas.

Depending on the concentration of contaminants in waters leaving a waste site and the importance of surface water transport in contaminant migration, bodies of standing water may receive potentially high levels of contaminants. Because circulation in enclosed basins is usually minimal, contaminant plumes or stratification may result. It is important to obtain samples that are representative of the water body, both areally and vertically.

Generally, the deciding factors in the selection of a sampling device are whether the sample will be collected from shore or an impoundment wall or from a boat, and the desired depth at which you wish to collect the sample.

The water bodies to be sampled may range in size from small, shallow, runoff-filled depressions, up to lakes several hundred acres or more in areal extent. Small bodies of water can typically be sampled from their banks. Sampling water from larger bodies requires the formulation of a logical, efficient sampling plan that takes into account the factors described under Section 5.1.2 of this Technical Memorandum. In general, samples are desired at points near the influx of contaminants, near areas of human recreation and water supply intake, or in areas designated as wetlands or wildlife habitats by the U. S. Fish and Wildlife Service (see publication FWS/OBS-79/31, December 1979).

The sampling devices most commonly used are pond samplers, dippers (or scoops) and weighted bottles, operated by hand. Access to sampling points may require the use of a boat.

Observations of the water's physical appearance, depth of the sample, location of the sampling point, and the time of sample collection should be recorded.

5.3.2.2 Running Water

Running Water includes rivers, streams, and drainage ditches. Water in motion has a high capacity to dissipate contaminants, especially volatile organic constituents. The velocity of water flow, volume of flow and distance of the sampling point from the contaminant source greatly influences the characteristics of a sample and should be measured and recorded when possible. Any sample collected from running water is, in effect, only an indicator of conditions present at one point in time and at one particular location.

Generally, the factors that will contribute to the selection of a sampler will include:

a. width and depth of the location being sampled

b. flow of waterway being sampled

c. whether the sample will be collected from the shore or a vessel launched on the waterway.

Natural or man-made drainage ways leaving or running adjacent to a site are prime locations for samples. Larger streams or rivers should also be sampled, particularly where drainages enter into them. Special attention should be given to rivers that supply public drinking water. Samples should be collected both upstream and downstream from the point of potential contaminant discharge.

Access to a sampling point on a river, stream, or ditch may be possible from the bank. If the river is wide, bridges may be used for access to points across the entire channel. A boat may be required to reach some sampling points. Near-surface samples may be collected using a pond sampler or dipper. A weighted bottle can be used to obtain samples at depth. In general, samples should be collected at downstream locations first progressing upstream to minimize interference with ambient water conditions.

If a low flow rate or shallow channel prohibit direct use of a dipper, a stainless steel shovel can be used to dig a small hole into which water can collect. Sufficient time should be allowed for disturbed sediments to settle before the sample is obtained.

When sampling running water, observations about the physical appearance of the water, its depth and rate of flow, the sample point location, and time of sample collection should be recorded.

5.3.2.3 Open Water

Open water is defined, for the purposes of this memorandum, as any body of water that is areally unconfined by land surface on at least one side and, in effect, represents an open hydrologic system which allows unrestricted interchange of water and chemical constituents. Included in this definition are: (1) oceans and their direct extensions (such as bays), (2) marshes, estuaries or other wetlands directly influenced by oceanic effects (for example, tides), and (3) lakes with surface areas and volumes large enough that they act effectively as an open system, such as Lake Superior.

In general, open systems are not as sensitive to degradation by point source contamination as are confined waters. However, local geologic constraints, human use of water, or existence of critical wildlife habitats may cause these waters to be highly sensitive to pollutants (especially near the contaminant source). Therefore, these water bodies may require more extensive sampling efforts and planning. Consideration should be given to the tidal stage and other similar effects in planning the details of a sampling program in open water. Sampling at the wrong tidal stage is a common error which can produce misleading results.

Methods for obtaining samples from open waters are similar to those described for standing water. Dippers and weighted bottles are the most commonly used equipment for sample collection. Boats typically are required to gain access to offshore sampling locations.

5.3.3 Sampling Equipment

The sampling of both aqueous and non-aqueous liquids from the above mentioned sources is generally accomplished through the use of one of the following samplers:

1. Pond sampler
2. Wheaton dip sampler
3. Kemmerer depth sampler
4. Bacon bomb sampler
5. Weighted bottle sampler

Material of construction of the sampler should be compatible with the media to be sampled and parameters to be analyzed.

In addition to the samplers, other equipment necessary for a sampling operation includes:

1. Sample containers, proper size and composition, lab cleaned
2. Field and travel blanks
3. Bound field notebook
4. Sample analysis request forms
5. Chain-of-custody records
6. Seals for legal sample security
7. Sample labels
8. Absorbant pads
9. Appropriate personnel protective clothing and safety equipment
10. Camera and film
11. Plastic bags for handling and transport of contaminated items

5.3.4 Sampling Methods

After choosing the appropriate sampler of the proper composition (i.e. glass, PFTE, PVC) follow the specific sampling protocol outlined below.

a. Pond Sampler

   i. Assemble the Pond Sampler ensuring adequate extension in order to obtain the sample without placing the sampling team in danger of falling in the impoundment being sampled.

   ii. Collect the sample in the beaker of the pond sampler at the desired depth and location.

   iii. Transfer the sample(s) into suitable sample containers.

b. Wheaton Dip Sampler

   i. Assemble the sampler in accordance with the manufacturer's instructions.

ii. Operate the sampler several times to ensure proper adjustment, tightness of the cap, etc.

iii. Collect the sample in the bottle of the sampler at the desired depth and location.

iv. Transfer the sample(s) into suitable sample containers, if the bottle provided with the sampler is not appropriate.

c. Kemmerer Depth Sampler

i. Set the sampling device so that the sealing end pieces are pulled away from the sampling tube, allowing the substance to pass through this tube.

ii. Lower the pre-set sampling device to the predetermined depth.

iii. When the sample is at the required depth, send down the messenger, closing the sampling device.

iv. Retrieve sampler.

v. Transfer the sample to a suitable sample container and cap.

d. Bacon Bomb Sampler

i. Lower the bacon bomb sampler carefully to the desired depth, allowing the line for the trigger to remain slack at all times. When the desired depth is reached, pull the trigger line until taut.

ii. Release the trigger line and retrieve the sampler. Transfer the sample to the sample container by pulling upon the trigger.

e. Weighted Bottle Sampler

i. Assemble the weighted bottle sampler.

ii. Lower the sampling device to the predetermined depth.

iii. When the sampler is at the required depth, pull out the bottle stopper with a sharp jerk of the sampler line and allow the bottle to fill completely (this is usually evidenced by the sensation of air bubbles).

iv. Retrieve sampler.

v. Transfer the sample to a suitable sample container and cap.

5.4 Groundwater Sampling Procedures

5.4.1 Scope

Groundwater can be sampled from public or private wells or monitoring wells installed for that purpose. While groundwater is found in seeps and springs, this section is concerned only with sampling groundwater from wells. Groundwater from seeps and springs should be sampled like surface water as discussed in Section 5.3.

5.4.2 Sampling Plan and Quality Assurance

Groundwater samples are usually collected from a network of wells in an area in order to give an idea of the vertical and horizontal extent of a contaminant plume. This information is used to evaluate the degree of hazard and to design site remedial actions.

Measurements of groundwater table elevation in wells may be used to establish the direction and gradient of groundwater movement.

Collection and analyses of samples from nested monitoring wells installed at various depths may provide an indication of vertical differences in groundwater quality and whether a vertical hydraulic gradient exists at the site.

Consideration should be given to detection and sampling of insoluble fluid phases of contaminants which may be floating on the water surface or may be encountered along the bottom of the water bearing formation.

The collection of samples on a regular, periodic basis may allow detection of time-dependent variations in contaminant concentration and/or contaminant movement.

Data from groundwater analyses are often used to identify the degree of hazard and to design site remedial actions.

Field measurement and sampling equipment that will enter the well should be cleaned prior to its entry, using approved methodologies. Whenever possible, sampling equipment should be laboratory cleaned and wrapped and dedicated to a specific well for the day's sampling. This shall apply to all bailers to be utilized to collected samples whose data will be submitted to the Division. Pumps and equipment not amenable to laboratory cleaning may be field cleaned utilizing approved methodologies.

The material involved in groundwater sampling is equally critical to the collection of high quality monitoring information. Reliance on inexpensive materials (i.e. PVC) may lead to the collection of unreliable data, particularly where the analyses of volatile, pH sensitive, or reduced chemical constituents are of interest. Integral sampling methods which minimize turbulence, atmospheric content, gas exchange, and depressurization are preferable for these applications. Materials which contact water samples during collection are as critical as sample containers. Recommended materials for bailers, pump parts, tubing, samplers and associated apparatus in decreasing order of preference are: Teflon, stainless steel 316, stainless steel 304, polypropylene, polyethylene, linear polyethylene, Vitron, conventional polyethylene, PVC.

Tubing utilized in well evacuation may consist of materials other than Teflon, but may not be utilized for sample collection and should be dedicated for use in only one well.

The need for field and trip blanks, as well as sample filtration, should be specified in the field sampling plan. Details for these procedures are included in section 5.2 of this technical memorandum.

5.4.3 Sampling Equipment

The equipment utilized for specific groundwater sampling episodes can vary greatly dependent on the following factors.

1. type of well, i.e. monitoring supply
2. depth of well
3. diameter of well casing
4. depth of water
5. contaminants likely to be encountered
6. analytes of interest

Equipment to be utilized for groundwater sampling generally falls into two categories; those used to evacuate the well casing and those used to grab a discrete sample for analysis. In some instances, the device utilized for evacuation may be the same utilized for sample withdrawal. In many instances, however, characteristics exhibited by the evacuation device may preclude its use in sample collection.

Types of equipment available for monitoring well evacuation and/or sampling include the following, though all may not be suitable for both.

1. Bottom fill bailers

    a. single check valve (bottom)

    b. double check valve (top and bottom)

    c. Teflon construction

    d. stainless steel construction

    e. stainless steel construction with Teflon check valve(s)

2. Suction lift pumps/centrifugal pumps

3. Portable submersible pumps

4. Air lift pumps

5. Bladder (gas squeeze) pumps

6. Gas displacement pumps

7. Gas piston Pumps

8. Packer Pumps

9. Continuous organics sampling system in conjunction with peristaltic pump

10. Syringe sampler

11. Bacon bomb

12. Kemmerer bottle

In addition to an evacuation and sampling device, other equipment necessary for a sampling episode include:

1. Water level indicator

    a. steel line and chalk

    b. electric tape

    c. air line

    d. electronic piezometer

2. Sample containers, proper size and composition

3. Preservatives, as needed

4. Ice or ice packs

5. Field instrumentation, as needed

6. Field and travel blanks

7. Bound field notebook

8. Sample analysis request forms

9. Chain of custody

10. Chain-of-custody forms

11. Sample labels, indelible

12. Appropriate personal safety equipment

13. Appropriate hand tools

14. Keys to locked wells, if needed

5.4.4 Sampling Methods

5.4.4.1. Field Measurements

Once a well has been located and properly identified, the following field measurements should be noted in the bound field notebook. A cross reference should be made between the field measurements identifying the well and the measurements of the well to be sampled, to ensure the proper well has been selected. The misidentification of a sampling point in the field will result in erroneous data that may affect management decisions.

a. Physical Measurements

i. presence and diameter of protective casing

ii. lock and serial number

iii. diameter and construction material of the well casing proper

iv. total depth of well from the top of casing (TOC), surveyor's mark, if present

v. depth from top of casing (TOC) to water (DOW)

vi. calculate the linear feet of water in the well by subtracting depth to water from total depth of well. The capacity of various well casing diameters are as follows:

Casing Diameter	Gallons/Linear Ft.
2"	.16
4"	.65
6"	1.47
8"	2.61

Now calculate the amount of water present in the well casing by multiplying the linear feet of water by the value above for the proper diameter casing.

Example:

Total depth of casing	100 ft.
Depth to water	- 20 ft.
Linear of water column	80 ft.
2" casing	x.16
Amount of water in casing	12.80 gallons

Alternately, use this formula to determine the gallons in any size pipe:

$$\frac{3.1416 \times r^2 \times h \text{ (in inches)}}{231}$$

b. Physio-Chemical Parameters

In addition to the physical measurements taken above and other information that may identify the well, the following physiochemical information should be recorded initially, during evacuation, and prior to sampling as outlined in section 5.2:

- pH
- temperature
- specific conductance
- dissolved oxygen
- alkalinity

5.4.4.2. Well Purging and Evacuation Procedures

a. Theory

In order to obtain a representative sample of groundwater, the water that has stagnated and/or thermally stratified in the well casing should be purged or evacuated. This evacuation procedure allows fresh or formation groundwater to enter the well. The optimum or preferred method to ensure that fresh water representative of the aquifer in contact with the well screen is being sampled is to perform a controlled sampling experiment. When indicator parameters such as pH, temperature and specific conductance, monitored with an in-line closed measurement cell, are observed to vary less than ±10 percent, the well is presumed to be adequately flushed for a representative sample. Evacuation of three to six well volumes is recommended, however, in wells with very low recoveries this amount may not be practical. In these instances, the well may be evacuated to near dryness and allowed to recover prior to sampling. Evacuation rates should be kept well below 10 gallons/minute and in most cases should be below 5 gallons/minute.

All newly constructed monitoring wells should be allowed to stabilize for a minimum of two weeks prior to sampling. Additionally, once a monitoring well is evacuated it should be sampled within two hours. If an evacuated well is allowed to sit longer than the prescribed two hours, it should be re-evacuated as the water contained in the well casing may no longer be representative of aquifer conditions.

b. Evacuation Methods

Evacuation of the well can be accomplished in several ways. In any instance, it is paramount to ensure that the evacuation procedure does not cause cross contamination from one well to the next. Therefore, the preferred method employs dedicated tubing and pumps. Since in many cases it may not be practical to dedicate a pump to a specific well, it is permissible to decontaminate this equipment, utilizing approved methods. Tubing should always be dedicated and never used for more than one well. The selection of an evacuation method most often relies on the depth to water (DOW) in the well. If the static DOW is less than 25 feet, a submersible pump should be utilized. As earlier mentioned, care should be utilized to ensure this does not act as a route of cross contamination. The pump should be

washed, rinsed, and a sample of the rinse water should be collected as a field blank to ensure the integrity of the sample. Hand-bailing may be utilized with a static level greater than 25 feet if no submersible pump is available, but this is not the recommended method due to a variety of reasons including the potential to introduce contaminants and aeration of the well water.

During evacuation, pump intake should not be set greater than 6 feet below the dynamic water level. This requires that the evacuation device may have to be lowered as purging continues.

5.4.4.3. Sampling Procedure for Bottom-fill Check Valve Bailer

After evacuation of the required volume of water from the well, sampling can begin. Sampling of the monitor well should occur as soon as possible after evacuation, preferably immediately. In most cases, the time lapse between evacuation and sampling should not exceed two hours.

The bailer should be laboratory cleaned and wrapped using approved methodologies, preferably by the laboratory performing the analysis. The field blank should be collected through the bailer prior to sample collection. Hand bailers come in a variety of sizes and volumes to accommodate most well casing diameters. The preferable materials of construction are, in order of decreasing preference, Teflon, stainless steel, polypropylene, polyethylene, Vitron, PVC (low plasticer content). Hand bailers should be slowly lowered into the well, using caution not to aerate the well water to be sampled.

The bailer may be lowered by hand using either a stainless steel cable or a new length of Teflon-coated cord. Cords made of other non-porous material such as polypropylene should be compatible with the material being sampled and dedicated to only one well. Lower the bailer opposite the well screen and pull up the cord to set the check valve. Retrieve the bailer and slowly transfer the sample to the appropriate sample containers, filling purgeable organic vials first.

The bailer and any other equipment entering the well should be laboratory cleaned, if possible, and handled with new surgical gloves to preclude any potential contamination sources. Nothing entering the well should be allowed to contact the ground or any other potentially contaminated surfaces, (i.e. gasoline pumps). If this should occur, that item should not be placed in the well or utilized for sampling. It is always a good practice to have an extra clean bailer on hand in the case of emergency.

5.4.4.4. Sampling Procedure for Suction Lift Pumps/Centrifugal Pumps

Suction lift pumps (i.e. diaphram, peristaltic and centrifugal) are pumps utilized at the ground surface with polyethylene tubing inserted into the well. They are used to evacuate the well, prior to sampling. The tubing should be new and dedicated to a particular monitoring well, and equipped with a foot valve to avoid having aerated water from the pump fall back into the well. The pump casing should be rinsed with tap then distilled water between sampling points.

The limitation posed by this type of pump is its suction capability. Generally, the groundwater level should be within 25 feet of the ground surface.

Due to the nature of these pumps, as well as their effect upon samples for chemical analysis, these devices should only be utilized for monitoring well evacuation and not groundwater sampling.

5.4.4.5. Sampling Procedure for Portable Submersible Pumps

When the groundwater level is greater than 25 feet, the use of suction lift pumps is prohibited and another evacuation device should be used. If the diameter of the well casing will allow, a portable submersible pump generally will be utilized.

The pump is carefully lowered into the well, trailing a discharge hose, electrical cables, and a stainless steel security cable. This security cable should be bearing most of the weight of the pump. These items can be bundled together at 10-foot intervals with plastic electrician's ties. Duct or electrical tape should not be used at a level that will be submerged into the water column.

The pump is then turned on and the proper evacuation volume allowed to discharge. If a portable gasoline generator is used, it should be placed some distance away from the well where the fumes will not affect sample quality. The generator should never be allowed to run while the sample is being collected.

Advantages of these pumps are their generally high flow rates, though they require a source of power, (i.e. portable generator).

As with suction lift pumps, they should be equipped with a foot valve and fitted with dedicated tubing.

Decontamination of these pumps is accomplished by first wiping them down with potable water (steam cleaning, high pressure rinse, and hand wipe are all acceptable), placing in a plastic trash can, and pumping a minimum of 20 gallons of clean tap water through the unit. Care should be taken to

observe safety precautions if the pump is hooked up to a power source (i.e. 120 V, 220 V).

Due to the nature of these pumps, as well as their effect upon samples for chemical analysis, these devices should only be utilized for monitoring well evacuation and not groundwater sampling.

5.4.4.6. Sampling Procedure for Air Lift Pumps

Air lift pumps bubble a gas at depth in the well. The water is transported upward as a result of the reduced specific gravity of the water being lifted to the surface. Water is forced up a discharge pipe or tube, which may be the outer casing or a small diameter pipe inserted into the well. The source of compressed gas may be a hand pump for depths less than 7 meters. For greater depths, air compressors or pressurizing air bottles can be used.

Considering the source of compressed gas and the aeration that occurs in the groundwater as a result of this gas, this mechanism is not acceptable for use in obtaining samples for chemical analysis. It may be used for well development only.

5.4.4.7. Sampling Procedure for Bladder Pumps (Gas Squeeze Pumps)

A bladder pump consists of a stainless steel housing that encloses a flexible membrane. Below the bladder, a screen is attached to filter any material that may clog the check valves that are located above and below the bladder. The pump works as follows: water enters the membrane through the lower check valve; compressed gas is injected into the cavity between the housing and bladder. The water moves through the upper check valve and into the discharge line. This upper check valve prevents back flow into the bladder.

The bladder pump is utilized much like the portable submersible pump, except that no electrical lines are lowered down the well. The source of gas for the bladder is either bottled gas or an on-site air compressor.

Disadvantages include the large gas volumes needed, especially at depth, potential bladder rupture, and difficulty in cleaning the unit.

The pumps cannot be used to collect samples for volatile organic analysis due to the pressure gradients to which the sample is exposed.

5.4.4.8. Sampling Procedure for Gas Displacement Pumps

Gas displacement pumps force a column of water to the surface without extensive mixing of the pressurizing gas and water. The pump is either lowered into the well or installed with the casing.

Gas displacement pumps are a reliable means for obtaining a highly representative groundwater sample. They are easy to disassemble and clean. Correct chamber pressurization minimizes the gas water interface, the degree of mixing, and sample degassing during transport.

The pumps cannot be used to collect samples for volatile organic analysis due to the pressure gradients to which the sample is exposed.

5.4.4.9. Sampling Procedure for Gas Piston Pump

The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. A stainless steel chamber is between two pistons. The alternating chamber pressurization activates the piston which allows water entry during the suction stroke and forces the water to the surface during the pressure stroke.

The pumps cannot be used to collect samples for volatile organic analysis due to the pressure gradients to which the sample is exposed.

5.4.4.10. Sampling Procedure for Packer Pumps

Packer pumps consist of two expandable parts that isolate a sampling unit between them. They deflate for vertical movement within the well and inflate when the desired depth is reached. The packers are constructed of rubber and can be used with submersible, gas lift, and suction pumps. This rubber may deteriorate with time and undesirable organics may enter the water.

5.4.4.11. Sampling Procedure for Bacon Bomb Sampler

The bacon bomb is constructed of stainless steel and is available in two sizes, 1.5 inches in diameter and 3.5 inches in diameter. The bacon bomb is useful in collecting samples at various vertical locations in the well casing water column. The major disadvantage of the bacon bomb sampler is that the sample becomes aerated during retrieval and transfer.

The bacon bomb is carefully lowered into the well to the required depth, allowing the line for the trigger to remain slack at all times. When at the required depth, pull trigger line until taut. Release the trigger line, retrieve the sampler, and fill the appropriate containers. Transfer the sample to the sample containers by pulling up on the trigger.

5.4.4.12. Kemmerer Depth Sampler

If sampling two intervals in the same well, the first interval to be sampled should be the interval nearest to ground surface. Prior to sampling, inspection of sampler should occur to ensure that it is constructed of approved materials.

Set the sampling device so that the sealing end pieces are pulled away from the sampling tube, allowing the substance to pass through this tube. Lower the pre-set sampling device to the predetermined depth. When the sample is at the required depth, send down the messenger, closing the sampling device. Retrieve sampler. Transfer the sample to a suitable sample container and cap.

5.4.4.13. Potable Well Sampling Procedure

The first step in sampling a potable well, whether it be a homeowner's well or a municipal production well is to obtain as much information as possible from the homeowner or water superintendent. This should include: depth of the well, formation in which it is completed, screen depth and length, diameter of casing, and when and who installed it. Caution should be utilized in applying this information unless confirmation can be obtained (i.e. drilling logs). With this information, determine the number of gallons to be evacuated. If no information is available evacuate for a minimum of 15 minutes. This evacuation is best accomplished from an outside faucet with a hose run away from the home. In this manner, overloading of the homeowner's septic system will be minimized. An inspection of the system should be performed to locate the well, pump, storage tanks, and any treatment systems that may be present. The sample access point should be chosen as close to the well head as possible, prior to the storage tank or any treatment. Collect the sample at the first tap or spigot and note in the field log where the sample was collected, and any systems (storage and/or treatment) between the well head and sample collection point. For long-term monitoring projects, a specific tap or faucet could be designed as the sample access point and utilized for the duration of the project.

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FIGURE 5-1

CHECKLIST FOR SURFACE WATER SAMPLING PROCEDURES

____ 1. Select locations for sampling (Section 5.3.2)

_____ general areal coverage

_____ vertical profile

_____ environmentally sensitive areas

_____ proximity to human activities

____ 2. Determine analyses to be performed

____ 3. Obtain sample bottles with correct preservatives and shipping containers (refer to Technical Memorandum 2)

____ 4. Obtain labels, chain of custody forms and other documentation (refer to Technical Memoranda 2 and 10)

____ 5. Select appropriate sampling equipment (Section 5.3.2 and 5.3.3)

_____ pond sampler (or dipper)

_____ Coliwasa

_____ weighted bottle

____ 6. Clean sampling equipment (refer to Technical Memorandum 11)

____ 7. Package sampling equipment (refer to Technical Memorandum 11)

____ 8. Package sample bottle sets (refer to Technical Memorandum 2)

____ 9. Collect samples (Sections 5.3.4)

____ 10. Conduct field tests (Sections 5.2.3)

____ 11. Label and package sample containers for shipment (refer to Technical Memoranda 2 and 10)

____ 12. Transport samples to shipper (refer to Technical Memoranda 2)

____ 13. Sign and date chain of custody form, reseal container, and relinquish to shipper (refer to Technical Memorandum 2)

FIGURE 5-2

CHECKLIST FOR GROUNDWATER SAMPLING PROCEDURES

____ 1. Select locations for sampling

_____ monitoring wells, installed

_____ existing wells, on site

_____ existing wells, off site

____ 2. Determine analyses to be performed

____ 3. Obtain sample bottles with correct preservatives and shipping containers (refer to Technical Memoranda 2 and 10)

____ 4. Obtain labels, chain of custody forms, and other documentation (refer to Technical Memorandum 2)

____ 5. Select appropriate flushing and sampling equipment (Section 5.4)

_____ bailer

_____ suction lift pump

_____ submersible pump

_____ air-lift sampler

____ 6. Clean sampling equipment (refer to Technical Memorandum 11)

____ 7. Package sampling equipment (refer to Technical Memorandum 11)

____ 8. Package sample bottle sets (refer to Technical Memorandum 2)

____ 9. Measure groundwater elevation (Section 5.4.2)

____ 10. Flush well prior to sampling (Section 5.4.4.2)

____ 11. Measure groundwater elevation (Section 5.4.2)

____ 12. Collect sample (Section 5.2.2 and 5.4.4)

____ 13. Conduct field tests (i.e., pH, conductivity, temperature, etc.) (Section 5.2.3)

____ 14. Filter metals sample from groundwater (Section 5.2.2.2)

____ 15. Label and package sample containers for shipment (refer to Technical Memoranda 2 and 10)

____ 16. Transport samples to shipper (refer to Technical Memoranda 2)

____ 17. Sign and date chain of custody form, reseal container and relinquish to shipper (refer to Technical Memorandum 2)

NO. 6

SOIL, SEDIMENT AND ROCK SAMPLING

300240

WOODWARD-CLYDE CONSULTANTS
HAZARDOUS WASTE MANAGEMENT PRACTICE
TECHNICAL MEMORANDUM NO. 6

SOIL, SEDIMENT AND ROCK SAMPLING

REVISION 1

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TABLE OF CONTENTS

TECHNICAL MEMORANDUM NO. 6
SOIL, SEDIMENT AND ROCK SAMPLING

Section		Page
6.1	Surface Soil and Sediment Sampling Procedures	1
6.1.1	Purpose	1
6.1.2	Sampling Methods and Equipment	1
6.2	Subsurface Soil and Sediment Sampling Procedures	2
6.2.1	Purpose	2
6.2.2	Manual Sampling Methods	2
6.2.3	Borehole Sampling Methods	3
6.2.3.1	Sampling Auger Cuttings	4
6.2.3.2	Sampling with Split-Barrel (Thick-Wall) Samplers	4
6.2.3.3	Sampling with Shelby Tubes	4
6.2.3.4	Other Samplers	5
6.3	Subsurface Rock Sampling	6
6.3.1	Purpose	6
6.3.2	Rock Coring Methods and Equipment	6
List of References		9

HAZARDOUS WASTE MANAGEMENT PRACTICE

TECHNICAL MEMORANDUM NO. 6
SOIL, SEDIMENT AND ROCK SAMPLING

6.1 Surface Soil and Sediment Sampling Procedures

6.1.1 Purpose

The purpose of this section is to provide procedures which may be used to obtain representative samples of surface soil and sediments. These procedures are intended for use in collecting environmental samples; however, care should be used in sampling because high concentrations of contaminants may be encountered. The following are general considerations for sampling surficial materials.

Samples of surficial materials are collected for analysis in order to provide data regarding the extent of contaminant migration as a result of: (1) transport of contaminated sediments off site and/or (2) the adsorption or reactivity (e.g., cation exchange capacity) of contaminants with surficial materials, and/or (3) the general chemical or physical nature of the surface sediments. Analysis of surface soil and sediment samples may serve to confirm or compliment data obtained from analysis of surface waters.

6.1.2 Sampling Methods and Equipment

Collection of surficial samples may require no special sampling equipment or highly detailed procedures. Samples may be obtained on or in the vicinity of a hazardous waste site and should be representative of the nature of local surface soils or sediment.

Soil and sediment samples naturally compliment surface water samples; under most circumstances surface waters will directly influence contamination of surface soils. Therefore, it is recommended that surface soil or sediment samples be collected at or near the locations of surface water samples. If such a relationship cannot be made (for example, if the presence of water is intermittant), samples of surficial materials should be collected in drainage ways leaving a site, in areas where overtopping of a dike or flooding is likely to occur, or in areas of obviously contaminated soils. Samples of surficial materials should be collected from the ground surface to a depth of approximately 6 inches.

Determination of the number of samples to be collected will be made in the site sampling plan. Exact locations for sampling should not be dictated because site conditions at the time of sampling may limit access or reveal previously unidentified areas where sampling would be beneficial. Rather, general areas for sampling or particular site conditions which warrant a sampling should be identified and the selection of the sampling point left to the judgment of field personnel.

Samples may be collected using a short, hand-pushed core tube or a stainless steel or polyethylene scoop or shovel. Disposable equipment is preferred, especially if the materials are heavily contaminated with oils, tars, or similar substances. Reused sampling equipment must be decontaminated between uses as described in Technical Memorandum No. 11.

6.2 Subsurface Soil and Sediment Sampling Procedures

6.2.1 Purpose

The purpose of this section is to provide procedures which may be employed in a subsurface sampling program to obtain samples of materials that are: (1) representative of subsurface conditions at the site, (2) appropriate to the types of analyses to be performed, and (3) cost effective toward meeting the goals of the project. The following general considerations should be used in selecting sampling procedures.

Sampling may consist of either a general survey or detailed exploration and may often encompass both. A general survey is designed to obtain preliminary information about subsurface conditions such as depth to rock and soil classification. Equipment often consists of hand-operated augers, probes, and samplers designed to provide quick identification of conditions through retrieval of small volume, disturbed samples. If undisturbed samples are required for analysis of soil properties, more elaborate equipment and stricter quality control procedures may be necessary. These samples may be submitted for physical analyses, such as permeability or chemical analyses, to identify contaminants in the soils.

Methods and equipment commonly used for soil sampling in geotechnical investigations are also used for hazardous waste site investigations. As was the case with procedures discussed in Technical Memorandum No. 3, determining the applicability of various soil sampling tools to particular subsurface conditions is a standard practice. Therefore, this memorandum does not present detailed explanations of sampling equipment design and operation. Rather, commonly used methods are discussed in terms of particular limitations or factors which may affect the uses of the methods for sampling potentially contaminated soil. Safety and quality assurance concerns are of prime importance and are addressed in separate documents.

6.2.2 Manual Sampling Methods

In general, hand sampling using manually operated equipment is most valuable as a general survey technique for shallow depths when precise data or high quality control is generally not required. The most common hand-operated samplers are augers, Porter, plug, tube, split-barrel or fixed piston samplers pushed or driven by hand. Hand augers are easily used at depths less than about 10 feet. Pushed samplers can be used to obtain samples within about 3 feet of the surface or, with appropriate extensions, ahead of an augered hole.

The advantages of these methods are low equipment costs, portability of equipment and relatively rapid acquisition of samples. Augers, tubes and split-barrel samplers can be easily decontaminated. Fixed-piston samplers generally require longer time to disassemble, clean and reassemble. Correlation of samples to depth can be very good when samples are retrieved at small intervals.

Disadvantages of the methods are evident in that relatively small volume, typically disturbed samples are obtained, samples may not be suitable for some laboratory testing procedures, and samples are retrievable only from relatively shallow depths. Care must be taken to prevent (to the extent possible) soil from upper portions of the hole from mixing with lower samples. This is most likely to be a problem when augers are used to advance a hole or obtain cuttings samples.

Because of the unpredictable disposal methods which have been used at many uncontrolled waste sites, sampling devices must never be forced into an abruptly hard material. The stiffness may be a natural lithology change, a rock ledge or cobble, or a buried drum. If resistance is encountered while augering or pushing a sampler, the procedure must be stopped. The log book entry will indicate the depth at which resistance was met (in addition to required log book information described in Technical Memorandum No. 10).

6.2.3 Borehole Sampling Methods

There are a large number of sampling methods and equipment which have been designed for obtaining soil samples at depth from boreholes advanced by drilling rigs (see Technical Memorandum No. 3 for discussions of drilling methods). Geologists and geotechnical engineers should be familiar with the method most suitable for a particular investigation. Several general types of sampling methods are commonly used; these techniques are discussed below in terms of sample quality, safety, and decontamination. Limitations (or advantages) indicated for the methods described in this section may be applicable to other methods of similar design and operation.

Logging of boreholes in soil (i.e. unlithified sediment overlying bedrock) is standard operating procedure. The same general borehole identification information is necessary for both soil and rock borings (refer to section 6.3.2 of this Technical Memorandum). However, certain additional information specific to soils (and perhaps artificial fill material or foundation material) may be required also. Commonly, a boring log form for soils is used that is distinguished from other log forms for bedrock. The reason is that the methods of soil boring advancement many be related to samplers which are driven into the soil material, and the penetration resistance is recorded on specially designed forms. Where possible, detailed geologic and engineering descriptions of overburden (soil and fill) should be logged using correct nomenclatures such as the Unified Soil Classification (ASCE, 1947; ASTM D-2487) on log forms approved by the Project Manager.

6.2.3.1 Sampling Auger Cuttings

Auger cuttings are commonly collected for chemical analyses (refer to Technical Memorandum No. 2 for discussion of sample containers). A stainless steel or plastic scoop can be used to obtain a sample from the cuttings pile. The shovel used by drilling personnel to move cuttings should be stainless steel.

Gloves and goggles will be the minimum protection during collection of samples. Under no circumstances will cuttings be handled without gloves, smelled or tasted to determine any physical property. After samples have been collected, they will be stored and shipped as specified in Technical Memorandum No. 2 and the site sampling plan.

6.2.3.2 Sampling with Split-Barrel and Liner-tube Samplers

Samples obtained using split-barrel samplers are typically logged for soil type and submitted for chemical analyses. Liner tubes may be incorporated in certain samplers to contain samples temporarily. The liner tubes may be constructed from brass, plastic or other inert materials which may be used to store and transport the samples. If a sample is to be stored in the liner tube, the tube ends should first be covered with Teflon film followed by a plastic slip cap. On each sample end, the Teflon film should be trimmed and the cap sealed with vinyl tape to the liner tube. If the sample is not to be stored in the liner, it can be transferred from the sampler to the appropriate sample container using either the liner tube or a stainless steel or plastic spoon (refer to Technical Memorandum No. 2).

Gloves and goggles are the minimum protection required during opening of the sampler and sample examination and transfer. Under no circumstances will a sample be handled without gloves, smelled or tasted to determine physical properties.

The sampler must be decontaminated between uses if chemical analyses are to be performed on samples or the borehole will be converted to a monitoring well. Refer to Technical Memorandum No. 11 for decontamination procedures.

Samples will be placed in appropriate containers, stored and shipped as specified in Technical Memorandum No. 2 and the site sampling plan.

6.2.3.3 Sampling with Shelby Tubes

Brass and stainless steel Shelby tubes are preferable undisturbed thin-wall samplers for hazardous waste investigations because they are inert. Plastic Shelby tubes are available and may be appropriate for sampling and storage of some materials. Steel Shelby tubes, however, are commonly coated inside and out with lacquer or zinc chromate to prevent corrosion.

Chemical constituents of these protective coatings are likely to be transferred to the sample to some degree and can adversely affect subsequent analyses. If chemical analyses are to be performed, the soil must be extruded from steel tubes immediately after sampling. Samples for chemical analysis must not be stored and shipped in the steel Shelby tubes. After the sample has been extruded, the outer surface of the sample must be scraped off (using a stainless steel knife) to a depth of about 1/2 to 1 inch. This procedure will eliminate the possibility of contamination of the analyzed sample from Shelby tube coatings and drilling muds. The area where Shelby tubes are extruded and equipment used must be kept clean and decontaminated. Aluminum foil or plastic may be used as a disposable cover for surfaces upon which samples will be laid.

Certified testing laboratories prefer to receive samples for chemical analysis that have already been extruded because they are commonly unequipped to do the extrusion themselves. Sample extrusion should be performed under conditions that will minimize loss of volatiles caused by aeration or other possible chemical disturbance to the sample prior to storage, shipment, and analysis.

To attain the greatest level of security against cross contamination, Shelby tubes should not be reused. If reuse is necessary, the Shelby tube must be thoroughly decontaminated if the subsequently sampled material is to be chemically analyzed. Less rigorous cleaning is required if physical test samples are to be collected. Procedures for decontamination are described in Technical Memorandum No. 11.

Samples destined for chemical analyses will be transferred to appropriate sample containers, stored and shipped as specified in Technical Memorandum No. 2 and the site sampling plan.

Shelby tubes are often used to collect relatively undisturbed samples for physical testing. The site sampling plan and/or site safety plan will indicate how such samples will be shipped. It may be feasible to store and ship samples for physical testing in the Shelby tube.

If this technique is used, the sampler must be sealed using standard procedures for geotechnical investigations. Generally plastic caps and tape are sufficient. The exterior of the Shelby tube must be decontaminated (see Technical Memorandum No. 11 for procedures). The tube can be placed into a plastic bag to further guard against accidental escape of contaminated soil. Tubes are stored and shipped according to procedures described in Technical Memorandum No. 2 and the site sampling plan.

6.2.3.4 Other Samplers

Many other types of soil samplers are in common use. Among these are the fixed-piston tube sampler, Denison Sampler, Pitcher Sampler, liner-tube

samplers and others which have been designed to meet specific requirements of particular geotechnical investigations. Further information on many samplers and sampling methods may be found in the references listed at the end of this memorandum. These pieces of equipment are typically of complex design and the need for decontamination on hazardous waste site investigations will probably prohibit their use for obtaining samples for chemical analysis primarily due to time constraints as well as difficulty in cleaning various components.

If used for hazardous waste site investigations, the same safety and quality assurance procedures must be applied as described for the other sampling methods. The site sampling plan and site safety plan will address these factors.

6.3 Subsurface Rock Sampling

6.3.1 Purpose

The purpose of this section is to discuss procedures which may be used to obtain samples of rock from a borehole. Details of drilling procedures commonly used in geotechnical and geologic investigations are not included. (Refer to Acker, 1974.) General considerations for subsurface rock sampling follow.

The reasons for embarking on a program of sampling of bedrock formations are generally the same as for other subsurface sampling--to obtain representative samples that are appropriate for delineation of the local subsurface stratigraphic succession as well as for desired testing in a manner that satisfies the goals of the project.

Rock sampling is ordinarily part of a detailed subsurface investigation. Prior to field work, a careful, thorough literature survey of regional and local geology should be performed. Expecting ahead of time the conditions that may be encountered allows efficient planning and may save costly down time or damage to equipment that is used in conditions for which it was not designed.

6.3.2 Rock Coring Methods and Equipment

Although rock samples are not generally analyzed for chemical contaminants, quality assurance procedures are still important because rock coring is often performed in aquifer zones. Monitoring wells, however, are commonly installed in cored holes. Therefore, adequate decontamination of equipment is required. Contamination of the aquifer or water bearing unit either vertically or between boreholes is undesired.

Boreholes in rock are most commonly drilled utilizing a rotary hydraulic or compressed air, percussion rig (or combination). Rigs can be truck-mounted, skid-type, etc. depending on accessibility of a borehole location.

Core barrels for rock sampling are available in a variety of designs and sizes. In general, subsurface conditions dictate selection of the particular method and such determinations are routinely made by geologists and geotechnical engineers. Additional information about various methods can be found in Acker (1974) and Woodward-Clyde Consultants (undated).

Decontamination of core barrels may not be as time consuming as for some soil samplers because core barrel design may not be as complicated. Procedures for decontamination are discussed in Technical Memorandum No. 11 and should be detailed in the site sampling plan.

Logging of rock borings is standard operating procedure, whether rock cores or drill cuttings are retrieved. Besides documentation of samples, the log should also contain a record of standard drilling information.

A typical borehole log should be performed in the field and contain the following information (Krynine and Judd, 1957, and Attewell and Farmer, 1976):

- Borehole identification;
- Borehole location information (coordinates, elevation, site name, boundaries);
- Borehole orientation and inclination;
- Name/affiliation of driller and inspector;
- Owner/client name and/or project number;
- Method of drilling and sampling and details of equipment;
- Record of drilling progress (location of drilling runs, samples, in situ tests);
- Use, extent, and diameter of casing;
- Detailed information on drilling rate vs depth;
- Detailed description of groundwater level, changes in standing water level, loss of drilling fluids (rotary hydraulic), or gain of water (percussion);
- Detailed geologic/engineering description of materials vs depth;
- Inspector's signature, dates of drilling and completion; and
- Method and description of borehole closure.

A separate as-built log should be prepared if a monitoring well or piezometer is constructed in the borehole. Details may or may not be included on the borehole log as desired.

For hazardous waste site investigations, field and laboratory characterization of the bedrock on borehole logs should include the types of information that permit evaluation of hydrologic flow and geochemical conditions at depth. Adequate characterization should include:

- Rock/soil description (degree of weathering, micro-structure or fabric, grain size, color, alteration, primary features;
- Correct nomenclature/classification;
- Logs of core recovery, RQD, fracture frequency, fracture spacing, width and orientation; and
- Fracture filling material (mineralization, breccia, gouge, sediment infillings).

Details of fracture characterization in drill cores can be found in Attewell and Farmer (1976) and the International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests (ISRM, 1978). Deere, et al. (1977) composed guidelines for geologic logging and sampling rock cores for engineering purposes.

There are numerous rock boring log forms available. Each Woodward-Clyde office has one available for use. Commonly, special forms are prepared to suit the needs and goals of a particular project or site. Such forms must be approved by the Project Manager.

LIST OF REFERENCES

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