EGG-WM-9707
Revision 0
December 1991

Idaho
National
Engineering
Laboratory

Managed
by the U.S.
Department
of Energy

RADIOACTIVE WASTE MANAGEMENT COMPLEX INVESTIGATIONS REPORT

(VOLUME I OF IV)

M. L. Paarmann
K. L. Ruebelmann
P. B. Swain, SAIC

EG&G Idaho

Work performed under
DOE Contract
No. DE-AC07-76ID01570

EGG-WM-9707
Revision 0

RADIOACTIVE WASTE MANAGEMENT COMPLEX INVESTIGATIONS REPORT

M. L. Paarmann
K. L. Ruebelmann
P. B. Swain, SAIC

Published December 1991

Idaho National Engineering Laboratory
EG&G Idaho, Inc.
Idaho Falls, Idaho 83415

Prepared for the
U. S. Department Of Energy
Office of Environmental Restoration and Waste Management
Under DOE Idaho Field Office
Contract No. DE-AC07-76ID01570

ACKNOWLEDGMENTS

This study was sponsored and funded by the U. S. Department of Energy under Contract No. DE-AC07-76ID01570. The authors wish to thank all of those who contributed in the preparation of this document: Jack Barraclough, Christine Hiaring, Joel Hubbell, Carroll Knutson, Pat Laney, Kelli McCormick, Deborah McElroy, Shirley Rawson, and Jim Tkachyk for providing insightful technical reviews of the report; LeRoy Knobel (USGS) for providing historical information on the ground water monitoring program at the RWMC; and Lee Freiburger for assisting in the preparation of maps showing the location of wells and boreholes in the vicinity of the RWMC. Special thanks to Sally Francis for editing the report and Dale Claflin for assistance with references and document clarity.

RADIOACTIVE WASTE MANAGEMENT COMPLEX

INVESTIGATIONS REPORT

EGG-WM-9707

December 1991

Reviewed by:

7/19/91

J. P. Shea — Date

ERP Independent Review Committee

Dale J. Claflin — 7/24/91

D. J.Claflin — Date

Patent Clearance

Approved by:

W. H. Sull — 11/13/91

W. H. Sullivan, Manager — Date

WAG-7

Abstract

ABSTRACT

This report summarizes key investigations pertinent to site characterization of the Subsurface Disposal Area at the Idaho National Engineering Laboratory Radioactive Waste Management Complex (RWMC). These investigations include those conducted as a result of the Consent Order and Compliance Agreement (COCA) entered into in 1986 between the United States Environmental Protection Agency (Region 10) and the United States Department of Energy, Idaho Operations Office, one-time investigations that provided relevant subsurface data on the vadose zone, and routine environmental monitoring of selected media for radionuclides. Data from the investigations are presented rather than interpreting the investigation results. A historical review of key reports that provide insight into site characteristics and into the potential for migration of waste radionuclide constituents is provided. Data from the COCA investigations conducted at the RWMC include the results from the Subsurface Investigation Program, a geophysical investigation, a hydrogeologic assessment, a source characterization study, the Pad A initial penetration investigation, an evaluation of the vapor vacuum extraction technology, and an assessment of the transport potential of nonaqueous liquid phase organics. Data collected from several one-time investigations for hazardous constituents in environmental media, including surface water, air, and soil, are summarized. Data collected for the environmental monitoring program are presented for ground water, surface water, air, and biota at the RWMC. The monitoring networks, sampling procedures, and quality assurance/quality control procedures are discussed.

Contents

CONTENTS

APPENDICES

APPENDIX 13-4. PHASE 1 SAMPLE ANALYSIS REPORT

APPENDIX 13-5. PHASE 2 SAMPLE ANALYSIS REPORT

APPENDIX 13-6. PHASE 3 SAMPLE ANALYSIS REPORT

APPENDIX 13-7. AIR SAMPLE RESULTS

FIGURES

TABLES

Acronyms

ACRONYMS

AEC	Atomic Energy Commission
BWP	Buried Waste Program
CCl	Carbon tetrachloride
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
COCA	Consent Order and Compliance Agreement
DCG	derived concentration guide
DOE-ID	U.S. Department of Energy
EAG	Environmental Analysis Group
EBR	Experimental Breeder Reactor
EG&G	EG&G Idaho, Inc.
EM	electromagnetic
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ETR	Engineering Test Reactor
EWR	Early Waste Retrieval
GC	gas chromatograph
GPR	ground penetrating radar
HCs	hydrocarbons
HEPA	high efficiency particular air (filter)
HPLC	high pressure liquid chromatography
HSL	Health Services Laboratory
HV	high volume
INEL	Idaho National Engineering Laboratory
ISV	in situ vitrification

LDU	Land Disposal Unit
LLW	low-level waste
LOP	Large Object Pit
LV	low volume
MAR	Monitoring Activities Review
MCL	maximum concentration levels
MDL	Method Detection Limit
MS	mass spectrometer
MSL	mean sea level
MTR	Materials Test Reactor
MTR	Materials Test Reactor
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NRF	Naval Reactor Facility
NRTS	National Reactor Testing Station
NWQL	(USGS) National Water Quality Laboratory
POC	purgeable organic compounds
PQL	practical quantification limit
RCG	recommended concentration guide
RCRA	Resource Conservation and Recovery Act
RESL	(DOE) Radiological and Environment Sciences Laboratory
RFI	RCRA Facility Investigation
RFP	Rocky Flats Plant
RI/FS	Remedial Investigation/Feasibility Study
RML	Radiation Measurements Laboratory
RWMC	Radioactive Waste Management Complex

RWMIS	Radioactive Waste Management Information System
SDA	Subsurface Disposal Area
SIP	Subsurface Investigation Program
TDA	Transuranic Disposal Area
TEGD	EPA RCRA Ground Water Monitoring Technical Enforcement Document
TR	Texaco Regal
TRU	transuranic
TSA	Transuranic Storage Area
USGS	U.S. Geological Survey
VOC	volatile organic compounds
VVE	vacuum vapor extraction
WERF	Waste Experimental Reduction Facility

1. Introduction

RADIOACTIVE WASTE MANAGEMENT COMPLEX INVESTIGATIONS REPORT

1. INTRODUCTION

Transuranic (TRU) and low-level nuclear wastes containing hazardous constituents have been disposed of in the Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex (RWMC). The SDA is a shallow landfill consisting of a series of trenches and pits that covers approximately 36 ha (88 acres) of land. Approximately 206,110 m^3 (7.3×10^6 ft^3) of TRU and low-level radioactive wastes were buried in these excavations and covered with a soil layer (EG&G, 1990a). Disposal of TRU waste at the SDA was stopped in 1970, but low-level waste (LLW) continues to be disposed of at the SDA. Since 1970, TRU waste has been stored above ground on asphalt pads in retrievable containers at the Transuranic Storage Area (TSA). Waste disposal at the RWMC has followed generally accepted practices in effect at the time and has changed as disposal methods have changed.

Environmental monitoring (surface and subsurface) for radionuclides has been conducted at the SDA since the 1960s. Recent environmental monitoring for TRU radionuclides indicated the presence of plutonium and americium in sedimentary interbeds with activities up to the microcuries/gm level in sediment at a depth of 34 m (110 ft) below ground level (Laney et al., 1988). In 1987, hazardous volatile organic compounds (VOCs) were discovered in the Snake River Plain Aquifer beneath and in the immediate vicinity of the SDA. In accordance with provisions of the Resource Conservation and Recovery Act (RCRA) corrective action Consent Order and Compliance Agreement (COCA) between the U.S. Department of Energy Idaho Operations Office (DOE-ID) and the U.S. Environmental Protection Agency (EPA) Region X, DOE-ID notified EPA of a release of hazardous constituents from a COCA solid waste management unit not previously established as having a release. Upon notification, DOE-ID initiated the actions specified in the COCA to prepare a RCRA Facility Investigation (RFI) Work Plan and to initiate further site and contaminant characterization under an RFI.

The RFI Work Plan and the RFI focused solely on nonradioactive hazardous constituents. After the RFI commenced, the Idaho National Engineering Laboratory (INEL) was placed on the Federal National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, based on chromium contamination in the ground water from other (non-SDA) waste sites at the INEL. Given the potential for the SDA investigation and remediation to be moved in the future from a RCRA to a CERCLA program and in recognition of the need to include all contaminants (radioactive and nonradioactive) to develop a comprehensive site solution, site characterization information pertaining to radionuclide monitoring needed to be incorporated into the RFI work. At that time, the RFI report was under development, and the report was expanded and split into two reports: (1) the RWMC Investigations Report (summarizing data collected for the RFI through August, 1990) and (2) the RWMC Conceptual Model Report (evaluating what is known about site physical characteristics and the nature and extent of contamination). The RWMC Conceptual Model Report will be completed August, 1991.

1.1 Purpose of RWMC Investigations Report

The RWMC Investigations Report summarizes key investigations and reports that are pertinent to site characterization conducted at the RWMC through August 1990. The status of 13 tasks identified in the RFI Work Plan at the SDA are summarized in this report. These 13 investigations were proposed to gain additional insight on the vadose zone at the RWMC and to determine the extent of contamination in the environment. Previously collected data that are relevant to site characterization and provide a better understanding of potential contamination transport were also included in the document. Radionuclide data were incorporated into the sections as required to develop a comprehensive site understanding and solution and given the potential for the program to be transitioned into the Remedial Investigation/Feasibility Study (RI/FS) process under CERCLA. Maps, figures, and tables in this document have been compiled from previously published documents and have not been verified for accuracy.

1.2 Scope of RWMC Investigations Report

The 13 tasks identified in the December 1988 RFI Work Plan are shown in Table 1-1. Cross-referenced with the tasks are the appropriate section numbers in this document. At the time of this report, Tasks 1, 2, 4, 5, and 11 are not completed as originally defined in the RFI Work Plan and data are not available for inclusion in this report. In addition, previously collected data referred to in Section 1.1 are shown in a separate column in Table 1-1. Radionuclide data are incorporated into this report as a result of the RFI being transitioned into the RI/FS process and are also included separately in Table 1-1.

Figure 1-1 presents a time frame for the investigations included in this study. Investigation summaries shown on the timeline include activities that were conducted pursuant to the RFI Work Plan, as part of routine monitoring at the RWMC, or to provide background information. The timeline reflects only the period of time discussed in each section of this report. For example, geophysical and biota investigations were conducted in the late 1970s, but they are not within the scope of this report.

The summaries in this report describe the investigations that were conducted and present the actual data rather than interpreting results. The purpose of each investigation is presented, the proposed strategy in the December 1988 RFI Work Plan is discussed (if applicable), the investigation procedures are reviewed, and the results are presented. This general outline was modified as needed for investigations not included in the RFI Work Plan (e.g., the soil gas survey) or for discussions of routine monitoring for radionuclides at the RWMC (e.g., air monitoring for particulate radionuclides).

Site-specific data have been obtained from 74 boreholes and 18 wells drilled on or near the RWMC. As used in this report, boreholes are distinguished from wells based on their penetrating the aquifer. Boreholes do not penetrate the aquifer; wells do penetrate the aquifer. Shallow boreholes, generally auger holes, penetrate to the first layer of basalt. Deep boreholes

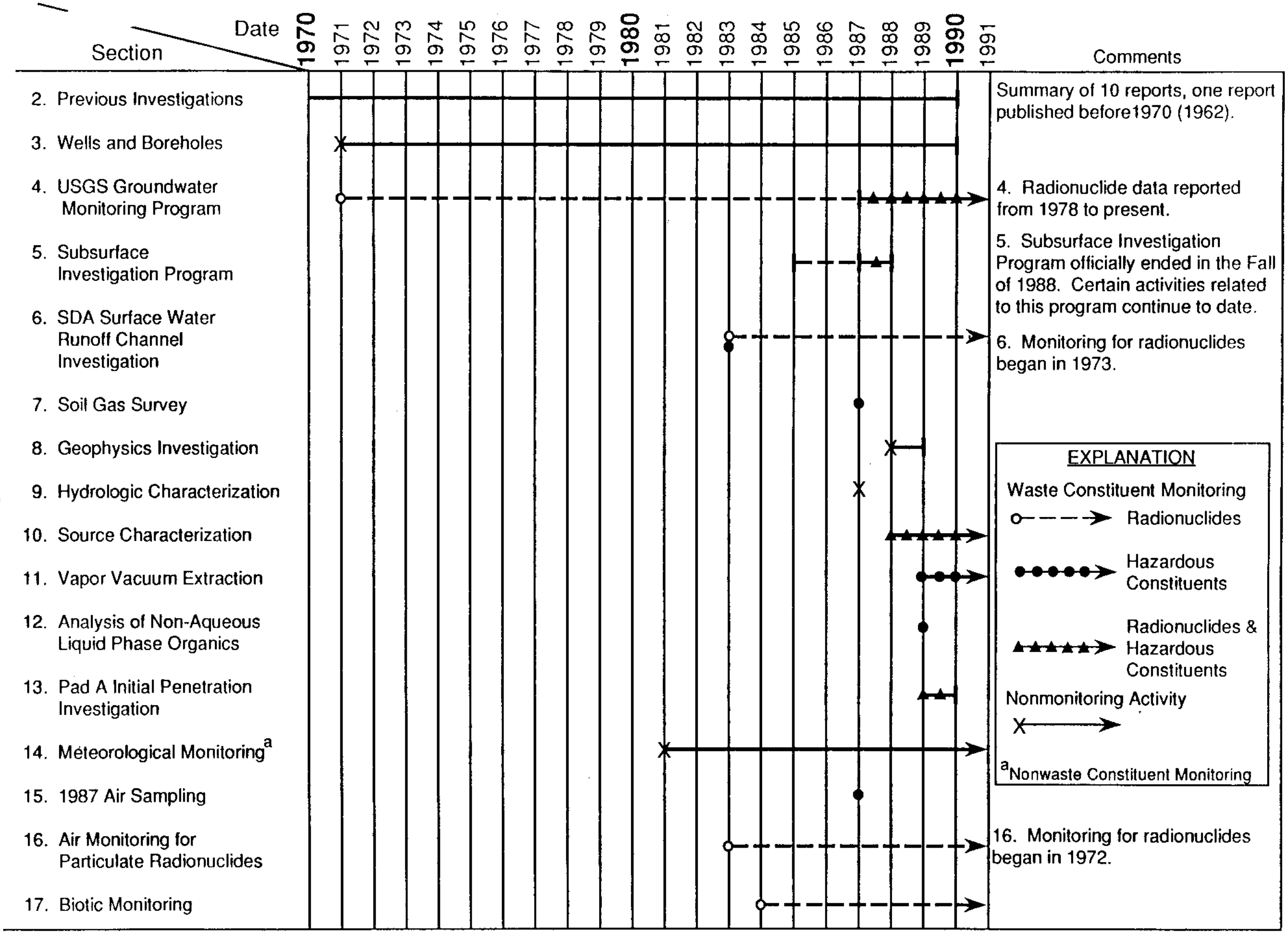
Table 1-1. Summary of RWMC investigations

RWMC Investigations	Task Number in December 1988 Work Plan	Previous Investigation for Site Characterization	Radionuclides Incorporated for RI/FS Transition	Section Number This Document
Bioassay of Small Mammals and Vegetation	1[a]		X	17
SDA Surface Water Runoff Channel Investigation	2[a]		X	6[b]
Source Characterization	3		X	10
Acid Pit Sampling	4[a]			
Subpit Sampling	5[a]			
Analysis of Non-aqueous Liquid Phase Organics	6			12
Geophysics Investigation	7			8
Subsurface Investigation Program	8		X	5
Hydrogeologic characterization	9			9
Ground water monitoring	9		X	4
Organic Transport Model Validation	11[a]			
Vapor Vacuum Extraction Demonstration	12			11
Pad A Initial Penetration	13			13
Previous Investigations		X		2
Wells and Boreholes		X		3
Soil Gas Survey		X		7
Meteorologic Monitoring		X		14
Air Monitoring				
1987 Air Sampling		X		15
Particulate Radionuclide Monitoring		X	X	16

---

a. Task not completed at the time of this report under the scope of the RFI Work Plan.

b. Hazardous constituents reported in Crockett (1983), radionuclide constituents have been routinely monitored for in surface water.



Summary of 10 reports, one report published before1970 (1962).

4. Radionuclide data reported from 1978 to present.

5. Subsurface Investigation Program officially ended in the Fall of 1988. Certain activities related to this program continue to date.

6. Monitoring for radionuclides began in 1973.

16. Monitoring for radionuclides began in 1972.

Figure 1-1. Time frame for investigations included in the RWMC Investigations Report penetrate the basalt, typically intercepting one or more of the sedimentary interbeds.

1.3 Data Validation

The EPA has published guidelines for review of analytical results obtained from the contract laboratory program to confirm that method requirements have been met. Analytical results are validated against the analytical procedures used in the analysis. These procedures specify performance requirements for items such as blanks; calibration standards; chain-of-custody; holding times; matrix spike, matrix spike duplicate; field duplicate; compound quantitation and reported detection limits; internal performance standards and tentatively identified compounds. Although the data presented herein may not meet the current EPA validation requirements for organic and inorganic data published in 1988 (EPA, 1988a; EPA, 1988b), these data did conform to the acceptance criteria that were in effect at that time although an auditable record may not be available for review.

Radionuclide data from 1983 to 1989 discussed in Sections 6, 16, and 17 of this report were subjected to a quality assurance program prior to inclusion in the Environmental Monitoring Annual Reports. The purpose of this program was to identify deficiencies in the sampling and measurement processes for corrective action and to ensure that results obtained through the environmental monitoring program were valid. This quality assurance program remains in effect to date and is documented in the applicable revision of the Environmental Handbook for the RWMC and Other Waste Management Facilities at the Idaho National Engineering Laboratory in force when the samples were analyzed. However, an auditable record of validations may not be available for inspection prior to 1991. Acceptance criteria have evolved over the years in conjunction with changes in standard operating procedures and with changes in analytical methodologies. Statistical treatment of the data, environmental standards, applicable detection limits, and a discussion of quality assurance can be found in Appendices A, B, C, and D, respectively, of the Environmental Monitoring Annual Reports referred to above (Blanchfield and Hoffman, 1984;

Reyes et al., 1985; Reyes et al., 1986; Tkachyk et al., 1987; Tkachyk et al., 1988; Tkachyk et al., 1989; and Tkachyk et al., 1990).

1.4 RWMC Investigations Report Organization

This report is organized into 17 sections:

- Section 2 provides a summary of previous investigations that are key to site characterization.
- Section 3 identifies the wells and boreholes that were drilled in the vicinity of the RWMC since the early 1970s. A brief history of the drilling programs is provided and well/borehole construction and completion information is presented in tables.
- Section 4 summarizes the U.S. Geological Survey (USGS) and EG&G Idaho, Inc. (EG&G Idaho) ground water monitoring programs at the RWMC.
- Section 5 summarizes the Subsurface Investigation Program (SIP), a comprehensive program established in 1983 to collect site-specific geologic and hydrologic data of the vadose zone to use for predicting radionuclide migration. Only a portion of the SIP was ever completed.
- Section 6 provides a summary of routine surface water monitoring for radionuclides and of a one-time sampling for hazardous constituents at the RWMC.
- Section 7 summarizes the results of a soil gas survey that was conducted in November 1987 to determine the identity, location, and relative concentrations of selected VOCs in the surficial sediments at the RWMC and adjacent areas.

- Section 8 presents the results of geophysical surveys conducted during 1989 to obtain additional information on waste and disposal pit configurations and shallow subsurface stratigraphy.

- Section 9 discusses two reports that summarize the current knowledge of the hydrogeology of the RWMC.

- Section 10 presents the results of a study to characterize the source of both hazardous and radionuclide constituents at the RWMC.

- Section 11 discusses the status of the vapor vacuum extraction demonstration. This remedial technology was proposed to remove volatile organic compounds from the vadose zone by pumping contaminated air from a borehole, and removing the volatile organics before discharge.

- Section 12 summarizes the results of a study to determine if machining oil contributes to the migration of other organics and radionuclides at the RWMC.

- Section 13 presents the results of the Pad A investigation to (1) evaluate the condition of waste containers, (2) conduct an engineering study to determine the accuracy of the waste generators' records, and (3) determine feasible methods of remediation.

- Section 14 discusses meteorological monitoring stations located at the RWMC and presents a summary of the type of information collected at each location.

- Section 15 summarizes the results of a one-time air sampling event for VOCs at the RWMC.

- Section 16 reviews the routine air monitoring program for particulate radionuclides at the RWMC.

- Section 17 discusses the biotic monitoring program for radionuclides that was implemented at the RWMC in 1984.

2. Previous Investigations

2. PREVIOUS INVESTIGATIONS

Concern about the potential for migration of radionuclides from wastes disposed of at the SDA has prompted numerous surface and subsurface investigations at the RWMC. This section provides a brief summary of key reports that provide insight into site characteristics and the potential for migration of waste radionuclide constituents from the SDA. The reports discussed cover the time period from 1962 to 1990. The majority of studies were completed after 1970, reflecting the growing concern about the potential for radionuclide contamination of the Snake River Plain Aquifer. These studies provide data on the surface soils, meteorology, hydrogeologic framework, and geochemistry of the vadose zone and the aquifer. Reports included in this section are

- Olmsted, F. H., 1962, Chemical and Physical Character of Ground Water in the National Reactor Testing Station, Idaho, USGS, IDO-22043.
- Barraclough, J. T., J. B. Robertson, V. J. Janzer, 1976, Hydrology of the Solid Waste Burial Ground as Related to the Potential Migration of Radionuclides at the Idaho National Engineering Laboratory, USGS Open-File Report 76-471, DOE/IDO-22056, August.
- Burgus, W. H. and S. E. Maestas, 1976, The 1975 RWMC Core Drilling Program, A Further Investigation of Subsurface Radioactivity at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, ERDA, IDO-10065.
- Humphrey, T. G. and F. H. Tingey, 1978, The Subsurface Migration of Radionuclides at the Radioactive Waste Management Complex, 1976-1977, TREE-1171, October.
- Humphrey, T. G., 1980, Subsurface Migration of Radionuclides at the Radioactive Waste Management Complex - 1978, EGG-2026.

- Rightmire, C. T. and B. D. Lewis, 1987, Hydrogeology and Geochemistry of the Unsaturated Zone, Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho, USGS Open-File Report 87-4198, DOE/ID-22073.

- Borghese, J. V., 1988, Hydraulic Characteristics of Soil Cover, Subsurface Disposal Area, Idaho National Engineering Laboratory, Master's Thesis, University of Idaho, Moscow, Idaho, September.

- Anderson, S. R. and B. D. Lewis, 1989, Stratigraphy of the Unsaturated Zone at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho, USGS Water Resources Investigations Report 89-4065, DOE/ID-22080, May.

- Pittman, J. R., 1989, Hydrological and Meteorological Data for an Unsaturated Zone Study Near the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, 1985-86, USGS Open-File Report 89-74, DOE/ID-22079, April.

- Knutson, C. F., et al., 1990, FY 89 Report RWMC Vadose Zone Basalt Characterization, EGG-WM-8949, July.

These reports are summarized in the following sections. In each case, the purpose, findings, and relevance to RWMC site characterization are presented.

2.1 Chemical and Physical Character of Ground Water in the National Reactor Testing Station, Idaho

2.1.1 Purpose of the Investigation/Report

This report is a preliminary appraisal of the nature and distribution of the ground water quality beneath the INEL, formerly referred to as the National Reactor Testing Station. The purpose of this study was to provide information pertinent to the management of the aqueous radioactive waste that was discharged to the ground water. By understanding the chemical and physical characteristics of the ground water, the attenuation processes influencing radionuclide transport can be identified and evaluated. In addition, an understanding of the ground water characteristics can determine usage and the type of treatment if required.

2.1.2 Summary of the Investigation

The study of the chemical and physical character of the ground water in the vicinity of the INEL was based on the analyses of 148 samples collected from 92 wells from 1949 to 1961 (see Table 1, p. 82 for sample summary). Because this time period predates completion of the wells at the RWMC, none of the chemistry data are site-specific. However, data from the report provide a general picture of the ground water quality in the vicinity during the late 1950s and early 1960s. The samples were collected using pumps and bailers and were assumed to represent the average conditions in the aquifer tapped within the completed zone(s). The concentrations of the dissolved constituents (Ca, Mg, Na, K, HCO_3, CO_3, SO_4, Cl, NO_3, F, SiO_2, and Fe) were analyzed using standard laboratory procedures and reported in parts per million as well as in equivalents per million. The temperature of most samples was measured with a mercury thermometer at the well head or pump discharge point at the time of sample collection. The color, hardness, and pH values were also recorded at the time of sampling.

In addition, geophysical surveys were conducted at 84 of the 92 identified wells during 1961 and 1962. A WIDCO logger was used to log the water resistivity and water temperature. Altogether, 113 temperature logs and 115 water resistivity logs were analyzed. The resistivity logs were converted to conductivity logs and specific conductance was derived by correcting the conductivity for temperature at 25°C and logging error since conductivity is temperature dependent. The ratio of the sum of ionized constituents (total dissolved ions) to the specific conductance was calculated at 0.543 in 88 samples. Therefore, the total dissolved constituents could be estimated from the logs by multiplying the specific conductance by a factor of 0.543.

The study tabulated and evaluated the chemical and physical data collected from the wells. In general, it was found that calcium and magnesium constitute more than 70% of the cation total and bicarbonate more than 70% of the anion total in the ground water beneath the INEL. However, small quantities of other chemical types, chiefly waters containing moderate to large percentages of chloride, do occur. At the RWMC the total percentage of sodium plus potassium; chloride, nitrate, and fluoride; and silica in ground water was 12-16%, <10%, and 25-30 ppm, respectively (Figures 8, 9, and 10 in Olmsted, 1962).

Based on the proportions of the various ionized constituents, the waters beneath the INEL were classified into four chemical types, designated A, B, C, and D. Type A water, in which calcium and magnesium equal or exceed 85% of the cation total, underlies the western half of the INEL Site and is derived chiefly from the drainage basins of the Little Lost River and Birch Creek to the northwest. Type B water, in which sodium and potassium exceed 15% of the cation total, underlies the eastern half of the INEL Site. The source of geochemical constituents is the mountains to the north and northeast, and Type B water is probably affected by irrigation in the Mud Lake region. Type C water, in which chlorine is the chief constituent, occurs in five areas within the INEL Site and includes (1) drainage from irrigated areas, (2) aqueous-waste discharged to wells at operational facilities, and (3) waters of various natural origins including thermal springs. Type D water, which is sulfate contaminated, is rare. Most of the Type D water occurs in a perched water body originating by seepage from the waste disposal pond at the Materials Testing Reactor. According to Figure 7 in Olmsted (1962), Type A water underlies the RWMC.

The data confirm that the chemical character of the ground water is not highly variable for an area of about 2.331 x 10^6 m^2 (900 mi^2). In the bicarbonate waters, the sum of determined constituents ranged from 143 to 273 ppm and averaged slightly more than 200 ppm; the sum of ionized constituents averaged less than 200 ppm. This fairly consistent chemical character of the ground water indicates moderately uniform chemical and physical characteristics of the water-bearing rocks throughout the region encompassing the INEL Site. The only exception is that concentrations as large as 928 ppm were determined for samples of sulfate contaminated waters (Type D water).

The data were evaluated to determine trends in lateral and vertical ground water movement. The areal variations in the chemical character and temperature were consistent with the regional south-southwestern direction of ground water movement indicated by the configuration of the water table. Except for a top layer of relatively fresh water as much as 15 m (50 ft) thick, which occurs in many parts of the INEL Site, the changes in ground water quality with depth were small in wells located away from waste discharge facilities.

2.1.3 Significance for Site Characterization at the RWMC

This study was the first comprehensive characterization of the ground water geochemistry at the INEL. A classification scheme was developed based on geochemical source area. Two of the four types of ground water (Type C and D) are chiefly contaminated with chlorine and sulfate, respectively. In addition, the physical and chemical data from this study confirmed the regional south-southwestern direction of ground water flow and indicated generally consistent ground water quality with depth.

2.2 Hydrology of the Solid Waste Burial Ground as Related to the Potential Migration of Radionuclides, Idaho National Engineering Laboratory

2.2.1 Purpose of the Investigation/Report

This investigation was conducted by the USGS in response to conflicting opinions on whether waste disposal operations at the SDA posed a threat to the Snake River Plain Aquifer. Three objectives were defined: (1) to evaluate the geologic, hydrologic, and geochemical variables that could affect the subsurface migration of waste radionuclides from the SDA; (2) to determine the extent of radionuclide migration, if any; and (3) to construct ground water

The period of investigation reported in Barraclough et al. (1976) extended from June 1971 through December 1974.

2.2.2 Summary of the Investigation

Subsurface information used to predict potential radionuclide migration was obtained by drilling wells, obtaining samples, and applying borehole geophysical techniques. Four observation wells (USGS Wells 87, 88, 89, and 90) were drilled by cable tool methods outside the SDA to depths about 15 m (50 ft) below the water table to define the stratigraphic sequence underlying the SDA, to determine the slope of the ground water surface, and to determine the general direction of ground water movement in the vicinity of the SDA. The approximate locations of these wells are shown on Figures 3-2 and 4-1 in Sections 3 and 4 of this report. Six boreholes (91 through 96) were located within the SDA to obtain representative stratigraphic coverage of the SDA and to avoid contact with buried waste in pits and trenches. These boreholes were continuously cored using air-rotary methods to depths ranging from 72 to 92 m (236 to 302 ft) in order to penetrate the 73-m (240-ft) interbed. Four geophysical logging methods were used: natural-gamma, gamma-gamma, neutron-epithermal neutron, and caliper. Fluid temperature and fluid conductivity logs were also run on the saturated portions of Wells 87, 88, 89, and 90. Natural-gamma, gamma-gamma, neutron, and caliper geophysical logs, total depths, construction details, and locations for these wells and boreholes are provided in Section 3 of this report.

2.2.2.1 Stratigraphy. Barraclough et al. (1976) established the subsurface stratigraphic framework at the SDA. They defined the 34-m (110-ft) and 73-m (240-ft) sedimentary interbeds and the intervening basalts [referred to in Barraclough et al. (1976) as Series A, B, C, and D but now referred to as Flow Groups A through D in Anderson and Lewis (1989)] based on interpretation of the geophysical logs. The lateral continuity of the sedimentary interbeds and basalts was determined by generating two structural cross sections, isopach maps, and structure maps of the sedimentary interbeds and intervening basalts. Selected sample cuttings of basalt, sedimentary interbeds, and surficial sediments were analyzed to determine hydrogeologic interbeds, and surficial sediments were analyzed to determine hydrogeologic parameters and characteristics. The results of particle size analysis, X-ray mineralogy, cation-exchange capacity, vertical hydraulic conductivity, and other parameters are reported for 59 samples from the 10 wells and boreholes (sampled intervals and results are included in Tables A-III through A-V, pp. 119-125 of Barraclough et al., 1976).

2.2.2.2 Hydrology. Four potential sources of surface water that could enter the SDA and come into contact with buried wastes were discussed: precipitation, local surface runoff from adjacent areas, a flood of the Big Lost River, or lateral underflow of water in surficial sand or gravel. Barraclough et al. (1976) concluded that the regional ground water gradient and direction of flow in the aquifer resulted from the combined effects of regional southwestward underground flow into the area, local precipitation, seepage from the Big Lost River, and seepage from the Big Lost River flood-water diversion ponds. The authors also recognized that the local direction of ground water flow reflects recharge from the diversion ponds and from the Big Lost River. Saturated and unsaturated flow in both the sedimentary interbeds and the basalts was discussed with regard to potential contaminant migration. Vertical hydraulic conductivities of the 34- and 73-m (110- and 240-ft) sedimentary interbeds were measured from 22 cores from the 10 wells and boreholes. Unsaturated flow was identified as being the principal mode of subsurface moisture movement between the land surface and the Snake River Plain Aquifer.

Visibly wet cores were observed in all of the interior boreholes within the approximate interval of 59 to 65 m (195 to 215 ft). Evidence of a perched water zone was observed in Boreholes 92, 93, and 96. Barraclough et al. (1976) concluded that this zone was perched on a dense basalt layer just above the 73-m (240-ft) sedimentary interbed. Borehole 92 was subsequently completed to monitor the perched water zone.

2.2.2.3 Radiochemistry. The radionuclides of greatest concern in this study were Sr-90, Cs-137, Pu-238, Pu-239, Pu-240, Pu-241, and Am-241 because of their long half-lives and the potential for biological harm. Basalt, sedimentary interbeds, and ground water were sampled for radionuclides.

Basalt cuttings from the ground water wells (87, 88, 89, and 90) were analyzed by gross gamma counting techniques to detect radioactive contamination. These analyses included both washed and unwashed samples of basalt. The sampled intervals and gross gamma values are provided in Table A-VII in Barraclough et al. (1976).

Sampling focused on the sedimentary interbeds because they were presumed to control the movement and adsorptive chemistry of subsurface radioactive waste solutions and suspensions. Samples were analyzed for waste isotopes (Cs-137, Sr-90, Co-60, Pu-239, and Am-241) and some of the natural isotopes (K-40, Bi-214, Pb-214, Ac-228, Th-232, and U-238). A total of 638 radiochemical determinations were made on 58 sedimentary samples. Of the total 638 separate analyses, 491 were for waste products. Eight samples were collected from the surficial sediments at the interior boreholes (91 through 96); 17 samples were collected from the 34-m (110-ft) interbed in Wells 87, 88, and 90 and from Boreholes 93 through 96; and 19 samples were collected from the 73-m (240-ft) interbed in Wells 87 and 89 and from all of the interior boreholes. The remaining 14 samples were collected from other sedimentary interbeds within the stratigraphic sequence. The results of the radiochemical analyses on the 58 samples are provided by well in Table A-VII (pp. 137-146) in Barraclough et al. (1976).

Eighty-three water samples of the Snake River Plain Aquifer were collected from Wells 87, 88, 89, and 90 from 1971 through 1974. Four samples were collected from the perched water zone in Borehole 92 during the study period. The water samples were analyzed by gamma spectrometry for H-3, Sr-90, Am-241, Pu-238, and Pu-239,-240.

2.2.2.4 Radioanalytical Results. Gross gamma analyses of the basalt cuttings and associated sediments from the ground water wells did not detect any waste constituents. However, because basalts have a high natural background gamma activity, low concentrations of wastes would not be distinguishable by the gross gamma method.

Significant concentrations (concentrations greater than two standard deviations above the net count rate) of radionuclide waste constituents including Co-60, Sr-90, Cs-137, Ba/La-40, Pu-238, Pu-239,-240, and Am-241 were found in four sedimentary interbed samples from the ground water wells located outside the SDA and in 23 samples from the interior boreholes. The greatest concentration of waste radionuclide constituents were found in 16 samples from the 34-m (110-ft) sedimentary interbed in the interior boreholes. Seven samples indicated radionuclide constituents from the waste in the 73-m (240-ft) interbed. It was proposed that some of the apparent statistically significant concentrations may have been the result of statistical error or sample contamination that occurred during drilling or sample handling operations. However, Barraclough et al. (1976) concluded that some radionuclide constituents had migrated from the SDA to the 34- and 73-m (110- and 240-ft) sedimentary interbeds.

Water samples from the Snake River Plain Aquifer obtained from Wells 87, 88, 89, and 90 contained trace quantities of waste radionuclides. The authors stated that the positive results were inconclusive because of possible artificial contamination from the drilling and well construction techniques and from the water sample collection methods. The four samples from the perched water zone in Borehole 92 contained H-3, Co-60, Sr-90, Cs-137, Pu-238, and Pu-239,-240 (Table III, p. 65 in the report contains sampling results). The concentrations in Borehole 92 were thought to be valid and not the result of artificial contamination.

Barraclough et al. made four conclusions based on their investigation: (1) sufficient quantities of surface water had penetrated the SDA to transport radionuclides to the 73-m (240-ft) interbed, (2) radionuclides had migrated to the 73-m (240-ft) sedimentary interbed at some of the sampled locations, (3) radionuclides had not migrated to the Snake River Plain Aquifer, and (4) radionuclides in the sedimentary interbeds were not expected to migrate to the aquifer in detectable concentrations if the quantity of water percolating through the SDA wastes was sufficiently reduced (Barraclough et al., 1976).

2.2.3 Significance for Site Characterization at the RWMC

This investigation was the first attempt to determine if the waste management practices used at the SDA from 1952 to 1970 had resulted in vertical radionuclide migration. To evaluate the potential for subsurface migration, the stratigraphic framework at the SDA was defined to an approximate depth of 180 m (600 ft) using geophysical logs from wells and boreholes, hydraulic and physical properties of the basalts and sedimentary interbeds were measured, and the local hydrology was characterized using a combination of surface and subsurface data. Radionuclides were measured in the sedimentary interbeds for the first time. Although the results were inconclusive, this study documented the need to minimize the potential for radionuclide migration from the SDA. Ground water monitoring at the SDA has continued as a result of this study.

2.3 The 1975 RWMC Core Drilling Program, A Further Investigation of Subsurface Radioactivity at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory

2.3.1 Purpose of the Investigation/Report

The purpose of this investigation was to confirm the results of an earlier study (Barraclough et al., 1976) that reported radionuclides (Co-60, Sr-90, Cs-137, Pu-238, Pu-239,-240, Am-241) present in samples from both the 34- and 73-m (110- and 240-ft) sedimentary interbeds at the RWMC. Deep boreholes were drilled, cored, and analyzed for radionuclides known to be present in the buried wastes. Stringent anticontamination measures were used to preclude inadvertent contamination of cores by radioactively contaminated surface soils.

2.3.2 Summary of the Investigation

Boreholes 96A, 96B, and 93A were installed near USGS Boreholes 96 and 93, which had been drilled as part of the earlier study (Barraclough et al., 1976) that had indicated potential radionuclide contamination. Initially, the boreholes were to be cored using a Christensen Diamond Products Rubber Sleeve Core Barrel. However, Borehole 96A was abandoned at a measured depth of 36.5 m (120 ft) because of inadequate core recovery using this type of equipment. The other two boreholes were cored from the top of the first basalt to the base of the 73-m (240-ft) sedimentary interbed using 8.5-cm (3.3-in.) diameter Longyear size PQ split core barrels. Core recovery averaged 99% in the basalt and 90 to 95% in the sedimentary interbeds. Tables on pages 17 through 25 in Burgus and Maestas (1976) present core descriptions. Lithologic logs were prepared for each borehole and geophysical logs were run (see Appendix 3-I of this report).

Elaborate procedures were used to avoid direct and indirect contamination of the cores during drilling, core recovery, core removal, shipment, and storage. These procedures are summarized below and on pages 12 through 15 in Burgus and Maestas (1976).

Precautions to prevent surface contamination by dust at the drilling site included protecting both the drilling equipment and the collected samples. Before drilling, the surface soil was scraped off in a 15 x 30.5 m (50 x 100 ft) area around each borehole and gravel was spread over the scraped area. After the surface casing was set, a 9.3 m^2 (100 ft^2) area around the borehole was covered with asphalt. A wooden platform was constructed around the borehole so tools inadvertently dropped would not touch the ground. A wooden table was provided for placement of tools. Drill string sections and casing were stored on the flatbed of a truck.

To prevent downhole contamination, the wellbore was kept covered except when drilling or coring. Casing was installed in short sections to minimize borehole collapse of the unconsolidated sedimentary interbed sections that were suspected of contamination. Air was used for cooling the bit and circulating cuttings to the surface. Before drilling, the air was routed through high efficiency particulate air (HEPA) filters; the air was recycled through a cyclone-type dust collector after use in the holes and vented to a point 15 m (50 ft) downwind of the hole. Drilling was not conducted under high wind conditions.

Sediment cores were collected using a bucket auger on the end of the drill string. The drill string and auger had to be removed from the borehole every 0.09 m (2 ft) to collect sediment samples. Cores were protected from contact with the borehole walls and from dust by collecting them in plastic sleeves, immediately transferring them to new coreboxes, and placing each box inside two plastic bags that were then sealed. The core barrel was wiped clean to prevent cross-contamination before being reused. Sampling team members wore disposable gloves while handling sediment cores. The cores were transported to the storage area, 11.3 km (7 mi) from the RWMC, twice each shift.

As a final precaution, dysprosium nitrate solution was spread as a tracer over a 762-m (2500-ft) area around each borehole. If contamination was found in collected samples, the samples were also analyzed for dysprosium. If dysprosium was present, the contamination could have come from the surface soils rather than the sedimentary interbeds (Burgus and Maestas, 1976, p. 15).

Fifteen samples were taken from the cores for radionuclide analysis: three from the 9-m (30-ft) sedimentary interbed, seven from the 34-m (110-ft) sedimentary interbed, four from the 73-m (240-ft) interbed, and one sample of broken basalt and grey clay from a measured depth of 27 m (89 ft). The samples were analyzed for Am-241, Ce-144, Cs-137, Co-60, Pu-238, Pu-239,-240, and Sr-90.

The levels of radioactivity detected in the 15 samples were at or below background levels of 2.0×10^{-7} μCi/g. Because of the uncertainty inherent in the laboratory methods for measuring such low radionuclide concentrations, the analytical results were not considered statistically positive. Because no statistically positive levels of radionuclides were detected, Burgus and Maestas concluded that the radionuclides reported in the earlier study were the result of contamination during drilling and coring.

2.3.3 Significance for Site Characterization at the RWMC

Burgus and Maestas (1976) was one of the first of several reports to evaluate the occurrence of radionuclides in the sedimentary interbeds. This report indicated that radionuclides were either not present or were present in very low concentrations in the sedimentary interbeds in the three boreholes sampled in 1975. These boreholes have since been plugged and cemented to surface.

2.4 The Subsurface Migration of Radionuclides at the Radioactive Waste Management Complex, 1976-1977

2.4.1 Purpose of the Investigation/Report

This study was initiated as part of an ongoing project to evaluate the hydrologic, radiologic, and geochemical parameters that control the potential subsurface migration of waste radionuclides and to evaluate the extent of radionuclide migration from buried waste at the RWMC. Sections 2.2 and 2.3 describe Barraclough et al. (1976) and Burgus and Maestas (1976), the previous investigations with similar scope and objectives. Two objectives were identified for this study: (1) to sample the sedimentary interbeds in the vadose zone for radiochemical analysis and (2) to analyze samples from the undisturbed soil zone immediately underlying buried waste but above the first basalt.

2.4.2 Summary of the Investigation

To meet the first objective, a total of nine boreholes (76-1, 76-2, 76-3, 76-4, 76-4A, 76-5, 76-6, 77-1, and 77-2) were drilled into the vadose zone beneath the RWMC. The shallowest borehole (77-2) was drilled to a depth of 27 m (87.4 ft) and completed in a perched water zone. The deepest borehole (Borehole 77-1) was continuously cored to a depth of 183 m (600 ft). The other seven boreholes ranged in depth from 65.5 m (215 ft) to 77 m (252.5 ft). The drilling and coring techniques for these boreholes followed those described in Section 2.3 of this report (Burgus and Maestas, 1976). The available subsurface data for these boreholes are included in Table 3-3 of Section 3 and Appendix 3-1 of this report.

Although one objective of the study was to sample the sedimentary interbeds for radionuclides, each borehole was sited to provide additional subsurface data. These boreholes were located to (a) obtain stratigraphic resolution of the 9-m (30-ft) interbed, (b) investigate the suspected occurrence of detectable radionuclide concentrations in a perched water zone such as was encountered in the Barraclough et al. (1976) study, (c) obtain continuous core coverage of the vadose zone, and (d) evaluate the stratigraphy in the TSA and in areas adjacent to some of the oldest buried wastes at the SDA.

Anticontamination measures were used to drill Borehole 77-2 because it was located to penetrate a zone beneath buried TRU waste in deteriorated containers in Pit 2 (Humphrey and Tingey, 1978). The waste in this area had been removed as part of the Early Waste Retrieval (EWR) demonstration. In addition to the anticontamination measures used in the 1975 drilling program (described in Section 2.3 of this report) the following techniques were used. Driller's tools were placed on a table covered with blotting paper which was changed daily, rather than on the ground. Core retainers and inner split sleeves were washed and wiped after each core was removed to avoid cross-contamination. Access to the drilling area was restricted by a barricade, and only drilling personnel were permitted to enter. An air support weather shield was erected around the drilling rig to further protect the samples from contamination.

The floors of waste disposal Pit 2 and Pit 11 were exposed after the buried wastes were removed as part of the EWR demonstration. Pit 2 was flooded in 1962 and 1969 which may have mobilized radionuclides. To meet the second objective of the investigation, soil samples were obtained from the pit floors directly beneath where wastes were buried. Twenty-five sediment samples were collected from three locations in Pit 2, and six sediment samples were recovered from one location in Pit 11. At each sampling location, samples were collected at 0.3-m (1-ft) stratigraphic intervals to construct a generalized cross-section of the sediment profile beneath the wastes.

Sediment subpit samples were collected as follows: (a) trenches were excavated in the bottoms of the pits directly adjacent to remaining wastes, (b) samples were collected by scraping a small section of soil off the trench wall and inserting a sample tube horizontally, (c) the tubes were withdrawn from the wall and the samples were removed from the tube, and (d) the samples were placed in clean polyethylene bags that were then double-bagged.

The core samples, subpit samples, and perched water samples were analyzed for Pu-238, Pu-239,-240, Am-241, Ce-144, Cs-137, and Co-60. Subpit samples from Pit 2 and core samples were also analyzed for Sr-90. The perched water from Borehole 77-2 was also analyzed for H-3. The results of these analyses are discussed below.

2.4.2.1 Core Sample Results. Some samples from the deep boreholes contained measurable levels of radionuclides. Of 303 analyses of 47 core samples, 17 analyses contained trace amounts of radioactivity at the 95% confidence level. Fifteen of the 17 samples were reanalyzed and only one sample at a depth of 73.3 m (221 ft) in Borehole 76-1 showed Sr-90 radioactivity at the 99% confidence level. It was concluded that the original detection of radionuclides in the first analyses resulted from sample contamination or from the inability to obtain reliable analyses of radionuclide concentrations that are at or below detection limits or at or near comparable background concentrations.

2.4.2.2 Subpit Sample Results. The trenches in Pit 2 and Pit 11 indicated that the sediment thickness between the bottom of the pits and the underlying basalt was 1.7 m (5.5 ft) and 3 m (10 ft), respectively. Radionuclides were detected beneath the buried wastes to a depth of about

2 m (6 ft). At all subpit sample locations, Pu-239,-240 was detected at statistically significant concentrations at the sediment/basalt interface. The concentrations decreased with depth.

2.4.2.3 Perched Water Results. Tritium was detected in some perched water samples from Borehole 77-2. Humphrey and Tingey concluded that the tritium source was from buried waste although no tritium was recorded as being disposed of at the RWMC.

2.4.3 Significance for Site Characterization at the RWMC

Humphrey and Tingey (1978) documented the first clear evidence of radionuclide migration from buried wastes beneath the waste disposal pits at the RWMC. However, the data from this study together with that from Barraclough et al. (1976) and Burgus and Maestas (1976) showed no conclusive evidence that radionuclide waste constituents originating from the buried wastes had migrated to the Snake River Plain Aquifer (Humphrey and Tingey, 1978). The authors further stated that the detected concentrations of radionuclides in the sedimentary interbeds were not of a level to indicate that the buried waste constituted a future hazard to the aquifer given current climatic conditions.

2.5 Subsurface Migration of Radionuclides at the Radioactive Waste Management Complex - 1978

2.5.1 Purpose of the Investigation/Report

Humphrey (1980) was the fourth of a series of investigations on potential radionuclide migration at the RWMC. The first investigation was initiated in 1971 by the USGS and is described in Section 2.2 of this report. The 1975 and 1976-1977 investigations are described in Sections 2.3 and 2.4 of this report, respectively. Data obtained from the earlier studies were contradictory and inconclusive with respect to migration of waste radionuclide constituents from buried wastes at the SDA into the sedimentary interbeds.

Hence, subsurface studies continued to determine if waste radionuclide constituents were migrating to the Snake River Plain Aquifer.

The purpose of this study was to continue the core work initiated in 1975, using the same improved coring techniques and anticontamination measures, and to continue the subpit sampling work initiated in 1976, in order to identify potential contaminant pathways and the radionuclide migration rate.

2.5.2 Summary of the Investigation

Five boreholes (78-1, 78-2, 78-3, 78-4, and 78-5) were drilled for this study. The locations of these boreholes are shown on Figure 3-2 in Section 3 of this report. The drilling procedures followed those documented in Burgus and Maestas (1976) described in Section 2.3 of this report. Boreholes 78-2, 78-3, and 78-5 were sited to either intercept suspected perched water zones or to obtain a more even distribution of boreholes over the SDA. Borehole 78-1 was drilled over Pit 12, after drum removal operations were completed under the EWR demonstration, to determine if waste radionuclide constituents had migrated from the pits. Borehole 78-4 was drilled for use by the USGS to conduct phase log studies to determine the vertical permeability of the vadose zone basalts and sedimentary interbeds.

Boreholes 78-1, 78-2, 78-3, and 78-5 were cored. Twenty-three sedimentary interbed samples were collected from cores of Boreholes 78-2, 78-3, and 78-5. Eleven samples were from the 34-m (110-ft) interbed, and 12 samples were from the 73-m (240-ft) interbed. The 23 samples were split and subjected to two separate, identical analytical procedures to determine the presence and concentrations of certain radionuclides known or suspected to be present in the wastes including Co-60, Cs-137, Ce-144, Sr-90, Pu-238, Pu-239,-240, and Am-241.

Geophysical logging was conducted on Boreholes 78-2, 78-3, and 78-5. Borehole 78-1 was not logged because the borehole was immediately cased and the diameter was too small (Humphrey, 1980). Borehole 78-4 was not logged because a comparable log suite was available at nearby boreholes. The available geophysical logs (gamma-gamma, gamma ray, and neutron) are provided in Appendix 3-1 of this report.

A total of 322 laboratory analyses on the 23 samples were conducted on the splits from the sedimentary interbeds in Boreholes 78-2, 78-3, and 78-5. Ten analyses (or 3.1%) showed significant amounts of radioactivity at the 95% confidence level. Four of the 10 samples were from the 34-m (110-ft) interbed, and the other six samples were from the 73-m (240-ft) interbed. Two samples from the 73-m (240-ft) interbed had radionuclide concentrations significant at the 99% confidence level. However, the second analysis of the same core material (split) neither confirmed the presence of radionuclides nor reinforced the earlier positive results. Of the 10 samples at the 95% confidence level, only one sample from the top of the 34-m (110-ft) interbed in Borehole 78-5 showed a statistically significant level of radioactivity for the same radionuclide (Pu-238) in both of the splits. Radioanalytical results can be found in Appendix B of Humphrey (1980).

Forty samples from archived cores of Boreholes 76-1, 76-2, 76-3, 76-4, 76-5, and 76-6 acquired during the earlier 1976 drilling program (Humphrey and Tingey, 1978) were also evaluated for this study. Two samples were from the 9-m (30-ft) interbed, 11 samples were from the 34-m (110-ft) interbed, and 27 samples were from the 73-m (240-ft) interbed. These 40 samples were also analyzed for Co-60, Cs-137, Ce-144, Sr-90, Pu-238, Pu-239,-240, and Am-241, for a total of 280 radionuclide determinations. No radionuclides were detected at the 95% confidence level from these samples.

The subpit sampling was conducted to determine the extent of radionuclide migration directly beneath buried waste (Humphrey, 1980). Twelve subpit samples were collected from two locations in the undisturbed zone immediately below the former drum disposal area in Pit 12 and above the underlying basalt. The subpit sampling procedures were the same as those reported in the 1976-77 study (Humphrey and Tingey, 1978) in Section 2.4 of this report. The sediment thickness between the bottom of the pit and the top of basalt ranged from 0.7 to 1 m (2.3 to 3.3 ft) at the sampled locations.

The subpit sample results indicated the presence of some radionuclides (Pu-239,-240) at the sediment-basalt interface. Analytical results indicated that radionuclide concentrations generally were highest near buried waste, greatly attenuated with distance from the waste, and were irregularly present at the soil-basalt interface (Humphrey, 1980).

Humphrey reported that the positive indications of radionuclides from the drilling could be the result of statistical variation, not of radionuclide migration. However, the author noted that the results of the 1978 core study were again inconclusive with respect to radionuclide migration. If migration had occurred, it was at barely detectable levels and of little health or safety concern (Humphrey, 1980). The margin of uncertainty resulted in initiation of the 1979 coring program; the program's findings were never published.

2.5.3 Significance for Site Characterization at the RWMC

The samples collected and analyses conducted for this study repeated the pattern of earlier studies; statistically significant radionuclide concentrations were found in a number of samples from the sedimentary interbeds, but the analysis of the split did not typically confirm the results. Thus, the presence of radionuclides in the sedimentary interbeds was still subject to question although the potential for radionuclide migration was becoming more evident.

This report confirmed the presence of radionuclides migrating from the buried wastes into the soil immediately below waste pits as reported in the 1976-77 study. The analytical results indicated that radionuclide concentrations were generally highest near buried wastes, greatly attenuated with distance from the waste, and were irregularly present at the soil-basalt interface (Humphrey, 1980).

2.6 Hydrogeology and Geochemistry of the Unsaturated Zone, Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho

2.6.1 Purpose of the Investigation/Report

The study developed a conceptual model of the hydrogeochemical environment of the shallow vadose zone of the Snake River Plain and determined how changes in that environment may influence the mobility and migration of radionuclides buried in the SDA at the RWMC.

2.6.2 Summary of the Investigation

Several methods were used to evaluate the hydrogeochemical environment including precipitation and sediment sampling, thin section analysis, X-ray diffraction, and stable isotope measurements. Precipitation samples were collected for chemical and isotopic analyses to establish the background levels for the principal chemical input to the system. Fracture filling/lining materials were examined in whole core and in thin section to determine their mode of emplacement and/or formation. X-ray mineralogic analyses were made on surficial sediment, sedimentary interbeds, and on sedimentary fracture fill to determine the origin of the sediment. Carbonate content and carbon and oxygen-isotope ratios were measured to determine the age and stability of the sedimentary surface.

2.6.2.1 Surficial Sediments. Surficial sedimentary samples were collected from trenches excavated beneath Pit 2 as part of the EWR demonstration. The east wall of Pit 15 was also sampled at approximate 0.3-m (1-ft) intervals to a depth of 5.3 m (17.4 ft). Four samples were collected from Pit 12 at depths of 0.91, 1.22, 1.52, and 1.83 m (3, 4, 5, and 6 ft) and analyzed for particle size distribution, bulk mineralogy, clay mineralogy, carbonate content, and cation-exchange capacity. The analytical results are presented in Tables 3, 4, and 5 in Rightmire and Lewis (1987). Samples collected from Pit 15 were analyzed for carbonate content and for carbon and oxygen isotope content of the carbonate.

The bulk mineralogy of surficial sediments collected from Pit 12, as determined by X-ray diffraction, was predominantly quartz and clay. The predominant particle size of surficial sedimentary material from Pit 12 samples was 0.004 mm (0.00015 in.) (clay size) with a layered silicate (clay) mineralogy. Mixed-layer (illite/smectite) clays and smectites comprised as much as 64% of the clay minerals and as much as 41% of the bulk mineralogy of the sedimentary samples. Clay material had the highest cation exchange capacity. The $CaCO_3$ content ranged from 36 to 62.9% in samples collected at a depth of 1.5 m (5 ft) from Pit 12 and from a 0.7 m (2.3 ft) caliche zone at an approximate depth of 3 m (9.8 ft) from Pit 15, respectively.

Stable isotope analyses (carbon-13 and oxygen-18) were conducted on calcareous surficial sediments from Pit 15. These analyses indicated that the surficial sediment profile to the first basalt represented deposition under cyclic climatic conditions. During periods of dry climate, loess-type material was deposited. Wetter periods [greater than 500 mm (19.6 in.) of precipitation a year] were characterized by leaching of carbonate from soil and disposition of alluvial sediments (Rightmire and Lewis, 1987).

Soil gas samples were collected from a series of probes installed at depths of 30.5, 61, and 76 cm (12, 24, and 30 in.) in the vicinity of the National Oceanic and Atmospheric Administration (NOAA) meteorological station at the Central Facilities Area (CFA) following the method described in Rightmire and Hanshaw (1973). Samples were collected monthly during the growing season (May to October) and at longer intervals thereafter to determine seasonal effects on the carbon dioxide concentration and on the stable isotope content. Gases from the vadose zone were observed to change not only seasonally during growth periods but also with fluctuations in barometric pressure. The stable isotope content of carbon dioxide in soil varied seasonally from atmospheric values during the nongrowing season to values representative of plant root respiration and/or microbial decomposition during periods of higher temperature.

2.6.2.2 Sedimentary Interbeds. Evaluation of archived core from nine boreholes (76-1, 76-2, 76-3, 76-4, 76-5, 76-6, 77-1, and 77-2) confirmed the presence of the major sedimentary interbeds between basalt flows at depths of 9, 34, and 73 m (30, 110, and 240 ft). From their core analyses, the authors concluded that (a) the 9-m (30-ft) interbed thins but is continuous under the RWMC; (b) the thickness of the 34-m (110-ft) interbed is discontinuous under the SDA; and (c) the thickness of the 73-m (240-ft) interbed is irregular [1.3 to 9.5 m (4 to 31 ft)] but continuous under the RWMC. Samples of the sedimentary interbeds from archived core were analyzed for particle-size distribution, bulk mineralogy, and clay mineralogy. A comparison of bulk and clay mineralogy for the surficial sediments and the 9-, 34-, and 73-m (30-, 110-, and 240-ft) interbeds is provided in Table 6 in Rightmire and Lewis (1987) (p. 32). These analyses were compared to previous analyses reported in Barraclough et al. (1976).

Core of sedimentary interbeds from Borehole 76-3 were collected for mineralogic composition and stable isotope content in addition to the analyses described above. Borehole 76-3 was selected for analyses because there was core of all three interbeds and fracture fill material. Bulk mineralogic analyses by X-ray diffraction were done on 12 samples. These analyses indicated that quartz, plagioclase, and clay minerals composed more than 95% of the samples. An additional 31 analyses were done on the 1-mm (0.039-in.) size fraction of samples to determine the clay mineralogy. Illite or mixed layer illite/smectite was identified as the major clay mineral phase in all sedimentary interbed samples. Table 8 of Rightmire and Lewis (1987) summarizes the clay mineral content of sedimentary samples (p. 39). Samples with the highest illite content were collected from the upper meter of the 34- and 73-m (110- and 240-ft) interbeds. Rightmire and Lewis state that the illite formation is probably related to baking by the overlying basalts (Rightmire and Lewis, 1987).

Fractures in the basalts were either open, partially-filled, or completely filled supporting the hypothesis of episodic sedimentation proposed by Rightmire and Lewis (1987). Fractures were filled/lined with sediments with a range of particle sizes from clay to fine sand. Clay-lined, sediment-filled fractures were observed down to the top of the 73-m (240-ft) interbed indicating significant vertical migration of clay-size particles (Rightmire and Lewis, 1987, p. 87). Caliche-lined fractures were observed in underlying basalts where the 34-m (110-ft) interbed was absent. Rightmire and Lewis propose that the caliche formation indicates that the basalt surface was exposed for a geologically significant period of time (Rightmire and Lewis, 1987).

Isotopic analyses were also done on the 31 samples from Borehole 76-3. Oxygen isotope values for the three sedimentary interbeds ranged from +3.38 to +18.11 o/oo indicating a predominance of detrital clays from the same source. However, the oxygen isotope content of clay minerals could be used as evidence of authigenic clay mineral formation or alteration (Rightmire and Lewis, 1987). Fracture-filling/lining clay material had a different isotopic signature indicating a different mode of origin.

2.6.2.3 Precipitation and Ground Water. Samples from precipitation events greater than 1 mm (0.039 in.) were collected at 1104 and 1116 East 21 Street, Idaho Falls, Idaho, (adjacent residences) and analyzed for deuterium and oxygen-18 content. Snow samples were collected on the INEL Site at locations adjacent to USGS Wells 22 and 83 and Site 9 for chemical analysis and to determine the water content. The chemical constituents analyzed for in the snowpack samples are summarized by site in Table 9 of Rightmire and Lewis (1987). These precipitation studies indicated that the major influences on the ground water hydrology were recharge introduced by underflow from tributary stream valleys, recharge from infiltration of snowmelt, and percolation through the vadose zone. The snowmelt waters are in chemical equilibrium with soluble atmospheric gases and have a stable isotope composition expected for meteoric waters.

Perched water samples collected from above the 73-m (240-ft) interbed in Well 92 were analyzed for deuterium and oxygen-18 to determine the source of the perched water. The results showed an anomalously light isotopic content. Rightmire and Lewis suggest that the perched water in Well 92 is related to the ground water in Well 89 based on the stable isotope content (Rightmire and

Lewis, 1987). The ground water in Well 89 is recharged from the diversion ponds located to the west of the RWMC. Perched water observed beneath the RWMC may be introduced into the vadose zone by vertical infiltration of Big Lost River water through the diversion ponds and lateral migration to the RWMC.

2.6.3 Significance for Site Characterization at the RWMC

Rightmire and Lewis proposed the following based on their isotope and chemical data: (a) the source of perched water observed beneath the RWMC is not from vertical infiltration through the ground surface at the RWMC, but instead, it results from lateral flow of water that infiltrated through the diversion ponds; and (b) greater mineralogic alteration can be expected in the 73-m (240-ft) sedimentary interbed (Rightmire and Lewis, 1987). The authors note it is not possible to prove conclusively that the deeper perched water beneath the RWMC is derived from diversion-pond recharge, but they suggest the hydrologic and isotopic data strongly support this hypothesis.

2.7 Hydraulic Characteristics of Soil Cover, Subsurface Disposal Area, Idaho National Engineering Laboratory

2.7.1 Purpose of the Investigation/Report

This investigation was conducted to determine the hydraulic properties of the soil material currently used to recontour and cover buried wastes at the SDA. Specific objectives of the study were (a) to measure saturated hydraulic conductivity, grain size distribution, dry bulk density, and porosity and (b) to determine the horizontal and vertical variations in these hydraulic characteristics. The study focused on the hydraulic properties of the material after it had been applied as backfill to the SDA. The hydraulic conductivity measurements were of particular interest because they are indicative of the relative resistance of the soil cover to moisture penetration by rainfall or snowmelt.

A previous study by Binda examined the physical properties of the geologic deposits used as a source of the soil cover (Binda, 1981). The Binda study examined the hydraulic characteristics of the source area soils before removal, transport, and placement at the SDA.

2.7.2 Summary of the Investigation

The 1988 Borghese study was conducted on a 0.08-km^2 (0.03-mi^2) area located in the southern portion of the SDA that contains more than 35,000 m^3 (45,782 yd^3) of fill and recontouring material from Spreading Areas A, B, C, and D. The sample locations are shown on Figure 5 in Borghese (1988). The study area was selected because the source area for the cover material was proposed as a borrow area for closure (Binda, 1981); all of the cover material in the sampled area was placed in the summer of 1985 and is the same age; and the thickness of the cover material was well established; therefore, inadvertent penetration of buried wastes could be avoided. Thirty locations, approximately 80 m (263 ft) apart, were selected for sampling to provide adequate areal coverage. Only 14 samples were tested because of time constraints and equipment problems.

Samples were collected using thin-walled sampling tubes attached via a drill rig adapter. Sample tube diameters were 5, 7.6, and 12.7 cm (2, 3, and 5 in.). The tubes were pushed into the ground to a depth of 50 cm (19 in.) and then rotated to shear off the bottoms of the samples before they were extracted. The 12.7-cm (5-in.) tubes were used for hydraulic properties testing because the samples were less compacted; therefore, more realistic permeability values could be measured.

The sample cores were subdivided into 10-cm (4-in.) intervals in the laboratory except for 5-cm (2-in.) sections at the top and bottom of the core that were excluded because they may have been altered during collection and/or transport. The 10-cm (4-in.) sample intervals were numbered 1 through 4 from top to bottom (shallowest to deepest). The size and volume of each interval was measured, the depth from land surface was documented, and a sample description was recorded (Appendices A through C of Borghese, 1988, provide this information by sample interval, pp. 53-57).

To measure saturated vertical hydraulic conductivity, the sampling tubes were converted into permeameters; manometers were installed between each 10-cm (4-in.) sample interval. Fluid input and output lines were attached to the sampling tube, leaks were sealed, and the sample was slowly saturated with a deaerated $CaSO_4$-thymol solution mixed with distilled water. This solution was designed to minimize gas dissolution, the stimulation of microbial activity, and the swelling of clays, each of which can significantly decrease the permeability of a soil sample. Once the sample was saturated, the permeameter was used to measure the saturated vertical hydraulic conductivity of each 10-cm (4-in.) interval.

After the hydraulic conductivity testing, the sample intervals were weighed, oven-dried at 115°C (239°F) for 24 hours, and reweighed before grain size distribution analysis. The hardened soil samples were ground in the ball mill for 1 hour and split for sieve analysis. Thirteen sieves were used for the particle size analysis with a range of openings between 0.043 and 25.4 mm (0.0017 and 1 in.). Clay aggregates between 3.35 and 25.4 mm (0.1319 and 1 in.) were removed from the analysis because their inclusion would bias the size distribution to the larger sizes.

Field and laboratory dry bulk densities were determined for the collected samples. Laboratory bulk densities were determined for each 10-cm (4-in.) sample interval, and field bulk densities were determined for the entire collected core sample. Porosity was determined using two methods. Porosity was derived from the ratio of the volume of the voids to the volume of the sample in Method 1. In Method 2, porosity was derived from dry bulk density and particle density. Porosity measurements were lower using Method 1 because this method does not take into account voids that are not fluid filled. Porosities calculated with Method 1 represent the pore space available for fluid flow.

To determine the particle size distributions, the 10-cm (4-in.) intervals in each core sample were averaged. The 13 samples analyzed for grain size contained between 44.3 and 88.7% fine- to medium-grained sand, with the remainder silt. However, because the clay aggregates were neither reground in the ball mill nor reshaken through the sieves, the particle size distributions may underestimate the silt fraction. Grain size distribution graphs are provided in Appendix E (pp. 64-76) of Borghese (1988). Method 1 porosities ranged between 25 to 39% in interval 4 of all samples. The dry laboratory bulk densities ranged from 1.0 to 1.9 g/cm^3. The field bulk densities for six samples ranged from 1.3 to 1.5 g/cm^3 (Appendix F, p. 78, Borghese, 1988). The hydraulic conductivity ranged from 7.0 x 10^{-5} to 1.5 x 10^{-3} cm/s in interval 4 of all tested samples (Table 4, p. 47, Borghese, 1988).

Borghese reported that the results of the study were inconclusive with respect to areal variations in hydraulic characteristics because of the limited number of analyzed samples. The results of the tested samples revealed that there was little vertical variation in the hydraulic properties of the soil cover material in the study area.

2.7.3 Significance for Site Characterization at the RWMC

This study was the first attempt to measure the hydraulic properties of borrow material after placement at the SDA. Previous investigations (Binda, 1981) had focused on the in situ hydraulic characteristics of the soils at the source area. Although Borghese stated results were inconclusive, she summarized that the soil cover was a heterogeneous deposit because of the areal variation in hydraulic conductivity at each sample site and because of the lack of distinct trends in the hydraulic characteristics.

2.8 Stratigraphy of the Unsaturated Zone at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho

2.8.1 Purpose of the Investigation/Report

This report describes the stratigraphy of the vadose zone at the RWMC using geologic data collected from 1971 to 1988. The stratigraphic relationships between basalt flow groups and sedimentary interbeds in the vadose zone and the uppermost portion of the aquifer were refined using a combination of subsurface data. The stratigraphic framework proposed in Anderson and Lewis (1989) is an extension of that described in Barraclough et al. (1976) and in Kuntz et al. (1980).

2.8.2 Summary of the Investigation

Anderson and Lewis (1989) evaluated geologic data from 45 wells and boreholes drilled at the RWMC from 1971 to September 1988 (Table 1, p. 50, summarizes the stratigraphic data by well/borehole). Geologic cross sections, structure and isopach maps and tables were interpreted from well cuttings, cores, geophysical logs, K-Ar (potassium-argon) dates, and geomagnetic properties. Gamma ray logs were used to correlate stratigraphic units described from cores, age determinations, and geomagnetic properties in 5 wells (Kuntz et al., 1980) to 40 other wells at the RWMC. Available lithologic and geophysical logs for these wells and boreholes are provided in Appendix 3-1 of this report.

Twenty basalt lava flows and seven major sedimentary interbeds were defined using the above correlation techniques. The flows were categorized into 10 flow-groups based on their relationship to overlying and underlying sedimentary interbeds. Each flow group is made up of from one to five petrographically similar flows that erupted from common source areas during periods of less than 200 years (Kuntz et al., 1980). The sedimentary interbeds accumulated during periods of volcanic quiescence ranging from thousands to hundreds of thousands of years. Informal alphabetic nomenclature was applied to each of the stratigraphic units following the convention established in Kuntz et al. (1980). Seven flow-groups (A, B, C, D, E, F, and G, shallow to deep) were previously described by Kuntz et al. (1980), and flow groups FG, H, and I were defined in this report. Sedimentary interbeds were referred to as A-B through H-I based on their position relative to the flow groups. For example, sedimentary interbed A-B lies between flow groups A and B. Sedimentary interbeds A-B, B-C, and C-D are typically referred to as the 9-, 34-, and 73-m (30-, 110-, and 240-ft) interbeds, respectively. The stratigraphic top and base, the altitude of the top and base (with respect to sea level), the range in unit thickness, and the number of wells/boreholes penetrating the unit are provided for each flow group and sedimentary interbed.

Eleven structure and seven isopach maps of the flow groups and sedimentary interbeds were generated to illustrate the lateral continuity of the units and to characterize the stratigraphic relationships (Figures 7 through 24, pp. 32-50). The stratigraphic sequence is relatively consistent with alternating volcanic and sedimentary layers. Based on their stratigraphic analysis, Anderson and Lewis (1989) showed that seven basalt flow groups (B, C, D, E, F, G, and I) and three sedimentary interbeds (C-D, F-G, G-H/I) are continuous across the RWMC. The sedimentary layers thicken in localized depressions on the underlying basalt surface. Stratigraphic relationships in the upper 91 m (300 ft) of the vadose zone were better defined than in the zone extending from 91 m (300 ft) to the aquifer because of more shallow borehole control. Only nine wells penetrate the aquifer in this area at an approximate depth of 180 m (600 ft).

2.8.3 Significance for Site Characterization at the RWMC

This report was the first comprehensive evaluation of the subsurface at the RWMC that used an integrated approach to define the vadose zone stratigraphy. The stratigraphy in the upper 91 m (300 ft) of the vadose zone was refined using subsurface data from multiple sources. Anderson and Lewis recognized that the complex stratigraphic relationships in the vadose zone ultimately control the potential for migration of buried waste from the RWMC to the Snake River Plain Aquifer. Detailed mapping of the basalt flow groups and sedimentary interbeds done by Anderson and Lewis will aid in predicting potential contaminant pathways in the vadose zone.

2.9 Hydrogeology and Meteorological Data for an Unsaturated Zone Study Near the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho, 1985-1986

2.9.1 Purpose of the Investigation/Report

This report presents the hydrological and meteorological data collected from 1985 to 1986 for the USGS test trench study. This study was conducted to obtain data for estimating surface water infiltration at the SDA. The data will be used to estimate recharge to the aquifer by quantifying evapotranspiration rates, soil-moisture content and variability, soil-moisture flux, hydraulic conductivities, soil-moisture velocities, and soil temperatures. The data are being used to calibrate a numerical model to predict the migration of radionuclides in the vadose zone.

2.9.2 Summary of the Investigation

Two test trenches were installed in the surficial sediment adjacent to the SDA to collect hydrological data from undisturbed and disturbed soil. Details on the installation and instrumentation of the test trenches are described in Pittman (1989) and in Section 5 of this report. During the study period, soil temperature and soil-water potential measurements were taken in the trenches every 12 hours from 30 sensors placed at selected depths from 0.5 to 6.1 m (1.6 to 20 ft). Weekly soil-moisture content measurements were collected in 9 neutron-probe access holes using a neutron moisture depth gauge. Wind speed, wind direction, relative humidity, and air temperature data were averaged every 6 hours. Solar radiation and precipitation data were collected with an anemometer, wind vane, and a relative and air temperature sensor over the 6-hour intervals.

Soil temperature, soil-water potential, and meteorological data are presented in the report. The findings indicate that the soil-water potentials in the undisturbed soils at the test trench ranged from the sensor detection limit of -1.0 bar to approximately -20.0 bars. Little or no changes in the soil-moisture profiles were observed at depths below 5 m (16.4 ft). The annual precipitation at the RWMC was 240 mm (9.4 in.) in 1986. Data tables are provided in Tables 1 through 19 (pp. 27-157) in Pittman (1989).

2.9.3 Significance for Site Characterization at the RWMC

Pittman (1989) reported that annual precipitation at the SDA is approximately 240 mm (9.4 in.), and that there was little or no change in the soil moisture below 5 m (16.4 ft). These data will be used to calibrate a numerical model of the vadose zone to predict the potential for radionuclide migration from buried wastes.

2.10 FY-89 Report RWMC Vadose Zone Basalt Characterization

2.10.1 Purpose of the Investigation/Report

This investigation was undertaken to collect the detailed information required to develop a three-dimensional subsurface model of the vadose zone basalts underlying the RWMC. The study consisted of three parts: (1) a literature review of the regional geology to provide insight on the paleoenvironment of the RWMC; (2) a petrophysical, petrological, and petrographic evaluation of basalt cores from the vadose zone at the RWMC to characterize and correlate the flows; and (3) surface/near surface statistical flow geometry studies of prospective basalt flow analogues to obtain typical flow lengths, widths, and thicknesses.

2.10.2 Summary of the Investigation

Based on a literature review in combination with subsurface data obtained from boreholes, Knutson et al. (1990) reported that basalt flows at the RWMC were formed by a modified plains style volcanism. The proposed volcanic-sedimentological model is a complex intercalation of basalt flows from vents in rift zones with sedimentary material between the rift zones.

The source vents for Flow Groups A and B (terminology from Anderson and Lewis, 1989) were mapped, and idealized basalt facies were defined based on the proximity to the vent source area. The authors concluded that the subsurface basalt flows at the RWMC were of a medial-to-distal facies, which significantly affects their petrophysical properties.

The unprocessed cores from 15 boreholes (76-2, 76-3, 76-4, 76-4A, 76-6, 77-2, 78-1, 78-2, 78-3, 78-5, 79-1, 79-2, 79-3, 93-A, and 96-A) at the RWMC were evaluated for this study. The broad stratigraphic framework used in Knutson et al. (1990) followed that in Anderson and Lewis (1989), described in Section 2.8 of this report. Flow groups as defined in Anderson and Lewis (1989) are subdivided into flow units on the basis of petrographic characteristics. Flow units are comprised of up to five individual flows that are defined by the presence of flow breaks. The ideal flow consists of four elements: a substratum, a lower vesicular zone, a central nonvesicular zone, and an upper vesicular zone. Petrologic descriptions of the cores are provided in Appendix A of Knutson et al. (1990).

Petrophysical evaluations for porosity, air permeability, density, equilibrium saturation, and pore-size distribution were conducted on selected cores. Permeability, porosity, and density were measured on 8.9-cm (3.5-in.) diameter full-sized cores in the field. Porosity, permeability, and grain density were also measured in 25 x 28-mm (1 x 1.1-in.) plugs cut from representative samples of each flow. Forty-four representative plugs of basalt samples were chosen for capillary pressure, pore-size distribution, and surface area analyses. These evaluations were in progress at the time the report was finalized. Porosity, permeability, grain density, and bulk density data are summarized by flow group, flow unit, and flow elements in Tables 1, 2, 3, and 4 (pp. 31, 37, 44, and 49), respectively, of Knutson et al. (1990). Equilibrium water saturation adsorption data were calculated on 44 basalt plugs from nine boreholes. The results of these analyses are provided in Table 5 (p. 55) of Knutson et al. (1990).

Geostatistical data were collected from the Box Canyon of the Big Lost River and the Hell's Half Acre to facilitate the construction of a three-dimensional model at the RWMC. The Box Canyon study provided data on vertical flow geometry and the Hell's Half Acre study provided data on horizontal flow geometry. These studies indicated that the flow geometries are a complex interfingering of lobes rather than planar stratified. Ratios of length to width to thickness in flows were measured at Box Canyon. Variograms were generated to evaluate kriging results for flow top geometries and flow thickness variations at the RWMC. Although enough geostatistical data at the surface were collected to construct a three-dimensional model at the RWMC by stochastic interpolation, the authors note there is inadequate wellbore (the departure point for the interpolation) quantitative data to make this type of modeling feasible.

2.10.3 Significance for Site Characterization at the RWMC

Knutson et al. (1990) represents the first attempt to characterize the basalts in the vadose zone at the RWMC using site-specific data from previously collected basalt cores. By integrating geostatistical data from surface/near surface studies with petrophysical evaluations of basalt core, the authors were able to develop a preliminary conceptual model to use for predicting the fate of contaminant transport in the vadose zone at the RWMC. The authors note that the lack of a quantitative geophysical suite of log data and the lack of a comprehensive database for subsurface information collected over the past 15 or 20 years significantly impacts the development of a three-dimensional model to be used for subsurface site characterization.

3. Wells and Boreholes

3. WELLS AND BOREHOLES

Wells and boreholes installed on or near the RWMC are summarized in this section. Details on well and borehole construction and instrumentation are presented in tabular form. An overview of drilling programs is provided in Section 3.1, historic drilling programs are described in Section 3.2, a chronology of drilling programs since 1970 is presented in Section 3.3, ongoing studies at the SDA are summarized in Section 3.4, and data limitations are described in Section 3.5.

3.1 Overview of Drilling Programs

At least 10 drilling programs have been conducted at the SDA since its first use in 1952. Some of these programs extended over periods of several years. Early drilling programs were initiated to monitor for the presence of radionuclides in surficial sediments. Later, it became necessary to monitor for radionuclides in the sedimentary interbeds. Recent monitoring programs have been expanded to include volatile organic constituents. A minimum of 74 boreholes and 18 wells have been drilled on or near the RWMC in conjunction with these drilling programs since the early 1950s. Additional wells located north and south of the SDA have been used for regional hydrogeologic evaluation but are not included in the tables in this report.

The terms used in this section and throughout this document are defined as follows:

- Boreholes are distinguished from wells based on their penetrating the aquifer. Boreholes do not penetrate the aquifer; wells do penetrate the aquifer.

- Shallow boreholes extend to the first layer of basalt and generally are auger holes.

- Deep boreholes penetrate the basalt, typically intercepting one or more of the sedimentary interbeds.

Many of the more recent boreholes are instrumented as vadose zone monitoring holes. A few deep boreholes monitor perched water.

The wells and boreholes at the RWMC and surrounding areas are shown on Figures 3-1 and 3-2. Data on these wells and boreholes are presented in a series of tables. Locations and drilling details such as depths of wells and land surface elevations are presented in Table 3-1 together with a summary of available data for each well. Construction details for wells are compiled in Table 3-2. Table 3-3 lists locations, drilling details, and available data for boreholes. Data from borehole investigations before 1970 are not included on the tables in this report although the locations of some of these boreholes are shown on Figure 3-2. Appendix 3-1 contains the available geophysical logs, completion diagrams, lithologic logs, and other data for the wells and boreholes.

Several wells near the RWMC are included in the tables although they are not part of the investigations described in Section 3.2. These include both production wells (i.e., EBR-I, Highway 3, Quaking Aspen Butte, and Rifle Range) and monitoring wells (i.e., USGS Wells 9, 86, 105, 106, and 109) that are either monitored for changes in water level or for water quality by the USGS (Figure 3-1). The RWMC production well is included because it is a drinking water source for the RWMC and is monitored as part of the USGS routine monitoring described in Section 4 of this report. A large number of USGS wells have been drilled on the INEL and surrounding areas to supplement the regional hydrogeologic ground water monitoring network; however, these wells are not included in this report because they are not in the vicinity of the RWMC.

3.2 Historic Drilling Programs at the SDA

Historic drilling programs are those investigations that were conducted before 1970. In 1960, 10 shallow boreholes (numbers 1-10) were installed by the USGS in the surficial sediments at the west end of the SDA in a program administered by the Atomic Energy Commission (AEC)(Figure 3-2). The borehole depths ranged from 3 to 6 m (10 to 20 ft). Subsequently, these shallow

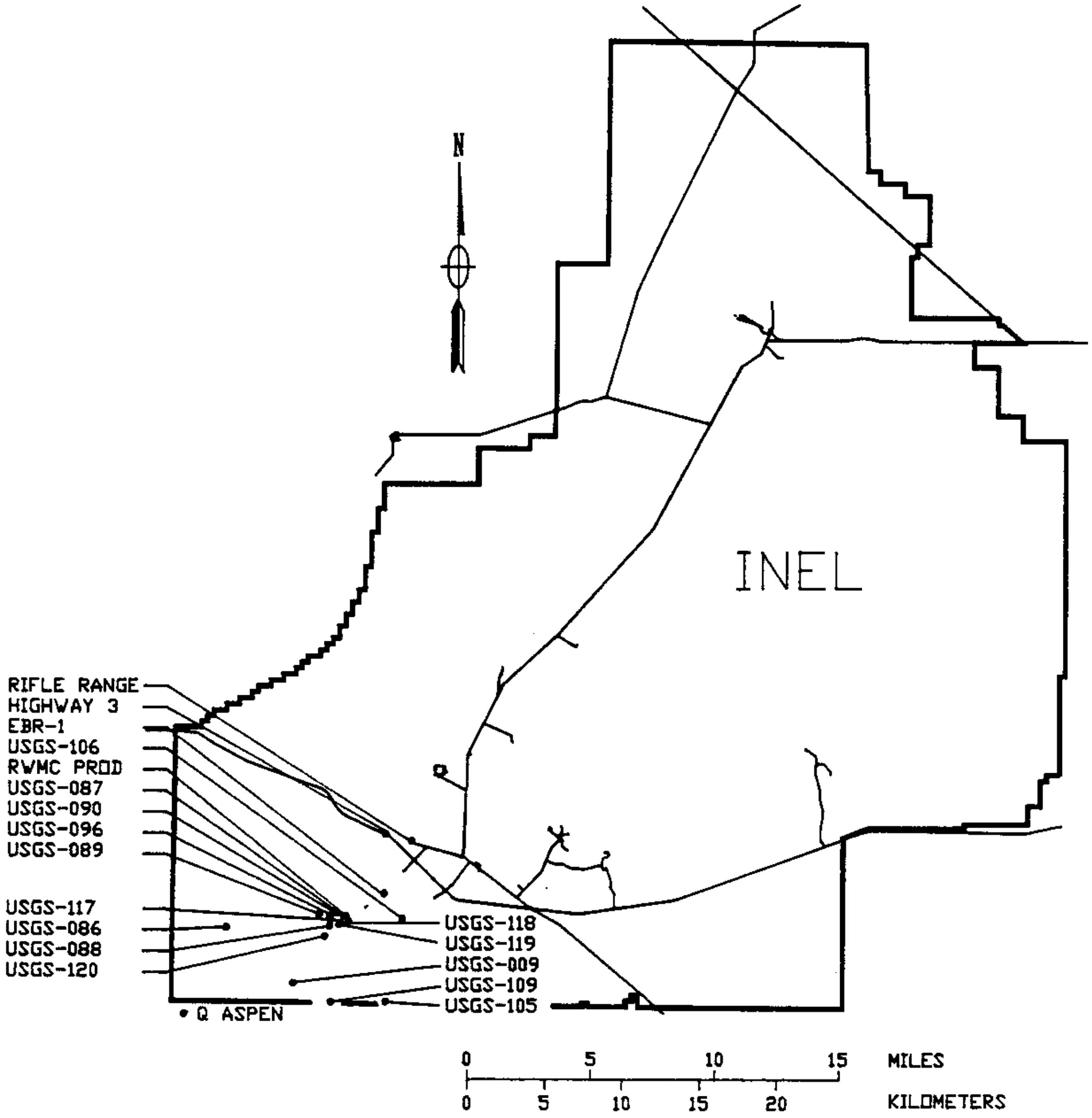


Figure 3-1. Approximate locations of selected wells near the RWMC.

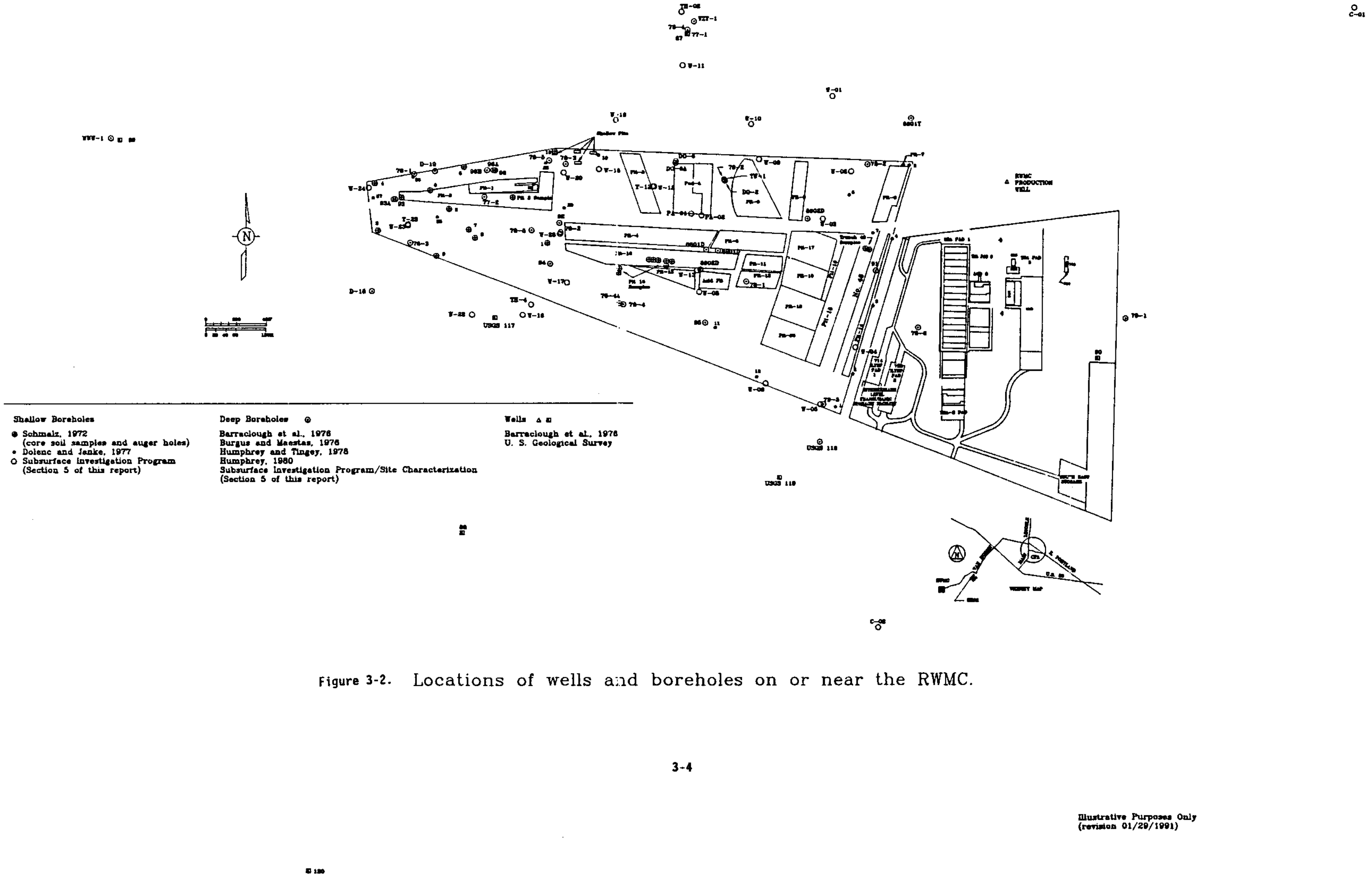


Figure 3-2. Locations of wells and boreholes on or near the RWMC.

Illustrative Purposes Only
(revision 01/29/1991)

Table 3-1. Locations and drilling details for wells on or near the RWMC

Well Name	Northing-Easting (ft) Latitude/Longitude[a]	Contractor Driller	Year Drilled	Well Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Total Depth Below LSD (Elevation) (ft)	Available Data[d]								
							CD	LL	DL	GR	GG	C	N	SS	WQ[e]
EBR-1	N-674,393.00 E-277,055.00 433051/1130026	Schoonover	1949	PD Active	5024.00	1075 (3949.00)	X	X	X					X	I
Highway 3	N-687,160.41 E-277,297.85 433256/1130025	Boley	1967	PD Active	4980.00	750 (4231.00)	X							X	NM
Quaking Aspen Butte	N-648,648.89 E-234,483.64 432632/1130959	McCabe Bros.	1982	PD Active	5190.00	1115 (4075.00)	X	X	X	X	X	X		X	I
Rifle Range	N-685,687.11 E-282,880.92 433243/1125908	Cushman	1988	PD Active	4967.00	625 (4342.00)			X	X		X	X	X	Q
RWMC Production	N-669,648.14 E-268,996.09 433003/1130214		1974	PD Active	5005.00	683 (4322.00)	X	X		X	X	X	X		M
USGS-9	N-655,267.74 E-257,724.53 432740/1130445	Strasser	1950	MW Active	5032.00	654 (4378.00)	X	X		X				X	I
USGS-86	N-667,073.33 E-243,477.99 432935/1130800	Volmer	1966	MW Active	5081.00	691 (4390.00)	X	X		X	X	X		X	Q

Table 3-1. (continued)

Well Name	Northing-Easting (ft) Latitude/ Longitude	Contractor Driller	Year Drilled	Well Type and Status	Land Surface Designation (LSD) (ft)	Total Depth Below LSD (Elevation) (ft)	Available Data								
							CD	LL	DL	GR	GG	C	N	SS	WQ
USGS-87	N-670,620.86 E-266,927.76 433013/1130241	Cushman	1971	MW Active	5016.00	673 (4343.00)	X	X		X	X	X	X	X	Q
USGS-88	N-667,361.44 E-265,429.59 432940/1130302	Cushman	1971	MW Active	5020.00	662 (4358.00)	X	X		X	X	X	X	X	Q
USGS-89	N-669,975.84 E-263,277.48 433005/1130328	Cushman	1972	MW Active	5029.00	646 (4383.00)	X	X	X	X	X	X	X	X	Q
USGS-90	N-668,535.00 E-269,588.18 432954/1130204	Cushman	1972	MW Active	5010.00	626 (4384.00)	X	X	X	X	X	X	X	X	Q
USGS-105	N-651,362.80 E-277,389.90 432703/1130017	Denning	1980	MW Active	5095.00	800 (4295.00)	X	X		X	X	X	X	X	M
USGS-106	N-669,059.70 E-280,997.40 432959/1125930	Denning	1980	MW Active	5015.00	760 (4255.00)	X	X		X	X	X	X	X	M

Table 3-1. (continued)

Well Name	Northing-Easting (ft) Latitude/ Longitude	Contractor Driller	Year Drilled	Well Type and Status	Land Surface Designation (LSD) (ft)	Total Depth Below LSD (Elevation) (ft)	Available Data								
							CD	LL	DL	GR	GG	C	N	SS	WQ
USGS-109	N-651,253.00 E-265,738.60 432701/1130255	Denning	1980	MW Active	5045.00	800 (4245.00)	X	X		X	X	X	X	X	Q
USGS-117	N-668,804.33 E-265,696.33 432955/1130259	McCabe Bros.	1987	MW Active	5012.00	655 (4357.00)	X	X	X	X	X	X	X	X	Q
USGS-118	N-668,000.77 E-267,783.00 432947/1130230	McCabe Bros.	1987	TH	5013.00	570 (4443.00)				X		X		X	NM
USGS-119	N-667,773.87 E-267,521.01 432945/1130234	McCabe Bros.	1987	MW Active	5031.00	705 (4226.00)	X	X	X	X		X	X	X	Q
USGS-120	N-665,248.35 E-264,506.91 432919/1130315	McCabe Bros.	1987	MW Active	5012.00	705 (4307.00)	X	X	X	X	X	X	X	X	Q

Table 3-1. (continued)

---

a. Northing and easting coordinates are based on the State of Idaho coordinate system. Latitude and longitude in degrees, minutes, and seconds. Thus, 432638/1124841 is 43°26'38" 112°48'41". Northing and easting coordinates provided by SAIC, 1990, Idaho Falls, Idaho. Latitude and longitude from USGS site schedules.

b. MW = monitoring well, PD = production well, TH = test hole.

c. Elevations in this table are with respect to mean sea level (MSL) or to the INEL datum 1.29 ft above MSL. Because the datum is typically not defined, reported elevations are assumed to be accurate to ±2 ft. Land surface designation rounded to the nearest foot (unpublished research results of Jaacks et al., SAIC, McLean, Virginia, January, 1990).

d. CD = construction/completion diagram, LL = lithologic log, DL = drillers log, GR = gamma ray log, GG = gamma gamma log, C = caliper log, N = neutron log, SS = USGS site schedule, WQ = water quality data.

e. Frequency of water quality measurements: I = intermittent, M = monthly, Q = quarterly, NM = not monitored (unpublished research results by SAIC, McLean, Virginia, October, 1990).

Table 3-2. Construction details for wells on or near the RWMC

			Casing Construction						Cement Data[d]		Completion Zone			
											Depth (Elevation) (ft)			
Well Name	Land Surface Designation (LSD)[a] (ft)	TD/PBTD[b] Below LSD (Elevation) (ft)	Casing (in.)	Top Below LSD (ft)	Base Below LSD (ft)	Materials[c]	Top Elevation (ft)	Bottom Elevation (ft)	Cemented Intervals Below LSD (ft)	Cement Type and Volume	Top (ft)	Base (ft)	Type	Ref.[e]
EBR-1	5024.00	1075	18	10	750	Steel	5014.00	4274.00	None	None	600	750	Perforated	2,5
		(3949.00)									(4424.00)	(4274.00)	Casing	
											750	1075	open hole	
											(4274.00)	(3949.00)		
Highway 3	4980.00	750	8-5/8	-1.46	680	Steel	4978.50	4300.00	0-30	Backfill	680	750	Open hole	2,3
		(4230.00)							30-35	Cement	(4300.00)	(4230.00)		
Quaking Aspen Butte	5190.00	1115	8	-1	19	Steel	5190.00	5171.00	0-19	Cement	1036	1074	Perforated	2,3
		(4075.00)	6	0	260	PVC	5190.00	4930.00			(4154.00)	(4116.00)	liner	
			5	0	295	Steel	5190.00	4895.00						
			4-1/2	295	1115	Steel	4895.00	4075.00						
RWMC Production	5005.00	683	18	0	108	Steel	5005.00	4897.00	0-108	CTS	590	610	Perforated	2,6
		(4322.00)	14	0	562	Steel	5005.00	4443.00	0-562 (est.)	CTS	(4415.00)	(4395.00)		
			10	0	658	Steel	5005.00	4347.00			625	635	Perforated	
											(4380.00)	(4370.00)		
USGS-9	5032.00	654	8	-2.6	235	Steel	5034.60	4797.00	UNK[f]	UNK	618	650	Perforated	2
		(4378.00)	6-1/4	237	459	Steel	4798.00	4573.00			(4414.00)	(4382.00)		
			6	459	654	Steel	4573.00	4378.00						

Table 3-2. (continued)

			Casing Construction						Cement Data[d]		Completion Zone			
											Depth (Elevation) (ft)			
Well Name	Land Surface Designation (LSD)[a] (ft)	TD/PBTD[b] Below LSD (Elevation) (ft)	Casing (in.)	Top Below LSD (ft)	Base Below LSD (ft)	Materials[c]	Top Elevation (ft)	Bottom Elevation (ft)	Cemented Intervals Below LSD (ft)	Cement Type and Volume	Top (ft)	Base (ft)	Type	Ref.[e]
Rifle Range	4967.00	625/ 620 (4342/ 4347)	8	-1	150	Steel	4968.00	4817.00	0-150	CTS	600 (4367.00)	620 (4347.00)	Perforated	2
			6	-1	310	Steel	4968.00	4657.00						
			5	305	625	Steel	4662.00	4342.00						
USGS-86	5081.00	691 (4390.00)	8	-2	48	Steel	5083.00	5033.00	None	None	48 (5033.00)	691 (4390.00)	Open hole	2
USGS-87[g]	5016.00	673 (4343.00)	10	0	18	Steel	5016.00	4598.00	0-18	CTS	580 (4436.00)	673 (4343.00)	Perforated steel liner	2,3 4
			8	0	375	Steel	5016.00	4641.00	0-374	CTS				
			6	-2.05	585	Steel	5018.05	4431.00	0-585	CTS				
			4	585	673	Steel	4431.00	4343.00						
USGS-88[g]	5020.00	662 (4358.00)	10	0	15	Steel	5020.00	5005.00	0-15	CTS	587 (4433.00)	635 (4385.00)	Perforated steel liner	2,3 4
			8	0	375	Steel	5020.00	4645.00	0-373	CTS				
			6	-1.8	587	Steel	5021.80	4433.00	0-587	CTS				
			4	587	662	Steel	4433.00	4358.00						
USGS-89[g]	5029.00	646 (4383.00)	10	0	24	Steel	5029.00	5005.00	0-24	CTS	573 (4456.00)	646 (4383.00)	Perforated steel liner	2,3 4
			8	0	290	Steel	5029.00	4739.00	0-290	CTS				
			6	-1.6	576	Steel	5030.60	4453.00	0-573	CTS				
			4	573	646	Steel	4456.00	4383.00						

Table 3-2. (continued)

Well Name	Land Surface Designation (LSD)[a] (ft)	TD/PBTD[b] Below LSD (Elevation) (ft)	Casing Construction						Cement Data[d]		Completion Zone			Ref.[e]
											Depth (Elevation) (ft)			
			Casing (in.)	Top Below LSD (ft)	Base Below LSD (ft)	Materials[c]	Top Elevation (ft)	Bottom Elevation (ft)	Cemented Intervals Below LSD (ft)	Cement Type and Volume	Top (ft)	Base (ft)	Type	
USGS-90[g]	5010.00	626	10	0	24	Steel	5010.00	4986.00	0-24	CTS	577	626	Perforated	2,3
		(4384.00)	8	0	300	Steel	5010.00	4710.00	0-300	CTS	(4433.00)	(4387.00)	steel liner	4
			6	-2.2	580	Steel	5012.20	4430.00	0-580	CTS				
			4	577	626	Steel	4433.00	4384.00						
USGS-105	5095.00	800	12	0	10	Steel	5095.00	5085.00	0-10	CTS	400	800	Open hole	2,7
		(4295.00)	8	0	400	Steel	5095.00	4695.00	0-30	CTS	(4695.00)	(4295.00)		
USGS-106	5015.00	760	12	0	10	Steel	5015.00	5005.00	0-10	CTS	400	760	8" and 10" Open	2,7
		(4255.00)	8	0	400	Steel	5015.00	4615.00	0-40	CTS	(4613.00)	(4255.00)	hole	
USGS-109	5045.00	800	12	0	10	Steel	5045.00	5035.00	0-10	CTS	600	800	4" Casing	2,7
		(4245.00)	8	0	175 (182)	Steel	5045.00	4870.00	0--25	CTS	(4445.00)	(4245.00)	Perforated	
			6	175	340	Steel	4870.00	4705.00						
			4	0	800	Steel	5045.00	4245.00						
USGS-117	5012.00	655	10-3/4	0	261	Steel	5012.00	4751.00	0-20	CTS	550	655	Perforated	2,3
		(4357.00)	8-5/8	-2	553.2	Steel	5014.00	4458.80	450-585	5 yds	(4462.00)	(4357.00)	steel liner	
			6-5/8	550	653	SS	4462.00	4359.00		EC grout				
USGS-118	5013.00	570/	6	-2	223	Steel	5015.00	4790.00	UNK	UNK	223	570	Open hole	1,2
		550									(4790.00)	(4443.00)		
		(4443/												
		4463)												

Table 3-2. (continued)

			Casing Construction						Cement Data[d]		Completion Zone			
											Depth (Elevation) (ft)			
Well Name	Land Surface Designation (LSD)[a] (ft)	TD/PBTD[b] Below LSD (Elevation) (ft)	Casing (in.)	Top Below LSD (ft)	Base Below LSD (ft)	Materials[c]	Top Elevation (ft)	Bottom Elevation (ft)	Cemented Intervals Below LSD (ft)	Cement Type and Volume	Top (ft)	Base (ft)	Type	Ref.[e]
USGS-119	5031.00	705	10-3/4	0	275.5	Steel	5031.00	4755.50	0-20	CTS	639	705	Perforated	2,3
		(4326.00)	8-5/8	-2	584	Steel	5033.00	4447.00	400-540	8 yds	(4392.00)	(4326.00)	steel liner	
			6-5/8	573	705	SS	4458.00	4326.00		EC grout				
USGS-120	5012.00	705	10-3/4	0	294	Steel	5012.00	4718.00	0-20	CTS	638	705	Perforated	2,3
		(4307.00)	8-5/8	-2	587	Steel	5014.00	4425.00	400-585	9 yds	(4374.00)	(4307.00)	steel liner	
			6-5/8	574.2	705	SS	4437.80	4307.00		EC grout				

---

a. Elevations in this table are with respect to mean sea level (MSL) or to the INEL datum 1.29 ft above MSL. Because the datum is typically not defined, reported elevations are assumed to be accurate to +2 ft. Land surface designation rounded to the nearest foot provided by SAIC, 1990, Idaho Falls, Idaho.

b. TD/PBTD: total depth of well/plugged back total depth.

c. Materials of construction. Steel = carbon steel, SS = stainless steel, PVC = PVC plastic.

d. Cement data. CTS = cemented-to-surface, EC = expanding cement.

e. 1. Field Notes (see Appendix 3-I) 2. Unpublished research results of SAIC, McLean, Virginia, October, 1990 3. USGS Site Schedule
4. Barraclough et al. (1976) 5. Nace et al. (1956) 6. Goldstein and Weight (1982) 7. Lewis and Goldstein (1982)

f. UNK = unknown.

g. Casing strings pressure cemented in place from casing shoe to surface (Barraclough et al., 1976).

Table 3-3. Locations and drilling details for boreholes on or near the RWMC

Borehole Number	Northing-Easting (ft) Latitude/ Longitude[a]	Contractor Driller	Year Drilled	Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD[d] Depth Below LSD (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e] CR	LL	CD	GL	GR	GG	C	N	Ref.[f]
76-1	N-669,749.00 E-265,187.20 433003/1130303	McCabe Brothers	1976	P&A Cemented to surface	5009.10	228.30 (4780.80)	8 6 4-3/4	0 - 15.8 15.8 - 85 85 - 228.3	10.0	6-1/2/Carbon steel	X	X	X		X	X		X	2,8
76-2	N-669,353.00 E-266,110.40 432960/1130253	McCabe Brothers	1976	P&A Cemented to surface	5010.50	252.50 (4758.00)	8 6 4-3/4	0 - 15.5 15.5 - 85 85 - 252.5	13.0	6-1/2/Carbon steel	X	X	X		X	X		X	2,8
76-3	N-669,286.40 E-265,160.90 432959/1130306	McCabe Brothers	1976	P&A Cemented to surface	5009.60	240.40 (4769.20)	8 6 4-7/8	0 - 22 22 - 120 120 - 240.4	~20.0	6-1/2/Carbon steel	X	X	X		X	X		X	2,8
76-4	N-668,889.31 E-266,520.19 432955/1130248	McCabe Brothers	1976	P&A Cemented to surface	5010.60	241.06/ 215.00 (4763.60/ 4795.60)	8 6 4-7/8	0 - 10.8 10.8 - 114.5 114.5 - 215	8.8	6-1/2/Carbon steel	X	X	X		X	X		X	2,8
76-4A	N-668,896.10 E-266,495.10 432956/1130248	McCabe Brothers	1976	P&A Cemented to surface	5010.90	254.00 (4756.90)	8 6 4-7/8	0 - 11.2 11.2 - 101.2 101.2 - 254	8.2	6-1/2/Carbon steel	X	X	X		X	X		X	2,8
76-5	N-669,810.70 E-266,045.00 433004/1130254	McCabe Brothers	1976	VZ Open	5011.40	245.00 (4766.40)	8 6 4-7/8	0 - 9.4 9.4 - 123 123 - 245	9.4	6-1/2/Carbon steel	X	X	X		X	X		X	2,8
76-6	N-668,734.00 E-268,425.50 432954/1130222	McCabe Brothers	1976	P&A Cemented to surface	5011.20	243.80/ 240.00 (4767.40/ 4771.20)	8 6 4-7/8	0 - 9.1 9.1 - 90 90 - 243.8	6.8	6-1/2/Carbon steel	X	X	X		X	X		X	2,8

Table 3-3. (continued)

Borehole Number	Northing-Easting (ft) Latitude/Longitude[a]	Contractor Driller	Year Drilled	Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD[d] Depth Below LSD (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e] CR	LL	CD	GL	GR	GG	C	N	Ref.[f]
77-1	N-670,620.80 E-266,927.80 433013/1130242	McCabe Brothers	1977	VVED Instrumented with gas ports	5016.90	600.00/ 385.00 (4416.90/ 4631.90)	8 6 5 4 3	0 - 4.7 4.7 - 60 60 - 259 259 - 489 489 - 600	4.7	6-1/2/Carbon steel	X	X	ID[h]		X	X		X	2,8
77-2	N-669,579.40 E-265,632.60 433002/1130259	McCabe Brothers	1977	PW	5014.40	87.40 (4927.00)	4-7/8	0 - 87.4	16.8	3/PVC pipe	X		X						2,8
78-1	N-669,032.90 E-267,306.00 432957/1130237	McCabe Brothers	1978	PW	5010.00	82.50/ 78.00 (4927.50/ 4932.00)	8 6 3	0 - 18.8 0 - 18.8 0 - 82.0	18.8 18.8 82.0	8/Carbon steel 6/Carbon steel 3/PVC pipe	X		X						2,7
78-2	N-669,781.70 E-268,098.90 433004/1130226	McCabe Brothers	1978	P&A Cemented to surface	5007.00	253.00/ 234.00 (4754.00/ 4773.00)	8 6 5	0 - 5 5 - 104 104 - 253	5.0	6-1/2/Carbon steel	X	X	X		X	X		X	2,7
78-3	N-669,787.60 E-266,151.10 433004/1130253	McCabe Brothers	1978	P&A Cemented to surface	5011.00	248.00/ 160.00 (4763.00/ 4851.00)	8 6	0 - 5 5 - 248	5.0	6-1/2/Carbon steel	X	X	X		X	X		X	2,7
78-4	N-670,648.60 E-266,930.30 433013/1130242	McCabe Brothers	1978	VVED Instrumented with gas ports	5018.00	350.00/ 343.00 (4668.00/ 4675.00)	UNK[g]	UNK	UNK	UNK		X	ID		X				2,7

Table 3-3. (continued)

Borehole Number	Northing-Easting (ft) Latitude/ Longitude[a]	Contractor Driller	Year Drilled		Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD[d] Depth Below LSD (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e]								Ref.[f]
												CR	LL	CD	GL	GR	GG	C	N	
78-5	N-669,365.00 E-265,931.00	McCabe Brothers	1978		P&A Cemented to surface	5010.00	252.00/ 227.00 (4758.00/ 4783.00)	8 6 5	0 - 22 22 - 129 129 - 252	12.0	6-1/2/Carbon steel	X	X	X	X	X	X		X	2,7
79-1	N-668,789.40 E-269,768.30 432955/1130204	McCabe Brothers	1979		P&A Cemented to surface	5018.00	245.50/ 240.00 (4772.57/ 4778.00)	8 6 5 4-3/4	0 - 4.8 4.8 - 203.4 203.4 - 237. 237.5 - 245.	4.8	6-1/2/Carbon steel	X	X	X	X	X	X			1,2
79-2	N-669,689.50 E-267,160.50 433003/1130239	McCabe Brothers	1979	VZ	Open, has blind metal flange cap, drill string in bottom (5-10')	5011.00	223.00/ 219.00 (4788.09/ 4792.00)	8 6 5	0 - 19.6 19.6 - 106.6 106.6 - 223	19.6(?)	6-1/2/Carbon steel	X	X	X	X	X	X		X	2
79-3	N-668,243.00 E-267,806.70 432949/1130230	McCabe Brothers	1979		P&A Cemented to surface	5008.00	262.00/ 257.00 (4746.00/ 4751.00)	8 6 5	0 - ~ 16.4 ~16.4 - ~235 ~235 - 262	16.40	6-1/2/Carbon steel	X	X	X	X	X	X			2,3
USGS-91	N-669,100.00 E-268,150.00 432957/1130225	Cushman	1972		P&A Cemented to surface	5006.50	255.25 (4751.25)	6 5 4 3-1/2	0 - 14.5 14.5 - 117 117 - 135.6 135.6 - 255.	None	Casing pulled		X	X		X	X	X	X	2,3
USGS-92	N-669,411.20 E-266,109.50 433000/1130253	Cushman	1972		PW Sealed with threaded plug	5007.70	247.90/ 213.50 (4759.80/ 4794.20)	6 5 3-1/4	0 - 19.25 19.25 - 190 190 - 247.9	19.25	6/Carbon steel									2,3

Table 3-3. (continued)

Borehole Number	Northing-Easting (ft) $ Latitude/Longitude[a]	Contractor Driller	Year Drilled	Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD[d] Depth Below LSD (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e]								Ref.[f]
											CR	LL	CD	GL	GR	GG	C	N	
USGS-93	N-669,566.20 E-265,066.80 433000/1113030	Cushman(?)	1972	P&A Cemented to surface	5010.60	246.25 (4764.35)	6 3-1/4	0 - 90.3 90.3 - 246.2	None	Casing pulled		X	X		X	X	X	X	2,3
USGS-94	N-669,150.00 E-266,050.00 432958/1130254	Cushman(?)	1972	P&A Cemented to surface	5008.20	302.25 (4705.95)	4	0 - 16.25 16.25 - 302.	None	Casing pulled		X	X		X	X	X	X	2,3
USGS-95	N-668,770.30 E-267,037.70 432954/1130240	Cushman	1972	P&A Cemented to surface	5007.20	246.25 (4761.25)	6 3-1/4	0 - 113.3 113.3 - 246.	None	Casing pulled		X	X		X	X	X	X	2,3
USGS-96	N-669,750.00 E-265,387.00 433004/1130258	Cushman	1972	P&A Cemented to surface	5009.50	236.25 (4773.25)	5 3-1/4	0 - 120.3 120.3 - 236.	None	Casing pulled		X	X		X	X	X	X	2,3
W01[i]	N-670,219.20 E-267,879.90 433009/1130230	Hawley Brothers	1985	VZ Auger Hole Instrumented	5008.60	7.74 (5000.86)	10 7-1/8	0 - 1.5 1.5 - 7.74	1.5	8/Carbon steel (Schedule 40)	X		ID[h]	X					2,5
W02[i]	N-669,736.20 E-267,991.00 433004/1130228	Hawley Brothers	1985	VZ Auger Hole Instrumented	5006.80	14.67 (4992.10)	10 7-1/8	0 - 2.0 2.0 - 14.67	2.0	8/Carbon steel (Schedule 40)	X	X	ID						2,5
W03[i]	N-669,434.40 E-267,805.20 433001/1130230	Hawley Brothers	1985	VZ Auger Hole Instrumented	5007.20	10.90 (4996.30)	10 7-1/8	0 - 1.2 1.2 - 11.72	1.2	8/Carbon steel (Schedule 40)	X	X	ID	X					2,5

Table 3-3. (continued)

Borehole Number	Northing-Easting (ft) Latitude/Longitude[a]	Contractor Driller	Year Drilled	Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD[d] Depth Below LSD (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e]								Ref.[f]
											CR	LL	CD	GL	GR	GG	C	N	
W04[i]	N-668,607.80 E-268,016.40 432953/1130227	Hawley Brothers	1985	VZ Auger Hole Instrumented	5010.40	24.90 (4985.50)	10 7-1/8	0 - 1.9 1.9 - 24.90	1.9	8/Carbon steel (Schedule 40)	X	X	ID[h]						5
W05[i]	N-668,241.70 E-267,786.50 432949/113020	Hawley Brothers	1986	VZ Auger Hole Instrumented	5010.00	16.00 (4994.64)	10 7-1/8	0 - 2.0 2.0 - 16.0	2.0	8/Carbon steel (Schedule 40)	X	X	ID						6
W06[i]	N-668,378.20 E-267,431.60 432950/1130235	Hawley Brothers	1986	VZ Auger Hole Instrumented	5009.60	11.83 (4998.37)	10 7-1/8	0 - 2.0 2.0 - 11.83	2.0	8/Carbon steel (Schedule 40)	X	X	ID						2,5
W08[i]	N-668,966.90 E-266,999.40 432956/1130241	Hawley Brothers	1985	VZ Auger Hole Instrumented	5011.50	22.24 (4989.30)	10 7-1/8	0 - 1.5 1.5 - 22.24	1.5	8/Carbon steel (Schedule 40)	X	X	ID						2,4
W09[i]	N-669,816.50 E-267,391.20 433005/1130236	Hawley Brothers	1986	VZ Auger Hole Instrumented	5008.80	14.83 (4994.00)	10 7-1/8	0 - 2.2 2.2 - 14.83	2.2	8/Carbon steel (Schedule 40)	X	X	ID						2,5
W10[i]	N-670,043.50 E-267,340.30 433007/1130237	Hawley Brothers	1985	VZ Auger Hole Instrumented	5006.80	10.33 (4996.50)	10 7-1/8	0 - 1.5 1.5 - 10.33	1.5	8/Carbon steel (Schedule 40)	X	X	ID						5
W11[i]	N-670,421.40 E-266,898.10 433011/1130243	Hawley Brothers	1986	VZ Auger Hole Instrumented	5010.10	16.50 (4993.60)	10 7-1/8	0 - 2.0 2.0 - 16.5	2.0	8/Carbon steel (Schedule 40)	X	X	ID						6

Table 3-3. (continued)

Borehole Number	Northing-Easting (ft) Latitude/Longitude[a]	Contractor Driller	Year Drilled	Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD[d] Depth Below LSD (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e] CR	LL	CD	GL	GR	GG	C	N	Ref.[f]
W12[i]	N-669,645.00 E-266,716.30 433003/1130245	Hawley Brothers	1985	VZ Auger Hole Instrumented	5013.60	4.17 (5009.40)	10 7-1/8	0 - 2.0 2.0 - 4.17	2.0	8/Carbon steel (Schedule 40)	X	X	ID[h]						5
W13[i]	N-669,105.20 E-266,986.00 432958/1130241	Hawley Brothers	1986	VZ Auger Hole Instrumented	5013.40	17.91 (4995.50)	10 7-1/8	0 - 2.0 2.0 - 17.91	2.0	8/Carbon steel (Schedule 40)	X	X	ID	X					6
W16[i]	N-668,821.30 E-265,873.50 432955/1130257	Hawley Brothers	1985	VZ Auger Hole Instrumented	5012.20	5.00 (5007.20)	10 7-1/8	0 - 2.0 2.0 - 5.0	2.0	8/Carbon steel (Schedule 40)	X	X	ID	X					5
W17[i]	N-669,028.70 E-266,158.50 432957/1130253	Hawley Brothers	1986	VZ Auger Hole Instrumented	5013.50	20.41 (4993.09)	10 7-1/8	0 - 2.0 2.0 - 20.41	2.0	8/Carbon steel (Schedule 40)	X	X	ID	X					6
W18[i]	N-669,755.20 E-266,363.60 433004/1130250	Hawley Brothers	1986	VZ Auger Hole Instrumented	5011.00	16.41 (4994.60)	10 7-1/8	0 - 2.0 2.0 - 16.41	2.0	8/Carbon steel (Schedule 40)	X	X	ID						6
W19[i]	N-670,071.00 E-266,474.10 433007/1130248	Hawley Brothers	1985	VZ Auger Hole Instrumented	5009.20	16.77 (4992.43)	10 7-1/8	0 - 2.0 2.0 - 16.77	2.0	8/Carbon steel (Schedule 40)	X	X	ID						5
W20[i]	N-669,733.60 E-266,138.00 433004/1130253	Hawley Brothers	1985	VZ Auger Hole Instrumented	5010.40	7.68 (5002.72)	10 7-1/8	0 - 2.0 2.0 - 7.68	2.0	8/Carbon steel (Schedule 40)	X	X	ID						5

Table 3-3. (continued)

Borehole Number	Northing-Easting (ft) Latitude/Longitude[a]	Contractor Driller	Year Drilled	Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD Depth Below LSD[d] (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e]								Ref.[f]
											CR	LL	CD	GL	GR	GG	C	N	
W22[i]	N-668,824.00 E-265,553.60 432955/1130301	Hawley Brothers	1985	VZ Auger Hole Instrumented	5011.00	8.92 (5002.08)	10 7-1/8	0 - 2.0 2.0 - 8.92	2.0	8/Carbon steel (Schedule 40)	X	X	ID						2,5
W23[i]	N-669,397.70 E-265,147.80 433000/1130320	Hawley Brothers	1985	VZ Auger Hole Instrumented	5012.30	19.85 (4992.45)	10 7-1/8	0 - 2.0 2.0 - 19.85	2.0	8/Carbon steel (Schedule 40)	X	X	ID						2,5
W24[i]	N-669,639.00 E-264,897.70 433003/1130310	Hawley Brothers	1986	VZ Auger Hole Instrumented	5012.00	9.58 (5002.42)	10 7-1/8	0 - 2.0 2.0 - 9.58	2.0	8/Carbon steel (Schedule 40)	X	X	ID						2,6
W25[i]	N-669,341.50 E-266,113.60 432960/1130253	Hawley Brothers	1986	VZ Auger Hole Instrumented	5010.90	15.50 (4995.40)	10 7-1/8	0 - 2.0 2.0 - 15.5	2.0	8/Carbon steel (Schedule 40)	X	X	ID						2,6
T12[i]	N-669,643.90 E-266,707.10 433002/1130245	Hawley Brothers	1985	VZ Auger Hole Instrumented	5013.90	5.00 (5008.90)	10 7-1/8	0 - 2.0 2.0 - 5.0	2.0	8/Carbon steel (Schedule 40)	X	X	ID						2,5
T23[i]	N-669,406.30 E-265,147.00 430001/130306	Hawley Brothers	1985	VZ Auger Hole Instrumented	5012.00	19.91 (4992.09)	10 7-1/8	0 - 2.0 2.0 - 19.91	2.0	8/Carbon steel (Schedule 40)	X	X	ID						2,6
C01[i]	N-670,774.40 E-271,231.40 433015/1130144	Hawley Brothers	1986	VZ Auger Hole Instrumented	5002.00	19.20 (4982.80)	10 7-1/8	0 - 2.0 2.0 - 19.20	2.0	8/Carbon steel (Schedule 40)	X	X	ID	X					2,5

Table 3-3. (continued)

Borehole Number	Northing-Easting (ft) Latitude/Longitude[a]	Contractor Driller	Year Drilled	Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD[d] Depth Below LSD (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e]								Ref.[f]
											CR	LL	CD	GL	GR	GG	C	N	
C02[i]	N-666,807.20 E-268,164.30 432935/1130225	Hawley Brothers	1985	VZ Auger Hole Instrumented	5033.20	5.41 (5027.79)	10 7-1/8	0 - 2.0 2.0 - 5.41	2.0	8/Carbon steel (Schedule 40)	X	X	ID[h]	X					2,5
D02[i]	N-669,678.80 E-267,168.00 433003/1130239	Hawley Brothers	1986	VVED Instrumented with gas ports	5012.00	243.00/ 235.20 (4769.00/ 4776.80)	12 7 6	0 - 23 23 - 104 104 - 235.2	23.0	11-7/8/Carbon steel 6/Casing pulled	X	X	X	X	X	X	X	X	2,9
D06	N-669,806.20 E-266,853.50 433004/1130243	Hawley Brothers	1986	VZ Instrumented	5012.10	126.42 (4885.68)	12 6-1/2	0 - 15 15 - 126.42	15.0	10/Carbon steel	X	X	ID	X	X	X		X	2,6
D06A	N-669,795.00 E-266,850.50 433004/1130025	Hawley Brothers	1986	TH Active, sealed at surface	5012.00	49.66 (4962.34)	12 3-5/8	0 - ~7 ~7 - 49.66	UNK	Carbon steel	X	X	X		X	X		X	2,6
D10	N-669,746.80 E-264,320.90 433004/1130318	Hawley Brothers	1987/ 1989	VZ Sealed at surface Not instrumented to date	5014.00	238.50 (4775.5)	7-7/8 5-7/8	0 - 234 234 - 238.50	220.00	6/Carbon steel	X		X	X	X	X	X	X	1,2
D15	N-668,975.90 E-264,915.80 432956/1130309	Hawley Brothers	1987	VZ Instrumented	5011.00	243.00 (4768.00)	11-1/4 9-7/8 7-7/8 5-7/8	0 - 6.4 6.4 - 106 106 - 125 125 - 243	6.4	11-1/4/Carbon steel	X	X	ID	X	X	X		X	2,9

Table 3-3. (continued)

Borehole Number	Northing-Easting (ft) Latitude/Longitude[a]	Contractor Driller	Year Drilled	Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD[d] Depth Below LSD (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e]								Ref.[f]
											CR	LL	CD	GL	GR	GG	C	N	
TW1	N-669,686.60 E-267,167.00 433003/1130239	Hawley Brothers	1985	VZ Instrumented	5011.30	240.00 (4772.63)	11-7/8 7-7/8 5-7/8	0 - 20 20 - 110 110 - 240	18.0	Carbon steel	X	X	ID[h]	X	X	X		X	2,9
PA01	N-669,469.50 E-266,949.50 433001/1130242	Hawley Brothers	1985	VZ Auger Hole instrumented	5008.80	14.67 (4994.13)	10 5-7/8 7-1/8	0 - 2.0 2.0 - 14.67	2.0	8/Carbon steel	X	X	ID	X					2,5
PA02	N-669,469.50 E-266,949.60 433001/1130242	Hawley Brothers	1985	VZ Auger Hole Instrumented	5008.80	14.67 (5002.24)	10 7-1/8	0 - 2.0 2.0 - 14.67	2.0	8/Carbon steel	X	X	ID	X					2,5
TH01	N-670,763.80 E-266,891.40 433014/1130243	Hawley Brothers	1985	P&A Backfilled to surface	~5017	5.91 (5011.09)	7-1/8	0 - 5.91	~2.0	Carbon steel	X	X		X					2,5
TH02	N-670,763.80 E-266,891.30 433014/1130243	Hawley Brothers	1985	VZ Auger Hole Instrumented	5016.60	6.13 (5010.47)	10 7-1/8	0 - 6.13	1.0	8/Carbon steel	X		ID	X					2,5
TH03	N-670,763.80 E-266,891.40 433014/1130243	Hawley Brothers	1985	P&A Backfilled to surface	~5017	5.03 (5011.97)	7-1/8	0 - 5.03	None	None	X	X	X						2,5
TH04	N-668,888.10 E-265,927.40 432955/1130309	Hand Augered	1985	VZ Auger Hole Instrumented	5010.00	11.15 (4998.85)	3	0 - 11.15	~2.0	8/Carbon steel	X	X	ID						2,5

Table 3-3. (continued)

Borehole Number	Northing-Easting (ft) Latitude/Longitude[a]	Contractor Driller	Year Drilled	Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD[d] Depth Below LSD (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e] CR	LL	CD	GL	GR	GG	C	N	Ref.[f]
TH05[j]	N-670,075.60 E-266,482.10 433007/1130248	Hawley Brothers	1986	VZ Auger Hole Instrumented	5009.80	15.58 (4994.22)	10 7	0 - 2.0 2.0 - 15.58	2.0	8/Carbon steel	X		ID	X					2
8801D	N-669,237.60 E-267,045.90 432959/1130240	Hawley Brothers	1988	VVED Instrumented with gas ports	5014.80	244.70/ 231.00 (4770.10/ 4783.80)	12-1/4 7-7/8 5-7/8	0 - 30.6 30.6 - 110 110 - 240	22.5 30.6	10/Carbon steel 8/Carbon steel	X	X	ID		X	X		X	1,2
8802D	N-669,434.60 E-267,706.10 433001/1130232	Hawley Brothers	1989/ 1988	PW	5009.00	221.00 (4879.16)	12-1/4 7-7/8 5-7/8	0 - 10.7 10.7 - 107 107 - 221	10.7 107.0 210.6	10/Carbon steel 6/Carbon steel 2/SS 210.6 - 220.6 SS wire-wrapped screen	X	X	X	X	X	X		X	1,2
8901D	N-669,231.10 E-267,120.30 432959/1130240	Denning	1989	VVED Extraction Well	5014.90	249.00/ 241.00 (4765.90/ 4773.90)	18.0 11-7/8 9-7/8 7-7/8 5-7/8	0 - 23.1 23.1 - 29 29 - 90 89 - 220 220 - 241	23.1 0 - 29 0 - 89 68 - 241	12/Carbon steel 10/Carbon steel 8/Carbon steel 4/Slotted stainless steel			X	X	X	X	X	X	1,2
8902D	N-669,111.92 E267,007.29	Denning	1990	VVED Instrumented with gas ports	5013.00	245.00 (4775.06)	9-7/8 8	0 - ~18 0 - 24.5	17.8 24.4	10/Carbon steel 8/Carbon steel		X	ID	X	X	X	X	X	1,2

Table 3-3. (continued)

Borehole Number	Northing-Easting (ft) Latitude/ Longitude[a]	Contractor/ Driller	Year Drilled	Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD[d] Depth Below LSD (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e]								Ref.[f]
											CR	LL	CD	GL	GR	GG	C	N	
8801T[j]	N-670,078.00 E-268,382.90 433007/1130222	Hawley Brothers	1988	TW	5010.00	50.60 (4459.40)	12-1/4 5-7/8	0 - 14.4 14.4 - 50.7	14.4	Carbon steel									1,2
NA-89-1[j]	N-669,015.51 E-259,865.52 432956/1130418	USGS	1989	VZ Open	UNK	238.00	3-1/4	0 - 238	238	Carbon steel					X	X		X	
NA-89-2[j]	N-674,104.40 E-257,488.80 433046/1130451	USGS	1989	VZ Open	UNK	235.00	3-1/4	0 - 235	235	Carbon steel				X	X	X		X	
NA-89-3[j]	N-665,118.90 E-264,394.30 432911/8113031	USGS	1989	VZ Open	UNK	182.00	3-1/4	0 - 182	182	Carbon steel					X	X		X	
93A	N-669,566.00 E-265,056.00	McCabe Brothers	1975	P&A cemented to surface	5010.00	233.20 (4776.84)	6-1/2	0 - 18.1 18.1 - 112 112 - 233.2		Casing pulled	X	X	X		X	X		X	4
96A	N-669,750.00 E-265,377.20	McCabe Brothers	1975	P&A cemented to surface	5007.00	120.00 (4887.00)	NG	NG		Carbon steel	X		X	X					4
96B	N-669,753.80 E-265,337.20 433004/1130304	McCabe Brothers	1975	P&A cemented to surface	5009.00	229.00 (4780.00)	6-1/2 6 5	0 - 20 20 - 125 125 - 229		Casing pulled	X	X	X		X	X		X	4

Table 3-3. (continued)

Borehole Number	Northing-Easting (ft) Latitude/Longitude[a]	Contractor Driller	Year Drilled	Borehole Type and Status[b]	Land Surface Designation (LSD)[c] (ft)	Borehole TD/PBTD[d] Depth Below LSD (Elevation) (ft)	Borehole Diameter (in.)	Depth Below LSD (ft)	Surface Casing Depth Below LSD (ft)	Casing Diameter (in.)/ Materials of Construction	Available Data[e] CR	LL	CD	GL	GR	GG	C	N	Ref.[f]
VZT-01[i]	N-670,770.90 E-266,970.70 433013/1130242	Pemberton	1988	VZ Open	5018.00	134.00 (4884.00)	UNK	UNK	UNK	UNK					X	X	X	X	2
WW-1[j]	N-669,960.60 E-263,200.00 433006/1130333	Pemberton	1985	VVED Instrumented with gas ports	5029.00	259.00 (4770.00)	5-7/8	UNK	UNK	UNK		X	X						2

---

a. Northing and easting coordinates are based on the State of Idaho coordinate system. Latitude and longitude in degrees, minutes and seconds. Thus, 432638/1124741 is 43°26'38" 112°48'41". Personal communication between Lee Kaschmitter, EG&G Idaho, Inc., Idaho Falls, and Patti Swain, SAIC, McLean, Virginia, September 19, 1990.

b. VVED = vapor vacuum extraction demonstration monitoring borehole, PW = perched water monitoring borehole, P&A = plugged and abandoned, VZ = vadose zone monitoring borehole, TH = test hole, TW = test well.

c. Elevations in this table are with respect to MSL or to the INEL vertical datum 1.29 ft above MSL. Because the datum is typically not defined, reported elevations are assumed to be accurate to ±2 ft. Elevations and depths provided in personal communication between Lee Kaschmitter, EG&G Idaho, Inc., Idaho Falls, Idaho, and Patti Swain, SAIC, McLean, Virginia, September 19, 1990.

d. TD/PBTD = total depth of borehole/plugged back total depth as reported in personal communication between Lee Kaschmitter, EG&G Idaho, Inc., Idaho Falls, Idaho, and Patti Swain, SAIC, McLean, Virginia, September 19, 1990.

e. Available Data: CR = core description, LL = lithologic log, CD = construction/completion diagram, GL = geologist's log, GR = gamma ray log, GG = gamma gamma log, C = caliper log, and N = neutron log.

f. 1. Field Notes (see Appendix 3-I) 2. Unpublished research results by SAIC, McLean, Virginia, October,1990. 3. Barraclough et al. (1976) 4. Burgus and Maestas (1976) 5. Hubbell et al. (1985) 6. Hubbell et al. (1986) 7. Humphrey (1980) 8. Humphrey and Tingey (1978) 9. Laney et al. (1988)

g. UNK = unknown.

h. ID = instrumentation diagram. Instrumentation details for shallow boreholes provided in Appendix 5-1 of this report.

i. Borehole diameter originally 7-1/8 in. and reamed to 10 in. with a hollow stem auger. Subsequently, 8-in. Schedule 40 carbon steel surface casing emplaced. Personal communication between Joel M. Hubbell, EG&G Idaho, Inc., Idaho Falls, Idaho and Patti Swain, SAIC, McLean, Virginia, October 23, 1990.

j. Personal communication between Joel M. Hubbell, EG&G Idaho, Inc., Idaho Falls, Idaho and P. Swain, SAIC, McLean, Virginia, April 18, 1990, concerning borehole construction details.

boreholes were filled and abandoned. The purpose of this program was to monitor for the presence of radionuclide-contaminated water (Schmaltz, 1972). Water was encountered on three occasions: as a result of the floods of 1962 and 1969 and from an unknown source in 1965 (Schmaltz, 1972). Cesium-137 was detected in three of the boreholes (Boreholes 4, 5, and 7). The USGS later augered shallow boreholes within 0.3 m (1 ft) of Boreholes 4, 5, and 7 to confirm or disprove the presence of cesium (Figure 3-2).

The Health Services Laboratory (HSL) augered four shallow boreholes at the SDA in 1969 to assess potential radionuclide migration in response to the excessive snowmelt and subsequent flooding at the SDA (Schmaltz, 1972). Two of these holes were augered near the edge of Trench 48 at depths of 6 m (20 ft) below land surface, and two holes were augered near the edge of Pit 10 at depths of 2 to 4 m (8 and 14 ft). Sediment and water samples from these areas were analyzed for radionuclides (Schmaltz, 1972; DOE, 1983). The detection of radionuclides at Pit 10 prompted the augering of additional shallow boreholes to obtain core samples. Three core samples were taken at the base of Pit 10, and two other shallow boreholes were augered 1.5 to 30.5 m (5 to 100 ft) from the edge of the excavated pit (Figure 3-2). The HSL also obtained core samples from the east and west ends of the base of Pit 2 to evaluate soil moisture content and potential radionuclide contamination.

3.3 Drilling Programs at the RWMC (1970-Present)

A number of drilling programs have been implemented at the RWMC since the 1970s to address various concerns at the SDA. USGS drilling programs are described in Section 3.3.1, AEC programs are discussed in Section 3.3.2, the Energy Research and Development Administration (ERDA) drilling program is reviewed in Section 3.3.3, DOE programs are summarized in Section 3.3.4, and the SIP is described in Section 3.3.5.

3.3.1 USGS Drilling Programs

The USGS implemented a drilling program in the early 1970s with the following objectives: (a) to characterize the geologic, hydrologic, and geochemical variables that controlled the potential subsurface migration of radionuclides; (b) to determine the extent of radionuclide migration, if any; (c) to monitor the ground water in the Snake River Plain Aquifer; and (d) to obtain hydrogeologic data for radiochemical analysis (Barraclough et al., 1976).

USGS Wells 87, 88, 89, and 90 were drilled to the aquifer in 1971 and 1972 to monitor water levels and water quality (Barraclough et al., 1976). Quarterly samples were collected for radionuclide analysis (DOE, 1983). These wells are located north, south, west, and east of the SDA, respectively (Figure 3-2).

Six deep observation boreholes (91, 92, 93, 94, 95, and 96) were installed in 1972 with the objectives of collecting basalt and sediment samples from the unsaturated zone and determining if radionuclides had migrated to the vadose zone (Barraclough et al., 1976)(Figure 3-2). The boreholes were sited to provide representative coverage of the SDA and to avoid contact with the wastes (Barraclough et al., 1976; DOE, 1983). These deep boreholes were drilled to approximate depths of 76 m (250 ft), cored and sampled, and immediately plugged with cement to avoid providing a contaminant migration route (Humphrey and Tingey, 1978). Borehole 92 was plugged back from 75 to 65 m (247 ft to 214 ft) for use in monitoring perched water (Barraclough et al., 1976).

In 1980, the USGS drilled Wells 103, 104, 105, 106, 107, 108, 109, and 110 at the southern boundary of the INEL Site (refer to Figure 3-1 for locations of Wells 105, 106, and 109). These wells were installed to intercept a predicted contaminant plume that was projected to reach the INEL Site boundary in 1980 based on modeling done in Robertson (1974). The SDA is about 6.4 km (4 mi) north of this boundary.

USGS Wells 117, 118, 119, and 120 were installed in the summer of 1987 in response to the detection of VOCs in the ground water at the SDA (Figure 3-2). These wells supplement the USGS ground water monitoring network in the vicinity of the SDA. Wells 119 and 120 were drilled deeper than the other ground water wells at the SDA to monitor a deeper portion of the aquifer (Wood, 1989). All of these wells are ground water monitoring wells except Well 118, which was continuously cored to a depth of approximately 170 m (560 ft) for further stratigraphic study.[a]

3.3.2 AEC Programs

In 1973, a program referred to in the Environmental Monitoring Annual Report as either the Subsurface Moisture Probe or the Subsurface Moisture Logging Program was initiated (Dolenc and Janke, 1977). As part of this program, 26 shallow holes were installed to the first basalt underlying the surface soil, and 5.1-cm (2-in.) perforated pipes were emplaced at the SDA (Figure 3-2). Monitoring of these holes became a part of the surveillance plan. The USGS monitored these holes twice annually for an unknown period of time (EG&G, 1985). Results of this program were reported in the Environmental Monitoring Annual Report through 1978. The program was designed to detect relative soil moisture content using neutron logs. The actual logs were not included in the annual environmental monitoring reports, but a discussion of seasonal moisture fluctuation and comparison with data from previous years were made. Locations and depths of these boreholes are shown on Figure 4 in Barraclough et al. (1976) and on Figure 3-2. At this time, only Boreholes 3, 4, 5, 19, 22, 26, and 27 are still in existence.

The USGS drilled Wells 97, 98, 99, 100, and 101 under contract to the AEC. These wells were installed in 1973 and 1974 to supplement the hydrogeologic ground water monitoring network. Wells 97, 98, and 99 are located near the Big Lost River and downgradient of the Naval Reactor Facility. Wells 100 and 101 were drilled downgradient of EBR-I (Goldstein and Weight, 1982). All five wells are used for monitoring water levels, but they are not included in this report because they are not in the vicinity of the RWMC.

---

[a] Personal communication between J. M. Hubbell, EG&G Idaho, Inc., Idaho Falls, Idaho, and C. Spooner, SAIC, McLean, Virginia, March 21, 1990.

3.3.3 ERDA Program

Boreholes 93A, 96A, and 96B were installed in 1975 under the ERDA program to determine if radionuclides reported in earlier studies (Barraclough et al., 1976) were the result of cross-contamination (Burgus and Maestas, 1976). The new boreholes were installed close to the USGS boreholes drilled in the early 1970s that had the highest reported levels of radionuclides. Strict anticontamination measures were followed. Borehole 96A was drilled 3 m (10 ft) west of Well 96, but the hole was abandoned at 37 m (120 ft). Borehole 96B was drilled as a replacement 12 m (40 ft) west of 96A (Figure 3-2). Boreholes 96B and 93A were cored continuously from the top of the first basalt to the base of the 73-m (240-ft) interbed (Burgus and Maestas, 1976).

3.3.4 DOE Programs

The DOE initiated drilling programs in 1976 to determine if the sedimentary interbeds in the vadose zone had been contaminated with radionuclides. Seven deep boreholes (76-1, 76-2, 76-3, 76-4, 76-4A, 76-5, and 76-6) were drilled to obtain samples of the 9-, 34-, and 73-m (30-, 110- and 240-ft) interbeds for radiochemical analysis. Each borehole was installed with the following specific objectives (Humphrey and Tingey, 1978):

- Boreholes 76-1 and 76-5 were drilled to obtain stratigraphic resolution of the 9-m (30-ft) interbed.

- Borehole 76-2 was sited near Well 92 to confirm the high radionuclide concentrations reported in the perched water zone.

- Borehole 76-3 was located at the southwest corner of the SDA to intercept some of the oldest waste at the site.

- Borehole 76-4 was drilled in the center of SDA to obtain core coverage.

- Borehole 76-4A was drilled as a replacement for 76-4.
- Borehole 76-6 was drilled in the TSA to study that area (DOE, 1983).

Deep Boreholes 77-1 and 77-2 were installed under the DOE program in 1977. Borehole 77-1 was cored to a depth of 183 m (600 ft) to provide a visual display of core (Humphrey and Tingey, 1978; DOE, 1983). Borehole 77-2 was drilled into the floor of Pit 2 to assess the impacts of the 1962 and 1969 floods and of deteriorated waste drums on potential radionuclide movement. Borehole 77-2 was drilled to a depth of 27 m (87 ft) and used to monitor a perched water zone (Humphrey and Tingey, 1978).

The DOE program drilled five deep boreholes in 1978 (78-1, 78-2, 78-3, 78-4, and 78-5) to obtain samples for radiochemical analysis (Humphrey, 1980)(Figure 3-2). These boreholes were installed to obtain core coverage in unsampled areas (Boreholes 78-3 and 78-5), to monitor perched water zones (Borehole 78-2), and to conduct phase-lag studies (Borehole 78-4) to obtain air permeability data on the basalt and sedimentary interbeds (Humphrey, 1980).

Deep boreholes 79-1, 79-2, and 79-3 were drilled in 1979 under the DOE program. Borehole 79-1 was drilled outside of the SDA as a control for comparison with boreholes on the SDA. Boreholes 79-2 and 79-3 were sited to provide more homogeneous coverage at the SDA (Figure 3-2). All three wells were cored to obtain samples (DOE, 1983). Radionuclides were detected at the 34-m (110-ft) interbed (DOE, 1983). As a result, drilling programs were temporarily suspended until a suitable approach could be developed.

3.3.5 Subsurface Investigation Program

The SIP at the SDA, administered jointly by EG&G Idaho and the USGS, was implemented in 1985. The program had two objectives: (1) to provide data on the subsurface migration of radionuclides and (2) to obtain data to field-calibrate a computer model that was designed to predict the long-term migration of radionuclides in the unsaturated zone. Both deep [depths of 76 m (250 ft)] and shallow boreholes were proposed (DOE, 1983).

Shallow boreholes augered in 1985 under the SIP included W01, W02, W03, W04, W08, W010, W12, W16, W19, W20, W22, W23, C02, T12, T23, PA01, PA02, TH01, TH02, TH03, and TH04 (Hubbell et al., 1985). These 20 boreholes were installed to collect soil samples for testing hydrologic and geologic properties, to delineate radionuclide migration, and to install in situ monitoring and collection equipment in excavated boreholes (DOE, 1983). The instrumentation in each borehole is summarized in Section 5 of this report.

In 1986, 11 shallow boreholes and three deep boreholes were installed under the SIP (Figure 5-1 of this report). The shallow boreholes included C01, W05, W06, W09, W11, W13, W17, W18, W24, W25, and TH05. The deep boreholes were D02, D06, and D06A (Hubbell et al., 1987).

The 1987 SIP included only a deep drilling program. Boreholes TW1 and D15 were drilled with the objective of providing representative samples of the 9-, 34-, and 73-m (30-, 110-, and 240-ft) sedimentary interbeds and of preparing the boreholes for in situ monitoring instrumentation (Laney et al., 1988).

Boreholes 8801D and 8802D were drilled in 1988 in response to the discovery of hazardous wastes in the subsurface and migration of VOCs and radionuclides. Borehole 8801T was also drilled in 1988 to use as a practice well to test drill rig readiness.[a]

3.4 Ongoing Studies

In 1989, Boreholes NA-89-1, NA-89-2, and NA-89-3 were drilled by the USGS to monitor the effects of recharge from the spreading areas on the

---

[a] Personal communication between J. M. Hubbell, EG&G Idaho, Inc., Idaho Falls, Idaho and C. Spooner, SAIC, McLean, Virginia, March 21, 1990.

moisture regime in the vadose zone. These 8.25-cm (3.25-in.) diameter vadose tests provide access for neutron logging. The USGS also installed Boreholes VZT-01 and WWW-1 to monitor the vadose zone.[a] Borehole VZT-01 was completed in 1988 but was never instrumented. The borehole was covered with plywood and a layer of soil.[b] Borehole WWW-1 was completed in the mid-1980s and is instrumented with gas sampling ports for the vapor vacuum extraction (VVE) demonstration.

Boreholes 8901D and 8902D were drilled in 1989 and 1990 by DOE. Borehole 8901D is the extraction hole for the VVE demonstration. Borehole 8902D is instrumented with gas sampling ports to measure the pressure and concentration of organic vapors. The VVE demonstration is described in Section 11 of this report.

3.5 Data Limitations

The primary sources for data in the tables are construction diagrams, lithologic logs, geophysical logs (collectively referred to as completion diagrams), and USGS site schedules. Where this information was not available, well data were taken from USGS site inventory sheets in Bagby et al. (1985). Some discrepancy exists between the site inventory data and the completion diagrams; therefore, some well depths and casing depths may not match between these two sources. Data for boreholes were also taken from completion and/or instrumentation diagrams when available. Additional data, particularly on borehole status, were accumulated from the text of various reports. Data on the earliest boreholes, such as those described in Schmaltz (1972) and those described in Dolenc and Janke (1977) are scarce or not available.

The USGS reports altitudes with respect to MSL whereas the INEL uses a datum of 1.29 ft above MSL. Because the datum is typically not defined, the

---

[a] Personal communication between J. M. Hubbell, EG&G Idaho, Inc., Idaho Falls, Idaho, and C. Spooner, SAIC, McLean, Virginia, March 21, 1990.

[b] Unpublished research results by SAIC, McLean, Virginia, October, 1990.

accuracy of reported elevations in Tables 3-1 through 3-3 is assumed to be ±2 ft. Additional discrepancies are introduced because the well elevations are surveyed inconsistently. According to the EPA RCRA Ground Water Monitoring Technical Enforcement Document (TEGD), the well elevation should be measured from a survey mark placed on the casing for use as a measuring point (EPA, 1986a). Not all wells or boreholes have been measured consistently in this manner at the SDA.[a] Elevations in Tables 3-1 through 3-3 are reported with respect to the land surface designation rather than a measuring point on the casing because the latter is typically not known. The TEGD requires casing height and water level measurements to be accurate within 0.003 m (0.01 ft)(EPA, 1986a).

---

[a] Personal communication between T. Nash, Morrison Knudson Ferguson Surveying, Idaho Falls, Idaho, and C. Spooner, SAIC, McLean, Virginia, April 2, 1990.

4. Ground Water Monitoring Near the RWMC

4. GROUND WATER MONITORING NEAR THE RWMC

Hydrogeologic data regarding the subsurface beneath the RWMC are collected through routine monitoring that is conducted as part of the USGS program. These data are used by EG&G Idaho in evaluating hydrogeologic conditions at the RWMC. The ground water quality monitoring conducted by the USGS is discussed in Section 4.1, and the compliance monitoring conducted by EG&G Idaho is described in Section 4.2.

4.1 USGS Ground Water Quality Monitoring

The USGS routinely samples ground water from 92 wells completed in the Snake River Plain Aquifer and 40 wells completed in discontinuous perched water zones at or near the INEL. These samples are analyzed for selected radionuclides, common ions, and chemical and physical characteristics. The USGS also periodically collects samples for specific studies conducted to characterize the subsurface; however, discussion of these studies is beyond the scope of this report. The Environmental Monitoring Unit at EG&G Idaho defines the RWMC monitoring wells as USGS 87, 88, 89, 90, 92, 117, 119, 120, and the RWMC production well (EG&G, 1989a). Well 92 is monitored for a shallow perched water zone. The approximate locations of these wells are shown in Figure 4-1. The ground water monitoring data collected from 1983 to 1989 for the SDA are summarized in appendices to this section. Ground water monitoring data for 1972 through 1982 are summarized in Bagby et al. (1985).

Wells 87, 88, 89, and 90 were drilled in 1971 and 1972 to approximately 15 m (50 ft) below the water table to establish the subsurface stratigraphic sequence, determine the water table gradient and direction of ground water movement, and monitor the upper portion of the Snake River Plain Aquifer for contamination (Barraclough et al., 1976). Well 92 was drilled in 1972 as a shallow observation borehole within the SDA to obtain stratigraphic information on the 34- and 73-m (110- and 240-ft) sedimentary interbeds. Perched ground water was encountered above the 73-m (240-ft) interbed. The borehole was cemented back to a depth of 65 m (213 ft) to allow perched water to accumulate. Wells 117, 119, and 120 were drilled in the summer of 1987 to

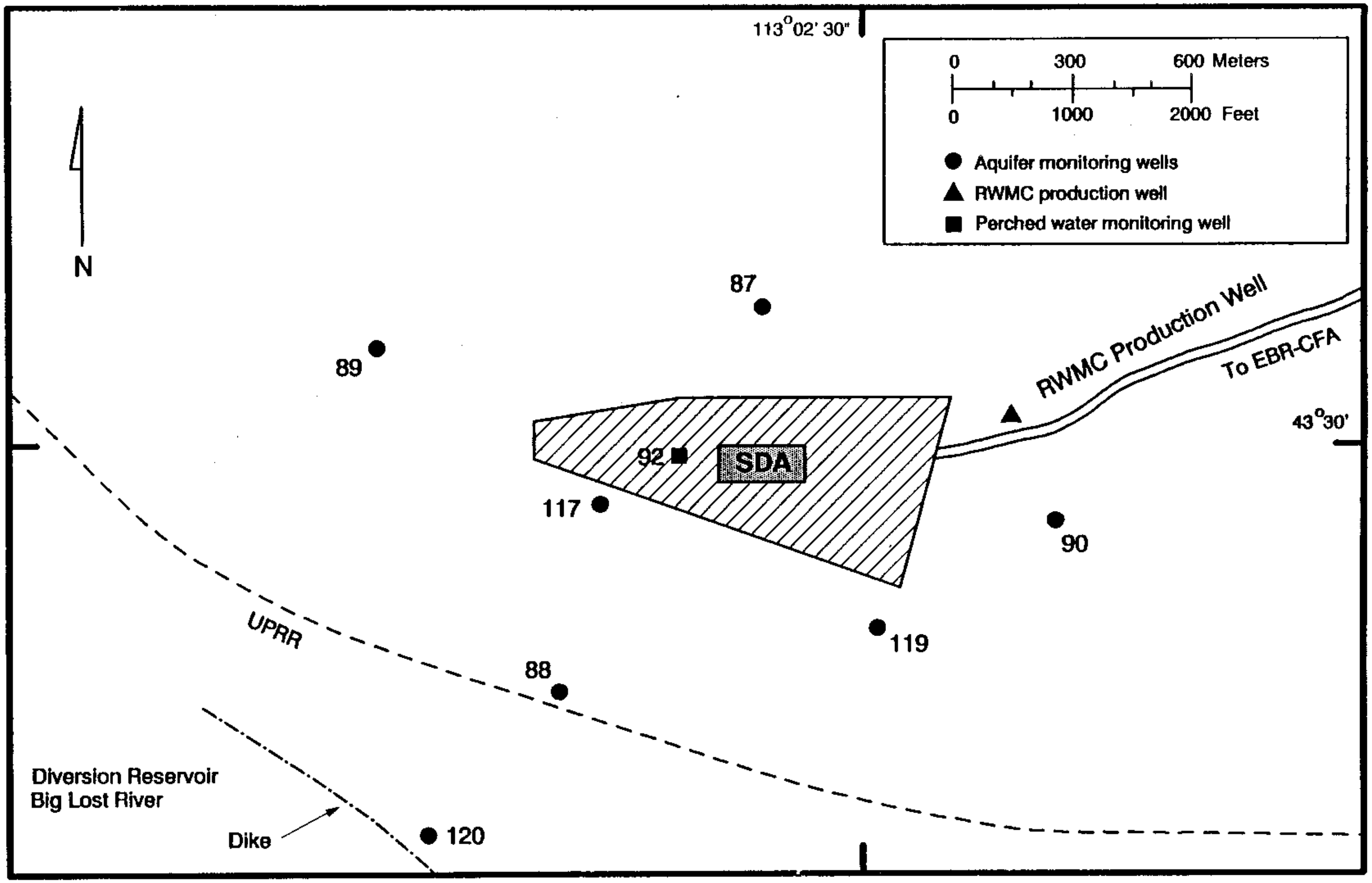


Figure 4-1. Approximate location of wells in the RWMC ground water monitoring network.

supplement the existing USGS ground water monitoring network. The RWMC production well, installed in 1974, provides potable water for RWMC personnel and operations. Well construction logs, lithology logs, geophysical logs, and USGS site schedules for these wells are included in this report in Appendix 3-1. The objectives of the USGS ground water monitoring program are reviewed in Section 4.1.1, the routine ground water monitoring at the RWMC is described in Section 4.1.2, the USGS sampling procedures are discussed in Section 4.1.3, the USGS quality assurance program is reviewed in Section 4.1.4, and the results of ground water monitoring at the RWMC for 1983 through 1989 are presented in Section 4.1.5.

4.1.1 Objectives of USGS Monitoring

USGS monitoring at the RWMC is conducted as part of site-wide monitoring that has been in effect since 1949 to monitor the quality of ground water beneath the INEL and the impact of INEL activities on water quality. Data from this program were entered into the WATSTORE database and published for the period from 1949 through 1982 (Bagby et al., 1985). The water quality constituents that are analyzed for in the site-wide program are shown in Appendices 4-1 through 4-9. Data from the USGS ground water monitoring program are used by EG&G Idaho to meet the following objectives (EG&G, 1988a):

- Assess the nature and extent of contamination and provide field data to validate the contaminant transport model
- Establish the baseline concentrations to evaluate remediation alternatives and their effectiveness and associated risks
- Assess the need for immediate mitigation activities and plans to protect offsite drinking water supplies.

4.1.2 Routine Ground Water Monitoring at the RWMC

USGS routine monitoring at the RWMC is part of the INEL site-wide program described in Section 4.1. The type, frequency, and depth of sampling generally depend on the information needed in a specific area (Bagby et al., 1985). Historically, the program at the RWMC has included the radionuclides H-3; Sr-90; gamma-emitting radionuclides (Co-60 and Cs-137); Pu-238; Pu-239,-240 (undivided); and Am-241. The chemical constituents have included sodium, chloride, nitrate, and total chromium. Physical parameters have included pH, temperature, and specific conductance. Table 4-1 provides a historical summary of the type and frequency of routine measurements made at the RWMC since 1976 as documented in the Environmental Monitoring Annual Reports. The current RWMC sample schedule shown in Table 4-2 was implemented in June 1989.[a] The Environmental Monitoring Unit at EG&G Idaho reviews the USGS monitoring data as it is received at DOE (EG&G, 1989a). Water samples are analyzed by the DOE Radiological and Environmental Sciences Laboratory (RESL) for gross gamma (Co-60 and Cs-137), Sr-90, Pu-238, Pu-239,-240, Am-241, Na, NO_3, H-3, Cl, and specific conductance (EG&G, 1989a). A synopsis of the results is presented in the Environmental Monitoring Annual Report.

The USGS initiated a reconnaissance sampling program for organic solutes in drinking water sources, ground water monitoring wells, and in perched water zones in 1980 (Leenher and Bagby, 1982). Wells 87, 88, 89, 90, and 92 were included in this sampling program. The results of the 1980 survey indicated that there was no organic contamination of the ground water based on a minimum detection level of 10 μg/L. By comparison, the current minimum detection limit for organic constituents using EPA Method 524 is 0.2 μg/L. VOCs were not sampled again until 1987.

In June 1987, the USGS began sampling for selected purgeable organic compounds (POCs) at the RWMC based on the knowledge that large quantities of carbon tetrachloride were disposed of at the facility.[a] Resampling in July and August of 1987 confirmed the presence of carbon tetrachloride, which resulted in a site-wide reconnaissance level sampling program for 36 POCs that

---

a. Personal communication between L. L. Knobel, USGS, Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, August 15-16, 1990.

Table 4-1. Historical summary of routine monitoring at the SDA (Wells 87, 88, 89, 90)

	RADIONUCLIDES						CHEMICAL CONSTITUENTS									
YEAR	H-3	Sr-90	γ-spec.[a]	Pu-238	Pu-239,-240 (undivided)	Am-241	Cl	Na	NO_3	Cr	NO_2-N	NO_2 + NO_3-N	PO_4 Ortho as P	POCs[b]	SPECIFIC CONDUCTANCE MEASURED	REFERENCE
1976[c]	S[d]		(γ and α-emitters)[e]													Dolenc and Janke (1977)
1977	T[f]		(γ and α-emitters)													Hedahl and Janke (1978)
1978	T	T	T	T	T										T	Adams et al. (1979)
1979	Q[g]	A[h]	S	A	A	A	A	A							Q	Wickham and Janke (1980)
1980	Q	Q	S	S	S	S	A								Q	Janke et al. (1981)
1981	Q	Q	S	S	S	S	T								Q	Janke and Zahn (1982)
1982	Q	Q	T	T	T	T	T	A	A						Q	Janke (1983)
1983	Q	Q	T	T	T	T	Q	A	A						Q	Blanchfield and Hoffman (1984)
1984	Q	Q	S	S	S	S	Q	A							Q	Reyes et al. (1985)
1985	Q	Q	S	S	S	S	Q	A							Q	Reyes et al. (1986)
1986	Q	Q	S	S	S	S	Q	A		A					Q	Reyes et al. (1987)
1987	Q	Q	S	S	S	S	Q	A						T	Q	Tkachyk et al. (1988)
1988	Q	Q	T	T	T	T	Q	A	A					Q	Q	Tkachyk et al. (1989)
1989	Q	Q	Q	Q	Q	Q	Q	A	A		A	A	A	Q	Q	Tkachyk et al. (1990)
1990	Q	Q	Q	Q	Q	Q	Q	A	A		A	A	A	Q	Q	[j]

---

a. Radionuclides analyzed for not specifically identified. Includes Co-60 and Cs-137.

b. POCs = Purgeable organic compounds.

c. Although Wells 87, 88, 89, and 90 were drilled during 1971 and 1972, the annual reports for the period from 1972 through 1976 were not available for review.

d. S = Semiannual.

e. The specific radionuclides that were analyzed for were not identified in the Annual Report.

f. T = Triannual.

g. Q = Quarterly.

h. A = Annual.

i. Schedule for Wells 87, 88, and 89, Refer to Table 4-2 for current sample schedule at the SDA.

j. Personal communication between L. L. Knobel, USGS, Idaho Falls, Idaho, and P. Swain, SAIC, McLean, Virginia, August 15-16, 1990.

Table 4-2. USGS sampling schedule at the RWMC since June 1989[a]

Well No.	January	April	July	October
87	8[b] + POC	8 + POC	8 + POC	8 + POC[c] Na + NO_3[d]
88	8 + POC	8 + POC	8 + POC	8 + POC Na + NO_3
89	3[e] + POC	8 + POC	3 + POC	8 + POC Na + NO_3
90	8 + POC	8 + POC	8 + POC	8 + POC Na + NO_3
92[f]	--	8	--	8
117	3 + POC	8 + POC	3 + POC	8 + POC Na + NO_3
119	3 + POC	8 + POC	3 + POC	8 + POC Na + NO_3
120	8 + POC	8 + POC	8 + POC	8 + POC Na + NO_3
RWMC[g]	3	8	3	8 + Na + NO_3

---

a. Personal communication between L. L. Knobel, USGS, Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, August 15-16, 1990.

b. USGS Laboratory Schedule 8: H-3, γ-spec., Sr-90, Pu-238, Pu-239,-240 (undivided), Am-241, Cl.

c. POC: 36 purgeable organic compounds (see Table 4-3), EPA Method 524.

d. NO_3: In October 1988, this schedule was changed to include NO_2-N, NO_2 + NO_3-N, and PO_4, ortho as P.

e. USGS Laboratory Schedule 3: H-3, Sr-90, Cl^-.

f. Sampled if there is enough water. Personal communication between L. L. Knobel, USGS, Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, August 15-16, 1990.

g. RWMC production well sampled monthly for POCs from October 1988 through October 1989. From October 1989 to July 1990, sampled quarterly. Sample schedule accelerated to monthly effective July 1990. Personal communication between L. L. Knobel, USGS, Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, August 15-16, 1990.

was completed in November 1987. The results of the reconnaissance level sampling are summarized in Mann and Knobel (1987). As shown in Table 4-1, these parameters have been monitored approximately quarterly at the RWMC since the detection of VOCs in 1987. The 36 POCs that the USGS monitored for at the RWMC are listed in Table 4-3.

The USGS also sampled for selected trace metals while conducting the site-wide reconnaissance level sampling for POCs from June 1987 to November 1987.[a] These trace metals were selected because they are the inorganic constituents for which the EPA has established primary drinking water standards 40 CFR 141.11(b).[a] The results of the reconnaissance sampling for trace metals are reported in Mann and Knobel (1988). The trace metals for which analyses were performed on ground water samples are summarized with their maximum contaminant levels (MCL) and minimum detection limits in Table 4-4. Trace metals are not routinely monitored at the SDA. Periodically, the USGS will sample for other chemical or radionuclide constituents as part of a special study or if there is a reason to suspect the presence of a specific constituent.[a] For example, the 1989 sampling for selected ions and trace metals was conducted as part of a USGS geochemical characterization study of the RWMC.[a]

4.1.3 Sampling Procedures

Historically, normal care was taken while collecting ground water samples although a formal sampling and analysis plan was not followed.[b] Sample collection procedures have become more stringent in the past few years in response to increased regulatory concerns. The field collection procedures described below have been used by the USGS for the past 6 years.[b] Conditions at the well during sample collection have been recorded in a field logbook and a chain-of-custody record has been used to track samples from the time of

---

[a] Personal communication between L. L. Knobel, USGS, Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, August 15-16, 1990.

[b] Personal communication between J. T. Barraclough, EG&G Idaho, Inc., Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, November 20, 1990.

Table 4-3. Purgeable organic compounds routinely analyzed for by the USGS in the ground water at the RWMC

Benzene
Bromoform
Carbon tetrachloride
Chlorobenzene
Chloroethane
2-Chloroethyl vinyl ether
Chloroform
Chlorodibromomethane
Dibromochloromethane
Dichlorobromomethane
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Dichlorodifluoromethane
1,2-Dibromoethylene
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethylene
1,2-trans-Dichloroethylene
1,2-Dichloropropane
Cis-1,3-Dichloropropene
Trans-1,3-Dichloropropene
1,3-Dichloropropene
Ethylbenzene
Methyl bromide
Styrene
Methylene chloride
1,1,2,2-Tetrachloroethane
Tetrachcloroethylene
Toluene
Trichlorofluoromethane
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
Vinyl chloride
Xylenes, mixed

Table 4-4. Trace metals analyzed in ground water from reconnaissance-level sampling at the INEL[a]

Constituent	Maximum Contaminant Level[b] (MCL) (μg/L)	Proposed MCL 5/22/89[c] (μg/L)	Reporting Level of NWQL (μg/L)
Arsenic	50	50	1
Barium	1,000	500	2
Beryllium	Not established		0.5 or 10
Cadmium	10	5	1
Chromium	50	100	1 to 7
Lead	50	5	5 or 10
Mercury	2	2	0.1
Selenium	10	50	1
Silver	50	50	1

---

a. Modified from Mann and Knobel (1988).

b. From 40 CFR 141.11, National Primary Drinking Water Regulations.

c. Proposed MCL not finalized as of the date of this report.

collection until delivery to the lab since 1987. Quality assurance sample pairs have been collected in the same manner (Wegner, 1989). Wells 87, 88, 89, 90, 117, 119, and 120 all have dedicated submersible pumps for sample collection. The RWMC production well is sampled at the well tap. Well 92 is sampled with either a bailer or thief sampler. The general field collection procedures are described in Section 4.1.3.1, sampling for purgeable organic compounds is reviewed in Section 4.1.3.2, the sampling procedures for trace metals are discussed in Section 4.1.3.3, radionuclide sampling procedures are described in Section 4.1.3.4, and sampling documentation is reviewed in Section 4.1.3.5.

4.1.3.1 General Field Collection Procedures. To ensure representative water samples, a volume of water equivalent to a minimum of three well-bore volumes is pumped from each well. At most wells, 5 to 10 well-bore volumes are pumped before collecting the samples. The diameter of the well bore, rather than the diameter of the casing, is used to calculate the minimum purge volume because of the potentially large difference between the two (Wegner, 1989). In addition, temperature, specific conductance, and pH are monitored during pumping. When these measurements stabilize, indicating probable hydraulic and chemical stability, a water sample is collected. Since 1987, field personnel collecting the samples wear disposable vinyl gloves.[a] The field personnel stand upwind of the wellbore where likelihood of the collector or the sample becoming contaminated is greatly minimized. Sample containers and preservatives differ depending on the type of constituent(s) for which analyses are requested. The sample containers and preservatives used by the USGS for the routine ground water monitoring at the SDA are summarized in Table 4-5.

The water samples for radiochemical constituents, purgeable organic compounds, trace metals, and other constituents are stored in a mobile field laboratory at a temperature of 4°C (39°F) after collection until they can be transferred to a secured storage area. After a sufficient number of samples

---

[a] Personal communication between L. L. Knobel, USGS, Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, August 15-16, 1990.

Table 4-5. Containers and preservatives used by the USGS for routine water samples collected at the RWMC[a]

	Container		Preservative			
Type of Constituent	Type	Size	Type	Size	Other Treatment	Analyzing Laboratory[b]
Nitrate	Polyethylene, amber	250 mL	HgCl	2 mL	Filter, chill 4°C	NWQL
Sodium	Polyethylene, amber	500 mL	None	None	None	NWQL
Chloride	Polyethylene, amber	500 mL	None	None	None	NWQL
Purgeable organic compounds	Glass, baked, amber	40 mL	None	None	Chill 4°C	NWQL
Selected trace metals	Polyethylene, acid-rinsed	500 mL	HNO_3	2 mL	Filter	NWQL
H-3	Polyethylene	500 mL	None	None	None	RESL
Pu-238	Polyethylene, acid-rinsed	1 L	HCL	20 mL	None	RESL
Pu-239,-240 (undivided)	Polyethylene, acid-rinsed	1 L	HCL	20 mL	None	RESL
Sr-90	Polyethylene, acid-rinsed	500 mL	HCL	10 mL	None	RESL
Am-241	Polyethylene, acid-rinsed	1 L	HCL	20 mL	None	RESL
Gamma spectrometry	Polyethylene, acid-rinsed	500 mL	HCL	10 mL	None	RESL

---

a. Source: Mann and Knobel (1990), Wegner (1989), personal communication between L. L. Knobel, USGS, Idaho Falls, Idaho and P. B. Swain, SAIC, McLean, Virginia, August 15-16, 1990.

b. NWQL: USGS National Water Quality Laboratory
RESL: DOE Radiological and Environmental Sciences Laboratory

have been collected, and before any holding-time limitations are met, they are delivered to the respective laboratories shown on Table 4-5. The holding time limitations for nitrates and organics are 8 days and 14 days, respectively (Wegner, 1989).

4.1.3.2 Purgeable Organic Compounds. For the organic compounds, baked 40 mL amber glass vials with inert septum caps, supplied by the USGS National Water Quality Laboratory (NWQL) in Arvada, Colorado, are used to collect the water samples. Four vials are collected at each well and care is taken to exclude air bubbles from the samples (Mann and Knobel, 1987). The sample delivery line is inserted to the bottom of the sample vial and a minimum of three vial volumes are allowed to overflow the vial. The vial is capped immediately and inspected for air bubbles; if bubbles are detected, the vial is drained, reflushed, and refilled. The exterior of the vial is dried, labeled, sealed with laboratory film, and stored in an ice chest (Wegner, 1989).

4.1.3.3 Trace Metals. For the trace metal study conducted by the USGS in 1987, sample containers and preservatives were supplied by the NWQL. The sampling protocol was as follows (Mann and Knobel, 1988): two 4-L polyethylene containers were thoroughly rinsed with well water before being filled with sample water and allowed to overflow; one sample container was used to rinse the exterior of an inert tubing intake for a peristaltic pump; the tubing was then inserted into the second sample container and the peristaltic pump was started to rinse the interior of the tubing and a new 0.45 micron membrane filter contained in an acrylic filter holder; after several volumes were pumped through the tubing and membrane filter, the acid rinsed bottles were filled with water and the preservatives added; the bottles were capped; and the caps sealed with laboratory film.

4.1.3.4 Radiochemical Constituents. A nonacid rinsed bottle is rinsed three times with well water before collecting a sample for tritium analysis (Knobel and Mann, 1988). For the radiochemical samples that are collected in a 1000-mL polyethylene bottle and acidified, the bottle is acid-rinsed in the laboratory, and 20 mL of reagent-grade hydrochloric acid are added to the bottle under a hood. The sample is then collected by carefully filling the preacidified bottle with water from the well (Wegner, 1989). A 500-mL bottle is sufficient for all target radionuclides except Pu-238, Pu-239,-240 (undivided), and Am-241, which require a 1000-mL sample (Knobel and Mann, 1988).

4.1.3.5 Sampling Documentation. Since 1987, conditions at the well during sample collection have been recorded in a field logbook and a chain-of-custody record has been used to track samples from the time of collection until delivery to the analyzing laboratory (Wegner, 1989). The field logbook sheets and chain-of-custody records are available for inspection at the USGS project office at the INEL.

4.1.4 Quality Assurance

The USGS collects water samples in accordance with a quality assurance plan for water quality activities conducted by personnel assigned to the INEL office (Mann and Knobel, 1990). The NWQL uses established internal quality control and quality assurance practices (Mann and Knobel, 1987; Mann and Knobel, 1988).

The USGS maintains a field quality assurance program that consists of collecting the following types of quality control samples (Wegner, 1989):

Duplicate samples	Samples collected at the same time and sent to different laboratories with the same identifier.
Blind replicate samples	Samples collected at the same time and sent to the same laboratory with different identifiers.
Blank samples	Samples of deionized or boiled deionized water sent to laboratories.
Equipment blanks	Samples of the deionized water rinsate used to decontaminate field equipment.

Spiked samples	Samples prepared by combining distilled or deionized water with chemical reagents to produce a known concentration of a constituent.

For the routine site-wide monitoring at the INEL, approximately 1 out of every 10 samples (10%) is a quality control sample.[a] A separate quality assurance program is not instituted for the RWMC.[a] Wegner (1989) conducted a comparative study to determine agreement between analytical results for individual water-sample pairs by laboratories involved in the USGS project office's quality assurance program from 1980 to 1988. Site-wide samples dedicated to quality assurance ranged from 17 to 50% in the period from 1980 to 1988 (Wegner, 1989).

Data validation and reporting used as of 1987 by the USGS are summarized in Jones (1987). The quality assurance manual of Friedmann and Erdmann (1982) contains applicable standards. Samples analyzed by NWQL are subjected to a computerized review for internal consistency of data, such as cation-anion balance, specific conductance, concentration relations, and dissolved-ion total-ion concentrations prior to release. The applicable tests are specified in Friedmann and Erdmann (1982). The samples which satisfy these internal checks are released to the requestor via the USGS computer network (Jones, 1987). Computer rejected samples are referred to a quality control office for inspection and resolution of the problems.

4.1.5 Results of USGS Ground Water Monitoring at the RWMC

The results of the chemical analyses performed on the ground water samples collected from 1983 through 1989 are presented in tables in Appendices 4-1 through 4-9. These tables are modified from the USGS WATSTORE database. The inorganic constituents and physical parameters that are routinely measured at the RWMC are found in columns 3 through 17; the routinely monitored POCs are found in columns 25 through 61. The selected

---

[a] Personal communication between L. L. Knobel, USGS, Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, August 15-16, 1990.

trace metals described in Mann and Knobel (1988) and listed in Table 4-4 are given in columns 62 through 70. Radiological analyses are conducted by RESL and these data are not included in the USGS WATSTORE database. The radionuclides analyzed by RESL in ground water samples at the RWMC are summarized in Table 4-6. The analytical data reported in the Environmental Monitoring Annual Reports for 1978 through 1988 are compiled in Appendix 4-10.

The reporting level is defined as the lowest measured concentration of a constituent that may be reliably reported using a given analytical method. For the POCs, the reporting level is 0.2 μg/L except for the samples collected in June 1987, which had a reporting level of 3.0 μg/L. The change in reporting levels from 3.0 to 0.2 μg/L represents the change in analytical method from EPA Method 624 to EPA Method 524. In general, the concentrations detected but below the reporting levels are indicated in the tables (appendices) by "below reporting levels (BR)." The reporting levels for the trace metals described in Mann and Knobel (1988) are summarized in Table 4-4. The detection limits for radionuclides routinely sampled at the RWMC are summarized in Table 4-6.

4.2 EG&G Compliance Monitoring

Drinking water has been routinely monitored at the INEL since the early 1950s.[a] A formal drinking water monitoring program was formulated at the beginning of 1988 to ensure that EG&G Idaho's requirements were more stringent than the minimum regulatory requirements for monitoring of drinking water systems (Tkachyk et al., 1989). Nineteen drinking water wells are monitored by EG&G Idaho including the RWMC production well at the SDA (EG&G, 1989b). Bacteriological, radiological, and chemical constituents are measured as part of the drinking water monitoring program. The Environmental Monitoring Unit at EG&G Idaho conducts the sampling of the ground water at the production wells utilizing written Standard Operating Procedures that have been in effect since 1988.

---

[a] Personal communication between J. T. Barraclough, EG&G Idaho, Inc., Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, November 20, 1990.

Table 4-6. Radionuclides routinely monitored at the RWMC[a]

Constituent	Detection Limit μCi/mL
Tritium	7×10^{-7} [b]
Strontium-90	2×10^{-9}
Plutonium-238	2×10^{-11}
Plutonium-239,-240 (undivided)	2×10^{-11}
Americium-241	2×10^{-11}
Gamma spectrometry	6×10^{-8}

---

a. Source: Tkachyk et al. (1989).

b. Detection limit at RESL since fourth quarter 1988 due to new instrumentation. Before this time the tritium detection level was 1×10^{-6} μCi/mL. Detection limit is based on a 10-mL sample counted for 20 minutes (Tkachyk et al., 1989).

4.2.1 Requirements

The requirements for the monitoring of drinking water are contained in the Federal Safe Drinking Water Act, 40 CFR 141-143, and the Idaho Regulations for Public Drinking Water Systems, IDAPA 16.01-8000-8900, and summarized in Table 4-7. The drinking water system at the INEL is classified as a "Community Drinking Water System" (EG&G, 1990b). The sampling frequency at the RWMC production well and the action levels for all production wells at the INEL are summarized in Table 4-8.

4.2.2 Sampling Collection and Analysis Procedures

The following discussion of sample collection procedures for the RWMC production well is modified from EG&G (1989b). The specific sampling guidelines for different constituents (including types of sample containers, preservatives, and holding times) are summarized in Table 4-9.

1. After water reaches the wellhead (minimum purge time), a grab sample is collected before and after sampling. The temperature, pH, conductivity data, and sampling time are recorded into the field logbook.

2. If a preservative has been previously added to the sample, chemical splash goggles, face shield, or protective eye wear are worn while sampling.

3. After the well has been purged and field measurements have stabilized, samples are obtained starting with the VOC samples. Samples for other constituents are collected after the VOC collection.

4. Three VOC vials are filled for every sample.

Table 4-7. Constituents sampled for compliance monitoring at the RWMC[a]

Constituent	Maximum Contaminant Level (ppm)	Regulatory Frequency	1988-1989 Frequency	Planned Frequency[b]
	Regulated VOCs			
Benzene	0.005	Quarterly sampling if detected.	Quarterly	Quarterly
Vinyl chloride	0.002		Quarterly	Quarterly
Carbon tetrachloride	0.005		Quarterly	Quarterly
1,2-dichloroethane	0.005		Quarterly	Quarterly
Trichloroethylene	0.005	Reduce to once a year if VOCs are less than MCLs for 3 years.	Quarterly	Quarterly
1,1-dichloroethylene	0.007		Quarterly	Quarterly
1,1,1-trichloroethane	0.200		Quarterly	Quarterly
para-dichlorobenzene	0.075		Quarterly	Quarterly
Unregulated VOCs				
Chloroform		Not yet established	Quarterly	Quarterly
Bromodichloromethane			Quarterly	Quarterly
Chlorodibromomethane			Quarterly	Quarterly
Bromoform			Quarterly	Quarterly
trans-1,2-dichloroethylene[c]	0.01		Quarterly	Quarterly
Chlorobenzene			Quarterly	Quarterly
m-dichlorobenzene			Quarterly	Quarterly
Dichloromethane			Quarterly	Quarterly
cis-1,2-dichloroethylene[c]	0.07		Quarterly	Quarterly
o-dichlorbenzene[c]	3.6		Quarterly	Quarterly
Dibromomethane			Quarterly	Quarterly
1,1-dichloropropene			Quarterly	Quarterly
Tetrachloroethylene[c]	0.005		Quarterly	Quarterly
Toluene[c]	2.0		Quarterly	Quarterly
p-xylene	10[d]		Quarterly	Quarterly
o-xylene			Quarterly	Quarterly
m-xylene			Quarterly	Quarterly
1,1-dichloroethane			Quarterly	Quarterly
1,2-dichloropropane[c]	0.05		Quarterly	Quarterly
1,1,2,2,-tetrachlorethane			Quarterly	Quarterly
Ethylbenzene[c]	0.7		Quarterly	Quarterly
1,3-dichloropropane			Quarterly	Quarterly
Styrene[c]	0.005		Quarterly	Quarterly
Chloromethane			Quarterly	Quarterly
Bromomethane			Quarterly	Quarterly
1,2,3,-trichloropropane			Quarterly	Quarterly
1,1,1,2-trichloroethane			Quarterly	Quarterly
Chloroethane			Quarterly	Quarterly
1,1,2-trichloroethane			Quarterly	Quarterly
2,2-dichloropropane			Quarterly	Quarterly
o-chlorotoluene			Quarterly	Quarterly
p-chlorotoluene			Quarterly	Quarterly

Table 4-7. (continued)

Constituent	Maximum Contaminant Level (ppm)		Regulatory Frequency	1988-1989 Frequency	Planned Frequency[b]
			Regulated VOCs		
Bromobenzene				Quarterly	Quarterly
1,3-dichloropropene				Quarterly	Quarterly
Ethylene dibromide[a](EDB)		0.00005[c]	States discretion.	Quarterly	Quarterly
1,2-dibromo-3-chloropropane (DBCP)				Quarterly	Quarterly
1,2,4-trimethylbenzene			Quarterly sampling if detected.	Quarterly	Quarterly
1,2,4-trichlorobenzene				Quarterly	Quarterly
1,2,3-trichlorobenzene				Quarterly	Quarterly
n-propylbenzene				Quarterly	Quarterly
n-butylbenzene				Quarterly	Quarterly
Naphthalene			Reduce to once a year if VOCs are less than MCLs for 3 years	Quarterly	Quarterly
Hexachlorobutadiene				Quarterly	Quarterly
1,3,5,-trimethylbenzene				Quarterly	Quarterly
p-isopropyltoluene				Quarterly	Quarterly
Isopropylbenzene				Quarterly	Quarterly
Tert-butylbenzene				Quarterly	Quarterly
Sec-butylbenzene				Quarterly	Quarterly
Fluorotrichloromethane				Quarterly	Quarterly
Dichlorodifluoromethane				Quarterly	Quarterly
Bromochloromethane				Quarterly	Quarterly
			Inorganics		
Arsenic	0.05		Triennial	Annual	Annual
Barium	1	5[c]	Triennial	Annual	Annual
Cadmium	0.010	0.005[c]	Triennial	Annual	Annual
Chromium	0.05	0.10[c]	Triennial	Annual	Annual
Lead	0.05	0.005[c]	Triennial	Annual	Annual
Mercury	0.002		Triennial	Annual	Annual
Selenium	0.01	0.05[c]	Triennial	Annual	Annual
Silver	0.05		Triennial	Annual	Annual
Fluoride	4.0		Triennial	Annual	Annual
Nitrate	10 (as Nitrogen)		Triennial	Annual	Annual
Sodium	20 (recommended)		Triennial	Annual	Annual
Cyanide	0.2		Triennial	Annual	Annual
			Organics		
Endrin	0.0002		These requirements are at the discretion of the State	Annual	Annual
Lindane	0.004	0.0002[c]		Annual	Annual
Methoxychlor	0.1	0.4[c]		Annual	Annual
Toxaphene	0.005			Annual	Annual
2,4-D	0.1	0.7[c]		Annual	Annual
2,4,5-TP Silvex	0.01	0.05[c]		Annual	Annual

Table 4-7. (continued)

Constituent	Maximum contaminant Level (ppm)	Regulatory Frequency	1988-1989 Frequency	Planned Frequency[b]
		Bacteriological		
Coliform Bacteria	<1 bacteria[e] per 100 cc of sample	Monthly	Monthly	Monthly
		Radiological		
Radium 226/228 or	5 pCi/L	Quadrennial	As Required	Annual
Gross Alpha	15 pCi/L	Quadrennial	Monthly	Annual
Gross Beta	50 pCi/L	Quadrennial	Monthly	Annual
Tritium[f]	20,000 pCi/L	Quadrennial	Monthly	Annual
Strontium-90[f]	8 pCi/L	Quadrennial	Semiannual at CFA and quarterly at the RWMC by the USGS	Annual
Manmade gamma emitting nuclides	Less than 4 mrem/yr to total body or target organ	Quadrennial	Occasional	Annual

---

a. Source: EG&G (1990b).

b. Sampling at the RWMC done on a monthly monitoring schedule because of past VOC detection.

c. Proposed May 22, 1989.

d. Total xylenes.

e. A requirement for zero bacteria per 100 cc of sample was proposed June 29, 1989, and became effective December 31, 1990.

f. The calculated limits for H-3 and Sr-90 were established assuming a dose of 4 mrem/yr to the whole body or bone marrow, respectively.

Table 4-8. Sampling frequency for primary drinking water standards at the RWMC production well[a]

Type of Constituent	Frequency	Action Level
Volatile Organic Compounds	Monthly	If the MCL for the regulated VOCs is exceeded, the State will be notified within 48 hours of the discovery, and three additional samples will be collected from the same sample point within 30 days. If the average of the four samples exceeds the MCL, then the State and the consuming public will be notified.
Inorganics (Metals)	Annually	If the MCL for the constituents is exceeded (excluding nitrate), the State will be notified within 48 hours of the discovery, and four additional samples will be collected from the same sample point within 30 days. If the average of the four samples exceeds the MCL, then the State and the consuming public will be notified.
Nitrate		If the sample for nitrate is exceeded, another sample must be drawn within 24 hours and the average of the two samples used to test compliance. If any of these constituents are detected of greater than 80% of the MCL on any sample, EG&G Idaho policy is to sample the water system again to confirm the concentration of the contaminant and initiate corrective action, if required.
Organics	Annually	If the MCL for the constituents is exceeded (excluding nitrate, the State will be notified within 48 hours of the discovery, and three additional samples will be collected from the sample point within 30 days. If the average of three samples exceeds the MCL, then the State and the consuming public will be notified.
Bacteriological	Monthly	If the MCL is exceeded, the State must be notified and two additional samples taken within 24 hours. At least one sample per day must be taken until two consecutive samples are less than 1 bacteria per 100 cc of water.
Radiological	Monthly	If the MCLs for radiological contamination are exceeded, the State will be notified within 48 hours, and the consuming public will be notified within one month. If gross beta measurements on a sample exceed 10 pCi/L, then separate analysis for Sr-90 will be performed to determine if the Sr-90 MCL, 8 pCi/L, is being approached. If gross alpha concentration activity exceeds 5 pCi/L, analysis for Ra-226 will be performed. If gross alpha activity exceed 15 pCi/L, monitoring is initiated on a quarterly basis.

a. Source: EG&G (1990b)

Table 4-9. Required containers, preservation techniques, and holding times[a]

Name	Container[b]	Preservation	Maximum Holding Time
Bacterial Tests:			
Coliform, fecal and total	P,G	Cool, 4°C,0.008% $Na_2S_2O_3$	6 hours
Fecal Streptococci	P,G	Cool,4°C,0.008% $Na_2S_2O_3$	6 hours
Inorganic Tests:			
Acidity	P,G	Cool, 4°C	14 days
Alkalinity	P,G	Cool, 4°C	14 days
Ammonia	P,G	Cool, 4°C,H_2SO_4 to pH<2	28 days
Biochemical oxygen demand	P,G	Cool, 4°C	48 hours
Bromide	P,G	None required	28 days
Biochemical oxygen demand, carbonaceous	P,G	Cool, 4°C	48 hours
Chemical oxygen demand	P,G	Cool, 4°C, H_2SO_4 to pH<2	28 days
Chloride	P,G	None required	28 days
Chlorine, total residual	P,G	None required	Analyze immediately
Color	P,G	Cool, 4°C	48 hours
Cyanide, total and amenable to chlorination	P,G	Cool, 4°C, NaOH to pH>12, 0.6g ascorbic acid	14 days
Fluoride	P	None required	28 days
Hardness	P,G	HNO_3 to pH<2, H_2SO_4 to pH<2	6 months
Hydrogen ion (pH)	P,G	None required	Analyze immediately
Kjeldahl and organic nitrogen	P,G	Cool, 4°C, H_2SO_4 to pH<2	28 days

Table 4-9. (continued)

Name	Container[b]	Preservation	Maximum Holding Time
Metals:			
Chromium VI	P,G	Cool, 4°C	24 hours
Mercury	P,G	HNO_3 to pH<2	28 days
Metals, except chromium VI and mercury	P,G	HNO_3 to pH<2	6 months
Other Analyses:			
Nitrate	P,G	Cool, 4°C	48 hours
Nitrate-nitrite	P,G	Cool, 4°C,H_2SO_4 to pH<2	28 days
Nitrite	P,G	Cool, 4°C	48 hours
Oil and grease	G	Cool, 4°C,H_2SO_4 to pH<2	28 days
Organic carbon	P,G	Cool, 4°C,HCL or H_2SO_4 to pH<2	28 days
Orthophosphate	P,G	Filter immediately, cool, 4°C	48 hours
Oxygen, dissolved probe	G bottle and top	None required	Analyze immediately
Winkler	do	Fix onsite and store in dark	8 hours
Phenols	G only	Cool, 4°C, H_2SO_4 to pH<2	28 days
Phosphorus (elemental)	G	Cool, 4°C	48 hours
Phosphorus, total	P,G	Cool, 4°C, H_2SO_4 to pH<2	28 days
Residue, total	P,G	Cool, 4°C	7 days
Residue, filterable	P,G	Cool, 4°C	7 days
Residue, nonfilterable (TTS)	P,G	Cool, 4°C	7 days
Residue, settleable	P,G	Cool, 4°C	48 hours
Residue, volatile	P,G	Cool, 4°C	7 days
Silica	P	Cool, 4°C	28 days

Table 4-9. (continued)

Name	Container[b]	Preservation	Maximum Holding Time
Other Analyses: (continued)			
Specific conductance	P,G	Cool, 4°C	28 days
Sulfate	P,G	Cool, 4°C	28 days
Sulfide	P,G	Cool, 4°C, add zinc acetate plus sodium hydroxide to pH>9	7 days
Sulfite	P,G	None required	Analyze immediately
Sulfactants	P,G	Cool, 4°C	48 hours
Temperature	P,G	None required	Analyze in field
Turbidity	P,G	Cool, 4°C	48 hours
Organic Tests:			
Purgeable halocarbons	G, Teflon-lined septum	Cool, 4°C, 0.008% $Na_2S_2O_3$	14 days
Purgeable aromatic hydrocarbons	G, Teflon-lined septum	Cool, 4°C, 0.008% $Na_2S_2O_3$ HCL to pH 2	14 days
Acrolein and acrylonitrile	G, Teflon-lined septum	Cool, 4°C, 0.008% $Na_2S_2O_3$. Adjust pH to 4-5	14 days
Phenols	G, Teflon-lined cap	Cool, 4°C, 0.008% $Na_2S_2O_3$	7 days until extraction, 40 days after extraction
Benzidines	G, Teflon-lined cap	Cool, 4°C, 0.008% $Na_2S_2O_3$	7 days until extraction
Phthalate esters	G, Teflon-lined cap	Cool, 4°C	7 days until extraction, 40 days after extraction
Nitrosamines	G, Teflon-lined cap	Cool, 4°C, store in dark, 0.008% $Na_2S_2O_3$	40 days after extraction
PCBs, acrylonitrile	G, Teflon-lined cap	Cool, 4°C	40 days after extraction
Nitroaromatics and Isophotrone	G, Teflon-lined cap	Cool, 4°C, 0.008% $Na_2S_2O_3$ store in dark	40 days after extraction

Table 4-9. (continued)

Name	Container[b]	Preservation	Maximum Holding Time
<u>Organic Tests</u>: (continued)			
Polynuclear aeromatic hydrocarbons	G, Teflon-lined cap	Cool, 4°C, 0.008% $Na_2S_2O_3$, store in dark	40 days after extraction
Maloethers	G, Teflon-lined cap	Cool, 4°C, 0.008% $Na_2S_2O_3$	40 days after extraction
Chlorinated hydrocarbons	G, Teflon-lined cap	Cool, 4°C	40 days after extraction
TCDD	G, Teflon-lined cap	Cool, 0.008% $Na_2S_2O_3$	40 days after extraction
Total organic halogens	G, Teflon-lined cap	Cool, 4°C, H_2SO_4 to pH<2	7 days
<u>Pesticide Tests</u>:			
Pesticides	G, Teflon-lined cap	Cool, 4°C, pH 5-9	40 days after extraction
<u>Radiological Tests</u>:			
Alpha, beta, and radium	P,G	HNO_3 to pH<2	6 months

---

a. Source: EG&G (1989b).

b. Polyethylene (P) or glass (G).

5. The bottles are sealed with parafilm tape after all the samples have been collected. The sample container is labeled with appropriate identification number, sampler name, time, date, facility, and well number.

6. The final grab sample for field measurements is collected and the pump shut off.

7. All applicable information is entered into the field logbook [i.e., beginning and ending flowmeter readings, well location, purge time, time pump started, date sampled, sample identification number, type of sample (grab or composite), time, sampler(s) name, operator(s) name, temperature, pH, and conductivity].

8. The samples are transported to the laboratory as soon as possible. The samples are packed with vermiculite and/or plastic air bubble packing using either ice that is triple bagged or blue ice.

4.2.2.1 Volatile Organic Compounds. Sample vials are filled slowly to avoid any unnecessary turbulence and aeration of the sample. A teflon or glass beaker can be used to fill the vials to avoid aeration of the sample. The vial is filled until there is a meniscus, then carefully capped, inverted, and gently tapped to ensure there are no air bubbles. If air bubbles appear, the sample is recollected with a new vial. Analysis of chemical constituents is performed by commercial laboratories that are certified by the State of Idaho or have reciprocity agreements with Idaho (EG&G, 1990b).

4.2.2.2 Radiological Samples. Samples are collected monthly at the RWMC for analysis by the RESL for gross alpha, gross beta, and tritium (EG&G, 1989c). RESL provides the sample containers: 1 500-mL preacidified polyethylene bottle for gross alpha/beta analysis and a 250-mL polyethylene bottle with no preservatives for tritium analysis. The 500 mL gross alpha/beta samples are preserved with 10 mL of 16 Normal nitric acid.

4.2.2.3 Bacteriological Sampling. The Environmental Monitoring Unit collects bacteriological samples from the water distribution systems. The minimum purge time is approximately 2 to 3 minutes before the sample is collected (EG&G, 1990b). Samples are collected in sterilized bags that contain sodium thiosulfate in the appropriate amount to preserve the sample at the prescribed volume (EG&G, 1989d). Analysis for coliform bacteria is performed by the Environmental Hygiene Laboratory located at CFA-612.

4.2.3 Quality Assurance

Analytical data obtained for the EG&G Drinking Water Monitoring Program are validated in accordance with EPA contract laboratory program data validation requirements. Quality control samples (duplicates, trip blanks, and spikes) are collected and sent to the laboratory as blind samples to ensure there is no analytical bias (Anderson, 1991). The analyzing laboratory runs quality control samples as required by the EPA methods. Technical review and data validation requirements for organic and inorganic analytes are included in Appendix A and B, respectively, of Anderson (1991). Included in the technical reviews for a particular analytical method are a discussion of holding times, detection limits, initial calibration, continuing calibration, internal standard performance, surrogate performance, laboratory reagent blanks and laboratory fortified blanks. Data validation reports for the drinking water sampling conducted as part of the Drinking Water Monitoring Program are available from June, 1988 to present.

5. Subsurface Investigation Program

5. SUBSURFACE INVESTIGATION PROGRAM

In 1983, the SIP was proposed to collect geologic and hydrologic information for characterizing the vadose zone at the RWMC to a depth of approximately 76.2 m (250 ft). The program was developed in response to previous subsurface geologic investigations that provided inconclusive evidence regarding the potential migration of radionuclides. These earlier investigations are described in Section 2 of this report. In the SIP plan, field and laboratory studies were proposed to address the specific hydrogeologic and geochemical data gaps that still existed following the previous geologic investigations. These studies were grouped into two primary categories: (1) a shallow drilling program to further characterize the surficial sediments and (2) a deep drilling program to further characterize the underlying basalt and sedimentary interbeds. The resulting investigation program began in 1984 and ended in the fall of 1988. Activities that had begun under the SIP were transitioned into the site characterization program after this time.

The following report describes the SIP activities that were completed between 1984 and 1988 and those site characterization activities from 1988 to 1990 that were transitioned from the SIP. A brief history of the program is presented in Section 5.1, the purpose of the SIP is described in Section 5.2, program activities are included in Section 5.3, and a description of the procedures that were used to complete the activities appear in Section 5.4. Section 5.5 summarizes the results of the SIP program and selected activities that were transitioned into the site characterization program.

5.1 Brief History of SIP Program

Studies of possible subsurface migration of radionuclides at the RWMC began in 1960. Studies performed from 1960 to 1980 are reported in the following documents: Schmalz (1972), Barraclough et al. (1976), Burgus and Maestas (1976), Humphrey and Tingey (1978), and Humphrey (1980). See Section 2 of this report for a discussion of the latter four reports. The results obtained from these previous efforts provided some useful information;

however, they were (a) inconclusive with regard to the extent of the potential migration of radionuclides, (b) employed techniques that were susceptible to possible cross-contamination during sample collection and handling processes, and (c) did not provide all the data required to model radionuclide transport through the subsurface environment. Therefore, DOE requested EG&G Idaho and the USGS INEL Project Office to prepare the SIP plan.

The planning effort for the SIP program was initiated in FY-82 and is described in DOE (1983). The plan was subjected to a peer review and then approved in early 1984. The remainder of FY-84 was spent preparing the procedures to drill/sample the surficial sediments overlying the basalt at the RWMC. In FY-85, 21 shallow boreholes were drilled and 19 were instrumented. In 1986, 11 additional shallow holes were augered and instrumented. Five deep boreholes were drilled in both FY-86 and FY-87. Three of these deep boreholes were instrumented.

In 1987, the detection of VOCs in ground water and VOC vapors encountered in two boreholes changed the scope of the program. As a consequence, a Corrective Action Plan and a RCRA RFI Work Plan were written to address the regulatory requirements associated with the RCRA COCA and to provide a plan for evaluating the distribution and migration of VOCs in the subsurface (EG&G, 1988a). The SIP was transitioned into the RWMC site characterization program in the fall of 1988, and the original scope of the program was expanded to include the subsurface transport of hazardous constituents, subsurface transport of mixed hazardous waste, and the regulatory requirements associated with a RCRA corrective action program.

5.2 Purpose of Investigation

The purpose of the SIP was to supply the geologic and hydrologic data required to characterize the migration of radionuclide and organic contamination in the vadose zone. These data were to support the eventual DOE decision regarding the possible retrieval of the buried TRU waste at the RWMC. Resulting evidence of significant migration would be used to argue for retrieval of the approximately 2 million cubic feet of this waste or for the development of additional methods to reduce the extent of the migration. Conversely, the lack of such evidence would support arguments for leaving the waste in place at a great cost savings.

The overall objectives of the SIP were to (a) field calibrate a model to predict the long-term migration of radionuclides in the vadose zone and (b) measure the actual migration of radionuclides to date (DOE, 1983). To achieve the first objective, the program implemented activities to drill boreholes, dig test trenches, install weighing lysimeters, evaluate the lithology of cores, conduct borehole geophysical surveys, and measure hydrologic properties. To achieve the second objective, the program implemented activities to collect cores from the deep boreholes, conduct radionuclide and organic analyses on the core samples, and complete the boreholes for subsequent gas and water sampling/analyses. These objectives were accomplished for the surficial sediments as part of the shallow drilling program and for the basalt and sedimentary interbeds as part of the deep drilling program.

Specific objectives were defined for each of the activities within the shallow and deep drilling programs. Test trenches and weighing lysimeters were installed under the shallow drilling program. Test trenches were installed and are monitored to determine the typical moisture content, unsaturated hydraulic conductivity, matric potential, soil-moisture flux, and soil-moisture velocity of the surficial sediments under actual and simulated conditions (Laney et al., 1988). Boreholes were instrumented to characterize the moisture availability, variability, and movement within each unit. The weighing lysimeters were installed and are monitored to define the physics of moisture entry into the vadose zone. The objective of the deep drilling and core sampling and geophysical surveys was to define the geologic characteristics of each lithologic unit and delineate the spatial variability. Hydrologic properties were measured to determine permeability values for surficial sediments and rock units. For the radionuclide and organic analyses of the collected core, the objective was to determine the type, concentration, and extent of contamination. In addition, water and gas samples were collected and analyzed to establish baseline data on the types and concentrations of contaminants and to estimate the fluctuation of contaminant concentrations in the organic vapors that diffuse from the buried waste.

5.3 Program Activities

The SIP field activities were implemented under two programs: the shallow drilling program and the deep drilling program. The shallow drilling program consisted of the (a) drilling, sampling, instrumentation, and monitoring of shallow boreholes; (b) installation, instrumentation, and monitoring of two test trenches; and (c) installation and sampling of weighing lysimeters. The deep drilling program consisted of the drilling, sampling, instrumentation, and monitoring of boreholes that were deep enough to penetrate the basalt and sedimentary interbeds. Data collected from the field activities were to be used for approximately 20 specific studies involving hydrogeology, geochemical migration, and modeling of the RWMC. However, the specific studies were never completed.[a] The following sections of the report describe field activities associated with the shallow and deep drilling programs. The shallow borehole installation, test trench, and weighing lysimeter activities are discussed in Section 5.3.1; the deep drilling activities are discussed in Section 5.3.2.

5.3.1 Shallow Drilling Program

Between 1985 and 1987, shallow boreholes, test trenches, and weighing lysimeters were completed in the surficial sediments near the SDA. A total of 32 shallow boreholes were drilled to an average depth of 5 m (16 ft), sampled, and instrumented with moisture sensing and sampling equipment. Continuous samplers were used to collect 226 cores from the shallow boreholes. Selected soil samples were described and sent to laboratories for radiochemical analyses and permeability testing. More than 140 samples were submitted for radiochemical analyses and 4 samples were submitted for permeability testing.

---

[a] Personal communication between J. M. Hubbell, EG&G Idaho, Inc., Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, November 7, 1990.

A total of 266 instruments were installed at multiple depths within each borehole including 19 tensiometers, 50 gypsum blocks, 59 thermocouple psychrometers, 98 heat-dissipation probes, 39 soil water samplers (porous cup lysimeters), and 2 neutron access tubes. Two test trench installations were completed and instrumented with psychrometers, tensiometers, and neutron access tubes. In addition, the weighing lysimeter installation was repaired and modified to enhance its effectiveness. The shallow borehole installations are described in Section 5.3.1.1, and the test trench and weighing lysimeter installations are described in Sections 5.3.1.2 and 5.3.1.3, respectively.

5.3.1.1 Shallow Borehole Installations. As part of the shallow drilling program, boreholes were drilled from land surface to the shallowest basalt using hollow stem augers. These shallow boreholes ranged in depth from 1.2 to 7.7 m (4 to 25 ft) with an average depth of 5 m (16 ft). Nineteen of the boreholes were located within the boundaries of the SDA with the remaining 13 boreholes in close proximity outside of the boundaries. In several locations, the auger encountered rock near the surface; therefore, the drill rig was moved until a suitable location was found with a minimum of 1.2 m (4 ft) of surficial sediment. The locations of the shallow boreholes are shown in Figure 5-1.

Continuous split-spoon samples were collected during drilling. These samples were collected using California split-spoon samplers with a 5-cm (2-in.) drive shoe that contained three 15.2-cm (6-in.) cellulose acetate or one 7-cm (18-in.) Lexan core liner(s). Following collection, each split-spoon sampler was triple-bagged at the drill site and transported to the field laboratory where it was split open. Geologic descriptions of the material in the drive shoe of the sampler were recorded at intervals of 0.53 m (21 in.) including depth, texture, color, moisture, presence of roots, and reaction to 5% HCL. Geologic descriptions of samples from shallow boreholes are provided in Hubbell et al. (1985), Hubbell et al. (1987), and Laney et al. (1988). Soil moisture samples were also collected from the drive shoe while processing the samples for storage. Radiochemical analyses were conducted on 112 of the

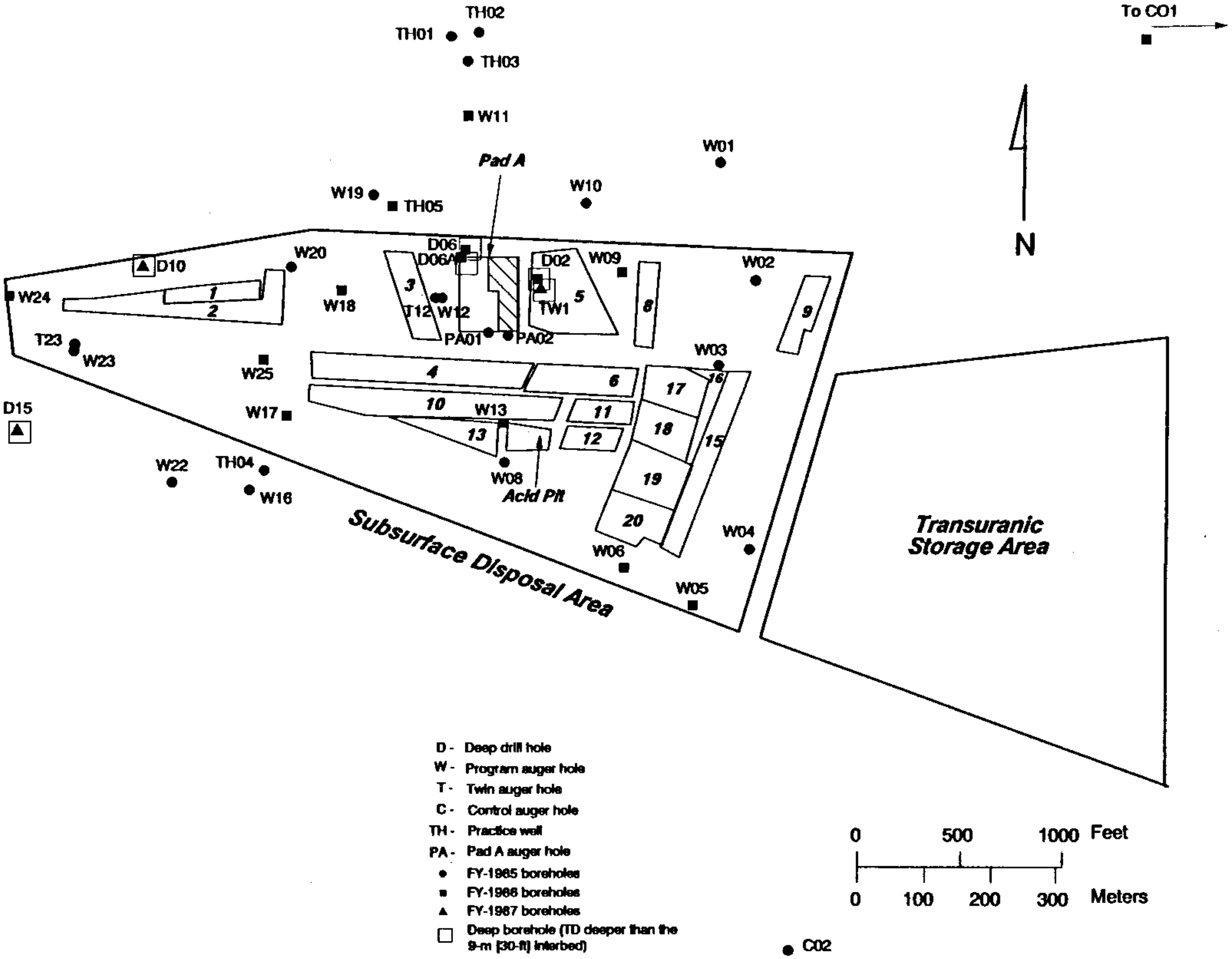


Figure 5-1. Locations of SIP boreholes drilled from FY-85 through FY-87 (modified from Laney et al., 1988, locations are approximated).

samples. In addition, 17 samples were collected during drilling using thin-wall tube samplers (Shelby tubes) for permeability evaluations. Four of the 17 samples were tested for permeability in 1989.

In each of the boreholes, one or two types of soil moisture monitoring instrumentation were installed before the hole was backfilled. Nineteen tensiometers were installed in 10 boreholes to measure the matric potential in the sediments within the range of 0 to 0.8 bars. Fifty gypsum blocks were installed in clusters of three within seven boreholes to measure the matric potential of the soil for the range of 0 to 10 bars. Seventy-one heat dissipation probes were installed in clusters of three within the shallow boreholes to measure the matric potential of the soil for the range of 0 to 1.0 bars. In addition, porous-cup lysimeters were installed in most of the shallow boreholes to collect soil-water samples for major ion and radiochemistry analyses. Table 5-1 summarizes the type of instrumentation installed in each borehole. The installation details for each borehole are included in Appendix 5-1.

All soil-moisture monitoring instruments are monitored approximately monthly. The data from all of the instruments, except the thermocouple psychrometers, are collected by visually reading the gauges and meters that are attached to the instrument lead wires at each borehole collar. Readings are recorded in field logbooks and entered into the RWMC database. The thermocouple psychrometers are read automatically with a datalogger and the data is downloaded directly to the RWMC database.

Aqueous samples are periodically collected from the suction cup lysimeters in the spring, fall, and sometimes in the summer. The samples are analyzed for general chemistry, radionuclides, and metals. Radiochemical analytical data collected for the shallow drilling program in FY-85 and FY-86 are summarized in Laney et al. (1988). Samples were collected from the suction cup lysimeters in FY-87, -88 and -89, but these data have not been summarized to date. Data were not collected from the suction cup lysimeters in 1990.

Table 5-1. Summary of shallow borehole instrumentation

Borehole	Tensiometer	Gypsum Block	Heat Dissipation Sensor	Psychrometer	Lysimeter
C01					2
C02					1
D06			6		2
D15			12		3
PA01	3	6			1
PA02	2				1
T12		3		3	
T23	1	12			1
TH02					1
TH04		2		2	1
TH05					2
TW1			9		2
W01	2			9	
W02					1
W03					1
W04					3
W05			2		3
W06	3		1		1
W08					1
W09			12		
W10		12			
W11			12		
W12		3			
W13			15		
W16				6	
W17	2		14		
W18			9	15	
W19		12		15	
W20	2				
W22				9	
W23	1				
W24	3		3		
W25			3		

---

a. Appendix 5-1 contains tabular data on installation dates and depths for each type of instrument.

5.3.1.2 Test Trench Installation. The test trench installation was installed in 1984 north of the SDA boundary and consists of two trenches: the east trench and the west trench (Figure 5-2). Data collection began at the west test trench on November 9, 1987, and at the east test trench on October 26, 1986 (Pittman, 1989). Each of the two trenches are constructed with two 2-m (6-ft) diameter culverts that are connected to form a T-shape (Figure 5-2). A vertical piece of culvert extends from 1 m (3 ft) above land surface to a depth of 4.3 m (14 ft) below land surface. A second culvert joins the vertical culvert at a 90 degree angle approximately 1.2 m (4 ft) below land surface and extends horizontally for 6 m (20 ft).

Both test trenches were installed to obtain detailed information from a small area on the hydrologic properties of the sediments under actual and simulated conditions. Data collected from the test trench installation were to be used as a control to calibrate the information collected from the shallow boreholes around the RWMC. Within each trench culvert, 22 instrument ports were prepared by drilling the 5.7-cm (2.3-in.) shallow boreholes to the required depth (up to 12 ft) and setting a 2.54-cm (1-in.) Schedule 40 PVC pipe within each hole (Figure 5-3). The annular space was then filled with polyurethane foam to seal and insulate each shallow borehole. In the west test trench, both thermocouple psychrometers and tensiometers were installed in the instrument ports to measure temperature and tension in the soils. In the east test trench, only thermocouple psychrometers were installed. The instruments were spatially located to collect data from disturbed and undisturbed soils, adjacent to simulated waste containers, and along the surficial sediment/basalt interface (Hubbell et al., 1985).

In addition, 15 neutron access tubes were installed in and around the test trench area to monitor soil moisture conditions (Figure 5-3). Each neutron access tube consists of a 3.8-cm (1.5-in.) inner diameter stainless steel pipe placed vertically in the soil. Holes for the tubes were hand-augered to the sediment/basalt interface while collecting undisturbed cores for bulk density, soil moisture, and in some instances, particle size analysis. A neutron moisture probe was inserted in each of the access tubes

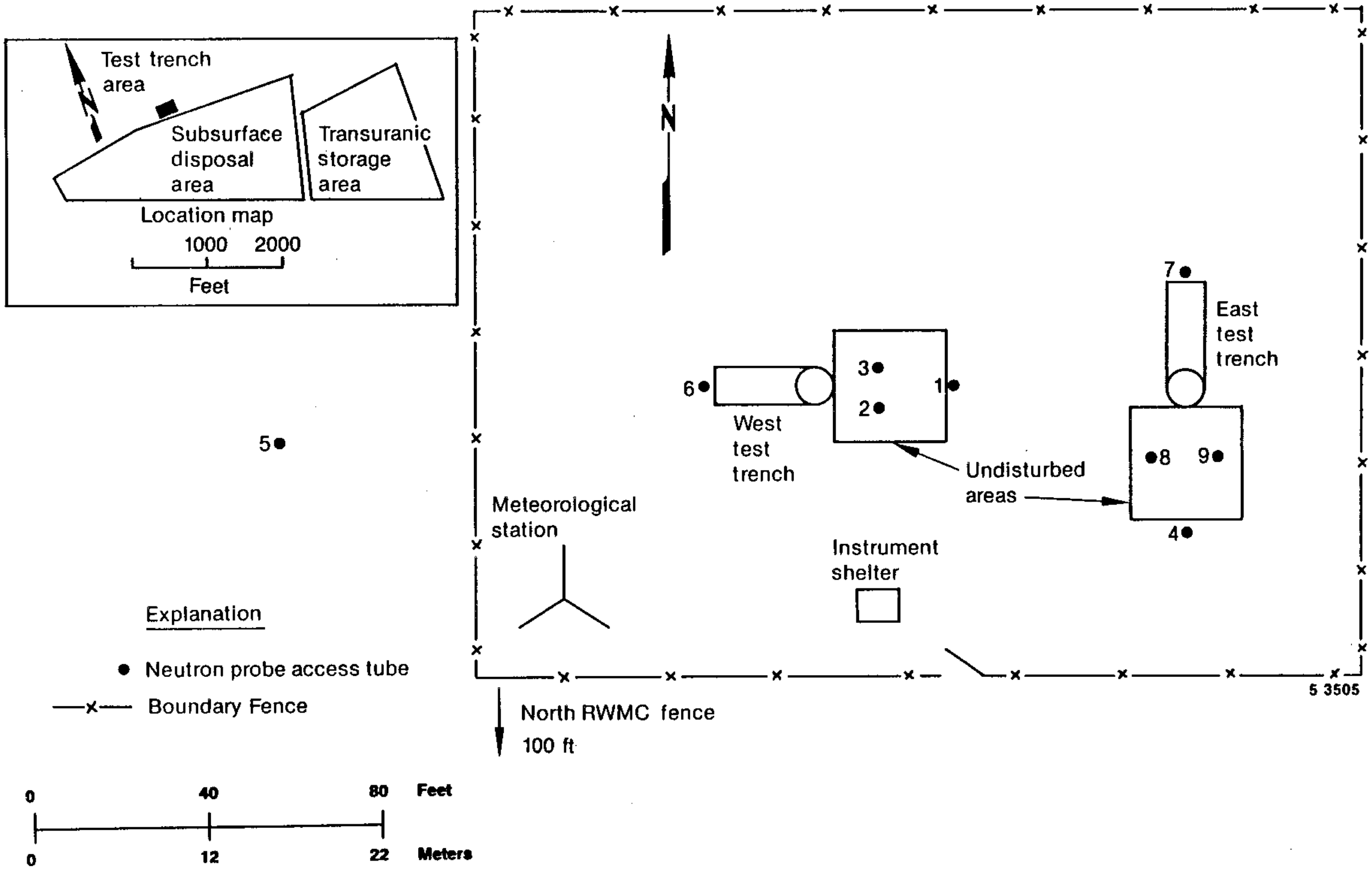


Figure 5-2. Location of test trench study area and associated neutron probe access tubes at the RWMC (Hubbell et al., 1988).

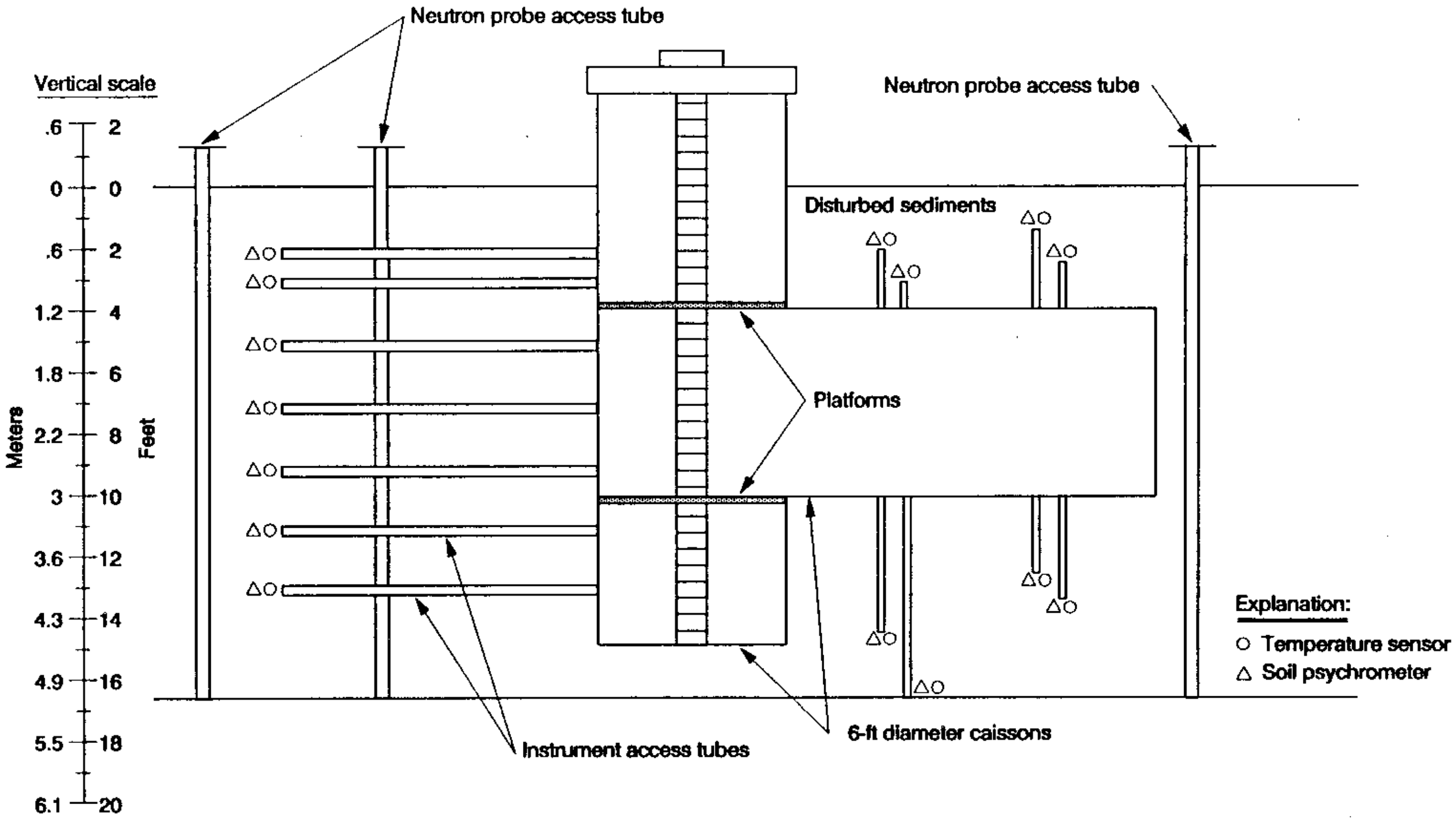


Figure 5-3. Installation details of the west test trench (Laney et al., 1988).

on a weekly to biweekly basis to record the soil moisture at 0.15-, 0.3-, and 0.6-m (0.5-, 1-, and 2-ft) increments to the bottom of the hole.

A micrometeorological station was also installed at the trench installation site to determine the effects of atmospheric conditions on subsurface soil moisture and temperature variations. Data collection began on June 18, 1986. Data obtained from the micrometeorological station are to be used by the USGS and the EG&G Idaho Geosciences Unit to develop mass balance equations for input into a numerical model of unsaturated zone water movement and for a migration model of the site, respectively. These efforts are ongoing. Hydrological and meteorological data collected from 1985-1986 are summarized in Pittman (1989), and data collected during 1987 are summarized in Davis and Pittman (1990).

A shelter was constructed at the trench installation site to protect the data acquisition equipment. Within the shelter, a Campbell Scientific CR-7X data logger records the hourly psychrometer and tensiometer data readings from both trenches. Data are stored internally in the CR-7X for up to 7 days and are retrieved weekly by remote accessing of the system using an IBM PC/AT. Data are also stored on cassette tape in the instrument shelter as a back-up to the system. A Campbell Scientific CR-21 data logger is also located in the instrument shelter to record meteorological data. These data are recorded in 6- and 24-hour summaries and downloaded remotely to the IBM system monthly.

5.3.1.3 Weighing Lysimeter Complex. Two weighing lysimeters were installed in 1979, to determine rates of soil moisture evaporation and plant transpiration in the upper few meters of surficial sediment. These instruments did not produce reliable data and consequently were shut down in the latter part of 1982. The weighing lysimeter activity of the SIP began in 1985 and consisted of making necessary repairs and modifications to bring the lysimeters back into operation such that they produced reliable data (Hubbell et al., 1985).

The weighing lysimeter complex is located 243 m (880 ft) north of the SDA (Figure 5-4). This installation is made up of two weighing lysimeters

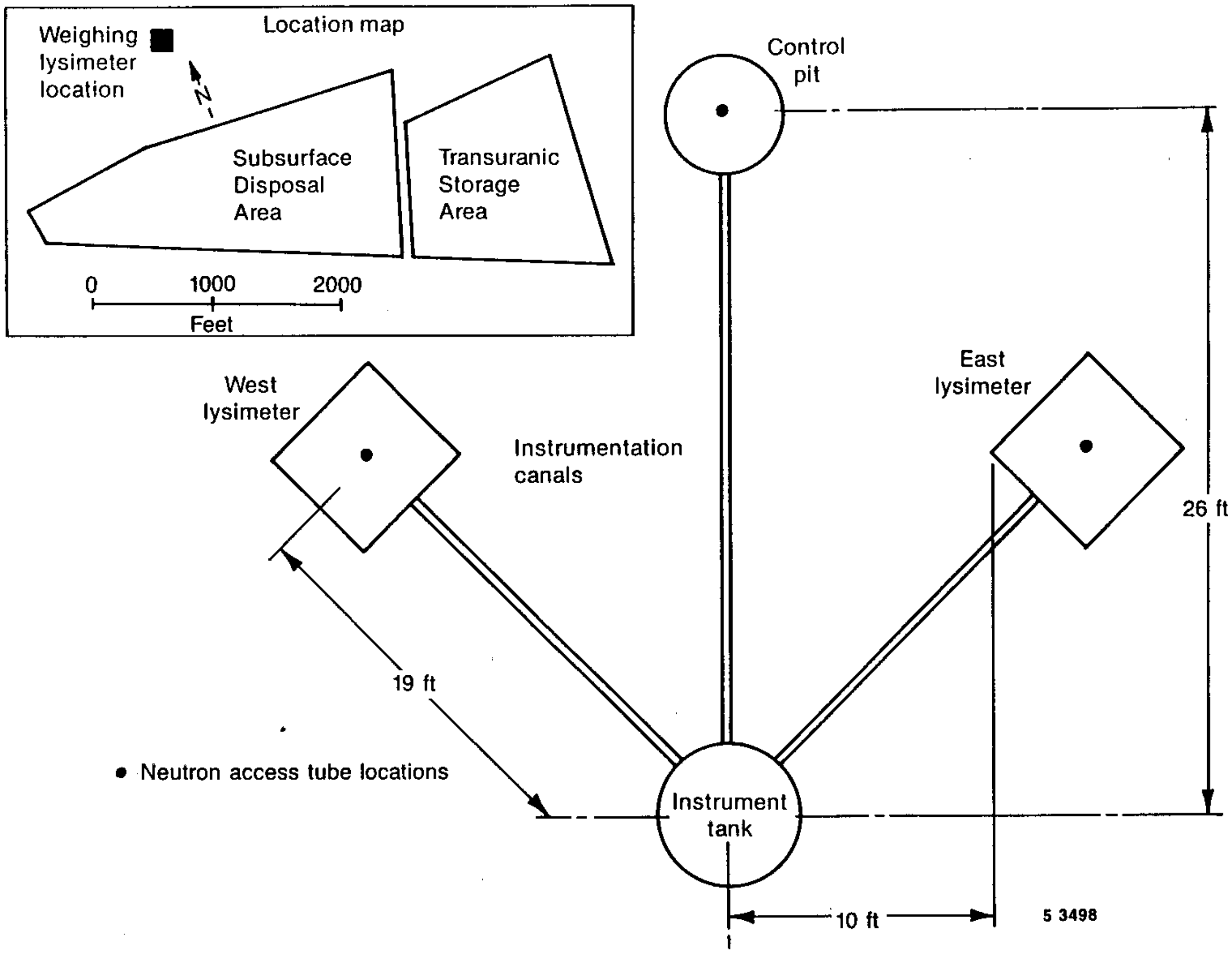


Figure 5-4. Location and layout of weighing lysimeter installation (Laney et al., 1988).

measuring 1.5 x 1.5 x 1.8 m (5 x 5 x 6 ft), a control pit 1.3 m (4.3 ft) in diameter, connecting pipe, and an instrument tank. The weighing lysimeters and control pit have identical sets of instrumentation (i.e. soil-moisture/temperature blocks, thermistors, and neutron access tubes) for data comparison. As shown in Figure 5-5, two soil-moisture/temperature blocks were inserted into the soil within the inner lysimeter box at depths of 5, 10, 20, 30, 60, 91, 122, and 151 cm (2, 4, 8, 12, 24, 36, 48 and 59.5 in.). In addition, a borehole was drilled into the center of each weighing lysimeter and control pit and cased for use as a neutron probe access tube. The neutron probe is used to calculate moisture content and field calibrate the soil moisture/temperature blocks for various moisture contents. Eight thermocouples were also attached to the outer sides of each lysimeter box at the same depths as the soil-moisture/temperature blocks, and one thermocouple was attached to each of the scales to monitor temperature. Sheets of cellutex insulation were attached over the thermocouples to mitigate the effects of temperature fluctuations outside the boxes. The weighing lysimeters were also equipped with suction candles at the bottoms of the inner containers to remove any excess water and equilibrate tensions to natural conditions.

Data were collected in 1986 from the 96 moisture/temperature blocks in the two lysimeters and control pit (32 at each installation) on a 6-hour basis. Readings were also taken on a 6-hour basis for the 16 thermocouples on the outside of the lysimeter boxes and from the scales. All these readings were recorded in the Campbell Scientific CR-7X data logger and remotely downloaded to an IBM PC. Approximately 40 to 50 percent of the moisture temperature blocks gave erratic data (Hubbell et al., 1987). In FY-87, the weighing lysimeters were repaired and modified. The laboratory calibration of the soil-sensors was not possible without their retrieval. Consequently, the collection of data from the soil-moisture/temperature sensors at the weighing lysimeter was discontinued (Laney et al., 1988).

The weighing lysimeter activity in FY-88 consisted of collecting weight data and neutron logging through the neutron probe access tubes. During the first and second quarters of FY-88, snow bridging between the lysimeter and the surrounding soil resulted in recording erratic weights. Data were also

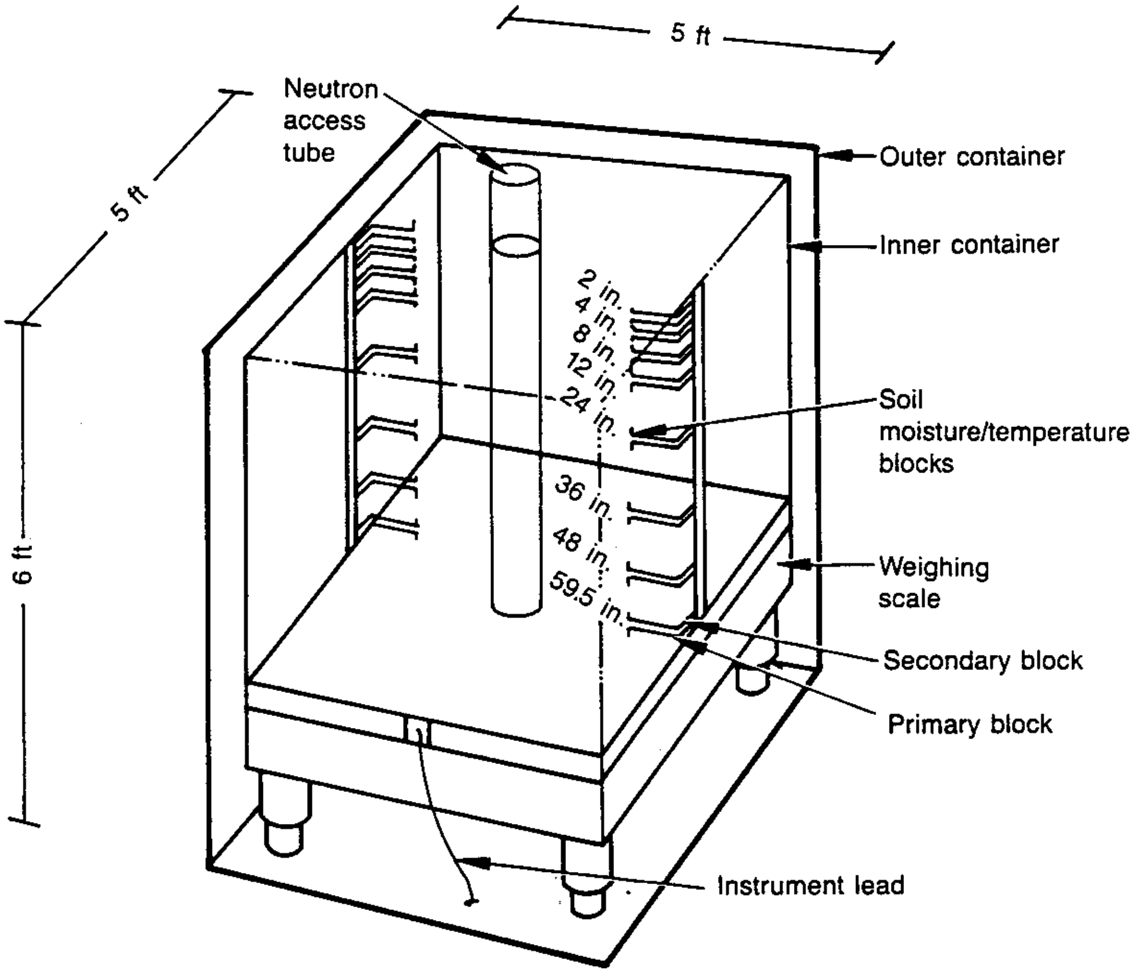


Figure 5-5. Weighing lysimeter instrumentation diagram showing locations and depths of instrumentation (Laney et al., 1988).

recorded during the third and fourth quarters of FY-88. Moisture profiles of soil in the weighing lysimeters were compared to moisture profiles of the control pit to verify that the lysimeter was operating correctly. In May, the lysimeter and control pit moisture profiles were matched using suction candles in the lysimeters. This match could not be maintained on a continuous basis during high moisture conditions, but the match was maintained from July to September when infiltration was restricted by evapotranspiration to the upper 0.3 m (1 ft) of soil. Erratic weights were recorded during high wind conditions as well (McElroy et al, 1989).

The collection of data from the weighing lysimeters continued in FY-90. Work continued on methods to automate the moisture profile matching of the lysimeter soil to ambient soil moisture and on improvements that will enable the lysimeter to work during thaw conditions. Statistical analyses will be performed to minimize the effects of wind loading.

5.3.2 Deep Drilling Program

Between 1986 and 1990, 10 boreholes (D02, D06, D06A, D15, TW1, D10, 8801D, 8802D, 8901D, and 8902D) were drilled into the basalt and sedimentary interbeds in the vadose zone beneath the SDA. Borehole 8801T was also drilled as a test hole outside the SDA. Each borehole was sampled at selected intervals for either chemical, geological, or hydrological analyses. Geophysical logs were run to identify interbed tops and thicknesses. Heat dissipation sensors and suction-cup lysimeters were installed in the sedimentary interbeds of selected boreholes. Several boreholes were completed with gas sampling ports. The locations of the deep boreholes drilled since 1988 are shown on Figure 5-6. The completion details for each deep borehole are provided in Section 5.5.2.

Core samples were collected from selected stratigraphic intervals. Before the drilling of Borehole D10 in 1987, the sampling was conducted at the following stratigraphic locations: (a) the surficial sediments; (b) 1.5 m (5 ft) into the top of the basalt; (c) 1.5 m (5 ft) above and below the 9-, 34-, and 73-m (30-, 110-, and 240-ft) sedimentary interbeds; and (d) in

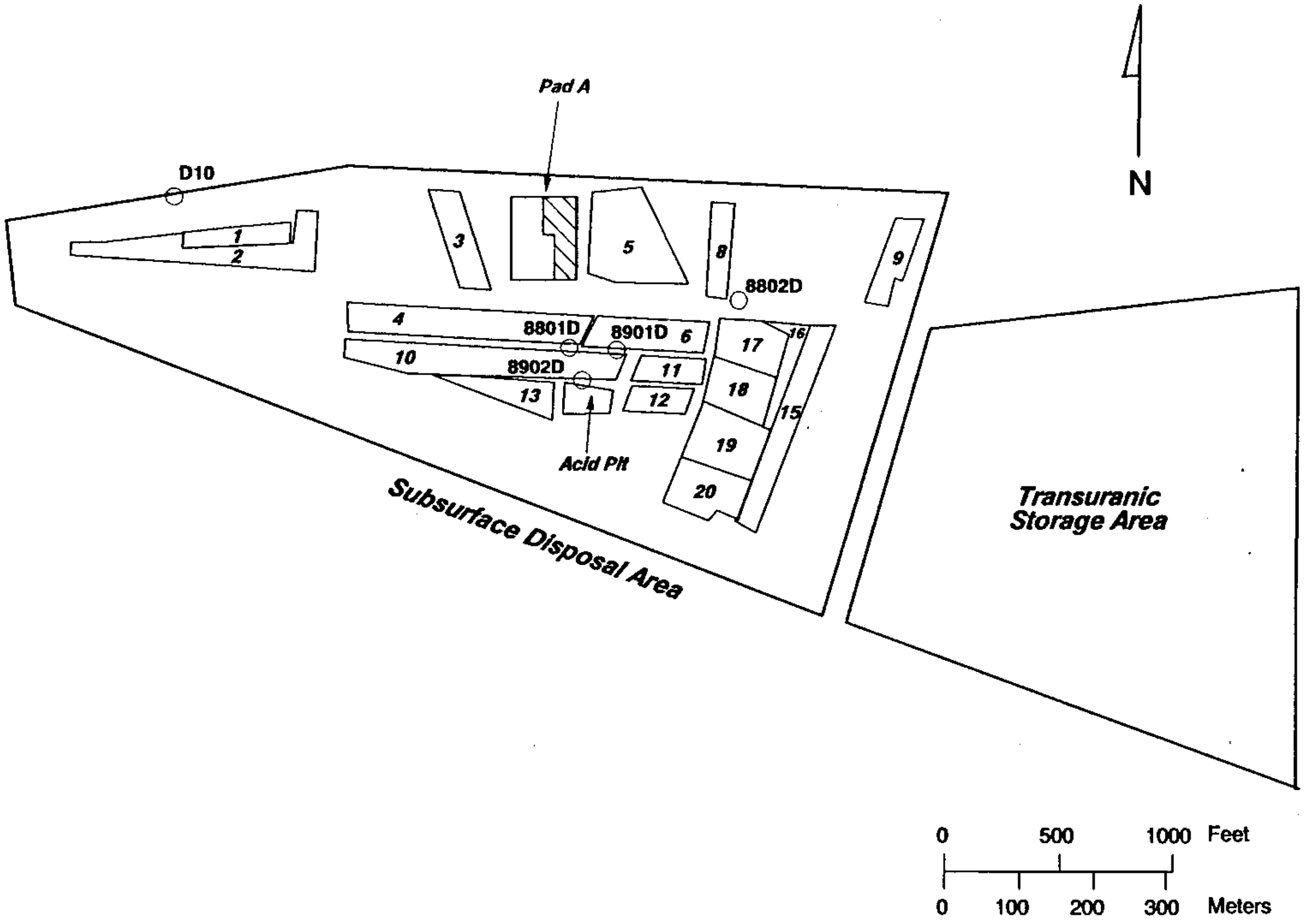


Figure 5-6. Locations of deep boreholes at the SDA drilled since 1988 (locations are approximated).

the sedimentary interbeds. Starting with Borehole D10, it was proposed that all future boreholes be continuously cored from surface to total depth.

Samples were collected for chemical, geological, and hydrological analyses. California Split Spoon samplers with cellulose acetate and Lexan liners were used to retrieve samples for chemical and lithological analyses. Shelby tubes were used to retrieve samples for permeability testing. Following retrieval, each core was described including sample depth, texture, color, moisture, and reaction to 5% HCl. Lexan and cellulose acetate liners were capped, sealed with electrical tape, and triple bagged. Shelby tubes were capped and sealed with electrical tape.

Interbed sediment samples were subjected to several analytical procedures to determine the presence of the radionuclides listed in Table 5-2. From this list, seven radionuclides were positively detected in samples from Boreholes D02, D06, D06A, D15, and TW1: Pu-238,-239, Pu-240, Am-241, Sr-90, Cs-137, Co-60, and Eu-154 (Laney et al., 1988). The samples from Boreholes D10, 8801D, 8802D, 8901D and 8902D were analyzed for target compounds of radionuclides and/or 40 CFR 264 Appendix IX chemicals based on an established order of priority. Borehole 8801D was assigned a priority for 40 CFR 264 Appendix IX analyses. Boreholes 8802D, D10, and 8902D were assigned first priority for radiochemical samples and second priority for Appendix IX. Samples from Borehole 8901D were to be analyzed only for radionuclides. Table 5-2 lists the target radionuclides in the boreholes drilled from 1988 to 1990. Table 5-3 is a list of the target compounds from 40 CFR 264 Appendix IX. Table 5-4 lists the sample collection requirements for the 40 CFR 264 Appendix IX constituents. The samples submitted for radiochemical and/or 40 CFR 264 Appendix IX analyses are summarized in Section 5.5.2.2.

Wireline geophysical logs were run in all boreholes after drilling had penetrated 1.5 m (5 ft) into the basalt underlying the 34-m (110-ft) interbed. The entire borehole was logged again after reaching a total depth below the 73-m (240-ft) interbed. The types of geophysical logs recorded were gamma ray, gamma-gamma, and neutron. Downhole television and caliper logs were also run in selected boreholes. The interbed tops and thicknesses were determined

Table 5-2. List of target radionuclides for the SIP[a]

Boreholes D02, D06, D06A, D10, D15, TW1		Boreholes 8801D, 8802D, 8901D, 8902D, D10 (deep)	
Radionuclide	Half-Life	Radionuclide	Half-Life
Actinium-228	6.13 hours	Actinium-228	6.13 hours
Americium-241	458 years	Americium-241	458 years
Antimony-124	60 days	Antimony-125	2.7 years
Cerium-141	33 days	Bismuth-212	60.6 minutes
Cerium-144	284 days	Bismuth-214	19.8 minutes
Cesium-134	2.05 days	Cerium-144	284 days
Cesium-137	30.2 years	Cesium-134	2.05 days
Cobalt-58	71.3 days	Cesium-137	30.2 years
Cobalt-60	5.27 years	Cobalt-60	5.27 years
Europium-152	12 years	Europium-152	12 years
Europium-154	16 years	Europium-154	16 years
Europium-155	1.81 years	Europium-155	1.18 years
Hafnium-181	42.5 days	Lead-212	10.6 hours
Iron-59	45 days	Lead-214	26.8 minutes
Manganese-54	303 days	Manganese-54	303 days
Mercury-203	46.9 days	Plutonium-238	87.7 years
Niobium-96	23.4 hours	Plutonium-239	24,000 years
Plutonium-238	87.7 years	Plutonium-240	6580 years
Plutonium-239	24,000 years	Plutonium-241	14.4 years
Plutonium-240	6,580 years	Protactinium-234	6.7 hours
Praseodymium-144	17.3 minutes	Radium-226	1600 years
Rhodium-106	30 seconds	Silver-110 m	253 days
Ruthenium-103	39.6 days	Strontium-90	28.8 years
Scandium-46	83.9 days	Thallium-208	3 minutes
Scandium-51	12.4 seconds	Thorium-234	24.1 days
Tantalum-182	115 days	Uranium-234	2.5 x 10^5 years
Zinc-65	245 days	Uranium-238	4.5 x 10^9 years
Zirconium-95	65 days	Zinc-65	245 days

---

a. Source: Banson et al. (1981); Walker et al. (1983); Laney et al. (1988); EG&G (1989e).

Table 5-3. List of target compounds from 40 CFR 264 Appendix IX[a]

Contaminant	Method/Instrument	Practical Quantitation Limits (μg/l)
Appendix IX (40 CFR 264) contaminants of primary concern at the SDA		
Carbon tetrachloride	GC/MS[b]	1
Trichlorethylene	GC/MS	1
Tetrachlorethylene	GC/MS	0.5
1,1,1-trichlorethane	GC/MS	5
Chloroform	GC/MS	0.5
Metals	Inductively coupled argon plasma emission spectrometer	2 - 800 μg/l
VOCs found at lower concentrations		
1,1,2-trichlorotrifluoroethane	GC/MS	10
1,1-dichloroethane	GC/MS	1
1,1-dichloroethylene	GC/MS	1
Dichlorofluoromethane	GC/MS	10
Toluene	GC/MS	2

---

a. Source: Koslow and Hubbell (1989).

b. Gas chromatograph/mass spectrometer.

Table 5-4. Sample collection requirements for 40 CFR 264 Appendix IX analyses[a]

Parameter	Sample Type	Container	Preservative[b]	Hold Time	Volume[c]
Metals	Liquid	Plastic/glass	HNO_3 to pH <2	6 months (except Mercury - 26 days)	1 L
	Solid	Glass	4 C	None specified	250 mL
Semivolatile organic compounds	Liquid	Amber glass	Dark, 4 C	7 days (extraction) analyses within 40 days	1 gal
	Solid	Glass	Dark, 4 C	12 days (extraction) analyses within 40 days	250 mL

---

a. Source: EPA (1986b).

b. Liquid samples designated for volatile organic analysis and shipped air freight should be packaged in a hermetically sealed container or be placed in a pressurized location to avoid formation of decompressive air bubbles that might invalidate any results.

c. These are minimum sample collection requirements; sample volumes may be larger than indicated to obtain a representative sample or to provide sufficient material for more than one sample preparation technique. Metals and semivolatile organic compounds may be analyzed from the same 250 mL sample volume.

from available gamma ray logs, which are included in Appendix 3-1 of this document.

Boreholes D15, TW1, and D06 were instrumented with heat dissipation sensors and suction cup lysimeters following the drilling and sampling. These instruments were installed in clusters of one lysimeter and three heat dissipation sensors to check for reproducibility of the measurements. The instrument clusters were attached to a PVC guide pipe and lowered into place so that instruments were placed at depths corresponding to the locations of the sedimentary interbeds. A layer of silica flour was tremied into the borehole to surround the instruments and provide a hydraulic connection with the surrounding sediments. A layer of bentonite below and above the silica flour layer was used to isolate the instruments from other portions of the borehole.

The heat dissipation sensors are monitored monthly when personnel and weather conditions permit. Readings are taken visually from meters attached to the instrument lead wires uphole. These readings are recorded in the field, and the data are entered in the RWMC database for reduction, plotting, and interpretation.

Six deep boreholes are instrumented with gas sampling ports (77-1, WWW-1, 78-4, 8801D, D02, and 8902D). Their locations are shown in Figure 5-7. Boreholes 8801D, D02, and 8902D were completed under the SIP. The depth of the sampling ports in 8801D, D02, and 8902D is shown on Table 5-5. For detailed information on all deep boreholes instrumented with gas sampling ports, see Section 11 of this report. The gas sampling procedures described in Section 5.4.3.3 refer to a one-time gas sampling event of Boreholes 77-1, WWW-1, 78-4, and 8801D that was conducted from May to June 1989. Gas samples collected from this one-time gas sampling event were analyzed by the purge and trap method with a GC/MS for the 34 VOCs listed in Table 5-6.

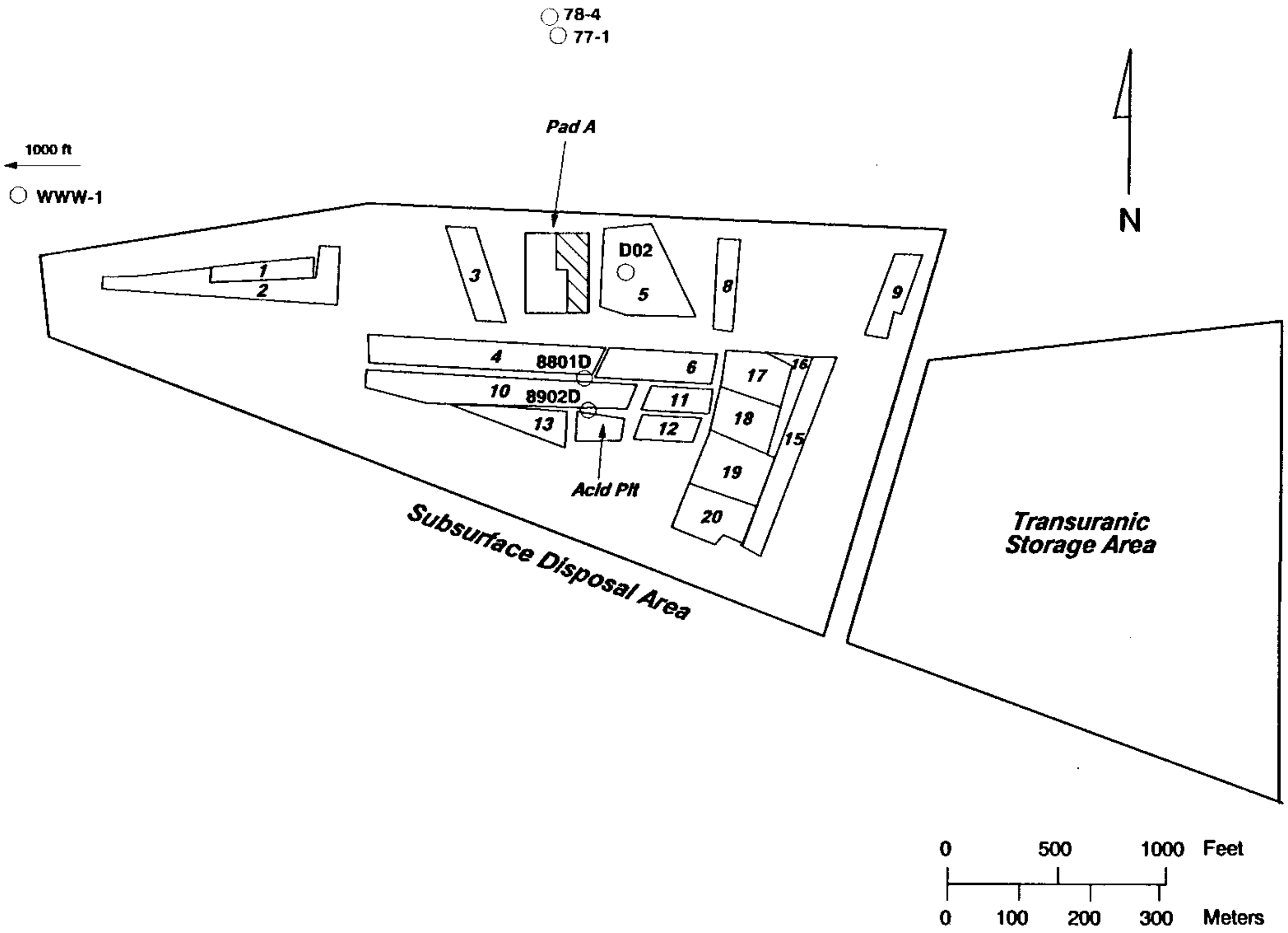


Figure 5-7. Locations of monitoring boreholes with gas sampling ports (locations are approximated).

Table 5-5. Depths of gas sampling ports in boreholes installed under the SIP deep-drilling program[a]

Borehole	Depth of Port (ft below land surface)	Port ID Number
8801D	32.8	GSP-8801D-9
	50.5	GSP-8801D-8
	77.5	GSP-8801D-7
	92.5	GSP-8801D-6
	102.5	GSP-8801D-5
	131.0	GSP-8801D-4
	167.2	GSP-8801D-3
	192.5	GSP-8801D-2
	230.0	GSP-8801D-1
8902D	30.0	GSP-8902D-8
	46.0	GSP-8902D-7
	70.5	GSP-8902D-6
	104.5	GSP-8902D-5
	130.0	GSP-8902D-4
	179.0	GSP-8902D-3
	199.0	GSP-8902D-2
	229.0	GSP-8902D-1
D02	27.5	GSP-D02-8
	59.5	GSP-D02-7
	68.5	GSP-D02-6
	100.0	GSP-D02-5
	125.0	GSP-D02-4
	165.5	GSP-D02-3
	192.5	GSP-D02-2
	231.0	GSP-D02-1

---

a. Boreholes 78-4, WWW-1, and 77-1 drilled prior to the SIP, have gas sampling ports. The depths of these ports are shown on Table 11-1 in Section 11 of this report.

Table 5-6. VOCs analyzed for in the SIP

Acetone
Benzene
2-butanone
Bromoform
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chlorodibromomethane
Chloroethane
2-chloroethylvinyl ether
Chloroform
cis-1,3-dichloropropene
Dichlorobromomethane
1,1-dichloroethane
1,2-dichloroethane
1,1-dichloroethene
1,2-dichloropropane
Ethylbenzene
2-hexanone
Methyl bromide
Methyl chloride
4-methyl-2-pentanone
Methylene chloride
Styrene
1,1,2,2-tetrachloroethane
Tetracholoroethene
Toluene
trans-1,2-dichloroethene
trans-1,3-dichloropropene
1,1,1-trichloroethane
1,1,2-trichloroethane
Trichloroethene
Vinyl acetate
Vinyl chloride
Total xylenes

5.4 Procedures

This section presents the procedures that were followed during all phases of the shallow and deep drilling program. The drilling and borehole completion procedures are summarized in Section 5.4.1; the instrument installation and monitoring procedures are summarized in Section 5.4.2; the soil, water, and gas sampling procedures are presented in Section 5.4.3; and the quality assurance/quality control procedures are summarized in Section 5.4.4.

5.4.1 Drilling and Borehole Completion Procedures

Ten deep boreholes were drilled to a depth of approximately 76.2 m (250 ft). Drill holes were augered through the surficial sediments, and the basalt and sedimentary interbeds were drilling using tricone or diamond coring bits. An air rotary circulation system was used to circulate cuttings to the surface and to lubricate and cool the bit face. The following drilling procedures were proposed as a standard approach for the deep boreholes (Laney et al., 1988). However, the drilling procedure for each deep borehole varied from the proposed procedures as described in Section 5.5.2.

1. The surficial sediments above the uppermost basalt layer were augered by RWMC operations or by a subcontractor. Some years the surficial sediments were sampled with a 18.4-cm (7-1/4 in) auger. The hole was reamed to a 30-cm (12-in.) diameter using a 30-cm (12-in.) auger bit.

2. The SIP drilling rig cored the first 1.5 m (5 ft) of the basalt below the surficial cover using an HWB or CP core barrel. The 1.5-m (5-ft) core hole was reamed using a 30-cm (12-in.) tricone bit. A 20.3- or 25.4-cm (8- or 10-in.) diameter surface casing was set and cemented into the drill hole from the surface to approximately 1.5 m (5 ft) into the underlying basalt.

3. The basalt was either cored continuously or drilled using a 20-cm (7-7/8-in.) tricone bit. In boreholes that were not cured continuously,

the basalt was drilled with the tricone bit to approximately 1.5 m (5 ft) above the 34-m (110-ft) interbed. The tricone drill string was changed out to an HXB or CP core drill string. Before coring, a samarium oxide or dysprosium tracer was placed in the borehole to check against cross-contamination of sample material between different rock units down the borehole. The interbed and approximately 1.5 m (5 ft) of the overlying and underlying basalt were cored. The borehole was reamed with a 20-cm (7-7/8-in.) bit. Bentonite was placed at the bottom of the borehold, and 15-cm (6-in.) casing was set into the bentonite layer.

4. After setting the 15-cm (6-in.) casing, a 15-cm (5-7/8-in.) tricone bit was used to drill out the bottom of the casing into the underlying basalt. The basalt was drilled with the tricone bit or continuously cored until the 73-m (240-ft) interbed was within approximately 1.5 m (5 ft). The drill string was changed out and replaced with the core bit in boreholes that were not continuously cored. The interbed and approximately 1.5 m (5 ft) of overlying basalt were cored. After coring was completed, the hole was reamed with the 15-cm (5-7/8-in.) tricone bit.

5.4.2 Instrument Installation and Monitoring Procedures

Four types of instruments are used to monitor soil moisture tension in the unsaturated zone at the RWMC. These instruments are tensiometers, thermocouple psychrometers, gypsum blocks, and heat dissipation probes. All four types of instruments were installed in shallow boreholes drilled for the shallow drilling activity. Only heat dissipation probes were installed in the boreholes for the deep drilling program. The location of shallow and deep boreholes instrumented as part of the instrumentation, sampling, and monitoring program are shown in Figure 5-8. The annual progress reports for FY-85 (Hubbell et al., 1985), FY-86 (Hubbell et al., 1987), and FY-87 (Laney et al., 1988) describe the theory of operation and calibration and installation procedures of the instrument systems. Specific standard operating procedures used to collect data from the instruments are published

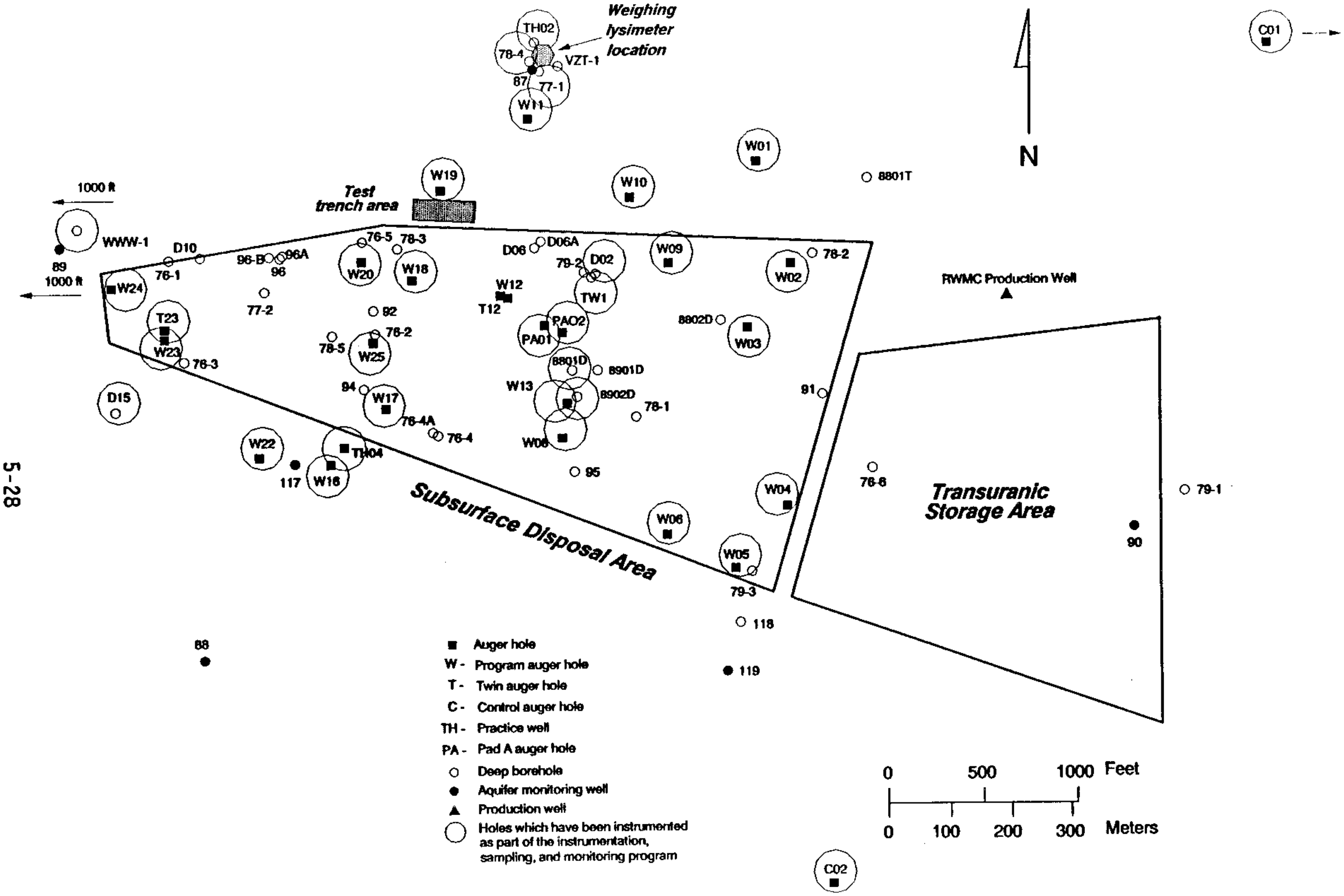


Figure 5-8. Shallow and deep boreholes instrumented as part of the instrumentation, sampling, and monitoring program (modified from Laney et al., 198P locations are approximate).

in the RWMC Subsurface Investigations Program Guidelines for Data Collection (Hubbell et al, 1988). The guidelines describe all aspects of data collection, compilation, and entry into the RWMC Data Management System. Safety requirements are also described in the report.

The following sections summarize the theory of operation, calibration, installation, and monitoring procedures that were used for each of these instruments. The tensiometer procedures are discussed in Section 5.4.3.1, the thermocouple psychrometer and gypsum block procedures are described in Sections 5.4.3.2 and 5.4.3.3, the heat dissipation procedures are discussed in Section 5.4.3.4, and the backfilling procedures that were used to backfill all of the boreholes following the instrumentation installation are described in Section 5.4.3.5.

5.4.2.1 Tensiometers. A Bourdon gauge tensiometer is used to measure the negative pressure (tension) that the soil exerts on the water within the soil. Each instrument is composed of a porous ceramic cup, connecting tube, and vacuum gauge as shown in Figure 5-9. When the cup is set at the desired location with a good hydraulic connection in the soil, water will move in or out of the cup wall until tensions equilibrate between the soil and the tensiometers. A Bourdon vacuum gauge is then read to give the tension in the soil. These instruments are capable of measuring tension from saturated conditions (zero bar tension) to 0.65 bar tension at the elevation of the RWMC.

The tensiometers were factory calibrated and accurate to 2 centibar (0.29 psi) tension as delivered to the RWMC. To check the factory calibration and determine that the instruments were functioning properly, the gauges were adjusted to zero pressure when unpressurized and a known vacuum was applied.

Before installation, each tensiometer was filled with fluid and allowed to sit a few minutes to saturate the ceramic cup. Next, the shallow borehole was backfilled to 4.4 cm (1.75 in.) above where the measuring point was to be located. The insertion tool was then driven 7.6 cm (3 in.) into the soil and

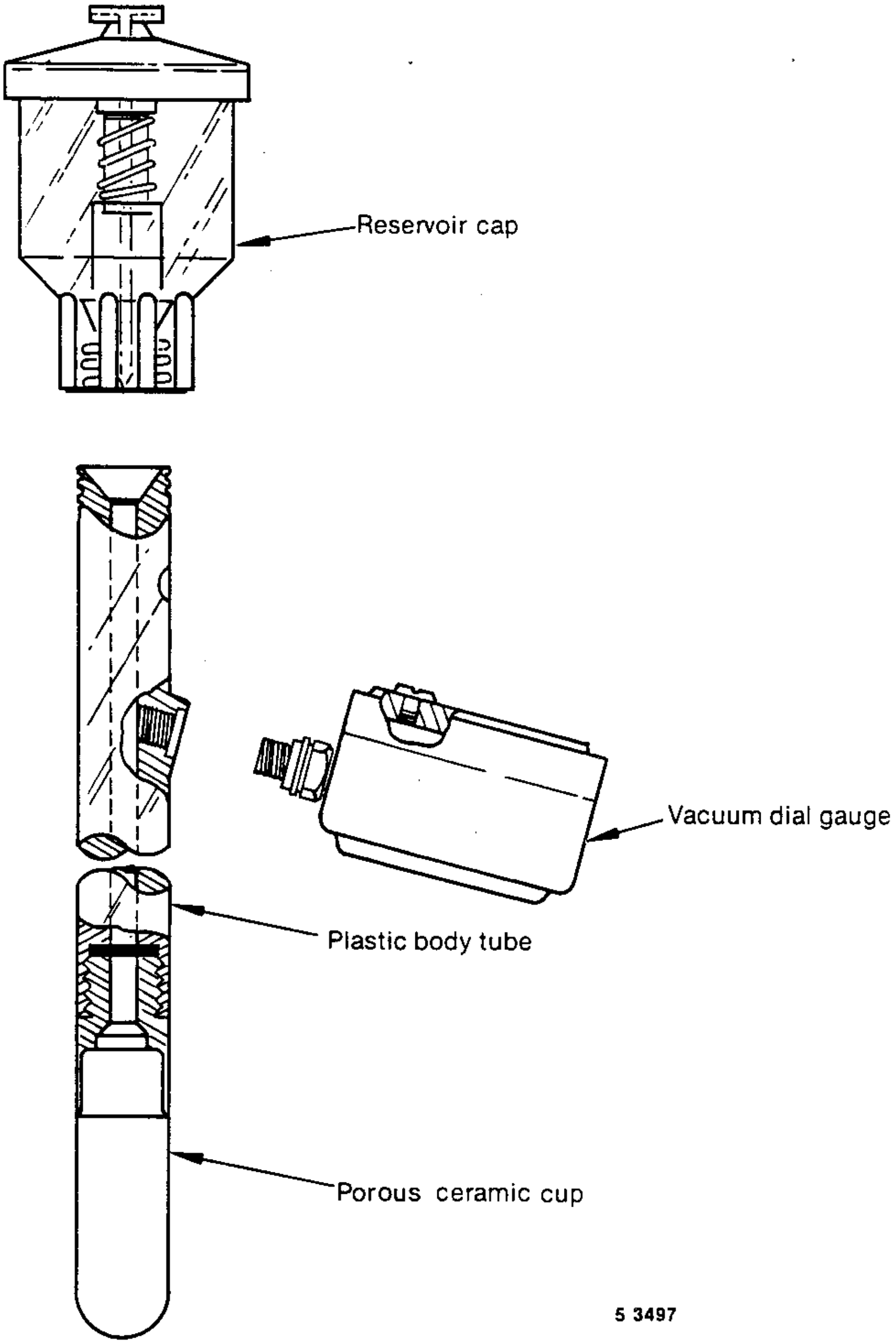


Figure 5-9. Bourdon gauge tensiometer (Soil Moisture Equipment Corp.).

removed. The tensiometer cup was placed in the hole made by the insertion tool. One instrument was set at each depth.

Measurements are obtained from the installed tensiometers by reading the vacuum gauge that is connected to the instrument. The reading is taken in centibars tension and recorded on a preprinted data collection sheet. The Bourdon gauge zero point is checked and adjusted before each reading is taken. The tensiometer reservoir is also checked and refilled if necessary.

5.4.2.2 Thermocouple Psychrometers. The thermocouple psychrometer is an electronic instrument used to measure the relative humidity in soil air (Figure 5-10). A thermocouple is cooled below the dew point so it collects a film of condensed water on the junction. The cooling is discontinued, and the junction starts to return to ambient temperature. Before ambient temperature is reached, evaporation of water from the junction holds the temperature constant at the wet bulb depression temperature. This temperature, along with the ambient (dry-bulb) temperature, is used to calculate the relative humidity. The soil tension can then be calculated from the relative humidity. These instruments can measure tensions from about 1 to 80 bars and are well suited for very dry soils.

Psychrometers were shipped to the RWMC from the factory with a one-point calibration reading at approximately 25 bars tension. This reading was used to derive the slope of a line for other readings. Before installation, each psychrometer was also checked in the laboratory at 17.9 bar to isolate defective instruments. This method involved placing numerous psychrometers in sealed 500-mL flasks of a NaCl solution to prevent vapors from escaping. The flasks sat overnight in a closed, insulated container, and then readings were taken. Psychrometers with excessively high or low readings were not used.

To install each instrument, shallow boreholes were backfilled to the desired depth, the instruments and lead wires were laid flat on the bottom, and the hole was backfilled to cover the instruments. The psychrometers were placed horizontally within each borehole in groups of three at each depth for

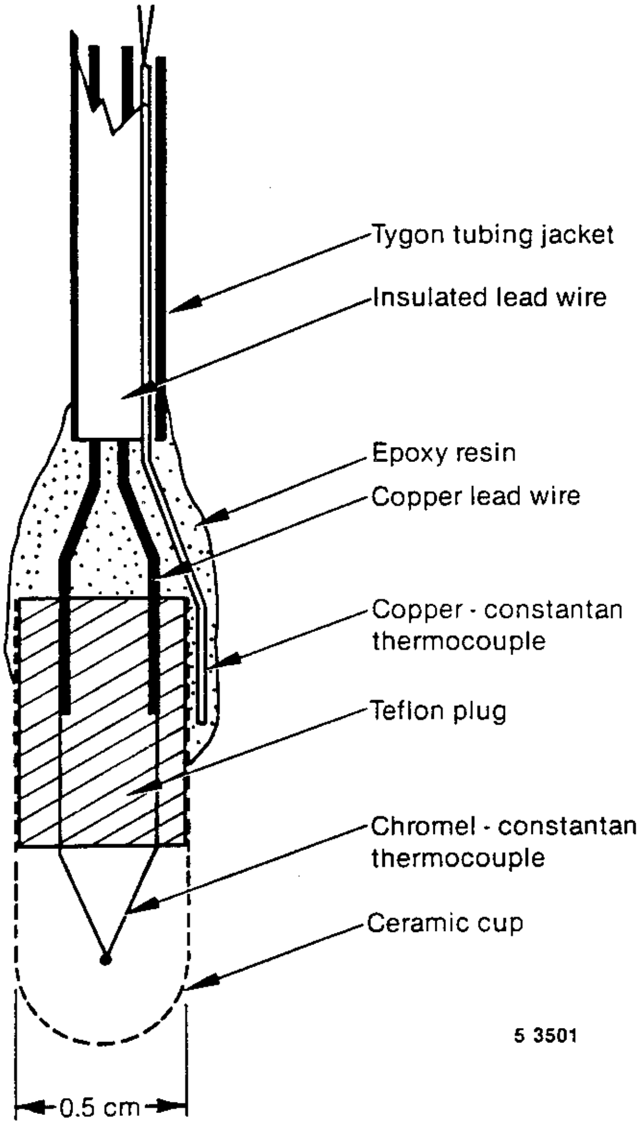


Figure 5-10. Cross section of a thermocouple psychrometer (Brown and Van Haveren, 1972).

most boreholes; 1 m (3.3 ft) of lead wire was coiled at the same level as the psychrometers to reduce the effects of temperature gradients.

The installed psychrometers are read monthly using a data logger. A Wescor HP-115 Data Acquisition System is attached to one borehole and left to scan the psychrometers. The HP-115 stores the field data in internal memory. After the data from all SIP psychrometers has been read and stored in internal memory, this information is downloaded to an IBM PC.

5.4.2.3 Gypsum Blocks. Gypsum blocks, or resistance blocks, measure soil moisture as a function of the resistance between two electrodes imbedded in gypsum. They can be calibrated to give readings in tension or moisture content and can measure tensions of 0 to 10 bars.

Gypsum blocks were calibrated by placing them in native soil from the SDA and drying the soil by applying various pressures in the soil using a pressure plate extractor. Readings were taken with a resistance meter during one drying cycle for tensions from 0 to 10 bars. All the gypsum blocks were calibrated except those located in Borehole TH04.

Before installation, each gypsum block was soaked in deionized water. The borehole was then backfilled to 1.9 cm (0.75 in.) below where the gypsum blocks were to be set. A slurry of deionized water and native backfill material was poured down the hole, the gypsum blocks were firmly pressed into this mixture to form a good hydraulic connection, and the hole was backfilled. Three gypsum blocks were set at each depth to compare readings.

A Model 5910A Soil Moisture Meter is used to collect data from the installed gypsum blocks. The meter is hand-held and operates on one 9-volt battery. The gypsum blocks are monitored approximately monthly.

5.4.2.4 Heat Dissipation Probes. Heat dissipation sensors measure moisture content by sensing the differences in heat conduction through a material with low thermal conductivity. The sensor has a miniature heater and a temperature sensor (thermistor) within the porous block. To measure soil moisture, a temperature is measured at the thermistor; the heater is heated for a specific time and the temperature remeasured. The difference in temperatures is then correlated to the soil matric potential.

The sensors were calibrated by the manufacturer in the range of 0 to 1.0 bar tension. They were installed in the surficial sediments by backfilling the shallow borehole to the designated monitoring depth, wetting the sensors in water, pouring a thin layer of slurry (water and native soil) to the bottom of the hole, and then pressing the sensor into the slurry. In the sedimentary interbeds, a silica flour and sand mixture was used to surround the heat dissipation sensors instead of the native soil. Most of the sensors were installed in clusters of three to check reproducibility of measurements. The installation was completed by backfilling shallow boreholes with native soil or with bentonite in the case of the deep boreholes.

Data are obtained from each heat dissipation sensor once per month by taking manual readings when personnel and weather conditions permit. A reading is obtained by connecting a modified Wheatstone bridge and galvanometer (Agwameter) to the electrical connector. Each reading is stored in the Agwameter and recorded on a preprinted data collection sheet.

5.4.2.5 Backfilling. The backfilling of each borehole was done systematically to avoid disturbing the natural flow systems in the unsaturated soil. Auger cuttings were used to backfill the holes. The cuttings were tamped in 5-cm (2-in.) layers with a long metal rod. Experiments were run in laboratory columns to practice backfilling the natural sediments in shallow boreholes (Hubbell et al., 1985). Samples of tamped materials were removed from the columns, and bulk densities were compared to those found in the field to determine the best backfilling and tamping methods. In deep boreholes, bentonite and cement were used to backfill.

Bentonite was used to seal the space between each instrument and the space above the instrumentation closest to land surface. This was done to inhibit downward saturated flow along instrument leads and isolate the borehole at discrete depths to allow the potentials to equilibrate. Bentonite layers 5 to 8 cm (2 to 4 in.) thick were typically placed at least 0.3 m (1 ft) away from the instruments. Both granular and pelletized bentonite were used to seal the boreholes. Tremie pipes were used to place the bentonite layers in order to reduce the amount of bentonite sticking to the walls of the borehole.

5.4.3 Sample Collection Procedures

Soil, aqueous, and gas sample procedures are summarized in this section. The soil sample collection procedures are included in Section 5.4.3.1. The aqueous and gas sample collection procedures are described in Sections 5.4.3.2 and 5.4.3.3, respectively.

5.4.3.1 Soil Sample Collection and Handling Procedures. This section summarizes the sample collection procedures for samples collected under the deep drilling program. Augering and sampling procedures for the surficial sediments are available through the Administrative Record Document Control library. The deep borehole sample collection procedures summarized below are included in Appendix 5-2. These procedures were outlined before completing Borehole 8801D and apply to Boreholes 8801D, 8802D (for the portion drilled in 1988) and D10 (for the portion drilled in 1988). Before completing Borehole 8801D, typically two sets of procedures were prepared for deep boreholes. One procedure was for soil sample collection (covered under the drilling procedures) and the second set of procedures was for sample handling including laboratory sample handling. These procedures are available through the Administrative Record Document Control library for SIP deep boreholes completed before Borehole 8801D.

Soil sample collection and handling procedures are used from the time the core is withdrawn from the borehole until the core sample is transported to the temporary storage area or sent for analysis. All core was recovered from the borehole by withdrawing the inner tube assembly from the outer tube assembly using a wireline. At the surface, the inner tube assembly was surveyed for both radioactivity and organic vapors before removal from the outer assembly. Then, the inner tube was removed from the outer shoe, labeled, and the open ends closed with plastic caps. The core within the inner tube was described including texture and general appearance. If the inner core barrel shoe contained core, the shoe was also labeled and the open ends capped. If any portions of the inner tube were empty, the empty section of the tube was cut off with a pipecutter, and a new plastic cap was placed on the open end.

For sediment samples submitted for chemical analysis, the following procedures were outlined. Sample bottles were prelabeled with the borehole identification number, sample identification number, date and time of sample collection, type of analysis (e.g., volatile organic analysis, metal, etc.), name of collector, and the time of collection recorded after sampling. This information was also recorded in the field logbook. If the entire core was not to be submitted for chemical analysis, then the designated sample interval was removed with a hacksaw. The archive sample was capped at both ends, labeled, and triple-bagged, and a label was affixed to the outside of the exterior plastic bag.

The cored interval to be sampled for chemical analysis was pushed from a tube into a stainless steel pan. For volatile organic analysis, two glass 250-mL containers were immediately filled using a stainless steel spoon and capped. Sample bottles were filled to minimize airspace. Care was taken to minimize the cobble fraction of the samples and depending on the contract chemical laboratory specifications, the remaining sediment (exclusive of volatile organic analyses) may have been vibrated through a 0.6-cm (1/4-in.) mesh, stainless steel sieve before transferring the sample into glass containers.

The fine-grained portion of the sample was mixed with a spoon. Radiation and organic vapor concentrations were measured after mixing, and the information recorded in the field logbook and on the chain of custody, sample analysis request form. For metal analysis, 1 L of sediment was collected in a 1-L glass container. A 1-L glass container was also used to collect 1-L sediment samples for extractables and other organic analyses. The outside rim of sample containers were wiped, lids affixed, and the outside of the glass container wiped clean.

Documentation on the sample was completed; documentation included the use of sample identification numbers, sample labels, sample tags, custody seals, field logbooks, and sample tracking. A unique sample identification number was assigned to each sample that was traceable throughout the sampling and analysis process, which consisted of numeric characters 0 through 9 and upper case alphabetic characters A through Z (not longer than 12 digits). Gummed labels were affixed to the sample containers and to any outer wrapping of the sample. These labels included the location of the top of the core, core identification number, borehole number, date collected, core interval, collector's initials, organic vapor reading, and radiation reading if above background. Samples selected for analysis were labeled with the borehole identification number, sample identification number, date and time of sample collection, analysis requested, method of preservation, name of collector, sample weight, and sample depth. All samples that were sent to the laboratory were given a sample tag in addition to a sample label to indicate the potential for hazardous constituents. The sample tag included the sample identification number, sampling location, sample collector, data and time of collection, analysis requested, concentration, and radiation screen results. Custody seals were used to detect tampering of samples between the time the samples were collected and the time the laboratory opened the samples for analysis. Logbooks were maintained to document the core retrieved and the sample selection process. Sample tracking was accomplished with the use of chain-of-custody forms.

The samples for chemical analyses were sealed and chain-of-custody forms were completed before packaging the samples for transport to the laboratory. The samples were packaged in accordance with procedures described in a standard operating procedure included in Appendix 5-2. Excess sediment in the stainless steel pan, excess core material, and any sample left in the shoe of the inner tube were archived for possible future testing. Archived samples were stored in a well-sealed, unbreakable container and were labeled, recorded in the logbook, and placed in the storage area.

The sample and analysis procedures proposed for each borehole subsequent to Borehole 8801D are summarized in the following documents. The actual sampling procedures for each deep borehole were obtained from the field logbooks and are described in Section 5.5.2.

- EG&G Idaho, Inc., 1989e, Sampling and Analysis Plan Boreholes 8802D, D10, and 8902D Radioactive Waste Management Complex, Subsurface Disposal Area, September.
- EG&G Idaho, Inc., 1988b, Sampling and Analysis Plan Borehole 8901D, Radioactive Waste Management Complex Subsurface Disposal Area, April.

5.4.3.2 Aqueous Sample Installation and Collection Procedures. Suction-cup lysimeters were installed in the boreholes at the RWMC to collect water samples and to estimate matric potentials. Most of the lysimeters were of the ceramic-cup construction, but a few teflon samplers were also installed. The ceramic-cup lysimeters were 66 cm (26 in.) long and 4.8 cm (1.9 in.) in diameter with the porous cup being 5.7 cm (2.2 in.) long. The teflon samplers were 46 cm (18 in.) long and 4.8 cm (1.9 in.) in diameter with the porous teflon section being 10 cm (4 in.) long.

In the laboratory, the lysimeters were prepared for installation by acid washing and inserting 0.6-cm (1/4-in.) diameter polyethylene access tubes. One tube was pushed through the neoprene plug so the end of the tubing reached to the bottom of the porous ceramic cup (Figure 5-11). A pressure-vacuum access tube used for evacuating and pressurizing the sampler was then inserted into the neoprene plug so that it extended through the plug about 2.5 cm (1 in.).

To install the lysimeters, the holes were backfilled with native material to the desired depth, and a small quantity of 200 mesh pure silica flour was poured into the borehole. Silica flour was mixed at a ratio of 3:1 with distilled water to make installation easier. Next, a lysimeter was placed in the borehole and another layer of 200 mesh silica sand was poured to

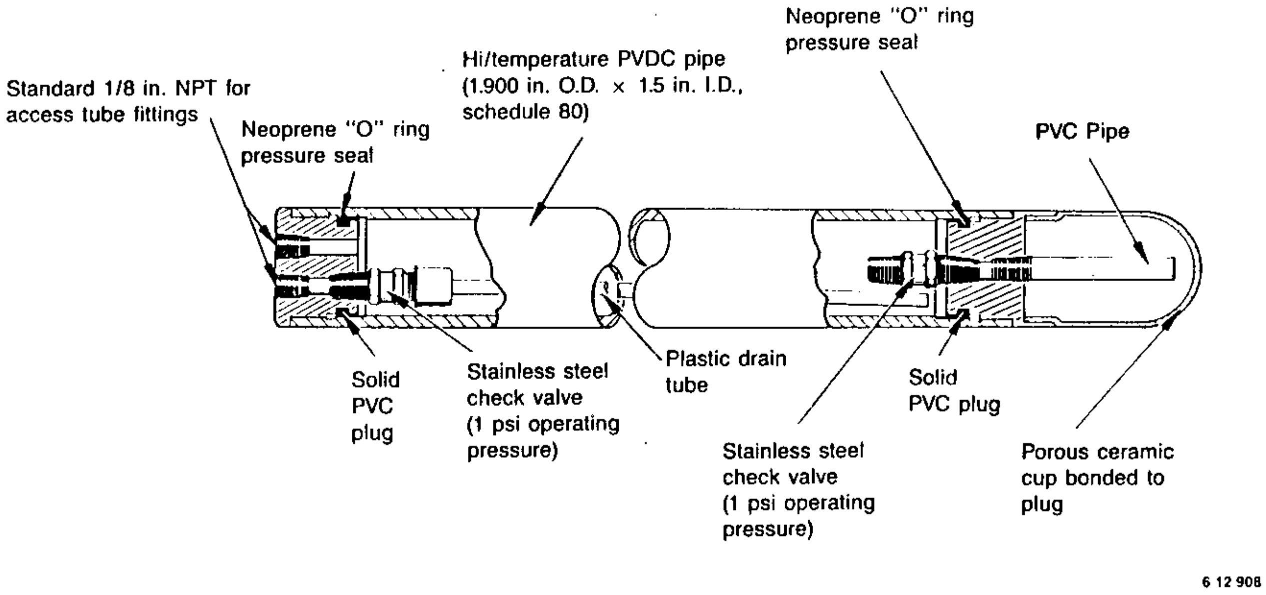


Figure 5-11. Cutaway view of porous cup lysimeter used in deep boreholes (Soilmoisture Corp.).

a depth of at least 15 cm (6 in.) around the cup of the lysimeter. The silica flour was covered with a thin layer of bentonite (5 to 7 cm) as a seal to prevent moisture from moving downward through the backfill materials directly into the silica flour. The borehole was backfilled with native soil and tamped continuously with a long metal rod to return the backfill to near its original bulk density.

At the surface, a 0.9 m (3 ft) long, 20-cm (8-in.) inner diameter steel casing was grouted 0.6 m (2 ft) into the top of the hole. The access tubing was rolled up and placed in plastic bags between samplings to protect the tubes from surface dust that might contain contamination.

Water samples were collected from the lysimeters by attaching the access tube to a pressure-vacuum hand pump and applying a vacuum of approximately 0.7 bar to the lysimeter. The pinch clamp on the pressure-vacuum access tube was then closed, and the lysimeter remained under vacuum for a period of a few days up to 2 weeks. The vacuum within the lysimeter causes the moisture to move from the soil, through the porous ceramic cup, and into the lysimeter. Following the 2-week period, the tension in the lysimeter had normally equilibrated with the soil tension; therefore, the soil tension could be read from the access tube with a Bourdon gauge before sampling. To recover the soil water samples, the end of the discharge tube is placed in a collection bottle, and the sampler is pressurized to force the collected water out of the sampler and into the collection bottle.

Samples were collected for chemical analysis after the remaining deionized water has been removed or flushed from around the lysimeters. These samples were collected as described previously, with the modification of using nitrogen to reduce reactions between air and the water sample. The lysimeter was purged of air by flowing nitrogen in the pressure-vacuum tube and out the discharge tube for several minutes before applying the vacuum. When the sample was removed from the lysimeter, nitrogen was used to force the water out of the lysimeter and into the collection bottle. Lysimeter water samples were collected approximately during the spring, summer, and fall.

5.4.3.3 Gas Sampling Procedures. Soil gas samples were collected in a one-time gas sampling event from Boreholes 8801D, WWW-1, 77-1, and 78-4. The following procedures are summarized from Ruebelmann and Peterson (1989). The specific procedures for sample collection are contained in EG&G Idaho Geoscience Unit Standard Operating Procedure #G-310. The current gas sampling procedures for deep boreholes instrumented with gas ports for the vapor vacuum extraction demonstration are summarized in Section 11 of this report. For the one-time sampling event, the samples were collected at the borehole collar using a sampling pump, sampling train, and gas-tight syringes. During sample collection, the portable sampling train apparatus was connected to the permanently installed collection tube that protruded from the borehole. The sampling train consisted of a GC septum for sample collection and the tubing/fittings required to attach one end to the borehole collection tube and the other end to the silicon tubing from the inlet to the sampling pump as shown in Figure 5-12. The sampling pump was a model MSR 482700 Flow Lite H personal sampling pump. The syringes were Hamilton Series 1000 Gastight Syringes with a Teflon Luer Lock.

After the sampling train was attached to the borehole collection tube and the sampling pump, the pump was turned on to purge three volumes of gas from the gas port. Next, organic vapor and explosive gas readings at the discharge port of the pump were recorded. After the gas port was purged, samples were collected from the sampling train while the pump was still operating. For each sample, the following steps were followed: (1) the needle of the syringe was inserted into the GC septum, (2) the minilock valve was opened to draw the sample into the syringe, (3) the plunger was drawn to the specified volume, (4) the minilock valve was left open with the needle still in the septum for 1 minute to allow any vacuum to subside, (5) the minilock valve was closed, (6) the needle was withdrawn from the septum, (7) all pertinent data were recorded on the sample tag that was attached to the syringe, and (8) the syringe was placed in a cooler at 4°C (39.2°F).

Following sample collection, the pump was turned off and the sampling train was removed from the gas port end. The pump was then turned back on to run ambient air through the sampling train for at least 5 minutes to clear out

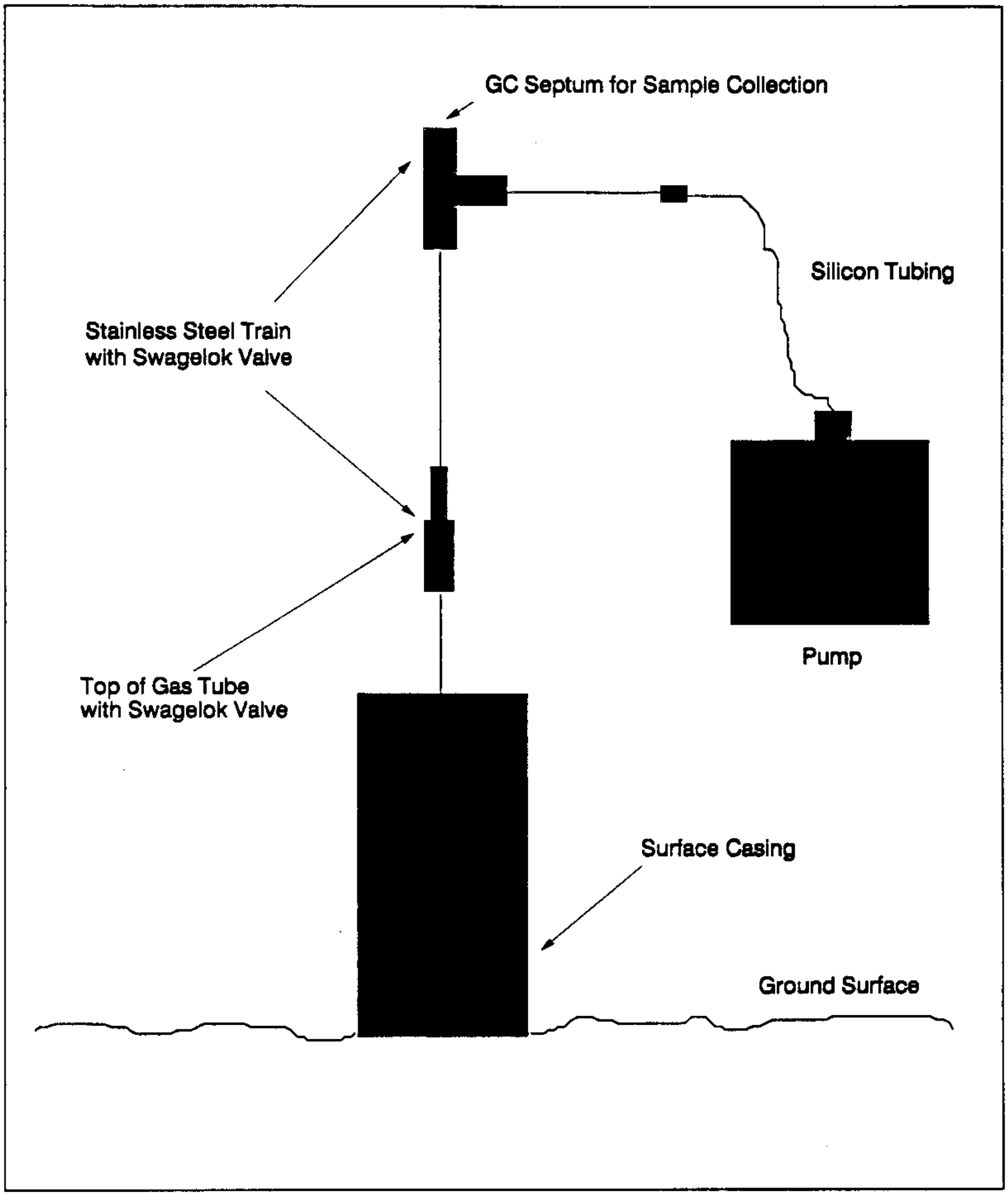


Figure 5-12. Diagram of sampling train (Ruebelmann and Peterson, 1989).

any residual gases in the train. All pertinent data were recorded in the laboratory notebook and the field logbook including the date, time of collection, pumping rate, pumping time, HNu readings, LEL readings, sampling port identification number, sample volume, personnel present, identities of associated quality assurance samples, and the syringe number.

Following documentation, the sampling syringes were wrapped with plastic packing material and packed with reusable ice packs into sturdy, thermally-insulated coolers. The cooler lid was sealed with a custody seal and the cooler carried directly to the laboratory on the same day of sampling. All samples were analyzed by the purge and trap method with a GC/MS for the 34 volatile organic constituents listed in Table 5-6.

5.4.4 Quality Assurance/Quality Control Procedures

Comprehensive quality assurance objectives for drilling procedures and for the soil, aqueous, and gas sampling for hazardous constituents were developed in 1988 to provide guidelines for all field and laboratory operations. For radionuclide constituents, these quality assurance objectives were instituted at the beginning of the SIP, and they are recorded in the sampling and analysis plans and in standard operating procedures for drilling. The goal was to (a) produce data of known and sufficient quality to estimate baseline concentrations of known contaminants, (b) assess the effectiveness of sampling procedures, and (c) supplement existing and future data to be used in making corrective action and remedial response alternative decisions. Standard procedures were developed so that known and acceptable levels of precision, accuracy, representativeness, comparability, and completeness could be documented (EG&G, 1988c). The results produced using established methodologies and standard operating procedures should be reproducible and comparable to other data reported at similar levels of precision and accuracy.

All drilling and sampling equipment subject to cross-contamination was cleaned and triple-bagged before use. Health physics surveys of the equipment were conducted before equipment was used during drilling and coring to screen for radionuclide cross-contamination between the surface and the borehole.

Wipe smears were taken of the drilling rig and drilling equipment, the decontamination area, and the subsurface investigations field laboratory at the start of each day and before and after each sampling event. The smears were counted using an alpha spectrometer and a beta/gamma counter. Field quality control measures were followed to provide quality assurance for samples submitted for Appendix IX analyses. Quality control measures included decontamination rinses of all sampling equipment with hexane, methanol, and deionized water before each sampling event. Other measures included field blanks, trip blanks, equipment blanks, spiked aqueous samples, and duplicate or replicate sediment samples. For all sampling, the ratio of quality control samples to normal samples averaged approximately 1 to 6.

Trip blanks for soil samples collected during drilling were included with each sample shipment to be analyzed for volatile organic constituents. They were prepared before the actual sampling event by an independent laboratory or the EG&G Idaho field sampling team using high pressure liquid chromatography (HPLC) grade water, packaged with the VOC samples, and shipped to the laboratory for analysis. The number associated with the sample trip blank was recorded in the sample logbook.

Physical analyses were performed on selected samples from both the shallow and deep drilling programs. The analyses to be performed and the associated precision, accuracy, and completeness goals for soil and sedimentary interbed samples are summarized in Table 5-7.

For soil sampling, an equipment blank was collected before sampling of the borehole, after the borehole was completed, and after the drill rig had been cleaned. Several pieces of drilling or sampling equipment (including a core tube) were chosen at random. After final decontamination and rinsing of the equipment, an additional rinse with HPLC-grade water was made, and the rinsate was collected for analysis. The initial equipment blank was submitted for Appendix IX analysis. Based on the Appendix IX analyses of the soil samples, the final equipment blanks were analyzed for the major constituents of concern.

Table 5-7. Precision, accuracy, and completeness objectives for hydrological, mineralogical, and geochemical properties[a]

Measurement Parameter (Method)	Reference	Experimental Conditions	Precision[b] (%)	Accuracy % Biased	Completeness (%)
Saturated hydraulic conductivity	Part 1				
(constant head)	Klute (1986) p. 694, ASTM D2434	Undisturbed sample	±50	±50	80
(falling head)	Klute (1986) p. 700	Undisturbed sample	±50	±40	80
Moisture retention	Part 1				
(hanging water column)	Klute (1986) p. 635	Undisturbed sample	±50	±50	80
(pressure plate)	Klute (1986) p. 648, ASTM D2325, D3152	Undisturbed sample	±50	±50	80
Moisture content	Part 1				
(graviometric)	Klute (1986) p. 503, ASTM D2216	Sealed sample	±2	±2	80
(volumetric)	Klute (1986) p. 696	Sealed sample	±2	±2	80
Bulk density	Part 1 Klute (1986) p. 364, ASTM D4531	Undisturbed sample	±2	±2	80
Porosity	Part 1 Klute (1986) p. 444	Undisturbed sample	±5	±5	80
Unsaturated hydraulic conductivity (Maulem)	Maulem (1976) Van Genuchten (1978)	Undisturbed sample	Not quantifiable	Not quantifiable	80

Table 5-7. (continued)

Measurement Parameter (Method)	Reference	Experimental Conditions	Precision[b] (%)	Accuracy % Biased	Completeness (%)
Particle size distribution (mechanical Sieve) (hydrometer)	Part 1 Klute (1986) p. 393 Klute (1986) p. 404	May be disturbed sample May be disturbed sample	±10 ±40	±40 ±10	80 80
Particle density (pycnometer)	Part 1 Klute (1986) p. 378	May be disturbed sample	±2	±2	80
Air permeability	API-RP-40	Undisturbed sample	±50	±50	80
Total organic carbon	Klute (1986) Part 2 p. 539 p. 581	May be disturbed; has not been sieved	±10	±10	90
Total carbon	Klute (1986) Part 2 p. 539	May be disturbed; has not been sieved	±10	±10	90
Mineralogic (X-ray diffraction)	Klute (1986) Part 1 p.331	<35 mesh	2 θ = ±0.05 on split samples	±5% rel. dev. on Qtz, Std. (100% intensity peak)	90
Cation exchange capacity	Richards (1954) p. 101 Part 2	May be disturbed has not been sieved	±10	±10	90

---

a. Source: Koslow and Hubbell (1989).

b. Precision represents the relative standard deviation reported with one sigma.

For aqueous samples, quality assurance/quality control measures required spiked samples prepared by an independent laboratory. These were included at a frequency of 1 in 10 aqueous samples. Split samples and equipment blanks were also included at a frequency of at least 1 in 10 samples. To preserve the integrity of water samples collected from suction lysimeters, three quality assurance/quality control measures were followed: (1) for each sampling event, one sample bottle was filled with distilled-deionized water in the lab and carried in an ice-chest in the field; (2) one set of four sample bottles was filled with standard solution from laboratory stock and submitted with each set of samples; and (3) field reagents were replaced with fresh reagents for each field trip.

For the gas sampling event reported in Section 5.5.2.2 of this report, the field blanks consisted of ambient air drawn into the syringe in the vicinity of the sampling area. An equipment blank was drawn from the sampling train while the pump was pulling ambient air through the system. Duplicates (or triplicates) were collected from a selected gas port immediately after collecting a normal sample. Standard samples were prepared before the sampling event by an EG&G Idaho laboratory not responsible for the analyses. Trip blanks were collected in the laboratory from a gas-sampling bulb filled with an inert, pure gas such as nitrogen. Trip blanks were transported to and from the field sampling location. Blanks collected in the field were transported to the analytical laboratory with the other samples (Ruebelmann and Peterson, 1989).

The transfer of samples from the field to the laboratory and through the testing process was documented using chain-of-custody procedures. Sample custody procedures included inventory and documentation during sample collection, shipment, and laboratory processing. The chain-of-custody form contained the following information: sample number for each sample, collection date, sample description, required analyses, and signatures of custody.

The sampling teams followed the health and safety practices that were outlined in EG&G (1989f). The sampling team leader completed a Safe Work

Permit before each sampling event. The industrial hygienist conducted an initial survey of the site before sampling was initiated to determine if contaminants existed in the ambient air conditions. Sampling personnel followed the personal protective guidance from the industrial hygienist and the health physicist.

Complete field and laboratory quality assurance/quality control procedures are described in the sampling and analysis plans (EG&G, 1988c). Specific routine procedures used to assess data precision, accuracy, and completeness are also included in this document.

5.5 Results

The data collected from the SIP Shallow and Deep Drilling Programs are presented in the following sections. Section 5.5.1 presents the results of the Shallow Drilling Program, and Section 5.5.2 presents the results of the Deep Drilling Program.

5.5.1 Shallow Drilling Program

A total of 226 cores were collected from the 32 shallow boreholes. Nearly 100% core recovery was obtained from the California split-spoon samplers (Hubbell et al., 1985). Almost all of the core samples were compacted from the sampling technique. On average, silt or clay samples appeared to be compacted to 77% of their original size. Sand samples usually showed little or no compaction. Completion diagrams for the shallow boreholes are included in Appendix 3-1 of this document.

Geologic descriptions were recorded at intervals of either 50 or 30 cm (20 or 12 in.) for core in the drive shoe of the sampler or the Shelby tube depending on sampling methodology. These descriptions are provided in Hubbell et al. (1985), Hubbell et al. (1987), and Laney et al. (1988).

Soil moisture samples were collected from the drive shoe of the split-spoon sampler while processing the samples for storage. Moisture contents for these samples are included in the geologic logs in Appendix A of Hubbell et al. (1985). The frequency distribution for moisture content and a graph of moisture content compared to sample texture for samples collected in 1985 are presented in Tables 5-8 and 5-9, respectively.

Core samples were sent to laboratories for chemical and hydraulic testing. The results of the radiochemical analyses that were completed on the core samples are presented in Appendix 5-3. Four samples from three shallow boreholes (W06, W09, and W24) were submitted for soil hydraulic property tests; three samples from the same three boreholes were also submitted for specific reservoir analyses. Tables in Section 5.5.2.2 summarize what samples were submitted for specific analyses. The analytical data from the soil hydraulic properties testing and air permeability analyses on shallow boreholes are presented in McElroy and Hubbell (1990). No geochemical or mineralogical analyses have been conducted on samples from shallow drilling programs.

Water quality data collected through mid-1988 from lysimeters at the SDA were evaluated to determine the geochemistry of soil pore waters and to better characterize the potential for radionuclide migration. Water chemistry data from lysimeters in Boreholes C01 (control borehole), W23, W08, PA01, and PA02 were selected for evaluation because the waters showed low bromide concentrations and represented the most complete suite of analyses available. The results of this investigation were reported by S. Rawson.[a] In addition, radiochemistry data from lysimeters in selected shallow boreholes at the SDA are presented in Table 5-10. Analytical data from soil water samples are being compiled from the period from 1988 to present.

Data from the instrumentation and monitoring collected through 1987 indicate a range of matric potentials in surficial sediments from saturation to -3.0 bars. A trend of decreasing matric potentials with increasing depth was observed in most boreholes instrumented in the surficial sediments

---

[a] Communication between S. A. Rawson, EG&G Idaho, Inc., Idaho Falls, Idaho, and R. R. Piscitella, EG&G Idaho, Inc., Idaho Falls, December 12, 1988.

Table 5-8. Frequency distribution for moisture content of auger hole samples[a]

Moisture Content[b] (% by mass)	Number of Samples	Percent of Total	Cumulative Percent
0-5	5	5	5
5-10	13	12	17
10-15	31	29	46
15-20	32	30	76
20-25	20	19	95
25-30	5	5	100
35+	1	>1	100
	107	100	

---

a. Source: Hubbell et al. (1987).

b. Moisture content based on oven-dried samples.

Table 5-9. Moisture contents for different textures of auger hole samples[a]

Texture	Moisture Content[b] (% by mass)	Number of Samples
Sand	6.7	11
Silty sand or sandy silt	16.2	49
Silt	14.0	9
Clayey silt or silty clay	19.5	30
Clay	13.8	5

---

a. Source: Hubbell et al. (1987).

b. Moisture content based on oven-dried samples.

Table 5-10. Summary of radiochemistry data from lysimeter water samples in shallow boreholes[a]

	Borehole	Lysimeter	Depth (ft-in.)	Collection Date	Pu-239,-240 10^{-11} µCi/mL	Pu-238 and/or Am-241 10^{-11} µCi/mL	Tritium[b] pCi/mL
1985							
	W06	L27	11-10	05/01/85	1.0 ± 3.0	1.0 ± 3.0	
1986							
	PA01	L15	14-4	06/13/86	7.0 ± 5.0	6.0 ± 5.0	(4.00 ± 2.00) x 10^{-1}
	PA02	L16	8-8	06/13/86	2.0 ± 3.0	13.0 ± 6.0	(-6.00 ± 4.00) x 10^{-3}
	W02	L01	14-0	1986			(-3.00 ± 2.00) x 10^{-3}
	W04	L03	24-6	1986			(4.00 ± 2.00) x 10^{-1}
		L04	15-5	08/26/86 and 09/04/86[c]	5.0 ± 4.0	7.0 ± 6.0	
		L05	6-2	06/13/86	2.0 ± 3.0	2.0 ± 3.0	(4.00 ± 2.00) x 10^{-1}
	W08	L12	22-1	1986			(-7.00 ± 4.00) x 10^{-2}
		L13	11-5	1986			(5.00 ± 3.00) x 10^{-1}
		L14	6-2	1986			(8.00 ± 6.00) x 10^{-2}
	W23	L08	11-11	1986			1.96 ± 0.08[d]
		L09	7-8	06/13/86	2.0 ± 4.0	5.0 ± 7.0	1.10 ± 0.30[d]
	TH4	L18	4-0	06/13/86	4.0 ± 7.0	13.0 ± 13.0	
1987							
	PA01	L15	14-4	04/30/87	8.0 ± 7.0	5.0 ± 7.0	
	W02	L01	14-0	04/30/87	2.0 ± 3.0	7.0 ± 5.0	
	W05	L25	10-0	04/30/87	4.0 ± 7.0	16.0 ± 12.0	
	W23	L08	11-1	05/01/87	6.0 ± 6.0	53.0 ± 13.0[d]	
	W25	L28	15-6	05/01/87	1.0 ± 4.0	2.0 ± 3.0	

---

a. Source: Hubbell et al. (1987); Laney et al. (1988).

b. Detection limit for tritium samples was 1 pCi/mL.

c. L04, W04 composite sample from 2 days sampling.

d. Positive results (greater than 3 sigma).

(McElroy and Hubbell, 1989). Subsurface hydraulic gradients were predominantly downward below 3 m (10 ft). From the surface to 2 m (7 ft) below land surface, neutron data indicate a zone strongly affected by cycles of precipitation and evapotranspiration (Laney et al., 1988). In this zone, both upward and downward hydraulic gradients were detected.

5.5.2 Deep Drilling Program

A total of 10 deep boreholes were drilled from 1986 to 1990. Table 5-11 summarizes the sampling information by borehole, the top and thickness of the sedimentary interbeds, core analyses, type of geophysical logs conducted, and samples analyzed for hazardous and radiological constituents. Geophysical logs of the boreholes included gamma-ray, gamma-gamma, neutron, TV, and caliper logs. Completion diagrams and geophysical logs for the boreholes are provided in Appendix 3-1 in Section 3. Drilling and sample core logbooks for boreholes drilled since 1988 are provided in Appendix 5-4. A summary of the core recovery from the sedimentary interbeds is included in Table 5-12.

5.5.2.1 Borehole Completion Details. This section describes the completion details for each of the deep boreholes that were drilled as part of the SIP between 1986 and 1990. The boreholes are presented in chronological order based on the drilling start date. Specific information is presented concerning each borehole such as the depth of the cored intervals, the types of drilling techniques used, the types of sample analyses conducted, and the problems encountered during the drilling and sampling process.

D06

Borehole D06 was initiated on August 11, 1986, by augering and sampling the surficial sediments. The borehole deflected from the vertical at 9 m (30 ft) and corkscrewed to a depth of 38 m (126 ft). A decision was made to complete it at that depth because the hole was too crooked to set casing. It was reamed to total depth, backfilled, and instrumented. No sediment core was obtained from either the 9-m (30-ft) or the 34-m (110-ft) interbed. The cored intervals are described in Appendix B of Hubbell et al. (1987).

Table 5-11. Deep drilling program summary of sampling, geophysical logs, chemical analyses, and borehole completions

Borehole	Total Depth, ft (Completion Date)	Cored Interval(s) (ft)	Sedimentary Interbeds Top of 30-ft, 110-ft, 240-ft (Thickness, ft)	Hydraulic Properties Testing	Air Permeability Analysis	Appendix IX	Radiochemistry	Borehole Logs[a]	Borehole Completion
D02	235 (9-86)	0 - 18	25 (4)[b]			-[c]	-	1,2,3,4,5	Eight gas sampling ports
		23 - 104	99 (5)[b]			-	-		
		223 - 235	223 (>20)[b]	X	X	-	X		
D06	126 (9-86)	1 - 9	40 (11)[b]			-	-	1,2,3,4,5	Porous cup lysimeters and heat-dissipation probes
		88 - 126	NP[d]			-	-		
			DNP[e]			-			
D06A	50 (10-86)	1 - 3	41.5 (2)			-	X	1,2,3	No instruments
		7 - 50	DNP						
			DNP						
TW1	237 (6-87)	17 - 21	28 (4)			-	-	1,2,3,4,5 (Not continuous caliper)	Porous cup lysimeters and heat-dissipation probes
		88 - 103	101 (7)			-	X		
		219 - 231	225 (>12)			-	X		
		233 - 233.6							
D15	252 (9-87)	1.5 - 7	32 (3.5)			-		1,2,3,4	Porous cup lysimeters and heat-dissipation probes
		32 - 40	96 (16)	X		-	X		
		45 - 47	222 (20)	X	X	-	X		
		88 - 117							
		217 - 243							
8801D	245 (8-88)	20 - 210	NP			-	-	1,2,3,4,5	Nine gas sampling ports
			103 (5)[b]			S: 1,2,3,5,6[f]			
			229 (>4)	X	X	S: 1,2,3,4,5, 6,7[f]	X		
8802D	129 (7-88)	6 - 221	25 (3)				-	1,2,3,4	Stainless steel screen and tubing for perched water sampling
	220 (7-89)		94 (8)[b]			-	-		
			DNP						
			Perched Water at 220 ft			W: 6[f]	X		
8801T	50.7 ( )	15 - 50	NP			-	-	None	Test hole
			DNP						
8901D	249 (6-89)	32 - 46	[d]			-	X	1,2,3,4,5	Stainless steel slotted pipe and riser completed for VVED
		89 - 113	103 (5)			-	-		
		219 - 254	229			-	X		

Table 5-11. (continued)

Borehole	Total Depth, ft (Completion Date)	Cored Interval(s) (ft)	Sedimentary Interbeds Top of 30-ft, 110-ft, 240-ft (Thickness, ft)	Hydraulic Properties Testing	Air Permeability Analysis	Appendix IX	Radiochemistry	Borehole Logs[a]	Borehole Completion
8902D	245 (2-90)	25 - 33	NP			-	-	1,2,3,4,5	Eight gas sampling ports
			101 (8)			-	-		
			223			S: 2,6[f]	-		
D10	95 (9-87)	8 - 95	32 (7)	X		-	-	1,2,3,4,5	Undecided
	239 (3-90)	239	92 (3)			-	-		
		94	223			S: 2,6[f]			

---

a. 1 = gamma, 2 = gamma-gamma, 3 = neutron, 4 = TV, 5 = caliper.

b. Value from Anderson and Lewis (1989).

c. Not submitted for analysis.

d. Not present.

e. Did not penetrate.

f. S = sediment, W = water, 1 = volatiles, 2 = semivolatiles, 3 = organophosphorous/pesticides, 4 = chlorinated herbicides, 5 = PCBs, 6 = metals, 7 = dioxins/furans.

Table 5-12. Summary of core recovery from sedimentary interbeds at deep boreholes

	30-ft Interbed		110-ft Interbed		240-ft Interbed	
Borehole	Cored (ft)	Recovery (%)	Cored (ft)	Recovery (%)	Cored (ft)	Recovery (%)
D06	NC[a]		89 - 92[b]	100	DNP[c]	
D02	25 - 29	60	99 - 101.2	0	224 - 235	60
D06A	47 - 49	50	DNP		DNP	
TW1	NC		101 - 103.5	30	226 - 231	20
D15	32 - 40	35	107 - 112	26	221 - 239	74
D10	32 - 39	77	92 - 96	0	223 - 234	40
8801D	NP[d]		103.1 - 104.1	63	229 - 244	47
8802D	24.9 - 29.9[e]	94	95-103	0	NC	
8901D	NP		103 - 108	0.4	229 - 249	55
8902D	NC		NC		NC	

---

a. NC = not cored.

b. Cored interval was sediment infilled-fractured basalt, the 110-ft interbed was not present.

c. DNP = did not penetrate.

d. NP = not present.

e. Cored interval includes basalt.

D02

Borehole D02 was initiated on August 21, 1986. The surficial sediment was sampled and the borehole was cored to 8.5 m (28 ft). Surface casing was set to 7.3 m (24 ft). The borehole was cored to the 34-m (110-ft) interbed, but no interbed sample was obtained because it was drier than expected and was blown away by the air rotary circulation system. Bentonite was placed at the bottom of the hole at 34 m (110 ft) to seal it, and the casing was set. Drilling resumed with a tricone bit to 68 m (223 ft), the upper part of the 73-m (240-ft) interbed, with samples collected from the cyclone separator. Shelby tubes were used to collect continuous cores within the interbed to a depth of 72 m (235 ft) without encountering the basalt. Borehole D02 was deepened to a total depth of 74 m (243 ft) on September 15, 1987, using a tricone bit. Caving problems caused abandonment of the hole before drilling into the basalt underlying the 73-m (240-ft) interbed.

Instrumentation was initiated but discontinued when VOCs were detected during removal of the 15-cm (6-in.) casing. Descriptions of the cored intervals are provided in Appendix B of Hubbell et al. (1987). These samples were analyzed for radiochemistry in FY-87.

In 1988, this borehole was completed with eight gas sampling ports. The gas sampling ports, consisting of 5-cm (2-in.) wire-wrapped stainless steel screen 45 cm (18 in.) long, were attached to the surface with 1-cm (3/8-in.) stainless steel tubing. All samplers were closed at land surface with Swagelok quick connect female attachments.

D06A

Drilling commenced on Borehole D06A September 17, 1986. This borehole was drilled to practice sampling techniques through the sedimentary interbeds. It was anticipated that the thickness of the 9-m (30-ft) interbed would be close to 3.3 m (11 ft) based on extrapolation from Borehole D06, located 60 m (20 ft) to the north. A California split spoon sampler was used to collect core from the surface to 0.84 m (2.75 ft), a 10-cm (4-in.) tricone bit was used to drill the next 1.2 m (4 ft), and an HXB core barrel was used to continuously core the borehole from 2.1 m (6.9 ft) to a total depth of 15.2 m (50 ft). The 9-m (30-ft) interbed was 60 cm (2 ft) thick compared to a thickness of 3.3 m (11 ft) at Borehole D06. The recovered interval included the basalt-sediment interface. Descriptions of cored intervals are included in Hubbell et al. (1987). The hole was stopped at this point. Borehole D06A is still open with a locking waterproof cap.

TW1

Borehole TW1 was drilled within 4.6 m (15 ft) of Borehole D02 to confirm the presence of radionuclides detected in the 73-m (240-ft) interbed at Borehole D02. The 34-m (110-ft) interbed in Borehole TW1 was approximately 2 m (7 ft) thick. The HXB core barrel, Shelby tube, and thin-wall Shelby tube sampling devices were used to core the 73-m (240-ft) interbed. Core recovery in the 240-ft interbed was poor (20%) for two reasons: (1) a Shelby tube was lost in the hole, and (2) a coarse, unconsolidated sand encountered at the base of the interbed could not be sampled. Repeated attempts to core this zone with high pressure air resulted in erosion and caving of the borehole. Borehole TW1 was consequently completed at a depth of 72 m (237 ft) and instrumented. Descriptions of cored intervals are provided in Appendix A of Laney et al. (1988).

D15

Borehole D15 was drilled approximately 91 m (300 ft) south of the SDA to provide background samples for quality assurance/quality control purposes. An HXB core barrel was used to sample the 9-m (30-ft) interbed with 35% core recovery. A thick, unconsolidated gravel zone was encountered in the 34-m (110-ft) interbed. Four different coring techniques were attempted to sample the gravel zone but failed: (1) the HXB core barrel, (2) the standard Shelby tube, (3) a thin-wall Shelby type tube, and (4) a California split-spoon sampler. Consequently, the open hole was cased from the surface to the base of the gravel zone with 20-cm (8-in.) casing. HXB coring resumed through the bottom of the casing to the base of the 34-m (110-ft) interbed. Core recovery in the interbed below the gravel was excellent (78%). Overall core recovery from the entire 34-m (110-ft) interbed was 26%. The gravel was circulated to the surface using high pressure air. Recovered gravel cuttings were evaluated to aid in the geologic interpretation of the interbed. The 73-m (240-ft) interbed was sampled with an HXB coring device with a recovery rate of 74%. Descriptions of cored intervals are provided in Appendix A of Laney et al. (1988). Borehole D15 was subsequently instrumented with suction lysimeters and heat dissipation sensors, and a locking cap was installed.

D10

After Borehole D15 was drilled, it was decided that all future holes would be cored continuously from surface to total depth, thus providing more site-specific subsurface information about the RWMC. However, only Borehole 8801D and part of 8802D were completed in this manner. Borehole D10 was continuously cored to a depth of 29 m (95 ft) when drilling was suspended in September 1987 because organic vapors were detected in the borehole. The hole was cored using a 8.9-cm (3 1/2-in.) rotary diamond core bit and back-reamed to the standard hole size instead of drilling with a tricone and back-reaming. The 9-m (30-ft) interbed was cored using an HXB core tool with 77% recovery. A few inches of sediment were encountered at the 34-m (110-ft) interbed, but no core was obtained.

Borehole D10 was completed to a total depth of 72.8 m (238.9 ft) in March 1990. The hole was cored continuously from depths of 2.6 to 72.7 m (8.5 to 238.5 ft) below land surface. The cored intervals and recovered samples are summarized in Table 5-13. The 9-m (30-ft) interbed was intercepted at 9.6 m (31.6 ft), and the 73-m (240-ft) interbed was penetrated at 68 m (223 ft). The 34-m (110-ft) interbed does not appear on the geophysical logs, but some soil was present at 28 m (92 ft).

8801D

Borehole 8801D was drilled during the summer of 1988 and was completed in August. Core was obtained from the 34- and 73-m (110- and 240-ft)

Table 5-13. Cored intervals in Borehole D10[a]

Cored Interval (ft)	Recovered (ft)	Sample Number	Comments
8.5 - 11.3	1.8	D-81	
11.3 - 12.0	0.3	D-82	
12.0 - 13.5	1.3	D-83	
13.5 - 17.4	3.9	D-84	
17.4 - 22.3	4.9	D-85	
22.3 - 24.6	2.3	D-86	
24.6 - 29.6	4.9	D-87	
29.6 - 31.5		D-88	
31.5 - 34.6	1.9	D-89	
34.6 - 36.0	1.2	D-90	
		D-91	
	2.0	D-92	
42.1 - 44.1	4.6	D-93	
44.1 - 49.1		D-94	
		D-95	
54.4 - 59.4	3.2	D-96	
59.4 - 62.9	2.6	D-97	
66.2 - 69.6		D-99	
69.6 - 74.6	4.3	D-100	
74.6 - 79.0	0.2	D-101	
79.0 - 79.9	5.0	D-102	
79.9 - 84.9	5.2	D-103	
84.9 - 90.2	4.4	D-104	
90.2 - 95.3		D-105	
QA Sample		D-106 Radiochemistry	
QA Sample		D-107 Radiochemistry	
94.3 - 96.0	0.3	D1001Z87	
96.5 - 101.25	4.8	D1002Z87	
101.25 - 106.1	4.7	D1003Z87	
106.1 - 111.0	5.3	D1004Z87	
111.0 - 116.0	5.0	D1005Z87	
116.0 - 121.0	5.0	D1006Z87	
121.0 - 126.0	5.0	D1007Z87	
128.0 - 130.9	2.9	D1008Z87	
130.9 - 135.9	5.0	D1009Z87	
135.9 - 140.5	4.6	D1010Z87	
140.5 - 145.8	4.9	D1011Z87	
145.8 - 151.5	4.9	D1012Z87	
151.5 - 154.5	2.5	core not good for analysis	
154.5 - 156.0	1.0	core not good for analysis	
156.0 - 161.0	5.3	D1013Z87	
161.0 - 166.0	3.7	no sample number assigned	
165.7 - 170.0	5.5	D1014Z87	
170.0 - 174.8	4.7	D1015Z87	
174.7 - 179.8	5.4	no sample number assigned	
179.8 - 184.0	4.2	D1016Z87	
184.0 - 188.5	4.5	D1017Z87	
189.0 - 190.3	1.4	D1018Z87	
193.7 - 196.5	2.5	D1019Z87	
196.5 - 201.5	5.1	D1020Z87	
201.5 - 206.5	4.5	D1021Z87	
206.5 - 211.0	4.3	D1022Z87	
211.0 - 215.7	4.7	D1023Z87	
215.5 - 217.0	1.5	D1024Z87	
217.0 - 220.5	3.4	D1025Z87	
220.5 - 223.0	2.6	D1026Z87	
223.0 - 225.5	1.6	D1027Z87	
225.5 - 227.5	1.8	D1028Z87	Sample submitted for 40 CFR Appendix IX
234.0 - 235.0	1.0	D1029Z87	
235.5 - 238.5	1.5	D1030Z87	

---

a. Source: Sample and core description Logbook I, Borehole D10, assigned to T. Clawson (samples D1001287 through D1030287) and deep drilling log (samples D-81 through D-107) (Appendix 5-4).

interbeds, intercepted at 31 and 70 m (103 and 229 ft), respectively; however, the 9-m (30-ft) interbed was not present. This borehole was continuously cored from approximately 7 m (20 ft) below land surface to a total depth of 75 m (245 ft) The cored intervals and recovered samples are summarized in Table 5-14. The 34- and 73-m (110- and 240-ft) sedimentary interbeds were sampled for Appendix IX, metals, VOCs, and radionuclides as summarized in Table 5-15. The analytical data from the Appendix IX analyses are included in Appendix 5-6.

This borehole was completed with nine gas sampling ports. The ports, consisting of 5-cm (2-in.) wire-wrapped stainless steel screen 45 cm (18 in.) long, were attached to the surface with 1-cm (3/8-in.) stainless steel tubing. All samplers were closed at land surface with Swagelok quick-connect female attachments.

8802D

Borehole 8802D was drilled to 39 m (129 ft) in 1988 before organic vapors were detected in the wellbore. This borehole was located to collect samples for priority pollutants, to obtain more even distribution of geologic data, and to explore for perched water zones. The borehole was cored continuously from 1.8 to 39.2 m (6 to 128.6 ft) below land surface. The cored intervals and recovered samples are summarized in Table 5-16. Core was recovered from the 9-m (30-ft) interbed intercepted at 8 m (25 ft) but not from the 34-m (110-ft) interbed. The 34-m (110-ft) interbed was penetrated at 28.6 m (94 ft) and had a thickness of approximately 1.4 m (4.6 ft) but was too unconsolidated for any core recovery. The well was capped from August 19, 1988, to June 27, 1989. Borehole 8802D was reentered and drilling continued until perched water was encountered at 67.4 m (221 ft). The borehole has been completed for monitoring a perched water zone.

8901D

Borehole 8901D was drilled in the summer of 1989 to a depth of 76 m (249 ft). This borehole was only cored through the three sedimentary

Table 5-14. Cored intervals in Borehole 8801D[a]

Cored Interval (ft)	Recovered (ft)	Sample No.	Comments
19.8 - 24.8	4.6	8801D01	
26.1 - 28.6	1.4	8801D02	
28.6 - 31.1	2.1	8801D03	
28.4 - 29.8	0	8801D04	
12.5 - 14.8	2.9	8801D05	Cored through grout
14.8 - 19.8	5.4	8801D06	Cored through grout
30.4 - 35.4	5.0	8801D07	
35.4 - 40.4	5.0	8801D08	
40.4 - 45.6	5.2	8801D09	
45.6 - 50.4	4.5	8801D10	
50.2 - 55.2	4.6	8801D11	
54.7 - 59.7	5.25	8801D12	
59.7 - 64.75	5.1	8801D13	
65.3 - 70.8	5.5	8801D14	
70.5 - 75.5	4.8	8801D15	
75.5 - 80.5	4.8	8801D16	
80.5 - 85.5	5.0	8801D17	
85.5 - 90.5	5.2	8801D18	
90.6 - 95.7	4.9	8801D19	
95.5 - 100.2	4.7	8801D20	
100.2 - 103.2	3.0	8801D21	
103.2 - 107.0	3.5	8801D22	Sample taken at 103.7 for 40 CFR Appendix IX
107.0 - 110.5	3.5	8801D23	
110.5 - 115.4	4.9	8801D24	
115.4 - 120.3	4.9	8801D25	
120.3 - 125.1	4.8	8801D26	
125.4 - 130.6	5.45	8801D27	
130.6 - 134.6	4.0	8801D28	
134.6 - 139.8	5.2	8801D29	
139.8 - 145.0	5.2	8801D30	
145.2 - 150.0	5.0	8801D31	
150.0 - 155.2	5.2	8801D32	
155.2 - 160.3	5.1	8801D33	
160.2 - 165.2	5.0	8801D34	
165.2 - 170.2	4.9	8801D35	
170.1 - 175.3	5.2	8801D36	
175.3 - 180.3	5.0	8801D37	
180.3 - 185.3	5.0	8801D38	
185.3 - 190.3	4.95	8801D39	
190.3 - 195.3	5.45	8801D40	
195.8 - 200.9	5.04	8801D41	

Table 5-14. (continued)

Cored Interval (ft)	Recovered (ft)	Sample No.	Comments
200.9 - 206.1	5.2	8801D42	
206.1 - 208.7	2.56	8801D43	
209.0 - 210.3	1.3	8801D44	
210.3 - 215.3	5.0	8801D45	
215.3 - 220.2	4.9	8801D46	
220.2 - 225.3	5.1	8801D47	
225.2 - 230.1	4.9	8801D48	Sample taken for 40 CFR Appendix IX radiochemistry[b]
230.1 - 233.3	2.5	8801D49	Sample taken for 40 CFR Appendix IX radiochemistry[b]
233.3 - 235.3	2.2	8801D50	Sample taken for radiochemistry[b]
235.1 - 240.1	0	8801D51	
240.8 - 242.3	1.3	8801D52	
241.7 - 244.7	0	8801D53	

---

a. Source: Borehole 8801D drilling core logbook (Appendix 5-4).

b. Radiochemistry samples were not collected or prepared according to stringent cross-contamination procedures detailed in the sampling and analysis plan for sample collection or the standard operating procedure for radiochemistry sample preparation.

Table 5-15. Summary of 40 CFR 264 Appendix IX chemical analysis for Borehole 8801D

Sample Number	Depth (ft)	Type	Weight/Volume	Analyses
8801D22A	103.2 - 104.0	Sediment	30 g	Pesticide/PCB
8801D22B	103.2 - 104.0	Sediment	- -[a]	Inorganics/metals
	103.2 - 104.0	Sediment	30 g	Semivolatile organics
	103.2 - 104.0	Sediment		Organophosphorous, pesticides, chlorinated herbicides
8801D22A	104.0 - 104.1	Sediment	5 g	Volatile organics
8801D48A	230.1	Sediment	5 g	Volatile organics
8801D48B	229.0 - 230.1	Sediment	- -[a]	Inorganics/metals
8801D48C	229.0 - 230.1	Sediment	- -[a]	Organophosphorous, pesticides, chlorinated herbicides
8801D48C	229.0 - 230.1	Sediment	30 g	Pesticide/PCB
8801D48C	229.0 - 230.1	Sediment	- -[a]	Dioxins/furans
8801D49B	230.1 - 231.1	Sediment	- -[a]	Inorganics/metals
8801D49C	230.1 - 231.1	Sediment	30 g	Semivolatile organics
8801D49C	230.1 - 231.1	Sediment	- -[a]	Organophosphorous, pesticides, chlorinated herbicides
8801D49C	231.1 - 231.1	Sediment	30 g	Pesticide/PCB
8801D49C	230.1 - 231.1	Sediment	- -[a]	Dioxins/furans
8801D22TBA	Trip blank	Water	5 mL	Volatile organics
8801D22TBB	Trip blank	Water	5 mL	Volatile organics

---

a. Unknown.

Table 5-16. Cored intervals in Borehole 8802D[a]

Cored Interval (ft)	Recovered (ft)	Sample Number
6.0 - 11.0	5.00	8802D01
10.1 - 15.0	4.90	8802D02
14.5 - 19.9	3.00	8802D03
19.9 - 24.9	5.10	8802D04
24.9 - 29.9	4.70	8802D05
30.0 - 35.0	4.90	8802D06
35.0 - 40.0	5.10	8802D07
40.0 - 45.0	5.25	8802D08
45.0 - 50.0	4.80	8802D09
50.0 - 55.0	5.10	8802D10
55.0 - 60.0	5.00	8802D11
60.0 - 65.0	4.40	8802D12
65.0 - 70.0	4.50	8802D13
70.0 - 75.0	4.85	8802D14
75.0 - 80.0	4.80	8802D15
80.0 - 85.0	5.00	8802D16
85.0 - 90.0	5.00	8802D17
90.0 - 95.0	5.10	8802D18
95.0 - 99.0	2.20	8802D19
98.4 - 101.8	0	8802D20
101.8 - 105.1	3.20	8802D21
105.1 - 109.1	4.10	8802D22
109.1 - 114.1	5.00	8802D23
114.1 - 119.1	5.05	8802D24
119.1 - 124.1	5.00	8802D25
124.1 - 126.4	2.30	8802D26
126.4 - 128.6	0.70	8802D27

---

a. Source: Sample and core description Logbook I, Borehole 8802D, assigned to T. Clawson (Appendix 5-4).

interbeds as shown in Table 5-17. Samples from the 9-, 34-, and 73-m (30-, 110-, and 240-ft) interbeds were collected for radionuclide analysis. The 9- and 73-m (30- and 240-ft) interbeds were cored continuously; however, only 0.6 cm (1/4 in.) of sediment was recovered from the 34-m (110-ft) interbed. Borehole 8901D was completed as the production well for the VVE demonstration with 52 m (170 ft) of stainless steel slotted pipe and riser pipe.

8902D

Borehole 8902D was drilled as a VVE demonstration replacement well for Borehole 8802D. It was completed in January 1990 to a total depth of 75 m (245 ft) for sampling of sedimentary interbeds. The interval from 7.6 to 10 m (25 to 33 ft) was cored before the decision was made to drill with a tricone bit; therefore, no additional cores were collected. After drilling was completed, samples were collected from sediments that collapsed into the hole [presumably from the 73-m (240-ft) interbed] by driving 20.3-cm (8-in.) steel casing approximately 2.4 m (8 ft) into the interbed and retrieving the casing to the surface. A sample was scraped from the bottom of the casing leaving a sediment rind around the interior edge of the casing. The sample was mixed and split into four 250-mL samples. Two of the samples were submitted for metals and semivolatiles analysis, and the remaining two were archived.[a]

Borehole 8902D was completed with eight gas sampling ports for the VVE demonstration. These ports, consisting of 5-cm (2-in.) wire-wrapped stainless steel screen 45 cm (18 in.) long, were attached to the surface with 1-cm (3/8-in.) stainless steel tubing. All samplers were closed at land surface with Swagelok quick-connect female attachments.

5.5.2.2 Analytical Data From the Deep Drilling Program. Selected samples were analyzed for 40 CFR 264 Appendix IX compounds and radionuclide

---

[a] Communication between J. M. Hubbell, EG&G Idaho, Inc., Idaho Falls, Idaho, and L. N. Peterson, EG&G Idaho, Inc., Idaho Falls, Idaho, April 18, 1990.

Table 5-17. Cored intervals in Borehole 8901D[a]

Cored Interval (ft)	Recovered (ft)	Sample No.	Comments
31.6 - 36.1	4.5	D01010890000	
36.1 - 40.9	4.75	D01020890000	
40.9 - 45.6	4.7	D01030890000	
88.8 - 93.4	4.6	D01040890000	
93.4 - 97.3	4.3	D01050890000	
97.3 - 101.8	4.5	D01060890000	
101.8 - 103.2	1.4	D01070890000	
108.8 - 113.0	4.2	D01080890000	
219.4 - 224.0	4.6	D01090890000	
224.0 - 229.1	5.1	D01100890000	
229.1 - 234.1	5.0	D01110890000	
234.1 - 239.1	2.3	D01120890000	
238.1 - 243.1	1.6	D01130890000	
243.1 - 245.9	2.1	D01140890000	
249.0 - 245.0	0		
		D0100E89A000	Equipment blank

---

a. Source: Sample and core description logbook I, Borehole 8901D, assigned to S. Budge (Appendix 5-4).

content. The sedimentary interbed samples submitted for 40 CFR 264 Appendix IX analyses (i.e., organics, semivolatiles, and metals) are summarized on Table 5-18. Chemical analyses on sedimentary interbed samples from Boreholes 8902D and D10 have not been qualified or validated but are included in Appendix 5-5. The data qualification report for the analytical data from sedimentary interbeds in Borehole 8801D is included in Appendix 5-6.

Radiochemical analyses for surficial sediments and the sedimentary interbeds in Boreholes D02, D06, and TW1 are presented in Table 5-19. Radiochemistry samples were collected from the 9-m (30-ft) interbed in Borehole 8901D; from the 34-m (110-ft) interbed in Borehole D15; and from the 73-m (240-ft) interbed in Boreholes D15, 8801D, and 8901D (Table 5-18).

Physical and hydraulic properties testing of the surficial sediments and sedimentary interbeds were conducted. Sixteen samples of the sedimentary interbeds were collected from five archived core boreholes and submitted for the hydraulic properties analyses shown on Table 5-20. An evaluation of the data and the analytical results are presented in McElroy and Hubbell (1990). Air permeability analyses were also completed on 11 samples from four deep boreholes. The type of analyses conducted on these samples are shown on Table 5-21. The analytical data are evaluated and presented in McElroy and Hubbell (1990). No geochemical or mineralogical analyses have been conducted on the samples from the deep drilling program.

Data from the instrumentation and monitoring program collected from 1985 through 1989 are currently being evaluated and summarized by the EG&G Idaho Geosciences Unit. The general range of matric potentials in the 9-, 34-, and 73-m (30-, 110-, and 240-ft) interbeds is from -0.3 to -1.7 bars. Preliminary results indicate downward moisture movement through the interbeds (McElroy and Hubbell, 1989).

Water quality data collected through mid-1988 from lysimeters at the SDA were evaluated to determine the geochemistry of soil pore waters and to better characterize the potential for radionuclide migration. Water chemistry data from lysimeters in Boreholes D06, D15, and TW1 were selected for evaluation

Table 5-18. Summary of sedimentary interbed samples selected for chemical analysis in Boreholes 8801D, D10, 8901D, and 8902D

Borehole	Sample Number	Depth (ft)	Type	Container	Analysis	Preservatives ($^{\circ}$C)	Comments
110-ft Interbed							
8801D	8801D22A	103.7	Interbed	40 mL AG[a]	Volatile organic analysis	4	
	8801D22B	103.2 - 103.7	Interbed	32 oz. AG	Metals, BNA, other inorganics	4	
	8801D22TBA	-	Trip blank	40 mL AG	Volatile organic analysis (624)	4/none	Prepared by Weston
	8801D22TBB	-	Trip blank	40 mL AG	Volatile organic analysis (624)	4/none	Prepared by Weston
	8801D21R2	101.2 - 103.1	Fracture fill		Radiochemistry		
	8801D22R01	106.1 - 107.0	Fracture fill		Radiochemistry		
	8801D45R01	210.3 - 215.3	Fracture fill		Radiochemistry		
	8801D46R01	215.3 - 220.2	Fracture fill (?)		Radiochemistry		
240-ft Interbed							
8801D	8801D48A	230.1	Interbed	120 mL AG	Volatile organic analysis	4	
	8801D48A	230.1	Interbed	120 mL AG	Volatile organic analysis	4	
	8801D48B	229.4	Interbed	950 mL AG	Metals	4	
	8801D48C	229.4	Interbed	950 mL AG	Other organics	4	
	8801D49A	232.6	Interbed	120 mL AG	Volatile organic analysis	4	
	8801D49A	232.6	Interbed	120 mL AG	Volatile organic analysis	4	
	8801D49B	230.1 - 231.05	Interbed	950 mL AG	Metals	4	Replicate
	8801D49C	230.1 - 231.05	Interbed	950 mL AG	Other organics	4	Replicate
8801D	8801D48R02A	229.0	Basalt/sediment interface	10 g	Radiochemistry		
	8801D48R02B	229.0	Basalt/sediment interface	1 g	Radiochemistry		
	8801D48R01A	230.1	Interbed	10 g	Radiochemistry		
	8801D48R01B	230.1	Interbed	1 g	Radiochemistry		
	8801D49R01	231.05 - 232.1	Interbed		Radiochemistry		
	8801D49R02		Top of core		Radiochemistry		
	8801D50R01	235.5	Interbed		Radiochemistry		
	8801D50R02		Bottom of core		Radiochemistry		
D10	D1028Z87A	225 - 227.5	Interbed	250 mL AG	Semivolatile, metals	4	
	D1028Z87B	225 - 227.5	Interbed	250 mL AG	Semivolatile, metals	4	Replicate

Table 5-18. (continued)

Borehole	Sample Number	Depth (ft)	Type	Container	Analysis	Preservatives (°C)	Comments
				240-ft Interbed			
8901D	D0111X89EA	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89DA	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89CA	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89BA	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89AA	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89EB	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89DB	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89CB	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89BB	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89AB	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89AD	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89AF	229.1 - 234.1	Interbed		Radiochemistry		
	D0111X89AG	229.1 - 234.1	Interbed		Radiochemistry		
8902D	D0201289A	?	Interbed	250 mL AG	Semivolatile, metals	4	
	D0201289B	?	Interbed	250 mL AG	Semivolatile, metals	4	Replicate

---

a. AG = Amber glass

Table 5-19. RWMC sediment sample radiochemical analysis results: samples from the deep drilling program[a]

		EG&G					RESL		
Sample	Depth (ft-in.)	Pu-238 (μCi/g)	Pu-239,240 (μCi/g)	Am-241 (μCi/g)	Sr-90 (μCi/g)	Cs-137 (μCi/g)	Pu-238 (μCi/g)	Pu-239,240 (μCi/g)	Am-241 (μCi/g)
Deep Hole D02									
D-13	1-2 to 1-8	2.6 ± 0.2 E-07[b]	1.13 ± 0.05 E-06[b]	1.52 ± 0.06 E-06[b]	1.9 ± 0.3 E-07[b]	7.2 ± 1.0 E-08[b]	--	--	--
D-17	9-2 to 9-8	6 ± 9 E-10	0.6 ± 1.1 E-09	0.3 ± 1.2 E-09	-2 ± 3 E-08	1 ± 8 E-09	--	--	--
D-20	15-6 to 16-0	1.49 ± 0.18 E-08[b]	2.55 ± 0.09 E-07[b]	5.0 ± 0.5 E-08[b]	1.3 ± 0.3 E-07[b]	10 ± 7 E-09	--	--	--
D-30	233-10 to 224-4	1.3 ± 1.3 E-09	8 ± 9 E-10	-0.1 ± 1.0 E-09	-2 ± 4 E-08	-2 ± 8 E-09	--	--	--
D-31	224-4 to 226-4	2.6 ± 1.1 E-09	7 ± 8 E-10	0.0 ± 1.2 E-09	2 ± 3 E-08	4 ± 7 E-09	--	--	--
D-34 (field split)	230-0 to 230-4	6.5 ± 1.9 E-09[b]	0.8 ± 1.0 E-09	0.3 ± 1.3 E-09	4 ± 3.0	-0 ± 7 E-09	--	--	--
D-34 (lab split)	230-0 to 230-4	3.22 ± 0.17 E-08[b]	5.8 ± 0.2 E-08[b]	--	--	--	--	--	--
D-34 (lab split, 4000-min count)	230-0 to 230-4	1.5 ± 0.4 E-09[b]	2 ± 3 E-10	--	--	--	--	--	--
D-34 (lab split, 4000-min count)	230-0 to 230-4	3.3 ± 0.6 E-09[b]	3 ± 4 E-10	--	--	--	--	--	--
D-34A (field split, 4000-min count)	229-8 to 230-0	2.4 ± 0.7 E-09[b]	3 ± 6 E-10	--	--	--	--	--	--
D-34A (lab split)	229-8 to 230-0	1.3 ± 1.1 E-09	-3 ± 7 E-10	--	--	--	--	--	--
D-34A (lab split)	229-8 to 230-0	1.4 ± 1.1 E-09	4 ± 6 E-10	--	--	--	--	--	--
D-35	232-3 to 232-7	1.6 ± 1.7 E-09	1.1 ± 1.0 E-09	-0.2 ± 1.2 E-09	2 ± 3 E-08	7 ± 7 E-09	--	--	--
D-36	233-9 to 234-2	1.8 ± 1.5 E-09	1.1 ± 1.4 E-09	-0.3 ± 1.2 E-09	2 ± 4 E-08	0 ± 6 E-09	--	--	--
D-37	234-9 to 235-2	1.4 ± 1.1 E-09	1.0 ± 0.9 E-09	0.2 ± 1.4 E-09	-3 ± 4 E-08	1.3 ± 0.7 E-08	--	--	--
Deep Hole D06A									
D-29	47-0 to 49-0	1.5 ± 1.2 E-09	7 ± 7 E-10	-2 ± 9 E-10	4 ± 3 E-08	5 ± 2 E-08	--	--	--
Deep Hole TW1									
D-42 (field split)	101-0 to 101-2	1.7 ± 0.2 E-08[b]	7.4 ± 0.4 E-07[b]	4.4 ± 0.2 E-07[b]	5 ± 4 E-08	--	--	No split available	--
D-42 (lab subsplit)	101-0 to 101-2	1.18 ± 0.17 E-08[b]	6.1 ± 0.3 E-07[b]	4.7 ± 0.2 E-07[b]	--	--	--	No split available	--
D-43A (field split)	101-2 to 101-7	4.6 ± 1.4 E-09[b]	1.97 ± 0.13 E-07[b]	1.03 ± 0.08 E-07[b]	4 ± 3 E-08	--	10 ± 3 E-09[b]	1.78 ± 0.13 E-07[b]	8.47 ± 0.95 E-08[b]
D-43 (field subsplit)	101-2 to 101-7	6.3 ± 1.7 E-09[b]	1.90 ± 0.13 E-07[b]	1.06 ± 0.09 E-07[b]	--	--	ND	1.68 ± 0.09 E-07[b]	9.08 ± .075 E-07[b]
D-43A (lab subsplit)	101-2 to 101-7	6.5 ± 1.6 E-09[b]	2.00 ± 0.13 E-07[b]	1.37 ± 0.11 E-07[b]	--	--	3.9 ± 1.3 E-09	1.7 ± 0.09 E-07[b]	1.07 ± 0.09 E-07[b]
D-47	225-9 to 225-11	-4 ± 6 E-10	8 ± 7 E-10	2 ± 9 E-10	6 ± 3 E-08	--	--	--	--
D-47 (lab subsplit)	225-9 to 225-11	7 ± 7 E-10	2 ± 6 E-10	0.5 ± 1.0 E-09	--	--			
D-48	226-10 to 227-7	0.8 ± 1.1 E-09	3 ± 6 E-10	1.2 ± 1.4 E-09	3 ± 3 E-08	3 ± 1.6 E-08	--	--	--
D-48 (lab subsplit)	226-10 to 227-7	5 ± 9 E-10	2 ± 7 E-10	0.7 ± 1.1 E-09	--	--	--	--	--
D-48 (lab subsplit)	226-10 to 227-7	6 ± 7 E-10	7 ± 7 E-10	0.6 ± 1.2 E-09	--	--	--	--	--

---

a. Source: Laney et al. (1988).

b. Sample result positive (i.e., greater than three sigma).

Table 5-20. Summary of soil hydraulic property tests (November 1989)[a]

					Moisture Characteristics						Particle Distribution		Unsaturated Hydraulic Conductivity	
Borehole	Depth (ft)	Sample Number	Date Sampled	Saturated Hydraulic Conductivity	Hanging Column	Pressure Plate	Initial Moisture Content	Dry Bulk Density	Porosity	Particle Density	Mechanical Sieve	Hydrometer	Calculated	Onestep
Surficial Sediments														
W06	1.7 - 2.7	D86W06XST09H	08/06/86	X	X	X	X	X	X	X	X	X	X	
	11.0 - 11.8	D86W06XST10H	09/06/86	X	X	X	X	X	X	X	X	X	X	
W09	6.0 - 7.0	D86W09XST20H	09/11/86	X	X	X	X	X	X	X	X	X	X	
W24	7.4 - 8.3	D86W24XST06H	08/01/86	X	X	X	X	X	X	X	X	X	X	
Sedimentary Interbeds														
D02	230.3 - 232.6	D86D02XD35XH	10/31/86	X	X	X	X	X	X	X	X	X	X	
	232.6 - 234.2	D86D02XD36XH	11/03/86	X	X	X	X	X	X	X	X		X	
	234.2 - 235.2	D86D02XD37XH	11/03/86	X	X	X	X	X	X	X	X		X	
D10	31.5 - 34.6	D87D10XD89XH	09/18/87	X	X	X	X	X	X	X	X	X	X	
	34.6 - 36.0	D87D10XD90XH	09/18/87	X	X	X	X	X	X	X	X	X	X	X
	34.6 - 36.0[b]	D87D10XD90XH-2	09/18/87	X	X	X	X	X	X	X	X	X	X	
D15	108.6 - 110.0	D87D15XD67XH	08/27/87	X	X	X	X	X	X	X	X	X	X	
	229.4 - 233.4	D87D15XD77BH	09/09/87	X	X	X	X	X	X	X	X	X	X	
	237.3 - 239.3	D87D15XD79AH	09/10/87	X	X	X	X	X	X	X	X	X	X	
8801D	230.1 - 233.3	D888801D49XH	07/25/88	X	X	X	X	X	X	X	X	X	X	
	230.1 - 233.3[b]	D888801D49XH-2	-	X	X	X	X	X	X	X	X	X	X	X
	233.3 - 235.3	D888801D50XH	07/25/88	X	X	X	X	X	X	X	X	X	X	
	240.8 - 242.3	D888801D52XH	07/28/88	X	X	X	X	X	X	X	X	X	X	
118[c]	225.0 - 230.0	D89118X0001H		X	X	X	X	X	X	X	X	X		
	240.0 - 244.0	D89118X0002H		X	X	X	X	X	X	X	X	X		
	569.0 - 572.0	D89118X0004H		X	X	X	X	X	X	X		X	X	

---

a. Source: McElroy and Hubbell (1990).

b. Duplicate samples

c. Borehole not completed under the SIP.

Table 5-21. Core analyses at simulated reservoir stress at selected boreholes[a]

Borehole	Sample No.	Depth (ft)	Helium Porosity	Vertical Air Permeability	Saturation	Apparent Sand Grain Density	Lithology	Moisture Content Analysis	Permeability at 50% Saturation
Surficial Sediments									
W24	D86W24XST06A	7.4 - 8.3	X	X	X	X	X	X	
W06	D86W06XST10A	11.0 - 11.8	X	X	X	X	X	X	
W09	D86W09XST20A	6.0 - 7.0	X	X	X	X	X	X	
Sedimentary Interbeds									
D02	D86D0ZXD35XA	230.3 - 232.6	X	X	X	X	X	b	
	D86D0ZXD36XA	232.6 - 234.2	X	X	X	X	X	b	X
	D86D0ZXD37XA	234.2 - 235.2	X	X	X	X	X	b	
D15	D87D15XD77AA	229.4 - 233.4	X	X	X	X	X	X	
	D87D15XD79AA	237.3 - 239.3	X	X	X	X	X	X	
8801D	D888801D49XA	230.1 - 233.3	X	X	X	X	X	X	
	D888801D50XA	233.3 - 235.4	X	X	X	X	X	X	X
	D888801D52XA	240.0 - 242.1	X	X	X	X	X	X	
118[c]	D89118X0001A	225.0 - 230.0	X	X	X	X		X	
	D89118X0002A	240.0 - 244.0	X	X	X	X		X	
	D89118X0004A	569.0 - 572.0	X	X	X	X		X	

---

a. Source: McElroy and Hubbell (1990).

b. Moisture content analysis not representative, samples were wetted for permeability measurements prior to hydraulic properties testing.

c. Borehole not completed under the SIP.

because the waters showed low bromide concentrations and, therefore, were considered to be the most representative. Potassium bromide was used as a tracer during placement of the suction lysimeters; therefore, low bromide concentrations indicated that the initial water system had been flushed. The results of this investigation were reported by S. Rawson.[a] In addition, waters were collected for radiochemical analyses to monitor radionuclide migration, and the results are reported in Hubbell et al. (1985) and Hubbell et al. (1987).

Perched water samples were collected July 19, 1989, for radionuclides, tritium, and VOAs. On September 27, 1989, samples were collected for radionuclides and metals from Borehole 8802D. Metals, cations, and tritium were analyzed for in samples collected January 1, 1990, from Borehole 8802D. The aqueous chemistry data are presented in Tables 4, 5, 6, and 7 of Hubbell (1990).

A tabulation of the results from the one-time gas sampling event are provided in Appendix 5-7. There are problems with the analytical results because of uncertainties in the field sampling and in the lab analysis. The quality control summary table for the formation gas samples is presented in Table 5-22. During the field sampling, a number of syringes did not have gas tight seals and/or the needle was plugged. This either prevented the collection of samples in some cases or caused uncertainty in the integrity of the sample. The range of the laboratory instrumentation was exceeded in many of the samples. The instruments for the analyses of gas samples were calibrated for 5 mL gas samples ranging in concentration from 20 to 200 mg/m^3 or 25 mL gas samples ranging in concentration from 4 to 40 mg/m^3. Many of the samples collected from the four boreholes exceeded these concentration limits; therefore, the concentrations could only be reported as estimated values for the 14 organic compounds detected. It is noted in Appendix 5-9 that this analytical difficulty causes reported concentrations to underestimate the

---

[a] Communication between J. M. Hubbell, EG&G Idaho, Inc., Idaho Falls, Idaho, and L. N. Peterson, EG&G Idaho, Inc., Idaho Falls, Idaho, April 18, 1990.

Table 5-22. Quality control table summary for formation gas samples^{a}

Borehole Number	Sample Number	Sample Volume	Chain of Custody	Holding Time	Surrogate Recovery	Tuning and Mass Cal	Initial Cal	Continuing Cal	Internal Standard	Method Blank
8801D	05/03/89									
	E8019X8901	OK	OK	OK	OK	OK	Two compounds exceeds % diff	4 compounds exceeds % diff	OK	Acetone 2-butanone
	E8018X8901	OK	OK	OK	OK	OK			OK	
	E8017X8901	OK	OK	OK	OK	OK			OK	
	E8016X8901	OK	OK	OK	OK	OK			OK	
	E8015X8901	Sample not collected								
	E801528901	OK	OK	OK	NO*	OK			OK	
	E801538901	OK	OK	OK	NO*	OK			OK	
	E8010S8901	OK	OK	OK	OK	OK			OK	
8801D	05/10/89									
	E801548901	5mL	OK	OK	OK	OK			OK	
	E8014X8901	5mL	OK	OK	OK	OK		3 compounds exceeds % diff	OK	4 compounds found in lab blank
	E8013X8901	5mL	OK	OK	NO*	OK			OK	
	E801328901	5mL	OK	OK	NO*	OK			NO*	
	E801338901	Sample not collected								
	E8012X8901	5mL	OK	OK	OK	OK			OK	
	E8011X8901	5mL	OK	OK	OK	OK			OK	
	E8010X8901	5mL	OK	OK	OK	OK			OK	
78-4	05/18/89									
	E7845X8901	OK	OK	OK	OK	OK			OK	
	E784528901	OK	OK	OK	OK	OK		6 compounds exceeds % diff	OK	2-butano methylene 1,1,1-trichlor
	E7844X8901	OK	OK	OK	OK	OK			OK	
	E784428901	OK	OK	OK	OK	OK			OK	
	E7843X8901	23 mL	OK	OK	NO*	OK			OK	
	E7842X8901	OK	OK	OK	NO*	OK			OK	
	E7840E8901	OK	OK	OK	NO*	OK			OK	
WWW-1	05/31/89									
	EWW17X8901	OK	OK	OK	OK	OK			OK	
	EWW16X8901	OK	OK	OK	OK	OK		8 compounds exceeds % diff	OK	4 compounds found in blank
	EWW1628901	Sample not collected								
	EWW1638901	OK	OK	OK	OK	OK			OK	
	EWW15X8901	OK	OK	OK	OK	OK			OK	
	EWW14X8901	OK	OK	OK	OK	OK			OK	
	EWW1428901	OK	OK	OK	OK	OK			OK	
	EWW10S8901	OK	OK	OK	OK	OK			OK	
WWW-1	06/06/89									
	EWW13X8901	OK	OK	OK	OK	OK			OK	
	EWW1328901	OK	OK	OK	OK	OK		7 compounds exceeds % diff	OK	2 blanks run
	EWW12X8901	OK	OK	OK	OK	OK			OK	
	EWW11X8901	OK	OK	OK	NO*	OK			OK	
	EWW1128901	OK	OK	OK	NO*	OK			OK	3 compounds reported
	EWW10X8901	OK	OK	OK	NO*	OK			OK	

T 5-22. (continued)

Borehole Number	Sample Number	Sample Volume	Chain of Custody	Holding Time	Surrogate Recovery	Tuning and Mass Cal	Initial Cal	Continuing Cal	Internal Standard	Method Blank
77-1	06/08/89							8 Compounds exceeds % diff		2-butanone 1,1,1-trichloroethane
	E7716X8901	OK	OK	>48 H	OK	OK			OK	
	E7715X8901	OK	OK	>48 H	NO*	OK			OK	
	E771528901	OK	OK	>48 H	OK	OK			OK	
	E7714X8901	OK	OK	>48 H	OK	OK			OK	
	E7713X8901	OK	OK	>48 H	OK	OK			OK	
	E7712X8901	OK	OK	>48 H	NO*	OK			OK	
	E7710T8901	OK	OK	>48 H	NO*	OK			OK	

---

a. Communication between L. D. Goodrich, EG&G Idaho, Inc., Idaho Falls, Idaho, and L. N. Peterson/C. J. Bonzon, EG&G Idaho, Inc., Idaho Falls, Idaho, December 26, 1989. Samples were validated in accordance with EPA requirements for data validation.

6. SDA Surface Water Runoff and Runoff Channel Investigation

6. SDA SURFACE WATER RUNOFF AND RUNOFF CHANNEL INVESTIGATION

The SDA has been flooded several times, resulting in water-filled waste disposal pits and trenches. These floods caused some waste boxes to break open, releasing their contents and allowing drums to float freely in the water. As a result of these events, there has been concern that hazardous or radiological waste materials may have migrated offsite in the surface runoff.

This section discusses a one-time sampling investigation for hazardous constituents and the routine monitoring for radionuclides in surface water runoff at the RWMC. These studies were conducted to determine the presence and/or extent of hazardous constituents or radionuclides that may have migrated from the SDA as suspended sediments in runoff. Section 6.1 describes a study designed to assess the potential migration of hazardous materials from the SDA along the surface water runoff channel. Section 6.2 addresses the routine monitoring at the RWMC for radionuclides in the surface water runoff.

6.1 Monitoring for Hazardous Constituents in Surface Water Runoff at the RWMC

This section discusses a study conducted to evaluate the potential migration of hazardous contaminants from surface water runoff at the SDA. The purpose and proposed strategy of the SDA surface water runoff channel investigation is presented in Section 6.1.1, the procedures for the runoff investigation conducted at the SDA in 1983 is described in Section 6.1.2, and a summary of the study results appears in Section 6.1.3.

6.1.1 Purpose of the SDA Surface Water Runoff Channel Investigation

The SDA surface water runoff channel investigation, as proposed in the December 1988 RFI Work Plan, was intended to determine if contaminant migration had occurred in response to flooding or to surface water runoff from the RWMC (EG&G, 1988a). Specific objectives of the study included:

- Determine if contaminant migration from surface water runoff at the RWMC was occurring
- Delineate affected areas
- Identify which contaminants migrated via this environmental pathway.

The proposed investigation was never completed as proposed based on evaluation of data included in a 1983 study. In the course of conducting the RFI, further information on sediment and runoff characteristics at the SDA was identified in Crockett (1983). The focus of the SDA surface water runoff and runoff channel investigation subsequently changed from evaluating hazardous constituents to simulating various flooding events using different computer models. The Crockett (1983) study was conducted to determine if hazardous materials buried at the RWMC were migrating from the burial site as particulate matter suspended in air or water. This study is included in Appendix 6-1 of this report and is briefly described in Section 6.1.2.

SDA drainageways are periodically regraded with heavy equipment to remove weeds and to discourage wildlife habitation. In addition, snow is scraped from the SDA after heavy snowfall, as are debris and sediment that interfere with flow. Soil from offsite is used to fill in areas subject to subsidence. These procedures homogenize the surface sediments and obliterate nearly all evidence of contaminant migration via surface water from any area except the runoff infiltration area north of the SDA, where regrading is unlikely.

6.1.2 Procedure for Investigation

After the flood in February 1982, a study was undertaken to determine if toxic metals or organic contaminants were migrating from the SDA via surface water or air. Twelve composite samples of surface soils were collected on September 13, 1982, and the sample analyses were conducted at an offsite laboratory about September 15, 1982. A description of the soil sampling locations is provided in Section 6.1.2.1, the sample collection procedure is summarized in Section 6.1.2.2, and analytical procedures and quality assurance/quality control methods are described in Sections 6.1.2.3 and 6.1.2.4, respectively.

6.1.2.1 Selection of Sampling Locations. Sample locations were sited in order to collect fine-grained sediments because these sediments have a higher probability of resuspension and a greater sorption capacity for metals and organics than do coarse sediments (Crockett, 1983). Rapidly-flowing runoff causes surficial erosion; thus, a heavy sediment load is carried. Where the flow rate is high, large and heavier particles such as gravel and coarse sand settle out of the load. When the runoff flow rate decreases, particles of suspended sediments such as silt and clay settle out of solution. Suspended clay minerals are deposited only after hours of quiescence. Crockett sampled in areas where low flow rates were likely in order to obtain primarily fine-grained sediment samples.

Sample locations within the RWMC are shown in Figure 6-1. These samples were located in relatively low-flow areas such as drainage ditches and depressions. Figure 6-2 illustrates the relative location of the control samples and of sample R-1. Each type of sample is described below.

- Sample R-1 was collected about 2 km (1.5 mi) north of the RWMC at the location where SDA surface water runoff is channeled and allowed to spread and infiltrate. This location would be expected to contain primarily fine-grained sediments.

- Four samples were collected in locations where the runoff flow rate would decrease, resulting in the deposition of finer-grained sediments. These samples are from the areas designated R-3, R-5, R-6, and R-7 on the SDA (Figure 6-1).

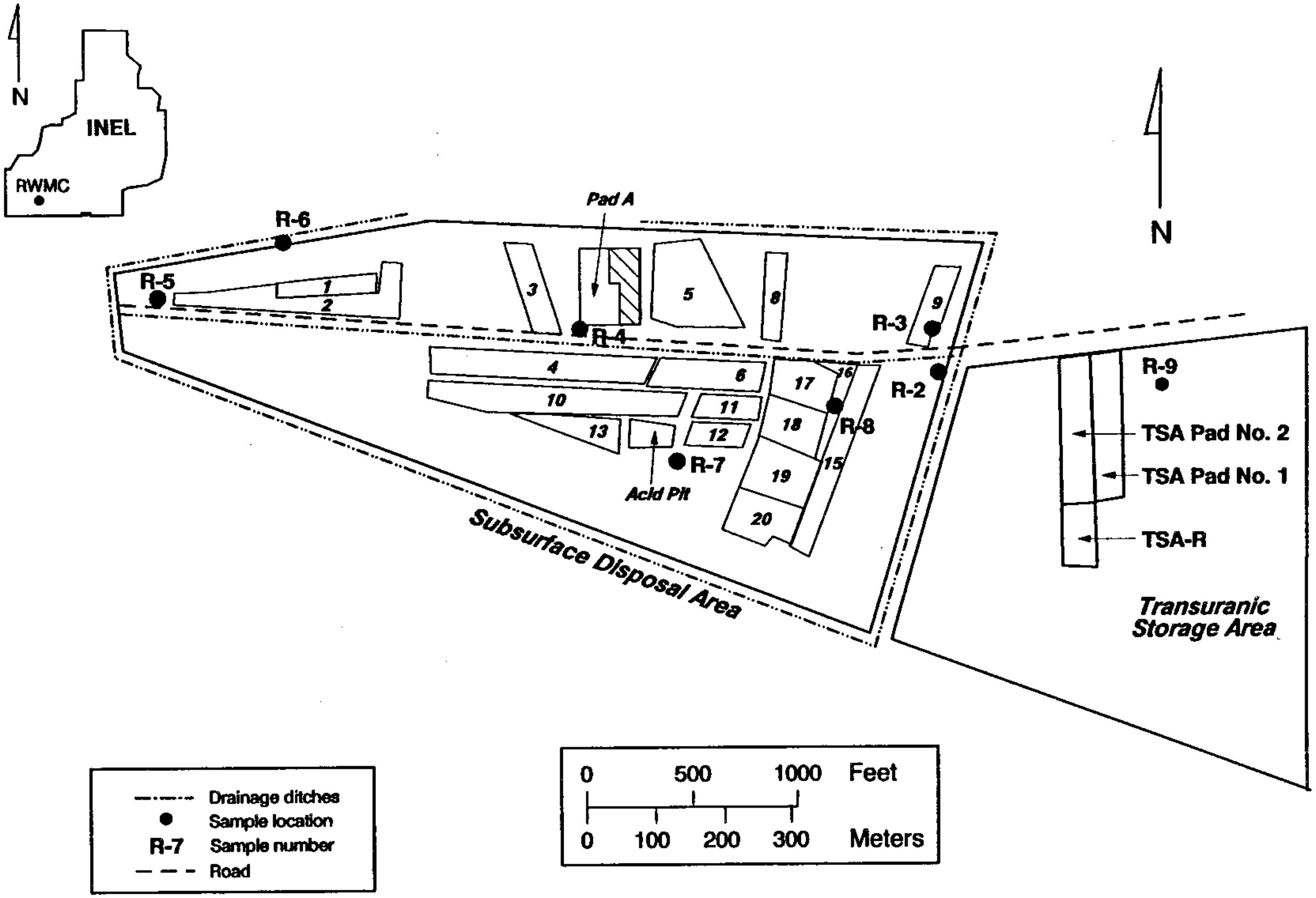


Figure 6-1. Location of RWMC soil sampling sites R-2 through R-9 (from Crockett, 1983, locations are approximate).

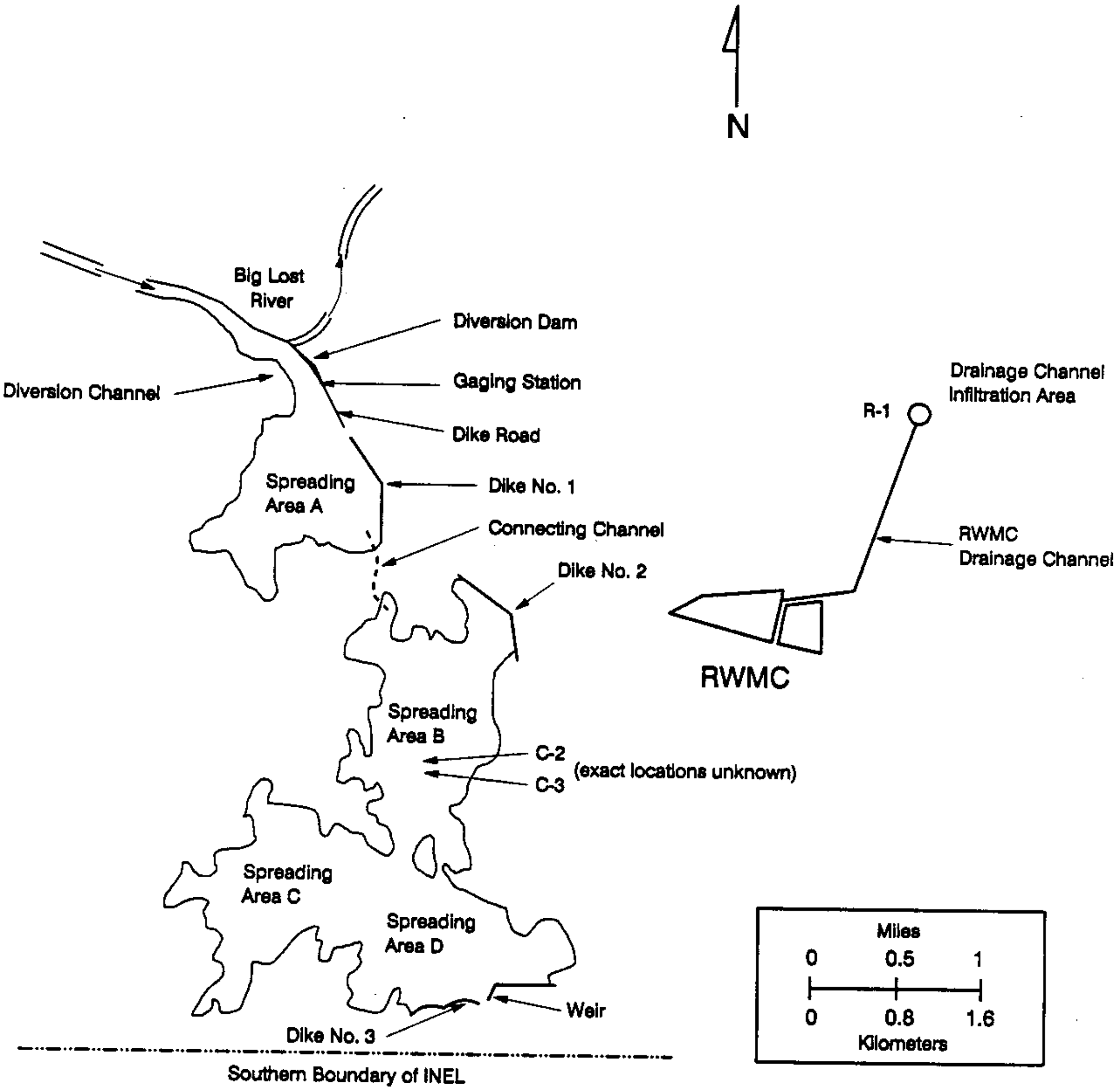


Figure 6-2. Location of sample R-1 and Spreading Area B where control samples were collected (exact locations not provided). Location of C-1 unknown. (Crockett, 1983).

- Two samples were collected from areas where more rapid flow was expected. Samples R-2 and R-4 were collected from a ditch on the eastern end of the SDA and from the culvert that receives runoff from Pad A, respectively. Both of these locations would be expected to have coarser-grained deposition. However, the heavier sediments collected at these locales may have been deposited here because they contain heavy metals.

- Sample R-8 was a composite collected from the bottom of active Pits 16 and 17.

- One sample (R-9) was taken from the TSA in the location where snow scraped from the SDA is deposited. The degree of contamination in this sample would depend on three factors: the amount of SDA surface soil scraped from the area during snow removal, the amount of contamination in the scraped soil, and the amount of in situ contamination from TSA activities.

- Three control samples were collected. Two of these samples (C-2 and C-3) were collected in the central portion of the Big Lost River spreading area (Spreading Area B), about 3 km (2 mi) west of the SDA (Figure 6-2). Spreading Area B is the source for soil material used at the SDA to fill depressions and areas subject to subsidence at the SDA. The other control sample (C-1) came from an undisturbed sagebrush area. The exact collection location for this sample was not given in the report.

6.1.2.2 Sampling Protocol. The following paragraphs present the sampling protocol that was used. Twelve samples were taken from locations on or near the SDA, as shown in Figure 6-1. The samples were all composites of five samples taken from a maximum depth of 5 cm (2 in.). In a given sample area, a steel sampling ring 10 cm (about 4 in.) in diameter and 5 cm (2 in.) in length was placed in five different locations, and a sample was collected. These five samples were composited to provide a single sample for that area. The horizontal sampling area was larger for the control area and smaller for the SDA samples, but the actual sample areas were not given in the report. Sampling equipment consisted of a trowel and a steel ring, which were both cleaned between each sample collection with Chlorothane Nu, a solvent used for radioactive decontamination. Samples were placed in clean 1-qt glass jars with teflon-lined lids (Crockett, 1983).

The samples were analyzed for 15 metals, chlorides, nitrates, and 112 organic priority pollutants including PCBs and dioxin. No analyses for radionuclides were conducted on these samples.

6.1.2.3 Analytical Procedures. Sample analyses were conducted by California Analytical Laboratories, Inc., a laboratory under contract with EPA. The analytical procedures used in the Crockett study were modified versions of EPA Methods 608, 613, 624, and 625 for organics, nitric acid digestion for all metals except boron and mercury, aqueous extract for boron, and the cold vapor technique for mercury, respectively. Chlorides and nitrates were measured using the American Public Health Association Methods 407C and 418C, respectively. Appendix 6-1 (pp. 8-11) presents further details on the analytical procedures. The analyzed compounds and elements and their respective detection limits are listed in Table 6-1.

6.1.2.4 Quality Assurance/Quality Control Methods. In addition to the internal quality assurance and quality control program required by the EPA for the analytical laboratory, other quality assurances/quality control measures were used. Quality control and quality assurance measures for this study included (a) collection of three control samples and two field duplicates and (b) submittal of spiked samples and standard samples from a simultaneous soil study being conducted at the then-proposed Waste Experimental Reduction Facility (WERF), which is located more than 16 km (10 mi) away from the SDA. Additional information about this quality assurance/quality control program can be found on page 11 in Appendix 6-1.

Table 6-1. List and detection limits of organic chemicals, metals, and nonmetallic inorganic constituents analyzed in RWMC and control soils (mg/kg)[a]

Volatiles	Detection Limit
acrolein	0.05
acrylonitrile	0.05
benzene	0.05
carbon tetrachloride	0.05
chlorobenzene	0.05
1,2-dichloroethane	0.05
1,1,1-trichloroethane	0.05
1,1-dichloroethane	0.05
1,1,2-trichloroethane	0.05
1,1,2,2-tetrachloroethane	0.05
chloroethane	0.05
2-chloroethylvinyl ether	0.05
chloroform	0.05
1,1-dichloroethene	0.05
trans-1,2-dichloroethene	0.05
1,2-dichloropropane	0.05
trans-1,3-dichloropropene	0.05
cis-1,3-dichloropropene	0.05
ethylbenzene	0.05
methylene chloride	0.05
chloromethane	0.05
bromomethane	0.05
bromoform	0.05
bromodichloromethane	0.05
fluorotrichloromethane	0.05
dichlorodifluoromethane	0.05
chlorodibromomethane	0.05
tetrachloroethene	0.05
toluene	0.05
trichloroethene	0.05
vinyl chloride	0.05

Acid Compounds	
2,4,6-trichlorophenol	0.5
p-chlor-m-cresol	0.5
2-chlorophenol	0.5
2,4-dichylorophenol	0.5
2,4-dimethylphenol	0.5
2-nitrophenol	0.5

Acid Compounds (cont)	Detection Limit
4-nitrophenol	2.0
2,4-dinitrophenol	1.0
4,6-dinitro-2-methylphenol	0.5
pentachlorophenol	0.5
phenol	0.5

Base/Neutral Compounds	
acenaphthene	0.5
benzidine	0.5
1,2,4-trichlorobenzene	0.5
hexachlorobenzene	0.5
hexachloroethane	0.5
bis (2-chloroethyl) ether	0.5
2-chloronaphthalene	0.5
1,2-dichlorobenzene	0.5
1,3-dichlorobenzene	0.5
1,4-dichlorobenzene	0.5
3,3′-dichlorobenzidine	0.5
2,4-dinitrotoluene	0.5
2,6-dinitrotoluene	0.5
1,2-diphenylhydrazine	0.5
fluoranthene	0.5
4-chlorophenyl phenyl ether	0.5
4-bromophenyl phenyl ether	0.5
bis (2-chloroisopropyl) ether	0.5
bis (2-chloroethoxy) methane	0.5
hexachlorobutadiene	0.5
hexachlorocyclopentadiene	0.5
isophorone	0.5
naphthalene	0.5
nitrobenzene	0.5
N-nitrosodiphenylamine	0.5
N-nitrosodipropylamine	0.5
bis (2-ethylhexyl) phthalate	0.5
phthalate	
benzyl butyl phthalate	0.5
di-n-butyl phthalate	0.5
di-n-octyl phthalate	0.5

Table 6-1. (continued)

Base/Neutral Compounds (cont)	Detection Limit
diethyl phthalate	0.5
dimethyl phthalate	0.5
benzo(a)pyrene	0.5
benzo(b)fluoranthene	0.5
benzo(k)fluoranthene	0.5
chrysene	0.5
acenaphthylene	0.5
anthracene	0.5
benzo(ghi)perylene	0.5
fluorene	0.5
phenanthrene	0.5
dibenzo(a,h)anthracene	0.5
indeno(1,2,3-cd)pyrene	0.5
pyrene	0.5
Pesticides	
aldrin	0.01
dieldrin	0.01
chlordane	0.1
4,4′-DDT	0.01
4,4′-DDE	0.01
4,4′-DDD	0.1
α-endosulfan	0.01
β-endosulfan	0.01
endosulfan sulfate	0.1
endrin	0.01
endrin aldehyde	0.1
heptachlor	0.01
heptachlor epoxide	0.01
α-BHC	0.01
β-BHC	0.01
δ-BHC	0.01
γ-BHC (lindane)	0.01
PCB-1242	0.1
PCB-1254	0.1
PCB-1221	0.1

Pesticides (cont)	Detection Limit
PCB-1232	0.1
PCB-1248	0.1
PCB-1260	0.1
PCB-1016	0.1
toxaphene	0.2
Metals	
antimony	0.1
arsenic	0.1
beryllium	0.01
boron	1.0
cadmium	0.2
chromium	0.2
copper	0.4
lead	0.3
mercury	0.03
nickel	0.3
selenium	1.0
silver	1.0
thallium	0.6
zinc	0.2
Inorganic Nonmetals	
chloride	na[b]
nitrate	na
Dioxins	
2,3,7,8-tetrachloro-dibenzo-p-dioxin	0.1

---

a. Source: Crockett (1983).

b. na = not available.

6.1.3 Results

The results of the Crockett study laboratory analyses are presented in Table 6-2. This table lists the analyses for the sediment samples, based on the sample wet weights. No results for organics were provided because only one organic contaminant was found in sample R-1. Results for samples R-8 and C-3 were rejected as statistical outliers. It was assumed that errors in the extraction procedure led to inaccurate results for these samples.

Crockett calculated the mean concentrations of metals in RWMC soils and compared these with the mean concentrations in WERF area soils, which were also used as background samples. Both of these areas were compared with average crustal abundance data for basaltic and granitic rocks. This comparison showed that the relative concentrations of metals in RWMC soils did not differ significantly from the metal concentrations in other soils derived from these rocks. These data are presented in Table 6-3.

In sample R-1, 0.055 mg/kg chloroform was detected. No other organic compound was detected in the other samples. Sample R-1 was assumed to be contaminated by the solvent used to clean the sample collection equipment between samples.

6.2 Monitoring for Radionuclides in Surface Water at the RWMC

Surface water runoff sampling for radionuclides is conducted routinely at the RWMC. The objectives of RWMC surface water monitoring are to (a) determine concentrations and total amounts of radionuclides in any surface waters leaving the RWMC, and as an interim measure, compare against derived concentration guides for the limits set for release to the public, (b) detect significant trends in radionuclide concentrations in surface waters at the RWMC, (c) provide an indication of confinement integrity for waste at the TSA and SDA, and (d) provide data for pathways analyses on radionuclide concentrations in surface water, which can be used for estimating dose to man (EG&G, 1989g). In addition to the routine monitoring of SDA surface water runoff, the Environmental Monitoring Unit periodically samples surface water

Table 6-2. Raw data for metals and nonmetallic inorganic constituents in RWMC soils (mg/kg)[a]

Constituent[b]	Detection Limit	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8[c]	R-9	C-1	C-2	C-3[c]
Barium	1.0	83	210	180	83	92	180	83	--	130	250	92	--
Boron	1.0	17	18	12	21	22	18	22	--	22	25	25	--
Chromium	0.2	5.1	3.5	2.7	4.7	5.1	2.5	3.3	--	2.4	5.8	7.9	--
Cadmium	0.2	0.65	0.45	0.45	0.62	0.55	0.34	0.50	--	0.52	1.1	0.36	--
Cobalt	0.4	3.5	2.2	2.2	2.5	3.1	2.7	2.1	--	2.3	4.8	2.0	--
Copper	0.4	9.2	8.3	5.5	8.1	8.0	4.5	6.6	--	6.2	11	4.3	--
Lead	0.3	10	8.2	8.2	11	9.2	8.3	9.2	--	6.8	12	7.8	--
Manganese	0.1	200	160	150	150	190	120	120	--	140	230	160	--
Nickel	0.3	12	6.7	5.9	6.9	8.0	5.7	5.9	--	7.1	8.3	4.0	--
Zinc	0.2	52	31	32	78	39	26	28	--	33	38	20	--
Chloride	--	400	160	240	400	160	80	64	64	160	130	130	240
Nitrate-N	--	0.53	0.22	0.57	0.17	0.14	0.26	0.20	0.18	0.74	0.57	1.0	0.27

---

a. Sample locations include ditches, depressions, disposal pits, sedimentation areas, control areas, and scraped snow deposition areas (refer to Figure 6-1 for sample locations).

b. Antimony, arsenic, beryllium, mercury, selenium, silver, thallium, and vanadium were not detected.

c. Metal results for samples R-8 and C-3 rejected due to extraction errors.

Table 6-3. Concentration of metals and inorganic nonmetallic compounds in surface soils at the RWMC and WERF

	Concentrations mg/kg						
	RWMC Surface Soil			WERF Surface Soil			
Constituent[a]	Exposed Mean[b]	95% Conf. Int.	Control Mean[b,c]	Mean[b] N = 12	95% Conf. Int.	Granite Average[d]	Basalt Average[d]
Boron	19	16 - 22	25	67	61 - 74	15	5
Cadmium	0.50	0.42 - 0.60	0.62	0.5	0.4 - 0.6	0.2	0.2
Chromium	3.5	2.7 - 4.6	3.3	4.4	3.7 - 5.3	4	200
Copper	6.9	5.6 - 8.4	6.8	ND[e]	NP[f]	10	100
Lead	8.8	7.8 - 9.9	9.9	1.7	1.0 - 2.9	20	5
Nickel	7.0	5.8 - 8.6	5.8	5.7	4.8 - 6.8	0.5	150
Zinc	37	27 - 51	27	19	16 - 23	40	100
Chloride	150	80 - 310	160	NP	NP	NP	NP
Nitrate-N	0.28	0.15 - 0.52	0.53	NP	NP	NP	NP

---

a. The following elements were not detected in RWMC surface soils or controls: antimony, arsenic, beryllium, mercury, selenium, silver, and thallium.

b. Estimated geometric mean.

c. One RWMC soil sample extract was rejected as an outlier for elemental analysis; n equals 8 and 2 for exposed and control soils. For the other inorganic constituents, n equals 9 and 3 for exposed and control soils.

d. Source: Crockett (1983).

e. ND = not detected.

f. NP = not provided.

runoff for special studies such as the potential migration of uranium waste containing soluble nitrate described in Reyes et al. (1987).

The procedure for collecting surface water samples have been consistent the past several years; however, the sample collection locations have varied slightly. Section 6.2.1 describes the surface water runoff sample collection locations, and Section 6.2.2 summarizes the sampling protocol. Sections 6.2.3 and 6.2.4 address the analytical procedures and the quality assurance and quality control procedures, respectively. The analytical results are presented in Section 6.2.5.

6.2.1 Selection of Sampling Locations

Because the annual rainfall at the INEL is low, no surface water flows from the SDA during most of the year. However, after heavy rainfalls or snowmelts there can be rapid runoff from the SDA (Tkachyk et al., 1988). The surface water runoff is diverted to a series of drainage ditches that converge near the SDA gate. From there, sump pumps transfer the water into the RWMC drainage ditch, which flows eastward along the northern edge of the TSA. This ditch is referred to as the RWMC drainage channel and is shown in Figure 6-2. Most of the water in this ditch either seeps into the ground or evaporates. The rest flows northward toward the Big Lost River.

Although this ditch receives drainage from both the SDA and the TSA, the sampling locations are selected to assess the impact from potential sources (Tkachyk et al., 1990). The current sampling locations are shown in Figure 6-3. The sampling collection locations are

- The discharge pipes from the SDA gate ditch (also called the SDA pump or the SDA pump discharge).

- The culvert pipes on the north end of the TSA asphalt pads (referred to as TSA-1, TSA-2, TSA-3, and TSA-4).

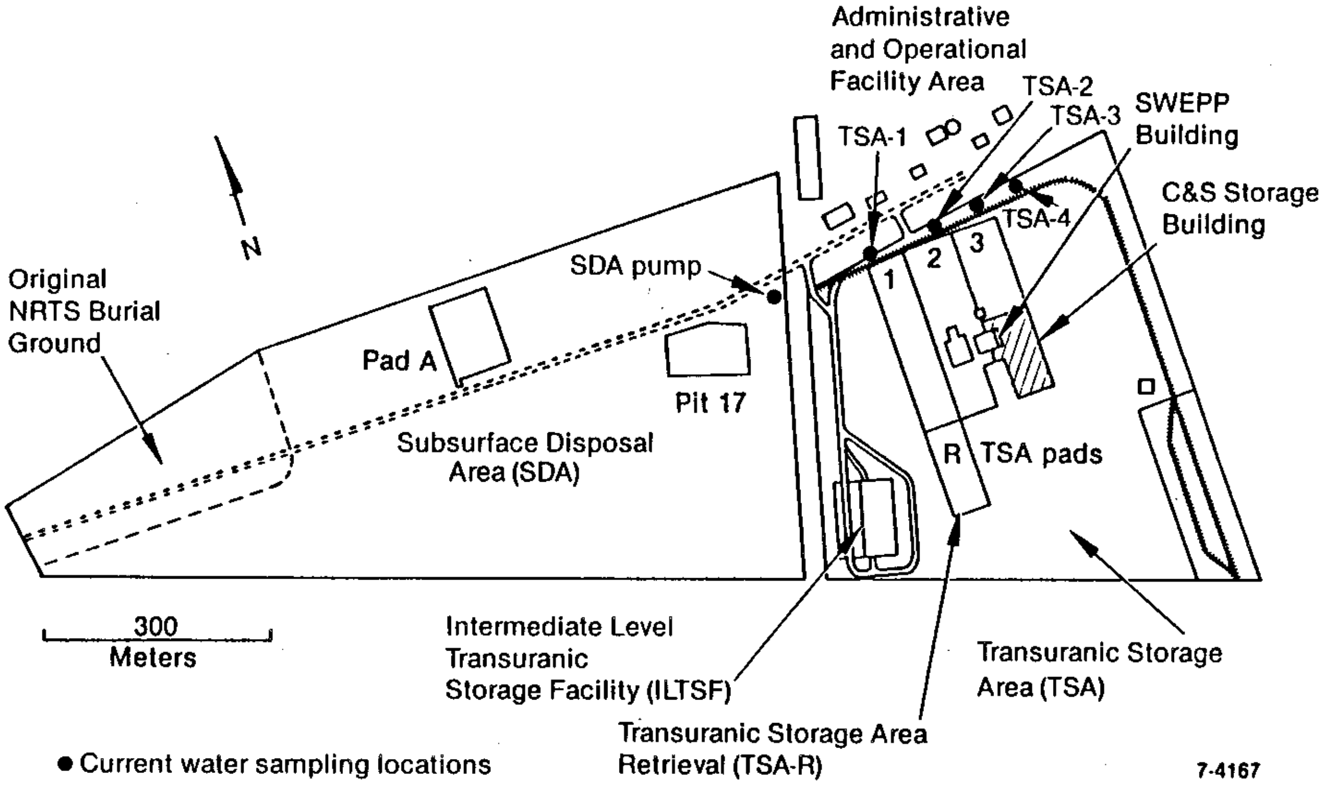


Figure 6-3. Locations for radionuclide sampling of surface water runoff. Location TSA-4 added to monitoring network in 1989 (Tkachyk et al., 1990).

Sampling at the SDA pump allows a direct assessment of radionuclide migration from the SDA via surface-water runoff; whereas, sampling at the TSA-1, TSA-2, TSA-3, and TSA-4 provides a direct assessment of radionuclide migration from the TSA pads (Tkachyk et al., 1990).

Control samples are collected primarily at two locations to provide background data for comparison. The SDA control location is a low, flat area next to INEL access road T-12 near the intersection of Highway 20/26 and Van Buren Avenue (Figure 6-4). Water collects after precipitation in this area, providing a source of standing water for surface water sampling. The TSA control location is an asphalt pad at the rest area on U.S. Highway 20/26. Both the SDA and TSA control locations are located about 6 km (3.7 mi) northeast of the RWMC as shown in Figure 6-4 (EG&G, 1989g).

6.2.2 Sampling Protocol

The sampling schedule for surface water including frequency, type of analysis, and quality assurance samples is summarized on Table 6-4. Water samples are collected during each quarter provided there is sufficient rainfall or snowmelt to produce surface water runoff from the TSA asphalt pads and to the SDA gate ditch. However, in most years, samples can be collected only in the spring (March or April) and the fall (October or November), when there is sufficient runoff to collect (Tkachyk et al., 1988).

According to the standard operating procedure, a total of 26 surface water samples should be collected each year from the following locations: four samples from each of the four TSA culverts, four samples from the SDA pump, and six samples from the control areas (EG&G, 1989g). This is a maximum number of samples; usually only two samples are collected (spring and fall) for each location because there is insufficient runoff for sample collection.

The procedure for sample collection varies, depending on whether standing water or running water is to be sampled. The sampling containers are 4-L polyethylene containers. In running water (as from the SDA pump discharge and the TSA culverts), the sample collection container is rinsed out in the

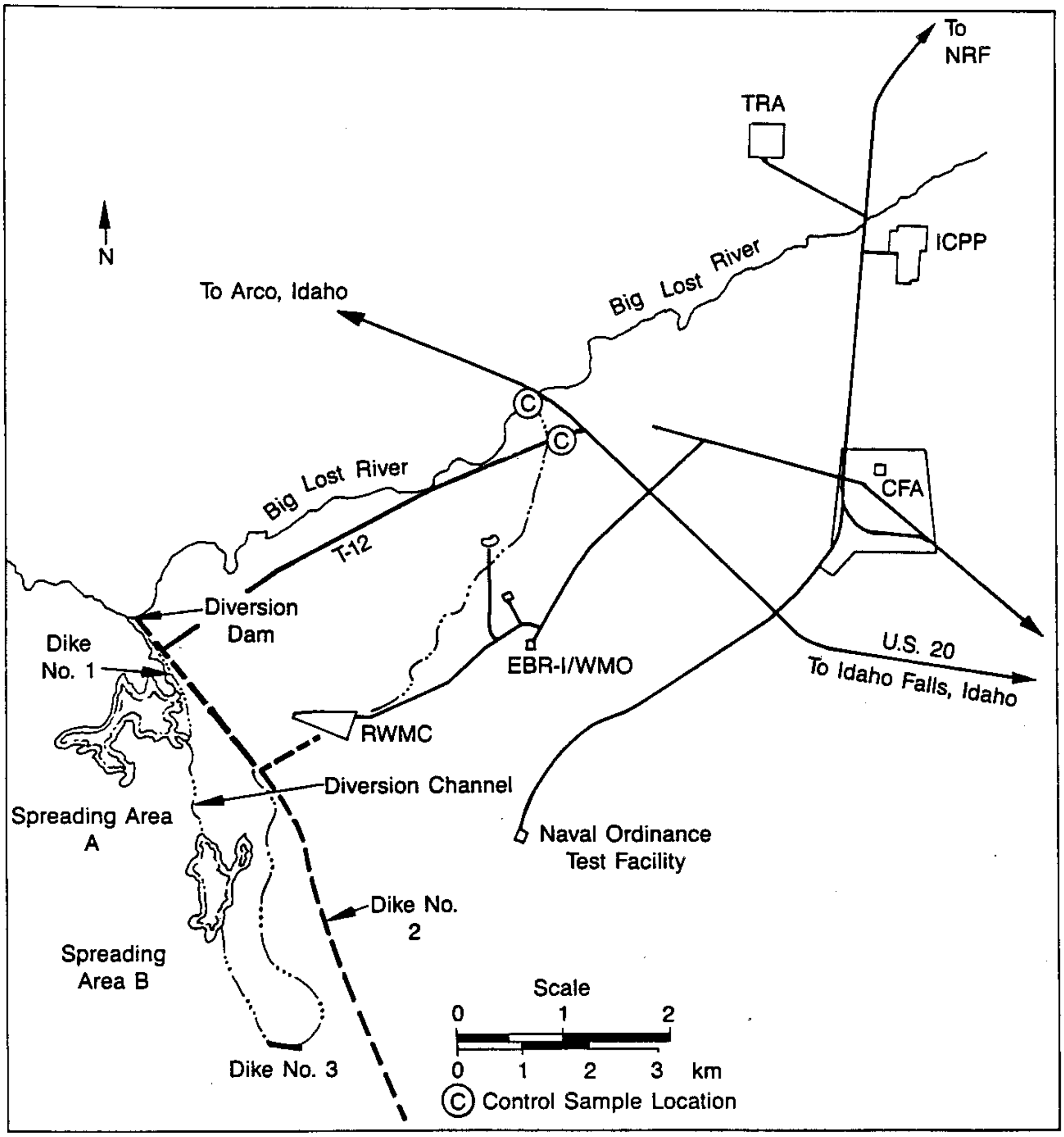


Figure 6-4. Approximate surface water control sample collection locations. Location of control samples varies by year, but is approximately 6 km (3.7 mi) northeast of the RWMC (modified from EG&G, 1989g).

Table 6-4. Surface water sampling schedule[a]

	TSA 1	TSA 2	TSA 3	TSA 4	SDA Pump	Controls (2)
1. Gross alpha, gross beta and gamma spectroscopy						
Frequency of sampling	Maximum once quarterly when present	Maximum once quarterly when present	Maximum once quarterly when present	Maximum once quarterly when present	Each day when water is leaving the SDA[b]	Taken concurrently when other samples are taken
Frequency of replicates	--	3 in second quarter if available	--	--	3 in second quarter if available	--
Total number of samples annually	4	4	4	4	4 typical[c]	6 typical
2. Radiochemistry for specific alpha and beta emitters (second quarter only)[d]	1	1	1	1	1	2
3. Quality assurance on sample handing and analysis[e]	--	--	--	--	--	--

1 laboratory split per year for radiochemical analysis
4 Reagent water blanks--one each quarter
6 known standards--2 each quarter for a minimum of two quarters for gamma analysis and 2 annually for radiochemistry

---

a. Source: modified from EG&G (1989g).

b. When 5 samples have been collected, contact the Environmental Monitoring Program Technical Leader for guidance on whether to continue sampling.

c. Water is not typically pumped in any other quarter than second quarter.

d. Radiochemical analysis will be run on the water samples collected in the spring after the thaw from each location. Samples from other time periods will be selected for radiochemical analyses when results of gross alpha, gross beta, or gamma spectroscopy indicate the need for radiochemistry.

e. QA sample analysis will include gamma spectroscopy and radiochemistry.

water to be sampled, then held under the running water until the container is filled. In standing water (such as at the control locations) the container is rinsed in the water to be sampled, then a teflon beaker that has been rinsed is used to dip water into the sampling container (EG&G, 1989g).

As soon as possible after collection, 80 mL of concentrated HNO_3 is added to each 4-L container. Two ashless filter tablets are then added to the sample containers. The sample containers are then sealed, dated, and identified by location. For samples collected from the SDA discharge pump, the total volume of water pumped from the SDA and/or water that left the SDA through the overflow culvert is recorded. Samples are surveyed for radioactivity and contamination by RWMC Health Physics. If no radioactivity above background is detected, the samples are taken to the Environmental Laboratory for preparation. If the radiation levels exceed ambient background, the samples are prepared at WMO-601 and shipped to the Radiation Measurements Laboratory (RML). The RML analyzes the samples for gross alpha, gross beta, and gamma spectroscopy. The second quarter samples are also submitted for specific alpha- and beta-emitting radionuclides (EG&G, 1989g).

6.2.3 Analytical Procedures

All samples are submitted to the laboratory and filtered. Both the filtrate and the particulate fractions are sampled for gross alpha, gross beta, and gamma-emitting radionuclides. The detection limits for the radionuclides analyzed for in RWMC surface water samples are listed in Tables 6-5 and 6-6. The detection limits have changed since 1983 in conjunction with changes in analytical methodology.

Radiochemical determinations for the presence of Am-241, Pu-238, Pu-239,-240, U-235, U-238, and Sr-90 are conducted on at least one set of samples, usually those collected in the spring (Tkachyk et al., 1990). This analysis is conducted on one sample from each sampling location and from the control locations (EG&G, 1989g).

Table 6-5. Detection limits for environmental-monitoring samples analyzed by gamma spectrometry, 1985-1989[a]

	Filtrate		Insoluble	
Radionuclides	10^{-2} pCi/mL	Total pCi	10^{-4} pCi/mL	Total pCi
Sc-46	0.6	25	4	1.5
Cr-52	6.0	250	75	30
Mn-54	0.6	25	4	1.5
Co-57	3	120	13	5
Co-58	0.6	25	4	1.5
Fe-59	1.0	40	6	2.5
Co-60	0.6	25	8	3
Zn-65	1.2	50	15	6
Nb-94	0.6	25	4	1.5
Nb-95	0.6	25	4	1.5
Zr-95	1.0	40	10	4
Ru-103	0.6	25	5	2
Ru-106	0.6	250	75	30
Ag-110m	0.8	30	4	1.5
Sb-124	1.6	60	10	4
Sb-125	1.0	40	8	3
Cs-134	0.6	25	4	1.5
Cs-137	0.8	30	6	2.5
Ce-141m	0.8	30	5	2
Ce-144	6	240	25	10
Eu-152	1.5	60	10	4
Eu-154	1.5	60	5	2
Eu-155	3	120	20	8
Hf-181	0.6	25	4	1.5
Ta-182	1.4	60	13	5
Hg-203	0.5	20	4	1.5
Am-241	4	160	25	10
Gross beta				
Gross alpha				

---

a. Source: Reyes et al. (1986); Reyes et al. (1987); Tkachyk et al. (1988); Tkachyk et al. (1989); Tkachyk et al. (1990). Note detection limits have varied since 1983 in accordance with changes in the analytical method.

Table 6-6. Detection limits for samples analyzed for radiochemistry, 1987-1989[a]

Media	Sample Description	Method of Treatment	Detection Limits (μCi/g or mL)	
Water	4-L collapsible polyethylene container containing 25 mL or conc. HNO_3 and two Whatman ashless filter tablets for 4000 mL water	Separate and dissolve paper pulp, reconstitute sample and boil down to 100 mL; analyze 1/2 sample on 2-L equivalent	Sr-90 Pu-238 Pu-239 Am-241	2×10^{-9} 2×10^{-11} 2×10^{-11} 2×10^{-11}

---

a. Source: Tkachyk et al., (1988); Tkachyk et al., (1989); Tkachyk et al., (1990).

6.2.4 Quality Assurance and Quality Control Methods

The quality assurance/quality control program for surface water sampling includes collecting control samples to determine background levels of radionuclides and collecting replicate samples. The quality assurance on sample handling and analysis consists of one laboratory split per year for radiochemical analysis, four reagent water blanks (one each quarter), and six known standards. Quality assurance sample analysis includes gross alpha, gross beta, gamma spectroscopy, and radiochemistry.

6.2.5 Results of the Surface Water Sampling

The results of the laboratory analyses are reported in a standardized format to facilitate long-range comparisons. Once the data are analyzed, they are compared to the established derived concentration guides in Table 6-7. These levels are set far below applicable dose limitations and are intended to indicate potential problems before they become significant. The data are also evaluated to determine if there is a significant increase in the radionuclide concentrations in the surface water runoff (EG&G, 1989g).

Most of the detected radionuclides are in concentrations at or near the detection limit and can be either the result of statistical variation or factors other than environmental contamination. Before 1985, only detections of radionuclides at concentrations greater than two times the standard deviation were considered positive. After 1985, only concentrations of radionuclides greater than three times the standard deviation were considered positive and were reported in the data tables. Concentrations between two and three standard deviations are considered questionable and are not reported (Reyes et al., 1986; EG&G, 1989g; Tkachyk et al., 1990).

Reported positive results represent the concentrations of radionuclides after subtracting the control sample location results. The concentrations of radionuclides in the suspended solids are reported separately from the radionuclides in the filtrate portion of the sample (EG&G, 1989g).

Table 6-7. 1989 Derived concentration guides[a]

	DCGs for the Public[b,c]
Radionuclide	DCG for Water (μCi/mL)
H-3	2×10^{-3}
Sc-46	2×10^{-5}
Cr-51	1×10^{-3}
Mn-54	5×10^{-5}
Co-58	4×10^{-5}
Fe-59	2×10^{-5}
Co-60	5×10^{-6}
Zn-65	9×10^{-6}
Sr-90	1×10^{-6}
Nb-95	6×10^{-5}
Zr-95	4×10^{-5}
Ru-103	5×10^{-5}
Ru-106	6×10^{-6}
Ag-110m	1×10^{-5}
Sb-125	6×10^{-5}
I-129	5×10^{-7}
I-131	3×10^{-6}
Cs-134	2×10^{-6}
Cs-137	3×10^{-6}
Ce-141	5×10^{-5}
Ce-144	7×10^{-6}
Eu-152	2×10^{-5}
Eu-154	2×10^{-5}
Ra-226	1×10^{-7}
Pu-238	4×10^{-8}
Pu-239[d]	3×10^{-8}
Am-241	3×10^{-8}
U-234	5×10^{-7}
U-235	6×10^{-7}
U-238	6×10^{-7}
Gross Alpha[d]	
Gross Beta[d]	

---

[a] Source: Tkachyk et al. (1989).

[b] This table contains water derived concentration guides based on concentrations that could be continuously ingested, and do not exceed an effective dose equivalent of 100 mrem/year.

[c] Derived concentration guides apply to radionuclide concentrations in excess of those occurring naturally or due to fallout.

[d] The derived concentration guides of Pu-239 and Sr-90 are the most restrictive and are appropriate to use for gross alpha and gross beta derived concentration guides, respectively.

The total curie quantity of each nuclide transported off the SDA is reported in the Environmental Monitoring Annual Report. This value is obtained by multiplying the average concentration of the total water sample collected during a runoff period by the total volume of water leaving the SDA during the same period. Increasing or decreasing trends are plotted as a function of volume and curie data over time (EG&G, 1989g).

Reported data in Table 6-8 on positive detections are summarized by sampling area for the period from 1984 through 1989. Cesium-137 is typically detected in environmental samples collected at the RWMC usually at ambient background levels (Tkachyk et al., 1990). The Cs-137 concentration in surface water runoff at the RWMC since 1978 is illustrated in Figure 6-5.

Table 6-8. Results of RWMC surface water sampling for radionuclides at sampling locations

		Concentrations[a] (10^{-9} µCi/mL)		
Date of Collection	Detected Radionuclide[b]	Detected in Filtrate	Detected in Particulate	Reference[c]
		SDA Pump		
03/14/84	Cs-137	16.2 ± 1.7	45.0 ± 3.4	1
	Pu-239,-240	0.16 ± 0.06	d	1
	Am-241	8.0 ± 0.20	d	1
	Sr-90	22.0 ± 2.0	d	1
03/19/84	ND[e]	NA[f]	NA	1
03/21/84	ND	NA	NA	1
03/22/84	ND	NA	NA	1
(replicate)	ND	NA	NA	1
03/28/84	ND	NA	NA	1
08/02/84	ND	NA	NA	1
03/19/85	ND	NA	NA	2
03/21/85	Cs-137	ND	6.0 ± 2.0	2
(replicate)	ND	NA	NA	2
04/01/85	ND	NA	NA	2
04/02/85	Total U	0.6 ± 0.2	ND	2
07/17/85	ND	NA	NA	2
02/18/86	Cs-137	ND	6.0 ± 0.5	3
04/22/88	Cs-137	ND	1.4 ± 4.0	5
03/89	ND	NA	NA	6
		TSA 1		
03/14/84	ND	NA	NA	1
06/19/84	ND	NA	NA	1
07/25/84	ND	NA	NA	1
10/25/84	ND	NA	NA	1
04/01/85	ND	NA	NA	2
09/09/85	Co-60	24.0 ± 2.0	ND	2
	Total U	ND	0.4 ± 0.05	2
06/30/87	ND	NA	NA	4
11/02/87[g]	Co-60	6.7 ± 0.08	1.6 ± 0.2	4
	C-137	4.8 ± 0.07	1.0 ± 0.2	4
04/22/88	C-137	ND	0.9 ± 0.2	5
09/29/88	Co-60	7.02 ± 0.58	ND	5
	C-137	ND	0.83 ± 0.16	5
03/89	ND	NA	NA	6
		TSA 2		
03/14/84	ND	NA	NA	1
06/19/84	ND	NA	NA	1
10/25/84	Pu-239,-240	0.13 ± 0.04	d	1
	Am-241	0.01 ± 0.005	d	1
04/01/85	ND	NA	NA	2
05/15/85	ND	NA	NA	2
09/09/85	Total U	ND	0.18 ± 0.07	2
02/18/86	Cs-137	ND	3.0 ± 0.3	3

Table 6-8. (continued)

		Concentrations[a] (10^{-9} µCi/mL)		
Date of Collection	Detected Radionuclide[b]	Detected in Filtrate	Detected in Particulate	Reference[c]
		TSA 2 (continued)		
09/19/86	Mn-54	ND	0.3 ± 0.06	3
	Co-58	ND	0.2 ± 0.05	3
	Co-60	ND	0.6 ± 0.1	3
	Sr-90	3.0 ± 0.6	ND	3
	Pu-239,-240	0.1 ± 0.04	ND	3
	Am-241	0.2 ± 0.02	ND	3
01/28/87	Co-60	ND	6.0 ± 1.0	4
	Cs-137	ND	7.5 ± 1.0	4
06/30/87	Mn-54	ND	0.078 ± 0.02	4
	Sr-90		2.2 ± 0.3[h]	4
	Sr-90		2.7 ± 0.3[h]	4
	Am-241		1.2 ± 0.1[h]	4
11/02/87	ND	NA	NA	4
04/22/88	Cs-137	ND	1.5 ± 0.2	5
09/28/88	Cs-137	ND	0.61 ± 0.11	5
03/89	Cs-137	ND	1.11 ± 0.30	6
		TSA 3		
10/25/84	ND	NA	NA	1
09/09/85	Total U	ND	0.5 ± 0.1	2
02/18/86	Cs-137	64.0 ± 6.0	ND	3
09/19/86	Co-60	ND	1.0 ± 0.1	3
	Sr-90	4.0 ± 0.6	d	3
	Cs-137	0.4 ± 0.01	ND	3
	Am-241	0.04 ± 0.01	d	3
01/28/87	Ru-106	ND	23.0 ± 2.0	4
	Cs-134	ND	1.3 ± 0.2	4
	Cs-137	ND	9.7 ± 1.2	4
06/30/87	Co-60	ND	0.09 ± 0.02	4
	Cs-137	ND	0.066 ± 0.013	4
06/30/87	Sr-90		1.2 ± 0.3[h]	4
11/02/87	ND	NA	NA	4
04/22/88	ND	NA	NA	5
09/28/88	Cs-137	ND	1.78 ± 0.14	5
03/89	ND	NA	NA	6
		CONTROL		
03/14/84	ND	NA	NA	1
03/19/84	ND	NA	NA	1
03/21/84	ND	NA	NA	1
03/28/84	ND	NA	NA	1
06/19/84	ND	NA	NA	1
07/25/84	ND	NA	NA	1
10/25/84	Pu-239,-240	0.09 ± 0.04	d	1
	Am-241	0.6 ± 0.2	d	1
	Total U	0.2 ± 0.1	d	1

Table 6-8. (continued)

Date of Collection	Detected Radionuclide[b]	Concentrations[a] (10^{-9} µCi/mL) Detected in Filtrate	 Detected in Particulate	Reference[c]
		CONTROL (continued)		
03/19/85	ND	NA	NA	2
04/01/85	ND	NA	NA	2
05/15/85	ND	NA	NA	2
09/09/85	Am-241	0.9 ± 0.2	ND	2
	Total-U	ND	0.8 ± 0.1	2
02/18/86	Ag-110	ND	0.6 ± 0.1	3
09/19/86	Mn-54	ND	0.3 ± 0.06	3
	Co-60	ND	0.8 ± 0.1	3
	Sr-90	8.0 ± 1.0	d	3
	Cs-134	ND	0.3 ± 0.06	3
	Cs-137	34.0 ± 4.0	ND	3
	Am-241	0.06 ± 0.01	d	3
01/28/87	Co-60	ND	1.1 ± 0.3	4
	Cs-137	ND	1.4 ± 0.3	4
06/30/87	Co-60	ND	0.09 ± 0.02	4
	Sb-125	04.6 ± 01.3	1.0 ± 0.2	4
	Cs-137		0.053 ± 0.012	4
	Sr-90	1.2 ± 0.2[h]		4
	Pu-239,-240	0.098 ± 0.02[h]		4
11/02/87[g]	Cs-137	8.2 ± 1.0	ND	4
04/22/88	ND	NA	NA	5
09/29/88	Cs-137	NA	0.63 ± 0.11	5
03/89	ND	NA	NA	6

---

a. Reported values in 1984 and 1985 represent analytical results with ≥ 2 standard deviations. From 1986 to present, only radionuclide concentrations of ≥ 3 standard deviations are considered positive detections. Since 1988, results between 2 and 3 standard deviations have been considered questionable and are not necessarily reported. Analytical uncertainties are presented as ± 1 standard deviation.

b. Concentrations are reported for only those radionuclides that are detected. Naturally occurring radionuclides (Ra-226, Th-232, Po-214, Bi-214, and K-40) were detected in samples collected from 1984 to 1987 but not reported in the tables.

c. References: 1. Reyes et al. (1985), 2. Reyes et al. (1986), 3. Reyes et al. (1987), 4. Tkachyk et al. (1988), 5. Tkachyk et al. (1989), 6. Tkachyk et al. (1990).

d. No analysis done.

e. Not detected.

f. Not applicable.

g. Discrepancy between data reported in tables and in text for samples collected 11/02/87.

h. Not reported if detection from either the filtrate or particulate fraction of sample.

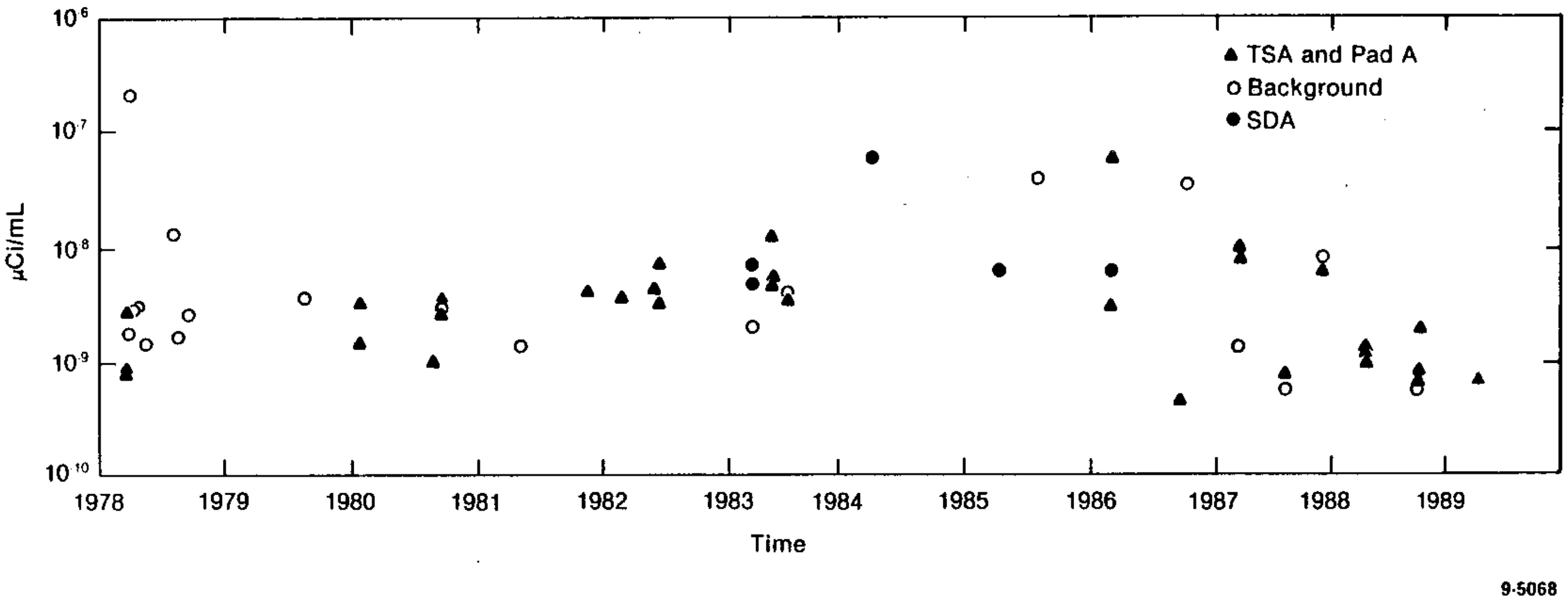


Figure 6-5. Cesium-137 concentrations in RWMC surface water runoff (Tkachyk et al. 1990).

7. Soil Gas Survey

7. SOIL GAS SURVEY

A soil gas survey was conducted in response to three events that suggested the presence of VOCs buried within the SDA. These events included (1) the detection of volatile organics in the ground water at the SDA, (2) the occurrence of organic vapors in wellbores being drilled within the SDA, and (3) the discovery that waste containing organic substances had been shipped to the SDA for disposal before 1970. The purpose of the soil gas survey is discussed in Section 7.1, the investigation procedure is described in Section 7.2, the results are summarized in Section 7.3, and the data quality is discussed in Section 7.4.

7.1 Purpose of the Soil Gas Survey

A soil gas survey was performed by Golder Associates of Redmond, Washington, from October 28 through November 6, 1987, to determine the identity, location, and relative concentration of selected chlorinated and aromatic VOCs in the vadose zone at the SDA and adjacent areas. This investigation resulted in the delineation of potential source areas for VOCs. The results of this investigation will be integrated with the other subsurface studies to refine the conceptual model for predicting both the vertical and lateral transport of waste organics through the vadose zone into ground water. The study by Golder is included in EG&G (1988a).

7.2 Investigation Procedure

The investigation procedure for the soil gas survey consisted of three parts: (1) constructing a sampling grid, described in Section 7.2.1; (2) developing a sampling procedure, discussed in Section 7.2.2; and (3) defining the procedures for soil gas analysis, reviewed in Section 7.2.3.

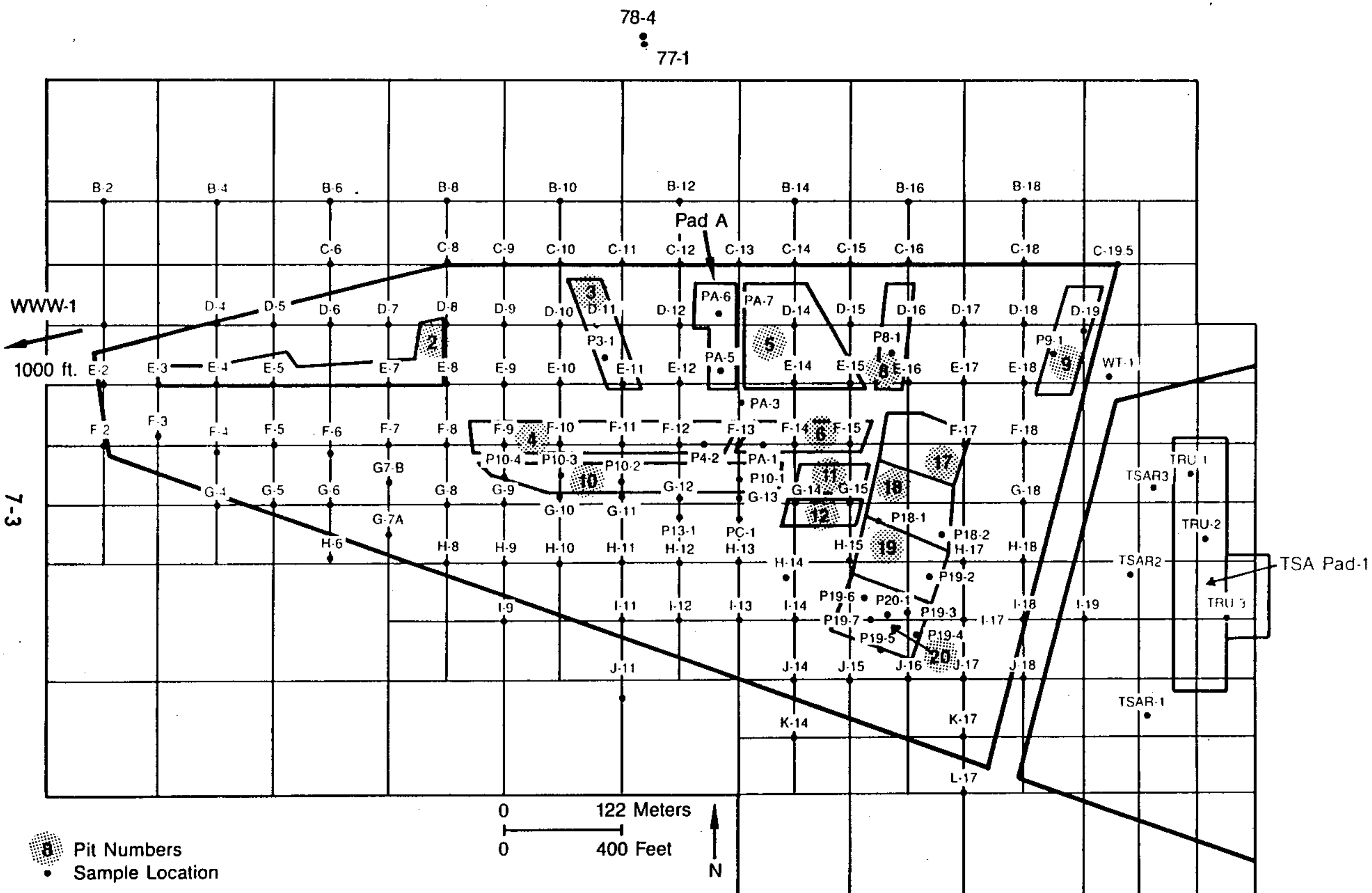
7.2.1 Sampling Grid

A sampling grid with 62-m (200-ft) spacing in north-south and east-west directions was defined to provide comprehensive coverage of the SDA. The survey included an area approximately 187 m (600 ft) beyond the SDA and overlapped a portion of the TSA (Figure 7-1). A total of 136 samples were collected within the 62-m grid, and an additional 63 samples were collected at supplemental locations including the overlapping portion of the TSA and at Boreholes 77-1, 78-4 and WWW-1.

7.2.2 Sampling Procedure

Soil gas was extracted by installing a 1.6-cm (5/8-in.) outer diameter carbon steel pipe into a 1-cm (1/2-in.) hole drilled approximately 76 cm (30 in.) into the ground using a hand-held electric drill. One end of the pipe was fitted with a metal cap to prevent clogging, and the pipe was driven into the hole with a sliding hammer. The cap was then displaced using a steel rod inserted through the pipe. A battery operated pump was attached to the top of the probe using a stainless steel quick-connect coupler and surgical rubber tubing. Three to 10 pipe volumes were pumped from the probe. An organic vapor analyzer (OVA or HNU) was used to monitor the discharge from the sampling pump. Gas concentrations in the discharge stream stabilized very quickly. The gas sample was collected from just inside the stainless steel quick-connect by inserting a hypodermic needle on a glass syringe through the surgical tubing. The syringe was then sealed and transported to the field analytical laboratory.

Exceptions to this procedure occurred at the west end of the SDA and where previously installed access tubes existed. West of row 9 in the sampling grid, sample probes were driven only 30 cm (12 in.) into the ground because of the health risk concern of TRU waste being present near the surface (Figure 7-1). Gas samples were collected from multiple depths in Boreholes 77-1, 78-4, and WWW-1 by pumping through the existing 0.6 cm (1/4 in.) inner diameter tubing. Samples from neutron access tubes, Pits 19 and 20, and within the TSA were collected by lowering a 0.6 cm (1/4 in.) inner diameter stainless tube down the existing access tube, sealing the top, and pumping the sample from the bottom of the access tube.



Note: Sampling locations Z-1 through Z-16 are outside the sampling grid shown on this map (northing and easting coordinates provided in Table 7-3).

Figure 7-1. Locations of sampling points for the soil gas survey (Laney et al., 1988).

7.2.3 Soil Gas Analysis

The soil gas samples were analyzed in the field at a laboratory set up in a trailer immediately north of the SDA. The analyses were performed with an HNU Model 321 field GC equipped with two silica capillary columns and electron capture and photoionization detectors. Standard mixtures of VOCs were prepared by serial dilution of pure chlorinated and aromatic compounds in dodecane or hexane. Soil gas samples were directly injected into the GC for analysis, and the response was compared to those of VOC standards. The samples were analyzed for the 12 VOCs shown in Table 7-1. Chloroform could not be resolved from the large concentrations of carbon tetrachloride and 1,1,1-trichloroethane; therefore, it may have been present, but it could not be identified.

Because the level of detection would vary from sample to sample depending on individual sample constituents and sample size, the analytical results reported by Golder Associates were those concentrations above the practical quantification limits (PQLs) that were based on typical sample amounts injected for GC analysis and daily detector response (EG&G, 1988a). For compounds detected above the detection limit but below the PQL, a "P" was entered in the table of results. Therefore, the results reported by Golder Associates are all useful values not requiring further screening of their analytical significance.

7.3 Results

Four of the 12 compounds screened by the survey were detected above the PQL: carbon tetrachloride, tetrachloroethylene, 1,1,1-trichloroethane, and trichloroethylene. A summary of the raw data for the soil gas survey data is provided in EG&G (1988a). Table 7-2 presents the same data; however, "ND" (not detected) has been entered for those samples that were below minimum detection levels, and "P" has been entered for constituents detected at an unquantified level. The alpha characters in the table refer to the sample location within the grid illustrated in Figure 7-1. Concentration plots of

Table 7-1. Target compounds for the RWMC soil gas survey[a]

Compound	Practical Quantification Limit ($\mu g/L$)
1,1,1-trichloroethane	0.01
Carbon tetrachloride	0.01
Trichloroethylene	0.01
Tetrachloroethylene	0.01
1,1-dichloroethylene	0.6
Methylene chloride	0.6
1,2-trans-dichloroethylene	0.6
Trans-1,3-dichloropropene	0.5
1,2-dichloropropane	0.6
1,1,2-trichloroethane	0.6
Benzene	1.0
Toluene	1.0

---

a. Source: Golder (1987) report in EG&G (1988a).

Table 7-2. Results of soil gas analysis at the SDA[a]

Grid	East	North	Sample Depth (in.)	1,1,1-Trichloroethane (ug/L)	Carbon tetrachloride (ug/L)	Trichloroethylene (ug/L)	Tetrachloroethylene (ug/L)	1,1-Dichloroethylene (ug/L)	Methylene chloride (ug/L)	1,2-Trans-dichloroethylene (ug/L)	Trans-1,3-dichloropropene (ug/L)	1,2-Dichloropropene (ug/L)	1,1,2-Trichloroethene (ug/L)	Benzene (ug/L)	Toluene (ug/L)
-- B															
B-02	200	2400	24	ND[b]	0.30	0.02	0.07	ND	ND	ND	ND	ND	ND	ND	ND
B-04	600	2400	2	ND	0.40	0.03	0.04	ND	ND	ND	ND	ND	ND	ND	ND
B-06	1000	2400	28	ND	0.05	ND	0.01	ND	ND	ND	ND	ND	ND	ND	ND
B-08	1400	2400	30	ND	1.00	0.04	0.05	ND	ND	ND	ND	ND	ND	ND	ND
B-10	1800	2400	29	ND	0.40	ND	0.03	ND	ND	ND	ND	ND	ND	ND	ND
B-12	2200	2400	21	ND	0.70	P[c]	P	ND	ND	ND	ND	ND	ND	ND	ND
B-14	2600	2400	30	ND	0.08	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
B-16	3000	2400	19	ND	0.20	0.04	0.02	ND	ND	ND	ND	ND	ND	ND	ND
B-18	3400	2400	18	ND	0.20	0.05	0.03	ND	ND	ND	ND	ND	ND	ND	ND
-- C															
C-06	1000	2200	17	ND	0.40	ND	0.04	ND	ND	ND	ND	ND	ND	ND	ND
C-08	1400	2225	28	ND	3.80	0.20	0.40	ND	ND	ND	ND	ND	ND	ND	ND
C-09	1600	2200	18	ND	2.00	ND	0.07	ND	ND	ND	ND	ND	ND	ND	ND
C-10	1800	2225	20	ND	5.00	1.00	0.80	ND	ND	ND	ND	ND	ND	ND	ND
C-11	2000	2200	28	ND	5.60	0.40	0.04	ND	ND	ND	ND	ND	ND	ND	ND
C-12	2200	2200	20	ND	3.10	0.80	0.20	ND	ND	ND	ND	ND	ND	ND	ND
C-13	2400	2200	31	ND	1.00	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C-14	2600	2200	31	P	19.00	3.00	1.00	ND	ND	ND	ND	ND	ND	ND	ND
C-15	2800	2200	18	ND	2.00	P	0.40	ND	ND	ND	ND	ND	ND	ND	ND
C-16	3000	2200	15	P	0.90	0.05	0.05	ND	ND	ND	ND	ND	ND	ND	ND
C-18	3400	2200	30	P	1.50	0.06	0.10	ND	ND	ND	ND	ND	ND	ND	ND
C-19.5	3700	2200	30	0.1	0.50	0.02	0.10	ND	ND	ND	ND	ND	ND	ND	ND
-- D															
D-02	200	2000	29	ND	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
D-04	600	2045	20	ND	0.20	0.01	0.04	ND	ND	ND	ND	ND	ND	ND	ND
D-05	800	2000	12	P	0.10	ND	0.04	ND	ND	ND	ND	ND	ND	ND	ND
D-06	1000	2000	12	P	0.10	0.04	0.20	ND	ND	ND	ND	ND	ND	ND	ND
D-07	1200	2000	12	ND	0.04	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND
D-08	1400	2000	12	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
D-09	1600	2000	17	P	0.10	ND	0.50	ND	ND	ND	ND	ND	ND	ND	ND
D-10	1800	2000	30	P	0.40	0.10	0.10	ND	ND	ND	ND	ND	ND	ND	ND
D-11	1925	2000	30	1.2	0.40	0.20	0.80	ND	ND	ND	ND	ND	ND	ND	ND
D-12	2200	2000	25	ND	1.00	240.0	0.01	ND	ND	ND	ND	ND	ND	ND	ND
D-14	2200	2000	32	P	50.00	28.00	6.00	ND	ND	ND	ND	ND	ND	ND	ND
D-15	2800	2000	30	ND	2.00	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
D-16	3000	2000	30	ND	0.50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
D-17	3200	2000	30	ND	0.30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
D-18	3400	2000	30	ND	1.00	ND	0.03	ND	ND	ND	ND	ND	ND	ND	ND
D-19	3600	1975	30	P	4.70	1.10	4.00	ND	ND	ND	ND	ND	ND	ND	ND

Table 7-2. (continued)

Grid	East	North	Sample Depth (in.)	1,1,1-Trichloroethane (ug/L)	Carbon tetrachloride (ug/L)	Trichloroethylene (ug/L)	Tetrachloroethylyene (ug/L)	1,1-Dichloroethylene (ug/L)	Methylene chloride (ug/L)	1,2-Trans-dichloroethylene (ug/L)	Trans-1,3-dichloropropene (ug/L)	1,2-Dichloropropene (ug/L)	1,1,2-Trichloroethene (ug/L)	Benzene (ug/L)	Toluene (ug/L)
-- E															
E-02	200	1800	12	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
E-03	400	1800	12	1.3	ND	0.60	1.00	ND	ND	ND	ND	ND	ND	ND	ND
E-04	600	1800	12	2.0	ND	4.00	0.03	ND	ND	ND	ND	ND	ND	ND	ND
E-05	800	1800	12	1.2	ND	0.01	0.20	ND	ND	ND	ND	ND	ND	ND	ND
E-06	1000	1800	12	ND	4.80	0.02	1.40	ND	ND	ND	ND	ND	ND	ND	ND
E-06	1000	1800	12	15.0	12.00	12.00	2.40	ND	ND	ND	ND	ND	ND	ND	ND
E-07	1200	1800	8	1.0	1.00	1.00	1.60	ND	ND	ND	ND	ND	ND	ND	ND
E-08	1400	1800	12	0.9	1.20	4.00	0.60	ND	ND	ND	ND	ND	ND	ND	ND
E-09	1600	1800	30	8.0	3.00	2.00	2.00	ND	ND	ND	ND	ND	ND	ND	ND
E-10	1800	1800	30	1.0	2.00	P	P	ND	ND	ND	ND	ND	ND	ND	ND
E-11	2000	1800	30	0.4	0.30	1.00	2.00	ND	ND	ND	ND	ND	ND	ND	ND
E-12	2200	1800	12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
E-14	2600	1800	30	8.0	P	ND	4.70	ND	ND	ND	ND	ND	ND	ND	ND
E-15	2800	1600	28	310.0	ND	4.00	7.00	ND	ND	ND	ND	ND	ND	ND	ND
E-15	2800	1800	28	48.0	5.00	0.80	5.20	ND	ND	ND	ND	ND	ND	ND	ND
E-15	2800	1800	28	170.0	P	1.60	6.00	ND	ND	ND	ND	ND	ND	ND	ND
E-15	2800	1800	28	120.0	ND	0.08	3.00	ND	ND	ND	ND	ND	ND	ND	ND
E-15	2800	1800	28	280.0	P	3.20	7.00	ND	ND	ND	ND	ND	ND	ND	ND
E-16	3000	1800	30	ND	0.20	ND	P	ND	ND	ND	ND	ND	ND	ND	ND
E-17	3400	1800	30	ND	2.00	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
E-18	3525	1800	35	10.00	12.00	9.40	2.10	ND	ND	ND	ND	ND	ND	ND	ND
E-19	3525	1800	30	ND	1000.00	150.0	40.00	ND	ND	ND	ND	ND	ND	ND	ND
E-19	3525	1800	30	P	1230.00	200.0	34.00	ND	ND	ND	ND	ND	ND	ND	ND
E-19	3525	1800	30	P	1400.00	100.0	25.00	ND	ND	ND	ND	ND	ND	ND	ND
E-19	3525	1800	30	P	900.00	690.0	30.00	ND	ND	ND	ND	ND	ND	ND	ND
E-19	3525	1800	30	P	640.00	80.0	20.00	ND	ND	ND	ND	ND	ND	ND	ND
E-19	3525	1800	30	P	1200.00	100.0	21.00	ND	ND	ND	ND	ND	ND	ND	ND
E-19.5	3700	1825	32	P	0.30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
-- F															
F-02	200	1600	30	ND	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
F-03	400	1625	12	ND	0.20	ND	0.70	ND	ND	ND	ND	ND	ND	ND	ND
F-04	600	1575	12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
F-05	800	1600	12	ND	0.02	ND	0.01	ND	ND	ND	ND	ND	ND	ND	ND
F-06	1000	1570	12	ND	0.07	ND	1.00	ND	ND	ND	ND	ND	ND	ND	ND
F-07	1200	1600	12	ND	0.10	ND	0.70	ND	ND	ND	ND	ND	ND	ND	ND
F-08	1400	1600	11	P	0.03	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
F-09	1600	1600	30	8.00	2.00	2.00	2.00	ND	ND	ND	ND	ND	ND	ND	ND
F-10	1800	1600	31	17.00	5.00	2.00	2.00	ND	ND	ND	ND	ND	ND	ND	ND
F-11	2000	1600	30	13.00	1.00	1.00	3.00	ND	ND	ND	ND	ND	ND	ND	ND
F-12	2200	1600	30	4.00	10.00	1.00	7.00	ND	ND	ND	ND	ND	ND	ND	ND
F-13	2400	1600	30	P	29.00	4.00	2.00	ND	ND	ND	ND	ND	ND	ND	ND
F-14	2600	1600	30	ND	0.09	0.05	0.10	ND	ND	ND	ND	ND	ND	ND	ND
F-15	2800	1600	26	P	13.00	3.00	2.00	ND	ND	ND	ND	ND	ND	ND	ND
F-17	3200	1600	30	0.02	P	P	P	ND	ND	ND	ND	ND	ND	ND	ND
F-18	3400	1600	20	2.00	ND	?	0.50	ND	ND	ND	ND	ND	ND	ND	ND

Table 7-2. (continued)

Grid	East	North	Sample Depth (in.)	1,1,1-Tri-chloroethane (ug/L)	Carbon tetra-chloride (ug/L)	Trichloro-ethylene (ug/L)	Tetra-chloro-ethylyene (ug/L)	1,1-Dichloro-ethylene (ug/L)	Methylene chloride (ug/L)	1,2-Trans-dichloro-ethylene (ug/L)	Trans-1,3-dichloro-propene (ug/L)	1,2-Di-chloro-propene (ug/L)	1,1,2-Tri-chloro-ethene (ug/L)	Benzene (ug/L)	Toluene (ug/L)
-- G															
G-04	600	1400	30	ND	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
G-05	800	1400	12	0.01	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
G-06	1000	1400	12	0.03	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
G-07A	1200	1300	12	ND	0.20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
G-07B	1200	1475	12	ND	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
G-08	1400	1400	12	ND	0.40	0.20	0.04	ND	ND	ND	ND	ND	ND	ND	ND
G-09	1600	1400	26	P	0.20	P	P	ND	ND	ND	ND	ND	ND	ND	ND
G-10	1800	1425	30	ND	23.00	7.00	12.00	ND	ND	ND	ND	ND	ND	ND	ND
G-11	2000	1425	32	ND	50.00	20.00	27.00	ND	ND	ND	ND	ND	ND	ND	ND
G-12	2200	1420	30	2.50	2.40	1.50	0.40	ND	ND	ND	ND	ND	ND	ND	ND
G-13	2400	1425	30	ND	2.00	3.30	0.50	ND	ND	ND	ND	ND	ND	ND	ND
G-14	2600	1400	32	ND	2.00	0.20	0.20	ND	ND	ND	ND	ND	ND	ND	ND
G-15	2800	1400	32	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
G-18	3400	1400	20	0.04	0.05	0.02	0.20	ND	ND	ND	ND	ND	ND	ND	ND
-- H															
H-06	1000	1225	31	ND	0.50	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND
H-08	1400	1200	12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
H-09	1600	1200	30	0.20	2.40	0.20	0.08	ND	ND	ND	ND	ND	ND	ND	ND
H-10	1800	1200	25	ND	2.00	0.10	0.03	ND	ND	ND	ND	ND	ND	ND	ND
H-11	2000	1200	30	ND	0.30	0.01	0.02	ND	ND	ND	ND	ND	ND	ND	ND
H-12	2200	1200	30	ND	1.00	0.80	1.00	ND	ND	ND	ND	ND	ND	ND	ND
H-13	2400	1200	30	ND	0.20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
H-14	2575	1150	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
H-15	2800	1200	30	ND	0.01	ND	0.01	ND	ND	ND	ND	ND	ND	ND	ND
H-17	3200	1200	30	4.00	ND	0.01	0.20	ND	ND	ND	ND	ND	ND	ND	ND
H-18	3400	1200	30	4.00	ND	ND	<0.08	ND	ND	ND	ND	ND	ND	ND	ND
-- I															
I-09	1600	1000	30	ND	4.00	0.20	0.08	ND	ND	ND	ND	ND	ND	ND	ND
I-11	2000	1000	30	ND	0.90	ND	P	ND	ND	ND	ND	ND	ND	ND	ND
I-12	2200	1000	25	0.70	0.30	ND	P	ND	ND	ND	ND	ND	ND	ND	ND
I-13	2400	1000	30	ND	0.40	ND	0.01	ND	ND	ND	ND	ND	ND	ND	ND
I-14	2600	1000	30	ND	1.10	P	P	ND	ND	ND	ND	ND	ND	ND	ND
I-14	2600	1000	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
I-17	3200	1000	31	3.00	ND	ND	0.08	ND	ND	ND	ND	ND	ND	ND	ND
I-18	3400	1000	30	ND	0.30	0.02	0.04	ND	ND	ND	ND	ND	ND	ND	ND
-- J															
J-11	2000	750	20	ND	0.03	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
J-14	2600	800	29	3.80	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
J-15	2800	800	27	180.0	P	ND	P	ND	ND	ND	ND	ND	ND	ND	ND
J-16	3000	800	26	0.01	0.01	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND
J-17	3200	800	30	0.20	0.30	0.06	0.04	ND	ND	ND	ND	ND	ND	ND	ND
J-18	3400	800	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 7-2. (continued)

Grid	East	North	Sample Depth (in.)	1,1,1-Trichloroethane (ug/L)	Carbon tetrachloride (ug/L)	Trichloroethylene (ug/L)	Tetrachloroethylyene (ug/L)	1,1-Dichloroethylene (ug/L)	Methylene chloride (ug/L)	1,2-Trans-dichloroethylene (ug/L)	Trans-1,3-dichloropropene (ug/L)	1,2-Dichloropropene (ug/L)	1,1,2-Trichloroethene (ug/L)	Benzene (ug/L)	Toluene (ug/L)
-- K															
K-14	2600	600	21	ND	0.40	0.03	0.02	ND	ND	ND	ND	ND	ND	ND	ND
K-17	3200	600	32	ND	0.06	ND	0.01	ND	ND	ND	ND	ND	ND	ND	ND
-- L															
L-17	3200	400	30	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
-- Neutron Access Tubes															
NAT-02	3360	770	13 ft	1.00	0.30	0.07	0.07	ND	ND	ND	ND	ND	ND	ND	ND
NAT-03	3470	1210	10 ft	5.00	4.00	1.00	0.40	ND	ND	ND	ND	ND	ND	ND	ND
NAT-04	3580	1650	10 ft	ND	5.00	1.00	0.40	ND	ND	ND	ND	ND	ND	ND	ND
NAT-05	3675	2120	9 ft	ND	4.00	0.40	0.30	ND	ND	ND	ND	ND	ND	ND	ND
NAT-07	3455	1675	10 ft	ND	22.00	4.00	1.00	ND	ND	ND	ND	ND	ND	ND	ND
NAT-19	1740	2090	15 ft	P	24.00	1.00	2.00	ND	ND	ND	ND	ND	ND	ND	ND
NAT-22	1265	1900	8 ft	P	19.00	0.50	ND	ND	ND	ND	ND	ND	ND	ND	ND
NAT-26	500	1920	11 ft	P	22.00	2.00	3.00	ND	ND	ND	ND	ND	ND	ND	ND
NAT-27	260	1775	12 ft	ND	8.00	ND	1.00	ND	ND	ND	ND	ND	ND	ND	ND
NAT-W02	3310	2070	10 ft	ND	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
-- Pit Samples															
P03-1	1950	1900	30	50.00	10.00	9.00	5.00	ND	ND	ND	ND	ND	ND	ND	ND
P04-1	2500	1600	31	ND	4.00	1.00	1.00	ND	ND	ND	ND	ND	ND	ND	ND
P04-2	2300	1600	31	ND	2300.00	9.00	10.00	ND	ND	ND	ND	ND	ND	ND	ND
P08-1	2950	1900	30	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P09-1	3500	1900	31	ND	0.30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P09-2	3510	1850	31	ND	1000.00	8.00	13.00	ND	ND	ND	ND	ND	ND	ND	ND
P10-1	2400	1485	26	0.40	3.80	P	1.80	ND	ND	ND	ND	ND	ND	ND	ND
P10-2	2000	1475	30	ND	160.00	21.00	19.00	ND	ND	ND	ND	ND	ND	ND	ND
P10-3	1800	1500	30	ND	100.00	30.00	9.00	ND	ND	ND	ND	ND	ND	ND	ND
P10-3	1800	1500	30	ND	470.00	4.00	10.00	ND	ND	ND	ND	ND	ND	ND	ND
P10-4	1600	1500	30	ND	28.00	22.00	2.00	ND	ND	ND	ND	ND	ND	ND	ND
P13-1	2200	1350	26	ND	0.08	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P18-1	2900	1350	28	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P18-2	3125	1300	25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P19-2	3075	1150	10 ft	ND	0.05	ND	0.01	ND	ND	ND	ND	ND	ND	ND	ND
P19-3	3000	1025	10 ft	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P19-4	3025	950	10 ft	P	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P19-5	2900	900	10 ft	ND	0.06	0.01	0.02	ND	ND	ND	ND	ND	ND	ND	ND
P19-6	2850	1075	10 ft	ND	0.20	0.03	0.04	ND	ND	ND	ND	ND	ND	ND	ND
P19-7	2875	1000	10 ft	P	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P20-1	2925	1025	10 ft	2.00	1.00	0.60	2.00	ND	ND	ND	ND	ND	ND	ND	ND
PA-1	2350	1850	30	ND	8.00	3.20	9.70	ND	ND	ND	ND	ND	ND	ND	ND
PA-2	2350	1750	30	ND	3.80	1.30	5.70	ND	ND	ND	ND	ND	ND	ND	ND
PA-3	2425	1750	29	ND	3.00	1.00	2.20	ND	ND	ND	ND	ND	ND	ND	ND
PA-4	2300	1900	29	ND	1.90	0.40	2.50	ND	ND	ND	ND	ND	ND	ND	ND
PA-5	2275	2000	25	ND	3.50	0.60	4.00	ND	ND	ND	ND	ND	ND	ND	ND

Table 7-2. (continued)

Grid	East	North	Sample Depth (in.)	1,1,1-Trichloroethane (ug/L)	Carbon tetrachloride (ug/L)	Trichloroethylene (ug/L)	Tetrachloroethylyene (ug/L)	1,1-Dichloroethylene (ug/L)	Methylene chloride (ug/L)	1,2-Trans-dichloroethylene (ug/L)	Trans-1,3-dichloropropene (ug/L)	1,2-Dichloropropene (ug/L)	1,1,2-Trichloroethene (ug/L)	Benzene (ug/L)	Toluene (ug/L)
PA-6	2350	2050	28	ND	12.00	4.60	13.00	ND	ND	ND	ND	ND	ND	ND	ND
PA-7	2425	2050	30	ND	5.40	4.60	7.80	ND	ND	ND	ND	ND	ND	ND	ND
PC-1	2400	1350	25	ND	2.00	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
-- Transuranic Storage Area															
TRU-1	3970	1475	20 ft	20.00	32.00	36.00	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRU-2	4044	1349	20 ft	0.40	3.00	0.60	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRU-3	4121	980	20 ft	24.00	22.00	6.00	0.20	ND	ND	ND	ND	ND	ND	ND	ND
TSAR1	3875	692	13	ND	0.30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TSAR2	3763	1211	22	ND	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TSAR3	3802	1462	27	ND	0.50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
-- Field Blanks															
XP-01	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-02	0	0	0	ND	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-03	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-04	0	0	0	ND	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-05	0	0	0	P	P	P	P	ND	ND	ND	ND	ND	ND	ND	ND
XP-06	0	0	0	ND	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-07	0	0	0	P	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-08	0	0	0	P	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-09	0	0	0	P	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-10	0	0	0	P	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-11	0	0	0	P	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-12	0	0	0	P	P	P	P	ND	ND	ND	ND	ND	ND	ND	ND
XP-13	0	0	0	P	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-14	0	0	0	P	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-15	0	0	0	P	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-16	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-17	0	0	0	ND	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-18	0	0	0	ND	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-19	0	0	0	ND	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-19	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-20	0	0	0	ND	0.05	0.05	0.05	ND	ND	ND	ND	ND	ND	ND	ND
XP-21	0	0	0	ND	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-22	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
XP-23	0	0	0	ND	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

---

a. Source: data from Golder (EG&G, 1988a).

b. ND indicates that the constituent was not detected.

c. P indicates that the constituent was detected in the sample at an unquantified level.

d. Field blanks collected by pulling ambient air through a probe and collecting a sample of the air in a syringe.

the four organics are shown on Figure 7-2 (Laney et al., 1988). Isopleth maps showing the areal distribution of the organic concentrations are presented in Figures 7-3 and 7-4.

At the TSA, moderate concentrations of carbon tetrachloride, trichloroethylene, and 1,1,1-trichloroethane were found. Because the neutron access tubes at the TSA are only open immediately above the basalt, the effect of overlying soil on VOC concentration is removed. Therefore, values measured in the neutron access tubes were generally higher than soil gas concentrations measured in the TSA. However, samples from both deep and shallow depths followed similar concentration profiles.

Concentration data plots for the primary waste constituents are discussed in Section 7.3.1, isopleth maps for the same constituents are described in Section 7.3.2, and the SDA perimeter samples are summarized in Section 7.3.3. The vertical distribution of gas in the study area is described in Section 7.3.4.

7.3.1 Concentration Data Plots

Cross plots of the four primary constituents indicate that carbon tetrachloride concentration correlates closely with the concentration of trichloroethylene and tetrachloroethylene [see Figures 7-2(a) and 7-2(b)]. This correlation indicates that these constituents may have been mixed together at the source(s). In contrast, the cross plot between carbon tetrachloride and 1,1,1-trichloroethane [Figure 7-2(c)] shows three distinct neighborhoods. One neighborhood represents samples high in carbon tetrachloride that did not contain detectable levels of 1,1,1-trichloroethane. A second neighborhood consists of samples high in 1,1,1-trichloroethane that did not contain carbon tetrachloride. The third neighborhood represents samples that contained both constituents in nearly equal proportions. These relationships suggest the presence of multiple sources, source areas where both constituents occur mixed in near equal proportions, and other source areas where they occur independently within the SDA. Whether three distinct source materials exist, two pure source materials that mix exist, or some

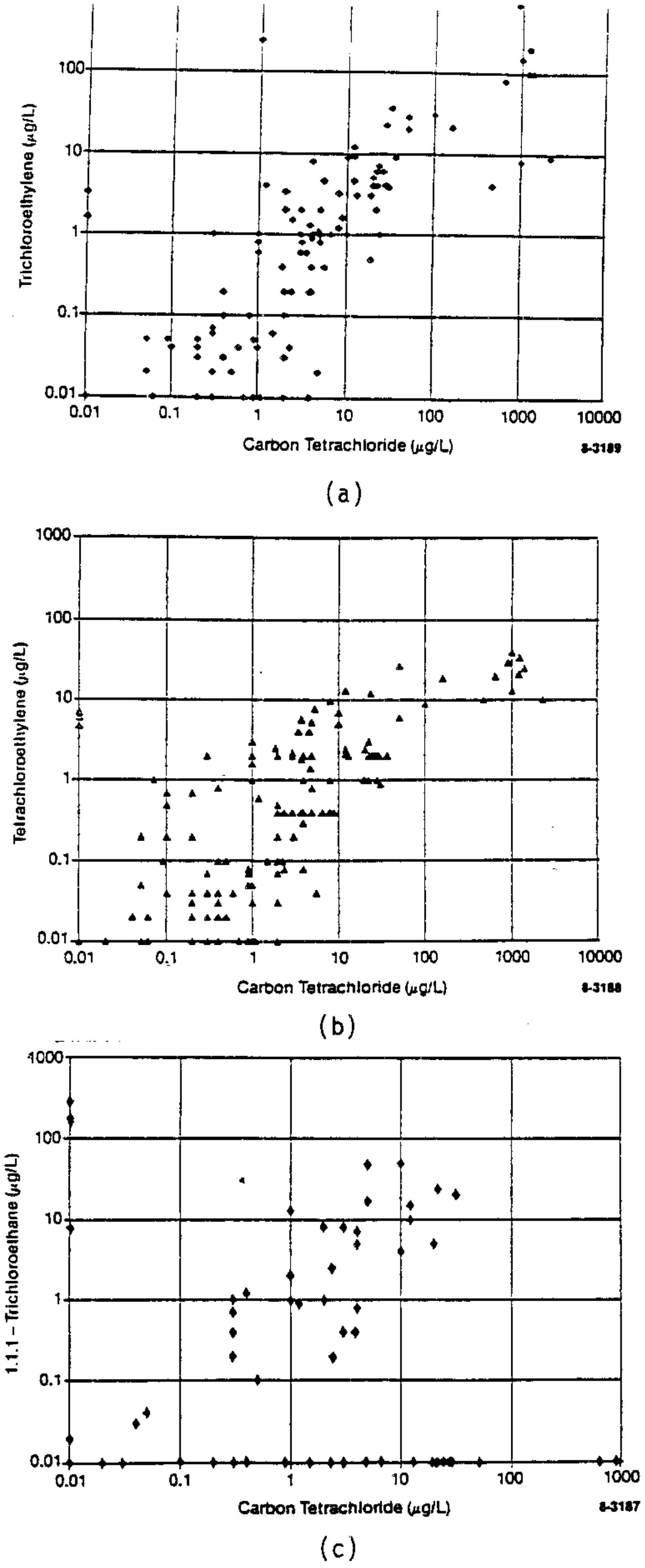
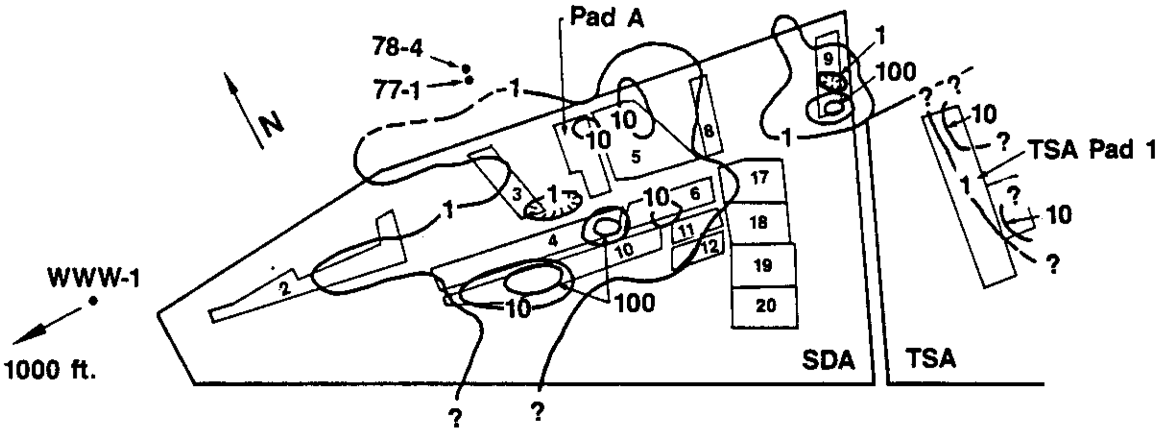
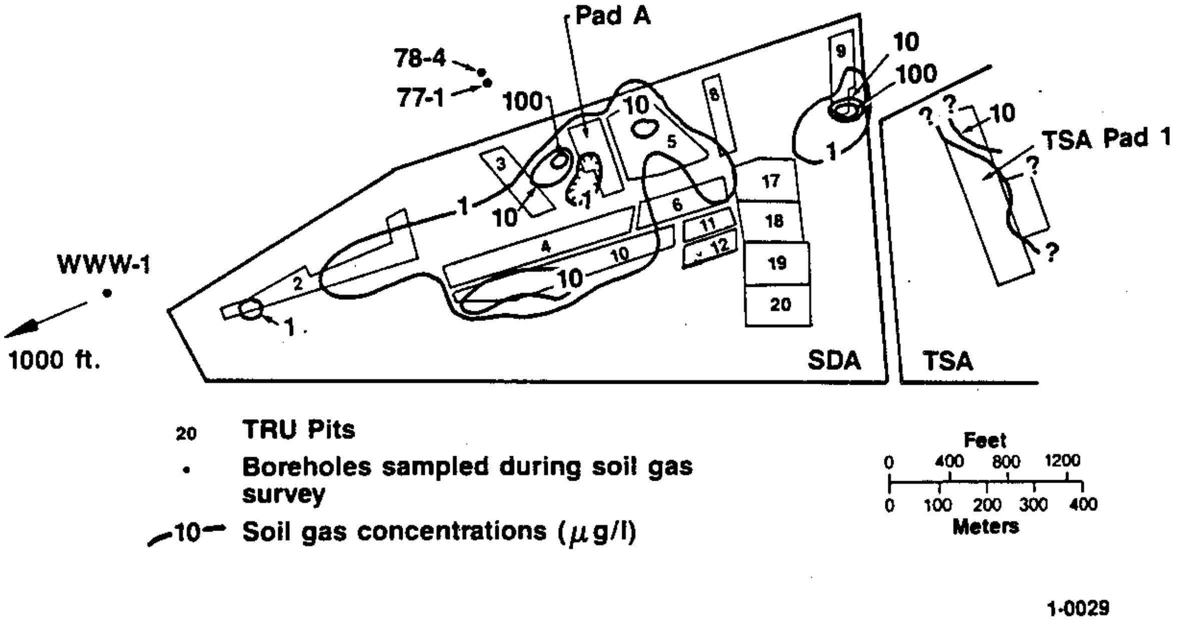


Figure 7-2. Ratio of carbon tetrachloride to (a) trichloroethylene (b) tetrachloroethylene; (c) 1,1,1-trichloroethane detected in soil gas survey samples (Laney et al., 1988).

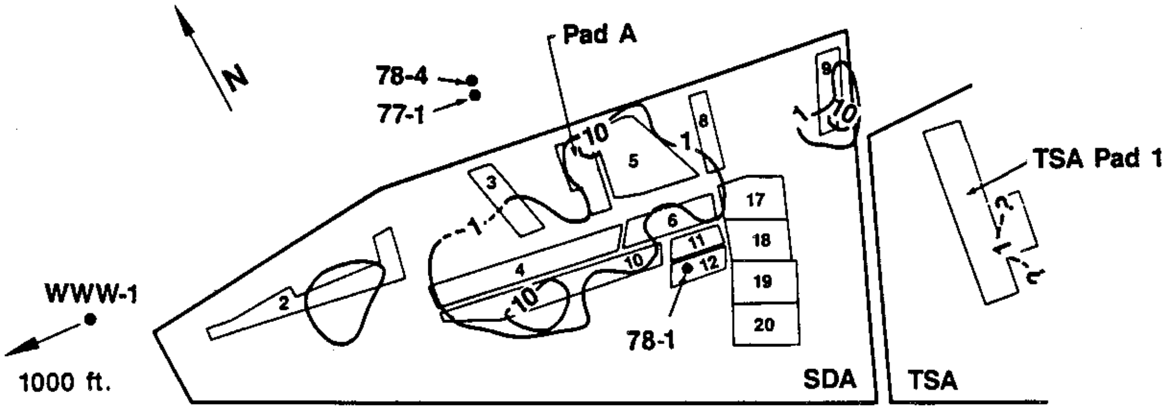


(a) Carbon tetrachloride

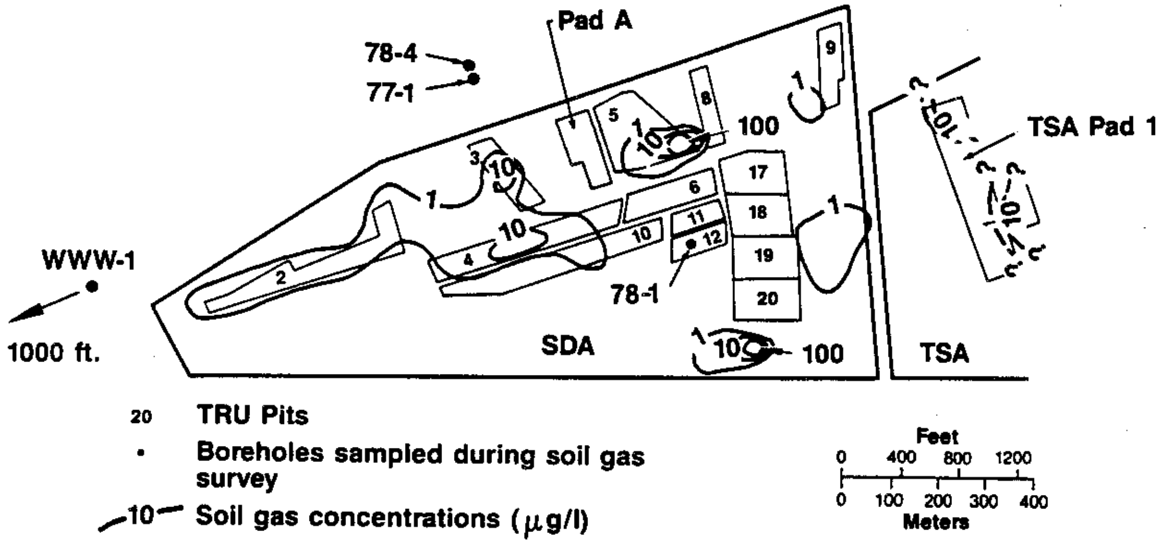


(b) Trichloroethylene

Figure 7-3. Isopleth maps of the concentration of (a) carbon tetrachloride, (b) trichloroethylene measured in soil gas at the RWMC (μg/L) (modified from Laney et al., 1988).



(a) Tetrachloroethylene



(b) 1,1,1-Trichloroethane

1-0030

Figure 7-4. Isopleth maps of the concentrations of (a) tetrachloroethylene, and (b) 1,1,1-trichloroethane measured in soil/gas at the RWMC (μg/L) (Laney et al., 1988).

other possibility exists is not clear from the data. The spatial distribution of the samples plotted on Figure 7-2(c) is shown on Figure 7-5 (Laney et al., 1988).

7.3.2 Isopleth Maps

Isopleth maps of each of the four organic constituents were generated by Golder to show the areal distribution of the wastes and to delineate prospective source areas (EG&G, 1988a). The spatial distribution of carbon tetrachloride is shown in Figure 7-3(a). The distribution of trichloroethylene and tetrachloroethylene are similar to that of carbon tetrachloride [Figures 7-3(b) and 7-4(a)] as expected from the data plots previously discussed. Carbon tetrachloride is the most prevalent organic throughout the SDA and tetrachloroethylene the least prevalent. These three compounds exhibit highest concentrations near the southern end of Pit 9, the northern end of Pit 5, the eastern end of Pit 4, and the western end of Pit 10. An area of lesser concentration occurs at and in the vicinity of Pit 2. Data are not available to resolve whether this area is a source or just an area of organic vapor accumulation. Only carbon tetrachloride appears to show plume movement beyond the SDA. There is a concentration of carbon tetrachloride under the drainage ditch along the north boundary of the SDA, and there may be a plume moving to the southwest.

The areal distribution of 1,1,1-trichloroethane was different from that of the other three VOCs [Figure 7-4(b)]. Highest concentrations of 1,1,1-trichloroethane were found in the southern end of Pit 5, the middle of Pit 3, and near the southeast corner of the SDA. High concentrations of 1,1,1-trichloroethane were also found associated with Pit 2; Trenches 24, 29, 32; and Pit 4. The area within Pit 4 highest in 1,1,1-trichloroethane does not correspond to the area highest in carbon tetrachloride [see Figure 7-3(a)].

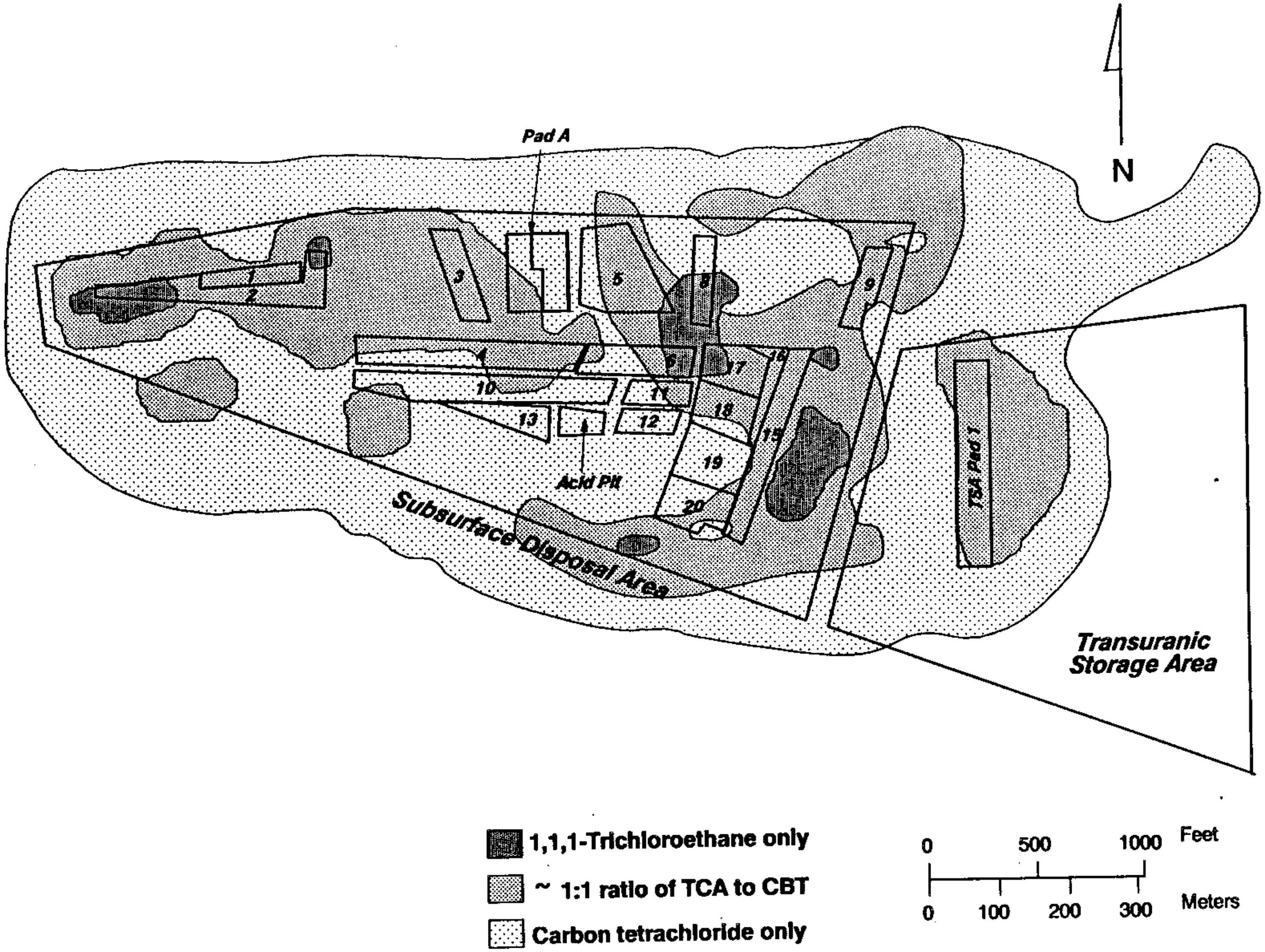


Figure 7-5. Distribution of carbon tetrachloride compared to the distribution of 1,1,1-trichloroethane at the RWMC (Laney et al., 1988).

7.3.3 SDA Perimeter Samples

Sixteen soil gas samples were also collected along roads running to the north, east, south, and west of the SDA. Detectable levels of carbon tetrachloride were found 762 m (2500 ft) north, 1036 m (3400 ft) east, 579 m (1900 ft) west, and 671 m (2200 ft) south of the SDA fence. Only the northernmost sample did not have detectable concentrations of VOCs. The summary of soil gas analyses conducted outside the perimeter of the SDA are presented in Table 7-3.

7.3.4 Vertical Distribution of Gas

Samples were taken from Boreholes 77-1, 78-4, and WWW-1 to obtain a profile of VOC concentrations with depth (Figure 7-1). Each borehole was instrumented with gas sampling ports at multiple depths as summarized in Table 11-1 in Section 11 of this report. The data are presented in Table 7-4. Maximum concentrations of VOCs generally occur within a range of 24 to 46 m (80 to 150 ft). At depths greater than approximately 52 m (170 ft), the concentrations drop off, but detectable levels were measured to a depth of 102 m (335 ft).

7.4 Data Quality

The high levels of VOCs found within several areas of the SDA required stringent levels of quality assurance and control to minimize cross-contamination and to maintain sample integrity. In order to achieve a high level of analytical confidence, four methods of quality assurance/quality control, listed below and described in the following subsections, were implemented throughout the project.

- Frequent sampling of the soil gas sampling apparatus

- Continuous monitoring of sample syringes

Table 7-3. Results of SDA perimeter soil gas analysis[a]

Grid	East	North	Sample Depth (in.)	1,1,1-Trichloroethane (ug/L)	Carbon tetrachloride (ug/L)	Trichloroethylene (ug/L)	Tetrachloroethylyene (ug/L)	1,1-Dichloroethylene (ug/L)	Methylene chloride (ug/L)	1,2-Trans-dichloroethylene (ug/L)	Trans-1,3-dichloropropene (ug/L)	1,2-Dichloropropene (ug/L)	1,1,2-Trichloroethene (ug/L)	Benzene (ug/L)	Toluene (ug/L)
** Outside the Grid															
Z-01	2300	2994	32	ND[b]	0.06	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z-02	2833	3000	13	ND	0.20	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z-03	3015	3558	17	ND	0.08	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z-04	3222	4138	31	ND	0.20	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z-05	3170	4585	23	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z-06	4504	1889	30	ND	2.00	0.03	0.10	ND	ND	ND	ND	ND	ND	ND	ND
Z-07	-90	2359	30	ND	0.20	0.01	0.20	ND	ND	ND	ND	ND	ND	ND	ND
Z-08	5860	2806	27	ND	0.20	0.01	0.01	ND	ND	ND	ND	ND	ND	ND	ND
Z-09	6497	3246	27	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z-10	-573	1627	21	ND	P[c]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z-11	-1355	2013	13	ND	P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z-12	-1881	2329	16	ND	0.03	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z-13	1528	412	30	ND	0.90	0.05	0.07	ND	ND	ND	ND	ND	ND	ND	ND
Z-14	1186	-33	30	ND	0.90	0.05	0.08	ND	ND	ND	ND	ND	ND	ND	ND
Z-15	842	-334	18	ND	0.20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Z-16	-873	-2980	28	ND	0.20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

---

a. Source: data from Golder (EG&G, 1988a).

b. ND indicates that the constituent was not detected.

c. P indicates that the constituent was detected in the sample at an unquantified level

Table 7-4. Results of analysis of deep borehole gas samples taken during soil gas analysis[a]

Grid	East	North	Sample Depth (in.)	1,1,1-Tri-chloroethane (ug/L)	Carbon tetra-chloride (ug/L)	Trichloro-ethylene (ug/L)	Tetra-chloro-ethylyene (ug/L)	1,1-Dichloro-ethylene (ug/L)	Methylene chloride (ug/L)	1,2-Trans-dichloro-ethylene (ug/L)	Trans-1,3-dichloro-propene (ug/L)	1,2-Di-chloro-propene (ug/L)	1,1,2-Tri-chloro-ethene (ug/L)	Benzene (ug/L)	Toluene (ug/L)
WWW1-1	-1600	1800	15	ND[b]	8.80	1.60	0.40	ND	ND	ND	ND	ND	ND	ND	ND
WWW1-2	-1600	1800	48	ND	8.00	1.12	0.40	ND	ND	ND	ND	ND	ND	ND	ND
WWW1-3	-1600	1800	74		30.00	3.80	0.90	ND	ND	ND	ND	ND	ND	ND	ND
WWW1-4	-1600	1800	112	P[c]	6.60	1.00	0.40	ND	ND	ND	ND	ND	ND	ND	ND
WWW1-5	-1600	1800	135	P	28.00	4.00	1.00	ND	ND	ND	ND	ND	ND	ND	ND
WWW1-6	-1600	1800	180	P	3.00	2.00	0.40	ND	ND	ND	ND	ND	ND	ND	ND
WWW1-7	-1600	1800	240	ND	0.90	P	P	ND	ND	ND	ND	ND	ND	ND	ND
77-1-2	2175	2900	171	P	2.30	0.04	0.10	ND	ND	ND	ND	ND	ND	ND	ND
77-1-3	2175	2900	153	5.00	20.00	5.00	2.40	ND	ND	ND	ND	ND	ND	ND	ND
77-1-4	2175	2900	112	5.00	20.00	4.00	1.00	ND	ND	ND	ND	ND	ND	ND	ND
77-1-5	2175	2900	104	0.80	4.00	0.90	0.40	ND	ND	ND	ND	ND	ND	ND	ND
77-1-6	2175	2900	66	7.00	4.00	8.00	2.00	ND	ND	ND	ND	ND	ND	ND	ND
78-4-1	2175	2975	335	ND	0.60	0.04	0.04	ND	ND	ND	ND	ND	ND	ND	ND
78-4-2	2175	2975	253	ND	2.00	0.03	0.03	ND	ND	ND	ND	ND	ND	ND	ND
78-4-3	2175	2975	227	ND	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
78-4-4	2175	2975	118	ND	26.00	6.00	2.00	ND	ND	ND	ND	ND	ND	ND	ND
78-4-5	2175	2975	78	ND	36.00	9.00	2.00	ND	ND	ND	ND	ND	ND	ND	ND

---

a. Source: data from Golder (EG&G, 1988a).

b. ND indicates that the constituent was not detected.

c. P indicates that the constituent was detected at an unquantified level.

- Daily quantification of VOC standards
- Periodic monitoring of VOCs at selected locations.

7.4.1 Frequent Sampling of the Soil Gas Sampling Apparatus

A blank sample of the sampling apparatus was typically collected at least once a day with subsequent sampling of any gas samples showing high levels of VOCs. Before collecting a quality assurance sample, the pump was run briefly to withdraw gases from the probe and sampling train. A sample was then collected with a syringe and analyzed with the GC. Those samples identified as "X" or "XP" in Tables 7-2 and 7-3 represent quality assurance checking of the gas sampling train.

7.4.2 Continuous Monitoring of Sample Syringes

Because the same sampling syringes were used multiple times, it became necessary to analyze for syringe VOC artifacts. Soil gas samples with high levels of VOCs left measurable levels of the four organic compounds in the sampling syringe. Consequently, each syringe was solvent rinsed with hexane and heated in an oven at 100°C (212°F) for 10 to 15 minutes to remove any residual VOC contamination. The syringes were tested after cleaning by drawing ambient air into the syringe and injecting the air into the GC.

7.4.3 Daily Quantification of VOC Standards

Approximately seven standard runs of multiple levels of the target VOCs were run daily to check the performance of the GC and to determine a response factor for each target VOC. These response factors were then used to calculate the concentrations found in individual soil gas samples.

7.4.4 Monitoring of VOCs at Selected Locations

In order to determine the effects of atmospheric pressure on the data quality, two sampling locations were selected for periodic monitoring that extended from October 30, 1987, to November 4, 1987, and from October 30, 1987, to November 5, 1987 at locations E-15 and E-19, respectively (Figure 7-1). This monitoring showed that soil vapor concentrations of carbon tetrachloride, trichloroethylene, and tetrachloroethylene all decreased from October 30 to minimum values on November 2. The values then increased on subsequent days. The ratios of the highest to lowest values recorded at location E-19 for the three compounds were 2.2 (1400/640 μg/L), 8.6 (690/80 μg/L), and 2.0 (40/20 μg/L), respectively (Table 7-2). Both tetrachloroethylene and trichloroethylene at location E-15 showed their lowest value for about the same period (October 30 to November 4), with the ratios of high/low being 2.3 (7/3 μg/L) and 50 (4/0.08 μg/L), respectively (Table 7-2). This ordered variability strongly suggested that an uncontrolled variable, such as atmospheric pressure, was affecting the inhalation and exhalation of soil gas and vapors from the subsurface to the atmosphere. These results indicate that soil vapor concentrations measured on different days are not directly comparable, and that precise mapping of contaminant vapors in the subsurface would be very difficult.

8. Geophysical Investigations

8. GEOPHYSICAL INVESTIGATIONS

The detection of small amounts of TRU radionuclides in the sedimentary interbeds and of trace concentrations of volatile organic constituents in the aquifer underlying the SDA in 1987 prompted a need to reevaluate current and past disposal practices and to better define the shallow subsurface stratigraphy in order to predict potential contaminant migration pathways. Previous geophysical investigations at the SDA were conducted in the late 1970s and early 1980s with limited success. The geophysical investigations discussed in this section address the objectives defined in the December 1988 RFI Work Plan to obtain additional information on (a) waste and disposal pit configurations and (b) the shallow subsurface stratigraphy (EG&G, 1988a).

Three separate geophysical studies were undertaken to meet these objectives. A ground penetrating radar (GPR) test designed by EG&G Energy Measurements and electromagnetic and magnetic surveys designed by UNC Geotech were conducted to obtain information on waste disposal pit configuration. A seismic reflection investigation was designed by the Kansas Geological Survey to obtain geologic information. The waste and disposal pit/trench investigations are described in Section 8.1, and the geological investigations are described in Section 8.2. Section 8.3 summarizes recent geophysical investigations at the SDA that were not conducted as part of the proposed investigations in the December 1988 RFI Work Plan.

8.1 Waste and Disposal Pit/Trench Investigations

The lack of information on waste form, classification, packaging, and location of buried waste is a potential problem in the evaluation, selection, and implementation of source control measures for the SDA. Waste location markers and records are unreliable because of antiquated storage methods practiced in early years (Brown and Quintana, 1988). Thus, geophysical techniques were selected that could potentially identify the exact disposal unit perimeter, the waste form, the packaging type, and the depth of overburden. Three specific objectives of these studies were defined: (1) identify the waste disposal unit perimeter boundaries, (2) determine the depth of soil covering the waste, and (3) provide resolution for waste targets approximately 0.03 m^3 (1 ft^3) in size and larger. The proposed investigation, as described in the December 1988 RFI Work Plan, is described in Section 8.1.1, the procedures for implementing the work plan strategy are discussed in Section 8.1.2, and the results of the waste and disposal pit/trench investigations are summarized in Section 8.1.3.

8.1.1 Proposed Strategy in RFI Work Plan

A four-phased investigation plan for identifying waste and disposal pit/trench configuration was proposed: (1) evaluate and select geophysical techniques for testing, (2) field test the selected techniques, (3) evaluate the results of the tested techniques, and (4) implement an integrated approach for geophysical investigation of the TRU and mixed waste pits and trenches at the SDA.

8.1.2 Procedures

The procedures for implementing the proposed strategy in the RFI Work Plan are discussed in the following sections. The selection of geophysical techniques is summarized in Section 8.1.2.1, the selection of test sites for the proposed geophysical techniques is described in Section 8.1.2.2, the procedures for implementing the geophysical surveys are discussed in Section 8.1.2.3, and the summary and conclusions are presented in Section 8.1.2.4.

8.1.2.1 Selection of Geophysical Techniques. Brown and Quintana (1988) reports the results of a preliminary investigation to determine which geophysical method(s) had the greatest applicability at the SDA for accomplishing the objectives stated in Section 8.1. The investigation used literature searches, discussions with experts, and demonstration trips to compare various geophysical techniques that are used for both hazardous waste sites and in other applications. The geophysical methods selected for testing at the SDA included GPR, electromagnetics (EM) or resistivity, and magnetics. A brief summary of the chosen geophysical methods and their applicability to the SDA is provided below.

8.1.2.1.1 Ground Penetrating Radar--GPR uses high frequency radio waves to acquire subsurface information. An electromagnetic pulse is transmitted into the ground, and the GPR detects and records the reflected signal from subsurface targets or stratigraphic interfaces. The GPR reflected signal can be in response to (a) natural geohydrologic conditions such as bedding, cementation, moisture and clay content, voids, and fractures and/or (b) manmade conditions such as buried pipes, drummed wastes, and other buried waste materials. The strength of the attenuated and/or reflected signal depends on the electrical properties of the soil, targets, or stratigraphic interfaces absorbing or reflecting the signal. Therefore, two targets at the same depth in two dissimilar soil types with differing electrical properties will appear to be at different depths.

8.1.2.1.2 EM Induction or Resistivity--EM induction or resistivity are techniques that use an induced electrical current in the earth to produce output voltage that is a function of subsurface conductivity (EM method) or its reciprocal, resistivity (resistivity method). Electrical conductivity or resistivity depends on natural geohydrologic conditions such as the type and thickness of soil or rock and its reservoir character: porosity, permeability, soil moisture content (water saturation), pore-filling fluid, and total dissolved solids content. These techniques can be used to delineate disposal unit boundaries, determine depth of cover to waste, indicate metal concentrations, and map contaminant plumes.

8.1.2.1.3 Magnetometry--A magnetometer measures the intensity of the earth's magnetic field. Ferrous materials, whether natural or manmade, create variations in the local strength of the magnetic field, which facilitates their detection. Variations in the magnetic field can be caused by the natural distribution of iron oxides within the soil or rock or by the presence of buried iron or steel objects. The magnetometer response is proportional to the mass of the ferrous target.

8.1.2.2 Selection of Test Sites. Previous geophysical surveys conducted in the late 1970s and early 1980s at the INEL Site demonstrated that the soil at the RWMC was not readily conducive to geophysical investigations because of signal attenuation caused by the clay and moisture content (EG&G, 1988a). Therefore, before acquiring geophysical data at the actual buried waste areas, the selected techniques were tested at the INEL Simulated TRU Waste Test Pit, also known as the Cold Pit. The Acid Pit and Pit 9 were also selected for the initial geophysical demonstration studies because of proposed sampling efforts at both locations. The location of these pits are illustrated on Figure 8-1.

8.1.2.2.1 <u>Cold Pit</u>--The Cold Simulated Waste Demonstration Test Pit (Cold Pit) was constructed in the summer of 1988. This pit was designed to function as a test site for experiments to characterize boundaries and contents and for the development of remediation procedures. The Cold Pit is located approximately 0.4 km (0.25 mi) south of the SDA and is in soil similar to that of the SDA (Brown and Quintana, 1988). The location of the Cold Pit with respect to the SDA is shown on Figure 8-1. The pit contains five sections, each with approximate dimensions of 12 x 9 x 3 m (39 x 30 x 10 ft). The southernmost section, referred to as both the Geophysics Demonstration Pit and the Large Object Pit (LOP), was designed and constructed for the primary purpose of testing various geophysical methods for their site-specific applicability to the SDA. The LOP and geophysical survey boundaries are illustrated in Figure 8-2.

The LOP was designed to validate geophysical mapping techniques and as such does not necessarily simulate an actual buried waste pit (Brown and Quintana, 1988). The contents of the pit include vertically and horizontally stacked metal drums, randomly dumped deteriorating rusted metal drums, large metal tanks and pipes, reinforced concrete blocks and boxes, cardboard drums, and plywood boxes. The plywood boxes, vertically stacked drums, randomly dumped drums, and lower layers of the horizontally stacked drums are filled with simulated cold (nonhazardous, nonradioactive) waste. The cardboard drums are filled with soil, and one large metal tank is filled with concrete. The remaining tanks, pipes, horizontal stacked drums, and concrete boxes are empty. Six vertical plastic pipes were also included in the LOP: two pipes are 10.2 cm (4 in.) in diameter and four are 7.6 cm (3 in.) in diameter.

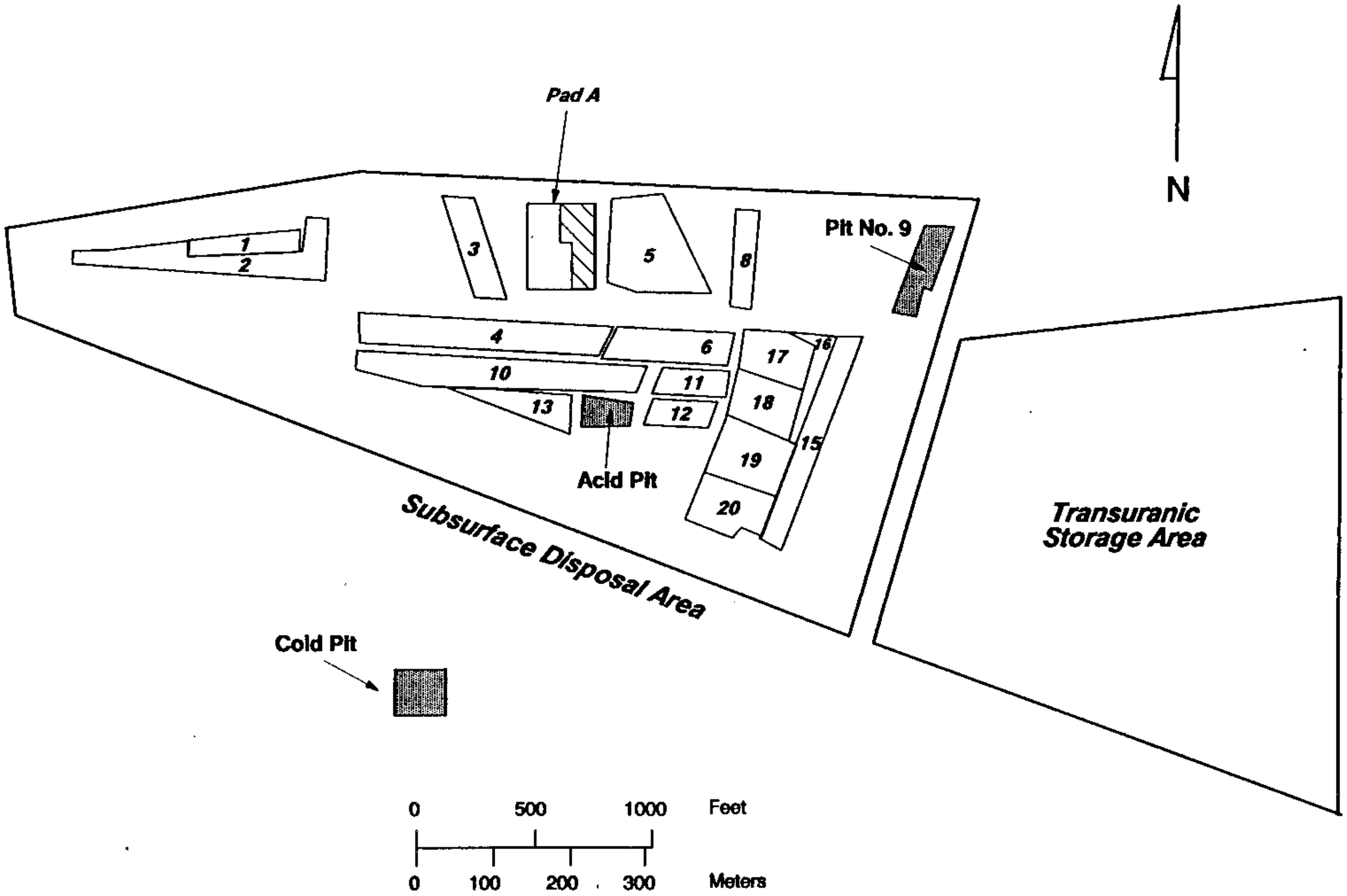


Figure 8-1. Approximate location of the Cold Pit, Acid Pit and Pit 9 at the SDA (modified from Hasbrouck, 1989).

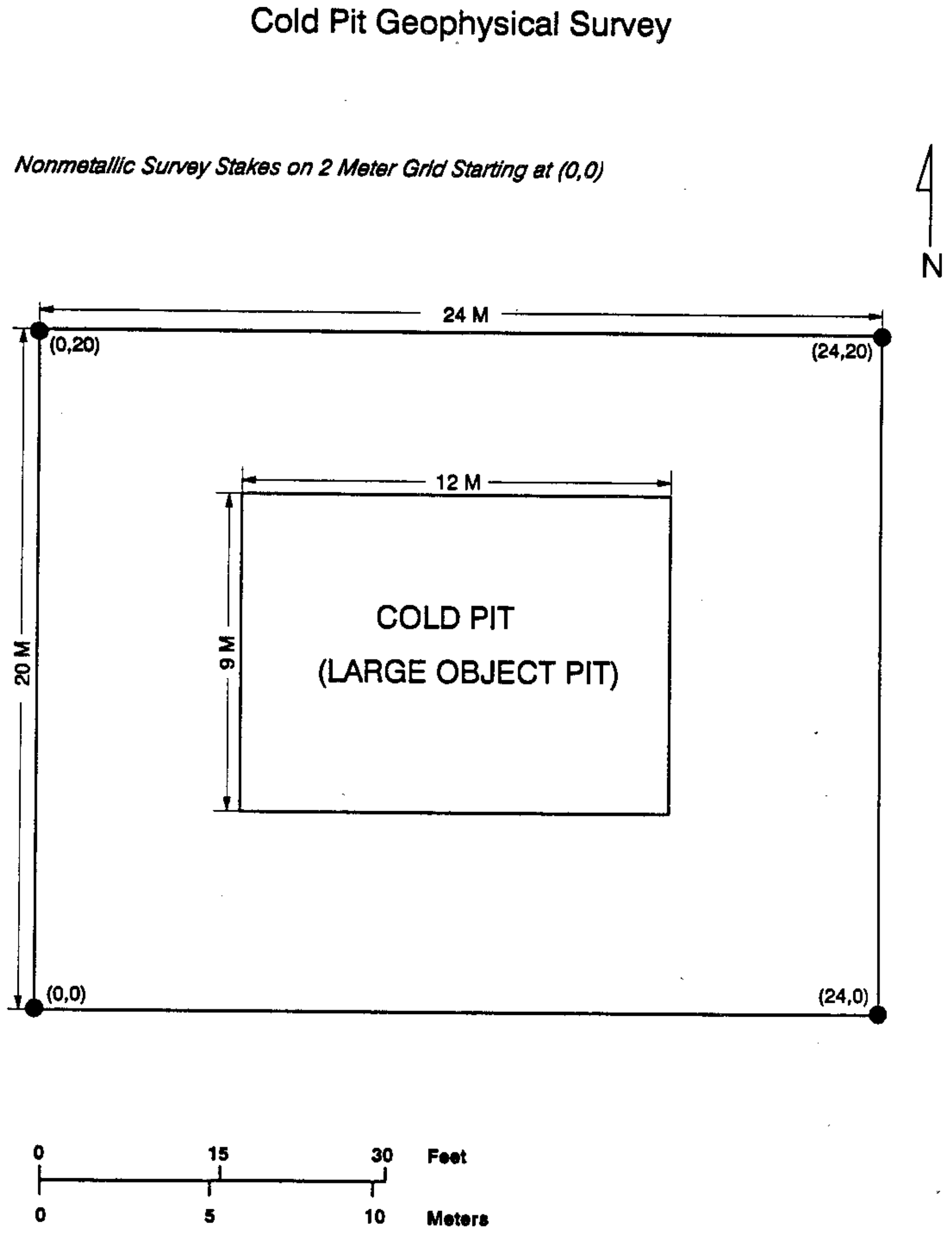


Figure 8-2. Cold test pit (LOP) and geophysical boundaries (unpublished sampling plan of K. L. Ruebelmann, EG&G Idaho, Inc., Idaho Falls, Idaho, January 30, 1989).

These pipes were specifically located and spaced to provide data indications for both pits and trenches.

The remaining four sections in the Cold Pit were set up to simulate (a) stacked boxes of waste, (b) stacked drums of waste, (c) randomly dumped boxes and drums of waste, and (d) randomly dumped drums of waste. Simulated waste in these four sections totalled 1200 cardboard drums (capacity of 208 L each) and 72 1.2 x 1.2 x 2.4-m (4 x 4 x 8-ft) cardboard drums. These packages contained cloth, wood, paper, metal, concrete, cinder block, glass, plastics, HEPA filters, and simulated sludge. To the extent possible, the conditions existing in actual waste pits located inside the SDA were simulated in the Cold Pit. The excavation and construction methods used on the Cold Pit were similar to those used on the actual waste pits before 1980. Since 1980, basalt has been removed using explosives to obtain both the desired depth and floor surface. The Cold Pit is significantly smaller in length and width than the actual waste pits, but the depth is comparable to that of pre-1980 actual pits.

8.1.2.2.2 Acid Pit--The Acid Pit was used for disposal of various wastes, possibly including radiologically contaminated acids and solvents. From 1954 to 1961, records indicate that this area was maintained as an open pit. The pit may have been used for disposal by RWMC operations as late as the early 1970s.[a] The Acid Pit is located south of Pit 10 and west of Pit 12; it has an approximate rectangular size of 60 x 32 m (197 x 104 ft) (Figures 8-1 and 8-3). Interviews with SDA personnel indicated that the pit was approximately 3 to 5 m (10 to 15 ft) deep at its deepest point, with the walls sloping to the deepest part of the pit. These historical interviews also indicated that a 3000-gal tank trailer may have been buried in the central portion of the pit.[a] Its presence should produce a distinctive geophysical response.

---

[a] Unpublished sampling plan for geophysical investigations at the RWMC by K. L. Ruebelmann, EG&G Idaho, Inc., Idaho Falls, Idaho, January 30, 1989.

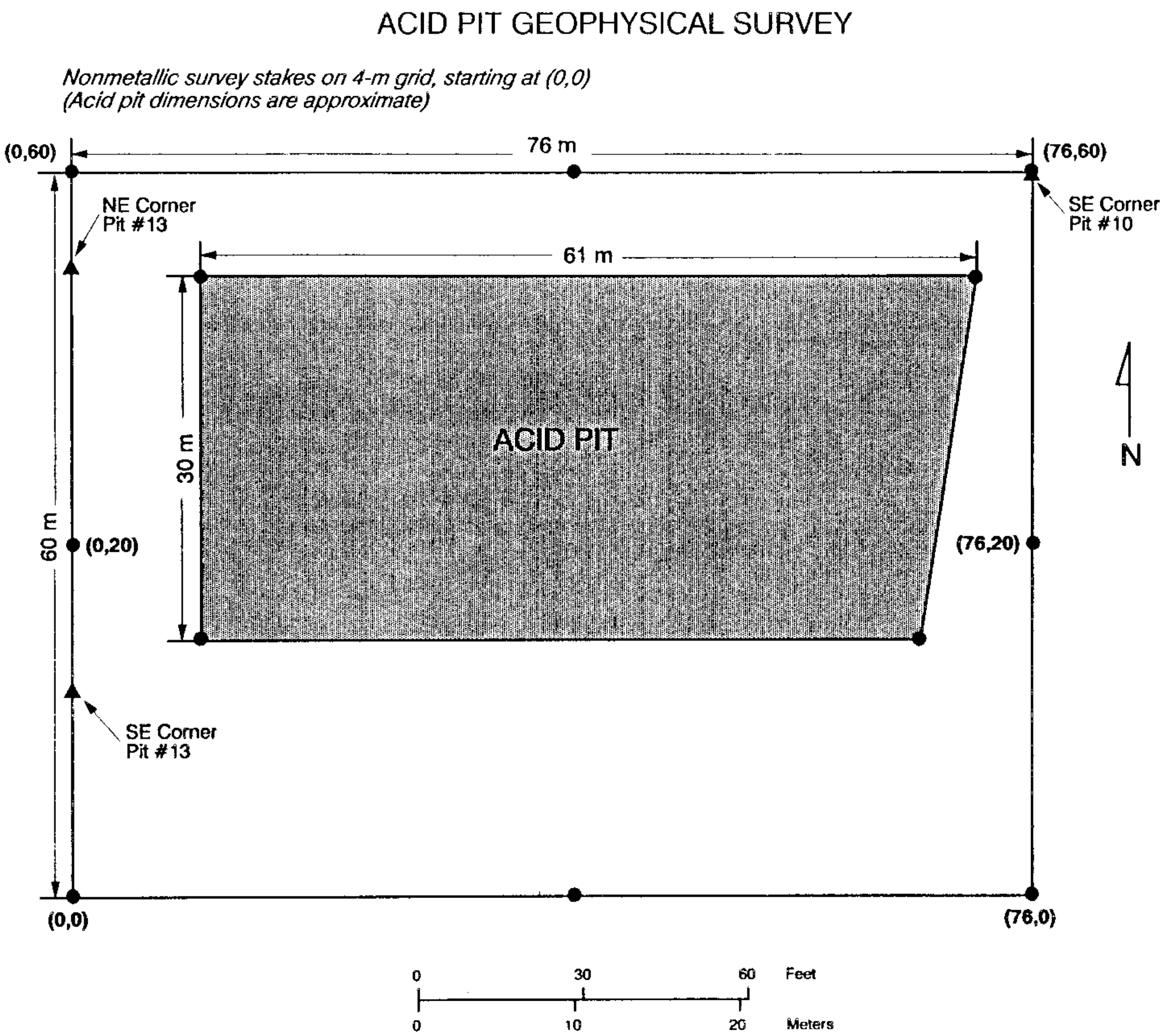


Figure 8-3. The Acid Pit and geophysical survey boundaries. The dimensions are approximate, from EG&G Drawing No. 46511 (unpublished sampling plan for geophysical investigations at the RWMC by K. L. Ruebel ,
Idaho, Inc., Idaho Falls, Idaho, January 30,

8.1.2.2.3 Pit 9--Pit 9 is located in the northeastern corner of the SDA. The dimensions of the pit measure approximately 110 m (360 ft) long x 30 m (100 ft) wide (Figure 8-4). This pit was used from November 1967 to June 1969 for the disposal of onsite waste. From May 1968 to September 1968, Pit 9 was used for disposal of TRU waste drums and boxes and boxes filled with contaminated empty drums (Ruebelmann, 1989). A total of 3921 drums and 2029 boxes (including 1302 boxes of empty drums) were randomly dumped rather than stacked within the pit. The distribution of boxes and drums are shown on Figure 8-4. The boxes were emplaced in the north end of the pit and the drums in the south end of the pit although there is a considerable area of mixed drums and boxes. This pit is targeted for use in demonstrating remotely operated waste retrieval that may be applied to the SDA as a whole.

8.1.2.3 Procedures for Implementing Geophysical Surveys. Multiple geophysical techniques were used to meet the objectives identified in Section 8.1. Two separate geophysical investigations were conducted. The GPR tests were conducted by EG&G Energy Measurements in the fall of 1988. The magnetic and electromagnetic investigations were conducted by UNC Geotech in the winter of 1989. The design and strategy of data acquisition for magnetics and electromagnetics were defined in the sampling and analysis plan for the geophysical investigations at the RWMC and are briefly summarized below.[a] A sampling and analysis plan was not prepared for the GPR test.

The survey strategy consisted of acquiring reconnaissance seismic surveys and using the results of these investigations to conduct more detailed surveys in areas of interest. Reconnaissance magnetic and electromagnetic surveys were acquired to determine geologic and cultural background noise, to identify gross anomalies, and to develop the best geophysical strategy for detailed analysis.[a] Detailed magnetic, electromagnetic, and refraction seismic surveys were acquired to further delineate anomalous areas.

---

[a] Unpublished sampling plan for geophysical investigations at the RWMC by K. L. Ruebelmann, EG&G Idaho, Inc., Idaho Falls, Idaho, January 30, 1989.

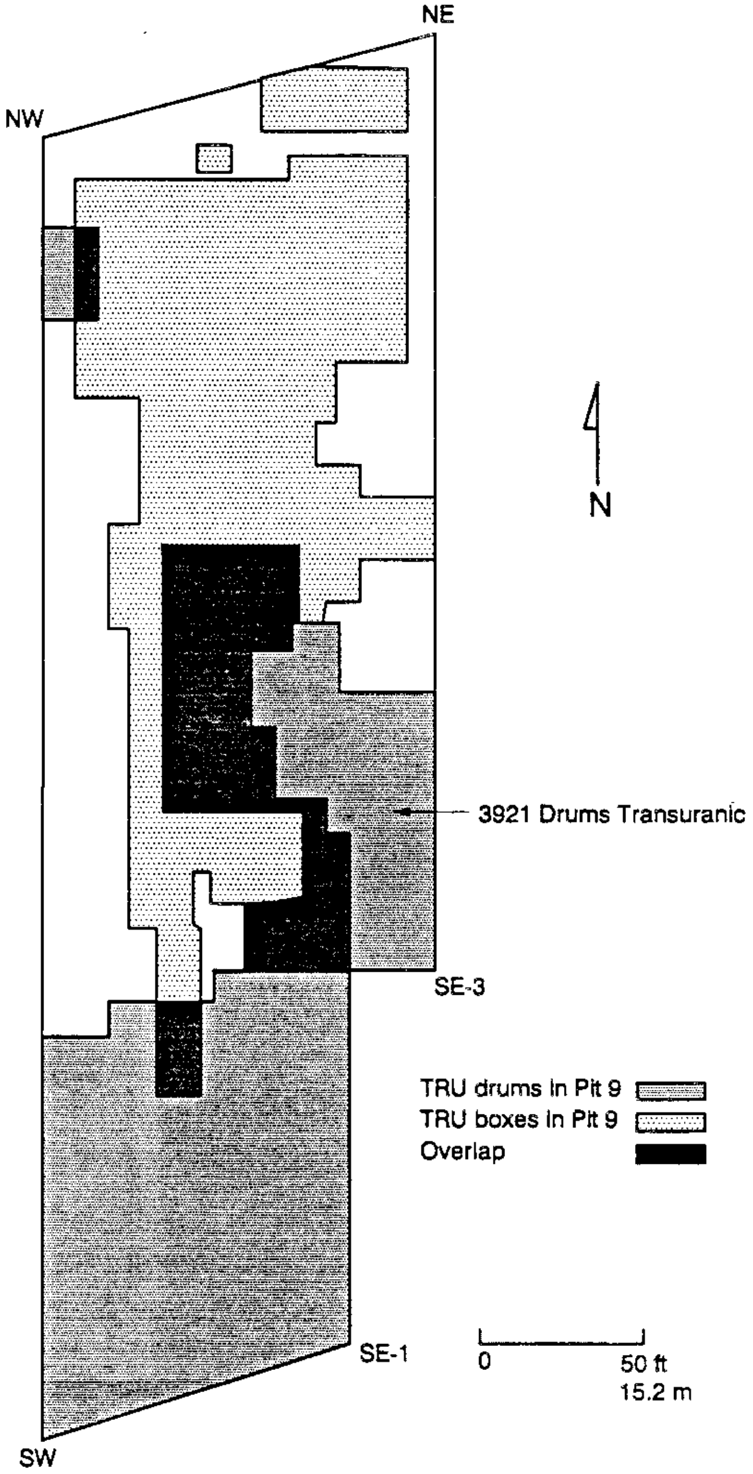


Figure 8-4. Distribution of TRU drums and boxes in Pit 9 (unpublished sampling plan for geophysical investigations at the RWMC by K. L. Ruebelmann, EG&G Idaho, Inc., Idaho Falls, Idaho, January 30, 1989).

The selected sites for testing the geophysical techniques were surveyed by the MK-Ferguson of Idaho Company on both 2- and 4-m (6.5- and 13-ft) centers. The stations at all pits were marked with either a wooden stake or a spray-painted point on the ground surface. All stations were referenced using the established RWMC survey coordinate system. The Cold Pit was surveyed with nonmetallic stakes on a 2-m (6.5-ft) grid starting at (0,0), and both the Acid Pit and Pit 9 were surveyed on a 4-m (13-ft) grid starting at (0,0). The survey grids extended beyond the historic pit boundaries of the Acid Pit. At Pit 9, the survey grid did not extend beyond the historic pit boundary to the east or south because of the presence of a power line and a road, respectively. The geophysical survey boundaries are illustrated on Figures 8-2, 8-3, and 8-5.

Total magnetic field and vertical gradient of the total magnetic field data were acquired with a proton precession magnetometer. EM data, both quadrature and inphase, were acquired with an instrument operating at 9.8 kHz. Very low frequency EM was obtained with an instrument that received signals from a minimum of two transmitting stations. Seismic data were acquired with a 12-channel, signal-enhancement seismograph with vertically oriented geophones and a sledge hammer source. All data were acquired, processed, and displayed according to the established quality assurance procedures included in the sampling and analysis plan.[a]

GPR was used at the Cold Pit in the LOP and in the sections that contained stacked boxes of waste, stacked drums of waste, and randomly dumped boxes and drums of wastes. Four passes were made within each section across the width of the pit. A 6- x 6-m (20- x 20-ft) area of the LOP was gridded and evaluated. The data from the gridded area were manipulated to generate a three-dimensional image of the buried waste. After testing at the Cold Pit, the equipment was moved to Pit 9 at the SDA. Pit 9 was traversed at 0.6-m (2-ft) intervals five times.

---

[a] Unpublished sampling plan for geophysical investigations at the RWMC by K. L. Ruebelmann, EG&G Idaho, Inc., Idaho Falls, Idaho, January 30, 1989.

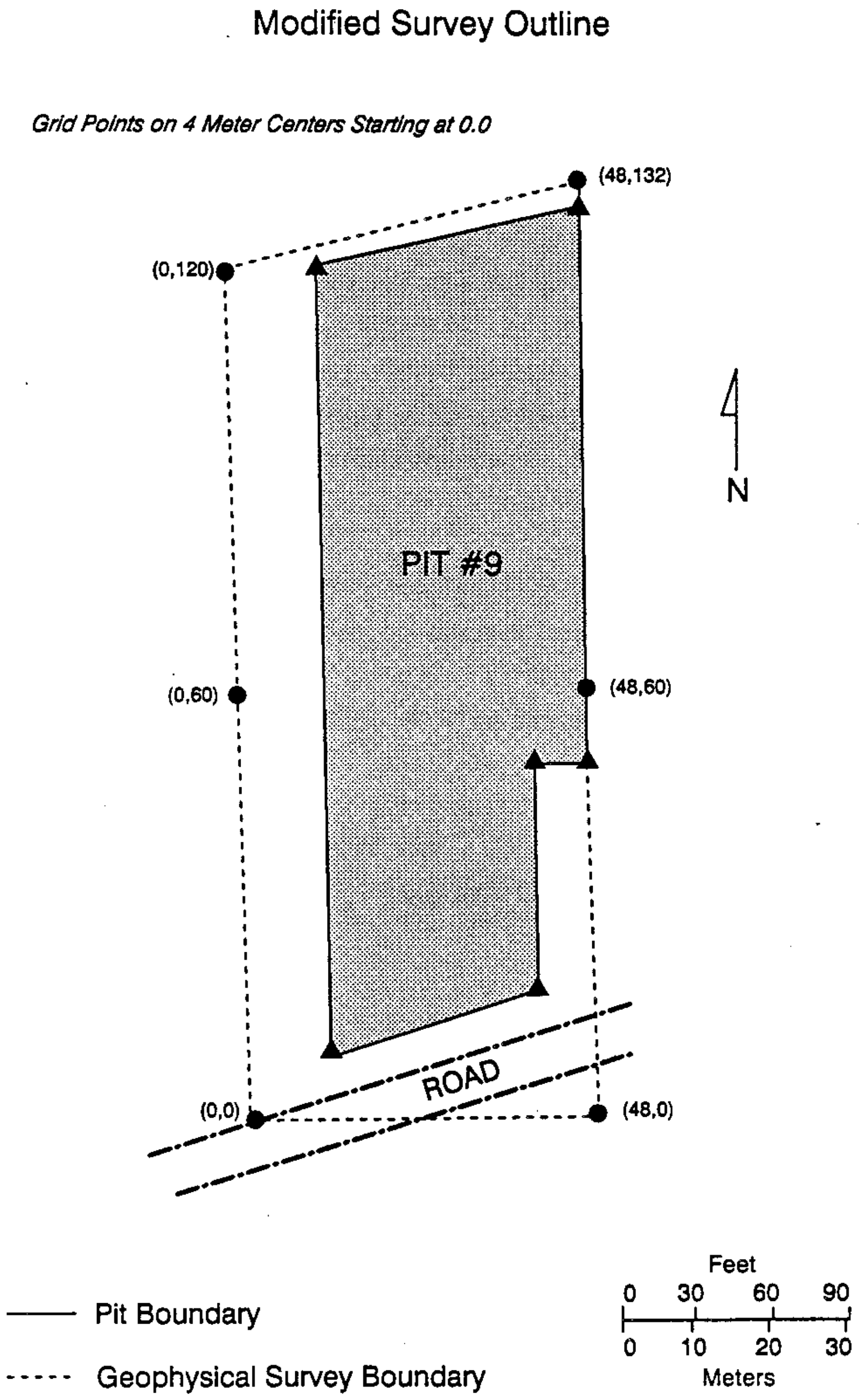


Figure 8-5. Pit 9 and geophysical survey boundaries (Pit 9 dimensions are approximate from EG&G Drawing No. 416411) (unpublished sampling plan for geophysical investigations at the RWMC by K. L. Ruebelmann, EG&G Idaho, Inc., Idaho Falls, Idaho, January 30, 1989).

The GPR hardware consisted of a 0.6 m wide x 1.2 m long x 25.4 cm high (2 ft wide x 4 ft long x 10 in. high) metal container that was dragged by hand along the soil surface. Two antennas were enclosed in the metal container: one that transmitted the signal and one that detected the reflected signal. The metal container had a surface-mounted handle to pull the unit, a data acquisition package to record data on 3.5-in. computer disks, and a liquid crystal display that showed the subsurface in real time.[a]

8.1.3 Results of the Waste/Disposal Pit Investigations

The magnetic, electromagnetic, and seismic surveys were conducted under harsh winter conditions with wind chills reported to -50°C (-58°F). Because of the extreme weather conditions, extra insulation for the instrumentation, including chemical warming pads, was required to operate the equipment down to approximately -31°C (-25°F) (Hasbrouck, 1989). The GPR tests were conducted from October 18 through 20, 1988.

Table 8-1 lists the geophysical techniques that were used in the surveys at the SDA. Reconnaissance magnetic and EM surveys were conducted at each pit to define the geologic and cultural background noise, to identify anomalous areas, and to develop the best geophysical approach for subsequent surveys. Detailed magnetic and induction EM surveys were conducted in selected areas over each pit. Very low frequency EM surveys were not conducted at any of the pits because of the limited resolution indicated on the reconnaissance surveys. Two refraction seismic profiles were conducted within the Acid Pit based on the results of the magnetic and EM reconnaissance surveys. An EM conductivity depth sounding (vertical profile) was conducted along one profile within the Acid Pit. All data were acquired, processed, and displayed according to the established quality assurance procedures in the Sampling and

---

[a] Unpublished Environmental Checklist for a GPR Demonstration at the Radioactive Waste Management Complex, EG&G Idaho, Inc., Idaho Falls, Idaho, July 7, 1988.

Table 8-1. Geophysical techniques used in the surveys[a]

Technique	Abbreviation Used in this Report	Typical Targets
Total magnetic field	Total magnetic field	Tanks, drums, ferromagnetic debris
Vertical gradient of total magnetic field	Magnetic gradient	Tanks, drums, ferromagnetic debris
Induction electromagnetics quadrature-phase (0.4, 1.6, 6.4, and 9.8 kHz)	EM conductivity	Soil types, contaminant plumes, stratigraphy
Induction electromagnetics inphase (9.8 kHz)	EM inphase	Metallic debris
Very low frequency electromagnetics	Very low frequency EM	Metallic debris, soil types
Refraction seismic	Refraction	Soil types, depth to bedrock, stratigraphy
Ground penetrating radar	GPR	Soil type, metallic and nonmetallic debris, drums, contaminant plumes

---

a. Modified from Hasbrouck (1989).

Analysis Plan.[a] GPR testing was conducted on selected areas in the Cold Pit and Pit 9. Table 8-2 summarizes the specific surveys conducted at each pit.

Separate profiles of the magnetic and EM data were interpreted for each type of geophysical technique (Hasbrouck, 1989). The interpretation from each technique was integrated and presented on a contour or base map to indicate the areal distribution of anomalous areas and/or the location of pit boundaries. Stacked profiles of the data presented by Hasbrouck (1989) were generated using a three-dimensional contouring computer program. The profiles used in the interpretations are presented in Appendix A of Hasbrouck (1989).

To calibrate the GPR to obtain depth information, a hollow metal cylinder, 15.2 cm (6 in.) in diameter and length, was buried to a depth of 0.3 m (1 ft) near the southwest corner of the Cold Pit. The radar was pulled over the target in one direction (east to west), then in the opposite direction. The distance from the ground surface to the metal target was measured on the display screen, thus allowing the establishment of relative depths. The depths of other unknown targets were extrapolated from the established depth relationship.[a]

8.1.3.1 Cold Pit. Five different geophysical techniques were used to resolve the pit boundary location in the LOP: total magnetic field, magnetic gradient, EM conductivity, EM inphase data, and GPR. A brief summary of the interpreted pit boundary location and discussions of the resolution of both metallic/nonmetallic debris and a high conductivity area are provided below.

A reconnaissance survey using total magnetic field, magnetic gradient, EM conductivity, and EM inphase were acquired on a 2-m (6.5-ft) spacing as illustrated in Figure 8-6. Profiles obtained in both north-south and east-west directions were interpreted separately, then stacked to delineate the pit boundary. Individual profiles of the separate geophysical data are

---

b. Unpublished sampling plan for geophysical investigations at the RWMC by K. L. Ruebelmann, EG&G Idaho, Inc., Idaho Falls, Idaho, January 30, 1989.

a. GPR survey information provided by EG&G Energy Measurements, Inc. Santa Barbara, California, 1989.

Table 8-2. Summary of surveys conducted[a]

Pit Name[b]	Survey Area (meters)	Survey Type	Techniques	No. of Stations	Notes
Cold Pit	20 x 24	Reconnaissance on 2-m grid	Total magnetic field	143	
			Magnetic gradient	143	
			EM conductivity	143	
			EM inphase very	143	
			low frequency EM	143	
	12 x 36.5		GPR	4 paths	
		Detail profile of lines 10E, 16E, 8N, 12N, and 18N at 1-m spacing	Total magnetic field	117	
			Magnetic gradient	117	
			EM conductivity	117	
			EM inphase very	117	
			low frequency EM	92	no line 12N
		Detail on 1-m grid	EM conductivity	525	
			EM inphase	525	
	9 x 12	Detail of LOP	GPR	5 paths	
Acid Pit	60 x 76	Reconnaissance on 4-m grid	Total magnetic field	320	
			magnetic gradient	320	
			EM conductivity	320	
			EM inphase very	320	
			low frequency EM	320	
		Detail profile of lines 20E, 32E, 44E, 56E, 20N, 32N, and 44N at 1-m spacing	Total magnetic field	431	
			Magnetic gradient	431	
			EM conductivity	431	
			EM inphase	431	
		Profile sounding line 32E	EM conductivity	222	
		Confirmation lines 32E and 20N at 1-m spacing	Total magnetic field	137	
		Profile of lines 32E and 32N	Refraction seismic		18 records
Pit 9	48 x 120	Reconnaissance on 4-m grid	Total magnetic field	373	
			Magnetic gradient	373	
			EM conductivity	373	
			EM inphase very	373	
			low frequency EM	373	

Table 8-2. (continued)

Pit Name[b]	Survey Area (meters)	Survey Type	Techniques	No. of Stations	Notes
	?		GPR	6 paths	
		Detail profile of lines 12N, 28N, 40N, 48N, 56N, 64N, 72N, 84N 96N, 108N, 20E, and 36E at 1-m spacing	Total magnetic field	444	No line 48N, 64N
			Magnetic gradient	444	No line 48N, 64N
			EM conductivity	540	
			EM inphase	540	
		Confirmation lines at 32N and 72N at 1-m spacing	Total magnetic field	98	

---

a. Modified from Hasbrouck (1989); Unpublished Report of Results of GPR Survey of the RWMC by EG&G Measurements, Inc., Santa Barbara, California, 1989.

b. Detailed listings of the acquired raw data are presented in Appendix B, Hasbrouck (1989).

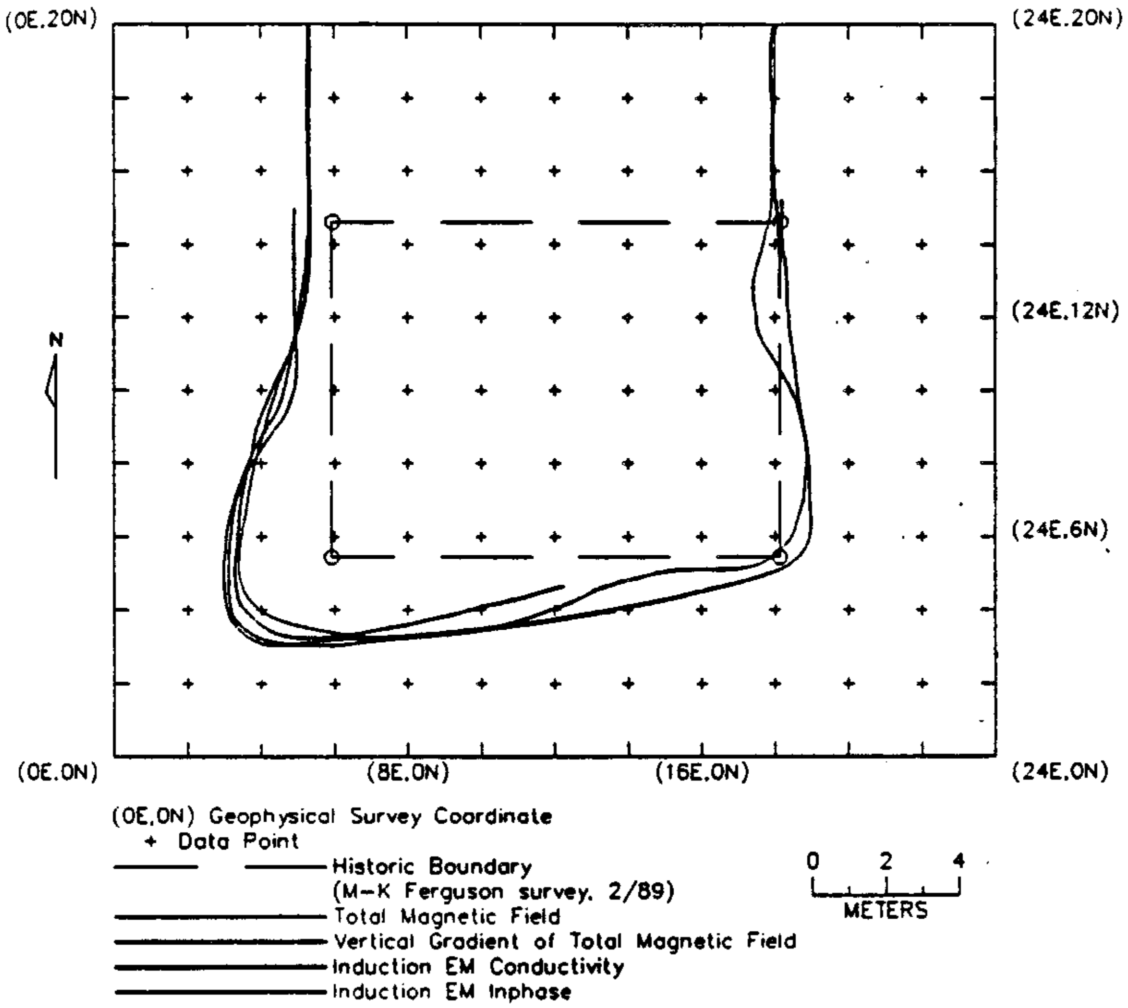


Figure 8-6. Cold Pit boundary interpreted from integrated geophysical approach (Hasbrouck, 1989).

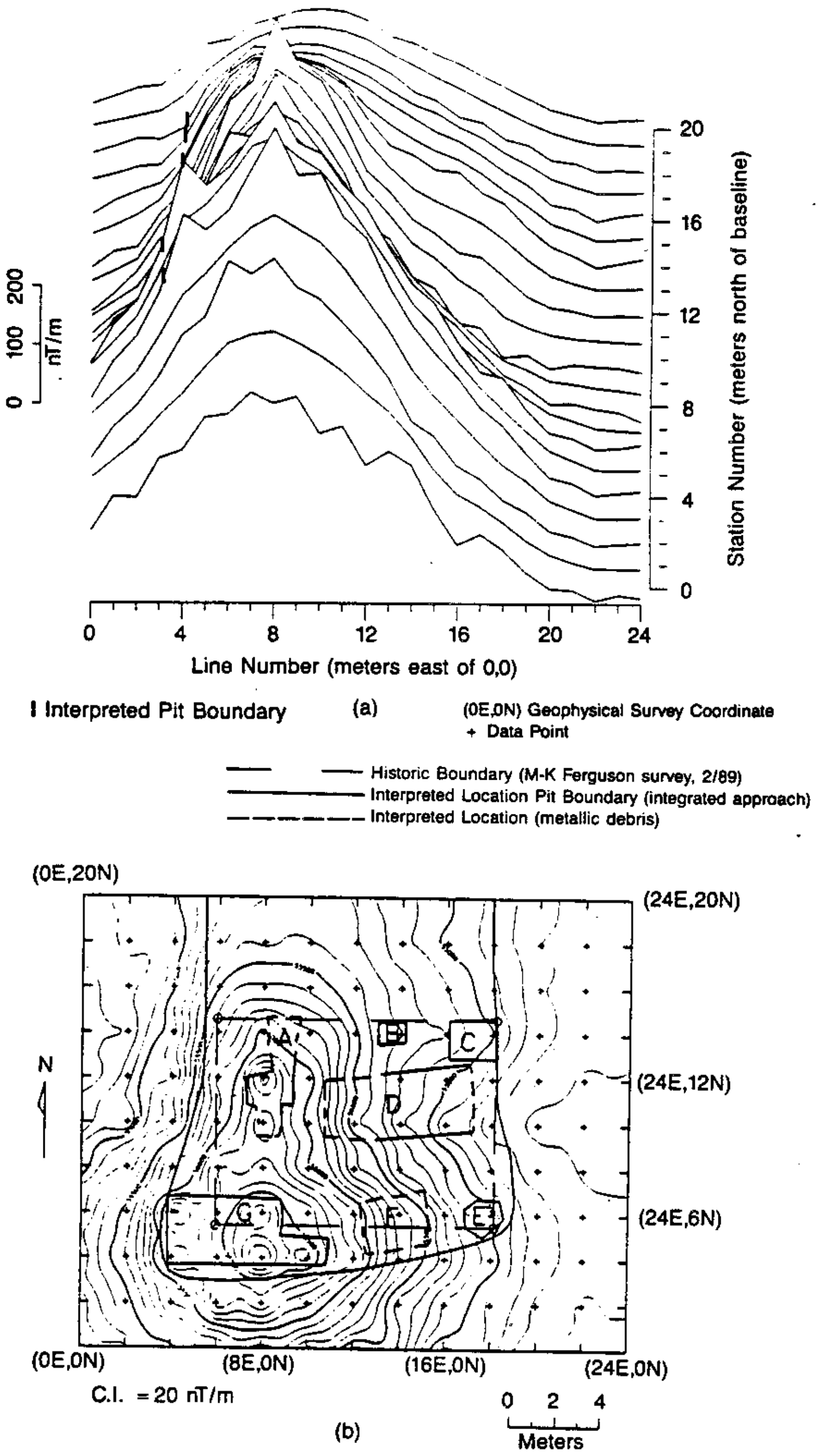
presented in Appendix A of Hasbrouck (1989). The stacked profiles are shown in Figures 8-7 through 8-10. The interpreted pit boundary is illustrated on the stacked profiles. The first significant change in slope along a profile was interpreted as an anomalous area, while the inflection point along a profile was interpreted as a pit boundary (Hasbrouck, 1989).

Nine paths were scanned across the Cold Pit with the GPR: six paths across the LOP and one path across three other sections of the Cold Pit. These scan paths are illustrated on Figure 8-11. The GPR unit was pulled across all the paths at as constant a speed as possible. However, maintaining a constant speed was not feasible in every case, resulting in some targets being compressed (when the speed was too fast) and other targets being expanded (when the speed was too slow). The collected data were saved on floppy disk and analyzed later.

8.1.3.1.1 Interpreted Pit Boundary--The pit boundary was interpreted from total magnetic field, magnetic gradient, EM conductivity, and EM inphase data and is shown in Figure 8-6. This figure illustrates that the pit boundary location differs with each geophysical technique. Only through the integrated use of the four techniques could the pit boundary be interpreted. Figures 8-7 through 8-10 display contour maps of the final interpreted location of the pit boundary using total magnetic field, magnetic gradient, EM conductivity, and EM inphase data. The historic boundary, the interpreted pit boundary, and the interpreted location of metallic debris are also illustrated on the contour maps.

The GPR was used to locate the eastern boundary of the LOP, shown as Path 5 in Figure 8-11(b). The data display from this path illustrates that the intensity of the pit's stratification and the ground interface are significantly reduced as the radar crosses the pit boundary. This intensity contrast provides a clear indication of the eastern boundary of the pit.

8.1.3.1.2 Resolution of Metallic Objects with Magnetic and EM Data--Seven distinct targets, or collections of targets, were interpreted



0-8175

Figure 8-7. Cold Pit total magnetic field stacked profiles with interpreted pit boundary (a) and contour map (b) (Hasbrouck, 1989).

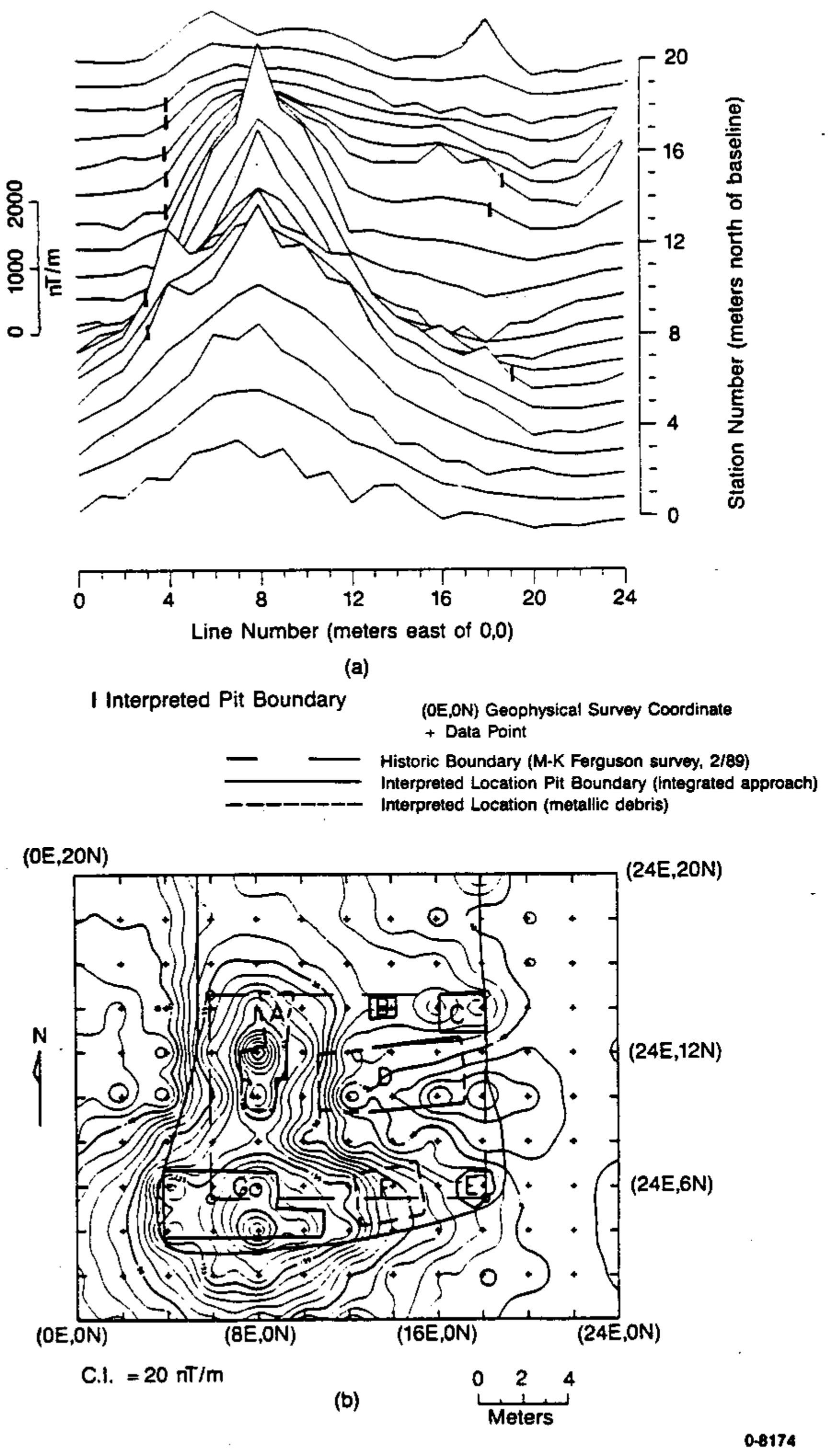


Figure 8-8. Cold Pit vertical gradient of total magnetic field stacked profiles with interpreted pit boundary (a) and contour map (b) (Hasbrouck, 1989).

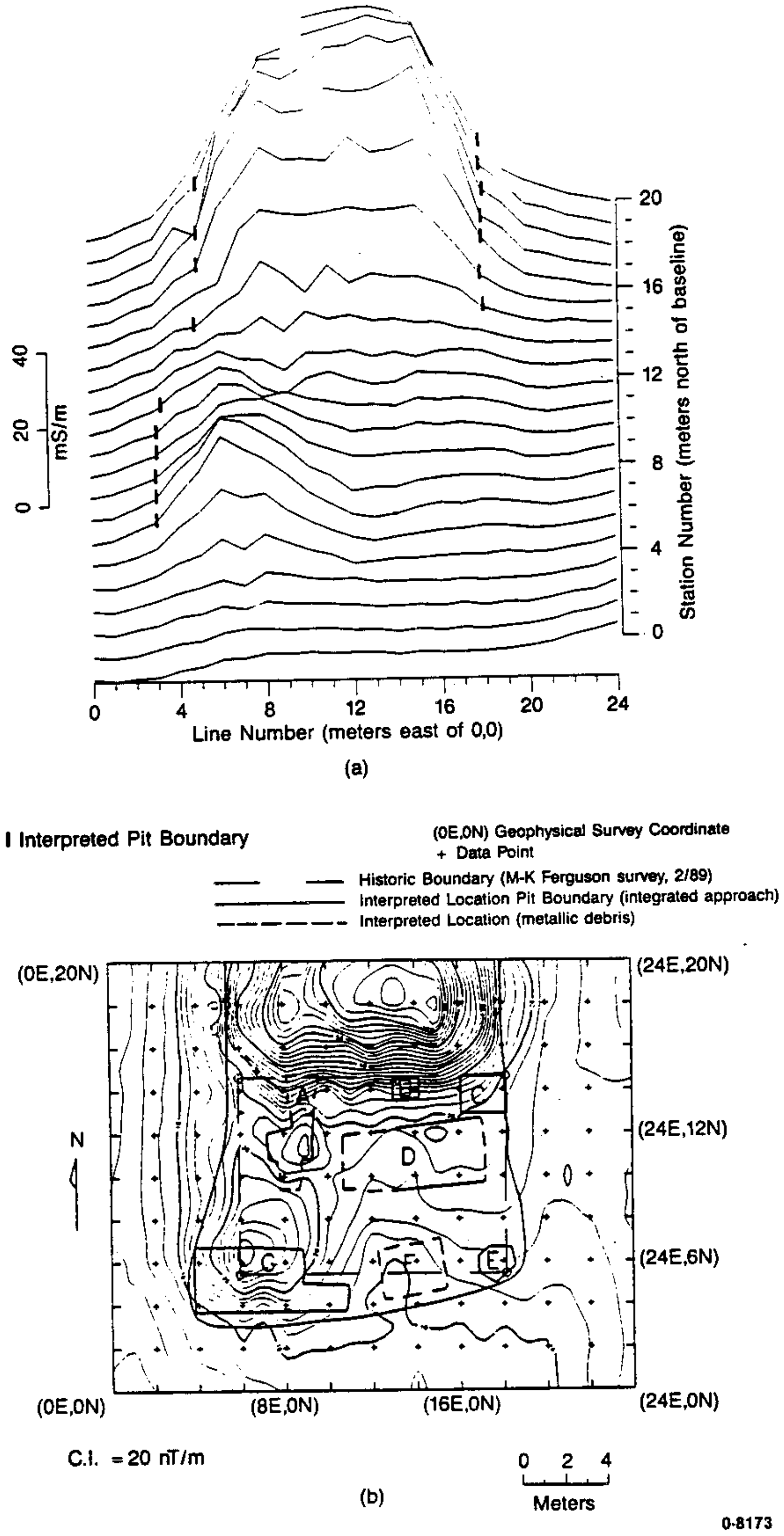


Figure 8-9. Cold Pit induction EM conductivity stacked profiles with interpreted pit boundary (a) and contour map (b) (Hasbrouck, 1989).

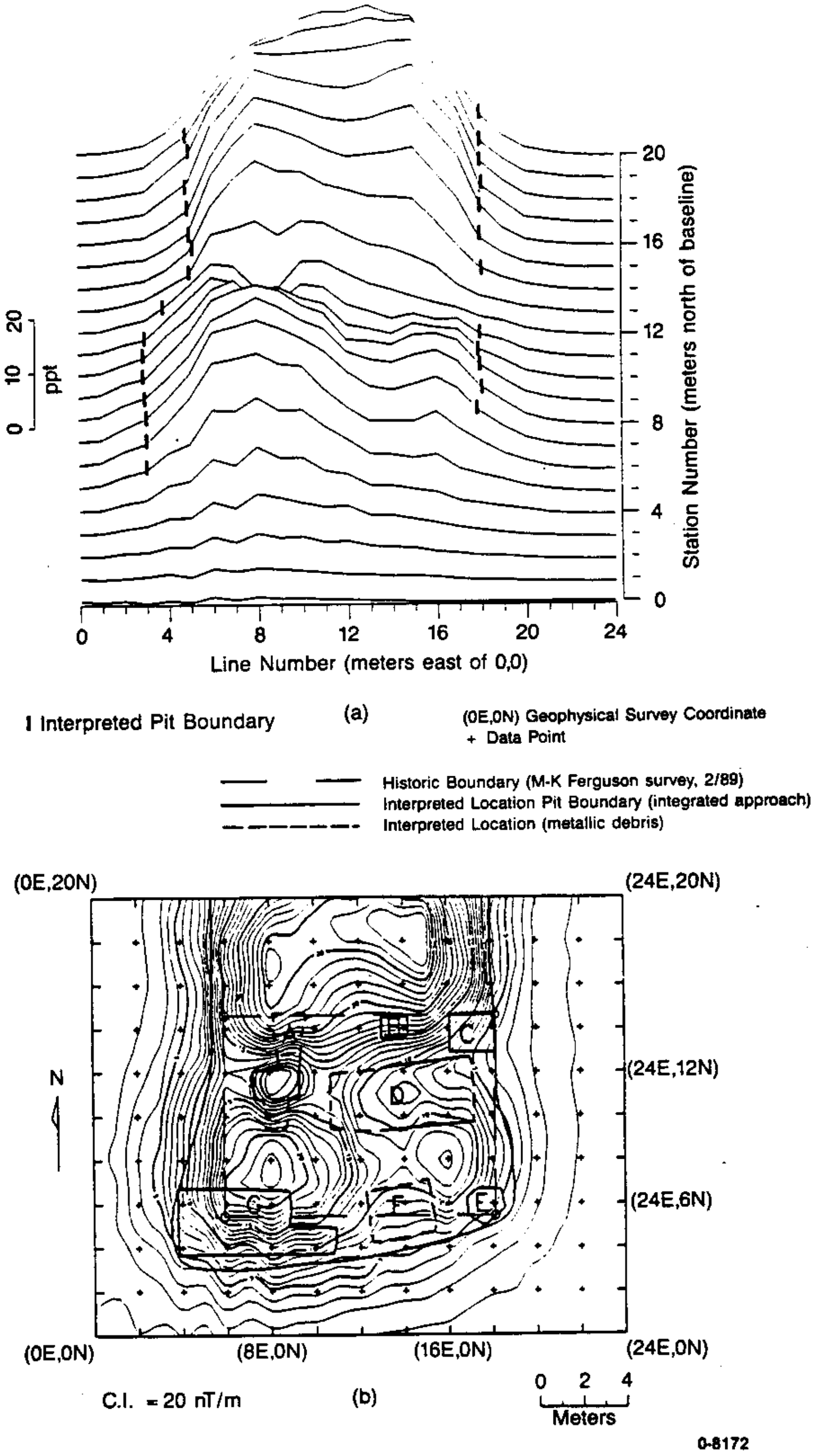


Figure 8-10. Cold pit induction EM inphase stacked profiles with interpreted pit boundary (a) and contour map (b) (Hasbrouck, 1989).

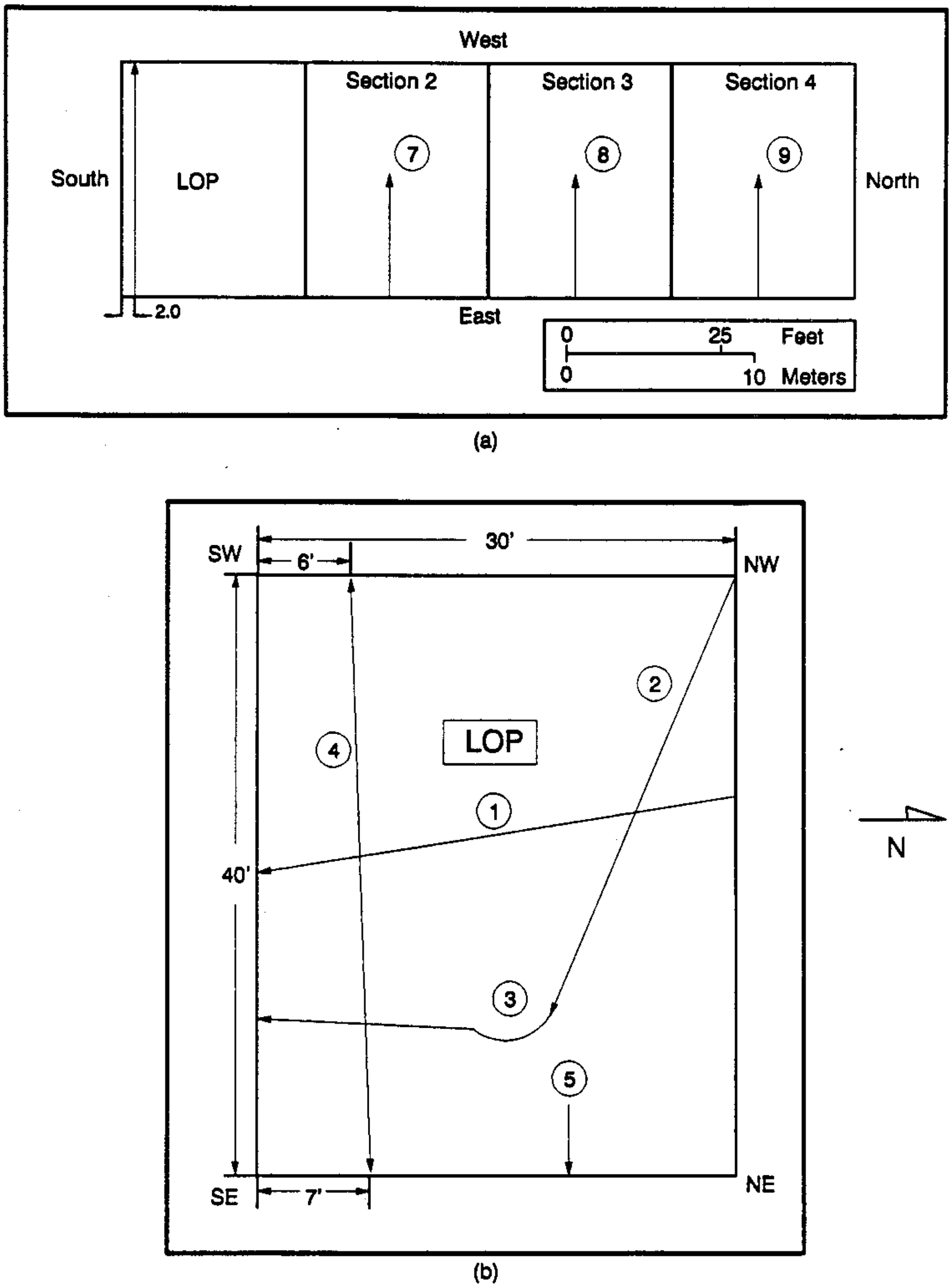


Figure 8-11. GPR test paths at the Cold Pit (a) and within the LOP (b) (EG&G Energy Measurements, Inc., Santa Barbara, California, 1989).

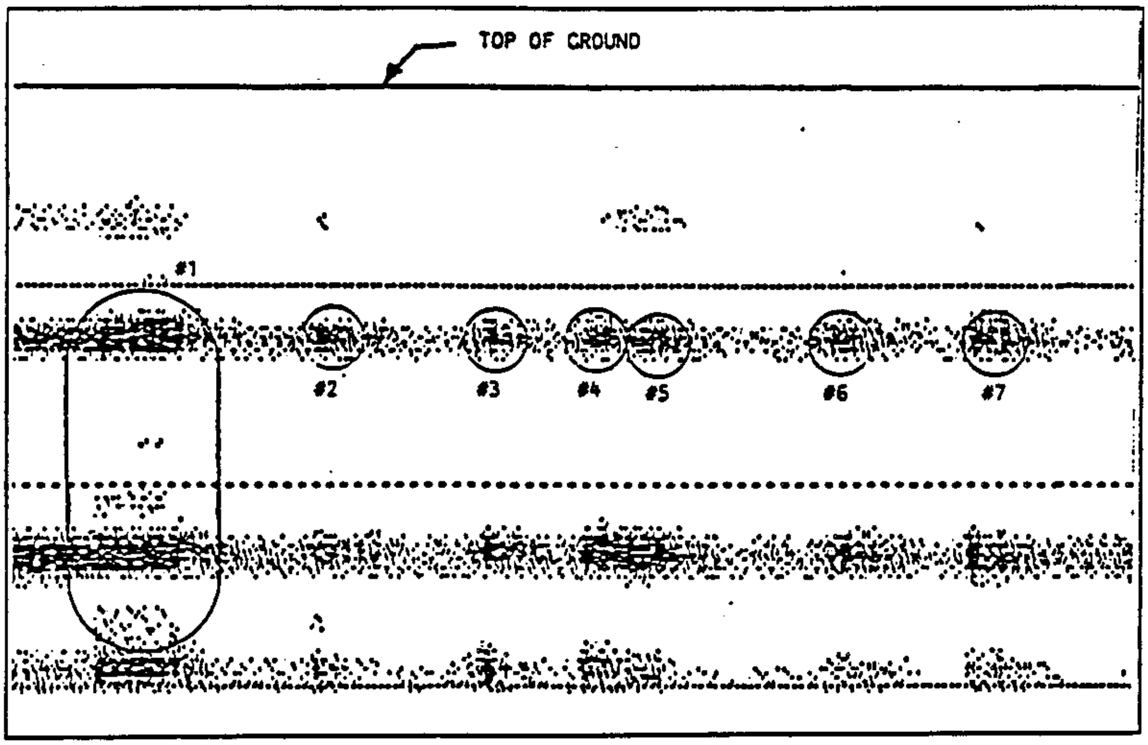
through the use of magnetic gradient and EM inphase data as illustrated in Figures 8-8 and 8-10. Target A was resolved using both magnetic gradient and EM inphase data. Targets D and F were evident only on the EM inphase data, while targets B, C, E, and G were evident only on the magnetic gradient data sets. Because the targets are buried close together, the geophysical responses of the targets interfere, precluding the identification and separation of individual responses. Therefore, target outlines can be interpreted but not defined (Hasbrouck, 1989). The EM inphase technique is limited by its inability to resolve metallic objects that are buried close together. This limitation results from a number of variables including type of object, depth of burial, in situ soil conductivity, and sources of other extraneous electromagnetic noise.

8.1.3.1.3 Resolution of Metallic/Nonmetallic Objects with GPR--The GPR data from the scan of path 6 in the LOP [Figure 8-11(a)] are discussed to illustrate the typical resolution using the GPR. The beginning of a path is shown on the left-hand side of the display, and the end of a path is located on the far right. The direction of travel is always from left to right. Data from the scan of path 6 are illustrated in Figure 8-12, and the data slightly overlap to provide continuity. The following observations were made by EG&G Energy Measurements[a] (see Figure 8-12):

- The intensity stripes on the visual displays are probable soil stratification. The stratification may result from changes in the dielectric constant of the soil. Stratification interfaces occur at 1.2, 2.4, and 3 m (4, 8, and 9.5 ft) below land surface along the scan of path 6.

---

[a] GPR survey information provided by EG&G Energy Measurements, Inc., Santa Barbara, California, 1989.



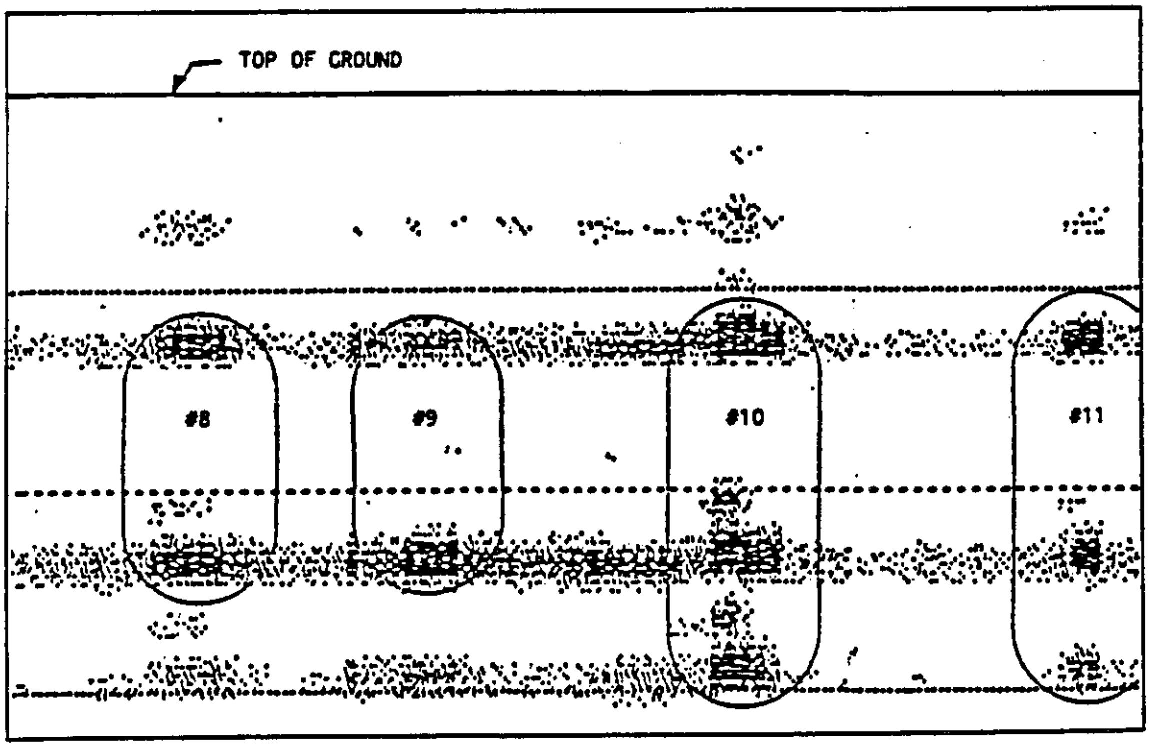


Figure 8-12. GPR data display of path 6 (EG&G Energy Measurements, Inc., Santa Barbara, California, 1989).

- Eleven targets were identified on the scan of path 6. The intensity of the return signal provides a high degree of confidence in the existence of target number 1. Targets number 2 through number 7 appear to be small and close together. Targets number 8 through number 11 are probable metallic objects based on their strong display intensity.

- All targets and/or their reflections show up on the three stratification interfaces precluding the accurate depth determination of the object.

- The apparent close spacing of targets number 4 and number 5 is probably an artifact caused by the inability to pull the radar over the pit surface at a constant velocity.

- Another object may be close to target number 10, but it is difficult to distinguish.

8.1.3.1.4 High Conductivity Area--An area of high conductivity and inphase amplitude was identified in the northern portion of the Cold Pit (Figures 8-9 and 8-10). Neither the total magnetic field data nor the magnetic gradient data indicated a magnetic anomaly in this area (Figures 8-7 and 8-8). Therefore, this area was interpreted as having no ferromagnetic metallic objects and as having a different, more conductive soil type than in other areas of the pit.

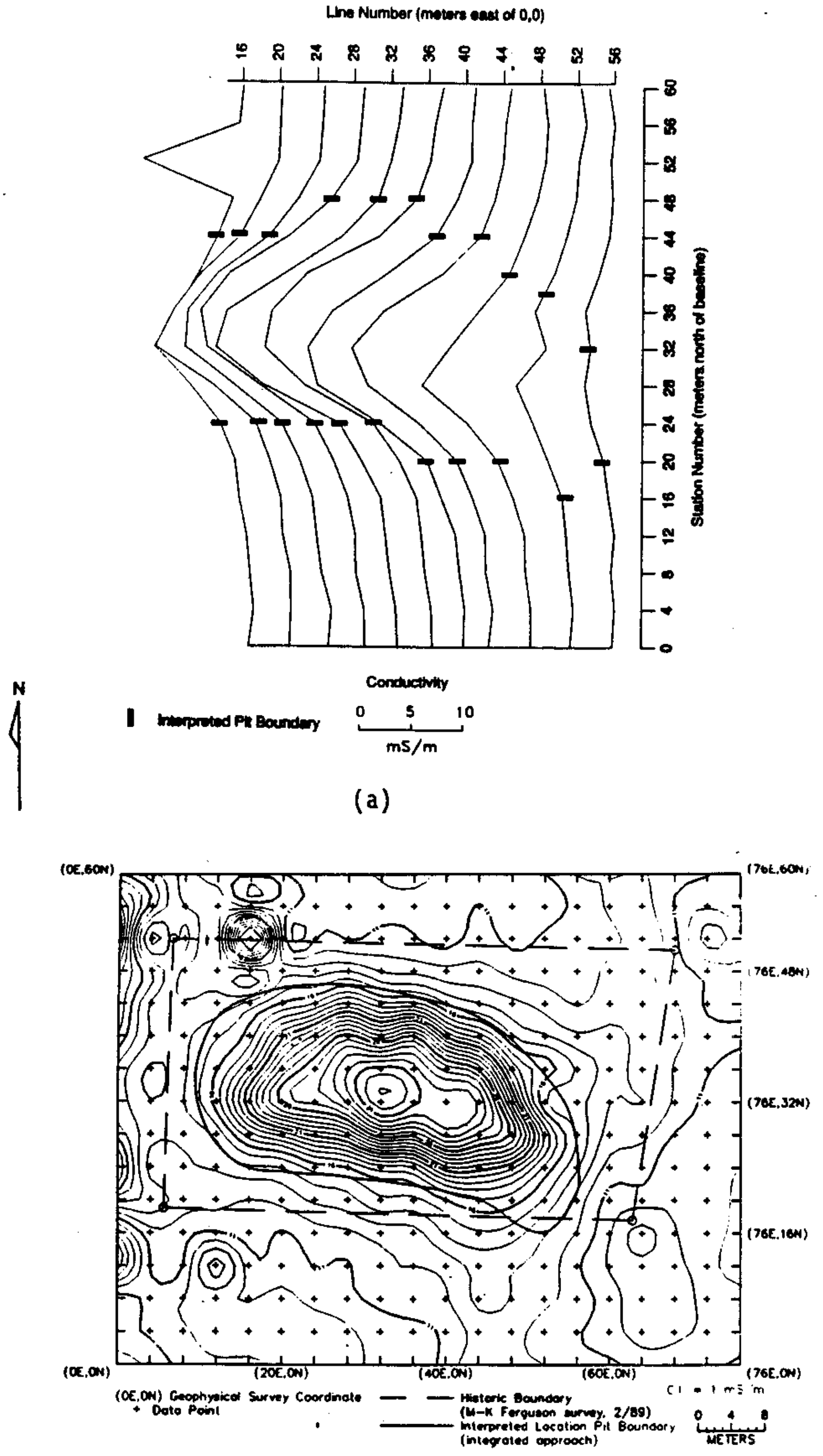
8.1.3.2 Acid Pit. Four types of geophysical techniques were used to resolve the pit boundary at the Acid Pit: total magnetic field, magnetic gradient, EM conductivity, and EM inphase data. A brief summary of the interpreted pit boundary, magnetic and EM anomalies, the conductivity depth section, and the refraction seismic data is presented below.

8.1.3.2.1 Interpreted Pit Boundary--A reconnaissance survey of total magnetic field, magnetic gradient, EM conductivity, and EM inphase data was acquired on a 4-m (13-ft) grid. These regional data sets were evaluated to determine which were applicable to the interpretation of the pit boundary. EM conductivity was the only useful data for determining the pit boundary location. The contour map and stacked profile for these data are presented in Figure 8-13. The EM conductivity data were interpreted in the same manner as at the Cold Pit. That is, the first significant change in slope along a profile was interpreted as an anomalous region, while the inflection point along the profile was interpreted as the pit boundary.

The EM conductivity signature observed may be in response to solvents that were dumped in the pit (Hasbrouck, 1989) and presumably flowed down the sloping pit walls and ponded in the center of the pit. The relatively high conductivity values in the central portion of the pit relative to the low background values outside of the pit support this hypothesis. The interpreted pit boundary is much smaller than the historic pit boundary as illustrated on Figure 8-13. This discrepancy may have been caused by the sloping of the pit walls or by the ponding or concentration of highly conductive material in the central portion of the pit. The pit geometry could not be determined because reliable interpretations were precluded because of the presence of an approximately 1 m (3.3 ft) thick frozen surface layer.

8.1.3.2.2 <u>Magnetic and EM Anomaly</u>--Detailed profile lines of total magnetic field, magnetic gradient, EM conductivity, and EM inphase were shot on a 1-m (3.3-ft) grid to delineate a magnetic and EM inphase anomaly located near station 32N along line 20E as shown in Figure 8-14. This anomaly could not be explained by surface culture. A computer generated model of the total magnetic field anomaly resembled the edge of a basalt flow as displayed in Figure 8-15. There was no geophysical evidence to confirm the presence of a 3000-gal tank thought to be located within the Acid Pit (Hasbrouck, 1989).

8.1.3.2.3 <u>Conductivity Depth Section</u>--EM conductivity data were acquired at 10-m (33-ft) stations along line 32E to an approximate effective depth of 50 m (164 ft) to generate a depth profile across the Acid Pit. Data were acquired in both a horizontal and vertical direction using four different coil spacings: 3.66, 10, 20, and 40 m (12, 33, 65, and 131 ft). A cross



(a)

(b)

Figure 8-13. Acid Pit induction EM conductivity stacked profiles with interpreted pit boundary (a) and contour map (b) (Hasbrouck, 1989).

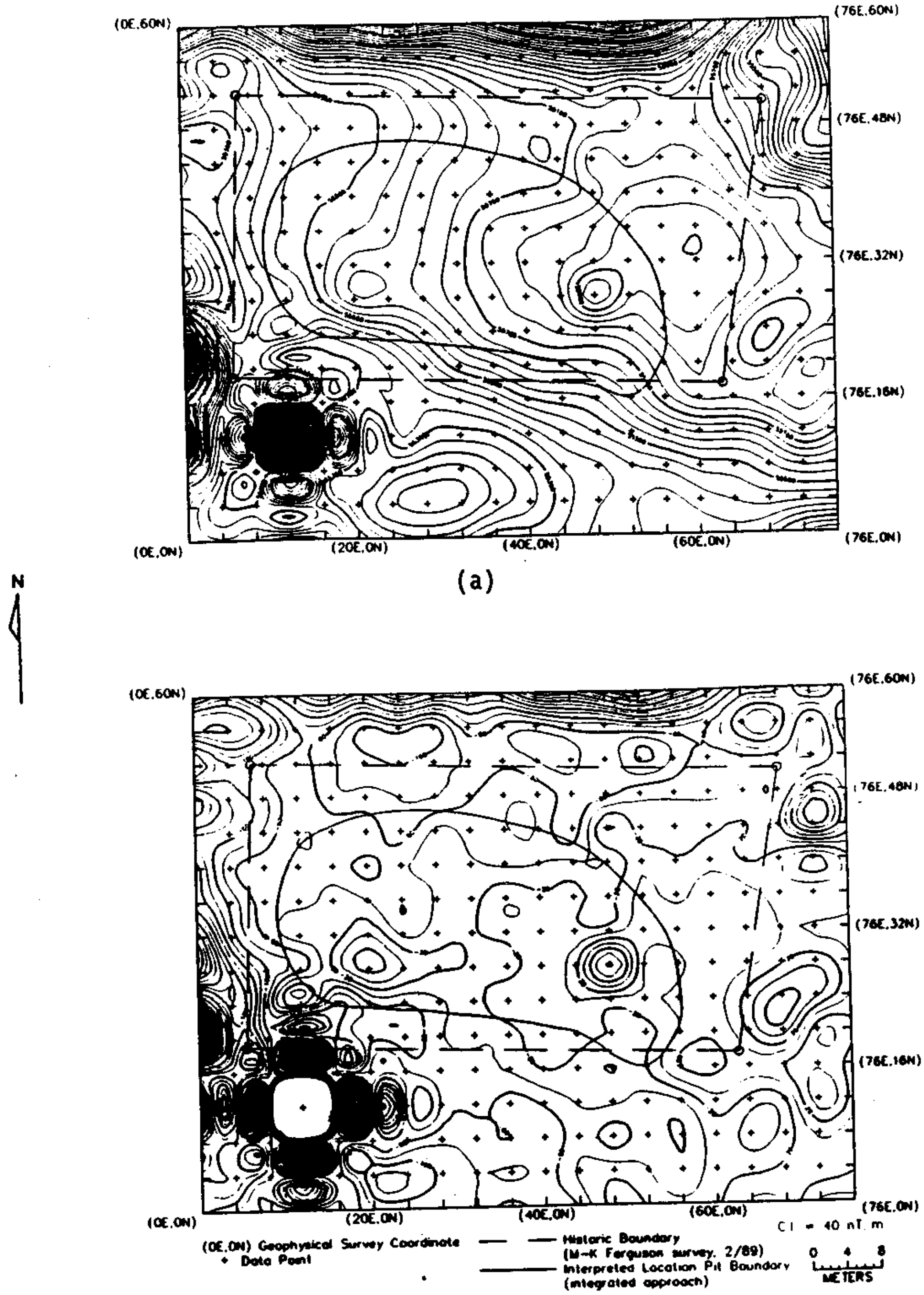


Figure 8-14. Acid Pit total magnetic field (a) and vertical gradient of total magnetic field (b) (Hasbrouck, 1989).

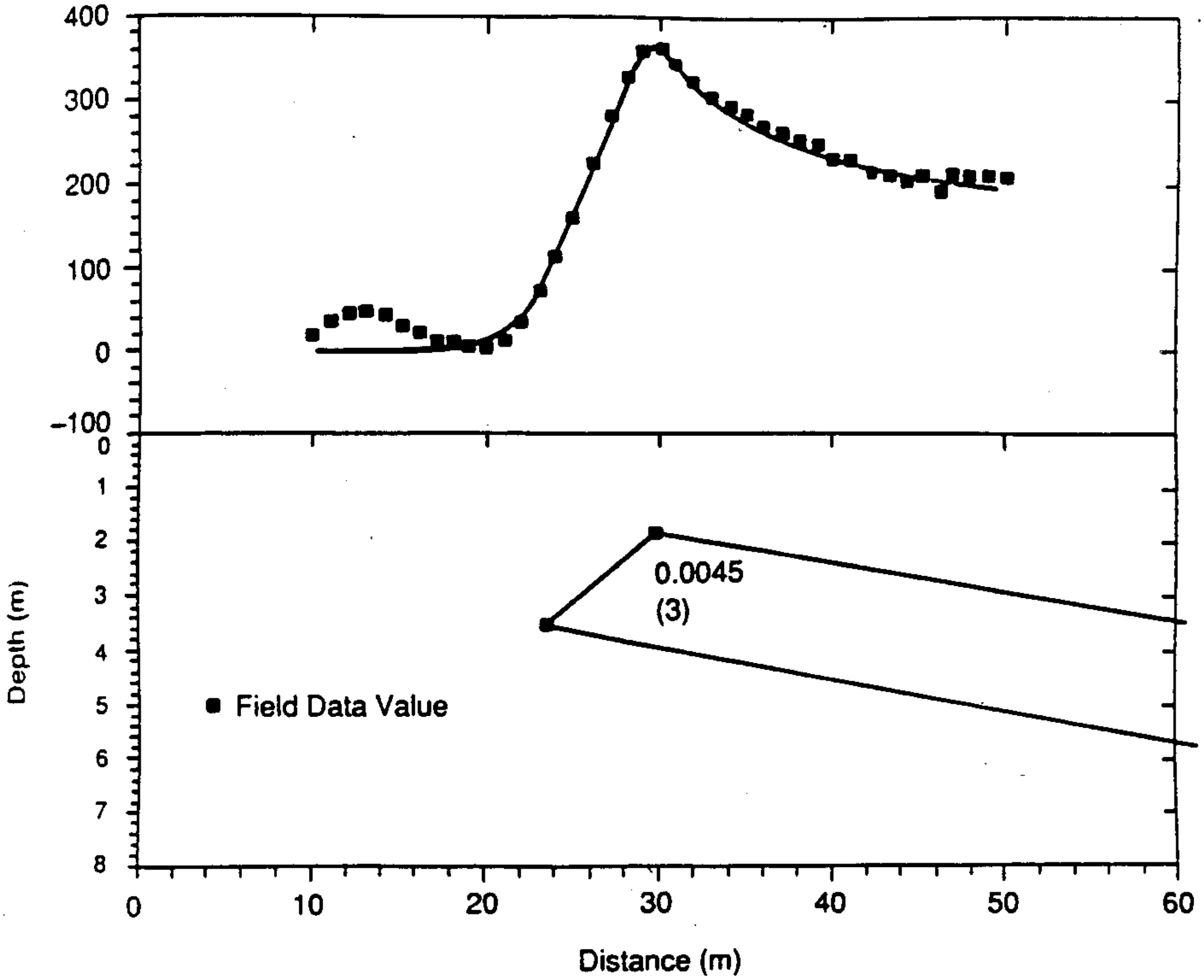


Figure 8-15. Acid Pit Line 20E computer model of total magnetic field anomaly (Hasbrouck, 1989).

section of conductivity variation versus depth was generated by converting apparent resistivity to apparent conductivity and plotting the data at the corresponding station and depth (Hasbrouck, 1989).

The conductivity high located between stations 30 and 38, and extending to an approximate depth of 5 m (16 ft), was interpreted as an indication of the solvent waste (Figure 8-16). The relatively high conductivity values extend to approximate depths of 18 m (59 ft) and may be the result of downward migration of the waste. At an approximate depth of 25 m (82 ft), a marked change in conductivity occurs that was interpreted as a change in the character of the basalts or a change in the relative thickness of the basalts and interbeds. The data interpretation was limited by the data acquisition grid (i.e., low resolution) and by the lack of understanding of the subsurface geology.

8.1.3.2.4 Refraction Seismic Data--Two refraction seismic surveys were acquired perpendicular to each other along lines 32E and 32N, based on the results of the magnetic and EM reconnaissance surveys. The offset between the seismic source and receiver was 2, 8, and 14 m (6.5, 27, and 46 ft), corresponding to an estimated depth of investigation of 6, 7.5, and 9 m (20, 25, and 29.5 ft). The velocity data detected at the receivers were a combination of seismic energy from the base of the 1 m (3.3 ft) frozen surface layer and from the bedrock; therefore, accurate depth determinations could not be made.

8.1.3.3 Pit 9. Six geophysical techniques were used to define the pit boundary location and the location of metallic debris: total magnetic field, magnetic gradient, EM conductivity, EM inphase, very low frequency EM, and GPR. Reconnaissance total magnetic, magnetic gradient, EM conductivity, EM inphase and very low frequency EM were acquired on a 4-m (13-ft) spacing.

Pit 9 is approximately 25-years old and covered with vegetation. A 4.5 m (15 ft) wide test area was cleared near the southern boundary of the pit (Figure 8-17) to provide the necessary ground contact for the GPR. Two inches

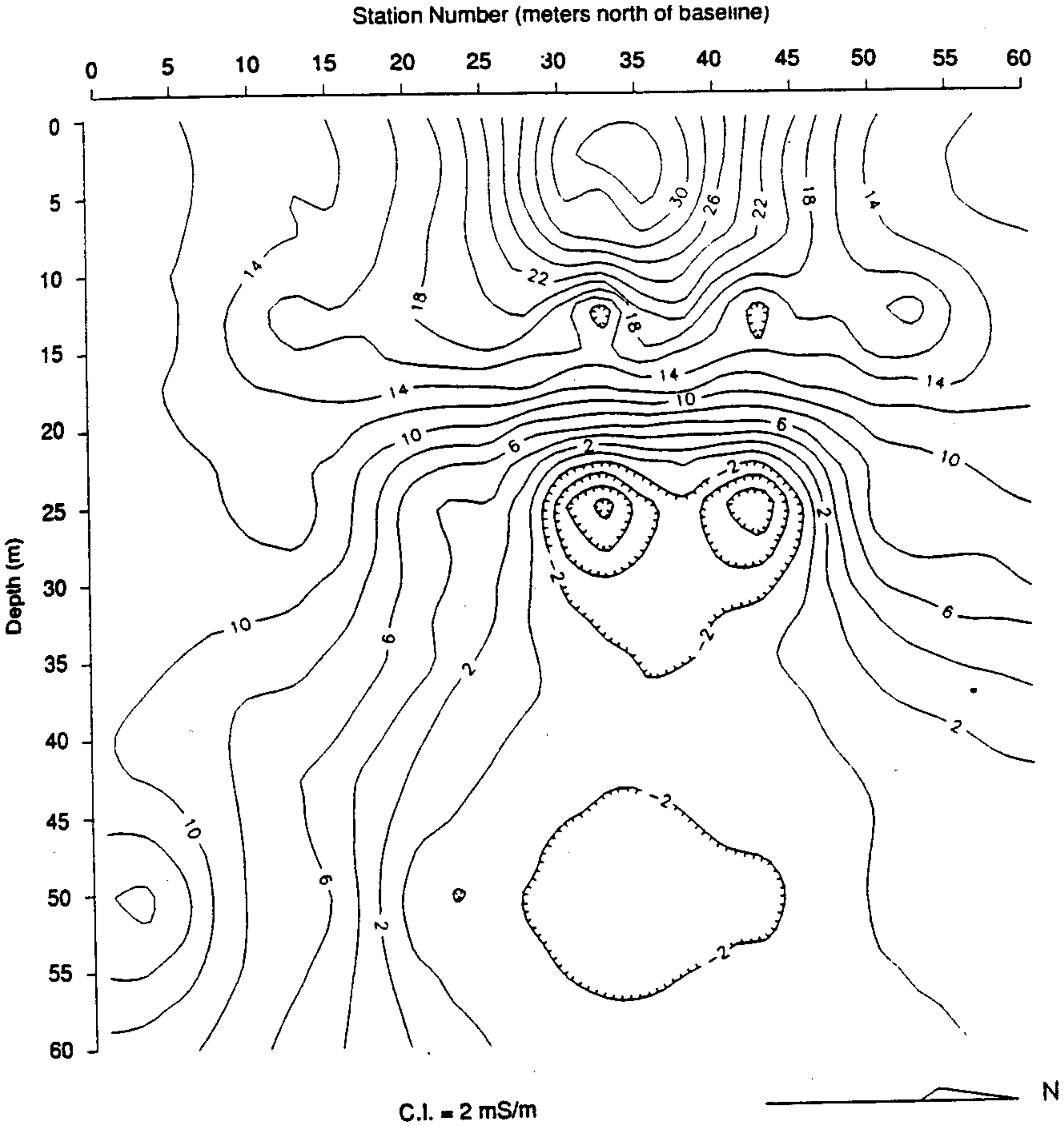


Figure 8-16. Acid Pit induction EM conductivity depth section line 32E (Hasbrouck, 1989).

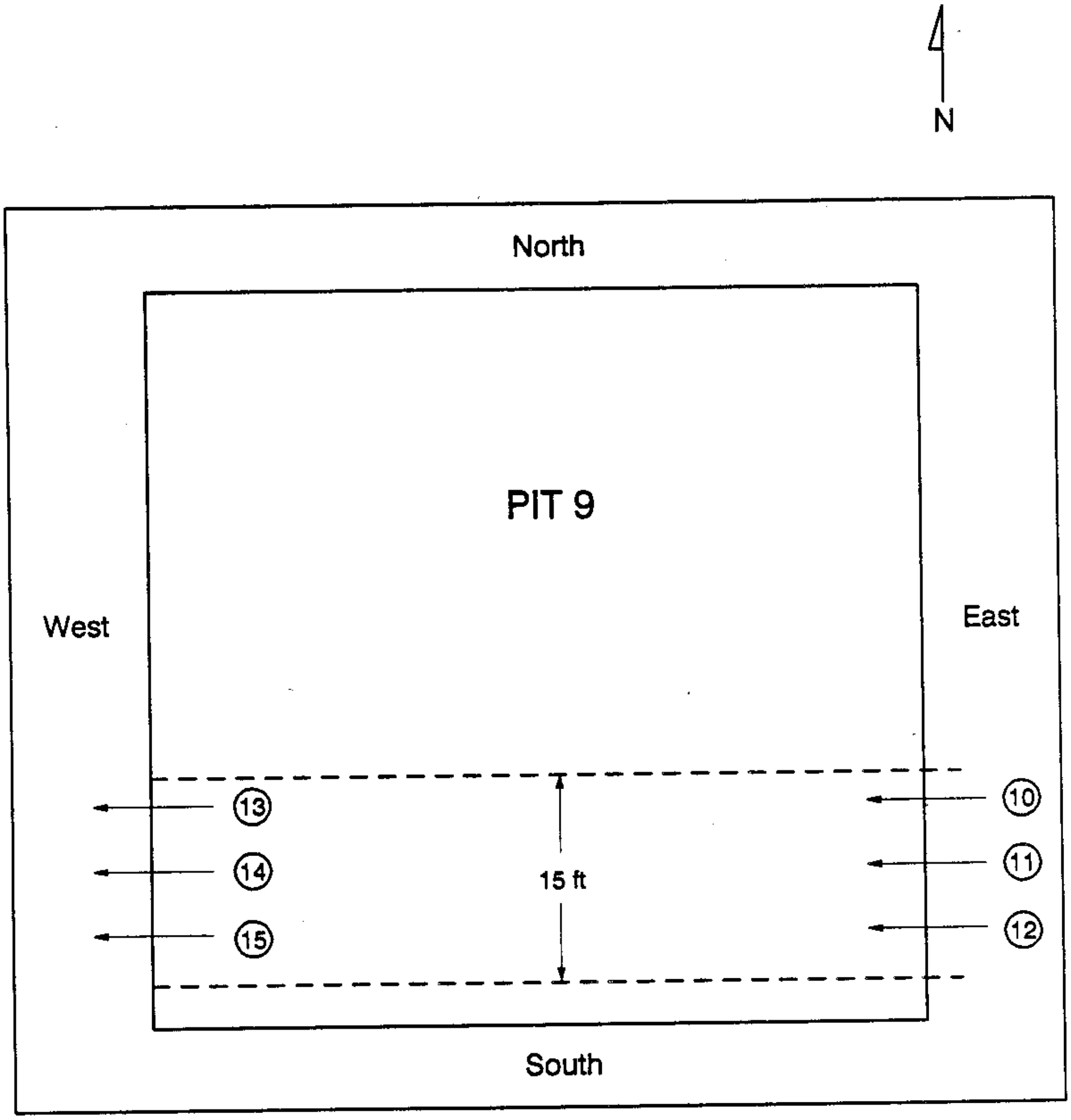


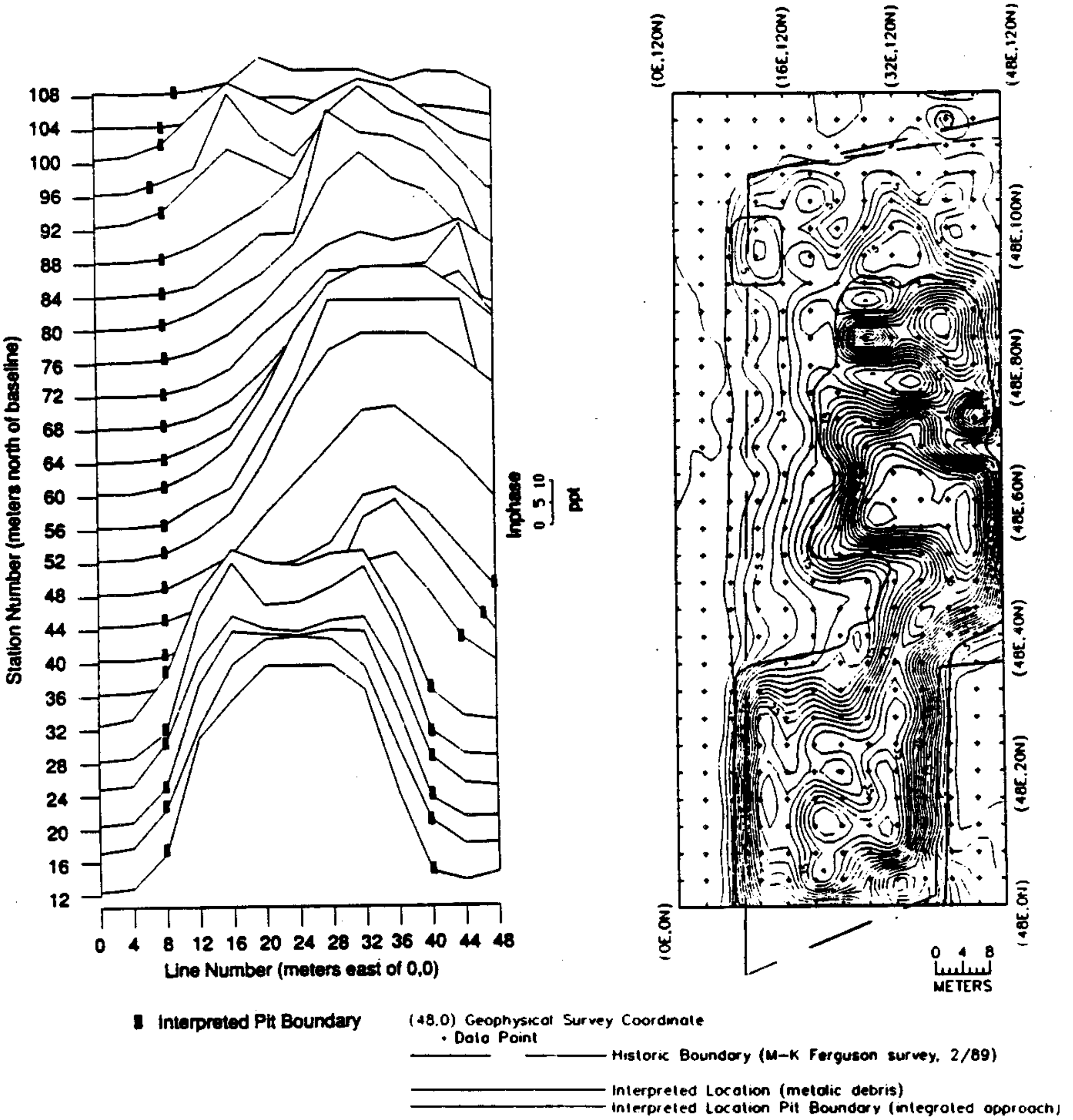
Figure 8-17. GPR test paths at Pit 9 (EG&G Energy Measurements, Inc., Santa Barbara, California, 1989).

of top soil were removed along the test swath, which extended from the western to the eastern boundary of Pit 9. Three scan paths were made in the cleared area along the west and east boundaries of Pit 9 (Figure 8-17). The GPR was not calibrated because the objective of the demonstration was to locate pit boundaries. Therefore, a dielectric constant for Pit 9 soil was not established, and no depth determinations could be made.

8.1.3.3.1 Pit Boundary Location--From evaluation of the reconnaissance data, it was determined that only the EM inphase was useful for interpreting the pit boundary location. The contour map and stacked profiles from these data are displayed in Figure 8-18. The data were interpreted in the same manner as at the Cold Pit and the Acid Pit (i.e., the inflection point along a profile was interpreted to be the pit boundary). However, north of station 36 the data were difficult to interpret because of the subtle character of the anomalies encountered. The interpreted pit boundary was 2 m (6.5 ft) beyond the historical pit boundary.

Using GPR, the eastern border of Pit 9 is indicated by the intensity of the soil stratification stripe. The displays from scan paths 10, 11, and 12 on the east boundary of Pit 9 are reviewed to illustrate the resolution of this geophysical technique (Figure 8-19). Immediately west of target number 3 on path 10, the intensity of the soil stratification stripe increases; this may indicate that the GPR had entered the pit [Figure 8-19(a)]. On path 11 west of the target, illustrated on Figure 8-19, the intensity of the soil stratification stripe increases; this may indicate the pit boundary. The intensity of the soil stratification did not change along path 12, thereby making the pit boundary indistinguishable.

8.1.3.3.2 Metallic Debris--Metallic debris in Pit 9 was interpreted by using a combination of EM inphase and magnetic data. There is general agreement between the waste drum location shown in Figure 8-4 and the anomalous areas indicated on the contoured representation of the geophysical data shown in Figures 8-18 and 8-20. Geophysical anomalies occur north of the reported drum boundary on both the total magnetic field and EM inphase data.



(a)

(b)

Figure 8-18. Pit 9 induction EM inphase stacked profiles with interpreted pit boundary (a) and contour map (b) (Hasbrouck, 1989).

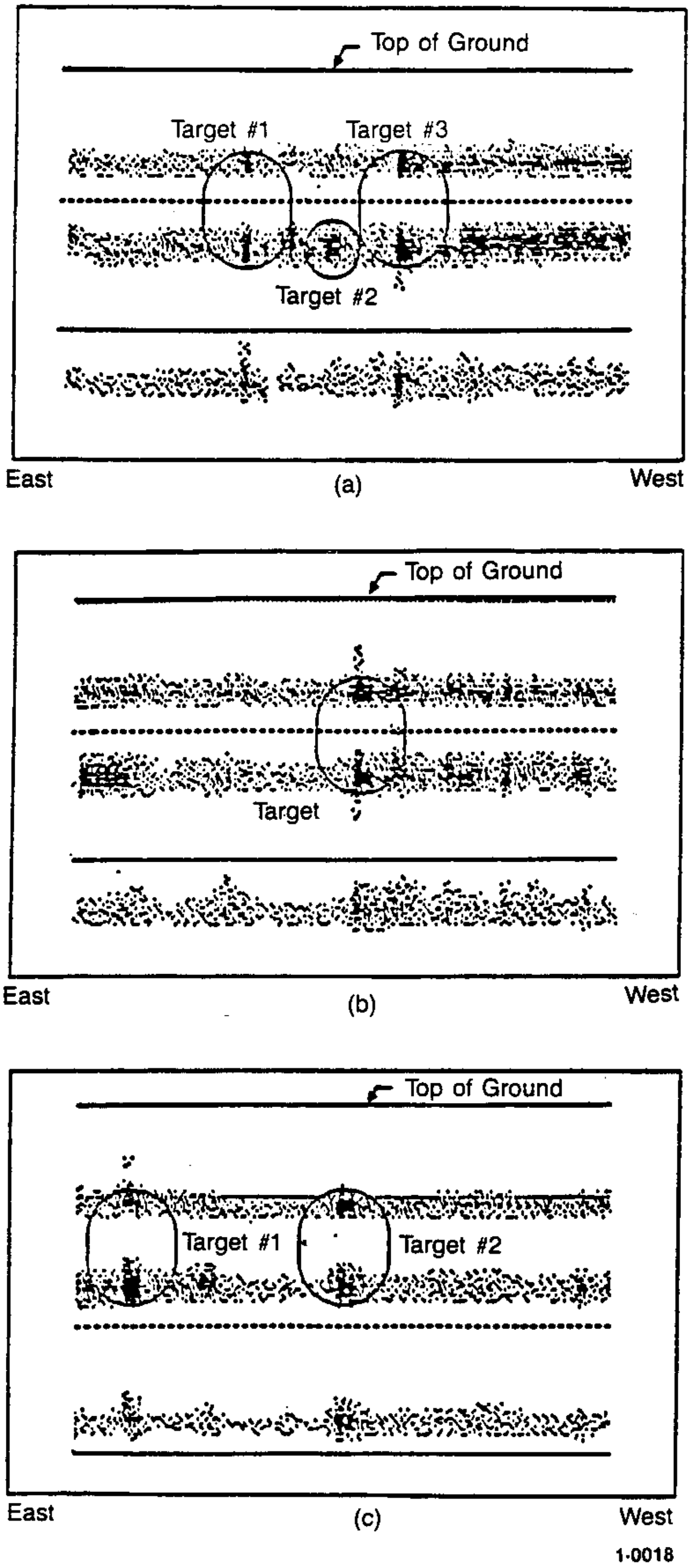


Figure 8-19. GPR data display of path 10 (a), path 11 (b), and path 12 (c) at Pit 9 (horizontal scale unknown, vertical scale not calibrated) (EG&G Energy Measurements, Inc., Santa Barbara, California, 1989).

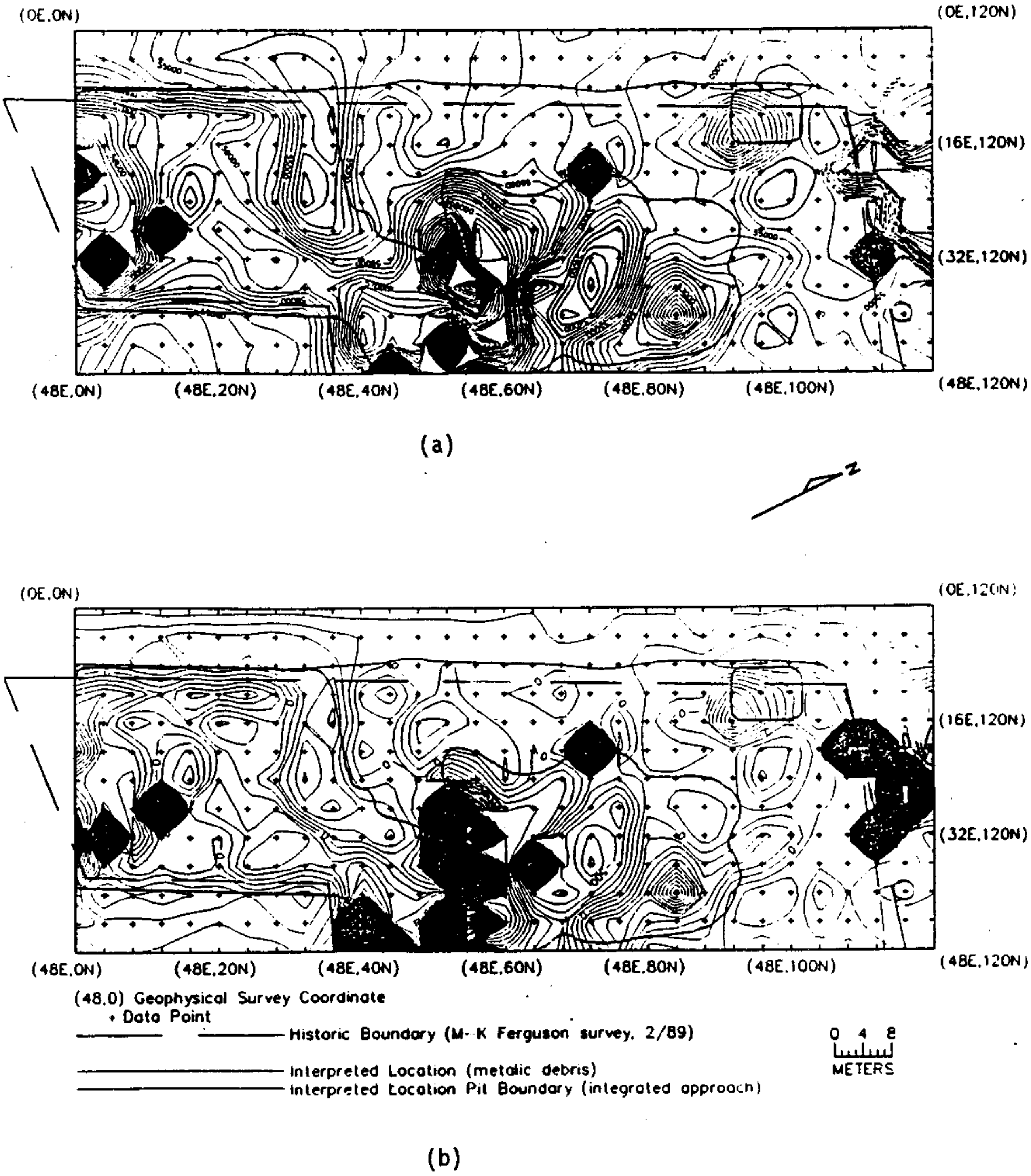


Figure 8-20. Pit 9 contour map of total magnetic field (a) and vertical gradient of total magnetic field (b) (Hasbrouck, 1989).

Anomalies at line 40E, station 84N; (on the total magnetic field data and on the EM inphase data) at line 28E, station 84N; and at line 44E, station 72N were interpreted to be metallic debris. Their presence could indicate that either the drums had moved north or other debris is present. Figure 8-21 is an integrated interpretation of the location of metallic debris using both geophysical techniques.

Other anomalies were interpreted to be (a) metallic debris that corresponded with the historic location of Pit 7 (line 40E, 116N), (b) the result of interference from a nearby power line, or (c) bad data resulting from an instrumentation problem. Other large magnetic anomalies (located between lines 28E and 48E, stations 52N and 60N) were interpreted to be large magnetic sources other than steel drums. However, it was not possible to define the specific type of object.

Several targets were delineated with the GPR. Along path 10, in Figure 8-19, three possible objects appear to be outside of the pit. Target number 3 is possibly a metal object based on the intensity of the signal. A single target was encountered along path 11, also in Figure 8-19. This target is probably real because of the intensity of the signal and it appears to coincide with the location of target number 3 on path 10. Two targets were identified on path 12 (see Figure 8-19) both probably outside of the pit boundary.

8.1.3.4 <u>Summary and Conclusions</u>. Magnetic and induction EM surveys (a) determined pit boundaries and (b) outlined, or confirmed the absence of, metallic debris at all of the surveyed pits. Pit boundary locations were no more accurate than the detailed sampling interval that was 1 or 2 m (3 or 7 ft) in this study. Metallic debris can be detected using a combination of EM techniques and measurements of orthogonal components of the magnetic field and its gradient. However, where objects are closely spaced, the geophysical responses of the objects interfere, making it difficult to identify the specific type of object. The subsurface geoelectric section can be defined by using detailed EM conductivity sounding data.

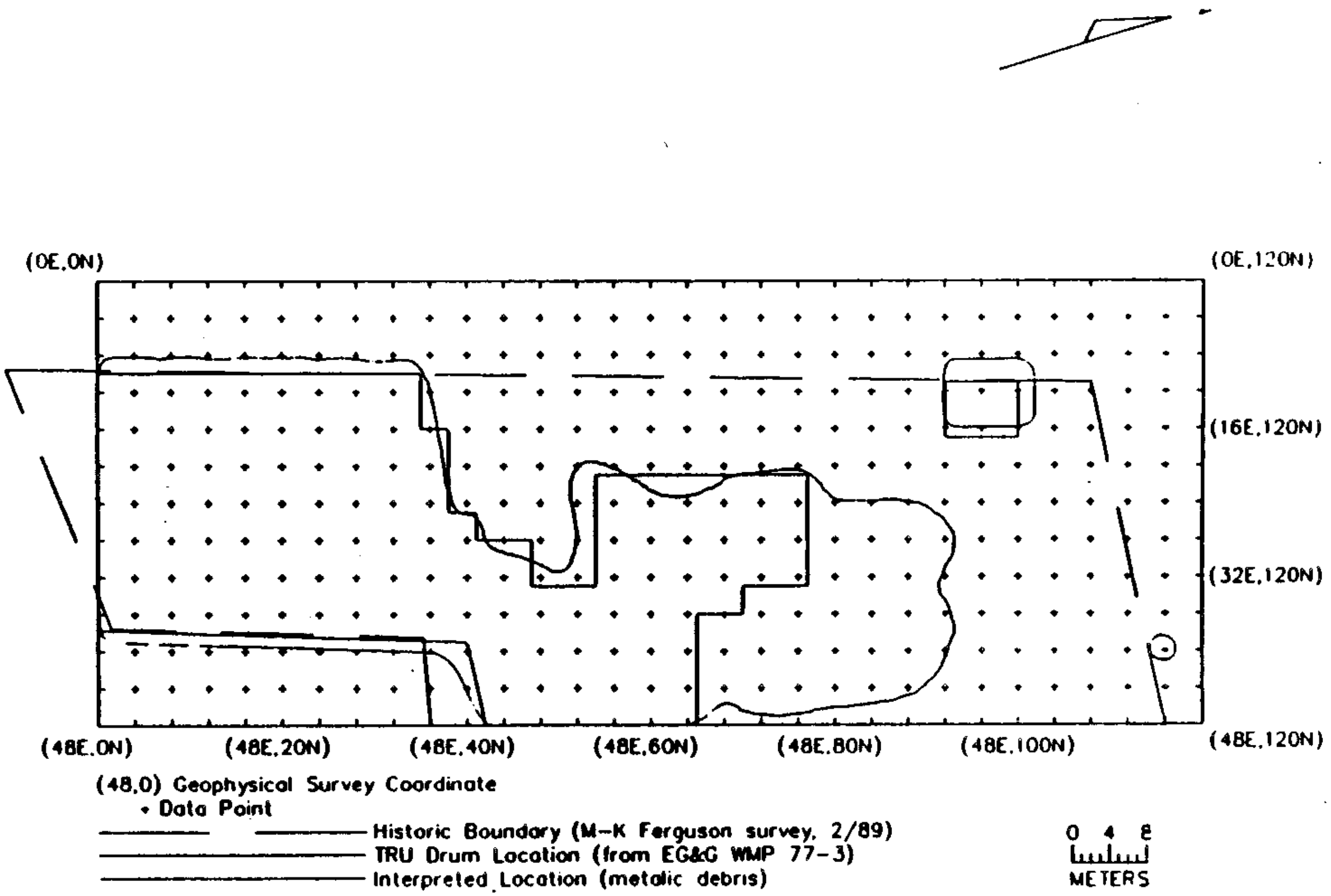


Figure 8-21. Pit 9 interpretation of the location of metallic debris (Hasbrouck, 1989).

Very low frequency EM was not useful because of its lack of resolution. A combination of compressional and shear wave refraction seismic data could be used in outlining pit boundaries and determining the depth of pits. However, this technique would not be useful in areas where there was a high concentration of metallic debris that would scatter the seismic energy. The refraction seismic data must also be acquired during a time of year when the ground surface is not frozen.

The GPR system was able to locate many targets but was unable to provide accurate depth and target alignment information. Because of these limitations, the system cannot be effectively used to support waste retrieval. The boundaries could be located on the Cold Pit but not on Pit 9. The age of Pit 9 and the amount of soil settling may have been the cause of the poor resolution of the Pit 9 boundaries. Four factors were identified as possibly contributing to the poor data resolution using GPR at the SDA:

1. Inappropriate antennas were used for the soil type and class of targets

2. The soil at the SDA attenuated the radio frequency signal much more than anticipated

3. The soil stratification at the SDA produced large target reflections that precluded accurate depth determination

4. Slight oscillations in part of the radio frequency circuitry produced bad data.

8.2 Geologic Investigations

Detailed stratigraphic and structural subsurface data are required to understand the subsurface features at the SDA and their continuity and to develop a conceptual model for predicting potential contaminant pathways. The identification of potential contaminant migration paths is required in order to develop effective monitoring procedures. Historically, detailed shallow subsurface data at the SDA have been obtained from extensive drilling programs that are both time consuming and expensive. Thus, the high resolution seismic reflection method was proposed to obtain the detailed stratigraphic and structural data required for site characterization. The objectives of the geologic investigation are summarized in Section 8.2.1, a description of the seismic reflection method is provided in Section 8.2.2, the procedures for acquiring the seismic data are described in Section 8.2.3, and the results of the seismic investigation method are discussed in Section 8.2.4.

8.2.1 Data Objectives

The objective of this investigation was to map the near surface stratigraphy at the SDA using the seismic reflection method. The stratigraphic interval extending from the top of the first basalt flow to below the 34-m (110-ft) interbed was specifically targeted for geophysical characterization. The geophysical data collected by the Kansas Geological Survey would be used to supplement other subsurface data obtained from wells and boreholes drilled in and around the SDA (EG&G, 1988a). The following requirements were identified: (1) determine basalt flow thicknesses and delineate voids and cracks between flows, if possible, (2) delineate sedimentary interbeds and map their thickness, and (3) determine the nature and extent of any perched water zones (EG&G, 1988a).

8.2.2 Description of the Seismic Reflection Method

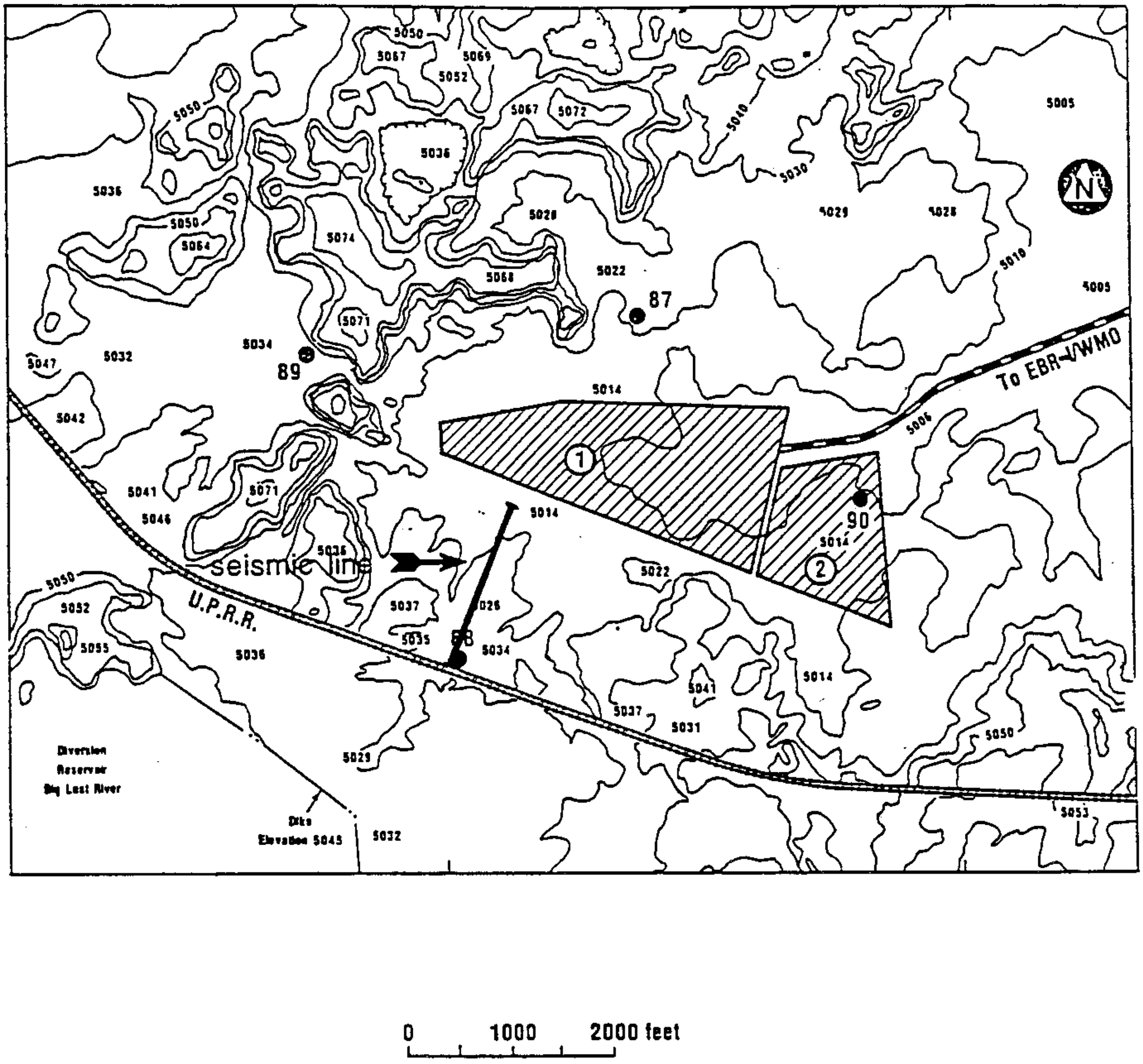
The seismic reflection technique depends on the existence of discrete velocity and/or density differences in the subsurface. Discrete changes in either the bulk density or seismic velocity produce acoustical contrasts. The measure of acoustical contrast (acoustical impedance) is the product of bulk density and the velocity of seismic waves traveling within a material. Typically, acoustical contrasts occur at boundaries between geologic layers; however, manmade boundaries such as tunnels or mines also produce an acoustical contrast. A source of seismic waves transmits energy onto subsurface layers where it is reflected back to surface receivers (geophones).

8.2.3 Procedures for Data Acquisition

Seismic data were collected along one 500-m (1640-ft) line that extended from about 50 m (164 ft) south of the SDA perimeter fence to approximately 50 m (164 ft) south of Well 88 (Figure 8-22). The lithology of the surface material varied from fine sand to basalt. The basalt outcrops along the line presented a potential problem in maintaining consistent source and receiver coupling to the ground.

The seismic reflection data were recorded using the common depth point acquisition method. Preacquisition testing was done in order to define a set of preferred field parameters and equipment for the conditions at the site. The following acquisition parameters were determined based on this preliminary testing. An end-on source-receiver geometry was used with a source-to-closest-receiver distance of 12 m (39 ft) and a source-to-farthest-receiver distance of 35 m (115 ft). These offset distances were selected to maximize recording reflections from an approximate depth of 30 m (94 ft). A 1-m (3-ft) shot and receiver group interval resulted in the resolution of a 0.5 m (2 ft) subsurface horizontal sampling interval. The receivers were three undamped 40-Hz geophones, connected in series on 14-cm (6-in.) spikes and equally spaced over the 1-m (3-ft) interval. Use of the 40-Hz geophones helped to attenuate much of the wind that was parallel to the line, and they produced a better response to reflection information between 75 and 100 Hz.

The source for the seismic data was a 0.50 caliber sport rifle fired into the ground. The 0.50 caliber was chosen because it has a characteristic high-frequency seismic pulse, its low ratio of ground-roll-to-body waves, and its total energy output. Holes could not be augered for the downhole placement of the rifle because of the near-surface and outcropping basalt. Because the surface rifle imparted 3 to 6 dB less recordable seismic energy into the ground than the downhole rifle, two shots were fired at each station to increase the total recorded seismic energy of the surface rifle. The second shot possessed approximately 3 dB more recordable seismic energy than the first. A silencer was used to damp the air wave and to provide a



Notes: Contour Interval 10 feet. Datum is Sea Level.
Observation Well (•) and number (87,88,89, and 90)
Tapping the Snake River Plain Aquifer

① Subsurface Disposal Area (SDA)

② Transuranic Storage Area (TSA)

Figure 8-22. Location of seismic reflection line at the SDA (Miller et al., 1988 in EG&G, 1988a).

containment vessel for any fragments generated as a result of firing into a hard surface. Data were acquired by the Kansas Geological Survey (EG&G, 1988a).

Data were recorded on an I/O DHR 2400 seismograph in the field. Data processing was done on a 32-bit Data General MV-20000 computer at the Kansas Geological Survey. Details on the field acquisition of the data and of data processing are provided by the Kansas Geological Survey (EG&G, 1988a).

8.2.4 Results of Seismic Reflection Method

The 34-m (110-ft) interbed was detected using the seismic reflection method. However, lateral variations in the velocity within the basalts coupled with substantial thickness variations in the unconsolidated surficial sediments made absolute depth calculations impossible. Based on refraction calculations, the surficial unconsolidated layer was calculated to range in thickness from 0 to approximately 8 m (26 ft). The 73-m (240-ft) interbed could be detected on some of the intermediate processed sections, and it could be feasible to map the 73-m (240-ft) reflector using seismic reflection designed to look deeper than 30 m (98 ft). The seismic investigation was only partially successful because of the lack of subsurface data for the study area. That is, the seismic line only tied in with one well, Well 88, which provided the only stratigraphic data for that area. In a stratigraphically complex area, such as at the SDA, additional subsurface well data are required in order to calibrate what the geophysical response means. Ongoing studies based on hydrologic and core data have demonstrated the heterogeneity of the shallow near-surface stratigraphy at the SDA (Wood, 1989; Knutson et al., 1990). The Kansas Geological Survey concluded that without additional drilling information, confident determination of the structure and stratigraphy at the SDA could not be made using the seismic reflection method (Miller et al., 1988 in EG&G, 1988a).

8.3 Recent Geophysical Investigations

Ebasco Services Incorporated (Ebasco) conducted a seismic refraction survey at the SDA in May 1989. This investigation was initiated to evaluate the potential contaminant migration from Pit 9 and the Acid Pit. Subpit sampling was proposed to assess contaminant migration out of the pits, minimize environmental impacts, and minimize worker health and safety risks.[a] To avoid encountering waste during sampling operations, sampling was proposed for the top of the basalt underlying the pits.

The seismic refraction survey was conducted to determine the depth to basalt at Pit 9 and the Acid Pit. The justification for using this geophysical technique was that depth can be calculated from the velocity difference of sound waves traveling through basalt versus the overlying fill material. Five lines were shot at both the Acid Pit and Pit 9. Two lines were located parallel to the longest dimension of the pit boundary. The other three lines were located perpendicular to the long axis of the pit. Details on field procedures and data acquisition were provided by Ebasco.[a]

Predicted depths to basalt within the Acid Pit ranged between 5 and 6 m (16.4 and 19.6 ft) based on the seismic refraction survey. The logs from shallow boreholes W08 and W13, located to the west of the Acid Pit, indicated the depth to basalt at approximately 6 and 5.5 m (19.6 and 18 ft), respectively. The predicted depths to basalt ranged between 4 and 5 m (13.1 and 16.4 ft) in Pit 9 based on the seismic. The depth to basalt based on subsurface control from Borehole W02 was approximately 4.5 m (14.7 ft) compared to 5 m (16.4 ft) based on seismic. The predicted depth to basalt based on seismic compared favorably with the measured depths determined from these boreholes drilled as part of the SIP. However, since the basalt surface is irregular, the accuracy of the depth determination based on seismic diminishes away from the survey lines.

---

a. Subpit sampling information provided by Ebasco Services, Inc., Bellevue, Washington, March 1990.

9. Hydrogeologic Characterization at the RWMC

9. HYDROGEOLOGIC CHARACTERIZATION AT THE RWMC

The hydrogeologic characterization investigation was proposed to conduct a quantitative assessment of existing information pertaining to the vadose zone below 73 m (240 ft) and to the aquifer beneath the RWMC. The focus of the investigation was to obtain insight on potential contaminant pathways. The proposed strategy for conducting the investigation is described in Section 9.1, the investigation procedures are discussed in Section 9.2, and the results are summarized in Section 9.3.

9.1 Proposed Strategy in Work Plan

The proposed strategy in the December 1988 RFI Work Plan consisted of collecting, compiling, and analyzing all existing hydrogeologic data pertinent to the RWMC (EG&G, 1988a). The existing data consisted of wellbore completion information, water level measurements in wells, gauging station measurements on the Big Lost River, INEL diversion-channel water level recorder measurements, and aquifer tests.

9.2 Investigation Procedures

The investigation procedure consisted of summarizing the existing hydrogeologic data. Two reports were issued that evaluated the existing hydrogeologic data and assessed the data needs: Wood (1989) and Jaacks et al.[a]. A proposed study on the hydraulics of the SDA was never completed. The following types of subsurface information were evaluated in Wood (1989) and Jaacks et al.[a]:

- Wellbore completion data

- Aquifer tests

---

[a] Unpublished research results Jaacks et al., SAIC, McLean, Virginia, January, 1990.

- Aquifer tests
- Water level measurements
- Diversion-channel water level recorder measurements
- Gauging station measurements on the Big Lost River.

9.2.1 Wellbore Completion Data

The seven wells that comprise the monitoring network used for water chemistry ground water monitoring are not on the RWMC. The location of these wells is illustrated on Figure 4-1 in Section 4 of this document. Well 87 is located approximately 244 m (800 ft) north of the SDA; Well 88 is approximately 610 m (2000 ft) to the south; Well 89 is approximately 457 m (1500 ft) west; and USGS 90 is approximately 244 m (800 ft) east. Wells 117 and 119 are situated along the southern perimeter of the SDA near the western and eastern corners of the facility. Well 120 is located near spreading Area A, dike 1, and is the farthest south of the seven wells mentioned. The RWMC production well is located approximately 85 m (279 ft) east of the SDA. Stratigraphic analysis based on geophysical and lithologic logs together with evaluation of construction and completion data from these wells were used to determine if the same stratigraphic interval was being monitored. Table 1 in Wood (1989) provides a summary of these data.

9.2.2 Aquifer Tests

Pumping tests have been conducted on the Snake River Plain Aquifer to determine its suitability as a water supply and to provide aquifer property data for regional studies (Mundorff et al., 1964). In 1987, pumping tests were conducted in Wells 87, 88, 89, 90, 117, 119, and 120. In 1989, an additional test was performed on Well 88 to examine the integrity of the well. The data from these tests are included in Appendix D of Wood (1989).

9.2.3 Water Level Measurements in Wells

The USGS has been collecting quarterly water level data from the ground water monitoring network since the wells were installed. The water level data for the ground water monitoring network at the RWMC has been compiled from the USGS field records and is summarized in Appendix C of Wood (1989).

The field data were recorded on water level measurement field forms at the well site. These data include the date, time, weather conditions, measuring datum, well site, and depth to water measurement. Data were collected four times a year.

9.2.4 INEL Diversion Channel Water Level Recorder Measurements

The INEL diversion system was constructed in 1958 to provide flood protection for the facilities at the INEL. The diversion area is separated into four spreading areas: A, B, C, and D. Area A holds about 2300 acre-ft, and the other three areas each hold about 5000 acre-ft (Barraclough et al., 1967). Figure 1 in Wood (1989) shows the locations of the spreading areas with respect to the SDA. Monthly discharges to the spreading areas were compiled in Figure 11 of Wood (1989).

9.2.5 Gauging Station Measurements on the Big Lost River

Two gauging stations were installed on the Big Lost River to measure flow rates. The upstream station is located below the SDA Diversion Dam and the downstream gauging station is located at the Lincoln Avenue Bridge, about 13 km (8 mi) below the diversion dam (USGS Gauging Stations #132520 and #132535). Gauging station data for the Big Lost River flows were evaluated to assess the recharge/discharge conditions and ground water flow patterns.

9.3 Results

The integrated studies of Wood (1989) and Jaacks et al.[a] provided a better understanding of the hydrogeologic environment based on existing data at the RWMC and resulted in the identification of additional data collection requirements. The wellbore completion data, including well-construction specifications, lithologic logs, geophysical logs, and sampling results were evaluated to determine the hydrogeologic framework. The aquifer test data were evaluated to determine aquifer characteristics. The available hydraulic data, including the water level measurements, the INEL diversion channel water level recorder measurements, and the gauging station data for the Big Lost River flows, were evaluated to assess the recharge/discharge conditions and ground water flow patterns. These evaluations were intended to provide an integrated picture of the hydrogeology of the RWMC basin.

9.3.1 Wellbore Completion Data

Wells 87, 88, 89, 90, and 117 reach a total depth approximately 15 m (50 ft) below the water table. Wells 119 and 120 tap a deeper interval in the Snake River Plain Aquifer and reach a total depth of approximately 213 m (700 ft). The aquifer well design was telescoped incorporating three strings of carbon steel casing. Twenty-five centimeter (10-in.) diameter surface casing was set through surficial sediments to the first basalt. Twenty centimeter (8-in.) protection casing was set to an approximate depth range of 91 to 114 m (300 to 375 ft). Fifteen centimeter (6-in.) long string casing was set above the production zone. Wells 87, 88, 89, and 90 were initially open hole completions, but the wells were subsequently worked over and a 10-cm (4-in.) perforated casing was placed in the open hole portion of the borehole. Wells 117, 119, and 120 are completed with 9.5 cm (6-5/8 in.) perforated stainless steel liners opposite the production zone. Construction details are provided in Table 3-2 in Section 3 of this report.

---

[a] Unpublished research results Jaacks et al., SAIC, McLean, Virginia, January, 1990.

9.3.2 Aquifer Tests

Pumping test data on Wells 87, 88, 89, 90, 117, 119, and 120 were used to estimate specific capacity, transmissivity, and hydraulic conductivity of the aquifer. Table 2 in Wood (1989) summarizes the aquifer properties that were determined from the pumping tests. The values for transmissivity range from 4.05 to 2.1 x 10^5 ft^2/day (30.3 to 1.6 x 10^6 gal/day/ft). Based on regional studies of the transmissivity at the INEL, the transmissivity near the SDA is estimated to be approximately 173,000 ft^2/day (1.3 x 10^6 gal/day/ft) (Robertson et al., 1974). Calculations using Robertson's value of 173,000 ft^2/day (1.3 x 10^6 gal/day/ft) and an aquifer thickness of 76 m (250 ft) give a hydraulic conductivity of about 213.4 m/day (700 ft/day) at the RWMC. Estimates of the effective porosity of the aquifer range from 5 to 15%, with 10% being the most accepted value (Robertson et al., 1974). This porosity estimate is a spatial average over a large volume of the aquifer because the aquifer is composed of massive basalt with an effective porosity of only a few percent and fractures and cinder zones with very high porosity. The calculated transmissivities ranged over 5 orders of magnitude reflecting the heterogeneous character of the aquifer. Wells open to shorter intervals in the aquifer had lower transmissivities than wells open to thicker sections of the aquifer.

9.3.3 Water Level Measurements in Wells

Hydrographs of Wells 87, 88, 89, and 90 were plotted for the period from 1980 to 1988. Evaluation of the hydrographs indicated that the surface of the water table fluctuated in response to discharge from the spreading areas. An anomalous rise in the water level of Well 88 noted in 1984 could be correlated to discharge to Spreading Areas A, B and C. Wood (1989) proposed two hypotheses to account for the anomalous rise in water level: (1) Well 88 taps an isolated zone within the aquifer or (2) Well 88 taps a zone with low transmissivity that is recharged from the spreading areas. Data were not available to conclusively determine which hypothesis was correct.

9.3.4 INEL Diversion Channel Water Level Recorder Measurements

Monthly discharge to the spreading areas was plotted for the period from 1965 to 1987. Hydrographs of discharge to the spreading areas revealed two wet periods: one in the mid-to-late 1960s and one in the mid-1980s. The amount of water discharged to the spreading areas depends upon two factors: the available runoff water flowing in the Big Lost River and the setting of the diversion gate. In the 1960s, the operating policy was to divert as much water as possible down the channel of the Big Lost River in order to enhance dilution and flushing of the aquifer (Wood, 1989). In recent years, including the high water years of the 1980s, this operating procedure was changed and more water was diverted to the spreading areas.

9.3.5 Recharge from the Big Lost River

Infiltration via recharge from the Big Lost River was estimated as the difference in measured flow at the two gauging stations described in Section 9.2.5. Plots in Wood (1989) illustrated the difference between the flow measured at the two gauging stations (infiltration) for the period from 1965 to 1989. The Big Lost River recharge was compared to discharge from the spreading areas and to water levels in the wells near the spreading areas and the RWMC. The hydrographs indicate that recharge from the Big Lost River is much less than flow to the spreading areas. High water levels observed in the aquifer wells coincides with recharge from the Big Lost River only when discharge into the spreading areas is high. Wood concluded that discharge to the spreading areas, rather than recharge from the Big Lost River, was the primary influence on water level fluctuations in the aquifer at the RWMC.

10. Source
Characterization

10. SOURCE CHARACTERIZATION

A source characterization investigation was conducted to identify the sources and burial locations of hazardous (organic) wastes at the SDA after the 1987 Golder soil gas survey at the SDA indicated the presence of 1,1,1-trichloroethane in the southeastern corner of the SDA and elevated levels of other organics at or near Pad A (EG&G, 1988a). Neither of these locations were believed to have received organic wastes; however, the trenches in the southeastern portion of the SDA had received INEL-generated wastes. The scope of the investigation was expanded further to include the identification of the sources and burial locations of radioactive waste at the SDA. Thus, this section addresses both hazardous and radioactive waste at the SDA. The purpose of the source characterization investigation is presented in Section 10.1, the proposed investigation plan is described in Section 10.2, the actual investigation plan is given in Section 10.3, the results of the investigation are summarized in Section 10.4, and the deficiencies in the data reported and in the methodologies used to obtain them are discussed in Section 10.5.

10.1 Purpose of the Source Characterization Investigation

The purpose of the source characterization investigation was to provide a summary of the available data on the identification and burial locations of hazardous (organic) and radioactively contaminated waste material disposed at the SDA from 1952 to 1970. The summary includes offsite and onsite generated wastes.

The specific objectives of the source characterization investigation, as outlined in the December 1988 RFI Work Plan, were as follows (EG&G, 1988a):

- Identify the sources and burial locations of hazardous (organic) and radioactive waste material buried between the years 1952 and 1970

- Obtain information on past waste management practices at the INEL to determine the extent of past use of organic and radioactive materials at the facility

- Obtain information on the types of material that were used between 1952 and 1970 for specific applications (e.g., identifying processes where 1,1,1-trichloroethane was used as a cleaner)

- Identify unique waste characteristics that could be attributed to organic hazardous and radioactive material processes

- Determine the quantities of hazardous material (both organic and radioactive) produced at the INEL from 1952 to 1970.

10.2 Investigation Plan

In order to achieve the data objectives (Section 10.1) for the organic and radioactive waste material characterization, general background information about the SDA would be obtained by: (a) compiling reports, drawings, and photographs; (b) retrieving data from computer data bases; and (c) conducting debriefing sessions with personnel who had worked at the RWMC for a number of years. A detailed investigation plan was adopted comprising the following activities:

- Continuing records and logbook searches

- Continuing the review of past photographs and technical drawings

- Interviewing/debriefing personnel familiar with past waste management practices at the INEL

- Correlating the analysis of information gathered with existing records.

These activities are described in more detail in the following sections.

10.2.1 Records and Logbook Searches

Records and logbook searches would be conducted during onsite interviews and debriefings to retrieve past records. The new information obtained would be used to update the current Buried Waste Program (BWP) library system on waste related information such as handling methods, geology, waste content codes and descriptions, environmental characterization, and past retrieval demonstrations.

10.2.2 Technical Drawings and Photographs

The investigation plan called for the examination of technical drawings made and photographs taken of the SDA from 1952 to 1970. At the time the investigation plan was initiated, photographs of the SDA had been retrieved from records storage and reviewed. In addition, photographs from the years 1966 to 1969 were assembled in a photo album as part of the BWP library. Photographs of Pits 9 and 10 had been reproduced and reviewed by the EG&G Idaho staff. Photographs of other pits and trenches would augment the information on past flooding events, waste handling methods, stacking, and dumping methods (EG&G, 1988a).

10.2.3 Onsite Generator Interviews/Debriefings

The investigation plan included interviewing and debriefing personnel familiar with past INEL site operations, processes, material usage, and waste management practices. The purpose of the interviews/debriefings was to obtain additional information on previous retrieval jobs, lessons learned, and suggestions regarding scheduled BWP retrieval demonstrations. The interview approach consisted of the following:

- Develop an interview questionnaire (Figure 10-1) that could be reviewed and modified for each facility at the INEL

- Identify key personnel familiar with past waste management practices at the INEL

INTERVIEW QUESTIONNAIRE

1. The Radioactive Waste Management Information System (RWMIS) indicates that the following was received from (onsite facility) and was buried and/or stored at the Radioactive Waste Management Complex (RWMC).

Date	Volume (M^3)	Containers

2. Are waste records or documents available at ____________ that can detail waste shipments to the RWMC?

   A. If so, do the documents concur with RWMIS data for waste content and waste volume?

   B. If records are not available, are other sources (letters, logbooks, personnel, etc.) available for detailing waste shipments?

3. Was the origin of each waste shipment from the same section, facility, or laboratory at ____________, or was the waste made up from several contributors?

4. Was there a particular area within the facility that might have generated a specific waste such as 1,1,1-trichloroethane?

5. What was the volume of waste generated from each facility that was included in the shipment?

6. Did any waste originate from facilities other than those located at ____________ that may have been included in the same shipment records?

7. What types of experimentation, production, testing, and/or research and development were being conducted in the facilities where the waste was generated?

8. What specific types of materials were used from 1952 to 1970 for each facility?

9. What types of radionuclides were used?

10. What chemicals or chemical compounds (nonradiological and radiological) were used in each facility?

Figure 10-1. SDA waste identification interview questionnaire (EG&G, 1988a).

11. What is the hazard classification of the material?

    A. Toxic
    B. Flammable
    C. Chemically reactive
    D. Fissile
    E. Pyrophoric
    F. Pathogenic
    G. Irritant
    H. Elevated temperature or pressure
    I. Corrosive
    J. Explosive
    K. Carcinogenic
    L. Mutagenic
    M. Teratogenic
    N. Asphyxiant

12. What was the physical classification of the material?

    A. Gaseous
    B. Vapor
    C. Solids
    D. Liquids
    E. Particulate matter
        1. Aerosol
        2. Dusts
        3. Fogs
        4. Fumes
        5. Mists
        6. Smoke
        7. Smog

13. To what chemical classification did these materials belong?

    A. Inorganics
        1. Halogen compound
        2. Acid
        3. Alkali
        4. Arsenic, phosphorous, selenium, sulfur, tellurium
        5. Compounds containing phosphates, nitrates, etc.
        6. Lead
        7. Other metals (including Alkali metals)
        8. Other compounds included in 49 CFR 172

    B. Organics
        1. Aliphatic hydrocarbons
        2. Alicyclic hydrocarbons
        3. Aromatic hydrocarbons

Figure 10-1. (continued)

4. Halogenated hydrocarbons
    a. Aliphatic
    b. Cyclic
    c. Aromatic
5. Phenolic compounds
6. Alcohols
7. Glycols and glycol derivatives
8. Epoxy compounds
9. Ethers
10. Ketones
11. Organic acids, acid halides, thioacids
12. Anhydrides, amides, lactones
13. Organic phosphates
14. Esters
15. Acetal and Aldehyde organics
16. Cyanides and nitriles
17. Aliphatic and alicyclic amines
18. Aliphatic nitro-, nitrate-, or nitrite compounds
19. Aromatic nitro and amino compounds
20. Heterocyclic and miscellaneous compounds
21. Other compounds included in 49 CFR 172 and 261

14. If any of the identified chemicals were used at ___________

    A. Is the volume of each chemical recorded in disposal documents?

    B. What type of container was the chemical disposed in?

    C. What was the packaging method?
        1. Packed in an inert material
        2. Mixed with cement
        3. Other

15. If it is believed that some of the chemicals, or chemical compounds, or other hazards were not disposed at the RWMC

    A. Was the chemical dispose at _______________?

    B. If so, in what types of containers were the chemical disposed in?

Figure 10-1. (continued)

16. Were any nonradiological hazards sent to the RWMC, such as

    A. Pressurized gas cylinders
    B. Batteries
    C. Explosives
    D. Initiating devices
    E. Tanks
    F. Fuel
    G. Miscellaneous

Figure 10-1. (continued)

- Interview identified personnel for each facility at the INEL Site. The sequence of the interviews would be conducted based on the amount of hazardous waste generated by the facility between 1952 and 1970, as indicated on the RWMIS database.

The resulting information would be used to determine additional organic and radioactive waste burial locations in the SDA and the nature and extent of those wastes. In addition, data on processes, container identities, types of materials, and unique waste characteristics would be obtained.

10.2.4 Correlation of Data with Existing Records

Data obtained in the document searches, photographs, drawings, and from the interviews would be compiled, analyzed, and entered into the BWP library and/or database. The data consolidation would help to assess the accuracy of the new data as well as improve the existing records in the area of source characterization. Finally, the new data would be analyzed to ensure that they conform with the objectives outlined for the source characterization of the wastes buried at the SDA.

10.3 Actual Investigation Plan

Data obtained from the investigation described in Section 10.2 are contained in Vigil (1989) and EG&G Idaho is continuing the investigation. Vigil summarizes the available information gathered in FY-89 on the general identification of hazardous and radioactive waste material disposed of in the SDA and compiles data from previous research in the 1970s and early 1980s. The report addresses both offsite and onsite generated waste. Ongoing research for the source term characterization effort conducted in FY-90 focuses specifically on liquid waste disposal at the SDA, primarily from onsite sources. Onsite generator interviews/debriefings are continuing. Historical archived documents reviewed in FY-90 for source term characterization were summarized by Hiaring.[a] Pell reviewed the FY-90 photographic search for wastes buried at the SDA.[b] All of the research described above targets waste material buried at the SDA from 1952 to 1970.

The following sections describe the actual sources of information used for the source characterization investigation. Records and logbook searches are described in Section 10.3.1, a review of technical drawings and photographs is summarized in Section 10.3.2, and onsite generator interviews are discussed in Section 10.3.3.

10.3.1 Records and Logbook Searches

Vigil (1989) relied on a number of sources for information on the waste disposed of at the SDA. The primary source was the RWMIS database, which contains information from shipping manifests and records of buried wastes at the SDA from 1954 to 1970. However, large shipments of various waste constituents were bulked together within one content description on shipping manifests (Vigil, 1989). Secondary sources included informal letters (notegrams), formal letters, tabulated data, and published reports.

Records and logbooks pertaining to the RWMC from 1952 to 1989 are archived in the Federal Records Center and the National Archives Region in Seattle, Washington. These offices store and maintain records generated by Federal agencies. Each office facility handles many records including paper documents, motion pictures, still photographs, maps, drawings, and electronic records. The record centers are provided for the economical, interim storage of noncurrent records of Federal agencies, pending transfer to the Office of the National Archives or other disposition authorized by law. Records in the Federal Records Center custody continue to be under legal control of the Federal agency that created them.

---

[a] Communication between C. M. Hiaring, EG&G Idaho, Inc., Idaho Falls, Idaho, and L. N. Peterson, EG&G Idaho, Inc., Idaho Falls, Idaho, September 28, 1990.

[b] Communication between B. E. Pell, EG&G Idaho, Inc., Idaho Falls, Idaho, and C. M. Hiaring, EG&G Idaho, Inc., Idaho Falls, Idaho, August 24, 1990.

One hundred fifty nine archive box receipts were requested from the Federal Records Center storage and examined by source term personnel for pertinent RWMC data. Fifty-eight boxes were selected for review of the contents that could be applicable to the SDA. The contents of 39 boxes from the Federal Records Center and 8 boxes from the National Archives Region were catalogued for content in 1990. A variety of materials was contained in the boxes (i.e., safe work permits, DOE Form ID-110 waste disposal records, receipts from disposal trips, and report drafts). Boxes from the years before 1970 were sparse.[a] Table 10-1 contains the box number and contents of each box investigated.

Disposal records (DOE Form ID-110) from archives and onsite hot waste logbooks for the period April 14, 1959, through March 1, 1963 used by health physics personnel at the SDA were reviewed. Interoffice memoranda, notegrams, and reports describing past waste disposal practices were also reviewed for information relating to liquid disposal at the SDA. The disposal of liquid waste from NRF, ICPP, TRA, and other INEL facilities at the SDA were reviewed.

10.3.2 Review of Technical Drawings and Photographs

Some technical drawings and photographs of operations at the RWMC were obtained and included in Vigil (1989). These drawings and photographs, however, did not provide any significant additional information about the sources of organic and radioactive wastes and their burial locations within the SDA.

Pell reviewed 82 boxes of photographic negatives covering the period from 1955 to 1969 for information regarding waste disposal at the RWMC.[b] Table 10-2 lists the RWMC pits and trenches with their open and closure dates. A listing of box numbers and narrative description of photographic subject

---

a. Communication from C. M. Hiaring, EG&G Idaho, Inc., Idaho Falls, Idaho, to L. N. Peterson, EG&G Idaho, Inc., Idaho Falls, Idaho, September 28, 1990.

b. Communication between B. E. Pell, EG&G Idaho, Inc., Idaho Falls, Idaho, and C. M. Hiaring, EG&G Idaho, Inc., Idaho Falls, Idaho, August 24, 1990.

Table 10-1. Contents of archived boxes reviewed for RWMC source term characterization[a]

Box Number	Contents
Federal Records Center	
1881	1962-1966 Radioactive shipments from onsite generators shipped to the ICPP.
2903	1964 decontamination log, 1967-1968 floor plan surveys, 1967-1968 service waste charts, 1968 safe work permits.
16183[b]	1961-1963 radioactive waste forms from offsite generators.
17226[b]	1965 ID-135 disposal records.
17227[b]	1966 on- and offsite disposal records, 1978 and 1979 records about Solid Waste Information and Management System and Transuranic Contaminated Waste Container Information Systems.
17228[b]	1967 ID-110 disposal records.
17229[b]	1968 ID-110 disposal records.
17230[b]	1969 ID-110 disposal records.
17231[b]	1970 ID-110 disposal records.
38932	TAD task 9 and 11. 1975 high gamma waste packaging, task plan work and scope, TRU waste storage document, National Reactor Testing Station (NRTS) burial ground document, Molten Salt Incinerator documents.
38933	Early Waste Retrieval and Initial Drum Retrieval program document, interim and final report, soil handling document, 1975 ICPP plant waste generating process, 1976 retrieval effort for TRA waste package in pit 15 at RWMC. INEL waste management plan for FY-1978, 1977 proposed Waste Isolation Pilot Plant TRU waste acceptance criteria. Related studies of waste retrieval (date and author unknown). Tingey waste management letters, 1977 injection well document, nuclear waste compactors, TREE-1064 Safety Review Document of the RWMC at INEL, UC-70 Nuclear Waste Management TID-4500, WMP-76-27 Molten Salt Combustor Demonstration, TREE-1311 1979 INEL Transuranic Storage Cell Penetration and Inspection, 1976 safety review Document for RWMC UC-70, Nam TID-4500, R63.

Table 10-1. (continued)

Box Number	Contents
38984	TRA Waste Management Plans for 1977, INEL Waste Management Plan for 1975 IDO-1005, C1-1243 Rev 1, Waste Management Plan for Aerojet Nuclear Company's Operations at NRTS, WP-77-11 1977, Long Range Waste Management Planning for Effective Utilization of the SDA, WMP-77-12 1974 - 1976, The Monitoring of Environmental Conditions within an INEL Transuranic Storage Cell, WMP-77-2 1975 - 1976, Moisture Exclusion Studies for Stored Transuranic Wastes, WMP-77-3 History of Buried Transuranic Waste at the INEL, WMP-77-10 1977, The Assessment of Solid Low Level Waste Management at the INEL, ACI-104, 1971, A Survey of NRTS Waste Management Practices, Vol. 1 (multiple revisions of this same report), WMP-77-16, Molton Salt Combustor Facility Test Program Plan, WMP-77-23, An Assessment of the Suitability of the Molten Salt Incinerator for Treating INEL Waste.
38937	Requisition for Hydrotherm Portable Monitor, requisition for gas/hydrogen-oxygen detector, in and out logs of RWMC workers, engineering drawing of Pit 11 grid, inside air support building location plan, regulatory guide Measurements of Radionuclide in the Environment Sampling and Analysis of Plutonium in Soil, costs of drum retrieval, initial drum retrieval weekly meeting report, advertisements for filters, 1974 initial drum retrieval safety analysis, detailed operating procedures for the surveillance plan for the NRTS Solid Radioactive Waste Storage and Disposal Areas, SWM-109, Operations Procedure for the Initial Drum Retrieval, WOB 114, Guidelines for Solid Radioactive Waste Handling at the INEL, safety review document of RWDSA, letters regarding a proposed new pit and soil cover, rollout drawings procedure compliance checklist, Initial Drum Retrieval summary report, correspondence with Irvin Industries about the air support building, CO emission control at the burial ground air support building, RWMC emergency action procedure, detailed operating procedures for handling NRF scrap cask at the RWMC, the RWMC core drilling plan, INEL RWMC solid radiative waste disposal/storage guidelines, investigation of subsurface deposits at the RWMC, TRU waste container form ID-137 69-70, 1974 monthly Environmental and Waste Management branch report.
42400	Offsite records and burial ground records pre-1961.
42411	Keypunch documents and ID-135

Table 10-1. (continued)

Box Number	Contents
42627	1979 decontamination and decommissioning letter files for Meservey, Chapen, Hine, and Smith. 1979 letter files for Duffy, Krupinski, Falconer, Dickson, Gray, and Adams.
45421	1979 Industrial Waste Management Information System graphics. 1980 Solid Radioactive Waste Volume Reduction at the INEL Via Compaction.
24401	1964-1965 safe work permits, radioactive material shipment records.
17723	Materials Test Reactor (MTR) incoming and outgoing radiative shipments, safe work permits, 1963 MTR waste shipments (no burial locations).
14311	MTR incoming and outgoing radioactive shipments, safe work permits, 1962 MTR waste shipments (no burial locations).
14420	1960 health physics log sheet, 1962 CPP and CFA miscellaneous radioactive shipments, 1961 health physics log sheets, Engineering Test Reactor (ETR) radioactive shipments, MTR radioactive shipments, safe work permits, Westinghouse radioactive shipments.
9118	Miscellaneous HP radiation measurements from CPP in 1961.
10455	Safe work permits, radioactive shipments, 1961 radioactive waste ID-110 forms.
12092	CAM filter counts, ETR water samples, a dosimeter log, 1960 ID-110 radioactive waste shipments.
4196	Smear sheets from health physics.
20770	Safe work permits.
18182	1964 safe work permits. 1963-1964 floor plans, 1963-1964 miscellaneous radioactive shipments.
17044	ID-110 radioactive waste shipments, outgoing and incoming radioactive shipments, safe work permits.

Table 10-1. (continued)

Box Number	Contents
18184	Discharge charts, safe work permits.
20770	Health physics surveys.
18183 96729 98376	Floor plans.
96728	1957 radioactive shipments (onsite), fuel shipments, hot laundry shipments, 1959 safe work permits, 1958 nonradioactive shipments, 1958 onsite radioactive shipments, 1958 fuel shipments, 1958 outside shipments.
98611	1957 IN-109 outgoing/onsite radioactive shipment records.
141694	TRA logs.
96636	IHP-30 1958 incoming shipments to burial grounds, laundry shipments, 1959 safe work permits, 1958 nonradioactive shipments, 1958 onsite radioactive shipments, 1958 fuel shipments, 1958 outside shipments.
98375	1959 incoming hot laundry shipment, 1959 outgoing nonradioactive shipments, 1959 safe work permits, 1959 hot waste shipments.
48019	Series of documents on historical and current day waste for each state or area.
8219(DOE)	1970 IDO-12072, <u>Radionuclide Distribution in the Regolith as a Result of Waste Disposal at the NRTS</u>, 1968 Tracer Studies at the Loss of Fluid Test (LOFT), 1963 Proposed Test to Determine the Feasibility of Underground Radioactive Gas Disposal, 1968 Gas Injection Experiment NRTS, Idaho - Measurement of Xenon-133 Flux and Surface Level Air Concentrations, 1965 Method and Cost Estimates for Injection of Radioactive Gaseous Effluent into Subsurface Geologic Environments, 1964 BNWL-47 Geophysical Seismic Evaluation Study at Hanford, 1965 IDO-12024 An appraisal of Gaseous Waste Disposal into the Lithosphere at the NRTS, 1947 Seismic Investigations of Large Explosions, Geophysical information from Petty Engineering, 1964 Final Report of Feasibility and Utility of Seismic Techniques for Determining and Mapping Subsurface Structure and Depth to Sub-Basaltic Rocks Snake River Plain, NRTS, IN, 1963 IDO-12023 Experience in Site Selection at the NRTS, 1965 Report on the Gas Injection

Table 10-1. (continued)

Box Number	Contents
	Tests Conducted at the NRTS Located in the state of Idaho, 1961 Completion report on Drilling, 1936 The theory of Acid Treatment of Oil Wells Producing from L. S. Reserves, 1966 U. S. Army Nuclear Defence Labs Radiological Decontamination and Waste Disposal Research State of the Art and future problems, 1963 Pressure Cementing of H^2O Wells on NRTS, Idaho, miscellaneous papers, expense estimates, purchase orders, articles from publications on spectral logging.
National Archives Regions	
1	1959 - 1962 health physic surveys, 1962 health and safety personnel training. Requests for health and safety services, 1962 CF, CPP, EICR health physics monthly reports, Special Power Excursion Reactor Test (SPERT) monthly reports, MTR health physics meeting.
2	1962 STEP/TAN monthly reports, industrial hygiene, health and safety records section reports, narrative activities report, radioactive waste reports - ETR, CPP CFA, MTR, SPERT, offsite trip reports, waste shipment security reports, annual health and safety report.
3	1960 - 1961 health and safety reports - ETR, MTR, SPERT. Monthly waste reports - CFA, CPP, MTR, ETR.
4	SPERT monthly waste report 1959 - 1961, safe work permits, 1958 MTR health physics records, CPP health physics records, CPP waste effluent, SPERT waste reports, health physics progress reports.
6	1959 AEC burial ground records (no burial locations), miscellaneous safety reports, health physics report 1-49, annual safety reports.
7	Radioactive shipments.
8	MTR radioactive shipments monitoring.

---

a. Source: Personal communication between C. M. Hiaring, EG&G Idaho, Idaho Falls, Idaho, and L. N. Peterson, EG&G Idaho, Idaho Falls, Idaho, September 28, 1990

b. Contents of the box copied.

Table 10-2. Open and closure date for pits and trenches at the RWMC[a]

RWMC Pit No.	Open Date	Close Date
1	11-01-57	10-01-59
2	10-01-59	07-01-63
3	12-15-61	01-03-63
4	01-03-63	09-26-67
5	06-18-63	12-22-66
6	05-18-67	10-22-68
7	09-19-66	10-05-68
8	03-06-67	11-?-69
9	11-08-67	06-09-69
10	08-07-68	07-08-71
11	04-14-70	10-16-70
12	07-02-70	09-12-72
13	07-20-71	07-29-74
14	07-01-74	03-31-76
15	06-25-75	07-03-84
16	05-22-78	10-25-84
17	05-05-84	Present
Acid Pit	01-01-54	01-01-61
Pad A	09-26-72	11-17-78
RWMC Trench No.		
1	07-08-52	10-01-54
2	10-01-54	12-21-54
3	12-22-54	04-22-55
4	04-22-55	11-21-55
5	11-04-55	03-29-56
6	03-22-56	09-04-56
7	08-14-56	12-20-56
8	12-13-56	05-07-57
9	01-17-57	09-06-57
10	07-19-57	02-07-58
11	02-11-58	07-25-58
12	01-03-58	01-16-59

Table 10-2. (continued)

RWMC Trench No.	Date Opened	Date Closed
13	01-09-58	04-24-59
14	04-16-59	07-30-59
15	07-31-59	10-16-59
16	10-17-59	04-12-60
17	11-01-59	07-01-60
18	05-10-60	07-20-60
19	07-05-60	11-29-60
20	12-01-60	06-30-61
21	12-13-60	01-10-61
22	02-01-61	04-25-61
23	06-20-61	09-15-61
24	10-01-61	07-31-62
25	08-01-61	07-27-62
26	04-13-62	08-17-62
27	08-20-62	01-04-63
28	12-26-62	03-12-63
29	11-19-62	03-20-63
30	03-02-63	09-12-63
31	03-25-63	11-22-63
32	04-01-63	11-18-63
33	10-11-63	08-11-64
34	03-18-64	08-27-64
35	08-28-64	01-19-65
36	12-01-64	07-24-65
37	12-24-64	07-01-65
38	05-15-65	09-16-65
39	07-20-65	11-05-65
40	10-07-65	01-13-66
41	01-04-66	10-04-66
42	05-09-66	01-17-67
43	10-20-66	06-01-67
44	01-13-67	03-24-67

Table 10-2. (continued)

RWMC Trench No.	Date Opened	Date Closed
45	02-28-67	09-27-67
46	09-25-67	03-14-68
47	02-28-68	08-05-68
48	08-08-68	05-02-69
49	11-18-68	06-30-69
50	07-01-69	11-01-69
51	10-30-69	04-08-70
52	03-04-70	07-04-70
53	07-01-70	10-12-70
54	09-23-70	05-04-71
55	04-07-71	03-12-82
56	12-29-71	02-01-73
57	12-28-72	06-11-74
58	02-20-74	08-17-81

---

a. Source: Communication between B. E. Pell, EG&G Idaho, Inc., Idaho Falls, Idaho, and C. M. Hiaring, EG&G Idaho, Inc., Idaho Falls, Idaho, August 24, 1990.

matter cross referenced with the appropriate pit or trench is currently being compiled as part of the ongoing source term investigation. The photographic negatives provide valuable information regarding disposal practices at the RWMC, the complex mixtures of materials buried at the SDA, and the quantity of material disposed of. Based on this information, statisticians may be able to evaluate the rolling movement of barrels and casks, assess the amount of leakage, and determine potential soil contamination. The negatives provide valuable insight on excavation practices, estimates of disposal area volume, and identification of unmarked pits and trenches that had their monuments destroyed by flooding and grading processes.

10.3.3 Onsite Generator Interviews/Debriefings

Vigil interviewed several individuals from various backgrounds for pertinent waste disposal information. These individuals included AEC officials, Site operating contract management, engineers, operations specialists, and heavy equipment operators (Vigil, 1989). The interview questionnaire (Figure 10-1), proposed in the early stages of the investigation, was abandoned for an informal approach to conducting interviews.

In FY-89, select personnel familiar with historic disposal practices at the SDA from 1952 to 1970 were interviewed to gather information on disposal methods at the SDA and the types of waste generated onsite and disposed of in the SDA. These individuals were employed by the AEC, DOE, ERDA, and various contractors at the INEL. Topics discussed by interviewees included trenches, pits, liquid disposal, and the location of disposed miscellaneous waste including MTR fuel elements, mercury, PM-2A evaporator, ion exchange resins, filter aid, Santowax, and TAN hot shop waste.

Trenches were used for the disposal of most of the waste that was generated at the INEL, and they were used exclusively from 1952 - 1957. Waste disposed of in trenches was classified as routine or non-routine, depending on the exposure rate at a point 3 feet above the ground surface. Routine waste had an exposure rate of less than 1 mR/hr at a point 3 feet above the ground surface and wastes were disposed of in 3 x 3 x 3 ft cardboard boxes. Approximately 3 feet of soil was usually (but not always) used to cover the emplaced waste to reduce the exposure rate. The soil was applied at the end of the working week. Non-routine waste had an exposure rate of greater than 500 mR/hr at a point 3 feet above the ground surface or was a plutonium/thorium source material, liquid, or slurry (Vigil, 1989). Before 1960, the non-routine waste was placed in a 2 x 2 x 3 ft wooden box or in a 30-gallon garbage can. Non-routine waste was immediately covered with soil to minimize the potential exposure rate. After 1960, non-routine waste was placed in a 10 x 10 x 6 ft steel boxes open at the top and bottom. This disposal method was more space effective.

Pits were used for the disposal of large containers of INEL low-level waste and for RFP TRU waste after 1957. These wastes were disposed of in both drums and boxes. Commercial and site-generated wastes were disposed of in pits, as well as unusual wastes such as jet engines (Vigil, 1989). In general, pits were gradually covered with soil as they became increasingly filled with waste.

Many interviewees remembered random dumping of waste as opposed to stacking barrels and other waste neatly in rows. Many noted that during the random dumping, barrels often did not remain intact and waste was spilled into the pits. Trenches were filled primarily with site-generated waste (i.e., highly radioactive contaminated waste items) and then covered with soil by bulldozers. Interviewees believed that the waste in trenches was probably not as compacted or well placed as that in the pits because of the disposal methods involved.

10.3.4 Schedule of Activities

The source term characterization effort will continue through FY-91 to support Phase 1 of the remedial investigation of the RWMC. Two INEL generator interviews per month will be conducted until May, 1991. Thirty-two boxes of data will be reviewed through May 1991. Photographs from 1964 through 1985 will be reviewed and compiled with narrative descriptions where possible.

Disposal information obtained through these research efforts will be compiled into a database.

The scope of the source term investigation was expanded under the site characterization program from that originally proposed in the December 1988 RFI Work Plan (EG&G, 1988a). Under the revised scope for the source characterization study, the mass and volume of disposed waste will be identified, the uncertainty of waste pit and trench boundary locations will be specified, waste constituents and waste forms (both chemical and physical) will be identified, and maps of the SDA depicting waste locations will be generated to facilitate identification of remedial units.

10.4 Results from the Investigation

The focus of the source characterization task was to identify the sources and quantities of organic and radioactive wastes generated by the INEL operations and buried at the SDA from 1952 to 1970. The results of the task for FY-89 are summarized in Vigil (1989). Results for FY-90 are currently being compiled by EG&G Idaho. The wastes are categorized as hazardous (organic) wastes or radioactive wastes. Hazardous waste are discussed in Section 10.4.1, and radioactive wastes are discussed in Section 10.4.2. The summaries in the following sections are based on Vigil's research on the identification of hazardous and radioactive waste material disposed at the SDA from both offsite and onsite generated wastes (Vigil, 1989).

10.4.1 Hazardous Waste

10.4.1.1 INEL-Generated Waste. Vigil (1989) identified hazardous waste buried at the INEL from several sources including shipping and receiving records, the RWMIS data base, and other documents and reports. The disposed wastes consist of toxic chemicals, pyrophoric materials, animal carcasses and excreta, and other hazardous materials that are also radioactively contaminated. Table 10-3, from Cerven and Clements (1987), estimates the total volume of potentially hazardous wastes, including organics, buried at the SDA at 1364 m^3 (48,344 ft^3). This volume includes an estimated 334.6 m^3

(11,816 ft^3) of buried TRU organic waste. Other constituents in this estimate include 23,400 gal of oils in Oil-Dri, a commercial absorbent; 10,200 gal of acids in various absorbent material; 27,600 gal of sodium (in contaminated pipe); and 6900 gal of caustic material. The organic wastes are described to contain mainly lathe coolant (machining oil and carbon tetrachloride) and used oils and degreasing agents such as trichloroethane, trichloroethylene, and perchloroethylene. The total volume of organic wastes buried in the SDA is estimated to be 88,400 gal. The total amount of hazardous materials listed in Table 10-3 also includes offsite generated wastes shipped to the SDA from 1960 to 1963.

In addition to solid wastes, significant volumes of liquid wastes were disposed in various seepage pits, the SDA Acid Pit, and in other solid waste pits and trenches within the SDA. The SDA Acid Pit, opened in January 1954 and closed in January 1961, is estimated to have received up to 500 gal of cleaning solvents and acid every 2 months. Operating practices for the pit were never documented; thus, few records of the types or volumes of liquids disposed in the pit have been found (Vigil, 1989). Entries in the RWMIS database also indicated that large quantities of Mercury, over 50 tons (3.4 m^3), were disposed of in Trench 27 (Vigil, 1989). The RWMIS database also includes entries that indicated 0.06 m^3 of mercury batteries and 0.06 m^3 of mercury oxidizer were disposed of in Pit 2 and Pit 13, respectively.

The results of a confirmatory study conducted in 1990 indicated that the RWMIS entry for mercury in Trench 27 was in error. Interviews with personnel, geophysical investigations, a soil gas survey and review of the original disposal record failed to conclusively demonstrate that 3.4 m^3 of mercury was disposed of in Trench 27 (Hiaring et al., 1991). The mercury originally thought to have been disposed of in Trench 27 was excessed to other federal agencies.

Table 10-3. Estimates of hazardous materials disposed of in the RWMC SDA[a]

Material	Volume (m^3)	Volume (ft^3)	Volume (gal)
Rags[b]	128.00	4,500.00	N/A[c]
Oil (in absorbent)	89.00	3,100.00	23,400
Lead	170.00	6,100.00	N/A
Asbestos/lagging	100.00	3,500.00	N/A
Ethylene glycol	1.50	50.00	390
Mercury[d]	8.50	300.00	2,240
Acids (HF, HCl, etc., in absorbent)	38.00	1,400.00	10,200
Organics (ether, etc.)	25.00	900.00	6,700
Santo Wax[e]	200.00	7,100.00	53,700
Sodium, sodium compounds and pipe	105.00	3,700.00	27,600
Batteries	0.50	20.00	N/A
Benzene	0.10	3.00	20
Animal carcasses and feces	71.00	2,500.00	N/A
Vehicles[f]	24.00	860.00	N/A
Cyanide	<0.01	<0.35	N/A
Meat with botulinus	0.05	0.25	N/A
Tritium vials	2.00	64.00	N/A
Zirconium chips	30.00	1,100.00	N/A
Caustic compounds (NaOH in absorbent, etc.)	26.00	930.00	6,900
Paint chips and cans	6.00	210.00	1,600
Gasoline (absorbed)	5.00	180.00	1,300
Ammonia bottles	0.20	7.00	N/A
Thallium oxide	<0.01	<3.00	N/A
TRU texaco regal oil	148.00	5,215.00	39,018
TRU carbon tetrachloride	92.00	3,263.00	24,413
TRU other organics	94.00	3,338.00	24,968
Total (approximate)	1,364.00	48,344.00	222,450[g]

---

a. Source: Cerven and Clements (1987).

b. The quantity identified assumes 5% of the total rag inventory at the RWMC is oil/solvent soaked.

c. N/A - Volume, in gallons, is an inappropriate measure for these materials.

d. Mercury volume reflects 3.4 m^3 erroneously reported to have been disposed of in Trench 27 and 5.0 m^3 reported to have been disposed of in Pit 15 according to a RWMIS potential hazardous material listing for 1970 to 1981 (Cerven and Clements, 1987). The entry is labeled as 24 drums of "mercuris (sic) waste unnumbered" from NRF.

e. Santo Wax is from the Organic Moderated Reactor Experiment (OMRE); it may not be a hazardous material.

f. Vehicles disposed of at the RWMC were assumed to be drive into the pits with fuel, oil, antifreeze, and batteries left in place. The volume indicated represents 5% of the total vehicle volume.

g. Gallons are not volume equivalent because of some solid materials.

10.4.1.2 Offsite-Generated Waste. The majority of organic wastes generated offsite were shipped from the Rocky Flats Plant. The volume of waste shipped annually to the SDA and the monthly volume processed at the SDA are estimated in Tables 10-4 and 10-5, respectively. Other offsite-generated wastes included about 934,777 kg of nitrate buried at the SDA between 1967 and 1970, an unknown amount of PCB-contaminated material buried in Pits 6, 9, or 10 and about 5500 empty 55-gal drums used for processing organic solvents and lathe coolant (Vigil, 1989).

10.4.2 Radioactive Waste

10.4.2.1 INEL-Generated Waste. A significant amount of radioactively contaminated liquids were also disposed of in the solid waste pits and trenches, with the Naval Reactor Facility and the Idaho Chemical Processing Plant (INEL facilities) being the largest contributors. The liquids included contaminated oils, caustic, organic solutions, and cyanide solutions (Vigil, 1989).

On July 8, 1952, the first trench was opened to receive radioactive waste generated at the INEL. All waste received from 1952 through 1957 was buried in trenches. Table 10-6 shows the estimated radioactivity of buried LLW mixed with buried TRU waste emplaced from 1953 to 1964. This estimate excludes waste in Pits 6, 9, and 10, which are believed to contain a significant amount of intermixed LLW and TRU waste. Table 10-7 shows the INEL-generated solid waste routinely disposed of in trenches from 1960 to 1969 (Vigil, 1989).

After 1957, pits were typically used for offsite generated TRU waste and large containers of INEL waste. The INEL waste was segregated from the Rocky Flats Plant TRU waste by virtue of the large volume of RFP TRU waste shipped to the site. However, INEL waste and RFP waste can be found in the same pit. The pits were also used to dispose of unusual waste such as jet engines. Seven jet engines used in experiments to determine if they could be powered by nuclear fuel were disposed of in Pit 3 (Cerven and Clements, 1987). RWMIS

Table 10-4. Organics shipped from Rocky Flats Plant to the SDA[a]

			Volumes in Gallons		
Year	SDA Status	Number of Drums	Texaco Regal Oil	Carbon Tetrachloride	Other Organics[b]
1966	Buried	267	2,000[c]	800[c]	No record
1967	Buried	5,518	22,247	14,831	4,255
1968	Buried	2,391	10,771	7,181	18,313
1969	Buried	533	4,000[c]	1,600[c]	2,400[c]
Total		8,709	39,018	24,413	24,968

---

a. Source: Vigil (1989).

b. Mostly 1,1,1-trichloroethane, trichloroethylene, perchloroethylene, and used oil.

c. Data estimated.

Table 10-5. Organic liquids from Rocky Flats Plant processed at the SDA monthly (1966-1969)[a]

Organic Liquid	Gal/Month	% of Total
Lathe coolant - 50% Texaco Regal Oil, 40% carbon tetrachloride	700	47
Trichloroethane	150	10
Miscellaneous - hydraulic oil, gearbox oil, spindle oil, Freon, Varsol, etc.	650	43

---

a. Source: Vigil (1989).

Table 10-6. Estimated radioactivity in LLW mixed with buried TRU waste[a]

Nuclide	Half-Life (years)	Emplaced		As of July 1, 1985[b]	
		Curies	%	Curies	%
NI-59	80,000	1,500	0.3	1500.0	20.2
Co-60	5.27	99,000	17.0	4214.3	56.8
Sr-90	29.0	1,000	0.2	563.5	7.6
Cs-137	30.17	1,000	0.2	576.2	7.8
MAP[c]	5.27	6,000	1.0	255.4	3.4
MFP[d]	30.17	500	0.1	288.1	3.9
UIβ/γ[e]	3.0	5,500	0.9	21.5	<0.3
Short-lived beta-gamma emitters	<<1[f]	468,500	80.3	Negligible	<0.0
Total		583,000	100.0	7419	100.0

---

a. Source: Vigil (1989).

b. Although LLW was buried with the TRU waste from 1954 through 1964, about half the activity was buried in 1962 and 1963. Therefore, these simplified calculations of radioactive decay were based on an assumed burial date of January 1, 1961 (24-year decay by the year 1985) for all of the LLW.

c. MAP = mixed activation products. Decay calculations are based on the half-life of Co-60, the dominant radionuclide.

d. MFP = mixed fission products. Decay calculations are based on the half-life of Cs-137, the dominant radionuclide.

e. UIβ/γ = unidentified β/τ emitters. Decay calculations are based on an estimated value of the effective half-life.

f. Much less than 1 year.

Table 10-7. Solid waste contributed by INEL facilities to the SDA (1960-1969)[a]

Facility Area	Volume (m^3)	Radioactivity (kCi)
NRF	442,000	3,000.00
TRA	310,000	1,000.00
ICPP	165,000	100.00
TAN	140,500	27.00
ANL	84,000	107.00
CFA	40,500	0.20
OMRE	24,300	0.20
GCRE	24,300	2.00
SPERT	5,400	0.04
ARA	5,100	3.00
Total	1,241,100	4,239.00

---

a. Source: Vigil (1989).

database information indicates that about 50% (by volume) of the waste in Pit 3 is Rocky Flats Plant TRU waste.

INEL-generated LLW has been classified as contaminated trash, process waste, contaminated equipment and materials, and activated metals. The contaminated trash includes protective clothing, paper, rags, packing material, glassware, tubing, and plastic sheeting. Process waste consists of filter cartridges and sludges, spent ion-exchange resins, and evaporator bottoms. Contaminated equipment and materials include gloveboxes, drain traps, ventilation ducts, shielding, and laboratory equipment. Most of the curie content in INEL LLW is attributable to activation products in fuel end-pieces and piping from nuclear reactors. Waste was transferred to the burial ground in shielded containers and disposed of uncompacted. The largest volume of waste is "routine combustible," such as paper, cardboard cartons, wooden boxes, plastic bags, plastic and rubber scraps, filters, and rags. The waste contains about 10% noncombustibles (contaminated valve fittings, piping, and tools). The total volume of LLW has been estimated as 14,158.7 m^3 (500,000 ft^3). Record searches indicate that 33,414.5 m^3 (1,180,000 ft^3) is closer to the actual volume.

10.4.2.2 Offsite-Generated Waste. Radioactive waste buried at the SDA includes waste generated from offsite sources. The offsite sources originated from different facilities including defense agencies, universities, commercial operations, and AEC contractors. The majority of offsite sources were received from 1960 to 1963. Table 10-8 illustrates the generators and volumes of offsite waste shipped to the INEL from 1954 to 1970.

The Rocky Flats Plant was the largest generator of offsite wastes. The Nuclear Regulatory Commission - Region V, Lawrence Radiation Laboratory, Rockwell International - Atomics International Division, and General Atomic Company shipped about 90% of the offsite generated wastes from 1960 to 1969 (Table 10-8) (Vigil, 1989).

Table 10-8. Waste shipments to the SDA for burial in TRU waste pits and trenches from 1954 through 1970[a,b]

Company/Laboratory	1960	1961	1962	1963	1966	1968	Total
University of California Lab. of Nuclear Medicine Rad. Biology			4.11				4.11
U.S. Bureau of Mines	5.01	6.34	4.50				15.85
U.S. Bureau of Mines		0.42					0.42
U.S. Naval Radiation Defense Lab.				8.04			8.04
University of Utah	9.57			10.54			20.11
University of Washington	2.38	4.98	2.49	3.12			12.97
Washington State University			1.67				1.67
Thiokol Chemical Corporation	2.12						2.12
Nuclear Engineering Co., Inc.		120.16	43.74				163.90
ICN[c]		19.87	52.84	7.25			79.96
Department of Health, Education, and Welfare		94.46					94.46
Memorial Hospital of Sheridan County				0.14			0.14
U.S. Marine Corps			13.42				13.42
U.S. Army Chemical Center		18.69	7.19				25.88
U.S. Army Chemical Center		1.05					1.05
Babcock-Wilcox	15.63						15.63
PM-1 Nuclear Power Plant						47.15	47.15
Colorado School of Mines Research Institute		0.42					0.42
Teledyne Wah Chang Corporation		4.53					4.53
Chicago Bridge and Iron, Co.[d]			0.03	0.23			0.26
Nuclear Regulatory Commission[e]		791.42					791.42
Lawrence Radiation Laboratory			492.20	1,749.28			2,241.48
Rockwell International Atomics International Division	459.95	841.39	70.32		18.83	1.81	1,392.30
General Atomic Company		210.53	275.32	228.97			714.82
Coors Porcelain Company[f]							
IT Corporation[g]			7.2	21.20			28.52

Table 10-8. (continued)

Company/Laboratory	1960	1961	1962	1963	1966	1968	Total
American Electronics, Inc.		10.42					10.42
Oregon Metallurgical Corp.		7.33					7.33
San Antonio Air Logistics Center	11.42	72.50					83.92
Total Volume							5,782.30

---

a. Source: Vigil (1989).

b. Remainder of waste received from the Rocky Flats Plant and INEL.

c. Formerly U.S. Nuclear Corporation, Burbank, CA.

d. Formerly Industrial X-Ray Engineers, Seattle, WA.

e. Formerly the Atomic Energy Commission, San Francisco, CA.

f. Waste shipped in 1964 and was included with Rocky Flats Waste (5.42)

g. Formerly California Salvage Co., San Pedro, CA.

10.5 Discussion of Results

Results obtained from Vigil (1989) and from the current work being conducted by EG&G Idaho are contradictory in some areas because of the primary information sources being used for the respective studies. Vigil relied primarily on the RWMIS database. Disposal forms indicating liquid disposal do not agree with data entered into the RWMIS database. The discrepancies between different information sources will be addressed as part of the ongoing source characterization effort.

All pre-1970 RWMIS data has a disclaimer, "1. Data contained in this listing are known to be incomplete and contain inaccurate nuclide breakdowns. Any attempts to match published document numbers with numbers in this list will result in discrepancies. 2. No official INEL documents used data from this data file."[a] Therefore, RWMIS entries should be cited with discretion.

---

[a] Communication between C. M. Hiaring, EG&G Idaho, Inc., Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, October 24, 1990.

11. Vapor Vacuum Extraction Demonstration

11. VAPOR VACUUM EXTRACTION DEMONSTRATION

Recent studies have indicated that measurable concentrations of VOCs occur in the vadose zone at distances of up to 1036 m (3400 ft) from the SDA boundary (Laney et al., 1988). Preliminary vapor transport analyses indicate that 90% of this VOC plume could be removed in approximately 10 years by applying the vapor vacuum extraction technology (Rauen, 1989). The VVE demonstration was proposed to assess the utility of this method as a remedial measure and to validate the assumptions that were used to predict the behavior of the vapor plume in transport modeling.

The VVE method is a remedial technology that removes VOCs from the vadose zone by pumping contaminated air from a borehole and treating it before discharge.

Section 11.1 presents the purpose of the VVE demonstration. The strategy that was proposed in the December 1988 RFI Work Plan is reviewed in Section 11.2. The procedures that were used in conducting the investigation are described in Section 11.3, and the results of the VVE demonstration are summarized in Section 11.4.

11.1 Purpose of the Investigation

The primary purpose of the VVE demonstration was to determine the effectiveness of VVE in removing organic vapors from the vadose zone. To accomplish this, data were to be collected from the process stream and surrounding monitoring boreholes before, during, and after a 4-month demonstration period. The collected data were to be used to (a) determine if organic vapors from the process stream could be removed to less than 25 ppm total VOCs at the system's effluent to meet OSHA regulations, (b) assess the system design features for use in a full-scale remedial process, (c) determine operational changes that would be required to operate the system as a full-scale remedial process, (d) refine the vapor transport model's estimate of time required to remediate organic vapors in the vadose zone, and (e) assist in permitting for full-scale operation.

Secondary objectives of the VVE system were to gather information about the physical properties of the stratigraphic section underlying the SDA, determine the extent of contamination, and verify the accuracy of models now being used at the SDA to predict the subsurface transport of contaminants. Data obtained from the VVE demonstration will be compared with computer simulations to refine the input assumptions and to increase the reliability of future computer-based predictive modeling.

11.2 Proposed Strategy in Work Plan

The proposed strategy outlined in Section 6.11 of the December 1988 RFI Work Plan consisted of conducting four tasks: (1) designing the VVE system, (2) collecting baseline data, (3) the demonstration test, and (4) data assessment. The scope of these tasks is summarized in the following sections. In Section 11.2.1, the VVE system design is discussed. The baseline data collection task and the VVE demonstration task are presented in Sections 11.2.2 and 11.2.3, and the data assessment task is described in Section 11.2.4.

The baseline data collection and system design tasks were completed in the spring of 1990. The demonstration test consisted of a 2-week test followed by a 4-month test initiated in April 1990. The data assessment task was completed in the fall of 1990.

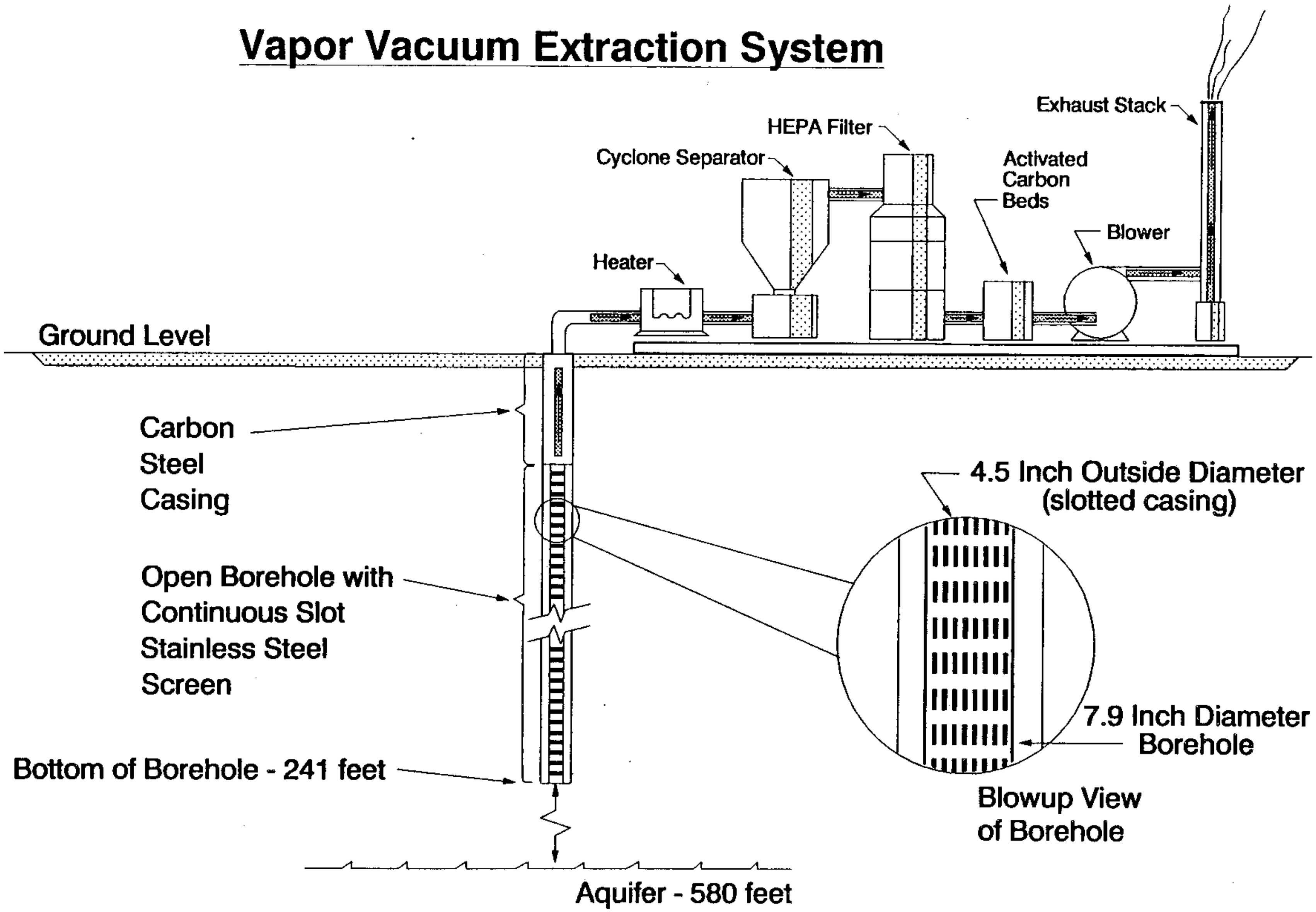
11.2.1 VVE System Design

The VVE system was designed to collect VOCs by establishing a partial vacuum on a borehole drilled into the contaminated zone. To accomplish this, an extraction well (Borehole 8901D) was drilled, cased, and screened in a suspected zone of high vapor concentration. Completion details for this borehole are described in Section 5 of this report. The borehole was connected to a blower system. The vacuum produced by the blower system at the well head induces a large-scale movement of air towards the extraction well. The extracted air is filtered through a processing system to remove radionuclides (or particulates) and VOCs so that the effluent will meet air quality standards before discharge to the atmosphere. A schematic view of the system is presented in Figure 11-1.

The major processing system equipment consists of a vacuum pump; a cyclone separator; a filtering system; a gas immersion heater; and associated gauges, piping, valves, and fittings. The vacuum pump has a variable-speed drive unit that regulates flow to a selected target rate. The vacuum pressure capability of the system is approximately -5 psi. The cyclone separator is designed to operate most efficiently in the flow range of 200 to 600 ft^3/min, and it is equipped with a particle receiver at its base where particles, including radionuclide contaminated particulates, can accumulate. The filtering system consists of prefilters, HEPA filters, and activated carbon filters. The gas immersion heater has a capacity of 15 kW and is designed to heat the flow stream through a temperature change of 10°C (50°F).

The subsurface gas stream enters the VVE processing system at the extraction well head (Borehole 8901D). First, the flow passes through the sampling station where particulate content, mass flow rate, temperature, and system vacuum pressure are measured. Ambient barometric pressure and ambient air temperature are also monitored and recorded. The extracted air stream then passes through a gas immersion heater that reduces the relative humidity of the stream below 50% to prevent water condensation in the system and to improve the adsorption efficiency of the activated carbon filter beds located downstream. Next, the air stream moves through a cyclone separator to remove particles that are greater than 15 μm and into the prefilter and HEPA filter housings where finer dusts (<15 μm) and radioactive particles are removed. After passing through the filters, the air stream enters one of two carbon adsorption housings where activated carbon removes the volatile organic vapors radon, and thoron. The air stream then exits the carbon bed as clean air and is discharged to the atmosphere.

The data acquisition system is hardwired to the instrumentation in the VVE processing system for data recording. The data acquisition system consists of a Wavetek data multimeter and a Compaq computer. The Wavetek system is designed to monitor and temporarily store data from 19 data



Not drawn to scale

ure 11-1. Schematic view of VVE system (Rau 89).

collection locations. The recorded data from the flow meters, thermistors, and pressure transducers are downloaded once a week to the Compaq computer. The downloaded data includes the (a) flow rate from the VVE demonstration extraction well (Borehole 8901D), (b) vacuum produced at the well head to achieve flow rate, (c) temperature of the subsurface flow, (d) atmospheric pressure at the extraction well location, (e) ambient outside air temperature at the extraction well, (f) temperature inside the Borehole 8901D cabinet, (g) temperature inside the Borehole 8901D instrument enclosure, and (h) the subsurface pressure in Borehole 8901D as measured by downhole pressure transmitters at various depths. The Wavetek system is programmed to record data from all stations at three time intervals: every 30 seconds for the first 60 minutes, every 5 minutes for the next 120 hours, and once per hour for the duration up to 120 days.

11.2.2 Baseline Data Collection

Existing Boreholes, 8801D, 8902D, D02, WWW-1, 78-4, and 77-1 were used for collecting baseline data. Each of these boreholes are completed with screened intervals for gas-port monitoring. Before the VVE demonstration was started, subsurface gas samples, pressure measurements, vertical permeability tests, gas-port tests, and gas-port correspondence tests were conducted at each port to establish the predemonstration monitoring conditions. The following sections describe the baseline data collection process. Section 11.2.2.1 describes the borehole completions, and Section 11.2.2.2 describes the predemonstration testing program.

11.2.2.1 Borehole Completion Details. Six boreholes were completed with gas sampling ports in support of the VVE demonstration. These are Boreholes 77-1, 78-4, WWW-1, 8801D, D02, and 8902D, which are located in the vicinity of the SDA as shown in Figure 11-2. The depths of the ports within each well are presented in Table 11-1. The following paragraphs describe the completion details and the gas port installation for each borehole.

Borehole 77-1 is located about 0.40 km (0.25 mi) north of the SDA and was continuously cored to a total depth of 183 m (600 ft). The hole was

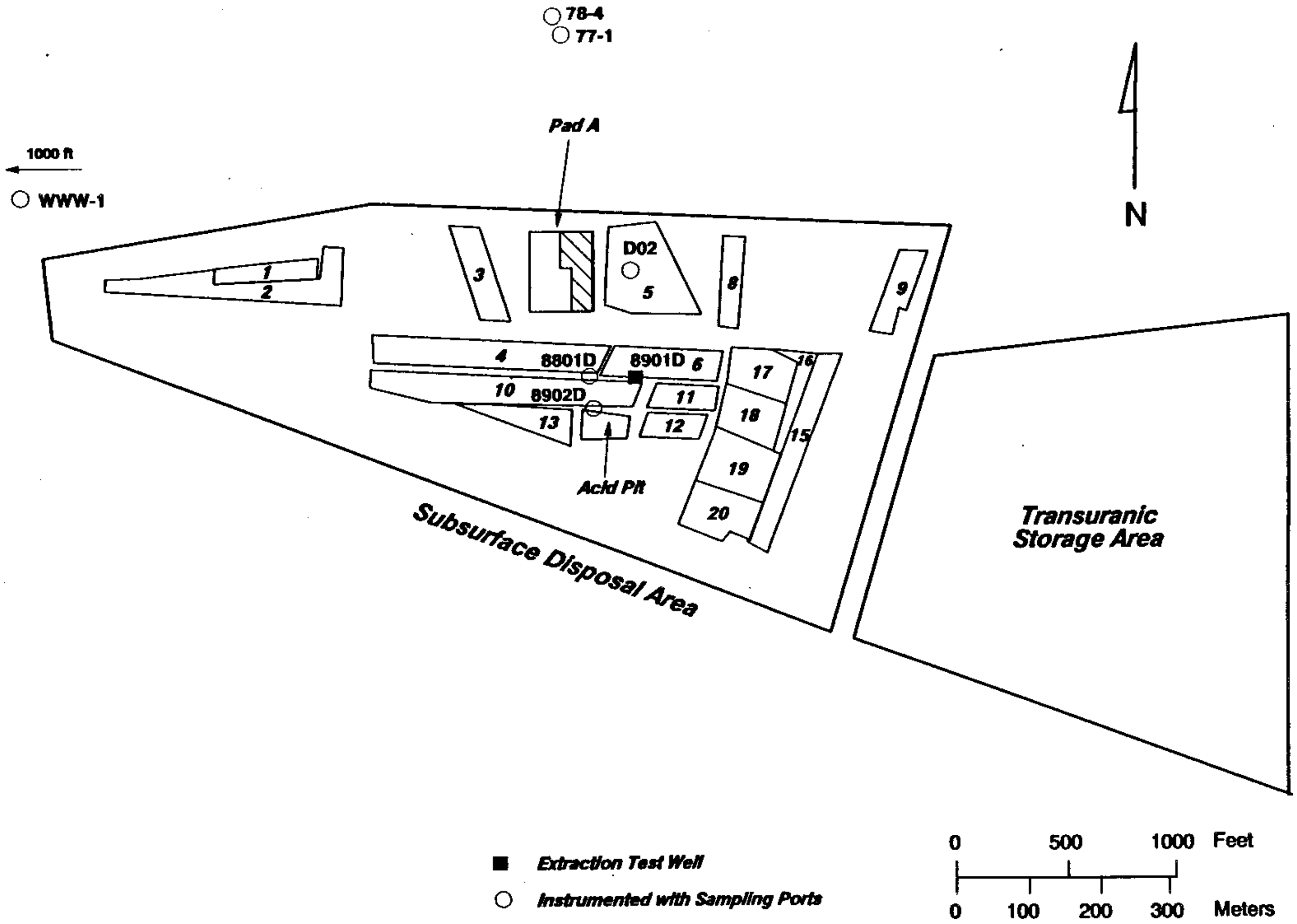


Figure 11-2. Approximate location of boreholes in the monitoring network for the VVE demonstration (Sisson and Ellis, 1990).

Table 11-1. Depth of gas sampling ports in VVE demonstration monitoring network

Borehole	Depth of Port [m (ft) below land surface]	Instrument ID Number
8801D	10 (32.8)	GSP-8801D-9
	15 (50.5)	GSP-8801D-8
	24 (77.5)	GSP-8801D-7
	28 (92.5)	GSP-8801D-6
	31 (102.5)	GSP-8801D-5
	40 (131.0)	GSP-8801D-4
	51 (167.2)	GSP-8801D-3
	59 (192.5)	GSP-8801D-2
	70 (230.0)	GSP-8801D-1
78-4	24 (78.0)	GSP-784-5
	36 (119.0)	GSP-784-4
	69 (227.5)	GSP-784-3
	77 (253.0)	GSP-784-2
	102 (335.0)	GSP-784-1
WWW-1	5 (15.3)	GSP-WWW1-7
	15 (48.0)	GSP-WWW1-6
	23 (74.0)	GSP-WWW1-5
	34 (112.0)	GSP-WWW1-4
	41 (135.0)	GSP-WWW1-3
	55 (180.0)	GSP-WWW1-2
	73 (240.0)	GSP-WWW1-1
77-1	20 (66.0)	GSP-771-6
	32 (104.0)	GSP-771-5
	34 (112.0)	GSP-771-4
	46 (151.0)	GSP-771-3
	58 (191.0)	GSP-771-2
	113 (371.0)	GSP-771-1 - inoperable
8902D	9 (30.0)	GSP-8902D-8
	14 (46.0)	GSP-8902D-7
	21 (70.5)	GSP-8902D-6
	32 (104.5)	GSP-8902D-5
	40 (130.0)	GSP-8902D-4
	55 (179.0)	GSP-8902D-3
	61 (199.0)	GSP-8902D-2
	70 (229.0)	GSP-8902D-1

Table 11-1. (continued)

Borehole	Depth of Port [m (ft) below land surface]	Instrument ID Number
D02	8 (27.5)	GSP-D02-8
	18 (59.5)	GSP-D02-7
	21 (68.5)	GSP-D02-6
	30 (100.0)	GSP-D02-5
	38 (125.0)	GSP-D02-4
	50 (165.5)	GSP-D02-3
	59 (192.5)	GSP-D02-2
	70 (231.0)	GSP-D02-1

cemented from total depth to 117 m (385 ft) below land surface. Borehole 78-4 was drilled about 9 m (30 ft) north of Borehole 77-1 to a total depth of 107 m (350 ft). At the time installation was started, 104 m (340 ft) remained open. Borehole WWW-1 is located 518 m (1700 ft) northwest of the SDA and was drilled to a total depth of 79 m (259 ft). Well 8801D is located in the center of the SDA and was drilled to a depth of 75 m (244.7 ft). Borehole D02 is located in the north-central portion of the SDA and was drilled to the 73-m (240-ft) interbed. Borehole 8902D is located in the central portion of the SDA and was drilled to a total depth of 75 m (245 ft).

The gas samplers in the boreholes are constructed of different materials. Borehole 77-1 has PVC screens connected to the surface through 0.6-cm (1/4-in.) plastic pipe. Borehole 78-4 has samplers constructed on 4 x 60 cm (1.5 in. x 2 ft) 30-mesh well points connected to the surface through 0.6-cm (1/4-in.) galvanized steel pipe. Gas samplers in Borehole WWW-1 consist of 1.9-cm (3/4-in.) copper tube (0.3 m) 1 ft long and drilled with 0.6-cm (1/4-in.) holes. The samplers are attached to the surface by 0.6-cm (1/4-in.) copper tube in 15-m (50-ft) lengths connected by brass Swagelok compression fitting soldered to ensure gas-tight seals. Boreholes 8801D, D02, and 8902D have gas samplers that are constructed of 5-cm (2-in.) wire-wrapped stainless steel screen that is 45 cm (18 in.) long. The samplers in these boreholes are attached to the surface with 0.95-cm (3/8-in.) stainless steel tubing and closed at land surface with Swagelok quick connect female attachments.

11.2.2.2 Predemonstration Borehole Testing Program. The gas port sampling and hydraulic testing activities that were conducted before the VVE demonstration was started are described in this section. The subsurface gas samples were collected to establish predemonstration contaminant concentration values.

The hydraulic testing consisted of four tests conducted in the following order: a gas port correspondence test, a gas port test, a vertical permeability test, and a staged pumping test. These tests were conducted sequentially to test the downhole instrumentation and to determine the vertical and horizontal permeability values required for the VVE demonstration final design. Each test is described below.

Gas samples were collected from each borehole sampling port for 2 months before the start of the demonstration. The gas samples were collected using a self-contained battery-powered vacuum kit and 1-L Tedlar sample bags. Before the sampling was started, each gas port was purged of three volumes of gas. During sampling, the vacuum kit tubing was connected to the sample-port tubing, the Tedlar bag was installed in the vacuum kit, and the vacuum was turned on. Following sample collection, the bag was sealed, documented, and transported to the GC that was located at the extraction point, the wellhead of Borehole 8901D. Each sample was analyzed for carbon tetrachloride, tetrachloroethylene, trichloroethylene, 1,1,1-trichlorethane (Rauen, 1989). These data were collected to establish a baseline for each of the compounds.

The gas port correspondence tests were conducted at each of the gas ports in the six boreholes to verify the transducer wiring and to provide an in situ calibration of each transducer with their power supplies. This test consisted of simultaneously applying a known positive pressure to the downhole pressure transducer and a reference transducer, then comparing the results to determine if the downhole transducer was calibrated to read true pressure values. The voltages from both transducers were recorded on a data logger and on a preprinted data sheet. The test was repeated at atmospheric pressure conditions. In addition, each gas port was tested for leakage by applying a vacuum at the well head end of the pressure transducer and observing the drift over a 15-minute period.

The gas port tests were conducted at each gas port within the six boreholes to determine horizontal permeability values in the basalt and to estimate the optimum sample port pumping volume for use during subsurface gas sampling. The GPT procedure consisted of injecting air into the gas port at a fixed rate and monitoring the gas port pressure at 5-second intervals for several minutes. The pressure was incremented and the test repeated. A resulting permeability value was estimated using curve matching techniques that compared the data to known solutions of a gas flow equation.

Vertical permeability tests were conducted in Boreholes 8801D, D02, and 8902D before the start of the VVE demonstration to measure the vertical permeability value at each of the gas ports. The VPT required that barometric and downhole pressure data be collected at 2.5-minute intervals. The procedure consisted of using a data logger to monitor the pressure for 1 week. Following the monitoring period, the data were downloaded to a portable computer for storage then analyzed to determine vertical permeability using a technique developed by Weeks.[a]

Finally, a staged pump test was performed in the extraction well (Borehole 8901D) to estimate the relationship between volumetric flow rate and pressure drop. In this test, a series of constant-flow tests were conducted and borehole pressures were monitored until steady-state conditions were established. The flow tests were conducted at constant mass flow rates of 25, 50, 75, and 100% of the designed flow rates. Pressures were measured every 2 minutes. The subsurface gas temperature was also measured in the borehole every 2 minutes. The resulting data were analyzed to determine the horizontal permeability value of the screened interval, which was used to establish the optimal pumping rate during VVE system operation.

11.2.3 VVE Demonstration

The demonstration test consisted of a 2-week test followed by a 4-month test. The purpose of the 2-week VVE demonstration test was to establish levels of radionuclides that might be transported by the VVE operation. The test provided data to support development of the computer model for organic vapor transport and to scale up the extraction system to the final cleanup configuration. Data collected during the test included the concentration of contaminants in subsurface gas and the extraction stream, subsurface gas

---

[a] Personal communication from E. J. Weeks, U.S.G.S., Idaho Falls, Idaho, 1988.

pressure, well head pressure, and system operating parameters. The operating parameters included relative humidity, well vacuum, heater temperature, HNu reading, electrical power frequency applied to the pump motor, vacuum at the pump, gas discharge temperature, pressure drops across filters, position of the extraction well valve, and rotameter flow reading for the flat filters.

The 4-month VVE demonstration was conducted from April to August 1990. Collected data included effluent mass flow rate, temperature of exhaust air, moisture content of exhaust air, well bore suction pressure, barometric pressure, time, and fan power. In addition, samples of the intake and exhaust gases were collected throughout the demonstration to evaluate the variations in the contaminant concentrations.

The VVE demonstration system start-up consisted of turning on the data acquisition system and the vacuum pump. First, the data multimeter was activated and the back-up power system was checked. The computer, which was programmed to start data acquisition automatically, was brought on line. Second, the vacuum pump was started. Its operating speed was increased slowly until the relative humidity of the air stabilized at 50% for 20 minutes. Once the system was at equilibrium, it ran automatically.

The gas flow at several VVE process-stream locations was sampled on a regular basis during operation. The first sampling port was located directly downstream of the sampling station. This sample port was connected to a GC for VOC analysis of the gas stream. The particles trapped in the particle receiver were sampled periodically and analyzed for alpha, beta, and gamma-emitting radionuclides in addition to VOCs. The effluent from the carbon adsorption beds was analyzed for total VOCs with a HNu to determine when the carbon media was beginning to saturate and become ineffective. Finally, the system's effluent to the atmosphere was continuously sampled for total VOCs using a HNu-201 Carbon Breakthrough Analyzer, which was equipped with an automatic detection system that would shutdown the operation if effluent concentrations exceeded allowable limits.

Routine maintenance on the VVE system consisted of changing filters/receivers and backing-up data. Filters and receivers that required replacement included the particle sample filter, cyclone particle receiver, prefilters, and the HEPA filters. Spare filter elements were available to replace the removed filters so that the system could be brought back on line quickly. Data recorded on the hard disk of the Compaq computer was transferred to a floppy disk at least once a week. This backup process allowed the data to be reviewed and analyzed on a regular basis.

11.2.4 Data Assessment

The data collected during the demonstration are being evaluated to assess the impact of the VVE system on the baseline conditions at the SDA. A summary report was completed November 21, 1990. The baseline data will be compared to model predictions to validate and verify the organic transport model. The system operating data (suction pressure versus effluent flow rate) will be evaluated to determine the efficiency of the demonstration system and the design of a full-scale system.

11.3 Procedures

This section summarizes the procedures that were used to collect the baseline data and to operate the VVE system. The sample collection procedures are described in Section 11.3.1. The predemonstration borehole testing procedures are presented in Section 11.3.2. The VVE system operation procedures are summarized in Section 11.3.3, and the quality assurance/quality control procedures are discussed in Section 11.3.4.

11.3.1 Gas Sample Collection Procedures for Boreholes

During the period from May 3 to June 8, 1989, subsurface gas samples were collected from Boreholes 8801D, 78-4, WWW-1, and 77-1. The sample collection procedures that were used during this sampling event are described in Section 11.3.1.1. The sample collection procedures that are currently used for the VVE demonstration are described in Section 11.3.1.2.

11.3.1.1 <u>Baseline Gas Sampling Procedures</u>. During the one-time gas sampling event in 1989, subsurface gas samples were collected at the borehole collar using a sampling pump, sampling train, and gas-tight syringes. During sample collection, the portable sampling train apparatus was connected to the permanently installed collection tube that protrudes from the borehole. The sampling train consisted of a GC septum for sample collection and the tubing/fittings required to attach one end to the borehole collection tube and the other to the silicon tubing connected to the sampling pump (Figure 11-3). The sampling pump was a model MSR 482700 Flow Lite H personal sampling pump. The syringes were Hamilton Series 1000 Gastight Syringes with a Teflon Luer Lock.

After the sampling train was attached to the borehole collection tube and the sampling pump, the pump was turned on to purge three volumes of gas from the gas port. Organic vapor and explosive gas readings at the discharge port of the pump were recorded. After the gas port was purged, samples were collected from the sampling train while the pump was still operating. The sample steps were as follows: (1) the needle of the syringe was inserted into the GC septum, (2) the minilock valve was opened to draw the sample into the syringe, (3) the plunger was drawn to the specified volume, (4) the minilock valve was left open with the needle still in the septum for 1 minute to allow any vacuum to subside, (5) the minilock valve was closed, (6) the needle was withdrawn from the septum, (7) all pertinent data were recorded on the sample tag that was attached to the syringe, and (8) the syringe was placed in a cooler at 4°C (39°F).

Following sample collection, the pump was turned off and the sampling train was removed from the gas port end. The pump was turned back on to run ambient air through the sampling train for at least 5 minutes to clear out any residual gases in the train. All pertinent data were recorded in the laboratory notebook and the field logbook including the date, time of collection, pumping rate, pumping time, HNu readings, LEL readings, sampling port identification number, sample volume, personnel present, identities of associated quality assurance samples, and the syringe number.

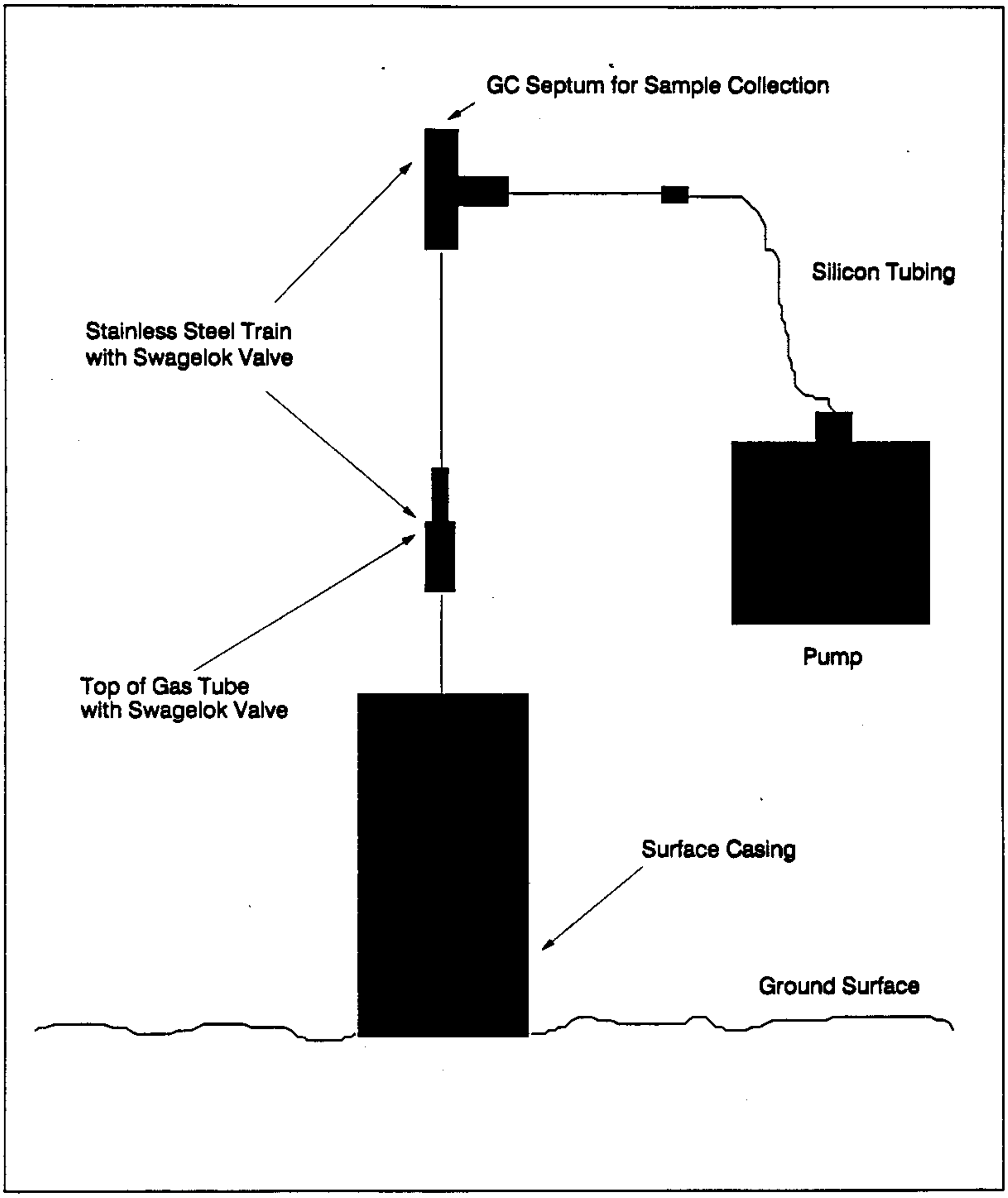


Figure 11-3. Diagram of sampling train (Rauen, 1989).

Following documentation, the sampling syringes were wrapped with plastic packing material and packed with reusable ice packs into sturdy, thermally-insulated coolers. The cooler lid was sealed with a custody seal, and the cooler was carried directly to the laboratory on the same day as sampling.

11.3.1.2 VVE Demonstration Gas Sampling Procedures. Subsurface gas samples were collected at the borehole collar using a self-contained battery-powered vacuum kit and Tedlar bags. The procedure consisted of transporting the testing apparatus to the borehole, purging the port line, collecting the gas sample, and transporting the samples to the laboratory. To purge the port line, the quick-connect fitting on the vacuum kit tubing was connected to the gas sampling port with the sample port valve in the closed position. The valve was opened and three volumes of gas were removed from the port. The purge time length for each port is presented in Table 11-2. After purging the gas port, samples were collected by installing a 1-L Tedlar bag into the vacuum kit box and following these steps: (1) close the sample vacuum box, (2) open the sample port valve, (3) turn on the sample vacuum box switch, (4) turn off the sample vacuum box switch when the sample bag is three-fourths full, (5) finish filling the sample bag, (6) open the sample vacuum box and close the valve on the sample bag, and (7) close the sample port valve. This procedure was repeated for each sampling port in each monitoring borehole.

Following sample collection, the vacuum kit was turned off and all pertinent data were recorded in the laboratory notebook and the field logbook including the date, time of collection, pumping rate, pumping time, HNu readings, LEL readings, sampling port identification number, sample volume, personnel present, identities of associated quality assurance samples, and the syringe number.

Following documentation, the sampling bags were packed with reusable ice packs into sturdy, thermally-insulated coolers. The cooler lid was sealed with a custody seal and the cooler carried directly to the Sentex Scentograph portable GC on the same day as sampling. Each sample was analyzed for carbon tetrachloride, tetrachloroethylene, trichloroethylene, and 1,1,1-trichloroethane.

Table 11-2. Purge times for gas ports[a]

Well 8801D

Port Number	Purge Time
1	76
2	64
3	54
4	41
5	32
6	31
7	23
8	19
9	12

Well 8902D

Port Number	Purge Time
1	76
2	63
3	56
4	41
5	34
6	23
7	20
8	16

Well DO-2

Port Number	Purge Time
1	76
2	64
3	54
4	40
5	32
6	22
7	20
8	10

Well WWW-1

Port Number	Purge Time
1	78
2	60
3	42
4	36
5	24

Well 78-4

Port Number	Purge Time
1	120
2	86
3	76
4	41
5	25

Well 77-1

Port Number	Purge Time
1	(Not instrumented at this time.)
2	
3	
4	
5	
6	

---

a. Source: 9.1 VVED System, Issue No. 006.

Standard sample custody procedures were followed during the gas-port sampling activity to track the collection and transport of each sample. Each sample was labeled in the field with a unique sample identification number that defined the task in the first character and the calendar year as the 7th and 8th characters. A field sample log was used for each sampling event that identified the sample location, field sample number, depth, type, time of sample, chemical analysis requirements, containers collected, sample collector initials, shipping method, date shipped, temperature, barometric pressure, personnel in attendance, and sample shipper initials. A chain-of-custody record was completed for each sample set to maintain a record of sample collection, transfer between personnel, and receipt by the laboratory.

11.3.2 Predemonstration Borehole Testing Procedures

This section summarizes the hydraulic testing procedures used during the testing of the VVE demonstration monitoring network. The gas port correspondence test is presented in Section 11.3.2.1. The gas port test and the vertical permeability test are described in Sections 11.3.2.2 and 11.3.2.3, respectively. The Staged Pump Test is discussed in Section 11.3.2.4.

11.3.2.1 Gas Port Correspondence Test. The gas port correspondence test was conducted at each of the gas ports within Boreholes D02, 8801D, and 8902D on March 19 and 20, 1990. At each borehole, the test procedure was initiated by decoupling a transducer from the connecting tubing and reconnecting it with Toughen tubing through a tee connector to a hand-held vacuum/pressure pump. An additional pressure transducer was connected to the open leg of the tee connection (herein referred to as the reference transducer). The pump was started and three tests were conducted. In the first test, a vacuum was applied and the voltages from both transducers were recorded. In the second test, a pressure was applied and again the voltages from both transducers were recorded. In the final test, the pump was turned off and voltages from both transducers were recorded at atmospheric pressure. All voltages were read using a multimeter that was connected as it would be during the operation of the VVE demonstration. All three tests were repeated for each transducer that was located at a gas port within each borehole.

The testing apparatus was directly transported to each borehole before the test was started. A Setra 270 pressure transducer was used as the reference transducer. A Wavetek model 52A multimeter was programmed for recording and temporarily storing the data. Tubing (consisting of Toughen tubing and a tee fitting) were configured for the simultaneous connection of the pump, reference transducer, and downhole transducer to be tested. A pump was used to apply the vacuum/pressure to the transducers.

During testing, the pump was adjusted until the reference transducer recorded a value of between 4 and 4.5 V for the first test, and between 0.5 and 1.0 V for the second test. The voltage reading from the reference transducer was then read through the front panel of the Wavetek, and the reading from the downhole transducer was read on the operational channel. The temperature and the time of testing were also recorded.

Following the calibration testing of each transducer, a leakage test was conducted. This test consisted of disconnecting each gas port at the wellhead. A vacuum was then applied at the wellhead end of the pressure transducer-valve assembly. The readings from each transducer were observed. If the readings remained steady, the system was assumed to be leak free. However, if the readings drifted, leakage was assumed to exist.

11.3.2.2 Gas Port Test. The gas port test was completed for each of the gas ports within the boreholes during the spring of 1990. Each test consisted of connecting the tubing from the flow meter and pump to the quick connector for the port. The multimeter was programmed to display dc voltage readings from the downhole pressure transducer and the flow meter at 10-second intervals. Finally, the pump was started and the port was pumped until steady-state conditions were established or for 15 minutes, whichever came first. Flow rate and pressure voltage readings were recorded until a steady-state was reached. During testing, if the flow meter or pressure reading recorded between 4.5 and 5 V, the valve on the pump was adjusted to prevent an over-range condition. Following the steady-state testing, the valve between the quick connector and the pump was closed and the recovering pressure was recorded at 10-second intervals over a 10-minute period. The test concluded by measuring the gas stream temperature and turning the pump off. This test was repeated at each gas port in each borehole within the monitoring network.

The testing apparatus was transported to each borehole before testing. The data acquisition system consisted of a Wavetek model 52A multimeter for acquiring the test data and a Compaq portable PC for storing the test data. A pump with a flow capacity between 1 and 7 L/min was supplied for each test. A portable flow meter was attached to the system that provided a manual reading of +/-5%. A thermometer was used to measure the gas stream temperature.

11.3.2.3 Vertical Permeabilities Test. The vertical permeabilities tests were conducted at the monitoring wells in the spring of 1990. These tests were fully automated using a data acquisition system composed of a Wavetek model 52A multimeter and a Compaq portable computer. The test procedure consisted of setting up the data acquisition system at the borehole and allowing it to run for 1 week. The data acquisition system was set up using the following steps: (1) verify that the power supplies, multiplexer, and RS232 cable are plugged in; (2) turn on the power to the Wavetek and Compaq systems; (3) start the data acquisition system by typing "VVE demonstration"; (4) periodically verify the data acquisition system is functioning by observing the display on the Wavetek and Compaq; and (5) strike a key on the keyboard to stop data acquisition. The data collected during each test was downloaded to floppy disks and delivered to the data management personnel. Any problems or observations were recorded in a logbook.

11.3.2.4 Staged Pump Test. A staged pump test was completed at Borehole 8901D on September 31, 1989. This test was conducted with the VVE demonstration system off. The data acquisition system, heater, and vacuum pump were started. The data acquisition system was the same as that used for the gas port test and vertical permeability test. Following startup, the heater outlet temperature sensor/controller was set for 21°C (70°F). The system flow was elevated to 100 ft^3/min as quickly as possible without exceeding 10.5-in. Hg on the vacuum gauge or 4.9 psi on the system gauge transmitter to the data acquisition system. Next, the speed controller was manually adjusted to maintain the 100 ft^3/min flow rate within +/- 5 ft^3/min. The pump was on until the steady-state flow rate had been maintained for 20 minutes. The pressures on the vacuum gauge, on the system gauge vacuum transmitter, and the elapsed time were recorded in the logbook. The pump and heater were turned off after the 20-minute period, but the data acquisition system ran for an additional hour. The data were downloaded to a floppy disk after the 1-hour period. This test procedure was repeated using steady-state flow rates of 300 and 500 ft^3/min.

11.3.3 VVE Demonstration Processing System Operation and Sampling Procedures

The following operation and sampling procedures were followed when the VVE demonstration processing system was operating. Immediately after the system was started, the carbon bed inlet relative humidity and temperature indicators were monitored. The relative humidity indicator was set so that it always read below 50% to minimize moisture condensation. The reading was lowered by increasing the setpoint on the temperature controller/sensor. The temperature was not allowed to exceed 38°C (100°F). A system flow rate specified by the results of the staged pump test was established by slowly ramping up and setting the pump motor speed on the variable-speed drive controller. The desired flow rate was obtained by incrementally increasing the flow rate in stages so that a vacuum of 4.5 psig was not exceeded. The VVE demonstration system then operated automatically under the final setpoint conditions while monitoring and logging the readings into the system logbook. The collected data were transferred to a floppy disk for processing by the data management personnel at least twice a week.

The particle sample filter, located in the flanged filter holder at the wellhead connection, was periodically sampled. To collect a sample, five valves were opened. The time required to adequately sample was established by trial and error. When sampling was complete, two valves were closed, and one was left open to remove the sample filter. Radioactive contamination handling procedures, as specified in the EG&G Radiological Controls Manual, were followed during the filter removal process. The filter element was removed from the housing and sealed in a shipping bag. The bag was transported to the laboratory for analysis of the filter. A new filter element was inserted into the housing that was reinstalled in the flanged filter holder.

The cyclone particle receiver was sampled periodically. This procedure consisted of removing the particle receiver from the base of the cyclone and installing a spare receiver. The removed particle receiver was delivered to the laboratory for analysis.

The prefilters and HEPA filters were sampled periodically when the VVE system was off. Spare filter elements were available as replacement so that the VVE system could be brought back on line quickly. The procedure consisted of removing the prefilter and HEPA filter elements and replacing them with new ones. The used filters were routed to the laboratory for analysis.

Gas samples were collected periodically at Borehole 8901D (the extraction well) for VOC analysis. A pumping station drew a sample from the process stream and expanded it to atmospheric pressure. The sample was automatically injected into the Sentex Scentograph GC that was located adjacent to the gas sampling port at the wellhead. The GC was equipped with a Toshiba 1100 Plus personal computer. The resulting chromatographs are stored in project files.

11.3.4 Quality Assurance/Quality Control Procedures

Quality assurance/quality control samples were collected as part of the one-time borehole baseline gas sampling event in 1989. These samples consisted of a trip blank, a field ambient air blank, and a blind standard. One quality assurance/quality control sample was included in each days sampling activity. Trip blanks were collected in the laboratory from a gas-sampling bulb filled with an inert pure gas (e.g., nitrogen) and transported to and from the field sampling location. Field blanks were composed of ambient air drawn into the Tedlar sampling bags in the vicinity of the sampling area. Standard samples were prepared before each sampling event by a separate EG&G laboratory not responsible for the analyses. In addition, duplicates (or triplicates) were collected from a selected gas port immediately after collection of a normal sample (Rauen, 1989). These data were validated by the DIRC committee in accordance with EPA requirements for data validation.

For the VVE demonstration, random blanks were run on a daily basis as a quality control measure to ensure system memory or carryover contamination did not occur. In addition, carbon tetrachloride standards (CCl_4) (i.e., Scott Specialty Gas, certified ±2%) of 205 and 1000 ppm were run on a daily basis to ensure a linear CCl_4 response from approximately 100 to 1000 ppm (Rauen, 1989).

A quality control audit was conducted to verify compliance with the sampling and analysis plan. The audit included a review of the field operation records, laboratory testing records, equipment calibration records, control of samples, numerical analyses, computer program documentation, transmittal of information, and control of records. The audit was performed by the field Quality Assurance Officer and the Analytical Quality Assurance Officer.

The sampling teams followed the health and safety practices that were outlined by the BWP health and safety plan (EG&G, 1989f). The sampling team leader completed a safe work permit before each sampling event. The industrial hygienist conducted an initial survey of the site before sampling was initiated to determine if contaminants existed in the ambient air conditions. Sampling personnel followed the personal protective equipment guidance and wore coveralls, safety glasses, a half-face respirator with GMA cartridges, and an organic vapor monitoring badge. The badges were turned into the industrial hygienist at the end of each sampling day and were sent to the laboratory for analysis.

11.4 Results

The results of the VVE demonstration are presented in this section. Results of the baseline data collection, the 2-week demonstration test, and the 4-month demonstration test are discussed in Sections 11.4.1, 11.4.2, and 11.4.3, respectively. The status of organic vapor transport model development is addressed in Section 11.4.4.

11.4.1 Baseline Data Collection

The results of the one-time baseline gas sampling of Boreholes 8801D, 78-4, WWW-1, and 77-1 in 1989 are included in Appendix 5-8 of Section 5 in this report. The results of the gas port correspondence test for Boreholes 8801D, D02, and 8902D indicated that the transducers were functioning properly and verified that the correct data acquisition systems channels were connected to the correct transducer. Some leaks were found and repaired.

The results of the sample port tests, including the gas port correspondence test, the vertical permeability test, gas port test, and staged pump test were inconclusive because of the pressure generated by flow through the 0.95-cm (3/8-in.) tubing connecting the sample ports to the ground surface. The problem was exaggerated for gas ports located in zones of high permeability because of higher flow rates (Sisson, 1990).

11.4.2 Two-Week VVE Demonstration Results

The 2-week test was started November 3, 1989, after some initial testing of equipment. The pumping rate varied from 497 to 523 ft^3/min during the test. Relative humidity for the extraction stream ranged between 30 and 40%, while the air temperature varied from 21 to 27°C (70 to 80°F). Vacuum pressure in the well ranged from 0.38 to 0.46 lb/in^2 of vacuum or 2.58 to 3.21 kPa (Sisson, 1990). Results of the two-week test are included in Sisson (1990) (Appendix 11-1). The downhole pressure analysis is discussed in Section 11.4.2.1, the borehole pressure measurements are reviewed in Section 11.4.2.2, results of the extraction well sampling are presented in

Section 11.4.2.3, and sampling of the monitoring boreholes is summarized in Section 11.4.2.4.

11.4.2.1 Downhole Pressure Analysis. Borehole pressure varies with barometric pressure. The barometric pressure is compared to borehole pressures at various depths in Borehole D02 as shown in Figure 11-4. Variations in borehole pressure are much smoother and lagged the barometric pressure by nearly 10 hours at depths of 71 m (233 ft). To precisely determine pumping effects, barometric pressure was removed from the borehole pressure measurements by a Fourier series transform. Reliable estimates of hydraulic properties could be made after establishing pumping effects thereby resulting in more accurate computer simulations (Sisson, 1990).

During the two-week test barometric pressure varied between 79 and 90 kPa while the borehole vacuum pressure was about 3 kPa in the extraction well. Subsurface gas pressure was measured for various depths approximately hourly at monitoring Boreholes 8801D and D02. The differential pressure sensors used initially were not satisfactory and were replaced with absolute pressure sensors specifically designed for atmospheric pressure monitoring. Both Boreholes D02 and 8901D had barometric pressure sensors.

11.4.2.2 Borehole Pressure Measurements. Extraction well vacuum is directly related to pumping rate. Figure 11-5 shows the relationship between borehole pressure and pumping rate at Borehole 8901D (the extraction well) for the 2-week demonstration. The data indicate that the underlying basalts are highly permeable. A linear regression calculation indicated that increasing the pumping rate to 1000 ft^3/m would result in a borehole vacuum pressure of 1 psiv (6.5 kPa).

The data acquisition system failed several times during the test and data were lost. Computer operating errors resulting from complex menus and unsuitable field conditions caused some of the failures. A programming error in the software in the data acquisition system was discovered about 2 months after the test, which caused the data acquisition system to lose 24 hours of

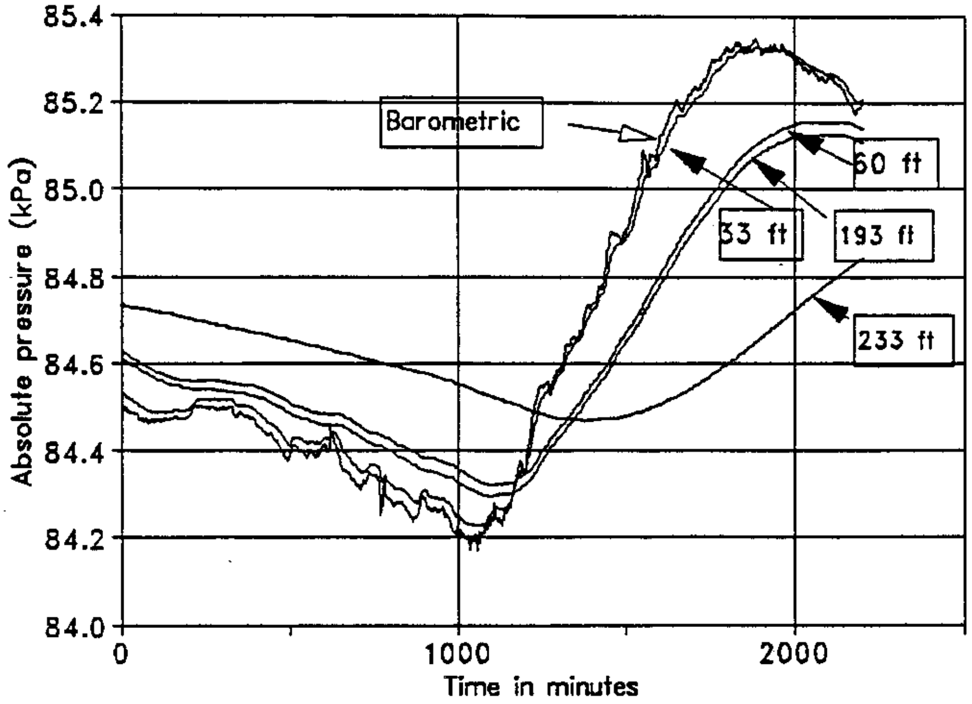


Figure 11-4. Downhole pressure fluctuations from barometric effects at Borehole D02 (Sisson, 1990).

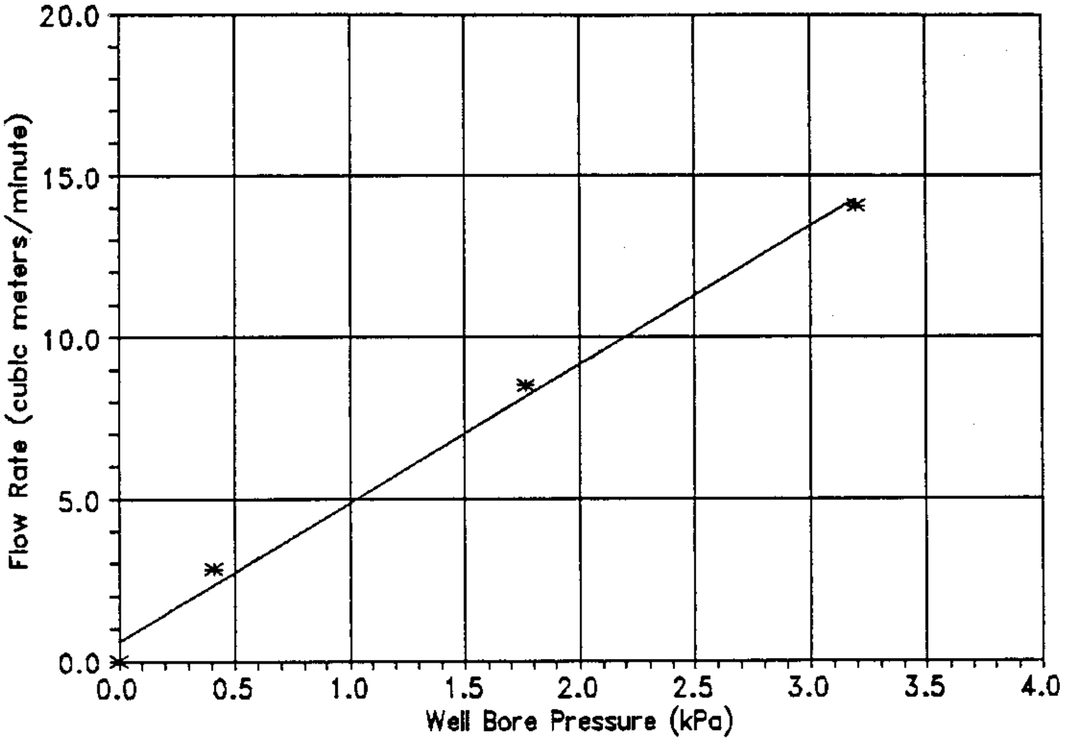


Figure 11-5. Flow rate at Borehole 8901D versus extraction well vacuum (Sisson, 1990).

data each time they occurred. Both problems were solved before beginning the 4-month test.

11.4.2.3 Extraction Well Sampling. The concentration of CCl_4 versus time from the extraction well are shown in Figure 11-6. The extraction rate for CCl_4 was estimated based on the sample concentrations and a pumping rate of 514 ft^3/min (Figure 11-7). The results indicated that approximately 76 kg (165 lb) of CCl_4 was extracted during the 12 days of the test at a rate of 6 kg/day (14 lb/day) (Sisson, 1990).

11.4.2.4 Monitoring Borehole Sampling. Subsurface gas samples were obtained from monitoring Boreholes 8801D, D02, WWW-1, and 78-4. Samples were taken using a small portable pump in Tedlar bags and transported to a field GC for analysis. A standard gas sample was also analyzed. A large variability in the standard gas concentration was observed in the standard sample as shown in Figure 11-8. The average concentration of the standard gas was 140 ppm with a standard error of 80 ppm (Sisson, 1990). Fluctuations in outside temperature caused the concentration variability, and the GC was moved inside.

Figure 11-9(a) shows the concentration of CCl_4 at a depth of 15 m (50 ft) in Borehole 8801D located 22 m (72 ft) from the extraction well. The concentration at 15 m (50 ft) is nearly constant except for 3 peaks above 2000 ppm. The source of the high values is unknown but may have resulted from samples being mixed-up or instrument error. Samples from a depth of 28 m (93 ft) show an erratic concentration pattern varying from 0 to more than 7000 ppm CCl_4 (Figure 11-9(b)). Samples from depths greater than 28 m (93 ft) show less concentration variation than those at shallower depths, but the CCl_4 concentration is also less at depth. At a depth of 27.4 m (90 ft), CCl_4 concentrations were about 2000 ppm compared to only 20 ppm at depths of concentration 59 and 70 m (193 and 230 ft).

The wide range in CCl_4 concentration from the same depth in the same well may be indicative of mechanical sampling problems with the gas sampling port. Some mechanical problems were identified and resolved.

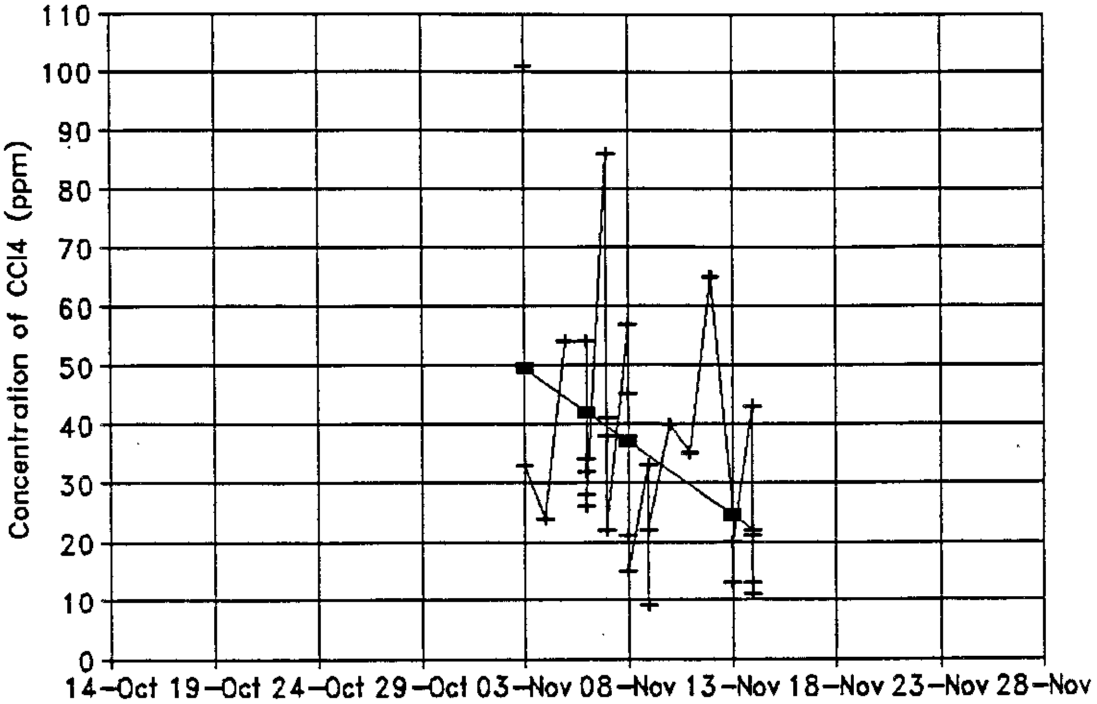


Figure 11-6. CCl_4 concentration in the extraction stream. Solid line fitted using linear regression (r-square = 0.12). (Sisson, 1990).

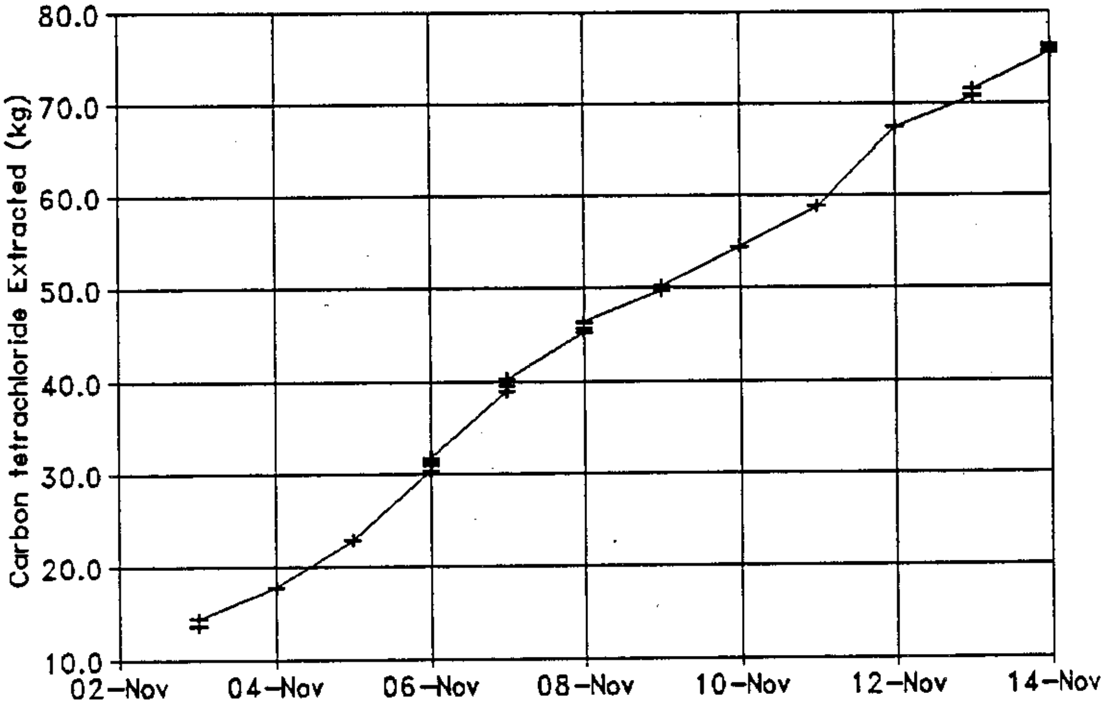


Figure 11-7. Cumulative CCl_4 extraction during the 2-week test (Sisson, 1990).

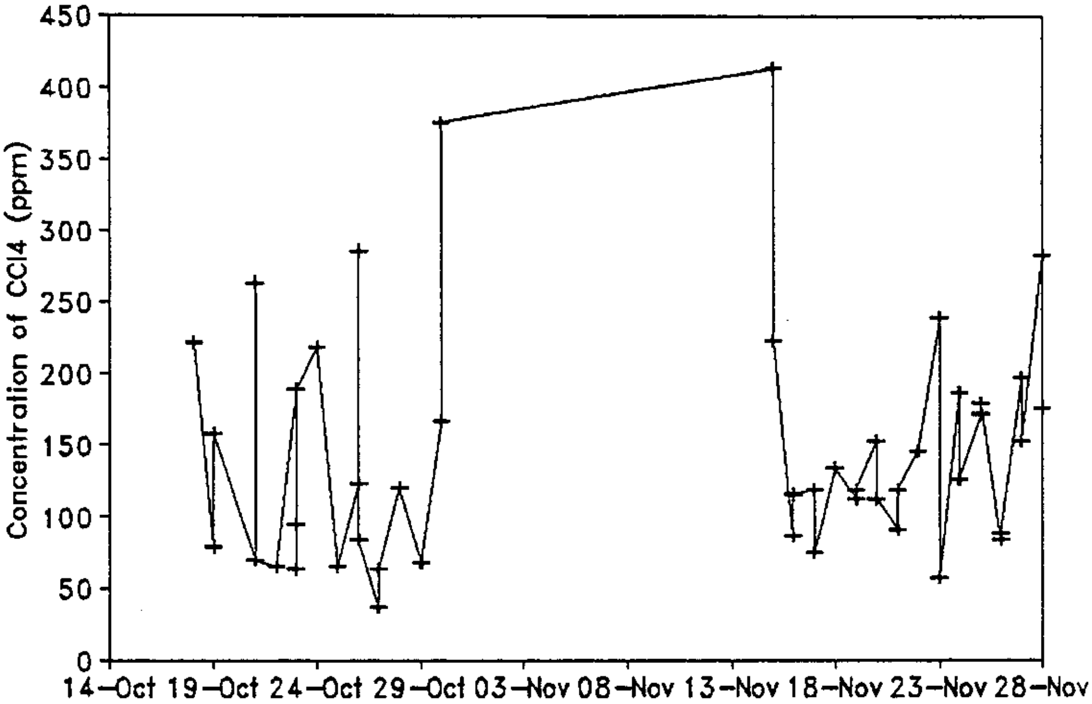


Figure 11-8. CCl_4 concentration of the standard gas estimated with the field Gas Chromatograph (Sisson, 1990).

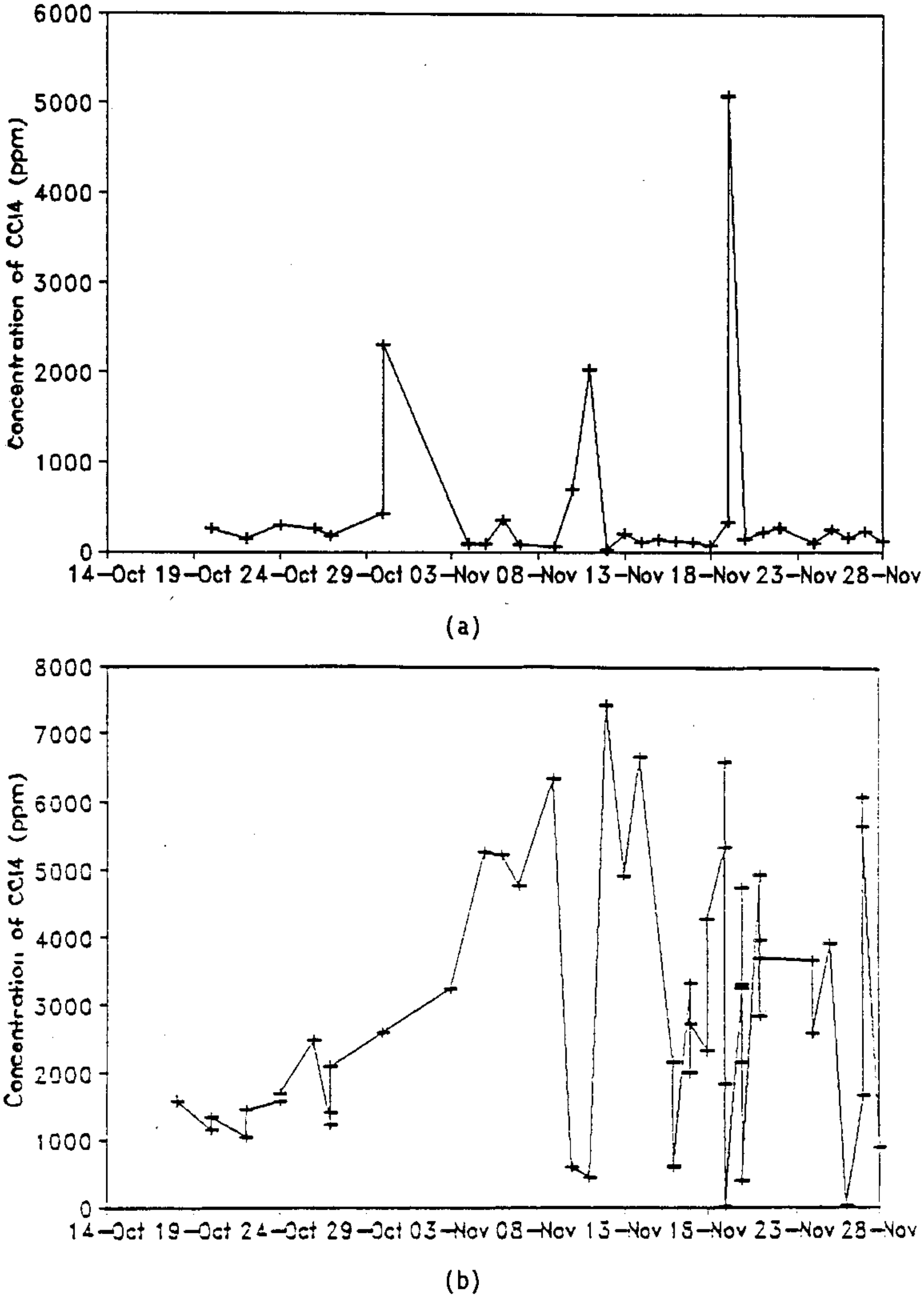


Figure 11-9. CCl_4 concentration at depths of (a) 15 m (50 ft) and (b) 28.3 m (93 ft) in Borehole 8801D during the two week test. (Sisson, 1990).

11.4.3 Four-Month Test Results

A 4-month test of the VVE system was started April 12, 1990. The following information is summarized from Sisson and Ellis (1990). The system was initially operated at 492 stdft^3/min but after a larger vacuum pump was installed it operated at 678 stdft^3/min. The VVE operated reliably with little maintenance for 2088 hours during the 4-month test and extracted a total of 77 million ft^3 of subsurface gas. Results of the flow test are described in Section 11.4.3.1, and gas sampling results are summarized in Section 11.4.3.2.

11.4.3.1 Flow Test Analysis. A well bore flow test was conducted on the extraction well (Borehole 8901D) during the 4-month test. Test results showed that approximately 50% of the subsurface gas was extracted from above the 34-m (110-ft) interbed. The remaining gas was extracted from a basalt rubble zone located between 58 and 59.4 m (190 and 195 ft). Even though the well screens prevented accurate flow measurements during the flow test, the data indicated that the basalt rubble zone strongly affected the flow of gas. Removal of the screen during testing would have provided more accurate results and would also allow the use of inflatable packers to isolate selected intervals.

11.4.3.2 Gas Sampling Analysis. Concentrations of VOCs were estimated from gas samples obtained from the extraction stream in Borehole 8901D during the 4-month test. Concentrations of CCl_4 over the 4-month period are shown in Figure 11-10. The concentration of CCl_4 and TCE averaged 232 ± 81 mg/m^3 and 87 ± 25 mg/m^3, respectively, over a 90 day pumping period. Cumulative volumes of CCl_4, TCE, and CCl_4 + TCE removed from the subsurface during the test are shown in Figure 11-11. Approximately 429 kg of CCl_4 and 164 kg of TCE were extracted during the 4-month test accounting for approximately 94% of the extracted VOCs.

Concentration of CCl_4 with depth was evaluated. The 4-month average concentration of CCl_4 versus depth is plotted in Figure 11-12 for Boreholes 8801D, 8902D, and D02. The concentration increased with depth to about

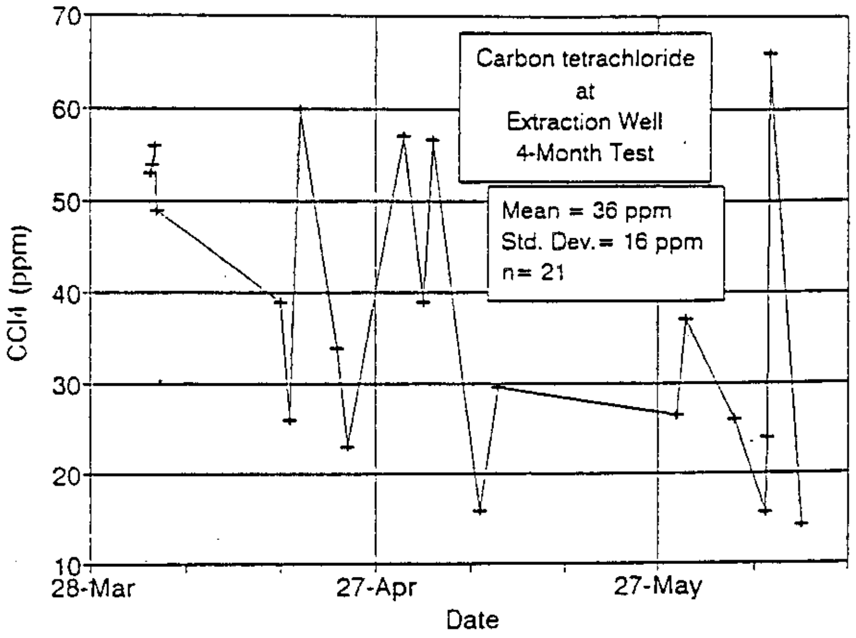


Figure 11-10. CCl_4 concentration in the extraction stream of Borehole 8901D during the 4-month test (Sisson and Ellis, 1990).

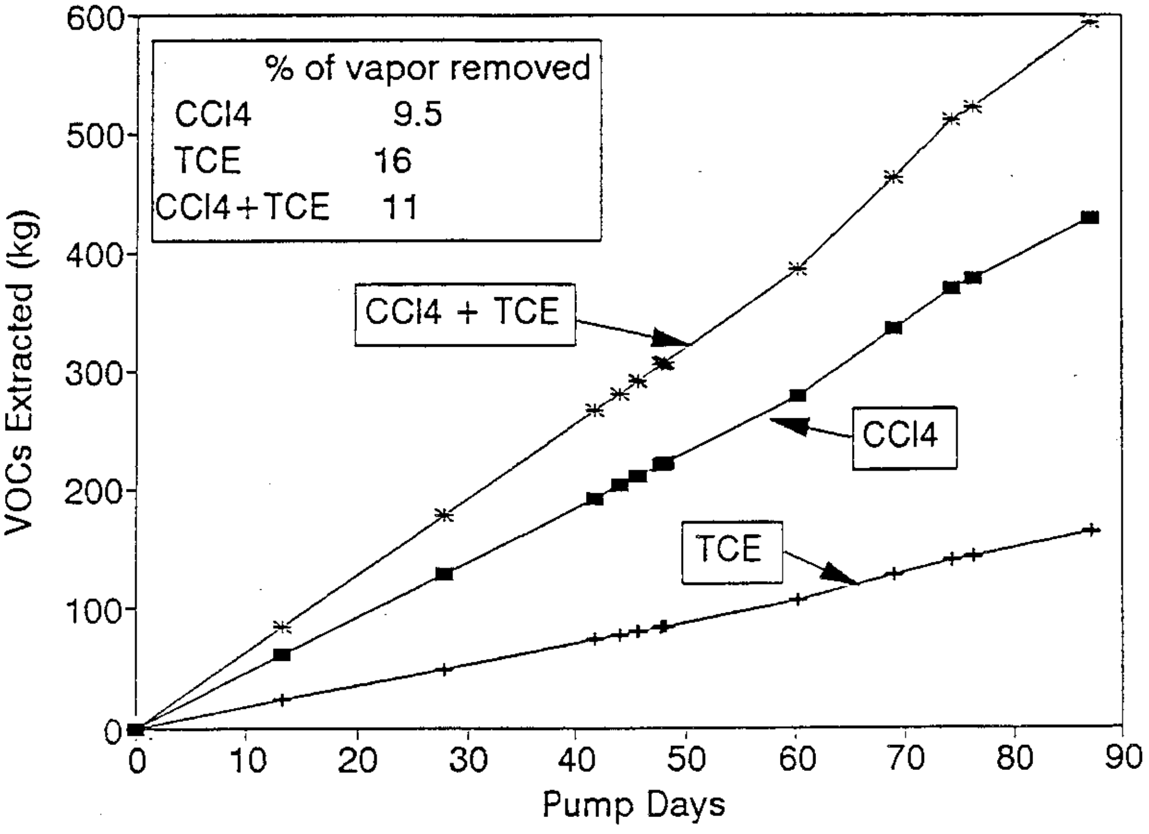


Figure 11-11. Cumulative extraction of CCl_4, TCE and CCl_4 plus TCE over 90 days (Sisson and Ellis, 1990).

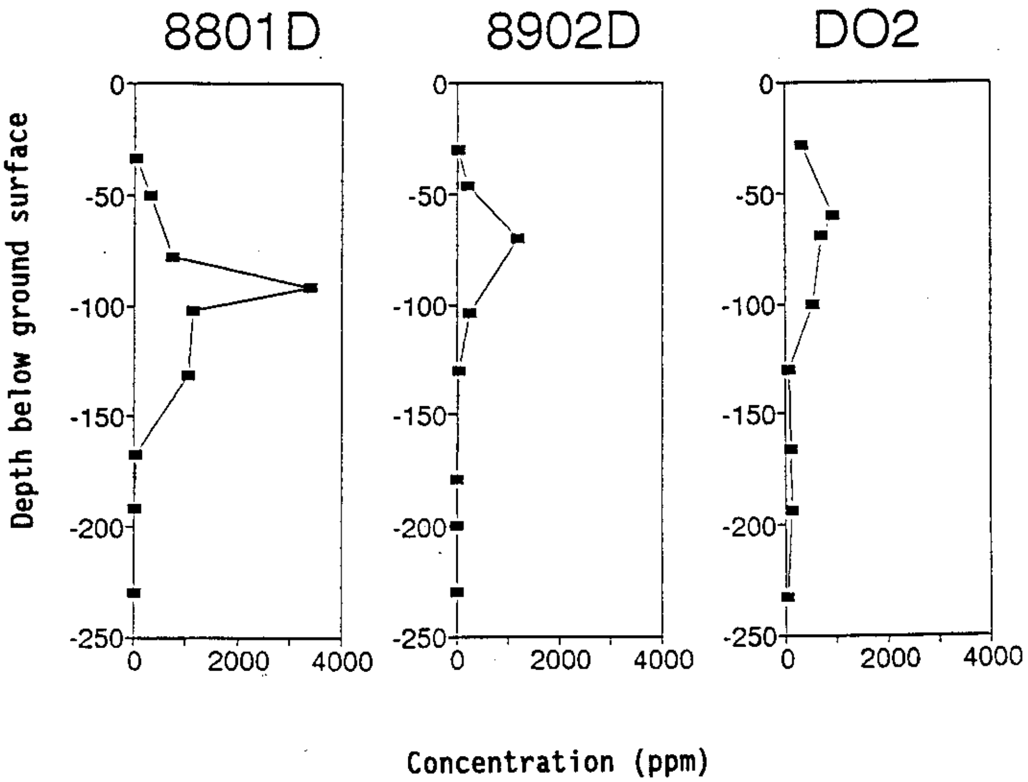


Figure 11-12. CCl_4 concentration as a function of depth in Boreholes 8801D, 8902D, and D02 (Sisson and Ellis, 1990).

30.5 m (100 ft) and then began to decrease. The concentration of CCl_4 at 28 m 92 ft) in Borehole 8801D was greater than 3000 ppm. This bulge may be caused by the dying source term effect. As the concentration of CCl_4 in the source (i.e., pits and trenches at the surface) is depleted, concentrations near the source term decline, and a bulge of high concentration migrates downward through the vadose zone. This effect has been predicted with numerical transport models. High concentrations of CCl_4 may occur at comparable depths in Borehole 8902D and D02, but no gas sampling ports are located at 28 m (92 ft) in these boreholes.

Changes in concentration of CCl_4 in Borehole 8801D versus time are shown in Figure 11-13. Concentrations of CCl_4 above 40 m (131 ft) increase with time while CCl_4 concentrations below this depth are decreasing with time. These trends suggest that pumping caused movement of CCl_4 from a zone of higher concentration into the area above 40 m (131 ft) and movement from a zone of lower concentration below 70 m (230 ft) toward the highly permeable rubble zone located between 58 and 59.4 m (190 and 195 ft) where 50% of the extracted gas came from.

The CCl_4 concentration in Borehole 8902D is shown in Figure 11-14. Concentrations increase with time at depths above 39.6 m (130 ft) and decrease or remain the same at depths of 39.6 m (130 ft) and below. This pattern is similar to that observed in Borehole 8801D. The concentration of CCl_4 in Borehole D02 is shown in Figure 11-15. Concentrations generally increase with time except at 39.6 m (130 ft) where concentrations decline and at 71 m (233 ft) where concentrations remain about the same.

11.4.3.3 Organic Vapor Transport Model Development. Both a two- and three-dimensional transport model were developed to evaluate the effectiveness of the VVE and other remedial actions. Initially, only a two-dimensional model was used. An updated three-dimensional model was completed later in September 1990. The VOC transport model will be calibrated based on

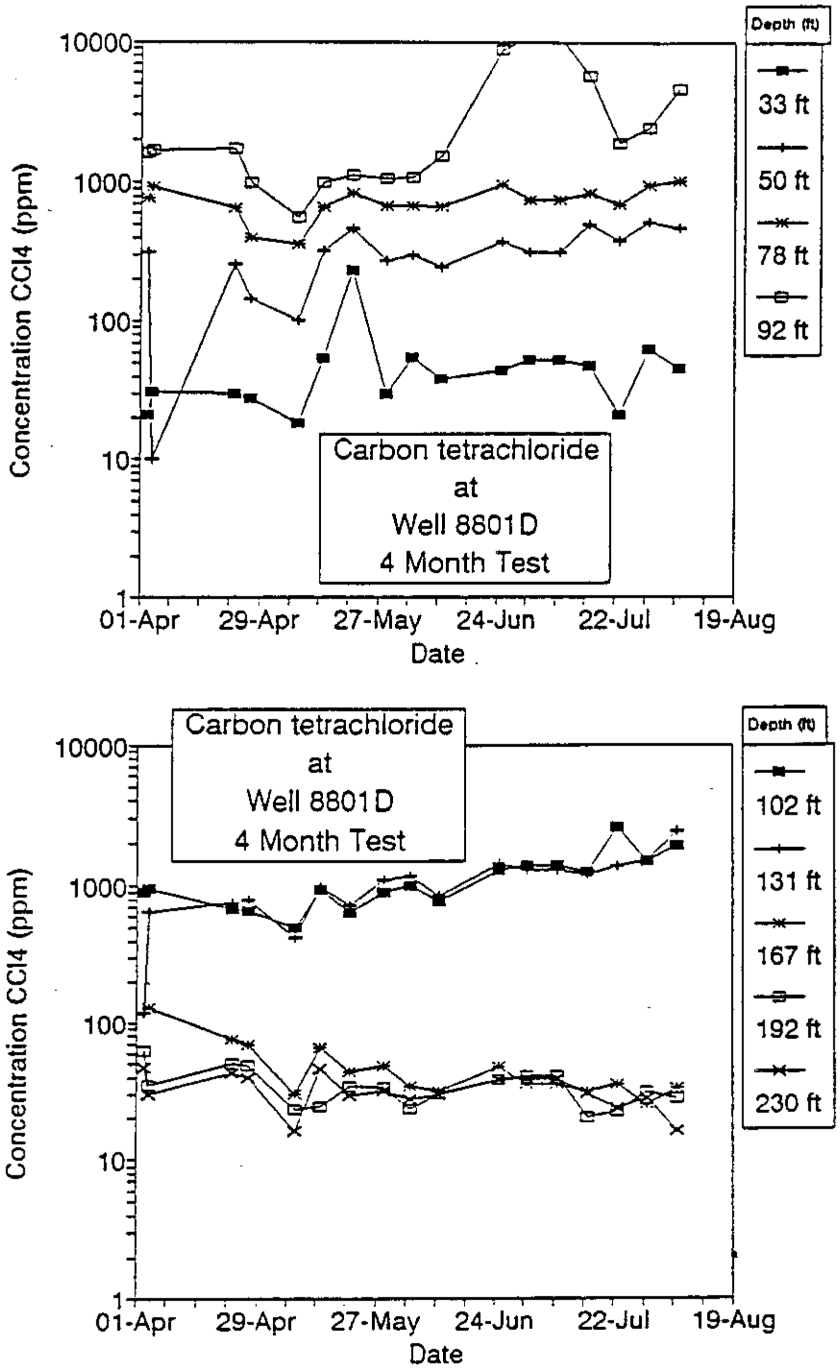


Figure 11-13. CCl_4 concentration as a function of depth in Borehole 8801D for the 4-month test (Sisson and Ellis, 1990).

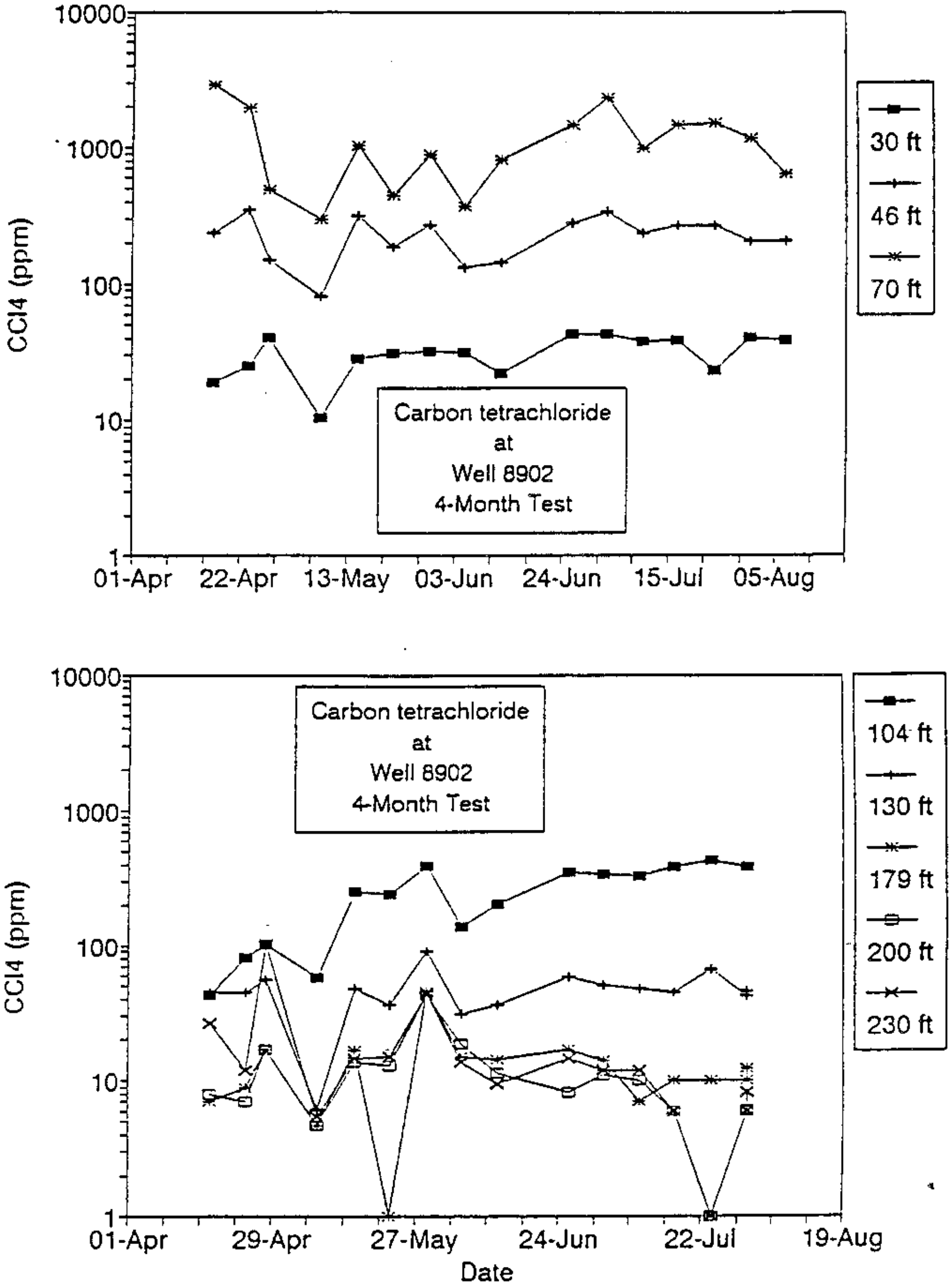


Figure 11-14. CCl_4 concentration as a function of depth in Borehole 8902D for the 4-month test (Sisson and Ellis, 1990).

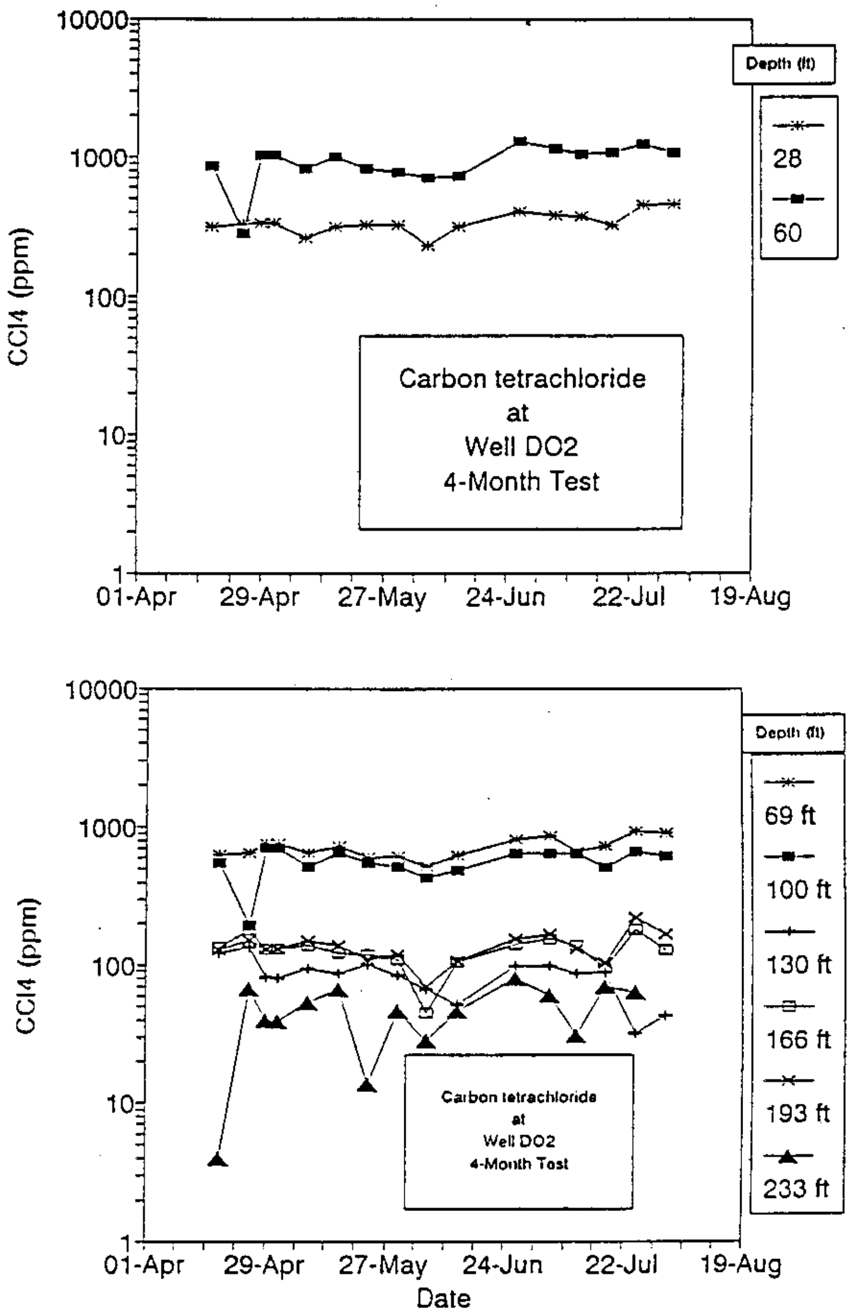


Figure 11-15. CCl_4 concentration as a function of depth in Borehole DO2 for the 4-month test (Sisson and Ellis, 1990).

concentrations observed in the monitoring boreholes over time, on pressure drawdowns in nearby monitoring boreholes, and on results from the tracer tests. Development of the two-dimensional model is discussed in Baca et al. (1988). The three-dimensional model is currently being calibrated and validated and simulation of the VVE is in progress.

12. Analysis of Nonaqueous Liquid Phase Organics

12. ANALYSIS OF NONAQUEOUS LIQUID PHASE ORGANICS

An inventory of the mixed wastes disposed at the SDA was compiled to establish if VOCs detected in 1987 had originated from the buried wastes. Vigil (1989) indicated that approximately 334,000 L (88,250 gal) of TRU-contaminated mixed waste sludges were buried in the SDA from 1966 to 1970. Before burial, the wastes were absorbed on calcium silicate and placed in 208-L (55-gal) steel drums that were then sealed. The analysis of nonaqueous liquid phase organics was proposed to evaluate the potential role of waste oil in the migration of VOCs and radionuclide contaminants from the SDA (EG&G, 1988a).

12.1 Purpose of Investigation

Three objectives were initially proposed for the investigation of nonaqueous liquid phase organics (EG&G, 1988a). The first objective was to gather information on specific physical properties of Texaco Regal (TR) machine oil (e.g., density and viscosity) to use in the organic transport model for the SDA. The physical properties data were to be used to determine if machining oil has significant mobility to be a potential vadose zone or ground water contaminant. The second stated objective was to validate the organic transport model data and assumptions with respect to the proposed migration of the organic plume. The third objective was to establish if machining oil acts as a transport mechanism for organic constituents or radionuclides. As the investigation ensued, the work that was conducted evolved to support the development of an organic transport model that included nonaqueous phase liquid transport, described in Sections 12.3 and 12.4.

Information in Sections 12.3 and 12.4 is summarized from two reports: Rawson and Walton (1989) and Rawson et al. (1989). Mixed waste sludges disposed of at the SDA are composed of light machine oil and various chlorinated solvents contaminated with TRU radionuclides. As determined from the SDA inventory records, carbon tetrachloride, trichloroethylene, tetrachloroethylene, and 1,1,1-trichloroethane make up the bulk of the solvents disposed of at the INEL Site from 1966 to 1970. The generator of the mixed waste sludges, Rocky Flats Plant, indicated that the lathe coolant used in machining activities consisted of 60% machine oil and 40% carbon tetrachloride. The source characterization study indicated that the particular nonaqueous organic of interest was TR Oil, a light machining oil originating from machining activities at the Rocky Flats Plant. Approximately 148,000 L (39,100 gal) of machine oil was disposed of in the SDA. The total amount of petroleum hydrocarbon waste disposed of at the SDA is approximately 237,000 L (62,600 gal) consisting of 89,000 L (23,500 gal) of radionuclide contaminated waste oil in addition to the machine oil. Table 12-1 lists the radionuclide content of buried TRU wastes. Table 12-2 provides volume estimates of the hazardous wastes disposed of in the SDA.

12.2 Proposed Strategy in Work Plan

The investigation strategy proposed in the December 1988 Work Plan followed a three-phased approach: (1) to collect chemical and physical data on TR Oils from Texaco, Inc., (2) to sample TR Oils for computer transport model validation, and (3) to conduct a paper study on the potential effects of TR Oil as a transport mechanism (EG&G, 1988a). It should be noted that the original organic transport model for the RWMC included migration of organic chemicals in only the vapor phase or as dissolved components of the aqueous phase. A new model to account for nonaqueous organic liquid migration was developed as part of the investigation.

12.3 Procedures

The following sections provide a summary of the investigation procedures for the analysis of nonaqueous liquid phase organics. Section 12.3.1 provides a brief description of how specific machine oil chemical and physical properties data were gathered, Section 12.3.2 discusses development of a multiphase flow and transport submodel for the organic transport model and underlying assumptions, and Section 12.3.3 presents the questions that were proposed to determine if machine oil is a potential transport mechanism for VOCs or radionuclides.

Table 12-1. Radionuclide content of buried TRU waste[a]

Uranium and Transuranic Radionuclide	Activity When Emplaced (in curies)	Activity Calculated as of January 1, 1985 (in curies)[b]
Pu-238	571.4	462
Pu-239	21,043	19,789
Pu-240	4,860	4,564
Pu-241	178,425	54,234
Pu-242	0.2	0.2
Am-241	48,007	46,548[c]
Ce-144	0	0
U-233	0.5	0.5
U-235	0.3	0.3
U-238	68	68
Total TRU radioactivity	252,975	125,666

Beta-Gamma Radionuclide	Activity When Emplaced (in curies)	Activity Calculated as of January 1, 1985 (in curies)
Co-60	<99,000	4,214.3
Ni-59	1,500	1,500
Sr-90	1,000	563.5
Cs-137	1,000	576.2
Mixed activation products[d]	6,000	255.4
Mixed fusion products[e]	500	288.1
Unidentified beta-gamma emittors[f]	5,500	21.5
Short-lived beta-gamma emittors[g]	<468,500	negligible

---

a. Source: Rawson and Walton (1989).

b. Radioactive decay calculations based on assumed burial date of January 1, 1961 (EG&G, 1988a).

c. Includes Am-241 contributed by decay of Pu-241 since waste was emplaced.

d. Radioactive decay calculations based on half-life of Co-60.

e. Radioactive decay calculations based on half-life of Cs-137.

f. Radioactive decay calculations based on effective half-life of 3 years (EG&G, 1988a).

g. Radioactive decay calculations based on effective half-life of much less than 1 year (EG&G, 1988a).

Table 12-2. Estimates of hazardous materials disposed of in the RWMC SDA[a]

Material	Volume (m^3)	Volume (ft^3)	Volume (gal)
Rags[b]	128	4,500	N/A[c]
Oil (in absorbent)	89	3,100	23,400
Lead	170	6,100	N/A
Asbestos/lagging	100	3,500	N/A
Ethylene glycol	1.5	50	390
Mercury[d]	8.5	300	2,240
Acids (HF, HCL, etc. in absorbent)	38	1,400	10,200
Organics (ether, etc.)	25	900	6,700
Santo wax[e]	200	7,100	53,700
Sodium, sodium compounds and pipe	105	3,700	27,600
Batteries	0.5	20	N/A
Benzene	0.1	3	20
Animal carcasses and feces	71	2,500	N/A
Vehicles[f]	24	860	N/A
Cyanide	<0.01	<0.35	N/A
Meat w/botulinus	0.05	0.25	N/A
Tritium vials	2	64	N/A
Zirconium chips	30	1,100	N/A
Caustic compounds (NaOH in absorbent, etc.)	26	930	6,900
Paint chips and cans	6	210	1,600
Gasoline (absorbed)	5	180	1,300
Ammonia bottles	0.2	7	N/A
Thallium oxide	<0.1	<3	N/A
TRU Texaco Regal Oil	148	5,215	39,018
TRU carbon tetrachloride	92	3,263	24,413
TRU other organics	94	3,338	24,968
Total (approximate)	1,364	48,344	222,450[g]

---

a. Source: Cerven and Clements (1987).

b. The quantity identified assumes 5% of the total rag inventory at the RWMC is oil or solvent soaked.

c. Not applicable volume. Gallons are inappropriate measures for these materials.

d. Mercury volume reflects 3.4 m^3 erroneously reported to have been disposed of in Trench 27 and 5.0 m^3 reported to have been disposed of in Pit 15 according to a RWMIS potential hazardous material listing for 1970 to 1981 (Cerven and Clements, 1987). The entry is labelled as 24 drums of "mercuris (sic) waste unnumbered" from NRF.

e. Santo Wax is from the Organic Moderated Reactor Experiment; it may not be a hazardous material.

f. Vehicles disposed of at the RWMC were assumed to be driven into the pits with fuel, oil, antifreeze, and batteries left in place. The volume indicated represents 5% of the total vehicle volume.

g. Gallons are not volume equivalent because of some solid materials.

12.3.1 Phase 1 - Characterization of Texaco Regal Oil

Texaco, Inc., was contacted directly for Material Safety Data Sheets and other literature concerning their Regal Oils. Rocky Flats Plant, the generator of the waste oil, was also contacted in order to obtain more specific data on the types of TR Oils used in their operations from 1966 to 1970, the period of interest.

Information collected from Texaco concerning TR Oils indicated that 20 different Regal Oils were formulated using from one to five different base oils. These base oils were (a) solvent refined heavy napthenic distillates, (b) hydrotreated heavy napthenic distillates, (c) solvent-dewaxed residual oils, (d) solvent-dewaxed heavy paraffinic distillates, and (e) C25 hydrotreated bright stock. The investigation involved collecting more data on the specific combination(s) of the base oils used at the time the wastes were generated. In addition, an attempt was made to collect specific chemical compositions for the base oils. Available chemical and physical properties of the oil are discussed in Section 12.4.1.

12.3.2 Phase 2 - Extension and Validation of the Organic Transport Model

The second phase of the investigation proposed sampling of TR Oil in the vadose zone for use in the generation and validation of a computer transport model for the machining oil. However, validation of the computer transport model through subpit sampling of the vadose zone has been delayed until the first quarter of FY-91. The machine oil itself is generally nontoxic but may have an influence on the vapor pressures of the chlorinated solvents mixed with it and on the viscosity of any available organic liquid phase. The mobility of any organic phase present in the vadose zone will be affected by the viscosity of the fluid. The current transport models in use at the SDA are based on assumptions that the dominant form of radionuclide transport is through dissolution or entrainment by soil moisture, and organic transport is via the vapor phase.

Before the investigation was conducted, the transport of organic materials via nonaqueous liquids (such as TR Oil) had not been included in the organic transport modeling. As part of Phase 2, a model for the flow and transport of a nonaqueous organic liquid was developed. A systematic approach was then implemented to evaluate the relative mobility of the contaminants in the subsurface. The approach is summarized as follows:

- Determine the key physical and chemical properties of the organic and radionuclide contaminants
- Develop a conceptual framework to describe the controlling processes and driving forces
- Formulate a mathematical model for multiphase flow and transport to complement existing models of organic vapor generation and transport, aqueous flow and transport, and multiphase flow and transport
- Implement the mathematical models with general computer codes
- Evaluate the transport model predictions using the available data for organic and radionuclide contaminants
- Predict the fate of codisposed machine oil
- Evaluate the relative rates of the contaminant migration.

12.3.3 Phase 3 - TR Oil as a Transport Mechanism

The third phase of the investigation was a paper study on the potential for TR Oil to act as a transport mechanism for VOCs and/or radionuclides. The paper study was proposed to determine if laboratory analysis of TR Oil would be necessary. The technical issues for this phase of the investigation are summarized in the following questions:

- What fractions of the various oils are present (i.e., the oil blends used)?

- What oil additives (if any) have been used, and what are their chemical compositions?

- What are the oil degradation rates?

- What degradation products (if any) are of potential concern?

- What are the reactions of breakdown products with other organic compounds or radionuclides or the breakdown action as a transport mechanism.

- How does radiolysis affect the oil?

- What is the expected oil stability in the SDA geochemical environment?

- Is there a potential for the formation of complexes with organics or radionuclides such as plutonium?

- What are the effects of oxygen and soil moisture on the degradation of machine oil?

12.4 Results

The following sections provide a summary of the results obtained from the investigation of nonaqueous liquid phase organics. Data for this section were summarized from two reports: Rawson and Walton (1989) and Rawson et al. (1989). Section 12.4.1 provides a detailed discussion of the chemical and physical properties of the TR Oil (machine oil), Section 12.4.2 presents the input assumptions and the results of the multiphase organic transport modeling, and Section 12.4.3 summarizes the results of the paper study on TR Oil as a potential transport medium for VOCs or radionuclides.

12.4.1 Characterization of Texaco Regal Oil

There was limited success in acquiring the information for Phase 1. A significant volume of the organic waste buried at the SDA consists of TR Oils used in foundry operations at the Rocky Flats Plant. No chemical and physical data on the specific TR Oils buried in the SDA were collected because data for the older TR oils are no longer available from Texaco or Rocky Flats Plant. The reported chemical and physical data refer to current TR Oil compositions or were taken from general technical references. The effect on computer simulations of compositional differences between the TR Oils used from 1966 to 1970 and now is unknown.

Characterizing the oils disposed between 1966 to 1970 was difficult because of the lack of detailed compositional information on any machine oil. Representatives of Texaco, Inc., were contacted in 1988 to collect details on TR Oil chemistry. Information acquired from Texaco indicated that the current TR Oils are a blend of the five different base oils discussed in Section 12.3.1. Detailed descriptions of base oils used in the current production of TR Oils are shown in Table 12-3. No data are available on the proportion of normal alkane (n-alkane) to napthenic oils used to generate the TR Oil produced in the late 1960s; therefore, general chemical characteristics were estimated from data on machine oil currently in use.

The machining oil fraction distilled from petroleum contains hydrocarbon compounds n-alkanes with carbon numbers ranging from C_{22} to C_{40} although in extreme cases the range may be from C_{20} to C_{50}. The machining oil fraction contains a wide range of branched alkanes, cycloalkanes, and mono- and polynuclear aromatics. The most common cycloalkanes or napthenes in machining oil consist of one to five carbon rings. The aromatics are primarily of the fused ring type, with phenanthrene derivatives more common than anthracene-based compounds. Heteroatomic compounds that contain nitrogen, sulfur, and oxygen are more prevalent in machining oil and are also more reactive. The hydrocarbon compounds in machine oil are assumed to be 64 to 70% n-alkane that are mostly branched, 21 to 29% napthenic hydrocarbons, and 8 to 9% aromatic hydrocarbons.

Table 12-3. Description of base oils used to formulate Texaco Regal Oil[a]

Base Oil Identification	CAS Number	Description of the Base Oil
C25 hydrotreated bright stock	72623-83-7	Complex combination of hydrocarbons (HCs) obtained by treating solvent deasphalted residual oil with hydrogen in the presence of a catalyst in two stages with dewaxing occurring between stages. Carbon numbers of HCs are greater than C25. Kinematic viscosity is approximately 440cSt at 40•C (104•F). Contains large proportion of saturated HCs (normal and branched paraffins).
Solvent-refined, heavy napthenic distillates	64741-96-4	Complex combination of HCs obtained as raffinate from a solvent extraction process. Carbon numbers of HCs are in the range of C20 through C50. Kinematic viscosity is at least 19cSt at 40•C (104•F). Contains few normal paraffins.
Hydrotreated heavy napthenic distillates	64742-52-5	Complex combination of HCs obtained by treating a petroleum fraction with hydrogen in the presence of a catalyst. Carbon numbers of HCs are in the range of C20 through C50. Kinematic viscosity is at least 19cSt at 40•C (104•F). Contains few normal paraffins.
Solvent-dewaxed residual oils	64742-62-7	Complex combination of HCs obtained by removal of long, branched HCs from residual oil by solvent crystallization. Carbon numbers of HCs are predominantly greater the C25. BP greater than 40•C (104•F).
Solvent-dewaxed heavy paraffinic distillates	64742-65-0	Complex combination of HCs obtained by removal of normal paraffins from a petroleum fraction by solvent crystallization. Carbon numbers of HCs are in the range of C20 to C50. Kinematic viscosity is at least 19cSt at 40•C (104•F).

---

a. Source: Rawson and Walton (1989).

b. CAS = Chemical Abstract Services.

Rocky Flats Plant personnel were also contacted to obtain data on the type of TR Oil used at the defense plant. They indicated that machine tools typically use 32- to 68-weight oils. These oils probably were produced from a mixture of the five base oils described in Table 12-3. Because 32- to 68-weight oils are currently used in machining operations at Rocky Flats Plant, the oil used from 1966 to 1970 was assumed to fall in the same category.

Physical properties data of the TR Oils in current use at Rocky Flats Plant were also obtained from the manufacturer. The kinematic viscosity of a 68-weight oil is 64.5 centistokes (cST) at 40•C (104•F) and 489 cST at 10•C (50•F). A 32-weight oil has a kinematic viscosity of 30.5 and 230 cST at temperatures of 40 and 10•C (104 and 50•F), respectively. Data from the 32-weight oil were used in computer simulations to ensure the most conservative case was modeled.

12.4.2 Extension and Validation of the Organic Transport Model

Validation of the computer transport model through subpit sampling of the vadose zone has been delayed until the first quarter of FY-91. A draft sampling and analysis plan and a health and safety plan have been prepared for this investigation.

To assess the role of TR Oil in promoting contaminant migration, oil transport in the vadose zone was simulated. The conceptual model for oil migration in the vadose zone considered multiphase flow. Organic compounds and radionuclides were modeled as coexisting immiscible liquids and a vapor phase. The simultaneous movement of water, machine oil, and air in the SDA vadose zone was the process simulated. The migration of machine oil relative to water and air was simulated using the multiphase MOFAT computer code. This two dimensional, multiphase Galerkin finite element computer code was implemented on the INEL Cray computer and on a Sun work station. The observed migration of VOCs at the SDA was previously modeled using one- and two-dimensional flow and transport codes to describe vapor generation and transport. The migration of radionuclides in the vadose zone was simulated with a three-dimensional aqueous flow and solute transport code. The majority of TRU radionuclides were assumed to migrate as colloids that do not undergo retardation during transport.

Once conceptual and mathematical models of contaminant migration were developed, input data were sought. The volume of TR Oil relative to VOCs was examined in light of the information collected during Phase 1 of the investigation. Table 12-4 presents the calculated masses and mole fractions of the VOCs of concern. The mole fractions were subsequently used to provide a vapor pressure for the source term of VOC migration in the organic vapor transport model. The density and molecular weights of the VOCs summarized in Table 12-4 were taken from the 68th edition of the Handbook of Chemistry and Physics as cited in Rawson and Walton (1989). The density and molecular weight of TR Oil was estimated from the Material Safety Data Sheet for a 32-weight oil. The calculations in Table 12-4 were based on the molecular weight and density data for a typical n-alkane. Volume data reported in Table 12-4 were taken from Table 12-2.

Volume estimates of the organic compounds generated at Rocky Flats Plant are perhaps the best defined for the TR Oil and carbon tetrachloride. A volume for miscellaneous organics from the Rocky Flats Plant (1,1,1-trichloroethane, trichloroethylene, perchloroethylene, and lubricating oils) was also available. To describe the volatile organic concentrations in the soil gas, the volume of miscellaneous organics was divided equally among the remaining VOCs in Table 12-3 (chloroform, trichloroethylene, tetrachloroethylene, and 1,1,1-trichloroethane). The TR Oil comprises approximately 15% of the hazardous organics buried at the SDA on a molar basis. Carbon tetrachloride comprises the highest proportion of the VOC contaminants with a mole fraction of 42% (Table 12-4).

Contaminant sources were also characterized for input to the multiphase transport model. A total of 237,000 L (62,616 gal) of TRU-contaminated machine oil and other unspecified oils (in absorbents) were estimated to have been disposed of at the RWMC. The total disposal area is estimated at 30,000 m^2 (322,928 ft^2). An average oil depth in the pits of 0.75 cm

Table 12-4. Amounts of organic chemicals disposed of in the SDA[a]

Organic Liquid	Volume (m^3)	Density (g/cc)	Mass (g)	Molecular Weight (g/mole)	Mole Fraction
Texaco Regal Oil	148	0.80	1.1858×10^8	352.69	0.147
Carbon tetrachloride	92	1.59	1.466×10^8	153.82	0.417
Chloroform	23	1.48	0.341×10^8	119.38	0.125
Trichloroethylene	23	1.46	0.337×10^8	131.39	0.112
Perchloroethylene	23	1.62	0.373×10^8	165.83	0.098
1,1,1-trichloroethane	23	1.34	0.308×10^8	133.40	0.101

---

a. Source: Rawson and Walton (1989).

(0.3 in.) was calculated using the assumption that oil was disposed of as free liquid. Before disposal, the oils were solidified through the addition of calcium silicate, but this process was ignored in the model for conservatism. Because it is unlikely that the oil is uniformly distributed in the pits, a maximum availability of 15 cm (6 in.) was assumed.

The physical and chemical characteristics of 32-weight TR Oil were used for the multiphase flow and transport analysis. The oil/water viscosity ratio was approximately 150. Heavier oils would migrate more slowly than the oils modeled in this simulation. Hydrologic properties of the sediments and basalts input into the model are summarized in Table 12-5. Basalt properties were derived from two sources. Fracture properties were based on tuff described in Wang and Narasimhan (1985), and basalt matrix properties were derived from a basalt sample collected from beneath the SDA (Rawson et al., 1989).

The model multiphase flow and transport domain was broken into 158 finite elements with 318 nodes comprising a one-dimensional simulation. The medium was modeled as two discrete layers. The sediments were assumed to cover the basalt to a depth of 5 m (16 ft). The grid spacing was nonuniform with a larger concentration of elements near the sediment/basalt interface where numerical problems are the greatest.

Pressure gradients in the gas phase will generally be low because the gas phase has a much lower viscosity than the two immiscible liquid phases (oil and water). Therefore, pressure gradients in the gas phase can be ignored when calculating migration of the liquid phases. Elimination of the gas flow equation is referred to as the Richards Approximation. In the continuity equations governing multiphase flow, the liquid saturation and the fluid conductivity are dependent upon the relative amounts of water, oil, and air in the soil. Constitutive relations for the multiphase system were derived using the van Genuchten model (Rawson et al., 1989).

Computer simulations were run for oil migration from the SDA for 10-, 20-, and 30-year periods. Net percolation of water through the pits was

Table 12-5. Hydrologic properties used in simulations[a]

Layer	Saturated Hydraulic Conductivity (cm/h)	Van Genuchten α (Eq.4)	Van Genuchten (Eq.4)	Residual Saturation (Eq.4)	Porosity
Sedimentary interbeds	25	0.0108	1.38	0.06	0.476
Basalts	5	0.161	2.11	0.062	0.28

a. Source: Rawson and Walton (1989).

assumed to be 5 cm/yr (2 in./yr) with 15 cm (6 in.) of total oil available for transport. The resulting simulations for oil pressure, oil saturation, and total saturation compared to subsurface depth are shown in Figures 12-1, 12-2, and 12-3.

Figure 12-1 shows oil pressure plotted as a function of depth in the vadose zone for 10-, 20-, and 30-year periods. The oil moves downward as a front under a positive head. The front appears to slow down once the oil enters the basalt, but the simulation suggests that the machine oil could penetrate 1 to 2 m (3 to 6 ft) into the basalt in a 30-year period.

The degree of oil saturation as a function of depth for 10-, 20-, and 30-year periods is illustrated in Figure 12-2. The oil front moves downward at near saturation. A residual saturation of up to 10% oil is left behind in the vadose sediments after 10 years but is eventually reduced to less than 6% after 30 years. These results are comparable to experimentally derived residual saturation values for migration of other organic liquids in the vadose zone. The residual oil saturation in the basalt ranges from 20% at 10 years to approximately 10% after 30 years and decreases further with time. The oil front at near-saturation conditions penetrated approximately 1 m (3 ft) of the basalt over the 30-year period.

Figure 12-3 presents the simulated total saturation (water plus the machine oil) as a function of depth for 10-, 20-, and 30-year periods. The oil front moves downward as shown in Figure 12-2. In this simulation, capillary perching of water develops at the interface between the sediment and the basalt. Residual saturations of water and oil in the vadose sediments were approximately 70% at the base of the pits after 10, 20, and 30 years. This increased to approximately 95% at the interface between the surface soil and the basalt. The total residual saturation left behind the oil fronts in the basalt varied between 20 to 35%.

The modeling simulations predicted that the TR Oil would migrate as a front that would have moved approximately 4 m (13 ft) from the base of the pits within 30 years of burial. Even if VOCs and machine oil are cosolvent,

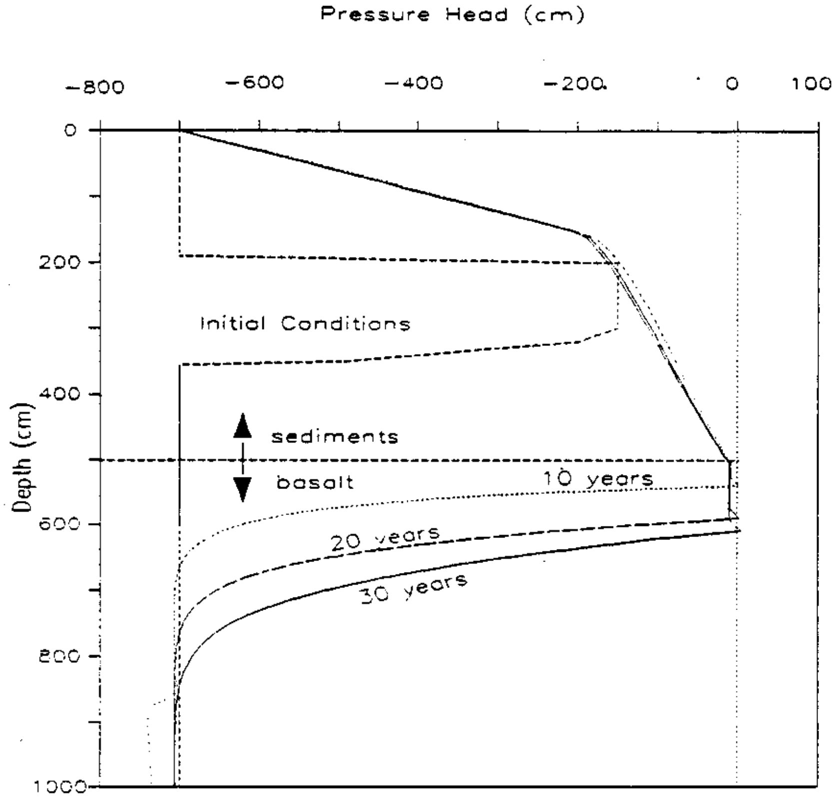


Figure 12-1. Simulated oil pressure head as a function of time and distance (Rawson and Walton, 1989).

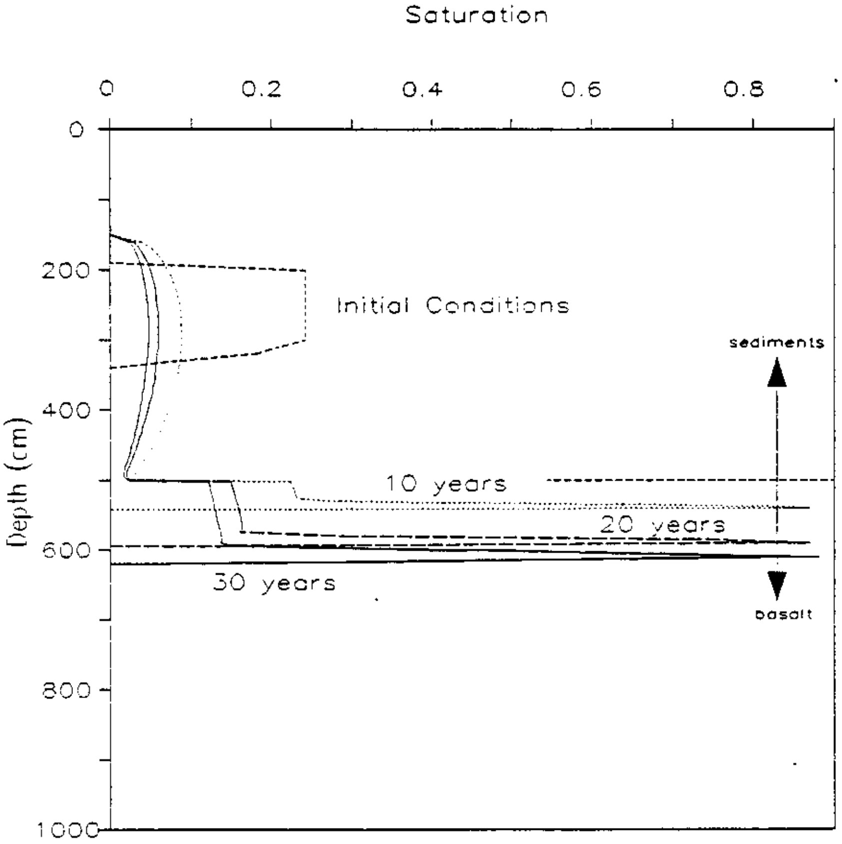


Figure 12-2. Simulated oil saturation as a function of time and distance (Rawson and Walton, 1989).

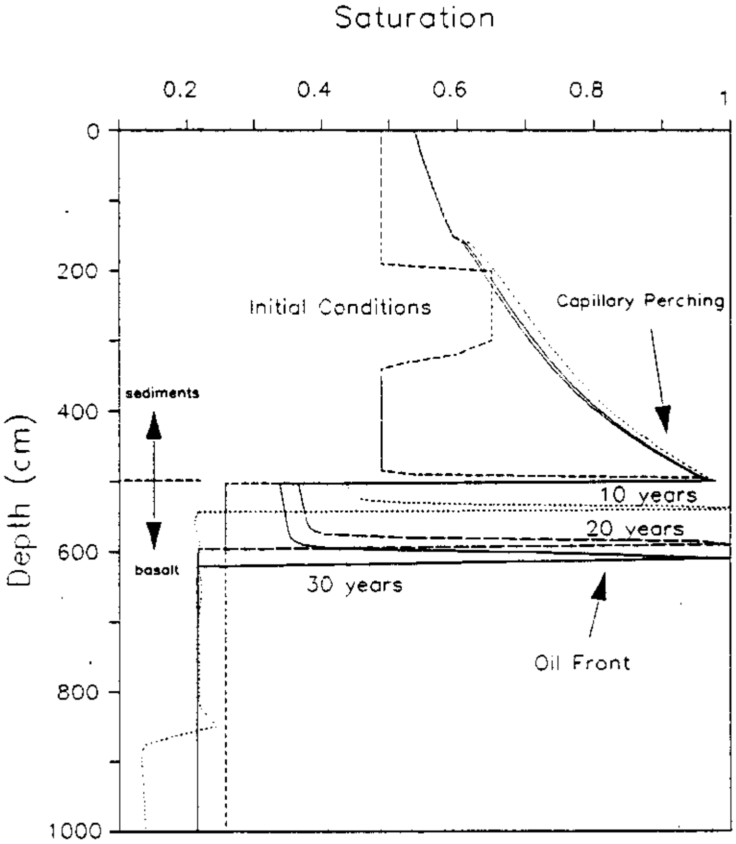


Figure 12-3. Simulated total saturation (oil + water) as a function of time and distance (Rawson and Walton, 1989).

the migration distance is still too low to account for the observed extent of VOC migration through the vadose zone to the aquifer. Likewise, if the machine oil has moved as predicted, it is not responsible for the TRU radionuclides present in the 34-m (110-ft) interbed.

12.4.3 TR Oil as a Transport Mechanism

The chemical interactions between the waste and the vadose zone must be understood to evaluate whether TR Oil contributes to the migration of other organic or radionuclide contaminants at the SDA. To date, few studies on the potential solubilization and transport of soil-adsorbed petroleum products through the vadose zone to ground water have been performed. The complexity of the chemical system at the SDA necessitates that certain simplifying assumptions be made. Soil gases and soil pore water are important components of the vadose zone. TR Oil and soil pore water interaction are ignored because the TR Oils are virtually insoluble in water. Likewise, VOC interaction with soil pore water is not discussed because VOCs will be preferentially partitioned into an organic carbon phase. The primary role of soil pore water as a transport mechanism for TR Oil is discussed below.

Organic waste components occur as nonaqueous organic liquids (TR Oil mixed with VOCs) and gases (air and VOCs). The VOCs are simple compounds, while the TR Oil is a complex mixture of hydrocarbons that have not been individually identified. The soil pore water is considered to be the aqueous liquid phase. The radioactive waste within the SDA primarily occurs as a solid phase, and the radionuclides associated with the TR Oil are assumed to be entrained particulates. For this investigation, only TR Oil interactions were considered. These interactions have been categorized into two chemical systems: (1) TR Oil and VOCs and (2) TR Oil and radionuclides.

The expected interactions between the TR Oil and the VOCs include the effect of TR Oil on vapor pressure and the sorption of VOCs on the sedimentary interbeds by organic carbon. The effect of the TR Oil on the vapor pressure of the VOCs was previously documented in the 1988 RFI Work Plan (EG&G, 1988a), and the potential sorption of the VOCs on organic carbon is discussed below.

The sorption of hydrophobic VOCs, such as those found in the soil gas at the SDA, has been described by a general predictive equation based on the relationship between the fraction of organic carbon in the sediment and the partitioning coefficient for the octanol-water system (Rawson and Walton, 1989). The use of this equation requires two assumptions: (1) the sorption process is reversible and linear over a range of particle sizes and organic matter content, and (2) the aqueous solution concentrations for the appropriate VOC are well below the aqueous solubility of the VOC in order to avoid dependence on the concentration of the VOC.

The natural organic carbon content in the surficial soils and sedimentary interbeds is very low. If TR Oil migrates from the SDA into the sedimentary interbeds, a source of organic carbon will be introduced and there will be a potential for sorption of VOCs by the TR Oil. The combination of TR Oil migration and sorption of VOCs by the oil could affect the source term in the organic vapor transport model by moving the source of the VOCs deeper into the subsurface.

The second chemical system is the interaction between the TR Oil and radionuclides. The radiolysis process is of interest in evaluating this interaction. Radiolysis resulting from alpha emissions by entrained TRU elements could occur between the TR Oil and radionuclides. Radiolysis results in the breakdown of long-chained hydrocarbons and the subsequent degradation of the TR Oil.

Hydrogen is the principal gaseous product resulting from the radiolysis of saturated hydrocarbons such as those in TR Oil. Radiation induced polymerization has been observed in some hydrocarbon systems. Aromatic compounds are much less affected by radiolysis than saturated compounds because their conjugated ring system is capable of degrading the excitation energy imparted by alpha particles without decomposition. Because TR Oil is predominantly n-alkanes (mostly branched), the overall effect of radiolysis on the TR Oil may be to quicken degradation in water-insoluble portions of the oil and to increase the relative portion of the water-soluble aromatic portions.

The possibility of radiolytic degradation of TR Oil contributing to the complexing of radionuclides in a water-soluble form is of most concern. Radiolytic reactions in the oil are expected to be localized around particulate plutonium because alpha particles have short penetration distances. Ongoing studies are focusing on the solubilization of plutonium by organic degradation products of the machine oil.

Petroleum derived products, such as TR Oil introduced into the subsurface, can undergo degradation by either microbial or oxidative reactions. Microbial degradation rates vary depending on the hydrological properties and the unique chemical environment of the site. Microbes appear to prefer n-alkanes, to saturated rings (napthenes), to aromatic constituents. Biodegradation will account for reduced quantities of n-alkanes; however volatilization tends to remove the light end hydrocarbons including xylene, benzene, and toluene. Light-fraction aromatics such as these are easily soluble and can be transferred into the ground water. The degradation rate of TR Oil is difficult to establish without more detailed information on the relative proportion of chemical compounds that comprise it.

The results of the paper study and computer simulations indicate that the TR Oil could be a transport mechanism for VOCs or radionuclides. TR Oil affects the VOCs by increasing their residence time, through cosolvency, in the source area. However, the simulated migration of TR Oil from the pits only slightly changes the residence time of the VOCs in the source area from original predictions. VOC migration is still best explained by diffusion in the vapor phase.

The potential for introducing a significant residual radionuclide source term into the vadose zone exists because any oil that migrates into the basalts would most likely contain entrained radionuclides. Although the predicted migration distance of radionuclides associated with the TR Oil is insignificant with respect to the distance to the ground water table, it would be difficult to remediate a source term within basalt with current technologies.

13. Pad A Initial Penetration Investigation

13. PAD A INITIAL PENETRATION INVESTIGATION

In 1987, a soil gas survey of the SDA conducted by Golder detected low concentrations of the following organic chemicals emanating from Pad A: trichloroethylene, tetrachloroethylene, carbon tetrachloride, and 1,1,1-trichloroethane (EG&G, 1988a). Because waste inventory records do not indicate that organic chemicals have been stored on Pad A, the source of the contamination is unknown. However, it is hypothesized that the detectable concentrations of organics on Pad A have migrated from adjoining waste pits/trenches or from waste stored on Pad A from the initial drum retrieval and the EWR demonstration (Laney et al., 1988). To verify the hypothesis and further determine the type and extent of the existing contamination in the area, the Pad A initial penetration investigation was proposed.

13.1 Purpose of Investigation

The Pad A initial penetration investigation was proposed to make a safe, controlled penetration into the north and south ends of Pad A to evaluate the condition of the waste containers, perform an engineering study to determine the accuracy of the waste generators' records, and determine methods and feasibility of remediating this and other waste at the SDA. Specifically, the investigation would (a) characterize the extent of chemical and/or radioactive contamination of the Pad A soil overburden and the interstitial soil between drums; (b) nondestructively determine the condition (wall thickness) of the exposed/retrieved drums; (c) analyze a representative sample of the waste within the retrieved drums; and (d) assess procedures, equipment, and instrumentation that may be applicable to future SDA activities.

13.2 Site Description

Pad A is an asphalt pad, 73 m (240 ft) wide x 98 m (320 ft) long x 5 cm (2 in.) thick, laid over a 8-cm (3-in.) pit run gravel base. It is located within the SDA, as shown in Figure 13-1. Pad A was formerly identified as

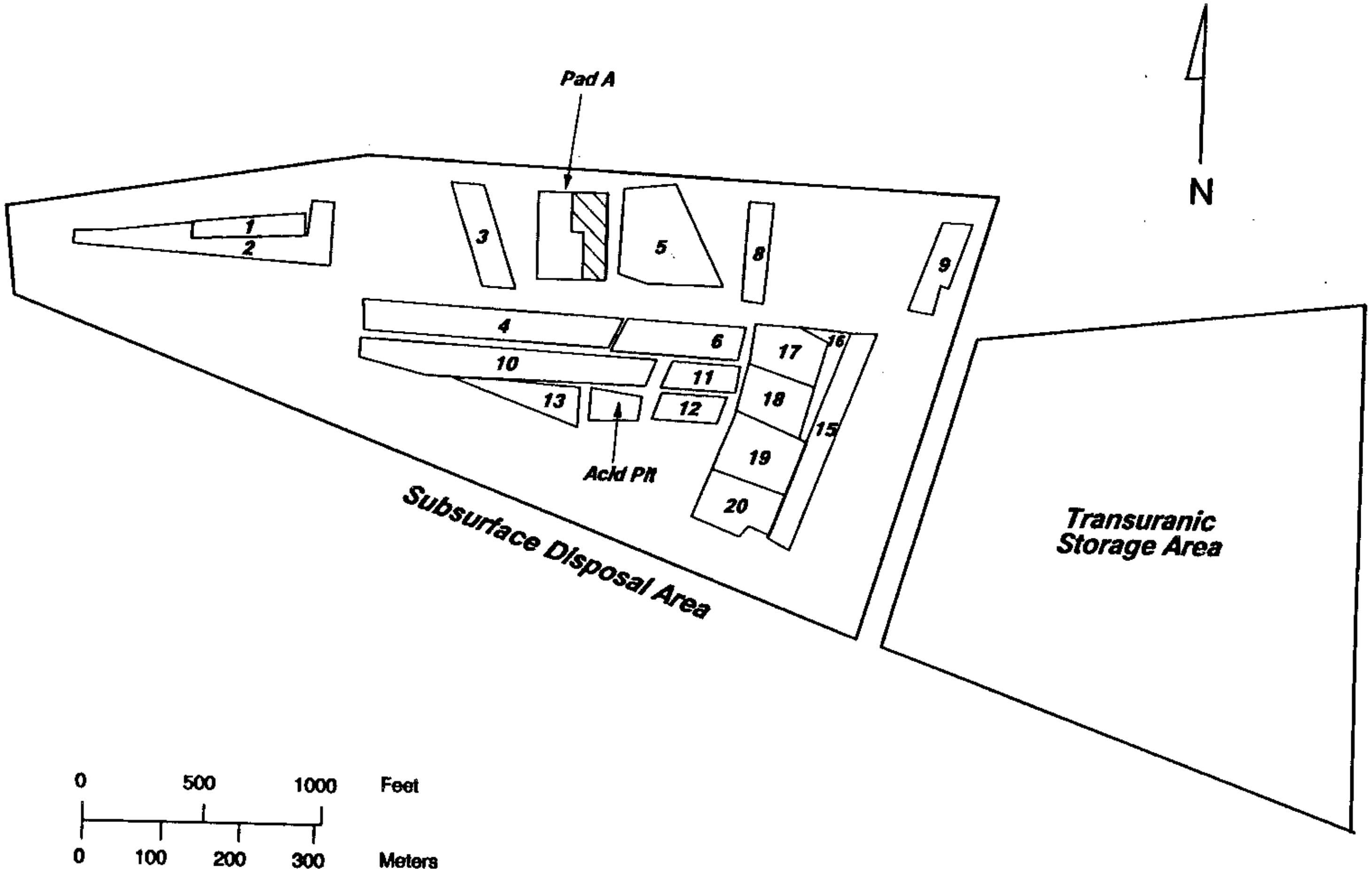


Figure 13-1. Pad A location within the SDA.

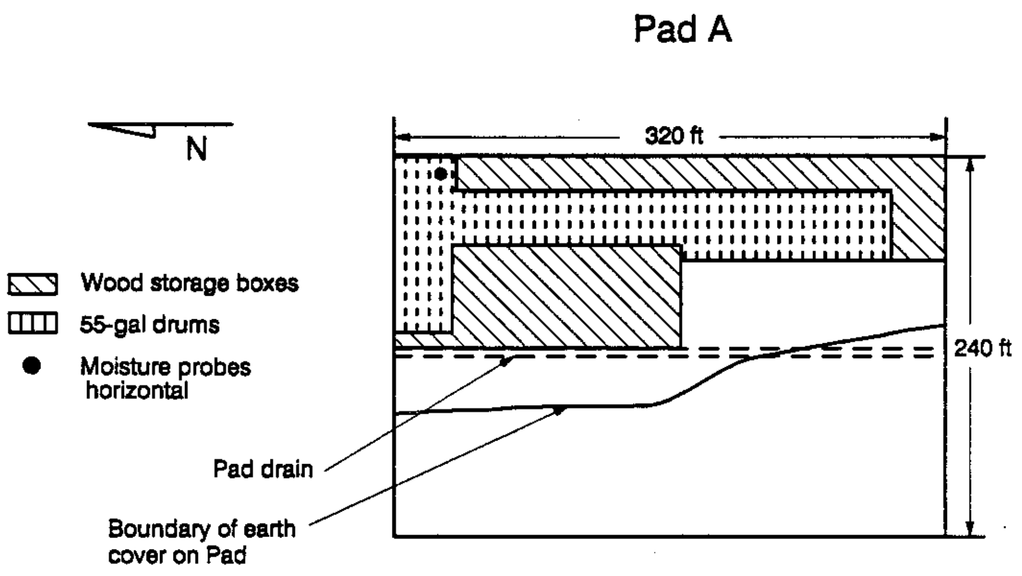
the Transuranic Disposal Area (TDA). The location was selected because of the presence of near-surface basalt, which made the site unsuitable for subsurface disposal. The pad is laterally sloped toward a center concrete drainage channel at a grade of approximately 1.6%. The center concrete drainage channel has a southward longitudinal slope of 0.31%.

Pad A was constructed in September 1972 for the above ground disposal of radioactive waste contaminated with less than 10 nCi/g of TRU radionuclides in a single container and exhibiting a dose rate of less than 200 mrem/h at the container surface. Plywood boxes 1.2 x 1.2 x 2.7 m (4 x 4 x 7 ft) were stacked vertically in staggered layers to a maximum of five high. Also 55-gal drums were laid on their side and stacked vertically in staggered layers to a maximum of 11 high. The height of the containers stacked around the outer edges of the disposal array was reduced to provide for an approximate 3:1 slope from the top to the base. The distribution of boxes and drums within Pad A is shown in Figure 13-2.

When Pad A was closed in November 1978, waste containers only occupied the eastern half of the pad. Closure was completed by placing plywood and/or polyethylene over some of the exposed waste containers and then applying a final clayey-silt soil cover. The final soil cover was approximately 0.9 m (3 ft) thick, with an exterior perimeter slope of approximately 3:1. The soil was brought to the pad from the spreading areas to the west and from the clean borrow areas to the south of the RWMC. After soil placement was complete, the area was seeded with crested wheatgrass (Agropyron cristatum) in an attempt to minimize soil erosion. Following closure, neither the original soil cover nor the vegetation seeding effort withstood the effects of subsidence and wind/water erosion. Currently, rills and gullies in the soil cover are present, and the grass cover is extremely sparse.

13.3 Proposed Strategy in Work Plan

The strategy for the Pad A initial penetration investigation, as proposed in the December 1988 RFI Work Plan, was to sample the Pad A cover



Pad Information

Date Opened	Date Closed	55-gal Drums	4 x 4 x 7 ft Wood Boxes	8 ft dia x 8 ft Concrete Vaults	Other	Total Volume Waste (m^3)
9/26/72	8/02/78	18609	2021	None (Transferred to Pit 16)	22	10477

Figure 13-2. Pad A configuration (modified from data collection quality assurance plan, contained in EG&G, 1988a).

soil, penetrate the pad, sample the interstitial soil between the drums, and retrieve 48 drums in order to inspect their condition and sample the contents (EG&G, 1988a). A three-phased approach was proposed for conducting the investigation. Phase 1 consisted of sampling and analyzing the cover soils. Phase 2 consisted of sampling and screening the cover soils. Phase 3 consisted of penetrating Pad A in two locations, sampling and analyzing the interstitial soil between the drums, removing the drums, sampling and analyzing the content of the drums, and restoring the site to its original condition. The strategy for each of the phases is described in detail in the following subsections.

13.3.1 Phase 1 - Cover Soil Sampling Strategy

The Phase 1 soil sampling was proposed to determine the type, concentration, and location of metal and volatile organic contamination in the cover soils. The sampling was conducted near two locations on Pad A: the south penetration location and the north penetration location, as shown on Figure 13-3. These locations were selected because they represented areas where the waste was buried the shortest and longest amounts of time, respectively. Each of the two sampling locations were approximately 232 m^2 (2500 ft^2) in size and were located directly over the area where the drums were to be retrieved in Phase 3.

The cover soil sampling strategy consisted of collecting four samples at each penetration location. The proposed sampling points were selected using an unaligned grid sampling method and are shown on Figure 13-4. Sampling depths ranged from 0.3 m (1 ft) to a maximum of 0.9 m (3 ft). Samples were preserved, documented, packaged, and sent to an EPA Contract Laboratory Program laboratory to be analyzed for 1,1,1-trichloroethane, trichloroethylene, carbon tetrachloride, tetrachloroethylene, total beryllium, total uranium, sodium nitrates, and potassium nitrates. These specific

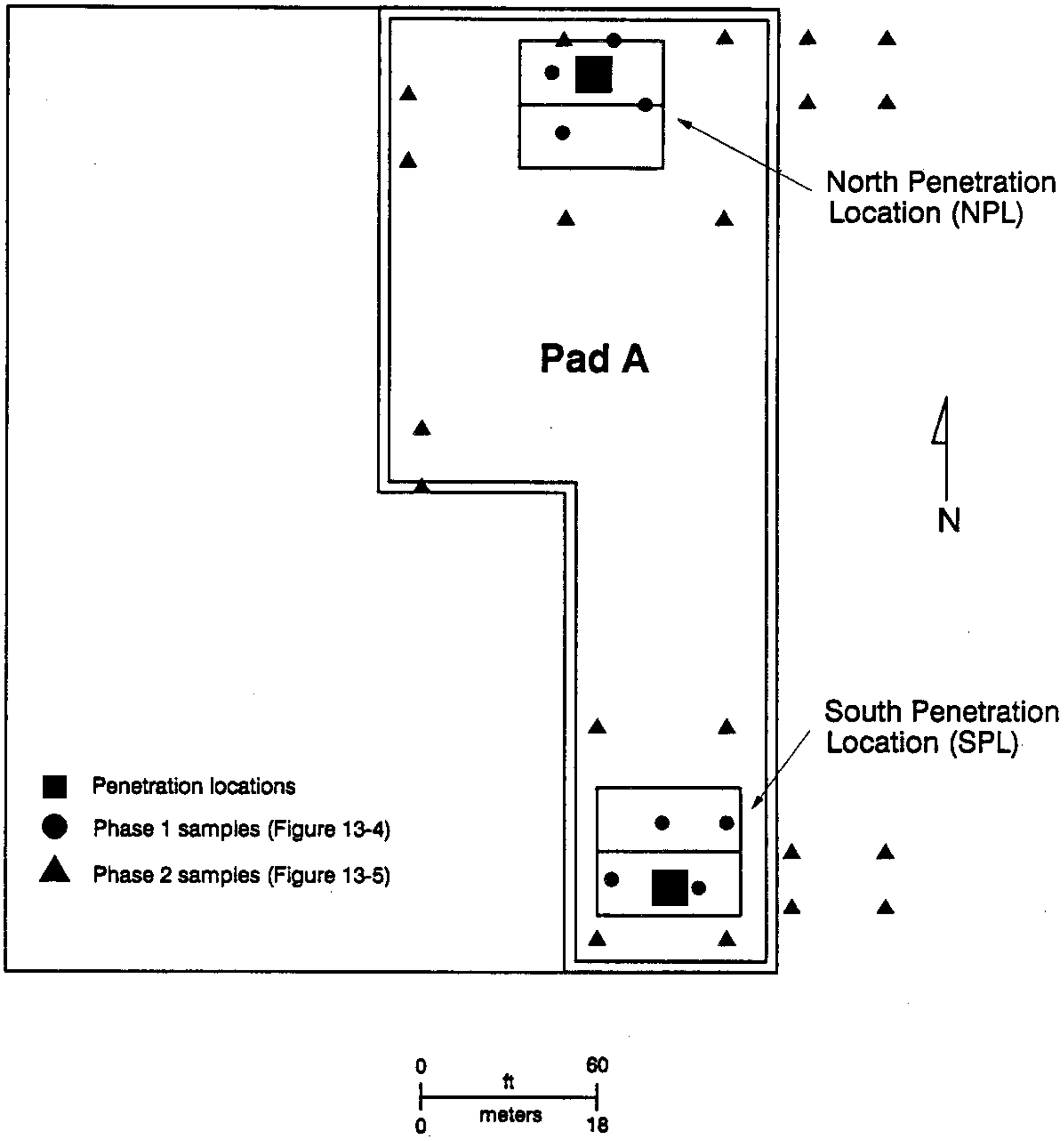
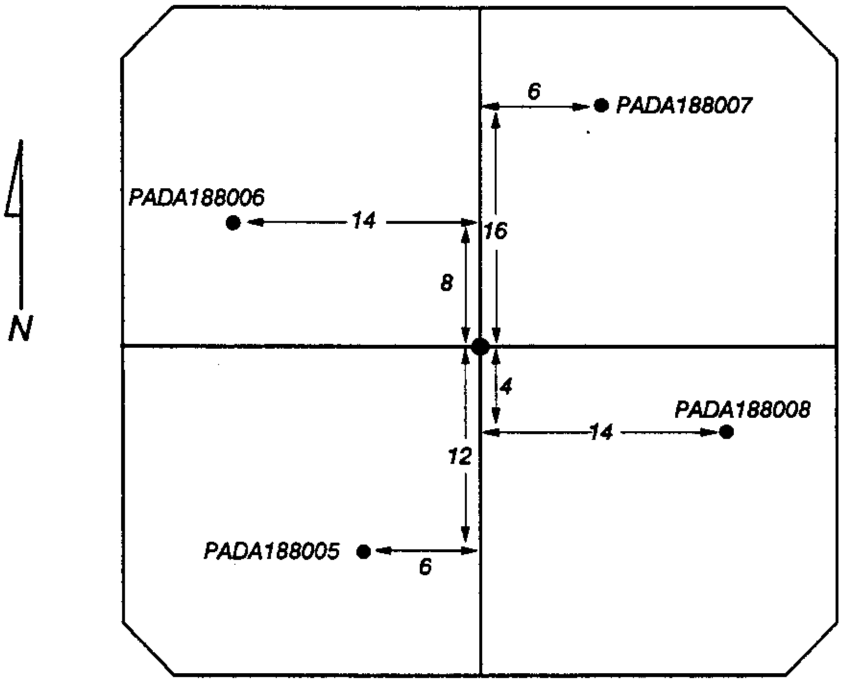


Figure 13-3. Proposed cover soil sampling locations (modified from Phase 1 sample analysis report, Appendix 13-4).

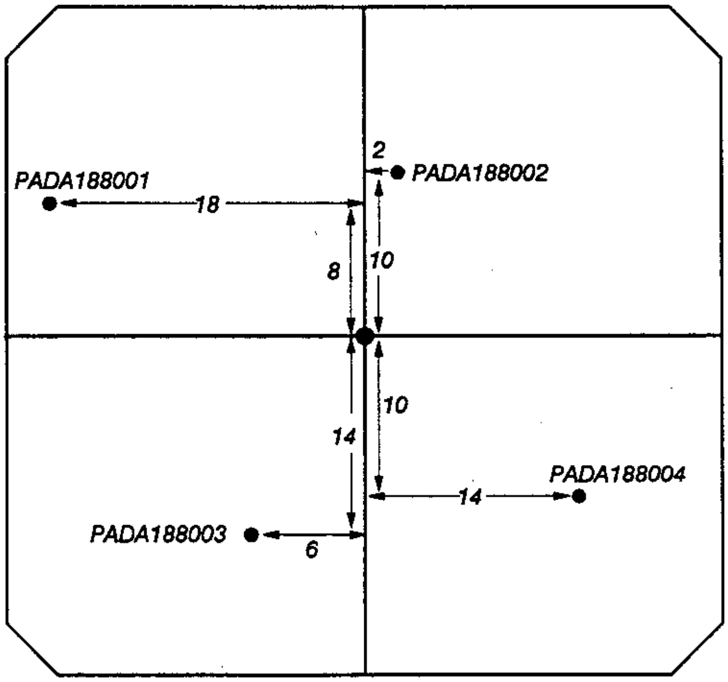


North Penetration

● - Sample location

PADA188001 - Sample ID number

All distances in feet from center node



South Penetration

NOTE: Not drawn to scale

Figure 13-4. Actual Phase 1 sampling locations (modified from Phase 1 sample collection logbook, Appendix 13-2).

compounds were selected because they were known to exist in the soil and the waste based on the results of previous studies as described in Horton.[a]

The Phase 1 cover soil sampling and analysis activities were conducted on August 18, 1988. The activities were conducted in accordance with the strategy presented in the RFI Work Plan. The sampling and analysis procedures that were followed are summarized in Section 13.4.

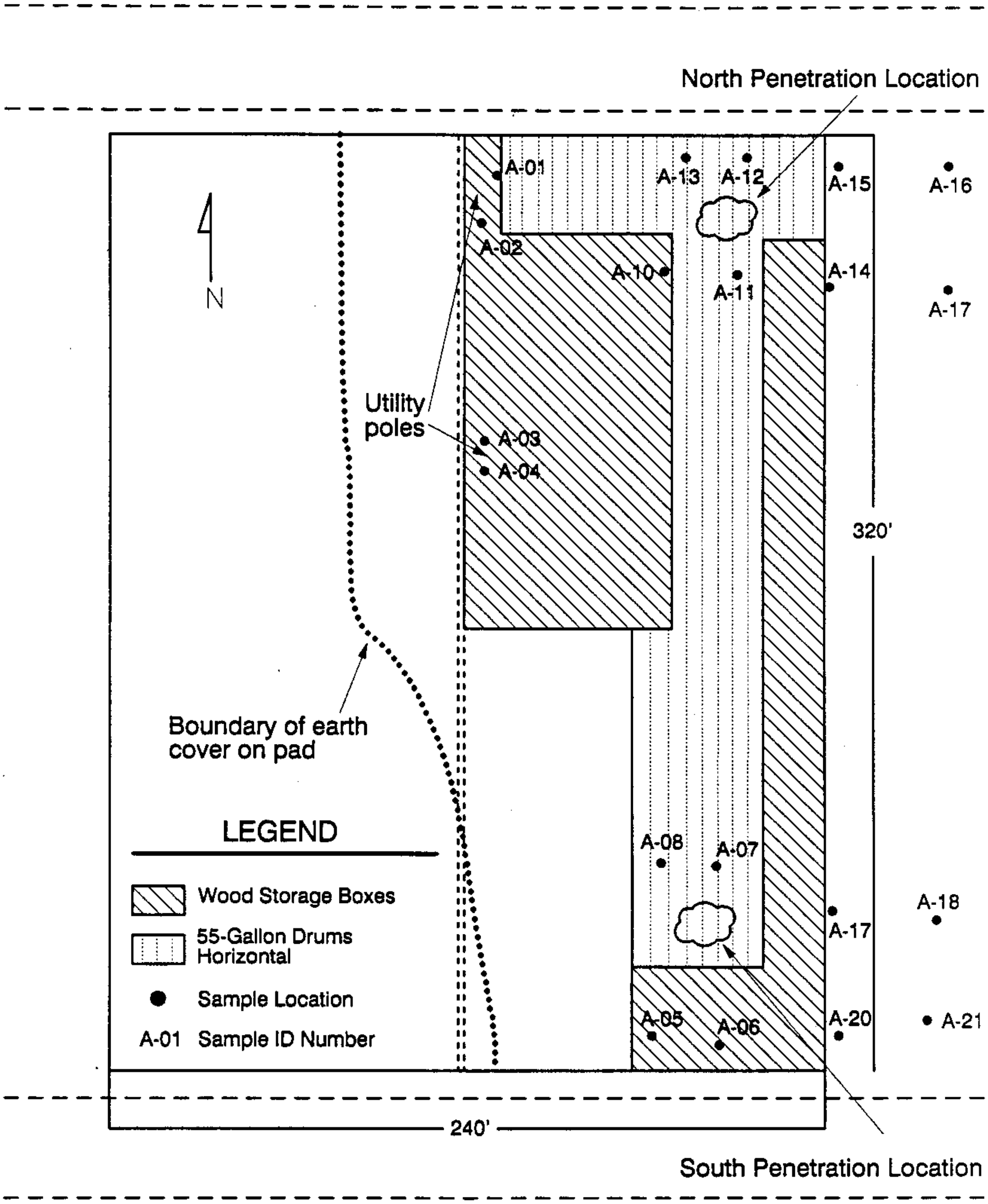
13.3.2 Phase 2 - Cover Soil Sampling/Screening Strategy

The Phase 2 sampling/screening of the cover soils was proposed to determine the lateral extent of volatile organic contamination. A total of 20 samples were to be collected at designated points within the north and south penetration locations. In addition, four grab samples were to be collected from locations on the mound where utility poles were to be installed. The designated sampling points were to be selected using a random sampling approach. All samples were to be collected from a depth of 15 cm (6 in.).

The Phase 2 sample/screening activities were conducted on November 21 and 22, 1988. The activities followed the sampling/screening strategy that was proposed in the work plan except for the total number of samples collected and analyzed. In actuality, 16 samples were collected from designated points within the north and south penetration locations, 4 grab samples from the utility pole locations, 1 background sample from the Big Lost River drainage that was used to identify analytical interferences, and 1 trip blank (Figure 13-5). Nineteen of these samples were analyzed. Three of the four samples that were collected from the utility pole locations (A-01, A-02,

---

[a] Pad A project plan information from R. B. Horton, EG&G Idaho, Inc., Idaho Falls, Idaho, August 12, 1988.



Notes: A-09: Background sample from Big Lost River Drainage

Figure 13-5. Actual Phase 2 sample locations (modified from Phase 2 sample analysis report, Appendix 13-5).

and A-04) were not analyzed because of time constraints and a change in priorities.[a]

Following collection, each sample was taken to a mobile laboratory located on or near the investigation site. In the mobile laboratory, the soil samples were screened for the presence of volatile organics by headspace analysis using gas chromatography with photoionization detection. The three VOCs analyzed by this method were trichloroethane, carbon tetrachloride, and tetrachloroethylene. These VOCs were selected for analysis because they were known to exist in the vicinity of Pad A based on the results of the Golder soil gas survey that was conducted in 1987. The sampling and analysis procedures that were followed are summarized in Section 13.4.

13.3.3 Phase 3 - Pad Penetration and Sampling Strategy

The Phase 3 pad penetration and sampling strategy was proposed to develop operating procedures that might be applicable to future SDA activities and to assess the type, concentration, and location of organic and radionuclide contamination within the soils and drums. This phase consisted of the operations required to penetrate the pad; retrieve the drums; and sample the cover soil, interstitial soil, and drum contents.

The first step of the operations required to penetrate the pad would be to flatten the two penetration locations in preparation for the containment building. A building would be required to protect the penetration operations from the elements and to control any radioactive material. The building, a 12-m (40-ft) diameter sprung fabric structure, would be erected next to Pad A and moved onto the south and north penetration locations with a crane. From within the building, excavation equipment would be used to remove and stockpile the cover soil adjacent to the dig area for sampling. It was anticipated that the cover soil depth after grading would be between 0.5 and

---

[a] Personal communication between J. W. Harris, ICF Technology, Inc., Pittsburgh, Pennsylvania, and J. F. Ginsberg, EG&G Idaho, Inc., Idaho Falls, Idaho, December 9, 1988.

1.7 m (1.5 and 5.5 ft). When the drums were exposed, they were to be visually inspected and retrieved if they appeared to be intact.

Following removal, the intact drums were to be wiped to determine surface contamination. Where possible, in situ ultrasonic testing was to be used to determine drum wall thickness. Drums were to be inspected for tags and labels that could provide information regarding waste contents and dates. After completing the inspection, the drums were to be placed in 314-L (83-gal) drum overpacks and stored in a cargo container on an unused portion of Pad A in preparation for radiological assay and content analysis.

Four soil piles were to be created during the Phase 3 operations: two large piles composed of cover soils and two small piles composed of interstitial soils. The strategy for sampling the large piles consisted of using a systematic grid sampling method that would allow the calculation of probabilities of detecting hot spots based on geometry in addition to the usual inferences concerning a mean that can be made from random sampling. The sample collection procedures to be used were the same as in Phase 1. The samples were to be sent to the Weston Analytical Laboratory for analysis of metal, salt, and volatile organic contamination using the same analysis procedures that were used in Phase 1.

The Phase 3 activities were scheduled to begin in December 1988, weather permitting, or otherwise during the third quarter of FY-89. The actual start-up of the penetration activities occurred in October 1989. The activities started at the south penetration location and progressed to the point of removing one unbreached drum from the exposed waste stack. The operations were stopped when it was discovered that other drums in the exposed waste stack were breached. At this time, there are no plans to resume the Phase 3 activities. Instead, a complete RI/FS investigation of Pad A is scheduled to begin in 1991.

13.4 Procedures

The following sections summarize the EG&G Idaho procedures followed throughout the investigation. Section 13.4.1 describes the Phase 1 sample collection and analysis procedures, Section 13.4.2 summarizes the Phase 2 sampling/screening procedures, Section 13.4.3 discusses the Pad A preparation and penetration procedures that were followed, and Section 13.4.4 summarizes the quality assurance aspects of the investigation. The sampling and analysis procedures, quality assurance/quality control plan, and health and safety plan are included in the December 1988 RFI Work Plan (EG&G, 1988a). Detailed operating procedures that were prepared before the start of the investigation are included in Appendix 13-1.

13.4.1 Phase 1 - Cover Soil Sampling

Before sample collection, a work station was set up on the unused portion of Pad A, east of the berm. The exclusion zone was defined by the industrial hygienist. Logbooks were kept to record dates, sampling locations and times, names of field team members, weather conditions, sampling procedures used, and problems encountered. The logbook used to record this information is included in Appendix 13-2. An initial entry of the site was made before sample collection to measure (a) the total organic vapors with an organic vapor analyzer and (b) the radioactivity with a radiation exposure meter. Detectable vapor levels were not encountered, and the field crew entered the site in Level C protective clothing.

Four soil samples were collected at each of the two locations. Sample collection points were established using the unaligned grid sampling method. This approach consisted of creating a grid by dividing each location into four square sectors and randomly selecting one sampling point within each square. Each square was 6 x 6 m (20 x 20 ft) in size. Before sampling, the center of each grid was marked with a stake, and distances were measured from this center stake to each sampling point using a steel tape. The selected sampling points are shown on Figure 13-4. A summary of the sample collection data is presented in Table 13-1.

Table 13-1. Summary of Phase 1 cover soil samples[a]

Sample ID	Sample Type	Sample Location[b]	Depth of Sample	Preservative Used (°C)	Date	Time
PADA188001	Soil	SPL	0-10 in.	4	8/18/88	1033
PADA188002	Soil	SPL	1-2 ft	4	8/18/88	1042
PADA188003	Soil	SPL	1-2 ft	4	8/18/88	1112
PADA188004	Soil	SPL	2-3 ft	4	8/18/88	1129
PADA188005	Soil	NPL	2-3 ft	4	8/18/88	1338
PADA188006	Soil	NPL	0-1 ft	4	8/18/88	1410
PADA188007	Soil	NPL	2-3 ft	4	8/18/88	1425
PADA188008	Soil	NPL	1-2 ft	4	8/18/88	1430
PADA188009	Spike	--	--	--[c]	8/18/88	1300
PADA1880E1	Equipment blank	--	--	--[c]	8/18/88	0900
PADA1880F1	Field blank	--	--	4	8/18/88	0920
PADA1880T1	Trip blank	--	--	4	8/18/88	1030

---

a. Source: Phase 1 sample collection logbook (Appendix 13-2).

b. SPL = South penetration location, NPL = North penetration location.

c. VOC = 4°C, metals = 4°C/HNO_3, nitrates = 4°C/H_2SO_4.

Each sample was collected using a stainless steel bucket-type hand auger and placed into a stainless steel pan. Sampling depths ranged from 0.3 m (1 ft) to a maximum of 0.9 m (3 ft). The soil that was collected in the tray was thoroughly mixed with a spoon and monitored for gross organic readings by the industrial hygienist. Enough sample was collected to fill one 60-mL container to be analyzed for volatile organics and one 250-mL container to be analyzed for specified metals and salts. These two containers comprised one sample that was preserved, labeled, packaged, and sent to the analytical chemistry lab for processing. Excess soil was returned to the auger hole from which it was taken. A complete list of equipment used during this phase of sample collection is included in the sampling and analysis plan (EG&G, 1988a).

All field sampling equipment was decontaminated before the collection of each sample. The field equipment (i.e., auger, spoons, and pans) was cleaned with deionized distilled water, rinsed with pesticide- or spectroscopic-grade hexane, rinsed a second time with deionized distilled water, wiped with a methanol soaked rag, and rinsed a third time with deionized distilled water. Following decontamination, each piece of equipment was double bagged and sealed. All rinsates and wastes generated during field operations were stored in 208-L (55-gal) drums, labeled as potential hazardous waste, and transported to the appropriate onsite storage facility.

The collected samples were managed by the sample leader. Samples were preserved to maintain their integrity from the time of collection until analyses were performed. Eight soil and four water samples were analyzed under Phase 1 of the investigation. The water samples consisted of a spike sample, equipment blank, field blank, and a trip blank (Table 13-1). All soil and water samples were preserved at a temperature of 4°C (39°F). In addition, the spike and equipment blank samples collected for metal and nitrate analyses were preserved with HNO_3 and H_2SO_4, respectively. Each sample was given a unique identification number (e.g., PADA188001). The number contained the task identifier (PADA), the phase number (1), and the calendar year (88). All remaining digits were used to ensure uniqueness of each sample collected. An E, F, or T was added at the end of the identification number to specify equipment blank, field blank, or trip blank, respectively. Each sample label contained the information required to enable cross referencing with the sample collection logbook including date, preservative, sample description, sample identification number, sampling team, and sampling organization. Custody seals were used to detect unauthorized tampering of samples between the time the sample was collected and analyzed. To maintain and document sample possession, chain-of-custody procedures were followed. Request for analysis forms were completed to eliminate confusion between samples intended to be completed by laboratory personnel.

Upon arrival at the laboratory, each sample was (a) inspected for leakage and to determine the condition of the sample label, (b) checked to determine if the information on the sample label agreed with the chain-of-custody record, (c) assigned a laboratory number, (d) logged into a laboratory logbook, and (e) stored in a secured sample storage room or cabinet until assigned to an analyst.

The Weston Analytical Laboratory conducted the analyses using standard EPA-approved methodology and quality assurance standards. The samples were analyzed for VOC concentrations using EPA Method 3810. The beryllium and total uranium concentrations in the samples were analyzed using EPA Methods 3050 and AS-3-1.3, respectively. The nitrate analyses were conducted using EPA Methods 504 and 505. The corresponding precision and accuracies for each of these methods are presented in Table 13-2. The procedures and documentation requirements for conducting these analyses were provided to the laboratory by EG&G Idaho in the statement of work.

13.4.2 Phase 2 - Cover Soil Sampling/Screening Procedures

A total of 22 soil samples were collected, at the discretion of the sampling coordinator, from randomly-selected points within the boundaries of the north and south penetration locations. Four additional samples were collected from the utility pole locations. Figure 13-5 shows the randomly-selected sampling locations. A summary of the sample collection data is presented in Table 13-3.

Table 13-2. Identified analytes and methods

	Method	Precision (%)	Accuracy (%)
Beryllium	3050	10/20	10/20
Carbon tetrachloride	8240	50/100	50/100
Tetrachloroethylene	8240	50/100	50/100
1,1,1-trichloroethane	8240	50/100	50/100
Trichloroethylene	8240	50/100	50/100
Uranium	AS-3-1	10/20	10/20
Nitrates	504 & 505	10/20	10/20

Table 13-3. Summary of Phase 2 cover soil samples[a]

Sample ID	Sample Type	Sample Location[b]	Depth of Sample (in.)	Preservative Used (°C)	Date	Time
A-01[c]	Soil	UPL	6	4	11/21/88	1422
A-02[c]	Soil	UPL	6	4	11/21/88	1434
A-03	Soil	UPL	6	4	11/21/88	1443
A-04[c]	Soil	UPL	8	4	11/21/88	1450
A-05	Soil	SPL	7	4	11/21/88	1502
A-06	Soil	SPL	6	4	11/21/88	1511
A-07	Soil	SPL	6	4	11/21/88	1520
A-08	Soil	SPL	6	4	11/21/88	1529
A-09	Background	Big Lost River drainage	6	4	11/21/88	1635
A-10	Soil	NPL	6	4	11/22/88	0938
A-11	Soil	NPL	6	4	11/22/88	0948
A-12	Soil	NPL	6	4	11/22/88	0957
A-13	Soil	NPL	6	4	11/22/88	1004
A-14	Soil	NPL	6	4	11/22/88	1010
A-15	Soil	NPL	6	4	11/22/88	1016
A-16	Soil	NPL	6	4	11/22/88	1023
A-17	Soil	NPL	6	4	11/22/88	1032
A-18	Soil	SPL	6	4	11/22/88	1040
A-19	Soil	SPL	6	4	11/22/88	1047
A-20	Soil	SPL	6	4	11/22/88	1053
A-21	Soil	SPL	6	4	11/22/88	1100
A-22	Trip blank	--	--	4	11/22/88	1100

---

a. Source: Phase 2 sample analysis report (Appendix 13-5).

b. UPL = Utility pole location.
SPL = South penetration location.
NPL = North penetration location.

c. Not analyzed.

Sample collection was conducted with a shovel and a stainless steel spoon. At each sampling point, the area was cleared with a shovel. Next, a hole was dug to a depth of not more than 0.3 m (1 ft). Before sampling, an area in the hole was scraped with a clean stainless steel spoon. Enough sample to fill a prepared 40-mL volatile organic analysis vial, approximately 75% full was collected. Spoons were decontaminated with deionized water and methanol following each use.

Sample management consisted of labeling each volatile organic analysis sample vial, placing it in a sample cooler with dry ice, and then hand carrying the cooler to the mobile laboratory for analysis. Each vial was labeled with a unique sample number. Sample numbers ranged from A-01 to A-22. The sample identification information was recorded in a logbook and is included as Appendix 13-3.

Each sampling vial was prepared before sampling and analysis by adding 20 mL of organic-free water to a clean 40 mL volatile organic analysis vial. Then, each vial was weighed to the nearest 0.1 g, and the value was recorded as the tar weight. During sampling, enough soil/sediment was introduced to occupy an additional 10 mL volume of the volatile organic analysis vial, leaving approximately 10 mL volume of headspace. Following sample collection, the vial was weighed again and refrigerated at 4°C (39°F).

Soils were screened for the presence of volatile organics by headspace analysis using gas chromatography with photoionization detection. Sample screening occurred within a mobile laboratory located near the investigation site. Each sample was brought to the mobile laboratory following collection, put in cold storage, and documented in the logbook. Before the analysis, the sample was warmed to ambient temperature from cold storage, shaken vigorously for 1 minute, and placed into a 90°C (194°F) water bath or oven for 1 hour. Finally, an aliquot of headspace above the sediment was sampled with a syringe and injected onto the analytical column.

The instrumentation used to analyze the samples was a Photovac series 10 S50 GC, which included a built-in integrator for data generation. This unit is an ambient temperature chromatograph that uses either zero grade air or ultra pure nitrogen as a carrier gas. The GC was tested before sample screening to ensure reliability and reproducibility of the data by comparing readings at known concentrations to standard curves. This was accomplished by developing three standard levels covering the expected sample concentration range and analyzing each level separately to produce a calibration curve. The GC was then used to analyze one or more of the standard levels, producing a response factor that was compared to the standard runs.

Samples were handled in daily sets. A standard was run at the beginning of each sample set, followed by a method blank. Method blanks were also analyzed after detection of a highly contaminated sample. In addition, a positive sample was split and run as a laboratory duplicate. Field duplicate samples and field blanks were also obtained and run at a rate of 1 per every 20 samples to assess the sampling accuracy.

13.4.3 Phase 3 - Pad A Preparation and Penetration Procedures

This phase of the Pad A initial penetration investigation consisted of the work conducted to prepare the two pads, erect a retrieval containment building, penetrate the pad, and retrieve the drums. First, each of the two sampling locations were flattened using a backhoe. To accomplish this, soil from the crown of the pad was moved to the sloping sideburden. Additionally, two areas adjacent to the east side of the pad were cleared to provide room for the crane that was used to lift the containment building from one location to the next. The removed cover soil was stockpiled adjacent to the dig area.

Next, the retrieval containment building was erected next to Pad A and moved to the first sampling location via the crane. A ventilation system was installed that was designed to accommodate 17 air changes per hour with dampening capabilities. This system was equipped with HEPA filters. During operations air quality was monitored continuously using both an alpha and beta continuous air monitor. In addition, air samples were taken during the penetration operations to assess radiological levels of contamination.

continuous air monitor. In addition, air samples were taken during the penetration operations to assess radiological levels of contamination.

Pad A penetration was accomplished within the containment building using a backhoe and personnel in Level B protective clothing. An area approximately 3.6 x 4.3 m (12 x 14 ft) was excavated until the first layer of drums was reached. A soil sample was collected directly above the first drum layer and analyzed for radiological compounds. The analysis results from this sample are included as Appendix 13-6. Removed soil was stockpiled within the confines of the pad and covered.

Once the drums were exposed, a smoke test was conducted to determine the direction and pattern of air flow at the opening. Appropriate adjustments were made to the ventilation system to ensure that flow was directed out through the duct system. The industrial hygienist sampled the area using a radiation exposure meter, portable alpha and beta/gamma instruments, and an organic vapor analyzer. The exposed drums were visually inspected for identification tags, labels, content code, corrosion, and integrity. The results of the evaluation were documented in the daily operations logbook. Breached drums were not retrieved, as specified in the health and safety plan. One intact drum was retrieved and placed adjacent to the retrieval pit. Then operations were ceased because of the breached drums.

13.4.4 Quality Assurance/Quality Control Field and Analytical Laboratory Procedures

The measuring and test equipment that was used in the field was controlled by a calibration program in accordance with QPP-149. The guidance of SW-846 was followed in determining instrument calibration frequency and concentrations based on the methodology employed for sampling. Other equipment used, such as the radiological and industrial hygiene instruments, was calibrated and standardized with the frequency and standards specified by the manufacturers. Equipment that failed calibration or became inoperable during use was removed from service and segregated to prevent inadvertent use.

collected and analyzed to determine some of the uncertainty because of random sampling errors. One equipment blank was collected per day per sampling apparatus to estimate incidental contamination of a sample during the collection procedure. Each equipment blank was collected using deionized water and analyzed for volatile organic and metal content. One trip blank was included in each sample shipping container to estimate contamination from the sample container and preservative during transport and storage. Trip blanks pertained to volatile organic samples only.

Analysis of method blanks and matrix spike samples served as a quality assurance check on the integrity of the laboratory handling procedures and matrix reactivity to the analytical method. Method blanks consisted of laboratory reagent grade water. These blanks were treated in the same manner as the samples and were reported as standard samples. A matrix spike is an aliquot of the investigative sample that is fortified with the analytes of interest and analyzed with an associated sample batch to monitor the effects of the investigative sample matrix on the analytical method. Matrix spikes were prepared by the EG&G Idaho Chemistry Sciences Group and included with the sample shipment.

Performance and system audits were performed for the Pad A penetration project. System audits consisted of evaluating all components of the applicable measurement systems to determine their proper selection and use. At least one systems audit was performed before or shortly after systems were operational to (a) verify that the quality assurance procedures were operational; (b) verify that correct sampling methodologies were chosen and that written procedures for sampling were available and followed; and (c) verify that specified equipment was available, calibrated, and in proper working order. Performance audits were conducted on field and laboratory activities as data were generated, reduced, and analyzed. Items audited included calibration records, daily entries in the logbooks, decontamination procedures, data logs, sampling procedures, analytical procedures, and efficiency of personnel and operations. Audits were performed by the BWP Quality Assurance Officer; the BWP Analytical Quality Assurance Officer; and the Environmental, Safety, and Quality Department. All audits were formally documented and records retained by the BWP Configuration Management and the Environmental, Safety, and Quality Department.

13.5 Results

The results of the analyses run on the eight samples collected during the Phase 1 cover soil sampling investigation are summarized on Tables 13-4 and 13-5. The halogenated VOC analyses in Table 13-4 indicate that no VOCs were detected in the soils. The metal and salt compound analyses in Table 13-5 indicate that uranium was not detected in any sample; beryllium was detected in seven out of eight samples at low concentrations of up to 1.34 mg/kg; sodium was detected in all samples and ranged from 1000 to 1709 mg/kg; potassium was detected in all samples and ranged from 2249 to 3508 mg/kg; and nitrate was detected in five out of seven of the samples with values that ranged from 5.0 to 45.7 mg/kg. The analysis report for these data is included in Appendix 13-4.

The results of the screening analyses run on the 19 samples collected during the Phase 2 cover soil sample/screening investigation are summarized in Table 13-6. The results indicate that no VOCs were detected in the soils. The analysis report for these data is included in Appendix 13-5.

The results of the gamma ray analyses for the two soil samples collected during Phase 3 indicate low values for Cs-137 and Am-241. The results of the Cs-137 analysis were 5.5E-02 pCi/g; the results of the Am-241 analysis were 4.0E-01 pCi/g. The analysis report for these data is included in Appendix 13-6.

The results of the two air samples that were collected within the containment structure during Phase 3 operations are summarized in Table 13-7. The analysis report for these data is included in Appendix 13-7.

Table 13-4. Phase 1 cover soils sample analyses for halogenated volatile organic compounds[a]

Analytical Information				
Sample Number	Analytical Method	Detection Limit (mg/kg)	Results (ppm) (mg/kg)	Comments (matrix)
PADA188001	EPA 8010	0.050	Analyzed but not detected	Soil
PADA188002	EPA 8010	0.050	Analyzed but not detected	Soil
PADA188003	EPA 8010	0.050	Analyzed but not detected	Soil
PADA188004	EPA 8010	0.050	Analyzed but not detected	Soil
PADA188005	EPA 8010	0.050	Analyzed but not detected	Soil
PADA188006	EPA 8010	0.050	Analyzed but not detected	Soil
PADA188007	EPA 8010	0.050	Analyzed but not detected	Soil
PADA188008	EPA 8010	0.050	Analyzed but not detected	Soil
PADA18800T	EPA 601	0.050 (μg/L)	Analyzed but not detected (ppb μg/L)	Trip blank
880830H	EPA 601	0.050	Analyzed but not detected	Lab water blank
880829H	EPA 601	0.050	Analyzed but not detected	Lab water blank
PADA1880E	EPA 601	0.050	Analyzed but not detected	Equipment blank
PADA1880F	EPA 601	0.050	Analyzed but not detected	Field blank
880829M	EPA 8010	0.050	Analyzed but not detected	Methanol blank

---

a. Source: Phase 1 sample analysis report (Appendix 13-4).

Table 13-5. Phase 1 cover soils sample analyses for inorganics[a]

Lab Sample #	Matrix[b]	Beryllium	Uranium	Sodium	Potassium	Nitrate as NO^3
8808s041-001	Water	0.005	1.000	5.000	5.000	0.500
8808s041-003	Soil	1.100	200.000	1000.000	2249.000	5.700
8808s041-005	Soil	1.000	200.000	1081.000	2634.000	5.000
8808s041-006	Soil	1.180	200.000	1351.000	3347.000	5.300
8808s041-007	Soil	1.150	200.000	1001.000	3122.000	5.500
8808s041-008	Water	0.964	11.100	50.500	50.000	1.900
8808s041-009	Soil	1.340	200.000	1520.000	3418.000	0.500
8808s041-010	Soil	1.060	200.000	1213.000	2544.000	45.700
8808s041-011	Soil	1.300	200.000	1709.000	3508.000	0.500
8808s041-012	Soil	1.250	200.000	1206.000	3118.000	0.500

---

[a] Source: Phase 1 sample analysis report (Appendix 13-4).

[b] Concentration units for water = µg/L; concentration units for soil = mg/kg

Table 13-6. Phase 2 screening analysis of VOCs[a]

Sample ID	Carbon Tetrachloride (ng/g)	Tetra-chloroethylene (ng/g)	Tri-chloroethylene (ng/g)
A-01[b]			
A-02[b]			
A-03	<600	<670	<650
A-04[b]			
A-05	<670	<750	<730
A-06	<700	<770	<760
A-07	<710	<790	<770
A-08	<610	<680	<670
A-09[c]	14000	<782	29000
A-10	<910	<1000	<1000
A-11	<1200	<1400	<1400
A-12	<1100	<1200	<1200
A-13	<1200	<1300	<1300
A-14	<980	<1100	<1100
A-15	<1100	<1200	<1200
A-16	<930	<1000	<1000
A-17	<970	<880	<1100
A-18	<790	<880	<860
A-19	<840	<930	<920
A-20	<1000	<1100	<1100
A-21	<890	<980	<970

---

a. Source: Phase 2 sample analysis report (Appendix 13-5).

b. Sample not analyzed.

c. Background sample.

Table 13-7. Results of Phase 3 air sampling

Sampling Site:		Pad A	Pad A
Sampling Type:		25-mL Air	25-mL Air
Customer Sample ID:		RWMC 2GC .	RWMC 1GC
Sampling Date:		Unknown	Unknown
Sampling Time:		Unknown	Unknown
Date Received:		01/09/89	01/09/89
Lab Sample ID:	Method Blank	9MIA0030	9MIA0029
Date Extracted:	01/16/89	01/16/89	01/16/89
Date Analyzed:	01/16/89	01/16/89	01/16/89
Comments:	Lab Blank	Field Blank	

Parameter	Method	PQL and Units	Result	Result	Result
VOCs[b]					
Acetone	EPA 624 M2[c]	2.0 mg/m^3 0.83 ppm	8.4 mg/m^3 3.5 ppm	3.4 mg/m^3 B 1.4 ppm B	BPQL[d] BPQL
2-Butanone	EPA 624 M2	2.0 mg/m^3 0.67 ppm	8.3 mg/m^3 2.8 ppm	5.8 mg/m^3 1.9 ppm B	BPQL BPQL
Carbon tetrachloride	EPA 624 M2	1.0 mg/m^3 0.16 ppm	BPQL BPQL	BPQL BPQL	4.1 mg/m^3 0.64 ppm
p-Dioxane	EPA 624 M2	2.0-4.0 mg/m^3 T1[e] 0.5-1.0 ppm T1	3.3 mg/m^3 J,T1 0.90 ppm J,T1	BPQL T1 BPQL T1	BPQL T1 BPQL T1
Methylene chloride	EPA 624 M2	1.0 mg/m^3 0.28 ppm	6.2 mg/m^3 1.8 ppm	6.5 mg/m^3 B 1.8 ppm B	6.2 mg/m^3 B 1.8 ppm B
Tetrachloroethylene	EPA 624 M2	1.0 mg/m^3 0.14 ppm	BPQL BPQL	BPQL BPQL	22.1 mg/m^3 3.2 ppm
Trichloroethlene	EPA 624 M2	1.0 mg/m^3 0.18 ppm	BPQL BPQL	BPQL BPQL	9.8 mg/m^3 1.8 ppm
Trichlorofluoromethane	EPA 624 M2	1.0 mg/m^3 0.17 ppm	BPQL BPQL	6.0 mg/m^3 1.0 ppm	5.3 mg/m^3 0.92 ppm
Others[b]	EPA 624 M2	(Appendix 13-10)	BPQL	BPQL	BPQL

---

a. Source: Phase 3 air sample analysis report (Appendix 13-6).

b. Target VOCs and their practical quantitation levels (PQLs) are provided in Table 1 (Appendix 13-10). The instrument was calibrated to quantitatively measure these compounds, therefore compounds reported as below PQL (BPQL) are unlikely to have been present above their PQLs.

c. M2 = A modification of EPA Method 624 was used because the method is designed for water samples. The PQLs listed apply to a volume of 25 mL. The results are reported in units of mg/m^3 an ppm. The ppm unit is on a volume compound per volume air basis and is determined by multiplying the weight of compound per volume of air concentration by 24.0 L (volume of 1.0 mole of gas at normal local temperature and pressure) and dividing by the compound's molecular weight (g/mole). Variations in temperature or pressure could introduce up to 25% uncertainty in the values reported in ppm units.

d. BPQL = Below practical quantitation level.

e. T1 = Tentatively identified compounds. These VOCs are not target compounds; consequently the instrument is not calibrated to quantitatively measure their abundances. The estimated practical quantitation level for these compounds is 10 to 20 µg/L for water samples and 10 to 20 µg/kg for solid samples.

14. Meteorological Monitoring

14. METEOROLOGICAL MONITORING

Several monitoring stations have been operated in or around the SDA for the purposes of (a) providing real-time data for operational and emergency requirements, (b) estimating the amount of ground water recharge from precipitation, and (c) determining evapotranspiration rates in an effort to characterize the potential for radionuclide migration in the vadose zone. A summary description of these monitoring stations and associated activities follows. The stations operated by EG&G Idaho are described in Sections 14.1 and 14.2; meteorological stations operated by the USGS are described in Section 14.3.

14.1 RWMC Meteorological Station

Meteorological monitoring in the immediate vicinity of the SDA began in 1979 with the installation of the Burial Ground Monitoring Site, located just outside the SDA to the northwest (Figure 14-1). This station, later renamed the RWMC, is operated by EG&G Idaho. The purpose of the station is to provide real-time wind speed and wind direction data for operational and emergency requirements. Data gathered from this station and numerous regional sites provides a basis to describe regional transport conditions. As shown in Figure 14-1, this location is well suited to provide meteorological data representative of the entire RWMC area.

The RWMC station is equipped with sensors to collect wind speed and direction at a height of 15 m (50 ft). It continues to operate and provides the longest available meteorological record. Sensors are calibrated annually or more frequently as needed. Data recovery has been better than 90% throughout the station's operating history; however, data recovery has been reduced as the equipment approaches the end of its operational life. Equipment replacement is being contemplated.[a] Data from the RWMC station are

---

[a] Personal communication between D. Ryan, SAIC, San Diego, California, and W. Talbot, EG&G Idaho, Inc., Idaho Falls, Idaho, February 9, 1990.

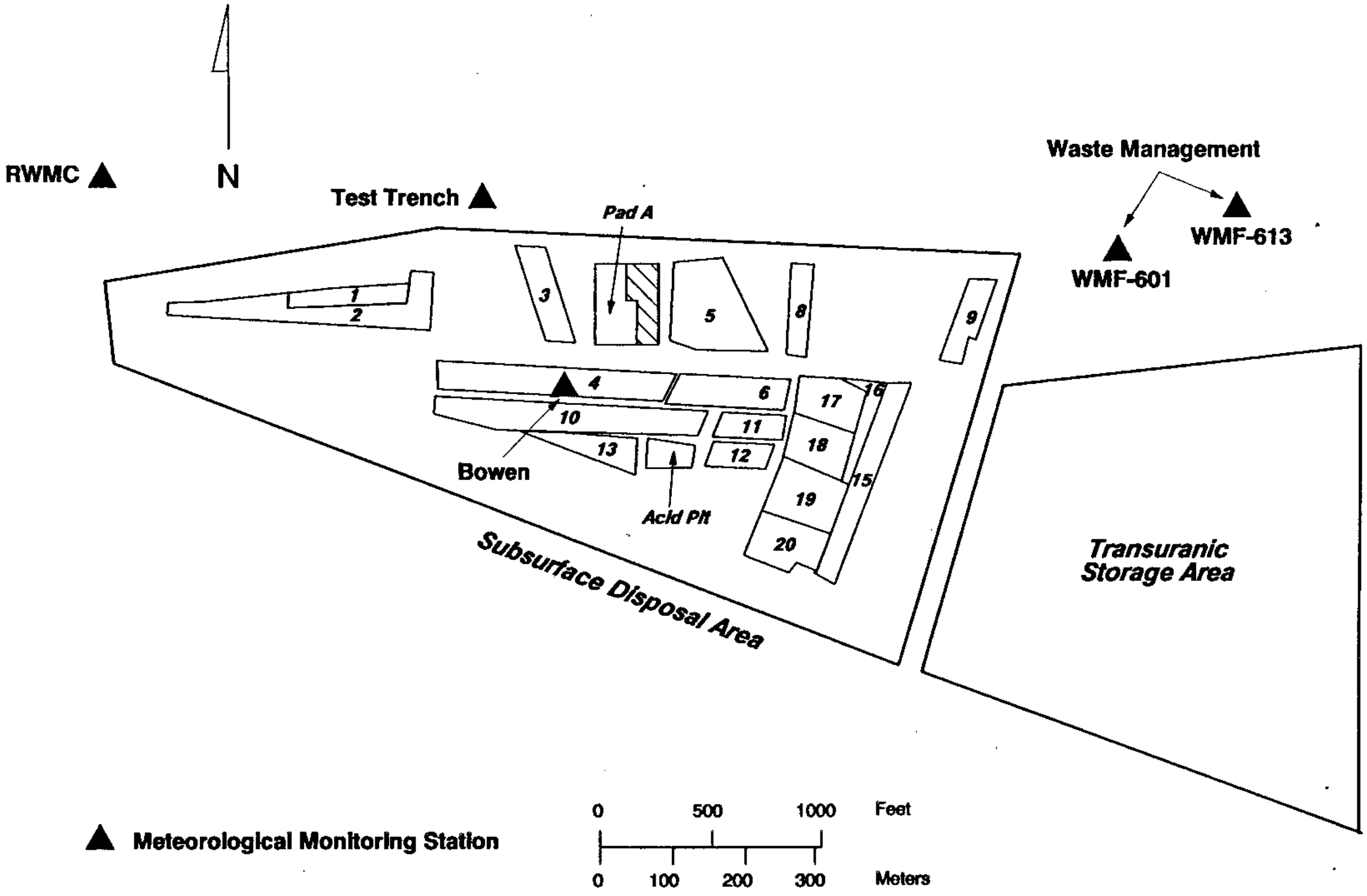


Figure 14-1. Approximate locations of meteorological monitoring stations in the vicinity of the RWMC.

fed to an EG&G Idaho central data receiving location every 6 minutes and are provided to the NOAA for analysis and archiving.

14.2 RWMC Waste Management Facility Stations

In support of emergency preparedness and daily operations, the RWMC waste management facilities measure wind speed, wind direction, and precipitation at Buildings 601 and 613 within the RWMC.[a] The monitoring program was initiated in Building 601 approximately 7 years ago and in Building 613 (Figure 14-1) approximately 2 years ago. Precipitation is collected on top of each of these buildings at a height of about 4 m (12 ft). Wind speed and wind direction are measured at the 9-m (30-ft) level, with sensors mounted on meteorological towers located beside the buildings. This placement is not expected to be suitable for characterizing the general regime because of the presence of turbulent building wake effects. Data from each of these sites are recorded solely on strip chart recorders (i.e., not digitized); therefore, they are not readily available for analysis.

14.3 USGS Stations

The USGS has operated two monitoring stations at the RWMC. The Test Trench site, described in Section 14.3.1, was installed in 1986. The Bowen Meteorological Station, described in Section 14.3.2, was installed in the center of the SDA in the summer of 1989.

14.3.1 Test Trench Site

Data gathering at the Test Trench site, located north of the SDA, was first initiated as part of a joint USGS and EG&G Idaho study of the geohydrology of the RWMC area (Figure 14-1). Details on the installation of the test trench site are provided in Section 5.3.1.2 of this report. In

---

[a] Personal communication between J. Bischoff, EG&G Idaho, Inc., Idaho Falls, Idaho and D. Ryan, SAIC, San Diego, California, February 12, 1990.

addition to collecting various hydrologic parameters, meteorological data were collected to obtain an accurate estimate of the amount of water that infiltrates the surficial sediment and eventually recharges the aquifer. This study, conducted in cooperation with the DOE, was designed to provide a basis for estimating the extent of, or the potential for, migration of radionuclide contamination in the unsaturated zone beneath the RWMC (Pittman, 1989).

Factory-calibrated equipment was installed in June 1986 to determine evapotranspiration rates. This equipment included an anemometer, a wind vane, an air temperature and relative humidity sensor, a heated rain gauge, and incoming and reflected solar radiometers. All sensors were placed at a height of 2 m (6.5 ft), a height suitable for measuring parameters necessary to determine evapotranspiration rates. This height, however, does not provide data suitable for characterizing the regional flow.

Data collection began on June 18, 1986. Data reported include 6-hour averages of global solar radiation, reflected solar radiation, mean wind speed, mean wind direction, mean wind vector, average relative humidity, average air temperature, and precipitation. Data for the period June to December 1986 are reported in Pittman (1989). With the exception of a data gap from 1987 to 1988, at which time all sensors were returned to the factory for calibration, data recovery was 80 to 90%. Precipitation continued to be collected continuously.

To enhance the capability to calculate evapotranspiration, additional sensors were ordered at the end of 1986. These sensors included spectral pyronometers, used to measure global sun and sky radiation and reflected short-wave radiation; precision infrared radiometers, used to measure long-wave terrestrial radiation; an infrared thermometer, used to measure surface temperature; additional anemometers; and temperature and relative humidity sensors.

Later, the monitoring program at the Test Trench site was discontinued in favor of a site located within the SDA because a fence around the SDA was causing too much turbulence in the near-ground field. Data collection was discontinued in January 1989, and the sensors were again sent for factory calibration.[a]

14.3.2 Bowen Meteorological Station

The new monitoring site, the Bowen Meteorological Station, which replaced the Test Trench site for the reason stated above, is centrally located within the SDA (Figure 14-1). Its configuration is different from that of the Test Trench station, but its purpose remains the same. The monitoring program is designed to measure precipitation; net radiation; wind speed and direction at a height of 2 m (6.5 ft); and temperature and vapor pressure at 0.5 m (1.5 ft) and 1.0 m (3 ft). Data recovery is estimated to be 80 to 90%.[a]

In addition to the above-mentioned sites, meteorological data are collected at several other locations at or near the INEL Site, as shown in Figure 14-2. Table 14-1 summarizes the locations for the map identification codes together with periods of record for air temperature, precipitation, and wind speed and direction as of December 31, 1988. The CFA site, located about 10 km (6 mi) east-northeast of the Bowen Meteorological Station, is equipped to collect data including wind speed and direction at the 6-m (20-ft) and 76-m (250-ft) levels, temperature, stability, precipitation, humidity, net radiation, and atmospheric pressure. These data are archived and analyzed by NOAA personnel. Because of its nearby location and similarity in terms of local topography and elevation, data from the CFA site are suitable to represent conditions at the RWMC.

---

[a] Personal communication between J. R. Pittman, USGS, Idaho Falls, Idaho, and D. Ryan, SAIC, San Diego, California, February 9, 1990.

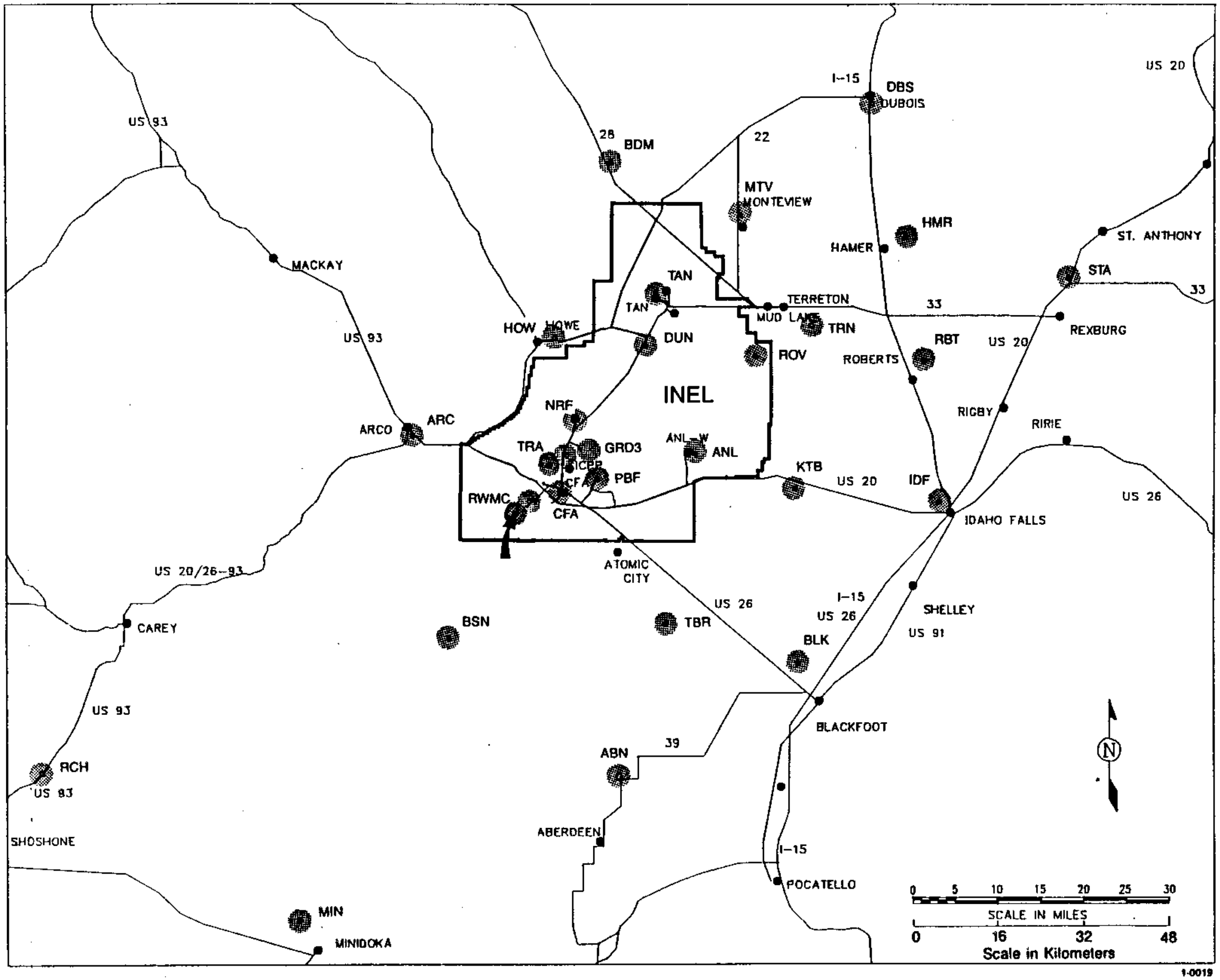


Figure 14-2. Geographic location of the 27 active INEL meteorological monitoring stations (Clawson et al., 1989).

Table 14-1. Active INEL meteorological monitoring stations and periods of record for air temperature, precipitation, and wind speed and direction[a]

Location	Code	Wind Speed and Direction	Air Temperature	Precipitation
		Onsite Stations		
Argonne National Lab-West[b,c]	ANL[c]	1964-present[d]	1964-present[d]	none
Central Facilities[b]	CFA	1950-present	1949-present	1950-present
Grid III	GRD3	1957-present[d,]	1979-present	none
Loss of Fluid Test	LOFT[e]	1953-present[d,]	1987-present[d]	none
Naval Reactor Facility	NRF	1956-present	none	none
Power Burst Facility	PBF	1964-present	none	none
Radioactive Waste Management Complex	RWMC	1977-present	none	none
Rover	ROV	1972-present	none	none
Sand Dunes	DUN	1956-present	none	none
Test Reactor Area	TRA	1971-present	none	none
		Offsite Stations		
Aberdeen	ABN	1968-present	none	none
Arco	ARC	1968-present	none	none
Big Southern Butte	BSN	1968-present	none	none
Blackfoot	BLK	1968-present	1971-present	none
Blue Dome	BDM	1968-present[f]	1954-present[f]	1954-1955
Dubois	DBS	1968-present	1971-present	none
Hamer	HMR	1971-present	none	none
Howe	HOW	1950-present[f]	1971-present	none
Idaho Falls	IDF	1968-present	none	none
Kettle Butte	KTB	1968-present	none	none
Minidoka	MIN	1968-present	1972-present	none
Monteview	MTV	1955-present[f]	1955-present[f]	1955-1963
Richfield	RCH	1968-present	1972-present	none
Roberts	RBT	1968-present	none	none
St. Anthony	STA	1968-present	1972-present	none
Taber	TBR	1968-present	none	none
Terreton	TRN[f]	1950-present[f]	1958-1961	1958-1961

---

a. Source: Clawson et al. (1989).

b. Instrumentation includes dew point temperature (period of record is from 1978 for CFA and ANL).

c. Station code is also referred to as EBR-II.

d. Meteorological variable is measured at multiple levels.

e. Station code is frequently identified as TAN.

f. Station was not operational for the entire period of record.

15. Air Sampling Investigation

15. AIR SAMPLING INVESTIGATION

An organic vapor sampling study was conducted at the SDA in order to quantify organic vapors detected at the surface during the drilling and instrumenting of two deep boreholes in 1987. The organic vapors were first detected on September 24, 1987, when the casing in Borehole D02 (which was installed in 1986) was pulled and some of the 34-m (110-ft) interbed was exposed. This episode caused a work stoppage. The following day, a work stoppage was caused by vapor emanating from Borehole D10, detected during drilling operations at a depth of 29 m (95 ft) below land surface [the 34-m (110-ft) interbed]. The objectives of the air sampling program are reviewed in Section 15.1; the investigation procedure is summarized in Section 15.2; analytical procedures and quality assurance/quality control methods are discussed in Sections 15.3 and 15.4, respectively; and the results of the investigation are presented in Section 15.5.

15.1 Purpose of the Air Sampling Investigation

Two objectives for the air sampling program were identified: (1) the collection and analysis of air samples at wellheads to assess formation gas concentrations associated with specific subsurface zones and (2) the collection and analysis of air samples at working levels above wellheads to assess worker exposure. The locations of the boreholes and sampling locations are shown in Figure 15-1.

15.2 Investigation Procedure

The procedures used for sample collection varied depending on the data objective. The procedures for air grab samples from wellheads are described in Section 15.2.1. Collection methods for breathing zone air concentration samples are discussed in Section 15.2.2.

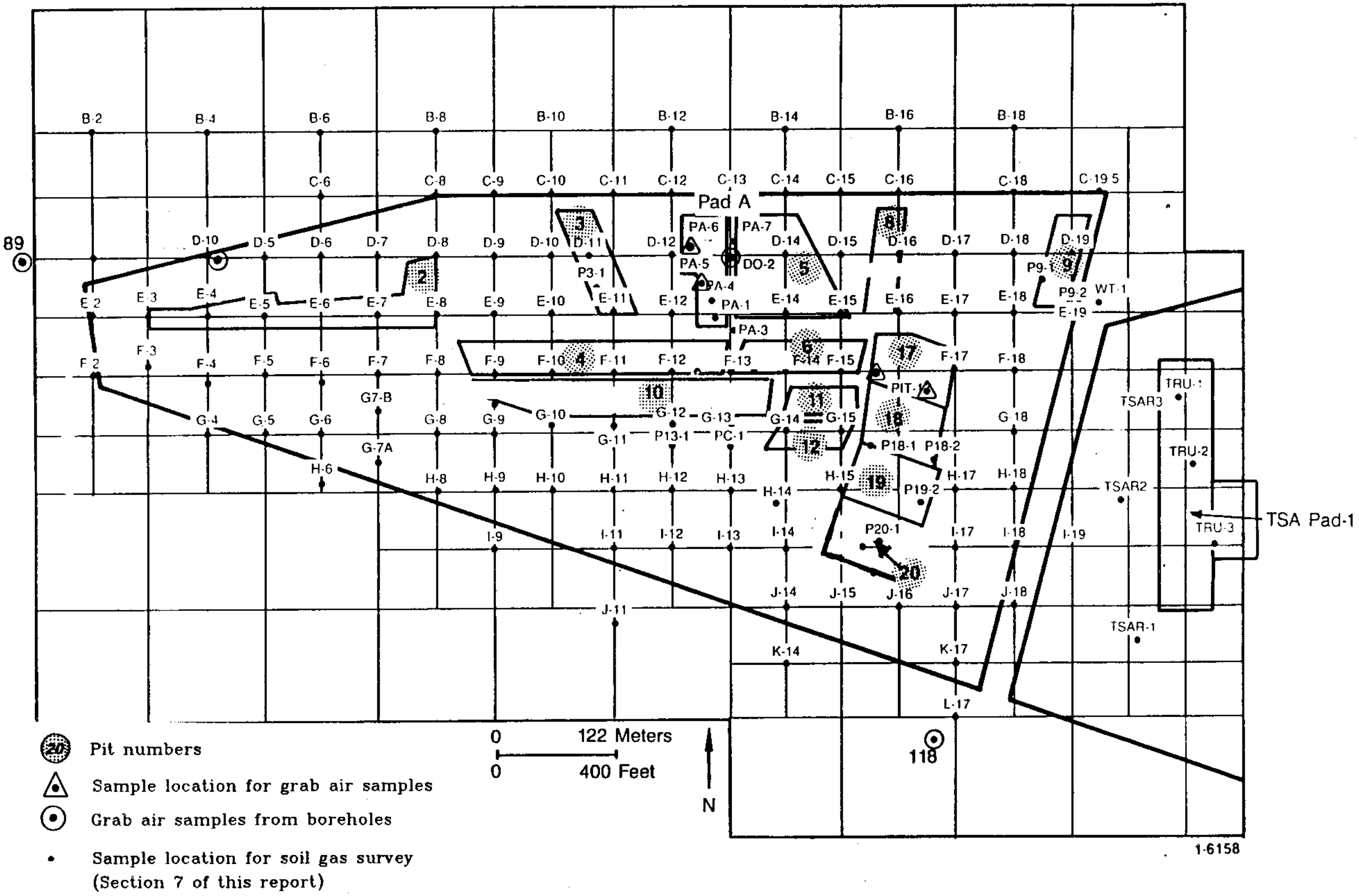


Figure 15-1. Sample locations for grab air samples at the SDA (EG&G, 1988a).

15.2.1 Air Grab Samples From Wellheads

Grab samples of air were collected on September 25 and 29, 1987, from Boreholes D02 and D10. The two boreholes were found plugged with rags or with a plastic bag. They were sampled by unplugging the wells and then collecting 25 mL of air from the wellhead. In addition to sampling at the two above mentioned borehole locations, Well 89 was sampled at the wellhead. This well had been cased and cemented to 176 m (576 ft), with several feet of open hole above the water table.

15.2.2 Breathing Zone Air Concentrations

Grab samples of organic vapors in the air were collected on September 30, 1987, at the following locations: west guard gate (blank), USGS Borehole 118, Borehole D02, Pad A subsidence hole, Pad A excavation area, Pit 17 west wall, Borehole D10, Pit 17 south end (blasting area), and Pad A open hole (locations are shown in Figure 15-1). The grab samples from Borehole D02, Borehole D10, Pit 17 west wall, Pit 17 south end, and west guard gate (blank) were collected at working level, which is approximately 0.9 to 1.5 m (3 to 5 ft) above the ground (commonly referred to as the breathing zone). The samples from the Pad A excavation area, Pad A open hole, Pad A subsidence hole, and Borehole 118 were collected just above the soil surface. These samples are referred to as source air samples. The concentrations taken closer to the source are expected to be higher than concentrations a worker would be expected to breathe while working at that location.

15.3 Analytical Procedure

The procedure for sample collection and analysis followed the Environmental Chemistry Standard Operating Procedure #414, Volatile Organic Analysis Sample Setup and Data Acquisition for Water and Soil Gas Samples (EG&G, 1988a, Vol. II). The air grab samples from wellheads were collected directly into 25 mL airtight Hamilton syringes in the field. The grab samples for breathing zone air concentrations were collected in either 5 or 25 mL airtight Hamilton syringes. The syringes were transported in a cooler packed with dry ice to the Chemical Sciences Laboratory at the CFA for analysis. Once at the CFA, the samples were transferred to a refrigerator [stored at 4°C (39°F)]. Air samples were analyzed by GC/MS using purge and trap sample introduction and automated sequencing, generally within 24 hours, but not more then 2 days after collection.

All glassware (including sparge tubes) was rinsed with laboratory reagent water and methanol and dried at 100°C (212°F) overnight before analysis. The volatile organic constituents were analyzed using the US EPA 10/86 Contract Laboratory Program Statement of Work for organic analyses with the following modifications: (a) 5 mL of reagent water was spiked with internal standards and surrogates and then added to the automatic liquid sampler sparge tubes using the normal procedure; and (b) the 5 or 25 mL air samples were than added to the sparge tubes.

15.4 Quality Assurance/Quality Control Methods

The Contract Laboratory Program Statement of Work for Organic Analyses (EPA, 1986c) analytical quality assurance/quality control protocols for water samples were used as a guideline to obtain data of known quality for these samples. For comparative purposes, control samples were taken. A field blank was taken at a deserted location on the INEL Site where organic vapor contamination was negligible or not directly attributable to nearby operations. The field blank for the air sampling was located at the west guard gate. Method blanks (samples taken in the laboratory) were taken to assess laboratory procedures. Trip blanks accompanied samples in order to assess any contamination that might have entered into the system during transport.[a] All of the data that were generated in association with these analyses are stored in the Environmental Chemistry Document Center.[b]

---

[a] Personal communication between P. N. Pink, EG&G Idaho, Inc., Idaho Falls, Idaho, and D. Ryan, SAIC, San Diego, California, February 15, 1990.

[b] Personal communication between G. S. Groenewold, P. N. Pink, and T. Hedahl, EG&G Idaho, Inc., Idaho Falls, Idaho, December 30, 1987.

15.5 Results

The results for the wellhead sampling program and the breathing zone air concentration sampling program are described in Sections 15.5.1 and 15.5.2, respectively.

15.5.1 Air Grab Samples From Wellheads

Results of the wellhead sampling program are provided in Table 15-1 for Boreholes D02 and D10. High levels of chlorinated organic compounds were measured at the wellheads of Boreholes D02 and D10, with fairly good sampling agreement as noted on the 2 sampling days. Same-day sampling resulted in more precise agreement. Significantly lower values were measured at Well 89 (Table 15-1). The reporting limits for these analyses were 5 mg/M^3 for each compound as reported by the laboratory. Carbon tetrachloride and trichloroethylene were the two compounds consistently found at the highest concentrations at Boreholes D02 and D10. These concentrations far exceed the American Conference of Governmental Industrial Hygienists guidance for 40-hour workweek repeated occupational exposures.

Comparison of the organics detected in each of the boreholes or wells from highest-to-lowest concentration (above the reporting limit) is shown in Table 15-2.

15.5.2 Breathing Zone Air Concentrations

Table 15-3 presents the results of the breathing and source level gas sample analyses. Organics were confirmed at the Pad A excavation area and subsidence hole, most notably carbon tetrachloride. Low levels of trichloroethane were observed from USGS Borehole 118. No significant organic compounds were attributed to air samples collected from Pit 17. Low levels of carbon tetrachloride observed in Pit 17 samples were attributed to laboratory

Table 15-1. Organic vapor concentrations for 1987 wellhead grab air samples[a]

Chemical	Reporting Limit (mg/M^3)	Borehole D02 (mg/M^3)		Borehole D10 (mg/M^3)			Well 89 (mg/M^3)	West Guard Gate Field Blank (mg/M^3)	Method Blank (mg/M^3)
Date Sampled:		9/25	9/29	9/25	9/25[b]	9/30	9/29	9/30	9/30
Carbon tetrachloride	5	900	1000	130	140	200	8	ND[c]	ND
Chloroform	5	210	230	9	12	(4)	(1)	(0.9)	(0.1)
1,1-dichloroethane	5	(3)	(3)[d]	NA[e]	NA	NA	ND	ND	ND
Tetrachloroethylene	5	20	62	9	9	7	(0.4)	ND	ND
Toluene	5	ND	(0.3)	NA	NA	NA	(0.8)	ND	ND
1,1,1-trichloroethane	5	95	120	14	15	11	(0.8)	(2.0)	(0.2)
Trichloroethylene	5	220	380	34	38	17	(3)	ND	ND
1,1,2-tricholotrifluoroethane	5	20	65	2	3	6	ND	ND	ND

---

a. Source: Personal communication between G. S. Groenewold, P. N. Pink and T. Hedahl, EG&G Idaho, Inc., Idaho Falls, Idaho, December 30, 1987. Data were validated in accordance with EPA Contract Laboratory Program requirements for data validation.

b. Replicate sample.

c. ND = not detected.

d. () detected below reporting limit.

e. NA = not analyzed.

Table 15-2. Organics detected in Boreholes D02 and D10 and Well 89 (listed by highest-to-lowest concentration)

Borehole D02	Borehole D10	Well 89
Carbon tetrachloride	Carbon tetrachloride	Carbon tetrachloride
Trichloroethylene	Trichloroethylene	
Chloroform	1,1,1-trichloroethane	
1,1,1-trichloroethane	Chloroform	
1,1,2-trichlorotrifluoroethane	Tetrachloroethylene	
Tetrachloroethylene	1,1,2-trichlorotrifluoroethane	

Table 15-3. Organic vapor concentrations for 1987 source and breathing level grab air samples[a]

		Source Sampling Locations				Breathing Level Sampling Locations[b]				Sampling Locations	
Chemical	PQL (mg/M^3)	Pad A Exacavation Area (mg/M^3)	Pad A Open Hole (mg/M^3)	Pad A Subsidence Hole (mg/M^3)	USGS Borehole 118 (mg/M^3)	Pit 17[c] (mg/M^3)	Pit 17 South End (Blasting Area) (mg/M^3)	Borehole D02 (mg/M^3)	Borehole D10 (mg/M^3)	West Guard Gate Field Blank (mg/M^3)	Method Blank (mg/M^3)
Chloroform	5	(2.0)[d]	ND	ND	(0.8)	0.9	(0.8)	(0.4)	0.9	(0.9)	(0.1)
1,1,1-trichloroethane	5	(1.0)	2.0	ND	(1.0)	1.0	(1.0)	(0.4)	1.0	(2.0)	(0.2)
Carbon tetrachloride	5	17.0	ND	11.0	ND	[e]	(1.0)	(3.0)	ND	ND	ND
Trichloroethylene	5	5.0	ND	5.0	(0.5)	ND	ND	(0.5)	ND	ND	ND
Perchloroethylene	5	(0.5)	ND	(4.0)	ND	ND	ND	ND	ND	ND	ND
Toluene	5	(1.0)	ND	(0.2)	ND	ND	ND	ND	ND	ND	ND
Acetone	10	(5.0)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	5	(0.4)	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-butanone	10	(1.0)	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-trichloro-trifluoroethane	5	(2.0)	ND	(3.0)	ND	ND	ND	ND	ND	ND	ND

---

a. Source: Personal communication between G. S. Groenewold, P. N. Pink and T. Hedahl, EG&G Idaho, Inc., Idaho Falls, Idaho, December 30, 1987. Data were validated in accordance with EPA Contract Laboratory Program requirements for data validation.

b. Samples taken 3 - 5 ft above ground.

c. Replicate samples were also taken at Pit 17 west wall. No measurable contamination was found.

d. () below PQL.

e. Value measured at 430 mg/M^3, but it was attributed to laboratory contamination.

contamination.[a] Carbon tetrachloride and trichloroethylene were observed in breathing level samples from Borehole D02 and Pit 17 south end. None of the measured quantities exceeded the American Conference of Governmental Industrial Hygienists guidance for 40-hour workweek repeated occupational exposures. The value for carbon tetrachloride at the Pad A Excavation Area source level, however, is slightly more than one-half the guidance value.

Low levels of chloroform and 1,1,1-trichloroethane were observed at all sampling locations. However, because these compounds were also observed in similar quantities in the field and method blanks (with the exception of the chloroform reading at the Pad A Excavation Area that was twice the field blank value), these concentration levels were not attributed to the samples.

As might be expected, the working level concentrations above Boreholes D02 and D10 were substantially lower than the concentrations at the borehole opening sampled on the previous 2 days (see Table 15-1).

---

[a] Personal communication between G. S. Groenewold, P. N. Pink, and T. Hedahl, EG&G Idaho, Inc., Idaho Falls, Idaho, December 30, 1987.

16. Air Monitoring for Particulates Radionuclides

16. AIR MONITORING FOR PARTICULATES RADIONUCLIDES

This section describes past and present environmental monitoring activities related to the investigation of particulate radionuclide concentrations in ambient air inside and around the perimeter of the RWMC and summarizes the results of these activities. Monitoring methods, the types of data obtained, quality assurance activities, and the storage and reporting of the data are described. Summaries of the data are presented including measured concentrations of radionuclides and radiation levels inside and around the perimeter. A comparison of results to standards is also provided.

Section 16.1 discusses the purpose of the investigation; Section 16.2 details a history of monitoring activities at the RWMC; Section 16.3 delineates investigation procedures including field sampling procedures, laboratory analytical methods, and programmatic quality assurance programs; and Section 16.4 provides monitoring program results obtained over several years.

16.1 Purpose of Investigation

The air monitoring program at the RWMC has evolved since monitoring began in 1972. Early monitoring program activities were modest and focused on worker safety issues rather than environmental concerns. Since that time, the program has been expanded, refined, and tailored to meet the following current objectives:

1. Determine concentrations of airborne radionuclides at the RWMC and compare these to derived concentration guides (DCGs). (DCGs are reference values provided by DOE for conducting radiological environmental protection programs at operational DOE facilities and sites for the protection of the public and environment)

2. Detect significant trends in concentrations of airborne radionuclides at the RWMC

3. Provide an indication of confinement integrity for waste at the RWMC

4. Provide data for pathways analyses on concentrations of airborne radionuclides that can be used for calculating dose to man.

5. Investigate the origins and mechanisms of suspension of airborne radionuclides (EG&G, 1989h).

The program emphasizes collecting and evaluating airborne particulate radionuclides because airborne radioactivity from the RWMC is predominantly in the particulate form. The dust is a result of soil resuspension because of wind and operational activities. Therefore, the program consists of a network of samplers for airborne particulates. The filters from these samplers are collected, weighed, and analyzed routinely to determine which radiological contaminants are present and their concentrations in air.

Table 16-1 provides a list of the gamma-emitting radionuclides most likely to be found in environmental samples collected at the RWMC and the most likely sources of those radionuclides. Based on a study conducted to evaluate the air monitoring program at the RWMC, it was concluded that the radionuclides in Table 16-1 represent 91% of the total inventory, 47% of the inhalation hazard, and 79% of the ingestion hazard associated with the low-level waste inventory in the SDA.[a]

The air monitoring program at the RWMC is part of a comprehensive radiological and hazardous materials environmental monitoring program at the INEL. Responsibilities for the current program are divided among many organizations. EG&G Idaho's Environmental Monitoring Unit is responsible for monitoring and related data management functions of the RWMC. The EG&G Radiation Measurements Laboratory (RML) performs gross alpha and gross beta

---

[a] Unpublished report by the Monitoring Activities Review, Idaho National Engineering Laboratory, Idaho Falls, Idaho, August 23, 1983.

Table 16-1. Gamma-emitting radionuclides most likely to be found in RWMC environmental samples[a]

Radionuclide	Expected Source		
	Waste Inventory of RWMC	Other INEL Facilities	Fallout
Cr-51	x	x	x
Mn-54	x	x	x
Co-58	x	x	x
Fe-59	x	x	x
Co-60	x	x	x
Nb-95	x	x	x
Zr-95	x	x	x
Ru-103	x	x	x
Ru-106	x	x	
Sb-125	x	x	x
Cs-134	x	x	x
Cs-137 (Ba-137m)	x	x	x
Ce-141	x	x	x
Ce-144	x	x	x
Eu-152	x	x	
Am-241	x	x	x

---

a. Source: Tkachyk et al. (1988).

analyses every 2 weeks and the routine gamma analyses for the Environmental Monitoring Unit samples. The Environmental Analysis Group of Westinghouse Idaho Nuclear Company, Inc. performs the specific alpha and beta analyses for Environmental Monitoring Unit samples. RESL performs routine monitoring outside the RWMC and around other operational facilities on the INEL Site. RESL does its own analyses.

16.2 Past Monitoring Activities

This section provides a discussion of the evolution of the air monitoring program at the RWMC. The air monitoring program design for particulates radionuclides, from 1983 to 1989, is summarized in Table 16-2.

Air monitoring was initiated at the RWMC in 1972 with a single low-volume (LV) air sampler. In 1974, health physics personnel used portable air monitors to measure airborne radioactivity at the SDA. The program was expanded in 1975 when six stationary LV samplers were placed around the SDA, thus, starting continuous air monitoring activity. The objectives of those early activities were designed to satisfy operational monitoring requirements and provide an early warning of hazardous concentrations of airborne radioactivity. At that time, the program was primarily designed for worker safety rather than to determine long-term trends in environmental radioactivity, radionuclide transport, or environmental protection/compliance functions (EG&G, 1984).

Beginning in 1976, filters from the LV samplers were individually analyzed for gross alpha and gross beta activity. They were also analyzed by gamma spectroscopy for 26 specific radionuclides. In 1977, four high-volume (HV) air samplers were added to the air monitoring network. In 1978, the six original LV samplers were replaced with eight HV samplers. In 1981, the 12 HV samplers were relocated around the SDA perimeter, and two more HV samplers were added to the monitoring network, bringing the total to 14. The monitoring locations are shown in Figure 16-1. In 1981, the HV samplers were

Table 16-2. RWMC air monitoring program design for particulate radionuclides, 1983 to 1989[a]

Year	Description	Frequency of Analyses	Type of Analyses	Station Locations
1983	14 high-volume air samplers operated at 0.6 m^3/min	Weekly	Gross alpha Gross beta Gamma spectrometry	Figure 16-1
1984, 1985	11 high-volume air samplers operated at 0.6 m^3/min (includes 1 control and 1 replicate)	Weekly Weekly Monthly	Gross alpha Gross beta Gamma spectrometry	Figure 16-2
1986	11 low-volume air samplers operated at 0.14 m^3/min[b] (includes 1 control and 1 replicate)	Biweekly Biweekly Monthly Quarterly	Gross alpha Gross beta Gamma spectrometry Radiochemistry	Figure 16-2
1987, 1988	13 low-volume air samplers operated at 0.14 m^3/min (includes 1 control and 1 replicate)	Biweekly Biweekly Monthly Quarterly	Gross alpha Gross beta Gamma spectrometry Radiochemistry	Figure 16-3
1989	8 low-volume air samplers operated at 0.14 m^3/min (includes 1 control and 1 replicate)	Semimonthly Semimonthly Monthly Quarterly	Gross alpha Gross beta Gamma spectrometry Radiochemistry	Figure 16-3

---

a. Source: Blanchfield and Hoffman (1984); Reyes et al. (1983); Reyes et al. (1986); Reyes et al. (1987); Tkachyk et al. (1988); Tkachyk et al. (1989); Tkachyk et al. (1990).

b. HV samplers were used in 1984 and 1985. LV samplers were operated in 1986.

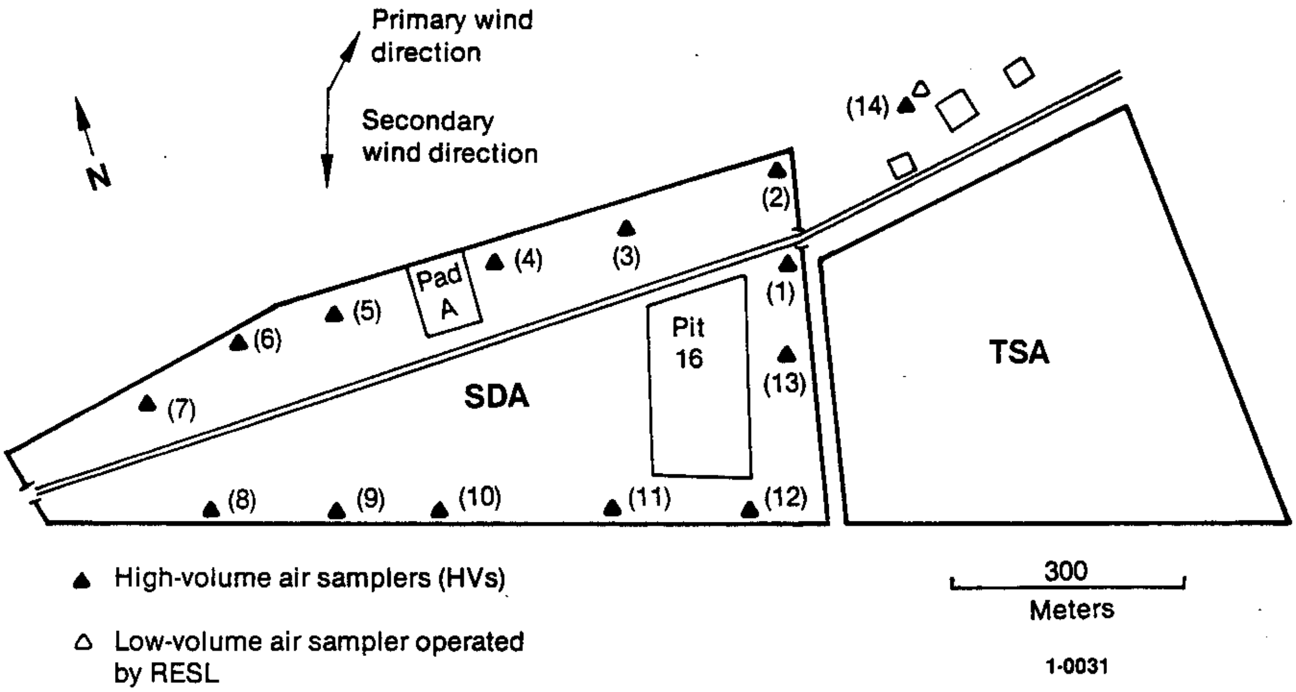


Figure 16-1. RWMC air monitoring locations, 1981 to 1983 (Blanchfield and Hoffman, 1984).

inspected weekly by Waste Technology Programs personnel and calibrated quarterly by the Health Physics Instruments Laboratory to operate at a constant flow rate of 20 ft^3/min ±10%.[a] Analysis of HV filters for gamma-emitting radionuclides began in 1977, and gross alpha and gross beta analysis of HV filters began in 1979 (EG&G, 1984). Filters were collected weekly, stored for 5 days to allow for decay of short-lived natural radioactivity, and analyzed weekly. A portion of the filter was used to estimate gross alpha and gross beta radioactivity. The radioactivity trapped on the entire filter surface was presumed to be evenly distributed. A subsample was used to estimate the gross alpha and gross beta activity.[a] The remaining portion of the filter was analyzed for 25 radionuclides by gamma spectroscopy. Radionuclide concentrations were estimated by dividing the measured total filter activity by the total volume of air sampled. The filters were cataloged and stored for 5 years.[a]

An in-depth RWMC Monitoring Activities Review (MAR) was conducted during 1983. The objectives of the MAR were to improve ongoing RWMC air monitoring activities and the understanding and use of the data generated by those activities.[a] The scope of the review covered the following areas: (a) objectives of the monitoring program; (b) sampling rationale (what to sample, where to sample, sample frequency, and number of samples); (c) sample collection methods; (d) sample preservation, storage and transfer; (e) sample analysis techniques and objectives; (f) data generation, reduction, and evaluation; and (g) data reporting. The MAR also included a detailed review of the procedures and data by a team of technical experts including laboratory personnel from EG&G Idaho, environmental specialists from DOE-ID and EG&G Idaho, a statistician from EG&G Idaho, and management personnel from EG&G Idaho.

A key result of the MAR was redefining the RWMC air monitoring program from one that assessed personnel safety and impact on the surrounding environment to one that (1) determined concentrations of airborne

---

[a] Unpublished report by the Monitoring Activities Review, Idaho National Engineering Laboratory, Idaho Falls, Idaho, August 23, 1983.

radionuclides at the RWMC and compared them against RCGs (Recommended Concentration Guide) for uncontrolled areas in DOE Order 5480.1, Chapter XI [Note: This order has since been superseded by Order 5400.5.]; (2) detected significant trends in concentrations at the RWMC; (3) provided an indication of confinement integrity; and (4) provided data for pathways analyses which can be used for calculating dose to man.[a] (Note: RCGs, which are DOE recommended guidelines for protection of the public from exposure to radiation, have been replaced by DCGs). Specific alert levels are given in Tables 16-3 and 16-4. Alert levels are a percentage of the DCG and allow initiation of necessary action before the DCG is exceeded.

The MAR also provided impetus for the initiation of a number of changes in sampling design, field procedures, laboratory procedures, data processing and reporting, and proposed additional studies to evaluate other possible future program design enhancements. Justification for each recommendation is provided in the committee report.[a] Some of the more sweeping changes suggested by the 1983 MAR are listed below:

- Reduce HV sample locations at the SDA from 14 to 6. Add an HV sampler to the TSA. [The MAR committee indicated that the program scope within the SDA could be reduced in order to lower costs, and this reduction would not result in significantly less information statistically nor impede objectives (EG&G, 1984)].

- Add an eighth HV sampler to the RWMC to be moved monthly to a different HV sample location. This HV air sampler will act as a replicate sampler to evaluate equipment reliability and sampling variability.

---

[a] Unpublished report by the Monitoring Activities Review, Idaho National Engineering Laboratory, Idaho Falls, Idaho, August 23, 1983.

Table 16-3. Alert levels of gamma-emitting radionuclides in air samples[a]

Radionuclide[b]	Alert Levels[c] for Air (μCi/ml)
Cr-51	1.3E-08
Mn-54	5.0E-10
Co-58	5.0E-10
Fe-59	2.0E-10
Co-60	2.0E-11
Nb-95	8.0E-10
Zr-95	1.5E-10
Ru-103	5.0E-10
Ru-106	7.2E-12
Sb-125	2.5E-10
Cs-134	5.0E-11
Cs-137 (Ba-137m)	1.0E-10
Ce-141	2.5E-10
Ce-144	7.5E-12
Eu-152	1.3E-11
Am-241	5.0E-15

---

a. Source: EG&G (1989h).

b. Listed radionuclides are those most likely to be found at the RWMC.

c. Alert levels are 25% of the most restrictive value for DOE DCGs for the public.

Table 16-4. Alert levels for alpha- and beta-emitting radionuclides in air samples[a]

Radionuclide	Alert Levels[b] for Air (µCi/ml)
Sr-90	2.3E-12
U-232	5.0E-15
U-233	2.3E-14
U-234	2.3E-14
U-235	2.5E-14
U-238	2.5E-14
Am-241	5.0E-15
Pu-238	7.5E-15
Pu-239,240	5.0E-15
Gross alpha activity	2.0E-14
Gross beta activity	9.0E-12

---

a. Source: modified from EG&G (1989h).

b. Alert levels for specific radionuclides are 25% of the most restrictive DCGs[c] for the public. The alert level for gross alpha activity is 100% of the restrictive DCG for specific alpha-emitters (in this case Pu-239,-240). The alert level for gross beta is 100% of the most restrictive DCG for specific beta-emitting fission products (in this case Sr-90) for the public.

c. Detected concentrations as a percentage of DCG values for the public are based on the DOE conversion factors provided in DOE Order 5400.5 dated February 8, 1990.

- Add a control HV sampler at the Experimental Breeder Reactor (EBR) (location designation EBR-I, about 3 km (1.9 mi) east-northeast of the RWMC) to provide information on background or ambient radioactivity and help evaluate questionable laboratory results. Ambient data are useful in the evaluation of the contribution of RWMC activities to public dose. The ambient level is that level of radioactivity that would be present at the RWMC location if the RWMC did not contain radioactive wastes. The ambient level consists of naturally occurring background radiation, radiation because of fallout from nuclear weapons testing, and radiation resulting from other activities at the INEL Site.

- Transfer responsibility for the continuous air monitors to health physics personnel. The purpose of the continuous air monitors remains one of worker safety and hazards analysis; therefore, the continuous air monitors will not be discussed further in the context of the environmental monitoring program.

- Provide monthly composites of filters from each sampler and perform monthly analyses by gamma spectroscopy. Composites were analyzed monthly, rather than weekly because the larger volume allowed lower concentrations of radionuclides to be measured with greater confidence.

- Analyze composites from each sampler by radiochemistry quarterly for Sr-90; total uranium; Pu-238; Pu-239,-240; and Am-241.

- Determine weight of particulates on each filter.

- Perform regular quality assurance activities including the use of blanks, splits, and spiked standard samples.

- Report uncertainties and actual values within 2 weeks of sample receipt.

- Establish alert levels at 10% of the RCGs for uncontrolled areas, with detailed follow-up procedures documented. Compare analytical results with RCGs only after first subtracting background concentrations. The proposed alert level was somewhat arbitrary, but judged to provide considerable protection while still allowing for expected variation.[a] The Alert level has been revised to 25% of the DCG (see Tables 16-3 and 16-4.)

- Report geometric rather than arithmetic means.

- Provide log concentration-versus-time plots to include data from several years in order to evaluate trends.

The MAR also suggested that a program be evaluated that used particle sizing heads in order to determine radioactivity associated with respirable airborne particulates. Using a computerized system for data management was mentioned. It was also suggested that replacing the HV samplers with LV samplers be evaluated as a cost-effective improvement to the air monitoring activities (i.e., to reduce the annual HV sampler maintenance and calibration costs), if the HV samplers could provide the air volume necessary to detect beta- and gamma-emitting and TRU radionuclides of interest. The HV samplers were replaced with LV samplers in 1986. In addition, during 1983, RML evaluated the effect of increased counting time on lowering the detection limits. PM_{10} (i.e., particles in the respirable range, nominal diameter of 10 micrometers or less) size selective inlet samplers are currently being evaluated and an additional one is on order.[b] The computerized data management system was implemented and is currently being upgraded.

The sweeping changes proposed in the MAR were implemented during 1984. Beginning on January 1984, the air monitoring network at the RWMC was reduced

---

[a] Unpublished report by the Monitoring Activities Review, Idaho National Engineering Laboratory, Idaho Falls, Idaho, August 23, 1983.

[b] Communication between J. W. Tkachyk, EG&G Idaho, Inc., Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, November 26, 1990.

from 14 HV samplers to a network of 11 HV samplers, including one control and one replicate. Six locations were within the SDA and three within the TSA. The selected monitoring locations are shown in Figure 16-2. RESL continued to operate an LV sampler near Building 601 but discontinued operation of the HV sampler during 1984.

The program in place in 1984 is described below. Each HV sampler drew air through a filter at about 20 actual ft^3/min. The filters from each HV sampler were collected weekly, composited monthly, and sent to the RML for analysis. A 3.2-cm (1.25-in.) diameter portion of each 20-cm (8-in.) or 25-cm (10-in.) HV filter was analyzed for gross alpha and gross beta activity using a gas flow proportional counter. The remaining portion of the filter was analyzed for 25 gamma-emitting radionuclides by gamma spectroscopy with a lithium-drifted germanium detector coupled to a multichannel analyzer. The radioactivity on the entire filter was presumed to be proportional to the portion analyzed. Radionuclide concentrations in air were estimated by dividing the total filter activity by the total volume of air sampled. Monthly comparisons, between stations and with the control, were made using analysis of variance and a multiple range test. The EG&G Idaho raw data were stored on magnetic tape at the RML until analyses and interpretations were completed. The magnetic tapes were then archived at the Computer Science Center Library, in Idaho Falls, Idaho. Air sampling data and information on any observed trends were stored in the Monitoring System Report and discussed in the Environmental Monitoring Annual Report. Results of RESL particulate studies were retained and reported by RESL (EG&G, 1984).

While the 1983 MAR resulted in major modifications to the air monitoring program, the program has continued to evolve since that time as the result of program reviews, operational requirements, upgrades in equipment/methodologies, and developments in guidance/regulatory requirements. Beginning in February 1985, new low background counting instrumentation was acquired for gross alpha and gross beta analysis. The new system allowed for detecting gross beta activity in most samples (Reyes et al., 1986). The use of radiochemical analyses for detecting specific alpha- and beta-emitting

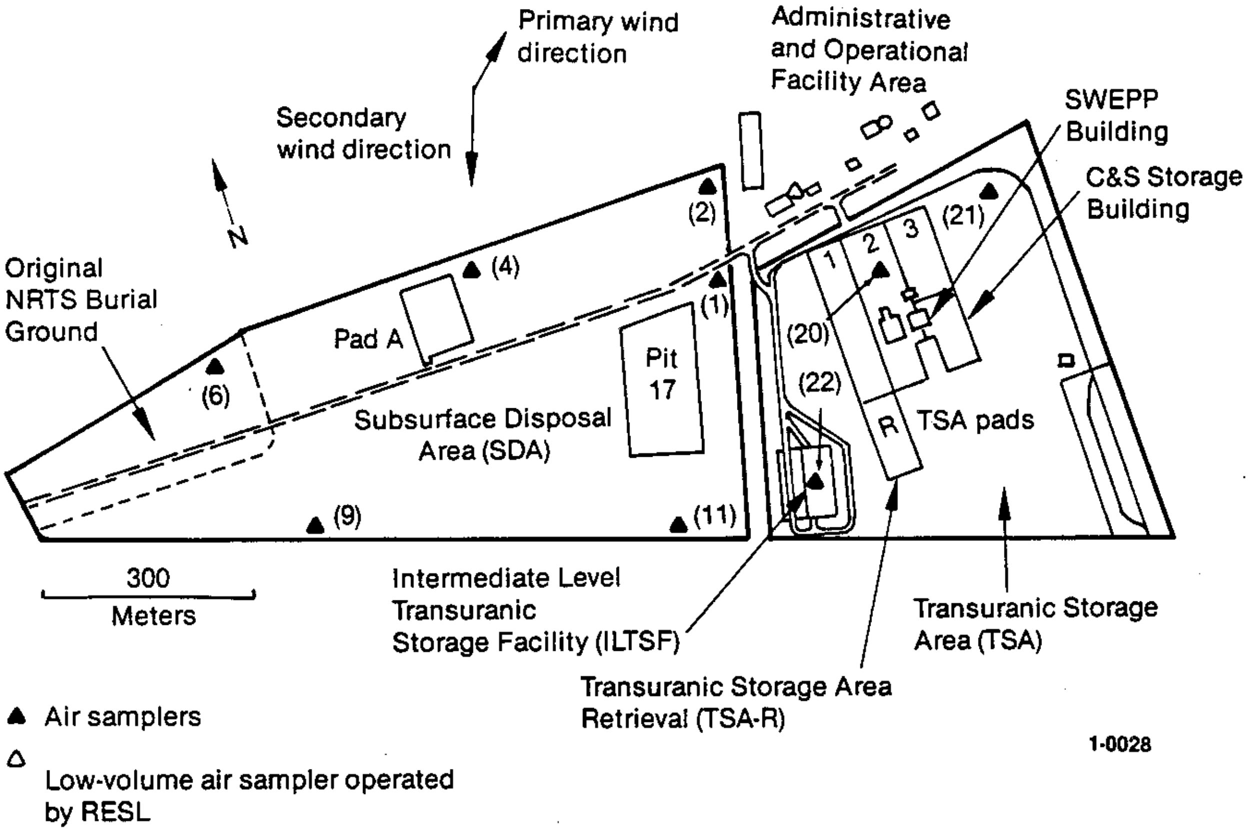


Figure 16-2. RWMC air monitoring locations, 1984 to 1986. High-volume samplers were operated during 1984 and 1985. Low-volume samplers were operated during 1986 (Reyes et al., 1987).

radionuclides for EG&G Idaho samples was initiated in 1986 (Reyes et al., 1987). All HV samplers had been replaced by LV samplers in 1986. In addition, two additional LV air samplers were added to the TSA in 1986 (Reyes et al., 1987). The locations of the samplers are shown on Figure 16-3. These additional monitors were installed following the observed increase in airborne plutonium activity at the RWMC during 1986. The additional coverage was proposed to better characterize any changes that might occur in the air concentrations. In conjunction with this, a committee was formed to evaluate (a) the 1986 environmental data, (b) RWMC operational waste storage and disposal practices, and (c) possible actions that could minimize airborne plutonium activity at the RWMC (Reyes et al., 1987). Committee membership included representatives from RWMC Operations, Safety, Environmental Monitoring, and DOE-ID. The Committee concluded its efforts in 1987. New sources of contamination were evaluated relating to the presence of Pu-239,-240 in the 1987 second quarter sample at location 2, with a higher ratio of Pu-239,-240 to Am-241 than seen previously in the soil (Tkachyk et al., 1988). During 1989, two additional samplers were placed in the SDA (at locations 2 and 11 on Figure 16-3), one in the TSA (location 24 on Figure 16-3), and a control at EBR-1. These samplers are designed to monitor for PM_{10} and operate in parallel with the LV samplers at those locations. The possibility of expanding the PM_{10} network is currently under evaluation. (Note: Because the installation of PM_{10} monitors is very recent, and data are not yet available from these systems, they will not be discussed further or considered in tables and figures indicating present monitoring network design.)

The monitoring program is continually evaluated, and necessary changes are implemented. A second MAR was conducted in 1988. This most recent MAR did not result in any major modifications to the air monitoring program and an action plan for implementation of MAR recommendations not previously addressed has been prepared.[a] Another MAR is scheduled for 1991. In addition, a study has recently been conducted to evaluate program objectives and compliance with

---

[a] Information on 1988 MAR provided by R. N. Wilhelmsen and K. C. Wright, EG&G Idaho, Inc., Idaho Falls, Idaho, November 1990.

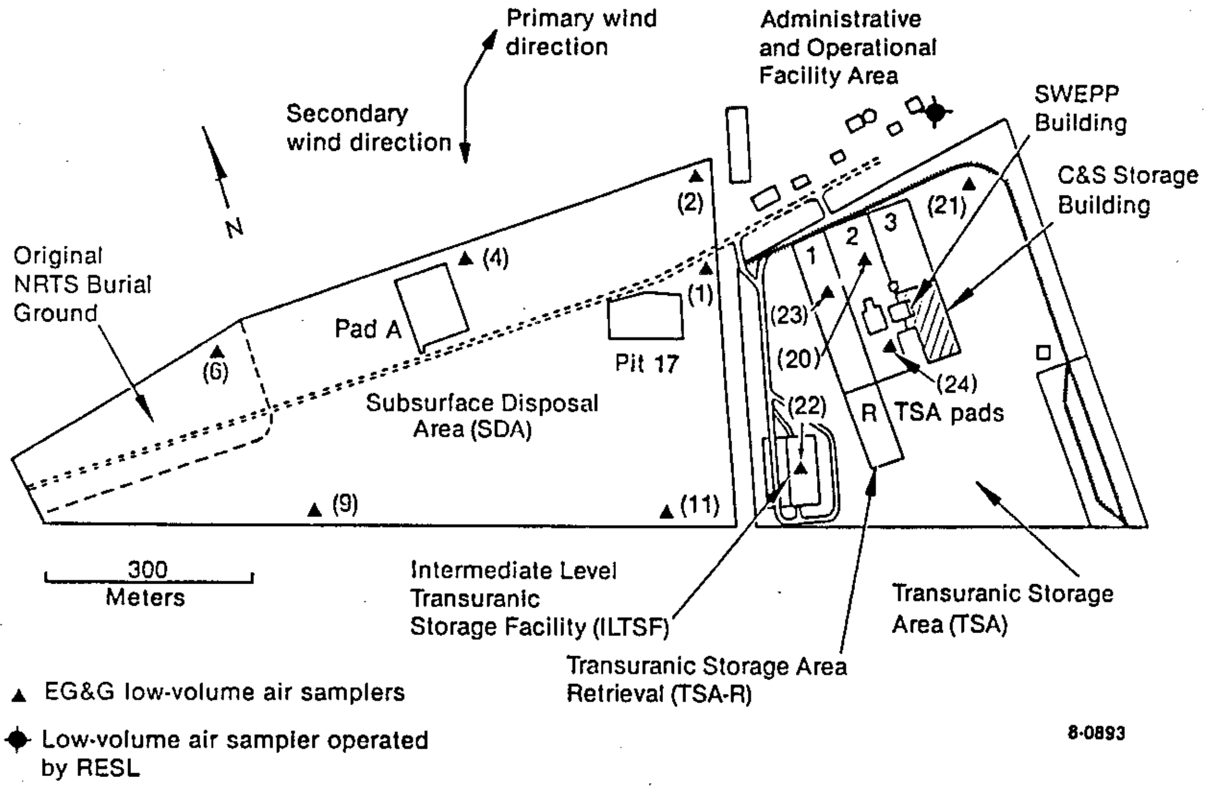


Figure 16-3. RWMC air monitoring locations, 1987 to 1989 (modified from Tkachyk et al., 1989).

DOE Orders and EPA regulations. The results are currently under review and a report is to be published soon.[a] The Environmental Monitoring Unit Quality Program Plan has been recently revised to establish the quality program requirements (EG&G, 1990c).

In addition to routine air monitoring by EG&G Idaho, RESL operates one HV sampler and one LV air sampler near WMF-613 (Figure 16-3). The LV air sampler has a prefilter and a back-up charcoal filter. The prefilter is analyzed weekly by RESL for gross alpha and gross beta activity. The back-up filter is analyzed for gross beta activity and for I-131 by gamma spectroscopy if the beta activity exceeds 7×10^{-14} µCi/mL. The LV filters are composited quarterly, weighed, and analyzed by gamma spectroscopy for gamma-emitting radionuclides; they are also analyzed by radiochemistry for Pu-238, Pu-239, and Am-241. The HV filters are collected monthly and analyzed for gamma-emitting radionuclides by gamma spectroscopy.

16.3 Investigation Procedure

This section provides a description of the investigation procedures used in the RWMC air monitoring program. Section 16.3.1 discusses aspects of the field sampling procedures, Section 16.3.2 provides an overview of the analytical methods, and programmatic quality assurance plans are discussed in Section 16.3.3. Field and laboratory quality assurance activities are discussed throughout these sections.

16.3.1 Field Sampling Procedures

As discussed previously, the current sampling program, shown in Figure 16-3, consists of LV samplers placed at six locations within the fence on the perimeter of the SDA and five samplers within the TSA. Two samplers are placed at location 4, which operate simultaneously to collect replicate samples. RESL operates a LV sampler near WMF-613. A control sampler is

---

[a] Communication between J. W. Tkachyk, EG&G Idaho, Inc., Idaho Falls, Idaho, and P. B. Swain, SAIC, McLean, Virginia, November 26, 1990.

located outside EBR-I. RESL also operates a LV air sampler at EBR-I, near the EG&G Idaho sampler. The prime factors influencing the selection of sampler locations were wind patterns, accessibility, and availability of electrical power (Tkachyk et al., 1989).

Standard Operating Procedure SOP-EM-EN-1.1, "Air Monitoring," delineates the field operating procedures and quality control checks associated with the air monitoring program (EG&G, 1989h). Filter handling procedures include the requirement to equilibrate unused filters and plastic bags (used to transport filters) for at least 24 hours before placement on the LV air samplers. Plastic bags are labelled for each LV sampler with location numbers and collection period dates. A clean filter is inserted into each bag and weighed on an analytical balance. Balances are checked for the presence of a current calibration sticker and zeroed before obtaining each weight. All data are entered in a sample log sheet. The filters are changed as near to the 1st and 15th day of each month as possible during nonhigh wind periods (i.e., less than 15 mph). Each used filter is replaced in its plastic bag, the total sample flow is read from the flow rate meter and recorded, and the air sampler flow rate is checked according to procedures and adjusted as necessary. If the sampler flow cannot be adjusted to the 5 ft^3/min calibration, instrument repair is initiated. Once the filters are collected, they are stored for 1 week to allow for moisture equilibration and the decay of natural radioisotopes. Samples are then weighed and net particulate values recorded. Samples are transported according to procedures to the RML for analysis. A blank filter is prepared for the first period of each month and submitted to the laboratory with field samples.

The samplers, manufactured by Hi-Q Environmental Products, Inc., have an oilless, carbon vane pump that maintains a maximum flow of 6.5 ft^3/min. Filter efficiency is 99.99% for 0.30-micron size particles. Filters are obtained from Gelman Sciences, Inc. Per manufacturer recommendations, the air flow of each sampler is to be calibrated annually to a flow rate of 5 ft^3/min. Electricians are responsible for maintenance and the Health Physics Instruments Laboratory is responsible for calibration.

The Environmental Monitoring Unit is responsible for collecting the air filter samples; filling out and providing the samples with an RML/Radiochemistry Analysis Request/Custody Form with all information necessary to properly analyze samples; and for preparing, identifying, and sending samples in appropriate clean containers. Environmental samples are always transported with an original custody form. Upon receipt of environmental air monitor samples in the laboratory, the custody form is signed. The samples are checked for proper identification and to ensure that all of the required information is on the analysis request form. If there is a problem with the information provided, the person requesting the analysis is immediately contacted for resolution.

16.3.2 Analytical Methods

Samples are collected and analyzed biweekly for gross alpha and gross beta activity. The biweekly samples are composited and counted/analyzed monthly for 25 gamma-emitting radionuclides as listed in Table 16-5. In addition, samples are composited and analyzed radiochemically for specific alpha and beta emitters on a quarterly basis. A summary of laboratory procedures and analysis methods is provided below.

The RML Procedures delineate the procedures inplace for the receipt of air filter samples, counting/analyzing the air filter samples, quality review, and reporting of radionuclide monitoring data results. Chain-of-custody is followed as described above. Techniques used to analyze the gross alpha- and beta-emitting radionuclides are used for biweekly samples. The RML operations personnel prepare, set up, and count each filter and blank. A 47-mm (~2-in.) sample is punched from the larger filter 24-mm (~4-in.) and counted directly (without radiochemistry) on a Tennelec LB 5100 Series II Model low background alpha-beta counting system. The system is used to measure alpha and beta levels in a sample with minimal background interference. Each filter and blank (background) is normally counted for 10 minutes. The source samples are generally loaded with additional blank samples (before and after the samples are counted), which are used to determine present background levels. To

Table 16-5. Radionuclides analyzed monthly by gamma spectrometry of RWMC air filter samplers and their absolute detection limits[a]

Radionuclide	Air Filters	
	10^{-9} pCi/mL	Total pCi
Sc-46	0.5	3.0
Cr-51	10.0	60.0
Mn-54	0.5	3.0
Co-58	0.5	3.0
Fe-59	0.8	5.0
Co-60	1.0	6.0
Zn-65	2.0	12.0
Nb-95	0.5	3.0
Zr-95	1.0	7.0
Ru-103	0.6	4.0
Ru-106	10.0	60.0
Ag-110m	0.5	3.0
Sb-124	1.0	7.0
Sb-125	1.0	6.0
Cs-134	0.5	3.0
Cs-137	0.8	5.0
Ce-141	0.6	4.0
Ce-144	3.0	20.0
Eu-152	1.5	8.0
Eu-154	0.6	4.0
Eu-155	3.0	15.0
Hf-181	0.5	3.0
Ta-182	1.6	10.0
Hg-203	0.5	3.0
Am-241	3.0	20.0

---

a. Source: Tkachyk et al. (1989); RML Procedures.

calibrate the Tennelec counting system, three radioactive sources are used: Cs-137, Sr-90, and Am-241. Calibration and background checks are made at the beginning of each day the Tennelec is to be used to ensure no contamination has occurred and to verify the calibration standard's activity.

All counting data from alpha/beta counting results are sent to the RML Data Management Section for final review and formal reporting of results. Reporting of gross alpha and beta analyses is described in RML Procedures. Once the gross activity concentration (pCi/cc) is determined, alpha activity is reported in the equivalent of Pu-239 and the beta activity in the equivalent of Cs-137 - Ba-137m. Collection dates, collection duration, sample flow rates, net particulate weight, and sample location numbers are input to a raw data file. All individual background counts and check source counts are entered in a personal computer. As part of the data reporting quality assurance/quality control, the average alpha and beta backgrounds and the standard deviations are determined and automatically compared with a running average background. If the current average deviates more than two standard deviations from the running average, the personal computer will flag it for further evaluation. The source check counts are also compared to the running average. A report is generated on the RML VAX computer and includes all pertinent sample information and the pCi/cc concentration for the gross alpha and gross beta for each filter sample.

Monthly analyses for gamma-emitting radionuclides are conducted as follows. The air filters are counted on germanium detectors, which are designated for only low-activity-level samples. Before the count, RML personnel are responsible for ensuring that the daily energy and efficiency calibration measurements have been made and are properly entered in the analysis routines. The preparation of standard source and calibration of the full energy peak efficiency follows that described in American National Standard Institute 42.14. Samples are mounted according to procedures and normally counted for 16 hours. Gamma-ray analysis of the spectra from the measurements of environmental samples is accomplished on the RML VAX-11/750 computer using the GNUL program, which has a feature that directs photopeak fitting to specific gamma-ray energies of interest. The program includes an environmental radionuclide library for radionuclide identification and an interference library to specify photopeak interferences that may need to be corrected in the gamma-ray spectrum analysis. Each sample spectrum has the ability to use the weighted average of up to 22 background spectra in the analysis. The natural radon/thoron parent and daughter activities are determined in the analysis but are not included in the final report. The analysis routine creates a disk file of the results.

Results of the gamma spectrometry analyses are provided to the RML Data Management Section for formal data quality checks. A monthly report is then generated. All radionuclides requested are included in the report with concentration values shown as true positive, false positive, negative, or zero. All positive results from the spectral analyses are examined, evaluated, and verified by technically trained and experienced RML personnel. The true positive results that satisfy the criteria in RML Procedures are considered to be real and are listed as such in an accompanying cover letter. This procedure verifies the (a) presence of valid photopeaks in the gamma-ray spectrum for a given computer spectral analysis, (b) that the correct radionuclides associated with the photopeaks have been selected, and (c) that the radioactivity reported for a selected radionuclide is correct. Criteria and methods for uncertainty (goodness-of-fit), area counts, photopeak intensity, energy calibration, flagging, reduced chi square, peak width, activity, half-life, entry-error check, and graphical displays are given in the procedure. Final approval requirements are also listed in RML Procedures.

Quarterly radiochemical analyses include determination of americium and plutonium concentrations via methodologies outlined in SP-FS, "Preparation of Filter Samples for the Determination of Radioactive Strontium and Actinides," as included in procedures SP-FS, RC-Sr-1, and RC-ACT-1, "Determination of Americium, Plutonium and Uranium in Environmental Samples" all of which are compiled in WINCO-186, (WINCO, 1987). According to the procedures, the appropriate tracers are added to the sample before the dissolution of the sample. Samples are then dissolved and chemically separated according to sample preparation procedures given in SP-FS. The actinides are gathered on a cerium/iron hydroxide precipitate and dissolved in concentrated nitric acid.

The isotopes of the actinides are separated from each other using an ion exchange resin. Americium is further purified from thorium by another ion exchange resin and from the rare earth metals by a Di(2-ethylhexyl)-phosphoric acid extraction. The purified radionuclides are gathered on a cerium fluoride precipitate, filtered, and counted for 1000 minutes in an alpha spectrometer with a surface barrier detector. A computer program is used to identify the alpha peaks in the spectrum and to calculate the quantity of activity in the total sample and the yield of the tracer added to the sample. A control and a blank prepared as described in the sample preparation procedures is analyzed with each set of samples in the exact same manner that the samples are analyzed. The minimum activity measured for all isotopes is 1.4×10^{-3} d/s/sample (disintegrations/second/sample), assuming a 70% chemical yield and using a low background (25 counts in 60,000 seconds) alpha spectrometer. Criteria for acceptability of samples with reference to the control and blank are given in RC-ACT-1 (WINCO, 1987).

Screening of laboratory results is performed as soon as the results are reported to the Environmental Monitoring Unit. If an analytical result is less than or equal to twice the analytical uncertainty (e.g., 6.0 ± 4.0 where 4.0 is one standard deviation), then the result is not considered detected by the analysis. If the analytical result is between two and three times the analytical uncertainty (e.g., 10.0 ± 4.0), detection is considered questionable. If the analytical result is greater than three times the analytical uncertainty (e.g., 14.0 ± 4.0), then the result is considered positive. If questionable results are obtained, checks are made. If the positive value cannot be explained by these checks and the value exceeds the established alert level after background, measured by the control sample has been subtracted, the Environmental Monitoring Technical Leader is notified. Nine suggested follow-up actions are proposed although a specific order cannot be defined for these actions because of the varied causes (EG&G, 1989h). Tables 16-3 and 16-4 list specific gamma-emitting and alpha- and beta-emitting radionuclides that are most likely to be found in environmental samples collected at the RWMC and their established alert levels. For positive gamma results for radionuclides not listed on Table 16-3, further screening is needed. Additional result reporting requirements are given in SOP-EM-EN-1.1 (EG&G, 1989h).

Gross alpha and gross beta results are reported within 1 week of sample delivery; gamma spectroscopy results are reported within 4 weeks; and radiochemistry results are reported within 8 weeks of delivery. Informal monthly reports are made to EG&G Idaho and DOE-ID personnel that include all air monitoring data received and any unusual results or occurrences.

Approximate detection limits of present methods used to analyze samples are presented in Tables 16-5 and 16-6. The detection limits given in Table 16-6 for radiochemical analyses are in terms of activity per unit weight or volume derived from the total activities in microcuries that must be present in the sample aliquot. The detection limits are calculated under the following conditions: a counting time of 1000 minutes, a counting efficiency of about 25%, a chemical yield of about 80%, a clean detector, and reagent blanks giving not more than about 5 counts in 1000 minutes in any given energy interval.

The absolute detection limits for gamma spectrometry analyses, provided in Table 16-5, are the total activities that must be present in the sample aliquot taken for analysis to be detected under the counting conditions described. Because the absolute detection limits must remain constant for a given counting time and efficiency, the detection limits in terms of concentration will become higher or lower as the sample size actually used in the analysis becomes smaller or larger. Description samples for gamma analysis and counting conditions for stated detection limits are provided in Table 16-7.

The quality assurance samples are prepared as nearly identically to the real samples as possible. Air samples are simulated by spotting known quantities of activity as uniformly as possible over the filters and drying.

Two levels of activity are checked to evaluate both the stated detection limits and to determine the accuracy and precision with which larger

Table 16-6. Sample description and detection limits for radiochemical analysis of air samples[a]

Media	Sample Description	Method of Treatment	Detection Limits (μCi/g or mL)	
Air	Sampled at 5 ft^3/min for 2 weeks on Versapor 1200 filters, 6 filters per quarter for a total of 1.7×10^{10} cc of air	Dry ash, dissolve and analyze the total sample of 6 filters	Sr-90 Pu-238 Pu-239 Am-241	2×10^{-16} 2×10^{-18} 2×10^{-18} 2×10^{-18}

---

a. Source: Tkachyk et al. (1989).

Table 16-7. Sample description and counting conditions for gamma spectrometry of air filter samples[a]

Media	Sample Description	Conditions of Counting
Air	Sampled at 5 ft^3/min for 2 weeks on 4-in. Versapor 1200 membrane filters for a total of 3×10^9 cc per filter.	Monthly composite sample of two 4-in. filters containing a total of about 6×10^9 cc of air are held flat over the detector and counted for 16 hours while being rotated.

---

a. Source: Tkachyk et al. (1989).

activities can be measured. The lower level consists of activities from about 1.5 to 3 times the stated absolute detection limit to maximize the influence of backgrounds, blanks, and incomplete separation of interferences from the sample on the net activity being measured. The higher level consists of activities sufficiently high to distinguish true result from results vastly different because of poor statistics. This precision requires from 500 to 2500 counts under the conditions described above, or about 1 to 6 x 10^{-6} μCi per sample.

16.3.3 Programmatic Quality Assurance Programs

In addition to the specific quality assurance/quality control measures discussed above with respect to sample collection and laboratory analysis, programmatic quality assurance programs are discussed in detail in the following references:

- Westinghouse Idaho Nuclear Company Environmental Sample Analysis Quality Assurance Program for the Nuclear and Environmental Measurements Section (Filby, et al., 1989).

- Analytical Chemistry Branch Procedures Manual, Radiological and Environmental Sciences Laboratory, U.S. Department of Energy (Bodnar and Percival, 1982).

16.4 Results

Annual summaries of the environmental surveillance program monitoring methods and results for all EG&G Idaho facilities are provided in annual reports. The reports provide both the results of the analyses, trends in radionuclide concentrations, and a discussion/evaluation of the data and trends. Because gross alpha detections are used only as an indicator to analyze for specific alpha emitters, they are not reported. Raw data, including data not contained in the annual reports, (e.g., total particulate levels) are available in the program database. Air monitoring program results for monitoring activities at the RWMC for several years are provided below.

A plot of quarterly averages of RWMC gross beta air concentrations (Cs-137 equivalent) since 1979 are shown in Figure 16-4. Monthly average gross beta concentrations for RESL LV samplers for the years 1979 to 1989 are plotted on Figure 16-5. Weekly averages (maximums, geometric means and control concentrations) at the SDA for each semimonthly sample period for 1987 and 1988 are shown in Figures 16-6 and 16-7.

Gamma-emitting radionuclides that could be present because of RWMC operations were not detected in RWMC samples in 1988 (Tkachyk et al., 1989). During 1988, monthly composites for gamma-emitting radionuclides for EBR-I control locations and RESL samples at the RWMC resulted in the detection of only Sb-125. These data are provided in Table 16-8. Gamma spectroscopy results for filter composites at the RWMC from 1983 through 1987 are provided in Table 16-9. In 1987, Cs-137 was the only gamma-emitting radionuclide detected that could be due to waste management operations. Concentrations of SB-125 detected in 1987 monthly composites at RWMC sample locations are shown in Table 16-10. The results of RESL analyses for gamma-emitting radionuclides on RWMC filters showed that the only radionuclide detected during 1987 was SB-125. Tables 16-9 and 16-11 provide the results of gamma spectrometry analysis of 1986 RWMC air filters collected by EG&G Idaho. Co-60 (see Table 16-9) was the only radionuclide detected during 1986 that could be attributed to waste management operations.

Figure 16-8 provides a plot of Pu-239,-240, and Am-241 quarterly filter composite concentrations measured at all RWMC locations since the first quarter of 1986. Figure 16-9 provides a plot for the years 1984 to 1986. Results of RESL analyses for specific alpha- and beta-emitting radionuclides during 1983, 1984, and 1985 are given in Table 16-12. Results of quarterly radiochemical analyses for specific alpha- and beta-emitting radionuclides for the years 1986, 1987, and 1988 are presented in Tables 16-13, 16-14, and 16-15. (The use of radiochemical analyses for the detection of specific alpha- and beta-emitting radionuclides for EG&G Idaho samples was initiated in 1986; data are provided from EG&G Idaho locations for the third and fourth quarter of the year).

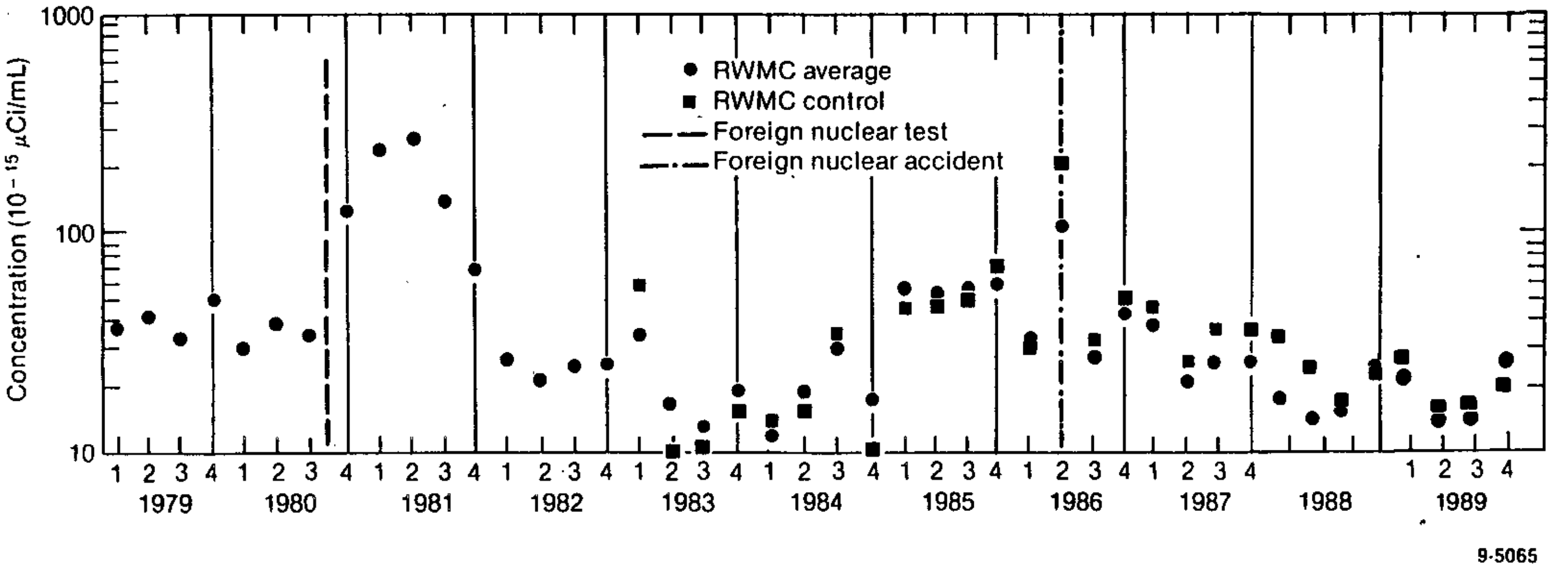


Figure 16-4. Quarterly averages of RWMC gross beta concentrations, 1979 to 1989 (Tkachyk et al., 1990).

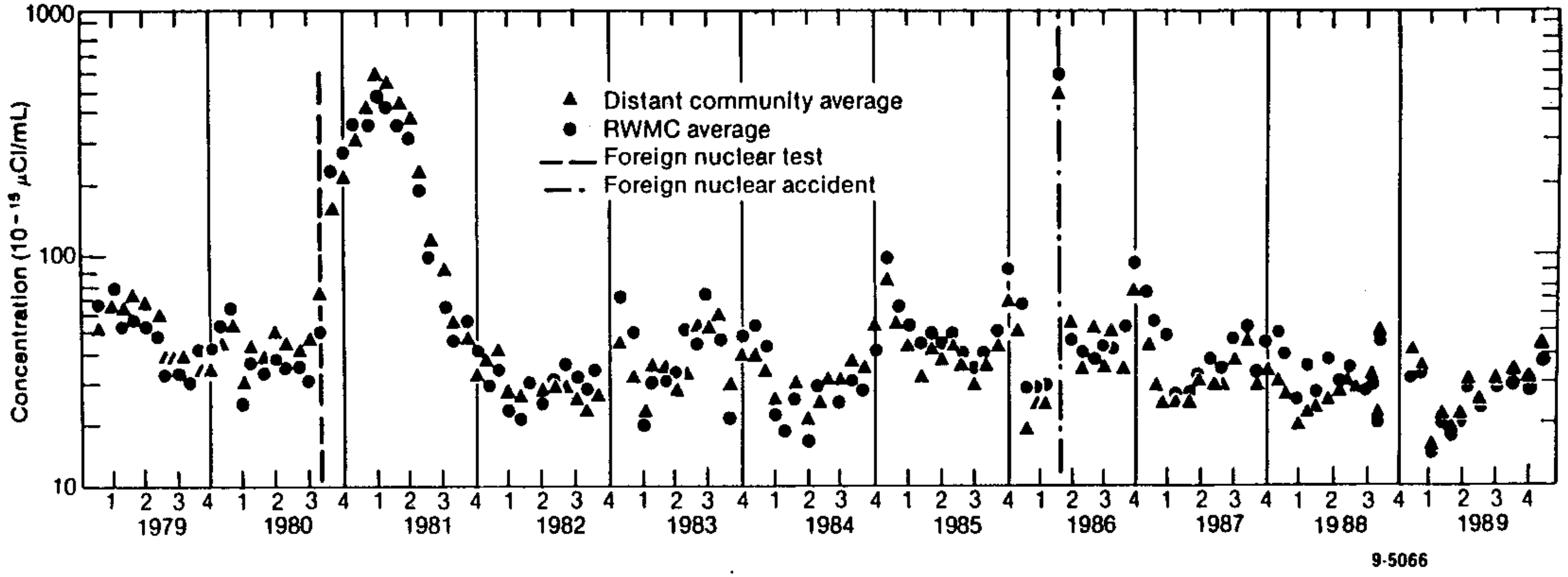


Figure 16-5. RESL monthly average gross beta concentrations from low-volume samplers, 1979 to 1989 (Tkachyk et al., 1990).

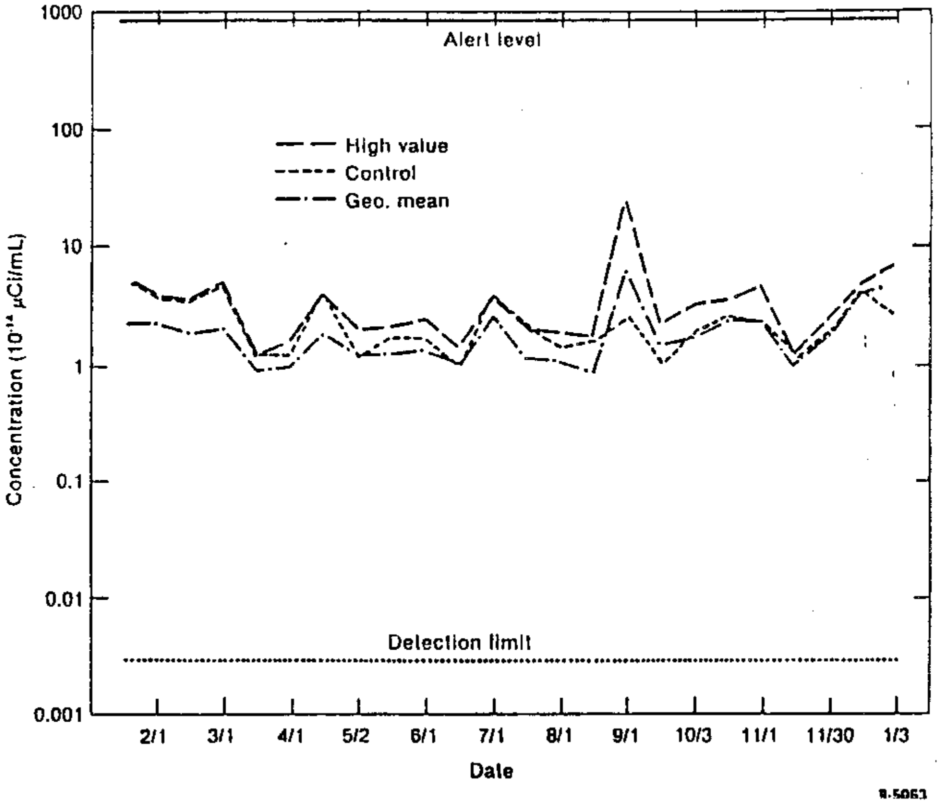


Figure 16-6. Gross beta concentrations measured at the SDA from low volume samplers in 1988 (Tkachyk et al., 1989).

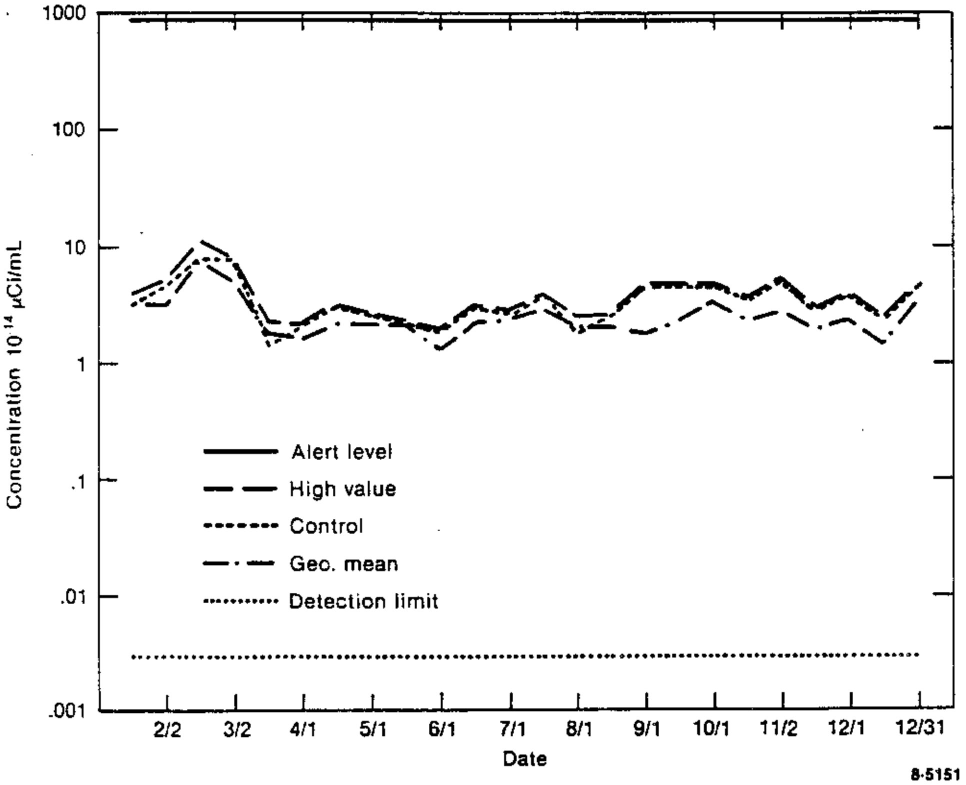


Figure 16-7. Gross beta concentrations measured at the SDA from low volume samplers, 1987 (Tkachyk et al., 1988).

Table 16-8. Antimony-125 detected at RWMC sample locations, 1988 (1×10^{-15} µCi/mL)[a]

Location	January	February	March	April	May	June	July	August-December
1	7.1 ± [b]0.6	6.7 ± 0.4	--[c]	9.48 ± 0.89	1.72 ± 0.46	10.80 ± 0.007		--
2	7.2 ± 0.3	8.2 ± 0.5	--	9.43 ± 0.66	3.02 ± 0.51	15.90 ± 0.007	1.08 ± 0.22	--
4	7.2 ± 0.5	7.7 ± 0.6	--	6.44 ± 0.6	4.37 ± 0.78	17.90 ± 0.007	--	--
4.2[d]	5.0 ± 0.5	6.8 ± 0.6	--	7.46 ± 0.73	2.20 ± 0.7	17.50 ± 0.008	--	--
6	4.2 ± 0.3	5.9 ± 0.4	--	2.46 ± 0.67	5.16 ± 1.5	15.10 ± 0.008	--	--
9	6.5 ± 0.3	6.0 ± 0.6	--	6.95 ± 0.6	3.30 ± 0.63	13.50 ± 0.008	1.06 ± 0.25	--
11	4.5 ± 0.6	7.3 ± 0.7	--	4.87 ± 0.37	--	9.45 ± 0.74	--	--
15	29.3 ± 0.1	25.7 ± 0.008	--	17.70 ± 0.009	6.97 ± 0.68	14.20 ± 0.007	4.88 ± 0.38	--
20	9.3 ± 0.4	14.9 ± 0.005	--	21.70 ± 0.018	3.04 ± 0.73	1.30 ± 0.24	1.39 ± 0.39	--
22	8.1 ± 0.6	10.6 ± 0.006	--	24.10 ± 0.018	3.77 ± 0.3	10.40 ± 0.004	--	--
23	3.1 ± 0.5	8.5 ± 0.6	--	22.60 ± 0.018	2.77 ± 0.58	16.90 ± 0.005	--	--
24	10.0 ± 0.006	12.8 ± 0.007	--	24.50 ± 0.009	--	12.40 ± 0.005	--	--

---

a. Source: Tkachyk et al. (1989). Tkachyk et al. (1989) provides a discussion regarding the use of a new fuel dissolution process at an INEL facility and its expected impact on Sb-125 levels during the first half of 1988.

b. The ± values are experimental random uncertainties in the counting measurement process and represent one standard deviation.

c. The "--" symbol indicates that the concentration was below the limit of detection (1×10^{-15} µCi/mL).

d. Indicates replicate sampler location.

Table 16-9. Results of gamma spectrometry analysis of RWMC air filters, 1983-1987[a]

Month(s)/Year Sampled	Sampler Location	Radionuclide	Concentration[b] (10^{-15} μCi/mL)	Percent of CG[c]	Percent of DCG[d]
1/83	2	Co-58	6.8 ± 2.3	0.00002	NA
	4	Co-58	6.5 ± 2.1	0.00002	NA
	10	Co-58	6.4 ± 2.0	0.00002	NA
	10	Ce-141	9.7 ± 3.0	0.00005	NA
2/83	10	Co-58	6.4 ± 2.3	0.00002	NA
3/83	--[e]	--	--	--	NA
4/83	6	Mn-54	6.7 ± 2.3	0.00007	NA
5/83	5	Ce-141	10.0 ± 3.0	0.00005	NA
	9	Mn-54	7.2 ± 2.0	0.00007	NA
	14	Co-58	6.8 ± 2.2	0.00002	NA
6/83	14	Mn-54	7.4 ± 2.1	0.00007	NA
7/83	1	Cs-137	14.0 ± 4.4	0.0007	NA
	3	Cs-137	13.5 ± 4.1	0.0007	NA
	4	Cs-137	11.1 ± 3.7	0.0006	NA
	4	Ce-144	410.0 ± 150	0.1	NA
	11	Co-60	14.8 ± 6.9	0.0002	NA
	15	Co-60	11.5 ± 5.4	0.0001	NA
8/83	5	Ru-103	8.3 ± 3.0	0.00004	NA
	5	Cr-51	78.0 ± 20.0	0.00002	NA
9/83	--	--	--	--	--
10/83	--	--	--	--	--
11/83	--	--	--	--	--
12/83	--	--	--	--	--
1/84	15	Ce-141	0.49 ± 0.2	0.00001	NA
2/84	--	--	--	--	--
3/84	--	--	--	--	--
4/84	4	Ce-144	2.9 ± 0.9	0.0015	NA
	11	Cs-137	0.78 ± 0.17	0.0002	NA

Table 16-9. (continued)

Month(s)/Year Sampled	Sampler Location	Radionuclide	Concentration[b] (10^{-15} µCi/mL)	Percent of CG[c]	Percent of DCG[d]
5/84	12 (Blank)	Ce-144	1.1 ± 0.4	0.0006	--
6/84	--	--	--	--	--
7/84	--	--	--	--	--
8/84	--	--	--	--	--
9/84	--	--	--	--	--
10/84	--	--	--	--	--
11/84	4	Cs-137	1.2 ± 0.2	0.0002	NA
	6	Cs-137	1.0 ± 0.2	0.0002	NA
12/84	--	--	--	--	--
1/85	6	Co-58	0.67 ± 0.15	NA	0.00003
	11	Cs-137	1.4 ± 0.3	NA	0.0004
	12(Blank)	Co-58	0.79 ± 0.2	NA	0.00004
	22(SWEPP)	Cs-137	1.3 ± 0.4	NA	0.0003
2/85	4	Cs-134	0.27 ± 0.09	NA	0.0001
		Cs-137	1.3 ± 0.19	NA	0.0003
	9	Cs-134	0.83 ± 0.13	NA	0.0004
		Cs-137	3.7 ± 0.3	NA	0.0009
3/85	1	Cs-137	3.1 ± 0.3	NA	0.0008
4/85	6	Cs-137	1.5 ± 0.2	NA	0.0004
	15[f]	Cs-137	1.0 ± 0.18	NA	0.0003
	22(SWEPP)	Cs-137	1.13 ± 0.19	NA	0.0003
5-12/85	--	--	--	--	--
1-3/86	--	--	--	--	--
4/86	2	Co-60	1.1 ± 0.3	NA	0.001
	4	Co-60	0.89 ± 0.32	NA	0.001
5-6/86	--[g]	--	--	--	--
7-10/86	--	--	--	--	--

Table 16-9. (continued)

Month(s)/Year Sampled	Sampler Location	Radionuclide	Concentration[b] (10^{-15} μCi/mL)	Percent of CG[c]	Percent of DCG[d]
11-12/86	--[h]	--	--	--	--
1-2/87	--	--	--	--	--
3/87	--	Cs-137	0.7 ± 0.2	NA	0.0002
4-8/87	--	--	--	--	--
9/87	15[f]	Cs-137	1.3 ± 0.3	NA	0.0003
10-12/87	--	--	--	--	--

---

a. Source: Blanchfield and Hoffman (1984); Reyes et al. (1985); Reyes et al. (1986); Reyes et al. (1987); Tkachyk et al. (1988).

b. Results from 1983 and 1984 are considered statistically positive ($\leq 2\ \sigma$). From 1985 through 1987, results presented are considered detections by the gamma spectroscopist. Analytical uncertainties presented are $\pm 1\ \sigma$.

c. Detected concentration in 1983 are a percent of concentration guide (CG) values for uncontrolled areas from DOE Order 5480.1, Chapter XI, Table II, Column 2. Detected concentrations in 1984 are a percent of CG values for uncontrolled areas from DOE Order 5480.1A, Chapter XI, Table II, Column 1.

d. Detected concentrations in 1985 and 1986 are a percent of DCG values for the public, based on the dose conversion factors provided by the draft *Committed Dose Equivalent Tables for the U.S. Department of Energy Population Dose Calculations*. Detected concentrations in 1987 are a percentage of DCG values for the public based on the dose conversion factors provided in DOE Order 5400.5 dated February 8, 1990.

e. No detections.

f. RWMC control location.

g. See Table 16-11 for results because of the Chernobyl Accident in the USSR. RESL also detected similar nuclides including Cs-134, Cs-137, Ru-103, and Ru-106d at onsite and offsite locations.

h. See Table 16-11 for those concentrations that are probably the result of releases from ICPP. RESL results are similar.

Table 16-10. Antimony-125 detected at RWMC sample locations, 1987 (10^{-14} μCi/mL)[a]

Location	January	February	March	April	May	June	July	August	September	October	November	December
1	1.85 ± 0.06	6.16 ± 0.14	0.34 ± 0.04	0.46 ± 0.05	--	0.60 ± 0.04	0.97 ± 0.05	1.07 ± 0.08	0.38 ± 0.05	--	--	0.64 ± 0.07
2	3.02 ± 0.06	6.20 ± 0.10	0.43 ± 0.04	0.61 ± 0.04	0.15 ± 0.03	0.90 ± 0.06	1.42 ± 0.06	1.21 ± 0.05	1.38 ± 0.05	--	--	0.74 ± 0.04
4	2.18 ± 0.06	5.91 ± 0.09	0.36 ± 0.04	0.47 ± 0.04	0.15 ± 0.03	0.62 ± 0.06	1.02 ± 0.05	1.29 ± 0.06	1.68 ± 0.09	--	--	0.54 ± 0.06
4.2	--[b]	--	0.45 ± 0.04	0.47 ± 0.04	0.13 ± 0.03	0.66 ± 0.08	1.19 ± 0.05	1.45 ± 0.09	2.54 ± 0.07	--	--	0.59 ± 0.05
6	1.96 ± 0.08	5.97 ± 0.09	0.51 ± 0.05	0.38 ± 0.06	--	0.65 ± 0.05	1.09 ± 0.06	1.33 ± 0.06	2.89 ± 0.07	--	--	0.49 ± 0.05
9	2.35 ± 0.10	6.10 ± 0.10	0.44 ± 0.04	0.56 ± 0.05	--	0.74 ± 0.08	1.40 ± 0.06	1.20 ± 0.05	2.80 ± 0.12	--	--	0.53 ± 0.05
11	2.67 ± 0.09	7.27 ± 0.15	0.52 ± 0.06	0.47 ± 0.07	0.20 ± 0.05	0.95 ± 0.12	1.52 ± 0.08	1.27 ± 0.08	1.52 ± 0.08	--	--	0.53 ± 0.07
15[c]	7.3 ± 0.1	10.09 ± 0.14	0.73 ± 0.06	2.55 ± 0.11	0.57 ± 0.05	1.55 ± 0.07	2.25 ± 0.07	2.78 ± 0.09	3.58 ± 0.16	--	--	0.78 ± 0.04
20	3.30 ± 0.07	7.03 ± 0.16	0.57 ± 0.10	0.78 ± 0.05	0.18 ± 0.06	0.85 ± 0.06	1.72 ± 0.07	1.70 ± 0.08	1.25 ± 0.04	--	--	0.75 ± 0.05
21	3.40 ± 0.08	6.75 ± 0.11	0.47 ± 0.06	1.13 ± 0.07	--	0.86 ± 0.08	1.82 ± 0.09	1.89 ± 0.10	1.34 ± 0.07	--	--	1.83 ± 0.14
22	3.79 ± 0.11	6.55 ± 0.10	0.38 ± 0.05	0.77 ± 0.15	--	1.06 ± 0.07	2.08 ± 0.10	1.68 ± 0.08	1.33 ± 0.06	--	--	0.72 ± 0.04
23	3.87 ± 0.11	6.88 ± 0.15	0.56 ± 0.05	0.87 ± 0.08	0.29 ± 0.08	1.21 ± 0.07	1.71 ± 0.08	2.18 ± 0.13	1.50 ± 0.05	--	--	0.61 ± 0.05
24	5.51 ± 0.15	7.33 ± 0.18	0.67 ± 0.05	0.89 ± 0.06	--	0.19 ± 0.03	1.69 ± 0.08	1.11 ± 0.04	0.97 ± 0.04	--	--	1.76 ± 0.14

---

a. Source: Tkachyk et al. (1988). Tkachyk et al. (1988) provides a discussion related to Sb-125 concentrations at other INEL facilities.

b. "--" indicates below detection limit.

c. Control sample location at the RWMC.

Table 16-11. Results of gamma spectroscopy analysis of RWMC air filters for radionuclides not related to waste management activities, 1986[a,b]

Month Sampled	Location	Radionuclides (Concentrations 10^{-14} µCi/mL)								
		Nb-95	Ru-103	Ru-106d	Sb-125	Cs-134	Cs-137	Ce-141	Te-129m	Te-132
May 1986 (first two weeks only)	4	0.21 ± 0.03	9.3 ± 0.2	2.8 ± 0.3	0.38 ± 0.1	4.3 ± 1.0	8.7 ± 0.8	--	8.4 ± 2	1.3 ± 0.1
	6	--[c]	9.5 ± 0.3	3.5 ± 0.6	--	4.6 ± 0.1	8.6 ± 2	0.2 ± 0.04	9 ± 3	1.7 ± 0.2
	15(control)	--	11.2 ± 0.2	4.0 ± 0.4	--	4.4 ± 0.8	9.5 ± 0.5	0.3 ± 0.05	8.4 ± 2	2.0 ± 0.2
	21	0.25 ± 0.05	10.6 ± 0.2	3.3 ± 0.4	0.41 ± 0.1	4.4 ± 1.0	9.2 ± 0.8	--	12 ± 1	1.5 ± 0.1
May 1986	1	--	1.5 ± 0.14	--	--	0.47 ± 0.10	--	--	--	16 ± 5
	1.2	--	6.4 ± 0.09	2.5 ± 2.6	0.27 ± 0.07	3.4 ± 0.06	6.6 ± 0.27	0.17 ± 0.04	0.23 ± 0.10	--
	2	0.30 ± 0.04	7.7 ± 0.16	2.8 ± 2.2	0.38 ± 0.07	3.6 ± 0.68	7.5 ± 0.35	0.23 ± 0.03	--	5.3 ± 0.6
	4	0.21 ± 0.03	6.6 ± 0.16	2.5 ± 0.19	--	3.2 ± 0.05	6.4 ± 0.60	0.12 ± 0.02	--	4.4 ± 0.5
	6	0.13 ± 0.02	6.8 ± 0.07	2.5 ± 0.37	0.23 ± 0.05	3.2 ± 0.10	6.4 ± 0.59	0.18 ± 0.03	--	3.7 ± 0.6
	9	0.20 ± 0.03	6.6 ± 0.09	2.4 ± 0.23	0.26 ± 0.06	3.0 ± 0.11	6.2 ± 0.79	0.20 ± 0.02	--	5.8 ± 0.9
	11	--	6.4 ± 0.10	2.3 ± 0.22	0.40 ± 0.07	3.2 ± 0.05	6.2 ± 0.24	--	0.39 ± 0.09	5.6 ± 0.7
	15(control)	0.16 ± 0.04	6.5 ± 0.12	2.9 ± 0.40	0.31 ± 0.07	3.3 ± 0.07	6.5 ± 0.84	0.14 ± 0.03	0.33 ± 0.09	6.6 ± 1.1
	20	--	4.4 ± 0.11	1.3 ± 0.20	0.24 ± 0.05	1.9 ± 0.35	4.0 ± 0.19	0.24 ± 0.08	--	--
	21	0.22 ± 0.03	7.4 ± 0.08	3.0 ± 0.21	0.29 ± 0.05	3.3 ± 0.08	6.9 ± 0.63	0.21 ± 0.02	--	4.4 ± 0.6
	22	0.22 ± 0.03	7.1 ± 0.09	2.6 ± 0.19	0.34 ± 0.06	3.1 ± 0.59	7.1 ± 0.31	0.16 ± 0.02	--	3.9 ± 0.5
June 1986	1.2	--	0.28 ± 0.05	--	--	--	--	--	--	--
	2	--	0.13 ± 0.02	--	--	0.05 ± 0.02	0.09 ± 0.02	--	--	--
	4	--	0.16 ± 0.02	--	--	--	--	--	--	--
	6	--	0.14 ± 0.03	--	--	--	0.13 ± 0.04	--	--	--
	9	--	0.23 ± 0.02	--	--	--	--	--	--	--
	11	--	0.22 ± 0.04	--	--	--	--	--	--	--
	20	--	0.12 ± 0.03	--	--	--	--	--	--	--
	21	--	0.18 ± 0.02	--	--	--	--	--	--	--
November 1986	1	--	--	--	1.76 ± 0.06	--	0.11 ± 0.02	--	--	--
	2	--	--	--	1.86 ± 0.07	--	--	--	--	--
	4	--	--	--	1.39 ± 0.05	--	--	--	--	--
	4.2	--	--	--	1.63 ± 0.07	--	--	--	--	--
	6	--	--	--	1.11 ± 0.06	--	--	--	--	--
	9	--	--	--	1.15 ± 0.06	--	--	--	--	--
	11	--	--	--	1.94 ± 0.06	--	--	--	--	--
	20	--	--	--	1.70 ± 0.09	--	--	--	--	--
	21	--	--	--	2.72 ± 0.07	--	--	--	--	--
	22	--	--	--	2.55 ± 0.07	--	--	--	--	--

Table 16-11. (continued)

Month Sampled	Location	Radionuclides (Concentrations 10^{-14} µCi/mL) Nb-95	Ru-103	Ru-106d	Sb-125	Cs-134	Cs-137	Ce-141	Te-129m	Te-132
December 1986	1	--	--	--	1.21 ± 0.05	--	--	--	--	--
	2	--	--	--	1.77 ± 0.06	--	--	--	--	--
	4	--	--	--	1.36 ± 0.06	--	--	--	--	--
	4.2	--	--	--	0.89 ± 0.05	--	--	--	--	--
	6	--	--	--	1.31 ± 0.07	--	--	--	--	--
	9	--	--	--	1.18 ± 0.08	--	--	--	--	--
	11	--	--	--	1.54 ± 0.08	--	--	--	--	--
	15(control)	--	--	--	3.35 ± 0.10	--	--	--	--	--
	20	--	--	--	0.93 ± 0.07	--	--	--	--	--
	21	--	--	--	1.64 ± 0.08	--	--	--	--	--
	22	--	--	--	1.87 ± 0.06	--	--	--	--	--

---

a. Source: Reyes et al. (1987).

b. All measurements before June 1986 reflect the influence of the Chernobyl incident in the USSR. Antimony-125 measurements from November 1986 on are due to minor ICPP releases.

c. "--" indicates radionuclides not detected.

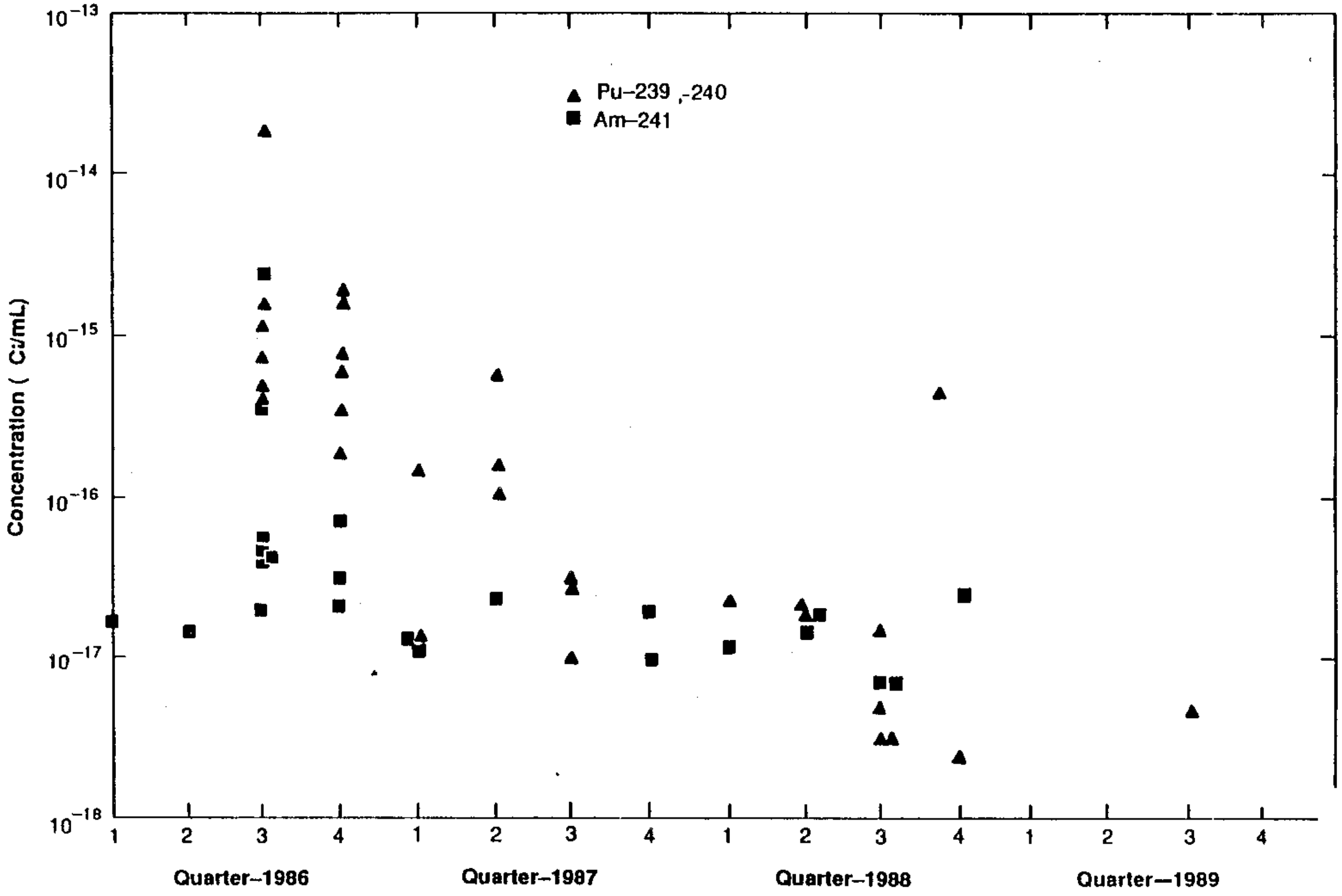


Figure 16-8. Am-241 and Pu-239,-240 concentrations from RWMC locations 1, 2, 4, 11, 20, 21, and 22, 1986 to 1989 (Tkachyk et al., 1990).

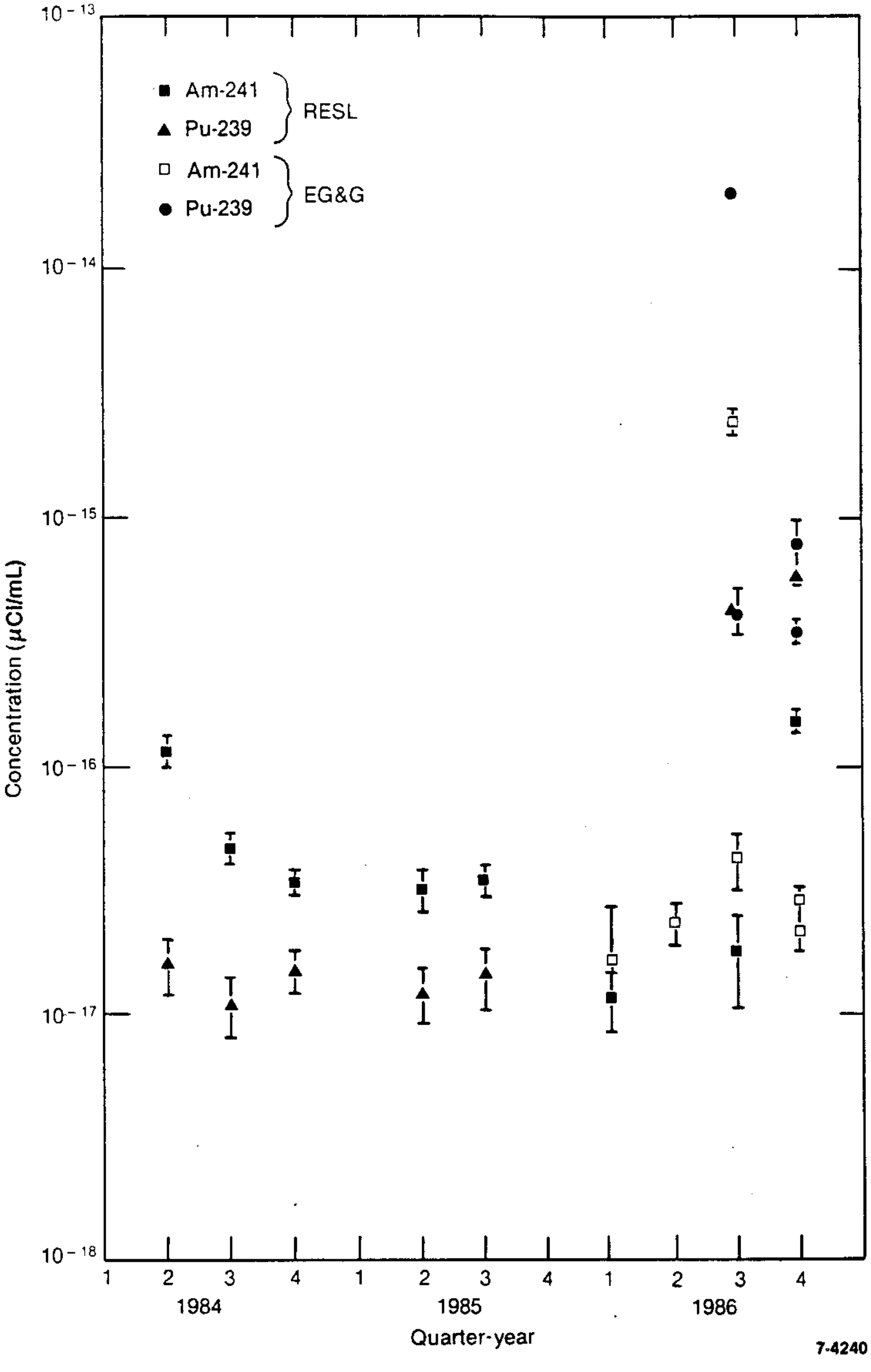


Figure 16-9. Am-241 and Pu-239,-240 concentrations from RWMC locations 1, 2 and RESL low-volume sampler, 1984 to 1986 (Reyes et al., 1987)

Table 16-12. Specific radionuclides detected by RESL in low-volume air sample filters, 1983-1985[a]

		Concentration (μCi/mL)[b]							
Sampler/ Location	Quarter/ Year	Pu-239,-240	Percent of CGs/DCGs	Am-241	Percent of CGs/DCGs	Sb-125	Percent of CGs/DCGs	Cs-137	Percent of CGs/DCGs
RWMC	1/83	--[c]	--	--	--	--	--	--	--
	2/83	$0.8 \pm 2.0 \times 10^{-17}$	0.01^{d}	$4.2 \pm 0.6 \times 10^{-17}$	0.02^{d}	--	--	--	--
	3/83	$2.2 \pm 0.4 \times 10^{-17}$	0.04^{d}	$8.8 \pm 0.9 \times 10^{-17}$	0.04^{d}	$2.7 \pm 1.3 \times 10^{-15}$	0.0003^{d}	--	--
	4/83	--	--	$1.2 \pm 0.3 \times 10^{-17}$	0.06^{d}	--	--	--	--
	1/84	--	--	--	--	--	--	--	--
	2/84	$1.6 \pm 0.4 \times 10^{-15}$	0.03^{d}	$11.7 \pm 1.2 \times 10^{-15}$	0.06^{d}	--	--	--	--
	3/84	$1.1 \pm 0.3 \times 10^{-15}$	0.02^{d}	$4.7 \pm 0.6 \times 10^{-15}$	0.02^{d}	$310.0 \pm 100.0 \times 10^{-15}$	0.0003^{d}	$130.0 \pm 40.0 \times 10^{-15}$	0.0003^{d}
	4/84	$1.5 \pm 0.3 \times 10^{-15}$	0.03^{d}	$3.4 \pm 0.4 \times 10^{-15}$	0.02^{d}	--	--	--	--
	1/85	--	--	--	--	--	--	--	--
	2/85	$1.2 \pm 0.3 \times 10^{-17}$	0.06^{e}	$3.2 \pm 0.6 \times 10^{-17}$	0.16^{e}	--	--	--	--
	3/85	$1.4 \pm 0.4 \times 10^{-17}$	0.07^{e}	$3.4 \pm 0.5 \times 10^{-17}$	0.17^{e}	--	--	--	--
	4/85	--	--	--	--	--	--	--	--
EBR-I	4/83	--	--	$0.36 \pm 1.5 \times 10^{-17}$	0.002^{d}	--	--	--	--
	3/84	--	--	$5.0 \pm 2.0 \times 10^{-15}$	0.03^{d}	--	--	--	--
	2/85	$1.0 \pm 0.3 \times 10^{-17}$	0.05^{e}	--	--	--	--	--	--

---

a. Source: Blanchfield and Hoffman (1984); Reyes et al. (1985); Reyes et al. (1986).

b. Results presented in 1984 are $\geq 2\ \sigma$; results presented for 1985 are $\geq 3\ \sigma$; analytical uncertainties presented for 1984 and 1985 are $\pm 1\ \sigma$.

c. No positive detections.

d. Detected concentrations as a percent of concentration guide values for uncontrolled areas from DOE Order 5480.1A, Chapter XI, Table II, Column 1.

e. Detected concentrations as a percent of DCG values for the public based on the dose conversion factors provided by the draft Committed Dose Equivalent Tables for the U.S. Department of Energy Population Dose Calculations.

Table 16-13. Specific alpha- and beta-emitting radionuclides detected at RWMC locations, 1986[a,b]

Sample Location	Quarter	Concentration (μCi/mL)			
		Sr-90	Pu-238	Pu-239,-240	Am-241
1	3	(5.0 ± 1.0) x 10^{-16}	(3.5 ± 0.4) x 10^{-16}	(1.9 ± 0.1) x 10^{-14}	(2.3 ± 0.2) x 10^{-15}
	4	--[c]	--	(3.3 ± 0.3) x 10^{-16}	(2.0 ± 0.3) x 10^{-17}
2	3	--	--	(4.0 ± 0.7) x 10^{-16}	(4.0 ± 1.0) x 10^{-17}
	4	--	--	(7.4 ± 1.7) x 10^{-16}	--
4	3	(2.9 ± 0.6) x 10^{-16}	--	--	(1.9 ± 0.5) x 10^{-17}
6	3	--	--	--	--
9	3	--	--	--	--
11	3	--	(1.3 ± 0.4) x 10^{-17}	(4.9 ± 0.5) x 10^{-16}	(3.5 ± 0.2) x 10^{-16}
15[d]	3	--	--	--	--
	4	--	--	--	--
20	4	--	--	(1.5 ± 3.0) x 10^{-15}	(6.8 ± 2.2) x 10^{-17}
21	4	--	--	(1.8 ± 0.6) x 10^{-15}	--
22	4	--	(2.5 ± 0.7) x 10^{-17}	(5.8 ± 0.6) x 10^{-16}	(3.0 ± 0.4) x 10^{-17}

---

a. Source: Reyes et al. (1987).

b. Uncertainties stated are one sigma.

c. Radionuclide not detected.

d. Location 15 is a control located at WMF-601.

Table 16-14. Specific alpha- and beta-emitting radionuclides detected at RWMC locations, 1987[a,b]

Sample Location	Calendar Quarter	Concentration (µCi/mL)[c] Sr-90	Pu-238	Pu-239, 240	Am-241
1	1	--[d]	--	--	$1.2 \pm 0.3 \times 10^{-17}$
	2	$3.2 \pm 0.6 \times 10^{-16}$	--	--	--
	3	--	--	--	--
	4	--	--	--	$2.2 \pm 0.6 \times 10^{-17}$
2	1	--	--	--	--
	2	--	$1.6 \pm 0.2 \times 10^{-17}$	$7.2 \pm 0.6 \times 10^{-16}$	$3.5 \pm 0.7 \times 10^{-17}$
	3	--	--	--	--
	4	--	--	--	$9 \pm 2 \times 10^{-18}$
11	1	$8 \pm 2 \times 10^{-17}$	--	--	--
	2	--	--	--	--
	3	--	--	--	--
	4	--	--	--	--
20	1	--	--	--	--
	2	--	--	--	--
	3	--	--	$1.0 \pm 0.2 \times 10^{-17}$	--
	4	--	--	--	--
22	1	--	--	$1.1 \pm 0.1 \times 10^{-16}$	--
	2	--	--	--	--
	3	--	--	--	--
	4	--	--	--	--
23	1	--	--	$1.2 \pm 0.2 \times 10^{-17}$	--
	2	--	--	$1.6 \pm 0.2 \times 10^{-16}$	--
	3	--	--	$3.7 \pm 0.6 \times 10^{-17}$	--
	4	--	--	--	--
24	1	--	$4 \pm 1 \times 10^{-18}$	$1.5 \pm 0.1 \times 10^{-16}$	--
	2	--	--	$1.0 \pm 0.1 \times 10^{-16}$	--
	3	--	--	$3.4 \pm 0.6 \times 10^{-17}$	--
	4	$4.2 \pm 0.08 \times 10^{-16}$[e]	$5.0 \pm 0.08 \times 10^{-15}$[e]	$1.8 \pm 0.1 \times 10^{-15}$[e]	$2.1 \pm 0.2 \times 10^{-16}$[e]

---

a. Source: Tkachyk et al. (1988).

b. Locations not included had no positive results.

c. Uncertainties stated are one sigma.

d. "--" indicates nuclide not detected.

e. Detection is based on biweekly sample taken December 1 to December 15 only.

Table 16-15. Alpha- and beta-emitting radionuclides measured at RWMC locations, 1988[a]

Sample Location	Quarter	Concentration (μCi/mL)			
		Sr-90	Pu-238	Pu-239,-240	Am-241
1	1	--[c]	--	--	--
	2	(4.1 ± 0.8) x 10^{-16}	--	--	(1.7 ± 0.4) x 10^{-17}
	3	--	--	(3 ± 1) x 10^{-18}	--
	4	--	--	--	--
2	1	--	--	--	--
	2	--	--	--	--
	3	--	--	(3 ± 1) x 10^{-18}	(7 ± 2) x 10^{-18}
	4	--	--	--	--
4	1	--	--	--	--
	2	--	--	--	--
	3	--	--	(1.8 ± 0.3) x 10^{-17}	(1.2 ± 0.3) x 10^{-17}
	4	--	--	--	--
4.2	1	--	--	--	--
	2	--	--	--	(1.4 ± 0.4) x 10^{-17}
	3	--	--	(1.4 ± 0.3) x 10^{-17}	--
	4	--	--	(2.0 ± 0.6) x 10^{-18}	--
6	1	--	--	--	--
	2	--	--	--	--
	3	--	--	(5 ± 1) x 10^{-18}	(7 ± 2) x 10^{-18}
	4	--	--	--	--
15	1	(1.8 ± 0.3) x 10^{-16}	--	--	--
	2	--	--	--	--
	3	--	--	--	--
	4	--	--	--	--
24	1	--	--	(2.1 ± 0.4) x 10^{-17}	--
	2	--	(8 ± 2) x 10^{-18}	(2.0 ± 0.3) x 10^{-17}	--
	3	--	--	--	--
	4	--	(1.6 ± 0.3) x 10^{-17}	(5.8 ± 0.5) x 10^{-16}	(3.9 ± 0.6) x 10^{-17}

---

a. Source: Tkachyk et al. (1989).

b. The ± values are experimental random uncertainties in the counting measurement process and represent one standard deviation.

c. "--" indicates that the radionuclide was not detected. Limits of detection are as follows: Sr-90, 2 x 10^{-16} μCi/mL; Pu-238 and Pu-239,-240, 2 x 10^{-18} μCi/mL; Am-241, 2 x 10^{-18} μCi/mL.

17. Biotic Monitoring

17. BIOTIC MONITORING

Plant and animals (biota) can affect the integrity of buried radioactive waste containment by channeling through the soil and allowing water to reach the waste or by transporting radionuclides to the surface. Thus, small mammals and vegetation are sampled to monitor the biological transport of radionuclides at the RWMC.

This section reports on the biotic monitoring activities at the RWMC from 1984 through 1988, the period of time for which biotic monitoring data have been routinely collected and described in the Annual Environmental Monitoring Reports for the RWMC. The results cover radioactive monitoring data on (a) vegetation and (b) small mammals. Section 17.1 presents the purpose of the biotic monitoring activities, Section 17.2 discusses a history of monitoring activities at the RWMC, and Section 17.3 describes investigative procedures. The monitoring results are provided in Section 17.4, and Section 17.5 discusses the quality assurance and quality control aspects of the studies. The detection limits used in the analytical methods are presented in Section 17.6.

17.1 Purpose of the Biotic Monitoring

The biotic monitoring program at the RWMC is part of an INEL-wide environmental monitoring program. Biotic monitoring at the RWMC was instituted to (a) determine if biota are transporting radionuclides from buried waste or contaminated soil, (b) provide guidance to RWMC operations regarding general biotic conditions that may compromise waste containment, and (c) detect significant trends in the radionuclide concentrations in biotic samples. The results of the monitoring activities are used as indicators of the biotic conditions at the RWMC where the primary concern is the possibility that radionuclides in buried waste may be brought to the surface by animal burrowing or root uptake (EG&G, 1989i).

17.2 Past Monitoring Activities

Before 1984, many short-term studies were conducted at the RWMC to investigate radionuclide uptake and movement within the RWMC ecosystem. They include a 1972-1973 study in which deer mice were collected near the SDA and analyzed for activation products, fission products, and TRU nuclides (Markham, 1978; Markham et al., 1978). The ecology of small 1977-1978 mammal populations at the SDA and in a nearby control area was documented in Groves (1981) and Groves and Keller (1983). In conjunction with the small mammal population research, a radioecology study measured the radionuclide concentration and radiation doses received by small mammals to provide information on the proportion of the population that was exposed to buried waste (Arthur and Markham, 1982). The effects of small mammal burrowing on radionuclide transport were evaluated in Arthur and Markham (1983). A biotic monitoring program administered by the EG&G Environmental Monitoring Unit was developed in FY-78 to make an initial assessment of radionuclide concentrations in small mammals, Russian thistle, and crested wheat grass. Biota tissues were analyzed for specific radioisotopes to provide information on (a) radionuclide buildup within the animal tissue and (b) plant uptake and possible transfer of radionuclides. Routine biotic monitoring at the RWMC began in 1984 and has continued to the present.

17.3 Monitoring Activities

The current biotic monitoring activities consist of collecting samples of vegetation and small mammals from representative areas at the RWMC according to the schedule given in Table 17-1. The sampling areas are illustrated in Figure 17-1 and include (a) the active area (Area 1); (b) Pad A (Area 2); (c) the inactive area (Area 3); (d) the previously flooded area (Area 4); and (e) the TSA (Area 5). Representative control samples of each biotic medium are also collected from areas unaffected by RWMC operations. The same representative sampling areas have been used since 1984 although the actual sample location within the representative area may vary. Vegetation and mammal samples have been collected annually in the representative areas

Tabl Biotic monitoring sample collection schedul

	Number of RWMC Samples[b]					QA Samples	
Sample Type	Collection Time	Gamma Spectroscopy	Radiochemistry	Controls	Counting Time	Gamma Spectroscopy	Radiochemistry
Even Years:							
Russian thistle	September 1	15	1	Three from near Frenchman's Cabin	16	1 split	N/A
Ground squirrels	April 1	21	1	Three from near Frenchman's Cabin	16	1 split	N/A
Excavated soil	August 15	15	1	Use results from routine soil sampling in the five representative areas as controls	2	--[c]	N/A
Spiked vegetation	September 20	N/A	N/A	N/A	16	1	1
Spiked small animals	June 1	N/A	N/A	N/A	16	1	1
Odd Years:							
Crested wheatgrass	July 15	15	1	Three from near Frenchman's Cabin	16	1 split	N/A
Perennials	September 1	15	1	Three from near Frenchman's Cabin	16	1 split	N/A
Deer mice	August 15	15	1	Three from near Frenchman's Cabin		1 split	N/A
Spiked vegetation	August 15	N/A	N/A	N/A		1	1
Spiked small mammals	September 15	N/A	N/A	N/A		1	1

---

a. Source: EG&G (1989i).

b. Ideally, three samples will be collected from each of the representative areas; however, three samples representing the specified medium may not be available within all areas (e.g., perennials on Pad A). All samples will be submitted to the RML for gamma spectroscopy analysis. Routine radiochemistry will be performed on one sample representing each sample type. Samples will be analyzed for Sr-90, Pu-238, Pu-239,-240, Am-241 and Total U. In addition, any vegetation or small mammal samples with detectable concentrations of Am-241 will be submitted to the Environmental Analysis Group for TRU analysis.

c. Quality assurance sample results from the routine soil sampling activity will be used. Three split samples and three known standards will be submitted during the even years.

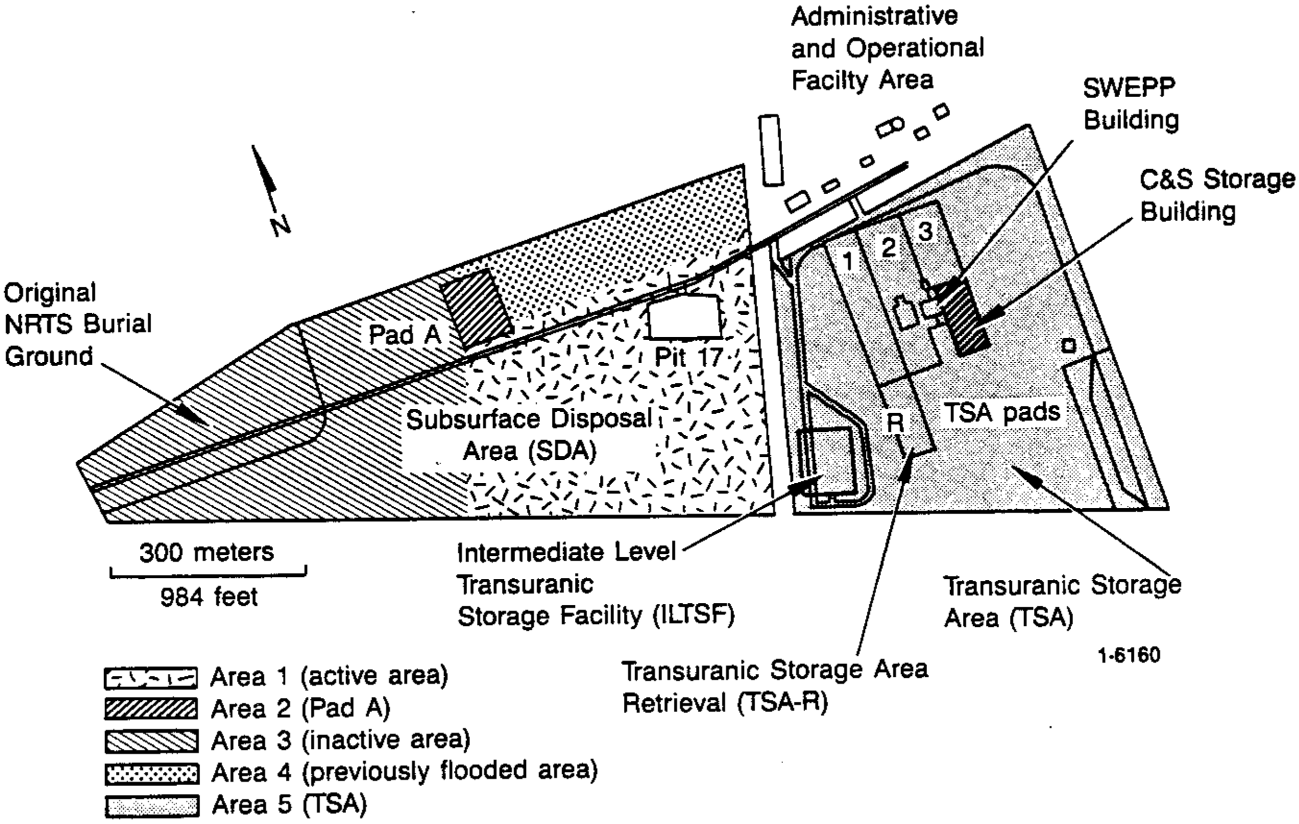


Figure 17-1. Five major areas of the RWMC used for mammal and vegetation collection (EG&G, 1989i).

since 1984 but the sampled species varies by year. All of the samples are then submitted to the RML at the INEL for gamma spectrometric analysis for gamma-emitting radionuclides.

Radiochemical analysis for specific alpha- and beta-emitting radionuclides (Am-241, Pu-238, Pu-239,-240, U-235, U-238, and Sr-90) is also performed on at least one sample representing each sample type. If Am-241 is detected in any vegetation or small mammal, those samples are submitted to the Environmental Analysis Group (EAG) for TRU analysis (EG&G, 1989i).

17.3.1 Sampling Procedures for Vegetation

Three samples are collected from each of the representative areas shown in Figure 17-1 and combined into one composite sample for analysis. The method of collection alternates each year, depending on the plant species to be collected. Crested wheat grass is clipped at ground level and Russian thistle are pulled from the ground within a 1- x 1-m (3 x 3-ft) frame. Rabbitbrush and sagebrush (perennials) are collected by clipping branches from designated plants. The samples are dried, milled, and weighed before being submitted to the RML for gamma spectrometric analysis. Selected samples are also submitted for radiochemical analysis for specific alpha and beta emitters. In addition to these samples, two or three control samples representative of each vegetation type at the RWMC are collected for analysis from the area around Frenchman's Cabin, located approximately 11.3 km (7 miles) southwest of the SDA at the base of Big Southern Butte (EG&G, 1989i).

17.3.2 Sampling Procedures for Small Mammals

Depending on whether the year is odd or even numbered, deer mice or ground squirrels are collected, composited, weighed, homogenized, and frozen before they are submitted to the RML for gamma spectrometric and specific alpha- and beta-emitter analyses (Table 17-1). For the deer mice, each composite consists of 10 mice, and three composites are collected in each representative area, when available. For the ground squirrels, a composite sample consists of three squirrels, and three composites are collected in each area. Depending on the availability, two to three control samples are collected from the Frenchman's Cabin area for analysis (EG&G, 1989i).

17.4 Analytical Methods

All the biota samples are submitted to the RML for gamma spectrometric analysis. Table 17-2 summarizes the gamma-emitting radionuclides that are most likely to be found in environmental samples collected at the RWMC. Radiochemical analyses for Sr-90, Pu-238, Pu-239,-240, Am-241, and Total U are also performed on one sample representing each sample type. In addition, any vegetation or small mammal samples with detectable concentrations of Am-241 are submitted for TRU analysis by the EAG (EG&G, 1989i).

Depending on the availability of data, the geometric mean for the raw data is calculated for each of the five representative areas and the control area. Data from the RWMC samples are summarized and compared with those for the controls.

17.5 Results of Biotic Monitoring

The analytical results of the biotic monitoring activities from 1984 through 1988 are summarized from the Environmental Monitoring Annual Reports. Detailed results of the yearly data are described in the following sections. Section 17.5.1 summarizes the radionuclide data on vegetation, and Section 17.5.2 summarizes the radionuclide data on small mammals.

17.5.1 Radioactivity in Vegetation

Russian thistle samples were analyzed for radionuclides in even numbered years and crested wheat grass samples were analyzed in odd numbered years. The results of the monitoring program for 1984 through 1988 are presented by sampling area in Tables 17-3 and 17-4.

Table 17-2. Gamma-emitting radionuclides which are most likely to be found in environmental samples collected at the RWMC[a]

Radionuclides			
Cr-51	Mn-54	Co-58	Fe-59
Co-60	Nb-95	Zr-95	Ru-103
Ru-106	Sb-125	Cs-134	Cs-137(Ba-137m)
Ce-141	Ce-144	Eu-152	Am-241

---

a. Source: EG&G (1989i).

Table 17-3. Gamma spectrometry data for radioactivity in vegetation at the RWMC[a]

		(Concentration, µCi/g)					
Year	Plant Species Collected	Area 1	Area 2	Area 3	Area 4	Area 5	Control
1984	Russian thistle	Cs-137 $(1.25 \pm 0.17) \times 10^{-6}$	Cs-137 $(0.20 \pm 0.06) \times 10^{-6}$	None Detected	Cs-137 $(0.37 \pm 0.05) \times 10^{-6}$	Cs-137 $(0.20 \pm 0.06) \times 10^{-6}$	Cs-137 $(0.20 \pm 0.04) \times 10^{-6}$
1985	Crested wheatgrass (sagebrush at Area 5)	ND[b]	ND	ND	ND	ND	ND
1986	Russian thistle	Co-60 $(1.9 \pm 0.6) \times 10^{-7}$ Cs-137 $(1.1 \pm 0.3) \times 10^{-7}$	ND	ND	ND	ND	ND
1987	Crested wheatgrass	ND	Cs-134 $(1.5 \pm 0.2) \times 10^{-7}$ $(1.3 \pm 0.3) \times 10^{-7}$ Cs-137 $(1.7 \pm 0.3) \times 10^{-7}$ $(1.0 \pm 0.2) \times 10^{-7}$	Sb-125 $(1.8 \pm 0.4) \times 10^{-7}$	ND	Cs-134 $(1.07 \pm 0.14) \times 10^{-7}$ Cs-137 $(3.7 \pm 0.4) \times 10^{-7}$ $(1.5 \pm 0.3) \times 10^{-7}$ $(0.69 \pm 0.19) \times 10^{-7}$ Sb-125 $(1.6 \pm 0.3) \times 10^{-7}$	ND
1988	Russian thistle	ND	ND	ND	ND	ND	ND

---

a. Source: Reyes et al. (1985); Reyes et al. (1986); Reyes et al. (1987); Tkachyk et al. (1988); Tkachyk et al. (1989).

b. Not detected.

Table 17-4. Radiochemical data on alpha- and beta-emitting radionuclides in vegetation at the RWMC[a]

		(Concentration, μCi/g)					
Year	Plant Species Collected	Area 1	Area 2	Area 3	Area 4	Area 5	Control
1984	Russian thistle	ND[b]	ND	ND	ND	ND	ND
1985	Crested wheatgrass	ND	ND	ND	Sr-90 $(4.8 \pm 0.4) \times 10^{-7}$ U-238 $(4 \pm 1) \times 10^{-9}$ U-234 $(6 \pm 1) \times 10^{-9}$	ND	U-238 $(1.2 \pm 0.3) \times 10^{-8}$ U-234 $(1.2 \pm 0.2) \times 10^{-8}$
1986	Russian thistle	ND	ND	ND	Am-241 $(2.5 \pm 0.5) \times 10^{-7}$	ND	ND
1987	Crested wheatgrass	NR[c]	NR	NR	NR	NR	NR
1988	Russian thistle	NR	NR	NR	NR	NR	NR

---

a. Source: Reyes et al. (1985); Reyes et al. (1986); Reyes et al. (1987); Tkachyk et al. (1988); Tkachyk et al. (1989).

b. Not detected.

c. Not reported.

1984. Russian thistle was collected in 1984, and the results of gamma spectrometry are given in Table 17-5. Cs-137 was detected in Areas 1, 2, 4, 5 and the control location. The maximum value detected was (1.25 ± 0.17) x 10^{-6} μCi/g at Area 1.

1985. Crested wheat grass was collected from four of the five representative areas at the RWMC. Because of the lack of crested wheat grass, sagebrush was collected in the TSA (Area 5). No gamma emitters were detected in the samples. However, Sr-90, U-238 and U-234 were detected at the SDA in Area 4 at concentrations of (4.8 ± 0.4) x 10^{-7} μCi/g; (4 ± 1) x 10^{-9} μCi/g; and (6 ± 1) x 10^{-9} μCi/g dry weight, respectively. The U-238 and U-234 concentrations were smaller than those measured in the control samples (1.2 ± 0.3) x 10^{-8} and (1.2 ± 0.2) x 10^{-8} μCi/g dry weight (Reyes et al., 1986).

1986. Russian thistle was collected in all five representative areas. Co-60 and Cs-137 were detected at Area 1 in the SDA at concentrations of (1.9 ± 0.6) x 10^{-7} μCi/g and (1.1 ± 0.3) x 10^{-7} μCi/g dry weight, respectively. Am-241 was detected in Area 4 with a concentration of (2.5 ± 0.5) x 10^{-7} μCi/g dry weight.

Three samples, two from Area 1 and one from Area 4, submitted for specific alpha and beta-emitting nuclides contained detectable concentrations of Sr-90, Pu-238, Pu-239,-240, and Am-241. Table 17-6 shows these measurements in comparison to prior measurements made at the RWMC (Reyes et al., 1987).

1987. Crested wheat grass was collected from all five representative areas of the RWMC. As shown in Table 17-7, gamma-emitting radionuclides (Cs-134, Cs-137, and Sb-125) were detected at Areas 2, 3, and 5. Cs-137 was detected in two locations: Areas 2 and 5. Cs-134 was measured at detectable concentrations in Areas 2 and 5. Areas 3 and 5 showed detectable levels of Sb-125. Samples from the control areas did not show detectable levels of any of these radionuclides.

Table 17-5. Radionuclide concentrations in Russian thistle collected at the RWMC, 1984[a]

Area - Sample Location	Radionuclide	Activity (10^{-6} μCi/g)
1-3	Cs-137	1.25 ± 0.17
2-2	Cs-137	0.20 ± 0.06
4-1	Cs-137	0.37 ± 0.05
5-3	Cs-137	0.20 ± 0.06
6-1 (control)	Cs-137	0.20 ± 0.04

---

a. Source: Reyes et al. (1985).

Table 17-6. Specific alpha- and beta-emitting nuclides found in Russian thistle samples in 1986[a]

		Concentration[b] (10^{-6} μCi/g)			
Area	Sample	Sr-90	Pu-238	Pu-239,-240	Am-241
1	Routine (1986)	2.3 ± 0.1	0.027 ± 0.005	1.05 ± 0.08	0.046 ± 0.008
1	Routine (1986)	--[c]	--	0.2 ± 0.03	--
4	Routine (1986)	1.1 ± 0.1	0.08 ± 0.01	3.1 ± 0.3	0.18 ± 0.02
Control	Routine (1986)	--	--	--	--
--	RESL	52	0.02	0.02	0.08
1	Contaminated sample (1984)	1000000	200	--	3
4	Routine (1984)	2	--	--	0.5

---

a. Source: Reyes et al. (1987).

b. Analytical uncertainties presented are ±1σ.

c. "--" Below detection limit.

Table 17-7. RWMC vegetation gamma-emitting radionuclide concentrations in crested wheatgrass in 1987[a]

Area	Concentration (10^{-7} µCi/g) Cs-134	Cs-137	Sb-125
1	--[b]	--	--
1	--	--	--
1	--	--	--
2	1.5 ± 0.2	1.7 ± 0.3	--
2	1.3 ± 0.3	--	--
2	--	1.0 ± 0.2	--
3	--	--	--
3	--	--	1.8 ± 0.4
3	--	--	--
4	--	--	--
4	--	--	--
4	--	--	--
5	1.07 ± 0.14	3.7 ± 0.4	1.6 ± 0.3
5	--	1.5 ± 0.3	--
5	--	0.69 ± 0.19	--
Control 1[c]	--	--	--
Control 1	--	--	--
Control 1	--	--	--
Control 2[d]	--	--	--
Control 2	--	--	--
Control 2	--	--	--

---

a. Source: Tkachyk et al. (1988).

b. "--" Not detected.

c. Control from lake beds.

d. Control from T-12.

Results of specific alpha and beta analyses (Sr-90; Pu-238; Pu-239,-240; Am-241; U-234; U-235; and U-238) of deep rooted perennial composite samples for Areas 1, 2, and 3 are shown in Table 17-8. Samples from all three areas showed detectable concentrations of Sr-90; Pu-239,-240; and U-234; U-235; and U-238. The highest concentrations occurred at Area 2 with Sr-90 detected at $(2.9 \pm 0.3) \times 10^{-7}$ μCi/g and Pu-239,-240 at $(1.5 \pm 0.2) \times 10^{-8}$ μCi/g dry weight.

Gamma spectroscopy results (Table 17-9) of deep rooted perennial samples from Area 1 showed detectable concentrations of Cs-137. No gamma emitting radionuclides attributable to waste management activities at the RWMC were detected in the deep rooted perennial vegetation (Tkachyk et al., 1988).

<u>1988</u>. Russian thistle samples were collected from the five representative areas at the RWMC. No gamma- or alpha-emitting radionuclides were detected in any media or control samples. Sr-90 was detected at levels slightly above those of the control (Tkachyk et al., 1989). However, these analytical data were not reported in the Annual Environmental Monitoring Report.

17.5.2 <u>Radioactivity in Small Mammals</u>

Deer mice are analyzed for radionuclides in odd-numbered years and ground squirrels are analyzed in even-numbered years. The results of the monitoring program for the period 1985 through 1987 for small mammals are summarized in Tables 17-10 and 17-11. No monitoring data were recorded for 1984 and 1988.

<u>1985</u>. Eighteen composites (three each from the five representative areas and three control samples) of deer mice were collected for analysis. Cs-137 was detected in Area 1 within the SDA at a concentration of $(9.3 \pm 0.4) \times 10^{-6}$ μCi/g. Sr-90; Pu-239,-240; Am-241; U-234; and U-238 were detected in samples from Area 1. The concentration of Sr-90 and U-234 was reported at $(8.6 \pm 0.2) \times 10^{-6}$ μCi/g and $(2.3 \pm 0.4) \times 10^{-8}$ μCi/g, respectively (Reyes et al., 1986). Concentrations of the other radionuclides were not reported.

Table 17-8. RWMC active area perennial vegetation alpha- and beta-emitting radionuclide concentrations, 1987[a]

	Concentration (μCi/g)[b]			
Nuclide	Area 1	Area 2	Area 3	Control
Sr-90	$2.8 \pm 0.3 \times 10^{-7}$	$2.9 \pm 0.3 \times 10^{-7}$	$2.6 \pm 0.3 \times 10^{-7}$	$8 \pm 2 \times 10^{-8}$
Pu-238	BDL[c]	BDL	BDL	BDL
Pu-239,-240	$2.8 \pm 0.8 \times 10^{-9}$	$1.5 \pm 0.2 \times 10^{-8}$	$3.7 \pm 0.9 \times 10^{-9}$	BDL
Am-241	BDL	BDL	BDL	BDL
U-234	$3.9 \pm 0.5 \times 10^{-8}$	$2.3 \pm 0.3 \times 10^{-8}$	$3.5 \pm 0.4 \times 10^{-8}$	$1.3 \pm 0.2 \times 10^{-8}$
U-235	$1.8 \pm 0.6 \times 10^{-9}$	$1.6 \pm 0.5 \times 10^{-9}$	$2.3 \pm 0.6 \times 10^{-9}$	BDL
U-238	$4.0 \pm 0.6 \times 10^{-8}$	$2.9 \pm 0.4 \times 10^{-8}$	$3.8 \pm 0.5 \times 10^{-8}$	$1.1 \pm 0.2 \times 10^{-8}$

---

a. Source: Tkachyk et al. (1988).

b. Analytical uncertainties are ± 1σ.

c. BDL - Below Detection Limit.

Table 17-9. RWMC perennial vegetation gamma-emitting radionuclide concentrations in 1987[a]

	Concentration (10^{-7} μCi/g)	
Location	Cs-134	Cs-137
1	--	0.88 ± 0.23
1	--	1.9 ± 0.3
1	--	1.9 ± 0.3
Control	--	1.5 ± 0.3
Control	1.02 ± 0.16	3.5 ± 0.4
Control	--	2.0 ± 0.3

---

a. Source: Tkachyk et al. (1988).

Table 17-10. Gamma spectrometry data on radioactivity in small mammals at the RWMC[a]

		(Concentration, µCi/g)					
Year	Plant Species Collected	Area 1	Area 2	Area 3	Area 4	Area 5	Control
1984		NR[b]	NR	NR	NR	NR	NR
1985	Deer mice	Cs-137 (9.3 ± 0.4) x 10^{-6}	ND[c]	ND	ND	ND	ND
1986	Ground squirrels	ND	ND	ND	ND	ND	ND
1987	Deer mice	Co-60[e] Cs-137 Cs-134 Sb-125 Eu-152 Eu-154	NS[d]	Cs-137 (4.1 ± 0.8) X 10^{-7}	Cs-137 (4.1 ± 0.8) x 10^{-7}	Co-60 Cs-134 Cs-137	ND
1988		NR	NR	NR	NR	NR	NR

---

a. Source: Reyes et al. (1985); Reyes et al. (1986); Reyes et al. (1987); Tkachyk et al. (1988); Tkachyk et al. (1989).

b. No data reported.

c. Not detected.

d. Not sampled.

e. Refer to Table 17-12 for concentrations.

Table 17-11. Radiochemical data on alpha- and beta-emitting radionuclides in small mammals at the RWMC[a]

		(Concentration, µCi/g)					
Year	Plant Species Collected	Area 1	Area 2	Area 3	Area 4	Area 5	Control
1984		NR[b]	NR	NR	NR	NR	NR
1985	Deer mice	Sr-90 $(8.6 \pm 0.2) \times 10^{-6}$ Pu-239,-240 Am-241 U-234 $(2.3 \pm 0.4) \times 10^{-8}$ U-238	ND[c]	ND	ND	ND	Sr-90 Pu-239,-240 Am-241 U-234, U-238
1986	Ground squirrels	--[d]	--[d]	--[d]	--[d]	--[d]	--[d]
1987	Deer mice	Sr-90 Pu-236 Pu-239,-240 U-234	ND	ND	Sr-90 Pu-239,-240 Am-241 U-234 U-238	Sr-90 Pu-238 U-239,-240 Am-241 U-234 U-238	Sr-90 U-234 U-238
1988		NR	NR	NR	NR	NR	NR

---

a. Source: Reyes et al. (1985); Reyes et al. (1986); Reyes et al. (1987); Tkachyk et al. (1988); Tkachyk et al. (1989).

b. No data reported.

c. Not detected.

d. No transuranic radionuclides or Sr-90 were detected above the concentration of the control samples (values not reported).

e. Refer to Table 17-13 for the concentration of radionuclide constituents.

1986. Nine composite samples of ground squirrels, seven from the RWMC and two controls, were collected for analysis. No alpha-, beta-, orgamma-emitting nuclides were detected in any of the samples above the concentration of the control samples (Reyes et al., 1987).

1987. Eight composite samples of deer mice (three from Area 1, one from Area 3, two from Area 5 and two control samples) were collected for analysis. Gamma-emitting nuclides detected in the samples included Co-60, Cs-134, Cs-137, Sb-125, Eu-152 and Eu-154. Concentrations are provided in Table 17-12. No gamma-emitting nuclides were detected in the controls. Cs-137 was detected at all three sample locations in Area 1 with a maximum concentration of $(520 \pm 40) \times 10^{-7}$ μCi/g.

Radiochemical analyses of composite samples from Areas 1, 4, and 5 showed detectable quantities of Sr-90, Pu-239,-240, U-234, and U-238, above the level of the control sample as shown in Table 17-13. Plutonium-238 was detected in samples from Areas 1 and 5; detectable concentrations of Am-241 were found in samples from Areas 4 and 5 (Table 17-13).

17.6 Data Quality

A quality assurance program has been in place at the RWMC for environmental monitoring activities since 1984. The objectives of the program are to (a) identify deficiencies in the sampling and measurement processes so that corrective action can be taken and (b) ensure that the results of the monitoring programs are valid. For biotic monitoring activities at the RWMC, standard operating procedure number SOP-EM-EN-1.4, currently provides the specific guidelines to ensure the validity of the biotic monitoring program (EG&G, 1989i).

Specific elements used to ensure that the objectives of the quality assurance program are met include:

- Organizational structure and responsibilities of managerial and program personnel

Table 17-12. RWMC small mammal gamma radionuclide concentrations in 1987[a]

	Concentration (10^{-7}µCi/g)					
	Area 1			Area 3	Area 5	
Nuclide	1	2	3		1	2
Co-60	--[b]	2.9 ± 0.8	6.7 ± 0.7	--	1.5 ± 0.3	1.9 ± 3
Cs-134	--	--	11.8 ± 0.8	--	--	2.7 ± 0.5
Cs-137	6.1 ± 0.8	3.3 ± 0.8	520 ± 40	4.1 ± 0.8	--	11.8 ± 1.2
Sb-125	--	7.8 ± 1.2	--	--	--	--
Eu-152	--	52.4 ± 1.8	14.3 ± 1.8	--	--	--
Eu-154	--	39 ± 3	7.4 ± 1.3	--	--	--

---

a. Source: Tkachyk et al. (1988).

b. "--" indicates radionuclide not detected.

Table 17-13. RWMC small mammal alpha- and beta-emitting radionuclide concentrations in 1987[a]

	Concentration (μCi/g)[b]			
Nuclide	Area 1	Area 4	Area 5	Control
Sr-90	$6.5 \pm 0.5 \times 10^{-7}$	$3.7 \pm 0.4 \times 10^{-7}$	$8.3 \pm 0.4 \times 10^{-6}$	$2.8 \pm 0.4 \times 10^{-7}$
Pu-238	$8 \pm 2 \times 10^{-9}$	--	$9 \pm 1 \times 10^{-9}$	--
Pu-239,-240	$3.0 \pm 0.2 \times 10^{-7}$	$2.7 \pm 0.8 \times 10^{-8}$	$9.9 \pm 0.8 \times 10^{-8}$	--
Am-241	--	$3.5 \pm 0.8 \times 10^{-8}$	$7 \pm 2 \times 10^{-8}$	--
U-234	$2.8 \pm 0.4 \times 10^{-8}$	$4.0 \pm 0.6 \times 10^{-8}$	$2.4 \pm 0.3 \times 10^{-8}$	$2.6 \pm 0.4 \times 10^{-8}$
U-235	--	--	--	--
U-238	$2.5 \pm 0.4 \times 10^{-8}$	$5.1 \pm 0.9 \times 10^{-8}$	$2.0 \pm 0.3 \times 10^{-8}$	$2.6 \pm 0.4 \times 10^{-8}$

a. Source: Tkachyk et al. (1988).

b. Analytical uncertainties are $\pm 1\sigma$.

c. "--" Indicates radionuclide below detection limit.

- Documented procedures that describe the precautions, prerequisites, and step-by-step sampling procedures for monitoring activities

- Document control processes for the preparation, revision, and approval of procedures

- Maintenance of records, pertaining to monitoring activities, such as planning documents, data sheets, sample results, and calibration records

- Analysis of quality control samples to assess accuracy of monitoring results

- Planned and periodic audits.

Radioanalytical laboratories provide results on quality control samples, and program personnel determine whether the analytical results for the control samples are acceptable.

17.7 Detection Limits

This section summarizes the detection limits used in the radioanalysis of the biotic samples. A detailed discussion of the limits are presented in Appendix C of the Environmental Monitoring Annual Reports.

17.7.1 Radiochemical Analysis

Table 17-14 contains the approximate detection limits of the radiochemical analytical methods used for the biotic samples. The detection limits are intended as guides to order-of-magnitude sensitivities. Actual detection limits may vary depending on background, yield, counting time, and sample weight.

Table 17-14. Approximate detection limits of radiochemical analytical methods

Media	Sample Description	Method of Treatment	Detection Limits (μCi/g)	
Vegetation	16-oz squat jar filled to rim below threads (Avg. wt: 150 g)	Ash and dissolve the total sample completely. Analyze the equivalent of 50 g of original sample.	Sr-90 Pu-238 Pu-239 Am-241	6×10^{-8} 6×10^{-10} 6×10^{-10} 6×10^{-10}
Animal Tissue	16-oz squat jar containing dried deer mice or one dried ground squirrel (Avg. wts: mice, 170 g; squirrel, 100 g)	Ash, dissolve, and analyze the equivalent of 50 g of the original sample.	Sr-90 Pu-238 Pu-239 Am-241	3×10^{-8} 3×10^{-10} 3×10^{-10} 3×10^{-10}

The detection limits in Table 17-14 are derived from the total activities in microcuries that must be present in the sample weight. The detection limits are calculated under the following conditions: a counting time of 1000 minutes, a counting efficiency of about 25%, a chemical yield of about 80%, and clean detection and reagent blanks giving not more than about 5 counts in 1000 minutes in any given energy interval. The detection limits are calculated according to the definition of detection limits given by L. A. Curie (Tkachyk et al., 1989). The detection limit equals $(2.71 + 4.66\ B^{1/2})/(t \times E \times Y \times 2.22 \times 10^{6})$ total μ/Ci, where "B" is the total background and blank correction, "t" is the counting time in minutes, "E" is the counting efficiency as a fraction, "Y" is the chemical yield as fraction, and 2.22×10^{6} is the disintegrations per minute per microcurie (dpm/μCi). These are absolute detection limits, in terms of total μCi per sample, and are about 3×10^{-6} for Sr-90 and about 3×10^{-8} for all other alpha-emitting radionuclides. To determine the detection limits as activity concentration, the absolute detection limits must be divided by the sample size taken for analysis.

17.7.2 Gamma Spectrometric Analysis

Table 17-15 gives absolute detection limits in the right hand column for vegetation samples. The corresponding data for animal tissue is not given. The absolute detection limits are the total activities that must be present in the sample weight taken for analysis to be detected under the counting conditions described for the radiochemical analysis and calculated according to the definition of L.A. Curie. This definition is detection limit = $(2.71 + 4.66B^{1/2})/(t \times E \times P \times 2.22)$ where "B" is the total correction in counts (Compton, background, blanks, etc. for the same counting time); "t" is the counting time in minutes; "E" is the counting efficiency as a fraction; "P" is the gamma-ray emission probability for the particular gamma ray being measured; and 2.22 is the disintegration per minute per picocurie (dpm/pCi) (Tkachyk et al., 1989).

The figures in the left hand column of Table 17-15 give the same detection limits expressed in terms of a pCi/unit weight for the average

Table 17-15. Detection limits for gamma spectrometry on vegetation samples at the RWMC[a]

Radionuclide	pCi/g	Total pCi
Sc-46	0.2	30
Cr-51	2.0	<300
Mn-54	0.2	30
Co-57	0.6	90
Co-58	0.2	30
Fe-59	0.4	60
Co-60	0.3	40
Zn-65	0.5	80
Nb-94	0.2	30
Nb-95	0.2	30
Zr-95	0.4	60
Ru-103	0.2	30
Ru-106	2.0	<300
Ag-110m	0.2	30
Sb-124	1.0	150
Sb-125	0.4	60
Cs-134	0.2	30
Cs-137	0.3	40
Ce-141	0.2	30
Ce-144	1.0	150
Eu-152	1.0	150
Eu-154	0.4	60
Eu-155	1.0	150
Hf-181	0.2	30
Ta-182	0.6	90
Hg-203	<0.2	30
Am-241	<0.5	80
Gross beta		
Gross alpha		

---

[a] Source: Tkachyk et al. (1989).

sample size expected to be analyzed. Because the absolute detection limits must remain constant for a given counting time and efficiency, the detection limits in terms of concentrations will become higher or lower as the sample size actually used in the analysis becomes smaller or larger. Table 17-16 contains the description of samples for gamma-spectrometric analysis and counting conditions for the stated detection limits.

Quality assurance samples are prepared as nearly identically to the real samples as possible. For dried vegetation and animal tissue, the samples (consisting of about 100 g for vegetation, 55 g for mice, or 85 g for ground squirrels) are spiked inhomogeneously with known quantities of radionuclides evaporated to dryness on about 100 mg of clean, dry minus 1000 mesh soil to obtain quantitative transfer without wetting the samples. These samples may not be subdivided without complete dissolution because of their fundamental inhomogeneity.

Table 17-16. Gamma-spectrometric analysis sample descriptions and counting conditions

Media	Sample Description	Conditions of Counting
Vegetation	16-oz squat jar filled to the bead below the threads after settling	The dry sample is counted in the squat jar for 16 hours with the jar being rotated as close to the detector as possible. Sample size about 150 g average.

18. References

18. REFERENCES

Adams, L. E., D. H. Janke, P. T. Dickman, 1979, Annual Report - 1978 Environmental Surveillance Report for the INEL Radioactive Waste Management Complex, TREE-1357, June.

Anderson, B. D., 1991, Drinking Water Monitoring Program Data Report for Primary and Secondary Drinking Water Standards, EGG-ESQ-9621, May.

Anderson, S. R. and B. D. Lewis, 1989, Stratigraphy of the Unsaturated Zone at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho, USGS Water Resources Investigations Report 89-4065, DOE/ID-22080, May.

Arthur, W. J. III, and O. D. Markham, 1982, "Radionuclide Export and Elimination by Coyotes at Two Radioactive Waste Disposal Areas in Southeastern Idaho," Health Physics, 43, 4, pp. 493-500.

Arthur, W. J. III, and O. D. Markham, 1983, "Small Mammal Soil Burrowing as a Radionuclide Transport Vector at a Radioactive Waste Disposal Area in Southeastern Idaho," Journal of Environmental Quality, 12, 1, pp. 117-122.

Baca, R. G., J. C. Walton, A. S. Rood, M. D. Otis, 1988, "Organic Contaminate Release From a Mixed Waste Disposal Site: a Computer Simulation Study of Transport Through the Vadose Zone and Site Remediation," in Proceedings of Tenth Annual DOE Low-Level Waste Management Conference, Denver, Colorado.

Bagby, J. C., L. J. White, R. G. Jensen, 1985, Water-Quality Data for Selected Wells On or Near the Idaho National Engineering Laboratory, 1949 through 1982, USGS Open-File Report 84-714, DOE/ID-22068, July.

Banson, M., T. Pigford, H. Levi, 1981, Nuclear Chemical Engineering, McGraw Hill.

Barraclough, J. T., W. E. Teasdale, R. G. Jensen, 1967, Hydrology of the National Reactor Testing Station, Idaho: 1965, USGS Open-File Report, IDO-22049.

Barraclough, J. T., J. B. Robertson, V. J. Janzer, 1976, Hydrology of the Solid Waste Burial Ground as Related to the Potential Migration of Radionuclides at the Idaho National Engineering Laboratory, USGS Open-File Report 76-471, IDO-22056, August.

Binda, R. E., 1981, Evaluation of Final Surface Cover Proposal for the INEL Subsurface Disposal Area, EG&G Idaho, Inc., Internal Technical Report WM-FI-81-007.

Blanchfield, L. A. and L. G. Hoffman, 1984, Annual Report 1983 Environmental Surveillance for the INEL Radioactive Waste Management Complex and Other Areas, EGG-2312, August.

Bodnar, L. Z. and D. R. Percival, 1982, RESL Analytical Chemistry Branch Procedures Manual, IDO-12096.

Borghese, J. V., 1988, Hydraulic Characteristics of Soil Cover, Subsurface Disposal Area, Idaho National Engineering Laboratory, Master's Thesis, UI-09/88, University of Idaho, Moscow, Idaho, September.

Brown, R. M. and B. J. Quintana, 1988, Geophysical Techniques for the Radioactive Waste Management Complex Subsurface Disposal Area, EGG-WM-8303, November.

Brown, R. W. and B. P. Van Haveren, 1972, Psychrometery in Water Relations Research, Utah Agricultural Experiment Station, Utah State University.

Burgus, W. H. and S. E. Maestas, 1976, The 1975 RWMC Core Drilling Program, A Further Investigation of Subsurface Radioactivity at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, U.S. Energy Research and Development Administration Office, Office of Waste Management, Idaho Operations Office Publication, IDO-10065.

Cerven, F. and T. L. Clements, 1987, Estimate of Hazardous Waste Constituents in the RWMC Subsurface Disposal Area, TWT-010-87, December.

Clawson, K. L., G. E. Start, N. R. Ricks, 1989, Climatography of the Idaho National Engineering Laboratory, NOAA, 2nd Edition, DOE/ID-12118, December.

Code of Federal Regulations, 40 CFR 141, "National Primary Drinking Water Regulations," Office of the Federal Register, July 1989.

Crockett, A. B., 1983, Screening for Hazardous Materials in RWMC Erodible Soils, EG&G Idaho, Inc., PG-WM-83-032, October.

Davis, L. C. and J. R. Pittman, 1990, Hydrological, Meteorological, and Geohydrological Data for an Unsaturated Zone Study Near the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho - 1987, USGS Open-File Report 90-114, DOE/ID-22086.

Devries, R. L., 1983, Failure of a Dike and Entry of Runoff Water into the RWMC SDA - 1982, EDF 103, Revision 1, January 18.

DOE (U.S. Department of Energy), 1983, A Plan for Studies of Subsurface Radionuclide Migration at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory, IDO-10016, November.

Dolenc, M. R. and D. H. Janke, 1977, Environmental Surveillance Report for the INEL Radioactive Waste Management Complex Annual Report - 1976, TREE-1078, May.

EG&G (EG&G Idaho, Inc.), 1984, Environmental and Other Evaluations of Low-Level Waste at the Radioactive Waste Management Complex, EGG-WM-6523, Idaho Falls, Idaho, February.

EG&G (EG&G Idaho, Inc.), 1985, A History of the Radioactive Waste Management Complex at the INEL, Revision 3, WM-F1-81-003, July.

EG&G (EG&G Idaho, Inc.), 1988a, RWMC RCRA Facility Investigation Work Plan, EGG-WM-8219, December.

EG&G (EG&G Idaho, Inc.), 1988b, Sampling and Analysis Plan Borehole 8901D, Radioactive Waste Management Complex, Subsurface Disposal Area, WM-8529, April.

EG&G (EG&G Idaho, Inc.), 1988c, Buried Waste Program Data Collection Quality Assurance Plan, EGG-WM-8220, Rev. 1, December.

EG&G (EG&G Idaho, Inc.), 1989a, "Review of USGS Data from Routine Monitoring of the Snake River Plain Aquifer in the Vicinity of the RWMC," SOP-EM-EN-1.6, from Environmental Handbook for the RWMC and Other Waste Management Facilities at the Idaho National Engineering Laboratory, EGG-ER-8045.

EG&G (EG&G Idaho, Inc.), 1989b, "EG&G Idaho Production Wells and Distribution Systems," SOP-EM-DW-1.4, from Environmental Handbook for the RWMC and Other Waste Management Facilities at the Idaho National Engineering Laboratory, EGG-ER-8045.

EG&G (EG&G Idaho, Inc.), 1989c, "Routine Collection of Water Samples for Radiological Analysis at RESL," SOP-EM-DW-1.1, from Environmental Handbook for the RWMC and Other Waste Management Facilities at the Idaho National Engineering Laboratory, EGG-ER-8045.

EG&G (EG&G Idaho, Inc.), 1989d, "Routine Collection of Water Samples for Bacteriological Analysis," SOP-EM-DW-1.2, from Environmental Handbook for the RWMC and Other Waste Management Facilities at the Idaho National Engineering Laboratory, EGG-ER-8045.

EG&G (EG&G Idaho, Inc.), 1989e, Sampling and Analysis Plan, Boreholes 8802D, D10, and 8902D, Radioactive Waste Management Complex, Subsurface Disposal Area, EG&G-WM-8540, September.

EG&G (EG&G Idaho, Inc.), 1989f, Health and Safety Plan for Operations Performed for the Buried Waste Program, EGG-WM-8504.

EG&G (EG&G Idaho, Inc.), 1989g, "Surface Water Sampling," SOP-EM-EN-1.3, from Environmental Handbook for the RWMC and Other Waste Management Facilities at the Idaho National Engineering Laboratory, EGG-ER-8045, September.

EG&G (EG&G Idaho, Inc.), 1989h, "Environmental Monitoring Standard Operating Procedure for Air Monitoring Programs at the RWMC", SOP-EM-EN-1.1, from Environmental Handbook for the RWMC and Other Waste Management Facilities at the Idaho National Engineering Laboratory, EGG-ER-8045, September.

EG&G (EG&G Idaho, Inc.), 1989i, "Environmental Monitoring Standard Operating Procedure, Biotic Monitoring," SOP-EM-EN-1.4, from Environmental Handbook for the RWMC and Other Waste Management Facilities at the Idaho National Engineering Laboratory, EGG-ER-8045, September.

EG&G (EG&G Idaho, Inc.), 1990a, Radioactive Waste Management Information for 1989 and Record-to-Date, DOE/ID-10054(89), June.

EG&G (EG&G Idaho, Inc.), 1990b, Drinking Water Monitoring Handbook for Operational Facilities at the Idaho National Engineering Laboratory, EGG-EV-9115, July.

EG&G (EG&G Idaho, Inc.), 1990c, Quality Program Plan for Environmental Monitoring Program, QPP-029, Revision 2, October.

EPA (U.S. Environmental Protection Agency), 1986a, RCRA Ground Water Monitoring Technical Enforcement Document (TEGD), EPA OSWER-9950.1, September.

EPA (U.S. Environmental Protection Agency), 1986b, Test Methods for Evaluation of Solid Waste Physical/Chemical Methods, 3rd Edition, Washington, D.C., SW-846.

EPA (U.S. Environmental Protection Agency), 1986c, "Contract Laboratory Program Statement of Work for Organic Analyses, Multi-Media, Multi-Concentration," EPA CLP SOW-788, Las Vegas, Nevada, October.

EPA (U.S. Environmental Protection Agency), 1988a, Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses, February 1.

EPA (U.S. Environmental Protection Agency), 1988b, Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses, July.

Filby, C. W. et al., 1989, Westinghouse Idaho Nuclear Company Environmental Sample Analysis Quality Assurance Program for the Nuclear and Environmental Measurements Section, WIN-139, Revision 3, Idaho Falls, Idaho, April.

Friedman, L. C. and D. E. Erdmann, 1082, "Quality Assurance Practices for the Chemical and Biological Analyses of Water and Fluvial Sediments," U. S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter A6, 181 p.

Goldstein, F. J. and W. D. Weight, 1982, Subsurface Information from 8 Wells Drilled at INEL, Southeastern Idaho, USGS Open-File Report 82-644, DOE/ID-22063, September.

Groves, C. R., 1981, The Ecology of Small Mammals on the Subsurface Disposal Area, Idaho National Engineering Laboratory Site, Idaho State University, M. S. Thesis.

Groves, C. R. and B. L. Keller, 1983, "Ecological Characteristics of Small Mammals on a Radioactive Waste Disposal Area in Southeastern Idaho," The American Midland Naturalist, 109, 2, pp. 253-265.

Hasbrouck, J. C., 1989, Geophysical Surveys at INEL/RWMC Cold Pit, Acid Pit, and Pit 9, UNC-5/89, UNC Geotech, May.

Hedahl, T. G. and D. H. Janke, 1978, Environmental Surveillance Report for the INEL Radioactive Waste Management Complex Annual Report - 1977, TREE-1251, April.

Hiaring, C. M. et al., 1991, Radioactive Waste Management Complex Trench 27 Mercury Investigation, EGG-WM-9730, June.

Hubbell, J. M. et al., 1985, Annual Progress Report FY-1985, Subsurface Investigation Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory, DOE/ID-10136, December.

Hubbell, J. M. et al., 1987, Annual Progress Report FY-1986, Subsurface Investigation Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory, DOE/ID-10153, January.

Hubbell, J. M., N. L. Hampton, L. C. Hull, 1988, RWMC Subsurface Investigations Program Guidelines for Data Collection, EG&G-BEG-8207, September.

Hubbell, J. M., 1990, Perched Ground Water at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory, EGG-ER-8779, October.

Humphrey, T. G., 1980, Subsurface Migration of Radionuclides at the Radioactive Waste Management Complex - 1978, EGG-2026.

Humphrey, T. G. and F. H. Tingey, 1978, The Subsurface Migration of Radionuclides at the Radioactive Waste Management Complex, 1976-1977, TREE-1171, October.

Janke, D. H., H. W. Reno, L. E. Wickham, 1981, Annual Report - 1980 Environmental Surveillance for the INEL Radioactive Waste Management Complex, EGG-2128, December.

Janke, D. H. and T. P. Zahn, 1982, Annual Report - 1981 Environmental Surveillance for the INEL Radioactive Waste Management Complex, EGG-2209, September.

Janke, D. H., 1983, Annual Report - 1982 Environmental Surveillance for the Radioactive Waste Management Complex and Other Areas, EGG-2256, August.

Jones, B. E., 1987, Quality Control Manual of the U. S. Geological Survey's National Water Quality Laboratory, USGS Open-File Report 87-457.

Knobel, L. L. and L. J. Mann, 1988, Radionuclides in Ground Water at the Idaho National Engineering Laboratory, Idaho, USGS Open-File Report 88-731, DOE/ID-22077, December.

Koslow, K. N. and J. M. Hubbell, 1989, Sampling and Analysis Plan for Buried Waste Program Archived Core Samples, EGG-WM-8803, June.

Klute, A., 1986, Methods of Soil Analysis, Part I, Physical and Mineralogical Methods, Society of Agronomy, Inc., Soil Sciences Society of America, Inc.

Knutson, C. F. et al., 1990, FY-89 Report RWMC Vadose Zone Basalt Characterization, EGG-WM-8949, July.

Kuntz, M. A., G. B. Dalrymple, D. E. Champion, D. J. Doherty, 1980, Petrography, Age, and Paleomagnetism of Volcanic Rocks at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho, with an Evaluation of Potential Volcanic Hazards, USGS Open-File Report 80-388.

Laney, P. T. et al., 1988, Annual Progress Report FY-1987, Subsurface Investigation Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory, DOE/ID-10183, April.

Leenher, J. A. and J. C. Bagby, 1982, Organic Solutes in Ground Water at the Idaho National Engineering Laboratory, USGS Water-Resources Investigation 82-15, DOE/IDO-22061, March.

Lewis, B. L. and F. J. Goldstein, 1982, Evaluation of a Predictive Ground Water Solute Transport Model at the Idaho National Engineering Laboratory, USGS Open-File Report 82-25, DOE/ID-22062, March.

Mann, L. J. and L. L. Knobel, 1987, Purgeable Organic Compounds in Ground Water at the Idaho National Engineering Laboratory, Idaho, USGS Open-File Report 87-766, DOE/ID-22074, December.

Mann, L. J. and L. L. Knobel, 1988, Concentrations of Nine Trace Metals in Ground Water at the Idaho National Engineering Laboratory, Idaho, USGS Open-File Report 88-332, DOE/ID-22075, May.

Mann, L. J. and L. L. Knobel, 1990, Radionuclides, Metals, and Organic Compounds in Water, Eastern Part of A & B Irrigation District, Minidoka County, Idaho, USGS Open-File Report 90-191, DOE/ID-22087, June.

Markham, O. D., 1978, Activation and Fission Products in the Environment Near the Idaho National Engineering Laboratory Radioactive Waste Management Complex, IDO-12085.

Markham, O. D., K. W. Puphal, T. D. Filer, 1978, "Plutonium and Americium Contamination Near a Transuranic Storage Area in Southeastern Idaho," Journal of Environmental Quality, 7, pp. 422-428.

Mavlem, L. T., 1986, "A new Model for Predicting the Hydraulic Conductivity for Unsaturated and Porous Media," Water Resources Research, Vol. 12, No. 3, pp. 513-522.

McElroy, D. L. et al., 1989, Annual Progress Report: FY-1988 -- Site Characterization Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory, DOE/ID-10233(88), July.

McElroy, D. L. and J.M. Hubbell, 1989, "Vadose Zone Monitoring at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory," Proceedings, Nuclear Waste Isolation in the Unsaturated Zone, Focus '89, p. 357-364.

McElroy, D. L. and J. M. Hubbell, 1990, Hydrologic and Physical Properties of Sediments at the Radioactive Waste Management Complex, EGG-BG-9147, September.

Miller, D. L. et al., 1989, Radiation Measurements Laboratory Quality Assurance Report - 1985-1987, ST-CS-001-89, EG&G Idaho, Inc., Idaho Falls, Idaho, January.

Mundorff, M. J., E. G. Crosthwaite, C. Kilburn, 1964, Groundwater for Irrigation in the Snake River Basin in Idaho, USGS Water Supply Paper 1654.

Nace, R. L. et al., 1956, Geography, Geology, and Water Resources of the National Reactor Testing Station, Idaho, Appendix 1, Basic Data on the Geography and Geology, USGS/USAEC, IDO-22033.

Olmsted, F. H., 1962, Chemical and Physical Character of Ground Water in the National Reactor Testing Station, Idaho, USGS, IDO-22043.

Pittman, J. R., 1989, Hydrological and Meteorological Data for An Unsaturated Zone Study Near the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, 1985-86, USGS Open-File Report 89-74, DOE/ID-22079, April.

Rauen, C. D., 1989, Sampling and Analysis Plan for the Radioactive Waste Management Complex Subsurface Disposal Area: Vapor Vacuum Extraction Demonstration, EGG-WM-8381, Rev. 1, October.

Rawson, S. A., J. C. Walton, R. G. Baca, 1989, Modeling Potential Migration of Petroleum Hydrocarbons from a Mixed Waste Disposal Site in the Vadose Zone, Proceedings of Petroleum Hydrocarbons and Organic Chemicals in Groundwater: Prevention, Detection, and Restoration, Houston, Texas, EG&G Idaho, Inc., November.

Rawson, S. A. and J. C. Walton, 1989, Potential Significance of Texaco Regal Oil to Contaminant Migration at the Subsurface Disposal Area: A Progress Report, EG&G Idaho, Inc., February.

Reyes, B. D., M. J. Case, T. P. Zahn, 1985, Annual Report - 1984 Environmental Surveillance for the INEL Radioactive Waste Management Complex and Other Areas, EGG-2386, August.

Reyes, B. D., M. J. Case, R. N. Wilhelmsen, 1986, Annual Report - 1985 Environmental Surveillance for the EG&G Idaho Radioactive Waste Management Areas at the Idaho National Engineering Laboratory, EGG-2451, August.

Reyes, B. D., J. W. Tkachyk, P. D. Ritter, R. N. Wilhelmsen, 1987, Annual Report - 1986 Environmental Surveillance for the EG&G Idaho Radioactive Waste Management Areas at the Idaho National Engineering Laboratory, EGG-2502, August.

Richards, L. A., 1954, "Diagnosis and Improvement of Saline and Alkali Soils, USDA Handbook, No. 60.

Rightmire, C. T. and B. B. Hanshaw, 1973, Relationship Between the Carbon Isotope Composition of Soil CO_2 and Dissolved Carbonate Species in Water, Water Resources Research, Vol. 9, pp. 958-967.

Rightmire, C. T. and B. D. Lewis, 1987, Hydrogeology and Geochemistry of the Unsaturated Zone, Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho, USGS Open-File Report 87-4198, DOE/ID-22073.

Robertson, J. B., 1974, Digital Modeling of Radioactive and Chemical Waste Transport in the Snake River Plain Aquifer at the National Reactor Testing Station, Idaho, USGS Open-File Report, DOE/IDO-22054.

Robertson, J. B., R. Schoen, J. T. Barraclough, 1974, The Influence of Liquid Waste Disposal on the Geochemistry of Water at the NRTS Idaho: 1952-1970, IDO-22053.

Ruebelmann, K. L. and L. N. Peterson, 1989, Sampling and Analysis Plan for Background Soil Gas Sampling from Boreholes 8801D, 78-4, WWW-1, and 77-1 FY-89, EGG-WM-8530, May.

Schmaltz, B. L., 1972, Radionuclide Distribution in Soil Mantle of the Lithosphere as a Consequence of Waste Disposal at the National Reactor Testing Station, IDO-10049, October.

Sisson, J. B., 1990, Preliminary Analysis of the 2 Week VVED Test, ERP-VVED-50.

Sisson, J. B. and G. C. Ellis, 1990, Summary Report of Results of the Vapor Vacuum Test at the RWMC, EGG-WM-9301, November.

Tkachyk, J. W., P. D. Ritter, R. N. Wilhelmsen, 1988, Annual Report - 1987 Environmental Surveillance for the EG&G Idaho Radioactive Waste Management Areas at the Idaho National Engineering Laboratory, EGG-2550, August.

Tkachyk, J. W. et al., 1989, Annual Report - 1988 Environmental Monitoring for EG&G Idaho Facilities at the Idaho National Engineering Laboratory, EGG-2564, August.

Tkachyk, J. W., K. C. Wright, R. N. Wilhelmsen, 1990, Annual Report - 1989 Environmental Monitoring for EG&G Idaho Facilities at the Idaho National Engineering Laboratory, EGG-2612, August.

Van Genuchten, M. T. H., 1978, Calculating the Unsaturated Hydraulic Conductivity with a New Closed Form Analytical Model, Research Report No. 78-WR-08, Princeton University, Department of Civil Engineering.

Vigil, M. J., 1989, Subsurface Disposal Area (SDA) Waste Identification (1952-1970 Emphasis), EG&G-WM-8727, September.

Walker, F. W., D. G. Miller, F. Feiner, 1983, Chart of the Nuclides, General Electric, Inc.

Wang, J. S. Y. and T. N. Narasimhan, 1985, Hydrologic Mechanisms Governing Fluid Flow in a Partially Saturated, Fractured, Porous Medium, Water Resources Research, 21(12), pp. 1861-1874.

Wegner, S. J., 1989, Selected Quality Assurance Data for Water Samples Collected by the U.S. Geological Survey, Idaho National Engineering Laboratory, Idaho, 1980 to 1988, USGS Open-File Report 89-4168, DOE/ID-22085, October.

Wickham, L. E. and D. H. Janke, 1980, Annual Report - 1979 Environmental Surveillance for the INEL Radioactive Waste Management Complex, EGG-2042, December.

WINCO (Westinghouse Idaho Nuclear Co.), 1987, Procedure Manual, WINCO-186, Idaho Falls, Idaho.

Wood, T. R., 1989, Preliminary Assessment of the Hydrology at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory, EGG-WM-8694, December.