REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
12/00/85

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
CLOSURE PLAN, BASIN F, ROCKY MOUNTAIN ARSENAL

5. FUNDING NUMBERS

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

EBASCO SERVICES, INC.
DENVER, CO

8. PERFORMING ORGANIZATION REPORT NUMBER

85347R01

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

ROCKY MOUNTAIN ARSENAL (CO.). PMRMA
COMMERCE CITY, CO

DTIC
ELECTE
MAR 03 1995
S G D

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

ROCKY MOUNTAIN ARSENAL SUBMITTED A REVISED PART B PERMIT APPLICATION TO THE COLORADO DEPARTMENT OF HEALTH ON NOVEMBER 28, 1985. THE CDH INFORMED THE RMA OF THE AGENCY'S DISAPPROVAL OF THE CLOSURE PLAN FOR BASIN F. THE REVISED BASIN F CLOSURE PLAN INCORPORATES ALL REQUIREMENTS STATED IN THE COLORADO HAZARDOUS WASTES MANAGEMENT ACT REGULATIONS (PART 265 SUBPART G AND SECTION 100) AND INCORPORATES CONSIDERATION OF THE COMMENTS CONTAINED IN THE OCTOBER 17, 1985 NOTICE OF DISAPPROVAL. THIS CLOSURE PLAN IS DIVIDED INTO SIX SECTIONS: INTRODUCTION, BASIN F OVERVIEW, WASTE CHARACTERISTICS, CLOSURE PLAN PROCEDURES SCHEDULE, CERTIFICATION OF CLOSURE. AT THE CONCLUSIONS OF THESE CLOSURE ACTIVITIES, THE BASIN F WILL NO LONGER BE A POTENTIAL SOURCE OF CONTAMINATION AND WILL BE SUITABLE FOR MODIFIED UNRESTRICTED USE (I.E. THE SITE WILL BE SUITABLE FOR GENERAL USE EXCLUDING USE OF ANY CONTAMINATED GROUND WATER THAT MAY BE BENEATH THE SITE.

14. SUBJECT TERMS

WASTE INVENTORY, GROUNDWATER, INCINERATION, LINERS, SOLIDIFICATION

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

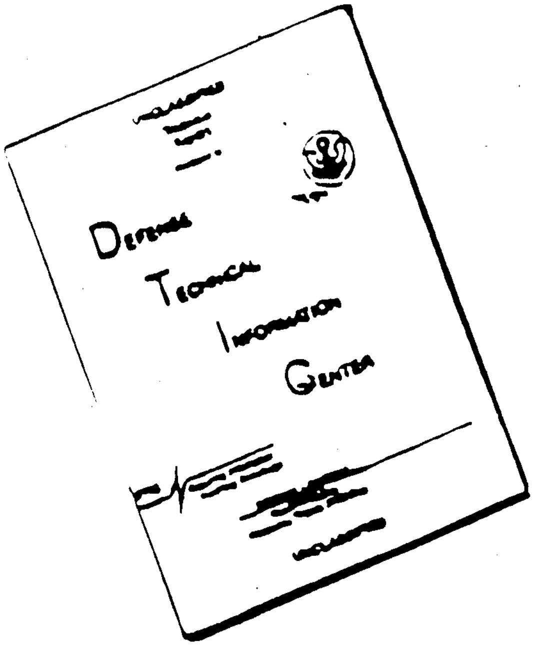
18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102


Defense
Technical
Information
Center

85347R01
ORIGINAL

CLOSURE PLAN
BASIN F

ROCKY MOUNTAIN ARSENAL

PREPARED FOR:
PROGRAM MANAGER - RMA CONTAMINATION CLEANUP

BY

EBASCO SERVICES INCORPORATED

DECEMBER 1985

FILE COPY

TABLE OF CONTENTS

Page

LIST OF TABLES iv

LIST OF FIGURES v

REGULATORY MATRIX vi

1.0 INTRODUCTION 1-1

2.0 BASIN F BACKGROUND

2.1 GENERAL DESCRIPTION AND LOCATION

2.1.1 Rocky Mountain Arsenal

2.1.1.1 Arsenal Location and History 2-1
2.1.1.2 Arsenal Geology 2-4
2.1.1.3 Arsenal Topography and Surface Hydrology 2-5
2.1.1.4 Arsenal Groundwater Hydrology 2-9
2.1.1.5 Arsenal Groundwater Quality 2-10

2.1.2 Basin F

2.1.2.1 Description and Location 2-14
2.1.2.2 Geology and Geohydrology in the Basin F Area 2-14
2.1.2.3 Groundwater Quality in the Basin F Area 2-16

2.2 BASIN F HISTORY OF USE 2-18

3.0 WASTE CHARACTERIZATION

3.1 WASTE CHARACTERISTICS 3-1

3.1.1 Basin F Liquid 3-1
3.1.2 Basin F Overburden, Liner, and Soil 3-3

3.2 CURRENT WASTE INVENTORY

3.2.1 Basin F Liquid 3-12
3.2.2 Overburden, Liner, and Contaminated Soils 3-14

3.3 DESCRIPTION OF PROCESSES GENERATING WASTES 3-15

TABLE OF CONTENTS

Page

4.0 CLOSURE PLAN

4.1 OBJECTIVES AND SCOPE OF CLOSURE PLAN 4-1

4.2 DETERMINATION OF CONTAMINATION

4.2.1 Sampling Program

4.2.1.1 Purpose 4-2
4.2.1.2 Past Sampling. 4-2
4.2.1.3 Additional Sampling. 4-3

4.2.2 Sampling Techniques

4.2.2.1 Liquids 4-4
4.2.2.2 Soils 4-4
4.2.2.3 Overburden 4-6

4.2.3 Analytical Techniques 4-7

4.2.4 Action Levels 4-8

4.3 CLOSURE PLAN ACTIVITIES

4.3.1 Overview of Closure 4-8

4.3.2 Interim Remedial Activities, Feasibility Studies and Design 4-11

4.3.2.1 Interim Remedial Activities 4-11
4.3.2.2 Basin F Waste Solidification 4-13
4.3.2.3 Conventional Incineration Technology . . 4-15
4.3.2.4 Advanced Incineration Technologies . . . 4-15
4.3.2.5 On-Post State-of-the-Art Waste Containment Facility 4-17

4.3.3 Liquid Removal, Treatment, and Disposal 4-18
4.3.4 Sediment and Liner Removal and Treatment 4-21
4.3.5 Contaminated Soil Removal 4-22
4.3.6 Equipment Decontamination and Disposal 4-23
4.3.7 Residual Disposal 4-23
4.3.8 Confirmation of Waste Removal 4-24
4.3.9 Site Restoration 4-24

TABLE OF CONTENTS

Page

4.4 REGULATORY REQUIREMENTS

4.4.1 Preclosure 4-25
4.4.2 Closure 4-25
4.4.3 Post Closure 4-27

4.5 HEALTH AND SAFETY PROGRAM 4-27

4.5.1 Management of the HASP 4-28
4.5.2 Personnel Protection 4-29

5.0 SCHEDULE 5-1

6.0 CERTIFICATION OF CLOSURE 6-1

REFERENCES

BIBLIOGRAPHY OF BASIN F REPORTS AND STUDIES FROM THE ROCKY MOUNTAIN ARSENAL INFORMATION CENTER

APPENDIX A ANALYTICAL RESULTS - BASIN F CORE SAMPLES AND OVERBURDEN

LIST OF TABLES

Table No.		Page
3-1	CHEMICAL CHARACTERIZATION OF BASIN F LIQUID (1977) . . .	3-2
3-2	VOLUME OF LIQUID CONTAINED IN BASIN F WITH RESPECT TO ELEVATION AND SURFACE AREA	3-13
4-1	PROTECTIVE CLOTHING LEVELS.	4-30
4-2	TYPES OF OPERATIONS WITH CORRESPONDING PROTECTIVE CLOTHING LEVEL	4-31

LIST OF FIGURES

Figure No.		Page
2-1	MAP OF RMA AND DENVER VICINITY	2-2
2-2	GENERAL MAP OF RMA	2-3
2-3	TOPOGRAPHIC MAP OF ROCKY MOUNTAIN ARSENAL WITH THE STANDARD PROJECT FLOOD OUTLINE SHOWN	2-7
2-4	PRECIPITATION DATA, 1977-1981, DENVER-STAPLETON AIRPORT	2-8
2-5	WATER TABLE ELEVATION, 3rd QUARTER, 1981	2-11
2-6	CHEMICAL CONTAMINATION PLUME ABOVE MANDATORY LIMITS	2-13
2-7	LOCATIONS OF DEEP BORINGS AND ASSOCIATED SHALLOW BORINGS NEAR BASIN F	2-15
2-8	WATER TABLE ELEVATIONS IN THE VICINITY OF BASIN F	2-17
2-9	VARIATION IN BASIN F LIQUID SURFACE ELEVATION	2-20
2-10	DISTRIBUTION OF DIMP AND DCPD	2-21
2-11	SCHEMATIC DIAGRAM OF BASIN F ENHANCED EVAPORATION SYSTEM	2-23
3-1	LOCATION OF BORING SITES WITHIN BASIN F	3-4
3-2	BASIN F OVERBURDEN THICKNESS (FT)	3-6
3-3	DISTRIBUTION OF SOIL TYPES IN BASIN F, 0-1 FT. BELOW THE LINER	3-7
3-4	DISTRIBUTION OF SOIL TYPES IN BASIN F, 1-2 FT. BELOW THE LINER	3-8
3-5	DISTRIBUTION OF SOIL TYPES IN BASIN F, 2-3 FT. BELOW THE LINER	3-9
3-6	CONTAMINANTS IDENTIFIED IN THE SWLP EXTRACTS OF THE SOILS IN BASIN F	3-11
4-1	EMPIRICAL CURVE TO DETERMINE BORING SPACINGS BASED ON AREA EXTENT OF SITES	4-5
4-2	CLOSURE PLAN FLOW CHART	4-10
5-1	SCHEDULE FOR CLOSURE OF BASIN F	5-2

SYNOPSIS OF GENERAL CHWMA CLOSURE REQUIREMENTS	LOCATION IN CLOSURE PLAN/COMMENTS
265.110 Applicability	
Sections 265.111-265.115 apply to the owners and operators of all hazardous waste management facilities	
265.111 Closure performance standard	
265.111(a) Must minimize need for further maintenance	Section 4.1. All wastes will be removed from site.
265.111(b) Must control, minimize, or eliminate, to the extent necessary to prevent threats to human health and the environment, post-closure escape of hazardous waste or related substances	Section 4.1. All wastes will be removed from site.
265.112 Closure plan; amendment of plan	
265.112(a) Plan must identify steps necessary to completely or partially close the facility at any point during its intended operating life and to completely close the facility at the end of its intended operating life. The plan must include at least:	Basin F is no longer active. Only residual wastes from past activities remain.
(1) A description of how and when the facility will be partially closed, if applicable, and finally closed. The description must identify the maximum extent of the operation which will be unclosed during the life of the facility, and how the requirement of Sections 265.111, 265.113-115, and the closure requirements for containers (265.178) will be met.	Section 4.3. No partial closures are anticipated, and no unclosures are expected. Section 5.0 shows closure schedule.
(2) An estimate of the maximum inventory of wastes in storage and in treatment at any time during the life of the facility.	Section 3.1.
(3) A description of the steps needed to decontaminate facility equipment during closure.	Section 4.3.
(4) An estimate of the expected year of closure and a schedule for final closure. The schedule must include the total time required to close the facility and the time required for intervening closure activities.	Section 5.0.

SYNOPSIS OF GENERAL CHWMA CLOSURE REQUIREMENTS	LOCATION IN CLOSURE PLAN/COMMENTS
265.112(b) The owner or operator may amend his closure plan at any time during the active life of the facility.	This Closure Plan represents a revision of the closure plan presented in the November 1984 Part B Permit Application.
265.112(c) The owner or operator must notify the Regional Administrator at least 180 days prior to the date he expects to begin closure.	See November 1984 Part B Permit Application.
265.113 Closure; time allowed for closure	
265.113(a) Hazardous wastes must be treated, removed, or disposed of on-site within 90 days after receiving the final volume of hazardous waste unless, in the judgment of the Regional Administrator, the activities required to comply with this paragraph will of necessity take longer than 90 days to complete, and the owner or operator has taken and will continue to take all steps to prevent threats to human health and the environment.	Section 5.0. Extended time period is required due to large volume of wastes and logistics of removing and treating liquid wastes, waste residues, and contaminated soils.
265.113(b) The owner or operator must complete closure activities within 180 days after receiving the final volume of hazardous wastes unless, in the judgment of the Regional Administrator, the activities required to comply with this paragraph will of necessity take longer than 90 days to complete, and the owner or operator has taken and will continue to take all steps to prevent threats to human health and the environment.	Section 5.0. Closure will require more than 180 days due to need for further feasibility studies, design, and implementation of closure activities. See also Section 4,3
265.114 Disposal or decontamination of equipment	
When closure is completed, all facility equipment and structures must have been properly disposed of, or decontaminated by removing all hazardous waste and residues.	Section 4.3
265.115 Certification of Closure	
Certification must be submitted by both the owner or operator and an independent professional engineer when closure is completed as specified in the approved closure plan.	Section 6.0.
265.118 Post closure plan	Not applicable as per 265.110(b) since all wastes will be removed from the Basin.
265.140 Financial requirements	Not applicable to states and federal government.

SYNOPSIS OF GENERAL CHWMA CLOSURE REQUIREMENTS		LOCATION IN CLOSURE PLAN/COMMENTS
265.228 Closure and Post-Closure of Surface Impoundments		
265.228(a)	Owner/operator may elect to remove standing liquids, waste and waste residues, liner, and underlying and surrounding contaminated soil.	Sections 4.2, 4.3. Waste materials will be removed from the impoundment.
265.228(b)	If owner/operator removes materials described above, or can demonstrate that these materials are not hazardous, then the impoundment is not further subject to the requirements of this Part.	Section 4.3. Waste materials will be removed from the impoundment.
265.228(c)	If some or all of the materials described above will be left in place, and the remaining materials are hazardous, then the owner/operator must close the impoundment and provide post-closure care as for a landfill (Section 265.310 and Subpart G, Section 265.117-120).	Not applicable.

1.0 INTRODUCTION

The Rocky Mountain Arsenal (RMA), a U.S. Army installation, has been managing a number of Resource Conservation and Recovery Act (RCRA) regulated hazardous waste facilities including Basin F. The RMA's Environmental Protection Agency (EPA) identification number as a generator and owner/operator of hazardous waste storage, treatment, and disposal facilities is C05 210 020 769.

On July 21, 1982, EPA Region VIII requested the RMA to submit a RCRA Part B permit application for the hazardous waste facilities. On May 23, 1983, the RMA submitted a draft RCRA Part B permit application, encompassing seven facilities, to EPA Region VIII. On May 10, 1984, EPA Region VIII issued a Notice of Deficiency of the application to the RMA.

On September 30, 1984, the State of Colorado received interim authorization from the EPA to administer equivalent state hazardous waste regulations in lieu of federal requirements. Under the state hazardous waste regulations, RCRA Part B permit application for which no decision had been reached by the EPA was to be resubmitted to the Colorado Department of Health (CDH), the State agency administering the hazardous waste regulations.

The RMA submitted a revised Part B application to the CDH on November 28, 1984. The CDH informed the RMA by a letter dated October 17, 1985, and received on October 28, 1985 of the agency's disapproval of the closure plan for Basin F. The CDH also indicated in that letter that the RMA is required to submit a revised closure plan for Basin F within 30 days after receipt of the Notice of Disapproval (§ 265.112(c)).

The revised Basin F Closure Plan incorporates all requirements stated in the Colorado Hazardous Waste Management Act Regulations (Part 265 Subpart G and Section 100) and incorporates consideration of the comments contained in the October 17, 1985 Notice of Disapproval. This Closure Plan is divided into six sections, summarized as follows:

- Section 1.0 - Introduction, provides an overview of Basin F closure requirements;
- Section 2.0 - Basin F, provides an overview of the sources of wastes, operating history of the facility, and pertinent site characteristics;
- Section 3.0 - Waste Characteristics, provides a waste inventory and a characterization of the wastes present in Basin F;
- Section 4.0 - Closure Plan, discusses the procedures to be employed for the closure of the Basin;
- Section 5.0 - Schedule, outlines the time frame within which the closure will be accomplished; and
- Section 6.0 - Certification of Closure, describes how the Basin F area will be certified as clean upon completion of closure activities.

The goal of this closure plan is to provide a course of action for the safe removal from the Basin of all waste materials and all hazardous constituents associated with the waste storage activities. This course of action has been designed to prevent the release of hazardous waste or hazardous constituents to the environment and to prevent any damage to human health or the environment. At the conclusion of these closure activities, the Basin F will no longer be a potential source of contamination and will be suitable for modified unrestricted use (i.e., the site will be suitable for general use excluding use of any contaminated groundwater that may be beneath the site).

2.0 BASIN F BACKGROUND

2.1 GENERAL DESCRIPTION AND LOCATION

2.1.1 Rocky Mountain Arsenal

2.1.1.1 Arsenal Location and History

The RMA occupies over 17,000 acres in Adams County, Colorado (Figures 2-1 and 2-2). The RMA is located approximately 9 to 10 miles northeast of the center of downtown Denver. Denver's Stapleton International Airport extends into the southern border of the RMA. Land use bordering the RMA includes agricultural (north and east of the RMA), light industrial manufacturing (south of the RMA), and residential (west and southeast of the RMA). Residential population within a radius of 15 miles from the west edge of the RMA totals approximately 1,500,000. This metropolitan area consists of the following Colorado cities: Denver, Aurora, Commerce City, Thornton, Northglenn, Federal Heights, Westminister, Broomfield, Arvada, Lakewood, Littleton, Englewood, Cherry Hills Village, Greenwood Village, Glendale, and the heavily populated unincorporated areas of Arapahoe, Jefferson, Boulder, and Adams County.

The property occupied by the RMA was purchased by the government in 1942. Throughout World War II, RMA manufactured and assembled chemical intermediate and toxic end-item products, and incendiary munitions. During the period 1945-1950, the Arsenal distilled available stocks of Levinstein mustard, demilitarized several million rounds of mustard-filled shells, and test fired 4.2 inch mortar rounds filled with smoke and high explosives. Also, many different types of obsolete World War II ordinance were destroyed by detonation or burning.

In 1946, certain portions of the Arsenal were leased to private industry for chemical manufacturing. The major leasee, Shell Chemical

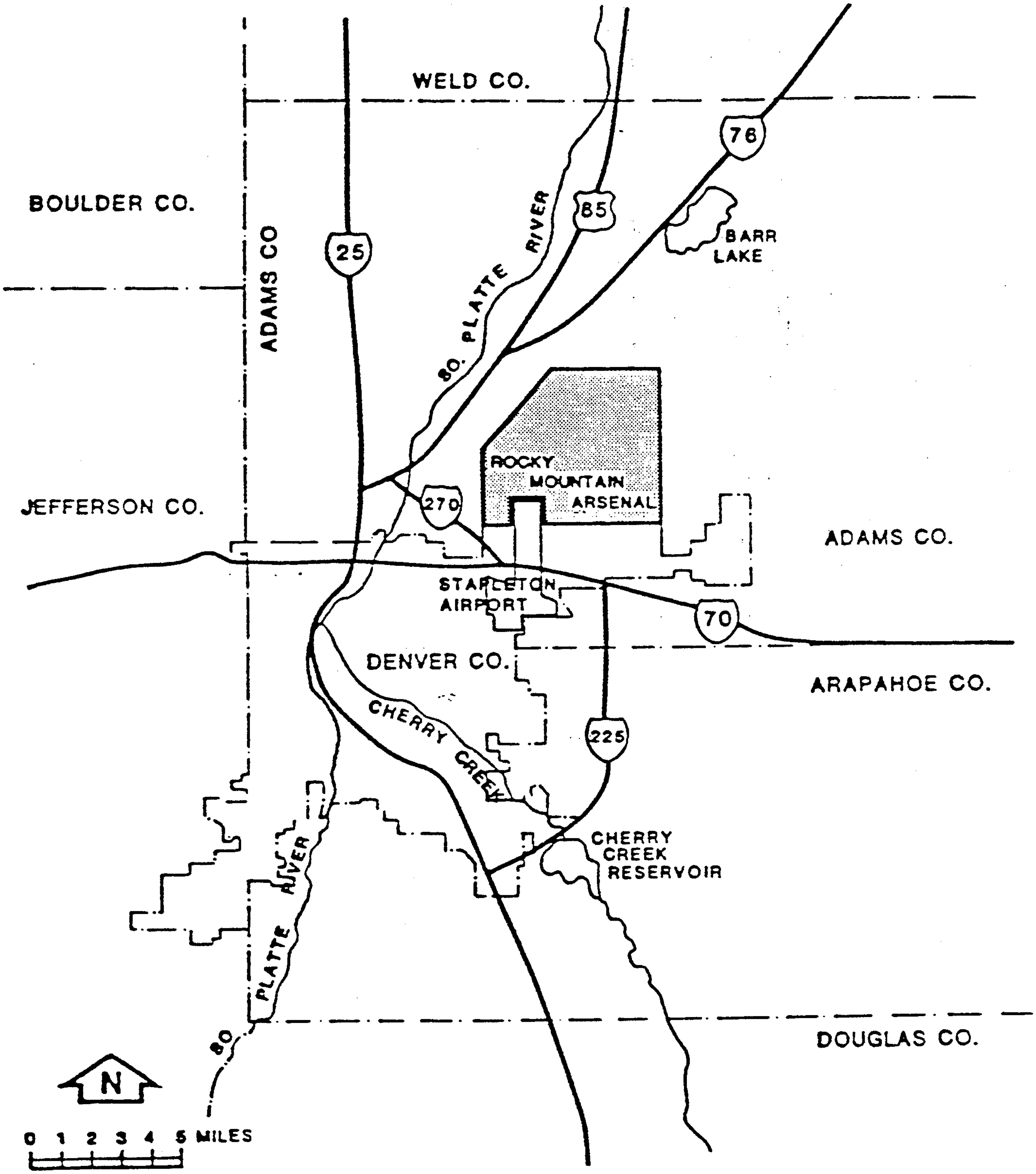


Figure 2-1: Map of RMA and Denver Vicinity (RMA Contamination Control Program Management Team, 1983)

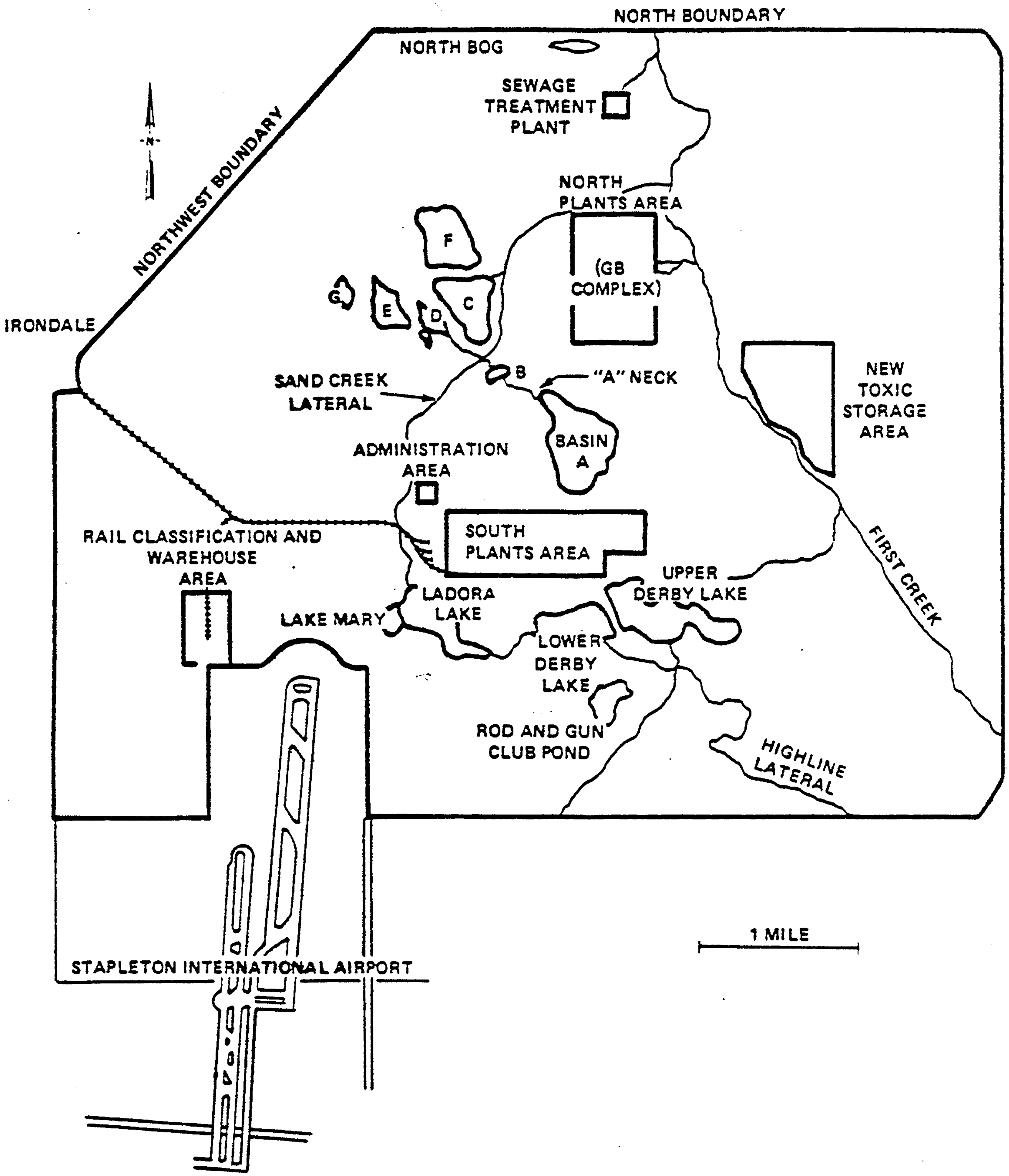


Figure 2-2: General Map of RMA (RMA Contamination Control Program Management Team, 1983)

Company (SCC), has leased a considerable portion of the manufacturing facilities at the RMA since 1952 for the manufacture of various pesticides and herbicides. Later, the RMA was selected by the Army as the site for construction of a facility to produce sarin (GB) nerve agent. This facility was completed in 1953, with the manufacturing operation continuing until 1957, and the munitions filling operations continuing until late 1969. Since 1970, the RMA has been involved primarily with the disposal of chemical warfare material. This disposal included the incineration of anti-crop agent (TX), mustard agent, explosive components, and the destruction of GB agent by caustic neutralization and incineration.

2.1.1.2 Arsenal Geology

The local stratigraphic units at the RMA are Pleistocene and Recent Alluvium (which includes a thin veneer of aeolian deposits on the topographic highs) and the underlying Denver formation. Alluvial soils (including the aeolian deposits) cover the entire Arsenal except in small areas (generally on topographic highs) where the alluvial gravel has been quarried and the underlying Denver formation is exposed. The thickness of the alluvium ranges from 9 ft to 127 ft, with the thickest alluvial deposits being found within buried channels across the Arsenal (May, 1982). The alluvium at the RMA consists of clays, silts, sands, gravel and boulders and is generally unconsolidated except in localized areas where calcium carbonate has cemented the sands and gravels into hard conglomerates. The grain size of the alluvium varies from clay size to boulders. Large boulders composed of igneous rock, chert, quartz, and petrified wood are found capping the topographic highs and in some of the deep channels on the Arsenal. Most of the finer-grained soils have been classified as ML or CL (using the Unified Soil Classification System). The sands are predominantly SM and SP and often contain gravel. The sands are lenticular and grade laterally into clays, silts, and gravels.

The Denver formation underlies the surficial alluvium (alluvial and aeolian) throughout the Arsenal. The formation within the RMA boundaries has a maximum thickness of 400 to 600 ft (May, 1982). The thickest sections are found in the south part of the Arsenal. The Denver formation under the Arsenal consists primarily of clay shale and lenticular bodies of compact sand. Thin zones of silt, clay, lignite, coal, siltstone, sandstone, and volcaniclastic sediments also occur. The clay shale in the formation is hard bentonitic and blocky in some areas of the Arsenal and more laminated and fissile in others. The laminated clay shale commonly contains carbonized leaves and wood fragments. Pyrite modules occur throughout the Denver sediment. The clay shale units can be homogeneous for a thickness of 10 to 30 ft, but usually become interbedded with thin zones of fine sand, sandstone, or siltstone. Many of the clay shales originated as delta plain deposits rich in volcanic ash. The thicker sand layers in the Denver area are composed predominantly of quartz sand grains with a matrix of silt. Some of these sand units are as thick as 50 to 60 ft and contain gravel size chert and quartz. The sands probably originated as deltaic channel deposits (May, 1982).

Additional information on the geology of the RMA, including cross-sections, is presented in a report entitled "Regional Groundwater Study of Rocky Mountain Arsenal" (May, 1982).

2.1.1.3 Arsenal Topography and Surface Hydrology

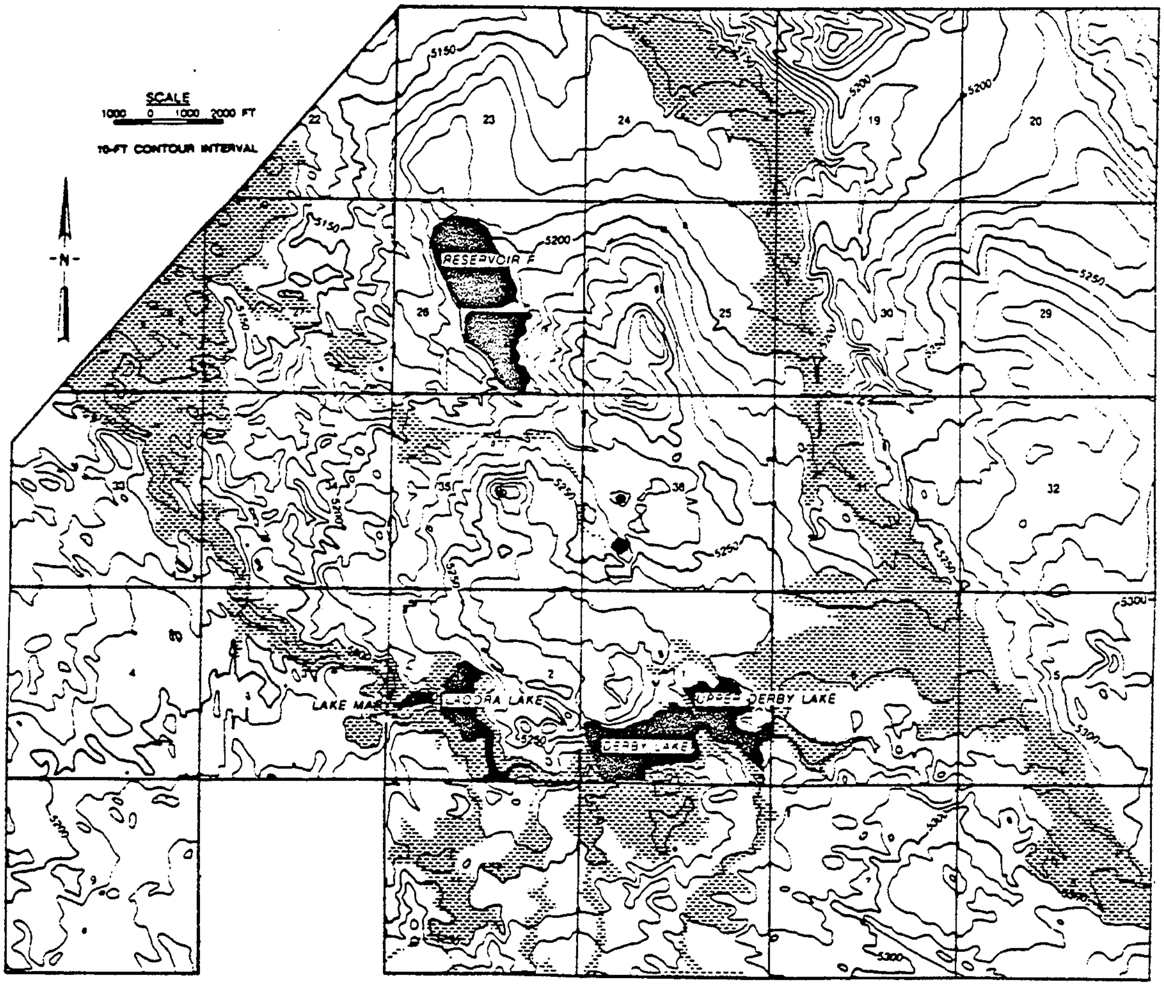
A topographical map of the RMA area is presented in Figure 2-3. Elevations range from a minimum of 5,123 ft (MSL) at the northwest boundary to a maximum of 5,323 ft (MSL) at the eastern boundary. The two prominent points or topographic highs on the Arsenal are located in Sections 25 and 35. The prevailing slope is about 0.6 percent to the northwest, therefore surface water flow is generally in that direction. Runoff is intermittent and usually follows heavy precipitation or snowmelt events. The annual precipitation for the RMA (recorded at adjoining Denver-Stapleton Airport) during 1977 to 1981 ranges from a low of 10 in. in 1977 to a little over 20 in. in 1979, (Resource Consultants Inc., 1979). This precipitation data is presented in Figure 2-4. Average annual precipitation recorded at Denver's Stapleton Airport over a period of record from 1944 to 1983 is 14.59 inches. Most of the yearly precipitation at the RMA occurs between March and August of each year.

By comparison, average evaporation rates (for pure water) are higher than precipitation rates. Average monthly evaporation rates in inches for the period from 1959-1978 are as follows:

Jan.	0.80	May	6.96	Sept.	6.52
Feb.	1.00	June	8.68	Oct.	4.46
Mar.	1.74	July	9.54	Nov.	2.20
Apr.	4.34	Aug.	8.78	Dec.	1.00

The annual average evaporation rate is over 56 inches or more than 40 inches greater than the average precipitation. It must be noted that evaporation of Basin F liquids does not necessarily reach the levels encountered with fresh water. For example, a 1969 study estimated the annual evaporation rate from Basin F to be 1.25 gpm per acre or about 24 inches (Buhts et al., 1979). It is likely that, due to concentration of the liquids over time, this evaporation rate is somewhat less than this value at the present time.

The two major watersheds which contribute runoff to the Arsenal are First Creek and Irondale Gulch. First Creek is a well defined channel that crosses the Arsenal. At times, the creek is intermittent with some flow coming from the sewage treatment plant in the northeastern part of the Arsenal. At other times, such as during the spring and during major storm events, the flow is continuous and has even caused some flooding on the Arsenal. Irondale Gulch has poorly defined channelization because the drainage area is smaller and because drainage patterns have been modified by the construction of



TOPOGRAPHIC MAP OF ROCKY MOUNTAIN ARSENAL WITH THE STANDARD PROJECT FLOOD OUTLINE SHOWN

Figure 2-3: Topographic Map of Rocky Mountain Arsenal with the Standard Project Flood Outline Shown

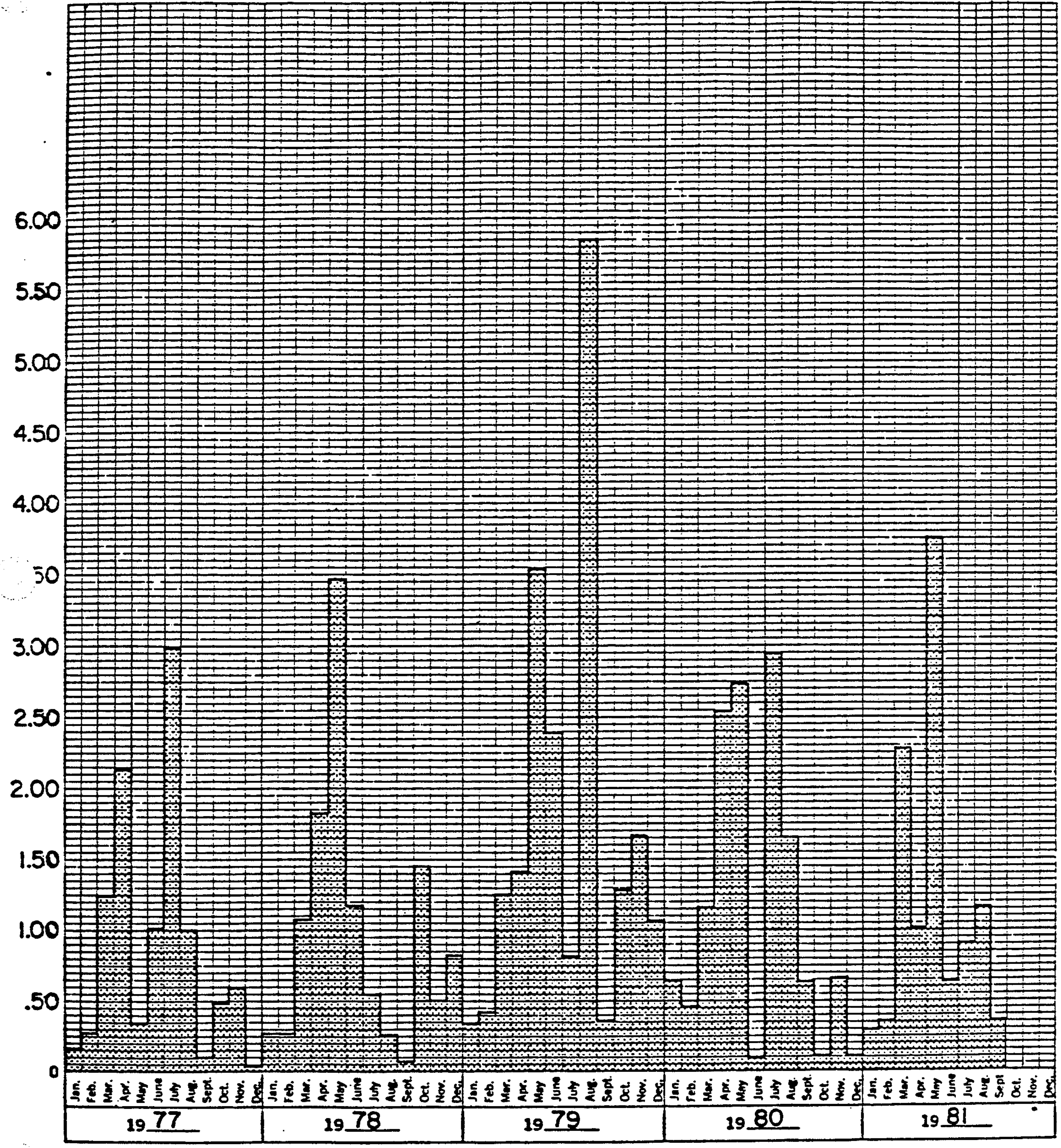


Figure 2-4: Precipitation Data, 1977 - 1981, Denver Stapleton Airport (Resource Consultants, Inc. 1982)

subdivisions (southeast of the Arsenal), the South Plants lakes, man-made channels, and storm drains. Other drainages also bring some water onto the Arsenal. Second Creek crosses near the extreme northeast corner of the Arsenal and Stapleton Airport drains a limited amount of water onto the Arsenal. Surface water drainage off the Arsenal occurs primarily in First and Second Creeks.

Additional information on the topography and surface hydrology of the RMA is presented in a report entitled "Surface Water Hydrologic Analyses, Rocky Mountain Arsenal, Colorado" (Resource Consultants, Inc., 1982).

2.1.1.4 Arsenal Groundwater Hydrology

The complex depositional history of the Denver formation and the alluvium has resulted in an equally complex groundwater regime at the RMA. The extent and geometry of the Denver formation is such that many of the groundwater recharge areas for the formation (off the Arsenal) are at higher elevations than the Arsenal. This situation provides the necessary hydraulic gradients for artesian conditions in the Denver aquifers at the RMA. Under artesian conditions, the groundwater in the Denver strata flows laterally up-dip and discharges into the alluvium.

A water table contour map constructed from third quarter 1981 data is shown in Figure 2-5. As indicated by the map, the regional water table gradients across the Arsenal are to the northwest. One of the most significant features on the map is the groundwater mound under the South Plants area (over 5,250 ft elevation). The mound has been present since 1957 and is probably due to leaking pipes in the area. Attempts have been made recently to repair the leaking pipes and reduce the mound. Intermittent operation of high capacity pump wells immediately outside the Arsenal boundaries cause periodic fluctuations in the adjacent water table on the Arsenal.

The primary alluvial groundwater flow routes are presented in Figure 2-5. The thickness of the arrow is intended to represent the amount of groundwater flow in that direction. The largest flow moves west and northwest from a point south of the South Plants lakes. The flow towards the north boundary of the Arsenal is smaller.

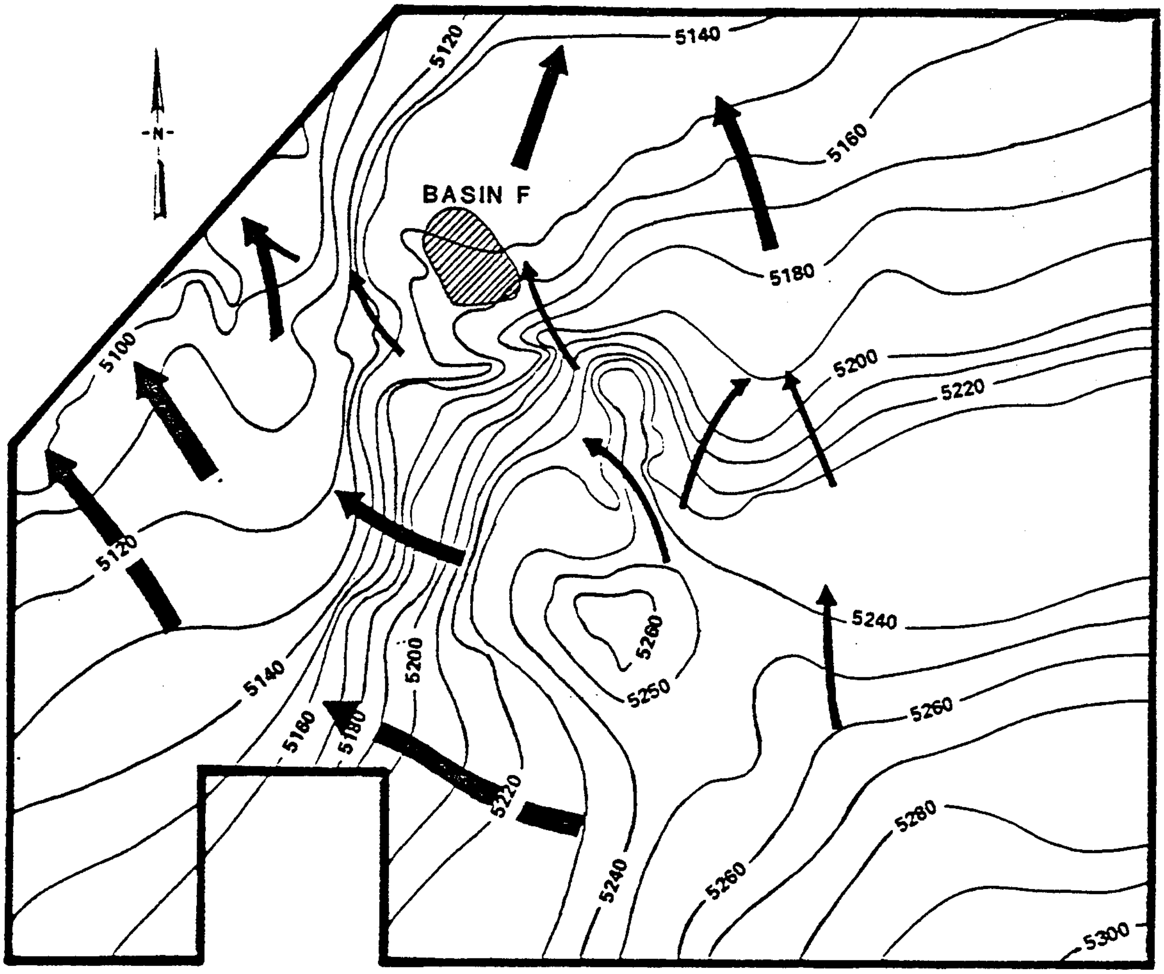
Denver sand units are in contact with the alluvium in many areas. Many of these sands are thin lenticular, however there are some thick water-bearing sands in contact with the alluvium particularly in the area of Basin F and northwest of Basin A. These sands could be making a significant contribution to groundwater flow in the alluvium in these areas.

In general, the alluvial water table throughout most of the Arsenal is controlled by the artesian head pressures from the Denver formation and remains fairly constant. The major features on the Arsenal that produce major localized, periodic or continual fluctuations in the water table with respect to inflow are the mound in the South Plants, the South Plants lakes, and First Creek.

Additional information on the groundwater hydrology at the RMA is presented in a report entitled "Regional Groundwater Study of Rocky Mountain Arsenal" (May, 1982).

2.1.1.5 Arsenal Groundwater Quality

Monitoring of groundwater quality at the RMA was intiated in the 1950's as a result of complaints by farmers pumping groundwater for irrigation purposes north and northwest of the Arsenal. Analysis of the water indicated high concentrations of chlorides. Data collected during this period of time was assembled and illustrated using isoconcentration maps. The maps indicated that Basin A was probably the major source of the chloride and that it migrated to the northwest through the "A-Neck" area (Figure 2-2) where it split, with one component proceeding west



Note: Arrows indicate direction and relative magnitude of groundwater flow.

Figure 2-5: Water Table Elevation, 3rd Quarter, 1981 (RMA Contamination Control Program Management Team, 1983) and then northwest exiting the northwest boundary of the arsenal, and the other component proceeding north through what is now the Basin F area and exiting the north boundary of the arsenal. The concentrations of chloride found in these plumes were far in excess of the natural concentrations found in the area.

In the years since, additional contaminants known to be associated with Arsenal activities have been added to the analytical parameter list for monitoring. This monitoring has indicated several key sources of contaminants on the Arsenal including the South Plants, Basin A, Basin F, and the Rail Classification Yard. To summarize the extent of and migration pathways of the contaminants, a composite plume map has been prepared. This map, presented in Figure 2-6, illustrates the distribution of some key chemical species in the groundwater of the Arsenal, including Diisopropylmethlylphosphonate (DIMP), Dibromochloropropane (DBCP), and Dicyclopentadiene (DCPD). In addition, significant concentrations of organic contaminants associated with the production of pesticides and herbicides have been found in the groundwater in the South Plants area. As indicated by the map, the major migration pathways from the interior of the Arsenal to the northwest and north boundaries have not changed since the 1950's when chloride monitoring was initiated. The plumes in the southwest corner of the Arsenal are the result of recent monitoring and represent concentrations of DBCP which appears to be originating in the Rail Classification Yard and migrating to the northwest. As expected, these pathways tend to follow the major groundwater flow paths as previously illustrated in Figure 2-4. Additional information on the groundwater quality and potential contamination sources at the RMA is presented in a report entitled "Selection of Contaminant Control Strategy for RMA" (RMA Contamination Control Management Team, 1983).

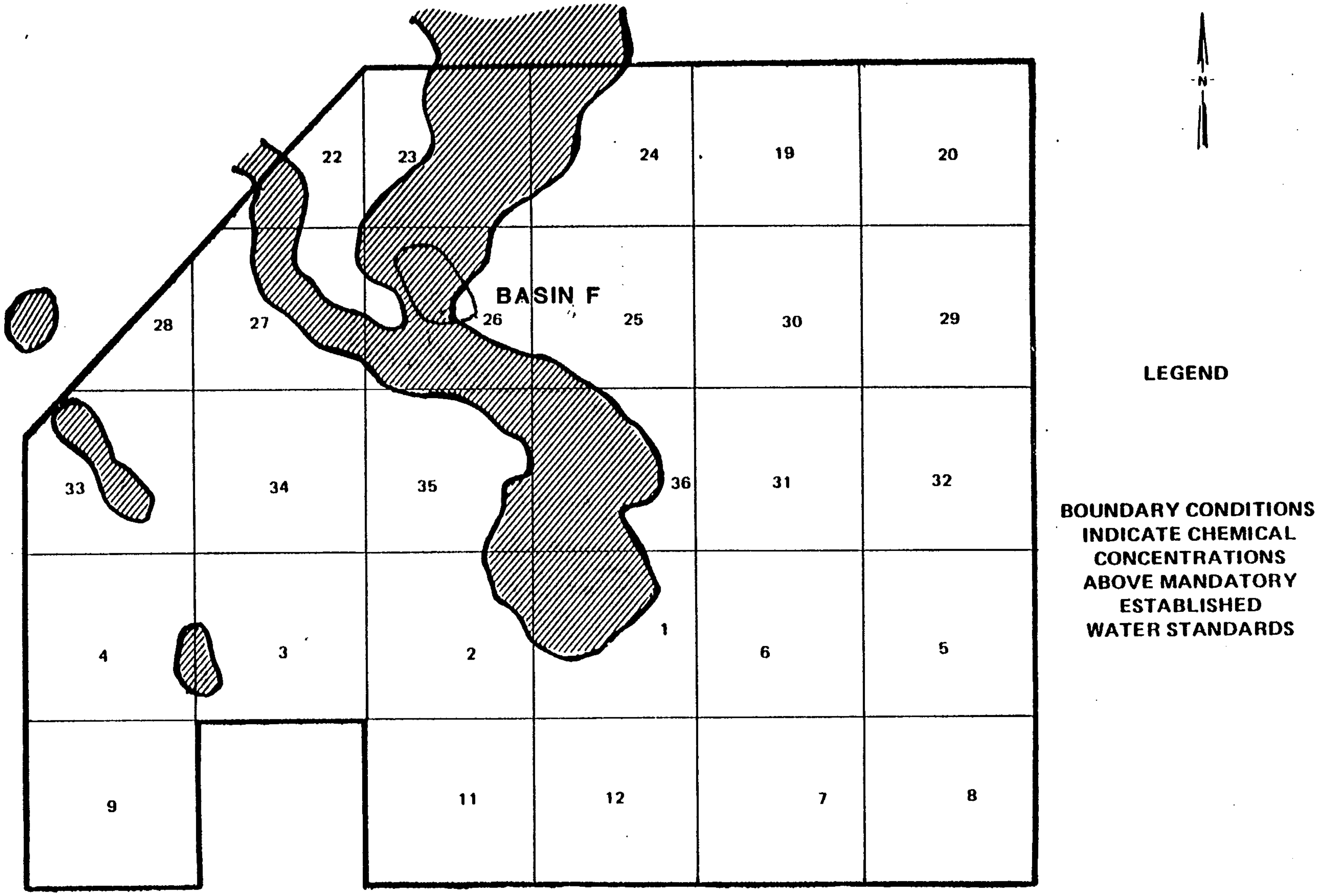


Figure 2-6 Chemical Contamination Plume Above Mandatory Limits (RMA Contamination Control Program Management Team, 1983)

2.1.2 Basin F

2.1.2.1 Description and Location

Wastes and waste streams from the various chemical processing operations conducted at the RMA since its establishment in 1942 were discharged into unlined evaporation basins (surface impoundments) identified as Basins A-E until an asphalt-lined evaporation basin designed for total retention was completed in 1956. This basin, designated Basin F, is located in the northwest part of the Arsenal in Section 26 (see Figure 2-2). The Basin as designed had a surface area of 90 acres at the maximum fluid level with a capacity of approximately 243 million gallons. The basin, roughly oval in shape, was created in a natural depression by constructing a dike around the area. It measured approximately 2,900 ft across at the north end and 1,600 ft across at the south end. As designed, the average depth of the basin was approximately 10 ft. An asphaltic membrane (approximately 3/8 inches thick) was placed on the bottom of the basin extending to a projected high water elevation of 5,200 ft (MSL) at the edge of the sealed area. After the asphalt had been placed, an earth blanket approximately one foot thick was placed on top of the membrane to protect it. A vitirified clay chemical sewer line with chemically resistant sealed joints was installed between the industrial facilities where the wastes were generated and Basin F to facilitate the transfer of liquid wastes to the Basin. In 1962, a low dike was placed across the southeast corner of the basin enclosing an area of approximately eight acres. This area is commonly referred to as "Little F".

2.1.2.2 Geology and Geohydrology in the Basin F Area

Detailed information on the geology and geohydrology in the Basin F area was obtained from studies conducted from 1977 to 1979 which involved the placement of numerous borings around Basin F (see Figure 2-7) (Buhts, et al., 1979; U.S. Army Engineer Waterways

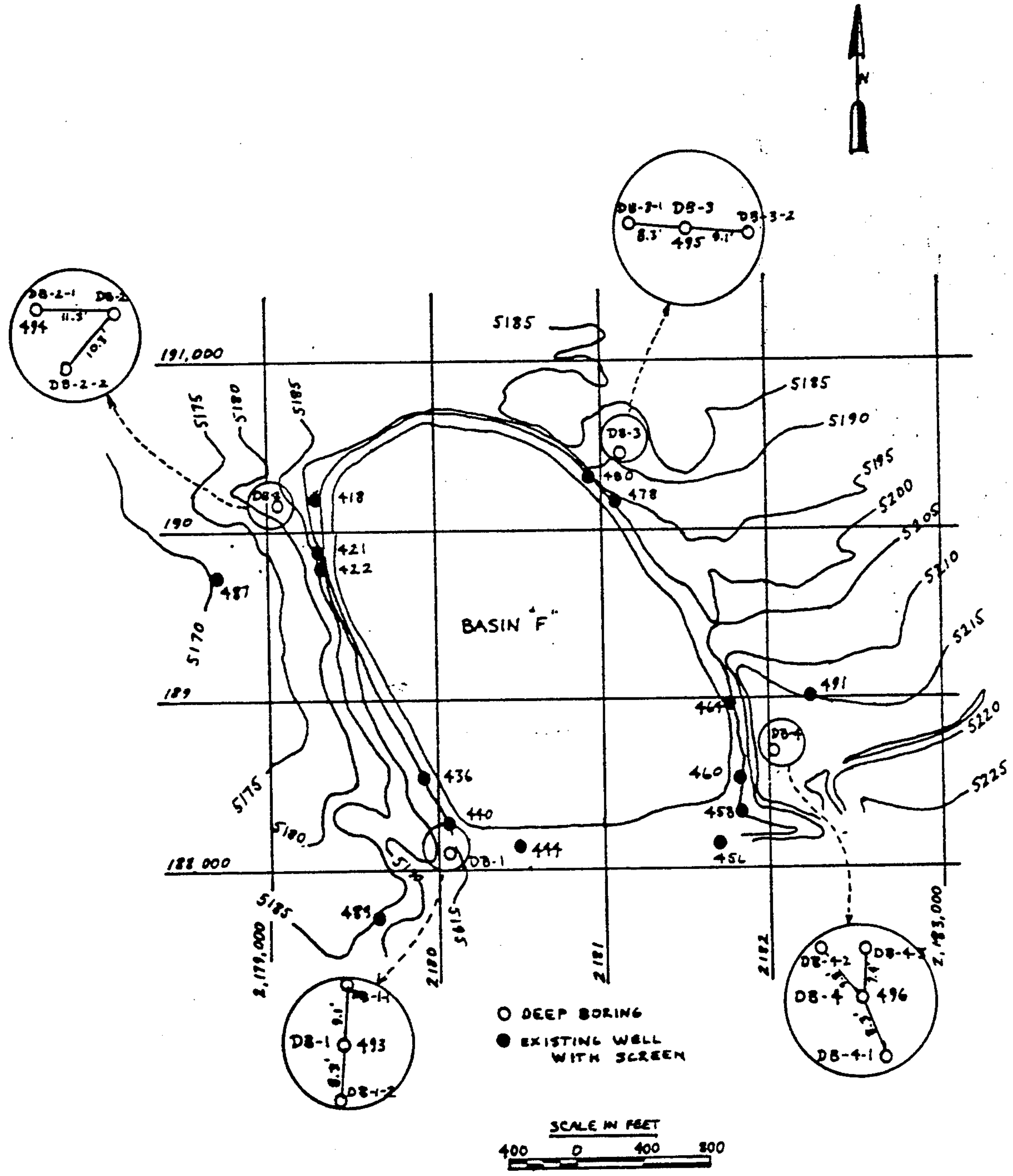


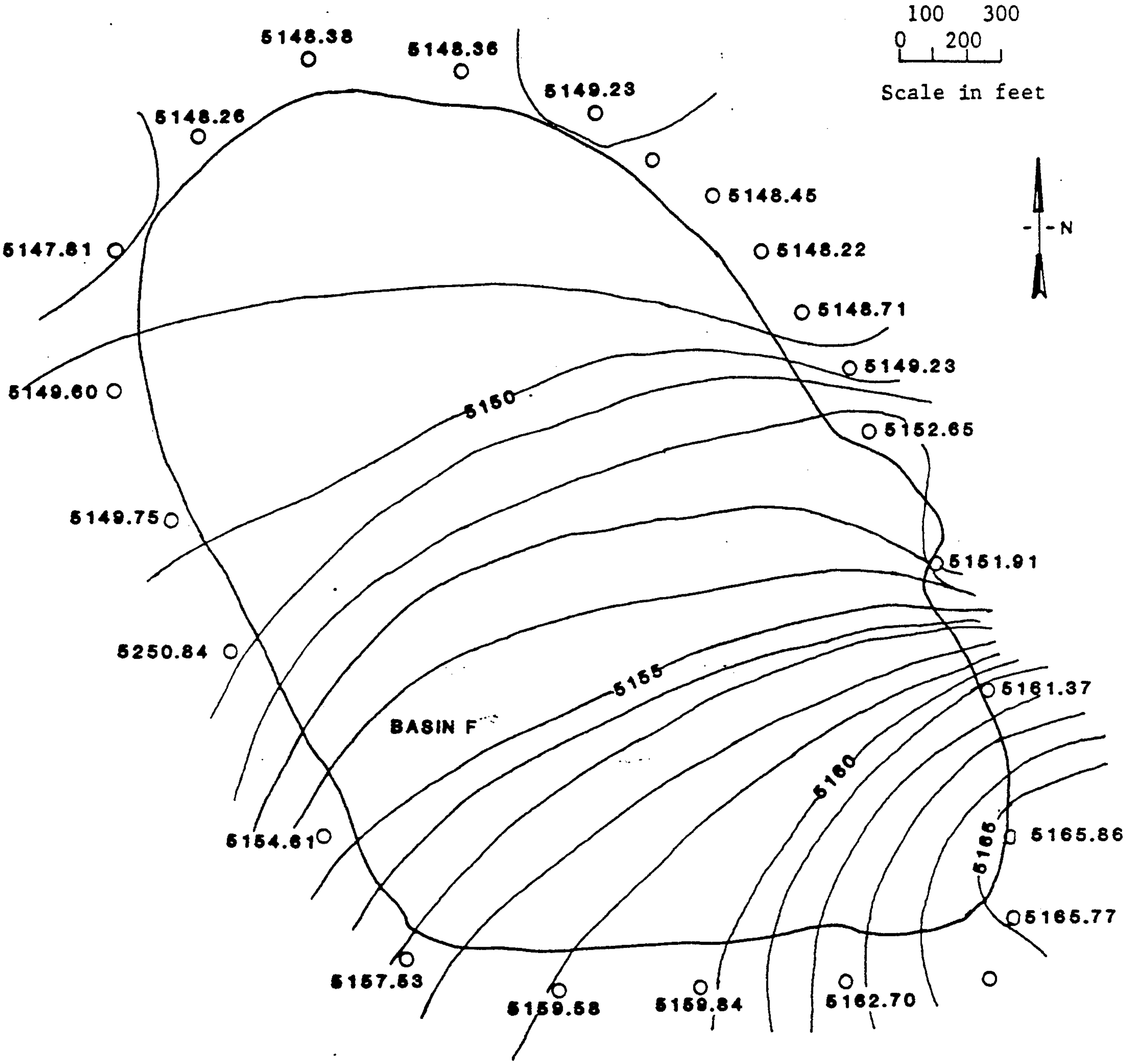
Figure 2-7: Locations of Deep Borings and Associated Shallow Borings Near Basin F (BUHTS, ET AL., 1979)

Experiment Station Geotechnical Laboratory, 1979). The alluvium has been found to range in thickness from 32 ft at boring Deep Boring #1 (DB-1) to 40 ft at boring DB-3. The alluvium in this area consists of silty sands, clayey silts, clayey sands, and silty to clayey gravels. A few thin clay lenses and some cemented materials were also found. The first stratum encountered in the Denver formation in each boring was generally a clay shale. Underlying this first stratum were various layers or lenses of clay or clay shales, sand, siltstone, and sandstone, all of variable thicknesses. In the Basin F area, the surface of the Denver formation appears to have little relief and slopes generally to the north truncating strata that surface at the Denver-Alluvium contact in that area.

A detailed water table contour map, Figure 2-8, was prepared based on data collected from a number of perimeter observation wells. The water table drops approximately 17 ft in elevation from south to north across the basin. The steepest gradient occurs in the southeast corner of the basin indicating an area of lower permeability. The saturated thickness in the alluvium under the basin was found to be 5 ft or less. The flow of groundwater beneath the basin has been estimated at approximately 50 gpm. The principal flow component beneath the basin is in a northwesterly direction. A groundwater divide occurs at the north end of the basin resulting in two major flow components out of the basin area, one towards the northwest and the other towards the northeast. The northwest component continues toward the northwest boundary of the Arsenal while the northeast component turns to the north and continues toward the north boundary of the Arsenal.

2.1.2.3 Groundwater Quality in the Basin F Area

At the four deep boring sites identified in Figure 2-7, multiple well screens were placed in water bearing sands located in the Denver area. Groundwater samples were collected and analyzed for a number of contaminants associated with past Arsenal activities (U.S. Army



Note: Contour interval of 1 foot

(Source: Interim Report on Basin F, 1978)

Figure 2-8: Water Table Elevations in the Vicinity of Basin F (BUHTS, ET AL., 1979)

Engineer Waterways Experiment Station Geotechnical Laboratory, 1979). Trace quantities of chlorinated pesticides were found in a number of the samples. Otherwise the samples were generally clean with the exception of the samples taken from Deep Boring #4, peizometer #1 (DB-4-1) where significant concentrations of chloride and DIMP were identified. Groundwater samples collected from alluvial or shallow monitoring wells in the area contained much higher concentrations of contaminants than did the samples from the Denver wells (Zabel et al., 1979). These included the contaminants DIMP, DBCP, and DCPD incorporated in the composite plume map (Figure 2-6) plus others such as chlorinated pesticides, organo-sulfur compounds, chloride, and fluoride. Individual contaminant plume maps are presented in Zabel et al., 1979, and RMA Contamination Control Program Management Team, 1983.

The plume maps indicate that contaminants flow under Basin F from the A-neck area and, therefore, it is difficult to determine the amount of contaminants introduced to the groundwater by Basin F. However, the high concentrations of contaminants such as DIMP, chloride, and the organo-sulfur compounds found in the groundwater at the northeast corner of Basin F indicate that the basin is probably a significant source of these contaminants. The associated contaminant plumes extend north and northeast of Basin F towards the north boundary of the Arsenal. In summary, the groundwater in the alluvium or in Denver sands in direct contact with the alluvium in the Basin F area contains relatively high concentrations of some contaminants while the groundwater in the deeper Denver sands is generally uncontaminated.

2.2 BASIN F, HISTORY OF USE

By early 1957, approximately 60 million gallons of waste had been transferred to Basin F. This waste from Army operations consisted mainly of aqueous solutions of various sodium salts including chloride, fluoride, hydroxide, methyl phosphonate, acetate, and sulfate. As time passed, additional wastes from the on-site production of pesticides by private corporations were disposed of in the basin. These wastes included numerous inorganic and organic contaminants.

Problems associated with the storage of liquid wastes in Basin F were encountered early in its operation and were caused by wave action against the shoreline that, at the time, had not been protected by riprap. In 1957, tears in the asphalt liner were found. The contents of Basin F were pumped into Basin C, an unlined facility, while repairs were made to the Basin F liner and riprap was installed. Some of the other problems that have been discovered since construction are: (a) fluctuating liquid levels that have caused cyclical exposures of the basin floor to sunlight and weather conditions (see Figure 2-9), and (b) evidence of groundwater contamination found as a result of chemical analysis of monitoring wells immediately adjacent to the basin (see Figure 2-10).

Through the years, various studies and activities were proposed or conducted, aimed at eliminating industrial waste discharge into Basin F and accomplishing its final cleanup. An attempt was made between 1962 and 1965 to dispose of the liquid waste by injection into a deep well located adjacent to the basin. Because of a marked increase in the number and intensity of earth tremors in the Denver area, this operation was discontinued. Other disposal alternatives were evaluated, including treatment and enhanced evaporation, but none were implemented until 1982 when an enhanced evaporation system was installed. From 1978 to 1982, the primary flow of waste into Basin F was approximately 300,000 gallons per year from the Hydrazine Blending Facility, and miscellaneous Army operations, and an undetermined amount of groundwater that infiltrated into the sewer line feeding the basin.

The potential for industrial waste discharge into Basin F was eliminated in 1982 when the chemical sewer feeding the basin was excavated from a point immediately north of the South Plants Area to the southeast corner of the basin. A portion of the line from the

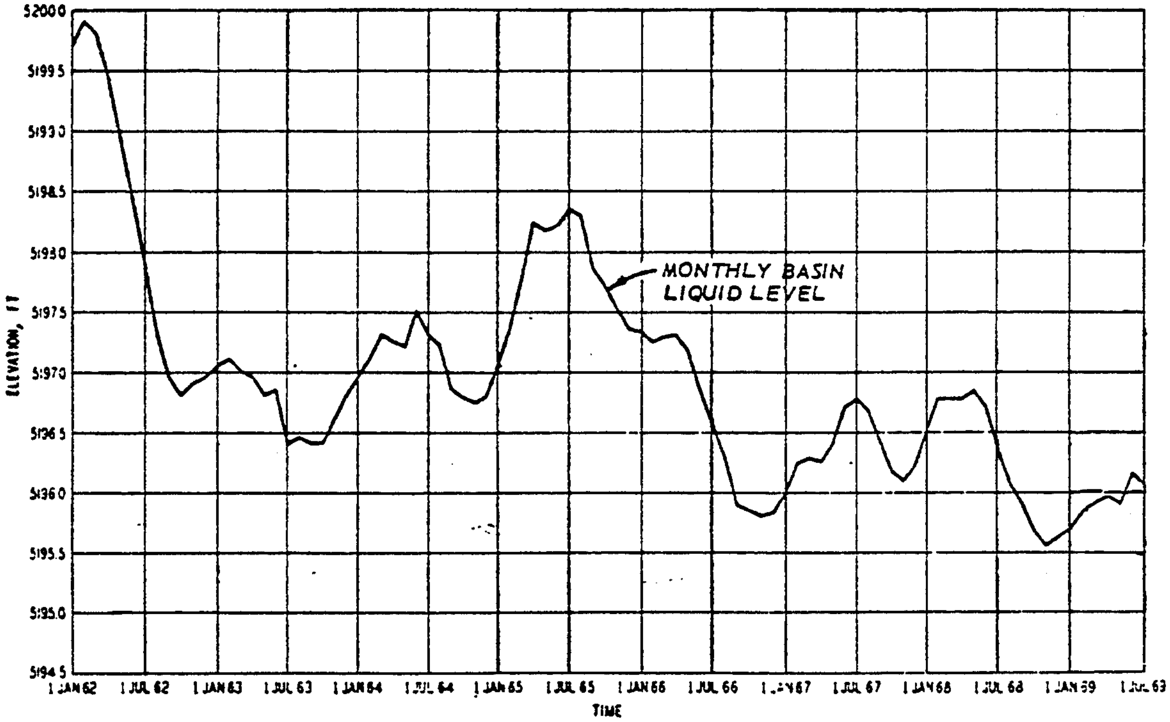
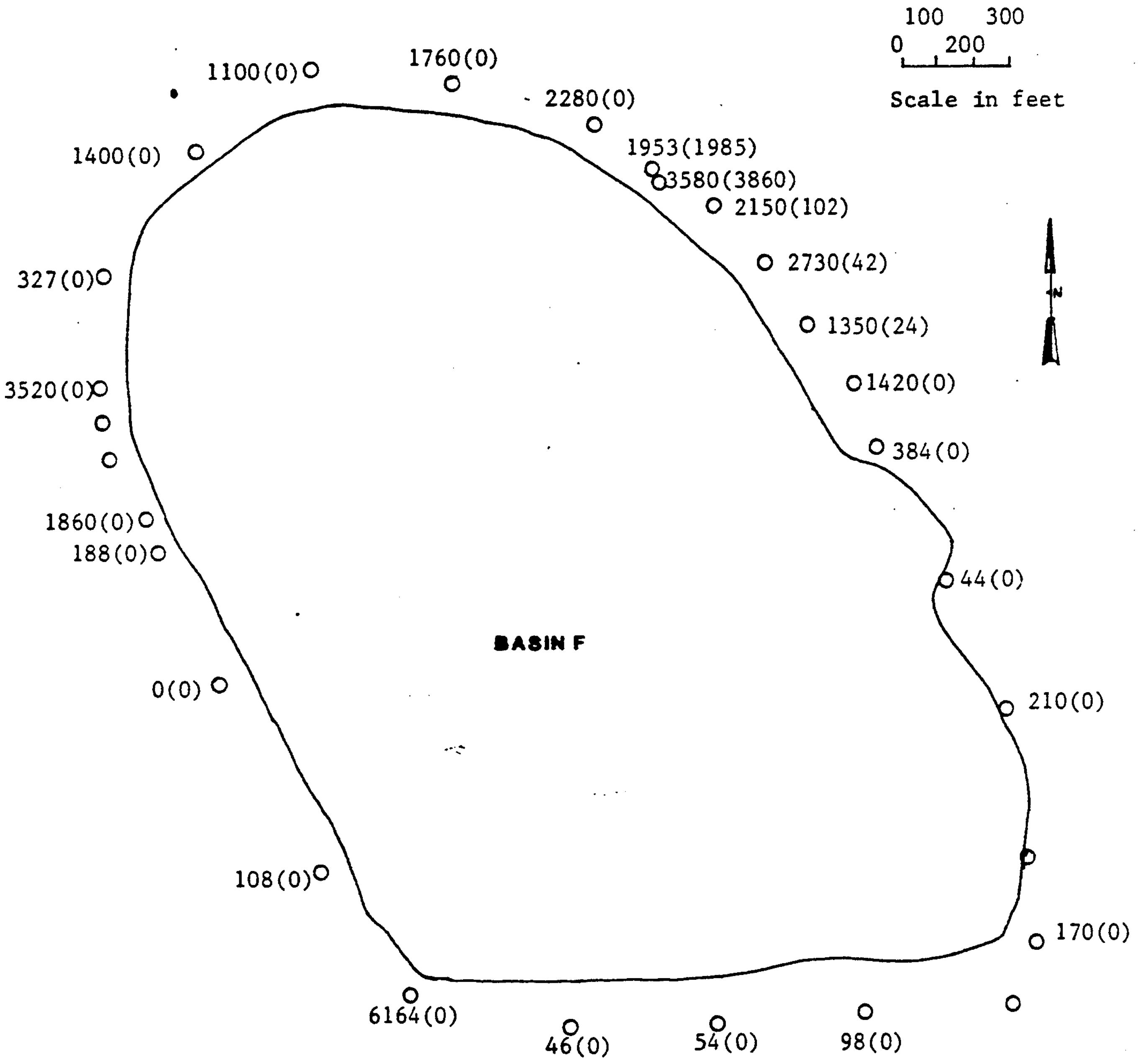


Figure 2-9: Variation in Basin F Liquid Surface Elevation (BUHTS ET AL., 1979)



Note: First number is DIMP concentration; second, in parenthesis, is DBCP.

Figure 2-10: Distribution of DIMP and DCPP (Concentrations in ppb) (BUHTS, ET AL., 1979)

North Plants Area was also excavated. The sewer line and associated contaminated soil excavated, consisting of approximately 12,000 cu yds of material, were stored in a lined waste pile in the southeast corner of Basin F.

Natural evaporation of the liquid in the basin has exceeded the inflow of waste over the past few years and therefore the volume of liquid in the basin has decreased significantly. As a result, the liquid pool has receded to the north end of the basin exposing the soil covering the liner in the southern end of the basin. An evaporation system consisting of a newly constructed dike on the exposed surface of the basin, a large pump, and a pipe network for liquid distribution was constructed in the basin to enhance evaporation of the liquid contents. A schematic of this system is presented in Figure 2-11. As designed, liquid from the existing pool is pumped through a supply line to two trickler lines which distribute the liquid over the exposed surface of the basin thus increasing the area for evaporation. Liquid from the inner trickler line will flow back into the existing pool while liquid from the outer trickler line will pond behind the new dike thus creating a new liquid pool and a larger exposed surface area for additional increased evaporation. This system was completely reconstructed during October 1985 and is now operable.

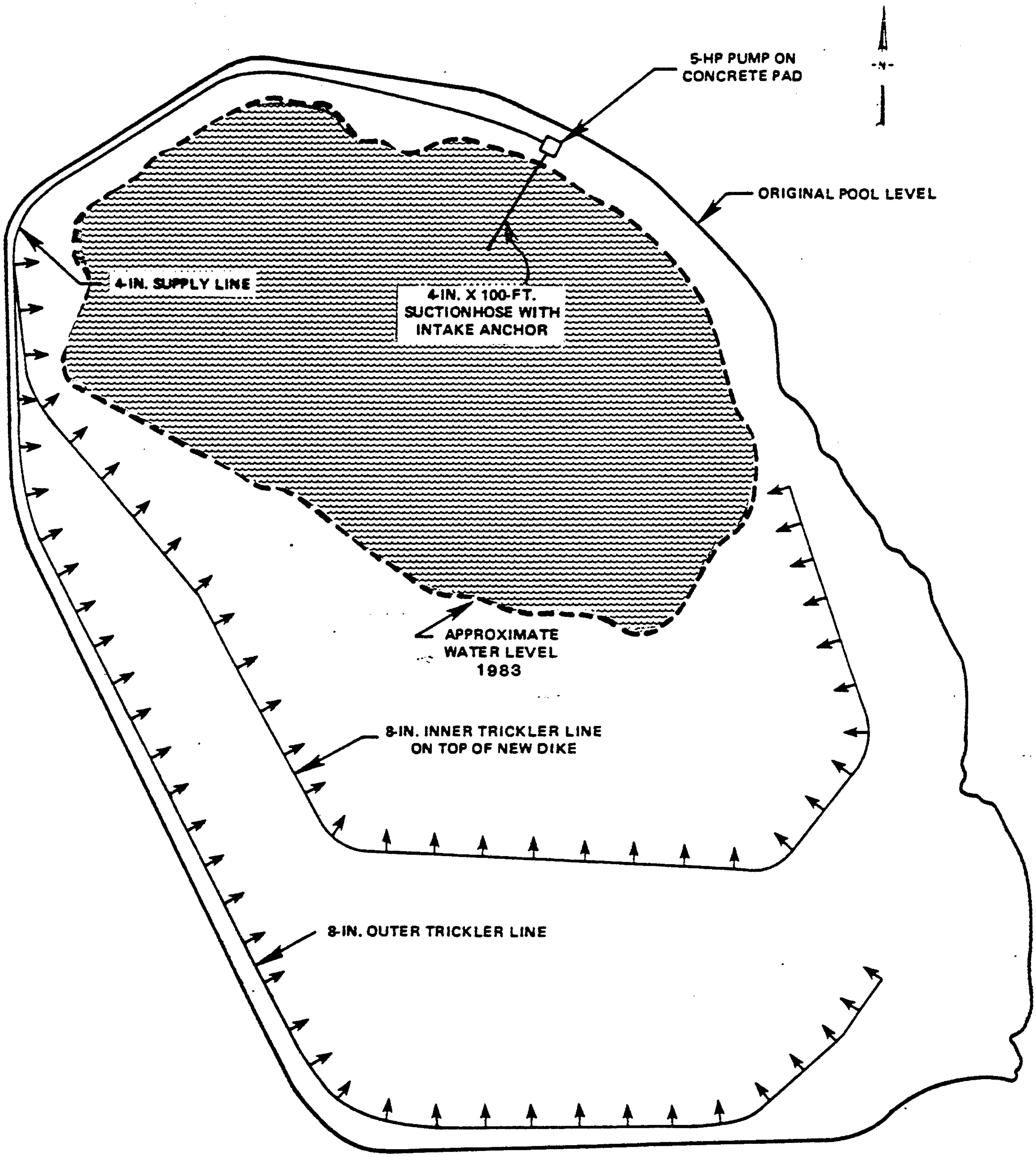


Figure 2-11: Schematic Diagram of Basin F Enhanced Evaporation System (RMA Contamination Control Program Management Team, 1983)

3.0 WASTE CHARACTERIZATION

3.1 WASTE CHARACTERISTICS

In addition to the actual liquid wastes contained within the Basin, three other categories of materials are present which may be considered waste materials. These are the Basin liner itself, the overburden above the liner (including precipitates), and any contaminated soil adjoining the Basin or beneath the liner. Overburden, liner and contaminated soils can be considered together for treatment and disposal.

3.1.1 Basin F Liquid

Numerous analyses have been conducted on Basin F liquid through the years. A comprehensive review of the previous analytical results was conducted in 1977 (Buhts et al., 1979). The results of this effort are summarized in Table 3-1. Contaminant concentrations in the liquid have likely increased since 1977 due to evaporation of water and the resulting concentration of the liquid. The liquid presently appears to be saturated with salts.

A crystalline precipitate forms in the liquid when a sample is taken and allowed to set and evaporate for a short period time. This crystalline precipitate is visible in the exposed area of the basin. As precipitation falls on the basin, some of the precipitated salts are probably redissolved thus allowing the liquid to maintain a fairly constant chemical character.

Limited testing to further define the physical characteristics of the liquid is being conducted in an ongoing study. Specific properties being evaluated include specific gravity and viscosity over a temperature range of 40°F to 100°F, and corrosivity. Physical observations have indicated that the liquid becomes very viscous at low temperatures and that the liquid is highly corrosive. Other studies,

TABLE 3-1

CHEMICAL CHARACTERIZATION OF BASIN F LIQUID

(Buhts et al., 1977)

Compound or Parameter	Units	Concentration Range*
pH	-	6.9 - 7.2
Aldrin	ppm	50.0 - 400
Isodrin	ppb	2.0 - 15
Dieldrin	ppb	5.0 - 110
Endrin	ppb	5.0 - 40
Dithiane	ppb	30.0 - 100
DIMP	ppm	10.0 - 20
DMMP	ppm	500.0 - 2,000
Sulfoxide	ppm	4.0 - 10
Sulfone	ppm	25.0 - 60
Chloride	ppm	48,000.0 - 56,000
Sulfate	ppm	21,000.0 - 25,000
Copper	ppm	700.0 - 750
Iron	ppm	5.0 - 6
Nitrogen	ppm	120.0 - 145
Phosphorus (total)	ppm	2,050.0 - 2,150
Hardness	ppm	2,100.0 - 2,800
Fluoride	ppm	110.0 - 117
Arsenic	ppm	1.0 - 1.3
Magnesium	ppm	35.0 - 40
Mercury	ppb	26.0 - 29
Cyanide	ppm	1.45 - 1.55
COD	ppm	24,500.0 - 26,000
TOD	ppm	20,500.0 - 22,500

*Based on the analysis of various samples from different locations and depths in the Basin.

described in Section 4.3.2 of this Closure Plan, will also include a more detailed analysis of the Basin F liquids. When these results become available, this Closure Plan will be updated and/or revised as necessary.

3.1.2 Basin F Overburden, Liner, and Soil

A comprehensive study of Basin F was conducted in 1982 to determine the distribution of contaminants in the overburden and in the soil underlying the liner, and to assess the condition of the liner (Myers and Thompson, 1982). This study involved the placement of 16 shallow borings in the exposed portion of the basin as indicated in Figure 3-1. At each boring location, the overburden was removed from an area approximately 2.5 ft in diameter down to the liner. Selected samples of the overburden were collected during removal. A steel caisson was placed in the hole on top of the liner to provide a clean area in which to penetrate the liner. A hole was cut in the liner large enough to permit passage of a 1.5 in. diameter split-spoon sampler. The soil beneath the liner was sampled with the split-spoon sampler by making three 1.5 ft drives at each location. This provided a continuous core 4.5 ft. long consisting of three sections. After sampling, each boring was grouted with cement to a point above the surface of the overburden to insure that the holes punched through the liner were securely sealed.

The sample cores and samples of the overburden were subjected to a series of analytic extraction procedures. Among those initially considered were EP Toxicity, solid waste leaching procedures (SWLP), and total extraction (bulk analysis). The EP Toxicity would yield a determination of whether the waste would be considered hazardous under RCRA. The SWLP is similar to the EP Toxicity Test with the exception that water with a neutral pH is used as an extract to more accurately simulate migration potential (Myers and Thompson, 1982). Bulk analyses utilize a solvent rinse to correlate the gross amount of contaminant held within the waste matrix available for potential release. It was determined that the SWLP and bulk analysis would yield sufficient information to determine the areal extent and depth of concern for contamination beneath the basin.

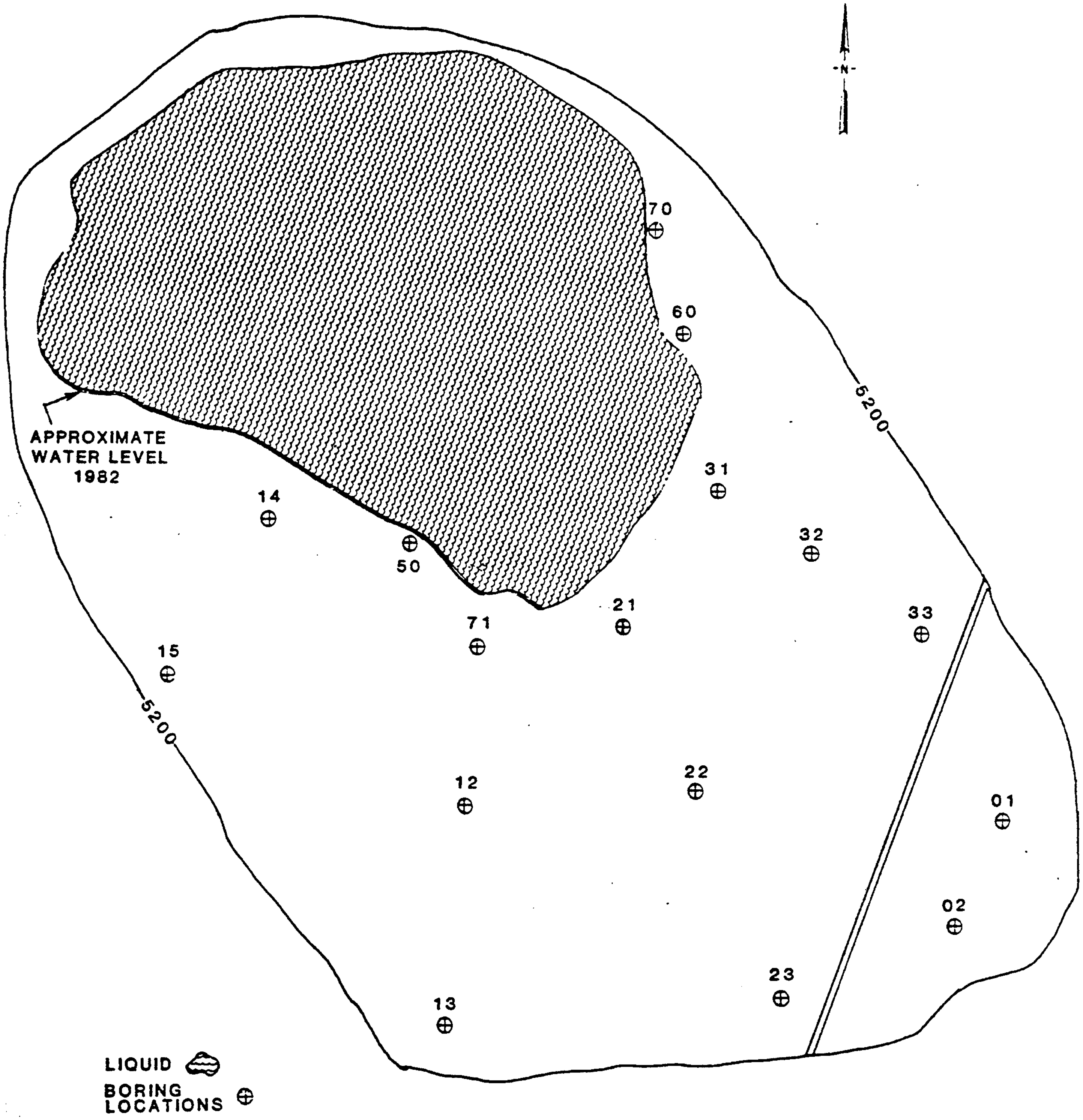


Figure 3-1: Location of Boring Sites within Basin F
(Myers and Thompson, 1982)

The overburden in the basin is composed of the original sand placed over the liner during construction plus additional material deposited on the layer through time as a result of precipitation of salts from the liquid, deposition of wind blown soil, and dumping of waste solids into the basin. In certain areas of the basin where the overburden has been exposed for long periods of time, it appears that some of the original sand cover has been lost, probably due to wind erosion. In order to provide an overall picture of the depth of overburden in the exposed portion of the basin, a contour map of depth was developed based on measurements taken during field activities. This contour map is presented in Figure 3-2. The minimum depth found was 0.65 ft. while the maximum depth found was 1.8 ft. No information was obtained on sediment depths under the existing liquid pool, however, they are likely to be as great or greater than those found in the exposed area of the basin.

During placement of the borings in the basin, the liner at each boring location was inspected and its condition noted. Over most of the basin, the liner was found to be in good condition with a reported thickness of approximately 3/8 in. The major exception was found in boring No. 2 (in "Little F") where the liner appeared to have been liquified and dispersed making it difficult to identify.

The soil cores taken in the basin were field classified using the Unified Soil Classification Systems (USCS). To illustrate the variations in soil types found with depth, a series of three horizontal cross-sections were prepared delineating the soil classification in the intervals 0-1 ft, 1-2 ft, and 2-3 ft. The horizontal cross-sections are presented in Figures 3-3, 3-4, and 3-5, in which specific soil groups are identified using a standard symbol. The predominant soil groups identified include silty clays, inorganic silts, and inorganic clays. Inorganic clays become more predominant with increasing depth. All of the soil types identified provide some capacity for holding-up or retaining contaminants since they are fine grained or contain clay or both.

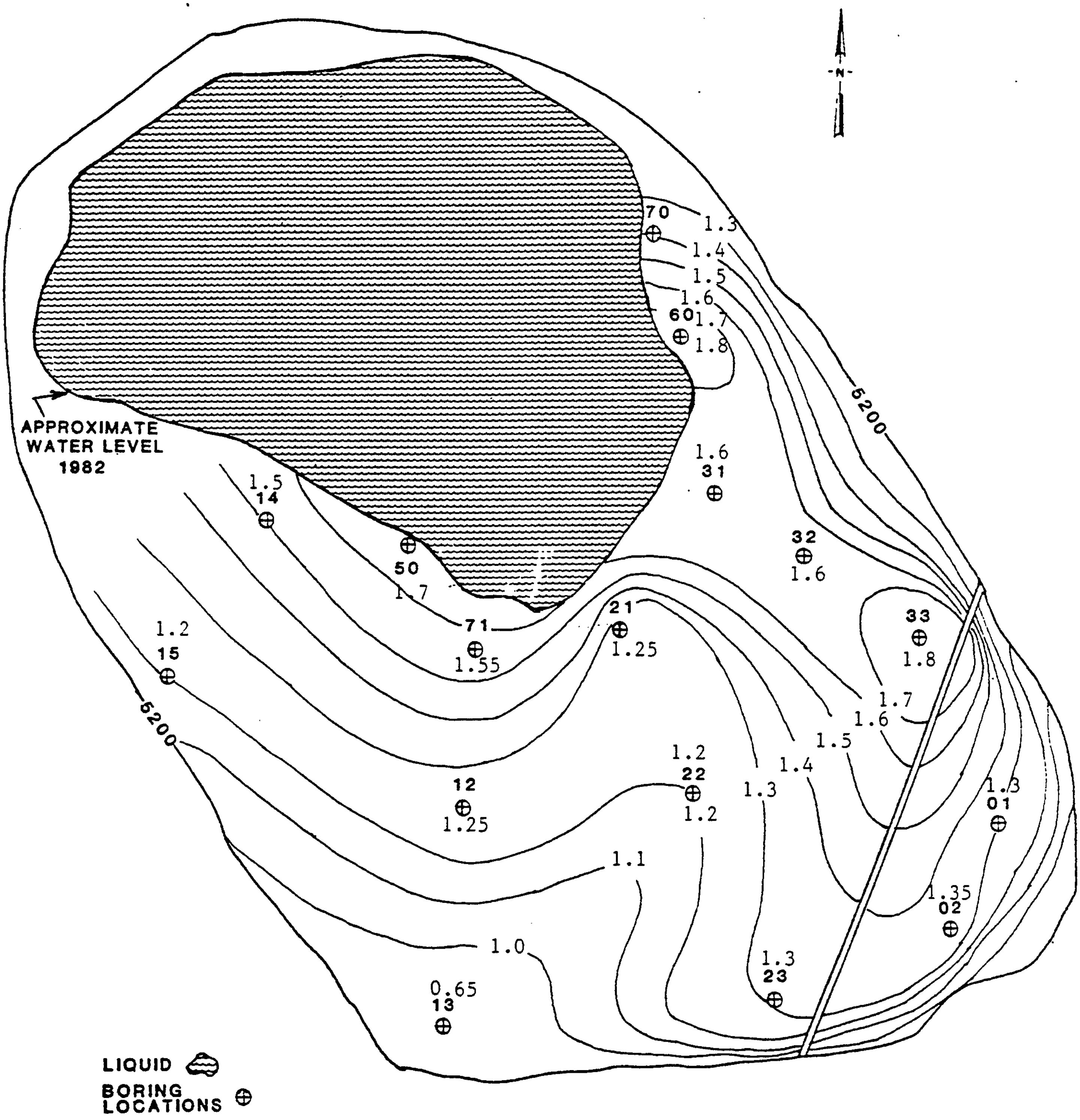


Figure 3-2: Basin F Overburden Thickness (ft) (Myers and Thompson, 1982)

BASIN F SUBLINER SOILS: 0-1 FT INTERVAL

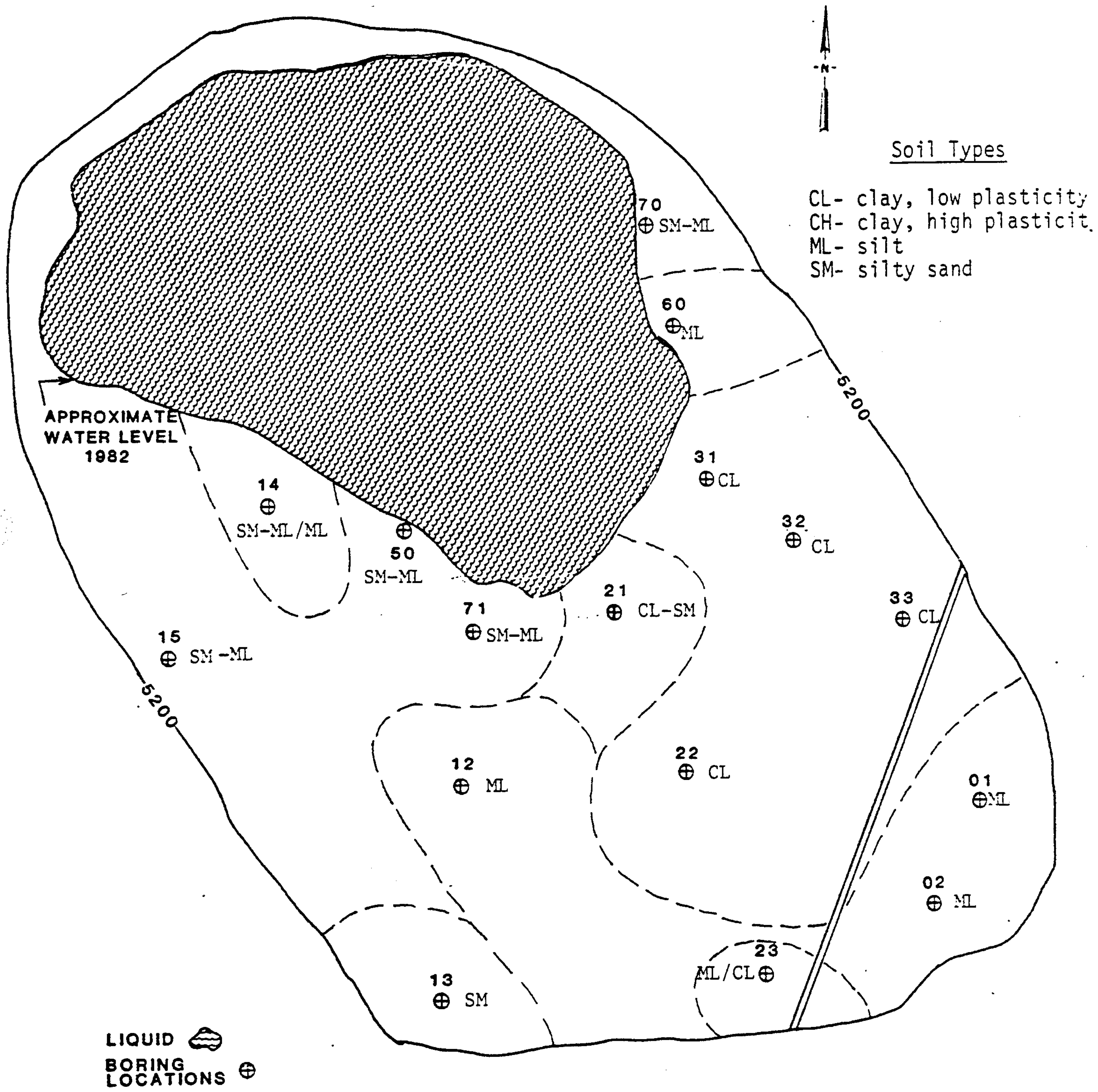
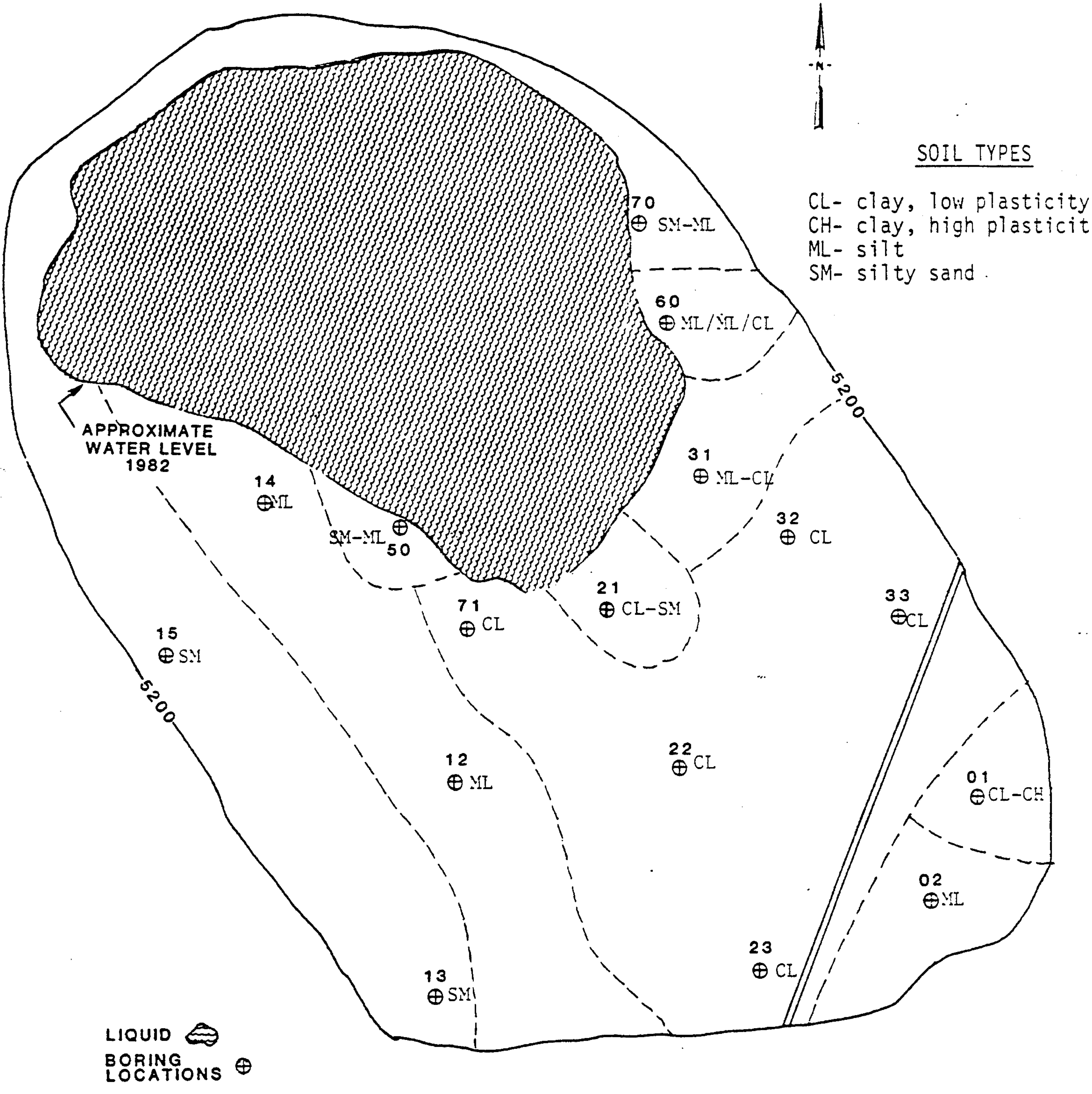


Figure 3-3: Distribution of Soil Types in Basin F, 0.0-1.0 ft Below the Liner (Myers and Thompson, 1982)



BASIN F SUBLINER SOILS: 1-2 FT INTERVAL

Figure 3-4: Distribution of Soil Types in Basin F, 1.0-2.0 ft Below the Liner (Myers and Thompson, 1982)

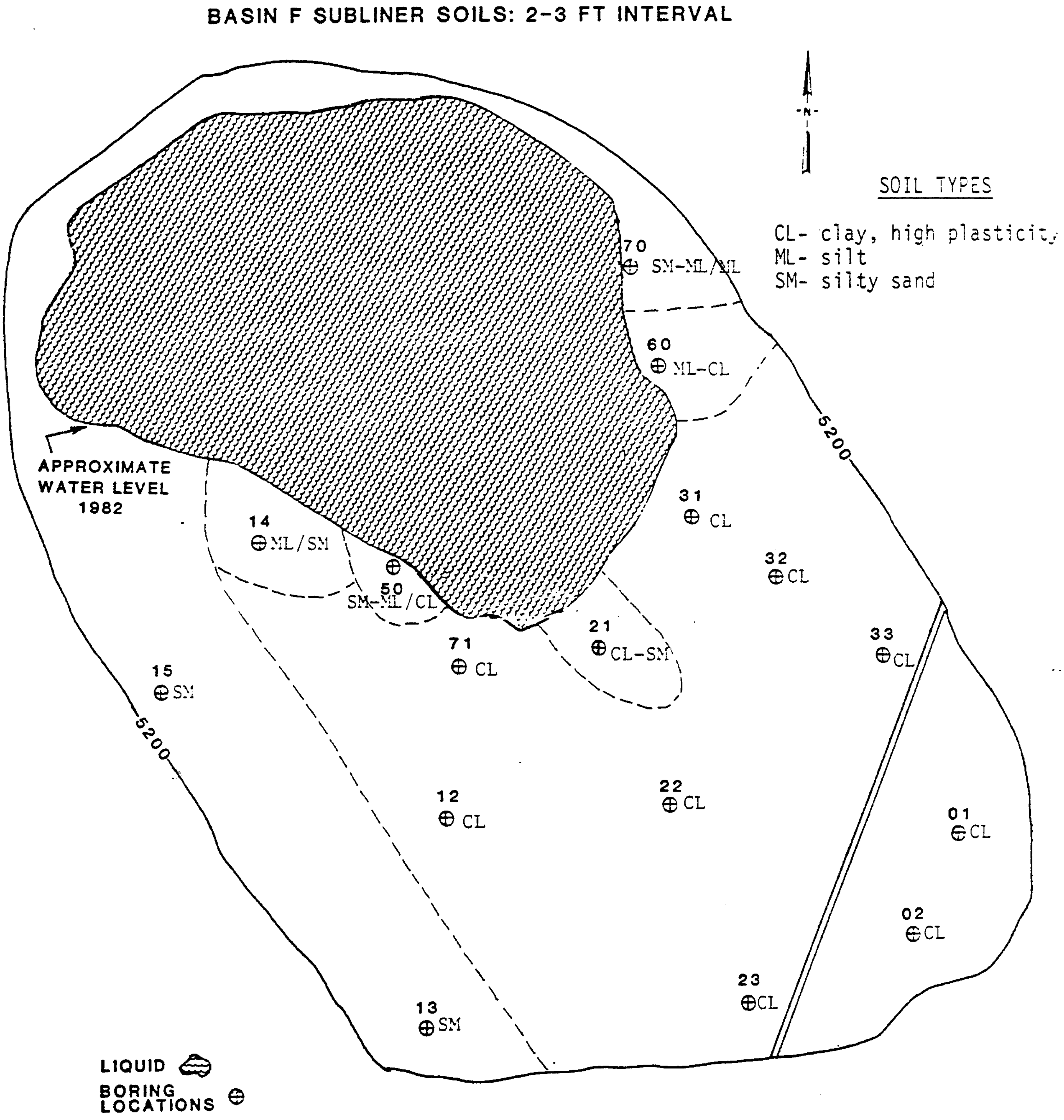
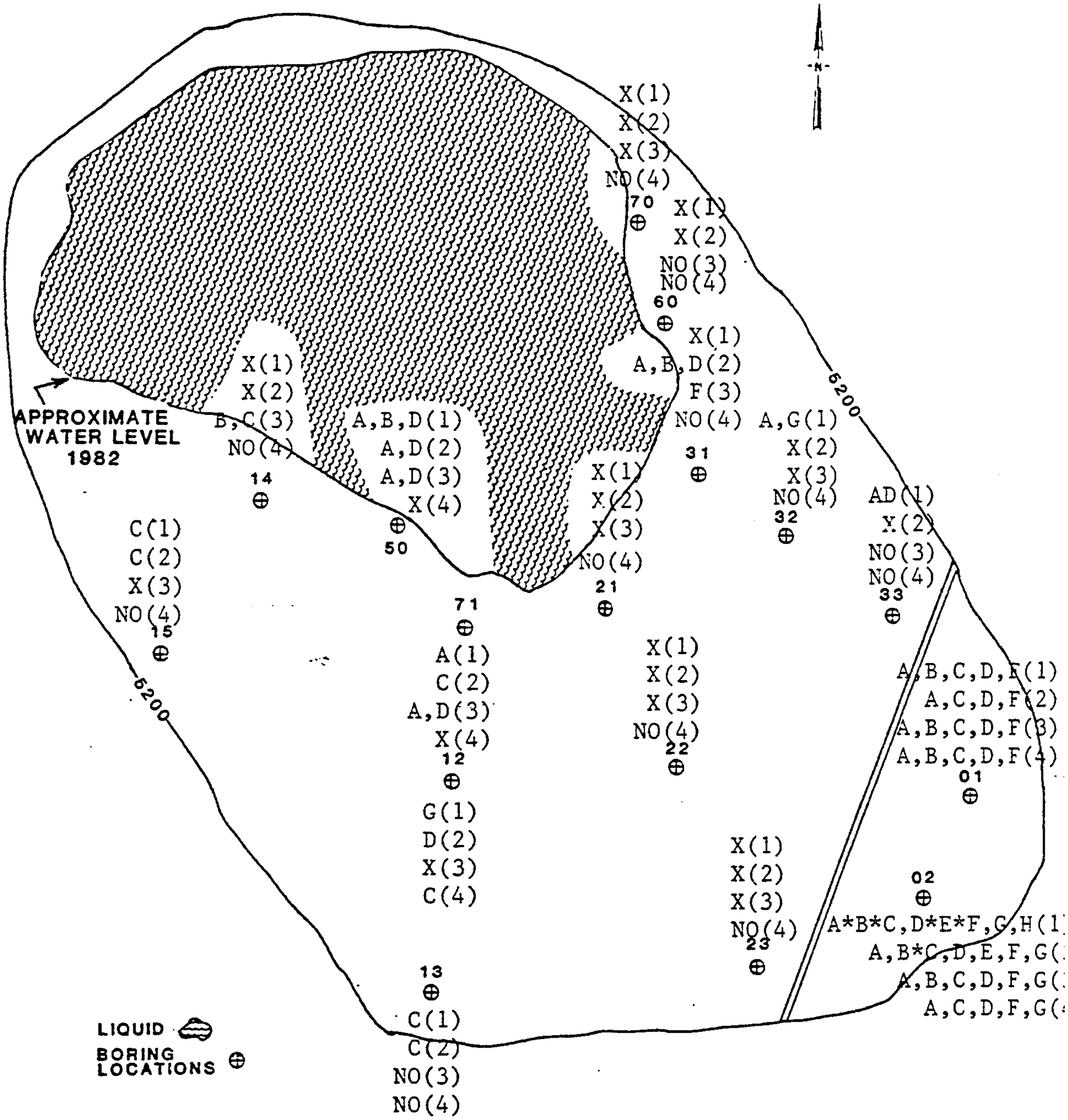


Figure 3-5: Distribution of Soil Types in Basin F, 2.0-3.0 ft Below the Linder (Myers and Thompson, 1982)

The extracts from the SWLP tests conducted on subsamples of the cores were analyzed for a select group of contaminants which had been identified previously in the Basin F liquid. Detailed results of these SWLP tests can be found in Appendix A of this Closure Plan. The concentrations of many of the contaminants in the SWLP extracts were very low or below detectable limits (Myers and Thompson, 1982). A plan map was developed for the purpose of summarizing the SWLP results on the cores. This map is presented in Figure 3-6. All the contaminants found above 100 times their respective water quality levels in the SWLP extracts of the boring cores from the first four, one-foot intervals under the liner are identified with respect to each boring site on the map. Those intervals from which samples were not analyzed or no contaminants were found in the extracts above their action levels are also identified.

The contaminants found in the extract above their respective action level concentrations include Aldrin, Dieldrin, Endrin, Isodrin, organo-sulfur compounds, DBCP, arsenic, and fluoride. Some of the borings (No. 21, 22, 23, 60, and 70) had no associated extracts with contaminant concentrations above the criteria shown in Table 3-2. Borings No. 1 and 2 (in "Little F") were found to have the greatest number of contaminants in the extracts for all intervals. Also, the concentrations of the contaminants in the extracts from these two borings were in general higher than those associated with the other borings.

The SWLP tests conducted on the overburden samples collected from five boring sites resulted in much higher concentrations of contaminants in the extracts than in those associated with the soils underlying the liner. In addition to the contaminants identified in the SWLP extracts from the cores, concentrations of DIMP and DCPD were found in some of the extracts from the overburden. In previous testing (required for filing of Part A of the RCRA permit for the Arsenal), an EP extract of the overburden from the basin was found to contain Endrin in excess of the associated 0.02 ppm criterion.



A	ALDRIN
B	DIELDRIN
C	ARSENIC
D	ENDRIN
E	ISODRIN
F	FLUORIDE
G	SULFURS

H	DBCP
X	ACTION LEVELS NOT EXCEEDED
NO	SAMPLE NOT ANALYZED
*	INDICATES CONCENTRATION EXCEEDS 100X THE ACTION LEVEL

NOTE: NUMBERS IN PARENTHESIS DENOTE INTERVALS BELOW LINER AS FOLLOWS:
(1) = 0.0-1.0 FT
(2) = 1.0-2.0 FT
(3) = 2.0-3.0 FT
(4) = 3.0-4.0 FT

Figure 3-6: Contaminants Identified in the SWLP Extracts of the Soils in Basin F (Myers and Thompson, 1982) (See Appendix A)

Only the extracts from the cores collected at Boring No. 2 from the 0-1 ft and 1-2 ft intervals exhibited concentrations exceeding 100 times their respective water quality levels (see Figure 3-6). For the 0-1 ft interval, the concentrations of Aldrin, Dieldrin, Endrin, and Isodrin in the extract exceed the criteria. In the 1-2 ft interval, only the concentration of Dieldrin in the extract exceeds the criteria.

As discussed previously, boring No. 2 was the only boring location in the study where the liner was found to be in poor condition. Contamination in the overburden or contaminated liquid (when this area was innundated) was probably able to migrate in high concentrations into the soil due to the deteriorated condition of the liner. In the other areas of the basin evaluated in this study, the liner appears to have maintained sufficient integrity to prevent the migration of large amounts of contaminants to the underlying soils.

3.2 CURRENT WASTE INVENTORY

3.2.1 Basin F Liquid

Table 3-2 presents a summary of the relationships between surface elevation, surface area, and liquid volume for the basin. The volume fluctuates with respect to varying meteorological conditions which affect precipitation and evaporation. The majority of the precipitation that falls within the perimeter dike of the basin flows into the existing liquid pools because the basin floor slopes to these areas. Rapid evaporation occurs in the hot, dry summer months. Energy absorption and thus evaporation of the liquid is enhanced by its dark color. This natural evaporation can be enhanced through use of the pumping and distribution system described earlier.

As a result of the elimination of waste flow to Basin F and natural evaporation, the volume of liquid in the basin has been significantly reduced. The volume is currently (November, 1985) estimated at approximately one million gallons or about 5,000 yd^3.

TABLE 3-2

VOLUME OF LIQUID CONTAINED IN BASIN F WITH RESPECT TO ELEVATION AND SURFACE AREA*

Elevation of Liquid Surface (ft)	Surface Area (square feet)	Total Volume (cubic feet)	Total Volume (gallons)
5,187.5	0	0	0
5,187.6	32,902	1,695	12,679
5,187.7	62,946	6,537	48,897
5,187.8	116,719	15,520	116,090
5,187.9	164,922	29,602	221,423
5,188.0	235,113	49,604	371,038
5,188.1	298,899	76,305	570,761
5,188.2	377,015	110,101	823,555
5,188.3	477,189	152,811	1,143,026
5,188.4	594,049	206,373	1,543,670
5,188.5	692,788	270,715	2,024,948
5,188.6	801,146	345,411	2,583,674
5,188.7	877,780	429,357	3,211,590
5,188.8	949,218	520,707	3,894,888
5,188.9	1,021,813	619,258	4,632,050
5,189.0	1,095,872	725,142	5,424,062
5,189.1	1,162,585	838,065	6,268,726
5,189.2	1,226,092	957,499	7,162,093
5,189.3	1,285,126	1,083,060	8,101,289
5,189.4	1,312,055	1,212,989	9,073,158
5,189.5	1,345,228	1,345,783	10,066,457
5,189.6	1,371,633	1,481,626	11,082,562
5,189.7	1,398,556	1,620,135	12,118,610
5,189.8	1,426,007	1,761,363	13,174,995
5,189.9	1,453,997	1,905,363	14,252,115
5,190.0	1,482,537	2,052,189	15,350,374
5,190.1	1,501,403	2,201,386	16,466,367
5,190.2	1,520,510	2,352,482	17,596,565
5,190.3	1,539,859	2,505,500	18,741,140
5,190.4	1,559,455	2,660,466	19,900,286
5,190.5	1,579,300	2,817,404	21,074,182
5,190.6	1,599,397	2,976,338	22,263,008
5,190.7	1,619,751	3,137,296	23,466,974
5,190.8	1,640,363	3,300,302	24,686,259
5,190.9	1,661,238	3,465,382	25,921,057
5,191.0	1,682,378	3,632,562	27,171,564

---

* Based upon survey conducted June 1984.

3.2.2 Overburden, Liner, and Contaminated Soils

Based on the results of preliminary soil sampling described in Section 3.1.2 (Myers and Thompson 1982), the overburden above the liner is considered to be hazardous. The liner may also be considered to be contaminated. The total volume of the overburden and liner is approximately 240,000 cubic yards. This calculation is based on an estimated average overburden and liner thickness of 1.6 ft. and a basin area of 93 acres (450,120 square yards).

The preliminary soil sampling analyses by Myers and Thompson (1982) also provides a basis for estimation of the volume of soil to be excavated. The results from those SWCP tests suggest that approximately six feet of soil needs to be removed from the "Little F Area" (approximately 8 acres), while six inches would be removed over the rest of the basin (approximately 85 acres). This provides a minimum estimate of 146,000 cubic yards of soil that will have to be removed from the basin. This approximation will be adjusted in accordance with the results of analysis of soils beneath the liner area now covered by liquid, of soils constituting the dikes surrounding the basin, and reanalysis of soils over the remainder of the basin. Some of this additional analytical work is currently underway, and all available sampling and analysis data will be used as it becomes available to fine tune appropriate sections of this Closure Plan. In addition, volume estimates will also be adjusted in accordance with action levels finalized at the time of closure.

A summary of the current, estimated volume of raw waste materials within Basin F is as follows:

Raw Waste Material	Current (1985) Estimated Volume, yd^3
Liquid (1 million gal)	5,000
Overburden and Liner	240,000
Underlying Soils	146,000
Sewer Debris and Soils	12,000
Total	403,000*

* Excludes adjoining soils which may have been contaminated by Basin F activities.

The "sewer debris and soils" are potentially contaminated wastes that were generated during the removal of the chemical sewer leading to Basin F. These wastes were deposited within Basin F.

3.3 DESCRIPTION OF PROCESSES GENERATING WASTES

The nature of wastes discharged into basin F varied considerably during its period of operation. During the first year of use, 1957, Army operations resulted in the discharge of approximately 60 million gallons of aqueous solutions of various sodium salts - chloride, fluoride, hydroxide, methyl phosphate, acetate and sulfate. Subsequent operations by private corporations led to discharge of organic and inorganic contaminants from onsite production of pesticides. During the final phase of operations, from 1978 to 1982, wastes were discharged from the hydrazine blending and storage facility (HBSF) and from miscellaneous Army operations at a rate of approximately 300,000 gallons per year. Discharges from the HBSF may have included the compounds anhydrous hydrazine (AH), monomethylhydrazine (MMH), unsymmetrical dimethylhydrazine (UDMH), and n-nitrosodimethylamine (NDMA). The compounds are either the fuels themselves (AH, MMH, and UDMH) or fuel degradation products (NDMA). HBSF wastewaters were treated (oxidized) with calcium hypochlorite prior to discharge, but the treatment may not have been completely effective in destroying these contaminants.

4.0 CLOSURE PLAN

4.1 OBJECTIVES AND SCOPE OF CLOSURE PLAN

This closure plan is designed to meet the following performance standards:

- Protect human health and the environment;
- Prevent the escape of hazardous waste, hazardous waste constituents, or waste decomposition products to the ground or surface waters or the atmosphere by eliminating sources of contamination; and
- Render the site suitable for modified unrestricted use (i.e. general use excluding use of any contaminated groundwater that may be beneath the site).

The specific activities that are necessary to accomplish the closure objectives at Basin F are outlined in Section 4.3 of this Plan. The criteria which will be used to determine the adequacy of the decontamination are presented in Section 4.2.4.

The following factors were taken into account in the development of this plan:

1. Closure activities will be conducted within an area bounded by the limits of Basin F. This boundary is defined by the original containment dike surrounding the liner in addition to any contiguous areas within the Basin F security fence judged contaminated based on action levels discussed in Section 4.2.4.
2. Areas outside the boundaries (fence line) specified above, including potentially contaminated soils located downwind from the former spray raft operation in the 1960's, are being addressed by the arsenal-wide remedial action strategy.

3. Groundwater contamination appears to be linked in part to disposal in Basin F. However, arsenal-wide groundwater contaminant migration is being addressed as part of the RMA conceptual strategy.

4. Because RMA is a federal facility, no financial requirements need be met (40 CFR Parts 264.110 and 264.140). In addition, because all wastes will be removed, no post closure activities will be required. However, ground water monitoring in this area will be continued as part of the arsenal-wide groundwater strategy.

4.2 DETERMINATION OF CONTAMINATION

4.2.1 Sampling Program

4.2.1.1 Purpose

The purpose of the sampling program is to obtain data necessary to evaluate the extent of contamination at or associated with Basin F. Specifically, analytical data are needed to assess treatment and disposal options for liquid wastes and to determine the exact volume of contaminated soils and other materials that need to be excavated, treated, and disposed of.

4.2.1.2 Past Sampling

Past sampling efforts have included collection of Basin F liquid samples (see Section 3.1.1). Results of this liquid sampling are summarized in Table 3-1 and are discussed in detail elsewhere (Buhts et al. 1979). Limited sampling of the overburden and subliner soils was also conducted in 1982 (see Section 3.1.2). This involved placement of 16 shallow boreholes in the portion of Basin F not covered by liquid. The results of this soil sampling are summarized in Figures 3-1 to 3-6 (Myers and Thompson 1982). Additional sampling in the Basin F area has been conducted more recently in support of litigation at the RMA, and this effort will be continued in the near future as part of Task 6 of the arsenal-wide contamination cleanup. Although these data are not yet available, they will serve to more clearly define the magnitude and extent of contamination problems in the Basin F area. Maximum use will be made of these existing and planned data collection activities. Although past and current sampling efforts have provided valuable insight into the contamination at Basin F, additional sampling and analysis will be needed to more accurately define closure requirements (more specifically, to aid in the final selection of treatment and disposal techniques and to more accurately define the soil removal requirements) and to verify the completeness of waste removal activities.

4.2.1.3 Additional Sampling

Additional sampling efforts at Basin F will focus on materials that will or may need to be removed for closure, i.e., the remaining liquid in the Basin, overburden (including the liner), soils beneath the liner, and soils adjoining the Basin, including containment dikes. The liquid must be sampled and analyzed again because the characteristics of this waste may have changed during the time period since previous sampling was conducted. In addition, the composition of this liquid will need to be carefully defined to permit an accurate assessment of the feasibility of various treatment technologies for this waste, e.g., incineration. Soils beneath the liner under the existing liquid pool also need to be characterized. Overburden above the liner will be sampled when borings are done for subliner soil sampling. Lastly, soils adjoining the Basin (but within the fence line) will be sampled to determine whether contamination attributable to past high liquid levels has occurred and to determine whether the contaminated soils that are found can be effectively treated.

4.2.2 Sampling Techniques

4.2.2.1 Liquids

Sampling of Basin F liquid will be conducted according to a simple random sampling strategy (EPA SW 846, Sec. 1-1). Approximately 15 samples will be collected using fluorcarbon, plastic, weighted bottles with the necessary sinker, stopper, and line assembly. Liquid will be sampled, removed, and treated prior to sampling of soils and overburden beneath the liquid pools.

4.2.2.2 Soils

The number of boreholes installed for soil sampling will be determined by utilizing a borehole spacing calculation method devised for all RMA damage assessment activities. In this method, borehouse spacing is dependent on the overall area of the site. The relationship between site area and the corresponding appropriate borehouse spacing is shown in Figure 4-1.

The portion of Basin F known as "Little F" must be considered separately from the remainder of the basin, because in this area preliminary studies revealed liner deterioration and higher levels of soil contamination than noted elsewhere. Consequently, "Little F" will have a greater density of boreholes. The area of "Little F" is approximately eight acres or 350,000 square feet. The corresponding borehole spacing, as determined for Figure 4-1, is about 95 feet. Accordingly, the total number of boreholes in "Little F" will be about 40. The remainder of Basin F occupies about 85 acres or 3.7 million square feet. From Figure 4-1, the appropriate borehole spacing in this area is about 145 feet. Thus, the total number of borings to be emplaced in the remainder of Basin F will be about 170. Borings in each area will be emplaced in two phases. Phase I will contain 30 percent of the total number of borings for each area, i.e., 12 in "Little F" and 50 in the remainder of the Basin. Soil will be excavated based on the results of Phase I sampling. Phase II will

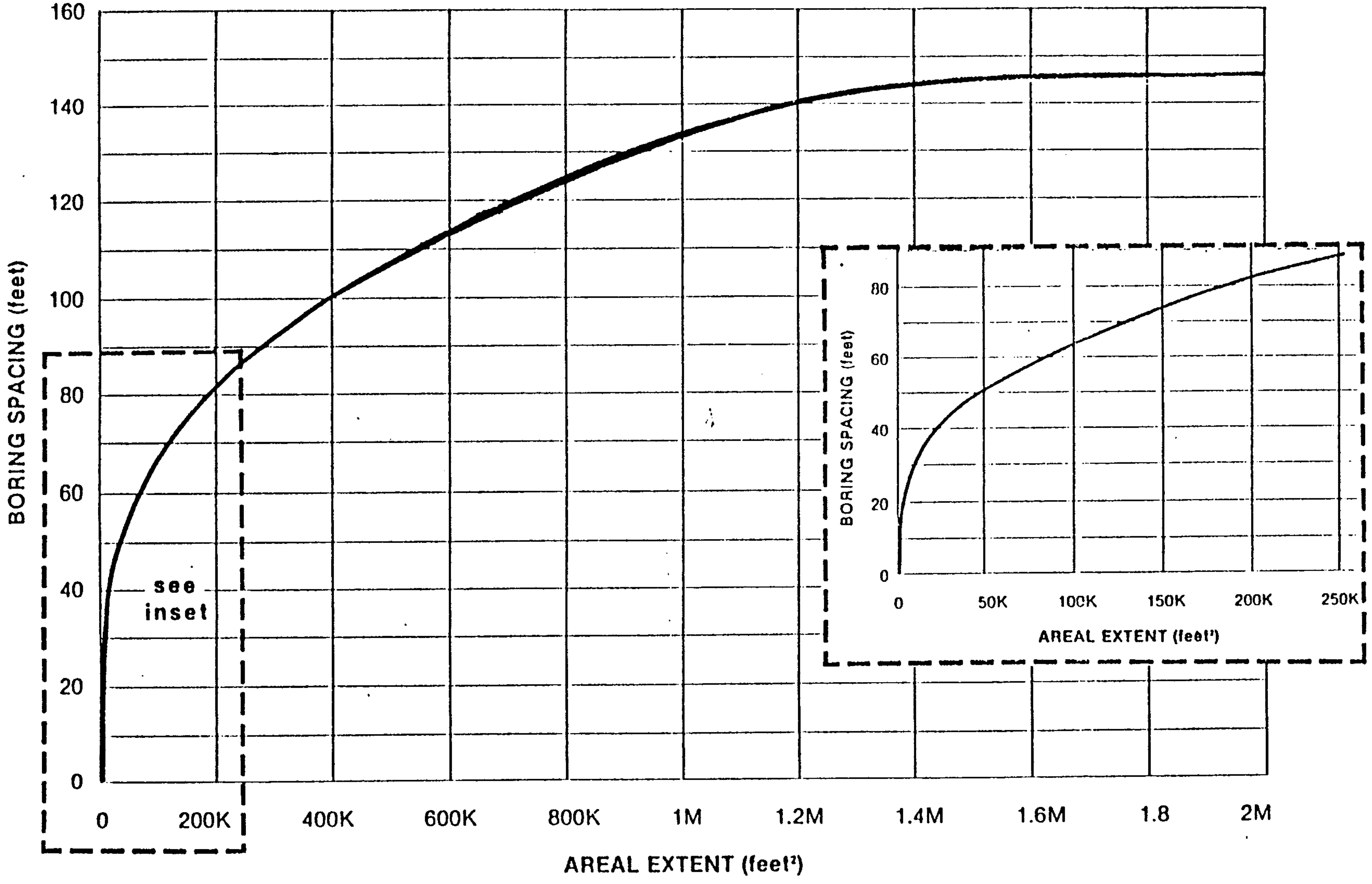


Figure 4-1

EMPIRICAL CURVE TO DETERMINE BORING SPACINGS BASED ON AREAL EXTENT OF SITES comprise 70 percent of the total number of borings and will be conducted after preliminary soil removal to confirm absence of contamination. If additional contamination is noted as a result of Phase II borings, excavations will be continued.

There is a possibility that soils outside the actual Basin F impoundment (dike) may have become contaminated due to wave action when the Basin was filled or due to aerosol drift. The sampling of the adjoining soils will initially be limited to the faces of the dike surrounding Basin F. Samples will be collected at 500-foot intervals around the perimeter of the Basin. A total of 15 samples will be collected during Phase I activities. If the analysis of these samples reveals the presence of contamination, then the spacing between samples in the suspected contaminated zone will be reduced to 100 feet, and the sampling area will be extended outward from the Basin to the fence line.

All soil borings will be made using a continuous core augering technique. This technique will allow for an examination of the entire length of the core. Cores will be stored in five-foot long clear plastic (polybutyrate) liners. Samples will be collected at vertical intervals of five feet. Samples will also be selected from horizons where contamination is usually evident.

4.2.2.3 Overburden

The overburden above the Basin F liner consists of sand emplaced during construction and additional material deposited by precipitation from the liquid. Wind blown soil and dumping of waste solids may have also added to the accumulation. Because this material was at least partly derived from the liquid, and wholly immersed in it, it is presumed to be hazardous. Therefore all overburden will be removed and disposed of as hazardous waste, and need not undergo rigorous diagnostic tests like the underlying soils. However, where penetrated during drilling for soil sampling, overburden will be sampled for purposes of description for the facility receiving the wastes. Overburden will be sampled at 10 percent of the borings done for soil sampling.

4.2.3 Analytical Techniques

Liquid samples to be collected from Basin F will be analyzed for the 14 substances included in the Extraction Procedure (EP) toxicity test, i.e., eight metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver) and six pesticides (endrin, lindane, methoxychlor, toxaphene, 2,4,5-trichlorophenoxypropionic acid, and 2,4-dichlorophenoxyacetic acid). In addition, all substances previously identified in the liquid (see Table 3-1) will be analyzed for. The presence of DBCP (dibromochloropropane) and DCPD (dicyclopentadiene) will be investigated. Finally, since the identified organic constituents in the Basin F liquid account for only about 10 percent of the total organic contgent of this waste (as measured by COD or TOD), a full Priority Pollutant scan will be run on a composite liquid sample. If significant concentrations of priority pollutants or other organic compounds of concern are found, then these compounds will be added to the list of analyses for the overburden, liner, and soils, and action levels will be established for their removal.

The analytical methods to be used shall be EPA-approved standard methods wherever practical. Where not practical, other properly validated and standardized methods such as ASTM or state-of-the-art methods for which appropriate precision, accuracy and interlaboratory comparison data have been generated may be substituted. These analyses will provide an up-to-date assessment of Basin F liquid contents.

Solid waste samples (soil and overburden) will undergo EP toxicity testing (EPA SW 846) in accordance with 40 CFR Section 261 Appendix II. This test is designed to simulate leaching that occurs in a sanitary landfill. The following analytical methods will be used on the extract:

PARAMETER	METHOD	REFERENCE
Toxic Metals	Atomic adsorption or	EPA, 1979, SW-846 Methods 3010, 3020, or 3050
	ICP Emission Spectroscopy	40 CFR Section 136 Dec. 3, 1979
Toxic Organics	Gas Chromatography	SW-846

4.2.4 Action Levels

To determine whether soil samples taken from the suspected contaminated areas should be considered contaminated or uncontaminated, a predetermined concentration level for each of the chemicals of concern will be established.

As part of the overall contaminant cleanup strategy for the arsenal, PM-RMA is developing contamination criteria levels for various contaminants present throughout the arsenal including the contaminants of concern in the Basin F area. This study will define the concentration levels for hazardous constituents in soils, below which they can be classified as "clean." To determine these action levels for various contaminants, PM-RMA is performing risk analyses for each of the contaminants. Upon completion, this "how clean is clean" study, and the resulting action levels, will be amended to this closure plan.

4.3 CLOSURE PLAN ACTIVITIES

4.3.1 Overview of Closure

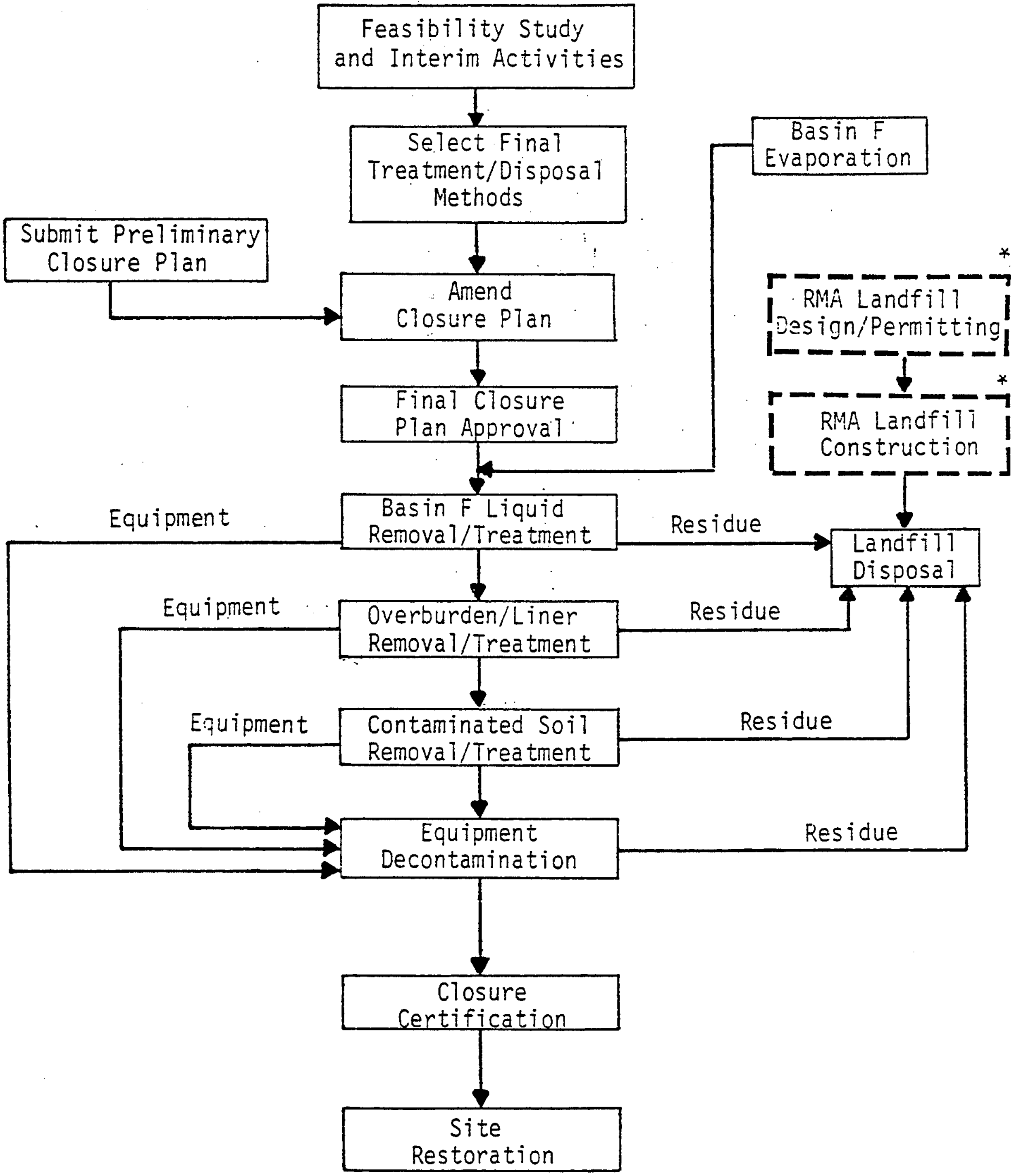
The closure of Basin F will involve the completion of studies to assess waste treatment methods, the sequential removal of liquid and solid wastes from the basin, and the restoration of the site following completion of waste removal activities. These activities have been grouped into the following steps:

- Evaluate and, as appropriate, implement remedial action strategies;
- Complete feasibility studies to define treatment and disposal techniques for Basin F liquids and solids;
- Dewater Basin F and "Little F," and treat and dispose of liquid wastes;
- Treat and dispose of waste sediments, overburden, and liner
- Identify, treat, and dispose of contaminated soils;
- Decontaminate treatment and removal equipment and dispose of decontamination wastes;
- Confirm waste removal;
- Restore site topography and vegetation.

Directly related to these activities (in fact, an outgrowth of the feasibility studies) will be the pilot testing, design, permitting, and construction of the treatment and/or disposal facilities to be used for Basin F wastes. For example, an on-post (RMA) landfill will be designed, permitted, and constructed to accept residues from Basin F closure activities. The activities needed to develop this landfill will proceed concurrently with Basin F closure activities. Figure 4-2 illustrates the basic flow of activities required to close Basin F. Because all wastes will be removed from the Basin, no post-closure monitoring will be required; however, the regional groundwater monitoring program will continue. Only vegetation maintenance will be needed, and that will only be required until the vegetation is established. Although groundwater beneath Basin F appears to have been contaminated to some degree by Basin F activities, it also appears that activities beyond the limits of this site closure may have contributed to the groundwater problems. Therefore, in keeping with the Arsenal-wide remedial action strategy, no separate groundwater decontamination activities will be performed as part of this closure plan.

Figure 4-2

CLOSURE PLAN FLOW CHART



* Shown for illustrative purposes only. Similar approach will be used for any selected treatment or disposal option.

4.3.2 Interim Remedial Activities, Feasibility Studies, and Design

A number of feasibility studies have been conducted by RMA to determine what the best methods for handling Basin F wastes will be. Additional studies are planned for the immediate future including on-post pilot operations to examine elements such as landfill liners and covers, in-situ solidification, incineration of waste liquids and solids, site reclamation, and others.

The ultimate goal of these studies is to develop the most cost-effective, environmentally sound approach to the cleanup of Basin F; however, the results of some of these studies have indicated that it may be possible to undertake one or more interim remedial activities which, while not optimal from the standpoint of final closure, will achieve some degree of cleanup or hazard reduction at the Basin. These interim actions could be undertaken while the feasibility studies and design efforts for final closure are completed. The following sections of the Closure Plan address the pertinent studies that have been, are being, or will be conducted which in some way impact the Basin F Closure Plan scenario.

4.3.2.1 Interim Remedial Activities

Due to its large size and the complex nature of the wastes contained within it, Basin F will require an extended closure period if the most environmentally sound and cost-effective treatment and disposal techniques are to be employed. On the other hand, it is desirable to carry out interim actions, when feasible, that minimize or reduce the threat of contaminant migration from the basin and that, to the extent possible, demonstrate or test technologies that have the capability to permanently immobilize, detoxify, destroy, or otherwise render harmless the Basin F contaminants. Some of these interim activities are described in following report sections; however, there are a number of other options that are also being considered. For example, the most pressing need at Basin F is for control of the Basin F liquids. There are a number of alternatives being considered to address this need.

As described earlier, dikes have been constructed across Basin F to separate the liquid into a number of individual pools. This increases the surface area of the liquid and hastens liquid evaporation. Enhanced evaporation systems (pumping and distribution facilities) have also been installed and operated to reduce liquid volumes. These efforts have had a substantial effect in reducing the volume of Basin F liquids from about 70 million gallons in 1983 to approximately 1 million gallons in late 1985. Although these dikes and evaporation efforts have obviously been effective, the drawback is that the surface of the liner forming Basin F has remained largely wetted. Thus, any deteriorated portions of the liner would be more susceptible to leakage. This is particularly true in the southeastern portion of the basin ("Little F") where a standing liquid pool is located near an area of the liner that is believed to be in a deteriorated condition. The liner in the northern (deeper) portion of the basin is believed to be in good condition, so a simple means of minimizing the leakage potential is to breach the dikes to allow all remaining liquids in the basin to flow into one common pool. This can be accomplished at minimal expense. The disadvantage of this strategy is that it will reduce the rate of evaporation of the remaining liquids.

A second interim action that is being considered to minimize the potential for migration of soluble contaminants to the groundwater is in-situ solidification of the Basin F liquids. A commercial vendor has offered a means of in-situ waste solidification, and the PM-RMA is currently negotiating with this firm to set up an on-site demonstration of their proprietary solidification/fixation process. This process reportedly can fix both inorganic and organic contaminants. It is a modification of a pozzolanic solidification using flyash, kiln dust, or Portland cement together with the proprietary chemical additive. As currently envisioned, the vendor will provide a trailer-mounted treatment system that will be used to solidify approximately 10 cubic yards of Basin F liquids and sludge. The solidified material will be subjected to a variety of tests to determine the effectiveness of the solidification process.

Additional remedial activities that are being considered include recontouring of the basin, pilot scale incineration of Basin F wastes (perhaps in the existing incinerator in Building 1611); groundwater interception and, perhaps, treatment; and others. As these interim measures are more fully evaluated and, where possible, implemented, this Closure Plan will be amended to reflect them.

4.3.2.2 Basin F Waste Solidification

Much of the work needed to characterize the performance of waste solidification techniques on Basin F liquids has been conducted over the past several years. The major waste solidification study completed to date (Myers and Thompson 1983) examined eight basic solidification processes, some with a number of variations in solidification and absorbent chemical additions. Each of these processes was cement or pozzolonic based. Five commercial solidification processes and a non-proprietary solidification process satisfactorily converted "concentrated" Basin F liquid to a solid form. Tests were conducted on a sample of Basin F liquid that was concentrated via evaporation to approximate the concentrations of contaminants that would be present if the volume of Basin F liquid were reduced to about 9 million gallons. (As noted earlier, it now appears that the total volume of liquid waste in Basin F is much less than 9 million gallons. As a result, contaminant concentrations would be expected to be higher now than those used in the solidification study. Despite this fact, it is believed that, perhaps with some slight modifications, the results of the solidification testing are still applicable).

This testing showed that the formulation of the solidification agents could be altered slightly to achieve desired variations in key parameters such as ultimate bearing capacity, permeability, ability to immobilize contaminants (as measured in leaching tests), release of ammonia gas, and others. Materials costs for solidification additives ranged from $0.10/gallon to $1.00/gallon of Basin F liquid (1983 dollars). The volume increase resulting from solidification, expressed as the ratio of final volume of solidified waste to the original volume of Basin F liquid ranged from 1.2 to 4.1, but seven of the ten variations on the six basic, acceptable processes had volume increases of 2.5 or less. Most of the solidified materials prepared in the study increased in strength with repeated wet/dry cycles, indicating that they would not deteriorate once emplaced in a landfill.

All of the solidified waste samples passed the EP toxicity test, but the limited statistical data indicate that there are real and substantial differences in the ability of the solidification processes to immobilize contaminants such as arsenic, copper, and mercury. On the other hand, the data also indicated that there are no substantial differences in the ability of the processes to immobilize gross organic contamination (as measured by TOC) in Basin F liquid. The leach data did demonstrate an order of magnitude reduction of contaminant levels in samples prepared by leaching of solidified Basin F liquid compared to the untreated liquid.

The only significant problem encountered in working with the solidification techniques was the release of large amounts of ammonia gas upon addition of the solidification agents. Formulations were developed, however, that minimized this problem, albeit at a higher expense in terms of solidification agent costs. An alternate solution to this problem would be to employ ammonia scrubbing systems to capture and collect this compound.

As noted above, six basic techniques (ten variations in total) were shown to satisfactorily solidify the Basin F liquid. Depending upon the final specifications established for this process, it is likely that a number of alternate formulations may be available which will prove effective on the Basin F liquids that will remain in the impoundment at the start of closure activities. Further pilot testing is required to ensure that this technique is viable on a full scale basis. As a result, no specific solidification process can be defined at this time. When the appropriate specifications are prepared (based upon pilot test results and disposal requirements among other factors), then contractors will be requested to submit bids for the construction and operation of a facility to stabilize the Basin F liquid, and perhaps solid, wastes.

4.3.2.3 Conventional Incineration Technology

One technology that holds promise for effectively destroying organic contaminants in the Basin F area is conventional, rotary kiln incineration. Feasibility studies to address this alternative will begin in early 1986. These studies will include a complete characterization of Basin F wastes, a literature review to identify the most suitable candidate incineration techniques, and bench scale test burns to obtain data on the destruction of organics, the effects of incineration on the inorganic matter, volume reductions obtainable, emissions control requirements, and other pertinent factors. If the results of these studies prove positive, then one or more incineration techniques will be pilot tested to obtain full-scale design information and to permit the accurate estimation of cost data for a full-scale incineration system.

4.3.2.4 Advanced Incineration Technologies

In addition to conventional incineration techniques, there are a number of promising innovative tratment technologies that could be used on Basin F wastes. The PM-RMA, in conjunction with the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), is about to undertake a task to examine these advanced technologies for application to Basin F wastes. The three technologies that have been selected to date are Circulating Bed Combustion, Molten Glass Incineration, and In-situ Vitrification.

Circulating bed combustion uses a fluidized bed of limestone to enhance incineration of hazardous wastes by providing a turbulent combustion zone and circulating solids to tie up salt and acid gas residues. The potential benefits of this technology over conventional incineration are lower capital costs due to reduced air pollution control requirements and lower operating costs due to lower fuel requirements.

Molten glass incineration utilizes a glass furnace containing a molten pool of glass into which hazardous wastes are fed. The pool of glass is maintained at 2300°F by electric resistance heaters. Within the furnace the organics are vaporized. They are then incinerated in a secondary chamber. The inorganics and metals are dissolved or suspended in the molten glass to form a slag. This slag is tapped off and quenched for disposal.

In-situ vitrification uses electric current to melt contaminated soil in-place. No excavation is required. The process is accomplished by placing carbon electrodes in the ground and passing electric current through the ground between the electrodes. The heat generated by the electric current melts the soil and rock, decomposes organic material, and dissolves or encapsulates inorganic materials. Upon cooling, the molten solid forms a glass-like block that resembles volcanic obsidian. Laboratory tests indicate that the vitrified soil has leaching characteristics similar to Pyrex glass. The advantages of this process are that in-situ treatment does not require excavation, transportation, reburial, or other intermediate materials handling.

Other advanced technologies may also be investigated, for example, fluidized bed combustion or ported kiln incineration. The task will include a review of the scientific and engineering literature and industrial data base to identify and evaluate these and other feasible technologies, and it will also include laboratory bench scale testing of at least the three technologies described above. The data generated will be analyzed to compare the effectiveness of the treatment technologies, and an engineering and economic analysis will also be performed on each technology to gauge its applicability to the Basin F closure scenario.

4.3.2.5 On-Post State-of-the-Art Waste Containment Facility

Based upon estimates of waste volumes presented in the previously submitted Closure Plan for Basin F, a conceptual design for a state-of-the-art, above ground hazardous waste containment facility to accept all wastes generated during the closure was prepared. The total estimated volume of waste materials to be deposited in this hypothetical containment facility was 520,000 cubic yards, and it was designed as a series of six cells, each with a waste capacity of about 100,000 cubic yards. Site selection criteria employed for the facility included a minimum 1 mile buffer zone around the site, a groundwater separation distance of 40 feet or more from the base of the fill, a site outside of the 100 year floodplain, and a site where the Denver sand formation was not in contact with the surficial alluvium.

The state-of-the-art above ground hazardous waste containment facility design incorporated the latest techniques for waste disposal including a double liner, leachate collection and leak detection systems, gas collection system, impermeable cover, stormwater management system, leachate collection system, site security, and other necessary features. Each active cell was to be covered by an air supported building to prevent rainfall from entering the waste materials. The projected cost of this containment facility (1984 dollars) including operations was nearly $38,900,000.

Although the containment facility's basic design will not change, the volume of material to be deposited in this facility may either increase or decrease depending upon the final treatment method selected. This is not a problem since the facility can be enlarged or reduced in size by altering the number of cells to be constructed. The latest estimates of waste volumes that will be placed in such a facility (based upon raw waste volumes as presented in Section 3.2 of this Closure Plan) are as follows:

Waste Material	Raw Waste Volume (cubic yards)	Treated Waste Volume (cubic yards)
Liquid	2,500*	6,200
Overburden and Liner	240,000	300,000
Underlying Soils	146,000	146,000
Sewer Debris and Soils	12,000	12,000
Total	400,500	464,200

* Assumes a 50 percent reduction in existing liquid waste volume due to evaporative losses prior to the start of closure activities.

If contaminated soils are found outside of the Basin proper, or if the extent of contamination beneath the liner is greater than currently anticipated, then the volume of waste to be deposited in the secure containment facility would increase accordingly.

Studies will be continued to finalize the design concept for this on-post containment facility as results from other feasibility investigations become available. This process will culminate in the design and construction of a disposal facility that will accept all wastes generated from Basin F closure activities including treated liquids, overburden, liner, contaminated soil, and equipment deemed not suitable for decontamination.

4.3.3 Liquid Removal, Treatment, and Disposal

The first step in the actual closure of Basin F will involve the removal, treatment, and disposal of residual liquid wastes and incident precipitation from the impoundment. As discussed above, methods have been defined to solidify these liquids in preparation for disposal, but incineration offers an attractive option for their total or near-total destruction. In-situ solidification may also prove to be possible. As a result, although this plan is currently being presented with removal and solidification as the treatment method of choice for these liquids, the plan may be amended once the results of the incineration and other feasibility studies are available.

Removal of the liquids from Basin F will accomplish two main goals. First, it will remove the hydraulic head that has the potential to drive contaminants downward to the groundwater. This is particularly important in the "Little F" area where the liner is believed to have deteriorated. In fact, the small dike creating the "Little F" pool will be immediately breached to allow this liquid (primarily rainwater that may have become contaminated as a result of its contact with the basin sediments) to flow into the main wastewater pool at the northern end of Basin F. It is believed that the liner beneath this main wastewater pool is competent and will effectively contain the liquids until they can be removed. The second goal to be achieved by removal of the Basin F liquids is that it will permit equipment access for the subsequent removal of overburden, liner, and contaminated soil materials.

The new enhanced evaporation system that was installed in October 1985 will be operated during summer months until one week before actual removal and treatment of the liquids begins. This will maximize the evaporation of water from the impoundment and minimize the waste volumes to be treated as well as the residue volume to be disposed of. The pumping system installed for the enhanced evaporation system will be used to draw the liquid from the basin. An auxiliary pumping system may also be used by the selected contractor to supplement the existing system. The liquids will be pumped to a treatment (solidification) facility located adjacent to the basin. The treatment facility will be located on a pad constructed of watertight materials. This pad will be capable of supporting the loads imposed by the treatment facility as well as the equipment used to transport the solidification materials and the solidified wastes. The pad will also be equipped with a sump to capture potential spills or leaks of waste liquids. The treatment equipment to be used to mix the solidification agents with the waste liquids will be selected by the waste treatment contractor, but it is anticipated that standard cement mixers or similar devices will be employed. Although the waste liquids may be corrosive, they will be in contact with steel equipment surfaces for only a brief period of time, and the equipment will be washed out at the end of each work day, so no significant corrosion problems are anticipated.

After the liquids have been thoroughly mixed with the solidification agent, the mixture will be poured into molds (most likely steel or fiberboard drums) and allowed to harden. Following hardening, which is expected to last no more than 24 hours, the solidified wastes will be loaded onto trucks for transport to the on-post hazardous waste RCRA-approved landfill for ultimate disposal. Only in the event that such a landfill is found not to be feasible on the RMA will these solidified wastes be hauled to an off-site RCRA-approved hazardous waste landfill.

Based upon past waste solidification studies, the addition of the solidification agent will increase the liquid waste volume by a factor of 1.25 to 2.50. The liquid waste volume is currently estimated to be 1.0 million gallons. Based upon the schedule established for performance of the closure activities (see Section 5.0) and based upon an average net evaporation rate from the Basin of 1.5 gpm/acre (Myer and Thompson 1983), it is estimated that approximately 0.5 million gallons of liquid will remain in Basin F at the initiation of the liquid waste solidification efforts. This corresponds to a liquid waste volume of 0.5 million gallons/7.48 gallons per cubic foot or 67,000 cubic feet of liquid. Assuming a conservative solidification volume increase of 2.5 times, the maximum amount of disposable waste materials to be generated from the solidification of Basin F liquids is 167,000 cubic feet or 6,200 cubic yards. Additional liquids from equipment washdowns may, depending upon analytical results, also need to be solidified. The volume of contaminated washwater that will be generated is difficult to determine, but assuming that a wastewater volume of 250,000 gallons will be generated over the course of closure and that it will all be found to be unacceptably contaminated (worst case), and further assuming a solidification volume increase of 2.5 times, an additional 83,600 cubic feet or 3,100 cubic yards of solidified wastes will be generated.

EP Toxicity Test results on samples of solidified Basin F liquids have shown that they do not exceed the criteria for the EP Test metals or pesticides, although some leaching of organics was noted. Nevertheless, the solidified wastes will be treated as hazardous wastes and will be disposed in the on-post or an off-site RCRA approved hazardous waste landfill. The enhanced evaporation system will be dismantled and disposed of as hazardous waste. All other equipment used for liquid removal and treatment will be decontaminated or, should decontamination prove to be inordinately expensive, will be disposed of a hazardous waste.

4.3.4 Sediment and Liner Removal and Treatment

Feasibility studies to examine the potential for using incineration as a means of destroying organic compounds and reducing waste volumes will be conducted on the Basin F sediment (overburden) and liner materials. This appears to represent the most attractive option for treatment of this waste; however, at the present time, the results of these feasibility study efforts cannot be predicted and a final decision on the treatment method be used for the sediments and liner has not been made. Nevertheless, it has been assumed for the purposes of establishing conservative estimates of waste volumes that incineration will not be employed and that sediment/liner stabilization will be accomplished using the same or similar techniques as those developed for the Basin F liquids, i.e., solidification using a cement-based or pozzolonic reaction. Developmental studies are ongoing to finalize the final design criteria for this process. In any event, it must be kept in mind that additional pilot work, design, and construction of treatment facilities will precede the actual removal and treatment of these waste materials.

Removal of the overburden and liner will be accomplished by a contractor, but it is anticipated that he will utilize standard earthmoving equipment such as rubber-tired front end loaders, pans, and dump trucks. Although the overburden and liner may be somewhat corrosive due to the presence of high salt concentrations, no specialized equipment is expected to be required for its removal since the equipment will be cleaned via brushing and steam cleaning at the end of each work day. This equipment will undergo final decontamination only after its use on the site is no longer necessary. All cleaning and decontamination wastes will be collected and analyzed. If contaminants are found to be present at levels in excess of the action levels described earlier, then these wastes will be solidified, stabilized, or otherwise treated (e.g., incinerated) prior to disposal in the hazardous waste landfill.

Based upon results obtained to date, a volume increase of about 25 percent can be anticipated for stabilization of the overburden and liner. (A volume reduction would be expected if incineration were to be selected as the preferred treatment method.) With a raw waste volume of 240,000 cubic yards, the total stabilized waste volume to be disposed of will be 300,000 cubic yards. The stabilization processing plant will be decontaminated, dismantled, and removed from the site following completion of treatment activities.

4.3.5 Contaminated Soil Removal

Because contaminant levels in the soils are not expected to be high, and because no stabilization is expected to be required to achieve adequate bearing capacity for landfill placement, no soil treatment is anticipated. (However, the incineration feasibility studies will include an assessment of the effects of incineration on soil organics content and volume reduction. If good results are obtained, then this treatment technology will be further evaluated). Soils will be sampled and assessed for degree of contamination using the methods and criteria described in Section 4.2. Soils found to be contaminated will be removed by a contractor using standard earthmoving equipment, e.g., rubber-tired front-end loaders, pans, and dump trucks. For the purpose of developing a conservative waste volume estimate, it has been assumed that the contaminated soils will be hauled directly to the on-post hazardous waste containment facility for final disposal. The current estimate of contaminated soil volume (including wastes generated during removal of the chemical sewer) is 158,000 cubic yards. If the soils are incinerated, this volume would be reduced; however, the exact magnitude of this volume reduction will not be known until the incineration feasibility studies are complete.

4.3.6 Equipment Decontamination and Disposal

Equipment used during Basin F Closure activities will undergo regular cleaning during the course of closure to prevent corrosive wastes from damaging equipment surfaces in contact with waste materials. When any particular piece of equipment is no longer needed within the restricted contamination zone, it will be decontaminated prior to leaving the site. Decontamination will consist of removal of all visible traces of contaminated materials by brushing, sweeping, wiping or other physical means followed by a wash with high-pressure water (using a detergent solution) or steam cleaning to be repeated a minimum of three times on each surface. The contractor's Certified Industrial Hygienist will be required to attest to the efficacy of the cleaning procedures used for the equipment used in the closure.

4.3.7 Residual Disposal

All hazardous wastes removed from or generated as a result of activities at Basin F are expected to be deposited in the on-post landfill described earlier. Wastes or nonrecoverable equipment which must be removed from the Basin F site but which, based upon the action levels discussed in Section 4.2.4, are found not to be hazardous will be disposed of off-post by the appropriate contractor.

4.3.8 Confirmation of Waste Removal

In order to prevent any possible release of hazardous constituents from the Basin F site in the future, all wastes must be removed down to the action levels specified in Section 4.2.4. All Basin F liquids, overburden, and liner will be removed, but only those soils found to be contaminated will be excavated from the Basin F subbase (beneath the liner), dikes, and adjoining areas. Upon completion of all excavation activities, the entire Basin F area will be subjected to a final soil sampling effort to ensure that no contaminated materials remain. This sampling effort will include those areas used for closure equipment storage, waste treatment, staging areas, and other associated activities. If contamination is discovered, it will be removed in accordance with the procedures identified earlier. Assuming that no soil contamination is found, the site will be certified clean by an independent registered professional engineer in accordance with CHSWMA regulations.

4.3.9 Site Restoration

Once it has been confirmed that all wastes have been removed from the Basin F site, the area will be regraded to restore it to as near original contours as is practicable without importing fill materials. Studies to be conducted in 1986 will identify the most suitable methods for land restoration and revegetation, but it is anticipated at this time that the site will be planted to native shortgrasses. The soils will be amended as necessary with fertilizers to promote rapid plant growth and prevent wind or water from eroding the site surface. Native grasses represent one of the more attractive revegetation alternatives due to their low post-closure maintenance requirements and their ability to survive well in the Denver area, but hardier species will also be considered to ensure the establishment of a dense vegetative cover on the Basin F site.

4.4 REGULATORY REQUIREMENTS

4.4.1 Preclosure

The U.S. EPA (Region VIII) and the Colorado Department of Health (CDH) are the two regulatory agencies which may be involved during the preclosure period for Basin F. CDH, under the Colorado Hazardous Waste Management Act, has primacy over the RCRA regulations (but not the 1984 RCRA amendments). EPA need only review any preclosure activities for compliance with the 1984 RCRA amendments even though these amendments do not apply directly to Basin F. CDH requirements for the closure plan and closure activities are essentially identical to those of RCRA and the waste numbering requirement is also the same.

The major preclosure activity is the preparation of this written closure plan that meets the closure performance standards of Part 264.111 and the closure requirements of Part 264.112 of the state hazardous waste regulations.

Any sampling program undertaken during preclosure will also meet the U.S. Occupational Safety and Health Administration (OSHA) standards for worker protection as well as U.S. Department of Transportation (DOT) requirements for hazardous waste sample shipment.

4.4.2 Closure

The regulatory agencies to be involved in closure activities include OSHA, CDH, and EPA. The most pertinent regulations are identified below.

(a) OSHA - In the past, OSHA regulations have not been enforced for RCRA closure activities. However, they may be required by CDH or as a result of a worker complaint or accident. Therefore, the OSHA requirements that should be met during closure are those concerning worker safety and protection during hazardous waste handling and site contamination.

Specific OSHA requirements that would apply are:

- (i) 29 CFR Part 1910.132 Personal Protective Equipment, General Requirements
- (ii) 29 CFR Part 1910.133 Eye and Face Protection
- (iii) 29 CFR Part 1910.134 Respiratory Protection
- (iv) 29 CFR Part 1910.135 Occupational Head Protection
- (v) 29 CFR Part 1910.136 Occupational Foot Protection

(b) CDH--The requirements that must be met during closure involve the timing of closure activities, the handling, disposal and decontamination of waste materials and final certification of closure.

- (i) 40 CFR Part 265.113 - Time allowed for closure
- (ii) 40 CFR Part 265.114 - Disposal or decontamination of equipment
- (iii) 40 CFR Part 265.115 - Certification of closure
- (iv) 40 CFR Part 265, Subpart I - Management of containers
- (v) 40 CFR Part 265.197 - Specific closure evaluation for contaminated tanks
- (vi) 40 CFR Part 262, Subpart B - Manifesting for hazardous waste transportation
- (vii) 40 CFR Part 262, Subpart C - Pretransport requirements (packing, labeling, etc.) for hazardous wastes
- (viii) 40 CFR Part 262, Subpart D - Recordkeeping for hazardous waste shipment

(c) DOT--The requirements that apply during closure involve the labeling, packaging and shipping of hazardous wastes.

- (i) 49 CFR Part 172 - Labeling, packaging, marking, placarding and documenting
- (ii) 49 CFR Part 173 - Hazardous waste preparation for shipping
- (iii) 49 CFR Part 178 - Containers

(d) EPA--The Colorado Department of Health (CDH) has primacy over RCRA provisions, with the exception of the 1984 RCRA amendments. However, it is unlikely that any RCRA amendment regulations will apply during closure of Basin F.

(e) Department of the Interior, Fish and Wildlife Service -- the Migratory Bird Treaty Act of 1918 may apply to migratory birds being killed by contact with contaminated liquids in Basin F. This Act precludes hunting or killing of select migrating birds except as permitted during open hunting seasons by licensed individuals. There are existing facilities in place at Basin F to scare away birds from the impoundment. These facilities will continue to be operated until all liquid pools are removed.

Requirements of the Federal Clean Water Act, administered by the U.S. EPA, may have to be observed if it becomes necessary to discharge effluent during closure operations. This is considered unlikely.

Requirements of the Federal Clean Air Act, also administered by EPA, may apply if there are volatile emissions from Basin F liquids during closure. This is also considered unlikely.

4.4.3 Post Closure

Post closure care will not be required since all wastes will be removed from Basin F.

4.5 HEALTH AND SAFETY PROGRAM

To ensure the safety of all personnel directly engaged in closure activities of Basin F, a Health and Safety Program (HASP) must be established. Although the cleanup contractor(s) will have primary responsibility to prepare a suitable HASP under the direction of a Certified Industrial Hygienist, the main aspects of a HASP, i.e., management and personnel protection, are briefly discussed here. The contractor(s) performing the closure activities will follow the framework established here to develop the site-specific health and safety plan.

4.5.1 Management of the HASP

The prime contractor working on the Basin F closure activities will have the responsibility to develop a comprehensive site specific health and safety plan and to implement the plan for all phases of the project. The plan must be administered by a Certified Industrial Hygienist (CIH) employed by the contractor. The primary responsibilities of the CIH will be to:

- Establish site control work zones;
- Assure that appropriate protective equipment is available and properly utilized by all on-site personnel;
- Assure that personnel are aware of the provisions of the health and safety plan and are instructed in the work practices necessary to ensure safety and in the planned procedures for dealing with emergencies;
- Assure that personnel are aware of the potential hazards associated with site operations;
- Monitor the safety performance of all personnel to ensure that the required work practices are employed;
- Correct any work practice or condition that may result in injury or exposure to hazardous substances;
- Arrange for medical examinations for specified project personnel;

- Arrange for on-site emergency medical care and first aid to be available;

- Notify RMA emergency officers (i.e., police and fire department) of the project team's operations and make emergency telephone numbers available to all team members;

- Provide adequate training specific to the expected hazards including, but not limited to, instructions and demonstrations on the use of required safety equipment, hand signals, monitoring equipment, the buddy system, response to accident and emergencies, removal of protective clothing and equipment, and decontamination of such equipment and of self;

- Provide baseline physicals for all employees engaged in closure activities to identify health and contaminant status of each employee prior to working at HBSF and to identify any restrictions affecting the use of protective clothing and equipment;

- Prepare any accident/incident reports;

- Keep daily logs of all significant safety related incidents that occur.

4.5.2 Personnel Protection

The general guidelines on personnel protection as presented here will be followed unless the on-site monitoring indicates otherwise. For the purpose of clarifying the use of various levels of protective clothing, operations which will be performed during the closure period can be classified into following types:

Type 1: Routine entry for inspection, data gathering and other administrative activities that require no contact with Basin F liquid, overburden, or contaminated soils.

Type 2: Entry to conduct sampling or abatement where the possibility of exposure to hazardous substances has been practically eliminated.

Type 3: Conduct of sampling or abatement procedures where possibility of exposure to hazardous substances exists only under unforeseen circumstances.

Type 4: Conduct of sampling and decontamination operations, where exposure to hazardous substances is probable or certain.

The protective clothing to be employed consists of three levels, i.e., modified Level A, modified Level B and modified Level D. The definitions and contents of the various protective clothing levels are outlined in Table 4-1. Table 4-2 outlines the levels of protective clothing to be employed during the sampling and decontamination period, correlated to the types of operation expected to occur. These tables should only be construed as guides. The exact protective measures to be employed during closure activities will be established by a Certified Industrial Hygienist (CIH) employed by the contractor selected to perform these activities.

TABLE 4-1
PROTECTIVE CLOTHING LEVELS

---

1) Level A (Modified):

Inner Clothing:
a) Undershirt, unimpregnated
b) Drawers, unimpregnated
c) Socks, unimpregnated

Liner: Coveralls, disposable, tyvek material
Outer Clothing: Suit - Coverall, Toxicological Agent Protective (TAP) M3
Gloves: Butyl (TAP) M4
Footwear: Boots, butyl, safety toe, TAP, M2A1
Headgear: Hood, butyl rubber, MSA (for SCBA)
Respirator: SCBA, Mine Safety Appliances or Scott

2) Level B (Modified):

Inner Clothing:
a) Drawers, unimpregnated
b) Undershirt, unimpregnated
c) Socks, unimpregnated

Outer Clothing: Apron, TAP, M2
Gloves: Butyl, TAP, M4
Footwear: Boots, butyl, safety toe, TAP, M2A1
Headgear: Hood, butyl rubber, MSA (for SCBA)
Respirator: SCBA, Mine Safety Appliances or Scott

3) Level D (Modified):

Inner Clothing:
a) Drawers, unimpregnated
b) Undershirt, unimpregnated
c) Socks, unimpregnated

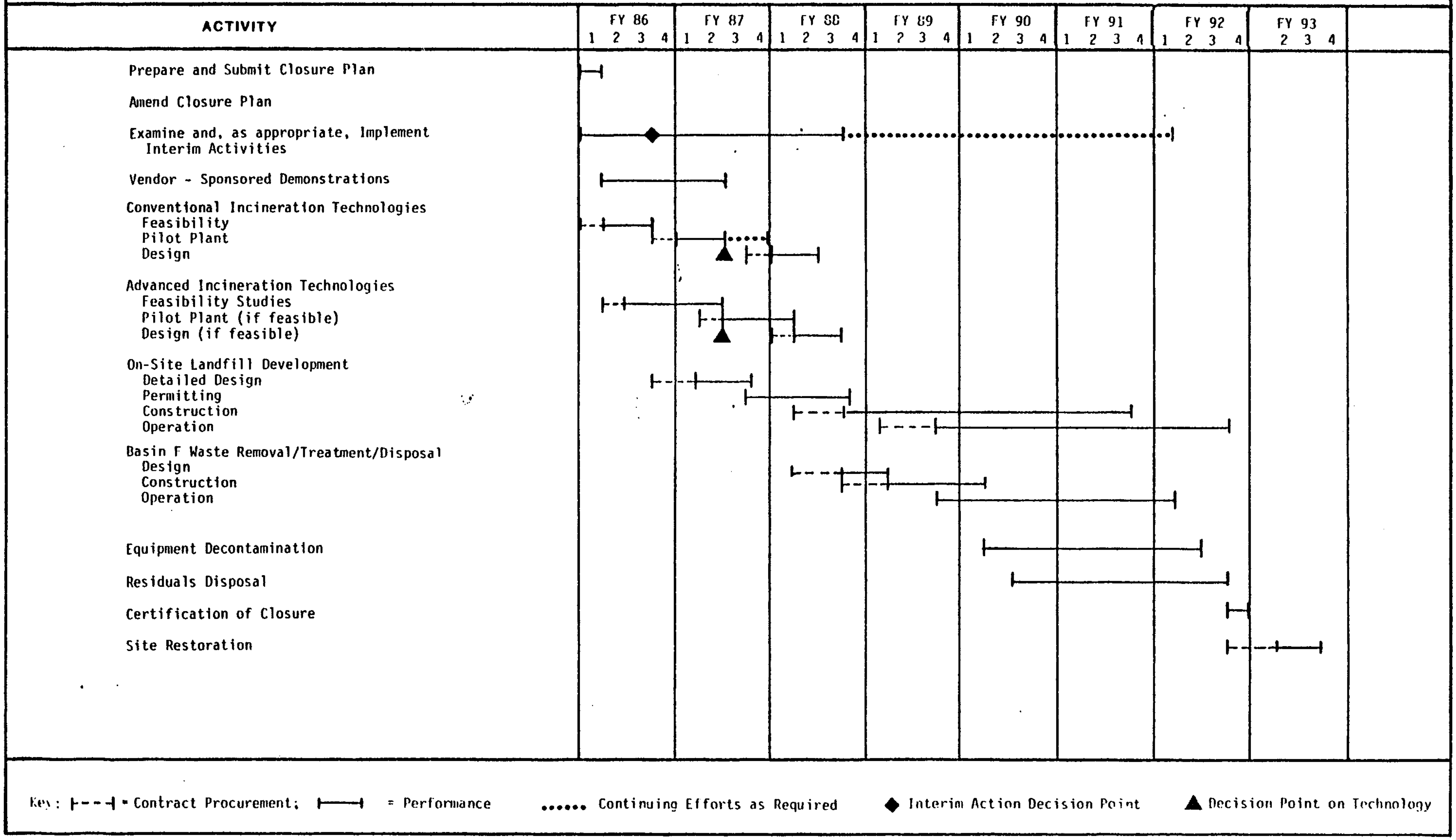
Outer Clothing: Coveralls, disposable, tyvek material
Gloves: Surgical, disposable
Footwear: Boots, butyl, safety toed, TAP, M2A1
Headgear: None
Respirator: SCBA, MSA or Scott

TABLE 4-2

TYPES OF OPERATIONS WITH CORRESPONDING PROTECTIVE CLOTHING LEVEL

	Types of Operation	Protective Clothing Level
Type 1:	Routine safety inspection. Collecting wipe samples of external surface of equipment, tanks, piping and structures, drilling operations for soil sampling, draining of basin via remote pump controls, excavation of soils and overburden.	Modified Level D unless results of air sampling and analysis show the need for Modified Level B gear.
Type 2:	Blending equipment and piping using closed loop rinsing, cleaning of contaminated equipment in an open system.	Modified Level B
Type 3:	Transfer of contaminated wastewater by pumping or of contaminated solid wastes with open heavy equipment.	Modified Level B clothing. In the event, the risk of exposure is higher, Modified Level A
Type 4:	Disassembly of equipment containing Basin F liquid, vapors, or overburden.	Modified Level A

FIGURE 5-1
BASIN F CLOSURE SCHEDULE



6.0 CERTIFICATION OF CLOSURE

Following all waste removal, decontamination, and disposal of residuals, the sampling activities described in Section 4.2 will be conducted. The U.S. Army Corps of Engineers, in conjunction with an independent registered professional engineer working for the cleanup contractor, will certify that all hazardous wastes and constituents have been removed from the SCSBS in accordance with the provisions of this plan.

REFERENCES CITED

Buhts, R.E., N.R. Francinques, A.J. Green. 1979. "Basin F Investigative Studies, Chemical Assessment and Survey." Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

May, J.H. 1982. "Regional Ground Water Study of the Rocky Mountain Arsenal, Denver, Colorado." Geotechnical Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Myers, T.E. and D.W. Thompson. 1982. "Basin F Overburden and Soil Sampling and Analysis Study, Rocky Mountain Arsenal." Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Myers, T.E. and D.W. Thompson. 1983. "Laboratory-Scale Solidification of Basin F Concentrate at Rocky Mountain Arsenal." Draft Report (available May 1983) Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Resource Consultants, Inc. 1982. "Surface Water Hydrological Analyses, Rocky Mountain Arsenal." Ft. Collins, CO.

RMA Contamination Control Program Management Team. 1983. "Selection of a Contamination Control Strategy for RMA." Rocky Mountain Arsenal, Commerce City, CO, and U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, MD.

U.S. Army Engineer Waterways Experiment Station, Geotechnical Laboratory. 1979. "Basin F Containment Hydrogeology Assessment, Rocky Mountain Arsenal, Denver, Colorado." Vicksburg, MS.

U.S. Environmental Protection Agency. 1982. "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods." SW-846 Second Edition, Revised April 1984; Office of Solid Waste and Emergency Response, Washington, D.C.

Zebel, R., D. Thompson, and P. Law. 1979. "Basin F to the North Boundary Area, Rocky Mountain Arsenal, Denver, Colorado, Volume I; Arsenal Investigation, and Volume II: Groundwater Analyses." U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

APPENDIX A

Analytical Results

SWLP, Bulk Organic and Bulk Metal Analysis of Core Samples and Overburden
Basin F

(Myers and Thompson, 1982)

Table A1

Analytical Results from SWLP Conducted on Samples from Boring No. 01

	Sample Identification				
	Core Subsamples				
Analyte	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft	3.0-4.0 ft	Overburden
pH	6.5*	8.2	8.2	8.7	7.2
Aldrin	0.30	0.61	0.71	0.40	5.07
Dieldrin	0.22	0.013	2.41	0.54	19.5
Endrin	0.40	0.20	2.22	0.91	24.4
Isodrin	0.11	0.005	0.005	0.11	0.41
DIMP	70	90	110	110	30
DMMP	-**	-	-	-	-
Dithiane	-	-	-	-	-
Sulfone	-	-	-	-	710
Sulfoxide	-	-	-	-	-
DBCP	-	-	-	-	0.010
Mercury	-	-	0.12	0.12	0.22
Arsenic	95	110	110	90	110
Fluoride (ppm)	7.0	9.5	12.3	15.2	3.3

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A2

Analytical Results from SWLP Conducted on Samples from Boring No. 02

Analyte	Sample Identification			
	Core Subsamples			
	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft	3.0-4.0 ft
pH	9.1*	9.1	9.1	9.1
Aldrin	49.7	8.10	1.42	0.30
Dieldrin	59.1	19.5	4.19	0.12
Endrin	76.3	17.0	4.04	0.40
Isodrin	20.1	0.52	0.11	0.065
DIMP	20	30	30	10.8
DMMP	-**	-	-	-
Dithiane	40	-	-	-
Sulfone	1600	630	530	760
Sulfoxide	1070	440	440	760
DBCP	0.60	0.09	0.09	0.17
Mercury	0.58	1.0	1.24	0.52
Arsenic	170	230	160	120
Fluoride (ppm)	6.1	4.8	7.3	4.3

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A3

Analytical Results from SWLP Conducted on Samples from Boring No. 11

	Sample Identification				
	Core Subsamples				
Analyte	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft	3.0-4.0 ft	Overburden
pH	5.3*	4.6	6.5	6.4	8.6
Aldrin	0.51	-**	0.30	-	8.51
Dieldrin	0.12	0.013	0.12	-	23.6
Endrin	0.04	-	0.71	-	39.4
Isodrin	0.005	0.005	0.005	-	0.11
DIMP	30	20	20	7	20
DMMP	-	-	-	-	0.07
Dithiane	-	-	-	-	-
Sulfone	-	-	-	-	1710
Sulfoxide	-	-	-	-	-
DBCP	-	-	0.022	-	0.07
Mercury	0.12	0.12	0.20	0.16	1.20
Arsenic	-	90	-	20	280
Fluoride (ppm)	0.75	0.95	0.71	1.2	14.8

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A4

Analytical Results from SWLP Conducted on Samples from Boring No. 12

	Sample Identification			
	Core Subsamples			
Analyte	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft	3.0-4.0 ft
pH	5.8*	5.4	5.5	6.0
Aldrin	-**	-	-	-
Dieldrin	-	0.12	-	-
Endrin	-	0.61	-	-
Isodrin	-	-	-	-
DIMP	30	10	10	6
DMMP	-	-	-	-
Dithiane	-	-	-	-
Sulfone	120	-	-	-
Sulfoxide	-	-	-	-
DBCP	-	0.013	-	-
Mercury	-	0.14	0.24	-
Arsenic	14	12	20	50
Fluoride (ppm)	0.48	0.54	0.95	1.95

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A5

Analytical Results from SWLP Conducted on Samples from Boring No. 13

	Sample Identification	
	Core Subsamples	
Analyte	0.0-1.0 ft	1.0-2.0 ft
pH	8.4*	8.2
Aldrin	-**	-
Dieldrin	-	-
Endrin	-	-
Isodrin	-	-
DIMP	40	40
DMMP	0.04	0.04
Dithiane	-	-
Sulfone	-	-
Sulfoxide	-	-
DBCP	-	-
Mercury	0.14	0.14
Arsenic	64	51
Fluoride (ppm)	1.7	1.1

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A6

Analytical Results from SWLP Conducted on Samples from Boring No. 14

	Sample Identification			
	Core Subsamples			
Analyte	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft	Overburden
pH	5.6*	5.8	5.6	8.1
Aldrin	-**	-	0.02	1.59
Dieldrin	-	0.10	0.21	3.24
Endrin	-	-	0.07	44.5
Isodrin	-	-	-	3.1
DIMP	20	20	20	120
DMMP	-	-	-	0.39
Dithiane	-	-	-	-
Sulfone	40	-	-	9160
Sulfoxide	-	-	-	1140
DBCP	-	-	-	1.01
Mercury	0.12	-	0.12	2.14
Arsenic	38	39	71	226
Fluoride (ppm)	1.9	2.1	2.0	15.2

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A7

Analytical Results from SWLP Conducted on Samples from Boring No. 15

Analyte	Sample Identification		
	Core Subsamples		
	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft
pH	5.3*	5.6	5.7
Aldrin	-**	-	-
Dieldrin	0.10	0.10	-
Endrin	0.08	0.07	-
Isodrin	-	-	-
DIMP	40	30	36
DMMP	-	-	-
Dithiane	-	-	-
Sulfone	90	-	-
Sulfoxide	-	-	-
DBCP	-	-	-
Mercury	-	0.12	-
Arsenic	160	170	20
Fluoride (ppm)	0.42	0.40	0.52

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A8

Analytical Results from SPLP Conducted on Samples from Boring No. 21

	Sample Identification		
	Core Subsamples		
Analyte	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft
pH	6.9*	4.8	4.9
Aldrin	-**	0.01	-
Dieldrin	-	-	-
Endrin	-	-	-
Isodrin	-	-	-
DIMP	60	40	20
DMMP	-	-	-
Dithiane	-	-	-
Sulfone	-	-	-
Sulfoxide	-	-	-
DBCP	-	-	-
Mercury	0.58	-	-
Arsenic	-	14	11
Fluoride (ppm)	0.90	1.52	1.4

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A9

Analytical Results from SPLP Conducted on Samples from Boring No. 22

	Sample Identification		
	Core Subsamples		
Analyte	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft
pH	4.9*	4.8	4.4
Aldrin	0.03	-**	-
Dieldrin	0.01	-	-
Endrin	-	-	-
Isodrin	0.08	-	-
DIMP	130	140	150
DMMP	-	-	-
Dithiane	-	-	-
Sulfone	-	-	-
Sulfoxide	-	-	-
DBCP	-	-	-
Mercury	-	-	-
Arsenic	-	-	14
Fluoride (ppm)	1.4	0.855	0.24

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A10

Analytical Results from SWLP Conducted on Samples from Boring No. 23

Analyte	Sample Identification Core Subsamples 0.0-1.0 ft	 1.0-2.0 ft	 2.0-3.0 ft
pH	4.8*	5.0	5.9
Aldrin	-**	-	-
Dieldrin	-	-	0.01
Endrin	-	-	-
Isodrin	-	-	-
DIMP	60	40	30
DMMP	-	-	-
Dithiane	-	-	-
Sulfone	-	-	-
Sulfoxide	-	-	-
DBCP	-	-	-
Mercury	0.20	-	-
Arsenic	15	29	22
Fluoride (ppm)	0.48	0.64	0.39

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A11

Analytical Results from SWLP Conducted on Samples from Boring No. 31

	Sample Identification			
	Core Subsamples			
Analyte	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft	Overburden
pH	5.7*	5.5	5.6	8.5
Aldrin	-**	0.30	-	28.4
Dieldrin	-	1.26	-	20.2
Endrin	-	2.22	-	17.7
Isodrin	0.10	0.005	0.10	8.19
DIMP	20	20	10	310
DMMP	-	-	-	60
Dithiane	-	-	-	-
Sulfone	-	-	-	3200
Sulfoxide	-	-	-	-
DBCP	-	0.03	-	0.46
Mercury	0.16	0.22	-	0.36
Arsenic	11	25	25	360
Fluoride (ppm)	0.66	1.0	3.9	7.8

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A12

Analytical Results from SPLP Conducted on Samples from Boring No. 32

	Sample Identification		
	Core Subsamples		
Analyte	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft
pH	5.5*	5.9	5.9
Aldrin	0.20	-**	0.10
Dieldrin	0.10	-	0.10
Endrin	0.10	-	0.10
Isodrin	-	0.10	0.10
DIMP	170	150	150
DMMP	-	-	-
Dithiane	-	-	-
Sulfone	100	-	-
Sulfoxide	-	-	-
DBCP	-	0.006	-
Mercury	0.16	0.36	-
Arsenic	14	12	14
Fluoride (ppm)	0.57	0.63	0.41

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A13

Analytical Results from SWLP Conducted on Samples from Boring No. 33

Analyte	Sample Identification Core Subsamples 0.0-1.0 ft	 1.0-2.0 ft
pH	5.5*	5.9
Aldrin	0.20	–**
Dieldrin	0.10	–
Endrin	0.20	–
Isodrin	0.10	–
DIMP	20	10
DMMP	–	–
Dithiane	–	–
Sulfone	–	–
Sulfoxide	–	–
DBCP	0.008	–
Mercury	–	0.16
Arsenic	14	28
Fluoride (ppm)	0.67	0.95

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A14

Analytical Results from SWLP Conducted on Samples from Boring No. 50

	Sample Identification			
	Core Subsamples			
Analyte	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft	3.0-4.0 ft
pH	6.2*	5.0	5.2	8.0
Aldrin	0.40	0.30	0.30	-**
Dieldrin	0.43	0.12	0.12	-
Endrin	0.71	0.30	0.50	-
Isodrin	0.11	0.11	0.005	-
DIMP	30	40	20	17
DMMP	-	-	-	-
Dithiane	-	-	-	-
Sulfone	40	-	-	-
Sulfoxide	-	-	-	-
DBCP	-	-	-	-
Mercury	0.12	0.12	0.40	0.38
Arsenic	-	-	-	20
Fluoride (ppm)	0.71	0.41	0.62	0.75

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A15

Analytical Results from SWLP Conducted on Samples from Boring No. 60

	Sample Identification	
	Core Subsamples	
Analyte	0.0-1.0 ft	1.0-2.0 ft
pH	5.2*	5.6
Aldrin	-**	-
Dieldrin	-	0.10
Endrin	-	0.10
Isodrin	0.10	-
DIMP	20	20
DMMP	-	-
Dithiane	-	-
Sulfone	-	-
Sulfoxide	-	-
DBCP	0.01	-
Mercury	0.54	0.16
Arsenic	-	11
Fluoride (ppm)	0.63	0.41

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A16

Analytical Results from SWEP Conducted on Samples from Boring No. 70

	Sample Identification			
	Core Subsamples			
Analyte	0.0-1.0 ft	1.0-2.0 ft	2.0-3.0 ft	Overburden
pH	4.7*	5.6	5.5	8.5
Aldrin	-**	0.10	-	0.27
Dieldrin	0.10	-	-	0.10
Endrin	0.70	-	-	0.61
Isodrin	-	0.10	0.10	-
DIMP	40	20	20	40
DMMP	-	-	-	-
Dithiane	-	-	-	-
Sulfone	-	-	-	840
Sulfoxide	-	-	-	-
DBCP	-	-	-	-
Mercury	0.22	-	0.42	0.28
Arsenic	12	11	11	81
Fluoride (ppm)	0.36	0.40	0.43	6.4

---

* All values other than pH are reported as ppb unless otherwise noted.

** Less than detection limit.

Table A17

Bulk Organic Analysis of the 0.0-1.0 ft Core Subsample from Boring No. 01

Tentative Identification	Level (μg/g)
Diisopropylmethylphosphonate	5
Toluene	0.6
1,1,2-Trichloroethane	2
Tetrachloroethylene	0.2
Unknown (*m/e* 79 base)	1
Xylene	0.1
Xylene	0.1
1,1,2,2-Tetrachloroethane	4
Pentachloroethane	0.3
Acetophenone	0.1
Unknown (*m/e* 79 base)	2
Unknown (*m/e* 79 base)	2
Unknown (*m/e* 79 base)	6
Unknown (*m/e* 79 base)	1
S_6 (molecular sulfur)	1
S_8 (molecular sulfur)	16
Unknown (*m/e* 275 base)	2
4-*tert*-Butyl-2-(*tert*-butylthio)pyridine	0.5

Table A18

Bulk Metal Analysis of the 0.0-1.0 ft Core Subsample from Boring No. 01

Analyte	Concentration (µg/g)
Silver	1.18
Aluminum	8750
Arsenic	<1.8
Boron	7.15
Barium	170
Beryllium	<0.08
Calcium	2130
Cadmium	<0.1
Cobalt	9.29
Chromium	13.1
Copper	<100
Iron	11300
Mercury	0.023
Potassium	2630
Magnesium	3050
Manganese	384
Molybdenum	6.19
Sodium	4250
Nickel	14.3
Phosphorus	579
Lead	27.1
Antimony	45.0
Selenium	<6.2
Tin	<50
Titanium	48.0
Thallium	24.4
Yttrium	16.2
Zinc	49.4
Fluoride	152

Table A19

Bulk Organic Analysis of the Overburden from Boring No. 11

Tentative Identification	Level (µg/g)
Dimethymethylphosphonate	40
Diisopropylmethylphosphonate	–
p-chlorophenylmethylsulfone	250
Chlorophenylmethylsulfone isomer	12
Aldrin	500
Isodrin	80
Dieldrin	530
Endrin	450
Benzene	20
Cyclohexene	130
Dimethyl disulfide	2
1,1,2-trichloroethane	6
Unknown (possibly N-methylacetamide)	80
MW 93 unknown	80
Weak unknown (*m/e* 78 base)	30
2° or 3° amine unknown	20
Unknown (*m/e* 57 base)	30
Alkane	5
Alkane	4
N-nitrosodipropylamine	200
2° or 3° amine unknown	25
N-containing unknown	20
2° or 3° amine unknown	30
Methylcyclopentadiene	2
Methylcyclopentadiene isomer	2
Unknown (*m/e* 79 base)	270
Hexachlorobutadiene	70
Monochlorinated unknown (MW 158)	177
Alkane	3

(Continued)

Table A19 (Continued)

Tentative Identification	Level (μg/g)
Hexachlorobicycloheptadiene	800
Alkane	8
Unknown	7
Aldrin-type pesticide (?), Weak!	7
Chlorinated unknown (MW 332)	300
Chlorinated unknown	10
Alkane	14
Alkane	8
Tetrachlorobenzene	70
Chlorinated unknown	250
Unknown (*m/e* 57 base)	20
S_8 (molecular sulfur)	300
Unknown	35
2° or 3° amine unknown	10
2° or 3° amine unknown	13
2° or 3° amine unknown	40
Aldrin-type chlorinated pesticide	180

Table A20

Bulk Metal Analysis of the Overburden from Boring No. 11

Analyte	Concentration (µg/g)
Silver	0.561
Aluminum	6830
Arsenic	<1.8
Boron	6.48
Barium	94.6
Beryllium	<0.08
Calcium	6110
Cadmium	0.55
Cobalt	5.66
Chromium	10.7
Copper	5220
Iron	7660
Mercury	0.057
Potassium	1810
Magnesium	2740
Manganese	189
Molybdenum	5.55
Sodium	23700
Nickel	13.8
Phosphorus	3100
Lead	35.6
Antimony	29.0
Selenium	<6.2
Tin	<50
Titanium	63.6
Thallium	15.0
Yttrium	9.56
Zinc	69.7
Fluoride	494

Table A21

Bulk Organic Analysis of the 0.0-1.0 ft Core Subsample from Boring No. 12

Tentative Identification	Level (µg/g)
p-Chlorophenylmethylsulfone	2.1
Toluene	8
1,1,2-Trichloroethane	1.1
Tetrachloroethylene	0.2
MW 98 unknown	30
Xylene	0.2
Unknown (*m/e* 79 base)	5
1,1,2,2-Tetrachloroethane	4
Pentachloroethane	0.2
MW 98 or 134 unknown	7.9
Unknown	2
S_6 (molecular sulfur)	1

Table A22

Bulk Metal Analysis of the 0.0-1.0 ft Core Subsample from Boring No. 12

Analyte	Concentration (μg/g)
Silver	1.26
Aluminum	7190
Arsenic	<1.8
Boron	6.31
Barium	133
Beryllium	<0.08
Calcium	18700
Cadmium	<0.1
Cobalt	6.34
Chromium	10.5
Copper	<100
Iron	10200
Mercury	0.010
Potassium	1840
Magnesium	3060
Manganese	257
Molybdenum	5.01
Sodium	811
Nickel	9.59
Phosphorus	558
Lead	19.7
Antimony	<2.0
Selenium	<5.2
Tin	<50
Titanium	84.5
Thallium	22.9
Yttrium	11.8
Zinc	37.3
Fluoride	95.0

Table A23

Bulk Organic Analysis of the Overburden from Boring No. 12

Tentative Identification	Level (μg/g)
Dieldrin	5.4
p-Chlorobenzene methyl sulfoxide	3.6
p-Chlorobenzene methyl sulfone	32
p-Chlorobenzene methyl sulfoxide isomer	1
Aldrin	1.4
Toluene	14
1,1,2-Trichloroethane	1
MW 98 unknown	3
Unknown	7
Xylene	0.3
N,N-dimethylactamide	2
Unknown	5
N-nitrosodipropylamine	20
MW 127 unknown	4
Unknown 2° or 3° amine	24
Weak unknown	1
Unknown (*m/e* 79 base)	8
Unknown	20
MW 153 chlorinated unknown	5
Methyl sulfonyl benzene (very weak)	0.3
Weak unknown	1
S_8 (molecular sulfur)	30
Unknown (275 base pk)	6
4-*tert*-Butyl-2(*tert*-butylthio)pyridine	8
Unknown MW 221 N-containing compound	4
Weak MW 131 unknown	4

Table A24

Bulk Metal Analysis of the Overburden from Boring No. 12

Analyte	Concentration (μg/g)
Silver	1.15
Aluminum	7280
Arsenic	<1.8
Boron	8.08
Barium	115
Beryllium	<0.08
Calcium	4440
Cadmium	<0.1
Cobalt	5.57
Chromium	9.76
Copper	613
Iron	9640
Mercury	0.091
Potassium	1790
Magnesium	2350
Manganese	205
Molybdenum	4.97
Sodium	14100
Nickel	10.4
Phosphorus	1350
Lead	17.4
Antimony	18.0
Selenium	<6.2
Tin	<50
Titanium	84.4
Thallium	18.1
Yttrium	9.90
Zinc	41.5
Fluoride	217

Table A25

Bulk Organic Analysis of the 0.0-1.0 ft Core Subsample from Boring No. 14

Tentative Identification	Level (µg/g)
DMMP	2.6
DIMP	1.5
p-Chlorophenylmethylsufone	0.9
Toluene	4.7
1,1,3-Trichloroethane	3.1
Tetrachloroethylene	0.2
Possibly N-methylacetamide	0.3
MW 98 unknown	3.2
Xylene	0.2
Xylene	0.5
Weak unknown	1.3
Xylene	0.3
1,1,2,2-Tetrachloroethane	11
Pentachloroethane	0.7
Acetophenone	0.5
Unknown (*m/e* 79 base)	7
S_6 (molecular sulfur)	5
S_8 (molecular sulfur)	20

Table A26

Bulk Metal Analysis of the 0.0-1.0 ft Core Subsample from Boring No. 14

Analyte	Concentration (μg/g)
Silver	1.53
Aluminum	6840
Arsenic	<1.8
Boron	9.82
Barium	120
Beryllium	<0.08
Calcium	9120
Cadmium	<0.1
Cobalt	7.90
Chromium	11.8
Copper	<100
Iron	10900
Mercury	0.015
Potassium	2200
Magnesium	4920
Manganese	294
Molybdenum	5.41
Sodium	895
Nickel	13.6
Phosphorus	606
Lead	22.5
Antimony	100
Selenium	<6.2
Tin	<50
Titanium	94.5
Thallium	28.3
Yttrium	14.5
Zinc	47.5
Fluoride	184

Table A27

Bulk Organic Analysis of the 0.0-1.0 ft Core Subsample from Boring No. 31

Tentative Identification	Level (μg/g)
DMMP	1.9
p-Chlorophenylmethylsulfone	0.6
Toluene	1
1,1,2-Trichloroethane	2
Unknown	3
Xylene	0.2
Unknown (m/e 79 base)	1
Xylene	0.1
1,1,2,2-Tetrachloroethane	7
Pentachloroethane	0.3
Acetophenone	0.1
Unknown (m/e 79 base)	4
Weak unknown (contains m/e 79)	2
S_6 (molecular sulfur)	2
S_8 (molecular sulfur)	6

Table A28

Bulk Metal Analysis of the 0.1-1.0 ft Core Subsample from Boring No. 31

Analyte	Concentration (µg/g)
Silver	1.47
Aluminum	9270
Arsenic	<1.8
Boron	14.6
Barium	177
Beryllium	<0.03
Calcium	18900
Cadmium	<0.1
Cobalt	8.31
Chromium	14.2
Copper	<100
Iron	12700
Mercury	0.030
Potassium	2680
Magnesium	5050
Manganese	329
Molybdenum	6.85
Sodium	655
Nickel	15.0
Phosphorus	562
Lead	23.6
Antimony	117
Selenium	<6.2
Tin	<50
Titanium	75.1
Thallium	35.2
Yttrium	14.9
Zinc	49.9
Fluoride	224

Table A29

Bulk Organic Analysis of the Overburden from Boring No. 31

Tentative Identification	Level (μg/g)
Aldrin	3,100
Isodrin	200
p-Chlorophenylmethylsulfone	70
Toluene	30
Hexachlorobutadien	220
Monochlorinated unknown (MW 158)	100
Hexachlorobicycloheptadiene	1,700
Chlorinated unknown	500
Tetrachlorobenzene	30
S_8 (molecular sulfur)	130
Unknown (m/e 275 base)	30
Dieldrin	550
Chlorinated unknown	30
Aldrin-type chlorinated pesticide	200

Table A30

Bulk Metal Analysis of the Overburden from Boring No. 31

Analyte	Concentration (µg/g)
Silver	0.65
Aluminum	7460
Arsenic	<1.8
Boron	8.70
Barium	126
Beryllium	<0.08
Calcium	16100
Cadmium	0.21
Cobalt	6.03
Chromium	11.3
Copper	2110
Iron	9190
Mercury	0.031
Potassium	2050
Magnesium	3600
Manganese	219
Molybdenum	5.54
Sodium	32700
Nickel	13.1
Phosphorus	2980
Lead	25.4
Antimony	55.0
Selenium	<6.2
Tin	<50
Titanium	91.6
Thallium	19.1
Yttrium	9.72
Zinc	49.2
Fluoride	336

Table A31

Bulk Organic Analysis of the 0.0-1.0 ft Core Subsample from Boring No. 33

Tentative Identification	Level (μg/g)
p-Chlorobenzene methyl sulfone	0.4
Toluene	6
1,1,2-Trichloroethane	2
Tetrachloroethylene	0.2
MW 98 Unknown	30
Xylene	0.2
Unknown (m/e 79 base)	4
Tetrachloroethane	5
Pentachloroethane	0.4
MW 98 or 134 unknown	11
Alkane	0.3

Table A32

Bulk Metal Analysis of the 0.0-1.0 ft Core Subsample from Boring No. 33

Analyte	Concentration (µg/g)
Silver	1.35
Aluminum	11500
Arsenic	<1.8
Boron	8.58
Barium	162
Beryllium	<0.08
Calcium	2990
Cadmium	<0.1
Cobalt	8.71
Chromium	14.8
Copper	<100
Iron	13600
Mercury	0.015
Potassium	2680
Magnesium	3380
Manganese	296
Molybdenum	8.31
Sodium	1030
Nickel	15.1
Phosphorus	432
Lead	24.6
Antimony	55.0
Selenium	<6.2
Tin	<50
Titanium	70.2
Thallium	32.9
Yttrium	15.0
Zinc	49.0
Fluoride	60.8

Table A33

Bulk Organic Analysis of the 0.0-1.0 ft Core Subsample from Boring No. 70

Tentative Identification	Level (μg/g)
Toluene	10
1,1,2-trichloroethane	3.0
Tetrachloroethylene	0.2
MW 98 unknown	30
Xylene	0.3
Unknown (*m/e* 79 base)	9
1,1,2,2-Tetrachloroethane	13
Pentachloroethane	0.8
MW 98 or 134 unknown	30
Unknown	0.7
Alkane	2

Table A34

Bulk Metal Analysis of the 0.0-1.0 ft Core Subsample from Boring No. 70

Analyte	Concentration (μg/g)
Silver	1.23
Aluminum	2590
Arsenic	<1.8
Boron	9.66
Barium	53.3
Beryllium	<0.08
Calcium	1300
Cadmium	<0.1
Cobalt	3.34
Chromium	4.49
Copper	<100
Iron	4040
Mercury	0.013
Potassium	385
Magnesium	1050
Manganese	123
Molybdenum	1.92
Sodium	124
Nickel	4.90
Phosphorus	230
Lead	12.4
Antimony	55.0
Selenium	<5.2
Tin	<50
Titanium	45.4
Thallium	3.77
Yttrium	5.63
Zinc	18.3
Fluoride	60.8