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ICATION TECHNICAL SUPPORT AND SERVICES

Rocky Mountain Arsenal

Water Quantity/Quality Survey

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Final Screening Program
Third and Fourth Quarters
Final Report
(Version 3.1)
Volume I

May 1988

Contract Number DAAK11-84-D-0016
Task Number 4

PREPARED BY

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
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PREPARED FOR

U.S. ARMY PROGRAM MANAGER'S OFFICE FOR
ROCKY MOUNTAIN ARSENAL

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THIS DOCUMENT PRESENTS THE RESULTS OF TASK 4 THIRD AND FOURTH QUARTER MONITORING EFFORTS. THIRD AND FOURTH QUARTER INVESTIGATIONS INCLUDED THE MEASUREMENT, COLLECTION, AND ANALYSIS OF SURFACE AND GROUND WATER DATA.

THE REPORT INCLUDES THE FOLLOWING:

1. SUMMARY OF GROUND AND SURFACE WATER MONITORING NETWORKS AND ANALYTICAL SUITE DEVELOPMENT FOR THIRD AND FOURTH QUARTERS
2. GEOCHEMICAL DATA FROM GROUND WATER AND SURFACE WATER ANALYSES PRESENTED IN TABLES WITH RMA DISTRIBUTION PLOTS FOR ALL ANALYTES
3. GAS CHROMATOGRAPHY/MASS SPECTROSCOPY RESULTS FOR NONTARGET ANALYTES
4. SURFACE AND GROUND WATER QUANTITY INFORMATION, INCLUDING WATER LEVEL, POTENTIOMETRIC SURFACE MAPS, AND SURFACE WATER MONITORING RESULTS.

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1.0 INTRODUCTION

1.1 TASK OBJECTIVES

A litigation-quality data base that includes both water quality and quantity information must be established to aid in Rocky Mountain Arsenal (RMA) environmental investigations. Task 4 was established to address this issue by collecting sufficient water quality and quantity information to help surface water and ground water geochemical and hydrologic assessments. Task 4 objectives include:

- Compliance with requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) governing the conduct of a Remedial Investigation/Feasibility Study (RI/FS) pursuant to the National Contingency Plan (NCP);
- Development of a core data base to use in litigation and RI/FS analysis; and
- Verification and assessment of the lateral and vertical extent and nature of contamination at RMA.

In order to achieve these objectives, five technical elements were performed:

- Review of historical data;
- Development of a comprehensive monitoring program;
- Execution of the monitoring program utilizing litigation-quality sampling and analysis procedures;
- Assessment of data on a quarterly basis for possible adjustment of the monitoring program; and
- Evaluation of the accumulated data at the end of the 1-year program to assess analyte concentrations and distribution patterns and changes to these distributions with respect to time.

These technical elements were addressed under the Initial Screening Program (ISP), Third Quarter, and Fourth Quarter Program assessments. The ISP sampled over 380 wells from September 1985 to February 1986, and provided basic water quality information for the selection of the Third and Fourth

Quarter Task 4 sampling networks. Results from this effort are included in the Final ISP Report (ESE, 1987b, RIC#87253R01). Third Quarter (spring 1986) and Fourth Quarter (summer 1986) sampling was conducted on reduced well networks of approximately 180 wells. These networks were comprised of a core network that will be used in future RMA sampling programs. The ISP water level network of approximately 850 wells was generally maintained for Third and Fourth Quarter monitoring.

This document presents the results of Task 4 Third and Fourth Quarter monitoring efforts. Third and Fourth Quarter investigations included the measurement, collection, and analysis of surface and ground water data. Information presented herein includes:

- Summary of ground and surface water monitoring networks and analytical suite development for Third and Fourth Quarters:
- Geochemical data from ground water and surface water sample analyses presented in tables, with RMA distribution plots for all ground water analytes;
- Gas chromatography/mass spectroscopy (GC/MS) results for nontarget analytes; and
- Surface and ground water quantity information, including water level and potentiometric surface maps, and surface water monitoring results.

Detailed interpretation of Task 4 data is beyond the stated scope-of-work for this task and will be conducted under subsequent RMA tasks.

1.2 BACKGROUND

1.2.1 RMA CHRONOLOGY OF EVENTS

RMA occupies more than 27 square miles (sq mi) in Adams County, Colorado, and is located approximately 9 miles (mi) northeast of downtown Denver (Figure 1.2-1). RMA was established in 1942 and has been used for the manufacture of chemical and incendiary munitions, as well as for chemical ordnance demilitarization. Industrial chemicals were manufactured at RMA from 1947 to 1982.

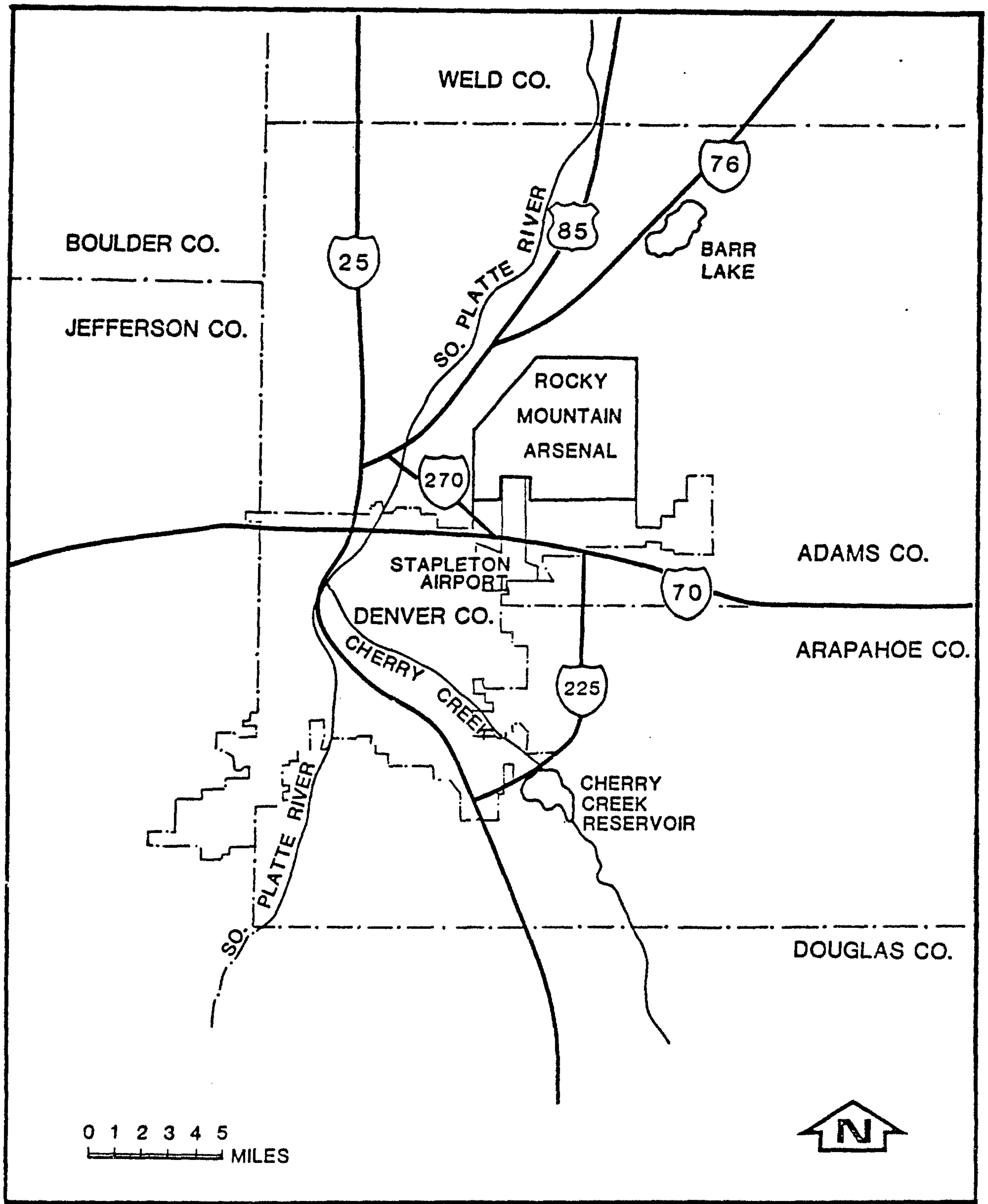

Figure 1.1-1
LOCATION MAP

SOURCE: RMA, 1983

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

The property occupied by RMA was purchased by the government in 1942. Throughout World War II (WWII), RMA manufactured and assembled chemical intermediate and toxic end-item products and incendiary munitions.

From 1945 to 1950, RMA distilled stocks of Levinstein mustard, demilitarized mustard-filled shells, and test-fired 10.7-centimeter (cm) mortar rounds filled with smoke and high explosives. Also, many different types of obsolete WWII ordnance were destroyed by detonation or burning.

In 1947, Colorado Fuel and Iron Corporation (CF&I) leased portions of RMA for the manufacture of chlorinated aromatic compounds. Julius Hyman and Company (Hyman) assumed the CF&I lease in 1950 to produce pesticides. Pesticide and herbicide manufacturing operations were later undertaken by Shell Chemical Company (SCC).

In the early-1950's, RMA was selected as the site for construction of a facility to produce chemical agents. The facility was completed in 1953, with manufacturing operations continuing until 1957. The munitions-filling operations continued until late 1969. Since 1970, RMA has been involved with the destruction and disposal of chemical warfare material.

Disposal practices at RMA included discharge of industrial waste effluents to unlined evaporation basins and burial of solid wastes at various locations. In addition, unintentional spills of raw materials, process intermediates, and end products have occurred within the manufacturing complexes at RMA. Many of these compounds are mobile in surface waters and ground waters.

In 1956, an asphalt-lined disposal basin (Basin F) was constructed at RMA. Disposal of wastes to Basin F began in 1956 and continued until June 1982, when the chemical sewer entering the basin was removed.

In 1954 and 1955, farms to the northwest of RMA experienced severe crop losses when contaminated well water was used for irrigation (USDHEW, 1965, RIC#85007R02). The U.S. Department of Health, Education, and Welfare (USDHEW) investigation concluded that the alluvial aquifer beneath RMA was contaminated. Primary contaminants were identified as chloride, fluoride, arsenic, chlorate, the herbicide 2,4-D, and pesticides aldrin and dieldrin. The study also reported that severe damage to crops and ground water supplies had resulted from this contamination. More recently, in 1974, the U.S. Army and Colorado Department of Health (CDH) reported that diisopropylmethylphosphonate (DIMP), which is a manufacturing by-product of GB nerve agent, and dicyclopentadiene (DCPD), a chemical used in insecticide production, had been detected in offpost surface water. Since 1978, dibromochloropropane (DBCP), a nematocide produced onsite by SCC and shipped from RMA by rail from 1970 to 1975, has been observed in offpost ground water.

In response to the detection of offsite contamination, the State of Colorado issued a Cease and Desist Order in 1975 which required RMA to initiate a regional hydrologic surveillance program. The program required quarterly collection and analysis of over 100 onpost and offpost surface water and ground water samples. In order to satisfy other operational and regulatory requirements at RMA, various other programs have been implemented and are utilized for monitoring and surveillance of surface and ground water.

1.2.2 GEOLOGY

RMA is located within the geologic province of the Denver Basin, a structural depression resulting from tectonic adjustments that began during the Laramide orogeny. The study area lies on a bedrock surface formed by the late Cretaceous to early Tertiary Denver Formation. Quaternary alluvial and eolian deposits overlay the Denver Formation (Figure 1.2-2). Regional dip is to the southeast.

1.2.3 HYDROGEOLOGY

The four major bedrock aquifers within the Denver ground water basin are the Laramie-Fox Hills, the Arapahoe, the Denver, and the Dawson Formations. Also, surficial alluvial deposits as well as crystalline rocks of the Front Range locally yield sufficient quantities of water to be considered aquifers. The strata of primary concern at RMA are the Denver Formation and

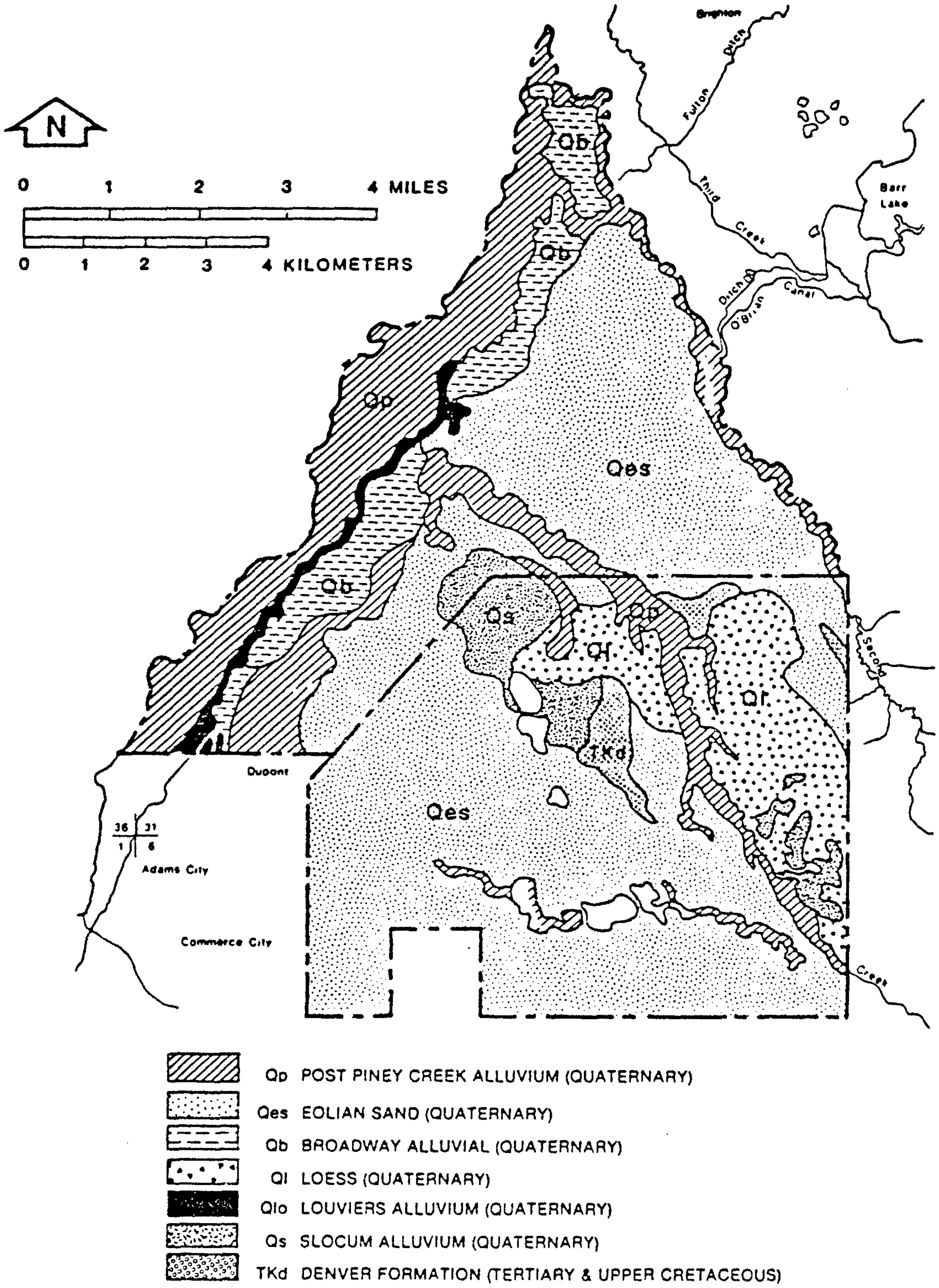

Figure 1.2-2
GEOLOGIC MAP OF
ROCKY MOUNTAIN ARSENAL AREA

SOURCE: USGS, 1981

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For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

the unconsolidated Quaternary alluvial and eolian surficial deposits. The alluvial aquifer and water-bearing zones within the Denver Formation comprise the ground water regime of concern within the study area.

1.2.3.1 Denver Formation

The Denver Formation unconformably overlies the Arapahoe Formation and consists of 250 to 400 feet (ft) of olive, bluish-gray, green-gray, and brown clay-shale and siltstone interbedded with poorly sorted, weakly lithified tan to brown, fine- to medium-grained sandstone and conglomerates. Lignite beds and carbonaceous shales are common, as are volcanic rock fragments and tuffaceous materials. The clay-shale is largely of bentonitic composition. Major water transmitting zones in the formation occur as lenticular sandstones. The lenses are irregularly distributed within thick clay-shale sequences and are discontinuous to semicontinuous and sinuous in nature.

1.2.3.2 Surficial Deposits (Alluvium)

The unconsolidated materials overlying the Denver Formation consist of alluvial and eolian deposits of Quaternary age. The material is composed primarily of alluvial fill, dune sand, and glacial outwash containing cobbles, boulders, and beds of volcanic ash as well as alluvial sands, gravels, silts, and clays. The combined thickness of the surficial materials ranges from less than 5 ft to 130 ft, with the thicker deposits infilling paleochannels cut in the surface of the Denver Formation.
A structure contour map of the top of the bedrock surface indicates several major paleochannels (Figure 1.2-3). Paleochannels in some areas may significantly influence ground water flow and, therefore, contaminant transport; however, the entire sequence of surficial materials should be considered capable of bearing water.

1.2.4 CONTAMINANTS

The presence of contaminated ground water at RMA has been recognized since the mid-1950's when the use of ground water for irrigation resulted in crop losses. Since then, numerous investigations have suggested widespread contamination by a variety of organic and inorganic chemicals. It has been

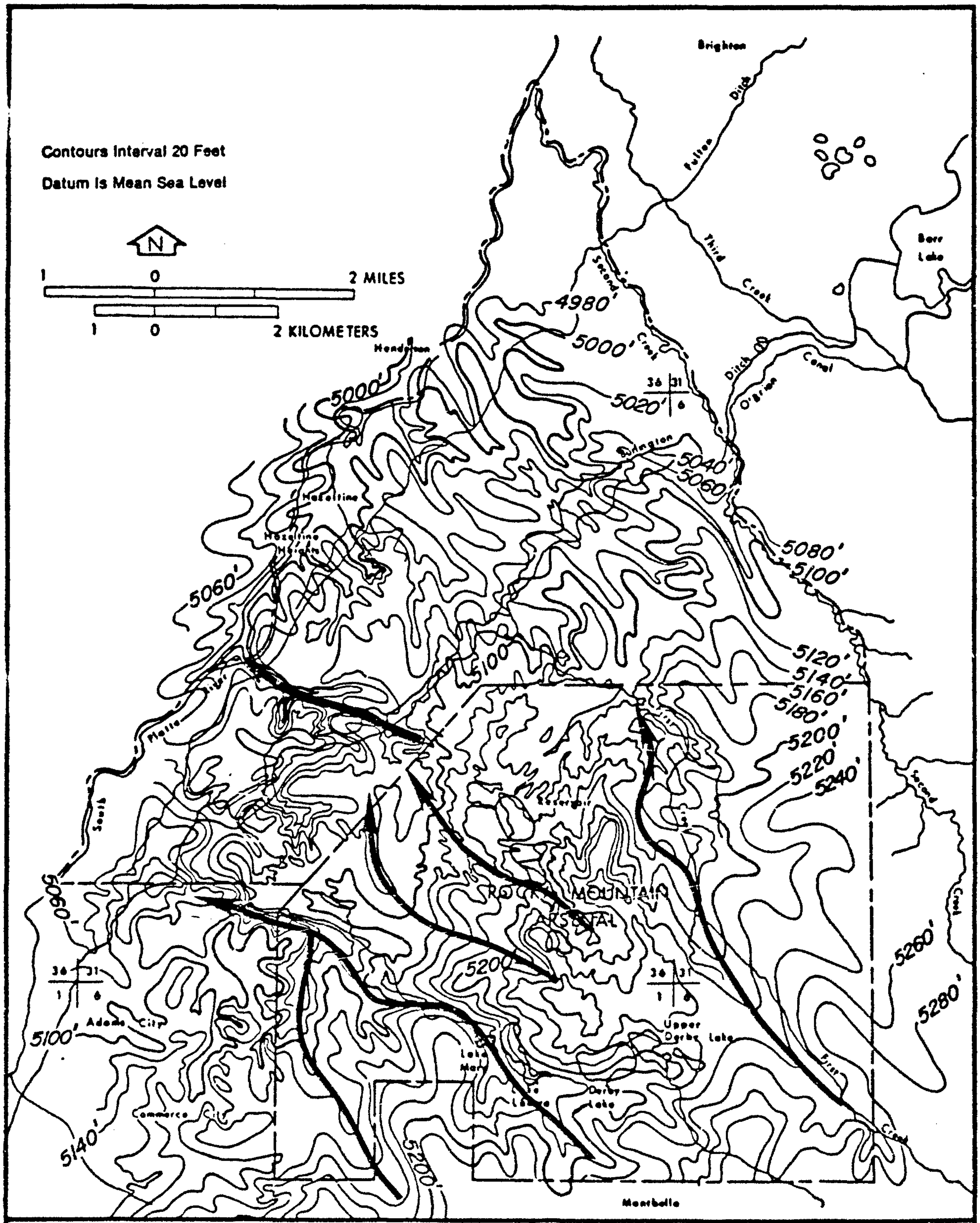

Figure 1.2-3
BEDROCK ELEVATIONS AND LOCATIONS OF MAJOR PALEOCHANNELS
SOURCE: ESE, 1988

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For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

well established that ground water degradation is directly related to past activities of the Army, SCC, and other industrial operators within RMA boundaries. Investigations have been conducted to identify the sources and extent of contamination, types of compounds present, migration mechanisms of those compounds within RMA, and changes in the nature and extent of contamination over time.

The number and type of chemical analyses performed and analytes detected in RMA ground water have varied over time because of several factors, including increased environmental knowledge and concern, improvements in analytical methods, and the status of RMA activities. The compounds of greatest environmental concern are those associated with the production and demilitarization of munitions by the Army, the production of pesticides by SCC, and other industrial operations.

The first ground water contamination investigations were conducted in the mid-1950's in response to crop loss claims by farmers utilizing large quantities of alluvial ground water for irrigation. The primary contaminants identified were chloride, fluoride, arsenic, herbicidal chemicals, and pesticides aldrin and dieldrin (Fairbanks and Kolmer, 1976, RIC#81266R68; USDHEW, 1965, RIC#85007R02).

In 1974, DIMP and DCPD were identified in surface water moving offpost (Fairbanks and Kolmer, 1976, RIC#81266R68). In response, a regional hydrologic surveillance program (360° Monitoring Program) was initiated, and DIMP, DCPD, and a number of other compounds were identified in RMA ground waters. Other major contaminants identified on an RMA-wide basis included DBCP, aldrin, dieldrin, endrin, isodrin, dithiane, oxathiane, and chlorophenylmethyl sulfide, sulfoxide, and sulfone (CPMS, CPMSO, and $CPMSO_2$).

Chloride originated from various brine solutions utilized in industrial processes and from cooling water discharges. DBCP, DCPD, CPMS, CPMSO, $CPMSO_2$, aldrin, dieldrin, endrin, and isodrin are all related to SCC pesticide manufacture. DIMP, fluoride, arsenic, dithiane, and oxathiane are all associated with Army agent manufacture, munitions filling, or munitions demilitarization.

Recent investigations have also identified a number of widely distributed volatile organic compounds in RMA ground water. These volatile organic compounds include toluene, xylene, benzene, chlorobenzenes, chloroform, methylene chloride, carbon tetrachloride, dichloroethylene, trichloroethylene, and tetrachloroethylene (Spaine, et al., 1984, RIC#85133R04). Prior to the Spaine investigation, several volatile organic compounds were detected in RMA ground water as early as 1979 (USATHAMA, 1985). These compounds included benzene, chlorobenzenes, chloroform, carbon tetrachloride, trichloroethylene, and tetrachloroethylene.

The compounds currently considered to be of major significance include fluoride, chloride, DIMP, dithiane, oxathiane, aldrin, dieldrin, endrin, DCPD, DBCP, CPMS, CPMSO, $CPMSO_2$, and a series of volatile organic compounds (see Section 2.3). The relative significance of these compounds is based on their detection and widespread occurrence, their potential origin in RMA industrial operations, the compound concentrations, and their environmental fate and impact.

1.2.5 CONTAMINANT SOURCES

Major contaminant sources have been identified through previous hydrogeologic investigations, chemical analyses of soil and ground water samples, and reviews of historical activities at RMA. The locations of these primary contaminant sources are depicted in Figure 1.2-4. Detailed descriptions of site activities performed and compounds detected are presented in the Task 4 Technical Plan (ESE, 1986, RIC#87013R01). General descriptions of major contaminant sources are presented below for South Plants, Basins A, B, C, D, E, and F, Rail Classification Yard, Sanitary Sewer System, and Industrial Waste System.

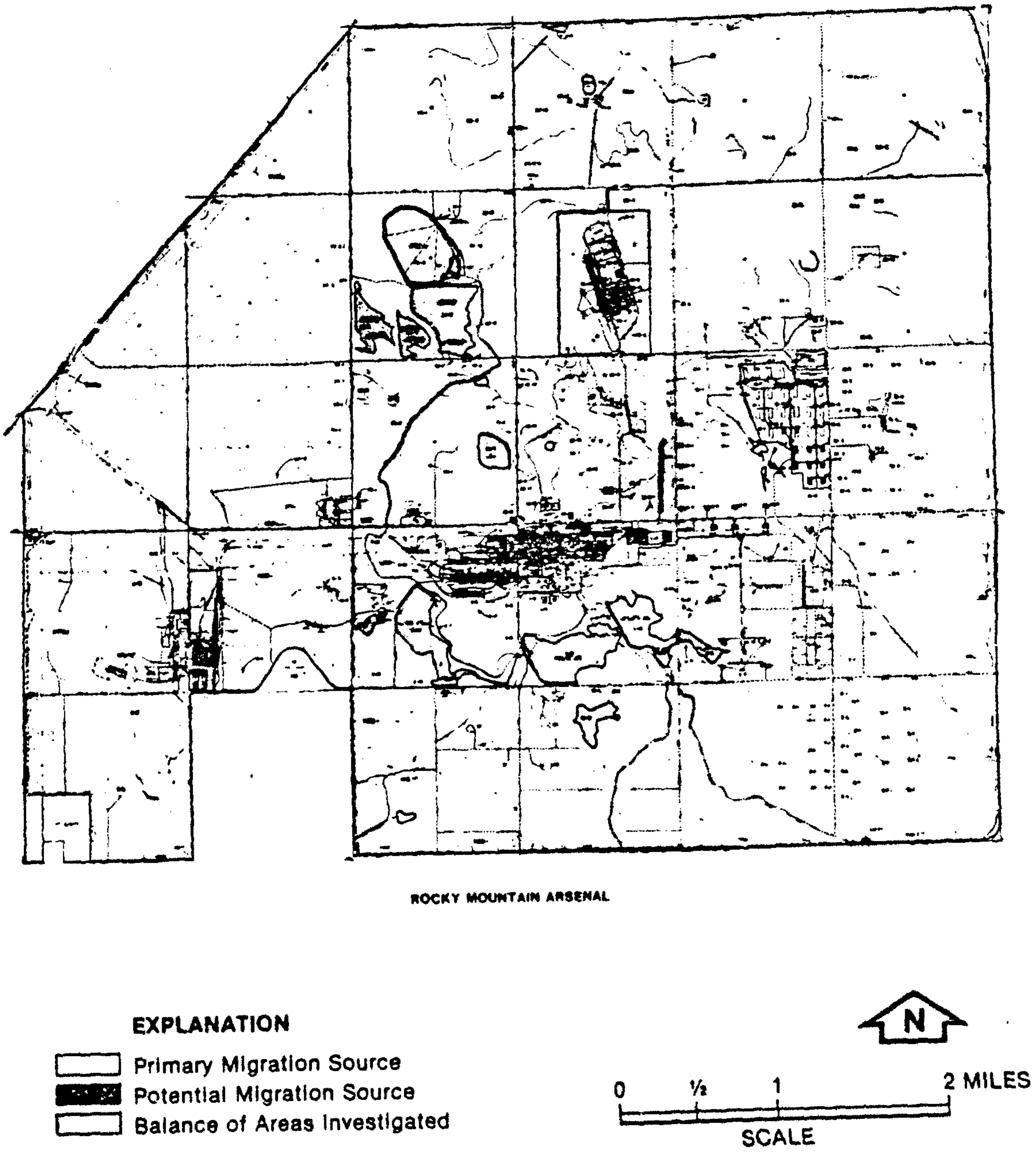

Figure 1.2-4
AREAS INVESTIGATED AS
MIGRATION SOURCES ON RMA

Prepared for:
U.S. Army Toxic and Hazardous
Materials Agency
Aberdeen Proving Ground, Maryland

South Plants - The South Plants Area (Sites 1-13 and 2-18; Figure 1.2-4) was part of the original RMA manufacturing complex. These facilities were used by the Army for production and storage of chemical-filled munitions, incendiary munitions, and intermediate products. SCC later used the facility for pesticide manufacture.

Basin A - Basin A (Site 36-1; Figure 1.2-4) was the original disposal site for most wastewater generated by military and lessee activities between 1942 and 1956. This site is an unlined, natural topographic depression that exceeded 125 acres during periods of maximum use.

Basins B, C, D, and E - Basins B through E (Sites 35-3, 26-3, 26-4, 26-5; Figure 1.2-4) are unlined, modified topographic depressions utilized to contain overflow from Basin A between 1943 and 1957. Basin C was again used in 1957 to contain liquids from Basin F (Site 26-6) during repair of the Basin F liner.

Basin F - Basin F (Site 26-6; Figure 1.2-4) is an asphalt-lined basin created by construction of a retention dike around a natural depression. This basin was constructed in 1956 in response to complaints from local farmers concerning ground water contamination. Basin F began receiving liquid waste in 1956 and was the disposal site for most liquid waste, some solid chemical wastes, and production wastewater from 1956 to December 1981.

Rail Classification Yard - DBCP was manufactured by SCC and shipped by rail from RMA. Contamination resulted from a suspected major DBCP spill near the middle of the yard (Site 3-4; Figure 1.2-4). Smaller spills may have also occurred but exact locations are uncertain.

Sanitary Sewer System - The Sanitary Sewer System consists of a network of drainlines, connectors, laterals, trunklines, lift stations, and manholes which transports wastewater generated throughout RMA to the sewage treatment plant in Section 24. Increases and decreases in flow over different sections of the system indicate interaction among the sewer system and surface water and/or ground water (Black and Veatch Consulting Engineers, 1979, RIC#81266R35).

Industrial Waste System - The industrial waste system, also referred to as the contaminated waste lines or chemical sewer system, consisted of sewer lines which carried Army and lessee wastes to Basin A and later to Basin F. Since 1982, large portions of the chemical sewer system have been excavated and disposed in Basin F. Instances of leakage into and out of these lines have been documented (May, 1982, RIC#82295R01).

2.0 PROGRAM DESIGN

2.1 GROUND WATER MONITORING PROGRAM

Ground water monitoring programs were developed for Third and Fourth Quarter onpost sampling to monitor ground water quality and quantity. Development of ground water programs is discussed in detail below.

2.1.1 GROUND WATER LEVEL NETWORK DESIGN

Objectives of the Third and Fourth Quarter water level monitoring include confirmation of ISP results, collection of quarterly water level data to assess seasonal water level fluctuations, and collection of data to be used in regional hydrologic assessments.

The ground water monitoring network for the Task 4 Third and Fourth Quarters (spring and summer, 1986) consisted of approximately 850 wells (630 alluvial and 220 Denver Wells) chosen for the measurement of static water levels and is essentially the same network developed for ISP water level monitoring. All wells monitored for water levels are screened in the alluvium or in the Denver Formation. The ISP network design for monitoring water levels is described in detail in the Task 4 Technical Plan (ESE, 1986, RIC#87013R01). Third and Fourth Quarter water level data are included in Appendix A.

2.1.2 GROUND WATER QUALITY SAMPLING NETWORK AND ANALYTICAL SCHEDULE DESIGN

2.1.2.1 Objectives

As stated in the ISP report, objectives of the Third and Fourth Quarter water quality sampling program include:

- Confirmation of ISP water quality results;
- Assessment of seasonal water quality fluctuations;
- Provision of temporal information with respect to vertical and aerial contaminant distribution; and
- Collection of data to help design the Fourth Quarter Task 4 effort.

Well network and analytical suite modifications were conducted for the Third and Fourth Quarter efforts to streamline Task 4 efforts without sacrificing essential water quality information, and to maintain a core well network for temporal comperisons between ISP, Third Quarter, and Fourth Quarter results. The Third Quarter water quality sampling objectives are discussed in great detail in the Final ISP Report (ESE, 1987b, RIC#87253R01).

2.1.2.2 Well Network Selection Process

Third Quarter

Although the same general water level well network that was used in the ISP was also used in the Third and Fourth Quarter programs, the ISP water quality well network was modified to produce the Third Quarter network. Several well selection criteria were used to evaluate wells and determine the revised Third Quarter network:

- Water Quality - Wells in background areas, wells with high analyte concentrations, and wells with transitional water quality were included in the revised well network;
- Proximity to Analyte Distribution Patterns--Wells that define the extent of lateral and vertical contaminant distribution were included in the network. Significant wells within analyte distribution patterns were also selected;
- Historical Data Discrepancies--Wells displaying significant discrepancies between ISP and historical chemical data were included in the Third Quarter revised network. If discrepancies were resolved following Third Quarter sampling, and if these well would provide no other benefit to the program, the wells were dropped from subsequent sampling programs;
- Well Construction Factors--Wells were selected for the Third Quarter revised network upon reexamination of previously conducted construction evaluations. Additional information regarding wells that were constricted or destroyed, or information regarding previous sampling techniques was used to further evaluate wells, and wells were added or removed from the network based on this information: and
- Ongoing Programs--The twelve Basin F monitoring wells were automatically included in the Third Quarter Sampling Program. Several of the wells in the ISP Basin F network were either of poor construction or were dry, and a modified Basin F network was recommended for sampling in the Third Quarter (Table 2.1-1).

Table 2.1-1. Basin F Replacement Monitoring Wells*

Well No.	Initial Screening Program	Third Quarter Program	Reason
23049	X	--	Well dry in Initial Screening Program
23095	X	--	Unacceptable construction
23108	X	--	Unacceptable construction
23142	X	X	Adequate construction
23185	--	X	Cluster
23186	--	X	Cluster
23187	--	X	Cluster
23191	--	X	Cluster
23192	--	X	Cluster
26011	--	X	Better construction, replace 26015,17
26015	X	--	Unacceptable construction
26017	X	--	Unacceptable construction
26020	X	--	Unacceptable construction
26041	X	X	Adequate construction
26073	X	X	Adequate construction
26076	X	--	Well dry
26083	--	X	Cluster - replace 26020
26084	--	X	Cluster - replace 26020
26085	X	X	Adequate construction
26127	X	X	Adequate construction
27016	X	--	Unacceptable construction

*X Indicates that well is in current and/or proposed program.

-- Indicates that well is not in current and/or proposed program.

Source: ESE, 1987.

This evaluation produced a recommended Third Quarter well network of 96 alluvial and 78 Denver wells (ESE, 1987b, RIC#87253R01). Prior to sampling, several wells were either added to or omitted from the Third Quarter network (Table 2.1-2). Wells were added if ISP results indicated that additional water quality information was necessary in certain areas. Wells were omitted if they were found to be destroyed or unsampleable. The resultant Third Quarter sampling network is comprised of 100 alluvial and 80 Denver wells. These wells are listed in Tables 2.1-3 and 2.1-4 and their locations are shown in Figures 2.1-1 and 2.1-2.

Fourth Quarter

Consistent sampling of a basic core network is required to provide adequate comparative temporal data. With this in mind, the Fourth Quarter network was generated from the Third Quarter Program. Alluvial and Denver wells were added to the Third Quarter network to produce the Fourth Quarter program if Third Quarter data indicated that samples from these wells should be analyzed to more clearly define contaminant distribution at RMA. Additionally, some wells originally designated for Third Quarter analysis were not sampled during the Third Quarter for various reasons and were included in Fourth Quarter sampling. Several other wells included in Third Quarter sampling were omitted from the Fourth Quarter sampling because of technical considerations or problems such as insufficient recharge for sampling or destruction of the well. Wells added and omitted to the Fourth Quarter Sampling Program are listed in Table 2.1-2. The Fourth Quarter sampling network consists of 99 alluvial and 83 Denver wells. These wells are listed in Tables 2.1-5 and 2.1-6, and their locations are shown in Figures 2.1-3 and 2.1-4.

2.1.2.3 Analytical Program Design

Third Quarter

In order to determine the Third Quarter analytical program, RMA was divided into four regions exhibiting distinct analyte groupings (Figure 2.1-5) as indicated by ISP and historical results These data indicate that chemical

Table 2.1-2. Wells Omitted from and Added to the Third and Fourth Quarter (FY86) Network Prior to Sampling

Third Quarter

Alluvial		Denver	
Added	Omitted	Added	Omitted
23199	02011	25014	02012
27005	03002	31007	03003
27016	23049X*		03004
33022	27056		04009
33023	33033		25012
33024			27054
34516			35059
36139			

Fourth Quarter

Alluvial		Denver	
Added	Omitted	Added	Omitted
02011	01030	02012	19019
03022	08003	03003	23180
24135	09001	03004	30005
27056	23166	04009	
33033	32001	24136	
	35034	24137	

* X: Indicates well is destroyed.

Source: ESE, 1987.

Table 2.1-3. Wells Sampled, Rocky Mountain Arsenal Task 4, Third Quarter (FY86) Alluvial Aquifer

Section	Total Wells	Well Number
01	5	012, 020, 021, 024, 030
02	4	008, 020, 034, 037
03	3	005, 008, 523
04	13	007, 010, 014, 016, 021, 024, 027, 029, 030, 031, 032, 033, 524
06	2	002, 003
07	1	001
08	1	003
09	3	001, 002, 005
11	1	002
12	1	002
22	3	021, 059, 060
23	10	095, 108, 125, 142, 166, 179, 182, 185, 188, 191
24	4	150, 158, 178, 185
25	4	008, 011, 015, 022
26	11	011, 015, 017, 020, 041, 073, 076, 083, 085, 127, 133
27	5	005, 016, 040, 053, 062
28	2	023, 027
30	1	009
31	1	006
32	1	001
33	8	002, 022, 023, 024, 025, 030, 060, 061
34	3	002, 008, 515
35	6	034, 037, 052, 058, 061, 065
36	7	001, 065, 075, 076, 082, 112, 139
Total =	100	

Source: ESE, 1987.

Table 2.1-4. Wells Sampled, Rocky Mountain Arsenal Task 4, Third Quarter (FY86) Denver Aquifer

Section	Total Wells	Well Number
01	6	014, 022, 023, 025, 031, 032
02	9	009, 010, 019, 030, 031, 035, 036, 038, 039
04	1	011
06	2	004, 005
07	2	004, 005
09	1	003
11	1	004
12	2	003, 004
19	3	015, 016, 019
22	1	024
23	7	177, 180, 183, 186, 187, 190, 192
24	1	159
25	6	009, 010, 013, 014, 016, 023
26	7	066, 084, 086, 128, 140, 142, 147
27	3	055, 057, 058
28	2	025, 026
30	3	005, 010, 011
31	2	007, 008
33	5	016, 026, 027, 032, 034
34	1	009
35	9	012, 013, 038, 039, 059, 062, 063, 067, 068
36	6	066, 083, 110, 113, 114, 121
Total =	80	

Source: ESE, 1987.

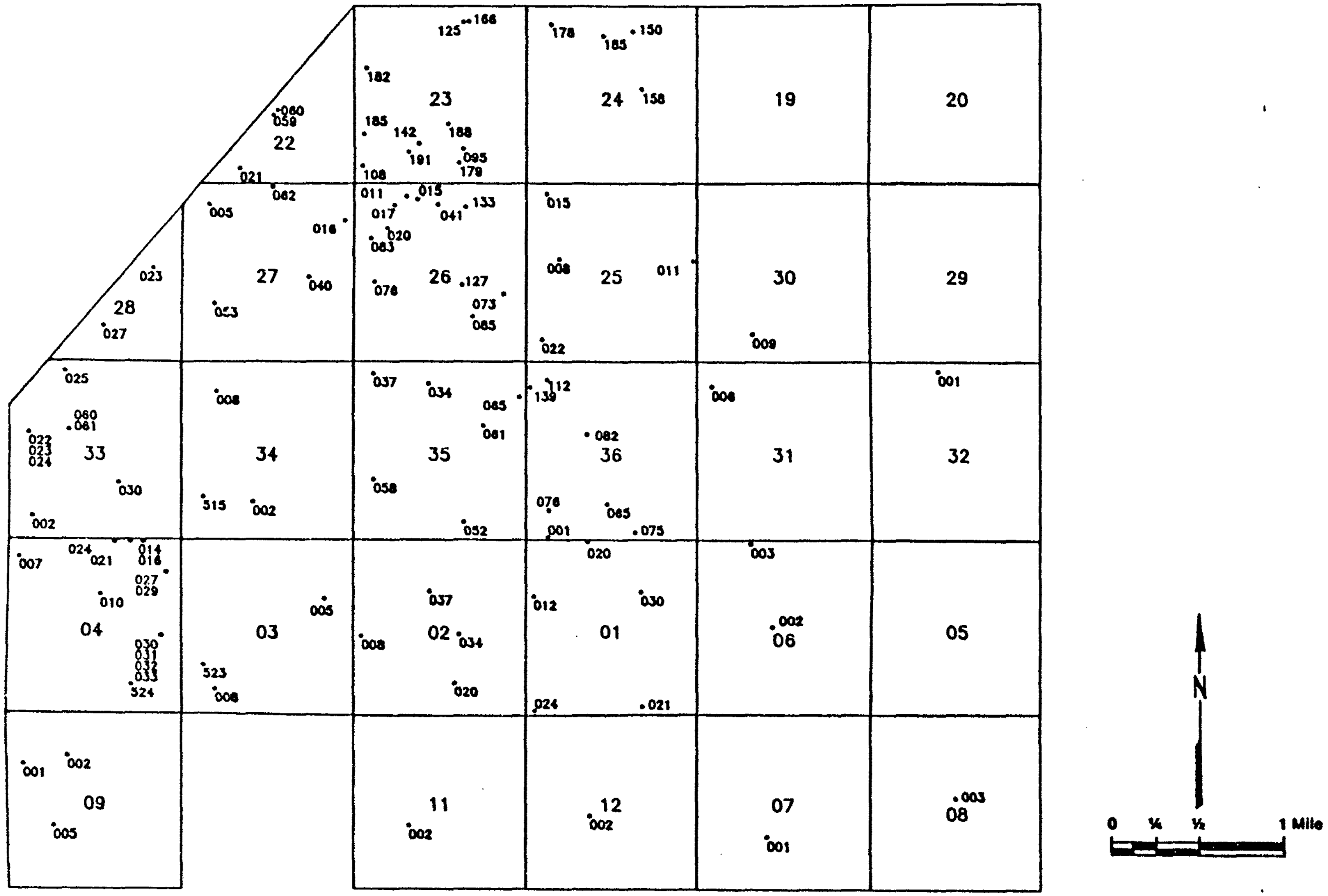

Figure 2.1-1
BASE MAP RMA TASK 4 THIRD QUARTER ALLUVIAL AQUIFER (FY86)

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Aberdeen Proving Ground, Maryland

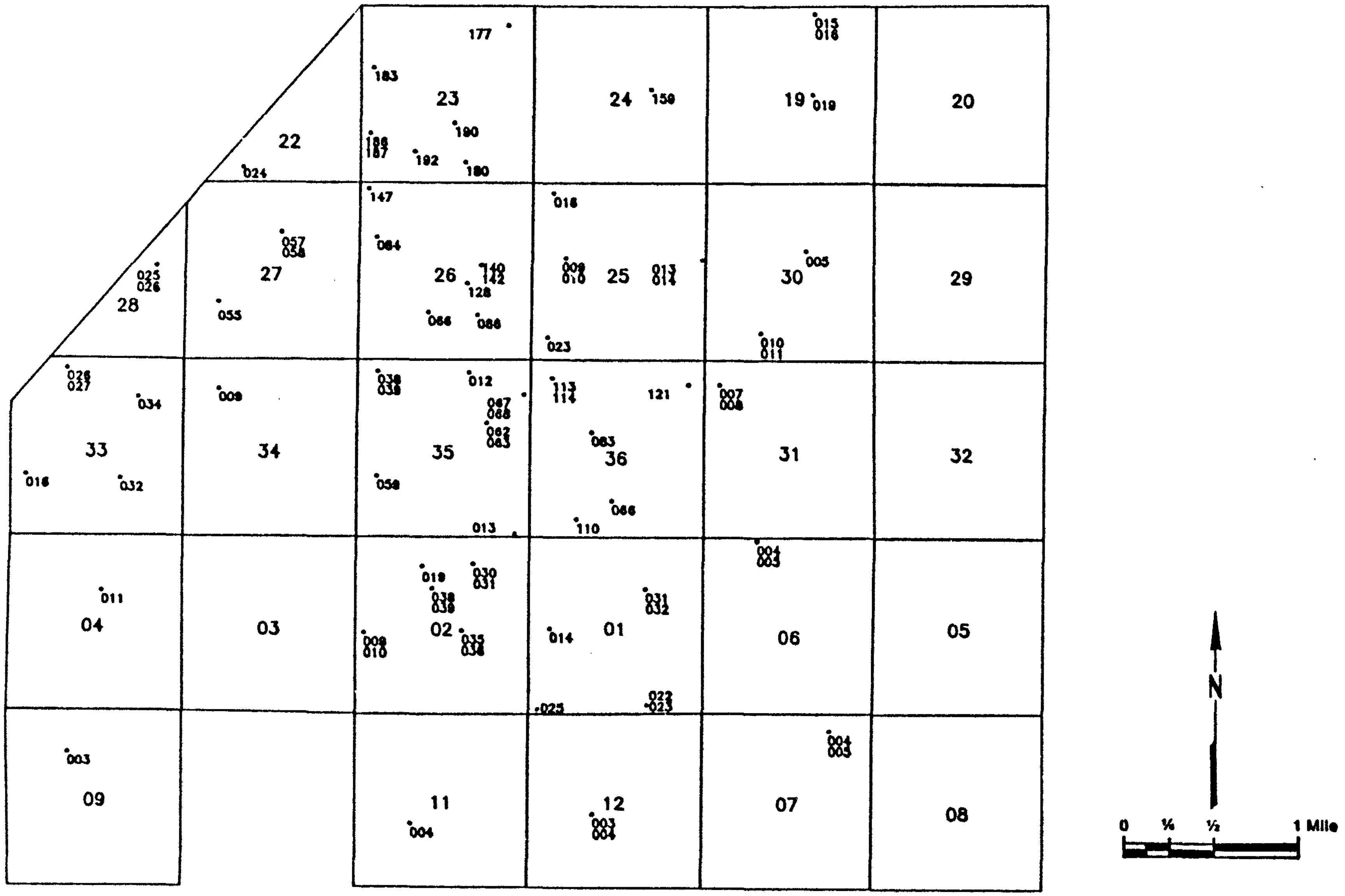

Figure 2.1-2
BASE MAP RMA TASK 4 THIRD QUARTER DENVER AQUIFER (FY86)

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Table 2.1-5. Wells Sampled, Rocky Mountain Arsenal Task 4, Fourth Quarter (FY86) Alluvial Aquifer

Section	Total Wells	Well Number
01	4	012, 020, 021, 024
02	5	008, 011, 020, 034, 037
03	4	002, 005, 008, 523
04	13	007, 010, 014, 016, 021, 024, 027, 029, 030, 031, 032, 033, 524
06	2	002, 003
07	1	001
09	2	002, 005
11	1	002
12	1	002
22	3	021, 059, 060
23	9	095, 108, 125, 142, 179, 182, 185, 188, 191
24	5	135, 150, 158, 178, 185
25	4	008, 011, 015, 022
26	11	011, 015, 017, 020, 041, 073, 076, 083, 085, 127, 133
27	6	005, 016, 040, 053, 056, 062
28	2	023, 027
30	1	009
31	1	006
33	9	002, 022, 023, 024, 025, 030, 033, 060, 061
34	3	002, 008, 515
35	5	037, 052, 058, 061, 065
36	7	001, 065, 075, 076, 082, 112, 139
Total =	99	

Source: ESE, 1987.

Table 2.1-6. Wells Sampled, Rocky Mountain Arsenal Task 4, Fourth Quarter (FY86) Denver Aquifer

Section	Total Wells	Well Number
01	6	014, 022, 023, 025, 031, 032
02	10	009, 010, 012, 019, 030, 031, 035, 036, 038, 039
03	2	003, 004
04	2	009, 011
06	2	004, 005
07	2	004, 005
09	1	003
11	1	004
12	2	003, 004
19	2	015, 016
22	1	024
23	6	177, 183, 186, 187, 190, 192
24	3	136, 137, 159
25	6	009, 010, 013, 014, 016, 023
26	7	066, 084, 088, 128, 140, 142, 147
27	3	055, 057, 058
28	2	025, 026
30	2	010, 011
31	2	007, 008
33	5	016, 026, 027, 032, 034
34	1	009
35	9	012, 013, 038, 039, 059, 062, 063, 067, 068
36	6	066, 083, 110, 113, 114, 121
Total =	83	

Source: ESE, 1987.

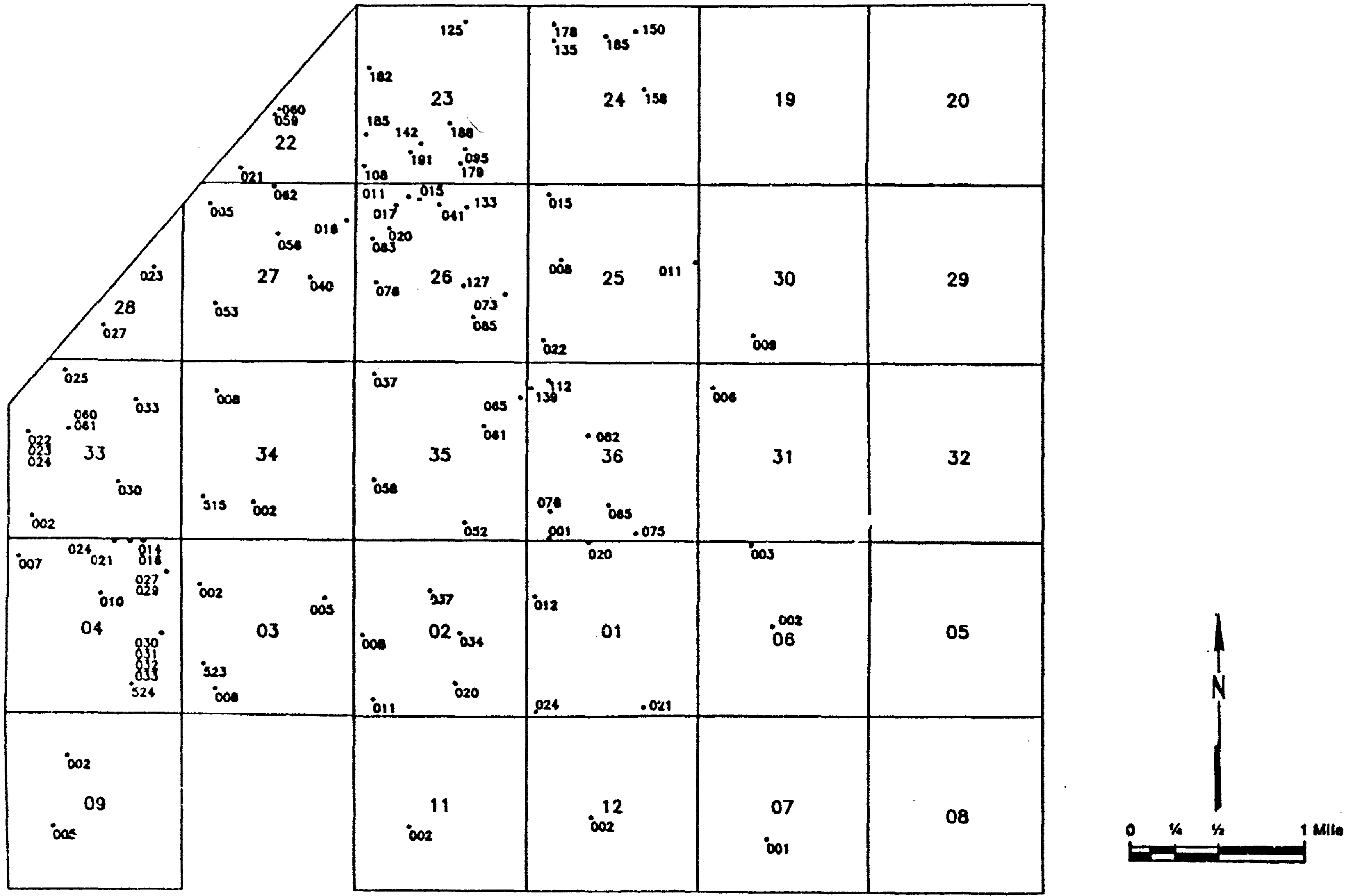

Figure 2.1-3
BASE RMA TASK 4 FOURTH QUARTER ALLUVIAL AQUIFER (FY86)

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Aberdeen Proving Ground, Maryland

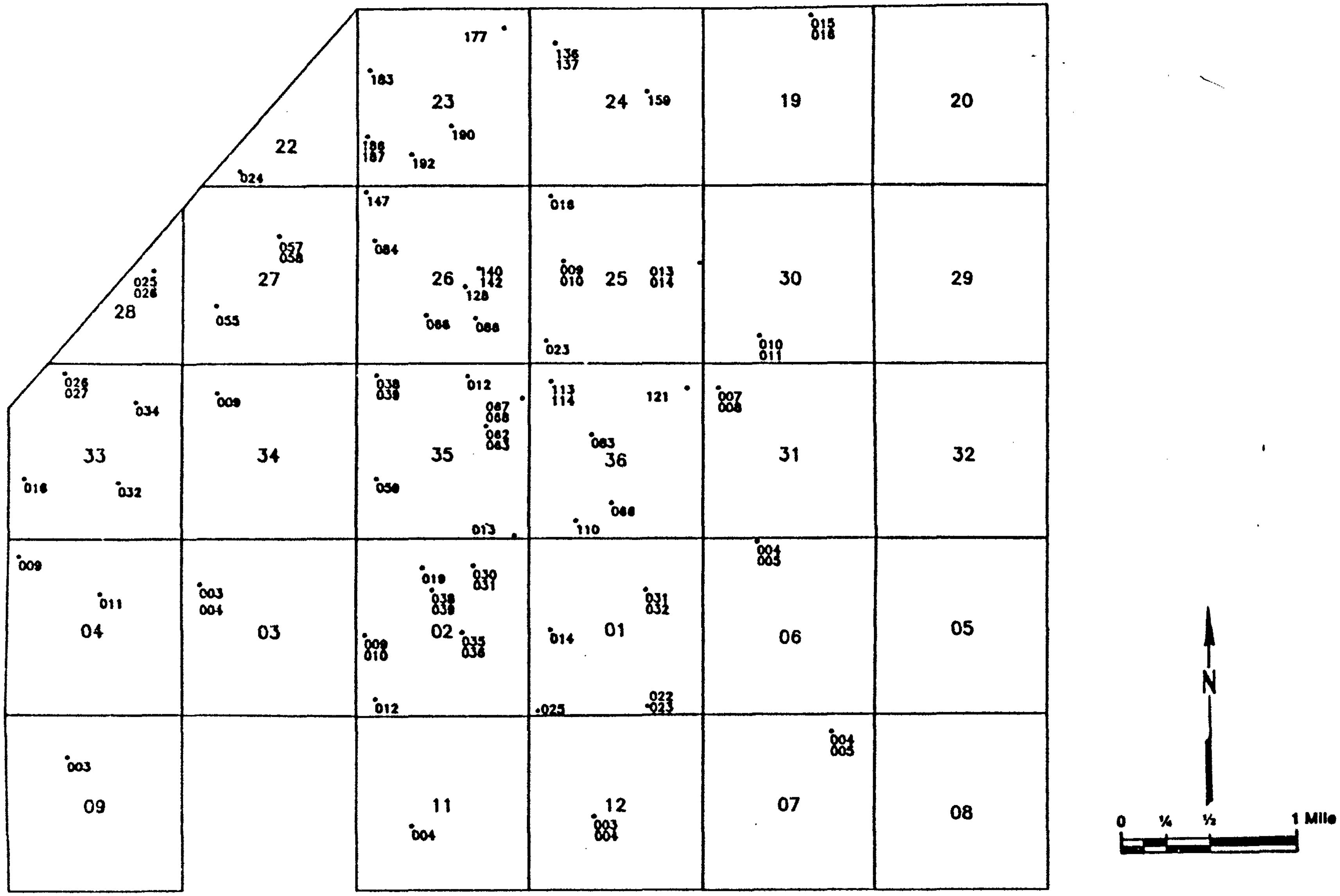

Figure 2.1-4
BASE MAP RMA TASK 4 FOURTH QUARTER DENVER AQUIFER(FY86)

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Aberdeen Proving Ground, Maryland

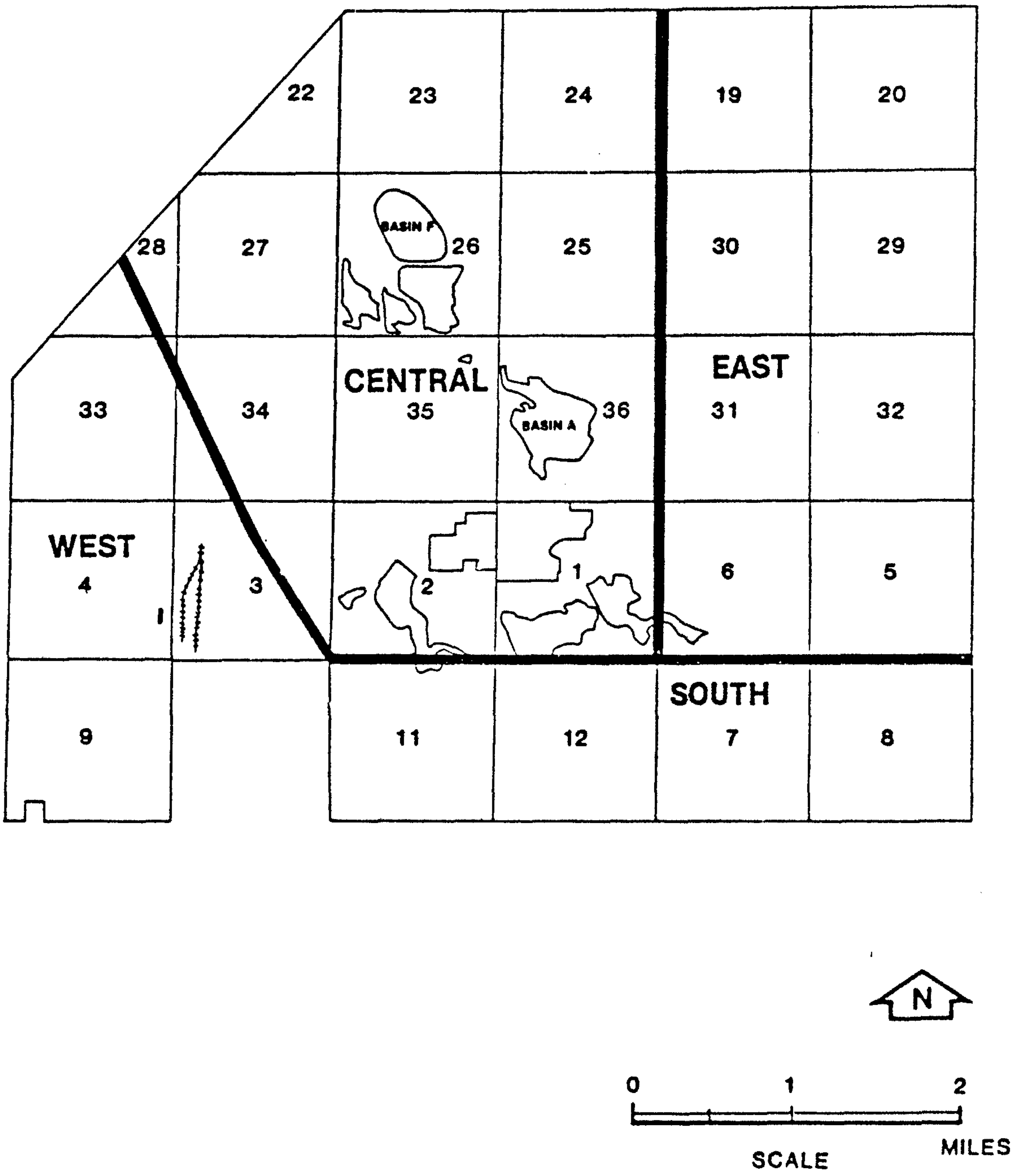

Figure 2.1-5
REGIONS OF RMA REQUIRING DIFFERENT
ANALYTICAL SUITES FOR THIRD QUARTER
AND FOURTH QUARTER (FY86) SAMPLING

Prepared for:
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For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

analyses of the complete RMA target analyte list were not necessary for all of RMA, and Third Quarter analytical suites were determined for each region (Table 2.1-7).

Samples from wells in all four regions were analyzed for organochlorine pesticides, DBCP, volatile organohalogens, volatile aromatics, chloride, fluoride, and sulfate. Samples from wells in the eastern, southern, and central regions were also analyzed for organosulfur compounds, DIMP/DMMP, DCPD, and MIBK; central region well samples were also analyzed for inductively coupled plasma (ICP) metals, arsenic, and mercury. In addition to the previously stated suites, the western region well samples were also analyzed for ICP metals and arsenic. Analytical suites for individual wells and analytical results are included in Appendix B.1.

Fourth_Quarter

Based on ISP and Third Quarter results, Fourth Quarter analytical suites were developed for each of the four RMA regions (Table 2.1-7). Analytical suites for Third and Fourth Quarter wells are essentially the same, with the exception of DIMP/DMMP which was added to the Fourth Quarter suite in the western region. Specific analytes for individual wells are listed in Appendix B.1.

GC/MS_Analysis

Following examination of ISP results, it was determined that analyses should be conducted to detect nontarget analytes and to confirm target analyte occurrences. To accomplish this, approximately 10 percent of samples collected from both the Third and Fourth Quarter networks were analyzed by GC/MS methods for nontarget analytes. These samples were independently selected each quarter to provide verification of target analytes and identification of nontarget analytes in wells of interest. Wells with samples that contain a large number of detectable analytes or with high baseline concentrations were given priority for GC/MS analysis. Wells selected and GC/MS analytical results are identified in Appendix B.2.

Table 2.1-7. Analytical Parameters Proposed for Task 4 Third and Fourth Quarter (FY86) Sampling

	West		Central		South		East		Offpost
Chemical/Group	3rd	4th	3rd	4th	3rd	4th	3rd	4th	4th
Organosulfur Compounds	-	-	x	x	x	x	x	x	x
Organochlorine Pesticides	x	x	x	x	x	x	x	x	x
DIMP/DMMP	-	x	x	x	x	x	x	x	x
DCPD/MIBK	-	-	x	x	x	x	x	x	x
DBCP	x	x	x	x	x	x	x	x	x
Volatile Organohalogens	x	x	x	x	x	x	x	x	x
Volatile Aromatics	x	x	x	x	x	x	x	x	x
Inorganics									
Chloride/Fluoride/Sulfate	x	x	x	x	x	x	x	x	x
ICP Metals	x	x	x	x	-	-	-	-	x
Arsenic	x	x	x	x	-	-	-	-	x
Mercury	-	-	x	x	-	-	-	-	x

Source: ESE, 1987.

2.1.2.4 Offpost Area

Offpost wells were sampled under Revision III of the 360° Monitoring Program. These 43 wells are not included in the Task 4 network, but sampling of these wells during the Fourth Quarter was requested to provide continuity between RMA sampling programs. An offpost well location map and Fourth Quarter offpost analytical results are included in Appendix B.1. Offpost sampling information gathered during the ISP and Third Quarter is included in the Offpost Contamination Assessment Report (ESE, 1987a, RIC#87202R01).

2.1.3 GROUND WATER MONITORING PROCEDURES

Procedures described below for the monitoring of RMA ground water include both methods for measurement of static water levels and for collection of water quality samples. These methods are also described in the Task 4 Technical Plan (ESE, 1986, RIC#87013R01).

Static water levels were measured with Soil Test Model DR-760A water level indicators. Total depths were measured with bottom-weighted, nylon-coated steel measuring tapes. Measured values were reported to the nearest tenth of a foot. All pertinent information obtained during the water level measurement phase was recorded on water-level measurement forms and in a bound field notebook. The following information was recorded for each well measured:

- Well number;
- Casing diameter;
- Date and time (24-hour system);
- Photoionizaton Detector (PID) readings (breathing-level zone and in well casing);
- Casing stickup above ground surface;
- Depth to water from top of casing;
- Total depth;
- Water-level measuring device;
- Observer's initials;
- Casing volume in gallons: and
- Pertinent comments (e.g., well conditions).

Ground water sampling methodology and techniques adhere to USATHAMA geotechnical requirements (USATHAMA, 1983) with respect to decontamination, collection, preservation, shipment, and chain-of-custody requirements. Further discussion of sample collection is provided in the Task 4 Technical Plan (ESE, 1986, RIC#87013R01).

The following is a summary of the sampling procedures employed during the Third and Fourth Quarters:

- Distribute labeled sample kits to sampling crews;
- Record well number, date, pertinent information (e.g., weather and well conditions), station elevation, casing diameter, screened interval, and field equipment identification (manufacturer and I.D. number);
- Measure and record well stickup, depth to water from top of well casing, total well depth from top of well casing, and PID (field organic vapor) readings;
- Calculate well casing volume;
- Lower submersible pump to a few feet below the maximum anticipated drawdown or to the bottom of the well. If well is constricted above water level and pump will not pass, lower bailer to a few feet below water level. Record depth to pump or bailer;
- Pump or bail five well-casing volumes. Measure and record time, pH, specific conductivity, and water temperature after each well volume. Measure and record PID readings by obtaining frequent background, wellhead, and discharge water values. If well is located within areas containing contaminants or if PID readings are above background levels, discharge water will be collected in barrels;
- Measure and record pumping rate, total pumping time, and total volume purged;
- Remove pump after purging is complete or when well is dewatered;
- Sample immediately. If well is dewatered, samples will be collected once sufficient recharge has been attained; a volume of approximately 2 gallons is necessary to fill the sample bottles. The field crew will periodically check the well for recovery to the 2-gallon mark. If sufficient recharge has not been attained within a 24-hour period, as many sample fractions as possible will be

collected. Sample using a bottom-filling stainless steel bailer. Measure pH, specific conductivity, and temperature of the water sample obtained from bailer. Record time and measured parameters on sampling sheet, in field notebook, and on sample labels;

- Decant portion of water into sample bottles, cap bottles, agitate bottles, and discard water. Carefully fill rinsed sample bottles directly from bailer. Record sample depth;
- Samples collected for metals analysis will be filtered in the field using 0.45-micron membrane filters and preserved with nitric acid to a pH of 2.0 or lower;
- Place bottles in ice chest immediately after filling;
- Complete chain-of-custody forms;
- Sign and date well-sampling form; and
- Seal cooler and secure with evidence tape prior to shipping samples.

All pertinent data obtained during ground water sampling have been recorded on field sampling data sheets and in a bound field notebook. The information recorded for each well sampled includes:

- Well number;
- Date and time (24-hour system);
- Pertinent observations (e.g., weather, well condition);
- Station elevation;
- Well stickup;
- Static water level and well depth (measured from top of well casing);
- Casing diameter;
- Number of gallons per casing volume;
- Screened interval;
- PID readings;
- Pump depth, measured pumping rates, total pumping time, and total volume of water removed;
- Water characteristics (color, odor, etc.);
- Measurements of pH, temperature, and conductivity;
- Identification of field equipment;

- Sampling description (number of bottles, sample fractions, sample depth);
- Field notebook number; and
- Signature of samplers and Field Team Coordinator.

Data collected and assessed monthly to determine water balance include lake stages, meter readings, precipitation information, Cherry Creek Reservoir evaporation data, and RMA stream stage information.

Records have been kept of all wells visited, including those found to be dry or constricted. Dry wells include wells with water levels below the bottom of the screened interval.

2.2 SURFACE WATER MONITORING PROGRAM

The surface water program implemented in the Third and Fourth Quarters is essentially the same as that developed for ISP monitoring. For surface water monitoring, emphasis was placed on generating a continuous, verifiable data base that provides the information necessary to compute the required monthly water balances. Additionally, these data will act as the essential base from which future studies involving ground water recharge, changes in contaminant migration, and the effects of expanding urbanization will rely. Strict adherence to the accepted sampling and measurement procedures has been emphasized to ensure the continued generation of the highest quality results possible.

2.2.1 SURFACE WATER QUANTITY MONITORING

Eleven stream gaging stations were included in the Third and Fourth Quarter surface water monitoring network. These stations were previously selected to provide representative coverage of inflows to and outflows from RMA, as well as gains and losses within the RMA surface water system. Each of these gaging stations is equipped with a channel control, designed to stabilize the effects of variable downstream flow conditions, and a Stevens Type F recorder for continuous water level recording.

In addition to these gages, the network also includes two raingage sites, four lake staff gages, and a pond monitoring station equipped with a Stevens

Recorder. Table 2.2-1 identifies each monitoring site, and the associated monitoring equipment installed. Figure 2.2-1 shows Third and Fourth Quarter surface water monitoring station locations equipped with Stephens recorders, lake locations, and raingage sites.

The Stevens recorders located at all of the stream gaging stations are capable of providing a continuous record of stream stage as a function of time. Through the utilization of rating curves or hydraulic computations, these data are converted to flow rates [i.e., cubic feet per second (cfs) or acre feet per day (ac-ft/d)].

The gaging stations at North and South First Creek, North and South Uvalda, and Peoria Interceptor use small weirs placed in the channels. These weirs which were installed prior to ESE involvement were not standard sizes, hence actual measurements of flow rates corresponding to a minimum of 6 different stages, were taken to construct rating curves. These rating curves were extrapolated using a HEC-2 modeling procedure. The HEC-2 procedure is a well accepted model used for discharge estimation where direct measurement data is unavailable. At the Havana station, a uniform concrete channel exists and has been rated to verify flow conditions.

Gaging stations at the Highline Lateral, Basin A Inflow, Ladora Weir, and South Plants Ditch all have weirs that do not require measurements at various stages to prepare rating curves. These weirs incorporate common forms for which stage-discharge formulas have been experimentally derived and long accepted.

A continuous recording gaging station has been established at Havana Pond to measure pond level. A survey of this pond was conducted so that stage-volume and stage-area curves could be prepared. Although similar gaging stations were not installed on the Lower Lakes (Upper and Lower Derby, Ladora, and Mary), staff gages exist and were read weekly.

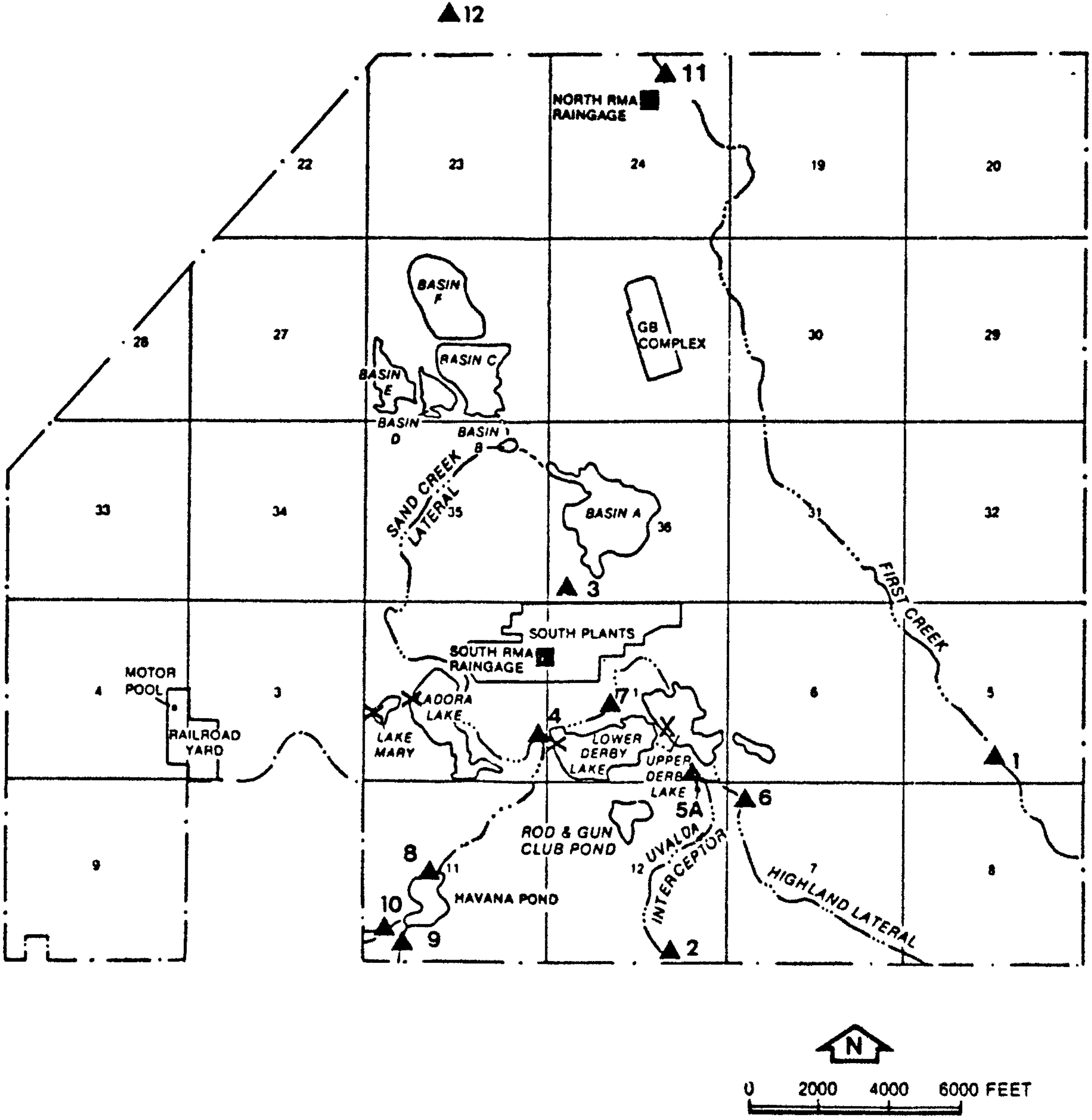
Two precipitation gages have been installed at RMA and are used in conjunction with precipitation data obtained at the National Weather Service station at Stapleton International Airport. The average of these three

Table 2.2-1. Surface Water Monitoring Network Description

Site	Monitoring Equipment
(1) South First Creek	Concrete Control and Stevens Recorder
(2) South Uvalda Interceptor	Concrete Control and Stevens Recorder
(3) Basin A Inflow	Vee Notch Weir and Stevens Recorder
(4) Ladora Weir	Rectangular Weir and Stevens Recorder
(5) North Uvalda Interceptor	Concrete Control and Stevens Recorder
(6) Highline Lateral	Cipolletti Weir and Stevens Recorder
(7) South Plants Ditch	Rectangular Weir and Stevens Recorder
(8) Havana Detention Pond	Stevens Recorder
(9) Peoria Interceptor	Concrete Control and Stevens Recorder
(10) Havana Interceptor	Stablized Channel Reach and Stevens Recorder
(11) North First Creek	Concrete Control and Stevens Recorder
(12) North First Creek at Highway 2	H Flume and Stevens Recorder
Upper Derby Lake	Staff Gage
Lower Derby Lake	Staff Gage
Ladora Lake	Staff Gage
Lake Mary	Staff Gage
North RMA Raingage	Tipping Bucket Raingage and Event Recorder
South RMA Raingage	Tipping Bucket Raingage and Event Recorder

Source: ESE, 1987.

RMA TASK 4 4/86



▲SURFACE WATER SAMPLING SITE

1	First Creek (entering RMA)
2	South Uvalda Interceptor
3	Basin A Inflow
4	Ladora Weir
5A	North Uvalda Interceptor (relocated)
6	Highline Lateral
7	South Plants Ditch
8	Havana Detention Pond
9	Peoria Ditch
10	Havana Interceptor
11	North First Creek
12	North Offpost Area

X	Lake Staff Gages
■	Raingage Sites

Figure 2.2-1
EXISTING STREAM FLOW MONITORING STATIONS

SOURCE: ESE, 1987

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gages was used to determine the precipitation input required for RMA surface water balance computations. The gages are of the tipping-bucket variety and transmit data by cable to seven-day event recorders.

2.2.2 SURFACE WATER QUALITY MONITORING

Task 4 Third and Fourth Quarter water quality sampling was scheduled for 46 potential surface water locations across RMA (Figure 2.2-2). Although not originally included in Task 4 efforts, it was requested that offpost surface water sampling be conducted at 11 potential sites during the Third and Fourth Quarters. Surface water sampling data were recorded on forms similar to those utilized in ground water sampling. These data included an accurate description of the sample location, stream conditions, stage discharge (where feasible), date, time, sample number, parameter measurements (pH, temperature, and specific conductance), sample appearance, fractions, and the sampler's name. Samples were collected by the surface grab method at mid-channel. Sample bottles were filled directly by holding them just below water surface with the sampler facing upstream to prevent contamination from boots or gloves. In the case of extremely low flows, samples were collected and decanted from stainless steel ladles. During the scheduled quarterly sampling events, many of the surface water sampling stations were dry due to their intermittent nature, and samples were unavailable. Documentation, chain-of-custody, filtering, preservation, and shipping procedures were identical to ground water sampling protocol.

2.3 ANALYTICAL_METHODS

The objectives of the chemical analysis program are to provide the PMO-RMA with reliable, statistically supportable, and legally defensible chemical data regarding type and concentration of analytes in RMA ground water and surface water. Both quantitative and semiquantitative analytical methods were used in the Task 4 Third and Fourth Quarter Programs.

2.3.1 QUANTITATIVE METHODS

The original Task 4 Technical Plan proposed analysis of 24 target analytes for all ground water and surface water samples. This proposed list was modified at several stages and, upon completion of ISP sampling, consisted of 50 analytes. Analytical methods used in Third and Fourth Quarter Program

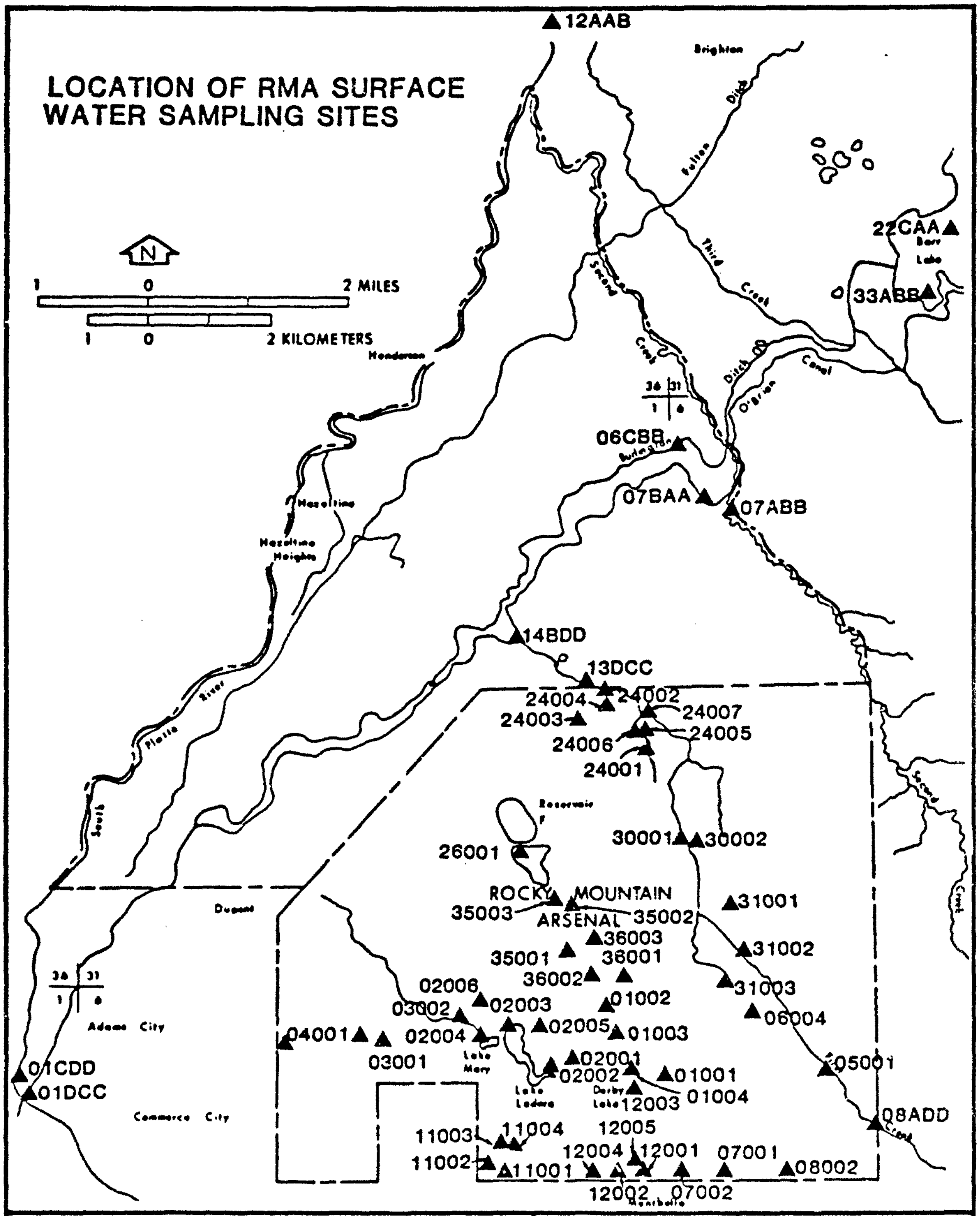

Figure 2.2-2
TASK 4, THIRD AND FOURTH QUARTER (FY86) SURFACE WATER QUALITY SAMPLING STATIONS

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quantitative analyses are listed in Table 2.3-1. These methods were certified according to USATHAMA protocol to obtain the lower detection limits and higher accuracy associated with quantitative determination. Table 2.3-1 presents the list of all final target analytes, sample holding times, a reference to the specific methods utilized for each parameter, and respective detection limits for each analyte.

2.3.2 SEMIQUANTITATIVE (GC/MS) METHODS

Semiquantitative methods (gas chromatography/mass spectrometry or GC/MS) were used in analysis of 10 percent of the samples to detect nontarget analytes and confirm target compound occurrences. The GC/MS methods used were USATHAMA Methods M-8 (purgeables/ volatiles) and BB-8 (extractables/ semivolatiles). Target analytes determined using these methods are presented in Table 2.3-2.

Analytes included in the GC/MS purgeable/volatile method were similar to the quantitative GC methods for volatile aromatics (Method W-8) and volatile organohalogens (Method Y-8). Determinations included in the GC/MS extractable method were similar to the following quantitative methods:

- Organochlorine Pesticides (S-8);
- Organosulfur Compounds (U-8);
- DBCP (Q-8);
- DCPD (R-8); and
- DIMP (T-8).

2.4 QUALITY_ASSURANCE/QUALITY_CONTROL_(QA/QC)

The QA program for Task 4 was consistent with the Field/Laboratory QA Plan developed for Task 1 activities. The plan was project-specific and described procedures for controlling and monitoring sampling and analysis activities as required under Task 4. As designed, the purpose of the Field/Laboratory QA Plan was to ensure production of valid and properly formatted data for precision, accuracy, and sensitivity of each method used for USATHAMA sampling and analysis efforts. The plan is based on USATHAMA April 1982 QA program requirements as modified by U.S. Army AMCCOM

Table 2.3-1. Chemical Analysis - Task 4 Third and Fourth Quarter (FY86) (Page 1 of 2)

Analysis/Analytes	Hold Time	Level of Certification	Reference Methods	RMA Method	Analytical Method	Method Detection Limit (µg/l)
Organochlorine Pesticides		Quantitative	EPA 608	S8	CAP-GC/ECD	
Aldrin	Extract as					0.07
Endrin	quickly as					0.05
Dieldrin	possible (no					0.06
Isodrin	more than 7					0.06
Hexachlorocyclopentadiene	days). Analyze					0.07
p,p´-DDE	within 40 days					0.05
p,p´-DDT	of extraction.					0.07
Volatile Organohalogens		Quantitative	EPA 601	Y8	PACK-GC/Hall	
Chlorobenzene	14 days					0.58
Chloroform	14 days					
Carbon Tetrachloride	14 days					1.40
trans-1,2-Dichloroethylene	14 days					2.40
Trichloroethylene (TCE)	14 days					1.20
Tetrachloroethylene	14 days					1.10
1,1 Dichloroethylene	14 days					1.10
1,1 Dichloroethane	14 days					1.20
1,2 Dichloroethane	14 days					0.61
1,1,1 Trichloroethane	14 days					1.70
1,1,2 Trichloroethane	14 days					1.00
Methylene Chloride	14 days					5.00
Organosulfur Compounds		Quantitative		U8	PACK-GC/FPD-S	
Chlorophenylmethylsulfone ($CPMSO_2$)	Extract as quickly as					4.70
Chlorophenylmethylsulfoxide (CPMSO)	possible (no more than 7 days).					1.30
Chlorophenylmethylsulfide (CPMS)	Analyze within 40 days of extraction.					4.20
1,4-Dithiane						1.10
1,4-Oxathiane						2.00
Dimethyldisulfide (DMDS)						1.80
Volatile Aromatics		Quantitative	EPA 602	W8	PACK-GC/PID	
Toluene	14 days					1.21
Benzene	14 days					1.34
Xylene (m-)	14 days					1.35
Xylene (o,p)	14 days					2.47
Ethylbenzene	14 days					1.00

Table 2.3-1. Chemical Analysis - Task 4 Third and Fourth Quarter (FY86) (Page 2 of 2)

Analysis/Analytes	Hold Time	Level of Certification	Reference Methods	RMA Method	Analytical Method	Method Detection Limit (µg/l)
DCPD/MIBK		Quantitative	EPA 608	R8	CAP-GC/FID	
Dicyclopentadiene	Extract as quickly as possible (no more than 7 days). Analyze extract within 30 days of extraction.					9.31
Methylisobutyl Ketone						13.00
DIMP/DMMP	Extract within 7 days of sampling. Analyze within 30 days of extraction.	Quantitative	EPA 622	T8	PACK-GC/FPD-P	
Diisopropylmethylphosphonate						10.00
Dimethylmethylphosphonate						15.20
DBCP		Quantitative		Q8	CAP-GC/ECD	
Dibromochloropropane	14 days					0.13
Metals		Quantitative				
Mercury	28 days		EPA 245	L8	Cold Vapor	0.20
Arsenic	6 months		EPA 206	A8	AA-Hydride Furnace	3.90
Potassium	6 months		EPA 258	AA8	AA-Flame	1260
ICP		Quantitative	EPA 200.7	B8	Inductively Coupled Plasma	
Calcium	6 months					500
Magnesium	6 months					500
Sodium	6 months					763
Cadmium	6 months					5.2
Chromium	6 months					6.0
Copper	6 months					7.9
Lead	6 months					18.5
Zinc	6 months					20.1
Inorganics		Quantitative	EPA 300	X8		
Chloride	28 days				Ion Chromatography	4,800
Fluoride	28 days				Ion Chromatography	1,200
Sulfate	28 days				Auto Analyzer	10,000
Nitrate/Nitrite	28 days				Ion Chromatography	10

Source: ESE, 1985.

Table 2.3-2. Compounds Analyzed by Semiquantitative Methods

Analysis/Analytes	Hold Time	Level of Certification	Reference Methods	Method
Purgeables	14 days	Semiquantitative	EPA 624	GC/MS
Ethylbenzene				
Benzene				
MIBK				
DMDS				
1,1-Dichloroethane				
1,2-Dichloroethane				
1,1,1-Trichloroethane				
1,1,2-Trichloroethane				
Methylene chloride				
Chloroform				
Carbon tetrachloride				
trans-1,2-Dichloroethylene				
Toluene				
Chlorobenzene				
Tetrachloroethylene				
Trichloroethylene				
m-Xylene				
o- and/or p-Xylene				
DBCP				
Dicyclopentadiene				
Bicycloheptadiene				
1,2-Dichloroethane				
Methylene chloride				
Ethylbenzene				
Extractables	Extract as quickly as possible. (No more than 7 days). Analyze extract within 40 days of extraction.	Semiquantitative	EPA 625 (neutral extraction)	GC/MS
Aldrin				
Atrazine				
Chlordane				
PCPMS				
PCPMSO				
$PCPMSO_2$				
DBCP				
DCPD				
4,4'-DDE				
4,4'-DDT				
Dieldrin				
DIMP				
Dithiane				
Endrin				
HCCPD				
Isodrin				
Malathion				
Oxathiane				
Parathion				
Supona				
Vapona				
2-Chlorophenol				
1,3-Dichlorobenzene				
Diethylphthalate				
Di-n-Octylphthalate				

Source: ESE, 1987.

Procurement Directorate and ESE, as well as certified analytical methods submitted to and approved by USATHAMA. The plan is presented in Appendix B of the Task 1 Technical Plan, with specific QA/QC requirements detailed in Section 5.0 of that document.

Field QC procedures for the Task 4 Third and Fourth Quarter efforts were consistent with EPA- and USATHAMA-approved methodologies. A summary of these procedures for all trip blanks, rinsate blanks, field blanks, and duplicates is presented in Table 2.4-1.

Table 2.4-1. Field QA/QC Procedures

QA Sample Type	Analytical Method*	Required Frequency	Preparation
Volatile Trip Blank	W8, Y8	One paint can with three volatile septum vials per week, each week samples for GC analysis are collected.	Transport filled blank volatile septum vials to field, open paint can and return to laboratory with samples.
Rinsate Blank	S8, U8, T8, W8, Y8, X8, K8, R8, Q8	One suite per week, each week samples are submitted.	Decontaminate bailer used to collect samples. Pour deionized water into cleaned bailer, then transfer to sample bottles. Perform while onsite. Not applicable if dedicated bailer is used.
Field Blank	S8, U8, T8, W8, Y8, X8, K8, Q8, R8	One suite per week, each week samples are submitted.	Pour organic free deionized water directly into sample bottles. Perform while onsite.
Duplicated	S8, U8, T8, W8, Y8, X8, K8, R8, Q8	One suite per week, each week samples are submitted.	Collect two suites of sample bottles while onsite.

* See Table 2.3-1 for parameters analyzed using method name.

Source: ESE, 1987.

3.0 DATA PRESENTATION

3.1 GROUND WATER MONITORING RESULTS

3.1.1 GROUND WATER QUANTITY DATA

Water levels were measured in approximately 850 wells in the spring (May/June) of 1986 and in the summer (August) of 1986 to provide insight into the potential horizontal and vertical components of ground water flow and flow rates. The network includes wells completed in the alluvium and the Denver Formation (Plate 1). Each well has been assigned to one of three designations based on the location of the screened interval: alluvial wells, which include wells with the top of the screened interval within the alluvium or within a 10-ft zone below the alluvial/bedrock contact: wells with the top of the screened interval 10 to 50 ft below the bedrock contact: and, wells with the top of the screened interval greater than 50 ft below the alluvial/bedrock contact. Water table/potentiometric surface maps were generated for the spring and summer of 1986 for each of the designations and are presented in Plates 2 through 7. The measured water level data are summarized in Appendix A.

3.1.1.1 Alluvial Water Levels

The water levels in approximately 630 wells were measured as part of the alluvial network, and are assumed to be representative of water table elevations. The Denver Formation wells with the top of the screened interval within 10 ft of the bedrock surface were included in the alluvial network. The water levels from these wells were used to construct the alluvial water table maps under the assumption that the uppermost 10 ft of the Denver Formation is highly weathered across RMA and, thus, the ground water from this zone is in potential hydraulic communication with the alluvial ground water. Another assumption inherent to the construction of the alluvial water table maps is that where the alluvium is unsaturated, water table conditions exist within the Denver Formation. Water levels in wells with screens in contact with the Denver Formation indicate that water table condition do occur within the Denver Formation in some areas of the arsenal.

During production of these maps, seemingly anomalous data points were critically evaluated and some previously tenuous well designations were revised. Criteria used for redesignation of well completion intervals included: continuation of the screened interval much deeper than 10 ft below the bedrock surface, reevaluation of the bedrock elevation, or resurvey of the ground surface elevation and location. Wells 25027, 25035, and 36112 were previously identified as alluvial wells; upon reevaluation, these wells were classified as Denver wells.

The alluvial water table contour maps for the spring and summer of 1986, presented in Plates 2 and 3 respectively, exhibit very similar water table configurations. The average ground water gradient in the alluvial aquifer is 35 ft per mile; however, gradients drop to less than 10 ft per mile in Section 23 and 24 and exceed 70 ft per mile in western portions of RMA.

Ground water flow is to the north-northwest in the eastern and northern portions of RMA. Along the western boundary of RMA, ground water flow direction acquires a more northerly flow component, with average gradients of 20 ft per mile. Third and Fourth Quarter maps are very similar although Fourth Quarter gradients along the western boundary of RMA are slightly higher than the previous quarter.

Localized features identified on the alluvial water level maps are:

- A prominent ground water mound, over 10 ft high, beneath the South Plants area;
- A broad area of very low ground water gradients in the southern and central zones of Section 23 and the western zone of Section 24;
- A 10 ft high ground water mound associated with the Irondale Containment System in Section 33;
- A ground water low which extends across the Northwest Boundary Containment System;
- A flattening of the gradient to the northwest across Basin F;
- A small ground water ridge extending along the western side of Basin F; and
- An area of low ground water gradients in the Derby Lakes area.

The alluvial water level contours have been reinterpreted for Section 36 since the ISP. The ground water ridge has been relocated to correspond to a bedrock ridge which borders the eastern side of Basin A. In addition, the 5,230 ft contour beneath Basin A has been deflected to the south to more accurately portray the water table conditions.

The differences between the water levels in the spring of 1986 and the summer of 1986 are slight, and generally range from 0 to 3 ft. Some of the more apparent changes in water levels are:

- The South Plants mound is slightly lower in the summer quarter;
- The low gradient area located to the southeast of the South Plants mound is more extensive in the summer quarter;
- The water levels associated with the south lakes area are a few feet lower in the summer quarter; and
- South of Basin A, the water table is lower by a few feet in the summer quarter.

The water table configuration between the ISP quarters and the spring and summer quarters of 1986 are similar. Changes in water levels over this period are on the order of 1 to 3 ft, with no distinct fluctuation patterns apparent. Figure 3.1-1 exhibits the percentages of alluvial wells with maximum or minimum water levels for each of the Task 4 monitoring quarters. The data indicate that onpost and offpost of the RMA, the alluvial water levels were highest in the summer of 1986 and lowest in the spring of 1986. Under RMA Task 44, a more complete analysis of seasonal fluctuations of water levels will be made with the historical water level data and data collected under future monitoring programs.

3.1.1.2 Denver_Formation_Potentiometric_Data

The Denver Formation contains several potentially distinct hydraulic zones based on historical and ongoing hydrologic and geologic assessments. However, the investigative effort needed to identify these zones was beyond the scope of Task 4. Therefore, the wells completed in the Denver Formation were assigned to one of the three previously mentioned depth-discrete designations in order to minimize the effect of combining potentiometric data from several potentially distinct hydrogeologic zones.

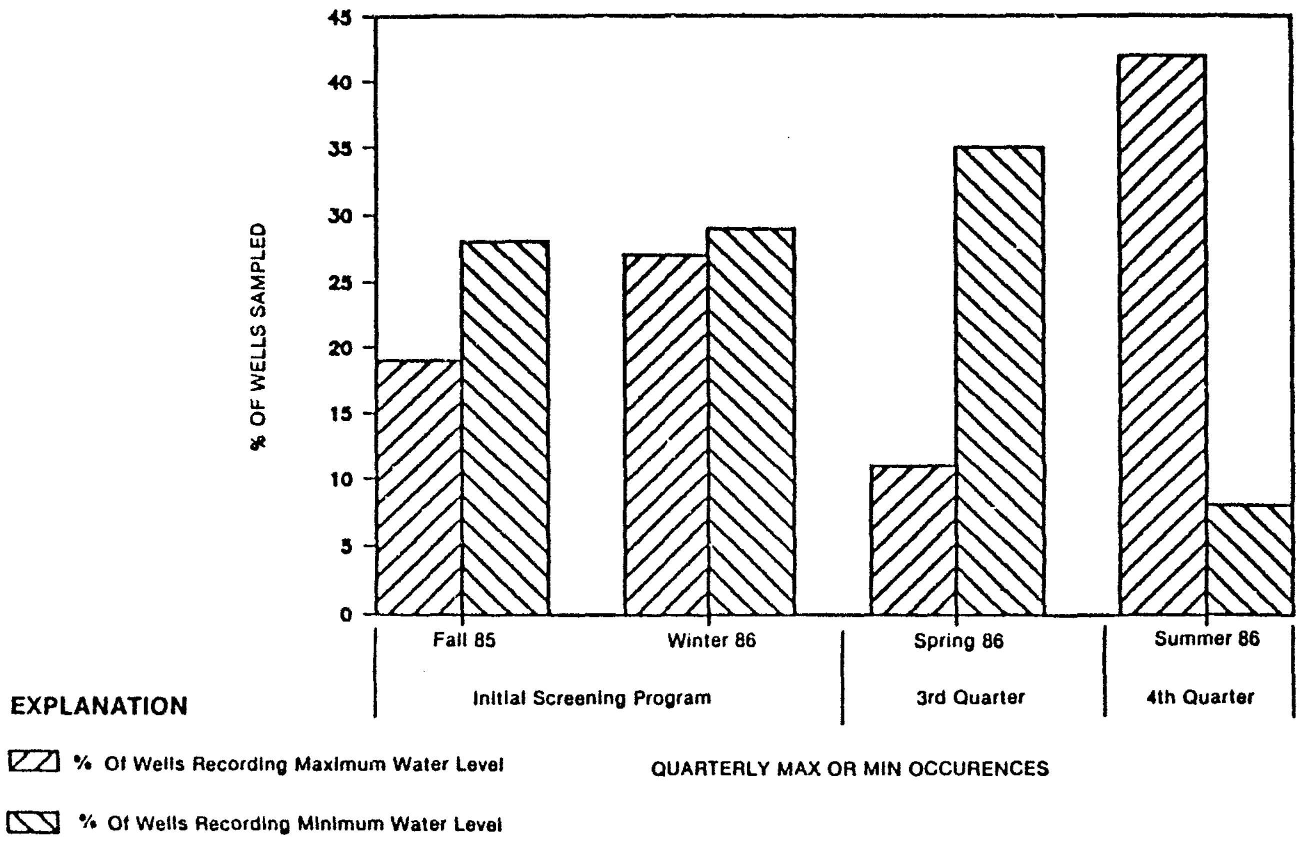

Figure 3.1-1
PERCENTAGES OF TASK 4 MONITORING
WITH QUARTERLY MAXIMUM/MINIMUM
WATER LEVELS (FY86)

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Water levels from approximately 150 wells completed with the top of the screened interval between 10 and 50 ft below the bedrock surface were used to construct spring and summer 1986 potentiometric surface maps presented in Plates 4 and 5, respectively. Water levels from approximately 90 wells with the top of screened interval located greater than 50 ft below the bedrock surface were used to construct spring and summer 1986 potentiometric surface maps presented in Plates 6 and 7, respectively. These depth-discrete intervals within the Denver Formation, formerly termed intermediate and lower, have no strict stratigraphic or hydrogeologic significance. However, the designations do serve to demonstrate the presence or absence of vertical trends within the Denver Formation.

Correlation of sandy zones within the Denver and assignment of completion intervals for existing wells to particular hydrogeologic units is currently ongoing under another RMA Remedial Investigation task.

The potentiometric maps for the 10- to 50-ft below bedrock Denver designation display similar potentiometric surfaces for the two periods investigated. Across the RMA, the ground water gradient in this interval is approximately 35 ft per mile and the ground water flow direction is from the southeast to the northwest. As previously stated, this regional gradient is based on the inclusion of water levels from potentially distinct hydrologic or "sandy" zones. Locally, within discrete "sandy zones, the ground water gradient may vary from the overall regional gradient. The ground water gradient ranges from a low of approximately 10 ft per mile in the Derby Lakes area to a high of 100 ft per mile northwest of the South Plants area. Localized features on the potentiometric maps include the following:

- A prominent ground water mound beneath the South Plants area;
- A prominent ground water high in the northern portion of Section 36 associated with a bedrock elevation high;
- A ground water ridge extending from the ground water high in Section 36 to the south and under Basin A;
- A broad area of low gradients in Sections 23 and 24;
- An area of low ground water gradients in the Derby Lakes area; and
- A small ground water trough associated with the Basin A-neck.

Interpretation of the potentiometric surface maps for the 10- to 50-ft below bedrock surface Denver designation has been revised since the production of the ISP report. Designations for two groups of cluster wells, 30006/30007 and 35053/35054, have been changed due to the position of the screen and changes in the interpretation of bedrock location. As a result, apparent ground water troughs in Sections 30 and 35 have been eliminated.

The spring and summer of 1986 potentiometric surface maps constructed for the greater than 50-ft below bedrock surface Denver designation display similar potentiometric surfaces to the maps constructed for the 10- to 50-ft Denver designation. Hydraulic gradients of approximately 35 ft per mile and a regional ground water flow direction to the northwest are also observed here. The ground water gradients range from a low of approximately 10 ft per mile east of the Derby Lakes to a high of approximately 80 ft per mile northwest of the South Plants area. The South Plants mound is present in the greater than 50-ft Denver potentiometric maps, but it is less pronounced and exhibits potentiometric surfaces approximately 10 ft lower than in the overlying Denver interval. Absent in the greater than 50-ft Denver potentiometric maps is the ground water high and ridge in Section 36.

A comparison of the greater than 50-ft Denver potentiometric surface maps to those of the ISP indicates similar potentiometric surfaces, except in Section 30 where the contours have been smoothed due to the well redesignation previously mentioned. A comparison between the Spring 1986 and Summer 1986 maps indicates that potentiometric surfaces were approximately 1 to 2 ft higher in the spring quarter.

3.1.1.3 Comparison of Alluvial and Denver Water Levels

A comparison of the water levels between the alluvial and Denver Formation aquifers is the first step in determining the potential for the vertical migration of contaminants. In general, the ground water gradients and flow directions are similar for all three designations. The alluvial water levels are generally less than 1 foot to a few feet higher than potentiometric surfaces in the underlying Denver. However, in some areas, alluvial water levels are a few feet lower than the corresponding potentiometric surface in the 10- to 50-ft Denver designation. In other areas, the alluvial water level may be up to 15 ft higher than the corresponding 10- to 50-ft Denver values. These larger head differences, where the alluvial water level is markedly higher than the Denver, occur in the South Lakes area, the Basin A-neck area, and the southwestern portion of Section 26. In addition, several cluster wells in the western area of the RMA and northeast of Basin F display slightly higher potentiometric surfaces in the 10- to 50-ft Denver designation than in the alluvial designation, though these differences are all less than 0.5 ft. The potentiometric surface across RMA averages 10 ft lower in the greater than 50 ft Denver wells as compared to the alluvial water table and the 10- to 50-ft Denver wells potentiometric surface.

3.1.2 GROUND WATER QUALITY DATA

The Third and Fourth Quarter ground water quality assessment was conducted in part to confirm analyte occurrences and contaminant distribution patterns determined by the ISP data. Third and Fourth Quarter analytical results are listed in Appendix B and analyte detections are displayed on Denver and alluvial well network maps in Appendix C.

3.1.2.1 Comparison of ISP, Third Quarter, and Fourth Quarter Analyte Distribution for Select Compounds

ISP ground water contaminant distribution plots are presented in Appendix C of the Final ISP (ESE, 1987b, RIC#87253R01), and distribution plots of individual Third and Fourth Quarter analytes are displayed in Appendix C of this document. Individual compound contaminant plots were constructed rather than summed as composite group plots because individual parameter plots more precisely display true contaminant distribution. Plots with total concentrations of a composite group (groups are listed in Table 2.1-7) such as total organochlorine pesticides may falsely imply high contaminant concentration in a given well, where actual concentrations are representative of occurrences of several group compounds slightly above detection limit.

Comparison of ISP and Third/Fourth Quarter results indicate that, in general, ISP ground water contaminant distribution patterns are confirmed by subsequent Task 4 analytical results. ISP, Third Quarter, and Fourth

Quarter comparisons were conducted for each analyte, and select analyte comparisons from each of the major composite groups are discussed below. These particular parameters were selected for discussion in this section because they were representative of one of the major composite groups (Table 2.1-7) or because they displayed one or more of the following characteristics:

- More extensive lateral and vertical distribution relative to other parameters in the group;
- Occurrences at higher concentrations relative to other parameters in the group;
- Chemical behavior representative of the composite group: and
- Of particular health concern.

Dieldrin. ISP distribution plots indicate that dieldrin occurs in alluvial wells sampled throughout the central portion of RMA, with concentrations greater than 1.0 micrograms/liter (ug/l) in samples from alluvial wells in Sections 36 and 26. In ISP Denver samples, dieldrin occurs primarily in Section 26, and concentrations occur in excess of 1.0 ug/l. ISP alluvial and Denver contaminant distribution patterns generally concur within those determined by historical data assessments.

Third and Fourth Quarter dieldrin distribution plots indicate that the alluvial dieldrin occurrence is similar to that shown in the ISP report, although low level ISP occurrences such as those in Section 8 are not confirmed by Third and Fourth Quarter analytical results. Well 35037 exhibited highest alluvial dieldrin concentrations, with 2.03 ug/l in the Third Quarter sample and 3.64 ug/l in the Fourth Quarter sample. Third and Fourth Quarter Denver dieldrin detections occur in the same general areas as ISP hits, except that occurrences in Sections 19 and 25 are not confirmed by the Third and Fourth Quarter data. The maximum Third Quarter Denver detection of 6.41 ug/l occurred in Well 26128, and the maximum Fourth Quarter Denver detection of 6.73 ug/l occurred in a sample from the same well.

$CPMSO_2$. Alluvial ISP $CPMSO_2$ distribution plots indicate that this analyte occurs primarily in Sections 1, 26, and 36 ground water with concentrations in excess of 100 ug/l. Denver ISP $CPMSO_2$ occurrences exceed 10 ug/l and are present primarily in the southern portion of Section 26 and in Sections 2 and 35. Historical compound distribution plots for total organosulfur compound occurrences generally confirm ISP distribution patterns.

Task 4 Third and Fourth Quarter alluvial distribution plots show similar $CPMSO_2$ occurrences as those generated from ISP data. However, Denver Third and Fourth Quarter data does not confirm ISP occurrences of $CPMSO_2$ in Sections 2, 26, and 35. The maximum $CPMSO_2$ Fourth Quarter alluvial concentration of 1,140 ug/l occurred in a sample from Well 26133, with the maximum Third Quarter concentration of 823 ug/l occurring in a sample from the same well. The maximum Third Quarter Denver detection of 14.9 ug/l occurs in Well 26128, but no $CPMSO_2$ was detected in any Fourth Quarter Denver samples.

Benzene. Benzene in ISP alluvial well samples occurs in continuous, relatively high concentrations in Sections 36, 26, and 23 and is also present as isolated detections in alluvial well samples from Sections 3, 4, 33, and 1. Alluvial ISP concentrations exceed 1,000 ug/l in Section 36. Although isolated occurrences are evident in many sections, principle Denver ISP benzene detections occur in samples from wells in Sections 25, 26, and 35 with maximum concentrations in excess of 150,000 ug/l occurring in Section 1. Historical volatile aromatic data were insufficient to provide comparison.

Third and Fourth Quarter data confirm alluvial benzene distributions presented in the ISP, and Denver benzene occurrences in the Third and Fourth Quarter networks generally concur with ISP results. However, Third and Fourth Quarter benzene occurrences in Sections 23, 25, 33, 35, and 36 Denver well samples indicate that ISP contaminant distribution patterns may be more laterally extensive than those indicated by the ISP results. Well 36001 exhibited highest Third and Fourth Quarter alluvial benzene concentrations of 27,300 ug/l and 26,400 ug/l, respectively. The maximum Denver Third Quarter and Fourth Quarter benzene concentrations of 212,200 ug/l and 330,000 ug/l, respectively, were detected in samples from Well 01014.

DBCP. DBCP occurs in excess of 10 ug/l in ISP samples from alluvial wells in Sections 1, 3, 4, 23, 26, and 36 with isolated occurrences throughout central and western RMA. Isolated detectable concentrations of DBCP in Denver ISP samples occur in Sections 2 and 6. Historical alluvial DBCP occurrences generally concur with ISP alluvial detections, although where Denver historical DBCP occurrences are documented in Section 26, no ISP Denver occurrences were recognized.

Alluvial DBCP detectable concentrations in Third and Fourth Quarter distribution plots confirm the contaminant distribution indicated by ISP data. Denver DBCP Third and Fourth Quarter data do not confirm ISP occurrences in Sections 2 and 6. The highest Third Quarter alluvial DBCP concentration of 141 ug/l and highest Fourth Quarter alluvial concentration of 257 ug/l both were detected in samples from Well 36001. No Denver DBCP occurrences were detected in Third Quarter analyses, though Fourth Quarter analysis from Well 12004 contained DBCP concentrations of 0.353 ug/l.

DIMP. ISP data indicate that DIMP occurs in excess of 1,000 ug/l in alluvial wells sampled from Sections 23, 26, 35, and 36. Denver DIMP ISP concentrations occur in excess of 1,000 ug/l in Sections 26 and 35, with isolated detections in Sections 1, 22, 23 and 28. ISP alluvial and Denver DIMP distribution patterns are similar to historical DIMP distribution plots.

DIMP contaminant distribution patterns determined from ISP data are confirmed for both alluvial and Denver plots by Third and Fourth Quarter analytical results. Samples from alluvial Well 23185 contained 4,810 ug/l and 4,690 ug/l DIMP as indicated by Third and Fourth Quarter analysis, respectively. DIMP concentrations of 10,100 ug/l occurred in samples from Denver well 35012 in both Third and Fourth Quarter analyses.

Chloroform. Alluvial ISP chloroform detections occur in samples from wells in Sections 1, 22, 23, 24, 26, 27 and 36, with isolated occurrences in Sections 2, 3, and 4. ISP Denver chloroform occurs principally in samples from wells in Section 2, though isolated detections also occur in Sections 3, 26, and 35. ISP alluvial concentration exceeds 1,000 ug/l in Sections 23, 24, 26, and 36, while Denver concentration exceeds 100 ug/l in Section 1. No historical chloroform contaminant distribution data are available for comparison.

Third and Fourth Quarter alluvial analytical results generally confirm ISP chloroform distribution patterns. However, Third Quarter detections occur in samples from wells in Section 27 and previously undetected chloroform occurs in Fourth Quarter samples from wells in Section 30. Third and Fourth Quarter Denver analytical data also confirm ISP Denver contaminant occurrences, though detections occur in Fourth Quarter samples collected from a Denver well in Section 30. The maximum Third Quarter concentration occurred in the sample from alluvial Well 23179 and contained 22,500 ug/l chloroform. The maximum Fourth Quarter concentration occurred in the sample from alluvial Well 26133 and contained 48,000 ug/l. Maximum Denver chloroform concentrations occurred in Well 02035, with occurrences of 195 ug/l and 165 ug/l in samples analyzed in Third and Fourth Quarter efforts, respectively.

Trichloroethene (TRCLE). ISP data indicate that alluvial ground water contains TRCLE in samples collected from wells in Sections 1, 4, 9, 23, 26, 27, and 33, with an isolated detection in Section 2 and concentrations in excess of 1,000 ug/l in Section 36. Denver TRCLE detections occur in samples from wells in Sections 2, 26, and 35 in concentrations of 10 ug/l. An isolated Denver detection occurs in Section 27. No historical TRCLE data was available for comparison.

Third and Fourth Quarter data confirm alluvial contaminant distribution patterns determined by ISP results, though a "new" detection occurs in Section 24 in both Third and Fourth Quarter analytical results. Denver Third and Fourth Quarter analytical results also confirm ISP results. Maximum alluvial occurrences were in samples from Well 36001, with TRCLE concentrations of 4,790 ug/l detected in Third Quarter analysis and 2,970 ug/l in Fourth Quarter analysis. Well 35013 contained maximum Denver TRCLE concentrations in both Third and Fourth Quarter analysis, with concentrations of 11.6 and 11.0 ug/l, respectively.

Arsenic. ISP data indicate that arsenic occurrences above the detection limit are present in ground water from alluvial wells in Sections 1, 22, 23, 26, 27, 35, and 36, with isolated low level detections in Sections 2, 3, 4, 9, 24, and 32. Maximum alluvial ISP concentrations in excess of 100 ug/l occur in Section 36 wells. Denver arsenic ISP detections occur in Sections 1, 2, 3, 22, 23, 26, 35, and 36; isolated detections occur in Sections 4, 8, 9, 19, 25, 28, 32, 33, and 34. Maximum Denver ISP concentrations of arsenic occur in excess of 20 ug/l. Available historic data is more localized than the ISP regional network, but historical occurrences are present within ISP distribution patterns for both the alluvial and Denver aquifers.

Third and Fourth Quarter data confirm ISP alluvial arsenic distribution, though occurrences are present in Third Quarter southern Section 1 wells that were not present in ISP data. These occurrences are not confirmed by Fourth Quarter data, and Fourth Quarter arsenic detections occur in Sections 22, 23, 24, and 25 that were not present in the same Third Quarter wells. Maximum Third Quarter alluvial arsenic concentration was 214 ug/l in Well 36076 with the maximum Fourth Quarter concentration of 1,180 ug/l in Well 26041. ISP Denver arsenic distribution is confirmed by Third and Fourth Quarter data. Third and Fourth Quarter data also indicate that alluvial ground water arsenic distribution may not be as laterally continuous as that indicated by ISP data, though this may be due to the different distribution of wells sampled in the ISP program. Maximum Third and Fourth Quarter Denver arsenic concentrations occur in Well 36110 (21.7 and 34.0 ug/l, respectively), although arsenic occurs at 53.9 ug/l in Well 36083 in Fourth Quarter results that was not detected in Third Quarter analysis. Third Quarter Denver arsenic occurrences in Sections 2, 4, 26, and 35 are not confirmed by Fourth Quarter analytical results, and Fourth Quarter Denver arsenic occurrences in other Sections 2, 26, and 35 wells were not present in Third Quarter analytical results from these wells.

3.1.2.2 GC/MS Confirmation and Nontarget Compound Identification

Target Compounds. Appendix B.2 presents the results for target compounds measured at wells selected for GC/MS analysis. Approximately 10 percent of the samples collected during each of the Third and Fourth Quarters of Task 4 were selected for GC/MS analysis. Samples were chosen to geographically cover RMA for both the alluvial and Denver aquifers and to analyze samples with the highest potential for confirmation (i.e., high enough concentrations of target compounds). In addition, samples from background wells were analyzed to identify any background nontarget compounds.

Specific GC/MS methods are discussed in Section 2.3. The certified reporting limits (CRL's) for semiquantitative volatile methods (GC/MS) are similar to those for quantitative (GC) methods, allowing for reasonable compound confirmation. Most of the CRL's for the semiquantitative extractable method were higher than CRL's for the comparable quantitative GC methods, making compound confirmation difficult in some instances. Interpretation of the confirmation results are not included as part of this data report.

Nontarget Compounds. Appendix B.2 presents the results for nontarget compounds identified during GC/MS confirmation analysis. All nontarget substances in each GC/MS analysis were reported if they exceeded a certain criteria based on the abundance of the most intense ion in the internal standard. No attempt has been made at present to summarize the nontarget compound data for this data report. The approach that has been used to report these unknowns, therefore, consists of keying these unknowns to their relative retention times.

The following two examples will demonstrate the method of reporting these unknowns into the USATHAMA database. For discussion, assume two unknowns are present in sufficient quantities in a volatiles analysis to satisfy criteria such that they must be reported. Assume they elute with relative retention times of 0.85 and 2.13. They will be identified as UNK085 and UNK213. Because relative retention times are unable to exceed 5.0, no values above UNK500 will be encountered for the volatiles and UNK501 through UNK999 are reserved for semivolatiles analysis.

An example for semivolatiles will demonstrate how they are to be reported into the database. Assume three unknowns are eluting at relative retention times 0.51, 1.22, and 3.54 relative to the internal standard exceed criteria and must be reported. Because values between UNK001 and UNK500 are reserved for unknowns from volatiles analysis, 500 is added to the value. Thus, these three unknowns would be reported into the USATHAMA database as UNK (051+500) or UNK551, UNK (122+500) or UNK 622, and UNK (354+500) or UNK 854.

3.1.2.3 Analyte Concentration Fluctuations

Collection of samples on a regular basis from a consistent monitoring well network, and determination of a consistent analytical suite provides data to evaluate temporal (seasonal) fluctuations in analyte concentration. Table 3.1-1 presents average concentrations of select compounds for each of the Task 4 quarters. The data do not exhibit a normal distribution as a majority of the detected contaminants occur at very low concentrations. There are a few high concentration detections. Because of this, standard deviation and mean values are not useful and were therefore not included in the report. Median values, however, are included in Table 3.1-1. Quarterly concentration frequencies for all analytes are included in Appendix B.1.

3.2 SURFACE WATER MONITORING RESULTS

3.2.1 WATER BALANCE

A generalized water balance has been computed on a monthly basis for the selected areas of hydrologic interest. These areas include Havana Pond (which includes the Havana Pond itself and the gages on the Havana and Peoria interceptors), the Lakes area (including Upper and Lower Derby and Ladora, and the gages at the Highline Lateral, North and South Uvalda, the South Plants Ditch, and the Ladora Weir), First Creek (which includes South and North First Creek gages), Basin A, and Lake Mary. The last two areas are treated separately because of their isolation from other surface water areas. Finally, a calculation of the difference in flows between the North and South Uvalda gages was prepared. The required water balance results for the Third and Fourth Quarters of fiscal year 1986 are given in Table 3.2-1. Appendix D.1 contains the computational procedures used to generate these water balances.

Table 3.1-1. Frequency of Onpost Occurrence For Select Compounds, Task 4 ISP, Third Quarter, and Fourth Quarter (FY86)

	Total Analyses	Total Detections	Total Frequency	Frequencies		Concentration Ranges		Median Values	
				Alluvial	Denver	Alluvial (μg/l)	Denver (μg/l)	Alluvial (μg/l)	Denver (μg/l)
ISP									
Dieldrin	288	68	0.236	0.327	0.142	0.061 - 3.14	0.064 - 5.56	0.240	0.115
DBCP	318	31	0.097	0.167	0.014	0.140 - 310	0.140 - 0.75	2.76	0.444**
DIMP	283	56	0.198	0.287	0.107	11.9 - 13,600	11.9 - 11,400	861	135
CPMSO$_2$	292	41	0.140	0.227	0.049	6.02 - 679	7.50 - 66.5	35.4	37.0
Benzene	318	46	0.145	0.103	0.196	1.35 - 29,100	1.35 - 151,000	11.6	4.05
Chloroform	288	68	0.236	0.283	0.064	1.85 - 211,000	2.49 - 430	11.2	6.10
Trichloroethylene	313	50	0.160	0.243	0.057	1.23 - 4,430	1.58 - 10.7	6.84	4.06
Arsenic	128	80	0.625	0.60	0.651	4.3 - 270	4.53 - 35.2	11.2	8.52
Third Quarter									
Dieldrin	178	24	0.135	0.160	0.103	0.083 - 2.03	0.112 - 6.41	0.287	0.578
DBCP	175	18	0.103	0.184	—*	0.239 - 141.0	—	1.47	—
DIMP	142	30	0.211	0.347	0.071	14.6 - 4,810	33.4 - 10,100	593	80.5
CPMSO$_2$	141	21	0.149	0.282	0.014	4.71 - 1,140	<10.5 - 14.9	71.9	14.9
Benzene	176	50	0.284	0.245	0.333	1.34 - 27,300	1.68 - 212,000	3.56	5.02
Chloroform	176	37	0.210	0.316	0.064	1.40 - 22,500	7.44 - 195	11.5	27.9
Trichloroethylene	176	29	0.165	0.252	0.052	1.58 - 4,790	2.07 - 11.6	7.13	10.3
Arsenic	150	26	0.173	0.247	0.077	4.83 - 214	5.81 - 21.7	8.69	13.4
Fourth Quarter									
Dieldrin	180	33	0.183	0.252	0.099	0.072 - 3.64	0.064 - 6.73	0.080	0.271
DBCP	182	23	0.126	0.222	0.012	0.149 - 257	<0.130 - 0.353	0.353	1.03
DIMP	175	33	0.188	0.284	0.075	13.8 - 4,690	37.9 - 10,100	87.0	584
CPMSO$_2$	145	17	0.117	0.233	—*	5.94 - 823	—	139	—
Benzene	182	19	0.104	0.111	0.096	2.69 - 26,400	1.67 - 330,000	2.49	22.0
Chloroform	182	41	0.225	0.303	0.132	1.43 - 48,000	1.59 - 162	8.09	13.3
Trichloroethylene	182	31	0.170	0.273	0.048	1.16 - 2,970	2.02 - 11.0	6.33	6.72
Arsenic	157	44	0.280	0.329	0.217	4.05 - 1,180	4.05 - 53.9	6.23	11.8

* No detections were found in the Denver Formation wells.

Table 3.2-1 Summary of Third and Fourth Quarter (FY86) Monthly Water Balances. (All units in acre feet)

ITEM	APR	MAY	JUN	JUL	AUG	SEP
1. HAVANNA POND WATER BALANCE						
A. Total measured volume of pond at the beginning of the month	4.3	17.3	14.6	15.6	23.1	19.2
B. Volume gains over the month						
Havana Interceptor	357.5	49.3	32.7	63.0	65.7	23.6
Peoria Interceptor	5.7	2.2	1.7	3.0	1.1	1.3
Direct precipitation	1.2	1.3	1.0	1.6	0.9	0.5
C. Volume losses over the month or study period						
Evaporation	1.6	4.7	6.4	8.9	6.6	4.9
Transpiration *						
D. Calculated volume of pond at the end of the month	367.1	65.4	43.6	74.3	84.2	39.7
E. Measured volume of pond at the end of the month	17.3	14.6	15.6	23.1	19.2	15.1
F. Measured gain or loss in volume over the month	13.0	-2.7	1.0	7.5	-3.9	-4.1
G. Measured minus calculated end of month volumes, i.e. unaccounted gains or losses	-349.8	-50.8	-28.0	-51.2	-65.0	-24.6
2. UPPER AND LOWER DERBY WATER BALANCE						
A. Total measured volume of Upper and Lower Derby at the beginning of the month	489.5	560.4	537.9	489.3	559.2	569.0
B. Volume gains over the month						
Highline Lateral	0.0	0.0	0.0	145.1	0.0	162.7
Uvalda Ditch at North Uvalda Gage	51.7	34.0	18.7	8.0	24.7	39.7
South Plants Ditch	0.0	0.0	0.0	0.0	0.0	0.0
Direct precipitation	11.7	8.7	6.7	9.0	4.8	2.9
C. Volume losses over the month or study period						
Evaporation	15.4	32.6	41.2	50.4	34.6	29.1
Transpiration *						
D. Calculated volume of Upper and Lower Derby at the end of month	537.5	570.5	522.1	601.0	554.1	745.2
E. Measured volume of Upper and Lower Derby at the end of month	560.4	537.9	489.3	559.2	469.0	516.9
F. Measured gain or loss in volume over the month	70.9	-22.5	-48.6	69.9	-90.2	-52.1
G. Measured minus calculated end of month volumes, i.e. unaccounted gains or losses	22.9	-32.6	-32.8	-41.8	-85.1	-228.3

Table 3.2-1 Summary of Third and Fourth Quarter (FY86) Monthly Water Balances. (All units in acre feet)(Continued, Page 2 of 3)

ITEM	APR	MAY	JUN	JUL	AUG	SEP
3. LAKE LADORA WATER BALANCE						
A. Total measured volume of Ladora at beginning of of the month	383.4	383.4	377.0	352.0	333.7	327.7
B. Volume gains over the month						
Inflow through Ladora Weir	0.0	0.0	0.0	19.8	20.4	23.9
Direct precipitation	9.5	7.2	6.0	7.8	4.1	2.5
C. Volume losses over the month or study period						
Evaporation	12.4	27.1	37.0	43.7	29.8	25.6
Transpiration *						
Outflow through Ladora Pump House	1.4	2.6	4.1	4.8	3.6	3.1
Currently ungaged spills +						
D. Calculated volume of Ladora at end of month	379.1	360.9	341.9	331.1	324.8	325.4
E. Measured volume of Ladora at the end of month	383.4	377.0	352.0	333.7	327.7	348.9
F. Measured gain or loss in volume over the month	0.0	-6.4	-25.0	-18.3	-6.0	21.2
G. Measured minus calculated end of month volumes, i.e. unaccounted gains or losses	4.3	16.1	10.1	2.6	2.9	23.5
4. FIRST CREEK WATER BALANCE						
A. Total measured flow at South First Creek gage over the month	147.2	91.6	46.2	4.0	6.4	7.7
B. Direct precipitation	0.0	0.0	0.0	0.0	0.0	0.0
C. Evaporation	0.0	0.0	0.0	0.0	0.0	0.0
D. Transpiration *						
E. Inflow from Sewage Treatment Plant	1.1	2.1	1.6	1.2	0.8	0.6
F. Total measured flow at North First Creek gage over the month	267.4	69.5	5.4	0.0	0.0	0.0
G. Calculated gain or loss across RMA for the month	1.1	2.1	1.6	1.2	0.8	0.6
H. Measured gain or loss across RMA for the month	120.2	-22.1	-40.8	-4.0	-6.4	-7.7
I. Measured minus calculated monthly gain/loss values, i.e. unaccounted gains or losses	119.1	-24.2	-42.4	-5.2	-7.2	-8.3
5. BASIN A MEASURED INFLOWS						
A. Total measured flow into Basin A for the month	4.3	1.0	0.9	0.8	0.8	0.2

Table 3.2-1 Summary of Third and Fourth Quarter (FY86) Monthly Water Balances. (All units in acre feet)(Continued, Page 3 of 3)

ITEM	APR	MAY	JUN	JUL	AUG	SEP
6. UVALDA DITCH BALANCE						
A. North Uvalda flows for the month **	51.7	34.0	18.7	8.0	24.7	39.7
B. South Uvalda flows for the month	138.5	56.8	58.3	63.3	52.1	34.8
C. North Uvalda measured flow minus South Uvalda flow for the month; i.e. gain or loss.	-86.8	-22.8	-39.6	-55.3	-27.4	4.9
7. LAKE MARY WATER BALANCE						
A. Total measured volume of Lake Mary at beginning of the month ++	m	m	m	m	m	m
B. Volume gains over the month						
Direct precipitation	1.2	0.9	0.8	1.0	0.6	0.3
C. Volume losses over the month or study period						
Evaporation	1.6	3.5	4.8	5.8	4.0	3.4
Transpiration *						
Currently ungaged spills +						
D. Calculated volume change of Lake Mary at end of month	-0.4	-2.6	-4.0	-4.8	-3.4	-3.1
E. Measured volume of Lake Mary at the end of month	m	m	m	m	m	m
F. Measured volume change of Lake Mary at end of month (based on stage and assumed constant area)	-1.0	-3.7	-4.8	-3.2	-2.3	-2.6
G. Measured minus calculated volume changes; i.e., unaccounted gains or losses	-0.6	-1.1	-0.8	1.6	1.1	0.5

* Transpiration is not included due to numerous unknown factors such as root depths, vegetation mixes, etc.

\+ Spills may have occurred from both Ladora and Mary. There are presently no facilities to gage such spills.

** To accurately compare gains or losses, Highline Lateral flows were subtracted from North Uvalda flows.

++ There is not a stage-volume relationship currently available for Lake Mary.

Source: ESE, 1987

3.2.1.1 Stream_Discharge_Data_Reduction

Initial data reduction required estimating the stage to the nearest 0.05 ft for each hour of each day. Once recorded, the hourly stages were converted into hourly discharges through the utilization of rating curves developed for the RMA monitoring sites (Appendix D.2). Following the conversion, hourly discharge values for each day were averaged and converted from cfs to acre-feet per day. The daily flow values were summed to obtain weekly and monthly values. Daily discharges for all gages are listed in Appendix D.4.

3.2.1.2 Lake_Stage_and_Meter_Reading_Data_Reduction

Five lakes and ponds were monitored as part of the water monitoring program. Monthly volume changes were calculated by determining the stage corresponding to the first hour of the first day for the month in question and for the following month. These values were converted to volumes using the stage volume curve. Finally, the volume from the first day of the following month was subtracted from the volume of the month in question to obtain the change in storage. Lake volume values as well as monthly volume changes are presented in the water balances as "measured" values.

For Upper Derby, Lower Derby, and Ladora Lakes, existing staff gages were read on a weekly basis. The volumetric changes were determined from these weekly staff gage readings as described above. Havana Pond is equipped with a Stevens-Type F water-level recorder for a continuous surface elevation record and was recently surveyed to provide accurate stage volume and stage-area curves.

The staff gage at Lake Mary was also read on a weekly basis. Necessary survey data were not available to prepare stage volume curves. In order to monitor volume changes, the surface area was determined for the lake by planimetering an aerial photograph. Assuming a surface area constant with stage over the range of fluctuations, the volume changes were determined by subtracting stage values representing the beginning of a month from those representing the end of the month and multiplying by the area in acres.

Appendix D.2 lists the weekly lake stages as well as the sewage treatment plant and Ladora pumphouse meter readings. Pump discharge volumes were calculated by subtracting the gallon reading representing the first of the month from that representing the last of the month and converting to acre-feet.

3.2.1.3 Precipitation

Precipitation data for use in the water balance were obtained by averaging the daily data obtained from the two gages installed at RMA and the daily data from the National Weather Service station at Stapleton Airport. Data from the three precipitation stations are shown in Table 3.2-2.

3.2.1.4 Transpiration

Transpiration is neglected in this analysis because of the lack of reliable information resulting from variable vegetation density and mixed consumptive use patterns by plants.

3.2.1.5 Evaporation

Values utilized for evaporation were taken from Corps of Engineers data obtained at Cherry Creek Reservoir, approximately 12 miles south of RMA. These values are calculated on a monthly basis and are presented in Table 3.2-2.

3.2.1.6 Overland Flow

The current water balance format does not include surface water runoff. Sufficient data does not exist to allow inclusion of overland flow in the analyses.

3.2.2 SURFACE WATER QUALITY

Of the 46 onpost sites identified for surface water quality analysis, 19 were sampled during the Third Quarter and 21 were sampled during the Fourth Quarter. The remaining sample locations for each quarter were dry and therefore not sampled. As previously discussed, it was requested that offpost locations also be sampled. Offpost sites that were not dry were sampled in April, June, and September. The April and June events roughly coincide with onpost Third Quarter sampling, and the September offpost

Table 3.2-2 Monthly Summary of Third and Fourth Quarter (FY86) Precipitation and Evaporation Values.

ITEM	APR	MAY	JUN	JUL	AUG	SEP
PRECIPITATION						
A. North Rocky Mountain Arsenal Gage (inches)	2.19	1.44	1.18	1.30	1.08	0.59
B. South Rocky Mountain Arsenal Gage (inches) *	m	1.35	m	m	m	m
C. Stapleton Airport Gage (inches)	2.59	1.30	1.07	1.69	0.53	0.43
Departure from normal (inches)	0.78	-1.17	-0.51	-0.24	-1.00	-0.80
Normal Stapleton precipitation (inches)	1.81	2.47	1.58	1.93	1.53	1.23
Maximum one day precipitation (inches)	0.97	0.64	0.38	0.89	0.17	0.13
D. Average RMA precipitation (inches)	2.39	1.36	1.13	1.50	0.81	0.51
EVAPORATION						
A. Cherry Creek Reservoir Data (inches) +	3.50	5.75	6.28	5.45	4.46	2.73

* Missing data has occurred during various months at the South precipitation gage. This has been due in part to lack of winterization and operational problems.

\+ Data obtained from U.S. Army Corps of Engineers in the form of pan evaporation values. These values were converted to lake values using the recommended coefficient of 0.70.

Source: ESE, 1987.

sampling coincides with onpost Fourth Quarter sampling. Analytical results for onpost surface water sampling are included in Appendix B.3. Offpost surface water analytical results are included in the Offpost Contamination Assessment Report (ESE, 1987a, RIC#87202R01).

Compound Distribution. RMA surface water contamination occurs primarily in samples collected from the South Plants-Basin A area. Organochlorine pesticides, purgeables, organosulfur compounds, DBCP, and HCCPD were detected in samples collected from RMA surface water sampling sites in this area for both Third and Fourth Quarter analysis. Purgeables were detected in Third Quarter samples collected from Sites 02004, 11001, and 31002. Organochlorine pesticides were detected for both Third and Fourth Quarter analysis in samples from Site 24001.

Eleven offpost sites were sampled during the Third Quarter sampling events (April and June), and nine sites were sampled during the Fourth Quarter sampling event (September). Dieldrin and DIMP were detected at Site 14BDD in the April event, while DCPD, DIMP, and dithiane were detected in samples collected from the same site during June offpost sampling. Chloroform was detected in a sample from Site 07BAA in Third Quarter (June) analysis. No contaminants were detected in offpost samples collected in the Fourth Quarter. Results of the Third and Fourth Quarter surface water quality sampling program are presented in Figures 3.2-1 and 3.2-2, respectively. A summary of analytes detected at sampling locations in two or more Task 4 sampling events is presented in Table 3.2-3.

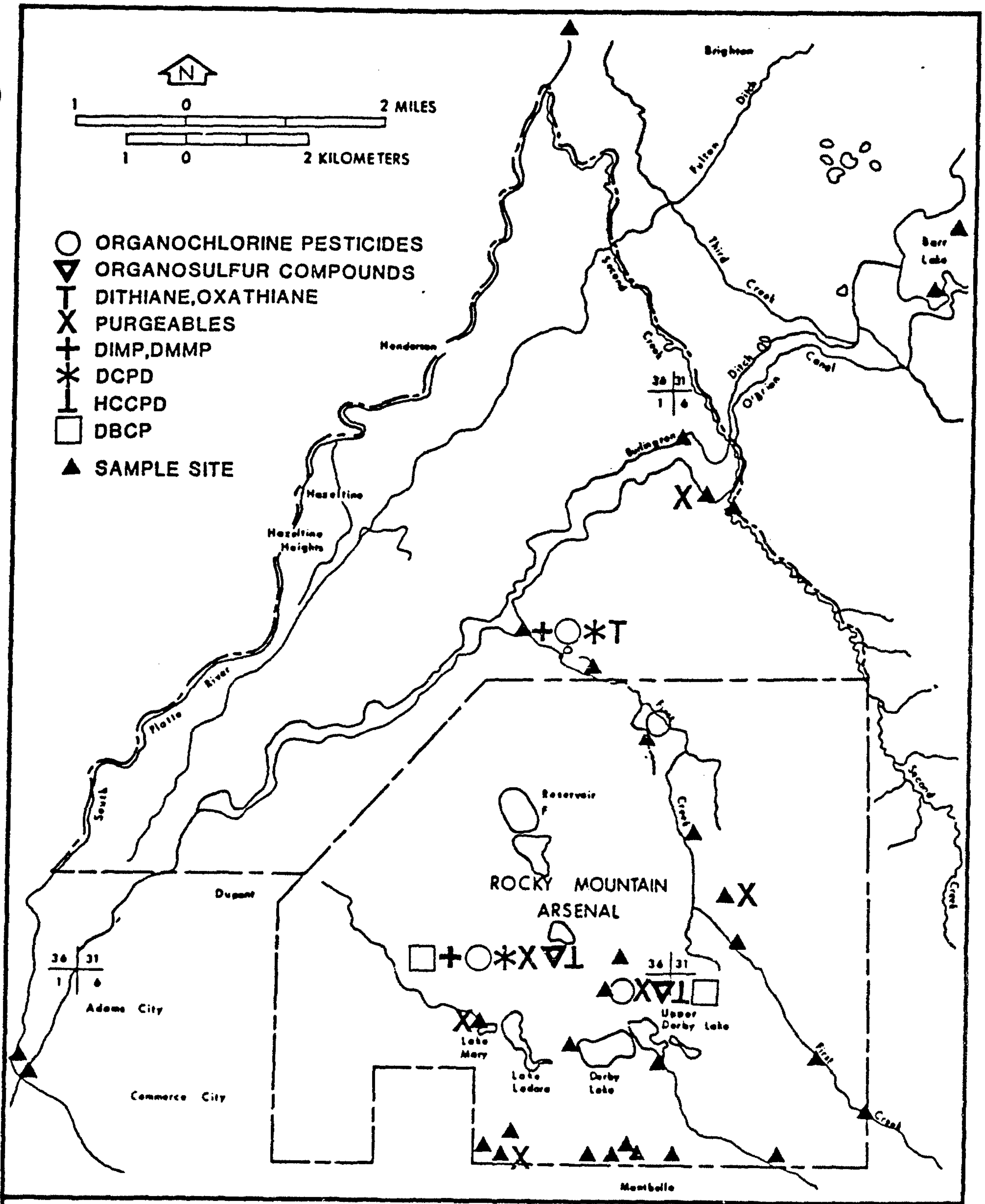

Figure 3.2-1
COMPOUND DISTRIBUTION IN RMA
SURFACE WATER, THIRD QUARTER (FY86)

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

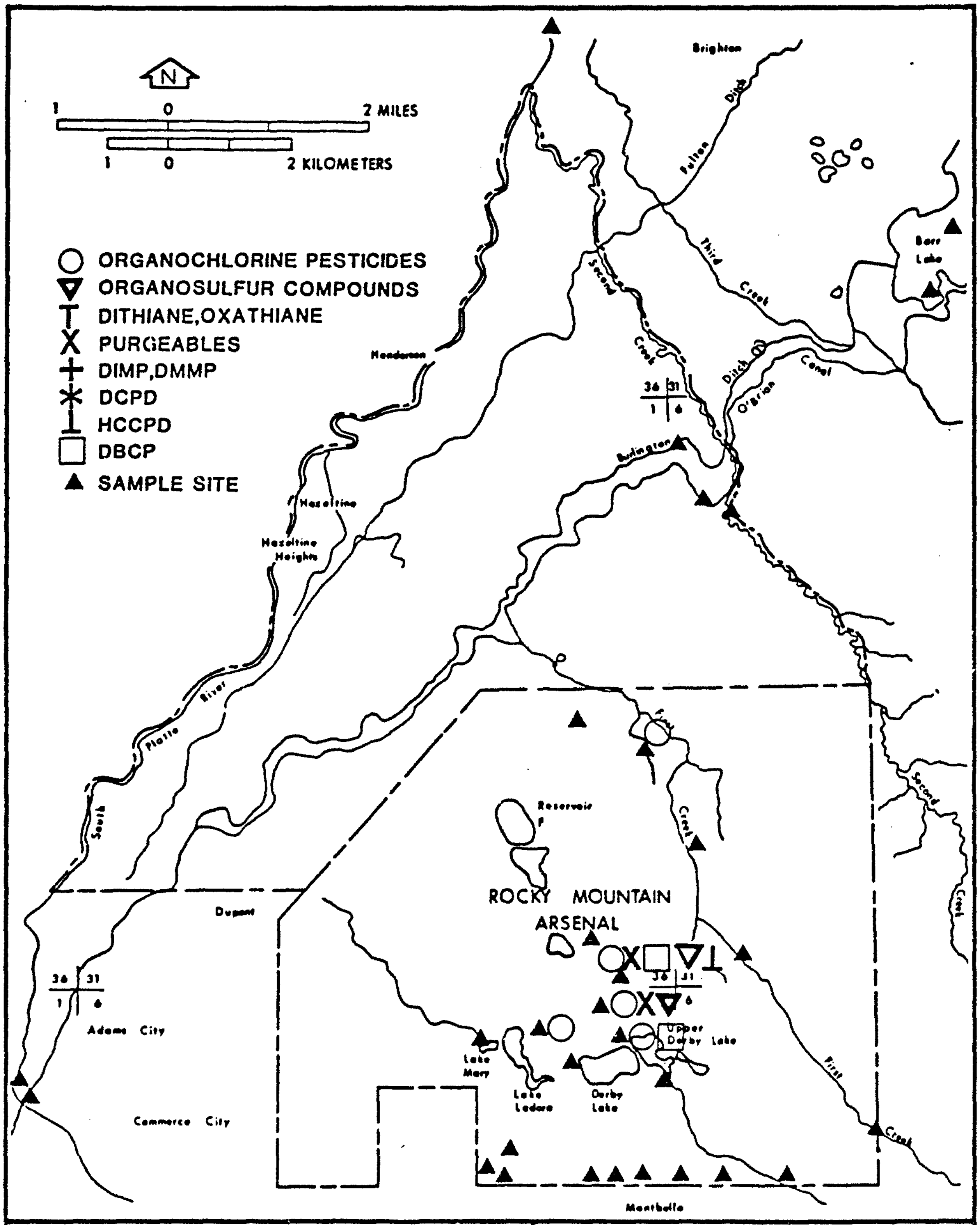

Figure 3.2-2
COMPOUND DISTRIBUTION IN RMA
SURFACE WATER, FOURTH QUARTER (FY86)

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Table 3.2-3. Analytes Detected in Two or More Sampling Events, Task 4, Rocky Mountain Arsenal Surface Water Sampling Program

Location	Compound	ISP	Third Quarter	Fourth Quarter
01-002	Dieldrin	x	x	x
	CPMSO	x	x	
	$CPMSO_2$	x	x	x
	Toluene		x	x
24-001	Aldrin	x	x	x
	Dieldrin		x	x
36-001	Hexachlorocyclopentadiene		x	x
	Aldrin		x	x
	Dieldrin		x	x
	Endrin		x	x
	CPMS	x	x	x
	CPMSO	x	x	x
	$CMPSO_2$		x	x
	Benzene	x	x	x
	Toluene	x	x	x
	(o.p)-Xylene	x	x	x
	1,1-Dichloroethylene	x	x	x
	trans-1,2-Dichloroethylene	x	x	x
	Chloroform	x	x	x
	Trichloroethylene	x	x	x
	1,1,2-Trichloroethane	x	x	x
	Tetrachloroethylene	x	x	x
	Chlorobenzene	x	x	x
	MIBK	x	x	x
	DCPD	x	x	
	DBCP	x	x	x
	Ethylbenzene	x	x	
	1,1,1-Trichloroethane	x	x	
14BDD	DIMP	x	x	

Source: ESE, 1987.

4.0 COMPLETION OF THIRD AND FOURTH QUARTER GROUND WATER MONITORING OBJECTIVES

Third and Fourth Quarter objectives are discussed in Section 2 and Task 4 efforts conducted to complete the objectives are discussed below:

- Confirmation of ISP Results. Third and Fourth Quarter efforts provide information to address this issue and is discussed in ground water and surface water sections included in this document.
- Assessment of Seasonal Water Quality and Quantity Fluctuations. Water level measurements were conducted over regular sampling intervals for a consistent well network, providing excellent data with which future RMA tasks may further assess ground water level fluctuations. Analysis of a consistent analytical suite on samples collected regularly from an established well network also generates quality data that may be used by future RMA tasks to further evaluate seasonal water quality fluctuations. Though regular surface water sampling is not always possible, the additional surface water data provided by Task 4 efforts may also facilitate assessments of seasonal water quantity and quality fluctuations.
- Improved Resolution of Aerial and Vertical Contaminant Distribution. Task 4 provides sufficient information to further assess contaminant distribution by supplying consistent analytical information for a regularly sampled Denver and alluvial core network. Temporal and spatial analyte concentration distributions can be assessed in future RMA tasks, and information can then be used to improve understanding of ground contaminant distribution.
- Collections of Additional Ground Water Quality Data to be Used with Hydrologic Data in Assessments of Regional Hydrogeologic Conditions. Future RMA tasks may use water quality and hydrologic information supplied by Task 4 to accomplish such tasks as construction of plume maps, correlation of contaminated horizons, and determination of contaminant flow patterns through and between alluvial and Denver aquifers.

Task 4 supplies critical data that will be used in conjunction with subsequent task information to refine current knowledge of hydrologic, geochemical, and geologic conditions at RMA.

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6.0 LIST OF ACRONYMS AND ABBREVIATIONS

ACM	asbestos containing material
QA	Air Quality Station
CDH-APCD	Colorado Department of Health - Air Pollution Control Division
CFI	Colorado Fuel and Iron Corporation
DAS	data acquisition system
EPA	Environmental Protection Agency
°F	degrees Fahrenheit
f/cc	fibers per cubic centimeter
GC/MS	gas chromatography/mass spectrometry
Hyman	Julius Hyman and Company
mph	miles per hour
um	micron or micrometer
ug/l	micrograms/liter
ug/m^3	micrograms per cubic meter
MOA	Memorandum of Agreement
MRI	Midwest Research Institute
NAAQS	National Ambient Air Quality Standards
NBCS	North Boundary Containment System
NCC	National Climatic Center
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PCM	phase contrast microscopy
PID	Photoionization Detector

PMO	Program Manager's Office
PM-10	particulate matter less than 10 microns
ppm	parts per million
QA	Quality Assurance
QC	Quality Control
RCI	Resource Consultants, Inc.
RIC	Rocky Mountain Arsenal Resource Information Center
RI/FS	Remedial Investigation/Feasibility Study
RMA	Rocky Mountain Arsenal
Shell	Shell Chemical Company
SIA	Stapleton International Airport
Spaine	Spaine <u>et al</u>., 1984
SVOC	semivolatile organic compound
TCDHD	Tri-County District Health Department
TEM	transmission electron microscopy
TSP	total suspended particulates
TWA	time-weighted average
USAEHA	U.S. Army Environmental Hygiene Agency
USAMBRDL	U.S. Army Medical and Bioengineering Research and Development Laboratory
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USDHEW	U.S. Department of Health, Education, and Welfare
VOC	volatile organic compound
WES	U.S. Army Waterways Experiment Station
WWII	World War II