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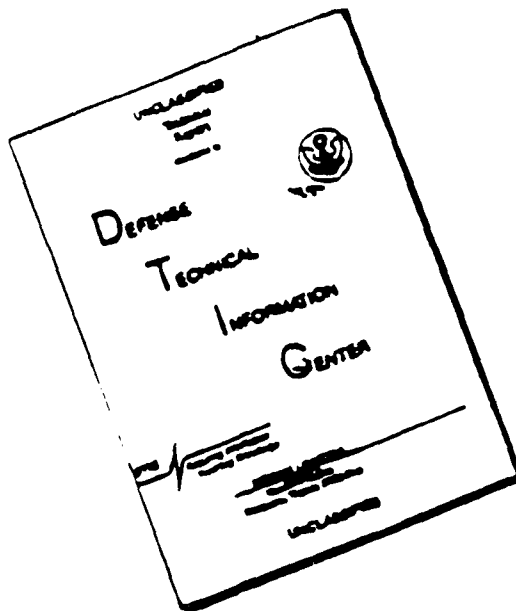
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PROGRAM MANAGER RMA CONTAMINATION CLEANUP

U.S. ARMY
MATERIEL COMMAND

— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

COMPREHENSIVE MONITORING PROGRAM

Contract Number DAAA15-87-0095

AIR QUALITY DATA ASSESSMENT REPORT FOR 1989

FINAL REPORT

JUNE 1990

Version 2.1

Volume II

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COMPREHENSIVE MONITORING PROGRAM

Contract Number DAAA15-87-0095

AIR QUALITY DATA ASSESSMENT REPORT FOR 1989

FINAL REPORT

JUNE 1990

Version 2.1

Volume II

**Rocky Mountain Arsenal
Information Center
Commerce City, Colorado**

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ACRONYMS AND ABBREVIATIONS

111TCE	1,1,1-Trichloroethane
112TCE	1,1,2-Trichloroethane
ADI	Acceptable Daily Intake
Atrazine	2-chloro-4-ethylamino-6-isopropylamino-s-trianine
BCHPD	Bicycloheptadiene
C ₆ H ₆	Benzene
CCl ₄	Carbon Tetrachloride
CH ₂ Cl ₂	Methylene Chloride
CHCl ₃	Chloroform
Chlordane	1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methano-1H-indene
C ₆ H ₅ Cl	Chlorobenzene
CMP FY89	Comprehensive Monitoring Program Fiscal Year 1989
CO	Carbon Monoxide
DBCP	Dibromochloropropane
DCLE11	1,1-Dichloroethane
DCLE12	1,2-Dichloroethane
DCPD	Dicyclopentadiene
DDD	Dichlorodipenyldichloroethane
DMB12	Dimethylbenzene
DMDS	Dimethyl Disulfide
EPA	Environmental Protection Agency
ETC ₆ H ₅	Ethylbenzene
GC/MS	Gas Chromatography/Mass Spectrometry
GC/ECD	Gas Chromatography/Electron Capture Detection
ICAP	Inductively Coupled Argon Plasma
Malathion	0,0-dimethyl-s-(1,2-dicarboxyethyl) phosphorodithioate
MEC ₆ H ₅	Toluene
MIBK	Methyl Isobutyl Ketone
NAAQS	National Ambient Air Quality Standards
NATICH	National Air Toxics Information Clearinghouse
NIOSH	National Institute of Occupational Safety and Health
NNDMEA	N-Nitrosodimethylamine
NO _x	Nitrogen Oxides

ACRONYMS AND ABBREVIATIONS (continued)

O ₃	Ozone
OTSP	Organics in Total Suspended Particulates
Parathion	Parathion (C ₁₀ H ₁₄ NO ₅ PS)
PMRMA	Program Manager Rocky Mountain Arsenal
PM-10	Respirable Particulates less than 10 microns
PPDDE	Dichlorodiphenylethane
PPDDT	Dichlorodiphenyltrichloroethane
SO ₂	Sulfur Dioxide
Supona	2-chloro-1-(2,4-dichlorophenyl) vinyl diethyl phosphate
SVOC	Semi-Volatile Organic Compounds
T12DCE	Trans-1,2-Dichloroethene
TCLEE	Tetrachloroethene
TRCLE	Trichloroethene
TSP	Total Suspended Particulates
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USEHA	U.S. Army Environmental Hygiene Agency
VOC	Volatile Organic Compounds
XYLENE	Xylene

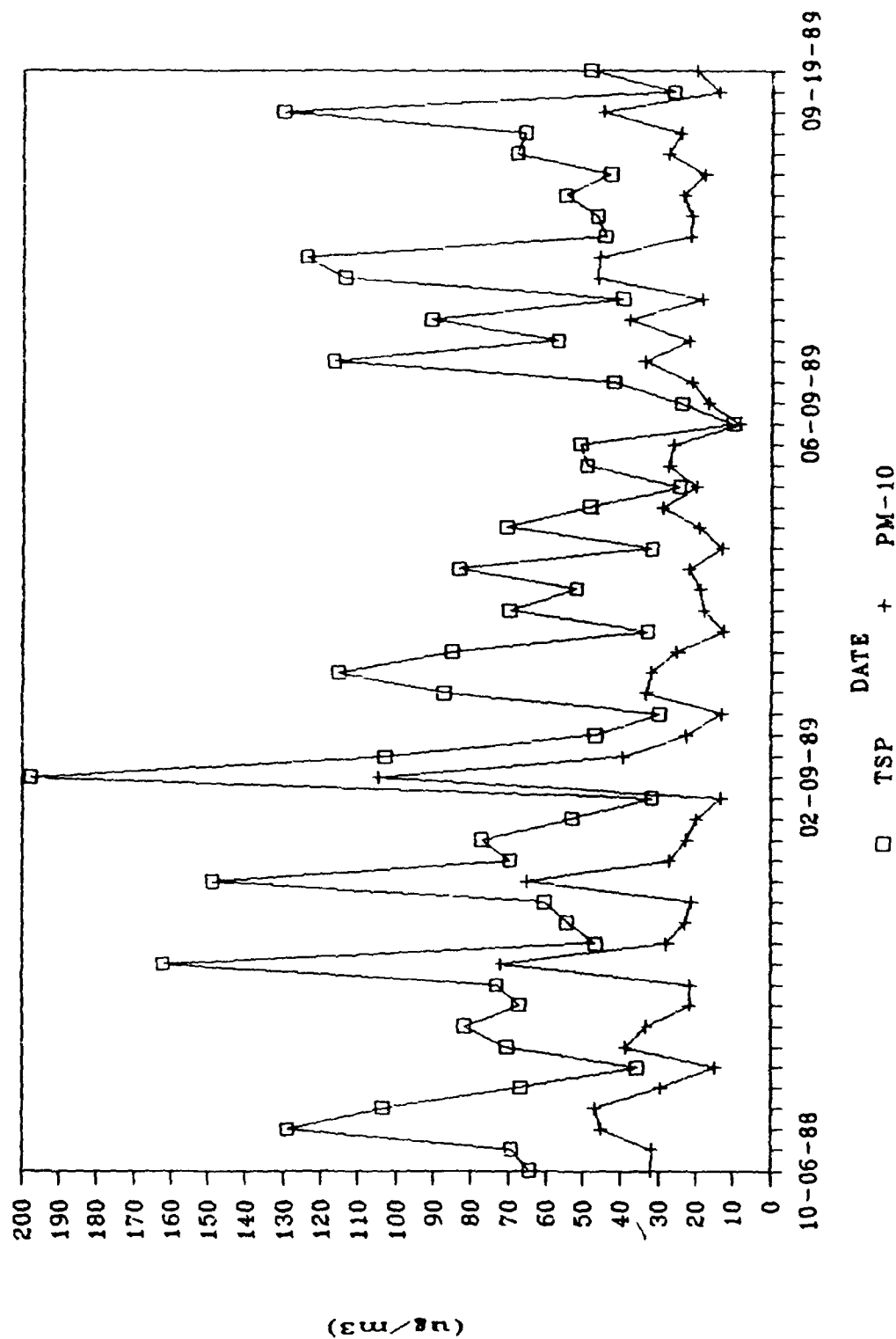


Figure 4.3-2

Comparison of TSP and
PM-10 at AQ2

CMPAR FY89

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U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

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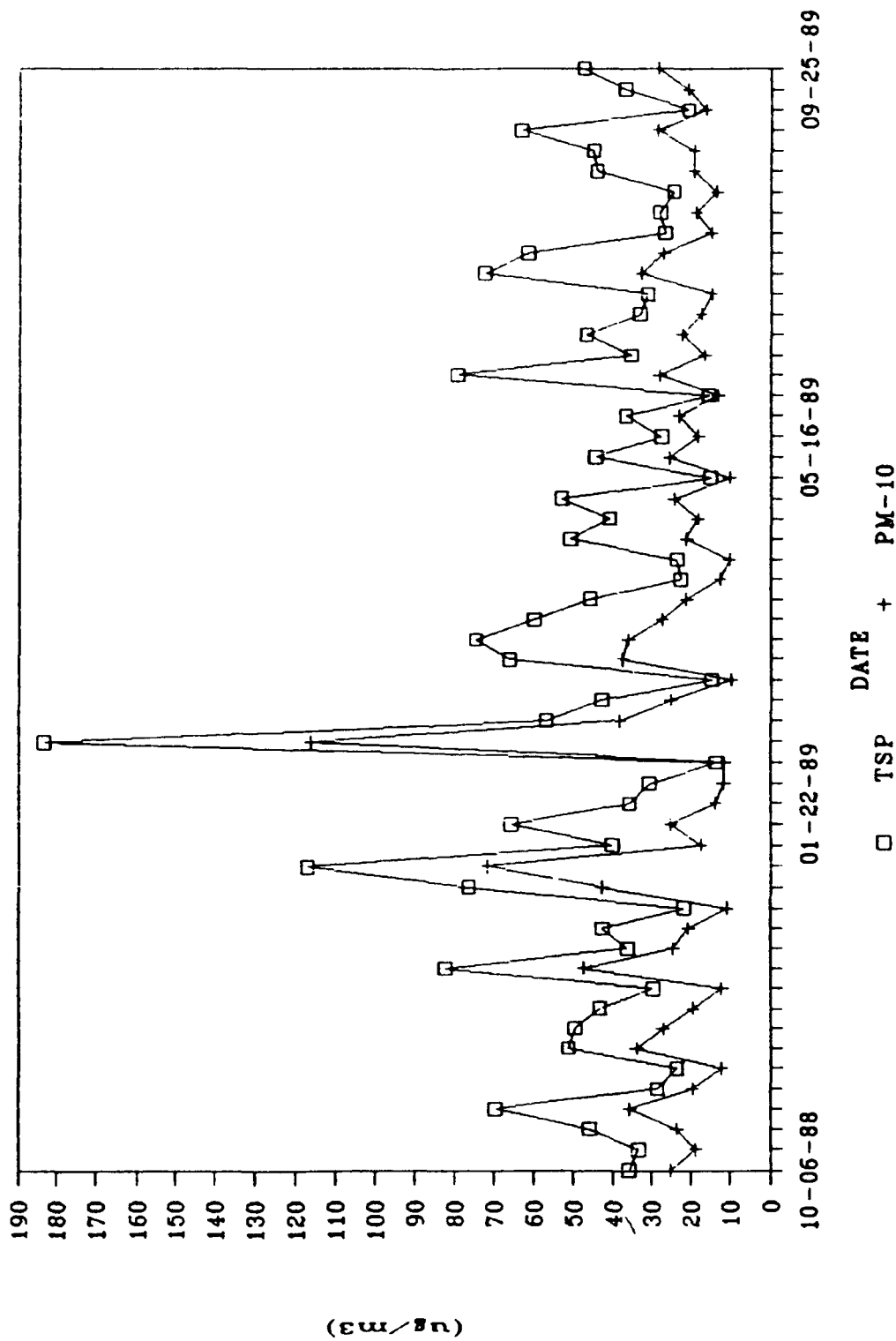


Figure 4.3-3

Comparison of TSP and
PM-10 at AQ5

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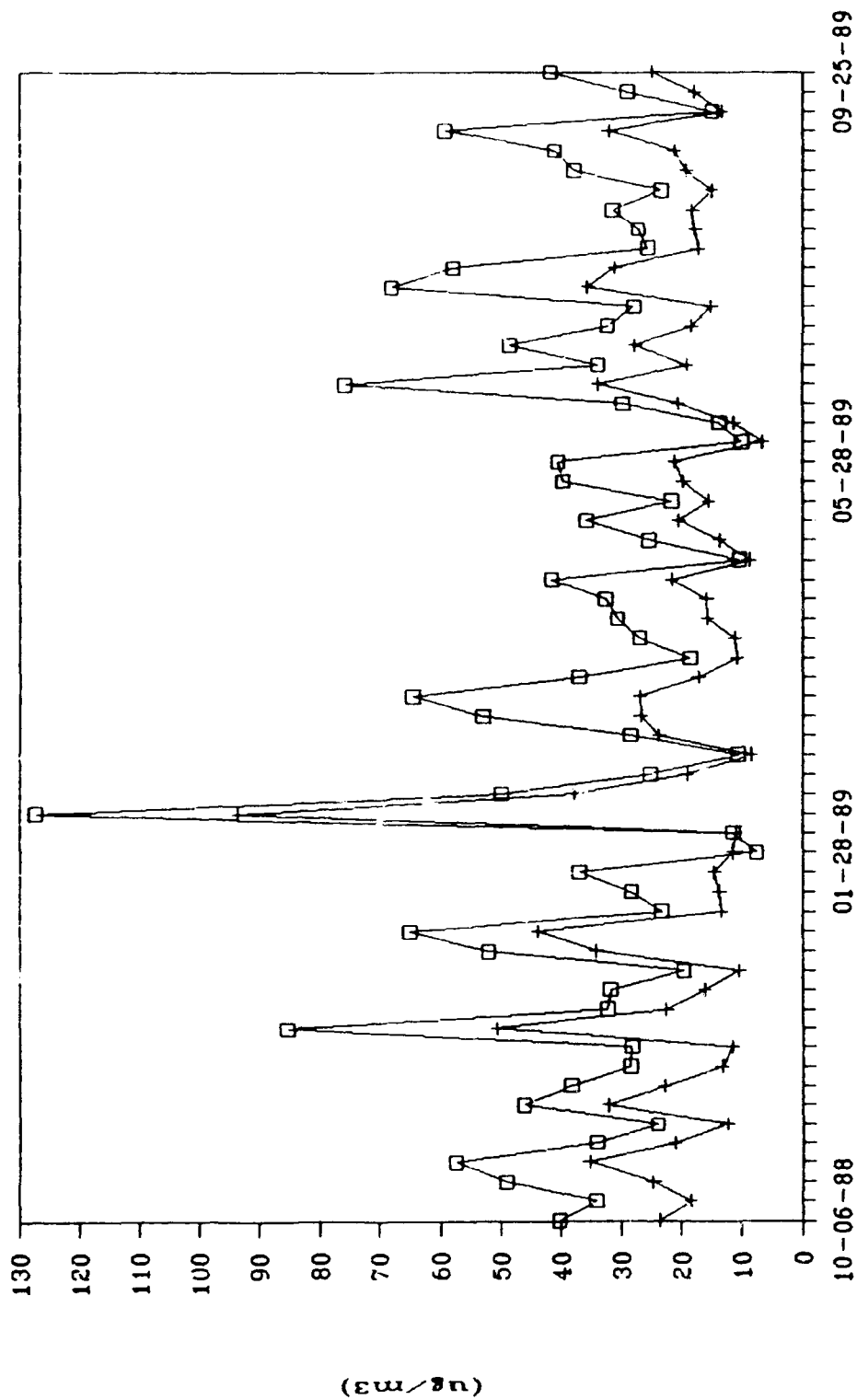


Figure 4.3-4

Comparison of TSP and
PM-10 at AQ9

CMPAR FY89

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Commerce City, Colorado

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TABLE 4.3-1 Concentrations of Respirable Particulates of Less Than
10 Microns for Phase 3 at IRA-F Sites
(in $\mu\text{g}/\text{m}^3$)

Summary of Arithmetic Mean Concentrations

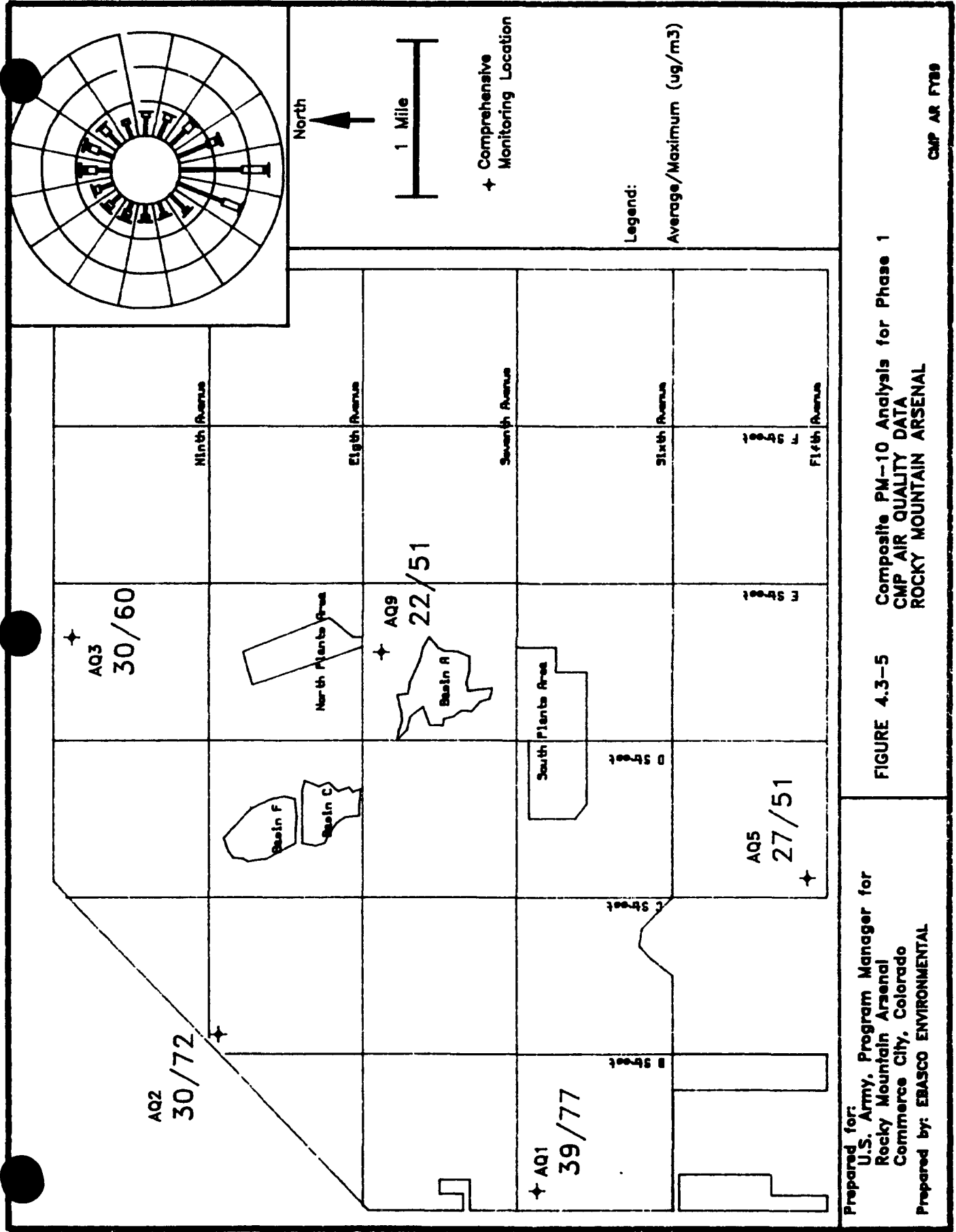
MONTH	FC1	FC3
JUN	18	16
JUL	35	26
AUG	18	18
SEP	21	23
OVERALL	23	22

Summary of Maximum Concentrations ††

MONTH	FC1	FC3
JUN	18	16
JUL	35	36
AUG	18	18
SEP	27	31
OVERALL	35	36

† Annual arithmetic mean standard is $50 \mu\text{g}/\text{m}^3$.

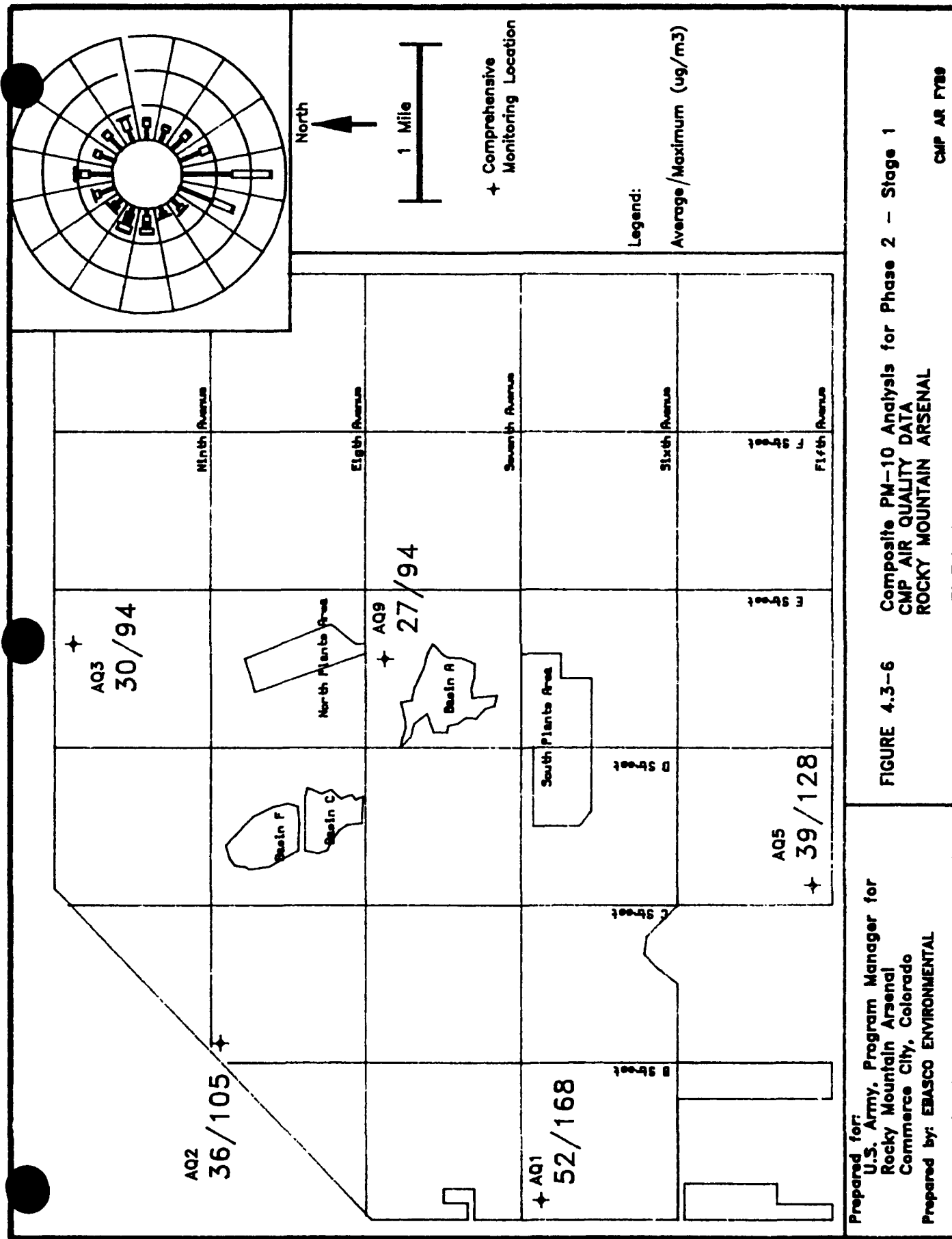
†† Maximum 24-hour standard is $150 \mu\text{g}/\text{m}^3$.

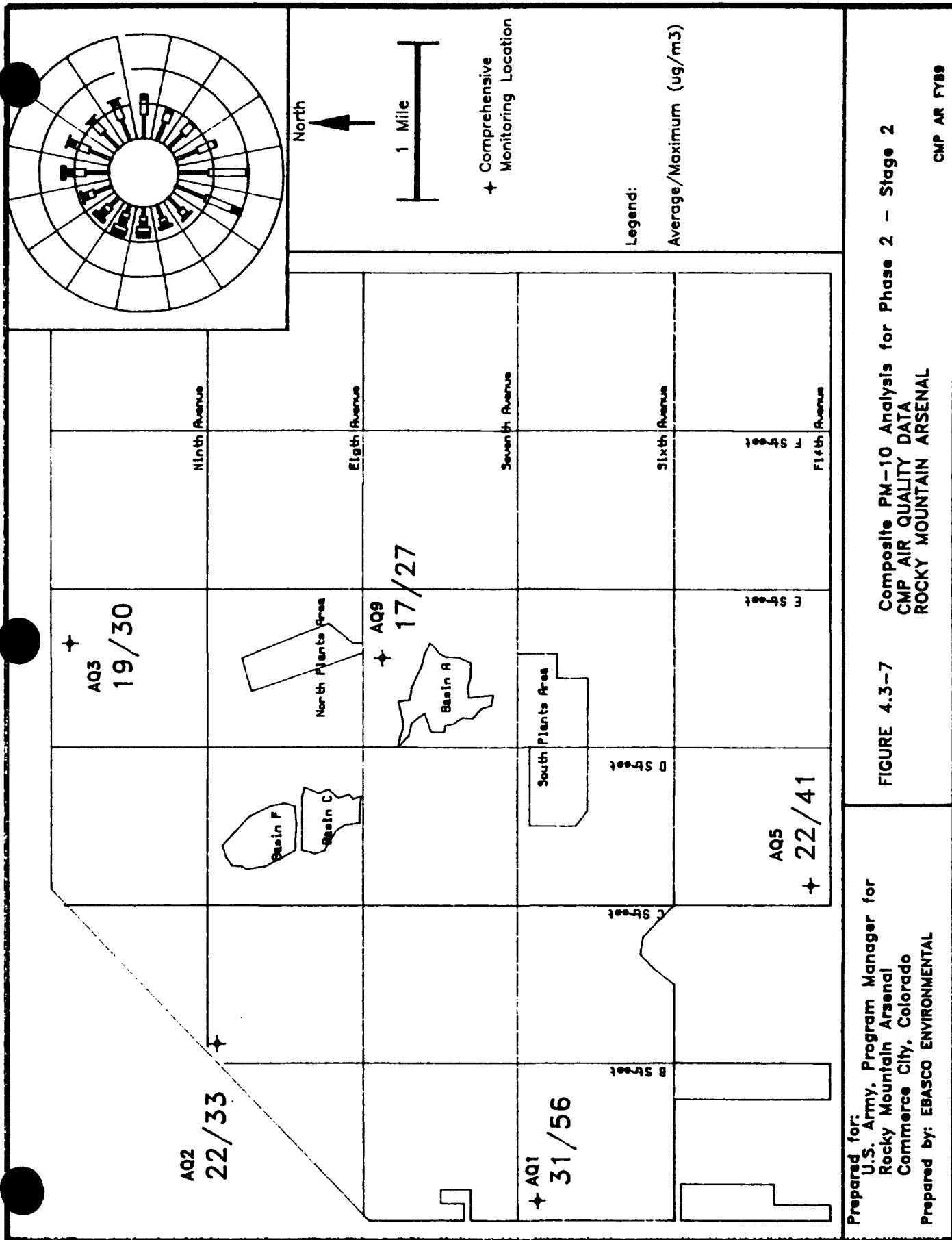


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 Rocky Mountain Arsenal
 Commerce City, Colorado
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FIGURE 4.3-5 Composite PM-10 Analysis for Phase 1
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AR FY89





4.0 RESULTS OF FY89 PROGRAM

4.1 Basis of Air Quality Data Evaluation

The purpose of the Air Monitoring Task of the CMP is to establish an ongoing baseline that can be used to verify ambient air quality at RMA and can be used as a guide to evaluate progress being made in remedial actions. As specified in the Technical Plan, the program has several related key objectives as follows:

- Verify and evaluate potential air quality health hazards that may exist within the RMA boundaries;
- Verify progress that has been made to date in removing potential air contaminants resulting from previous activities;
- Establish a database that can be augmented to verify progress made in future remedial activities;
- Provide real-time guidelines, standardized procedures and data, as appropriate, to indicate impacts of ongoing remedial activities; and
- Extend the rigorous database for further use at RMA.

Both the data monitoring programs and the data verification and evaluation programs have been directed towards these objectives. To the extent possible, the data analyses have been related to causative factors associated with contaminants detected. This requires that consideration be given to a number of variables unique to air quality assessment:

- Transient meteorological conditions: parameters such as wind direction, wind speed, atmospheric stability, inversions, temperature and precipitation;
- RMA land disturbances: in particular, remedial construction and excavation activities;
- Natural surroundings including topography, soil types and vegetation; and

- Ambient contaminant levels directly upstream from the RMA area, and in particular, metropolitan Denver.

In summary, measured background levels of TSP, PM-10, metals, VOC, SVOC and asbestos within RMA cannot be evaluated in terms of the stated objectives without identifying causative and contributing factors including off-Arsenal sources. Consequently, a computer database matrix of ambient concentrations and significant influencing parameters has been established. As the database is expanded over several years, it will have increasing statistical significance and additional applications. For example, if ambient levels of parameters show decreasing concentration levels under similar meteorological and terrain activity conditions, this would indicate either that progress is being made in remedial activities or that the natural depletion of the contaminant is taking place. If no change in conditions is evident and contaminant levels are above normal background expectations, this would confirm the persistence of a given element and/or indicate the ineffectiveness of remedial actions and the need for additional or alternate mitigating actions.

Computerized documentation and analysis have provided the following information for this Air Quality Data Assessment Report:

- For each sampling station, a list including the compounds detected at that station, the range of concentrations reported, the maximum concentration, pertinent weather conditions and other causative factors (i.e., close-by remedial activity). High event monitoring activities were similarly documented and reported.
- Comparison of measured TSP, PM-10, metals, arsenic, mercury, VOCs and SVOCs with available regional data and with regulatory guidelines, threshold limit values (TLV), and other air toxic guidelines as appropriate. Comparisons with standards and guidelines are discussed further in this section for each specific group of analytes.
- Comparison of significant (high or low) contaminant levels under similar causative conditions to indicate remedial progress or lack of progress. As basic examples, VOC and SVOC values at an RMA site over a particular season could result from remedial activity, infusions from outside the arsenal, or specific meteorological conditions. Similarly, high metals levels could result from strong wind speeds from a persistent direction, infusions from Denver, significant excavation activities, or all of the above concurrently. The computer matrix compiled over the life of the CMP delineates these causative relationships for this and future reports.

- Identification of meteorological conditions, excavation activities, or discrete sources and influences that may trigger high levels of contaminant activity and require special precautions and mitigating actions.

In addition to the above, this CMP Air Quality Data Assessment Report for FY89 provides the results of the Interim Action Basin F Cleanup Program from the initiation of remedial activities at Basin F in 1988, through September 30, 1989. Evaluation of those data includes the following by-products:

- Incorporation of all remedial activity monitoring data into the CMP, and assessment of these data as a subset of the overall database; and
- Specific standardized guidelines and criteria for air monitoring support of excavation and remedial activities at RMA. Criteria have been based on available literature, existing state-of-the-art techniques, and direct FY88 and FY89 experience with air quality monitoring and contaminants of concern at RMA; guidelines include specific instrumentation, monitoring procedures and techniques, real-time prediction and alert procedures, and models relating to Health and Safety.

It is noted that during the CMP FY88 and FY89 periods, Basin F remediation activities were in progress from March 22, 1988 to May 4, 1989. The post remediation period from May 5, 1989 to September 30, 1989 continued through the conclusion of CMP FY89. The CMP, Basin F Remediation Monitoring Program, and follow-on IRA-F data provide results of potential air contaminant levels prior to, during and subsequent to the remediation program, and reflect remedial progress. The results of this assessment are provided in this report under the phases and stages shown in Table 4.1-1.

Table 4.1-1 Basin F Remediation Phases

Phase	Dates	Activity	Monitoring Data Available
1	3/22/88 - 12/12/88	Basin F clean-up. Stockpiling of clay for future capping of basin.	CMP FY88, CMP FY89, Basin F Remediation Monitoring Program, RIFS Odor Program
2	(Stage 1) 12/13/88 - 2/15/89	Capping of basin with clay.	CMP FY89, Basin F Remediation Monitoring Program, RIFS Odor Program
	(Stage 2) 2/16/89 - 5/5/89	Capping of basin with topsoil. Grading and reseedling of basin and surrounding area. Liner installed over holding pond.	
3	5/6/89 - 9/30/89	Pumping of accumulated waste pile liquids to holding pond.	CMP FY89, IRA-F

Finally, the CMP/Basin F Air Quality Modeling Programs have included the development and application of several standard and special purpose models for assessing potential contaminant impacts, including the Industrial Source Complex (ISC) Model and a PUFF advection model (USEPA, 1986). The CMP staff has coordinated these modeling activities with the Remedial Activity Air Quality Team, and has incorporated significant modeling results and evaluations into this report. In particular, dispersion modeling has assisted appreciably in addressing impacts from potential emission sources, both on and off the Arsenal. During FY88, dispersion modeling was employed to evaluate CMP monitored data at Basin F, the South Plants and Basin A. Both the ISC and PUFF Model were also used effectively in the Basin F cleanup program to assess real-time contamination levels during remedial activities and to provide a forewarning of potential hazardous conditions.

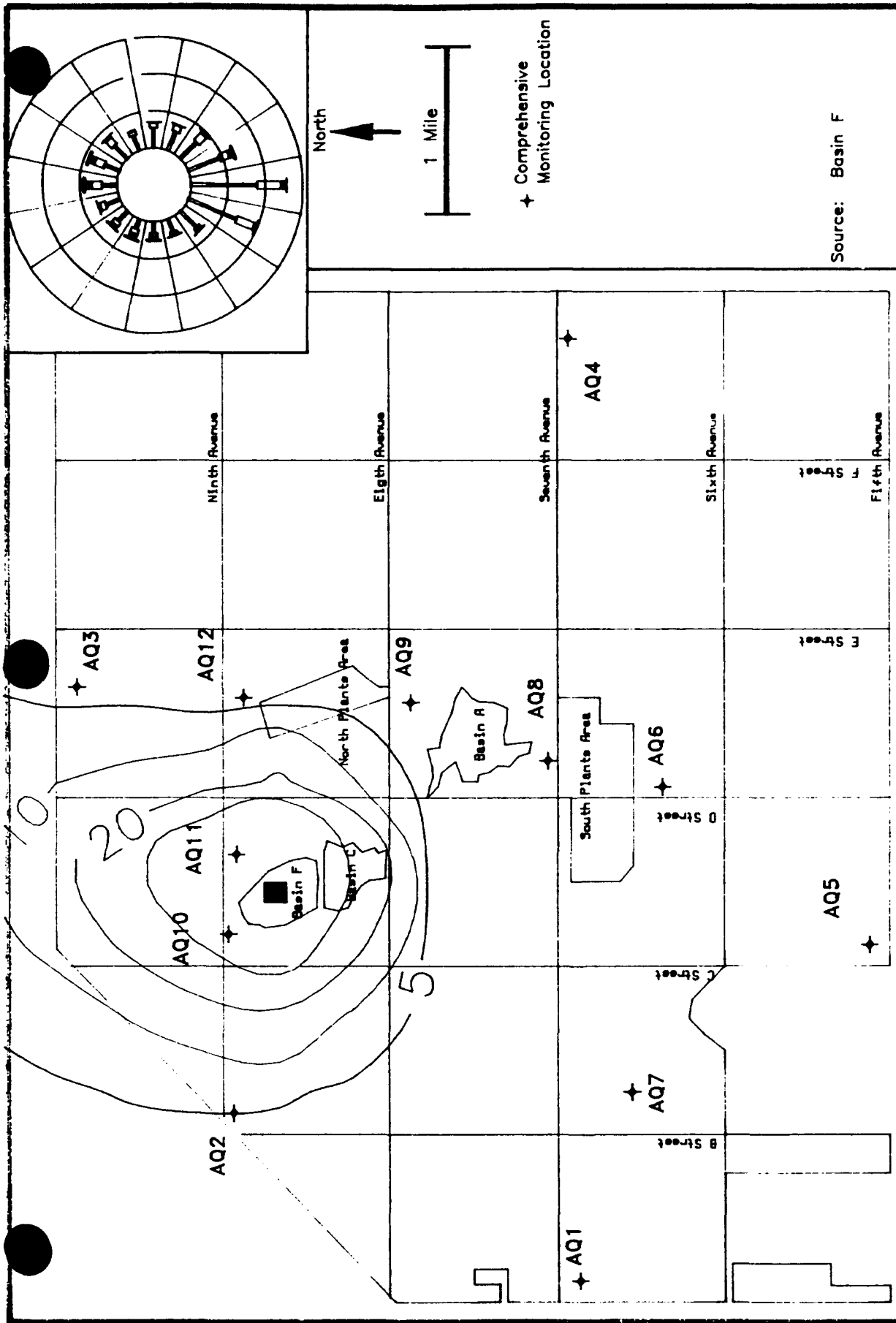
In this FY89 Report, which provides a joint analysis of CMP and Basin F data over a 19-month period to evaluate remedial impacts and post-remedial progress, dispersion models have again been used to identify both potential source impacts and overriding meteorological factors. One objective for example, is to substantiate that concentrations measured under the three remedial phase periods occurred under the influence of typical (and not anomalous) meteorological factors. For example,

Figures 4.1-1 through 4.1-4 show mean dispersion patterns for the Phase 1, the Phase 2 Stage 1 and Phase 2 Stage 2 remediation periods, and the Phase 3 post-remediation period for an area source centered at Basin F. The dispersion patterns shown here directly influence the sampling results for each of the CMP and Basin F parameters measured during the remediation assessment periods. A brief description of these dispersion patterns is provided below.

The dispersion pattern, or X/Q contours, can be best depicted by a factor which relates ambient concentration X, to source strength, Q; thus incorporating all meteorological factors but not including any actual source measurements. The X/Q contours were obtained from the EPA ISC Model (using Basin F as an area source); they reflect the influences of wind speed, wind direction, atmospheric stability, and inversion conditions on the spread of pollutants for the monitoring period for each phase. The X/Q values do not indicate ambient concentrations, but indicate relative strength, or potential for concentration levels, based on meteorological conditions and an unspecified source strength. Nevertheless, the higher concentration levels generally correspond to higher X/Q values when there is a significant source impact. As can be seen during Phases 1 and 2, the higher X/Q values are close to the Basin F source and directly downstream from prevailing wind patterns. The dispersion patterns are also skewed to the north of Basin F, reflecting the prevailing flow during the monitoring periods; this is also clearly shown in the wind rose insert for each figure. As a consequence of these dispersion and meteorological patterns, one might anticipate higher concentrations of potential Basin F source contaminants during remediation activities to be located adjacent to Basin F and just to the north of the Basin. Monitoring results, to be discussed in this section, clearly substantiate this premise.

The dispersion pattern is similar for the Phase 3 period, although there were seasonal variations. The dispersion patterns in fact, were closely identical for each phase of the remediation period. The implication, therefore, is that any significant variations in monitoring results are most likely a function of source emissions rather than meteorological factors. As a brief example, high SVOC levels for several contaminants were noted during the Phase 1 period. During Phase 2 and Phase 3, these potential contaminant levels decreased significantly (under similar dispersion conditions), inferring that the potential Basin F emissions sources for these compounds were effectively contained at the conclusion of the Phase 1 period. Similar consequences for each of the monitored parameters will be discussed in the remainder of this section.

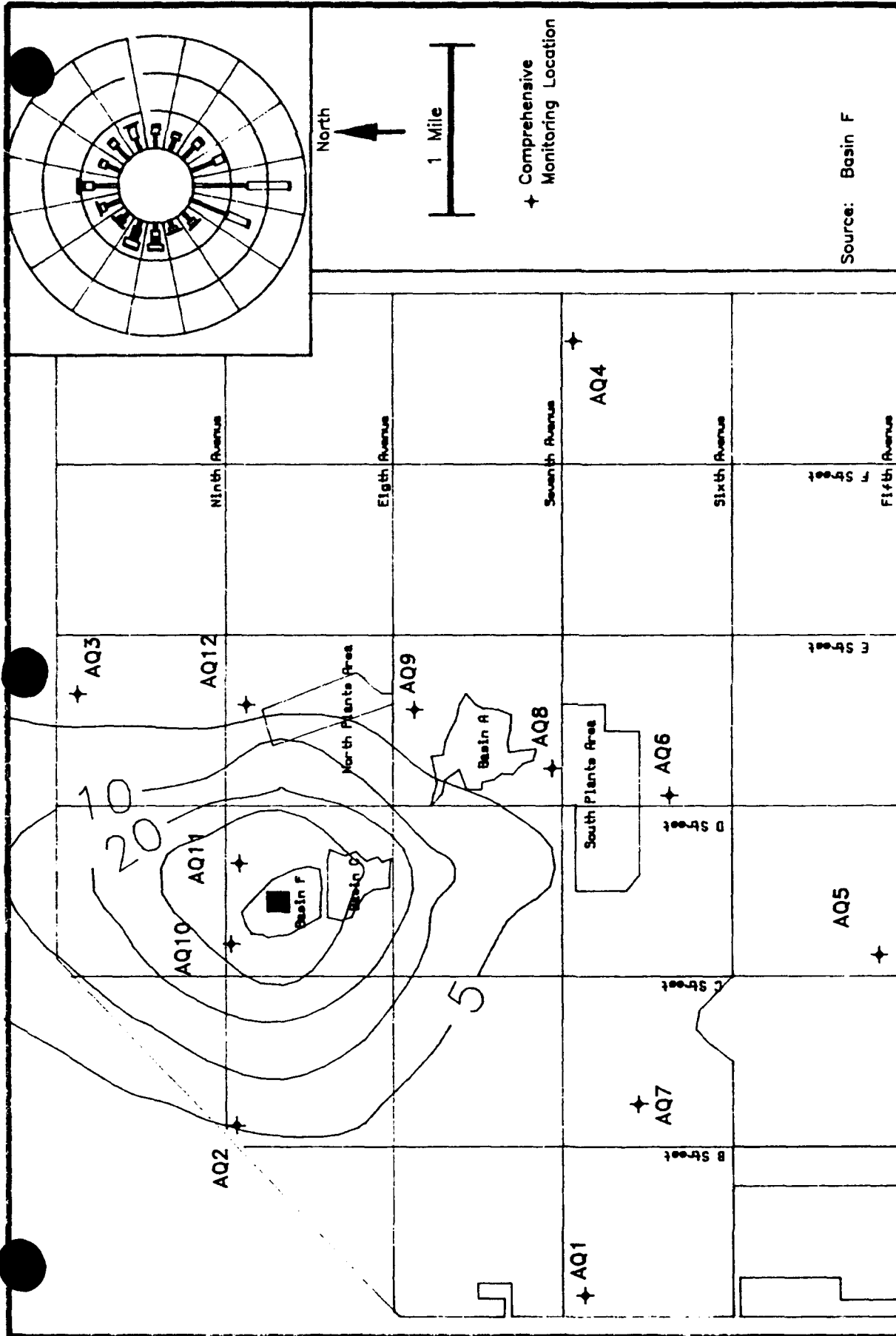
The following sections provide specific monitoring results and data evaluation for all parameters collected during the FY88 and FY89 Program; the data results of the Air Remedial Investigation Report (ESE, 1988) are also incorporated into the CMP database for long-term statistical assessment and the overall contamination assessment, as appropriate.



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 Rocky Mountain Arsenal
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FIGURE 4.1-1 x/Q Dispersion for Phase 1
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AR FY89

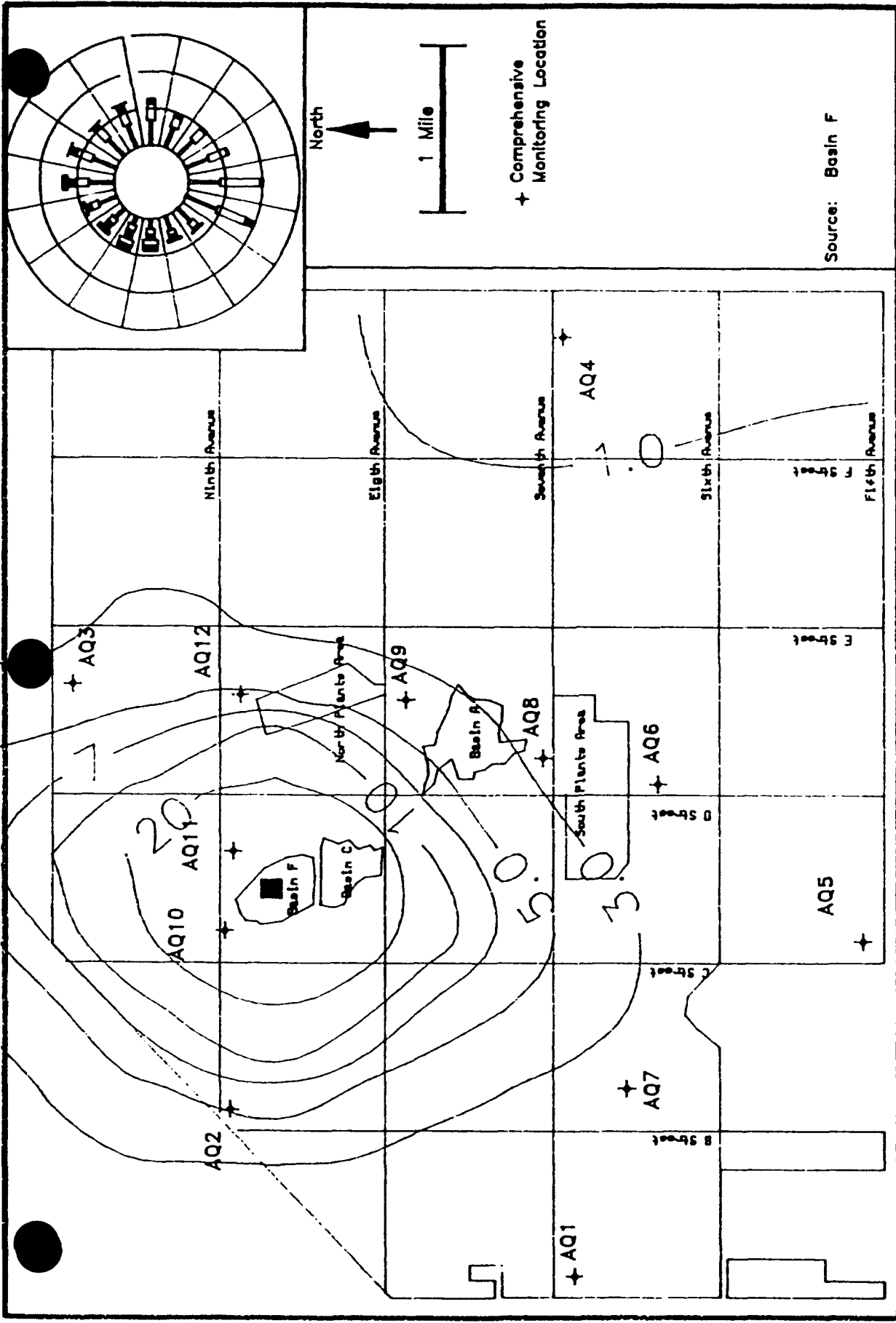


Source: Basin F

FIGURE 4.1-2 x/Q Dispersion for Phase 2 - Stage 1
CMP AIR QUALITY DATA
ROCKY MOUNTAIN ARSENAL

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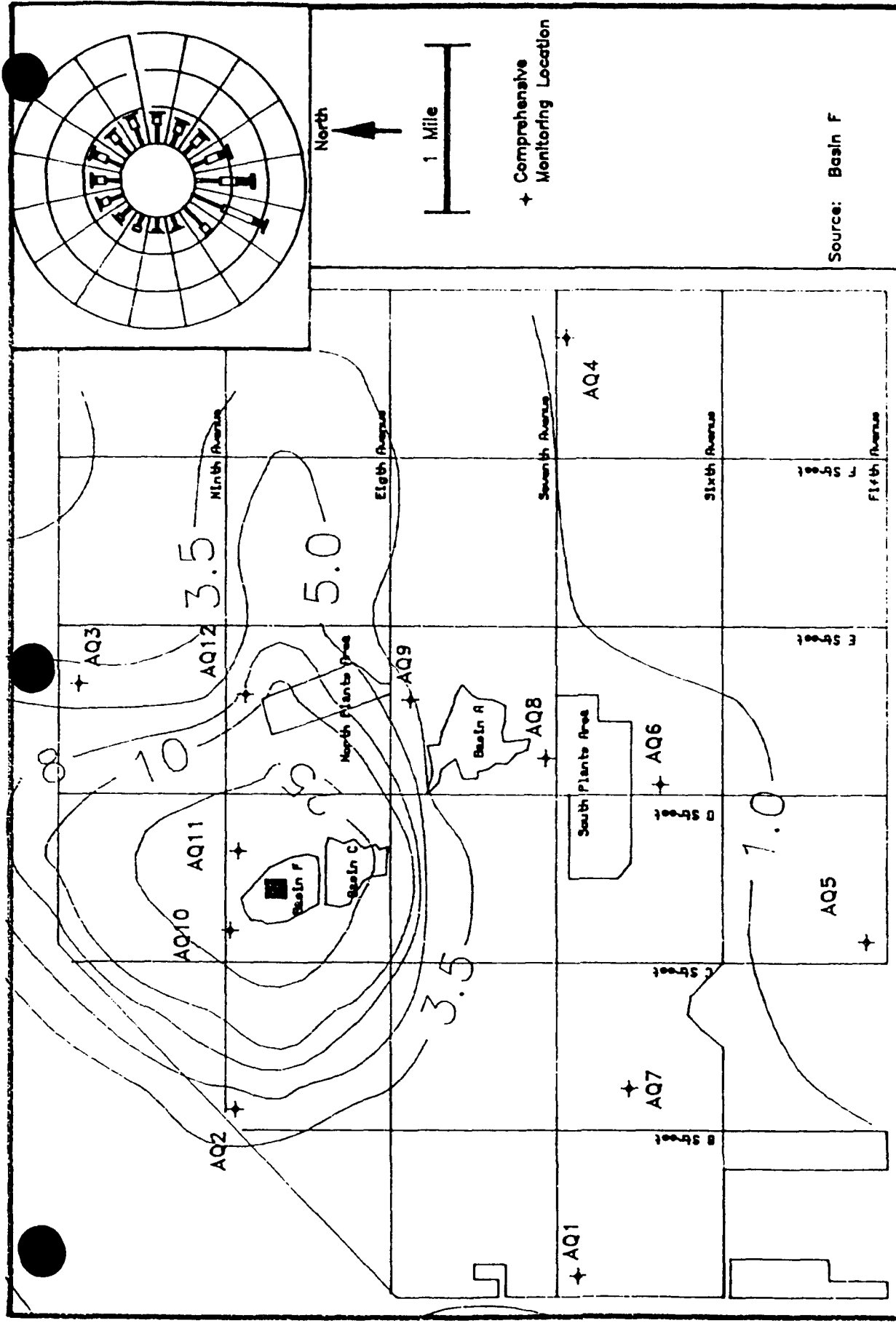
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FIGURE 4.1-3 x/Q Dispersion for Phase 2 - Stage 2
 CMP AIR QUALITY DATA
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FIGURE 4.1-4 x/Q Dispersion for Phase 3
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AR FY80

4.2. Total Suspended Particulates (TSP)

4.2.1 CMP FY89 TSP Results

Details of the FY89 sampling program for TSP at each of the monitoring locations are given in Table 4.2-1. Recoveries are based on the total number of planned days during the period after initiation. Samples were considered not valid if there were equipment malfunctions or the sample filter was damaged. According to PSD guidelines, a minimum of 23 hours of sampling was required for a valid sample.

Table 4.2-1 Summary of RMA Total Suspended Particulates (TSP) Monitoring for FY89

Station	No. Samples	% Recovery
AQ1	60	100
AQ2	56	93
AQ3	58	97
AQ4	56	93
AQ5	59	98
AQ5B	60	100
AQ6	58	97
AQ7	57	95
AQ8	58	97
AQ9	60	100
AQ10*	55	92
AQ11	60	100
AQ12	59	100
Total:	756	97

* The portable TSP monitor, AQ10, was placed just north of Basin F remedial activity on August 7, 1988, and remained at this location to the end of the FY89 program.

TSP data are often reported by using the annual geometric mean values. This approach is based on early EPA guidance regarding standards, and is applied because the TSP monitoring data can be expected to fit a log-normal distribution. Under a log-normal distribution, there are a relatively large number of low concentrations and a small number of high concentrations. An arithmetic mean value would be greatly affected by the few very large values, while a geometric mean is much less affected by these extremes.

An arithmetic mean can be characterized as:

$$A = 1/n (a_1 + a_2 + a_3 + \dots + a_n)$$

While a geometric mean is the nth root of the product of the n observations:

$$G = (a_1 \cdot a_2 \cdot a_3 \dots a_n)^{1/n}$$

Where a_i is the nth observation (of TSP data);
n is the total number of valid observations;
A is the arithmetic mean of the sample; and
G is the geometric mean of the sample.

Monthly and annual TSP results for the FY89 Program for each monitoring station are summarized in Table 4.2-2 and Figure 4.2-1. Figure 4.2-2 shows the X/Q dispersion pattern for the CMP FY89 monitoring period. Table 4.2-2 provides annual and geometric means as well as maximum concentrations in standard volumes measured during the monitoring program. The 24-hour sequential data are provided in Appendix A.

The data indicate that arithmetic mean values ranged from a high of $105 \mu\text{g}/\text{m}^3$ at AQ11, just to the north of the Basin F perimeter, to a low of $37 \mu\text{g}/\text{m}^3$ at AQ9 in the RMA interior. Geometric mean values ranged from a high of $67 \mu\text{g}/\text{m}^3$ to a low of $32 \mu\text{g}/\text{m}^3$. The overall geometric mean for the 12-month period can be compared to existing annual ambient air quality standards for TSP. Stations AQ2, located north-northwest of Basin F, and AQ11, located north-northeast of the Basin F perimeter, both exceeded the secondary annual geometric mean standard of $60 \mu\text{g}/\text{m}^3$. None of the 12 monitoring sites exceeded the primary annual geometric standard of $75 \mu\text{g}/\text{m}^3$ for the CMP FY89 period. There were 27 exceedances of the 24-hour secondary TSP standard of $150 \mu\text{g}/\text{m}^3$ and 10 exceedances of the primary standard of $260 \mu\text{g}/\text{m}^3$. All of these exceedances occurred during the Basin F remediation period and almost all of the exceedances were at sites close to the Basin F cleanup activities. Several exceedances, however, also occurred at RMA stations when very high TSP levels (in excess of $400 \mu\text{g}/\text{m}^3$) were measured at downtown Denver and when prevailing winds were from the south. Individual events will be discussed subsequently in this section. Table 2.1-1 shows all ambient air quality standards, including TSP.

TABLE 4.2-2 Total Suspended Particulates (TSP) Sampling Results for CMP FY89
(in ug/m³)

Summary of Geometric Mean Concentrations †													
MONTH	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12
OCT	54	83	53	49	41	42	38	48	43	42	109	169	101
NOV	56	63	33	32	36	40	32	36	32	32	62	66	42
DEC	68	71	42	35	46	47	39	45	41	39	86	98	36
JAN	57	67	34	26	51	45	29	35	38	26	74	142	59
FEB	44	73	26	24	39	35	28	30	29	29	39	151	32
MAR	56	73	34	33	50	47	37	40	36	37	62	119	97
APR	41	56	26	31	33	30	27	26	25	26	39	48	29
MAY	45	46	33	32	38	36	33	36	42	32	38	37	33
JUN	34	37	27	31	28	29	27	30	28	25	34	28	27
JUL	57	84	49	48	46	47	48	50	62	44	61	54	53
AUG	35	51	33	30	31	31	32	32	32	29	41	36	34
SEP	49	61	49	44	40	41	50	57	41	34	39	35	34
ANNUAL	48	61	36	34	40	39	34	37	36	32	54	67	43

Summary of Arithmetic Mean Concentrations													
MONTH	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12
OCT	56	87	56	50	43	44	39	49	44	43	112	228	108
NOV	57	66	34	32	39	41	32	38	34	33	66	66	44
DEC	75	91	48	40	52	52	44	49	46	44	115	111	40
JAN	68	76	37	30	58	54	36	41	42	32	92	231	118
FEB	67	94	40	37	62	58	48	51	46	45	54	213	45
MAR	51	80	37	37	54	50	39	42	38	40	69	151	156
APR	45	59	30	32	37	34	30	30	29	28	43	54	33
MAY	45	49	34	34	38	36	33	36	46	33	40	39	34
JUN	40	50	35	39	36	36	34	36	36	33	41	35	34
JUL	59	92	52	51	49	50	51	53	65	47	65	57	57
AUG	35	51	33	32	32	32	33	33	33	27	42	36	35
SEP	52	70	52	52	43	43	51	54	46	37	45	39	39
ANNUAL	55	70	41	39	45	44	39	43	42	37	66	105	62

TABLE 4.2-2 (continued)

Summary of Maximum Concentrations ¹¹													
MONTH	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12
OCT	81	129	76	72	69	73	54	68	61	57	158	542	165
NOV	69	62	46	37	51	53	42	54	49	46	115	72	71
DEC	134	162	93	79	82	83	71	73	76	85	279	261	72
JAN	131	149	68	63	117	113	79	88	79	65	175	738	425
FEB	179	198	113	102	183	172	143	156	130	127	146	561	116
MAR	86	115	53	58	75	68	57	59	55	65	122	294	467
APR	64	64	51	43	53	48	54	49	50	41	71	93	49
MAY	52	71	41	45	44	46	42	45	78	40	57	56	43
JUN	75	117	92	82	79	78	76	77	84	76	73	76	80
JUL	82	124	80	74	72	73	76	78	78	68	90	84	86
AUG	48	68	42	52	44	44	43	41	47	38	49	43	48
SEP	82	130	82	92	67	64	64	63	70	59	75	66	65
ANNUAL	179	198	113	102	183	172	143	156	130	127	279	738	467

¹ Annual geometric mean standard is 75 ug/m³.

¹¹ Second-maximum 24-hour standard is 150 ug/m³.

Note: FY89 is the period from October 1, 1988 to September 30, 1989.

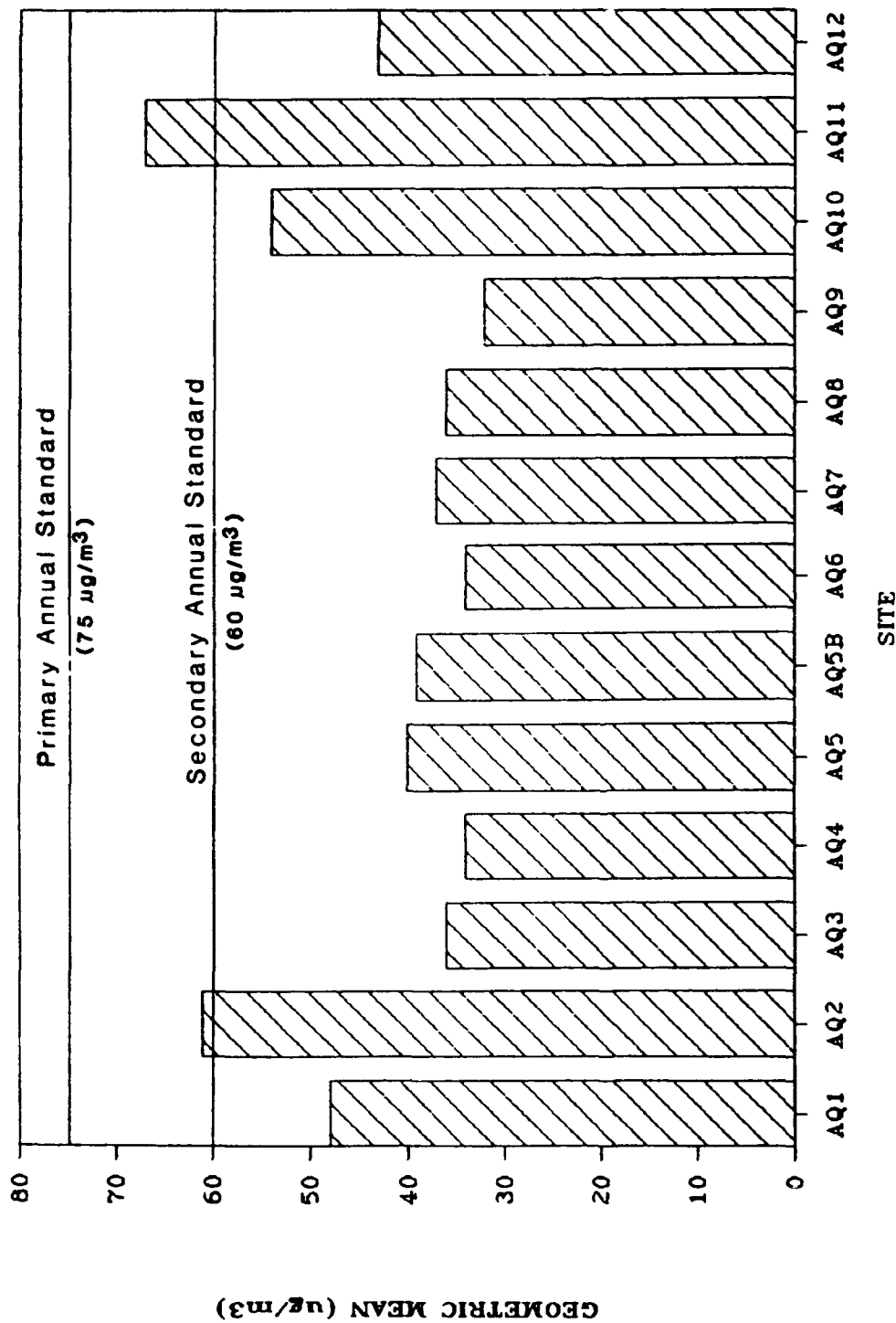


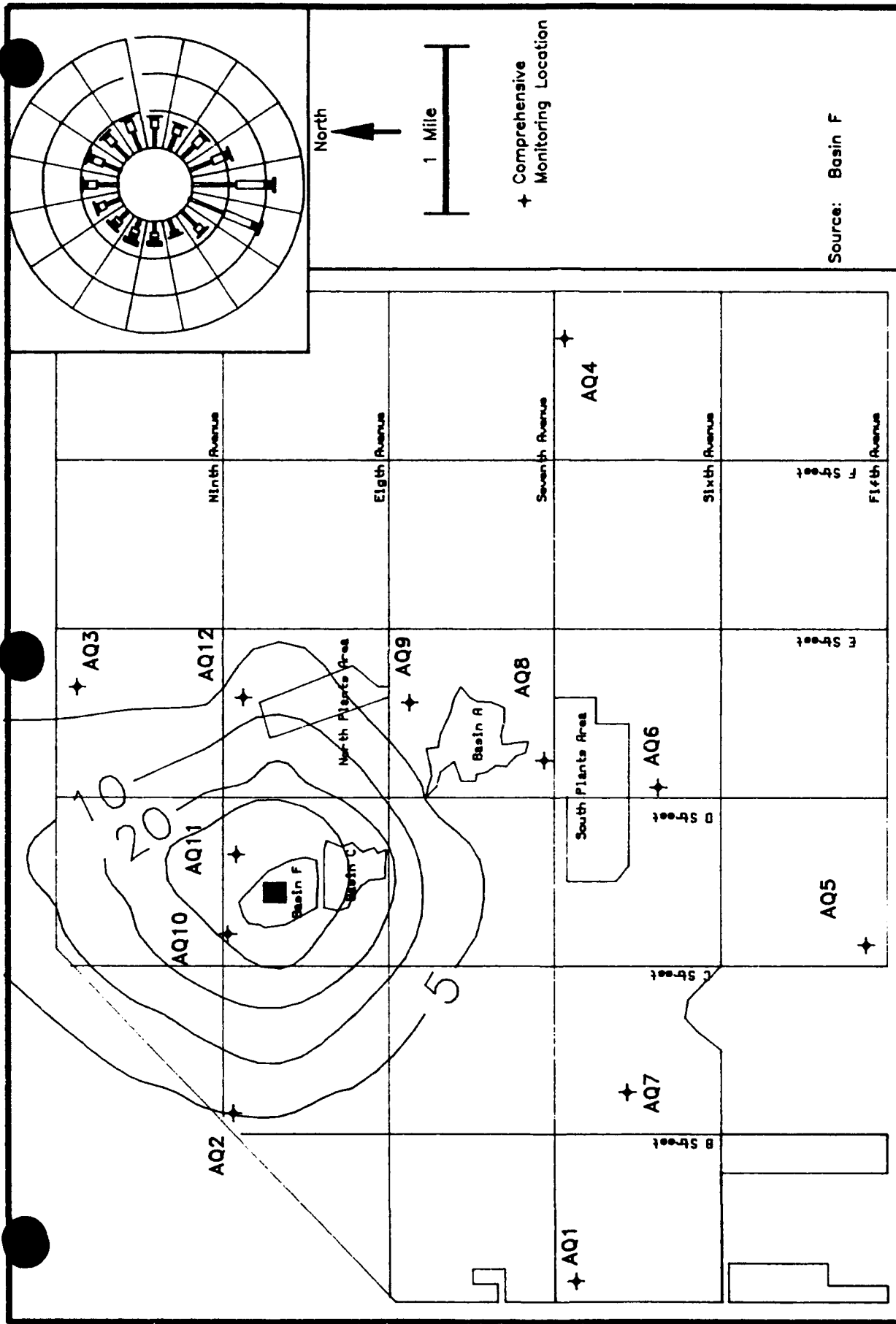
Figure 4.2-1

CMP Total Suspended
Particulates Results for
FY89

CMPAR FY 89

Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.



Prepared for:
 U.S. Army, Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by: EBASCO ENVIRONMENTAL

FIGURE 4.2-2 x/Q Dispersion for CMP FY89
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AR FY89

4.2.2 Assessment of Basin F TSP Impacts

4.2.2.1 CMP TSP Monitoring Results. Because of the varying source impacts from Basin F during the remedial and post-remedial monitoring periods, results and comparisons with all monitored data were considered with respect to the different phases and stages of the cleanup operations. Table 4.2-3 provides a description of geometric mean, average and maximum TSP monitoring results by month from the start of CMP FY88 to the conclusion of CMP FY89. At the bottom of the monthly data is a summary of the concentrations for each phase of the monitoring period. Also, in order to establish pre-remedial baseline lines, results of the 1986-1987 IR Program are provided (ESE, 1988) (only average and maximum values are shown for these data as geometric means were not calculated). Phase 1 shows results of CMP FY88 and FY89 data which were concurrent with remediation activity; Phase 2 (Stage 1) shows results of the FY89 program after the initial cap was placed on Basin F, but extensive ground moving activities were in progress; Phase 2 (Stage 2) shows results during the final Basin F remedial and landscaping activity. Phase 3 provides post-remedial TSP monitoring data during the last five months of the CMP FY89.

It is clear from these data that Basin F remedial activity had very significant impacts on those CMP stations that were located immediately adjacent to or downwind from Basin F, especially AQ10, 11, and 12. The highest monthly average and maximum 24-hour concentrations occurred in the latter months of Phase 1 and in Phase 2, Stage 1, when earth moving activities were most intense. A maximum 24-hour TSP value of $738 \mu\text{g}/\text{m}^3$ was measured at AQ11 on January 22, 1989. At all stations, TSP levels decreased to pre-remedial baseline values at the conclusion of remediation activity (Phase 3). Figure 4.2-3 also provides a graphical depiction of this progression for arithmetic means and maximum values at AQ10, the CMP mobile station immediately downwind and north of Basin F; analysis of other stations close to Basin F provide similar results. It is noted that AQ12, which measured high TSP levels during remediation activities, was not next to Basin F but was adjacent to the Borrow Pit which supplied fill-in dirt for the final Basin F ground cover. The transitory impacts of remediation activity are clearly defined in these data.

The RMA TSP interior and boundary monitoring stations at farther distances from Basin F showed minimal impacts from the remediation activity and smaller variations that were mostly attributed to seasonal and other meteorological conditions. This is particularly true of AQ1 and AQ2 which were located at the western and northwestern boundaries of RMA, thereby receiving the greatest impacts from metropolitan Denver. The highest levels at these stations were measured during the winter period (January and February, 1989) coincident with days when downtown Denver experienced very high TSP values. These were periods of intense inversions and the movement of

TABLE 4.2-3 Total Suspended Particulates (TSP) Sampling Results for CMP Phases 1-3
(in $\mu\text{g}/\text{m}^3$)

Summary of Geometric Mean Concentrations													
MONTH	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12
PHASE 1													
MAR	70	93	37		55	60	45	58	59	93		70	44
APR	43	60	33		38	36	35	40	40	35		38	31
MAY	34	41	29		29	28	26	30	30	25		43	26
JUN	38	61	38		37	36	35	39	39	36		95	77
JUL	54	74	45		46	46	42	45	48	45		89	67
AUG	58	80	54	50	45	45	43	49	50	47	62	68	93
SEP	44	72	37	31	29	30	27	31	36	35	86	81	61
OCT	54	83	53	49	41	42	38	48	43	42	109	169	101
NOV	56	63	33	32	38	40	32	36	32	32	62	66	42
DEC	82	87	51	43	55	55	45	50	52	52	104	84	44
PHASE 2 - STAGE 1													
DEC	60	57	37	30	41	42	36	41	35	32	76	91	32
JAN	57	67	34	26	51	45	29	35	38	26	74	143	59
FEB	58	143	40	39	52	47	41	41	44	42	54	239	57
PHASE 2 - STAGE 2													
FEB	29	37	13	12	25	23	17	19	16	16	24	76	13
MAR	56	73	34	33	50	47	37	40	36	37	62	119	97
APR	41	56	26	31	33	30	27	26	25	26	39	48	29
MAY	46	71	30			30	31	32	78	25	57	43	28
PHASE 3													
MAY	44	41	34	32	38	37	33	37	34	33	35	36	34
JUN	34	37	27	31	28	29	27	30	28	25	34	28	27
JUL	57	84	49	48	46	47	48	50	62	44	61	54	53
AUG	35	51	32	30	31	31	32	32	31	29	41	36	34
SEP	48	61	49	44	40	41	50	53	41	34	39	35	34
PHASE 1	50	68	40	40	39	39	35	40	40	38	81	74	55
PHASE 2-1	58	76	37	30	48	45	33	38	39	31	68	145	49
PHASE 2-2	44	58	26	27	37	34	29	30	29	28	44	72	41
PHASE 3	42	52	37	37	36	36	36	38	38	32	41	37	36

TABLE 4.2-3 (continued)

Summary of Arithmetic Mean Concentrations *													
MONTH	A01	A02	A03	A04	A05	A05B	A06	A07	A08	A09	A010	A011	A012
PHASE 1													
MAR	71	94	55		59	62	50	61	63	93		83	47
APR	50	65	41		45	42	43	46	46	43		49	37
MAY	36	42	31		31	29	27	32	31	27		55	28
JUN	42	65	42		40	38	37	41	42	39		101	102
JUL	57	76	48		43	48	43	47	49	47		95	70
AUG	66	97	60	58	50	50	47	55	55	52	69	76	163
SEP	56	88	51	42	39	39	36	41	42	36	120	157	93
OCT	56	87	56	50	43	44	39	49	44	43	112	228	108
NOV	57	66	34	33	39	41	32	38	34	33	66	66	44
DEC	92	104	61	51	59	59	50	54	56	59	159	118	49
PHASE 2 - STAGE 1													
DEC	64	57	40	32	47	48	40	46	39	34	86	107	35
JAN	68	76	37	30	59	54	36	41	42	32	92	231	118
FEB	90	150	57	53	85	79	67	70	64	63	73	292	66
PHASE 2 - STAGE 2													
FEB	32	38	13	13	29	27	18	22	18	18	24	94	14
MAR	61	80	37	37	54	50	39	42	38	40	69	151	156
APR	45	59	36	32	37	24	38	30	29	28	43	54	33
MAY	48	71	30			30	31	32	78	25	57	43	28
PHASE 3													
MAY	44	43	34	34	38	38	34	37	35	34	36	38	35
JUN	40	50	35	39	36	36	34	36	36	33	41	35	34
JUL	59	91	52	51	49	50	51	53	65	47	65	57	57
AUG	35	51	33	32	32	32	33	33	33	29	42	36	35
SEP	52	70	52	52	43	43	51	54	46	37	45	39	39
PRE-REM	55	52	35	42	42		38	39	38	36	44	38	35
PHASE 1	56	77	47	47	43	43	39	45	44	43	99	103	79
PHASE 2-1	73	88	44	37	62	59	45	50	47	41	84	214	81
PHASE 2-2	49	64	30	31	42	39	32	34	34	31	51	96	77
PHASE 3	46	61	41	42	40	40	40	42	43	36	46	41	40

TABLE 4.2-3 (continued)

Summary of Maximum Concentrations ††													
MONTH	AQ1	AQ2	AQ3	AQ4	AQ5	AQ5B	AQ6	AQ7	AQ8	AQ9	AQ10	AQ11	AQ12
PHASE 1													
MAR	79	111	95		83	78	70	80	86	93		126	54
APR	88	118	97		87	83	86	86	87	86		101	31
MAY	53	63	43		47	45	36	50	43	38		118	45
JUN	67	96	73		64	62	61	63	75	67		166	238
JUL	82	100	74		64	65	56	65	59	62		152	111
AUG	105	196	96	120	82	81	78	91	87	89	108	115	590
SEP	94	138	94	84	71	69	63	75	72	46	252	369	190
OCT	81	129	76	72	69	73	54	66	61	57	158	542	165
NOV	69	82	46	37	51	53	42	54	48	46	115	72	71
DEC	134	162	93	79	82	83	71	73	76	85	279	201	72
PHASE 2 - STAGE 1													
DEC	87	80	64	45	76	78	62	65	62	52	141	189	52
JAN	131	149	68	63	117	113	79	88	79	65	175	738	425
FEB	179	198	113	102	183	172	143	156	130	127	146	561	116
PHASE 2 - STAGE 2													
FEB	47	47	21	17	43	40	26	32	26	25	29	148	20
MAR	86	115	53	58	75	68	57	59	55	65	122	294	467
APR	64	84	51	43	53	48	54	49	50	41	71	93	49
MAY	48	71	30			30	31	32	78	25	57	43	28
PHASE 3													
MAY	52	51	41	45	44	46	42	45	43	40	45	56	43
JUN	75	117	82	80	79	78	76	77	84	76	73	76	60
JUL	82	124	80	74	72	73	76	78	78	68	90	84	86
AUG	48	68	42	52	44	44	43	41	47	38	49	43	48
SEP	82	130	82	92	63	64	64	63	70	59	75	66	65
PRE-REM	143	112	80	47	109		151	101	95	82	71	91	77
PHASE 1	134	196	96	120	87	83	86	91	87	93	279	542	590
PHASE 2-1	179	198	113	102	183	172	143	156	130	127	175	738	425
PHASE 2-2	86	115	53	58	75	68	57	59	78	65	122	294	467
PHASE 3	82	130	82	92	79	78	76	78	84	76	90	84	66

† Annual primary geometric mean standard is 75 ug/m³.

†† Second-maximum 24-hour standard is 150 ug/m³.

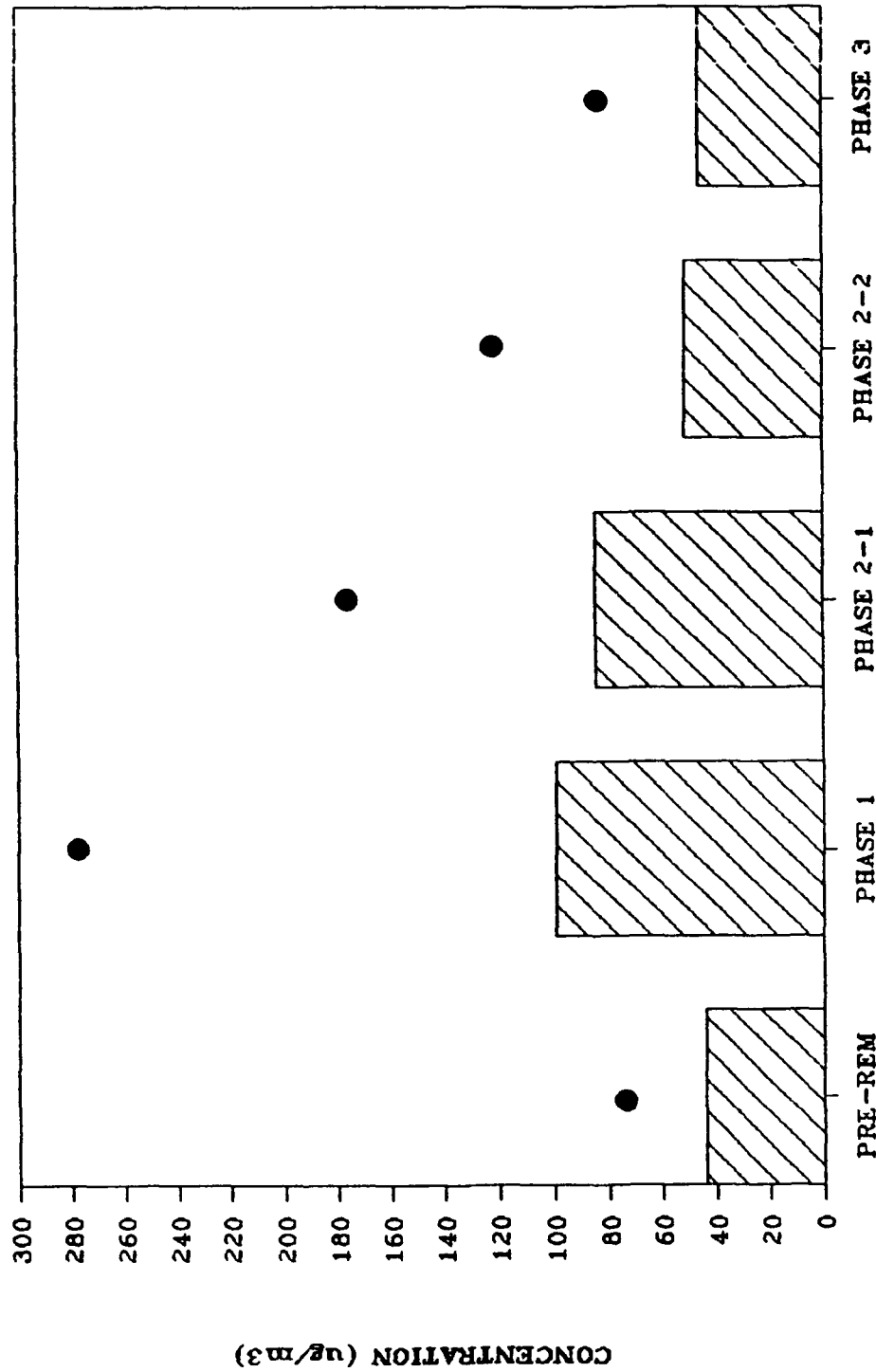
Note: Pre-Rem refers to data collected during the Air Remedial Investigation (Environmental Science & Engineering, Inc., 1988).

Phase 1 is from March 22 to December 12, 1988.

Phase 2, Stage 1 is from December 13, 1988 to February 15, 1989.

Phase 2, Stage 2 is from February 16 to May 5, 1989.

Phase 3 is from May 6 to September 30, 1989.



 ARITHMETIC MEAN

 MAXIMUM

Figure 4.2-3

TSP Concentrations at
 AQ10 During Remediation
 Phases

CMPAR FY 89

Prepared for:
 U.S. Army Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado

Prepared by:
 R.L. Stollar & Associates, Inc.
 Ebasco Services, Inc.

potential "brown cloud" conditions from downtown Denver in the direction of the Arsenal. This will be discussed subsequently and individual cases will also illustrate these phenomena. On the other hand, AQ8, in the interior of RMA, indicated some seasonal variations but apparently minimal impacts from Basin F and occasional impacts from Denver.

The results of the CMP data reflecting TSP Basin F remedial impacts are further substantiated by data collected under the Basin F Interim Remediation Monitoring Program and the follow-on IRA-F monitoring program discussed in the next section.

4.2.2.2 Basin F TSP Monitoring Results. During FY88 and FY89, the CMP air monitoring network at RMA was supplemented and augmented by two major monitoring programs associated with Basin F cleanup activities. These were the Basin F Interim Remediation Air Monitoring Program and the follow-on IRA-F Air Monitoring Program. These programs ran continuously from May 1988 through September 1989; the IRA-F Program is still in operation. The network of stations and parameter monitors is discussed in Sections 3.3 and 3.4.

Geometric mean, arithmetic mean and maximum TSP concentrations collected under the special Basin F monitoring programs, by month and phase are shown in Table 4.2-4. Data from phases 1 and 2 comprise the Basin F Interim Remediation Monitoring Program and Phase 3 data comprise the IRA-F Program. Detailed daily results are also provided in Appendix L.

The Basin F network was designed specifically to evaluate impacts surrounding the remedial activity during and after cleanup operations. The progress of impacts is illustrated graphically in Figure 4.2-4 which shows TSP levels during each phase of the program at nine monitoring stations. In all cases concentration levels dropped significantly during Phase 3, the post-remedial period. Individual station impacts reflect the distance from specific remedial activity. For example, BF1/FC1 located at the north end of the basin showed highest levels during the full remediation phase and dropped off to typical RMA baseline levels at the conclusion of remediation work. (All Basin F monitoring stations fell off to RMA background levels during Phase 3 at the conclusion of remediation.) The geometric mean TSP concentration at BF1/FC1 was $105 \mu\text{g}/\text{m}^3$ during Phase 1, dropped to $78 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 1, $62 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 2, and was $49 \mu\text{g}/\text{m}^3$ during the Phase 3 portion of the monitoring program. A maximum 24-hour concentration of $399 \mu\text{g}/\text{m}^3$ was measured at BF1 during the Phase 1 remediation period.

Station BF2/FC2, at the northeast perimeter of the Basin F compound, downwind of prevailing wind flow and in close proximity to extensive ground moving activities, measured the highest TSP concentrations during the remediation program. The geometric mean TSP concentration was 122

TABLE 4.2-4 Total Suspended Particulates (TSP) Sampling Results for Basin F/IRAF Phases 1-3
(in $\mu\text{g}/\text{m}^3$)

Summary of Geometric Mean Concentrations 1												
MONTH	BF1/FC1	BF2/FC2	BF2C/FC2D	BF3/FC3	BF4/FC4	BF5	FC5	BF6	BF7	RIFS1	RIFS1D	RIFS2

PHASE 1												
MAY	121	45	63		84	88		80	43			
JUN	75	81	112		130	59		100	47			
JUL	113	144	177	114	143	74		102	60			
AUG	32	88	75	60	83	67		56	49			
SEP	173	171	263	51	119	51		101	38			
OCT	163	185	192	99	166	75		126	63			
NOV	251	132	75	49	92	34		43	29			
DEC	149	210	180	61	138	73		58	44			
PHASE 2 - STAGE 1												
DEC	88	213	625	63	73	55		74	40	81	74	51
JAN	66	90	142	40	62	42		69	36	60	65	42
FEB	100	114	75	97	112	86		102	36	85	105	52
PHASE 2 - STAGE 2												
FEB	58	82	134	53	63	50		235	44	35	48	25
MAR	65	111	120	62	78	38		128	35	58	45	64
APR	64	65	98	53	95	58		87	60	67	86	
MAY	46	36	46	38	104	47		44	44	59		
PHASE 3												
MAY	45	43	44	42	46	41						
JUN		25	27	34	27	26	46		40			
JUL		54	59	59	62		64		27			
AUG	45	42	42	48	42		59					
SEP	58	45	46	44	46		49					
PHASE 1	105	122	135	68	117	64		89	47			
PHASE 2-1	78	119	190	53	72	48		76	44	68	75	45
PHASE 2-2	62	81	104	55	80	45		109	40	56	59	40
PHASE 3	49	39	40	44	42	31	54		32			

TABLE 4.2-4 (continued)

Summary of Arithmetic Mean Concentrations 1

MONTH	BF1/FC1	BF2/FC2	BF2C/FC2D	BF3/FC3	BF4/FC4	BF5	FC5	BF6	BF7	RIFS1	RIFS1D	RIFS2
PHASE 1												
MAY	122	48	63		95	95		102	50			
JUN	84	96	140		143	63		102	49			
JUL	119	190	190	116	144	75		105	61			
AUG	87	106	100	69	96	93		61	55			
SEP	221	252	331	79	158	59		249	40			
OCT	175	204	202	114	174	76		142	64			
NOV	121	235	121	52	112	37		49	31			
DEC	106	238	204	65	169	91		60	47			
PHASE 2 - STAGE 1												
DEC	95	327	626	69	74	61		139	54	82	75	55
JAN	94	112	162	42	69	50		80	38	67	65	44
FEB	105	118	75	102	116	87		102	77	102	112	67
PHASE 2 - STAGE 2												
FEB	65	88	134	56	70	50		235	44	48	48	31
MAR	69	162	166	67	83	39		187	36	62	47	25
APR	70	72	99	59	108	58		87	61	70	59	
MAY	47	37	46	35	104	47		44	44	59		
PHASE 3												
MAY	45	43	44	42	46	41						
JUN		28	30	36	31	30	40		41			
JUL		61	67	65	70		67		36			
AUG	46	42	43	48	43		60					
SEP	69	48	50	49	50		54					
PHASE 1	123	173	178	85	137	74		112	51			
PHASE 2-1	96	173	267	60	79	56		96	50	76	77	51
PHASE 2-2	60	110	134	60	88	47		147	45	62	64	48
PHASE 3	53	43	45	47	46	35	57		34			

TABLE 4.3-4 (continued)

Summary of Maximum Concentrations **												
MONTH	BF1/FC1	BF2/FC2	BF2C/FC2D	BF3/FC3	BF4/FC4	BF5	FC5	BF6	BF7	R1FS1	R1FS1D	R1FS2
PHASE 1												
MAY	128	66	63		158	128		202	98			
JUN	163	246	318		295	104		129	76			
JUL	164	370	296	151	167	82		141	71			
AUG	155	277	235	175	175	260		109	94			
SEP	399	591	622	274	324	120		470	75			
OCT	315	305	305	286	233	95		283	81			
NOV	251	502	282	96	204	46		81	46			
DEC	149	367	354	98	280	167		70	70			
PHASE 2 - STAGE 1												
DEC	161	687	659	111	94	85		236	89	98	95	81
JAN	276	285	255	59	132	120		171	52	193	77	71
FEB	154	147	75	143	162	95		105	86	162	143	101
PHASE 2 - STAGE 2												
FEB	107	115	134	83	116	50		275	44	73	48	47
MAR	104	514	471	106	130	55		493	52	99	59	57
APR	104	103	107	107	160	71		91	76	111	109	
MAY	47	41	46	46	104	47		44	44	59		
PHASE 3												
MAY	47	50	50	48	51	46						
JUN		38	39	50	40	44	46		45			
JUL		89	96	94	103		97		79			
AUG	49	44	45	51	47		68					
SEP	105	89	70	69	40		76					
PHASE 1	399	591	622	286	324	260		470	94			
PHASE 2-1	276	687	659	143	162	120		236	89	193	143	101
PHASE 2-2	107	514	471	107	160	71		493	76	111	109	57
PHASE 3	105	89	96	94	103	46	87		45			

* Annual geometric mean standard is 75 ug/m3.

** Second-maximum 24-hour standard is 150 ug/m3.

Note: Phase 1 is from May 3 to December 12, 1988.

Phase 2, Stage 1 is from December 13, 1988 to February 15, 1989.

Phase 2, Stage 2 is from February 16 to May 4, 1989.

Phase 3 is from May 5 to September 30, 1989.

The Basin F sites were redesignated as "FC" sites upon commencement of the IRAF program. Sites BF3 and BF4 remained in operation until June, when they were moved slightly within the same area and designated as "FC" sites under the IRAF program.

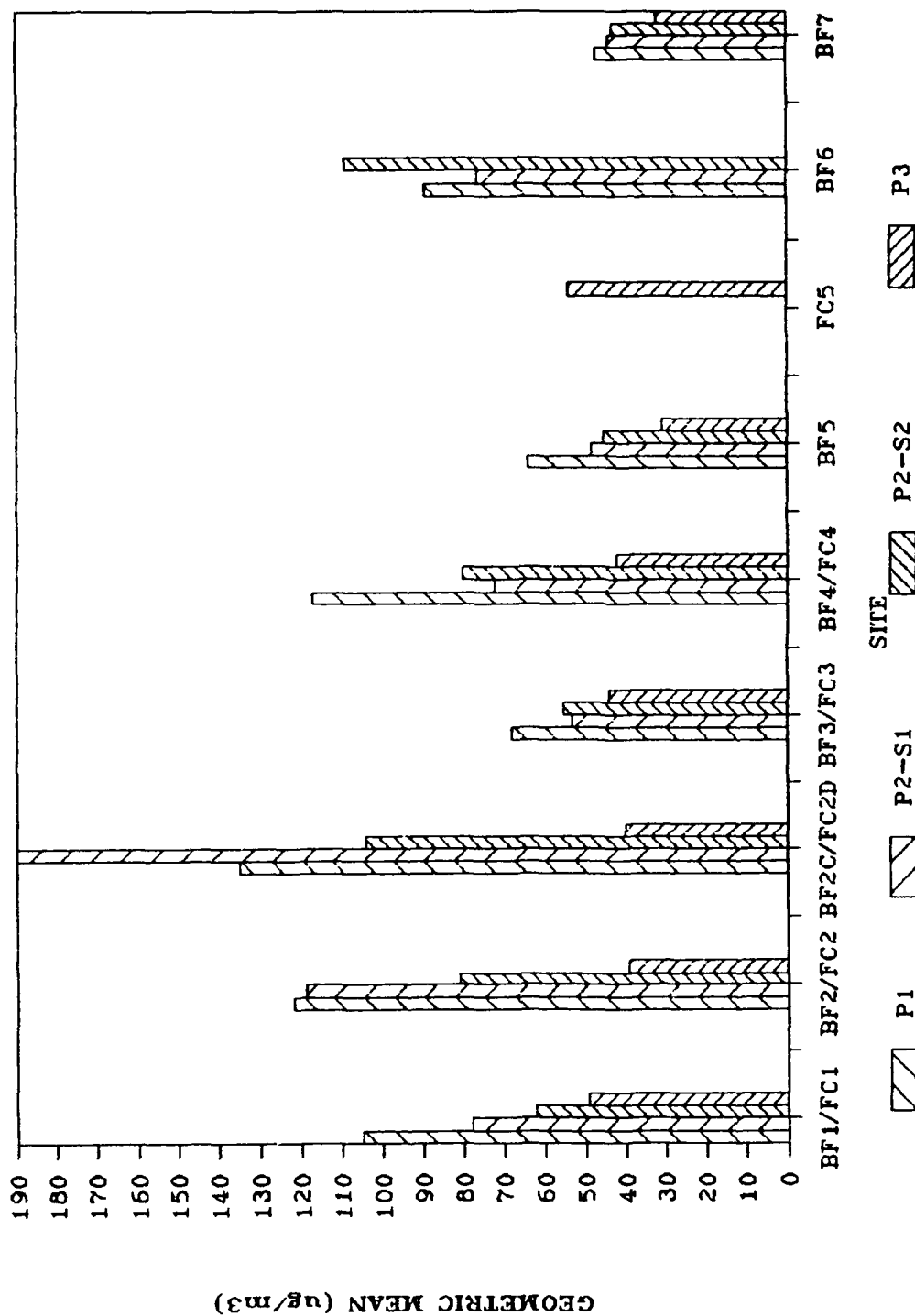


Figure 4.2-4

Basin F IRAF

TSP Results by Phase

Prepared for:

U.S. Army Program Manager for

Rocky Mountain Arsenal

Commerce City, Colorado

Prepared by:

R.L. Stollar & Associates, Inc.

Ebasco Services, Inc.

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$\mu\text{g}/\text{m}^3$ during Phase 1, $119 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 1, $81 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 2, and then dropped to $39 \mu\text{g}/\text{m}^3$ during the Phase 3 post-remedial period. Maximum 24-hour concentrations of $902 \mu\text{g}/\text{m}^3$ during Phase 1, $687 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 1, and $514 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 2, were measured at this site on days when extensive remedial activity was proceeding adjacent to the monitoring station. The collocated station BF2C/FC2D showed similar results.

Station BF3/FC3, at the southern perimeter of Basin F measured geometric mean TSP concentrations of 68, 53, 55 and $44 \mu\text{g}/\text{m}^3$, respectively during Phase 1, Phase 2 Stage 1, Phase 2 Stage 2, and Phase 3. A maximum concentration of $286 \mu\text{g}/\text{m}^3$ was measured during the Phase 1 period. The significant decrease in TSP concentrations along the southern perimeter can be attributed, to some extent, to the slightly greater distance from remedial and dirt moving activities. However, the primary explanation is the prevailing wind pattern experienced over the RMA area and the resultant pollutant dispersion pattern. The dispersion and meteorological influences are best illustrated in Figure 4.1-1, previously shown, which indicates the atmospheric dispersion pattern that corresponds to the Phase 1 monitoring period. The relationship between TSP levels, dispersion factors and remedial causal factors will be discussed in further detail in the next section for each phase of the remedial program. It is apparent from the dispersion pattern that the distribution of high TSP concentrations from the Basin F source is skewed to the north of the remedial activity. As noted, BF3/FC3 along the southern perimeter measured lesser TSP levels than the stations along the northern perimeter. This was also true of other potential contaminants such as metals, VOCs and SVOCs that may have been emitted from Basin F (these will be discussed in subsequent sections).

Station BF4/FC4, along the northwest perimeter of Basin F, measured TSP levels equivalent to BF1/FC1 with the geometric mean value of $117 \mu\text{g}/\text{m}^3$ in Phase 1 decreasing to $42 \mu\text{g}/\text{m}^3$ during the Phase 3 post-remedial period. A maximum 24-hour TSP concentration of $324 \mu\text{g}/\text{m}^3$ was measured during the Phase 1 remediation period.

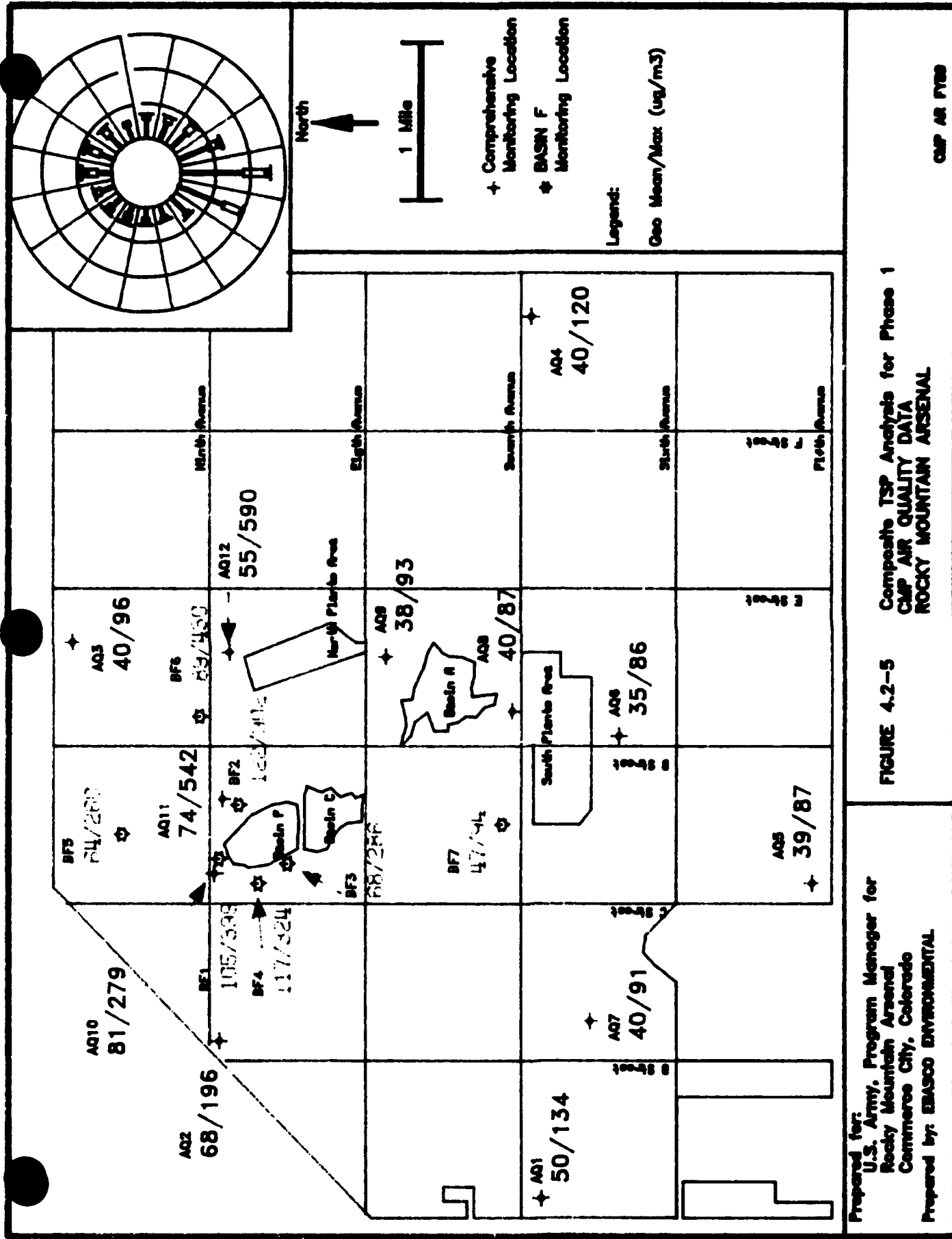
Station BF5, about one mile north of the Basin F compound, indicated substantially lower TSP values than those from the four sites previously discussed for all phases and stages of the remedial program. Station BF5 was not only a greater distance from the source activity but was also slightly outside the prevailing dispersion pattern. Some influence from Basin F, nevertheless was apparent. The geometric mean TSP levels decreased from $64 \mu\text{g}/\text{m}^3$ during Phase 1 to $48 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 1, to $45 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 2, to $31 \mu\text{g}/\text{m}^3$ during a two-month monitoring period in Phase 3.

BF6 was located approximately 3500 ft northeast of the Basin F source but was directly downstream from the prevailing wind flow. Concentrations remained moderate throughout the remediation program, especially during the Phase 2, Stage 2, period where a geometric mean concentration of $109 \mu\text{g}/\text{m}^3$ was measured and a maximum 24-hour concentration of $493 \mu\text{g}/\text{m}^3$ was observed. This can be attributed to the stations proximity to hauling traffic associated with the final cleanup activities. Sampling at BF6 was terminated at the conclusion of the remediation program and there are no Phase 3 data. During the last 4 months of Phase 3, BF6 was moved closer to Basin F at the liquid storage pond (Pond A) and redesignated FC5. The TSP geometric mean concentration during this period was $54 \mu\text{g}/\text{m}^3$.

In contrast, BF7 approximately 1 1/2 miles south of Basin F, and upstream from the source in the direction of the prevailing flow, reflected minimal impacts from Basin F activities. Geometric mean concentrations decreased from $47 \mu\text{g}/\text{m}^3$ in Phase 1, to $44 \mu\text{g}/\text{m}^3$ in Phase 2, Stage 1, to $43 \mu\text{g}/\text{m}^3$ in Phase 2, Stage 2, to $32 \mu\text{g}/\text{m}^3$ during the post-remedial phase. These values were, in fact, equivalent to other RMA interior monitoring stations reflecting some minimal influence from Basin F, but primarily other local as well as seasonal effects.

In summary, the conclusions of the Basin F TSP monitoring program are that the highest concentrations were confined to the immediate vicinity of the remedial activity and directly downstream from this activity as reflected by the atmospheric dispersion patterns. At the conclusion of the remediation activity, TSP levels at all monitoring stations were close to typical interior RMA baseline values.

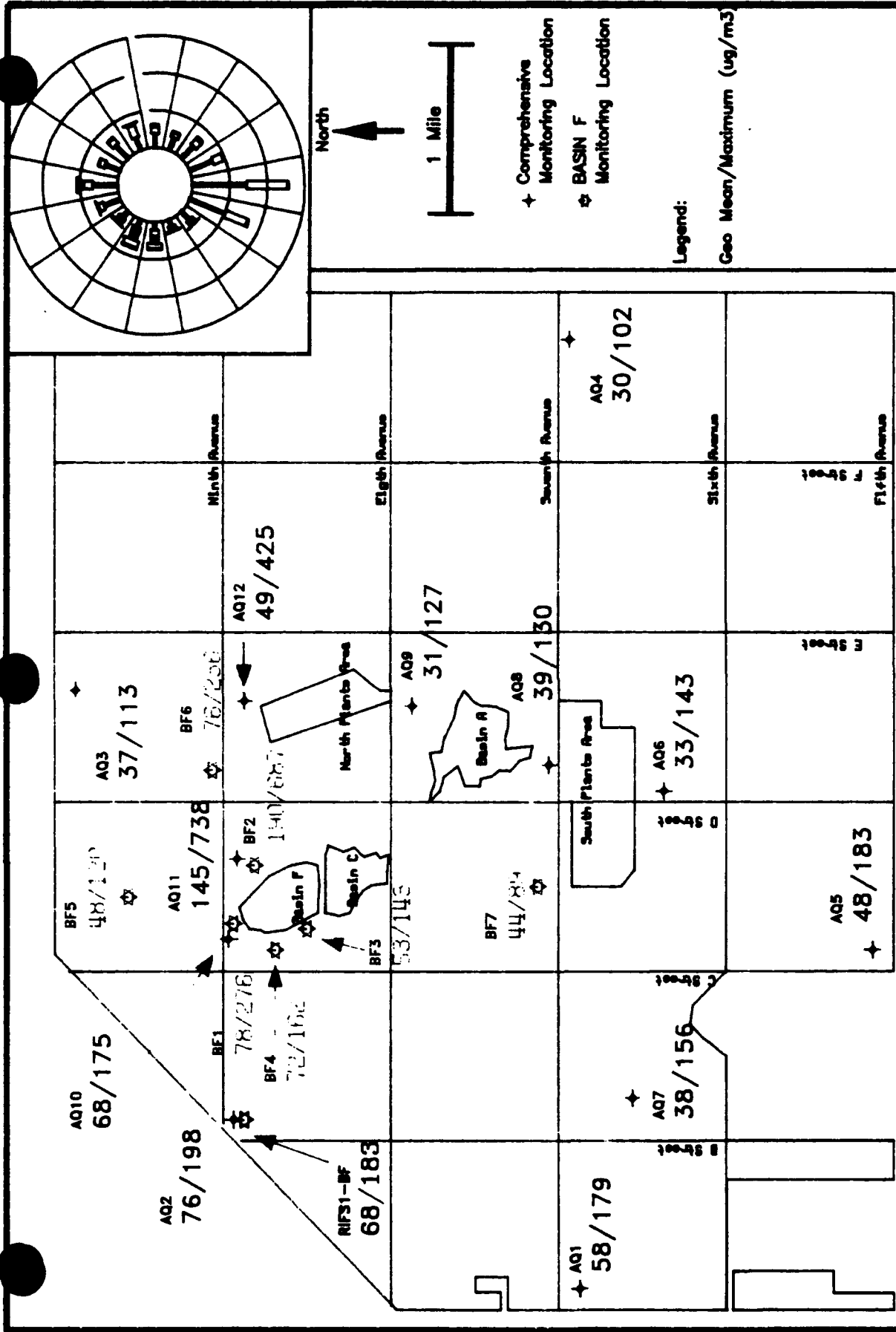
4.2.2.3 Analysis of Combined CMP/Basin F TSP Monitoring Results. Figures 4.2-5, 4.2-6, 4.2-7 and 4.2-8, which combine CMP and Basin F data for each phase of the remedial activity, provide a comprehensive depiction of TSP levels across RMA during the total 19-month monitoring period and reinforce conclusions obtained from analysis of the individual monitoring data. During Phases 1 and 2, the principal TSP impact was in close proximity to Basin F remedial activity and downstream from the prevailing wind flow. BF2, at the northeast corner of Basin F and adjacent to much of the remedial activity, recorded the highest geometric mean value of $135 \mu\text{g}/\text{m}^3$ and the highest average value of $173 \mu\text{g}/\text{m}^3$ during the Phase 1 remedial period. On certain occasions, during periods of intense remediation activity and dirt hauling, 24-hour TSP levels reached as high as $600 \mu\text{g}/\text{m}^3$ to above $900 \mu\text{g}/\text{m}^3$ adjacent to the activity. (A maximum level of $902 \mu\text{g}/\text{m}^3$ was recorded at BF2 during Phase 1.) These high levels, however, were localized; TSP monitoring sites at distances of one mile or more from Basin F and at the RMA perimeters reflected little or no impact from the operations. During Phase 1, interior RMA CMP sites showed average and geometric mean values from $35 \mu\text{g}/\text{m}^3$ to $40 \mu\text{g}/\text{m}^3$ and maximum values from $86 \mu\text{g}/\text{m}^3$ to 97



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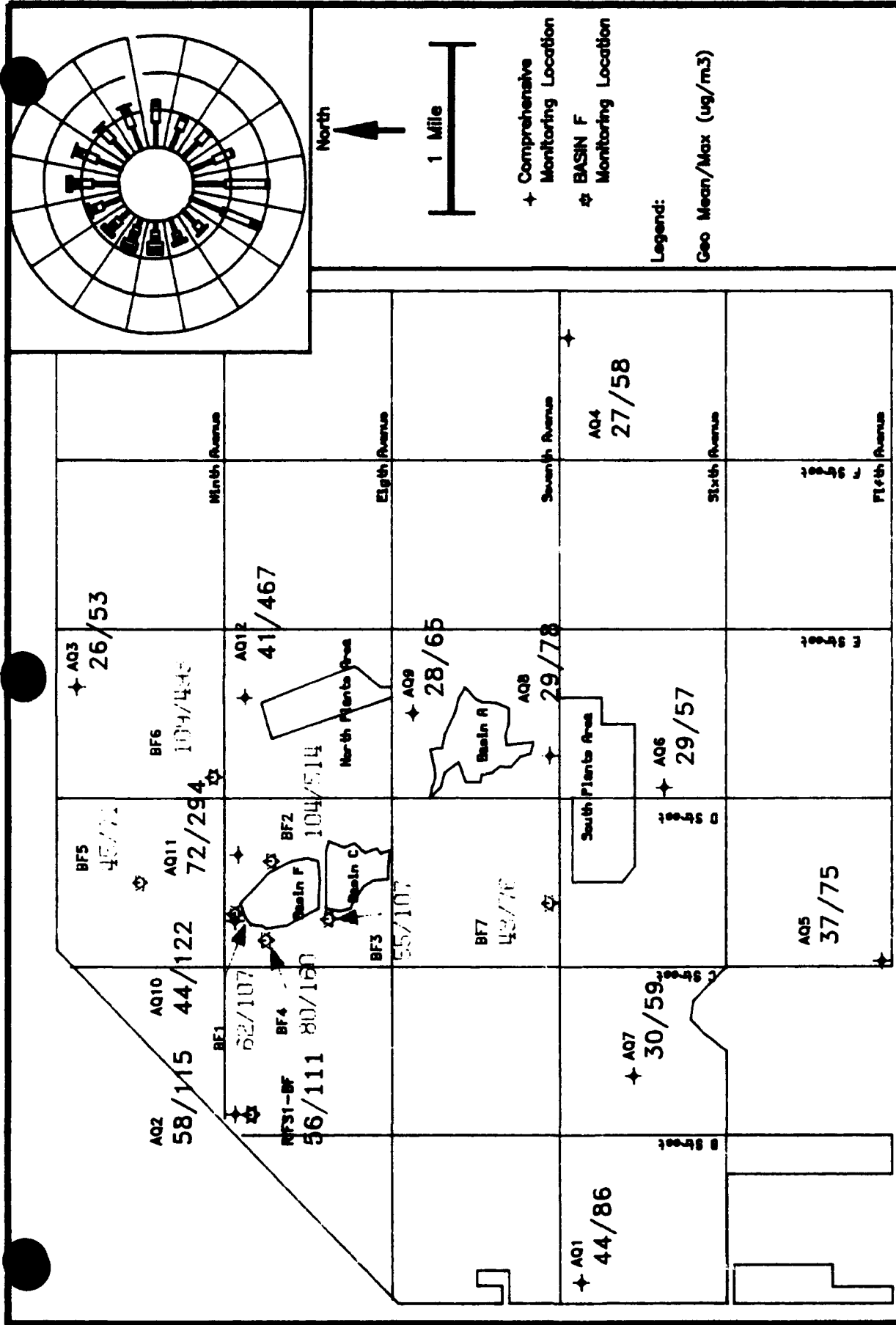
FIGURE 4.2-5 Composite TSP Analysis for Phase 1
 CAMP AIR QUALITY DATA
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CAMP AIR FY88



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FIGURE 4.2-6 Composite TSP Analysis for Phase 2 - Stage 1
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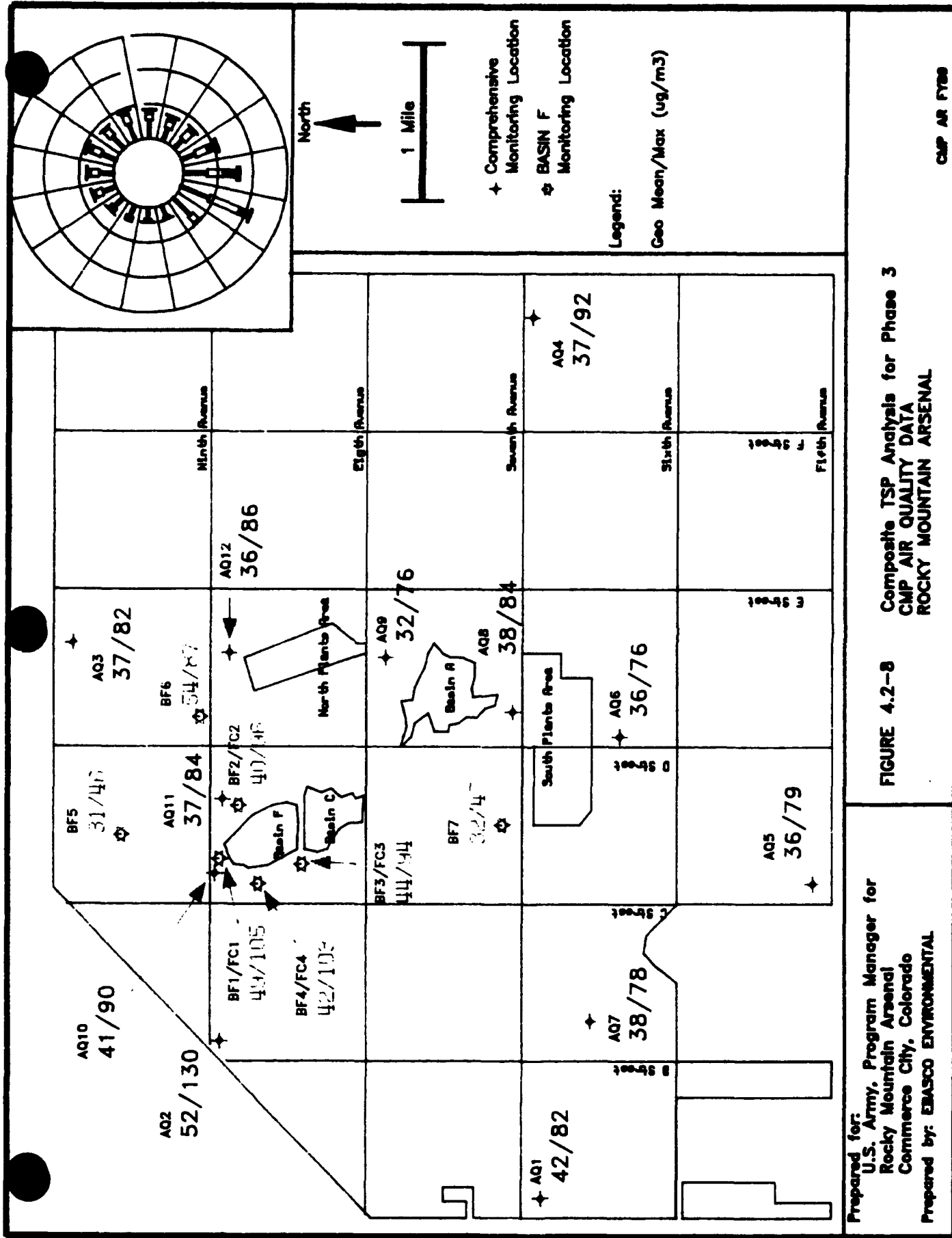


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FIGURE 4.2-7

Composite TSP Analysis for Phase 2 - Stage 2
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**FIGURE 4.2-8 Composite TSP Analysis for Phase 3
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 ROCKY MOUNTAIN ARSENAL**

CMP AIR FY88

$\mu\text{g}/\text{m}^3$. In fact, several of these stations were primarily influenced by other local and regional factors. This was especially true of CMP stations AQ1 and AQ2 along the eastern and northeastern boundaries of RMA, which are the closest sites to metropolitan Denver. Prior to the Basin F remediation effort, these two stations measured the highest TSP levels of the 12 RMA monitoring sites (RI Monitoring Program, ESE, 1988). During Basin F remediation activity, TSP levels were significantly higher at the Basin F sites; however, during the post-remedial period AQ1 and AQ2 again measured the highest TSP levels across the RMA complex. Figure 4.2-9 shows a bar graph distribution of TSP geometric mean values at the 12 CMP monitoring sites. Note that AQ10 and AQ11, immediately downstream from Basin F, and AQ12 adjacent to Borrow Pit dirt moving activities, show high TSP levels during the Phase 1 and Phase 2 remediation periods and then decrease significantly during the Phase 3, post-remedial period. Other RMA internal locations show little variation in geometric means throughout the 19-month remedial monitoring program. However, AQ1 and AQ2 at the western boundaries closest to metropolitan Denver, maintained moderately high TSP levels for all phases of the program. Peak values occurred at these sites during the winter Phase 2 (Stage 1) period and somewhat lesser values were measured during the summer Phase 3 period.

During the Phase 3 remedial period, the data reflected a significant decrease in Basin F concentrations that were more comparable to other RMA monitoring sites (and regional background levels). Note that the prevailing winds and dispersion patterns (as shown in Figures 4.1-1 through 4.1-4) were essentially the same as the early phases, and the conclusion must be that Basin F became a minor source of blowing dust. During Phase 3, AQ2 at the northwestern boundary of RMA reflected the highest mean and maximum values of the 19 TSP monitoring sites; this result is consistent with the pre-remedial monitoring results of the RI program (ESE, 1988).

4.2.2.4 Individual Day Remedial Assessment Comparisons. It is important to note that individual daily impacts varied substantially, depending upon the specific meteorological conditions and the specific remediation activity. Figure 4.2-10, for example, shows a Phase 1 day (September 24, 1988) when light to moderate winds were blowing across Basin F from the south and southwest for several hours in the direction of the AQ11 monitor at the northeast corner of the Basin F perimeter. Most other wind directions throughout the day were variable. The wind rose (in the top right corner of the figure) indicates the frequency of occurrence of wind speed and wind direction. Station AQ11 reported a TSP level of $389 \mu\text{g}/\text{m}^3$ for this 24-hour period; station AQ12, also downwind from Borrow Pit activity, reported $64 \mu\text{g}/\text{m}^3$. All other stations reported relatively low TSP values. AQ10, close to Basin F but not directly downwind from the apparent source, measured $55 \mu\text{g}/\text{m}^3$. AQ3, farther downwind, reported $35 \mu\text{g}/\text{m}^3$, indicating that the high TSP values were primarily a function of *local remediation activity* that fell off quickly with distance

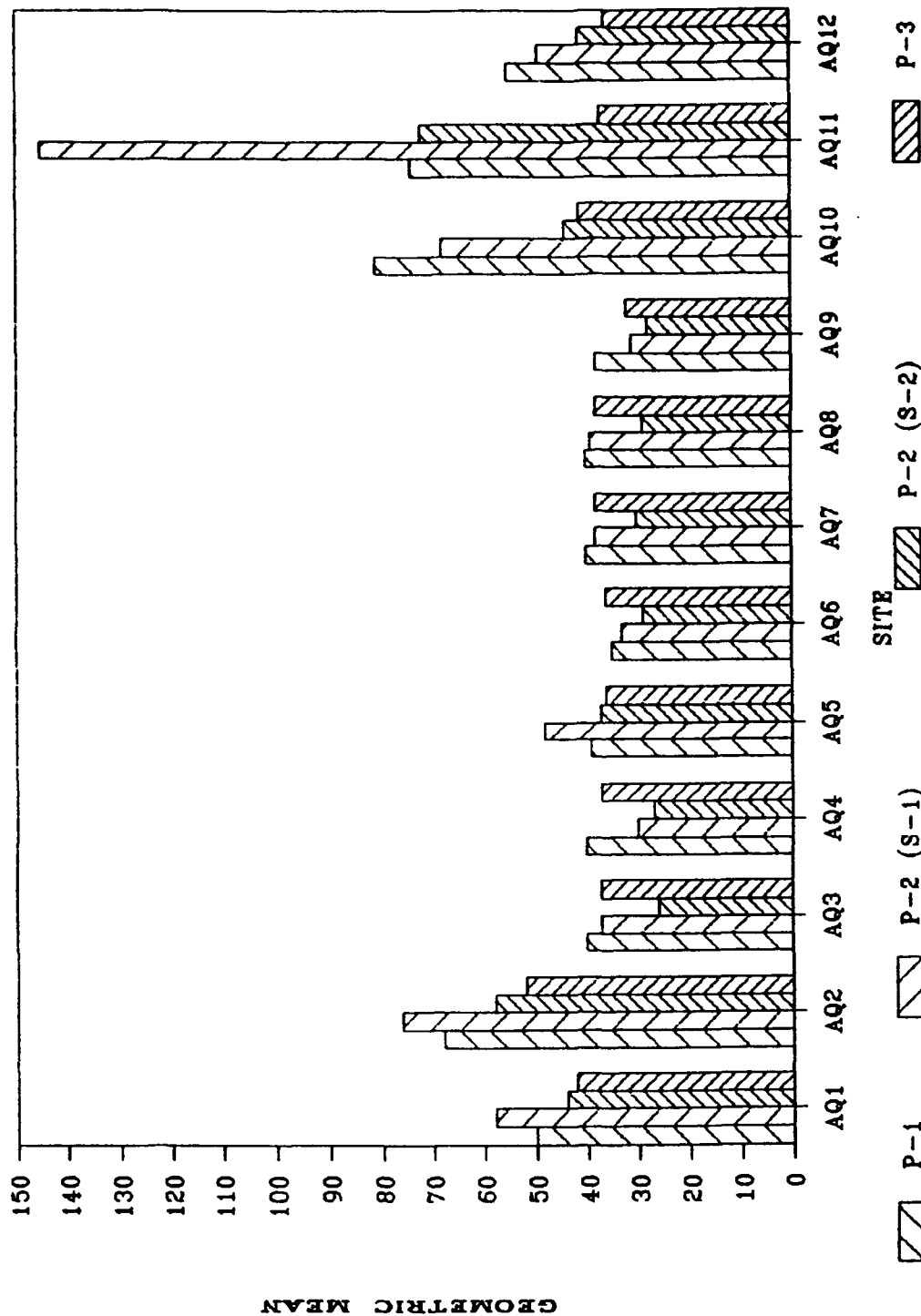


Figure 4.2-9

TSP Geometric Means
by Phase for CMP

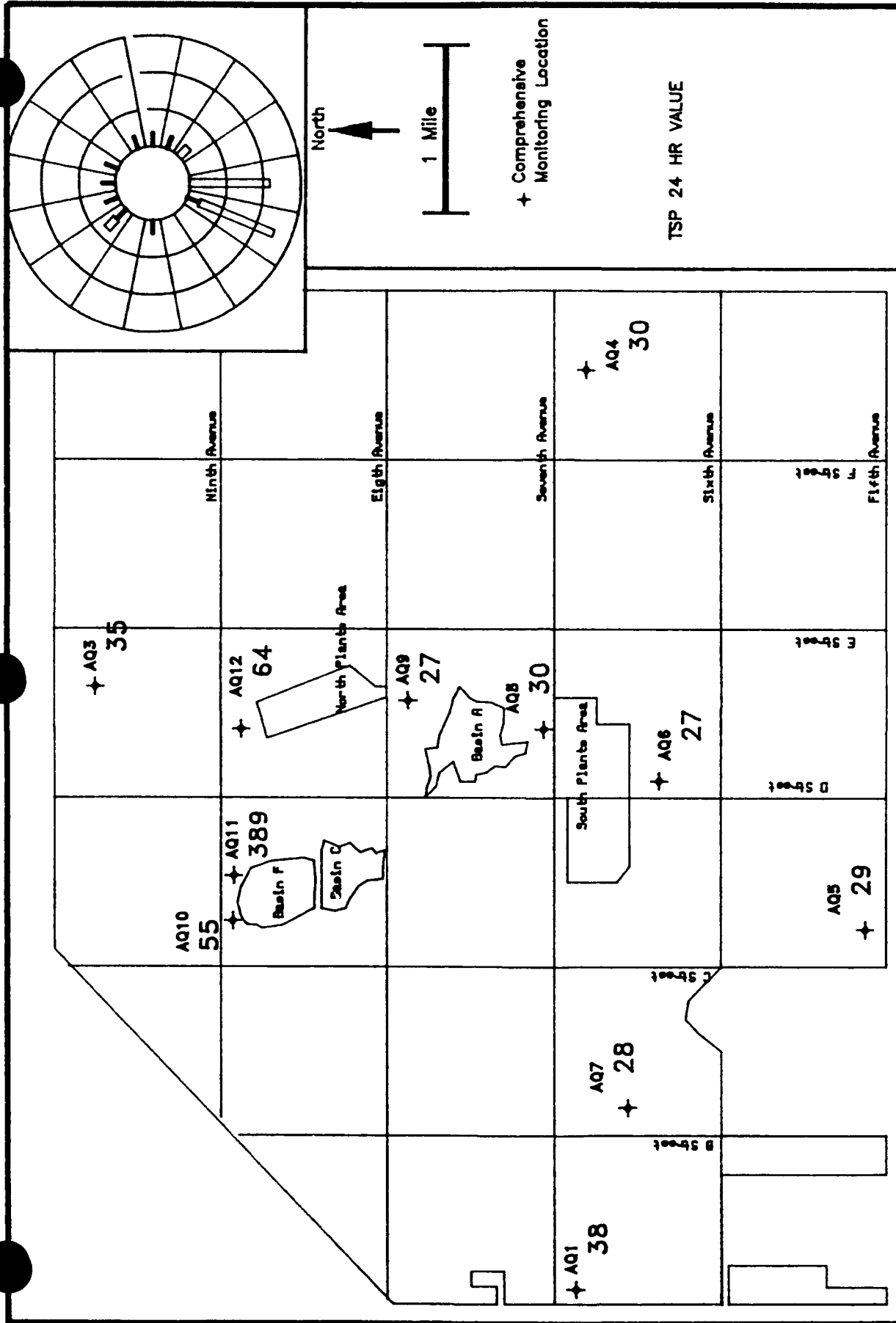
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FIGURE 4.2-10 TSP RESULTS FOR 9/24/88 (ug/m3)
 CMP AIR QUALITY MONITORING PROGRAM
 ROCKY MOUNTAIN ARSENAL

CMP AR FY89

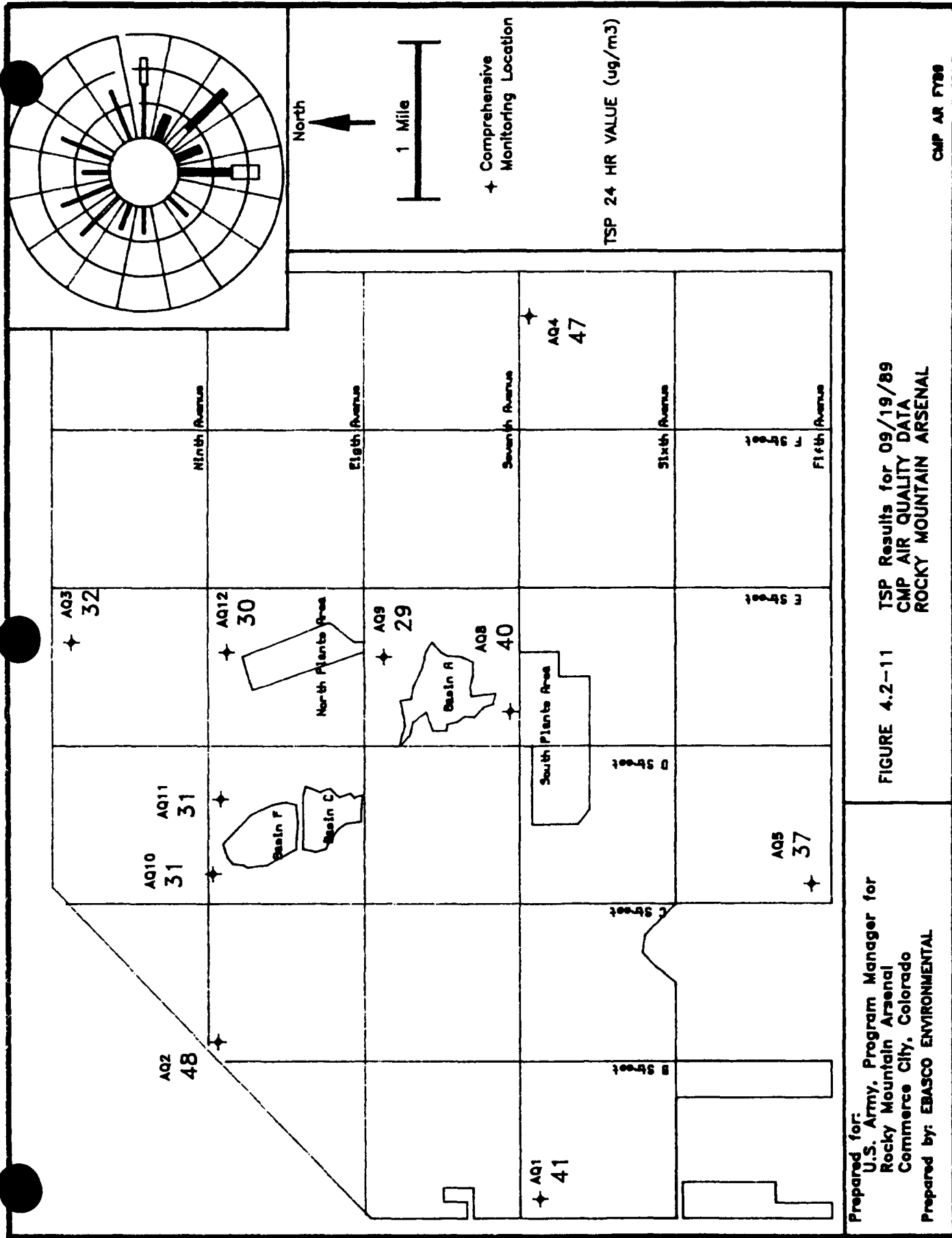
from the source. All stations upwind from Basin F measured considerably lower values. During a Phase 3 day on September 19, 1989, again with prevailing southerly wind conditions, all TSP values across RMA were at low levels including the previous impacted Basin F sites that became the lowest at the Arsenal (see Figure 4.2-11). The wind rose shown on this figure suggests modest potential impacts from a Basin F source; however, this was not reflected on this post-remedial day.

On another Phase 1 day, June 8, 1988, when stations AQ11 and AQ12 again reported high TSP levels of $166 \mu\text{g}/\text{m}^3$ and $238 \mu\text{g}/\text{m}^3$, respectively, TSP values were generally higher across the Arsenal as well as throughout metropolitan Denver (see Figure 4.2-12). The major difference in this event was that strong winds persisted for several hours, with speeds in excess of 20 mph and peak gusts in excess of 25 mph. On a Phase 3 day, June 21, 1989, when prevailing winds were again strong with peak gusts from the northwest in excess of 25 mph, TSP concentrations, as expected were generally moderate to high across RMA (similar to the June 8, 1988 event); however, concentrations at CMP stations AQ11 and AQ12 were comparable to the other RMA sites, reflecting the effectiveness of the post-remedial mitigation actions (see Figure 4.2-13).

4.2.3 Special TSP Causal Effects

The impacts of metropolitan Denver on Arsenal TSP levels will be discussed further in Section 4.2.4. Several studies were also conducted during CMP FY88 and FY89 relating the impacts of wind gusts and source locations to TSP concentrations measured at the various monitoring locations. This section provides a brief update on the status of these investigations.

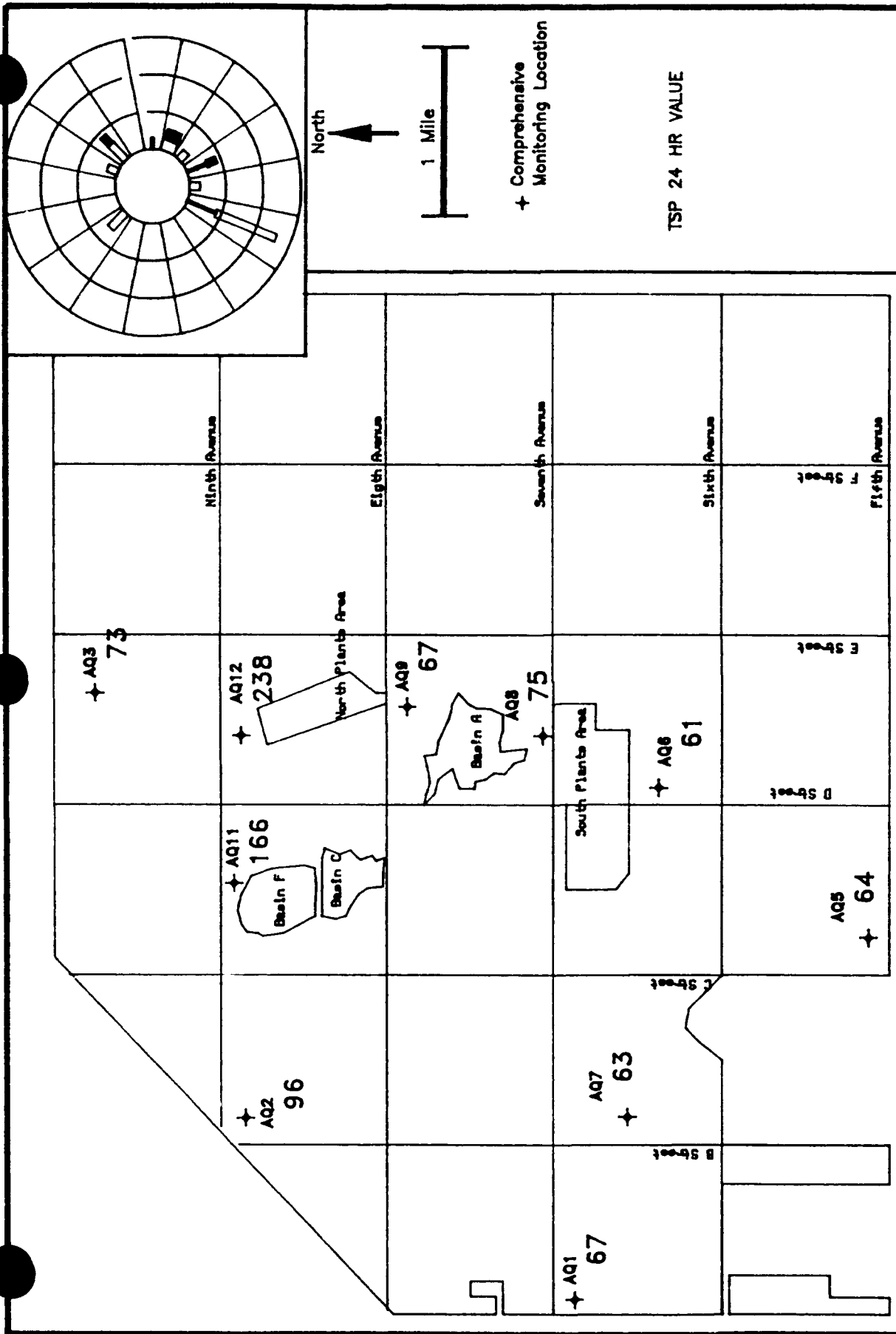
4.2.3.1 Wind Speed Effects. In the CMP FY88 study examining all monitoring days in which 24-hour TSP levels were in excess of $75 \mu\text{g}/\text{m}^3$ at one or more monitoring stations, it was apparent that high TSP levels at RMA resulted from a combination of localized remedial activity *and* moderate-to-strong wind gusts. This condition continued through the Phase 1 and Phase 2 periods; however, during the post-remedial Phase 3 period, local RMA remedial activity no longer posed a significant source of high TSP levels. Although strong and gusty winds were the principal cause of high TSP levels, one important exception should be noted. This was the frequent occurrence of moderate to high TSP levels at the western boundary, at stations AQ1 and AQ2, when wind speeds were not high. An explanation for this pattern is that the Denver metropolitan area provided a significant source of airborne particulates during the winter inversion periods (that were not monitored during the CMP FY88 period). Principal impacts of RMA were at those monitoring stations in close proximity to Quebec Street and Highway 2. Furthermore, on several days during the winter of FY89, very high TSP levels were measured across RMA under relatively low wind speed conditions. On each of these days downtown Denver experienced especially high TSP (and



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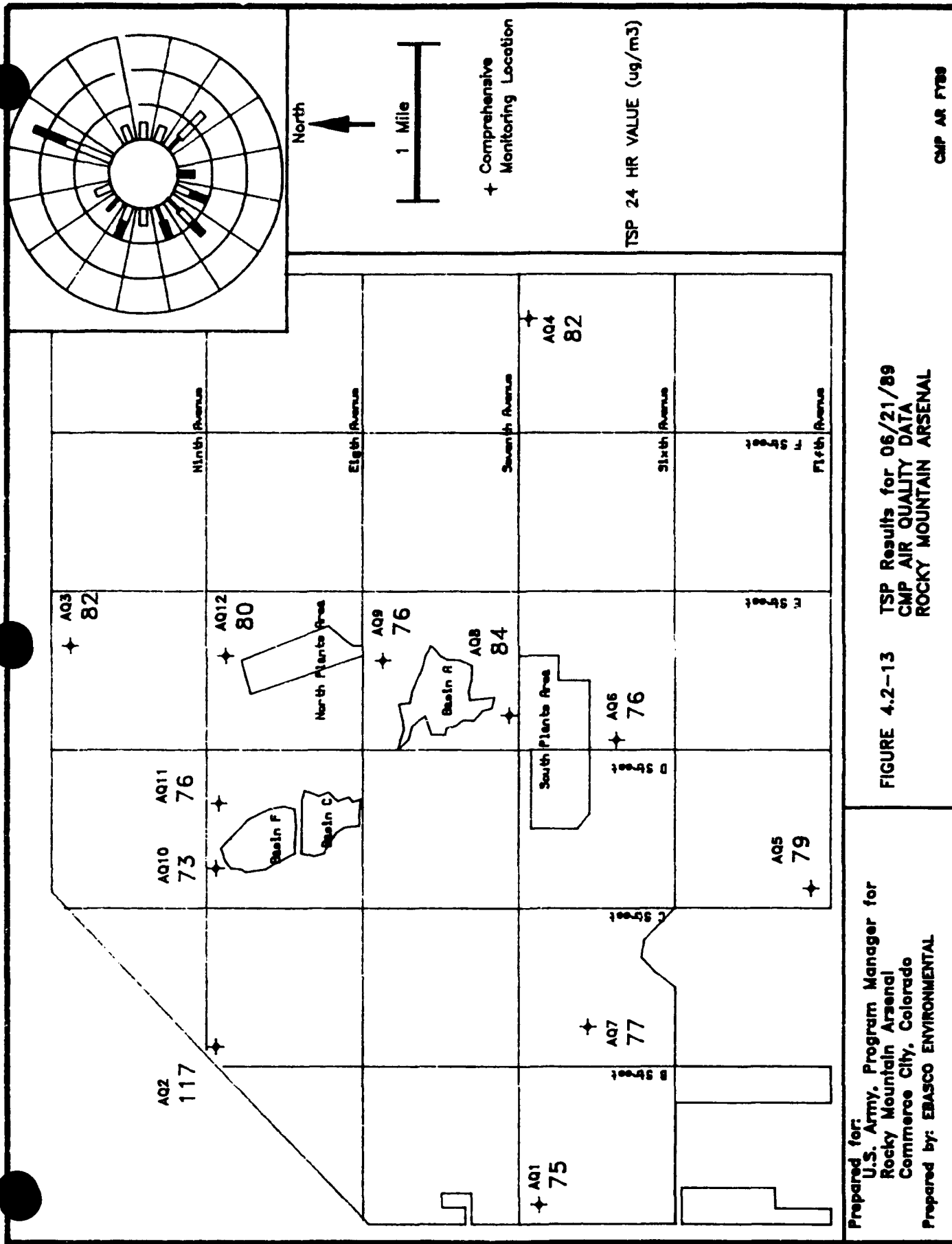
FIGURE 4.2-11 TSP Results for 09/19/89
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

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FIGURE 4.2-12 TSP RESULTS FOR 6/08/88 (ug/m3)
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FIGURE 4.2-13 TSP Results for 06/21/89
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

PM-10) levels and prevailing winds were from the south. These high TSP levels apparently resulted in metropolitan area impacts reaching the Arsenal area. These episodes are discussed in more detail in Section 4.2.4.1.

4.2.3.2 Wind Direction Effects. In addition to wind speed, there are other factors contributing to higher TSP levels. Previously shown atmospheric dispersion patterns show the relationship of meteorological conditions and the distribution of average TSP levels across RMA during the Phase 1, Phase 2 and Phase 3 remedial periods. It is evident that wind direction and distance from a potential source were major contributing factors to higher TSP concentrations at various stations, especially north of Basin F during the remediation phases. Figure 4.2-14 is a plot which shows the relationship of TSP levels versus hours that winds were blowing from Basin F in the direction of station AQ11 ($\pm 30^\circ$) during Phase 1. There is an apparent correlation between TSP levels and hours of downwind flow, as indicated by the solid line. The correlation coefficient is 0.39.

Figure 4.2-15 is a plot of similar data during the Phase 3 period and shows a much broader scatter (correlation coefficient -0.03) indicating that Basin F was no longer a significant source impacting AQ11 just to the north of the remedial activity. There remain a number of cases with moderate to high wind speeds and low TSP values, as well as some cases with relatively low wind speeds and high TSP values that might be explained by different combinations of wind speed, maximum gusts, and soil conditions.

4.2.3.3 Source Factors. In addition to strong winds, high TSP concentrations at AQ11 and other RMA sites can be attributed to other factors, including the influx of emissions from other sources (i.e., other RMA source areas and ground disturbance activities), the exposure of loose soil caused by local mitigation measures, general atmospheric dispersion conditions, or past and recent precipitation. For example, very recent ground excavations as in the case of Basin F are likely to result in higher TSP levels directly downstream from this activity. However, subsequent heavy precipitation or the use of dust suppressants, or compaction of the excavation area would significantly reduce impacts. In spite of this variability, it was possible to identify several distinct sources contributing to TSP levels across the CMP monitoring network during the FY88 - FY89 period. These include:

- During the remediation, Phase 1 period, Basin F was a major TSP contributing source at monitoring stations AQ3, AQ10, AQ11 and AQ12, with greatest impacts close to the Basin F perimeter. After remediation, Basin F was no longer a significant contributor of TSP in the RMA area;

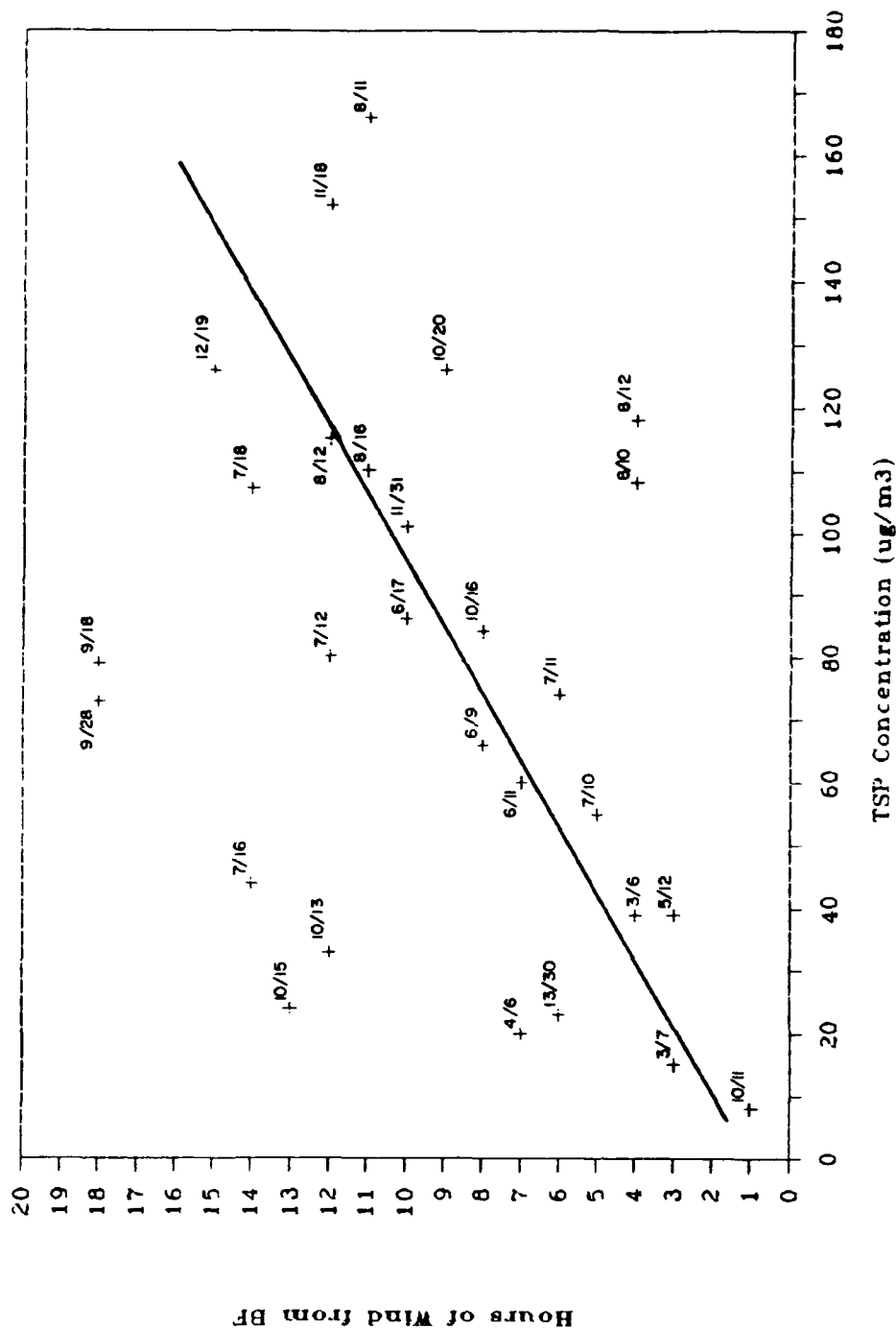
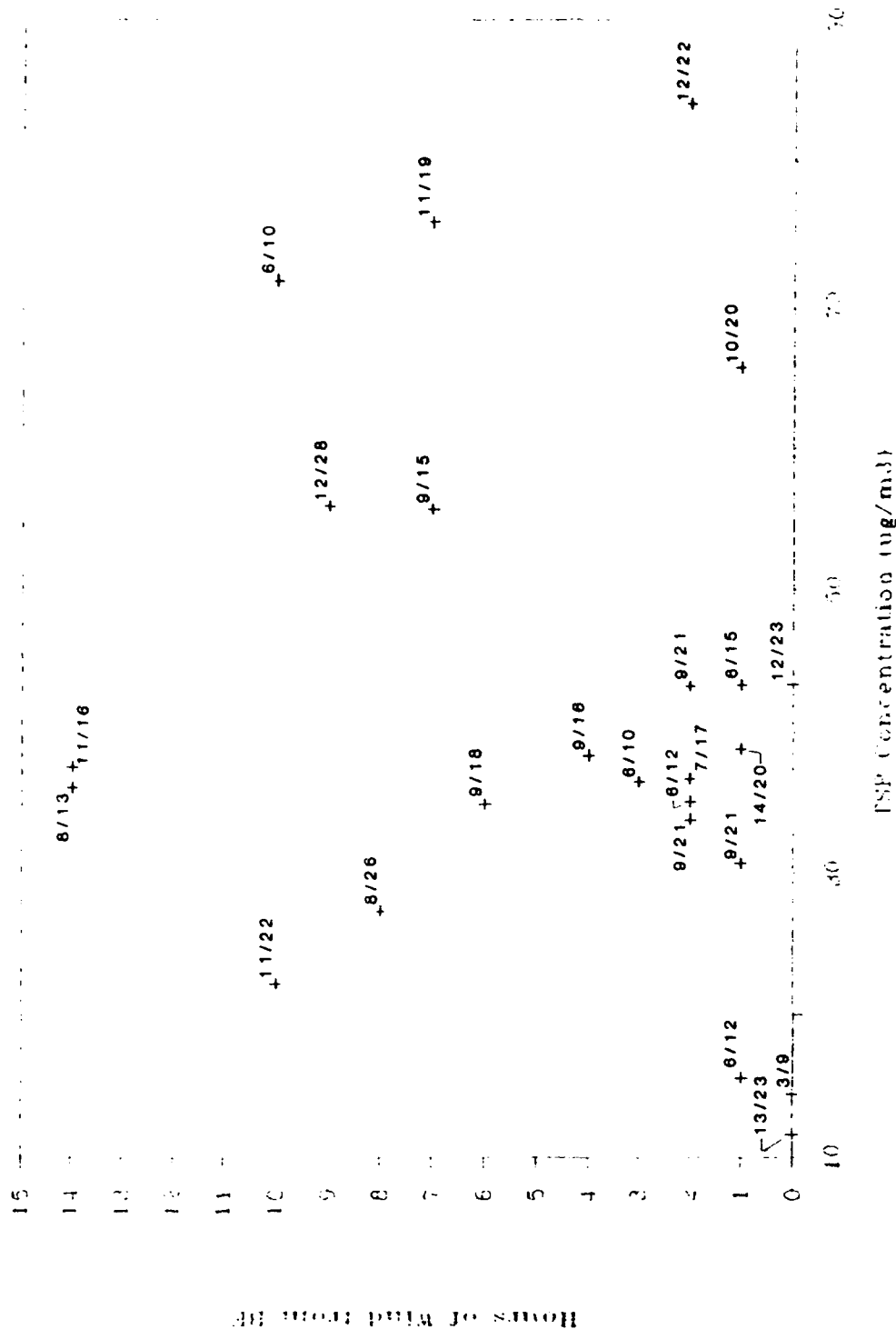


Figure 4.2-14
 Site AQ 11 TSP
 Concentrations vs. Hours
 of Wind Speed from
 Direction of Basin F
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Figure 4.2-15

Site AQ11 TSP
Concentrations vs. Hours
of Wind Speed from
Direction of Basin F -
Phase 3

CMPAR FY89

- During Phase I the Borrow Pit was an additional contributing TSP source for station AQ12 when hauling operations were in progress. After remediation, the Borrow Pit was no longer a significant source of blowing dust;
- Basin A was a potential contributing source, depending upon the status of mitigating activities and wind direction. However, during the FY88 and FY89 Program, AQ8 and AQ9, located upwind and downwind from Basin A, measured very modest increases in TSP concentrations with strong wind and gust scenarios. A likely explanation is the placement of dust suppressants over Basin A in mid-March of 1988 and continuing into the summer season. The generally low TSP concentrations measured at Basin A indicate the effectiveness of the mitigation program.
- The Denver metropolitan area may be considered a major contributing source for the perimeter sites, especially stations AQ1 and AQ2. Station AQ2 at the western boundary of RMA measured a moderately high TSP average of $70 \mu\text{g}/\text{m}^3$ for the FY89 monitoring period. This was the highest level of all CMP monitoring stations with the exception of AQ11 directly adjacent and downwind from the Basin F remediation work. This suggests that suspended particulate matter drifts into the Arsenal from metropolitan Denver traffic and industrial activity. Also, on several days with intense ground inversion conditions, Denver "brown cloud" impacts were experienced across the Arsenal. This will be discussed in the next section.

4.2.4 Denver Metropolitan Area TSP Influences.

4.2.4.1 CMP FY89 Period Results. It is evident from these assessments that RMA activities were not the only TSP sources that influenced the Arsenal and its adjacent boundary areas. As previously noted, the 1986-1987 Remedial Investigation study clearly established that prior to remediation, TSP values were highest at the perimeter stations and lowest in the interior of the Arsenal, suggesting that the principal long-term major sources in the area were the industrial or transportation activities of metropolitan Denver. The Basin F Remediation Program temporarily altered this situation at several sites in the interior of RMA; however, Denver was still a major contributor. Station AQ2 was in a unique location during the FY88 - FY89 programs because it experienced impacts both from the Basin F Remediation Program and from the metropolitan Denver area.

Table 4.2-5 is a summary of Denver metropolitan area TSP data measured concurrently with the FY89 program as well as with the Basin F remediation phases. Figure 4.2-16 shows the geographic

Table 4.2-5 Denver Metropolitan Area Total Suspended Particulates (TSP)
(in $\mu\text{g}/\text{m}^3$)

Geometric Means

STATION	Phase 1	Phase 2-1	Phase 2-2	Phase 3	FY89
Adams City	87.7	103.0	81.7	71.0	77.6
414 14th Street	83.7	137.4	-	-	95.0 *
CAMP/2105 Broadway	107.9	192.2	132.2	98.9	121.6
1050 S. Broadway	74.1	135.2	93.7	63.4	82.5
208 3rd Street	62.9	62.7	57.0	96.2	71.0
4857 S. Broadway	64.4	84.9	-	-	67.8 *

Maximum Values

STATION	Phase 1	Phase 2-1	Phase 2-2	Phase 3	FY89
Adams City	283.0	244.0	85.0	131.0	244.0
414 14th Street	242.0	183.0	-	-	183.0
CAMP/2105 Broadway	260.0	472.0	256.0	149.0	472.0
1050 S. Broadway	162.0	278.0	162.0	100.0	278.0
208 3rd Street	153.0	179.0	144.0	385.0	385.0
4857 S. Broadway	152.0	94.0	-	-	94.0

* The last sampling day at this station was December 27, 1988.

Annual geometric mean standard is $75 \mu\text{g}/\text{m}^3$.

Second-maximum 24-hour standard is $150 \mu\text{g}/\text{m}^3$.

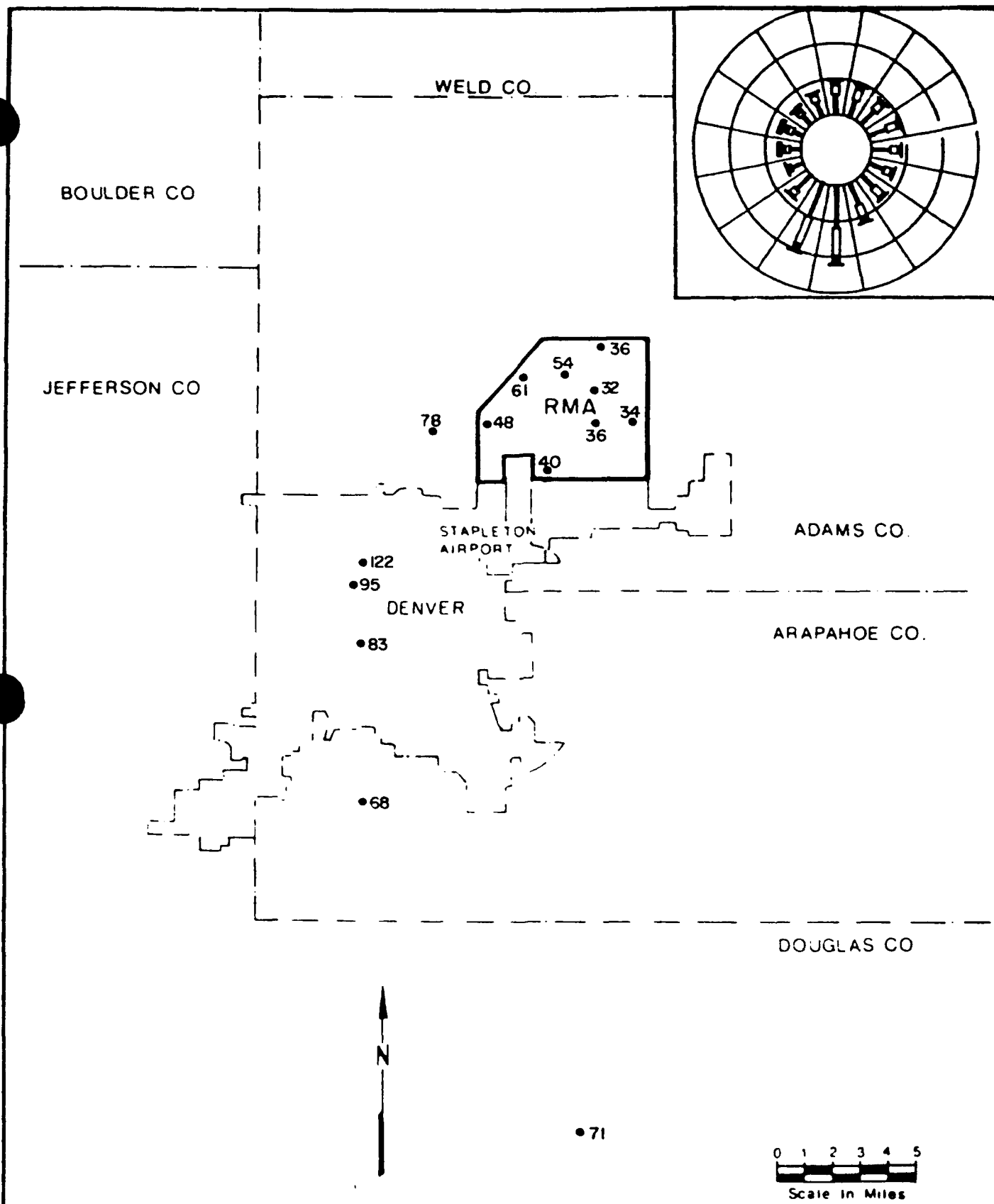
Phase 1 is from March 22 to December 12, 1988.

Phase 2, Stage 1 is from December 13, 1988 to February 15, 1989.

Phase 2, Stage 2 is from February 16 to May 5, 1989.

Phase 3 is from May 6 to September 30, 1989.

FY89 is the period from October 1, 1988 through September 30, 1989.



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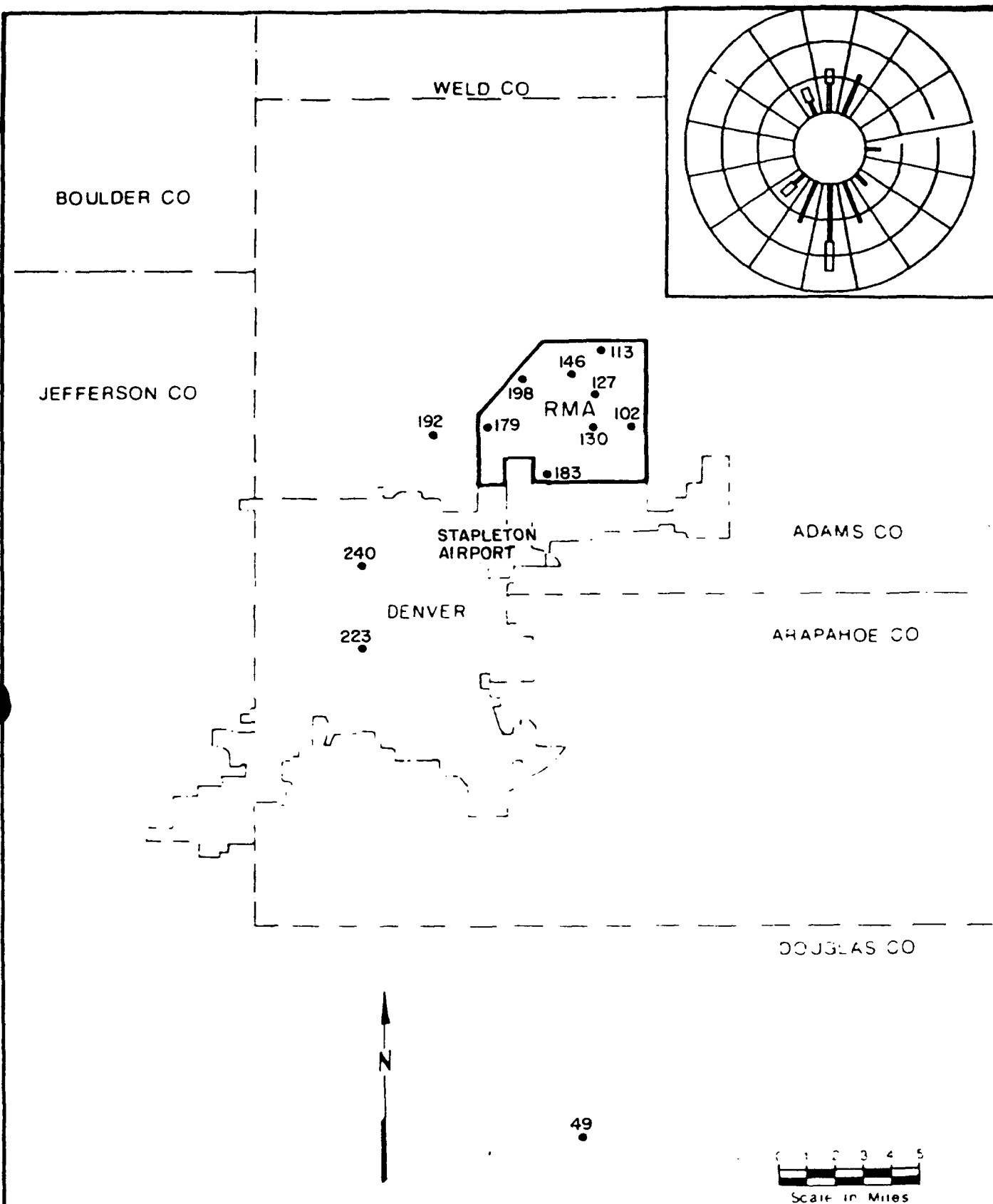
Figure 16
 Denver TSP Data for FY89
 Geometric Means ($\mu\text{g}/\text{m}^3$)
 CMP AR FY 89

distribution of TSP geometric mean levels across the metropolitan area, including RMA for FY89. As noted, the highest levels were in the downtown area at CAMP (2105 Broadway), where TSP concentrations have exceeded the ambient air quality primary and secondary standards for the past 15 years or more. During 1987, the annual geometric mean TSP concentration at the CAMP site was $119 \mu\text{g}/\text{m}^3$; during 1988, the annual mean was $123 \mu\text{g}/\text{m}^3$; and during a nine-month period in 1989 corresponding to the FY89 CMP period, the geometric mean was $122 \mu\text{g}/\text{m}^3$. These values all exceeded the secondary annual geometric mean standard of $60 \mu\text{g}/\text{m}^3$. During 1989, maximum 24-hour TSP concentrations in downtown Denver also frequently exceeded the 24-hour standard of $150 \mu\text{g}/\text{m}^3$. A maximum level of $472 \mu\text{g}/\text{m}^3$ was recorded at CAMP on January 4, 1989. A second maximum of $386 \mu\text{g}/\text{m}^3$ was recorded on February 15, 1989.

Other Denver TSP monitoring stations also exceeded the 24-hour and annual standards. Figure 4.2-16 shows a north-south distribution of relatively high TSP levels, centered over downtown Denver and extending close to the RMA boundaries. On several occasions, under intense inversion conditions, high TSP levels also engulfed the Arsenal. Figure 4.2-17, for example depicts a day, February 9, 1989, when all RMA monitoring sites were in excess of $100 \mu\text{g}/\text{m}^3$. The winds were relatively light, averaging 6 mph, and the prevailing wind was from the south. Maximum TSP concentrations on this day were $240 \mu\text{g}/\text{m}^3$ at CAMP and $223 \mu\text{g}/\text{m}^3$ at 1050 S. Broadway in Denver. The wind rose pattern shown in Figure 4.2-17 reflects the spread of pollutants from south to north across the Arsenal area. Figure 4.2-18 depicts a similar occurrence, January 4, 1989, when high TSP levels were reported across RMA. On this day prevailing winds were again from the south. The maximum concentration in downtown Denver was $472 \mu\text{g}/\text{m}^3$. This was a widespread regional phenomenon, as even Castle Rock to the south of Denver reported a high TSP value of $165 \mu\text{g}/\text{m}^3$.

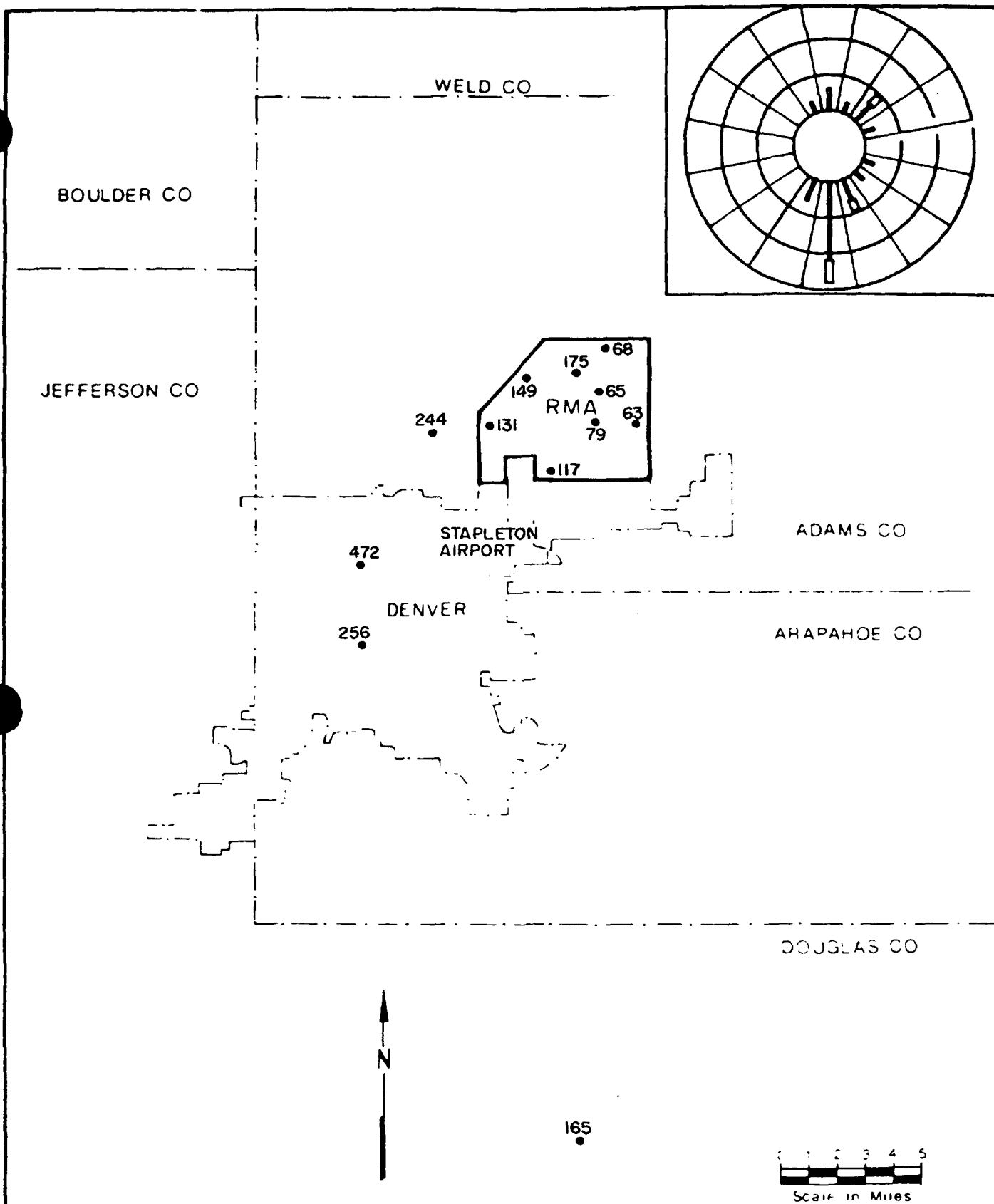
As a general rule, concentrations fell from the center of Denver and were typically about 50 percent lower in the outlying suburbs including RMA. During 1986-1987 prior to Basin F remediation activity, the average concentration at RMA for *all sites* was $40 \mu\text{g}/\text{m}^3$. The boundary sites, AQ1 and AQ2, averaged $56 \mu\text{g}/\text{m}^3$ and were comparable to other suburban measurements, whereas the interior RMA sites averaged $38 \mu\text{g}/\text{m}^3$. As will be noted in the next section, this condition was temporarily altered during Basin F remediation activities.

One important difference between high TSP values measured in metropolitan Denver and those at RMA is that those experienced in metropolitan Denver were frequently associated with high pollution-type episodes in which industrial and vehicle traffic emissions were trapped under a blanketing inversion that spread across the area. In these cases winds were generally light to moderate. Occasionally, these metropolitan Denver impacts extended to the vicinity of RMA;



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Figure 4.2-17
 Denver Area TSP Data
 ($\mu\text{g}/\text{m}^3$) for 2-9-89
 CMP AR FY 89



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Figure 4.2-18
 Denver Area TSP Data
 ($\mu\text{g}/\text{m}^3$) for 1-4-89
 CMP AR FY 89

however, during remedial operations at RMA, higher concentrations were invariably associated with strong wind gusts that lifted dirt which had been loosened by handling.

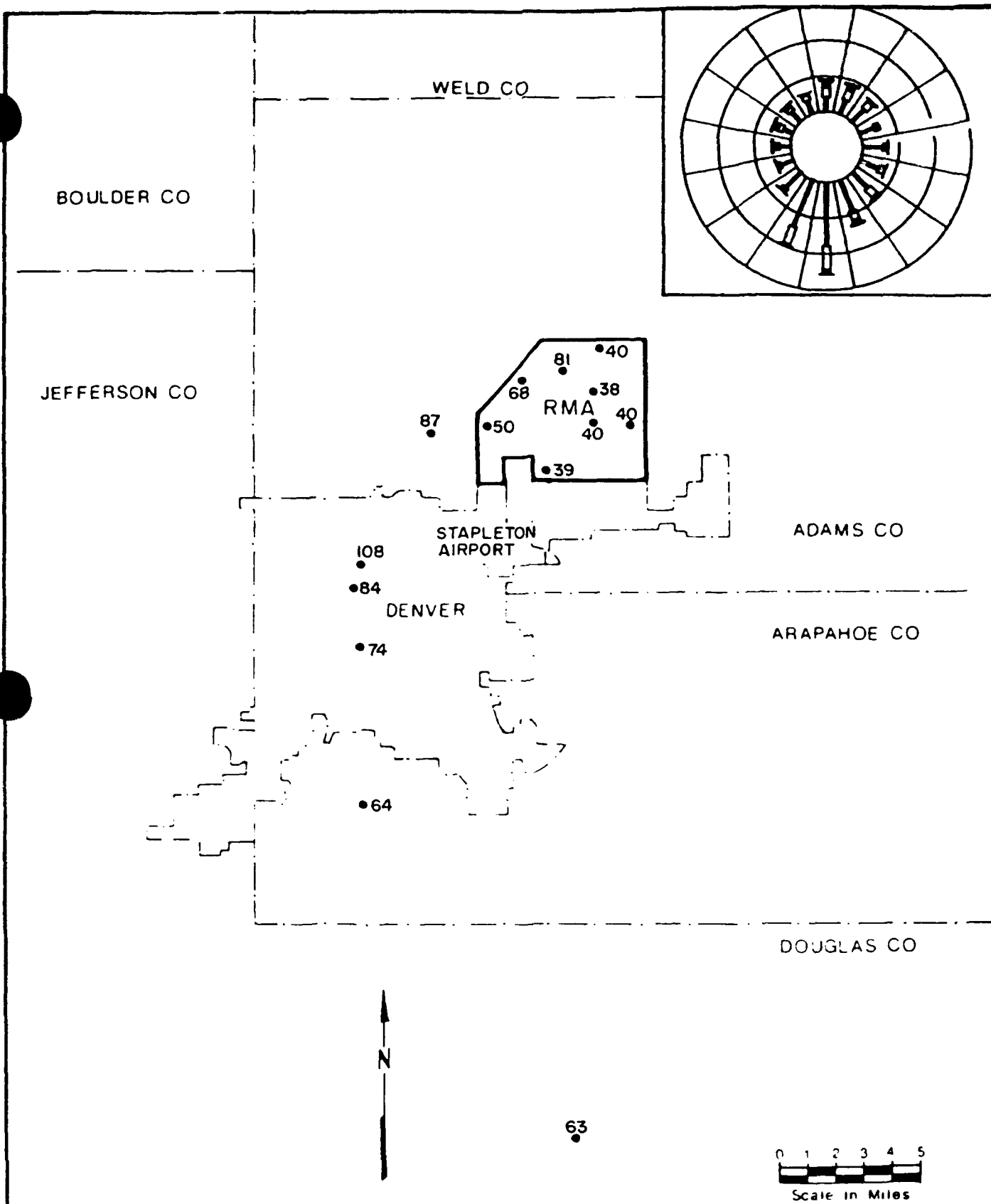
4.2.4.2 Comparison of Denver Metropolitan TSP Data With Basin F Remediation Phases. Table 4.2-5 also shows mean and maximum TSP values for metropolitan Denver during the various phases of the Basin F remediation program. A comparison of these results with Tables 4.2-3 and 4.2-4, which provide CMP and Basin F Remedial Monitoring Program data for the same periods, shows that metropolitan Denver levels were consistently higher than RMA levels except in the immediate vicinity of Basin F during the more intense periods of remedial activity.

Figures 4.2-19 through 4.2-22 show the geographic distribution of TSP levels across the metropolitan Denver and Arsenal areas for each of the remedial phase periods. In Phase 1, the corridor of high TSP levels is shown oriented north-south in the direction of the prevailing wind pattern. The highest concentration (geometric mean of $108 \mu\text{g}/\text{m}^3$) was in downtown Denver and concentrations decreased towards the Arsenal, except for the high TSP level ($81 \mu\text{g}/\text{m}^3$) shown in the center of the Arsenal in the vicinity of Basin F. However, the local nature of this source is shown by lower TSP levels at the Arsenal boundaries; moderately higher TSP levels at AQ1 and AQ2 at the western RMA boundaries reflect the impacts from Denver more than the Basin F activities.

In Phase 2 (Stage 1), the impacts of Denver winter inversion conditions are illustrated with very high geometric mean levels measured at downtown Denver ($192 \mu\text{g}/\text{m}^3$) and progressing towards the Arsenal at decreasing levels. TSP concentrations north of Basin F were reduced below those recorded in central Denver, but were still more than those along the eastern portion of the Arsenal. The downwind concentrations remained at a moderate level ($68 \mu\text{g}/\text{m}^3$) as significant landscaping and dirt moving were in progress during this period. During Phase 2 (Stage 2) and Phase 3, the distribution of high TSP levels across Denver maintained its orientations from north to south at somewhat reduced levels (reflecting the spring and summer seasons). However, with the termination of Basin F remedial activities, Arsenal TSP levels were typical of rural or semi-urban baseline values with the exception of higher concentrations on the western boundary closest to metropolitan Denver.

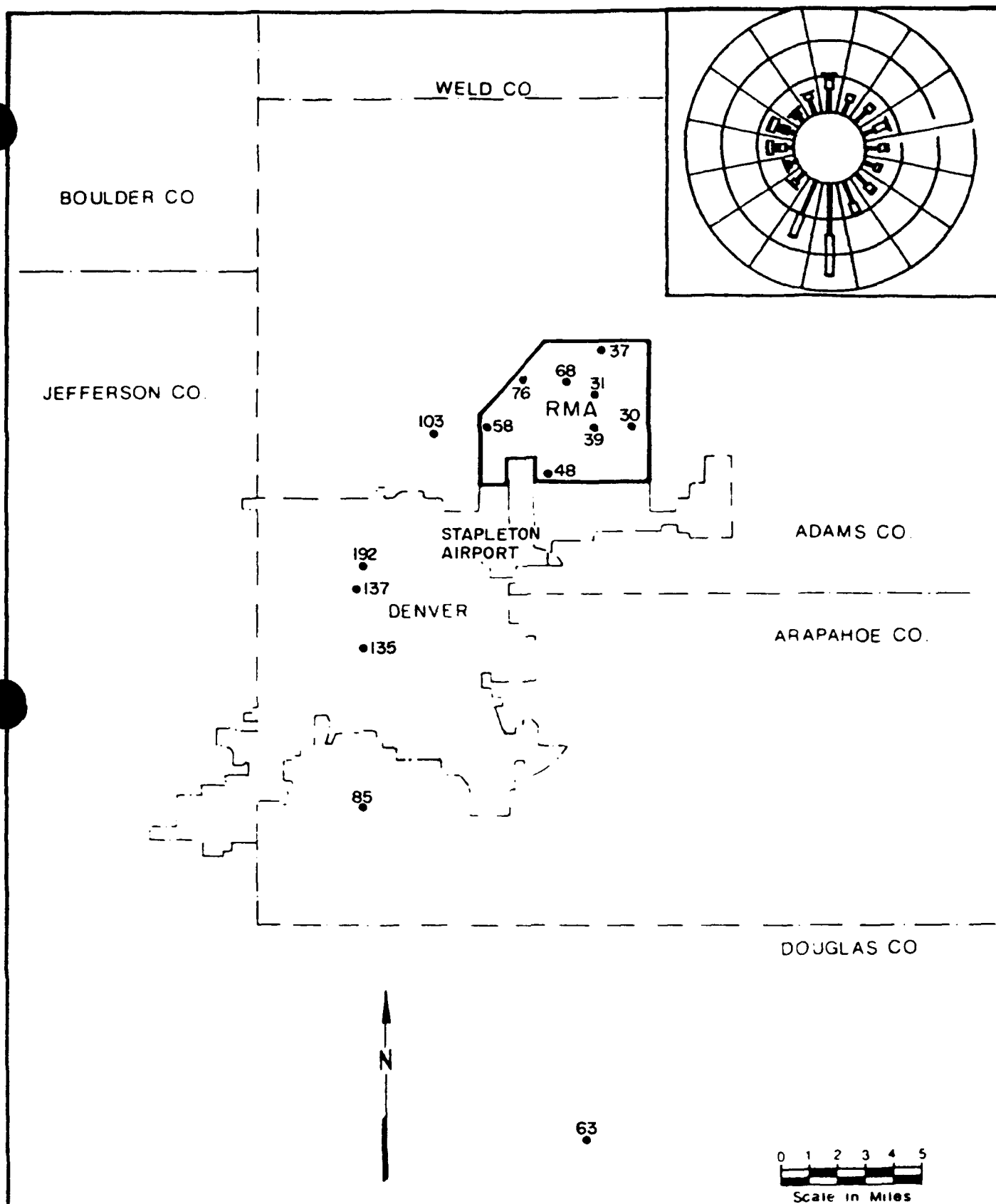
4.2.5 Analysis Implications for Mitigation and Controls

The general results of these investigations indicate that many of the RMA sources were localized and that although very high concentrations were frequently measured adjacent to remedial activities, concentrations fell off considerably with distance from the source. Consequently, those



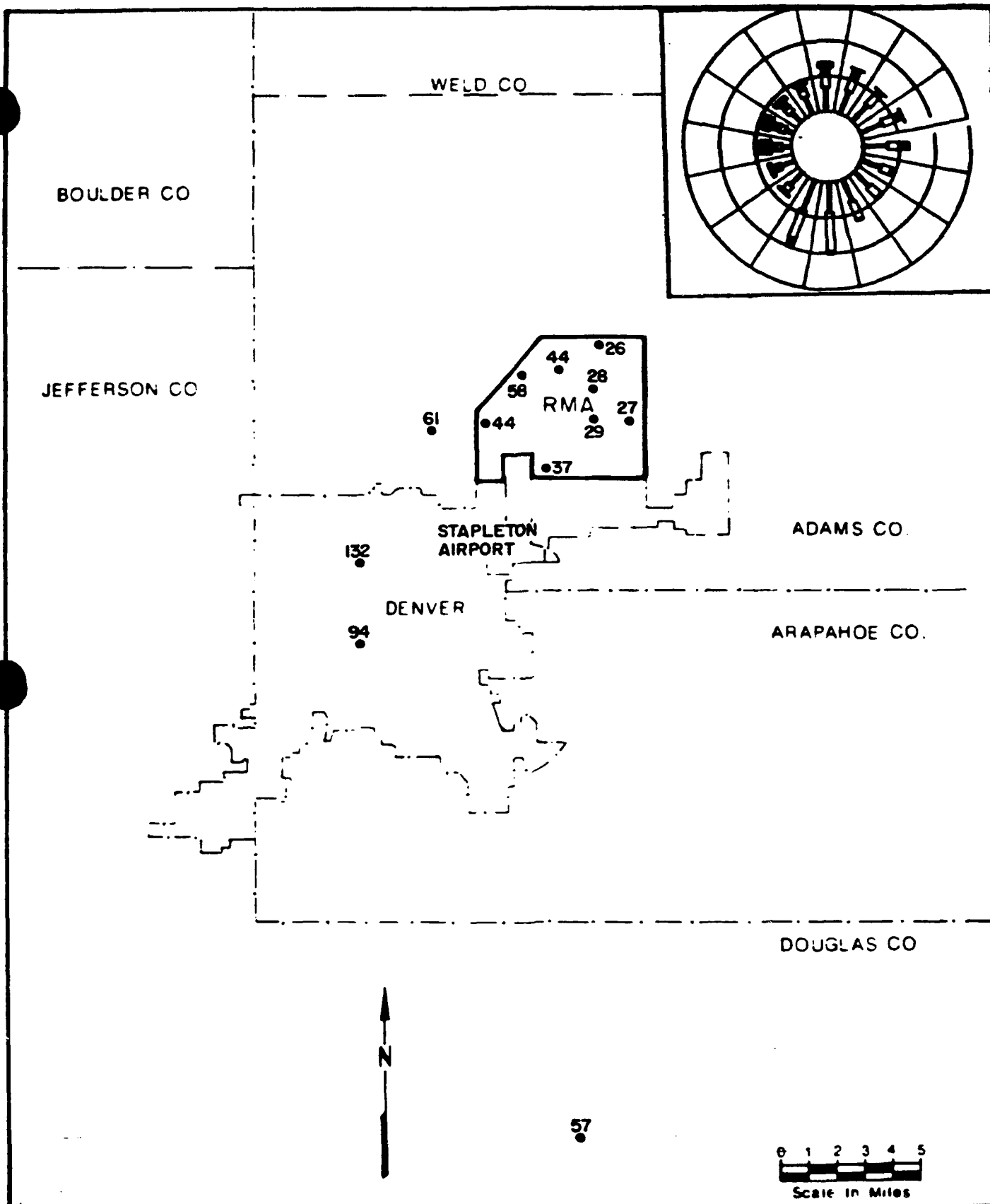
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Figure 4.2-19
 Denver Area TSP Data for Phase I
 Geometric Means ($\mu\text{g}/\text{m}^3$)
 CMP AR FY 89



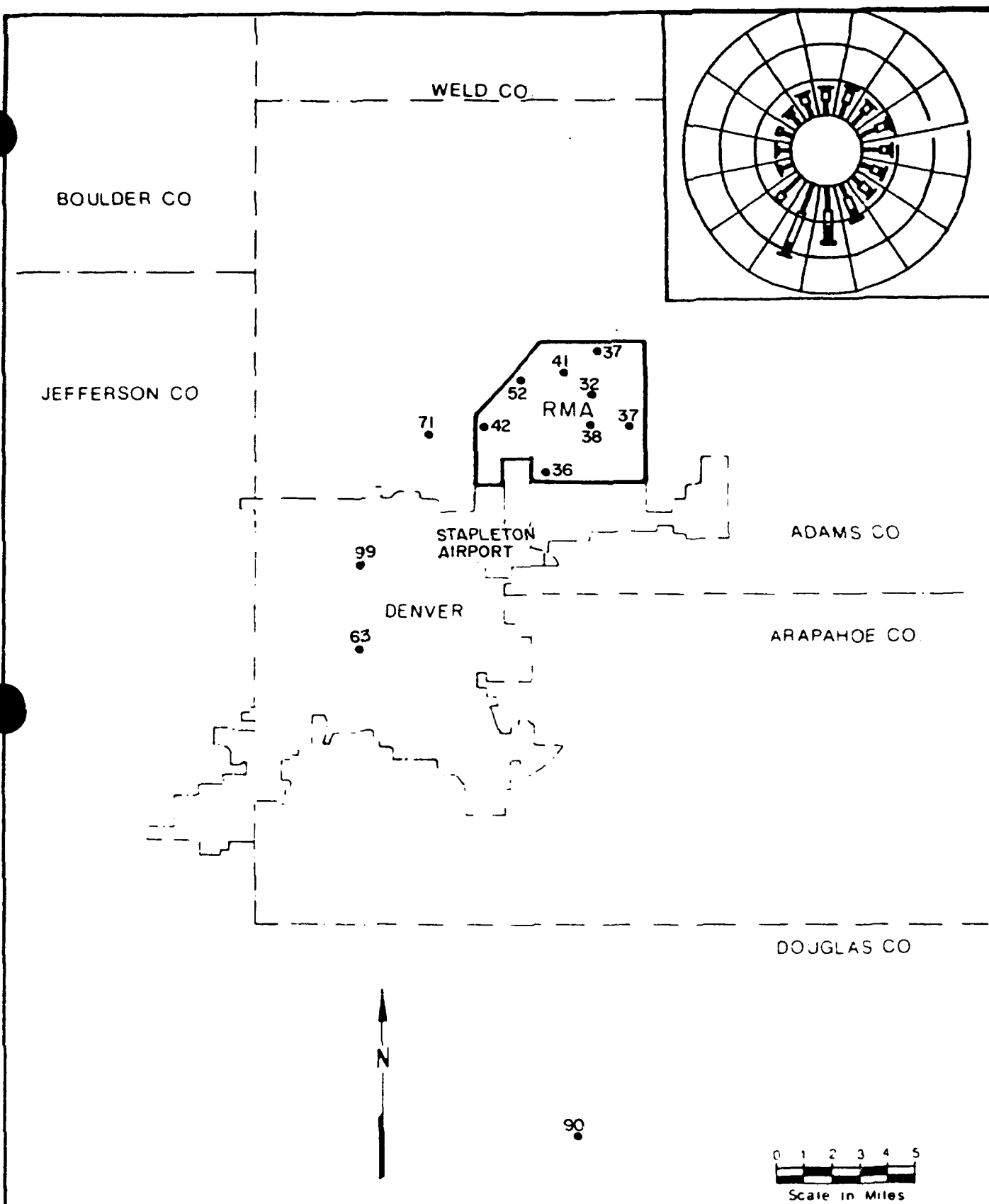
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Figure 4.2-20
 Denver Area TSP Data for Phase 2-
 Stage I Geometric Means ($\mu\text{g}/\text{m}^3$)
 CMP AR FY 89



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Figure 4.2-21
 Denver Area TSP Data for Phase 2-
 Stage 2 Geometric Means ($\mu\text{g}/\text{m}^3$)
 CMP AR FY 89



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Figure 4.2-22
 Denver Area TSP Data for Phase 3
 Geometric Means ($\mu\text{g}/\text{m}^3$)
 CMP AR FY 89

sources well into the RMA interior were less likely to cause impacts off the Arsenal, while those sources closer to the boundaries were more likely to cause temporary impacts at the boundary when strong or gusty winds were blowing in the appropriate direction.

Also, certain atmospheric conditions and diurnal factors can spread pollutants greater distances from the disturbing source. The ongoing CMP monitoring program and the summarized results, with emphasis on causative factors, form the basis for practical mitigating actions. For example, when monitoring shows excessive TSP levels, chemical stabilizers, covers and landscaping, as in the core of Basin F, can be used over sensitive areas, and dirt excavation, hauling and unloading can be minimized during periods of high winds and poor dispersion potential (as reflected by air quality models), particularly when impacts would be towards nearby boundaries.

4.2.6 Summary

TSP levels at RMA can be attributed to two principal sources: (1) the influx of industrial or urban traffic emissions from metropolitan Denver, and (2) remedial activity producing wind-blown dust, usually during high wind episodes. Because of increased remedial activity at RMA during the FY88 and FY89 CMP monitoring periods, there was a noticeable increase in TSP levels at sites adjacent to or directly downwind from construction work, primarily at Basin F. However, the impacts from the Arsenal-generated sources were localized and fell off rapidly with distance from the source. At the termination of the Basin F cleanup program, TSP concentrations downwind from Basin F decreased significantly.

4.3 Respirable Particulate Matter

4.3.1 CMP PM-10 Monitoring Program

Respirable particulate matter, those particles with aerodynamic diameters less than 10 microns, referred to as PM-10, was monitored at five separate locations for the FY89 monitoring period. A collocated monitor also operated at Site AQ5 during the program. Two additional monitors were added to the network during FY89 because of the increased emphasis placed on PM-10 impacts by the EPA and other regulatory agencies. The new CMP PM-10 monitoring sites were located at AQ1 on the eastern boundary and AQ3 at the northern boundary of the Arsenal. A synopsis of the PM-10 monitoring effort for FY89 is given in Table 4.3-1.

Table 4.3-1 Summary of RMA CMP FY89 Sampling for Respirable Particulates of Less Than 10 Microns (PM-10)

Station	Number of Samples	Percent Recovery
AQ1	57	95
AQ2	59	98
AQ3	58	97
AQ5	56	93
AQ9	60	100
AQ5D ¹	57	95
Program Total	347	96

1 AQ5D is a collocated station. The intent and operation of collocated stations are discussed in Section 7.4, Quality Assurance.

Average and 24-hour maximum concentrations for the CMP FY89 PM-10 program are shown in Table 4.3-2. As shown previously in Table 2.1-1, the annual PM-10 standard is an arithmetic mean of $50 \mu\text{g}/\text{m}^3$ and the 24-hour standard is $150 \mu\text{g}/\text{m}^3$. Twenty-four hour sequential data are provided in Appendix B. There were no exceedances of the PM-10 annual ambient air quality standards at RMA during FY89. There was one exceedance of the 24-hour ambient standard of $150 \mu\text{g}/\text{m}^3$. This measurement was $168 \mu\text{g}/\text{m}^3$ and occurred on February 9, 1989, when all RMA and metropolitan Denver PM-10 monitoring sites recorded especially high PM-10 concentrations. This episode will be discussed in further detail subsequently.

As in the case of TSP, higher PM-10 levels at some RMA monitoring sites may be attributed to Basin F remedial efforts. However, these impacts, as documented in the CMP FY88 Assessment Report, were localized and decreased significantly with distance from remedial activity. The principal PM-10 source appeared to be industrial and vehicle traffic activity from metropolitan Denver, especially during the winter and peak inversion seasons. AQ1 and AQ2 at the western and northwestern boundaries of the Arsenal (and closest to Commerce City traffic) measured the highest PM-10 levels throughout the CMP FY89 period; annual average concentrations were $33 \mu\text{g}/\text{m}^3$ at

TABLE 4.1-2 Concentrations of Respirable Particulates of Less Than
10 Microns (PM-10) for CMP FY89
(in $\mu\text{g}/\text{m}^3$)

Summary of Arithmetic Mean Concentrations

MONTH	AQ1	AQ2	AQ3	AQ5C	AQ5E	AQ9
OCT	38	37	34	25	27	25
NOV	32	26	20	21	23	18
DEC	44	38	31	29	33	27
JAN	44	30	24	26	30	19
FEB	57	37	35	40	44	34
MAR	39	25	22	27	29	21
APR	25	20	18	17	18	15
MAY	28	24	20	20	22	18
JUN	21	20	18	19	18	18
JUL	26	38	25	23	21	25
AUG	17	22	17	17	15	17
SEP	27	26	26	23	23	22
ANNUAL	33	29	24	24	25	22

Summary of Maximum Concentrations ††

MONTH	AQ1	AQ2	AQ3	AQ5C	AQ5E	AQ9
OCT	47	47	46	36	41	35
NOV	43	39	34	34	37	32
DEC	77	72	60	47	51	51
JAN	95	65	50	71	74	44
FEB	168	105	94	116	128	94
MAR	56	33	30	37	41	27
APR	38	29	29	25	26	22
MAY	34	29	24	26	28	21
JUN	33	34	31	28	26	34
JUL	35	46	35	33	31	36
AUG	20	27	19	19	18	19
SEP	39	45	37	29	28	32
ANNUAL	168	105	94	116	128	94

† Annual arithmetic mean standard is $50 \mu\text{g}/\text{m}^3$.

†† Maximum 24-hour standard is $150 \mu\text{g}/\text{m}^3$.

Note: FY89 is the period from October 1, 1988 to September 30, 1989.

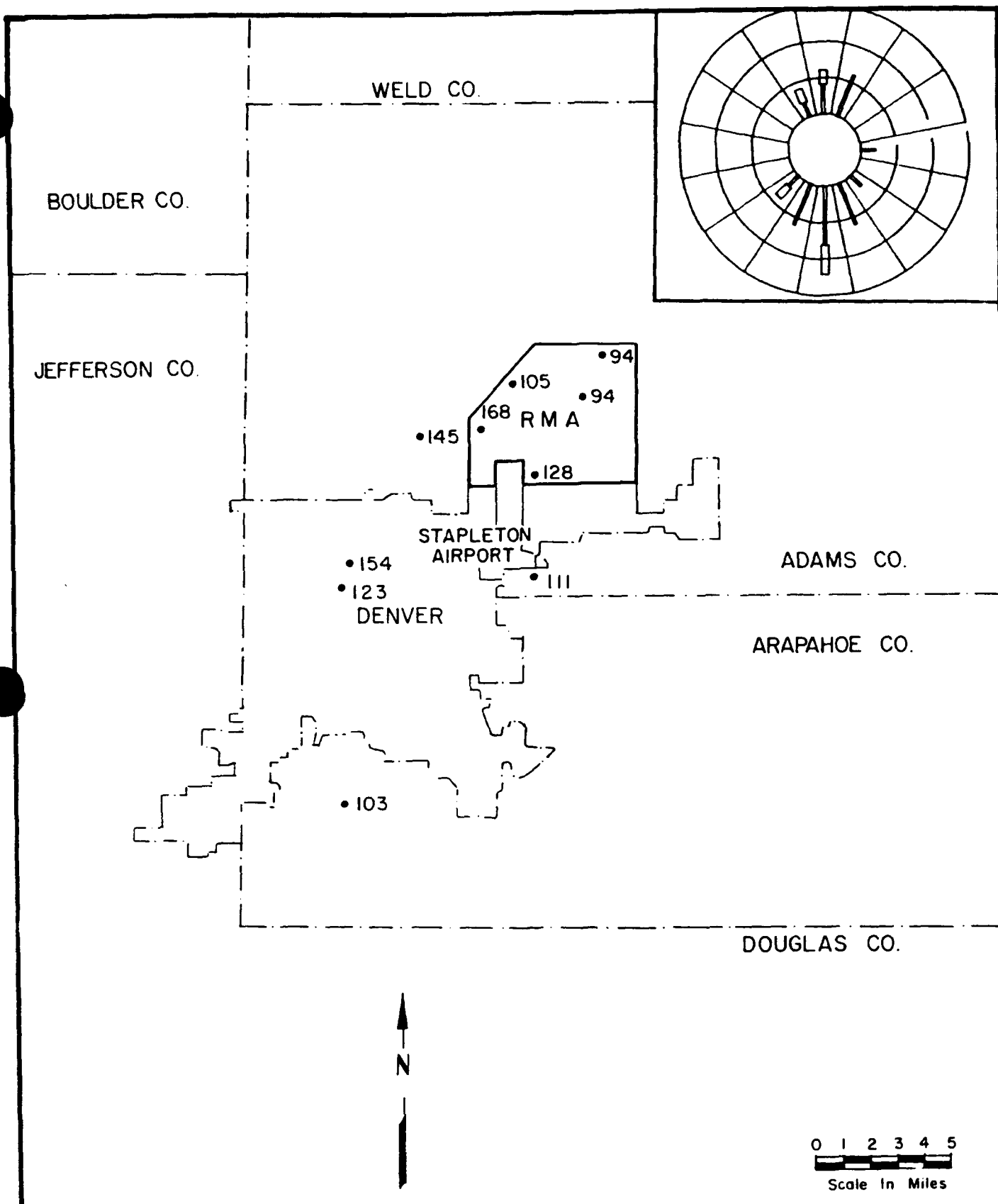
AQ1 and $29 \mu\text{g}/\text{m}^3$ at AQ2. Stations AQ3, AQ5 and AQ9, farther from Denver industrial impacts, measured $24 \mu\text{g}/\text{m}^3$, $24 \mu\text{g}/\text{m}^3$ and $22 \mu\text{g}/\text{m}^3$, respectively.

Maximum PM-10 concentrations at all locations occurred during the winter period. The maximum concentration at all the RMA stations occurred on the same date, February 9, 1989. (This is the same date previously discussed when very high TSP levels also occurred across the Arsenal.) The February 9th PM-10 data are shown in Figure 4.3-1, which also shows the wind rose for the 24-hour period. On this date the PM-10 24-hour measurement at downtown Denver (CAMP site) was $154 \mu\text{g}/\text{m}^3$ and prevailing winds were from the south and were generally light; consequently it appears that the dispersion of TSP, PM-10 and other potential contaminants drifted from downtown Denver in the direction of the Arsenal and other points north of the city.

Of the 60 PM-10 monitoring days during CMP FY89, the highest 24-hour concentrations were measured 40 times at AQ1 at the western boundary and 19 times at AQ2 at the northwestern boundary. On only one occasion, when PM-10 levels were very low, was the highest 24-hour value measured at an interior RMA site; this was $16 \mu\text{g}/\text{m}^3$ measured at AQ5 on September 13, 1989. PM-10 concentrations were consistently higher during the fall and winter periods (also reflected by Denver data). However, even during the spring and summer periods, RMA PM-10 values were higher along the western perimeter than at the interior sites.

4.3.2 Basin F PM-10 Impacts

4.3.2.1 CMP Data. As in the case of TSP, Table 4.3-3 provides a breakdown of PM-10 concentrations during the three phases of the Basin F remedial program. These data indicate potential PM-10 impacts on the five RMA monitoring sites during the Basin F remedial and post-remedial periods. There were no violations of any PM-10 ambient standards during the Phase 1 period. The Phase 2, Stage 1 period (remedial landscaping/hauling) indicated occurrences of the highest PM-10 levels, but they were most likely attributed to the winter seasonal impacts over RMA from metropolitan Denver. The highest average concentration ($52 \mu\text{g}/\text{m}^3$) for the two month period (December 13, 1988 through February 15, 1989) occurred at AQ1 at the western RMA boundary. The highest 24-hour PM-10 concentration of $168 \mu\text{g}/\text{m}^3$ also occurred at AQ1; this was an exceedance of the 24-hour ambient standard of $150 \mu\text{g}/\text{m}^3$. As previously noted, this occurred on February 9, 1989, when metropolitan Denver and all Arsenal stations received their highest PM-10 levels (see Figure 4.3-1). During the Phase 3 post-remedial period, PM-10 levels were consistently low across the Arsenal, ranging from an average value of $26 \mu\text{g}/\text{m}^3$ at AQ2 to $20 \mu\text{g}/\text{m}^3$ at AQ9. The low values can be attributed principally to the improved dispersion of all



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FIGURE 4.3-1
PM-10 Results for 02/09/89
CMP AR FY 89

TABLE 4.3-3 Concentrations of Resuspendable Particulates of Less Than 10 Microns (PM-10)
for Phases 1-3
(in ug/m3)

Summary of Arithmetic Mean Concentrations #						
MONTH	A01	A02	A03	A05C	A05D	A09
PHASE 1						
MAR		27		26		36
APR		23		19		20
MAY		19		14		15
JUN		24		17		15
JUL		30		23		22
AUG		37		25	36	25
SEP		33		20	20	22
OCT	38	37	34	25	27	25
NOV	32	26	20	21	23	18
DEC	57	50	42	36	39	37
PHASE 2 - STAGE 1						
DEC	36	29	24	25	28	20
JAN	44	30	24	28	30	19
FEB	80	53	47	55	61	47
PHASE 2 - STAGE 2						
FEB	27	18	16	18	19	14
MAR	29	25	22	27	29	21
APR	25	20	18	17	18	15
MAY	25	19	16	15	15	14
PHASE 3						
MAY	29	26	21	22	24	19
JUN	31	20	19	19	18	18
JUL	26	38	25	23	21	25
AUG	17	22	17	17	15	17
SEP	27	26	26	23	23	22
PRE-REM		36		33		18
PHASE 1	39	30	30	22	27	22
PHASE 2-1	52	36	30	35	39	27
PHASE 2-2	31	22	19	21	22	17
PHASE 3	24	26	21	21	20	20

TABLE 4.3-3 (continued)

Summary of Maximum Concentrations ¹¹						
MONTH	AQ1	AQ2	AQ3	AQSC	AQSD	AQ9
PHASE 1						
MAR		46		34		36
APR		43		39		39
MAY		27		19		18
JUN		41		19		18
JUL		42		35		30
AUG		67		39	42	42
SEP		61		37	33	41
OCT	47	47	46	36	41	35
NOV	48	39	34	34	37	32
DEC	77	72	60	47	51	51
PHASE 2 - STAGE 1						
DEC	51	44	40	43	45	34
JAN	95	65	50	71	74	44
FEB	168	105	94	116	128	94
PHASE 2 - STAGE 1						
FEB	38	23	19	25	27	19
MAR	56	33	30	37	41	27
APR	38	29	29	25	26	22
MAY	25	19	16	15	15	14
PHASE 3						
MAY	34	29	24	26	28	21
JUN	33	34	31	28	26	34
JUL	35	46	35	33	31	36
AUG	20	27	19	19	18	19
SEP	39	45	37	29	28	32
PRE-REM		94		90		36
PHASE 1	77	72	60	47	51	51
PHASE 2-1	168	105	94	116	128	94
PHASE 2-2	56	33	30	37	41	27
PHASE 3	39	46	37	33	31	36

¹ Annual arithmetic mean standard is 50 ug/m³.

¹¹ Maximum 24-hour standard is 150 ug/m³.

Note: Pre-Rem refers to data collected during the Air Remedial Investigation (Environmental Science & Engineering, Inc., 1988).

Phase 1 is from March 22 to December 12, 1988.

Phase 2, Stage 1 is from December 13, 1988 to February 15, 1989.

Phase 2, Stage 2 is from February 16 to May 5, 1989.

Phase 3 is from May 6 to September 30, 1989.

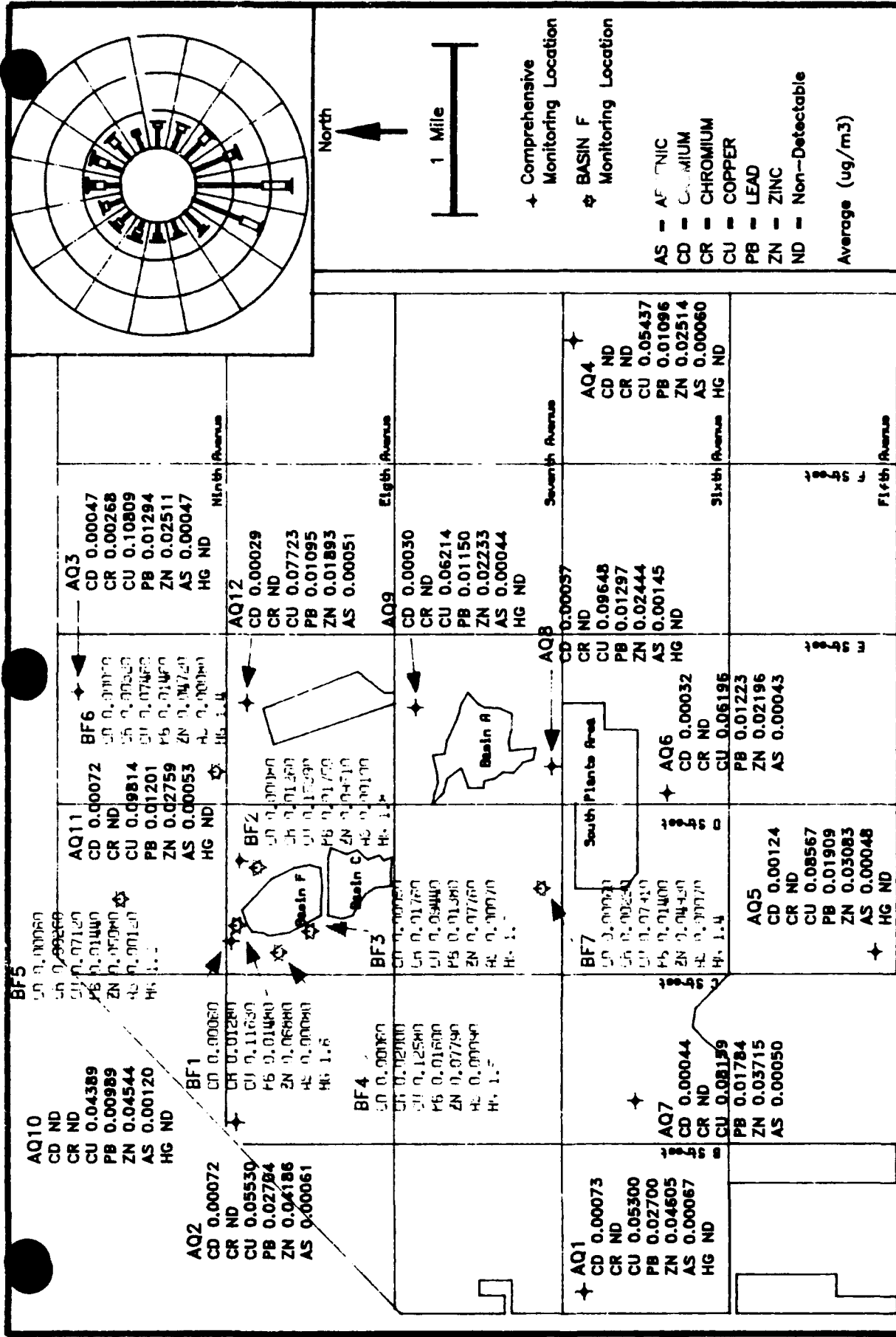
pollutants during the summer season; however, the cessation of remedial activity may have had a minor influence in decreasing PM-10 values.

Because the CMP did not measure PM-10 immediately adjacent to Basin F operations, it is difficult to identify the full impact of Basin F operations on PM-10 levels. It is likely that PM-10 monitoring at AQ10 and AQ11, where very high TSP levels were monitored during the Phase 1 and Phase 2 periods (see Table 4.2-3), would also have resulted in higher PM-10 levels. A study conducted during the CMP FY88 (Phase 1 programs) indicated that PM-10 levels ranged from 36 percent to 42 percent of the TSP levels. During FY89, these ratios ranged from 43 to 63 percent with particularly high ratios during the winter season. Figures 4.3-2, 4.3-3 and 4.3-4 show the corresponding FY89 sequential concentration for PM-10 and TSP for AQ2, AQ5 and AQ9 (the same stations evaluated in FY88). As in the case of the FY88 data, the PM-10 to TSP ratio was lower at AQ2 than at AQ5 and AQ9. If it can be assumed that AQ2 received more direct impacts from Basin F because of its closer proximity to the remedial area, this would again substantiate the FY88 premise that remedial impacts were less for smaller particulates than for TSP.

4.3.2.2 Basin F Data. PM-10 was not measured in the immediate vicinity of Basin F during the Basin F Interim Remedial Monitoring Program. However, because of the increased emphasis placed on PM-10, monitoring of this criteria pollutant was initiated during the IRA-F follow-on monitoring program (Phase 3) to determine if any residual or post-remedial PM-10 impacts resulted from the Basin F cleanup activities. The program consisted of monitoring every 12 days at FC1, downwind from Basin F and at FC3, upwind from Basin F. Results are shown in Table 4.3-4. Twenty-four hour sequential data are provided in Appendix P.

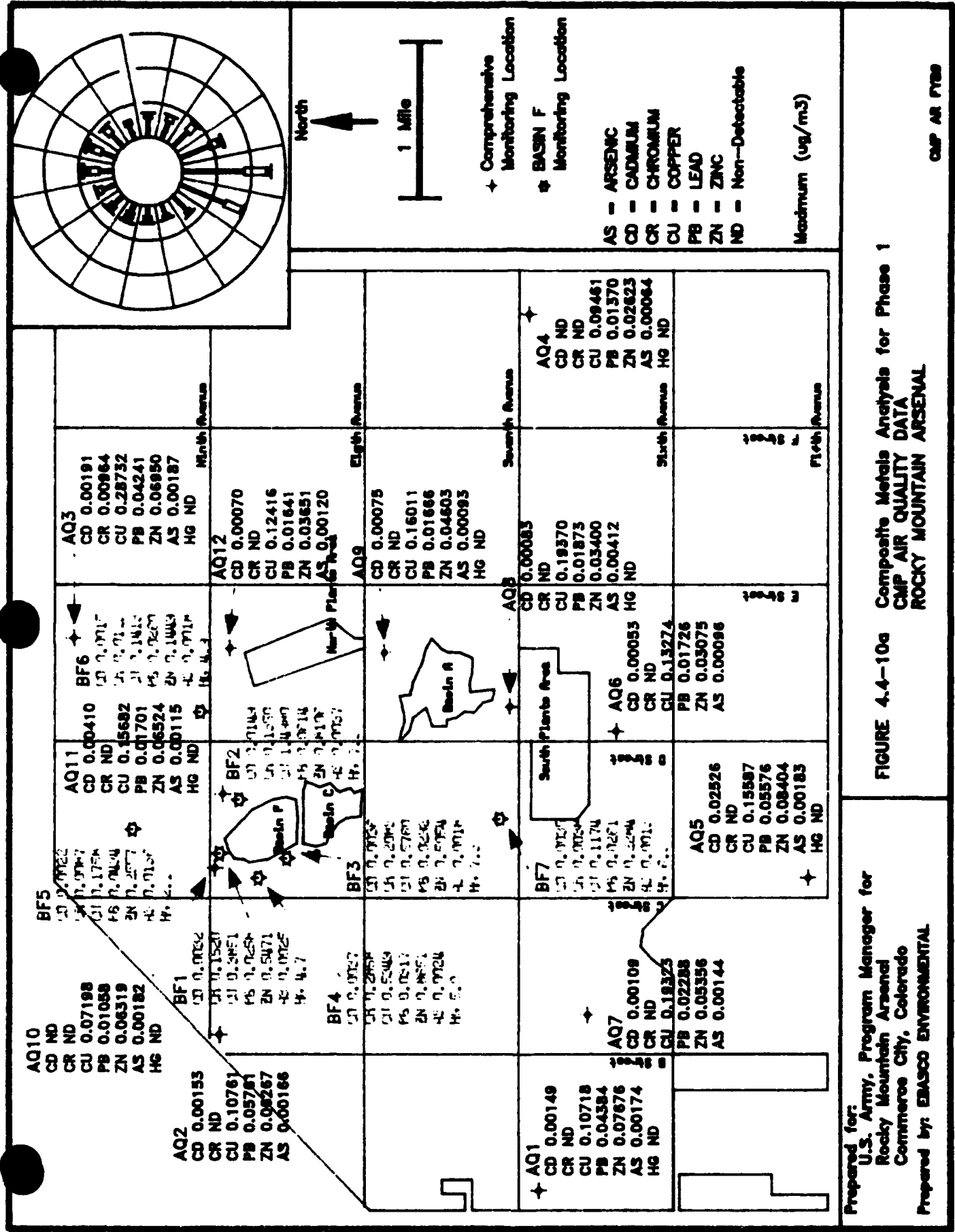
During the Phase 3 period, FC1 measured an average concentration of $23 \mu\text{g}/\text{m}^3$ and a 24-hour maximum concentration of $35 \mu\text{g}/\text{m}^3$. FC3 measured an average concentration of $22 \mu\text{g}/\text{m}^3$ and a maximum concentration of $36 \mu\text{g}/\text{m}^3$. The results of both monitoring stations were almost identical and also comparable to other RMA interior monitoring sites, suggesting no post-remedial PM-10 impacts from the Basin F operations.

4.3.2.3 Combined Basin F and CMP Data Analysis. Individual CMP and Basin F PM-10 monitoring data for the three designated phases of the Basin F remedial programs assessment have been shown in Tables 4.3-3 and 4.3-4. Figures 4.3-5 through 4.3-8 depict average and maximum PM-10 values for both sets of data for the remedial phases. On these figures, the data for AQ5 represent the higher values of the AQ5 or AQ5D concentration. The wind roses reflecting transport of particles from a potential Basin F source are also shown on these figures. As noted from the previous discussions, these data show no apparent impact from the Basin F operation



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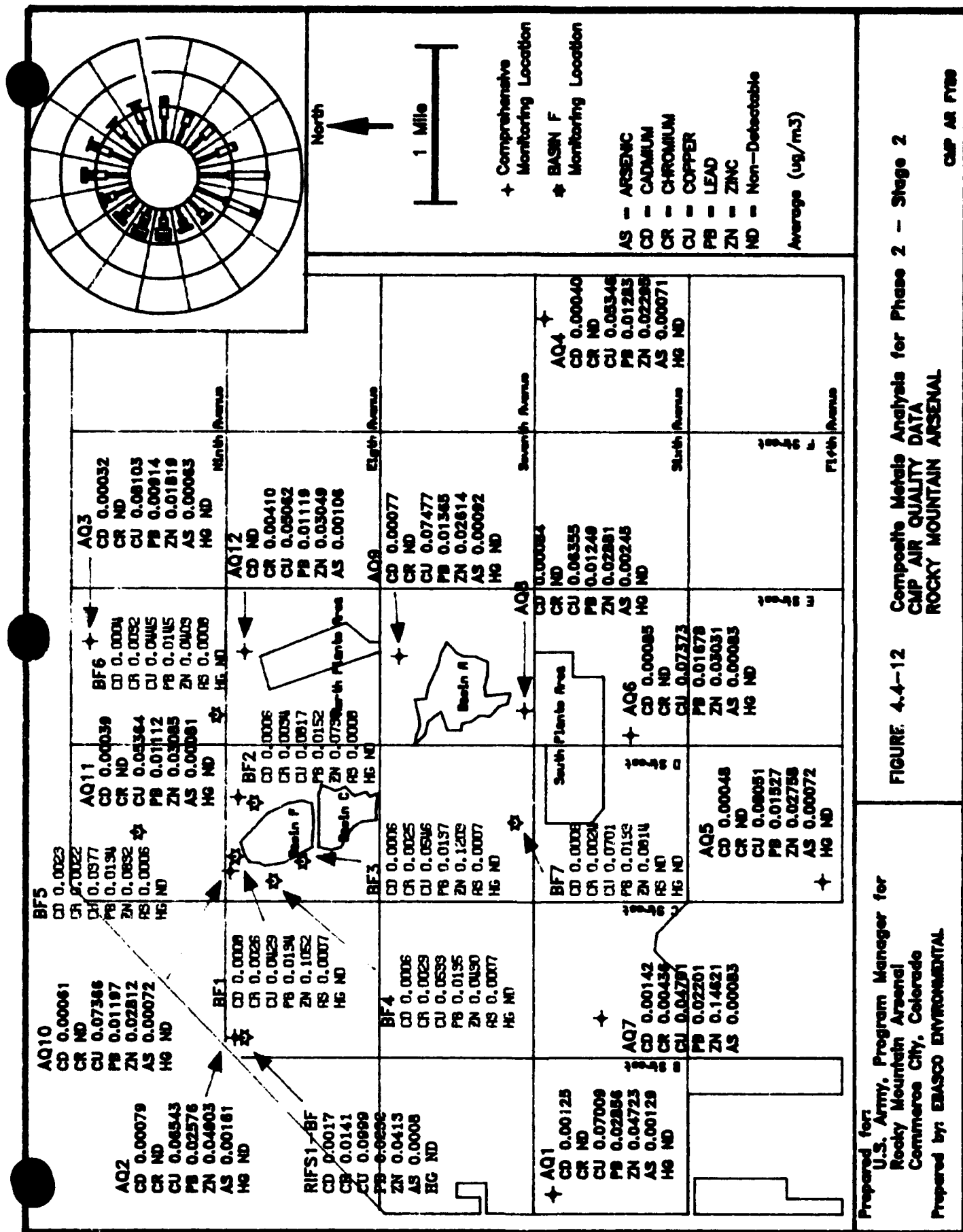
**FIGURE 4.4-10 Composite Metals Analysis for Phase 1
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL**



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FIGURE 4.4-10a Composite Metals Analysis for Phase 1
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AIR PY88



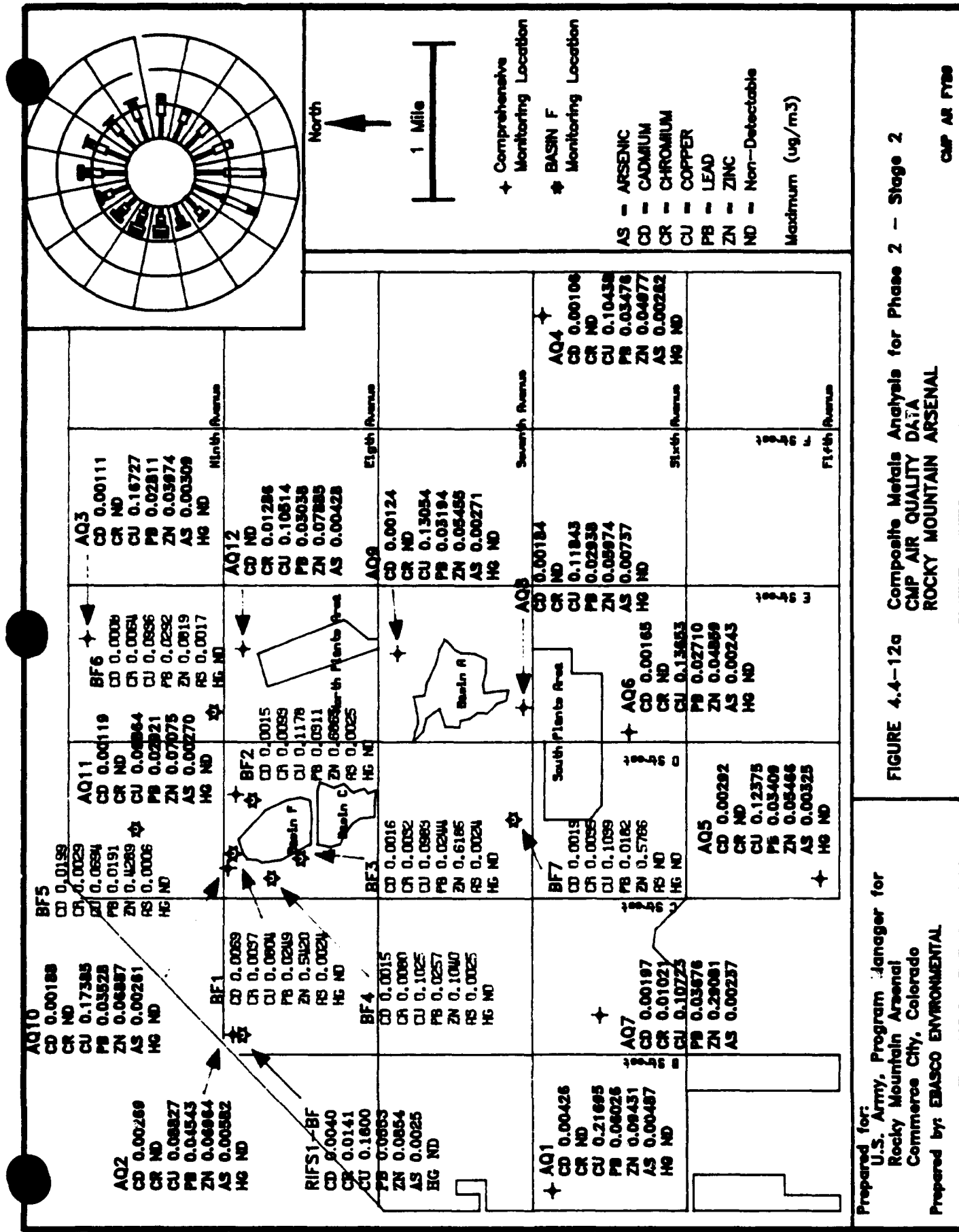
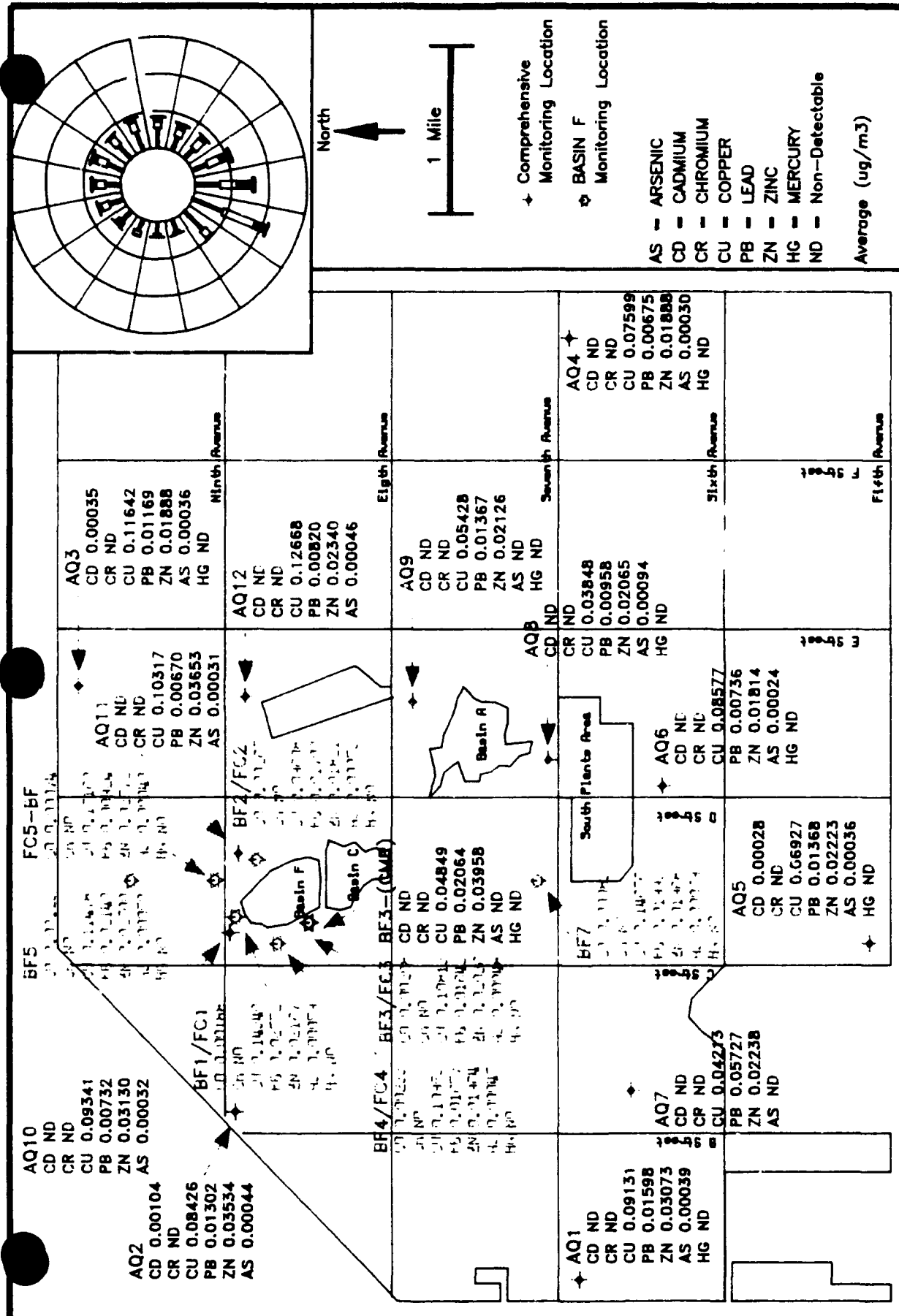


FIGURE 4.4-12a Composite Metals Analysis for Phase 2 - Stage 2

CMP AIR QUALITY DATA
ROCKY MOUNTAIN ARSENAL

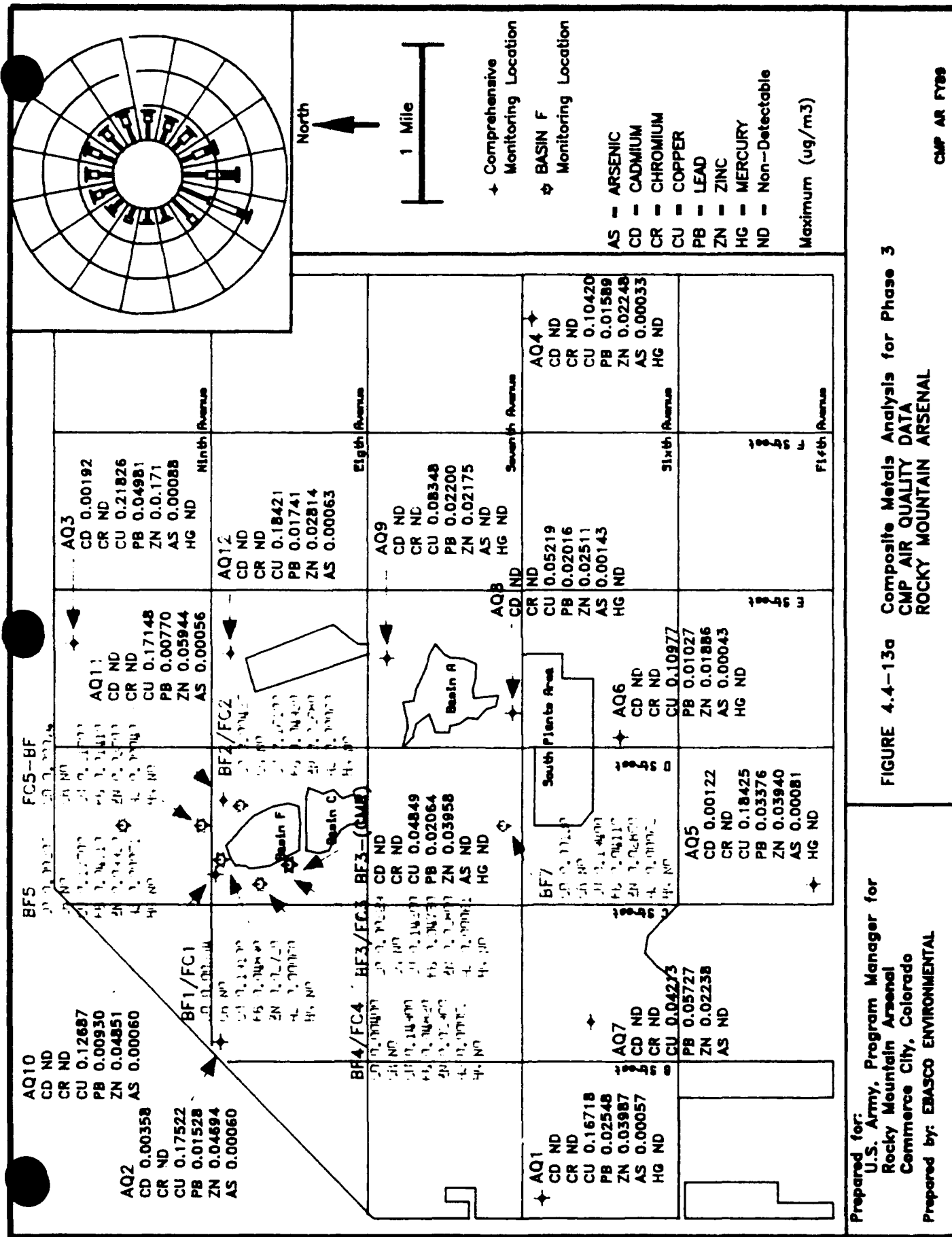
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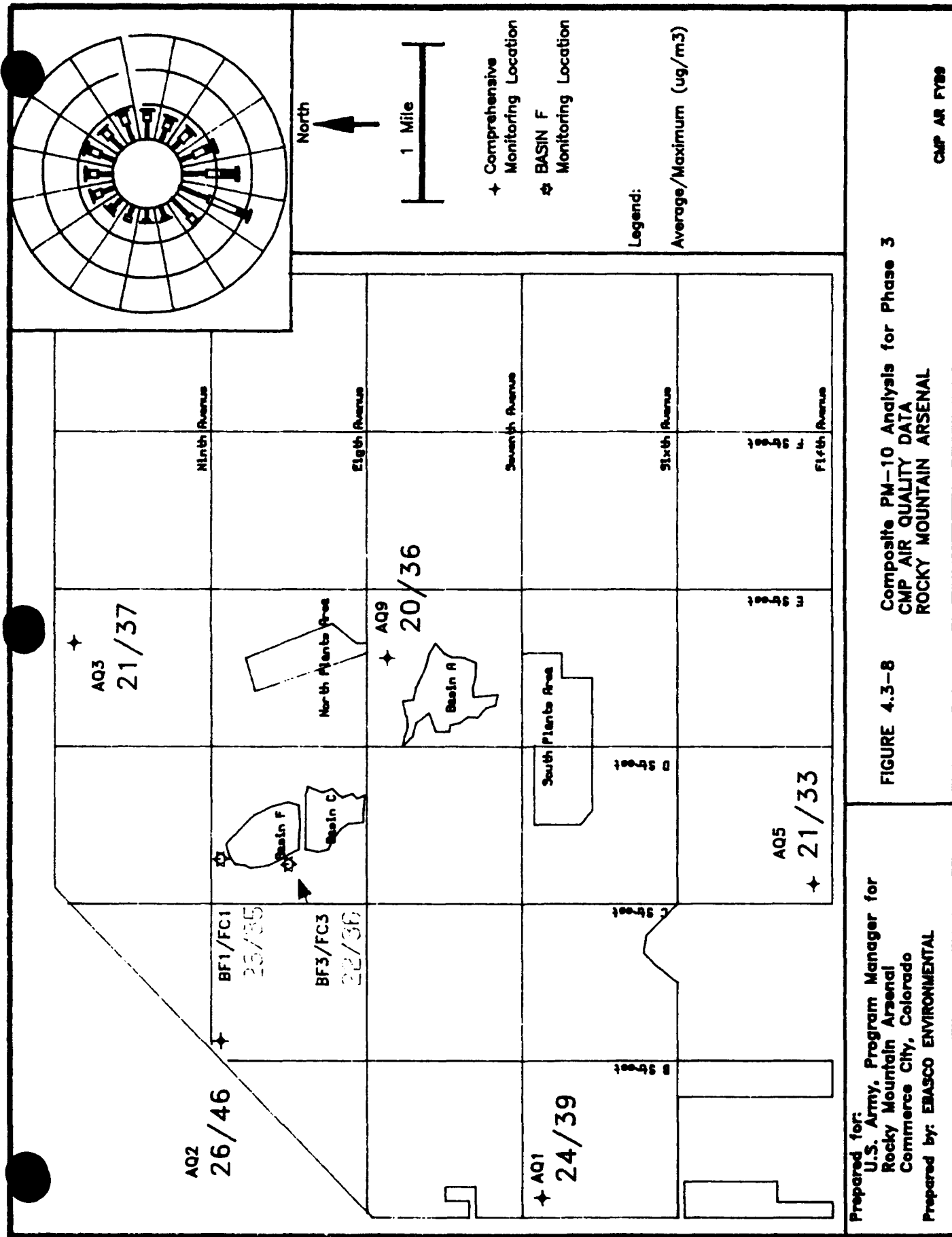
FIGURE 4.4-13 Composite Metals Analysis for Phase 3
CMP AIR QUALITY DATA
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FIGURE 4.4-13a Composite Metals Analysis for Phase 3
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AR FY89



either during or after remedial activities. On the contrary, the highest TSP mean levels were at the western RMA boundary, upstream from the Basin F prevailing flow.

Because PM-10 data were not collected immediately adjacent to Basin F during remedial activities, it cannot be concluded from these data that no PM-10 impacts resulted during the remedial program. Some elevated PM-10 levels were likely experienced in conjunction with high TSP levels that were occasionally measured. Data illustrated on Figures 4.3-5 through 4.3-7 during Phase 1 and Phase 2 remedial activities suggest that any PM-10 impacts from Basin F operations were highly localized and did not spread to the RMA boundaries. The Phase 3 data (Figure 4.3-8) covering a period when Basin F PM-10 monitoring was conducted show no post-remedial PM-10 impacts either at Basin F or across the Arsenal.

4.3.3 Metropolitan Denver PM-10 Data

As in the case of TSP, PM-10 concentrations were higher in metropolitan Denver than they were at RMA. The distribution of PM-10 data across metropolitan Denver and the Arsenal suggest that there was an influx of PM-10 into the Arsenal from the Denver area. PM-10 arithmetic mean and maximum concentrations for Denver during FY89 and for the Basin F remedial phases are shown in Table 4.3-5.

Figures 4.3-9 through 4.3-12 show the distribution of PM-10 values across metropolitan Denver and the Arsenal for the FY89 period and the three remedial phases. The highest PM-10 values within the metropolitan area appeared to be confined to downtown Denver and at Adams City following prevailing wind flow. During the Phase 1 remediation period, PM-10 levels were generally uniform across both the metropolitan area and the Arsenal, with the highest average concentration of $40 \mu\text{g}/\text{m}^3$ reported at Adams City. There was no evidence of high PM-10 levels at the Arsenal interior, although PM-10 monitoring was not conducted immediately adjacent to Basin F.

During the Phase 2 (Stage 1) winter period, downtown Denver experienced a maximum average PM-10 level of $72 \mu\text{g}/\text{m}^3$ and a maximum 24-hour value of $154 \mu\text{g}/\text{m}^3$, while Adams City reached an average value of $73 \mu\text{g}/\text{m}^3$ and a maximum value of $145 \mu\text{g}/\text{m}^3$. As noted previously, several intense winter inversion episodes contributed to these results. During this period, the Arsenal area also measured high PM-10 levels on several days with maximum concentrations at the western and southern boundaries. Interior Arsenal sites indicated lower PM-10 concentrations, apparently less influenced by dispersion impacts from the metropolitan area.

Table 4.1-5 Denver Metropolitan Area Respirable Particulates or Less than 10 Microns (PM-10) (in ug/m3)

Arithmetic Means

STATION	Phase 1	Phase 2-1	Phase 2-2	Phase 3	FY89
Adams City	40.5	72.8	27.2	31.0	39.1
8101 Ralston	27.2	36.0	27.2	34.8	31.4
1633 Florence	26.7	31.2	26.3	26.0	28.7
414 14th Street	30.6	71.7 *	39.3 *	32.2	40.0
CAMP/2105 Broadway	28.7	45.1	37.2	27.4	34.0
1050 S. Broadway	31.2	49.7 *	35.2	29.7	33.5
4857 S. Broadway	23.1	39.9	27.4	23.6	27.2

Maximum Values

Adams City	103.0	145.0	36.0	50.0	145.0
8101 Ralston	56.0	57.0	59.0	78.0	78.0
1633 Florence	94.0	77.0	56.0	49.0	94.0
414 14th Street	66.0	123.0	59.0	54.0	123.0
CAMP/2105 Broadway	123.0	154.0	62.0	45.0	154.0
1050 S. Broadway	68.0	64.0	57.0	51.0	68.0
4857 S. Broadway	48.0	103.0	44.0	39.0	103.0

* Incomplete data set.

Annual arithmetic mean standard is 50 ug/m3.
Maximum 24-hour standard is 150 ug/m3.

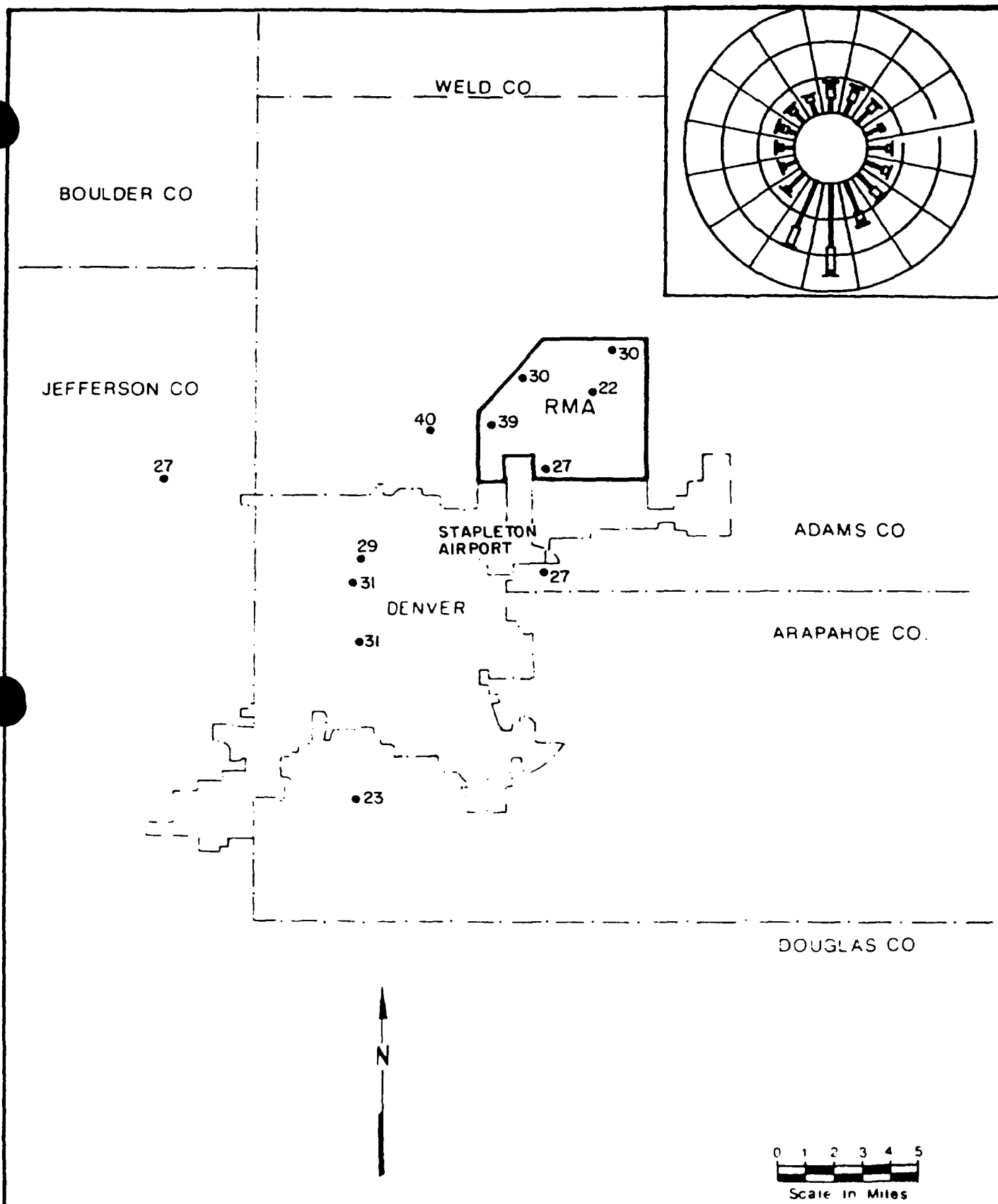
Phase 1 is from March 22 to December 12, 1988.

Phase 2, Stage 1 is from December 13, 1988 to February 15, 1989.

Phase 2, Stage 2 is from February 16 to May 5, 1989.

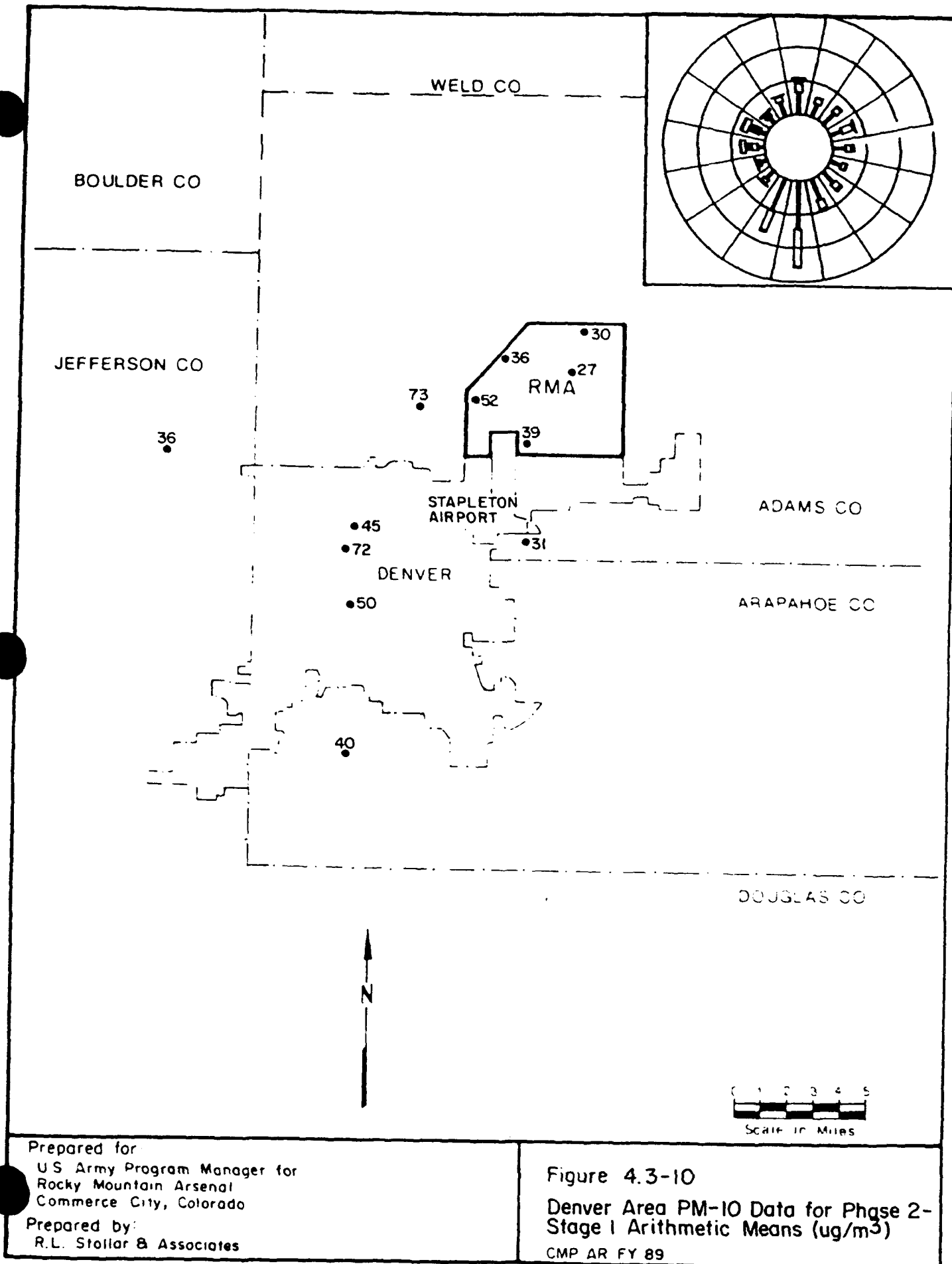
Phase 3 is from May 6 to September 30, 1989.

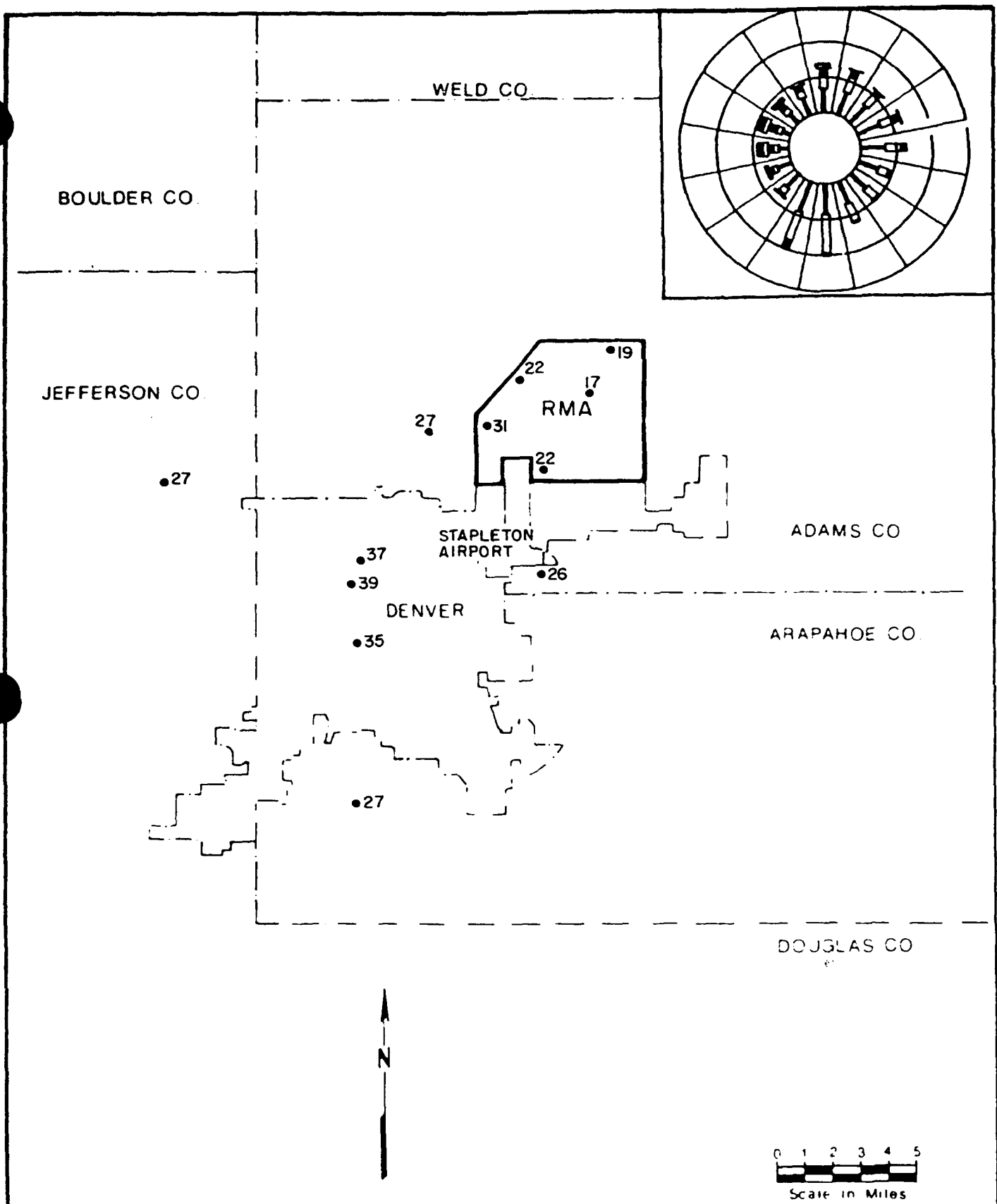
FY89 is the period from October 1, 1988 through September 30, 1989.



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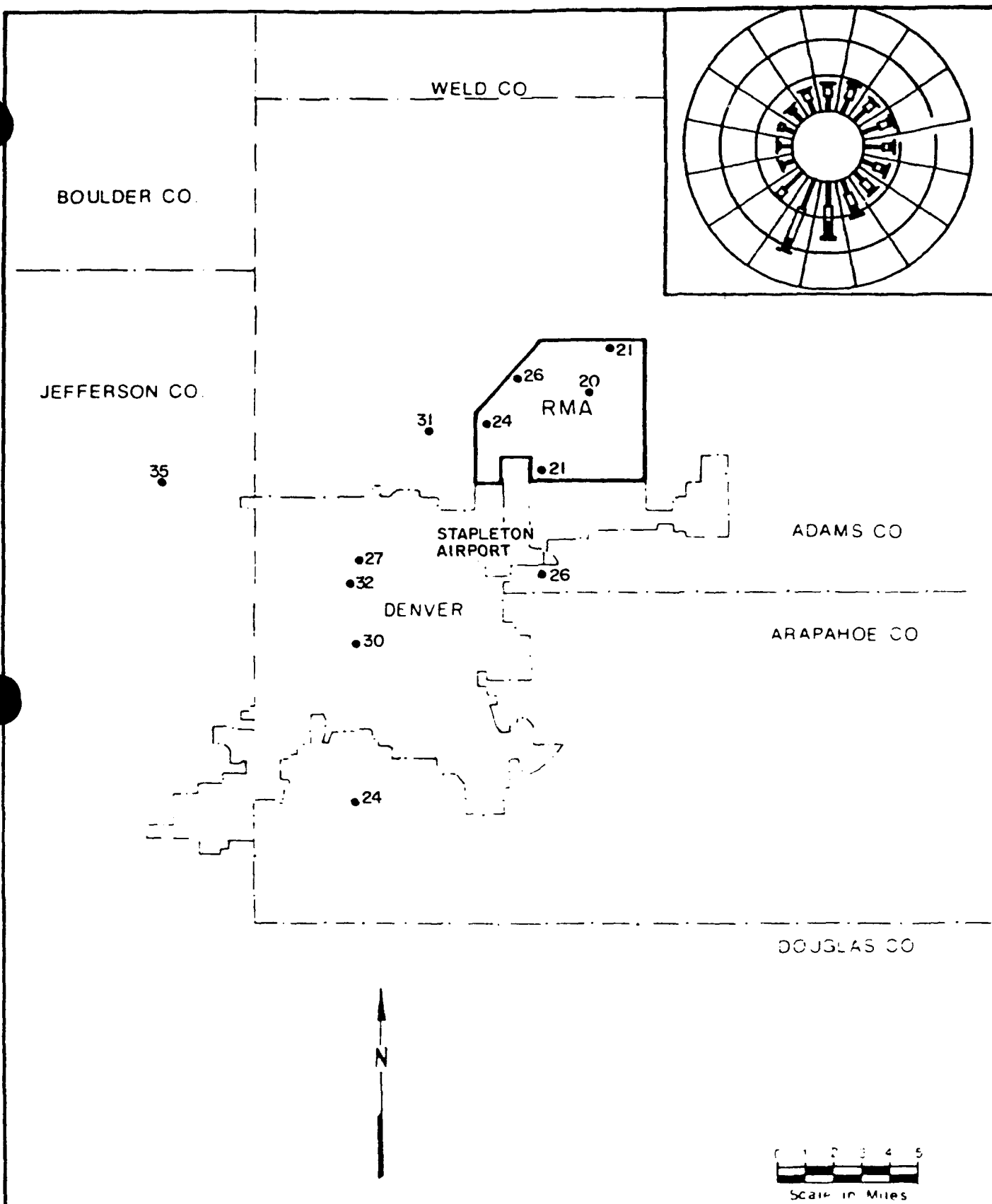
Figure 4.3-9
 Denver Area PM-10 Data for Phase I
 Arithmetic Means ($\mu\text{g}/\text{m}^3$)
 CMP AR FY 89





Prepared for:
 U.S. Army Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by:
 R.L. Stollar & Associates

Figure 4.3-11
 Denver Area PM-10 Data Phase 2-
 Stage 2 Arithmetic Means ($\mu\text{g}/\text{m}^3$)
 CMP AR FY 89



Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
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Figure 4.3-12
Denver Area PM-10 Data for Phase 3
Arithmetic Means ($\mu\text{g}/\text{m}^3$)

CMP AR FY 89

During the Phase 2 (Stage 2) and Phase 3 periods, metropolitan Denver PM-10 levels decreased significantly, although the highest concentrations remained at downtown Denver and Adams City (in the direction of the prevailing wind flow). RMA values were again slightly higher at the western and southern boundaries; interior Arsenal stations reported their lowest PM-10 levels for the 19-month monitoring period during Phase 3.

4.3.4 Summary of PM-10 Analysis.

It would appear that strong gusty winds were conducive to higher PM-10 values at RMA, but at a much lesser extent than for TSP. The highest PM-10 readings were observed during strong atmospheric inversion conditions during the winter months. There were no annual violations of the PM-10 standards and one 24-hour exceedance of the standard on a day when all metropolitan Denver PM-10 monitoring sites also recorded very high levels. As in the case of TSP, there were potentially two principal sources of PM-10 impacting RMA and its surroundings: (1) the influx of PM-10 emissions from metropolitan Denver, and (2) remediation activity sources at RMA, especially during high wind episodes. However, unlike the TSP assessment, the data do not indicate a detectable increase in average PM-10 levels during the remedial activity. This may be the result of the lack of PM-10 monitoring stations immediately adjacent to remedial activities; however, it would appear that any PM-10 remediation-generated emissions were localized and fell off significantly with distance from the activity, producing negligible off-post impacts.

4.4 Metals

A total of six metallic ions were analyzed from the TSP filters after the filters were weighed, including arsenic, cadmium, chromium, copper, lead and zinc. Mercury was measured using Hydrar tubes and analyzed using the Rathje and Moncero method (AIHA, May 1976).

4.4.1 Metals Monitoring Strategies

There were basically two components of the CMP FY89 metals monitoring effort. The first component was routine monitoring which involved every 6th day sampling at two sites, as shown in Table 4.4-1.

Table 4.4-1 Summary of Routine Metals Sampling for FY89

Station	Number of Samples	Percent Recovery
AQ3	52	87
AQ5	52	87
AQ5C ¹	53	88
Program Total:	157	87

1 AQ5C is a collocated station. The intent and operation of collocated stations are discussed in Section 7.4, Quality Assurance. A collocated sampler at AQ5 was installed and operated throughout the routine program.

The second component involved "high event" monitoring during specified high wind episodes (i.e. as a minimum, winds in excess of 10 mph). Twelve high event episodes were conducted for each event for the six metal ion components and also for mercury. Monitoring was conducted at ten to twelve locations across the Arsenal depending upon meteorological conditions and selected source activities or special interests. CMP FY89 special source monitoring included Basin F, Basin A, the South Plants, and the Hydrazine Plant complex.

The high event program for metals was altered slightly during FY89 in order to allow for a more effective collection of metals samples. Experience in FY88 indicated that it was difficult to mobilize for high wind scenarios, especially during the summertime when high winds were associated with convective thunderstorm activity and wind speeds and directions were highly variable. On the other hand, analysis of high event metals conditions could be readily accomplished by post-analysis of meteorological conditions and the analysis of TSP samples already collected. As metals laboratory analyses are obtained from TSP sample filters that are strategically located at 12 interior and perimeter Arsenal sites, this approach provided a practical and cost-effective method of obtaining the desired information. As a consequence, the CMP FY89 high event metals program included both direct mobilization episodes around Basin F, Basin A, the South Plants, and the Hydrazine Plant and post-analysis episodes at strategically located monitoring sites across the Arsenal. In most cases, winds were in excess of 10 mph, and gusts were frequently in excess of 25 mph, thus meeting the wind speed criteria established for high event analysis. In several cases, however, high TSP levels provided the criteria for high event metals analyses.

One difficulty that occurred during the program was that in July and August, 1989, it was determined in the quality assurance review that filters provided by the manufacturer contained high zinc and arsenic concentrations and consequently invalidated several routine and high event metals samples obtained during this period. These samples were replaced with additional post analyses events that met the high event criteria; however, there was a two-month gap in the collection period.

4.4.2 CMP FY89 Metals Monitoring Results

Average and maximum concentrations for the full CMP metals monitoring program for arsenic, cadmium, chromium, copper, lead and zinc are shown in Table 4.4-2, with detailed data in Appendix C. Stations AQ3, AQ5 and AQ5C cover the entire period in accord with the Technical Plan. All other CMP monitoring stations data, including two Basin F mobile sites, comprise results of high event monitoring periods. It should be noted that this analysis includes data from high event samples that missed the laboratory holding time for analysis within 6 months of the sample date.

Results of the CMP FY89 metals monitoring program were generally comparable to CMP FY88 results. Metals levels detected were very low to insignificant with respect to ambient standards and health criteria (to be discussed in Section 4.4.5). With several exceptions, metals levels were fairly consistent across the Arsenal and for the most part were representative of their proximity to the Denver urban environment. For example, the highest average lead value was $0.0291 \mu\text{g}/\text{m}^3$ at AQ7 at the interior western area of the Arsenal. The 24-hour maximum lead value was $0.0984 \mu\text{g}/\text{m}^3$ at AQ5 along the southern RMA perimeter. During FY88, the highest measured average lead value was $0.0270 \mu\text{g}/\text{m}^3$ and the 24-hour maximum value was $0.0576 \mu\text{g}/\text{m}^3$, both at AQ2 along the northwestern perimeter.

The maximum average cadmium value was $0.0012 \mu\text{g}/\text{m}^3$ measured at AQ7 and the maximum 24-hour value was $0.0057 \mu\text{g}/\text{m}^3$ measured at AQ3.

Chromium was detected only at two CMP locations during FY89. The maximum average value was $0.0040 \mu\text{g}/\text{m}^3$ at AQ7; a maximum 24-hour value of $0.0129 \mu\text{g}/\text{m}^3$ was measured at AQ12. In FY88, chromium was detected only at AQ3.

TABLE 4.4-2 SUMMARY OF EMP METALS CONCENTRATIONS FOR FY89
(in $\mu\text{g}/\text{m}^3$)

	CADMIUM	CHROMIUM	COPPER	LEAD**	ZINC	ARSENIC	MERCURY
AVERAGE VALUES							
AG1	0.000877	†	0.075963	0.025911	0.044301	0.000951	†
AG2	0.000878	†	0.072279	0.021127	0.044055	0.001186	†
AG3	0.000598	†	0.096154	0.013714	0.022810	0.000827	†
AG4	0.000346	†	0.062264	0.010202	0.021722	0.000534	†
AG5	0.000669	†	0.081152	0.021277	0.032267	0.000649	†
AG6	0.000514	†	0.079748	0.012073	0.024225	0.000538	†
AG7	0.001172	0.003983	0.046035	0.029060	0.121448	0.000704	†
AG8	0.000666	†	0.056274	0.012125	0.027285	0.002000	†
AG9	0.000596	†	0.078929	0.013056	0.027331	0.000671	†
AG10	0.000489	†	0.073640	0.010578	0.031514	0.000701	†
AG11	0.000360	†	0.073347	0.010040	0.035471	0.000690	†
AG12	†	0.003514	0.075971	0.010195	0.028125	0.000861	†
BFG	†	†	0.048486	0.020637	0.039584	†	†
BFG	†	†	0.058762	0.015919	0.033861	†	†
MAXIMUM VALUES							
AG1	0.004258	†	0.216952	0.060260	0.094310	0.004875	†
AG2	0.003580	†	0.175219	0.045431	0.069639	0.005823	†
AG3	0.005735	†	0.218258	0.058837	0.070024	0.004237	†
AG4	0.001062	†	0.104381	0.034763	0.049773	0.002623	†
AG5	0.005276	†	0.192351	0.098442	0.115558	0.004551	†
AG6	0.001653	†	0.136534	0.027104	0.048587	0.002473	†
AG7	0.001970	0.010208	0.107229	0.057267	0.290812	0.002373	†
AG8	0.001842	†	0.118427	0.029376	0.059744	0.007368	†
AG9	0.001245	†	0.160112	0.031944	0.054549	0.002713	†
AG10	0.001884	†	0.173848	0.035278	0.068372	0.002615	†
AG11	0.001191	†	0.171482	0.029214	0.070754	0.002699	†
AG12	†	0.012863	0.184211	0.030376	0.078852	0.004283	†
BFG	†	†	0.048486	0.020637	0.039584	†	†
BFG	†	†	0.058762	0.015919	0.033861	†	†

† ALL VALUES BELOW ORL

** Calendar quarter lead standard is $1.5 \mu\text{g}/\text{m}^3$. Criteria and guidelines for other metals are outlined in Table 4.4-8.

The highest average copper level, $0.0962 \mu\text{g}/\text{m}^3$ was detected at AQ3 near the northern RMA boundary; the maximum 24-hour value of $0.2183 \mu\text{g}/\text{m}^3$ was measured at AQ3. Copper concentrations at some other sites across RMA are only slightly less than these values. The highest CMP copper levels during FY88 were also measured at AQ3.

A maximum average zinc level of $0.1214 \mu\text{g}/\text{m}^3$ was measured at AQ7. A maximum 24-hour value of $0.2908 \mu\text{g}/\text{m}^3$ was also measured at AQ7. This appeared to be an isolated high measurement (out of five total samples) resulting in the high average concentration at this station. During FY88, the highest zinc levels were measured at AQ1 and AQ2 at the western boundary. During FY89, zinc levels at these stations were next highest after AQ7.

The maximum average arsenic level was $0.0020 \mu\text{g}/\text{m}^3$ and the maximum 24-hour concentration was $0.0074 \mu\text{g}/\text{m}^3$, both at AQ8. During FY88, AQ8 also measured the highest arsenic levels under the CMP.

Mercury was not detected throughout the CMP FY89 Monitoring Program. The lower certified reporting limit for mercury is 0.089 ug. Mercury sampling was conducted during 12 separate episodes for a total of 116 samples.

From the above results, it appears that direct Basin F impacts were minimal at the CMP monitoring locations. This is not to imply that Basin F was not a specific source of several metals components, especially during more intense remedial activities. The Basin F Remedial Monitoring Program was used to complement the CMP for close-in monitoring of remedial impacts, and, indeed for several elements, (i.e. chromium, copper, mercury and zinc) concentrations were higher immediately adjacent to the remedial activity as measured under the Basin F monitoring program. This suggests that metals impacts from Basin F were highly localized and decreased rapidly with distance from the remedial activities.

An analysis of average and maximum metals concentrations for the FY89 high event monitoring program indicated, somewhat surprisingly, that the highest concentrations for almost all of the metals constituents occurred on two or three winter days (January 4, February 9, and March 11, 1989) when intense inversion conditions existed over the Denver area and winds were light to moderate from the south. The inference is that TSP, PM-10 (both previously discussed) and metals were dispersed northward in the direction of the Arsenal. These high event days were selected because of uniformly high TSP levels measured at the RMA monitoring sites and the expected correlation between high TSP concentrations and proportionally high metals levels. This is somewhat in contrast to the CMP FY88 results in which almost all high metals concentrations

were associated with strong and gusty wind conditions; however, the FY88 monitoring period did not include the winter season. The FY89 winter impacts have been documented and three events are discussed further in Section 4.4.4 which provides an analysis of metals source factors.

4.4.3 Assessment of Basin F Metals Impacts

4.4.3.1 CMP Data. In order to fully evaluate remedial impacts from the Basin F cleanup operations, it is necessary to consider all CMP, Basin F Remedial Monitoring Program, and IRA-F data for the entire remedial and post-remedial periods. CMP FY89 metals results were discussed in the previous section. Table 4.4-3 incorporates both CMP FY88 and FY89 data and stratifies results for each monitoring station for the Phase 1 and Phase 2 remediation periods and the Phase 3 post-remedial period. These data reflected no significant metals impacts from Basin F at CMP monitoring sites over the 19-month monitoring period. For each metal element analyzed, variations (at 14 fixed and mobile monitoring stations) were small and likely reflected individual wind and TSP conditions as well as some seasonal differences. There appears to be some decreases in total metals during the post-remedial period. This, however, may have resulted from meteorological and seasonal influences during the five-month post-remedial period. The lack of a significant remediation and post-remediation pattern substantiate the premise that Basin F metals impacts were highly localized and decreased rapidly with distance from the remedial activities. It is also interesting that the CMP metals levels measured during the FY88 and FY89 programs that encompassed the Basin F remediation period were comparable to high event metals data collected under the 1986-1987 Remedial Investigation Program shown in Table 4.4-4 below.

TABLE 4.4-3 SUMMARY OF CNP METALS CONCENTRATIONS BY PHASE
(in $\mu\text{g}/\text{m}^3$)

	CADMIUM	CHROMIUM	COPPER	LEAD**	ZINC	ARSENIC	MERCURY
AVERAGE VALUES							
PHASE 1							
AQ1	0.000727	†	0.052996	0.026991	0.046046	0.000675	†
AQ2	0.000717	†	0.055301	0.027037	0.041856	0.000615	†
AQ3	0.000471	0.002680	0.108094	0.012940	0.025115	0.000472	†
AQ4	†	†	0.054367	0.010960	0.025140	0.000597	†
AQ5	0.001244	†	0.085670	0.019090	0.030828	0.000482	†
AQ6	0.000321	†	0.061958	0.012233	0.021960	0.000428	†
AQ7	0.000440	†	0.081590	0.017839	0.032150	0.000501	†
AQ8	0.000373	†	0.096483	0.012968	0.024437	0.001454	†
AQ9	0.000296	†	0.062143	0.011499	0.022326	0.000444	†
AQ10	†	†	0.043888	0.009889	0.045437	0.001196	†
AQ11	0.000722	†	0.098143	0.012011	0.027587	0.000535	†
AQ12	0.000286	†	0.077228	0.010950	0.018927	0.000508	†
PHASE 2 - STAGE 1							
AQ3	0.001207	†	0.085848	0.019109	0.025026	0.001007	†
AQ5	0.001326	†	0.089639	0.033968	0.042749	0.001026	†
PHASE 2 - STAGE 2							
AQ1	0.001247	†	0.070093	0.028559	0.047217	0.001287	†
AQ2	0.000787	†	0.065431	0.025759	0.049034	0.001609	†
AQ3	0.000329	†	0.081032	0.009143	0.018153	0.000633	†
AQ4	0.000407	†	0.053458	0.012827	0.022954	0.000705	†
AQ5	0.000485	†	0.080511	0.015271	0.027584	0.000719	†
AQ6	0.000947	†	0.073725	0.016783	0.030312	0.000834	†
AQ7	0.001417	0.004364	0.047011	0.022008	0.146214	0.000833	†
AQ8	0.000841	†	0.063551	0.012492	0.028814	0.002445	†
AQ9	0.000769	†	0.074765	0.013648	0.026143	0.000918	†
AQ10	0.000614	†	0.073663	0.011971	0.028115	0.000719	†
AQ11	0.000394	†	0.053639	0.011119	0.030854	0.000811	†
AQ12	†	0.004098	0.050616	0.011193	0.030488	0.001062	†
PHASE 3							
AQ1	†	†	0.091311	0.015979	0.030726	0.000388	†
AQ2	0.001037	†	0.084262	0.013020	0.035341	0.000445	†
AQ3	0.000346	†	0.116425	0.011625	0.018882	0.000361	†
AQ4	†	†	0.075984	0.006749	0.018377	0.000298	†
AQ5	0.000280	†	0.069275	0.013683	0.022226	0.000358	†
AQ6	†	†	0.085772	0.007364	0.018138	0.000242	†
AQ7	†	†	0.042132	0.057267	0.022332	†	†
AQ8	†	†	0.038484	0.009581	0.020646	0.000736	†
AQ9	†	†	0.054277	0.013668	0.021256	†	†
AQ10	†	†	0.093414	0.007323	0.031296	0.000323	†
AQ11	†	†	0.103172	0.006696	0.036533	0.000310	†
AQ12	†	†	0.126681	0.008199	0.023400	0.000458	†
BF3	†	†	0.048486	0.020637	0.039584	†	†
BF6	†	†	0.058762	0.016919	0.033861	†	†

† All values below CRL.

** Calendar quarter lead standard is 1.5 $\mu\text{g}/\text{m}^3$. Criteria and guidelines for other metals are outlined in Table 4.4-8.

Note: Summarized data include samples that missed the laboratory holding time for analysis.

TABLE 4.4-3 (Continued)

	CADMIUM	CHROMIUM	COPPER	LEAD**	ZINC	ARSENIC	MERCURY
MAXIMUM VALUES							
PHASE 1							
AQ1	0.001494	‡	0.107176	0.043839	0.076761	0.001743	‡
AQ2	0.001526	‡	0.107696	0.057614	0.062668	0.001664	‡
AQ3	0.001913	0.009636	0.287323	0.042419	0.069499	0.001872	‡
AQ4	‡	‡	0.094512	0.013698	0.026226	0.000641	‡
AQ5	0.025265	‡	0.155868	0.055761	0.084038	0.001826	‡
AQ6	0.000533	‡	0.132744	0.017265	0.030751	0.000958	‡
AQ7	0.001093	‡	0.193226	0.022883	0.053563	0.001441	‡
AQ8	0.000832	‡	0.193701	0.018730	0.034092	0.004122	‡
AQ9	0.000746	‡	0.160112	0.016663	0.046030	0.000926	‡
AQ10	‡	‡	0.071980	0.010580	0.063189	0.001616	‡
AQ11	0.004098	‡	0.156818	0.017014	0.065236	0.001154	‡
AQ12	0.000697	‡	0.124163	0.016409	0.036511	0.001201	‡
PHASE 2 - STAGE 1							
AQ3	0.005735	‡	0.215672	0.058837	0.070024	0.004237	‡
AQ5	0.005276	‡	0.192351	0.098442	0.115958	0.004551	‡
PHASE 2 - STAGE 2							
AQ1	0.004258	‡	0.216952	0.060260	0.094310	0.001775	‡
AQ2	0.002686	‡	0.088272	0.045431	0.069639	0.001111	‡
AQ3	0.001115	‡	0.167273	0.028106	0.039742	0.003090	‡
AQ4	0.001062	‡	0.104332	0.034763	0.049773	0.002623	‡
AQ5	0.002923	‡	0.123754	0.034095	0.054662	0.003246	‡
AQ6	0.001653	‡	0.136534	0.027104	0.043587	0.002433	‡
AQ7	0.001970	0.010206	0.107229	0.036759	0.029812	0.002377	‡
AQ8	0.001842	‡	0.118427	0.029376	0.059744	0.001366	‡
AQ9	0.001245	‡	0.130539	0.031944	0.054549	0.002713	‡
AQ10	0.001884	‡	0.173848	0.055278	0.068872	0.002615	‡
AQ11	0.001191	‡	0.098640	0.029214	0.070754	0.002699	‡
AQ12	‡	0.012863	0.105145	0.030376	0.078952	0.004283	‡
PHASE 3							
AQ1	‡	‡	0.167180	0.025478	0.039675	0.000574	‡
AQ2	0.003580	‡	0.175219	0.015281	0.046939	0.000599	‡
AQ3	0.001918	‡	0.218258	0.049808	0.031711	0.000882	‡
AQ4	‡	‡	0.104196	0.015888	0.022461	0.000532	‡
AQ5	0.001221	‡	0.184251	0.033756	0.039404	0.000812	‡
AQ6	‡	‡	0.169768	0.010271	0.018864	0.000426	‡
AQ7	‡	‡	0.042132	0.057267	0.022382	‡	‡
AQ8	‡	‡	0.052188	0.020263	0.025110	0.001431	‡
AQ9	‡	‡	0.083477	0.021998	0.021751	‡	‡
AQ10	‡	‡	0.126874	0.009303	0.046506	0.000597	‡
AQ11	‡	‡	0.171482	0.007696	0.059436	0.000553	‡
AQ12	‡	‡	0.184211	0.017406	0.028141	0.000626	‡
BF3	‡	‡	0.048486	0.020637	0.039584	‡	‡
BF6	‡	‡	0.058762	0.016919	0.033861	‡	‡

‡ All values below CRL.

** Calendar quarter lead standard is 1.5 $\mu\text{g}/\text{m}^3$. Criteria and guidelines for other metals are outlined in Table 4.4-8.

Note: Summarized data include samples that missed the laboratory holding time for analysis.

Table 4.4-4 Metals Data Summary for 1986-1987 Remedial Investigation Program

Metals	Detection Limit ($\mu\text{g}/\text{m}^3$)	Range of Values Above Detection Limits ($\mu\text{g}/\text{m}^3$)	
		From TSP Filters ¹	From PM-10 Filters ²
As	0.003	0.005 - 0.012 (2)*	NHADL**
Cd	0.002	0.002 - 0.017 (21)	0.002 - 0.003 (4)
Cr	0.003	0.003 - 0.050 (19)	NHADL
Cu	0.016	0.026 - .912 (81)	0.019 - 0.029 (3)
Hg***	0.063	NHADL	NHADL
Pb	0.008	0.010 - 0.062 (66)	0.009 - 0.037 (6)
Zn	0.010	0.128 - 10.2 (11)	NHADL

Source: ESE, 1988.

1 Total number of TSP filters analyzed = 87.

2 Total number of PM-10 filters analyzed = 7.

* Number of hits above detection limits.

** NHADL - No hits above detection limits.

*** Hg collected on Hopcalite™ media.

4.4.3.2 **Basin F Data.** Table 4.4-5 shows average and maximum metals values for the Basin F Remedial Monitoring Program and for the IRA-F Monitoring Program for Phase 1, Phase 2 and Phase 3 of the remediation activities. All Phase 1 data and Phase 2 (Stage 1 and Stage 2) data were obtained from the Basin F Remedial Monitoring Program and cover the period from March 22, 1988 through May 5, 1989. The Phase 3 data were obtained from the IRA-F Monitoring Program and cover a period from May 6, 1989 through September 30, 1989. Sequential data for both programs are provided in Appendices L and Q.

Figures 4.4-1 through 4.4-7 graphically depict maximum and average concentrations for each metal component. The data are also stratified by the remedial phase periods.

The metals summaries and corresponding figures show that several metals components, in particular chromium, copper, zinc and mercury, appeared to be impacted by Basin F remedial operations, especially at the sites immediately around the Basin F perimeter. Chromium, for example, reached its highest levels during the Phase 1 remedial operations at the four monitoring sites immediately surrounding the Basin F perimeter (Figure 4.4-1). The maximum average value was $0.0200 \mu\text{g}/\text{m}^3$

TABLE 4.4-5

SUMMARY OF BASIN F TRAFRIFIS METALS CONCENTRATIONS FOR PHASES 1-3
in ug/m3

AVERAGE VALUES

	CD	CR	CU	PB	ZN	AS	HG	NH3
PHASE 1								
BF1	0.0006	0.0128	0.1163	0.0148	0.0688	0.0008	1.6	
BF2	0.0008	0.0101	0.1516	0.0175	0.0727	0.0009	1.6	
BF20	0.0005	0.0126	0.1539	0.0172	0.0951	0.0010	1.8	
BF3	0.0005	0.0176	0.0944	0.0138	0.0776	0.0007	1.5	
BF4	0.0006	0.0206	0.1258	0.0160	0.0779	0.0009	1.5	
BF5	0.0006	0.0026	0.0712	0.0144	0.0506	0.0012	1.2	284.1
BF6	0.0005	0.0032	0.0746	0.0146	0.0472	0.0006	1.4	280.9
BF7	0.0006	0.0023	0.0791	0.0140	0.0493	0.0007	1.4	ND
PHASE 2 - STAGE 1								
BF1	0.0009	0.0036	0.0569	0.0200	0.2243	0.0008	1.3	
BF2	0.0006	0.0037	0.0646	0.0220	0.0931	0.0011	1.2	
BF20	0.0006	0.0045	0.0687	0.0215	0.1476	0.0013	ND	
BF3	0.0007	0.0026	0.0566	0.0181	0.1952	0.0009	1.2	
BF4	0.0007	0.0028	0.0578	0.0202	0.1494	0.0009	ND	
BF5	0.0006	0.0031	0.0522	0.0159	0.3260	0.0008	ND	ND
BF6	0.0005	0.0027	0.0679	0.0167	0.0524	0.0006	ND	ND
BF7	0.0005	0.0033	0.0684	0.0173	0.1915	0.0007	ND	ND
RIFS1	0.0023	ND	0.0790	0.0327	0.0539	0.0010	ND	ND
RIFS10	0.0031	ND	0.0851	0.0405	0.0509	0.0013	ND	ND
RIFS2	0.0013	ND	0.0784	0.0276	0.0337	0.0010	ND	ND
PHASE 2 - STAGE 2								
BF1	0.0008	0.0026	0.0429	0.0134	0.1052	0.0007	ND	
BF2	0.0005	0.0031	0.0528	0.0148	0.0716	0.0008	ND	
BF20	0.0005	0.0034	0.0817	0.0152	0.0730	0.0007	ND	
BF3	0.0006	0.0025	0.0546	0.0137	0.1203	0.0007	ND	
BF4	0.0006	0.0029	0.0533	0.0135	0.0430	0.0007	ND	
BF5	0.0023	0.0022	0.0377	0.0134	0.0832	ND	ND	ND
BF6	0.0004	0.0032	0.0445	0.0145	0.0403	0.0008	ND	ND
BF7	0.0006	0.0024	0.0701	0.0133	0.0814	ND	ND	ND
RIFS1	0.0017	0.0141	0.0999	0.0232	0.0413	0.0008	ND	ND
RIFS10	0.0042	ND	0.1072	0.0231	0.1105	0.0007	ND	ND
RIFS2	0.0011	ND	0.0899	0.0218	0.0363	0.0010	ND	ND
PHASE 3								
FC1	0.0019	ND	0.1434	0.0255	0.0217	0.0006	ND	
FC2	0.0027	ND	0.0961	0.0170	0.0182	0.0005	ND	
FC20	0.0015	ND	0.1366	0.0178	0.0195	0.0005	ND	
BF3/FC3	0.0021	ND	0.1081	0.0164	0.0204	0.0005	ND	
BF4/FC4	0.0023	ND	0.1095	0.0166	0.0196	0.0005	ND	
BF5	0.0012	ND	0.1148	0.0214	0.0250	0.0005	ND	
FC5	0.0007	ND	0.1516	0.0092	0.0257	0.0004	ND	
BF7	0.0008	ND	0.1466	0.0199	0.0197	0.0006	ND	
RIFS1	0.0010	ND	0.1362	0.0223	0.0303	0.0006	ND	

LEGEND: CD Cadmium ZN Zinc
 CR Chromium AS Arsenic
 CU Copper HG Mercury
 PB Lead NH3 Ammonia

TABLE 4.4-5

(CONTINUED)

MAXIMUM VALUES

	CD	CR	CU	PB	ZN	AS	HG	NH3
PHASE 1								
BF1	0.0032	0.1520	0.3851	0.0258	0.5471	0.0025	4.7	
BF2	0.0149	0.1350	1.4980	0.0614	0.8106	0.0037	7.3	
BF2C	0.0019	0.1350	0.6349	0.0397	0.5623	0.0026	7.3	
BF3	0.0036	0.2083	0.5750	0.0292	0.5054	0.0018	7.3	
BF4	0.0037	0.2852	0.5349	0.0317	0.6651	0.0024	5.0	
BF5	0.0022	0.0087	0.1758	0.0434	0.2557	0.0136	2.1	321.9
BF6	0.0015	0.0123	0.1413	0.0260	0.1449	0.0018	4.9	366.8
BF7	0.0035	0.0038	0.1174	0.0261	0.2284	0.0013	6.3	ND
PHASE 2 - STAGE 1								
BF1	0.0037	0.0149	0.0839	0.0499	0.9703	0.0024	1.5	
BF2	0.0016	0.0083	0.1226	0.0428	0.4959	0.0031	3.0	
BF2C	0.0013	0.0082	0.0983	0.0366	0.4762	0.0025	ND	
BF3	0.0016	0.0037	0.0858	0.0430	0.9151	0.0032	2.1	
BF4	0.0016	0.0038	0.1004	0.0436	1.1316	0.0026	ND	
BF5	0.0016	0.0075	0.0975	0.0260	3.3576	0.0028	ND	ND
BF6	0.0013	0.0044	0.1065	0.0312	0.1476	0.0012	ND	ND
BF7	0.0012	0.0110	0.1116	0.0247	1.0643	0.0012	ND	ND
RIFS1	0.0067	ND	0.1490	0.1080	0.1110	0.0038	ND	ND
RIFS1D	0.0065	ND	0.1570	0.0674	0.0655	0.0039	ND	ND
RIFS2	0.0032	ND	0.1680	0.0779	0.0676	0.0034	ND	ND
PHASE 2 - STAGE 2								
BF1	0.0069	0.0037	0.0804	0.0249	0.5420	0.0024	ND	
BF2	0.0015	0.0093	0.1112	0.0311	0.6365	0.0025	ND	
BF2C	0.0009	0.0082	0.1178	0.0239	0.3462	0.0018	ND	
BF3	0.0016	0.0032	0.0983	0.0244	0.6185	0.0024	ND	
BF4	0.0015	0.0080	0.1025	0.0257	0.1040	0.0025	ND	
BF5	0.0199	0.0029	0.0694	0.0191	0.4289	ND	ND	ND
BF6	0.0008	0.0064	0.0936	0.0292	0.0819	0.0017	ND	ND
BF7	0.0016	0.0035	0.1039	0.0182	0.5766	ND	ND	ND
RIFS1	0.0040	0.0141	0.1600	0.0553	0.0854	0.0023	ND	ND
RIFS1D	0.0042	ND	0.1360	0.0381	0.3350	0.0067	ND	ND
RIFS2	0.0021	ND	0.1310	0.0325	0.0501	0.0023	ND	ND
PHASE 3								
FC1	0.0033	ND	0.1910	0.0489	0.0272	0.0006	ND	
FC2	0.0043	ND	0.1610	0.0493	0.0268	0.0006	ND	
FC2D	0.0029	ND	0.2290	0.0502	0.0280	0.0005	ND	
BF3/FC3	0.0033	ND	0.1420	0.0475	0.0280	0.0006	ND	
BF4/FC4	0.0040	ND	0.1490	0.0482	0.0296	0.0005	ND	
BF5	0.0021	ND	0.1750	0.0471	0.0393	0.0005	ND	
FC5	0.0007	ND	0.2160	0.0141	0.0350	0.0004	ND	
BF7	0.0013	ND	0.1940	0.0411	0.0285	0.0006	ND	
RIFS1	0.0021	ND	0.2360	0.0401	0.0465	0.0006	ND	

LEGEND: CD Cadmium ZN Zinc
 CR Chromium AS Arsenic
 CU Copper HG Mercury
 PB Lead NH3 Ammonia

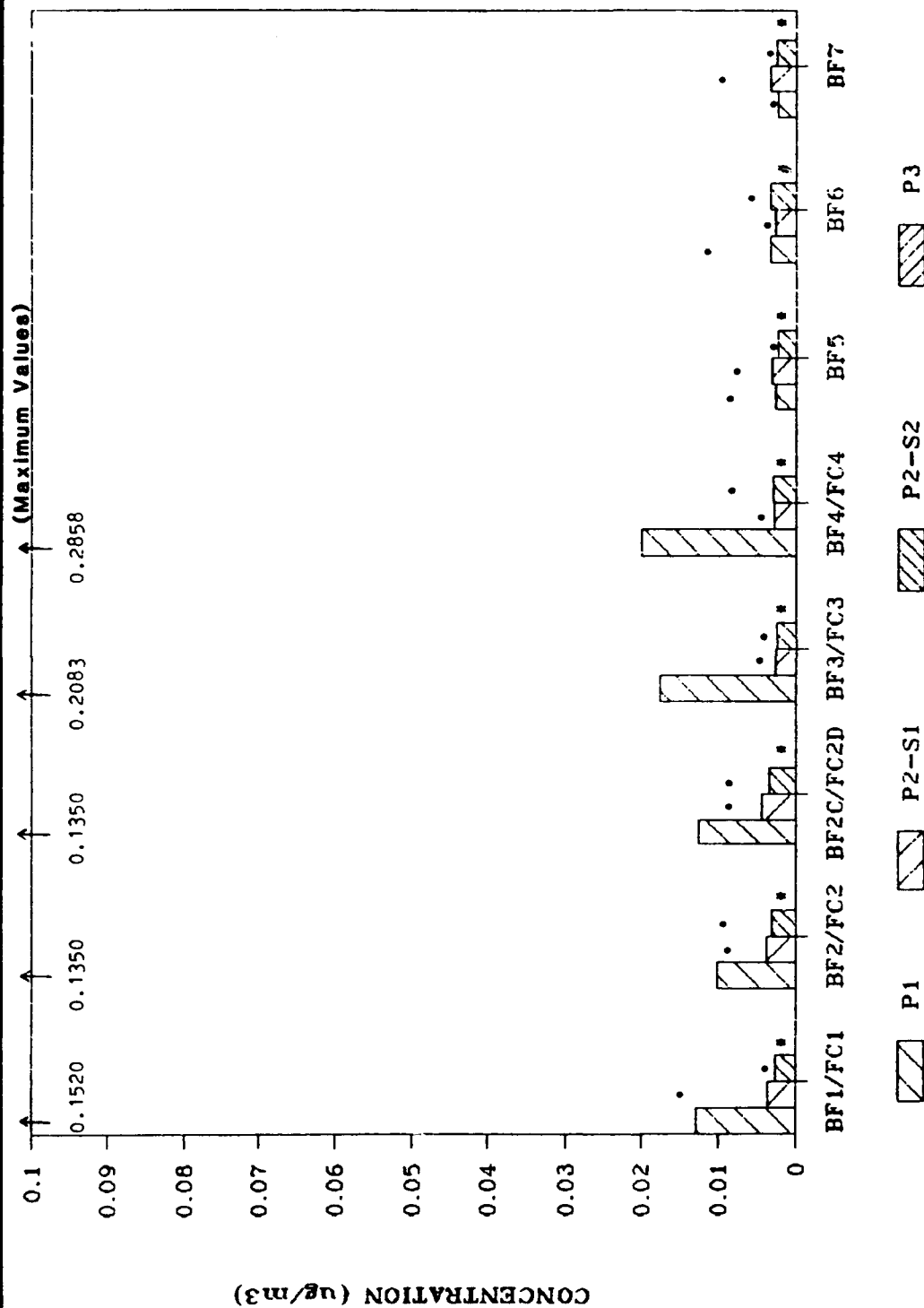


Figure 4.4-1
Chromium Results
by Phase
CMPAR FY89

Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

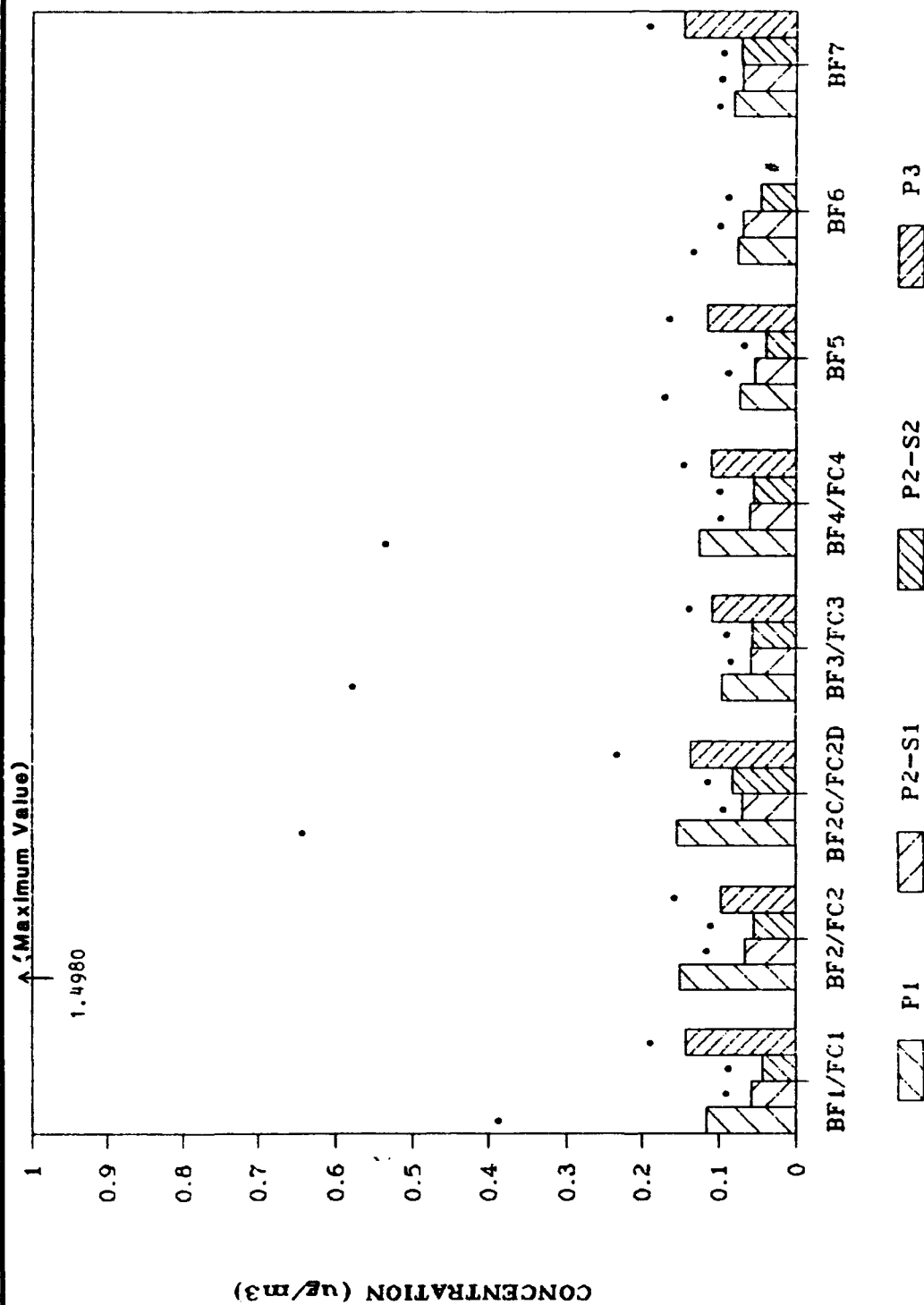


Figure 4.4-2
Copper Results
by Phase

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Commerce City, Colorado
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CMPAR FY89

- MAXIMUM 24-HOUR CONCENTRATION
- # NO SAMPLES TAKEN DURING THIS PHASE
- * NOT DETECTED DURING THIS PHASE

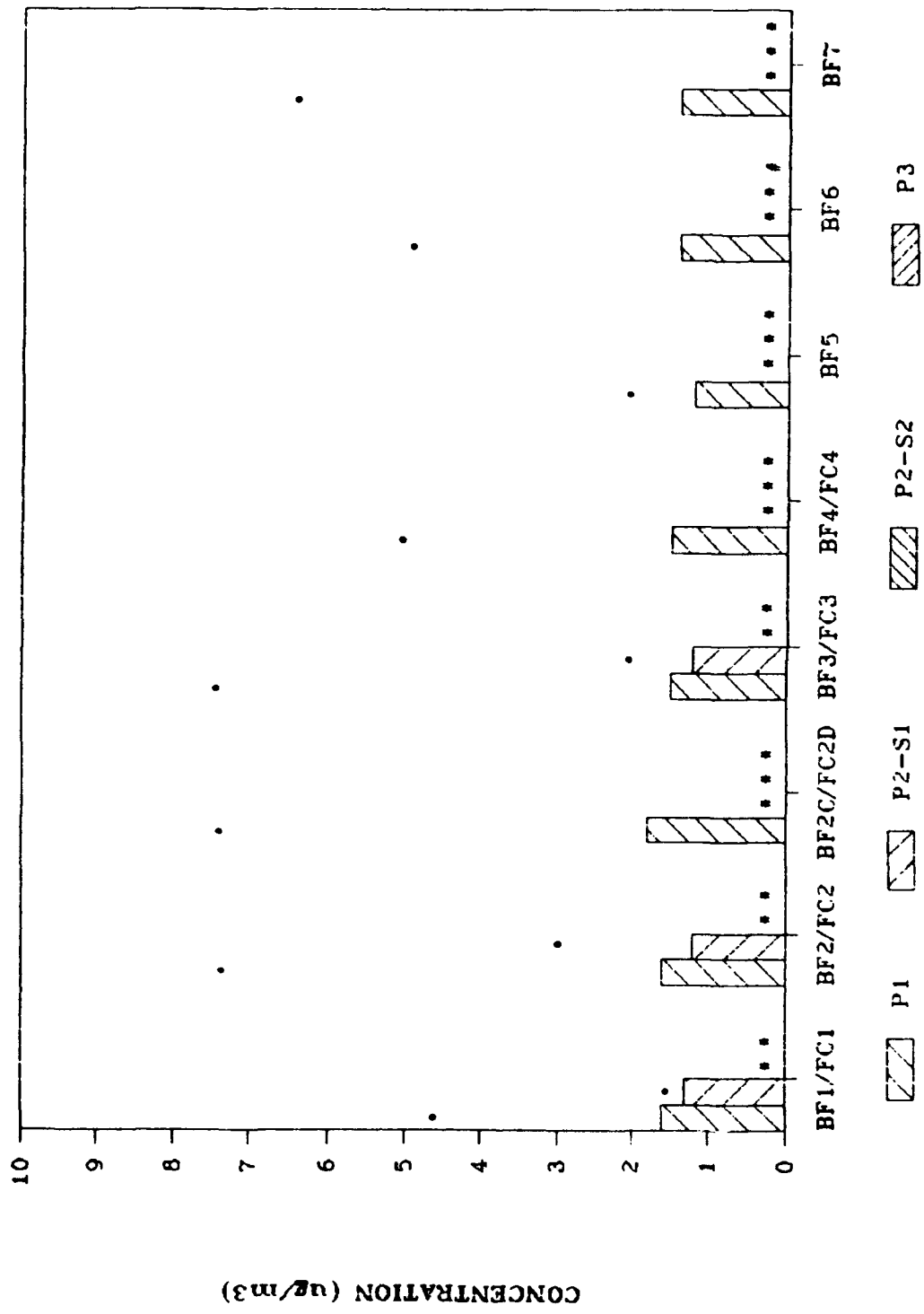


Figure 4.4-3

Mercury Results
by Phase

CMP AR FY 89

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Commerce City, Colorado
Prepared by:
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- MAXIMUM 24-HOUR CONCENTRATION
- # NO SAMPLES TAKEN DURING THIS PHASE
- * NOT DETECTED DURING THIS PHASE

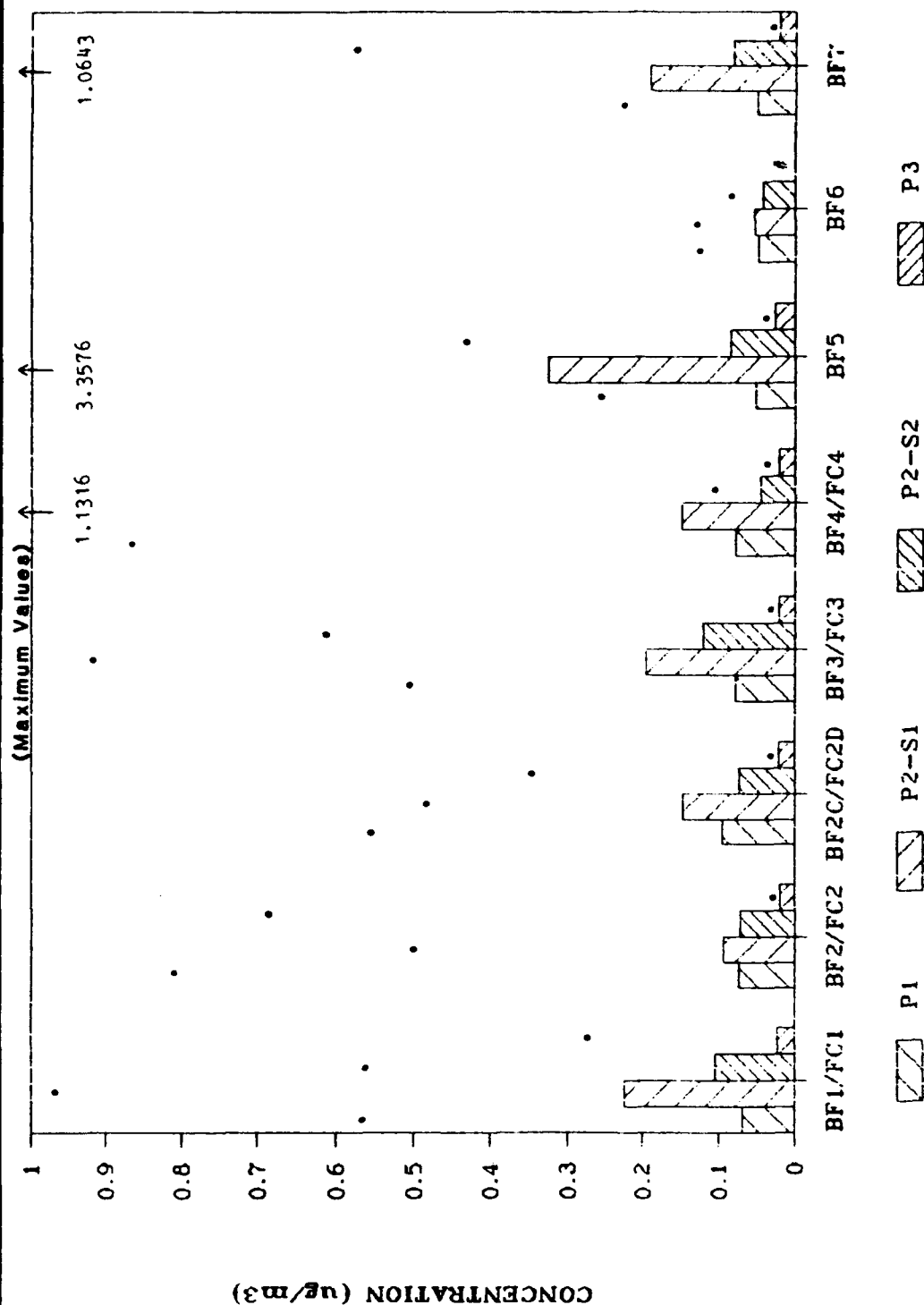


Figure 4.4-4

Zinc Results
by Phase

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Commerce City, Colorado

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- MAXIMUM 24-HOUR CONCENTRATION
- # NO SAMPLES TAKEN DURING THIS PHASE
- * NOT DETECTED DURING THIS PHASE

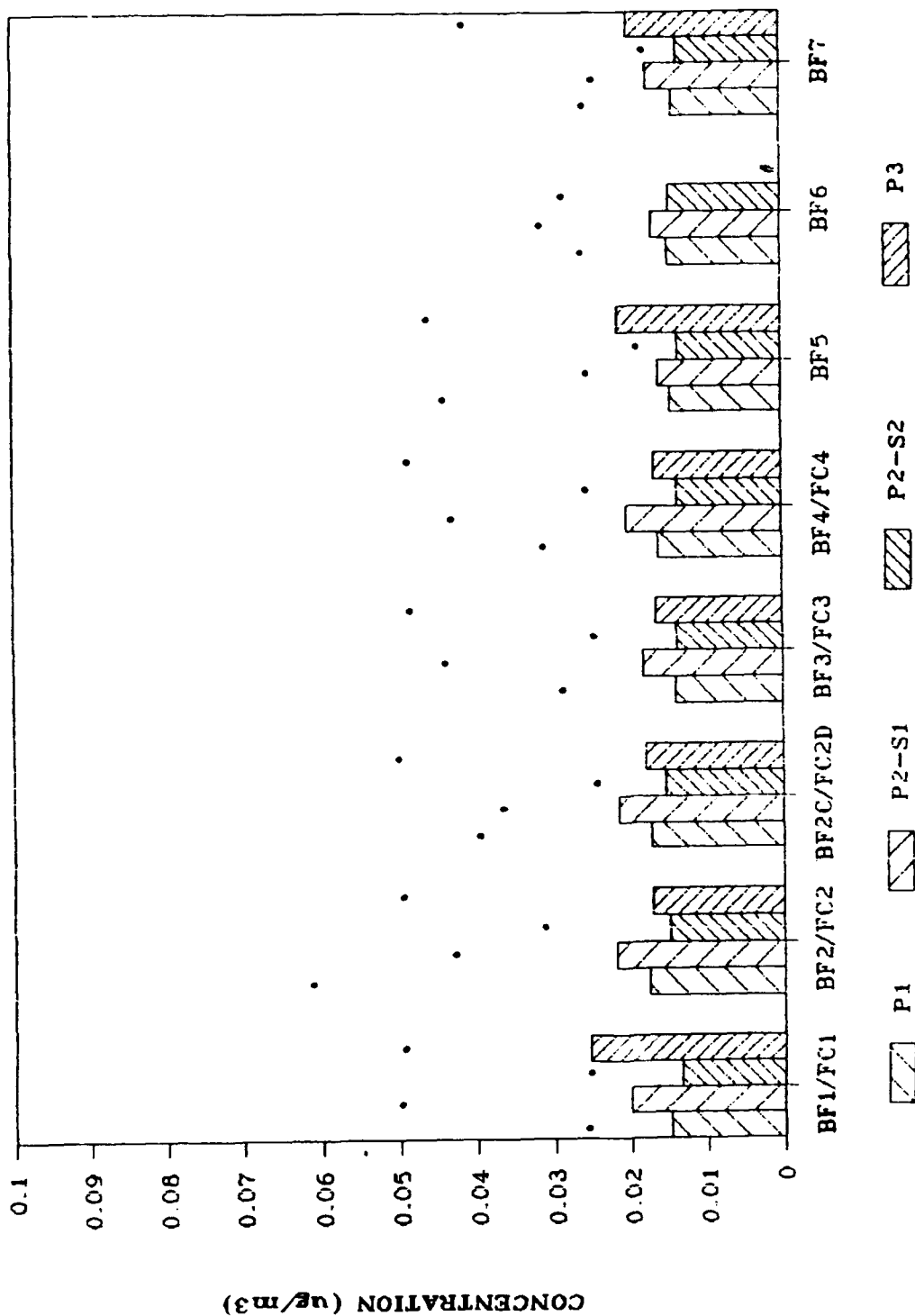


Figure 4.4-5

Lead Results
by Phase

CMPAR FY89

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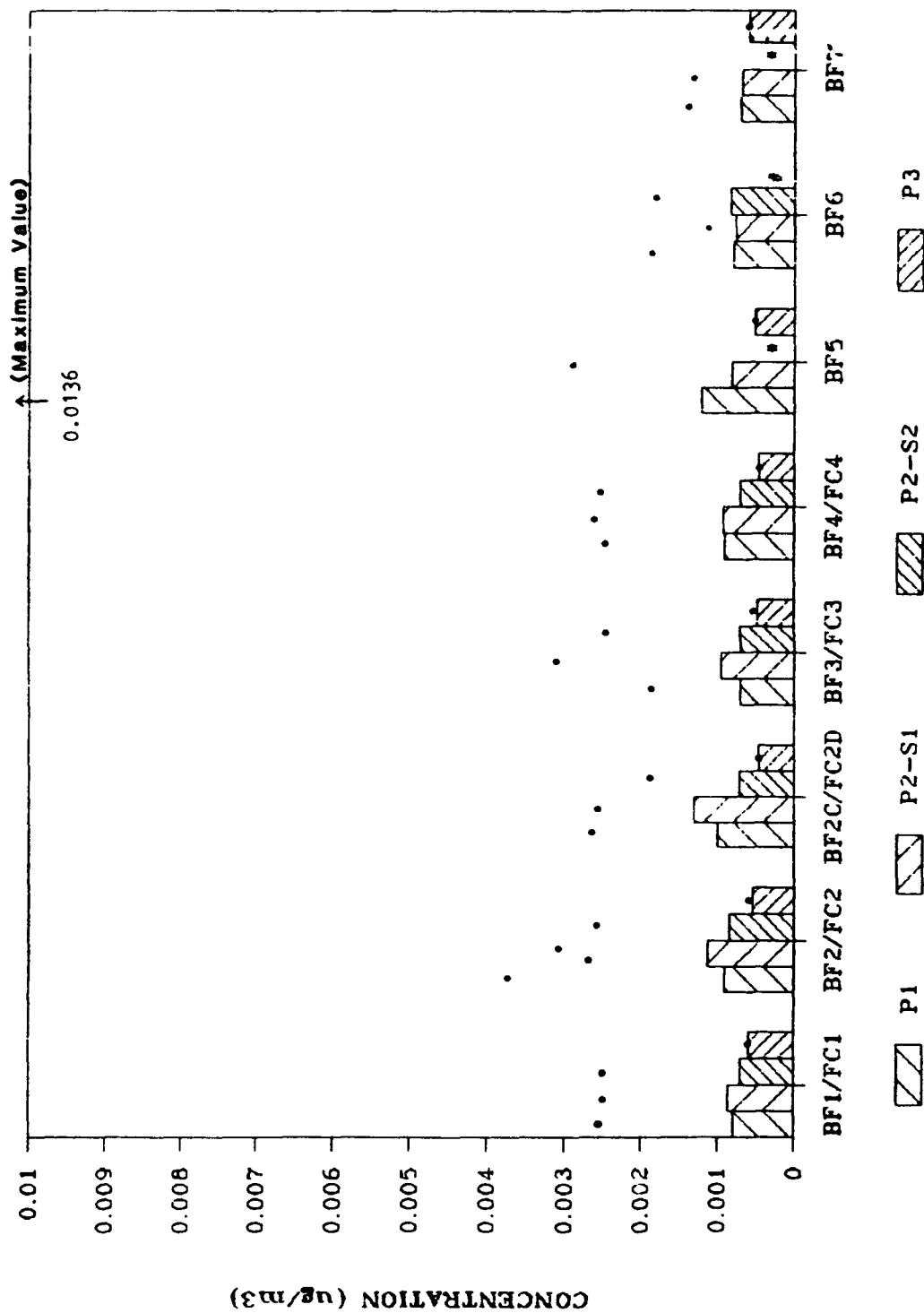


Figure 4.4-6
Arsenic Results
by Phase

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U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

CMPAR FY 89

- MAXIMUM 24-HOUR CONCENTRATION
- # NO SAMPLES TAKEN DURING THIS PHASE
- * NOT DETECTED DURING THIS PHASE

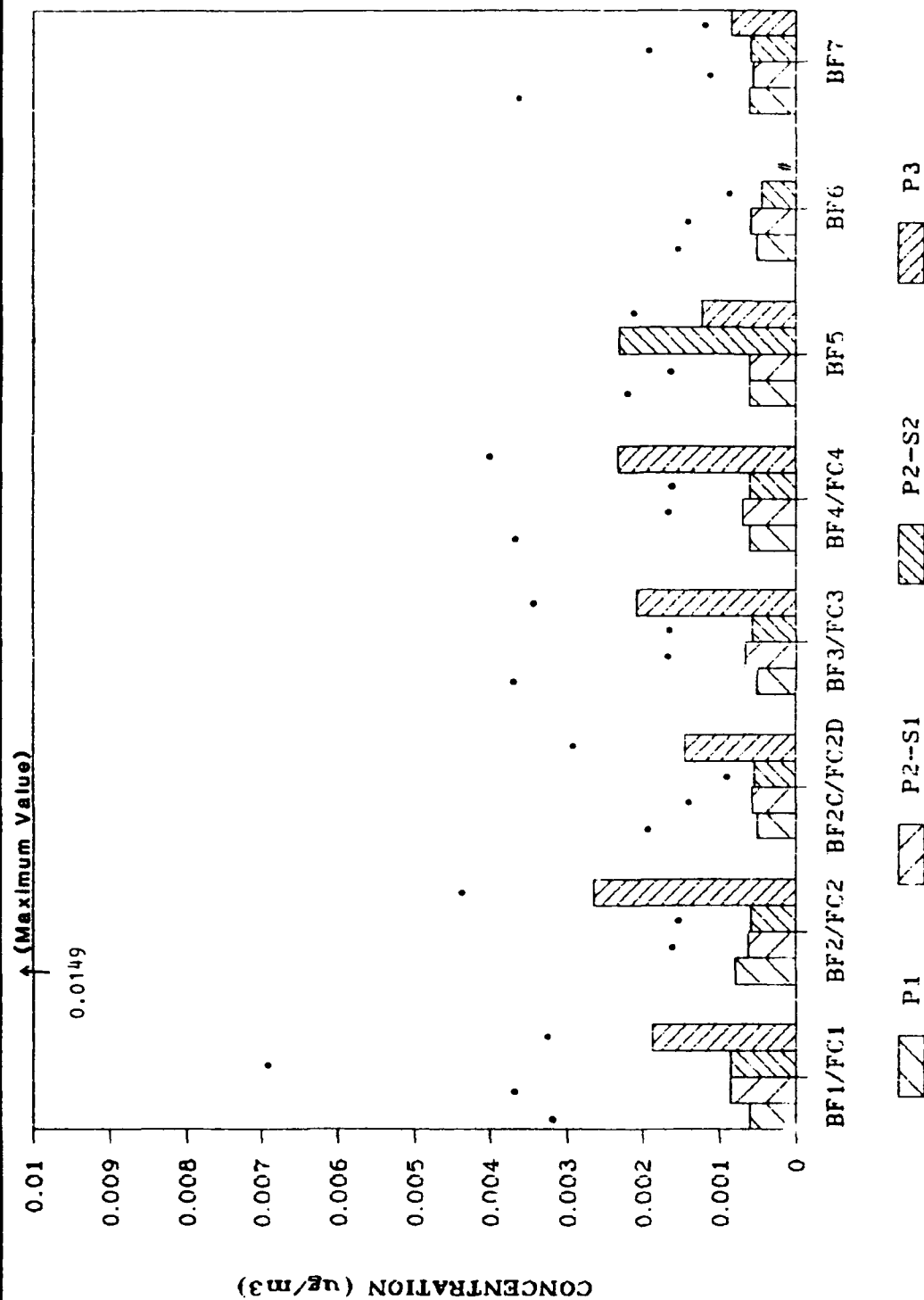


Figure 4.4-7
Cadmium Results
by Phase

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U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
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Ebasco Services, Inc.

CMPAR FY89

- MAXIMUM 24-HOUR CONCENTRATION
- # NO SAMPLES TAKEN DURING THIS PHASE
- * NOT DETECTED DURING THIS PHASE

at BF4 and the maximum 24-hour value was $0.2858 \mu\text{g}/\text{m}^3$, also at BF4; these values decreased substantially at the more distant Basin F monitoring sites (BF5, BF6 and BF7), and were comparable to maximum values at CMP monitoring sites.

During the Phase 2 period, chromium levels surrounding Basin F decreased by a factor of 10 or more and were comparable to levels at the more distant Basin F and CMP monitoring sites. During Phase 3, chromium was not detected at any of the sites.

It would appear from these results that some chromium impacts occurred in the immediate vicinity of Basin F during the early stages of the remediation program. These impacts were highly localized and decreased to typical background levels at the conclusion of the remediation activities. The health impacts of the higher chromium levels during remediation, and other metals, will be discussed in Section 4.4.5.

A similar, though less conclusive, pattern was shown for copper levels in the vicinity of Basin F (Figure 4.4-2). Moderately high copper concentrations were measured at the Basin F perimeter sites during Phase 1 and decreased with distance. The maximum average value was $0.1539 \mu\text{g}/\text{m}^3$ at BF2 and the maximum 24-hour value was $1.4980 \mu\text{g}/\text{m}^3$ at BF2. During Phase 2 maximum copper levels at the Basin F perimeter decreased to values comparable to the more distant Basin F monitoring sites and the CMP monitoring sites. However, during the Phase 3 monitoring period mean copper concentrations again increased to the highest levels measured during the 19-month monitoring period. One explanation is that this was a seasonal phenomenon, as almost all CMP monitoring sites across the Arsenal also showed increased copper levels during the Phase 3 period. Nevertheless, several high maximum 24-hour copper concentrations measured near the perimeter of Basin F during the Phase 1 remediation period indicate that Basin F may have been a source of copper emissions during more intensive cleanup activities.

Mercury measurements during the Phase 1 monitoring period were roughly equivalent at all seven sites (Figure 4.4-3). A maximum 24-hour value of $7.3 \mu\text{g}/\text{m}^3$ occurred during Phase 1 at BF2 and BF3. Some very sporadic, localized mercury impacts were noted during Phase 2 (Stage 1), with minimal to no impact recorded during Phase 2 (Stage 2) or Phase 3.

Zinc concentrations followed an atypical pattern with the highest levels at Basin F being recorded during the Phase 2 (Stage 1) dirt moving and landscaping period, rather than the Phase 1 remediation period (Figure 4.4-4). This could be a function of the soil being moved during the covering period; however, this could also be a function of an analytic problem in that subsequent quality assurance review identified high zinc (and arsenic) levels in some TSP filters prior to

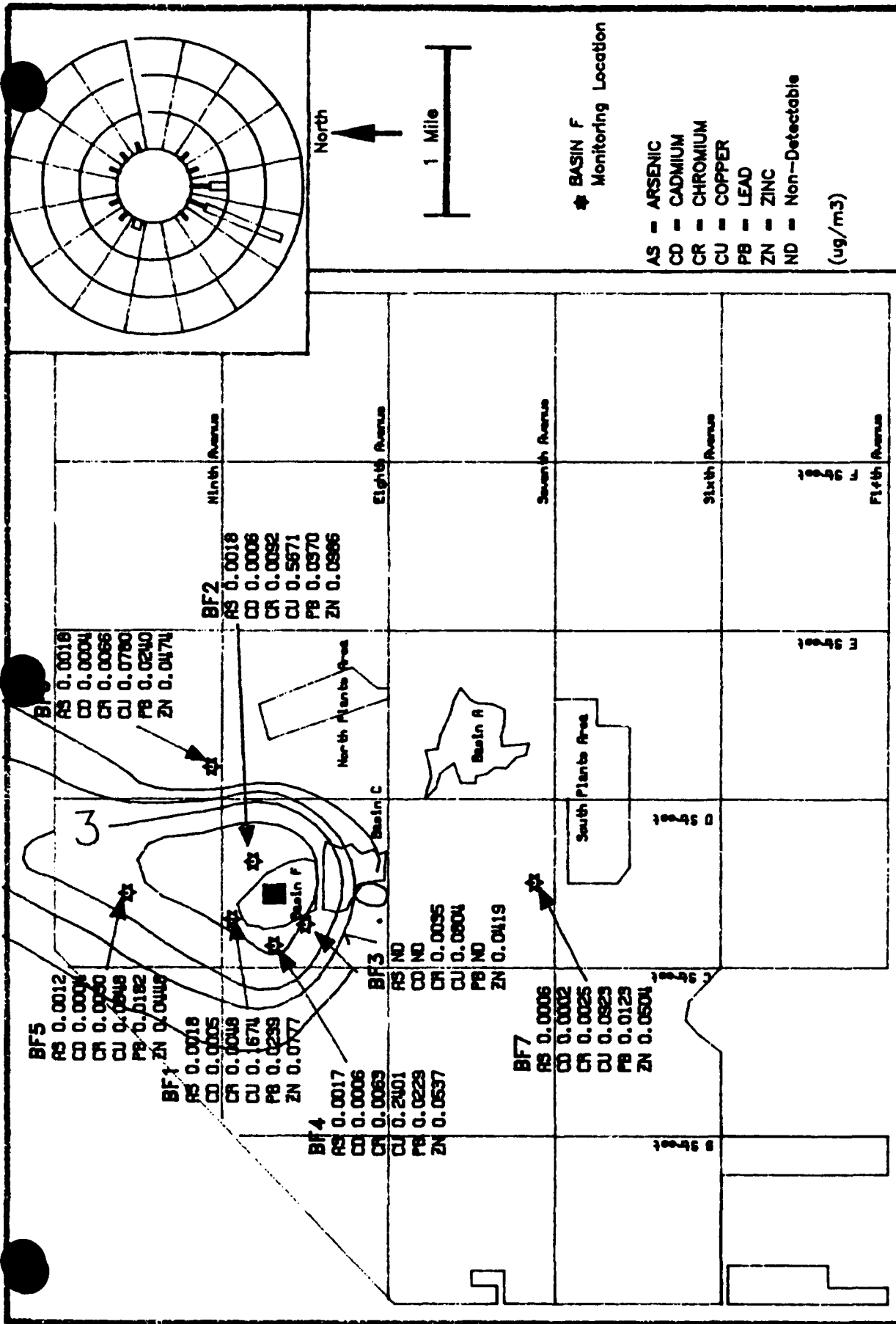
sampling. Nevertheless, the zinc levels are reported here as analyzed. The maximum average zinc level recorded in Phase 2 was $0.3260 \mu\text{g}/\text{m}^3$ at BF5; the maximum 24-hour level was $3.3576 \mu\text{g}/\text{m}^3$ at BF5. During Phase 3, zinc levels at Basin F were comparable to other CMP concentrations across the Arsenal.

Arsenic and lead concentrations reflected minimal changes during the Phase 1, Phase 2 and Phase 3 periods and were comparable to other measurements at the CMP monitoring sites (Figures 4.4-5 and 4.4-6). A one time 24-hour maximum arsenic level of $0.0136 \mu\text{g}/\text{m}^3$ was measured at BF5 during Phase 1; all other 24-hour maximum values were equivalent to CMP levels. The maximum 24-hour Basin F lead value during Phase 1, $0.0614 \mu\text{g}/\text{m}^3$ at BF2, was less than the maximum CMP 24-hour value of $0.0984 \mu\text{g}/\text{m}^3$ measured at AQ5 during Phase 2, Stage 1 and less than the value $0.108 \mu\text{g}/\text{m}^3$ measured at RIFS1 during Phase 2, Stage 1. There appeared to be no Basin F impacts from these metals.

Cadmium concentrations indicated small differences at all Basin F stations during the Phase 1 and Phase 2 periods (Figure 4.4-7). During Phase 3, cadmium concentrations were actually slightly higher than during the earlier Basin F remediation periods. It is noted that the cadmium levels were nevertheless very low; the highest average concentration was $0.0027 \mu\text{g}/\text{m}^3$ measured at BF2. There is no explanation why cadmium levels were slightly higher in the vicinity of Basin F during the post-remedial phase. It is noted that the highest 24-hour cadmium concentration, $0.0253 \mu\text{g}/\text{m}^3$, was measured at CMP station AQ5 at the extreme southern end of the Arsenal. As will be discussed in Section 4.4.5, all cadmium concentrations were well below general toxic guidelines.

Ammonia was monitored during the Basin F program at three sites (BF5, BF6 and BF7) on one day per week which was predicted to have the greatest impacts from Basin F activities. Monitoring was conducted during both Phase 1 and Phase 2. Detectable levels were collected only during Phase 1 with a maximum reading of $822 \mu\text{g}/\text{m}^3$ at BF5 and a highest average reading of $284 \mu\text{g}/\text{m}^3$, also at BF5. No ammonia sampling was conducted in Phase 3.

Another approach to assessing remedial progress is to consider Basin F impacts that were observed on individual days during the remedial and post-remedial periods. All Basin F air monitoring during the Phase 1 period was conducted for worst-case, 24-hour periods based on dispersion model analysis and remedial activity. An example of the dispersion of metals resulting from Basin F remedial activities (Phase 1) is shown in Figure 4.4-8. This figure shows metals concentrations for September 6, 1988, with X/Q dispersion values overlaying the monitoring data for seven Basin F stations. This type of analysis identifies, to the fullest extent, the potential dispersion of metals and other contaminants resulting from remedial actions. On this day winds



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FIGURE 4.4-8

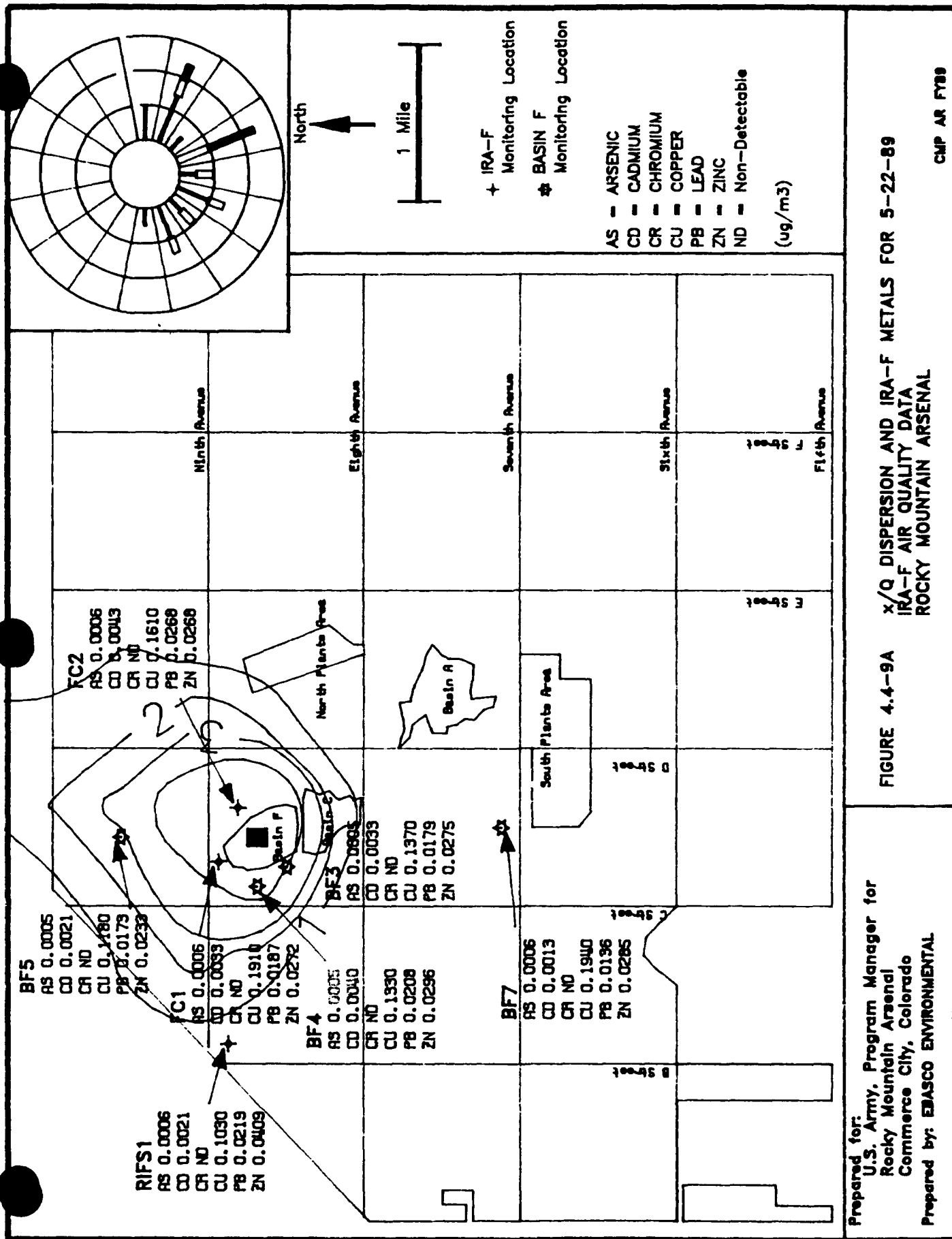
X/Q DISPERSION AND BASIN F METALS FOR 9/06/88
 BASIN F AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL
 CAMP AR FY88

were from the south-southwest at moderate speeds. Peak levels for most metals occurred at the closest downstream sites. Sites further downstream, as well as upstream, from Basin F measured lesser values, thereby substantiating the dispersion pattern and identifying Basin F as a potential metals source. Consider next the dispersion of metals on May 22, 1989, a day in the post-remedial period (Phase 3). The X/Q dispersion pattern and the reported concentrations for this day are shown in Figure 4.4-9A. The dispersion pattern is similar to the one for the Phase 1 day. However, inspection of the data reveals a decrease in concentrations for several metals as well as a diverse pattern of concentrations that are no longer related to the Basin F source dispersion patterns.

In these two examples, the basin is most easily identified as a Phase 1 source for zinc and chromium, as their concentrations clearly decreased from Phase 1 to Phase 3; the concentration trends of the other metals were less defined. Arsenic concentrations showed reductions in levels at the downwind sites and minimal changes upwind. Copper had substantially lower concentrations at the immediate downwind site BF2 as well as at site BF4; values at all other sites were slightly higher. Note, however, that the highest Phase 3 levels of copper, zinc and arsenic were measured at the upwind off-site BF7, with concentrations of similar magnitude. These results indicate that the observed concentrations most likely were background levels or from non-Arsenal sources and therefore, indicate a reduced impact from Basin F. Cadmium and lead levels did not follow the dispersion patterns very closely on either of the example days; no general conclusions can be drawn regarding Basin F impacts on these metals from the data.

A second Phase 3 comparison to the Phase 1 example day is shown on Figure 4.4-9B, which shows the X/Q dispersion pattern and reported metals concentrations for August 14, 1989. This day again had similar dispersion and meteorological characteristics to the Phase 1 day previously discussed. Although only sites next to Basin F were sampled on this date, it is readily apparent that most of the metals concentrations were much lower than the levels on the Phase 1 day. These data further support the conclusion that Basin F impacts were evident during Phase 1 but were significantly reduced by Phase 3.

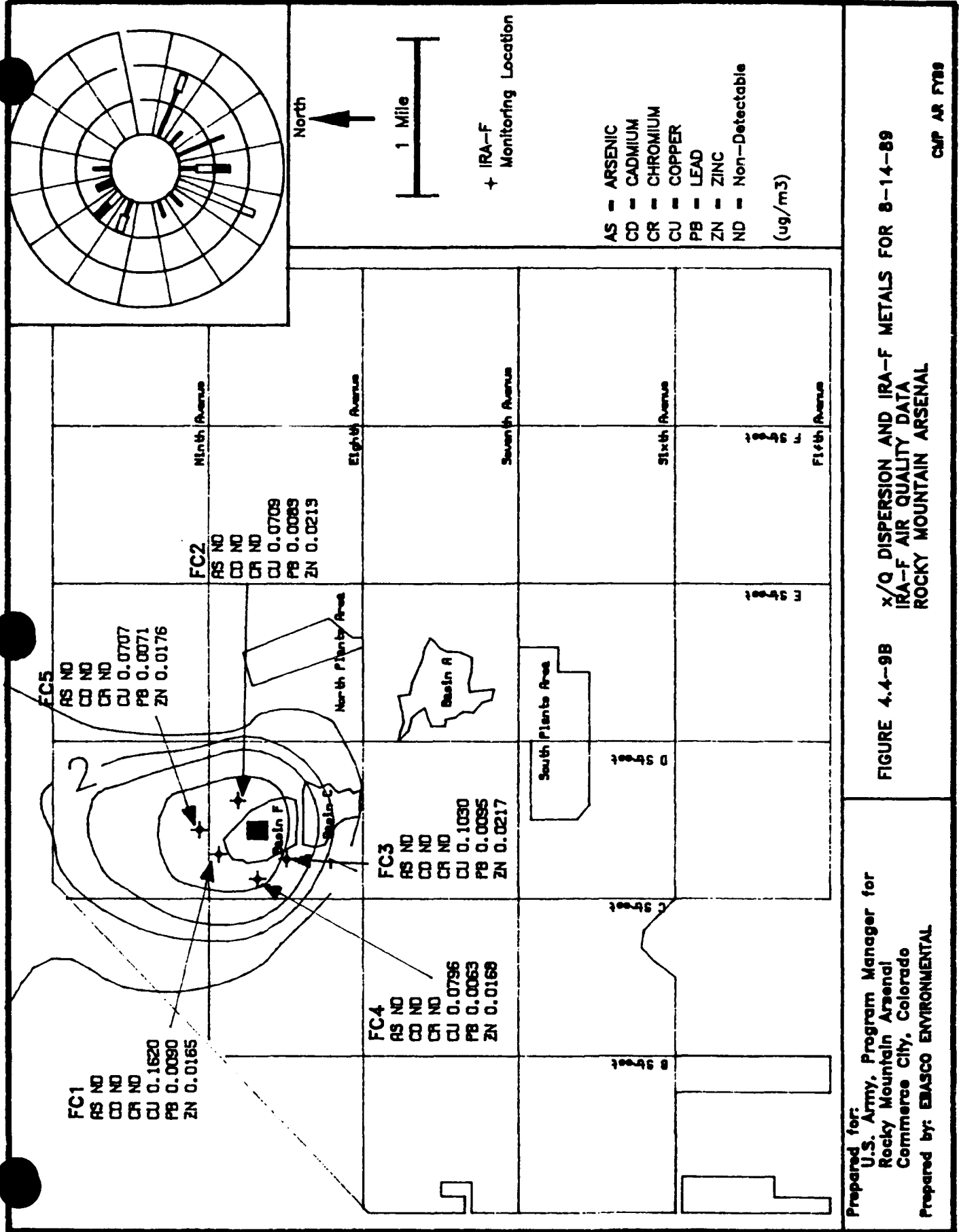
4.4.3.3 Combined CMP and Basin F Data Analyses. Individual CMP and Basin F metals monitoring data for the three phases of the remedial monitoring programs have been shown in Tables 4.4-3 and 4.4-5. Figures 4.4-10 through 4.4-13A provide a depiction of all available data across the Arsenal complex. Corresponding wind roses are also shown in these figures. These data confirm individual results previously discussed in addition to showing the influences of meteorology and atmospheric dispersion impacts, distance from a potential source, and the source influence itself. For example, Figures 4.4-10 and 4.4-10A show average and maximum concentrations



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FIGURE 4.4-9A

X/Q DISPERSION AND IRA-F METALS FOR 5-22-89
 IRA-F AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL



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FIGURE 4.4-9B x/q DISPERSION AND IRA-F METALS FOR 8-14-89
 IRA-F AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

during Phase 1 for CMP sites and seven Basin F sites, and indicate the highest levels of chromium, copper, lead and zinc adjacent to Basin F and immediately downstream from the source, as reflected by the prevailing wind flow. Station BF2, which was located in the northeast corner of the Basin immediately downstream from the prevailing flow and which was the closest station to much of the remedial activity, measured highest concentrations for most metals (there were several exceptions, i.e., the highest chromium levels were at BF4). In general, except for cadmium and lead, metals values decreased with distance from the Basin F source. In the case of lead, the decrease most likely reflected higher metals levels associated with greater ground disturbances around Basin F rather than substantively greater percentages of metals deposited in the Basin F surrounding soils. It is noted that several metals compounds (i.e., cadmium, lead, and arsenic) showed highest concentrations along the RMA boundaries during the Phase 1 period, suggesting that there were neither Basin F nor Arsenal sources.

Figure 4.4-11 reflects Phase 2 (Stage 1) distribution of metals and confirms decreases in several metals compounds that may have resulted from Basin F remediation (i.e., chromium, copper and mercury). These metals indicated little variation across the Arsenal. Since TSP levels continued to remain high around Basin F during this phase of remediation with similar dispersion patterns, a logical conclusion is that potential metals contaminants associated with the Basin F source resulted from the remediation process and were reduced during the reclamation efforts.

Figures 4.4-12, 4.4-12A, 4.4-13 and 4.4-13A show the distribution of average and maximum metals concentrations at Basin F and across RMA during the Phase 2 (Stage 2) and Phase 3 post-remedial period. All metals levels were typical of background regional levels. Dispersion conditions were similar to the previous remedial phase periods, inferring that any metals components that were indigenous to the Basin F compound were contained during the remediation process, although as previously noted, cadmium was slightly higher in the vicinity of Basin F during the Phase 3 period.

4.4.4 Analysis of Metals Source Factors

It appears that metals monitored in the RMA vicinity resulted from many causes. Several metal elements may have been deposited in the soil around Basin F; others may have resulted from industrial and transportation activities in the Denver metropolitan area. There were overriding baseline levels of all the metals components typical of the area's semi-urban environment. With the exception of transportation and industry related components, the metals were probably transported primarily by wind-blown dust and soil particles. This is evident from Figure 4.4-14, which shows the relationship between total metals (the sum of concentrations of all targets) collected under the Basin F program and TSP levels at Basin F during all remediation phases for

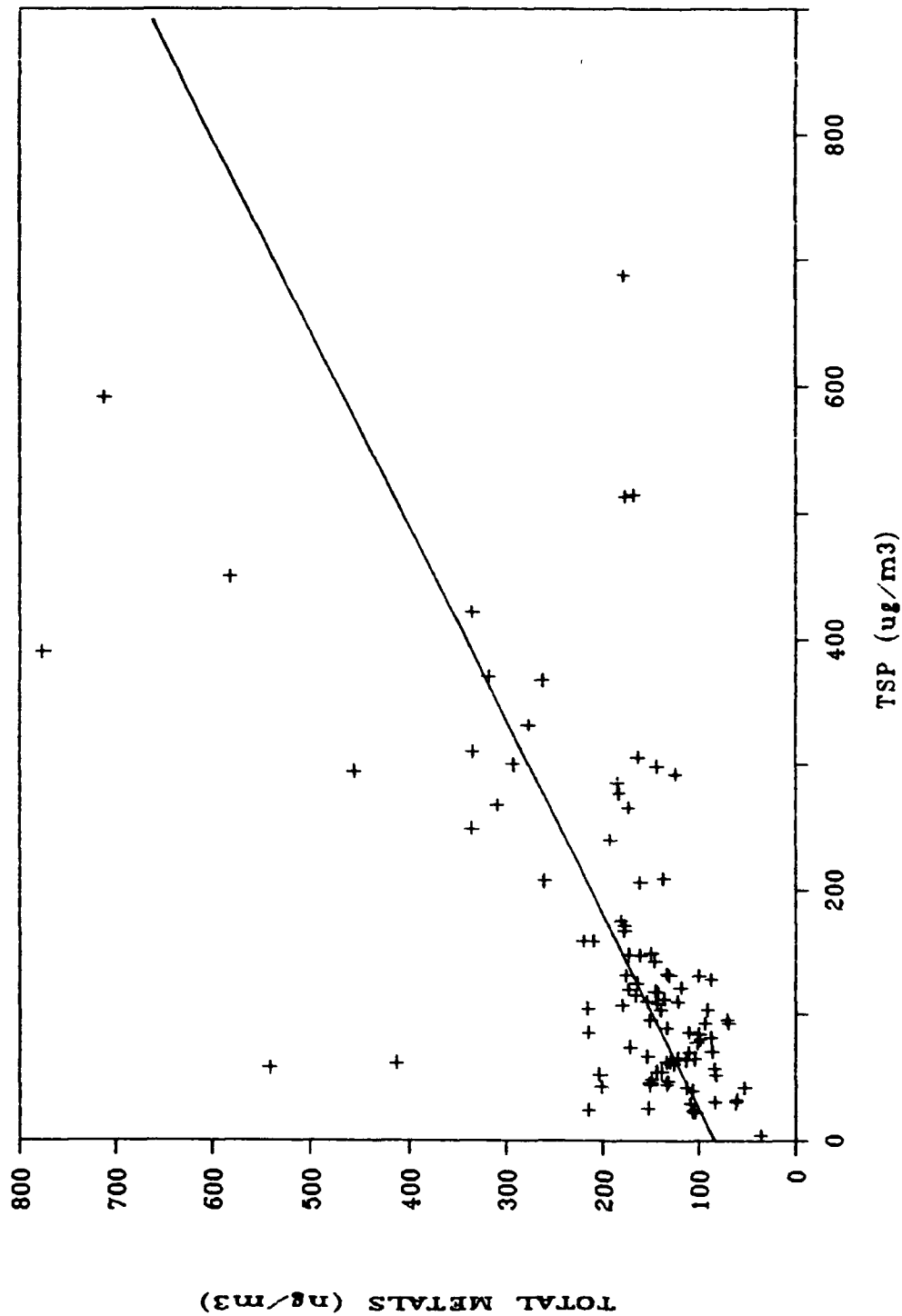


Figure 4.4-14

TSP Concentration vs.
Total Metals
Concentration at Basin F
Site 2

CMPAR FY89

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Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

R. L. Stollar & Associates, Inc.
Ebosco Services, Inc.

Site BF2. Although there were typical variations in this database (the correlation factor is 0.68), the general inference is that the higher the TSP levels, the higher the levels of metals collected in the sample filters.

As higher TSP ambient concentrations were associated with strong winds and particularly with wind gusts, it is not surprising that relatively high metals were also associated with strong and gusty winds. In the CMP FY88 Assessment Report, a table was presented (Table 4.2-16) that showed in almost every case, the highest metal concentration for each element at each monitoring station was associated with average 24-hour winds in excess of 10 mph and wind gusts in excess of 25 mph (Stollar, 1989). During FY89, however, the very highest metals readings were not associated with strong winds, as discussed below.

Table 4.4-6 presents a table that includes both FY88 and FY89 data and compares maximum metals concentrations at each monitoring site with average and maximum wind conditions. The Basin F remedial phases are also identified in the table. Again, many of the highest metals concentrations were associated with strong wind events, especially for cadmium, arsenic and copper at several of the stations. However, there was a very significant difference in the FY89 data. The FY88 data did not include winter season monitoring, while CMP FY89 encompassed a full 12 months of monitoring. Approximately two-thirds of the cases with the highest metals levels (covering the 19-month monitoring period), occurred on three winter days; these were January 4, 1989, February 9, 1989, and March 11, 1989. These were not days with especially strong winds or gusts, but were days with very high TSP levels at all RMA monitoring sites that experienced impacts from metropolitan Denver. On each of these days, the prevailing wind was from the south or south-southwest and TSP levels in downtown Denver were extremely high. On January 4, 1989, the Denver CAMP site measured $472 \mu\text{g}/\text{m}^3$, on February 9, CAMP measured $240 \mu\text{g}/\text{m}^3$, and on March 11, CAMP measured $164 \mu\text{g}/\text{m}^3$. TSP was above average at all other metropolitan Denver stations, as was PM-10. This may have resulted in higher metals levels drifting into the Arsenal area along with suspended particulates under strong inversion conditions (and most likely associated brown cloud conditions). Two of these cases (January 4 and February 9, 1989) have been previously documented for TSP and PM-10 (Figures 4.2-17, 4.2-18 and 4.3-1). The metals distribution for March 11, 1989, which was a "high event" day is shown in Figure 4.4-15. On this day wind speeds averaged 8 mph with hourly speeds ranging from 2 mph to 10 mph. There were also no substantial wind gusts on this day. The atmospheric dispersion pattern (not shown on this figure) indicates transport of pollutants from the south-southwest to the north-northeast (in the direction of the Arsenal from metropolitan Denver). This is substantiated by primarily south-southwest and south winds shown on the wind rose insert on Figure 4.4-15. Atmospheric stability reflected inversion conditions through the morning and late afternoon to evening periods, with

Table 4.4-5 Observed Maximum Metals Concentrations
and Associated Wind Speeds at CMP Sites

Metal	Maximum Concentration (ug/m ³)	Phase	Date	Maximum Wind Speed Gust (mph)	Average Wind Speed (mph)	# Hours Gust ≥ 22 mph	Dominant Wind Direction
Station AQ1 (15 Samples)							
Cadmium	0.00426	P2-S2	03-11-89	14.9	7.8	0	SSW
Chromium	ND	-	-	-	-	-	-
Copper	0.21695	P2-S2	03-11-89	14.9	7.8	0	SSW
Lead	0.06026	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.09431	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00487	P2-S2	03-17-89	49.5	14.9	8	WNW
Mercury	ND	-	-	-	-	-	-
Station AQ2 (11 Samples)							
Cadmium	0.00358	P3	05-28-89	25.8	10.3	3	SSW
Chromium	ND	-	-	-	-	-	-
Copper	0.17522	P3	05-28-89	25.8	10.3	3	SSW
Lead	0.05761	F1	03-22-88	25.4	9.2	5	NNE
Zinc	0.06964	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00582	P2-S2	03-17-89	49.5	14.9	8	WNW
Mercury	ND	-	-	-	-	-	-
Station AQ3 (52 Samples)							
Cadmium	0.00573	P2-S1	01-28-89	39.7	14.6	13	N
Chromium	0.00964	P1	07-14-88	16.2	9.8	0	SSW
Copper	0.28732	F1	09-24-88	14.1	8.6	0	S
Lead	0.05894	P2-S1	02-09-89	17.6	5.9	0	S
Zinc	0.07002	P2-S1	01-04-89	16.9	6.3	0	S
Arsenic	0.00424	P2-S1	02-15-89	20.3	6.0	0	NNW
Mercury	ND	-	-	-	-	-	-
Station AQ4 (13 Samples)							
Cadmium	0.00106	P2-S2	03-23-89	30.5	9.9	5	NNE
Chromium	ND	-	-	-	-	-	-
Copper	0.10438	P2-S2	03-11-89	14.9	7.8	0	SSW
Lead	0.03476	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.04977	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00262	P2-S2	03-11-89	14.9	7.8	0	SSW
Mercury	ND	-	-	-	-	-	-

Table 4.4-6

(continued)

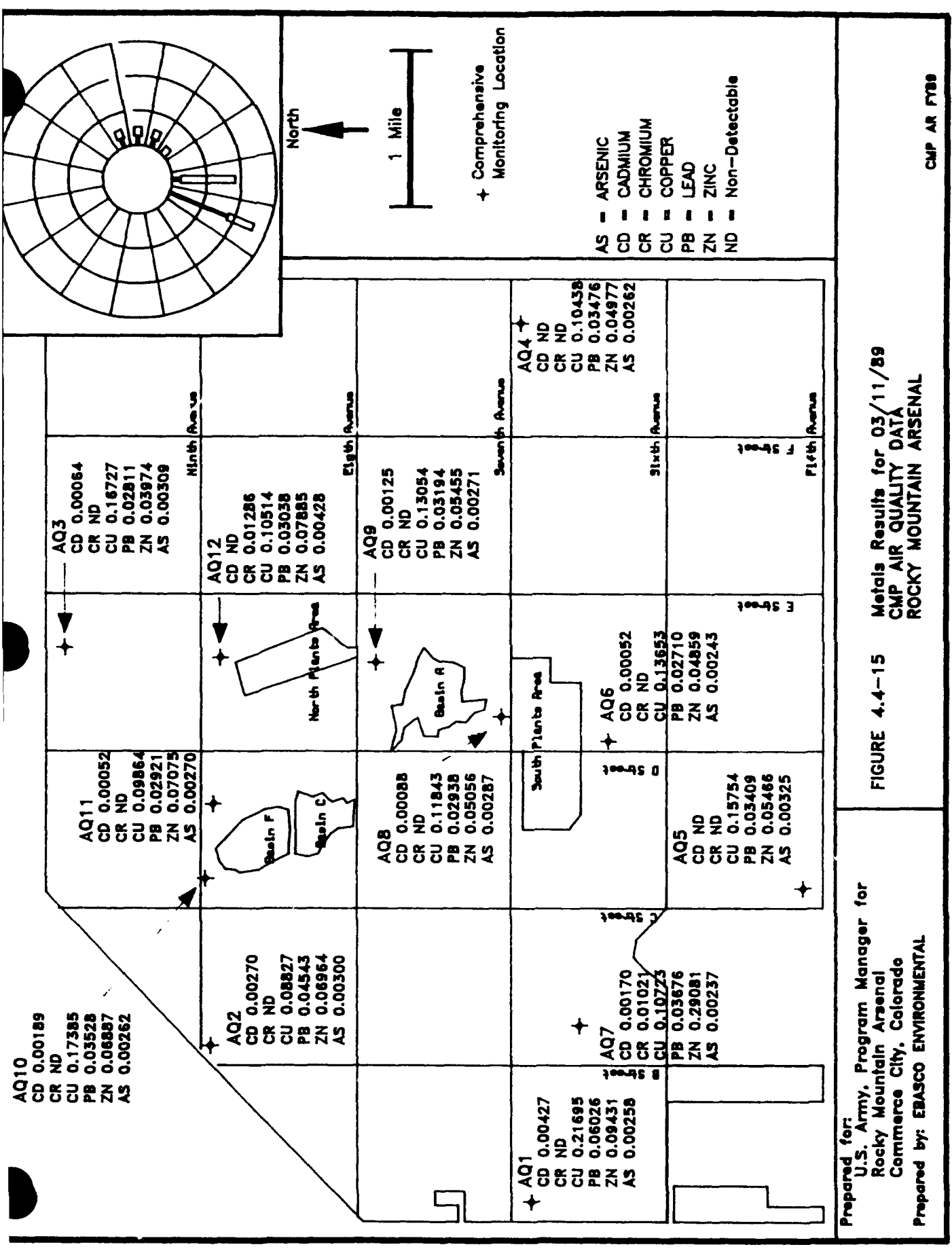
Metal	Maximum Concentration ($\mu\text{g}/\text{m}^3$)	Phase	Date	Maximum Wind Speed Gust (mph)	Average Wind Speed (mph)	# Hours Gust ≥ 22 mph	Dominant Wind Direction
Station A05 (52 Samples)							
Cadmium	0.02526	P1	05-21-88	30.9	15.4	9	NNW
Chromium	ND	-	-	-	-	-	-
Copper	0.19235	P2-S1	01-04-89	16.9	6.3	0	S
Lead	0.09844	P2-S1	02-09-89	17.6	5.9	0	S
Zinc	0.11596	P2-S1	01-04-89	16.9	6.3	0	S
Arsenic	0.00455	P2-S1	02-15-89	20.3	6.0	0	NNW
Mercury	ND	-	-	-	-	-	-
Station A06 (8 Samples)							
Cadmium	0.00165	P2-S2	04-22-89	28.8	12.2	6	SSW
Chromium	ND	-	-	-	-	-	-
Copper	0.13653	P2-S2	03-11-89	14.9	7.8	0	SSW
Lead	0.02710	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.04859	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00243	P2-S2	03-11-89	14.9	7.8	0	SSW
Mercury	ND	-	-	-	-	-	-
Station A07 (5 Samples)							
Cadmium	0.00197	P2-S2	04-22-89	28.8	12.2	6	SSW
Chromium	0.01021	P2-S2	03-11-89	14.9	7.8	0	SSW
Copper	0.19323	P1	04-03-88	26.8	11.9	4	WSW
Lead	0.05727	P3	06-21-89	31.7	10.5	7	SW
Zinc	0.29081	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00237	P2-S2	03-11-89	14.9	7.8	0	SSW
Station A08 (13 Samples)							
Cadmium	0.00184	P2-S2	04-04-89	41.9	11.3	7	NW
Chromium	ND	-	-	-	-	-	-
Copper	0.19370	P1	04-03-88	26.8	11.9	4	WSW
Lead	0.02938	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.05974	P2-S2	04-22-89	28.8	12.2	6	SSW
Arsenic	0.00737	P2-S2	05-04-89	50.8	9.0	6	ENE
Mercury	ND	-	-	-	-	-	-

Table 4.4-a

(continued)

Metal	Maximum Concentration (ug/m3)	Phase	Date	Maximum Wind Speed Gust (mph)	Average Wind Speed (mph)	# Hours Gust >22 mph	Dominant Wind Direction
Station AQ9 (8 Samples)							
Cadmium	0.00124	P2-S2	03-11-89	14.9	7.8	0	SSW
Chromium	ND	-	-	-	-	-	-
Copper	0.16011	P1	11-04-88	36.4	23.9	7	WNW
Lead	0.03194	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.05455	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00271	P2-S2	03-11-89	14.9	7.8	0	SSW
Mercury	ND	-	-	-	-	-	-
Station AQ10 (13 Samples)							
Cadmium	0.00188	P2-S2	03-11-89	14.9	7.8	0	SSW
Chromium	ND	-	-	-	-	-	-
Copper	0.17385	P2-S2	03-11-89	14.9	7.8	0	SSW
Lead	0.03528	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.06887	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00261	P2-S2	03-11-89	14.9	7.8	0	SSW
Mercury	ND	-	-	-	-	-	-
Station AQ11 (13 Samples)							
Cadmium	0.00410	P1	05-03-88	33.0	6.5	1	ENE
Chromium	ND	-	-	-	-	-	-
Copper	0.17146	P3	07-03-89	47.8	12.0	8	SSW
Lead	0.02921	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.07075	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00270	P2-S2	03-11-89	14.9	7.8	0	SSW
Mercury	ND	-	-	-	-	-	-
Station AQ12 (9 Samples)							
Cadmium	0.00070	P1	04-21-88	25.7	10.8	5	NE
Chromium	0.01286	P2-S2	03-11-89	14.9	7.8	0	SSW
Copper	0.12421	P3	05-28-89	25.8	10.8	3	SSW
Lead	0.03038	P2-S2	03-11-89	14.9	7.8	0	SSW
Zinc	0.07885	P2-S2	03-11-89	14.9	7.8	0	SSW
Arsenic	0.00428	P2-S2	03-11-89	14.9	7.8	0	SSW

Note: Includes data from samples that missed the laboratory holding time for analysis.



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FIGURE 4.4-15 Metals Results for 03/11/89
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

neutral conditions during the mid-day period. Table 4.4-6 shows that March 11, 1989 was by far the day when concentrations reached maximum levels for almost all metals constituents occurring at AQ1, AQ4, AQ6, AQ10 and AQ12; the meteorological data suggest that the source of these high metals concentrations was not indigenous to the Arsenal.

As noted, most metals concentrations at RMA on these winter inversion episode days were higher than CMP monitoring results under the various high wind scenarios. Nevertheless, chromium, zinc and mercury were higher as measured under the Basin F Remedial Monitoring Program adjacent to Basin F remediation activities. During the Phase 3 post-remedial period, Basin F concentrations for the most part decreased to levels below those at the RMA boundaries. The inference, as previously stated, is that higher concentrations of chromium, zinc and mercury resulted during Basin F remediation activity in the immediate vicinity of the basin and decreased to typical RMA interior baseline levels after remediation was completed. Higher metals levels also occurred across RMA from lifting of soils during high wind and high gust conditions. Nevertheless, somewhat higher metals concentrations occurred during metropolitan Denver inversion episodes when suspended particulates, including metals constituents, drifted northward across the Arsenal area.

Table 4.4-7 below summarizes the locations of maximum metals concentrations from both the CMP and Basin F monitoring programs throughout the 19-month period. The implications of maximum short-term (24-hour) and long-term metals concentration with respect to toxic guidelines will be discussed in the next section.

Table 4.4-7 Maximum Concentrations Measured at RMA for CMP and Basin F/IRA-F Concurrent Programs $\mu\text{g}/\text{m}^3$

Metal	Maximum Long-Term Average Concentration	Location	Phase	Maximum 24-Hour Concentration	Location	Phase
Arsenic	0.0016	AQ2	P2-S2	0.0136	BF5	P1
Cadmium	0.0027	FC2	P3	0.0253	AQ5	P1
Chromium	0.0200	BF4	P1	0.2858	BF4	P1
Copper	0.1539	BF2	P1	1.4980	BF2	P1
Lead	0.0573	AQ7	P3	0.0984	AQ5	P2-S1
Zinc	0.3260	BF5	P2-S1	3.3576	BF5	P2-S1
Mercury	1.8000	BF2	P1	7.3000	BF2	P1

4.4.5 Assessment of Metals Concentrations Relative to Toxic Guidelines

In order to assess the significance of the measured metals concentrations relative to health standards and available toxic guidelines, a literature search was performed to compile standards and guidelines. This was necessary because the USEPA and the State of Colorado have promulgated standards and published air toxic guidelines only for lead. Sources that were reviewed included the ACGIH TLV Handbook, the NIOSH Pocket Guide to Chemical Hazards, and the NATICH Database Report on State, Local, and EPA Air Toxic Activities (ACGIH, 1986; NIOSH, 1985; U.S. Department of Commerce, 1988).

The tabulation of guideline concentrations is presented in Table 4.4-8. For each target metal, the name and Chemical Abstract number is presented, along with TLV and TLV/420 concentrations, expressed as $\mu\text{g}/\text{m}^3$. The reason for presenting the TLV/420 is that this value is used by many states in air toxic regulations as an annual concentration guideline not to be exceeded. Two additional columns of Table 4.4-8 present "typical" state toxic guidelines, both for short-term (1- to 24-hour) and annual averages. There is a great deal of variability in air toxic guideline concentrations from state to state, sometimes by large factors. Therefore, in order to determine typical values the median of all NATICH listed values was selected.

The highest CMP FY89 and Basin F metals concentrations for the remediation period and post-remediation period were then compared to the appropriate guideline values. For example, 24-hour sample results were compared to the 24-hour guideline, and the long-term average values of the monitoring period were compared to the annual guideline. This is a conservative approach, as most of the sample days in the CMP and Basin F database were based on high event, or worst-case scenarios. The last two columns of Table 4.4-8 show the percentage of the highest CMP and Basin F program maximum 24-hour and average metals concentrations to the guidelines. It can be seen that all metals results were well below levels of concern with the possible exception of chromium. Chromium maximum levels, however, decreased significantly during the Phase 2 and post-remedial Phase 3 periods.

Chromium results indicate a 24-hour maximum concentration of $0.2858 \mu\text{g}/\text{m}^3$, which was 57 percent of the typical guideline value; the long-term average value was $0.0200 \mu\text{g}/\text{m}^3$, or 20 percent of the annual guideline. However, these levels resulted mainly from the one maximum 24-hour measurement at BF4 during Phase 1. All other maximum chromium measurements at Basin F were considerably lower. The second highest chromium measurement was $0.2083 \mu\text{g}/\text{m}^3$ at BF3, 42 percent of the short-term guideline. Chromium decreased with distance from Basin F, and was not detected during Phase 3.

Table 4.4-8 RMA Target Metals Compounds Comparison to Health Guidelines

Target Name	CAS #	TLV/420* ($\mu\text{g}/\text{m}^3$)	EPA Standards	Typical Guidelines**	PHASES 1 AND 2			
					Maximum**		% of Guideline	
					24-Hr	Long-Term	24-Hr	Long-Term
Arsenic	7440-38-2	200		1	0.0136	0.0016	1.36	1.60
Cadmium	7440-43-9	50		0.4	0.0253	0.0023	6.32	2.30
Chromium	7440-47-3	50		0.5	0.2858	0.0200	57.16	20.00
Copper	7440-50-8	1000		10	1.4980	0.1539	14.98	1.54
Lead	7439-92-1	150	1.5***		0.0984	0.0340	N/A	2.27
Zinc	7440-66-6	5000 ****		3	3.3576	0.3260	8.39	10.87
Mercury*****	7439-97-6	50		50	7.3	1.8	14.60	N/A
PHASE 3								
Arsenic	7440-38-2	200		1	0.0006	0.0006	0.06	0.60
Cadmium	7440-43-9	50		0.4	0.0043	0.0027	1.07	2.70
Chromium	7440-47-3	50		0.5	ND	ND	ND	ND
Copper	7440-50-8	1000		10	0.2290	0.1516	2.29	1.52
Lead	7439-92-1	150	1.5***		0.0573	0.0573	N/A	3.82
Zinc	7440-66-6	5000 ****		3	0.0393	0.0257	0.10	0.86
Mercury*****	7439-97-6	50		50	ND	ND	ND	ND

* TLVs are taken from either ACGIH or NIOSH.

** Concentrations in $\mu\text{g}/\text{m}^3$.

*** Based on EPA 3-month average standard.

**** Zinc TLV is for zinc oxide.

***** Mercury guideline is based on a 10-hour time-weighted average.

Basin F appeared to be a localized source of copper and zinc. The short-term maximum copper level of $1.4980 \mu\text{g}/\text{m}^3$ was 15 percent of the mean 24-hour typical guideline, while the short-term maximum level of $3.3576 \mu\text{g}/\text{m}^3$ for zinc was 1.8 percent of the guideline. These levels occurred at BF2 and BF5 during Phase 1 and Phase 2, Stage 1. Annual averages for copper and zinc were 2 percent and 11 percent of the annual guideline, respectively. During Phase 3, copper and zinc levels dropped to less than 2 percent of the 24-hour and annual guidelines.

The maximum 24-hour cadmium measurement was at the southern perimeter of the Arsenal at AQ5, $0.0253 \mu\text{g}/\text{m}^3$, and was 6 percent of the short-term guideline. The maximum long-term average at FC2, $0.0027 \mu\text{g}/\text{m}^3$, was 3 percent of the annual guideline. A cadmium source appeared to be off the Arsenal, although slightly higher cadmium concentrations occurred in the vicinity of Basin F during the post-remedial period.

Arsenic was measured at highest levels at AQ2 and AQ5 during Phases 1 and 2. However, maximum short-term and long-term averages were 1 percent and 2 percent of the respective typical 24-hour and annual guidelines. During Phase 3, maximum arsenic levels were less than 1 percent of the 24-hour and annual guidelines.

Lead, which is an EPA criteria pollutant, has been a source of concern in the metropolitan Denver area in the past. There is an apparent influx of lead into the Arsenal area from Denver. However, the maximum average level measured at AQ7, near the southwest boundary of RMA, was $0.0573 \mu\text{g}/\text{m}^3$, or 4 percent of the Colorado monthly standard of $1.5 \mu\text{g}/\text{m}^3$.

The maximum 24-hour mercury measurement of $7.3 \mu\text{g}/\text{m}^3$ was at BF2 during Phase 1, and was 15 percent of the typical guideline. The highest long-term average for mercury, $1.8 \mu\text{g}/\text{m}^3$, was also measured at BF2. Mercury was not detected in the latter part of Phase 2 nor in Phase 3 at the Basin F sites, and was not detected throughout the CMP FY89 and IRA-F programs.

4.4.6 Summary

Ambient metals concentrations distributed across RMA were generally proportional to TSP concentrations. Relatively high metals concentrations were associated with high and gusty winds; however, there were many exceptions on a day-by-day basis. The extreme maxima were associated with poor dispersion conditions and light winds during winter and occurred on days with high particulate levels over Denver. Basin F appeared to be a potential source of chromium, mercury, copper and zinc during Phase 1 remedial activities, but concentrations were localized and decreased rapidly with distance from the source. After remediation, metals levels in the vicinity of Basin

F were typical of RMA baseline concentrations. None of the metals measured during the CMP high event days nor the Basin F monitoring program indicate significant toxic or contamination levels.

4.5 Asbestos

Asbestos sampling was conducted at 4 sites for FY89 in accord with the locations and schedule described in Table 4.5-1. Sites were selected in the vicinity of asbestos sources within the RMA compound, as well as to maintain continuity with previous monitoring.

Table 4.5-1 Synopsis of FY89 Asbestos Monitoring

Station	Number of Samples	Percent of Recovery
AQ1	30	97
AQ6	30	97
AQ8	29	94
AQ12	30	97
Program Total:	119	96

A minimum detectable level of 7 fibers/mm² (which for target volumes is equivalent to less than 0.001 fibers/ml) was established for the laboratory sample analyses. Concentrations were determined by dividing the observed counts by the fractional area observed and by the sample volume. All the samples collected during this period had counts below the minimum detection limit, with the exception of samples collected on January 4 and February 10, 1989. A total of 6 detections were recorded, with concentrations ranging from 0.001 to 0.014 fibers/ml. On both January 4 and February 10, the ground was covered with at least 2 inches of snow. These dates also coincide with high levels of TSP, PM-10 and metals that may have resulted from metropolitan Denver impacts, as previously discussed. It is evident that asbestos concentrations were below significant levels in the general ambient confines of RMA. Potential contamination from asbestos, however, could be restricted to selected enclosed areas or very localized outside areas. Specialized and more intensive monitoring beyond the scope of this program would be required to identify

these conditions. Since minimal detections were measured in CMP FY88 and FY89, CMP FY90 monitoring will be reduced to seasonal sampling.

4.6 Volatile Organic Compounds (VOCs)

4.6.1 CMP VOC Sampling, Analysis and Reporting Strategies

The CMP Technical Plan calls for VOC seasonal monitoring at four RMA perimeter sites during the spring, fall and winter periods, and six high event sampling episodes to be conducted at four perimeter sites and four mobile sites during specified meteorological criteria as outlined previously in Table 3.2-2.

VOC monitoring was initiated under the CMP FY88 program after laboratory certification methods were approved. It was subsequently determined that the certification ranges established by PMRMA were too low and did not realistically identify the levels of VOC activity for certain RMA target analytes, especially in the vicinity of Basin F remedial activity. Because recertification is a lengthy process, several adjustments were made to the program, including lowering the volume flow rate significantly. Also, the analytical laboratory estimated various VOC target analyte levels beyond the certification weight range. This problem and the methods of retrieving meaningful data are discussed in Section 7.0, Quality Assurance. During FY89, with the completion of the Basin F cleanup work, the number of target analytes exceeding target detection limits was reduced significantly. However, those samples that were above the detection limits were again established using the best available laboratory detection limits. Actions have also been established to raise the certified detection limits.

As will be demonstrated in this report (and also discussed in the CMP FY88 Air Quality Assessment Report), the fact that certain target analytes were measured and analyzed above certification limits is a reflection of the limited certification ranges and does not necessarily imply that these levels represent potential contamination risks. The available data, in fact, reflect the contrary. This is especially substantiated by the more extensive Basin F Remedial Monitoring Program database that has been incorporated into the report. The data listings of all CMP VOCs collected during FY89 are provided in Appendix E. In this section, all of the sample results are summarized and evaluated, and data above certified reporting limits were incorporated into the analysis.

Emphasis during the CMP FY89 Program was placed on: (1) four fixed perimeter sites to establish a long-term database and to evaluate potential Arsenal and off-Arsenal VOC impacts at RMA

boundaries; and (2) four or more interior RMA mobile sites to measure potential Arsenal internal source impacts. Because of the intense Basin F remedial activity began during FY88, CMP VOC sampling was centered around Basin F and was supplemented by more intensive Basin F Remedial Monitoring Program sampling in order to establish a viable database for remedial assessment. During FY89, the Basin F Remedial Monitoring Program and the follow-on IRA-F Monitoring Program continued an intensive monitoring effort around Basin F. These results will be discussed in Section 4.6.3.2. The CMP FY89 VOC program not only included monitoring of Basin F sites, but also Basin A, the South Plants, the Hydrazine Plant and RMA perimeter sites in order to establish a broader background of VOC levels across the Arsenal and at future projected remedial locations. CMP FY89 results will be discussed in Section 4.6.2. Combined Basin F and CMP VOC results will be discussed in Section 4.6.3.3 and will include FY88 and FY89 data obtained during the three phases of the remedial assessment programs which are outlined in Table 4.1-1.

As noted previously, CMP VOC monitoring consisted of seasonal monitoring and high event (mostly summertime) monitoring when VOCs are likely to be most prevalent. For the most part, all high event monitoring met the specified meteorological criteria of temperatures in excess of 75° F at the start of the monitoring period. Since the wind criteria of less than 5 mph was extremely difficult to predict during the summer seasons, especially during mid-afternoon when convective activity was at its highest levels, emphasis was placed on mobilizing for light wind days, generally between 5 and 8 mph. Because of the variability of light winds, each high event monitoring episode concentrated on a particular potential source with several samplers surrounding the source area.

As reported in the CMP FY88 Air Quality Assessment Report, it appeared that the VOC high event temperature criteria, while appropriate with respect to potential volatile compound releases, did not always produce the best conditions for collecting high ambient concentrations. Very high temperature conditions most frequently corresponded to *the best dispersion conditions* (i.e., unstable air and variable winds) and thus actually reduced sampled ion concentrations except immediately adjacent to a source. Results from the Basin F Program, which monitored for a continuous 24-hour period, indicated that the highest ambient VOC levels were likely to occur under a surface inversion just before daytime heating began or in late afternoon when the inversion set in. For this reason, VOC levels from Basin F were sometimes higher than those measured at the same CMP locations. Experience gained in the CMP FY88 program therefore formed the basis for modifications and improvements to the FY89 high event program. Although the VOC high event monitoring was initiated on very warm days with temperatures in excess of 75° F, the monitoring was generally continued through the 24-hour period in order to capture the impacts of volatile organic compounds released under the warm temperatures and then trapped under inversion conditions. The Basin F and CMP monitoring strategies strongly complemented each other, and

provided patterns for assessing impacts under variable conditions relating to wind flow, temperature ranges, air quality dispersion, source activity and diurnal influences.

4.6.2 CMP FY89 VOC Monitoring Results

VOCs were monitored in FY89 for seasonal and high event conditions as presented in Table 4.6-1. Table 4.6-2 shows a summary of results of the sampling of 22 target VOCs at various fixed and mobile locations across RMA. The tables indicate the average and maximum levels at each site.

Table 4.6-1 Synopsis of FY89 Monitoring for Volatile Organic Compounds (VOC)

Date	Period	Site Locations
November 30, 1988*	1200 - 1200 (Dec. 1)	AQ1, AQ2, AQ3, AQ5, AQ5C
March 21, 1989 *	1300 - 1400 (March 22)	AQ1, AQ2, AQ3, AQ5, AQ5C
June 15, 1989*	1300 - 1300 (June 16)	AQ1, AQ2, AQ3, AQ5, AQ5C
June 28, 1989	0900 - 1600	AQ1, AQ2, AQ3, AQ5, AQ5C, BF2, BF3, BF4, BF6
July 5, 1989	0800 - 1600	AQ1, AQ2, AQ3, AQ5, AQ5C, BF2, BF3, BF4, BF6
July 8, 1989	0800 - 1600	BF2, BF3, BF4, BF6
July 8, 1989	0800 - 0800 (July 9)	BF2, BF2C, BF3, BF4, BF6
July 21, 1989	0800 - 0800 (July 22)	Mobile Sites #1 - 10
August 10, 1989	1000 - 1000 (August 11)	Mobile S
August 15, 1989	1000 - 1000 (August 16)	Mobile Sites #1 - 8, AQ6
September 6, 1989	0900 - 0800 (Sept. 7)	Mobile Sites #1, 2, 4

* Seasonal monitoring; all others were high event monitoring cases.

It should be noted that seasonal sampling was conducted under fall, winter and spring conditions and all high event sampling episodes were conducted in the summer season to meet high event criteria. Levels were comparable to CMP FY88 results outside the range of Basin F impacts, with several exceptions. This includes considerably higher concentrations of methylene chloride

TABLE 4.6-2

SUMMARY OF 1989 VOLATILE ORGANIC COMPOUND (VOC) CONCENTRATIONS
(in ug/m³)

AVERAGE VALUES

	111TCE	TCE112	DCLE11	DCLE12	BCHPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5	DBCP
AQ1	2.074	†	†	0.088	†	2.278	0.429	13.130	0.138	†	†
AQ2	1.444	†	†	0.174	†	1.954	0.439	11.041	0.107	†	†
AQ3	1.042	†	†	0.105	0.083	1.305	0.436	7.467	0.099	†	†
AQ5	2.854	†	†	0.130	†	1.824	0.522	15.419	0.077	†	†
AQ6	2.863	†	†	0.065	†	1.516	0.485	1.985	0.170	†	†
CMP/BF2	0.858	†	†	†	†	0.797	0.343	5.138	0.363	†	†
CMP/BF3	1.326	†	†	†	†	0.767	0.294	21.641	0.058	†	†
CMP/BF4	1.445	†	†	†	†	0.992	0.520	8.977	0.084	†	†
CMP/BF6	1.080	†	†	0.041	†	0.879	0.334	15.710	0.156	†	†
AQ01	1.782	†	†	0.051	0.074	1.147	0.572	3.996	1.023	0.026	†
AQ36	1.929	†	†	†	†	1.035	0.457	1.112	0.360	†	†

MAXIMUM VALUES

	111TCE	TCE112	DCLE11	DCLE12	BCHPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5	DBCP
AQ1	3.238	†	†	0.273	†	4.646	0.671	55.740	0.451	†	†
AQ2	2.450	†	†	0.480	†	4.282	0.871	47.376	0.365	†	†
AQ3	1.316	†	†	0.403	0.112	2.801	0.796	34.008	0.310	†	†
AQ5	5.264	†	†	0.495	†	4.392	0.914	60.102	0.206	†	†
AQ6	2.863	†	†	0.065	†	1.516	0.485	1.985	0.170	†	†
CMP/BF2	1.151	†	†	†	†	1.112	0.403	14.205	0.981	†	†
CMP/BF3	1.907	†	†	†	†	0.932	0.373	38.977	0.096	†	†
CMP/BF4	1.887	†	†	†	†	1.364	1.050	16.664	0.143	†	†
CMP/BF6	1.246	†	†	0.047	†	1.124	0.436	41.716	0.192	†	†
AQ01	3.552	†	†	0.201	0.468	2.396	1.164	18.476	3.931	0.082	†
AQ36	2.019	†	†	†	†	1.127	0.486	1.234	0.466	†	†

† ALL VALUES BELOW DRL

LEGEND: 111TCE 1,1,1-Trichloroethane
TCE112 1,1,2-Trichloroethane
DCLE11 1,1-Dichloroethane
DCLE12 1,2-Dichloroethane
BCHPD Bicycloheptadiene
C6H6 Benzene
CCL4 Carbon Tetrachloride
CH2CL2 Methylene Chloride
CHCL3 Chloroform
CLC6H5 Chlorobenzene
DBCP Dibromochloropropane

AVERAGE VALUES

	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMA	DMB12	T12DCE	TCLEE	TRCLE	XYLENE
IQ1	#	#	0.913	6.940	#	#	1.432	#	1.443	0.131	1.948
IQ2	0.170	#	0.580	7.084	#	#	0.861	#	1.183	0.074	1.297
IQ3	#	#	0.296	3.572	#	#	0.527	#	0.813	0.052	0.709
IQ5	#	#	0.503	6.839	#	#	0.766	#	2.315	0.057	1.207
IQ6	#	#	0.233	2.505	0.475	#	0.300	#	0.482	#	0.869
MP/BF2	#	#	0.193	2.852	#	#	0.249	#	0.360	#	0.715
MP/BF3	#	#	0.218	2.929	#	#	0.246	#	0.354	#	0.710
MP/BF4	#	#	0.252	3.901	0.089	#	0.338	#	0.988	0.115	0.970
MP/BF6	#	#	0.166	2.316	#	#	0.152	#	1.137	0.610	0.538
IQ01	#	#	0.165	2.060	0.079	#	0.214	#	0.286	0.030	0.576
IQ36	#	#	0.165	1.976	0.173	#	0.211	#	0.768	0.123	0.561

MAXIMUM VALUES

	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMA	DMB12	T12DCE	TCLEE	TRCLE	XYLENE
IQ1	#	#	2.656	10.791	#	#	4.418	#	3.924	0.238	3.759
IQ2	0.574	#	1.677	11.333	#	#	2.513	#	3.349	0.107	2.519
IQ3	#	#	0.801	8.619	#	#	1.850	#	1.972	0.038	1.413
IQ5	#	#	0.749	10.016	#	#	1.563	#	3.022	0.086	2.276
IQ6	#	#	0.233	2.505	0.475	#	0.300	#	0.482	#	0.869
MP/BF2	#	#	0.448	4.756	#	#	0.641	#	0.669	#	1.701
MP/BF3	#	#	0.366	6.284	#	#	0.495	#	0.619	#	1.315
MP/BF4	#	#	0.533	7.216	0.229	#	0.788	#	2.221	0.181	2.091
MP/BF6	#	#	0.299	3.959	#	#	0.331	#	2.406	1.436	1.050
IQ01	#	#	0.389	3.502	0.603	#	0.487	#	0.797	0.111	1.319
IQ36	#	#	0.168	2.043	0.333	#	0.212	#	0.929	0.139	0.573

ALL VALUES BELOW CRL

LEGEND:	DCPD	Dicyclopentadiene
	DMDS	Dimethyldisulfide
	ETC6H5	Ethylbenzene
	MEC6H5	Toluene
	MIBK	Methylisobutylketone
	NNDMA	N-Nitrosodimethylamine
	DMB12	Dimethylbenzene
	T12DCE	Trans-1,2-Dichloroethene
	TCLEE	Tetrachloroethene
	TRCLE	Trichloroethene
	XYLENE	Xylene

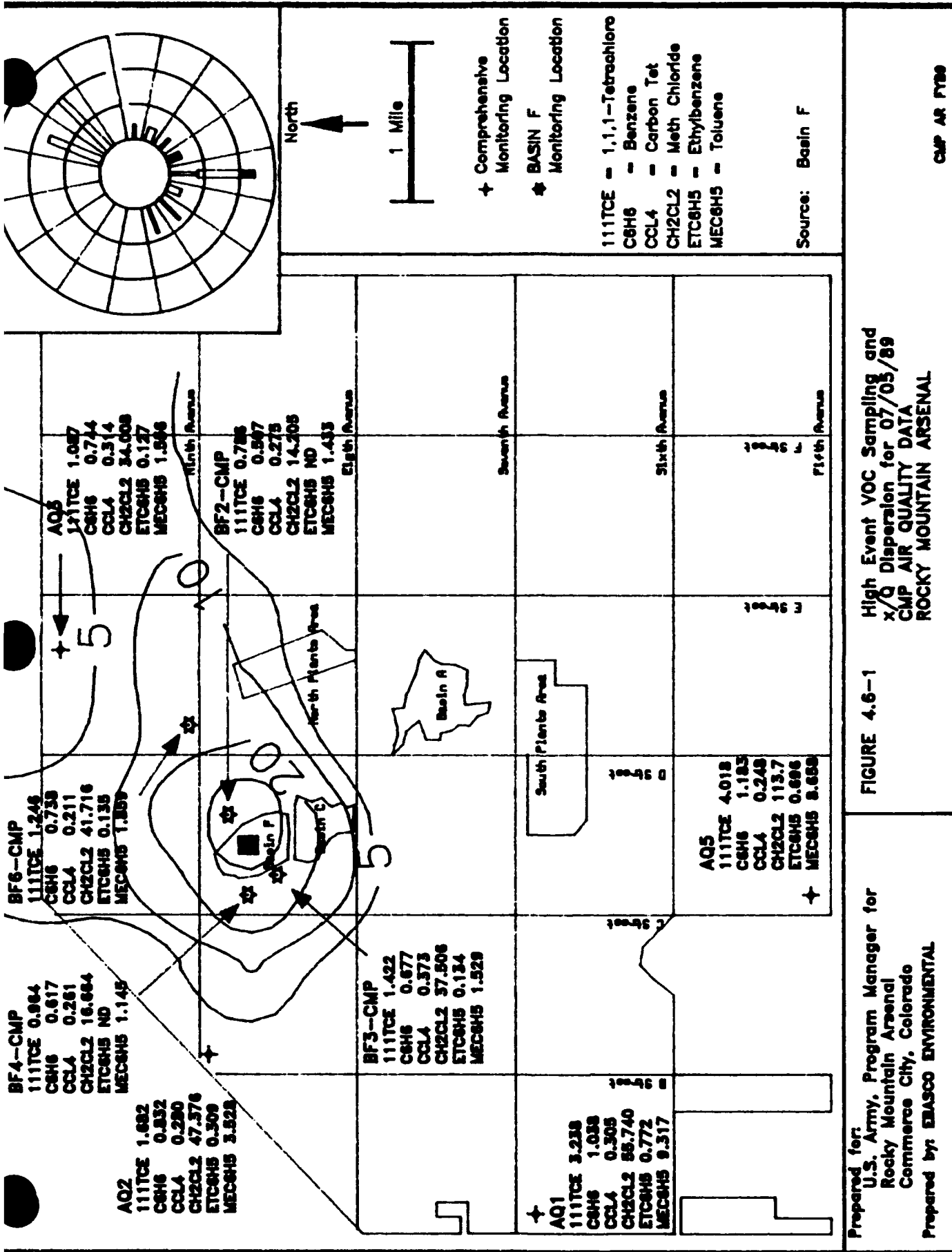
measured in FY89 than in FY88. As the highest levels were, for the most part, measured at the RMA perimeter sites, these appeared to be regional impacts, although the source of these contaminants is unknown. The highest 24-hour concentration of methylene chloride, $60.10 \mu\text{g}/\text{m}^3$, was measured at AQ5 at the southern extremity of RMA. The second highest 24-hour concentration, $55.74 \mu\text{g}/\text{m}^3$, was measured at AQ1 at the western boundary of RMA. Tetrachloroethane and 1,1,1-trichloroethane were other compounds that, on average, measured slightly higher levels in FY89 than FY88, but these differences were less significant than the methylene chloride comparisons between FY88 and FY89.

Within the range of Basin F impacts and especially at CMP Basin F monitoring sites, CMP VOC levels were significantly lower in FY89 than in FY88. This is because the CMP FY88 VOC high event program was conducted entirely during the remedial activity period (Phase 1), while the FY89 VOC high event was conducted during the post-remedial (Phase 3) period. These results will be discussed in further detail in the next section which reviews Basin F remedial impacts.

Other VOC high event episodes in FY89 were conducted at perimeter sites, Basin A, the South Plants and the Hydrazine Plant. All mobile samples taken from RMA Section 1, including those collected around the South Plants and Hydrazine Plant, were grouped together and designated in Table 4.6-2 as "AQ01". Mobile samples collected in Section 36 were grouped together and designated as "AQ36". Because VOC levels vary considerably as a result of meteorological dispersion conditions and source characteristics, it is necessary to also examine these impacts on an individual daily basis. Several examples are provided below.

4.6.2.1 July 5, 1989. VOCs were monitored under the CMP at four perimeter stations and four Basin F locations from 0800 to 1600 hours on this date. Figure 4.6-1 shows site locations and sampling results for selected compounds, along with a wind rose corresponding to the monitoring period. The maximum temperature on this date was 98°F , with primarily east-northeast winds at 8 mph. Atmospheric stability was unstable (A category), changing to neutral towards the end of the monitoring period.

Assuming Basin F as a potential source, the dispersion pattern indicates greater impacts close to Basin F, with a plume extending to the southwest. Nevertheless, stations AQ1 and AQ5, farther downwind from the Basin F source, recorded the maximum concentrations of several VOCs on this date. AQ5 recorded the highest values of 1,1,1-trichloroethane ($4.02 \mu\text{g}/\text{m}^3$), methylene chloride ($113.70 \mu\text{g}/\text{m}^3$), toluene ($8.66 \mu\text{g}/\text{m}^3$), and tetrachloroethene ($3.02 \mu\text{g}/\text{m}^3$). The second highest concentrations of these compounds were measured at AQ1. Levels of carbon tetrachloride and



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 Commerce City, Colorado
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FIGURE 4.6-1 High Event VOC Sampling and x/q Dispersion for 07/05/89
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

ethylbenzene are fairly evenly distributed across the monitoring sites, indicating no clear source for these compounds.

The higher VOC concentrations at the RMA perimeter sites, which were farther from maximum dispersion impacts, suggests that Basin F was not a principal source of several volatile organic compounds that had previously been identified during the Phase I remedial activity period.

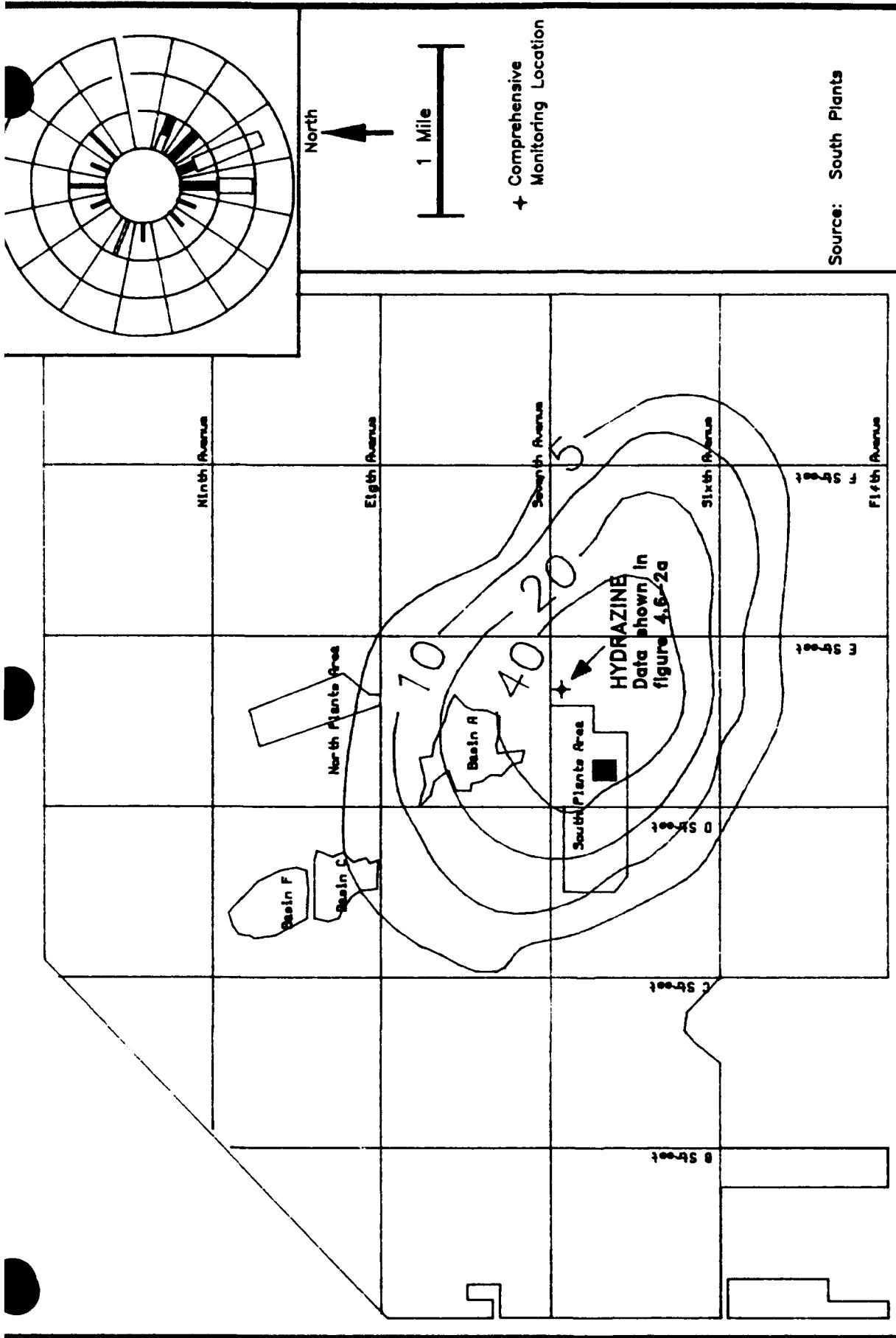
4.6.2.2 July 21, 1989. VOCs were monitored on this date at eight mobile sites in the vicinity of the Hydrazine Plant. Figures 4.6-2 and 4.6-2A show the wind rose and dispersion pattern as well as site locations and monitoring results for selected compounds for this 24-hour sample which began at 0800 hours.

The maximum temperature on this date was 86°F, with south-southeast winds at an average of 12 mph. Atmospheric stability was stable during nighttime hours, very stable in the early morning, and became unstable during the day. Strong dispersion to the northwest of the Hydrazine Plant is evident from Figure 4.6-2 as well as from the results measured in the Hydrazine area (Figure 4.6-2A).

Concentrations of VOCs were uniformly distributed across the Hydrazine Plant, however, elevated concentrations were measured at the northwest and western mobile sites including Mobile 1, Mobile 2 and Mobile 8. A maximum concentration of 1,1,1-trichloroethane was 3.11 $\mu\text{g}/\text{m}^3$ recorded at Mobile 8. In addition, the highest concentrations of dichloroethane, chloroform, toluene, and tetrachloroethene were also measured at Mobile 8, downwind from the prevailing flow. (This can be deduced by reviewing data in Appendix E). A maximum methylene chloride value of 18.48 $\mu\text{g}/\text{m}^3$ was measured at Mobile 1. It is possible that the Hydrazine Plant may be a minor source of several of these compounds; however, levels were well below toxic guidelines as discussed in Section 4.6.4.

4.6.2.3 August 15, 1989. Monitoring of VOCs on this date occurred at two mobile sites in Basin A, six mobile sites near South Plants, and at AQ6 upwind of the prevailing southwesterly wind. The maximum temperature was 80°F with wind speeds ranging from 3 to 12 mph. The monitoring period started at 1000 and continued for 24 hours. Figures 4.6-3 and 4.6-3A show dispersion and wind rose patterns, site locations, and monitoring results for this sampling day.

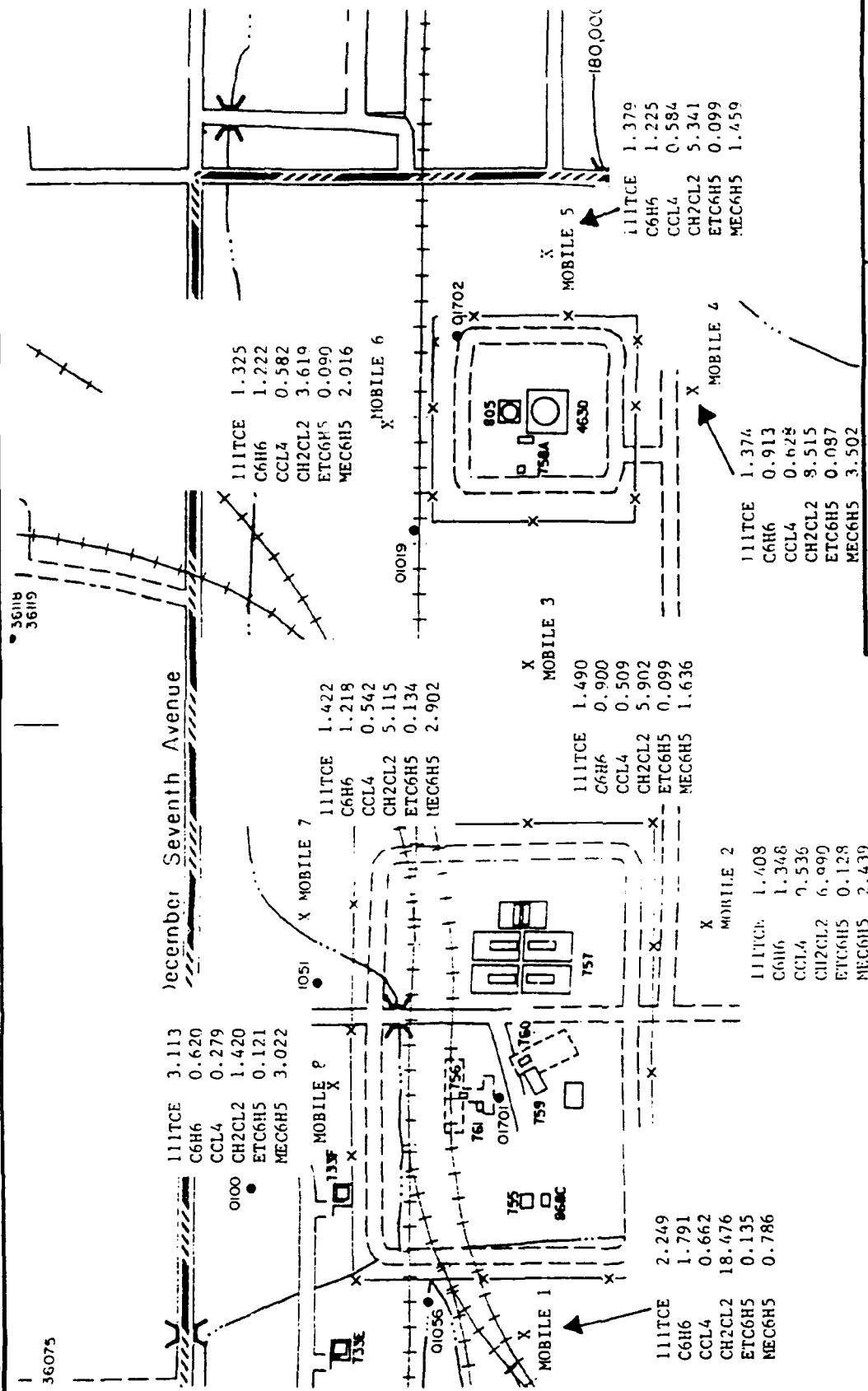
Atmospheric stability was unstable to neutral throughout the day, with moderate northeast winds. Stable conditions persisted throughout the night, when the winds switched to southwesterly, and remained stable through the early morning hours, with light and variable winds. The dispersion



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FIGURE 4.6-2 x/Q Dispersion for 07/21/89
 CMP AIR QUALITY DATA
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CMP AR FY89



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U.S. Army Program Manager for

Rocky Mountain Arsenal

Commerce City, Colorado

Prepared by:

R.L. Stollar & Associates, Inc.

Ebasco Services, Inc.

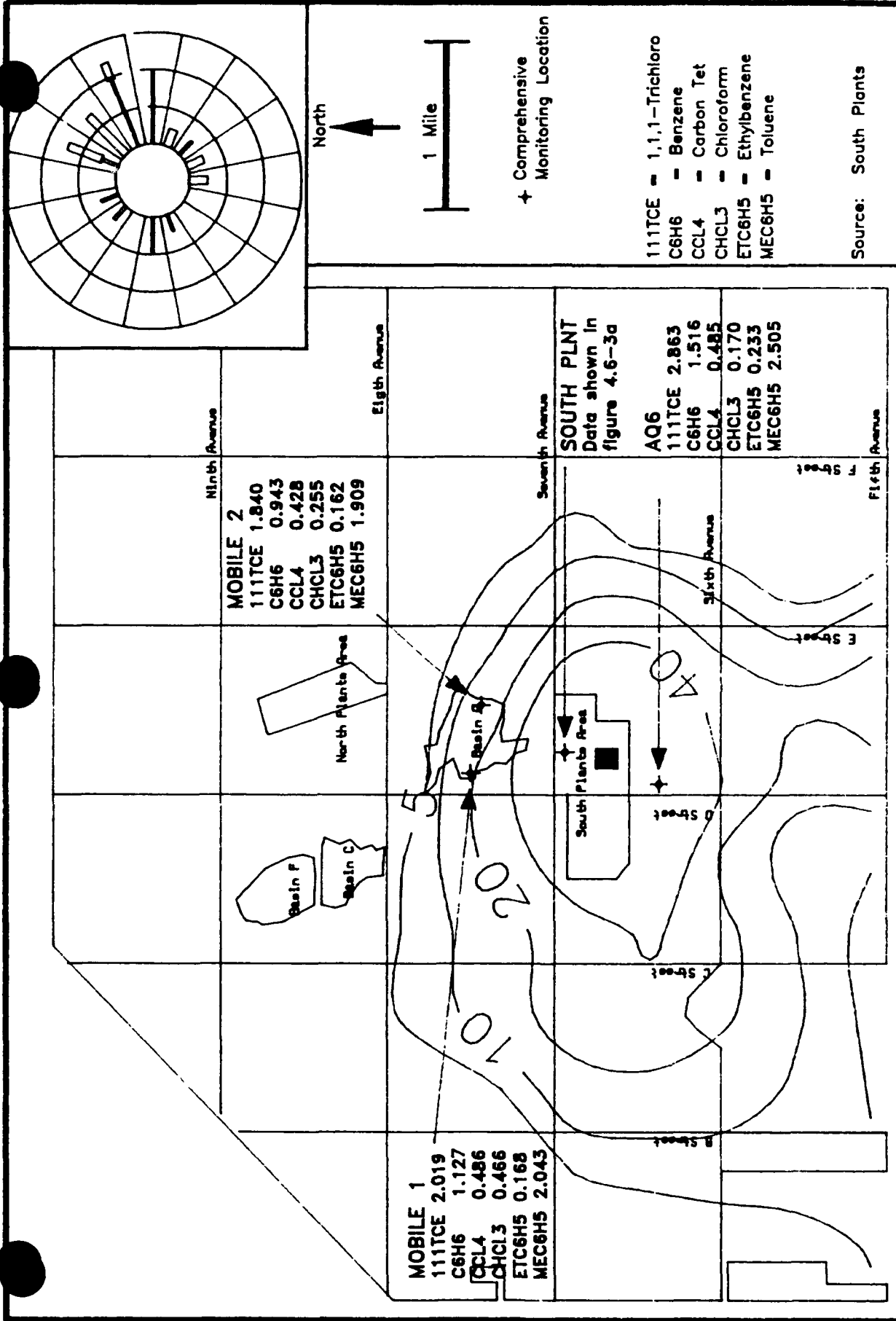
Figure 4.6-2A

High Event VOC Sampling

for 7/21/89

Hydrazine Plant

CMPAR FY89



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FIGURE 4.6-3 x/Q Dispersion for 08/15/89
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

TABLE 4.6-3

SUMMARY OF CMP VOLATILE ORGANIC COMPOUNDS (VOC) CONCENTRATIONS FOR PHASES 1-3

in ug/m³

AVERAGE VALUES

	111TCE	TCE112	DCLE11	DCLE12	BCMPD	C6H6	CCl4	CH2CL2	CHCL3	CLC6H5	DBCP
PHASE 1											
AQ1	0.987	‡	‡	0.053	‡	2.659	0.417	1.890	0.336	0.086	‡
AQ2	2.450	‡	‡	‡	‡	4.282	0.354	3.995	0.365	‡	‡
AQ3	0.875	‡	‡	0.058	0.121	2.192	0.362	0.971	0.159	‡	‡
AQ4	1.112	‡	‡	0.135	‡	4.349	0.858	1.614	0.923	‡	‡
AQ5	1.846	‡	‡	‡	‡	2.465	0.456	3.287	0.193	‡	‡
AQ6	0.378	‡	‡	‡	‡	2.907	0.288	0.635	6.010	‡	‡
AQ9	0.842	‡	‡	‡	‡	1.569	0.525	0.967	0.162	‡	‡
AQ01	0.822	‡	‡	0.044	‡	1.353	0.407	1.715	1.159	0.097	‡
AQ36	0.460	‡	‡	‡	‡	0.534	0.360	0.673	0.556	‡	‡
CMP/BF1	0.822	‡	‡	‡	‡	10.532	0.324	0.818	0.268	0.324	0.148
CMP/BF2	0.837	‡	0.040	‡	2.675	3.007	0.395	4.744	3.031	0.472	2.902
CMP/BF3	1.059	‡	0.139	0.041	‡	2.679	0.660	0.637	0.345	‡	‡
CMP/BF4	0.533	‡	‡	‡	‡	1.427	0.378	0.605	0.427	‡	‡
PHASE 2 - STAGE 2											
AQ1	0.702	‡	‡	0.273	‡	3.350	0.461	0.563	0.032	‡	‡
AQ2	0.633	‡	‡	0.480	‡	2.201	0.871	0.629	0.030	‡	‡
AQ3	0.741	‡	‡	0.408	‡	0.683	0.796	0.430	0.074	‡	‡
AQ5	2.015	‡	‡	0.495	‡	1.372	0.914	1.177	0.045	‡	‡
PHASE 3											
AQ1	2.214	‡	‡	0.053	‡	1.132	0.338	19.853	0.069	‡	‡
AQ2	1.380	‡	‡	0.044	‡	1.096	0.323	16.860	0.047	‡	‡
AQ3	1.052	‡	‡	‡	‡	1.013	0.346	11.812	‡	‡	‡
AQ5	2.331	‡	‡	0.050	‡	1.118	0.337	24.012	0.044	‡	‡
AQ6	2.863	‡	‡	0.065	‡	1.516	0.485	1.985	0.170	‡	‡
CMP/BF2	0.858	‡	‡	‡	‡	0.797	0.343	9.138	0.363	‡	‡
CMP/BF3	1.326	‡	‡	‡	‡	0.767	0.294	21.641	0.058	‡	‡
CMP/BF4	1.445	‡	‡	‡	‡	0.992	0.520	8.977	0.084	‡	‡
CMP/BF6	1.080	‡	‡	0.041	‡	0.879	0.334	15.710	0.156	‡	‡
AQ01	1.782	‡	‡	0.051	0.074	1.147	0.572	3.996	1.023	0.026	‡
AQ36	1.929	‡	‡	‡	‡	1.035	0.457	1.112	0.360	‡	‡

‡ ALL VALUES BELOW CRL

LEGEND:	111TCE	1,1,1-Trichloroethane	CCl4	Carbon Tetrachloride
	TCE112	1,1,2-Trichloroethane	CH2CL2	Methylene Chloride
	DCLE11	1,1-Dichloroethane	CHCL3	Chloroform
	DCLE12	1,2-Dichloroethane	CLC6H5	Chlorobenzene
	BCMPD	Bicycloheptadiene	DBCP	Dibromochloropropane
	C6H6	Benzene		

AVERAGE VALUES

	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMA	DMB12	T12DCE	TCLEE	TRCLE	XYLENE
PHASE 1											
AG1	‡	‡	0.713	8.610	0.074	‡	0.930	‡	0.864	0.110	1.689
AG2	0.574	‡	1.677	11.333	‡	‡	2.513	‡	3.349	0.090	1.890
AG3	‡	‡	0.285	3.979	0.078	‡	0.438	‡	0.699	0.097	0.725
AG4	‡	‡	‡	11.640	‡	‡	‡	‡	‡	‡	‡
AG5	‡	‡	0.332	3.853	0.066	‡	0.410	‡	0.776	0.094	0.880
AG8	‡	‡	‡	0.704	‡	‡	‡	‡	‡	‡	‡
AG9	‡	‡	‡	0.525	‡	‡	‡	‡	‡	‡	‡
AGQ1	‡	‡	0.258	2.481	0.072	‡	0.253	‡	0.354	0.105	0.813
AG36	‡	‡	‡	0.656	‡	‡	‡	‡	‡	0.303	‡
CMP/BF1	0.171	0.148	0.521	5.120	0.075	‡	0.251	‡	0.406	0.079	1.422
CMP/BF2	1.719	0.578	2.394	9.443	0.099	‡	0.337	‡	0.606	0.497	3.542
CMP/BF3	‡	‡	0.242	2.810	0.054	‡	0.270	‡	0.554	‡	0.526
CMP/BF4	‡	0.144	0.158	2.070	0.045	‡	0.258	‡	0.170	‡	0.597
PHASE 2 - STAGE 2											
AG1	‡	‡	0.894	9.311	‡	‡	1.439	‡	0.817	0.091	3.759
AG2	‡	‡	0.599	7.488	‡	‡	0.878	‡	1.043	‡	2.519
‡	‡	‡	0.283	6.223	‡	‡	0.379	‡	0.407	‡	0.902
‡	‡	‡	0.675	10.016	‡	‡	0.982	‡	2.928	‡	2.276
PHASE 3											
AG1	‡	‡	0.338	4.866	‡	‡	0.435	‡	0.825	0.134	0.981
AG2	‡	‡	0.208	5.532	‡	‡	0.304	‡	0.508	0.089	0.692
AG3	‡	‡	0.132	1.006	‡	‡	0.136	‡	0.562	‡	0.409
AG5	‡	‡	0.364	5.306	‡	‡	0.428	‡	1.906	‡	0.929
AG6	‡	‡	0.233	2.505	0.475	‡	0.306	‡	0.482	‡	0.869
CMP/BF1	‡	‡	0.193	2.852	‡	‡	0.249	‡	0.360	‡	0.715
CMP/BF3	‡	‡	0.218	2.929	‡	‡	0.248	‡	0.354	‡	0.710
CMP/BF4	‡	‡	0.252	3.901	0.089	‡	0.338	‡	0.988	0.115	0.970
CMP/BF6	‡	‡	0.166	2.316	‡	‡	0.152	‡	1.137	0.610	0.538
AGQ1	‡	‡	0.165	2.060	0.079	‡	0.214	‡	0.286	0.030	0.576
AG36	‡	‡	0.165	1.976	0.173	‡	0.211	‡	0.768	0.123	0.561

‡ ALL VALUES BELOW CRL

LEGEND: DCPD Dicyclopentadiene
 DMDS Dimethyldisulfide
 ETC6H5 Ethylbenzene
 MEC6H5 Toluene
 MIBK Methylisobutylketone
 NNDMA N-Nitrosodimethylamine

DMB12 Dimethylbenzene
 T12DCE Trans-1,2-Dichloroethene
 TCLEE Tetrachloroethene
 TRCLE Trichloroethene
 XYLENE Xylene

TABLE 4.6-3

(Continued)

MAXIMUM VALUES

	111TCE	TCE112	DCLE11	DCLE12	BCHPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5	DBCP
PHASE 1											
AQ1	3.022	†	†	0.148	†	4.646	0.697	5.527	1.546	0.230	†
AQ2	2.450	†	†	†	†	4.282	0.354	3.995	0.365	†	†
AQ3	1.450	†	†	0.175	0.394	3.715	0.496	1.513	0.310	†	†
AQ4	2.964	†	†	0.358	†	13.376	2.277	3.330	2.901	†	†
AQ5	5.264	†	†	†	†	4.392	0.687	7.788	0.503	†	†
AQ8	0.547	†	†	†	†	4.426	0.457	0.753	11.762	†	†
AQ9	1.081	†	†	†	†	1.821	0.614	1.504	0.169	†	†
AQ01	1.703	†	†	0.062	†	1.795	0.658	5.686	4.649	0.333	†
AQ36	0.753	†	†	†	†	0.637	0.626	0.870	0.802	†	†
CMP/BF1	1.610	†	†	†	†	44.293	0.516	2.436	0.506	1.415	0.414
CMP/BF2	1.076	†	0.062	†	12.649	7.370	0.621	22.840	14.520	2.527	17.039
CMP/BF3	1.595	†	0.271	0.054	†	4.635	1.123	0.981	0.625	†	†
CMP/BF4	0.937	†	†	†	†	2.332	0.674	1.083	0.708	†	†
PHASE 2 - STAGE 2											
AQ1	0.702	†	†	0.273	†	3.350	0.461	0.563	0.032	†	†
AQ2	0.633	†	†	0.480	†	2.201	0.871	0.629	0.030	†	†
AQ3	0.741	†	†	0.408	†	0.683	0.796	0.430	0.074	†	†
AQ5	2.015	†	†	0.495	†	1.372	0.914	1.177	0.045	†	†
PHASE 3											
AQ1	3.232	†	†	0.066	†	1.351	0.405	55.740	0.114	†	†
AQ2	1.682	†	†	0.048	†	1.279	0.430	47.376	0.048	†	†
AQ3	1.095	†	†	†	†	1.251	0.445	34.008	†	†	†
AQ5	3.104	†	†	0.056	†	1.230	0.488	60.102	0.049	†	†
AQ6	2.863	†	†	0.065	†	1.516	0.485	1.985	0.170	†	†
CMP/BF2	1.151	†	†	†	†	1.112	0.403	14.205	0.981	†	†
CMP/BF3	1.907	†	†	†	†	0.932	0.373	38.977	0.096	†	†
CMP/BF4	1.887	†	†	†	†	1.304	1.050	16.664	0.143	†	†
CMP/BF6	1.246	†	†	0.047	†	1.124	0.436	41.716	0.292	†	†
AQ01	3.552	†	†	0.201	0.468	2.396	1.164	19.476	3.931	0.082	†
AQ36	2.919	†	†	†	†	1.127	0.486	1.234	0.466	†	†

† ALL VALUES BELOW CRL

LEGEND:	111TCE	1,1,1-Trichloroethane	CCL4	Carbon Tetrachloride
	TCE112	1,1,2-Trichloroethane	CH2CL2	Methylene Chloride
	DCLE11	1,1-Dichloroethane	CHCL3	Chloroform
	DCLE12	1,2-Dichloroethane	CLC6H5	Chlorobenzene
	BCHPD	Bicycloheptadiene	DBCP	Dibromochloropropane
	C6H6	Benzene		

MAXIMUM VALUES

	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMEA	DMB12	T12DCE	TCLEE	TRCLE	XYLENE
PHASE 1											
AQ1	†	†	2.656	34.438	0.152	†	4.418	†	3.924	0.262	4.854
AQ2	0.574	†	1.677	11.333	†	†	2.513	†	3.349	0.090	1.890
AQ3	†	†	0.801	9.619	0.141	†	1.850	†	1.972	0.210	1.515
AQ4	†	†	†	27.551	†	†	†	†	†	†	†
AQ5	†	†	0.954	9.260	0.243	†	1.563	†	2.929	0.169	3.069
AQ8	†	†	†	1.105	†	†	†	†	†	†	†
AQ9	†	†	†	0.814	†	†	†	†	†	†	†
AQ01	†	†	0.723	6.000	0.120	†	0.647	†	0.762	0.182	2.228
AQ36	†	†	†	1.071	†	†	†	†	†	0.510	†
CMF/BF1	0.430	0.347	2.000	10.366	0.219	†	0.541	†	0.851	0.104	6.031
CMF/BF2	5.628	1.896	13.041	23.525	0.326	†	0.628	†	1.049	2.632	16.240
CMF/BF3	†	†	0.350	4.672	0.065	†	0.435	†	0.906	†	0.857
CMF/BF4	†	0.261	0.238	2.921	0.049	†	0.382	†	0.212	†	0.867
PHASE 2 - STAGE 2											
AQ1	†	†	0.894	9.311	†	†	1.439	†	0.817	0.091	3.759
AQ2	†	†	0.599	7.458	†	†	0.878	†	1.043	†	2.519
AQ3	†	†	0.283	6.223	†	†	0.375	†	0.407	†	0.902
AQ6	†	†	0.675	10.016	†	†	0.982	†	2.928	†	2.276
PHASE 3											
AQ1	†	†	0.772	9.317	†	†	0.992	†	1.041	0.238	2.327
AQ2	†	†	0.309	10.157	†	†	0.397	†	1.257	0.107	0.897
AQ3	†	†	0.202	1.556	†	†	0.274	†	1.354	†	0.630
AQ5	†	†	0.696	7.672	†	†	0.786	†	3.022	†	1.873
AQ6	†	†	0.233	2.505	0.475	†	0.300	†	0.432	†	0.869
CMF/BF2	†	†	0.448	4.756	†	†	0.641	†	0.659	†	1.701
CMF/BF3	†	†	0.366	6.284	†	†	0.495	†	0.619	†	1.315
CMF/BF4	†	†	0.533	7.216	0.229	†	0.788	†	2.221	0.181	2.091
CMF/BF6	†	†	0.299	3.959	†	†	0.331	†	2.406	1.436	1.050
AQ01	†	†	0.389	3.502	0.603	†	0.487	†	0.793	0.111	1.719
AQ36	†	†	0.168	2.043	0.333	†	0.212	†	0.929	0.139	0.573

† ALL VALUES BELOW CRL

LEGEND: DCPD Dicyclopentadiene
 DMDS Dimethyldisulfide
 ETC6H5 Ethylbenzene
 MEC6H5 Toluene
 MIBK Methylisobutylketone
 NNDMEA N-Nitrosodimethylamine

DMB12 Dimethylbenzene
 T12DCE Trans-1,2-Dichloroethene
 TCLEE Tetrachloroethene
 TRCLE Trichloroethene
 XYLENE Xylene

pattern indicates that high concentrations may occur in the immediate vicinity of the South Plants, with relatively uniform dispersion across RMA.

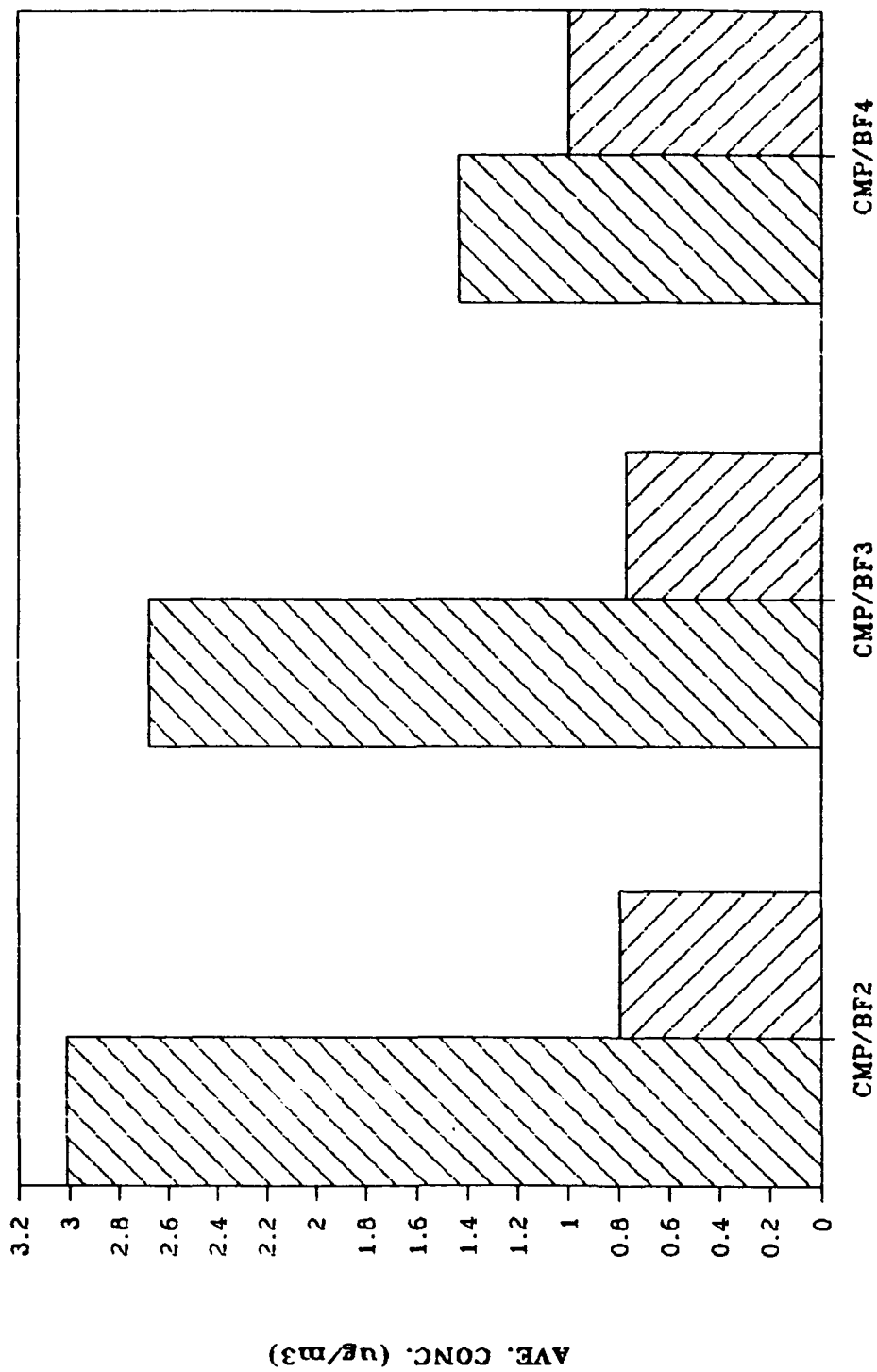
The VOC levels shown in Figures 4.6-3 and 4.6-3A are comparable to averages recorded at the perimeter sites with the exception of chloroform. The maximum chloroform value of $3.93 \mu\text{g}/\text{m}^3$ was recorded at Mobile 5 in the northeast corner of South Plants. It is also interesting that the highest levels of most compounds measured on August 15 were located at Mobile 6, just south of the railroad tracks and Building 534D. These levels were slightly higher than other South Plants values, but as noted, were comparable to VOC concentrations measured during the CMP at other RMA sites.

4.6.3 Basin F VOC Impacts

In order to fully evaluate remedial impacts from the Basin F cleanup operations, it is necessary to consider all CMP, Basin F Remedial Monitoring Program and IRA-F data for the entire remedial and post-remedial periods.

4.6.3.1 CMP Data. CMP FY89 VOC results were discussed in the previous section. Table 4.6-3 incorporates both CMP FY88 and FY89 data and stratifies results for the Phase 1 and Phase 2 remediation periods and the Phase 3 post-remedial period. The VOC CMP data show variations across the Arsenal during the three separate phases of evaluation. It should be noted that these variations can be a function of meteorological conditions, seasonal impacts and source characteristics. Nevertheless, with the exceptions discussed in Section 4.6.2, VOC target element variations outside the immediate vicinity of Basin F remediation activities were generally at comparable levels during each phase of the 19-month monitoring period. Variations were also apparent at CMP Basin F monitoring locations. Several target compounds that were previously identified in the FY88 report as potential contaminants emitted from the Basin F source and associated remediation activity were noticeably reduced during the FY89 Phase 3 period. These include benzene, chloroform, ethylbenzene, toluene and dimethyl disulfide.

Figures 4.6-4 through 4.6-8 show graphical depictions of concentration levels for these target compounds at CMP monitoring stations adjacent to Basin F. In most cases the decrease in concentrations between Phase 1 and Phase 3 is evident. This is particularly true of the BF2 results. BF2 was not only adjacent to the most intense remedial work, but was also directly downstream from the prevailing flow off Basin F. In contrast, BF3, which was upstream from Basin F indicated much lower impacts than BF2 with the exception of benzene. This was true for all VOC compounds measured at BF3 with the above exception and those compounds that are regionally



 P-1
  P-3

Prepared for:

U.S. Army Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado

Prepared by:

R. L. Stollar & Associates, Inc.
 Ebasco Services, Inc.

Figure 4.6-4

Average Benzene
 Concentrations for
 Phases 1 and 3

CMP AR FY 89

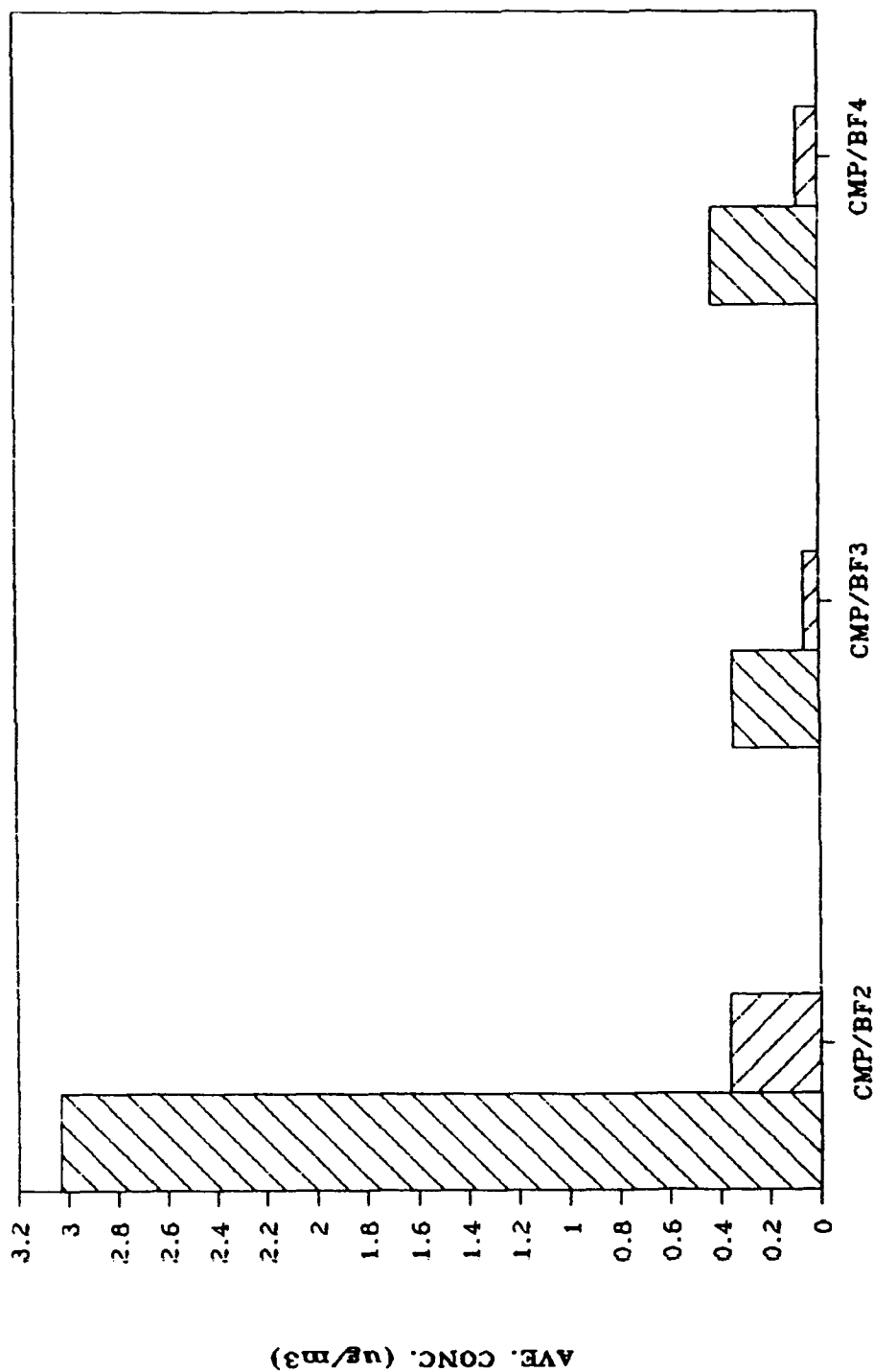


Figure 4.6-5

Average Chloroform
Concentrations for
Phases 1 and 3

CMPAR FY 89

Prepared for:

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

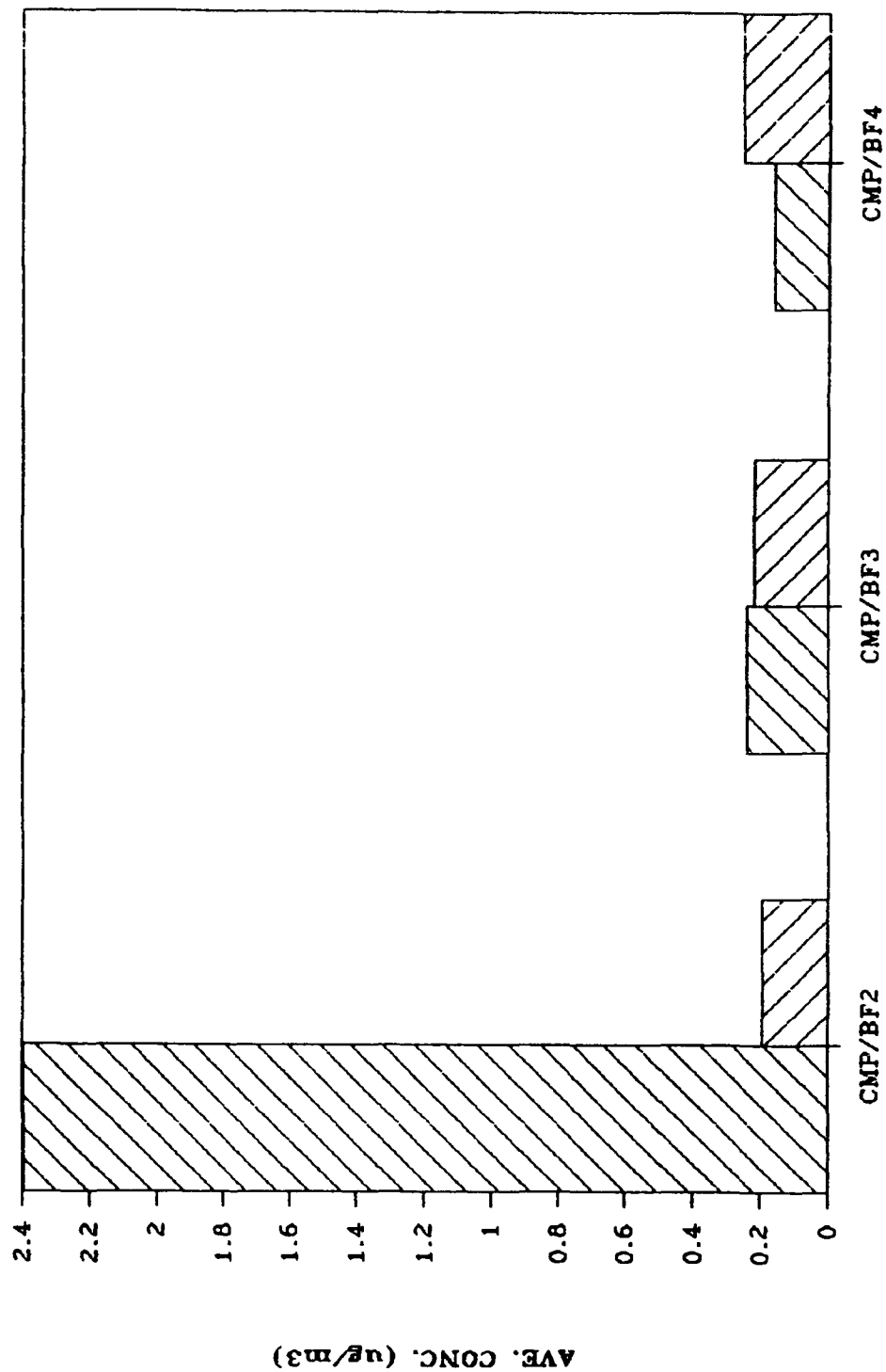


Figure 4.6-6

Average Ethylbenzene
Concentrations for
Phases 1 and 3

CMPAR FY89

Prepared for:

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

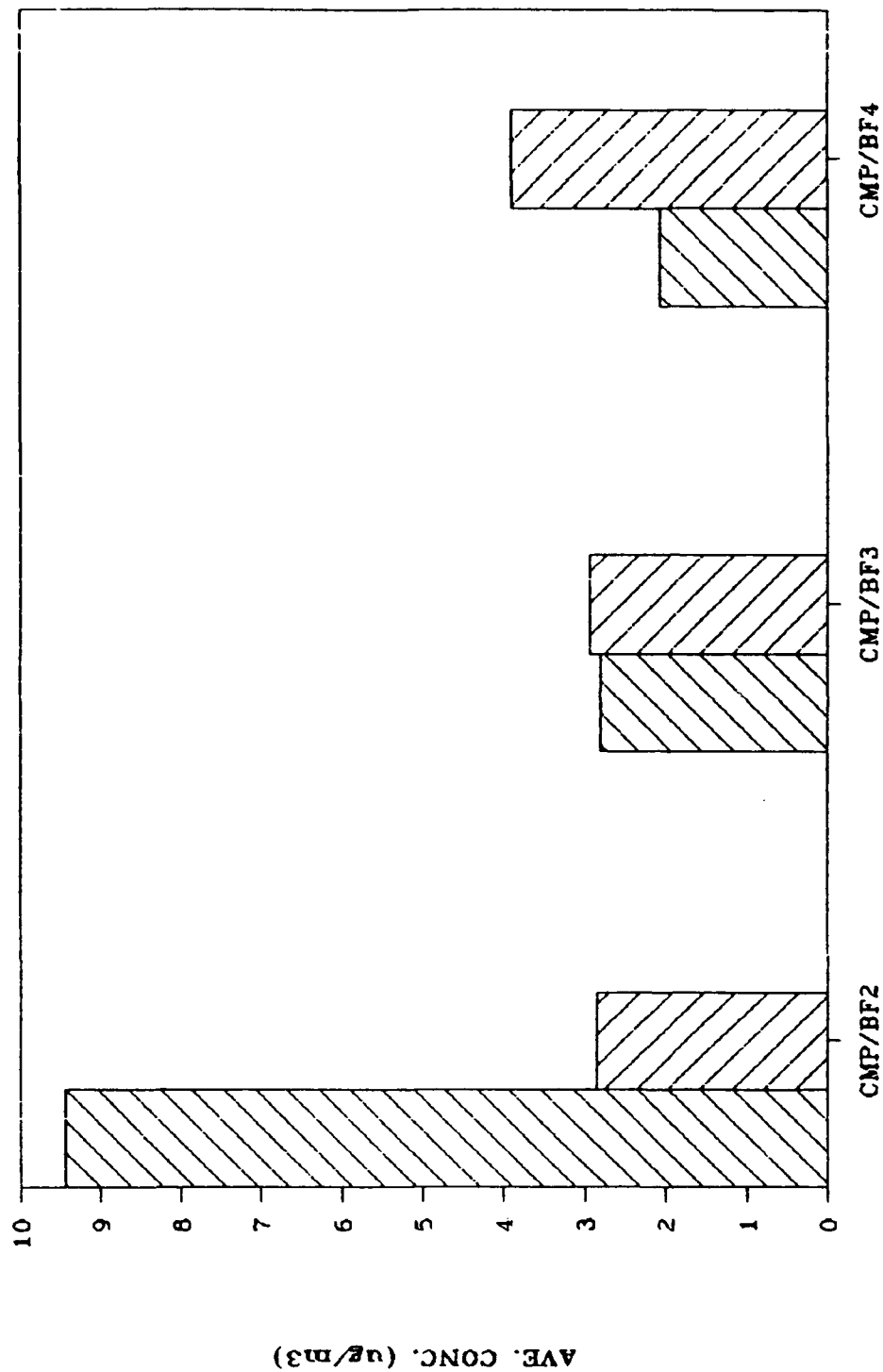


Figure 4.6-7
Average Toluene
Concentrations for
Phases 1 and 3

CMPAR FY 89

Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
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Ebasco Services, Inc.

generic to the Arsenal and metropolitan Denver. As an example, toluene decreased at BF2 between Phase 1 and Phase 3, reflecting the decrease in remedial activity and containment of potential sources. At BF3 and BF4, there was little change in toluene levels, and Phase 3 results were comparable at all three sites (levels were, in fact, slightly higher at BF4 during Phase 3). The inference is that the final Phase 3 toluene concentrations represented regional background levels. This is substantiated by Phase 3 data from other sites.

It is important to note that the emphasis in the CMP has been to provide a broad pattern of baseline air quality conditions at Arsenal remediation locations, interior locations, and perimeter sites. Because of the more intense monitoring efforts under the Basin F Remedial Monitoring and IRA-F programs, the CMP effort has been to supplement and confirm data collected from the other programs. Nevertheless, CMP results for FY88 and FY89 have been consistent with Basin F results. Much more detailed and statistically conclusive results from the Basin F monitoring programs adjacent to the remedial operations are provided in Section 4.6.3.2. The CMP data, however, also reflect the dispersal characteristics of potential Basin F contaminants outside the immediate vicinity of Basin F and impacting Arsenal perimeter areas. The decrease in potential contaminant levels with increased distance from Basin F is clearly evident; these results are provided in further detail in Section 4.6.3.3.

4.6.3.2 Basin F Data. Table 4.6-4 shows average and maximum VOC concentrations for the Basin F Remedial Monitoring Program and for the IRA-F Monitoring Program for each phase of the remedial and post-remedial activities. All Phase 1 data and Phase 2 data (Stage 1 and Stage 2) were obtained from the Basin F Remedial Monitoring Program and RIFS Odor Program and cover the period from March 22, 1988 to May 5, 1989. The Phase 3 data were obtained from the IRA-F Monitoring Program and cover the post-remedial period from May 6 to September 30, 1989. Concentrations greater than the CRL were included in the average and maximum summaries only when estimates of the actual values were available from the lab. Sequential data for both the Basin F and IRA-F programs are provided in Appendices M and R. RIFS data are presented in Appendix U.

Table 4.6-4 provides a detailed summary for each VOC target compound for each remediation phase at the seven Basin F and two RIFS monitoring sites. It can be seen from these data that several VOC compounds measured higher levels in the vicinity of Basin F during the Phase 1 and/or Phase 2 periods, while noticeable decreases for these same compounds were then measured in the Phase 3 post-remedial period. Specific VOCs observed at higher levels during the remediation period included methylene chloride, acetone, chloroform, 1,1,1-trichloroethane, carbon tetrachloride, toluene, bicycloheptadiene, dimethyl disulfide, dicyclopentadiene, chlorobenzene, xylene and dichloroethane. Several of the higher levels during Phase 1 were the result of isolated maximum values such as for acetone, dimethyl disulfide, methyl ethyl ketone, methylene chloride, chloroform, chlorobenzene, xylene and dichloroethane. Some of the

4.6-4

SUMMARY OF BASIN F/IRAF VOC CONCENTRATIONS FOR PHASES 1-3
(in ug/m3)

AVERAGE VALUES

	ACET	C6H6	BCHPD	CCL4	111TCE	112TCE	CHCL3	CLC6H5	CS2	BCPD	11DCLE	12DCLE
PHASE 1												
1	9.02	2.45	1.82	0.65	9.44	ND	2.14	0.05	0.02	1.60	ND	0.04
2	9.87	3.49	9.96	0.61	8.05	ND	6.95	0.12	0.03	4.53	0.02	0.30
2C	5.78	2.94	8.84	0.38	7.12	ND	5.24	0.08	0.02	3.42		
3	8.36	1.94	0.49	0.52	6.94	ND	0.80	ND	0.02	0.52	ND	0.03
4	9.38	2.54	0.55	0.42	10.53	0.05	0.91	0.03	0.02	0.48	ND	ND
5	12.50	2.19	0.43	0.53	8.54	ND	0.88	0.02	0.02	0.34	ND	0.03
6	11.23	1.86	0.11	0.33	8.82	ND	0.30	ND	ND	0.05	ND	0.02
7	14.25	2.15	0.03	0.36	6.24	ND	0.14	ND	0.03	0.03	ND	0.02
FS1		4.00	0.09	0.47	1.95	ND	0.34	0.03		0.35	ND	0.05
PHASE 2 - STAGE 1												
1	13.62	3.97	0.25	1.04	5.50	ND	0.77	0.02	0.03	0.45	ND	ND
2	11.82	3.79	0.88	0.92	5.85	ND	1.89	0.03	0.03	0.32	ND	0.06
2C	13.33	3.85	0.12	1.11	7.93	ND	0.73	ND	0.04	0.08	ND	ND
3	9.42	3.32	0.09	0.88	5.03	ND	0.48	ND	ND	0.18	ND	0.02
4	13.55	3.78	0.13	0.75	5.22	ND	0.39	ND	0.05	0.21	ND	0.03
5	7.93	2.45	0.47	0.97	4.18	ND	0.33	ND	0.06	0.06	ND	0.02
6	8.37	3.24	0.06	1.23	4.73	ND	0.35	ND	0.05	ND	ND	0.03
	8.61	3.51	0.03	1.20	5.26	ND	0.35	0.03	0.31	0.04	ND	0.02
		5.89	ND	1.35	2.77	ND	0.31	0.04		ND	ND	0.24
FS1D		7.32	ND	1.74	3.41	ND	1.44	0.03		ND	ND	0.16
FS2		4.95	0.03	1.99	2.49	ND	1.08	0.03		ND	ND	0.36
PHASE 2 - STAGE 2												
1	7.78	2.00	0.06	0.78	3.50	ND	0.30	0.03	0.02	0.13	ND	0.03
2	6.90	1.65	0.03	0.70	2.57	ND	0.37	0.02	0.02	0.04	ND	0.02
2C	20.79	1.01	0.06	0.58	3.19	0.46	0.31	ND	ND	ND	ND	ND
3	6.71	1.71	0.03	0.68	2.54	ND	0.18	0.02	0.02	0.03	ND	0.03
4	6.36	2.15	0.04	0.67	2.42	ND	0.17	ND	0.02	0.03	ND	0.02
5	3.71	1.19	0.02	0.51	1.89	0.19	0.15	0.03	ND	ND	ND	0.02
6	3.95	1.41	ND	0.70	2.17	ND	0.18	0.03	ND	ND	ND	ND
7	6.49	1.70	0.02	0.76	3.40	ND	0.13	0.03	ND	ND	ND	0.02
FS1		2.10	ND	0.63	1.64	ND	0.11	0.03		ND	ND	0.04
FS1D		2.28	ND	0.53	1.22	ND	0.11	0.04		ND	ND	0.06
FS2		2.37	ND	0.89	1.30	ND	0.14	ND		ND	ND	0.08
PHASE 3												
1		1.15	ND	0.35	1.09	ND	0.15	0.02		ND	ND	0.03
2		1.00	ND	0.40	1.01	ND	0.27	0.02		ND	ND	0.03
2C		1.16	ND	0.40	1.08	ND	0.31	0.02		ND	ND	0.03
3		1.07	ND	0.42	1.09	ND	0.11	0.02		ND	ND	0.03
4		1.19	ND	0.40	1.16	ND	0.11	0.02		ND	ND	0.03
5		1.06	ND	0.45	0.94	ND	0.10	0.03		ND	ND	0.03
5		0.89	ND	0.36	0.95	ND	0.19	0.02		ND	ND	0.02
7		1.15	ND	0.42	1.25	ND	0.09	0.03		ND	ND	0.02
		1.28	ND	0.39	1.15	ND	0.12	0.03		ND	ND	0.03

Legend: ACET Acetone 111TCE 1,1,1-Trichloroethane CS2 Carbon disulfide
 C6H6 Benzene 112TCE 1,1,2-Trichloroethane BCPD Dicyclopentadiene
 BCHPD Bicycloheptadiene CHCL3 Chloroform 11DCLE 1,1-Dichloroethane
 CCL4 Carbon Tetrachloride CLC6H5 Chlorobenzene 12DCLE 1,2-Dichloroethane

AVERAGE VALUES

	DMDS	ETC6H5	MCBD	MEK	CH2CL2	MIBK	T12DCE	TCLEE	MEC6H5	TRCLE	XYLEN_T
PHASE 1											
1	7.86	1.09		1.17	10.48	ND	ND	2.12	9.34	0.26	5.61
2	5.34	1.58		0.79	7.57	ND	ND	5.07	20.95	0.12	8.57
2C	6.69	1.56		0.89	10.47			3.41	23.55	0.14	7.72
3	0.50	0.81		0.57	7.17	ND	ND	1.13	8.27	0.21	4.23
4	0.91	0.92		0.68	6.36	ND	ND	1.13	8.51	0.29	5.02
5	0.92	0.77		1.29	7.77	ND	ND	1.21	5.47	0.24	3.94
6	0.04	0.78		0.79	15.89	ND	ND	1.02	7.96	0.18	4.36
7	0.02	0.89		0.79	4.99	ND	ND	1.07	5.60	0.17	4.57
FS1	0.03	1.72			4.19	0.10	ND	1.56	8.00	0.12	5.44
PHASE 2 - STAGE 1											
1	ND	1.59	ND	3.31	4.01	ND	ND	1.55	5.24	0.17	6.75
2	0.02	1.49	ND	3.25	2.52	ND	ND	1.57	5.05	0.11	6.35
2C	ND	1.28	ND	3.72	4.23	ND	ND	1.33	5.29	0.11	5.87
3	ND	1.45	ND	3.64	3.52	ND	ND	1.37	4.81	0.15	6.40
4	ND	1.94	ND	3.83	3.64	ND	ND	1.59	5.02	0.17	8.17
5	ND	0.85	ND	2.13	2.12	ND	ND	0.94	3.30	0.09	3.72
6	ND	1.02	ND	3.65	1.48	ND	ND	1.14	3.78	0.14	3.84
	ND	1.19	ND	3.61	3.07	ND	0.02	1.20	4.05	0.17	4.45
	ND	2.00			4.42	ND	ND	1.86	8.21	0.17	7.49
FS1D	ND	2.36			5.39	ND	ND	2.06	10.83	0.16	9.45
FS2	ND	1.61			4.46	ND	ND	1.35	7.81	0.11	6.09
PHASE 2 - STAGE 2											
1	0.02	1.07	ND	3.71	4.14	ND	ND	5.29	3.65	5.98	4.88
2	ND	0.52	ND	3.09	6.11	ND	ND	0.78	2.84	0.24	2.68
2C	ND	0.46	ND	2.57	19.01	ND	ND	0.66	2.82	0.14	2.64
3	ND	0.58	ND	3.01	23.81	ND	ND	0.78	3.19	0.08	2.98
4	ND	0.79	ND	2.96	3.23	ND	ND	0.94	3.62	0.16	3.98
5	ND	0.41	ND	2.47	1.29	ND	ND	0.61	2.45	0.07	2.22
6	ND	0.51	ND	2.97	2.81	ND	ND	0.65	2.82	0.05	2.87
7	ND	0.61	ND	3.53	2.94	ND	ND	0.85	3.52	0.04	3.12
FS1	ND	0.72			2.38	ND	ND	0.93	6.10	0.06	3.30
FS1D	ND	0.67			1.23	ND	ND	0.82	6.66	0.04	3.75
FS2	ND	0.69			1.33	ND	ND	0.77	6.03	0.04	3.14
PHASE 3											
1	ND	0.45			0.74	0.03	ND	0.71	1.78	0.30	2.13
2	ND	0.60			0.55	0.02	ND	0.61	1.80	0.04	1.95
2C	ND	0.38			0.37	0.02	ND	0.53	2.10	0.04	1.89
3	ND	0.42			0.73	0.03	ND	0.55	1.65	0.04	1.95
4	ND	0.47			0.92	0.04	ND	0.70	2.20	0.05	2.18
5	ND	0.36			0.31	ND	ND	0.56	1.67	0.06	1.83
6	ND	0.41			1.15	0.04	ND	0.54	1.86	0.44	1.87
7	ND	0.36			0.45	0.02	ND	0.69	1.98	0.04	1.78
FS1	ND	0.48			0.48	ND	ND	0.70	2.26	0.05	2.36

DMDS	Dimethydisulfide	CH2CL2	Methylene Chloride	MEC6H5	Toluene
ETC6H5	Ethyl Benzene	MIBK	Methylisobutylketone	TRCLE	Trichloroethane
MCBD	Hexachlorobutadiene	T12DCE	Trans-1,2-Dichloroethene	XYLEN_T	Total Xylenes
MEK	Methyl Ethyl Ketone	TCLEE	Tetrachloroethene		

MAXIMUM VALUES

	ACET	C6H6	BCHPD	CCL4	111TCE	112TCE	CHCL3	CLC6H5	CS2	DCPD	11DCLE	12DCLE
PHASE 1												
BF1	47.73	6.89	17.98	3.89	72.54	ND	18.51	0.45	0.08	4.58	ND	0.23
BF2	55.53	10.83	39.46	6.68	53.40	ND	37.15	0.80	0.24	29.12	0.08	1.89
BF2C	28.58	9.22	26.19	1.60	28.58	ND	31.14	0.52	0.05	8.30		
BF3	81.65	5.20	2.69	4.00	62.88	ND	3.11	ND	0.05	6.04	ND	0.24
BF4	112.12	6.52	12.25	5.61	67.00	1.12	18.03	0.39	0.03	3.74	ND	ND
BF5	121.38	6.82	2.64	1.19	40.48	ND	5.65	0.05	0.04	2.15	ND	0.15
BF6	41.93	5.74	0.50	1.17	71.11	ND	1.70	ND	ND	0.41	ND	0.09
BF7	151.22	6.47	0.13	1.41	22.06	ND	0.67	ND	0.14	0.14	ND	0.04
RIFS1		9.59	0.49	0.95	4.78	ND	1.33	0.12		3.77	ND	0.25
PHASE 2 - STAGE 1												
BF1	56.24	8.87	1.77	1.93	9.45	ND	3.24	0.06	0.09	3.36	ND	ND
BF2	42.24	7.78	6.66	2.21	17.47	ND	16.41	0.10	0.12	2.48	ND	0.59
BF2C	44.49	6.07	0.46	1.75	28.90	ND	1.57	ND	0.22	0.18	ND	ND
BF3	30.04	6.83	0.85	2.52	11.48	ND	1.19	ND	ND	1.27	ND	0.11
BF4	54.75	8.97	1.51	1.30	15.74	ND	0.92	ND	0.29	1.37	ND	0.24
BF5	22.34	4.71	7.27	1.59	8.55	ND	0.75	ND	0.71	0.60	ND	0.12
BF6	24.5	8.57	0.37	2.25	8.04	ND	0.86	ND	0.31	ND	ND	0.10
	14.23	9.64	0.08	2.39	9.75	ND	0.90	0.11	1.99	0.17	ND	0.08
		11.80	ND	8.59	6.38	ND	1.06	0.32		ND	ND	3.41
RIFS1D		14.20	ND	4.46	5.38	ND	10.00	0.06		ND	ND	1.09
RIFS2		10.90	0.74	9.76	4.65	ND	10.00	0.10		ND	ND	3.80
PHASE 2 - STAGE 2												
BF1	24.39	4.08	0.91	1.13	12.51	ND	1.11	0.08	0.12	2.54	ND	0.10
BF2	22.60	3.23	0.23	1.16	5.29	ND	0.71	0.08	0.09	0.35	ND	0.08
BF2C	43.47	2.55	0.41	1.38	8.00	4.00	0.72	ND	ND	ND	ND	ND
BF3	22.49	4.14	0.12	1.09	5.16	ND	0.60	0.07	0.09	0.17	ND	0.10
BF4	17.73	4.34	0.29	0.97	6.66	ND	0.48	ND	0.09	0.12	ND	0.06
BF5	7.11	2.44	0.04	0.76	3.34	1.90	0.36	0.09	ND	ND	ND	0.07
BF6	6.29	2.60	ND	0.87	4.22	ND	0.44	0.09	ND	ND	ND	ND
BF7	16.22	3.10	0.04	0.99	8.54	ND	0.26	0.09	ND	ND	ND	0.06
RIFS1		6.72	ND	2.83	8.75	ND	0.30	0.17		ND	ND	0.21
RIFS1D		3.35	ND	0.80	1.66	ND	0.27	0.12		ND	ND	0.14
RIFS2		5.73	ND	1.24	2.64	ND	0.27	ND		ND	ND	0.34
PHASE 3												
BF1		2.43	ND	0.61	1.79	ND	0.33	0.07		ND	ND	0.04
BF2		2.72	ND	0.79	1.79	ND	0.69	0.07		ND	ND	0.08
BF2C		2.55	ND	0.69	1.77	ND	0.76	0.11		ND	ND	0.10
BF3		2.78	ND	0.97	1.80	ND	0.30	0.05		ND	ND	0.10
BF4		3.00	ND	0.81	2.14	ND	0.33	0.05		ND	ND	0.09
BF5		2.04	ND	0.77	1.29	ND	0.17	0.08		ND	ND	0.09
FC5		1.45	ND	0.94	1.41	ND	0.34	0.05		ND	ND	0.09
BF7		2.10	ND	0.73	2.00	ND	0.16	0.07		ND	ND	0.04
		2.57	ND	0.55	2.14	ND	0.30	0.08		ND	ND	0.10

LEGEND:	ACET	Acetone	111TCE	1,1,1-Trichloroethane	CS2	Carbon disulfide
	C6H6	Benzene	112TCE	1,1,2-Trichloroethane	DCPD	Dicyclopentadiene
	BCHPD	Bicycloheptadiene	CHCL3	Chloroform	11DCLE	1,1-Dichloroethane
	CCL4	Carbon Tetrachloride	CLC6H5	Chlorobenzene	12DCLE	1,2-Dichloroethane

MAXIMUM VALUES

	DMDS	ETC6H5	HCB0	MEK	CH2CL2	MIBK	T12DCE	TCLEE	MEC6H5	TRCLE	XYLEN_T
PHASE 1											
BF1	36.72	4.95		8.48	54.80	ND	ND	16.02	35.55	1.47	25.94
BF2	24.06	8.91		8.14	55.34	ND	ND	23.17	90.10	0.78	49.91
BF2C	23.69	4.95		4.60	72.36			9.14	158.04	1.06	17.20
BF3	4.97	3.98		5.27	57.64	ND	ND	2.30	49.41	1.00	10.51
BF4	8.07	2.39		5.22	58.14	ND	ND	3.40	49.91	1.81	10.39
BF5	3.95	2.48		6.46	50.81	ND	ND	3.32	14.49	1.00	10.52
BF6	0.28	1.79		5.74	179.09	ND	ND	2.61	51.49	0.62	12.90
BF7	0.10	2.38		4.32	30.26	ND	ND	2.66	19.61	0.90	11.56
RIFS1	0.11	3.00			13.70	0.51	ND	2.80	16.50	0.26	9.22
PHASE 2 - STAGE 1											
BF1	ND	4.38	ND	14.78	23.52	ND	ND	3.19	13.32	0.57	17.26
BF2	0.08	4.2	ND	14.2	15.73	ND	ND	4.48	11.43	0.34	15.77
BF2C	ND	2.25	ND	9.56	19.59	ND	ND	3.49	8.55	0.22	11.22
BF3	ND	3.75	ND	13.24	23.71	ND	ND	2.83	11.14	0.34	15.57
BF4	ND	8.97	ND	13.22	19.77	ND	ND	5.52	19.52	0.65	28.28
BF5	ND	1.99	ND	10.54	6.51	ND	ND	2.58	8.42	0.17	10.39
BF6	ND	2.5	ND	10.11	2.74	ND	ND	2.33	6.95	0.47	7.68
	ND	2.93	ND	8.45	7.56	ND	0.05	2.57	7.8	0.44	9.29
	ND	6.16			32.50	ND	ND	3.44	23.90	0.61	15.72
RIFS1D	ND	5.69			22.90	ND	ND	3.44	30.80	0.32	22.43
RIFS2	ND	5.32			17.00	ND	ND	2.99	29.60	0.31	19.58
PHASE 2 - STAGE 2											
BF1	0.05	3.62	ND	8.60	28.85	ND	ND	24.02	6.93	40.43	13.54
BF2	ND	1.18	ND	7.64	72.80	ND	ND	2.14	6.22	2.86	6.76
BF2C	ND	1.50	ND	10.25	59.83	ND	ND	1.98	8.57	0.47	8.50
BF3	ND	1.28	ND	7.17	433.69	ND	ND	2.10	7.49	0.21	7.10
BF4	ND	1.72	ND	4.83	14.06	ND	ND	2.04	8.38	0.55	8.92
BF5	ND	1.11	ND	5.54	5.18	ND	ND	1.51	5.67	0.15	6.31
BF6	ND	0.94	ND	7.16	5.74	ND	ND	1.44	5.22	0.11	5.72
BF7	ND	1.11	ND	8.85	6.30	ND	ND	2.27	6.77	0.07	6.25
RIFS1	ND	2.28			20.50	ND	ND	3.82	21.00	0.21	7.39
RIFS1D	ND	1.07			2.75	ND	ND	1.67	10.40	0.10	7.01
RIFS2	ND	2.06			4.91	ND	ND	2.59	16.50	0.07	8.51
PHASE 3											
BF1	ND	1.04			3.43	0.14	ND	1.69	3.24	1.52	4.62
BF2	ND	3.99			3.26	0.18	ND	1.35	2.97	0.12	5.07
BF2C	ND	1.02			0.82	0.09	ND	1.33	4.40	0.14	4.27
BF3	ND	1.19			4.24	0.20	ND	1.63	2.87	0.09	5.27
BF4	ND	1.25			4.06	0.21	ND	2.50	5.00	0.11	5.29
BF5	ND	0.75			0.44	ND	ND	1.16	3.25	0.19	3.80
FC5	ND	1.05			6.77	0.15	ND	1.44	3.62	0.93	3.82
BF7	ND	0.61			0.74	0.09	ND	1.60	2.93	0.07	2.70
	ND	0.87			0.92	ND	ND	1.40	3.54	0.10	4.31

LEGEND: DMDS Dimethydisulfide CH2CL2 Methylene Chloride MEC6H5 Toluene
 ETC6H5 Ethyl Benzene MIBK Methylisobutylketone TRCLE Trichloroethane
 HCB0 Hexachlorobutadiene T12DCE Trans-1,2-Dichloroethene XYLEN_T Total Xylenes
 MEK Methyl Ethyl Ketone TCLEE Tetrachloroethene

variations in the compound levels may be regional sources that were measured at higher levels because of specific seasonal and other meteorological influences and not necessarily because they were emitted as a result of Basin F remediation activities. Several VOCs measured may also have resulted from gasoline and diesel fume releases from heavy vehicle activities associated with the remediation, including 1,1,1-trichloroethane, benzene, chloroform, ethyl benzene and toluene. Also, several of these compounds were observed at higher levels at the two RIFS Odor Program sites. These sites were adjacent to moderate to heavy Commerce City traffic activities, including railroad freight car movements; and higher VOC levels may well have resulted from these urban sources. Nevertheless, a portion of these volatile organic compounds can be assumed to have resulted from previous waste disposal activities in the Basin F compound, and were emitted at higher levels during the remediation process.

Figures 4.6-9 through 4.6-13 show bar graph depictions of bicycloheptadiene, chloroform, dicyclopentadiene, dimethyl disulfide and toluene measured during each phase of the remediation activities and after the completion of the cleanup program. A significant decrease of these potential compounds was observed at the termination of the remediation program. Also noted from these data is the decrease in concentration levels (even during Phase 1) with distance from the Basin F source. This suggests that Basin F was the principal emitter of these potential contaminants, and that the impacts were local and decreased beyond the immediate vicinity of the remediation activities. This is confirmed by CMP monitoring stations at RMA's more distant monitoring sites and at the boundaries and will be discussed further in the next section.

As in the case of metals, another approach to assessing remedial progress for VOCs is to consider Basin F impacts that were observed on individual days during the remedial and post-remedial periods. All Basin F monitoring during the Phase 1 and Phase 2 periods was conducted for worst-case 24-hour periods based on dispersion model analysis and remedial activity. An example of the dispersion of VOCs resulting from Basin F Phase 1 remedial activities is shown in Figure 4.6-14. This figure shows VOC concentrations for August 12, 1988, with X/Q dispersion values overlaying the monitoring data for the seven Basin F monitoring sites. Again, this type of analysis identifies, to the fullest extent, the potential dispersion of VOCs and other contaminants resulting from remedial actions at Basin F. During this sample period, the winds were variable in direction and flowed at moderate speeds. The maximum temperature was 88°F. The dispersion pattern shows a broad distribution of 24-hour Basin F impacts of dimethyl disulfide, bicycloheptadiene, and ethylbenzene to the west through west-northwest, and a secondary distribution to the northeast. The VOC concentrations at upwind site BF7 were nondetectable. At the perimeter sites around Basin F, the levels were highest at site BF1 immediately downwind of the basin, and at BF2 near the site of the most intense remedial activity. At the downwind off-site BF5, levels dropped off considerably. These data support the conclusion that Basin F was a source of the reported contaminants.

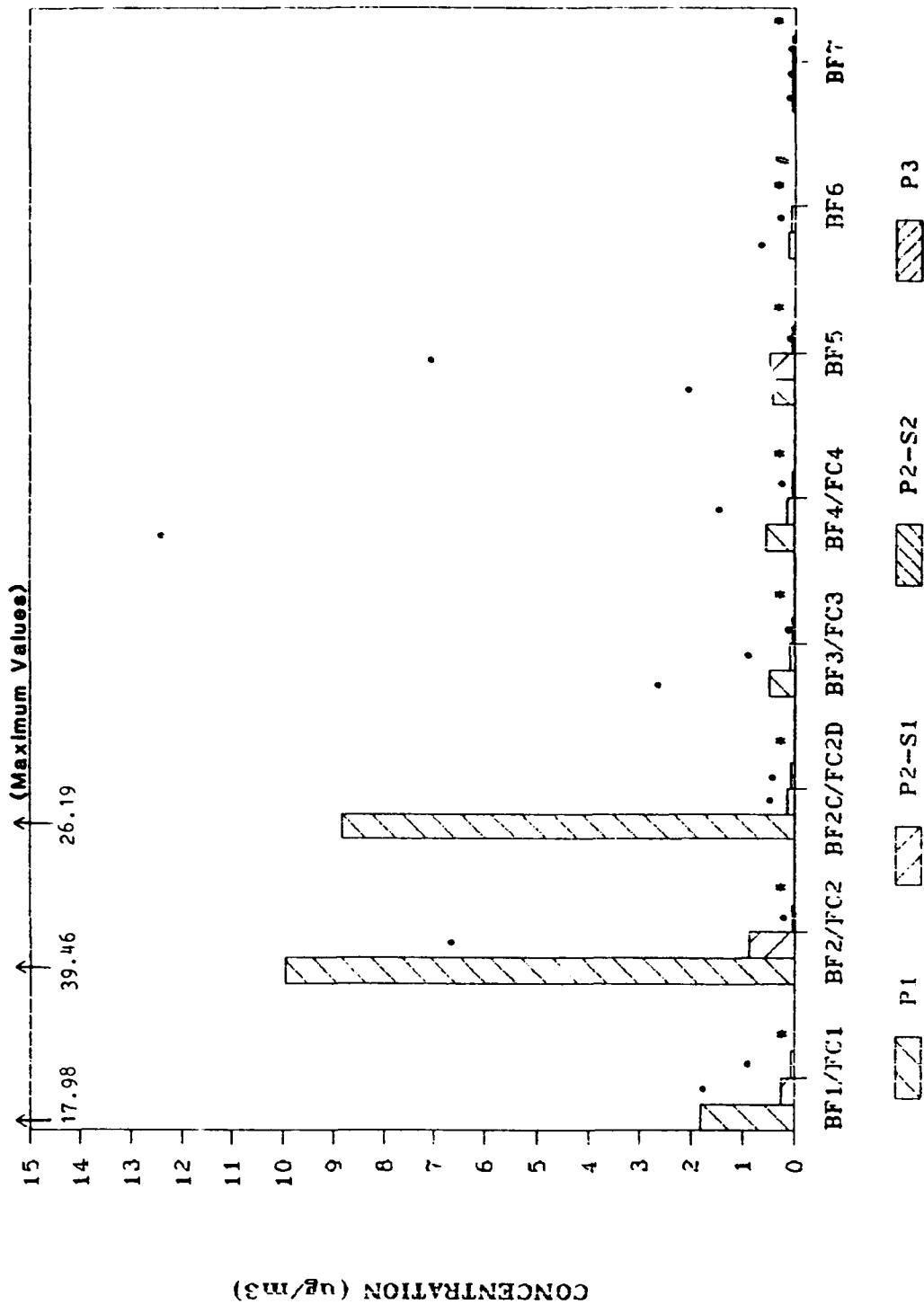


Figure 4.6-9

Bicycloheptadiene Results
by Phase

CMPAR FY 89

Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

• MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE

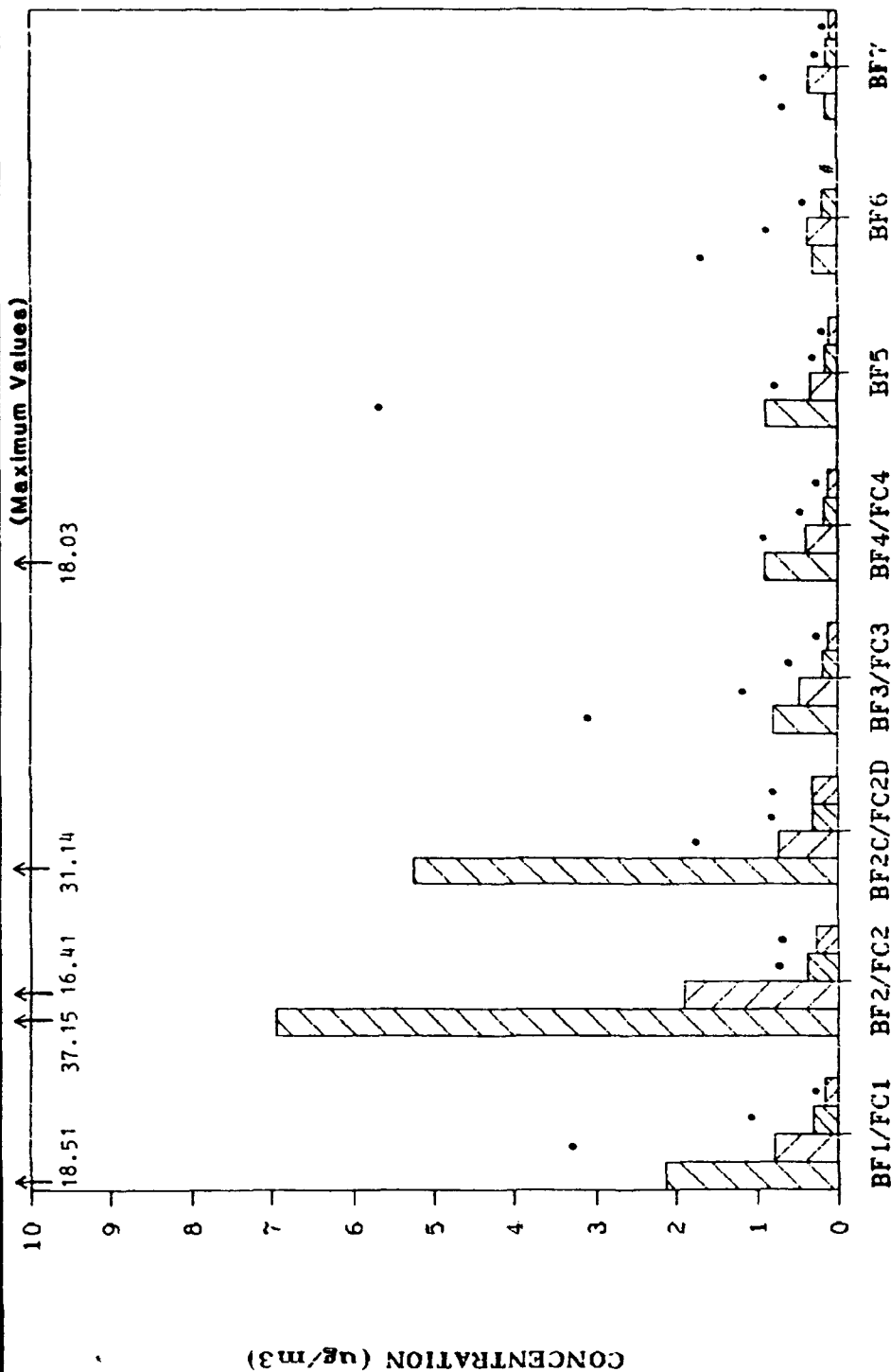


Figure 4.6-10

Chloroform Results
by Phase

CMPAR FY 89

Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

• MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE

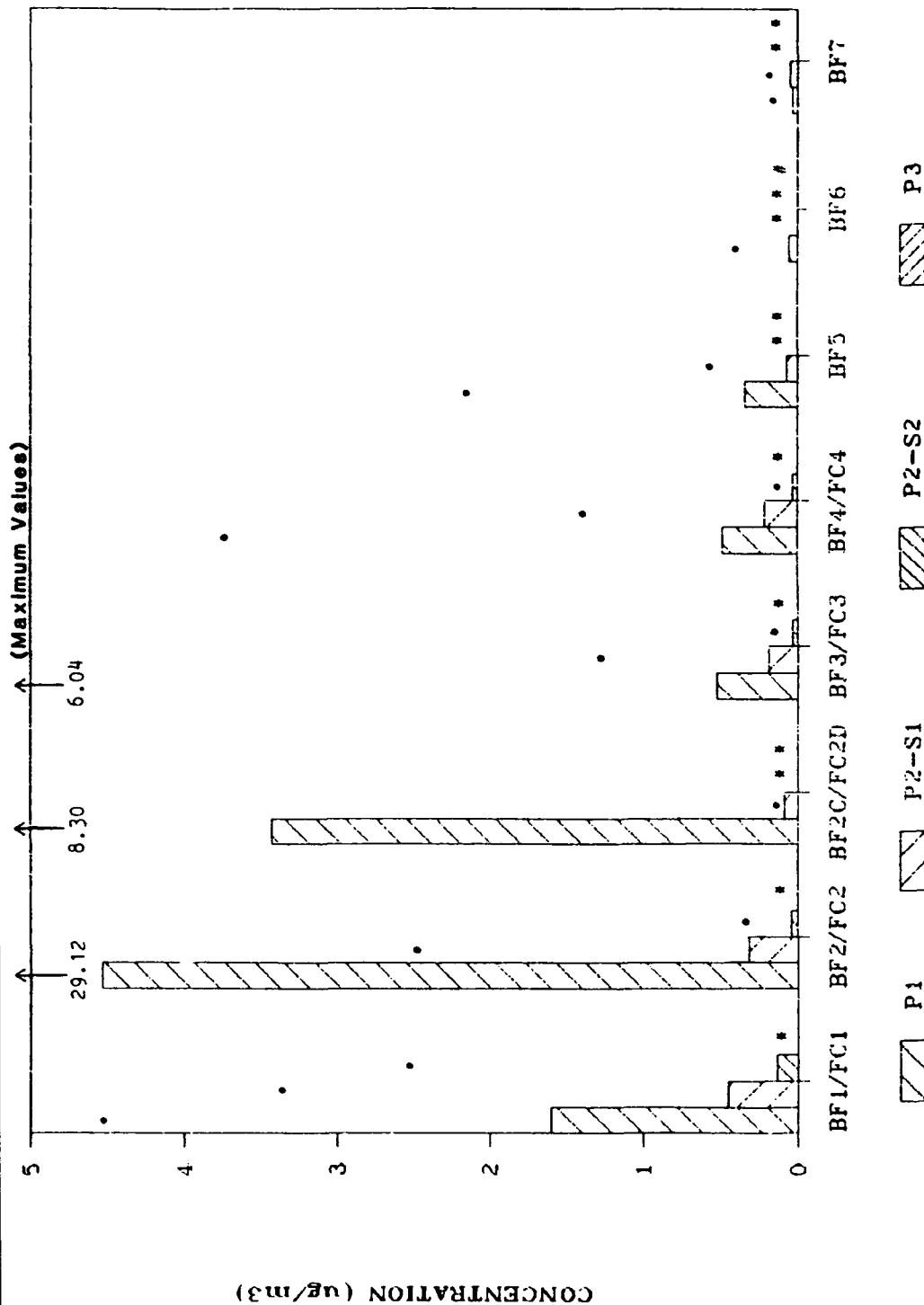


Figure 4.6-11

Dicyclopentadiene Results
by Phase

CMPAR FY 89

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U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

• MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE

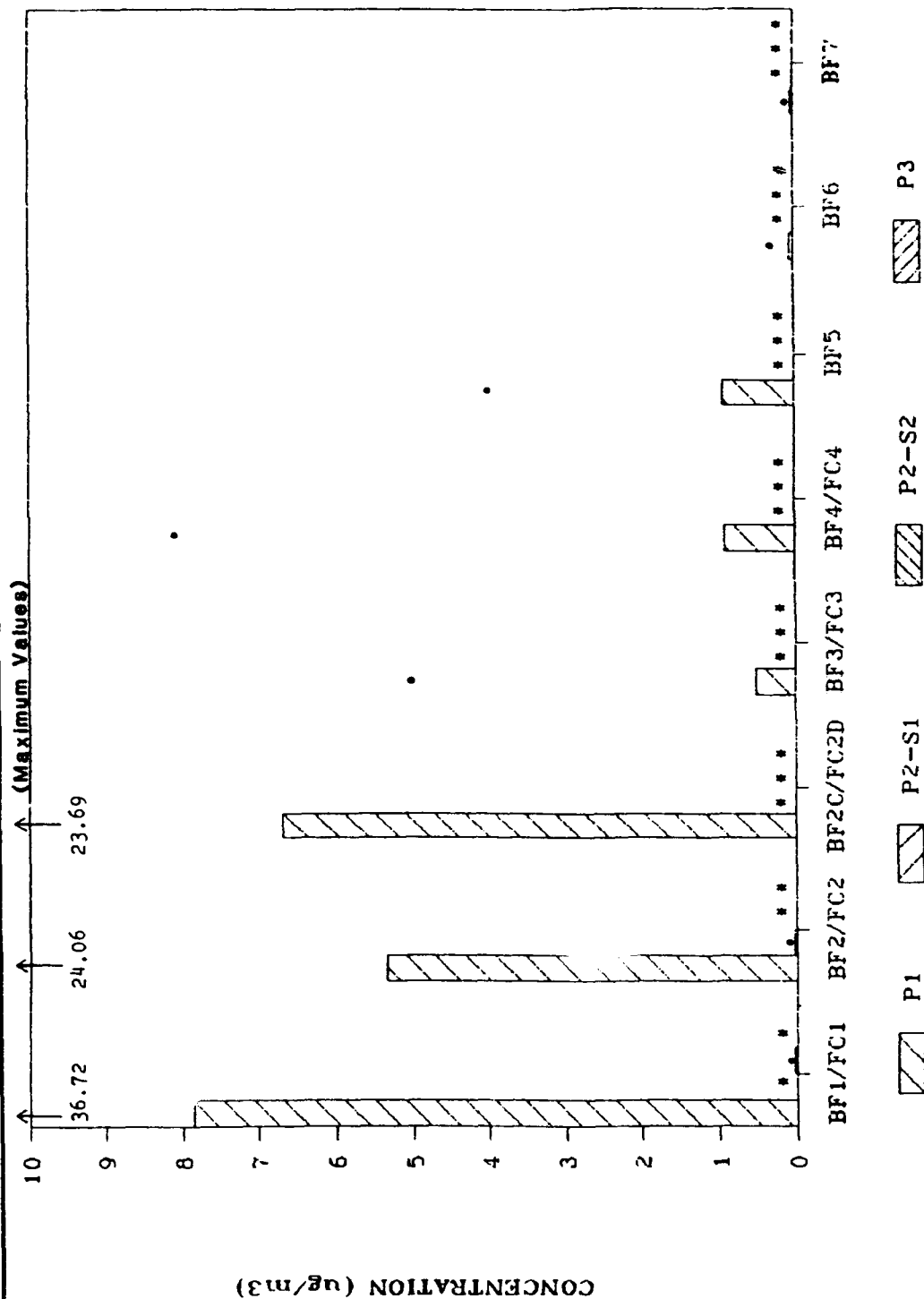


Figure 4.6-12

Dimethyl disulfide Results
by Phase

CMPAR FY89

Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

• MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE

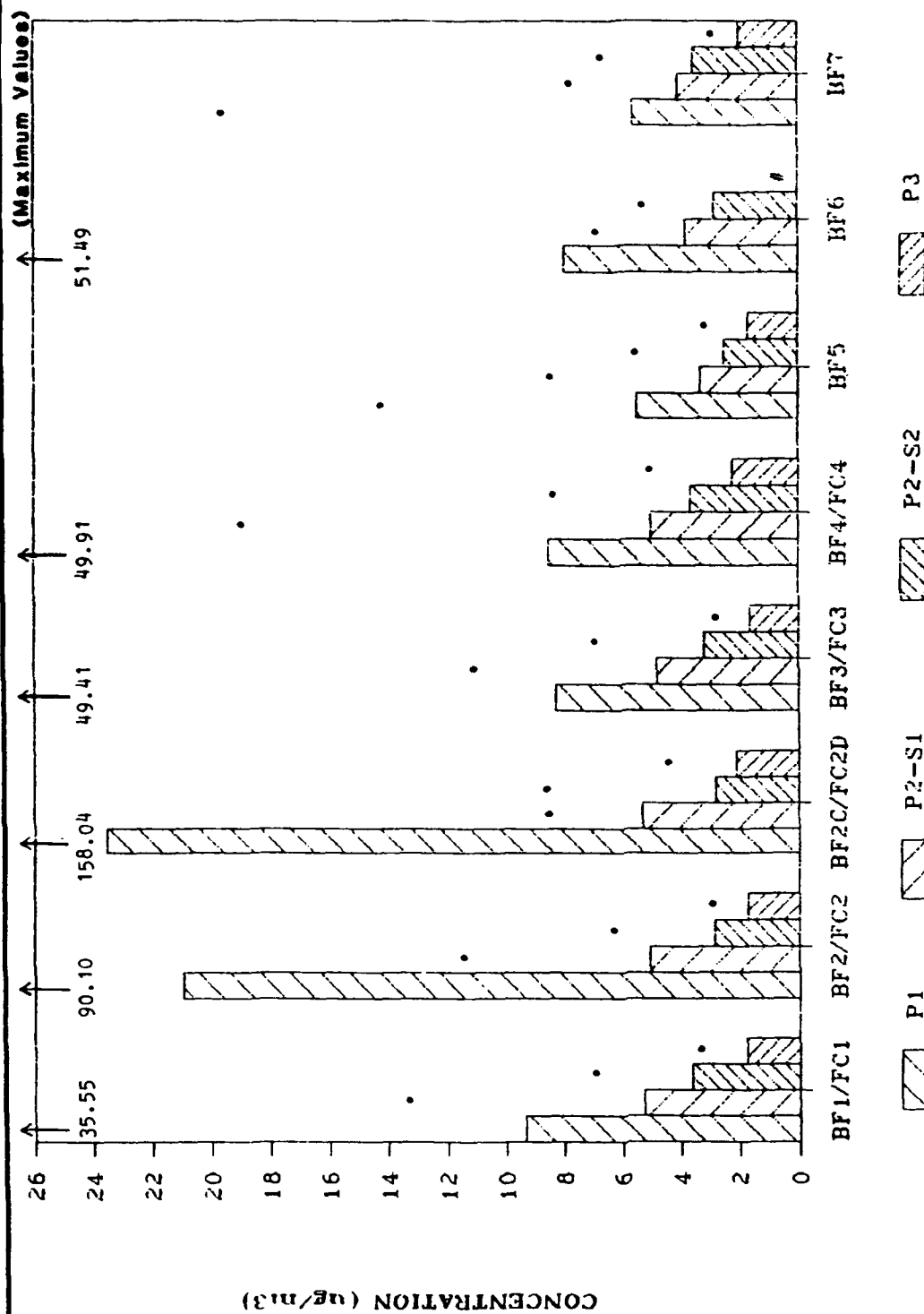


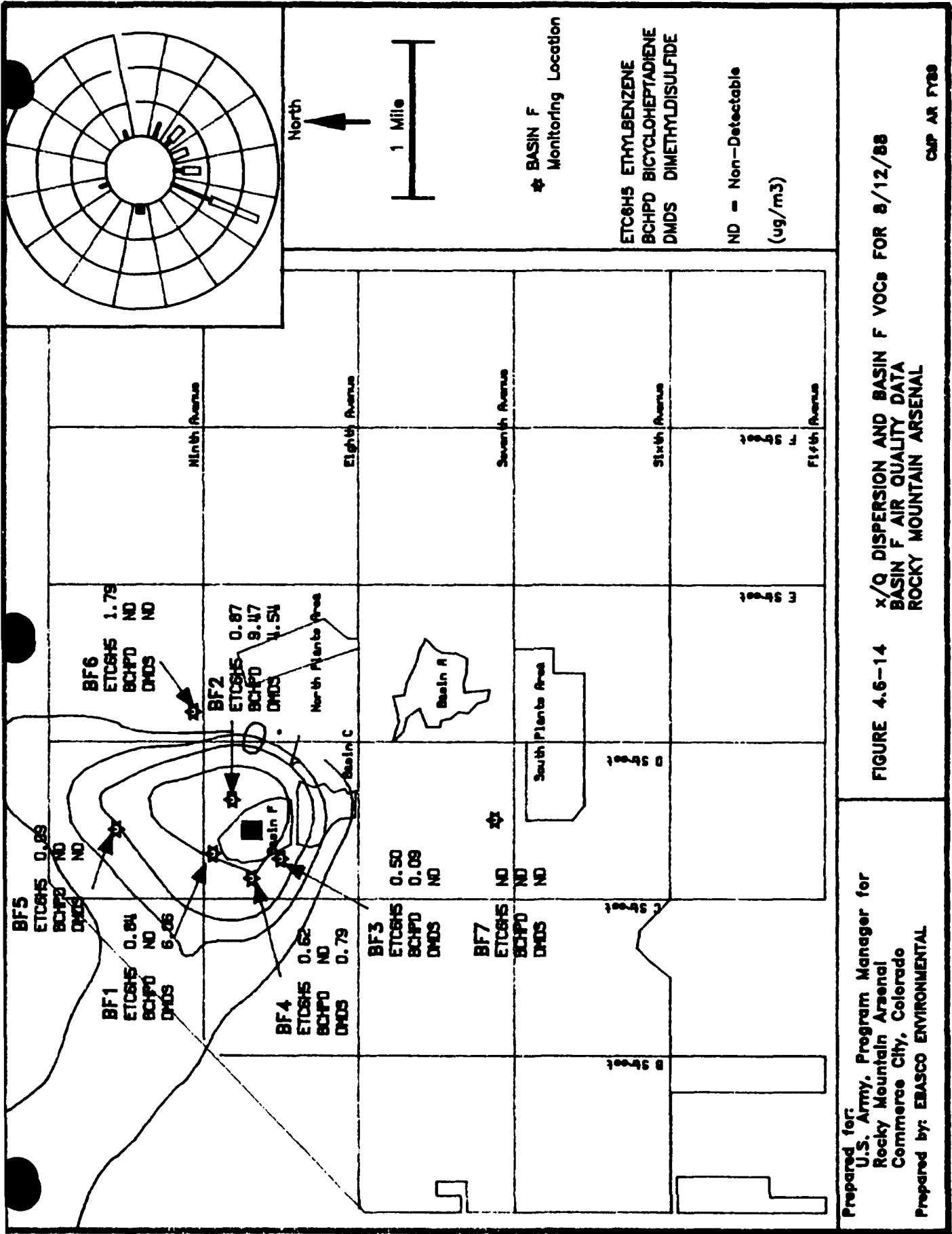
Figure 4.6-13

Toluene Results
by Phase

CMPAR FY 89

Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

• MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE



Prepared for:
 U.S. Army, Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by: EBASCO ENVIRONMENTAL

FIGURE 4.6-14 x/Q DISPERSION AND BASIN F VOCs FOR 8/12/88
 BASIN F AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AR FY88

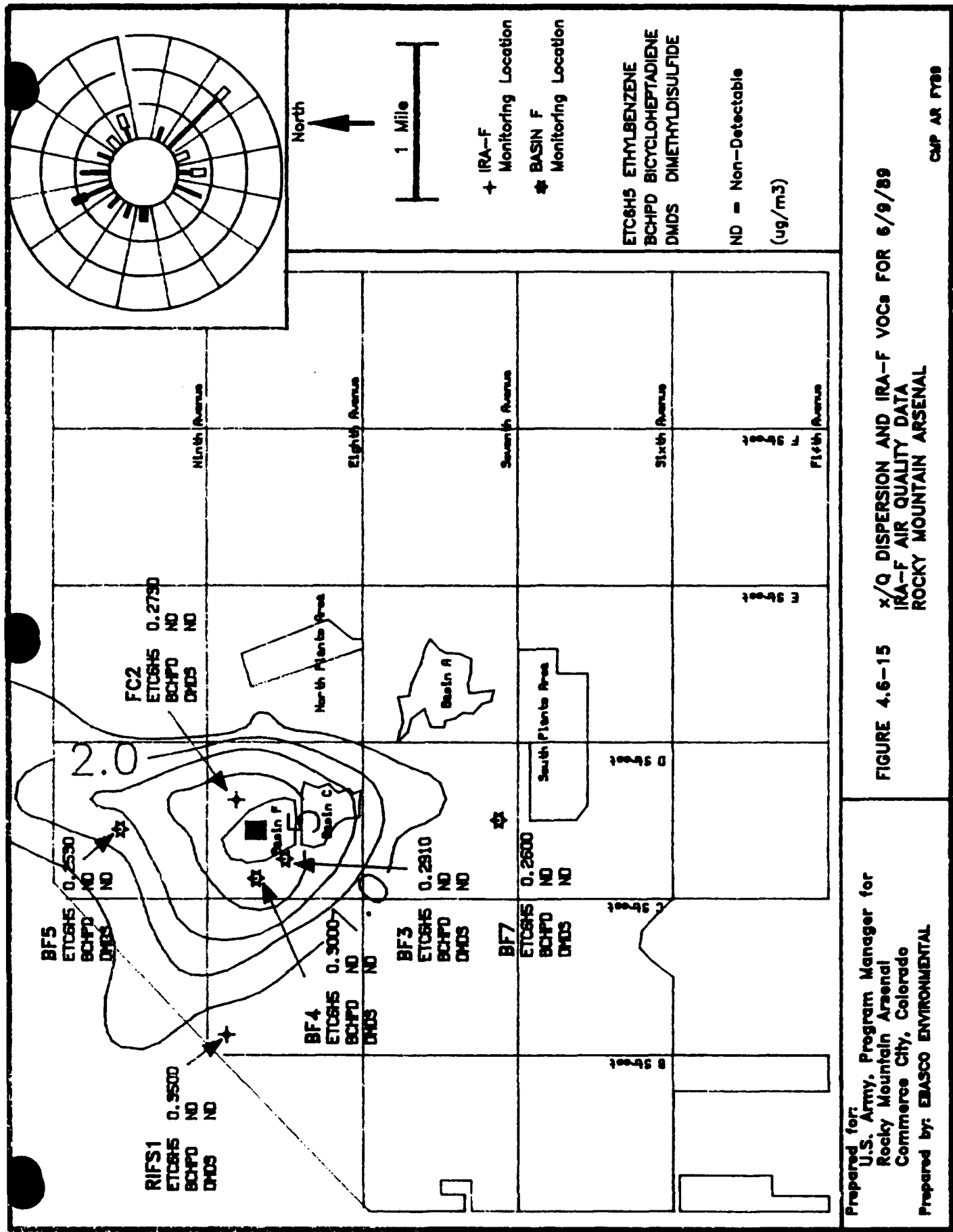
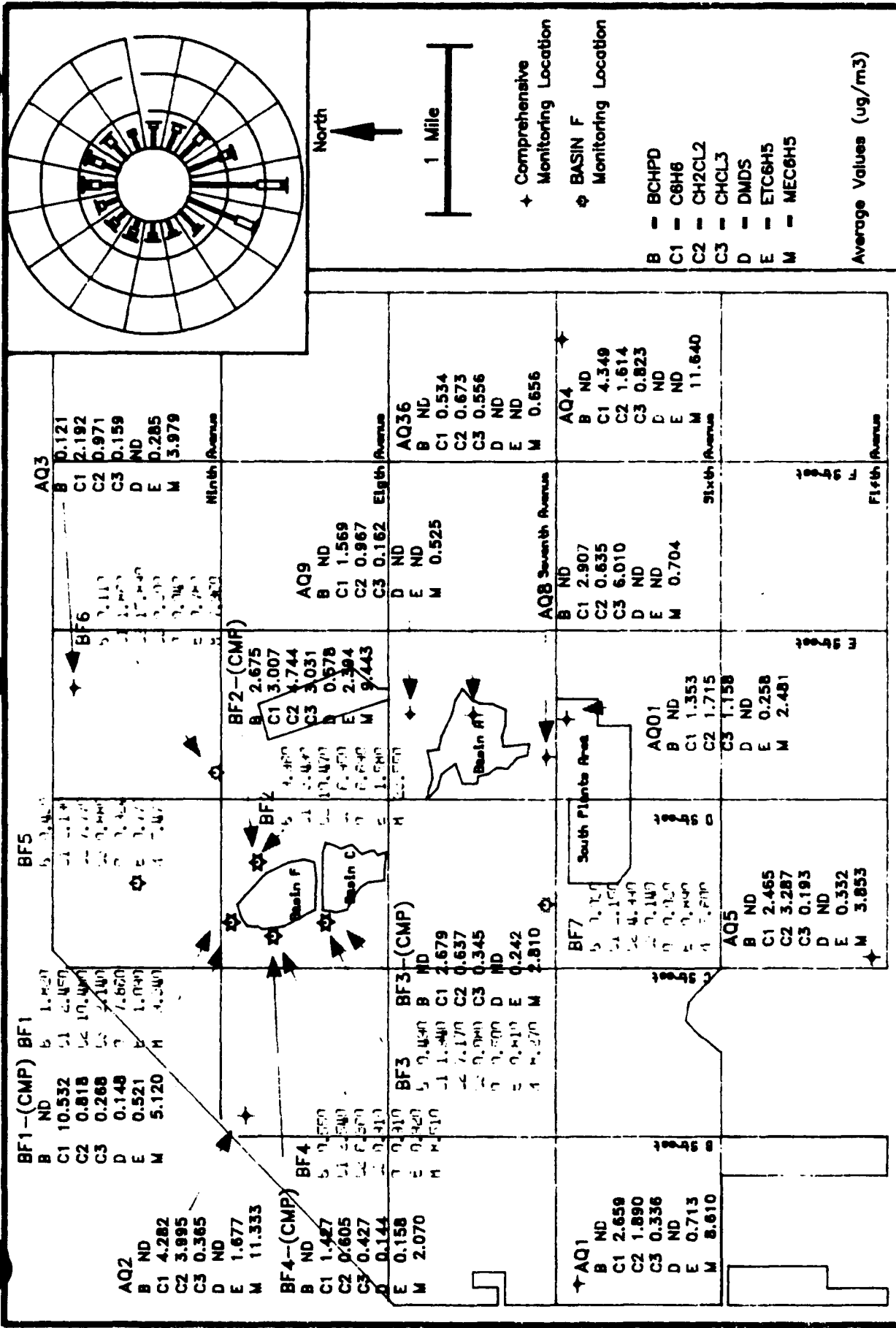


Figure 4.6-15 shows the X/Q dispersion pattern and the results for a Phase 3 (post-remedial) sample period, June 8-9, 1989, with similar dispersion characteristics as August 12, 1988. Winds on this sample day were moderate from the northwest in the late afternoon but relatively light and from predominantly the southeast and southwest thereafter. The maximum temperature was in the low 70s. There were no detectable amounts of dimethyl disulfide or bicycloheptadiene during the sample period, indicating that Basin F was not a source of these compounds on this day. The concentration pattern of ethylbenzene shows that the concentrations at sites BF5 (downwind), BF7 (upwind), and RIFS1 were nearly as high or higher than those at the basin's perimeter sites. This uniform pattern of concentrations indicates these values were most likely due to background levels, with no significant contribution from Basin F. This example substantiates other results that Basin F no longer was a significant source of these contaminants in Phase 3, as it was in Phase 1.

4.6.3.3 Combined CMP and Basin F Data Analyses. Individual CMP and Basin F VOC monitoring data for the three phases of the remedial monitoring programs have been shown in Tables 4.6-3 and 4.6-4. Figures 4.6-16 through 4.6-19 provide an illustration of all available average and maximum VOC data across the Arsenal complex. CMP data collected in the vicinity of Basin F are shown next to the Basin F data on these figures and printed in blue. The wind roses reflecting dispersion patterns are also shown in these figures. As noted from the previous discussions, the data show impacts for certain VOC compounds including benzene, chloroform, ethylbenzene, toluene, and dimethyl disulfide adjacent and immediately downstream from Basin F during the Phase 1 period. Further downstream, impacts were minimal and representative of the regional levels effecting the Arsenal. At the RIFS Odor Program sites, higher levels of several compounds appeared to be representative of Commerce City urban influences. It appears from the data that Basin F VOC impacts were localized close to remediation activities. During Phase 2, the impacts decreased for most of the VOC components, and during the Phase 3, post-remedial phase, VOC concentrations at all CMP and Basin F monitoring sites were back to what appear to be normal baseline, levels. Table 4.6-5 summarizes maximum average and maximum 24-hour concentrations for both the CMP and Basin F programs. This includes data from RIFS Sites 1 and 2. It is noted that RIFS Site 2 was located approximately one half mile north of the arsenal's northern boundary.

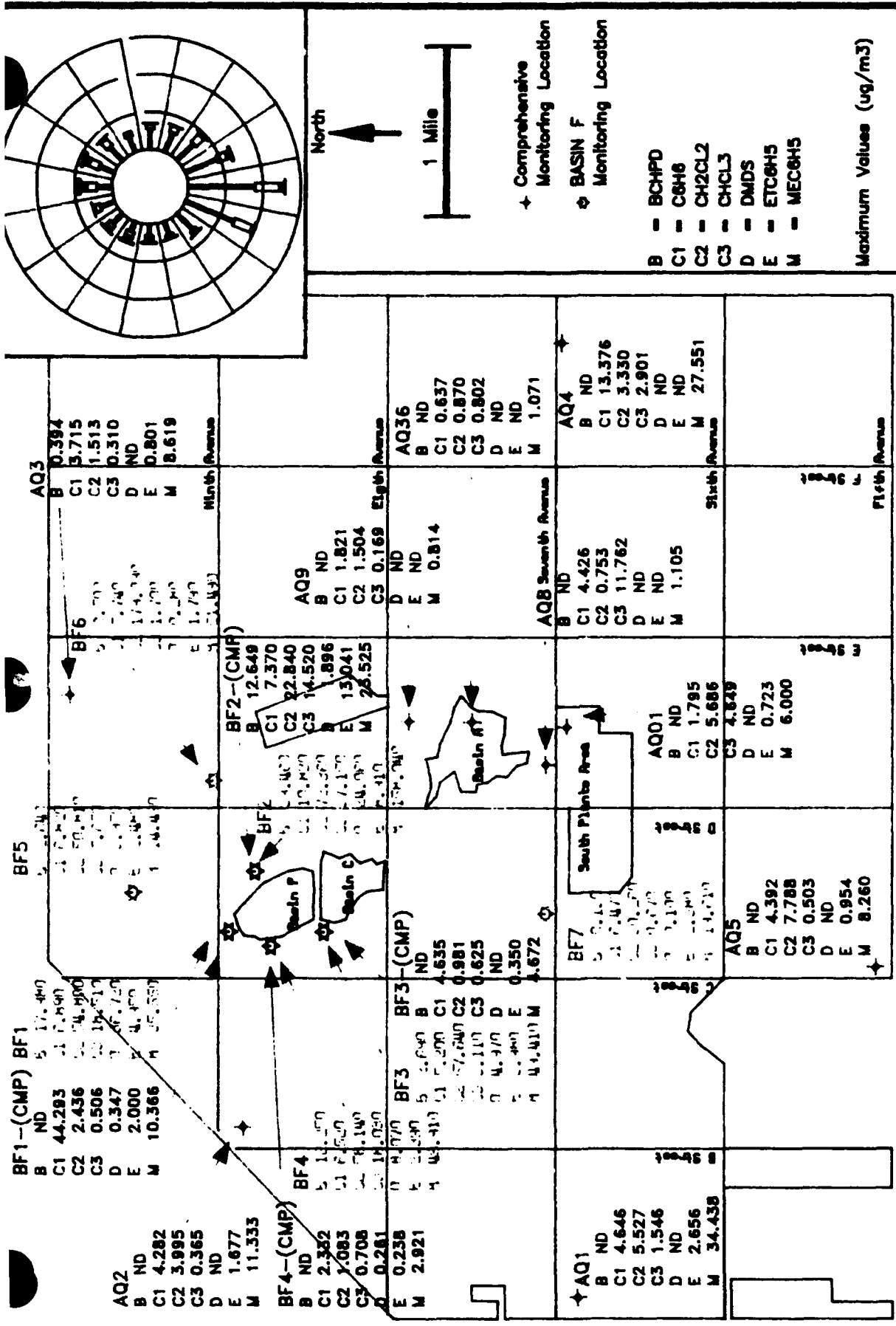
4.6.4 Summary of Results and Assessment of VOC Toxicity Levels

In order to assess the significance of measured VOC concentrations relative to health standards and guidelines, a literature search was conducted using sources similar to those identified in the metals assessment. Again this was necessary because the State of Colorado has not published air toxic regulations or promulgated standards. Guideline values were then compared with maximum concentrations measured for the CMP Basin F, IRA-F and RIFS programs.



Prepared for:
 U.S. Army, Program Manager for
 Rocky Mountain Arsenal
 Commerce City, Colorado
 Prepared by: EBASCO ENVIRONMENTAL

FIGURE 4.6-16 Composite VOC Analysis for Phase 1
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL



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 Rocky Mountain Arsenal
 Commerce City, Colorado
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FIGURE 4.6-16a Composite VOC Analysis for Phase 1
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AIR FY88

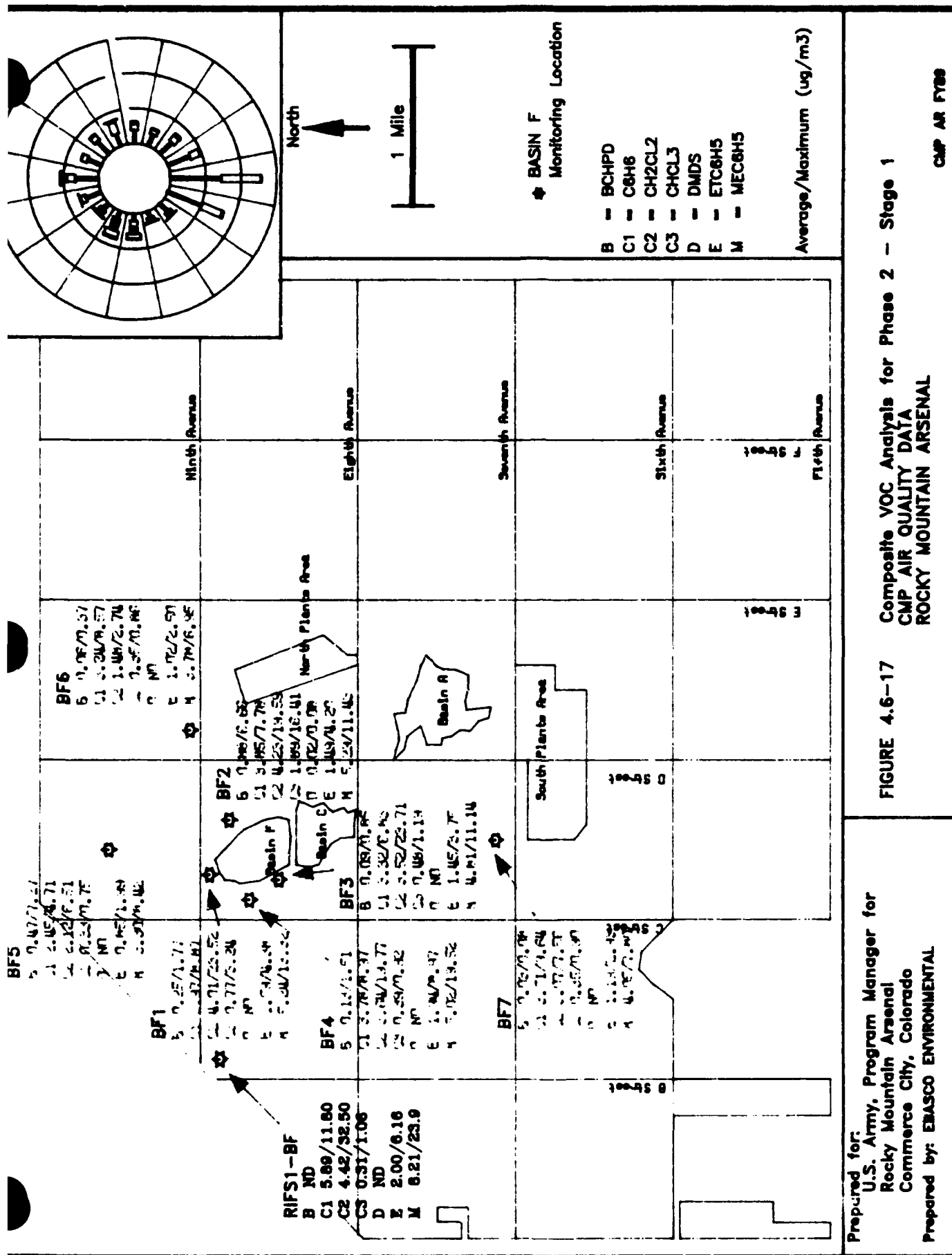
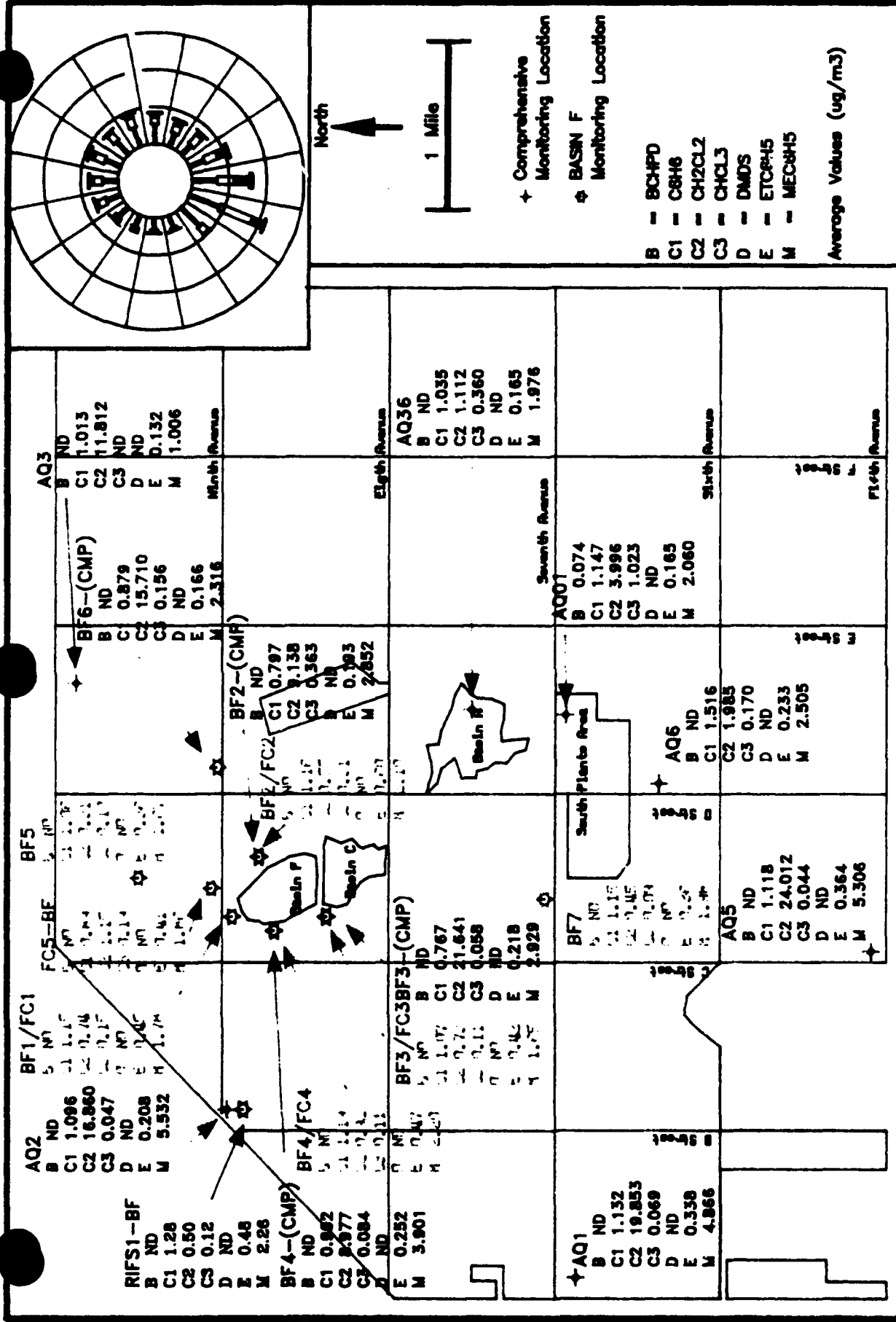


FIGURE 4.6-17 Composite VOC Analysis for Phase 2 - Stage 1
CMP AIR QUALITY DATA
ROCKY MOUNTAIN ARSENAL

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CMP AIR FY88



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FIGURE 4.6-19 Composite VOC Analysis for Phase 3
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

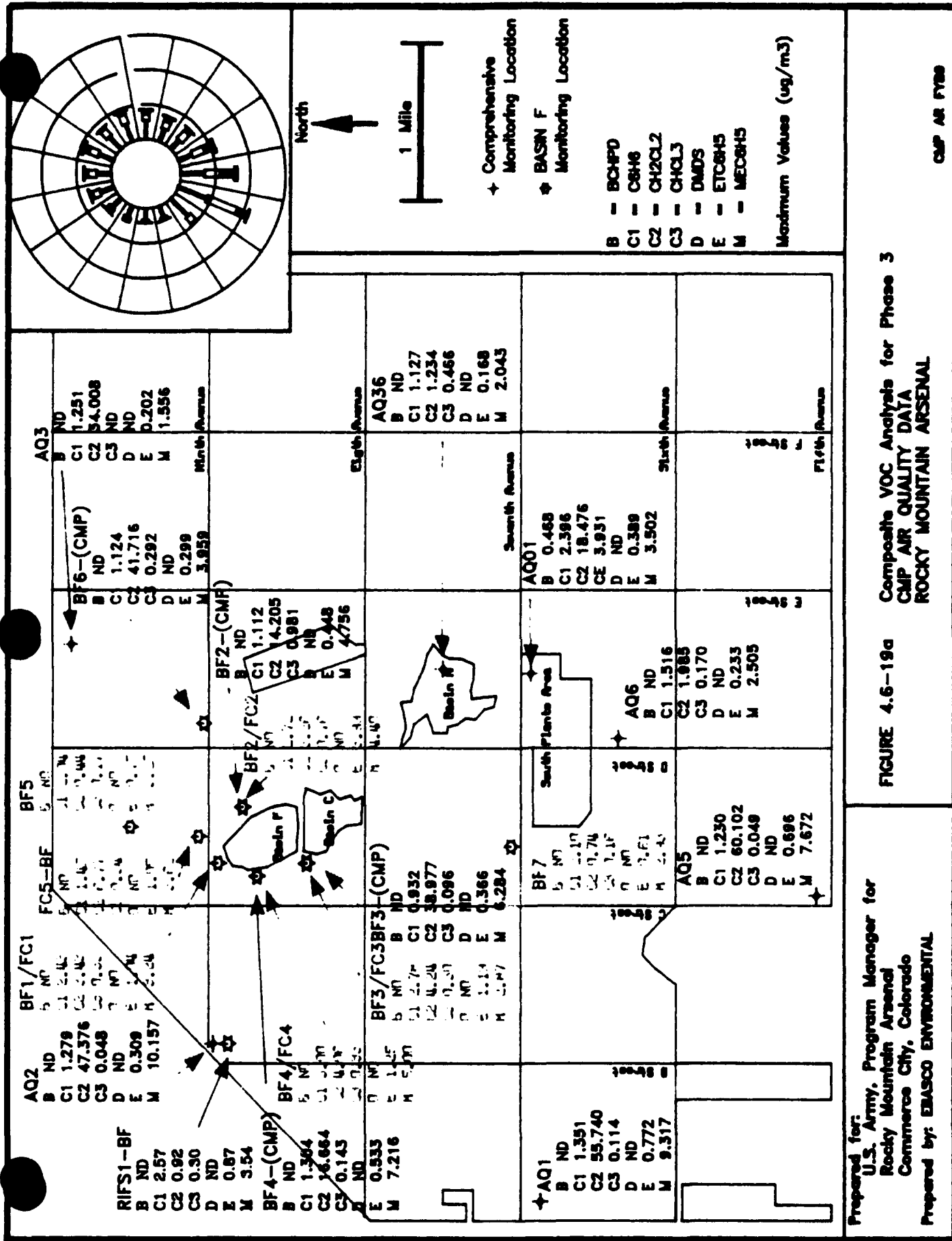


Table 4.6-5 Maximum Concentrations and Locations of Volatile Organic Compounds
(in $\mu\text{g}/\text{m}^3$)

VOC	Maximum Long-Term Average	Location	Phase	Maximum 24-Hour Concentration	Location	Phase
1,1,1-Trichloroethane	10.53	BF4	P1	72.54	BF1	P1
1,1,2-Trichloroethane	0.46	BF2	P2-S2	4.00	BF2	P2-S2
1,1-Dichloroethane	0.14	CMP/BF3	P1	0.27	CMP/BF3	P1
1,2-Dichloroethane	0.49	AQ5	P2-S2	3.80	RIFS2	P2-S1
Bicycloheptadiene	9.96	BF2	P1	39.46	BF2	P1
Benzene	10.53	CMP/BF1	P1	44.29	CMP/BF1	P1
Carbon Tetrachloride	1.99	RIFS2	P2-S1	9.76	RIFS2	P2-S1
Methylene Chloride	24.01	AQ5	P3	433.69	BF3	P2-S2
Chloroform	6.95	BF2	P1	37.15	BF2	P1
Chlorobenzene	0.47	CMP/BF2	P1	2.53	CMP/BF2	P1
Dibromochloropropane	2.90	CMP/BF2	P1	17.04	CMP/BF2	P1
Dicyclopentadiene	4.53	BF2	P1	29.12	BF2	P1
Dimethyl Disulfide	7.86	BF1	P1	36.72	BF1	P1
Ethylbenzene	2.39	CMP/BF2	P1	13.04	CMP/BF2	P1
Toluene	23.55	BF2	P1	158.04	BF2	P1
Methyl Isobutyl Ketone	0.47	AQ6	P3	0.60	Mobile 6	P3
N-Nitrosodimethylamine	ND					
Dimethylbenzene	3.06	RIFS2D	P2-S1	8.03	RIFS2D	P2-S1
Trans-1,2-Dichloroethene	ND			0.05	BF7	P2-S1
Tetrachloroethene	5.29	BF1	P2-S2	24.02	BF1	P2-S2
Trichloroethene	6.98	BF1	P2-S2	40.43	BF1	P2-S2
Xylene	8.57	BF2	P1	49.91	BF2	P1

Note: Data from both within and above the certified range are summarized here.
Long-term refers to averages by phase.

P1 = Phase 1
P2-S1 = Phase 2-Stage 1
P2-S2 = Phase 2-Stage 2
P3 = Phase 3

Table 4.6-6 RMA Target Volatile Organic Compounds (VOC) Comparison to Health Guidelines for Phases 1 and 2

Target Name	CAS #	TLV (ppm)	TLV/420 (µg/m³)	Short-term Avg ADI	1 Yr Avg ADI	Typical Guidelines (µg/m³)	RMA Phases 1 and 2**			RMA CMP Boundary Evaluation**					
							Subchronic	Chronic	Annual	Maximum Conc.*		% of Guideline		Max. Boundary Conc. (µg/m³)	% of Guideline
										24-Hr	Long-Term	24-Hr	Long-Term		
1,1,1-Trichloroethane	71-55-6	350	494.8	38500	22050	24500	38000	72.54	10.53	<1	<1	5.26	2.45	<1	<1
1,1,2-Trichloroethane	79-00-5	10	141			225	107	4.00	0.46	2	<1	ND	ND	ND	ND
1,1-Dichloroethane	75-34-3	200	2105	4830	483	8100		0.27	0.14			ND	ND	ND	ND
1,2-Dichloroethane	107-06-2	10	105					3.80	0.49			0.50	0.50		
Bicycloheptadiene	121-46-0							39.46	9.96			0.39	0.12		
Benzene	71-43-2	10	83			150	72	44.29	10.53	30	15	13.38	4.35	9	6
Carbon Tetrachloride	56-23-5	5	82			300		9.76	1.99	3	>100	2.28	0.91	<1	>100
Methylene Chloride	75-09-2	50	452			7000		433.69	23.81	6	43	7.79	4.00	<1	7
Chloroform	67-66-3	10	126		35	250		37.15	6.95	15	>100	2.90	0.82	1	>100
Chlorobenzene	108-90-7	75	901	185.5	19.95			2.53	0.47			0.23	0.09		
Dibromochloropropane	96-12-8	0.001	0.025					17.04	2.90			ND	ND	ND	ND
Dicyclopentadiene	77-73-6	5	70.26			500		29.12	4.53	6		0.57	0.57	<1	
Dimethyldisulfide	624-92-0							36.72	7.86			ND	ND	ND	ND
Ethylbenzene	100-41-4	100	1127	3395	350	4350		13.04	2.39	<1		2.66	1.68	<1	
Toluene	108-88-3	100	978	5250	5250	5600	400	158.04	23.55	3	6	34.44	11.64	<1	3
Methylisobutyl ketone	108-10-1	50	531.46	175				0.51	0.10			0.24	0.08		
N-Nitrosodimethylamine	62-75-9							ND	ND	ND	ND	ND	ND	ND	ND
Dimethylbenzene	95-47-6	100	1126.70	3360	700	4350	1450	8.03	3.06	<1	<1	4.42	2.51	<1	<1
Trans-1,2-Dichloroethene	156-60-5	200	2062			13000		0.05	ND	<2	ND	ND	ND	ND	ND
Tetrachloroethene	127-18-4	50	882		70	3350	21	24.02	5.29	<1	25	3.92	3.35	<1	16
Trichloroethene	79-01-6	50	696			2700	2,439	40.43	6.98	1	>100	0.31	0.11	<1	5
Xylene	108-38-3	100	1126.70	3500	700	4350	1450	49.91	8.57	1	<1	4.85	3.76	<1	<1

* In µg/m³.

** Data from both within and above the certified range are summarized here.

Legend: ADI = Acceptable Daily Intake

Table 4.6-7 RMA Target Volatile Organic Compounds (VOC) Comparison to Health Guidelines for Phase 3

Target Name	CAS #	TLV (ppm)	TLV/420 (µg/m ³)	Short-term Avg ADI	1 Yr Avg ADI	Typical Guidelines (µg/m ³)	RMA Phases 3				RMA CMP Boundary Evaluation**			
							Maximum Conc.*		% of Guideline		Max. Boundary Conc. (µg/m ³)		% of Guideline	
							24-Hr		Long-Term		24-Hr		Long-Term	
							Annual	Shrt-term	Annual	Shrt-term	Annual	Shrt-term	Annual	Shrt-term
1,1,1-Trichloroethane	71-55-6	350	494.8	38500	22050	24500	38000	2.14	1.25	<1	3.24	2.33	<1	<1
1,1,2-Trichloroethane	79-00-5	10	14.1			225	107	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	75-34-3	200	2105	4830	483	8100		ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	107-06-2	10	105					0.10	0.03	ND	0.07	0.05	ND	ND
Bicycloheptadiene	121-46-0							ND	ND		ND	ND		
Benzene	71-43-2	10	83			150	72	3.00	1.28	2	1.35	1.13	1	2
Carbon Tetrachloride	56-23-5	5	82			300		0.97	0.45	<1	0.49	0.35	<1	52
Methylene Chloride	75-09-2	50	452			7000	55.55	6.77	1.15	<1	60.10	24.01	1	43
Chloroform	67-66-3	10	126		35	250	0.43	0.76	0.31	<1	0.11	0.07	<1	16
Chlorobenzene	108-90-7	75	901	185.5	19.95			0.11	0.03		ND	ND		
Dibromochloropropane	96-12-8	0.001	0.025					ND	ND	ND	ND	ND	ND	ND
Dicyclopentadiene	77-73-6	5	70.26			500		ND	ND	ND	ND	ND	ND	ND
Diethylidithiophene	624-92-0							ND	ND		ND	ND		
Ethylbenzene	100-41-4	100	1127	3395	350	4350		3.99	0.60	<1	0.77	0.36	<1	1
Toluene	108-88-3	100	978	5250	5250	5600	400	5.00	2.26	<1	10.16	5.53	<1	
Methylisobutyl ketone	108-10-1	50	531.46		175			0.21	0.04		ND	ND		
N-Nitrosodimethylamine	62-75-9										ND	ND		
Dimethylbenzene	95-47-6	100	1126.70	3360	700	4350	1450	1.81	0.67	<1	0.99	0.43	<1	<1
Trans-1,2-Dichloroethene	156-60-5	200	2062			13000		ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	127-18-4	50	882		70	3350	21	2.50	0.71	<1	3.02	1.91	<1	9
Trichloroethene	79-01-6	50	696			2700	2.439	1.52	0.44	<1	0.24	0.13	<1	5
Xylene	108-38-3	100	1126.70	3500	700	4350	1450	5.29	2.36	<1	1.87	0.98	<1	<1

* In µg/m³.

** Data from both within and above the certified range are summarized here.

Legend: ADI = Acceptable Daily Intake

Page 223 is missing from the original.

The tabulation of guideline concentrations is presented as Tables 4.6-6, 4.6.6A and 4.6-7 for each target VOC for the remedial period (Phases 1 and 2) and the post-remedial period (Phase 3). The name and Chemical Abstract number is presented, along with TLV and TLV/420 concentrations. The value TLV/420 is used because this value is employed by many states in air toxic regulations as an annual concentration guideline "not to be exceeded." The next two columns of information are derived from the Superfund Health Risk Evaluation document (USEPA, 1986), and correspond to acceptable subchronic, and chronic unit risk values (10^{-6} risk). The EPA document defines subchronic exposures as those lasting 30 to 90 days; therefore the subchronic concentration guidelines should be thought of as acceptable 30 to 90 day average concentrations. The chronic levels reflect a 1 year constant exposure. The next two columns of Tables 4.6-6 and 4.6-7 present "typical" state toxic guidelines, both for short-term (1 to 24-hour) and annual averages. There is a great deal of variability in air toxic guideline concentrations from state to state; therefore, in order to determine typical values, the median of all National Air Toxics Information Clearinghouse (NATICH) listed values was selected.

The next two columns show the 24-hour maximum and the average maximum values measured from either the CMP Basin F or RIFS programs. The VOC data for each phase were then compared to the appropriate guideline values. The 24-hour values were compared to the 24-hour guideline values; the maximum average values were compared to the maximum long-term guideline values.

The next two columns of Tables 4.6-6, 4.6-6A and 4.4-7 show the percentage of the highest 24-hour maximum concentrations and the highest maximum average concentrations to the guidelines. An evaluation of these data should consider the fact that both the CMP and Basin F programs selected worst-case periods for sampling. The final columns of Tables 4.6-6 and 4.6-7 only show the percentage of RMA boundary monitoring station maximum concentrations and provide a comparison to the guidelines.

A conservative approach is employed in this evaluation in order to identify potential areas of concern and needed emphasis in ongoing CMP activities. It is not the purpose of this study to provide a rigorous health risk assessment, but rather to provide data for such an assessment and to evaluate remedial progress over the long-term period of continuing cleanup activities. Consequently, this report summarizes two separate databases; that certified by PMRMA methods, and that which is either above the certified range or not certified by PMRMA. Results from the Basin F program, out-of-certified range data analyses, and nontarget data analyses have substantially assisted in assessing remedial progress and in identifying future needs and requirements. These data, however, may not meet full specifications of PMRMA certification.

All PMRMA certified and reviewed data, which consist of the majority of the CMP metals, VOC, SVOC and OTSP data employed in this report, are provided in Appendices C, E, F and G. These data meet the most rigorous standards for quantification of the target analytes. The other data must be considered as less rigorous estimates of atmospheric concentrations, which still can be used for meaningful analysis and interpretation.

For the most part, even by applying a generalized and conservative approach, concentration levels remained well below available toxic guidelines and standards even during the Phase 1 period. In several instances, where a level of possible concern was identified, the post-remedial, Phase 3 data show these concerns no longer exist.

A review of the CMP and Basin F target analyte data results and potential toxic concerns for several pertinent compounds follows. Nontarget analyte data will be considered in Section 4.6.5.

Benzene. The highest short-term benzene level, $44.3 \mu\text{g}/\text{m}^3$, was measured on a CMP high event monitoring day, August 26, 1988, in the vicinity of BF1 (at the northern perimeter of Basin F). This was an anomalously high reading and one of the few occasions when a CMP monitor in the vicinity of Basin F measured higher levels than the Basin F program monitors. This concentration was 30 percent of the 24-hour typical guideline of $150 \mu\text{g}/\text{m}^3$. Maximum 24-hour benzene concentrations ranged from $0.64 \mu\text{g}/\text{m}^3$ to $13.4 \mu\text{g}/\text{m}^3$ at other CMP and Basin F monitoring stations. The second highest 24-hour level was at AQ4 at the southeast boundary of RMA.

It would appear from the data that baseline benzene concentrations were evenly distributed in the RMA vicinity, with short-term peaks occasionally reported as a result of cleanup or construction activities at Basin F and elsewhere; these include diesel emissions from trucks and other heavy equipment, both on and off the Arsenal.

The highest long-term benzene average, $10.5 \mu\text{g}/\text{m}^3$ at station BF1-(CMP), was 15 percent of the long-term median typical guideline of $72 \mu\text{g}/\text{m}^3$ for toxic concern (See Table 4.6-6). Note again that this was based on worst-case averages, including one anomalously high measurement. The maximum Basin F long-term average was $3.97 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 1 at BF1, or 6 percent of the guideline.

Bicycloheptadiene. - The highest 24-hour bicycloheptadiene level, $39.5 \mu\text{g}/\text{m}^3$, was measured under the Basin F Monitoring program at BF2 on the northeast perimeter of Basin F. The next highest 24-hour measurement was only $18.0 \mu\text{g}/\text{m}^3$ at BF1. Bicycloheptadiene appears to be a highly localized source in the vicinity of Basin F. The highest maximum average, $9.96 \mu\text{g}/\text{m}^3$ was

also measured at BF2. Basin F monitoring program measured levels of bicycloheptadiene *dropped off significantly* from the Basin F perimeter, and CMP measurements were all well below those at the Basin F sites. There is no apparent toxic guideline for bicycloheptadiene.

Methylene Chloride. The maximum 24-hour methylene chloride value, $434 \mu\text{g}/\text{m}^3$, was measured at BF3 during Phase 2, Stage 2. Station BF6 reported a maximum 24-hour level of $179 \mu\text{g}/\text{m}^3$ during Phase 1, and BF2 a maximum value of $72.8 \mu\text{g}/\text{m}^3$ during Phase 2, Stage 2. The maximum measured 24-hour concentration was 6 percent of the short-term guideline of $7000 \mu\text{g}/\text{m}^3$.

Basin F appears to be a localized source of methylene chloride, with downstream flow in the direction of BF3 and BF6. The maximum long-term average of methylene chloride was $24.0 \mu\text{g}/\text{m}^3$ at AQ5, or 43 percent of the long-term annual guideline of $55.55 \mu\text{g}/\text{m}^3$. Again, as this is an average of selected worst-case conditions, this assessment is conservative. Methylene chloride values fell off significantly with distance from Basin F. The CMP maximum levels ranged from $0.43 \mu\text{g}/\text{m}^3$ to $60.1 \mu\text{g}/\text{m}^3$ (at AQ5). Average values ranged from $0.43 \mu\text{g}/\text{m}^3$ to $24.0 \mu\text{g}/\text{m}^3$.

Chloroform. The maximum 24-hour chloroform level, $37.1 \mu\text{g}/\text{m}^3$, was measured at station BF2 during Phase 1. The next highest 24-hour chloroform level, $18.5 \mu\text{g}/\text{m}^3$, was measured at BF1. The long-term maximum average value, $6.95 \mu\text{g}/\text{m}^3$ was also measured at BF2 during Phase 1 and was greater than 100 percent of the typical annual guideline. Long-term averages at CMP sites ranged from 0.03 to $6.01 \mu\text{g}/\text{m}^3$. These data suggest that there are localized sources of chloroform in the vicinity of South Plants and BF2.

The maximum 24-hour chloroform level, $37.1 \mu\text{g}/\text{m}^3$, was 15 percent of the guideline of $250 \mu\text{g}/\text{m}^3$; however, the maximum long-term average at BF2, $6.95 \mu\text{g}/\text{m}^3$, was 16 times higher than the annual typical guideline of $0.43 \mu\text{g}/\text{m}^3$. This guideline appears unrealistically low relative to other guidelines. The TLV/420 value is $126 \mu\text{g}/\text{m}^3$, and the ADI chronic long-term guideline is $35 \mu\text{g}/\text{m}^3$; consequently, the maximum long-term concentration, $6.95 \mu\text{g}/\text{m}^3$, was 6 and 17 percent of these respective guidelines.

Dimethyl Disulfide. A 24-hour maximum dimethyl disulfide level of $36.7 \mu\text{g}/\text{m}^3$ was measured at BF1 during Phase 1. The next highest value $24.1 \mu\text{g}/\text{m}^3$, was measured at BF2. The maximum averages were $7.86 \mu\text{g}/\text{m}^3$, measured at BF1, and $6.69 \mu\text{g}/\text{m}^3$, measured at BF2. Both Basin F and CMP maximum and average values decreased to non-detectable after Phase 2, Stage 1.

Basin F appears to be a localized source of dimethyl disulfide. The component drifted to the north under prevailing inversion flow, but levels also decreased significantly with distance. There

were no dimethyl disulfide concentrations measured to the south of Basin F sites at CMP or Basin F monitoring stations. There are no suggested guideline values for dimethyl disulfide.

Ethylbenzene. A 24-hour maximum ethylbenzene level of $13.0 \mu\text{g}/\text{m}^3$ was measured at the CMP station BF2 monitor during Phase 1. The second maximum 24-hour concentration of $8.97 \mu\text{g}/\text{m}^3$ was measured at the Basin F program BF4 station. The maximum long-term average value, $2.39 \mu\text{g}/\text{m}^3$, was also measured at CMP station BF2 and was less than 1 percent of the annual guideline. Measurements at the CMP boundary indicated a maximum average of $1.68 \mu\text{g}/\text{m}^3$ at AQ2 during Phase 1. Basin F appears to be one localized source of ethylbenzene. However, the 24-hour maximum level, $13.0 \mu\text{g}/\text{m}^3$, was less than 1 percent of the 24-hour guideline of $4350 \mu\text{g}/\text{m}^3$.

Toluene. A 24-hour maximum toluene concentration of $158 \mu\text{g}/\text{m}^3$ was measured at BF2 during Phase 1. Maximum 24-hour values decreased to less than $10 \mu\text{g}/\text{m}^3$ at other Basin F monitoring sites by the end of Phase 2. Outlying CMP monitoring stations showed a maximum short-term toluene level of $34.4 \mu\text{g}/\text{m}^3$ at AQ1 on the western RMA boundary and $27.6 \mu\text{g}/\text{m}^3$ at AQ4 on the eastern boundary during Phase 1. CMP values were $10 \mu\text{g}/\text{m}^3$ or less during Phase 3. The maximum 24-hour short-term measurement was 3 percent of the 24-hour guideline of $5600 \mu\text{g}/\text{m}^3$. The long-term maximum average toluene level, $23.6 \mu\text{g}/\text{m}^3$ at BF2 was 6 percent of the annual guideline of $400 \mu\text{g}/\text{m}^3$.

The higher toluene levels in the vicinity of Basin F indicated a source of this compound from the cleanup operations. However, higher short-term and average toluene levels at the RMA boundary stations also suggested other sources of toluene, most likely from metropolitan Denver traffic and industrial activities. Average levels of toluene were lower and more uniform during Phase 3 at all Basin F and CMP sites.

Other Comparisons. Tables 4.6-6 and 4.6-7 compare toxic guidelines with CMP and Basin F Program maximum short-term and longer-term concentrations for these and 15 other VOC compounds. The last four columns also provide a comparison of highest RMA boundary site concentrations and the guidelines. At the boundaries, most of the measured analyte concentrations were less than 1 percent of the various guidelines. One analyte that was above one percent, benzene, does not appear to be entirely associated with remediation activities, but may result from both on-Arsenal and off-Arsenal activities. Carbon tetrachloride and chloroform were identified as concerns because of the very low annual levels established by state guidelines. Chloroform has been discussed previously. For carbon

tetrachloride, the annual guideline (median value) is $0.67 \mu\text{g}/\text{m}^3$. The maximum average carbon tetrachloride level measured was $1.99 \mu\text{g}/\text{m}^3$ at RIFS2, during Phase 2 Stage 1. This is greater than 100 percent of the guideline; however, the fraction is reduced to only 2.4 percent if the TLV/420 value, $82 \mu\text{g}/\text{m}^3$, is used as a guideline.

The EPA conducted a study of air toxic in the Denver area during the summer of 1987 and the winter of 1987/88. A total of 182 VOC samples were collected at three sites in the metropolitan area, including Arvada, the Auraria campus near downtown Denver and at National Jewish Hospital in east Denver. The VOCs were analyzed by gas chromatography with either flame ionization detection or electron capture detection during the summer and with the mass spectrometer in winter. Because the sensitivity of these methods is so different, a strict interseasonal comparison of the results cannot be made.

Generally, the highest VOCs were observed at the Auraria site during the winter months. Table 4.6-8 provides a listing of the maximum concentrations for all target VOCs which are on the CMP target list. Highest Denver study concentrations were seen for toluene and meta- and para-xylene. The mean wintertime concentrations at Auraria were $28 \mu\text{g}/\text{m}^3$ for toluene, $21 \mu\text{g}/\text{m}^3$ for m- and p-xylene, and $12 \mu\text{g}/\text{m}^3$ for benzene, indicating that both the mean and extreme concentrations were significantly higher in downtown Denver than they were at the Arsenal. It is difficult to draw any absolute conclusion from these data because the quantification of the extreme values under any analytical method is less reliable than the lower values.

Table 4.6-f Comparison of EPA Air Toxic Study and RMA Results for VOCs

Analyte	Maximum Concentration for Denver Study ($\mu\text{g}/\text{m}^3$)	Maximum Concentration At RMA ($\mu\text{g}/\text{m}^3$)	
1,2-Dichloroethane	49	4	
1,1,1-Trichloroethene	44	73	
Carbon Tetrachloride	3	10	
Trichloroethene	4	40	
Tetrachloroethene	14	24	
Benzene	83	44	
Toluene	294	158	
Ethylbenzene	22	13	
o-Xylene	13	8	
m- and p-Xylene	252	50	(Total Xylenes)
Chlorobenzene	83	3	

Where toxic guidelines vary significantly, perhaps a more meaningful evaluation would be a comparison of the RMA measured VOC compounds with typical urban VOC levels. Table 4.6-9 compares the CMP VOC results to published EPA studies for both the Denver metropolitan area as well as a summary of "air toxic" results from studies across the country. CMP concentrations are generally found to be less than the concentrations reported by the EPA urban airshed studies. While the average maximum levels of chloroform, benzene, and carbon tetrachloride identified as concerns at the RMA boundaries, and other compounds identified as potential source emissions from Basin F, were equivalent to or below Denver and other urban sources levels, this is not to negate concern over these compounds or suggest that some potentially toxic air compounds may not have been emitted from various RMA sources and remedial activities. Analysis of results, indeed, suggests continued monitoring of these compounds with additional emphasis placed on identifying specific RMA local and regional emission sources. As noted previously, Basin F activities appeared to contribute to the release of bicycloheptadiene, methylene chloride, dimethyl disulfide, benzene, ethylbenzene and toluene. Many of these may be the result of previous Arsenal production activities; others are typical industrial and traffic related compounds and are released throughout the Denver urban metropolitan area. Several of these compounds were directly related to cleanup actions including emissions from vehicles and heavy equipment. Chloroform was identified in the South Plants on several occasions. Other compounds monitored at RMA were randomly distributed and it appears that the source was from industrial activity and vehicle traffic outside of the Arsenal. Arsenal VOC measurements need to be evaluated quantitatively in terms of other urban sources. The CMP FY90 Program will continue to address this issue.

In general, compounds measured at RMA did not appear to present toxic health risks significantly different from the urban environment of metropolitan Denver. Organic compounds that were unique to Basin F decreased rapidly with distance from this source and were at lower levels at the RMA boundaries.

Table 4.6-9 Ambient Volatile Organic Compounds (VOC) Concentrations from Various Studies

Target Name	1987 EPA NMOC Study Means $\mu\text{g}/\text{m}^3$	1988 EPA UATMP Mean $\mu\text{g}/\text{m}^3$	FY89 CMP* Basin F Mean $\mu\text{g}/\text{m}^3$	FY89 CMP* Basin A Mean $\mu\text{g}/\text{m}^3$	FY89 CMP* S. Plants Mean $\mu\text{g}/\text{m}^3$	FY89 CMP* Perimeter Mean $\mu\text{g}/\text{m}^3$
1,1,1-Trichloroethane	18.6	6.7	1.177	1.929	1.782	1.853
1,1,2-Trichloroethane	-	3.0	-	-	-	-
1,1-Dichloroethane	13.7	2.0	-	-	-	-
1,2-Dichloroethane	25.1	8.1	0.041	-	0.051	0.112
Benzene	6.5	5.2	0.859	1.035	1.147	1.840
Bicycloheptadiene	-	-	-	-	0.074	0.063
Carbon Tetrachloride	-	2.1	0.373	0.457	0.572	0.456
Chlorobenzene	7.4	3.0	-	-	0.026	-
Chloroform	-	30.8	0.165	0.360	1.023	0.105
Dicyclopentadiene	-	-	-	-	-	0.170
Dimethyldisulfide	-	-	-	-	-	-
Ethylbenzene	-	7.0	0.207	0.165	0.165	0.573
Methylene Chloride	78.4	18.1	13.867	1.112	3.996	11.764
Methylisobutyl Ketone	-	-	0.089	0.173	0.079	-
m-Xylene (120MB)	59.1	18.7	0.247	0.211	0.214	0.896
N-Nitrosodimethylamine	-	-	-	-	-	-
o-Xylene	7.4	5.7	0.733	0.561	0.576	1.290
p-Xylene	59.1	18.9	-	-	-	-
Tetrachloroethylene	34.1	13.1	0.710	0.768	0.286	1.438
Toluene	32.0	16.4	3.000	1.976	2.060	6.109
Trans-1,2-Dichloroethylene	9.7	4.4	-	-	-	-
Trichloroethylene	20.8	10.4	0.362	0.123	0.030	0.078

Source: U.S. EPA, 1988. 1987 Nonmethane Organic Compound and Air Toxics Monitoring Program, Final Report, Vol. 11, "Toxic Species."
EPA-450/4-88-012. Research Triangle Park, North Carolina: U.S. EPA Office of Research and Development.

* Data from both within and above the certified range are reported here.

Legend: NMOC = Nonmethane Organic Compound
IEMP = Integrated Environmental Monitoring Program
UATMP = Urban Air Toxics Monitoring Program

4.6.5 VOC Nontarget Analyte Results

Volatile organic compound samples from the CMP were analyzed not only for target VOCs compounds but also for any nontarget compounds that were observed. The target compound list was derived based on analyses of a variety of previous air monitoring and source characterization studies as well as the types of chemical processes, raw feed materials, and by-products that were associated with previous operations at RMA. The target list represents potential contaminants of concern that would be specific to RMA. Tentative identification and semi-quantification of nontarget compounds was performed in order to evaluate the significance of nontarget compounds and to update the target analyte list.

4.6.5.1 Laboratory Procedures. The laboratory analysis and data processing procedures for nontarget VOCs differed from target VOC procedures. Target VOCs were directly compared to responses and retention times from standards for that analyte on a gas chromatograph/mass spectrometer (GC/MS) system. Nontarget VOCs were tentatively identified by analyzing the total ion chromatogram for any peak that was greater than 10 percent of the internal standard area. The observed mass spectrum was compared to a library of spectra contained in the master spectral library, from the National Bureau of Standards/Wiley/Stirs Spectra, which contains approximately 72,000 compounds. A best fit match and a level of uncertainty was obtained. Semi-quantification could then be performed using an estimated response factor of one. Because the nontarget VOC results were not verified by use of an authentic standard, these results must be considered tentative identifications. The amounts which were calculated are estimates and must be used with caution.

4.6.5.2 Summary of Nontarget VOCs The essential questions regarding observed nontarget compounds include: (1) what actual compounds or chemical types were detected, (2) how often did they occur, (3) at what site did they occur, (4) at what levels, and (5) what toxicity or significance is associated with these levels. Some of the nontarget compounds were grouped into categories based on similar chemical and toxicological characteristics. All simple alkanes and cycloalkanes were grouped together into the aliphatic hydrocarbon category. The group of freons are multichlorofluorinated ethane and methane hydrocarbons. Freons are commonly used as propellants or refrigerants. The toxicity of the compounds in each group was relatively uniform as judged by Threshold Limit Values (TLVs) established by the American Council of Government

and Industrial Hygienists (ACGIH, 1986). For example, the TLVs for dichlorodifluoromethane, trichlorofluoromethane, and trichlorotrifluoroethane were all approximately 5 to 7.5 mg/m³.

Table 4.6-10 presents a summary listing of all nontarget compounds or compound groups that were detected from the CMP monitoring sites during the FY89 program. It includes the number of detections for each compound or compound group, and the maximum and minimum concentrations at each site. The total number of observed nontarget VOCs was 1,687. There were 949 detections of simple aliphatic hydrocarbons where the observed maximum concentration of 40 µg/m³ was detected at site AQ01. The simple aliphatic hydrocarbons represented over 56 percent of all observed nontarget detections. There were 87 detections of simple non-halogenated aromatic hydrocarbons (benzenes) with the maximum concentration of approximately 0.6 µg/m³ observed at sites BF2 and BF3. These aromatic hydrocarbons represented 5 percent of all observed nontarget VOCs. The next largest group of nontarget compounds was composed of ketones and aldehydes, representing 10 percent of all nontarget detections. These groups are common components of urban airsheds and are reaction products of hydrocarbon emissions as part of the "smog" reactions process.

The Tenax trapping and desorbing procedure is known to produce interferences when the packing material comes in contact with ozone, NO_x, chlorine and temperatures higher than 200°C. The compounds observed from the reaction of Tenax with the above are benzaldehyde, acetophenone, phenol, and benzene. Precautions are taken during the sampling and handling process to minimize the exposure of the tubes to these situations. Phenol is detected uniformly across all sites indicating the possible reaction of the Tenax with NO₂. Benzene-type compounds and benzaldehyde were also uniform except for site AQ01. More samples were taken at AQ01, which consisted of several mobile sites in the South Plants area.

Silane is a compound used to coat the analytical columns, liners and injection ports and is a common laboratory contaminant. There were 23 detections of Carene, which is a component in turpentine. Most of the other detections of methylated cyclohydrocarbons were uniform among the sites except for site AQ01, where the concentrations were not as intense but more frequent because of additional samples taken at these sites.

Typical urban air sheds have been shown to contain many VOC compounds, with both industrial and vehicular sources being major emitters. The emissions include both aliphatic and aromatic hydrocarbons, and the freon-type of halogenated aliphatics. These VOCs can then react in the photochemical smog process to form other groups of compounds, most notably aldehydes and ketones. These compound types represented the majority of the nontarget compounds observed,

Table 4.6-10 Summary of VOC Blank Montarsets for FY89

Maximum and Minimum Data in ug/g3

UNKNOWN ID	AQ1			AQ2			AQ3			AQ5			AQ6		
	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS
Aldehydes			0			0			0			0	0.04	0.04	1
Alkanes	0.90	0.01	46	0.60	0.01	47	0.40	0.01	31	0.60	0.01	51	2.00	0.01	23
Alkenes	0.02	0.02	3	0.02	0.01	2	0.02	0.01	2	0.03	0.02	2	0.08	0.06	2
Benzaldehyde	0.10	0.10	1	0.10	0.09	2	0.09	0.04	3	0.20	0.06	3	0.50	0.50	1
Benzenes	0.07	0.01	7	0.30	0.02	9	0.10	0.01	6	0.05	0.01	9	0.20	0.04	3
Butyl acetate	0.02	0.02	1			0			0	0.02	0.02	1	0.30	0.30	1
Camphor			0			0			0			0			0
Carene			0			0			0			0	0.10	0.10	1
Cyclohydrocarbons	0.01	0.01	1			0			0	0.07	0.04	2	0.05	0.05	1
Decanol			0	0.01	0.01	1			0	0.02	0.02	1			0
Dichlorobenzene			0	0.02	0.02	1			0	0.02	0.02	1			0
Dimethyl cyclohexane			0			0			0			0			0
Fragras	0.20	0.20	1	0.20	0.20	1	0.10	0.07	3	0.40	0.20	2	2.00	2.00	1
Heptane	0.05	0.05	1	0.20	0.02	2			0	0.05	0.05	1	0.40	0.40	1
Heptanol			0			0			0			0			0
Hexane	0.30	0.02	3	0.30	0.03	3	0.20	0.06	2	0.50	0.03	3	0.50	0.50	1
Isoprenes	0.20	0.01	6	0.20	0.03	6	0.08	0.02	6	0.40	0.01	10	0.20	0.20	1
Limosene			0	0.02	0.02	1	0.02	0.02	1	0.05	0.05	1			0
Methyl cyclohexane	0.10	0.01	3	0.10	0.01	3	0.07	0.02	2	0.10	0.01	3	0.20	0.20	1
Methyl cyclopentane	0.20	0.20	1	0.20	0.02	2	0.10	0.10	1	0.20	0.20	1	0.30	0.30	1
Methyl hexane	0.20	0.01	2	0.20	0.20	1	0.10	0.10	1	0.20	0.02	2			0
Naphthalene			0	0.01	0.01	1			0	0.01	0.01	1			0
Nitrogen containing cpd.	0.03	0.03	1	0.05	0.05	1	0.06	0.06	1	0.06	0.06	1			0
Oxygenated cpd.			0			0			0			0	0.03	0.01	2
Pentadiene			0			0			0	0.04	0.04	1			0
Pentane	0.30	0.30	1			0			0			0			0
Phenol	0.04	0.01	2	0.05	0.04	2	0.10	0.03	2	0.08	0.03	3			0
Propanol			0			0			0			0			0
Silane compound	0.10	0.01	7	0.20	0.01	7	0.10	0.02	6	0.10	0.01	5			0
Trimethyl cyclohexane	0.02	0.02	1	0.04	0.01	2	0.01	0.01	1	0.03	0.02	2			0
Trimethyl cyclohexane + unknown			0			0			0			0			0
Trimethyl cyclopentane			0			0			0			0			0
Trioxocane			0			0			0			0			0

Table 4.6-10 (Continued)

Maximum and Minimum Data in ug/m3

UNKNOWN ID	BF2			BF3			BF4			BF6		
	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS
Aldehydes	0.03	0.02	3	0.05	0.02	4	0.07	0.05	2	0.03	0.03	1
Alkanes	3.00	0.01	66	3.00	0.01	69	3.00	0.01	66	3.55	0.01	44
Alkenes	0.02	0.01	3	0.04	0.01	5	0.05	0.02	5	0.05	0.01	2
Benzaldehyde	0.80	0.06	3	1.00	0.02	4	1.00	0.07	3	0.10	0.06	2
Benzenes	0.60	0.10	2	0.60	0.20	2	0.50	0.03	4	0.02	0.01	2
Butyl acetate			0			0			0			0
Campher			0			0			0			0
Carene	0.10	0.02	3	0.20	0.09	3	0.05	0.05	1	0.05	0.05	1
Cyclohydrocarbons			0			0			0			0
Decanol			0			0	0.02	0.02	1	0.04	0.04	1
Dichlorobenzene			0			0			0	0.01	0.01	1
Dimethyl cyclohexane			0			0			0			0
Freons	0.80	0.06	4	1.00	0.09	4	0.10	0.06	3	0.30	0.20	2
Heptane			0			0	0.10	0.10	1	0.20	0.20	1
Heptanol			0			0			0	0.01	0.01	1
Hexane	0.30	0.04	2	0.20	0.02	3	0.20	0.02	2	0.30	0.03	2
Ketones	0.60	0.02	10	0.50	0.01	10	0.50	0.01	11	0.60	0.02	6
Limonene			0	0.05	0.05	1			0	0.05	0.05	1
Methyl cyclohexane	0.05	0.01	2	0.07	0.02	2	0.07	0.01	3	0.10	0.02	3
Methyl cyclopentane	0.10	0.01	2	0.10	0.02	2	0.10	0.01	2	0.20	0.02	2
Methyl hexane			0			0			0	0.06	0.06	1
Naphthalene	0.04	0.04	1	0.04	0.04	1	0.60	0.06	1			0
Nitrogen containing comp.	0.01	0.01	1	0.04	0.04	1			0	0.10	0.10	1
Oxygenated comp.			0			0			0			0
Pentadiene			0			0			0			0
Pentane			0			0			0			0
Phenol	0.70	0.03	2	0.70	0.02	2	0.70	0.05	2	0.07	0.05	2
Propanol	0.50	0.20	2	1.00	0.70	2	0.70	0.60	2	0.80	0.80	1
Silane compound	0.05	0.01	5	0.10	0.02	6	0.10	0.01	4	0.20	0.01	7
Trisethyl cyclohexane	0.03	0.03	1	0.05	0.05	1	0.04	0.04	1	0.03	0.03	1
Trisethyl cyclohexane + unknown			0			0			0			0
Trisethyl cyclopentane			0			0			0			0
Trisocane			0			0			0	0.01	0.01	1

Table 4.6-10 (Continued)

Maximum and Minimum Data in ug/m3

UNKNOWN ID	AQ01			AQ36			TOTAL		
	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS
Aldehydes	1.00	0.01	29	0.02	0.02	1	1.00	0.01	41
Alkanes	4.00	0.01	450	2.90	0.01	56	4.00	0.01	949
Alkenes	0.20	0.01	20	0.16	0.04	4	0.20	0.01	50
Benzaldehyde	0.80	0.20	15	0.70	0.60	2	1.00	0.02	39
Benzenes	0.40	0.01	37	0.30	0.04	6	0.60	0.01	87
Butyl acetate	0.40	0.10	6	0.20	0.20	2	0.40	0.02	11
Camphor	0.02	0.01	2	0.01	0.01	1	0.02	0.01	3
Carene	0.40	0.02	12	0.20	0.10	2	0.40	0.02	23
Cyclohydrocarbons	0.10	0.01	9	0.05	0.05	1	0.10	0.01	14
Decanol			0			0	0.04	0.01	4
Dichlorobenzene			0			0	0.02	0.01	3
Dimethyl cyclohexane	0.06	0.02	4	0.05	0.05	1	0.06	0.02	5
Freons	3.00	0.01	16	1.70	1.20	2	3.00	0.01	39
Heptane	0.70	0.10	16	0.30	0.36	2	0.70	0.02	25
Heptanol			0			0	0.01	0.01	1
Hexane	0.70	0.10	13	0.40	0.40	2	0.70	0.02	36
Isotones	0.40	0.01	51	0.20	0.10	4	0.60	0.01	121
Limonene			0			0	0.05	0.02	5
Methyl cyclohexane	0.40	0.07	17	0.20	0.20	2	0.40	0.01	41
Methyl cyclopentane	0.40	0.08	17	0.20	0.20	2	0.40	0.01	33
Methyl hexane	0.20	0.02	10	0.08	0.08	1	0.20	0.01	18
Naphthalene	0.06	0.02	8			0	0.60	0.01	13
Nitrogen containing comp.			0			0	0.10	0.01	7
Oxygenated comp.	0.02	0.01	8	0.02	0.01	2	0.03	0.01	12
Pentadiene			0			0	0.04	0.04	1
Pentane			0			0	0.30	0.30	1
Phenol	0.05	0.01	3			0	0.70	0.01	20
Propanol	0.03	0.03	2			0	1.00	0.03	9
Silane compound	0.20	0.01	13			0	0.20	0.01	60
Trimethyl cyclohexane	0.03	0.01	3	0.01	0.01	1	0.05	0.01	14
Trimethyl cyclohexane + unknown	0.02	0.02	1			0	0.02	0.02	1
Trimethyl cyclopentane	0.20	0.10	3			0	0.20	0.10	3
Trioxocane			0			0	0.01	0.01	1

and, therefore, most of the nontarget compounds appeared to be related to the influx of urban VOCs onto RMA.

The summary of VOC blank unknowns for FY89 is found in Table 4.6-11. The total number of observed nontarget detections in the VOC blanks was 24. Thirteen detections were found at site AQ1 and six detections at site AQ01. All detections were at low levels ranging from $0.01 \mu\text{g}/\text{m}^3$ to $0.09 \mu\text{g}/\text{m}^3$. The origin of the contamination can be traced to three possibilities, including crew handling, sample exposure during shipping and storage, and breakdown products from the adsorbing media.

4.7 Semi-volatile Organic Compounds (SVOCs)

4.7.1 SVOC Monitoring, Analysis and Reporting Strategies

The CMP Technical Plan called for SVOC seasonal monitoring at four RMA perimeter sites during the spring, summer, fall and winter periods, and six high event sampling episodes to be conducted at four fixed perimeter sites or at other fixed or mobile sites as appropriate. Initially, the program only specified fixed perimeter locations because of power limitations; however, suitable generators were procured to provide more flexibility to the program. Because there was intense remedial activity at Basin F during FY88, some emphasis was placed on sampling in its immediate vicinity, similar to the emphasis for monitoring VOCs. However, RMA perimeter sites were also routinely sampled under the high event program in order to establish pesticide levels around the Arsenal boundaries. During FY89, high event SVOC monitoring was conducted at Basin F and also at the South Plants, Basin A and the Hydrazine Plant.

For the most part, all CMP high event SVOC monitoring met the specified meteorological criteria of 75°F or greater. Two wind criteria scenarios were established for the SVOC high event sampling as shown previously in Table 3.2-3, one for light winds similar to VOC sampling, and a second for winds in excess of 10 mph in order to capture SVOCs adhering to windborne particles. The monitoring program contained samples of both situations. Also, as in the case of VOCs, the CMP FY89 SVOC monitoring period was extended to 24 hours to attempt to capture semi-volatile organic compounds trapped under early morning or late afternoon inversion conditions.

Table 4.6-11 Summary of VOC Blank Unknowns for FY89, Maximum and Minimum Data in $\mu\text{g}/\text{m}^3$

Unknown ID	Max.	AQ1		Max.	AQ2		Max.	AQ3	
		Min. #	Hits		Min. #	Hits		Min. #	Hits
Alkanes	0.05	0.01	5			0			0
Bezaldehyde	0.01	0.01	1			0			0
Freons			0			0	0.04	0.03	2
Hexane	0.05	0.05	1			0			0
Ketones	0.02	0.01	2			0			0
Oxygenated cpd.	0.01	0.01	4			0			0
Silane compound			0	0.01	0.01	2			0

Unknown ID	Max.	AQ01		Max.	BF2		MAX.	TOTAL	
		Min. #	Hits		Min. #	Hits		MIN#	HITS
Alkanes	0.05	0.05	1			0	0.05	0.01	6
Bezaldehyde			0			0	0.01	0.01	1
Freons	0.30	0.30	1	0.05	0.05	1	0.30	0.03	4
Hexane	0.02	0.02	1			0	0.05	0.02	2
Ketones	0.09	0.03	2			0	0.09	0.01	4
Oxygenated cpd.	0.01	0.01	1			0	0.01	0.01	5
Silane compound			0			0	0.01	0.01	2

4.7.2 CMP FY89 Semi-Volatile Organic Compounds Monitoring Results

Seasonal and high event semi-volatile organic compounds were monitored during the FY89 program at the times and locations given in Table 4.7-1. A complete listing and summary of SVOCs is provided in Appendix F.

Table 4.7-1 Synopsis of Semi-Volatile Organic Compounds (SVOC) Monitoring

Date	Period	Site Locations
November 14, 1988*	1000 - 1800	AQ2, AQ3, AQ5, AQ5E, AQ9
March 21, 1989*	1230 - 1330 (25-hr)	AQ1, AQ2, AQ3, AQ5E, AQ5F
July 7, 1989	1200 - 1200 (24-hr)	BF2, BF2C, BF3, BF4, BF6
August 3, 1989	0900 - 1700	BF2, BF2C, BF3, BF4, BF6
August 3, 1989	1730 - 0930 (16-hr)	BF2, BF2C, BF3, BF6
August 10, 1989	1000 - 0930 (24-hr)	AQ6, AQ8, AQ9, Mobile, Mobile C
August 17, 1989	1000 - 1000 (24-hr)	HT6NP, HT9EP, HM1SP, HT8WP, HM1SC (monitoring around Hydrazine Plant)
August 23, 1989	0900 - 1700	BF2, BF2C, BF3, BF4, BF5
August 23, 1989	1700 - 0900 (16-hr)	BF2, BF2C, BF3, BF4, BF5
September 7, 1989	1000 - 1000 (24-hr)	Mobile 1, Mobile 2, Mobile 3, Mobile 4

* Seasonal monitoring; all others were high event monitoring cases.

The results indicate no detections of SVOCs throughout the FY89 CMP monitoring period. There are several explanations for this relating to the significant decrease in SVOC emissions from Basin F after completion of the remediation program, and also to a change in the laboratory analytic methods. As prescribed by the CMP Technical Plan, the F-7 GC/MS method is the certified method for the analysis of SVOCs. During FY88, the H-7 GC/ECD method was also used to confirm low levels of SVOC pesticides. The H-7 method is about 100 times more sensitive to pesticides than is the F-7 method. However, during CMP FY89, the backup H-7 method was discontinued for SVOCs and was used strictly for OTSPs, so that very low pesticides concentrations were not detected under F-7 during FY89.

It should be noted, however, that during CMP FY88, pesticides were detected under the F-7 method at high event monitoring sites adjacent to Basin F and even at RMA perimeter sites. Consequently, the failure to detect any SVOCs in FY89 does substantiate a decrease in these potential contaminants in the post-remedial period. This is further confirmed by substantial decreases in SVOCs measured under the Basin F monitoring programs which employed both H-7 and F-7 analytical methods. These results will be discussed in Section 4.7.3. Finally, the CMP OTSP monitoring program, which employs the H-7 certified method for pesticide analysis, indicated a significant decrease in detections during the FY89 Phase 2 and Phase 3 programs, or, in some cases, very low pesticide levels comparable to regional background concentrations. For the analyses presented here (Section 4.7) results of both the pesticide and GC/MS SVOC analysis are presented, because pesticide target analytes are on the SVOC target list as well.

4.7.3 Basin F SVOC Impacts

4.7.3.1 CMP Data. As previously discussed, in order to fully evaluate remedial impacts from the Basin F cleanup operations, it is necessary to consider all CMP, Basin F Remedial Monitoring Program, and IRA-F SVOC data for the entire remedial and post-remedial periods. CMP FY89 SVOC data results were discussed in the previous section. Table 4.7-2 incorporates both CMP FY88 and FY89 data and stratifies results for each monitoring station for the Phase 1 and Phase 2 remediation periods and the Phase 3 post-remedial period. Seasonal and high event data are included in this table. There was no SVOC sampling conducted under the CMP during Phase 2, Stage 1.

The data confirm conclusions previously discussed. Low to modest concentrations of chlordane, dieldrin, endrin, isodrin, PPDDT and parathion were measured in the vicinity of Basin F during the Phase 1 remediation phase and, in all cases, considerably lower concentrations were measured at the RMA perimeter sites. During Phase 2 and Phase 3 there were no detections of SVOCs under the CMP.

4.7.3.2 Basin F Data. Table 4.7-3 shows average and maximum SVOC values for the Basin F Remedial Monitoring Program and for the IRA-F Monitoring Program for Phase 1, Phase 2 and Phase 3 of the remediation activities. All Phase 1 data and Phase 2 data (Stage 1 and Stage 2) were obtained from the Basin F Remediation Monitoring Program and cover the period from March 22, 1988 to May 5, 1989. The Phase 3 data were obtained from the IRA-F Monitoring Program and cover a period from May 6, 1989 to September 30, 1989. Sequential data for both programs are provided in Appendices N and S.

Table 4.7-2 Summary of CMP Semi-Volatile Organic Compounds (SVOC) Concentrations by Phase
(in ug/m3)

Average Values

	Chlordane	Dieldrin	Endrin	Isodrin	PPDDE	PPDDT	Atrazine	Malathion	Parathion	Supona
PHASE 1										
AQ1	0.0011	0.0036	0.0013	0.0006	0.0006	0.0014	‡	‡	‡	‡
AQ2	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
AQ3	0.0010	0.0060	0.0014	‡	‡	0.0008	‡	‡	‡	‡
AQ4	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
AQ5	0.0011	0.0021	0.0014	‡	‡	0.0023	‡	‡	‡	‡
AQ6	‡	‡	0.0040	‡	‡	‡	‡	‡	‡	‡
AQ8	‡	‡	‡	‡	0.0390	‡	‡	‡	‡	‡
AQ9	‡	‡	‡	‡	0.0198	‡	‡	‡	‡	‡
CMP/BF1	‡	0.2245	0.1208	0.0363	‡	0.0069	‡	‡	‡	‡
CMP/BF2	‡	0.3971	0.1343	0.1122	‡	0.0350	‡	‡	0.1311	‡
CMP/BF3	‡	0.0423	0.0178	0.0054	‡	‡	‡	‡	‡	‡
CMP/BF4	0.0036	0.0584	0.0166	0.0040	‡	0.0022	‡	‡	‡	‡
PHASE 2 - STAGE 2										
AQ1	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
AQ2	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
PHASE 3										
AQ6	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
AQ8	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
AQ9	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
CMP/BF2	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
CMP/BF3	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
CMP/BF4	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
CMP/BF5	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
CMP/BF6	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
AQ01	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡

‡ ALL VALUES BELOW CRL

LEGEND: PPDDE Dichlorodiphenylethane
PPDDT Dichlorodiphenyltrichloroethane

Table 4.7-2 (Continued)

Maximum Values

	Chlordane	Dieldrin	Endrin	Isodrin	PPDDE	PPDDT	Atrazine	Malathion	Parathion	Supona
PHASE 1										
AQ1	0.0023	0.0060	0.0028	0.0008	0.0008	0.0034	§	§	§	§
AQ2	§	§	§	§	§	§	§	§	§	§
AQ3	0.0024	0.0217	0.0027	§	§	0.0010	§	§	§	§
AQ4	§	§	§	§	§	§	§	§	§	§
AQ5	0.0028	0.0044	0.0032	§	§	0.0067	§	§	§	§
AQ6	§	§	0.0040	§	§	§	§	§	§	§
AQ8	§	§	§	§	0.0390	§	§	§	§	§
AQ9	§	§	§	§	0.0387	§	§	§	§	§
CMP/BF1	§	0.2245	0.1208	0.0363	§	0.0069	§	§	§	§
CMP/BF2	§	0.7210	0.2371	0.2525	§	0.0585	§	§	0.2099	§
CMP/BF3	§	0.0423	0.0178	0.0054	§	§	§	§	§	§
CMP/BF4	0.0036	0.0584	0.0160	0.0040	§	0.0022	§	§	§	§
PHASE 2 - STAGE 2										
AQ1	§	§	§	§	§	§	§	§	§	§
AQ2	§	§	§	§	§	§	§	§	§	§
§	§	§	§	§	§	§	§	§	§	§
§	§	§	§	§	§	§	§	§	§	§
PHASE 3										
AQ6	§	§	§	§	§	§	§	§	§	§
AQ8	§	§	§	§	§	§	§	§	§	§
AQ9	§	§	§	§	§	§	§	§	§	§
CMP/BF2	§	§	§	§	§	§	§	§	§	§
CMP/BF3	§	§	§	§	§	§	§	§	§	§
CMP/BF4	§	§	§	§	§	§	§	§	§	§
CMP/BF5	§	§	§	§	§	§	§	§	§	§
CMP/BF6	§	§	§	§	§	§	§	§	§	§
AQ01	§	§	§	§	§	§	§	§	§	§

§ ALL VALUES BELOW CRL

LEGEND: PPDDE Dichlorodiphenylethane
 PPDDT Dichlorodiphenyltrichloroethane

TABLE 4.7-3 Summary of Basin F/IRAF/RIFS Semi-Volatile Organic Compounds (SVOC) for Phases 1-3
(in ug/m3)
Average Values

	ALD	ATZ	CLDAN	PPDDE	PPDDT	DLDRN	ENDRN	ISODR	MLTHN	PRTHN	SUPONA
PHASE 1											
BF1	0.1913	ND	ND	ND	ND	0.1408	0.0719	0.0076	ND	ND	ND
BF2	0.4579	ND	ND	ND	ND	0.2768	0.1209	0.0424	ND	ND	ND
BF2C	0.5263	ND	ND	ND	ND	0.2475	0.1142	0.0584	ND	ND	ND
BF3	0.0662	ND	ND	ND	ND	0.0809	0.0250	0.0017	ND	ND	ND
BF4	0.0499	ND	ND	ND	ND	0.0477	0.0234	0.0030	ND	ND	ND
BF5	0.0221	ND	ND	ND	ND	0.0193	0.0096	0.0011	ND	ND	ND
BF6	0.0058	ND	ND	ND	ND	0.0083	0.0031	0.0004	ND	ND	ND
BF7	0.0016	ND	ND	ND	0.0008	0.0038	0.0011	0.0003	ND	ND	ND
RIFS1	ND	ND							ND	ND	ND
PHASE 2 - STAGE 1											
BF1	0.0106	ND	ND	ND	ND	0.0075	0.0041	0.0013	ND	ND	ND
BF2	0.0154	ND	ND	ND	ND	0.0107	0.0044	0.0010	ND	ND	ND
BF2C	0.0071	ND	0.0071	0.0013	0.0007	0.0079	0.0047	0.0008	ND	ND	ND
BF3	0.0026	ND	ND	ND	ND	0.0032	0.0017	0.0005	ND	ND	ND
BF4	0.0034	ND	ND	ND	ND	0.0027	0.0014	0.0007	ND	ND	ND
BF5	0.0010	ND	ND	ND	ND	0.0010	0.0008	ND	ND	ND	ND
BF6	0.0006	ND	ND	0.0007	ND	0.0012	0.0011	0.0003	ND	ND	ND
BF7	ND	ND	ND	ND	ND	0.0008	0.0007	ND	ND	ND	ND
RIFS1	ND	ND							ND	ND	ND
RIFS1D	ND	ND							ND	ND	ND
RIFS2	ND	ND							ND	ND	ND
PHASE 2 - STAGE 2											
BF1	0.0023	ND	ND	ND	ND	0.0057	0.0024	0.0003	ND	ND	ND
BF2	0.0022	ND	ND	ND	ND	0.0076	0.0019	ND	ND	ND	ND
BF2C	0.0017	ND	ND	0.0007	ND	0.0077	0.0023	ND	ND	ND	ND
BF3	0.0006	ND	ND	ND	ND	0.0031	0.0010	ND	ND	ND	ND
BF4	0.0007	ND	ND	ND	ND	0.0020	0.0010	ND	ND	ND	ND
BF5	0.0005	ND	ND	ND	ND	0.0011	0.0007	ND	ND	ND	ND
BF6	0.0004	ND	ND	ND	ND	0.0015	0.0008	ND	ND	ND	ND
BF7	ND	ND	ND	ND	ND	0.0009	ND	ND	ND	ND	ND
RIFS1	ND	ND	0.0007	ND	0.0006	0.0006	ND	ND	ND	ND	ND
RIFS1D	ND	ND	0.0006	ND	ND	0.0006	ND	ND	ND	ND	ND
RIFS2	ND	ND							ND	ND	ND
PHASE 3											
FC1	0.0013	ND	0.0006	ND	ND	0.0047	0.0008	0.0005	ND	ND	ND
FC2	0.0024	ND	0.0008	ND	0.0007	0.0121	0.0017	0.0006	ND	ND	ND
FC2D	0.0027	ND	0.0008	ND	0.0006	0.0130	0.0016	0.0039	ND	ND	ND
BF3/FC3	0.0008	ND	0.0008	ND	0.0004	0.0074	0.0010	0.0005	ND	ND	ND
BF4/FC4	0.0009	ND	0.0008	ND	ND	0.0061	0.0012	0.0004	ND	ND	ND
BF5	0.0004	ND	0.0005	ND	ND	0.0015	0.0004	ND	ND	ND	ND
FC5	0.0012	ND	0.0006	ND	ND	0.0032	0.0006	ND	ND	ND	ND
BF7	0.0004	ND	0.0007	ND	ND	0.0024	0.0004	0.0005	ND	ND	ND
RIFS1	ND	ND	0.0007	ND	ND	0.0012	0.0004	ND	ND	ND	ND
LEGEND:											
ALDRN	Aldrin			PPDDE	Dichlorodiphenylethane			ISODR	Isodrin		
ATZ	Atrazine			PPDDT	Dichlorodiphenyltrichloroethane			MLTHN	Malathion		
CLDAN	Chlordane			DLDRN	Dieldrin			PRTHN	Parathion		
				ENDRN	Endrin			SUPONA	Supona		

Table 4.7-3 (Continued)
Maximum Values

	ALDRN	ATZ	CLDAN	PPDDE	PPDDT	DLDRN	ENDRN	ISODR	MLTHN	PRTHN	SUPONA
PHASE 1											
BF1	0.8366	ND	ND	ND	ND	0.4904	0.2497	0.0604	ND	ND	ND
BF2	2.8290	ND	ND	ND	ND	2.2960	0.9020	0.8610	ND	ND	ND
BF2C	2.5773	ND	ND	ND	ND	2.1478	1.0954	0.9450	ND	ND	ND
BF3	0.4288	ND	ND	ND	ND	1.6568	0.5458	0.0226	ND	ND	ND
BF4	0.3478	ND	ND	ND	ND	0.3265	0.2591	0.1136	ND	ND	ND
BF5	0.1723	ND	ND	ND	ND	0.0499	0.0275	0.0080	ND	ND	ND
BF6	0.0369	ND	ND	ND	ND	0.0256	0.0093	0.0016	ND	ND	ND
BF7	0.0124	ND	ND	ND	0.0017	0.0479	0.0050	0.0007	ND	ND	ND
RIFS1		ND							ND	ND	ND
PHASE 2 - STAGE 1											
BF1	0.0830	ND	ND	ND	ND	0.0361	0.0223	0.0114	ND	ND	ND
BF2	0.1244	ND	ND	ND	ND	0.0355	0.0147	0.0100	ND	ND	ND
BF2C	0.0210	ND	0.0360	0.0060	0.0010	0.0310	0.0130	0.0020	ND	ND	ND
BF3	0.0234	ND	ND	ND	ND	0.0130	0.0061	0.0034	ND	ND	ND
BF4	0.0321	ND	ND	ND	ND	0.0099	0.0042	0.0072	ND	ND	ND
BF5	0.0080	ND	ND	ND	ND	0.0030	0.0010	ND	ND	ND	ND
BF6	0.0020	ND	ND	0.0020	ND	0.0040	0.0040	0.0004	ND	ND	ND
BF7	ND	ND	ND	ND	ND	0.0010	0.0010	ND	ND	ND	ND
RIFS1		ND							ND	ND	ND
RIFS1D		ND							ND	ND	ND
RIFS2		ND							ND	ND	ND
PHASE 2 - STAGE 2											
BF1	0.0190	ND	ND	ND	ND	0.0190	0.0070	0.0010	ND	ND	ND
BF2	0.0230	ND	ND	ND	ND	0.0340	0.0100	ND	ND	ND	ND
BF2C	0.0090	ND	ND	0.0010	ND	0.0330	0.0100	ND	ND	ND	ND
BF3	0.0050	ND	ND	ND	ND	0.0110	0.0030	ND	ND	ND	ND
BF4	0.0040	ND	ND	ND	ND	0.0070	0.0040	ND	ND	ND	ND
BF5	0.0020	ND	ND	ND	ND	0.0030	0.0010	ND	ND	ND	ND
BF6	0.0010	ND	ND	ND	ND	0.0050	0.0010	ND	ND	ND	ND
BF7	ND	ND	ND	ND	ND	0.0017	ND	ND	ND	ND	ND
RIFS1	ND	ND	0.0007	ND	0.0007	0.0009	ND	ND	ND	ND	ND
RIFS1D	ND	ND	0.0006	ND	ND	0.0009	ND	ND	ND	ND	ND
RIFS2		ND							ND	ND	ND
PHASE 3											
FC1	0.0041	ND	0.0010	ND	ND	0.0188	0.0015	0.0005	ND	ND	ND
FC2	0.0103	ND	0.0015	ND	0.0010	0.0444	0.0045	0.0011	ND	ND	ND
FC2D	0.0088	ND	0.0011	ND	0.0006	0.0424	0.0034	0.0106	ND	ND	ND
BF3/FC3	0.0017	ND	0.0019	ND	0.0004	0.0240	0.0021	0.0006	ND	ND	ND
BF4/FC4	0.0016	ND	0.0014	ND	ND	0.0179	0.0022	0.0005	ND	ND	ND
BF5	0.0004	ND	0.0005	ND	ND	0.0023	0.0004	ND	ND	ND	ND
FC5	0.0033	ND	0.0007	ND	ND	0.0159	0.0008	ND	ND	ND	ND
BF7	0.0004	ND	0.0010	ND	ND	0.0053	0.0006	0.0005	ND	ND	ND
RIFS1	ND	ND	0.0007	ND	ND	0.0033	0.0004	ND	ND	ND	ND

LEGEND: ALDRN Aldrin PPDDE Dichlorodiphenylethane ISODR Isodrin
 ATZ Atrazine PPDDT Dichlorodiphenyltrichloroethane MLTHN Malathion
 CLDAN Chlordane DLDRN Dieldrin PRTHN Parathion
 SUPONA Supona

Table 4.7-3 provides a detailed summary for each SVOC target compound for each remediation phase at seven Basin F monitoring sites. It can be seen from these data that a number of SVOCs were measured at higher concentrations in the vicinity of Basin F during the Phase 1 period. These compounds then decreased significantly during the Phase 3, post-remedial period. Specific SVOCs observed at higher levels during the remediation activities were aldrin, dieldrin, endrin and isodrin. In all cases, concentrations of these constituents were higher in the immediate vicinity of Basin F activities and decreased to low levels with distance from the Basin F potential source.

Several SVOCs analyzed including atrazine, malathion, parathion and Supona were nondetectable, or measured at very low levels at all Basin F sites for all three phases of the remedial program, suggesting that Basin F was not a potential source of these compounds.

Figures 4.7-1 through 4.7-4 show a bar graph depiction of the concentration levels of aldrin, dieldrin, endrin and isodrin for each phase of the remediation activities and after completion of the cleanup program. Concentration levels were highest during Phase 1 at those stations immediately adjacent to Basin F, with a significant decrease with distance from the source. During Phase 2 and Phase 3, concentrations decreased with the exception of dieldrin at all monitoring sites to levels that can be considered typical regional background concentrations. Dieldrin levels were slightly higher at several Basin F stations during Phase 3 than Phase 2. This may be a seasonal influence or a minor residual effect from Basin F. SVOC results, in general, were considerably below Phase 1 concentrations and well below contaminant health guidelines discussed in Section 4.7.4.

As in the case of metals and VOCs, another approach to assessing remedial progress for SVOCs is to consider Basin F impacts that were observed on individual days during the remedial and post-remedial periods. All Basin F air monitoring during the Phase 1 period was conducted for worst-case 24-hour periods based on dispersion model analysis and remedial activity. An example of the dispersion of SVOCs resulting from Basin F remedial activities is shown in Figure 4.7-5. This figure shows Phase 1 SVOC concentrations for August 23, 1988, with X/Q dispersion values overlaying the monitoring data for seven Basin F stations. Again, this type of analysis identifies, to the fullest extent, the potential dispersion of contaminants resulting from remedial actions.

During this sampling period, winds followed basically a typical diurnal cycle, with south to north flow during the night and north to south during the day. Wind speeds were mostly light and the maximum temperature was 88°F. On this day there were no detectable amounts of any pesticides at the upwind off-site Station BF7. Concentrations of aldrin, dieldrin, endrin and isodrin ranged from nondetectable to 0.7858 $\mu\text{g}/\text{m}^3$ at the Basin F perimeter sites, but dropped considerably in

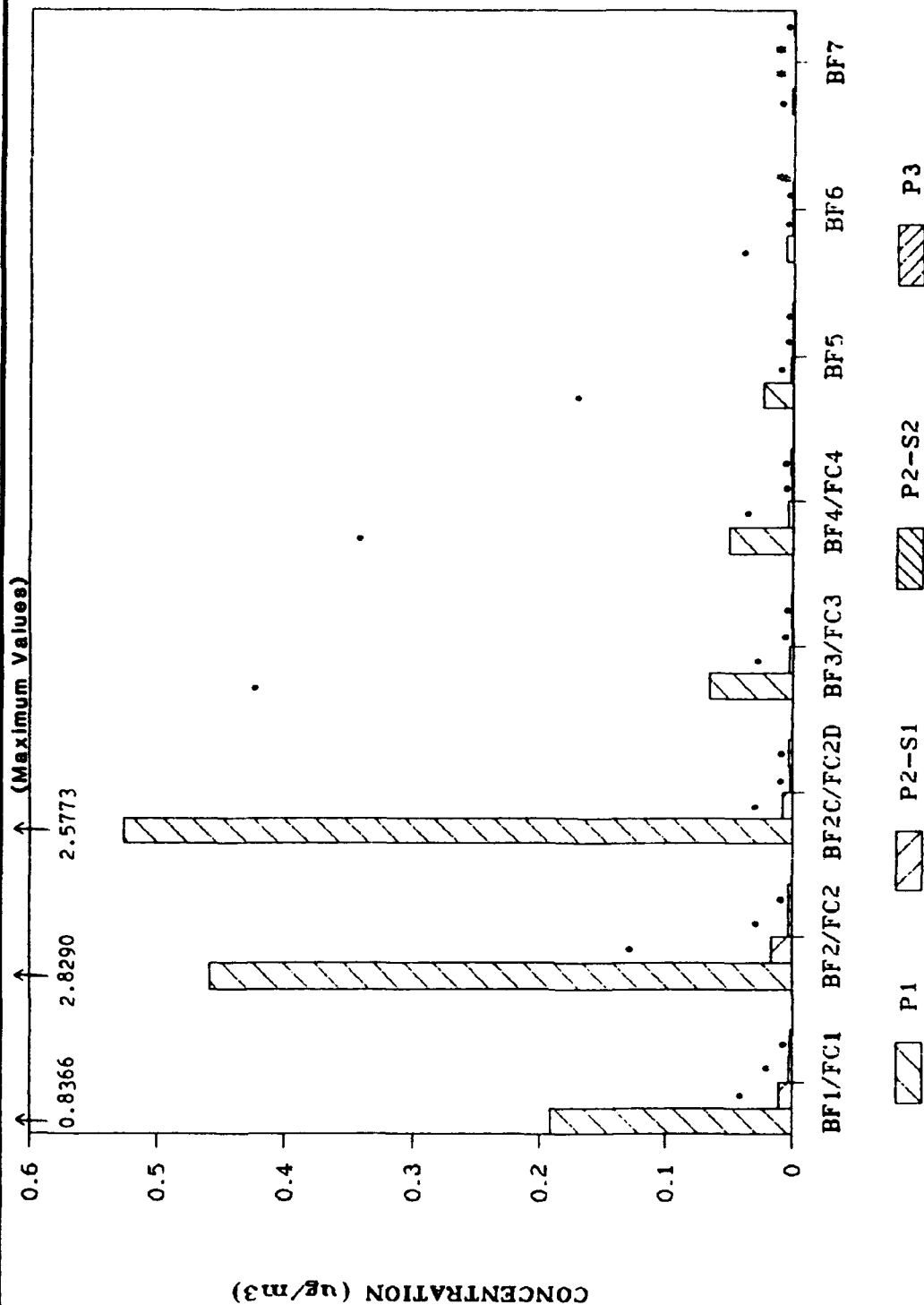


Figure 4.7-1
Aldrin Results
by Phase

Prepared for:
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Services, Inc.

CMPAR FY89

- MAXIMUM 24-HOUR CONCENTRATION
- # NO SAMPLES TAKEN DURING THIS PHASE
- * NOT DETECTED DURING THIS PHASE

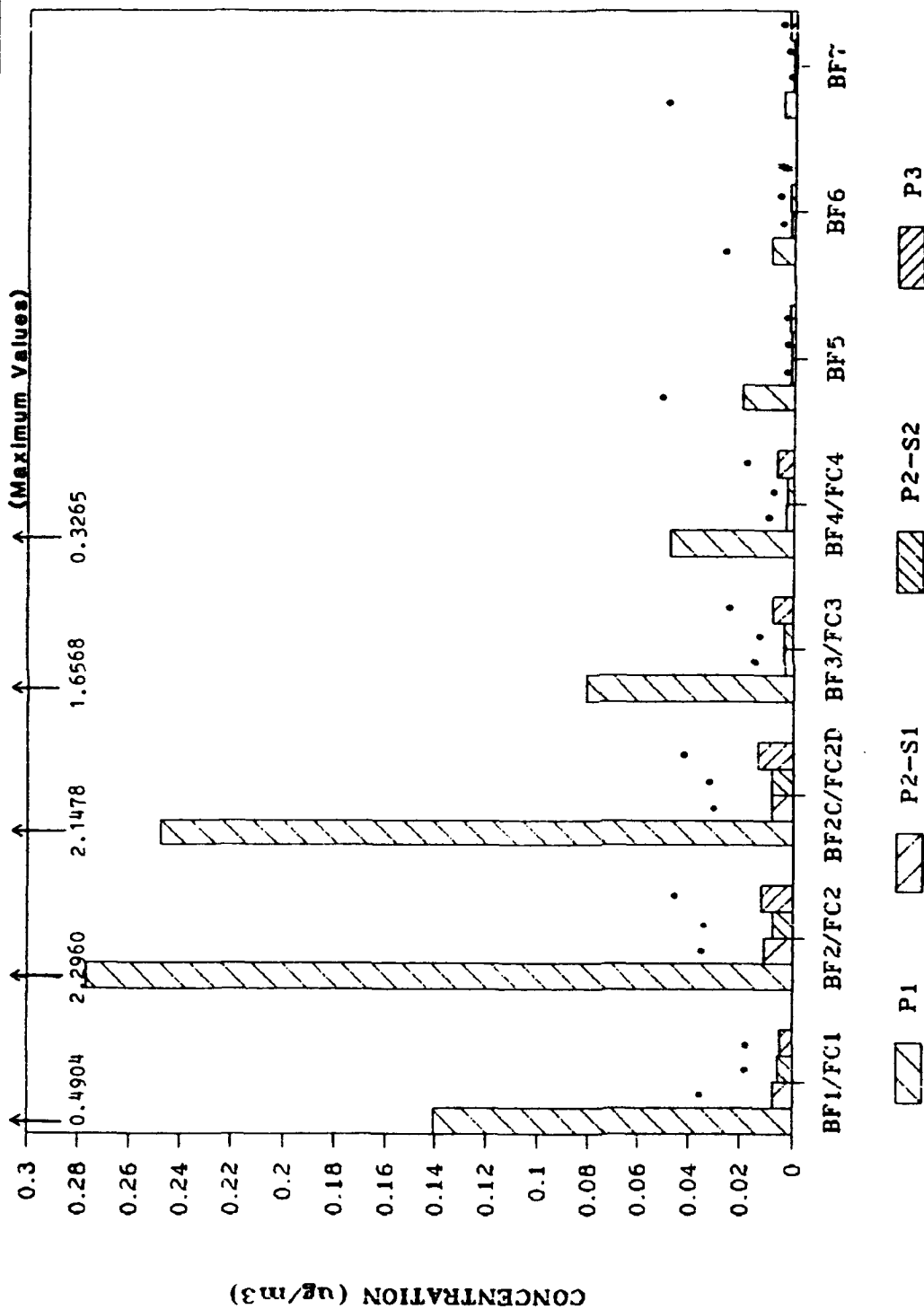


Figure 4.7-2

Dieldrin Results
by Phase

CMPAR FY 89

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U.S. Army Program Manager for
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Commerce City, Colorado

Prepared by:

R.L. Stollar & Associates, Inc.
Ebisco Services, Inc.

• MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE

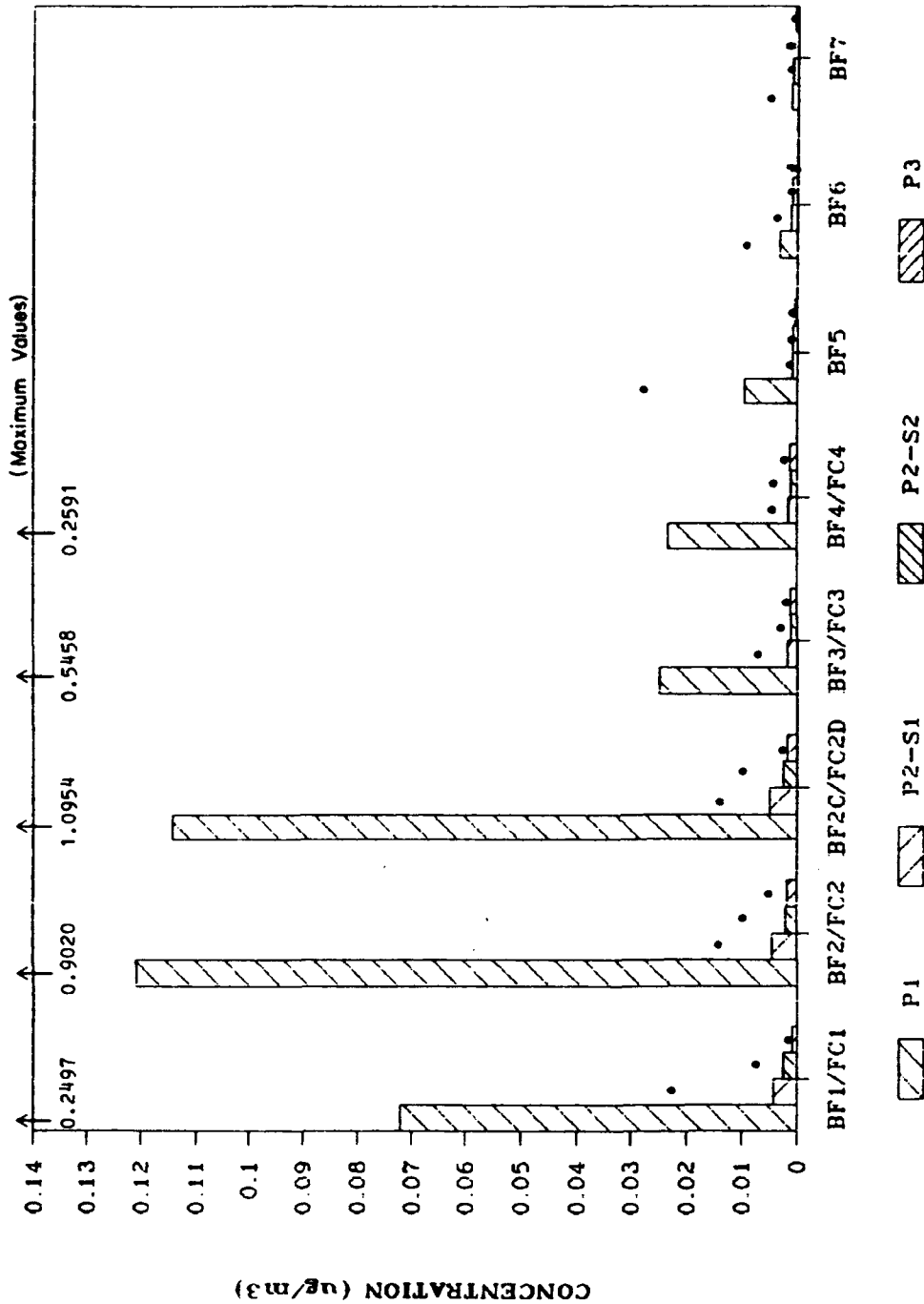
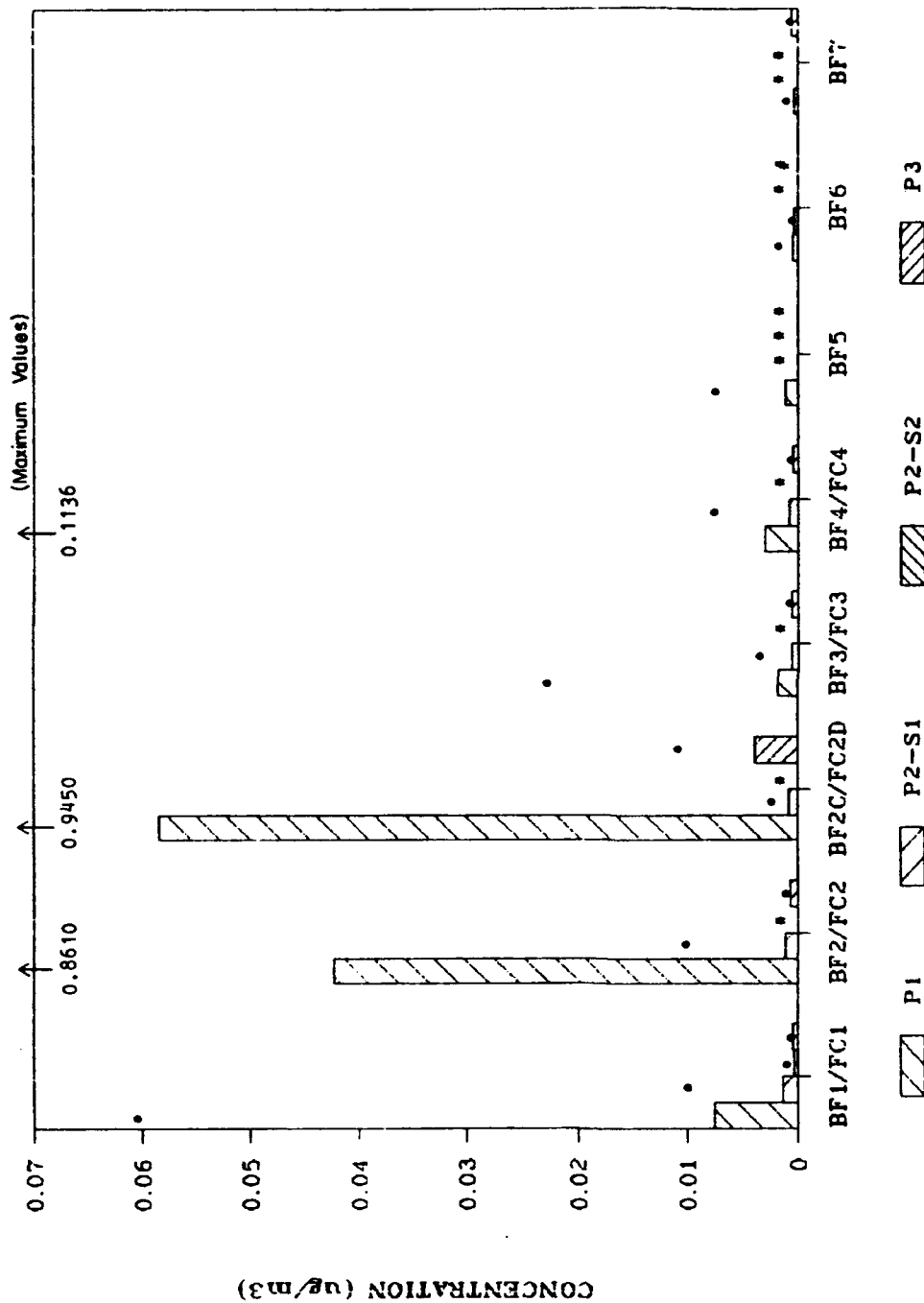


Figure 4.7-3
Endrin Results
by Phase

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Ebasco Services, Inc.

CMP AR FY89

• MAXIMUM 24-HOUR CONCENTRATION
NO SAMPLES TAKEN DURING THIS PHASE
* NOT DETECTED DURING THIS PHASE



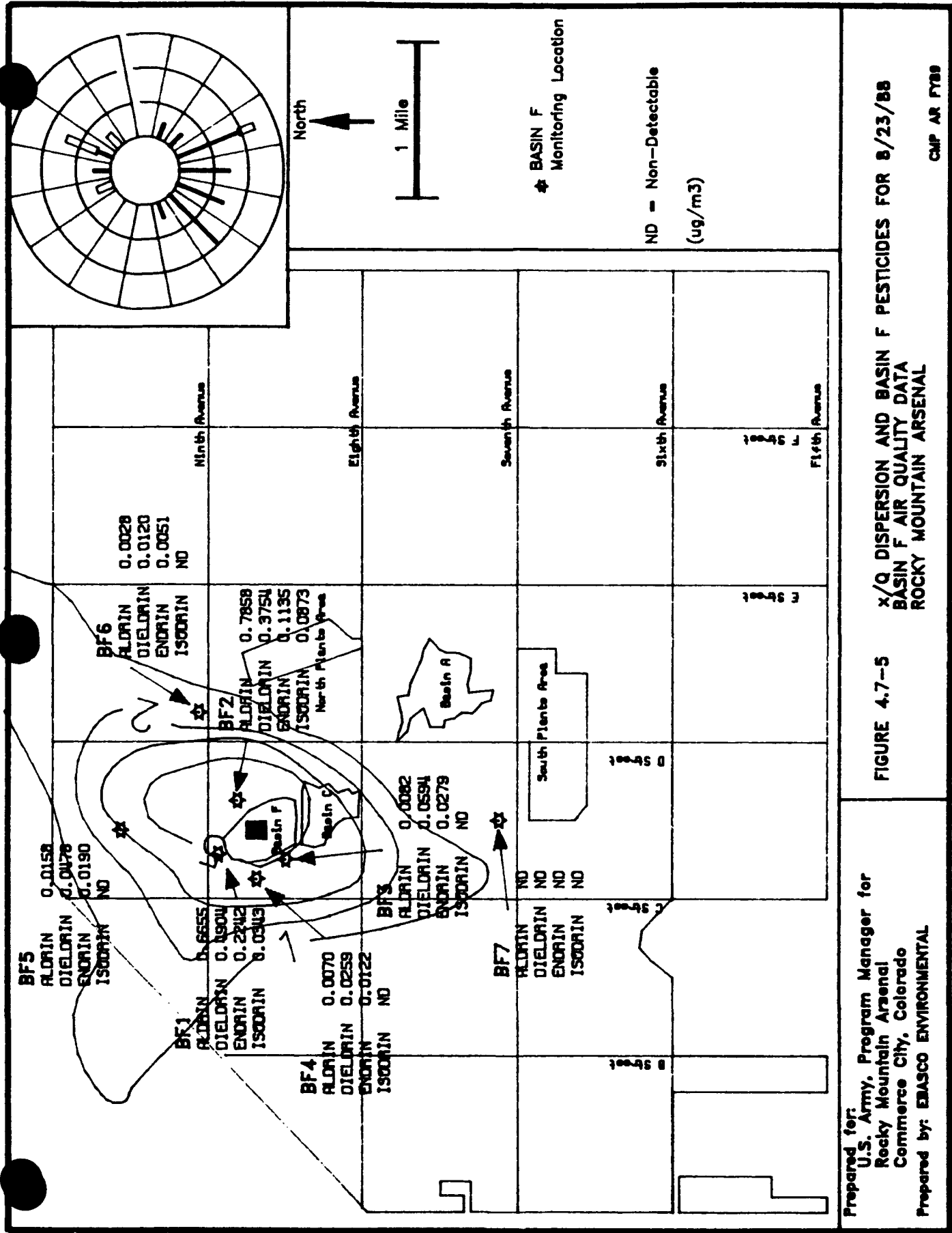
• MAXIMUM 24-HOUR CONCENTRATION
 # NO SAMPLES TAKEN DURING THIS PHASE
 * NOT DETECTED DURING THIS PHASE

Figure 4.7-4
 Isodrin Results
 by Phase

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CMPAR FY89



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 Rocky Mountain Arsenal
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 Prepared by: EMBSCO ENVIRONMENTAL

FIGURE 4.7-5

X/Q DISPERSION AND BASIN F PESTICIDES FOR 8/23/88
 BASIN F AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

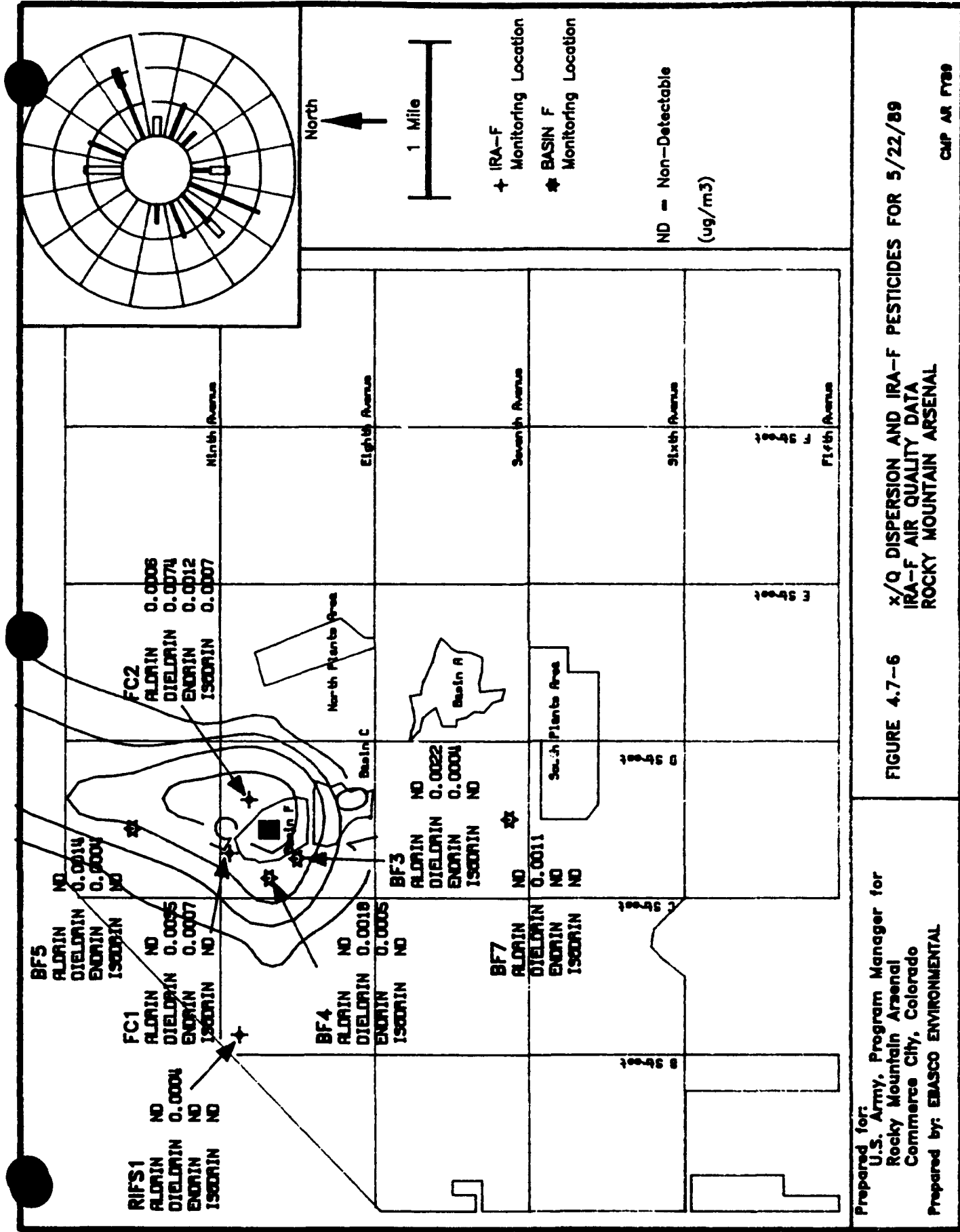
CMP AR FY88

value to less than $0.0478 \mu\text{g}/\text{m}^3$ at the downwind sites BF5 and BF6. The actual concentrations followed quite closely the predicted dispersion pattern. These results indicate Basin F was clearly a source of these pesticides during the remediation phase.

A Phase 3 sample period with similar dispersion characteristics to the Phase 1 example was May 21-22, 1989 as shown in Figure 4.7-6. The winds during this period reflected a typical diurnal pattern, with light south-southwesterly flow at night and light to moderate north-northeasterly flow during the day. Maximum temperatures reached the mid 70s. It is readily apparent that the contaminant levels were much lower on this day than they were on the Phase 1 day, with the maximum dieldrin value reaching $0.0074 \mu\text{g}/\text{m}^3$ at FC2. However, the upwind and downwind off-site concentrations were considerably lower than the perimeter stations, showing that the predicted dispersion pattern was again followed quite closely. Apparently, Basin F was still a minor source of several pesticides on this Phase 3 day, although the concentrations were much smaller than in Phase 1.

4.7.3.3 Combined CMP and Basin F Data Analyses. Individual CMP and Basin F SVOC monitoring data for the three phases of the remedial monitoring programs have been shown in Tables 4.7-2 and 4.7-3. Figures 4.7-7 through 4.7-10 provide a summary of average and maximum CMP and Basin F SVOC data across the Arsenal complex. The wind roses reflecting potential transport of contaminants are also shown in these figures. As noted from the previous discussions, the Phase 1 data show impacts of aldrin, dieldrin, endrin and isodrin immediately adjacent and downwind from Basin F. Farther downwind, SVOC concentrations decreased and became minimal at the RMA perimeter sites as represented by the CMP data. During Phase 2, SVOC levels decreased significantly both in the immediate vicinity of Basin F as well as downstream. During Phase 3, all Basin F and CMP SVOC monitoring data continued to reflect low or nondetectable concentration levels with the exception of dieldrin. The dieldrin levels, however, still remained low with a maximum 24-hour concentration of $0.0444 \mu\text{g}/\text{m}^3$ reported at FC2. The pattern shown on Figures 4.7-9 and 4.7-10 indicates that Basin F may have been a very weak source of pesticides during the Phase 2 Stage 2 and Phase 3 periods. In Figures 4.7-8 through 4.7-10 representing the Phase 2 and Phase 3 periods, OTSP results from the CMP perimeter sites were employed instead of the nondetectable SVOC (F-/) results, providing a more sensitive analysis of potential pesticide levels; all average values during these periods, however, were either non-detectable or less than $0.001 \mu\text{g}/\text{m}^3$, suggesting little or no impacts from Basin F post-operations at the boundaries of the Arsenal.

In summary, the data indicate that Basin F was the principal emitter of several potential SVOC pesticides during remediation activities. These impacts were local and decreased significantly

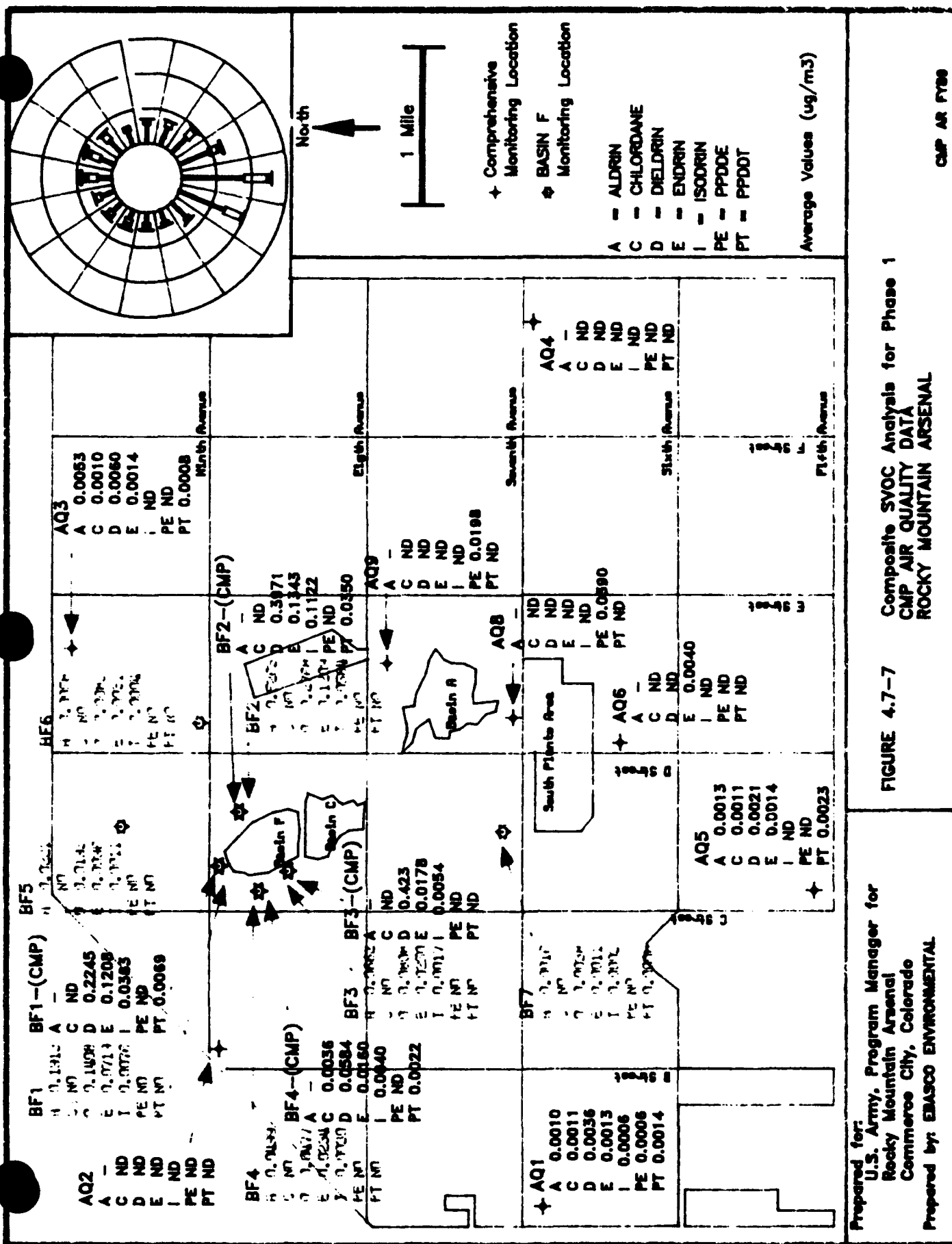


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 Prepared by: EBASCO ENVIRONMENTAL

FIGURE 4.7-6

X/Q DISPERSION AND IRA-F PESTICIDES FOR 5/22/89
 IRA-F AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AR FY88



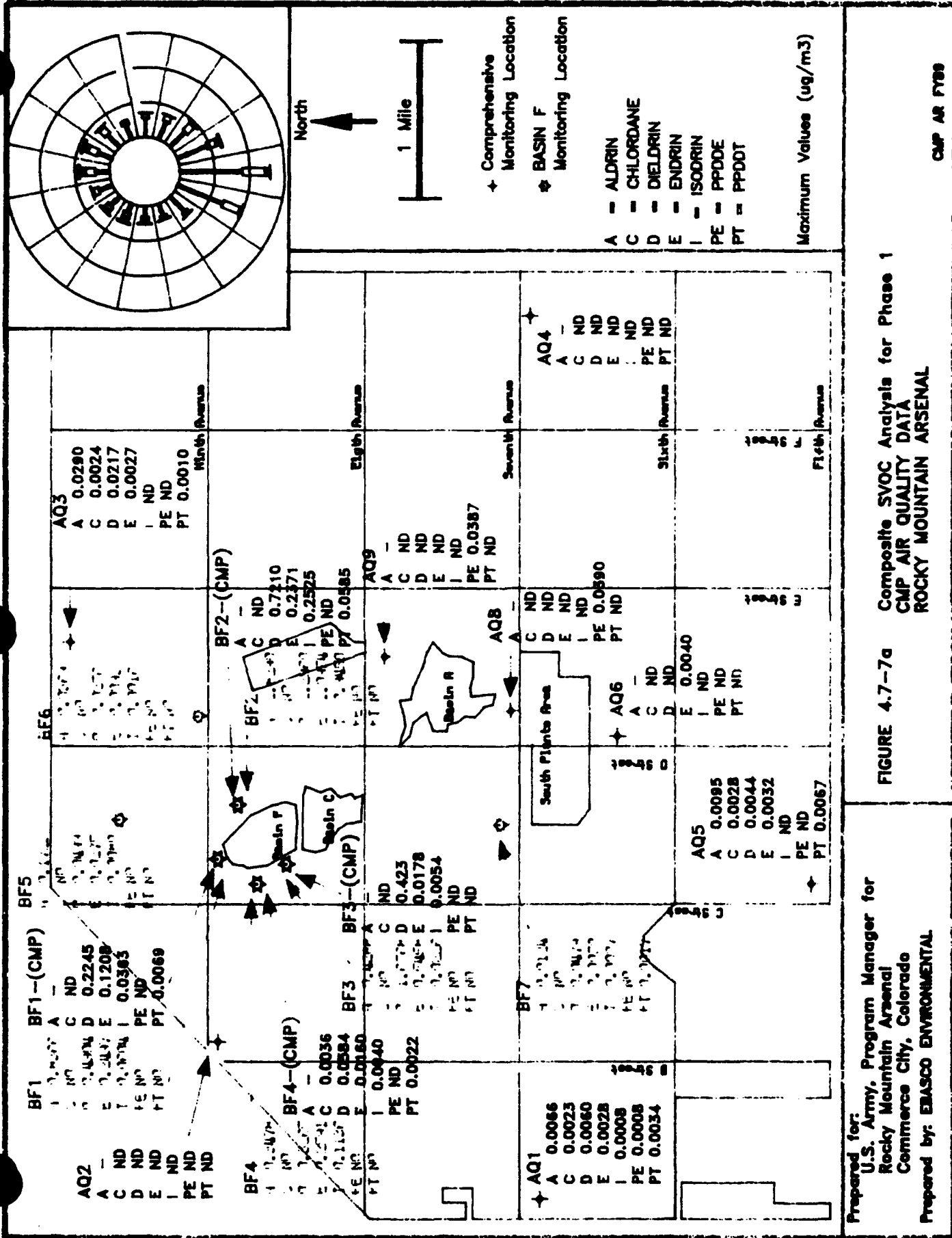
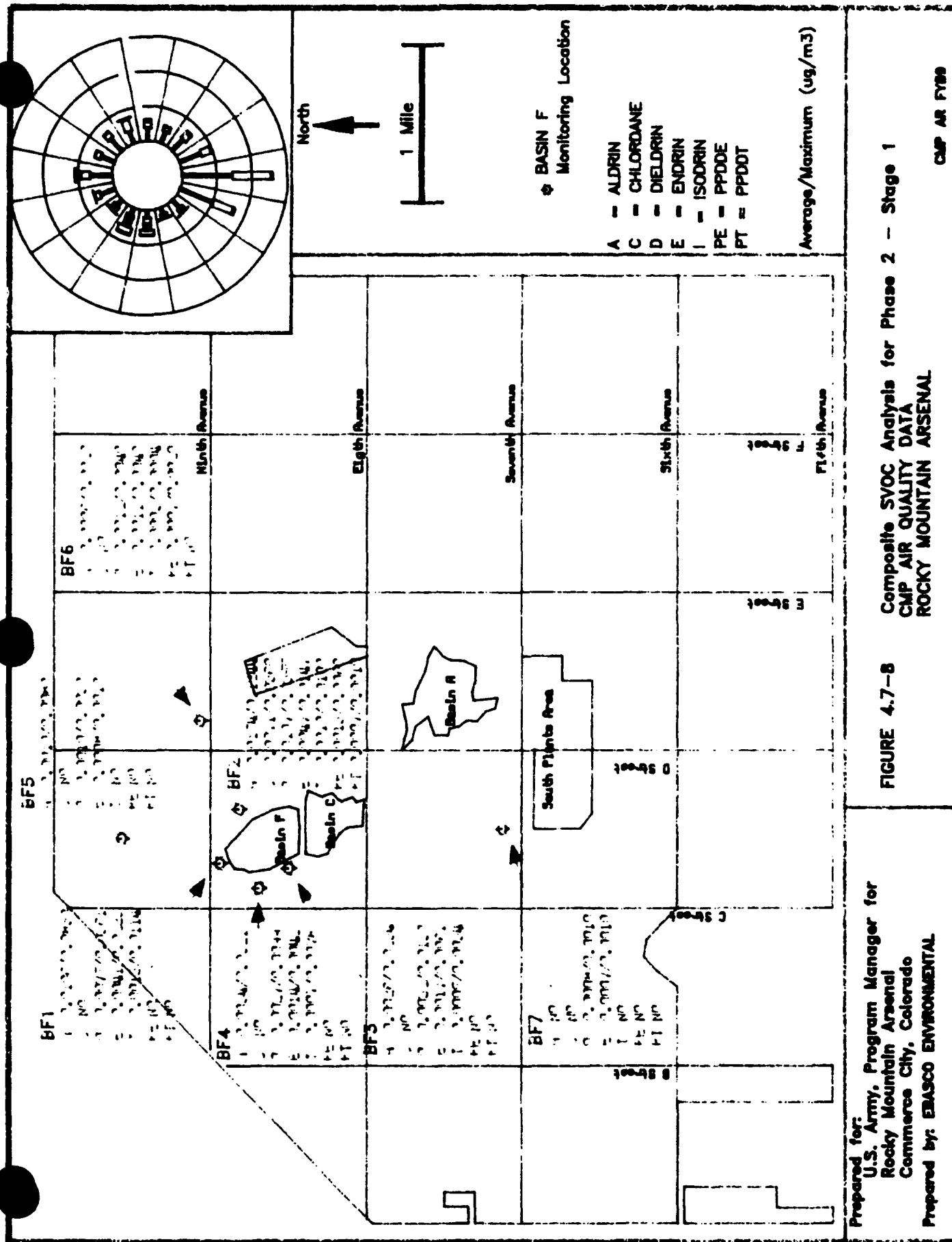
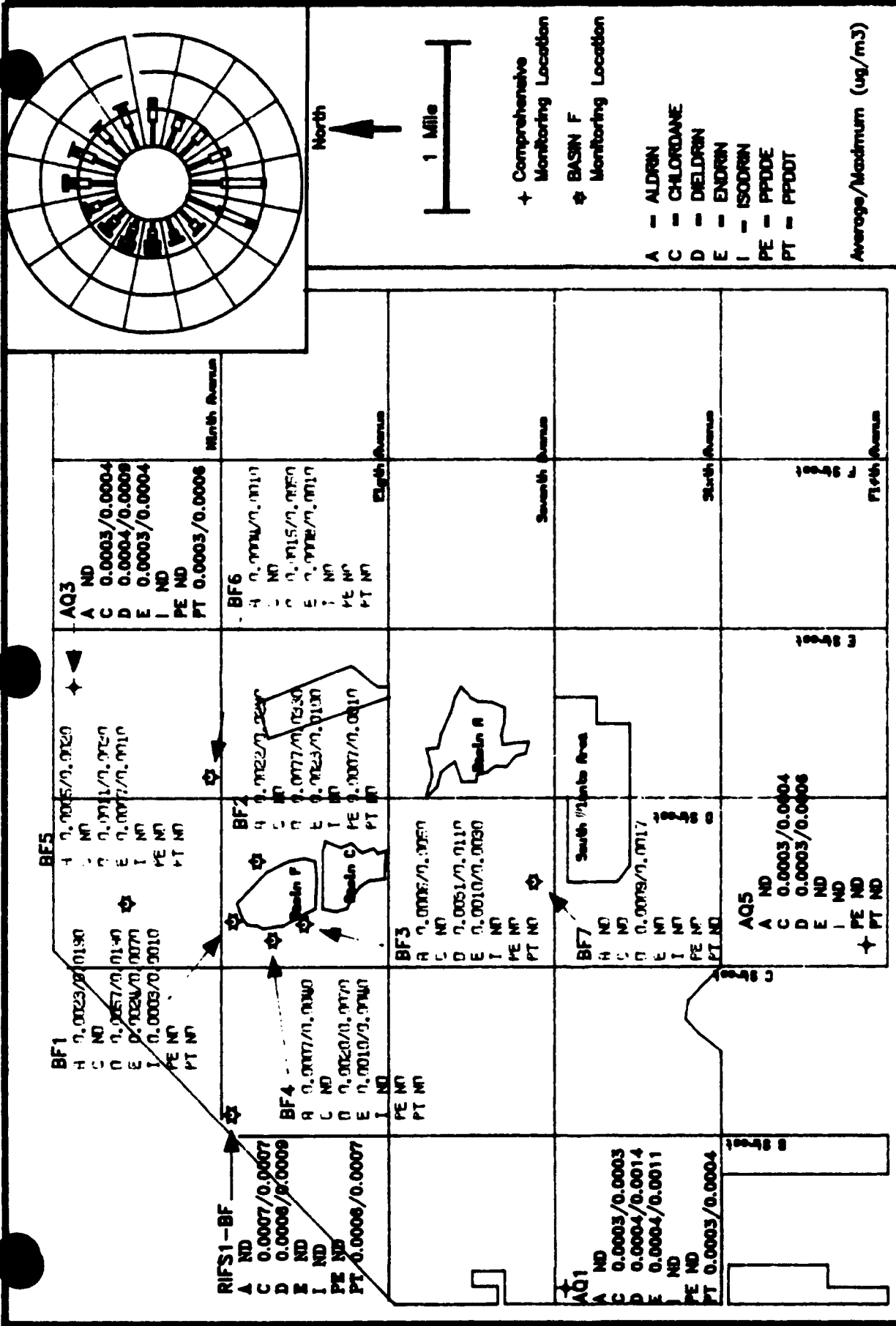


FIGURE 4.7-7a Composite SVOC Analysis for Phase 1
CMP AIR QUALITY DATA
ROCKY MOUNTAIN ARSENAL

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Prepared by: EBASCO ENVIRONMENTAL



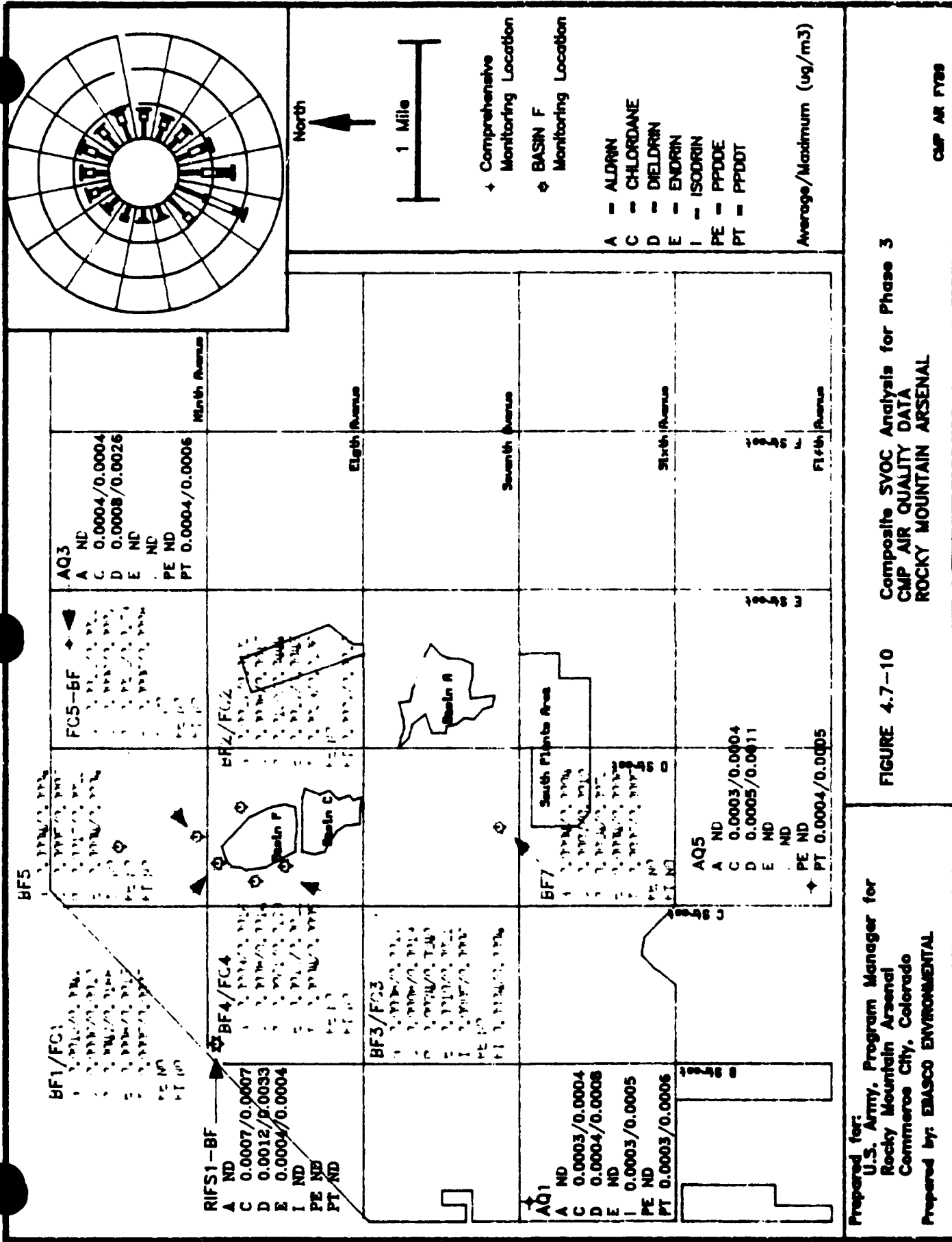


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FIGURE 4.7-9

Composite SVOC Analysis for Phase 2 - Stage 2
 CMP AIR QUALITY DATA
 ROCKY MOUNTAIN ARSENAL

CMP AIR FY08



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FIGURE 4.7-10 Composite SVOC Analysis for Phase 3
CMP AIR QUALITY DATA
ROCKY MOUNTAIN ARSENAL

beyond the immediate vicinity of Basin F. Downstream monitoring stations reflected higher concentration levels than upstream stations, however, the more distant stations, as reflected by the CMP perimeter locations, indicated low to minimal SVOC levels. During Phase 2 and Phase 3, pesticide levels appeared to decrease to levels typical of the regional baseline.

4.7.4 Summary of Results and Assessment of SVOC Toxicity Levels

Table 4.7-4 shows the locations of both maximum long-term average and maximum short-term SVOC concentrations for the combined CMP and Basin F data analyses results for the three phases of the remediation evaluation. In order to assess the significance of the measured SVOC concentrations with respect to health standards and guidelines, a literature search was conducted using references identical to those identified in the metals and VOC assessments.

A tabulation of guideline concentrations for comparison with measured SVOC concentrations is presented in Table 4.7-5; refer to Section 4.6.4 for a more detailed description of the contents of this table. The Phase 1 and Phase 2 remediation periods are grouped together and the Phase 3 post-remedial period is shown separately. Again, the comparison is very conservative because all CMP and Basin F data reflect averages of selected *worst-case* conditions. Nevertheless, this comparison is useful for identifying potential concerns during remedial operations and areas where CMP monitoring emphasis or remedial mitigation measures may be most appropriately directed. A review of the CMP and Basin F target analyte data results and potential toxic concerns follows.

The highest 24-hour aldrin concentration, $2.83 \mu\text{g}/\text{m}^3$ was measured at BF2 during Phase 1. This level was slightly greater than the recommended typical 24-hour guideline of $2.5 \mu\text{g}/\text{m}^3$. This high level was very localized in the immediate vicinity of remedial work on the northeast perimeter of the Basin F Exclusion Zone. The maximum 24-hour, or short-term, levels at the other perimeter sites ranged from $0.35 \mu\text{g}/\text{m}^3$ to $0.84 \mu\text{g}/\text{m}^3$. At the more distant Basin F sites, BF5, BF6 and BF7, maximum 24-hour aldrin values were $0.17 \mu\text{g}/\text{m}^3$, $0.04 \mu\text{g}/\text{m}^3$ and $0.01 \mu\text{g}/\text{m}^3$ respectively, or less than 7 percent of the short-term guideline. The CMP SVOC sampling did not measure aldrin, but aldrin measured under the organics in total suspended particulates program (see Section 4.8) using the pesticide analytical method measured 24-hour maximum aldrin values of $0.001 \mu\text{g}/\text{m}^3$ to $0.005 \mu\text{g}/\text{m}^3$ during Phase 1, or about 0.2 percent of the guideline (at RMA boundaries).

Table 4.7-4 Maximum Average Long-Term and Short-Term Semi-Volatile Organic Compounds Concentrations (in $\mu\text{g}/\text{m}^3$)

SVOC	Maximum Long-Term Average	Location	Phase	Maximum Short-Term Concentration	Location	Phase
Aldrin	0.5263	BF2	P1	2.8290	BF2	P1
Chlordane	0.0071	BF2	P2-S1	0.0360	BF2	P2-S1
Dieldrin	0.3971	CMP/BF2	P1	2.2960	BF2	P1
Endrin	0.1343	CMP/BF2	P1	1.0954	BF2	P1
Isodrin	0.1122	CMP/BF2	P1	0.9450	BF2	P1
PPDDE	0.0390	AQ8	P1	0.0390	AQ8	P1
PPDDT	0.0350	CMP/BF2	P1	0.0585	CMP/BF2	P1
Atrazine	ND	-	-	ND	-	-
Malathion	ND	-	-	ND	-	-
Parathion	0.1311	CMP/BF2	P1	0.2099	CMP/BF2	P1
Supona	ND	-	-	ND	-	-

Legend: PPDDE = Dichlorodiphenylethane
 PPDDT = Dichlorodiphenyltrichloroethane
 P1 = Phase 1
 P2-S1 = Phase 2-Stage 1
 P2-S2 = Phase 2-Stage 2
 P3 = Phase 3

The maximum average aldrin concentration of $0.53 \mu\text{g}/\text{m}^3$ was measured at BF2 and was 88 percent of the typical annual guideline of $0.595 \mu\text{g}/\text{m}^3$. This average level was observed during Phase 1, which was an approximately 7-month sampling period. If the more restrictive ADI chronic guideline of $0.105 \mu\text{g}/\text{m}^3$ is used, aldrin at BF2 would be above the recommended significant level. However, it should be stressed that these data represent selected worst-case monitoring periods during peak remedial activity and do not necessarily correspond to the annual ambient concentrations for which the guideline was established. Nevertheless, personnel working routinely in the vicinity of this location wore protective clothing and respirators. There were no other locations that exceeded the annual guidelines. Average concentrations again fell off quickly from the BF2 monitoring location and decreased significantly by Phase 3. Long-term average concentrations at the CMP boundary stations were less than 1 percent of the typical guideline.

Several SVOCs detected near Basin F followed the same patterns as aldrin, although aldrin indicated the highest percentages with respect to toxic guidelines. The highest 24-hour endrin measurement was $1.10 \mu\text{g}/\text{m}^3$ at BF2 during Phase 1, or 68 percent of the 24-hour guideline of $1.6 \mu\text{g}/\text{m}^3$. Other Basin F perimeter 24-hour maximum levels ranged from $0.26 \mu\text{g}/\text{m}^3$ to $0.55 \mu\text{g}/\text{m}^3$ during

Table 4.7-5

RMA Target Semi-Volatile Organic Compounds and OTSP Comparisons to Health Guidelines

Target Name	CAS #	Short-term		Typical Guidelines (µg/m ³)	RMA Phases 1 and 2				RMA CMP Boundary Evaluation						
		TLV (ppm)	TLV/420 (µg/m ³)		1 Yr Avg ADI	Subchronic Chronic	Maximum Conc.*	% of Guideline		Max. Boundary Conc. (µg/m ³)	% of Guideline				
								24-Hr	Long-Term		24-Hr	Long-Term			
Aldrin	309-00-2	0.015	0.60	0.105	2.5	0.595	2.8290	0.5263	>100	88	0.0290*	0.0053*	1	<1	
Chlordane	57-74-9	0.027	1.19	0.175	5	1.19	0.0360	0.0071	<1	<1	0.0028	0.0011	<1	<1	
Dieldrin	60-57-1	0.015	0.60		4	0.595	2.2960	0.3971	57	67	0.0217	0.0060	<1	1	
Endrin	72-20-8	0.006	0.24		1.6	0.238	1.0954	0.1343	68	47	0.0032	0.0014	<1	<1	
Isodrin	465-73-6						0.9450	0.1122				0.0008	0.0006		
PPDDE	72-55-9					1.8	0.0390	0.0390		2	0.0008	0.0006	<1	<1	
PPDDT	50-29-3	0.063	2.38	1.75	10	2.381	0.0585	0.0350	<1	1	0.0067	0.0023	<1	<1	
Atrazine	1912-24-9	0.519	11.90		80		ND	ND	ND	ND	ND	ND	ND	ND	
Malathion	121-75-5	0.679	23.81	70	100	33.3	ND	ND	ND	ND	ND	ND	ND	ND	
Parathion	56-38-2	0.008	0.24		1.6	0.238	0.2099	0.1311	13	55	ND	ND	ND	ND	
Supona	2701-86-2						ND	ND	ND		ND	ND	ND	ND	

Phase 3

Aldrin	309-00-2	0.015	0.60	0.105	2.5	0.595	0.0103	0.0027	<1	<1	ND	ND	ND
Chlordane	57-74-9	0.027	1.19	0.175	5	1.19	0.0019	0.0008	<1	<1	ND	ND	ND
Dieldrin	60-57-1	0.015	0.60		4	0.595	0.0444	0.0130	1	2	ND	ND	ND
Endrin	72-20-8	0.006	0.24		1.6	0.238	0.0045	0.0017	<1	<1	ND	ND	ND
Isodrin	465-73-6						0.0106	0.0039			ND	ND	ND
PPDE	72-55-9					1.8	ND	ND		ND	ND	ND	ND
PPDT	50-29-3	0.063	2.38	1.75	10	2.381	0.0010	0.0007	<1	<1	ND	ND	ND
Atrazine	1912-24-9	0.519	11.90		80		ND	ND	ND	ND	ND	ND	ND
Malathion	121-75-5	0.679	23.81	70	100	33.3	ND	ND	ND	ND	ND	ND	ND
Parathion	56-38-2	0.008	0.24		1.6	0.238	ND	ND	ND	ND	ND	ND	ND
Supona	2701-86-2						ND	ND	ND	ND	ND	ND	ND

* Using OTSP Aldrin monitoring results.

Legend: PPDE = Dichlorodiphenylethane
 PPDT = Dichlorodiphenyltrichloroethane
 ADI = Acceptable Daily Intake

Phase 1, decreasing to less than $0.01 \mu\text{g}/\text{m}^3$ during Phases 2 and 3. Maximum levels at outlying RMA boundary stations measured below $0.01 \mu\text{g}/\text{m}^3$, or less than one percent of the short-term guideline.

The maximum long-term average endrin concentration was $0.13 \mu\text{g}/\text{m}^3$ at BF2-(CMP) during Phase 1, or 47 percent of the annual guideline of $0.238 \mu\text{g}/\text{m}^3$. Downstream Basin F stations were less than $0.01 \mu\text{g}/\text{m}^3$, which is only 4 percent of the annual guideline. At the RMA boundaries, endrin averaged below $0.0014 \mu\text{g}/\text{m}^3$, or less than one percent of the annual guideline.

The maximum 24-hour dieldrin concentration of $2.30 \mu\text{g}/\text{m}^3$ was measured under the Basin F program at BF2 during Phase 1; this was 57 percent of the 24-hour guideline of $4 \mu\text{g}/\text{m}^3$. The 24-hour maximum values at other Basin F perimeter locations ranged from $1.66 \mu\text{g}/\text{m}^3$ at BF3 to $0.33 \mu\text{g}/\text{m}^3$ at BF4. Dieldrin at downstream Basin F stations ranged from $0.03 \mu\text{g}/\text{m}^3$ to $0.05 \mu\text{g}/\text{m}^3$, or about two percent of the 24-hour guideline. Concentrations of 24-hour dieldrin at CMP boundary stations were in the range of $0.02 \mu\text{g}/\text{m}^3$, or less than one percent of the 24-hour guideline.

The highest average dieldrin concentration was $0.40 \mu\text{g}/\text{m}^3$ at BF2-(CMP) during Phase 1. This was 67 percent of the annual guideline of $0.59 \mu\text{g}/\text{m}^3$ but represented the mean of only samples which are specifically selected to capture high events. Dieldrin at downstream Basin F stations ranged from below $0.01 \mu\text{g}/\text{m}^3$ to $0.02 \mu\text{g}/\text{m}^3$, or about three percent of the annual guideline. RMA boundary sites based on both SVOC and OTSP samples measured dieldrin concentrations at or below $0.006 \mu\text{g}/\text{m}^3$ during all phases, or about one percent of the long-term guideline.

Isodrin was detected only during Phase 1 at the CMP sites. The maximum average was $0.1122 \mu\text{g}/\text{m}^3$ and occurred at CMP/BF2. The maximum 24-hour concentration of $0.9450 \mu\text{g}/\text{m}^3$ was measured at BF2 during Phase 1. Levels of isodrin continued to decrease through Phase 2 Stage 2, but showed a slight increase for Phase 3.

Aldrin, endrin and dieldrin were the three principal pesticides measured during the Basin F and CMP monitoring programs. Parathion was detected one time during Phase 1 at the BF2-(CMP) station. The concentration was $0.21 \mu\text{g}/\text{m}^3$, or about 13 percent of the short-term guideline. All other samples were nondetectable for parathion. Chlordane, isodrin, PPDDE and PPDDT were measured at considerably lesser values and were all less than one percent of the short-term and long-term guidelines.

Several target SVOC compounds analyzed under the CMP and Basin F air monitoring programs were not detected. These included Supona, malathion and atrazine.

In summary, Basin F appeared to be a potential source of several SVOC compounds measured under the CMP and Basin F monitoring programs. In particular these included aldrin, endrin and dieldrin. Highest levels were clustered about Basin F. Monitoring station BF2, on the northeast perimeter of the basin measured the highest concentrations for most SVOC compounds; these levels were close to toxic guidelines for selected worst-case monitoring scenarios. All other monitoring stations were well below the guidelines; concentrations decreased rapidly with distance from Basin F, and reached negligible and/or regional baseline levels at the RMA boundaries (see last two columns of Table 4.7-5). Levels during Phase 2 and Phase 3 decreased dramatically from the Phase 1 values.

The decrease in concentrations from Basin F potential sources with distance as well as the impacts of prevailing wind flow are illustrated in dispersion model results for various individual worst-case sampling events shown in this report. These data confirm monitoring results and can be used to estimate impacts beyond the monitoring network.

4.7.5 SVOC Nontarget Analyte Results

The SVOC target compound list was derived from a variety of previous air monitoring and source characterization studies. The analysis included the types of chemical processes, raw feed materials, and by-products that were associated with previous operations at Rocky Mountain Arsenal. The target list represents potential contaminants of concern that are specific to RMA. However, tentative identification and semi-quantification of nontarget compounds was also performed in order to evaluate the significance of nontarget compounds and to update the target analyte list if justified.

4.7.5.1 Laboratory Procedures. The laboratory analysis and data processing procedures for nontarget SVOCs differed significantly from target SVOC procedures. For target SVOCs, an actual sample of the target compound was injected into the gas chromatograph/mass spectrometer (GC/MS). The important parameters for unambiguously identifying and quantifying the target compound, including the retention time, mass spectra, and response factor, were determined for each target compound, specifically for the GC/MS instrument used. These authentic standard verifications were not be conducted for nontarget SVOCs.

For nontarget SVOCs, a tentative identification was performed by analyzing the mass spectra for any chromatographic peak which was greater than 10 percent of the internal standard compound area. The observed mass spectrum was compared to spectra contained in the mass spectral library of the National Bureau of Standards (NBS). The measure of the degree of match was determined (this is called the "fit factor"). A high fit factor implied that the observed mass spectra for the unknown peak closely matched the mass spectra for a compound contained in the NBS library. A semi-quantification of the amount of the tentatively identified compound was then performed using an estimated response factor of one. Because the nontarget SVOC results were not verified by use of an authentic standard, these results were considered tentative identifications and semi-quantifications of the amounts of the compound observed are estimated values.

4.7.5.2 Summary of Nontarget SVOCs Table 4.7-6 presents a grouped listing of all nontarget SVOCs detected at all CMP monitoring sites during FY89. It includes the number of detections for each compound or compound group and the maximum and minimum concentrations. The total number of observed nontarget SVOCs was 132 with a maximum concentration of $100 \mu\text{g}/\text{m}^3$ coming from unknown hydrocarbons and fatty acid esters. There were 18 detections of phthalate compounds. Phthalate compounds are ubiquitous in the environment, as they are commonly found in many types of plastic products. There were 28 detections of simple non-halogenated aliphatic alkanes and hydrocarbons, which represented 21 percent of all observed nontarget SVOCs. The next most commonly observed nontarget SVOC with 13 detections was toluene diisocyanate which is a possible decomposition product of the PUF material.

The analysis of polyurethane foam detects breakdown products from the PUF. These observations have been made by Hunt et. al (1986). Compounds such as phenol; 2-ethyl hexanoic acid; 2,4 and 2,6 toluene diisocyanate; 2-methyl, 2-propenamine, 2,6 bis (1,1-dimethylethyl)-4-methyl/ phenol, chlorooctane, and ethenyl oxyisooctane have been associated with this type of analysis.

There was a decrease in the amount of unknowns detected in the SVOC analysis since the FY88 report (462 to 132 detections). Phthalate detections dropped from 115 to 18, possibly indicating laboratory contamination is under better control. Some aliphatic and aromatic ketones were detected at low levels, 7 to $30 \mu\text{g}/\text{m}^3$. Only 11 detections were actual nontargets that could be placed into a chemical grouping. The number of unknowns dropped from 89 for FY88 to 11 for FY89.

The summary of SVOC blank nontargets is listed in Table 4.7-7. The blanks where nontargets were detected came from the sites with the most potential for contamination, site AQ01 from the South Plants area and BF2, which is located northeast of Basin F.

Table 4.7-6 SUMMARY OF SVOC MONITARGETS FOR FY89

Maximum and Minimum Data in ug/m3

UNKNOWN ID	AQ6			AQ8			AQ9			AQ01			DF2		
	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS
Aliphatic ester			0			0			0			0			0
Aliphatic hydrocarbon			0			0			0			0	6	6	1
Aliphatic ketone			0			0			0			0			0
Benzopyranone			0			0			0	10	10	3			0
Cyclic alkane			0			0			0			0			0
Cyclic hydrocarbon			0			0			0			0			0
Diisocyanatotoluene			0			0			0	9	6	4	10	8	2
Diethylethylphenol			0			0			0	10	10	1	10	10	1
Diethylfuran	10	10	1	10	10	1			0	10	10	1			0
Ethylethylbenzene			0			0			0	20	5	5			0
Ethylhexanoic acid			0			0			0			0			0
Fatty acid	8	8	1	7	7	1	10	8	2	10	10	3	10	6	4
Fatty acid ester			0			0			0			0			0
Hydrocarbon	20	20	1	10	7	2	20	20	1	10	6	9	5	6	1
Isocyanonaphthalene			0			0			0			0			0
Methylbenzoxazolinone			0			0			0			0			0
Naphthalene			0			0			0	20	20	3			0
o-nitrobenzoic acid			0			0			0	5	5	3			0
Phenylethanone			0	10	10	1	10	10	1			0			0
Phenylethylketone			0			0			0	10	8	2	10	10	1
Phthalate ester			0	7	7	1			0	10	5	4	8	7	2
Tert.butylphenol			0			0			0			0			0
Unknown			0	10	10	1	8	8	1	10	8	3	7	7	1
Unknown aromatic			0			0			0			0			0

Table 4.7-6 (Continued)

Maximum and Minimum Data in ug/gS

UNKNOWN ID	BF3			BF4			BF5			BF6			TOTAL		
	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS
Aliphatic ester	5	5	1			0			0			0	5	5	1
Aliphatic hydrocarbon	20	5	3	7	7	1			0	10	6	2	20	5	7
Aliphatic ketone	30	30	2			0			0			0	30	30	2
Benzopyranone			0			0			0			0	10	10	3
Cyclic alkane			0			0			0			0			0
Cyclic hydrocarbon	8	8	1			0			0			0	8	8	1
Diisocyanatotoluene	8	6	4	10	10	1			0	7	6	2	10	6	13
Diethylethylphenol			0			0			0			0	10	10	2
Dimethylfuran			0			0			0			0	10	10	3
Ethenylethylbenzene			0			0			0			0	20	5	5
Ethylhexanoic acid			0			0			0			0			0
Fatty acid	10	5	6	7	6	2	7	6	2	8	8	1	10	5	22
Fatty acid ester	100	7	4			0			0	9	4	2	100	4	6
Hydrocarbon	100	6	5	7	7	1	7	7	1	10	10	1	100	6	22
Isocyanonaphthalene			0			0			0			0			0
Methylbenzoxazolinone			0			0			0			0			0
Naphthalene			0			0			0			0	20	20	3
o-Phenoic acid			0			0			0			0	5	5	3
Phenylethanone			0			0			0			0	10	10	2
Phenylethylketone	10	10	1			0	7	7	1	10	10	1	10	7	6
Phthalate ester	10	7	5	10	6	4	6	6	1	10	10	1	10	5	18
Tert.butylphenol	8	8	1			0			0	6	6	1	8	6	2
Unknown	30	6	2	7	7	1	6	6	1	6	6	1	30	6	11
Unknown aromatic	10	10	1			0			0			0	10	10	1

Table 4.7-7 SUMMARY OF SVOC BLANK NONTARGETS FOR FY89

Maximum and Minimum Data in ug/m3

UNKNOWN ID	AQ01			BF2			TOTAL		
	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS	MAX.	MIN.	# HITS
Aliphatic hydrocarbon			0	9	9	1	9	9	1
Ethylhexanoic acid	30	30	1			0	30	30	1
Isocyanonaphthalene			0	30	30	1	30	30	1
Methylbenzoaxazoline	9	9	1			0	9	9	1

4.8 Organics in Total Suspended Particulates (OTSP)

OTSP compounds were monitored under the CMP FY89 program routinely (every sixth day) at three RMA perimeter sites as shown in Table 4.8-1.

Table 4.8-1 Synopsis of Monitoring for Organics in Total Suspended Particulates (OTSP)

Station	Number of Samples	Percent Recovery
AQ1	52	85
AQ3	51	84
AQ5E	52	85
AQ5F*	50	>100

* Collocated station

4.8.1 CMP FY89 OTSP Monitoring Results

Results of the CMP organics in total suspended particulates (OTSP) monitoring program are summarized in Table 4.8-2. More detailed sequential listings are provided in Appendix G.

OTSP levels in FY89 were highest during the initial months of the monitoring period which overlapped the last portions of remedial activities and decreased significantly during the Phase 2 remedial period and the Phase 3 post-remedial period. An analyses of these data is discussed in the following section.

4.8.2 Assessment of CMP OTSP Data Monitored During Basin F Remedial Evaluation Phases

The CMP impacts for the three remedial evaluation phases are provided in Table 4.8-3, which shows that pesticide concentrations were significantly lower during the post-remedial periods. During the Phase 1 remedial period the average concentration of aldrin was $0.005 \mu\text{g}/\text{m}^3$ with a 24-hour maximum value of $0.029 \mu\text{g}/\text{m}^3$ at AQ3, downstream from Basin F. During Phase 2 and Phase 3, aldrin was nondetectable at all of the CMP perimeter monitoring stations.

TABLE 4.8-2 SUMMARY OF FY89 ORGANICS IN TOTAL SUSPENDED PARTICULATES (TSP) CONCENTRATIONS
(in ug/m3)

Site	Aldrin	Chlordane	Dieldrin	Endrin	Isodrin	PPDDE 1	PPDDT 2
Average Values							
AQ1	0.0006	0.0003	0.0005	0.0004	0.0003	‡	0.0004
AQ3	0.0023	0.0003	0.0009	0.0005	0.0004	‡	0.0004
AQ5	0.0007	0.0003	0.0005	0.0004	0.0004	‡	0.0004
Maximum Values							
AQ1	0.0066	0.0004	0.0015	0.0011	0.0005	‡	0.0008
AQ3	0.0290	0.0004	0.0061	0.0026	0.0024	‡	0.0006
AQ5	0.0095	0.0005	0.0028	0.0013	0.0008	‡	0.0005
Minimum Values							
AQ1	0.0003	0.0003	0.0003	0.0003	0.0003	‡	0.0003
AQ3	0.0003	0.0003	0.0003	0.0003	0.0003	‡	0.0003
AQ5	0.0003	0.0003	0.0003	0.0003	0.0003	‡	0.0003

‡ All values below CRL.

1 PPDDE = Dichlorodiphenylethane

2 PPDDT = Dichlorodiphenyltrichloroethane

TABLE 4.8-3

SUMMARY OF CMP ORGANICS IN TOTAL SUSPENDED PARTICULATES (TSP) FOR PHASES 1-3
(in ug/m3)

Site	Aldrin	Chlordane	Dieldrin	Endrin	Isodrin	PPDDE 1	PPDDT 2
Average Values							
PHASE 1							
AQ1	0.0010	0.0003	0.0010	0.0006	0.0003	0.0005	0.0007
AQ3	0.0053	0.0003	0.0022	0.0013	0.0005	‡	0.0004
AQ5	0.0013	0.0003	0.0013	0.0009	0.0003	0.0004	0.0006
PHASE 2							
AQ1	‡	0.0003	0.0004	0.0004	‡	‡	0.0003
AQ3	‡	0.0003	0.0004	0.0003	‡	‡	0.0003
AQ5	‡	0.0003	0.0003	‡	‡	‡	‡
PHASE 3							
AQ1	‡	0.0003	0.0004	‡	0.0003	‡	0.0003
AQ3	‡	0.0004	0.0008	‡	‡	‡	0.0004
AQ5	‡	0.0003	0.0005	‡	‡	‡	0.0004
Maximum Values							
PHASE 1							
AQ1	0.0066	0.0005	0.0062	0.0026	0.0005	0.0058	0.0047
AQ3	0.0290	0.0005	0.0061	0.0041	0.0024	‡	0.0012
AQ5	0.0095	0.0008	0.0074	0.0046	0.0008	0.0023	0.0050
PHASE 2							
AQ1	‡	0.0003	0.0014	0.0011	‡	‡	0.0004
AQ3	‡	0.0004	0.0009	0.0004	‡	‡	0.0006
AQ5	‡	0.0004	0.0006	‡	‡	‡	‡
PHASE 3							
AQ1	‡	0.0004	0.0008	‡	0.0005	‡	0.0006
AQ3	‡	0.0004	0.0026	‡	‡	‡	0.0006
AQ5	‡	0.0004	0.0011	‡	‡	‡	0.0005

‡ All values below CRL.

1 PPDDE = Dichlorodiphenylethane

2 PPDDT = Dichlorodiphenyltrichloroethane

Dieldrin averaged $0.002 \mu\text{g}/\text{m}^3$ at AQ3 with a 24-hour maximum value of $0.007 \mu\text{g}/\text{m}^3$ reported at AQ5. During Phases 2 and 3, dieldrin decreased to average levels of less than $0.001 \mu\text{g}/\text{m}^3$. The maximum 24-hour value was $0.003 \mu\text{g}/\text{m}^3$ at AQ3. These may be typical regional baseline levels of dieldrin in the RMA area.

Endrin measured an average value of $0.001 \mu\text{g}/\text{m}^3$ at AQ3 during Phase 1, while the maximum 24-hour value was $0.005 \mu\text{g}/\text{m}^3$ at AQ5. During the post-remedial period, endrin was not detected at the RMA perimeter sites.

Isodrin measured an average value of $0.001 \mu\text{g}/\text{m}^3$ at AQ3 during Phase 1 with a 24-hour maximum value of $0.002 \mu\text{g}/\text{m}^3$. During Phase 2 and Phase 3, isodrin was measured only at AQ1 with an average value of less than $0.001 \mu\text{g}/\text{m}^3$ and a maximum value of $0.001 \mu\text{g}/\text{m}^3$.

PPDDE was measured at very low levels during Phase 1 and was nondetectable in Phases 2 and Phase 3. PPDDT was highest during the Phase 1 period; however, the highest 24-hour maximum concentrations of $0.005 \mu\text{g}/\text{m}^3$ were at AQ1 and AQ5 suggesting little impact from Basin F operations. Levels of chlordane were essentially the same throughout the three phases of remediation with very low values reflecting typical baseline concentrations.

In summary, all of the OTSP compounds were measured at very low levels at the RMA perimeter sites. Pesticide levels were, in fact, significantly lower during the remediation period at perimeter sites than levels measured in the immediate vicinity of Basin F during this period, again suggesting that Basin F impacts were highly localized. The highest OTSP pesticide levels measured during remediation presented no toxic concern and remained about one percent of toxic guidelines (as presented in the previous SVOC section).

The OTSP program served a function in that most of the pesticides measured under CMP at RMA boundary stations were nondetectable under the certified gas chromatography/mass spectrometry (GC/MS) analysis method. However, gas chromatography/electron capture detection (GC/ECD) techniques used to measure pesticides under the OTSP program have a lower detection limit and a higher precision. Consequently, the levels of pesticides at the RMA boundaries were more precisely identified under this program. A nontarget analysis of OTSPs was not performed.

4.8.3 Basin F OTSP Monitoring Results

OTSP was monitored at 10 different locations during the Basin F remediation monitoring program. This number was subsequently reduced to five sites during the IRA-F follow-on program. Results

of pesticide concentrations from the Basin F monitoring programs have been incorporated into the Basin F SVOC data discussed in the previous section.

5.0 CONTINUOUS AIR MONITORING PROGRAM

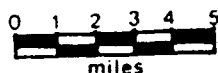
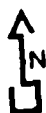
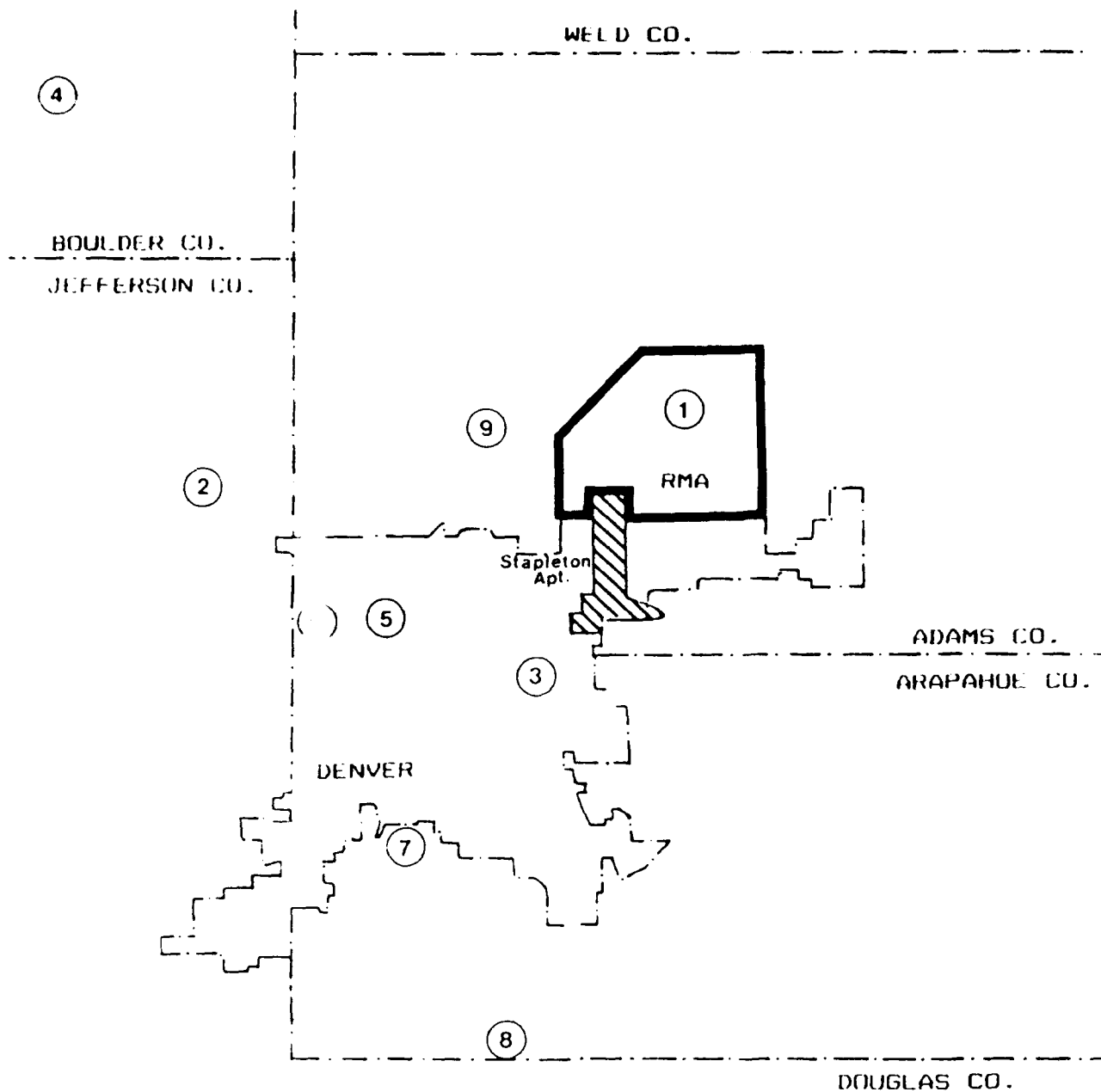
5.1 Program Overview

The Continuous Air Monitoring Program is described in Section 3.6. As noted, the readings were taken continuously, and recorded automatically in a data acquisition system. The hourly averages of the sampling data for carbon monoxide (CO), ozone (O₃), sulfur dioxide (SO₂), nitric oxide (NO), nitrogen dioxide (NO₂) and nitrogen oxides (NO_x) are presented in Appendix I for the period May 6, 1989 through September 30, 1989 and are summarized in this section. A description of the atmospheric characteristics of these gases is found in Sections 2.1.3 through 2.1.6.

The purpose of this program was to identify background concentrations of pollutants which play a role in possible future remediation activities. An assessment of these data yields additional insight into the atmospheric characteristics in and around the RMA site. It provides a general overview of the gaseous concentrations, as well as highlighting any anomalous values. This analysis helps to identify the effect of wind patterns on RMA air quality. A frequently occurring diurnal drainage wind pattern with a south to north air flow at night and a north to south air flow during the day affects all six gas concentrations to some extent. Diurnal drainage winds are described in more detail in Section 2.2. Daytime photochemical activity primarily influences O₃ and NO₂. A summary of average and 1-hour maximum concentration as measured during the FY89 program, as well as additional analyses, is provided in this section.

A second major objective of the Continuous Air Monitoring Program was to compare the RMA concentrations with those of nearby regional continuous air monitoring sites. These adjacent sites are administrated by the Colorado Department of Health - Air Pollution Control Division (CDH). Locations of the CDH continuous air monitoring sampling sites are illustrated in Figure 5.1-1 and described in Table 5.1-1.

The Continuous Air Monitoring Program served to establish baseline levels of gaseous constituents for future air quality assessments. These values can be compared with various meteorological data such as wind direction and stability to identify possible migration patterns of these gaseous pollutants from metropolitan Denver onto RMA. Also, baseline levels may be used to predict the impact a future source may have on the environment. The results shown here represent a 5-month sample over the spring and summer seasons, and cannot be reliably used to estimate annual patterns or extremes. A more complete assessment including a complete annual cycle will be provided in the subsequent (FY90) report.



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Figure 5.1-1

RMA and Colorado
Department of Health
Continuous Air Quality
Monitoring Sites

CMP AR FY 89

Table 5.1-1 RMA and Colorado Department of Health
Gaseous Emissions Monitoring Sites

Site Number	Site Name	Site Address	Reported Parameters					
			CO	O3	SO2	NO	NO2	NOx
1	RMA	8th Avenue at D Street	X	X	X	X	X	X
2	Arvada	57th at Garrison	X	X				
3	Albion	14th at Albion	X					
4	Boulder	2320 Marine	X	X				
5	Camp	2105 Broadway	X	X	X		X	
6	Carriage	13rd and Julian	X	X				
7	Englewood	3300 South Huron	X	X			X	
8	Highland	8100 South University	X	X				
9	Welby	78th at Steele	X	X	X		X	

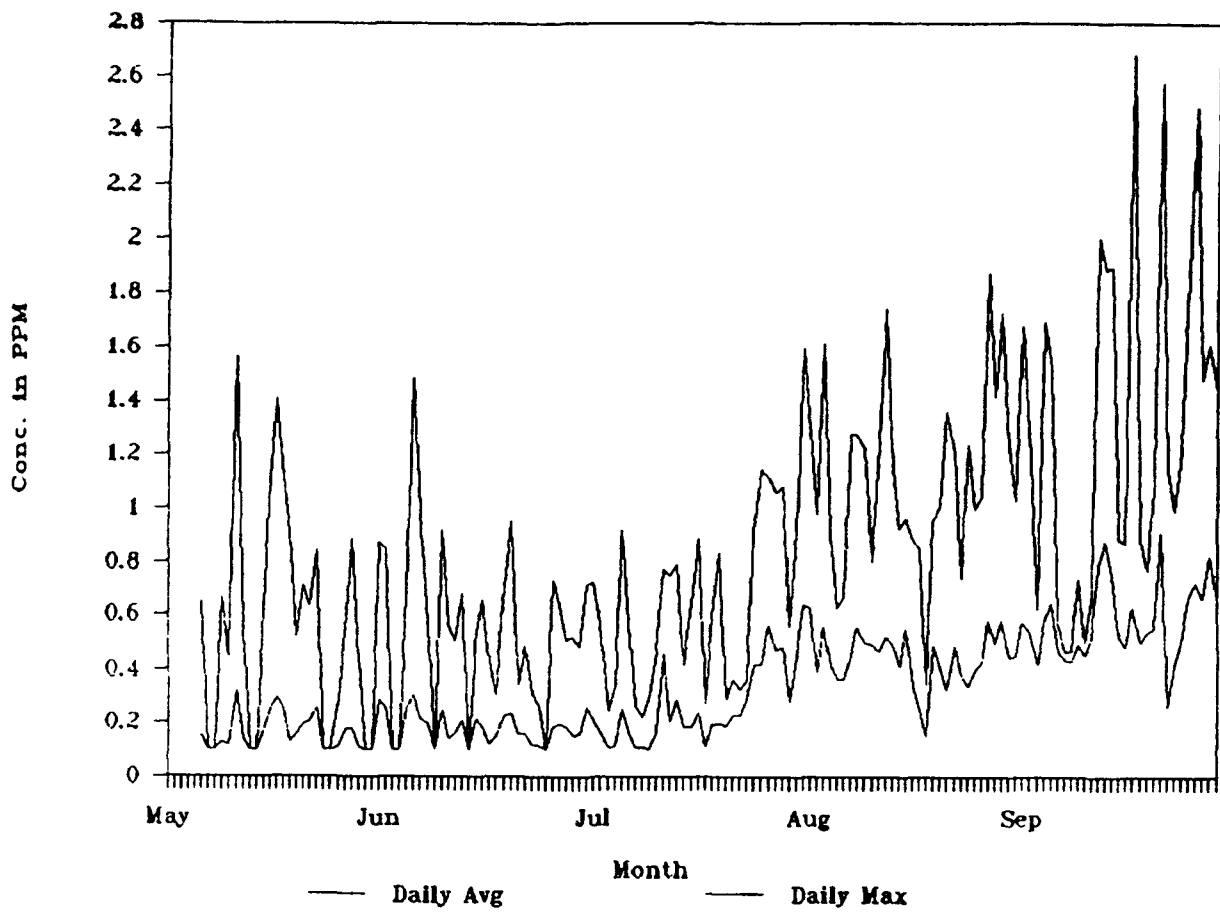
5.2 Summary of Results

A variety of tables and graphs were used to summarize the continuous air quality data. Mean values refer to daily averages and the 1-hour maximum value refers to the highest 1-hour average value recorded daily. Additional comparisons were made with National Ambient Air Quality Standards (NAAQS). Comparisons of RMA data to values from Colorado Department of Health sites were also reported. The analyses for carbon monoxide, ozone, and sulfur dioxide are presented individually in the following subsections. For nitric oxide, nitrogen dioxide, and nitrogen oxides, a combined analyses is provided because of the similarities in their chemical composition and concentration characteristics. Case studies were presented to examine the possible sources of some extreme concentrations observed at RMA.

5.3 Carbon Monoxide (CO)

The series of daily mean and 1-hour maximum carbon monoxide values are illustrated in Figure 5.3-1. The daily maximum was often five times greater than the daily average, and occasionally it reached 10 times the average. On a few days, generally with persistent winds blowing from the north through the southeast, the daily maximum and mean were virtually the same. Figure 5.3-1 also demonstrates a portion of the annual cycle in CO values in metropolitan Denver. Both the mean and maximum values increased with the approach of autumn. Monthly summaries of the 1-hour and 8-hour averages are shown in Tables 5.3-1 and 5.3-2. The maximum observed 1-hour concentration was 2.7 ppm and the maximum 8-hour concentration was 1.9 ppm. The National Ambient Air Quality Standard for the 1-hour average (35 ppm) and the 8-hour average (9 ppm) was never exceeded throughout the sampling period. Again the summarized data showed a slight increase over the 5-month sampling period. Historically, CO values for metropolitan Denver increased throughout autumn and reached their peak during winter. However, a collection of a complete year's data is needed before the annual cycle or seasonal patterns can be established for the RMA site.

As noted in Section 5.1, the Colorado Department of Health monitored CO concentrations at eight sites in the metropolitan Denver area. A comparison of the 1-hour and 8-hour monthly extremes among these stations and RMA is shown in Figure 5.3-2 through 5.3-3. For the 1-hour data, RMA reflects considerably lower concentrations than all sites except the Highland site at the southern edge of the metropolitan area. The 8-hour data showed the lowest concentrations at RMA compared to all eight sites. A likely explanation for this difference may be that vehicle emissions are a major source of CO and the RMA site is somewhat removed from the major vehicular traffic of the Denver metropolitan area. There were also minimal CO sources within the RMA complex.



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Figure 5.3-1

Graphical Depiction of
Carbon Monoxide FY89
(May 6, 1989-Sept. 30, 1989)

CMP AR FY89

Table 5.3-1 Summary of Carbon Monoxide 1-Hour Average Values in ppm¹
May 6, 1989 (1200 MST) through September 30, 1989 (2400 MST)

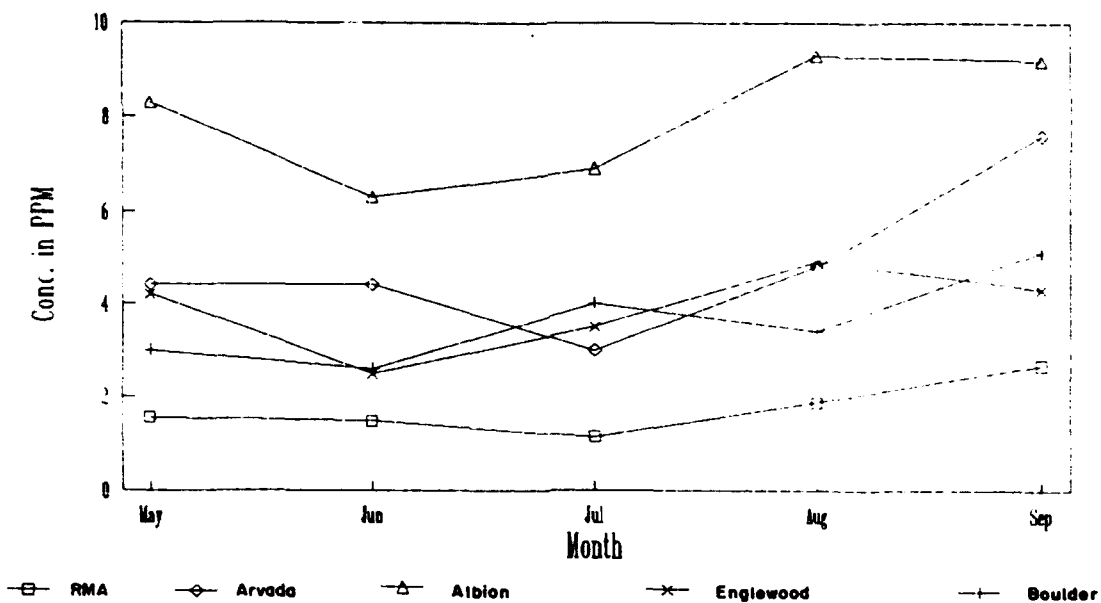
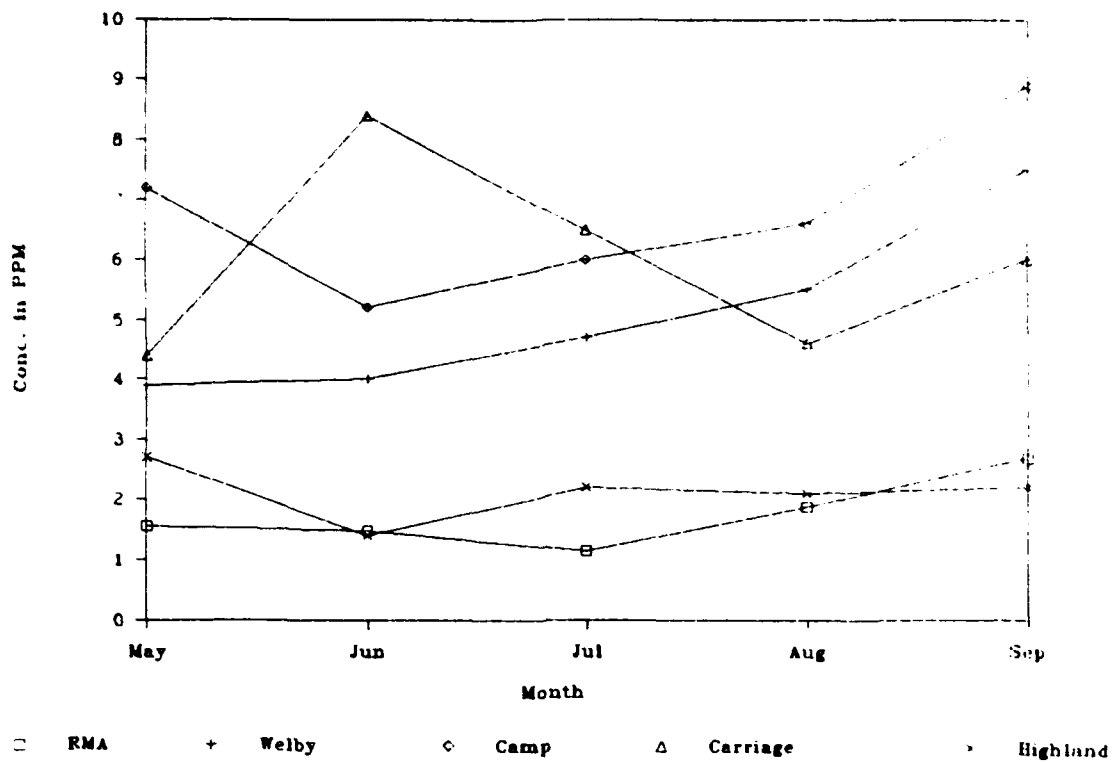
	May	June	July	August	September
Mean	0.2	0.2	0.3	0.5	0.6
Maximum	1.6	1.5	1.1	1.9	2.7
2nd Highest Maximum	1.4	1.1	1.1	1.7	2.6
Minimum	0.1	0.1	0.1	0.1	0.1
Mean for Entire Period	0.3				

Table 5.3-2 Summary of Carbon Monoxide 8-Hour Average Values in ppm²
May 6, 1989 (1200 MST) through September 30, 1989 (2400 MST)

	May	June	July	August	September
Mean	0.2	0.2	0.3	0.5	0.6
Maximum	0.6	0.6	0.8	1.0	1.9
2nd Highest Maximum	0.6	0.6	0.8	1.0	1.8
Minimum	0.1	0.1	0.1	0.1	0.1
Mean for Entire Period	0.3				

¹Federal and Colorado Ambient Air Quality Standard for maximum 1-hour average values is 35 ppm, not to be exceeded more than once per year.

²Federal and Colorado Ambient Air Quality Standard for maximum 8-hour average values is 9 ppm, not to be exceeded more than once per year.



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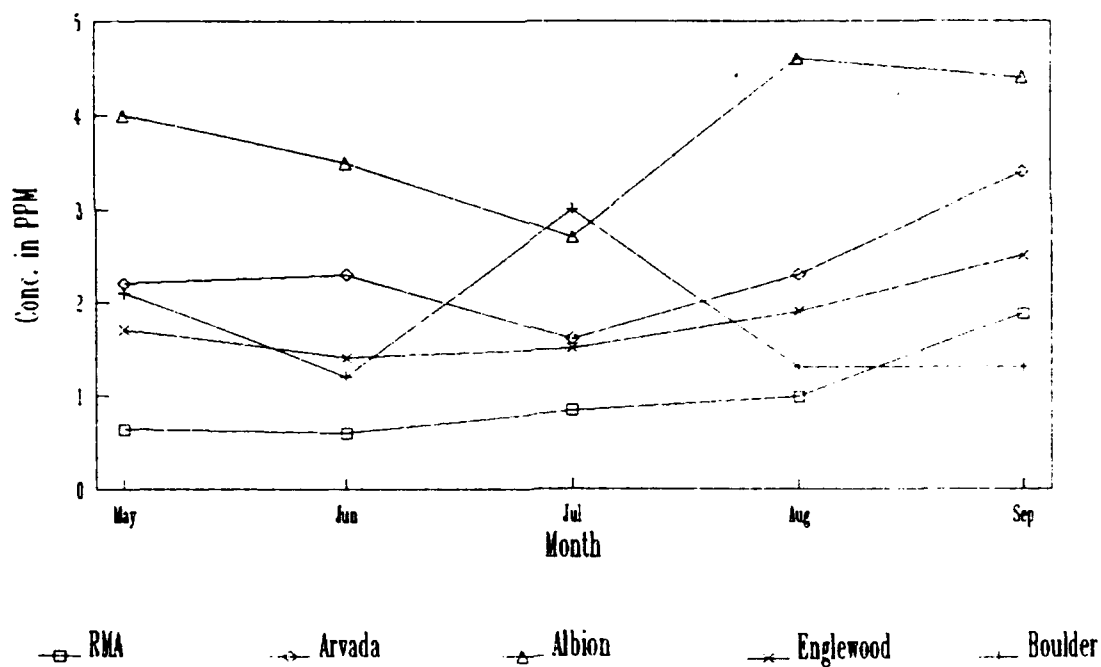
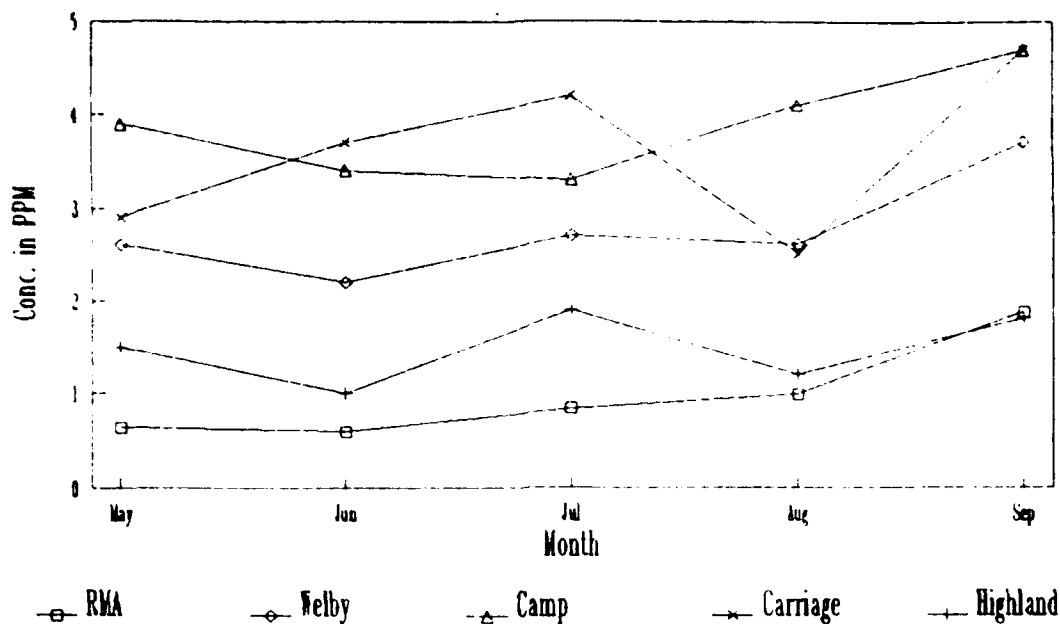
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Figure 5.3-2

CMP and Colorado
 Department of Health Site
 1-Hour Carbon Monoxide
 Values (May 1989-Sept.
 1989)

CMP AR FY89



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Figure 5.3-3

CMP and Colorado

Department of Health Site

8-Hour Carbon Monoxide

Values (May 1989-Sept.
1989)

CMP AR FY89

A distinct diurnal pattern is illustrated in Figure 5.3-4. Since there were no major stationary sources of carbon monoxide in the RMA area, the data suggest that emissions from the metropolitan rush-hour vehicular traffic accounted for the high hourly average values between 0700 MST and 1000 MST. This might lead one to expect high values corresponding to the evening rush hour; instead, these values decreased. The decrease in these values may be attributed to the increased level of instability and dispersion in the atmosphere throughout the afternoon and early evening hours primarily during the spring and summer monitoring period. Perhaps just as important, a diurnal wind shift prevalent in the afternoon brings air from the north which generally contains lower concentrations of CO.

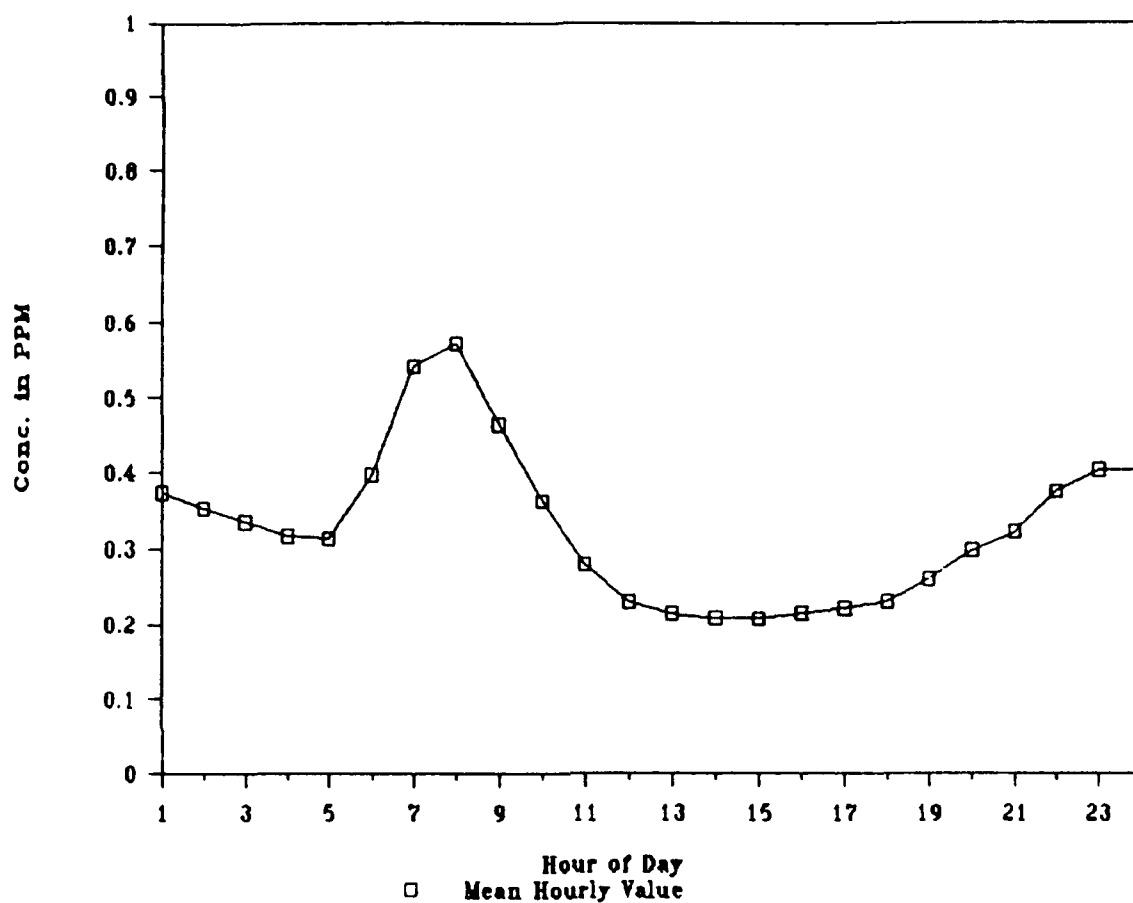
Appendix I presents the daily summary of the CO values as well as graphs depicting daily mean and maximum values for each month.

5.4 Ozone (O₃)

The daily mean and maximum 1-hour ozone values are depicted in Figure 5.4-1. The daily mean ozone values increased slightly from May through July and then declined from August through September. The daily maximum values were somewhat similar in the long term, but day-to-day correlation of the values was not evident. A monthly summary of these data is reported in Table 5.4-1. The highest reading of 0.104 ppm was slightly below the primary 1-hour National Ambient Air Quality Standard of 0.120 ppm for ozone. The monthly maximum values were fairly consistent through the summer months. Maximum values of ozone correlated well with the mean values. A peak in maximum values occurred during late July and August, which is to be expected, since during this portion of the year the number of daylight hours and the intensity of solar radiation are near their maximum.

One significant feature of the 5-month database was the very definite drop in the maximum and mean ozone values for September 11 - 12. This can be seen with greater clarity in the September ozone graph in Appendix I. During this period a major storm system developed over the entire Denver area. This system produced widespread cloud cover and a significant drop in solar radiation intensity was noted. Since ozone is produced by solar radiation, this system may have influenced the ozone levels.

A comparison of the highest 1-hour average ozone values with those at the seven Colorado Department of Health (CDH) monitoring sites is presented in Figure 5.4-2. Generally, the RMA site values were similar to those reported by the CDH sites. In particular, the data from the RMA



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Figure 5.3-4
Graphical Depiction of
Carbon Monoxide Diurnal
Pattern FY89 (May 6, 1989-
Sept. 30, 1989)
CMP AR FY89

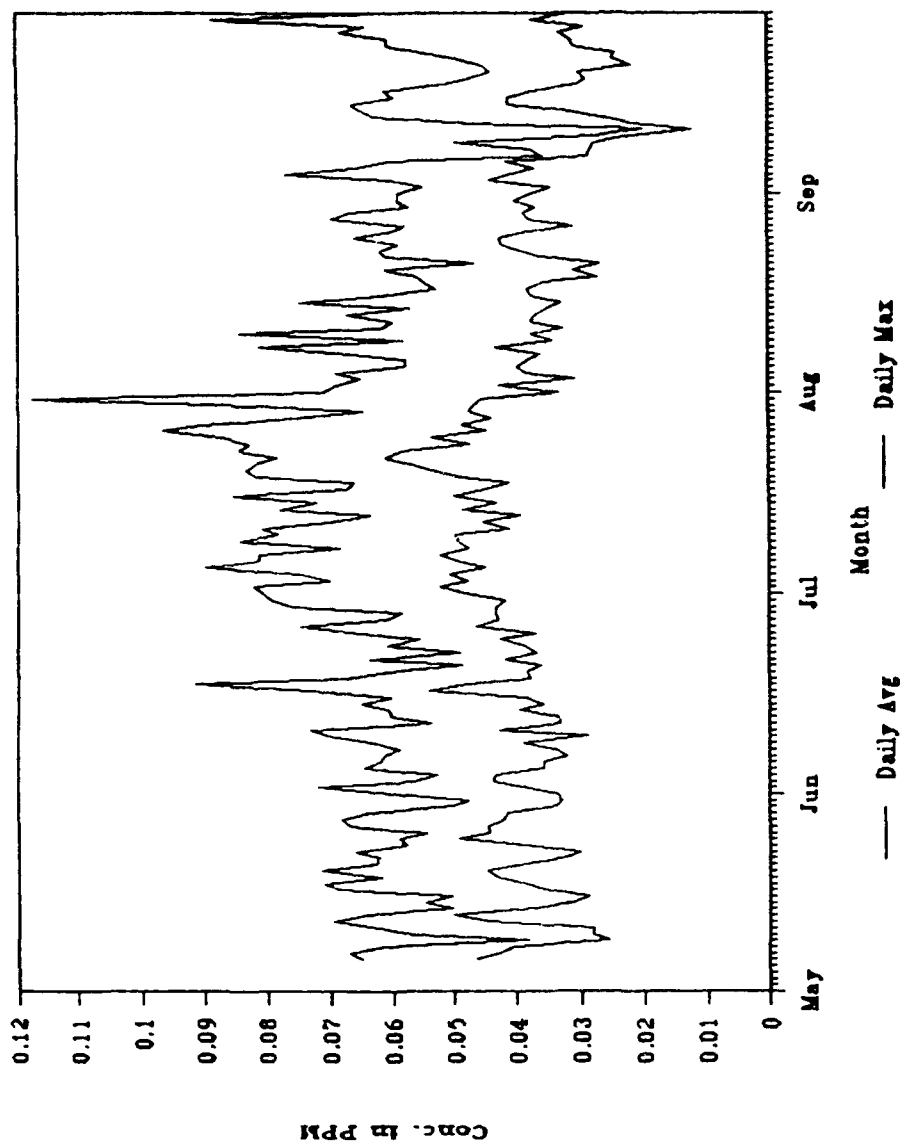


Figure 5.4-1

Graphical Depiction of
Ozone FY89 (May 6,
1989-Sept. 30, 1989)

CMPAR FY 89

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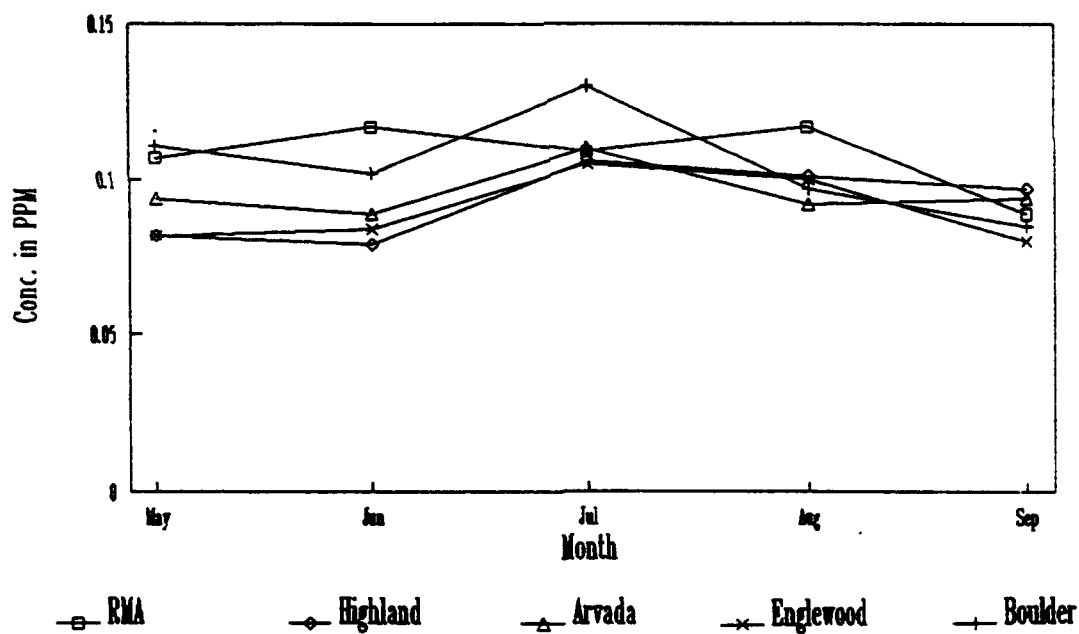
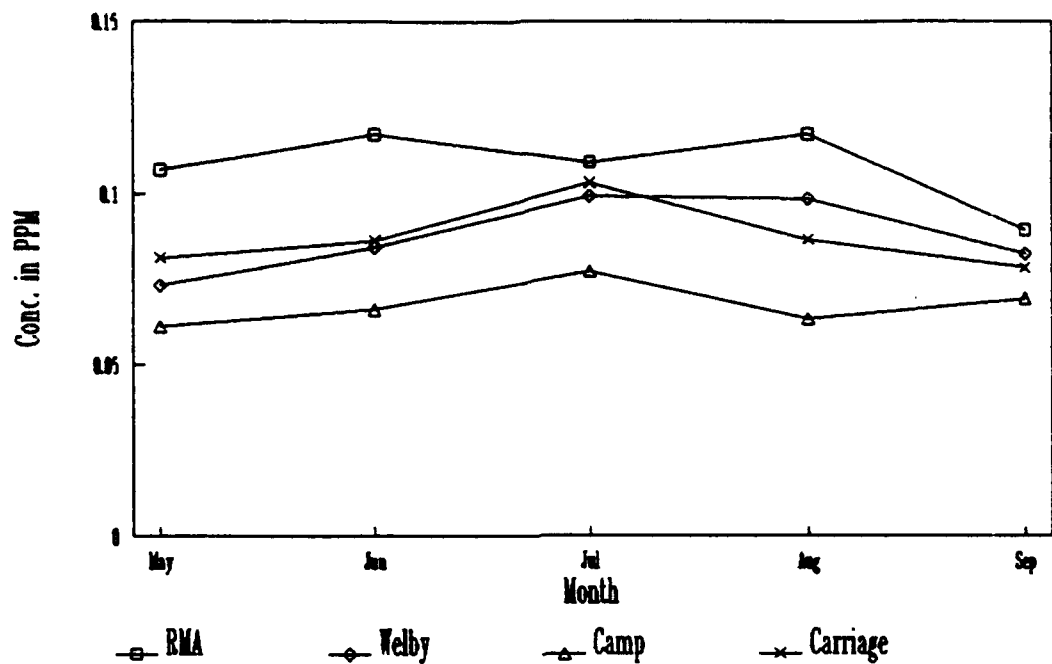
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Table 5.4-1 Summary of Ozone 1-Hour Average Values in ppm¹
May 6, 1989 (1200 MST) through September 30, 1989 (2400 MST)

	May	June	July	August	September
Mean	0.038	0.039	0.048	0.036	0.032
Maximum	0.071	0.091	0.097	0.104	0.089
2nd Highest Maximum	0.071	0.081	0.090	0.092	0.088
Minimum	0.001	0.001	0.001	0.001	0.001
Mean for Entire Period	0.039				

Federal and Colorado Ambient Air Quality Standard for maximum 1-hour average values is 0.120 ppm. The statistically estimated number of days with exceedances averaged over a 3-year period is not to be more than 1 per year.



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Figure 5.4-2
 CMP and Colorado
 Department of Health
 Sites 1-Hour Ozone Values
 (May 1989-Sept. 1989)
 CMP AR FY89

site were similar to those found at the Welby Site, as would be expected since this site is the closest of the CDH sites to the RMA.

The mean diurnal pattern for ozone is shown in Figure 5.4-3. A very distinct diurnal cycle can be seen from this graph. The lower concentrations occurred around the morning hours from 0500 MST to 0700 MST since ozone is not produced extensively until well after the sun rises in the morning. Conversely, a broad maximum was evident during the daylight hours from 1100 MST to 1800 MST because solar radiation plays a major role in ozone formation. The greatest mean ozone value occurred at 1300 MST concurrent with maximum solar radiation.

The peak value for August, which was recorded as 0.104 ppm, at 1300 MST on August 1, 1989 appeared to have been the result of unusually heavy atmospheric electrical activity. In fact, during the hours of 1200 MST through 1600 MST, major thunderstorms passed through the area. Ozone levels were significantly high throughout that period.

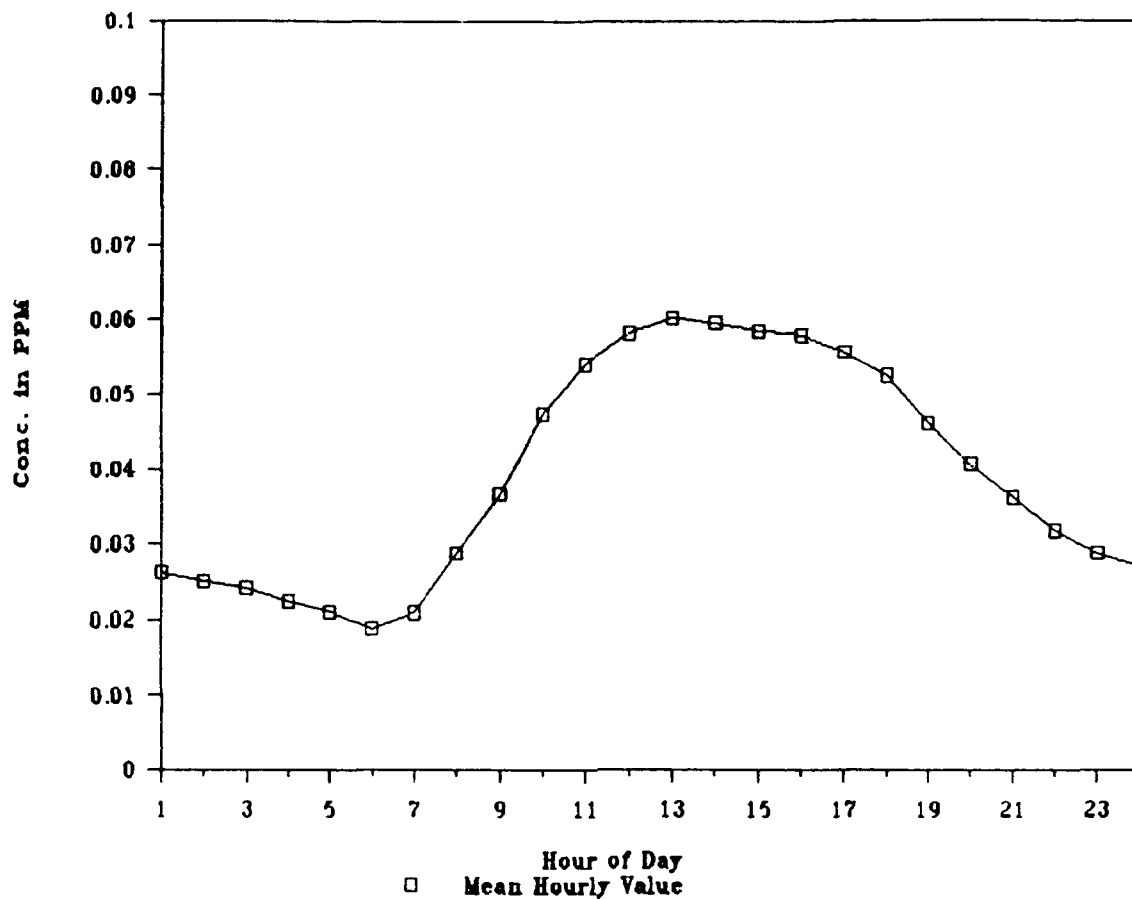
A listing of the ozone data as well as detailed monthly graphs used to generate the figures and tables in this section are resented in Appendix I.

5.5 Sulfur Dioxide (SO₂)

The series of daily mean and 1-hour maximum sulfur dioxide concentrations are shown in Figure 5.5-1. The vast majority of both the daily mean and 1-hour maximum values were at the lower detection limit (0.001 ppm). In fact, the daily mean sulfur dioxide values showed no significant change over the 5-month sampling period. The relatively higher values of sulfur dioxide appeared to be "episodic" in nature, and were not related to a diurnal cycle or other recurring event. The maxima were likely the result of winds blowing persistently from major off-site sources. Section 5.7 discusses two possible examples of this effect.

A summary of the 1-hour, 3-hour and 24-hour averages is given in Tables 5.5-1 through 5.5-3 respectively. For this 5-month period, the highest 3-hour reading was 0.200 ppm and the highest 8-hour reading was 0.004 ppm, both well below the existing National Ambient Air Quality Standards of 0.500 ppm and 0.140 ppm, respectively. One generalization which can be made from the data is that the mean and maximum values show no evident trend.

Figures 5.5-2 and 5.5-3 show a comparison among the RMA air quality monitoring site and two Colorado Department of Health (CDH) monitoring sites (the Welby and CAMP sites) for 3-hour

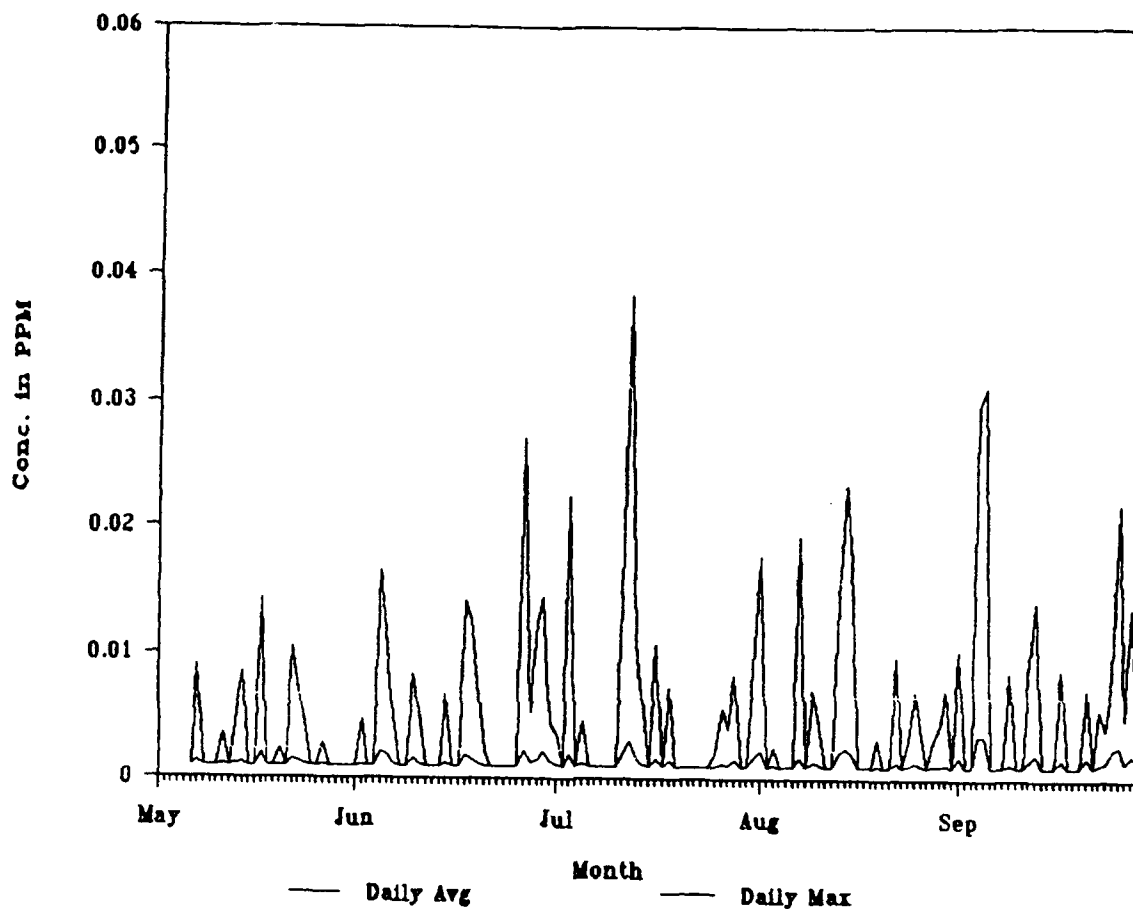


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Figure 5.4-3
Graphical Depiction of
Ozone Diurnal Pattern FY89
(May 6, 1989-Sept. 30, 1989)

CMP AR FY89



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Commerce City, Colorado

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Figure 5.5-1

Graphical Depiction of
Sulfur Dioxide FY89
(May 6, 1989-Sept. 30,
1989)

CMP AR FY89

Table 5.5-1 Summary of Sulfur Dioxide 1-Hour Average Values in ppm¹
May 6, 1989 (1200 MST) through September 30, 1989 (2400 MST)

	May	June	July	August	September
Mean	0.001	0.001	0.001	0.001	0.002
Maximum	0.014	0.027	0.038	0.023	0.031
2nd Highest Maximum	0.011	0.016	0.022	0.019	0.030
Minimum	0.001	0.001	0.001	0.001	0.001
Mean for Entire Period	0.001				

Table 5.5-2 Summary of Sulfur Dioxide 3-Hour Average Values in ppm²
May 6, 1989 (1200 MST) through September 30, 1989 (2400 MST)

	May	June	July	August	September
Mean	0.001	0.001	0.001	0.001	0.002
Maximum	0.005	0.011	0.017	0.013	0.020
2nd Highest Maximum	0.005	0.011	0.017	0.013	0.020
Minimum	0.001	0.001	0.001	0.001	0.001
Mean for Entire Period	0.001				

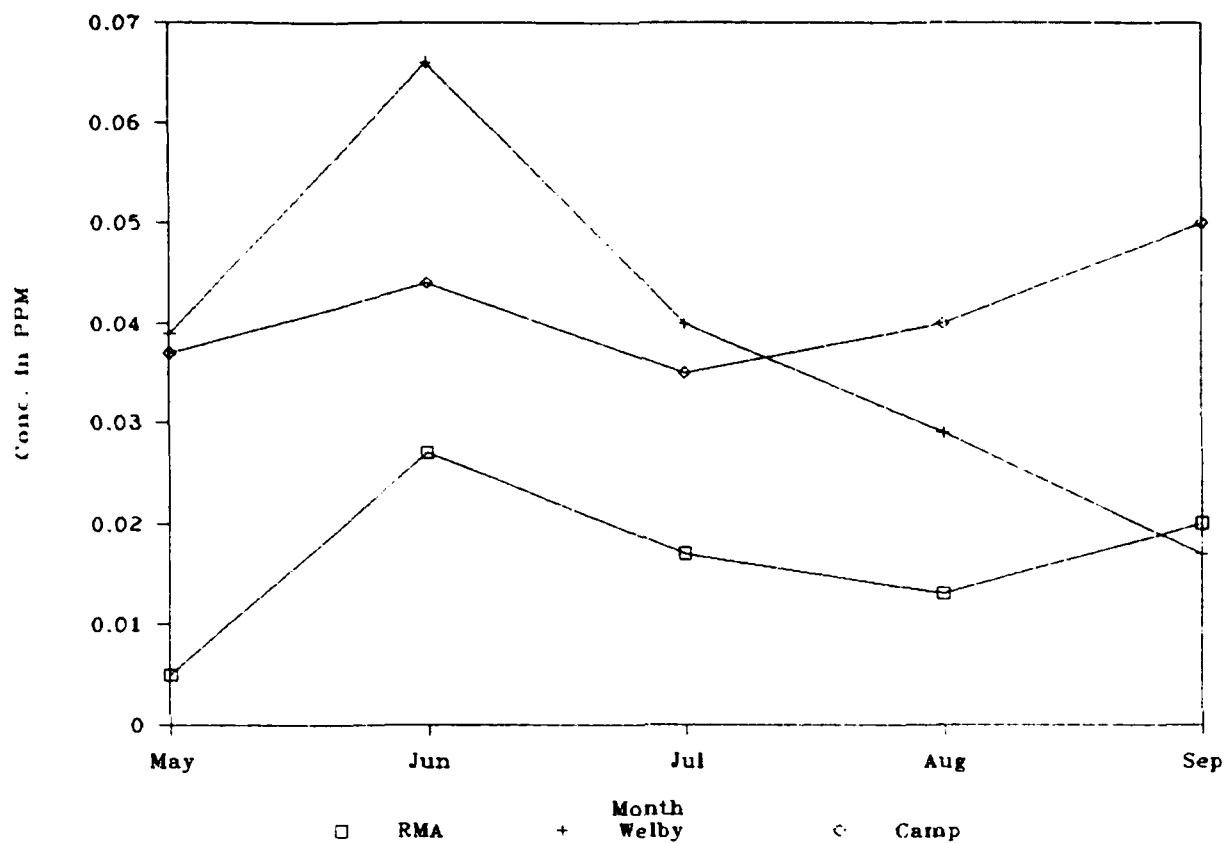
Table 5.5-3 Summary of Sulfur Dioxide 24-Hour Average Values in ppm³
May 6, 1989 (1200 MST) through September 30, 1989 (2400 MST)

	May	June	July	August	September
Mean	0.001	0.001	0.001	0.001	0.002
Maximum	0.002	0.003	0.004	0.003	0.003
2nd Highest Maximum	0.002	0.003	0.004	0.003	0.003
Minimum	0.001	0.001	0.001	0.001	0.001
Mean for Entire Period	0.001				

¹Federal and Colorado Ambient Air Quality Standard for annual arithmetic mean is 0.30 ppm.

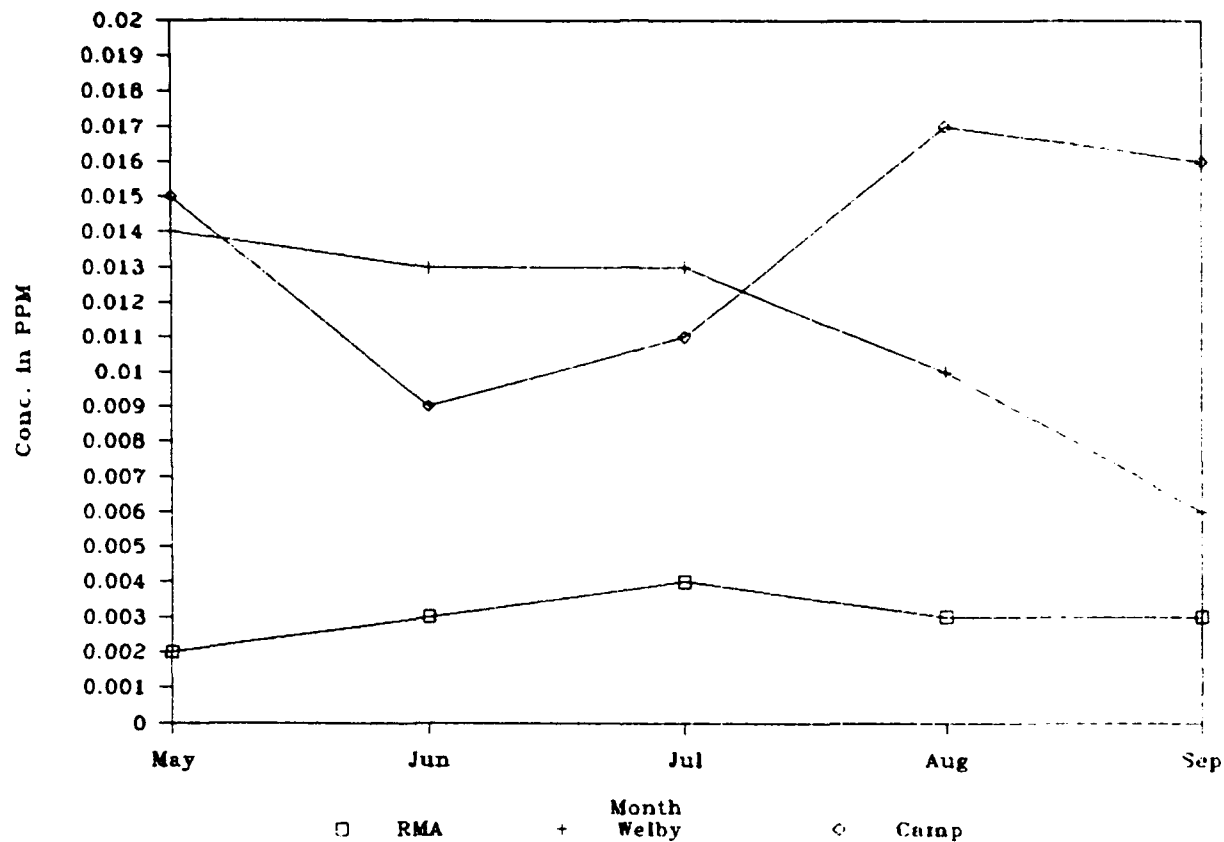
²Federal and Colorado Ambient Air Quality Standard for maximum 3-hour average values is 0.500 ppm, not to be exceeded more than once per year.

³Federal and Colorado Ambient Air Quality Standard for maximum 24-hour average values is 0.140 ppm, not to be exceeded more than once per year.



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Figure 5.5-2
CMP and Colorado
Department of Health Sites
3-Hour Sulfur Dioxide Values
(May 1989-Sept. 1989)
CMP AR FY89



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Figure 5.5-3
CMP and Colorado
Department of Health Sites
24-Hour Sulfur Dioxide
Values (May 1989-Sept.
1989)

CMP AR FY89

and 24-hour averages, respectively. Overall, the values reported from the RMA site were lower than those from the two CDH sites for both 3- and 24-hour averages.

The diurnal pattern of sulfur dioxide, as found in Figure 5.5-4, showed a slight increase during the hours of 0800 MST through 1000 MST for each day. This maximum may have reflected a build-up of emissions as a result of stable atmospheric conditions during the early morning hours. As the sun rises and atmospheric heating occurs, this inversion breaks up. Typically the diurnal wind flow between 0800 MST and 1000 MST was from metropolitan Denver and could have transported this SO₂ contaminated air toward RMA. No analysis was performed to evaluate this factor.

Appendix I presents a listing of the data used to generate the graphs for this section as well as monthly summaries of daily sulfur dioxide concentrations.

5.6 Nitric Oxide (NO), Nitrogen Dioxide (NO₂), and Nitrogen Oxides (NO_x)

Nitric oxide (NO), nitrogen dioxide (NO₂), and nitrogen oxides (NO_x) data exhibited comparable patterns throughout this 5-month sampling period. This resulted from the fact that: 1) NO and NO₂ have similar sources and removal mechanisms, and 2) the concentration of NO_x is the sum of NO and NO₂. The series of daily mean and 1-hour maximum values are shown in Figures 5.6-1 through 5.6-3. There was no long-term trend readily evident in the data, and the mean and maximum values showed only a slight relationship to one another for all three gases. The only National Ambient Air Quality Standard that exists for these gases is the annual arithmetic mean concentration for NO₂, which is 0.053 ppm. For the 5-month sampling period the mean value for NO₂ was 0.009 ppm, well below the standard. In fact, none of the mean daily values exceeded that annual average standard.

Tables 5.6-1 through 5.6-3 show hourly mean and maximum values for all three gases. Appendix I offers more detailed listings of the average daily values. It is interesting to note that the latter part of September displayed higher values than the remainder of the 5-month period. An extension of these data beyond September, as will be presented in the FY90 report, may provide a clearer picture of seasonal trends.

Figure 5.6-4 compares data between the RMA site and the Colorado Department of Health monitoring sites for the highest monthly 24-hour average of NO₂. The RMA site showed the lowest values, as it did with CO average values (refer to Figures 5.3-2 and 5.3-3), for all months

Table 5.6-1 Summary of Nitric Oxide (NO) 1-Hour Average Values in ppm
May 6, 1989 (1200 MST) through September 30, 1989 (2400 MST)

	May	June	July	August	September
Mean	0.006	0.006	0.006	0.007	0.007
Maximum	0.074	0.037	0.052	0.044	0.104
2nd Highest Maximum	0.051	0.037	0.033	0.042	0.081
Minimum	0.001	0.001	0.001	0.001	0.001
Mean for Entire Period	0.006				

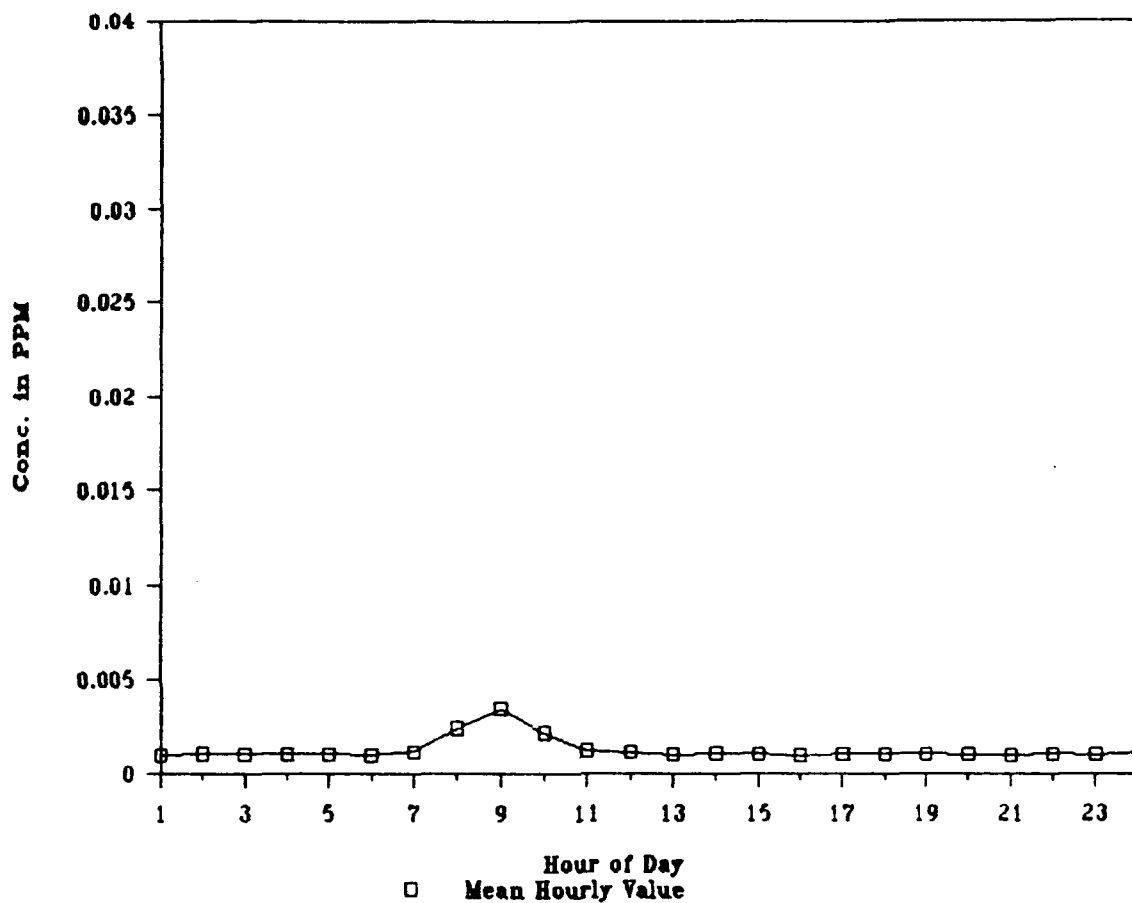
Table 5.6-2 Summary of Nitrogen Dioxide (NO₂) 1-Hour Average Values in ppm¹
May 6, 1989 (1200 MST) through September 30, 1989 (2400 MST)

	May	June	July	August	September
Mean	0.010	0.008	0.008	0.009	0.010
Maximum	0.064	0.039	0.041	0.041	0.074
2nd Highest Maximum	0.048	0.038	0.038	0.041	0.055
Minimum	0.001	0.001	0.001	0.001	0.001
Mean for Entire Period	0.009				

Table 5.6-3 Summary of Nitrogen Oxides (NO_x) 1-Hour Average Values in ppm
May 6, 1989 (1200 MST) through September 30, 1989 (2400 MST)

	May	June	July	August	September
Mean	0.016	0.015	0.015	0.017	0.018
Maximum	0.122	0.078	0.089	0.081	0.180
2nd Highest Maximum	0.118	0.067	0.067	0.075	0.129
Minimum	0.001	0.001	0.001	0.001	0.001
Mean for Entire Period	0.016				

¹Federal and Colorado Ambient Air Quality Standard for annual arithmetic mean is 0.053 ppm.



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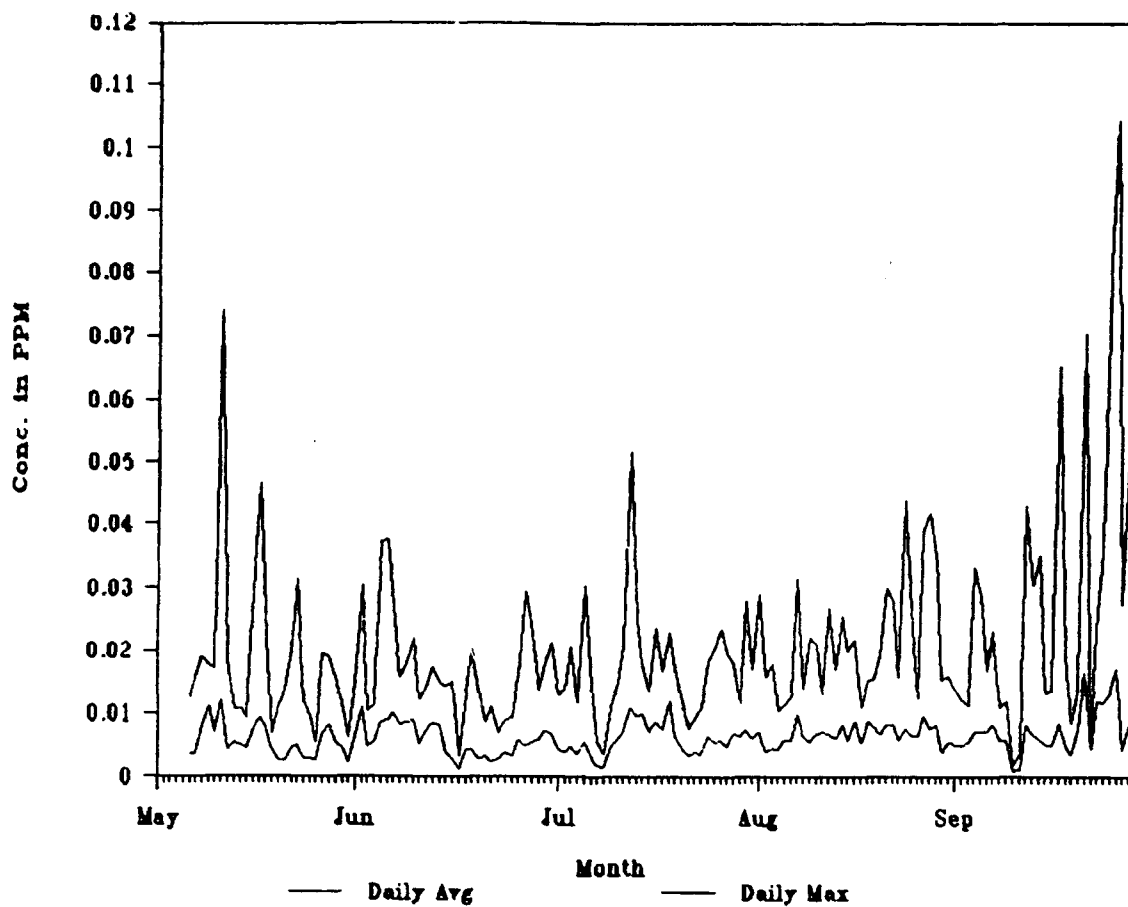
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Ebasco Services, Inc.

Figure 5.5-4

Graphical Depiction of
Sulfur Dioxide Diurnal
Pattern FY89 (May 6,
1989-Sept. 30, 1989)

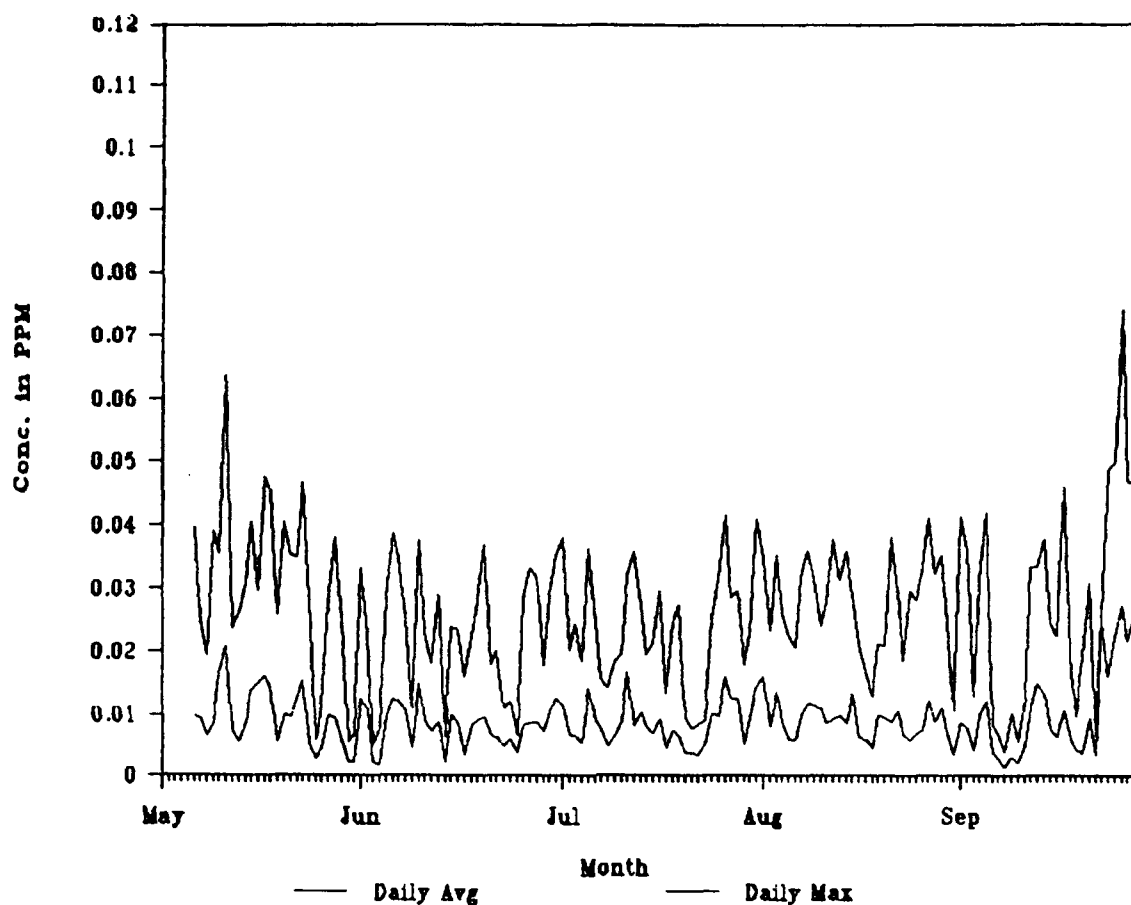
CMP AR FY89



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Figure 5.6-1
Graphical Depiction of
Nitric Oxide FY89 (May 6,
1989-Sept. 30, 1989)

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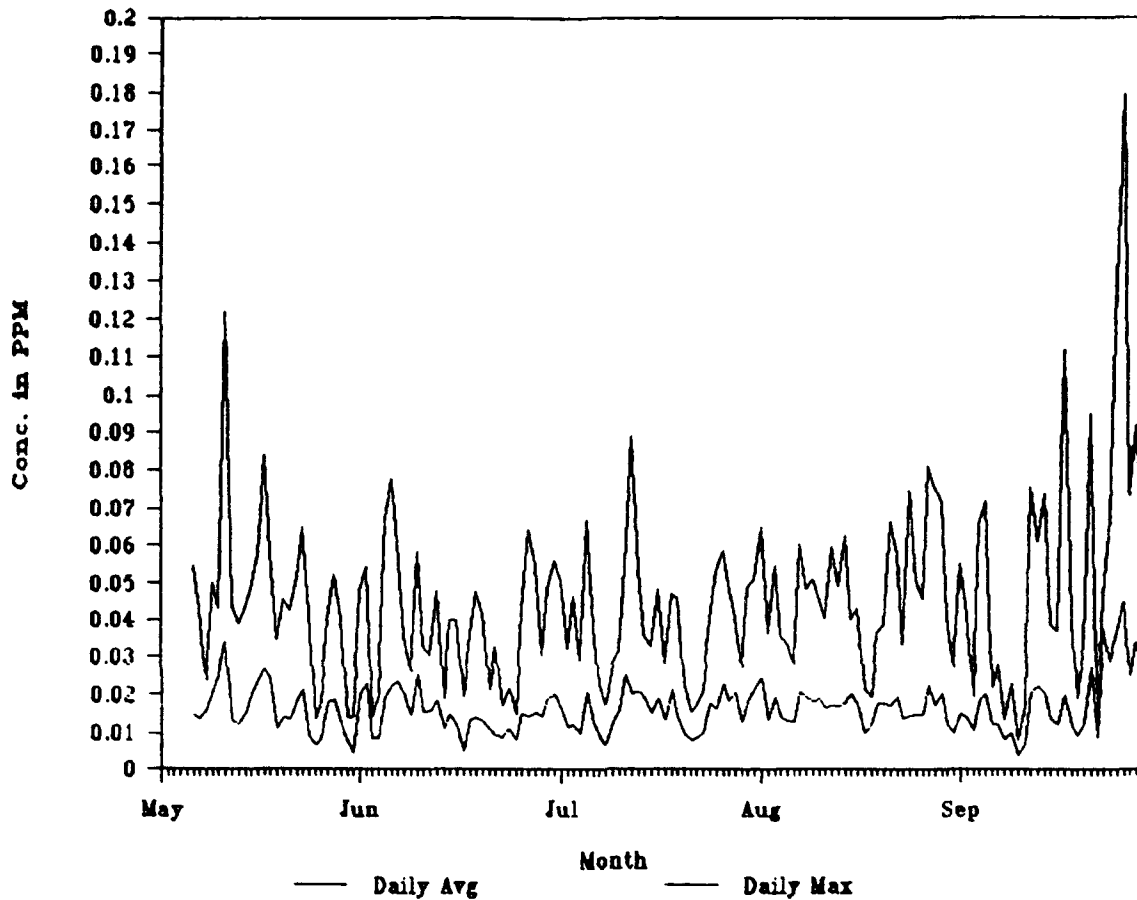
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Figure 5.6-2

Graphical Depiction of
Nitrogen Dioxide FY89
(May 6, 1989-Sept. 30,
1989)

CMP AR FY89



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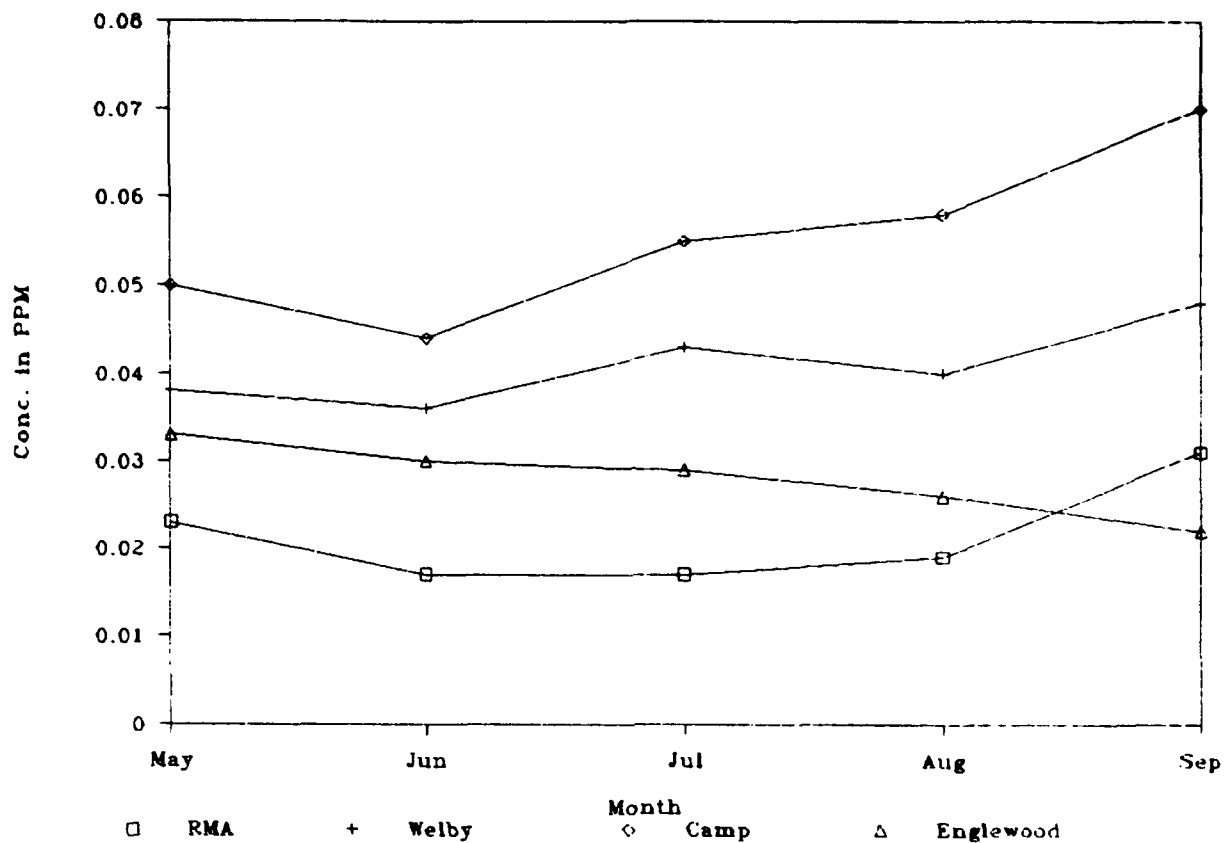
Prepared by :

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Figure 5.6-3

Graphical Depiction of
Nitrogen Oxides FY89
(May 6, 1989-Sept. 30,
1989)

CMP AR FY89



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Figure 5.6-4

CMP and Colorado
Department of Health Sites
24-Hour Nitrogen Dioxide
Values (May 1989-Sept.
1989)

CMP AR FY89

except September. RMA was located farther from the major traffic routes of the Denver metropolitan area than the other sites which may account for lower NO₂ concentrations.

Figures 5.6-5 through 5.6-7 show diurnal concentration patterns for NO, NO₂, and NO_x. An increase in values occurred from 0600 MST through 0900 MST resulting from the impact of early morning rush-hour traffic. There was a subsequent decrease in average values throughout the afternoon. One possible removal mechanism involves photochemical reaction with O₃. It is generally understood that as the ozone concentration levels increase, the concentration levels of NO, NO₂, and NO_x decrease in major urban areas. This was supported by the RMA database when a comparison was made between ozone (Figure 5.4-3) and nitrogen oxides (Figures 5.6-5 through 5.6-7). A second possible factor for this decrease in the afternoon may be the break-up of the morning inversion and the diurnal wind shift as discussed in section 5.3.

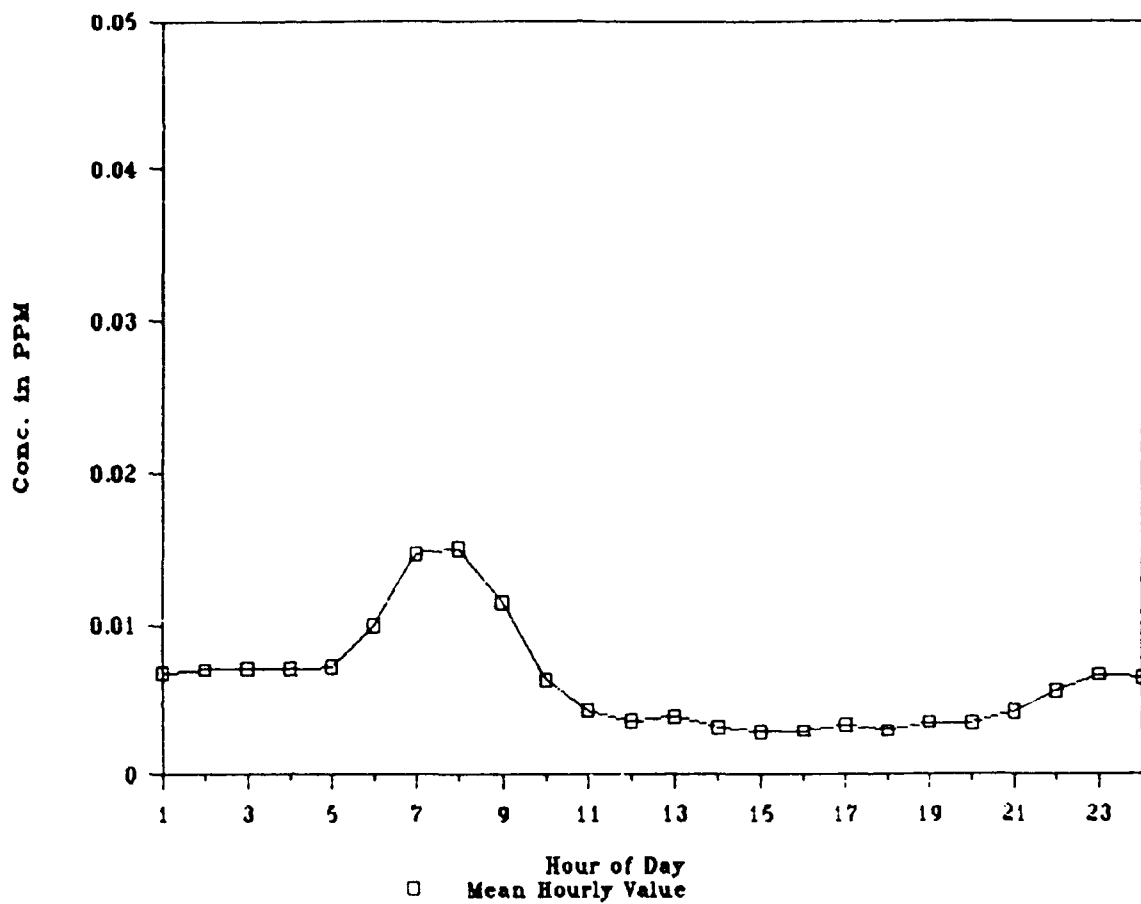
5.7 High Pollution Events

After reviewing the data for the Rocky Mountain Arsenal, two probable episodes of pollutant migration onto the Rocky Mountain Arsenal from the Denver area were identified. Both of these events occurred in the latter part of September 1989 during the early morning hours. An investigation of these two incidents is presented in this section.

5.7.1 Episode One - September 27, 1989

The concentrations of nitrogen oxides (NO_x), nitric oxide (NO), and nitrogen dioxide (NO₂), increased dramatically between 0800 MST and 0900 MST on September 27, 1989 as presented in Table 5.7-1. At 0900 MST the hourly concentrations of 0.180 ppm for NO_x, 0.074 ppm for NO₂, and 0.104 ppm for NO were the highest recorded values for the 5-month sampling period. These values reflect dramatic and sudden increases when compared to those recorded prior to the episode at 0700 MST. The following approximate increases were noted: 300 percent for NO_x, 500 percent for NO, and 200 percent for NO₂.

To further evaluate these increases, several meteorological parameters for this time period were reviewed. For several hours prior to this episode, the atmosphere was very stable (referred to in Table 5.7-1 as stability category F), indicating the presence of an early morning surface inversion. During this inversion, there was very little vertical dispersion of atmospheric pollutants. Emissions from nearby sources were likely to be trapped as plumes, in a relatively thin layer well above the ground, but within the stable, inversion layer. As the sun began to heat the ground and break up the inversion, a well-mixed layer may have developed at the surface and expanded throughout the



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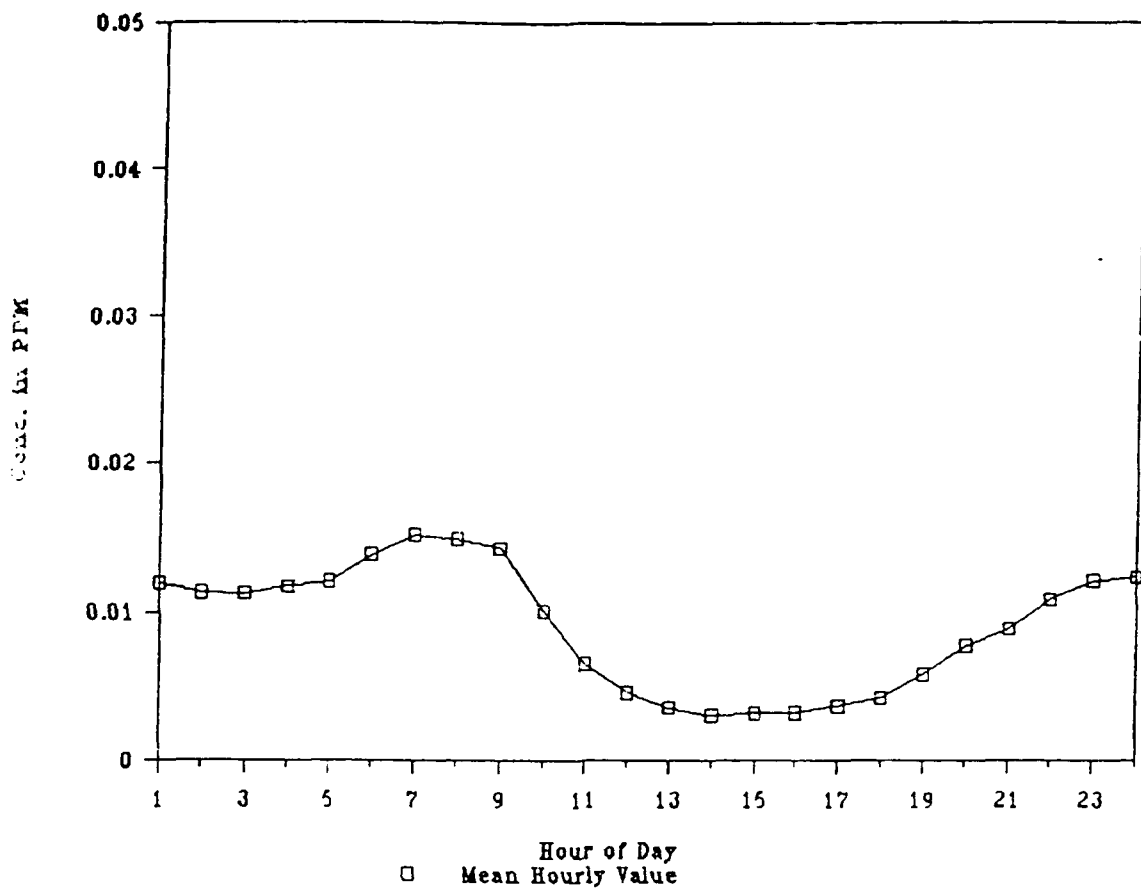
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Figure 5.6-5

Graphical Depiction of
Nitric Oxide Diurnal Pattern
FY89 (May 6, 1989-Sept.
30, 1989)

CMP AR FY89



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Commerce City, Colorado

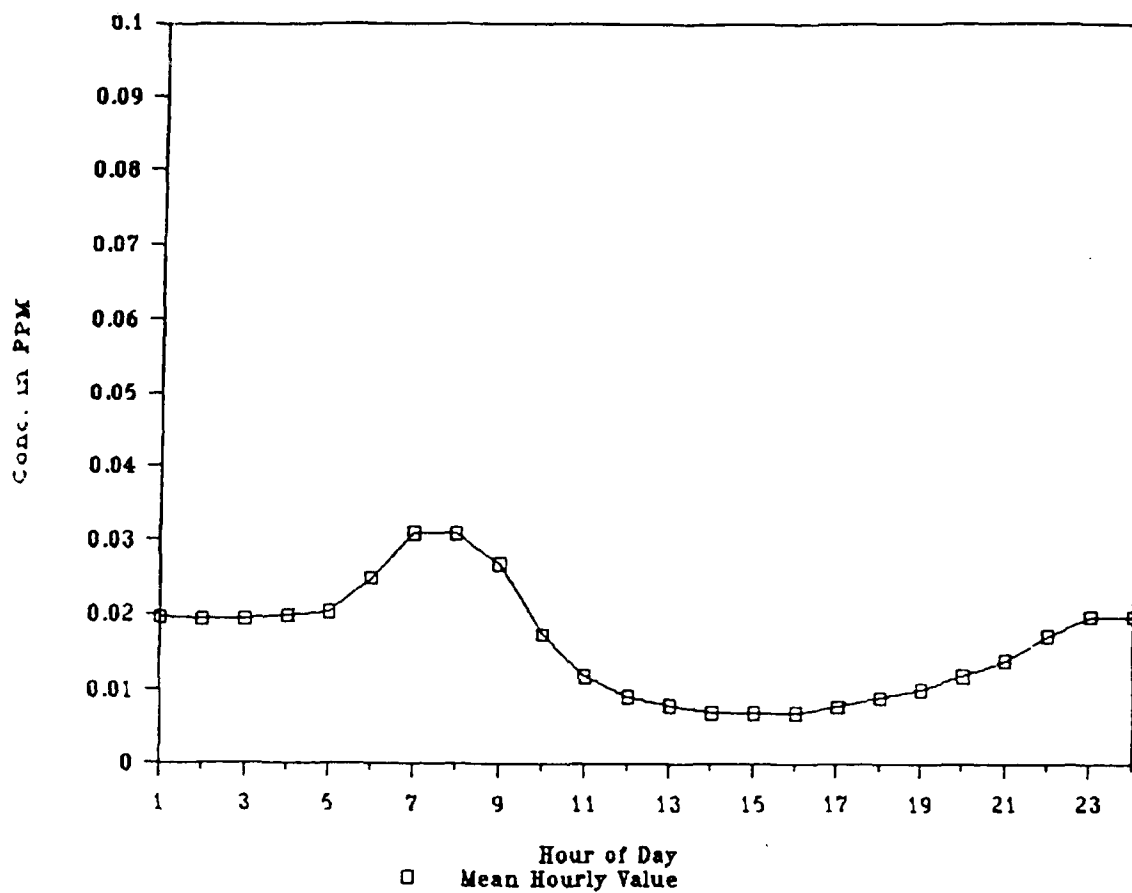
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Figure 5.6-6

Graphical Depiction of
Nitrogen Dioxide Diurnal
Pattern FY89 (May 6,
1989-Sept. 30, 1989)

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Prepared by :
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Ebasco Services, Inc.

Figure 5.6-7
Graphical Depiction of
Nitrogen Oxides Diurnal
Pattern FY89 (May 6,
1989-Sept. 30, 1989)
CMP AR FY89

e 5.7-1

Relevant Air Quality and Meteorological Data
For September 27, 1989

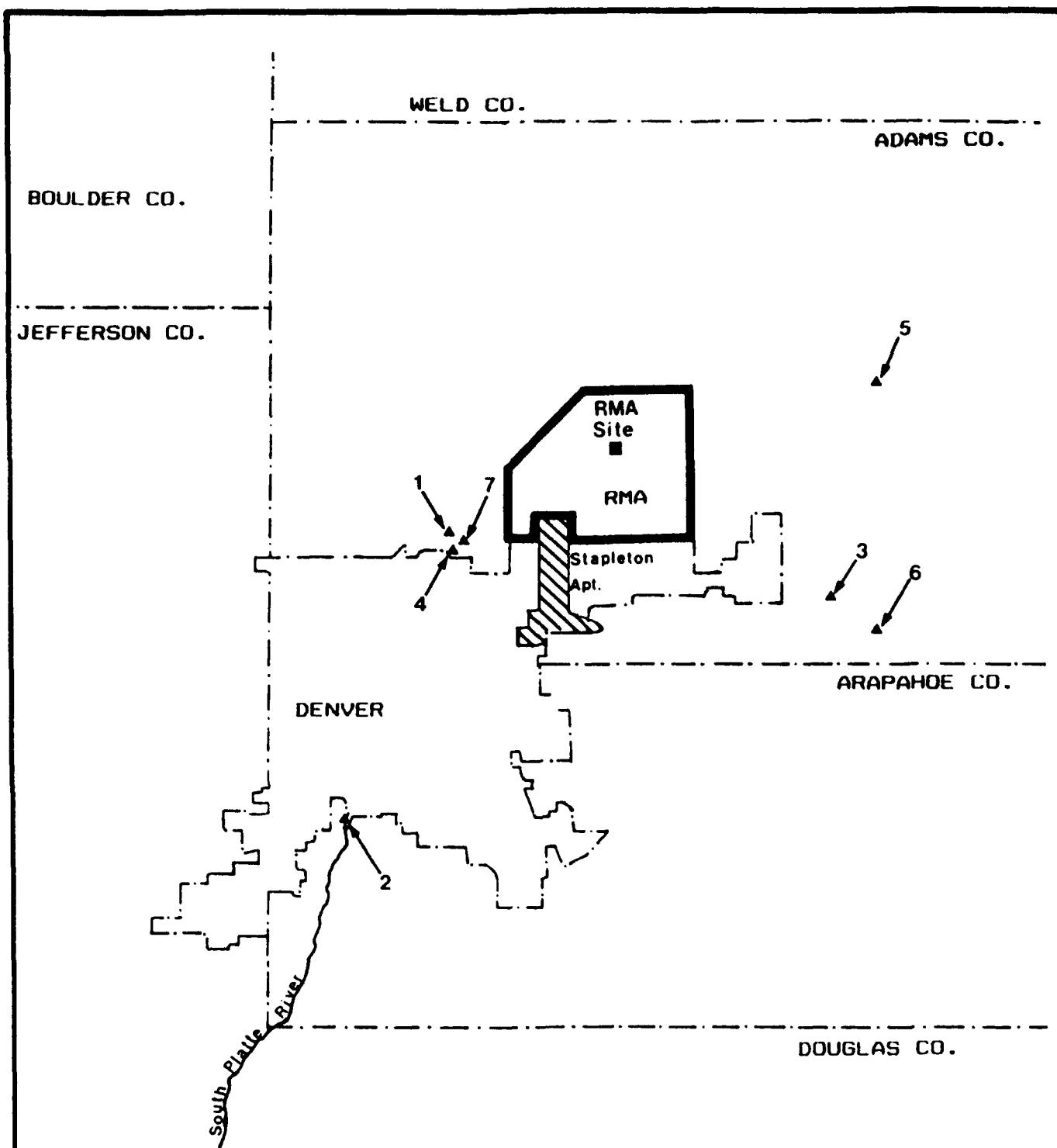
Time (MST)	CO ppm	SO ₂ ppm	NO ppm	NO ₂ ppm	NOx ppm	Wind Speed mph	Wind Dir. Degrees	Temp. °F	Stability Class.
500	0.5	0.001	0.006	0.025	0.032	1.9	258	55.6	F
600	0.6	0.002	0.011	0.032	0.044	3.2	206	56.5	F
700	0.7	0.001	0.021	0.031	0.053	4.1	241	56.6	F
800	1.7	0.007	0.079	0.049	0.129	4.1	215	59.5	B
900	2.5	0.022	0.104	0.074	0.180	3.7	212	66.9	A
1000	1.2	0.008	0.023	0.046	0.070	2.7	183	74.9	A

morning. Eventually this expansion reached the layer in which the plume was trapped. The pollutants were then rapidly mixed into the surface layer, and high ground level concentrations of the plume's constituents were recorded. (This is generally referred to as a fumigation condition.) As this mixed layer continued to expand, the pollution levels at the surface eventually decreased.

The meteorological conditions recorded during the morning of September 27 tend to support this type of atmospheric scenario. At 0700 MST, there was a stability category F which changed to a stability category B at 0800 MST, thus indicating unstable conditions. This subsequent change in the stability category can be attributed to the marked rise in temperature, as indicated by the 10°F increase from 0700 MST to 0900 MST. The surface wind direction steadied to a predominantly south-southwest direction (210 to 215 degrees), while the upper level winds were more westerly. At approximately 700 ft above the ground, the wind direction was southwesterly (240 degrees), as indicated by the 0500 MST National Weather Service weather sounding.

These high levels of NO_x, NO, and NO₂ found at RMA may be attributed to the trapped inversion emissions from several point sources located within the area. In the Tri-County area consisting of Adams, Arapahoe, and Denver counties, there are a number of NO_x point sources. Figure 5.7-1, along with Table 5.7-2, identify the primary point sources for NO_x in this area including the Cherokee Plant of the Public Service Company of Colorado, the Colorado Interstate Gas Refinery and the Conoco Refinery. All are located near one another in Commerce City, approximately 5 miles southwest (approximately 235 to 245 degrees) from the RMA continuous air quality monitoring site. Considering both the direction of the upper level winds and the height of the emission stacks for all three plants (which are several hundred feet high), this would place the RMA continuous monitoring site downwind of these plants. The atmospheric conditions that existed on this day suggest that these plants were the probable primary sources for the elevated NO_x, NO, and NO₂ readings detected during this episode.

These high concentrations for NO_x, NO, and NO₂ persisted for a period of approximately two hours and decreased back to nominal levels at 1000 MST. This occurred when the surface wind direction changed from a southwesterly (210 to 215 degrees) direction to a more southerly flow (180 degrees). The decrease probably corresponded to a similar southerly shift in the upper level wind direction which may have veered the plume away from the RMA continuous air quality monitoring site. Also, with the continued atmospheric mixing, the NO_x concentration of the air coming from any local point source would have sufficient time to disperse vertically and the concentrations would have been considerably lower.



▲ approx. location



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Figure 5.7-1

Primary Point Sources of
Nitrogen Oxides in
Denver, Adams and
Arapahoe Counties

CMP AR FY 89

Table 5.7-2 Major Point Sources of Nitrogen Oxides (NOx)
Denver, Adams, and Arapahoe Counties

Total Point Source Emission: 29,190 Tons/Year

Source Ranking	Source Name	Tons/Year	% of Total Emissions
1	Public Service Company of Colorado - Cherokee	19979	68.4
2	Public Service Company of Colorado - Arapahoe	4489	15.4
3	Co. Interstate Gas Company - Watkins Station	718	2.5
4	Conoco Plant	486	1.7
5	Koch Hydrocarbon Company	454	1.6
6	Amoco Production Company - Wattenberg Plant	407	1.4
7	Colorado Refining Corporation	368	1.3

Table 5.7-3 Major Point Sources of Sulfur Dioxide (SO₂) in
Denver, Adams, and Arapahoe Counties

Total Point Source Emission: 16,786 Tons/Year

Source Ranking	Source Name	Tons/Year	% of Total Emissions
1	Public Service Company of Colorado - Cherokee	11753	70.0
2	Conoco Plant	2166	12.9
3	Public Service Company of Colorado - Arapahoe	1511	9.0
4	Colorado Refining Corporation	973	5.4

In reviewing the data from Table 5.7-1, the levels of sulfur dioxide (SO₂) also increased in relative concentration but not as significantly in absolute concentration as those of NO_x. Major sources of SO₂ are listed in Table 5.7-3 and located in Figure 5.7-2. As with NO_x, the same three sites near the Rocky Mountain Arsenal are major point sources of SO₂.

Likewise, the levels of carbon dioxide (CO) increased sharply (over 350 percent) between the morning hours of 0700 MST and 0900 MST as shown in Table 5.7-1. Although there are some point sources near the RMA, their contribution to the total emission rate within the area was not nearly as high as those from vehicular emissions in metropolitan Denver. It appears that these high values were attributed to the heavy early morning rush-hour traffic in the region southwest of RMA (around downtown Denver).

5.7.2 Episode Two - September 29, 1989

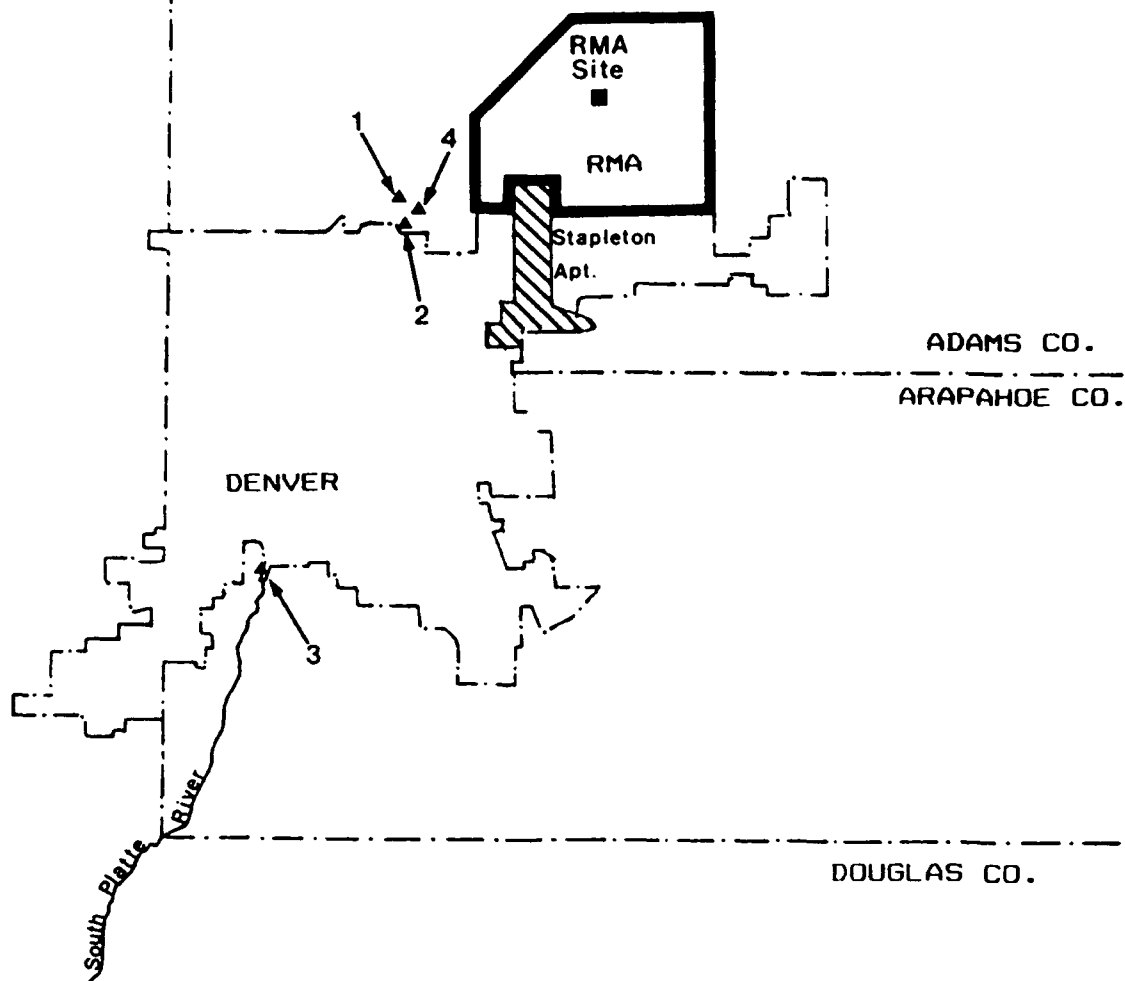
The second episode occurred on September 29, 1989 between the hours of 0800 MST and 0900 MST. Pertinent air quality and meteorological data are found in Table 5.7-4. The patterns of gaseous concentrations and meteorological parameters were found to be similar to those of Episode One. The concentrations of NO_x, NO, and NO₂ rose markedly from 0800 MST to 0900 MST but were not as high as those on September 27, 1989. Unstable atmospheric conditions quickly developed during the morning from a stability category E at 0700 MST to a stability category A at 0900 MST. The surface winds shifted from a southerly to a southwesterly component for the two hours during this episode. According to the National Weather Service weather sounding taken at 0500 MST at Stapleton Airport, the upper level winds were not as well defined as those on September 27, 1989, which may be why the concentrations were not as high. The CO concentrations showed a significant jump during these hours (approximately 150 percent).

5.7.3 Summary

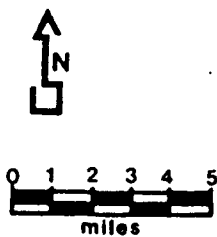
In general, these two events showed similar patterns. This pattern became more predominant during the late fall and throughout the winter seasons. The episodes showed that the peak values for NO_x and SO₂ observed at RMA were related to a narrow set of meteorological conditions in the area. Other peak episodes of NO_x and SO₂ concentrations at RMA were likely to be dependent on certain meteorological factors and source characteristics from nearby facilities. Increases in CO concentrations were not related primarily to point sources, but were driven more by regional contributions of vehicular emissions. These events were necessarily taken from summer or early fall conditions. A full annual cycle of data will be available for the FY90 report and may shed more light on the nature of extreme conditions.

BOULDER CO.
JEFFERSON CO.

WELD CO.



▲ approx. location



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U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
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Figure 5.7-2

Primary Point Sources of
Sulfur Dioxide in Denver,
Adams and Arapahoe
Counties

CMP AR FY89

Relevant Air Quality and Meteorological Data
For September 29, 1989

Time (MST)	CO ppm	SO ₂ ppm	NO ppm	NO ₂ ppm	NOx ppm	Wind Speed mph	Wind Dir. Degrees	Temp. °F	Stability Class.
500	0.8	0.001	0.009	0.029	0.040	5.5	179	52.9	F
600	0.9	0.001	0.022	0.030	0.053	5.6	164	51.7	D
700	1.1	0.001	0.029	0.028	0.058	5.8	176	51.2	E
800	1.6	0.008	0.051	0.040	0.092	4.7	238	57.0	C
900	1.3	0.014	0.036	0.046	0.084	2.5	226	63.0	A
1000	1.0	0.001	0.007	0.027	0.035	3.4	180	67.5	A
1100	0.8	0.003	0.006	0.031	0.038	4.0	299	70.6	A
1200	0.7	0.003	0.003	0.025	0.029	3.4	309	74.1	A

6.0 METEOROLOGY MONITORING AND DISPERSION MODELING PROGRAMS

6.1 Meteorology Program Overview

The meteorological program and station locations are described in Section 3.5. A modification to the program placed meteorological monitoring, maintenance and data processing and analysis under CMP responsibilities in FY89. Complete listings of all data collected and used in this report are provided in Appendix J. Pertinent summaries of wind speed, wind direction, temperature, relative humidity, barometric pressure, solar radiation, precipitation and stability are shown in the following sections.

6.1.1 Program Objectives

The meteorological assessment has several objectives. The first is to identify atmospheric conditions associated with typical and potentially high contamination levels resulting from existing sources and remedial activity at RMA. Prevailing wind flow, wind speed, peak wind gusts, temperature and precipitation all influence the release and spread of atmospheric emissions. A meteorological database has, therefore, been established to identify typical relationships as well as to examine seasonal and diurnal effects. For example, gusty winds will cause higher levels of total suspended particulates, inhalable particulates of less than 10 microns, metals and possibly semi-volatile organic compounds. This information is pertinent to interpreting air sampling results. Certain pollutant emissions may be more prevalent in summer than in winter which may be an important factor for remediation planning. Also, diurnal influences (such as the formation of a drainage wind pattern during nighttime and early morning inversion periods) will result in significantly higher levels of certain pollutants. This information, again, is useful in assessing the potential spread of contaminants and possible mitigating measures during remedial activities.

Another objective of the meteorological assessment is to determine the representativeness of the meteorological data with respect to associated air quality conditions. Meteorological factors change not only from season to season, but also from year to year. Variations in these elements, as noted, will influence air sampling results. A particular sampling program, a period with anomalous precipitation or drought conditions, extensive snow cover, strong winds, very warm temperatures, or even generally poor dispersion conditions will have a direct influence on pollutant levels at specific monitoring site locations. Again, this information is essential for interpreting the results. Consequently, this meteorological data will be useful in assessing remediation progress over the total period of the CMP.

In addition to the above factors, the meteorological program directly supports air quality model applications that are used in pollution dispersion evaluations and predictions. These, in turn, are employed for assessing impacts beyond the RMA boundary, or in predicting realtime pollution levels during remedial activities.

6.1.2 Data Recovery

Details of the recovery of FY89 meteorological data for each parameter of the composite database are give in Table 6.1-1. Recoveries are based on the total number of hours of possible data during the period October 1, 1988 through September 30, 1989 (8760 hours). Observations (hourly values) were considered not valid or missing if there was less than 45 minutes of valid recorded data for that parameter or if there were equipment malfunctions or calibrations.

Table 6.1-1 Summary of RMA Meteorological Monitoring for FY89

Parameter	No. Samples	% Recovery
Wind Speed	8,742	99.8
Wind Direction	8,742	99.8
Sigma Theta	8,742	99.8
Temperature	8,742	99.8
Relative Humidity	8,711	99.4
Barometric Pressure	7,866	89.8
Solar Radiation	7,816	89.2
Precipitation	8,760	100.0
Maximum Gust	8,542	97.5
Stability	8,741	99.8
Program Total:	85,404	97.5

6.1.3 Databases

A single, representative composite database was developed from data collected at all five RMA sites. From October 1, 1988 through January 31, 1989, the Basin F data were the primary source for the composite database. From February 1, 1989 through early May 1989, Meteorological Station I (M1) was the primary source for the composite database. By early May 1989, the new monitoring location, M4, had been installed, calibrated, and made operational. From early May 1989 through September 30, 1989, the M4 data were the primary source for the composite database. This site will continue to be the primary site into FY90. Data from other sites were also used to

fill in or substitute for the invalid or missing data. The amount of substituted data is generally very small (3 percent or less). Certain parameters always come from different sites for the composite database since no site has all the parameters. Relative humidity was from M1, solar radiation was from M2 and maximum gust was from M3. These will follow into FY90 with the exception of maximum gust which will be from M1. Wintertime precipitation (October 1, 1988 through April 15, 1989) was taken from Stapleton International Airport since snowfall is somewhat difficult to monitor accurately. Complete listings of the composite database used for this report are provided in Appendix J. The composite database provides a suitably representative sample of meteorological conditions at RMA for FY89.

All summaries shown in this report were prepared under the CMP and taken from the FY89 composite database. All data have been thoroughly checked for quality, including the substituted data. Long-term climatological Denver Stapleton Airport means (Section 2.2) were used for comparison. The FY88 data, which were also used for comparison, are provided in Section 5.0 of the FY88 Air Quality Data Assessment Report (Stollar, 1989). Pertinent summaries of all of the above parameters follow.

6.2 Summary of Results

A summary of monthly and annual (October 1, 1988 through September 30, 1989) meteorological data for FY89 RMA is provided in Table 6.2-1. All parameters summarized in this table are based on hourly averaged values with the exception of maximum gust, which is the maximum instantaneous wind speed for the period. The analysis method is indicated on the table for each column of data. Maximum speed is the maximum one-hour average wind speed value for the month. The predominant wind direction indicates the sector (of 16 possible sectors) from which the wind is blowing most frequently during the reported period.

The monthly means and extremes of temperature values clearly depict the typical annual cycle; however, there were some anomalous conditions (warm January, cold February, warm July). The precipitation data also reveal an annual cycle, but it is somewhat masked by individual events. Wind speed data show the strongest winds during the spring months, but the maximum gusts were clearly dominated by single events. Except for one month (February), the predominant wind direction was from the south or south-southwest, consistent with the expected prevailing wind pattern. Stability patterns show a maximum of stable conditions in the fall and winter and a maximum of unstable conditions in the spring and summer. A neutral stability condition prevailed during all months with almost half the total frequency of occurrence.

Table 6.2-1 Summary of Rocky Mountain Arsenal Monthly Meteorological Conditions for FY89 (October 1, 1988 through September 30, 1989)

		Temperature (F)					Mean	Mean	Ttl Daily	Precipitation (")		
		-----					Relative	Station	Solar	-----		
		Avg	Avg	Extr	Extr		Humidity	Pressure	Radiation		Max	# of
Month		Max	Min	Max	Min	Mean	(%)	("Hg)	(Ly/Hr)	Total	24-Hr	Days

1	Oct	67.5	40.5	78.3	25.5	53.3	41	24.81	0.16	0.03	0.02	2
2	Nov	52.1	29.0	73.6	15.3	40.3	40	24.59	0.11	0.56	0.27	3
3	Dec	42.9	18.6	69.0	-0.6	29.6	51	24.72	0.10	1.05	0.35	6
4	Jan	46.3	22.4	63.0	4.1	33.9	44	24.67	0.12	1.14	0.63	5
5	Feb	27.8	12.6	64.2	-21.6	20.0	73	24.77	0.18	0.64	0.18	12
6	Mar	54.1	29.4	76.3	-2.7	41.8	53	24.65	0.25	0.50	0.27	5
7	Apr	60.7	38.8	83.7	12.0	50.0	48	24.74	0.32	0.43	0.34	3
8	May	69.5	46.0	92.1	27.2	57.9	54	24.68	0.36	3.74	1.26	13
9	Jun	74.4	53.2	94.2	44.1	63.5	53	24.71	0.33	1.58	0.98	8
10	Jul	87.6	61.6	99.6	54.9	74.9	37	24.79	0.40	0.51	0.43	5
11	Aug	82.2	59.0	90.1	53.8	70.2	47	24.72	0.27	0.69	0.35	8
12	Sep	72.9	50.1	90.3	32.0	61.3	50	24.74	0.32	1.54	0.39	7
13	Yr	61.7	38.6	99.6	-21.6	49.9	49	24.71	0.24	12.41	1.26	77

		Wind Speed (MPH)			Predominant Wind Direction	Atmospheric Stability Category (% occurrence)					
Month		Mean Speed	Maximum Speed	Maximum Gust							
						A	B	C	D	E	F
1	Oct	7.0	24.4	37.0	SOUTH	18.7	6.1	5.1	37.8	13.8	18.6
2	Nov	8.6	27.5	41.1	SOUTH	13.9	3.2	7.1	47.9	12.6	15.3
3	Dec	7.4	27.7	42.7	SOUTH	12.1	4.3	5.8	45.2	16.1	16.5
4	Jan	9.3	30.5	46.0	SOUTH	8.6	3.0	5.9	57.7	13.4	11.4
5	Feb	7.1	22.9	39.8	ENE	5.7	4.5	4.9	51.3	22.1	11.6
6	Mar	9.2	32.6	49.5	SOUTH	11.8	4.6	5.7	47.2	21.8	9.0
7	Apr	9.9	31.3	45.1	SSW	12.5	5.0	6.9	52.4	17.4	5.8
8	May	9.1	33.2	50.9	SSW	20.7	6.6	7.7	45.8	11.6	7.7
9	Jun	8.4	30.4	42.6	SSW	21.3	6.3	7.5	41.5	16.9	6.5
10	Jul	8.8	27.5	54.0	SSW	28.1	6.3	5.9	40.9	12.0	6.9
11	Aug	8.1	26.0	72.5	SSW	26.1	7.5	4.7	39.5	12.8	9.4
12	Sep	8.5	24.9	41.6	SSW	18.0	4.8	5.0	45.9	17.5	8.8
13	Yr	8.5	33.2	72.5	SOUTH	16.5	5.2	6.0	46.0	15.6	10.6

Legend: Maximum Speed = Maximum 1-Hr Average Wind Speed Value for the Month
Maximum Gust = Maximum Instantaneous Wind Speed for the Month

A = Extremely Unstable
B = Unstable
C = Slightly Unstable

D = Neutral
E = Stable
F = Extremely Stable

The parameters are discussed in more detail below. Included are discussions of FY89 conditions in comparison to FY88 data (where applicable) and to the long-term climatology at Stapleton. Also, specific conditions, extreme events, and anomalous conditions are described for each parameter.

6.2.1 Temperature

The RMA FY89 annual mean temperature, 49.9°F, was very close to normal. The year itself was near or slightly warmer than normal with the exception of February which was 13.6°F below normal. The maximum monthly average was 74.9°F in July and the minimum monthly average was 20.0°F in February. The maximum temperature, 99.6°F, was recorded in July during a short heat wave, and the minimum temperature, - 21.6°F, was recorded in February during an intense cold wave. The time series of daily maximum and minimum temperature through the FY89 program is shown in Figure 6.2-1, indicating the extreme events and the day-to-day variability in temperature.

6.2.2 Relative Humidity

The annual mean relative humidity, 49 percent, was near normal. All months followed quite closely to normals with higher values in the winter and spring due to lower temperatures and increased amounts of precipitation, and lower values in the summer and fall due to higher temperatures. The maximum monthly average was 73 percent in February and the minimum monthly average was 37 percent in July.

6.2.3 Barometric Pressure

The annual mean station barometric pressure, 24.71 in of mercury (Hg), was almost identical to long-term normals. All months followed the normals quite closely. The maximum monthly average was 24.81 in Hg in October and the minimum monthly average was 24.59 in Hg in November.

6.2.4 Solar Radiation

The solar radiation values included nighttime values to show the increase in solar radiation in the spring and summer due to the length of the days. The annual mean solar radiation was 0.24 langleys per hour (ly/hr). Values were slightly higher in the summer with lower values in the winter. The maximum monthly average was 0.40 ly/hr in July and the minimum monthly average

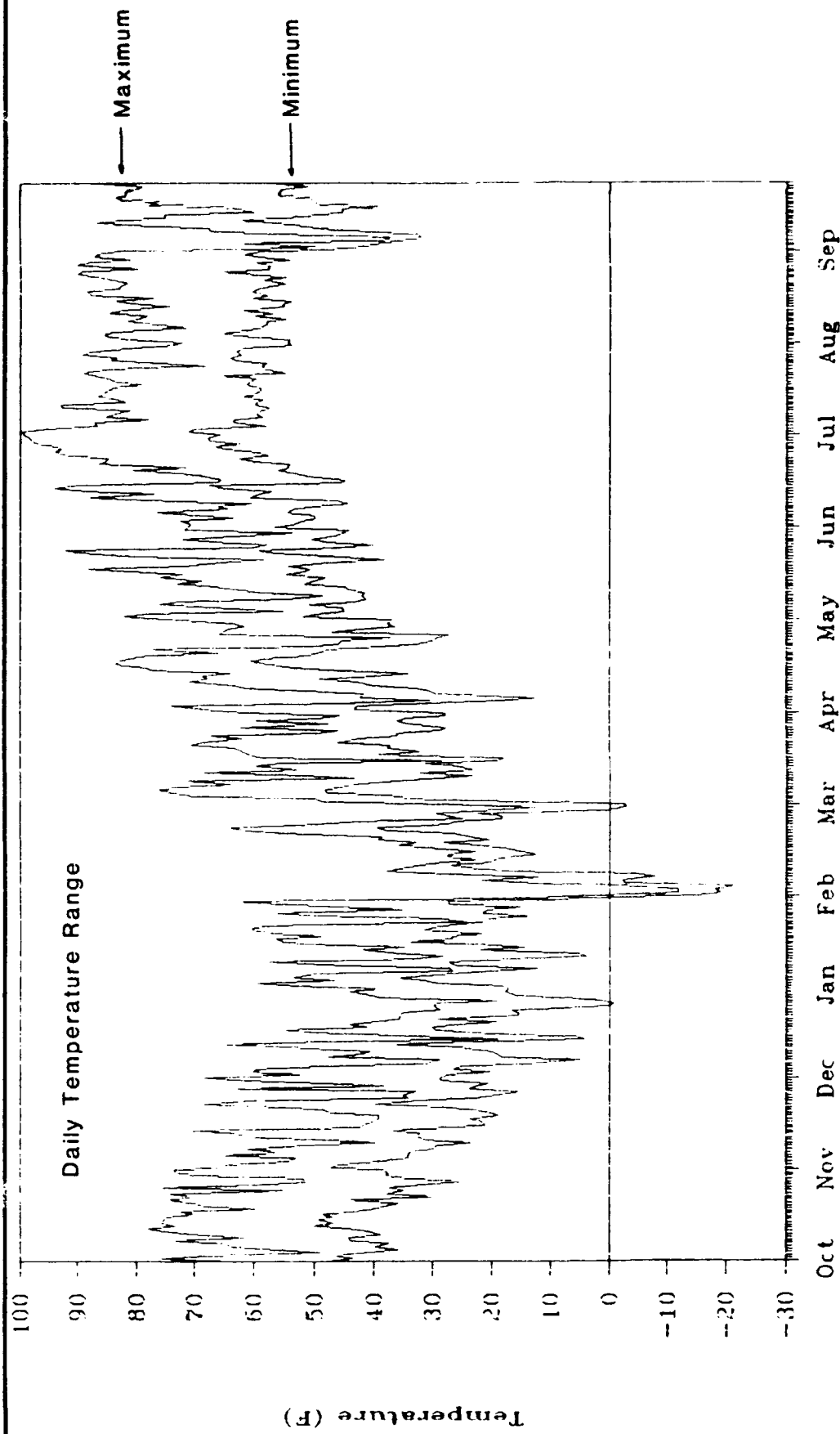


Figure 6.2-1

RMA Graphical Depiction
of Temperature (Oct. 1,
1988-Sept. 30, 1989)

CMPAR FY89

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Rocky Mountain Arsenal
Commerce City, Colorado

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was 0.10 ly/hr in December. The RMA area generally has an abundance of sunshine throughout the year as was evident in FY89.

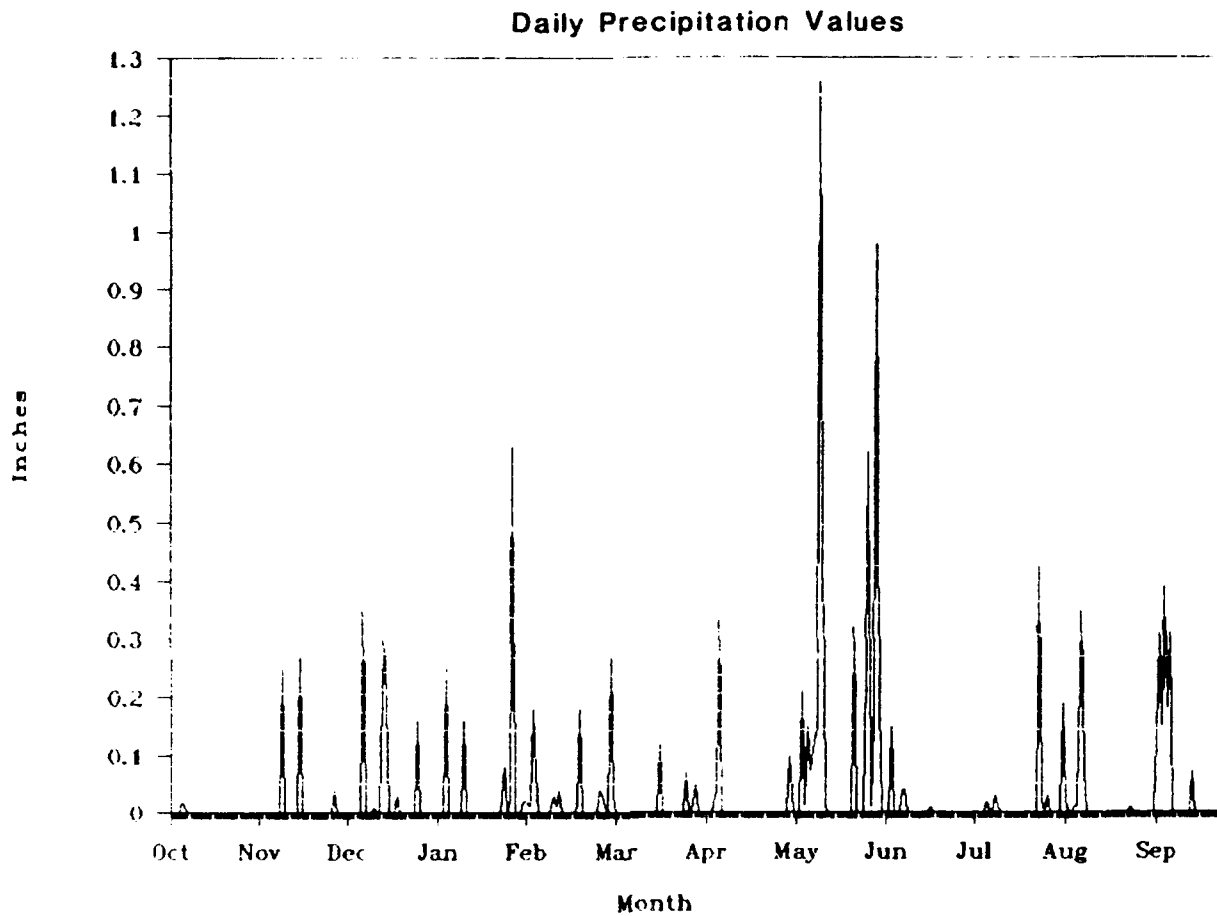
6.2.5 Precipitation

Precipitation for the FY89 period from October 1, 1988 through September 30, 1989 totaled 12.41 in at RMA, compared with the climatological mean of 15.31 in for this same period, or 2.90 in below normal. Stapleton data for FY89 was much closer to normal. The spatial variability associated with summertime thunderstorm activity may account for this difference. During the colder seasons, precipitation was primarily in the form of snow with a total of 52.4 in falling in 33 days. The heaviest monthly precipitation total, 3.74 in, was measured during May. The month of May generally records the heaviest precipitation, with a long-term mean of 2.47 in and an all-time maximum of 7.31 inches. Spring and summertime heavy precipitation events frequently occur in the Denver area; when these storms are intense and stagnate over a site, the majority of the monthly precipitation may be recorded in one or two days.

The rest of the FY89 monitoring period was normal to drier than normal with only December and January being somewhat above normal. The driest month was October with only 0.03 inches. A time series of daily total precipitation during the FY89 program is shown in Figure 6.2-2. Heavier precipitation events in May and June are highlighted. Also, it can be seen that total monthly precipitation was often a reflection of one or a small number of heavy rainfall events.

6.2.6 Winds

Hourly mean wind speeds for the entire CMP FY89 program averaged 8.5 mph compared to a 30-year climatological mean value (at Stapleton Airport) of 8.8 mph. This close comparison is important because pollutant levels, especially those associated with dust particles (i.e., TSP, PM-10, metals and SVOCs) are generated by high wind speeds. The data suggest that FY89 was close to average for all months with respect to potential wind-generated transport of dust particles. The maximum monthly average was 9.9 mph in April and the minimum monthly average was 7.0 mph in October. The maximum gust, 72.5 mph, was recorded in August and was associated with a downburst or a microburst from a thunderstorm. Spring of FY88 had somewhat higher wind speeds than the spring of FY89; the wind speeds for the summer months were similar for both years. Also, the predominant wind direction for the RMA in FY89 was south, identical to the Stapleton Airport 30-year record. Slight differences occurred from month to month. The normal prevailing direction was south for all months; but in FY89, the RMA had a predominant east-northeast wind in February, south-southwest winds for spring and summer and south winds in the



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Figure 6.2-2
RMA Graphical Depiction of
Precipitation (Oct. 1, 1988-
Sept. 30, 1989)

CMP AR FY89

fall and winter months. FY88 compared quite closely to FY89's predominant directions. The time series of daily mean wind speeds, maximum gusts, and predominant wind directions during the program are shown in Figure 6.2-3. Maximum gust data is missing from April 25 through May 2, 1989; therefore, this area on the graph has been interpolated.

There is a slight disparity between the 5-year seasonal and annual wind roses for Stapleton and the corresponding wind roses for the CMP monitoring periods shown in Figures 6.2-4 through 6.2-8. The CMP wind roses show tendencies for a more south-southwest to north-northeast flow, even though the south to north is the most common flow pattern at Stapleton. An easterly component is also evident in the RMA wind roses, especially during spring. The secondary northerly component's weakness seen in FY88 data was not evident in FY89. The northerly flow was stronger in FY89 and more nearly normal. The FY89 wind patterns were more evenly distributed in all directions than the FY88 ones. Otherwise, there was excellent correspondence of all wind roses.

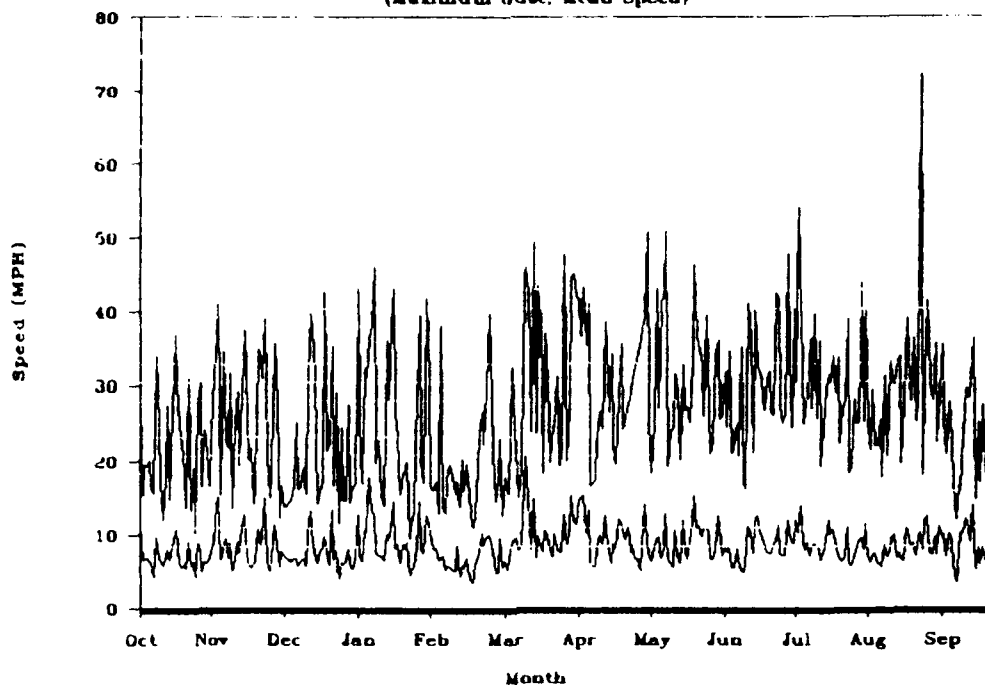
6.2.7 Atmospheric Stability

Atmospheric stability is an important parameter relating to the dispersion of air pollutants. Along with wind speed and wind direction, it is a key parameter in air quality dispersion models and reflects the potential of the atmosphere to diffuse pollutants horizontally and vertically. Table 6.2-1 shows the frequency distribution for all atmospheric stability categories A through F during the CMP monitoring period. A full joint frequency distribution (JFD) of wind speed, wind direction and stability is provided in Appendix J. Categories A, B and C, which indicate good dispersion or "unstable" conditions and occur primarily during midday and afternoon periods and more often in the warmer seasons, were measured 16.5, 5.2 and 6.0 percent of the time respectively, or a total of 27.7 percent of the time. Categories E and F, which reflect poor dispersion or "stable" conditions and occur during morning hours and more often in the colder seasons, were measured 15.6 and 10.6 percent of the time, or a total of 26.2 percent. The remainder of the cases, 46.0 percent, were in category D, which reflects neutral atmospheric or moderate to strong wind conditions (a frequent occurrence at RMA). Generally dispersion correlations are good under D stability, although as noted in this report, strong winds also have the potential of increasing the emissions of dust-associated particles.

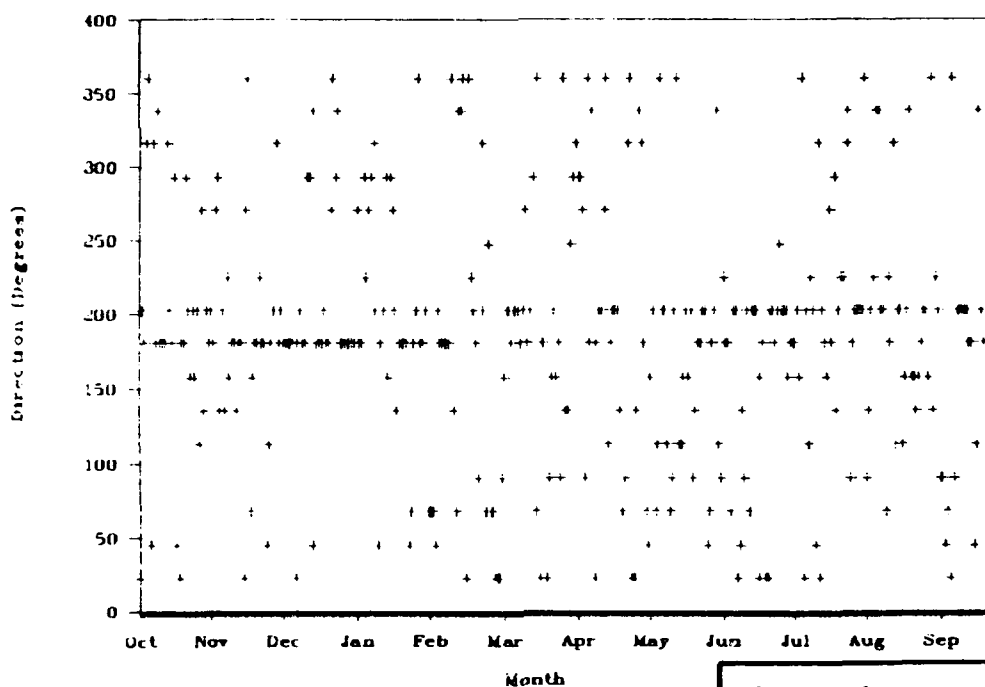
The stability data for FY89 appear to be typical of the Denver area. The inversion conditions associated with poor dispersion categories E and F were less frequent during the spring and summer and occurred primarily in the nighttime and early morning periods. During the winter there were many inversion periods that lasted continuously for several days and intensified the "brown cloud"

Daily Wind Speed Values FY89

(Maximum Gust, Mean Speed)



Daily Predominant Wind Direction FY89



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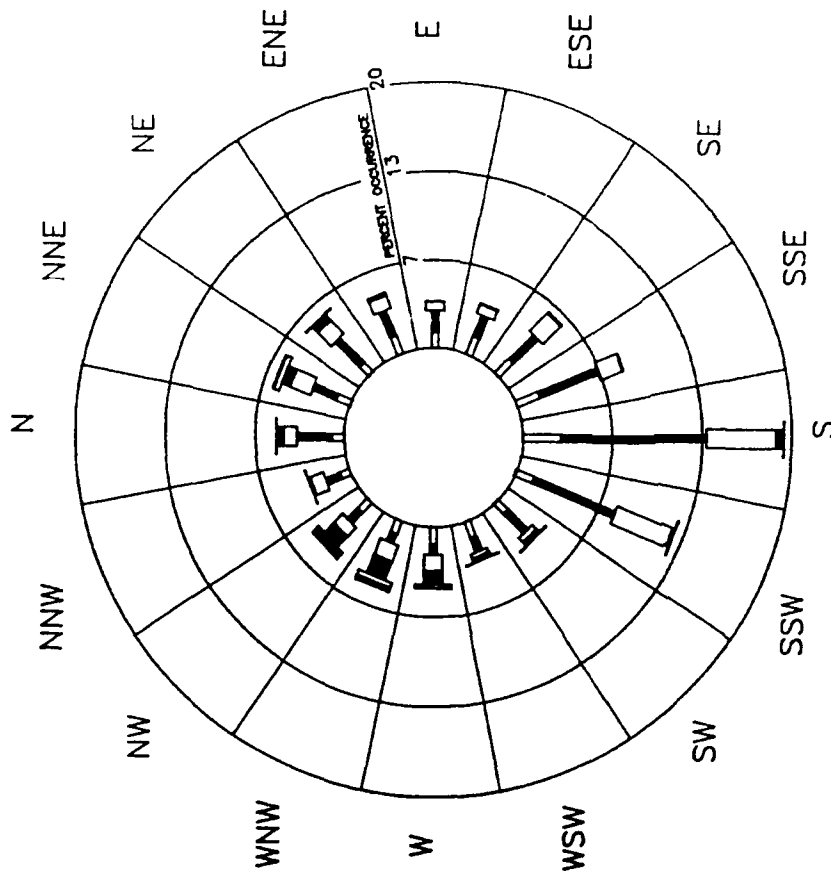
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Figure 6.2-3

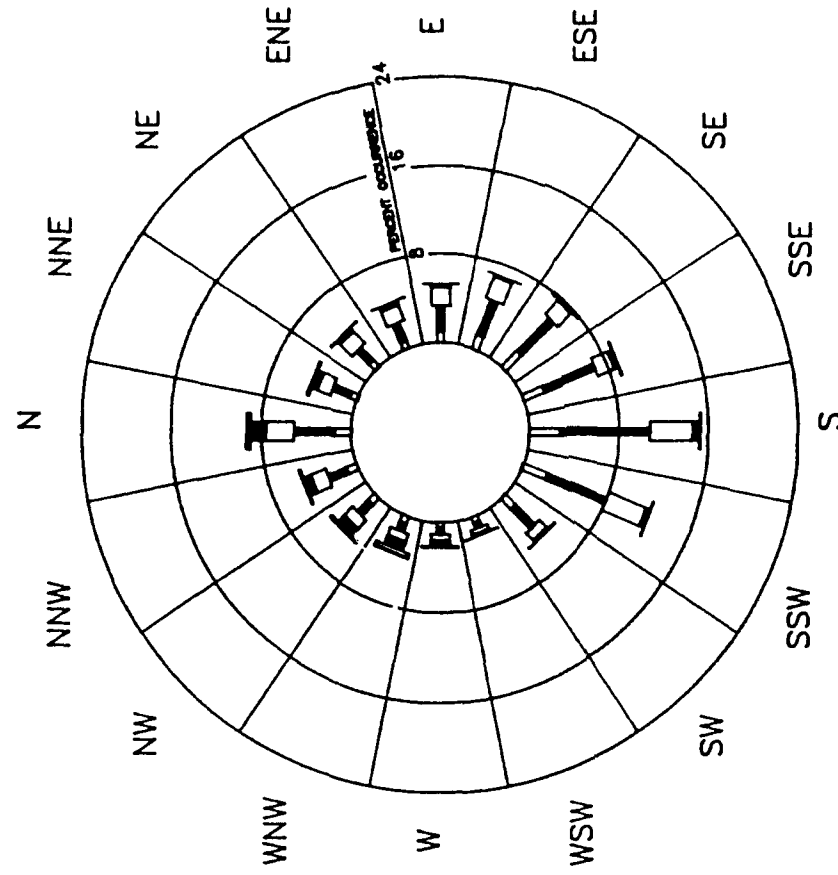
RMA Graphical Depiction of
Wind Speed and Wind
Direction (Oct. 1, 1988-
Sept. 30, 1989)

CMP AR FY89

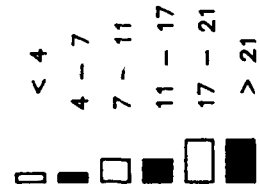
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Stapleton Airport



WIND SPEED CLASSES(KNOTS)



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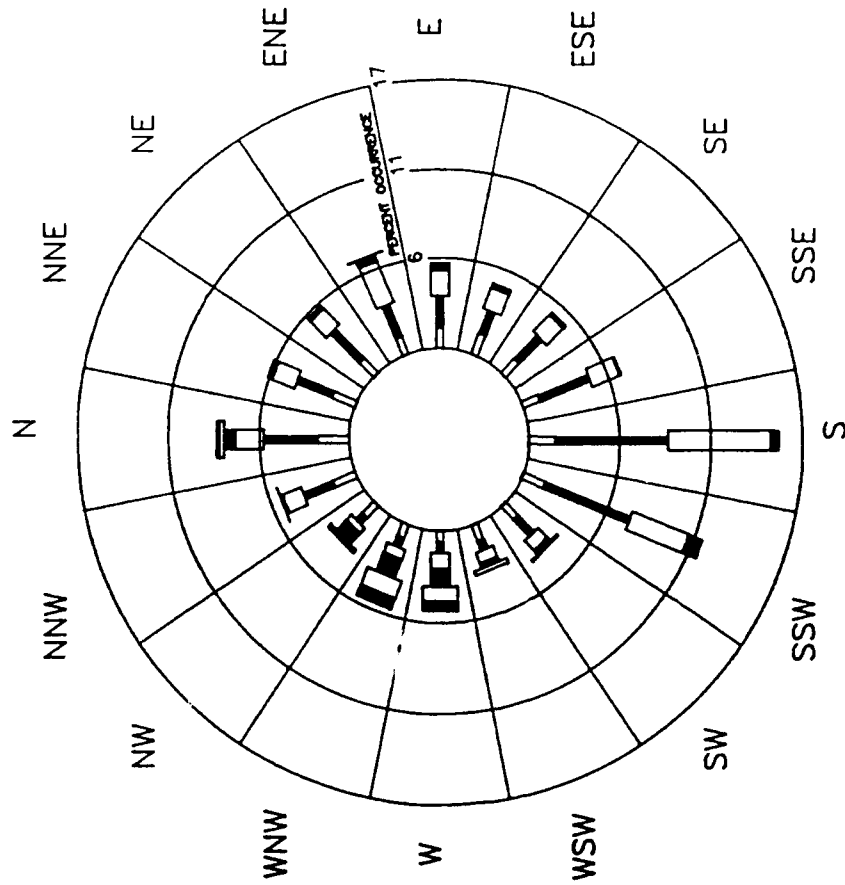
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Figure 6.2-4

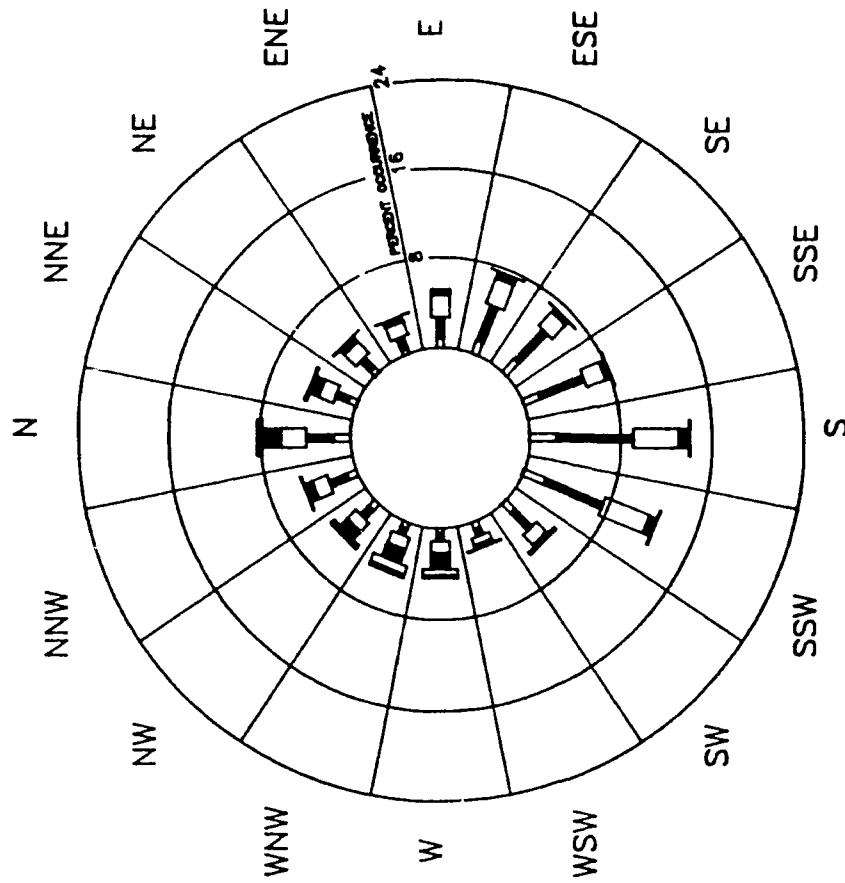
Wind Roses for RMA (Oct.
1 - Dec. 20, 1988) and
Stapleton Airport 1982-86
Fall

CMPAR FY89

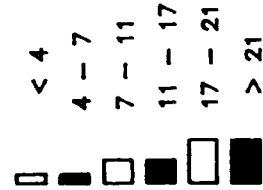
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Stapleton Airport



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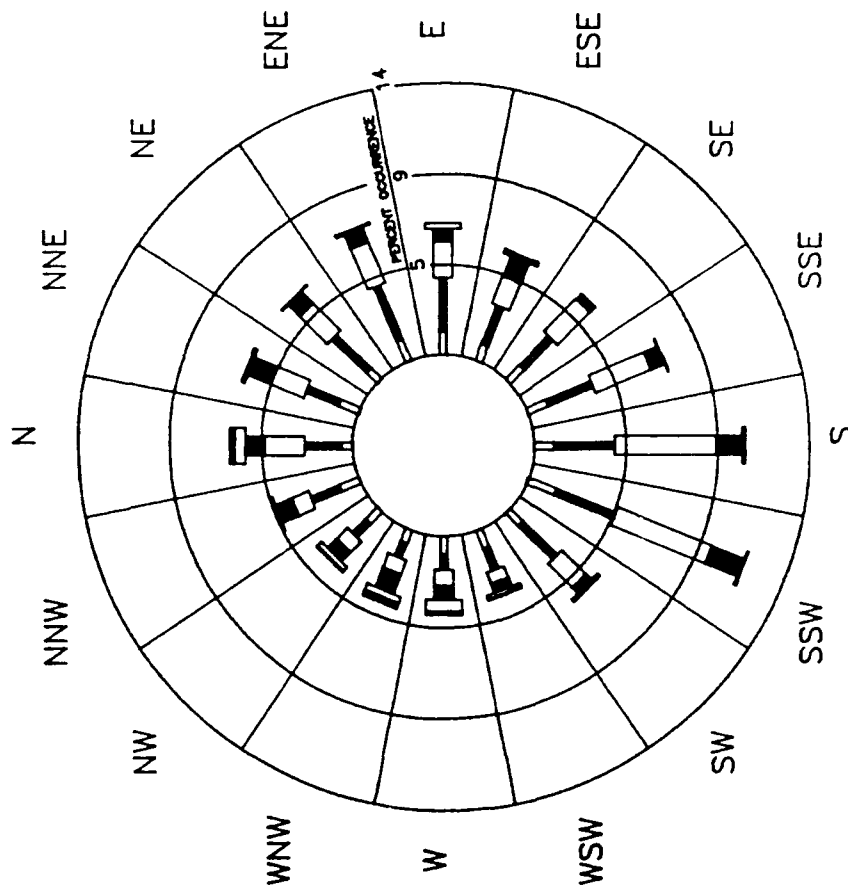
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Figure 6.2-5

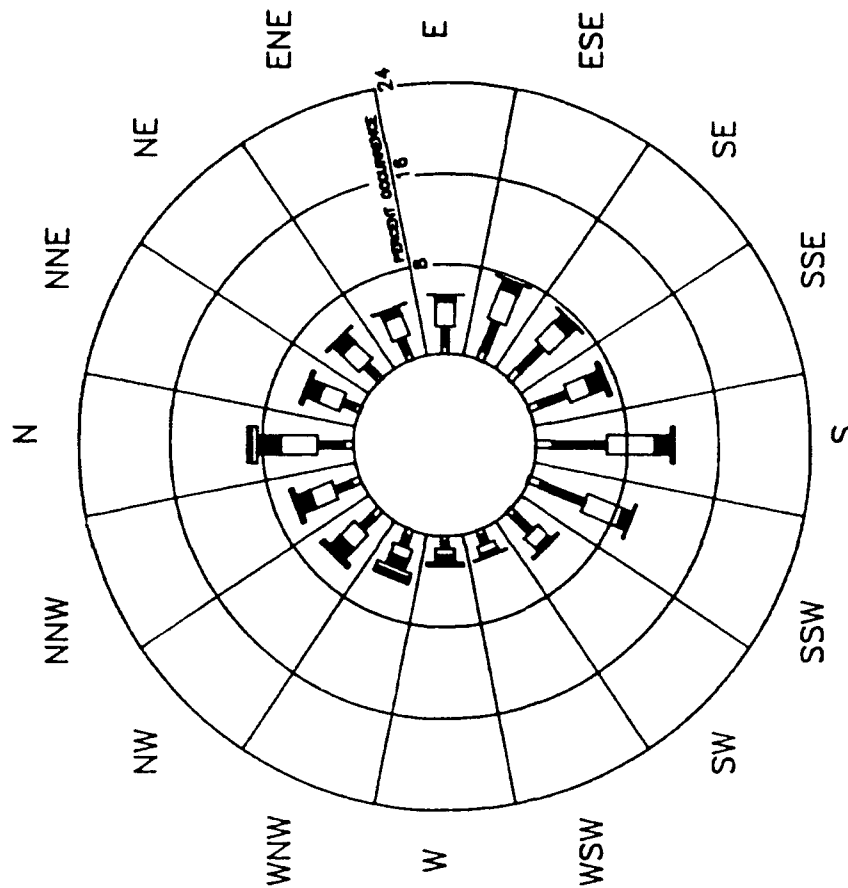
Wind Roses for RMA (Dec.
21, 1988-March 19, 1989)
and Stapleton Airport
1982-86 Winter

CMP AR FY89

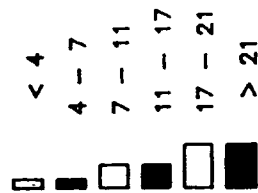
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Stapleton Airport



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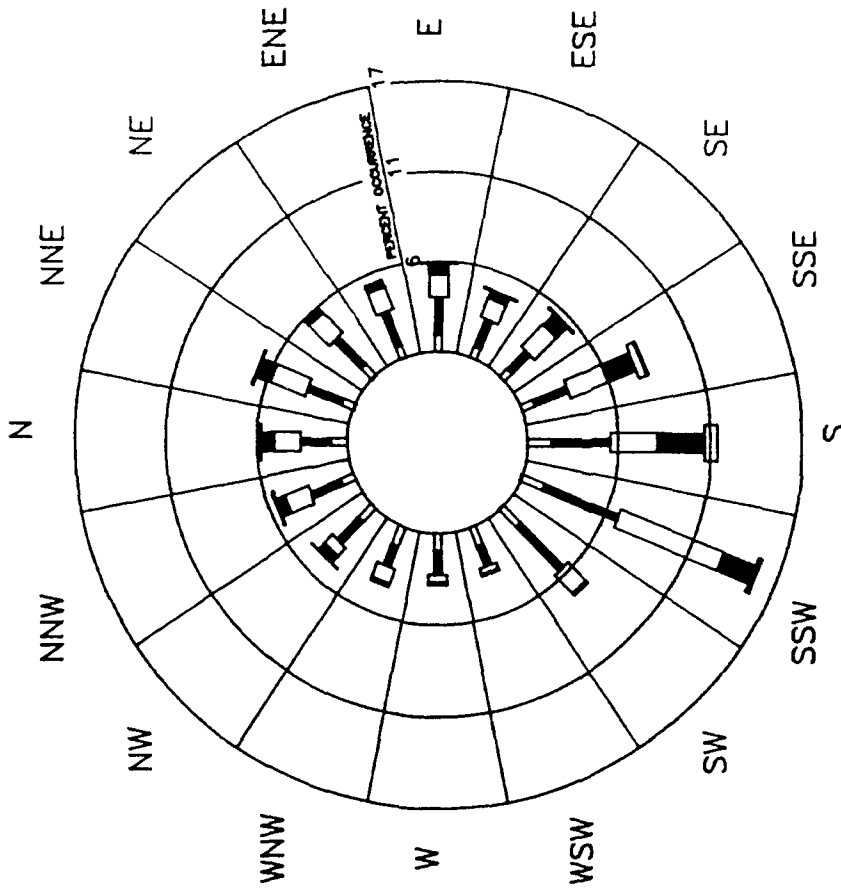
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Figure 6.2-6

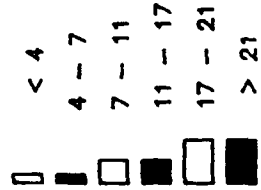
Wind Roses for RMA
(March 20-June 20, 1989)
and Stapleton Airport
1982-86 Spring

CMP AR FY89

Rocky Mountain Arsenal



WIND SPEED CLASSES(KNOTS)



Stapleton Airport

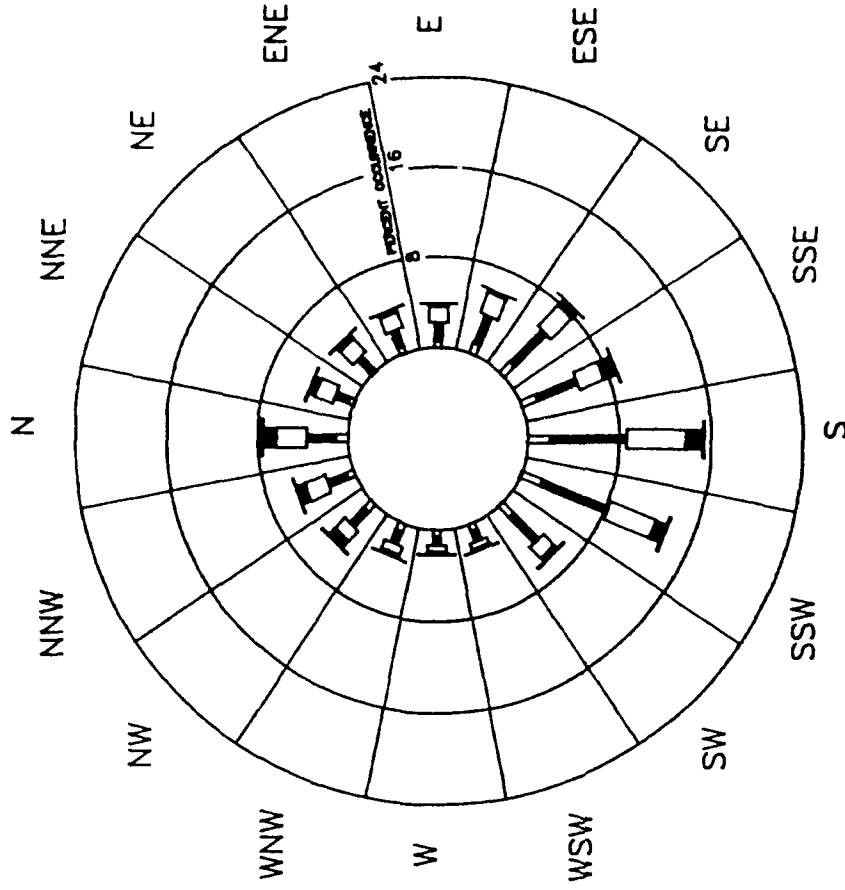


Figure 6.2-7

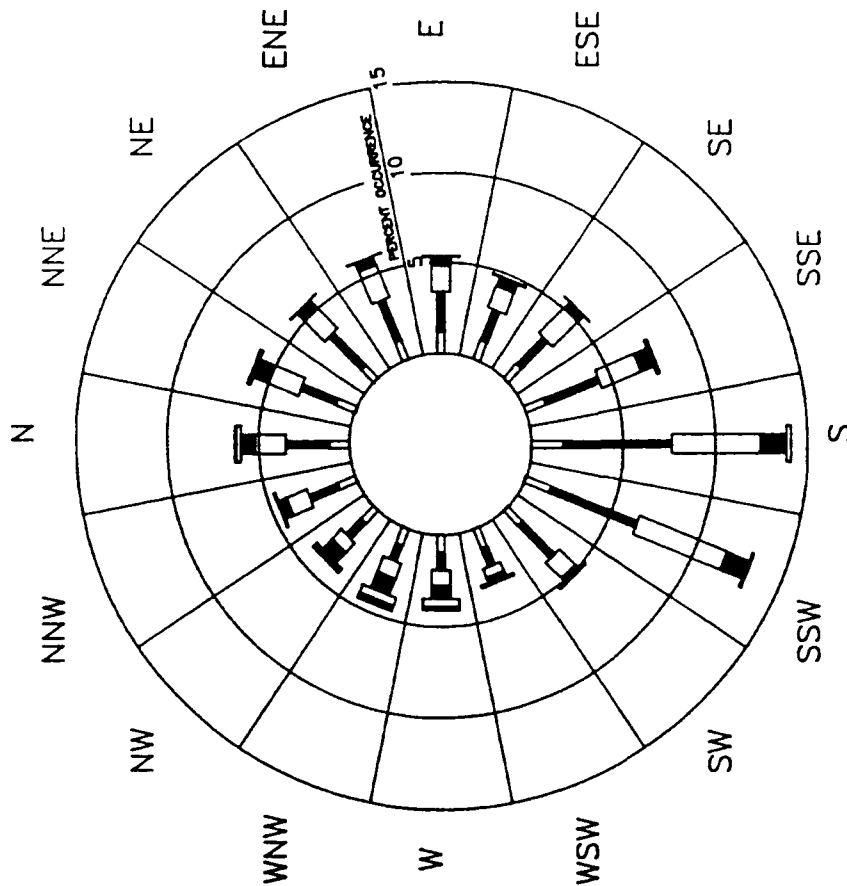
Wind Roses for RMA
(June 21-Sept. 30, 1989)
and Stapleton Airport
1982-86 Summer

CMPAR FY89

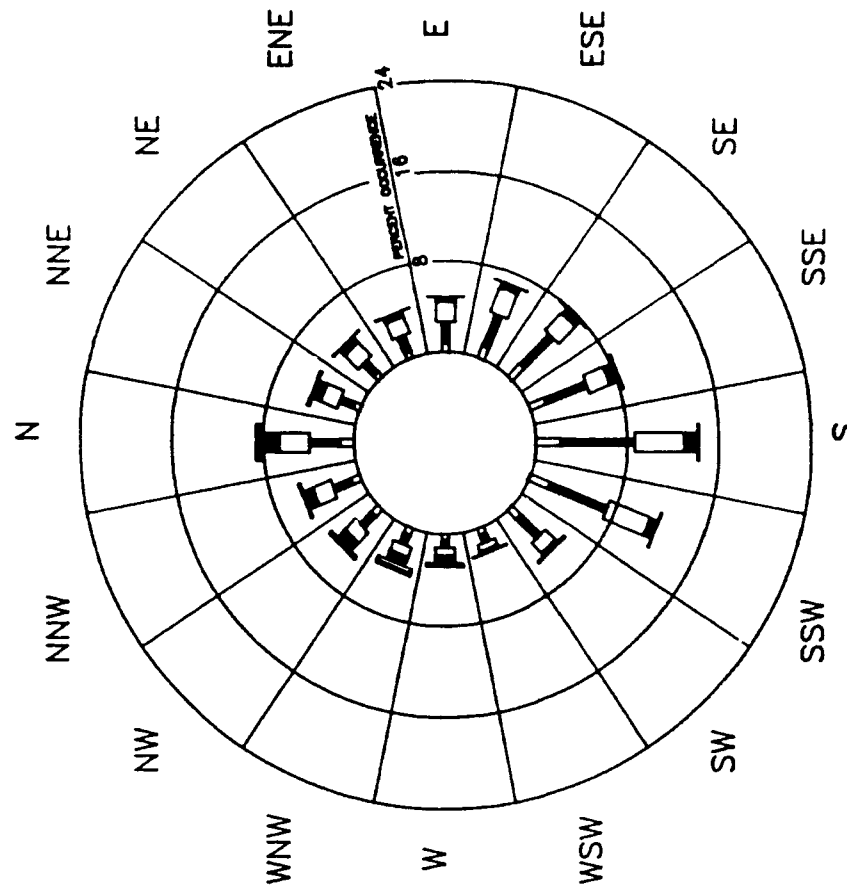
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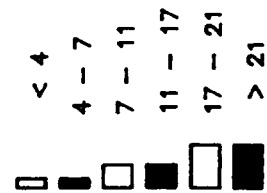
Rocky Mountain Arsenal



Stapleton Airport



WIND SPEED CLASSES(KNOTS)



Prepared for:

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

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Figure 6.2-8

Wind Roses for RMA
(Oct. 1, 1988-Sept. 30,
1989) and Stapleton
Airport 1982-86 Annual

CMPAR FY89

over the Denver area. During spring and summer the dispersion potential was more typically bimodal, with excellent dispersion during the day and poor dispersion at night.

6.3 Seasonal and Diurnal Influences

Dispersion characteristics are closely related to diurnal cycles in atmospheric stability and wind patterns. During the daytime when dispersion conditions are good (Classes A, B and C), winds are highly variable and frequently gusty. At night when the inversions set in and dispersion is poor, winds are generally light and follow a drainage pattern from south to north. These patterns are reflected in seasonal and annual FY89 RMA and long-term (5-year Stapleton) wind roses for separate periods of the day as illustrated in Figures 6.2-9 through 6.2-13. All seasons resemble one another, which is typical of the Denver area. The FY89 RMA diurnal wind roses showed a predominance of south to south-southwesterly flow during the midnight to 8 A.M. period; from 8 A.M. to noon there was a slight transition, but south and southwesterly flow still prevailed; from noon until 8 P.M., however, winds were highly variable, with perhaps slightly more flow from easterly components; 8 P.M. to midnight was a transition period, with the winds beginning to shift from southeast back to south and south-southwest.

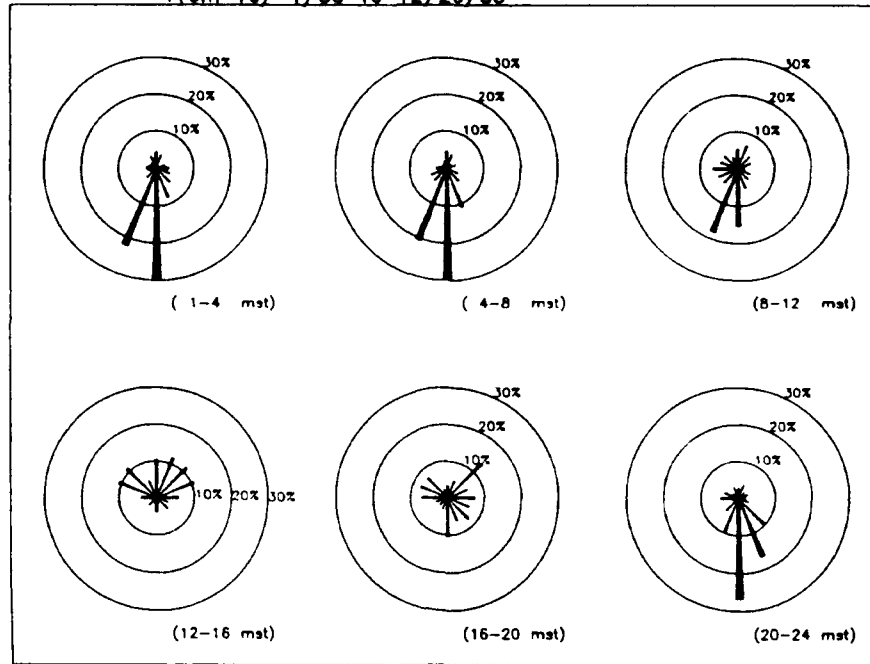
The representativeness of the FY89 diurnal wind patterns is illustrated by a close comparison with the long-term diurnal wind roses. FY88 diurnal wind roses also compared quite well to FY89 diurnal wind roses.

6.4 Summary and Conclusions

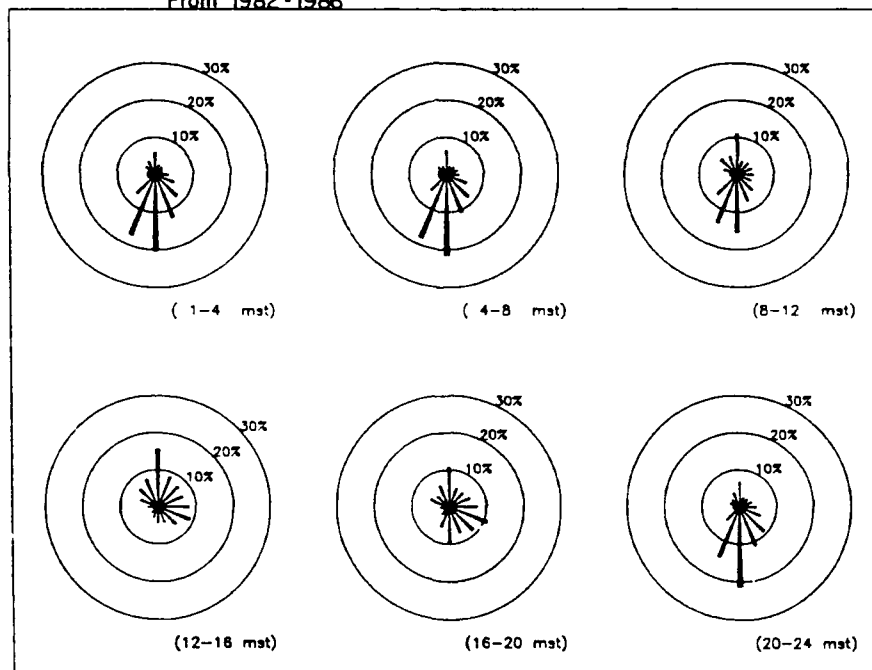
Although mean weather patterns change from year to year, it appears that the FY89 meteorological data, with minor differences, were representative of long-term data and provide a useful instrument for assessing contamination impacts during this period and for future remedial progress evaluations.

The data also suggest important guidelines for mitigation that may be appropriate during remedial activities. Emissions from daytime activities would contribute lesser impacts than nighttime and early morning activities because there are better and more variable dispersion conditions during the day. At night, inversions are prevalent and dispersion conditions are poor. Also winds at night are channelled north and northeast of the remediation source. A factor that should be taken into account, therefore, is the distance from a remediation source to sensitive areas north of the Arsenal, such as public roads and residential areas beyond RMA boundaries. However, dispersion

ROCKY MOUNTAIN ARSENAL DIURNAL WIND ROSES
From 10/ 1/88 To 12/20/88



DENVER STAPLETON FALL DIURNAL WIND ROSES
From 1982-1986

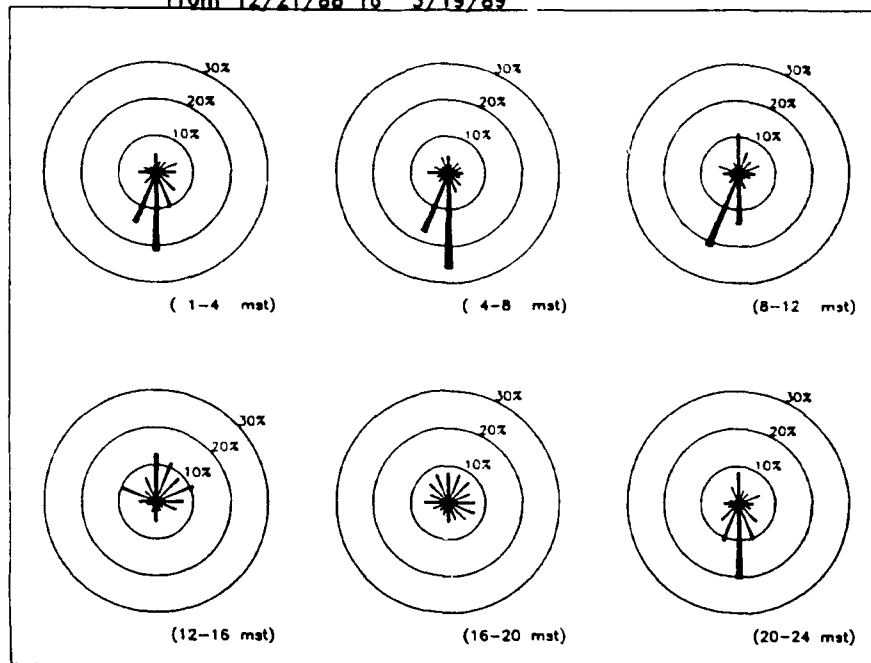


Prepared for :
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Prepared by :
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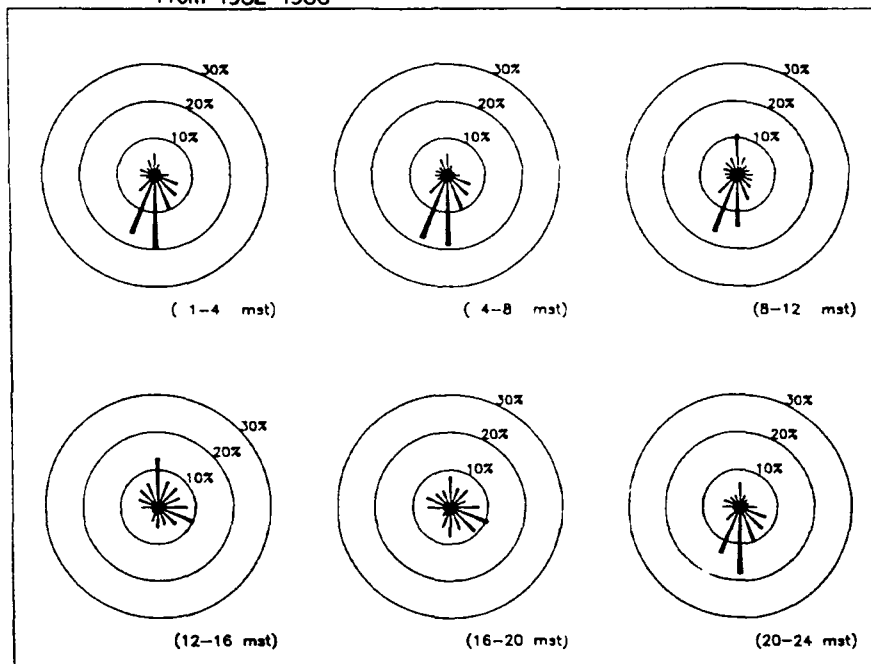
Figure 6.2-9
RMA and Stapleton Airport
Fall Wind Rose
Comparisons

CMP AR FY89

ROCKY MOUNTAIN ARSENAL DIURNAL WIND ROSES
From 12/21/88 To 3/19/89



DENVER STAPLETON WINTER DIURNAL WIND ROSES
From 1982-1986



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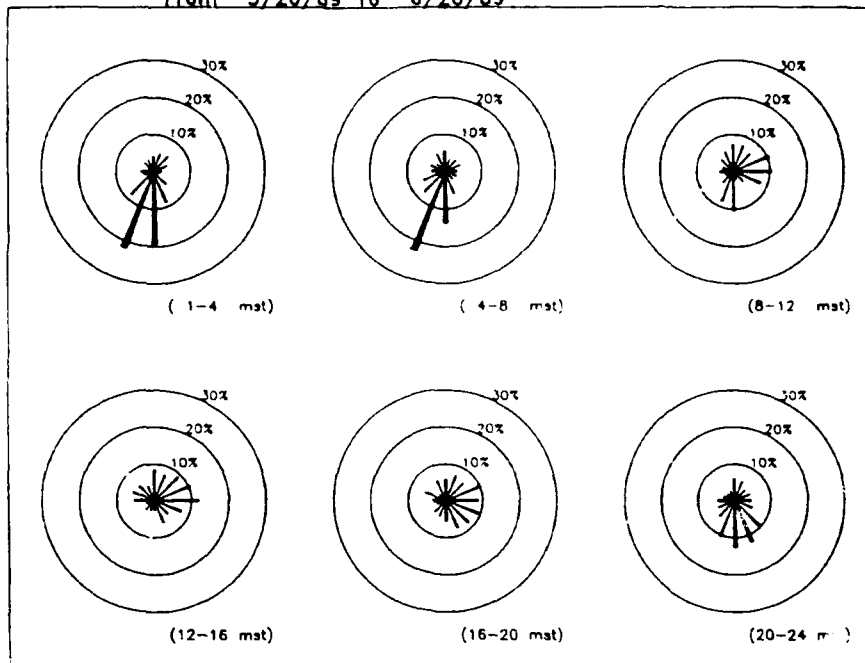
Figure 6.2-10

RMA and Stapleton Airport
Winter Wind Rose
Comparisons

CMP AR FY89

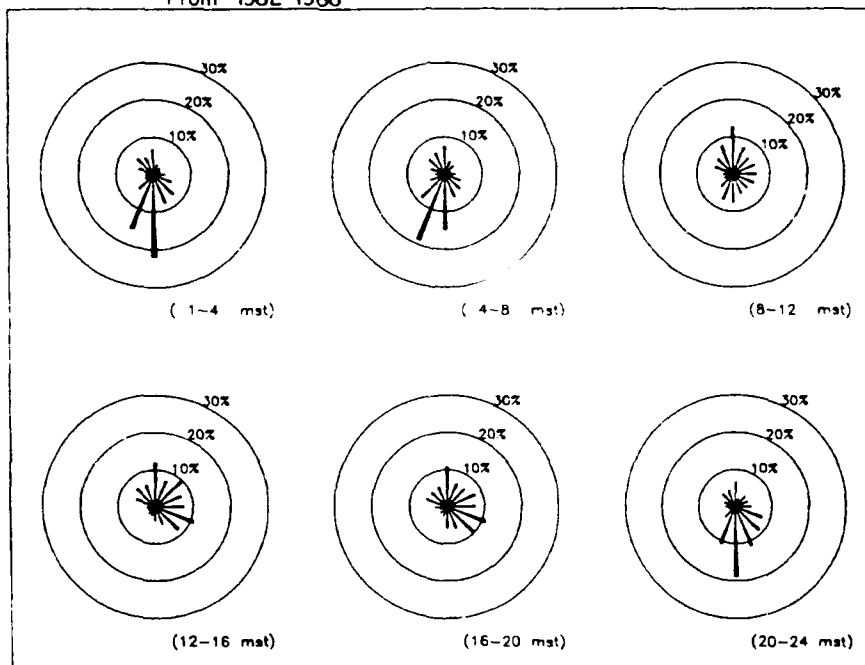
ROCKY MOUNTAIN ARSENAL DIURNAL WIND ROSES

From 3/20/89 To 6/20/89



DENVER STAPLETON SPRING DIURNAL WIND ROSES

From 1982-1986



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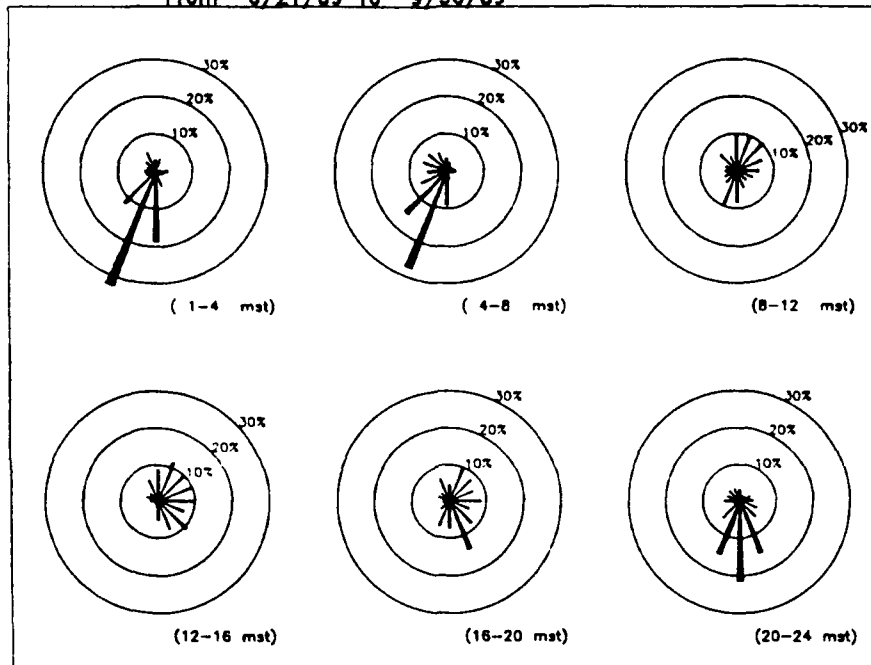
Figure 6.2-11

RMA and Stapleton Airport
Spring Wind Rose
Comparisons

CMP AR FY89

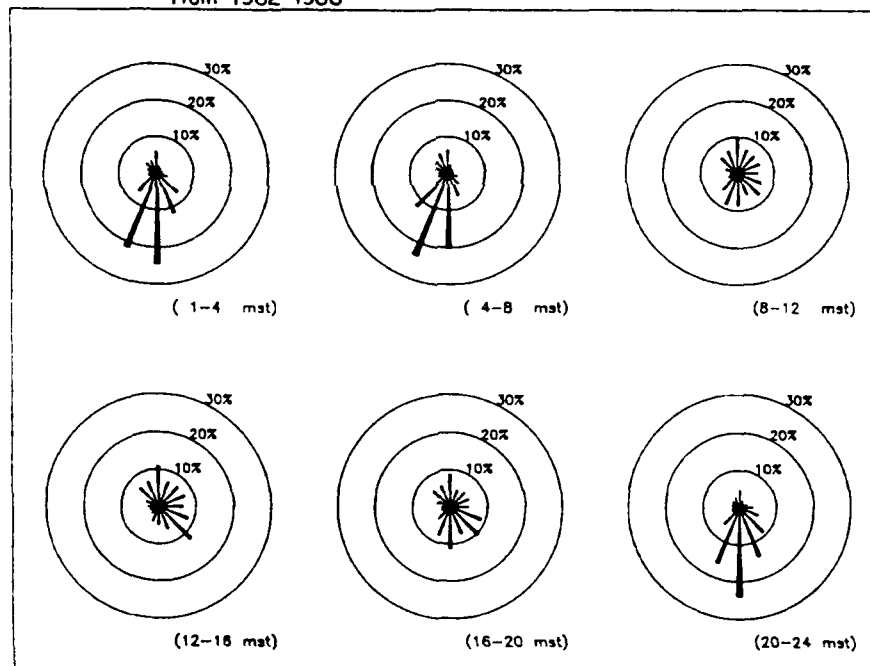
ROCKY MOUNTAIN ARSENAL DIURNAL WIND ROSES

From 6/21/89 To 9/30/89



DENVER STAPLETON SUMMER DIURNAL WIND ROSES

From 1982-1986



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Commerce City, Colorado

Prepared by :

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Ebasco Services, Inc.

Figure 6.2-12

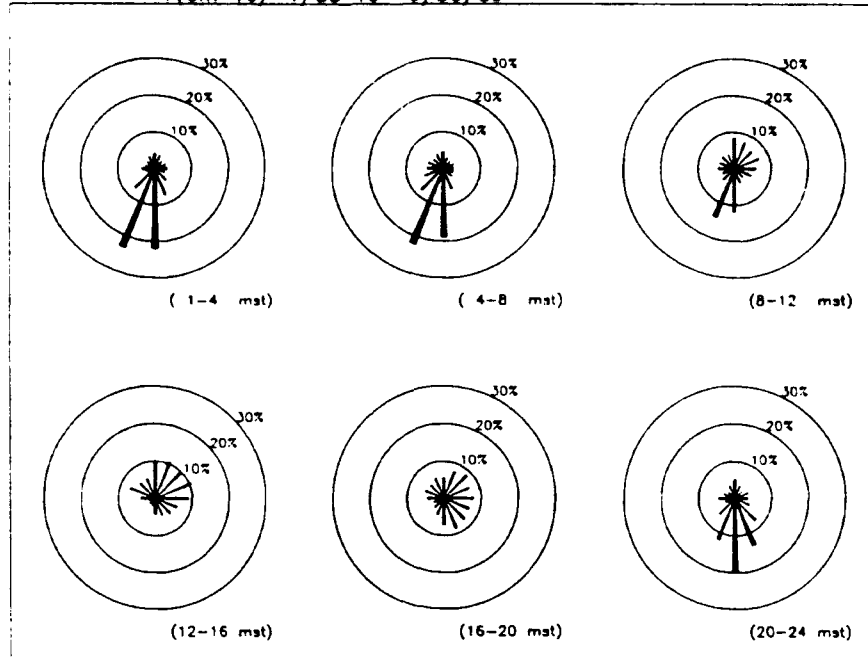
RMA and Stapleton Airport
Summer Wind Rose

Comparisons

CMP AR FY89

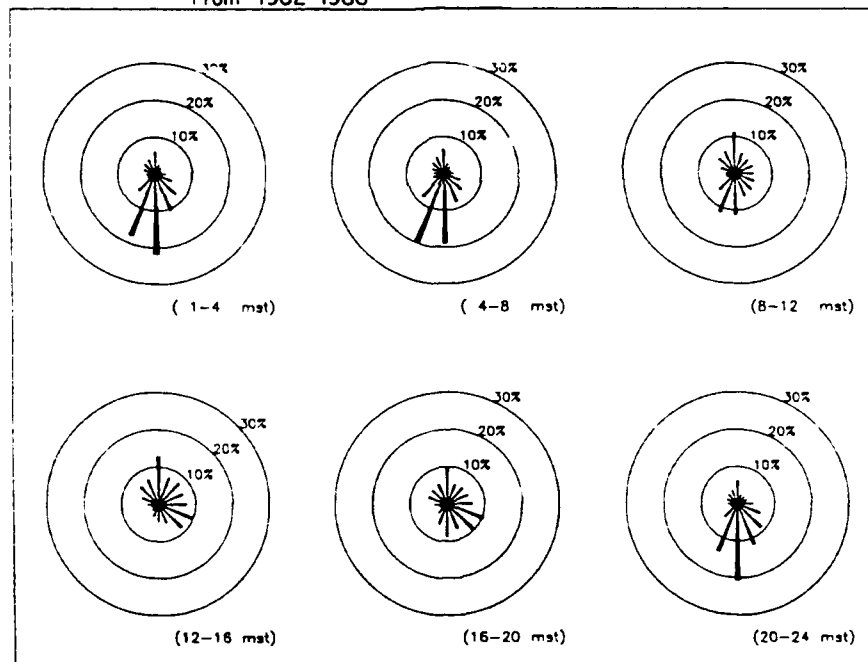
ROCKY MOUNTAIN ARSENAL DIURNAL WIND ROSES

From 10/ 1/88 To 9/30/89



DENVER STAPLETON ANNUAL DIURNAL WIND ROSES

From 1982-1986



Prepared for :

U.S Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :

R. L. Stollar & Associates, Inc.
Ebasco Services, Inc.

Figure 6.2-13

RMA and Stapleton Airport
Annual Wind Rose
Comparisons

CMP AR FY89

potential apparently decreases significantly with distance from a ground emissions source and depends upon meteorological conditions.

In this section, typical impacts were inferred based on seasonal and diurnal meteorology. For real-time applications or for short-term and long-term assessments, these influences must be incorporated into atmospheric dispersion models along with detailed source emission characteristics. Model approaches employed in the present report and recommended for future remedial progress evaluations are discussed in the next section.

6.5 Atmospheric Dispersion Model

6.5.1 Model Applications

One of the objectives of the CMP assessment program is the identification of atmospheric conditions that may trigger high contamination levels and may require special precautions and mitigating actions. A related task is the development and/or application of air dispersion prediction techniques and models that use available site data and provide forecasts of potential contamination impacts. The Basin F program developed and applied such modeling techniques as an integral part of its program to provide for the health and safety of workers and the general public. The CMP closely coordinated these operational activities and incorporated dispersion model results into this report. These techniques appear to be effective and are recommended for future remedial and air quality assessment applications. Specific models used in remedial operations and in data assessments are discussed below.

The models employed were the EPA Industrial Source Complex (ISC) Model (USEPA, 1986) and the INPUFF2 (PUFF advection) model (USEPA, 1986). These are standard and approved EPA models used for general purposes to predict air quality impacts. They are often used in environmental impacts statements and in air quality permit applications. For Basin F remedial activities, they were modified to support the ongoing cleanup operations, and in particular, *to use real-time air quality data and real-time meteorological data.*

Because precise measurements of source emissions could not be determined, a unique approach was devised to use X/Q values, in conjunction with measured ambient concentrations, to predict short-term (operational) and longer-term (assessment) impacts. The X/Q values, as noted in previous discussions relating to the CMP and Basin F monitoring results, do not indicate ambient concentrations, but rather, indicate relative strength, or potential concentration levels based on meteorological conditions and on an undetermined emission source strength. In the Basin F

program, the X/Q values were calibrated with real-time monitoring data to predict ambient concentrations in support of the remedial operations. Appendix J documents basic features of the EPA INPUFF2 and ISC models. In Gaussian dispersion models, the ground level concentrations of contaminants in a plume can be computed by:

$$X = \frac{Q}{\pi \sigma_y \sigma_z u} \cdot \exp \left[-1/2 \left(\frac{ESH}{\sigma_z} \right)^2 \right]$$

Where X = predicted ground level concentration
 Q = source emissions
 σ_y = horizontal dispersion coefficient (function of distance from source)
 σ_z = vertical dispersion coefficient (function of distance from source)
 u = mean wind speed at plume level
 ESH = effective stack height, (or plume height level assumed for Basin F application)

When the source emission term is not determined, the equation can be written as follows:

$$X/Q = \frac{1}{\pi \sigma_y \sigma_z u} \cdot \exp \left[-1/2 \left(\frac{ESH}{\sigma_z} \right)^2 \right]$$

For the present assessment applications, assuming that Q is constant, or near constant (at any given time), the relationship between an observed (monitored) concentration at a specific grid location where a X/Q was calculated, and at another *unmonitored* location where a X/Q was also determined was the ratio between the two values. This was a very simple approach, but was highly effective in determining the spread of a dispersion plume beyond and between the monitoring networks. The technique will allow for the prediction of future concentrations during ongoing operations, assuming that emissions do not significantly change during a particular operation. As remedial progress continues and emissions are eventually reduced, observed concentrations for a specified X/Q should also be reduced. Thus, the model has the potential to evaluate remedial progress under comparable meteorological and air dispersion conditions.

The PUFF model was used primarily for short-term predictions at Basin F in conjunction with real-time operations. Air monitoring was conducted using HNU, OVA, ammonia and dust monitors

at various remedial activity areas and along the Exclusion Zone perimeter. Perimeter readings were taken at 4 fixed locations and also downstream from Basin F, based on the prevailing wind, where maximum concentrations were anticipated. Concurrent with each monitoring reading, the PUFF model was run to determine the trajectory of the contamination plume. The X/Q values of the model were then immediately matched with actual monitored data to determine the potential distribution of the plume trajectory and the likelihood of Level B exceedances outside the protected areas. A maximum limit of 1 ppm was established for expansion of the Exclusion Zone and/or evacuation of personnel without protective clothing and equipment.

Both the PUFF model and the ISC model have the capability to provide longer-term X/Q dispersion assessments. Because the PUFF model operates on 15-minute trajectories, it takes much longer to run, and the ISC model was primarily employed for 24-hour assessments and beyond. However, the PUFF model can be used to assess longer-term episodes if more refined or sensitive analyses are required.

The results of the CMP and Basin F monitoring programs, discussed in Section 4, were compared with dispersion analyses obtained from the EPA Industrial Source Complex model. As noted, these evaluations provided highly useful information for associating dispersion patterns and meteorological conditions with observed and potential air contamination levels. When a distinct source was evident, such as Basin F, the model identified the spread of the dispersion plume downstream from the source. The concurrent monitored data then provided a mechanism for calibrating and projecting ambient concentrations throughout the Arsenal and beyond its boundaries. The model identified worst-case meteorological conditions and seasonal and diurnal effects, thus providing a basis for mitigation actions. For future assessments, it provides a basis for evaluating remedial progress by ensuring that monitoring results are compared to similar worst-case meteorology and seasonal conditions.

The effectiveness of model applications is evident from the data and comparisons shown in the proceeding sections. There is considerable scatter which can be attributed to many factors beyond the simplified model's present capabilities. These include variations in source emissions and remedial production activity, both of which obviously result in variations in concentration levels downstream from the source; the existence of other potential area and local sources, which present a "noise" factor in the database; short-term meteorological influences that are not integrated into the hourly Industrial Source Complex database (this suggests the special advantage in using the short-term PUFF trajectories); and the general complexity of the dispersion process that is not entirely identified in the model.

In summary, the PUFF and Industrial Source Complex models, using the X/Q calibration approach, were workable vehicles for projecting contamination levels during remedial activities and for assessing remedial progress. It is not the purpose of the CMP to do extensive research investigations to improve model validation and applications. Nevertheless several practical follow-on efforts may be applied in future CMP evaluations that would not only improve the models but would also provide considerable insight into the general assessment of RMA contamination levels during subsequent remedial activities. These are discussed below.

6.5.2 Additional Model Approaches and Analyses

6.5.2.1 Source Emissions Characterization. The standard dispersion model predicts ambient concentrations based upon meteorological factors and a known, or estimated, emission source. The Basin F real-time application, as well as for the CMP, have to a certain extent effectively bypassed the emissions term and substituted a mechanism (X/Q values) for providing contamination levels based upon concurrent monitoring data. More precise data on emission releases at potential RMA contamination sources will add an additional dimension to the modeling and prediction capabilities. Data indicating the combination of emission levels, meteorological factors and resultant ambient concentrations will also allow for still further refinements of the model. In the Basin F situation, after eliminating a proposed pugmill as a key feature in the remedial cleanup activities, ambient concentrations, for the most part, did not pose a serious problem and the X/Q method was very effective for routine operations. However, should subsequent cleanup activities at RMA require air quality impact assessments, precise emissions data and characterizations will enhance prediction capabilities.

6.5.2.2 Remedial Activity Production Data. It is evident from the Basin F monitoring results during remedial operations and from the previous Remedial Investigation Program results prior to remedial operations, that the cleanup activities resulted in increases in some of the monitored pollutants, in particular TSP, pesticides, organic compounds and some metals. It may be assumed that these increases were a direct consequence of and proportional to the extent of remedial efforts on a day-to-day basis. Various information pertaining to the status and intensity of cleanup operations, including the tons of soil and sludge removed and hauled each day, the type and number of vehicles and type of equipment employed, storage areas and uncovered waste pile areas, the number of gallons of liquid transported, and any other emission-producing factors related to operations would be especially useful in assessing relative emissions potential and in refining model prediction capabilities. These data were available, to a limited extent, during the Basin F operations, but not necessarily on a real-time basis; this made it difficult to interpret the cause of higher contamination events and the extent of mitigation efforts that were needed. It should be

noted that many industrial real-time air quality prediction systems are directly related to production factors (Edson, 1976, 1977, 1978), and this approach would have equally valid application for waste cleanup operations.

6.5.2.3 Local and Regional Emissions Inventory. One of the difficulties in analyzing the CMP and Basin F data was that there were obviously other local and regional air emissions sources in the RMA vicinity that contributed to air pollution levels measured at RMA monitoring sites. As noted in the data evaluations, Denver was a source of TSP, PM-10, some metals, and undoubtedly certain organics. Also various industrial sources and farming areas in North Denver, Commerce City and Adams County may have contributed to organics and other potential contaminants. An attempt is being made to identify these sources in order to properly evaluate their contribution to RMA monitored data. In addition, they present an unknown factor in the dispersion model prediction evaluations unless properly identified. Consequently an inventory of local, off-RMA sources is highly desirable for the interpretation of baseline data and remedial progress at RMA. Work has begun on this effort and it is anticipated that such an inventory of sources will be included in the FY90 report, and that these data will contribute to the overall analyses. Much of this information is available in the Colorado Department of Health files and from the final Air Toxics Study for Denver conducted by EPA. This report was discussed briefly in Section 4.6.4.

6.5.2.4 Empirical/Statistical Adjustments. A final approach for model improvement is the application of empirical techniques and pertinent, or unique, physical relationships to improve model capabilities. As examples, it is generally agreed that organics are released into the atmosphere at warmer temperatures and also under certain favorable air pressure conditions; TSP, metals, and PM-10 are generally higher after certain threshold wind gust levels are achieved. Also, very localized, topographic site-specific characteristics may be evident in the spread of potential air contaminants over the area which are not considered in the dispersion model. The database now being collected provides a mechanism for establishing some of these influences; some have already been identified in the present report. It is anticipated that this effort will continue in the FY90 program, and if possible, validated relationships will be incorporated into model applications.

7.0 QUALITY ASSURANCE PROGRAM

7.1 Overview and General Guidance

The CMP Quality Assurance Program for Air Monitoring was designed to provide quantitative evidence that the data generated were accurate, precise, and meets the requirements of the project and needs of the data user. The monitoring and analytical techniques used were certified by PMRMA or USEPA, with each method having its own prescribed quality control and quality assurance procedures. The basic guidelines for developing monitoring methods and procedures are described in the following documents:

- "CMP Field Procedures Manual";
- "PMRMA Certified Analytical Methods";
- "Ambient Monitoring Guidelines for Prevention of Significant Deterioration," EPA-450/4-87-007;
- "Ambient Air Quality Monitoring, Data Reporting, and Surveillance Provisions," 40 Code of Federal Regulations, Parts 51, 52, 53 and 58;
- "Quality Assurance Handbook for Air Pollution Measurement Systems," Volumes I, II and IV, EPA-600/9-76-005, EPA-600/4-77-027a, and EPA-600/4-82-060; and
- "Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air," EPA-600/4-84-041 and updates.
- Chemical Quality Assurance Plan, Version 1.0, July, 1989.

Under PMRMA definitions, quality assurance is the total integrated program for assuring and documenting the reliability of monitoring and measurement data and for integrating quality planning, quality assessment and quality improvement efforts to meet user requirements. Integrated into the QA plan is quality control which is the routine application of procedures for obtaining prescribed performance standards in the monitoring and measurement process.

For the purposes of the CMP Air Monitoring Program, quality control using project guidelines were those procedures that were routinely followed during the normal operation of the monitoring

system. These included periodic field "spikes" and field blank sample analysis, collocated sample analysis, calibration of field and laboratory equipment, preventive maintenance, site inspections, and routine data screening and validation checks. Quality assurance (or quality assessment) were those procedures performed on a routine but less frequent basis to validate the data generation process. These assurance procedures were performed by a person not involved with the corresponding day-to-day project activities. Quality assurance procedures included system and performance audits, standard intercomparisons, crosschecking of reported data values against original raw data records and data from other similar locations, and periodic evaluation of internal quality control data. The objectives of the quality control and quality assurance procedures were to produce data that met RMA requirements measured in terms of precision, accuracy, representativeness, comparability, and completeness.

The remainder of this section is divided into the following subsections: a brief overview of the laboratory quality assurance and quality control program, a description of the field quality control results, a description of the field quality assurance results and a description of quality assurance associated with data processing. More detailed discussions are provided in the CMP Field Procedures Manual (Stollar, 1988).

7.2 Laboratory Quality Control and Quality Assurance Program Overview

The laboratory quality assurance and quality control program was extremely rigorous and was based on PMRMA certification procedures. These procedures assured the accuracy and integrity of the collected database through a control chart process. The certification program consisted first of rigorous precertification and certification procedures that were satisfactorily completed before sampling and data collection. Second, prescribed routine quality control and quality assurance procedures were followed during the sampling program to ensure that the entire sampling method was performing comparable to the level demonstrated during certification.

The laboratory certification procedures consisted of determining several key parameters. Extraction or desorption efficiencies were determined by spiking the sample media with known amounts of the target analytes and performing the analyses along the analytical guidelines. Recovery rates for each of the compounds were determined from the mean of multiple spiking tests, and the standard deviation of the recovery data was used to validate the method. A range of concentrations was used to test the linearity of the laboratory instrument response and to certify an analytical range for each target analyte, with limits denoted as the upper and lower certified reporting limits. The extraction efficiency and the certified reporting limits were incorporated into a method accuracy correction and validation algorithm that was part of the data processing system.

Reporting ranges were determined at the time of certification. Values found below this range were reported as "less than" the lower reporting limit. An upper limit did not apply to TSP and PM-10 measurements. For SVOCs and metals analysis, extract solutions were diluted for reanalysis if the initial readings were above the certified range and holding times for the extracts had not yet expired.

The VOC laboratory analysis technique differed significantly from other techniques because there was no possibility of diluting or reanalyzing samples. The VOC Tenax sorption tube was placed into an oven at the inlet to the analytical instrument. This oven or thermal desorber was quickly heated to desorb all the compounds off of the Tenax. A small air flow was passed through the tube, which allowed these compounds to be quickly injected into the analytical instrument. Therefore this method technique was a "one shot" technique, and if the sample concentration was outside certified limits, there was no way to dilute and reanalyze the sample. In the FY89 program, there were instances where a sample had collected an amount above the certified range for some compounds. An assessment of the concentration was made by using the concentration curve above the certified range. Such results represented the best estimate of the observed concentrations; however, these data were not certified in accordance with PMRMA standards and were likely to represent a low estimate of actual concentrations.

The above measures of laboratory accuracies and extraction efficiencies were directly incorporated into the database processing system that was used to report air quality data. This system is the Installation Restoration Data Management System (IRDMS). In IRDMS, the raw laboratory results are sent to EBASCO, the data is checked for errors, corrected for accuracy, adjusted for flow volumes, and sent to DP Associates and held in the QC holding database. Once the Army has accepted the data as meeting the QA criteria, it is then loaded into the useable database. Data outside of certified ranges and rejected under the QA criteria are placed in a rejected data file for informational use only. The resulting product is a high-quality analytical database that was available to field personnel for calculating ambient concentration data.

7.3 Field Quality Control Program

7.3.1 Organization

The field monitoring team was organized to conduct several activities that provided data quality control for the program. At the outset, a monitoring team supervisor was designated and a set of procedures was drawn up to address quality control. The field supervisor and project manager insured that the quality control procedures were implemented.

Standard field data sheets were used by the project team. Each team member was trained in the use and entry of data on this form. Forms were documented in project files, and copies were distributed to the project manager for periodic review. Calibration data sheets were also drawn up for the project and the calibration team was trained in their use. The field and calibration data sheets were stored on-site and a copy was sent to the project manager. The field supervisor was responsible for ensuring that these records were maintained, routinely reviewed and updated, and used by the data processing personnel.

7.3.2 Field Program Quality Control

For each of the sampling techniques used, the air quality technical plan specifies target flow rates and sampling durations. These values were used during the field sampling activities and were documented by periodic equipment calibrations as well as checks during each sampling event. Quality assurance limits were set up using the EPA Quality Assurance Handbooks for acceptable instrument performance. Whenever a flow rate or elapsed timer was outside of acceptable limits, corrective maintenance was performed to bring the defective component or activity back into tolerance.

The high-volume field equipment used to sample TSP, PM-10 and metals was electronically flow-controlled to maintain a constant flow rate. A certified flow measuring orifice was routinely used to calibrate the flow rate set point. Calibrations were performed once per quarter or more frequently if needed. For the SVOC and OTSP high-volume samplers, a flow rate gauge was used to monitor the flow rate of the sampler. During calibration of these samplers, a range of flow rates was measured with the orifice, and a linear regression was developed relating the sample indicator reading to the orifice flow rate. The maximum deviation of any flow rate point from the linearly interpolated value should be less than 7 percent for the TSP, PM-10, SVOC, and OTSP samplers.

The low-volume field sampling equipment, which measured VOCs, mercury and ammonia, were Gilian constant flow sampling pumps equipped with rotameters. Before each field sampling event the pumps were calibrated and set to specific flow rates as determined by a certified mass flowmeter. During a sampling event, personnel routinely inspected the rotameter to ensure correct flow rate readings.

7.3.3 Quality Control Field Sample Results

7.3.3.1 VOC Quality Control Results. The specified requirement for determining efficiency of the sampling technique is to compare the volume of air sampled to establish acceptable sampling volumes. The Tenax collector for VOC sampling will not capture all of a particular compound greater than a specified sample volume. The sampling volume should not exceed the established "breakthrough" volume for the compound of interest.

The sampling media employed consists of a front sorbent tube containing Tenax and a second or back tube containing Tenax and charcoal. This combination did not exhibit any breakthrough results.

The standard VOC method prescribes the use of collocated samples as a quality assurance procedure that can be used to increase confidence in the data that are generated. This technique has been used by the CMP and results are discussed in Section 7.4. The recommended performance criteria is that the mean difference between the pairs of collocated samples should generally be within 25 percent of the sample mean.

Field blank values were also compared to field sample analytical values. As stated in the VOC method, the blank sorbent trap should contain less than 10 ng of the target compounds before it is sent to the field. Table 7.3-1 presents a summary of the target VOC blank values for all of the field and trip blanks during FY89. For most of the target compounds, field blank levels were less than the certified reporting limit (which generally corresponds to approximately 10 ng per sample). However, some field blanks showed detectable levels of benzene, methylene chloride, carbon tetrachloride and toluene. Benzene was detected in all field blanks, and two samples had methylene chloride levels above the certified reporting limit. Levels of toluene detected were near the lower certified reporting limit, and carbon tetrachloride was detected in only one blank. Therefore, because blank correction was not performed during the CMP on VOC data, the benzene and methylene chloride data especially should be considered conservative, and the actual ambient concentrations may be lower than presented in this report.

7.3.3.2 Semi-Volatile Organics and Organics in TSP Quality Control Results. Quality control samples for semi-volatile organic compounds and organics in total suspended particulates consisted of field blanks, trip blanks and aerated field spikes. The SVOC and OTSP sampling methods were identical; both consisted of a polyurethane foam sorbent plug and quartz filter used in a high-volume sampler. In the SVOC analytical method, gas chromatograph/mass spectrometer (GC/MS), was used for detection. This analytical device measured a wide variety of compounds, other than

7.3-1 CMP Target Volatile Organic Compounds (VOC) Blank Values
(in ug)

Tag #	111TCE	112TCE	110CLE	120CLE	BCMPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5	DBCP
15784 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0408 LT	0.013 >C	0.1200 LT	0.006 LT	0.0095 LT	0.011
15785 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0286 LT	0.013	0.0468 LT	0.006 LT	0.0095 LT	0.011
15791 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0286	0.028	0.0468 LT	0.006 LT	0.0095 LT	0.011
15792 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0286 LT	0.013	0.0468 LT	0.006 LT	0.0095 LT	0.011
21764 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0160 LT	0.013 LT	0.0080 LT	0.006 LT	0.0095 LT	0.011
21765 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0200 LT	0.013 LT	0.0080 LT	0.006 LT	0.0095 LT	0.011
21771 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0200 LT	0.013	0.0120 LT	0.006 LT	0.0095 LT	0.011
21772 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0240 LT	0.013 LT	0.0080 LT	0.006 LT	0.0095 LT	0.011
21782 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0140 LT	0.013 LT	0.0080 LT	0.006 LT	0.0095 LT	0.011
21783 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0100 LT	0.013 LT	0.0080 LT	0.006 LT	0.0095 LT	0.011
21797 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0220 LT	0.013	0.0700 LT	0.006 LT	0.0095 LT	0.011
21821 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0220 LT	0.013 GT	0.1000 LT	0.006 LT	0.0095 LT	0.011
21822 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.0200 LT	0.013	0.0220 LT	0.006 LT	0.0095 LT	0.011
MAX	0.0175	0.0085	0.007	0.006	0.012	0.0408	0.028	0.1200	0.006	0.0095	0.011
MIN	0.0175	0.0085	0.007	0.006	0.012	0.0100	0.013	0.0080	0.006	0.0095	0.011
AVG	0.0175	0.0085	0.007	0.006	0.012	0.0227	0.014	0.0388	0.006	0.0095	0.011

Tag #	BCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMEA	12DMB	T12DCE	TCLEE	TRCLE	XYLENE
15784 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
15785 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
15791 LT	0.013 LT	0.0135 LT	0.0085	0.062 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
15792 LT	0.013 LT	0.0135 LT	0.0085	0.030 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
21764 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
21765 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
21771 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
21772 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
21782 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
21783 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
21797 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
21821 LT	0.013 LT	0.0135 LT	0.0085	0.026 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
21822 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.0115 LT	0.015 LT	0.0095 LT	0.0405
MAX	0.013	0.0135	0.0085	0.062	0.005	0.0295	0.008	0.0115	0.015	0.0095	0.0405
MIN	0.013	0.0135	0.0085	0.023	0.005	0.0295	0.008	0.0115	0.015	0.0095	0.0405
AVG	0.013	0.0135	0.0085	0.027	0.005	0.0295	0.008	0.0115	0.015	0.0095	0.0405

LEGEND:	111TCE	1,1,1-Trichloroethane	BCPD	Dicyclopentadiene
	112TCE	1,1,2-Trichloroethane	DMDS	Dimethyl Disulfide
	110CLE	1,1-Dichloroethane	ETC6H5	Ethylbenzene
	120CLE	1,2-Dichloroethane	MEC6H5	Toluene
	BCMPD	Bicycloheptadiene	MIBK	Methyl Isobutyl Ketone
	C6H6	Benzene	NNDMEA	N-Nitrosodimethylamine
	CCL4	Carbon Tetrachloride	12DMB	Dimethylbenzene
	CH2CL2	Methylene Chloride	T12DCE	Trans-1,2-Dichloroethene
	CLC6H5	Chlorobenzene	TCLEE	Tetrachloroethene
	CHCL3	Chloroform	TRCLE	Trichloroethene
	DBCP	Dibromochloropropane	XYLENE	Xylene

the target analytes, yet had a moderately high detection limit. For OTSP samples, a gas chromatograph/electron capture detector (GC/ECD) was used. This device analyzed only the organochlorine pesticides for which it was certified and had a very low detection limit. All organochlorine pesticides, with the exception of aldrin, were included in the SVOC target list. The aldrin concentrations reported for the OTSP technique must be used with caution. In actual field sampling there is the potential for stripping or oxidation of aldrin, and the recovery of spiked aldrin samples is known to be low (USEPA, 1984).

SVOC field spiking results for two separate events are presented in Table 7.3-2. These numbers were compared to standard method recommendations for analytical recoveries (collection efficiencies) of 75 percent or greater for acceptable method performance, with standard deviations of field spiking results of 15 percent or less. Concentration of compounds with low or erratic recoveries must be used with caution.

The SVOC field blanks results indicate that all field blanks for all target SVOCs were below the lower certified reporting limit. The OTSP field blanks were less than the lower certified reporting limit except for one sample on 04/10/89. Sample 16093 detected PPDDT at $0.256 \mu\text{g}/\text{m}^3$. The reason for the contamination may be linked to snow collecting on the filter during sampling.

7.3.4 Data Processing

A series of formal steps was implemented to ensure the quality of data generated under this program. For all analytes the laboratory determined the weight on each sample; the IRDMS adjusted this weight by a method accuracy correction; the monitoring team calculated a volume associated with each sample; and the adjusted weight was divided by the sample volume to obtain a concentration.

The quality assurance group reviewed the laboratory quality control data, including surrogate and spiked recoveries and general compliance with the PMRMA quality control methodology. The acceptability of each lot was addressed by the laboratory and was reviewed for approval by the quality assurance team. The control charts were reviewed to indicate method control and submitted to PMRMA. The laboratory provided a paper copy and a diskette of uncorrected sample weights; the printout of diskette data was compared with the papercopy results and any discrepancies were resolved. For each target compound in each group of data, a check was made of at least one sample to assess the method accuracy correction.

Table 7.3-2 Summary of Semi-volatile Organic Compounds Results of Field Spiking

Sample ID	Atrazine % Recov.	Chlordane % Recov.	CPMSO % Recov.	CPMSO ₂ % Recov.	Dieldrin % Recov.	Endrin % Recov.	Isodrin % Recov.	Malathion % Recov.	PPDE % Recov.	PPDT % Recov.	Parathion % Recov.	Supona % Recov.
22251	90.00	100.00	20.00	50.00	80.00	100.00	5.00	90.00	100.00	100.00	90.00	90.00
22586	90.00	100.00	20.00	60.00	90.00	100.00	8.00	90.00	100.00	100.00	90.00	90.00

Legend: CPMSO = Chlorophenyl methylsulfoxide
 CPMSO₂ = Chlorophenyl methylsulfone
 PPDE = Dichlorodiphenyldichloroethylene
 PPDT = Dichlorodiphenyltrichloroethane

The field team generated a sample volume computation on spreadsheet software using the field calibration, flow check and timing data. Spreadsheet entries were checked and volume computations were verified by the quality assurance group. The data processing group generated sample concentrations from the weight and volume data. A series of group checks and record checks verified the conduct of the quality control effort, holding times, and that data were within certified limits. Finally, the quality assurance program provided documentation that the database was generated in accordance with quality assurance procedures.

7.4 Assessment of Data Precision and Collocated Duplicate Sampling Results

The CMP collocated sampling effort was performed at Site AQ5, and the pairs of samplers were located approximately 3 meters from one another. Collocated samples were obtained for every sampling event. Results were calculated for all target compounds and detailed data are presented in Appendix H. Table 7.4-1 presents an overall summary of the collocated sampling results. For each target compound, the number of pairs of collocated data was tabulated, as well as the number of those pairs for which both samples were greater than the lower certified reporting limit. For TSP and PM-10 parameters, the standard EPA protocol is to delete data μa . for which either value is less than $20 \mu\text{g}/\text{m}^3$ from the overall precision calculations. The precision results were based on all data points collected for the VOC compounds, regardless of whether or not they were greater than certified reporting limits.

For the CMP, the 95 percent confidence limits were calculated on the basis of standard statistical techniques for normal distributions. If these results were within 25 percent of the sample mean, the collocated samples were classified as equivalent.

The observed 95 percent confidence limits for total suspended particulates, inhalable particulates and lead all fell within the ± 25 percent guideline. The 95 percent confidence limits for the other target metals (except for chromium and copper) also generally fell within an approximate ± 30 percent precision range. Samples were not detected at AQ5 for chromium above the lower certified reporting limit, and, therefore, precision numbers were not calculated. For copper, the average percent difference between the reference and collocated sampler was 33 percent, and the standard deviation was 48, as presented in Appendix H. The average percent difference indicates there may have been a potential bias between the reference and collocated samplers, and the standard deviation of 48 also indicates a lack of reproducibility. The average value of copper measured at site AQ5 was $0.081 \mu\text{g}/\text{m}^3$, which was compared to the minimum detection limit of approximately $0.001 \mu\text{g}/\text{m}^3$ for target volumes. Therefore the bias and non-reproducibility of the copper results cannot be explained on the basis of sample data points being very close to detection

Table 7.4-1 Collocated Sample Comparisons for FY89 at AQ5

Target	# Pairs	# >LCRL*	Average %	+95% Limit	-95% Limit
TSP	59	5	-1.9	9.3	-12.0
PM-10	53	23	3.1	13.4	-9.0
Cadmium	52	17	-4.9	21.2	-28.2
Chromium	52	0			
Copper	52	51	32.9	90.3	-43.8
Lead	52	47	0.3	23.0	-22.7
Zinc	52	52	-0.3	18.5	-18.8
Arsenic	52	26	0.6	19.9	-19.1
<u>VOC **</u>					
1,1,1-Trichloroethane	7	7	17.1	70.4	-46.3
1,1,2-Trichloroethane	7	0			
1,1-Dichloroethane	7	0			
1,2-Dichloroethane	7	0			
Bicycloheptadiene	7	0			
Benzene	7	7	5.3	67.5	-59.9
Carbon Tetrachloride	7	7	-0.3	68.8	-69.2
Methylene Chloride	7	7	-30.1	56.9	-99.4
Chloroform	7	5	12.6	66.7	-48.9
Chlorobenzene	7	0			
Dibromochloropropane	7	0			
Dicyclopentadiene	7	0			
Dimethyl Disulfide	7	0			
Ethylbenzene	7	7	4.9	60.6	-53.6
Toluene	7	7	0.8	44.7	-43.6
Methyl Isobutyl Ketone	7	0			
N-Nitrosodimethylamine	7	0			
Dimethylbenzene	7	7	8.7	70.8	-58.5
Trans-1,2-Dichloroethane	7	0			
Tetrachloroethene	7	6	-5.7	18.0	-26.1
Trichloroethene	7	0			
Xylene	7	6	-9.7	77.3	-63.5
<u>OTSP</u>					
Aldrin	49	4	3.9	15.4	-9.9
Chlordane	49	6	4.0	26.5	-20.9
Dieldrin	49	19	-16.4	13.5	-36.7
Endrin	49	2	-13.7	6.7	-26.1
Isodrin	49	2	-13.4	-1.5	-17.4
PPDDE	49	0			
PPDDT	49	0			

Table 7.4-1 Collocated Sample Comparisons for FY89 at AQ5 (continued)

Target	# Pairs	# >LCRL*	Average %	+95% Limit	-95% Limit
<u>SVOC</u>					
Atrazine	9	0			
Chlordane	9	0			
Chlorophenyl Methylsulfoxide	9	0			
Chlorophenyl Methylsulfone	9	0			
Dieldrin	9	0			
Endrin	9	0			
Isodrin	9	0			
Malathion	9	0			
PPDDE	9	0			
PPDDT	9	0			
Parathion	9	0			
Supona	9	0			

* For TSP and PM-10, below LCRL refers not to LCRL, but 20 ug/m3.

** For VOCs, precision calculations were based on all observations both above and below certified reporting limits.

Legend: PPDDE = Dichlorodiphenyldichloroethylene
PPDDT = Dichlorodiphenyltrichloroethane

limits. An explanation for these results cannot be offered at this time. However, note that average copper levels were less than 1 percent of toxic guidelines.

Average percentage differences for VOC compounds were compared to the guidelines stated in the standard methods of "general agreement of ± 25 percent." All target VOC compounds met this criteria except for methylene chloride (discussed in Section 7.3.3.1), which reported field blank levels equal to many of the actual sample values. Therefore, the lack of reproducibility could very likely be attributed to the influence of high field blank results. For many of the target VOC compounds, the 95 percent confidence limits varied. Some compounds experienced higher ranges, up to approximately ± 70 percent with methylene chloride near $\pm 80\%$. For example, the carbon tetrachloride average percent difference was -0.3 percent, indicating no bias between samples. The ± 95 percent limits were approximately 70 percent. The average carbon tetrachloride level observed at site AQ5 was $0.52 \mu\text{g}/\text{m}^3$, compared to a lower certified limit of $0.04 \mu\text{g}/\text{m}^3$ for target volumes. This indicates that the slightly higher variability of carbon tetrachloride could be attributed to many of the data points being very close to the detection limit.

Nine collocated pairs of samples were taken during FY89 for semi-volatile organic compounds. For all the target SVOCs, values were below lower certified reporting limits. Therefore there were no precision results available for SVOCs.

There were 49 collocated pairs of samples taken during FY89 for OTSP. Average percent differences for all OTSPs were within the ± 25 percent guideline. The 95 percent confidence limits ranged from approximately -37 to 27 percent, indicating little bias between samples.

7.5 Quality Assurance Field Procedures

CMP air monitoring quality assurance procedures included system quality assurance audits, performance audits of sampling equipment, and comparisons of calibration standards to other reference standards.

7.5.1 System Audits

System audits are the external inspection and review of monitoring operation and documentation. System quality assurance audits of the air sampling program for CMP were conducted by the project quality assurance coordinator. Operations that were audited included sample handling and use of sample containers or collectors, and documentation.

7.5.2 Performance Audits of Field Sampling Equipment

Performance audits were performed by personnel independent of the project. The audits consisted of testing the calibration of samplers with calibration standards other than those used to assess daily operation of the samplers.

An independent performance audit was performed on all high-volume samplers. Detailed results of the audits can be found in the CMP Project files. For each sampler, the operator-determined flow rate was compared to the auditor flow rate and a percent difference was calculated. The results were compared to EPA guidelines of ± 7 percent for an acceptable audit result. Field personnel were informed of any discrepancy and performed the required corrective action for this audit.

EPA guidelines were employed to summarize overall accuracy among the network of samplers. Calculation procedures are detailed in the Federal Register, Vol. 51, #53, March 19, 1986. The procedures call for calculating the average percent difference, standard deviation, and ± 95 percent confidence limits for all audit points for any particular type of sampler in the monitoring network. Three types of samplers were examined, including TSP samplers, PM-10 samplers, and the SVOC/OTSP samplers. For each type of sampler, the number of audits performed were recorded along with the average percent difference and the ± 95 percent confidence limits. These were compared to EPA recommended probability limits of ± 20 percent for satisfactory accuracy. Results can be found in the CMP Project files.

7.5.3 Calibration and Certification of Standards

The accuracy of flow calibration equipment was critically important for the type of monitoring performed in the CMP. Flow rate standards were calibrated against NBS traceable or other authoritative standards. Appropriate calibration intervals are yearly for the high-volume orifices and three to six months for the mass flow meter low-volume standards. The high-volume orifices and mass flow meter standards used in the CMP network were certified and compared to standards contained in the USEPA Region VIII Quality Assurance laboratory.

8.0 CONCLUSIONS

This report focuses on results of the CMP for FY89 and includes analyses and comparisons to data for preceding monitoring programs at RMA and for other programs which ran concurrently. The data were used to characterize the air quality at RMA and also to describe both the impacts of Basin F remedial activities and the cessation of those activities.

Analyses of these data were used to characterize potential sources for air contaminants which were observed, including both RMA and metropolitan Denver influences. On-site meteorological data were also used to describe those conditions associated with the average and the extreme events. Dispersion modeling was used to evaluate potential sources.

The FY89 program continued the monitoring for similar compounds which were sampled during the FY88 program. These include total suspended particulates, PM-10, asbestos, volatile organic compounds, semi-volatile organic compounds, organics in total suspended particulates, mercury, arsenic, and other metals. The following discussion summarizes the results of the analyses for each group of air quality parameters.

8.1 Total Suspended Particulates

TSP levels at RMA can be attributed to two principal sources: (1) the influx of particulates from metropolitan Denver, and (2) remedial activity sources which helped to produce wind-blown dust, particularly during very dry episodes. Intense remedial activity was initiated during FY88 and continued into FY89. These activities were concluded in several steps, including the completion of intrusive activities (December 12), the completion of the development of the clay caps (February 15), and the completion of all topsoil remediation activities (May 5). The TSP data clearly reflect the impact of these activities, with dramatic decreases in TSP levels around Basin F after the conclusion of remedial activities. During the height of the Basin F activities, the TSP levels which could be attributed to remediation activities decreased significantly with distance from the basin. This feature was observed both in the FY88 and FY89 data. In addition, there were several episodes during which impacts from metropolitan Denver completely overwhelmed impacts from potential on-site sources. At the eastern and northern boundaries of RMA, the TSP levels were well below those of metropolitan Denver, and were more representative of rural conditions.

8.2 Respirable Particulates (PM-10)

Respirable particulates are generated by dry windy conditions, but to a much lesser extent than for TSP. There were no violations of the annual PM-10 standard at RMA during FY89, and there was only one violation of the 24-hour standard. The high PM-10 levels at RMA could be related to relatively high PM-10 levels in metropolitan Denver. Remediation activities played no apparent role in increasing PM-10 levels.

8.3 Metals

Ambient concentrations of metals across RMA were generally proportional to levels of TSP. Maximum concentrations were sampled on days when there were high TSP and PM-10 levels, which in turn were attributed to sources off the Arsenal. During remediation activities, Basin F appeared to be a source of mercury, chromium, copper and zinc, and these concentrations decreased rapidly with distance from Basin F. Following closure of the basin, the metals levels were reduced to those typical of baseline conditions.

8.4 Asbestos

Asbestos was detected at RMA on only two days during FY89. These detections occurred on days during which there were relatively high levels of TSP, which had in turn been attributed to metropolitan Denver sources. There were no detections of asbestos during FY88, and the FY89 results confirm that there is no evident source of ambient asbestos fibers on RMA.

8.5 Volatile Organic Compounds

During the Basin F remediation, on-site activities appeared to be a source of several volatile organic compounds, including bicycloheptadiene, dimethyl disulfide, benzene, toluene, and ethylbenzene. Some of these emissions could have resulted from the emissions from heavy equipment which was used during remediation. Chloroform was identified near both Basin F and the South Plants. Levels of VOCs which were attributed to RMA sources decreased rapidly with distance from those sources, and levels at RMA boundaries were similar to or less than those within the urban environment of metropolitan Denver.

8.6 Semi-Volatile Organic Compounds

Basin F appeared to be a source of several semi-volatile organic compounds, including aldrin, dieldrin, and endrin. The highest levels were detected in the immediate vicinity of Basin F during the remediation efforts. Results from BF2, at the northeast perimeter of Basin F, showed the highest levels of SVOCs, but at the RMA boundaries, these levels were reduced to roughly background levels.

8.7 Organics in Total Suspended Particulates

These compounds, essentially the organo-chlorine pesticides, were at or near the detection limit at the RMA boundary sites. Highest levels were sampled during the Basin F remediation effort, and nearest to Basin F itself. Following the completion of the remedial activities, these levels were reduced to near background levels in the vicinity of Basin F as well.

8.9 Criteria Pollutants

Ambient concentrations of the criteria pollutants, including sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone were monitored on RMA for roughly five months during FY89. Generally the air quality at the RMA monitoring location was cleaner than that at other sites in the Denver area. The RMA data showed no violations of any short-term or long-term standards for these pollutants. Episodes with relatively high concentrations at RMA were related to potential nearby sources under certain meteorological conditions.

8.10 General Interpretations

All data reported in this report must be interpreted and used with full regard to the limitations of the program. These include sampling frequency, analysis limitations, and the fact that the samples were collected on a limited number of days during a limited observation period. The interpretations must also consider any possible influences of metropolitan Denver sources on RMA ambient air quality. As more data are collected under subsequent programs, these conclusions will be refined and reinterpreted.

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