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THE FISCAL YEAR 1990 SURFACE WATER REPORT IS DIVIDED INTO SIX SECTIONS AND TWO APPENDICES. SECTION 1 PROVIDES A BRIEF HISTORICAL REVIEW OF THE SURFACE WATER PROGRAM AT THE RMA. SECTION 2 PROVIDES THE GENERAL SETTING, THE DEFINED DRAINAGE BASIN AND SURFACE WATER FEATURES AT RMA. SECTION 3 PROVIDES A DETAILED DISCUSSION OF FY90 SURFACE WATER CMP STRATEGIES AND METHODOLOGIES. SECTION 4 PRESENTS THE WATER QUALITY AND QUANTITY DATA COLLECTED DURING FY90 IN THE MAJOR RMA DRAINAGE BASINS. SECTION 5 PROVIDES AN ASSESSMENT OF THE COLLECTED SURFACE WATER DATA. SECTION 6 PROVIDES CONCLUSIONS AND EXAMINES TRENDS OF FY90 DATA COMPARED TO PREVIOUS YEAR DATA. APPENDIX A INCLUDES INFORMATION RELATED TO SURFACE WATER QUANTITY AND APPENDIX B INCLUDES INFORMATION RELATED TO SURFACE WATER QUALITY.

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Appendix B

4.0 PROGRAM RESULTS

4.1 SURFACE-WATER QUANTITY RESULTS

This section presents hydrologic information that was obtained during Water Year 1990. This information comprises climatic, stream, lake and pond data, including results from each component of the surface-water monitoring network that was established under previous contracts and newly established during the 3 years of the surface-water CMP. The components of the surface-water quantity program addressed in this section are gaging station data, lake and pond data, discharge to streams, lakes or channels that originate on RMA, and climatological data. The climatic data includes RMA temperature, precipitation and evaporation conditions. Volumes calculated for lakes, streams and effluents (e.g., Sewage Treatment Plant) are presented in this section. Hydrographic analyses are presented for surface-water trends and extremes for quantity monitoring stations during Water Year 1990. Hydrographic results of quantity monitoring stations are presented to illustrate surface-water trends and extremes during Water Year 1990. Appendix A contains all detailed water quantity information compiled during Water Year 1990.

4.1.1 1990 CLIMATOLOGICAL CONDITIONS

The prevailing climatic conditions that affect surface-water at RMA include temperature, precipitation and evaporation. Weather statistics have been compiled for Water Year 1990 by the CMP Surface-Water Element using several sources of data. Precipitation and temperature information was obtained from the National Weather Service Station located 2 miles south of RMA at Stapleton Airport and the CMP air element of RMA which monitors four weather towers located throughout the Arsenal. An additional rain gage near the South Plants area was monitored by the CMP Surface-Water Element, and evaporation data were obtained by the USACOE from Cherry Creek Reservoir. Table 4.1-1 summarizes Water Year 1990 weather statistics, which includes monthly totals and averages of temperature, precipitation and evaporation data. A comparison of precipitation data from Stapleton Airport with evaporation data from Cherry Creek Reservoir is displayed in Figure 4.1-1; whereas, Figure 4.1-2 compares monthly totals of precipitation data collected from Stapleton Airport, CMP air element and the South Plants rain gage. There was minimal variation between the South Plants rain gage and CMP air elements precipitation data in Water Year 1990, but Stapleton Airport recorded higher monthly precipitation totals for 8 months of

Table 4.1-1 Monthly Temperature, Precipitation and Evaporation Data, Water Year 1990

	CMP AIR ELEMENT[1]		STAPLETON AIRPORT[2]		SOUTH PLANTS RAIN GAGE[3]	CHERRY CREEK[4]
MONTH	Average Temp (F)	Total Precipitation (inches)	Average Temp (F)	Total Precipitation (inches)	Total Precipitation (inches)	Total Evaporation (inches)
October	51.06	0.29	51.3	0.81	0.57	4.30
November	42.73	0.03	42.8	0.15	0.23	2.70
December	27.68	0.22	27.3	0.81	0.16	0.90
January	36.16	0.32	36.4	0.74	0.48	0.70
February	32.44	0.11	33.3	0.55	0.24	0.90
March	38.45	1.97	39.5	3.10	2.22	1.60
April	47.47	0.58	49.1	1.01	0.79	3.20
May	54.89	1.58	56.6	1.51	1.50	6.27
June	71.78	0.28	72.6	0.21	0.29	9.97
July	68.87	2.58	70.8	3.57	2.32	7.72
August	69.70	2.42	71.3	1.96	1.23	7.71
September	65.44	1.18	66.9	1.46	1.01	6.37
Monthly Ave.	50.56	0.96	51.49	1.32	0.92	4.36
YEARLY TOTALS		11.56		15.88	11.04	52.34

1 CMP, Air Element compilation of four meteorological towers on RMA.
2 NOAA Monthly Summaries, Stapleton Airport Weather Station.
3 South Plant Rain Gage with no temperature recorded, Monitored by CMP Surface-Water personnel.
4 Department of Defense, Corps of Engineers, Cherry Creek Reservoir.

the year (Table 4.1-1, Figure 4.1-2). Appendix A-11 contains the daily precipitation records for each month in Water Year 1990 based on data collected by the CMP air element at RMA.

Temperatures measured at the Stapleton Airport weather station followed a general trend of decreasing temperatures from September to January and increasing temperatures from January to August. June was the hottest month in Water Year 1990 with an average temperature of 72°F, whereas December was the coldest month with an average temperature of 27°F. The highest daily mean temperature was 86°F recorded on June 27, and the lowest daily mean temperature was -3°F recorded on December 21 and 22. The average annual temperature for Water Year 1990 was 51.5°F, based on the Stapleton Weather Station (Table 4.1-1).

Evaporation followed a normal decreasing trend from September to January and an increasing trend from January to August with a deviation from normal in June which recorded 9.97 in. of evaporation; a high for Water Year 1990. January had the lowest monthly recording of 0.70 in. of evaporation. Water Year 1990 had an accumulated total of 52.34 in. of evaporation which exceeded precipitation by 36 in. and averaged 4.36 in. of evaporation per month. Total monthly precipitation was lower than total evaporation in every month except January and March (Figure 4.1-1). Evaporation values had been determined by collecting daily pan evaporation readings in conjunction with nomograph data at Cherry Creek Reservoir. The nomograph determined evaporation by using mean daily temperature, solar radiation, mean daily dew point temperature and wind movement data. Due to freezing, the months of November 1989 through April 1990 were estimated from earlier years.

Based on the National Weather Service records at Stapleton Airport (Table 4.1-1), the total precipitation for Water Year 1990 was 15.88 inches. This is marginally higher than last year's total and is 1.23 in. greater than the Weather Service 30-year normal precipitation. Recent extreme annual precipitation amounts recorded at Stapleton Airport are a high of 23.3 in. in 1967 and a low of 8.45 in. during 1962. The highest monthly total for Water Year 1990 was 3.57 in. recorded in July and the lowest monthly total was 0.15 in. in November. The most precipitation to fall within a 24-hour period in Water Year 1990 was 1.34 in. on July 9, which was during a 9-day period of rain, between July 3 and July 11, in which a total of 1.64 in. of rain fell. Frequent summer thunderstorms contributed significant amounts of precipitation on RMA in July and August.

During summer thunderstorms some areas of RMA may receive a measurable amount of precipitation while other areas may receive none at all. The acquisition of the CMP air element precipitation record and the surface-water element South Plants rain gage assist in documenting this phenomena. A 7-day period of rain from August 14 to August 20 displayed large variations in accumulated rainfall. Stapleton weather station recorded 0.75 in. during this period, whereas the CMP air element and the South Plants rain gage recorded 2.03 in. and 0.63 in. respectively.

CMP surface-water personnel observed during the summer that many afternoon storms on RMA were regionally isolated and covered only sections of the Arsenal, usually moving in from the west. The CMP air element has four meteorological monitoring stations on RMA (Figure 2.3-2) The meteorological tower M4 was the primary station used for data collection, but substitutions were made from stations M1, M2 and M3, if needed. The M4 tower is located near the south boundary of Section 25 about 5 mi north of Stapleton's weather station, and is 1.5 mi north of the South Plants rain gage. The other meteorological towers are located in Sections 25, 26 and 36 (Figure 2.3-2). Stapleton's weather stations recorded higher precipitation for 8 months of Water Year 1990 and lower precipitation for the remaining 4 months. The CMP air element rain gage followed the same precipitation trends as Stapleton, but recorded less precipitation (4.32 in.) for the year. The South Plants Rain Gage located just south of the plant near "D" Street (Figure 2.3-2) had fluctuating monthly values compared to the Stapleton Weather Station and CMP air element records during Water Year 1990 but the yearly total was 11.04 in., less than 0.5 in. difference when compared to the CMP air element's yearly total. Average monthly temperatures from Stapleton and the CMP air element were consistent during Water Year 1990 and differed by less than 1 degree between stations.

4.1.2 HAVANA INTERCEPTOR GAGING STATION

Havana Interceptor is located in the Irondale Gulch drainage basin and receives storm sewer runoff from the southern portion of Montbello and also receives surface runoff from the undeveloped area east of Montbello (Figure 2.3-2). The drainage area above the station is 5.23 sq mi, of which 2.6 sq mi is urban storm sewer drainage. Stream stage is monitored with a Campbell Scientific CR-10 (digital) data logger/bubbler system. This station does not have a staff gage or a Stevens Type F (analog) recorder backup in place due to the lack of a suitable location for this type of equipment.

4.1.2.1 Stage-Discharge Relationships

The stage-discharge relationship at the Havana Interceptor gaging station is depicted by the rating curve for the station. HEC-2 channel analysis (USACOE, 1982) was employed to develop the Havana Interceptor rating curve. The rating curve is validated and refined by obtaining instantaneous discharge measurements throughout the year.

4.1.2.1.1 Continuous Stage Data

The discharge record for Havana Interceptor was produced by converting the digital stage data of the CR-10 data logger to computed instantaneous discharge values derived from the newly revised stage-discharge relationship. The computed instantaneous discharge values are then compiled and reduced to mean daily discharges (Appendix A-8). Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards, where "excellent" means that about 95 percent of the reported daily mean discharges for a specified time period are within ±5 percent of actual; "good" within ±10 percent; "fair" within ±15 percent; and "poor" means that approximately 95 percent of the reported daily mean discharges have less than "fair" accuracy (Rantz, 1982).

The continuous stage record at Havana Interceptor for Water Year 1990 is considered poor. Periods of estimated records include:

- December 4, 10, 11, 13-15, 20-31, 1989;
- January 1, 31, 1990;
- February 2-4, 15-17, 1990;
- April 1-14, 1990;
- May 1-31, 1990;
- June 1-11, 24-30, 1990;
- July 1-3, 10-31, 1990; and
- August 1, 7-24, 1990.

Stage data were collected at the Havana Interceptor station throughout the freezing months of Water Year 1990; however, ice conditions in the channel sometimes produced erroneous stage values when flow was not occurring and the record was estimated during these periods between December 1989 and February

1990. A significant portion of data were lost between April and August during Water Year 1990 due to malfunctions in the station's CR-10 data logger. Estimates of stream stage based on observed stage readings during weekly monitoring rounds and flow at Peoria Interceptor were used to fill in areas of missing or incorrect data in the Havana Interceptor stage record. Peoria Interceptor's record was used to make these estimates because changes in stage at the two stations are very similar and the stations are also located within the same drainage basin. The CR-10 unit was replaced in August 1990 and performed satisfactorily the remainder of Water Year 1990.

4.1.2.1.2 Rating Curves and Equations

The methodology for rating curve development and rating curve verification generally followed standard procedures described in USGS Water Supply Paper 2175 (Rantz, 1982). Rating equations were developed to mathematically describe the straight-line segments of the rating curve and are presented in Appendix A-4.

The rating curves for each of the gaging stations at RMA have varying degrees of accuracy for the defined and extrapolated regions, primarily because of the structure's complex hydraulic behavior at various stages or the lack of verifiable instantaneous discharge measurements at high and/or very low flows as described in Appendix A-3.1. Havana Interceptor is the only RMA surface-water station that does not have a structure that controls the water surface profile upstream of the station. Each rating equation, therefore, has a unique characteristic curve that represents the combined factors of channel geometry, channel bed conditions, bank geometry and channel approach conditions, artificial structure size and type, and streamflow conditions. Structure, channel control and rating curve types for each station are described in Table 4.1-2.

A theoretical rating curve was previously developed for Havana Interceptor using the USACOE Water Surface Profile Model, HEC-2 (USACOE, 1982), to predict gage heights and corresponding discharges from channel geometry. This method of determining the stage-discharge relationship was considered best, as limited verifiable instantaneous discharge and staff measurements were available for empirical rating curve development in Water Year 1989. During Water Year 1990, however, nine verified instantaneous discharge and staff measurements were taken (Appendix A-5). These subsequent measurements indicated that a slight adjustment was justified in the lower region of the rating curve. Since there were no verified instantaneous discharge and staff measurements made in the upper region of the rating curve, rating curve

Table 4.1-2 Surface-Water Structures, Channel Control and Rating Curves at RMA Gaging Stations

Station	Structure	Control	Rating
Irondale Gulch Drainage Basin			
Havana Interceptor	Concrete-lined Channel	Channel	Theoretical
Peoria Interceptor	90° V-notch Weir Plate/Sharp-crested	Section	Empirical
Ladora Weir	Standard Suppressed Rectangular Weir	Section	Empirical-Laboratory
South Uvalda	Broad-crested Weir with V-notch	Compound	Empirical
North Uvalda	Broad-crested Weir with V-notch	Compound	Empirical
Highline Lateral	Cipolletti Weir	Section	Empirical
South Plants Ditch	90° V-notch Weir Plate/Sharp-crested Suppressed Rectangular Weir	Section	Empirical-Laboratory
First Creek Drainage Basin			
South First Creek	V-notch concrete weir	Section	Empirical
North First Creek	V-notch concrete weir	Section	Empirical
First Creek Off-Post	Concrete Triangular-throated flume	Section	Empirical-Laboratory
South Platte Drainage Basin			
Basin A	90° V-notch Weir Plate	Section	Empirical-Laboratory
Basin F	Galvanized sheet-metal 200mm long-throated flume	Section	Empirical-Laboratory

revision was confined to the lower region. The adjusted rating curve is considered good, both in the defined and extrapolated regions. The rating curve for Havana Interceptor is presented in Appendix A-3.2.

4.1.2.2 Surface-Water Hydrologic Conditions

Havana Interceptor's drainage area is a predominantly urban watershed and flow at the station is intermittent. Sources of surface-water at Havana Interceptor and other RMA continuous monitoring stations are presented in Table 4.1-3. Discharge records for Havana Interceptor and all other RMA surface-water monitoring stations are presented in Appendix A-8. Streamflow conditions for Havana Interceptor including mean monthly discharge, maximum daily discharge, minimum daily discharge and total monthly streamflow volume are presented in the following sections.

4.1.2.2.1 Streamflow Characteristics and Extremes

Havana Interceptor exhibits flow characteristics typical of stations not influenced by diversions and inflows from controlled releases. Flow is derived primarily from off-post sources and contributes to the overall inflow volume of water to RMA. Precipitation occurring on RMA does not contribute significantly to flow in Havana Interceptor since tributary drainage is limited and poorly defined.

Maximum flows occur primarily in the spring and summer as the result of snowmelt runoff, thunderstorms and extended rainfall events. A significant proportion of precipitation produces runoff to this station due to reduced infiltration in the urban watershed area. Minimum flows occur primarily in the fall and winter when conditions are dry or when water in the channel is frozen. The maximum monthly runoff volume during Water Year 1990 was 220.96 ac-ft (0.79 in. over the 5.22 sq mi drainage area) and occurred in May 1990. The minimum monthly runoff volume was greater than 0.00 ac-ft but less than 0.01 ac-ft which is the minimum volume that can be reported reliably. Only trace amounts of flow occurred in December 1989 and January 1990.

Diurnal fluctuations were recorded at Havana Interceptor during Water Year 1990. Daily peaks in streamflow during baseflow conditions generally occur in the evening to early morning, indicating that reduced evapotranspiration rates and evening or nightly lawn watering may contribute to streamflow during this time period. Similar diurnal flow conditions are present at Peoria Interceptor and South

Table 4.1-3 Surface-Water Sources at RMA Gaging Stations

Station	Primary Source of Surface-water	Secondary Source of Surface-water
Irondale Gulch Drainage Basin		
Havana Interceptor	Urban Runoff	Direct Precipitation
Peoria Interceptor	Urban Runoff	Direct Precipitation
Ladora Weir	Controlled Releases from Lower Derby Lake	None
South Uvalda	Baseflow (ground-water inflow)	Urban Runoff/Direct Precipitation
North Uvalda	Controlled Releases from Highline Lateral and/or South Uvalda	Urban Runoff/Direct Precipitation
Highline Lateral	Controlled Flow diverted from South Platte River	None
South Plants Ditch	Watershed Runoff	None
First Creek Drainage Basin		
South First Creek	Baseflow (ground-water inflow)/Watershed Runoff	Direct Precipitation/ Controlled Flow from Highline Canal
North First Creek	Baseflow (ground-water inflow)/Watershed Runoff	Direct Precipitation/ Controlled Flow from Highline Canal
First Creek Off-Post	Baseflow (ground-water inflow)/Watershed Runoff	Controlled Flow from Highline Canal
South Platte Drainage Basin		
Basin A	Baseflow (ground-water inflow)	Watershed Runoff
Basin F	Direct Precipitation	Watershed Runoff

Uvalda Interceptor; however, direct comparisons are difficult to make due to differences in the storm sewers and open channel drainages contained within the respective drainage areas.

4.1.2.2.2 Annual Streamflow Analysis

Streamflow at Havana Interceptor varied considerably throughout Water Year 1990 as illustrated in the monthly total discharge hydrograph (Figure 4.1-3). Minimal flows occurred from October 1989 through February 1990; however, streamflow was significantly higher from March 1990 through September 1990. The mean daily peak flow was recorded in May, 1990 and the instantaneous discharge peak occurred in July 1990.

Total discharge fluctuated cyclicly from mid-winter to mid-summer with each month varying from high water volume to moderately low water volume. These fluctuations are reflected in the monthly precipitation record which also displays a similar pattern (Figure 4.1-2). The initial water volume peak of 192.91 ac-ft in March 1990 is indicative of a late winter response to thawing, increased precipitation and snowmelt runoff. A period of low precipitation reduced flow to only 33.02 ac-ft in April 1990; however, high precipitation in May 1990 increased the water discharge volume to 220.96 ac-ft, which was the maximum monthly water volume for Havana Interceptor in Water Year 1990. Late spring was relatively dry at RMA and the total discharge was reduced significantly in June 1990 to 30.43 acre-feet. Several long duration storm events occurred during July 1990 and subsequently increased the total discharge volume to 165.92 acre-feet. Water volumes generally decreased throughout the summer, as soil moisture was depleted due to increased evapotranspiration and reduced amounts of precipitation. The total discharge volumes measured in August 1990 and September 1990 were 133.79 ac-ft and 93.60 ac-ft respectively. A total of 901.45 ac-ft (2.94×10^8 gallons) was measured at the station during Water Year 1990. This is equivalent to 3.11 in. of runoff from the watershed (28.2 percent of the precipitation measured at the South Plants Rain Gage).

4.1.2.2.3 Mean Monthly, Maximum Daily and Minimum Daily Flows

The mean monthly flows at Havana Interceptor ranged from only trace amounts in December 1989 and January 1990, to a maximum of 3.6 cfs in May 1990. Mean monthly flows were highest in late winter and mid-spring. Maximum daily flows were generally 6 to 17 times greater than the mean monthly flows, which indicates that the maximum high flow events are usually short duration and do not contribute significantly to the mean monthly discharge. Minimum daily flows were as low as 0.00 cfs during November and December 1989, and January through March 1990. Maximum daily flows ranged from 0.76 cfs in February 1990 to 48.0 cfs in May 1990. A monthly summary of daily minimum, maximum and mean discharges for all RMA surface-water monitoring stations during Water Year 1990 is presented in Table 4.1-4. Annual plots for these values are illustrated in Figure 4.1-14 and Figure 4.1-25.

4.1.2.2.4 Streamflow Storm Runoff Hydrographs

Streamflow storm hydrographs observed at RMA during Water Year 1990 represent flow conditions in response to precipitation events typical for this area of Colorado. Precipitation data were acquired by the CMP air element and are used for comparisons with the stream hydrographs. Six high or extended storm events (March 5, 6, 1990; May 29, 30, 1990; July 7-11 and 29, 1990; August 14-20, 1990; September 17-21, 1990) were analyzed to describe their effect on flow conditions at Havana Interceptor (Table 4.1-5). The storms that occurred during late winter and spring produced high accumulations of precipitation over 2-day periods. Storm duration for the March 1990 event totaled 22 hours, and the duration of the May 1990 event was 10 hours. Storm events occurring in the summer generally exhibited high accumulations of precipitation occurring over 5 days or more with several discrete thunderstorms of short duration (usually 3 hours or less) occurring within these multiday events. The single day event recorded during the summer (July 29, 1990) was a brief thunderstorm with a very high amount of precipitation measured.

Havana Interceptor responded to storm events in a manner that is typical of watersheds affected by urbanization. Stream response occurred shortly after the onset of precipitation, and peak flow was usually reached in less than 3 hours. Streamflow recession was also relatively rapid, and generally lasted 6 to 10 hours. Other RMA surface-water monitoring stations that exhibit a storm response similar to Havana Interceptor include Peoria Interceptor, South Uvalda and Basin A.

Table 4.1-4 Summary of Daily Minimum and Maximum Discharges, Instantaneous Minimum and Maximum Discharges and Mean Daily Discharge for Each Month of Record, at RMA Gaging Stations during Water Year 1990

Station	Daily Minimum Discharge (cfs)	Instantaneous Minimum Discharge (cfs)	Daily Maximum Discharge (cfs)	Instantaneous Maximum Discharge (cfs)	Daily Mean Discharge (cfs)
October 1989					
Havana Interceptor	0.01	0.00	3.7	12	0.27
Peoria Interceptor	0.00	0.00	0.77	5.8	0.06
Ladora Weir	0.00	0.00	0.00	0.00	0.00
South Uvalda	0.26	0.22	1.8	4.4	0.40
North Uvalda	0.00	0.00	1.0	6.6	0.07
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.06	0.05	0.42	0.45	0.27
North First Creek	0.00	0.00	0.00	0.00	0.00
First Creek Off-Post	0.00	0.00	0.02	0.02	0.01
Basin A	T	T	T	T	T
Basin F	0.00	0.00	0.00	0.00	0.00
November 1989					
Havana Interceptor	0.00	0.00	2.8	16	0.16
Peoria Interceptor	0.00	0.00	1.6	11	0.08
Ladora Weir	0.00	0.00	0.00	0.00	0.00
South Uvalda	0.31	0.29	1.2	4.5	0.44
North Uvalda	0.00	0.00	0.00	0.00	0.00
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.46	0.43	0.82	1.7	0.59
North First Creek	0.00	0.00	0.00	0.00	0.00
First Creek Off-Post	0.02	0.01	0.05	0.10	0.03
Basin A	NR	NR	NR	NR	NR
Basin F	0.00	0.00	0.00	0.00	0.00
December 1989					
Havana Interceptor	0.00	0.00	T	T	T
Peoria Interceptor	0.00	0.00	0.26	1.6	0.03
Ladora Weir	0.31	0.22	1.2	3.6	0.44
South Uvalda	0.00	0.00	0.00	0.00	0.00
North Uvalda	0.00	0.00	0.00	0.00	0.00
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.39	0.35	0.83	1.1	0.63
North First Creek	0.00	0.00	0.00	0.00	0.00
First Creek Off-Post	0.00	0.00	0.09	0.20	0.03
Basin A	NR	NR	NR	NR	NR
Basin F	0.00	0.00	0.00	0.00	0.00

T = (> 0.00 cfs, < 0.005 cfs)
Reported values rounded to two significant figures.
NR = no record

Table 4.1-4 Summary of Daily Minimum and Maximum Discharges, Instantaneous Minimum and Maximum Discharges and Mean Daily Discharge for Each Month of Record, at RMA Gaging Stations during Water Year 1990 (continued)

Station	Daily Minimum Discharge (cfs)	Instantaneous Minimum Discharge (cfs)	Daily Maximum Discharge (cfs)	Instantaneous Maximum Discharge (cfs)	Daily Mean Discharge (cfs)
January 1990					
Havana Interceptor	0.00	0.00	T	T	T
Peoria Interceptor	0.00	0.00	0.34	1.6	0.06
Ladora Weir	0.00	0.00	0.00	0.00	0.00
South Uvalda	0.29	0.26	1.2	5.3	0.45
North Uvalda	0.00	0.00	0.00	0.00	0.00
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.59	0.51	1.1	1.2	0.83
North First Creek	0.00	0.00	0.42	7.7	0.03
First Creek Off-Post	0.00	0.00	0.00	0.00	0.00
Basin A	NR	NR	NR	NR	NR
Basin F	0.00	0.00	0.00	0.00	0.00
February 1990					
Havana Interceptor	0.00	0.00	0.76	6.7	0.09
Peoria Interceptor	T	0.00	0.37	1.9	0.03
Ladora Weir	0.00	0.00	0.00	0.00	0.00
South Uvalda	0.30	0.29	0.94	3.2	0.40
North Uvalda	0.00	0.00	0.00	0.00	0.00
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.74	0.61	1.2	1.3	0.91
North First Creek	0.00	0.00	0.46	1.0	0.16
First Creek Off-Post	0.00	0.00	0.15	0.16	0.02
Basin A	NR	NR	NR	NR	NR
Basin F	0.00	0.00	0.00	0.00	0.00
March 1990					
Havana Interceptor	0.00	0.00	28	410	3.1
Peoria Interceptor	T	T	4.6	27	0.86
Ladora Weir	0.00	0.00	0.00	0.00	0.00
South Uvalda	0.33	0.31	12	74	1.7
North Uvalda	0.00	0.00	0.00	0.00	0.00
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.82	0.79	11	24	2.0
North First Creek	0.40	0.28	18	27	2.5
First Creek Off-Post	0.17	0.02	6.3	9.4	1.8
Basin A	NR	NR	NR	NR	NR
Basin F	0.00	0.00	0.26	1.3	0.02

T = (> 0.00 cfs, < 0.005 cfs)
Reported values rounded to two significant figures.
NR = No record

Table 4.1-4 Summary of Daily Minimum and Maximum Discharges, Instantaneous Minimum and Maximum Discharges and Mean Daily Discharge for Each Month of Record, at RMA Gaging Stations Water Year 1990 (continued)

Station	Daily Minimum Discharge (cfs)	Instantaneous Minimum Discharge (cfs)	Daily Maximum Discharge (cfs)	Instantaneous Maximum Discharge (cfs)	Daily Mean Discharge (cfs)
April 1990					
Havana Interceptor	0.00	0.00	4.8	59	0.56
Peoria Interceptor	T	0.00	1.9	25	0.16
Ladora Weir	0.00	0.00	0.00	0.00	0.00
South Uvalda	0.28	0.15	3.6	40	0.71
North Uvalda	0.00	0.00	0.03	0.04	T
Highline Lateral	0.00	0.00	0.00	0.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.80	0.79	1.7	2.3	1.2
North First Creek	0.84	0.77	1.8	1.9	1.2
First Creek Off-Post	0.79	0.74	2.00	2.1	1.2
Basin A	NR	NR	NR	NR	NR
Basin F	0.00	0.00	0.00	0.00	0.00
May 1990					
Havana Interceptor	0.04	0.00	48	190	3.6
Peoria Interceptor	T	0.00	6.5	29	0.40
Ladora Weir	0.00	0.00	0.00	0.00	0.00
South Uvalda	0.40	0.26	15	83	1.4
North Uvalda	0.00	0.00	1.7	14	0.09
Highline Lateral	0.00	0.00	24	29	3.9
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.48	0.45	3.1	6.0	1.0
North First Creek	0.20	0.17	1.5	2.1	0.79
First Creek Off-Post	0.11	0.07	1.4	1.5	0.63
Basin A	NR	NR	NR	NR	NR
Basin F	0.00	0.00	0.00	0.00	0.00
June 1990					
Havana Interceptor	0.02	0.00	3.2	45	0.51
Peoria Interceptor	0.04	0.01	1.2	18	0.14
Ladora Weir	0.00	0.00	19	21	3.8
South Uvalda	0.41	0.26	2.9	33	0.78
North Uvalda	0.00	0.00	18	26	4.6
Highline Lateral	0.00	0.00	22	30	10
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.03	0.01	1.4	1.9	0.40
North First Creek	0.00	0.00	0.84	1.1	0.07
First Creek Off-Post	0.00	0.00	0.92	1.2	0.13
Basin A	NR	NR	NR	NR	NR
Basin F	0.00	0.00	0.00	0.00	0.00

T = (> 0.00 cfs, < 0.005 cfs)
Reported values rounded to two significant figures.
NR = No record

Table 4.1-4 Summary of Daily Minimum and Maximum Discharges, Instantaneous Minimum and Maximum Discharges and Mean Daily Discharge for Each Month of Record, at RMA Gaging Stations Water Year 1990 (continued)

Station	Daily Minimum Discharge (cfs)	Instantaneous Minimum Discharge (cfs)	Daily Maximum Discharge (cfs)	Instantaneous Maximum Discharge (cfs)	Daily Mean Discharge (cfs)
July 1990					
Havana Interceptor	0.11	0.00	24	460	2.7
Peoria Interceptor	0.05	0.00	6.7	72	0.63
Ladora Weir	0.00	0.00	0.06	0.06	0.02
South Uvalda	0.34	0.22	14	320	1.4
North Uvalda	0.00	0.00	0.79	6.0	0.05
Highline Lateral	0.00	0.00	16	18	4.7
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.00	0.00	1.8	8.8	0.58
North First Creek	0.00	0.00	0.00	0.00	0.00
First Creek Off-Post	0.00	0.00	0.05	0.40	0.01
Basin A	NR	NR	NR	NR	NR
Basin F	0.00	0.00	0.01	0.24	T
August 1990					
Havana Interceptor	0.00	0.00	21	450	2.2
Peoria Interceptor	0.02	0.00	4.7	40	0.49
Ladora Weir	0.00	0.00	10	33	0.51
South Uvalda	0.39	0.24	19	360	2.3
North Uvalda	0.00	0.00	13	20	0.72
Highline Lateral	0.00	0.00	19	23	4.4
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.03	0.01	68	310	3.3
North First Creek	0.00	0.00	9.0	23	1.3
First Creek Off-Post	0.00	0.00	14	18	1.2
Basin A	NR	NR	NR	NR	NR
Basin F	0.00	0.00	0.04	0.52	T
September 1990					
Havana Interceptor	0.47	0.02	18	370	1.6
Peoria Interceptor	0.02	0.00	5.1	44	0.37
Ladora Weir	0.00	0.00	11	11	3.1
South Uvalda	0.42	0.34	7.8	82	0.95
North Uvalda	0.00	0.00	18	26	1.3
Highline Lateral	0.00	0.00	17	20	9.8
South Plants Ditch	0.00	0.00	0.00	0.00	0.00
South First Creek	0.06	0.03	0.82	2.5	0.37
North First Creek	0.00	0.00	2.8	3.1	0.58
First Creek Off-Post	0.06	0.05	2.1	2.2	0.38
Basin A	NR	NR	NR	NR	NR
Basin F	0.00	0.00	0.00	0.00	0.00

T = (> 0.00 cfs, < 0.005 cfs)
Reported values rounded to two significant figures.
NR = No record

Table 4.1-5 Comparison of High and Extended Precipitation Events and Mean Daily Discharges for Water Year 1990

Date	3/5	3/6	5/29	5/30	7/7	7/8	7/9	7/10	7/11	7/29
TOTAL DAILY PRECIPITATION* (in)	0.60	0.81	0.98	0.26	0.09	0.22	0.64	0.12	0.02	0.90
MEAN DAILY DISCHARGE (cfs)										
South Uvalda	8.20	12.00	15.00	4.50	0.90	1.60	14.00	1.10	0.70	7.60
Peoria Interceptor	2.80	4.40	6.40	1.60	0.37	1.30	2.90	0.20	0.10	6.60
Havana Interceptor	13.00	24.00	48.00	4.00	0.83	2.50	24.00	4.60	0.41	23.00
Basin A	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
South First Creek	1.20	11.0	1.30	2.30	0.01	0.01	0.53	0.19	0.44	0.45
North First Creek	0.57	4.90	0.36	1.10	0.00	0.00	0.00	0.00	0.00	0.00
First Creek Off-Post	0.22	0.26	0.17	0.79	0.00	0.02	0.04	0.03	0.02	0.05
Basin F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0[illegible]
North Uvalda	0.00	0.00	0.00	0.00	0.14	0.10	0.08	0.02	0.00	T
Ladora Weir	0.00	0.00	0.00	0.00	0.06	0.06	0.06	0.02	0.00	0.00
Highline Lateral	0.00	0.00	0.00	0.00	0.00	0.00	0.03	3.10	15.00	0.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

T = Discharge >0.00 cfs, <0.005 cfs
* = Precipitation data from CMP Air Element
NR = No record

SWAR-90.TB2

Table 4.1-5 Comparison of High and Extended Precipitation Events and Mean Daily Discharges for Water Year 1990 (continued)

Date	8/14	8/15	8/16	8/17	8/18	8/19	8/20	9/17	9/18	9/19	9/20	9/21
TOTAL DAILY PRECIPITATION* (in)	0.03	0.72	0.00	0.19	0.06	0.98	0.05	0.04	0.72	0.09	0.10	0.01
MEAN DAILY DISCHARGE (cfs)												
South Uvalda	0.51	19.00	1.10	2.50	0.83	11.00	1.10	0.90	7.80	2.30	1.00	0.67
Peoria Interceptor	0.02	1.90	0.10	0.87	0.10	4.60	1.30	0.03	5.10	2.00	1.40	0.17
Havana Interceptor	0.53	6.60	1.90	4.30	1.70	13.00	5.40	0.89	18.00	4.90	2.70	1.20
Basin A	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
South First Creek	0.03	0.40	0.22	0.11	0.41	68.00	17.00	11.00	3.00	4.60	0.56	0.56
North First Creek	0.00	0.00	0.00	0.00	0.00	8.90	9.00	0.00	0.00	0.00	0.00	0.00
First Creek Off-Post	0.00	0.02	0.00	0.00	0.00	1.40	14.00	0.07	0.09	0.08	0.08	0.08
Basin F	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
North Uvalda	0.02	0.03	0.00	0.00	0.00	0.00	0.00	T	T	T	0.00	0.00
Ladora Weir	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Highline Lateral	0.00	0.00	0.00	0.00	0.00	0.00	8.30	11.00	13.00	16.00	11.00	11.00
South Plants Ditch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

T = Discharge >0.00 cfs, <0.005 cfs
* = Precipitation data from CMP Air Element
NR = No record

4.1.3 Peoria Interceptor Gaging Station

Peoria Interceptor is located in the Irondale Gulch drainage basin and receives runoff from the industrial area south of RMA (Figure 2.3-2). The station measures runoff from a 0.644 sq mi area that is predominantly urban storm sewer drainage, plus a small portion of residential Montbello. Stream stage is monitored with a Campbell Scientific CR-10 (digital) data logger/bubbler system, a Stevens Type F (analog) recorder as a backup and a Style C staff gage. The CR-10 data logger/bubbler system was installed at the station in early December 1989. Prior to the installation of the CR-10 data logger the station operated an Omnidata DP115 Datapod in conjunction with the Stevens Type F recorder.

4.1.3.1 Stage Discharge Relationships

The stage-discharge relationship is depicted by the rating curve for the station. Peoria Interceptor's rating curve was developed using measured instantaneous discharge values and corresponding staff gage readings. The current rating curve is the result of refinements made possible by additional instantaneous discharge measurements collected during Water Year 1990 that served to more accurately define the stage-discharge relationship at this station.

4.1.3.1.1 Continuous Stage Data

The water-discharge record for Peoria Interceptor was produced by converting the digital stage data of the DP115 Datapod (from October 1, 1989, to December 5, 1989) and of the CR-10 data logger (remainder of Water Year 1990) to computed instantaneous discharge values derived from the current stage-discharge relationship. The computed instantaneous discharge values are then compiled and reduced to mean daily discharges (Appendix A-8). Relative accuracy ratings of the daily mean discharges were determined for each station as described in Section 4.1.2.1.1.

The continuous stage record for Water Year 1990 is considered poor. Periods of estimated records include:

- December 21, 1989;
- February 15-18, 1990;
- July 30, 31, 1990;

- August 1, 4-7, 16, 18, 20-23, 1990; and
- September 19-22, 1990.

Estimated records during December 1989 and February 1990 were due to freezing conditions that caused the recorders to collect erroneous data, however, flows were at or near zero based on staff gage readings. Remaining estimates were due to high-water levels at Havana Pond which caused a backwater condition at Peoria Interceptor during July, August and September, 1990. Estimates approximated baseflow conditions with diurnal fluctuations during periods when backwater existed at the station. The stage record contained some other irregularities and inaccuracies caused by the following conditions:

- Trash and vegetation debris accumulated in the control section, causing stage to increase slightly;
- Minor leakage occurred under the metal V-notch plate on the weir; and
- The intake pipes leading to the stilling well accumulated excess silt, causing a minor lag time in response to stage changes. This problem affected only the strip chart/Datapod record.

4.1.3.1.2 Rating Curves and Equations

The methodology for rating curve development and rating curve verification followed the procedures described in Section 4.1.2.1.2.

Peoria Interceptor's original structure consisted of a flat-crested weir constructed of a narrow plank positioned perpendicular to flow and embedded into the banks on both sides of the channel. During Water Year 1989, a V-notch was cut in the existing wood plank, and a 90° V-notch steel plate was attached to the wooden control structure. The stage-discharge relationship for the modified control structure on Peoria Interceptor was originally developed using the empirical laboratory rating for a 90° V-notch weir. For flows with water depths greater than the maximum flow through the V-notch, the previously defined rating curve was adjusted by adding the maximum flow through the V-notch to each of the previously defined discharge and corresponding gage height values.

During Water Year 1990, the gage datum was converted from zero on the staff gage to zero head above the V-notch weir for a more stable datum. Instantaneous discharge measurements made during the year were used to redefine the lower end of the Peoria Interceptor rating curve using a best fit analysis (Appendix A-5). The rating curve is considered poor in both the defined and extrapolated regions. High water levels in Havana Pond periodically created a backwater condition in the Peoria Interceptor channel, and submergence of the Peoria Interceptor structure. No rating has been derived for this highly variable flow condition, and flow values were estimated. The rating curve for Peoria Interceptor is presented in Appendix A-3.2.

4.1.3.2 Surface-Water Hydrologic Conditions

Peoria Interceptor receives runoff from a relatively small urban drainage area and flow at the station is intermittent. Sources of surface-water at Peoria Interceptor and other RMA continuous monitoring stations are presented in Table 4.1-3. Discharge records for this station during Water Year 1990 are presented in Appendix A-8. Streamflow conditions for Peoria Interceptor including mean daily discharge, mean monthly discharge, maximum daily discharge, minimum daily discharge and total monthly streamflow volume are presented in the following sections.

4.1.3.2.1 Streamflow Characteristics and Extremes

Flow characteristics at Peoria Interceptor are typical of stations not influenced by diversions and inflows from controlled releases. Flow is derived almost entirely from off-post sources. Precipitation occurring on RMA has little effect on flow in Peoria Interceptor due to a short channel length and the lack of any well-defined tributary drainage channels. A significant amount of precipitation that falls in the off-post urban drainage area, however, results as runoff to the station due to minimal infiltration rates.

Diurnal fluctuations were recorded at Peoria Interceptor during Water Year 1990. Daily peaks in streamflow during baseflow conditions generally occur in the evening to early morning, indicating that reduced evapotranspiration rates and evening or nightly lawn watering may contribute to streamflow during this time period. Similar diurnal flow conditions are present at Havana Interceptor and South Uvalda Interceptor; however, direct comparisons are difficult to make due to differences in the storm sewers and open channel drainages contained within the respective drainage areas.

Maximum flows usually occur from the late winter through summer as a result of snowmelt runoff, thunderstorms and multi-day rainfall events. Minimum flows occur primarily during the fall and winter when conditions are dry or when water in the channel is frozen. The maximum monthly runoff volume during Water Year 1990 was 52.88 ac-ft (1.56 in. over the 0.644 sq mi drainage area) and occurred in March 1990. The minimum monthly runoff volume was 1.57 ac-ft (<0.05 in. over the 0.644 sq mi drainage area) and occurred in February 1990. The maximum monthly discharge volume at Peoria Interceptor was approximately 34 times greater than the minimum monthly discharge volume.

4.1.3.2.2 Annual Streamflow Analysis

Streamflow at Peoria Interceptor varied considerably throughout Water Year 1990 as illustrated in the monthly total discharge hydrograph (Figure 4.1-4). Minimal flows occurred from October 1989 through February 1990. Streamflow was higher the remainder of the year; however, April 1990 and June 1990 had relatively low discharge volumes. The mean daily peak flow was recorded in March 1990 and the instantaneous discharge peak occurred in July 1990.

Peoria Interceptor received low flow volumes during the fall to mid-winter. The total discharge volume measured from October 1989 through February 1990 was only 15.83 ac-ft (Appendix A-8). Total discharge fluctuated cyclicly from mid-winter to mid-summer with each month alternating from a relatively high water volume to moderately low flow volumes. Precipitation records reflect a similar pattern for total monthly precipitation (Figure 4.1-2). The highest monthly discharge volume for this station was 52.88 ac-ft in March 1990 which is indicative of a late winter response to thawing, increased precipitation and snowmelt runoff. Flow volume was reduced to 9.66 ac-ft during April 1990 in response to infrequent and low magnitude precipitation events. Although rainfall was still infrequent during May 1990, a large magnitude storm contributed a significant volume of water to the station and the monthly total increased to 24.36 acre-feet. Late spring was relatively dry at RMA and the total discharge fell to only 8.25 ac-ft during June 1990. Several long duration rainfall events during July 1990 contributed to the last flow volume peak at Peoria Interceptor during Water Year 1990, and a total of 38.62 ac-ft was measured at the station. Water volumes decreased the remainder of Water Year 1990 as soil moisture was depleted due to increased evapotranspiration and reduced amounts of precipitation. The total discharge volumes measured during August 1990 and September 1990 were 30.35 ac-ft and 22.27 ac-ft respectively. A total of 202.22 ac-ft (6.59×10^7 gallons) was measured at the station during Water Year 1990. This is equivalent to 5.39 in. of runoff from the watershed (48.8 percent of the precipitation measured at the South Plants rain gage).

4.1.3.2.3 Mean Monthly, Maximum Daily and Minimum Daily Flows

Mean monthly flows at Peoria Interceptor ranged from 0.03 cfs in December 1989 and February 1990 to a maximum of 0.76 cfs in March 1990. Mean monthly flows were highest in late winter and early summer. Maximum daily flows ranged from 5 to 20 times greater than the mean monthly flows, which indicates that the maximum high flow events are usually short duration and do not always contribute significantly to the mean monthly discharge. Minimum daily flows were low as 0.00 cfs during October 1989 through January 1990. Maximum daily flows ranged from 0.26 cfs during December 1989 to 6.7 cfs during July 1990. A monthly summary of daily minimum, maximum and mean discharges for all RMA surface-water monitoring stations during Water Year 1990 is presented in Table 4.1-4. Annual plots for these values are illustrated in Figure 4.1-15 and Figure 4.1-26.

4.1.3.2.4 Streamflow Storm Runoff Hydrographs

Streamflow storm hydrographs observed at RMA during Water Year 1990 represent flow conditions in response to precipitation events typical for this area of Colorado. Six high or extended storm events (March 5, 6, 1990; May 29, 30, 1990; July 7-11 and 29, 1990; August 14-20, 1990; September 17-21, 1990) were analyzed as described in Section 4.1.2.2.4.

Peoria Interceptor responded to storm events in a manner that is typical of watersheds affected by urbanization. Stream response occurred shortly after the onset of precipitation, and peak flow was usually reached in less than 3 hours. Streamflow recession generally lasted 6 to 26 hours. Streamflow recession varied depending on the magnitude and duration of the storm event, and the antecedent soil moisture conditions. Other RMA surface-water monitoring stations that exhibit a storm response similar to Peoria Interceptor include Havana Interceptor, Peoria Interceptor and Basin A.

4.1.4 LADORA WEIR GAGING STATION

Ladora Weir is located in the Irondale Gulch drainage basin and monitors controlled flow that is discharged from Lower Derby Lake and directed to Ladora Lake or Sand Creek Lateral (Figure 2.3-2). Stream stage is monitored with an Omnidata DP115 Datapod (digital) recorder in conjunction with a Stevens Type F (analog) recorder and a Style C staff gage.

4.1.4.1 Stage Discharge Relationships

The stage-discharge relationship for Ladora Weir is depicted by the station's established rating curve, which was previously developed using the empirical laboratory rating for the structure (Appendix A-3.2).

4.1.4.1.1 Continuous Stage Data

The discharge record for Ladora Weir during Water Year 1990 was produced by converting the digital stage data of the DP115 Datapod to computed instantaneous discharge values derived from the newly refined stage-discharge relationship. The computed instantaneous discharge values are then compiled and reduced to mean daily discharges. Stripcharts were digitized by hand periodically during the year when Datapod records were inaccurate or missing portions of data. Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards as described in Section 4.1.2.1.1.

The continuous stage record for Ladora Weir is considered poor for Water Year 1990. Periods of estimated records include:

- August 30, 31, 1990; and
- September 1-10, 1990.

Estimated records during August and September 1990 were due to reconstruction of the weir in July 1990. Any other irregularities and inaccuracies of the record were caused primarily by the occurrence of minor leakage under and around the weir blade which caused a slightly lower stage than actual at very low flow.

4.1.4.1.2 Rating Curves and Equations

The methodology for rating curve development and rating curve verification is described in Section 4.1.2.1.2. The stage-discharge relationship for Ladora Weir was previously developed using the empirical laboratory rating for a 6-ft standard suppressed rectangular weir. Instantaneous discharge measurements used to confirm the permanence of the rating or to allow any adjustments to be made to the rating were not collected prior to 1990. Four verified instantaneous discharge and staff measurements, made during Water Year 1990, were used to more accurately define the rating curve.

These measurements indicated that the original rating curve required a slight adjustment to the high end. The adjusted rating curve is considered fair when the head is at least 0.20 ft above the weir crest to prevent the nape from clinging to the crest (USBR, 1974). Flow with heads less than 0.20 ft can only be estimated. Reconstruction of Ladora Weir in July 1990 changed flow characteristics at the station, therefore, a new rating curve must be developed. The current rating curve for Ladora Weir is presented in Appendix A-3.2.

4.1.4.2 Surface-Water Hydrologic Conditions

Ladora Weir receives controlled releases from Lower Derby Lake (Table 4.1-3), therefore, flow at the station is intermittent. Streamflow records for Ladora Weir including mean monthly discharge, maximum daily discharge, minimum daily discharge and total monthly streamflow volume are presented in the following sections.

4.1.4.2.1 Streamflow Characteristics and Extremes

Flow characteristics at Ladora Weir are typical of stations with diversions and inflows from controlled releases. Flow is derived entirely from Lower Derby Lake. Precipitation occurring on RMA has no effect on flow in Ladora Weir due to the lack of any tributary drainages. Ladora Weir was dry throughout most of Water Year 1990; however, flow was recorded during June 1990 through September 1990. A maximum volume of 224.67 ac-ft flowed through the station during June 1990.

4.1.4.2.2 Annual Streamflow Analysis

Streamflow at Ladora Weir was intermittent in Water Year 1990 and is illustrated in Figure 4.1-5. Specific analysis of streamflow trends, maximum or minimum flows, or runoff depths is not meaningful at this station since all flow is controlled. A total of 440.00 ac-ft (1.43×10^8 gallons) was measured at the station during the year.

4.1.4.2.3 Mean Monthly, Maximum Daily and Minimum Daily Flows

Mean monthly flows at Ladora Weir ranged from 0.00 cfs during October 1989 through May 1990 to a maximum of 3.8 cfs in June 1990. The maximum daily flow was 19.0 cfs in June 1990 and the minimum daily flow was 0.00 cfs for the majority of Water Year 1990. A monthly summary of daily minimum, maximum and mean discharges for all RMA surface-water monitoring stations during Water Year 1990 is presented in Table 4.1-4. Annual plots for these values are illustrated in Figure 4.1-16 and Figure 4.1-27.

4.1.4.2.4 Streamflow Storm Runoff Hydrographs

Analysis of response to precipitation events is not meaningful at Ladora Weir since all flow at the station is controlled (Table 4.1-5).

4.1.5 SOUTH UVALDA GAGING STATION

South Uvalda is located near the southern boundary of RMA at 56th Street in the Irondale Gulch drainage basin and receives runoff from the northern portion of Montbello and from the undeveloped area east of Montbello (Figure 2.3-2). The station measures runoff from a 7.723 sq mi area of which 4.118 sq mi is urban storm sewer drainage. The Uvalda Interceptor flows in a northerly direction to Sixth Avenue, where it is diverted to either Upper Derby Lake or Lower Derby Lake. Stream stage is monitored with a Style C staff gage, a Campbell Scientific CR-10 (digital) data logger/bubbler system and a Stevens Type F (analog) recorder as a backup.

4.1.5.1 Stage Discharge Relationships

The stage-discharge relationship is depicted by the rating curve for the station. South Uvalda's rating curve was developed empirically using instantaneous discharge measurements and corresponding staff gage readings. The current rating curve is the result of refinements made possible by additional instantaneous discharge measurements collected during Water Year 1990 that served to more accurately define the stage-discharge relationship at this station.

4.1.5.1.1 Continuous Stage Data

The discharge record for South Uvalda was produced by converting the digital stage data of the CR-10 data logger to computed instantaneous discharge values which are then compiled and reduced to mean daily discharges (Appendix A-8). Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards as described in Section 4.1.2.1.1.

The continuous stage record for Water Year 1990 is considered good. Periods of estimated records include:

- December 19-22, 1989;
- February 14-16, 1990;
- April 3-5, 1990; and
- June 20-22, 1990.

Estimated records during December 1989 and February 1990 were due to freezing conditions that caused the CR-10 data logger to collect erroneous data. Data backup was not available for these periods because the Stevens Type F recorder was taken out of service from December 20, 1989, to February 27, 1990, while the stilling well water was frozen. The estimates were made based on observations of the staff gage during weekly visits. Remaining estimates were due to unrecoverable sections of stage data during April 1990 and June 1990. The stage record contained some other irregularities and inaccuracies caused by the following conditions:

- Excess debris, such as vegetation and trash, accumulated in the channel, in the control and around the staff gage; and
- The intake pipes leading to the stilling well accumulated excess silt, causing a lag time between channel and strip chart response; however, this has no affect on the digital stage record.

4.1.5.1.2 Rating Curves and Equations

The methodology for rating curve development and rating curve verification is described in Section 4.1.2.1.2. The rating curve for the South Uvalda structure was previously derived and was based on field measurements of instantaneous discharge and corresponding staff measurements. The South Uvalda structure is a compound broad-crested weir with a V-notch. Ten verified instantaneous discharge and staff measurements, made during Water Year 1990, were used to more accurately define the rating curve and justify a slight adjustment near the high end of the rating curve (Appendix A-5). The adjusted curve is considered good, both in the defined and extrapolated regions. The rating curve for South Uvalda is presented in Appendix A-3.2.

4.1.5.2 Surface-Water Hydrologic Conditions

'alda Interceptor is a man-made channel within the Irondale Gulch drainage basin. The channel is deep ough to intercept near-surface ground water which causes flow to be perennial. Streamflow at the South Uvalda gaging station can increase from baseflow conditions to flood stage over a relatively short period of time due to a rapid response to precipitation that is received in urbanized areas of its drainage basin. Sources of surface-water at South Uvalda and other RMA continuous monitoring stations are presented in Table 4.1-3. Streamflow conditions for South Uvalda including mean daily discharge, mean monthly discharge, maximum daily discharge, minimum daily discharge and total monthly streamflow volume are presented in the following sections.

4.1.5.2.1 Streamflow Characteristics and Extremes

Flow characteristics at South Uvalda are typical of stations without diversions and inflows from controlled releases. Flow is derived almost entirely from off-post sources. Most precipitation occurring on RMA does not contribute to surface-water runoff to Uvalda Interceptor because the channel is bermed along the majority of its length.

Diurnal fluctuations were recorded on strip charts at South Uvalda during Water Year 1990. Daily peaks in streamflow during baseflow conditions generally occur in the evening to early morning, indicating that reduced evapotranspiration rates and evening or nightly lawn watering may contribute to streamflow during this time period. Similar diurnal flow conditions are present at Peoria Interceptor and Havana

Interceptor; however, direct comparisons are difficult to make due to differences in the storm sewers and open channel drainages contained within the respective drainage areas.

Maximum flows usually occur from the late winter through summer as a result of snowmelt runoff, thunderstorms and multi-day rainfall events. The maximum monthly runoff volume during Water Year 1990 was 140.79 ac-ft (0.34 in. over the 7.723 sq mi drainage area) and occurred in August 1990. Minimum flows occur primarily during the fall and winter when dry weather causes streamflow to remain at baseflow conditions or when ice conditions exist in the channel. The minimum monthly runoff volume was 22.10 ac-ft (0.05 in. over the 7.723 sq mi drainage area) and occurred in February 1989. The maximum monthly discharge volume at South Uvalda was approximately six times greater than the minimum monthly discharge volume.

4.1.5.2.2 Annual Streamflow Analysis

Streamflow at South Uvalda varied throughout Water Year 1990 and is illustrated in the monthly total discharge hydrograph (Figure 4.1-6). Minimal flows occurred from October 1989 through February 1990. Streamflow was higher the remainder of the year, but April 1990 and June 1990 had relatively low discharge volumes. The mean daily peak flow was recorded in August 1990 and the instantaneous discharge peak was also recorded in the same month.

South Uvalda received low flow volumes during the fall to mid-winter and the total discharge volumes measured from October 1989 through February 1990 ranged between 22.10 ac-ft to 27.69 ac-ft (Appendix A-8). Total discharge fluctuated cyclicly from mid-winter to mid-summer with each month varying from a relatively high water volume to moderately low flow volumes. Total discharge increased substantially during March 1990 to 104.55 ac-ft. The increased flow volume is indicative of a late winter response to thawing, increased precipitation and snowmelt runoff. Flow volume was reduced to 42.49 ac-ft during April 1990 due to infrequent and low magnitude precipitation events. Although rainfall was still infrequent during May 1990, a large magnitude storm contributed a significant volume of water to the station and the monthly total increased to 85.82 acre-feet. Late spring was relatively dry at RMA and the total water-discharge dropped to 46.27 ac-ft during June 1990. Several long duration rainfall events during July 1990 contributed to increased flow, and 88.24 ac-ft was measured at the station. Maximum discharge occurred during mid-summer and a total of 140.79 ac-ft was measured in August 1990. Water volumes decreased the remainder of Water Year 1990 as soil moisture was depleted due to increased evapotranspiration and reduced amounts of precipitation. The total discharge volume measured during September 1990 was 56.35 acre-feet. The cyclical pattern of flow volumes in Water Year 1990 was similar to the precipitation record except during August 1990, when flow had increased to the yearly high of 140.79 ac-ft and precipitation had decreased considerably from the previous month (Figure 4.1-6 and Figure 4.1-2). A total of 688.72 ac-ft (2.24×10^8 gallons) was measured at South Uvalda during the year. This is equivalent to 1.67 in. of runoff from the watershed (15.1 percent of the precipitation measured at the South Plants rain gage).

4.1.5.2.3 Mean Monthly, Maximum Daily and Minimum Daily Flows

Mean monthly flows at South Uvalda ranged from 0.38 cfs in November 1989 to a maximum of 2.3 cfs in August 1990. Mean monthly flows were highest in late winter and mid-summer. Maximum daily flows ranged from 19.0 cfs in August 1990 to 1.2 cfs from November 1989 through January 1990. The maximum daily flows were generally six times greater than the corresponding mean monthly flows. Minimum daily flows ranged from 0.26 cfs to 0.42 cfs during Water Year 1990. A monthly summary of daily minimum, maximum and mean discharges for all RMA surface-water monitoring stations during Water Year 1990 is presented in Table 4.1-4. Annual plots for these values are illustrated in Figure 4.1-17 and Figure 4.1-28.

4.1.5.2.4 Streamflow Storm Runoff Hydrographs

Streamflow storm hydrographs observed at RMA during Water Year 1990 represent flow conditions in response to precipitation events typical for this area of Colorado. Six high or extended storm events (March 5, 6, 1990; May 29, 30, 1990; July 7-11 and 29, 1990; August 14-20, 1990; September 17-21, 1990) were analyzed as described in Section 4.1.2.2.4.

South Uvalda responded to storm events in a manner that is typical of watersheds affected by urbanization. Stream response occurred shortly after the onset of precipitation and peak flow was often reached in less than 1 hour but usually took approximately 2 hours. Streamflow recession ranged from 2 hours to 24 hours but normally lasted 19 hours. Antecedent soil moisture and storm magnitude have an influence on the streamflow recession rate at the station. Other RMA surface-water monitoring stations that exhibit a storm response similar to South Uvalda include Peoria Interceptor, Havana Interceptor and Basin A.

4.1.6 NORTH UVALDA GAGING STATION

The North Uvalda station is located in the Irondale Gulch drainage basin and monitors flow to Lower Derby Lake (Figure 2.3-2). The station receives controlled discharges of water from Uvalda Interceptor and/or Highline Lateral Canal. Stream stage is monitored with an Omnidata DP115 Datapod (digital) recorder in conjunction with a Stevens Type F (analog) recorder and a Style C staff gage.

4.1.6.1 Stage Discharge Relationships

The stage-discharge relationship for North Uvalda is established by the station's newly derived rating curve. The rating curve for the station was redeveloped empirically during Water Year 1990 by obtaining instantaneous discharge measurements and corresponding staff measurements.

4.1.6.1.1 Continuous Stage Data

The discharge record for North Uvalda during Water Year 1990 was produced by converting the digital stage data of the DP115 Datapod to computed instantaneous discharge values derived from the current stage-discharge relationship. The computed instantaneous discharge values are then compiled and reduced to mean daily discharges. Stripcharts were digitized for part of the year when Datapod records were inaccurate or missing portions of data. Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards as described in Section 4.1.2.1.1.

The continuous stage record for North Uvalda is considered good for Water Year 1990. Periods of estimated records include:

- April 17, 1990; and
- May 18, 1990.

The estimated 1-day of record in April 1990 was due to the station's stilling well not responding to the minimal flow that occurred that day. The estimate made in May 1990 was caused by the malfunction of the Stevens Type F recorder. Any other irregularities and inaccuracies of the record may be caused by the following conditions:

- Excess debris, such as trash and vegetation, accumulated in the channel, in the control and around the staff gage at times; and
- The intake pipes leading to the stilling well accumulated silt, which causes a delay in the recorder's response to changes in stream stages.

4.1.6.1.2 Rating Curves and Equations

The methodology for rating curve development and rating curve verification is described in Section 4.1.2.1.2. The rating curve for the North Uvalda structure was previously derived and was based on field measurements of instantaneous discharge and corresponding staff measurements. The North Uvalda structure is a compound broad-crested weir with a V-notch. During Water Year 1990 the staff gage datum was changed and channel aggradation occurred; therefore, it was necessary to develop a new rating curve. Five verified instantaneous discharge and staff measurements made during Water Year 1990 were used to develop the new rating curve (Appendix A-5). The new rating curve is considered fair, both in the defined and extrapolated regions. The rating curve for North Uvalda is presented in Appendix A-3.2.

4.1.6.2 <u>*Surface-Water Hydrologic Conditions*</u>

Flow at North Uvalda is intermittent since it receives controlled discharges from Uvalda Interceptor and/or Highline Lateral Canal (Table 4.1-3). The channel directs flow to the eastern side of Lower Derby Lake. Streamflow conditions for North Uvalda including mean monthly discharge, maximum daily discharge, minimum daily discharge and total monthly streamflow volume are presented in the following sections.

4.1.6.2.1 Streamflow Characteristics and Extremes

Flow characteristics at North Uvalda are typical of stations with diversions and inflows from controlled releases. Essentially all flow at the monitoring station is derived from controlled releases. Precipitation occurring on RMA has little or no affect on flow at North Uvalda because berms that line the channel prevent surface-water runoff from flowing into the drainage. North Uvalda was dry throughout most of Water Year 1990 but received intermittent flows in October 1989 and in April 1990 through September 1990 from Highline Lateral and Uvalda Interceptor. A maximum volume of 270.74 ac-ft was measured at the station during June 1990.

4.1.6.2.2 Annual Streamflow Analysis

Streamflow at North Uvalda was intermittent during Water Year 1990 and is illustrated in Figure 4.1-7. Specific analysis of streamflow trends, maximum or minimum flows, or runoff depths is not meaningful at this station since all flow is controlled. A total of 406.21 ac-ft (1.32 x 10^8 gallons) was measured during Water Year 1990 at the station.

4.1.6.2.3 Mean Monthly, Maximum Daily and Minimum Daily Flows

Mean monthly flows at North Uvalda ranged from 0.00 cfs during November 1989 through March 1990 to a maximum of 4.6 cfs in June 1990. The maximum daily flow was 18.0 cfs in both June 1990 and September 1990. The minimum daily flow was 0.00 cfs for the majority of Water Year 1990. A monthly summary of daily minimum, maximum and mean discharges for all RMA surface-water monitoring stations during Water Year 1990 is presented in Table 4.1-4. Annual plots for these values are illustrated in Figure 4.1-18 and Figure 4.1-29.

4.1.6.2.4 Streamflow Storm Runoff Hydrographs

Analysis of response to precipitation events is not meaningful at North Uvalda since all flow at the station is controlled (Table 4.1-5).

4.1.7 HIGHLINE LATERAL GAGING STATION

The Highline Lateral station is located in the Highline Lateral within the Irondale Gulch drainage basin and monitors South Platte River water delivered to Upper Derby Lake and/or Lower Derby Lake via North Uvalda (Figure 2.3-2). Stream stage is monitored with a Stevens Type F (analog) recorder and a Style C staff gage.

4.1.7.1 Stage Discharge Relationships

The stage-discharge relationship for Highline Lateral is depicted by the station's rating curve. The rating curve for station was developed empirically by obtaining instantaneous discharge measurements and corresponding staff measurements.

4.1.7.1.1 Continuous Stage Data

The Highline Lateral discharge record from October 1989 through April 1990 was based on weekly observations of the station. The discharge for the remainder of Water Year 1990 was produced by converting the daily strip-chart-stage record to a daily digitized-stage record. Digital stage data are then converted to computed instantaneous discharge values derived from the current stage-discharge relationship. The computed instantaneous discharge values are then compiled and reduced to mean daily discharges. Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards as described in Section 4.1.2.1.1.

The continuous stage record for Highline Lateral is considered good for Water Year 1990 and no periods of record were estimated. Some irregularities and inaccuracies of the record are caused by the following conditions:

- Wave action in the feeder channel caused the recorder to produce a broad irregular trace on the strip charts, making the stage record difficult to interpret; and,

- A staff gage positioned on the weir caused irregular flow.

4.1.7.1.2 Rating Curves and Equations

The methodology for rating curve development and rating curve verification is described in Section 4.1.2.1.2. The rating curve for the Highline Lateral structure was previously derived and was based on field measurements of instantaneous discharge and corresponding staff measurements. The Highline Lateral structure is a 6-ft Cipolletti Weir. The Cipolletti Weir laboratory rating equation was not used because of significant approach velocities and because a staff gage is welded to the weir blade within the flow field. Sixteen verified instantaneous discharge and staff measurements, made during Water Year

1990, were used to refine the existing rating curve (Appendix A-5). These measurements indicated that a slight adjustment was necessary at the high end of the rating curve to give a better stage-discharge relationship. The adjusted rating curve is considered fair, both in the defined and extrapolated regions. The rating curve for Highline Lateral is presented in Appendix A-3.2.

4.1.7.2 Surface-Water Hydrologic Conditions

The Highline Lateral gaging station is located along the Highline Lateral irrigation ditch which delivers Army-owned shares of irrigation water diverted from the South Platte River (Table 4.1-3). Flow in the channel is intermittent and can be directed to Lower Derby Lake and/or Upper Derby Lake. Highline Lateral contributes to the overall inflow volume of water at RMA. Streamflow conditions including mean monthly discharge, maximum daily discharge, minimum daily discharge, and total monthly streamflow volume are presented in the following sections.

4.1.7.2.1 Streamflow Characteristics and Extremes

Flow characteristics at Highline Lateral are typical of stations with diversions and inflows from controlled releases. Essentially all flow at the monitoring station is derived from controlled releases. Precipitation occurring on RMA has little or no effect on flow at the station because berms that line the channel prevent surface-water runoff from flowing into the drainage. Highline Lateral was dry throughout most of Water Year 1990, but received intermittent flows in May 1990 through September 1990. A maximum volume of 621.06 ac-ft was measured at the station during June 1990.

4.1.7.2.2 Annual Streamflow Analysis

Streamflow at Highline Lateral was intermittent during Water Year 1990 and is illustrated in Figure 4.1-8. Specific analysis of streamflow trends, maximum or minimum flows, or runoff depths is not meaningful at this station since all flow is controlled. A total of 2,003.21 ac-ft (6.53×10^8 gallons) was measured during Water Year 1990.

4.1.7.2.3 **Mean Monthly, Maximum Daily and Minimum Daily Flows**

Mean monthly flows at Highline Lateral ranged from 0.00 cfs during October 1989 through April 1990 to a maximum of 10.0 cfs in June 1990. The maximum daily flow occurred in May 1990 and was 24.0 cfs. Minimum daily flows of 0.00 cfs occurred during every month in Water Year 1990. A monthly summary of daily minimum, maximum and mean discharges for all RMA surface-water monitoring stations during Water Year 1990 is presented in Table 4.1-4. Annual plots for these values are illustrated in Figure 4.1-19 and Figure 4.1-30.

4.1.7.2.4 Streamflow Storm Runoff Hydrographs

Analysis of response to precipitation events is not meaningful at Highline Lateral since all flow at the station is controlled (Table 4.1-5).

4.1.8 SOUTH PLANTS DITCH GAGING STATION

South Plants Ditch gaging station is located in the Irondale Gulch drainage basin and monitors surface runoff from a small watershed between Lower Derby Lake and the South Plants area (Figure 2.3-2). Flow is diverted to either the eastern or western end of Lower Derby Lake via 2 weirs that are set at different elevations. Stream stage is monitored with a Stevens Type F (analog) recorder and a Style C staff gage.

4.1.8.1 Stage Discharge Relationships

The stage-discharge relationship for South Plants Ditch is depicted by the station's previous rating curve. The rating curve for station was developed empirically by obtaining laboratory measurements for a 90 degree V-notch weir and a sharp-crested suppressed rectangular weir.

4.1.8.1.1 Continuous Stage Data

The South Plants Ditch discharge record from October 1989 through March 1990 was based on weekly observations of the station. The discharge for the remainder of Water Year 1990 was based on the daily strip-chart-stage record. Since the station did not receive any flow during Water Year 1990 it was not necessary to convert the daily strip-chart-stage record to a digital format for reduction. The discharge record for Water Year 1990 is presented in Appendix A-8. The continuous stage record for South Plants Ditch is considered excellent for Water Year 1990 and no periods of the record were estimated. Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards as described in Section 4.1.2.1.1.

4.1.8.1.2 Rating Curves and Equations

The methodology for rating curve development and rating curve verification is described in Section 4.1.2.1.2. The rating curve for South Plants Ditch was previously developed using a combination of the empirical laboratory ratings for a 90° V-notch weir and a sharp-crested suppressed rectangular weir. The station received zero flow during Water Year 1990; therefore, the current rating curve could not be refined. The rating curve is considered poor, both in the defined and extrapolated regions. The rating curve for South Plants Ditch is presented in Appendix A-3.2.

4.1.8.2 Surface-Water Hydrologic Conditions

South Plants Ditch receives runoff from an approximately 0.055 sq mi watershed located between Lower Derby Lake and the South Plants area (Table 4.1-3). Stream flow at the station is rare with only one flow occurring in the last two water years. Rapid infiltration of precipitation in the watershed prevents any significant amount of runoff from reaching the ditch. Generally, flow cannot occur at the station unless antecedent soil moisture is high before a storm event occurs. Conditions for South Plants Ditch including mean monthly discharge, maximum daily discharge, minimum daily discharge and total monthly streamflow volume are presented in the following sections.

4.1.8.2.1 Streamflow Characteristics and Extremes

South Plants Ditch did not receive flow during the year and historically flow has been intermittent. Essentially all flow at the monitoring station is derived from surface-water runoff.

4.1.8.2.2 Annual Streamflow Analysis

The monthly discharge volume hydrograph for South Plants Ditch is presented in Figure 4.1-9. Specific analysis of streamflow trends, maximum or minimum flows, or runoff depths is not possible at this station since zero flow occurred during Water Year 1990.

4.1.8.2.3 Mean Monthly, Maximum Daily and Minimum Daily Flows

Mean monthly flows at South Plants Ditch were 0.00 cfs for the entire water year. Maximum and minimum daily flows were 0.00 cfs for all months. A monthly summary of daily minimum, maximum and mean discharges for all RMA surface-water monitoring stations during Water Year 1990 is presented in Table 4.1-4. Annual plots for these values are illustrated in Figure 4.1-20 and Figure 4.1-31.

4.1.8.2.4 Streamflow Storm Runoff Hydrographs

Analysis of response to precipitation events is not possible at South Plants Ditch since zero flow was recorded at the station during Water Year 1990 (Table 4.1-5).

4.1.9 SOUTH FIRST CREEK GAGING STATION

The South First Creek gaging station is located in First Creek and monitors flow entering RMA from a 26.38 sq mi watershed that contains 0.197 sq mi of storm sewer drainage from an urbanized area (Figure 2.3-2). First Creek enters RMA along its eastern border in Section 8. Stream stage is monitored with a Style C staff gage, a Campbell Scientific CR-10 (digital) data logger/bubbler system and a Stevens Type F (analog) recorder as a backup.

4.1.9.1 Stage Discharge Relationships

The stage-discharge relationship is depicted by the station's established rating curve. South First Creek's rating curve was developed using instantaneous discharge measurements and corresponding staff gage readings. The current rating curve is new for Water Year 1990 and is the result of instantaneous discharge measurements collected during the year that served to more accurately define the stage-discharge relationship than the previous rating.

4.1.9.1.1 Continuous Stage Data

The discharge record for South First Creek was produced by converting the digital stage data of the CR-10 data logger to computed instantaneous discharge values derived from the current stage-discharge relationship. The computed instantaneous discharges are then compiled and reduced to mean daily discharges (Appendix A-8). Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards as described in Section 4.1.2.1.1.

The continuous stage record for Water Year 1990 is considered good. Periods of estimated records include:

- December 18-22, 1989; and
- February 14-16, 1990.

Estimated records during December 1989 and February 1990 were due to freezing conditions that caused the CR-10 data logger to record erroneous data. The analog backup record was not available during this period due to ice in the station's stilling well; therefore, the estimates were based on observations of the staff gage during weekly visits to the station. Other irregularities and inaccuracies were caused by the following condition:

- Intake pipes are installed too high to equilibrate the stream and stilling well at periods of very low flow. This problem affected only the analog record.

4.1.9.1.2 Rating Curves and Equations

The methodology for rating curve development and rating curve verification is described in Section 4.1.2.1.2. The rating curve for the South First Creek structure was empirically derived, based on field measurements of instantaneous discharge and corresponding staff measurements. The South First Creek structure is a compound concrete weir with a V-notch. Nineteen verified instantaneous discharge and staff measurements were made during Water Year 1990 (Appendix A-5). These measurements were used to define and develop a new rating for the station. A high flow extrapolation was performed on the upper region of the rating curve due to a lack of instantaneous discharge and staff measurements in this region. The staff gage datum changed in December 1989. Subsequent to this change, an *e* value (gage height of zero flow in feet) of -0.04 was applied to the new rating relationship. The new rating curve is considered to be good in the defined region and fair in the extrapolated region. The rating curves for South First Creek are presented in Appendix A-3.2.

4.1.9.2 Surface-Water Hydrologic Conditions

The South First Creek gaging station is located on the southeastern border of the Arsenal. Flow at the station is intermittent; however, the station is dry for only short periods during the summer. Field observations indicate that First Creek behaves both as an influent and effluent stream depending on the season. Sources of surface-water at South First Creek and other RMA continuous monitoring stations are presented in Table 4.1-3. Water-discharge records for this station during Water Year 1990 are presented in Appendix A-8. Streamflow conditions for South First Creek including mean daily discharge, mean monthly discharge, maximum daily discharge, minimum daily discharge and total monthly streamflow volume are presented in the following sections.

4.1.9.2.1 Streamflow Characteristics and Extremes

South First Creek exhibits flow characteristics that are typical of stations that monitor streams in watersheds that do not contain a significant amount of urbanization. Flow is derived from ground-water discharge and surface-water runoff from precipitation. Precipitation that falls in the off-post drainage area can affect flow to the station in varying degrees depending on soil and channel bank moisture content, and recharge to the near-surface ground-water system at different times of the year.

Diurnal fluctuations were recorded on hydrographs at South First Creek during Water Year 1990 from mid-spring through the summer. Daily peaks in streamflow during baseflow conditions generally occur in the evening to early morning, indicating that reduced evapotranspiration rates may contribute to streamflow during this time period.

Maximum flows occurred during the late winter and mid-summer as a result of snowmelt runoff, thunderstorms and multi-day rainfall events. Minimum flows occurred primarily during the fall through mid-winter and in the late summer when conditions are dry or when water in the channel is frozen. The maximum monthly runoff volume during Water Year 1990 was 203.70 ac-ft (0.14 in. over the 26.38 sq mi drainage area) and occurred in August 1990. The minimum monthly runoff volume was 16.42 ac-ft

(0.01 in. over the 26.38 sq mi drainage area) and occurred in October 1989. The maximum monthly discharge volume at South First Creek was approximately 12 times greater than the minimum monthly discharge volume.

4.1.9.2.2 Annual Streamflow Analysis

Streamflow at South First Creek varied considerably throughout Water Year 1990 and is illustrated in the monthly total discharge hydrograph (Figure 4.1-10). South First Creek received low flow volumes during the fall through mid-winter and late summer. Total discharge gradually increased from October 1989 to February 1990, averaging approximately 38 ac-ft per month, but had a relatively sharp volume increase to 119.76 ac-ft in March 1990. The increase in March 1990 is indicative of a late winter response to thawing, increased precipitation and snowmelt runoff. Discharge volumes declined after March 1990 until June 1990. The total discharge volume in June 1990 was only 23.92 ac-ft which is indicative of the relatively dry spring that occurred at RMA during Water Year 1990. Precipitation increased considerably in July 1990; however, the net effect on discharge volume was minimal at South First Creek, increasing to only 35.84 acre-feet. Although net precipitation was minimal, two major storm events contributed to the monthly high water volume of 203.70 ac-ft that was recorded at South First Creek during August 1990. The high water volume was likely due to increased baseflow conditions that was created from the high amount of precipitation received the previous month. Flow received during August 1990 was the maximum at the station for the water year. Total monthly water volume decreased considerably to 22.00 ac-ft during September 1990 in response to reduced amounts of precipitation and increased evapotranspiration rates. The station received a total of 729.11 ac-ft (2.38 x 10^8 gallons) during the year. This is equivalent to 0.52 in. of runoff from the watershed (4.7 percent of the precipitation measured at the South Plants Rain Gage).

4.1.9.2.3 Mean Monthly, Maximum Daily and Minimum Daily Flows

Mean monthly flows at South First Creek ranged from 0.27 cfs in October 1989 to a maximum of 3.3 cfs in August 1990. Mean monthly flows were highest in late winter and mid-summer. Maximum daily flows were generally two times greater than the mean monthly flows, which indicates that the maximum high flow events are usually short duration and do not always contribute significantly to the mean monthly discharge. However, the maximum daily flow was more than 20 times greater than the mean monthly flow in August 1990. Minimum daily flows were as low as 0.00 cfs during July 1990. Maximum daily flows ranged from 0.42 cfs during October 1989 to 68.0 cfs during August 1990. A monthly summary of daily minimum, maximum and mean discharges for all RMA surface-water monitoring stations during Water Year 1990 is presented in Table 4.1-4. Annual plots for these values are illustrated in Figure 4.1-21 and Figure 4.1-32.

4.1.9.2.4 Streamflow Storm Runoff Hydrographs

Streamflow storm hydrographs observed at RMA during Water Year 1990 represent flow conditions in response to precipitation events typical for this area of Colorado. Six high or extended storm events (March 5, 6, 1990; May 29, 30, 1990; July 7-11, and 29, 1990; August 14-20, 1990; September 17-21, 1990) were analyzed as described in Section 4.2.2.4.

South First Creek responded to storm events in a manner that is typical of natural watersheds. The response times to precipitation events varied throughout the year depending on the baseflow conditions present at the time of the storm and the spatial distribution of rainfall. The response time for the winter storm event took approximately 8 hours and streamflow recession lasted approximately 24 hours. Response times from the mid-spring to the mid-summer months were generally 2 to 4 hours with streamflow recession times ranging from 24 to 48 hours. Dry soil conditions usually lead to longer response times at this station, while conditions of high ground-water levels will contribute to more rapid response times. Similar responses to storm events are evident at North First Creek and First Creek Off-Post.

4.1.10 NORTH FIRST CREEK GAGING STATION

The North First Creek gaging station is located in the First Creek drainage basin and monitors flow leaving northern RMA (Figure 2.3-2). This 36.70 sq mi drainage area is primarily a natural watershed. First Creek enters RMA along its eastern border in Section 8 and flows across RMA to the north were it exits in Section 24. Stream stage is monitored with a Style C staff gage, a Campbell Scientific CR-10 (digital) data logger/bubbler system and a Stevens Type F (analog) recorder as a backup.

4.1.10.1 Stage Discharge Relationships

The stage-discharge relationship is depicted by the station's rating curve. North First Creek's rating curve was developed using instantaneous discharge measurements and corresponding staff gage readings in conjunction with a HEC-2 analysis (U.S. Army Corps of Engineers, 1982). The current rating curve for Water Year 1990 is the result of refinements made possible through the collection of instantaneous discharge measurements during the year that served to more accurately define the stage-discharge relationship.

4.1.10.1.1 Continuous Stage Data

The discharge record for North First Creek was produced by converting the digital stage data of the CR-10 data logger to computer instantaneous discharge values derived from the current stage-discharge relationship. The computer instantaneous discharges are then compiled and reduced to mean daily discharges (Appendix A-8). Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards as described in Section 4.1.2.1.1.

The continuous stage record for Water Year 1990 is considered good. Periods of estimated records include:

- January 19, 20, 1990; and
- February 15-17, 1990.

Estimated records were due to freezing conditions that caused the CR-10 data logger to record erroneous data. The analog backup record was not available during this period due to ice in the station's stilling well; therefore, estimates were based on observations of stage during weekly visits to the station. Other irregularities and inaccuracies were caused by the following conditions:

- Intake pipes are installed too high to equilibrate the stream and stilling well at periods of very low flow. This problem affected only the analog record; and
- Excess debris, such as vegetation and trash, accumulated in the channel upstream of the weir and around the staff gage.

4.1.10.1.2 **Rating Curves and Equations**

The methodology for rating curve development and rating curve verification is described in Section 4.1.2.1.2. The rating curve for North First Creek was empirically derived, based on field measurements of instantaneous discharge and corresponding staff measurements. The North First Creek structure is a compound concrete weir with a V-notch. The empirical stage-discharge relationship was developed using one verified instantaneous discharge measurement in combination with a HEC-2 analysis. During the Water Year 1990, the gage datum was converted from zero on the staff gage to zero head above the weir. Nine verified instantaneous discharge and staff measurements made during Water Year 1990 confirmed the permanence of the converted rating curve (Appendix A-5). The rating curve is considered good, both in the defined and extrapolated regions. The rating curve for North First Creek is presented in Appendix A-3.2.

4.1.10.2 Surface-Water Hydrologic Conditions

The North First Creek gaging station is located near the northern border of the Arsenal in Section 24. Flow at the station is intermittent and the station was dry for several months during Water Year 1990. Gain/loss studies indicate that First Creek upstream of the North First Creek station behaves as an influent stream and as an effluent stream depending on the season. Sources of surface-water at North First Creek and other RMA continuous monitoring stations are presented in Table 4.1-3. Discharge records for this station during Water Year 1990 are presented in Appendix A-8. Streamflow conditions for North First Creek including mean daily discharge, mean monthly discharge, maximum daily discharge, minimum daily discharge and total monthly streamflow volume are presented in the following sections.

4.1.10.2.1 Streamflow Characteristics and Extremes

North First Creek exhibits flow characteristics that are typical of natural watersheds. Flow is derived from ground-water discharge and surface-water runoff from precipitation. Precipitation that falls in the off-post drainage area can affect flow to the station in varying degrees depending on soil and channel bank moisture content, and recharge to the near-surface ground-water system at different times of the year. First Creek also has several small tributaries on RMA that can contribute a minor amount to flow during snowmelt runoff or during large storm events.

Maximum flows occurred during the late winter and mid-summer as a result of snowmelt runoff, thunderstorms and multi-day rainfall events. Minimum flows occurred primarily during the fall through mid-winter and in the late spring when water in the channel is frozen or when conditions are dry. The maximum monthly runoff volume during Water Year 1990 was 153.78 ac-ft (0.08 in. over the 36.70 sq mi drainage area) and occurred in March 1990. The minimum monthly runoff volume was 0.00 ac-ft in October through December 1989 and July 1990.

4.1.10.2.2 Annual Streamflow Analysis

Streamflow at North First Creek varied considerably throughout Water Year 1990 and is illustrated in the monthly total discharge hydrograph (Figure 4.1-11). North First Creek received zero flow during the fall (October 1989 through December 1989) of Water Year 1990. Low water volumes were measured during January 1990 and February 1990 and were 1.75 ac-ft and 8.91 ac-ft respectively. Total discharge increased dramatically during March 1990 and a total of 153.78 ac-ft was measured at the station. The increase in March 1990 is indicative of a late winter response to thawing, increased precipitation, snowmelt runoff, and elevated ground-water levels. Water-discharge volumes declined after March 1990 until July 1990 when the total water volume returned to 0.00 acre-feet. Gain/loss studies indicate that First Creek was influent during June 1990 and remained in that state until mid-August 1990. Substantial amounts of precipitation occurring during July 1990 did not produce flow at the station; however, the return of flow in mid-August appears to be a baseflow response to the precipitation that was received the prior month. A total of 77.20 ac-ft was measured in August 1990. Total monthly water volume decreased to 34.33 ac-ft during September 1990 in response to reduced amounts of precipitation and increased evapotranspiration rates. A total of 399.94 ac-ft (1.30×10^8 gallons) was measured at the station during the year. This is equivalent to 0.20 in. of runoff from the watershed (1.8 percent of the precipitation measured at the South Plants Rain Gage).

4.1.10.2.3 Mean Monthly, Maximum Daily and Minimum Daily Flows

Mean monthly flows at North First Creek ranged from 0.00 cfs in October through December 1989 and July 1990 to a maximum of 2.5 cfs in March 1990. Mean monthly flows were highest in late winter and mid-summer. Maximum daily flows averaged six times greater than the mean monthly flows, which indicates that the maximum high flow events are usually short duration and do not always contribute significantly to the mean monthly discharge. Minimum daily flows were 0.00 cfs during October 1989 through February 1990 and June through August 1990. Maximum daily flows ranged from 0.42 cfs during January 1990 to 18.0 cfs during March 1990. A monthly summary of daily minimum, maximum and mean discharges for all RMA surface-water monitoring stations during Water Year 1990 is presented in Table 4.1-4. Annual hydrograph plots for North First Creek are illustrated in Figure 4.1-22 and Figure 4.1-33.

4.1.10.2.4 Streamflow Storm Runoff Hydrographs

Streamflow storm hydrographs observed at RMA during Water Year 1990 represent flow conditions in response to precipitation events typical for this area of Colorado. Six high or extended storm events (March 5, 6, 1990; May 29, 30, 1990; July 7-11, and 29, 1990; August 14-20, 1990; September 17-21, 1990) were analyzed as described in Section 4.1.2.2.4.

North First Creek responded to storm events differently throughout the year. Although only two of the storms analyzed induced a flow response at the station, the response times to precipitation events varied depending on the baseflow conditions present at the time of the storm and the spatial distribution of rainfall. Storm events occurring in July and September 1990 did not produce any flow at the station when it was initially dry. The response time for the late-winter storm event took approximately 4 hours and approximately 30 hours for flow to peak which is indicative of a the lag time for watershed drainage to reach the stream. Streamflow recession lasted approximately 36 hours. The station responded almost immediately to the August 1990 storm event and peak flow occurred approximately 8 hours after the first response. Streamflow recession lasted for 3 days.

4.1.11 FIRST CREEK OFF-POST GAGING STATION

The First Creek Off-Post gaging station is located in the First Creek drainage basin approximately 0.5 mi north of 96th Avenue and monitors streamflow that has exited RMA (Figure 2.3-2). This 37.32 sq mi drainage area is primarily a natural watershed. First Creek enters RMA along its eastern border in Section 8 and flows across RMA to the north where it exits in Section 24 and continues to the northwest. The First Creek Off-Post station is located directly upstream of First Creek's confluence with O'Brian Canal. Stream stage is monitored with a Omnidata DP115 Datapod (digital) recorder in conjunction with a Stevens Type F (analog) recorder and a Style C staff gage.

4.1.11.1 Stage Discharge Relationships

The stage-discharge relationship is represented by the station's rating curve. First Creek Off-Post's rating curve was developed empirically in the laboratory, and was verified for Water Year 1990 with instantaneous discharge measurements collected throughout the year.

4.1.11.1.1 Continuous Stage Data

The discharge record for First Creek Off-Post during Water Year 1990 was produced by converting the digital stage data of the DP115 Datapod to computed instantaneous discharge values derived from the current stage-discharge relationship. The computed instantaneous discharges are then compiled and reduced to mean daily discharges (Appendix A-8). The station did not have a Stevens Type F recorder installed until November 1989 and the DP115 Datapod was retrofitted in late February 1990. Stripcharts were digitized by hand periodically during the year when datapod records were inaccurate or missing portions of data. Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards as described in Section 4.1.2.1.1.

The continuous stage record for Water Year 1990 is considered good. Periods of estimated records include:

- October 11-31, 1989;
- November 1-6, 1989;
- December 16-19, 1989;
- February 7-26, 1990; and
- June 6-28, 1990.

Estimated records during October 1989 and November 1989 were made because the station was receiving very low flows (based on observations of stage during weekly visits) and did not have a Stevens Type F recorder operating at that time. The estimates during December 1989 were due to freezing conditions that caused the Stevens Type F recorder to collect erroneous stage data. The recorder was removed from the station late in December 1989 and was returned to service at the end of February 1990, therefore, estimates made during February 1990 are due to the missing records during that time. These estimates are also based on observations of stage during weekly monitoring of the station.

Other irregularities and inaccuracies may be caused by the following conditions:

- The intake pipe to the stilling well accumulated sediment and had to be flushed occasionally. Sediment slows the response time to stage changes.
- Algal growth in the notch of the flume restricted flow somewhat and had to be removed once during the year.

4.1.11.1.2 Rating Curves and Equations

The methodology for rating curve development and rating curve verification is described in Section 4.1.2.1.2. The stage-discharge relationship for First Creek Off-Post was developed using the empirical laboratory rating for a triangular-throated flume with 3:1 sloping sidewalls in the throat. Eight verified instantaneous discharge and staff measurements made during Water Year 1990 confirmed the permanence of the rating curve (Appendix A-5). The rating curve is considered good in both the defined and extrapolated regions. The rating curve for First Creek Off-Post is presented in Appendix A-3.2.

4.1.11.2 Surface-Water Hydrologic Conditions

The First Creek Off-Post gaging station is located in off-post Section 14 approximately 0.5 mi north of RMA. Flow at the station is intermittent and the station was dry for several months during Water Year 1990. Gain/loss studies indicate that First Creek behaves as an influent stream and as an effluent stream depending on the season. Sources of surface-water at First Creek Off-Post and other RMA continuous monitoring stations are presented in Table 4.1-3. Discharge records for this station during Water Year 1990 are presented in Appendix A-8. Streamflow conditions for First Creek Off-Post including mean daily discharge, mean monthly discharge, maximum daily discharge, minimum daily discharge and total monthly streamflow volume are presented in the following sections.

4.1.11.2.1 Streamflow Characteristics and Extremes

First Creek Off-Post exhibits flow characteristics that are typical of natural watersheds. Flow is derived primarily from ground-water discharge. Surface-water runoff, precipitation and effluent from the Sewage Treatment Plant located on RMA contribute minor amounts to flow at the station. Precipitation that falls in the off-post drainage area and on RMA can affect flow to the station in varying degrees depending on soil and channel bank moisture content, and recharge to the near-surface ground-water system at different times of the year. First Creek also has several small tributaries on RMA that can contribute a minor amount to flow during snowmelt runoff or during large storm events.

Maximum flows occurred during the late winter and mid-summer as a result of snowmelt runoff, thunderstorms and multi-day rainfall events. Minimum flows occurred primarily during the fall through mid-winter and in late spring through early summer when water in the channel is frozen or when conditions are dry (Figure 4.1-12). The maximum monthly runoff volume during Water Year 1990 was 111.45 ac-ft (0.06 in. over the 37.32 sq mi drainage area) and occurred in March 1990. The minimum monthly runoff volume was 0.00 ac-ft in January 1990.

4.1.11.2.2 Annual Streamflow Analysis

Streamflow at First Creek Off-Post varied considerably throughout Water Year 1990. The station received very low flow volumes during the fall through mid-winter (October 1989 through February 1990) of Water Year 1990. Total discharge volume during this period was only 4.92 acre-feet. Total discharge increased substantially during March 1990 and a total of 111.45 ac-ft was measured at the station. The increase in March 1990 is indicative of a late winter response to thawing, increased precipitation, snowmelt runoff and elevated ground-water levels. Water-discharge volumes steadily declined after March 1990 until July 1990 when the total water volume fell to 0.79 acre-feet. Gain/loss studies indicate that First Creek was influent during June 1990 and remained in that state until mid-August 1990. Substantial amounts of precipitation were received during July 1990 and produced only minimal flow at the station; however, the return of flow in mid-August appears to be a baseflow response to the precipitation that were received the prior month. A total of 71.86 ac-ft was measured in August 1990, which was the second highest flow volume during the water year. Total monthly water volume decreased to 22.81 ac-ft during September 1990 in response to reduced amounts of precipitation and increased evapotranspiration rates. The station received a total of 329.00 ac-ft (1.07 x 10^8 gallons) during the year. This is equivalent to 0.17 in. of runoff from the watershed (1.5 percent of the precipitation measured at the South Plants rain gage).

4.1.11.2.3 Mean Monthly, Maximum Daily and Minimum Daily Flows

Mean monthly flows at First Creek Off-Post ranged from 0.00 cfs in January 1990 to a maximum of 1.8 cfs in March 1990. Mean monthly flows were highest in late winter and mid-summer. Maximum daily flows averaged approximately five times greater than the mean monthly flows. Minimum daily flows were 0.00 cfs during October and December 1989, and January, February, June, July and August 1990. Maximum daily flows ranged from 0.02 cfs during October 1989 to 14.0 cfs during August 1990. A monthly summary of daily minimum, maximum and mean discharges for all RMA surface-water monitoring stations during Water Year 1990 is presented in Table 4.1-4. Annual hydrograph plots for First Creek Off-Post are illustrated in Figure 4.1-23 and Figure 4.1-34.

4.1.11.2.4 Streamflow Storm Runoff Hydrographs

Streamflow storm hydrographs observed at RMA during Water Year 1990 represent flow conditions in response to precipitation events typical for this area of Colorado. Six high or extended storm events (March 5, 6, 1990; May 29, 30, 1990; July 7-11, and 29, 1990; August 14-20, 1990; September 17-21, 1990) were analyzed as described in Section 4.1.2.2.4.

First Creek Off-Post responded to storm events differently throughout the year. Station response to the late winter storm was relatively rapid, approximately 2 hours, but after an initial small flow peak at 8 hours and recession of nearly 40 hours, the station exhibited a delayed high magnitude response 3 days after the initial precipitation. Streamflow recession lasted for 2 weeks. Response to the spring storm took approximately 4 hours; however, peak flow did not occur until 2 days after the onset of the precipitation event. Stream flow recession took approximately 4 days. The station responded to the extended event during early summer in approximately 16 hours after the onset of precipitation and flow remained at a relatively consistent stage for 2 days after the storm had ended. Recession was rapid and took only 8 hours for flow to terminate. Late July 1990 produced a high magnitude thunderstorm and the station exhibited peak flow within only 2 hours and recession lasted approximately 2 days. Mid-summer had an extended storm event lasting 7 days. The station did not have a significant response to the storm until the 6th day when heavy rain produced a flow peak in 12 hours followed by 3 days of recession. Finally, the late summer extended storm event did not produce any discernible change in flow at the station.

Generally, First Creek Off-Post's flow peaks occurred much later than the precipitation peaks of a given storm event. The station's delayed response times are attributable to its spatial relation within the watershed. Flow peaks occur as a result of surface-water runoff that has a considerable length to travel before it reaches the station. This fact in conjunction with other factors such as baseflow conditions, storm proximity, antecedent soil moisture and channel bank moisture content all affect the resultant storm hydrograph.

4.1.12 BASIN A GAGING STATION

Basin A is located in the South Platte drainage basin and monitors baseflow and storm sewer drainage from the northwest side of the South Plants area (Figure 2.3-2). Stream stage is monitored with an Omnidata DP115 Datapod (digital) recorder in conjunction with a Stevens Type F (analog) recorder and a Style C staff gage.

4.1.12.1 Stage Discharge Relationships

The stage-discharge relationship for Basin A is depicted by the station's rating curve, which was previously developed using the empirical laboratory rating for the structure.

4.1.12.1.1 Continuous Stage Data

The discharge record for Water Year 1990 was produced by converting the digital stage data of the DP115 Datapod to computed instantaneous discharge values derived from the current stage-discharge relationship. The computed instantaneous discharge values are then compiled and reduced to mean daily discharges. Flow was usually below the reportable limit of 0.01 cfs and, therefore, is reported as trace (T=>0.00 cfs but <0.005 cfs). Stripcharts were digitized by hand periodically during the year when datapod records were inaccurate or missing portions of data. The majority of the stage record for Water Year 1990 is missing because a section of concrete channel upstream of the station collapsed, causing flow to be diverted away from the recorder. Flow was diverted from the station from November 1, 1989, to June 21, 1990, when the collapsed channel was repaired. Repair of the channel did not last long however, and subsequently collapsed again on July 9, 1990, diverting flow the remainder of the water year. Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards as described in Section 4.1.2.1.1.

The continuous stage record for Basin A is considered good for periods when flow through the station, occurred, but poor for the remainder of the year. Inaccuracies of the stage record were caused primarily by the occurrence of debris that periodically accumulated in the notch of the weir.

4.1.12.1.2 Rating Curves and Equations

The methodology for rating curve development and rating curve verification is described in Section 4.1.2.1.2. The stage-discharge relationship for Basin A was developed using the empirical laboratory rating for a 90° V-notch weir. No instantaneous discharge measurements were made during Water Year 1990 to confirm the permanence of the rating or to allow any adjustments to be made to the rating (Appendix A-5). The rating curve is considered fair when the head is greater than 0.20 ft above the V-notch and the nape is prevented from clinging to the crest (USBR, 1974). Note that flows with heads less than 0.20 ft can only be estimated, therefore, the rating is considered poor. The rating curve for Basin A is presented in Appendix A-3.2.

4.1.12.2 Surface-Water Hydrologic Conditions

Basin A receives baseflow and watershed runoff from the South Plants area (Table 4.1-3). The drainage area to the station is 0.055 sq miles. Streamflow conditions for Basin A including mean monthly discharge, maximum daily discharge, minimum daily discharge and total monthly streamflow volume are presented in the following sections.

4.1.12.2.1 Streamflow Characteristics and Extremes

Flow characteristics at Basin A are relatively constant with only minor fluctuations throughout the year. Except for large magnitude storm events, precipitation occurring on RMA has little affect on flow in Basin A. Usually, only trace flows occur at the station at any given time. Due to the stream bank failure and the subsequent diversion of water away from the recording station for the majority of the year, any flow analysis of the Basin A station would be meaningless.

4.1.13 Basin F Gaging Station

The Basin F station is located in the South Platte drainage basin and monitors flow derived from surface-water runoff in the former Basin F IRA area (Figure 2.3-2). The station is new for Water Year 1990 and was constructed in October 1989. Stream stage is monitored with an Omnidata DP115 Datapod (digital) recorder in conjunction with a Stevens Type F (analog) recorder. The station operated the Stevens Type F recorder from November 1989 and was retrofitted with the Omnidata DP115 Datapod in late April 1990.

4.1.13.1 Stage Discharge Relationships

The stage-discharge relationship for Basin F is depicted by the station's rating curve, which was previously developed using the empirical laboratory rating for the structure.

4.1.13.1.1 Continuous Stage Data

During periods of flow at Basin F, the water-discharge record for Water Year 1990 was produced by digitizing stripcharts and converting the resultant digital stage data to computed instantaneous discharge values derived from the current stage-discharge relationship. The computed instantaneous discharge values are then compiled and reduced to mean daily discharges. The digital record of the DP115 Datapod proved unreliable and was not used to produce discharge records during the year. Relative accuracy ratings of the daily mean discharges were determined for each station based on USGS standards as described in Section 4.1.2.1.1.

The continuous stage record for Basin F is considered good for Water Year 1990 except for the estimated period which is considered fair. The estimated period of record was:

- March 9, 1990.

The estimate was due to an unexplainable flow peak that resulted from a moderate storm event occurring several days earlier.

4.1.13.1.2 Rating Curves and Equations

The methodology for rating curve development and rating curve verification is described in Section 4.1.2.1.2. The stage-discharge rating equations for Basin F were developed using the empirical laboratory rating table for a 200 mm RBC flume. A low-flow extrapolation was performed to extend the rating relationship below 0.0367 cfs (0.07 ft of head). No verified instantaneous discharge measurements and staff measurements were made during Water Year 1990 to confirm the permanence of the rating or to allow any adjustments to be made to the rating. The rating curve is considered good in both the defined and extrapolated regions. The rating curve for Basin F is presented in Appendix A-3.2.

4.1.13.2 Surface-Water Hydrologic Conditions

Basin F receives flow from direct precipitation and natural watershed runoff from the former Basin F area and surrounding area in Section 24 (Table 4.1-3). Streamflow conditions for Basin F including mean monthly discharge, maximum daily discharge, minimum daily discharge and total monthly streamflow volume are presented in the following sections.

4.1.13.2.1 Streamflow Characteristics and Extremes

Flow at Basin F is intermittent and only received flow several times during the water year. Except for very large magnitude storm events, precipitation occurring on RMA rarely produces flow at the station. A maximum volume of 1.31 ac-ft was measured at the station during March 1990.

4.1.13.2.2 Annual Streamflow Analysis

Streamflow at Basin F was very low in Water Year 1990 and is illustrated in Figure 4.1-13. The station received maximum flow during March 1990, (which accounted for 93 percent of the total flow at the station during Water Year 1990. A total of 1.41 ac-ft (4.59×10^5 gallons) was measured at the station during Water Year 1990.

4.1.13.2.3 Mean Monthly, Maximum Daily and Minimum Daily Flows

Mean monthly flows at Basin F ranged from 0.00 cfs for most of the year to 0.02 cfs during March 1990. The maximum daily flow was 0.26 cfs also during March 1990. The minimum daily flow was 0.00 cfs and occurred in every month of Water Year 1990. A monthly summary of daily minimum, maximum and mean discharges for all RMA surface-water monitoring stations during Water Year 1990 is presented in Table 4.1-4. Annual plots for these values are illustrated in Figure 4.1-24 and Figure 4.1-35.

4.1.13.2.4 Streamflow Storm Runoff Hydrographs

The Basin F station responded to three storm events during the water year (Table 4.1-5). The station responds to storm events in a manner that is typical of natural watersheds and varies depending on storm magnitude and soil moisture conditions at the time of the precipitation event. The station had a 3-day response time to the precipitation that occurred on March 5, 1990. Flow was intermittent after the flow peak and recession took approximately 6 days. This event was the first flow recorded at the station and appears to have been in response to snowmelt runoff in conjunction with a significant storm event when antecedent soil moisture content was high. Storm response, peak and recession of the July 29, 1990, event took approximately 2 hours. This response is indicative of the high runoff rate that results from a very short duration/high magnitude thundershower, typical of Colorado weather during the early summer. In August 1990 an extended storm produced a similar hydrograph at Basin F; however, the response did not occur until 5 days after the onset of precipitation. This response appears to have been caused in part by low antecedent soil moisture conditions in the watershed prior to the storm event. After several days of steady precipitation the ground became saturated and runoff to the station occurred for a short time period.

4.1.14 STREAMFLOW INFLOW/OUTFLOW COMPARISON

Surface-water inflow from off-post sources enters RMA via Havana Interceptor, Peoria Interceptor, Uvalda Interceptor, Highline Lateral and First Creek. The inflow sources encompass a total drainage area of approximately 40 sq mi, not including the Highline Lateral drainage area. The maximum monthly surface-water inflow volume was 778.75 ac-ft (2.54×10^8 gallons) during September 1990. The minimum monthly inflow volume was 61.91 ac-ft (2.0 x 10^7 gallons) during October 1989. A summary of monthly inflow volumes entering RMA from these sources is illustrated in Table 4.1-6.

Surface-water exits RMA via First Creek in Section 24. Outflow is measured at the Sewage Treatment Plant and at the North First Creek monitoring station. The maximum surface-water outflow volume was measured in March 1990 and totaled 155.58 ac-ft (5.07 x 10^7 gallons) during December 1989. Outflow volumes are summarized in Table 4.1-7.

The total volume of water entering RMA via Havana Interceptor, Peoria Interceptor, South Uvalda, Highline Lateral and South First Creek was 4524.71 ac-ft (1.47 x 10^9 gallons). However, the volume of water flowing off-post was only 419.85 ac-ft (1.37 x 10^8 gallons). The inflow volume of water exceeds the outflow volume approximately 11 times. A comparison of inflow and outflow volumes measured during Water Year 1990 is presented in Figure 4.1-36.

4.1.15 LAKE AND POND TRENDS AND EXTREMES

South Plant Lakes and Havana Pond storage volumes have been calculated for Water Year 1990 using area/stage relationships established by previous contractors (Ebasco Services, Inc., et al., 1989a). These water bodies are all located in the Irondale Gulch Drainage Basin, but the storage volumes from Lake Mary have not been established and cannot be presented because the lake area has never been surveyed. In the Water Year 1989 report, previously established and surveyed stage/elevation information did not correspond to the Water Year 1989 survey information that was compiled for the Surface-Water CMP. All elevation data in the Water Year 1990 report is referenced to the newer stage/elevation information from the Surface-Water CMP 1989 survey used in the RLSA Surface-Water CMP FY89 report (Appendix A-1.1). Net average volumes were calculated for each water body based on previously determined elevation/volume relationships with the revised stage/elevation relationships presented in the FY89 report. Average net volumes for each water body were determined for the weeks with sufficient data. The lakes and Havana Pond are typically frozen or below gage in December, January and February, hence there are several weeks with no volume calculations.

Estimated precipitation and evaporation volumes were calculated by multiplying the average monthly lake/pond areas by the precipitation or evaporation depth in feet to yield an acre-feet value. Table 4.1-8 summarizes average storage volumes for the South Plants Lakes and Havana Pond.

Table 4.1-6 Summary of RMA Inflow Volumes Water Year 1990

Summary of Monthly Inflow Volume from Off-Post Sources								
	Station							
Month	Havana Interceptor (ac-ft)	Peoria Interceptor (ac-ft)	South Uvalda (ac-ft)	Highline Lateral (ac-ft)	South First Creek (ac-ft)	Monthly Total (gallons x 1000)	Monthly Total (ac-ft)	Cummulative Total (ac-ft)
October	16.74	3.93	24.81	.00	16.42	20,169	61.90	61.90
November	9.34	4.84	22.73	.00	35.33	23,538	72.24	134.14
December	T	2.06	26.88	.00	38.74	22,052	67.68	201.82
January	T	3.43	27.69	.00	51.23	26,832	82.35	284.17
February	4.74	1.57	22.10	.00	50.76	25,796	79.17	363.34
March	192.91	52.88	104.55	.00	119.76	153,172	470.10	833.44
April	33.02	9.66	42.49	.00	68.77	50,158	153.94	987.38
May	220.96	24.36	85.82	241.39	62.64	206,957	635.17	1622.55
June	30.43	8.25	46.27	621.06	23.92	237,832	729.93	2352.48
July	165.92	38.62	88.24	286.87	35.84	200,544	615.49	2967.97
August	133.79	30.35	140.79	269.36	203.70	253,492	777.99	3745.96
September	93.60	22.27	56.35	584.53	22.00	253,739	778.75	4524.71
Total	901.45	202.22	688.72	2,003.21	729.11	1,474,281	4,524.71	

Table 4.1-7 Summary of RMA Outflow Volumes Water Year 1990

Summary of Monthly Outflow Volume Leaving RMA					
	Station				
Month	Sewage Treatment Plant (ac-ft)	North First Creek (ac-ft)	Monthly Total (gallons x 1000)	Monthly Total (ac-ft)	Cumulative Total (ac-ft)
October	1.68	.00	547	1.68	1.68
November	1.29	.00	420	1.29	2.97
December	1.11	.00	362	1.11	4.08
January	1.40	1.75	1,026	3.15	7.23
February	1.08	8.91	3,255	9.99	17.22
March	1.80	153.78	50,692	155.58	172.80
April	1.65	71.29	23,766	72.94	245.74
May	1.48	48.77	16,373	50.25	295.99
June	1.92	3.91	1,900	5.83	301.82
July	2.55	.00	831	2.55	304.37
August	2.23	77.20	25,881	79.43	383.80
September	1.72	34.33	11,746	36.05	419.85
Total	19.90	399.94	136,799	419.85	

Table 4.1-8 Average Storage, Precipitation and Evaporation Volumes for South Plants Lakes and Havana Pond, Water Year 1990

Month	Average Storage Volume (ac-ft)	Average Storage Volume (gallons)	Precipitation (ac-ft)	Evaporation (ac-ft)
Lower Derby Lake				
October	275.38	89,602,975	3.59	19.03
November	278.70	90,906,291	0.67	12.03
February	244.90	79,828,105	2.29	3.74
March	248.80	81,131,421	12.99	6.71
April	247.50	80,642,678	4.22	13.37
May	244.66	79,717,323	6.26	26.00
June	232.70	75,820,408	0.85	40.28
July	226.82	73,904,534	14.21	30.74
August	228.05	74,305,303	7.83	30.80
September	234.30	76,341,735	5.89	25.72
*10 Month Average	246.18	80,212,583	5.88	20.84
Ladora Lake				
October	280.10	91,264,703	3.53	18.75
November	287.00	93,512,923	0.67	11.99
March	315.28	102,730,000	14.71	7.59
April	305.25	99,377,845	4.68	14.83
May	279.52	91,075,722	6.57	27.30
June	298.45	94,243,665	0.96	45.36
July	311.82	101,600,000	16.81	36.35
August	270.68	88,195,394	8.33	32.79
September	328.18	106,930,000	.13	31.12
*9 Month Average	297.36	96,888,511	7.04	25.12

* Differences in months are due to early freezing or below gage stages reflected by individual lakes.

Table 4.1-8 Average Storage, Precipitation and Evaporation Volumes for South Plants Lakes and Havana Pond, Water Year 1990 (continued)

Month	Average Storage Volume (ac-ft)	Average Storage Volume (gallons)	Precipitation (ac-ft)	Evaporation (ac-ft)
Havana Pond				
October	18.05	5,881,214	0.79	4.22
November	11.18	3,642,768	0.11	2.02
February	11.72	3,818,716	0.43	0.70
March	35.68	11,625,579	4.49	2.32
April	22.29	7,262,728	1.14	3.62
May	23.23	7,569,008	1.70	7.06
June	25.97	8,461,779	0.26	12.35
July	39.30	12,805,080	5.54	11.97
August	47.81	15,577,884	3.45	13.56
September	33.86	11,032,570	2.10	9.16
*10 Month Average	26.91	8,768,058	2.00	6.70
Upper Derby Lake				
March	15.70	5,115,515	2.69	1.39
April	13.40	4,366,109	0.80	2.52
May	56.60	18,441,921	2.91	12.07
June	187.15	60,978,897	0.91	43.15
July	217.38	70,828,708	16.77	36.27
August	241.88	78,811,519	9.78	38.47
September	222.98	72,653,350	6.95	30.33
*7 Month Average	136.44	44,456,109	5.83	23.46

* Differences in months are due to early freezing or below gage stages reflected by individual lakes.

4.1.15.1 Havana Pond

Based on the Water Remedial Investigation (Ebasco Services, Inc., et al., 1989) storage volume information, the average storage volumes for Havana Pond ranged from a low of 7.15 ac-ft in December to a high of 63.58 ac-ft in August (Appendix A-9, Table A-9.5). During most of December 1989 and January 1990 the pond water was below gage and/or frozen, and storage volumes could not be calculated. The average monthly net storage volume for the 10-month record of no solid freezing on the pond was 26.91 ac-ft or 8,768,058 gallons (Table 4.1-8, Figure 4.1-37). No water was released to Sand Creek Lateral from Havana Pond in Water Year 1990.

The storage volume relationship for Havana Pond appears to be erroneous when comparing inflow volumes for Havana and Peoria Interceptors (Table 4.1-6). In March 1990, there was a total of 245.8 ac-ft of inflow through these interceptors which discharge into Havana Pond. This creates a water balance problem at Havana Pond because, based on weekly staff gage readings which are used in the storage volume table (Ebasco Services, Inc., et al., 1989a), the pond averaged only 35.68 ac-ft in March 1990. Havana Pond has a high infiltration rate but it is unlikely that this much water is infiltrating. Based on field observations, it appears that the pond has a greater average depth than that used in the storage volume calculations, which could be giving erroneously small storage volume values for Havana Pond.

4.1.15.2 Upper Derby Lake

Upper Derby Lake had large volume fluctuations in Water Year 1990. Water from Upper Derby Lake can be released by Army personnel into Lower Derby Lake through a culvert that stretches under the Lakes Road. When Upper Derby Lake reaches a staff gage of approximately 6.80 ft, water is spilled into Eastern Upper Derby Lake through a culvert under E Street. Throughout most of July, August and September 1990, Eastern Upper Derby Lake was at a high stage, taking in a large volume of water from Highline Lateral. Only minor amounts of Upper Derby Lake water could be released to Lower Derby Lake during the construction of the new Lower Derby Lake spillway. This caused a large volume of water to spill into Eastern Upper Derby Lake. There is no staff gage at Eastern Upper Derby Lake, but when Upper Derby Lake reaches a staff gage reading of approximately 9.0 ft, Eastern Upper Derby Lake will begin to spill over into a ditch on its northwest bank. The ditch runs a northeast course until it connects with First Creek approximately 1 mile away. Several discharge measurements were taken in

July 1990 where the lake spills over into the ditch and near the confluence of the ditch and First Creek, where a new sampling location station (SW06002) was surveyed. Flow rates were approximately 0.29 gpm to 0.57 gpm at the site where Eastern Upper Derby Lake water enters the ditch. Near the confluence of the ditch and First Creek, flow rates ranged from 0.02 gpm to 0.07 gpm indicating a net loss of surface-water to ground-water as water flows through the ditch. A rough estimate of the volume of lake water that eventually entered First Creek ranged from 2,000 gal to 7,500 gal during this period. Average weekly storage volumes for Upper Derby Lake ranged from a minimum of 3.70 ac-ft in November 1989 to a maximum of 291.60 ac-ft in September 1990 (Appendix A-9, Table A-9.2). During most of October 1989 through February 1990, Upper Derby Lake was below gage and/or frozen; therefore, storage volumes could not be accurately calculated. The average monthly net storage volume for the 7-month record was 136.44 ac-ft or 44,456,109 gallons (Table 4.1-8, Figure 4.1-38).

4.1.15.3 Lower Derby Lake

During the summer months of Water Year 1990, Lower Derby Lake was maintained at a low volume due to the construction of a spillway on its northwest bank and reinforcement work on its western dam. The lake was filled to a gage reading of 16.8 ft on September 28, 1990, to test the spillway. Lower Derby Lake's average weekly storage volume ranged from a low of 199.00 ac-ft in early September 1990 to a high of 293.30 in October 1989 (Appendix A-9, Table A-9.3). During most of December 1989 and January 1990, the lake was frozen, and storage volumes could not be accurately calculated. The average monthly net storage volume for the 10-month record of no freezing on the lake was 246.18 ac-ft or 80,212,583 gallons (Table 4.1-8, Figure 4.1-39).

4.1.15.4 Ladora Lake

The storage water at Ladora Lake is derived primarily from Lower Derby Lake via Ladora Weir and secondarily from Havana Pond via Sand Creek Lateral. During Water Year 1990, no water was discharged into Sand Creek Lateral downstream of Ladora Weir, and in most of July and August, water was not discharged into Ladora Lake through Ladora Weir due to construction activity at the weir. A spillway was completed on the west side of the lake in the Fall 1989. The spillway was designed to handle overspill at a stage of 12.8 feet. Average weekly net storage volumes at Ladora Lake ranged from a minimum of 246.90 ac-ft in early June to a maximum of 346.80 ac-ft in late June (Appendix A-9, Table A-9.4). In most of December 1989, January 1990 and February 1990, the lake was frozen, and storage volumes could not be accurately calculated. The average monthly net storage volume for the 9-month record of no solid freezing on the lake was 297.36 ac-ft or 96,888,511 gallons (Table 4.1-8, Figure 4.1-40).

4.1.15.5 Lake Mary

Stage at Lake Mary is monitored weekly from observed staff gage readings. Lake Mary's water is derived from Ladora Lake. Storage volumes are not calculated here because the lake area has never been surveyed. Water levels at Lake Mary ranged from 0.08 ft in February 1990 to 1.02 ft in May and July 1990.

4.1.16 SEWAGE TREATMENT PLANT TRENDS AND EXTREMES

Water discharge from the Sewage Treatment Plant (STP) originates from treated water that is used on RMA. The water is discharged from a 6-in. PVC pipe into a plastic-lined channel which leads to First Creek. The discharge water from the plant is monitored daily by Army personnel and observed routinely by RLSA personnel. Discharge records are summarized in Table 4.1-9 and presented in detail in Appendix A-10.

A total of 6,485,700 gal of water was discharged from the STP during Water Year 1990 (Table 4.1-9). The monthly discharge varied from a minimum of 351,900 gal during February to a maximum of 831,800 gal in July. The average monthly discharge for Water Year 1990 was 540,475 gal (17,728 gal per day). A minimum of 66,100 gal was recorded during the week of March 3, 1990, and a maximum of 214,700 gal was recorded during the week of July 14, 1990 (Appendix A-10). A graph displaying total weekly and cumulative weekly discharge data from the sewage treatment plant (STP) (Figure 4.1-41) shows a fluctuating monthly record with generally higher values in the summer months.

4.2 SURFACE-WATER QUALITY RESULTS

The results of the CMP Water Year 1990 surface-water quality monitoring program are presented in this section. Results are segregated into the following major categories for discussion: (1) target organic compounds, (2) nontarget organic compounds, (3) trace inorganic constituents, (4) field parameters, and (5) major inorganic constituents. Table 3.2-1 lists the sites from which surface-water samples were

Table 4.1-9 Sewage Treatment Plant Monthly Flow Summaries, Water Year 1990

Month	Monthly Total (gallons)	Monthly Total (acre-feet)	Daily Average (gpd)	Daily Average (gpm)
October	546,400	1.68	17,626	12.24
November	419,300	1.29	13,977	9.71
December	360,700	1.11	11,635	8.08
January	457,600	1.40	14,761	10.25
February	351,900	1.08	12,568	8.73
March	587,300	1.80	18,945	13.16
April	537,700	1.65	17,923	12.45
May	481,300	1.48	15,526	10.78
June	624,200	1.92	20,807	14.45
July	831,800	2.55	16,832	18.63
August	727,500	2.23	23,468	16.30
September	560,000	1.72	18,667	12.96
AVERAGE FOR YEAR	540,475	1.66	17,728	12.31
TOTAL FOR YEAR	6,485,700	19.90		

collected during Water Year 1990. Table 3.2-2 summarizes analytical methods and certified reporting limits (CRLs) that were used by Data Chem and ESE laboratories. An evaluation of quality control samples, including blanks, duplicates, and confirmatory analyses, is provided in Section 4.5.

4.2.1 SURFACE-WATER QUALITY PROGRAM OVERVIEW

The CMP Water Year 1990 program for analysis of a target list of organic and inorganic chemical species is described in the CMP Surface-Water Technical Plan (RLSA, 1989). This list includes organic compounds, major inorganic constituents, trace inorganic constituents, and field parameters. Gas chromatography/mass spectrometry (GC/MS) analyses were performed on samples of surface-water inflows to the south and southeast boundaries of RMA and a sample of the outflow from RMA in First Creek. Several other surface-water samples were randomly selected for GC/MS confirmatory analyses. The purpose of the GC/MS program was to confirm results for analytes reported by GC methods and to further characterize the quality of surface water at RMA by identifying the presence of nontarget compounds. Analytical results reported include those listed in Appendix B. Analytical results are included for 27 samples collected during the spring, 22 collected during high events, and 13 collected during the fall.

Separate discussions are presented for (1) target organic compounds, (2) nontarget organic compounds, (3) trace inorganic constituents, (4) field parameters, and (5) major inorganic constituents for each drainage basin. Trace inorganic constituents, as defined herein, are constituents reported at concentrations generally less than 0.1 milligrams per liter (mg/l). Major inorganic constituents are constituents reported at concentrations generally greater than 0.1 mg/l. Calculations for carbonate and bicarbonate concentrations and an ion balance analysis are included in the major inorganic constituent discussion.

4.2.2 OCCURRENCE OF TARGET ORGANIC COMPOUNDS

The occurrences of target organic compounds are presented in this section. The target organic compounds for this study have been grouped according to the method of analysis and are listed in Table 4.2-1. The concentrations reported in the following sections are concentrations that exceeded the Certified Reporting Limit. Table 4.2-2 provides a tabulated summary of the occurrence of target organic compounds, including the sampling locations within the RMA drainage basins, sampling event, target

Table 4.2-1 CMP Surface-Water List of Target Organic Compounds by Method

Volatile Organohalogen Method	Organochlorine Pesticide Method
1,1-Dichloroethane	Aldrin
1,1-Dichloroethene	Chlordane
1,1,1-Trichloroethane	Dieldrin
1,1,2-Trichloroethane	Endrin
1,2-Dichloroethane	Hexachlorocyclopentadiene
1,2-Dichloroethene	Isodrin
Carbon tetrachloride	2,2-Bis(parachlorophenyl)-1,1-dichloroethene (PPDDE)
Chlorobenzene	2,2-Bis(parachlorophenyl)-1,1,1-trichloroethane (PPDDT)
Chloroform	
Methylene chloride	**Hydrocarbon Method**
Tetrachloroethene	Dicyclopentadiene (DCPD)
Trichloroethene	Methylisobutylketone (MIBK)
	Bicycloheptadiene (BCHPD)
Volatile Aromatic Method	
Benzene	**Organophosphorus Pesticides Compound Method**
Ethylbenzene	Atrazine
Toluene	Malathion
Xylene (m)	Parathion
Xylenes (o,p)	Supona
	Vapona
Organosulfur Compound Method	
1,4-Dithiane	**Phosphonate Method**
1,4-Oxathiane	Diisopropylmethylphosphonate (DIMP)
Benzothiazole	Dimethylmethylphosphonate (DMMP)
Dimethyldisulfide	
p-Chlorophenylmethylsulfone	**DBCP Method**
p-Chlorophenylmethylsulfoxide	Dibromochloropropane (DBCP)
p-Chlorophenylmethylsulfide	

Table 4.2-2 Occurrences of Target Organic Compounds in Surface-Water Samples, Water Year 1990

Sampling Location	Sampling Event*	Target Compound	Concentration (µg/l)
<u>Irondale Gulch Drainage Basin</u>			
SW01002	Spring	CL6CP	0.317
		Dieldrin	0.149
		DMMP	0.679
		Endrin	0.213
		PPDDE	0.227
		PPDDT	0.189
		Parathion	35.3
	High Event 1 March 13, 1990	Aldrin	0.914
		Atrazine	74.7
		BTZ	7.73
		CCL4	1.87
		CHCL3	72.6
		CL6CP	1.06
		CPMS	8.47
		CPMSO	258
		CPMSO2	79.0
		DBCP	201
		DIMP	3.14
		Dieldrin	4.96
		DMMP	1.86
		Endrin	2.34
		Isodrin	1.20
		PPDDE	0.313
		Parathion	69.7
		Supona	1.93
		TCLEE	6.69
SW01004	Spring	Aldrin	0.0936
		Chlordane	0.211
		DIMP	0.978
SW02006	Spring	CHCL3	5.76
SW11001	Spring	Atrazine	8.10
		Dieldrin	0.138
	High Event 1 March 6, 1990	Atrazine	11.2
		Dieldrin	0.0583
		Isodrin	0.0777
		Vapona	0.718

Table 4.2-2 Occurrences of Target Organic Compounds in Surface-Water Samples, Water Year 1990 (continued)

Sampling Location	Sampling Event*	Target Compound	Concentration (µg/l)
Irondale Gulch Drainage Basin (continued)			
SW11001 (continued)	High Event 2 March 13, 1990	Atrazine	22.1
		CL6CP	0.0685
		Dieldrin	0.0796
	Fall	12DCE	14.4
		TCLEE	14.8
		TRCLE	14.3
SW11002	Spring	Atrazine	10.2
		Chlordane	0.293
		PPDDT	0.0880
	High Event 1 March 6, 1990	Atrazine	13.1
		CHCL3	2.45
	High Event 2 March 13, 1990	Atrazine	79.7
		CL6CP	0.0731
		PPDDE	0.305
		Parathion	1.33
	High Event 3 July 9, 1990	111TCE	4.82
SW12004	Spring	Chlordane	0.418
		Endrin	0.0787
		PPDDT	0.0674
SW12005	High Event 2 March 13, 1990	Aldrin	0.0914
		Atrazine	5.26
	High Event 3 March 28, 1990	Atrazine	11.4
		CL6CP	0.104
SW12006	High Event July 21, 1990	CL6CP	0.566
SW12007	Spring	DIMP	0.521

Table 4.2-2 Occurrences of Target Organic Compounds in Surface-Water Samples, Water Year 1990 (continued)

Sampling Location	Sampling Event*	Target Compound	Concentration ($\mu g/l$)
First Creek Drainage Basin			
SW24001	Spring	Aldrin	0.0703
SW24002	High Event March 9, 1990	Aldrin	0.0880
SW24003	Spring	DIMP	1.65
SW30002	Spring	CHCL3	0.764
SW37001	High Event 1 Nov. 29, 1989	Atrazine	9.43
		Chlordane	0.236
		DCPD	48.4
		DIMP	160
		TCLEE	0.878
	Spring	Chlordane	0.319
		DCPD	12.9
		DIMP	38.5
	High Event 2 March 9, 1990	DIMP	14.1
	Fall	Atrazine	12.2
		DCPD	19.5
		DIMP	124
		Endrin	0.230
		Parathion	1.35
South Platte Drainage Basin			
SW26001	High Event 1 March 13, 1990	Endrin	0.311
	High Event 2 August 19, 1990	Dieldrin	0.734
		Endrin	0.284
SW36001	Spring	112TCE	1.16
		11DCE	4.63
		12DCE	15.1
		Aldrin	0.783
		Atrazine	39.1
		BCHPD	22.1
		C6H6	44.8
		CHCL3	198
		CL6CP	0.258
		CLC6H5	993
		DBCP	15.2

Table 4.2-2 Occurrences of Target Organic Compounds in Surface-Water Samples, Water Year 1990 (continued)

Sampling Location	Sampling Event*	Target Compound	Concentration (µg/l)
South Platte Drainage Basin (continued)			
SW36001 (continued)	Spring	DCPD	47.8
		Dieldrin	2.13
		DMMP	1.31
		Endrin	0.171
		ETC6H5	65.2
		Isodrin	0.935
		MEC6H5	16.7
		MIBK	783
		PPDDE	0.195
		PPDDT	0.561
		Parathion	61.5
		Supona	5.84
		TCLEE	78.2
		TRCLE	42.7
		XYLEN	75.0
	Fall	11DCE	2.08
		12DCE	9.02
		Aldrin	1.02
		Atrazine	7.12
		C6H6	3.96
		CHCL3	92.8
		CL6CP	0.0718
		CLC6H5	327
		CPMSO	17.0
		CPMSO2	194
		DBCP	5.43
		DCPD	20.4
		Dieldrin	3.99
		DMMP	0.771
		Endrin	1.39
		ETC6H5	16.1
		Isodrin	0.516
		MEC6H5	3.23
		Parathion	43.2
		Supona	11.6
		TCLEE	34.5
		TRCLE	15.3
		XYLEN	29.6

* Spring = April 12 through April 19, 1990
Fall = September 4 through September 7, 1990
µg/l = micrograms per liter

organic compound reported and concentration. A geographical representation of the target organic compound concentrations by drainage basin is provided in Figures 4.2-1, 4.2-2, and 4.2-3. The following discussions summarize the analytical results by method and sampling event for all sample results that met CMP Quality Assurance/Quality Control (QA/QC) requirements. A discussion of the QA/QC protocol and a summary of the rejected data are provided in Section 4.5.

4.2.2.1 Volatile Organohalogens

Compounds in the volatile organohalogen group are listed as follows:

1,1,1-Trichloroethane (111TCE)
1,1,2-Trichloroethane (112TCE)
1,1-Dichloroethane (11DCLE)
1,1-Dichloroethene (11DCE)
1,2-Dichloroethane (12DCLE)
1,2-Dichloroethene (12DCE)
Carbon tetrachloride (CCL4)
Chlorobenzene (CLC6H5)
Chloroform (CHCL3)
Methylene chloride (CH2CL2)
Tetrachloroethene (TCLEE)
Trichloroethene (TRCLE)

The analytical results for volatile organohalogens are summarized below.

Volatile organohalogens at concentrations exceeding the CRLs were reported in three samples collected during the spring sampling event. The compounds 112TCE, 11DCE, 12DCE, CLC6H5, CHCL3, TCLEE, and TRCLE were reported in one sample collected from the South Platte drainage basin (Basin A; SW36001). The concentrations of these compounds were: 1.16 micrograms per liter (μg/L) of 112TCE, 4.63 μg/L of 11DCE, 15.1 μg/L of 12DCE, 993 μg/L of CLC6H5, 198 μg/L of CHCL3, 78.2 μg/L of TCLEE, and 42.7 μg/L of TRCLE. CHCL3 was reported in one sample collected from the First Creek drainage basin in First Creek near North Plant (SW30002; 0.764 μg/L) and one sample collected from the Irondale Gulch drainage basin from South Plants steam effluent ditch (SW02006; 5.76 µg/L).

Volatile organohalogens at concentrations exceeding the CRLs were reported present in two samples collected during the fall sampling event. The compounds 11DCE, 12DCE, CLC6H5, CHCL3, TCLEE, and TRCLE were reported present in one sample collected from the South Platte drainage basin (Basin A; SW36001). The concentrations of these compounds were 2.08 µg/L of 11DCE, 9.02 µg/L of 12DCE, 327 µg/L of CLC6H5, 92.8 µg/L of CHCL3, 34.5 µg/L of TCLEE, and 15.3 µg/L of TRCLE. The compounds 12DCE (14.4 µg/L), TCLEE (14.8 µg/L), and TRCLE (14.3 µg/L) were reported present in one sample collected from the Irondale Gulch drainage basin in Peoria Interceptor (SW11001).

Volatile organohalogens at concentrations exceeding the CRLs were reported present in three samples collected during high event sampling. 111TCE (4.82 µg/L) was reported present in the Irondale Gulch drainage basin at the Havana Interceptor (SW11002; July 9, 1990). CHCL3 (2.45 µg/L) was reported present in one sample collected from the Irondale Gulch drainage basin at the Havana Interceptor (SW11002; March 6, 1990). The compounds CCL4 (1.87 µg/L), CHCL3 (72.6 µg/L), and TCLEE (6.69 µg/L) were reported present in a sample collected from the Irondale Gulch drainage basin in the South Plants Water Tower Pond (SW01002; March 13, 1990). The compound TCLEE (0.878 µg/l) was reported present in a sample collected from the First Creek drainage basin at First Creek Off-Post (SW37001; November 29, 1989).

4.2.2.2 Volatile Aromatics

Compounds in the volatile aromatic group are listed as follows:

Benzene (C6H6)
Ethylbenzene (ETC6H5)
m-Xylene (13DMB)
Toluene (MEC6H5)
Xylenes (o,p) (XYLEN)

The analytical results for volatile aromatics are summarized below.

Volatile aromatic compounds at concentrations exceeding the CRLs were reported present in one sample collected during the spring sampling event. The compounds C6H6 (44.8 μg/L), ETC6H5 (65.2 μg/L), MEC6H5 (16.7 μg/L), and XYLEN (75.0 μg/L) were reported present in one sample collected from the South Platte drainage basin at Basin A (SW36001).

Volatile aromatic compounds at concentrations exceeding the CRLs were reported present in one sample collected during the fall sampling event. The compounds C6H6 (3.96 μg/L), ETC6H5 (16.1 μg/L), MEC6H5 (3.23 μg/L), and XYLEN (29.6 μg/L) were reported present in one sample collected from the South Platte drainage basin at Basin A (SW36001).

No concentrations of volatile aromatic compounds above the CRL were reported present in samples collected during any high events.

4.2.2.3 Organosulfur Compounds

Compounds in the organosulfur group are listed as follows:

- p-Chlorophenylmethyl sulfide (CPMS)
- p-Chlorophenylmethyl sulfoxide (CPMSO)
- p-Chlorophenylmethyl sulfone (CPMSO2)
- 1,4-Dithiane (DITH)
- 1,4-Oxathiane (OXAT)
- Dimethyldisulfide (DMDS)
- Benzothiazole (BTZ)

The analytical results for organosulfur compounds are summarized below.

No concentrations of organosulfur compounds above the CRLs were reported present in samples collected during the spring sampling event.

Organosulfur compounds at concentrations exceeding the CRLs were reported present in one sample collected during the fall sampling event. The compounds CPMSO (17.0 μg/L) and CPMSO2 (194 μg/L) were reported present in one sample collected from the South Platte drainage basin at Basin A (SW36001).

Organosulfur compounds at concentrations exceeding the CRLs were reported present in one sample collected during high event sampling. The compounds BTZ (7.73 μg/L), CPMS (8.47 μg/L), CPMSO (258 μg/L), and CPMSO2 (79.0 μg/L) were reported present in one sample collected from the Irondale Gulch drainage basin at the South Plants Water Tower Pond (SW01002; March 13, 1990).

4.2.2.4 Organochlorine Pesticides

Compounds in the organochlorine pesticide group are listed as follows:

Aldrin
Chlordane
Dieldrin
Endrin
Hexachlorocyclopentadiene (CL6CP)
Isodrin
2,2-Bis(parachlorophenyl)-1,1-dichloroethene (PPDDE)
2,2-Bis(parachlorophenyl)-1,1,1-trichloroethane (PPDDT)

The analytical results for organochlorine pesticides are summarized below.

Organochlorine pesticides at concentrations exceeding the CRLs were reported present in eight samples collected during the spring sampling event. The compounds aldrin (0.783 μg/L), dieldrin (2.13 μg/L), endrin (0.171 μg/L), CL6CP (0.258 μg/L), isodrin (0.935 μg/L), PPDDE (0.195 μg/L), and PPDDT (0.561 μg/L) were reported present in one sample collected from the South Platte drainage basin (Basin A; SW36001). Organochlorine pesticides were reported present in five samples from the Irondale Gulch drainage basin: the sample from South Plants Water Tower Pond (SW01002) contained dieldrin (0.149 μg/L), endrin (0.213 μg/L), CL6CP (0.317 μg/L), PPDEE (0.227 μg/L), and PPDDT (0.189 μg/L); the sample from Upper Derby Lake (SW01004) contained aldrin (0.0936 μg/L) and chlordane (0.211 μg/L); the sample from Havana Interceptor (SW11002) contained chlordane (0.293 μg/L) and PPDDT (0.088 μg/l); the sample from Peoria Interceptor (SW11001) contained dieldrin (0.138 μg/L); and the sample from the Storm Sewer (SW12004) contained chlordane (0.418 μg/L), endrin (0.0787 μg/L), and PPDDT (0.0674 μg/L). Two samples collected from the First Creek drainage basin were reported to contain concentrations of organochlorine pesticides; aldrin (0.0703 μg/L) was reported present in the sample collected from the Sewage Treatment Plant (SW24001) and chlordane (0.319 μg/L) was reported present in the sample collected at the First Creek Off-Post monitoring station (SW37001).

Organochlorine pesticides at concentrations exceeding the CRLs were reported present in two samples collected during the fall sampling event. In the South Platte drainage basin, aldrin (1.02 μg/L), dieldrin (3.99 μg/L), endrin (1.39 μg/L), CL6CP (0.0718 μg/L), and isodrin (0.516 μg/L) were reported present in one sample from Basin A (SW36001). In the First Creek drainage basin, endrin (0.230 μg/l) was reported present in one sample collected from First Creek Off-Post (SW37001).

Organochlorine pesticides at concentrations exceeding the CRLs were reported present in six samples collected during high event sampling. In the Irondale Gulch drainage basin, samples collected from South Plants Water Tower Pond (SW01002), Peoria Interceptor (SW11001), Havana Interceptor (SW11002), South Uvalda (SW12005), and Army Reserve Storm Sewer (SW12006) contained organochlorine pesticides. Aldrin (0.914 μg/l), dieldrin (4.96 μg/l), endrin (2.34 μg/l), CL6CP (1.06 μg/l), isodrin (1.20 μg/l), and PPDDE (0.313 μg/l) were reported present in one sample from South Plants Water Tower Pond (SW01002) on March 13, 1990. A sample from Peoria Interceptor (SW11001) on March 6, 1990, was reported to contain dieldrin (0.0583 μg/l) and isodrin (0.0777 μg/l). A second sample from Peoria Interceptor (SW11001) March 13, 1990, was reported to contain dieldrin (0.0796 μg/l) and CL6CP (0.0685 μg/l). CL6CP (0.0731 μg/l) and PPDDE (0.305 μg/l) were reported present in the sample from Havana Interceptor (SW11002) March 13, 1990. Aldrin (0.0914 μg/l) was reported present in a sample from South Uvalda (SW12005; March 13, 1990). CL6CP (0.104 μg/l) was reported present in another high event sample from South Uvalda (SW12005) on March 28, 1990. CL6CP (0.566 μg/l) was reported present in a sample from the Army Reserve Storm Sewer (SW12006; July 21, 1990). Aldrin (0.0880 μg/l) was reported present in a sample from the First Creek drainage basin at North First Creek (SW24002) on March 9, 1990. Endrin (0.311 μg/l) was reported present in a storm sample from Basin F in the South Platte drainage basin (SW26001; March 13, 1990). Dieldrin (0.734 μg/l) and endrin (0.284 μg/l) were reported present in a high event sample from Basin F (SW26001; August 19, 1990). Chlordane (0.236 μg/l) was reported present in a sample collected at First Creek Off-Post (SW37001; November 29, 1989) in the First Creek drainage basin.

4.2.2.5 Hydrocarbons

Compounds in the hydrocarbon group, are listed as follows:

Bicycloheptadiene (BCHPD)
Dicyclopentadiene (DCPD)
Methylisobutylketone (MIBK)

The analytical results for hydrocarbons are summarized below.

Hydrocarbons were reported present at concentrations exceeding the CRLs in two samples collected during the spring sampling event. BCHPD (22.1 μg/L), DCPD (47.8 μg/L), and MIBK (783 μg/L) were reported present in one sample from Basin A in the South Platte drainage basin (SW36001). DCPD (12.9 μg/L) was reported present in one sample from the First Creek drainage basin at First Creek Off-Post (SW37001).

DCPD was reported present in two samples collected during the fall sampling event. One sample from the South Platte drainage basin at Basin A (SW36001) was reported to contain DCPD at 20.4 μg/L. One sample from the First Creek drainage basin at First Creek Off-Post (SW37001) was reported to contain DCPD at 19.5 μg/L.

A hydrocarbon concentration above the CRL was reported present in one sample collected during high event sampling in the First Creek drainage basin. DBCB (48.4 μg/L) was reported present at First Creek Off-Post (SW37001: November 29, 1989).

4.2.2.6 Organophosphorus Compounds

Compounds in the nitrogen phosphate pesticides (organophosphorus) group are listed as follows:

Atrazine
Malathion
Parathion
Supona
Vapona

The analytical results for organophosphorus compounds are summarized below.

Organophosphorus compound concentrations exceeding the CRLs were reported present in four samples collected during the spring sampling event. One sample from the South Platte drainage basin (Basin A; SW36001) was reported to contain atrazine (39.1 μg/L), parathion (61.5 μg/L), and supona (5.84 μg/L). Two samples from the Irondale Gulch drainage basin were reported to contain atrazine. The sample from Peoria Interceptor (SW11001) was reported to contain 8.10 μg/L of atrazine, and the sample from Havana Interceptor (SW11002) was reported to contain 10.2 μg/L of atrazine. Parathion (35.3 μg/L) was reported present in one sample from the Irondale Gulch drainage basin (South Plants Water Tower Pond; SW01002).

Two samples collected during the fall sampling event were reported to contain concentrations of organophosphorus compounds that exceeded the CRLs. One sample from the South Platte drainage basin (Basin A; SW36001) was reported to contain atrazine (7.12 μg/L), parathion (43.2 μg/L), and supona (11.6 μg/L). One sample from the First Creek drainage basin (First Creek Off-Post; SW37001) was reported to contain atrazine (12.2 μg/L) and parathion (1.35 μg/L).

Organophosphorus compounds at concentrations exceeding the CRLs were reported present in samples collected from four locations in the Irondale Gulch drainage basin and from one location in the First Creek drainage basin during high events. A high event sample from North Uvalda (SW01002) on March 13, 1990, was reported to contain atrazine (74.7 μg/L), parathion (69.7 μg/L), and supona (1.93 μg/L). One sample collected from Peoria Interceptor (SW11001) on March 6, 1990, was reported to contain atrazine (11.2 μg/L) and vapona (0.718 μg/L). A high event sample collected from Havana Interceptor (SW11002) on March 6, 1990, was reported to contain atrazine (13.1 μg/L), and another sample from Havana Interceptor (SW11002) on March 13, 1990, was reported to contain atrazine (79.7 μg/L) and parathion (1.33 μg/L). Atrazine was reported present in two high event samples collected at South Uvalda (SW12005) at concentrations of 5.26 μg/L on March 13, 1990, and 11.4 μg/L on March 28, 1990. A high event sample collected at Peoria Interceptor (SW11001) on March 13, 1990, was reported to contain atrazine (22.1 μg/L). An organophosphorus compound was detected in one sample collected in the First Creek drainage basin during a high event. Atrazine (9.43 μg/L) was reported present at First Creek Off-Post (SW37001; November 29, 1989).

4.2.2.7 Phosphonates

Compounds in the phosphonate group are listed as follows:

Diisopropylmethylphosphonate (DIMP)
Dimethylmethylphosphonate (DMMP)

The analytical results for phosphonates are summarized below.

Phosphonates at concentrations exceeding the CRLs were reported present in five samples collected during the spring sampling event. Three samples from the Irondale Gulch drainage basin were reported to contain phosphonates. DIMP was reported present in Upper Derby Lake (SW01004; 0.978 μg/L) and Highline Lateral (SW12007; 0.521 μg/L), and DMMP was reported present in South Plants Water Tower Pond (SW01002; 0.679 μg/L). Two samples from the First Creek drainage basin were reported to contain phosphonates. DIMP was reported present in North Bog (SW24003; 1.65 μg/L) and First Creek Off-Post (SW37001, 38.5 μg/L). DMMP (1.31 μg/L) was reported present in one sample from the South Platte drainage basin (Basin A; SW36001).

Phosphonates at concentrations exceeding the CRLs were reported present in two samples collected during the fall sampling event. DIMP (124 μg/L) was reported present in one sample from the First Creek drainage basin (First Creek Off-Post; SW37001). DMMP (0.771 μg/L) was reported present in one sample from the South Platte drainage basin (Basin A; SW36001).

Phosphonates at concentrations exceeding the CRLs were reported present in three samples collected during high events. One sample from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002) on March 13, 1990, was reported to contain DIMP (3.14 μg/L) and DMMP (1.86 μg/L). DIMP was reported present in two samples from the First Creek drainage basin at First Creek Off-Post on November 29, 1989 (160 μg/L) and on March 9, 1990 (14.1 μg/L).

4.2.2.8 Dibromochloropropane (DBCP)

The analytical results for DBCP are summarized below.

DBCP was reported present at a concentration exceeding the CRL in one sample collected during the spring sampling event. One sample from the South Platte drainage basin (Basin A; SW36001) was reported to contain DBCP at 15.2 μg/L.

DBCP was reported present at a concentration exceeding the CRL in one sample collected during the fall sampling event. One sample from the South Platte drainage basin (Basin A; SW36001) was reported to contain DBCP at 5.43 μg/L.

DBCP was reported present at a concentration exceeding the CRL in one sample collected during a high event sampling. One sample from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002) on March 13, 1990, was reported to contain DBCP at 201 μg/L.

4.2.3 Occurrence of Nontarget Organic Compounds

GC/MS analyses were performed to confirm CMP target compound analyses and to provide information regarding the potential presence of nontarget compounds at specific locations. Confirmational GC/MS results for CMP target compounds are discussed in Section 4.5. The results of GC/MS analyses for nontarget compounds are discussed below, including identification of the nontarget compounds, sampling locations, sampling events, and reported concentrations.

Seven samples were collected for GC/MS analyses during the spring sampling event. Of these seven samples, no nontarget organic compounds were reported present.

Three samples were collected for GC/MS analyses during the fall sampling event. Of these three samples, a single nontarget compound, n-nitroso-di-n-propylamine (7.01 μg/L), was reported present in a sample collected from South Platte drainage basin at Basin A (SW36001).

One sample was collected for GC/MS analysis during a high event. No nontarget organic compounds were reported present in this sample.

4.2.4 Occurrence of Trace Inorganic Constituents

Trace inorganic constituents analyzed for this study include six trace metals and arsenic. Trace metals generally occur in natural waters at concentrations less than 0.1 mg/L (Hem, 1989). Trace metals for which analyses were performed include cadmium, chromium, copper, lead, mercury, and zinc. Twenty-seven sites were sampled during the spring sampling event, 13 sites were sampled during the fall sampling event, and 22 samples were collected at 12 sites during high events. Samples from all events were submitted for total recoverable analyses. The occurrence of reported trace inorganic constituents in surface-water samples is presented in Table 4.2-3. A geographical representation of the reported trace inorganic constituent concentrations is provided in Figures 4.2-4, 4.2-5 and 4.2-6. The following discussions summarize the analytical results by constituent and sampling event for all sample results that meet CMP QA/QC requirements. A discussion of the QA/QC protocol and a summary of rejected data are provided in Section 4.5.

4.2.4.1 Arsenic

A total of 27 samples collected during the spring sampling event were analyzed for total arsenic. Of these 27 samples, there were three reported concentrations exceeding the CRL. The maximum reported concentration (73.1 μg/L) was for a sample collected from the First Creek drainage basin at the Sewage Treatment Plant (SW24001). Other reported concentrations were for samples from the Irondale Gulch drainage basin at Upper Derby Lake (SW01004; 2.49 μg/L) and the South Platte drainage basin at Basin A (SW36001; 71.6 μg/L).

A total of 13 samples were analyzed for total arsenic during the fall sampling event. Of these 13 samples, there were three reported concentrations exceeding the CRL. The maximum reported concentration (81.9 μg/L) was for a sample from the South Platte drainage basin at Basin A (SW36001).

Other reported concentrations were for samples from the First Creek drainage basin at North First Creek (SW24002; 2.75 μg/L) and the Sewage Treatment Plant (SW24001; 70.6 μg/L).

A total of 22 samples were analyzed for total arsenic during high event sampling. Of these 21 samples, there were seven reported concentrations exceeding the CRL (Table 4.2-3). The minimum (2.92 μg/L) and maximum (92.2 μg/L) reported concentrations were for samples from the First Creek drainage basin

Table 4.2-3 Occurrence of Trace Inorganic Constituents in Surface-Water Samples, Water Year 1990

Sampling Location	Sampling Event*	Trace Metal	Concentration ($\mu g/l$)
Irondale Gulch Drainage Basin			
SW01001	Fall	Zinc	33.5
SW01002	Spring	Copper	29.7
	High Event 1 March 13, 1990	Arsenic	32.5
		Copper	39.8
SW01004	Spring	Arsenic	2.49
SW11001	Spring	Cadmium	9.80
		Copper	21.3
		Zinc	115
	High Event 1 March 6, 1990	Zinc	61.6
	High Event 2 March 13, 1990	Chromium	17.4
		Copper	24.3
		Lead	52.3
		Zinc	152
	Fall	Zinc	33.7
SW11002	Spring	Zinc	106
	High Event 1 March 6, 1990	Zinc	80.5
	High Event 2 March 13, 1990	Copper	22.9
		Zinc	144
	High Event 3 July 9, 1990	Chromium	19.7
		Copper	24.3
		Lead	63.6
		Zinc	188
SW11003	Spring	Zinc	20.8
SW12001	Fall	Zinc	46.3

Table 4.2-3 Occurrence of Trace Inorganic Constituents in Surface-Water Samples, Water Year 1990 (continued)

Sampling Location	Sampling Event*	Trace Metal	Concentration (μg/l)
Irondale Gulch Drainage Basin (continued)			
SW12004	Spring	Copper Lead	29.3 65.4
	High Event	Zinc	74.2
	Fall	Zinc	60.9
SW12005	High Event 1 March 8, 1990	Zinc	29.4
	High Event 2 March 13, 1990	Chromium Zinc	20.5 24.9
SW12006	High Event July 21, 1990	Copper Zinc	19.6 63.6
First Creek Drainage Basin			
SW08003	High Event 1 May 30, 1990	Arsenic	3.01
	High Event 3 July 9, 1990	Zinc	127
	Fall	Zinc	21.1
SW24001	Spring	Arsenic	73.1
	Fall	Arsenic	70.6
SW24002	Fall	Arsenic Zinc	2.75 54.7
SW37001	High Event 1 November 29, 1989	Arsenic	4.10
	High Event 2 March 9, 1990	Arsenic	2.92
	Fall	Zinc	21.2

Table 4.2-3 Occurrence of Trace Inorganic Constituents in Surface-Water Samples, Water Year 1990 (continued)

Sampling Location	Sampling Event*	Trace Metal	Concentration (μg/l)
South Platte Drainage Basin			
SW26001	High Event 1 March 13, 1990	Arsenic	39.9
		Copper	23.6
		Zinc	30.0
	High Event 2 August 19, 1990	Arsenic	92.2
		Chromium	38.2
		Copper	102
		Lead	80.5
		Zinc	184
SW36001	Spring	Arsenic	71.6
	Fall	Arsenic	81.9
		Zinc	33.6
Sand Creek Drainage Basin			
SW04001	High Event July 9, 1990	Arsenic	11.1
		Chromium	32.2
		Copper	137
		Lead	585
		Zinc	530

* Spring=April 12 through April 19, 1990
Fall =September 4 through September 7, 1990
μg/l =micrograms per liter

at First Creek Off-Post (SW37001) on March 9, 1990, and Basin F (SW26001) on August 19, 1990, respectively.

4.2.4.2 Cadmium

A total of 27 samples were analyzed for total cadmium during the spring sampling event. Of these 27 samples, there was one reported concentration exceeding the CRL for a sample from the Irondale Gulch drainage basin at Peoria Interceptor (SW11001; 9.80 μg/L).

A total of 13 samples were analyzed for total cadmium during the fall sampling event. No concentrations of cadmium exceeding the CRL were reported present in these samples.

A total of 22 samples were analyzed for total cadmium during high event sampling. No concentrations of cadmium exceeding the CRL were reported present in these samples.

4.2.4.3 Chromium

A total of 27 samples were analyzed for total chromium during the spring sampling event. No concentrations of chromium exceeding the CRL were reported present in these samples.

A total of 13 samples were analyzed for chromium during the fall sampling event. No concentrations of chromium exceeding the CRL were reported present in these samples.

A total of 22 samples were analyzed for total chromium during high event sampling. Five concentrations exceeding the CRL were reported present. The minimum reported concentration (17.4 μg/L) was for a sample from the Irondale drainage basin at Peoria Interceptor (SW11001) on March 13, 1990. The maximum reported concentration (38.2 μg/L) was for a sample from Basin F in the South Platte drainage basin (SW26001) on August 19, 1990.

4.2.4.4 Copper

A total of 27 samples were analyzed for total copper during the spring sampling event. Of these 27 samples, three concentrations exceeding the CRL were reported. The minimum and maximum concentrations were reported for samples from the Irondale Gulch drainage basin at Peoria Interceptor (SW11001; 21.3 µg/L) and South Plants Water Tower Pond (SW01002; 29.7 µg/L), respectively.

A total of 13 samples were analyzed for total copper during the fall sampling event. No concentrations of copper exceeding the CRL were reported present in these samples.

A total of 22 samples were analyzed for total copper during high event sampling. Eight concentrations exceeding the CRL were reported present. The minimum reported concentration (19.6 µg/L) was for a sample from the Irondale Gulch drainage basin at Army Reserve Storm Sewer (SW12006) on July 21, 1990. The maximum reported concentration (137 µg/L) was for a sample from the Motor Pool in the Sand Creek drainage basin (SW04001) on July 9, 1990.

4.2.4.5 Lead

A total of 27 samples were analyzed for total lead during the spring sampling event. One concentration exceeding the CRL was reported for a sample from the Irondale Gulch drainage basin at Storm Sewer (SW12004; 65.4 µg/L).

A total of 13 samples were analyzed for total lead during the fall sampling event. No concentrations of lead exceeding the CRL were reported.

A total of 22 samples were analyzed for total lead during high event sampling. Four concentrations exceeding the CRL were reported. The minimum reported concentration (52.3 µg/L) was for a sample from the Irondale Gulch drainage basin at Peoria Interceptor (SW11001) on March 13, 1990. The maximum reported concentration (585 µg/L) was for a sample from the Motor Pool in the Sand Creek drainage basin (SW04001) on July 9, 1990.

4.2.4.6 Mercury

A total of 27 samples were analyzed for total mercury during the spring sampling event. No concentrations of mercury exceeding the CRL were reported.

A total of 13 samples were analyzed for mercury during the fall sampling event. No concentrations of mercury exceeding the CRL were reported.

A total of 22 samples were analyzed for mercury during high event sampling. No concentrations of mercury exceeding the CRL were reported.

4.2.4.7 Zinc

A total of 26 samples were analyzed for zinc during the spring sampling event. Three concentrations exceeding the CRL were reported. The minimum (20.8 μg/L) and maximum (115 μg/L) reported concentrations were for samples from the Irondale Gulch drainage basin at Havana Pond (SW11003) and Peoria Interceptor (SW11001), respectively.

A total of 13 samples were analyzed for total zinc during the fall sampling event. Eight concentrations exceeding the CRL were reported. The minimum reported concentration (21.1 μg/L) was for a sample from South First Creek (SW08003) in the First Creek drainage basin. The maximum reported concentration (60.9 μg/L) was for a sample from Storm Sewer (SW12004) in the Irondale Gulch drainage basin.

A total of 22 samples were analyzed for total zinc during high event sampling. Thirteen concentrations exceeding the CRL were reported. The minimum reported concentration (24.9 μg/L) was for a sample from South Uvalda in the Irondale Gulch drainage basin (SW12005) on March 13, 1990. The maximum reported concentration (530 μg/L) was for a sample from the Motor Pool in the Sand Creek drainage basin (SW04001) on July 9, 1990.

4.2.5 FIELD PARAMETER MEASUREMENTS

Field parameters measured for this study included alkalinity, specific conductance, pH, and temperature. Field data were collected from 27 sites during the spring sampling event, 13 sites during the fall sampling event and 22 sites during high events. Appendix B presents field water-quality data for each sampling period. The following discussions summarize the field parameter measurements by parameter and sampling event.

4.2.5.1 Total Alkalinity

Alkalinity is the capacity of water to neutralize a strong acid. Alkalinity is used in this report to indicate total alkalinity as calcium carbonate ($CaCO_3$) in milligrams per liter (mg/L) of $CaCO_3$. Alkalinity was measured by titrating the sample with sulfuric acid to a pH endpoint of 4.3. During field operations, titrations to four pH endpoints were measured and reported when the starting pH of the sample was above 8.3. A pH endpoint of 4.3 was used in subsequent calculations of carbonate species in accordance with Standard Method 403 (APHA, 1985).

A total of 27 measurements were reported for alkalinity during the spring sampling event. The minimum (30 mg/L) and maximum (475 mg/L) reported measurements were for samples from the Irondale Gulch drainage basin at Havana Pond (SW11003) and at South Uvalda (SW12005), respectively.

A total of 13 measurements were reported for alkalinity during the fall sampling event. The minimum reported measurement (48 mg/L) was for a sample from the Irondale Gulch drainage basin at Storm Sewer (SW12004). The maximum reported measurement (420 mg/L) was for a sample from the First Creek drainage basin at North First Creek (SW24002).

A total of 18 measurements were reported for alkalinity during high event sampling. The minimum reported measurement (13 mg/L) was for a sample from the Irondale Gulch drainage basin at Army Reserve Storm Sewer (SW120006) on July 20, 1990. The maximum reported measurement (282 mg/L) was for a sample from the First Creek drainage basin at North First Creek (SW24002) on March 9, 1990.

4.2.5.2 Specific Conductance

A total of 27 measurements were reported for specific conductance during the spring sampling event. The values reported herein are corrected to 25°C. The maximum reported measurement (4598 μmhos/cm) was for a sample from South Plants Water Tower Pond (SW01002). The minimum reported measurement (200 μmhos/cm) was for a sample from the Irondale Gulch drainage basin at Havana Pond (SW11003).

A total of 13 measurements were reported for specific conductance during the fall sampling event. The maximum reported measurement (4361 μmhos/cm) was for a sample from the First Creek drainage basin at North First Creek (SW24002). The minimum reported measurement (189 μmhos/cm) was for a sample from the Irondale Gulch drainage basin at Peoria Interceptor (SW11001).

A total of 21 measurements were reported for specific conductance during high event sampling. The maximum reported measurement (1916 μmhos/cm) was for a sample from the First Creek drainage basin at First Creek Off-post (SW37001) on November 29, 1989. The minimum reported measurement (58.2 μmhos/cm) was for a sample from the Irondale Gulch drainage basin at Army Reserve Storm Sewer (SW12006) on July 21, 1990.

4.2.5.3 pH

A total of 27 measurements were reported for pH during the spring sampling event. The maximum reported measurement (9.77) was for a sample from the Irondale Gulch drainage basin at Havana Interceptor (SW11002). The minimum reported measurement (6.64) was for a sample from the First Creek drainage basin at South First Creek Boundary (SW08001). The majority of the samples were basic.

A total of 13 measurements were reported for pH during the fall sampling event. The maximum reported measurement (10.48) was for a sample from the Irondale Gulch drainage basin at Havana Interceptor (SW11002). The minimum reported measurement (7.44) was reported for two samples from the First Creek drainage basin, at Sewage Treatment Plant (SW24001) and North First Creek (SW24002).

A total of 21 measurements were reported for pH during high event sampling. The maximum reported measurement (14.62) was for a sample from the Sand Creek drainage basin at Motor Pool (SW04001) on July 9, 1990. The minimum reported measurement (6.90) was for a sample from the Irondale Gulch drainage basin at Havana Interceptor (SW11002) on March 6, 1990.

4.2.5.4 Temperature

A total of 27 measurements were reported for temperature during the spring sampling event. The maximum reported measurement (18.6°C) was for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006). The minimum reported measurement (5.90°C) was for a sample from the First Creek drainage basin at First Creek North Boundary (SW24004).

A total of 13 measurements were reported for temperature during the fall sampling event. The maximum reported measurement (32.1°C) was for a sample from the Irondale Gulch drainage basin at Havana Interceptor (SW11002). The minimum reported measurement (16.5°C) was for a sample from the Irondale Gulch drainage basin at South Uvalda (SW12005).

A total of 21 temperature measurements were reported during high event sampling. The maximum reported measurement (25.3°C) was for two samples from the Irondale Gulch drainage basin at Army Reserve Storm Sewer (SW12006) on July 21, 1990 and the First Creek drainage basin at Eastern Upper Derby Lake Ditch (SW06002) on April 27, 1990. The minimum reported measurement (8.40°C) was for a sample from the Irondale Gulch drainage basin at Havana Interceptor (SW11002) on March 6, 1990.

4.2.6 Occurrence of Major Inorganic Constituents

Major inorganic constituents that occur naturally at concentrations greater than 0.1 mg/L include calcium, chloride, fluoride, potassium, magnesium, sodium, nitrate-nitrite, and sulfate (Appendix B). The following discussions summarize the occurrences of each major inorganic constituent by sampling event for sample results that met CMP QA/QC requirements. A discussion of the QA/QC protocol and a summary of rejected data are provided in Section 4.5.

4.2.6.1 Calcium

A total of 19 samples were analyzed for calcium during the spring sampling event. There were 19 reported concentrations exceeding the CRL. The maximum reported concentration (639 mg/L) was for a sample from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002). The minimum reported concentration (8.13 mg/L) was for a sample from the Irondale Gulch drainage basin at Havana Pond (SW11003).

A total of 13 samples were analyzed for calcium during the fall sampling event. There were 13 reported concentrations exceeding the CRL. The maximum reported concentration (477 mg/L) was for a sample from the First Creek drainage basin at North First Creek (SW24002). The minimum reported concentration (22.3 mg/L) was for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006).

A total of 21 samples were analyzed for calcium during the high event sampling. There were 20 reported concentrations exceeding the CRL. The maximum reported concentration (173 mg/L) was for a sample from the South Platte drainage basin at Basin F (SW26001) on August 19, 1990. The minimum reported concentration (3.11 mg/L) was for a sample from the Irondale Gulch drainage basin at Peoria Interceptor (SW11001) on March 6, 1990.

4.2.6.2 Chloride

A total of 27 samples were analyzed for chloride during the spring sampling event. There were 27 reported concentrations exceeding the CRL. The maximum reported concentration (667 mg/L) was for a sample from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002). The minimum reported concentration (33.0 mg/L) was for a sample from the Irondale Gulch drainage basin at Highline Lateral (SW12007).

A total of 13 samples were analyzed for chloride during the fall sampling event. There were 13 reported concentrations exceeding the CRL. The maximum reported concentration (453 mg/L) was for a sample from the First Creek drainage basin at North First Creek (SW24002). The minimum reported concentration (15.1 mg/L) was for a sample from the Irondale Gulch drainage basin at Peoria Interceptor (SW11001).

A total of 22 samples were analyzed for chloride during the high event sampling. There were 22 reported concentrations exceeding the CRL. The maximum reported concentration (250 mg/L) was for a sample from the First Creek Drainage basin at First Creek Off-Post (SW37001) on November 29, 1990. The minimum reported concentration (0.482 mg/L) was for a sample from the Sand Creek drainage basin at Motor Pool (SW04001) on July 9, 1990.

4.2.6.3 Fluoride

A total of 27 samples were analyzed for fluoride during the spring sampling event. There were 27 reported concentrations exceeding the CRL. The maximum reported concentration (4.96 mg/L) was for a sample from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002). The minimum reported concentration (0.233) was for a sample from the Irondale Gulch drainage basin at Havana Pond (SW11003).

A total of 13 samples were analyzed for fluoride during the fall sampling event. There were five reported concentrations exceeding the CRL. The maximum reported concentration (2.51 mg/L) was for a sample from the First Creek drainage basin at First Creek Off-Post (SW37001). The minimum reported concentration (0.91 mg/L) was for a sample from the Irondale Gulch drainage basin at Storm Sewer (SW12004).

A total of 22 samples were analyzed for fluoride during the high event sampling. There were 17 reported concentrations exceeding the CRL. The maximum reported concentration (3.34 mg/L) was for a sample from the First Creek drainage basin at First Creek Off-Post (SW37001) on November 29, 1989. The minimum reported concentration (0.165 mg/L) was for a sample from the Irondale Gulch drainage basin at Army Reserve Storm Sewer (SW12006) on July 21, 1990.

4.2.6.4 Potassium

A total of 27 samples were analyzed for potassium during the spring sampling event. There were 27 reported concentrations exceeding the CRL. The maximum reported concentration (53.3 mg/L) was for a sample from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002). The minimum reported concentration (2.53 mg/L) was for a sample from the Irondale Gulch drainage basin at Highline Lateral (SW12007).

A total of 13 samples were analyzed for potassium during the fall sampling event. There were 13 reported concentrations exceeding the CRL. The maximum reported concentration (7.23 mg/L) was for a sample from the First Creek drainage basin at First Creek Off-Post (SW37001). The minimum reported concentration (3.26 mg/L) was for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006).

A total of 22 samples were analyzed for potassium during the high event sampling. There were 21 reported concentrations exceeding the CRL. The maximum reported concentration (19.2 mg/L) was for a sample from the South Platte drainage basin at Basin F (SW26001) on August 19, 1990. The minimum reported concentration (1.92 mg/L) was for a sample from the Irondale Gulch drainage basin at South Uvalda (SW12005) on March 8, 1990.

4.2.6.5 Magnesium

A total of 27 samples were analyzed for magnesium during the spring sampling event. There were 27 reported concentrations exceeding the CRL. The maximum reported concentration (202 mg/L) was for a sample from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002). The minimum reported concentration (0.814 mg/L) was for a sample from the Irondale Gulch drainage basin at Havana Pond (SW11003).

A total of 13 samples were analyzed for magnesium during the fall sampling event. There were 13 reported concentrations exceeding the CRL. The maximum reported concentration (134 mg/L) was for a sample from the First Creek drainage basin at North First Creek (SW24002). The minimum reported concentration (2.59 mg/L) was for a sample from the Irondale Gulch drainage basin at Havana Interceptor (SW11002).

A total of 22 samples were analyzed for magnesium during the high event sampling. There were 22 reported concentrations exceeding the CRL. The maximum reported concentration (60.5 mg/L) was for a sample from First Creek Off-Post (SW37001) on November 29, 1989. The minimum reported concentration (0.488 mg/L) was for a sample from the Irondale Gulch drainage basin at Peoria Interceptor (SW11001) on March 6, 1990.

4.2.6.6 Sodium

A total of 27 samples were analyzed for sodium during the spring sampling event. There were 27 reported concentrations exceeding the CRL. The maximum reported concentration (417 mg/L) was for a sample from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002). The minimum reported concentration (34.3 mg/L) was for a sample from the Irondale Gulch drainage basin at Highline Lateral (SW12007).

A total of 13 samples were analyzed for sodium during the fall sampling event. There were 13 reported concentrations exceeding the CRL. The maximum reported concentration (626 mg/L) was fo [illegible] nple from the First Creek drainage basin at North First Creek (SW24002). The minimum [illegible] orted concentration (11.3 mg/L) was for a sample from the Irondale Gulch drainage basin at Peoria Interceptor (SW11001).

A total of 22 samples were analyzed for sodium during the high event sampling. There were 22 reporte[illegible] concentrations exceeding the CRL. The maximum reported concentration (380 mg/L) was for a sample from the First Creek drainage basin at First Creek Off-Post (SW37001) on November 29, 1989. The minimum reported concentration (1.59 mg/L) was for a sample from the South Platte drainage basin at Basin F (SW26001) on August 19, 1990.

4.2.6.7 Nitrate-Nitrite (as N)

A total of 27 samples were analyzed for nitrate-nitrite (as N) during the spring sampling event. There were 27 reported concentrations exceeding the CRL. The maximum reported concentration (6.42 mg/L) was for a sample from the First Creek drainage basin at First Creek Toxic Yard A (SW31001). The minimum reported concentration (0.0210 mg/L) was for a sample from Ladora Lake (SW02003).

A total of 13 samples were analyzed for nitrate-nitrite (as N) during the fall sampling event. There were 13 reported concentrations exceeding the CRL. The maximum reported concentration (4.30 mg/L) was for a sample from the First Creek drainage basin at Sewage Treatment Plant (SW24001). The minimum reported concentration (0.275 mg/L) was for a sample from North First Creek (SW24002).

A total of 22 samples were analyzed for nitrate-nitrite (as N) during the high event sampling. There were 22 reported concentrations exceeding the CRL. The maximum reported concentration (6.78 mg/L) was for a sample from the Irondale Gulch drainage basin at Havana Interceptor (SW11002) on July 9, 1990. The minimum reported concentration (0.178 mg/L) was for a sample from the Irondale Gulch drainage basin at Storm Sewer (SW12004) on March 8, 1990.

4.2.6.8 Sulfate

A total of 27 samples were analyzed for sulfate during the spring sampling event. There were 27 reported concentrations exceeding the CRL. The maximum reported concentration (2570 mg/L) was for a sample from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002). The minimum reported concentration (43.7 mg/L) was for a sample from the Irondale Gulch drainage basin at Upper Derby Lake (SW01004).

A total of 13 samples were analyzed for sulfate during the fall sampling event. There were 13 reported concentrations exceeding the CRL. The maximum reported concentration (2000 mg/L) was for a sample from the First Creek drainage basin at North First Creek (SW24002). The minimum reported concentration (27.2 mg/L) was for a sample from the Irondale Gulch drainage basin at North Uvalda Interceptor (SW01001).

A total of 22 samples were analyzed for sulfate during the high event sampling. There were 22 reported concentrations exceeding the CRL. The maximum reported concentration (480 mg/L) was for a sample from the First Creek drainage basin at First Creek Off-Post (SW37001) on November 29, 1989. The minimum reported concentration (1.52 mg/L) was for a sample from the South Platte drainage basin at Basin F (SW26001) on August 19, 1990.

4.2.7 TOTAL WATER CHEMISTRY CALCULATIONS FOR MAJOR INORGANIC CONSTITUENTS.

Water chemistry calculations that were performed on field and major inorganic constituent results from the spring, fall, and high sampling events are presented below. Calculations include carbonate and bicarbonate concentrations and an ion balance analysis. Table 4.2-4 summarizes these calculations. These calculations provide information for comparative interpretation of the surface-water chemical characteristics of investigative samples and for validation of the analytical and field program results for

Table 4.2-4 Calculations for Major Inorganic Constituents, Water Year 1990

Sampling Location	CO_3 (mg/l)	HCO_3 (mg/l)	Cation Sum (meq/l)	Anion Sum (meq/l)	Charge-Balance Error Actual Value (%)	Charge-Balance Error Absolute Value (%)
Spring Sampling Event						
Irondale Gulch Drainage Basin						
SW01001	NA	306	8.80	9.19	2.1	2.1
SW01002	NA	382	68.14	78.91	7.3	7.3
SW02006	45.6	155	9.17	9.83	3.5	3.5
SW11001	NA	148	5.15	4.80	-3.6	3.6
SW11002	63.6	95.2	13.66	11.73	-7.6	7.6
SW11003	NA	36.6	2.17	4.37	33.7	33.7
First Creek Drainage Basin						
SW08001	NA	311	8.83	8.48	-2.0	2.0
SW08003	15.6	292	9.30	8.86	-2.4	2.4
SW24001	NA	204	8.12	7.28	-5.4	5.4
SW24002	NA	379	13.60	13.03	-2.2	2.2
SW24003	108	0	26.12	23.17	-6.0	6.0
SW24004	24	349	14.29	13.51	-2.8	2.8
SW30002	NA	401	12.62	13.10	1.9	1.9
SW31001	14.4	361	11.50	11.86	1.5	1.5
SW31002	NA	460	10.79	12.94	9.1	9.1
SW37001	56.4	318	18.01	17.82	-0.5	0.5
South Platte Drainage Basin						
SW36001	NA	279	9.78	9.64	-0.7	0.7

Table 4.2-4 Calculations for Major Inorganic Constituents, Water Year 1990 (continued)

Sampling Location		CO_3 (mg/l)	HCO_3 (mg/l)	Cation Sum (meq/l)	Anion Sum (meq/l)	Charge-Balance Error Actual Value (%)	Charge-Balance Error Absolute Value (%)
Fall Sampling Event							
Irondale Gulch Drainage Basin							
SW01001		NA	112	2.53	3.15	10.9	10.9
SW02001		9.6	139	5.80	6.82	8.1	8.1
SW02006		38.4	29.3	5.69	7.02	10.4	10.4
SW11001		45.6	32.9	1.98	3.33	25.3	25.3
SW11002		54	0	3.06	4.28	16.5	16.5
SW12001		NA	273	7.19	8.06	5.7	5.7
SW12004		NA	59	2.23	2.43	4.3	4.3
SW12005		NA	224	6.12	6.05	-0.6	0.6
First Creek Drainage Basin							
SW08003		NA	372	9.46	10.58	5.6	5.6
SW24001		NA	149	4.76	5.65	8.5	8.5
SW24002		NA	512	62.29	63.40	0.9	0.9
SW37001		NA	350	19.99	18.45	-4.0	4.0
South Platte Drainage Basin							
SW36001		NA	157	7.74	7.48	-1.7	1.7
High Event Sampling							
SW11001ST	03/06/90	NA	20.7*	0.60	0.75	10.5	10.5
SW11001ST2	03/13/90	NA	30.5	1.64	1.72	2.4	2.4
SW11002ST	03/06/90	NA	21	0.68	0.73	4.0	4.0

Table 4.2-4 Calculations for Major Inorganic Constituents, Water Year 1990 (continued)

Sampling Location		CO_3 (mg/l)	HCO_3 (mg/l)	Cation Sum (meq/l)	Anion Sum (meq/l)	Charge-Balance Error Actual Value (%)	Charge-Balance Error Absolute Value (%)
High Event Sampling (continued)							
SW11002ST2	03/13/90	28.8	8.5*	1.44	2.14	19.5	19.5
SW12004ST	03/08/90	NA	20*	1.44	1.48	1.4	1.4
SW12005ST	03/08/90	NA	51*	1.92	2.25	7.9	7.9
SW12005ST2	03/13/90	NA	81*	2.25	2.63	7.7	7.7
SW12006ST	07/21/90	NA	16	0.56	0.46	-9.9	9.9
First Creek Drainage Basin							
SW06002	07/18/90	NA	123	4.51	4.52	0.1	0.1
SW06002ST1	07/27/90	NA	110	3.86	3.98	1.5	1.5
SW08003ST	03/09/90	NA	328*	8.69	9.68	5.4	5.4
SW08003ST2	05/30/90	NA	205	5.27	5.75	4.4	4.4
SW08003ST3	07/10/90	NA	217*	5.30	6.28	8.4	8.4
SW24002ST	03/09/90	NA	344*	11.16	12.08	3.9	3.9
SW37001ST	03/09/90	NA	276*	12.30	12.63	1.3	1.3
South Platte Drainage Basin							
SW26001ST	03/13/90	1.2	148*	3.63	4.29	8.3	8.3
SW26001ST2	08/19/90	80.4	62.2*	11.23	3.96	-47.9	47.9

CO_3 = Carbonate
HCO_3 = Bicarbonate
NA = pH less than 8.3
mg/l = milligrams per liter
meq/l = milliequivalents per liter
% = percent
* = Alklinity measurement at pH 4.3 was not analyzed. Alkalinity measurement at pH 4.5 was used for calculation of bicarbonate concentration.

major inorganic constituents. Calculations were performed on 47 samples for which carbonate system species concentrations could be calculated and for which major inorganic constituent analyses results were available. An explanation of methodologies used in the calculations is also provided.

4.2.7.1 Carbonate System Species

The contribution of carbonate species to an aqueous system is dependent on the pH of that system. Phenolphthalein and total alkalinity are terms that relate to the acid-neutralizing capacity of the aqueous system caused by the presence of carbonate and bicarbonate ions. Phenolphthalein and total alkalinity are measured, and the carbonate species are then calculated according to the relative results. For example, waters with pH less than 8.3 have no phenolphthalein alkalinity, and the bicarbonate concentration (as $CaCO_3$) is the total alkalinity (APHA, 1985). The actual bicarbonate concentration (in mg/L) in waters with pH less than 8.3 is a factor of 1.22 higher than the total alkalinity to account for the stoichiometric conversion from $CaCO_3$ to bicarbonate. In this study, 33 samples had a measured pH less than 8.3, and the corresponding bicarbonate concentrations were calculated. Waters with pH greater than 8.3 have a phenolphthalein alkalinity and a total alkalinity. The concentration of the carbonate species is dependent on the magnitude of the two alkalinities. In this study, the phenolphthalein alkalinity was less than one-half the total alkalinity, and the calculation of the carbonate species was as follows:

$$[CO^{=}_3] = (2 \times P) \times 0.60$$
$$[HCO^{-}_3] = (T - 2 \times P) \times 1.22$$

where $[CO^{=}_3]$ is the concentration of the carbonate ion, P is the phenolphthalein alkalinity, 0.60 is the stoichiometric conversion factor for carbonate, $[HCO^{-}_3]$ is the concentration of the bicarbonate, T is the total alkalinity, and 1.22 is the stoichiometric conversion factor for bicarbonate. Thirteen samples had measured pH values greater than 8.3, and the corresponding carbonate and bicarbonate calculations were performed.

The results of the calculations for the carbonate system species are shown in Table 4.2-4. One sample collected during the spring sampling event (SW12005) and three samples collected during high events (SW01002ST2, March 13, 1990; SW04001ST, July 9, 1990; and SW11002ST, July 9, 1990) had a measured pH greater than 8.3, but the phenolphthalein alkalinity was not measured in the field; therefore, accurate carbonate and bicarbonate ion concentrations could not be calculated. Bicarbonate alkalinity concentrations were calculated using a pH endpoint of 4.5 for 11 high event samples that were not titrated to a pH endpoint of 4.3. These samples are as follows: from the Irondale Gulch drainage basin, Peoria Interceptor (SW11001, March 6, 1990), Havana Interceptor (SW11002, March 13, 1990), Storm Sewer (SW12004, March 8, 1990), and South Uvalda (SW12005, March 8, 1990 and March 13, 1990); from the First Creek drainage basin, South First Creek (SW08003, March 9, 1990 and July 10, 1990), North First Creek (SW24002, March 9, 1990), and First Creek Off-Post (SW37001, March 9, 1990); and from the South Platte drainage basin, Basin F (SW26001, March 13, 1990 and August 19, 1990). The results of the carbonate and bicarbonate calculations are reported below by sampling event.

Calculated carbonate concentrations for samples collected during the spring sampling event range from 14.4 mg/L to 108 mg/L. The minimum value (14.4 mg/L) corresponds to a sample collected from First Creek drainage basin at First Creek Toxic Yard A (SW31001), and the maximum value (108 mg/L) corresponds to a sample collected from First Creek drainage basin at North Bog (SW24003). Calculated bicarbonate concentrations for samples collected during the spring sampling event ranged from 0 mg/L to 460 mg/L. The minimum value (0 mg/L) corresponds to a sample collected from First Creek drainage basin at North Bog (SW24003), and the maximum value (460 mg/L) corresponds to a sample collected from First Creek drainage basin at First Creek Toxic Yard B (SW31002).

Calculated carbonate concentrations for samples collected during the fall sampling event range from 9.6 mg/L to 45.6 mg/L. The minimum value (9.6 mg/L) corresponds to a sample collected from Irondale Gulch drainage basin at Ladora Weir (SW02001), and the maximum value (45.6 mg/L) corresponds to sample collected from Irondale Gulch drainage basin at Peoria Interceptor (SW11001). Calculated bicarbonate concentrations for samples collected during the fall sampling event range from 0 mg/L to 512 mg/L. The minimum value (0 mg/L) corresponds to a sample collected from Irondale Gulch drainage basin at Havana Interceptor (SW11002), and the maximum value (512 mg/L) corresponds to a sample collected from First Creek drainage basin at North First Creek (SW24002).

Calculated carbonate concentrations for samples collected during high event sampling range from 1.2 mg/L to 80.4 mg/L. The minimum value (1.2 mg/L) corresponds to a sample collected from South Platte drainage basin at Basin F (SW26001ST; March 13, 1990), and the maximum value (80.4 mg/L) corresponds to sample collected from South Platte drainage basin at Basin F (SW26001ST2; August 19, 1990). Calculated bicarbonate concentrations for samples collected during storm sampling event range from 8.5 mg/L to 344 mg/L. The minimum value (8.5 mg/L) corresponds to a sample collected from Irondale Gulch drainage basin at Havana Interceptor (SW11002ST2; March 13, 1990), and the maximum value (344 mg/L) corresponds to a sample collected from First Creek drainage basin at North First Creek (SW24002ST; March 9, 1990).

4.2.7.2 Ion Balance Calculations

Ion balance calculations are based on principles of electroneutrality for which a balance of molar concentrations of positively and negatively charged ionic species can be derived. Ion balance calculations consist of converting major inorganic constituent results to milliequivalents per liter (meq/l), summing the cation and anion fractions, and statistically comparing the results. Parameters used in performing ion balance calculations included reported concentrations for calcium, magnesium, sodium, potassium, chloride, sulfate, fluoride, nitrate-nitrite (as N), carbonate, and bicarbonate. It should be noted that the ion balance analysis presented herein is based on total recoverable analyses for major inorganic constituents, whereas the principles of electroneutrality apply to dissolved concentrations. The basis for the performance of the ion balance analysis is the observation during Water Year 1988 and 1989 that, in general, there were no appreciable differences between the dissolved and total concentrations of major inorganic constituents (RLSA, 1990a and 1990b).

A summary of the ion balance calculations is shown in Table 4.2-4. Complete information regarding ion balance calculations is provided in Appendix B. Summary Table 4.2-4 shows the cation and anion totals for each sample in meq/l and the percent difference between these totals. Percent differences are known as the "charge-balance error," commonly expressed as the difference between the anion and cation totals divided by the sum total (Freeze and Cherry, 1979). The actual charge-balance error and the absolute value of the calculated charge-balance error are listed for each sample. The charge-balance error indicates the magnitude and direction of deviation between cation and anion species, with positive numbers representing samples in which the anion total exceeds the cation total. A review of the actual values for the charge-balance error listed in Table 4.2-4 indicates the anion total exceeded the cation total in 32 samples and the cation total exceeded the anion total in 15 samples. The absolute value of the charge-balance error indicates the magnitude of the difference between the two totals.

A criterion of less than 5 percent is generally accepted as indicative of favorable analytical results with respect to the absolute charge-balance error (Freeze and Cherry, 1979). Ion balance calculations indicate that 51 percent of sample results meet this criteria. Twenty-four samples had absolute charge-balance errors that were less than 5 percent. Of the remaining ion balance calculations, 15 samples had absolute charge-balance errors between 5 and 10 percent, and eight samples had absolute charge-balance errors greater than 10 percent. Eighteen samples had absolute charge-balance errors greater than 6 percent, which are assumed indicative of analytical error. Fourteen of the 18 samples had positive charge-balance errors, indicating the anion total exceeds the cation total. This type of charge-balance error may occur for the following reasons: (1) the analytical suite may not include all positively charged species that contribute to the sum of cation charges (i.e., iron, manganese, aluminum, etc., were not analyzed in the surface-water samples) or (2) concentrations that are close to the method concentration limit are subject to larger potential errors in analysis than concentrations that greatly exceed the method concentration limit. A third factor that may bias the results of the charge balance is the potential for error in field alkalinity titrations. Laboratory titrations of alkalinity on samples with alkalinity concentrations of approximately 800 mg/L (as $CaCO_3$) and 1000 mg/L ($CaCO_3$) may be subject to analytical error of up to plus or minus 10 and 8 percent, respectively, at the 95 percent confidence level (APHA, 1985). Errors in field titrations may be expected to be greater than those observed in the laboratory because of natural interferences in sample composition and variations in field sample handling. The positive charge balance errors may be explained, in part, by these factors.

Ion balance calculations were used to cross-check database values and field results. Initial ion balance calculations indicated a cation sum problem for sample SW26001ST2. A review of the database revealed a high concentration of TSS (1900 mg/L). It is likely that particulates contributing to the TSS had cations sorbed onto charged surfaces that were released to the ionic state upon acidification of the unfiltered sample. This process results in an increase in the measured cation concentration and is a plausible explanation of the significant negative charge-balance error.

4.3 SEDIMENT TRANSPORT

This section presents the Water Year 1990 results for total suspended sediment quantity and stream bottom sediment quality at RMA. TSS analyses were performed on 72 samples obtained at 29 sites with flowing water. Three methods of collection were used for TSS sampling. Analyses of stream bottom sediment quality were performed on 16 samples and one duplicate that had been collected at nine sites during the fall and spring sampling events.

4.3.1 SEDIMENT QUANTITY

TSS samples were collected during the spring, fall and high event sampling periods of Water Year 1990. Table 3.2-1 lists the sites from which TSS samples were collected. TSS samples were also collected during the surface-water/ground-water interaction study (gain/loss) along First Creek in June 1990. Results of the TSS samples that were collected, corresponding flow rates and flow characteristics are summarized in Table 4.3-1.

Eighteen TSS samples were collected during the spring using the grab method, seven of these samples had TSS concentrations greater than the certified recording limit (CRL = 4.00 mg/L). Twenty-six TSS samples were collected at 13 locations in the fall using the grab method in conjunction with the DH-48 method. Nine samples out of the 26 were below the CRL during this sampling period with five below CRL from the grab method and four below CRL from the DH-48 method. Nineteen high event TSS samples were collected in Water Year 1990 during summer thunderstorms, snowmelt periods or when there was flow of water at locations normally dry most of the year. The high event TSS samples were collected predominantly using the grab method, although two samples were collected by the ISCO automated sampler. Of the nineteen high event TSS samples that were collected throughout Water Year 1990, only two were below the CRL. During the Gain/Loss study along First Creek conducted in June, all nine TSS samples were collected by the DH-48 sampler and five were above the CRL.

A comparison of TSS collection equipment was performed during the fall sampling event. Thirteen TSS samples were collected using a DH-48 sampler and 13 were collected using a grab method at the same location. Methodology of these sampling methods is detailed in Section 3.0. Out of 13 grab samples eight samples were above the CRL and out of 13 DH-48 samples nine were above the CRL. The TSS concentrations of these samples are summarized in Table 4.3-1. The average TSS for the grab method samples that were above the CRL was 253 mg/L. The average TSS for the DH-48 method samples that were above the CRL was 236 mg/L. Out of the thirteen sites, four sites had equal TSS concentrations. Out of the remaining nine sites, one site had a difference in TSS concentration of 96 mg/L and the remaining eight sites had a net difference of 4 mg/L.

A comparison of TSS quantities versus flow rate RMA wide indicates no correlation. At RMA TSS amounts are more dependent on the nature of the drainage and when the flow occurred than on the amount of flow. Basin F had a TSS concentration of 1900 mg/L at a flow rate of 0.57 cfs when a high

Table 4.3-1 Summary of Total Suspended Solids (TSS) Results and Flow Characteristics

Location Number	Location Name	Sampling Event	Date	Collection Method	TSS (mg/l)	Flow Rate (cfs)	Flow Characteristics
Irondale Gulch Drainage Basin							
SW01001	North Uvalda Interceptor	Spring	4/17/90	G	10.0	0.12	Base flow
		Fall	9/06/90	D	19.0	0.06	Base flow
				G	22.0		
SW02001	Ladora Weir	Annual	9/05/90	D	17.0	NA	Peak flow
				G	12.0		
SW02006	South Plants Steam Effluent	Spring	4/19/90	G	<4.0	0.07	
		Fall	9/04/90	D	<4.0	0.39	
				G	<4.0		
SW07001	Uvalda Ditch A	Annual	4/13/90	G	45.0	0.1	
SW07002	Uvalda Ditch B	Annual	4/13/90	G	<4.0	0.24	
SW11001	Peoria Interceptor	HiEv[1]	3/06/90	G	19.0	15.28	Rising limb
		HiEv[2]	3/13/90	G	200.0	12.06	Rising limb
		Spring	4/16/90	G	33.0	0.05	Base flow
		Fall	9/04/90	D	11.0	0.02	Base flow
				G	40.0		
SW11002	Havana Interceptor	HiEv[1]	3/06/90	G	29.0	5.01	Falling limb
		HiEv[1]	3/13/90	G	220.0	16.99	Rising limb
		Spring	4/16/90	G	<4.0	0.01	Base flow
		HiEv[1]	7/09/90	G	320.0	125.52	Falling limb
		Fall	9/05/90	D	<4.0	0.47	Base flow
				G	<4.0		

Table 4.3-1 Summary of Total Suspended Solids (TSS) Results and Flow Characteristics (continued)

Location Number	Location Name	Sampling Event	Date	Collection Method	TSS (mg/l)	Flow Rate (cfs)	Flow Characteristics
Irondale Gulch Drainage Basin (continued)							
SW12001	Uvalda Ditch C	Spring	4/13/90	G	<4.0	0.69	
		Fall	9/06/90	D	10.0	0.26	
				G	6.0		
SW12004	Storm Sewer	HiEv[2]	3/08/90	G	80.0	0.97	
		Spring	4/13/90	G	32.0	<0.01	
		Fall	9/04/90	D	15.0	<0.01	
				G	23.0		
SW12005	South Uvalda	HiEv[2]	3/08/90	G	20.0	3.04	Falling limb
		HiEv[1]	3/29/90	G	120.0	3.22	Rising limb
		Spring	4/16/90	G	<4.0	0.39	Base flow
		Fall	9/06/90	D	100.0	0.54	Base flow
				G	<4.0		
SW12006	Army Reserve Storm Sewer	HiEv[1]	7/21/90	G	19.0	0.16	
SW12007	Highline Lateral	Annual	5/16/90	G	140.0	9.64	Peak flow
First Creek Drainage Basin							
SW05001	South First Creek (old)	G/L	6/27/90	D	28.0	0.17	
SW06002	Eastern Upper Derby Lake Ditch	HiEv[1]	7/18/90	G	<4.0	0.17	
		HiEv[1]	7/27/90	D	<4.0	0.60	
SW08001	South First Creek Boundary	Annual	4/18/90	G	<4.0	0.97	

Table 4.3-1 Summary of Total Suspended Solids (TSS) Results and Flow Characteristics (continued)

Location Number	Location Name	Sampling Event	Date	Collection Method	TSS (mg/l)	Flow Rate (cfs)	Flow Characteristics
First Creek Drainage Basin (continued)							
SW08003	South First Creek (New)	HiEv[2]	3/09/90	G	20.0	2.52	Falling limb
		Spring	4/18/90	G	<4.0	1.04	Base flow
		HiEv[1]	5/30/90	Isco	<4.0	2.84	Rising limb
		G/L	6/27/90	D	<4.0	0.26	Base flow
		HiEv[1]	7/09/90	Isco	82.0	2.08	Rising limb
		Fall	9/07/90	D	13.0	0.16	Base flow
				G	9.0		
SW08004	South First Creek Retention Pond	G/L	6/27/90	D	<4.0	0.17	
SW24002	North First Creek	HiEv[2]	3/09/90	G	20.0	3.34	Peak flow
		Spring	4/1[illegible]/90	G	5.0	1.08	Base flow
		Fall	9/[illegible]7/90	D	18.0	<0.01	Base flow
				G	11.0		
		G/L	6/27/90	D	<4.0	0.21	Base flow
SW24004	First Creek North Boundary	Annual	4/17/90	G	68.0	1.12	
SW30002	First Creek Near North Plant	Annual	4/19/90	G	<4.0	1.25	
		G/L	6/28/90	D	20.0	0.03	
SW31001	First Creek Toxic Yard A	Annual	4/17/90	G	82.0	>0.01	
SW31002	First Creek Toxic Yard B	Annual	4/19/90	G	<4.0	NA	
SW37001	First Creek Off-Post	HiEv[2]	3/09/90	G	7.5	4.51	Falling limb
		Spring	4/19/90	G	20.0	0.98	Base flow
		G/L	6/28/90	D	<4.0	0.03	Base flow
		Fall	9/07/90	D	18.0	0.08	Base flow
				G	<4.0		
SW37010	Off-Post First Creek	G/L	6/28/90	D	380.0	0.02	

Table 4.3-1 Summary of Total Suspended Solids (TSS) Results and Flow Characteristics (continued)

Location Number	Location Name	Sampling Event	Date	Collection Method	TSS (mg/l)	Flow Rate (cfs)	Flow Characteristics
First Creek Drainage Basin (continued)							
SW37011	Off-Post First Creek	G/L	6/28/90	D	55.0	0.10	
SW37012	Off-Post First Creek	G/L	6/28/90	D	8.0	0.17	
South Platte Drainage Basin							
SW26001	Basin F	HiEv[2]	3/13/90	G	46.0	0.03	Falling limb
		HiEv[1]	8/19/90	D	1900.0	0.57	Rising limb
				G	1900.0		
SW36001	Basin A	Spring	4/19/90	G	<4.0	0.01	Base flow
		Fall	9/05/90	D	<4.0	0.03	Base flow
				G	<4.0		
Sand Creek Drainage Basin							
SW04001	Motor Pool Area	HiEv[1]	7/09/90	G	350.0	NA	

HiEv[1] = High Event Due to Storm
HiEV[2] = High Event Due to Snowmelt
CRL = 4.0 mg/l
cfs = cubic feet per second
Rising limb = pre-peak period prior to a high event
Falling limb = post-peak period following a high event
G/L = Gain/Loss Interaction Study
D = DH-48 sampler
G = Grab method
Isco = Automated sampler
NA = Not available

SWAR-90.TB2

event sample was collected in August 1990 (Table 4.3-1). This station has sparse vegetation in its drainage area hence a significant amount of TSS was transported. Havana Interceptor had a TSS concentration of 320 mg/L in a sample collected at a flow rate of 125 cfs during a July rain storm. Havana Interceptor's drainage area contains mainly commercial and light industrial zones with a large amount of pavement, hence a small amount of TSS was transported even with a very high flow.

4.3.2 SEDIMENT QUALITY

Stream bottom sediment samples were collected at eight sampling locations during the 1990 spring sampling event and at three sample locations during the fall. Table 3.2-1 lists the sites from which stream bottom sediments were collected during Water Year 1990. Table 3.2-2 summarizes analytical sediment methods and CRLs that were used by DataChem and ESE laboratories.

The distributions of target organic compound and trace inorganic constituent concentrations during the spring and fall 1990 sampling events are discussed below. The concentrations that exceeded the CRLs are reported in this section. Table 4.3-2 lists the target organic compounds for which sediment samples were analyzed. Target organic compound concentrations that exceeded the CRLs are summarized in Table 4.3-3, and target trace inorganic constituent concentrations that exceeded the CRLs are summarized in Table 4.3-4. Figure 4.3-1 shows the geographic distribution of target organic compounds and trace inorganic compounds that were reported during the spring and fall 1990 sampling events. The following discussions summarize the analytical results by compound and sampling event for all sample results that met CMP QA/QC requirements. A discussion of the QA/QC protocol and a summary of the rejected data are provided in Section 4.5.

4.3.2.1 Organic Compounds

The sediment samples were analyzed for the groups of target organic compounds listed in Table 4.3-2. Several compounds from the organochlorine pesticide group and DBCP were reported at concentrations exceeding the CRLs in the sediment samples. The concentrations of these compounds are discussed below by sampling event.

Table 4.3-2 CMP Sediment List of Target Organic Compounds by Method

Volatile Organohalogen Method

- 1,1-Dichloroethane
- 1,1-Dichloroethene
- 1,1,1-Trichloroethane
- 1,1,2-Trichloroethane
- 1,2-Dichloroethane
- 1,2-Dichloroethene
- Carbon tetrachloride
- Chlorobenzene
- Chloroform
- Methylene chloride
- Tetrachloroethene
- Trichloroethene

Volatile Aromatic Method

- Benzene
- Ethylbenzene
- Toluene
- Xylenes (o,p)

Organosulfur Compound Method

- 1,4-Dithiane
- 1,4-Oxathiane
- Benzothiazole
- Dimethyldisulfide
- p-Chlorophenylmethylsulfone
- p-Chlorophenylmethylsulfoxide
- p-Chlorophenylmethylsulfide

Organochlorine Pesticide Method

- Aldrin
- Chlordane
- Dieldrin
- Endrin
- Hexachlorocyclopentadiene
- Isodrin
- 2,2-Bis(parachlorophenyl)-1,1-dichloroethene (PPDDE)
- 2,2-Bis(parachlorophenyl)-1,1,1-trichloroethane (PPDDT)

Hydrocarbon Method

- Dicyclopentadiene (DCPD)
- Methylisobutylketone (MIBK)
- Bicycloheptadiene (BCHPD)

Organophosphorus Pesticides Compound Method

- Atrazine
- Malathion
- Parathion
- Supona
- Vapona

Phosphonate Method

- Diisopropylmethylphosphonate (DIMP)
- Dimethylmethylphosphonate (DMMP)

DBCP Method

- Dibromochloropropane (DBCP)

Table 4.3-3 Occurrences of Target Organic Compounds in Stream Bottom Sediment Samples, Water Year 1990

Sampling Location	Sampling Event[1]	Compound	Concentration (µg/g)
Irondale Gulch Drainage Basin			
SW01002B	Spring	Aldrin	3.30
		Chlordane	0.340
		DBCP	0.0132
		Dieldrin	1.20
		Endrin	0.0410
		Isodrin	0.0300
SW02006B	Spring	Aldrin	0.500
		Chlordane	0.880
		Dieldrin	0.880
		Endrin	0.0550
		Isodrin	0.0360
		PPDDE	0.0160
	Fall	Aldrin	0.881
		Chlordane	0.160
		CL6CP	0.00287
		Dieldrin	0.291
		Endrin	0.0180
		Isodrin	0.0207
		PPDDE	0.0168
		PPDDT	0.132
SW11001B	Fall	DBCP	0.00667
SW12004B	Fall	Chlordane	0.0358
		Dieldrin	0.00240
SW12005B	Spring	Aldrin	0.0540
		Isodrin	0.00880
First Creek Drainage Basin			
SW08003B	Spring	Aldrin	0.0100
		Dieldrin	0.00504
SW24002B	Spring	Dieldrin	0.00383
SW37001B	Spring	DBCP	0.0145

Table 4.3-3 Occurrences of Target Organic Compounds in Stream Bottom Sediment Samples, Water Year 1990 (continued)

Sampling Location	Sampling Event[1]	Compound	Concentration (µg/g)
South Platte Drainage Basin			
SW36001B	Spring	Aldrin	4.90
		Chlordane	11.0
		DBCP	0.110
		Dieldrin	1.70
		Isodrin	1.30
		PPDDE	0.100

[1] Spring - April 12 through April 19, 1990
Fall - September 4 through September 7, 1990

µg/g = micrograms per gram
DBCP = dibromochloropropane
PPDDE = 2,2-bis(parachlorophenyl)-1,1-dichloroethene
CL6CP = hexachlorocyclopentadiene
PPDDT = 2,2-bis(parachlorophenyl)-1,1,1-trichloroethane

Table 4.3-4 Occurrences of Trace Inorganic Constituents in Stream Bottom Sediment Samples, Water Year 1990

Sampling Location	Sampling Event[1]	Compound	Concentration ($\mu g/g$)
Irondale Gulch Drainage Basin			
SW01002B	Spring	Arsenic	1.85
		Copper	187
		Lead	27.9
		Mercury	0.137
		Zinc	114
SW02006B	Spring	Copper	131
		Lead	96.7
		Mercury	4.30
		Zinc	306
	Fall	Lead	28.2
		Mercury	3.67
		Zinc	74.3
SW11001B	Spring	Lead	25.5
		Zinc	67.9
SW12004B	Fall	Lead	13.1
		Zinc	88.8
SW12005B	Spring	Lead	17.4
		Zinc	112
First Creek Drainage Basin			
SW24002B	Spring	Arsenic	2.28
		Lead	9.36
SW37001B	Spring	Arsenic	2.27
		Lead	13.1
		Mercury	0.0382
South Platte Drainage Basin			
SW36001B	Spring	Arsenic	28.0
		Lead	87.0
		Mercury	0.940
		Zinc	264

[1] Spring - April 12 through April 19, 1990
Fall - September 4 through September 7, 1990
$\mu g/g$ = micrograms per gram

Aldrin

Five concentrations exceeding the CRLs were reported during the spring sampling event. The maximum reported concentration (4.90 µg/L) was for a sample collected from the South Platte drainage basin at Basin A (SW36001; 4.90 µg/g). Other reported concentrations included three samples collected in the Irondale Gulch drainage basin at South Uvalda station (SW12005; 0.0540 µg/g), South Plants steam effluent (SW02006; 0.500 µg/g), and South Plants Water Tower Pond (SW01002; 3.30 µg/g). The minimum concentration (0.0100 µg/g) was for a sample collected from the First Creek drainage basin at South First Creek monitoring station (SW08003).

There was one reported concentration that exceeded the CRL during the fall sampling event for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006; 0.881 µg/g).

CL6CP

Of eight samples, no concentrations of CL6CP above the CRL were reported during the spring sampling event.

One concentration exceeding the CRL was reported during the fall sampling event for a sample collected from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006; 0.00287 µg/g).

Chlordane

Three samples with concentrations that exceeded the CRL were reported during the spring sampling event at concentrations ranging from 0.340 µg/g to 11.0 µg/g. The maximum reported concentration (11.0 µg/g) was for a sample collected from the South Platte drainage basin at Basin A station (SW36001). Other reported concentrations were for samples obtained from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002; 0.340 µg/g) and South Plants steam effluent (SW02006; 0.880 µg/g).

Two samples with concentrations that exceeded the CRL were reported during the fall sampling event were collected from the Irondale Gulch drainage basin. The maximum reported concentration

(0.160 μg/g) was for a sample from South Plants steam effluent (SW02006). The other reported concentration (0.0358 μg/g) was for a sample from Storm Sewer location (SW12004).

DBCP

Three concentrations exceeding the CRL were reported during the spring sampling event. The maximum reported concentration (0.110 μg/g) was for a sample from the South Platte drainage basin at Basin A station (SW36001). Other reported concentrations were for samples from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002; 0.0132 μg/g) and the First Creek drainage basin at First Creek Off-Post station (SW37001; 0.0145 μg/g).

One concentration exceeding the CRL was reported during the fall sampling event for a sample from the Irondale Gulch drainage basin at Peoria Interceptor (SW11001; 0.00667 μg/g).

Dieldrin

Five concentrations exceeding the CRL were reported during the spring sampling event. The maximum reported concentration (1.70 μg/g) was for a sample from the South Platte drainage basin at Basin A station (SW36001). Other reported concentrations in the First Creek drainage basin include the minimum reported concentration (0.00383 μg/g) for a sample from North First Creek station (SW24002) and a reported concentration for a sample from South First Creek station (SW08003; 0.00504 μg/g). Two concentrations of dieldrin were reported for samples from Irondale Gulch at South Plants steam effluent (SW02006; 0.880 μg/g) and South Plants Water Tower Pond (SW01002; 1.20 μg/g).

Two concentrations above the CRL were reported during the fall sampling event for a sample from the Irondale Gulch drainage basin. The maximum reported concentration (0.291 μg/g) was for a sample from the South Plants steam effluent (SW02006), and the other reported concentration was for a sample from the Storm Sewer (SW12004; 0.00240 μg/g).

Endrin

Two concentrations above the CRL were reported during the spring sampling event for a sample from the Irondale Gulch drainage basin. The maximum reported concentration (0.0550 μg/g) was for a sample from the South Plants steam effluent (SW02006), and the other reported concentration was for a sample from the South Plants Water Tower Pond (SW01002; 0.0410 μg/g).

One concentration above the CRL was reported during the fall sampling event for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006; 0.0180 μg/g).

Isodrin

Four concentrations exceeding the CRL were reported during the spring sampling event at concentrations ranging from 0.00880 μg/g to 1.30 μg/g. The maximum reported concentration (1.30 μg/g) was for a sample from the South Platte drainage basin at Basin A station (SW36001). Other reported concentrations were for samples from the Irondale Gulch drainage basin at South Uvalda station (SW12005; 0.00880 μg/g;), South Plants Water Tower Pond (SW01002; 0.0300 μg/g), and South Plants steam effluent (SW02006; 0.0360 μg/g).

One concentration above the CRL was reported during the fall sampling event for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006; 0.0207 μg/g).

PPDDE

Two concentrations above the CRL were reported during the spring sampling event. The maximum reported concentration (0.100 μg/g) was for a sample from the South Platte drainage basin at Basin A station (SW36001). The other reported concentration (0.0160 μg/g) was for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006).

One concentration exceeding the CRL was reported during the fall sampling event for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006; 0.0168 μg/g).

PPDDT

No concentration of PPDDT exceeding the CRL was reported during the spring sampling event.

One concentration exceeding the CRL was reported during the fall sampling event for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006; 0.132 μg/g).

4.3.2.2 Inorganic Constituents in Stream Bottom Sediments

Stream bottom sediments were collected from eight locations during the spring sampling event and from three locations during the fall sampling event. Samples were analyzed for the trace inorganic constituents: arsenic, mercury, cadmium, chromium, copper, lead, zinc, and cyanide. The reported occurrences of these constituents in stream bottom sediment samples during the spring and fall sampling events are summarized in Table 4.3-4 and shown on Figure 4.3-1. The following discussions summarize the occurrences of each inorganic constituent by sampling event for sample results that met the CMP QA/QC requirements. A discussion of the QA/QC protocol and a summary of rejected data are provided in Section 4.5.

Arsenic

Four concentrations exceeding the CRL were reported during the spring sampling event. The maximum reported concentration (28.0 μg/g) was for a sample from the South Platte drainage basin at Basin A station (SW36001). Other reported concentrations were for samples from the First Creek drainage basin at First Creek Off-Post station (SW37001; 2.27 μg/g) and North First Creek station (SW24002; 2.28 μg/g). The minimum reported concentration (1.85 μg/g) was for a sample from the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002).

No concentration of arsenic exceeding the CRL was reported during the fall sampling event.

Cadmium and Chromium

No concentration of cadmium and chromium exceeding the CRLs was reported during either the spring or fall sampling event.

Copper

Two concentrations exceeding the CRL were reported during the spring sampling event for a sample from the Irondale Gulch drainage basin. The reported concentrations were at South Plants Water Tower Pond (SW01002; 187 $\mu g/g$) and South Plants steam effluent (SW02006; 131 $\mu g/g$).

No concentration of copper exceeding the CRL was reported during the fall sampling event.

Lead

Seven concentrations exceeding the CRL were reported during the spring sampling event. The maximum reported concentration (96.7 $\mu g/g$) was for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006). The minimum reported concentration (9.36 $\mu g/g$) was for a sample from the First Creek drainage basin at North First Creek station (SW24002). Lead was reported for a sample from First Creek drainage basin at First Creek Off-Post station (SW37001; 13.1 $\mu g/g$). Lead was also reported in a sample from the South Platte drainage basin at Basin A (SW36001; 87.0 $\mu g/g$). Three additional concentrations of lead were reported in samples from the Irondale Gulch drainage basin at South Uvalda station (SW12005; 17.4 $\mu g/g$), Peoria Interceptor station (SW11001; 25.5 $\mu g/g$), and South Plants Water Tower Pond (SW01002; 27.9 $\mu g/g$).

Two concentrations exceeding the CRL were reported during the fall sampling event for a sample from the Irondale Gulch drainage basin. The maximum reported concentration (28.2 $\mu g/g$) was for a sample from South Plants steam effluent (SW02006). The other reported concentration (13.1 $\mu g/g$) was for a sample from Storm Sewer (SW12004).

Mercury

Four concentrations exceeding the CRL were reported during the spring sampling event. The maximum reported concentration (4.30 $\mu g/g$) was for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006). Other reported concentrations were for samples from the First Creek drainage basin at First Creek Off-Post station (SW37001; 0.0382 $\mu g/g$), the Irondale Gulch drainage basin at South Plants Water Tower Pond (SW01002; 0.137 $\mu g/g$), and the South Platte drainage basin at Basin A station (SW36001; 0.940 $\mu g/g$).

One concentration exceeding the CRL was reported during the fall sampling event for a sample from the Irondale Gulch drainage basin at South Plants steam effluent (SW02006; 3.67 μg/g).

Zinc

Five concentrations exceeding the CRL were reported during the spring sampling event. The minimum (67.9 μg/g) and maximum (306 μg/g) reported concentrations were for samples from the Irondale Gulch drainage basin at Peoria Interceptor station (SW11001) and South Plants steam effluent (SW02006), respectively. Other reported Irondale Gulch concentrations were for samples from South Uvalda (SW12005; 112 μg/g) and South Plants Water Tower Pond (SW01002; 114 μg/g). Zinc was reported for a sample from the South Platte drainage basin at Basin A station (SW36001; 264 μg/g).

Two concentrations exceeding the CRL were reported during the fall sampling event for samples from the Irondale Gulch drainage basin. The maximum reported concentration (88.8 μg/g) was for a sample from Storm Sewer (SW12004), and the minimum reported concentration (74.3 μg/g) was for a sample from South Plants steam effluent (SW02006).

4.4 SURFACE-WATER/GROUND-WATER INTERACTION

In order to assess contaminant migration onto and off of RMA, it is necessary to study the surface-water/ground-water interaction. The surface-water element investigated three areas on RMA where surface-water/ground-water interaction may be occurring. Water levels obtained from Havana Pond, the South Plants Lakes and adjacent wells were compared and are presented as hydrographs in Figures 4.4-1 to 4.4-5. A gain/loss study was performed along First Creek in which instantaneous discharge measurements were obtained in conjunction with water level data from nearby wells to determine whether the creek was receiving ground-water discharge or recharging to ground water. Figure 3.4-1 shows the location of the wells and surface-water sites that were used in this study. Table 3.4-1 lists the wells that were used in the surface-water/ground-water interaction study.

Lake water levels were observed on a weekly basis and water levels from First Creek were monitored continuously at three gaging stations. Instantaneous discharge measurements for gain/loss analysis were obtained in April and June 1990 and well water level data were collected in February, March, April, June, July, August and September 1990. Ion data and organic data from surface-water and ground-water samples were not obtained at the same time in Water Year 1990 hence water chemistry was not compared. The lakes were sampled in the spring of 1990 and wells in the area were sampled in the fall of 1989. The three areas that are addressed in this section of the report are First Creek, South Plants Lakes and Havana Pond.

4.4.1 Surface-Water/Ground-Water Interaction in the South Plants Lakes and Havana Pond Areas

The hydrograph of Havana Pond and nearby wells that are completed in the alluvium (11002 and 11007) suggests an interaction between the pond and ground water (Figure 4.4-1). The water levels in the wells were lower than those of the pond, suggesting that the pond is recharging the ground water to the north and west. A lack of wells on the east and south sides of the pond precludes a determination of water movement there. A calculation of Havana Pond water that had entered the pond after a storm indicated that 35.12 ac-ft infiltrated within 7 days.

The water levels that were obtained from Upper Derby Lake and adjacent alluvial wells (01001, 01069, 01070 and 01073) indicate interaction between the lake and ground water (Figure 4.4-2). The water levels from adjacent wells were lower than the lake indicating that the lake recharges the ground water. Wells 01070 and 01073 had the lowest water level elevations suggesting a greater potential for the lake to recharge the ground water to the west and northwest in the direction of these wells. Upper Derby Lake had a high water level in July when a large volume of water was transported to the lake from Highline Lateral. The well water levels did not mimic the lake during this month indicating a possible lag time before the ground water was recharged.

The hydrograph of Lower Derby Lake and nearby wells (01024, 01028, 01049, 01070, 01073, 01074, 01075 and 01076) also indicates a correlation between the lake and the ground water (Figure 4.4-3). Two of these wells (01028 and 01076) are screened in the Denver Formation and the remainder are completed in the alluvium. Water levels elevations in Wells 01028, 01049, 01075 and 01076 were similar to Lower Derby Lake's water level most of the year. The water levels from Wells 01070 and 01073 located to the east and north were generally higher than the lake levels. Ground-water levels from Wells 01024 and 01074, located southwest and west of the lake, were lower than the lake levels. This data indicates that ground-water discharges to the lake from the northeast and the lake recharges the ground water to the southwest. Lower Derby Lake was maintained at a low stage during the summer of Water Year 1990 to allow construction of a spillway on its northwest bank. Due to this activity, Wells 01075 and 01076 were not used in the study in August and September.

The water levels of Ladora Lake and nearby wells (02001, 02026, 02034, 02050, 02052, 02055, 02059 and 02060) show a relationship between surface water and ground water (Figure 4.4-4). All wells are screened in the alluvium except Well 02060 which is screened in the Denver Formation. Water levels in this well mimicked lake levels but were higher than the lake levels and water levels in the other wells, including adjacent Well 02059. The water level of Ladora Lake was higher than the wells located on its west side and lower than those along its northeast side. This suggests ground-water discharges to the lake from the east and northeast recharges from the lake to the ground water towards the west.

The hydrograph of Lake Mary and adjacent alluvial wells (02008, 02050 and 02056) indicates ground-water and surface-water interaction (Figure 4.4-5). In relationship to Lake Mary water levels, ground-water levels were higher southeast of the lake (02050) and lower northwest of the lake (02008). These data suggest that ground-water discharges to the lake from the southeast and the lake recharges the ground water to the northwest.

4.4.2 Surface-Water/Ground-Water Interaction Along First Creek

Instantaneous discharge measurements were obtained during April 1990 and June 1990 along First Creek to determine the gain-loss relationships and the degree of ground-water/surface-water interaction along this creek. Discharge measurements were obtained at 11 sites in April 1990 and 10 sites in June 1990 during periods of base flow along First Creek; concurrent water levels were taken at 10 adjacent ground-water wells during the June study (Figure 3.4-1).

In April the data indicate that First Creek was effluent (gaining). Flow rates progressively increased from 0.89 cfs near the south boundary of RMA to 1.08 cfs at the North First Creek monitoring station near the north boundary of RMA where First Creek exits the Arsenal (Figure 3.4-1). First Creek displayed an influent (losing) behavior downstream from the Arsenal to the First Creek Off-Post monitoring station (SW37001), which had a flow rate of 0.97 cfs.

Gain-loss relationships on First Creek change according to the seasons. In June 1990 the creek was influent from the south boundary in Section 8 with a flow rate of 0.21 cfs to Section 5 where flow terminated. From Section 5 through Section 31, 30 and 24 the stream characteristics fluctuated. The creek displayed stagnant, dry or very low flow conditions and where the creek exited Section 24 to the north, it was dry once again. During this time, the creek had stagnant water from RMA's northern boundary to a private pond located one-fourth mile north of the Arsenal. Downstream from the pond, First Creek began to flow again with 0.17 cfs at site SW37012 but it became influent as flow rates progressively decreased to the First Creek Off-Post monitoring station (SW37001) which had a flow rate of 0.01 cfs.

Generally, the majority of First Creek on RMA was effluent in the spring and influent in the summer. The well water levels obtained in June were compared with stream stages at adjacent monitoring stations in order to determine the ground-water/surface-water relationships. The only surface-water monitoring station with a sufficient amount of nearby wells is North First Creek (Figure 3.4-1). The station was dry in the channel during this time of year, but there was water in the stilling well. North First Creek has an elevation of 5,141 ft at the zero mark on the staff gage. Approximately 1,000 ft downstream from the station, Well 24183 had a water level elevation of 5,132 feet. Well 24106, adjacent to the station, had a water level of 5,141 ft, indicating that ground water was very close to the surface here. Wells 24096 and 24107 are located southeast of the North First Creek monitoring station. The water levels in these wells were 5,147 ft, 6 ft higher than the surface-water station. The data suggests there is a steep ground-water gradient between these wells and the surface-water station.

4.5 QUALITY ASSURANCE/QUALITY CONTROL RESULTS OF WATER-QUALITY DATA

QA is defined for the CMP as the program for assuring and documenting the reliability of monitoring and measurement data. The QA program functions to assess the precision, accuracy, and comparability of the analytical results generated by the Surface-Water CMP. QC is the routine application of procedures for attaining and maintaining the QA-prescribed standards of performance in the sampling and analysis process. The QA/QC program implemented during the Surface-Water CMP is based on the CMP Surface Water Technical Plan (RLSA, 1989a), the RMA Chemical Quality Assurance Plan (PMRMA, 1989), the requirements of the CMP contract (PMRMA, 1989), and the QA programs of the subcontract laboratories.

The requirements of the QA/QC program include the collection and analysis of field QC samples, which consist of field blanks, trip blanks and duplicate (split) samples. Additional samples are collected for confirmatory GC/MS analysis. Field sampling procedures for QC samples follow the same protocol used for investigative samples, including sample collection, handling, storage, preservation, documentation and shipping procedures. The QA/QC Plan stipulates the frequency at which field QC samples are to be collected and submitted to the program laboratories.

Laboratory QC data are also generated according to the QA/QC Plan, and all such data are reported weekly to PMRMA in a QA Status Report accompanied by precision and accuracy control charts for each sample lot. Laboratory QC procedures include the delineation of control limits for matrix spike and surrogate spike recoveries and the evaluation of method blank data. QC data are examined in relation to the criteria established for these procedures during the analytical certification process. Deviations from the established QC criteria during routine analyses are identified by the laboratory and appropriate corrective actions are taken. The data are then reviewed for reliability by the Program QA Officer. Any data deemed unacceptable by project management QA personnel are not entered into the Installation Restoration Data Management System (IRDMS). Rejected data are transferred to a rejected database file for informational purposes only. Table 4.5-1 catalogs the analytes and samples rejected during the Water Year 1990 Surface Water CMP on the basis of laboratory QC data. Because the data rejection process is strictly concerned with laboratory aspects of the QA/QC Plan, it is not discussed further in this Annual Report.

4.5.1 EVALUATION OF FIELD QC BLANK DATA

Field QC data are generated by collecting field and trip blanks at a rate of 5 percent each of the total number of investigative samples collected. Field blanks are sample bottles filled in the field with distilled, organic-free water during sample collection. Laboratory analyses of field blanks indicate whether ambient site conditions or sampling procedures may have introduced extraneous contaminants into the investigative samples. Trip blanks are samples of distilled/deionized, organic-free water transported to the field site and returned with the investigative samples to the laboratory unopened. Trip blank analysis reveals whether contaminants may have been introduced into samples during transport and handling.

Three field blanks and two trip blanks were collected and analyzed during the Water Year 1990 Surface-Water CMP. No volatile organic, semivolatile organic, or trace metal target analytes were detected in these blanks. Low-level major ion contamination (e.g., calcium, chloride, and/or nitrate) was detected

Table 4.5-1 Surface-Water Rejected Data, Water Year 1990

Rejected Compound	Number of Rejections	Sample Location	Sample Date
Organic Compounds			
Aldrin	6	SW06002	07/18/90
		SW08003ST2	05/30/90
		SW11001B	09/04/90
		SW11001B	04/16/90
		SW12004B	09/04/90
		SW12005B	04/16/90
Atrazine	4	SW04001ST	07/09/90
		SW08003ST3	07/09/90
		SW11002ST	07/09/90
		SW12006ST	07/21/90
Benzene	7	SW08003ST	03/09/90
		SW11001ST	03/06/90
		SW11002ST	03/06/90
		SW12004ST	03/08/90
		SW12005ST	03/08/90
		SW24002ST	03/09/90
		SW37001ST	03/09/90
Bicyclo[2.2.1] hepta-2,5-diene	2	SW06002ST1	07/27/90
		SW12006ST	07/21/90
2,2-bis(p-Chlorophenyl)-1,1,1-trichloroethane	2		
		SW11001B	04/16/90
		SW12005B	04/16/90
Dibromochloropropane	1	SW12005B	04/16/90
Dimethyldisulfide	12	SW01001	09/06/90
		SW02001	09/05/90
		SW02006	09/04/90
		SW08003	09/07/90
		SW08003FB	09/07/90
		SW08003TB	09/07/90
		SW11001	09/04/90
		SW11002	09/05/90
		SW12001	09/06/90
		SW12004	09/04/90
		SW24001	09/06/90
		SW24002	09/07/90
Dimethylmethylphosphonate	1	SW06002	07/18/90
Diisopropylmethylphosphonate	1	SW06002	07/18/90

Table 4.5-1 Surface-Water Rejected Data, Water Year 1990 (continued)

Rejected Compound	Number of Rejections	Sample Location	Sample Date
Ethylbenzene	7	SW08003ST	03/09/90
		SW11001ST	03/06/90
		SW11002ST	03/06/90
		SW12004ST	03/08/90
		SW12005ST	03/08/90
		SW24002ST	03/09/90
		SW37001ST	03/09/90
Hexachlorocyclopentadiene	1	SW06002	07/18/90
Malathion	4	SW04001ST	07/09/90
		SW08003ST3	07/09/90
		SW11002ST	07/09/90
		SW12006ST	07/21/90
Parathion	4	SW04001ST	07/09/90
		SW08003ST3	07/09/90
		SW11002ST	07/09/90
		SW12006ST	07/21/90
Supona	4	SW04001ST	07/09/90
		SW08003ST3	07/09/90
		SW11002ST	07/09/90
		SW12006ST	07/21/90
Toluene	7	SW08003ST	03/09/90
		SW11001ST	03/06/90
		SW11002ST	03/06/90
		SW12004ST	03/08/90
		SW12005ST	03/08/90
		SW24002ST	03/09/90
		SW37001ST	03/09/90
Vapona	4	SW04001ST	07/09/90
		SW08003ST3	07/09/90
		SW11002ST	07/09/90
		SW12006ST	07/21/90
m-Xylene	7	SW08003ST	03/09/90
		SW11001ST	03/06/90
		SW11002ST	03/06/90
		SW12004ST	03/08/90
		SW12005ST	03/08/90
		SW24002ST	03/09/90
		SW37001ST	03/09/90

Table 4.5-1 Surface-Water Rejected Data, Water Year 1990 (continued)

Rejected Compound	Number of Rejections	Sample Location	Sample Date
Xylene	7	SW08003ST	03/09/90
		SW11001ST	03/06/90
		SW11002ST	03/06/90
		SW12004ST	03/08/90
		SW12005ST	03/08/90
		SW24002ST	03/09/90
		SW37001ST	03/09/90
Inorganic Compounds			
Calcium	9	SW01004	04/12/90
		SW01005	04/12/90
		SW02003	04/12/90
		SW02004	04/12/90
		SW07001	04/13/90
		SW07002	04/13/90
		SW12001	04/13/90
		SW12004	04/13/90
		SW12005ST3	03/28/90
Zinc	2	SW12004	04/13/90
		SW12005ST3	03/28/90

in all three field blanks and in one trip blank, but because of the pervasiveness of these ions and the low concentrations observed relative to the investigative samples, the observed blank artifacts were judged not to indicate significant potential problems with investigative sample data. The generally very low incidence of field QC blank artifacts implied that the Water Year 1990 surface-water and sediment data were not compromised by field or laboratory practices.

4.5.2 EVALUATION OF DUPLICATE ANALYSES DATA

Duplicate samples are defined under the CMP as two identical sets of sample bottles submitted to the laboratory for the same analyses. Duplicates are collected by alternately filling pairs of identical sample bottles at the sampling site. The analyses of duplicate samples provide a measure of the data variability resulting from the sampling and analytical methods and can serve to identify potential problems in field and laboratory protocols. In compliance with the CMP Technical Plan, six of the sites in the Water Year 1990 CMP Surface-Water Network (or approximately 10 percent) were selected at random for duplicate sample collection and analysis.

Duplicate sample results are summarized statistically using the standard USEPA relative percent difference (RPD) parameter. Included in this summary are only those duplicate analyses for which at least one positive identification and quantitation was recorded. The RPD for each detection pair is calculated by calculating the absolute value of the difference between the two matched values, dividing this difference by the average of the two values, and then multiplying this quotient by 100. The RPD for a matched pair of results is, therefore, expressed as the percent difference that one duplicate result deviates from the average of the two matched results; an RPD value of 67 percent represents a reported concentration that is a factor of two different than that of the duplicate. In general, RPD values are meant to provide a general indication of reproducibility and should not be evaluated quantitatively.

Target analyte detections and RPDs for the duplicate samples collected during the Water Year 1990 Surface-Water CMP are shown in Table 4.5-2. The RPD values ranged from a low of 0 percent (observed for multiple organic and inorganic analytes) to a high of 105 percent (observed for fluoride). Other RPDs in excess of 67 percent, representing duplicate results that differed by more than a factor of two, were calculated for the two reported pairs of zinc detections (94 and 67 percent) and for an isolated copper detection pair (76 percent). The highest RPDs observed for organic analyte detection pairs were 96 and 52 percent, calculated for chlordane and DBCP, respectively. However, these two detection pairs were near the method CRLs for these analytes, and reproducibility of results near the CRLs is not generally as good as for results well above the CRL. In general, RPDs appeared higher in duplicate sediment samples than in the duplicate surface-water samples, which is reasonable considering the greater heterogeneity of the sediment samples.

Average RPD values were calculated for each class of target analytes to minimize outlier bias and render a better general assessment of sampling and analytical precision. As shown in Table 4.5-2, average RPDs of 12.1 percent, 18.2 percent, and 15.3 percent were calculated for the volatile organic, semivolatile organic, and inorganic analytes, respectively. These values indicate a similar degree of precision for the three classes of analytical data. The overall weighted (geometric) mean of the RPDs over all the classes of analytes is 15.1 percent. On average, duplicate analytical results deviate by a factor of 1.2 from each other for the Water Year 1990 Surface-Water CMP. This modest average deviation indicates that Water Year 1990 Surface-Water investigative data are of acceptable precision and that sampling and analytical methods can be considered reliable.

4.5.3 Evaluation of GC/MS Confirmation Results

The QA/QC Plan requires the collection of additional duplicate samples for confirmatory GC/MS analyses at approximately 10 percent of the sites included in surface-water sampling events. These analyses are used to verify GC method detections of volatile and semivolatile organic analytes and, hence, serve to measure the efficacy of the routine GC methods used for all organics analyses under the CMP. Nearly all organic analytes routinely analyzed by GC techniques can also be determined by GC/MS methods for confirmation purposes. For some samples; however, GC/MS cannot verify GC results because the CRLs for GC/MS methods are generally higher. The greatest disparity in CRLs between GC and GC/MS analyses occurs in the semivolatile analyses of pesticides.

The GC detections and accompanying GC/MS confirmation data are presented in Table 4.5-3 for 11 surface-water and sediment samples collected during the Water Year 1990 sampling events. Table 4.5-4 summarizes these data and presents the total number of confirmed and unconfirmed detections for each sample and for volatile and semivolatile analyses in general. Using the historical guidelines of previous RMA investigations, detections are considered confirmed if the GC and GC/MS concentrations are within one order of magnitude of each other.

Table 4.5-2 Summary of Surface-Water Duplicate Sample Analyses, Water Year 1990

Sampling Location	Analyte	Result[1]	Duplicate Result[1]	Relative Percent Difference (RPD)
VOLATILE ORGANICS				
Surface-Water Samples				
SW11001	1,2-Dichloroethene	14.4	14.4	0
	Tetrachloroethene	14.8	12.7	15.2
	Trichloroethene	14.3	13.7	4.29
SW36001	1,1,1-Trichloroethane	1.16	0.992	15.9
	1,1-Dichloroethene	4.63	4.28	7.86
	1,2-Dichloroethene	15.1	14.5	4.05
	Benzene	44.8	32.1	33.0
	Chloroform	198	198	0
	Chlorobenzene	993	1030	3.66
	Dibromochloropropane	15.2	14.7	3.34
	Dicyclopentadiene	47.8	56.0	15.8
	Ethylbenzene	65.2	67.5	3.47
	Methyl isobutyl ketone	783	754	3.77
	Tetrachloroethene	78.2	63.0	21.5
	Toluene	16.7	14.0	17.6
	Trichloroethene	42.7	37.3	13.5
	Xylene	75.0	77.1	2.76
Sediment Samples				
SW11001B	Dibromochloropropane	0.00667	0.0113	51.5
Average				12.1
SEMIVOLATILE ORGANICS				
Surface-Water Samples				
SW36001	Aldrin	0.783	0.642	19.8
	Atrazine	39.1	41.1	4.99
	Bicyclo[2.2.1]hepta-2,5-diene	22.1	23.8	7.41
	2,2-bis(p-Chlorophenyl)-1,1-dichloroethene	0.195	0.168	14.9
	2,2-bis(p-Chlorophenyl)-1,1,1-trichloroethane	0.561	0.465	18.7
	Dieldrin	2.13	2.34	9.40
	Diisopropylmethylphosphonate	<0.392	0.433	9.94
	Dimethylmethylphosphonate	1.31	1.35	3.01
	Endrin	0.171	0.145	16.5
	Hexachlorocyclopentadiene	0.258	0.175	38.3
	Isodrin	0.935	0.807	14.7
	Parathion	61.5	62.0	0.810
	Supona	5.84	5.87	0.512

Table 4.5-2 Summary of Surface-Water Duplicate Sample Analyses, Water Year 1990 (continued)

Sampling Location	Analyte	Result[1]	Duplicate Result[1]	Relative Percent Difference (RPD)
Sediment Samples				
SW11001B	Chlordane	<0.138	0.0486	95.8
Average				18.2
INORGANICS				
Surface-Water Samples				
SW01005	Chloride	44200	47300	6.78
	Fluoride	1070	1050	1.89
	Magnesium	19600	19900	1.52
	Nitrate	1070	1070	0
	Potassium	4780	4460	6.93
	Sodium	58600	61600	4.99
	Sulfate	96300	104000	7.69
SW11001	Calcium	22300	22300	0
	Chloride	15100	16500	8.86
	Fluoride	3000	928	105
	Magnesium	3410	3410	0
	Nitrate	1130	826	31.1
	Potassium	3760	3900	3.66
	Sodium	11300	11300	0
	Sulfate	29100	31500	7.92
	Zinc	33.7	67.8	67.2
SW12005	Calcium	86400	87100	0.807
	Chloride	47700	42500	11.5
	Fluoride	1380	1430	3.56
	Magnesium	27300	27800	1.81
	Nitrate	4650	4490	3.50
	Potassium	4080	3860	4.79
	Sodium	89200	89200	0
	Sulfate	12900	111000	15.0

Table 4.5-2 Summary of Surface-Water Duplicate Sample Analyses, Water Year 1990 (continued)

Sampling Location	Analyte	Result[1]	Duplicate Result[1]	Relative Percent Difference (RPD)
SW36001	Arsenic	71.6	72.8	1.66
	Calcium	66200	65200	1.52
	Chloride	76100	76500	0.524
	Fluoride	2140	2240	4.57
	Magnesium	25200	24500	2.82
	Nitrate	521	566	8.30
	Potassium	5530	5340	3.50
	Sodium	97700	96100	1.65
	Sulfate	133000	133000	0
<u>Sediment Samples</u>				
SW02006B	Copper	<58.6	131	76.4
	Lead	79.7	96.7	19.3
	Zinc	110	306	94.2
SW11001B	Lead	6.62	10.2	42.6
Average				15.3

[1]Concentration units are $\mu g/l$ for surface-water samples and $\mu g/g$ for sediment samples.

Table 4.5-3 GC and GC/MS Confirmation Results for the Surface-Water Monitoring Program, Water Year 1990

Sampling Location	Sample Event	Analyte	GC Analysis Result[1,2]	GC/MS Confirmatory Result[1,2]	Confirmation Status[3]
VOLATILE ORGANICS					
Surface-Water Samples					
SW36001	4/90	1,1,2-Trichloroethane	1.16	<10.0	3
		1,1-Dichloroethene	4.63	<10.0	3
		1,2-Dichloroethene	15.1	<50.0	3
		Benzene	44.8	<10.0	2
		Chloroform	198	220	1
		Chlorobenzene	993	29.8	2
		Dibromochloropropane	15.2	19.0	1
		Dicyclopentadiene	47.8	40.3	1
		Ethylbenzene	65.2	<10.0	2
		Methyl ethyl ketone	783	<14.0	2
		Toluene	16.7	<10.0	2
		Tetrachloroethene	78.2	53.7	1
		Trichloroethene	42.7	37.0	1
		Xylene	75.0	83.2	1
SW36001	9/90	1,1-Dichloroethene	2.08	<1.00	2
		1,2-Dichloroethene	9.02	<5.00	2
		Benzene	3.96	<1.00	2
		Dibromochloropropane	5.43	<12.0	3
		Dicyclopentadiene	20.4	<5.50	2
		Toluene	3.23	<1.00	2
		Xylene	29.6	<2.00	2
SW02006	4/90	Chloroform	5.76	4.10	1
SW37001	11/89	Dicyclopentadiene	48.4	34.0	1
		Tetrachloroethene	0.878	<0.560	2
	9/90	Dicyclopentadiene	19.5	<5.50	2
Sediment Samples					
SW01002B	4/90	Dibromochloropropane	0.0132	<0.360	3
SW36001B	4/90	Dibromochloropropane	0.110	<0.360	3
SW37001B	4/90	Dibromochloropropane	0.0145	<0.360	3

Table 4.5-3 GC and GC/MS Confirmation Results for the Surface-Water Monitoring Program, Water Year 1990 (continued)

Sampling Location	Sample Event	Analyte	GC Analysis Result[1,2]	GC/MS Confirmatory Result[1,2]	Confirmation Status[3]
SEMIVOLATILE ORGANICS					
Surface-Water Samples					
SW36001	4/90	Aldrin	0.783	<13.0	3
		Atrazine	39.1	40.8	1
		Hexachlorocyclopentadiene	0.258	<54.0	3
		Dieldrin	2.13	<26.0	3
		Dimethylmethyl Phosphonate	1.31	<13.0	3
		Endrin	0.171	<18.0	3
		Isodrin	0.935	<7.80	3
		2,2-bis(p-Chlorophenyl)-1,1-dichloroethene	0.195	<14.0	3
		2,2-bis(p-Chlorophenyl)-1,1,1-trichloroethane	0.561	<18.0	3
		Parathion	61.5	<37.0	2
		Supona	5.84	<19.0	3
SW36001	9/90	Aldrin	1.02	<13.0	3
		Atrazine	7.12	<5.90	2
		Hexachlorocyclopentadiene	0.0718	<54.0	3
		p-Chlorophenyl methyl sulfoxide	17.0	<15.0	2
		p-Chlorophenyl methyl sulfone	194	252	1
		Dieldrin	3.99	<26.0	3
		Dimethylmethyl Phosphonate	0.771	<13.0	3
		Endrin	1.39	<18.0	3
		Isodrin	0.516	<7.80	3
SW11002	4/90	Chlordane	0.293	<37.0	3
		2,2-bis(p-Chlorophenyl)-1,1-dichloroethene	0.088	<18.0	3
		Atrazine	10.2	<5.90	2
SW24001	4/90	Aldrin	0.0703	<13.0	3
SW37001	11/90	Atrazine	9.43	<5.90	3
		Chlordane	0.236	<37.0	3
		Diisopropylmethyl Phosphonate	<0.392	160	2
	9/90	Atrazine	12.2	<5.90	2
		Diisopropylmethyl Phosphonate	124	113	1
		Endrin	0.230	<18.0	3
		Parathion	1.35	<37.0	3

Table 4.5-3 GC and GC/MS Confirmation Results for the Surface-Water Monitoring Program, Water Year 1990 (continued)

Sampling Location	Sample Event	Analyte	GC Analysis Result[1,2]	GC/MS Confirmatory Result[1,2]	Confirmation Status[3]
SEMIVOLATILE ORGANICS (continued)					
Sediment Samples					
SW01002B	4/90	Aldrin	3.30	7.20	1
		Chlordane	0.340	<0.670	3
		Dieldrin	1.20	<0.560	2
		Endrin	0.0410	<0.270	3
		Isodrin	0.0300	<0.270	3
SW02006B	4/90	Aldrin	0.500	<0.670	3
		Chlordane	0.880	<0.670	2
		Dieldrin	0.880	<0.560	2
		Endrin	0.0550	<0.270	3
		Isodrin	0.0360	<0.270	3
		2,2-bis(p-Chlorophenyl)-1,1-dichloroethene	0.0160	<0.510	3
SW36001B	4/90	Aldrin	4.90	15.7	1
		Chlordane	11.0	<0.670	2
		Dieldrin	1.70	2.72	1
		Isodrin	1.30	0.965	1
		2,2-bis(p-Chlorophenyl)-1,1-dichloroethene	0.100	<0.510	3

1 Concentration units are µg/l for surface-water samples and µg/g for sediment samples.

2 A "less than" value in this column indicates a nondetect in the analysis; the reported value is the CRL for that analyte.

3 1 = GC result confirmed by GC/MS within one order of magnitude.
2 = GC result not confirmed by GC/MS.
3 = GC result not confirmable because of higher GC/MS CRL.

CRL = Certified Reporting Limit
GC = gas chromatography
MS = mass spectrometry
µg/l = micrograms per liter
µg/g = micrograms per gram

Table 4.5-4 Summary of Surface-Water Confirmation Results, Water Year 1990

Sampling Location		Number of of GC Detections	Number of Confirmed Detections	Number of Unconfirmed Detections[1]	Number of Unconfirmable
VOLATILE ORGANICS					
SW36001	4/90	14	6	5	3
SW36001	9/90	7	0	6	1
SW02006	4/90	1	1	0	0
SW37001	11/89	2	1	0	1
	9/90	1	0	1	0
SW01002B	4/90	1	0	0	1
SW36001B	4/90	1	0	0	1
SW37001B	4/90	1	0	0	1
Total		28	8	12	8
SEMIVOLATILE ORGANICS					
SW36001	4/90	11	1	1	9
SW36001	9/90	9	1	2	6
SW11002	4/90	3	0	1	2
SW24001	4/90	1	0	0	1
SW37001	11/89	3	0	2	1
	9/90	5	1	1	3
SW01006B	4/90	5	1	1	3
SW02006B	4/90	6	0	2	4
SW36001B	4/90	5	3	1	1
Total		48	7	11	30

[1] GC detections that could not be confirmed because of higher GC/MS CRLs.

CRL =Certified Reporting Limit
GC =gas chromatography
MS =mass spectrometry

As shown in Table 4.5-4, a total of 28 volatile organics detections were reported by GC methods in samples also analyzed by GC/MS. Eight of these detections (29 percent) were confirmed by the GC/MS data within the order-of-magnitude historical criterion, whereas 12 detections (43 percent) were not confirmed. An additional seven (29 percent) of the 28 volatile organic detections could not be confirmed because the reported GC concentrations were below the GC/MS method CRLs.

Of 48 total semivolatile GC detections summarized in Table 4.5-4, seven were confirmed and eleven were not confirmed by GC/MS analyses based on the order-of-magnitude historical guidelines. The remaining 30 GC results were unconfirmable because of higher GC/MS CRLs. Thus, 15 percent of the semivolatile GC detections were confirmed, 23 percent were not confirmed, and 63 percent were too low-level to be confirmed by the existing certified GC/MS methods.

In summary, GC/MS confirmation of routine GC analytical data was sometimes not possible because of the low concentrations of target compounds generally encountered in the investigative surface-water and sediment samples. The GC/MS analyses were most successful in confirming volatile organics data because the GC/MS method CRLs more closely approached the GC method CRLs for volatiles analyses than for semivolatile analyses.

5.0 DATA ASSESSMENT

5.1 SURFACE-WATER QUANTITY DATA ASSESSMENT

Surface-water quantity results obtained in Water Year 1990 are discussed and compared to Water Years 1988 and 1989 surface-water CMP results. Significant differences from previous years, apparent trends, anomalies, etc., are identified.

5.1.1 STREAM FLOW DATA

Items of interest in a stream flow monitoring program include relative flow rates and volumes as well as variability of flow. Stream flow at RMA gaging stations and lake volumes have been monitored during the 3 years of the CMP and comparisons of these data are presented in the following sections.

5.1.1.1 Rates and Volumes of Flow

The stations that had the largest rates and volumes of flow during Water Year 1990 were those measuring inflow to RMA, totaling 4,681 ac-ft for the year and 3,861 ac-ft for the 6 months of April through September, 1990. Surface-water inflow during these 6 months in Water Year 1990 was similar to inflow during Water Year 1988, but was considerably larger than inflow during Water Year 1989. The Irondale Gulch drainage basin received about 84 percent of the total inflow into RMA with only 38 percent of that inflow coming from natural runoff because of the large importation of water via Highline Lateral during Water Year 1990. During the months of April through September, Highline Lateral contributed 46 percent of the RMA inflow in 1988, 23 percent in 1989, and 57 percent in 1990. The natural runoff inflow in the Irondale Gulch drainage basin (South Uvalda, Peoria Interceptor, and Havana Interceptor stations) was 1758 ac-ft in Water Year 1990 (38 percent of all RMA inflow). First Creek contributed only 16 percent to the total RMA inflow during Water Year 1990.

Of the three Irondale Gulch drainage basin natural inflows, the Havana Interceptor conveyed the largest volume of water to RMA: 901 ac-ft during Water Year 1990 and 678 ac-ft (96 percent) during April through September. This annual volume represents a unit runoff from the 5.227 sq mi drainage area of 3.23 in., about 29 percent of the precipitation measured at the South Plants Rain Gage during the year.

The runoff for the months of April through September was 678 ac-ft in 1990 compared to 543 ac-ft for the same period in 1989 and 734 ac-ft for the same period in 1988 (Table 5.1-1. The volume of inflow to RMA via the Havana Interceptor was 51.3 percent of the total Irondale Gulch drainage basin natural inflow in Water Year 1990, although the Havana Interceptor drainage area is only about 38 percent of the total Irondale Gulch drainage area.

During Water Year 1990, the second largest Irondale Gulch natural inflow to RMA was recorded at the South Uvalda gaging station and measured 689 ac-ft. During the 6 months of April through September an inflow to RMA of 460 ac-ft was measured compared to 439 ac-ft in 1989 and 386 ac-ft in 1988 (Table 5.1-1). The unit runoff from Uvalda Interceptor's 7.723 sq mi drainage area was 1.67 in., 15.1 percent of the precipitation measured at the Scuth Plants rain gage. These figures are approximately one-half of comparable figures for the Havana Interceptor, a relationship consistent with 1989 and 1988. This relationship infers that significantly more infiltration of precipitation takes place in the South Uvalda watershed than the Havana Interceptor watershed, although both are about 50 percent urban. Although the drainage area contributing to the South Uvalda station is about 57 percent of the Irondale Gulch drainage basin south of RMA, the volume of runoff produced was only 39 percent of the total natural runoff in Water Year 1990.

The Peoria Interceptor station measures flow on the smallest drainage area (0.644 sq mi) and measured the smallest inflow (168 ac-ft) during Water Year 1990. The unit runoff of the Peoria Interceptor drainage area was 4.89 in., about 44 percent of the precipitation measured at the South Plants rain gage. The runoff for April through September 1990 was 122 ac-ft, which is only 41 percent of the volume measured during the same period in 1989 and 44 percent of the volume measured during the same period in 1988. Although the watersheds of Uvalda Interceptor and Havana Interceptor are considerably larger than the Peoria Interceptor watershed, the runoff volume at Peoria Interceptor has been proportionally larger than the drainage area would suggest. This is an anomaly that was also present during 1989 and 1988 and currently is unexplained.

The runoff volume entering RMA via First Creek during Water Year 1990 was 729 ac-ft. This annual volume represents a unit runoff of 0.52 in., which is only 4.7 percent of the precipitation measured at the South Plants rain gage. The low percentage is likely caused by the higher rate of infiltration that occurs in a largely undeveloped watershed of this area during storm events. An intense storm centering

Table 5.1-1 Summary of RMA Inflow Water Volumes, April through September, Water Years 1988, 1989 and 1990

	1988 (ac-ft)	1989 (ac-ft)	1990 (ac-ft)
NATURAL INFLOW			
Irondale Gulch Drainage Basin			
Havana Interceptor	734	543	678
Peoria Interceptor	257	275	112
South Uvalda	386	439	460
First Creek Drainage Basin			
South First Creek	501	263	417
Sub-Total	1878	1520	1667
CONTROLLED INFLOW			
Irondale Gulch Drainage Basin			
Highline Lateral	1592	461	2194
Total RMA Inflow	3470	1981	3861

on a developed watershed as opposed to an undeveloped watershed can result in a significantly different runoff. Historically, the unit runoff measured at South First Creek gaging station has represented a minor percentage of precipitation measured at the Stapleton Airport rain gage. The April through September 1990 runoff measured at the South First Creek gaging station was 417 ac-ft, considerably greater than the 263 ac-ft measured during the same time period in 1989 but similar to the 501 ac-ft measured during the same time period in 1988 (Table 5.1-1).

Highline Lateral contributed 2,194 ac-ft of the 3,952 ac-ft of water measured from the Irondale Gulch drainage area during Water Year 1990; however, the water in Highline Lateral is controlled flow diverted from the South Platte River and is not representative of watershed runoff. The amount of water released to Highline Lateral is dependent on the utilization of Army-owned shares of irrigation water. The amount has varied considerably during the 3 years of the Surface-Water CMP and is illustrated in Table 5.1-1. Highline Lateral accounted for approximately 47 percent of all inflow to RMA during Water Year 1990.

The measured outflow of First Creek at the North First Creek monitoring station, which includes 10.32 additional sq mi of drainage area, was significantly less than the inflow at South First Creek (400 ac-ft vs 729 ac-ft). This relationship is typical of previous years and represents about a 45 percent loss of surface-water flow to infiltration, evaporation and transpiration. However, the 6 month flow from April through September at North First Creek was approximately 5.5 times less than flow at South First Creek during Water Year 1990 compared to only 1.5 times less during Water Year 1989. North First Creek records do not exist for 1988; therefore, it is unclear what amount of surface-water loss is normal between South First Creek and North First Creek. The 400 ac-ft volume is a unit runoff of only 0.20 in from the 36.70 sq mi drainage area, about 1.8 percent of the precipitation measured at the South Plants rain gage during the same time period.

5.1.1.2 Variability of Flow Rates

The variability of flow rates affects the accuracy of measurement. The more variable flows are generally the most difficult to measure accurately. The ratio of the daily maximum discharge to the mean daily discharge is an index of variability, and was calculated monthly for April through September during Water Years 1988, 1989, and 1[illegible] (Table 5.1-2) for the 12 stream gaging stations. In 1990, the greatest variability occurred at the Peoria Interceptor station (May = 18.8), the Ladora Weir (August = 19.6), the North Uvalda station (May = 18.9), and the South First Creek station (August = 20.6). The ratios of daily maximum discharge to mean daily discharge have varied moderately each year at RMA surface-water monitoring stations. However, the gaging stations located on First Creek had the least variability during the observed 6-month period for 1988, 1989, and 1990 (Table 5.1-2).

A second index, the ratio of the instantaneous maximum discharge to the mean daily discharge from April to September 1990, displays somewhat the same pattern (Table 5.1-3). Ratios exceeded 200 at the Havana Interceptor station in August (205.5), and the Peoria Interceptor station in June (225.0) and at the South Uvalda station in July (227.8). Instantaneous maximum discharges at all of the First Creek stations were relatively small in comparison to the mean daily discharge. The average ratios of computed instantaneous maximum discharge to mean daily discharge have remained relatively consistent from year to year (Table 5.1-3.). Havana Interceptor has historically displayed the greatest variability while stations on First Creek and stations monitoring controlled flow typically possess the least variability.

5.1.2 LAKE AND POND STAGE DATA

Average monthly stage values for Upper Derby Lake, Ladora Lake, Lake Mary, and Havana Pond for Water Years 1989 and 1990 are presented in Table 5.1-4. Weekly stage readings were started by the CMP in April, 1988.

5.1.2.1 Upper Derby Lake

Upper Derby Lake receives water from the Highline Lateral during the summer months, therefore, it is typically at maximum stage from June to September and at minimum stage during the winter months. Because Highline Lateral deliveries were considerably larger and storage was limited in Lower Derby Lake in Water Year 1990 compared to 1989, the stages in the summer of 1990 were approximately 3 ft to 4 ft higher than in 1988 and 1989. The high stage in Upper Derby Lake produced outflow to eastern Upper Derby lake. Once eastern Upper Derby Lake reached its maximum capacity, overflow was directed to First Creek via the Upper Derby Lake Overflow ditch.

Table 5.1-2 Ratio of Daily Maximum Discharge to Mean Daily Discharge, April through September, Water Years 1988, 1989, and 1990

	April			May			June			July			August			September			Average Ratio[1]		
	88	89	90	88	89	90	88	89	90	88	89	90	88	89	90	88	89	90	88	89	90
								(dimensionless)													
Irondale Gulch Drainage Basin																					
Havana Interceptor	6.3*	4.2*	8.6	13.7	8.6*	13.3	7.0	14.4	6.3	8.6	23.7	8.9	6.7	4.7	9.5	5.6	5.0	11.2	8.0*	10.1*	9.6
Peoria Interceptor	11.7*	7.0*	13.8	11.5	6.0	18.8	5.9	15.8	12.5	4.1	15.0	12.5	4.1	7.2	10.5	6.9	6.2	15.5	7.4*	9.5*	13.9
Ladora Weir	--*	NR	--	5.9	--	--	1.4	--	5.0	3.9	11.8	3.0	5.7	1.6	19.6	6.8	1.5	3.5	4.7*	5.0	7.8
South Uvalda	3.4*	8.0*	5.1	10.9	6.2	10.7	13.3	8.0	3.7	5.3	11.8	10.0	7.6	9.4	8.3	6.0	5.5	8.2	7.6*	8.2*	7.7
North Uvalda	4.5*	NR	T	5.7	28.3	18.9	12.7	18.6	3.9	6.8	--	15.8	6.5	2.7	18.1	1.3	1.2	13.8	6.3*	12.7	<14.1
Highline Lateral	--*	--	--	2.4	3.5	6.2	26.2	20.6	2.1	3.4	--	3.4	3.1	15.6	4.3	3.5	--	1.7	7.7*	13.2	3.5
South Plants Ditch	--*	--	--	20.0	--	--	--	3.8	--	--	--	--	--	--	--	--	--	--	20.0*	3.8	--
First Creek Drainage Basin																					
South First Creek	1.2*	1.7*	1.4	4.5	3.7	3.1	2.1	2.2	3.5	5.2	10.0	3.1	4.9	8.5	20.6	3.3	5.1	2.2	3.5*	5.2*	5.7
North First Creek	NR	1.7*	1.5	NR	3.0	1.9	NR	3.3	12.0	NR	--	--	NR	--	6.9	NR	--	4.8	NR	2.7*	5.4
First Creek Off-Post	NR	NR	1.7	NR	NR	2.2	NR	NR	7.1	NR	3.0*	5.0	NR	NR	11.7	NR	NR	5.5	NR	3.0*	5.5
South Platte Drainage Basin																					
Basin A	T*	T	--	16.8	9.0	--	T	12.0	T	T	T	T	T	T	--	T	T	--	<16.8*	10.5	--
Basin F	NR	NR	--	NR	NR	--	NR	NR	--	NR	NR	--	NR	NR	--	NR	NR	--	NR	NR	--

1 Zero discharges, periods of no record and trace flows excluded from ratio average
* Partial Month
NR No Record
-- Mean Daily Discharge = 0.00 cfs
T Trace flow (>0.00 cfs, <0.005 cfs)

Table 5.1-3 Ratio of Computed Instantaneous Maximum Discharge to Mean Daily Discharge, April through September, Water Years 1988, 1989, and 1990

	April			May			June			July			August			September			Average Ratio[1]		
	88	89	90	88	89	90	88	89	90	88	89	90	88	89	90	88	89	90	88	89	90
	(dimensionless)																				
Irondale Gulch Drainage Basin																					
Havana Interceptor	44.2*	11.5*	105.4	336.8	57.9*	51.7	266.5	378.4	88.2	287.9	524.3	171.8	192.7	98.8	205.5	51.0	88.6	232.2	196.5*	193.3*	142.5
Peoria Interceptor	72.2*	22.2*	192.3	27.7	41.0	85.3	45.7	37.5	225.0	31.8	87.9	135.8	40.8	75.0	90.9	21.0	28.0	133.3	39.9*	48.6*	143.8
Ladora Weir	--*	NR	--	29.3	--	--	1.6	--	5.5	4.3	12.7	3.0	11.3	1.6	64.7	20.9	1.5	3.5	13.5*	5.3	19.2
South Uvalda	56.1*	53.1*	56.3	31.3	94.4	59.3	131.7	91.7	42.3	47.8	117.6	227.8	82.1	152.0	158.3	53.7	122.0	86.3	67.1*	105.1*	71.7
North Uvalda	30.5*	NR	T	21.3	100.9	155.6	26.4	48.4	5.7	111.6	--	120.0	16.1	2.7	27.8	1.7	1.2	20.8	34.6*	38.3	66.0
Highline Lateral	--*	--	--	2.4	3.7	7.4	42.9	22.8	2.8	4.3	--	3.8	3.1	21.7	5.2	4.2	10.9	2.0	11.4*	14.8	4.2
South Plants Ditch	--*	--	--	52.6	--	--	--	180.0	--	--	--	--	--	--	--	--	--	--	--*	180.0*	--
First Creek Drainage Basin																					
South First Creek	1.7*	2.2*	1.9	6.7	7.3	6.0	12.0	3.9	4.8	15.0	23.8	15.2	7.4	18.0	93.0	9.8	--	6.8	8.8*	11.0*	21.3
North First Creek	NR	2.1*	1.6	NR	5.8	2.7	NR	6.2	15.7	NR	--	--	NR	--	17.7	NR	--	5.3	NR	4.7*	8.6
First Creek Off-Post	--	NR	1.8	NR	NR	2.4	NR	NR	9.2	NR	4.0	40.0	NR	--	15.0	NR	NR	5.8	NR	4.0	12.4
South Platte Drainage Basin																					
Basin A	T*	T	--	57.5	45.0	--	T	52.0	--	T	T	T	T	T	--	T	T	--	<57.5*	<48.5	T
Basin F	NR	NR	--	NR	NR	--	NR	NR	--	NR	NR	T	NR	NR	T	NR	NR	--	NR	NR	T

1 Zero discharges, periods of no record and trace flows excluded from ratio average
* Partial Month
NR No Record
-- Mean Daily Discharge = 0.00 cfs
T Trace flow (>0.00 cfs, <0.005 cfs)

SWAR-90.TB2

Table 5.1-4 Evaporation, Precipitation, Lake Stage and Sewage Treatment Plant Discharge Data

Month	Water Year	Climatic: Total Precipitation[1] (inches)	Climatic: Total Evaporation[2] (inches)	Lake and Pond Stages[3]: Upper Derby (feet)	Lower Derby (feet)	Ladora Lake (feet)	Lake Mary (feet)	Havana Pond (feet)	Sewage Treatment Plant Discharge (total gallons)
10/87	WY88	1.24	3.60	0	15.3	11.6	0.67	1.89	266,500
11/87		1.62	1.89	0	14.7	11.7	0.52	2.72	231,000
12/87		1.30	0.63	0	14.6	12.0	0.62	2.15	335,500
01/88		0.40	0.49	NR	NR	NR	NR	NR	374,200
02/88		0.60	0.63	NR	NR	NR	NR	NR	528,200
03/88		1.28	1.12	NR	NR	NR	NR	NR	573,400
04/88		0.65	2.24	0	13.79	12.20	1.33	1.23	571,000
05/88		4.26	3.50	2.83	14.28	12.17	1.18	3.29	643,000
06/88		1.28	5.75	6.98	14.13	12.42	0.97	2.88	556,200
07/88		2.19	5.48	4.77	16.48	12.15	1.07	2.46	510,500
08/88		1.83	5.81	5.30	16.72	11.96	0.65	2.75	696,500
09/88		0.90	4.62	5.18	16.88	11.74	0.28	2.39	633,100
WY TOTAL		17.55	35.76						5,919,100
10/88	WY89	0.06	4.80	6.65	16.88	12.05	0.16	1.82	438,600
11/88		0.47	2.70	5.22	16.45	12.16	0.30	0	452,000
12/88		1.04	0.90	NR	NR	NR	NR	NR	400,900
01/89		1.14	0.70	NR	NR	NR	NR	NR	446,800
02/89		0.66	0.90	NR	15.78	12.35	0.83	0	264,800
03/89		0.56	1.60	0	15.90	12.27	1.02	0	340,000
04/89		1.00	3.20	1.03	15.70	12.20	0.86	1.69	118,400
05/89		3.83	6.80	3.22	15.26	12.12	0.62	2.76	334,000
06/89		2.04	6.94	6.80	16.06	12.08	0.60	3.16	377,900
07/89		1.64	9.98	5.38	15.12	11.85	0.71	2.13	652,100
08/89		1.28	7.64	5.05	13.66	11.98	0.72	3.04	862,400
09/89		1.55	6.80	4.40	12.75	11.33	0.77	2.47	583,500
WY TOTAL		15.27	52.96						5,271,400

Table 5.1-4 Evaporation, Precipitation, Lake Stage and Sewage Treatment Plant Discharge Data (continued)

Month	Water Year	Climatic		Lake and Pond Stages[3]					
		Total Precipitation[1] (inches)	Total Evaporation[2] (inches)	Upper Derby (feet)	Lower Derby (feet)	Ladora Lake (feet)	Lake Mary (feet)	Havana Pond (feet)	Sewage Treatment Plant Discharge (total gallons)
10/89	WY90	0.81	4.30	NR	12.56	11.66	0.74	1.75	546,400
11/89		0.15	2.70	NR	12.63	11.80	0.61	1.11	419,300
12/89		0.81	0.90	NR	NR	NR	NR	NR	360,700
01/90		0.74	0.70	NR	NR	NR	NR	NR	457,600
02/90		0.55	0.90	NR	11.98	NR	NR	1.19	351,900
03/90		3.10	1.60	2.35	12.05	12.30	0.31	2.83	587,300
04/90		1.01	3.20	2.13	12.03	12.13	0.63	2.09	537,700
05/90		1.51	6.27	4.16	11.96	11.65	0.92	2.08	481,300
06/90		0.21	9.97	8.10	11.73	12.00	0.86	2.34	624,200
07/90		3.57	7.72	8.72	11.60	12.24	0.90	3.09	831,800
08/90		1.96	7.71	9.10	11.63	11.48	0.90	3.54	727,500
09/90		1.46	6.37	8.75	11.73	12.54	0.87	2.83	560,000
WY TOTAL		15.88	52.34						6,485,700

1 Precipitation values are recorded from Stapleton International Airport
2 Evaporation values are based on pan evaporation data from Cherry Creek Reservoir
3 Lake and pond stage data represent average monthly values
NR Not recorded
Note: A 0 stage value for Upper Derby Lake or Havana Pond indicates that the water level was below the staff gage or the lake or pond was dry

5.1.2.2 Lower Derby Lake

The stage of Lower Derby Lake is normally held fairly constant throughout the year. This was the case during Water Year 1990, although the stage was held at about 12 ft, due to spillway construction activities, compared to 15 ft to 16 ft through most of Water Years 1988 and 1989.

5.1.2.3 Ladora Lake

Consistent with the historical record, the Ladora Lake stage varied by only about 1 ft during Water Year 1990. The stage of Ladora Lake is maintained at a relatively constant level in order to meet the process water needs at RMA.

5.1.2.4 Lake Mary

The measured stages of Lake Mary during Water Year 1990 were consistent with the historical record, varying between a low in the winter and highest stages in the summer.

5.1.2.5 Havana Pond

The measured stages in Havana Pond during Water Year 1990 ᵛ ɜ consistent with the historical record. The stage reached its maximum in August in response July and August thunderstorms.

5.1.3 Evaporation and Precipitation Data

Monthly evaporation and precipitation data for Water Years 1988, 1989 and 1990 are presented in Table 5.1-4. Evaporation measured during Water Year 1990 was essentially same as Water Year 1989; however, evaporation was approximately 30 percent less during Water Year 1988.

Precipitation measured at Stapleton Airport during Water Year 1990 was about the same as during Water Year 1989, and 1.67 in less than Water Year 1988. However, as shown in Table 4.1-1, the precipitation measured on RMA during Water Year 1990 was significantly less than the Stapleton precipitation. More years of record are needed to determine if there is a consistent difference between the two locations.

5.2 SURFACE-WATER QUALITY ASSESSMENT

This section provides an assessment of Water Year 1990 surface-water quality results, as presented in Sections 4.2. The discussion utilizes and compares historical surface-water quality and the assessment presented in the FY89 Surface-Water Data Assessment Report to identify spatial and temporal trends in surface-water quality during the reporting period. The quality and accuracy of the pre-RI data are not entirely known; therefore, comparisons between CMP and historical data, including the pre-RI data, should be made with this in mind. Contamination is also assessed on the basis of interpreted upstream baseline conditions. In Section 6.0 of this report, conclusions are drawn regarding the trends identified in this section as related to potential RMA and off-post source areas and the possible relationships between stream discharge and contaminant concentration.

Mechanisms for the distribution and concentrations of chemical constituents in surface water and stream sediments are diverse and can complicate interpretation of data. Concentrations of chemical constituents can vary both spatially and temporally.

Spatial variations in concentrations of chemical constituents can occur over large areas as the result of varying physical factors along a stream reach and in local areas within a channel cross section as a function of depth and flow velocity. Factors affecting large-scale spatial variations in constituent concentrations include proximity to contaminant source areas, dilution as the result of changes in stream flow/discharges volume, and chemical degradation/transformation as a function of exposure to sunlight and biological mechanisms.

Temporal variations in concentrations of chemical constituents at a given location can occur as a function of seasonal discharge changes, bed load transport, changes in base-flow chemistry, deposition of wind-blown particulates in the channel, and/or washing of these particulates into the reach during high events and seasonal environmental fluctuations (e.g., temperature).

With respect to data assessment, surface water must be considered a dynamic system capable of producing wide fluctuations in concentrations of chemical constituents, both temporally and spatially. Current chemical/discharge data must often be assessed in concert with historical chemical/discharge data to recognize the physical and chemical mechanisms influencing contaminant detections and basic water chemistry at a given location.

For inorganic constituents, water-quality baseline ranges are defined as concentrations in water entering RMA that may represent naturally occurring conditions and/or anthropogenic influences. Elevated concentrations of inorganic constituents are defined as concentrations that are elevated with respect to water-quality baseline ranges.

For the purposes of clarity and consistency, the water-quality assessment will be discussed according to the major drainage basins described in previous sections of this report. The drainage basins include the First Creek drainage basin (Section 5.2.1), Irondale Gulch drainage basin (Section 5.2.2), South Platte drainage basin (Section 5.2.3), and Sand Creek drainage basin (Section 5.2.4). Conclusions are discussed in Section 6.0.

5.2.1 FIRST CREEK DRAINAGE BASIN

Surface-water CMP locations sampled for water-quality analysis in the First Creek drainage basin are listed in Table 3.2-1 and shown on Figure 2.3-3.

5.2.1.1 Organic Compounds in Surface Water.

Samples collected from five of the 11 First Creek drainage basin surface-water sampling locations during Water Year 1990 contained concentrations of organic compounds exceeding the CRL (Figure 4.2-2 and Table 4.2-2). Four of these five sites, however, yielded only a single organic compound detection each. Vapona, which was the compound most frequently detected above the CRL during Water Year 1989 within the First Creek drainage basin, was not reported in samples collected during Water Year 1990.

The furthest upstream organic compound detection in the First Creek drainage basin during 1990 occurred at the First Creek Near North Plants (SW30002). Chloroform was reported at this site during the spring sampling event. Historical data indicate that vapona was the only organic compound previously reported in samples collected from this location.

Aldrin was reported in samples collected at the Sewage Treatment Plant (SW24001) during the spring sampling event and at the North First Creek monitoring station (SW24002) during a high event (March 9, 1990). Historical data indicate that aldrin has been previously reported at the Sewage Treatment Plant location, but not at the North First Creek monitoring station.

DIMP was reported in samples collected from the North Bog (SW24003) and First Creek Off-Post (SW37001) monitoring stations. At the First Creek Off-Post monitoring station (SW37001), DIMP was detected above the CRL in all four 1990 samples (high event 1 (November 29, 1989), spring, high event 2 (March 9, 1990), and fall) collected from this site. Historical data confirm the presence of DIMP in surface water at both of these locations.

In addition to DIMP, several other target organic compounds were reported at concentrations above the CRL in samples collected from the First Creek Off-Post monitoring station (SW37001) during the high event 1, spring and fall sampling events. During the November 29, 1989, high event sampling, atrazine, chlordane, DCPD, and TCLEE were reported. During the spring event, DCPD and chlordane were reported. During the fall event, DCPD, endrin, atrazine, and parathion were reported. Historical data indicate the presence of all the compounds reported at this site in 1990 except parathion and TCLEE. However, parathion was not analyzed as a target compound prior to 1989.

5.2.1.2 Inorganic Constituents in Surface Water

Inorganic constituents in surface water within the First Creek drainage basin during Water Year 1990 have been evaluated by comparison with established baseline concentration ranges that have been interpreted to represent concentrations entering RMA in the surface water. Surface water samples collected where First Creek enters RMA at the South First Creek Boundary (SW08001) have historically been interpreted to be representative of baseline concentrations. CMP Water Years 1988 through 1990 and historical WRI data (Ebasco, 1989a) have been tabulated in Table 5.2-1 and were used to identify the presence of elevated inorganic constituents elsewhere within the First Creek drainage basin. Because dissolved fraction analyses were not conducted on samples collected during Water Year 1990, only the total recoverable water-quality baseline concentration ranges were established. Baseline ranges established for the First Creek drainage basin have not been segregated by flow rate because of incomplete records. The maximum assumed values for Water Year 1990 water-quality baseline ranges were represented by

Table 5.2-1 Baseline Surface-Water Quality Concentration Ranges for Inorganic Constituents Entering RMA in the First Creek Drainage Basin at First Creek South Boundary (SW08001)[1]

Analyte	Total Recoverable Concentrations	Units
Major Inorganic Constituents		
Calcium	24.4 - 117	mg/l
Magnesium	17.5 - 26.9	mg/l
Potassium	3.84 - 5.64	mg/l
Sodium	58.1 - 92.6	mg/l
Chloride	32.0 - 63.3	mg/l
Fluoride	1.10 - 1.22	mg/l
Sulfate	11.8 - 141	mg/l
Nitrate	0.0805 - 1.28	mg/l
Trace Metals		
Arsenic	<2.35 - 6.56	µg/l
Cadmium	<6.78 - <8.40	µg/l
Chromium	<16.8 - <24.0	µg/l
Copper	<18.8 - <26.0	µg/l
Mercury	<0.100	µg/l
Lead	<43.4 - <74.0	µg/l
Zinc	<18.0 - <22.0	µg/l

[1] Represents CMP and WRI Report (Ebasco, 1989a) data
mg/l =milligrams per liter
µg/l =micrograms per liter
< =less than

the highest concentrations reported in surface water where First Creek enters RMA at the South First Creek Boundary (SW08001) for each constituent.

Table 5.2-2 presents the elevated inorganic constituents reported in the First Creek drainage basin for Water Year 1990 with respect to baseline ranges listed in Table 5.2-1. All monitoring stations except Eastern Upper Derby Lake Ditch (SW06002) sampled in 1990 contained elevated concentrations of inorganic constituents. Elevated concentrations of trace metals, however, were limited to three sample locations.

Zinc was reported above baseline concentrations in samples collected from the South First Creek monitoring station (SW08003) during a high event (July 9, 1990), and at the North First Creek monitoring station (SW24002) during the fall sampling event. Neither sampling location reported concentrations of zinc during previous sampling events.

Arsenic was reported above baseline concentrations in samples collected from the Sewage Treatment Plant (SW24001) during both the spring and fall sampling events. Historically, elevated concentrations of arsenic have been reported at this sampling location.

A fall 1990 surface-water sample at North First Creek monitoring station (SW24002), however, contained concentrations of these major ions exceeding 1990 and historical CMP levels at all sites within the First Creek drainage basin. Historical data indicate the continued existence of major ions above baseline ranges within the First Creek drainage basin. Water Year 1988 and 1989 CMP data indicated that the North Bog (SW24003) had the highest concentrations of most of the major ions in the First Creek drainage basin. Water Year 1990 concentrations of calcium, magnesium, sodium, chloride, fluoride, and sulfate at this location agree with historical levels.

In addition to identifying inorganic constituents above baseline levels, surface-water samples collected from the First Creek drainage basin were also characterized by water composition type. Approximately 15 percent of the samples collected were not included in this assessment because ion balance errors were greater than 10 percent or analytical results did not meet CMP QA/QC requirements. This characterization allowed for assessment of seasonal changes in composition within the First Creek drainage basin and comparison to a similar ion characterization from the Water Year 1989 CMP data.

Table 5.2-2 Elevated Inorganic Constituent Concentrations for First Creek Drainage Basin Sample Locations for Water Year 1990[1]

Sampling Location	Sampling Period	Calcium mg/l	Magnesium mg/l	Potassium mg/l	Sodium mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate mg/l	Arsenic µg/l	Zinc µg/l
SW08003	High Event 1			8.75							
	High Event 2								1.73		
	High Event 3								3.44		127
	Fall			5.68		65.5					
SW24001	Spring					68.7	1.61		2.86	73.1	
	Fall			5.79					4.30	70.6	
SW24002	High Event		28.0	10.8	103	76.8	1.25	200			
	Spring		35.4	5.78	118		1.46	239			
	Fall	477	134		626	453	10.0	2000			54.7
SW24003	Spring	138	88.7	5.87	270	330	2.22	486			
SW24004	Spring		36.6	6.36	122		1.49	245			
SW30002	Spring		31.6	6.05	107		1.65	223			
S[illegible]	Spring		36.1		108		2.02	157	6.42		
SW31[illegible]	Spring			7.03			1.44	180			
SW37001	High Event 1	147	60.5		380	250	3.34	480			
	High Event 2		32.2	11.6	121	94.9	1.49	255			
	Spring	119	47.1	6.57	184	124	1.89	333	2.55		
	Fall		45.5	7.23	246	162	2.51	383			

[1] Concentrations are elevated with respect to establish baseline surface-water quality ranges listed in Table 5.2-1. CMP 1990 concentrations of cadmium, chromium, copper, mercury, and lead were not elevated at any location with respect to baseline concentrations. All reported values are total recoverable concentrations.
mg/l = milligrams per liter
µg/l = micrograms per liter

A list of surface-water samples characterized by chemical composition is presented by sampling event in Table 5.2-3. First Creek surface water entering RMA was characterized as calcium bicarbonate water. Within eastern-central RMA, First Creek surface-water composition changes to a sodium bicarbonate water. Surface water at the North Bog (SW24003) and First Creek surface water downstream of RMA were characterized as sodium sulfate water.

A variation in the trends in water composition noted above occurred during the spring 1990 sampling event. At this time, First Creek surface water at First Creek North Boundary was characterized as calcium bicarbonate water. This may have been anomalous because calcium was only slightly higher than sodium in concentration, and construction activities affecting the First Creek channel were occurring approximately 150 yards upstream during sampling.

As shown in Table 5.2-3, few changes in water composition have been identified at sites sampled during 1989 and 1990. Where these changes occur, they appear to be related to the flow rate. At North First Creek monitoring station (SW24002), surface water was characterized as sodium sulfate rather than sodium bicarbonate during extremely low flow (<0.01 cfs) in the fall of 1990. At First Creek North Boundary (SW24004), surface water was characterized as calcium bicarbonate when discharge was 1.1 cfs and as sodium sulfate when discharge was 0.14 cfs. These data indicate that portions of the reach having different water compositions and may shift as a result of variable stream discharge. Thus, water composition may change as the result of varying dilution of baseflow at times of high versus low stream discharge.

5.2.2 IRONDALE GULCH DRAINAGE BASIN

Surface-water CMP locations sampled in the Irondale Gulch drainage basin during Water Year 1990 are listed in Table 3.2-1 and shown in Figure 2.3-3.

5.2.2.1 Organic Compounds in Surface Water

Target organic compounds reported in surface water entering RMA at the southern boundary during Water Year 1990 sampling events include the organochlorine pesticides, aldrin, chlordane, dieldrin, endrin, isodrin, hexachlorocyclopentadiene, PPDDE, and PPDDT; the organophosphorus compounds

Table 5.2-3 First Creek Drainage Basin Surface-Water Chemical Characterization for Water-Year 1990 CMP[1] and Water-Year 1989 CMP

Surface-Water Monitoring Station	FY90 Spring Samples	FY90 Fall Samples	FY90 High Event Samples	FY89 Samples
SW08001	$CaHCO_3$	-	-	$CaHCO_3$
SW08003	$CaHCO_3$	$CaHCO_3$	$CaHCO_3$	$CaHCO_3$
			$CaHCO_3$	
			$CaHCO_3$	
SW24001	$NaHCO_3$	$NaHCO_3$	-	-
SW24002	$NaHCO_3$	$NaSO_4$	$NaHCO_3$	$NaHCO_3$
SW24003	$NaSO_4$-	-	$NaSO_4$	
SW24004	$CaHCO_3$	-	-	$NaSO_4$
SW31002	$CaHCO_3$	-	-	$CaHCO_3$
SW31001	$NaHCO_3$	-	-	$NaHCO_3$
SW37001	$NaSO_4$	$NaSO_4$	$NaSO_4$	$NaSO_4$

- Water type was not characterized because samples were not collected or the analytical results did not meet QA/QC requirements.

1 Surface-water samples from the following sites were not included in this assessment due to charge balance errors in excess of 10 percent or other QA/QC problems:

Location	Event
SW06002	High Event (07/18/90)
SW06002	High Event (07/27/90)
SW30002	Spring

atrazine, parathion, and vapona; and the volatile organohalogen compounds chloroform, 1,1,1-trichloroethane, 1,2-dichloroethene, trichloroethene, and tetrachloroethene (Figure 4.2-1 and Table 4.2-2). Organic compounds were reported in samples collected from six of 10 sites sampled in 1990 along the RMA southern boundary in Sections 7, 11, and 12.

Atrazine and the organochlorine pesticides were the most frequently reported surface-water contaminants at the southern RMA boundary locations. Atrazine was detected above the CRL in the spring and high event (March 13, and March 28, 1990) and samples collected from the South Uvalda (SW12005), Peoria Interceptor (SW11001), and Havana Interceptor (SW11002) monitoring stations. Organochlorine pesticides were reported in spring and high event samples collected at the Storm Sewer (SW12004), South Uvalda (SW12005), Peoria Interceptor (SW11001), and Havana Interceptor (SW11002) monitoring stations. The organochlorine pesticide hexachlorocyclopentadiene was reported in a high event sample collected from the Army Reserve Storm Sewer (SW12006) on July 21, 1990.

The organophosphorus compounds parathion and vapona were reported in high event samples collected from the Havana Interceptor (SW11002) on March 13, 1990, and Peoria Interceptor (SW11001) on March 6, 1990, respectively.

Chloroform and 1,1,1-trichloroethane were each reported once in high event samples collected from the Havana Interceptor (SW11002) on March 6, 1990, and July 9, 1990, respectively. The volatile organohalogens 1,2-dichloroethene, trichloroethene, and tetrachloroethene were reported in a single high event sample collected from the Peoria Interceptor (SW11001).

There appears to be very little temporal consistency in organic compound occurrences in surface water along the southern RMA boundary during the last two Water Years. Several compounds previously reported in samples collected at southern boundary locations in Water Year 1989 (including DMMP, CPMSO, and xylenes [o,p]) were not reported in Water Year 1990. In addition, many of the organic compounds reported in samples collected during Water Year 1990 have historically not been reported for these sampling locations.

Atrazine was the most temporally consistent organic compound reported above the CRL at sites during Water Year 1990 sampling events. Dieldrin was detected above the CRL at three sites during Water Year

1990 and was temporally consistent at two of the three sites where the sites were sampled more than once. The most consistent organic compound occurrence from 1988 through 1990 at southern RMA boundary sites was hexachlorocyclopentadiene. The occurrence of hexachlorocyclopentadiene was reported along the southern RMA boundary at the South Plants Water Tower Pond (SW01002; 1990), Uvalda Ditch A (SW07001; 1989), Peoria Interceptor (SW11001; 1989 and 1990), Havana Interceptor (SW11002; 1988, 1989, 1990), Havana Pond (SW11003; 1988), South Uvalda (SW12005; 1988 and 1990), and the Army Reserve Storm Sewer (SW12006; 1990).

Of the six monitoring stations located in the South Plants Lakes area in Sections 1 and 2 sampled during Water Year 1990, only one location had concentrations of target organic compounds exceeding the CRL. Aldrin, chlordane, and DIMP were reported at Upper Derby Lake (SW01004) during the spring. Pre-CMP historical data indicate that these compounds have not previously been reported in surface water in the South Plants Lakes area. Compounds reported during historical CMP sampling events in this area include dieldrin, endrin, isodrin, and DMMP.

The remaining surface-water sampling locations in the Irondale Gulch Drainage Basin are located in the South Plants area. Water Year 1990 samples were collected from the South Plants steam effluent (SW02006) and South Plants Water Tower Pond (SW01002) monitoring stations. Several organochlorine pesticides, parathion, and DMMP were reported in a sample collected from the South Plants Water Tower Pond (SW01002) during the spring. A high event sample collected in March at this location contained 19 target organic compounds. Most of the compounds detected above the CRL were also reported for a sample collected at this location in Water Year 1989. Historical data indicate that most of these compounds have previously been reported at this location.

Chloroform was the only target organic compound reported at the South Plants steam effluent monitoring station (SW02006). Historical data indicate that both chloroform and DMMP have previously been reported at this location.

5.2.2.2 Inorganic Constituents in Surface Water

Samples collected from the upstream locations SW07001, SW07002, SW11001, SW11002, SW11003, SW12001, and SW12005 during Water Year 1990 were used in conjunction with 1988 and 1989 CMP results at these sites to establish representative inorganic water-quality baseline concentration ranges for the Irondale Gulch Drainage basin. Baseline concentration ranges were established for both low flow and elevated flow conditions. Because dissolved fraction analyses were not conducted on samples collected during Water Year 1990, only the total recoverable water-quality baseline concentration ranges were established. These baseline concentration ranges are presented in Table 5.2-4. The maximum assumed values for Water Year 1990 water-quality baseline ranges are represented by the highest concentration reported in upstream RMA southern boundary locations for each constituent during Water Years 1988 through 1990.

An exception to the method of establishing maximum concentration for baseline ranges is the assumed maximum value for sulfate during base flow. The sulfate concentration at Uvalda Ditch A (SW07001) during the spring sampling event was 1,340 mg/L. This value was considered anomalous with respect to baseline concentrations and was not used to revise the maximum baseline concentration for sulfate during base flow. This reported value will therefore be considered elevated with respect to established baseline concentration ranges in subsequent discussions. Table 5.2-5 presents the inorganic constituents reported at elevated concentrations with respect to baseline ranges (Table 5.2-4) in the Irondale Gulch drainage basin for Water Year 1990.

Sulfate and copper were reported at elevated concentrations in individual samples collected along the southern RMA boundary. Sulfate was reported above baseline concentrations at Uvalda Ditch A (SW07001). Although the data from this location were used with other data to establish baseline levels this concentration was considered anomalous, as previously discussed, and is considered elevated with respect to baseline concentrations. Copper was reported above baseline concentrations at the Storm Sewer (SW12004). A trend of consistent detections of sulfate and copper above baseline concentrations at these locations is not supported by historical data; however, the elevated copper concentration is only slightly higher than the historical CRL for copper.

At the South Plants Water Tower Pond monitoring station (SW01002), elevated concentrations of all major ions plus arsenic and copper were reported in 1990 samples. Historical data from the Water Year 1988 CMP and the WRI Report (Ebasco, 1989a) similarly show the occurrence of all these constituents above baseline levels except copper.

Table 5.2-4 Baseline Surface-Water Quality Concentration Ranges for Inorganic Constituents Entering RMA in the Irondale Gulch Drainage Basin During Base and Elevated Flow Conditions

Analyte	Total Recoverable Concentration		Units
	Base Flow	Elevated Flow	
Major Inorganic Constituents			
Calcium	14.7 - 86.4	6.32 - 17.5	mg/l
Magnesium	1.91 - 34.2	0.931 - 5.33	mg/l
Potassium	1.93 - 23.2	1.97 - 6.70	mg/l
Sodium	6.47 - 202	2.38 - 27.0	mg/l
Chloride	4.85 - 200	0.740 - 37.5	mg/l
Fluoride	0.484 - 3.00	<0.482 - 1.22	mg/l
Sulfate	17.0 - 210	2.49 - 30.0	mg/l
Nitrate	0.021 - 19.0	0.400 - 7.08	mg/l
Trace Metals			
Arsenic	<2.35 - 2.64	<2.35 - 4.74	µg/l
Cadmium	<8.40 - 9.8	<6.78	µg/l
Chromium	<16.8 - <24.0	<16.8 - <24.0	µg/l
Copper	<18.8 - 21.3	<18.8 - <26.0	µg/l
Mercury	<0.100 - 0.229	<0.100	µg/l
Lead	<43.4 - <74.0	<43.4 - <74.0	µg/l
Zinc	<18.0 - 115	<18.0 - 190	µg/l
Cyanide	<5.00 - 6.91	<2.50 - <5.00	µg/l

Note: Data incorporated from sites SW07001, SW07002, SW11001, SW11002, SW11003, SW12001, SW12002, and SW12005 for Water Years 1988, 1989, and 1990. Water Year 1990 data were not available for site SW12002.

mg/l = milligrams per liter
µg/l = micrograms per liter
< = less than

Table 5.2-5 Elevated Inorganic Constituent Concentrations for Irondale Gulch Drainage Basin and South Platte Drainage Basin Sample Locations for Water Year 1990[1]

Sampling Location	Sampling Period	Calcium mg/l	Magnesium mg/l	Potassium mg/l	Sodium mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Arsenic µg/l	Copper µg/l	Chromium µg/l	Lead µg/l
<u>Irondale Gulch Drainage Basin</u>												
SW01002	Spring	639	202	53.3	417	667	4.96	2570		29.7		
SW01002	High Event	59.8	20.0		96.0	57.6	1.44	101	32.5	39.8		
SW02006	Fall						5.00					
SW07001	Spring							1340				
SW12004	Spring									29.3		
<u>South Platte Drainage Basin</u>												
SW26001	High Event 1	36.6	10.3	13.8				34.2	39.9			
SW26001	High Event 2	173	24.5	19.2					92.2	102	38.2	80.5
SW36001	Spring								71.6			
SW36001	Fall								81.9			

[1] Concentrations are elevated with respect to establish baseline surface-water quality ranges listed in Table 5.2-1. CMP 1990 concentrations of cadmium, chromium, copper, mercury, and lead were not elevated at any location with respect to baseline concentrations. All reported values are total recoverable concentrations.

mg/l = milligrams per liter
µg/l = micrograms per liter

Fluoride was reported above baseline concentrations in a sample collected from the South Plants steam effluent (SW02006). Historically, elevated concentrations of fluoride have apparently not been reported at this site.

In addition to assessing elevated inorganic constituents, surface-water samples collected from the Irondale Gulch drainage basin were also characterized by water type. Approximately one-half of the samples collected were not included in this assessment because ion balance errors were greater than 10 percent or analytical results did not meet CMP QA/QC requirements. A list of the characterized surface-water types is presented in Table 5.2-6.

In general, the composition of surface water in the Irondale Gulch drainage basin was characterized as either a calcium or sodium bicarbonate water. Only one surface-water sample, collected from the South Plants Water Tower Pond (SW01002), was characterized as a calcium sulfate water. The water type frequently changed during high events from what it had been characterized during lower flow-rate conditions. Three high event samples, which had been characterized as calcium or sodium bicarbonate water during lower flow-rate events, were characterized as sodium chloride water at the higher flow rate. Surface water at the Havana Interceptor monitoring station (SW11002) was characterized as sodium chloride during low flow-rate condition and as sodium bicarbonate during high event conditions. This condition may be the result of dilution of baseflow by surface runoff during high events and indicates that surface runoff is contributing bicarbonate to these water bodies.

5.2.3 South Platte Drainage Basin

The surface-water CMP locations sampled in the South Platte drainage basin are Basin A monitoring station (SW36001) and Basin F monitoring station (SW26001) and are shown in Figure 2.3-3.

5.2.3.1 Organic Compounds in Surface Water

Samples collected from Basin A (SW36001) during the spring sampling event contained 26 target organic compounds and samples collected during the fall sampling event contained 23 target organic compounds. Samples collected during the fall sampling event contained organic contaminants at generally lower concentrations than samples collected during the spring sampling event. Water Years 1988 and 1989

Table 5.2-6 Irondale Gulch Drainage Basin Surface-Water Chemical Characterization for Water Year 1990[1]

Surface-Water Monitoring Station	1990 Spring Samples	1990 Fall Samples	1990 Storm Event Samples
SW01001	$NaHCO_3$	--	--
SW01002	$CaSO_4$	--	--
SW02001	--	$CaHCO_3$	--
SW02006	$NaHCO_3/CO_3$	--	--
SW11001	$NaHCO_3$	--	NaCl
SW11002	NaCl	--	$NaHCO_3$
SW12004	--	$CaHCO_3$	NaCl
SW12005		$CaHCO_3$	$NaHCO_3$
			NaCl
SW12006	--	--	$CaHCO_3$

-- Water type was not characterized because samples were not collected or the analytical results did not meet QA/QC requirements.

1 Surface-water samples from the following sites were not included in this assessment due to charge balance errors in excess of 10 percent or other QA/QC problems:

Location	Event	Location	Event
SW01001	Fall	SW11001	High Event (03/13/90)
SW01002	High Event (03/13/90)	SW11002	Fall
SW01004	Spring	SW11002	High Event (03/13/90)
SW01005	Spring	SW11002	High Event (07/09/90)
SW02003	Spring	SW11003	Spring
SW02004	Spring	SW12001	Spring
SW02006	Fall	SW12001	Fall
SW07001	Spring	SW12004	Spring
SW07002	Spring	SW12005	Spring
SW11001	Fall	SW12005	High Event (03/29/90)
SW11001	High Event (03/06/90)	SW12007	Spring

CMP data indicate a temporal trend in the presence of a large number of organic constituents that persist at this location.

At the new Basin F monitoring station (SW26001), samples were collected only during high events. In the two samples collected, endrin was reported in both high event samples and dieldrin was reported in one high event sample.

5.2.3.2 Inorganic Constituents in Surface Water

The concentrations of inorganic constituents reported at Basin F (SW26001) and Basin A (SW36001) monitoring stations were compared with established water-quality baseline levels for the adjacent Irondale Gulch drainage basin (Table 5.2-4) to determine concentrations that were elevated with respect to baseline concentrations. Elevated concentrations are listed in Table 5.2-5.

The new Basin F monitoring station (SW26001) had elevated levels of the major ions calcium, magnesium, and potassium during both high events. A slightly elevated detection of sulfate was also reported at this location during the first high event. The apparent presence of elevated inorganic constituents at this site may be due to its location at an undefined channel, where recently disturbed soil was observed immediately upstream from the station. As evidence of this condition, the sample collected during the second high event had a very high concentration of TSS (1900 mg/L).

The trace metals arsenic, lead, copper, and chromium were detected above baseline levels at the Basin F monitoring station (SW26001). Arsenic was reported above baseline levels during both high events and chromium, copper, and lead were detected above baseline levels only during the second high event.

The only inorganic constituent reported above baseline levels at Basin A (SW36001) was arsenic. Elevated arsenic levels were reported during both spring and fall sampling events. Water Year 1988 and 1989 CMP data indicate the consistent presence of arsenic at the Basin A monitoring station (SW36001).

In addition to identifying inorganic constituents above baseline levels, surface-water samples collected from the South Platte drainage basin were also characterized by water type. One of the four samples collected during Water Year 1990 was not included in this assessment because the ion balance error was greater than 10 percent. Surface water from the South Platte drainage basin was not characterized by chemical composition during Water Year 1989 therefore no comparison was made with the Water Year 1990 characterizations.

A list of surface-water samples characterized by chemical composition is presented by sampling event in Table 5.2-7. South Platte surface water at the Basin F monitoring station (SW26001), which was sampled only during high events, was characterized as calcium bicarbonate water. Surface water at Basin A (SW36001) was characterized as sodium bicarbonate water during the spring sampling event and sodium sulfate during the fall sampling event. The difference in chemical composition of the surface water at Basin A (SW36001) appears to be related to variable flow rate. The flow rate was measured at 0.0113 cfs during the spring sampling event and at 0.03 cfs during the fall sampling event.

5.2.4 SAND CREEK DRAINAGE BASIN

The surface-water CMP location sampled in the Sand Creek drainage basin is Motor Pool (SW04001) and is shown in Figure 2.3-3. This monitoring station was sampled only during one high event.

5.2.4.1 Organic Compounds in Surface Water

There were no organic compounds reported in the high event surface-water samples collected at this site.

5.2.4.2 Trace Metals in Surface Water

The concentrations of inorganic constituents detected in the high event sample from the Motor Pool (SW04001) on July 9, 1990, were compared to the water-quality baseline levels established from the adjacent Irondale Gulch drainage basin listed in Table 5.2-4. Elevated concentrations of arsenic, chromium, copper, lead, and zinc were reported in this high event sample. These reported detections, however, are not supported by the 1989 high event sample from this location.

Table 5.2-7 South Platte and Sand Creek Drainage Basins Surface-Water Chemical Characterization for Water Year 1990 CMP[1]

Surface-Water Monitoring Station	FY90 Fall Samples	FY90 Storm Event Samples	FY90 Spring Samples
South Platte Drainage Basin			
SW26001	–	–	$CaHCO_3$
SW36001	$NaHCO_3$	$NaSO_4$	
Sand Creek Drainage Basin			
SW24002	–	–	–

– Water type was not characterized because samples were not collected or the analytical results did not meet QA/QC requirements.

[1] Surface-water samples from the following sites were not included in this assessment due to charge balance errors in excess of 10 percent or other QA/QC problems:

Location	Event
SW06001	High Event (08/19/90)
SW04001	High Event (07/09/90)

5.3 SEDIMENT TRANSPORT

This section assesses sediment transport quantity and quality results for Water Year 1990, as presented in Sections 4.3. The discussion utilizes and compares Water Year 1990 total suspended solids results and bottom sediments quality results with Water Year 1989 results.

5.3.1 SEDIMENT QUANTITY

The number of surface-water CMP sites sampled for total suspended solids was increased considerably for Water Year 1990 and is presented in Table 4.3-1. Only five TSS sampling sites were common to Water Years 1990 and 1989. Streamflow and temporal conditions differed considerably between 1989 and 1990 sampling events, therefore, correlation between CMP sediment quantity data is not considered practical without further sampling.

Comparisons of TSS concentrations to corresponding flow rates collected during sampling events in Water Year 1990 do not indicate that a strong correlation exists between the two parameters (Table 4.3-1). For example, TSS values for samples collected during the gain/loss study on 6/28/90 at SW37012, SW37011, SW37010 increase in the downstream direction, with a value of 8.0 mg/L at SW37012 to a maximum value of 380 mg/L at SW37010. However, a sample collected at First Creek Off-Post (SW37001) has a value less than the CRL (4.00 mg/L) and is located approximately 500 ft downstream of SW37010. Since all flow rates were very low, the abrupt downstream decrease in TSS may be attributable to decreased stream eddies allowing suspended sediment to settle rapidly.

Generally, TSS concentrations are approximately five times greater in samples collected during high events than samples collected during base flow conditions. However, high flow rates do not always directly relate to high TSS values, but are more correspondent to the nature of the drainage area (i.e., vegetation, urbanization etc.). For example, the highest TSS value recorded during Water Year 1990 was 1900 mg/L at the Basin F monitoring station (SW26001), however, the corresponding discharge was only 0.57 cfs. The lack of vegetation in the surrounding watershed had a significant effect on TSS. Conversely, a high event during March 1990 produced a discharge of 4.51 cfs at the First Creek Off-Post monitoring station (SW37001), but the TSS value reported for this flow was only 7.5 mg/L. The First Creek drainage basin, like the Basin F watershed, is not affected by urbanization; however, significantly more vegetation canopy in the First Creek drainage basin may have been one reason for such a low TSS concentration. As shown in Table 4.3-1, TSS versus discharge is highly variable at each station with more than one sampling event.

The concentration of TSS in surface water can be affected for a number of reasons. Although higher flow rates can increase TSS, a variety of conditions can have a strong influence on TSS concentration i.e., sampling technique, temporal variation, stream depth, stream bed material, vegetation canopy, wash load (amount of material washed into the channel during rainfall or snowmelt runoff) and turbulent streamflow fluctuation. Two methods of collection were used to obtain TSS samples during the fall event. Samples were obtained directly into sample bottles and also collected with a DH-48 sampler. Comparison of the two methods indicates that samples acquired with the DH-48 had TSS concentrations approximately 39 percent greater than samples obtained directly into sample bottles.

5.3.2 STREAM-BOTTOM SEDIMENT QUALITY ASSESSMENT

This section provides an assessment of Water Year 1990 stream-bottom sediment quality results as presented in Section 4.3.2. The discussion utilizes and compares historical data along with the assessment presented in the FY89 Surface-Water Water Data Assessment Report to identify spatial and temporal trends in stream-bottom sediment quality during the reporting period. In Section 6.0 of this report, the trends identified in this section are related to potential RMA and off-post source areas.

For purposes of clarity and consistency, stream-bottom sediment quality assessment will be discussed according to the major drainage basins as described in previous sections of this report. The drainage basins include the First Creek drainage basin (Section 5.3.2.1), Irondale Gulch drainage basin (Section 5.3.2.2), South Platte drainage basin (Section 5.3.2.3), and Sand Creek drainage basin (Section 5.3.2.4). Conclusions are discussed in Section 6.0.

5.3.2.1 First Creek Drainage Basin

Surface-water CMP sites sampled for stream-bottom sediment quality analysis in the First Creek drainage basin during Water Year 1990 are as follows; South First Creek (SW08003), North First Creek (SW24002), and First Creek Off-Post (SW37001) and are shown in Figure 1.3-2.

5.3.2.1.1 Organic Compounds in Stream-Bottom Sediments

Only three organic compounds were detected above the CRLs in the stream-bottom sediment samples collected during Water Year 1990 (Table 4.3-2). The distribution of organic compounds in stream-bottom sediment is shown in Figure 4.3-1. Dieldrin was reported at both the South First Creek (SW08003) and North First Creek (SW24002) monitoring stations. Aldrin was also reported at the South First Creek monitoring station (SW08003). DBCP was detected above the CRL at the First Creek Off-Post monitoring station (SW37001). However, aldrin, dieldrin, and DBCP were not reported in any of the surface-water samples collected from these monitoring stations during 1990.

Stream-bottom sediment sampling results from Water Year 1989 indicate that atrazine was detected above the CRL during the spring at both the South First Creek (SW08003) and First Creek Off-Post (SW37001) monitoring stations. In addition, dieldrin was detected above the CRL in the fall Water Year 1989 sample collected from South First Creek (SW08003). No organic compounds were detected above the CRL in Water Year 1989 at the North First Creek monitoring station (SW24002). Thus, the only stream-bottom sediment sample result from Water Year 1990 that confirmed historical results was the detection of dieldrin above the CRL at South First Creek (SW08003).

Surface-water and stream-bottom sediment samples collected from the South First Creek (SW08003), North First Creek (SW24002), and First Creek Off-Post (SW37001) monitoring stations did not have occurrences of any organic compounds in common.

5.3.2.1.2 Trace Metals in Stream-Bottom Sediments

The occurrence of trace metals exceeding the CRLs in stream-bottom sediment samples was limited to two monitoring station locations (Table 4.3-3). The distribution of trace metals in stream-bottom sediment is shown in Figure 4.3-1. Arsenic and lead were reported in samples collected at the North First Creek (SW24002) and First Creek Off-Post (SW37001) monitoring stations. In addition, mercury was also reported in the sample collected at the First Creek Off-Post (SW37001) monitoring station. Surface-water samples collected at these locations during the spring 1990 did not contain trace metals above the CRL; however, a fall 1990 surface-water sample at North First Creek (SW24002) did contain arsenic.

The lead detection at North First Creek (SW24002) was the only 1990 trace metal detection confirmed by Water Year 1989 results. Water Year 1989 trace metal detections of chromium, copper, and zinc were not confirmed in sediment samples collected during 1990.

Surface-water and sediment samples collected at the North First Creek (SW24002) and First Creek Off-Post (SW37001) monitoring stations had reportable concentrations of arsenic. However, the arsenic concentrations reported in the surface-water samples were approximately three orders of magnitude lower than concentrations reported in the sediment samples. The surface-water and sediment samples collected at the South First Creek monitoring station (SW08003) did not have similar occurrences of trace metals. The sediment sample collected at this location had no reportable concentrations of trace metals, while the surface-water sample had reportable concentrations of arsenic and zinc.

5.3.2.2 Irondale Gulch Drainage Basin

Surface-water CMP locations sampled for stream-bottom sediment quality analysis in the Irondale Gulch drainage basin during Water Year 1990 are South Plants Water Tower Pond (SW01002), South Plants steam effluent (SW02006), Peoria Interceptor (SW11001), Storm Sewer (SW12004), South Uvalda Interceptor (SW12005) and are shown in Figure 2.3-3.

5.3.2.2.1 Organic Compounds in Stream-Bottom Sediment

Stream-bottom sediment samples were collected from five of the 18 sample locations within the Irondale Gulch drainage basin. The distribution of organic compounds in stream-bottom sediment is shown in Figure 4.3-1.

The three sediment samples collected from locations along the southern RMA boundary all contained organic compounds. DBCP was reported in sediment samples collected from the Peoria Interceptor (SW11001). Aldrin and isodrin were reported in sediment samples collected from the South Uvalda monitoring station (SW12005). Chlordane and dieldrin were reported in a sediment sample collected from the Storm Sewer (SW12004).

Surface-water samples collected at the southern RMA boundary during 1990 contained chlordane, dieldrin, and aldrin at the same locations these compounds were reported in stream-bottom sediments. The concentrations reported in surface-water samples were at least two orders of magnitude lower than concentrations reported in sediment samples. This is not unexpected, but may be observed due to the greater tendency of these compounds to sorb to soils rather than occur in solution in water, as a function of their low solubility and high partition coefficients.

Historical 1989 CMP stream-bottom sediment results indicate that the compounds reported at the Storm Sewer (SW12004) and South Uvalda (SW12005) monitoring stations in 1990 have not previously been reported at these locations. This condition may be attributable to the dynamics of sediment bed load transport. At the Peoria Interceptor (SW11001), however, the 1990 reported occurrence of DBCP was similar to a reported occurrence at this site in 1989.

Target organic compounds were reported in sediment samples collected in the South Plants area at the South Plants Water Tower Pond (SW01002) and South Plant steam effluent (SW02006) sample locations. A sediment sample collected from the South Plants Water Tower Pond (SW01002) had reported concentrations of aldrin, chlordane, dieldrin, endrin, isodrin, and DBCP. Surface-water samples collected at this site in 1990 contained all these compounds except chlordane. A sediment sample collected at the South Plants steam effluent ditch location (SW02006) during the spring contained aldrin, chlordane, dieldrin, endrin, isodrin, and PPDDE. These same compounds were also reported along with PPDDT and hexachlorocyclopentadiene in a sediment sample collected at this location during the fall. Surface-water samples collected at this location in 1990 did not contain any of the organic compounds reported in sediment.

Water Year 1989 stream-bottom sediment data indicate that aldrin, dieldrin, isodrin, and DBCP are consistently reported above the CRL in sediment samples collected at the South Plants Water Tower Pond (SW01002). At the South Plants steam effluent ditch location (SW02006), Water Year 1989 data indicate the consistent presence of aldrin, dieldrin, endrin, and isodrin.

5.3.2.2.2 Trace Metals in Stream-Bottom Sediments

The distribution of trace metals in stream-bottom sediment in Water Year 1990 is shown in Figure 4.3-1. Lead and zinc were the only trace metals reported in sediment samples collected along the southern RMA boundary in Water Year 1990. These trace metals were reported in samples collected from the Peoria Interceptor (SW11001), South Uvalda (SW12005), and Storm Sewer (SW12004) locations. Water Year 1989 data indicate the repeated presence of these trace metals at the southern RMA boundary except for lead at the South Uvalda (SW12005) sample location. Water Year 1989 reported occurrences of arsenic, copper, and chromium along the southern RMA boundary were not repeated in 1990 sediment data, although copper and chromium were reported in surface-water samples collected in 1990 in this area at SW12004 and SW12005, respectively.

Five trace metals were reported in sediment samples collected in the South Plants area in Water Year 1990. Arsenic, copper, lead, mercury, and zinc were detected above the CRLs in a sediment sample collected from the South Plants Water Tower Pond (SW01002). Copper, lead, mercury, and zinc were reported in sediment collected at the South Plants steam effluent sample location (SW02006). Comparison of Water Years 1989 and 1990 CMP data indicate a consistent trend over time in the occurrence of the reported trace metals at the South Plants steam effluent sample location (SW02006). Comparison of South Plants Water Tower Pond (SW01002) data from Water Years 1989 and 1990 indicate an inconsistent trend in the occurrence of trace metals. Because Water Year 1988 sediment samples were not collected from these monitoring locations, data are not available for comparison.

5.3.2.3 South Platte Drainage Basin

One surface-water CMP location was sampled for stream-bottom sediment quality analysis in the South Platte drainage basin during Water Year 1990 (Basin A; SW36001) and is shown in Figure 2.3-3.

5.3.2.3.1 Organic Compounds in Stream-Bottom Sediments

Six organic compounds were reported in a stream-bottom sediment sample collected at the Basin A monitoring station (SW36001) during the spring sampling event. Five of these six compounds were also reported in the spring surface-water sample from this location. There was no corresponding surface-water detection of chlordane at the Basin A monitoring station (SW36001). DBCP was the only organic constituent in stream-bottom sediment at this site confirmed by Water Year 1989 analytical results.

5.3.2.3.2 Trace Metals in Stream-Bottom Sediments

Sediment collected at the Basin A monitoring station (SW36001) contained arsenic, lead, mercury, and zinc. Arsenic, lead, and mercury were also reported in 1989 sediment data results at this site. Arsenic and zinc were the only trace metals with a corresponding occurrence in surface water at this site during 1990.

5.3.2.4 Sand Creek Drainage Basin

Stream-bottom sediment samples were not collected from the Sand Creek drainage basin during Water Year 1990.

5.4 SURFACE-WATER AND GROUND-WATER INTERACTION ASSESSMENT

The data collected during Water Year 1990 helped to determine the RMA surface-water sites that interact with ground water as presented in Section 4.4. The discussion of the assessment has been divided into sections for the First Creek drainage basin and the Irondale Gulch drainage basin and utilizes prior CMP information for comparison when possible. Figure 3.4-1 illustrates the locations of wells that were used in the surface-water/ground-water interaction study.

5.4.1 FIRST CREEK DRAINAGE BASIN

Instantaneous discharge measurements were collected for the gain/loss studies along First Creek twice during Water Year 1990. Water levels were also obtained from monitoring wells located near First Creek during one of the gain/loss studies. However, the number of wells proximal to First Creek was insufficient for a reliable determination of surface-water/ground-water interaction. Discharge data, however, indicate that First Creek fluctuates from effluent conditions during the spring to influent during the summer. These apparent conditions are in agreement with Water Year 1989 gain/loss results. First Creek's interaction with ground water is also apparent at other times of the year. Fl[illegible]as observed at the First Creek Off-Post monitoring station while zero flow was observed approximately [illegible] mi upstream at the North First Creek monitoring station. This condition existed during the collection of a high event sample on November 29, 1989, and indicates that a surface-water/ground-water interaction was present north of RMA.

5.4.2 IRONDALE GULCH DRAINAGE BASIN

Ground-water and surface-water interaction is indicated by the water levels in Havana Pond, Upper Derby Lake, Lower Derby Lake, Ladora Lake and Lake Mary in conjunction with adjacent wells. The relation between lake and pond levels with adjacent monitoring well water levels are depicted in Figures 4.4-1 to 4.4-5.

Water levels indicate that Havana Pond is recharging ground water to the north and west; however, the conditions to the south and east are unknown since wells are not present in this area. The CMP data from Water Years 1988 and 1989 also support this assessment. Recharge to ground water is significant at Havana Pond. Calculation of the infiltration rate after an August storm event indicated that 46 percent of the pond's storage volume was lost to ground-water recharge and evaporation within 10 days.

Monitor well water levels near Upper Derby Lake indicate that ground water is being recharged to the west and northwest of the lake. A similar recharge to ground water occurred during Water Year 1989 based on water level data from the same monitor well network.

Lower Derby Lake, based on Water Years 1988 and 1989, recharged ground water to the northwest and the west, and received discharge from ground water from the southeast and east. However, the direction from which recharge and discharge occurred during Water Year 1990 differed from previous years. Lower Derby Lake recharged ground water to the southwest and ground water discharged to the lake from the northeast in Water Year 1990. This difference from previous years may have been partially due to the lower stage the lake was maintained at during the year while construction of the Lower Derby Lake spillway was underway. The high stage that Upper Derby Lake was maintained during Water Year 1990 may also have contributed to the change in direction of recharge and discharge to and from ground water.

Ladora Lake appears to recharge ground water to the west and receives ground-water discharge from the east and northeast based on Water Year 1990 water level data. Water level data collected during Water Years 1988 and 1989 support similar assessments.

During Water Year 1990, Lake Mary recharged ground water to the northwest and received ground-water discharge from the southeast. This is consistent with the assessments made in Water Years 1988 and 1989.

6.0 CONCLUSION

6.1 SURFACE-WATER QUANTITY CONCLUSIONS

The surface-water measurements obtained during Water Year 1990 represent the most complete and accurate data which have been obtained to date at the RMA. The completeness and accuracy of flow measurements was improved principally by the installation of bubbler and Datapod systems. Most of these systems were installed during the previous water year, thus Water Year 1990 was the first complete year of operation and records.

Likewise, Water Year 1990 was the first complete year of on-post precipitation measurements. Such records contribute significantly to the hydrologic information base of RMA and will improve trend analyses of the flow data in future years.

The major volume of surface-water inflow onto RMA occurs in the Irondale Gulch drainage basin with most of the flow conveyed via the Highline Lateral. Since flow is controlled in Highline Lateral, fluctuations in discharge are minimal compared to the urban natural inflows conveyed through Havana Interceptor, Peoria Interceptor, and Uvalda Interceptor. Conversely, discharge in First Creek is also natural but exhibits minimal fluctuations. This is primarily due to the low percentage of urbanization in the First Creek drainage basin.

A large proportion of surface water flowing onto RMA is lost to infiltration, evaporation, and transpiration (RMA inflow = 4,681 ac-ft, outflow = 329 ac-ft). Most of the surface-water flowing onto RMA is stored in the South Plants Lakes and Havana Pond where it is allowed to evaporate and infiltrate into the ground-water system. The ground-water and surface-water interaction data collected during Water Year 1990 showed that at various times of the year First Creek fluctuates between being a gaining and losing stream throughout RMA. However, inflow was approximately two times greater than outflow during the year.

Digital acquisition equipment (data logger/bubbler systems) have proven to be accurate and reliable under most conditions at RMA. This equipment has increased the amount of stage data being accurately collected throughout the year at active stations during periods of freezing.

6.2 SURFACE-WATER QUALITY CONCLUSIONS

This section provides a discussion of the possible relationships between discharge and contaminant concentration and the potential sources of contamination of surface-water quality. An attempt will be made to relate the contaminant distributions and trends assessed in Section 5.2 of this report to potential RMA and off-post source areas.

Two idealized relationships between concentrations of chemical constituents and stream discharge are shown in Figures 6.2-1 and 6.2-2. Figure 6.2-1 represents physical conditions that produce a direct relationship between concentration and discharge. This direct relationship exists in cases in which a constituent having a constant or negligible base-flow concentration becomes elevated as the result of overland flow containing high concentrations of the constituent into surface water during high events. This relationship has been demonstrated in other studies in the United States (Milligan, et.al., 1984; Novotony and Chesters, 1981) in situations representing nonpoint source runoff (e.g., gasoline and petroleum products washing from city streets to surface water during high events). In such cases, concentrations of given constituents at a sampling location can be transient, and chemical constituents can be introduced into the channel in either dissolved and/or particulate form. The second idealized relationship, shown in Figure 6.2-2, represents physical conditions producing an inverse relationship between concentration and discharge. This relationship exists in cases in which a constituent having a relatively constant base-flow concentration is diluted by surface runoff having a lower or negligible concentration of that constituent.

A third physical condition affecting concentrations (not depicted) would involve windblown deposition of particulates directly into the channel, causing fluctuations in chemical concentrations independent of discharge.

Throughout the United States, nonpoint source water pollution has been shown to be a potentially significant source in introducing organic and inorganic contaminants to surface water. The Colorado Nonpoint Source Task Force and the Colorado Water Quality Control Division (CWQCD) recently published an assessment of Colorado nonpoint pollution sources (CWQCD, 1989). The state's assessment focused on nonpoint sources of sediment, salinity, metals, bacteria, and nutrients that may impact surface-water quality. To date, baseline ranges for expected concentrations have not been established for nonpoint sources of inorganic or organic constituents. The state's assessment does, however, demonstrate that nonpoint pollution has impacted Colorado surface-water quality.

The discussion of potential contamination sources and conclusions for the surface-water evaluation will be presented according to the major drainage basins described in previous sections. These drainage basins include the First Creek drainage basin (Section 6.2.1), Irondale Gulch drainage basin (Section 6.2.2), South Platte drainage basin (Section 6.2.3), and Sand Creek drainage basin (Section 6.2.4).

6.2.1 First Creek Drainage Basin

6.2.1.1 Organic Compounds in Surface Water

Target organic compounds were not reported in First Creek surface water entering RMA or along southern reaches of First Creek during Water Year 1990. This would appear to indicate the inconsistent nature of Water Year 1989 detections of dieldrin, endrin, DBCP, and vapona in First Creek surface water near the southeast RMA boundary. These historical detections suggest an inconsistent source, such as windblown material originating either on-post or off-post or other nonpoint source origins.

Detection of chloroform at First Creek Near North Plant (SW30002) was the furthest upstream organic compound occurrence in 1990 in the First Creek drainage basin. Historically, chloroform has not been reported at this location and its occurrence in 1990 suggests an inconsistent mechanism for introduction of this compound into the stream reach, such as nonpoint source runoff or surface-water/ground-water interaction. Chloroform ground-water contamination has been identified in the North Plants area (RLSA, 1990c).

Aldrin was reported in samples collected at the Sewage Treatment Plant (SW24001) and North First Creek (SW24002) monitoring stations in 1990. The occurrence of aldrin at the Sewage Treatment Plant (SW24001) is supported by similar detections in pre-CMP historical data. This inconsistent occurrence may be related to small amounts of chemical infiltration into the sanitary sewer system. The anomalous detection of aldrin at North First Creek during a high event suggests an inconsistent source, such as nonpoint source runoff.

DIMP was the only target organic compound reported in a sample collected from the North Bog (SW24003). Historically, this compound has been reported at this surface-water location in approximately 50 percent of the samples collected. The presence of DIMP in the North Bog (SW24003) may be attributable to the possible seasonal changes in the gaining/losing nature of First Creek along this reach of the stream.

DIMP, DCPD, TCLEE, atrazine, parathion, endrin, and chlordane were reported in samples collected at the First Creek Off-Post monitoring station (SW37001). The absence of these compounds in upstream samples and their presence in ground-water samples collected from nearby Monitoring Well 37343 indicate that ground water is discharging to First Creek along this reach of the stream. The concentrations and number of compounds reported appear to be inversely related to the discharge measured at this location. This substantiates the conclusion that ground water/base flow contribution to the creek accounts for the presence of the reported organic compounds. These observations are corroborated by historical CMP data.

6.2.1.2 Inorganic Constituents in Surface Water

The occurrence of a large number of major ion detections above established baseline concentrations in the First Creek drainage basin during Water Year 1990 is consistent with historical data. In general, however, these elevated levels are less than two times the established baseline concentrations and may represent natural variations in water chemistry unassociated with RMA activities.

The highest concentrations of major ions were reported at the North First Creek (SW24002), North Bog (SW24003), and First Creek Off-post (SW37001) monitoring stations. Elevated major ion concentrations in these areas may be related to variations in surface-water/ground-water interaction.

Major ion concentrations in the First Creek drainage basin generally show an inverse relationship between concentration and discharge. A few exceptions to this trend, however, have been observed. Potassium concentrations, for example, were frequently higher during high events in 1990.

Arsenic concentrations above baseline concentrations at the Sewage Treatment Plant (SW24001) during 1990 are consistent with historical data. The presence of arsenic at this site and not elsewhere in the First Creek drainage basin indicates that arsenic may be related to RMA sources.

6.2.2 IRONDALE GULCH DRAINAGE BASIN

6.2.2.1 Organic Compounds in Surface Water

Sixteen organic compounds were reported in surface water entering RMA along the southern boundary. Atrazine and the organochlorine pesticides were the most frequently reported compounds. Parathion, vapona, and organohalogen compounds were also reported.

Most of the reported compounds at the southern RMA boundary are not exclusive to RMA activities and are, or have been, commercially available. Therefore, their occurrence at the southern RMA boundary may or may not be related to RMA activities. The spatial and temporal inconsistencies in the occurrence of these compounds indicates discontinuous nonpoint sources. Potential sources for this contamination include: (1) windblown sediment from on-post or off-post sources and (2) nonpoint source runoff from areas south of RMA. The volatile nature of the organohalogen compounds may reduce the likelihood that windblown sediment is the mechanism for their distribution. Their occurrence suggests surface runoff or nonpoint source pollution from off-post areas.

There appears to be a direct relationship between discharge and the concentration of atrazine in surface water along the southern RMA boundary during 1990. Atrazine concentrations increased during high events as compared to concentrations reported during base flow conditions. This may indicate that an off-post nonpoint source of contamination may be responsible.

The occurrence of organic compounds at Upper Derby Lake (SW01004) in Water Year 1990 is not temporally consistent with historical data from this site. The inconsistent nature of this contamination suggests that the occurrence of these compounds may be attributable to a nonpoint source.

Consistent 1990 and historical detections of chloroform have been reported at the South Plants steam effluent ditch (SW02006). This occurrence may be related to chloroform ground-water contamination, which occurs in the South Plants because underground steam pipes may intersect the shallow ground-water table. The continued presence of chloroform may also be related to the use of chlorinated potable water for steam generation at South Plants.

Consistent 1990 and historical detections of several organic compounds have been reported at the South Plants Water Tower Pond (SW01002). Many of the same compounds generally occur at higher concentrations in the nearby ground-water monitoring Well 01061. This suggests that contamination at this site may be the result of contaminated ground water discharged into the pond.

6.2.2.2 Inorganic Constituents in Surface Water

The concentrations of inorganic constituents reported at southern RMA boundary locations in the Irondale Gulch drainage basin were used to establish baseline concentration ranges. These baseline ranges for surface water were compared to inorganic constituent concentrations in the South Plants and South Plants Lakes areas to assess the distribution of inorganic contaminants at elevated levels with respect to baseline ranges. Because baseline ranges indicate concentrations of inorganic constituents representative of surface water entering RMA, concentrations of inorganic constituents reported above these baseline ranges may indicate potential surface-water/ground-water interaction. Elevated inorganic constituent detections were limited primarily to samples collected from the South Plants Water Tower Pond (SW01002) in Water Year 1990. Concentrations of the major ions, plus arsenic and copper, were reported above baseline concentrations at this site. As with organic compound occurrence at this site, the mechanism for the elevated inorganic constituents may be contamination caused by discharge of ground water into the pond.

In general, major ion concentrations in the Irondale Gulch drainage basin showed an inverse relationship between concentration and discharge during 1990. Some exceptions, however, did occur. Nitrate concentrations at the Havana Interceptor monitoring station (SW11002), for example, showed a direct relationship between concentration and discharge during 1990. Trace metal occurrence in the Irondale Gulch drainage basin during 1990 shows no clear relationship between concentration and discharge.

6.2.3 SOUTH PLATTE DRAINAGE BASIN

6.2.3.1 Organic Compounds in Surface Water

Basin A (SW36001) is the sampling site generally having the highest organic compound concentrations within the CMP surface-water sampling network. The two samples collected at this site in 1990 contained a variety of organic compounds from each of the organic analytical methods listed in Table 4.2-1. Surface water at Basin A (SW36001) emanates from a storm sewer, which apparently intercepts ground water beneath the South Plants. The surface water leaving Basin A (SW36001) infiltrates and/or evaporates in Basin A.

The two samples collected at Basin A (SW36001) during 1990 indicate a general inverse relationship between contaminant concentration and discharge. Organic contaminant concentrations were generally lower during the fall sampling event when flow was approximately two-thirds higher than the spring. This inverse relationship between discharge and the concentration and number of organic compounds has been observed during both Water Years 1988 and 1989 CMP at this site (RLSA, 1990a,b) and lends credence to the hypothesis that relatively high concentrations and large numbers of compounds are related to the ground-water contamination observed in this area.

Dieldrin and endrin were reported at the Basin F monitoring station (SW26001) in Water Year 1990 during high events. This station monitors surface-water runoff that occurs only during a high event. Because other waste-pile related organic constituents were not detected and have higher solubilities in water relative to dieldrin and endrin (i.e., VOCs), the dieldrin and endrin detections suggest an inconsistent source, such as windblown material. The physical location of this monitoring station also supports the conclusion that windblown material may be the potential source of dieldrin and endrin observed in these samples. This site is located west of the Basin F waste-pile and consists of a wide, poorly defined drainage that collects water only during high events.

6.2.3.2 Inorganic Constituents in Surface Water

Arsenic was the only trace metal reported above baseline levels at Basin A (SW36001) in Water Year 1990. Historically, arsenic has consistently occurred at this site and is probably related to RMA sources.

There does not appear to be a clear relation between arsenic concentration and discharge at the Basin A monitoring station. Arsenic concentrations varied only slightly between the two 1990 sampling events, even though discharge varied by approximately a factor of three.

At the Basin F monitoring station (SW26001), 1990 data indicate the presence of elevated concentrations of the major ions calcium, magnesium, potassium, and sulfate. In addition, elevated concentrations of the trace metals arsenic, lead, copper, and chromium were also reported during at least one of the two sampling events.

Elevated occurrences of calcium, magnesium, potassium, and arsenic at Basin F monitoring station (SW26001) were reported for both 1990 sampling events and showed a direct relation to discharge. Higher concentrations were reported in the sample collected when discharge was greater. This relationship suggests nonpoint source runoff may be contributing to these elevated inorganic constituents. The inconsistent detections of chloride, sulfate, lead, copper, and chromium also appear to suggest an inconsistent RMA nonpoint source contribution of these constituents. Given the nature of flow at this site, which occurs only during high events, overland flow from the drainage area containing the Basin F waste-pile appears to be the most likely mechanism for the nonpoint source contribution of these inorganic constituents.

6.2.4 SAND CREEK DRAINAGE BASIN

6.2.4.1 Organic Compounds in Surface Water

There were no organic compound detections above CRLs in surface water at the Motor Pool monitoring station in 1990. One detection of dieldrin at this site in 1989 suggests that an inconsistent source, such as windblown material, may be responsible.

6.2.4.2 Inorganic Constituents in Surface Water

The elevated levels of arsenic, chromium, copper, lead, and zinc at the Motor Pool monitoring station (SW04001), detected in 1990, suggests an inconsistent source because elevated levels of these compounds were not detected in 1989. Because discharge was not measured at this site during the 1989 or 1990 sampling events, it is unknown whether the elevated levels of these compounds are related to flow rates.

6.3 SEDIMENT TRANSPORT CONCLUSIONS

This section provides a discussion of the total suspended solids results and the sediment quality results that were assessed in Sections 5.2 and 5.3. When applicable, contaminant distributions and trends will be related to potential RMA and off-post sources.

6.3.1 SEDIMENT QUANTITY CONCLUSION

The factors that control the concentration of total suspended solids in surface water are highly variable. Comparison of TSS concentration to discharge rate did not reveal any significant correlation at RMA sampling sites. Samples collected with a DH-48 had TSS concentrations approximately 39 percent greater than samples obtained directly into sample bottles.

6.3.2 STREAM-BOTTOM SEDIMENT QUALITY CONCLUSION

This section discusses potential sources of contamination and conclusions for the stream-bottom sediment evaluation and is presented according to the major drainage basins as described in previous sections. The drainage basins include the First Creek drainage basin (Section 6.3.2.1), Irondale Gulch drainage basin (Section 6.3.2.2), South Platte drainage basin (Section 6.3.2.3), and Sand Creek drainage basin (Section 6.3.2.4).

6.3.2.1 First Creek Drainage Basin

6.3.2.1.1 Organic Compounds in Stream-Bottom Sediment

Aldrin, dieldrin and DBCP were reported in stream-bottom sediments collected along First Creek. These compounds were not reported in surface-water samples collected from the same sampling locations. In addition, historical data indicate a lack of consistency in the types and locations of organic compounds in First Creek sediments. These observations indicate that organic contaminants in First Creek sediments are not widespread and are probably attributable to an inconsistent source, such as windblown material or other nonpoint sources. The dynamic nature of bed load transport may possibly contribute to their inconsistent occurrence. These data may also indicate that the sources of the compounds in each medium are different or that the source of the stream-bottom sediment contamination does not contribute to surface-water contamination.

6.3.2.1.2 Trace Metals in Stream-Bottom Sediments

Trace metals were not reported in stream-bottom sediments collected along the southern reach of First Creek. Arsenic, lead, and mercury were reported in samples collected along the northern section of First Creek. Arsenic was the only trace metal reported in both surface-water and sediment samples collected at the same sampling locations (SW24002 and SW37001). The concentrations of arsenic reported in the surface-water samples were approximately 1,000 times lower than that measured in the sediments. The occurrences of these trace metals in sediments from the northern reaches of First Creek and not the southern reaches indicate that they may be related to RMA activities.

6.3.2.2 Irondale Gulch Drainage Basin

6.3.2.2.1 Organic Compounds in Stream-Bottom Sediments

Concentrations of aldrin, chlordane, dieldrin, isodrin, and DBCP were reported in stream-bottom sediments from Irondale Gulch drainage basin sites along the southern RMA boundary in 1990. Most of these detections are inconsistent with Water Year 1989 stream-bottom sediment data. Water Year 1989 data reported several other organic compounds at the same locations. DBCP, however, has been consistently reported in stream-bottom sediments from the Peoria Interceptor. The general lack of consistency in the type and location of organic compounds in stream-bottom sediments along the southern RMA boundary indicates that an inconsistent source, such as windblown material, may be responsible. The dynamic nature of bed load transport may also contribute to these inconsistencies. Because the compounds reported in sediment along the southern RMA boundary were commercially available, it is unknown whether they are directly related to RMA sources.

Organic compounds reported in stream-bottom sediment samples collected from the South Plants at the South Plants Water Tower Pond (SW01002) and South Plants steam effluent (SW02006) sample locations during 1990 are relatively consistent with Water Year 1989 results. Both the persistent occurrence of organic compounds at these sites and their location within South Plants indicates that contamination is probably related to RMA sources.

6.3.2.2.2 Trace Metals in Stream-Bottom Sediments

Relatively consistent detections of lead and zinc have been reported in stream-bottom sediments from the Irondale Gulch drainage basin at the three sites along the southern RMA boundary where bottom sediments were collected during Water Years 1989 and 1990. These metals have also been reported in surface water at these sites. Their consistent occurrence may represent natural baseline levels or sources south and upstream of RMA.

Arsenic, mercury, copper, lead, and zinc were reported in the two stream-bottom sediment samples collected from the South Plants area. Lead and zinc concentrations at these sites were slightly higher than those reported at southern RMA boundary sites in 1990. Water Year 1989 data indicate that arsenic and copper have previously been reported at sites along the southern RMA boundary. The existence of mercury only at South Plants sampling sites indicates mercury is related to RMA sources. Relatively high levels of mercury have consistently been reported in all four sediment samples collected during 1989 and 1990 at the South Plants steam effluent sample location (SW02006).

6.3.2.3 South Platte Drainage Basin

6.3.2.3.1 Organic Compounds in Stream-Bottom Sediments

A majority of the organic compounds detected in a stream-bottom sediments from Basin A monitoring station (SW36001) were also detected in surface-water samples collected from this location. The presence of the organic compounds is probably related to RMA activities.

The presence of chlordane in sediments, but not in surface water, is inconsistent with 1989 CMP data. Chlordane was detected in surface water during both 1989 sampling events but was not detected in sediments.

6.3.2.3.2 Trace Metals in Stream-Bottom Sediments

Arsenic, lead, mercury, and zinc were detected above CRLs in stream-bottom sediments during 1990 at the Basin A monitoring station (SW36001). Elevated levels of arsenic, lead, and mercury were also reported for the 1989 sediment sample collected at this site. These trace metals are likely to be the result of RMA activities. Only arsenic and zinc had corresponding surface-water detections at this site in 1990.

6.3.2.4 Sand Creek Drainage Basin

Stream-bottom sediment samples were not collected from the Sand Creek drainage basin during Water Year 1990.

6.4 SURFACE-WATER/GROUND-WATER INTERACTION CONCLUSIONS

Gain/loss studies conducted along First Creek during Water Year 1990 indicate that interaction between surface water and ground water occurs. Flow in First Creek varies temporally and spatially, generally behaving as an effluent (gaining) stream during the spring and early summer months and as and influent (losing) stream during the late summer through winter months.

The South Plants Lakes had interactions of surface water with ground water that were similar to previous CMP results. Generally, the lakes (Upper Derby Lake, Lower Derby Lake, Ladora Lake, and Lake Mary) recharge ground water to the west and northwest. However, Lower Derby Lake appeared to recharge ground water to the southwest during Water Year 1990, which is not consistent with previous years. Ground-water discharge to the lakes generally occurs from the east and southeast. Again, Lower Derby Lake was not consistent with previous years and appeared to receive ground-water discharge from the northeast during Water Year 1990. The recharge/discharge direction change from previous years at Lower Derby Lake may have been caused by the low water level maintained in the lake during the year in conjunction with a high water level that was maintained at Upper Derby Lake. Construction of the

Lower Derby Lake spillway required that lake's stage be held lower than normal. Upper Derby Lake accepted flow from Highline Lateral and Uvalda Interceptor which is normally directed to Lower Derby Lake. The resultant high stage at Upper Derby Lake could have influenced the direction of ground-water recharge. Upper Derby Lake does not appear to receive any significant discharge from ground-water.

The hydrograph of Havana Pond and adjacent monitoring wells indicate that the pond is recharging ground water to the north and west; however, the lack of wells on the east and south sides of the pond precludes a determination of the water movement there. Based upon infiltration calculations, a high percentage of pond storage volume is lost to ground-water recharge.

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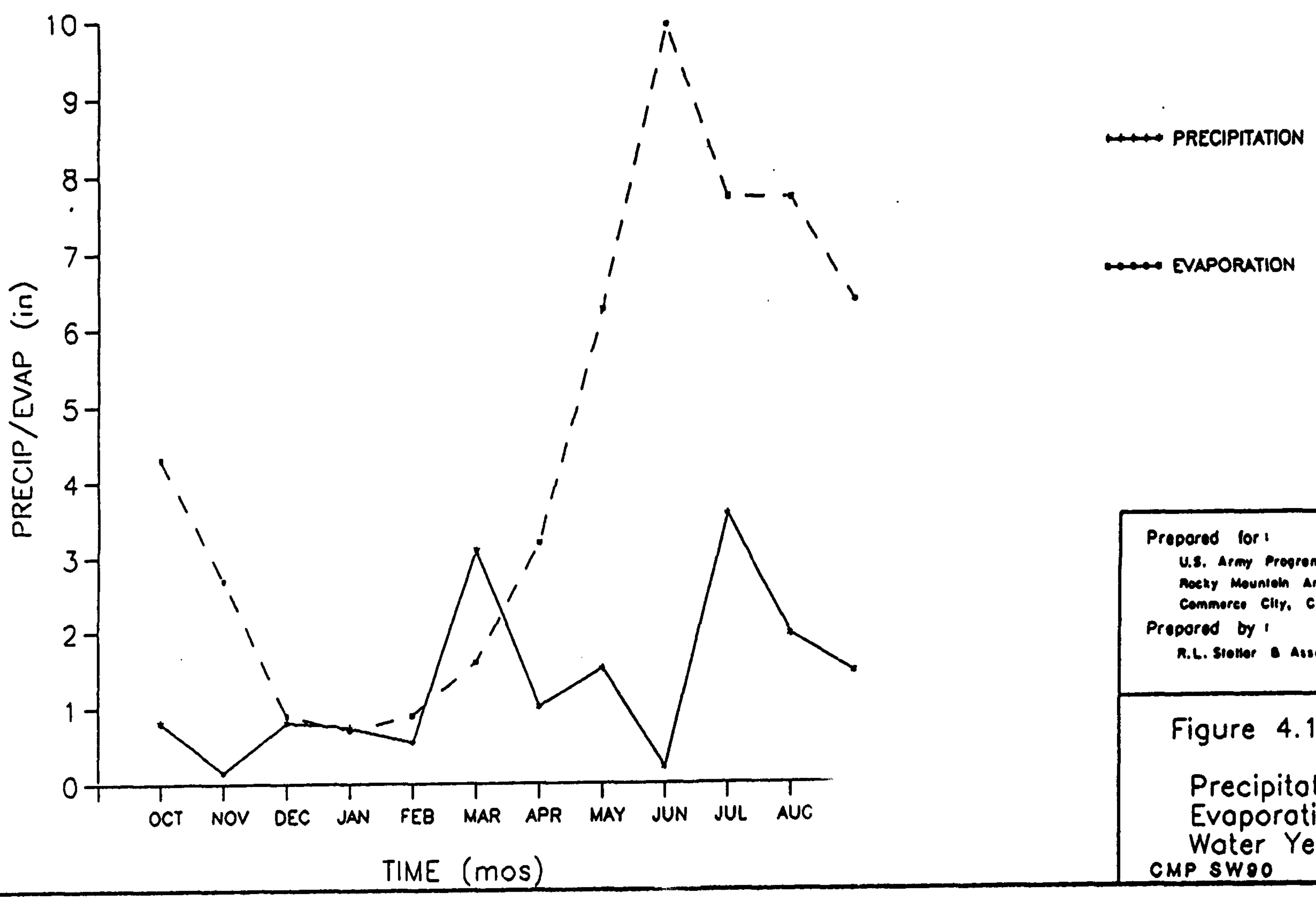

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Figure 4.1-1

Precipitation and Evaporation for Water Year 1990

CMP SW90

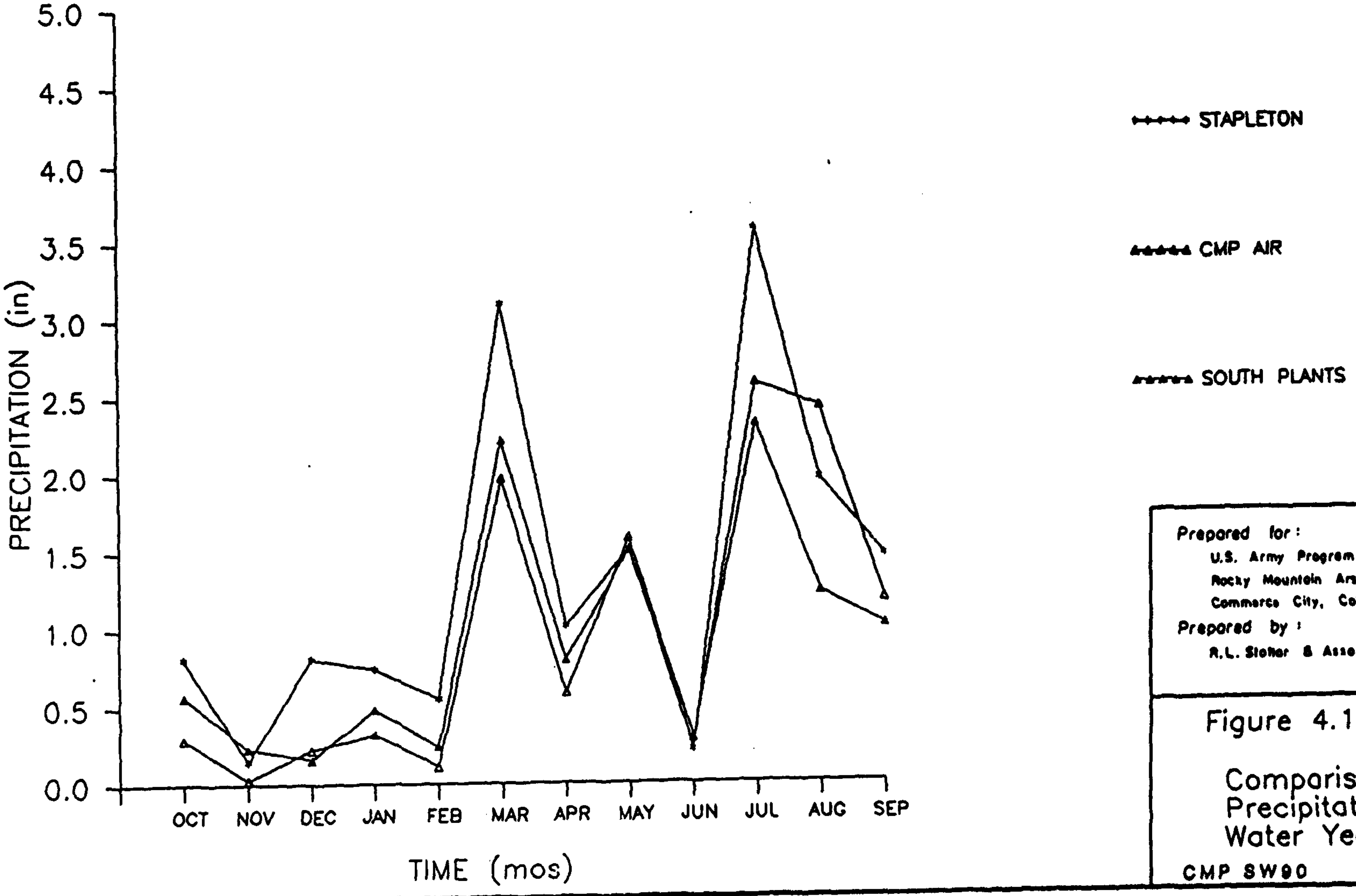

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Figure 4.1-2

Comparison of
Precipitation Data
Water Year 1990

CMP SW90

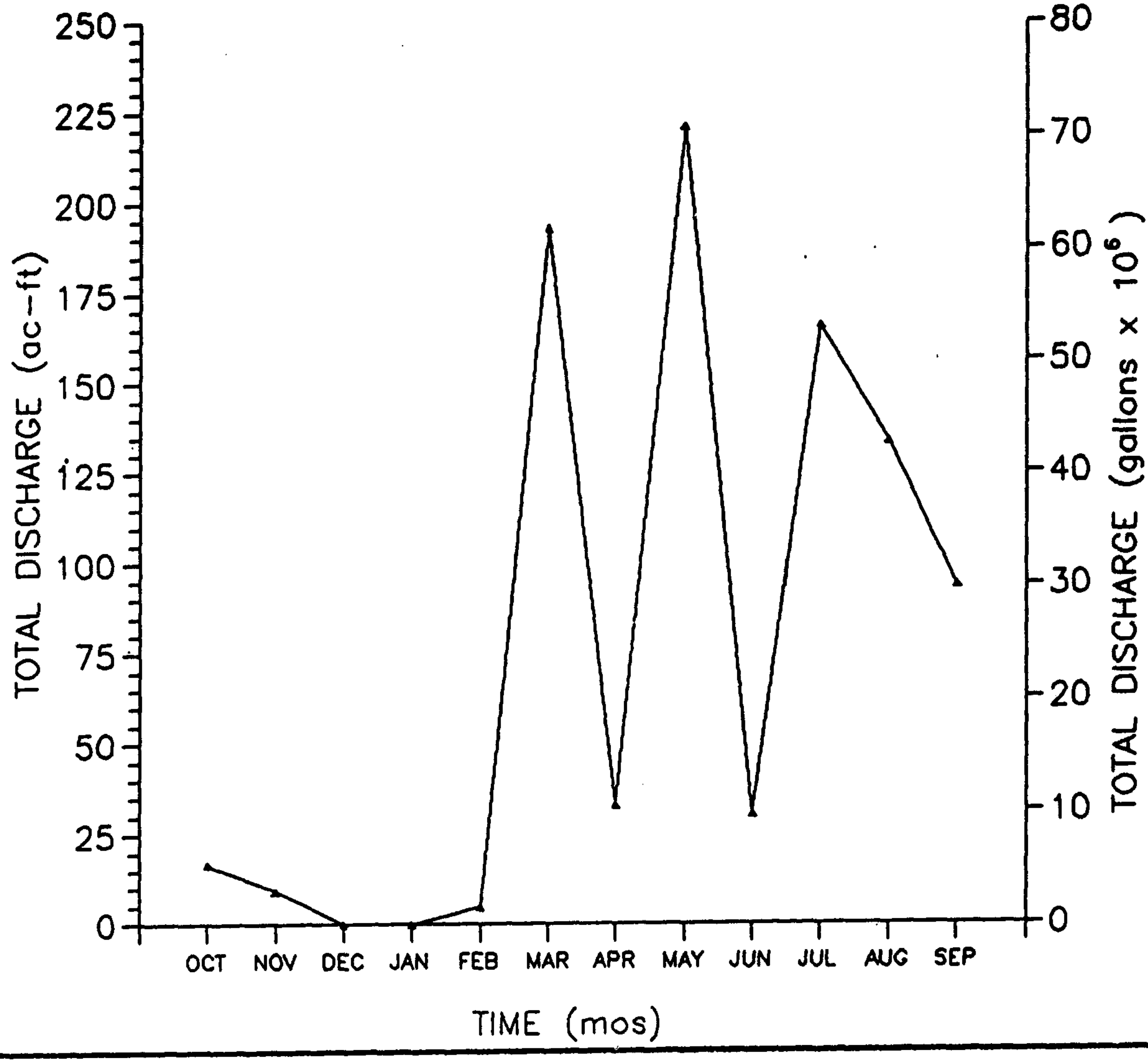

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Figure 4.1-3

Havana Interceptor
Monthly Total Discharge
WY90

CMP SW90

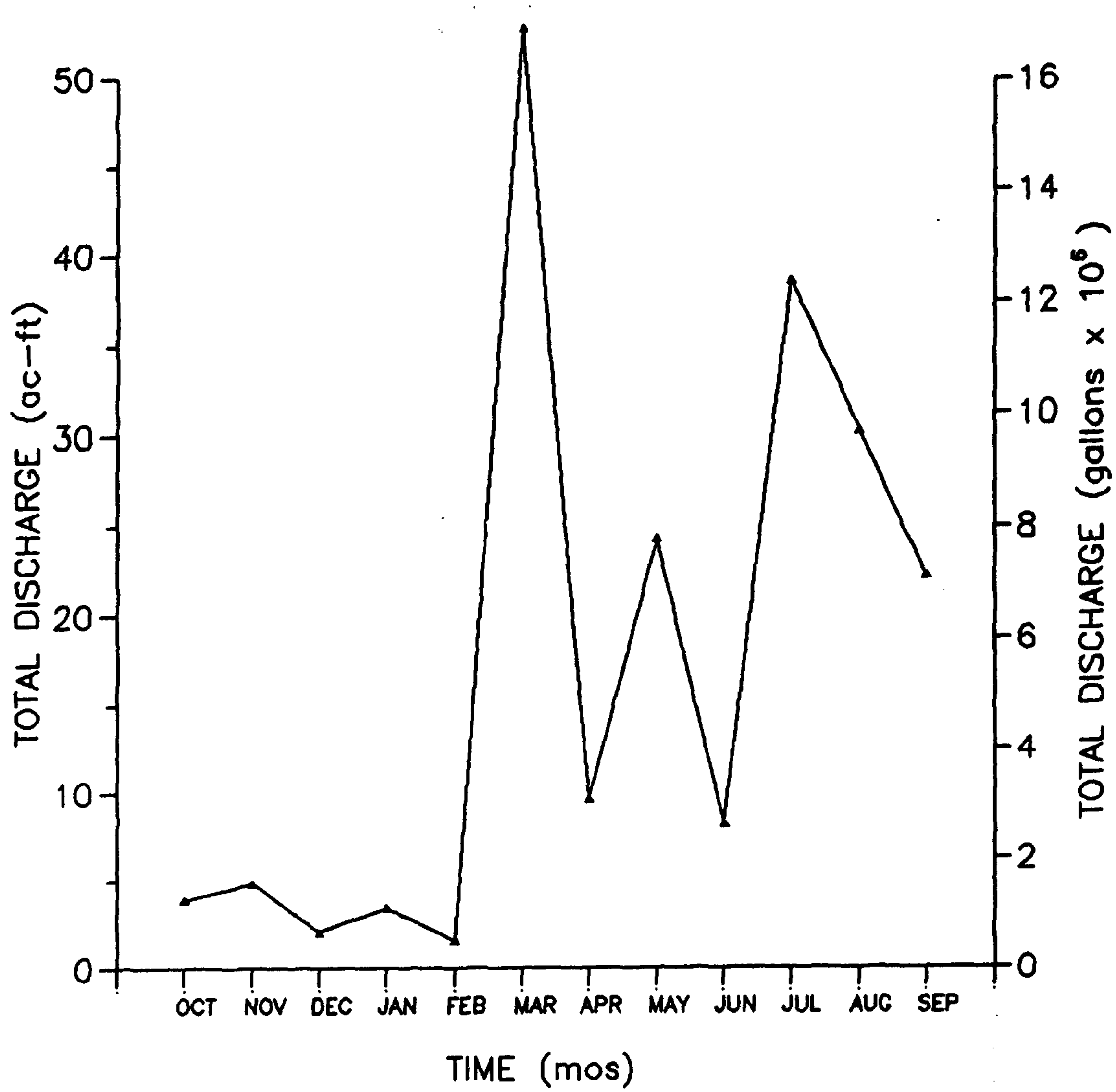

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Figure 4.1-4

Peoria Interceptor
Monthly Total Discharge
WY90

CMP SW90

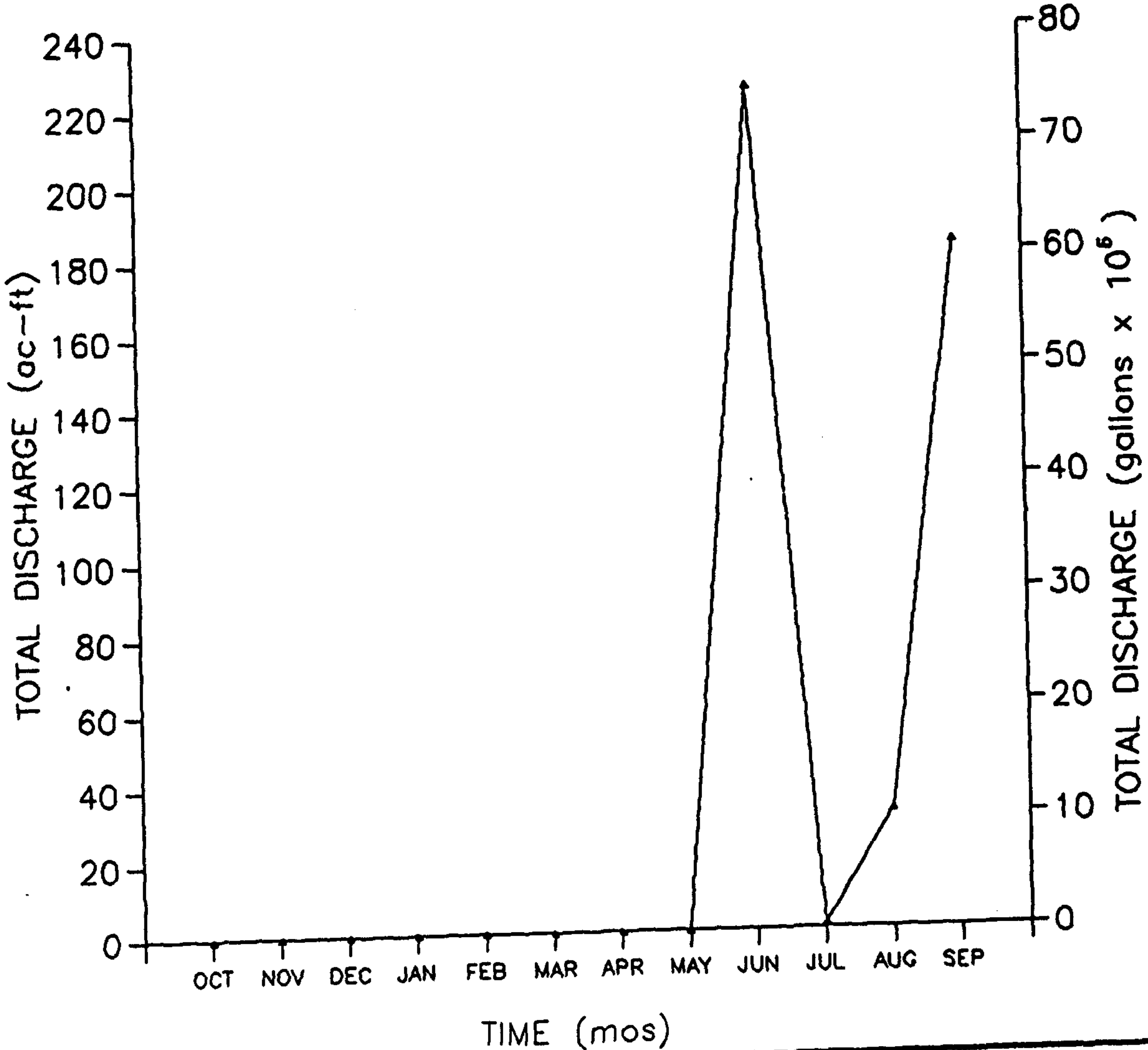

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Figure 4.1-5

Ladora Weir
Monthly Total Discharge
WY90
CMP SW90

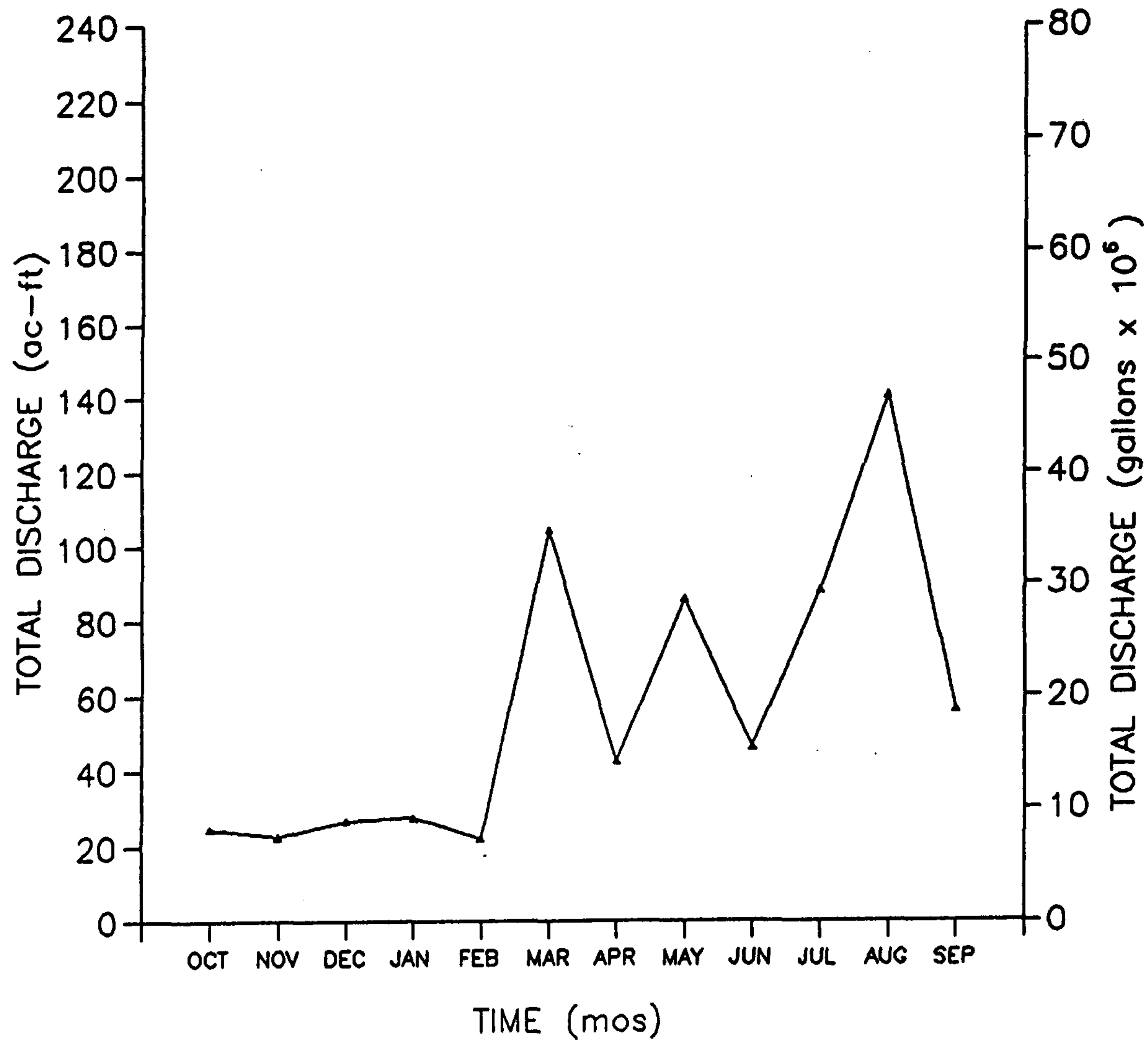

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Figure 4.1-6

South Uvalda
Monthly Total Discharge
WY90

CMP SW90

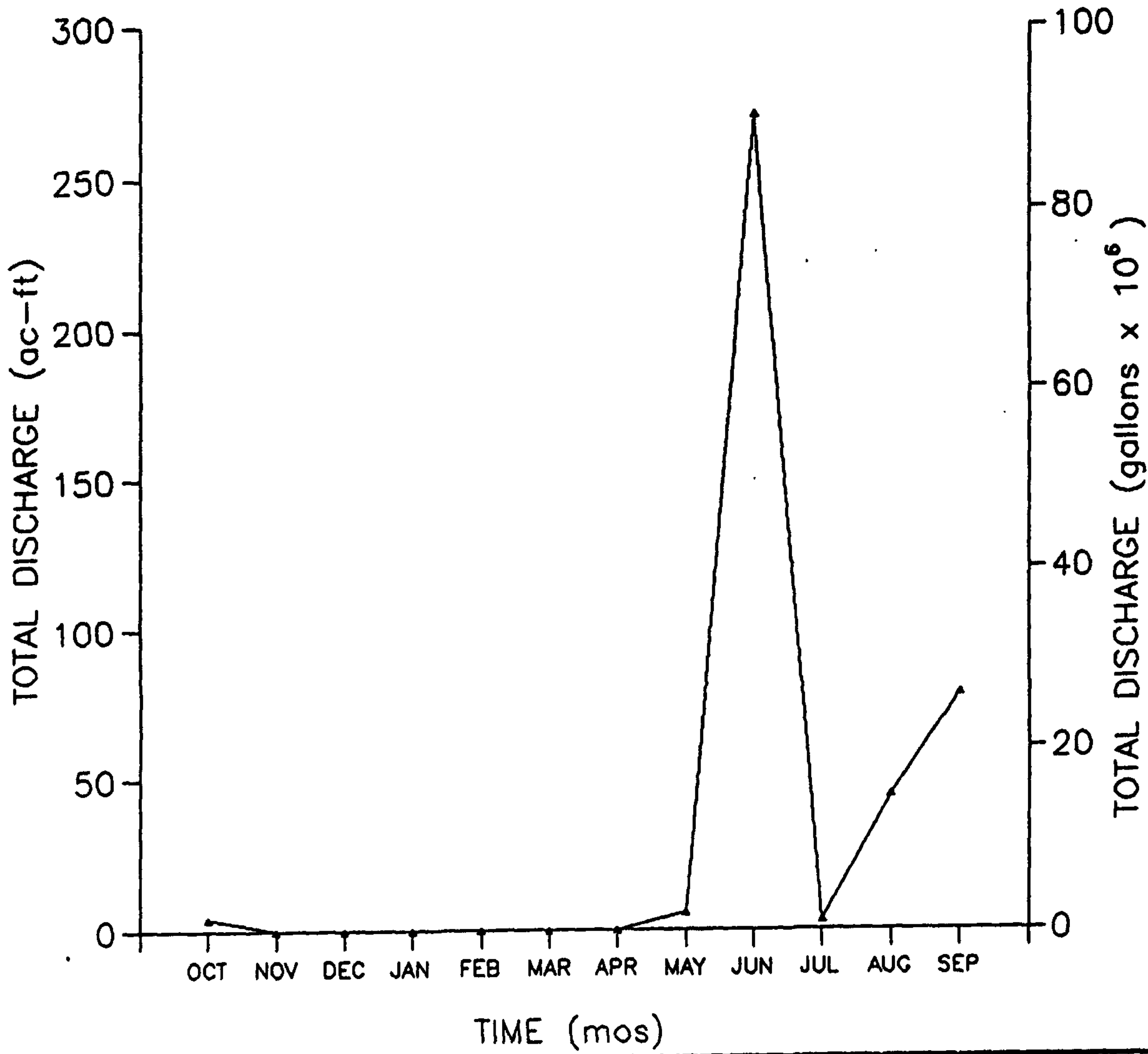

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Figure 4.1–7

North Uvalda
Monthly Total Discharge
WY90
CMP SW90

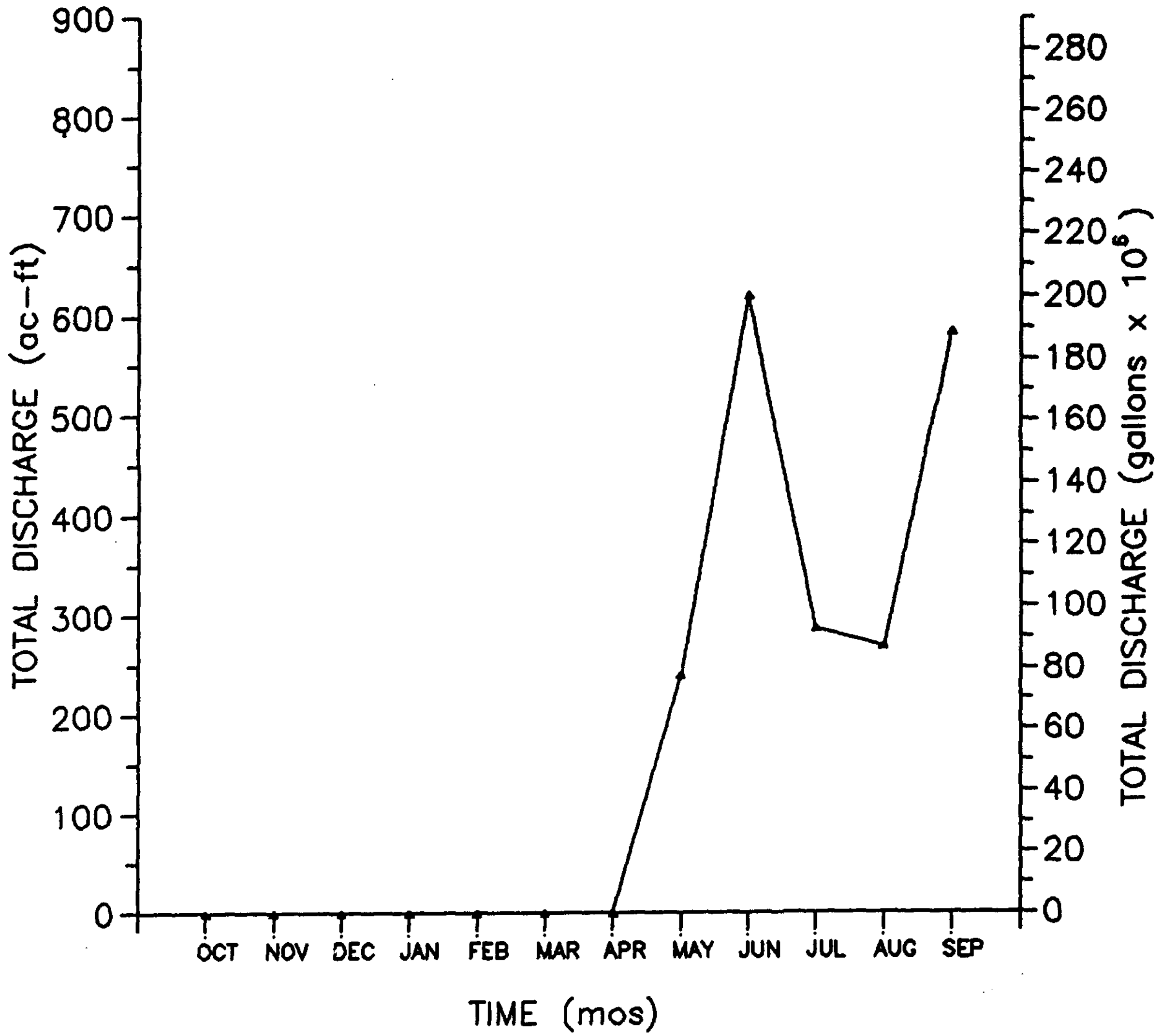

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Figure 4.1-8

Highline Lateral
Monthly Total Discharge
WY90

CMP SW90

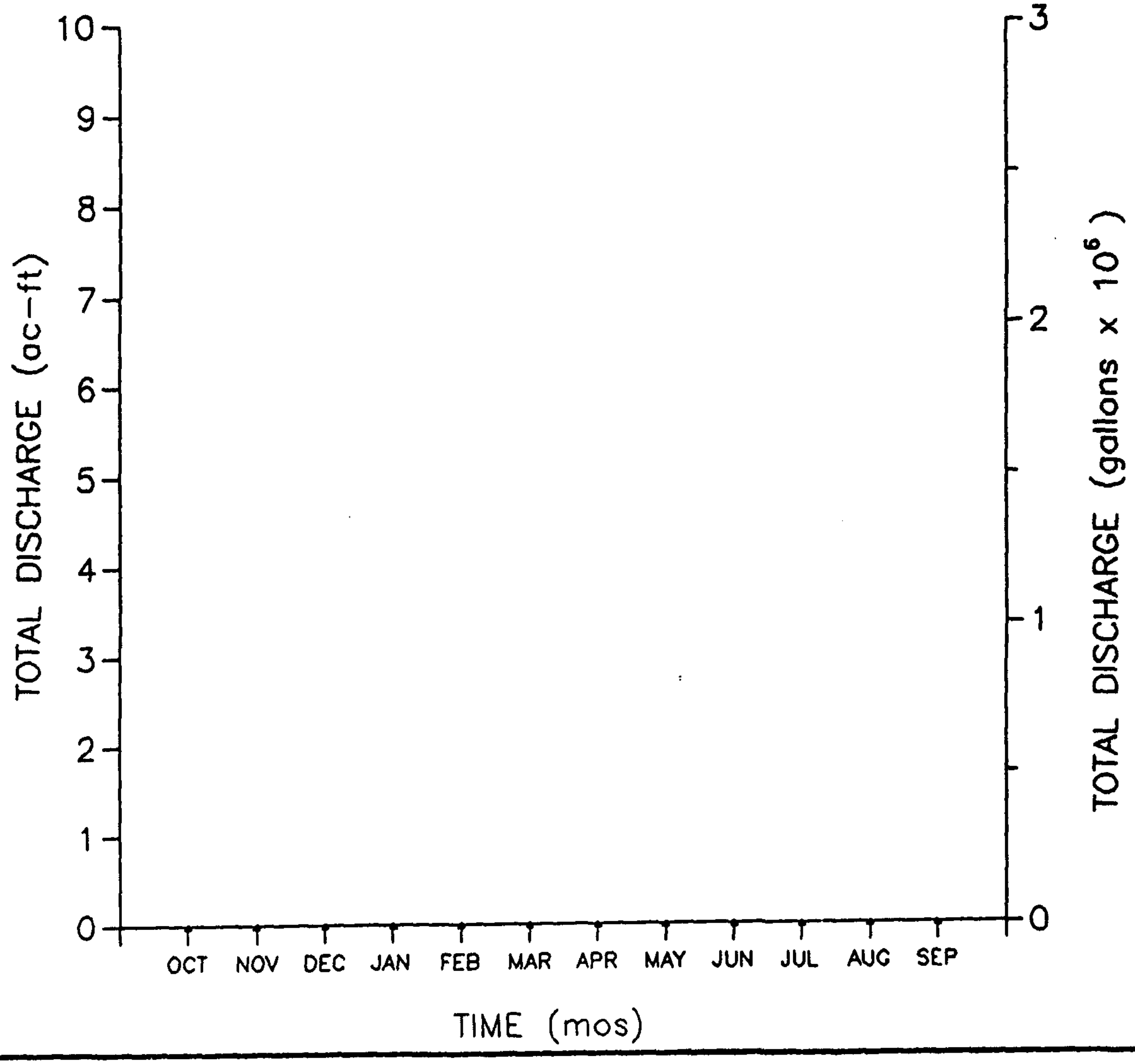

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Figure 4.1-9

South Plants Ditch
Monthly Total Discharge
WY90

CMP SW90

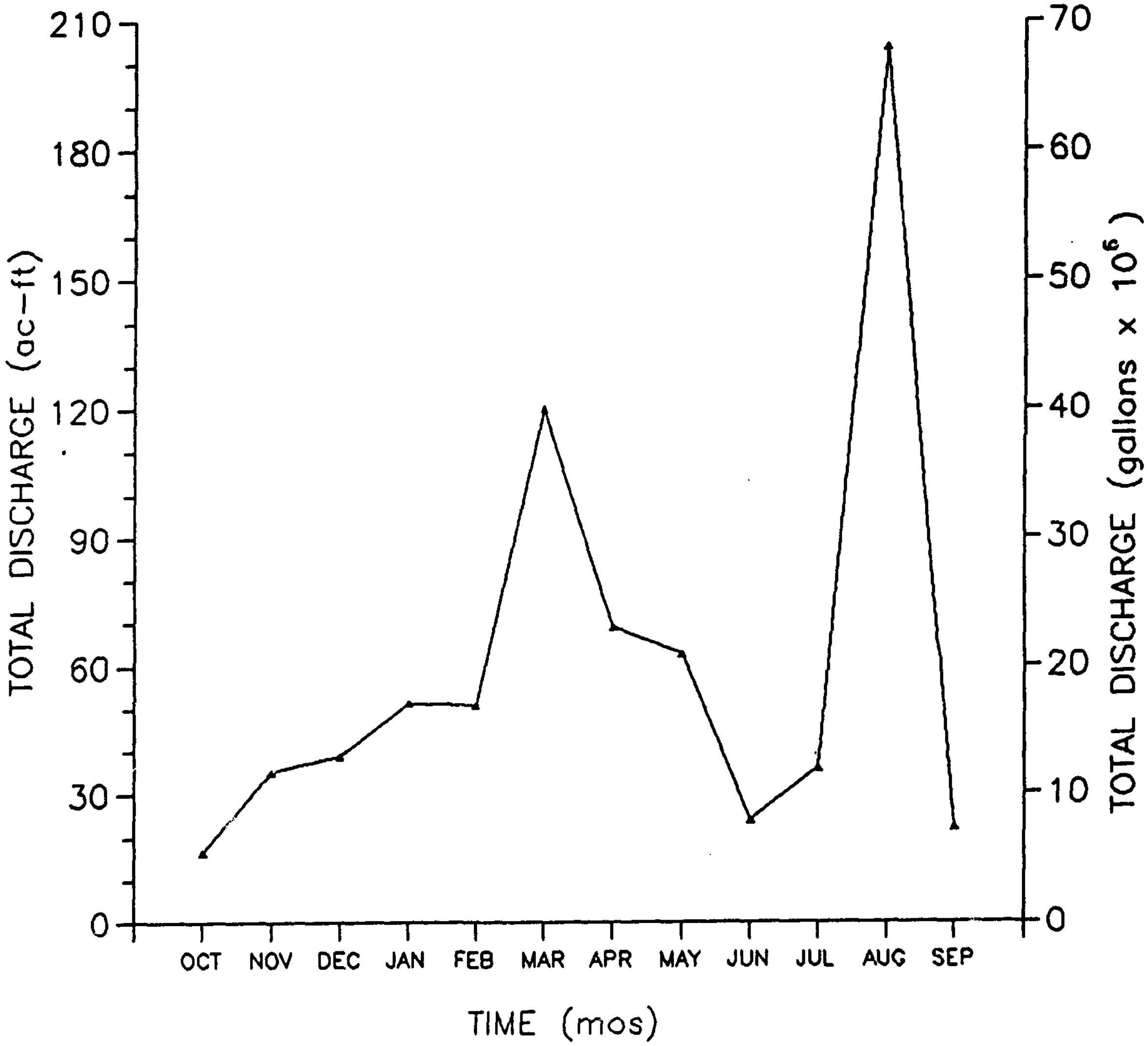

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Figure 4.1-10

South First Creek
Monthly Total Discharge
WY90

CMP SW90

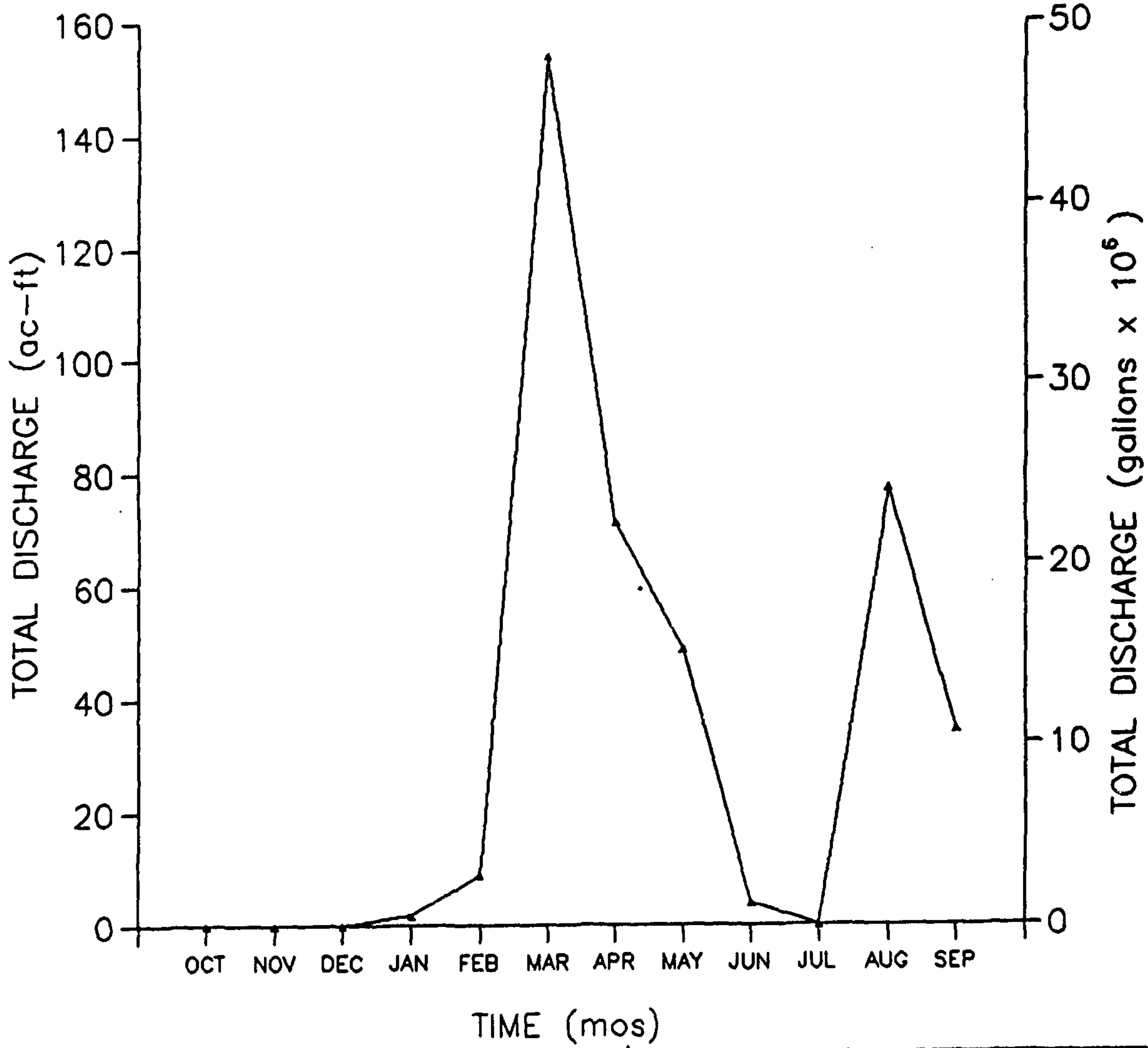

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Figure 4.1–11

North First Creek
Monthly Total Discharge
WY90

CMP SW90

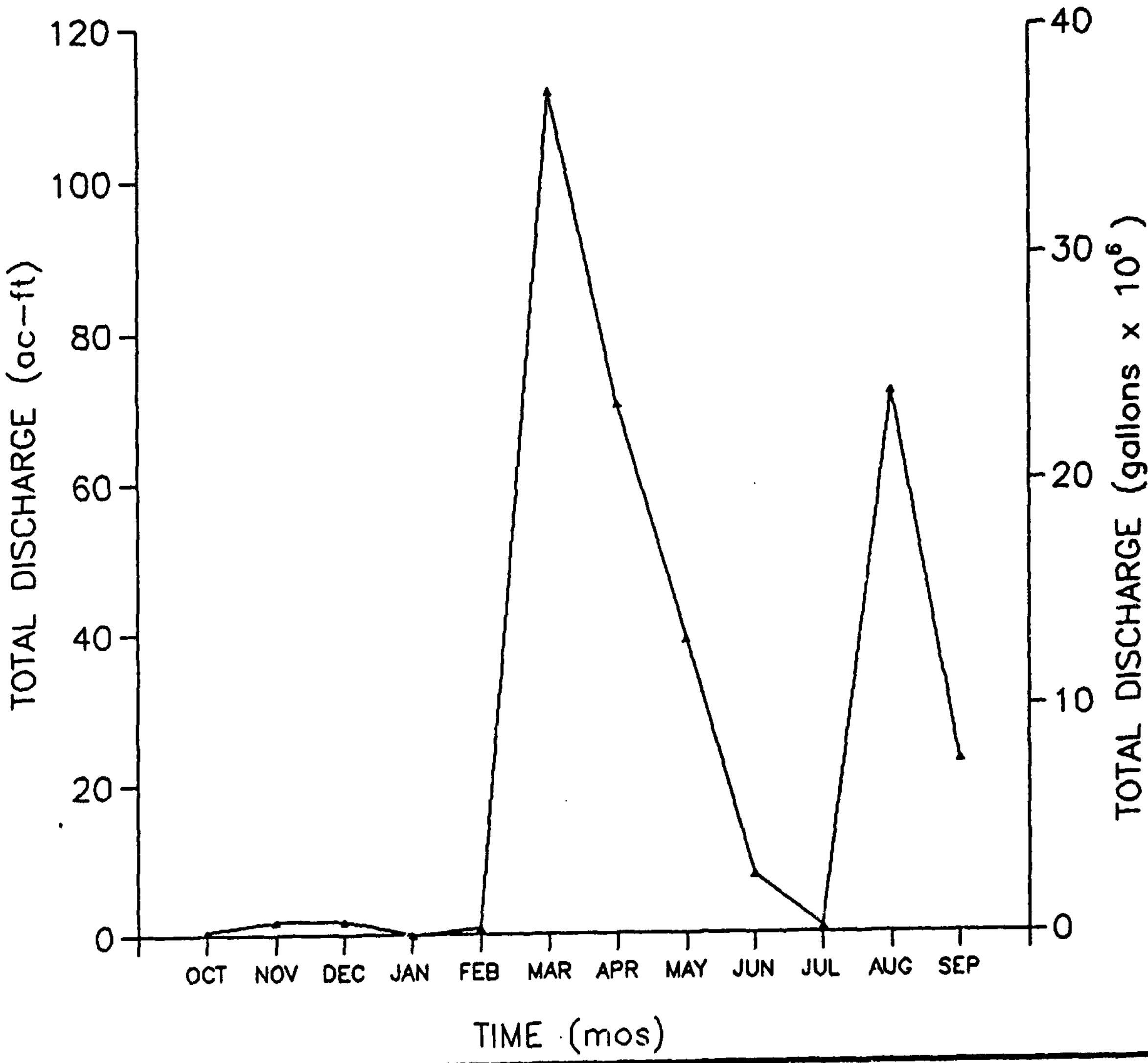

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Figure 4.1-12

First Creek Off-Post
Monthly Total Discharge
WY90

CMP SW90

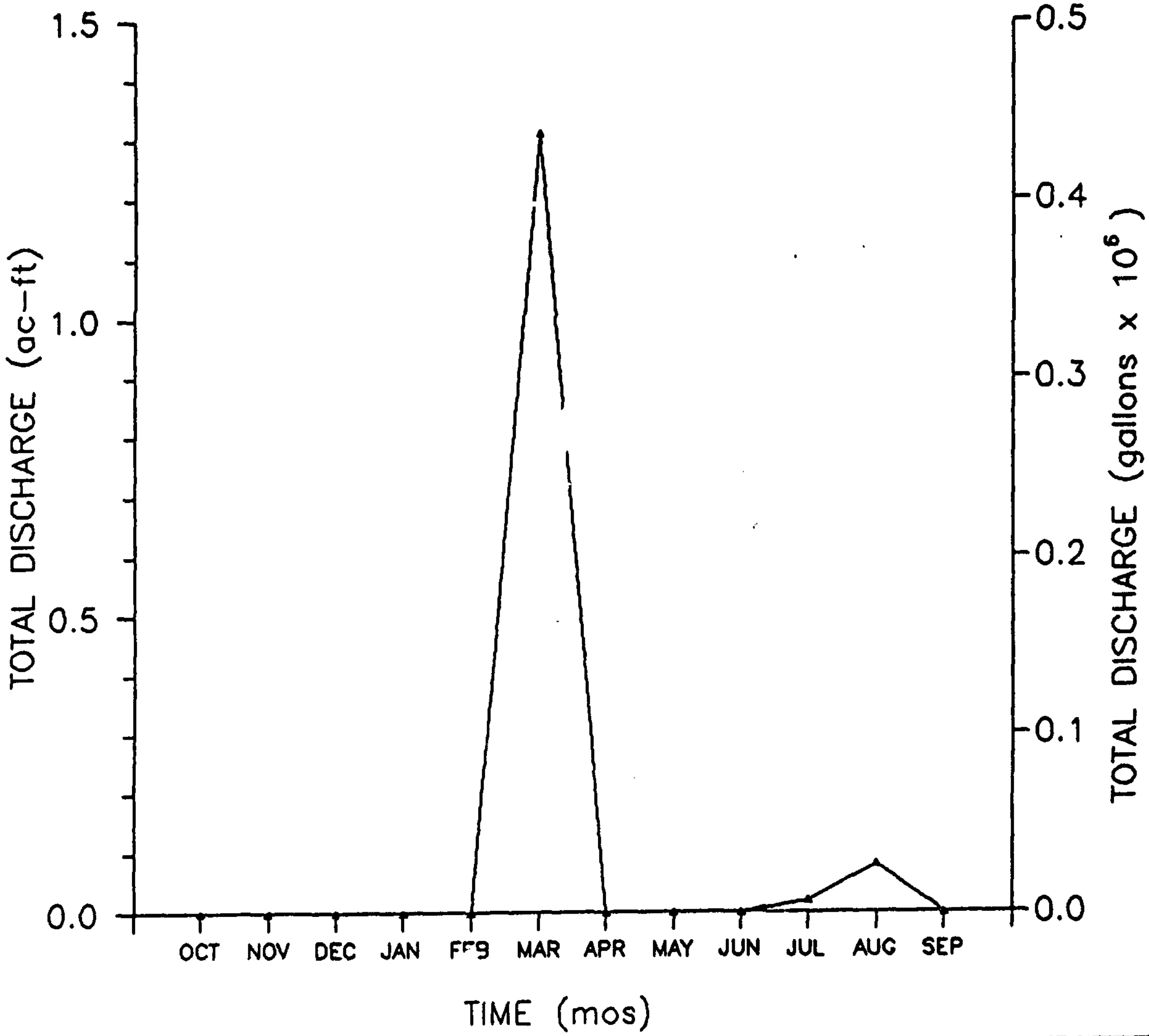

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Figure 4.1-13

Basin F
Monthly Total Discharge
WY90

CMP SW90

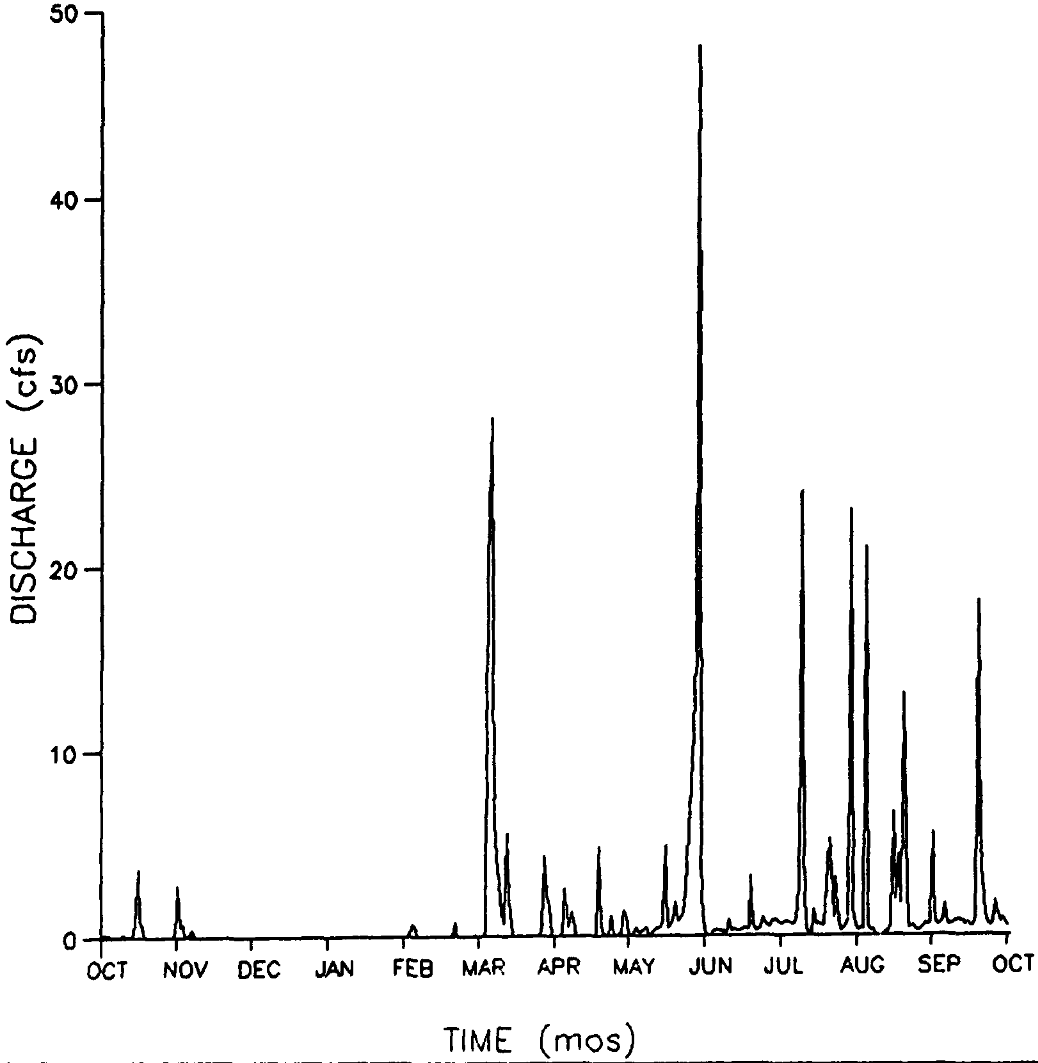

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Figure 4.1-14

Havana Interceptor
Daily Mean Discharge
Hydrograph for WY90

CMP SW90

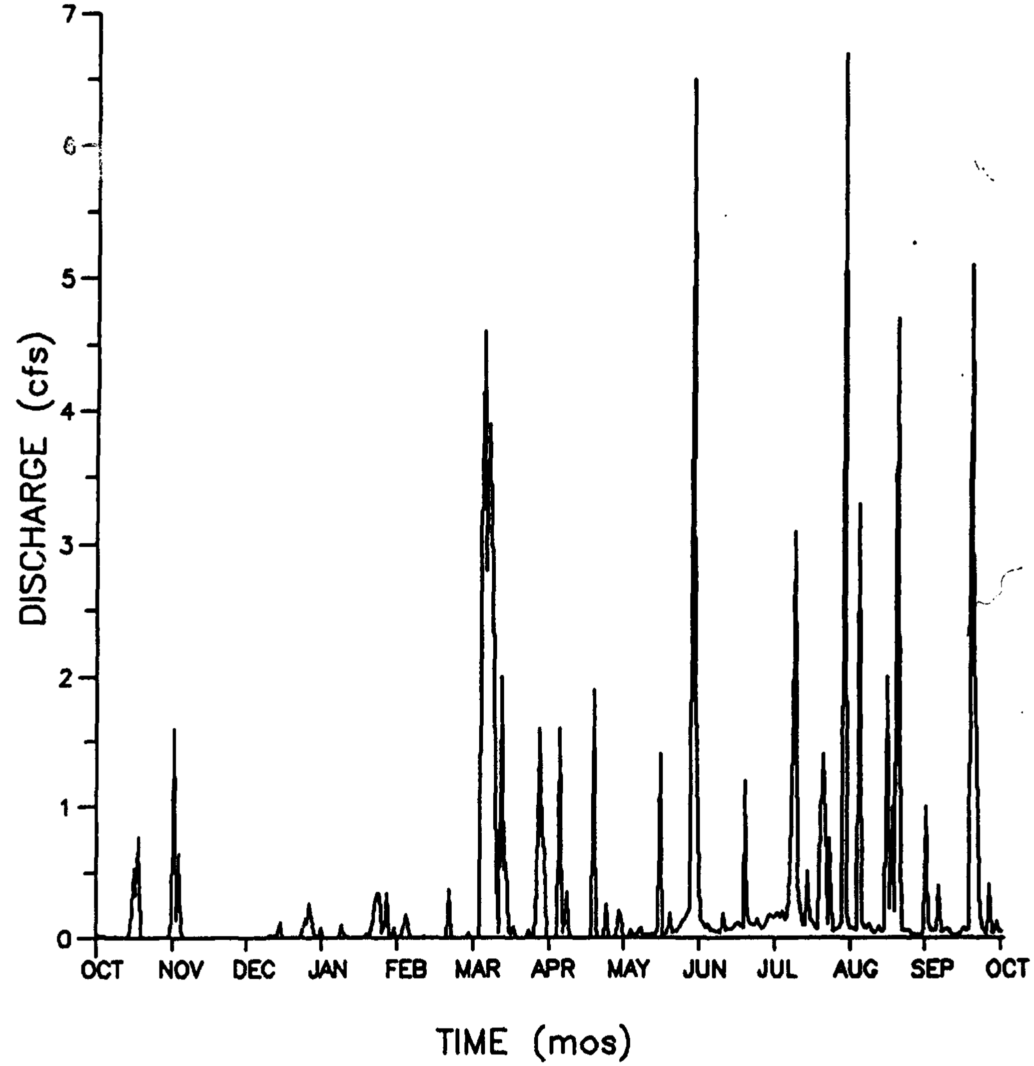

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Figure 4.1-15

Peoria Interceptor
Daily Mean Discharge
Hydrograph for WY90

CMP SW90

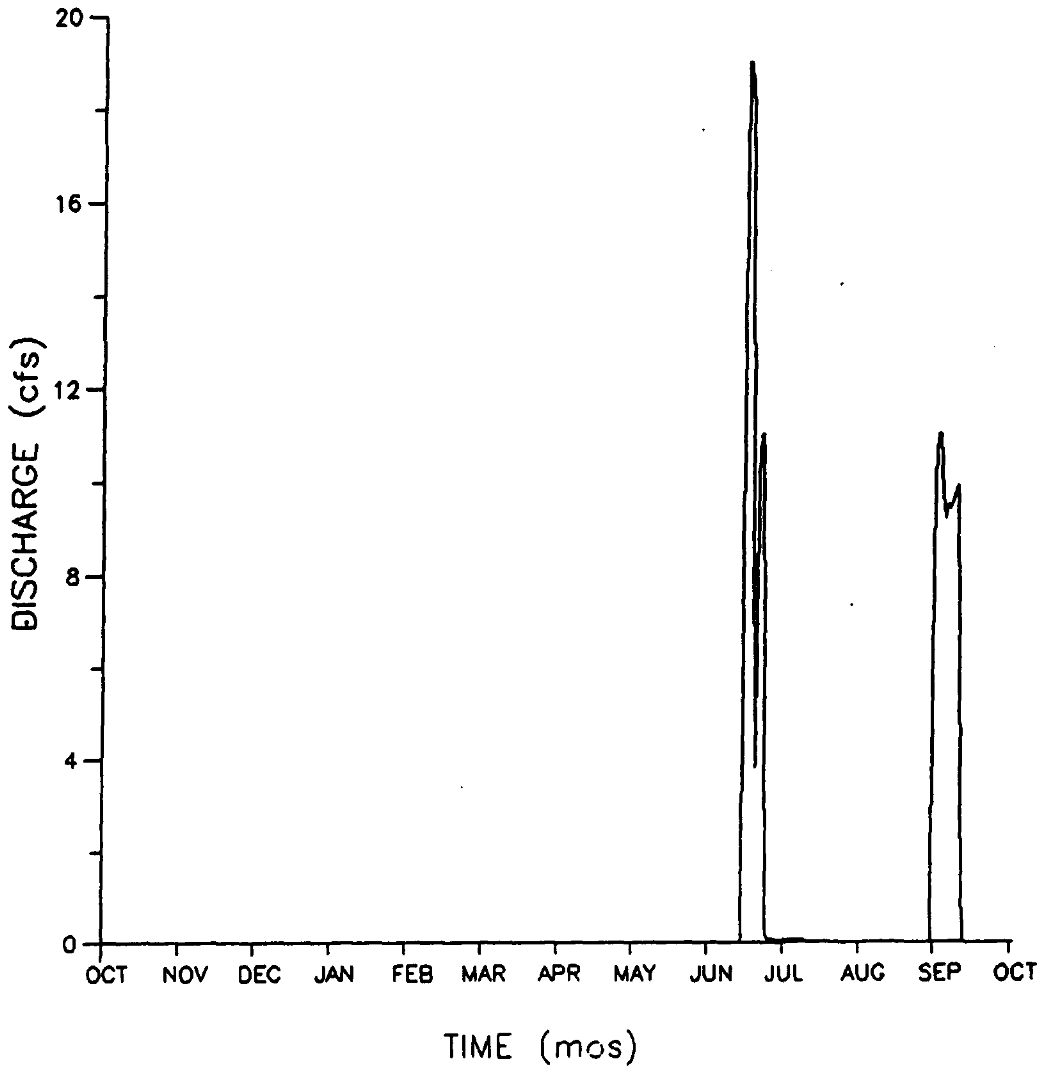

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Figure 4.1-16

Ladora Weir
Daily Mean Discharge
Hydrograph for WY90

CMP SW90

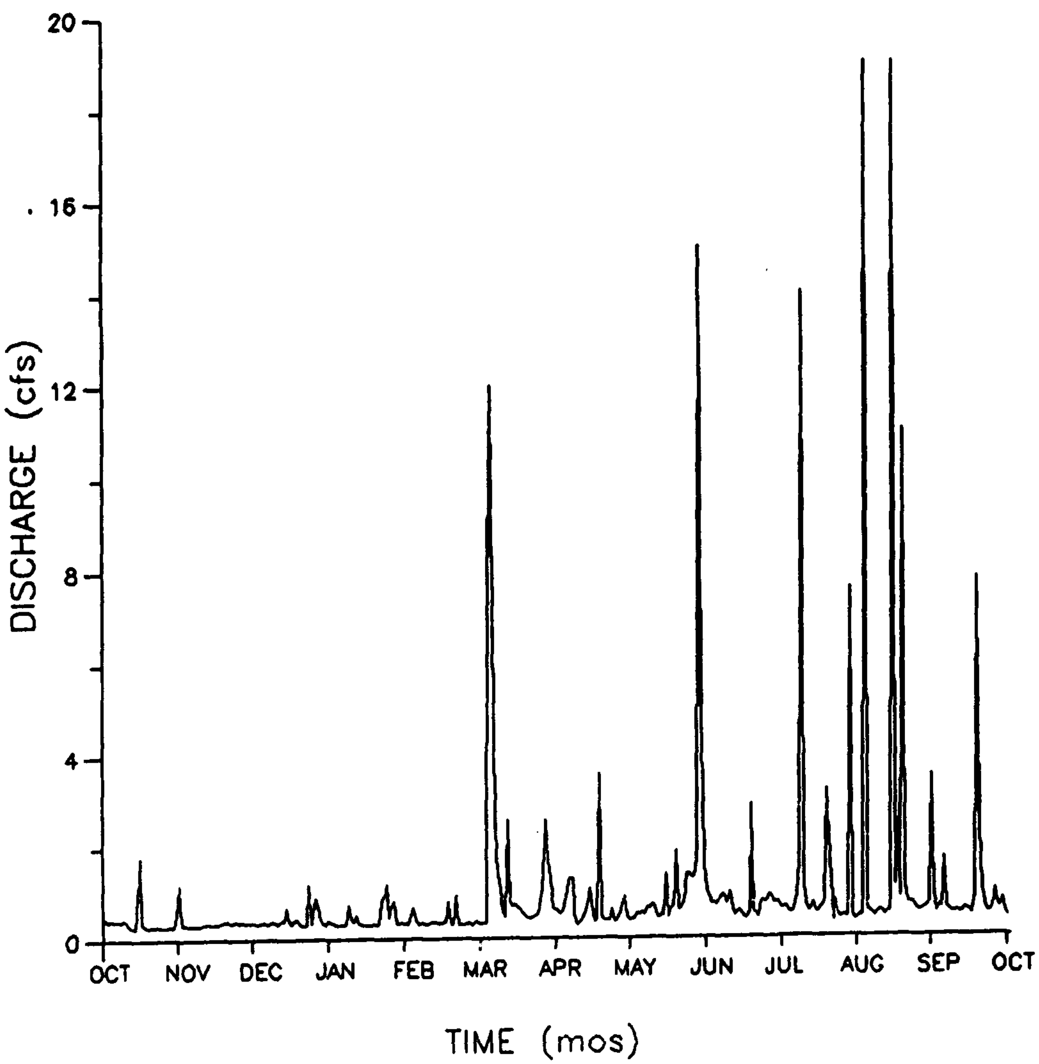

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Figure 4.1-17

South Uvalda
Daily Mean Discharge
Hydrograph for WY90

CMP SW90

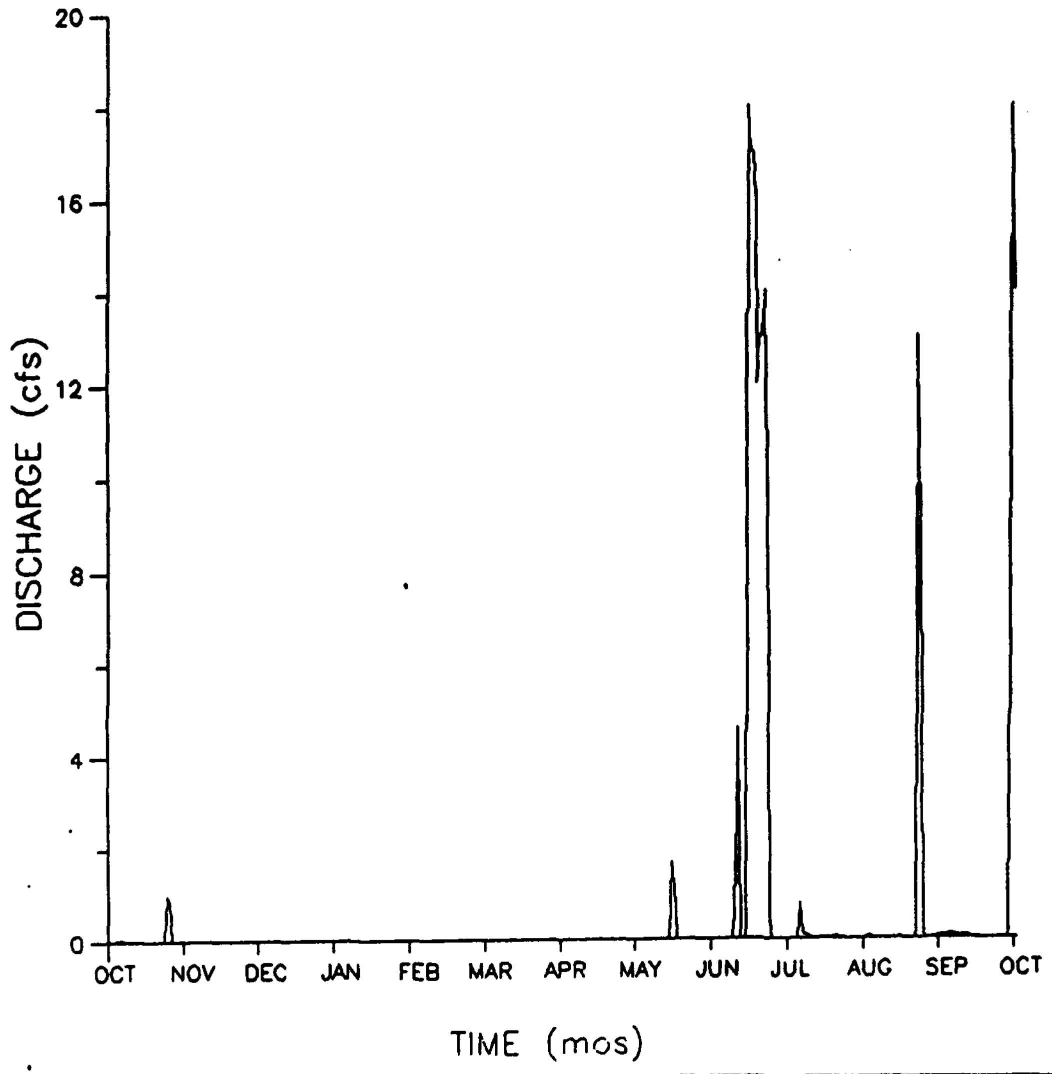

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Figure 4.1-18

North Uvalda
Daily Mean Discharge
Hydrograph for WY90

CMP SW90

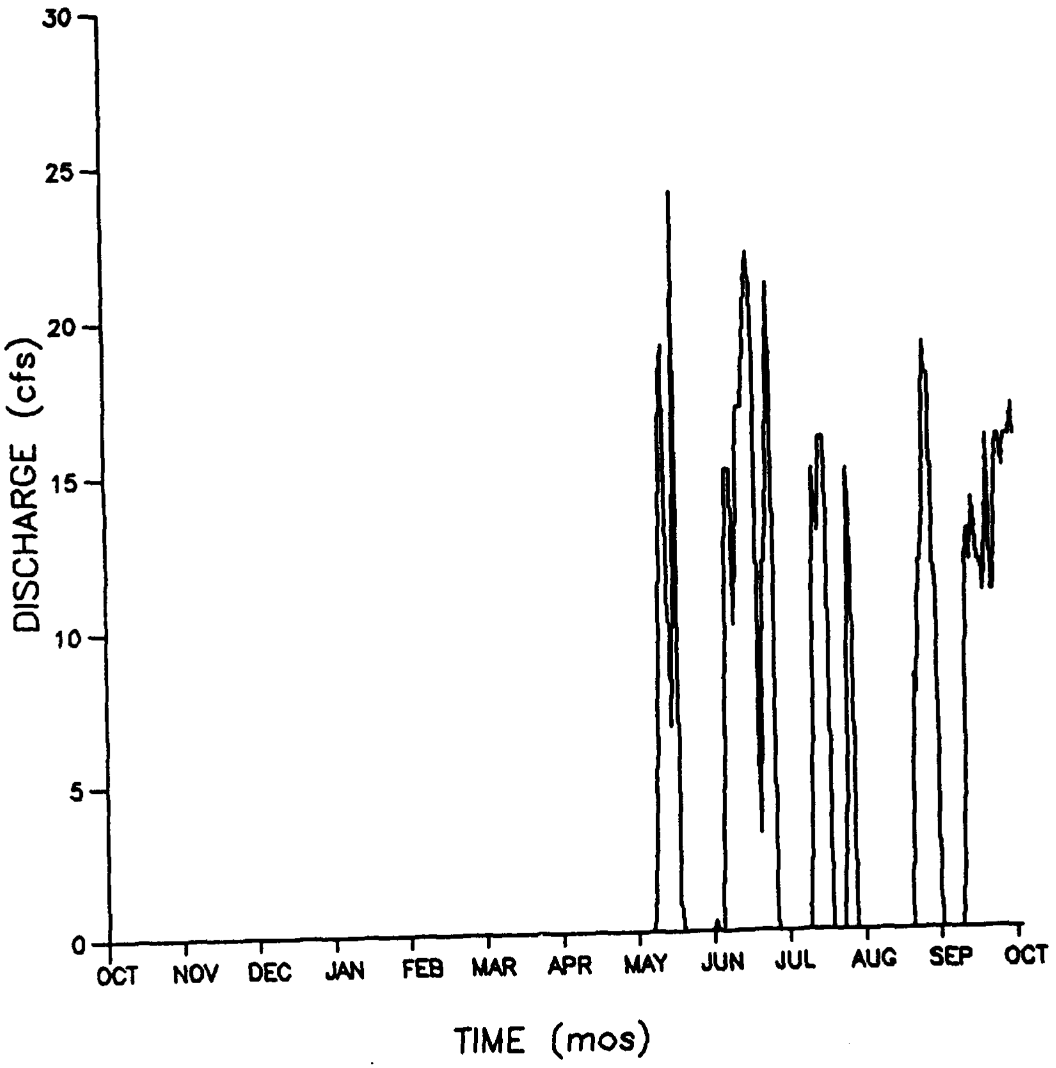

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Figure 4.1-19

Highline Lateral
Daily Mean Discharge
Hydrograph for WY90

CMP SW90

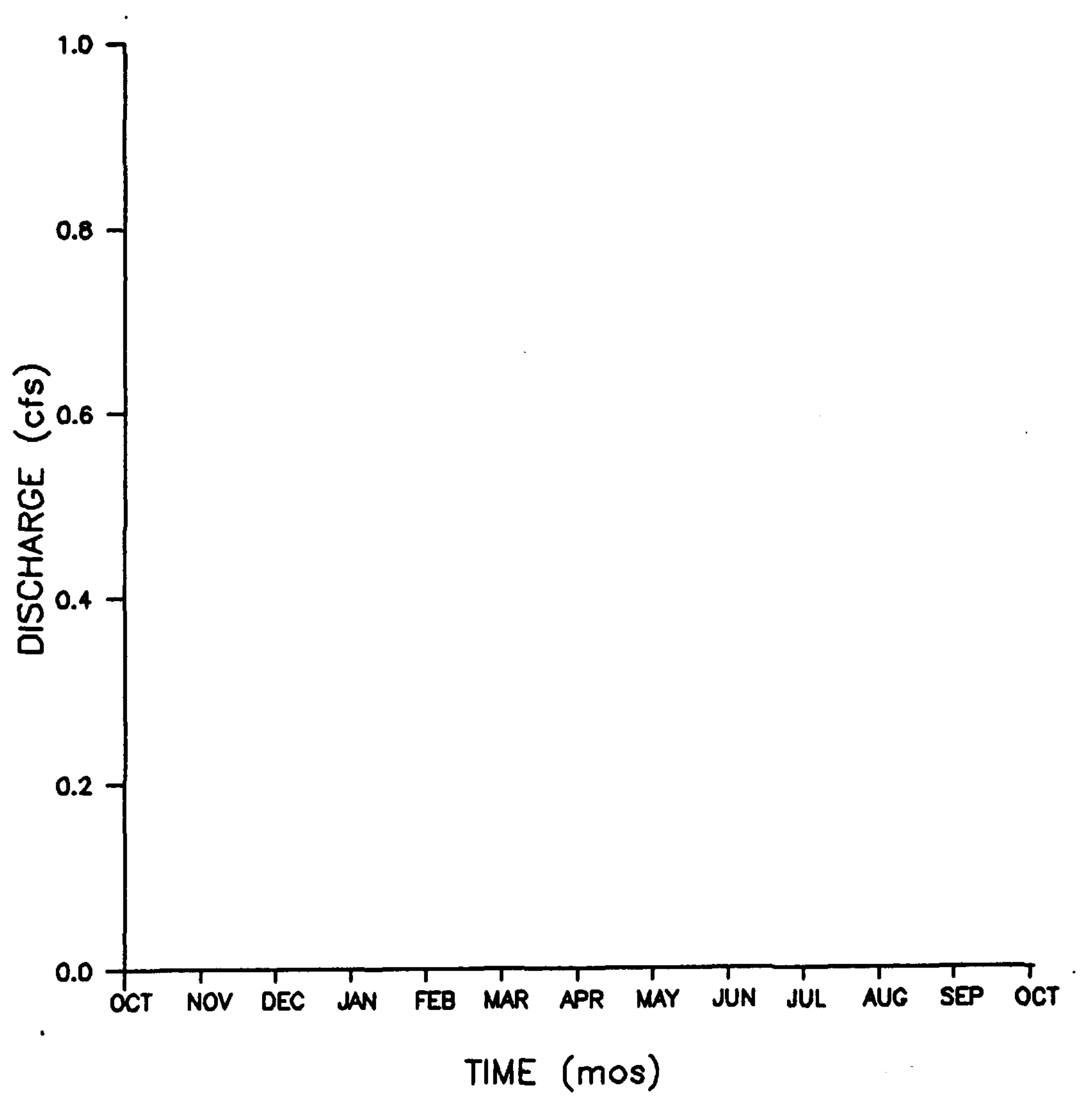

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Figure 4.1-20

South Plants Ditch
Daily Mean Discharge
Hydrograph for WY90

CMP SW90

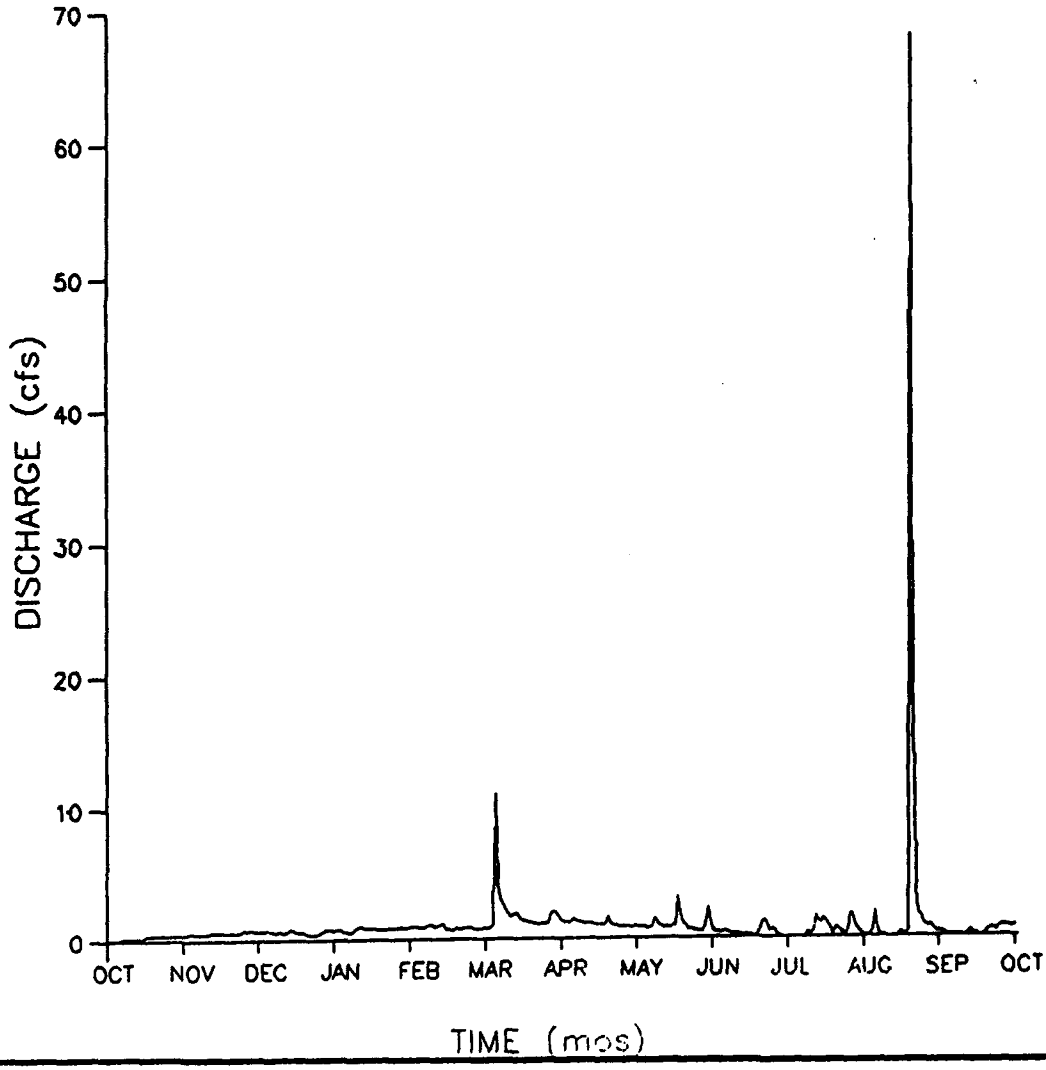

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Figure 4.1-21

South First Creek
Daily Mean Discharge
Hydrograph for WY90

CMP SW90

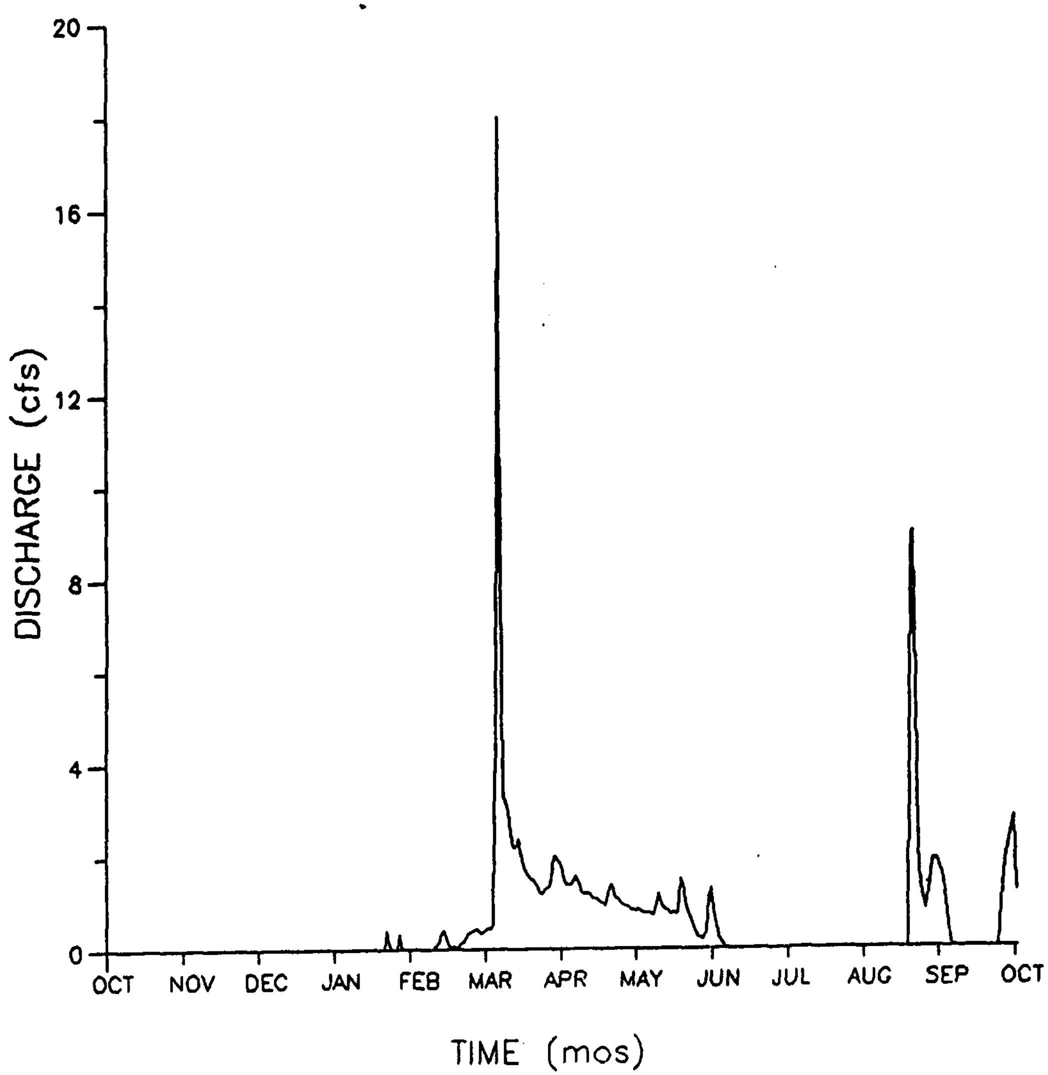

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Figure 4.1-22

North First Creek
Daily Mean Discharge
Hydrograph for WY90

CMP SW90

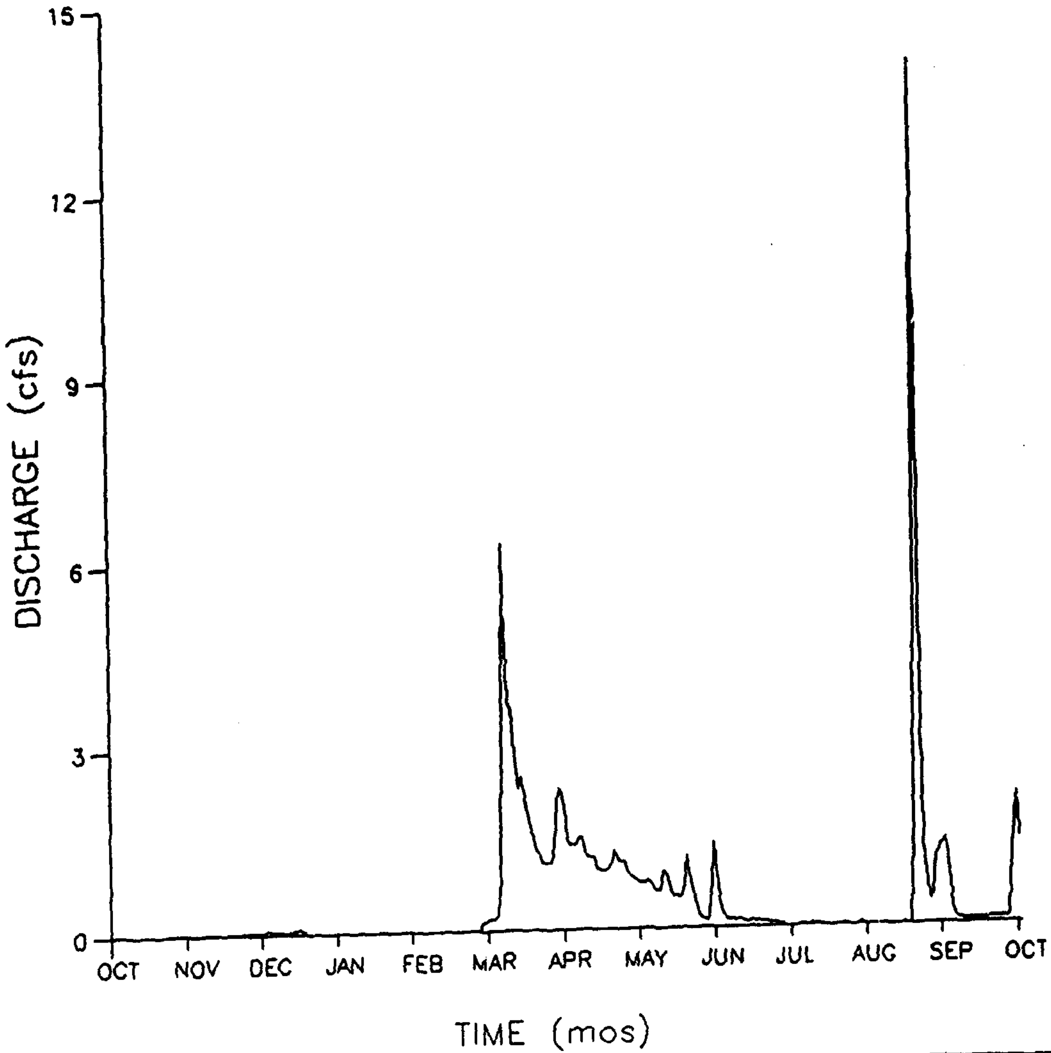

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Figure 4.1-23

First Creek Off-Post
Daily Mean Discharge
Hydrograph for WY90

CMP SW90

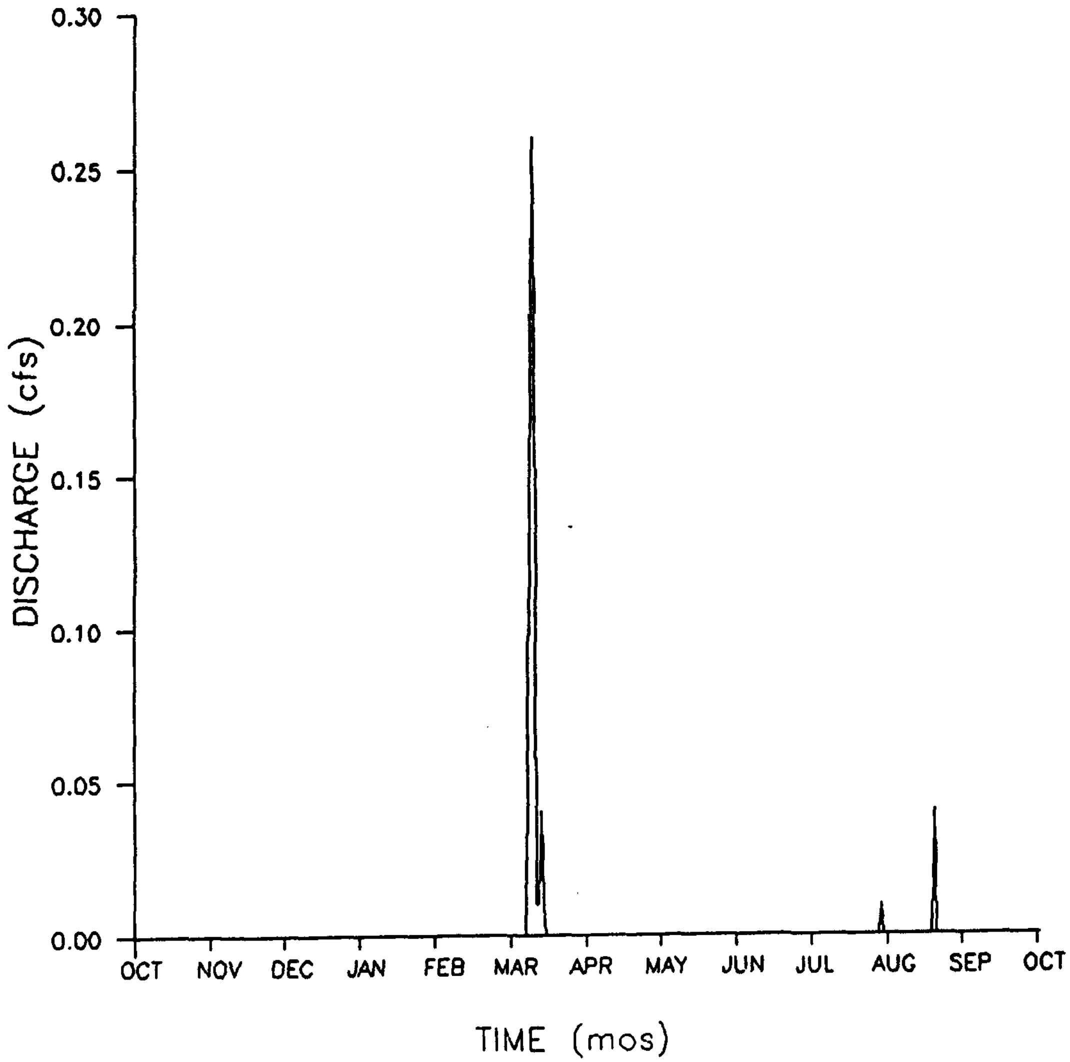

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Figure 4.1-24

Basin F
Daily Mean Discharge
Hydrograph for WY90

CMP SW90

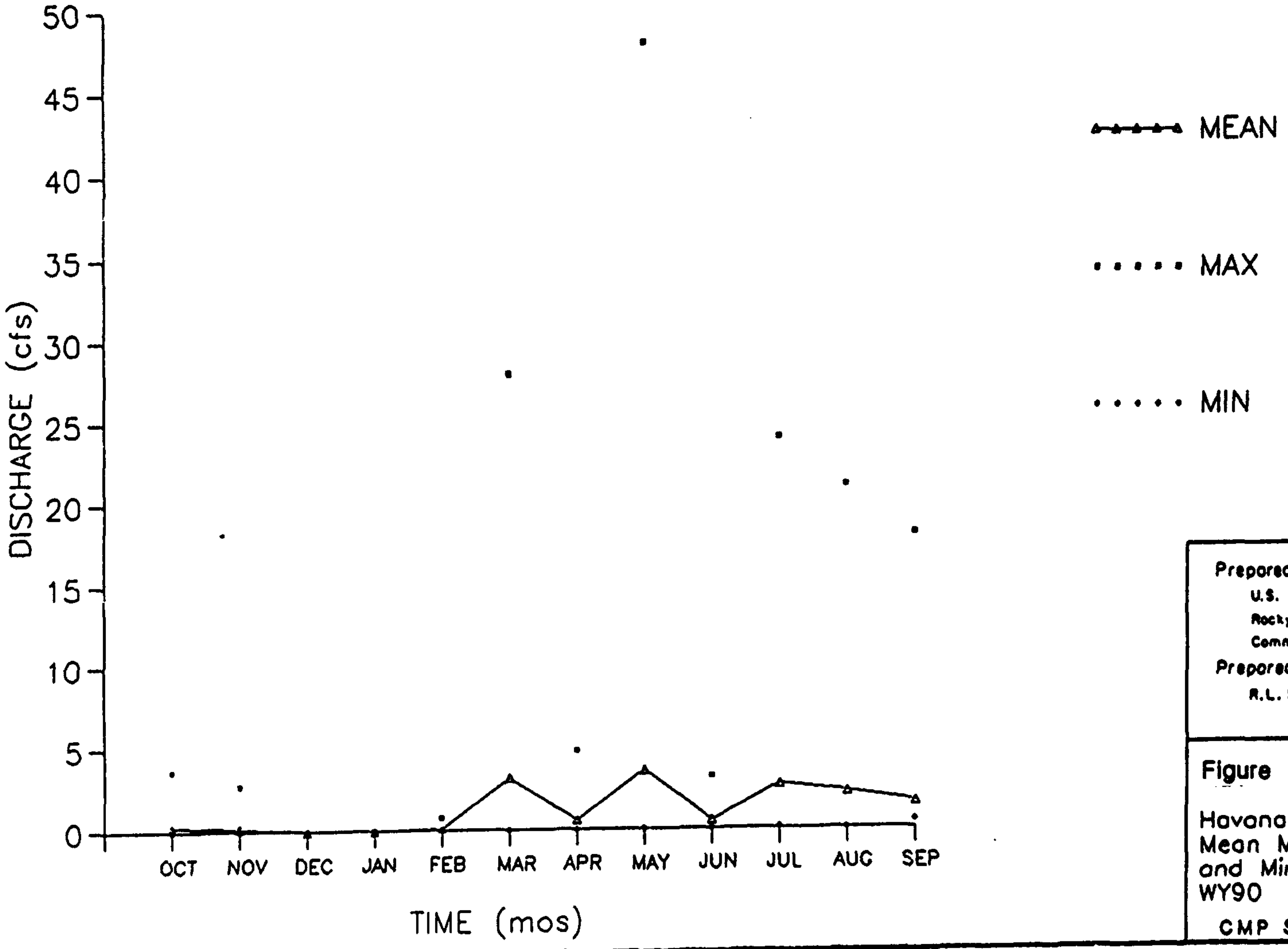

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Figure 4.1-25

Havana Interceptor
Mean Monthly, Maximum Daily
and Minimum Daily Discharge
WY90

CMP SW90

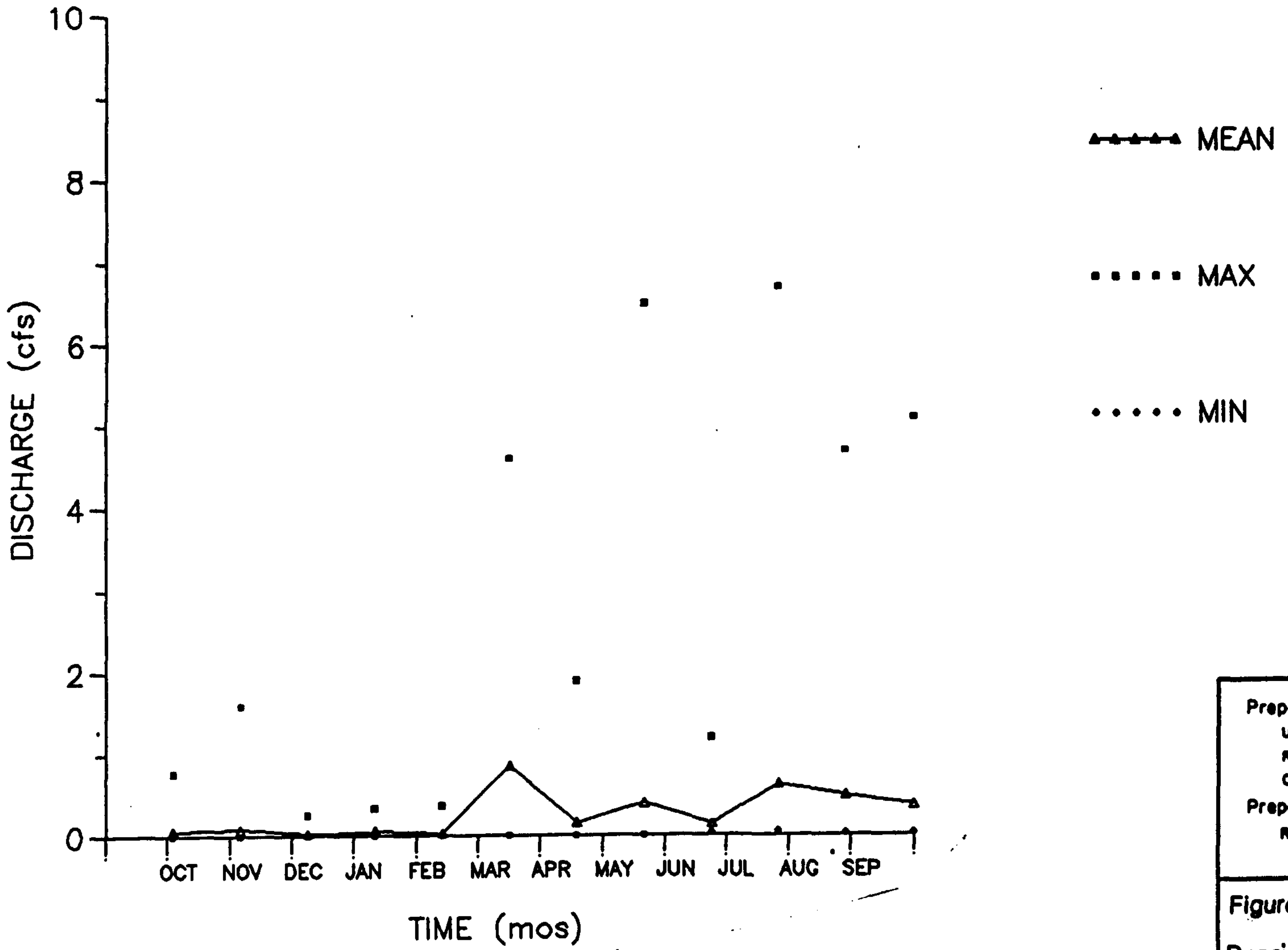

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Figure 4.1-26

Peoria Interceptor
Mean Monthly, Maximum Daily
and Minimum Daily Discharge
WY90

CMP SW90

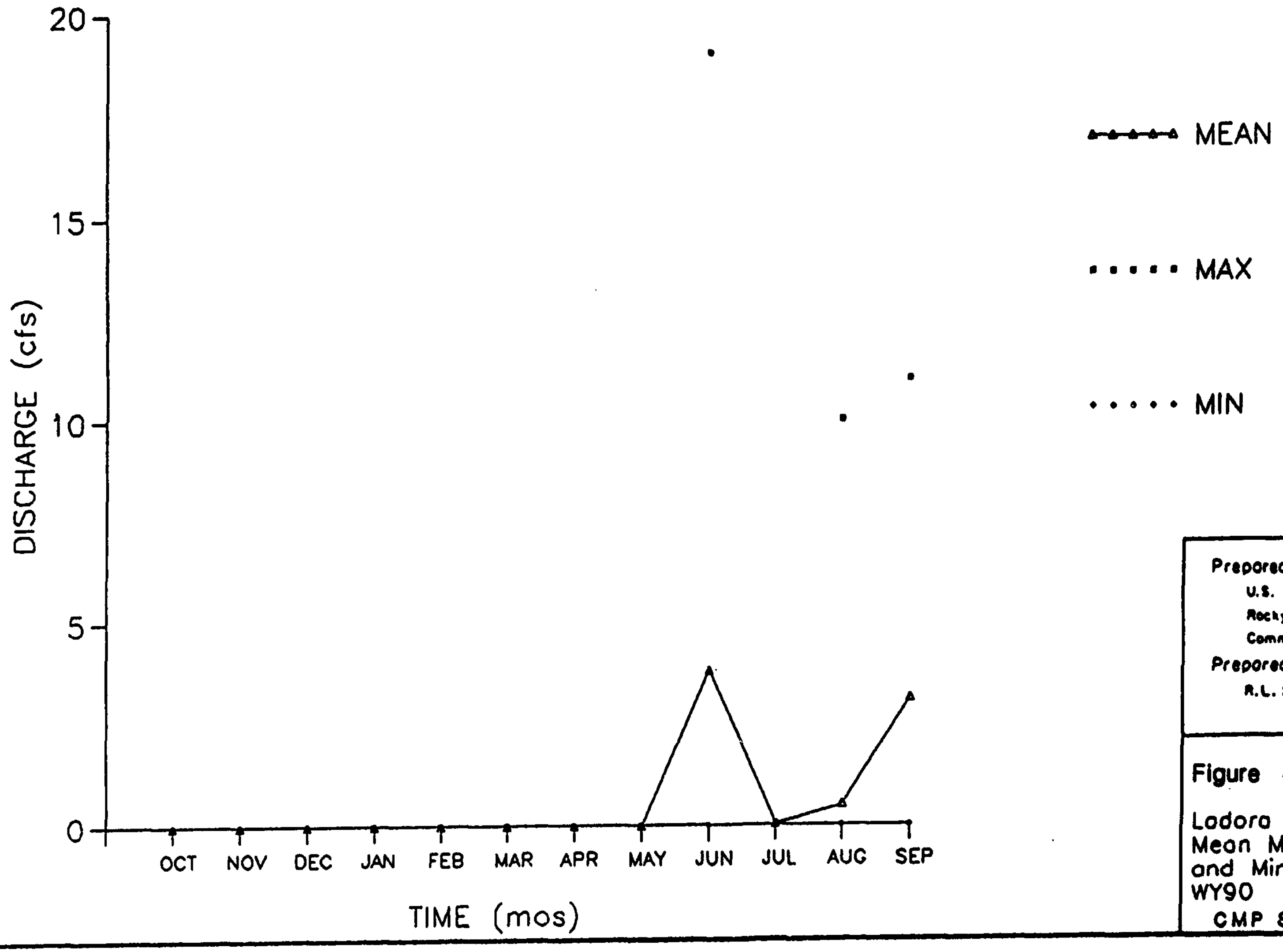

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Figure 4.1-27

Ladora Weir
Mean Monthly, Maximum Daily
and Minimum Daily Discharge
WY90
CMP SW90

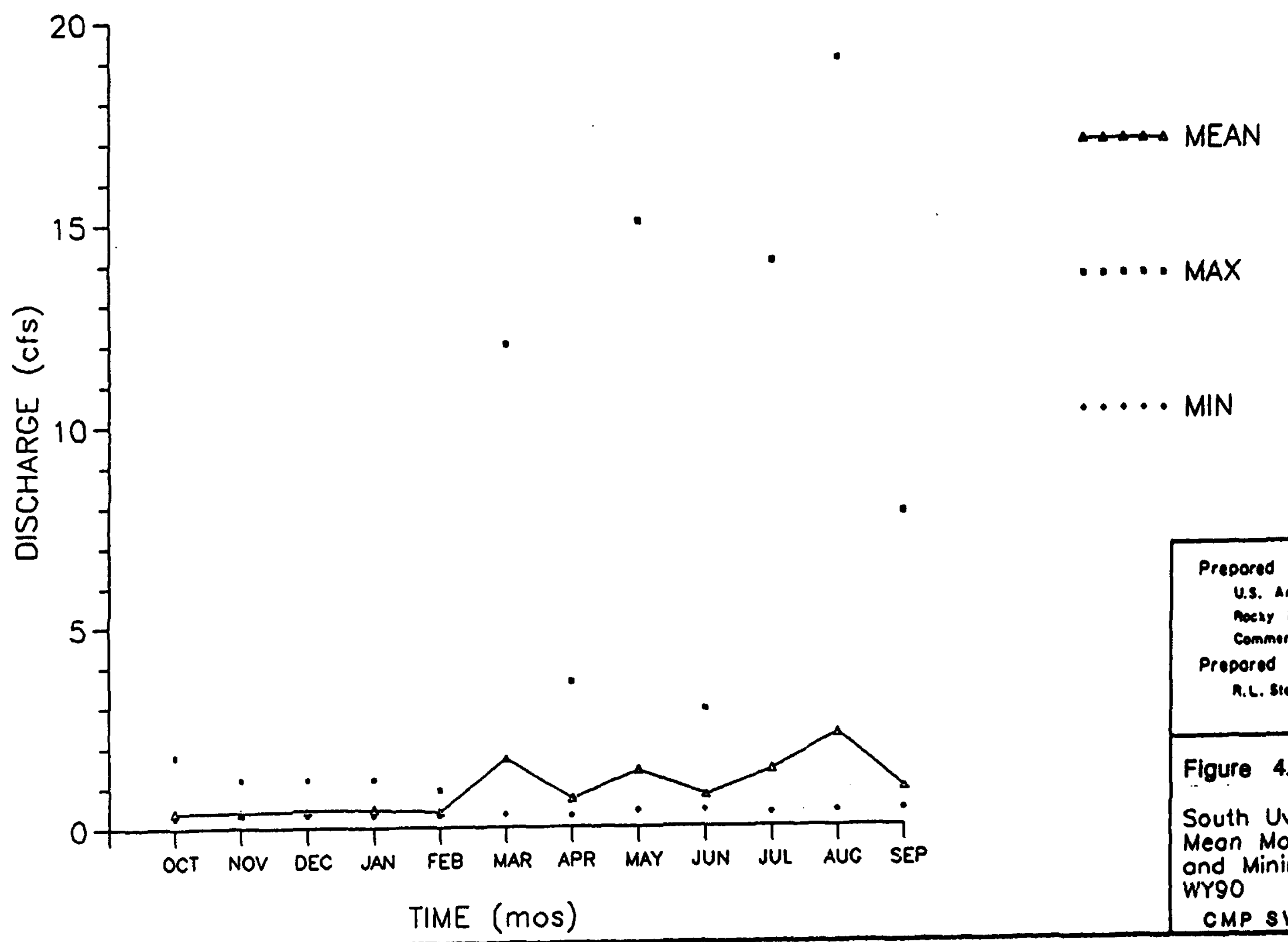

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Figure 4.1-28

South Uvalda
Mean Monthly, Maximum Daily
and Minimum Daily Discharge
WY90

CMP SW90

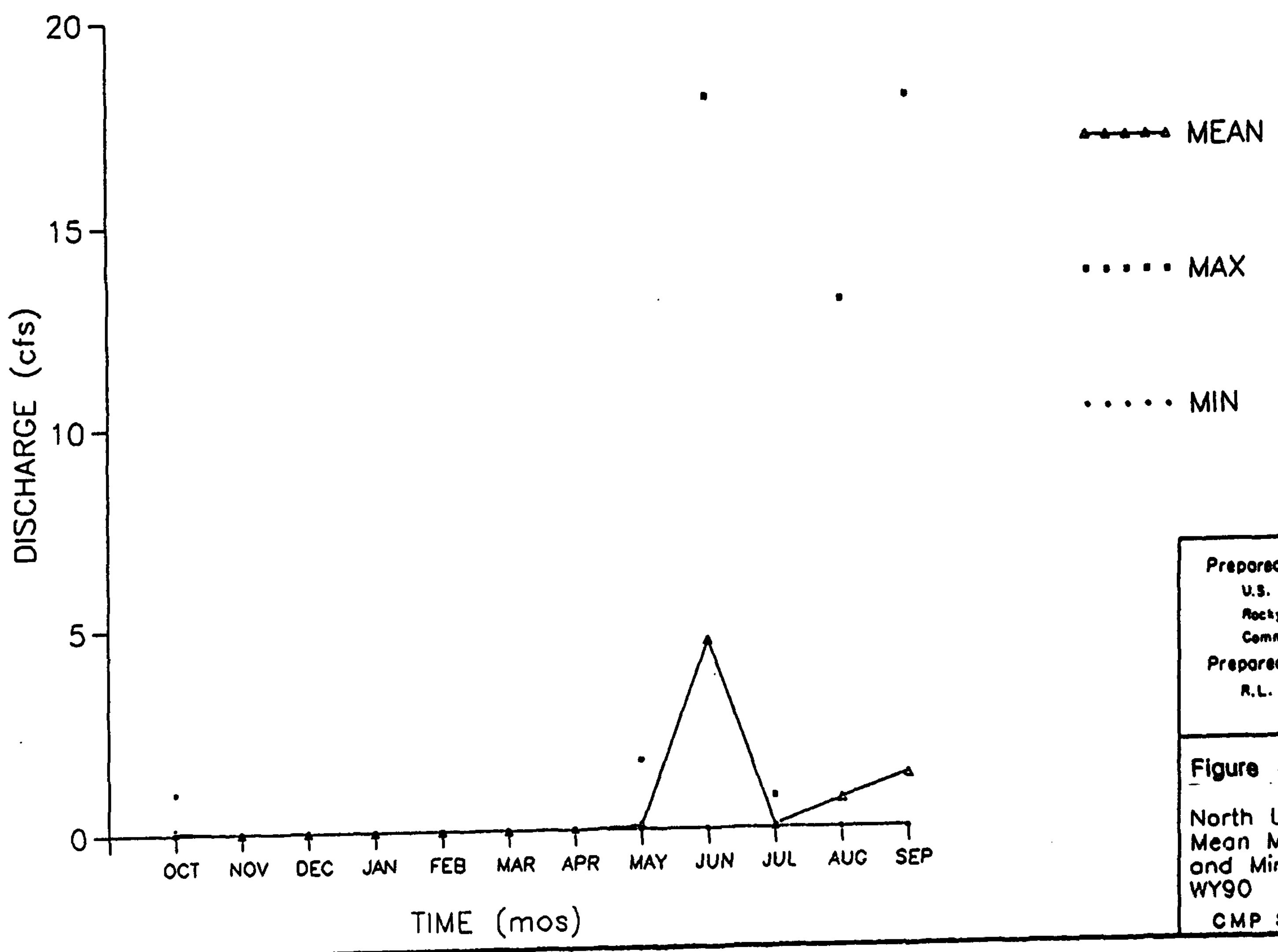

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Figure 4.1-29

North Uvalda
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY90

CMP SW90

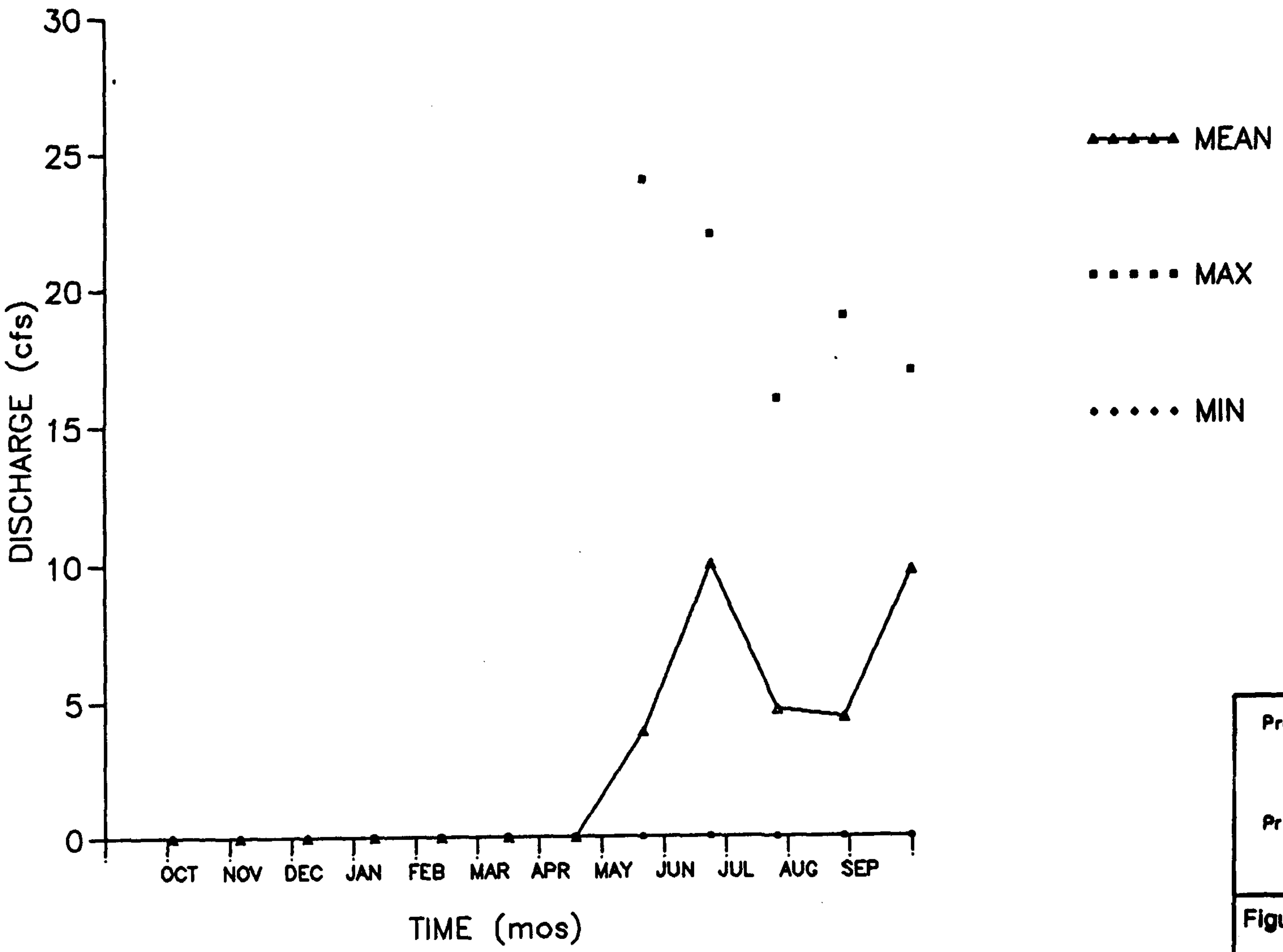

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Figure 4.1-30

Highline Lateral
Mean Monthly, Maximum Daily
and Minimum Daily Discharge
WY90

CMP SW90

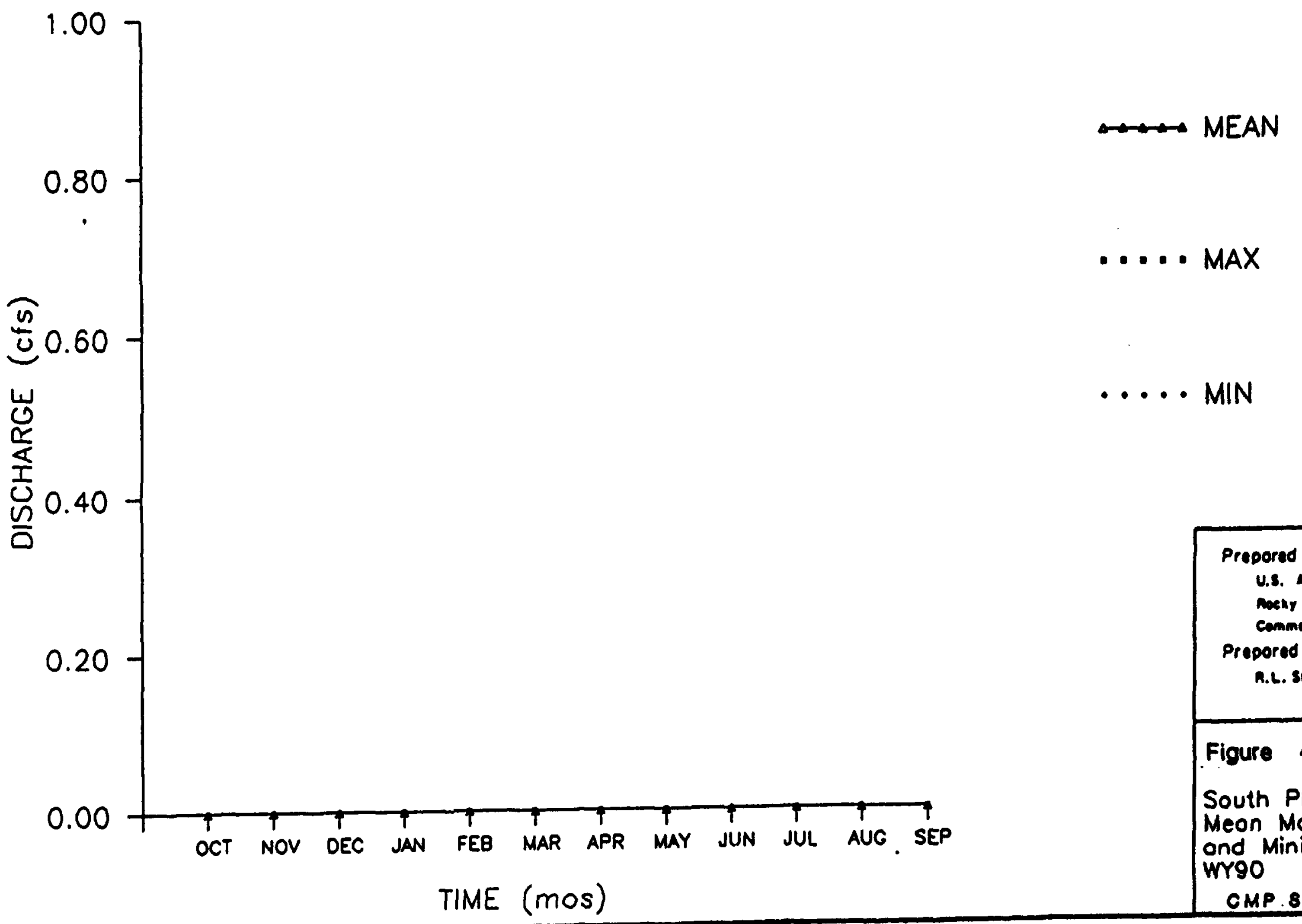

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Figure 4.1-31

South Plants Ditch
Mean Monthly, Maximum Daily
and Minimum Daily Discharge
WY90

CMP.SW90

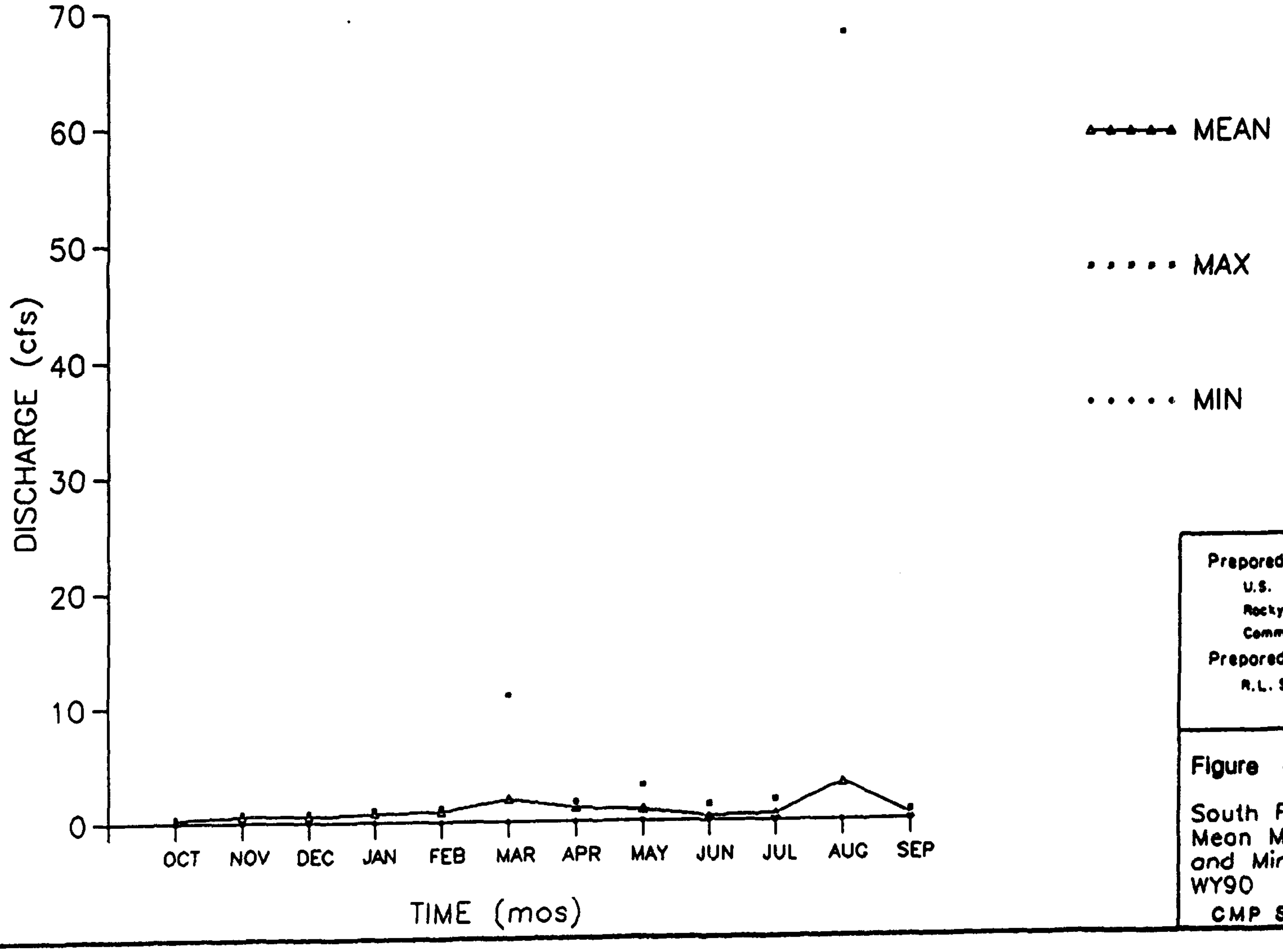

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Figure 4.1-32

South First Creek
Mean Monthly, Maximum Daily and Minimum Daily Discharge
WY90
CMP SW90

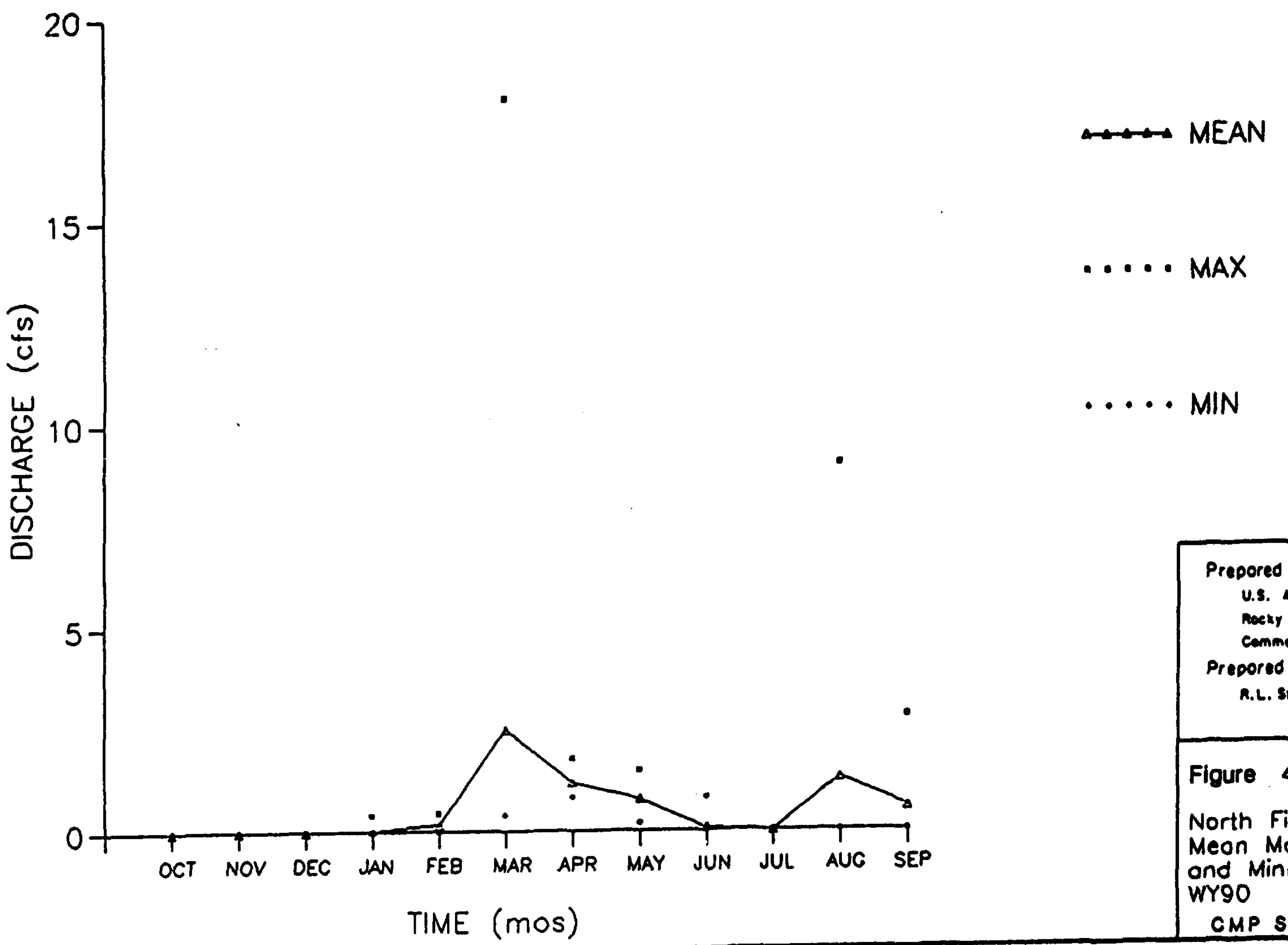

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Figure 4.1-33

North First Creek
Mean Monthly, Maximum Daily
and Minimum Daily Discharge
WY90

CMP SW90

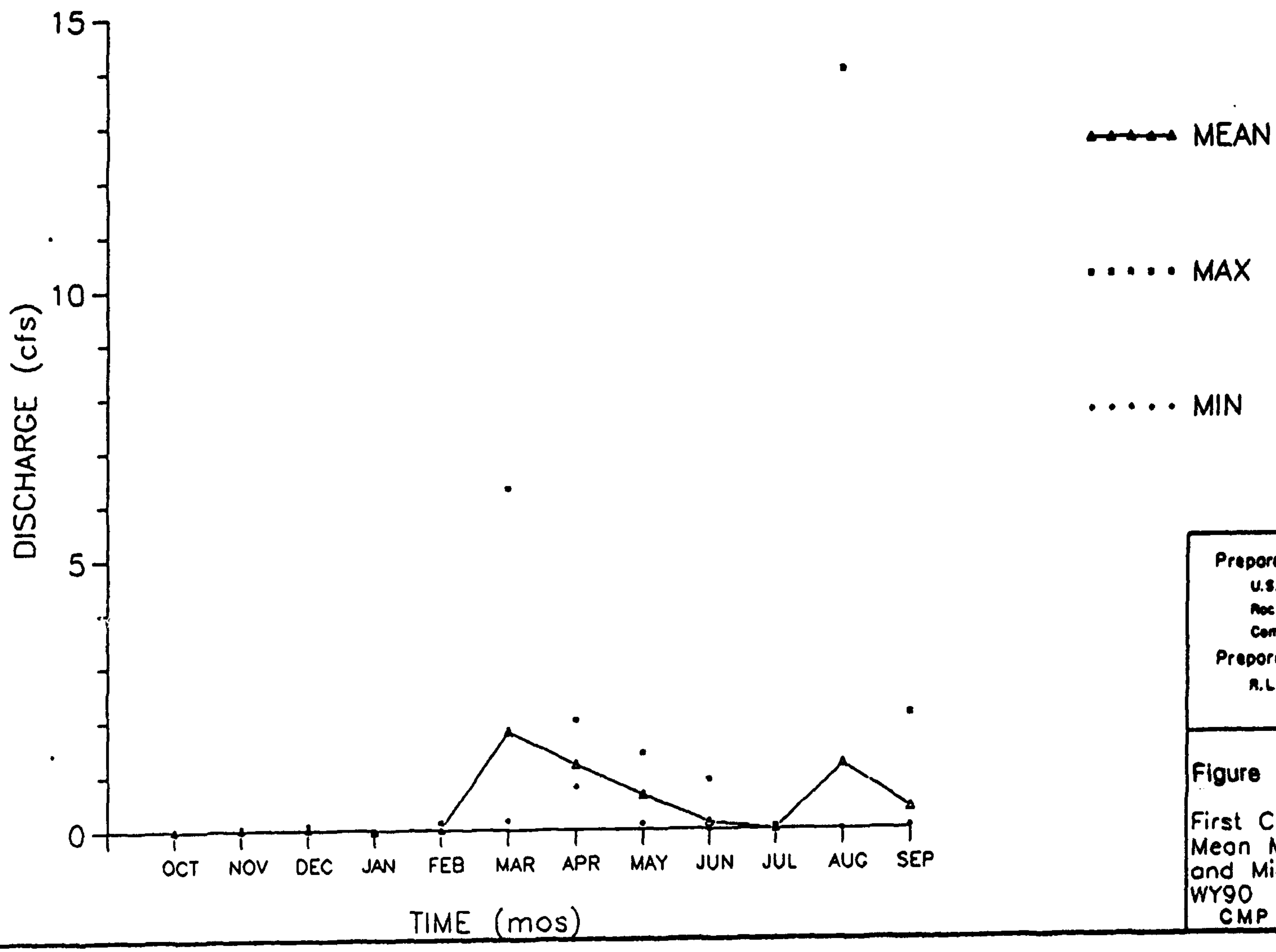

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Figure 4.1-34

First Creek Off-Post
Mean Monthly, Maximum Daily
and Minimum Daily Discharge
WY90
CMP SW90

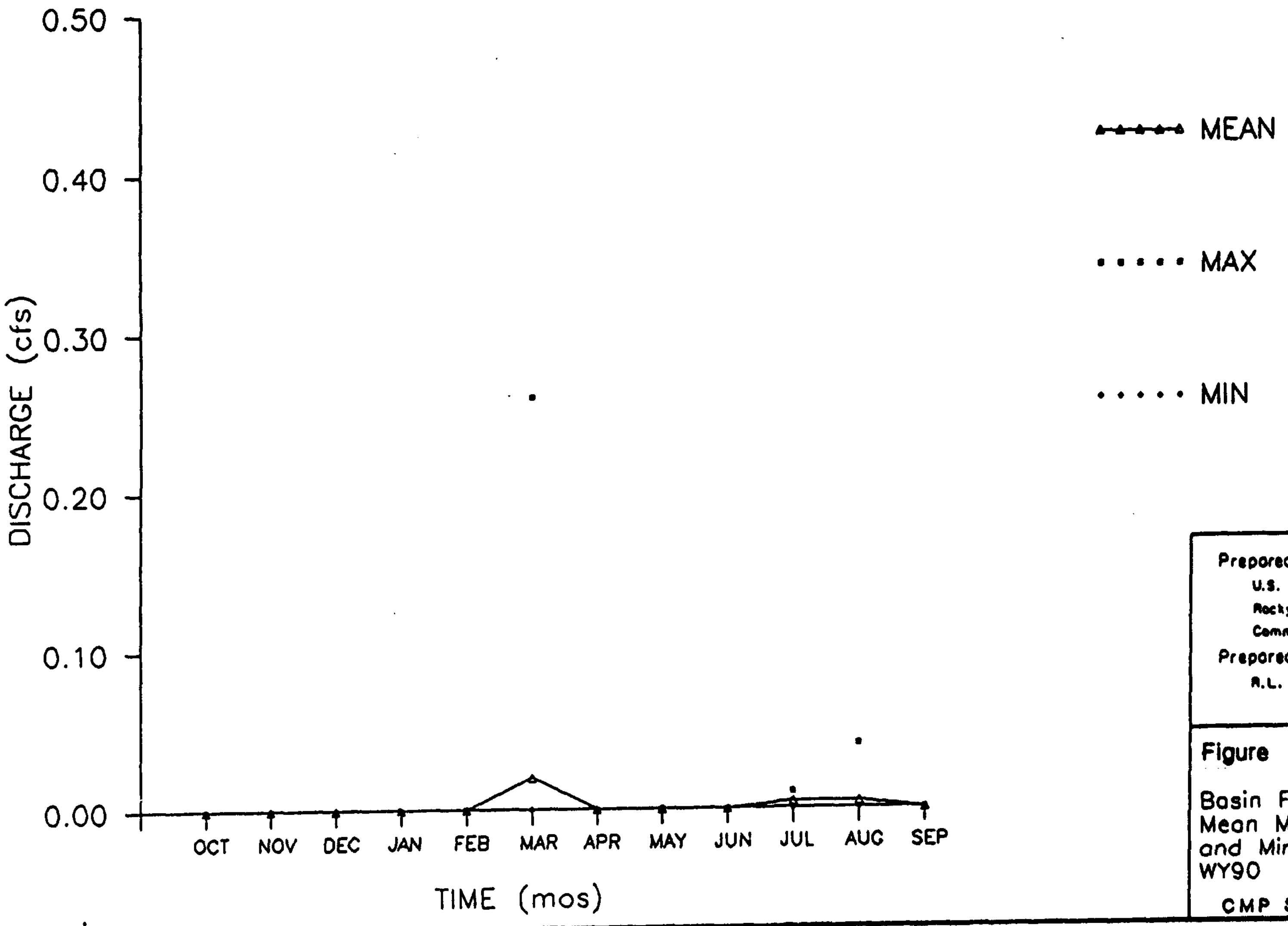

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Figure 4.1-35

Basin F
Mean Monthly, Maximum Daily
and Minimum Daily Discharge
WY90

CMP SW90

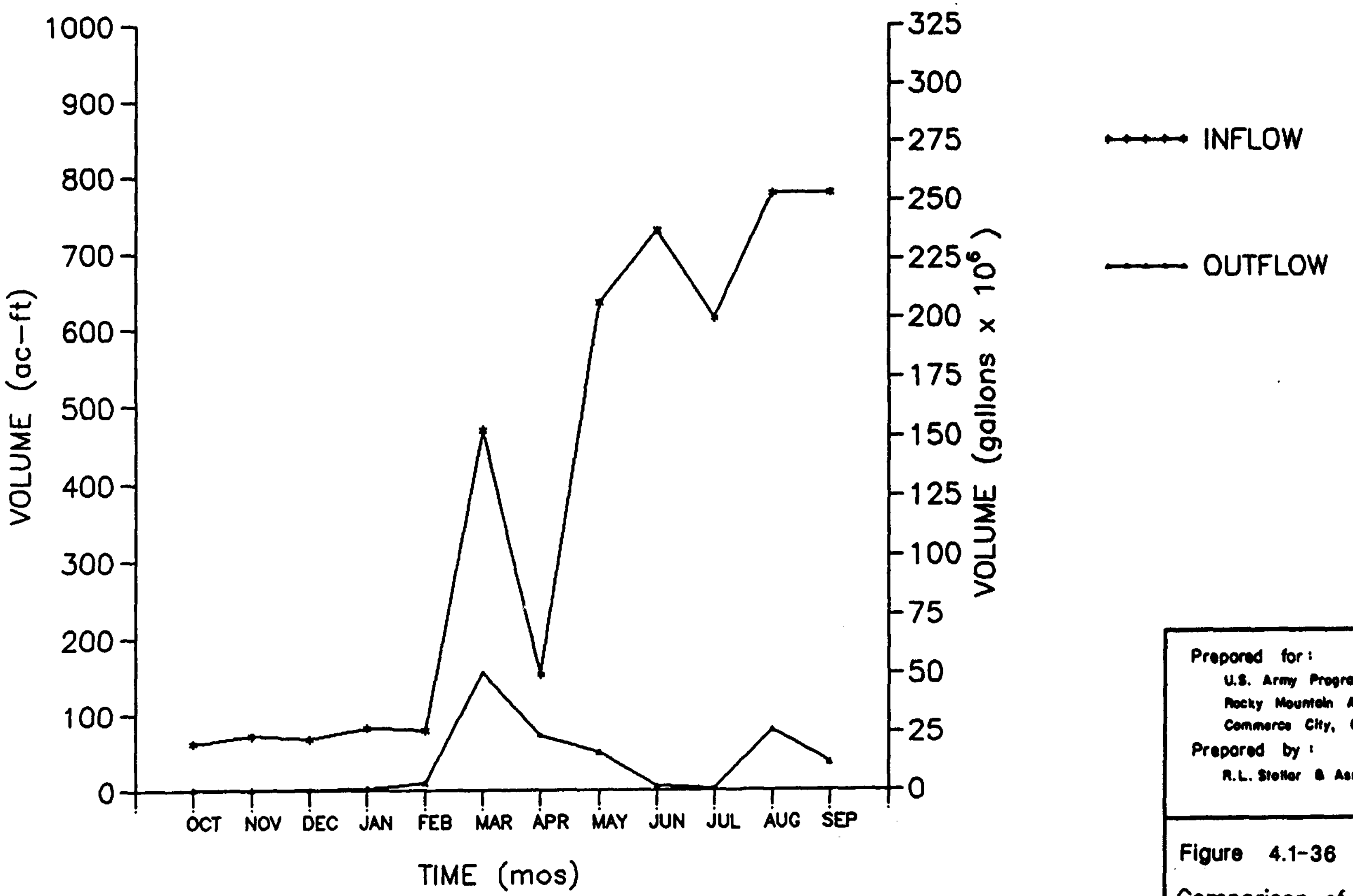

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Figure 4.1-36

Comparison of RMA Inflow and Outflow Volumes WY90

CMP SW90

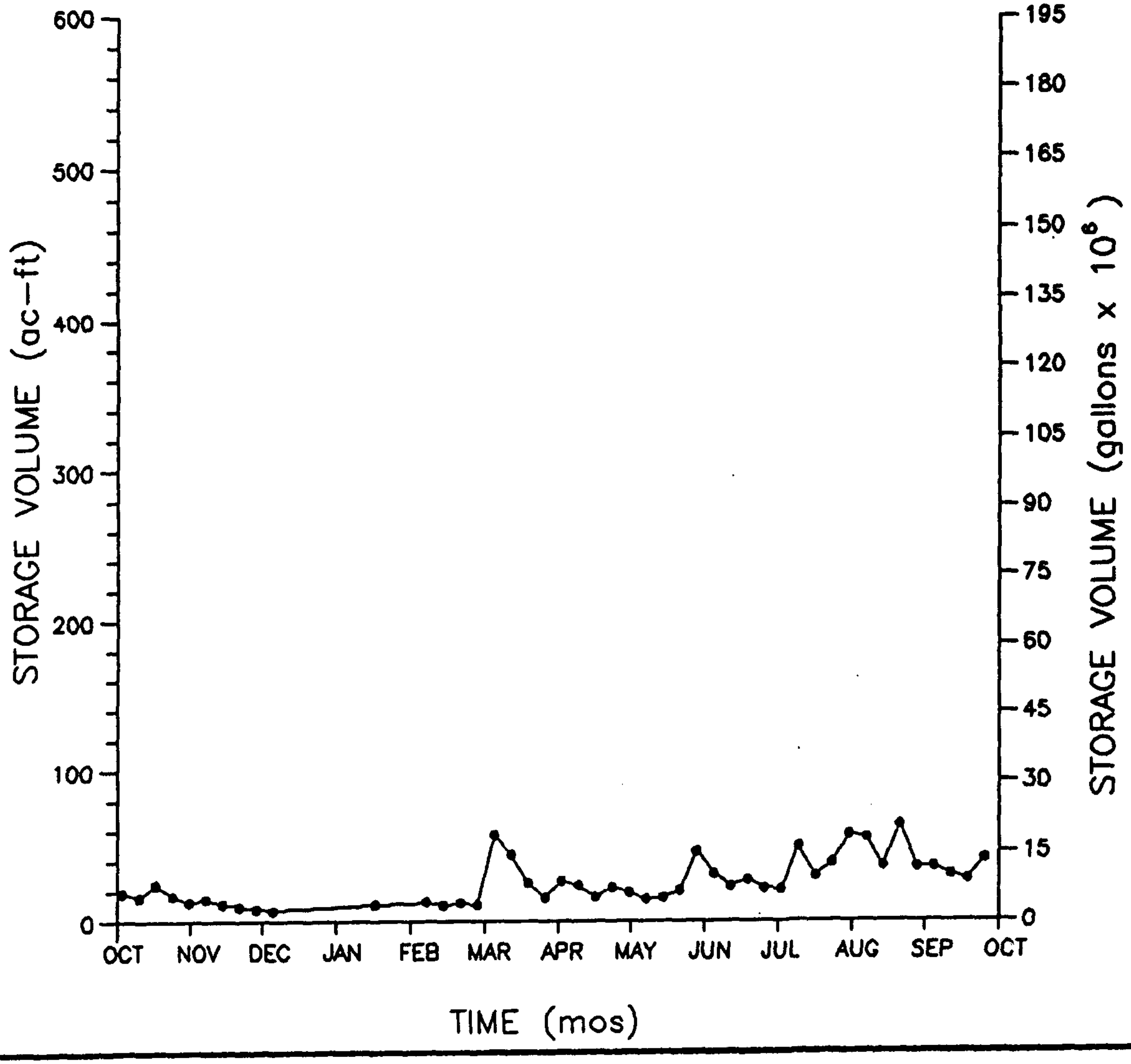

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Figure 4.1-37

Havava Pond
WY90 Storage Volume

CMP SW90

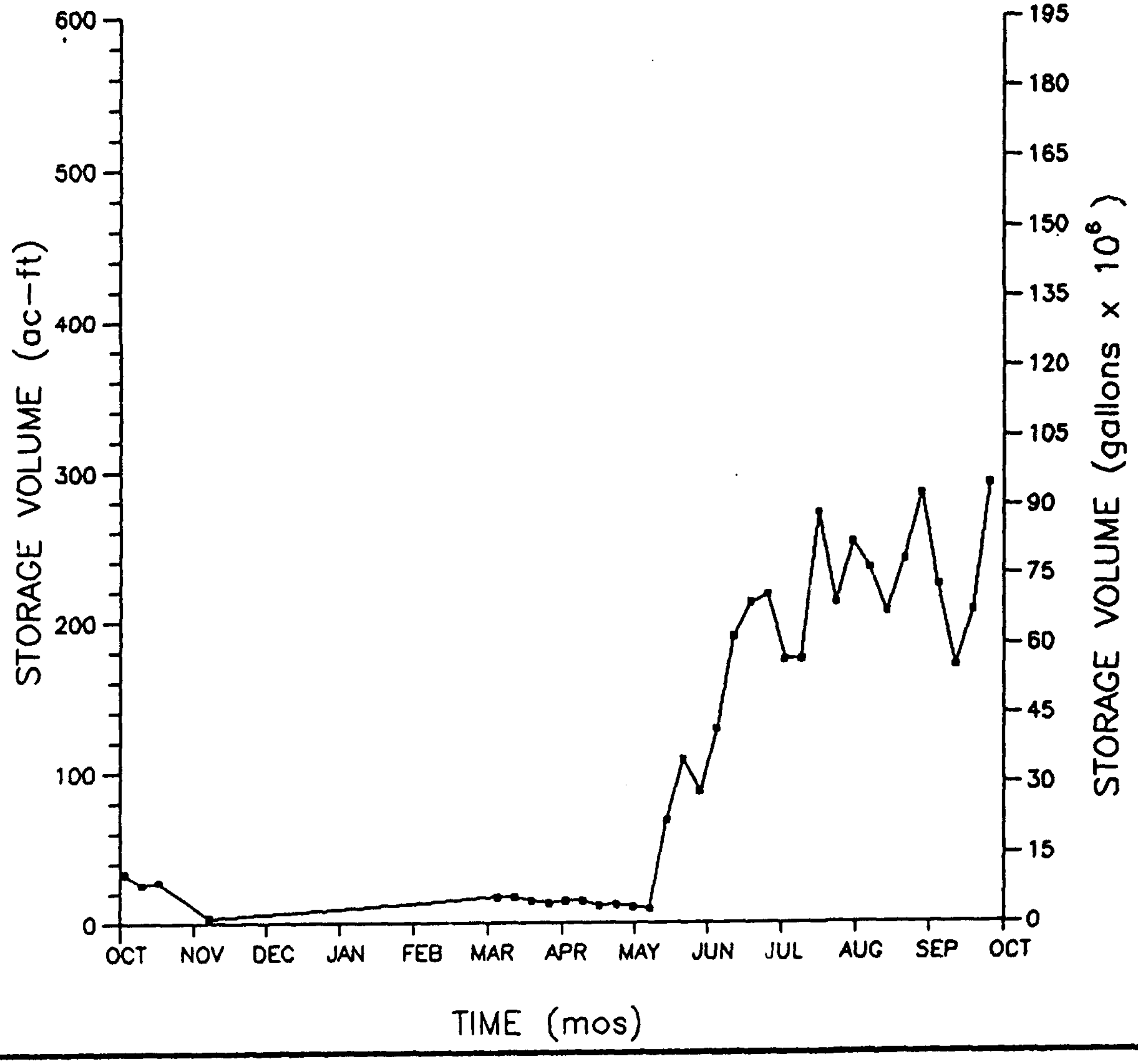

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Figure 4.1-38

Upper Derby Lake
WY90 Storage Volume

CMP SW90

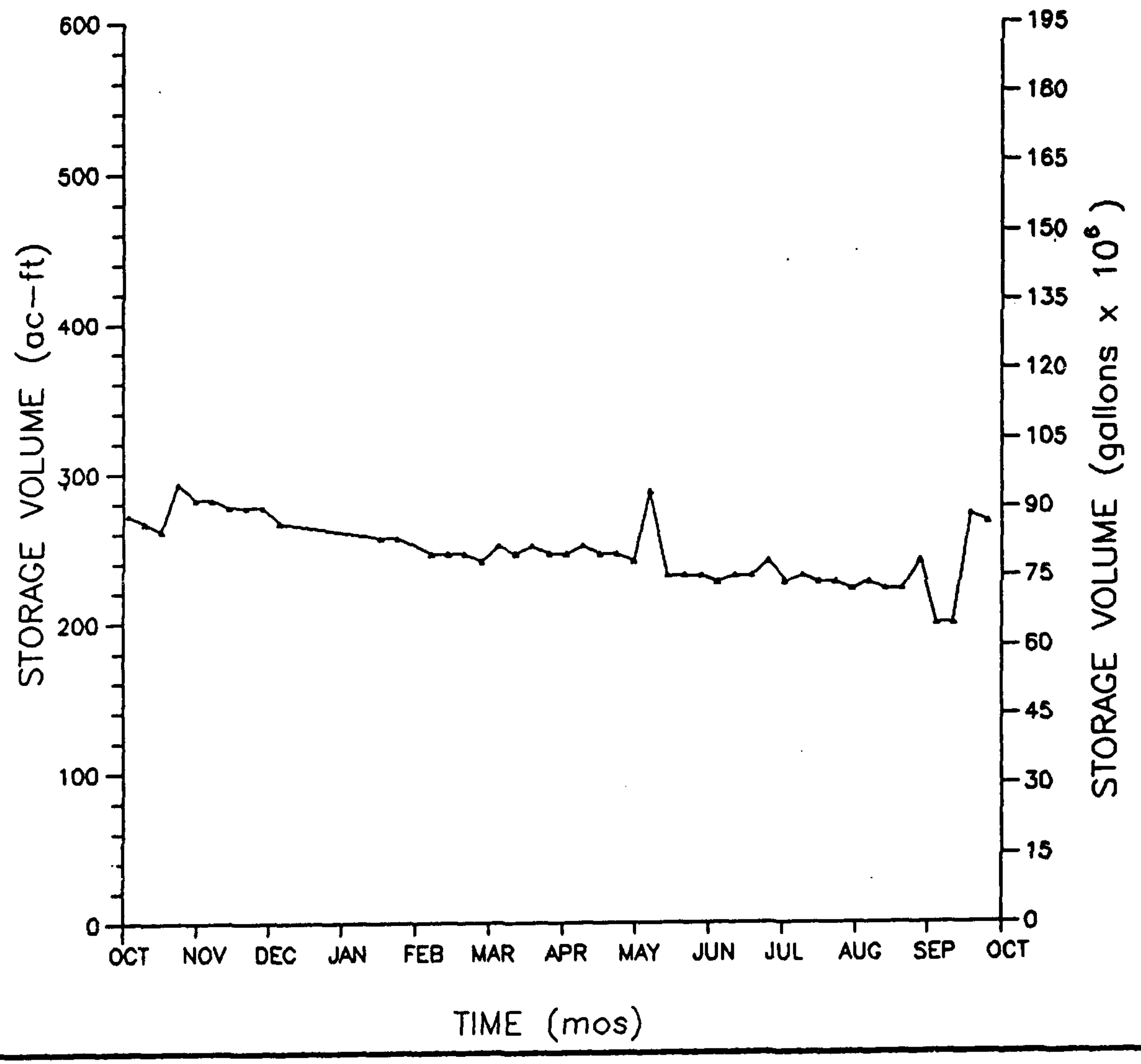

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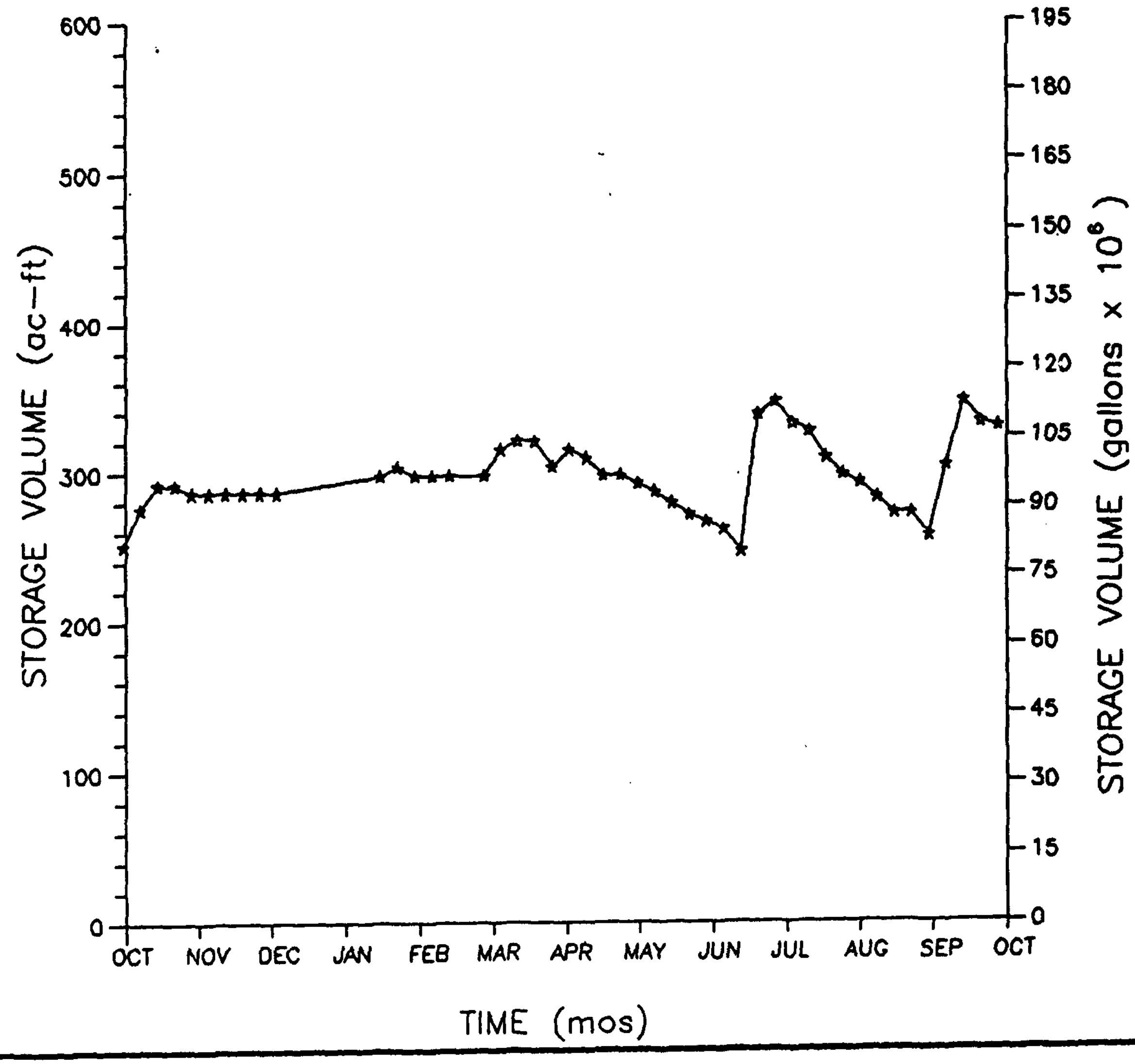
Figure 4.1-39

Lower Derby Lake
WY90 Storage Volume

CMP SW90



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Commerce City, Colorado
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Figure 4.1-40

Ladora Lake
WY90 Storage Volume

CMP SW90

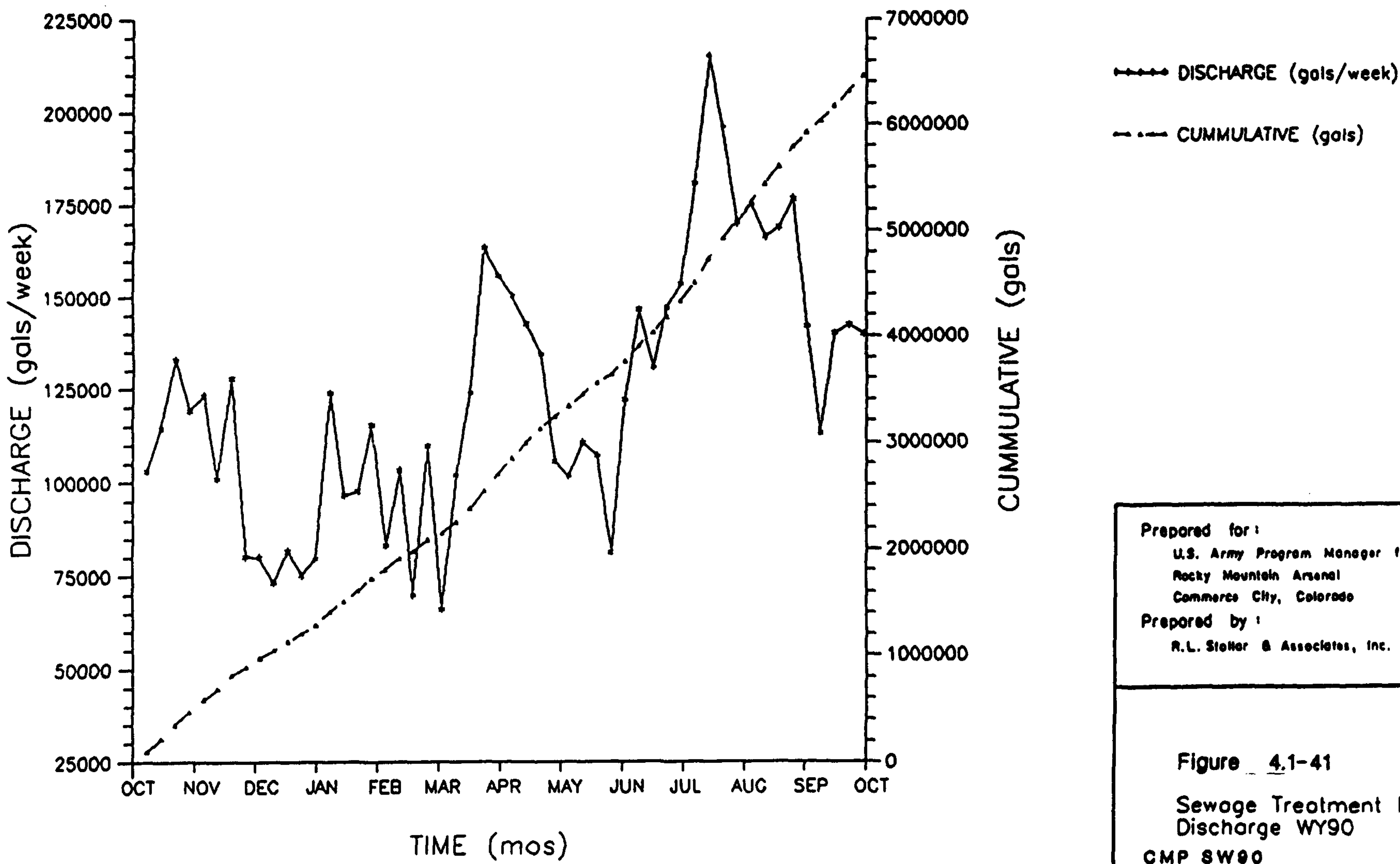

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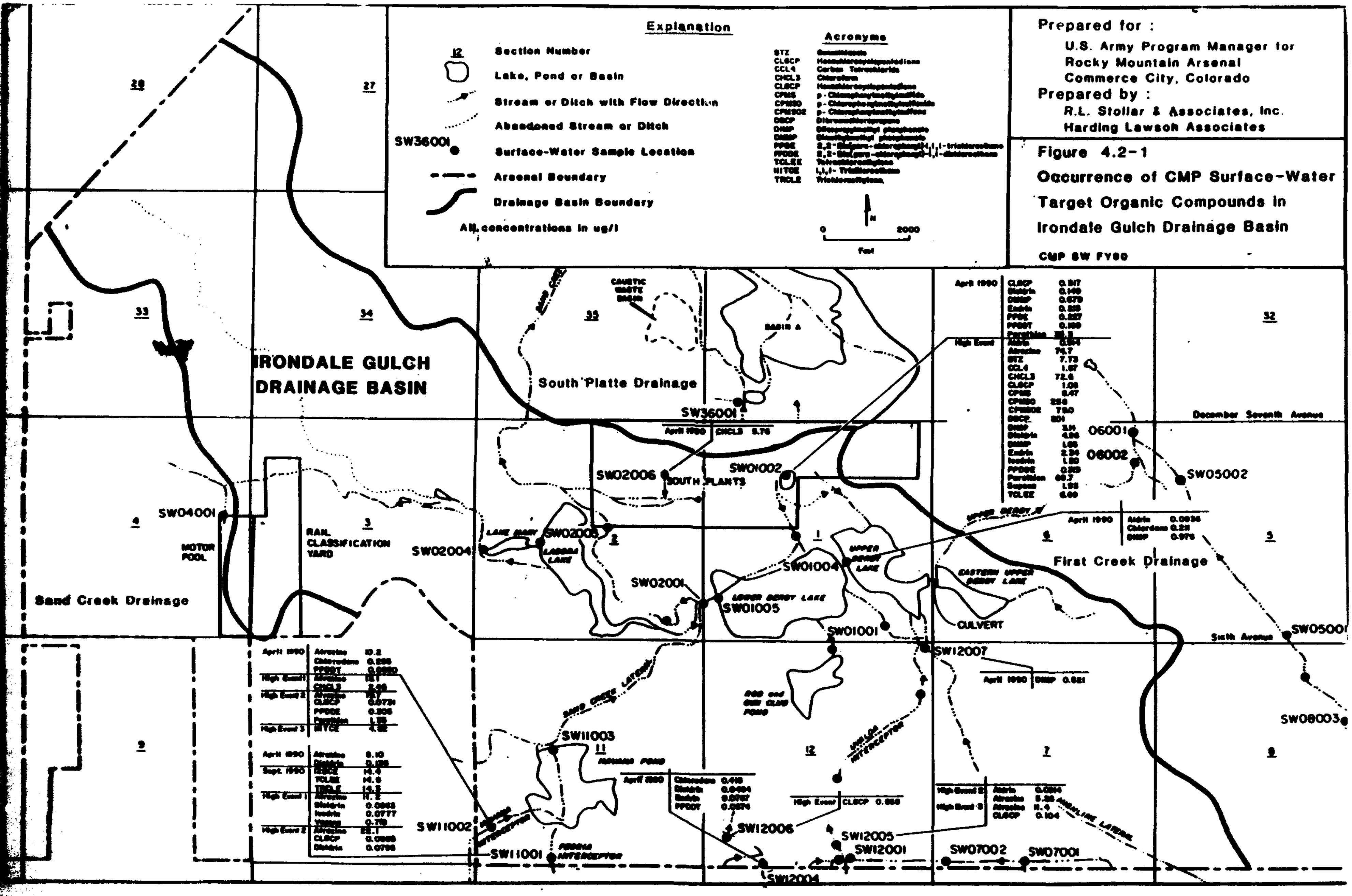
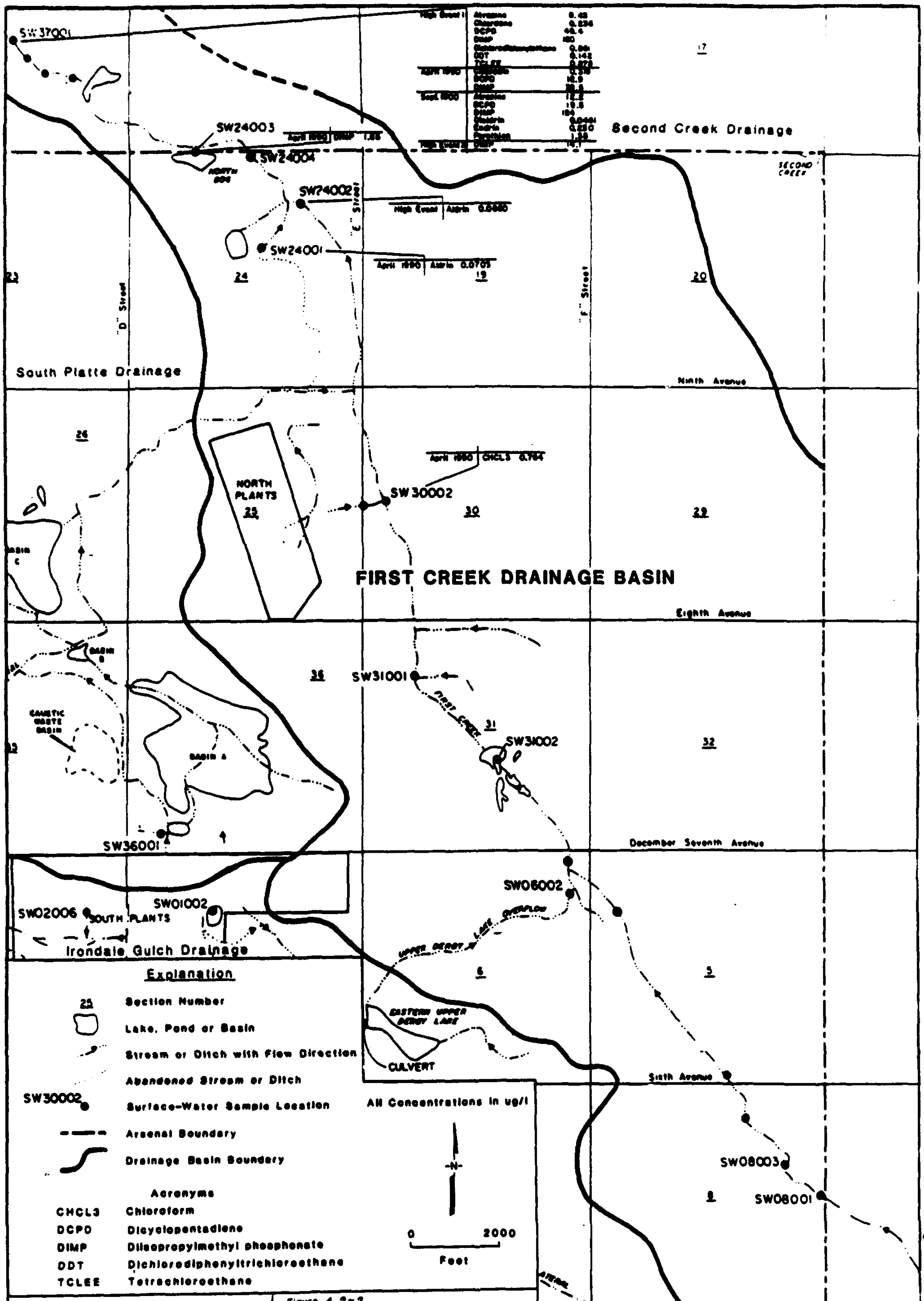
Figure 4.1-41

Sewage Treatment Plant Discharge WY90

CMP SW90


Explanation
Section Number
Lake, Pond or Basin
Stream or Ditch with Flow Direction
Abandoned Stream or Ditch
SW36001
Surface-Water Sample Location
Arsenal Boundary
Drainage Basin Boundary
All concentrations in ug/l
Acronyms
Feet
0
2000
Prepared for :
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
Harding Lawson Associates
Figure 4.2-1
Occurrence of CMP Surface-Water
Target Organic Compounds in
Irondale Gulch Drainage Basin
CMP SW FY90
IRONDALE GULCH
DRAINAGE BASIN
South Platte Drainage
Sand Creek Drainage
First Creek Drainage
RAIL CLASSIFICATION YARD
MOTOR POOL
SOUTH PLANTS
CULVERT
December Seventh Avenue
Sixth Avenue
SW04001
SW02004
SW02005
SW02006
SW36001
SW01002
SW02001
SW01004
SW01005
SW01001
SW12007
SW11003
SW11002
SW11001
SW12006
SW12005
SW12001
SW12004
SW07002
SW07001
06001
06002
SW05002
SW05001
SW08003
28
27
33
34
35
32
4
3
2
1
6
5
9
11
12
7
8
April 1990
CHCL3
5.76
High Event
April 1990
DIMP
0.021
High Event
CLDCP
0.066



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Commerce City, Colorado
Prepared by:
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Figure 4.2-2
Occurrence of CMP Surface-Water Target Organic Compounds in First Creek Drainage Basin
CMP SW FY90

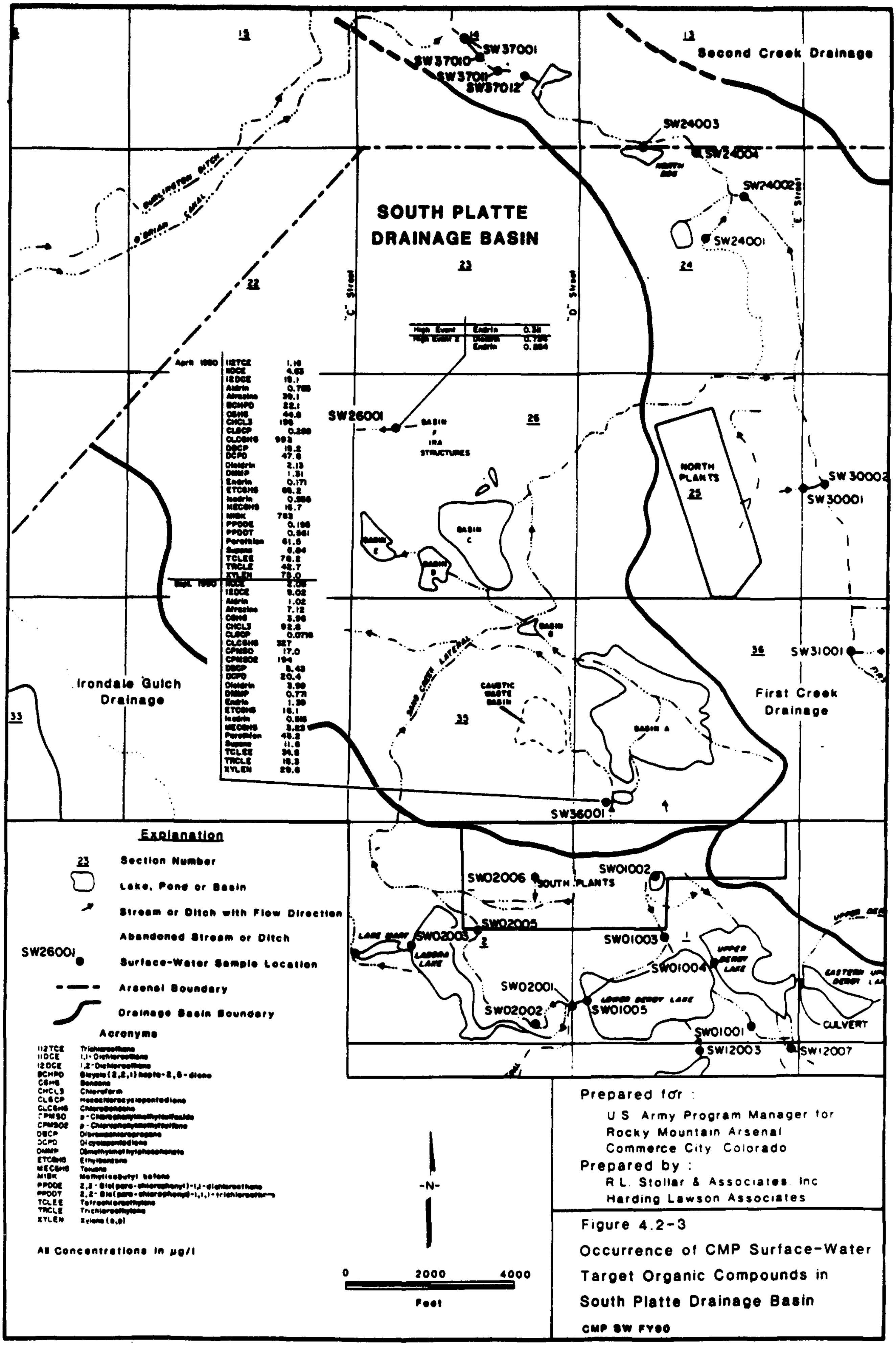

Figure 4.2-3
Occurrence of CMP Surface-Water Target Organic Compounds in South Platte Drainage Basin

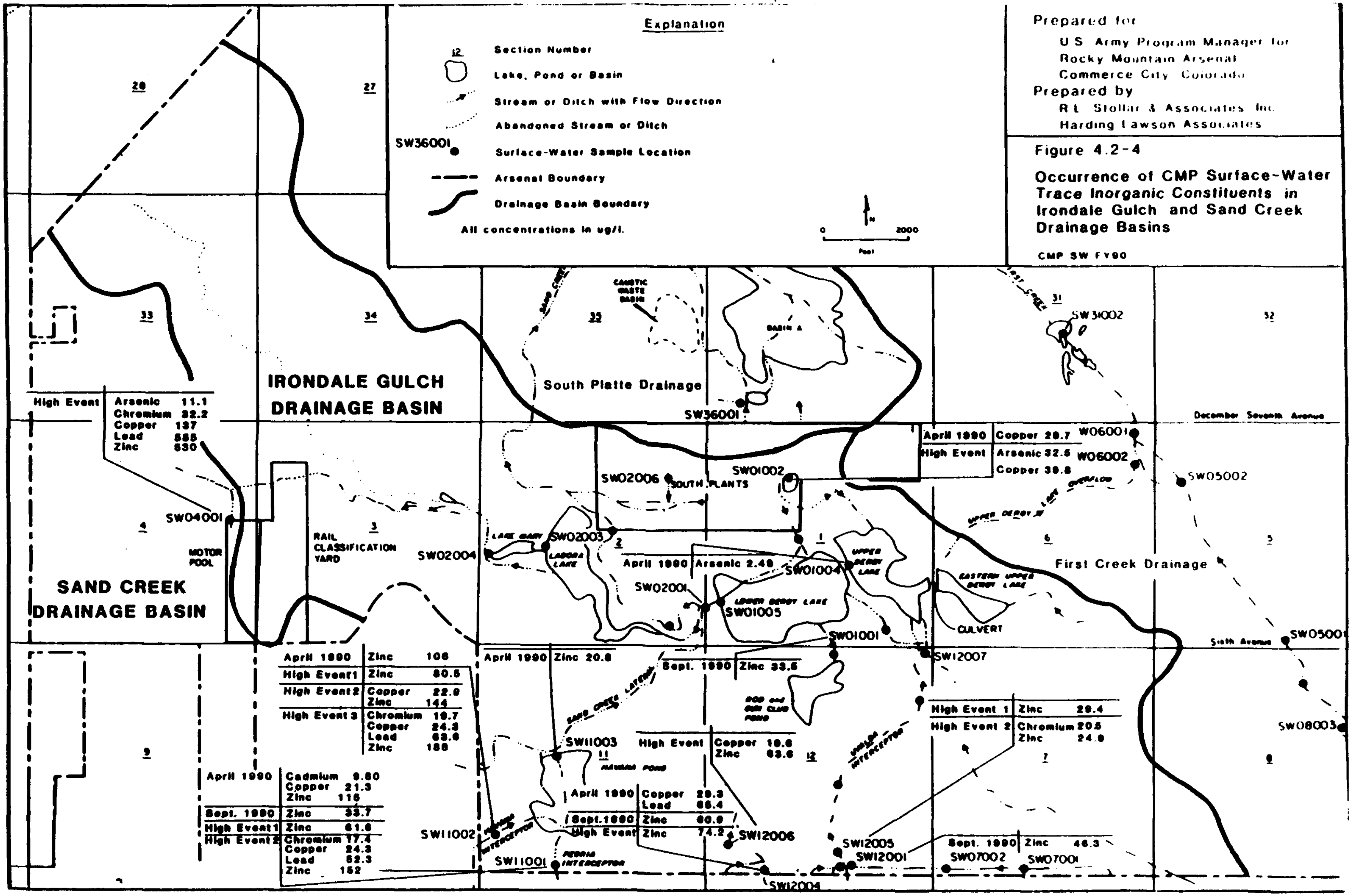
Explanation
Section Number
Lake, Pond or Basin
Stream or Ditch with Flow Direction
Abandoned Stream or Ditch
SW36001 Surface-Water Sample Location
Arsenal Boundary
Drainage Basin Boundary
All concentrations in ug/l.
0 2000
Feet
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Figure 4.2-4
Occurrence of CMP Surface-Water Trace Inorganic Constituents in Irondale Gulch and Sand Creek Drainage Basins
CMP SW FY90
IRONDALE GULCH DRAINAGE BASIN
SAND CREEK DRAINAGE BASIN
South Platte Drainage
First Creek Drainage
SOUTH PLANTS
RAIL CLASSIFICATION YARD
MOTOR POOL
CULVERT
December Seventh Avenue
Sixth Avenue
High Event Arsenic 11.1 Chromium 32.2 Copper 137 Lead 585 Zinc 530
April 1990 Copper 29.7
High Event Arsenic 32.5 Copper 39.8
April 1990 Arsenic 2.49
April 1990 Zinc 106
High Event1 Zinc 80.5
High Event2 Copper 22.9 Zinc 144
High Event3 Chromium 19.7 Copper 24.3 Lead 63.6 Zinc 188
April 1990 Zinc 20.8
Sept. 1990 Zinc 33.5
High Event Copper 19.6 Zinc 63.6
April 1990 Copper 29.3 Lead 65.4
Sept.1990 Zinc 60.9
High Event Zinc 74.2
April 1990 Cadmium 9.80 Copper 21.3 Zinc 116
Sept. 1990 Zinc 33.7
High Event1 Zinc 61.6
High Event2 Chromium 17.4 Copper 24.3 Lead 52.3 Zinc 152
High Event 1 Zinc 29.4
High Event 2 Chromium 20.5 Zinc 24.9
Sept. 1990 Zinc 46.3
SW04001
SW02004
SW02003
SW02006
SW01002
SW36001
SW02001
SW01004
SW01005
SW01001
SW12007
SW11003
SW11002
SW11001
SW12006
SW12005
SW12001
SW12004
SW07002
SW07001
SW08003
SW05001
SW05002
W06001
W06002
SW31002

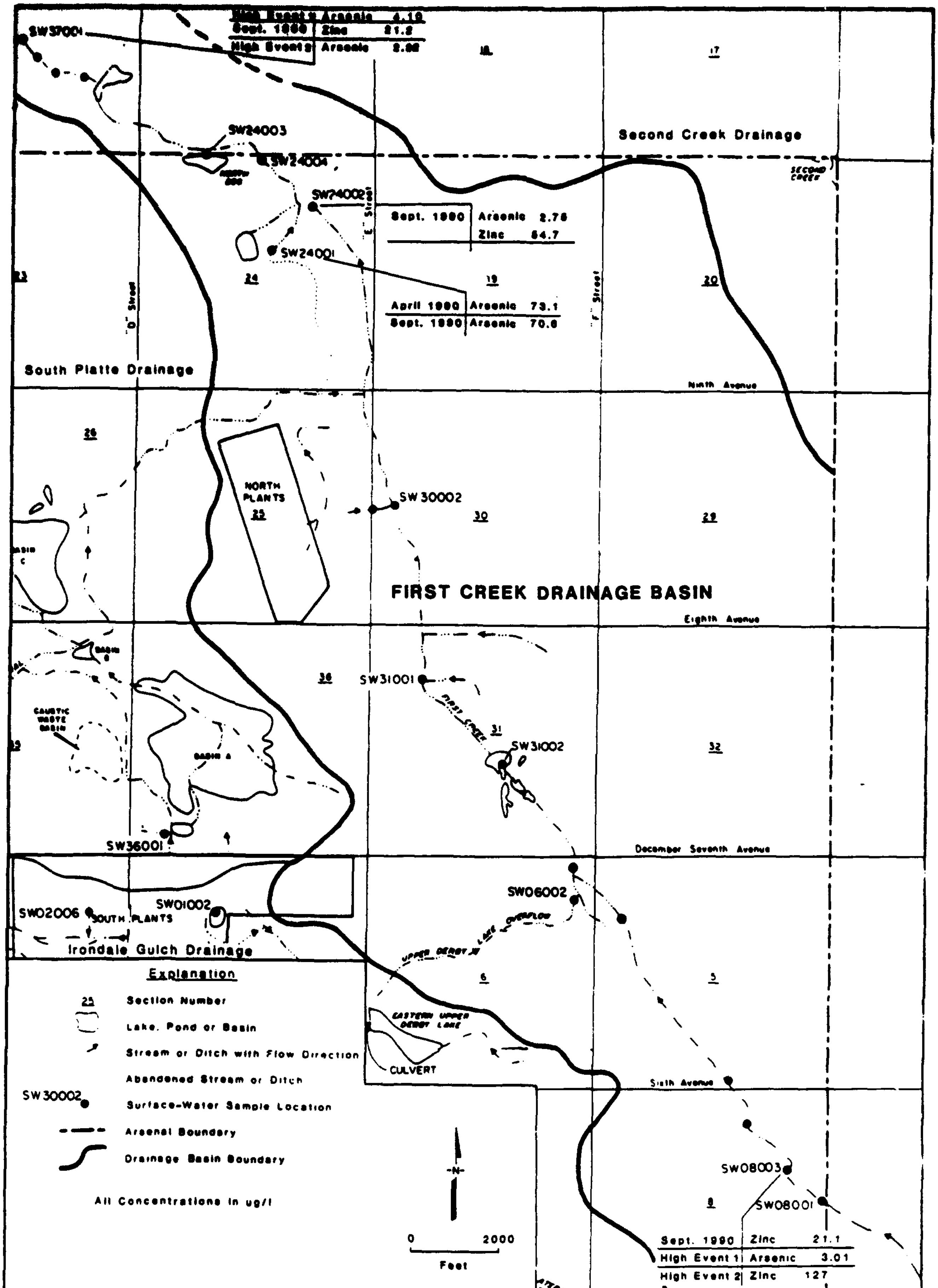

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Figure 4.2-5

Occurrence of CMP Surface-Water Trace Inorganic Constituents in First Creek Drainage Basin

CMP SW FY90

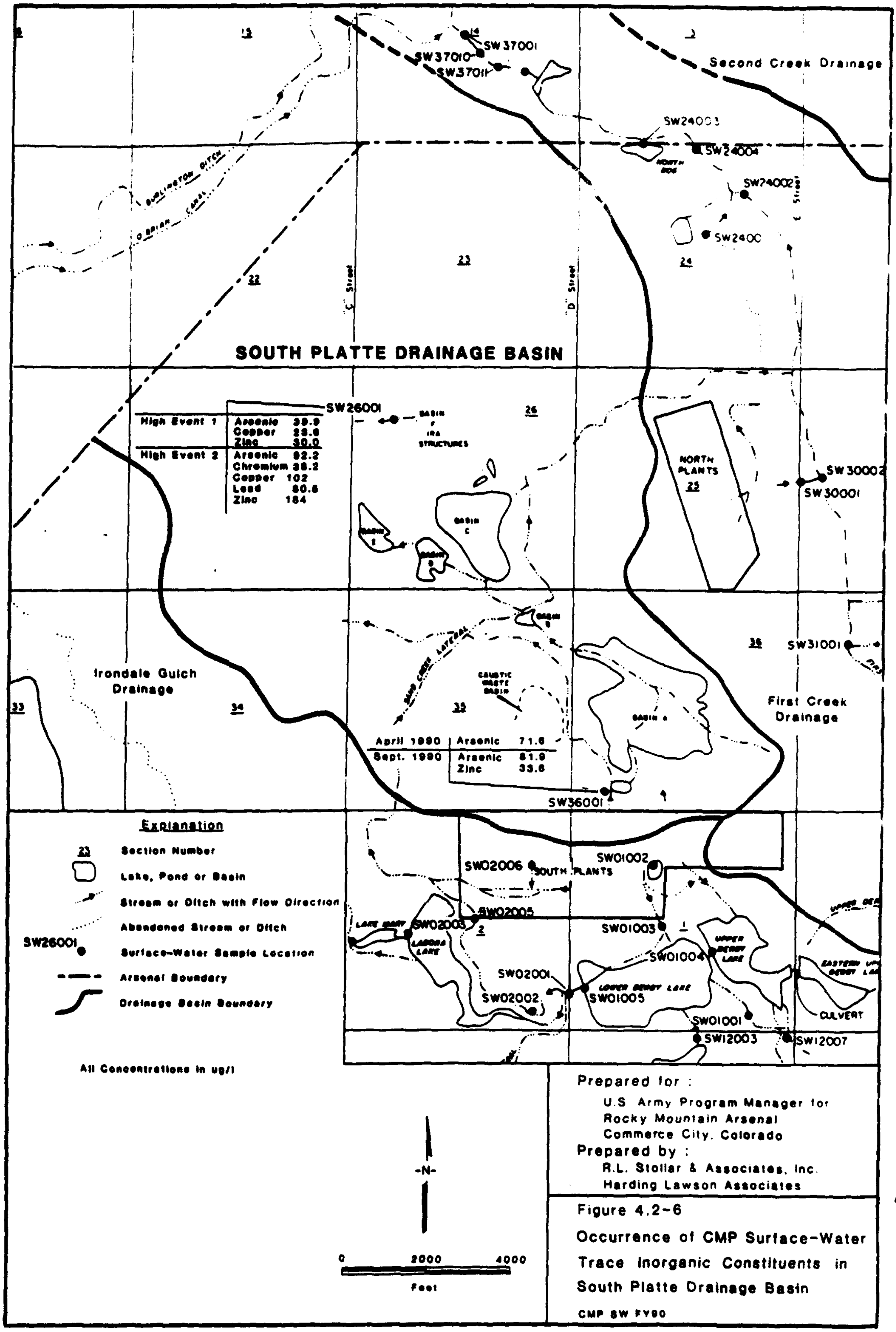

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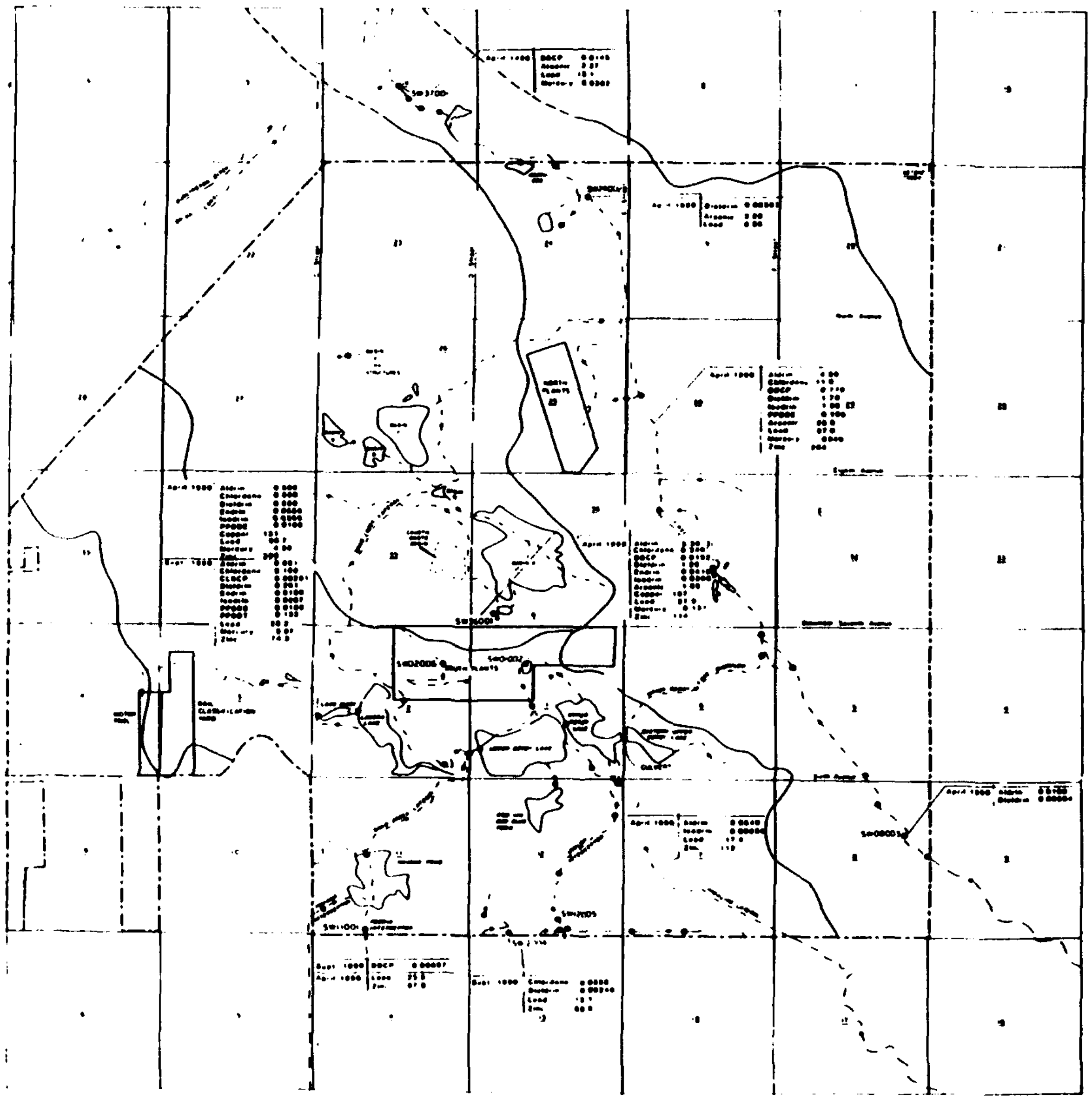
Figure 4.2-6
Occurrence of CMP Surface-Water Trace Inorganic Constituents in South Platte Drainage Basin

CMP SW FY90



Legend

- Section Number
- Lake, Pond or Basin
- Stream or Ditch with Flow Direction
- Abandoned Stream or Ditch
- Surface Water Sample Location
- Arsenal Boundary
- Drainage Basin Boundary

Acronyms

DBCP

PPDDE

CLDCP

PPDDT

FEET

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Figure 4.3-1

FY90 CMP Organic and Trace Inorganic Constituents for Stream Bottom Sediment Samples

CMP SW FY90

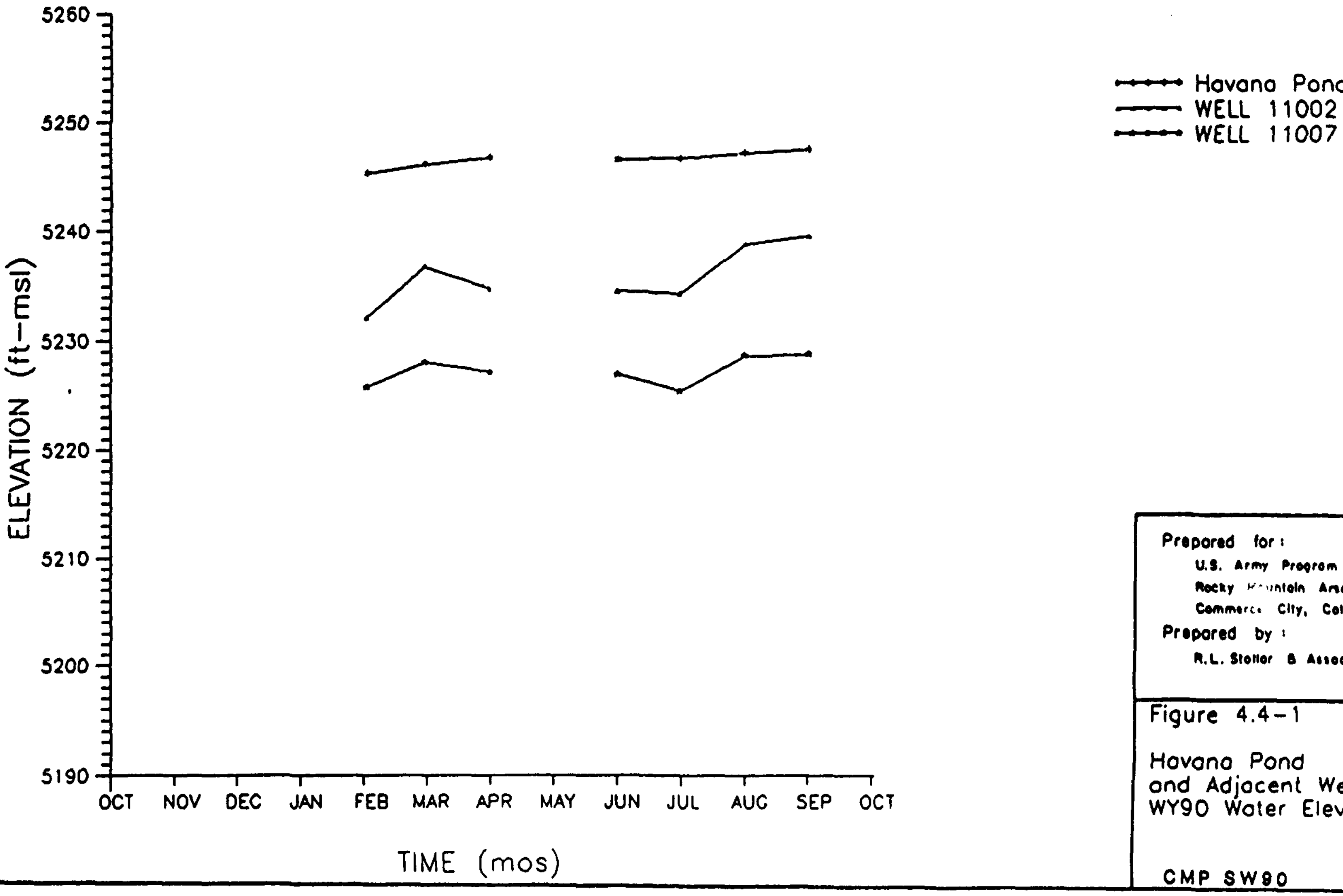

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Figure 4.4-1

Havana Pond
and Adjacent Wells
WY90 Water Elevations

CMP SW90

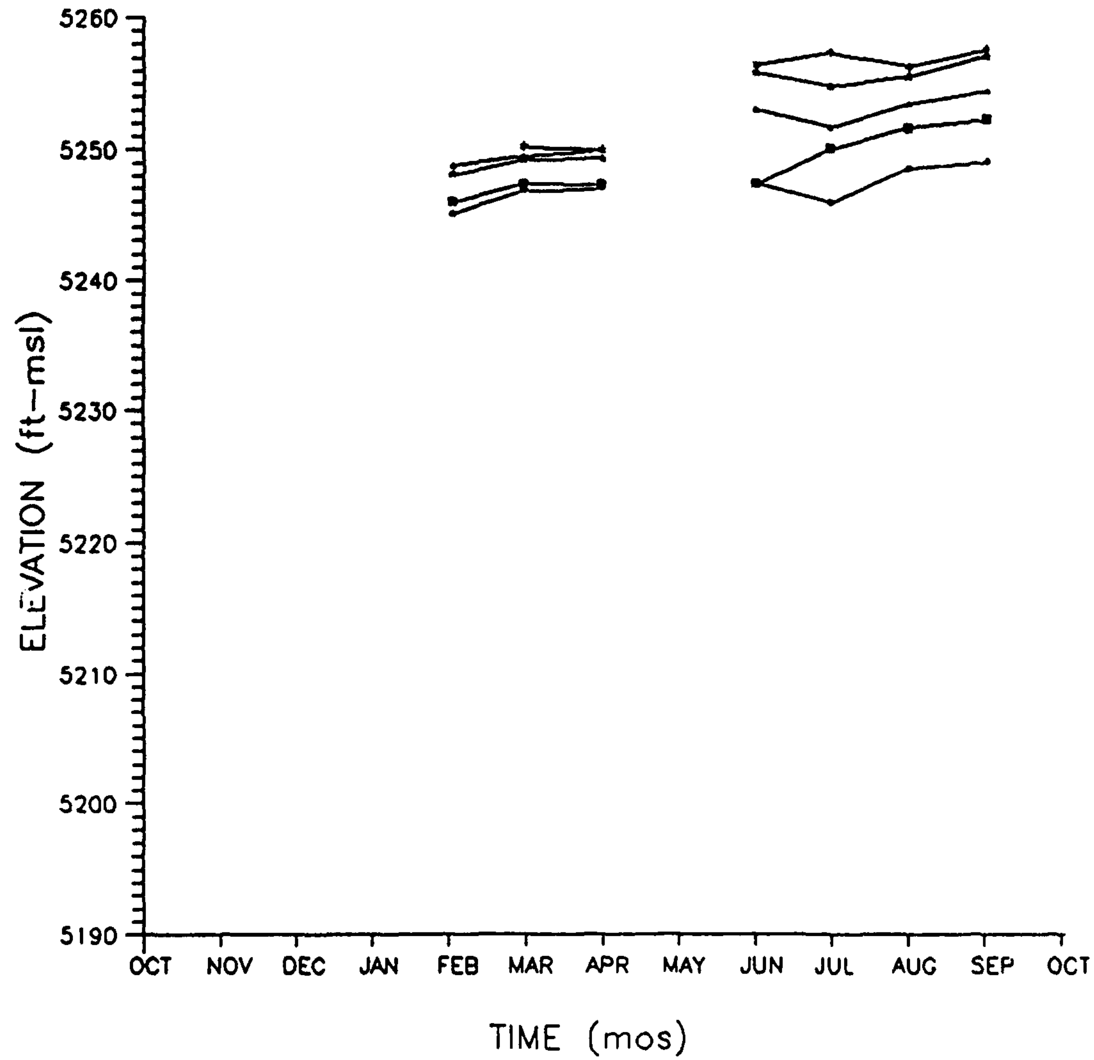

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Figure 4.4-2

Upper Derby Lake
and Adjacent Wells
WY90 Water Elevations

CMP SW90

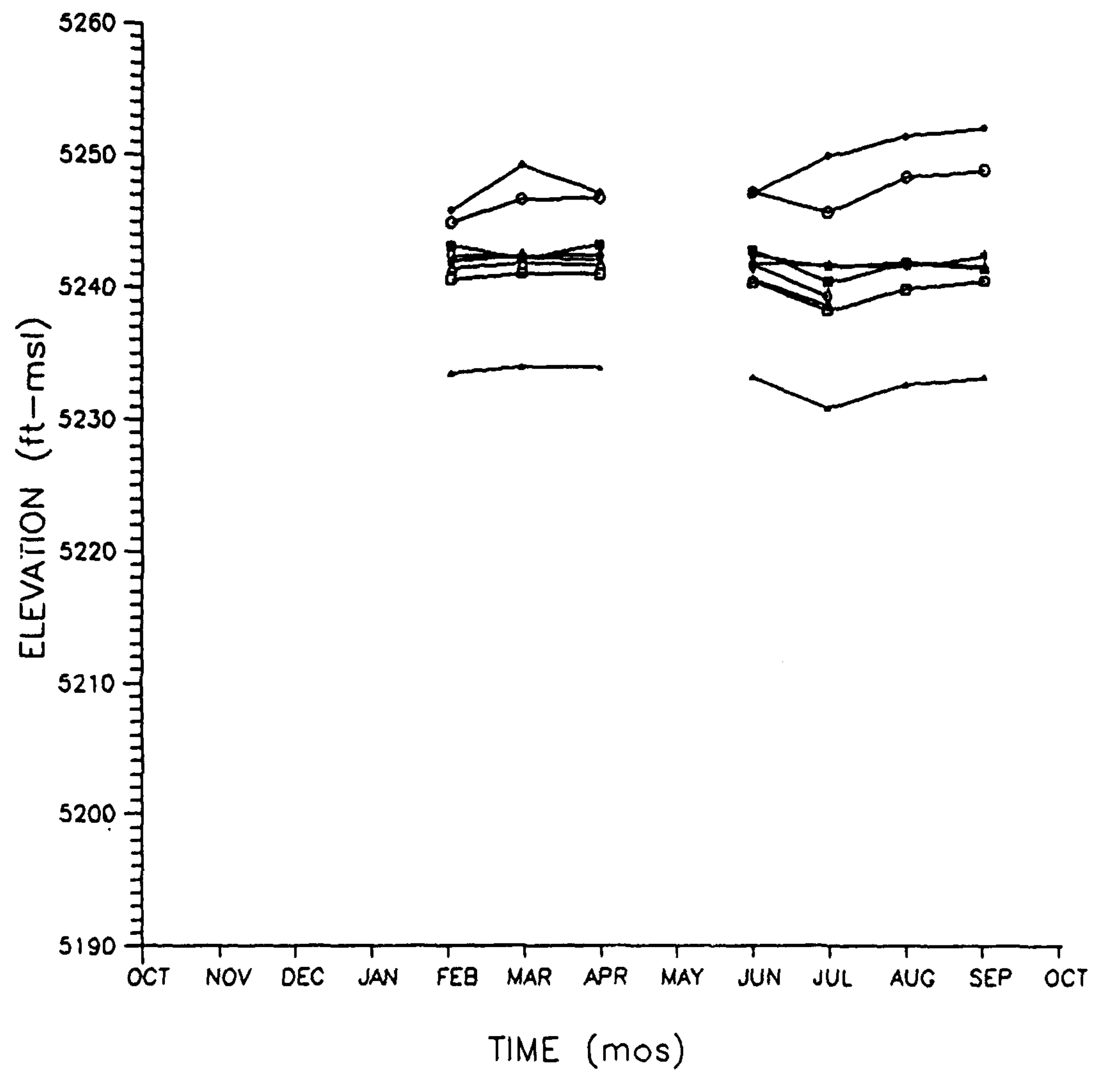

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Figure 4.4-3

Lower Derby Lake
and Adjacent Wells
WY90 Water Elevations

CMP SW90

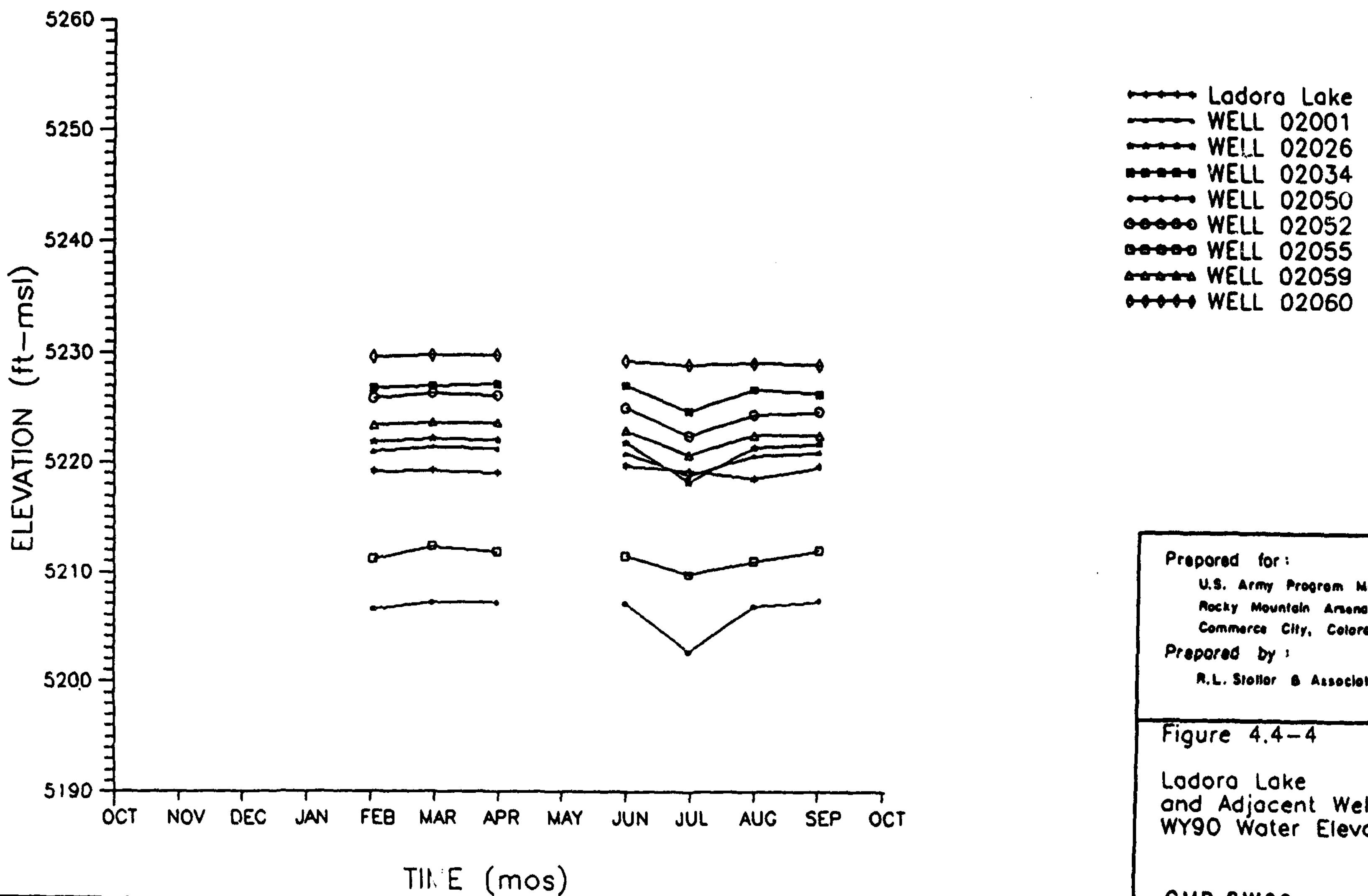

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Figure 4.4-4

Ladora Lake
and Adjacent Wells
WY90 Water Elevations

CMP SW90

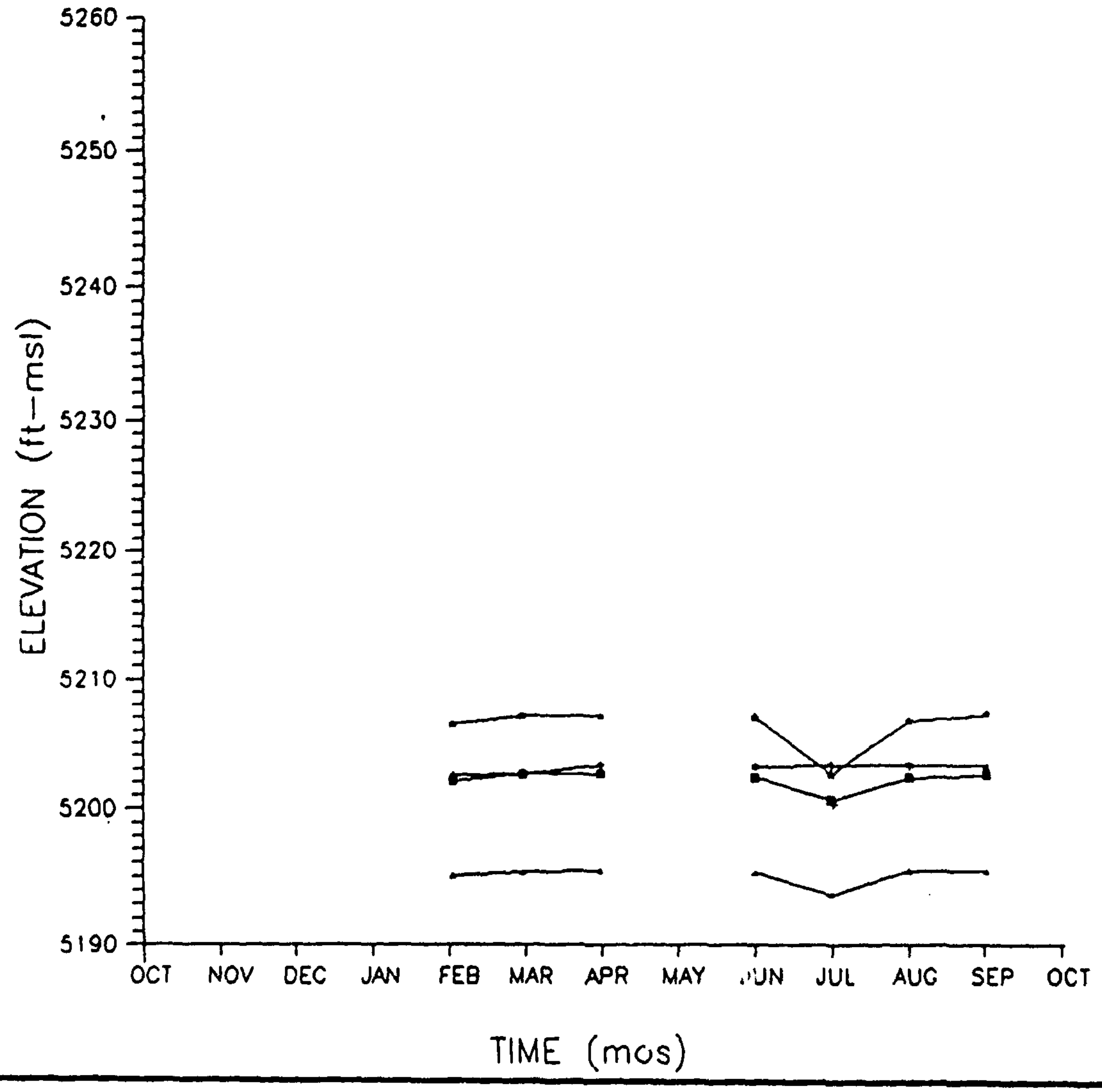

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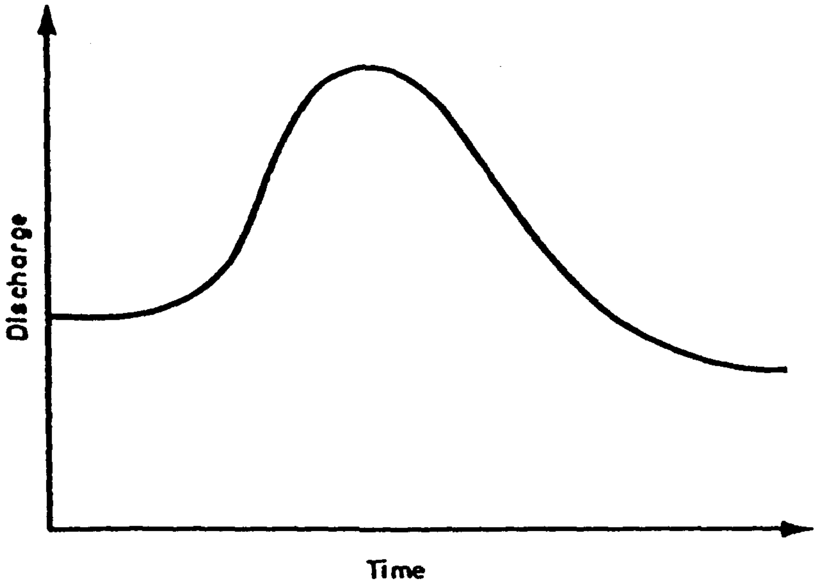
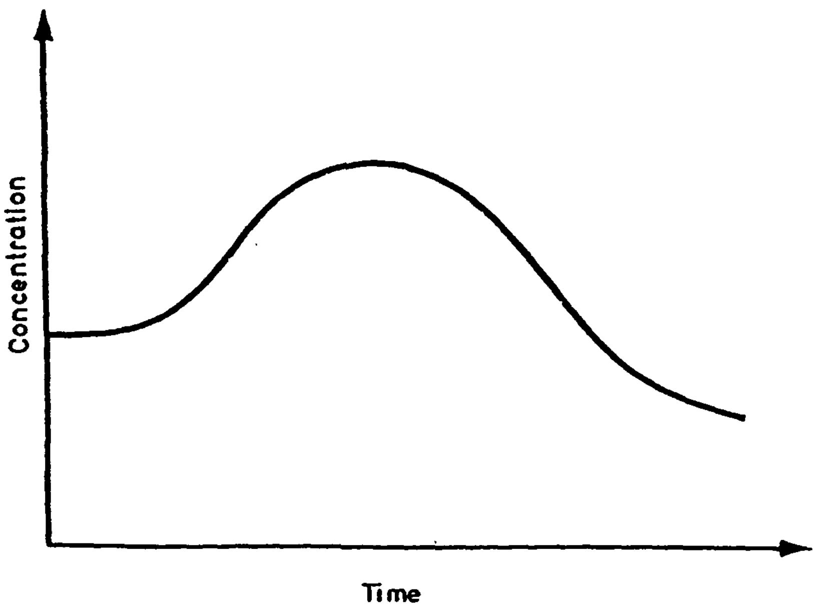
Figure 4.4-5

Lake Mary
and Adjacent Wells
WY90 Water Elevations

CMP SW90





EXPLANATION

——— Dissolved Concentration in Water

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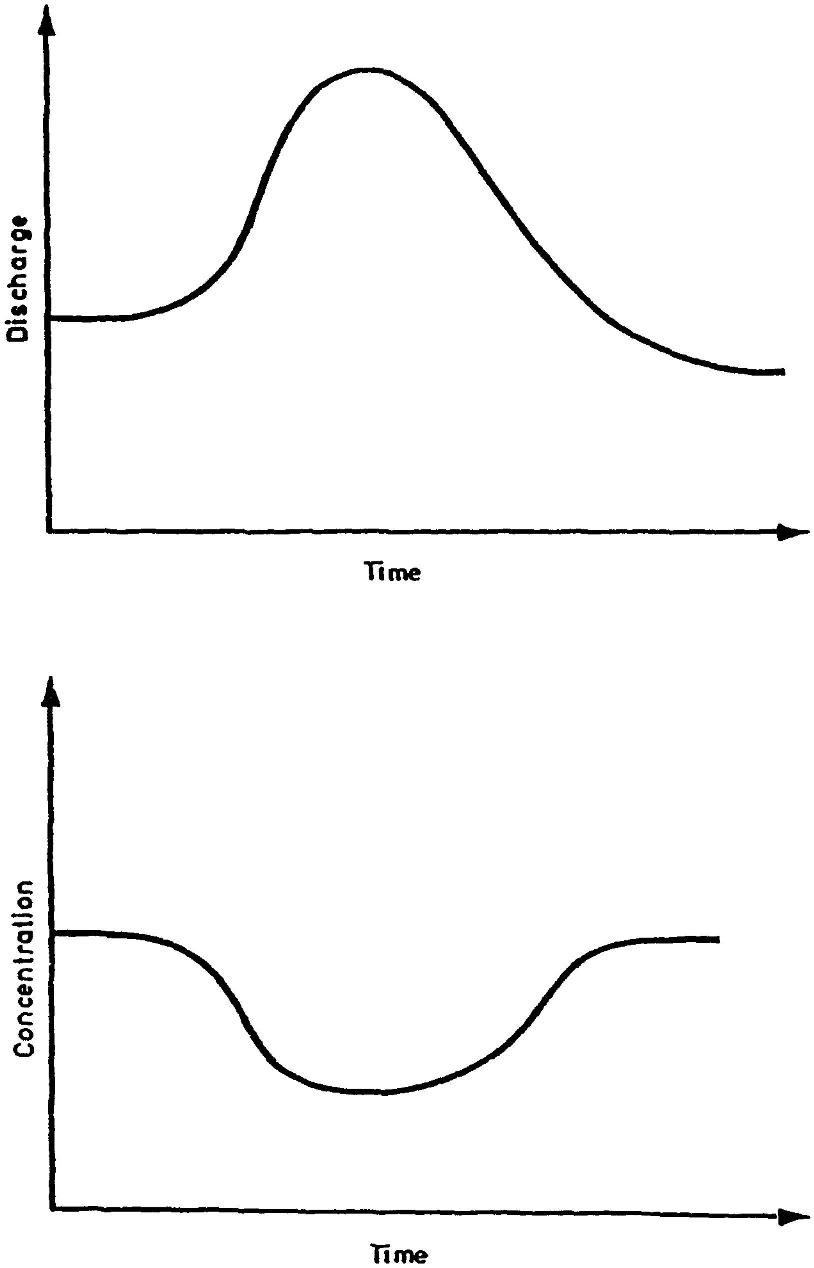
Figure 6.2-1

Direct Relationship Between Discharge and Concentration

CMP SW FY90



EXPLANATION

——— Dissolved Concentration in Water

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Figure 6.2-2

Inverse Relationship Between Discharge and Concentration

CMP SW FY90