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THE PURPOSE OF THIS REPORT IS TO PROVIDE AN EXAMINATION OF THE TRENDS AND CONTAMINANT CONCENTRATIONS AT INTERNAL AND BOUNDARY CONTAINMENT SYSTEMS. IN ADDITION, EMPHASIS HAS BEEN PLACED ON EXAMINING THE CONFIGURATION OF CONTAMINANT PLUMES IMMEDIATELY UPGRADIENT OF THESE SYSTEMS TO ASSESS WHY CERTAIN CONTAMINANTS ARE ABSENT IN CONTAINMENT SYSTEMS' INFLUENT. THE FOLLOWING SECTIONS BRIEFLY DESCRIBE SITE CONDITIONS, AND PRESENT THE RESULTS OF THESE EVALUATIONS: SECTION 1.0 INTRODUCTION AND BACKGROUND. SECTION 2.0 METHODOLOGY. SECTION 3.0 RESULTS AND DISCUSSION. SECTION 4.0 CONCLUSIONS. SECTION 5.0 REFERENCE. ALSO INCLUDED IN THE REPORT PRIMARY FLOWPATH CONCENTRATION PROFILES AS APPENDIX A.

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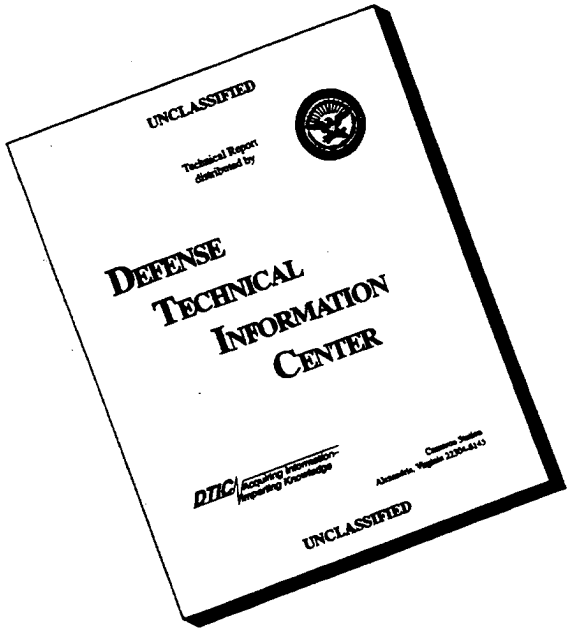

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WHITE PAPER

GROUNDWATER CONTAMINANT CONCENTRATION TRENDS AT ROCKY MOUNTAIN ARSENAL

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EXECUTIVE SUMMARY

The groundwater monitoring history at the Rocky Mountain Arsenal (RMA) has provided the opportunity to evaluate trends in contaminant concentrations at internal and boundary groundwater containment systems. The primary purpose of this assessment was to help optimize long-term operation of internal and boundary containment systems by providing some insight into long-term trends in contaminant concentrations.

The results of this study demonstrate the total organic contaminant concentrations approaching the RMA boundaries are decreasing overall. Along several plume flowpaths, steep concentration gradients are observed spatially for several organic contaminants. Concentrations decrease to below Offpost Preliminary Remediation Goals or analytical reporting limits upgradient of the Basin A-Neck area and the RMA boundaries. Although determining the mechanisms responsible for these decreases is not within the scope of this report, they undoubtedly include a combination of cessation of manufacturing/ disposal activities, implementation of IRAs and other site-specific management activities, and natural attenuation mechanisms.

1.0 INTRODUCTION

Chemical production and disposal activities at the Rocky Mountain Arsenal (RMA) began over 50 years ago and ended in 1982. Groundwater monitoring has been conducted at least since the mid-1970s. The nature and extent of contamination was defined for the Remedial Investigation (RI) and has subsequently been monitored by the Comprehensive and Groundwater Monitoring Programs (CMP and GMP, respectively). In addition to these programs, IRA and Feasibility Study (FS) investigations and routine boundary system monitoring have provided detailed information in specific areas.

Onpost data collected at RMA over the last two decades indicate that groundwater contaminant concentrations are changing, albeit slowly in many cases, throughout the unconfined flow system (UFS). While the mass of contaminants in groundwater may be small relative to the mass contained in soils, knowledge of groundwater contaminant concentration trends has implications for the long-term operation of containment systems and future groundwater monitoring needs. Ensuring effective boundary system operations is critical because they will be an important component of the final remedy at RMA.

The purpose of this report is to provide an examination of the trends in contaminant concentrations at internal and boundary containment systems. In addition, emphasis has been placed on examining the configuration of contaminant plumes immediately upgradient of these systems to assess why certain contaminants are absent in containment systems' influent. The following sections will briefly describe site conditions, and present the results of these evaluations.

1.1 BACKGROUND

1.1.1 Hydrogeology

In the September 1993 Morrison Knudsen (MK) report, "Groundwater Flows and Recharge on the RMA," distributed to the Organizations and State, three onpost unconfined groundwater flow systems were identified. These are the Irondale, Central, and First Creek Flow Systems. The Central Flow System contains the majority of contaminant mass in groundwater, the major historical production and disposal areas (i.e., South Plants and Basins A through F), and the western portion of the North Boundary Containment System (NBCS). Figures 1-1 and 1-2 illustrate unconfined groundwater flow directions and approximate flows, respectively, for the three systems.

Hydraulic conductivities, groundwater flows, and flow velocities are substantially lower in the Central Flow System than in the Irondale and First Creek Flow Systems. Groundwater in the Central Flow System is primarily derived from local recharge, whereas regional flow is dominant in the other two flow systems. Flow in the South Plants portion of the Central Flow System is influenced by a groundwater mound, which has declined recently as sources of artificial recharge have been eliminated (i.e., shutdown of South Plants water lines and sewers). Historical water-level declines have occurred in other areas of the Central Flow System as other sources of artificial recharge were eliminated (e.g., Basin C flushing and Basin F closure),

Total unconfined groundwater flows are approximately 15-20 gallons per minute (gpm) in the Central system; 3,500 to 4,000 gpm in the Irondale system; and 250 gpm in the First Creek Flow System. The Central Flow System is comprised of individual flow

streams which are generally in the range of a few gpm, with Basin A/Basin A-Neck ranging from 10-15 gpm.

The primary migration pathway from Basin A is through the Basin A-Neck paleochannel through the Basin A-Neck Containment System (BANCS), and to the northwest toward the Northwest Boundary Containment System (NWBCS). Since the alluvium is unsaturated outside of this narrow paleochannel, the majority of UFS flow in southern and southwestern Section 26 occurs within the channel.

CMP and GMP migration pathway interpretations have shown that contaminants migrate north from Basin A-Neck, under Basins C and F, and to the NBCS. Shell believes that currently this interpretation is incorrect because it is contrary to the occurrence of saturated alluvium and flow pathways derived from water-table maps. Some component of flow may have been toward the NBCS historically when Basin A was used in the 1940s and 1950s and water levels were higher.

1.1.2 Nature and Extent of Contamination

Numerous investigations have been conducted to determine the nature and extent of UFS contamination at RMA [Water RI (Ebasco 1989), RI Study Area Reports (Ebasco 1989a-g), RI Summary Report (Ebasco 1992a), CMP Reports (Stollar 1989, 1990, and 1991), 1991 GMP (HLA 1992)]. Therefore, a detailed description of nature and extent will not be presented here. However, to evaluate general trends in contaminant concentrations, a general understanding of contaminant distributions is necessary.

The Final Detailed Screening of Alternatives (DSA) (Ebasco 1992b) and Draft Final Detailed Analysis of Alternatives (DAA) (Ebasco 1993) provided an overview of the nature and extent of UFS contamination at the RMA. Due to hydrogeologic characteristics

and the presence of internal and boundary containment systems, the individual plumes were simplified into 5 plume groups in the DSA and DAA. These 5 plume groups are: Northwest Boundary, Western, North Boundary, Basin A, and South Plants. Figure 3.1-1 of the DAA is provided here as Figure 1-3.

Both the Northwest and Western plume groups consist of low-level groundwater contamination with much of the flow passing through upgradient intercept systems (e.g., Basin A-Neck IRA, and Rail Classification Yard (Railyard) and Motor Pool IRA systems). Data collected from recently installed monitoring wells indicate that a small component of contaminated flow in the Northwest plume group originates from South Plants (i.e., continuation of the South Plants Southwest Plume). This flow, flow from Basin A-Neck, and small flows from Sand Creek Lateral and western portions of former Basins C and F migrate to the NWBCS and are captured and treated.

The North Boundary plume group consists of plumes primarily originating from Basins C and F as well as from the North Plants. Contaminated groundwater within this plume group is captured and treated at the NBCS. Highly contaminated groundwater north of former Basin F is pumped from the Basin F IRA extraction well to the BANCS for treatment and reinjection.

The South Plants plume group consists of the various plumes which originate within South Plants and are influenced by the groundwater mound (e.g., flow radially from the mound). As described in MK (1993), any contaminated groundwater originating or influenced by the mound is integrated into the regional flow patterns and eventually captured and treated at one of the internal or boundary containment systems.

The Basin A plume group consists of the contaminant plumes which originate from northern portions of South Plants and from the various disposal areas within and adjacent to the basin. Groundwater within the basin is contained by a bedrock ridge and the majority of groundwater flows through Basin A-Neck, where it is captured and treated.

In a comprehensive evaluation of the Denver Formation at RMA, MK (1994) concluded that very few wells which are completed solely within the confined flow system (CFS) are consistently contaminated. The paper concluded that CFS detections were localized and most likely resulted from contaminant introduction during well installation or sampling processes. Consequently, virtually all of the contaminant mass which is found in groundwater on the RMA resides within the UFS.

2.0 METHODOLOGY

2.1 GENERAL APPROACH

The water-quality data used for this evaluation were either compiled from published reports or extracted from the RMA environmental database. The report emphasizes the evaluation of trends immediately upgradient of the RMA boundaries and internal systems because trends in these areas will have a direct impact on the long-term operation of the systems and because trends could be readily evaluated by assessing treatment plant influent water quality. The treatment plant influent is readily evaluated because it is monitored frequently and provides a composite sample of the groundwater intercepted.

2.1.1 Changes in Contaminant Concentrations and Dissolved Weight at Containment Systems

Temporal concentration changes in treatment plant influent were evaluated to assess trends in contaminant concentrations in groundwater approaching the containment systems. In some instances (i.e., the Railyard and Motor Pool), temporal concentration changes in individual upgradient monitoring wells were evaluated to assess trends in contaminant concentrations approaching the systems. Since boundary system treatment plant influent concentrations and flows are measured, it is possible to estimate the contaminant mass flux at each system. These data have been used as the primary means of evaluating contaminant concentration trends upgradient of the boundary systems.

2.1.2 Plume Axis Concentration Profiles

During this investigation, it was found that the spatial characteristics of numerous onpost plumes have a dramatic impact on the concentrations of contaminants approaching the boundary systems. Thus, the overall configuration of the plumes were examined in terms of how this phenomenon affects internal and boundary containment systems.

Spatial changes in these contaminant plumes can be evaluated by examining wells located along the main axis of each plume. This method requires a sufficient number of monitoring points located along the plume axis or primary flowpath and provides essentially a 2-dimensional cross-sectional view of the contaminant plume. Monitoring wells that define plume axes in the fiscal year (FY) 1990 CMP sampling event (Fall 1989) were used to show the profiles for selected organics. Contaminant concentration profiles were generated along plume axes for benzene, chlorobenzene, chloroform, DBCP, DCPD, dieldrin, DIMP, tetrachloroethene, and trichloroethene (TRCLE).

3.0 RESULTS AND DISCUSSION

3.1 EVALUATION OF INFLUENT CONCENTRATIONS, AND DISSOLVED WEIGHT OF BOUNDARY CONTAINMENT SYSTEMS

To illustrate temporal concentration trends near the boundary systems, the treatment plant influent concentrations and estimated mass flux (weight) for individual analytes are shown for each system. Since changes in extraction well pumping rates and total flow rates affect influent concentrations, average flows and concentrations were used in a simple mass balance approach to calculate changes in average influent mass intercepted at each system. Contaminant removal is typically reported in pounds in operations reports therefore, contaminant weight in pounds is reported on the figures.

3.1.1 North Boundary Containment System (NBCS)

The NBCS became operational in its present configuration in late 1981. The treatment plant was modified in 1990 and a total of 15 recharge trenches were installed in 1988 and 1990 under the Boundary System Improvements IRA.

3.1.1.1 Influent Concentrations and Weight

Figures 3-1 through 3-8 show influent concentrations and weight of chloroform, CPMSO2, DBCP, DCPD, dieldrin, DIMP, tetrachloroethene, and TRCLE. These 8 compounds were chosen for analysis because they comprise over 90 percent of the contaminant mass intercepted by the NBCS. The volatile compounds were added to the monitoring program in 1987, therefore, their sampling histories are shorter than for the other analytes.

Except for dieldrin, concentrations have declined overall between FY1984 and 1993. Decreases in concentrations and weight are especially significant for chloroform, DBCP, DCPD, and tetrachloroethene. The significant decrease in chloroform influent concentrations between 1988 and 1989 (65% decrease) coincides with decreases in upgradient monitoring wells. Higher concentrations and weight of most contaminants in 1988 coincided with higher pumping rates of the A manifold which intercepts the highest concentrations in the North Boundary Plume. Although concentrations of dieldrin have been more consistent over time, based on the decreasing concentrations in wells located near Former Basin F on Figure A-12, decreases in influent concentrations are anticipated in the future.

Figure 3-9 illustrates the overall decrease in total concentrations for the sum of the 8 contaminants. These data indicate that although short-term increases in particular contaminants may occur due to operational changes, the long-term trend in concentrations is downward.

3.1.2 Northwest Boundary Containment System (NWBCS)

The NWBCS was installed in 1984 to intercept a contaminant plume that emanated primarily from South Plants/Basin A. Under the Boundary System Improvements IRA, the NWBCS soil-bentonite barrier was extended 665 ft to the northeast and two extraction wells were installed in 1990 to intercept contaminated flow in a small bedrock channel (Northeast Extension). Three extraction wells and four recharge wells were installed in northwestern Section 27 in 1991 [Southwest Extension (SWE)] to intercept a dieldrin plume that is separated from the main NWBCS plume by a zone of uncontaminated groundwater. The SWE is not contiguous with the original system because it is unnecessary to intercept this uncontaminated groundwater between the plumes.

3.1.2.1 Influent Concentrations and Weight

Table 3-1 lists the analytes detected in the NWBCS influent each fiscal year and the average influent concentrations for the three most commonly detected contaminants (i.e., chloroform, DIMP, and dieldrin). Between FY1988 and FY1993, the number of analytes detected decreased from 10 to 2.

Figures 3-10, 3-11, and 3-12 show influent concentration and weight trends for chloroform, DIMP, and dieldrin, respectively. While chloroform and DIMP concentrations show decreasing trends, dieldrin concentrations have remained relatively constant. Increased dieldrin flux since 1987 is attributed to increasing pumping rates and in late FY1991, commencement of operation of the SWE. Figure 3-13 illustrates the overall decrease in total weight for the 7 contaminants that comprise over 90 percent of the mass intercepted historically by the NWBCS (i.e., chloroform, DBCP, DCPD, dieldrin, DIMP, tetrachloroethene, and TRCLE).

Since operation of the NWBCS began in 1984, concentrations of DBCP, DCPD, tetrachloroethene, and TRCLE have decreased and are no longer detected in the NWBCS influent. Of these compounds, only low levels of TRCLE are still detected in upgradient monitoring wells and extraction wells.

Groundwater quality data downgradient of the BANCS indicate that groundwater that has been treated and reinjected at the BANCS has probably not reached the NWBCS. Thus, the beneficial effects of the BANCS do not appear to be responsible for the observed decreases at the NWBCS.

3.1.3 Irondale Containment System

The Irondale Containment System (ICS) became operational in 1981. In 1991, the original system was modified to include additional extraction and recharge wells and a new adsorber. Four extraction wells (east row) located approximately 2,000 ft upgradient of the original ICS and 9 recharge wells were installed adjacent to the original system. After startup of the east row in April 1991, downgradient concentrations decreased and operation of all of the original Irondale extraction wells (i.e., the center and west rows) was discontinued in September 1992. In September 1993, 8 of the original Irondale extraction wells in the center row were put back into operation for the remainder of the year.

3.1.3.1 Influent Concentrations and Weight

Figure 3-14 shows that the influent concentration of DBCP has declined overall since 1987. Higher influent concentrations and weight in 1991 were caused by startup of the IRA extraction systems (i.e., Railyard and Irondale east row) but have since declined as the size of the contaminated area has been reduced. As shown on Figure 3-14, average treatment plant influent concentrations of DBCP have been below the Offpost PRG of 0.195 ug/l since 1991, are continuing to decline, and were approximately 0.08 ug/l in 1994. Those decreases in influent concentrations are consistent with concentration decreases in the monitoring wells located within the DBCP plume.

TRCLE has been monitored in the Irondale influent since 1988. TRCLE concentrations decreased each year until the Motor Pool and east row extraction wells became operational in late 1991 (Figure 3-15). After an initial increase caused by the additional pumping, concentrations have continued to decrease

slightly and are below the Offpost PRG of 3 ug/l. This is consistent with long-term TRCLE concentration declines observed in the monitoring wells located within the Motor Pool TRCLE plume.

3.1.4 Summary of Boundary Containment System Data

The previous sections show that total organic contaminant mass flux at each of the three boundary systems is decreasing and indicate that contaminant concentrations are declining onpost upgradient of the systems. The relatively low concentration levels that reach the boundary systems and the decreases in concentrations and mass are likely a result of the combined effects of IRAs, reductions in source strength, and various natural attenuation mechanisms. Data from RMA indicate further concentration declines at the boundary systems should occur as a result of all of these factors. Consequently, boundary system operations already have been and will continue to be optimized in the future as a greater portion of the groundwater approaching the systems meets Offpost PRGs.

3.2 EVALUATION OF INTERNAL GROUNDWATER CONTAINMENT SYSTEMS

Water-quality data are presented in the following section for the Basin A-Neck, Railyard, and Motor Pool IRA groundwater containment systems.

3.2.1 Basin A-Neck Containment System (BANCS)

The BANCS intercepts and treats contaminated groundwater originating from Basin A, various disposal areas within and adjacent to the basin, and from northern portions of South Plants. The system began operation in July 1990.

3.2.1.1 Influent Concentrations

Evaluation of BANCS influent water-quality data is complicated because the BANCS treatment plant influent sump also receives the effluent stream from the North of Basin F IRA extraction well and air stripper (approximately 2 gpm of a total 13 gpm flow). Consequently, the BANCS influent water-quality data are affected by contaminants present north of Basin F that are not effectively removed by the air stripper. Flow data are not readily available for mass balance calculations, therefore, contaminant concentrations from the Basin F air stripper effluent are included in the discussion so that semi-quantitative conclusions about the trends in the BANCS influent can be made.

Table 3-2 presents BANCS average influent concentrations for FY1991 through FY1993. No conclusions about long-term trends can be drawn from these data, however, the data indicate some short-term decreases may be present for atrazine, chlordane, chloroform, CPMSO, DCPD, DIMP, PPDDT, and TRCLE.

Although concentrations of numerous contaminants are quite high (i.e., >10,000-1,000,000 ug/l) in the South Plants North and Basin A Plumes, by the time contaminant plumes migrate to Basin A-Neck, concentrations for several contaminants have decreased to near or below Offpost PRGs.

Table 3-3 lists the 31 offpost chemicals of concern (COCs) for which Offpost PRGs have been established and the number of COCs exceeding their respective PRGs in at least one well in Sections 1 and 36. The table also shows the number of contaminants exceeding Offpost PRGs in the influent to the BANCS and the NWBCS. Thirty of the 31 COCs exceed Offpost PRGs in at least one well in Section 1 and all 31 COCs exceed PRGs in at least one well in Section 36. However, only 15 COCs exceed

Offpost PRGs in the influent to BANCS. Comparison of BANCS influent, air stripper effluent, and upgradient monitoring-well data indicates that three contaminants (i.e., chloroform, hexachlorocyclopentadiene, and DBCP) exceed PRGs because of pumping from Basin F. Therefore, only 12 of the 31 Offpost COCs actually exceed PRGs in groundwater at Basin A-Neck. Included in the group that do not exceed PRGs are benzene, chloroform, and DBCP which are mobile compounds that are present in extremely high concentrations in South Plants. Chloroform at low concentrations continues to migrate to the NWBCS, and DBCP formerly migrated to the NWBCS. Dieldrin is less mobile but also migrates from the Basin A-Neck area to the NWBCS. Therefore, the low concentrations of many contaminants at Basin A-Neck would appear to be due to source reduction and/or responses to attenuation mechanisms, not the leading edges of advancing plumes.

Although approximately 90 percent of the dissolved mass of organics in groundwater at RMA occurs in Sections 1, 2, and 36, these data indicate that source reduction and/or attenuation mechanisms are reducing concentrations as the contaminant plumes migrate toward Basin A-Neck. Additional concentration reductions occur between Basin A-Neck and the NWBCS as only one COC (dieldrin) exceeds the Offpost PRG in the NWBCS influent.

3.2.2 Rail Classification Yard

An historical spill(s) in the Railyard is the suspected source of the DBCP plume emanating from this area. The Railyard IRA, which began operation in September 1991, consists of 7 groundwater extraction wells located at the north end of the Railyard. Groundwater treatment and reinjection occurs at the Irondale treatment plant.

3.2.2.1 Upgradient Wells

Groundwater monitoring data indicate that DBCP concentrations in groundwater near the source and upgradient of the IRA system are declining. Monitoring Wells 03009, 03501, 03503, and 03523 are located within the historical plume and upgradient of the IRA extraction wells and have historically exhibited concentrations up to 56 ug/l. DBCP concentrations versus time for these wells are shown on Figure 3-16. DBCP concentrations in all four wells have decreased such that the highest observed concentrations are currently approximately 1 ug/l.

3.2.3 Motor Pool

Suspected discharge of TRCLE through a floor drain to an unlined ditch in Section 4 is the likely source of the Motor Pool groundwater plume (Ebasco 1989g). The Motor Pool IRA, which began operation in September 1991, consists of two groundwater extraction wells on the north end of the Motor Pool. As in the Railyard, treatment and reinjection occurs at the Irondale treatment plant. Soil vapor extraction (SVE) was also conducted as a part of the IRA in an attempt to remediate soils. The SVE pilot system was operated for approximately 5 months during Fall 1991 and verification testing was conducted during September/ October 1993. Data in the following paragraphs indicate that operation of the Motor Pool IRA extraction wells may become unnecessary in the foreseeable future.

3.2.3.1 Upgradient Wells

Monitoring-Wells 04035, 04048, and 04049 are located upgradient of the Motor Pool IRA extraction wells and in the immediate vicinity of the suspected source of the TRCLE. As shown on Figure 3-17, TRCLE concentrations decreased to near or below

5 ug/l in 1990 and in 1994 concentrations were below the CRL of 0.56 ug/l in the two wells sampled. Based on soil vapor concentrations obtained in the SVE verification testing program for the IRA, the Army concluded that the soil remediation portion of the IRA was complete in 1993 (PMRMA 1993). Thus, it is possible that the SVE has had some beneficial impact on the decline in TRCLE concentrations in groundwater. The effect of operation of the SVE system on groundwater concentrations was not evaluated under the IRA, however.

Alluvial cluster Wells 04030, 04031, 04032, and 04033 are located approximately 1,000 ft downgradient from the source and 150 ft upgradient of the IRA extraction wells. Well 04030 is the shallowest of the four wells and has often contained the highest historical concentrations of TRCLE. Figure 3-18 illustrates that TRCLE concentrations in Well 04030 have decreased steadily from 176 ug/l in late 1989 to 4.07 ug/l in 1994, consistent with the decreasing trend in the source area. TRCLE concentrations in Well 04031 have decreased from 351 ug/l in 1984 to 5.6 ug/l in 1992 (Figure 3-18). TRCLE concentrations are not shown for Wells 04032 and 04033 because concentrations typically decrease with depth in this area and are below the CRL in these wells.

3.3 PRIMARY FLOWPATH CONCENTRATION PROFILES

For many contaminant plumes at RMA, steep concentration gradients are observed downgradient of source areas, particularly in Basin A/South Plants and near former Basin F. The steep gradients of these plumes appear to be largely responsible for the relatively low number of Offpost COCs detected in the influent to internal and boundary containment systems compared to upgradient areas. To illustrate this phenomenon, several contaminant concentration versus distance profiles have been generated. Any temporal trends in these contaminant profiles

were examined by preparing profiles for multiple sampling events on the same graph.

The plumes that have been evaluated are the South Plants North/Basin A, Basin F, and South Tank Farm Plumes. The monitoring wells chosen for the profiles approximate plume centerlines in the 1990 CMP sampling event (Fall 1989). Contaminant plumes with high concentrations or low Offpost PRGs were selected for this analysis and included benzene, chlorobenzene (Basin A Plume only), chloroform, DBCP, DCPD (Basin F Plume only), dieldrin, DIMP (Basin F Plume only), tetrachloroethene, and TRCLE (Basin A Plume only) (Figures A-1 to A-14). Data sets were selected from sampling programs with adequate numbers of wells to show the plume profile. Since the wells within the profile often have different sampling histories, the evaluation of temporal trends is limited in some cases.

The plume profiles and detailed discussion of each (South Plants North/Basin A and Basin F Plumes) are provided in Appendix A. The following paragraphs summarize the results of these analyses.

3.3.1 South Plants North/Basin A Plumes

The concentration profiles show that concentrations of contaminants in the South Plants North/Basin A Plume decrease significantly (up to six orders of magnitude for chloroform) from the source areas toward Basin A-Neck (Figures A-1 to A-7). The leading edges of many of the South Plants North plumes appear to be static over the period of the last several monitoring events. The plumes which appear to be more or less static include benzene, chlorobenzene, chloroform, tetrachloroethene, and TRCLE. The DBCP plume is receding. These data indicate that attenuation processes (i.e. adsorption, dilution, volatilization, biodegradation, etc.) are reducing contaminant mass within these

plumes at a rate that equals or exceeds the mass entering the plumes from source areas.

These processes greatly reduce the contaminant mass that actually reaches the BANCS. As shown in Table 3-3, of the 31 Offpost COCs present in the South Plants North/Basin A Plume, only 12 exceed Offpost PRGs in the BANCS influent. Temporal concentration decreases are observed in specific wells for all of the contaminants evaluated with many wells at their lowest concentration levels in the most recent sampling event for chlorobenzene, chloroform, DBCP, DIMP, and TRCLE.

Figures 3-19 and 3-20 show the plume centerline profiles from South Plants/Basin A through Basin A-Neck, to the NWBCS for DBCP and DIMP, respectively. Figure 3-19 shows that a continuous DBCP plume was present over the greater than 3-mile distance to the NWBCS in 1979. Concentrations have decreased such that the only detections in 1994 were only 2,000 ft downgradient of South Plants.

Figure 3-20 shows that the concentrations of DIMP, which is one of the more persistent RMA organic analytes, also decrease along the flowpath. In 1994, concentrations were sharply lower in wells located immediately downgradient of the BANCS. Concentrations of DIMP near the NWBCS have been decreasing since 1978, which is consistent with the decreasing trend in DIMP concentrations in the NWBCS influent.

3.3.2 Basin F

Groundwater contaminant concentrations north of former Basin F decrease with distance by several orders of magnitude along the profiles for the majority of compounds evaluated (i.e., benzene, chloroform, DBCP, DCPD, dieldrin, DIMP, and tetrachloroethene)

(Figures A-8 to A-14). Within plume axes, concentrations of benzene and chloroform decrease to below Offpost PRGs upgradient of the NBCS. Table 3-4 shows that 17 of 31 Offpost COCs exceed PRGs in at least one well in Section 25 and 27 COCs exceed PRGs in at least one well in Section 26. Only 6 COCs exceed PRGs in the NBCS influent, however, comparison of influent concentrations to Offpost PRGs is complicated at the NBCS because contaminant concentrations are not uniform across the length of the NBCS. Generally, lower concentrations are present at the eastern end. Since influent concentrations represent a composite sample of groundwater intercepted, NBCS influent concentrations are lower than those of respective contaminant plumes flowing into extraction wells.

Temporal decreases in concentrations are observed along the plume profiles for benzene, chloroform, DBCP, DCPD, and DIMP. These temporal decreases in concentrations are consistent with decreases in influent concentrations at the NBCS.

3.3.3 South Tank Farm Plume

Figure 3-21 is the plume centerline profile of the benzene plume in the South Tank Farm Plume (STFP). Concentrations decrease abruptly to below reporting limits between Wells 02502 and 02504. This is the same area where dissolved oxygen concentrations increase. Based on these data and laboratory studies, Shell believes aerobic biodegradation is a likely mechanism for this attenuation. The rate of attenuation of benzene approximates the rate of mass contributing to the plume from the source.

The leading edge of the benzene plume has been monitored closely under the STFP IRA since 1988 and is illustrated for 10 sampling events on Figure 3-22. The configuration of the plume varies only slightly over time with only small variations in the

distribution caused by hydrologic changes. Cross-contamination of samples likely caused the plume extent to be overestimated for the Spring 1988 event.

3.4 COMPARISON OF ORGANIC CONCENTRATIONS TO CHLORIDE

Natural attenuation mechanisms that may be reducing groundwater contaminant concentrations and limiting the spread of contaminant plumes include biodegradation, volatilization, chemical degradation, adsorption, dilution, and dispersion. Determining which mechanisms are occurring for specific contaminants is extremely difficult and typically relies on inferential evidence. However, since chloride is a conservative contaminant that is present in proximity with the organic contaminant plumes, comparison of organic concentration trends to trends in chloride concentrations provides an indication of the attenuation not due solely to dilution.

Figure 3-23 shows the summed organics and chloride concentration profiles for the South Plants North Plume between South Plants and Basin A-Neck in Fall 1989. The summed organics concentrations decrease by 3 orders of magnitude while chloride concentrations are consistent. Since DIMP is not a significant component of the South Plants plume but has additional Basin A sources, Figure 3-24 is a similar graph with DIMP subtracted from the total organic concentrations. This figure shows that organic concentrations decrease from over 1,000,000 ug/l in South Plants to below 800 ug/l at Basin A-Neck. Dithiane and CPMSO2 comprise the majority of the remainder of organics in the BANCS influent (i.e., averaging a total of 550 ug/l in FY1993).

Assuming comparable sources, reductions in organic concentrations due to dilution should be proportional to those observed for chloride since dilution is essentially the only mechanism which

would affect chloride. One argument against this comparison is that additional chloride sources may be active in Basin A. Figure 3-25 shows the chloride concentration profile from South Plants to the NWBCS. This figure shows that chloride concentrations are relatively constant through the BANCS all the way to the NWBCS. Additional chloride sources are unlikely between the BANCS and NWBCS. This data indicates that attenuation mechanisms other than dilution are active for the organics.

In Section 3.1, the organics concentrations at the boundary systems were shown to be decreasing. The relatively consistent chloride concentrations in the influent to the NBCS and NWBCS in Figures 3-26 and 3-27, respectively, further indicate that other mechanisms besides dilution are reducing organic contaminant concentrations at RMA.

4.0 CONCLUSIONS

Monitoring data at the Rocky Mountain Arsenal (RMA) has provided the opportunity to evaluate the trends in groundwater contaminant concentrations at internal and boundary containment systems. Evaluation of these data from 15 years of monitoring have shown that contaminant concentrations upgradient of the RMA boundaries have been dynamic and are decreasing overall.

Various factors, including implementation of IRAs, cessation of production activities, and the effects of natural attenuation mechanisms are effectively reducing contaminant concentrations and may be expected to cause additional decreases at the boundary systems such that operations should be optimized over time. For example, the majority of the Irondale Containment System is likely to be unnecessary in a few years with interception of the DBCP plume being accomplished solely by the Railyard System. With continued operation of the BANCS and decreasing flows from former Basin F, portions of the NWBCS may also be unnecessary in the foreseeable future.

Many onpost groundwater plumes appear to be at equilibrium (e.g., they are no longer increasing in extent) or are receding. Along several plume flowpaths steep concentration gradients are observed for many organic contaminants and concentrations fall below Offpost PRGs or analytical reporting limits upgradient of the North, Northwest, or Basin A-Neck Containment Systems. These relatively stable plume configurations reduce the need for frequent comprehensive regional groundwater monitoring.

5.0 REFERENCES

Ebasco Services Inc. (Ebasco), 1989. Final Water Remedial Investigation Report, Volumes I-III, Version 3.3. July.

Ebasco Services Inc. (Ebasco), 1989a. Final Remedial Investigation Report, Volume VI, Southern Study Area, Version 3.3. June.

Ebasco Services Inc. (Ebasco), 1989b. Final Remedial Investigation Report, Volume VII, Eastern Study Area, Version 3.3. June.

Ebasco Services Inc. (Ebasco), 1989c. Final Remedial Investigation Report, Volume VIII, South Plants Study Area, Version 3.3. July.

Ebasco Services Inc. (Ebasco), 1989d. Final Remedial Investigation Report, Volume IX, North Plants Study Area, Version 3.3. July.

Ebasco Services Inc. (Ebasco), 1989e. Final Remedial Investigation Report, Volume X, Central Study Area, Version 3.3. July.

Ebasco Services Inc. (Ebasco), 1989f. Final Remedial Investigation Report, Volume XI, North Central Study Area, Version 3.3. July.

Ebasco Services Inc. (Ebasco), 1989g. Final Remedial Investigation Report, Volume XII, Western Study Area, Version 3.3. May.

Ebasco Services Inc. (Ebasco), 1992a. Final Remedial Investigation Summary Report, Volumes I-VI, Version 3.2. January.

Ebasco Services Inc. (Ebasco), 1992b. Final Development and Screening of Alternatives Report, Water Volumes I-II, Version 4.1. December.

Ebasco Services Inc. (Ebasco), 1993. Draft Final Detailed Analysis of Alternatives Report, Volumes I-VII, Version 2.0. July.

Harding Lawson Associates (HLA), 1992. Groundwater Monitoring Program Final Annual Groundwater Monitoring Report for 1991, Volumes I and II. September.

Morrison Knudsen Corporation (MK), 1993. White Paper: Groundwater Flows and Recharge on the Rocky Mountain Arsenal. September.

Morrison Knudsen Corporation (MK), MK-Environmental Services, 1994. White Paper: Evaluation of the Denver Formation at Rocky Mountain Arsenal. April.

Program Manager for Rocky Mountain Arsenal (PMRMA), 1993. 1993 Motor Pool Area IRA Verification Program Results. Remedial Action Branch A, Rocky Mountain Arsenal, Commerce City, Colorado. December.

Stollar, R.L. & Assoc., Inc. 1989. Comprehensive Monitoring Program Annual Ground Water Monitoring Report for 1988, Final Report. June.

Stollar, R.L. & Assoc., Inc. 1990. Comprehensive Monitoring Program Annual Ground Water Monitoring Report for 1989, Final Report. Version 2.0. June.

Stollar, R.L. & Assoc., Inc. 1991. Comprehensive Monitoring Program Annual Ground Water Monitoring Report for 1990, Final Report. Version 1.1. August.

TABLE 3-1
NORTHWEST BOUNDARY CONTAINMENT SYSTEM
INFLUENT DETECTIONS AND AVERAGE CONCENTRATIONS

INFLUENT DETECTIONS

Analyte	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
12DCE	X	-	-	-	-	-
Aldrin	X	X	-	X	-	-
Atrazine	NA	-	-	-	X	-
Chloroform	X	X	X	X	X	X
Chlordane	-	-	X	X	-	-
CPMSO2	X	-	-	-	-	-
DBCP	X	-	-	-	-	-
DCPD	X	-	-	-	-	-
DDVP	NA	-	NA	X	-	-
DIMP	X	X	X	X	-	-
Dieldrin	X	X	X	X	X	X
Endrin	X	X	-	-	-	-
Isodrin	X	X	-	X	-	-
Parathion	NA	X	-	-	-	-
PPDDT	-	-	-	X	-	-
SUPONA	NA	-	NA	X	-	-
TCLEE	-	-	-	-	-	-
TRCLE	-	X	-	-	-	-
Total	10	8	4	9	3	2

INFLUENT DETECTION FREQUENCY > 25 PERCENT

Average Concentration, ug/l

Analyte	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Chloroform	29.75	34.73	15.55	14.19	9.08	5.23
DIMP	3.88	3.32	3.04	1.82	< 2.0	< 2.0
Dieldrin	0.33	0.39	0.436	0.405	0.352	0.329
3 Analytes						

Notes: X = Analyte detected at least once - = Analyte not detected
NA = Not Analyzed

TABLE 3-2
BASIN A-NECK CONTAINMENT SYSTEM
OFFPOST PRGS AND
AVERAGE INFLUENT CONCENTRATIONS, ug/l

Analyte	Offpost PRG	FY 1991	FY 1992	FY 1993
12DCLE	1.1	13.8	11.7	13.8
13DCLB	6.5	< 1.0	NA	NA
Aldrin	0.05	0.104	0.18	0.33
Arsenic	2.35	23.9	16.4	39.9
Atrazine	4.03	26.9	< 4.03	< 4.03
Benzene	3	1.36	1.2	1.7
CCL4	0.99	< 0.99	< 0.99	< 0.99
Chlordane	0.095	2.18	< 0.095	< 0.095
Chlorobenzene	25	1.39	0.83	1.56
Chloroform	15	13.4	67.7	11.4
CL6CP (HEX)	0.23	0.217	0.378	0.168
CPMS	30	5.25	4.09	4.45
CPMSO	36	< 11.5	10.5	9.1
CPMSO2	36	314	482	414
DBCP	0.195	0.296	0.33	0.36
DCPD	46	4.55	3.48	3.05
Dieldrin	0.05	0.266	0.64	0.59
DIMP	600	809	1084	697
Dithiane	18	99.4	141.2	137
Endrin	0.2	0.246	0.297	0.23
Ethylbenzene	200	< 1.37	< 1.37	< 1.37
Fluoride	4000	-	1507	1540
Isodrin	0.06	0.22	0.345	1.05
Malathion	100	< 0.37	< 0.5	< 0.5
Oxathiane	160	12.8	16.6	18.9
PPDDE	0.054	0.075	0.22	0.275
PPDDT	0.049	0.26	0.32	< 0.24
TCLEE	5	2.19	1.9	2.7
Toluene	1000	< 1.47	< 1.47	< 1.47
TRCLE	3	7.57	6.44	6.0
Xylene	1000	< 1.36	< 1.36	< 1.36

TABLE 3-3
SOUTH PLANTS/BASIN A PLUMES
CONTAMINANT CONCENTRATIONS EXCEEDING
OFFPOST PRELIMINARY REMEDIATION GOALS (PRGs)

Analyte	Offpost PRG, ug/l	Exceed PRG in Section 1[1]	Exceed PRG in Section 36[1]	BANCS Influent[2]	NWBCS Influent[2]
12DCLE	1.1	X	X	X	-
13DCLB	6.5	X	X	-	-
Aldrin	0.05	X	X	X	-
Arsenic	2.35	X	X	X	-
Atrazine	4.03	X	X	-	-
Benzene	3	X	X	-	-
CCL4	0.99	X	X	-	-
Chlordane	0.095	X	X	-	-
Chlorobenzene	25	X	X	-	-
Chloroform	15	X	X	X*	-
CL6CP (HEX)	0.23	X	X	X*	-
CPMS	30	X	X	-	-
CPMSO	36	X	X	-	-
CPMSO2	36	X	X	X	-
DBCP	0.195	X	X	X*	-
DCPD	46	X	X	-	-
Dieldrin	0.05	X	X	X	X
DIMP	600	-	X	X	-
Dithiane	18	X	X	X	-
Endrin	0.2	X	X	X	-
Ethylbenzene	200	X	X	-	-
Fluoride	4000	X	X	-	-
Isodrin	0.06	X	X	X	-
Malathion	100	X	X	-	-
Oxathiane	160	X	X	-	-
PPDDE	0.054	X	X	X	-
PPDDT	0.049	X	X	X	-
TCLEE	5	X	X	-	-
Toluene	1000	X	X	-	-
TRCLE	3	X	X	X	-
Xylene	1000	X	X	-	-
Total	31	30	31	15	1

Notes: X = Analyte detected > PRG. - = Less Than PRG. * = Flow from Basin F Well causes exceedence. [1] PRG exceeded by at least one UFS well in RMA database after 1/1/1989.
[2] Average influent concentration for FY 1992/1993.

TABLE 3-4
NORTH BOUNDARY PLUME
CONCENTRATIONS EXCEEDING
OFFPOST PRELIMINARY REMEDIATION GOALS (PRGs)

Analyte	Offpost PRG, ug/l	Exceed PRG in Section 25[1]	Exceed PRG in Section 26[1]	NBCS Influent[2]
12DCLE	1.1	X	X	-
13DCLB	6.5	-	-	-
Aldrin	0.05	X	X	X
Arsenic	2.35	X	X	-
Atrazine	4.03	-	X	-
Benzene	3	X	X	-
CCL4	0.99	X	X	X
Chlordane	0.095	X	X	-
Chlorobenzene	25	-	X	-
Chloroform	15	X	X	-
CL6CP (HEX)	0.23	-	X	-
CPMS	30	-	X	-
CPMSO	36	X	X	-
CPMSO2	36	-	X	-
DBCP	0.195	X	X	-
DCPD	46	-	X	-
Dieldrin	0.05	X	X	X
DIMP	600	X	X	-
Dithiane	18	-	X	-
Endrin	0.2	X	X	X
Ethylbenzene	200	-	-	-
Fluoride	4000	-	X	-
Isodrin	0.06	X	X	-
Malathion	100	-	-	-
Oxathiane	160	-	X	-
PPDDE	0.054	X	X	-
PPDDT	0.049	X	X	X
TCLEE	5	X	X	X
Toluene	1000	-	X	-
TRCLE	3	X	X	-
Xylene	1000	-	-	-
Total	31	17	27	6

Notes:

X = Analyte detected > PRG
- = Less Than PRG

[1] PRG exceeded by at least one UFS well in RMA database after 1/1/1989.
[2] Average NBCS influent concentration for FY 1992/1993.

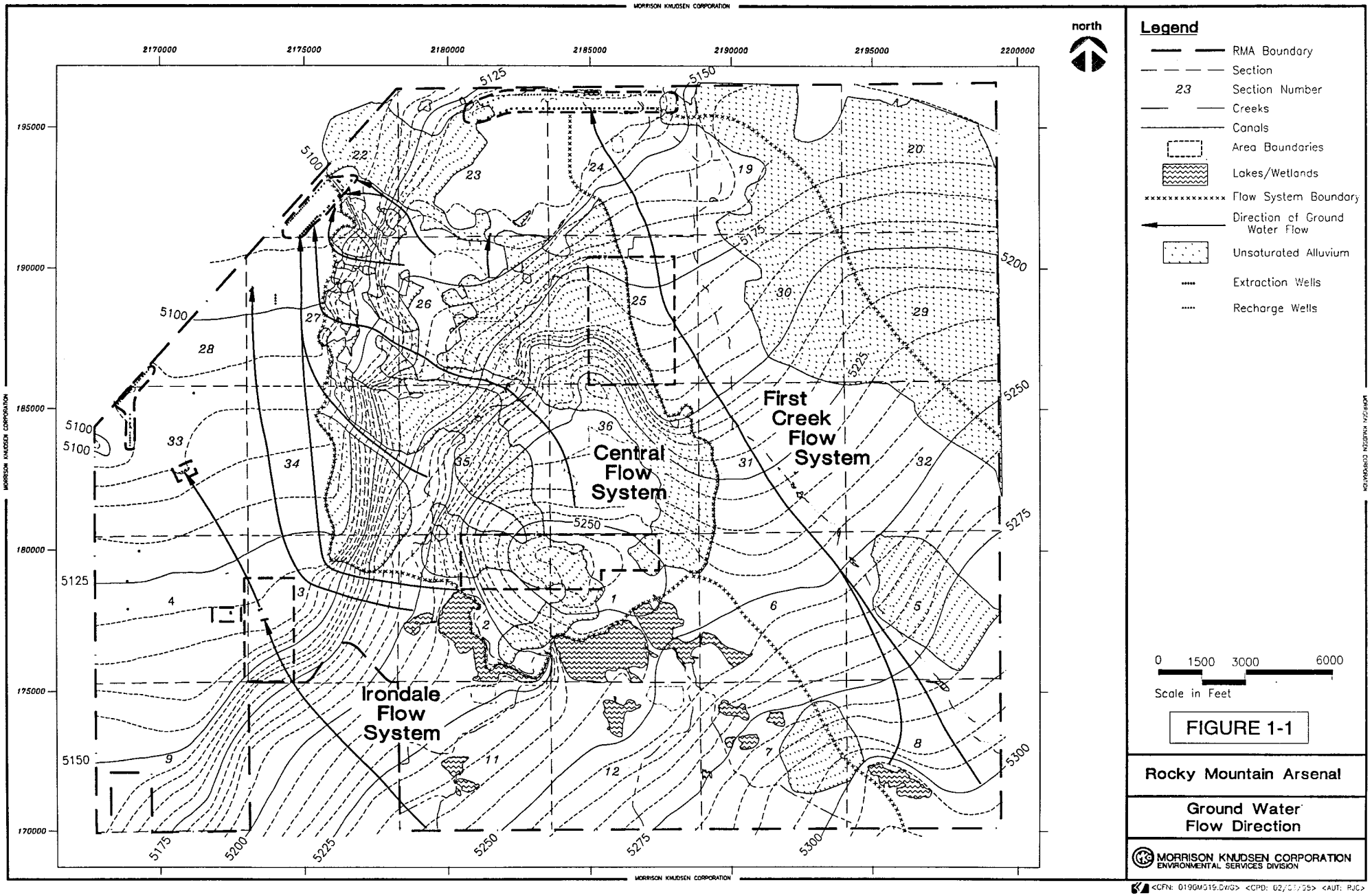


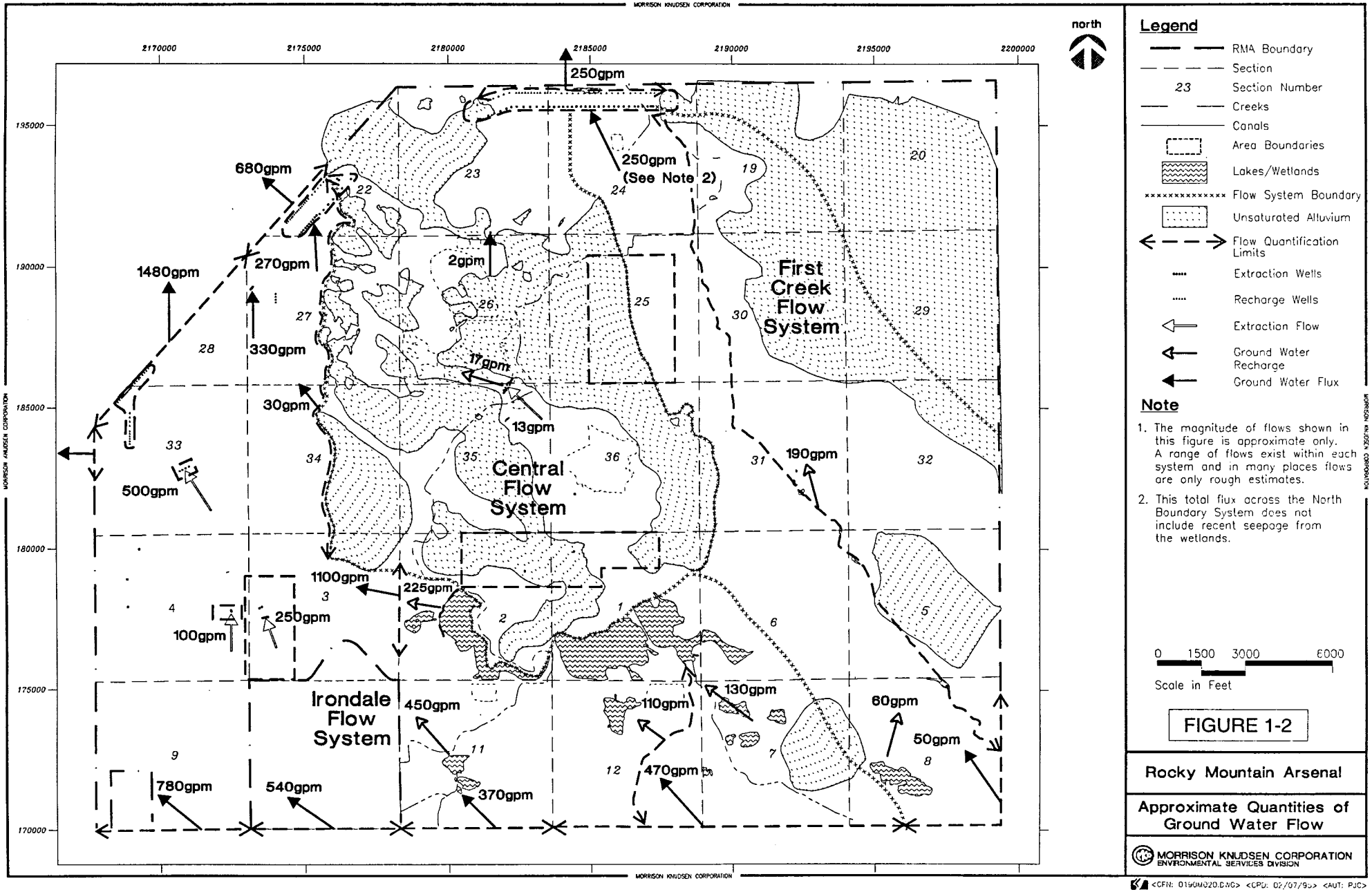
FIGURE 1-1

Rocky Mountain Arsenal

Ground Water Flow Direction

MORRISON KNUDSEN CORPORATION
ENVIRONMENTAL SERVICES DIVISION

<CFN: 0190M019.DWG> <CPD: 02/07/95> <AUT: RJC>



Legend

- RMA Boundary
- Section
- 23 Section Number
- Creeks
- Canals
- Area Boundaries
- Lakes/Wetlands
- Flow System Boundary
- Unsaturated Alluvium
- Flow Quantification Limits
- Extraction Wells
- Recharge Wells
- Extraction Flow
- Ground Water Recharge
- Ground Water Flux

Note

1. The magnitude of flows shown in this figure is approximate only. A range of flows exist within each system and in many places flows are only rough estimates.
2. This total flux across the North Boundary System does not include recent seepage from the wetlands.

0 1500 3000 6000

Scale in Feet

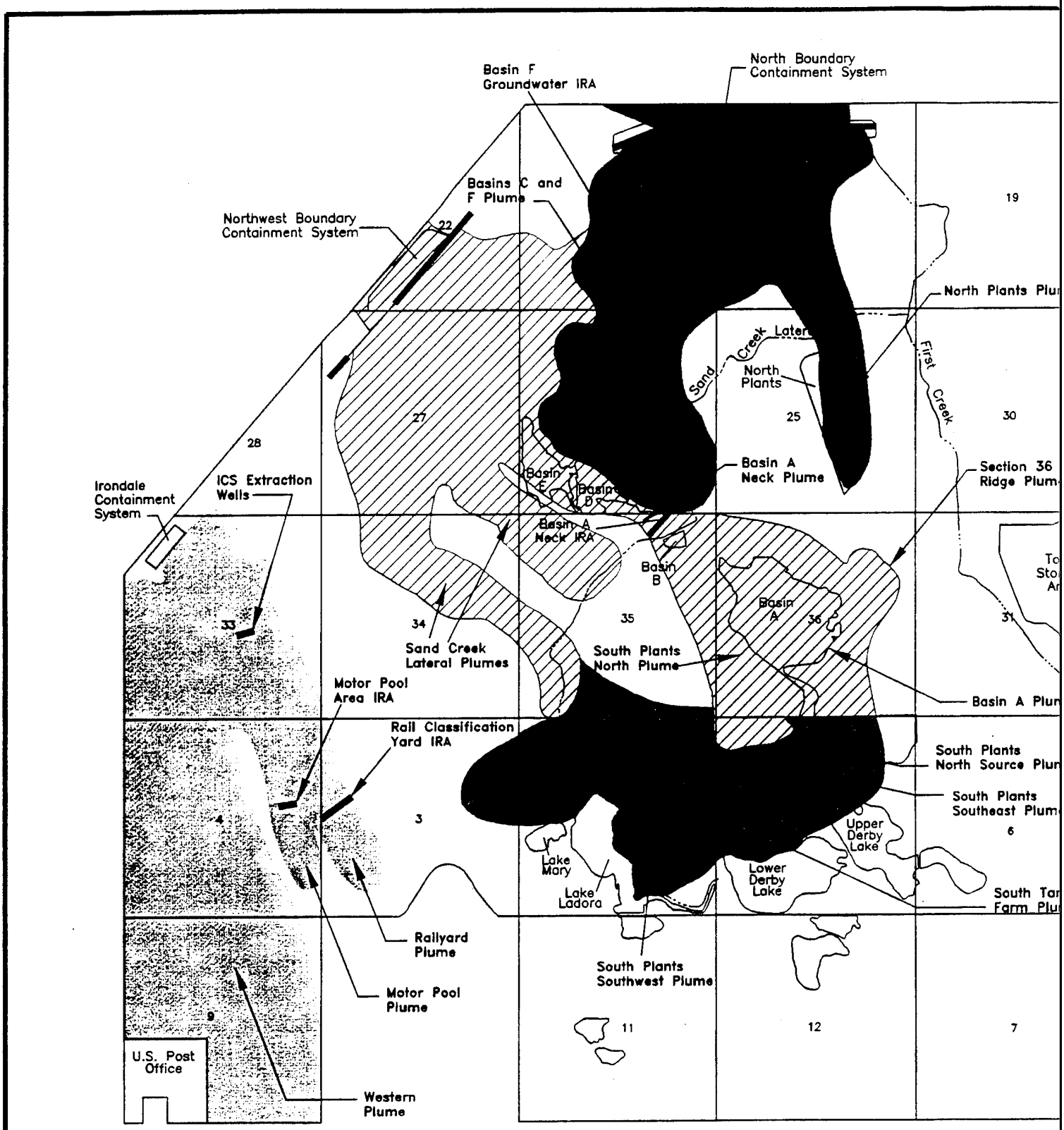
FIGURE 1-2

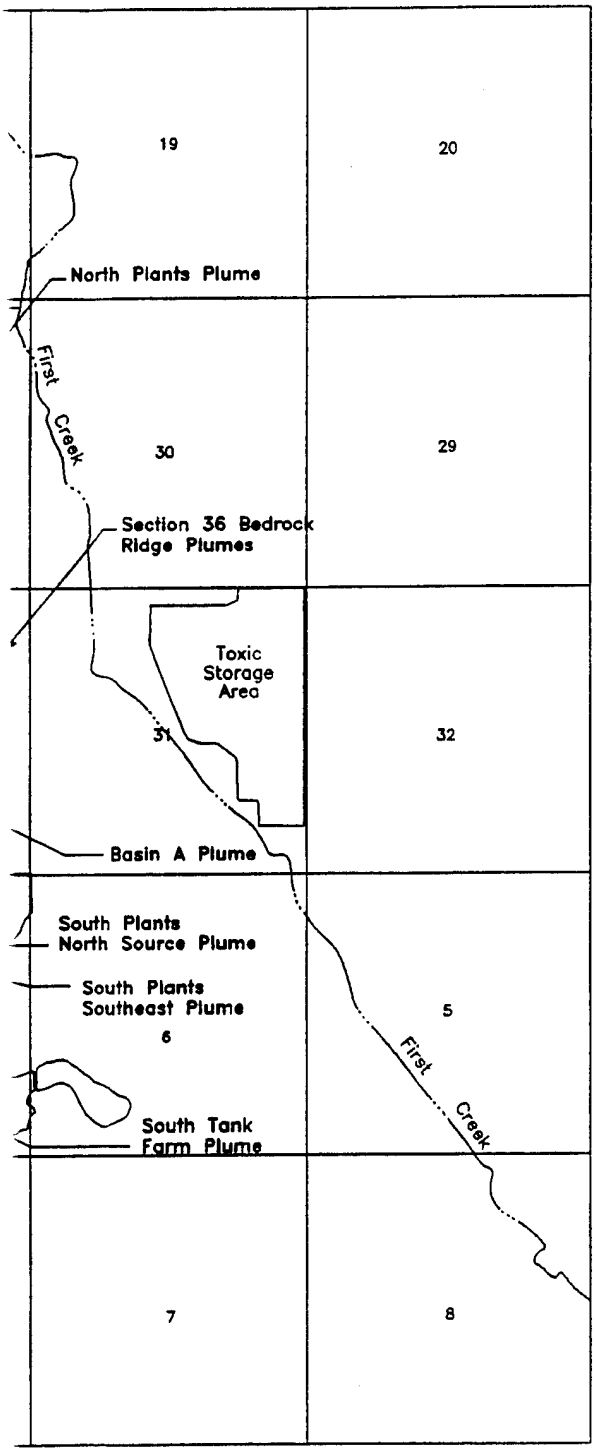
Rocky Mountain Arsenal

Approximate Quantities of Ground Water Flow

MORRISON KNUDSEN CORPORATION
ENVIRONMENTAL SERVICES DIVISION

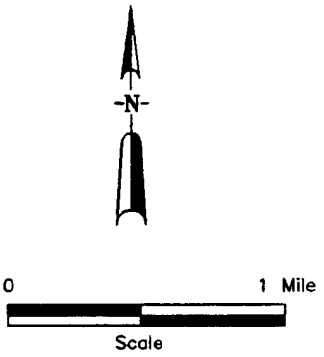
<CFN: 0190M020.DWG> <CPD: 02/07/90> <AUT: PJC>


Basin F
Groundwater IRA
North Boundary
Containment System
Basins C and
F Plume
Northwest Boundary
Containment System
22
19
North Plants Plu
Sand
Creek Later
North
Plants
First
Creek
25
30
27
28
Basin A
Neck Plume
Section 36
Ridge Plum
Irondale
Containment
System
ICS Extraction
Wells
Basin
E
Basin
B
Basin A
Neck IRA
Basin
B
33
34
35
Basin
A
36
31
Sand Creek
Lateral Plumes
South Plants
North Plume
Basin A Plun
Motor Pool
Area IRA
Rail Classification
Yard IRA
South Plants
North Source Plun
South Plants
Southeast Plum
4
3
6
Upper
Derby
Lake
Lake
Mary
Lake
Ladora
Lower
Derby
Lake
South Tar
Farm Plu
Railyard
Plume
Motor Pool
Plume
South Plants
Southwest Plume
9
11
12
7
U.S. Post
Office
Western
Plume



LEGEND

- North Boundary Plume Group
- Northwest Boundary Plume Group
- Western Plume Group
- South Plants Plume Group
- Basin A Plume Group
- Line of Extraction Wells
- WES Model Boundary
- DAA Model Boundary



SOURCE: Water DSA Plume Map

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

FIGURE 3.1–1
Historical Total Organic Plumes for
Unconfined Flow System (from DSA)

Prepared by:
EBASCO SERVICES INCORPORATED

FIGURE 1-3

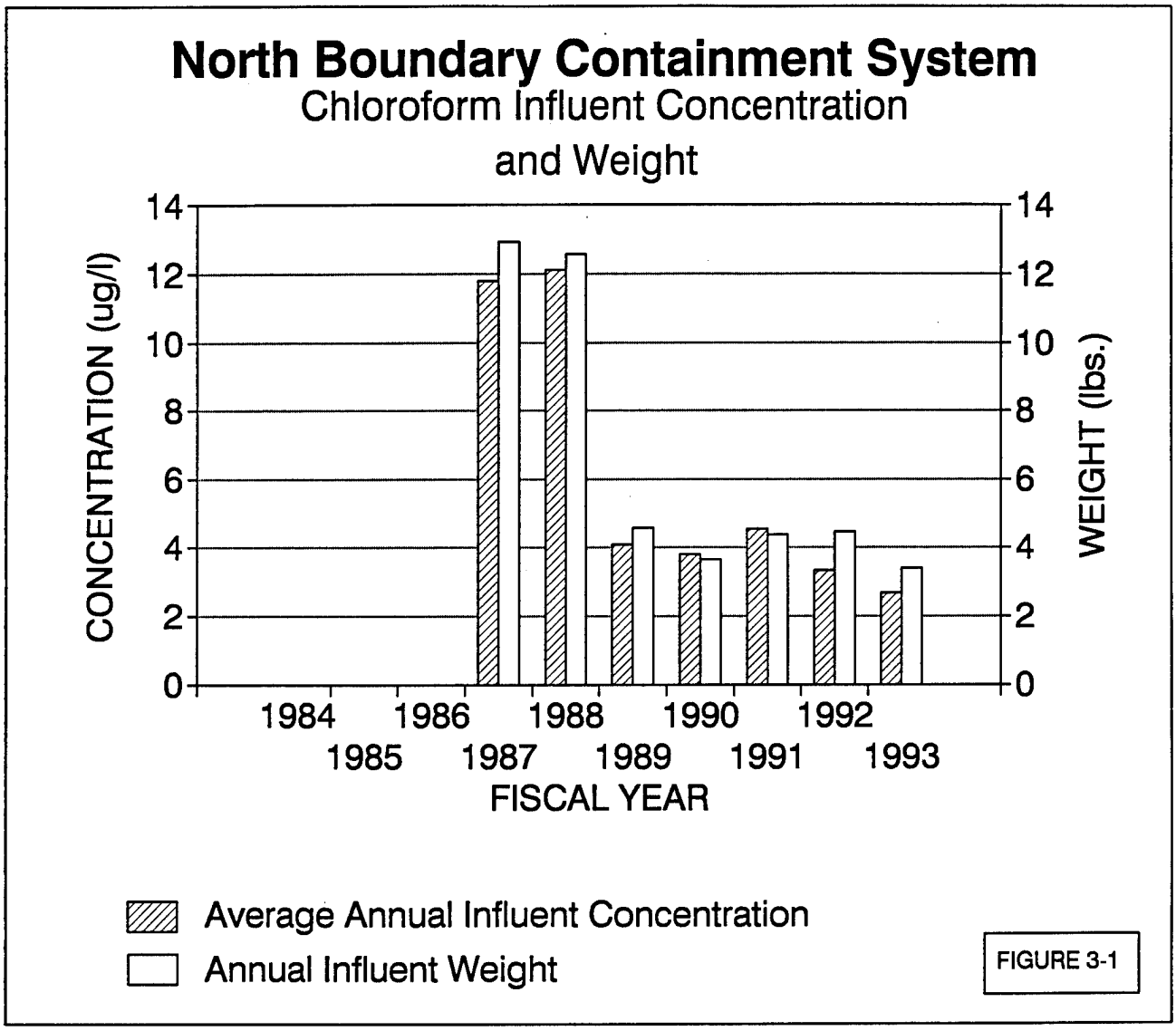
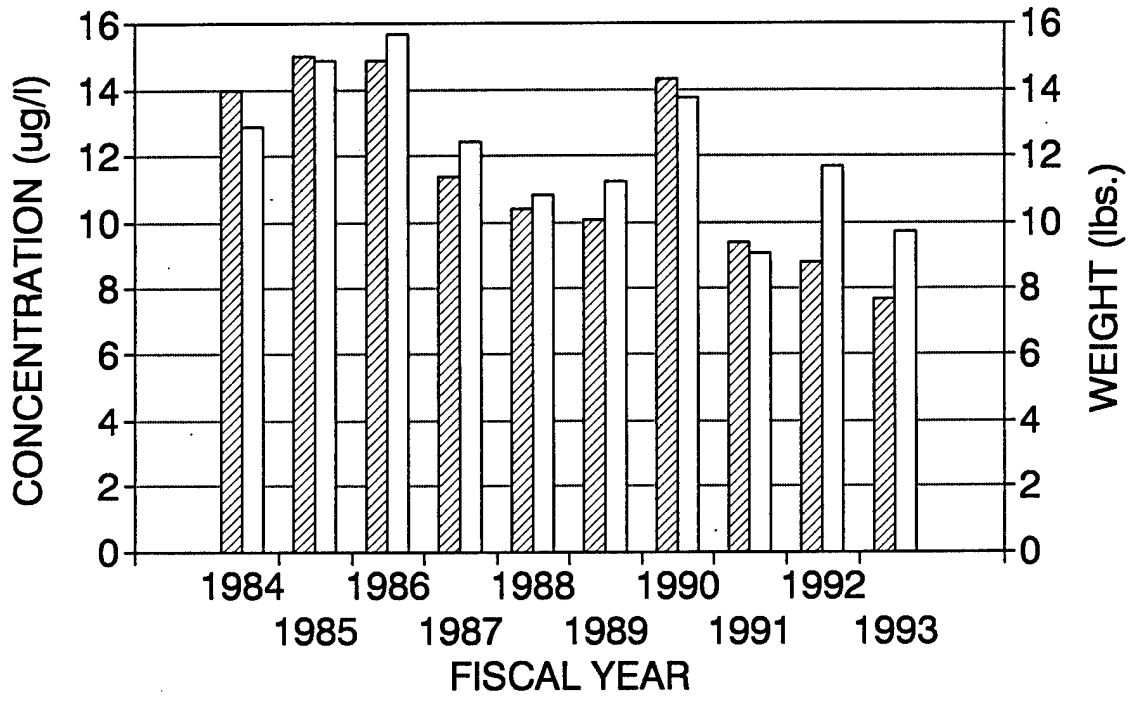

North Boundary Containment System
Chloroform Influent Concentration
and Weight
CONCENTRATION (ug/l)
WEIGHT (lbs.)
0
2
4
6
8
10
12
14
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
FISCAL YEAR
Average Annual Influent Concentration
Annual Influent Weight

FIGURE 3-1

North Boundary Containment System

CPMSO2 Influent Concentration and Weight



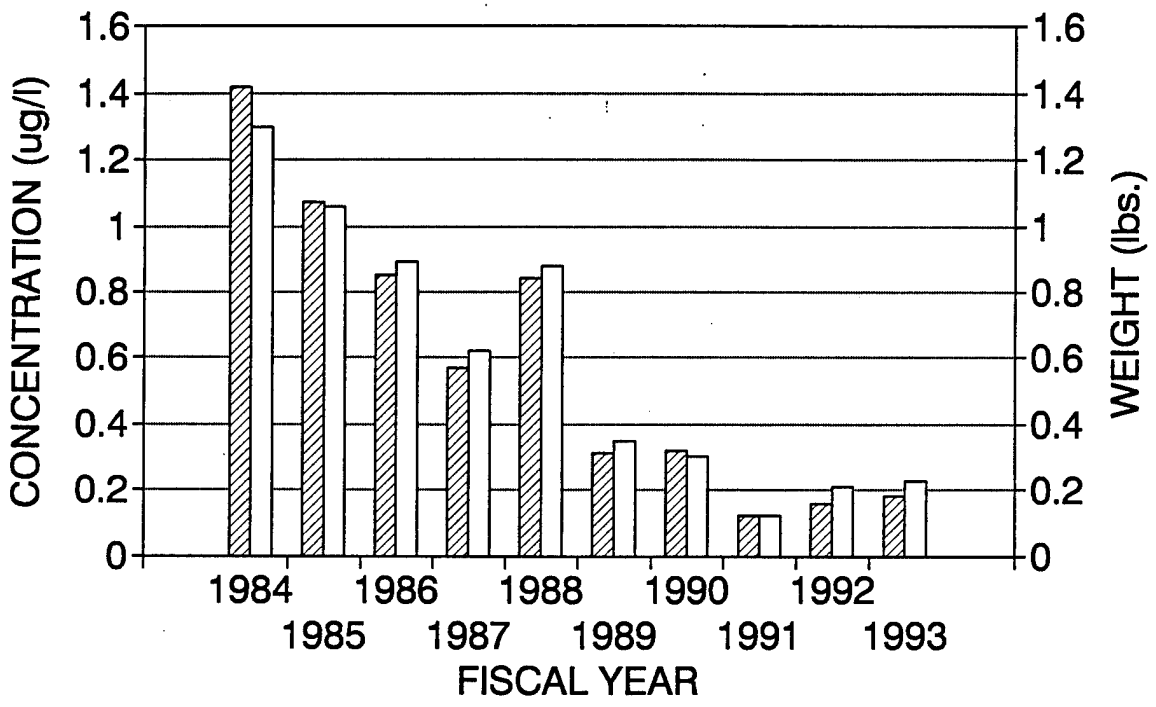
Chlorophenylmethyl Sulfone Average Annual Influent Concentration

Chlorophenylmethyl Sulfone Annual Influent Weight

FIGURE 3-2

North Boundary Containment System

DBCP Influent Concentration
and Weight



Dibromochloropropane Average
Annual Influent Concentration

Dibromochloropropane Annual Influent Weight

FIGURE 3-3

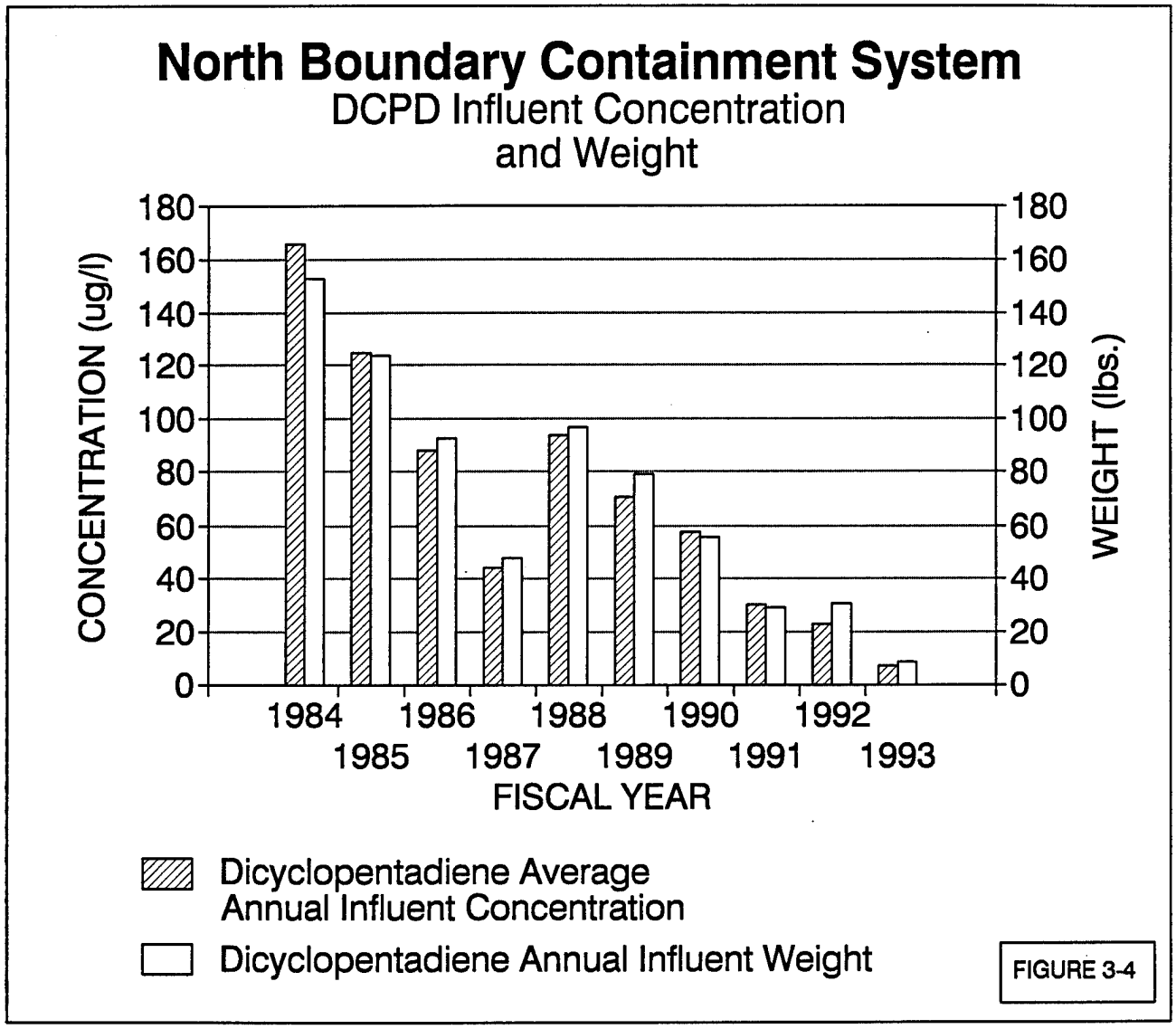

North Boundary Containment System
DCPD Influent Concentration
and Weight
CONCENTRATION (ug/l)
WEIGHT (lbs.)
180
160
140
120
100
80
60
40
20
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
FISCAL YEAR
Dicyclopentadiene Average
Annual Influent Concentration
Dicyclopentadiene Annual Influent Weight

FIGURE 3-4

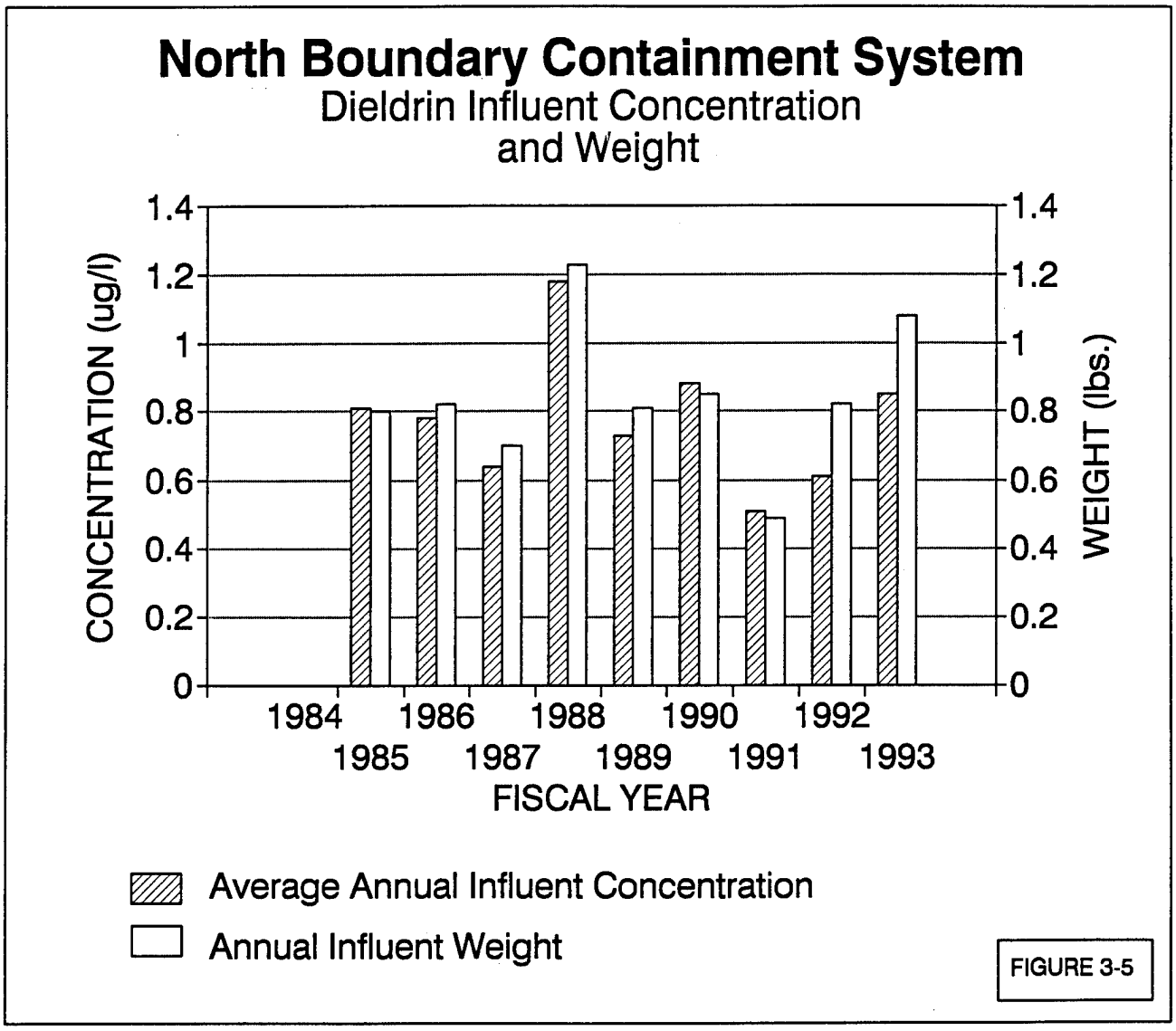
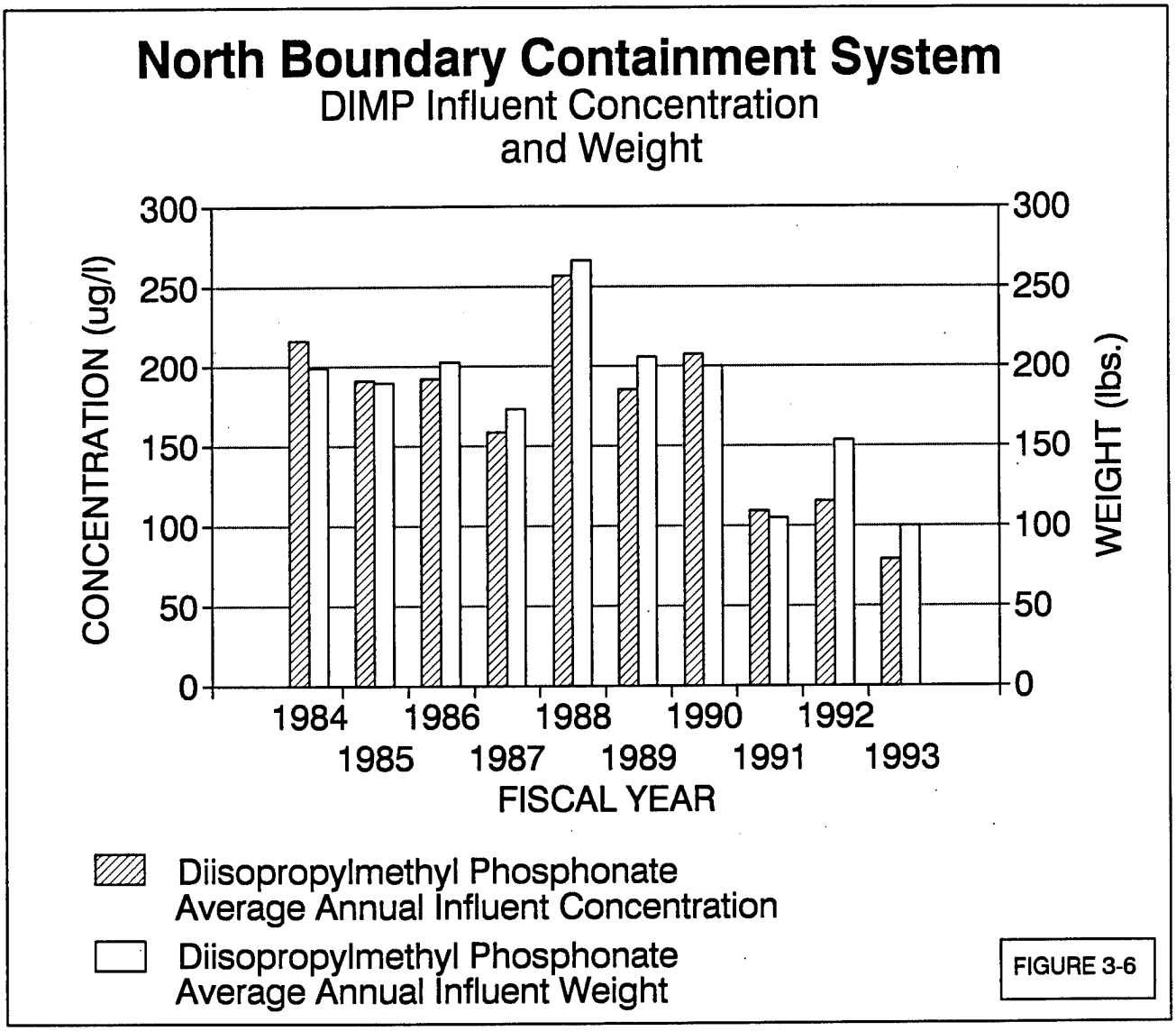

North Boundary Containment System
Dieldrin Influent Concentration
and Weight
CONCENTRATION (ug/l)
WEIGHT (lbs.)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
FISCAL YEAR
Average Annual Influent Concentration
Annual Influent Weight

FIGURE 3-5


North Boundary Containment System
DIMP Influent Concentration
and Weight
CONCENTRATION (ug/l)
WEIGHT (lbs.)
300
250
200
150
100
50
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
FISCAL YEAR
Diisopropylmethyl Phosphonate
Average Annual Influent Concentration
Diisopropylmethyl Phosphonate
Average Annual Influent Weight
FIGURE 3-6

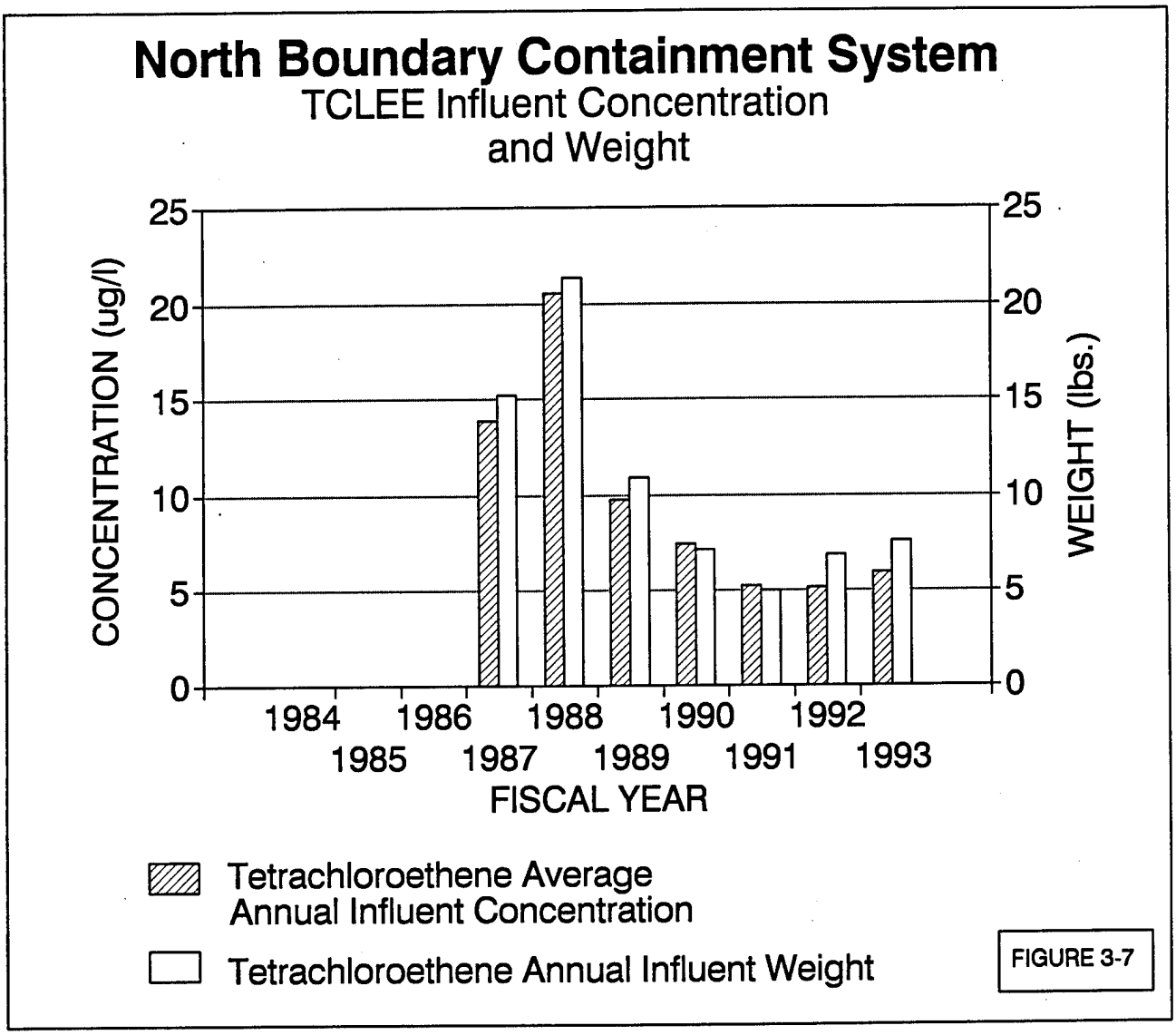
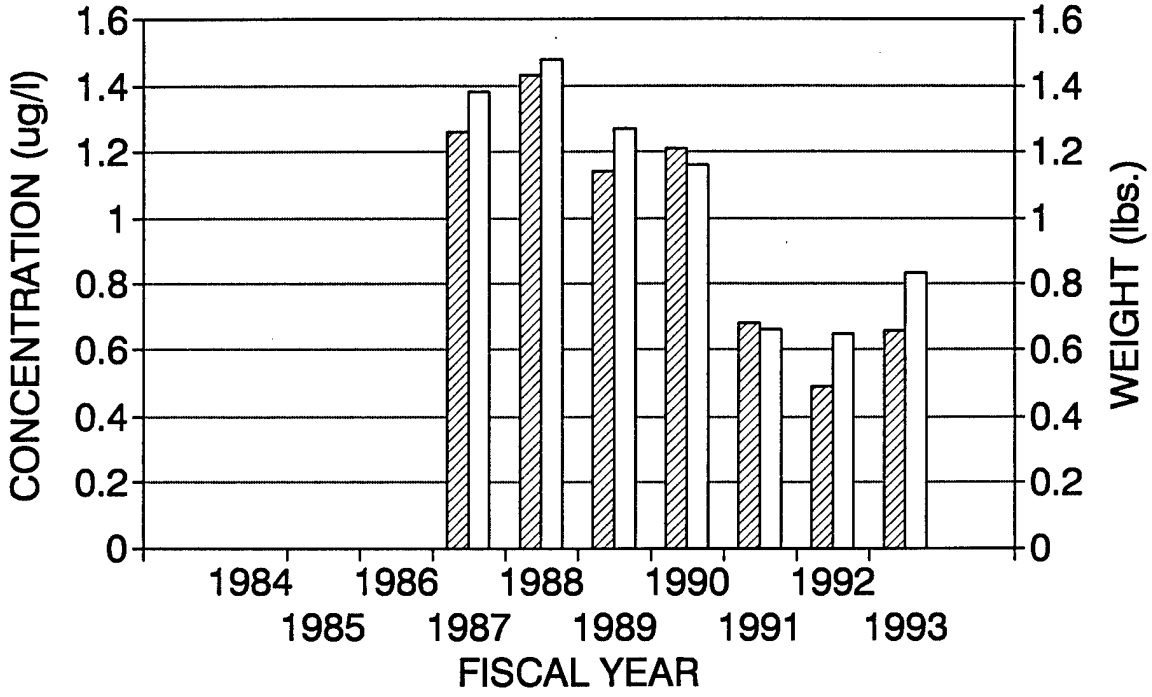

North Boundary Containment System
TCLEE Influent Concentration
and Weight
CONCENTRATION (ug/l)
WEIGHT (lbs.)
25
20
15
10
5
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
FISCAL YEAR
Tetrachloroethene Average
Annual Influent Concentration
Tetrachloroethene Annual Influent Weight

FIGURE 3-7

North Boundary Containment System

TRCLE Influent Concentration
and Weight



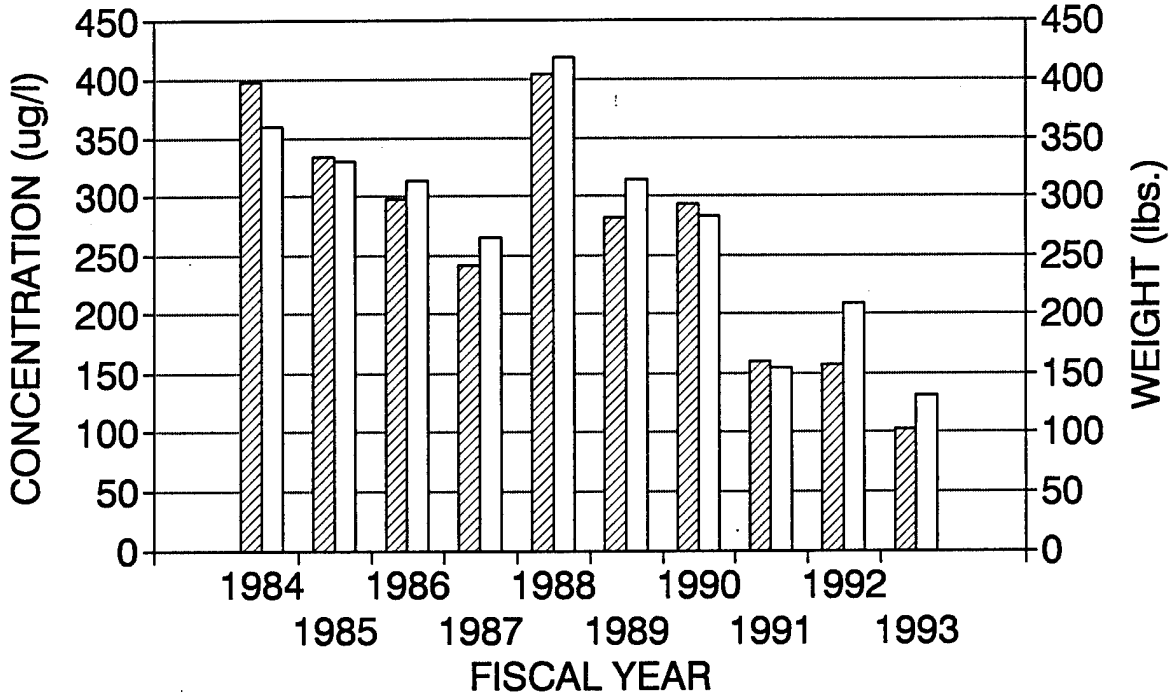
Trichloroethene Average
Annual Influent Concentration

Trichloroethene Annual Influent Weight

FIGURE 3-8

North Boundary Containment System

Summed Organics Influent Concentration and Weight



Average Annual Influent Concentration

Annual Influent Weight

FIGURE 3-9

Northwest Boundary Containment System

Chloroform Influent Concentration and Weight

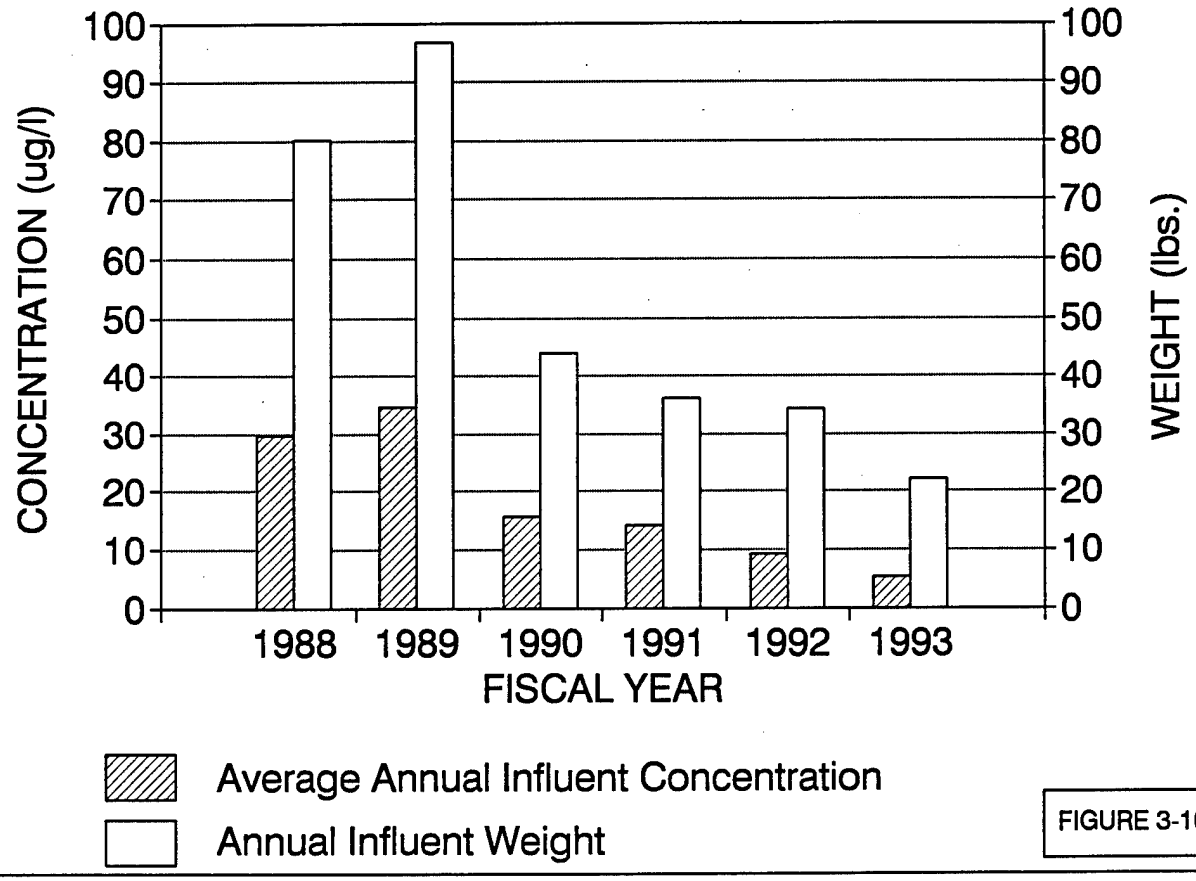
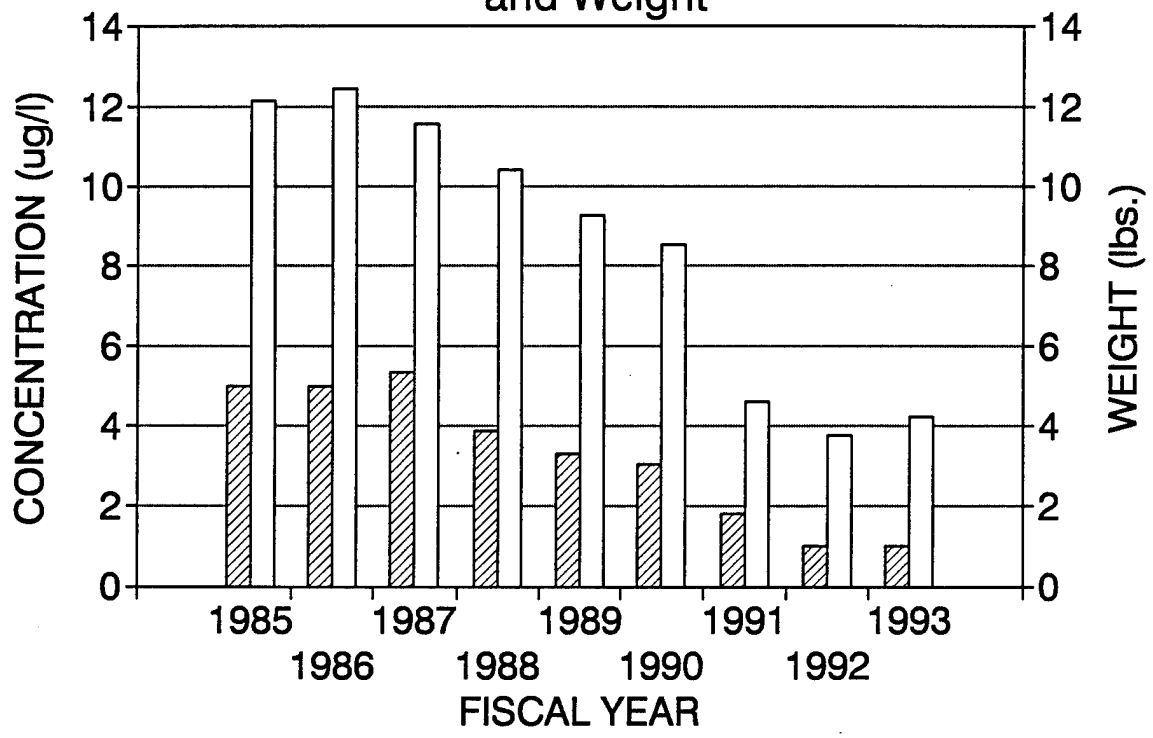


FIGURE 3-10

Northwest Boundary Containment System

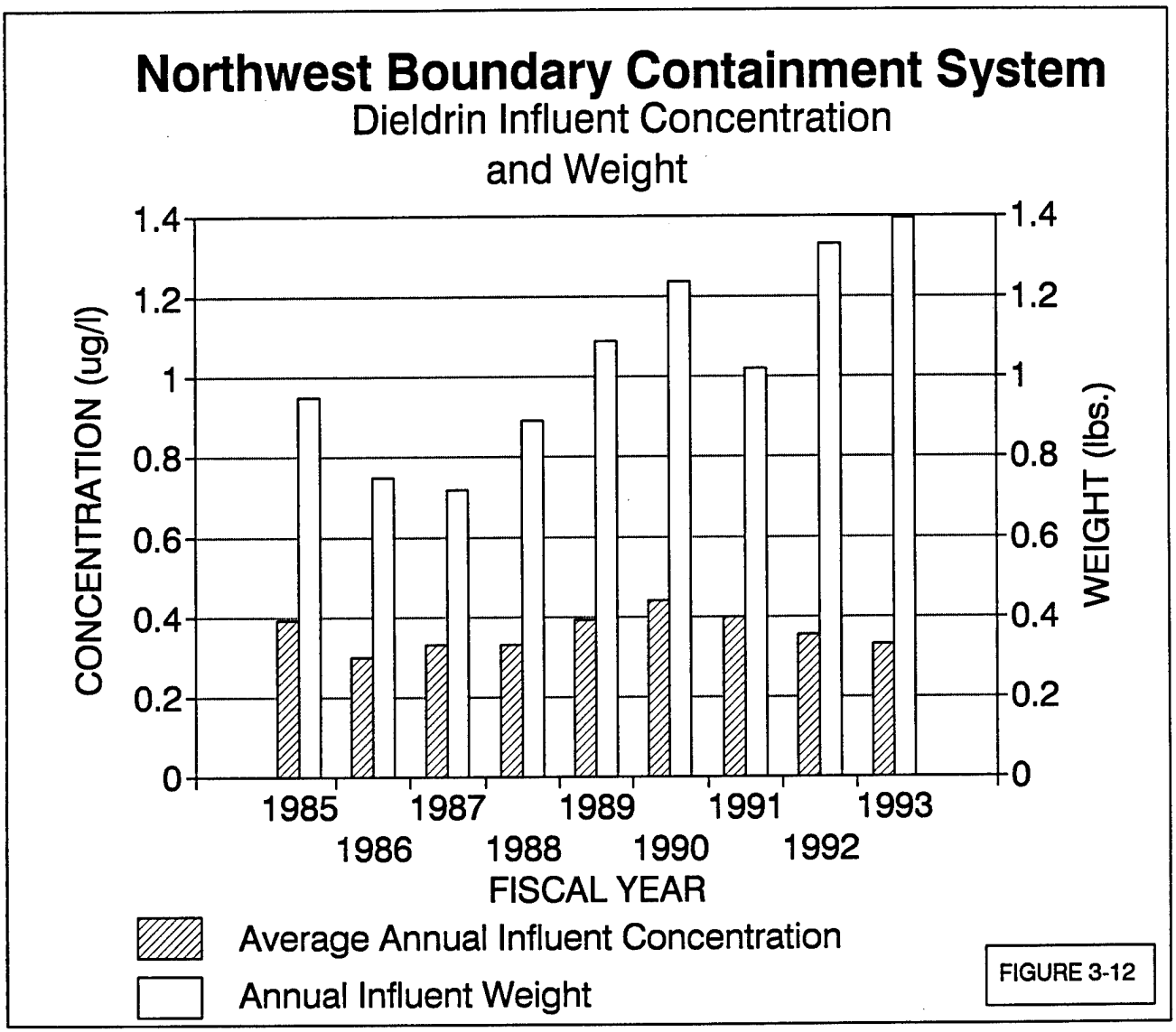
DIMP Influent Concentration and Weight

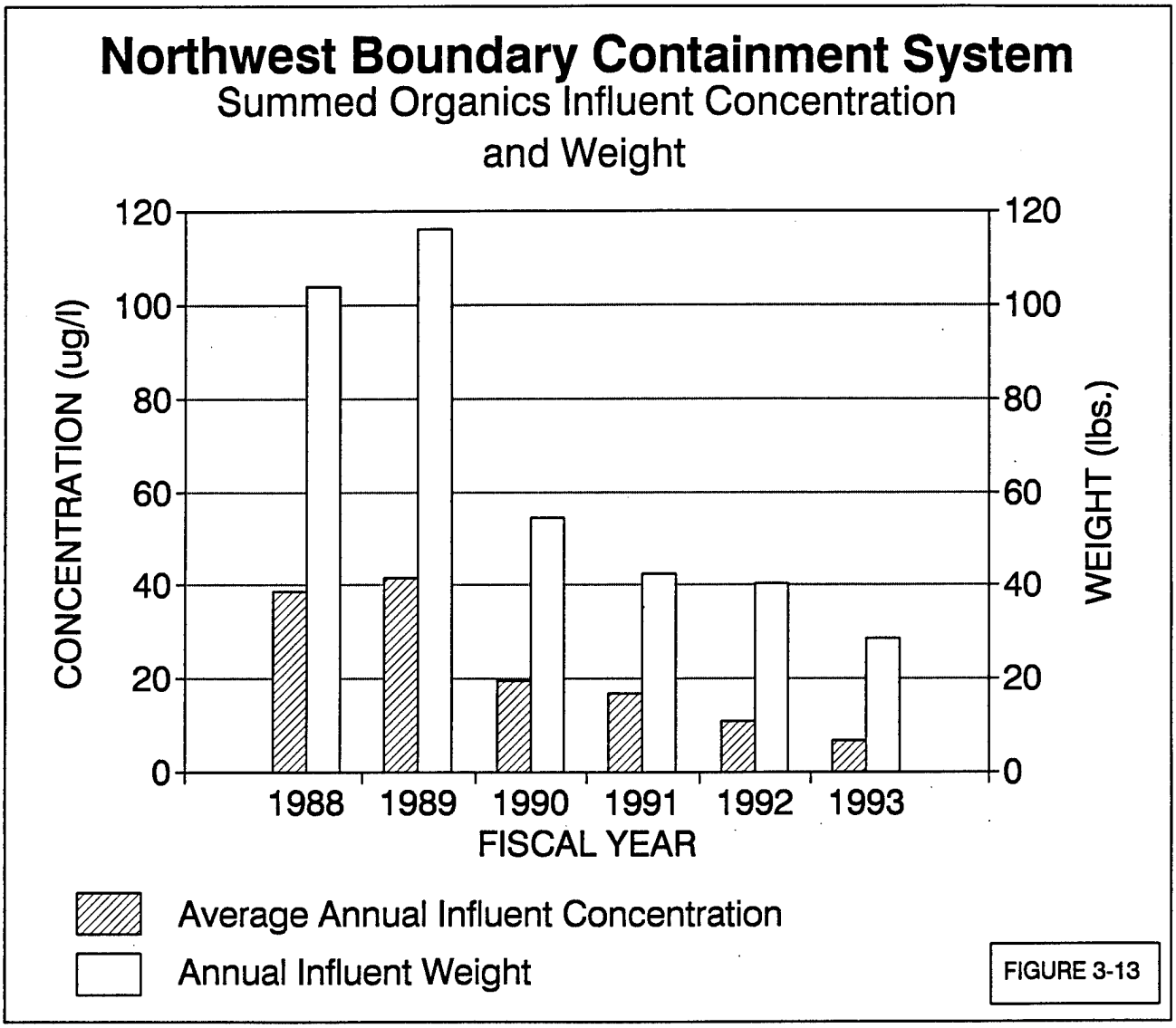


Diisopropylmethyl Phosphonate Average Annual Influent Concentration

Diisopropylmethyl Phosphonate Annual Influent Weight

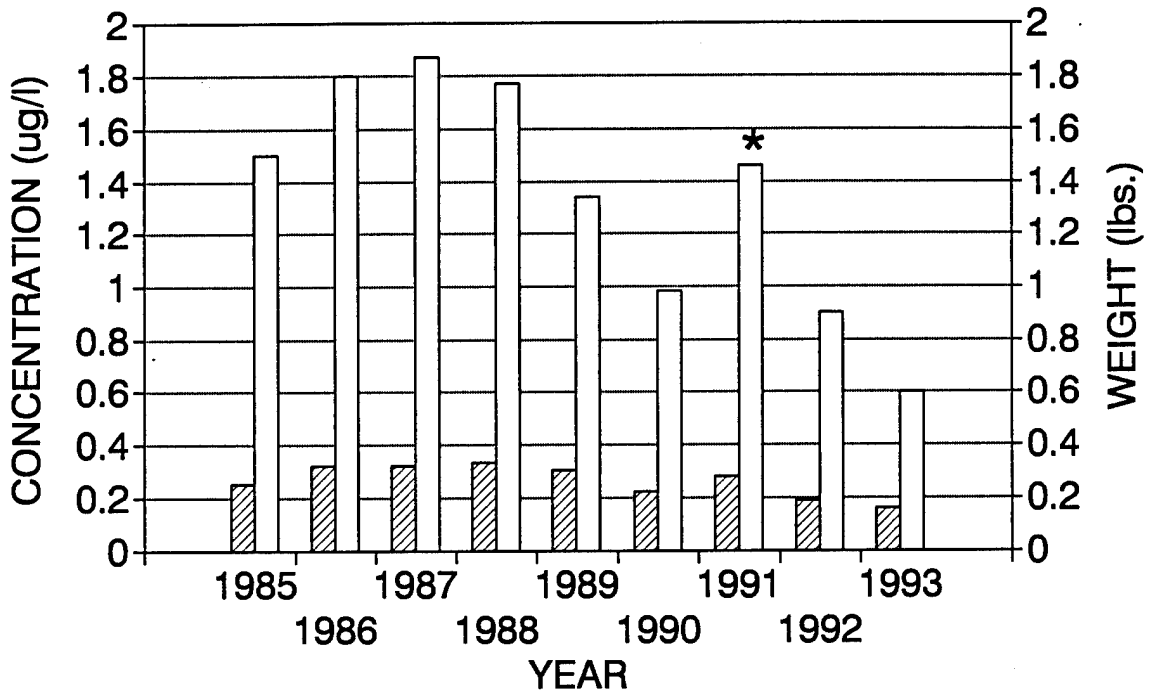
FIGURE 3-11


Northwest Boundary Containment System
Dieldrin Influent Concentration
and Weight
CONCENTRATION (ug/l)
WEIGHT (lbs.)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1985
1986
1987
1988
1989
1990
1991
1992
1993
FISCAL YEAR
Average Annual Influent Concentration
Annual Influent Weight
FIGURE 3-12


Northwest Boundary Containment System
Summed Organics Influent Concentration
and Weight
CONCENTRATION (ug/l)
WEIGHT (lbs.)
120
100
80
60
40
20
0
1988
1989
1990
1991
1992
1993
FISCAL YEAR
Average Annual Influent Concentration
Annual Influent Weight
FIGURE 3-13

Irondale Containment System

DBCP Influent Concentration and Weight



Dibromochloropropane Average Annual Influent Concentration

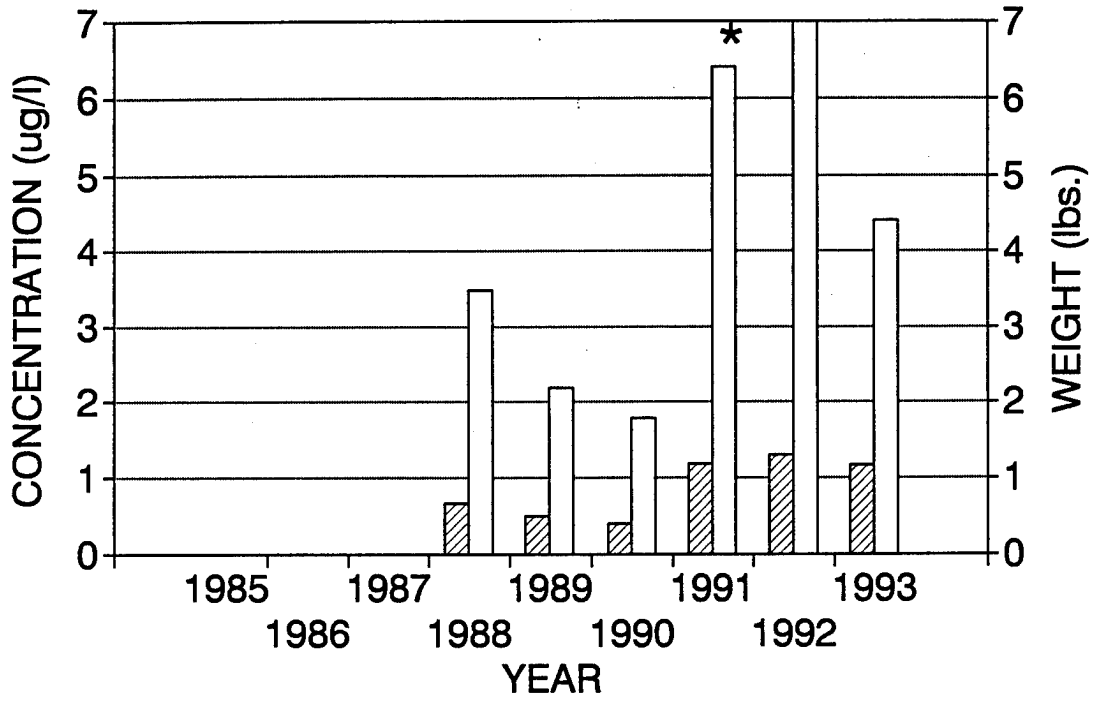
Annual Influent Weight

*The Rail Classification Yard IRA Extraction System became Operational, 1991.

FIGURE 3-14

Irondale Containment System

TRCLE Influent Concentration and Weight



Trichloroethene Average Annual Influent Concentration

Trichloroethene Annual Influent Weight

*The Motor Pool IRA Extraction System became Operational, 1991.

FIGURE 3-15

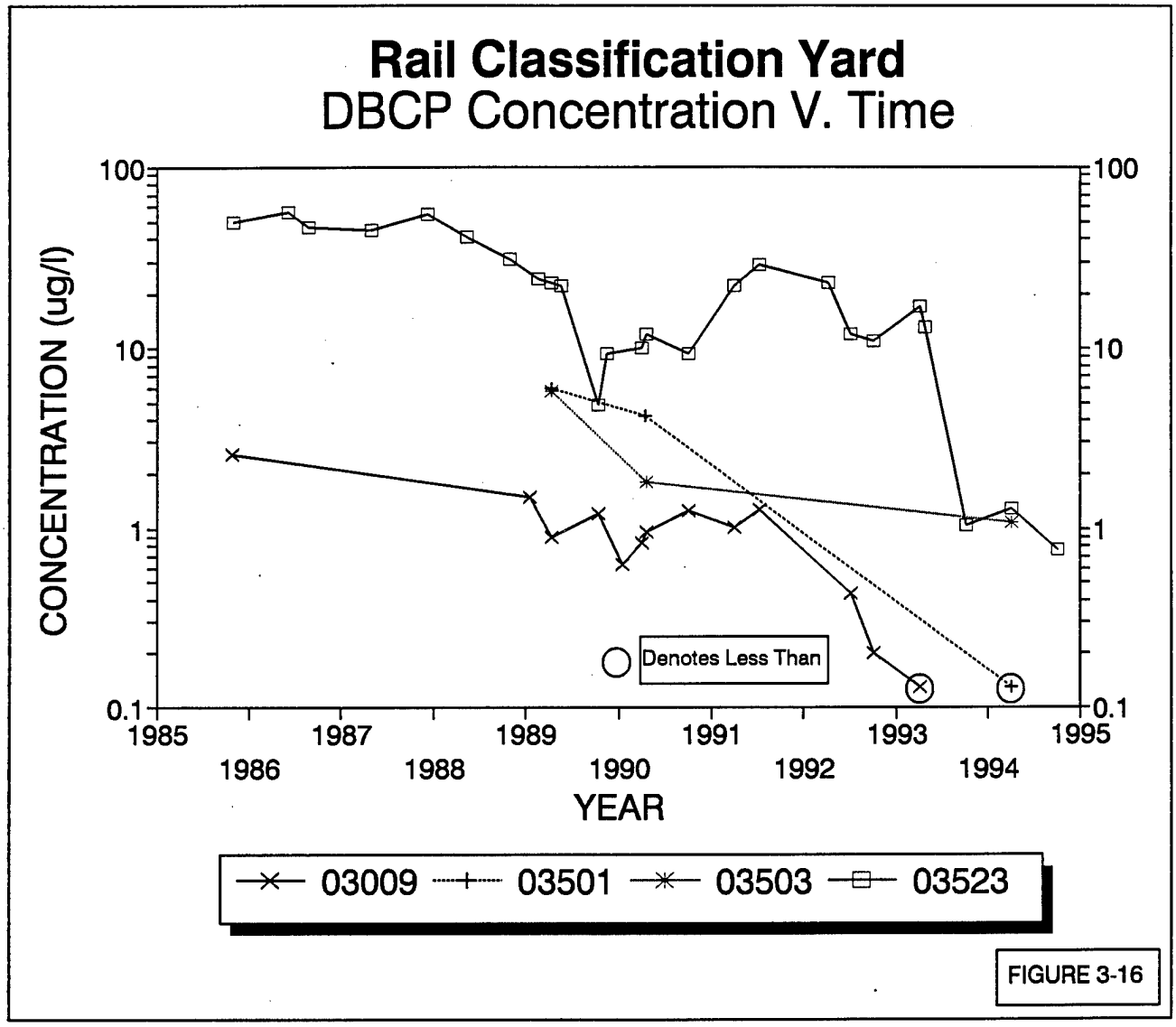

Rail Classification Yard
DBCP Concentration V. Time
CONCENTRATION (ug/l)
100
10
1
0.1
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
YEAR
Denotes Less Than
03009
03501
03503
03523

FIGURE 3-16

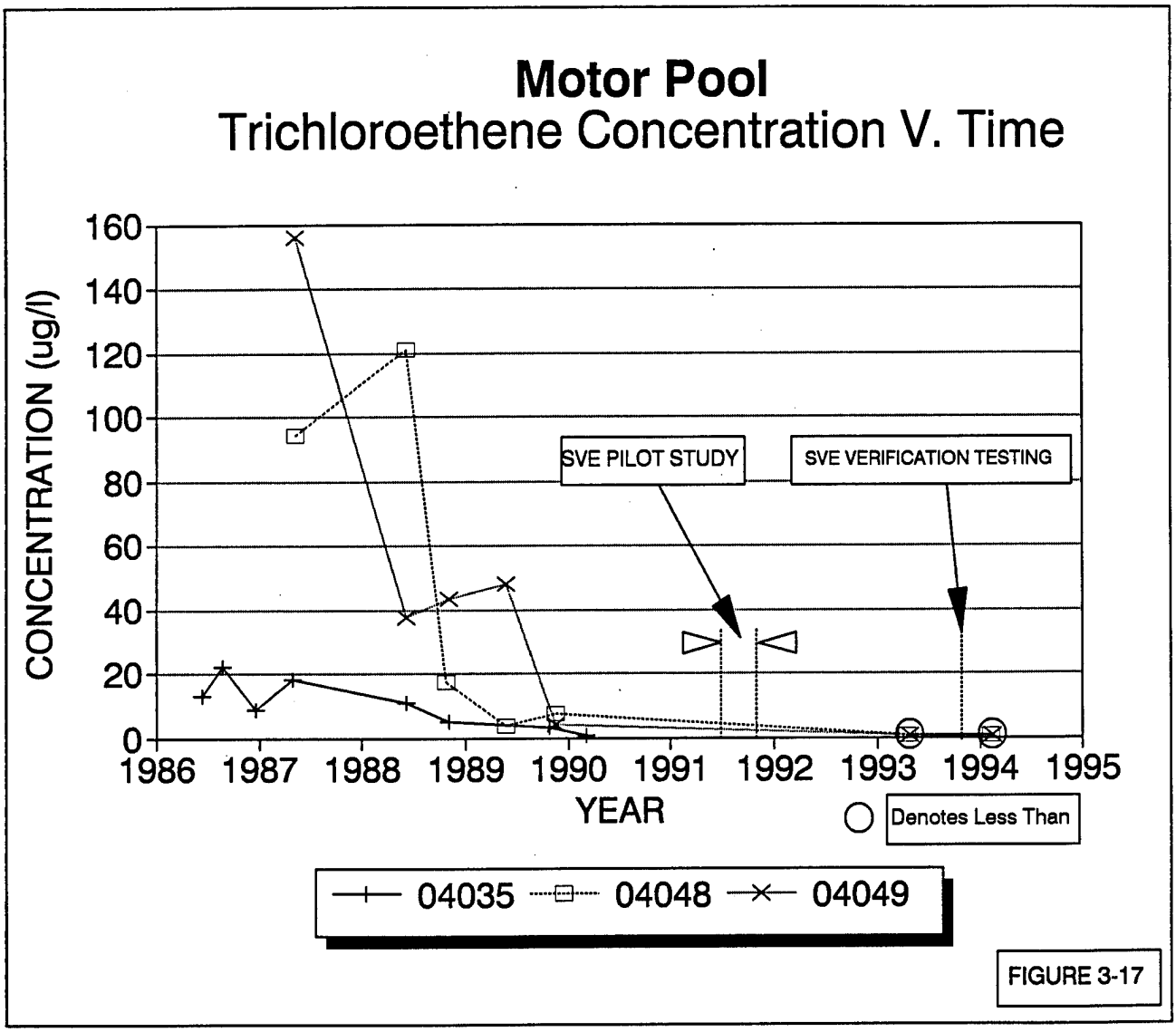

Motor Pool
Trichloroethene Concentration V. Time
CONCENTRATION (ug/l)
160
140
120
100
80
60
40
20
0
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995
YEAR
SVE PILOT STUDY
SVE VERIFICATION TESTING
Denotes Less Than
04035
04048
04049

FIGURE 3-17

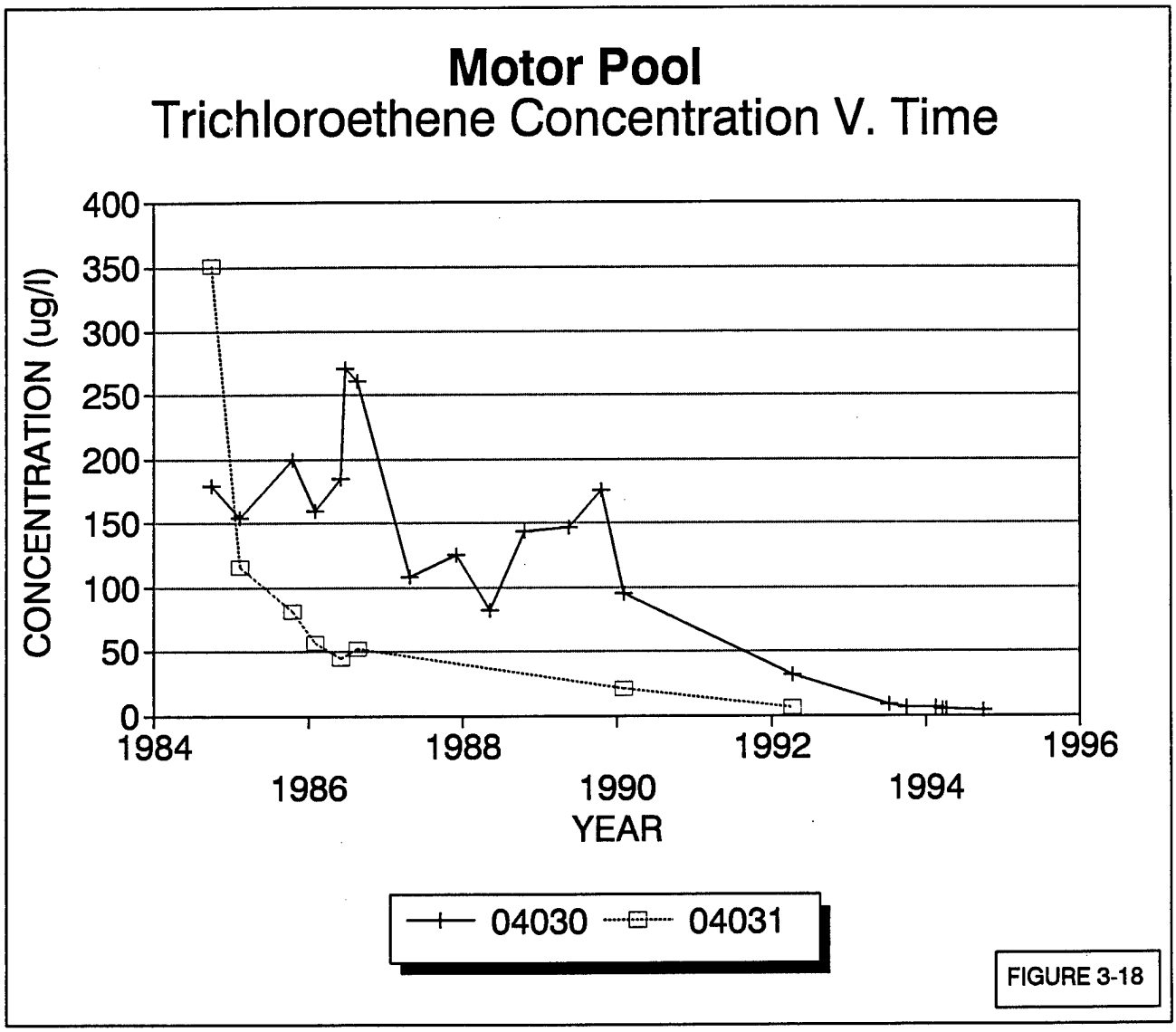
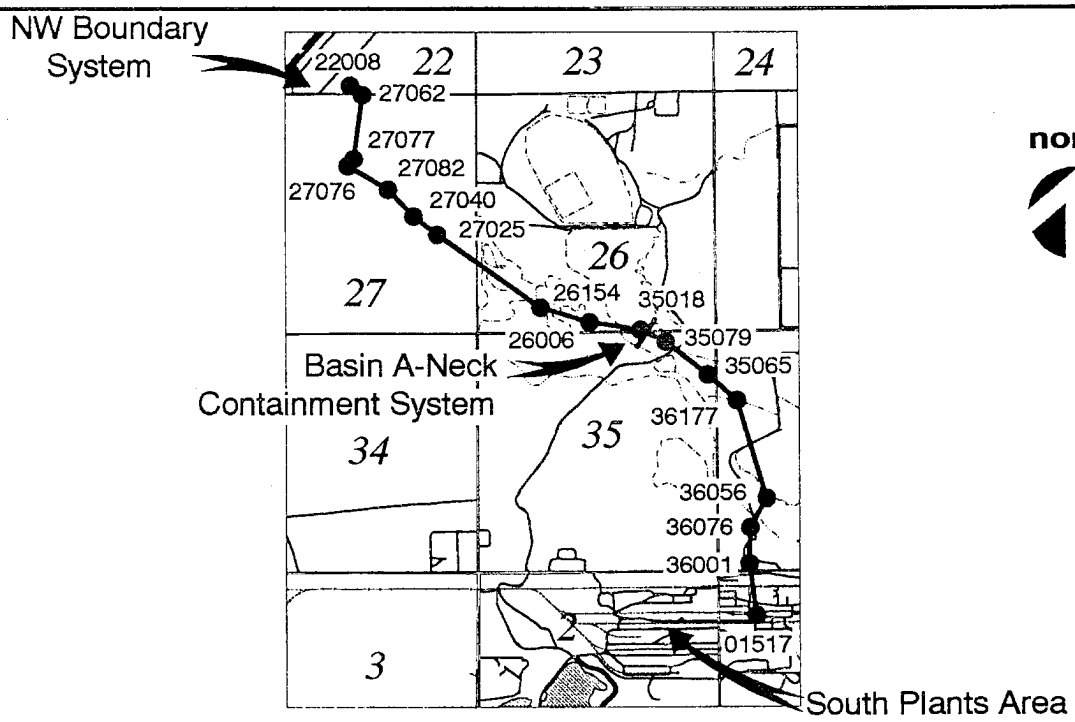
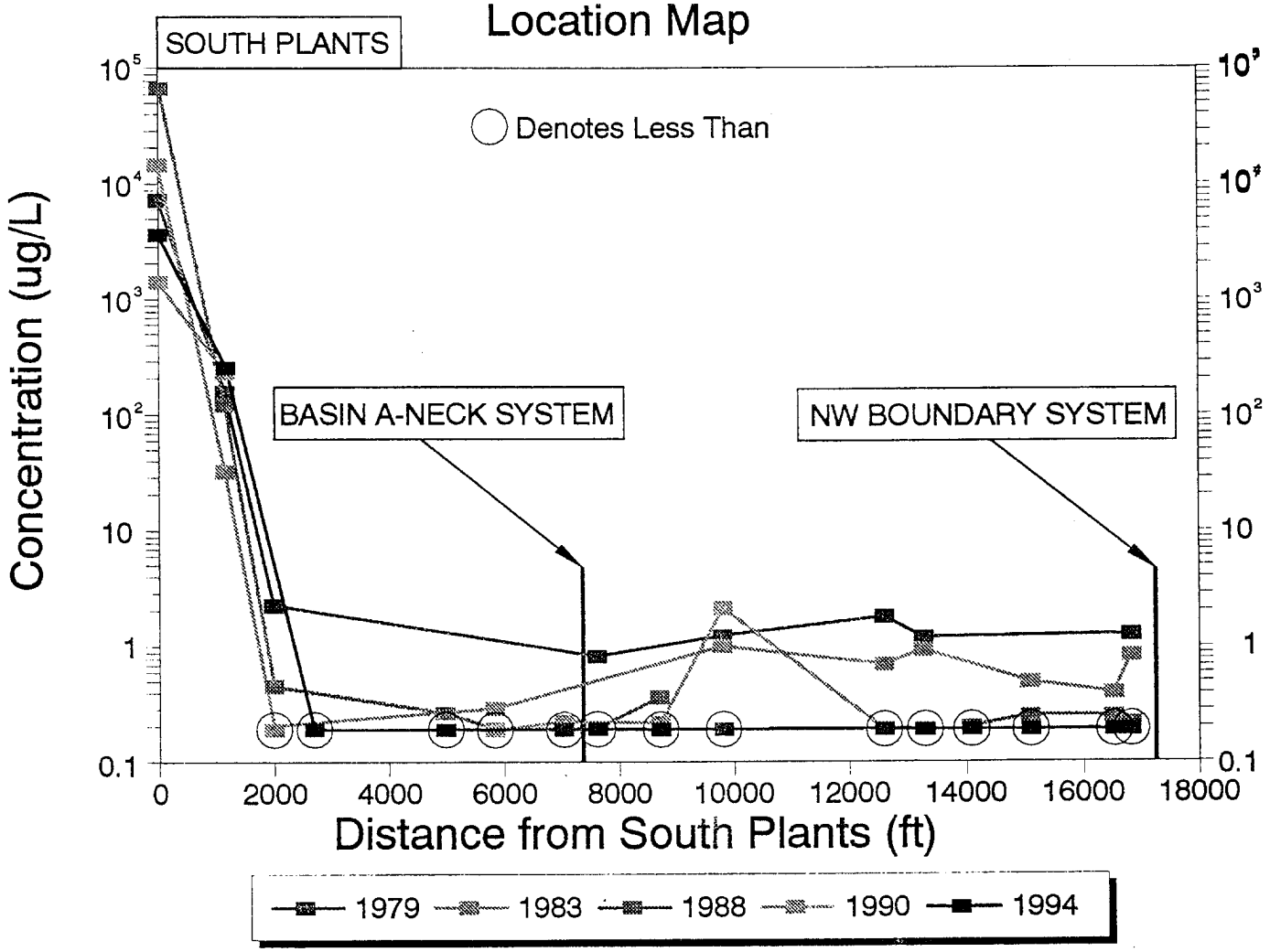

Motor Pool
Trichloroethene Concentration V. Time
CONCENTRATION (ug/l)
400
350
300
250
200
150
100
50
0
1984
1986
1988
1990
1992
1994
1996
YEAR
04030
04031

FIGURE 3-18

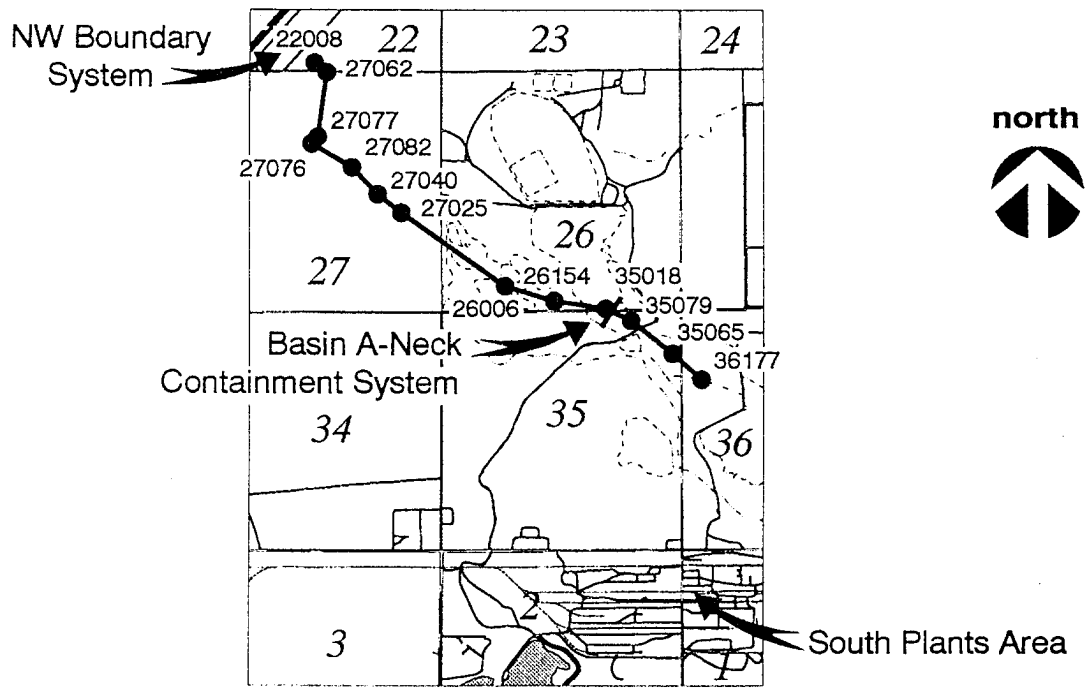


Location Map

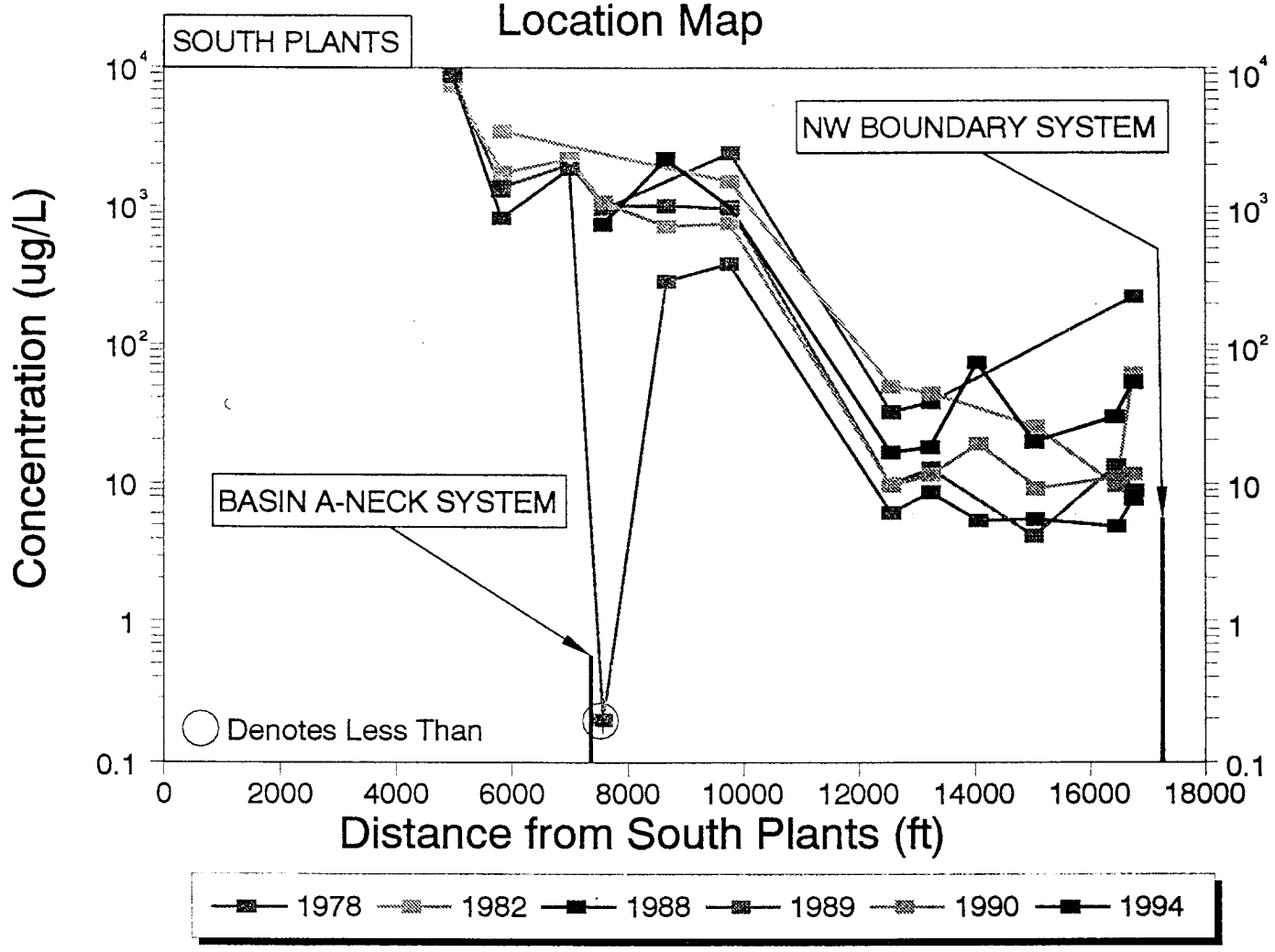


South Plants To NWBCS DBCP Plume Centerline Concentration V. Distance

FIGURE 3-19

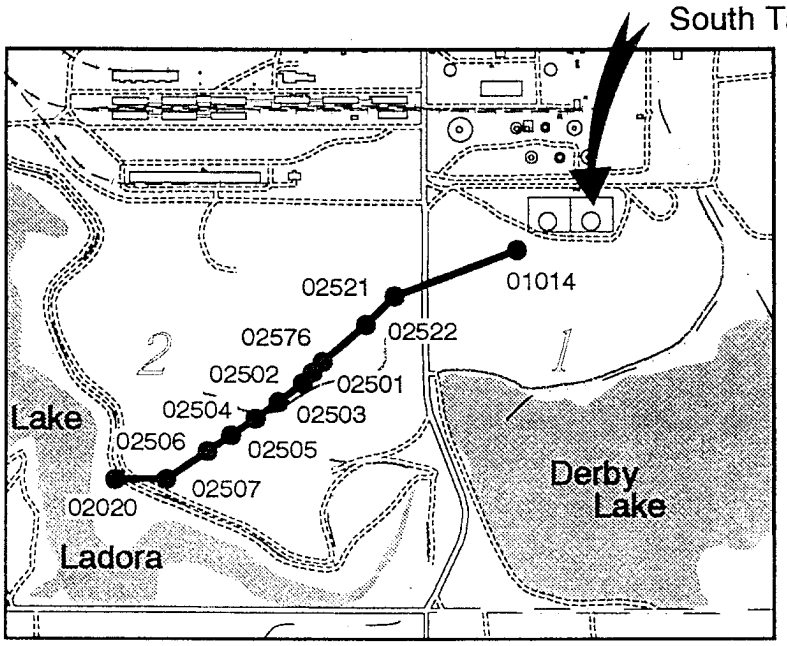


Location Map

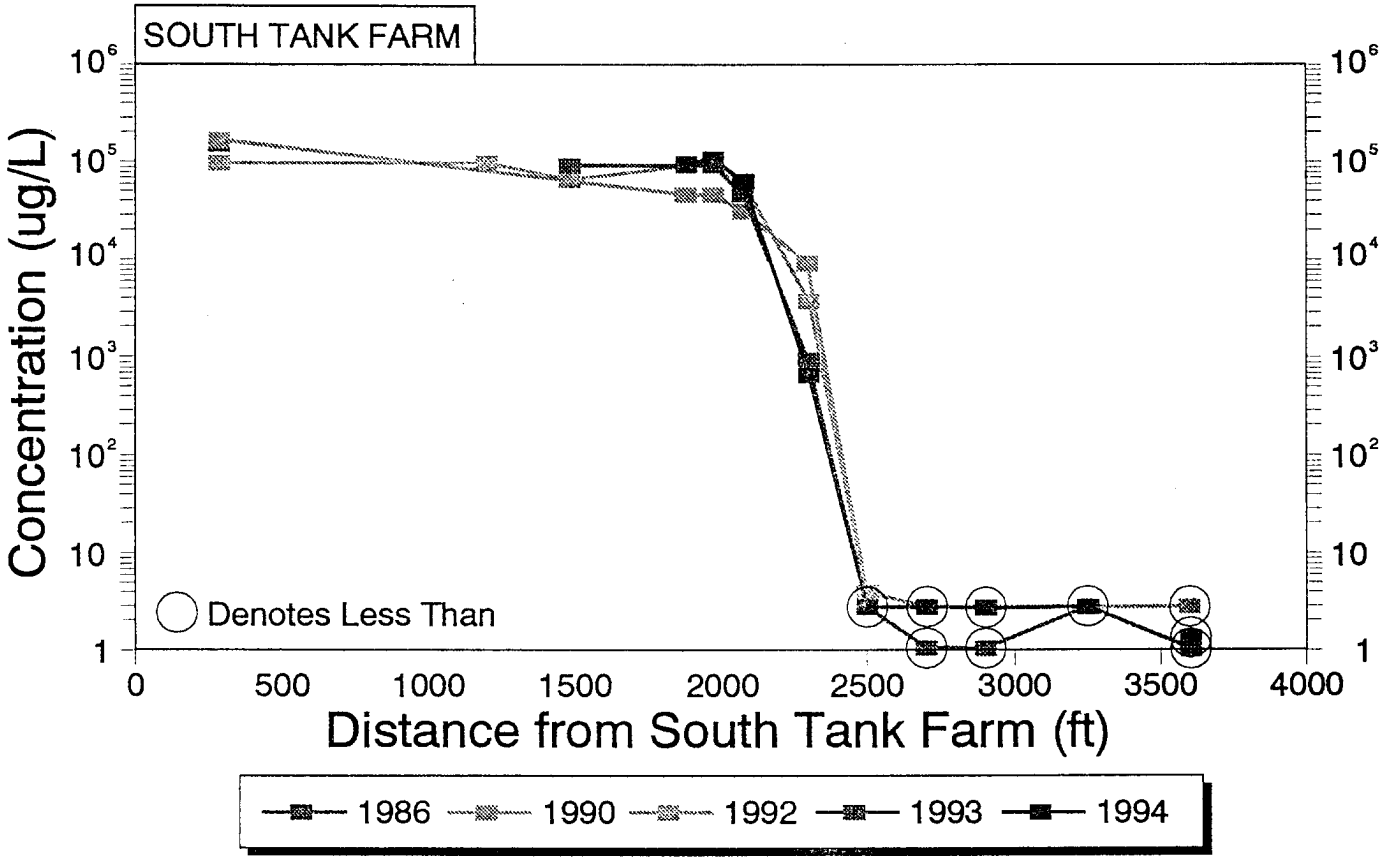


South Plants To NWBCS DIMP Plume Centerline Concentration V. Distance

FIGURE 3-20



Location Map



South Tank Farm Plume
Benzene Concentration V. Distance

FIGURE 3-21

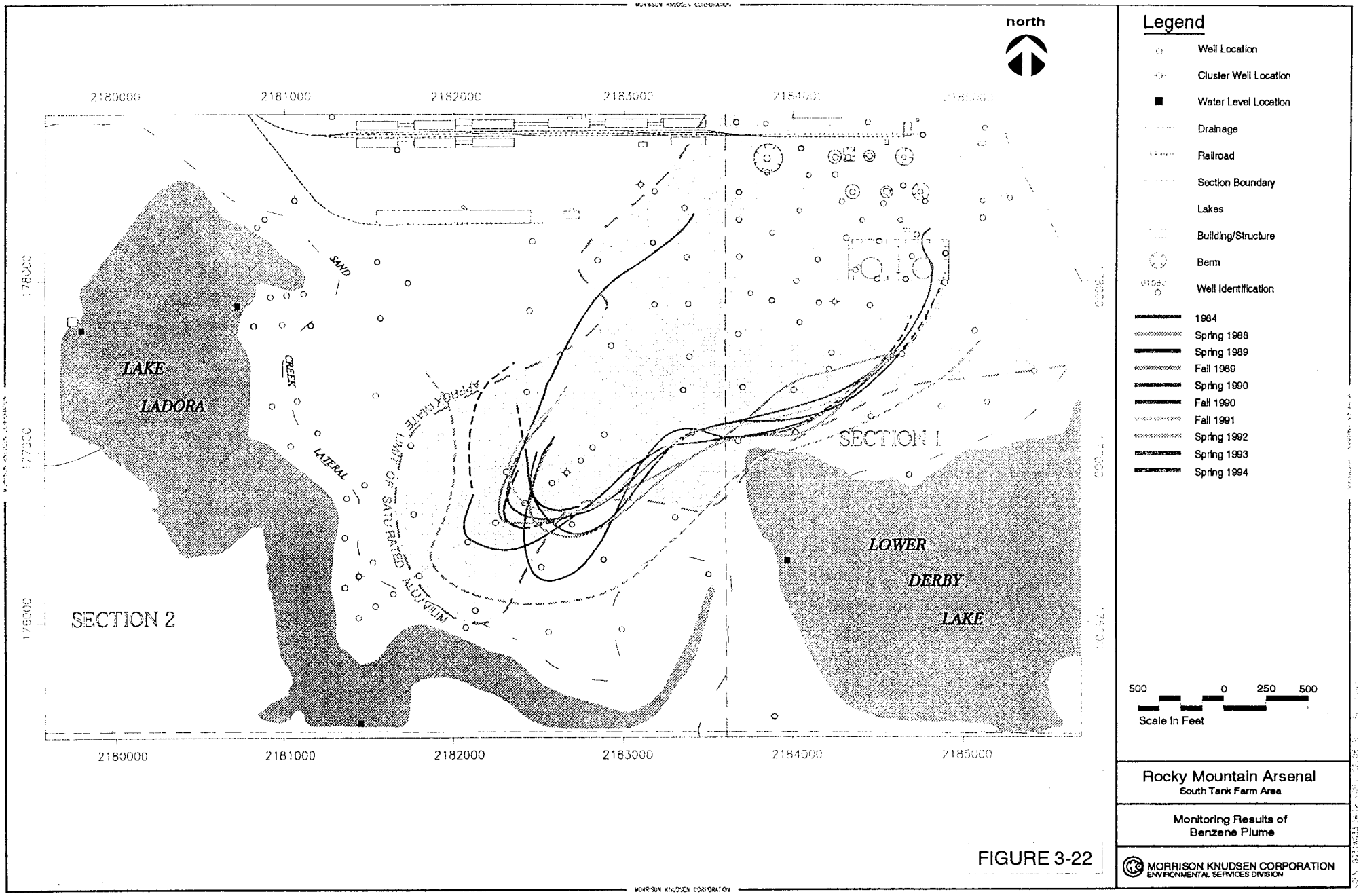
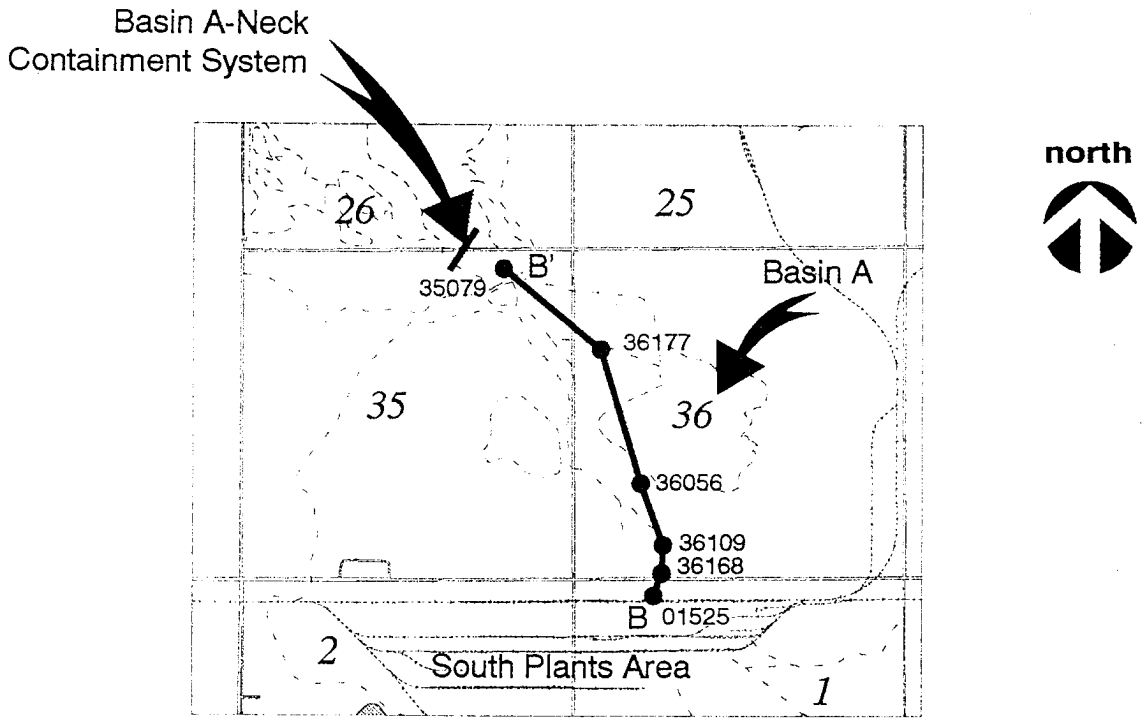
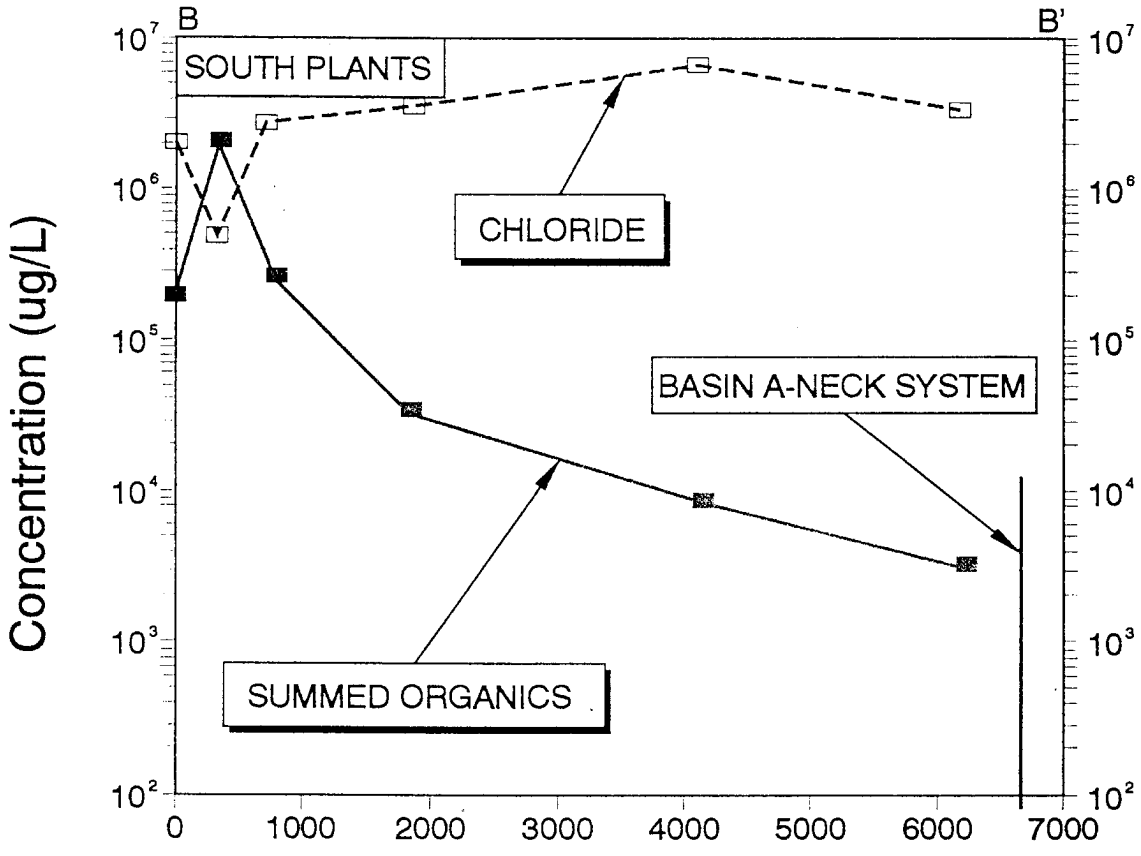

north
2180000
2181000
2182000
2183000
2184000
2185000
178000
177000
176000
LAKE
LADORA
SAND
CREEK
LATERAL
APPROXIMATE LIMIT OF SATURATED ALLUVIUM
SECTION 1
SECTION 2
LOWER
DERBY
LAKE
Legend
Well Location
Cluster Well Location
Water Level Location
Drainage
Railroad
Section Boundary
Lakes
Building/Structure
Berm
Well Identification
1984
Spring 1988
Spring 1989
Fall 1989
Spring 1990
Fall 1990
Fall 1991
Spring 1992
Spring 1993
Spring 1994
500 0 250 500
Scale In Feet
Rocky Mountain Arsenal
South Tank Farm Area
Monitoring Results of
Benzene Plume
MORRISON KNUDSEN CORPORATION
ENVIRONMENTAL SERVICES DIVISION

FIGURE 3-22

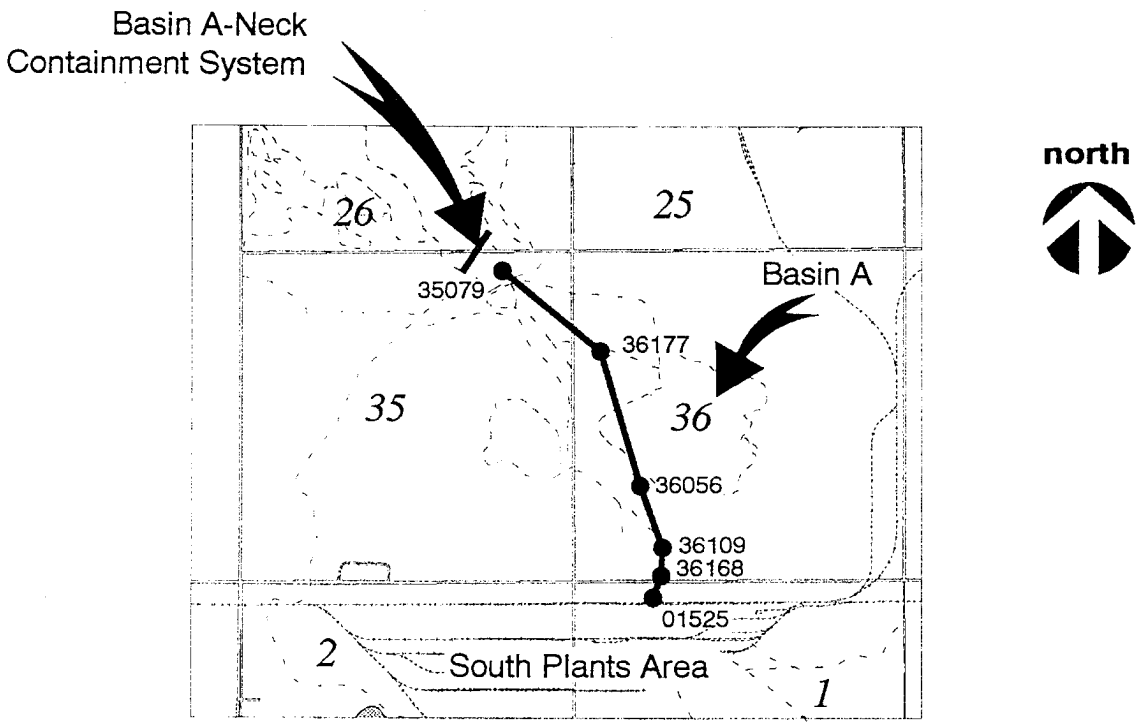


Location Map

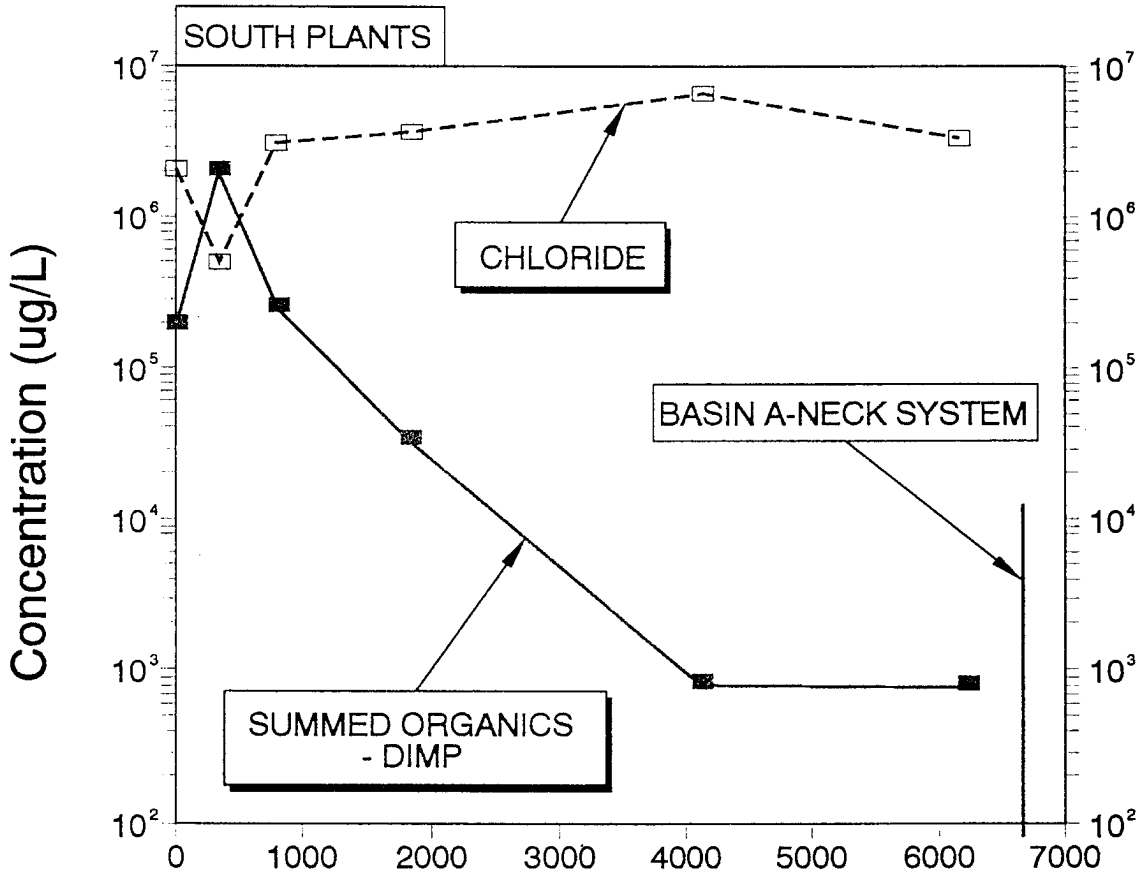


South Plants North Plume
1989 Concentration V. Distance

FIGURE 3-23



Location Map

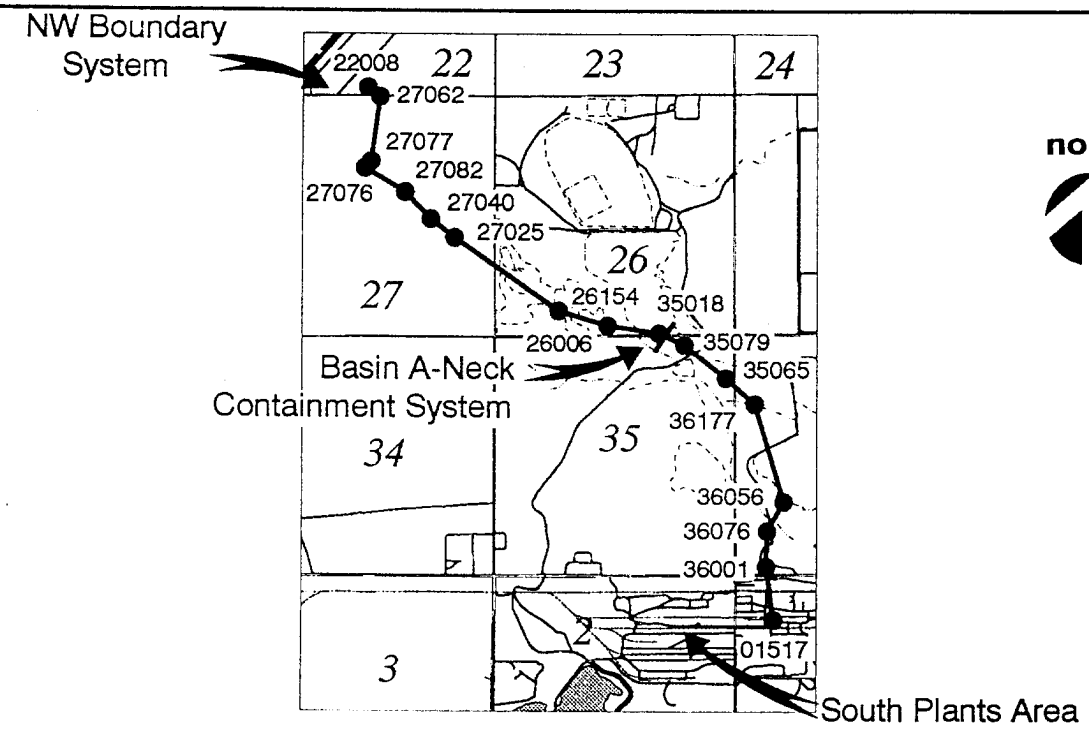


Distance from South Plants (ft)

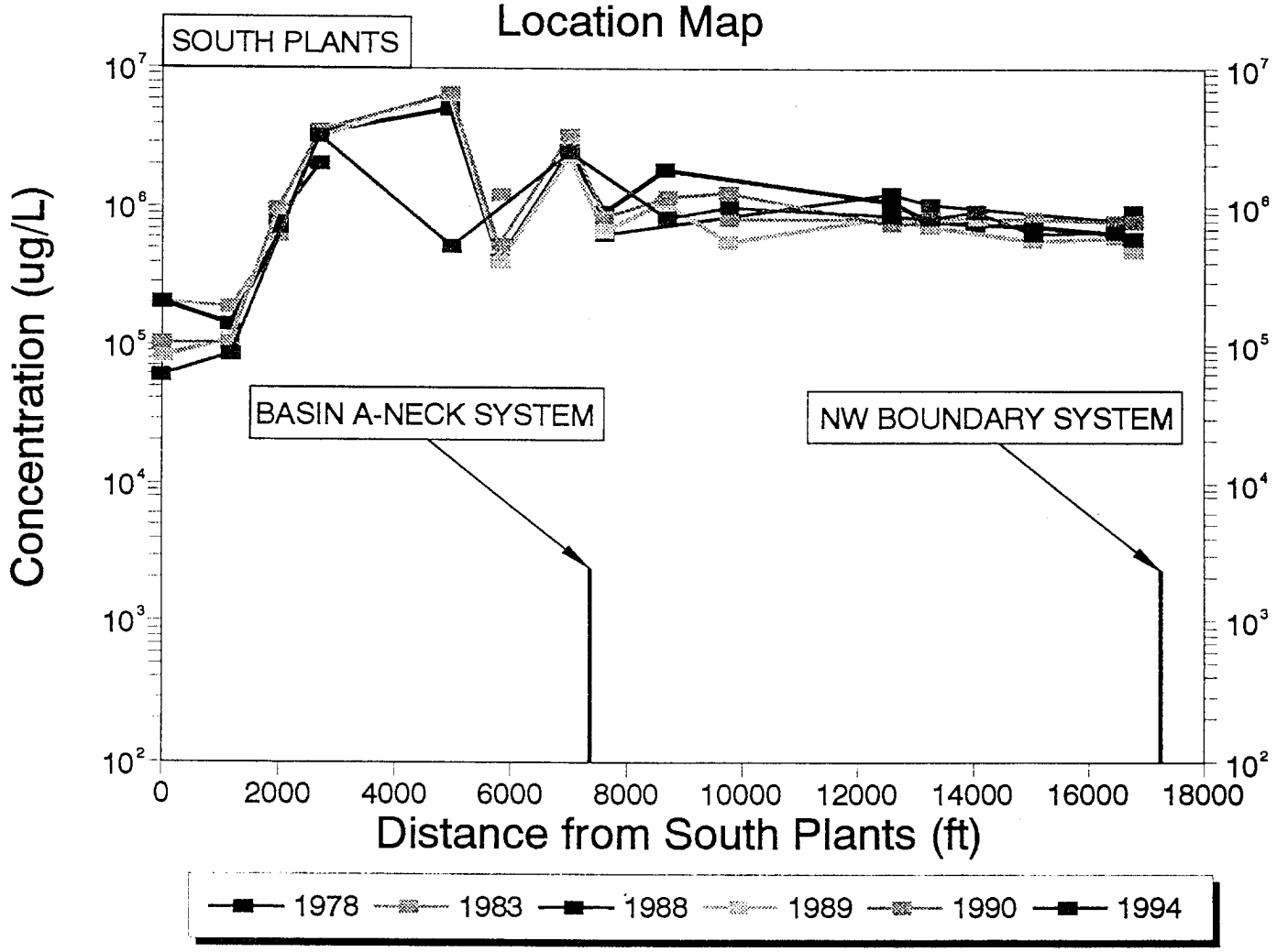
South Plants North Plume
1989 Concentration V. Distance

FIGURE 3-24

<CFN: 0103G073.DWG> <CPD: 02/08/95> <AUT:RJC>



Location Map



South Plants To NWBCS Chloride Plume Centerline Concentration V. Distance

FIGURE 3-25

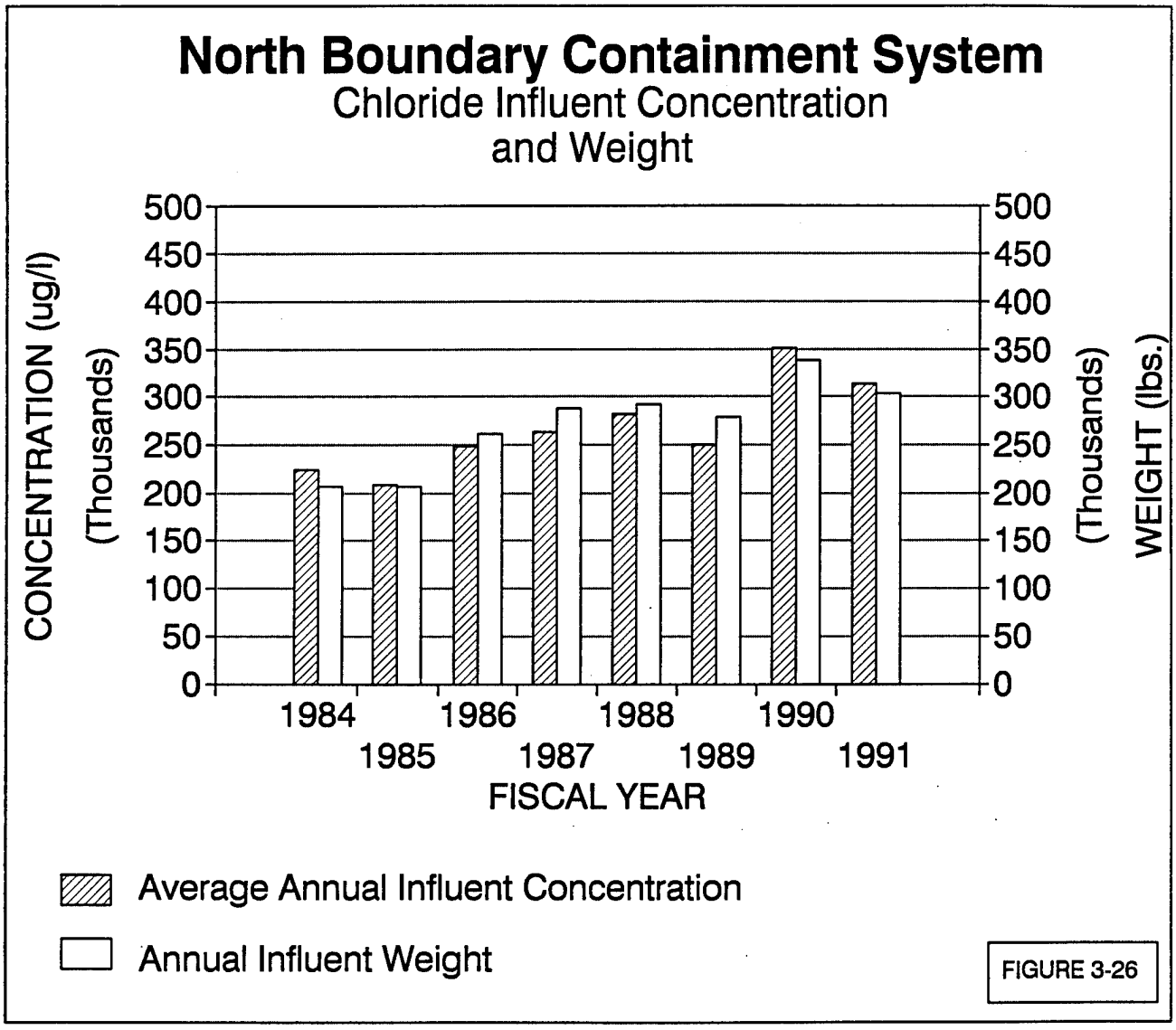

North Boundary Containment System
Chloride Influent Concentration
and Weight
CONCENTRATION (ug/l)
(Thousands)
WEIGHT (lbs.)
(Thousands)
500
450
400
350
300
250
200
150
100
50
0
1984
1985
1986
1987
1988
1989
1990
1991
FISCAL YEAR
Average Annual Influent Concentration
Annual Influent Weight

FIGURE 3-26

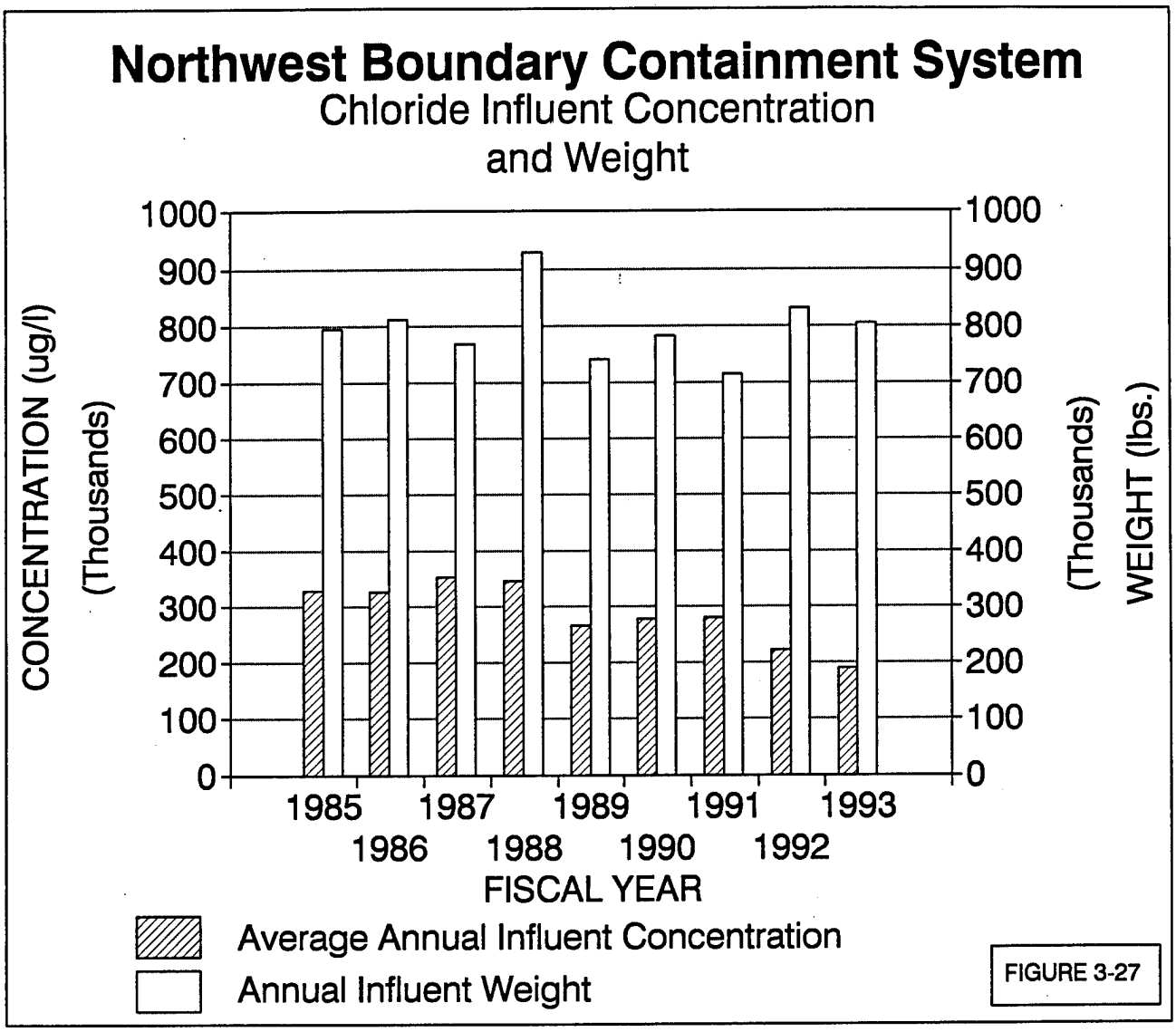

Northwest Boundary Containment System
Chloride Influent Concentration
and Weight
CONCENTRATION (ug/l)
(Thousands)
WEIGHT (lbs.)
(Thousands)
1000
900
800
700
600
500
400
300
200
100
0
1985
1986
1987
1988
1989
1990
1991
1992
1993
FISCAL YEAR
Average Annual Influent Concentration
Annual Influent Weight

FIGURE 3-27

APPENDIX A

PRIMARY FLOWPATH CONCENTRATION PROFILES

APPENDIX A

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APPENDIX A

PRIMARY FLOWPATH CONCENTRATION PROFILES

The following paragraphs summarize the analysis of plume axis profiles for the South Plants North/Basin A and Basin F Plumes.

A.1 South Plants North/Basin A Plume

The following plume axis profiles show the spatial and temporal changes in contaminant concentrations along the primary migration pathway. The profiles indicate that the leading edges and centers of mass of many of the South Plants North plumes are more or less static. This phenomenon results in a reduced contaminant loading at the Basin A-Neck Containment System (BANCS).

Benzene. Figure A-1 shows a 5 order-of-magnitude decrease in benzene concentrations with distance along the flow direction north of South Plants. Concentrations in monitoring wells located near the BANCS and in the influent typically are below the Offpost PRG of 3 ug/l and are near or below reporting limits. Between 1988 and 1994, the plume appears to be somewhat static with no significant concentration change near the BANCS. Concentrations have decreased over time in Well 36177.

Chlorobenzene. Figure A-2 shows a 5 order-of-magnitude decrease in chlorobenzene concentrations with distance along the flow direction north of South Plants. Concentrations in monitoring wells located near the BANCS and in the influent are below the Offpost PRG of 25 ug/l. Between 1988 and 1994, the plume appears to be static with no significant advancement.

Chloroform. Figure A-3 shows a 6 order-of-magnitude decrease in chloroform concentrations to below the Offpost PRG with distance along the flow direction north of South Plants. Flow from the Basin F IRA causes the BANCS influent to occasionally exceed the

Offpost PRG of 15 ug/l. Between 1988 and 1994, the plume appears to be somewhat static and concentrations have decreased in Wells 36177 and 36168.

DBCP. Figure A-4 shows a 5 order-of-magnitude decrease in DBCP concentrations to below reporting limits along the flow direction within 2,000 ft of South Plants. Concentrations in monitoring wells located nearest the BANCS are near or below reporting limits. Flow from the Basin F IRA causes the BANCS influent to exceed the Offpost PRG of 0.195 ug/l.

Dieldrin. Concentrations are variable, however, Figure A-5 shows a 2 order-of-magnitude overall decrease in dieldrin concentrations along the flow direction. Significant temporal decreases in concentrations are observed in the area of Wells 36056 and 36603. The dieldrin concentrations in the BANCS influent exceed the Offpost PRG of 0.05 ug/l.

Trichloroethene and Tetrachloroethene. Figure A-6 shows a 3 order-of-magnitude decrease in trichloroethene concentrations to near the Offpost PRG of 3 ug/l along the flow direction. The BANCS influent exceeds the Offpost PRG. A similar trend is seen for tetrachloroethene (Figure A-7) and concentrations decrease to below the Offpost PRG of 5 ug/l in monitoring wells located near the BANCS and in the influent.

A.2 Basin F Plume

Concentrations north of former Basin F also decline toward the NBCS. Spatial decreases in concentrations for the contaminants evaluated for the Basin F Plume are less than those for the South Plants/Basin A plumes, however, temporal decreases are more evident along the profiles. Of the 17 and 27 Offpost COCs that exceed Offpost PRGs in at least one well in Sections 25 and 26,

respectively, only 6 exceed Offpost PRGs in the NBCS influent (Table 3-4).

Benzene. Figure A-8 shows a 2 order-of-magnitude overall decrease in benzene concentrations with distance along the flow direction north of Basin F. Lower concentrations at Well 23241 suggest that this well may not be located along the plume axis. Concentrations in monitoring wells located nearest the NBCS are below the Offpost PRG of 3 ug/l and near or below reporting limits. Concentrations are at their lowest levels in 1994 in every well sampled.

Chloroform. Figure A-9 shows approximately a 3 order-of-magnitude decrease in chloroform concentrations with distance along the flow direction after 1989. Between 1987 and 1989, concentrations were relatively consistent. Since 1989, concentrations near the NBCS have been substantially lower than previous years and are below the Offpost PRG of 15 ug/l.

In 1994, significant decreases are seen with concentrations either below the CRL or at their lowest levels in 7 of 10 wells sampled. These temporal decreases are consistent with decreases in NBCS influent concentrations.

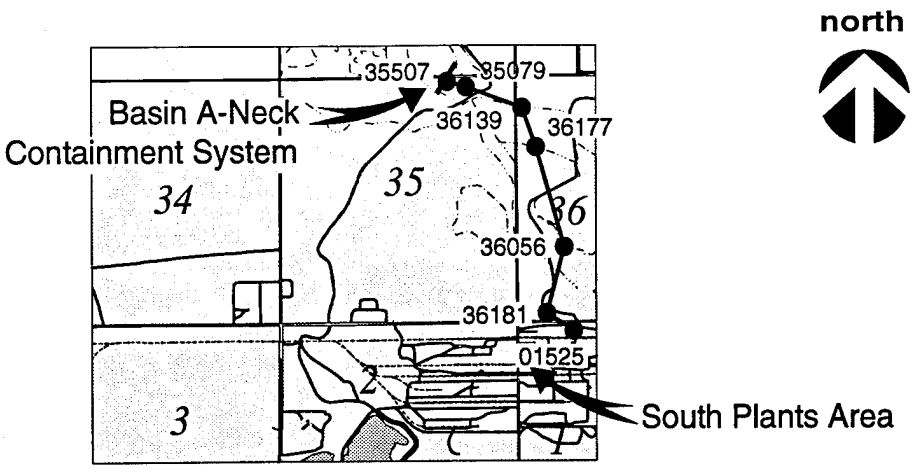
DBCP. Figure A-10 shows approximately a two order-of-magnitude decrease in DBCP concentrations along the flow direction in 1994. Between 1979 and 1994, concentrations have decreased throughout much of the plume axis and in 1994, the concentrations are at their lowest levels for wells in the northern half of Section 24 and near Former Basin F. Concentration declines are seen for Wells 26173, 26133, 24049, 24008/24201, and 24101. These temporal decreases are consistent with decreases in NBCS influent concentrations.

DCPD. Figure A-11 shows approximately an order-of-magnitude decrease in DCPD concentrations along the flow direction in 1994. Between 1979 and 1994, concentrations have decreased throughout the plume axis and in 1994, the concentrations are either below the CRL or at their lowest levels in 10 of 12 wells sampled. Steady concentration declines are seen for Wells 26173, 26133, 23095, 23106, 23053, 23004/23223, 23160/23231, and 23123. These temporal decreases are consistent with decreases in NBCS influent concentrations.

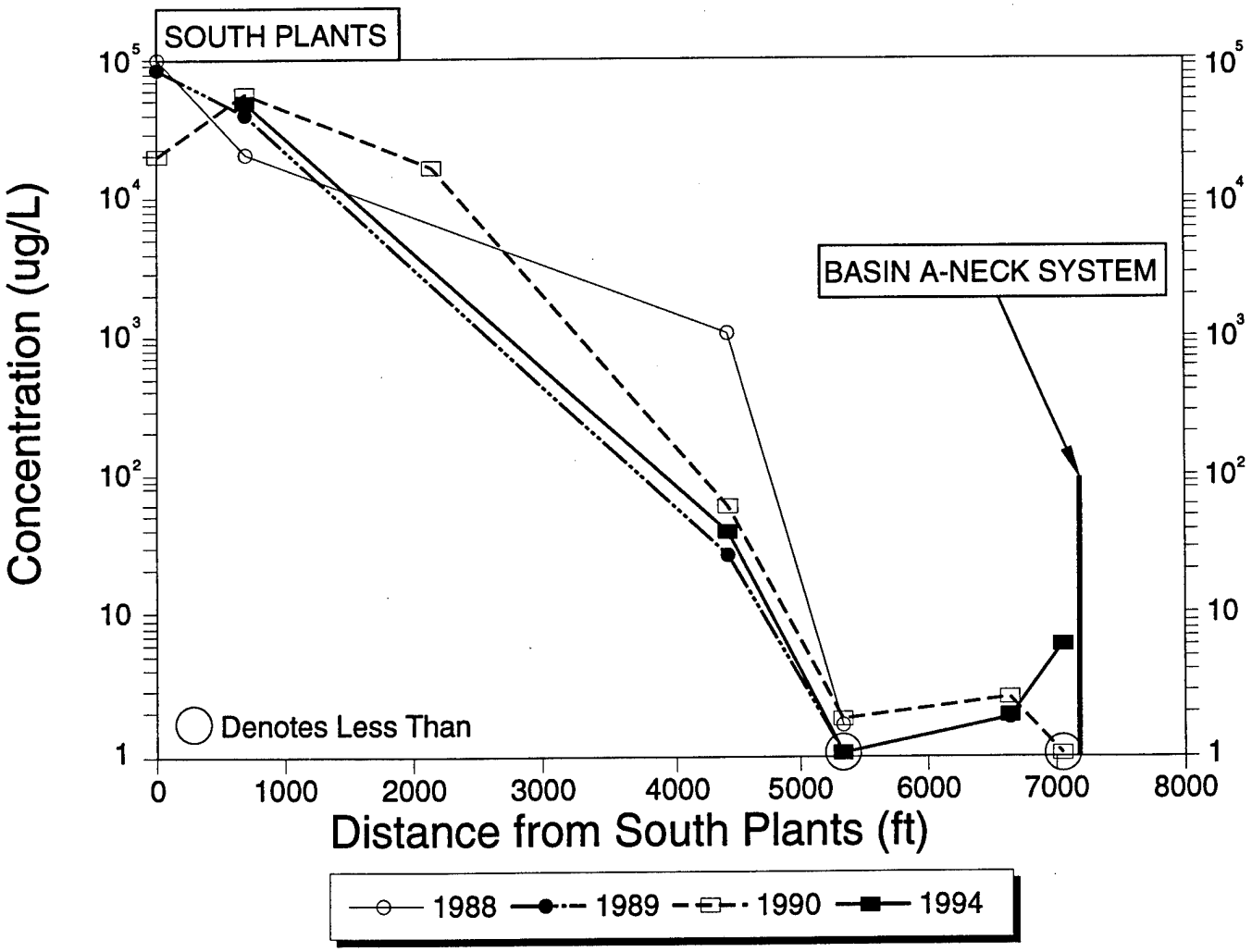
Dieldrin. Figure A-12 shows consistent or increasing concentrations along the primary flowpath. In the 1990 and 1994 profiles, the highest dieldrin concentrations occur at the NBCS, with the lowest concentrations near Basin F. Some of the highest concentrations occurred in 1990 and the concentrations were uniformly lower throughout the plume profile in the monitoring wells sampled in 1994.

DIMP. DIMP is one of the more persistent RMA analytes and spatial concentration decrease is less than for other contaminants evaluated (Figure A-13). Its profile is similar to that of dieldrin. Temporal decreases are apparent since 1988 with significant decreases in 1993 or 1994. Eleven of 12 wells sampled were at their lowest concentration levels in 1994. These temporal decreases are consistent with decreases in NBCS influent concentrations.

Tetrachloroethene. Figure A-14 shows approximately an order-of-magnitude decrease in tetrachloroethene concentrations along the flow direction in 1994. Between 1987 and 1994, temporal concentrations are relatively consistent overall.



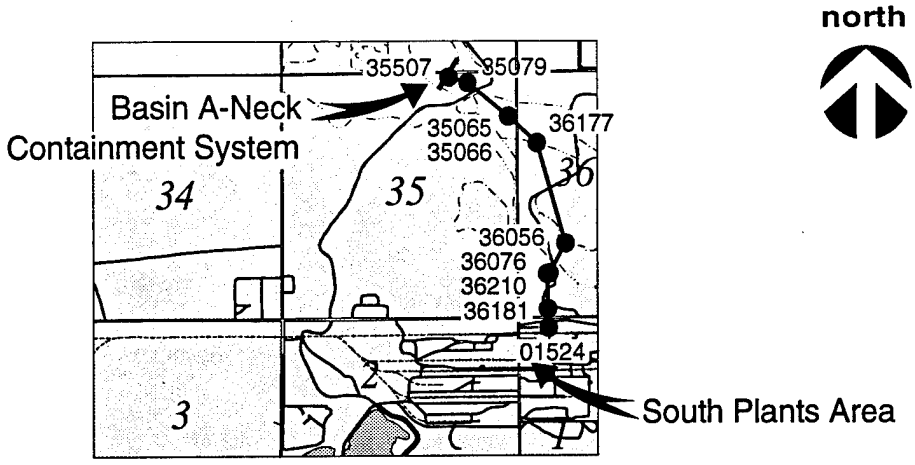
Location Map



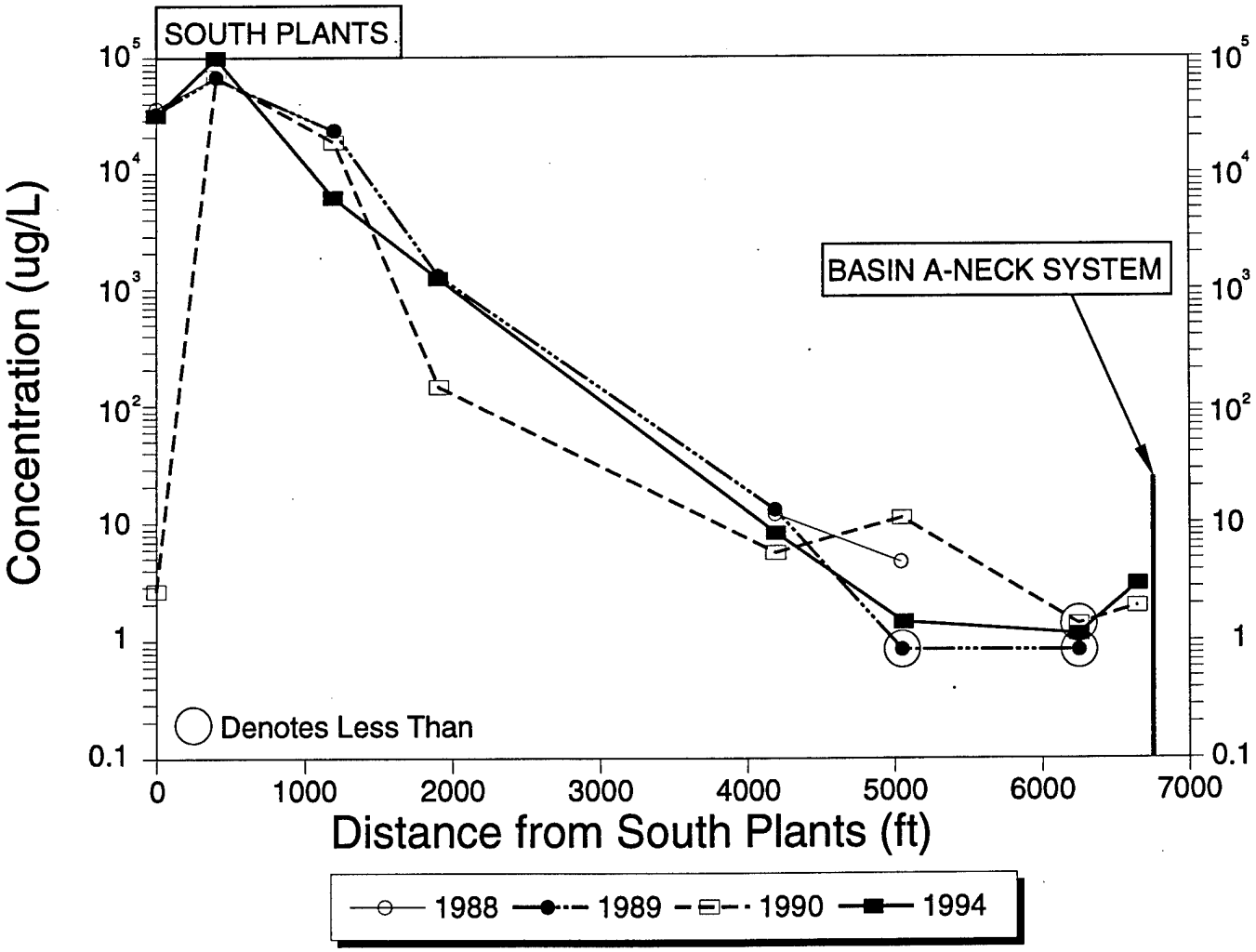
South Plants/Basin A Plume Centerline Benzene Concentration V. Distance

FIGURE A-1

<CFN: 0103G038.DWG> <CPD: 02/08/95> <AUT:RJC>



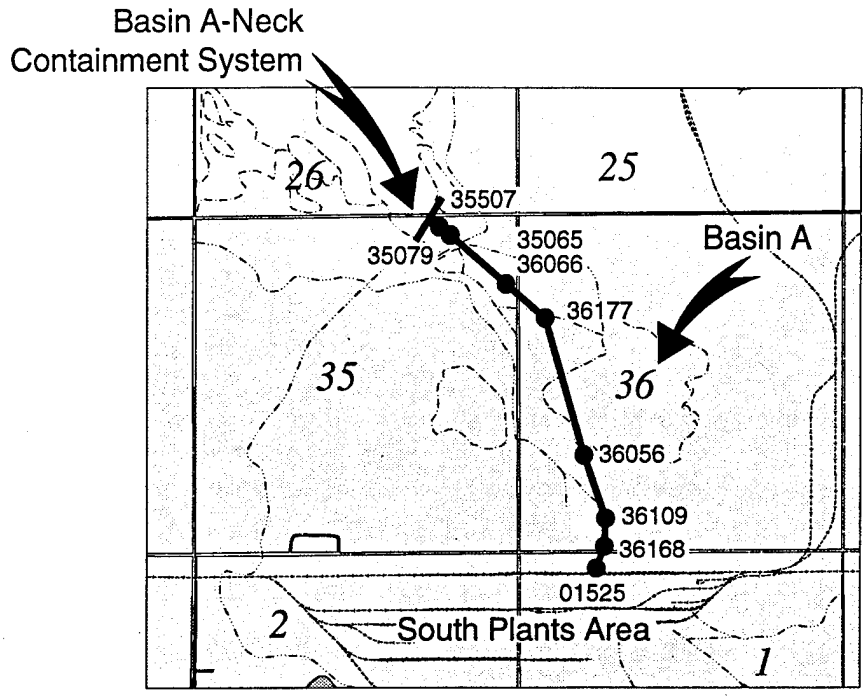
Location Map



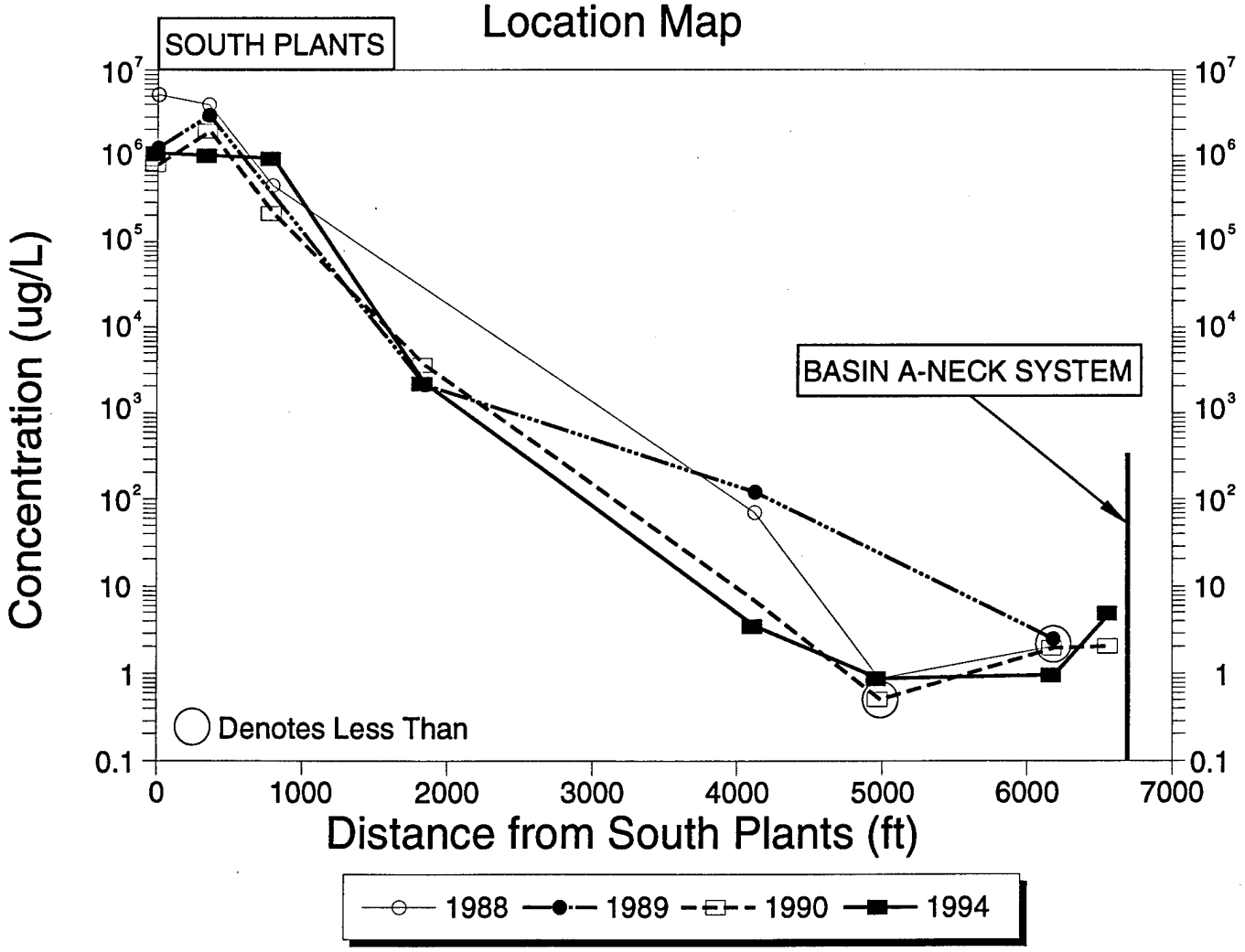
South Plants/Basin A Plume Centerline Chlorobenzene Concentration V. Distance

FIGURE A-2

<CFN: 0103G039.DWG> <CPD: 02/08/95> <AUT:RJC>



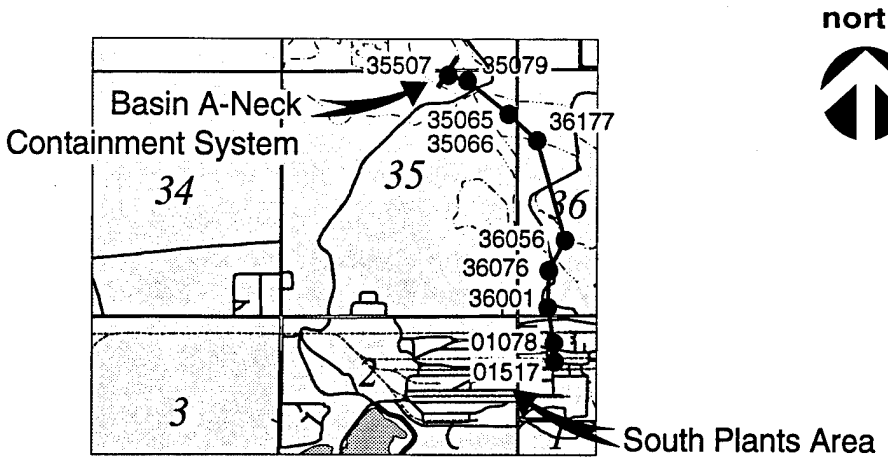
Location Map



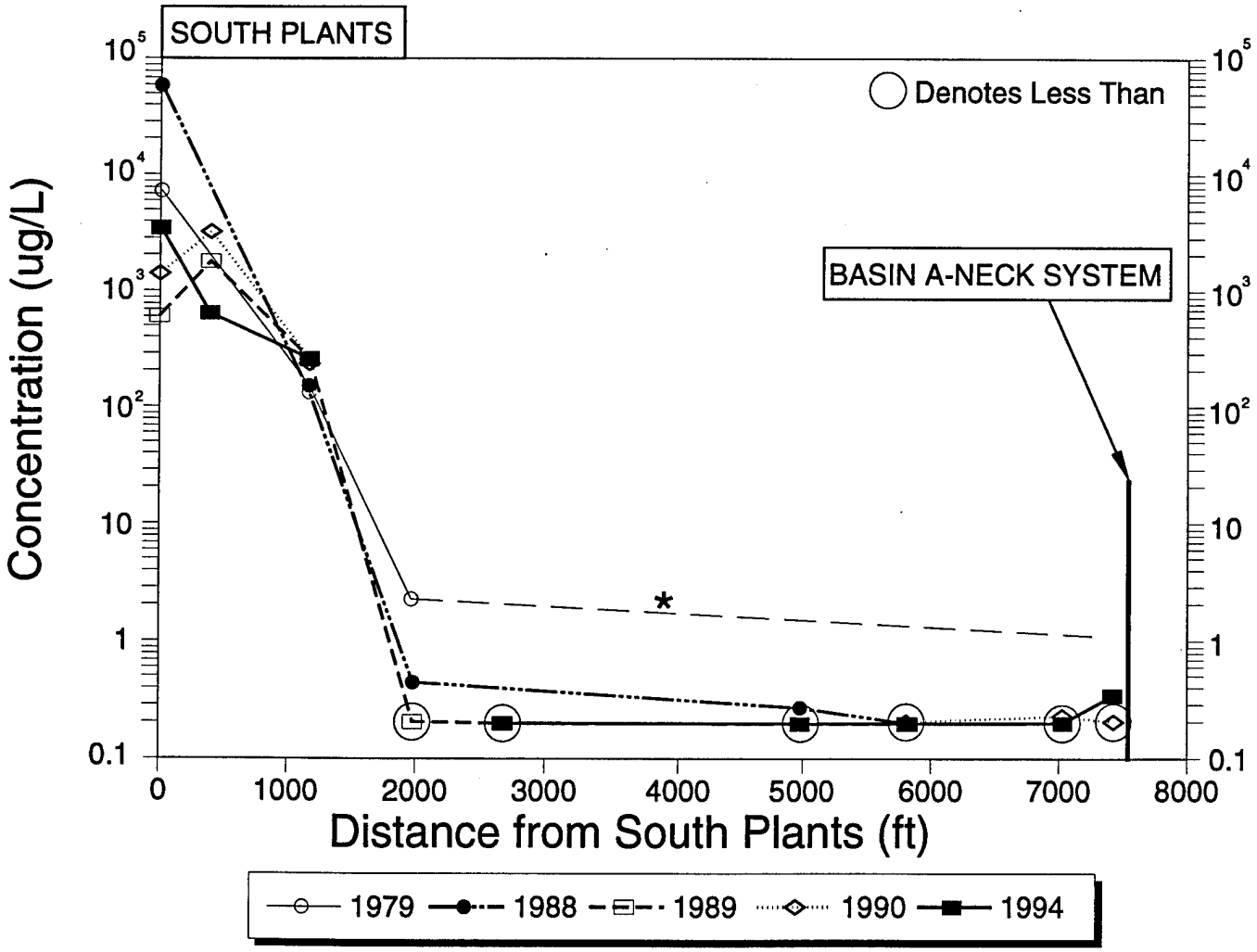
South Plants/Basin A Plume Centerline
Chloroform Concentration V. Distance

FIGURE A-3

<CFN: 0103G071.DWG> <CPD: 02/08/95> <AUT:RJC>



Location Map

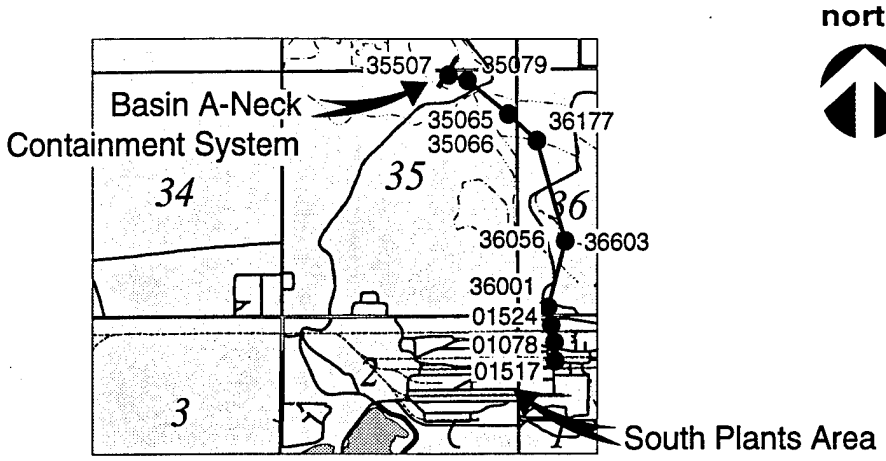


South Plants/Basin A Plume Centerline DBCP Concentration V. Distance

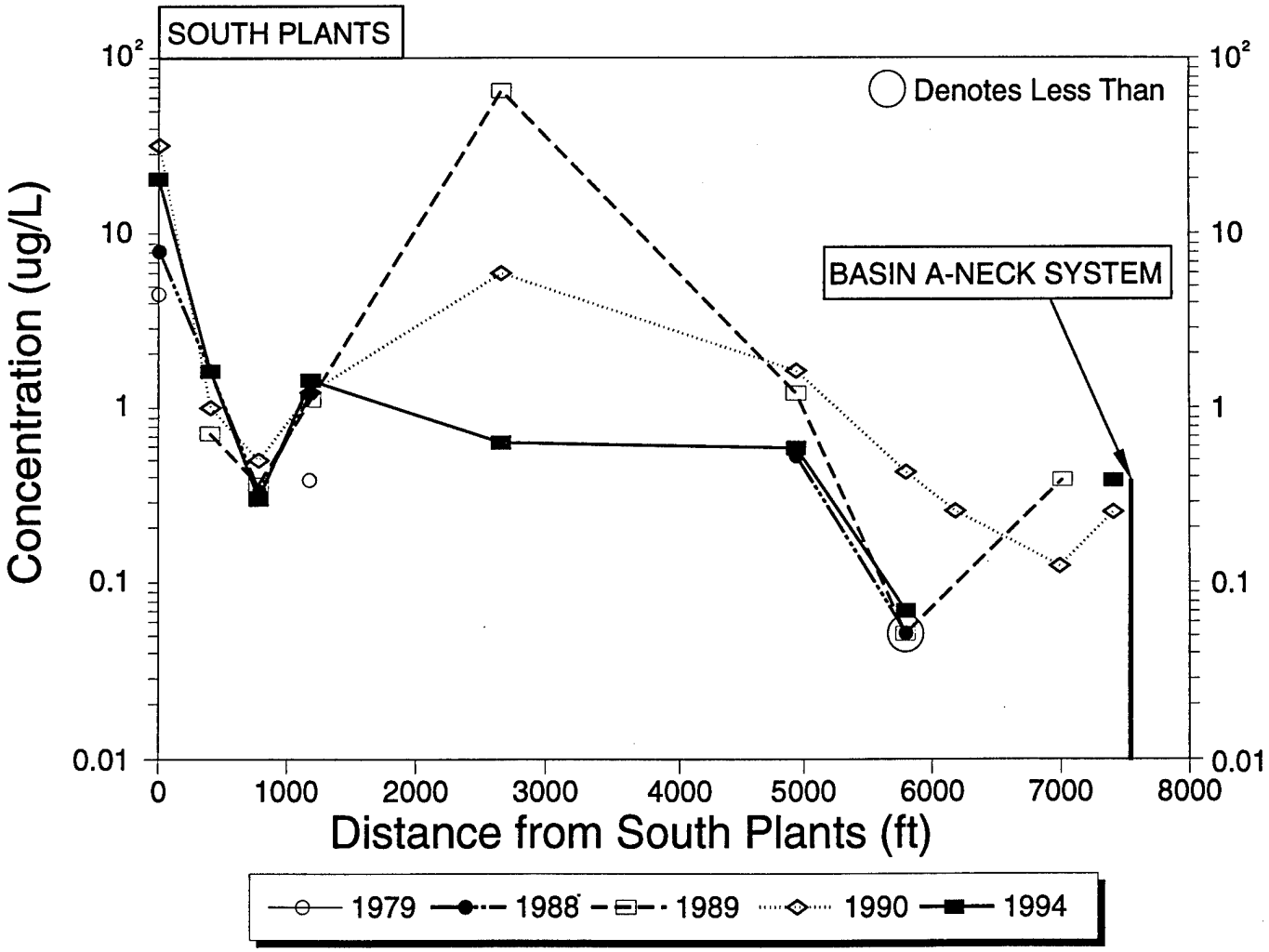
* Inferred from Figure 3-19

FIGURE A-4

<CFN: 0103G045.DWG> <CPD: 02/08/95> <AUT:RJC>



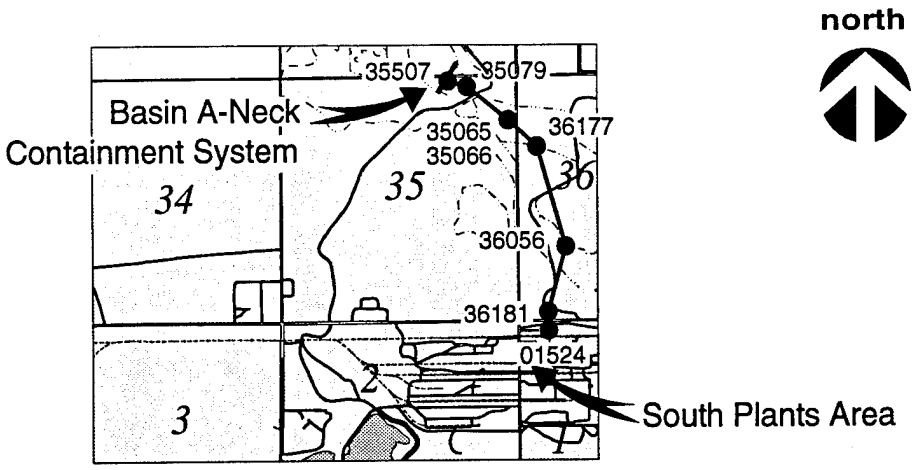
Location Map



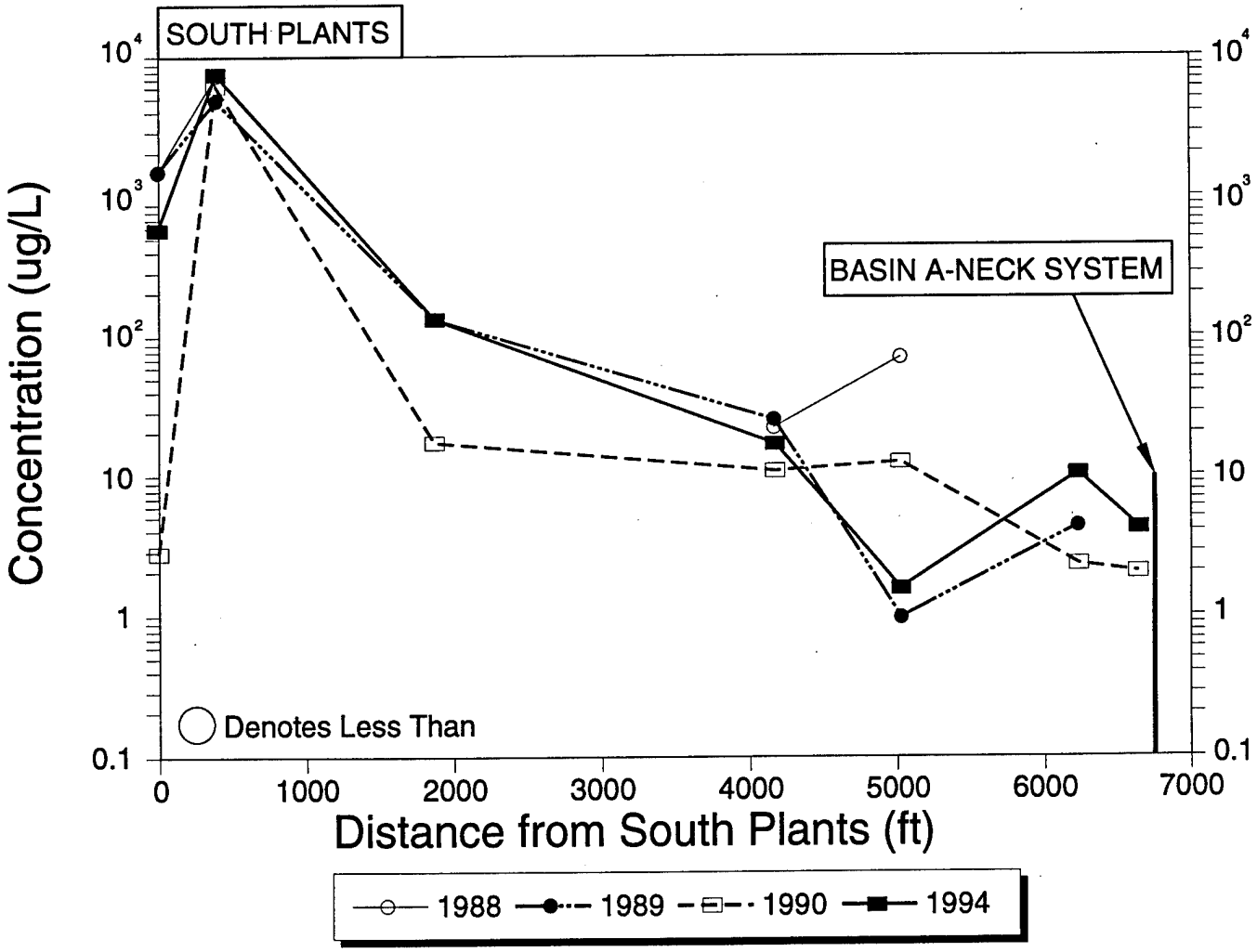
South Plants/Basin A Plume Centerline Dieldrin Concentration V. Distance

FIGURE A-5

<CFN: 0103G046.DWG> <CPD: 02/08/95> <AUT:RJC>



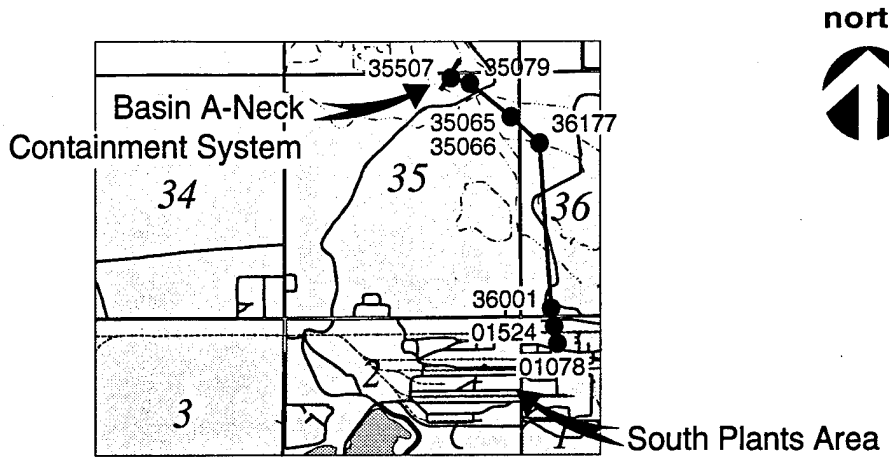
Location Map



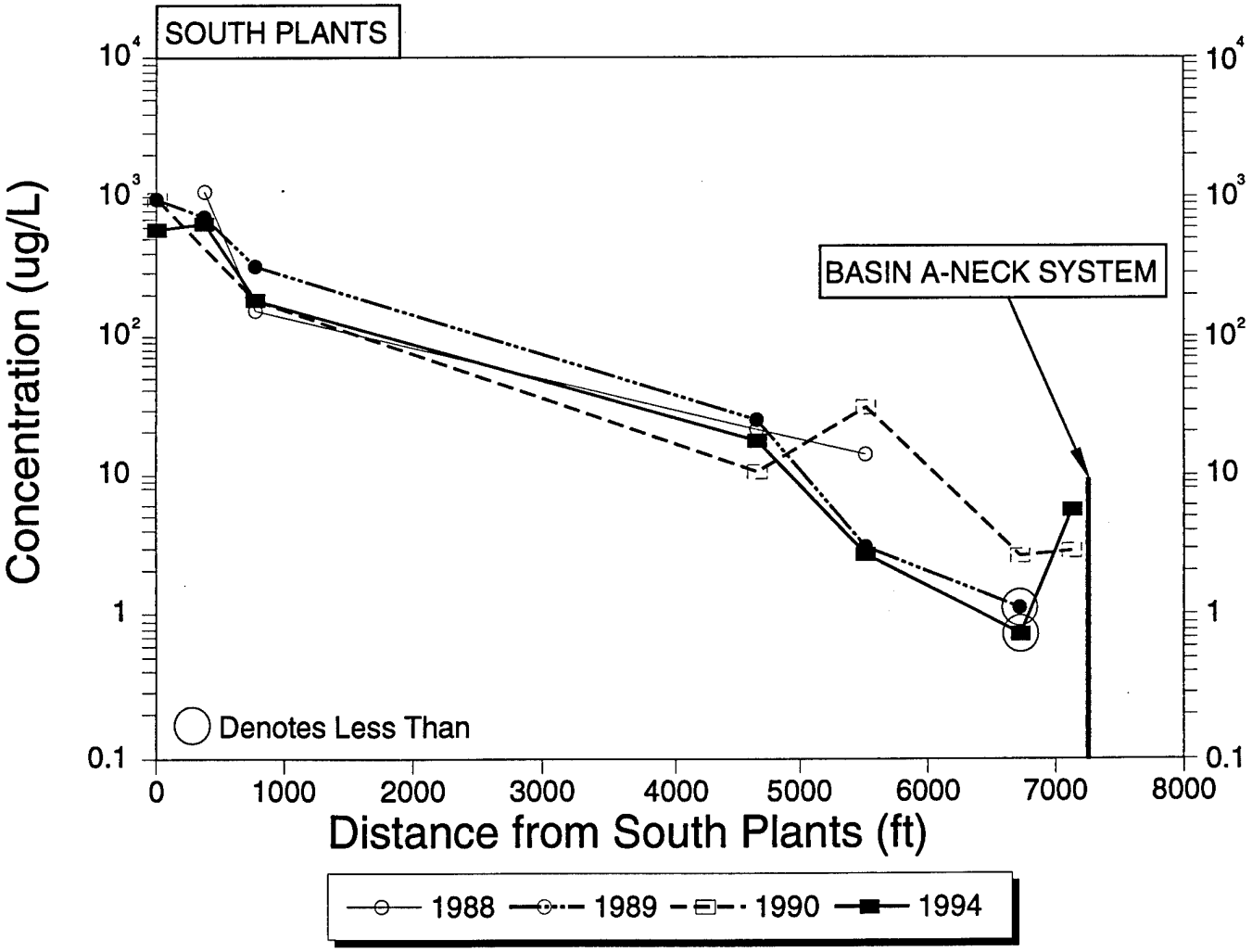
South Plants/Basin A Plume Centerline TRCLE Concentration V. Distance

FIGURE A-6

K:\CFN: 0103G040.DWG> <CPD: 02/08/95> <AUT:RJC>



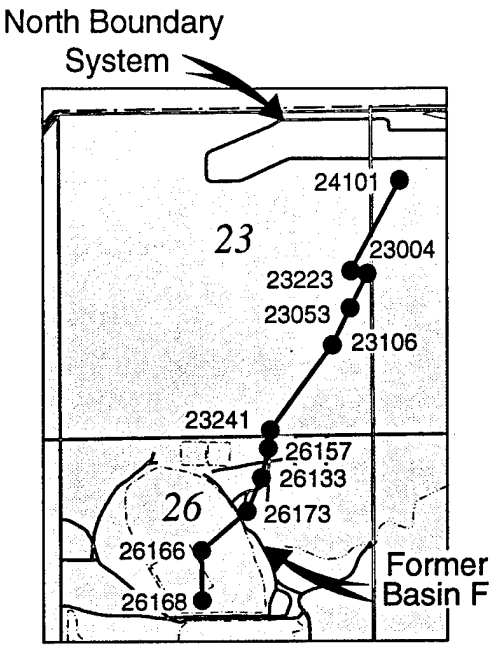
Location Map



South Plants/Basin A Plume Centerline TCLEE Concentration V. Distance

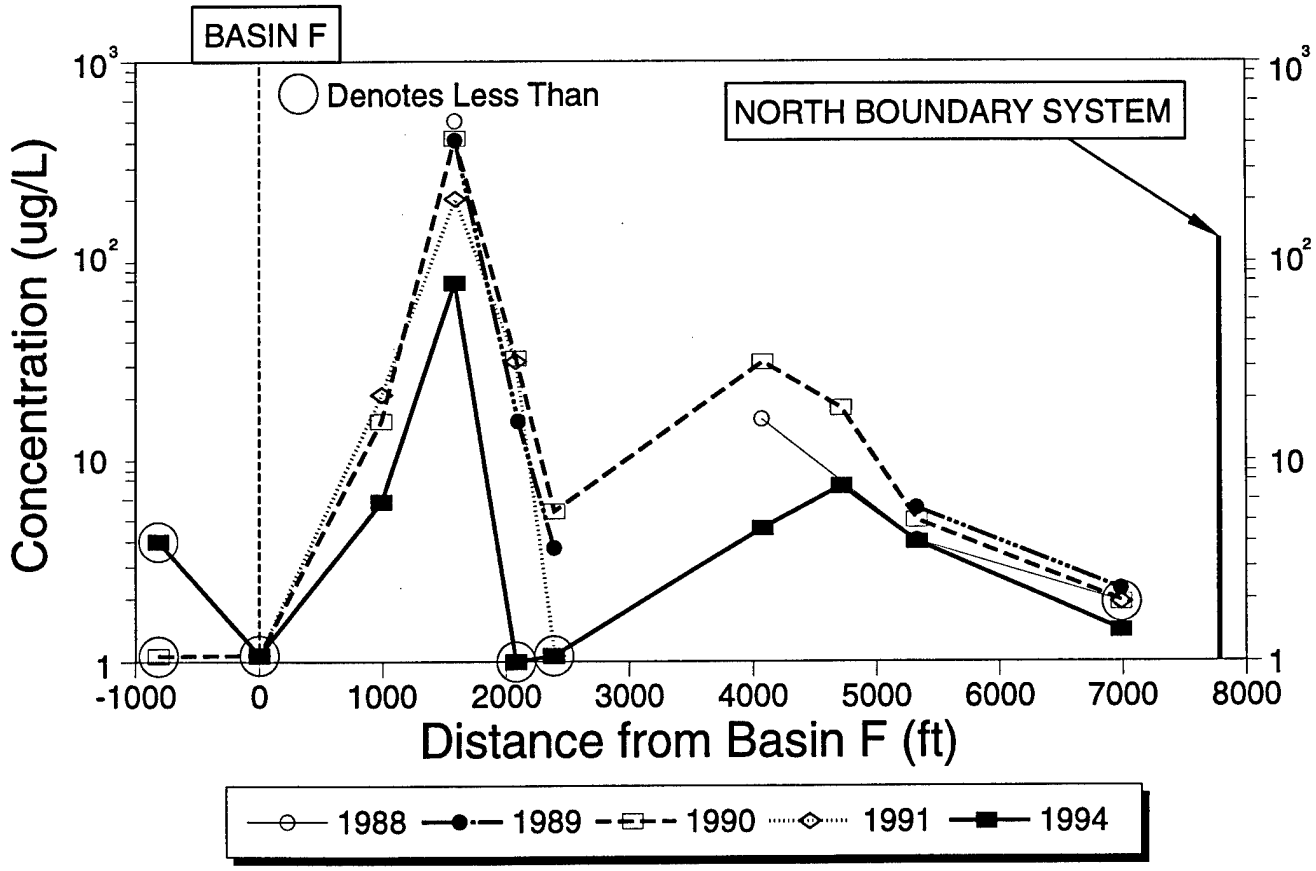
FIGURE A-7

<CFN: 0103G044.DWG> <CPD: 02/08/95> <AUT:RJC>



north

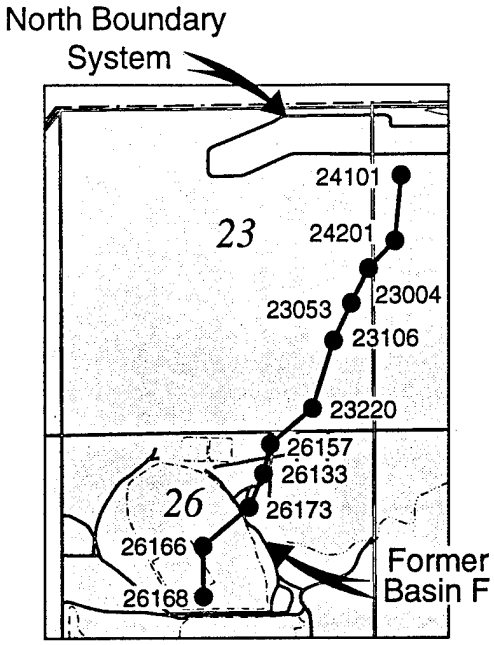
Location Map



Basin F Plume Centerline
Benzene Concentration V. Distance

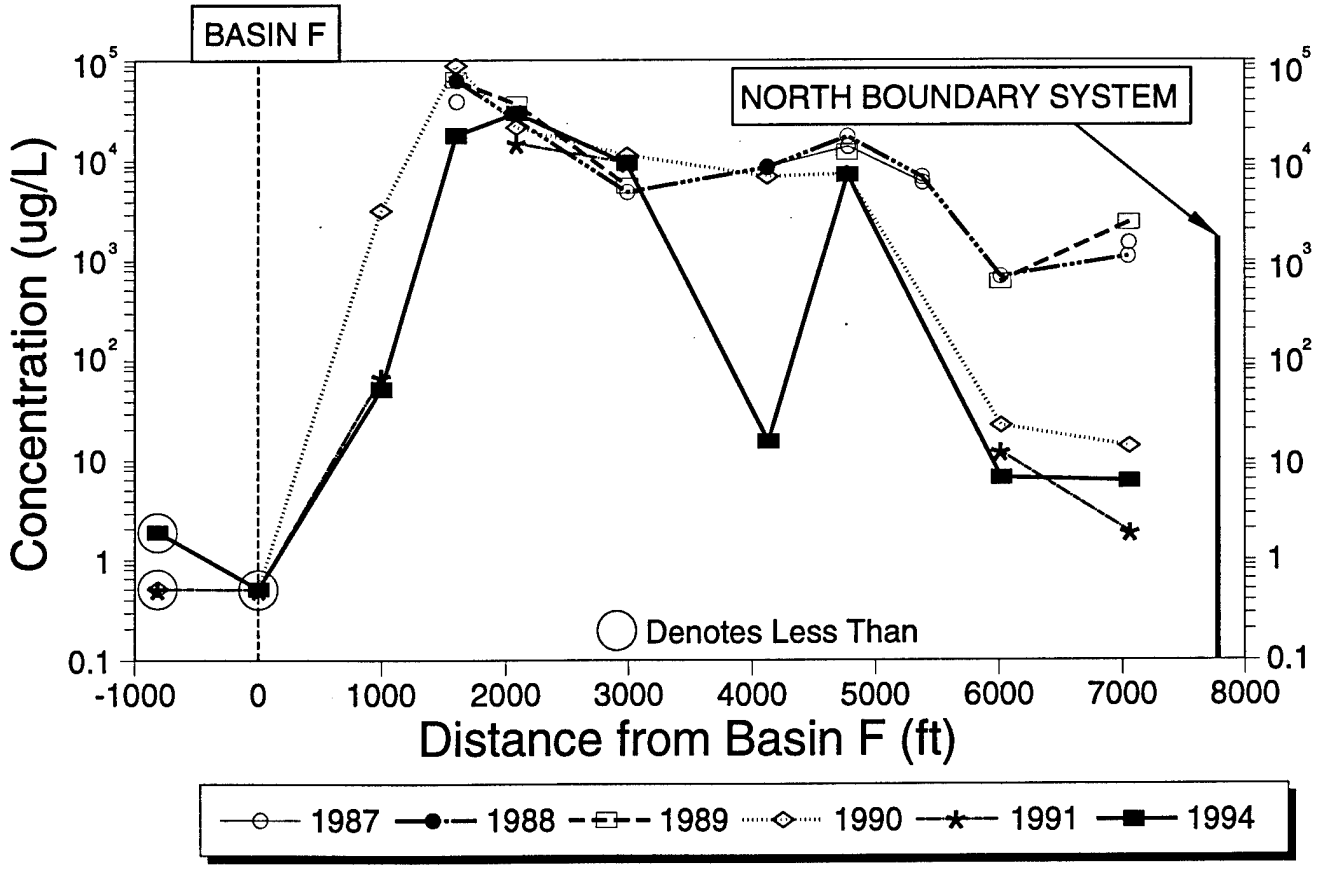
FIGURE A-8

<CFN: 0103G034.DWG> <CPD: 02/08/95> <AUT:RJC>



north

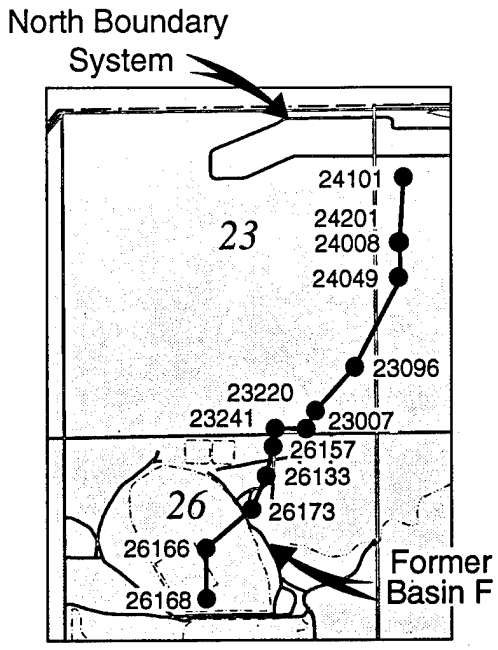
Location Map



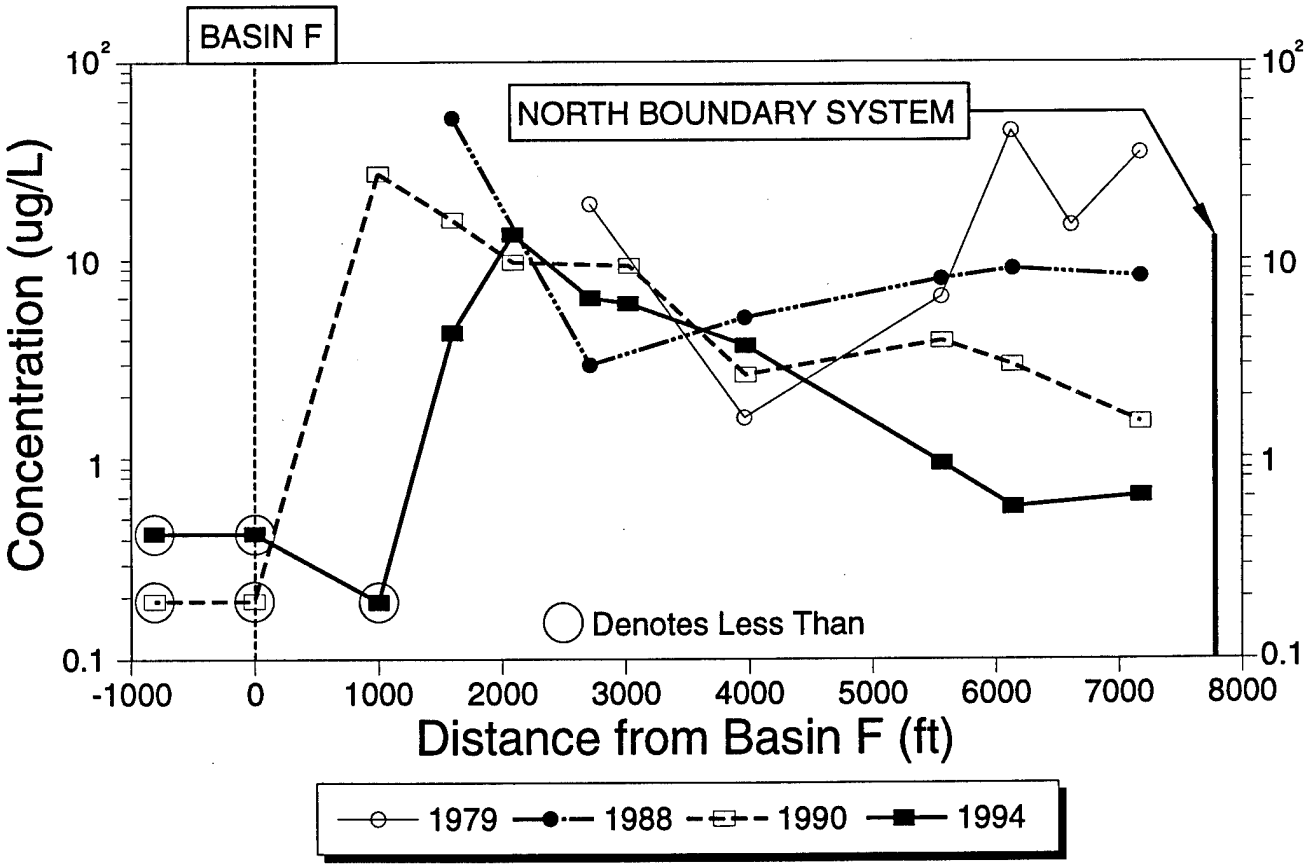
Basin F Plume Centerline
Chloroform Concentration V. Distance

FIGURE A-9

<CFN: 0103G036.DWG> <CPD: 02/08/95> <AUT:RJC>



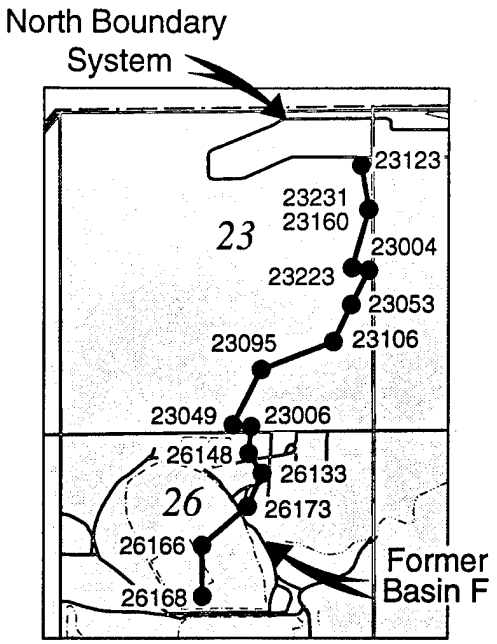
Location Map



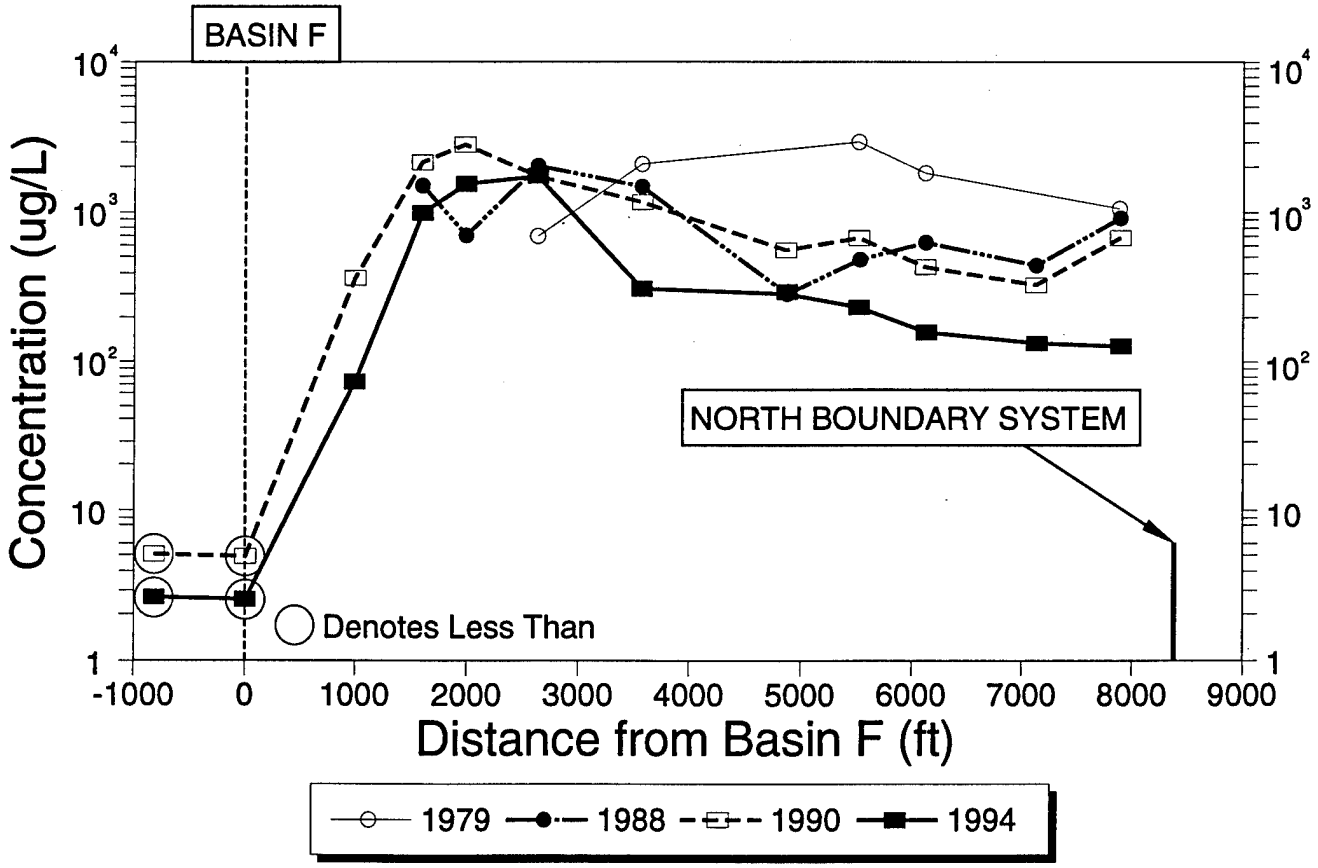
Basin F Plume Centerline
DBCP Concentration V. Distance

FIGURE A-10

<CFN: 0103G033.DWG> <CPD: 02/08/95> <AUT:RJC>



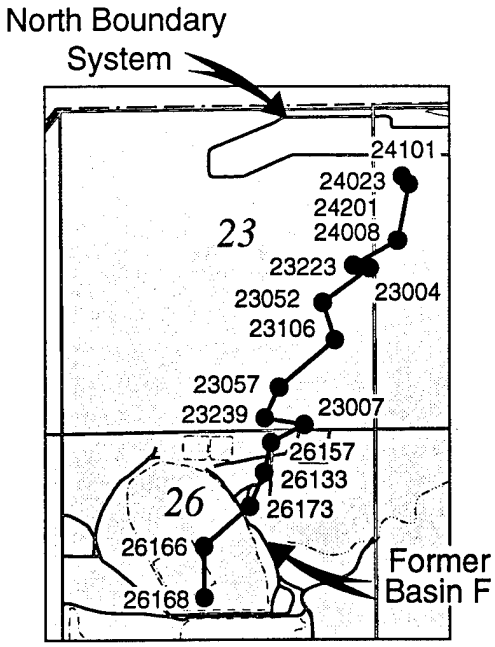
Location Map



Basin F Plume Centerline
DCPD Concentration V. Distance

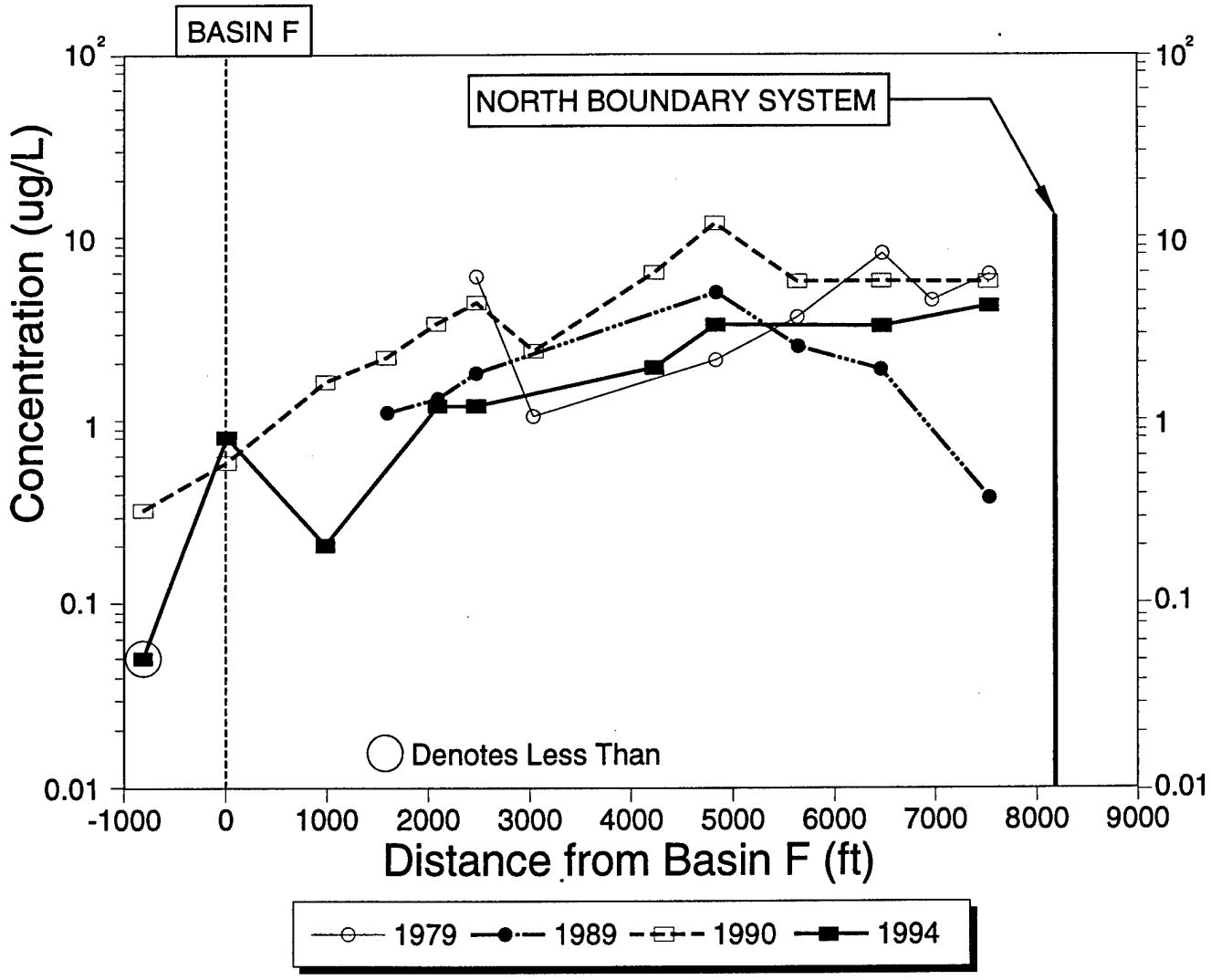
FIGURE A-11

<CFN: 0103G031.DWG> <CPD: 02/08/95> <AUT:RJC>



north

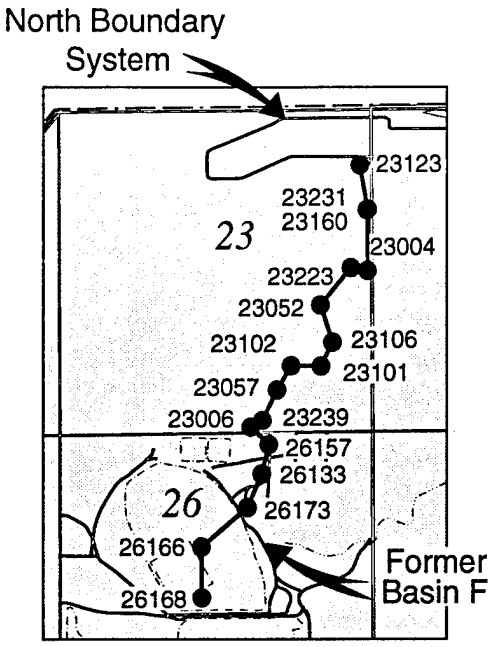
Location Map



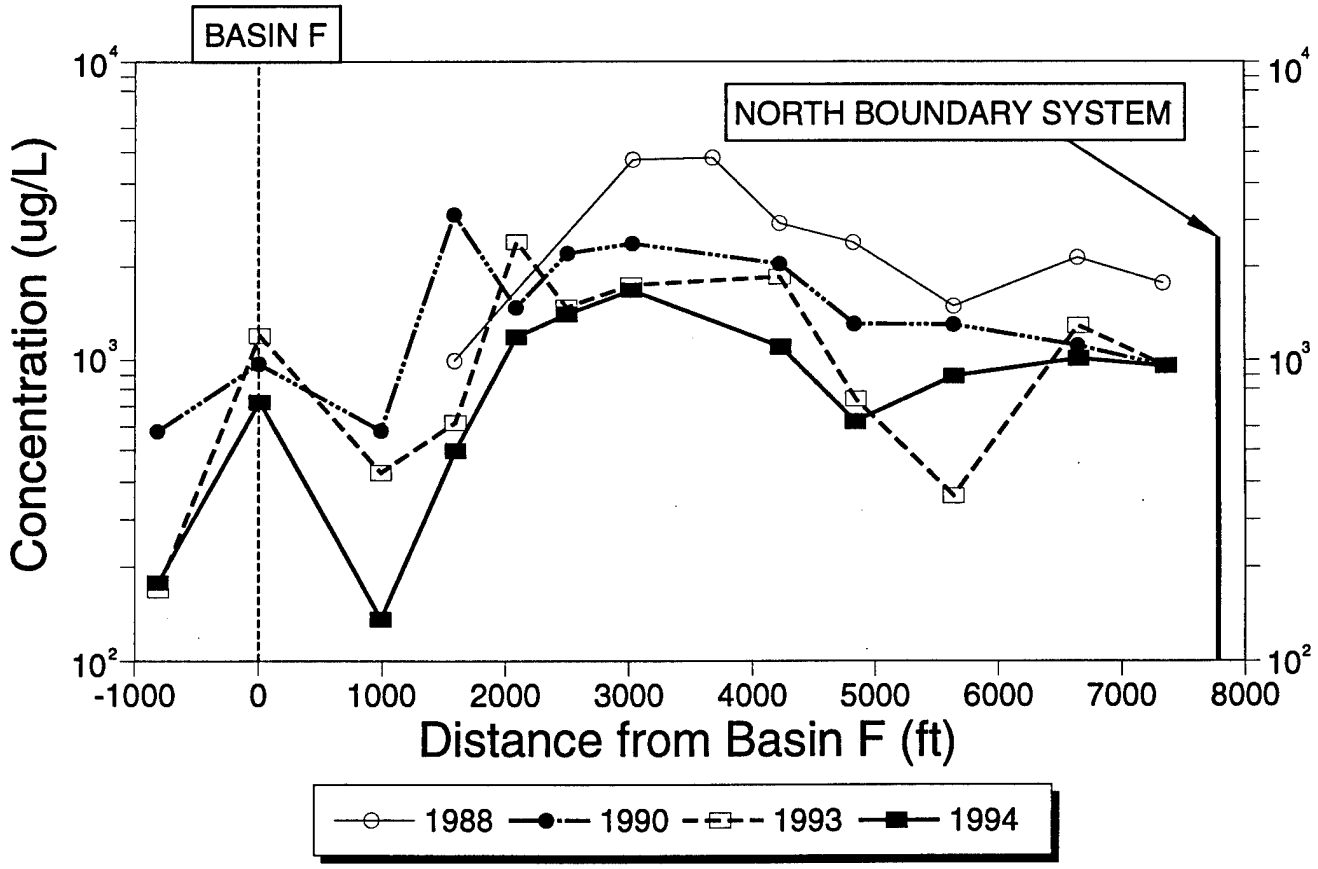
Basin F Plume Centerline
Dieldrin Concentration V. Distance

FIGURE A-12

<CFN: 0103G035.DWG> <CPD: 02/08/95> <AUT:RJC>



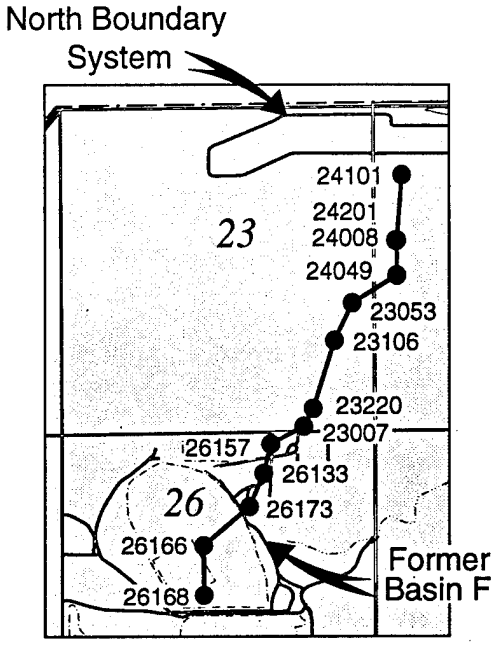
Location Map



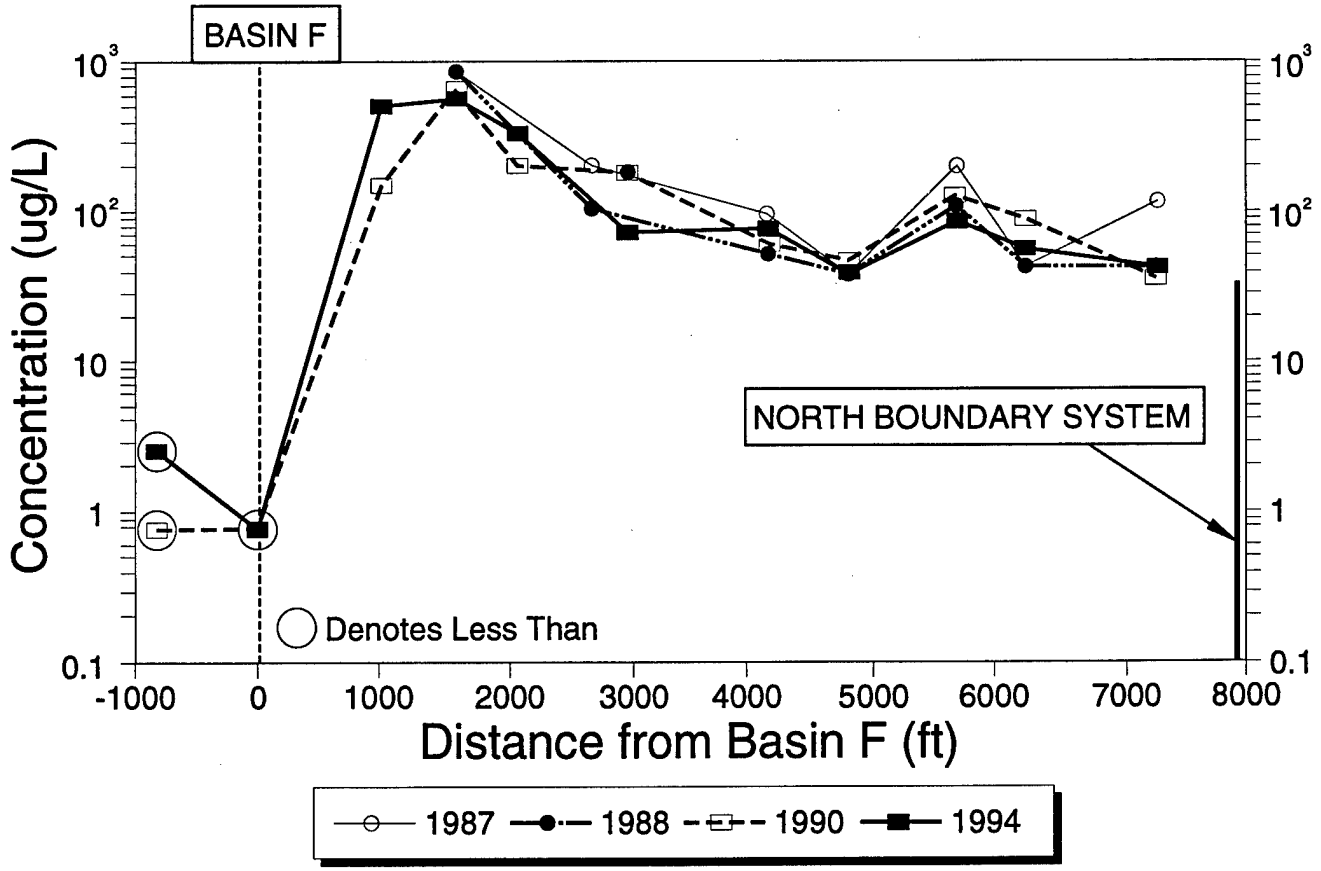
Basin F Plume Centerline
DIMP Concentration V. Distance

FIGURE A-13

<CFN: 0103G032.DWG> <CPD: 02/08/95> <AUT:RJC>



Location Map



Basin F Plume Centerline
TCLEE Concentration V. Distance

FIGURE A-14

K:\<CFN: 0103G037.DWG> <CPD: 02/08/95> <AUT:RJC>