PN-ABY-066

ISN 98451

The Hashemite Kingdom of Jordan

Ministry of Water and Irrigation

Water Quality Improvement and Conservation Project

Zarqa River Conveyance Study

Part 2: Data Evaluation

Consolidated Consultants
Harza Engineering

Development Alternatives, Inc.

USAID

The Technical Assistance Team Includes:

Development Alternatives, Inc.
Science Applications International Corp.
Harza Environmental Services, Inc.
Development Associates, Inc.

United States Agency for International Development
Contract No. 278-0288-00-C-4026-00

May 1995

Report 3114-95-3A-02

EXECUTIVE SUMMARY

The Zarqa River Conveyance Study, a component of the Jordan Water Quality Improvement Project, is being performed by Harza Engineering Company and consolidated consultants in two phases:

Phase A Conceptual Study
- Part 1 Data collection
- Part 2 Data Evaluation
- Part 3 Selection of Preferred Alternative

Phase B Feasibility and Environmental Assessment

This Comprehensive Report pertains to Phase A, Part 2 - Data Evaluation.

The data evaluation studies were directed at channel efficiency and water quality. Since 1980, seven studies were performed which attempted to define the magnitude and location of water losses or gains in the Zarqa River channel. These studies or at least the results of these studies were obtained as a part of the data collection activities and reviewed. In addition an earlier review by ISPAN was obtained and considered. The JVA has a comprehensive and extensive water quality monitoring program that includes the Zarqa River and the King Abdullah Canal. Selected reports and data sets were collected, translated, and evaluated to determine if a quality problem exists and what are the sources of the poor quality water.

Of the six studies of channel efficiency, all were based on discharge measurements, all except one included the reach between King Talal Dam and the Thahab Weir, the number of days measured varied between one and 12, all except one study were performed in one day or sequential days, most assumed pumping was negligible because of the time of year, and most estimates of pumping, spring flow, evaporation, diversions, and the effect of variable inflow were inadequate.

The analysis consisted of evaluating all of the data as a single data base. The trends or general conclusions drawn from such a body of data are considered to be representative and the errors compensating. A high value was placed on the opinions of the people from the Irrigation Department and the JVA who are most familiar with the studies and the river.

It is concluded that little or no loss occurs in the reach of River between KTD and the Thahab Weir. Between Thahab Weir and the Abu Zeighan Weir, losses do occur when flows in the river

are greater than about 1,000 l/s and these losses vary between 10 and 15 percent. A short-duration, fairly intense measurement program will be performed on the lower reach of the river in late July or August to provide one more estimate of channel efficiency and to clarify the magnitudes of the losses in the reaches from Thahab Weir to Hwaret Weir and from Hwaret Weir to Abu Zeighan Weir.

The selected water quality data were plotted and compared over time and at various locations on the Zarqa River and in the King Abdullah Canal. An evaluation of the data presented no surprises.The following observations have been made:

> The water in the KAC north of the Zarqa River, which primarily originates from the Yarmouk River has been and continues to be of good quality and suitable for irrigation without restriction.
>
> The quality of the water released from KTD is of marginal quality and may be deteriorating.
>
> The water from the saline springs and seeps would be toxic to crops.
>
> The mixing of water from KTD and the seeps and springs results in an irrigation supply that must either be diluted or will cause significant reductions in the yields of vegetable and citrus crops.

From these and other observations, it is concluded that the deteriorization of the KTD releases occurs in the reach of river between the Hwaret Weir and The Abu Zeighan Weir and that the elimination of this source of pollution will improve the quality of the irrigation supply to the Valley. It is further concluded that alternatives to either divert the seeps and springs away from the KTD releases or the KTD releases away from the seeps and springs should be evaluated during Part 3.

Table of Contents

EXECUTIVE SUMMARY I

Table of Contents i

1. INTRODUCTION 1
    1.1 Authorization 1
    1.2 Mobilized Staff 2
    1.3 Background 2

2. PROJECT SETTING 4
    2.1 Area Characteristics 4
    2.2 Geologic Setting 5
    2.3 Hydrogeology 6

3.0 CONVEYANCE EFFICIENCY 7
    3.1 Previous Investigations 7
    3.2 Analysis of Channel Efficiency Data 14
        3.2.1 Field Inspection 14
        3.2.2 Preliminary Geological and Hydrological Assessment 15
        3.2.3 Analysis of Measurements 16
        3.2.4 Conclusions 16

3.3 Discharge Measurement Program 17

4. WATER QUALITY OF ZARQA RIVER 18
    4.1 Water Quality Monitoring Program 18
    4.2 Water Quality Parameters 18
    4.3 Water Quality Data Collection 19
    4.4 Analysis of Water Quality Data 21
        4.4.1 Electrical Conductivity 21
        4.4.2 pH Values 26
        4.4.3 Other Water Quality parameters 26
    4.5 Conclusions 28

List of Tables

Table 2.1 Drainage Areas 5
Table 3.1 June 1980 Water Balance Study 8
Table 3.2 July 1981 Gain-Loss Measurements 9
Table 3.3 Data from the October 1984 Study 11
Table 3.4 Conveyance Gains and Losses from the October 1984 Study 11
Table 3.5 Flow Measurements of October 1987 - June 1988 Study 12
Table 3.6 Conveyances Losses of October 1987 - April 1988 Study 13
Table 3.7 Monthly Conveyance Efficiencies 14
Table 4.1 Daily Water Quality Data end of section
Table 4.2 Water Quality Measured at Various Locations end of section
Table 4.3 EC Data from 1980 to 1994 at Various Locations end of section
Table 4.4 pH Data from 1992 to 1994 at Various Locations along the Zarqa River end of section
Table 4.5 Water Quality Data at Various Locations Along the Zarqa River end of section
Table 4.6 Quality of Outflow from Kherbet Samra Treatment Plant end of section
Table 4.7 EC and pH Values of Water in the Zarqa River and of Springs and Seepage Entering the River end of section
Table 4.8 Average Monthly EC Values at KAC-Maadi 23
Table 4.9 Monthly EC Values 29

List of Exhibits

Exhibit No.	Title
1	Location Map
2	Geomorphic-Topographic Zones
3	Variation of Conveyance Loss with Discharge (Hashem and Hijazi, 1984)
4	Conveyance Gains and Losses between KTD and Thahab Weir
5	Conveyance Gains and Losses between Thahab Weir and Abu Zeighan Weir
6	Monthly EC Values, Zarqa River
7	Electrical Conductivity, Zarqa River - April 1993 through March 1995
8	Daily Outflow and EC Values at KTD - April 1003 through March 1995
9	Electrical Conductivity, Zarqa River - April through October, 1994
10	Monthly Outflow and EC Values at KTD - 1990-1994
11	EC Values - Zarqa River - April and October, 1992-1994
12	EC Values Zarqa River - April through October, 1994
13	pH Values, Zarqa River and KAC- April though October 1994
14	Daily Outflow and pH Values at KTD - April 1993 through March 1995
15	pH Values - Zarqa River - April and October, 1992 - 1994
16	pH Values, Zarqa River - April through October 1994
17	pH Values - KAC and Zarqa River - April 1993 through March 1995
18	Boron Concentrations, Zarqa River and KAC - April and October - 1992 through 1994
19	Boron Concentrations, Zarqa River - April through October 1994
20	Chloride Concentrations, Zarqa River and KAC - April and October - 1992 through 1994
21	Chloride Concentrations, Zarqa River - April through October 1994
22	Sodium Concentrations, Zarqa River and KAC - April and October - 1992 through 1994
23	Sodium Concentrations, Zarqa River - April through October 1994
24	HCO3 concentrations, Zarqa River and KAC - April and October - 1992 through 1994
25	NO3 Concentrations, Zarqa River and KAC - April and October - 1992 through 1994
26	SAR Values, Zarqa River and KAC - April and October - 1992 through 1994
27	Potassium Concentrations, Zarqa River and KAC - April and October - 1992 through 1994
28	Calcium Concentrations, Zarqa River and KAC - April and October - 1992 through 1994
29	Magnesium Concentrations, Zarqa River and KAC - April and October - 1992 through 1994
30	Sulphate Concentrations, Zarqa River and KAC - April and October - 1992 through 1994

1. INTRODUCTION

The United States Agency for International Development (USAID) is supporting investments to assist the Government of Jordan in improving the management and conservation of water resources. As a part of this assistance, the Jordan Water Quality Improvement and Conservation Project (WQIC) was initiated under Contract No. 278-0288-C-00-4026-00, between Development Alternatives, Inc. (DAI) and USAID.

The Zarqa River Conveyance Study was included as a part of the WQIC program to evaluate the potential for improving the conveyance efficiency of water released from King Talal Dam (KTD) and the quality of water diverted from the Zarqa River at Abu Zeighan Weir. The objective of this study is to assess the technical, environmental, economic and financial feasibility of conveying water efficiently and improving quality in the 23 kilometers reach of the Zarqa River between KTD and the Abu Zeighan Weir.

The study is being performed in two phases. Phase A consists of a conceptual study to identify feasible alternatives and priorities. Phase A is divided into three parts; 1) data collection and evaluation, 2) analysis of data, and 3) identification and evaluation of alternatives to mitigate channel efficiency or quality impacts leading to the selection of a preferred alternative. Phase B includes an environmental assessment of the preferred alternative, an economic and financial analysis and a preliminary design for the elements of the preferred alternative. There are four deliverables associated with this study. In Phase A, an Inception Report, a Comprehensive Survey Report, and a Conceptual Studies Report will be completed within 30 days, 60 days and 150 days respectively after the notice to proceed is given. In Phase B, a Feasibility Report, to include the preliminary designs, will be submitted within 90 days after the notice to proceed for the feasibility study is given.

This Comprehensive Report is concerned with Part 2 of Phase A which includes an analysis of the data collected in Part I and a preliminary determination of alternatives.

1.1 Authorization

This study is being performed as a part of the Jordan Water Quality Improvement and Conservation Project by Harza Engineering Company (Harza) in association with Consolidated Consultants (CC) under a subcontract with DAI.

1.2 Mobilized Staff

Part 2 of Phase A, data analysis was performed Harza staff. The personnel mobilized to perform this effort included the following individuals:

Individual	Company	Position
Michael Saunders	Harza	Project Manager
Khalid Jawed	Harza	Lead Engineer
Monica Cheng	Harza	Sr. Hydrologist
David Bogan	Harza	Irrigation and Water Quality

1.3 Background

In the later part of the 1970's, the Jordan Valley Authority (JVA) began to suspect that all of the water released from King Talal Reservoir was not reaching the King Abdullah Canal (KAC). In 1980, the JVA performed a two-day study that appeared to confirm this suspicion. Over the next ten years a total of six studies were performed in an attempt to confirm that losses do occur, to quantify the losses, and to identify the river reaches within which the losses were occurring. In 1994, two additional studies were performed, one by the University of Jordan which consisted of a water balance study of the river using estimated and actual data provided by the JVA, and one by ISPAN which consisted of a review of the other studies. The ISPAN review was done to support funding by USAID of additional study of the Zarqa River channel conveyance efficiency.

In addition to the issue of conveyance efficiency, the poor quality of the Zarqa River is an issue of increasing concern. Greater diversions from the KAC to Amman for municipal and industrial (M&I) use has resulted in a greater use of the poorer quality Zarqa River water for irrigation on lands in the Jordan Valley south of the Zarqa River. During the summer months of 1994, all of the water diverted into the KAC from the Yarmouk River was used in Amman or on the lands north of the Zarqa River. The application of Zarqa River water to the lands south of the River has evidently resulted in decreased yields and damage to the citrus trees. The deterioration of the quality of the Zarqa River water is caused primarily by a series of salt springs and seeps located in the lower reach of the river - the same reach that is generally considered to have the lowest channel efficiency.

The objective of this study, therefore, is to:

1. Develop a defendable argument with respect to channel losses,
2. If warranted, recommend a plan to improve channel efficiency, and
3. Identify the means to improve the quality of water entering the KAC from the Zarqa River.

In addition, if appropriate, the plan will incorporate the generation of hydroelectric power.

2. PROJECT SETTING

2.1 Area Characteristics

The Zarqa River originates in the central part of Jordan at an elevation of about 1,600 meters near Salkhad and drains to the Jordan River at an elevation of -300 meters. The river drains an area of about 3,500 square miles at its confluence with the Jordan River, about 3,400 square miles at the KAC, and about 3,300 square miles at King Talal Dam. The easternmost part of the basin is a high-desert plateau. Toward the west, the basin changes to a highlands and then becomes progressively steeper until it reaches the Jordan Valley. The average precipitation over the basin is about 250 mm per year and the average runoff is about 70 million cubic meters (MCM) per year.

King Talal Dam is located about 40 km upstream of the confluence of the Zarqa River with the Jordan River and about 23 km upstream from the KAC. A location map is shown on Exhibit 1. King Talal dam was constructed in the 1960's and raised in the 1980's. The dam is about 110 m high and impounds a reservoir of about 86 MCM at the normal pool level (El. 179).

Over the 23-mile reach to the Jordan Valley, the Zarqa River flows through a winding, steep-sided valley. In this reach there are three weirs, the Tel El Thahab Weir (Thahab), the Hwaret Weir, and the Abu Zeighan Weir.

The Thahab Weir is located approximately 13 kilometers downstream of King Talal Dam (KTD). The Tel El Thahab Weir is a concrete diversion weir which is used to divert water from the river into Carrier Pipes I and II for irrigation in the Valley. The capacity of these pipes are 1,000 l/s and 1,770 l/s respectively.

The Hwaret Weir is located approximately 5 km downstream of the Tel El Thahab Weir. The Hwaret Weir served a canal with a capacity of 800 l/s for irrigation in the Valley which also could be supplied from a turnout in Carrier Pipe I. The weir and canal are in poor condition and have been abandoned by the JVA.

The Abu Zeighan Weir is located at the eastern edge of the Valley and diverts Zarqa River water into the KAC through the Abu Zeighan Canal. The canal has a capacity of 7,500 l/s.

The drainage areas of interest at the KTD and the weirs are given in Table 2.1.

Table 2.1 Drainage Areas

Location	Drainage Area, km^2
Above KTD	3,300
Between KTD and The Thahab Weir	99
Between The Thahab Weir and Hwaret Weir	35
Between Hwaret Weir and the Abu Zeighan Weir	9

2.2 Geologic Setting

The study area, which extends from KTD to the Abu Zeighan Weir, consists of four distinctive geomorphic-topographic zones. The zones, classified in accordance with criteria established by the Ministry of Agriculture and the Natural Resources Authority, are:

Highlands - elevations exceed 800 m
Escarpment - elevation ranging from 800 m . to sea level
Foothills - elevation ranging from seal level to -200 m
Rift Zone - elevation below -200 m

The extent of the zones are shown on Exhibit 2. The highlands are relatively far away from the river and are characterized by upper cretaceous sediments of the lower part of the Ajlun Group. Steep cut slopes dominate in the areas of highlands. In the escarpment area, lower Cretaceous and occasionally Jurassic rocks are exposed. The Cretaceous rocks consist primarily of the Kurnub formation which is mainly a friable sandstone and some intercalations of calcareous sandstone. The Jurassic rocks consist mainly of limestone and dolomitic limestone. The foothills area are composed of Triassic rocks which consist of limestone, shales, marls, and marly limestones. Finally, in the Rift Zone, Quaternary rocks of the Lisan Formation, alluvium, colluvium, and soil(s) are present.

Kurnub Sandstones of early Cretaceous age are exposed at KTD and extend downstream until Jurassic rocks, which are older, are exposed. The Jurassic rocks remain exposed until rocks of the Triassic age (the oldest rocks) are exposed. These rocks are followed by the Jurassic rocks again which are overlain by Quaternary deposits.

The Triassic-Jurassic rocks exposed in the area and which are encountered in deep wells drilled in the Jordan Valley and other parts of Jordan are known as the Zarqa Group which is further divided into two formations, the Main formation (Z1) and the Azab Formation (Z2). The Azab Formation

is exposed in the river channel for about five kilometers below the KTD. Over the next 3.5 miles, the Main formation is exposed, and then the Azab Formation is exposed to the vicinity of the Thahab Weir. Downstream of the Thahab Weir, the Quaternary deposits cover the Azab formation to varying depths.

2.3 Hydrogeology

Infiltration occurs over the highland zone through an Upper Aquifer Complex (UAC). A groundwater divide in the highlands recharge area causes some of the water in the UAC to move toward the east and some to move toward the west. The water moving toward the west (toward the Jordan Valley) appears on the escarpment as base flow, seepages, and springs. This water is of good quality. Most of the infiltrated water moves toward the east (away from the Jordan Valley). As it moves to the east, the water infiltrates downwards through the different aquifers until it finally recharges a Lower Aquifer Complex (LAC). When the infiltrated water reaches the LAC, it changes direction to the west and finally issues as springs or is encountered in deep wells with thermal brackish water in the Jordan Valley.

In the study area, the Kurnub and Zarqa Groups are exposed, however the Zarqa Group is essentially restricted to the Zarqa River channel and its flanks downstream of KTD. The Kurnub Group is recharged annually in the highlands from rainfall. The annual recharge explains the presence of fresh-water springs and wells in the highlands and along the upper elevations along the Zarqa River. Wells that penetrate the Zarqa Group are saline and thermal. In the highlands, the Kurnub and Zarqa Groups are separated, but as the water flows toward the west, the two Groups form one static water level (JICA 1995).

According to the hydrogeological conditions prevailing in the area, the Zarqa River from KTD to the Abu Zeighan Weir should be continuously recharged through springs and seepage from the exposed Zarqa Group in the channel and from the exposed Kurnub Group at higher elevations.

3.0 CONVEYANCE EFFICIENCY

The Operation Division of JVA suspected that water was being lost in conveyance in the 23-km reach of Zarqa River channel between KTD and the Abu Zeighan Weir as early as 1980 when a first attempt was made to quantify these losses. Since that time, at least seven additional studies (as of 1994) have been performed in an attempt to determine the magnitude of the losses and to locate the subreaches where these losses occur.

3.1 Previous Investigations

Five of the six studies performed to evaluate Zarqa River flows and conveyance losses were performed by the JVA and a sixth study was performed by Harza Engineering Company as a part of a larger study of the potential for providing storage on the side wadis of the Jordan Valley. A seventh study was performed by the University of Jordan using water balance data obtained from the JVA for 1990-93. These water balance data were analyzed or re-analyzed in an attempt to determine the magnitude of conveyance losses and to identify where any losses might occur. The studies are summarized in chronological order below.

3.1.1 Joudeh, Omar. Water Balance Study of Zarqa River Downstream of King Talal Dam. JVA, Hydrology and Groundwater Division, 1980.

The study was performed by the Groundwater and Hydrology Division of the JVA on June 29 and 30, 1980. Discharge measurements were made at seven locations along the river, from KTD to Abu Zeighan Weir, and on the main Swalha Canal, the Abu Zeighan Canal, and in a small irrigation ditch upstream from the Swalha Canal. All measurements were made using a Price Type A current meter. Measurements were performed in June on the assumption that the irrigation season was over and that pumping from the river would be negligible. The approximate locations of the survey sites can be identified on Exhibit 1. The results of the survey are presented in Table 3.1

Table 3.1 June 1980 Water Balance Study

Site	Discharge l/s	Loss l/s	Gain l/S	Pumping l/s	Evaporation l/s	% of Release
1	1820 (at KTD)					
		175		10		-10
2	1635					
			87			+ 5
3	1722					
			47			+ 3
4	1769 (d/s of Thahab Weir)					
		174				-10
5	1595					
6	659 (Swalha Canal off Hwaret Weir)					
		8				—
7	908 (area of springs)					
		246		20		-14
8	642 (Abu Zeighan Canal)					
9	20 (ditch of the Swalha Canal)					
	TOTALS	603	134	30	60	-20

From this analysis, it is determined that slightly more than 90 percent of the reported channel loss of 469 l/s occurs in the reach beginning about one kilometer downstream from the Thahab Weir. Most of this loss occurs between the area of the springs and the Abu Zeighan Weir; however a significant portion of the loss occurs between the Thahab and Hwaret Weirs.

Two other observations were reported as a part of the study: 1) The releases at the dam reported by the KTD personnel were about 13 percent higher than flows measured by current meter immediately below the dam, and 2) The water discharge near Deir Alla as measured by the East Ghor Canal Department (sic) was about 21 percent less than the simultaneous current meter measurement. Therefore, any channel efficiency studies relying on such information would have to be suspect if not invalid.

The study also provides useful information with respect to the location of losses. A limitation of the study was that it was done at a single time and flow.

3.1.2 Joudeh, Omar and Ismail Hashem. Gain-Loss Measurements on Zerqa River Near Deir Alla (Preliminary Report), JVA, Hydrology and Groundwater Division, 1981.

This preliminary report summarized flow measurements taken on July 18-21, 1981 at three locations, the Thahab Weir, the Hwaret Weir, and the Abu Zeighan Weir. Gains and losses were evaluated between these locations.

At the Thahab Weir, measurements were taken above the weir from which water diverted to the pipeline was subtracted. At the Hwaret Weir, measurements were made for both the canal and the remaining flow in the channel downstream of the weir. The reported discharge at Abu Zeighan is the combined flow at Abu Zeighan Weir plus the water in the Deir Alla canal.

Table 3.2 July 1981 Gain-Loss Measurements

Station	Flow(cms)				Loss(%)				
	7/18	7/19	7/20	7/21	7/18	7/19	7/20	7/21	Average
Al Thahab Weir	1.308	1.363	1.361	1.320					
					12.2	23.0	11.8	8.2	13.8
Hwaret Weir	1.148	1.049	1.201	1.212					
					5.9	18.7	–	5.9	10.1
Abu Zeighan Canal	1.080	0.853	–	1.140					

The flow rate above the Thahab Weir increased about four percent from day 1 to day 2 and then decreased about three percent over the next two days. Other reviews of these data suggested that "losses increased significantly while the flow was increasing but decreased sharply... when the flow decreased". A flow increase of four percent and a decrease of three percent cannot be considered significant with the described measurement procedure. Rather it is more likely that the large losses are attributable to inaccurate flow measurements. It is suggested that the average loss is the more significant figure.

3.1.3 Hijazi, Daoud. Untitled, Measurements Taken 1 March, 1984, JVA, 1984.

This study considered the lower part of the Zarqa River channel between Thahab Weir and the Abu Zeighan Weir. Only handwritten notes were available for review. According to an earlier review by ISPAN, the study did not account for diversions from the river at the Hwaret weir and by pumping.

entering the reach which was measured as 0.421 cms. The flow measurements immediately above and below the saline hot spring indicate that the flow increased by about 10 l/s, nominally from the spring. A third measurement at downstream of Swalha bridge showed the channel gaining an additional 14 l/s. The flow at Abu Zeighan Weir was estimated to be about 20 l/s (it appears that this estimate was not the result of a measurement), but as abstractions for irrigation were not considered, it has no meaning with respect to channel losses.

Due to a lack of basic information, these data were not used in the subsequent analysis.

3.1.4 Hashem, Ismail and Daoud Hijazi. A Report on Water Losses Between King Talal Dam and Irrigation Line, JVA, Ground Water Directorate, 1984.

This study used new data collected in October 1983 and March 1984 and old data to compute conveyance losses. The new data was collected when releases from KTD were varying. A handwritten draft of the report excluding tables and exhibits was located and reviewed.

Three measurement sites were considered: Site 1 from KTD to the Thahab Weir, Site 2 from Thahab Weir to Hwaret Weir, and Site 3 from the Hwaret Weir to the Abu Zeighan Canal.

The information reviewed was not sufficient to draw any conclusions. Therefore, the comments reported by ISPAN are repeated here:

> "Abstractions for irrigation were estimated based on the area irrigated. The authors recognized the limitations of this study. However, the study concludes that the losses in the Zarqa River channel range from 8 to 25 percent, with most of the losses occurring below the El Thahab Weir. "

For information, the author's data is plotted on Exhibit 3 to show the variation of conveyance loss with discharge. (It is not known who plotted the data or what data are included.)

3.1.5 Hijazi, Daoud. Untitled, Measurements made on 2 to 4, and 6 to 9 October 1984, JVA, 1984.

Streamflow measurements were taken at six or seven locations along the river on each of seven days in October 1984. In addition, two water stage recorders were installed, one downstream of the KTD and the other just upstream of Al Thahab Weir to determine the stage fluctuations in the river during the measurement period. The measurements are listed in Table 3.3.

Table 3.3 Data from the October 1984 Study

Site	Location	Flow (l/s)						
		10/2	10/3	10/4	10/6	10/7	10/8	10/9
1	Below King Talal Dam	3429	--	--	--	--	2898	--
2	Above Al Thahab Weir	3674	3268	--	2951	3115	2996	2939
3	Below Al Thahab Weir	3324	2899	2110	2928	2953	2944	2551
4	Flow in Swalha Canal at Hwaret Weir	1034	1179	1127	978	918	954	940
5	Flow in Swalha Canal & below Hwaret Weir	2887	3021	3072	2666	2714	3074	2626
6	Below Hwaret Weir	1853	1842	1945	1688	1796	2120	1686
7	At Swalha Bridge	1801	1728	1703	1718	1957	1922	1818
8	At AbuAl Zeighan Weir	1603	1781	1775	--	1484	1520	1578

This study concludes that, in the reach between KTD and Al Thahab Weir, a small gain occurs, and that the loss in the reaches of Al Thahab to Hwaret Weir and Swalha to Abu Zeighan Weir, and mixed results for the reach between Hwaret to Swalha Bridge. No pumping diversion for irrigation or evaporation losses were included in the analyses.

The estimated gains and losses are summarized in Table 3.4 for each reach as follows:

Table 3.4 Conveyance Gains and Losses from the October 1984 Study

Reach	Gain(+)/Loss(-) in %	
	October 2-3	October 7-9
KTD to Al Thahab Weir	+1.2	+ 4.1
Al Thahab to Hwaret Weir	-5.1	- 0.4
Hwaret to Swalha Bridge	-4.5	+ 1.7
Swalha to Abu Zeighan Weir	-4.1	-19.5

Note: Gains and losses were computed averages of measurements taken on the indicated days. Data of October 4 and 6 were not included in analyses.

3.1.6Harza Engineering Company in association with Arab Consulting Engineers, Storage Facilities in the Jordan Valley, Final Report on Technical, Economic and Financial Feasibility and Preliminary Design, Vol ii, Part II- Main Report, April 1989.

Harza/Arabtech made streamflow measurements between October 1987 and June 1988 at six locations in an attempt to define gains or losses in three reaches of the river. Nine sets of current meter measurements were taken below King Talal Dam, upstream and downstream from the Al Thahab Weir, upstream and downstream from the Hwaret Weir, and at the Abu Zeighan Weir. The release from KTD was kept constant for at least 12 hours prior to and during the measurements. This was done to avoid fluctuations during the observations and to eliminate the effect of bank storage. No measurements were made during the period of December 1987 through March 1988 because of rain which resulted in significant flows from the intervening areas between the measuring points. The measurements are presented in Table 3.5.

Table 3.5 Flow Measurements of October 1987 - June 1988 Study

	Flows (m^3/s)								
Reach	Oct12	Oct17	Nov 9 1987	Apr19	Apr24	May22	May30	Jun12 1988	Jun27
D/S from KTD	4002	4145	1466	1663	1955	5390	4908	3733	3598
U/s of Thahab	4186	4062	1508	1479	1855	5918	4663	3327	3351
D/S of Thahab	2917	2788	495	255	631	3677	3566	1683	2346
U/S of Hwaret	3064	3009	476	286	733	3966	3320	2067	2034
D/S of Hwaret	1854	–	436	286	733	3294	2405	1402	1511
U/S of Abu Zeighan Zeighan	1997	–	534	452	853	3344	2503	1451	1501

The gains and losses of each reach are summarized in Table 3.6. This study did not consider contribution from springs, losses due to evaporation, nor irrigation diversions. Based on the study, minor losses occurred between KTD and Al Thahab Weir. For the lower reach, the results are mixed with gains predominating. It is also noted that the largest gains were measured when then total flow was less than 1,000 l/s.

Table 3.6 Conveyances Losses of October 1987 - April 1988 Study

Reach	Oct12	Oct17	Gain(+)/Loss(-) in % Nov 9	Apr19	Apr24	May22	May30	Jun12	Jun27
KTD to U/S of Thahab Weir	+4.6	-2.0	+2.9	-11.1	-5.1	+9.8	-5.0	-10.9	-6.9
D/S of Thahab to U/S of Hwaret	+5.0	+7.9	-3.9	+12.2	+16.2	+7.9	-6.9	+22.8	-13.3
D/S of Hwaret to Abu Zeighan	+7.7	–	+22.5	+55.8	+16.4	+1.5	+4.1	+3.5	-0.7

The gains and losses are not consistent. It is likely that releases from KTD, diversions for irrigation, the spring flows, and evaporation are dependent on the season which in turn affects the results of gain or loss.

3.1.7 University of Jordan. Baseline Report on Water Conveyance Efficiency in the Zarqa River below King Talal Dam, 1994.

JVA water records for the period of 1990-1993 were reviewed by the University of Jordan. A water balance was established for the various inflow and outflow components of the Zarqa River System. Inflows were defined as flow releases from the dam as determined from gate settings, leakage estimated from piezometric readings, and estimated spills and spring flows. Outflow components included water diverted to Carrier Pipes I and II at Thahab Weir, to the Swalha Canal, to the KAC at Abu Al Zeighan, and water deliveries to farmers in DA 53 along the Zarqa river.

Monthly conveyance efficiencies were defined as the ratio of outflow to inflow. Monthly conveyance efficiencies from KTD to Abu Zeighan Weir for the dry season from April to September are summarized in Table 3.7.

Table 3.7 Monthly Conveyance Efficiencies

Year	Conveyance Efficiency (%) Monthly Range	Monthly Average
1990	78-91	85
1991	69-90	79
1992	59-91	81
1993	72-92	86

The use of release information from the dam probably is not appropriate for estimating channel losses. The procedure followed at the dam to release a quantity of water requested by the Irrigation Operations group in the Valley is to set the generator output based on a graph and the elevation difference between the reservoir and the powerhouse floor. This does not result in an accurate determination of flow. The use of rating curves at other locations for the determination of the channel flows also probably is not appropriate for a channel efficiency determination. A further limitation of the water balance study is that without streamflow measurements at intermediate locations, the channel reaches with losses or gains can not be identified.

3.2 Analysis of Channel Efficiency Data

The analysis consisted of an inspection of the river from KTD to the Abu Zeighan Weir, a consideration of the preliminary geological and hydrogeological findings with respect to channel efficiency, a review of the data or at least the results of each of the previous studies, a consideration of present and future conditions, and a determination of the usefulness of additional measurements. From this analysis, conclusions concerning the direction and content of subsequent studies were made.

3.2.1 Field Inspection

Harza and Consolidated Consultants performed a field reconnaissance of the entire reach of river below KTD and held discussions with the Operations and Water Quality Groups of the JVA. During the inspection of the reach between KTD and the Thahab Weir, three or four small irrigated areas were observed, each with a small pump for supplying irrigation water. In addition, a major quarrying effort by the Jordan Cement Plant exits several kilometers upstream from Thahab. The

river bed consists of large cobbles, gravel and course sand, and the underlying alluvial strata is of fine sand and gravel. There is some possibility of interflow below the bed but not to the extent that it would cause losses. The fine material deposited in the channel as a result of the quarrying operation further serves to seal the channel and prevent losses between the quarry and the Thahab weir.

Below Thahab, there were some significant irrigated croplands; however, the areas located on the right bank are supplied from the Carrier Pipe systems. Lands on the left bank, primarily located downstream from Hwaret Weir still apparently pump from the river. The river bed is typically alluvial with bed material consisting of gravel, sand and coarse to fine silt. This type of bed generally is not conducive to deep percolation. .

It is the general consensus of the JVA staff that there are no losses in the reach between KTD and the Thahab Weir. They further suggested that the losses shown in the previous studies may be due to flow measuring limitations and/or pumping from the river. In the other two downstream subreaches, Thahab Weir to Hwaret Weir and Hwaret Weir to the Abu Zeighan Weir, there is a general consensus among the JVA personnel that losses do occur.

3.2.2 Preliminary Geological and Hydrological Assessment

From the preliminary geologic investigations, the reach of river from KTD to the Thahab Weir is considered to have either no losses or to gain small amounts of water. The gain results from seepage and springs in the Kurnub Formation originating from infiltrated rainfall. The discharge from these springs and seepages is quite small and probably totally disappears in the summer season. In the lower reach, between Thahab Weir and the Abu Zeighan Weir, the preliminary geologic studies indicate that in the upstream portion of the reach, there is a zone of fresh-water gaining and in the downstream part, a zone of saline water gaining.

The preliminary hydrogeologic studies indicated that the reach between KTD and the Thahab Weir probably gains water as a result of the springs and seeps, but in a very small amount. Between the Hwaret Weir and the Abu Zeighan Weir, brackish and thermal springs and seeps are present over most of the reach and continuously recharge the surface water flowing in the Zarqa River.

3.2.3 Analysis of Measurements

Each of the studies contain some measure of poor assumptions and procedural errors, and the results are affected by unaccounted for influences. Some of the studies were performed over sequential days and some investigated seasonal impacts. Inflows may have been varying, spring flows and irrigation return flows varied, and the effect of bank storage was not usually considered. Therefore, an analysis of each of the studies would not be especially fruitful. Instead, the studies were considered as a single body of data to identify trends and general conclusions that are valid in spite of the individual study deficiencies.

A comparison was made between each of the measurements and the flow into KTD to determine if the gains or losses were correlated with high or low average monthly flows. The average monthly flows into KTD were compared with long-term average monthly flows and classified as drier than average, average, or wetter than average. There was no correlation as both gains and losses occurred in both wetter than average and drier than average months.

In the reach between KTD and the Thahab Weir, the individual measured gains and losses show no particular correlation with month or release from KTD. As shown on Exhibit 4, none of the losses are substantial and the average of all the measurements (excluding one day in 1984 which appeared to be incorrect) indicate, for all practical purposes, no gain or loss.

Measurements from each of the six studies and the average of the study measurements for the reach between Thahab and Abu Zeighan are presented on Exhibit 5. From an inspection of these data, it can be concluded that losses probably occur in this reach once the flow in the river exceeds about 1,000 l/s. The average of all values, presented as 0% on Exhibit 5 would be a loss of about 10 percent if the low-flow, high-gain values were eliminated. Water into and out of bank storage could cause measurements to show gains or losses. If bank storage caused similar quantities of gains and losses, it could be concluded, from an inspection of Exhibit 5, that some other factor, such as percolation, is causing a loss of water.

3.2.4 Conclusions

Based on the opinions of the JVA, the preliminary geologic and hydrogeologic assessments, taking into account the magnitude of the gains and losses with respect to the accuracy of the measurements, the difficulty of construction of any structural solution to losses, and the dispersion of the gains and losses around zero, it is concluded that any gain or loss within the reach between KTD and Thahab is minor and eliminating the loss could not be accomplished economically.

Based on the available information, it is concluded that losses of 10% to 15% occur in the reach between Thahab Weir and the Abu Zeighan Weir. This is considered sufficient to proceed with the conceptual analysis of structural solutions to mitigate this loss.

To develop a consensus with respect to the assumption of channel loss in the lower reach, the interested agencies should cooperatively develop a program design and implement a discharge measurment program.

3.3 Discharge Measurement Program

In July or August, after the hydrogeological and geological investigations are completed, Harza and Consolidated will implement a flow measurement program. The measurements will be taken at selected locations in order to confirm the assumption of losses. The design of the program will take into account the information collected during the previous studies and the reviews of these prior studies. Late July or August have been selected to minimize the possibility of rain, to lessen the chance of return flows and spring flows affecting the results, and to facilitate observations of spring and seepage activity.

Each set of measurements will include measuring at KTD to quantify the release from KTD, upstream of Thahab Weir to confirm the assumption of no losses between KTD and the Thahab Weir, and at other locations below the Thahab Weir. Tentatively, releases of 2,000 cms and 3,000 cms will be studied. The KTD will be requested to maintain these releases for a fixed period prior to taking measurements and to keep the releases constant during the measurement period. Each flow will be measured for two successive days and the initial flow will be measured again on the last day of measurements. Temporary staff gages (removed after a measurement) will be used to monitor any change in the river level during the measurement. Although the staff at King Talal Dam will be requested to keep a constant release, the hourly release data will be obtained to check the consistency of releases after the measurements are completed. The possibility of installing water level recorders for the planned monitoring of the losses has been reconsidered, and, in our opinion, installation of recorders will not increase the accuracy of the loss determination.

4. WATER QUALITY OF ZARQA RIVER

As diversions from the King Abdullah Canal (KAC) to Amman increase as a result of increasing demand for municipal and industrial (M&I) water, the irrigation supply for the Valley must increasingly depend on releases from KTD. The quality of the releases from KTD are marginally acceptable for irrigation and, as the releases are conveyed through the lower reaches of the Zarqa River, the quality is further degraded by saline seeps and springs emanating from the Zarqa Formation. The result is an irrigation supply that reportedly is causing some damage to crops an reductions in yield.

It is the consensus of the operating personnel of the JVA that the saline seeps and springs are too extensive to control efficiently and that the best solution is to divert the fresh water around the reach of river containing the saline springs and seeps. This study was performed assess the quality of the Zarqa River water, identify any trends in the quality, and evaluate the impact of the Zarqa River water on the diversion to and water already contained in the KAC.

4.1 Water Quality Monitoring Program

The Laboratory of Soil and Environment Directorate of the JVA is operating and maintaining about 65 to 70 water quality monitoring stations on KAC, the side wadis, the Zarqa River, at various dam sites and on canals carrying diversions from weirs or outflows from treatment plants.

This analysis of the quality of the Zarqa River will make use of the water quality data for the Zarqa River and for the stations on the KAC at which the water quality is affected by the diversions from Zarqa River. In addition, a special water quality monitoring study of the Zarqa River from the Sawalha Bridge to the Abu Zeighan Weir, undertaken by the Irrigation Department of the JVA, was reviewed.

4.2 Water Quality Parameters

The water quality parameters collected include, for various programs, Electric Conductivity (EC) and Acidity (pH), and for special studies, Boron ions (B), Calcium ions (Ca), Chloride ions (Cl), Potassium ions (K), Magnesium ions (Mg), Sodium ions (Na), Carbonates (HCO3), Nitrates (NO3), Sulfate (SO_4), and Sodium Absorption Ratio (SAR).

4.3 Water Quality Data Collection

The water quality data collection efforts, performed as a part of this study, concentrated on the following stations which are considered appropriate to study the Zarqa River water quality and its impact.

Downstream from King Talal Dam (KTD)
Abu Zeighan Canal
King Abdullah Canal (KAC)- Sawalha
King Abdullah Canal (KAC)- Maadi
Intermediate stations on the Zarqa River

The station, KAC-Maadi is located downstream from the confluence of KAC and outflow from Abu Zeighan Weir. The KAC-Sawalha is upstream from the confluence.

There is a substantial amount of water quality data in many reports. The reports made available to the Project Team were reviewed and selected data were translated. These data are summarized below:

Summary of Tabulated Data

Table No.	Period of Measurement	Measurement Stations	Parameters Measured
4.1	Daily 4/93 - 5/95	Downstream from KTD Abu Zeighan Weir KAC Sawalha KAC, Maadi	EC, pH
4.2	Intermittent days 4/6/94 - 10/26/94	Downstream from KTD Thahab Weir Bridge with Pipe Abu Zeighan Weir KAC Maadi	EC, pH, Na, Cl, B

Table No.	Period of Measurement	Measurement Stations	Parameters Measured
4.3	Monthly Intermittent years and stations 1980 to 1991. Fairly complete 1992 - 1994	Treatment Plant (in Amman?) Downstream from KTD Woman Spring Man Spring Abu Zeighan Weir KAC Sawalha KAC - Maadi	EC
4.4	Monthly 1992 - 1994	Treatment Plant Downstream from KTD Woman Spring Man Spring Abu Zeighan Weir KAC Sawalha KAC - Maadi Zarqa River below Abu Zeighan (?)	pH
4.5	Monthly Data April and October 1986 - 1994	1986-1992 - KTD 1992 - 1994 Treatment Plant Downstream from KTD Woman Spring Man Spring Abu Zeighan Weir KAC Sawalha KAC - Maadi Zarqa River below Abu Zeighan (?)	EC, pH, Na, K, Ca, Mg, Cl, SO_4, HCO_3, NO_3, B, SAR
4.6	Average of values taken over 1 year	Kherbet Samra Treatment Plant	EC, TDS, Na, SAR, Cl, B, T-N, pH, TSS, TFCC
4.7	One day in 1994	Various along the Zarqa River mostly in downstream reach.	EC, pH, spring flow

These tables are located at the end of this section.

4.4 Analysis of Water Quality Data

The selected water quality data were plotted and evaluated to define general relationships between time and/or location and certain of the water quality parameters. Subsequent analysis was directed toward a better definition of any problems identified in the preliminary analysis with the idea of identifying structural or operational solutions to the problems.

4.4.1 Electrical Conductivity

Crop tolerance and yield potential is influenced by irrigation water salinity. In term of the electrical conductivity of the water the following relationships can serve as a guide to relative tolerances of crops. The values presented are averages of several crops grown in the Valley in the indicated category.

Crop Tolerance and Yield Potential As Influenced
by Irrigation Water Salinity (EC - μmohs/cm)

Yield Potential (%of maximum)	100%	90%	75%	50%
Crop				
Vegetables	1.4	2.0	2.9	4.3
Citrus	1.1	1.6	2.2	3.2

EC values obtained in the data collection phase were plotted as a time series in Exhibits 6 through 10 and by month in Exhibits 11 and 12. From the plot of monthly data shown on Exhibit 6, the good quality of the Yarmouk River water, represented by KAC-Sawalha, is confirmed (EC $\approx$ 1). The plot also appears to confirm the general consensus that there is a relatively close relationship between EC at Abu Zeighan and at KAC-Maadi. Ominously, over the last two years, there appears to be a trend of increasing EC at both Abu Zeighan and KTD, but especially at Abu Zeighan.

The daily values of EC between April 93 and Mar 95, presented in Table 4.1 are plotted on Exhibit 7. The plot of these data generally support the indications of the monthly data as far as the relative quality of water at the indicated locations. The upward trend in EC at Abu Zeighan is confirmed; however the upward trend in EC at KTD appears to have reversed. The extreme values of EC in

the winter months is explained as an inverse relation with flow as can be seen on Exhibit 8, which plots release from KTD against EC at KTD.

Exhibits 9 and 10 are additional time-series plots of available EC data. Exhibit 9, which represents the dry season in 1994, indicates an increase of EC from about 1.9 to about 2.4 at KAC-Maadi over the season. This increase probably had a significant effect on the yield of crops. Exhibit 10 indicates that the quality of releases from KTD is already poor, with EC values varying from about 1.5 to 2.75. The poorest quality releases generally occur in the winter months. Releases are generally lower during these occurrences as are reservoir water levels.

On Exhibit 11, EC values for the months of April and October, the beginning and ending of the dry season, are shown for 1992, 1993, and 1994. The close relationship between the quality at Abu Zeighan and KAC_Maadi is evident. The very poor quality of the two major springs (EC $\approx$ 9) is probably indicative of all the seeps and springs in the lower reach. The Zarqa?? location is believed to be downstream of the Abu Zeighan Weir. One would expect a direct relationship between the EC values at the springs and Abu Zeighan; however, the springs appear to hold constant or slightly decrease, while at Abu Zeighan, the EC values increase. This phenomenon suggests some other occurrence in 1994. On Exhibit 12, the close relationship between EC at Abu Zeighan and KAC-Maadi is confirmed. It is surprising that there are any deviations because it was reported that all the water in the KAC was diverted from the Zarqa river during this period. From a comparison of EC values at KTD and the Thahab Weir, it can be concluded that there is no deterioration of quality between the two locations.

To make clear the deterioration of EC at KAC-Maadi with time, the monthly data for this location was isolated and summarized in Table 4.8.

Table 4.8 Average Monthly EC Values at KAC, Maadi
(mmhos/cm)

Month	Period		
	1987-92	1993-94	1994
January	1.12	1.75	2.11
February	1.03	2.13	3.26
March	1.29	1.73	1.88
April	1.50	2.06	2.53
May	1.59	2.27	2.79
June	1.33	2.57	2.82
July	1.68	2.33	2.40
August	1.54	2.45	2.71
September	1.83	2.48	2.63
October	1.94	2.60	2.95
November	1.95	2.16	1.82
December	1.59	2.04	1.37
Average	1.53	2.21	2.44

From an inspection of Table 4.8, it is evident that during the period from 1987 through 1992, the monthly average values ranged between a low of 1.03 in February to a high of 1.95 in November, with a yearly monthly average of approximately 1.5. During the period 1993-94 the EC values increase significantly. The monthly average values for 1993-1994 vary from a low of 1.73 in March to a high of 2.6 in October for an annual average of 2.2. For the months of April through October, the season of maximum irrigation, average monthly values increased from 1.6 during 1987-92 to 2.4 in 1993-94. For the months of November through March, during the same corresponding periods, the average monthly values increase from an average of 1.4 to 2.0. From an inspection of data for 1994, records show that the situation continues to deteriorate at an alarming rate. The values of EC vary from 1.37 to 3.26, with an annual average of 2.44.

It can be concluded that water quality at KAC-Maadi is deteriorating due to an increase in salinity. Comparing the recorded EC values with the generalized crop limits and yield potential values, the crops in the Valley could be currently experiencing yield reductions on the order of 25 percent and, if the trend of increasing EC continues, the yield reductions will continue to increase.

One reason for the deterioration of the quality of the water available at KAC-Maadi is the increase in the diversion of good quality Yarmouk River water (identified as KAC-Sawalha) from the KAC for use in Amman. Formerly, the good quality water was available to dilute the poorer quality water from the Zarqa River. In 1994, from April through August, there was little or no water available for dilution. These diversions to Amman will continue or increase unless another source of water can be found.

A second reason for the deterioration of the quality of water at KAC-Maadi is the deteriorization of the quality of the Zarqa River.

The monthly EC values for the period 1987 through 1994 at KTD, the Abu Zeeghan Weir, and the KAC-Maadi are presented in Table 4.9.

The data indicate that water quality at Abu Zeighan and KAC-Maadi has deteriorated significantly during the last two years of record, 1993 and 1994. Generally the EC values at Abu Zeighan have been the same or only slightly higher than those at KTD through 1993. In 1993 and 1994, the data indicate that for some reason water quality in the river is deteriorating in the reach between KTD and Abu Zeighan. The water quality data presented in Table 4.2, which was collected at various locations along the river during 1994, indicate that the increase in salinity is occurring in the reach of the river between the bridge with pipe (Sawalha Bridge) and the Abu Zeighan Weir.

Table 4.7 presents data gathered during a special study conducted by JVA at 25 locations along the Zarqa River. These data show the increase in salinity in the river, moving downstream from Bridge 3 to the Abu Zeighan Weir, due to inflow from seepage and springs. Reportedly, there has been a significant increase in saline inflow, from less than 20 l/s to more than 150 l/s, during the last two years. The special study shown in Table 4.7 indicates the inflow from seepage and springs was approximately 189 l/s. The reported increase in saline inflow has been attributed to Abu Zeighan test well No.1 which was drilled in December 1993. This well was under very high pressure and the outflow could not be controlled. In an attempt to stop the flow nearly 100 tons of cement were

Table 4.9

Monthly EC Values

(mmhos/cm)

JANUARY

	KTD	Abu Zeighan	KAC, Maadi
1987	1.49		0.89
1988	2.46	2.54	0.89
1989	2.30		1.02
1990	2.81	2.22	1.01
1991	2.73	2.64	2.3
1992			0.63
1993	2.10	1.76	1.39
1994	2.44	5.62	2.11

FEBRUARY

	KTD	Abu Zeighan	KAC, Maadi
1987	1.19		0.78
1988	2.34	2.33	0.67
1989	1.78		1.9
1990	2.72		1.08
1991	1.76	2.08	1.24
1992	1.15		0.53
1993	1.68	1.71	0.99
1994	2.62	4.58	3.26

MARCH

	KTD	Abu Zeighan	KAC, Maadi
1987	1.44		0.71
1988	1.17	1.16	0.51
1989	1.55		1.69
1990	2.13		1.78
1991	2.34	2.17	2.15
1992	1.03	1.15	0.91
1993	1.60	1.63	1.58
1994	2.58	4.20	1.88

APRIL

	KTD	Abu Zeighan	KAC, Maadi
1987	1.20		1.12
1988	1.27	1.16	0.97
1989	1.56		1.7
1990	2.44		2.2
1991	2.24	1.75	1.83
1992	1.10	1.19	1.17
1993	1.58	1.77	1.58
1994	1.95	2.55	2.53

MAY

	KTD	Abu Zeighan	KAC, Maadi
1987	1.36		1.28
1988	1.03	1.09	1.2
1989	1.72		1.8
1990	2.21	2.21	2.21
1991	1.79	2.04	1.82
1992	1.12	1.28	1.25
1993	1.57	1.74	1.74
1994	2.02	2.75	2.79

JUNE

	KTD	Abu Zeighan	KAC, Maadi
1987	1.28		1.41
1988	1.01	1.03	1.22
1989	1.58		1.6
1990	1.75	1.77	1.89
1991	1.74	1.92	1.85
1992	1.26	1.28	1.20
1993	1.60	2.34	2.32
1994	2.02	2.89	2.82

JULY

	KTD	Abu Zeighan	KAC, Maadi
1987	1.29		1.69
1988	1.10	1.15	1.22
1989	1.56		1.82
1990	1.85	1.81	2
1991	1.86	2.22	1.92
1992	1.25	1.42	1.40
1993	1.61	2.33	2.27
1994	2.01	3.01	2.40

AUGUST

	KTD	Abu Zeighan	KAC, Maadi
1987			1.55
1988	1.41	1.35	1.69
1989	1.66		1.82
1990	1.95	1.94	2.19
1991	2.10	2.28	2.17
1992	1.23	1.40	1.39
1993	1.58	2.22	2.18
1994	2.20	2.76	2.71

SEPTEMBER

	KTD	Abu Zeighan	KAC, Maadi
1987	1.78		1.97
1988	1.18	1.19	1.4
1989	1.68		1.8
1990	2.16	2.09	2.21
1991	2.35	2.56	2.24
1992	1.24	1.40	1.36
1993	1.72	2.27	2.32
1994	2.39	2.89	2.63

OCTOBER

	KTD	Abu Zeighan	KAC, Maadi
1987	2.01		2.22
1988	1.28	1.21	1.33
1989	2.03		2.07
1990	2.30	2.28	2.42
1991	2.61	2.72	2.27
1992	1.31	1.39	1.42
1993	1.90	2.25	2.25
1994	2.43	3.13	2.95

NOVEMBER

	KTD	Abu Zeighan	KAC, Maadi
1987	1.70		1.81
1988	1.79	1.69	1.62
1989	2.22		1.75
1990	2.59	2.64	2.49
1991	2.52	2.79	2.19
1992	1.77	1.85	1.85
1993	2.13	2.51	2.50
1994	3.00	3.75	1.82

DECEMBER

	KTD	Abu Zeighan	KAC, Maadi
1987	1.52	2.4	1.75
1988	1.86		1.6
1989	2.59		1.17
1990	2.78	2.8	2.79
1991	1.50	2.09	0.91
1992	1.84	1.94	1.34
1993	2.12	2.62	2.71
1994	2.28	4.02	1.37

injected into the well. The attempt was only partially successful as the high piezometric pressure in the well began washing the cement out. In addition, it was reported that about 60 meters of the well had caved in. In the Spring of 1994, the JVA were able to control the flow. Subsequently, JVA engineers noted that the seepage and spring flows increased. The increase in seepage and spring flow could be the cause of the jump in EC value at Abu Zeighan in 1994.

The analysis of currently available data supports the conclusion that the water quality at KAC-Maadi is deteriorating, has reached levels that are causing damage to the irrigation sector, and may continue to deteriorate. The current salinity levels are high enough to cause significant yield reductions in irrigated crops. The data also supports the conclusion that a major source of the pollutants causing the degradation of the water quality occurs in the lower reach of the Zarqa River. In addition, the data supports an argument that even if a solution is found to the problem in the lower reach of the river, the quality at KTD is such that yield reductions will continue to occur, although not to the same level.

4.4.2 pH Values

Exhibits 13 through 17 present plots of PH versus time for various locations. At most locations along the Zarqa River, pH varies between 7.5 to 8.5 which is in the upper range of suitability for irrigation but within the normal range of pH values for irrigation water which is between 6.5 to 8.4.

The mixing of acid water from Woman and Man Springs with the water from the Sawalha Bridge improves the water quality at Abu Zeighan by lowering the pH values. The mixing of higher pH water from KAC-Sawalha with the water from Abu Zeighan increases the pH values which is reflected by the water quality at KAC-Maadi. Exhibit 14 shows a direct relationship between release from KTD and the pH value of the water.

4.4.3 Other Water Quality parameters

The periodic measurements of B, Ca, Cl, K, Mg, Na, HCO_3, SAR, NO_3, and SO_4 performed from April to October 1994 and the April and October monthly average values from April 1992 to October 1994 are plotted on Exhibits 18 through 30. The range of water quality variation for non-spring water is small compared to the difference between that of water from spring and non-spring. Most of the time the value of these water quality parameters is most favorable at KAC-Sawalha.

Boron is reported to cause no irrigation problems if the ion concentration is less than 0.7 mg/l. In the range of 0.7 to 2.0, increasing problems can occur. Most of the Boron (B) ion concentrations

are below 0.7 mg/l (Exhibits 18,19). Occasionally, during the mid-summer months, the values at KAC-Maadi are between 0.7 and 1.0 mg/l. Therefore, most of the time, the boron ion concentrations will cause no problems when the water is used for irrigation and, at worst, only a mild problem.

The Cl concentrations are shown on Exhibits 20 and 21. The Cl concentration at KAC-Sawalha is below 4 mg/l and is considered to have no restriction on its use for irrigation. The Cl concentrations at locations on the Zarqa River and at KAC-Maadi are not only in the range that would subject the use of the water for irrigation to moderate and severe restrictions, but also the concentration appears to be increasing with time. while the springs do exacerbate the problem, the concentrations of releases from KTD already are high enough to restrict use of the water for irrigation.

The comments for chloride ions can be repeated for sodium as shown on Exhibits 22 and 23. Moderate to severe restrictions should be placed on the use of the Zarqa River water for irrigation. In addition, an increasing trend in the concentration of sodium ions is evident. Based the concentrations of B, Cl, and Na ions, it can be concluded that the toxicity of water from Woman and Man Springs is very high.

The concentration of HCO_3 ions at all locations on Zarqa River (Exhibit 24) is in the range of 4 to 10 mg/l and, therefore, the use of this water for irrigation would be subject to slight to moderate and severe restrictions. The NO_3 concentrations indicated on Exhibit 25 at all locations on Zarqa River are between 5 to 30 mg/l and the use of the water for irrigation would be subject to slight to moderate restrictions. The NO_3 concentration of KAC-Sawalha, and Woman and Man Springs are also in the same range.

The SAR values of non-spring water at locations along the Zarqa River all fall in the range of 0-3 and 3-6 (Exhibit 26) with the corresponding EC values greater than 0.7 and 1.2 mmhos/cm respectively. This means that there would be no restriction on irrigation use on the basis of the SAR values.

The nutrient elements of potassium, calcium, and magnesium, and sulphates are plotted in Exhibits 27 through 30 without comment.

4.5 Conclusions

It can be concluded from the current analysis that the major cause of the deterioration of the qulaity of the KTD releases is the seeps and springs that are located along the Zarqa River between the Hwaret Weir and the Abu Zeighan Weir.

The water from the King Talal Reservoir is only marginally acceptable for irrigation based on general criteria.

Prevention of the mixing of KTD releases and water from the seeps and springs will significantly improve the quality of the water diverted into the KAC.

Structural alternatives to prevent the mixing and, at the same time, improve the channel efficiency should be evaluated.

Even with a structural solution to mitigate the effect of the seeps and springs, operational changes may be necessary to permit continuance of the use of water from King Talal Reservoir for irrigation without restriction.

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
APR 93	1	1.63	8.30	0.81	8.36	1.69	8.30	1.70	8.32	1.29	8.33
	2										
	3	1.63	8.29	0.83	8.34	1.68	8.29	1.68	8.30	1.69	8.30
	4	1.59	8.30	0.82	8.35	1.66	8.30	1.24	8.31	1.74	8.30
	5	1.59	8.30	0.82	8.30	1.73	8.30	1.34	8.31	1.34	1.31?
	6	1.61	8.30	0.82	8.26	1.69	8.30	1.32	8.33	1.68	8.30
	7	1.61	8.29	0.83	8.35	1.69	8.29	1.41	8.31	1.73	8.30
	8	1.58	8.28	0.83	8.20	1.61	8.28	1.29	8.30	1.37	8.30
	9										
	10	1.58	8.29	0.83	8.34	1.73	8.29	1.52	8.34	1.68	8.34
	11	1.60	8.21	0.84	8.32	1.66	8.28	1.41	8.29	1.39	8.29
	12	1.60	8.25	0.86	8.33	1.71	8.29	1.69	8.31	1.69	8.31
	13	1.57	1.28?	0.82	8.33	1.72	8.29	1.72	8.33	1.72	8.32
	14	1.59	8.27	0.86	8.30	1.68	8.27	1.68	8.27	1.71	8.27
	15	1.57	8.27	0.89	8.30	1.64	8.27	1.68	8.27	1.67	8.27
	16										
	17	1.57	8.27	0.85	8.30	1.65	8.28	1.47	8.27	1.68	8.28
	18	1.62	8.27	0.87	8.30	1.68	8.27	1.49	8.27	1.71	8.30
	19	1.58	8.29	0.86	8.33	1.69	8.29	1.67	8.33	1.69	8.32
	20	1.55	8.29	0.86	8.31	1.65	8.29	1.64	8.30	1.64	8.30
	21	1.59	8.69	0.81	8.33	1.69	8.69	1.69	8.21	1.79	8.20
	22	1.57	8.29	0.88	8.32	1.69	8.29	1.69	8.30	1.69	8.30
	23										
	24	1.52	8.29	0.79	8.30	1.69	8.26	1.62	8.30	1.62	8.30
	25	1.54	8.30	0.86	8.32	1.63	8.30	1.63	8.32	1.63	8.32
	26	1.56	8.29	0.83	8.32	1.66	8.29	1.65	8.32	1.66	8.32
	27	1.52	8.30	0.85	8.33	1.66	8.30	1.67	8.33	1.66	8.31
	28	1.50	8.29	0.82	8.32	1.64	8.29	1.65	8.32	1.69	8.32
	29	1.52	8.31	0.84	8.35	1.62	8.30	1.66	8.32	1.66	8.31
	30										
MAY 93	1										
	2										
	3	1.53	8.31	0.82	8.33	1.68	8.30	1.72	7.32	1.68	8.31
	4	1.55	8.30	0.85	8.32	1.67	8.30	1.73	8.32	1.72	8.32
	5	1.59	8.30	0.86	8.32	1.77	8.30	1.83	8.32	1.81	8.32
	6	1.55	8.38	0.87	8.32	1.65	8.28				
	7										
	8	1.55	8.30	0.88	8.34	1.69	8.30	1.68	8.32	1.66	8.31
	9	1.49	8.28	0.82	8.33	1.64	8.28	1.63	8.33	1.70	8.33
	10	1.55	8.30	0.87	8.30	1.66	8.29	1.63	8.31	1.60	8.30
	11	1.53	8.28	0.86	8.32	1.70	8.28	1.70	8.33	1.71	8.32
	12	1.52	8.30	0.82	8.33	1.66	8.30			1.65	8.33
	13	1.57	8.29	0.92	8.33	1.70	8.28	1.77	8.33	1.73	8.32
	14										
	15	1.60	8.30	0.87	8.34	1.80	8.30	1.60	8.32		
	16	1.57	8.30	0.88	8.34	1.73	8.30	1.73	8.32	1.64	8.32
	17	1.58	8.30	0.94	8.34	1.79	8.30	1.80	8.32	1.79	8.31
	18	1.58	9.30	0.92	8.33	1.78	8.30	1.79	8.32	1.79	8.32
	19	1.55	8.30	0.84	8.33	1.83	8.30	1.88	8.32	1.79	8.32
	20	1.57	8.30	1.00	8.33	1.81	1.29?	1.82	8.32	1.83	8.32
	21										
	22	1.57	8.30	0.90	8.32	1.80	8.30	1.53	8.30	1.77	8.31
	23	1.53	8.38	0.86	8.32	1.79	8.27	1.81	8.30	1.74	8.30
	24	1.52	8.31	0.85	8.34	1.71	8.30	1.79	8.31	1.82	8.32
	25										
	26	1.56	8.30	0.85	8.34	1.84	8.30	1.86	8.32	1.89	8.32
	27	1.54	8.30	0.87	8.35	1.82	8.30	1.79	8.33	1.81	8.32
	28										
	29	1.52	8.31	0.84	8.34	1.77	8.30	1.75	8.32	1.76	8.32
	30										
	31										

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
JUN 93	1										
	2										
	3										
	4										
	5	1.58	8.32	0.88	8.35	1.87	8.32	1.85	8.34	1.87	8.33
	6	1.58	8.31	0.86	8.35	1.83	8.30	1.89	8.24	1.89	8.32
	7	1.58	8.30	0.88	8.34	1.83	8.30	1.88	8.33	1.85	8.31
	8	1.54	8.30	0.85	8.34	1.81	8.30	1.81	8.32	1.81	8.31
	9	1.58	8.31	0.89	8.34	1.85	8.30	1.87	8.32	1.85	8.31
	10										
	11										
	12	1.53	8.31	0.85	8.34	1.78	8.30	1.79	8.31	1.79	8.31
	13	1.56	8.29	0.88	8.34	1.88	8.29	1.88	8.30	1.81	8.30
	14	1.57	8.29	0.85	8.32	2.25	8.26	2.17	8.26	2.20	8.26
	15	1.57	8.34	0.88	8.32	2.06	8.24	2.06	8.24	2.17	8.24
	16	1.59	8.28	0.82	8.31	2.15	8.18	2.13	8.18	2.20	8.18
	17	1.57	8.26	0.87	8.31	2.10	8.17	2.12	8.18	2.12	8.18
	18										
	19	1.60	8.24	0.89	8.30	1.95	8.11	1.98	8.18	1.98	8.17
	20	1.55	8.24	0.88	8.28	2.09	8.11	2.08	8.17	2.08	8.17
	21										
	22	1.51	8.24	0.85	8.26	1.99	8.11	2.02	8.16	2.02	8.16
	23	1.55	8.22	0.85	8.23	2.17	8.00	2.11	8.14	2.11	8.14
	24	1.55	8.18	0.86	8.18	2.40	8.00	2.40	8.02		
	25										
	26	1.57	8.18	0.89	8.23	2.02	8.00	2.02	8.06	2.04	8.06
	27	1.56	8.16	0.87	8.18	2.11	7.95	2.11	8.09	2.12	8.09
	28	1.46	8.19	0.80	8.28	2.10	8.00	2.08	8.09	2.12	8.07
	29	1.53	8.19	0.87	8.27	2.11	8.09	2.14	8.14	2.14	8.14
	30	1.60	8.20	0.83	8.28	2.32	8.06	2.27	8.18	2.33	8.17
JUL 93	1	1.63	8.19	0.92	8.20	2.16	8.06	2.01	8.14	2.16	8.14
	2										
	3	1.52	8.20	0.86	8.21	2.05	8.06	2.05	8.16	2.05	8.14
	4	1.49	8.19	0.85	8.22	2.24	8.04	2.17	8.16	2.34	8.17
	5	1.53	8.18	0.83	8.22	2.20	8.06	2.20	8.16	2.17	8.17
	6	1.57	8.24	0.88	8.28	2.15	7.91	2.14	8.13	2.15	8.13
	7	1.55	8.24	0.84	8.28	2.19	8.09	2.18	8.16	2.19	8.16
	8	1.54	8.24	0.84	8.28	2.19	8.12	2.17	8.17	2.19	8.18
	9										
	10	1.50	8.26	0.85	8.28	2.04	8.05	2.04	8.17	2.04	8.17
	11	1.51	8.28	0.83	8.39	2.11	8.08	2.11	8.17	2.11	8.16
	12	1.55	8.27	0.86	8.29	2.21	8.08	2.21	8.17	2.21	8.17
	13	1.57	8.27	0.88	8.29	2.13	9.07	2.13	8.18	2.13	8.17
	14	1.60	8.25	0.87	8.29	2.21	8.04	2.21	8.18	2.21	8.18
	15	1.52	8.22	0.90	8.26	2.20	8.04	2.16	8.15	2.17	8.16
	16										
	17	1.58	8.22	0.91	8.28	2.14	8.10	2.14	8.17	2.21	8.18
	18	1.65	8.23	0.90	8.29	3.37	8.11	2.92	8.17	4.00	8.18
	19	1.58	8.22	0.87	8.28	3.29	8.11	3.25	8.18	3.25	8.17
	20	1.60	8.23	0.90	8.28	2.23	8.10	2.18	8.17	2.18	8.17
	21	1.62	8.23	0.93	8.26	2.41	8.03	2.29	8.14	2.41	8.14
	22	1.55	8.23	0.85	8.36	2.43	7.93	2.37	8.18	2.37	8.18
	23										
	24	1.59	8.21	0.91	8.23	2.33	8.10	2.33	8.16	2.26	8.14
	25	1.53	8.30	0.85	8.24	2.25	8.08	2.25	8.13	2.25	8.13
	26	1.54	8.21	0.88	8.24	2.13	8.00	2.14	8.13	2.15	8.12
	27	1.53	8.20	0.88	8.22	2.39	7.80	2.29	8.14	2.39	8.13
	28	1.57	8.16	0.84	8.23	2.14	7.86	2.14	8.13	2.19	8.20
	29	1.48	8.15	0.84	8.16	2.43	7.88	2.18	8.09	2.43	8.14
	30										
	31	1.53	8.19	0.85	8.24	2.21	8.00	2.19	8.16	2.21	8.16

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
AUG 93	1	1.61	8.18	0.89	8.21	2.32	8.00	2.29	8.13	2.33	8.04
	2	1.59	8.14	0.87	8.43	2.24	8.00	2.24	8.09	3.24	8.11
	3	1.59	8.13	0.86	8.18	2.21	8.00	2.21	8.08	2.20	8.08
	4	1.54	8.11	0.84	8.14	2.26	7.96	2.26	8.09	2.24	8.10
	5	1.55	8.18	0.90	8.20	2.32	7.90	3.32	8.11	2.32	8.01
	6										
	7	1.62	8.19	0.90	8.22	2.24	8.00	2.23	8.17	2.18	8.16
	8	1.60	8.18	0.89	8.20	2.30	7.92	2.30	8.16	2.30	8.16
	9	1.54	8.19	0.84	8.23	2.18	8.00	2.18	8.16	2.18	8.16
	10	1.53	8.18	0.84	8.24	2.37	7.91	2.35	8.13	2.25	8.13
	11										
	12	1.51	8.18	0.83	8.24	2.12	7.93	2.11	8.12	2.12	8.11
	13										
	14	1.51	8.20	0.86	8.22	2.03	8.00	2.03	8.13	2.03	8.13
	15	1.59	8.21	0.90	8.26	2.33	7.98	2.32	8.16	2.30	8.16
	16	1.58	8.21	0.86	8.27	2.51	8.00	2.44	8.18	2.45	8.18
	17	1.58	8.19	0.88	8.22	2.50	8.02	2.50	8.18	2.35	8.16
	18	1.58	8.16	0.89	8.23	2.48	8.00	2.48	8.11	2.49	8.12
	19	1.53	8.15	0.89	8.18	2.03	8.00	2.03	8.08	2.03	8.08
	20										
	21	1.51	8.13	0.78	8.17	1.13	8.00	1.82	8.11	1.32	8.11
	22	1.55	8.14	0.86	8.16	2.07	7.97	2.05	8.12	2.13	8.12
	23	1.58	8.12	0.84	8.15	2.38	7.94	2.38	8.09	2.38	8.11
	24	1.58	8.11	0.87	8.13	2.33	8.00	2.33	8.06	2.33	8.08
	25	1.60	8.18	0.85	8.21	2.27	7.96	2.15	8.09	2.15	8.09
	26	1.59	8.13	0.85	8.18	2.27	8.00	2.23	8.08	2.23	8.08
	27										
	28	1.59	8.14	0.85	8.18	2.22	7.96	2.21	8.09	2.21	8.09
	29	1.63	8.12	0.86	8.16	2.28	7.97	2.27	8.09	2.28	8.08
	30										
	31										
SEP 93	1	1.59	8.13	0.85	8.15	2.03	7.97	2.04	8.09	2.03	8.09
	2	1.56	8.13	0.87	8.16	2.03	7.97	2.03	8.10	2.02	8.10
	3										
	4	1.59	8.14	0.87	8.17	2.18	7.98	2.17	8.10	2.18	8.10
	5	1.56	8.12	0.88	8.15	2.18	6.76	2.18	8.08	2.29	8.09
	6	1.60	8.12	0.90	8.17	2.17	8.00	2.13	8.07	2.17	8.09
	7	1.60	8.12	0.70	8.15	2.24	7.97	2.24	8.06	2.21	8.09
	8	1.61	8.13	0.90	8.16	2.25	8.00	2.25	8.10	2.25	8.10
	9	2.31	8.13	0.91	8.16	4.93	8.00	4.54	8.10	4.94	8.05
	10										
	11	1.73	8.15	0.95	8.18	2.34	7.91	1.78	8.11	2.03	8.08
	12	1.59	8.13	0.91	8.15	2.15	7.97	2.14	8.12	2.15	8.10
	13	1.61	8.15	0.91	8.17	2.14	7.96	2.11	8.08	2.14	8.07
	14	1.61	8.13	0.89	8.14	1.94	7.93	1.94	8.06	1.95	8.07
	15	1.66	8.15	0.91	8.16	2.01	7.97	1.97	8.06	2.00	8.06
	16	1.62	8.14	0.92	8.15	2.40	7.97	2.40	8.00	2.40	8.00
	17										
	18	1.66	8.09	0.93	8.11	2.23	7.90	2.23	8.06	2.23	8.07
	19	1.63	8.10	0.92	8.12	2.18	7.96	2.15	8.06	2.15	8.06
	20	1.69	8.09	0.89	8.12	2.13	7.97	2.13	8.06	2.13	8.08
	21	1.66	8.10	0.90	8.12	2.10	7.97	2.10	8.06	2.08	8.07
	22	1.69	8.09	0.92	8.13	2.09	8.00	2.08	8.07	2.08	8.07
	23	1.86	8.15	1.00	8.14	2.52	7.90	2.44	8.11	2.42	8.07
	24										
	25	1.60	8.14	0.85	8.15	2.09	7.97	2.09	8.11	2.09	8.10
	26	1.75	8.13	0.90	8.15	2.10	7.95	2.06	8.10	2.10	8.10
	27	1.70	8.14	0.91	8.17	2.32	7.94	2.32	8.11	2.32	8.10
	28	1.70	8.13	0.93	8.16	2.28	7.96	2.28	8.10	2.13	8.07
	29	1.70	8.13	0.90	8.15	2.20	7.96	2.20	8.10	2.20	8.10
	30	1.80	8.08	0.94	8.08	2.42	7.70	2.38	8.00	2.42	8.00

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
OCT 93	1										
	2	1.65	8.06	0.94	8.09	2.13	7.80	2.13	8.00	2.13	8.00
	3	1.70	8.15	0.89	8.15	2.14	8.00	2.14	8.13	2.14	8.11
	4	1.69	8.11	0.90	8.12	2.18	7.90	2.18	8.07	2.18	8.08
	5	1.77	8.15	0.92	8.16	2.17	8.00	2.16	8.12	2.16	8.12
	6	1.60	8.09	0.87	8.12	2.01	7.88	2.04	8.06	2.17	8.10
	7	1.76	8.12	0.90	8.13	2.10	7.89	2.10	8.10	2.12	8.90
	8										
	9	1.76	8.08	0.91	8.08	2.13	7.90	1.87	8.04	2.11	8.04
	10	1.76	8.08	0.90	8.10	2.10	7.90	2.08	8.04	2.10	8.04
	11	1.83	8.11	0.95	8.11	2.30	7.95	2.28	8.08	2.40	8.08
	12	1.83	8.10	0.92	8.10	2.22	7.95	2.18	8.08	2.22	8.08
	13	1.83	8.11	0.85	8.13	2.26	7.97	2.24	8.10	2.24	8.10
	14	1.83	8.11	0.90	8.13	2.28	7.96	2.20	8.10	2.25	8.10
	15										
	16	2.00	8.10	0.95	8.12	2.30	7.91	2.33	8.10	2.27	8.09
	17	1.90	8.09	0.91	8.11	2.28	7.93	2.28	8.09	2.28	8.09
	18	1.90	8.10	0.90	8.12	2.47	7.88	2.47	8.07	2.47	8.08
	19	1.97	8.10	0.91	8.12	2.30	7.92	2.40	8.09	2.40	8.08
	20	1.97	8.10	0.91	8.12	2.46	7.91	2.44	8.08	2.46	8.08
	21	1.97	8.90	0.97	8.11	2.36	7.92	2.33	8.08	2.34	8.09
	22										
	23	1.92	8.09	0.90	8.12	2.22	7.91	2.22	8.08	2.22	8.09
	24	1.97	8.08	0.95	8.12	2.39	7.94	2.39	8.09	2.39	8.09
	25	2.08	8.12	0.90	8.15	2.60	8.00	2.60	8.15	2.70	8.12
	26	2.08	8.15	0.95	8.13	2.60	7.88	2.52	8.11	2.02	8.11
	27	2.06	8.11	0.91	8.12	2.56	7.96	2.52	8.11	2.52	8.11
	28	2.00	8.11	0.89	8.11	2.32	7.95	2.32	8.10	2.32	8.11
	29										
	30	2.01	8.11	0.88	8.11	2.48	7.96	2.07	8.09	2.09	8.09
	31	1.99	8.10	0.86	8.14	2.31		2.28	8.06	2.28	8.07
NOV 93	1	2.00	8.11	0.85	8.12	2.40	7.96	2.40	8.01	2.40	8.08
	2	2.04	8.11	0.88	8.12	2.37	7.98	2.37	8.08	2.34	8.08
	3	2.07	8.10	0.91	8.13	2.42	7.97	1.97	8.10	2.36	8.09
	4	2.08	8.11	0.97	8.13	2.50	7.94	2.50	8.08	2.34	8.09
	5										
	6	2.09	8.10	0.96	8.12	2.60	7.95	1.93	8.08	2.57	8.08
	7	2.18	8.08	1.00	8.10	3.00	7.88	2.90	8.06		
	8										
	9	2.20	8.07	1.02	8.10	2.66	7.89	2.66	8.12		
	10	2.26	8.11	1.04		2.66	7.92	2.66	8.07	2.58	8.10
	11	2.22	8.11	1.03	8.13	2.58	7.96	2.58	8.09	2.58	8.08
	12										
	13	2.04	8.10	0.94	8.11	2.40	7.92	2.02	8.09	2.06	8.06
	14										
	15	2.21	8.09	0.99	8.13	2.58	8.00	2.57	8.06	2.57	8.06
	16	2.18	8.08	0.98	8.12	2.58	8.00	2.57	8.07	2.45	8.08
	17	2.18	8.10	1.00	8.12	2.55	8.00	2.55	8.09	2.37	8.08
	18	2.13	8.11	0.98	8.11	2.57	8.00	2.46	8.08	2.59	8.05
	19										
	20	2.21	8.11	0.98	8.13	2.68	8.00	2.17	8.09	2.68	8.08
	21	2.18	8.12	0.98	8.14	2.55	8.00	2.55	8.08	2.46	8.08
	22	2.09	8.11	0.93	8.13	2.54	7.95	2.53	8.09	2.53	8.09
	23	2.06	8.11	0.94	8.13	2.52	8.00	2.52	8.09	2.52	8.09
	24	2.09	8.11	0.93	8.13	2.57	8.00	2.56	8.09	2.64	7.98
	25	2.00	8.04	0.90	8.15	2.56	8.02	2.54	7.99	2.38	8.10
	26										
	27	2.09	8.11	0.93	8.13	2.56	7.96	2.54	8.10	2.56	8.08
	28	2.09	8.10	0.95	8.13	2.55	7.98	2.55	8.09	2.44	8.04
	29	2.24	8.10	0.98	8.13	2.69	7.90	2.28	8.09	1.77	8.07
	30	2.14	8.10	0.94	8.12	2.53	7.94	2.53	8.09	2.53	8.08

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
DEC 93	1	2.10	8.10	0.94	8.11	2.48	7.96	2.47	8.09	2.47	8.09
	2	2.14	8.10	0.95	8.12	2.58	7.96	2.58	8.08	2.58	8.08
	3										
	4	2.04	8.09	0.91	8.12	2.50	7.96	2.50	8.08	2.43	8.08
	5	2.02	8.10	0.90	8.13	2.63	7.94	2.62	8.08	2.64	8.08
	6	2.08	8.30	0.88	8.45	2.49	8.02	2.52	8.15	2.42	8.10
	7	2.20	8.14	0.96	8.18	2.64	7.96	2.64	8.08	2.58	8.08
	8	2.16	8.17	0.96	8.35	2.53	7.74	2.55	8.00	2.55	8.05
	9	2.20	8.11	0.95	8.16	2.56	7.83	2.55	8.02	2.50	8.04
	10										
	11	2.20	8.12	0.94	8.14	2.60	7.96	2.60	8.05	2.52	8.05
	12	2.22	8.12	0.94	8.13	2.58	7.96	2.23	8.07	2.00	8.08
	13	2.20	8.13	0.97	8.15	2.66	7.93	2.66	8.06	2.66	8.06
	14	2.20	8.12	0.97	8.13	2.61	7.95	2.60	8.06	2.60	8.06
	15	2.22	8.13	0.95	8.14	2.66	7.95	2.66	8.07	2.43	8.08
	16	2.21	8.13	0.95	8.14	2.68	7.94	2.66	8.07	2.66	8.07
	17										
	18	2.22	8.12	0.95	8.15	3.40	7.81	1.76	8.11	2.17	8.10
	19	2.16	8.18	0.92	8.41	2.95	7.70	2.13	8.22	1.71	8.37
	20	2.22	8.17	0.95	8.26	3.72	7.79	2.03	8.11	1.98	8.11
	21	2.25	8.12	0.98	8.16	3.64	7.68	2.47	8.10	2.40	8.10
	22	2.14	8.13	0.94	8.21	2.78	7.83	2.76	8.10	2.80	8.08
	23	2.16	8.13	0.92	8.19	2.72	7.86	2.44	8.09	2.43	8.09
	24										
	25	2.13	8.11	0.95	8.14	2.57	7.81	2.28	8.07	2.24	8.07
	26	2.16	8.11	0.93	8.13	2.58	7.82	2.53	8.08	2.58	8.06
	27	2.15	8.11	0.93	8.14	2.92	7.81	2.87	7.90	2.82	7.91
	28	2.13	8.11	0.95	8.14	3.04	7.76	2.98	7.91	3.02	7.80
	29	1.95	8.06	0.87	8.21	3.47	7.63	3.33	7.91	3.55	7.96
	30	2.11	8.09	0.93	8.17	3.61	7.79	3.38	7.88	3.43	7.89
	31	2.20	8.08	0.94	8.17	3.04	7.87	3.02	7.91	2.97	7.95
JAN 94	1	2.27	8.08	0.93	8.18	2.97	7.91	2.97	8.00	2.99	7.99
	2	2.08	8.09	0.86	8.17	3.33	7.87	3.32	7.91	3.20	8.02
	3	2.19	8.14	0.97	8.26	2.83	7.65	2.77	7.95	2.84	7.92
	4	2.26	8.03	0.94	8.17	3.82	7.92	3.12	8.00	2.74	7.95
	5	2.32	7.82	0.91	8.09	4.56	7.78	2.19	7.94	1.65	8.03
	6	3.36	7.64	0.93	8.11	6.25	7.87	1.08	8.11	1.13	8.06
	7										
	8	2.30	8.08	0.98	8.11	7.11	7.80	1.26	8.11	1.26	8.12
	9										
	10	2.89	7.65	1.03	8.13	7.03	7.80	1.68	8.11	4.53	8.02
	11	2.40	8.02	1.03	8.12	7.13	7.81	5.40	8.02	4.11	8.02
	12	2.73	7.80	1.03	8.10	6.30	7.79	4.10	8.03		
	13	2.50	7.81			6.20	7.79				
	14										
	15	2.19	7.52	0.86	7.85	3.69	7.53	1.92	7.65	1.68	7.36
	16	2.02	8.10	0.91	7.89	2.67	7.89	1.90	7.94	1.87	7.68
	17	2.41	7.48	0.90	8.32	4.17	7.61	1.62	7.94	1.91	8.03
	18	2.50	7.51	0.97	8.06	3.80	7.59	2.10	7.94	1.81	7.99
	19	2.65	8.00	0.97	8.11	5.00	7.81	2.22	8.08	1.60	8.20
	20	2.36	7.62	0.88	8.07	3.66	7.78	1.90	8.10	1.58	8.30
	21										
	22	2.50	7.88	0.98	8.16	3.86	7.88	2.65	8.13	2.25	8.39
	23	2.16	8.03	0.95	8.34	2.77	7.68	1.90	8.02	1.74	7.89
	24	2.51	8.01	1.00	8.29	3.80	7.89	3.70	8.07	3.20	8.08
	25	2.51	8.00	0.98	8.10	3.78	8.00	2.61	8.09	2.56	8.10
	26	2.55	7.94	0.96	8.12	4.40	7.95	1.30	8.11	1.26	8.10
	27	3.06	7.79	0.97	8.11	5.33	7.80	3.86	8.07	3.79	8.08
	28										
	29	5.73	7.55	0.97	8.11	7.36	7.81	1.56	8.10	1.63	8.09
	30	6.00	7.50	0.97	8.10	8.00	7.74	7.70	7.84	7.71	7.84
	31	3.36	7.74	0.97	8.11	7.79	7.76	7.79	7.86	7.76	7.90

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
FEB 94	1	2.30	7.49	0.99	8.08	3.43	8.30	3.17	7.36	3.35	7.68
	2	4.43	7.46	1.00	8.09	6.60	7.79	5.08	8.03	5.45	8.12
	3	2.39	8.00	1.03	8.10	3.86	7.80	3.86	8.01	3.43	8.02
	4										
	5	3.08	7.61	0.97	8.11	6.77	7.81	1.08	8.10	1.07	8.09
	6	3.29	7.68	0.98	8.11	6.58	7.80	1.05	8.09	1.07	8.09
	7	6.42	7.36	0.99	8.11	7.40	7.76	1.09	8.09	1.09	8.10
	8	2.76	7.96	0.99	8.11	6.05	7.94	1.25	8.10	2.08	8.09
	9	2.80	7.82	0.98	8.11	5.51	7.84	2.11	8.09	1.91	
	10	3.71	7.68	0.97	8.11	6.41	7.91	2.63	8.08	2.29	8.07
	11										
	12	2.44	7.89	0.94	8.11	4.05	7.92	1.86	8.09	1.93	8.08
	13	2.26	8.30	0.95	8.48	4.51	8.06	2.44	8.35	2.22	8.08
	14	2.60	7.16	0.97	8.16	4.51	8.05	4.22	8.09	2.86	8.09
	15	3.14	8.30	0.95	8.09	6.08	7.68	1.20	8.09	1.30	8.04
	16	2.80	7.76	0.94	8.14	6.38	7.89	1.20	8.12	1.29	8.10
	17	2.14	7.96	0.88	8.33	4.77	8.02	1.06	8.38	1.07	8.36
	18										
	19	2.13	7.90	0.98	8.20	7.80	7.73	1.17	8.20		
	20	2.24	8.03	0.97	8.29	5.14	8.05	1.11	8.26	1.08	8.22
	21	2.22	8.00	0.96	8.25	5.71	8.00	4.67	8.10	5.40	8.06
	22	2.27	8.10	0.98	8.36	5.50	8.03	1.58	8.27	1.47	8.20
	23	2.16	8.08	0.93	8.27	6.40	8.00	1.31	8.25	1.45	8.20
	24	2.14	8.02	0.94	8.24	2.90	7.90	2.40	8.08	2.68	8.06
	25										
	26	2.08	8.08	0.94	8.23	2.89	7.94	1.90	8.11		
	27	2.08	8.06	0.94	8.16	3.20	7.90	2.07	8.06		
	28	2.40	7.69	0.94	8.12	4.20	7.90	1.06	8.12	1.05	8.10
MAR 94	1	2.26	8.00	0.97	8.12	5.28	8.00	1.02	8.12	1.03	8.10
	2	2.17	8.02	0.95	8.12	4.15	8.02	1.02	8.11	1.02	8.10
	3	2.18	8.00	0.96	8.12	7.28	7.88	1.05	8.10	0.97	8.25
	4										
	5	2.24	8.02	0.99	8.14	3.20	7.93	2.12	8.08	2.14	8.08
	6	2.08	8.04	0.96	8.11	3.61	7.89	2.17	8.00	2.19	8.02
	7	2.01	8.06	0.93	8.14	3.23	7.90	2.20	8.06	2.55	7.95
	8	2.24	7.83	0.92	8.40	4.24	8.06	1.65	8.25	1.81	8.40
	9	2.22	7.95	0.91	8.09	5.89	7.87	1.82	8.08		
	10	2.06	8.19	0.90	8.37	5.70	8.00	2.22	8.22	1.96	8.36
	11										
	12										
	13										
	14										
	15										
	16	2.06	8.11	0.85	8.31	6.41	8.05	1.29	8.31	1.32	8.30
	17	2.05	8.11	0.90	8.33	6.49	8.00	1.37	8.33	1.46	8.29
	18										
	19	1.96	8.12	0.86	8.32	6.74	8.01	1.64	8.30	2.28	8.27
	20	1.98	8.25	0.88	8.40	3.35	7.98	1.82	8.34	1.82	8.30
	21	1.98	7.94	0.89	8.15	3.87	7.84	2.24	8.06	2.74	8.22
	22	1.88	8.11	0.88		2.82	8.04	2.17	8.06	2.37	7.99
	23	1.89	8.12	0.89	8.18	2.79	7.89	2.46	8.10	2.23	8.09
	24	1.93	8.10	0.91	8.18	2.57	7.79	2.09	8.06	1.99	8.11
	25										
	26	1.89	8.15	0.88	8.30	2.81	7.93	1.98	8.11	1.99	8.11
	27	1.91	8.12	0.85	8.30	2.80	7.91	1.92	8.10	2.18	8.10
	28	1.85	8.13	0.94	8.26	3.73	7.91	2.47	8.11	2.60	8.07
	29	1.98	8.09	0.66	8.13	2.58	7.85	2.41	8.03	2.35	8.03
	30	1.93	8.09	0.66	8.13	2.45	7.90	2.44	8.00	2.56	8.00
	31	1.88	8.07			2.55	7.84	2.54	7.91	2.58	7.90

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
APR 94	1										
	2	1.89	8.07	0.84	8.09	2.51	7.73	2.29	8.04	2.51	8.00
	3	1.88	8.08	0.91	8.10	2.53	7.80	2.51	8.00	2.79	7.96
	4	1.91	8.03	0.89	8.06	2.66	7.70	2.56	7.84	2.66	7.80
	5	1.99	8.02	0.91	8.21	2.57	7.88	2.55	7.90	2.64	7.92
	6	1.90	8.05	0.93	8.09	2.59	7.60	2.54	7.82	2.70	8.00
	7	1.95	7.88	0.89	8.05	2.35	7.63	2.34	7.78	2.44	7.88
	8										
	9	1.94	7.82	0.88	7.94	3.43	8.58	1.62	7.69	2.43	8.12
	10	1.86	8.08	0.91	8.11	2.66	7.71	2.04	7.90	2.28	8.00
	11	1.80	8.00	0.90	8.05	2.75	7.61	2.36	7.83		
	12	1.84	8.11	0.90	8.15	2.61	7.83	2.48	8.02	2.91	7.96
	13	1.90	7.98	0.92	8.10	2.67	7.66	2.55	7.81	3.16	7.72
	14	1.88	7.78	0.91	7.86	2.67	7.74	2.47	7.66	2.70	7.67
	15										
	16	1.91	8.10	0.93	8.13	2.57	7.80	2.16	8.00	2.83	7.76
	17	1.81	8.06	0.91	8.10	2.49	7.69	2.27	7.89	2.50	7.72
	18	1.81	8.08	0.93	8.08	2.43	7.63	2.38	7.78	2.80	7.83
	19	1.84	7.96	0.91	8.07	2.54	7.66	2.54	7.72	2.69	7.69
	20	1.82	8.00	0.95	8.06	2.48	7.69	2.45	7.79	2.71	7.88
	21	1.90	7.98	0.94	8.05	2.64	7.71	2.61	7.90	2.79	7.90
	22										
	23	1.83	8.08	0.93	8.08	2.52	7.87	2.50	8.00	2.73	7.89
	24	1.85	7.98	0.94	8.07	2.53	7.71	2.50	7.81	2.53	7.83
	25	1.83	8.00	0.93	8.07	2.49	7.73	2.48	7.84	2.57	7.83
	26	1.88	8.00	0.93	8.06	2.52	7.69	2.50	7.79	2.63	7.86
	27										
	28	1.95	7.96	0.96	8.06	2.66	7.64	2.64	7.79	2.70	7.78
	29										
	30	1.90	8.00	0.93	8.10	2.58	7.80	2.58	0.90	2.60	7.90
MAY 94	1										
	2	1.81	8.05	0.91	8.11	2.56	7.85	2.56	7.90	2.76	7.84
	3	1.89	8.02	0.94	8.06	2.65	7.74	2.60	7.80	2.78	7.70
	4	1.85	8.00	0.91	8.06	2.59	7.69	2.59	7.79	2.75	7.74
	5	1.84	7.98	0.92	8.06	2.59	7.70	2.58	7.74	2.68	7.70
	6										
	7	1.87	8.08	0.93	8.12	2.60	7.79	2.60	7.87	2.80	7.99
	8	1.88	7.94	0.93	8.06	2.70	7.66	2.68	7.81	2.73	7.66
	9	1.90	7.99	0.94	8.06	2.72	7.68	2.70	7.77	2.78	7.79
	10	1.86	8.03	0.93	8.09	2.66	7.76	2.66	7.89	2.68	7.84
	11	1.88	7.97	0.98	8.03	2.68	7.66	2.75	7.81	2.88	7.79
	12	1.91	8.07	0.98	8.16	2.65	7.73	2.71	7.98	2.59	7.96
	13										
	14	1.92	7.95	0.94	8.03	2.72	7.65	2.70	7.77	2.60	7.88
	15	1.87	7.98	0.97	8.02	2.62	7.64	2.62	7.77	2.75	7.74
	16	1.93	7.92	0.95	8.02	2.68	7.75	2.66	7.77	2.80	7.70
	17	1.84	7.86	0.97	8.00	2.60	7.61	2.60	7.73	2.74	7.74
	18	1.90	8.00	0.94	8.03	2.83	7.64	2.78	7.75	2.88	
	19	1.90	8.02	0.97	8.06	2.83	7.69	2.79	7.79	2.98	7.91
	20										
	21										
	22										
	23										
	24										
	25										
	26	1.90	8.00	0.97	8.08	2.89	7.70	2.80	7.80	2.94	7.77
	27										
	28	1.90	7.98	0.97	8.05	2.90	7.72	2.89	7.81	3.00	7.70
	29	1.92	8.03	0.96	8.08	2.80	7.69	2.76	7.89	2.98	7.77
	30	1.91	8.02	0.96	8.06	2.80	7.79	2.80	7.85	2.98	7.81
	31	1.78	7.93	0.87	8.10	2.60	7.70	2.75	7.83	2.55	7.82

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
JUN 94	1	1.80	8.00	0.89	8.07	2.66	7.68	2.66	7.86	2.90	7.80
	2	1.88	7.91	0.92	7.96	2.68	7.64	2.68	7.79	2.84	7.76
	3										
	4	1.84	7.85	0.89	7.92	2.76	7.68	2.72	7.79	2.80	7.79
	5	1.93	8.00	0.94	8.08	2.62	7.73	2.62	7.84	2.62	7.85
	6	1.90	7.98	0.94	8.11	2.77	7.80	2.77	7.86	2.78	7.87
	7	1.95	7.78	0.92	7.98	2.85	7.67	2.85	7.73	2.56	7.68
	8	1.93	7.85	0.92	7.86	2.85	7.84	2.83	7.81	2.88	7.55
	9										
	10										
	11	1.93	7.96	0.90	8.02	2.73	7.75	2.73	7.84	2.55	7.78
	12	1.92	7.94	0.95	7.91	2.80	7.62	2.80	7.76	2.76	7.75
	13	1.92	7.92	0.90	8.05	2.84	7.69	2.84	7.78	2.72	7.80
	14	1.92	7.90	0.95	8.03	2.74	7.66	2.74	7.75	2.60	7.79
	15	1.84	7.92	0.89	8.00	2.31	7.66	2.30	7.74	2.46	7.66
	16	1.68	7.95	0.93	8.10	2.76	7.71	2.77	7.85	2.78	7.91
	17										
	18	1.81	7.93	0.90	8.04	2.90	7.77	2.90	7.79	2.90	6.68
	19	1.98	7.85	0.94	7.96	2.84	7.66	2.84	7.88	2.79	7.90
	20	1.86	7.90	0.89	8.08	3.13	7.74	3.12	7.79	3.14	7.78
	21	1.89	7.94	0.93	8.09	2.66	7.74	2.66	7.79	2.63	7.65
	22	1.83	7.98	0.86	8.11	2.60	7.73	2.60	7.77	2.68	7.72
	23	1.81	7.94	0.86	8.09	2.60	7.74	2.60	7.77	2.70	7.79
	24										
	25	1.90	7.92	0.89	8.09	2.79	7.70	2.79	7.77	2.64	7.79
	26	1.93	7.95	0.91	8.11	2.89	7.80	2.88	7.81	2.90	7.80
	27	1.91	7.93	0.90	8.09	2.90	7.76	2.88	7.79	2.96	7.86
	28	1.90	7.99	0.93	8.11	2.94	7.76	2.87	7.88	3.32	7.70
	29	1.93	7.94	0.89	8.09	2.88	7.80	2.88	7.84	2.93	7.81
	30	1.93	7.94	0.92	8.06	2.91	7.78	2.90	7.80	2.88	7.80
JUL 94	1										
	2	1.90	8.02	0.90	8.13	2.70	7.80	2.70	7.84	2.73	7.83
	3	1.85	8.00	0.85	8.11	2.84	7.79	2.84	7.80	2.88	7.14
	4	1.93	8.09	0.93	8.20	3.40	7.88	3.50	7.87	2.76	7.13
	5	1.87	8.00	0.88	8.12	2.70	7.90	2.77	7.91	2.88	7.90
	6	1.95	8.00	0.86	8.13	2.40	7.88	2.20	7.90		
	7	2.00	8.04	0.94	8.12	2.30	7.94	3.28	8.00	2.29	8.53
	8										
	9	1.83	8.11	0.90	8.33	2.46	8.00	2.11	8.08	2.35	8.24
	10	1.89	8.00	0.87	8.11	2.52	7.90	2.48	7.90	2.63	7.91
	11	1.87	8.19	0.89	8.26	2.96	8.18	2.96	8.18	3.44	8.17
	12	1.90	8.15	0.89	8.28	2.66	8.10	3.08	8.10	2.66	8.00
	13	1.95	8.19	0.92	8.26	2.43	7.97	2.43	8.09	2.38	8.10
	14	1.90	8.21	0.95	8.28	3.00	7.90	3.17	8.09	3.00	8.00
	15										
	16	1.89	8.25	0.89	8.33	2.17	8.07	2.17	8.11	2.20	8.30
	17	1.92	8.24	0.92	8.39	3.43	8.13	3.43	8.12	3.20	8.12
	18	1.95	8.24	0.93	8.44	3.06	8.11	3.07	8.11	2.60	8.18
	19	1.95	8.20	0.94	8.41	2.07	8.31	2.07	8.30	2.14	8.31
	20	2.05	8.07	0.97	8.30	2.82	7.98	2.78	7.97	3.04	7.73
	21	1.94	8.20	0.91	8.30	2.58	7.88	2.58	8.00	2.55	8.00
	22										
	23	1.93	8.07	0.91	8.29	1.99	8.08	1.99	8.06	2.00	8.06
	24	1.95	8.08	0.94	8.30	2.13	8.00	2.98	8.00	2.93	8.00
	25	1.96	8.09	0.92	8.35	2.18	8.10	2.18	8.10	2.28	8.10
	26	1.90	8.08	0.96	8.29	2.63	7.89	2.60	8.00	2.74	8.02
	27	1.92	8.18	0.88	8.31	2.82	7.82	2.82	7.86	2.90	8.00
	28	1.97	8.11	0.95	8.30	1.99	8.09	1.99	8.09	1.88	8.03
	29										
	30	1.92	8.08	0.90	8.30	2.65	8.00	2.65	8.00	2.82	8.06
	31	1.85	8.00	0.97	8.21	2.80	7.90	2.80	8.03	3.09	7.99

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
AUG 94	1	1.90	8.18	0.88	8.44	1.91	8.18	1.91	8.18	1.91	8.18
	2	1.88	8.11	0.90	8.38	1.88	8.10	1.88	8.10	1.97	8.18
	3	1.89	8.17	0.95	8.44	2.17	8.15	2.17	8.17	2.29	8.20
	4	1.94	8.08	0.94	8.40	2.64	7.84	2.56	7.83	2.61	7.88
	5										
	6	1.95	8.00	0.90	8.29	2.24	7.78	2.04	7.80	2.20	7.89
	7	1.91	8.11	0.91	8.46	2.55	8.07	2.52	8.07	2.55	8.10
	8	1.95	8.11	0.89	8.40	2.99	8.06	2.95	8.08	2.08	8.30
	9	2.04	8.14	0.94	8.40	2.58	8.12	2.58	8.12	2.56	8.17
	10	1.96	8.20	0.85	8.39	2.17	8.18	2.17	8.18	2.72	8.22
	11										
	12										
	13	1.96	8.20	0.89	8.45	2.55	8.11	2.32	8.11	2.44	8.18
	14	1.97	8.16	0.92	8.40	2.22	8.17	2.02	8.20	2.10	8.39
	15	1.96	8.14	0.90	8.30	2.21	8.10	2.05	8.10	1.99	8.11
	16	1.96	8.08	0.88	8.29	2.11	7.89	2.11	7.89	2.25	8.06
	17	1.94	8.12	0.93	8.36	2.95	7.77	2.72	7.96	2.90	8.07
	18	1.99	8.11	0.93	8.36	2.86	7.82	2.80	8.00	2.75	8.00
	19										
	20										
	21	2.05	8.07	0.92	8.30	2.25	8.07	2.04	8.10	2.07	8.10
	22	2.02	8.07	0.94	8.30	2.37	8.02	2.36	8.10	2.22	8.11
	23	1.99	8.11	0.84	8.38	2.64	7.81	2.64	8.04	2.82	8.04
	24	2.13	8.11	0.91	8.39	2.96	7.83	2.62	8.00	2.54	8.01
	25	2.09	8.00	0.94	8.22	2.85	7.76	2.77	7.90	2.82	7.94
	26										
	27	2.02	8.10	0.89	8.33	2.59	7.84	2.31	7.97	2.19	8.20
	28	2.07	8.06	0.92	8.28	2.99	7.80	2.79	8.00	2.89	7.96
	29	2.02	8.05	0.92	8.26	3.00	7.75	2.90	7.90		
	30	2.04	8.08	0.84	8.38	2.58	7.90	2.25	8.00	2.34	8.10
	31	2.08	8.08	0.89	8.30	2.74	7.74	2.72	7.90	2.78	7.83
SEP 94	1	2.10	8.05	0.92	8.29	2.76	7.78	2.69	7.91	2.94	7.99
	2										
	3	2.04	8.11	0.88	8.37	2.67	7.85	1.85	8.05	3.05	8.09
	4	2.15	8.09	0.93	8.40	2.92	7.86	2.58	8.05	2.72	8.05
	5	2.15	8.19	0.99	8.49	2.94	8.02	2.76	8.12	2.78	8.11
	6	2.12	8.09	0.89	8.40	2.80	7.90	2.63	8.00	2.81	8.03
	7	2.07	8.09	0.89	8.40	2.76	7.90	2.29	8.00	2.63	8.08
	8	2.18	8.10	0.96	8.44	2.65	8.10	2.26	8.26	2.36	8.13
	9										
	10	2.14	8.02	0.95	8.37	2.84	7.88	2.46	8.00	2.48	8.00
	11	2.04	8.10	0.89	8.40	2.74	7.87	2.43	7.97	2.50	8.00
	12	2.09	8.22	0.89	8.60	2.81	7.96	2.41	8.20	2.69	8.00
	13	2.26	8.09	0.94	8.30	2.86	7.84	2.52	7.98	2.58	7.96
	14	2.16	8.09	0.92	8.38	2.99	7.82	2.61	8.00	2.52	8.20
	15	2.14	8.48	0.92	8.66	2.94	8.08	2.70	8.28	2.82	7.98
	16										
	17	2.14	8.10	0.94	8.40	2.78	7.86	2.52	8.00	2.72	8.00
	18	2.16	8.14	0.92	8.38	2.89	7.84	2.57	8.00	2.25	8.14
	19	2.20	8.09	0.93	8.38	2.96	7.90	2.68	8.00	2.80	8.08
	20	2.15	8.10	0.93	8.30	2.74	7.86	2.55	8.00	2.49	8.06
	21	2.22	8.09	0.94	8.30	2.92	7.86	2.68	8.00	2.60	8.00
	22	2.22	8.09	0.95	8.35	2.99	7.86	2.71	8.04	2.84	8.00
	23										
	24	2.28	8.10	0.96	8.37	2.99	7.84	2.32	8.00	2.40	8.08
	25	2.28	8.18	0.94	8.40	2.94	7.88	2.72	8.00	2.69	8.04
	26	2.28	8.16	0.94	8.32	3.04	7.86	2.71	8.05	2.79	8.10
	27	2.28	8.16	0.97	8.43	3.00	7.89	2.78	8.00	2.84	8.00
	28	2.30	8.16	0.98	8.45	2.93	7.80	2.75	7.98	2.34	8.08
	29	2.30	8.08	1.16	8.00	2.86	7.80	2.67	8.00	3.00	8.09
	30										

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
OCT 94	1	2.29	8.10	0.95	8.30	3.08	7.83	1.93	8.11	1.96	8.25
	2	2.28	8.50	0.95	8.41		8.10	5.20	8.29	5.55	8.26
	3	2.33	8.18	0.97	8.31	3.10	7.80	2.83	8.06	2.64	8.22
	4	2.28	8.24	0.97	8.39	2.97	7.97	2.70	8.06	2.77	8.04
	5	2.28	8.38	0.92	8.40	2.90	7.90	2.90	8.18	3.00	8.08
	6	2.28	8.32	0.97	8.39	2.82	7.91	2.83	8.08	3.14	8.20
	7										
	8	2.40	8.46	0.98	8.46	2.87	8.00	2.54	8.10	2.62	8.09
	9	2.31	8.32	0.96	8.40	3.17	7.98	2.61	8.09	2.61	8.10
	10	2.35	8.50	0.99	8.54	3.08	8.00	2.77	8.10	2.74	8.08
	11	2.40	8.40	0.98	8.40	2.94	7.94	2.86	8.10	2.91	8.16
	12	2.44	8.35	0.99	8.36	3.04	7.84	3.02	8.00	2.79	8.00
	13	2.35	8.18	0.97	8.30	2.87	7.87	2.87	7.94	2.59	8.00
	14										
	15	2.19	8.18	0.90	8.34	2.68	7.85	2.30	8.09	2.46	8.10
	16	2.25	8.13	0.90	8.14	4.35	7.90	1.92	8.07	2.26	8.28
	17	2.28	8.14	0.90	8.24	2.88	7.88	2.84	8.00	2.48	8.08
	18	2.28	8.15	0.76	8.20	3.38	7.94	2.78	8.08	1.89	8.11
	19	2.33	8.21	0.93	8.29	3.28	7.92	3.00	8.28	2.88	8.11
	20			0.94	8.29	3.26	7.89	3.45	8.00	3.06	8.06
	21										
	22	2.28	8.19	0.95	8.30	2.77	7.92	3.01	8.25	3.24	8.09
	23			0.92	8.28	2.85	7.93	2.42	8.00	2.66	8.06
	24	2.27	8.17	0.93	8.30	3.06	7.85	3.04	8.08	2.77	8.07
	25	2.37	8.07	0.96	8.26	3.03	7.82	3.41	8.06	2.44	8.10
	26										
	27			0.97	8.24	3.17	7.86	2.83	8.00	3.04	8.06
	28										
	29	2.34	8.06	0.94	8.22	2.81	7.86	2.38	8.00	2.26	8.00
	30	2.39	8.00	0.97	7.70	2.97	7.70	2.69	7.79	2.62	8.00
	31	2.29	8.09	0.96	8.07	3.05	7.81	2.95	7.92	3.00	8.00
NOV 94	1	2.22	8.00	0.90	8.21	2.77	7.83	2.67	8.00	2.77	8.00
	2			0.94	8.20	3.03	7.80	3.00	7.91	3.28	7.90
	3			0.94	8.29	3.11	7.80	3.11	8.00	2.91	7.67
	4										
	5			0.95	7.87	4.03	7.65	1.68	7.82	1.75	7.70
	6										
	7			0.93	8.08	2.92	7.56	0.95	8.08		
	8			0.87	8.16	4.50	7.60	1.18	8.15	1.19	8.17
	9			0.87	8.12	5.53	7.64	1.20	8.06	1.16	8.08
	10			0.58	8.13	5.26	8.10	1.04	8.41		
	11										
	12			0.93	8.18	4.32	7.18	1.83	8.10	1.82	8.20
	13	2.19	8.19	0.97	8.17	3.94	7.90	2.02	8.06	3.98	8.00
	14										
	15			0.98	8.29	2.20	7.80	1.90	7.90	2.00	8.00
	16			0.89	8.30	1.68	7.47	0.91	8.29	0.90	7.98
	17			0.98	8.30	4.41	7.66	1.09	8.30		
	18										
	19			0.83	8.30	6.08	7.79	1.04	8.30	0.88	8.33
	20			0.95	8.31	7.21	7.71	1.09	8.30	1.16	8.31
	21			1.04	8.31	2.76	7.80	1.13	8.31	1.17	8.22
	22			1.08	8.33	3.16	7.86	1.22	8.33	1.18	8.22
	23			1.14	8.28	3.15	7.74		8.00	3.00	8.00
	24										
	25										
	26			0.96	8.31	4.50	7.76				
	27			0.53	8.22	4.69	7.60	0.54	8.32	0.48	8.33
	28			0.83	8.30	4.57	7.60	0.54	8.32	0.74	8.31
	29			0.92	8.26	4.35	7.63	0.93	8.26	0.92	8.26
	30			0.98	8.28	2.07	7.70	0.99	8.28	0.89	8.16

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
DEC 94	1	2.54	7.67	0.95	8.27	5.89	7.67	0.97	8.24	0.99	8.18
	2										
	3										
	4	1.81	7.79	0.93	8.26	3.72	7.60	0.95	8.26		
	5	1.97	7.80	0.88	8.30	4.08	7.60	0.93	8.30	0.90	8.38
	6	2.58	7.51	0.75	8.00	6.29	7.73	0.75	7.91	0.76	8.05
	7	2.84	7.45	0.97	8.24	6.77	7.83	0.96	8.20	0.85	8.26
	8	3.07	7.44	1.08	8.31	7.18	7.66	1.10	8.29		
	9										
	10	1.98	8.22	1.20	8.36	2.77	7.61	1.23	8.35	1.68	8.03
	11	1.75	8.35	1.03	8.34	2.20	7.56	1.11	8.31	1.14	8.32
	12	1.66	8.32	1.03	8.43	2.34	7.54				
	13	1.76	8.34	1.06	8.38	2.57	7.66				
	14	1.66	8.06	1.02	8.31	2.67	7.53	2.22	7.96	2.08	7.98
	15	1.58	8.05	1.03	8.30	2.46	7.55	2.26	7.97	1.78	7.80
	16										
	17	1.44	8.20	0.89	8.38	2.00	7.51	1.63	7.92		
	18	1.80	7.66	0.85	8.38	4.08	7.38	1.93	8.31	1.98	8.04
	19										
	20	1.22	7.54	0.86	8.30	3.00	7.32	0.87	8.30	0.84	8.34
	21	2.00	7.44	0.63	8.30	5.27	7.68	0.76	8.30	0.63	8.22
	22	2.73	7.28	0.66	8.08	7.74	7.78	0.71	8.14		
	23										
	24	3.14	7.08	0.74	8.27	8.22	7.62	0.74	8.27	0.74	8.33
	25	1.53	8.27	0.79	8.26	3.79	7.76	2.57	7.90	1.51	7.80
	26	1.52	8.21	0.87	8.35	3.87	7.92	1.00	8.32	1.02	8.22
	27	1.47	8.26	0.85	8.38	2.10	7.46	0.94	8.38	0.95	8.31
	28	1.69	7.76	0.86	8.43	3.38	7.40	1.83	8.03	1.83	8.14
	29										
	30										
	31	2.22	7.44	0.86	8.39	3.07	7.47	2.74	8.19	2.19	8.22
JAN 95	1	2.29	7.40	0.84	8.48	6.45	7.50	1.95	8.37	0.93	8.43
	2	2.38	7.49	0.85	8.40	6.60	7.33	0.89	8.40	0.85	8.35
	3	1.93	8.22	0.78	8.43	6.11	7.56				
	4	1.73	7.88	0.76	8.43	8.72	7.67	2.55	8.32		
	5	1.41	8.19	0.79	8.46	2.18	7.87	1.97	8.14		
	6										
	7	1.25	8.29	0.83	8.44	2.02	7.17	2.02	7.87		
	8	1.38	8.14	0.82	8.49	6.68	7.14	2.07	8.21	1.66	8.08
	9	2.21	7.30	0.83	8.48	4.58	7.86	2.39	8.21	2.39	8.21
	10	1.62	7.73	0.79	8.44	4.72	7.99	1.90	8.25	2.00	8.18
	11	2.14	8.30	0.81	8.39	2.87	7.80	2.70	8.35	1.61	8.18
	12	1.98	7.29	0.76	8.47	2.47	7.75	2.10	7.92	2.07	8.21
	13										
	14	1.94	7.46	0.78	8.49	2.58	7.86	1.84	8.11	1.69	8.39
	15	1.63	7.60	0.81	8.48	3.79	7.41	0.83	8.44	0.83	8.41
	16	1.24	8.24	0.87	8.44	2.56	7.54	0.85	8.37	0.86	8.46
	17	1.80	7.42	0.78	8.46	2.19	7.64	0.78	8.45	0.80	8.35
	18	1.44	7.93	0.79	8.47	2.25	7.77	1.84	8.03	1.33	8.44
	19	2.74	7.11	0.78	8.43	8.16	7.22	0.12	8.41	0.83	8.45
	20										
	21	1.88	8.50	0.81	8.48	2.47	7.29	0.83	8.48	0.76	8.32
	22	1.29	8.21	0.76	8.51	2.28	7.40	0.78	8.48	0.82	8.46
	23	2.18	7.38	0.87	8.51	4.55	7.50	0.87	8.46	0.87	8.44
	24	1.71	7.58	0.77	8.50	2.49	8.26	0.79	8.50	0.88	8.43
	25	1.71	7.64	0.78	8.49	3.27	7.31	0.80	8.46	0.87	8.36
	26	1.60	7.56	0.79	8.51	2.60	7.50	0.81	8.47	0.88	8.48
	27										
	28	1.78	7.63	0.84	8.46	3.45	7.31	0.82	8.36	0.91	8.32
	29	1.49	8.30	0.81	8.47	2.41	7.78	1.06	8.04	1.56	8.02
	30	1.71	7.75	0.80	8.47	3.41	7.90	0.88	8.26	0.86	8.41
	31	1.83	7.56	0.80	8.43	2.72	7.70	2.03	8.09	2.62	8.20

Table 4.1

DAILY WATER QUALITY DATA

		KTD		KAC, SWALHA		ABU ZEIGHAN		KAC, MAADI			
								Morning		Afternoon	
		EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH	EC (mmhos/cm)	PH
FEB 95	1	1.43	8.24	0.80	8.43	2.19	7.77	1.89	8.86	2.27	8.08
	2	1.44	8.28	0.81	8.47	3.66	7.80	1.99	8.06	1.58	8.18
	3										
	4	1.44	8.28	0.80	8.48	3.63	8.10	1.56	8.14	1.46	8.25
	5	0.39	8.07	0.79	8.48	2.02	8.41	0.79	8.46	0.79	8.48
	6	1.53	8.18	0.81	8.49	4.06	7.28	0.81	8.46	0.85	8.47
	7	1.47	8.21	0.78	8.55	2.72	8.03	1.14	8.24	0.92	8.41
	8			0.76	8.57	1.31	7.62	0.77	8.58		
	9			0.72	8.48	2.97	7.58	0.73	8.47	0.75	8.41
	10										
	11			0.53	8.39	4.21	7.36	0.53	8.39	0.53	8.33
	12			0.55	8.49	4.30	7.35	0.57	8.46	0.57	8.44
	13			0.49	8.40	4.26	7.50	0.89	8.30	0.51	8.20
	14			0.51	8.45	4.21	7.24	0.53	8.45	0.53	8.38
	15	1.47	8.37	0.53	8.38			0.54	8.43	0.55	8.36
	16	1.44	8.30	0.54	8.44	2.18	7.76	1.46	7.99	1.52	8.04
	17										
	18	1.43	8.35	0.58	8.45	3.78	7.99	0.66	8.38	1.32	8.17
	19	1.44	8.28	0.59	8.46	3.39	7.73	1.80	7.90	1.49	8.08
	20	1.44	8.48	0.60	8.48	2.77	7.77	2.28	8.09	1.28	8.23
	21	1.44	8.34	0.63	8.41	2.20	7.77	1.92	7.86	2.72	8.08
	22	1.43	8.44	0.61	8.46	2.49	7.77	2.21	7.90	2.71	7.77
	23	1.42	8.25	0.63	8.48	2.20	7.88	1.17	7.93	1.86	7.93
	24										
	25	1.44	8.36	0.67	8.44	2.52	7.61	1.58	8.00	1.73	8.08
	26	1.53	8.20	0.64	8.49	3.68	7.76	1.81	8.08	1.68	8.19
	27	1.44	8.31	0.66	8.46	2.78	7.12	2.51	7.99	2.17	8.08
	28	1.43	8.19	0.67	8.56	2.08	7.84	1.15	8.03	2.27	7.89
MAR 95	1	1.43	8.27	0.70	8.47	2.53	7.70	2.54	7.86	3.10	7.82
	2										
	3										
	4										
	5										
	6	1.43	8.34	0.69	8.51		7.36	1.89	8.32	1.57	8.30
	7	1.53	8.13	0.71	8.43		7.73	1.46	8.24	0.93	8.26
	8	1.39	8.28	0.70	8.44	3.41	7.84	3.38	7.87	1.84	8.03
	9	1.40	8.41	0.80	8.49	2.39	7.82	3.32	7.94	1.93	7.91
	10										
	11	1.37	8.16	0.69	8.42	2.53	7.80	1.61	7.93	1.41	8.06
	12	1.36	8.26	0.69	8.42	3.29	7.83	1.73	8.05	1.71	7.96
	13	1.39	8.33	0.72	8.42		8.05	2.93	8.20	2.06	8.05
	14	1.38	8.22	0.71	8.30	2.02	7.81	2.02	7.74	2.41	7.74
	15	1.38	8.25	0.72	8.33	2.24	7.75	2.24	7.75	2.22	7.82
	16	1.35	8.31	0.72	8.36	2.08	7.71	2.08	7.76	2.15	7.75
	17										
	18	1.35	8.29	0.72	8.37	2.17	7.72	2.00	7.57	2.32	7.74
	19	1.37	8.45	0.72	8.57	3.03	7.85	2.11	8.05	1.67	7.90
	20	1.35	8.26	0.73	8.37	3.07	7.72	2.32	7.89	1.46	8.22
	21	1.34	8.37	0.71	8.48	2.35	7.84	2.31	7.86	1.79	7.89
	22	1.34	8.35	0.72	8.46	3.43	7.84	3.20	7.90	3.23	7.86
	23	1.32	8.27	0.75	8.40	2.26	7.70	2.26	7.77	2.06	7.82
	24										
	25	1.30	8.31	0.73	8.31	2.22	7.74	1.50	7.87	1.81	7.82
	26	1.34	8.29	0.81	8.45	2.23	7.76	2.21	7.79	2.11	7.85
	27	1.34	8.38	0.81	8.49	2.37	7.84	2.37	7.84	2.61	7.68
	28	1.34	8.29	0.81	8.50	2.26	7.84	2.26	7.88	2.34	7.82
	29	1.34	8.31	0.79	8.52	2.23	7.83	2.23	7.81	2.13	7.83
	30	1.24	8.28	0.81	8.51	2.35	7.76	1.86	7.92	1.73	7.84

Table 4.3

EC Data from 1980 to 1994 at Various Locations along Zarqa River

(mmhos/cm)

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	Treatment Plant												
	KTD	1.31	0.95	0.9	0.93	0.8	0.8				0.9		1.66
	Woman Spring												
	Man Spring												
	Abu Zeighan Canal												
	KAC, Sawalha												
	KAC, Maadi												

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	Treatment Plant												
	KTD			1.74		2.19	1.11			2.58	1.34		
	Woman Spring												
	Man Spring												
	Abu Zeighan Canal												
	KAC, Sawalha												
	KAC, Maadi												

NO AVAILABLE DATA FROM 1982 THROUGH 1984

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	Treatment Plant												
	KTD			1.9					1.45	1.5	1.8	1.8	1.8
	Woman Spring												
	Man Spring												
	Abu Zeighan Canal												
	KAC, Sawalha												
	KAC, Maadi												

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	Treatment Plant												
	KTD			1.9				1.89		2.73	2.7	0.73	
	Woman Spring												
	Man Spring												
	Abu Zeighan Canal												
	KAC, Sawalha										1.66	1.3	0.79
	KAC, Maadi			2.03				2.24		2.27	2.17	1.11	0.99

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	Treatment Plant												
	KTD	1.49	1.19	1.44	1.20	1.36	1.28	1.29		1.78	2.01	1.70	1.52
	Woman Spring												
	Man Spring												
	Abu Zeighan Canal												2.4
	KAC, Sawalha	0.89	0.71	0.53	0.96	0.86	1.04	1.2		1.21	1.66	1.23	1.17
	KAC, Maadi	0.89	0.78	0.71	1.12	1.28	1.41	1.69	1.55	1.97	2.22	1.81	1.75

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1988	Treatment Plant												
	KTD	2.46	2.34	1.17	1.27	1.03	1.01	1.10	1.41	1.18	1.28	1.79	1.86
	Woman Spring												
	Man Spring												
	Abu Zeighan Canal	2.54	2.33	1.16	1.16	1.09	1.03	1.15	1.35	1.19	1.21	1.69	
	KAC, Sawalha	1.83	0.6	0.58	0.8	0.87	0.81	0.96	0.98	0.87	1.21	0.81	
	KAC, Maadi	0.89	0.67	0.51	0.97	1.2	1.22	1.22	1.69	1.4	1.33	1.62	1.6

Table 4.3

EC Data from 1980 to 1994 at Various Locations along Zarqa River

(mmhos/cm)

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	Treatment Plant												
	KTD	2.30	1.78	1.55	1.56	1.72	1.58	1.56	1.66	1.68	2.03	2.22	2.59
	Woman Spring												
	Man Spring												
	Abu Zeighan Canal												
	KAC, Sawalha	0.86	0.92	0.81	0.9	0.89	0.84	0.89	0.91	0.93	0.91	0.91	0.9
	KAC, Maadi	1.02	1.9	1.69	1.7	1.8	1.6	1.82	1.82	1.8	2.07	1.75	1.17

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	Treatment Plant												
	KTD	2.81	2.72	2.13	2.44	2.21	1.75	1.85	1.95	2.16	2.30	2.59	2.78
	Woman Spring												
	Man Spring												
	Abu Zeighan Canal	2.22				2.21	1.77	1.81	1.94	2.09	2.28	2.64	2.8
	KAC, Sawalha	0.9	0.87	0.95	0.97	1.01	0.87	0.94	0.85	0.81	0.92	1.4	0.88
	KAC, Maadi	1.01	1.08	1.78	2.2	2.21	1.89	2	2.19	2.21	2.42	2.49	2.79

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	Treatment Plant												
	KTD	2.73	1.76	2.34	2.24	1.79	1.74	1.86	2.10	2.35	2.61	2.52	1.50
	Woman Spring												
	Man Spring												
	Abu Zeighan Canal	2.64	2.08	2.17	1.75	2.04	1.92	2.22	2.28	2.56	2.72	2.79	2.09
	KAC, Sawalha	0.92	0.91	0.93	0.89	0.89	0.91	0.93	0.85	0.93	0.98	0.94	0.77
	KAC, Maadi	2.3	1.24	2.15	1.83	1.82	1.85	1.92	2.17	2.24	2.27	2.19	0.91

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1992	Treatment Plant	1.41	1.21	1.16	1.53	1.69	1.68	2.11	1.74	2.20	2.44	2.18	1.80
	KTD		1.15	1.03	1.10	1.12	1.26	1.25	1.23	1.24	1.31	1.77	1.84
	Woman Spring	8.88	9.46	8.83	9.51	9.73	8.89	9.70	9.57	9.27	9.27	9.33	8.95
	Man Spring	8.16			8.01	9.03	8.23	8.95	8.68	8.73	8.68	8.72	8.33
	Abu Zeighan Canal			1.15	1.19	1.28	1.28	1.42	1.40	1.40	1.39	1.85	1.94
	KAC, Sawalha	0.54	0.49	0.51	0.78	0.93	0.96	0.90	0.92	0.92	0.96	0.93	0.71
	KAC, Maadi	0.63	0.53	0.91	1.17	1.25	1.20	1.40	1.39	1.36	1.42	1.85	1.34

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	Treatment Plant	1.84	1.48	1.61	2.28						2.55	2.60	2.06
	KTD	2.10	1.68	1.60	1.58	1.57	1.60	1.61	1.58	1.72	1.90	2.13	2.12
	Woman Spring	9.21	9.16	8.97	9.20	9.30	9.95	9.49	8.98	9.83	9.35	9.15	9.21
	Man Spring	8.50	8.55	8.24	8.53	8.64	8.86	8.67	8.24	9.04	8.59	8.38	8.74
	Abu Zeighan Canal	1.76	1.71	1.63	1.77	1.74	2.34	2.33	2.22	2.27	2.25	2.51	2.62
	KAC, Sawalha	0.63	0.66	0.75	0.82	0.88	0.89	0.95	0.85	0.90	0.93	0.94	0.92
	KAC, Maadi	1.39	0.99	1.58	1.58	1.74	2.32	2.27	2.18	2.32	2.25	2.50	2.71

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994	Treatment Plant	2.28	2.17	1.90		2.30	2.62	2.53	2.49	2.70	2.51	2.43	1.04
	KTD	2.44	2.62	2.58	1.95	2.02	2.02	2.01	2.20	2.39	2.43	3.00	2.28
	Woman Spring	9.07	8.93	9.08	8.86	8.55	8.58	8.26	8.29	8.15	8.40	8.11	8.68
	Man Spring	8.23	8.09	8.27	7.99	7.69	7.34	7.55	7.14	7.00	7.10	6.90	7.29
	Abu Zeighan Canal	5.62	4.58	4.20	2.55	2.75	2.89	3.01	2.76	2.89	3.13	3.75	4.02
	KAC, Sawalha	0.90	0.88	0.93	0.91	0.96	0.95	0.92	0.93	0.93	0.93	0.95	0.98
	KAC, Maadi	2.11	3.26	1.88	2.53	2.79	2.82	2.40	2.71	2.63	2.95	1.82	1.37

Table 4.4

pH Data from 1992 to 1994 at Various Locations along Zarqa River

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1992	Treatment Plant	8.17	8.43	7.92	8.07	8.21	8.13	8.16	8.14	7.98	8.08	8.16	8.06
	KTD		8.42	8.34	8.28	8.12	8.16	8.25	8.23	8.21	8.27	8.23	8.23
	Woman Spring	6.69	7.13	6.82	6.75	6.56	6.84	6.65	6.84	6.63	6.53	6.78	6.77
	Man Spring	6.81			6.81	6.53	6.75	6.68	6.75	6.61	6.55	6.66	6.59
	Abu Zeighan Canal			8.33	8.15	8.12	8.17	8.28	8.28	8.23	8.28	8.23	8.23
	KAC, Sawalha	8.21	8.30	8.34	8.43	8.29	8.24	8.26	8.30	8.19	8.28	8.24	8.22
	KAC, Maadi	8.32	8.43	8.34	8.26	8.19	8.17	8.27	8.26	8.25	8.29	8.25	8.23
	Zarqa River ??	8.19	8.40	8.33	7.99	7.38	7.68	7.70	7.82	7.88	7.74	8.08	7.98

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	Treatment Plant		8.28	8.26	7.77							8.06	8.16
	KTD	8.22	8.30	8.30	8.29	8.30	8.29	8.22	8.13	8.12	8.11	8.10	8.11
	Woman Spring	6.87	7.20	6.92	6.94	7.13	6.83	6.82	6.98	6.80	7.00	6.87	6.86
	Man Spring	6.73	7.15	6.73	6.82	7.11	6.80	6.79	6.87	6.64	6.91	7.34	6.81
	Abu Zeighan Canal	8.28	8.29	8.29	8.30	8.30	8.11	8.03	8.00	7.93	7.91	7.97	7.96
	KAC, Sawalha	8.27	8.34	8.36	8.34	8.34	8.34	8.25	8.19	8.13	8.10	8.14	8.13
	KAC, Maadi	8.44	8.31	8.33	8.29	8.33	8.11	8.12	8.10	8.06	8.09	8.09	8.03
	Zarqa River ??	8.30	8.30	7.90	7.71	8.19	7.92	7.78	7.85	7.61	7.94	7.76	7.70

Year	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994	Treatment Plant	8.10	8.10	8.20		7.68	7.79	7.96	8.05	8.00	8.90	7.74	7.77
	KTD	7.83	7.89	7.79	7.79	7.87	7.79	8.21	7.87	7.98	8.14	7.68	7.76
	Woman Spring	6.88	6.81	6.82	6.71	6.55	6.50	7.09	6.80	6.62	7.57	7.46	7.57
	Man Spring	6.89	7.73	6.62	6.55	6.53	6.48	7.10	6.68	6.42	6.61	6.77	6.55
	Abu Zeighan Canal	7.86	7.86	7.85	7.71	7.66	7.60	7.93	7.90	7.93	7.92	7.91	7.46
	KAC, Sawalha	8.13	8.24	8.16	8.07	8.09	8.04	8.22	8.30	8.38	8.31	8.31	8.36
	KAC, Maadi	8.13	8.12	8.10	7.79	7.77	7.76	8.19	7.94	8.12	8.04	7.99	8.20
	Zarqa River ??	8.00	7.91	7.75	7.51	7.50	7.39	7.86	7.95	7.56	7.69	7.49	7.99

Table 4.5

Water Quality Data at Various Locations along Zarqa River

Month of April

1992	EC	pH	Na	K	Ca	Mg	Cl	SO4	HCO3	NO3	B	SAR
Treatment Plant	1.53	8.07	42.00	0.26	?	?	5.67	3.40	7.00	30.40	0.48	1.88
KTD	1.10	8.28	3.51	0.25	?	?	4.02	4.03	4.81		0.32	1.87
Woman Spring	9.01	6.85	36.50	3.30	?	?	49.00	26.40	18.70		2.69	9.87
Man Spring	8.01	6.81	41.75	2.97	?	?	38.95	21.80	19.20		2.62	10.04
Abu Zeighan Canal	1.19	8.15	3.63	0.28	?	?	4.19	3.15	4.50		0.32	1.84
KAC, Sawalha	0.78	8.43	2.55	0.13	?	?	2.40	1.00	4.25		0.25	1.59
KAC, Maadi	1.17	8.26	3.42	0.25	?	?	3.33	3.18	4.53		0.32	1.74
Zarqa River ??	1.70	7.99	6.56	0.75	?	?	6.68	4.40	5.76		0.51	3.02

1993	EC	pH	Na	K	Ca	Mg	Cl	SO4	HCO3	NO3	B	SAR
Treatment Plant	2.28	8.30	8.00	0.51	10.18	3.10	7.87	4.80	8.40	57.20	0.65	3.10
KTD	1.85	8.29	6.00	0.40	5.83	3.50	6.56	2.88	6.30	19.60	0.32	2.18
Woman Spring	9.20	6.94	52.20	2.86	24.80	9.70	51.20	17.90	22.00	14.00	3.25	12.58
Man Spring	8.53	6.82	45.00	2.57	24.20	9.00	44.01	17.20	22.80	11.20	2.62	11.10
Abu Zeighan Canal	1.68	8.29	6.60	0.43	6.10	3.60	7.10	2.52	7.20	28.00	0.28	3.00
KAC, Sawalha	0.82	8.38	2.93	0.09	2.72	2.40	2.38	1.02	4.70	5.70	0.19	1.83
KAC, Maadi	1.30	8.30	5.00	0.19	4.77	3.10	4.65	2.80	5.50	14.00	0.17	2.54
Zarqa River ??	3.30	7.60	14.60	0.80	9.00	7.70	15.70	7.98	8.80	14.00	0.78	5.50

1994	EC	pH	Na	K	Ca	Mg	Cl	SO4	HCO3	NO3	B	SAR
Treatment Plant												
KTD	1.95	7.89	8.22	0.60	5.86	3.70	8.29	3.42	7.35	33.70	0.58	3.81
Woman Spring	8.73	6.66	47.00	3.21	25.62	9.50	43.49	18.38	21.70	11.20	2.50	11.22
Man Spring	7.92	6.49	45.00	3.00	20.86	8.80	37.44	16.64	19.97	11.20	2.70	11.69
Abu Zeighan Canal	2.44	7.62	12.80	0.72	6.88	3.90	9.10	4.82	8.10	22.04	0.76	5.51
KAC, Sawalha	0.87	8.09	2.67	0.17	3.22	1.80	2.22	2.04	4.36	11.20	0.12	1.52
KAC, Maadi	2.40	7.75	11.67	0.72	6.20	4.20	11.30	3.88	7.90	28.00	0.66	2.12
Zarqa River ??	3.48	7.51	17.00	0.86	8.60	7.30	12.40	7.24	7.97	16.80	0.82	6.03

Month of October

1992	EC	pH	Na	K	Ca	Mg	Cl	SO4	HCO3	NO3	B	SAR
Treatment Plant	2.44	8.08	9.20	0.60	?	?	8.74	6.60	8.88	19.04	0.54	3.53
KTD	1.31	8.27	4.59	0.26	?	?	4.81	3.03	5.16	8.39	0.30	2.31
Woman Spring	9.27	6.53	45.80	3.30	?	?	46.70	30.80	21.00	4.48	2.13	9.76
Man Spring	8.68	6.55	45.70	3.10	?	?	42.70	28.00	20.50	2.80	2.01	9.97
Abu Zeighan Canal	1.39	8.28	4.59	0.29	?	?	5.18	3.00	5.64	10.08	0.33	2.19
KAC, Sawalha	0.96	8.28	3.37	0.13	?	?	3.84	1.80	3.88	2.80	0.19	1.93
KAC, Maadi	1.42	8.29	4.89	0.29	?	?	5.19	3.55	5.32	5.23	0.31	2.34
Zarqa River ??	3.30	7.74	13.30	0.75	?	?	14.89	9.80	7.32	11.48	0.64	4.36

1993	EC	pH	Na	K	Ca	Mg	Cl	SO4	HCO3	NO3	B	SAR
Treatment Plant												
KTD												
Woman Spring	9.55	6.82	57.10	30.00	21.40	9.90	50.02	18.60	21.38	8.40		
Man Spring	8.72	6.77	50.00	2.33	20.23	9.40	45.72	16.86	2.60	5.70		0.71
Abu Zeighan Canal	2.18	7.91	9.33	0.58	6.18	4.10	9.20	3.17	8.50	11.20	0.36	4.12
KAC, Sawalha	0.92	8.08	3.00	0.11	3.00	2.70	2.80	1.56	4.70	11.20	0.11	1.78
KAC, Maadi	2.25	8.19	10.21	0.67	6.32	4.90	10.86	2.77	7.71	29.30	0.49	4.45
Zarqa River ??	3.70	7.88	14.00	0.97	8.46	8.30	16.84	8.28	8.80	16.80	0.54	5.86

1994	EC	pH	Na	K	Ca	Mg	Cl	SO4	HCO3	NO3	B	SAR
Treatment Plant												
KTD	2.43	8.14	11.81	0.79	6.30	4.45	11.81	3.26	8.73	43.80	0.54	5.10
Woman Spring	8.27	6.66	43.30	3.14	24.00	8.50	42.60	18.40	17.20	16.80	2.04	10.58
Man Spring	7.00	6.65	34.00	2.86	23.00	7.50	36.11	14.28	17.12	16.80	1.87	8.71
Abu Zeighan Canal	2.90	7.89	15.00	0.90	8.20	4.00	14.25	4.22	9.80	8.40	0.58	6.08
KAC, Sawalha	0.95	8.33	3.50	0.16	3.40	2.00	2.32	1.20	6.00	13.44	0.75	2.07
KAC, Maadi	2.95	8.02	14.60	0.87	7.60	4.73	15.74	3.70	9.45	44.80	0.66	5.89
Zarqa River ??	3.28	7.66	16.50	0.85	8.00	6.00	21.24	2.10	9.30	28.00	0.75	6.24

Table 4.6

Quality of Outflow from Kherbet Samra Treatment Plant

Parameter	Unit	Range	Average	
			Yearly (3/93 - 2/94) [25 Readings]*	Irrigation Period (4/93 - 10/93) [13 Readings]**
EC	ds/m	1.74 - 2.3	2.10	2.18
TDS	mg/L	946 - 1362	1209	1266
Na	me/L	8.13 - 11.4	9.52	9.74
SAR	-----	4.5 - 6.2	5.18	5.1
Cl	me/L	4.44 - 9.93	8.42	9.40
B	mg/L	0.55 - 0.8	0.66	0.7
T-N	mg/L	79 - 113	98	94
pH	su	7.3 - 9.1	7.9	8.0
TSS	mg/L	62 - 196	138	174
TFCC	MPN/100 ml	2 - 1.7E4	329	283

* Except for SAR, Cl & T-N: (13) readings; TDS & B: (15) readings; Na: (21) readings.
** Except for SAR & Cl: (7) readings; T-N & B: (8) readings; Na: (10) readings.

Table 4.7
EC AND pH VALUES OF WATER IN THE ZARQA RIVER AND OF SPRINGS AND SEEPAGE ENTERING THE RIVER

No	Location	EC mmhos/cm	pH	App. Flow l/s	Incr. Flow l/s
1	King Talal Release	1.36	8.31	50	-
2	River sample at Bridge 1	1.46	8.14	-	-
3	River sample at Bridge 2	1.34	8.31	-	-
4	River sample	1.37	8.38	-	-
5	River sample at Bridge 3	1.37	8.20	-	-
6	River sample at Bridge 4	2.28	7.33	-	-
7	River sample opposite to salt well	2.96	7.26	55	5
8	Spring sample 100 m east of Man and Woman springs	2.23	6.99	-	-
9	River sample upstream from 8	4.49	7.15	86	31
10	River sample upstream from Man and Woman springs	4.54	7.30	104	18
11	Sample from Man spring	5.77	6.85	-	-
12	Sample from Woman spring	6.83	6.65	-	-
13	River sample downstream from Man and Woman springs	4.77	7.32	119	15
14	River sample upstream from salt spring (item 15)	4.82	7.61	-	-
15	Sample from salt spring	6.63	6.59	-	-
16	River sample downstream from salt spring (item 15)	4.82	7.53	131	12
17	Sample from salt spring	8.46	6.52	-	-
18	River sample downstream from salt spring (item 17)	5.02	7.33	138	7
19	Sample from salt spring	10.98	6.38	-	-
20	River sample downstream of salt spring (item 19)	7.78	6.71	206	68
21	Sample from salt spring	12.19	7.16	-	-

No	Location	EC mmhos/cm	pH	App. Flow l/s	Incr. Flow l/s
22	River sample 600 m upstream of Abu Zeighan bridge	8.19	6.91	210	4
23	River sample 300 m upstream of Abu Zeighan bridge	7.61	7.10	225	15
24	River sample at Abu Zeighan bridge	8.56	7.45	239	14
25	River sample upstream before diversion to Abu Zeighan	7.49	7.57	-	-
	Total flow from springs and seepage = 189 l/s				

Table 4.2

WATER QUALITY MEASURED AT VARIOUS LOCATIONS

		QUALITY PARAMETERS				
		EC	pH	NA	CL	B
DATE	SITE	(m.mhos/l)		(mg/l)	(mg/l)	(ppm)
4.6.94	D/S KTD	1.94	7.77			
	EL THAHAB WEIR	1.90	8.05			
	BRIDGE WITH PIPE	1.94	7.90			
	ABU ZEIGHAN	2.59	7.60			
	KAC,MAADI	2.54	7.82			
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
4.7.94	D/S KTD			8.00	8.28	0.68
	EL THAHAB WEIR					
	BRIDGE WITH PIPE			8.22	8.29	0.58
	ABU ZEIGHAN					
	KAC,MAADI			11.67	11.21	0.66
	WOMAN SPRING	8.73	6.66	47.00	41.49	2.50
	MAN SPRING	7.92	6.49	45.00	37.44	2.70
	KAC,SWALHA	0.89	8.05			
4.13.94	D/S KTD	1.97	7.83			
	EL THAHAB WEIR	1.96	7.98			
	BRIDGE WITH PIPE	2.02	7.78			
	ABU ZEIGHAN	2.67	7.66			
	KAC,MAADI	2.55	7.81			
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
4.14.94	D/S KTD			8.00	8.15	0.49
	EL THAHAB WEIR					
	BRIDGE WITH PIPE			8.22	9.16	0.44
	ABU ZEIGHAN					
	KAC,MAADI			11.67	12.22	0.52
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
4.20.94	D/S KTD	1.92	7.79			
	EL THAHAB WEIR	1.82	8.00			
	BRIDGE WITH PIPE	1.88	7.87			
	ABU ZEIGHAN	2.48	7.69			
	KAC,MAADI	2.45	7.79			
	WOMAN SPRING	8.99	6.75			
	MAN SPRING	8.00	6.60			
	KAC,SWALHA	0.95	8.06			

Table 4.2

WATER QUALITY MEASURED AT VARIOUS LOCATIONS

		QUALITY PARAMETERS				
		EC	pH	NA	CL	B
DATE	SITE	(m.mhos/l)		(mg/l)	(mg/l)	(ppm)
4.21.94	D/S KTD			8.22	8.21	0.50
	EL THAHAB WEIR					
	BRIDE WITH PIPE			8.22	8.85	0.47
	ABU ZEIGHAN					
	KAC,MAADI			12.72	12.50	0.49
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
4.28.94	D/S KTD	1.95	7.84	8.00	8.25	0.72
	EL THAHAB WEIR	1.95	7.96			
	BRIDGE WITH PIPE	1.98	7.82	8.22	8.80	0.81
	ABU ZEIGHAN	2.66	7.64			
	KAC,MAADI	2.64	7.79	12.18	12.11	0.84
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
5.4.94	D/S KTD	1.92	7.95			
	EL THAHAB WEIR	1.85	8.00			
	BRIDGE WITH PIPE	1.87	7.81			
	ABU ZEIGHAN	2.59	7.69			
	KAC,MAADI	2.59	7.79			
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
5.5.94	D/S KTD			8.00	8.26	0.63
	EL THAHAB WEIR					
	BRIDGE WITH PIPE					
	ABU ZEIGHAN					
	KAC,MAADI			12.22	12.26	0.52
	WOMAN SPRING	8.33	6.59			
	MAN SPRING	7.40	6.52			
	KAC, SWALHA	0.92	8.06			
5.11.94	D/S KTD	1.93	7.88			
	EL THAHAB WEIR	1.88	7.96			
	BRIDGE WITH PIPE	1.93	7.74			
	ABU ZEIGHAN	2.68	7.66			
	KAC,MAADI	2.60	7.81			
	WOMAN SPRING					
	MAN SPRING					
	KAC, SWALHA					

Table 4.2

WATER QUALITY MEASURED AT VARIOUS LOCATIONS

		QUALITY PARAMETERS				
		EC	pH	NA	CL	B
DATE	SITE	(m.mhos/l)		(mg/l)	(mg/l)	(ppm)
5.12.94	D/S KTD			8.00	8.00	0.28
	EL THAHAB WEIR					
	BRIDGE WITH PIPE			8.67	8.62	0.29
	ABU ZEIGHAN					
	KAC.MAADI			12.22	12.26	0.52
	WOMAN SPRING					
	MAN SPRING					
	KAC, SWALHA					
5.18.94	D/S KTD	1.94	7.71			
	EL THAHAB WEIR	1.90	8.00			
	BRIDGE WITH PIPE	2.00	7.77			
	ABU ZEIGHAN	2.82	7.64			
	KAC.MAADI	2.68	7.75			
	WOMAN SPRING					
	MAN SPRING					
	KAC, SWALHA					
5.19.94	D/S KTD			8.67	9.47	0.22
	EL THAHAB WEIR					
	BRIDGE WITH PIPE			8.67	9.47	0.25
	ABU ZEIGHAN					
	KAC,MAADI			12.18	12.89	0.61
	WOMAN SPRING	8.66	6.50			
	MAN SPRING	7.97	7.55			
	KAC,SWALHA	0.97	8.06			
5.26.94	D/S KTD	1.99	7.84	7.67	8.56	0.23
	EL THAHAB WEIR	1.90	8.00			
	BRIDGE WITH PIPE	1.99	7.80	8.22	9.17	0.38
	ABU ZEIGHAN	2.89	7.70			
	KAC,MAADI	2.80	7.80	12.64	14.07	0.60
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
6.1.94	D/S KTD	1.92	7.77			
	EL THAHAB WEIR	1.80	8.00			
	BRIDGE WITH PIPE	1.86	7.82			
	ABU ZEIGHAN	2.66	7.68			
	KAC,MAADI	2.66	7.86			
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					

Table 4.2

WATER QUALITY MEASURED AT VARIOUS LOCATIONS

		QUALITY PARAMETERS				
		EC	pH	NA	CL	B
DATE	SITE	(m.mhos/l)		(mg/l)	(mg/l)	(ppm)
6.2.94	D/S KTD			8.00	8.45	0.73
	EL THAHAB WEIR					
	BRDGE WITH PIPE			8.67	9.22	0.55
	ABU ZEIGHAN					
	KAC,MADI			12.64	12.97	0.60
	WOMAN SPRING	8.85	6.47			
	MAN SPRING	7.73	7.42			
	KAC,SWALHA	0.92	7.96			
6.11.94	D/S KTD			8.00	8.16	0.65
	EL THAHAB WEIR					
	BRIDGE WITH PIPE			8.80	8.76	0.50
	ABU ZEIGHAN					
	KAC,MAADI			12.08	12.88	0.78
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
6.15.94	D/S KTD	1.95	7.73			
	EL THAHAB	1.84	7.92			
	HRIDGE WITH PIPE	1.93	7.70			
	ABU ZEGHAN	2.21	7.66			
	KAC,MAADI	2.20	7.74			
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
6.22.94	D/S KTD	1.82	7.71	8.00	8.08	0.54
	EL THAHAB WEIR	1.83	7.98			
	BRIDGE WITH PIPE	1.88	7.78	8.00	8.78	0.58
	ABU ZEIGHAN	2.90	7.73			
	KAC,MAADI	2.60	7.77	12.92	13.07	0.70
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
6.29.94	D/S KTD	2.04	7.80			
	EL THAHAB WEIR	1.93	7.94			
	BRIDGE WITH PIPE	2.02	7.80	8.40	8.32	0.62
	ABU ZEIGHAN	2.88	7.80			
	KAC,MAADI	2.88	7.84	14.17	13.95	0.77
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					

Table 4.2

WATER QUALITY MEASURED AT VARIOUS LOCATIONS

		QUALITY PARAMETERS				
		EC	pH	NA	CL	B
DATE	SITE	(m.mhos/l)		(mg/l)	(mg/l)	(ppm)
7.6.94	D/S KTD	2.09	7.89	7.71	7.88	0.53
	EL THAHAB WEIR	1.94	8.00			
	BRIDGE WITH PIPE	1.98	7.89	8.00	8.62	0.48
	ABU ZEIGHAN	2.42	7.88			
	KAC,MAADI			10.00	9.22	0.60
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
7.13.94	D/S KTD	1.97	7.97	8.00	8.29	0.63
	EL THAHAB WEIR	1.95	8.19			
	BRIDGE WITH PIPE	2.02	8.18	9.33	9.56	0.66
	ABU ZEIGHAN	2.43	7.47			
	KAC,MAADI	2.43	8.09	15.50	14.79	0.94
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
7.20.94	D/S KTD	2.07	7.79	9.00	8.28	0.66
	EL THAHAB WEIR	2.05	8.07			
	BRIDGE WITH PIPE	2.20	7.99	9.33	8.60	0.65
	ABU ZEIGHAN	2.82	7.48			
	KAC,MAADI	2.78	7.47	12.50	12.02	0.70
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
7.27.94	D/S KTD	2.04	7.88	9.33	9.16	0.62
	EL THAHAB WEIR	1.92	8.18			
	BRIDGE WITH PIPE	2.21	7.93	8.67	9.26	0.56
	ABU ZEIGHAN	2.82	7.82			
	KAC,MAADI	2.82	7.89	12.08	12.99	0.71
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
8.3.94	D/S KTD	2.00	7.80	11.67	9.26	0.59
	EL THAHAB WEIR	1.89	8.17			
	BRIDGE WITH PIPE	2.03	7.89	11.25	9.26	0.53
	ABU ZEIGHAN	2.17	8.15			
	KAC,MAADI	2.17	8.17	9.67	12.96	0.67
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					

Table 4.2

WATER QUALITY MEASURED AT VARIOUS LOCATIONS

		QUALITY PARAMETERS				
		EC	pH	NA	CL	B
DATE	SITE	(m.mhos/l)		(mg/l)	(mg/l)	(ppm)
8.10.94	D/S KTD					
	EL THAHAB WEIR	1.99	8.20			
	BRIDGE WITH PIPE	2.11	7.90	10.00	10.02	0.61
	ABU ZEIGHAN	2.17	8.18			
	KAC,MAADI	2.17	8.18	12.80	12.78	0.66
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
8.17.94	D/S KTD	2.19	7.83	10.80	9.26	0.76
	EL THAHAB WEIR	1.94	8.12			
	BRIDGE WITH PIPE	2.22	7.97	10.00	11.11	0.80
	ABU ZEIGHAN	3.24	7.90			
	KAC,MAADI	2.72	7.49	14.00	12.96	0.90
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
8.24.94	D/S KTD	2.20	7.92	10.80	10.19	0.72
	EL THAHAB WEIR	2.13	8.11			
	BRIDGE WITH PIPE	2.27	7.89	10.60	10.19	0.73
	ABU ZEIGHAN	2.99	7.83			
	KAC,MAADI	2.92	8.00	14.53	12.87	0.87
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
8.31.94	D/S KTD	2.22	7.73			
	EL THAHAB WEIR	2.08	8.08			
	BRIDGE WITH PIPE	2.22	7.81	10.80	10.19	0.73
	ABU ZEIGHAN	2.74	7.74			
	KAC,MAADI	2.72	7.90	13.40	11.11	0.82
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
9.7.94	D/S KTD	2.30	7.77	10.31	12.04	0.75
	EL THAHAB WEIR	2.07	8.09			
	BRIDGE WITH PIPE	2.19	7.99	13.07	13.89	0.87
	ABU ZEIGHAN	2.70	7.90			
	KAC,MAADI	2.29	8.00	11.23	9.29	0.67
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					

Table 4.2

WATER QUALITY MEASURED AT VARIOUS LOCATIONS

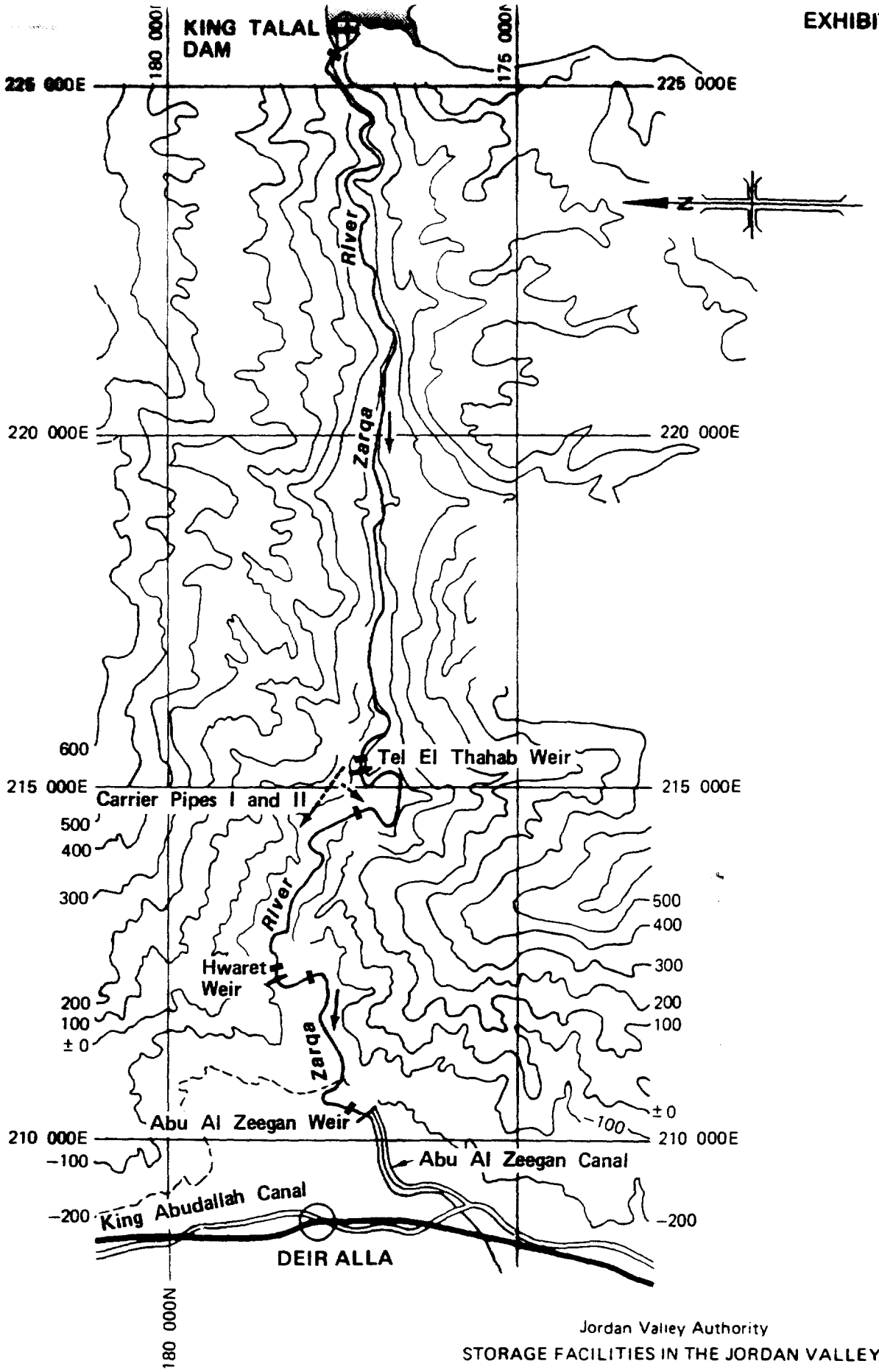
		QUALITY PARAMETERS				
		EC	pH	NA	CL	B
DATE	SITE	(m.mhos/l)		(mg/l)	(mg/l)	(ppm)
9.14.94	D/S KTD	2.09	7.23	10.66	11.11	0.65
	EL THAHAB WEIR	2.19	8.09			
	BRIDGE WITH PIPE	2.34	7.80	10.83	9.26	0.71
	ABU ZEIGHAN	2.99	7.82			
	KAC,MAADI	2.91	8.00	14.17	10.19	0.82
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
9.21.94	D/S KTD	2.28	7.89	10.00	11.11	0.90
	EL THAHAB WEIR	2.22	8.09			
	BRIDGE WITH PIPE	2.39	8.00	10.66	9.45	0.66
	ABU ZEIGHAN	2.92	7.89			
	KAC,MAADI	2.98	8.00	13.33	10.19	0.74
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
9.28.94	D/S KTD					
	EL THAHAB WEIR	2.40	8.19			
	BRIDGE WITH PIPE	2.52	8.19	10.83	10.19	0.67
	ABU ZEIGHAN	2.93	7.80			
	KAC,MAADI	2.75	7.98	12.50	9.26	0.59
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
10.5.94	D/S KTD	2.30	8.00	11.30	10.28	0.38
	EL THAHAB WEIR	2.28	8.38			
	BRIDGE WITH PIPE	2.34	8.33	11.30	11.11	0.54
	ABU ZEIGHAN	2.90	7.90			
	KAC,MAADI	2.90	8.38	14.16	13.89	0.60
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
10.12.94	D/S KTD	2.40	7.88			
	EL THAHAB WEIR	2.44	8.35			
	BRIDGE WITH PIPE	2.52	8.09	11.36	12.44	0.54
	ABU ZEIGHAN	3.04	7.84			
	KAC,MAADI	3.02	8.00	14.09	16.66	0.67
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					

Table 4.2

WATER QUALITY MEASURED AT VARIOUS LOCATIONS

		QUALITY PARAMETERS				
		EC	pH	NA	CL	B
DATE	SITE	(m.mhos/l)		(mg/l)	(mg/l)	(ppm)
10.19.94	D/S KTD	2.39	8.35	12.08	12.04	0.36
	EL THAHAB WEIR	2.33	8.21			
	BRIDGE WITH PIPE	2.43	8.19	12.92	11.60	0.54
	ABU ZEIGHAN	3.28	7.92			
	KAC,MAADI	2.00	8.28	15.55	15.70	
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
10.25.94	D/S KTD	2.41	7.80			
	EL THAHAB WEIR	2.37	8.07			
	BRIDGE WITH PIPE	2.49	8.07			
	ABU ZEIGHAN	3.02	7.84			
	KAC,MAADI	2.41	8.09			
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					
10.26.94	D/S KTD			10.83	12.70	0.42
	EL THAHAB WEIR					
	BRIDGE WITH PIPE			11.66	12.10	0.55
	ABU ZEIGHAN					
	KAC,MAADI			14.58	16.70	0.70
	WOMAN SPRING					
	MAN SPRING					
	KAC,SWALHA					

EXHIBIT 1



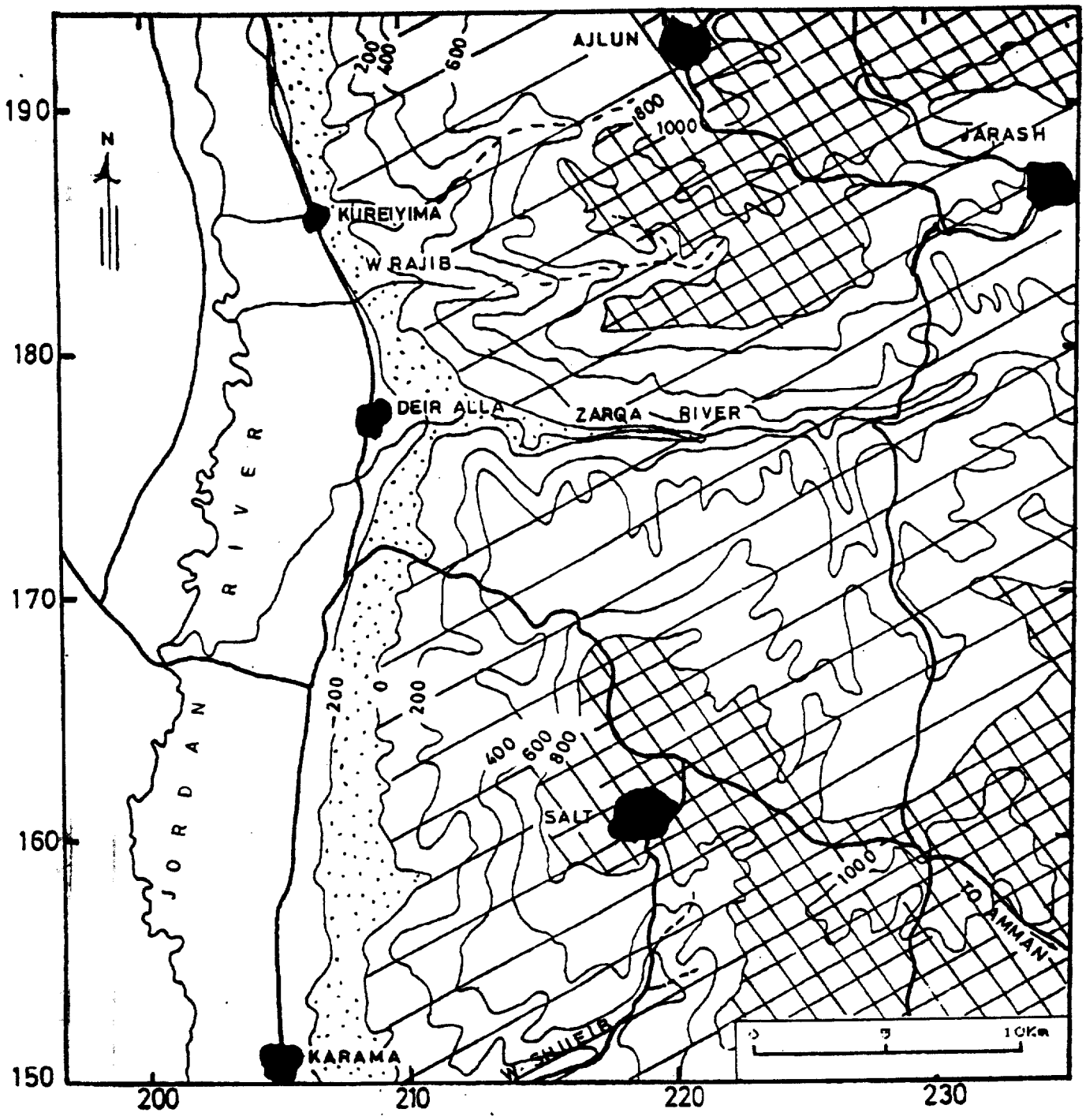
Jordan Valley Authority

STORAGE FACILITIES IN THE JORDAN VALLEY

LOCATION MAP

HARZA ENGINEERING COMPANY 2026B1188

EXHIBIT 2



HIGHLANDS ABOVE 800 METERS

FOOT HILLS -200 - 0 METERS

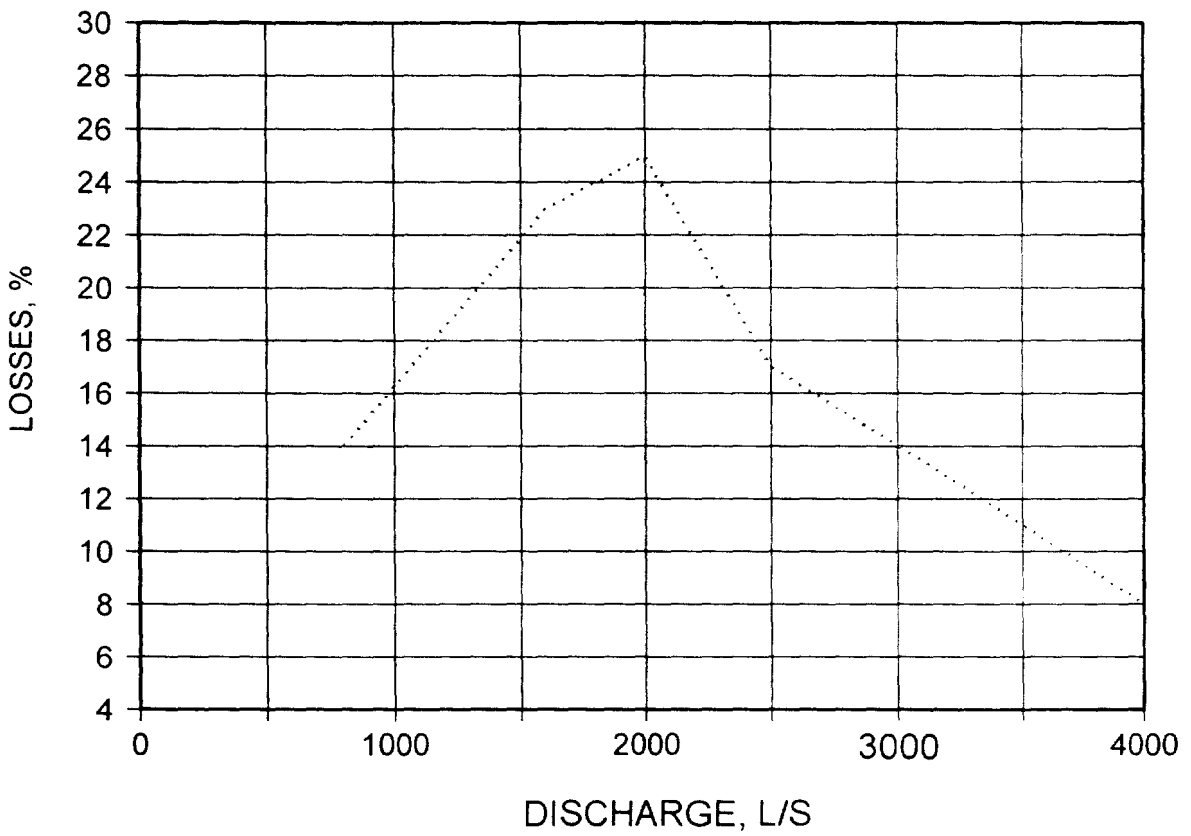
ESCARPMENT 0 - 800 METERS

RIFT VALLEY

Jordan Valley Authority
STORAGE FACILITIES IN THE JORDAN VALLEY

REGIONAL GEOMORPHIC - TOPOGRAPHIC ZONES

LOSSES IN THE ZARQA RIVER AS A FUNCTION OF DISCHARGE



EXH32.DRW, MAY 95

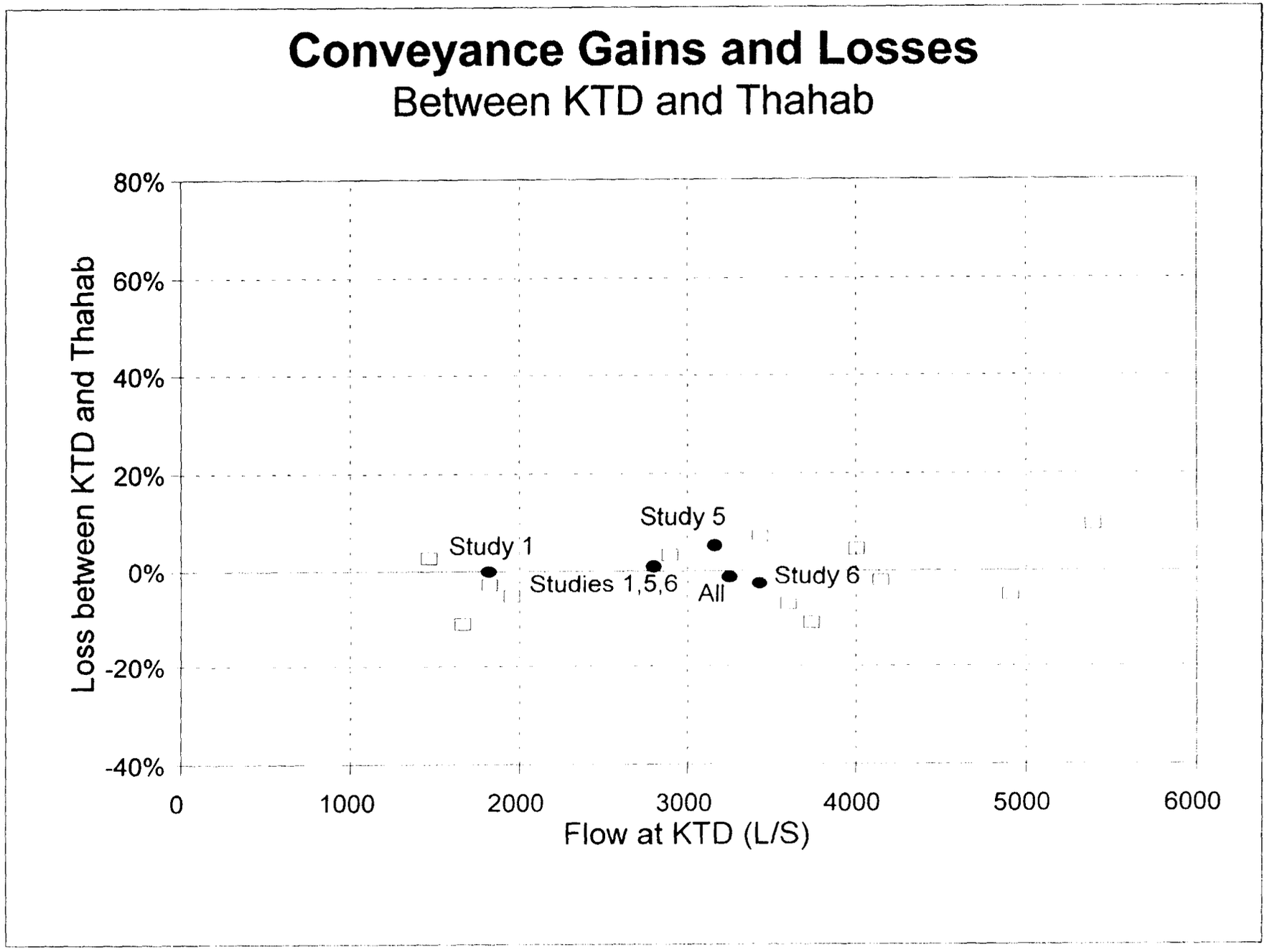

Conveyance Gains and Losses
Between KTD and Thahab
80%
60%
40%
20%
0%
-20%
-40%
Loss between KTD and Thahab
0
1000
2000
3000
4000
5000
6000
Flow at KTD (L/S)
Study 1
Studies 1,5,6
Study 5
All
Study 6

EXHIBIT 4

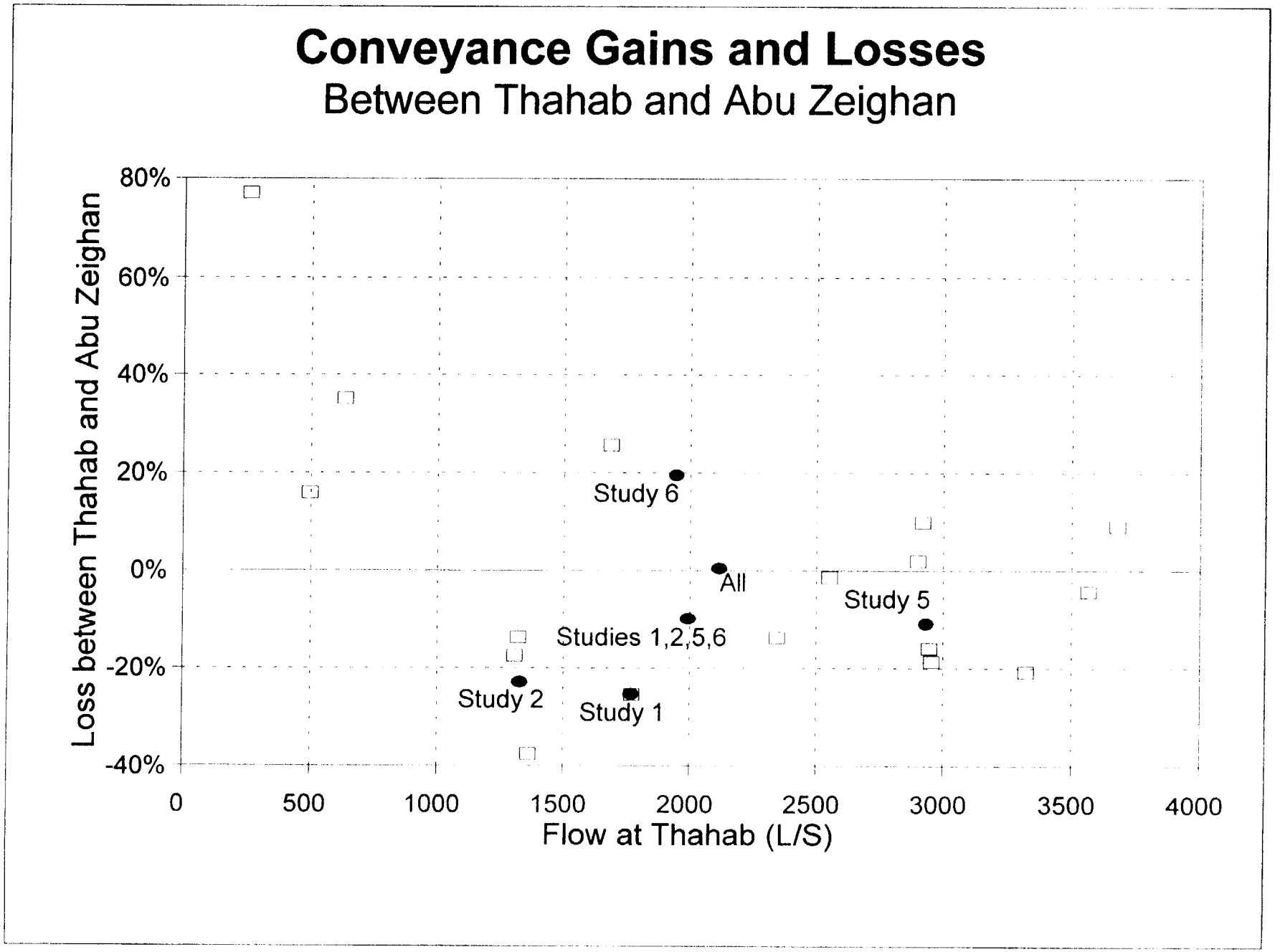

Conveyance Gains and Losses
Between Thahab and Abu Zeighan
Loss between Thahab and Abu Zeighan
80%
60%
40%
20%
0%
-20%
-40%
0
500
1000
1500
2000
2500
3000
3500
4000
Flow at Thahab (L/S)
Study 6
All
Study 5
Studies 1,2,5,6
Study 2
Study 1

EXHIBIT 5

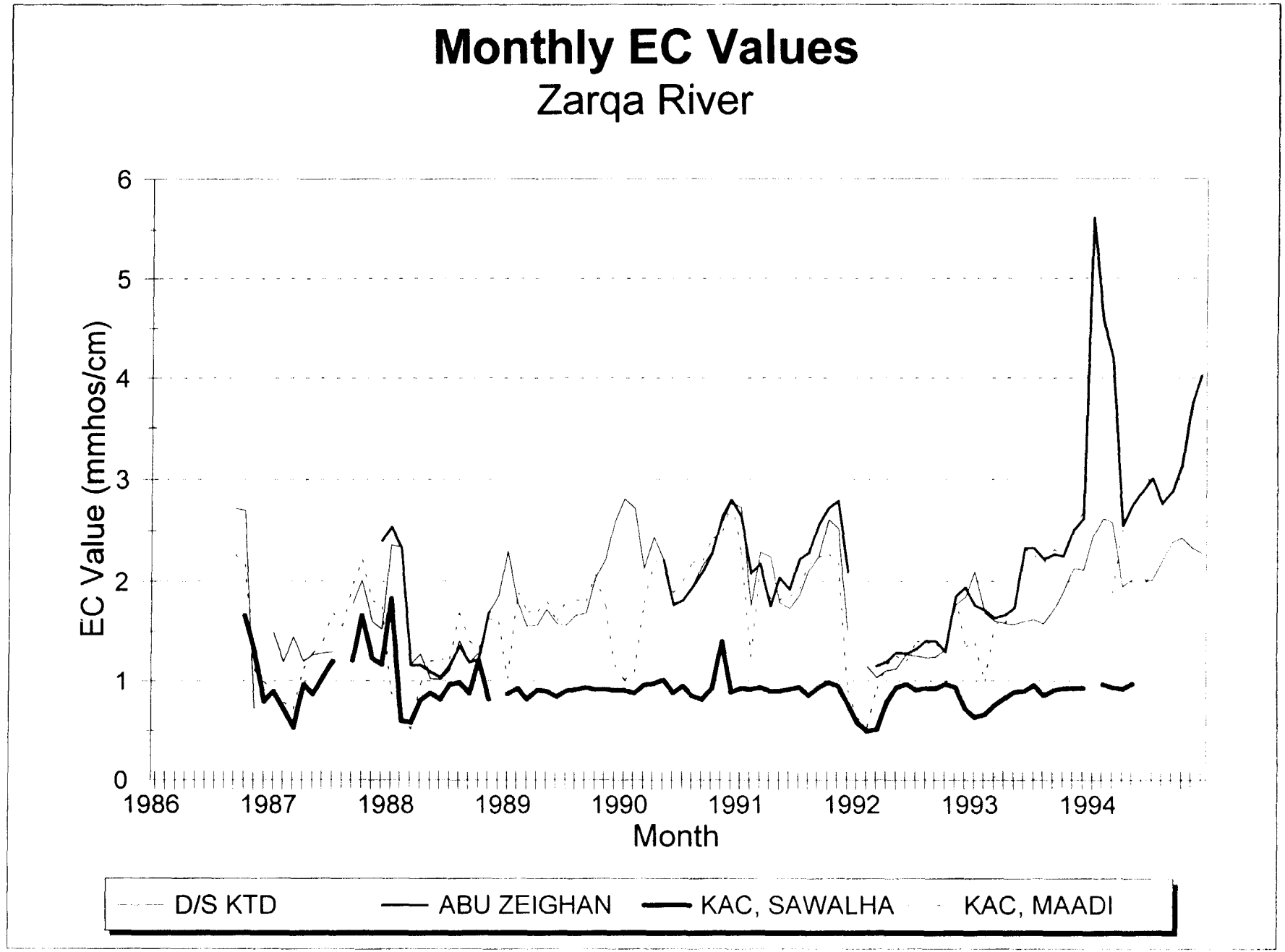

Monthly EC Values
Zarqa River
EC Value (mmhos/cm)
0
1
2
3
4
5
6
1986
1987
1988
1989
1990
1991
1992
1993
1994
Month
D/S KTD
ABU ZEIGHAN
KAC, SAWALHA
KAC, MAADI

EXHIBIT 6

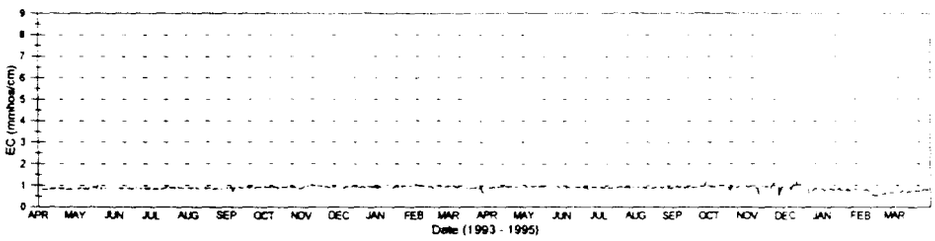
67

EXHIBIT 7

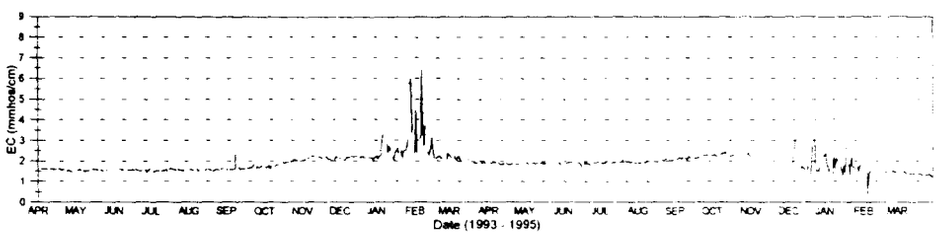
Electrical Conductivity, Zarqa River

April 1993 through March 1995

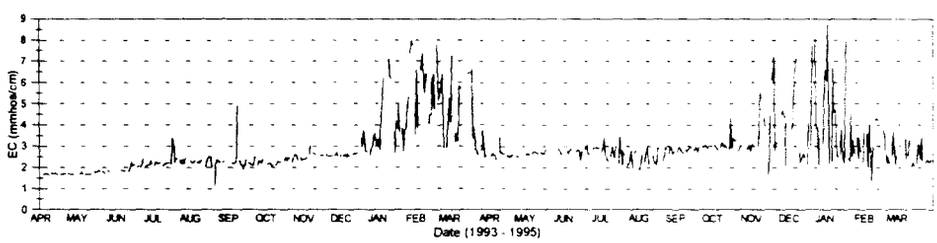
KAC Sawalha



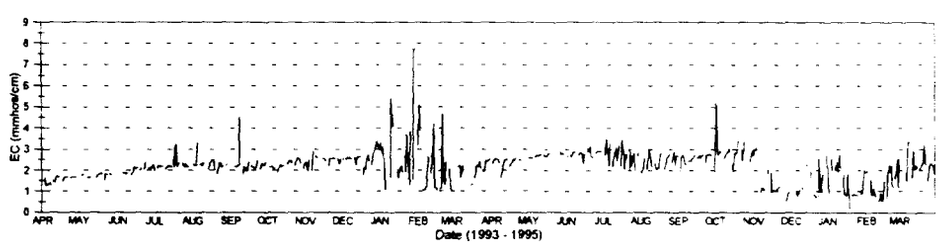
KTD



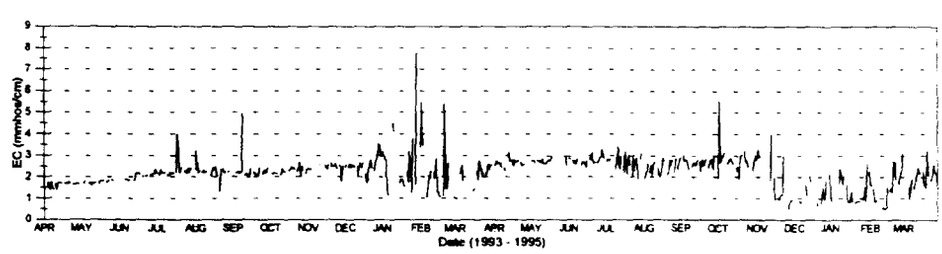
Abu Zeighan



KAC, Maadi (A.M.)



KAC, Maadi (P.M.)



Daily Outflow and EC Values at KTD

April 1993 - March 1995

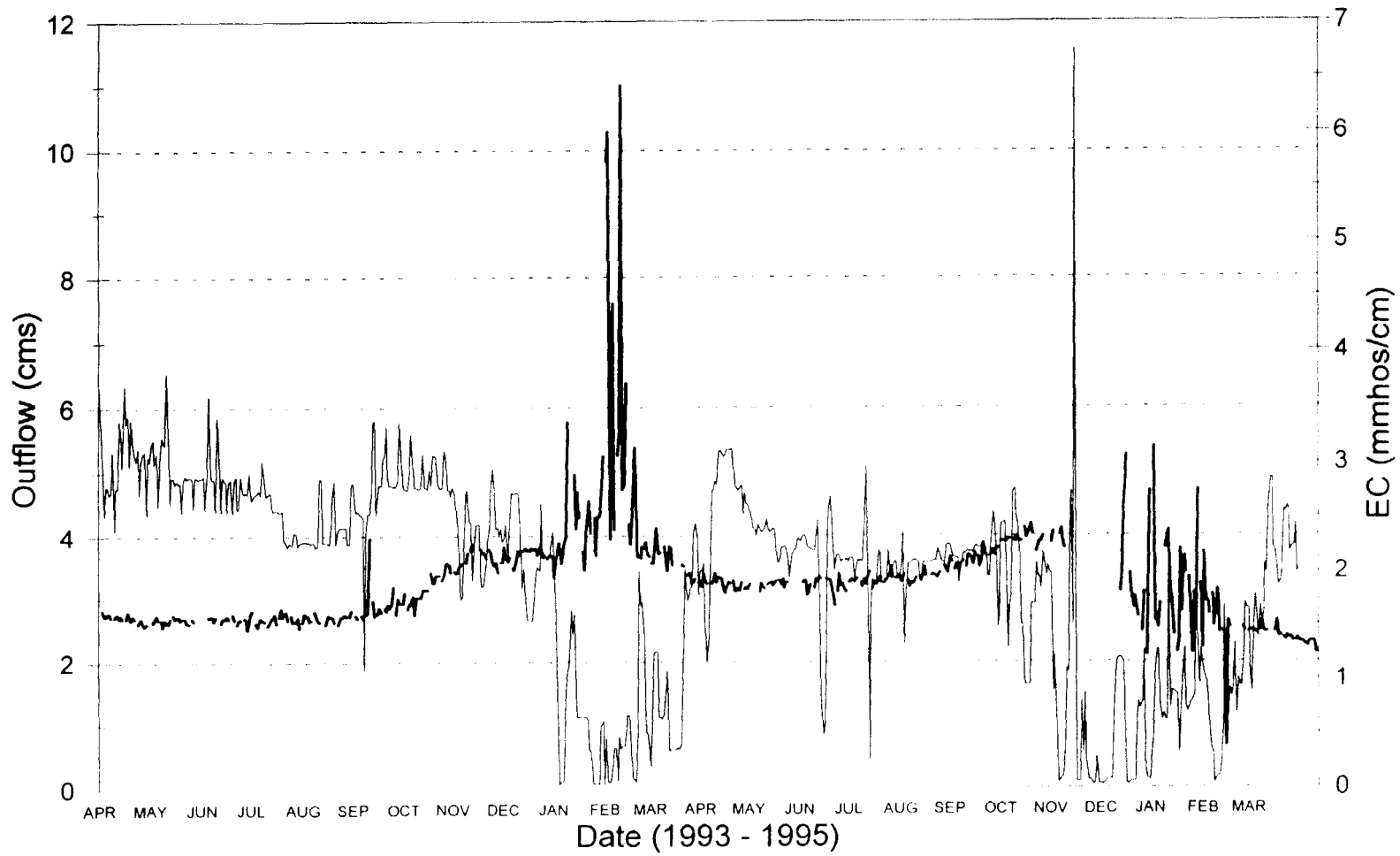
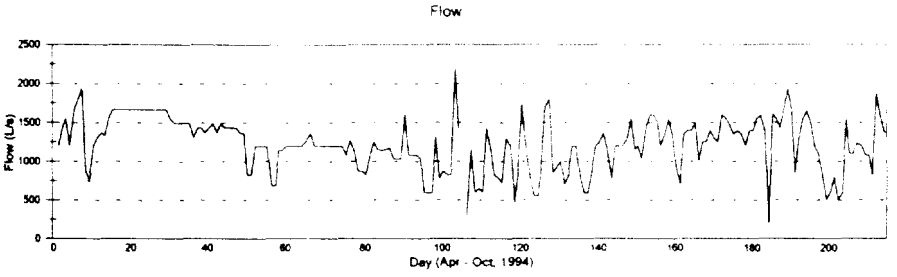


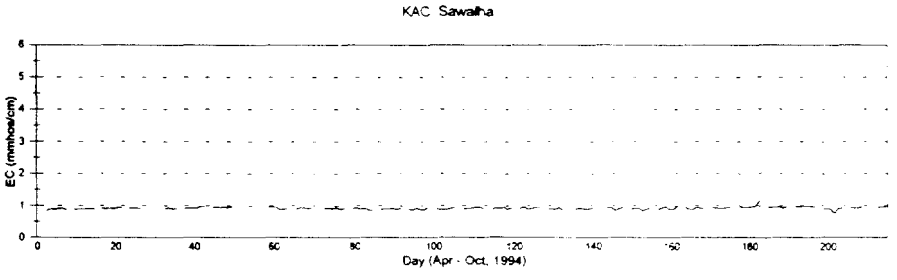
EXHIBIT 8

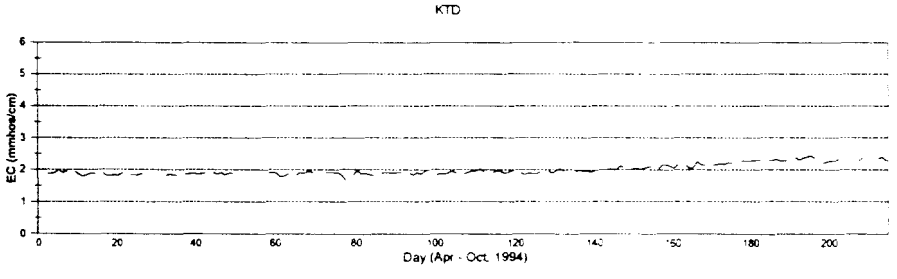
65

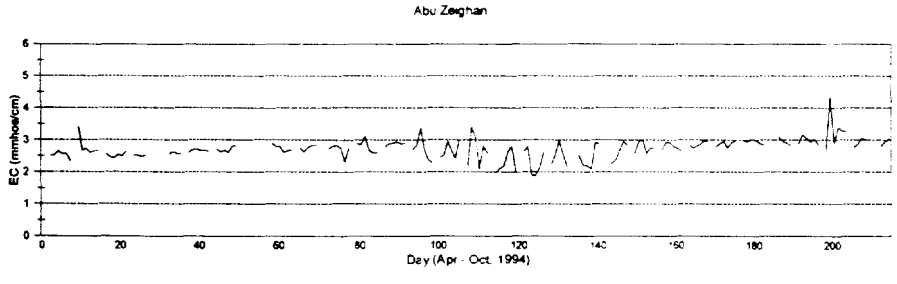
Electrical Conductivity, Zarqa River

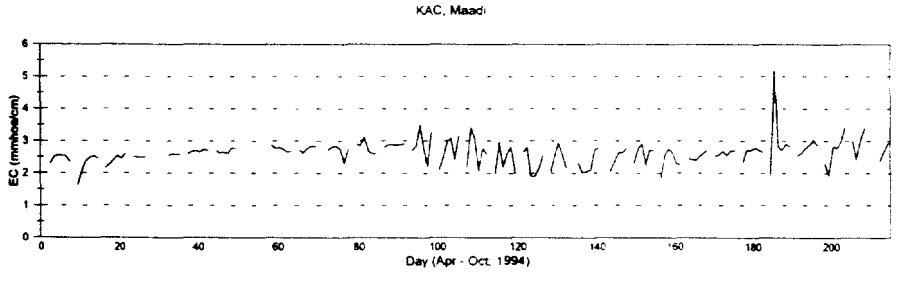
April through October, 1994











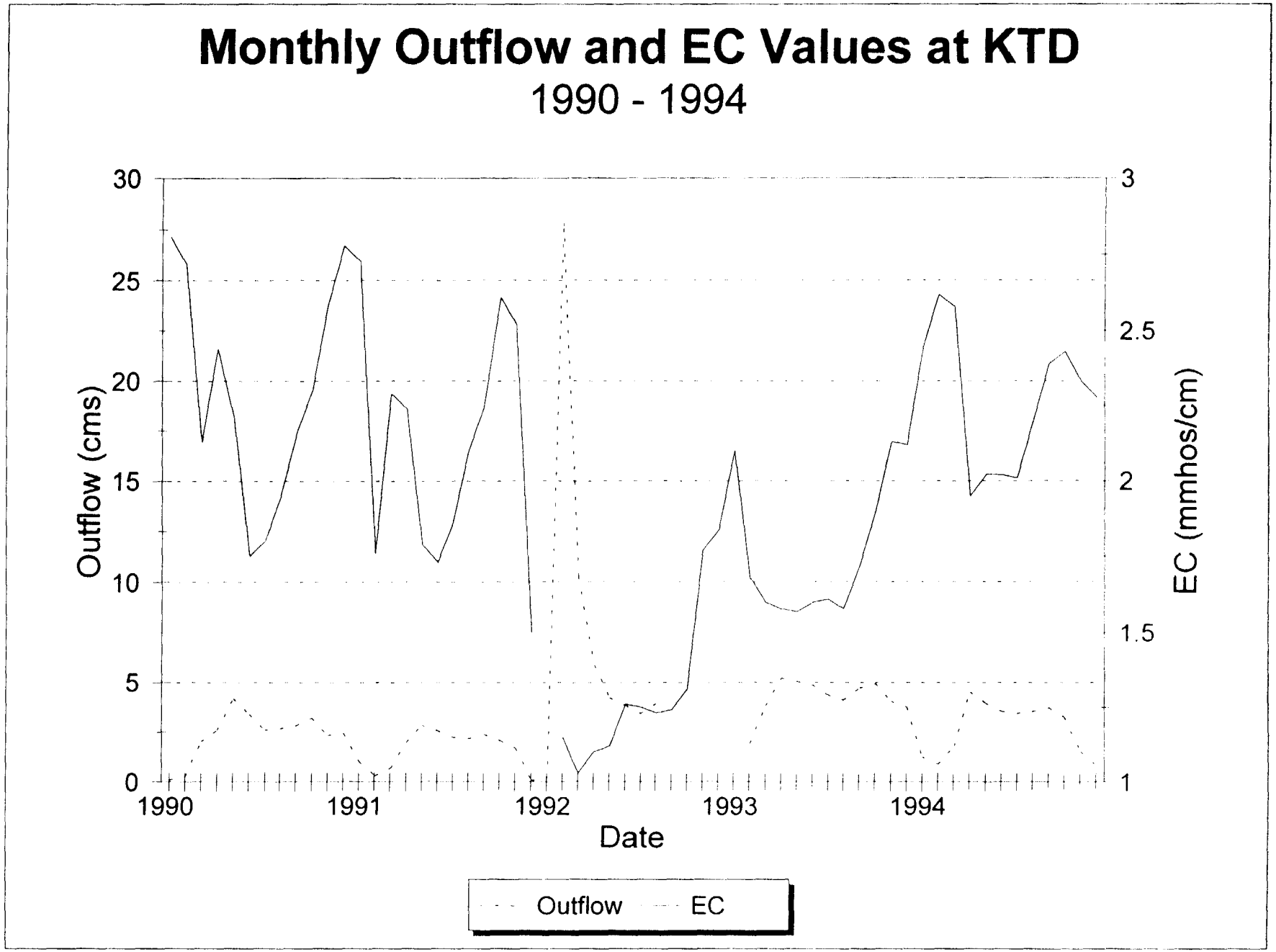

Monthly Outflow and EC Values at KTD
1990 - 1994
Outflow (cms)
EC (mmhos/cm)
Date
30
25
20
15
10
5
0
3
2.5
2
1.5
1
1990
1991
1992
1993
1994
Outflow
EC

EXHIBIT 10

EC Values, Zarqa River

April and October, 1992-1994

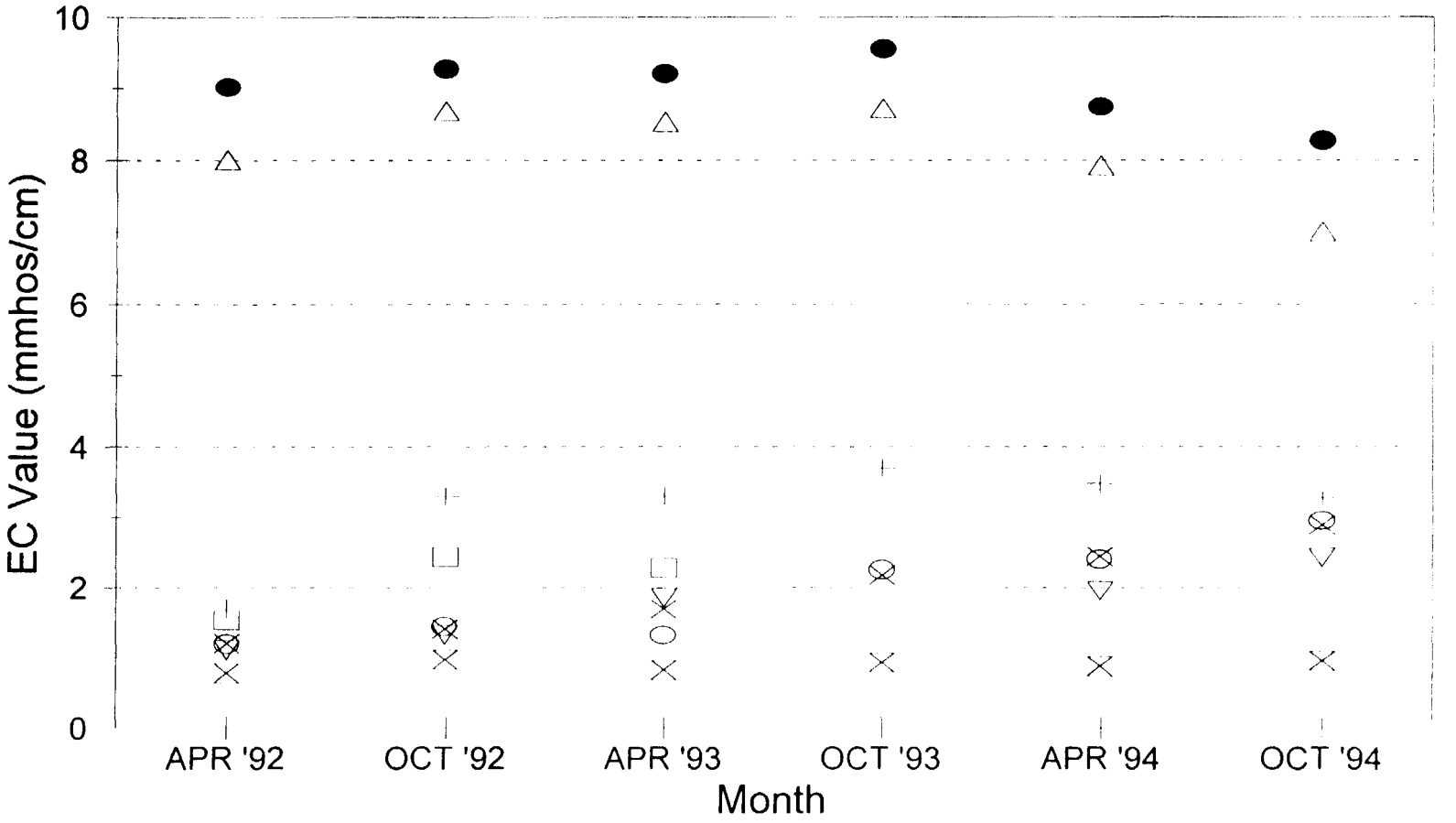
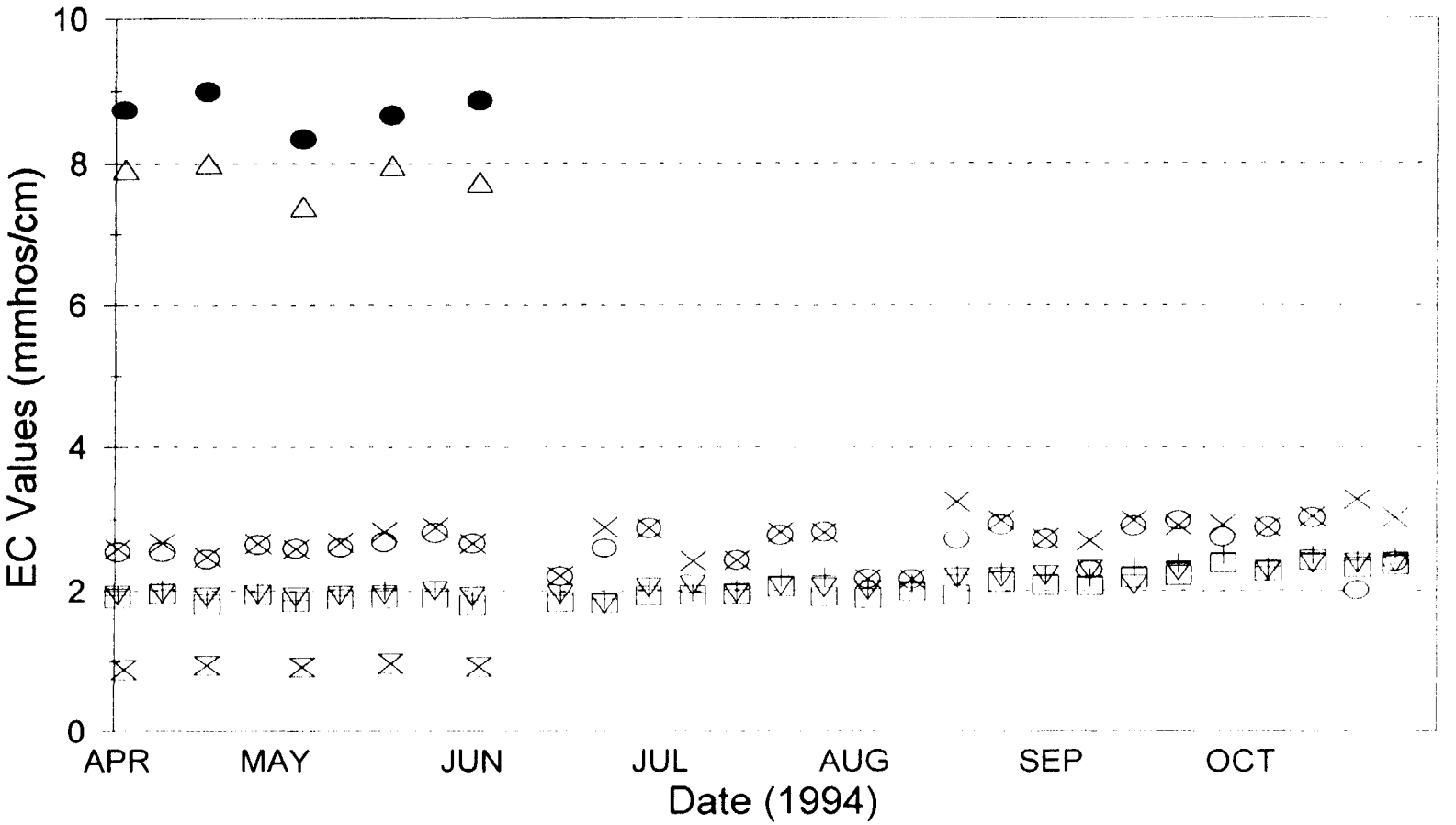


EXHIBIT 11

72

EC Values, Zarqa River

April through October, 1994



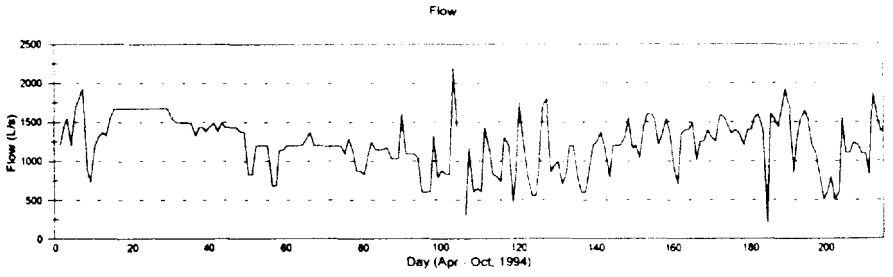
▽ D/S KTD	□ EL THAHAB WEIR	+ BRIDGE W/PIPE	× ABU ZEIGHAN
○ KAC, MAADI	● WOMAN SPRING	△ MAN SPRING	⊠ KAC, SAWALHA

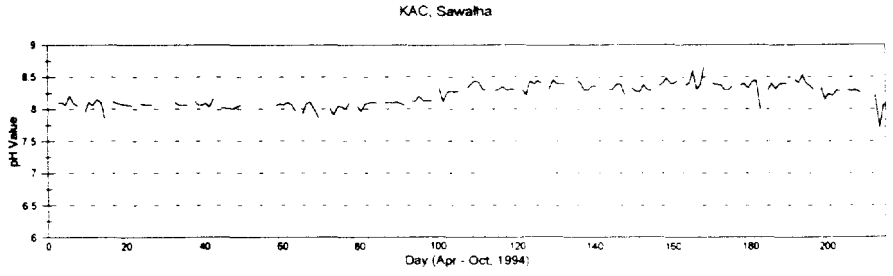
EXHIBIT 12

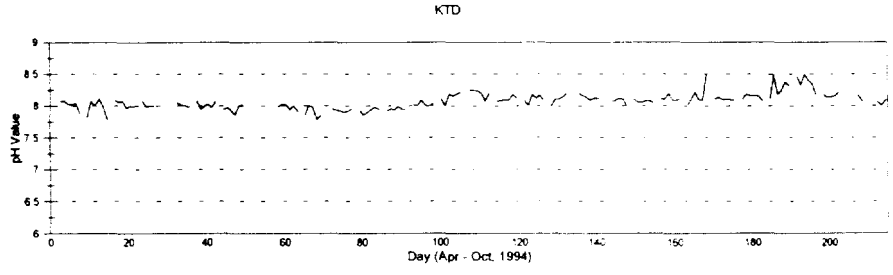
73

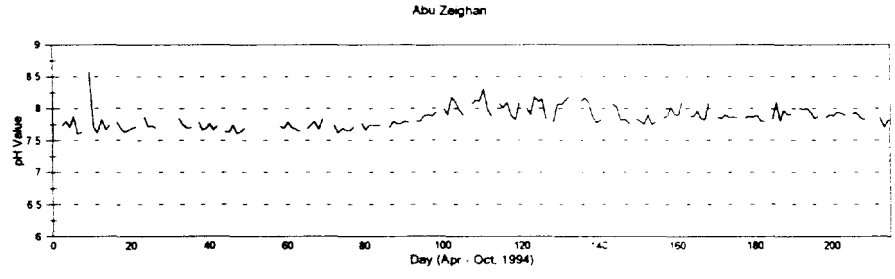
pH Values, Zarqa River and KAC

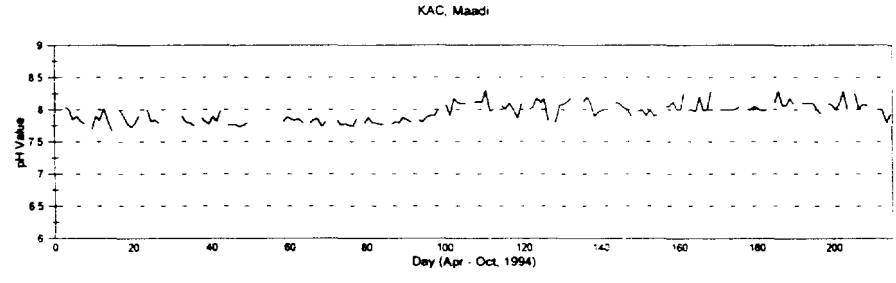
April through October, 1994











Daily Outflow and pH Values at KTD

April 1993 - March 1995

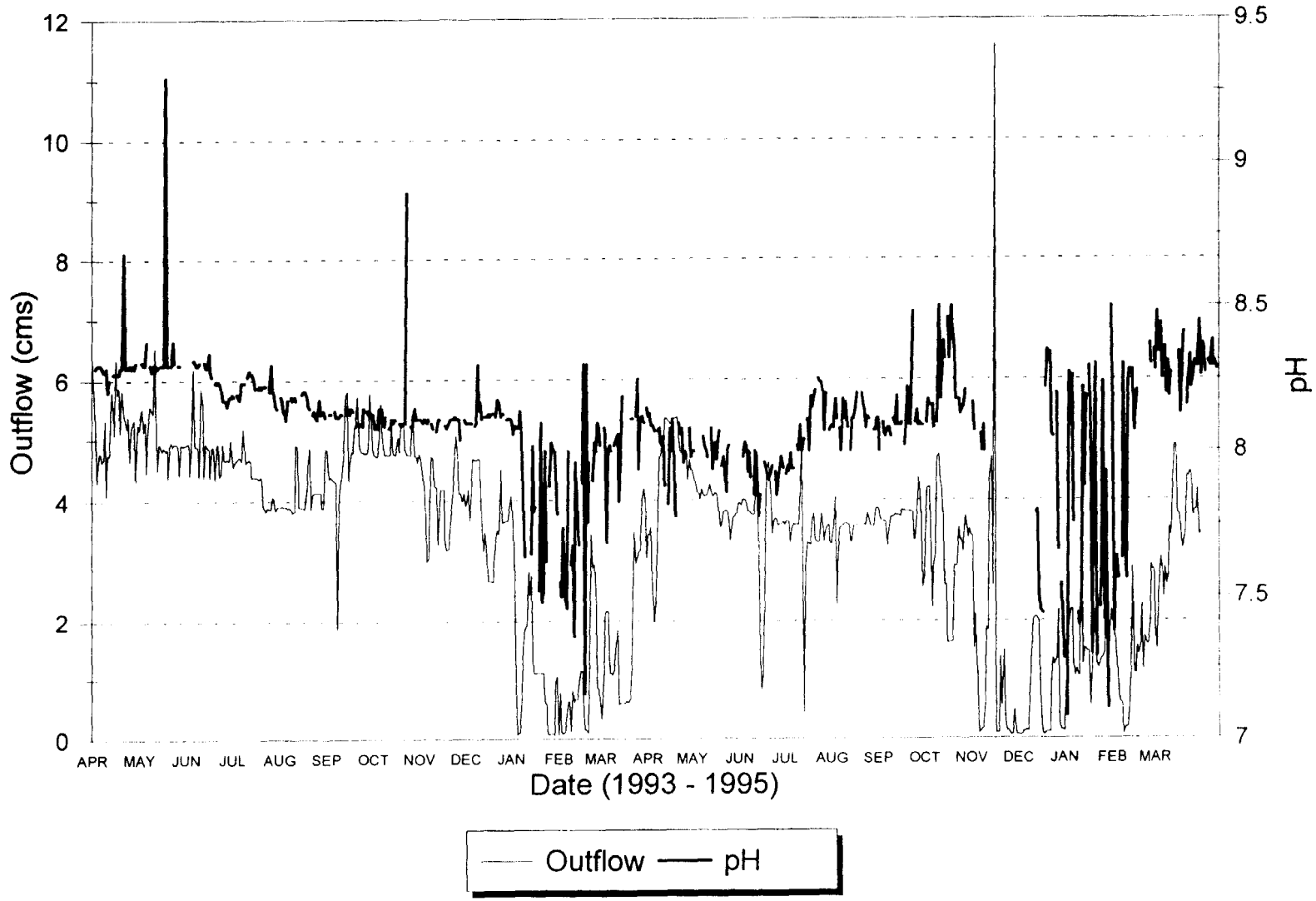
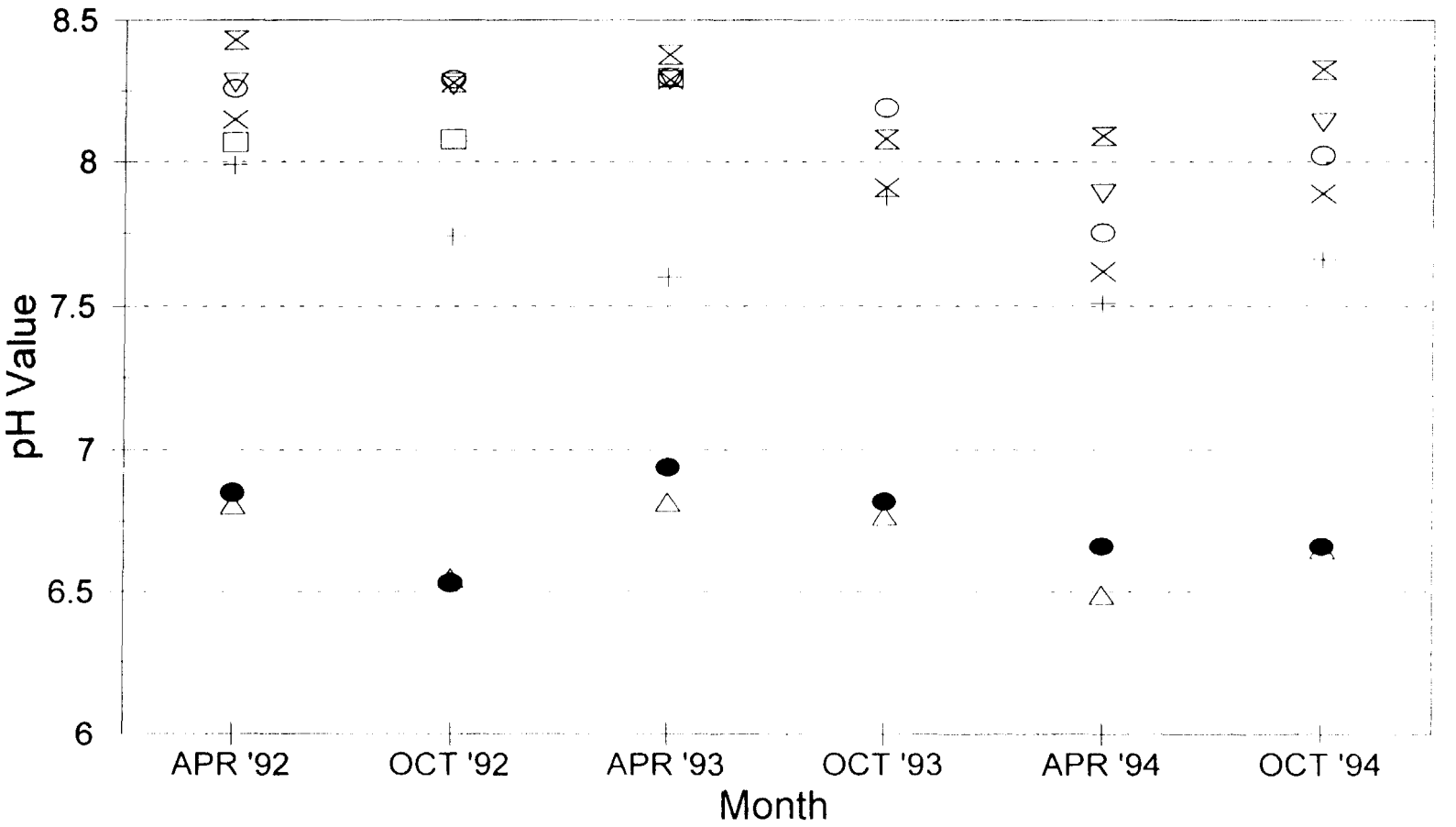


EXHIBIT 14

15

pH Values, Zarqa River

April and October, 1992-1994



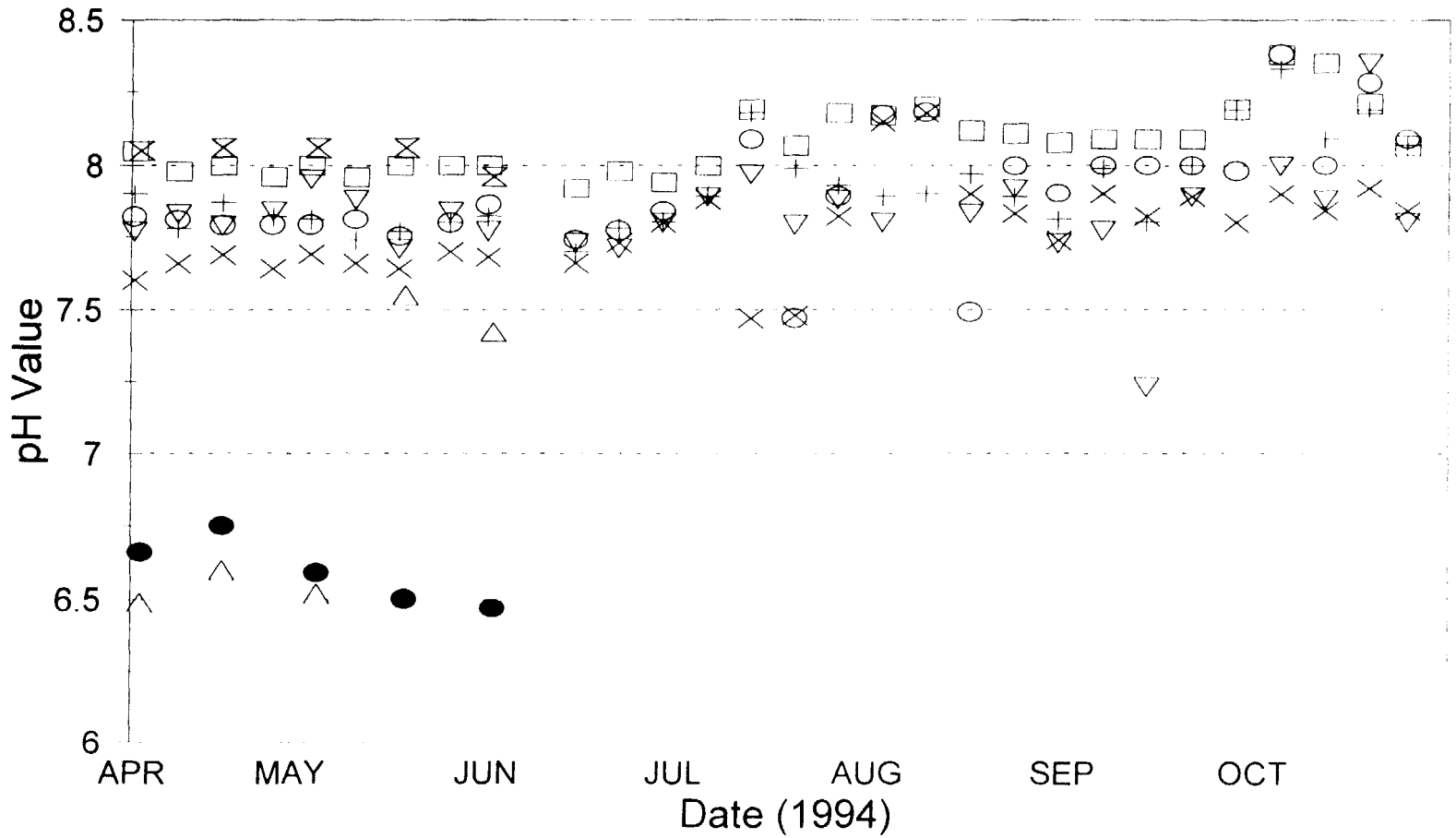
□ Treatment Plant	▽ KTD	● Woman Spring	△ Man Spring
+ Zarqa River ??	× Abu Zeighan Canal	⊠ KAC, Sawalha	○ KAC, Maadi

EXHIBIT 15

76

pH Values, Zarqa River

April through October, 1994



▽ D/S KTD	□ EL THAHAB WEIR	+ BRIDGE W/PIPE	× ABU ZEIGHAN
○ KAC, MAADI	● WOMAN SPRING	△ MAN SPRING	⊠ KAC, SAWALHA

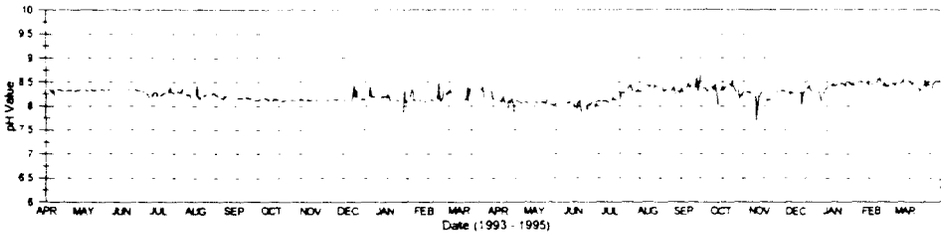
EXHIBIT 16

EXHIBIT 17

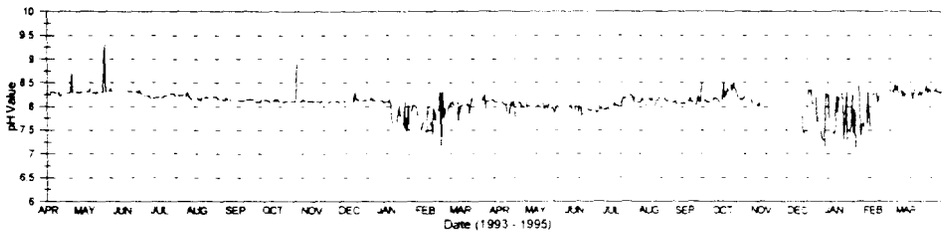
pH Values, KAC and Zarqa River

April 1993 through March 1995

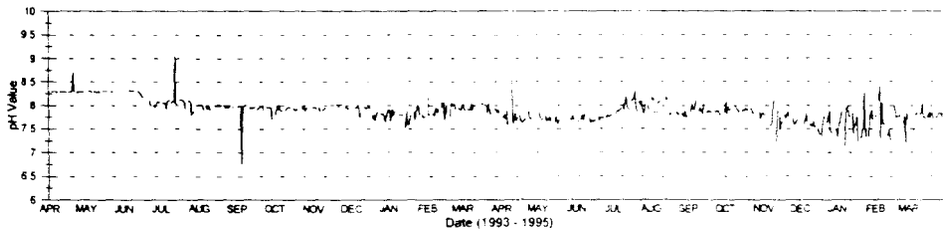
KAC Sawalha



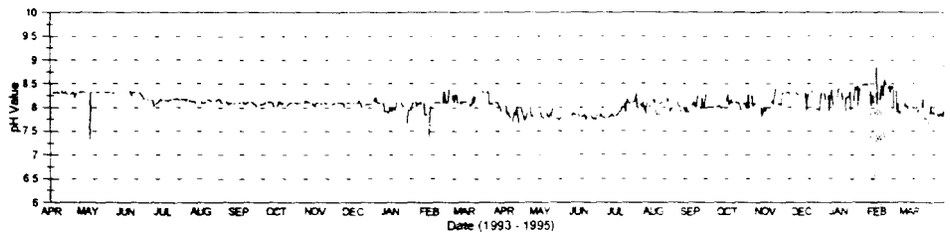
KTD



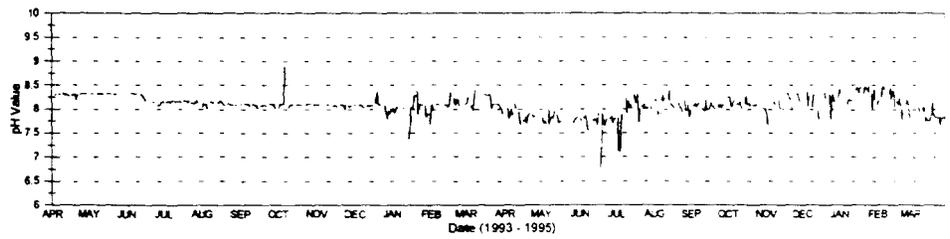
Abu Zeighan



KAC, Maadi (A.M.)



KAC, Maadi (P.M.)



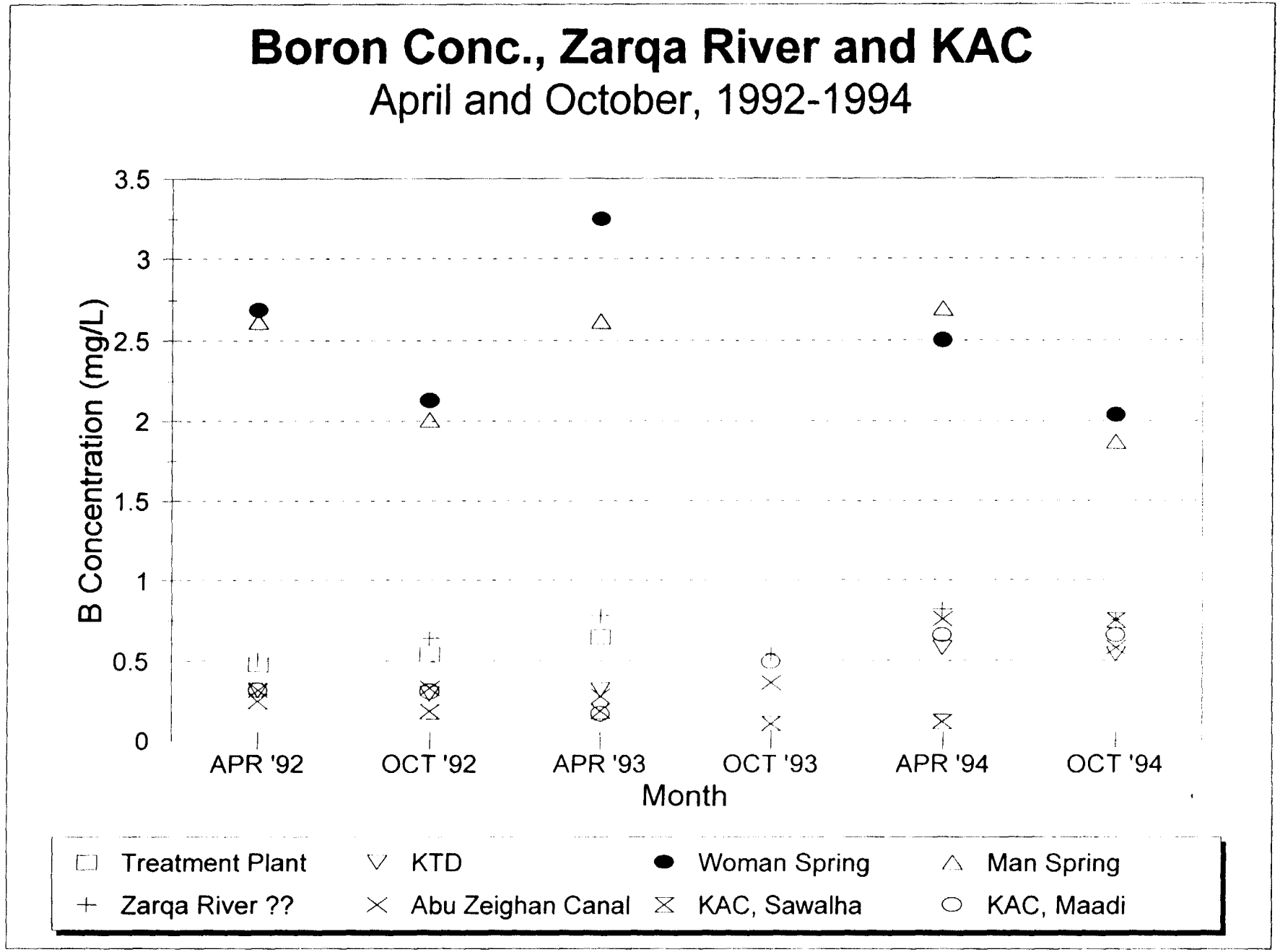
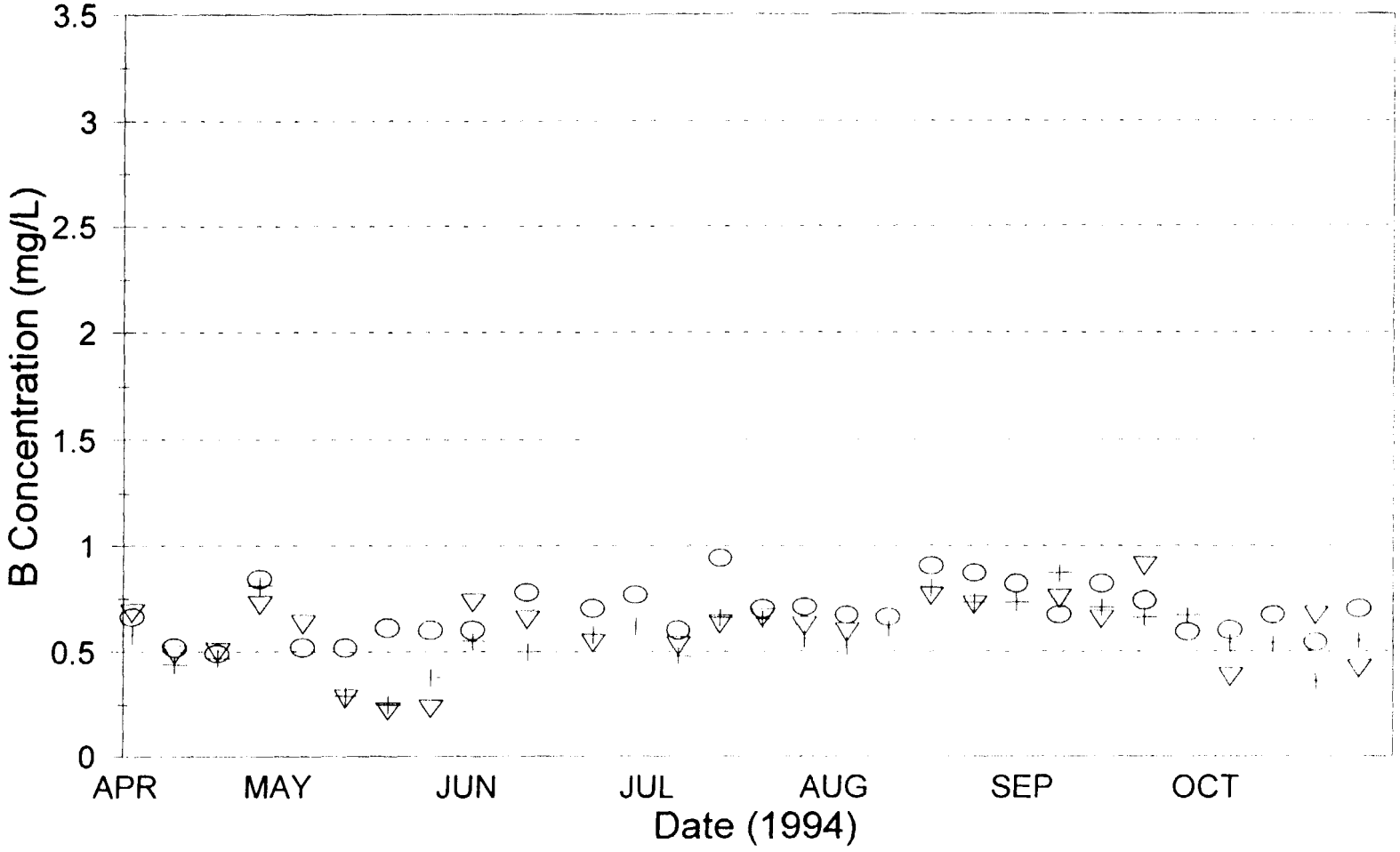

Boron Conc., Zarqa River and KAC
April and October, 1992-1994
B Concentration (mg/L)
3.5
3
2.5
2
1.5
1
0.5
0
APR '92
OCT '92
APR '93
OCT '93
APR '94
OCT '94
Month
Treatment Plant
KTD
Woman Spring
Man Spring
Zarqa River ??
Abu Zeighan Canal
KAC, Sawalha
KAC, Maadi

EXHIBIT 18

Boron Concentrations, Zarqa River

April through October, 1994

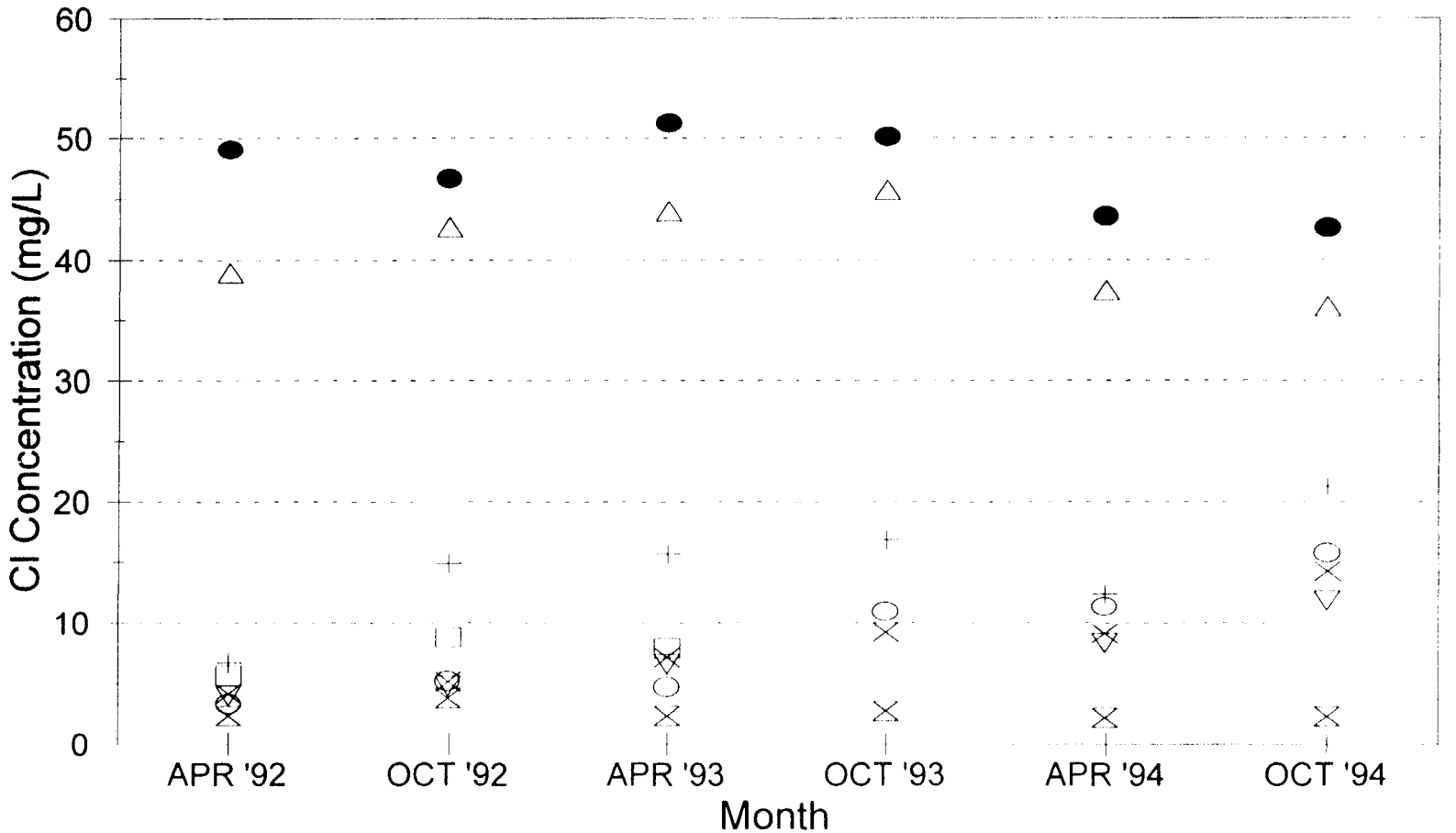


▽ D/S KTD + BRIDGE W/PIPE ○ KAC, MAADI

EXHIBIT 19

Chloride Conc., Zarqa River and KAC

April and October, 1992-1994



□ Treatment Plant	▽ KTD	● Woman Spring	△ Man Spring
+ Zarqa River ??	× Abu Zeighan Canal	⧖ KAC, Sawalha	○ KAC, Maadi

EXHIBIT 20

Chloride Concentrations, Zarqa River

April through October, 1994

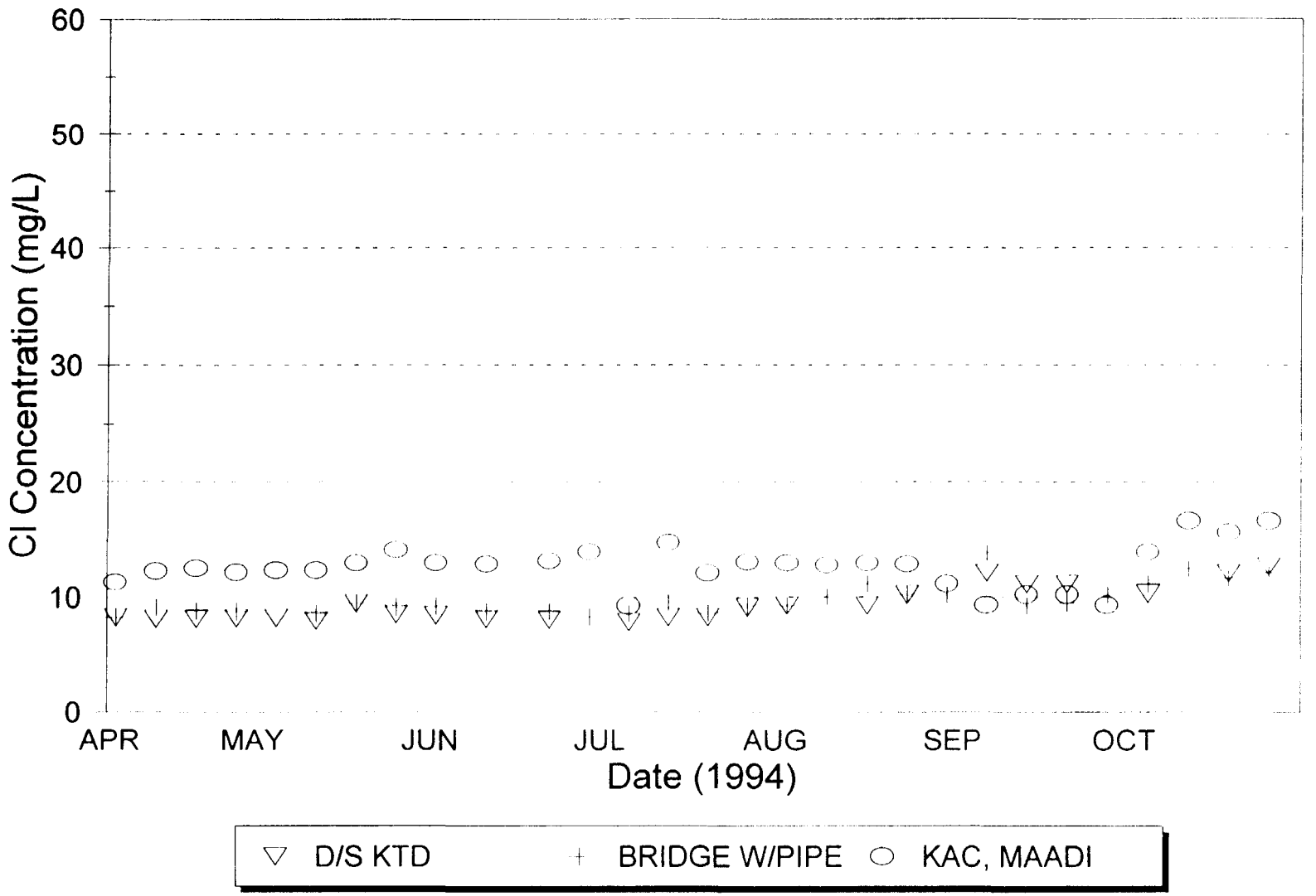


EXHIBIT 21

Sodium Conc., Zarqa River and KAC

April and October, 1992-1994

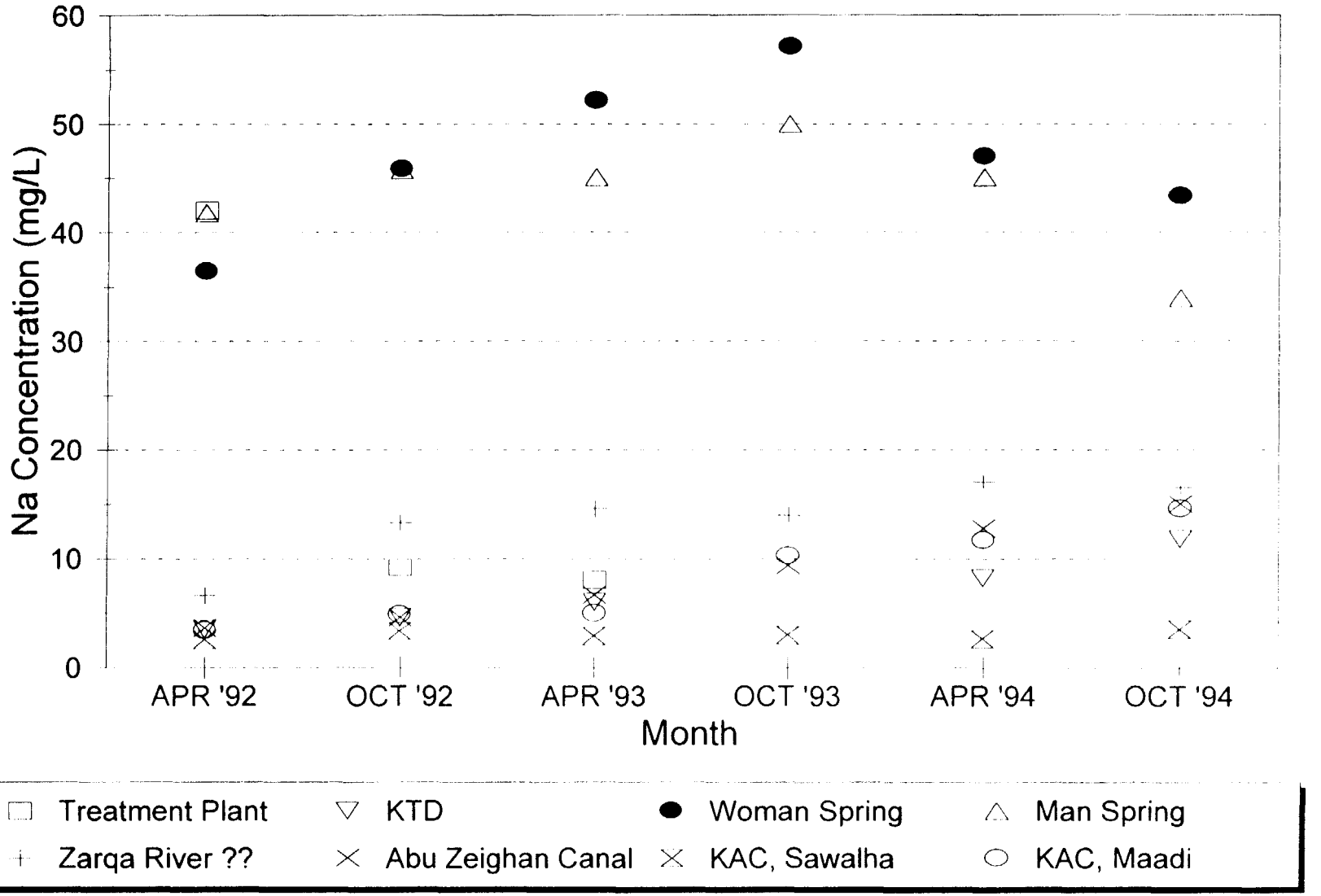


EXHIBIT 22

Sodium Concentrations, Zarqa River

April through October, 1994

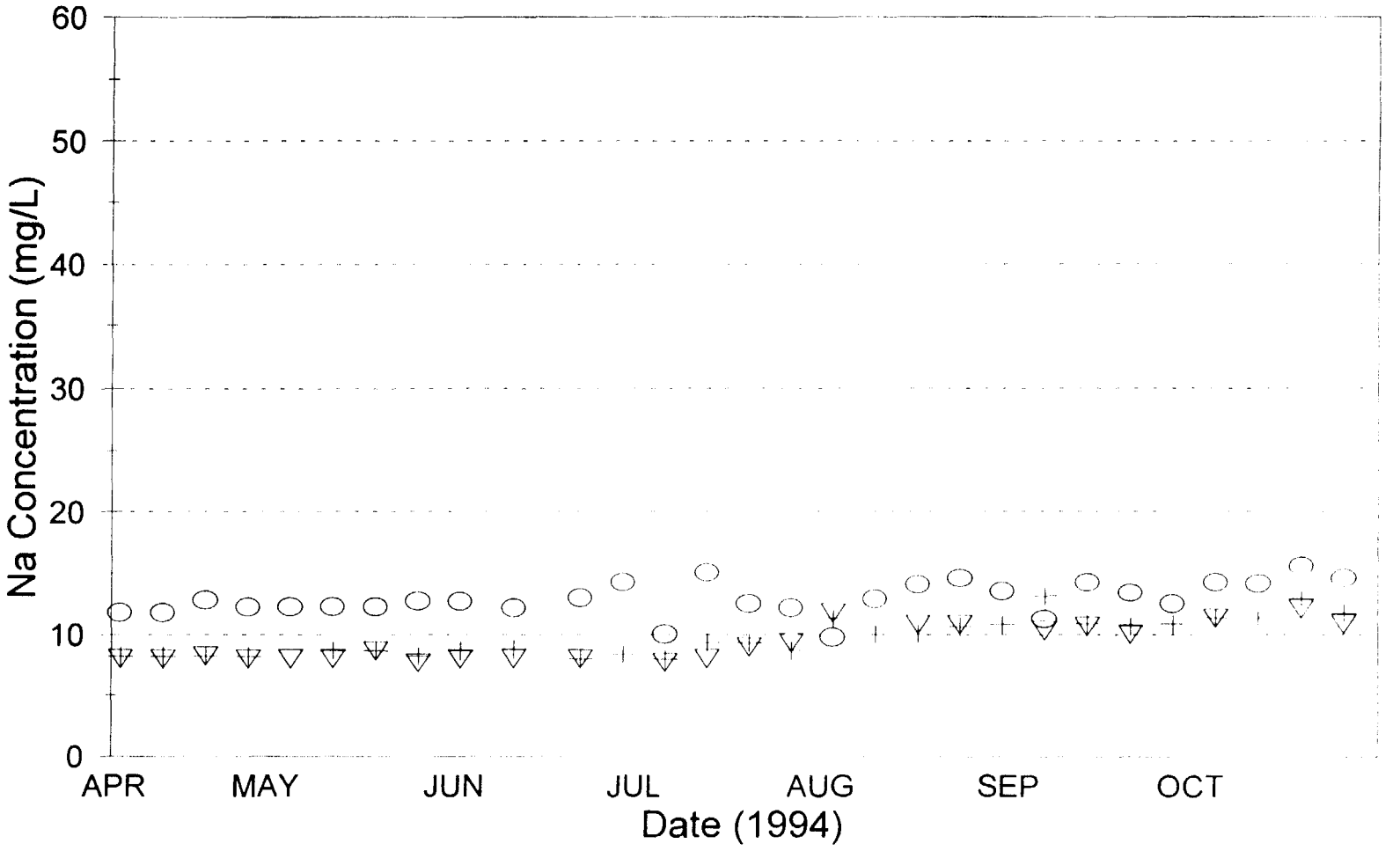
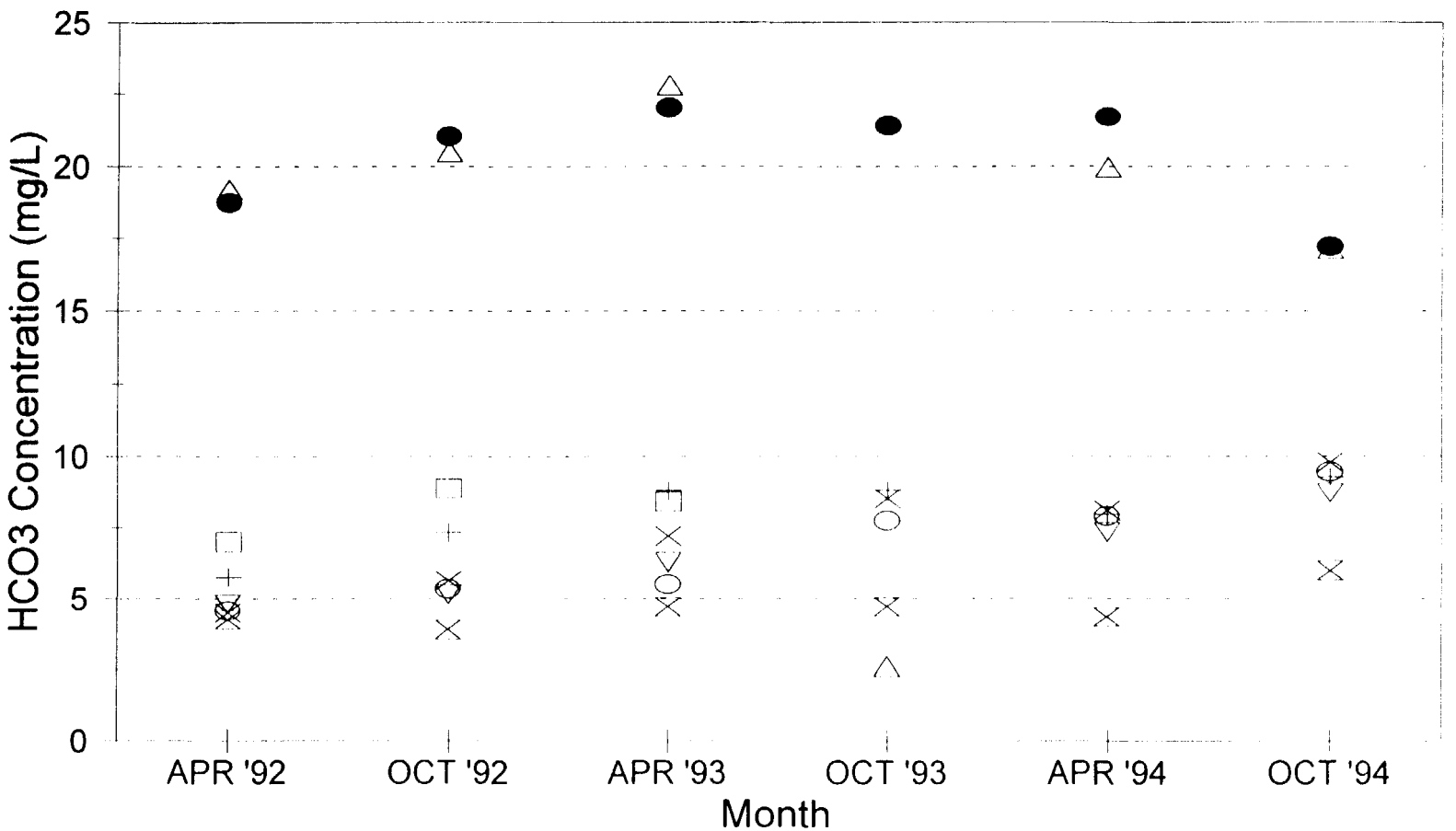


EXHIBIT 23

HCO3 Conc., Zarqa River and KAC

April and October, 1992-1994

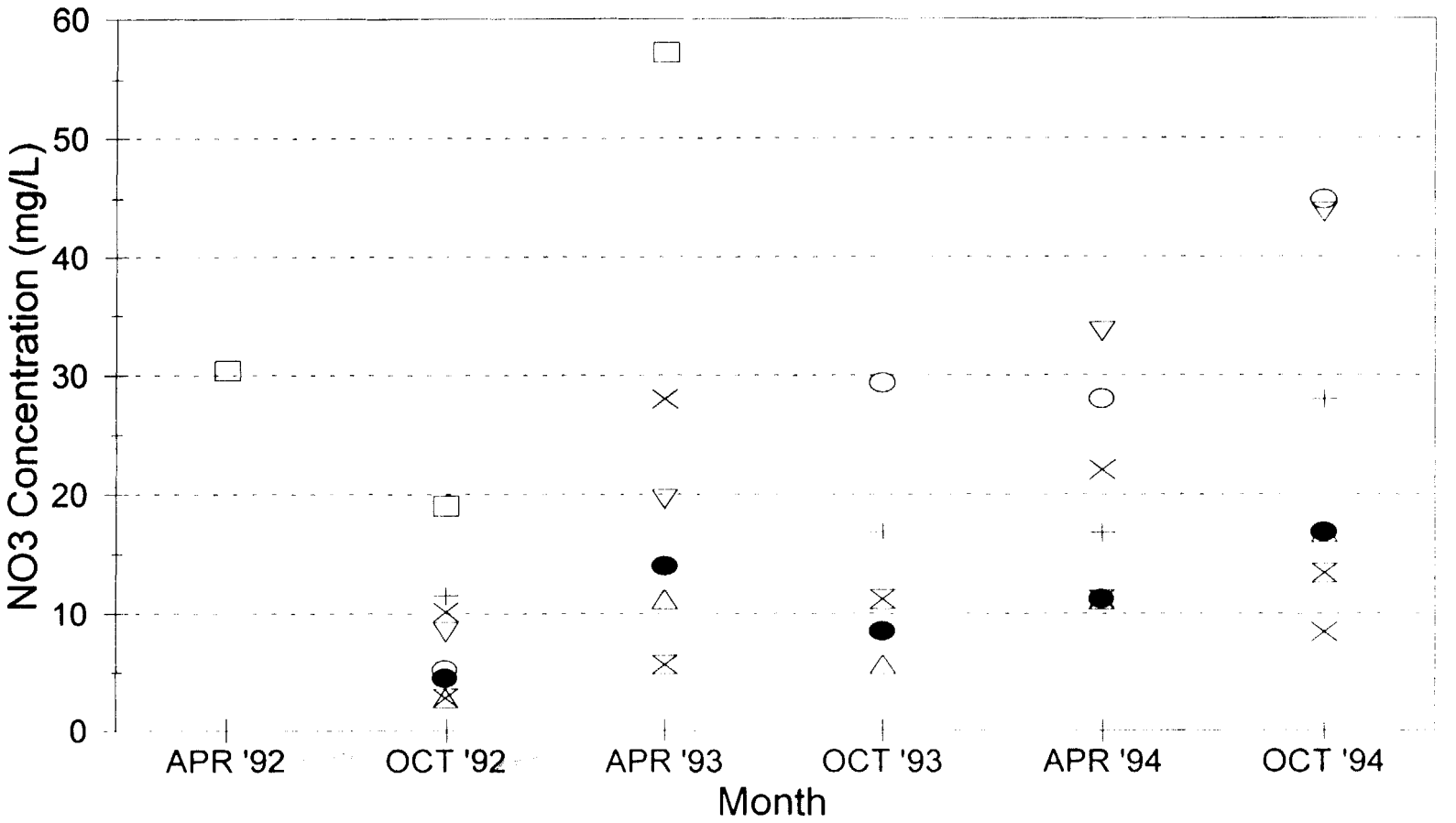


□ Treatment Plant	▽ KTD	● Woman Spring	△ Man Spring
+ Zarqa River ??	× Abu Zeighan Canal	⊠ KAC, Sawalha	○ KAC, Maadi

EXHIBIT 24

NO3 Conc., Zarqa River and KAC

April and October, 1992-1994

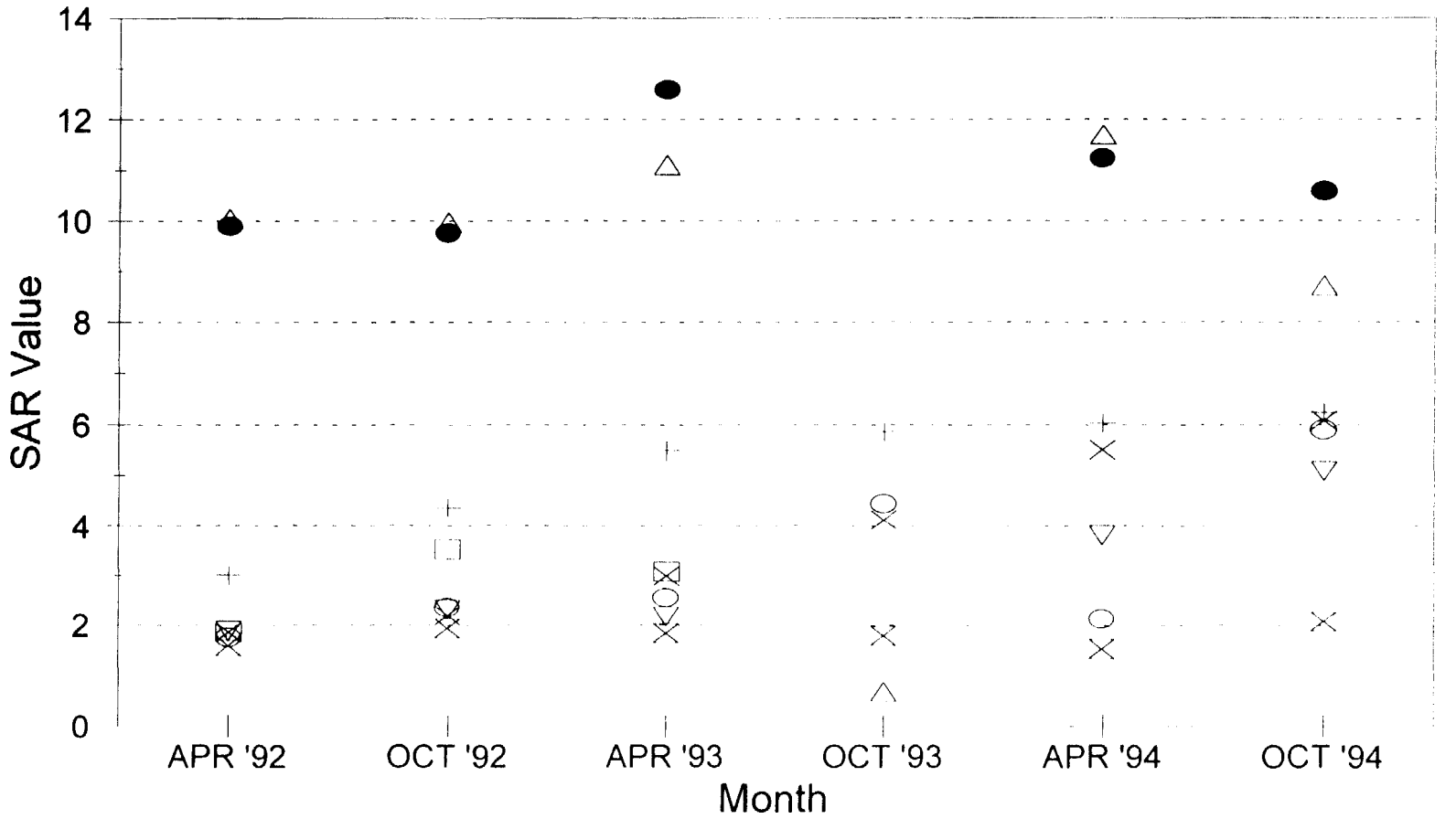


□ Treatment Plant	▽ KTD	● Woman Spring	△ Man Spring
+ Zarqa River ??	× Abu Zeighan Canal	⊠ KAC, Sawalha	○ KAC, Maadi

EXHIBIT 25

SAR Values, Zarqa River and KAC

April and October, 1992-1994

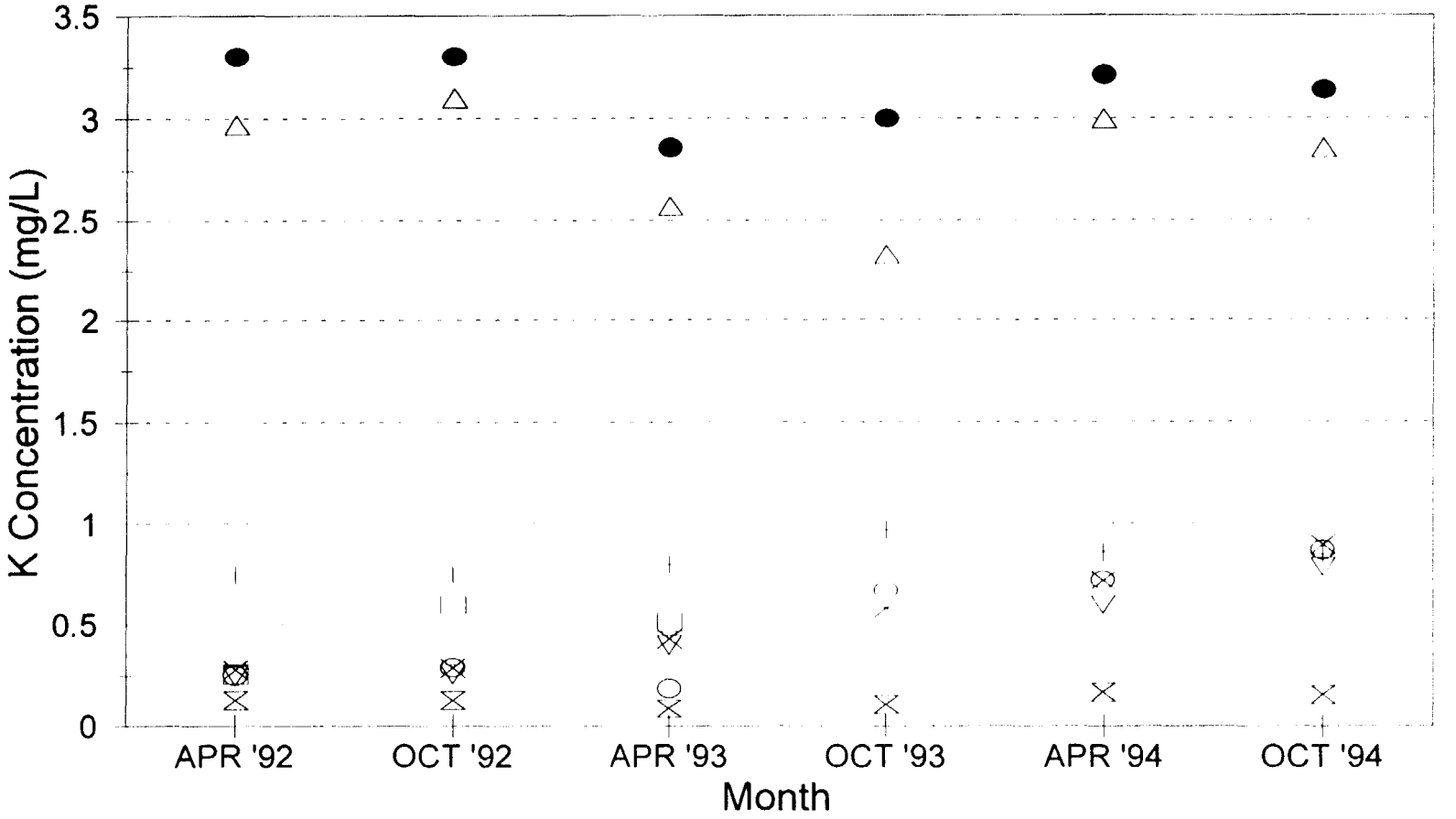


□ Treatment Plant	▽ KTD	● Woman Spring	△ Man Spring
+ Zarqa River ??	× Abu Zeighan Canal	⊠ KAC, Sawalha	○ KAC, Maadi

EXHIBIT 26

Potassium Conc., Zarqa River and KAC

April and October, 1992-1994

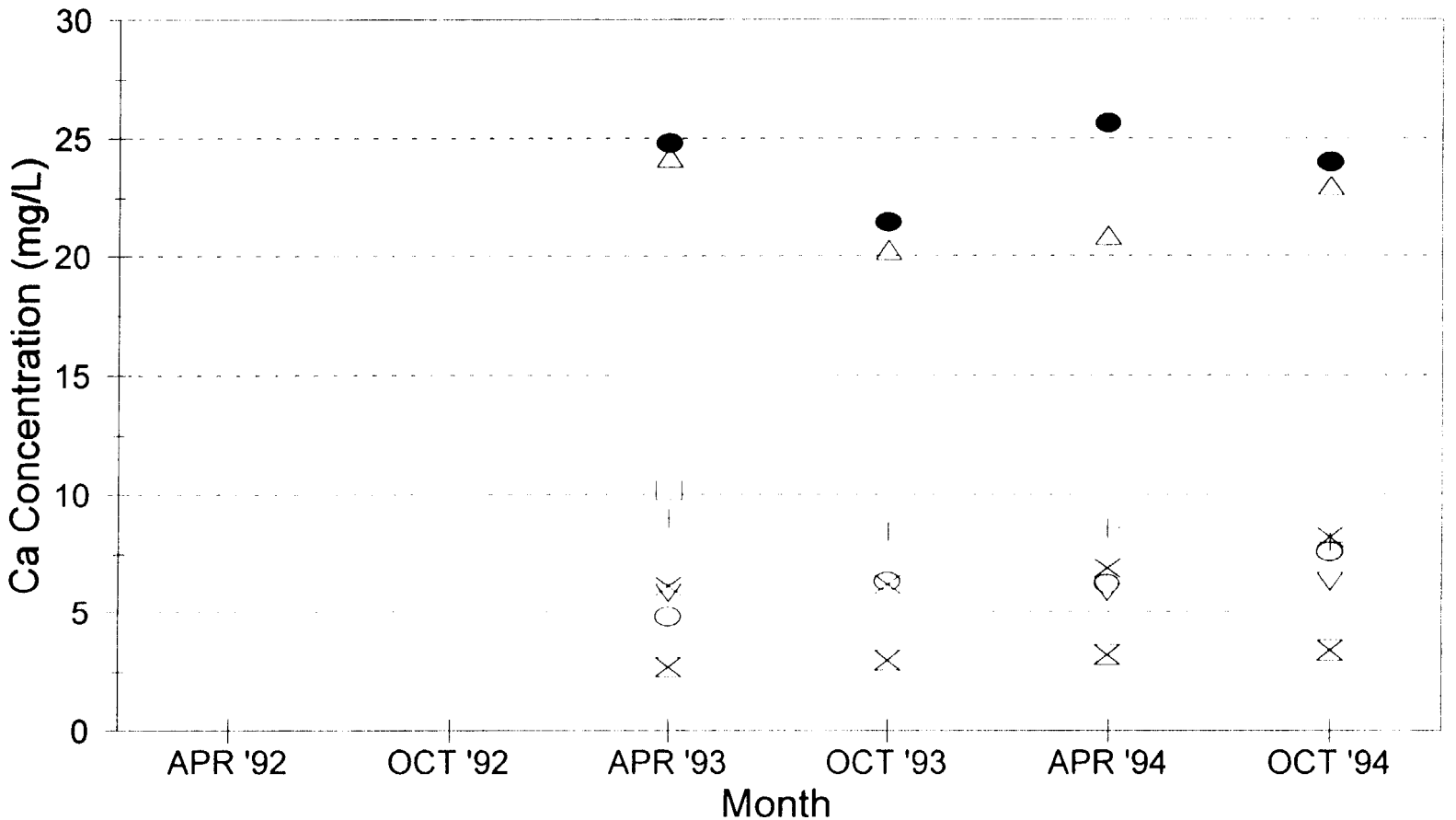


□ Treatment Plant	▽ KTD	● Woman Spring	△ Man Spring
+ Zarqa River ??	× Abu Zeighan Canal	⊠ KAC, Sawalha	○ KAC, Maadi

EXHIBIT 27

Calcium Conc., Zarqa River and KAC

April and October, 1992-1994



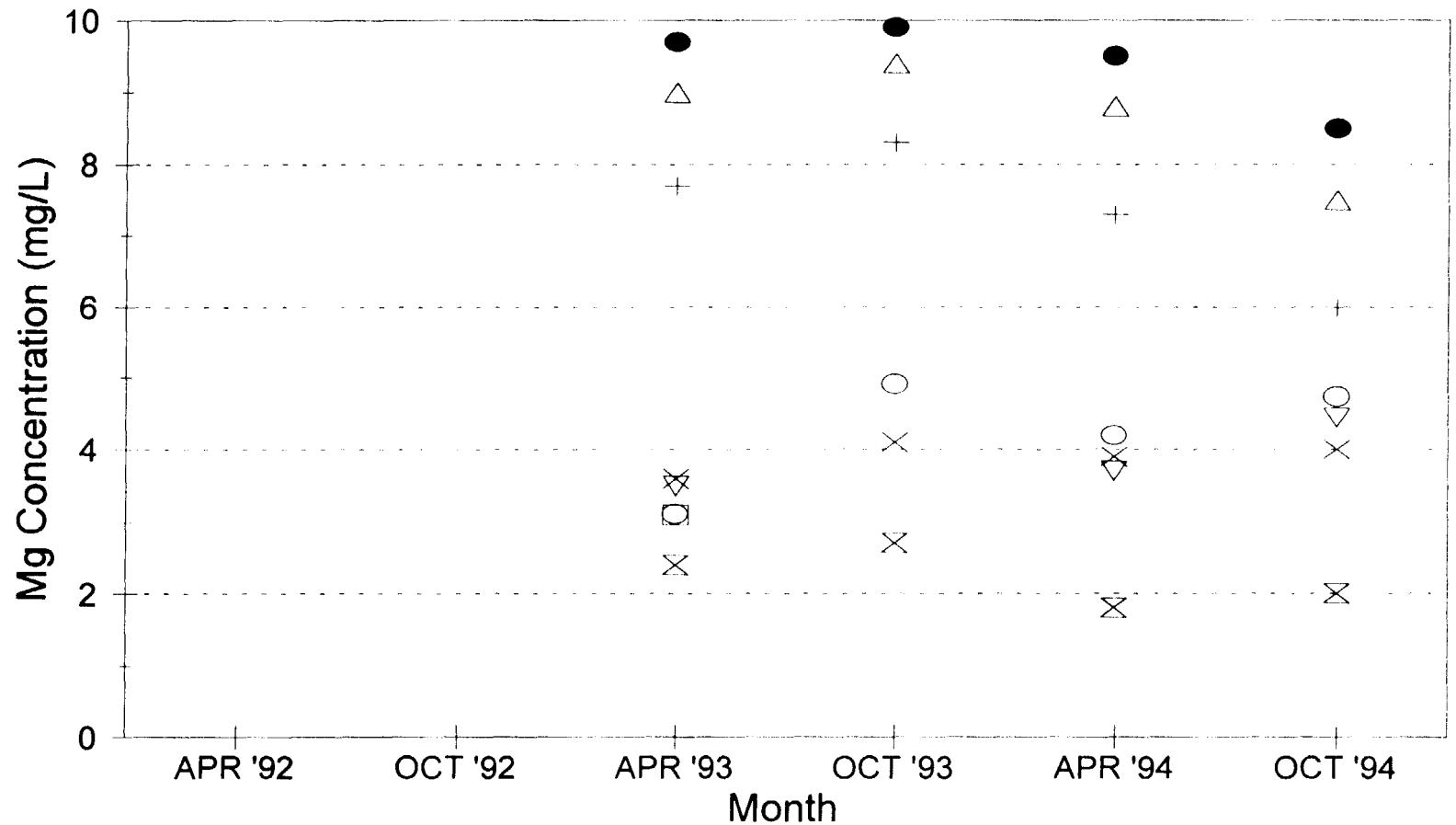
□ Treatment Plant	▽ KTD	● Woman Spring	△ Man Spring
+ Zarqa River ??	× Abu Zeighan Canal	⧖ KAC, Sawalha	○ KAC, Maadi

EXHIBIT 28

59

Magnesium Conc., Zarqa River and KAC

April and October, 1992-1994



□ Treatment Plant	▽ KTD	● Woman Spring	△ Man Spring
+ Zarqa River ??	× Abu Zeighan Canal	⊠ KAC, Sawalha	○ KAC, Maadi

EXHIBIT 29

90

Sulphate Conc., Zarqa River and KAC

April and October, 1992-1994

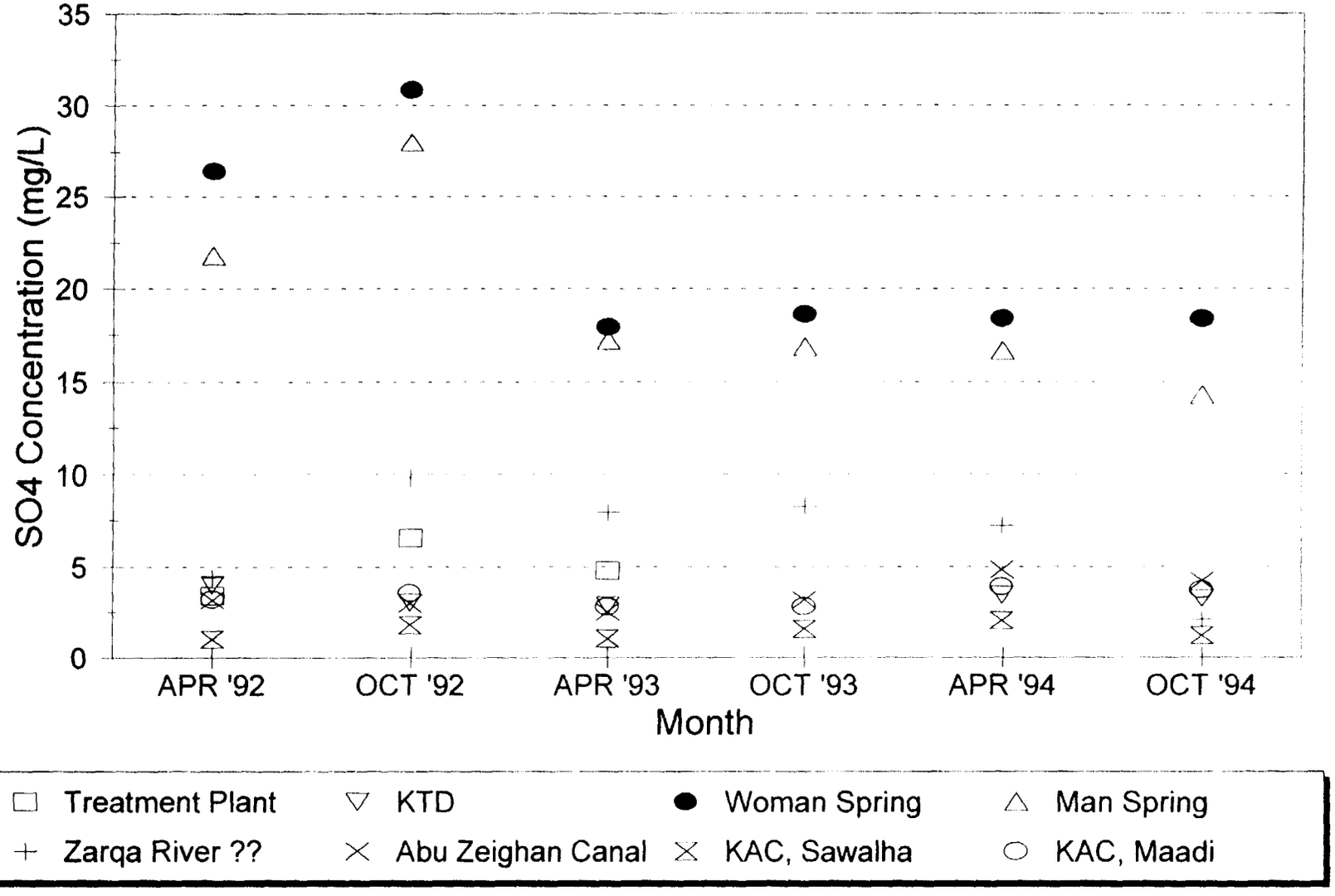


EXHIBIT 30

9/