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TEMPORAL AND SPATIAL CHANGES IN WATER QUALITY OF THE EUPHRATES RIVER - IRAQ

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Abstract

Iraq, for the first time in its long history, is facing a dire water crisis that depends on the decrease in the quantities and degradation in the qualities of the water that enters its borders via Tigris and Euphrates rivers. These two rivers are supplying more than 98% of Iraq's water demands for various purposes. Water pollution, desertification, drought, and deterioration in water quality are taking a toll on people and the environment. Degradation of these rivers has become a serious problem. There are many reasons leading to this degradation in quality and quantity of surface water in the river basins, many of them influenced by natural factors such a rainfall, soil erosion, temperature, weathering of rock and the dissolution of water-soluble salts, and anthropogenic changes that have direct effects on the water quality and flow rates. It was found that the water quality of the Euphrates River, which we focus on here, deteriorated due to the decrease in the discharge rate of the river and increase in the concentration of pollutants of the flow throughout the course of the river. This happened due to many reasons, such as irrigation return waters, impacts of dams, disposal of untreated wastewater from domestic use, disposal of untreated industrial wastewater, increasing number of people throwing their solid waste into the river, and illegal practices with complete disregard for the river environment such as in-house slaughtering or illegal wash car places and the water diversion from Al-Tharthar depression. In addition to these negative factors, the very gentle gradient of the river makes self purification of the river slow and not very effective.

This work aims to study the temporal and spatial changes in water quality of the surface water of the Euphrates River in Iraq, and its effects on the ecological system by monitoring and investigating more than 20 water quality parameters and elemental concentration as well as elemental load throughout the course of the river. Overall, this study has three goals: First, to reveal the changes in water quality parameters. Second, to identify the reasons for these changes. Third, as results of all these changes, many negative consequences concerning human beings and aquatic life happen, so we should try to limit and mitigate the negative consequences concerning these changes by submitting proposals for improvement. The main period of study extended to more than two years, where the results were compared in two ways: first, between three sites, and second, with the results for the same parameters from previous studies. The study also revealed that there is a large difference in water flow rate between years, as well as during the year itself, which depends on whether the year is dry or wet, besides the fact that the water discharge from Euphrates is completely controlled by upstream countries. There are marked changes in the concentration of elements and some components, when we compared the results with previous studies, indicating an increase in concentration of pollutants over the years, and fluctuation in discharge quantities with a decreasing trend. Iraq, which is a downstream country, is affected by these changes, and with the absence of any binding water sharing agreement, the effects of these changes will be disastrous. The analysis of the river water revealed a progressive degradation in quality, where the lower stretch of Euphrates is the area that has the most serious degradation in water quality, especially the region that extends from south of Bagdad to Qurna city in the south of Iraq. The study ends with a set of conclusions and recommendations, as well as a list of references which this study has depended on.

DEDICATION

I dedicate this humble work and all my works to my mother, who taught me the meaning of tender. To my wife, who taught me the meaning of sacrifice, and thanks for her support and encouragement, to my brother and my sister, to my kids, to all who loves Iraq and drank from the water of Tigris and Euphrates with all my love...

ACKNOWLEDGMENTS

My great thanks are to my supervisor Prof. Dr. Magnus Larson whom I see as a man full of enthusiasm to learn, to search, and to teach. His advices, criticisms and valuable comments have been very useful to me and orienting me in the right direction.

I would like to thank Mr. Riad Ghraib to Gave me a chance for complete my post graduate study with all my respect and appreciation.

I would like to thank Mr. Qasem Al Taiar and Ms Ahlam from Karbala water supply office for helping me in taking samples from the river within third sample station area, analysing the water samples and for supplying me with the data.

I would like to thank the staff of Al Anbar water supply laboratory for helping me in taking samples from the river within sample area station 2, analysing the water samples and for supplying me with the data.

Information used to develop (figure 6.5 and table 6.4) was kindly provided by Dr. Hassan Al Janabi.

Many thanks to Mr Assad for help to explain how to use Multivariate statistical techniques (MST) in spatial-temporal analysis. MST was used to segregate and examine the water quality data procured from the sample analysis.

Finally, I want the person that I have forgotten, while I was writing these sentences, to forgive me.

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Term	Explanation
A.D	Calendar based on the traditionally reckoned year of the birth of Jesus
Alk	Alkalinity
APHA	American Public Health Association
B.C.	Before Christ
BCM	Billion cubic meter
BOD	Biochemical oxygen demand
DO	Dissolved oxygen
DW	Drinking Water
EC	Electrical conductivity
EOD	East outfall drain
EPA	Environmental protection agency
FAO	Food and agricultural organization
GAP	Great Anatolia Project
GWD	General water directorate
Hard	Hardness
JTC	Joint Trilateral Committee
MCL	Maximum contamination level
MOD	Main outfall drain
MOE	Ministry of environment
MOMPW	Ministry of municipalities and public works
MOWR	Ministry of water resource
NGO	Non government organization
TDS	Total dissolved solid
TSS	Total suspended solid
Turb	Turbidity
UNEP	United nation environment program
WHO	World health organization

CHAPTERS

Chapter 1

Introduction

1.1 Background

The region of Iraq was known in Europe by the ancient Greek name Mesopotamia. Mesopotamia literally means "The land between the rivers". It has been identified as the cradle of civilization (figure 1.1). Since 4000 B.C., Iraq has been home to several great ancient successive civilizations such as Sumerian, Akkadian, Assyrian, and Babylonian (web reference 21).

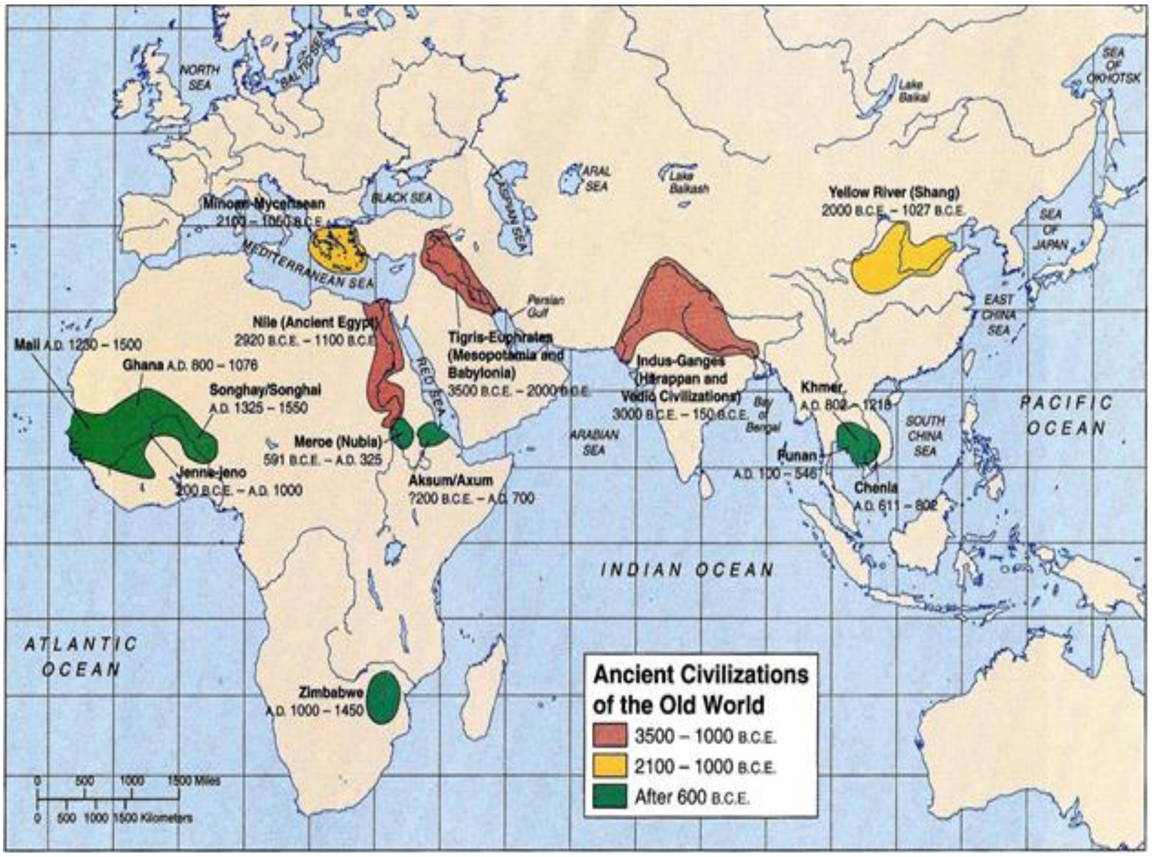


Figure 1.1 Ancient civilizations of the old world (Web reference 25)

Owing to the extremely arid climate, and the topography of the land (it is almost flat), however, the farmland of the Mesopotamian alluvial have suffered from *"salt accumulation and water logging problems since 2400B.C, during the Sumerian age"* (web reference 42). Many of these ancient civilizations disappeared over the years due to the absence of care for the irrigation canals systems.

Note: the italic text between markers (here and in other places) indicates that the text is quoted from another author (citation is given).

1.2 Historical overview of ancient water systems in Mesopotamia

General information

Mesopotamia has harsh climate, little rain, and is supplied basically from surface water of Tigris and Euphrates Rivers, which carry a lot of silt. Accumulated silt over years increase the fertility of the farm land. In Mesopotamia and for 6000 years irrigation has been an important base for farming and food production (web reference 1). Mesopotamia's river basin reveals evidence of irrigation projects dating back over six millennia (Bagis, 1989). The basin produced an extra supply of food, and by 3000 B.C, farmers in Mesopotamia had invented the sickle, hoe and plough, which improved the efficiency (web reference 43). The increase in food production (by using these new inventions) made it possible for some people to give up farming and live in cities. The irrigation systems of Mesopotamia were different from the ones in modern day. It was open systems consisting of canals, gated ditches, levees, and gates which played significant roles in the improvement of Mesopotamian civilizations. These canals with inventions were representing the major irrigation system measures and it reflects the urban lifestyles, because they were the start of development. They allowed increased crop production, which led to a reliable source of food, which meant that a larger population could be supported. Inventions and improved agriculture helped not only to develop the ancient Mesopotamian economy, but it also aided to a large extent in the building of cities by the Sumerians and the Akkadians. Major cities like Ur, Lagash, and Uruk emerged on the Euphrates tributaries (web reference 2) and the branches of the Tigris (figure 1.2). Adding to irrigation, rivers provided the necessary resources for food such as fish, which was abundantly available, birds, as well as reeds and clay which was used for building materials.

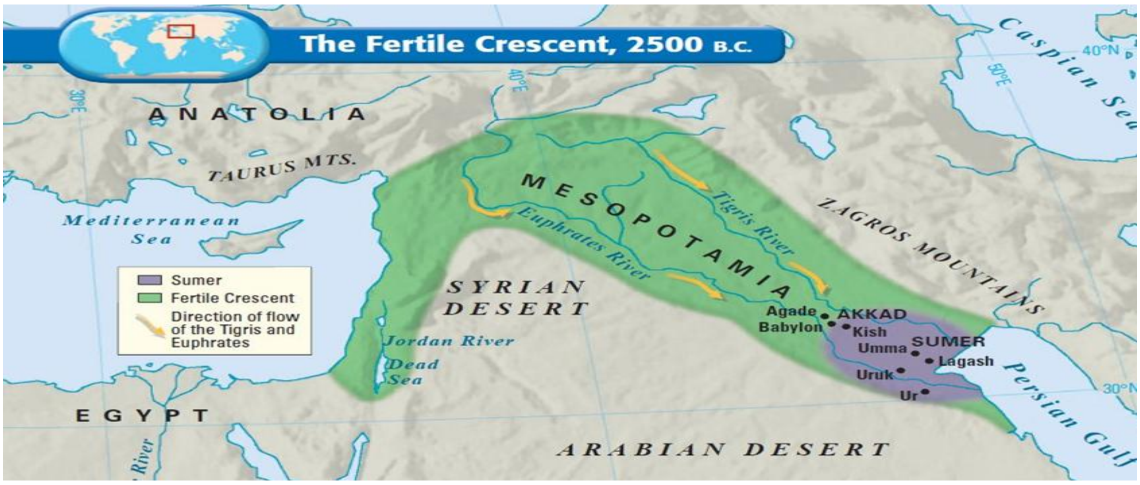


Figure 1.2 Ancient cities on Tigris and Euphrates (web reference 2).

The main principal of irrigation in Mesopotamia was of the basin type, taking the water from the river by digging a gap in the bank and allowing the water to flow throw open ditches, then closing the gap after having irrigated the land by filling back the bank with mud; thus, it was an open channel system (figure 1.3). Some ditches and canals may have been used for long time before they were deserted. Thus, the irrigation system in Mesopotamia was able to support an increasing population in the ancient cities. When King Sargon II, invaded Armenia in 714 B.C., he saw the “qanat” which is a “*tunnel used to bring water from an underground source in the hills down to the foothills”* (web reference 44) and applied it in his kingdom.

The city of Lagash (one of the Sumerian cities) was located downstream in the irrigation system based on the Euphrates River, and for this reason, it suffered always from shortage of water in a dry year, and it received the most polluted water. Entemena of Lagash (Entemena was a son of En-anna-tum I), decided to open a new canal to withdraw water from Tigris River, but the addition of poor-quality water from the Tigris river led to rapid salinization of the soil (web reference 1).

The engineers in Mesopotamia carried out constructions such as weirs, diversion dams, and reservoirs for water storage. They lifted the water to higher levels for supplying canals that carried water long distances across the flat land (figure 1.3). The Mesopotamian irrigation procedures were more extensive than for the Nile civilization. Engineers in Mesopotamia may have learned design and perform irrigation projects from the ancient nation of Urartu (a kingdom centred on Lake Van in the Armenian Highland). The Mesopotamian irrigation projects were quite advanced and matched only by the Chinese and Egyptian civilizations (web reference 1).

During the Abbasids Caliphate, which was based in Baghdad from year 762 A.D until its demise in the year 1258 A.D (web reference 30), they renovated some existing irrigation projects and extended others to become large-scale projects. One of these projects drew water from the Euphrates at five separate locations, and conveyed it in parallel canals across the flat land to irrigate a large area south of Baghdad. This irrigation system improved the agriculture and increased food production, thus supporting the constancy of the Baghdad civilization, which is remembered up these days through different legends (e.g., Scheherazade, the Caliph of Baghdad, and the Arabian Nights) (web reference 21). It is worth to note that the system (open canal) required a lot of physical maintenance besides causing a lot of salinization in the soil and increasing the salinity downstream.

Because of weakness and extravagant overspending, the central government of the Abbasids began to fail in the 12th century. A contributing reason was probably the silt-carrying capacity of the river and poor maintenance, causing the canals to become silt-choked, which led to a deteriorated irrigation system, and the lands becoming subject to over-logging. “*The deathblow to the irrigation system was natural: massive floods about 1200 AD shifted the courses of both the Tigris and the Euphrates, cutting off most of the water supply to the Nahrwan Canal”* (web references 1).

Around 2400 B.C the Al Nahrwan canal was built, which is considered to be one of the earliest canals in ancient civilization. It was constructed to provide water for domestic use and irrigation, and this canal is long 300 km long (web reference 4).

The Abbasids (during the last period) were too incompetent to carry out maintenance and repairs, and the agricultural system collapsed. In 1258AD Mongols devastated Iraq and destroying everything they encountered (web reference 1). After the Mongolian attack, most of Iraq land remained a desert for a long period of its history.

Problems at that time

The plains of Mesopotamia are very flat, poorly drained, and have a harsh climate, so that the region has always had persistent problems with poor soil, drought, frequent flood waves, silt accumulate, water logging and salt accumulation. The "*floods were violent and unpredictable, destroying villages and taking many lives"* (web reference 43). Floods sometimes caused rivers to branch out or change courses. A lot of troubles to the farmers' crops have been caused by rivers changing their course (Frenken, 2009).

Because of variations in the natural environment, causing problems like drought or flooding, Mesopotamian engineers had to worry about many issues regarding water storage and flood control, as well as irrigation water. Water carries a lot of silt which accumulated in the canals, choking them without continual maintenance. Another problem was the difficulty associated with draining the excess water from farmland, and because of this water logging occurred, which led to salt accumulation in farmland. It is worth to note that the plain of Mesopotamia is almost flat, and the bed of the Euphrates is higher than that of the Tigris (Isaev, 2009). This implied that during flooding the excess water from Euphrates found its way across the land into the Tigris River. Engineers at that time tried to use this gradient and take this phenomenon into account in their irrigation schemes, by using Euphrates as the supply "river", and Tigris as a drain "channel".

Figure 1.3: The irrigation systems used in Mesopotamia (web reference 31).

1.3 Preview

Tigris and Euphrates rivers can be classified as large rivers by world standards. The water sheds of both these rivers are mainly situated within Turkey, Syria, and Iraq. The Euphrates, which is around 3000 km, is the longest international river in western Asia. The total flow of the Euphrates is not as great as that of the Tigris. The river regimes are similar, with the mean annual discharge of the Euphrates being (31-33) BCM/year (or 983-1046) m^3/s. These numbers represent the discharge value through Euphrates at Iraqi-Syria border before dam construction (Jehad, 1984).

Euphrates rise in the highlands of Turkey and it is formed from the Karasu and Murat tributary rivers. It is fed by melting snows, with 88% of total flow coming from tributaries within Turkey. The maximum flows of the Euphrates occur in April and May, and the discharge during these two months accounts for 42% of the annual total (Shahin, 2007). Minimum flows occur during August to October and contribute only 8.5% of the total annual discharge. In Syria, there are three tributaries which pour their water into the river, and their share is 10% of the total flow in the river. In Iraq there are no tributaries, but about 2% comes from wadi. The river joins downstream with Tigris and forms Shat Al Arab, which flows for another190 km before pouring into the Arabian Gulf (Bagis, 1989).

Water quality control is an important protection issue. Understanding the chemical, physical and biological dynamics of a river are important for assessing the consequences of the river degradation, and it is critical for maintaining water quality and for limiting the effects of degradation. The analysis of existing water quality parameters and knowing the trend of their changes are useful for making quantitative decisions that deal with water quality, because these decisions are the foundation for the planning of water pollution control programs.

In all riparian countries, the water from Euphrates is used for domestic, municipal, industrial, agricultural, hydropower production and in lesser degree for recreational purposes. Day after day, with increasing demand in these sectors as a normal result of urbanization and the rapid growth in population, also including climate change, water becomes more and more precious.

As a result of natural factors and improper human activities in many riparian countries, problems arise with the river water. Spatial and temporal changes in the characteristics of these rivers have occurred over the years and led to an increase in the environmental problems, including water contamination. The water of Euphrates and Tigris rivers come from rain and snowmelt which falls on the mountains located in the south of Turkey and the north of Iraq. Water discharges from these rivers are changeable according to the season of the year, and from year to year, and combined with this fluctuation in flow discharge, there is a large difference in the concentration of pollutants with respect to time and place.

The causes of this deterioration are not only natural, but mostly man-made, aggravated by natural occurrence of drought conditions and the nature of soil that the river is passing through. The upstream riparian countries, particularly Turkey, has tended to develop their water use projects unilaterally, without careful consideration for the environment and the actual water potentiality of the river basin, causing several problems. By constructing control structures, including dams, reservoirs, and diversion structures, the drought conditions have been prolonged, thereby inflicting harm on the Iraq economy and environment. As a result, Iraq may not be able to meet the water requirements for human needs in near future (Trondalen, 2006).

On the other hand, Iraqi water resources have suffered from severe pollution and an unreasonable management policy during the last years. Iraq passed through many crises such as wars, armed conflicts, and the sanctions forced by UN. These crises, combined with the neglect of governments to support infrastructure projects and limited environmental awareness among people, have harmed Iraq's water resources sector (IAU, 2010). The Euphrates River has been subjected to the continual disposals of industrial and irrigation wastes directly into the river without quality monitoring, adding pollutants that are harmful to the aquatic life.

Euphrates River has problems of both quantity and quality. In the last four decades, Iraq has passed through dry years, which make the matter worse, large dams and reservoirs have been constructed upstream; consequently, the discharge from this river has continuously decreased. The large evaporation losses together with the dissolution of salts from the soils of the depressions in artificial lakes, bad governance politics and war effects, and traditional irrigation, all these factors having contributed to the water degradation and acted to increase salinity in the river water and rendered it unsuitable even for irrigation purposes. For example, increasing salinity in the delta downstream is a continuous problem. The concentration of dissolved solids has increased far beyond the upper permissible limit given by WHO standard, which is equal to 1500mg/l (Al-Tikrity, 2001). Increasing dissolved solids typically means increasing substances which is harmful to aquatic life.

1.4 Objectives

The main objectives of this thesis are:

- To determine the spatial and temporal changes in water quality throughout the course of Euphrates River in Iraq, together with the main pollution sources that define the water quality, by investigating a number of water quality parameters.

- To identify the reasons for these changes.

- To estimate the effects of these changes, including many negative consequences for human beings and aquatic life. Aquatic organisms are highly sensitive to change in physical and chemical properties of water such as dissolved gases (O_2 and CO_2) pH, alkalinity, hardness, nutrients, and other limnological characteristics.

- To limit and mitigate the negative consequences concerning these changes by submitting proposals, suggestions and appropriate solutions to improve the water quality in Euphrates River.

1.5 Procedures

Pollutants that are introduced into the aquatic environment are distributed in water, sediment, and biota, and in this study the focus is on the first one. The quality of water was monitored during different sampling periods (e.g., 2002, 2003, 2009, and 2010), and the results compared for the same parameters at three different stations along the river, as well as with previous studies. Proper assessment of the water quality in the Euphrates River requires analysis of data on chemical, biological and physical parameters over a sufficient time throughout the course of the river.

A literature review was first performed about water resources in Iraq focusing on the Euphrates River, both concerning the hydrology and water quality, and on sources of pollution for rivers in Iraq. The morphology of Euphrates River and the main pollution sources were identified. Monitoring of the water quality in the river through a number of parameters provided the basic information. These data provided valuable insights into the spatial and temporal variation in water quantity and quality.

In this context more than 20 water quality parameters of the surface water of the Euphrates River were investigated. Different physical, chemical, and biological parameters were examined from three sampling stations, in order to evaluate the quality of the river and to observe the changes in concentration of pollutants in the water.

Three sampling stations located along the studied stretch of the Euphrates River were chosen. The stretch investigated exceeded 2000 km in length with the first station in the upper part of Euphrates River (in Turkey). Data from this station were obtained by a Turkish team during 2002 and 2003 and it represents the upstream quality*. The station encompasses 13 locations (see appendix 3 for more details about locations), and each location includes 19 parameters, implying that more than 500 samples were analysed for each sampling event. The information from this station was used as a base line in the comparison with the other stations. The second sampling station is located on the Syria-Iraq border, in Husaibah (within Iraq), and the sampling were performed during 2009 and 2010, where 7 locations were chosen and each location included 18 parameters (more than 200 samples were analysed for each event). The last sampling station is located within Karbala province (middle stretch of Euphrates within Iraq), and this represent the downstream conditions for the stretch chosen. The period of study extended during the whole of 2010, and it encompassed 39 locations along the river within Karbala, including 16 parameters with more than 650 samples analysed per event (see appendix 1). All these samples were collected and analyzed by professional teams in official laboratories. The flow system were analysed and measured as well as the change in flow discharge along the river over years

The period study covered more than two years, and the results were compared in two ways: first, between the three sites, and second, for a specific parameter with results from previous studies. The statistical analysis revealed patterns of change in time and space that were related to changes in factors determining the water quality, such as dam construction, land use, impact of urbanization, industrial and commercial development, and demographic characteristics. The analysis was carried out for a number of parameters, for example, turbidity, salinity, BOD, TSS, DO, TDS, and some others.

Proposals and some remedial measures to improve the water quality in the Euphrates River were also discussed.

* There are several studies for successive years available on upstream quality water. The study (water quality of surface water in lower Euphrates basin; Mehmet and et al, 2010) has been chosen to represent upstream water quality because:

- The study was approved by Turkish Standards Institution.
- The flow rate during the period of study (which is in 2002 and 2003) for the first sample station through Euphrates at the Syria-Iraqi border is similar to the flow rate for the period of study (which is in 2009 and 2010) at the second and third sample station.

Chapter 2

Water Resources in Iraq

2.1 Location:

The water resources in Iraq are concentrated to the Tigris and the Euphrates Rivers, which represent together 98% of the water resources in the country (FAO, 1994). Euphrates and Tigris are two of the largest three rivers in the area that are commonly referred to as the Middle East (figure 2.1). These two rivers play an extremely important role for the water availability of this area. Within this area, just these two rivers together with the Nile are classified as large by world standards (Al-Hadithi, 1978). Euphrates and Tigris (with some of their tributaries) originate in the highlands of Turkey, and flow through a region between 45 degrees North and 25 degrees North latitude. Euphrates crosses Syria before flowing into Iraq and meeting Tigris, which also crosses Syria, and together they form Shat Al Arab in the south of Iraq, jointly flowing 190 km before pouring their water into the Gulf. Iraq is located between latitudes 29° and 38°N, and longitudes 39° and 49°E (a small area lies west of 39°), encompassing 438,320 km^2. It includes 924 km^2 of inland waters and it is the 58th largest country in the world (web reference 20).

Figure 2.1 Middle East countries (web reference 8)

The Middle East is considered one of the most important regions in the world. This importance is due to several reasons: it contains many resources and it has been the birthplace of many great ancient civilizations. Most of the seven ancient wonders of the world were located within this district. The Middle East includes many countries such as Turkey, Cyprus, Iran, Afghanistan, Saudi Arabia, Yemen, Oman, United Arab Emirates, Qatar, Bahrain, Kuwait, Iraq, Syria, Jordan, Lebanon, and Israel. The Middle East is literally in the middle of the Eastern Hemisphere, where Europe is to the west of these countries and Asia to the east.

2.2 Historical evolution

In the Middle East, water, which is regarded as one of the most precious resources, is becoming scarce. Thus, in this arid region water is causing an increase in political hostilities. Tigris and Euphrates basins, which are mainly located in three countries within the Middle East, that is, Turkey, Syria, and Iraq, play important roles in the water availability of this district. The water is an essential resource for survival and economic activities for all human beings. Tigris and Euphrates river basin has been home to the rise and fall of great civilizations such as the Sumerians and Babylonians. The first attempts to manage water resources in the world were found in ancient Iraq, both in terms of legislation, as in the code of Hammurabi, which is shown in figure 2.2 (web reference 9), or in the construction of canals, dykes, and control structures (web reference 4). These ancient **c**ultures used the rivers extensively. Because of arid climate and the topography of the land (almost flat), several problems appeared, though. The lands on the Mesopotamian alluvial have suffered from salt accumulation and waterlogging since the 3rd millennium B.C., and year after year with poor management and weak maintenance of the canal system the situation has been getting worse. The irrigated lands were progressively abandoned, thereby ancient civilizations have disappeared (web reference 20).

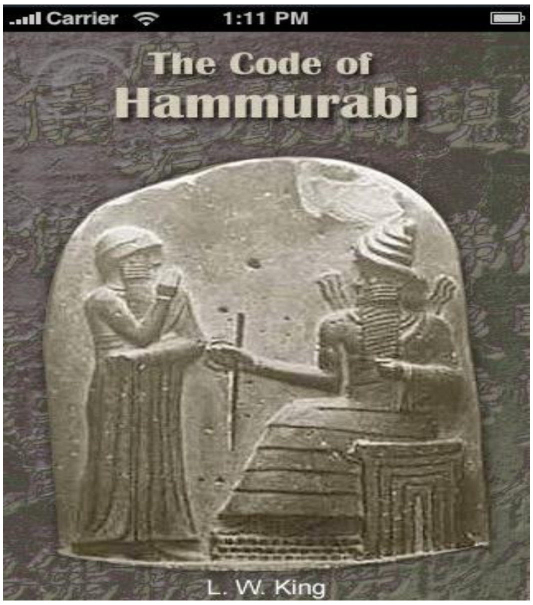


Figure 2.2: The upper part of the stela of Hammurabi (Code of laws) (web reference 9)

Before water shortage, Iraq thrived with efficient irrigation systems and flood control structures. The first flood control (date unknown) structures were built on the Habbaniya and Abu Dibbs lakes (now it is called Al Razaza), followed in 1911 with the construction of the Al Hindiah Barrage on the Euphrates (Frenken 2009).

In the past, Iraq used to receive (31-33) BCM/year of water at Iraqi-Syria border (different authors has given somewhat different numbers). Riparian countries tend to find most of their water from those two rivers. The water policies of upstream countries, "*with more than three decades of war in Iraq, sanctions and neglect of infrastructure combined with limited environmental awareness, have undermined Iraq's water resource management system"* (IAU, 2010). Increase in salinity concentration, deterioration of water quality, decrease in water flow rates, and the disappearance of major waterways which are illustrated in figure 2.3, are impacting the everyday lives of people, as well as the aquatic system and other organisms in Iraq.

Figure 2.3: The drought in Iraq waterways (web reference 10)

Turkey, in the last few decades has tended to develop their water use plans unilaterally, without careful consideration for the environment and the actual water potentiality of the river basin, causing a severe shortage of water in Iraq and sometimes in Syria. Two of the main objectives in Turkey are to use the rivers for hydroelectric power and irrigation. A new project called GAP was started there in the 1960s (Dagan, 2004). This project was first introduced to provide irrigation water and electricity power to the poorest districts within Turkey. It involves the construction of 22 new dams and hydroelectric power plants (about 19) on the Euphrates River alone (Bagis, 1989).

Before the 1950s Syria made little use of the Euphrates and Tigris rivers. After 1970 Syria executed large-scale projects to utilize the water of these rivers, and at present time 80-90% of the surface water in Syria comes from the rivers (Beaumont, 1996). The construction of dams on the Euphrates, as well as on its main tributary, Khabur, supplies water for irrigation. In Syria the dam is not only important for irrigation but also for energy production. Also, Syria is experiencing a large increase in the urban population, and these factors altogether have contributed to increased water requirements and needs.

Due to seasonal fluctuations in the Euphrates River flow and the effects of external water control structures along the river in upstream countries (Turkey and Syria), and because of Iraq is located downstream of the river, taking in account that most of the head water of Iraqi rivers originate outside of Iraq, water storage was and still is one of Iraq's main priorities. In addition, one should take in account that irrigation periods do not coincide with the maximum flow in the rivers and that Iraq is the most arid of the three riparian countries. Thus, Iraq's water resources is highly correlated with the condition of water resources in upstream countries (Turkey and Syria), which creates an exposed position. All water projects within the river basin undertaken in Turkey and Syria have direct impact on the water flowing into Iraq. This makes Iraq very vulnerable to any changes these two countries make on the rivers.

The problems in Iraq are more pressing than in Turkey and Syria. Iraq is very dry and more flat making it prone to evaporation. Iraq has extremely dry periods, sometimes lasting up to six months from May to October. The temperature during this time can get up to 120 degrees Fahrenheit. The climate is a major factor in producing high evaporation, but the artificial lakes upstream the dams, which have large open water areas that increase the quantity of evaporation and increase the pollutant concentration in the storage water, also contributes to the loss of water from the system through evaporation.

Urbanization, industrialization, increase in population, and expansion in farming and traditional irrigation systems used, all these factors lead to increased water demand in these three countries. With the construction of many dams in Turkey and Syria, the quantities of water that enter Iraq have decreased, and with the execution of an ambitious water management plan for Turkey (GAP), the quantities of water will decrease more and more.

All the factors mentioned above, in combination with natural factors like climate change and other human activities, which include the intensive use of pesticides and chemicals in farming that follow with the return irrigation flow into rivers, as well as discharging untreated sewage water into waterways, have led to deterioration in water quality and quantity that enters Iraq through the Tigris and Euphrates rivers.

2.3 Main rivers system

The Tigris and Euphrates rivers are the main sources of water in Iraq with a river basin area of 126,900 km^2 for Tigris and 177,600 km^2 for Euphrates without tributaries (Frenken, 2009). Both these rivers originate in the highlands of Turkey and share their physical, climatic, hydrologic, and geomorphologic characteristics (figure 2.4). However, there are different perspectives on to how treat these two river basins, and some specialists have identified these rivers as twins. Thus, for purposes of integrated water resources management, it is useful to treat them as belonging to a single basin (Kliot, 1994). It is worth to note that the Tigris and Euphrates have different flow patterns and flow rates.

Figure 2.4 Tigris and Euphrates rivers (web reference 11)

2.3.1 River Morphology

The **Tigris River** is the second longest river in Southwest Asia with a length of 1840 km (Kolars, 1994). It has its origin in the highland of eastern Turkey, and then flows south-eastward along the Syrian-Turkey border for 32 km before entering Iraq. The average annual flow volume of Tigris as it enters Iraq is estimated to be 21.2 km^3. It has 18 tributaries, and six of them are fed to Tigris within Iraq as illustrated from upstream to downstream in table 2.1. Most of these tributaries originate from the melting of snow caps accumulated during the winter months. Tigris is joining with the Euphrates at Qurna south of Iraq and forming Shat Al Arab, which flows 190 km before emptying into the Arabian Gulf (Isaev, 2009).

Table 2.1: Information about Tigris tributaries (web reference 32).

Tributary name	**Origin**	**Ave. flow rate for period 1974-1991 m^3/s**	**Basin area Km^2**
Greater Zab	Turkey	417.93	25810
Lesser Zap	Iran	244.1	21475
Al-Adhaim	Iraq	25.04	13000
Diyla	Iran	181.95	31896
Nahr Al Tib	Iran	31.7	8000
Al-Karkha	Iran	199.71	46000

The **Euphrates River** is the longest and one of the most historically important rivers of South-western Asia in terms of catchment area and length, and the second largest in terms of water volume. It is almost 3000 km long from Murat which is regarded as one of the two major tributaries to the confluence with the Tigris River at Qurna in south of Iraq (Quadir, 2007). Some 40% of the river lies within Turkey (about 1230 km), while the rest is divided among the two downstream riparian countries, with 25% being in Syria (about 710 km) and 35% in Iraq (about 1060 km) (Frenken, 2009). Euphrates River has its source in the highlands of Eastern Turkey near Mount Ararat in Lake Van at an elevation of around 4500m above sea level (figure 2.5). It drops on the average 2m/km of length in Turkey, as illustrated in table 2.2. The Euphrates River is formed in Turkey by the joining of four tributaries; the major tributaries are Murat (650 km long and 40,000 km^2 catchment area) and Karasu (470 km long and 22,000 km^2 catchment area), and the minor tributaries are Munzur and Peril. These four streams, which all originate in Turkey, are joined together around the city of Elazig at the location of Keban Dam and form the Euphrates River (mainly Murat and Karasu), which follows a south-eastern route to enter Syria at Karakmis point. The Euphrates continues its south-eastern course and is joined by three more tributaries within Syria, the Sajur which flows into the Euphrates on the left bank and Khabur and Balikh which flow into the Euphrates on the right bank. All of these three tributaries (within Syria) rise in the foothills of the Taurus Mountains along the Turkish-Syria border. Within Iraq there is no tributary feeding Euphrates River, with exception of the water coming from “wadis” in the upper reaches of Iraq (Hillel, 1994).

Table 2.2 Euphrates tributaries (web reference 32)

Tributaries name	**Length (km)**	**Catchment area (km^2)**	**Ava. flow rate for period 1974-1991 m^3/s**
Karasu	450	22000	Not available
Murat	650	40000	Not available
Munzur	Not available	Not available	Not available
Peril	Not available	Not available	Not available
Sajur	108	2042	4.12
Balikh	100	14400	6.34
Khabur	486	37081	45.01

Figure 2.5: The main tributaries of Euphrates River (web reference 12)

The annual discharge through Euphrates River (before dam construction in Turkey) is about 30BCM/year on the Turkey-Syria border (Kolars, 1994; Altinbilek, 1997). To this, a further 1.8 BCM/year is added within Syria from three tributaries, Sajur, Bligh and Khabur. The total flow of the Euphrates at Hit in north-west Iraq is given as 31.8 BCM (Beaumont, 1985).

The flow contribution percentage-wise for each country to the Tigris and Euphrates rivers is illustrated in table 2.3 and figure 2.6.

Table 2.3: The contribution water percentages on Tigris and Euphrates Rivers (web reference 32).

Country	**Euphrates**	**Tigris**
Turkey	88%	52%
Syria	10%	-----
Iraq	2%	36%
Iran	------	12%

The Euphrates and Tigris rivers join together approximately northwest of Basra south of Iraq, where the Shatt Al Arab is formed and continues until it empties its water in to the Gulf. The width of the river here varies from 232 m to 800 m, depending on the season and flow rate (Isaev 2009).

Shatt Al Arab carries the water of these two rivers and the southern marshlands to the Gulf, and the total river length is 195 km and the catchment area is up to 108000 km^2. It has one tributary, the Karun River which originates in Iran with a mean annual flow volume of 24.7 km^3. A large quantity of fresh water is brought by Karun River into the Shat Al Arab River (Daniel, 1994).

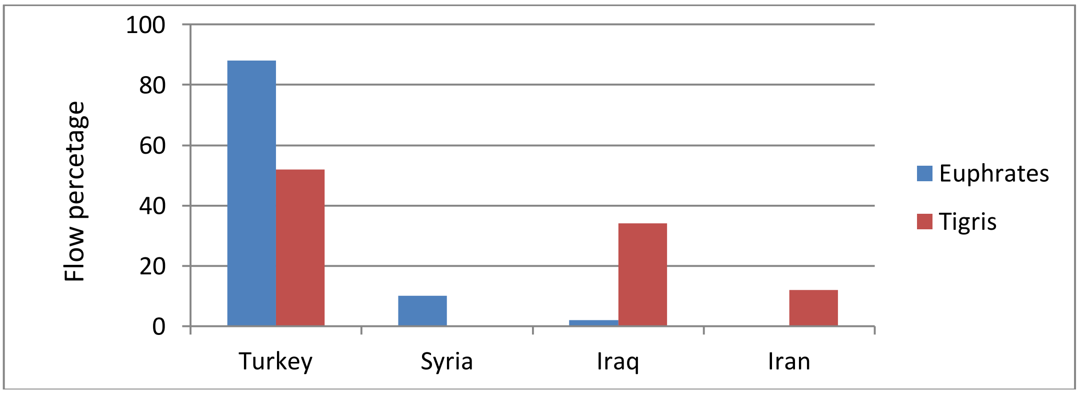


Figure 2.6: Contribution percentage-wise from each country to the flow in the Tigris and Euphrates rivers (extracted from several sources).

2.3.2 River basin

The Euphrates river basin lies primarily in three countries, Turkey, Syria, and Iraq, although small portions are within Saudi Arabia and Kuwait (figure 2.7).

Figure 2.7: Tigris and Euphrates River basins (web reference 45).

Hydrological characteristics vary greatly over the river basin. The rainfall of the area that lies in Turkey (which represents the headwaters of the rivers) (located from 45 deg north to 37 deg north) is abundant and seasonal. The area from 37 deg north to 25 deg north has arid or semi arid climate, where the river runs through the dry area within Syria and Iraq (Isaev 2009).

The farmland irrigated by water from Euphrates and its tributaries is: 1,777,000 ha located within Turkey, 800,000 ha within Syria and 2,500,000 ha within Iraq (Altinbilek, 2004). The total drainage basin area for Euphrates and its tributaries is 444,000 km^2 (Beaumont, 1978), and each country's share of the area is illustrated in table 2.4.

Table 2.4:The basin area in Euphrates riparian countries (Shahin, 2007).

Country	**% Of total basin area**	**Basin area km^2**
Turkey	28	124320
Syria	17	75480
Iraq	40	177600
Saudi Arabia	15	66600

As illustrated in table 2.5 the part of the basin within Turkey can be divided into three sub-basins with regard to the variation in topography and climate within the basin.

Table 2.5: The sub-basins within upstream river basin

Sub-basin name	**Area part**
Upper	Karasu tributary and the region of Keban dam
Middle	Murat tributary basin
Lower	Area from Karkaya dam to Karakmis dam

The upper and middle sub-basin are distinguished by higher altitudes and abundant precipitation compared to the lower sub-basin. Also, the temperature in upper sub-basin and in the middle one is much lower than along the river in the lower sub-basin. This part of basin has been regulated for hydro-electric power, agricultural, and urban water supply.

Through a series of dams and reservoirs, Turkey has the ability to “manage”, control, and harness the flow through Euphrates according to its needs. It has the ability to store large quantities of water and use it for irrigation and as well as for other purposes.

The part of the basin within Syria, which has a total area of about 75,480 km^2, as mentioned in table 2.4, has the same characteristic as the 3^{rd} sub-basin in terms of the climate conditions. Syria has arid climate and a large need for water from Euphrates River (Wakil, 1993). Owing to rapid population growth, which has led to increase in water demand, electric power supply, and food needs, Syria has focused on agricultural development in the river basin. In order to satisfy all these objectives, in addition to produce electricity, Syria sought to construct three large dams and a very large reservoir (Al Assad Lake). Also, it has a new plan to construct more dams and reservoirs in future.

The part of the river basin within Iraq has the largest catchment area among all the riparian countries. Iraq needs Euphrates water for food production and domestic water supply more than it needs it for energy production (Iraq has abundant oil which it can use to produce electricity). Iraq has constructed series of dams, reservoirs, and regulators along Euphrates River. However, Iraq has had problems with water quantity and quality, especially after upstream dam construction. The salinity that steadily increases along the river worsens the situation. Also, decrease in the quantity of water from the Euphrates is regarded as a continuous problem in Iraq.

2.3.3 Euphrates flow regime

Understanding the flow pattern of a river is very important in order to interpret water quality changes. Euphrates River has almost a yearly regular regime, characterized by two months of high discharge, which are the months of April and May, with maximum floods occurring between mid-April and early May under the combined effect of melting snow and rains (see figure 2.8). The river flow during just these two months is approximately 42% of the total annual flow (Kolars, 1994). This period is followed by eight dry months from July to February, and the flow in the river is decreasing after June reaching its minimum values around September to October. It is worth to note that the annual flow of Euphrates varies considerably from year to year.

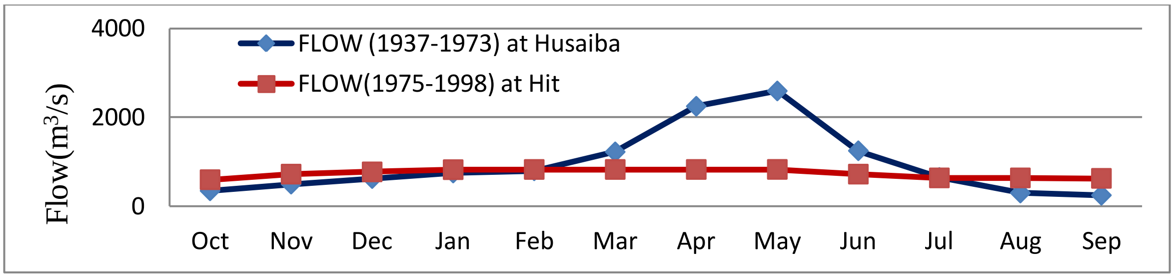


Figure 2.8: Monthly average discharge in m^3/s (numbers extracted, improved, and averaged from Jawad (2003) and other studies)

All major tributaries on the Euphrates River are located within the most "upper part" (upstream) of the River, which means that there is a big difference in the control of Tigris and Euphrates rivers. Thus, a single dam in the "upper part" of the Euphrates River will be able to prevent a major portion of flow through the river. Ataturk dam in Turkey is large enough to prevent huge quantity of river water and achieve very high level of flow control. On the Tigris River, however, there are more than 17 tributaries feeding the river with water, which implies that the control of this river requires the operation of a series of major dams on the individual tributaries to provide good control of the river flow.

The Euphrates flows rapidly in the upper course due to large differences in elevations. The first major tributary is Karasu, and it rises to an elevation of 3290 m amsl. The second major tributary is Murat, which rises to an elevation of 3520 m amsl. When they join together at the Keban dam, they have dropped sharply to an elevation of 693 m amsl. In the middle stretch, Euphrates passes a wide floodplain in Syria. The river drop 163m within Syria, and the river velocity becomes slower. Furthermore, along the last stretch in Iraq, the river drops only 53m over more than 800 km, and owing to this very gentle gradient, the velocity becomes very low and the river is consider to be a slow running stream (Shahin, 2007).

The flow in the Euphrates River depends on snow-melt and it is closely linked to the precipitation in the highlands of Turkey. Thus, the flow is highly seasonal, with high precipitation of snow during the winter resulting in peak flow in the river during the spring. If the highlands receive low precipitation it results in drought and water shortages in Iraq, and to a lesser degree in Turkey and Syria.

As a result of this climate, wide fluctuations in discharge occur and this in turn causes irregularities in the Tigris and Euphrates flow regime. The fluctuation discharge ratio in Tigris is threefold the value in Euphrates and ranges from 1 to 80 times in Tigris at Bagdad (Cressey, 1958), which means the flow could be reach up to 80 times the average flow, whereas in Euphrates, the value ranges from 1 to 28 times. A year, based on the annual flow in the Iraq Rivers, is generally classified as a wet year, average wet year, or dry year, depending to the natural factors of variation and the upstream management policy (storage or release).

The flow regime of Euphrates River in Iraq has changed remarkably after the construction of several dams in Turkey and Syria. In 1974 - 1975 the first clear changes were observed after the filling of Keban dam in Turkey and the Al-Tabaqa dam in Syria, leading to marked deficit in the river discharge in Iraq (Beaumont 1998). After 1987 several dams in Turkey and Syria were put into operation. The flow regime in Euphrates River became regulated by the upstream countries, particularly Turkey.

In order to compare between the natural flow regime (before dam construction) and the regulated flow regime (after dam construction), a statistical analysis was carried out as shown in tables 2.6 and 2.7, where most dams over Euphrates were constructed between 1974 and 1990.

Table 2.6 Natural flow of the Euphrates River at Hit[*1] (Beaumont 1998).

Euphrates flow as	**Natural flow (1924-1973) in billion m^3 / year**	**Year**
Min flow	16.8 (14)*[2]	1961
Max flow	53.5 (49.5)	1969
Mean flow	33 (33.2)	Mean flow for this period

[*1] Hit site within Iraq was used as the key point where Euphrates inflow to Iraq is observed before the operation of Haditha dam in 1985.
(...)*[2] Means another author give another number.

Table 2.7 Regulated flow of the Euphrates river at Husaibah[3] (Beaumont 1998).

Euphrates flow as	**Regulated flow (1990-2007) in billion m^3 / year**	**Year**
Min flow	9.56	(2000-2001)
Max flow	30.00	(1995-1996)
Mean flow	18.38	Mean flow for this period

[*3] Husaibah site within Iraq was used as the key point where Euphrates inflow to Iraq is observed after the operation of Haditha dam in 1985.

The above tables demonstrate that the river flow is controlled by the dam construction in upstream countries after 1974.

Owing to the large variation in discharge between years and during the year itself, and because Tigris and Euphrates have been engineered through the years to become nearly totally controlled by the upstream countries, it has become extremely difficult for Iraq, which is the most downstream country, to plan irrigation schedules or managing its water resources.

What has worsened the situation is that all riparian countries are pursuing their own water resources development projects individually without any cooperation, binding water sharing agreement, or considering integrated water resources management principals.

Chapter 3

Water Quality and pollution sources in Iraq

3.1 River water quality

The river water quality of the Euphrates, using the parameter TDS as an indicator for water quality, is varying greatly from place to place along the river (see figure 3.1) and over time (see figure 3.2). This variation is due to a combination of natural factors and human activities. Euphrates starts with good water quality at the head of the river, usually the TDS there is lower than 250 ppm, but the TDS gradually increases downstream, and at the mouth of the river into Shat al Arab, the salinity reaches over 4000 ppm and the quality becomes poor.

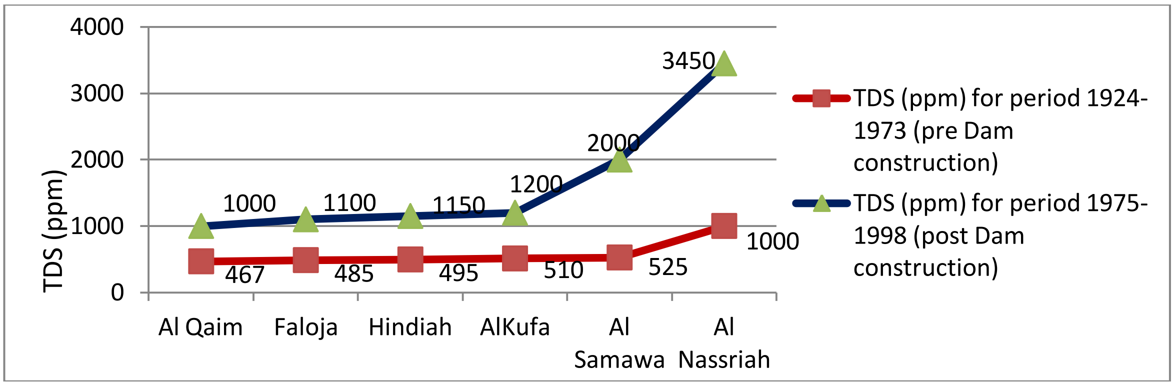


Figure 3.1 Mean annual TDS along Euphrates River for two periods (before and after dam's construction), numbers extracted from (Al-Hadithi, 1978) and (Partow, 2001).

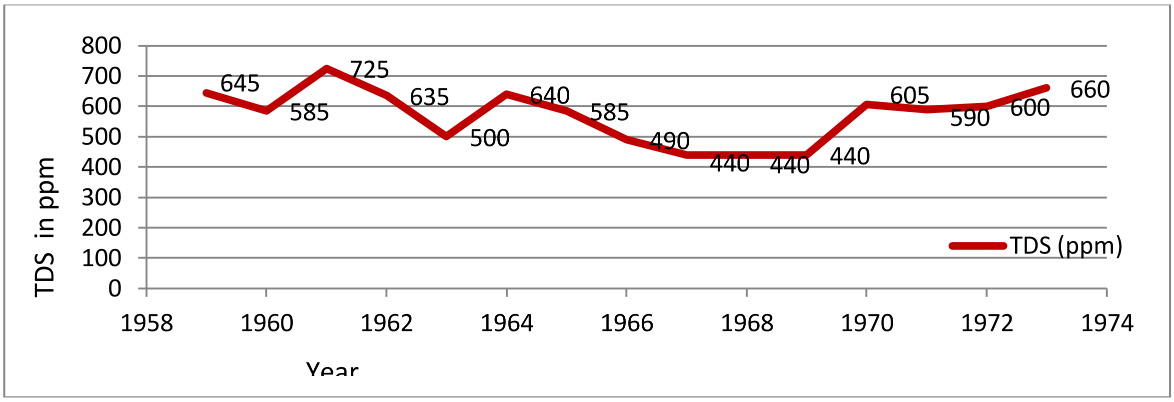


Figure 3.2 Mean annual TDS at Fallujah Gauging station, numbers extracted from (Al-Hadithi, 1978) and (Partow, 2001).

It is clearly demonstrated by the above figures that the salinity increases steadily along the stretch of the river and marked changes have occurred over time.

Increasing in the salinity of water (expressed as TDS) is a problem in several rivers in the world (FAO, 1976). From knowledge of the water quality status, we can determine the ability of the river to support the aquatic life or the extent of different water usages. If the salinity passes 1000 mg/l, water becomes less usable and it is no longer potable for human consumption (WHO, 1997). Above 3000 mg/l, it is not suitable for most municipal or agricultural usages. According to the United Nations Food and Agricultural Organization (FAO, 1976), water quality guidelines recommend a salinity level of 480 ppm for irrigation and human consumption. The FAO guidelines classify water within the range 480-1920 ppm as slightly-to-moderately restrictive for irrigation usage. The Iraqi Bureau for standards set the salinity level for potable water at 1000 ppm TDS (UNEP, 2003).

In this study the numbers in the table 3.1 are employed to classify the water quality.

Table 3.1 Water quality classification

Class	**Salinity degree**	**Salinity value (ppm)**
C1	Very low	Less than 100
C2	Low-medium	Less than 500
C3	High	Less than 1500
C4	Very high	More than 1500

The water quality is affected by contaminants from many different sources, which may be natural or due to man-made activities, as well as organic or inorganic. Contaminants include leaves, toxic chemicals, petroleum products, agricultural chemicals, and heavy metals. All these contaminants have serious effects on water quality and they restrict the water uses. Thus, pollutants limit the use of water to support the local economies. As a result of dam construction and reservoirs in upstream countries, especially in Turkey, the salinity has increased leading to lower suitability for domestic use (Rahi and Halihan, 2009). It has also affected the ecological system, which is already fragile (Jawad, 2003).

The water quality of Euphrates River within Iraq is not satisfactory, especially south of Bagdad, mostly because irrigation water from Turkey, Syria, and Iraq flows back into the river. Dissolved fertilizer chemicals used on the farming land (Muir, 2009) pollute the return irrigation water and when this water reaches the waterways, it pollutes the freshwater and increases the concentration of pollutants in the river water.

In general, the water quality of the Euphrates River has deteriorated due to the decrease in quantity and the increase in the salinity of the flow that enters Iraq. The decrease in flow released from Turkey and Syria via Euphrates is the primary cause of the alteration of water quality. Increase in water salinity may happen due to many reasons, either natural or from man-made effects. For example, if untreated wastewater (either from industry or domestic) or solid waste reaches a water course, it contaminates the water and increases the salinity; consequently, deterioration in water quality will occur.

3.2 Water quality parameters and water quality standards

Different parameters provide important information about the overall water quality and how healthy the water is. Data for such water quality parameters should be recorded and analysed to establish the quality of the water and its suitability for different types of use. The work should be done by an expert team, and tested by a certified laboratory to yield reliable results. Water quality parameters (and related) that should be sampled include: pH, dissolved oxygen, biological oxygen demand (BOD), water temperature, air temperature, conductivity, total dissolved solids, K, Na, Cl, F, SO_4, NH_3, NO_3, PO_4, total suspended solid, alkalinity, acidity, hardness, Ca, Mg, turbidity, and flow measurements.

These parameters may be used to determine if the quality of water is sufficient for different purposes, such as domestic uses, recreation, irrigation, and for aquatic organisms.

Understanding water quality parameters and their characteristics is important to identify the quality of the water, to know the reasons which led to changes in the quality, and to help in interpreting these changes. Thereby a set of water quality standards for monitoring the river can be developed, and these standards are useful for water quality protection and environmental restoration. Water quality standards also support efforts to maintain water quality conditions for protecting the environment. They should be consistent with the requirements of the clean water act. Water quality standards help to identify the reasons for water pollution and prevent water quality deterioration, by enforcing procedures such as, efficient treatment of wastewater and runoff, controlling discharges from mining sites, minimizing the use of fertilizers and chemicals in farming, and protection of river banks from erosion.

In this chapter total dissolved solid will be considered in detail, whereas in appendix 1 there is extensive information about other water quality parameters.

3.3 Total Dissolved Solid

- *Definition and constituents*

One of the most important measures of water quality is the amount of dissolved minerals in the water, which is denoted Total Dissolved Solids (TDS). Total Dissolved Solids is a measure of the combined content of all inorganic and organic substances such as: dissolved minerals, some salt components, dissolved metals, some cations (positively charged ions), and some anions (negatively charged ions) that are dissolved in the water (inorganic constituents comprise most of the total concentration of TDS). It could be found in form molecules or ions.

TDS concentrations are equal to the sum of (cations) and (anions) in the water expressed in mg per unit volume of water (mg/L), or how many parts of these charged ions which exist in million parts of solution (ppm) (web reference 38). The major constituents are usually, calcium, magnesium, sodium, and potassium cations and the anions carbonate, bicarbonate, chloride, sulphate and, nitrate and there are minor (less common) elements and components (cations and anions) as illustrated in table 3.2.

Table 3.2 Constituents of TDS in river water (extracted from several sources)

The principal Common constituents	**Less common constituents**
Calcium	Strontium
Carbonate	Barium
Bicarbonate	Thallium
Nitrate	Arsenic lead
Phosphates	
Sodium	
Potassium	
Sulphate	
Chloride	
Iron	
Manganese	
Magnesium	
Aluminium	

Water has the ability to pick up impurities and small particles. It is considered as one of the best solvents, and it is often known as the universal solvent. Pure water in nature is rare; water with hundred percent colourless, free of some elements and components will be odourless and tasteless, and this water does not exist except in laboratories. The increment in concentrations of dissolved solids in water affects its taste. TDS can be employed to establish potential water usage or to evaluate the quality of supplied water; it affects everything that consume, lives in, or uses water. "*Although TDS is not generally considered a primary pollutant (e.g. it is not deemed to be associated with health effects) it is used as an indication of aesthetic characteristics of water quality and as an aggregate indicator of the presence of a broad array of chemical contaminants*" (web reference 5).

- *Reasons for TDS*

TDS in river-water could originate from natural sources, for example, mineral springs, carbonate deposits, salt deposits, ground water intrusion, leaves, silt, soil erosion, and plankton (organic sources). Dissolved solids could also come from inorganic materials such as weathering and dissolution of rocks. Rocks (which may release metals into the water) that contain calcium magnesium, bicarbonate, nitrogen, iron, flour, phosphorous, sulphur components, and other minerals, could contribute to the TDS concentrations. Many of these materials form salts which dissolve in water and yield another charged compounds that contain both a metal and a non-metal.

Increase in TDS concentration in water could come also as a result of mining, oil and gas drilling processes near rivers, or from untreated industrial wastewater or untreated municipal wastewater that reaches the waterways, urban run-off, and agricultural run-off (more particular and harmful elements of TDS are chemicals, pesticides, and herbicide used in agriculture which come with surface runoff). Chemicals used in the water treatment process contribute to the TDS concentration. Other sources that may add significantly to the TDS loading of water include: salts used on streets during the winter for road de-icing, anti-skid materials, and point/non-point untreated wastewater discharges. Drinking water in pipes used to distribute water to consumers could pick up metals such as lead or copper (web reference 38), and water containing these heavy metals could have health effects, if drinking water standards are exceeded.

Concentrations of TDS in water throughout the course of the river are varying owing to different factors, such as flow, pollutant load, mineral solubility of geological region, and the ability of the river for self purification. Table 3.3 can be used as a generalization of the relationship of TDS to water quality problems.

Table 3.3 Major components and their relation to water quality (modified from Craun, 1975)

Major components	**Relation to water quality**
Cations combined with Carbonates CaCO3, MgCO3 etc	Associated with hardness, scale formation, bitter taste
Cations combined with Chloride NaCl, KCl etc	Salty or brackish taste, increase corrosively

- *Effects of TDS*

Reliable information about health risks which result from excessive TDS concentrations in domestic water is not always available. However, it is quite clear that the TDS affects the taste of water. The results of early epidemiological studies demonstrated that the presence of some elements with low concentrations in drinking water may have beneficial effects (the presence of these elements with limited concentration in the water improves the taste). TDS is not expected to harm human health at concentrations below 500 ppm (web reference 5). It is not considered evidence of water pollution. However, high TDS concentrations in water usually indicate high level of hardness in water. It has aesthetic problems and unwanted effects such as a bitter and salty taste in domestic water, it affects quality in food production (canning) and soft drink industry. Also, the presence of some elements or components of TDS can have bad effects on human health and aquatic organisms, since it can be toxic to aquatic life through increase in salinity or changes in the composition of the water. Substances may be included that are toxic to people or aquatic life such as heavy metals. Some constituents of TDS such as chlorides, sulphates, magnesium, calcium, and carbonates could cause corrosion or encrustation in water networks (Sawyer, 1967). Elevated TDS levels (above 500 mg/L) result in excessive sedimentation in pipe network, water heaters, industry boilers, and household measures such as tea kettles and steam irons, and corrosion may occur (Tihansky, 1974).

There are several opinions about health effects associated with the ingestion of TDS in drinking water, not any of them identified exactly results, however, "*in early studies, inverse relationships were reported between TDS concentrations in drinking water and the incidence of cancer*" (Burton, 1977), coronary heart disease (Schroeder, 1960), arteriosclerotic heart disease (Schroeder, 1966), and cardiovascular disease (Sauer, 1974).

“*Total mortality rates were reported to be inversely correlated with TDS levels in drinking water”* (Craun, 1975).

Another study has the converse result, “*a summary of an Australian study reported that mortality due to all categories of ischemic heart disease and acute myocardial infarction was increased in a community with higher levels of soluble solids, calcium, magnesium, sulphate, chloride and fluoride, alkalinity, total hardness and pH, when compared with a community in which levels were lower”* (Meyers, 1975).

In Iraq, the number of people with cancer that live in Nassriah and Al Basra (southern Iraq), where the TDS concentration of the water is very high (most downstream), is much larger than for the people who have the same disease and that live in Al Ramadi or Bagdad, where the TDS is much lower. Thus, the second opinion (Australian study) seems more reasonable. High TDS levels generally indicate hard water and the presence of pollution in the river, which imply health, environmental and economic risks.

Calculation and measured

Basically there are two methods to measure the concentration of TDS in the water: **gravimetric** method and **conductivity** method (web reference 5). The first method is the most accurate and involves evaporating the samples of water by putting it in an oven and measuring the mass of the dried residues. This method is generally the best, although it takes a long time. It is preferred to use this method especially when inorganic salts comprise the great portion of TDS. The second method is based on the parameter EC of the water which has a strong correlation with the concentration of dissolved charged ions in the water. The principle of this method is that the ions that are released from the dissolved solids, which exist in the water, change the characteristic and make the water able to transmit electrical currents, which is easily measured by a conductivity meter or a TDS meter. Pure H_20 has zero TDS which means virtually zero conductivity (web reference26). “*Conductivity usually about 100 times the total cations or anions expressed as equivalents”* (web reference 38). To calculate the value of TDS, it’s done firstly by measuring the EC then multiply the resulting value by a factor within a range from 0.5 to 1 (web reference 5).

It is worth to note that both total dissolved solids tests provide a qualitative measure of the amount of dissolved ions, but does not give specific information about the nature of these ions or the relationships between them. In addition, the test does not give us information about water quality issues, such as: hardness, taste, acidity, salinity, or corrosiveness, in spite of the strong correlation between these factors and TDS concentration. Therefore, total dissolved solids are used as an indicator parameter to determine and describe the general quality of the water.

Standards

The concentration value of total dissolved solid in water affects its taste and palatability, so we have to monitor the quality of water always throughout the course of the river and compare the results with standards see table 3.4. Several studies about TDS were conducted, and the derived results indicate different levels of reaction, from tolerance to outright toxicity depending on TDS concentration and its constituents.

Table 3.4 The TDS limits standard

Value of TDS ppm	**Availability**	**Reference**
Domestic usages		
Less than 100	Unacceptable for domestic	(Bruvold, 1969)
100	Threshold of acceptable aesthetic criteria for domestic	(web reference 26)
100-500	Acceptable for domestic(EPA)	(WHO, 1997)
500-1000	Unwanted for domestic(EPA)	(WHO, 1997)
exceed 1000	Unfit for human consumption	(Web reference 38)
non-domestic usages		
Around 1000	Tolerate for Most aquatic ecosystems involving mixed fish fauna	(web reference 5)
approximately up to 2900	Safe For terrestrial animals and poultry	(web reference 5)
Up to 7100	Dairy cattle	(web reference 5)

If the derived results give us a high concentration of TDS it means there are potential concerns. Thus, further investigations are required and procedures taken before using the water. However, increased concentration of TDS in domestic water makes it unfit due to change in taste and other unwanted results. Domestic water with very low concentration of TDS may also be unwanted by consumers because it is flat and has dull taste.
In some cases, such as high pH, high turbidity, or low concentration of dissolved oxygen the effects of high TDS could be more toxic (web reference 5). Some specialist set values for palatability (tastiness) of fresh water in relation to its TDS level as shown in table 3.5.

Table 3.5 The palatability of domestic water (modified from Bruvold, 1969)

Palatability (tastiness)	TDS concentration ppm
Unacceptable (because of its flat and insipid taste)	extremely low concentrations
Excellent	Less than 300
Good	300-600
Fair	600-900
Poor	900-1200
Unacceptable	Greater than 1200

River water can be classified by the amount of TDS as:

- fresh water < 1500 mg/L TDS (Ela, 2007)
- brackish water 1500 to 5000 mg/L TDS
- saline water > 5000 mg/L TDS

3.4 Pollution sources and transport

There are many sources for water pollution, but they can mainly be divided into two classes according to the source of the pollution (web reference 46): (1) point source pollution which comes from a single location and is discharged into the river at a specific place, causing a direct effect on the river; such sources include industrial waste water from factories, waste water from sewage treatment plants, landfills, oil spill from a tanker, and return irrigation water via drainages; and (2) non-point source pollution, or diffused source, which originates from a wide area along the banks of the river and it comes from many different scattered sources; this type is more difficult to treat than the first type and more costly, including construction activities, hydrologic modification, and spread agricultural runoff.

Another type of pollution is the trans-boundary pollution, which enters the river in one place, but the effects extend for thousands of kilometres away from its origin. Pollution that is transferred through international rivers like Euphrates belongs to this type as well as radioactive waste.

Excess erosion in the river banks produces sediment and suspended particles that reduce light penetration. Dissolved contaminants reduce the oxygen carrying capacity of water, thereby, harming aquatic organisms. Excess nutrient in the river water causes algae and bacteria to grow rapidly, and this will increase the oxygen consumption and the turbidity (web reference 47).

There are many sources of water pollution; some of these include petroleum fuels and by-products, sewage, solid waste, heavy metals, herbicides, pesticides, radioactive waste, heated water sources, toxic wastes, nutrient and sediments. Untreated wastewater and animal wastes can cause biological pollution which restricts water usage and contaminate aquatic organisms. The Euphrates is polluted with chemicals from agriculture, industry, and sewage making it an unreliable source for domestic use and restricting it for other usage.

3.4.1 Impacts of dams and reservoirs

Water management projects often have several unwanted results, especially with regard to the impact on the overall ecology of the river. The construction of new dams and reservoirs (figure 3.3) and the execution of irrigation plans, such as extension of agriculture and reclamation of new farmland on the Euphrates river basin, have had significant impacts on the environment and society of all riparian countries, especially on Iraq which is located most downstream.

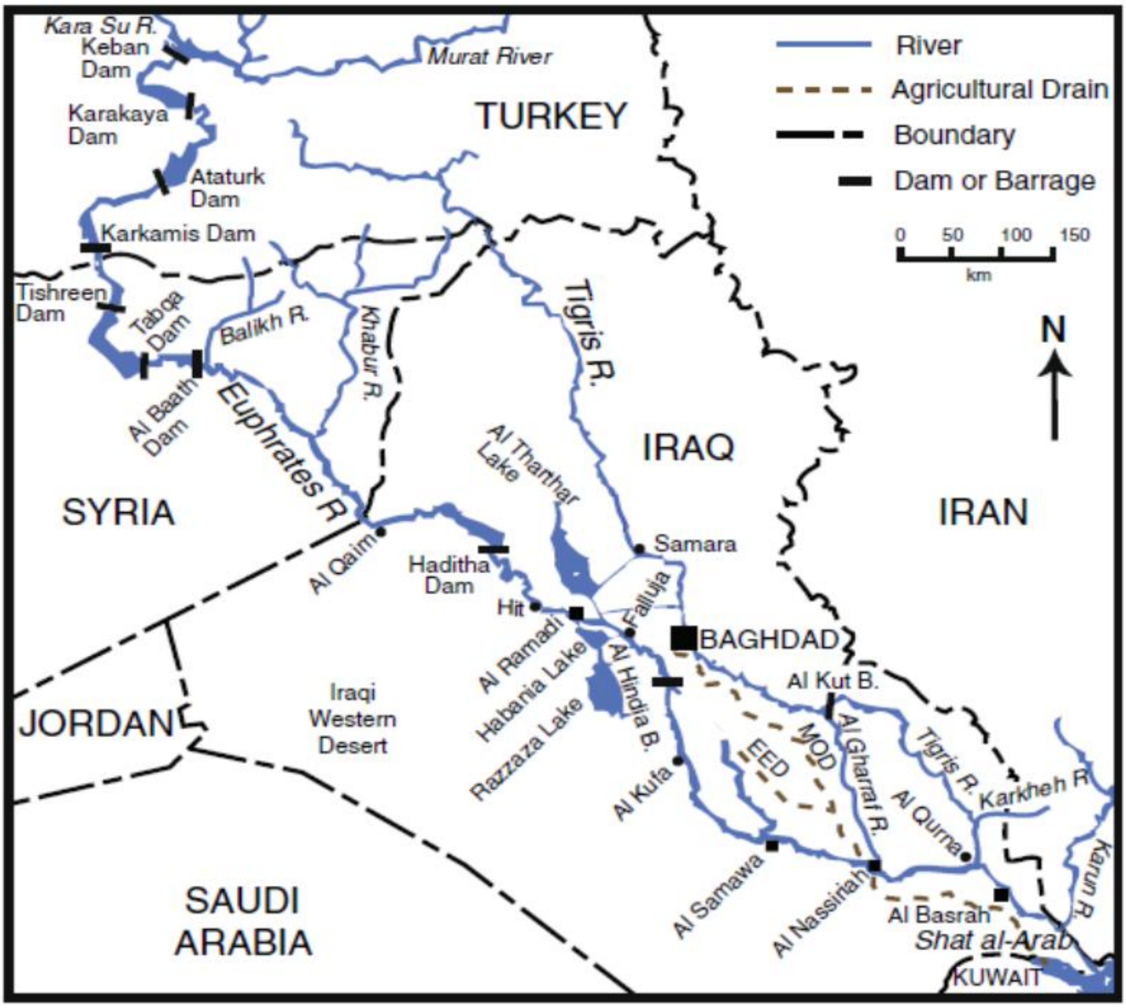


Figure 3.3: Dams on Euphrates River in riparian countries (Hillel, 1994).

The most important impact of dams and reservoirs concerns the flow regime. The creation of multi-purpose dams with large reservoirs for water storage requires large surface area (figure 3.4), which lead to high rate of evaporation due to the harsh climate in the riparian countries, especially in Syria and Iraq as shown in table (3.5).

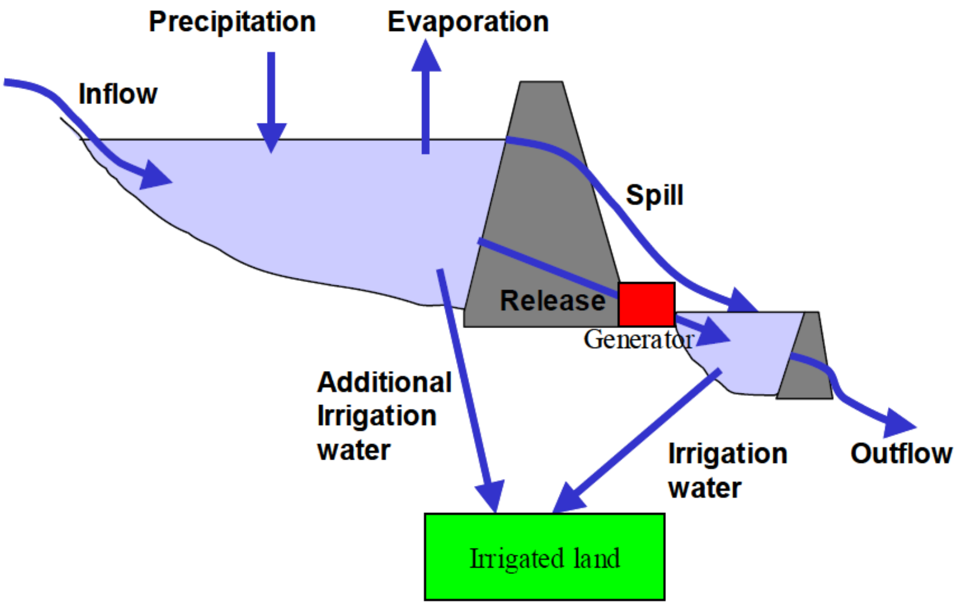


Figure 3.4 Schematic description of the water balance for a reservoir within a river watershed (Kavvas, 2010)

Table 3.6 Average annual evaporation quantities from reservoirs over Euphrates River basin (Hillel, 1994)

Country	**Annual evaporation from reservoirs km^3**
Turkey	2
Syria	1
Iraq	5

It is demonstrated in the above table that the total amount of available water in Euphrates is decreased by 8 km^3 yearly due to evaporation, and that the salinity concentration increases steadily as a result of the increase in evaporation rate and the decrease in the quantity of water flow rate.

Turkey and Syria completed their first dams on the Euphrates (Keban in Turkey, Tabaqa in Syria) within one year in 1975, and it is worth to note that in this year, the region was hit by severe drought and the river flow toward Iraq was reduced from 15.3 km^3 in 1973 to 9.4 km^3 in 1975 (Shapland, 1997) and (Kaya, 1998). Thus, a large crisis occurred in these riparian countries.

In 1981 another crises occurred between these countries when Turkey decided to further fill up the Keban dam to temporarily increase hydroelectric power production (web reference 5).

Keban dam which is considered to be the first dam within the South-eastern Anatolian project (GAP; see figure 3.5), which is considered to be the largest project of integrated water management of the whole Tigris and Euphrates river system within Turkey. This project, which was originally designed and planned in the 1960s, involves construction of 22 dams and 19 hydropower plants on the Tigris and the Euphrates rivers (Kolars, 1994). Three dams on the Euphrates are in operation (Keban, Karkaya, and Ataturk; information about these dams are given in table 3.7), while four still remain under construction and the other in planning to be fully implemented in the coming years. The electric power that is expected to be produced from this project is about 27.4 billion KW/h/ year, and it irrigates an area of 1.7 million ha of farm land. It will utilise up to 9km^3 of water each year. This project is based to 80% on the Euphrates River and 20% on the Tigris river water (Altinbilek, 2004).

Figure 3.5: The GAP project region (Kolars, 1994).

Syria has three dams on Euphrates in operation, these dams are: Teshreen, Tabaqa and Al Bath, and it also has a large reservoir named Al Assad Lake.

What is quite clear from the information above is that the building of new dams and reservoirs by Iraq's neighbouring countries is projected to lead to severe loss in the quantity of surface water that enters Iraq.

Table 3.7 Important information about Major Turkish dams (numbers extracted from several sources).

Dam name	Keban	Karkaya	Ataturk
Capacity (billion cubic meter)	30.7	9.54	48
Dead storage (billion cubic meter)	14.4	5.54	36
Live storage (billion cubic meter)	16.3	4.00	15
Artificial lake area km^2	680	297	817
Electric capacity (mega Watt)	124	1800	2400
Annual electric production Mkw/h	5870	7500	8900
Reclaiming area thousand hectares	900	1100	900
Year (starting in work)	1974	1986	1991 1st stage
Water need (BCM/year)		9.1	15-17 after completion

Effects of the dams on Iraq

The dam projects of Turkey on the Euphrates River could negatively affect the irrigation and power production in Iraq, as well as the environment, recreation, and fisheries, and also generate health hazards. The decrease in river flow rates and the effects of drought and evaporation of water that is stored in reservoirs will cause deterioration in water quality due to the concentration of pollutants and salts in the remaining water. What makes the quality of water worse is the relative increase in industrial wastewater, return irrigation wastewater, and untreated sewage water that reach the waterway, which has led to the disqualification of 1.3 million acres in Iraq. Seven provinces located on the river in addition to 25 cities, 50 towns, and nearly 4,000 villages inhabited by 5.5 million citizens and 1.5 million farmers are directly affected because of the lack of river water (FAO, 1994).

It is worth to note that 40% of the total electricity production in Iraq depends on the water of the Euphrates River, which means that any decrease in flow rate will directly affect electricity production having indirect effects on the economical and industrial sectors. It has been estimated that each billion m^3 of water shortage in the river flow will lead to a decrease of approximately (260) thousand acres of farmland (Al Hadithi, 1978).

One substantial advantage for Turkey of the Ataturk dam is the ability to storing a large amounts of water (15-17 BCM/year), see table 3.6 (Dagan, 2004). Ataturk Dam gives the possibility to transfer water to the plains of Urfa, which leads to a reduction in the flow of the Euphrates River entering Syria (remaining quantity is ranging from 13 to 15 BCM/year after completing all construction processes). Syria needs a quantity of water estimated to be about 7.5 BCM/year to secure water for irrigation projects and other requirements, whereas Iraq water requirements are about 19 BCM/year (Frenken, 2009). The results of the diversion of water to the plains of Urfa add to the decrease in the quantity, causing an increase in salinity of the water entering Syria and Iraq. This diminishes the availability of the irrigation water as well as reduces the river fisheries, and causes damage to the downstream farms.

It is worth to note that the anticipated combined demand for water from the all riparian countries is greater than the actual discharge of the river. However, the development of irrigation projects, as has been planned in upstream countries, will reduce Iraqi irrigation potential unless an agreement is reached on the sharing of river water between all riparian countries.

In 2008, Turkey, Syria, and Iraq formed a Joint Trilateral Committee (JTC) on the management of the water in the Tigris-Euphrates basin, and on the 3rd of September 2009 an "understanding document" was signed, implying that Turkey will ensure a flow of at least 500 m^3 per second into Syria. Syria in turn will allow 60% of the amount that it receives from Turkey into Iraq (EtE, 2011).

3.4.2 Drainage from agricultural areas

Poor irrigation practices have led to major salinization and degradation of land and water. Inefficient irrigation techniques that are practiced have contributed to an increase in the salinity of the soil. Irrigation practices such as flood and furrow requires a lot of water to flood the farm land (see figure 3.6). As a result for this practice, a large quantity of excess water will be "generated", which either seep into the groundwater or reaches to the river. Thus, intensive cultivation of crops using fertilizers and pesticides leads to contamination of the river water.

Figure 3.6: Traditional irrigation system in Iraq (FAO, 1994)

Compared with other sectors, the agriculture sector is the largest "consumer" in terms of water withdrawal in all riparian countries. The area of farm land increases steadily, and the quantity of water used to irrigate this land is increasing correspondingly. Using traditional ways of irrigation, as a logical result, the quantity of return water from irrigation is also increasing.

In case of Iraq, there are more than 16 drains working and conveying drainage wastewater along Euphrates River stretch. These drains play a significant role in altering the quality of Euphrates river water. As demonstrated in the figure 3.7, these drains discharging return irrigation water (which contains high concentration of dissolved solid TDS) into the river. This will led to an increase in the salinity in Euphrates River. The final quality depends on how much water flows through the river and in which quality, as well as how much return water enters the river and the concentration of the water in the drains. The relationship between these factors is given by the following mass balance equation:

$$TDS(final) = \frac{Q\ (Euph) * TDS\ (Euph) + Q(drain) * TDS\ (drain)}{Q\ (total)}$$

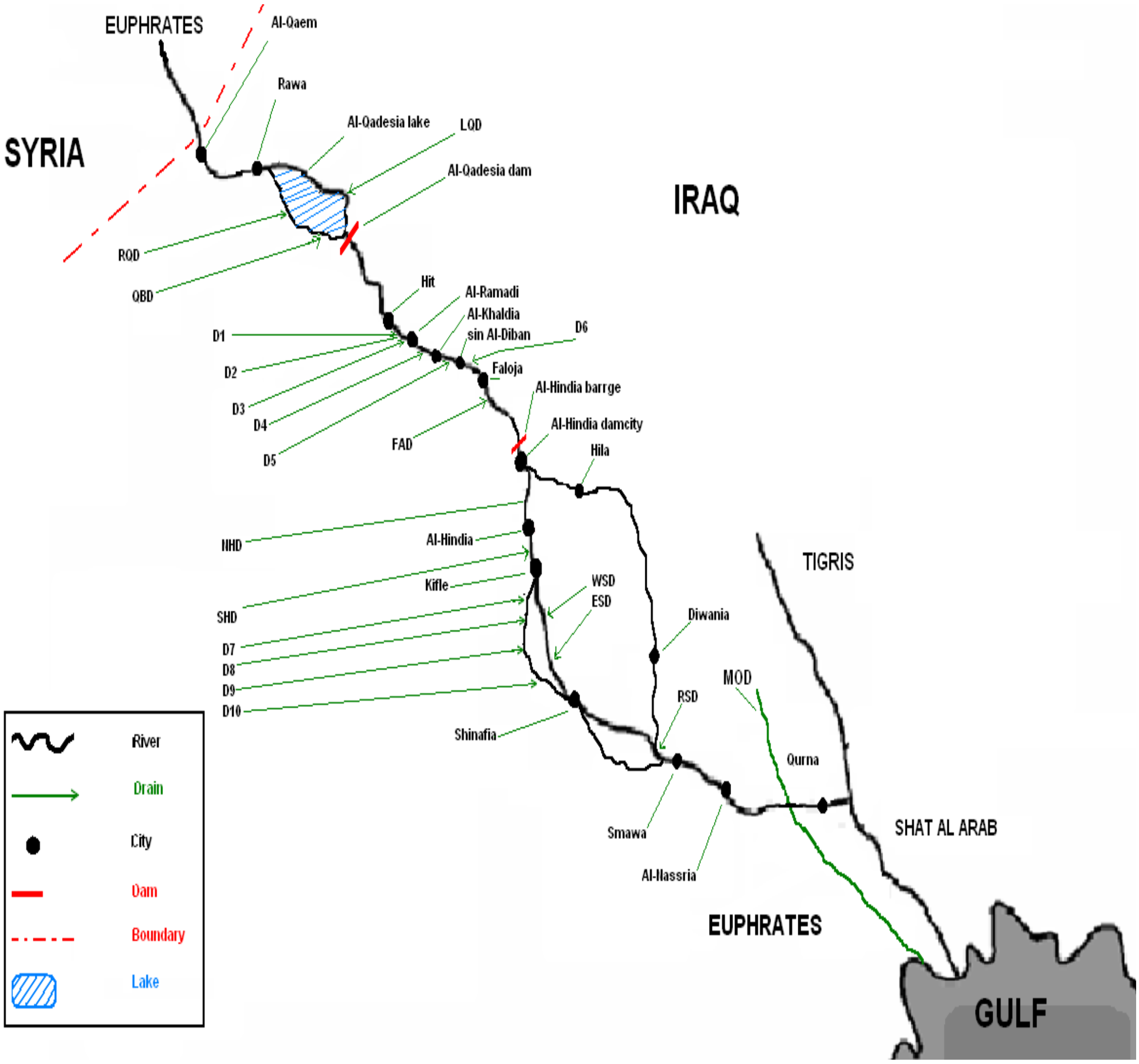


Figure 3.7: Return water from irrigation into Euphrates River.

The high nitrate concentration in the river water is mainly from irrigation runoff from agriculture fields, where chemical fertilizers have been used intensively. Excess nutrients cause a massive increase in the growth of algae or plankton that overwhelms huge area of the river. As a result, the watercourse choked with organic substances and organisms, consequently, the water become deficient of oxygen, which will affect the aquatic life.

Owing to the increase in farm land in all riparian countries during last thirty years, the discharge from drainage systems into the Euphrates River has increased, causing an increase in the concentration of salinity particularly in the lower reaches of the river. This has led to water quality deterioration and changed the suitability of the water for irrigation as well as for other uses.

In the later stage of the GAP, when much more farm land is subject to irrigation, this will increase the quantity of return irrigation water into the river. Syria and Iraq want to curb the pollution and decrease the quantity of polluted water to Euphrates. In order to increase water transport efficiency, reclaim new lands, minimise losses and waterlogging, and improve water quality by relieving the high salt concentrations and preventing additional amounts of return irrigation water, a number of new drains were constructed, especially in the southern part of Iraq. One of the drains was formerly called the third river and it functions as a main out-fall drain (MOD denotes the main out-fall drain, see figure 3.8). It collects drainage water from more than 150 000 km^2 of agricultural land (Shahin, 2007), which is located between the Tigris and Euphrates Rivers, from north of Bagdad to the Gulf. The outfall drain exits from the plain through a siphon under the Euphrates River and releases it's water into Shat Al Basra canal, which itself discharges into the Gulf. The length of this watercourse is 565 km with a total discharge 210 m^3/s (UNEP, 2003).

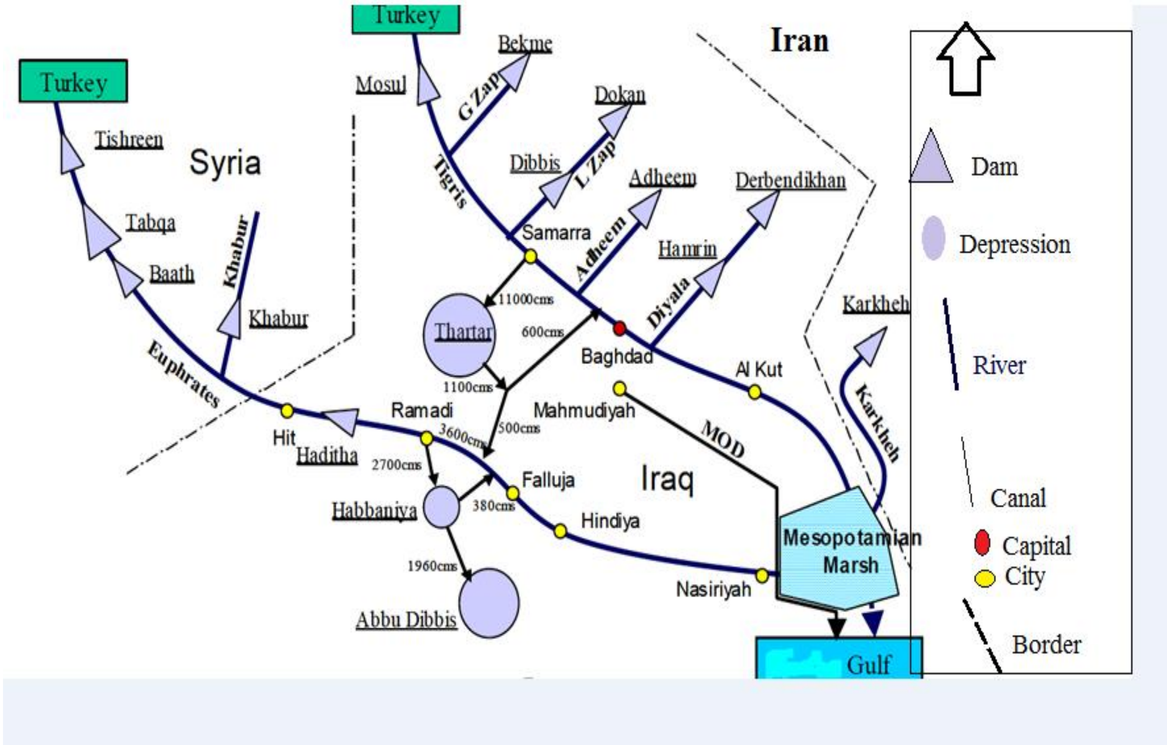


Figure 3.8: New drain system in Iraq (Kavvas et al., 2006)

3.4.3 Industrial water

The number of industries in all Euphrates riparian countries has grown extensively and rapidly. There are a lot of factories which are located along the Euphrates River banks, and these factories take their water from the river and discharge their liquid waste into the same river directly without treatment, or with partial treatment only. Thus, this indiscriminate disposal of waste from industry sites causes significant water pollution. Most of the industrial plants are owned either by the government or private industry, and they do not have effective treatment plants or the plants are out of order.

There are different factories within the Euphrates River basin, including carpet and garments dyeing, cotton textiles, paper and pulp, textile mills, leather processing, oil industry and exploration, petro chemistry, mining and resource extraction, thermal power stations, food industry and building material. These are typical major water polluting industries in the river basin within all riparian countries. Different chemicals are used in these industries as basic material or productivity improver.

Iraq has more than 137 plants with high capacity (web reference 32), although they have suffered from decades of wars, economic sanctions and lack of investment in this sector. Most of these plants are unfit to ensure proper environmental conditions, almost all of them are old, and without wastewater treatment unit. Thus, the waste water from these plants has high concentration of pollutants.

Some sources claim that the Euphrates receives more than 41 million cubic meters per year directly from these industrial plants, and only 21% of this quantity meets environmental standards (web reference 32). It is worthwhile to note that most of the industrial plants in Iraq lack suitable environmental technology to treat the discharged water.

3.4.4 Wars and contaminated industrial sites

Three decades of war and bad government policy have led to adverse environmental pollution affecting human and wildlife systems. The successive wars in Iraq have exponentially elevated the health risk and environmental issues, where these constant conflicts have caused an extreme burden on the water resources due to major military operations.

Many polluted and contaminated areas, ammunition detonation sites as well as potential contamination from the use of depleted uranium ammunition, which threat human health, have been identified. At these sites, chemical weapon attacks occurred during the Iraqi war periods, and the discharges of untreated effluent or spillage chemicals from these sites into surface water have led to aggravated pollution in the river water.

There is a pipe network in the region that transport oil back and forth throughout Iraq, see figure 3.9. Pipeline infrastructure has been sabotaged and damaged by insurgents resulting in further oil spillages, which reached to the river via surrounding watercourses and polluted the water.

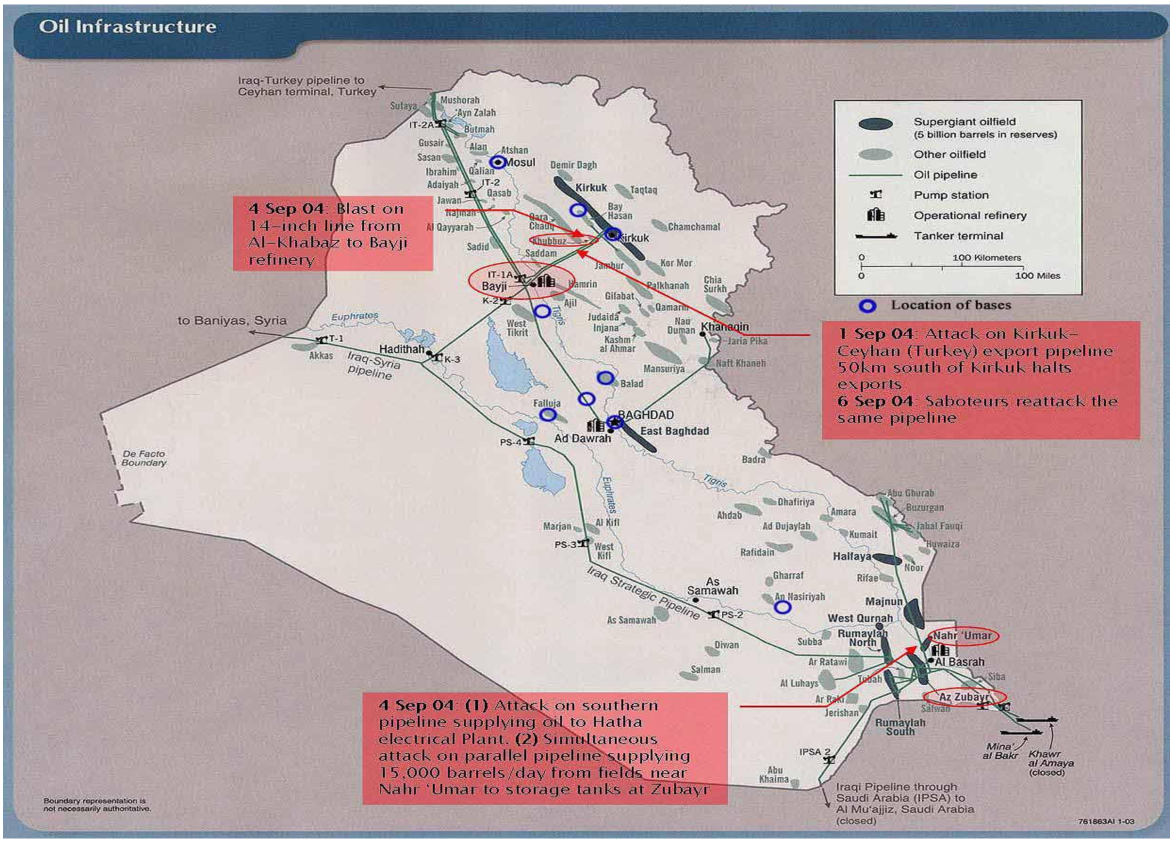


Figure 3.9: Iraq Oil pipe systems (MOE, 2006).

UNEP evaluated about 300 polluted locations throughout Iraq (UNEP, 2003), and most hot-spot sites and oil-polluted sites are summarized in table 3.8.

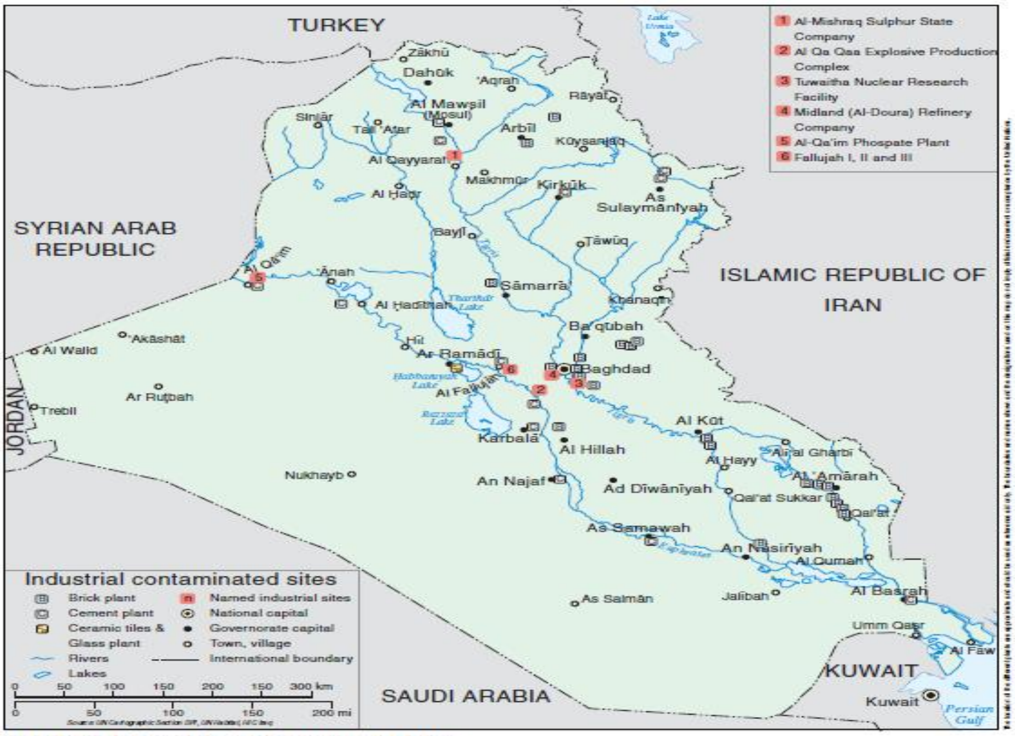
Table 3.8: The hot-spot sites and oil polluted sites in Iraq (web reference 32)

Type of industry	**No. Of sites**
Conventional Arm Industry	38
Oil production and export	15
Oil and Chemical refining	6
Mining	2
Agriculture/Pesticides	1
Steel	1
Cement	16
Chemicals (excluding arms-related)	6

The wastewater from these sites have different contaminants, such as chemicals, hazardous and toxic materials, dual-use materials, pesticides, Persistent Organic Pollutants (POPs), heavy metals, carcinogens, and others (Rahi 2009).

Three of the six most contaminated sites among the industrial activities mentioned above are situated near Euphrates and discharge their waste water into the river directly as shown in figure 3.10:

- Al-Qaim Phosphate plant
- Al- Qa Qaa Institution
- Al- Fallujah I,II and III



Newly identified industrial sites and sectors of concern in Iraq

Figure 3.10: The main contaminated sites in Iraq (web reference 32)

The discharge of wastewater from the Al Qaim phosphate plant causes eutrophication in the Lake Al Qadisiya reservoir and Euphrates River downstream (MOE, 2006).

3.4.5 Sewage water

In comparison to irrigation, the demand for water supply and sanitation in Iraq is a comparatively small component in the water balance (see table 3.9), but the wastewater from domestic use contains more pollutants than the return irrigation water.

Table 3.9 Percentage of water consumption for various purposes in Iraq

Sector	**Percentage from total demand**
Irrigation	88%
Industry	7%
Domestic	5%

Most of the domestic wastewater in the river basin cities enters the sewer lines or open drain area and is then discharged untreated into Euphrates River. The collection of wastewater does not necessarily guarantee complete treatment before being discharged into the Euphrates River. More than 75% of collected wastewater flow is untreated and it is diverted directly into river.

Euphrates River also receives input of storm water, which is gathered through inlets from city streets. The streets in most cities and towns in all riparian countries contain various kinds of pollutants and solid waste, which are transported with the runoff to the water course; thus, polluting the river.

Most of the water treatment plants which are located within the river valley are deficient, many of them non-functional or only partially functional. Citizens not served by any treatment and not having septic tanks they discard their wastewater into the river through open canals, which finally reach the river. In addition to wastewater and domestic sewage, rainwater could reach the river.

In Iraq, the estimated percentage of the population that is served through public sewerage networks is around 26.8%, through septic tanks 50%, through covered drains 7.1%, and through open drains 15.1%. According to the MOMPW, only 17% of the wastewater is taken to the water treatment plants before being discharged into the watercourse, the rest of the wastewater reaches the river without complete treatment or reaches directly to waterway, often causing serious pollution (Geopolicity, 2010).

Testing for drinking water contamination from coliform bacteria during the first 36 weeks of 2009 in all 18 governorates showed that more than 16 governorates have over 13% of the samples contaminated (UNEP, 2003).

Sewage disposal in waterways affects the aquatic environment and pose high health risks, consequently, leading to water-related illnesses such as diarrhoea, hepatitis, typhoid, and cholera (WHO 1997). Such disposal contains all kinds of chemicals and viruses which cause pollution along river stretch. Theoretically, sewage waste could contain high concentration of heavy metals (Cd, Zn, Cu, Ni, Pb, and Cr) that have high toxicity, but it is not possible to obtain reliable information about these elements.

3.4.6 Solid waste

Solid waste is considered the most visible and easily detected form of pollution among the common sources. It is a serious problem due to most of the methods used to dispose of it results in damage to the environment, from visual disturbance to increased health risks. Health risks from waste are caused by many factors, including the nature of raw waste, its composition and components. People in all riparian countries “generate” a large quantity of different types of solid waste (see table 3.10). They are used to indiscriminately throw away their solid waste on a daily basis, and most of this waste ends up littering roadsides, floating on surface water, or being collected in ugly dumps and, to a lesser degree, collected and placed in landfills.

Table 3.10 Types of solid waste

Type of solid waste	Most materials
Refuse	Commercial, industrial and residential waste
Garbage	Food waste and organic material
Rubbish	Tin cans, glass, paper, wood cloth grass
Ashes	Resulting from coal for cooking and heating
Trash	Tree, branches and big boxes

In addition to the aforementioned types, there is clinical waste, which is regarded to be the most dangerous one. The collection of clinical waste from hospitals and medical centers should be performed in specific ways and burned in special medical incinerator, such as the one shown in figure 3.11.

Figure 3.11: Modern medical waste incinerator (web reference, 13)

As shown in figure 3.12, more than 90% of the incinerators in Iraq's hospitals' are not functioning (WHO, 1997). Hence, clinical waste is being mixed with domestic waste and dumped in uncontrolled landfills.

Figure 3.12: Most of Iraqi hospitals do not contain incinerators or if they do malfunctioning is common (web reference 9).

A random sample has been chosen from domestic solid waste in Karbala city, which is located in the middle of Iraq and within the river basin. The weight of the sample was 1000 kg, and after isolating the different material in the sample, the results found are presented in table 3.11.

Table 3.11 Material contained in solid waste sample from Karbala municipality

Material	**ratio**
Organic waste	70 %
Plastic	6.5 %
Paper	5.9 %
Wood	5 %
Metal	7.5 %
Cloth and others	5.1 %

3.4.7 Flow diversion from Al Tharthar Lake to the Euphrates

In Iraq there is more water available from the Tigris River than from Euphrates River. Historically, Baghdad, the capital city of Iraq, is occasionally exposed to flooding due to high flows in the Tigris River. The most recent large flood happened in 1950, as shown in figure 3.13.

Figure 3.13: Al Rasheed Street in the middle of Baghdad in 1950 during flood (web, 14).

Iraq decided to develop a scheme to solve the flooding problem by controlling the river flow. The solution was diverting the excess water from Tigris to Euphrates via the Al-Tharthar Depression to compensate for the scarcity in river water during summer time, and to protect Baghdad and other cities from flooding. In order to accomplish this purpose, a set of canals, barrages and regulators were built (see figure 3.14). One regulator was constructed on the Tigris near city Samarra to divert excess water during flood times into the Tharthar depression, which has a capacity of about 30 km^3. On Euphrates, Al Ramadi barrage was built, to divert the flood water into Habbaniya Lake, then after, into Al Razaza Lake.

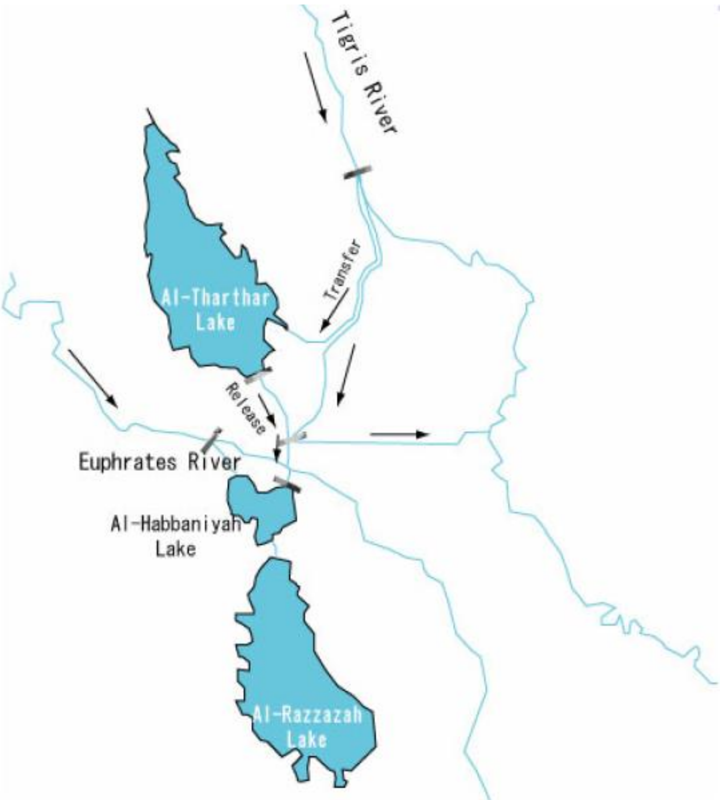


Figure 3.14: Diversion system between Tigris and Euphrates (web reference 32).

Experiments have shown that this diversion caused considerable increase in the salinity in Euphrates River, due to the very large evaporation rate, dissolution of salt and gypsum from soil of the depressions, and salt ground water effects. These three significant reasons have seriously diminished water quality and rendered the water here unsuitable for all purposes.

3.4.8 Population growth and urbanisation

Turkey, Syria, and Iraq are suffering from continued population growth, which typically causes a huge pressure on available resources. As illustrated in table 3.12, the population growth rates experienced by all riparian countries during this century have increased remarkably.

Table 3.12 Population of Euphrates riparian countries in millions capita (Population Reference Bureau, 1995), the predict year for this study is 2025.

Country	**1940s**	**1960s**	**1972**	**1995**	**2025 (expected)**
Turkey	17.8	27.7	37.6	61.4	95.6
Syria	2.5	4.4	6.6	14.7	33.5
Iraq	4.1	6.7	10.4	20.6	52.6
Sum.	24.4	38.8	54.6	96.7	181.7

From the 1940s to the present time the population has increased between three- and five-fold (PRB, 1995). Some experts expect that the population of these countries will double between 1995 and 2025, especially in Syria and Iraq.

In addition to the increase in population, there is also an increase in water demand due to urbanization, which in turn leads to an increase in the standard of living of the population. Urbanization and an increasing population imply an increase in water consumption for domestic, industrial, and agricultural purposes. This increase in water demand (see table 3.13) consequently means an increase in the discharged waste water from all these sectors into river water. The table shows predictions for year 2020 for separated studies by Kilot (1994), Kolars (1994) and Altinbilek (1997).

Table 3.13 Potential water demand on the Euphrates after the year 2020 in BCM/year (Kolars, 1994: Kliot, 1994: Altinbilek, 1997) different authors quotes different numbers.

Country	**Kolars 1994**	**Kilot 1994**	**Altinbilek 1997**
Turkey	21.600	21.500	14.500
Syria	11.995	13.400	5.500
Iraq	17.000	16.000	15.500
Total demand	50.595	50.900	35.500
Available water	32.720	31.000	31.680
Balance	-17.875	-19.900	-3.820

The degradation of the Euphrates river water quality clearly follows the population growth in all riparian countries. Large suburban residential areas have developed without adequate infrastructure, and sewage treatment plants are not enough for this expansion. Most of the solutions in this case are by constructing new bypasses to discharge the untreated wastewater into the river directly, which causes river pollution.

3.4.9 Natural sources

Part of the flow in Euphrates comes from groundwater. Aquifers feed the river with water through rock cracks and springs. This groundwater, which “originates” from the underground, contributes to the river water and affects its quality. Many components, ions and elements result from weathering and are mixed with the river water. Other components, particles and elements come from the soil bank or the bed of the river. So processes like rock weathering or soil erosion are contributing to the concentration of pollutants along the river.

Global warming and climate change may have adverse impacts on the environment, especially the water resources. There are many predicted and observed changes attributed to climate change and global warming, such as an increase in the Earth’s temperature, change in precipitation patterns, and significant change in precipitation rates. The increase in water consumption for various sectors has exacerbated the crises concerning water. Euphrates River is highly dependent on the precipitation, adding to this, the evaporation within the river basin is very high. These two points makes the river especially vulnerable to climate change and global warming.

Spread of drought, frequent dust storms, water scarcity, and degradation in water quality are potential evidences for the severity and magnitude of global warming and climate change (see figure 3.15 and figure 3.16).

Figure 3.15: Sand storm over Iraq (UNEP, 2003)

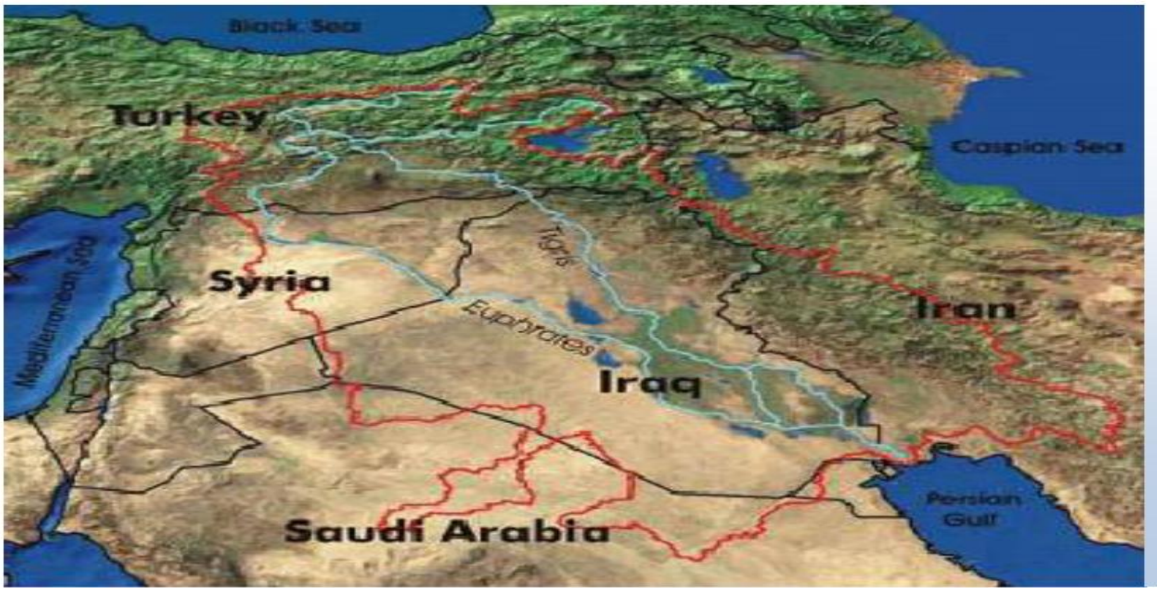


Figure 3.16: Spread drought over Iraq (UNEP, 2006)

All rivers and water bodies have a natural ability to self-clean and remove certain amount of pollutants by degrading or dispersing it. This ability is different from one water body to another according to several factors, such as the temperature, size of the water body, discharge velocity, type of pollutant, the distance between points for pollutant release, and the contact time.

Thus, the dissolved oxygen concentration depends on velocity of flow through Euphrates River which in turn depends strongly on the inclination of river bed. The inclination of the Euphrates River bed in Iraq is very low, see figure 3.17.

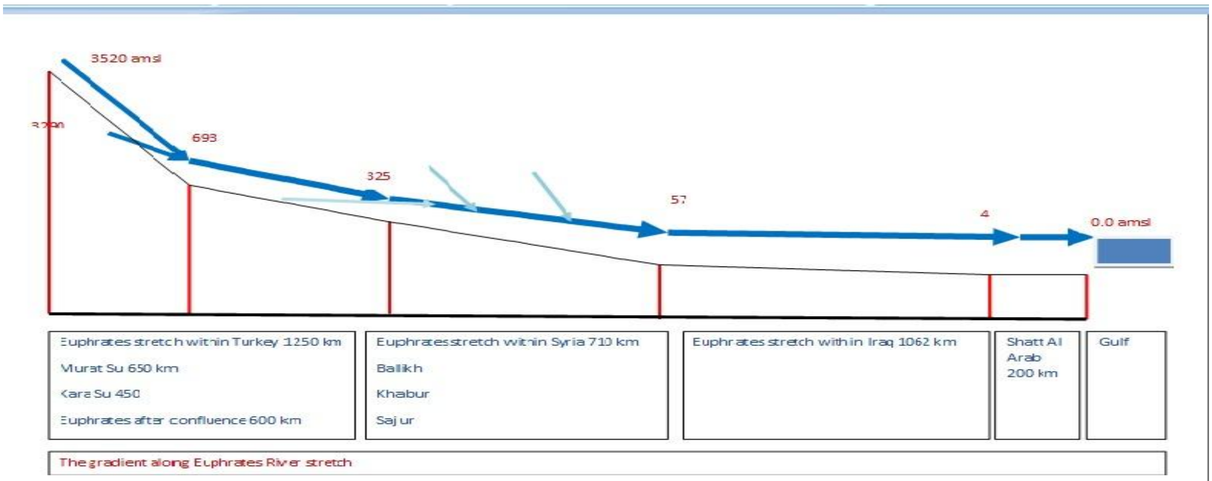


Figure 3.17: The inclination of Euphrates river bed in Iraq

When the Euphrates River reaches Al-Qaim city in Iraq, the elevation has become 57 amsl, and the distance from this city to Al Qurna city in the south of Iraq, where the Euphrates meet Tigris River, is about 1062 km (Kaya, 1998). This means that the gradient is about 0.0053%, compared with 0.037% in Syria and 0.061% after Keban and 0.435% before Keban in Turkey. What is quite clear from these numbers is that the Euphrates has a very small gradient in Iraq, resulting in low velocities along this river stretch, which means limited entrainment of oxygen and associated self-purification and ingestion of pollutants.

3.5 Effects of water pollution

Everybody contributes to water pollution, and it is not possible to have a developed society without some form of pollution. Pollutants in river water result in many detrimental effects: they harm living organisms, cause hazards to human health, animals, birds, and aquatic organisms, and limit water uses and reduce reproductive ability.

In Iraq, the effects of water pollution are primarily noted in the agricultural and industrial sectors. However, devastating effects are also observed on people, because most of the water purification plants in Iraq are not working properly and are inadequate. The plants do not covering all districts and a lot of people are forced to drink water directly from the river, which results in water-borne diseases such as dysentery, cholera hepatitis, and typhoid.

Chapter 4

Euphrates river study area characteristics

4.1 Study area and climatology

The Euphrates River flows within three of the Middle East countries: Turkey, Syria, and Iraq (see figure 4.1). **Turkey** is bordered by eight countries: Bulgaria to the north-west, Greece to the west, Georgia to the north-east, Armenia, Azerbaijan and Iran to the east, and (Iraq and Syria to the south-east).

Syria is surrounded by six countries: Lebanon and Mediterranean Sea to the west, Turkey to the north, Iraq to the east, Jordan to the south, and (Palestine and Israel) to the south-west.

Figure 4.1 Euphrates study area (web reference 16)

As stated in table 4.1, **Iraq** has a total area of 438,320 km^2 (Geopolicity, 2010), and it is bordered by six countries: Jordan to the west, Syria to the northwest, Turkey to the north, Iran to the east, and (Kuwait and Saudi Arabia) to the south. In addition, Iraq has a short coastline with a length of about 58km in the northern Arabian (Persian Gulf). The average population density is 57 persons per km^2 and the average population growth is estimated to 3.6% (web reference 20).

The number of dams with an elevation of more than 15 m is 31, whereas the number of dams with an elevation of more than 150 m is 3. The number of dams under construction with an elevation of more than 60 m is 19 (Shahin, 2007).

Table 4.1 Data on countries in the study region for year 2009 (Geopolicity, 2010)

Country	**Population**	**Area (km^2)**	**Income US$ /Cap/day**
Turkey	72,561,312	783 562	13,1
Syria	21,906,000	185 180	2,7
Iraq	31,234,000	438 317	3,6

Geographically, Iraq consists of four different regions, as illustrated in figure 4.2. The largest one is the **desert region**, which is located in the western and south-western parts of Iraq. In this district there are small water courses that are dry most of the year. The second region is the **rolling upland region** which is located between the upper Euphrates and the upper Tigris (within Iraq). This area is recognized by the difficulty for irrigation due to the river water existing in deep valleys. The third region is the central and south eastern **alluvial plain** between Tigris and Euphrates. The final region is the **highland** in the north and northeast of Iraq. Most of this region is in the mountains and agriculture is available only in a few valleys (Daniel, 1994).

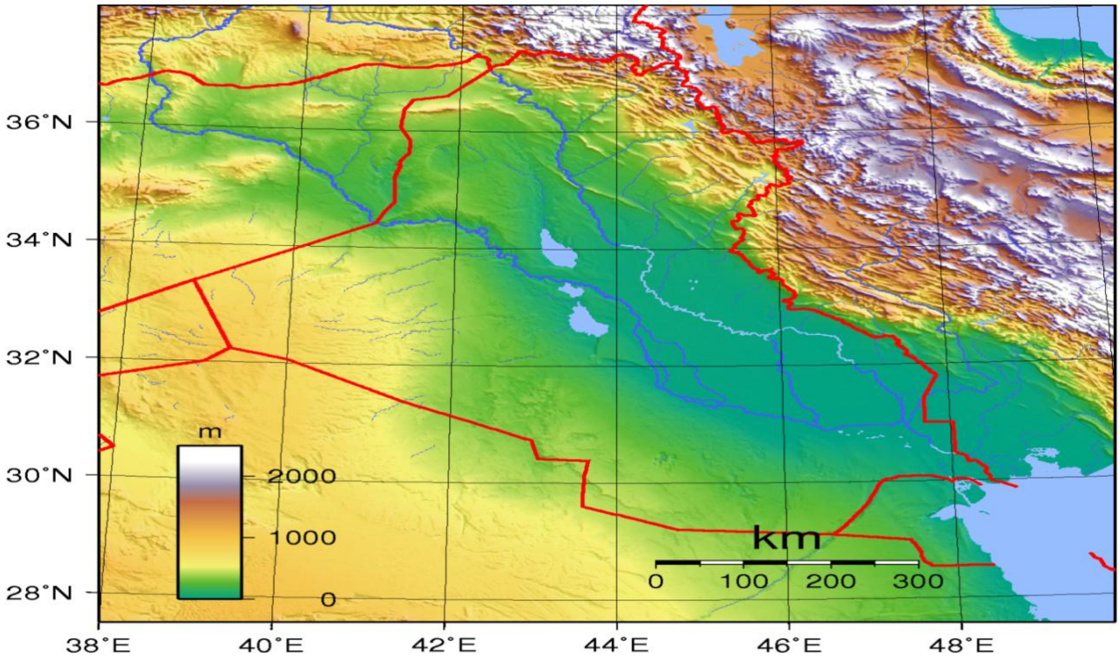


Figure 4.2 Topography of Iraq (web reference17)

Different patterns of climate inter-cross, affecting the Euphrates river basin. The climate in Turkey (upstream) is characterised by long harsh cold winters with abundant precipitation, where the temperature increases gradually from north to south. Summer rains are more excessive than the winter rains. Extremely cold temperatures of down to (-45) deg C occur in the winter, while the hottest month in Turkey is August with a mean maximum temperature of 24-28 deg C (Beaumont, 1996) The prevalent climate types in Syria (river basin part) and in Iraq (downstream) are the continental, subtropical, and semi-arid types. The average temperatures in Iraq range from higher than 48 deg C (120 Fahrenheit) in July and August to below freezing in January (see figure 4.3). Minimum temperature in the winter time range from near freezing in the northern parts to 2 deg C in the western desert and to 4 deg C in the alluvial plain of southern Iraq. Summers are dry and extremely hot with a shade temperature of 43 deg C during July and August, dropping at night to 26 deg C. The winter in Iraq is cold while the summer is very hot resulting in a high rate of evaporation in the middle and southern part of the country that reaches up to 17 mm per day during summer (Dagan, 2004).

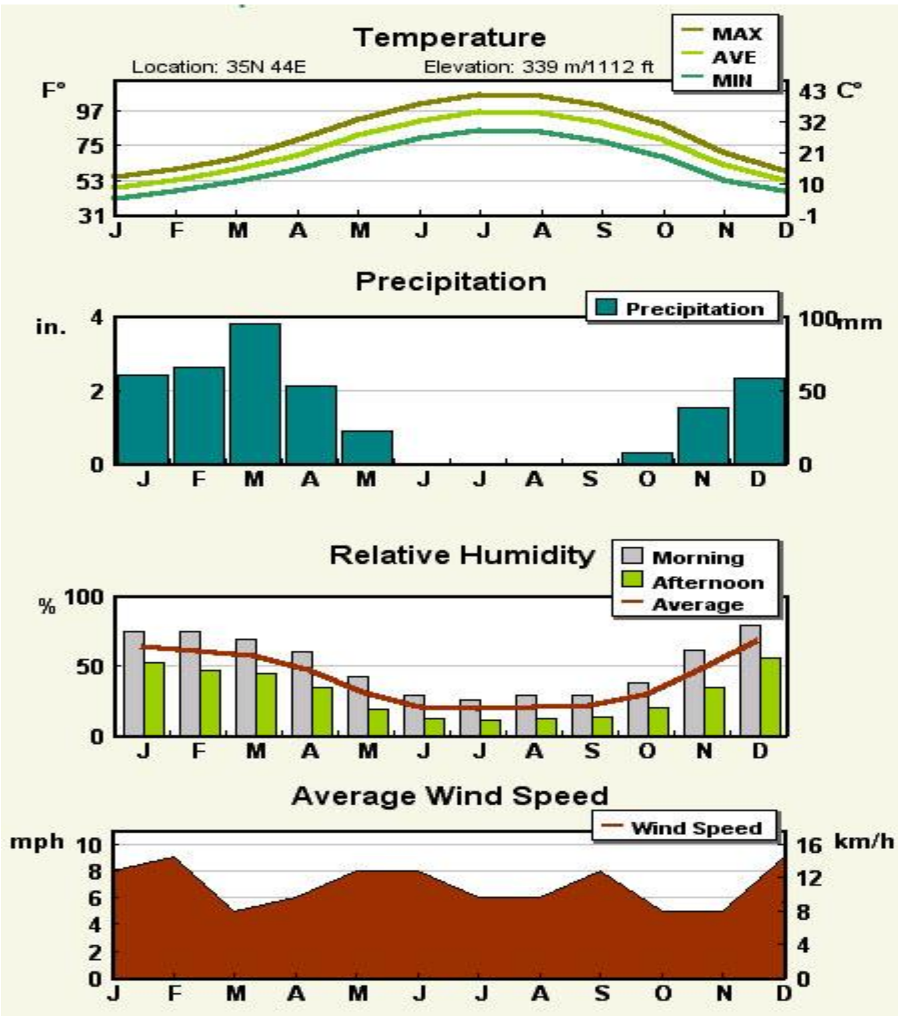


Figure 4.3 Mean annual climate parameters over Iraq (web reference 18)

The precipitation in Iraq is seasonal, but there is a large spatial and temporal variation in the rainfall pattern. In general, precipitation there occurs between November and April, although most of it occurs during the period from December through March.

Average annual rainfall is estimated at 154 mm, but it ranges from less than 100 mm in the central plain and southern desert of Iraq, which represent about 60% of Iraq area, to 1200 mm in the north and north-east mountainous regions, which have a Mediterranean climate, see figure 4.4.

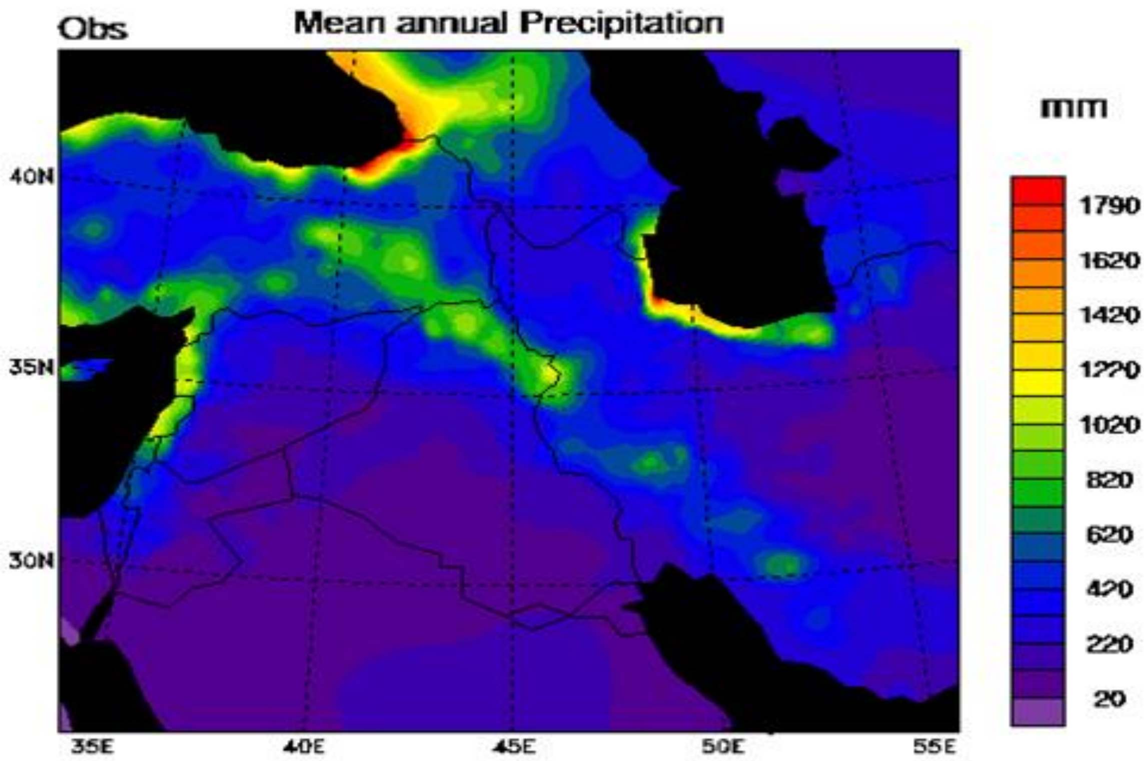


Figure 4.4 Mean annual precipitations over riparian countries (UNEP, 2003)

In Iraq, there is about 11.48 million hectares possible to cultivate, which equal 26% of total area, and the area which is used as farming land constitutes 8 million ha of the total cultivatable area. However, it may be reduced to 3-5 million ha due to increase in soil salinity (FAO, 1994).

4.2 Land use and catchment properties

Turkey is more abundant than other riparian countries in water resources, see table 4.2. Current estimates of water available for Turkey is 3439 m^3 per person per year, (UN/WWAP, 2003) having higher levels of precipitation than other riparian countries.

Table 4.2 Availability of water in riparian countries (UN/WWAP, 2003)

Country	**Water availability m^3/capita/year**
Turkey	3439
Syria	1622
Iraq	3287

Turkey has sought to use the river for electric power production and irrigation by building a series of dams on the river.

Syria lies in an arid region which is reliant on the Euphrates River for over half of its water needs (Wakil, 1993). It has focused on using Euphrates River for agricultural development and food production to satisfy self-food sufficiency. However, it experiences rapid population growth that has led to an increase in water needs. Syria has built three big dams on the Euphrates River to satisfy these purposes.

To understand the water needs in **Iraq**, the land use should be examined in detail (see table 4.3). There is a close correlation between water needs and land use, where the needs are mainly linked to agricultural development (the largest consumer sector) and to a lesser degree to energy production and others uses.

Table 4.3 Percentages and areas of land use in Iraq (web reference 32)

Type of use	**% from total Iraq area**	**Area km^2 *1000**
Total arable land	27	118.3
Natural pastures	9	39.4
Natural forests	3	13.1
Barren Mountains	1.5	6.5
Desert	33	144.6
Surface water and developed lands	26.5	116.1

The combination of precipitation shortage and harsh climate (very hot), as well as the high rates of evaporation, has increased the desert area in Iraq (evaporation within Turkey is around 6%, whereas it is 14% within Syria and Iraq). Soil and plants rapidly lose the little moisture obtained from rain. Consequently, the vegetation cannot survive without extensive irrigation (Helen, 1990).

70% of the cultivated area in Iraq is under irrigation, whereas the remaining 30% are under rain-fed cultivation. The total irrigated area during the period from 1995 to 1997 ranged between 3,055 to 3,404 million ha (UNEP, 2003).

Iraq has many problems in the water sector and it has been further hampered by high levels of salinity in lower stretch basin (Beschorner, 1992). This area is characterized by dense agricultural activities, and weak irrigation system, return wastewater from agriculture disposed to Euphrates River through drainage system, and wrong practices in agricultural (intensive fertilization) and traditional technique irrigation, which have worsened the problems in water and soil.

4.3 Hydrologic characteristic

Understanding the hydrological characteristics of the river basin is crucial to assess the effects of water management projects carried out on the rivers. In addition to the need for agricultural and industrial uses, the Euphrates and the Tigris rivers are of vital importance to people in domestic water use. They are essential resources for economic activities in all three riparian countries and they contribute to the electricity production. Most of the urban centers in these countries and a large portion of its population are located along and near the Tigris and Euphrates rivers.

The river is largely fed from the snow precipitation over the upland of eastern Turkey, where the annual total precipitation is more than 1000 mm, while the precipitation over Syria and Iraq is much less than this quantity. The flow of Euphrates is highly regulated and controlled by a series of dams and reservoirs constructed by Turkey, Syria, and Iraq.

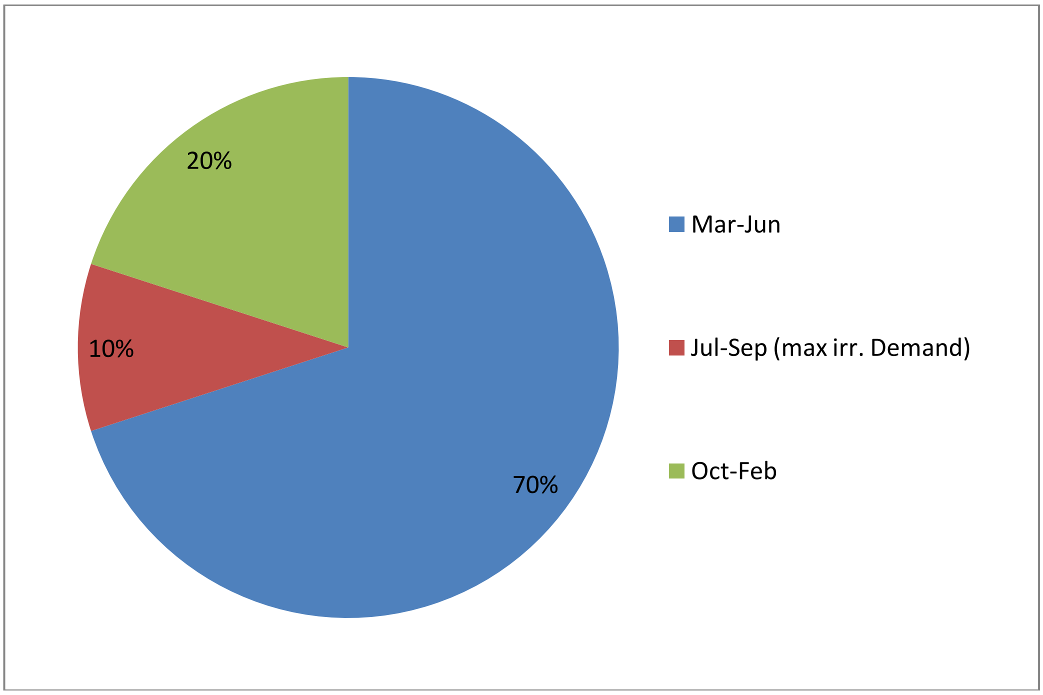
Almost all the major rivers and tributaries crossing Iraq have their origin in Turkey and Iran. Iraq only contributes with a tiny quantity of flow to the Euphrates River, however, on the Tigris River, Iraq contributes the majority of the total flow via greater and lesser Zab, the Adhaim, and the Diyla River. Iraq contributes 48.1% of water potential to the Tigris (some tributaries have their heads out of Iraq which reduces the Iraq contribution) and 2%-3% to the Euphrates. Iraq has much greater control of the water in the Tigris than it has of the Euphrates. Approximately more than 98% of the Euphrates flow originates outside Iraq compared to only 52% of the Tigris flow.

What is quite clear from these figures is that Turkey has main control of the water in the Euphrates River, since 88% of the river flow is generated within country, and it has a gigantic water system consisting of several reservoirs and many dam structures. It has the ability to store a water volume equivalent to 1.38 times the average annual flow of the Euphrates River through its reservoirs.

The Euphrates and the Tigris river **hydrology** is to a large degree determined by the snow melt and is largely linked to the precipitation in the highlands of Turkey (and in Iran, for some of the tributaries to Tigris River). The annual flow of the Euphrates River is highly seasonal. The value exhibits a wide range, estimated to be between 33% and 275% of the annual average flow, which range, from 31 to 33 BCM (983 to 1046 m^3/s). Turkey contributes with about 88%, and Syria contributes with 10%, and the remaining 2% comes from Wadis inside Iraq (FAO, 1994). Precipitation in the river basin is confined to winter time from October through April, and a large proportion of the total precipitation falls as snow on the uplands, staying in solid state on the mountain slopes until an increase in temperature occurs in early summer (April and May). The river flow during these two months is estimated to be 42% of the annual total flow (Beaumont, 1996) and (Shahin, 2007).

The availability of water through Euphrates River is not coinciding with irrigation requirements of the river basin in terms quantity and time, as illustrated in figure 4.5. The peak river flow occurs in April and May due to the combined action of snow melt and rainfall, while the low season flow occurs during the period from July to December. The lowest flows occur in August and September when water is most needed to irrigate the land for winter crops (Fletcher, 2007). For this reason, all riparian countries have sought to focus their efforts to increase water storage capacities by building new dams, water diversion projects, and reservoirs, which use their storage water for irrigation and electrical power production (see figure 4.6 a, b and c).

Figure 4.5 Percentage of flow during a year in natural flow state of the Euphrates River; numbers extracted from (Fletcher, 2007) and (Shahin, 2007)



Nowadays the flow in the Tigris and Euphrates in Iraq are largely dependent on the water released from Turkey. This release has been carefully engineered during the last years to become nearly totally controlled. Thus, among all riparian countries, Turkey has the strongest position with regard to its ability to hold the Euphrates water through its dams and capacities of its reservoirs. The series of Turkish dams and reservoirs provide full control of the flow in the river both in terms of total quantity released and the timing of the water release.

Iraq has been hit by severe scarcity of water in recent years. Because of inadequate quantity of water during the last four decades, Iraq nearly faced two conflicts with Syria and Turkey over the Euphrates River, and these two crises stimulated Iraq to build strong water management system. The first “conflict” occurred in 1974-1975 after Syria completed the construction of Al Tabaqa dam and during filling of Al Assad reservoir. The other “conflict” was in 1990 after Turkey completed the Ataturk dam.

Iraq developed its water control structures on Tigris and Euphrates much earlier than the other riparian countries. Nowadays Iraq has a highly controlled and fairly flexible water system. Tigris (with its tributaries) and Euphrates are equipped with a series of dams, reservoirs, barrages, and regulators, where the structures allows for downstream control of the Euphrates flow, making it possible to store excess discharge during wet seasons or wet years and utilize it during dry seasons or dry years.

Figure 4.6: Dams and reservoirs over Euphrates River. Source: Google earth.

a) Tabaqa Dam-Syria b) Birercik- turkey c) Al Qadisiya Dam-Iraq

4.3.1 Euphrates flow and its variation in time and space

The flow of Euphrates into Iraq has decreased over time. In past times, Iraq used to receive (31-33) BCM/yr (983 to 1046 m^3/s) as a mean annual natural flow. As shown in figure 4.7, between 1946 and 1975, the mean annual flow of Euphrates dropped to become 28 BCM (887.8 m^3/s) at the Syria-Iraq border. However, this quantity of flow decreases, by using the river water for various purposes, to 14 BCM (444 m^3/s) in Nassriah, located in southern Iraq.

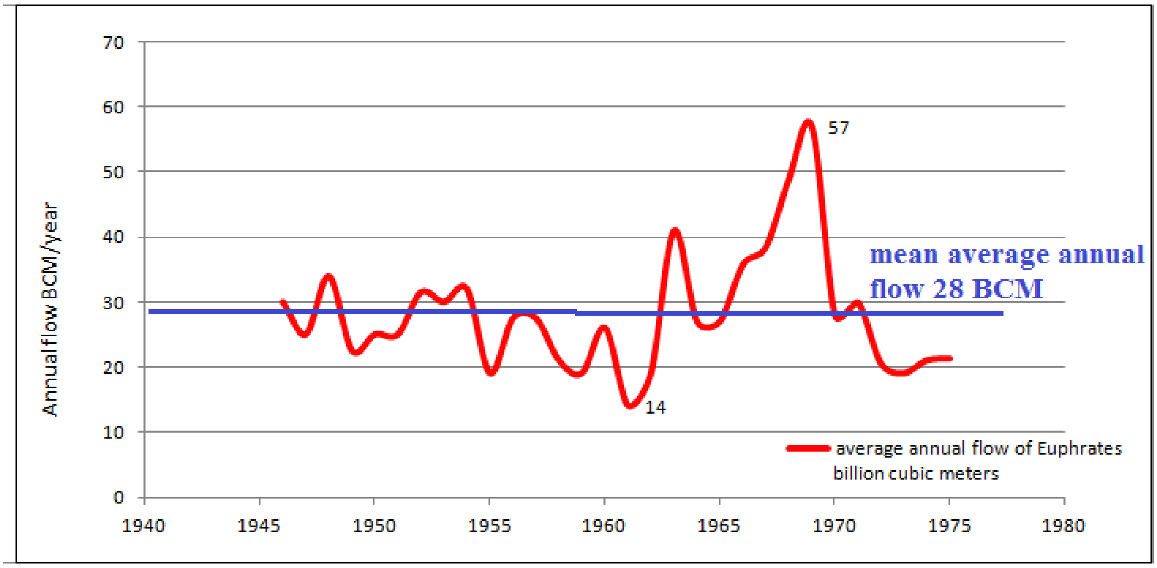


Figure 4.7 Annual average flows via Euphrates River at Syria-Iraqi border before dams' construction period (1946-1975), note: flow numbers extracted and averaged from several sources).

The current annual flow of Euphrates that enters Iraq has dropped dramatically, as illustrated in figure 4.8, with dam construction in all riparian countries and increased withdrawal of water for irrigation. The mean annual flow has decreased to become within a range from 16 to 20 BCM/year (507 to 634m^3/s) and the mean annual average is 18.3 BCM (580m^3/s).

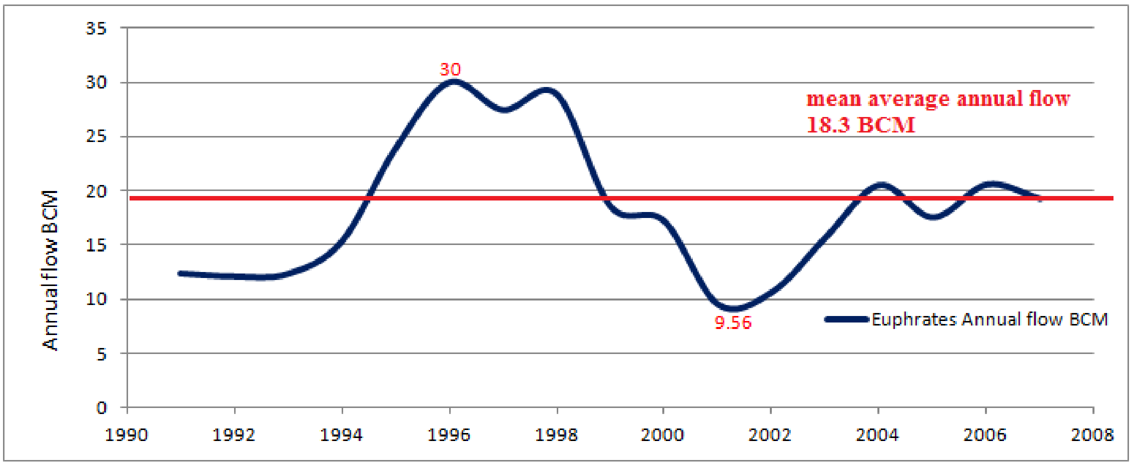


Figure 4.8 Annual average flows via Euphrates River at Syria-Iraqi border after dams' construction period (1991-2007) (note: flow numbers extracted, and averaged from several sources)

The Euphrates flow pattern over the year has also changed as illustrated in figure 4.9.

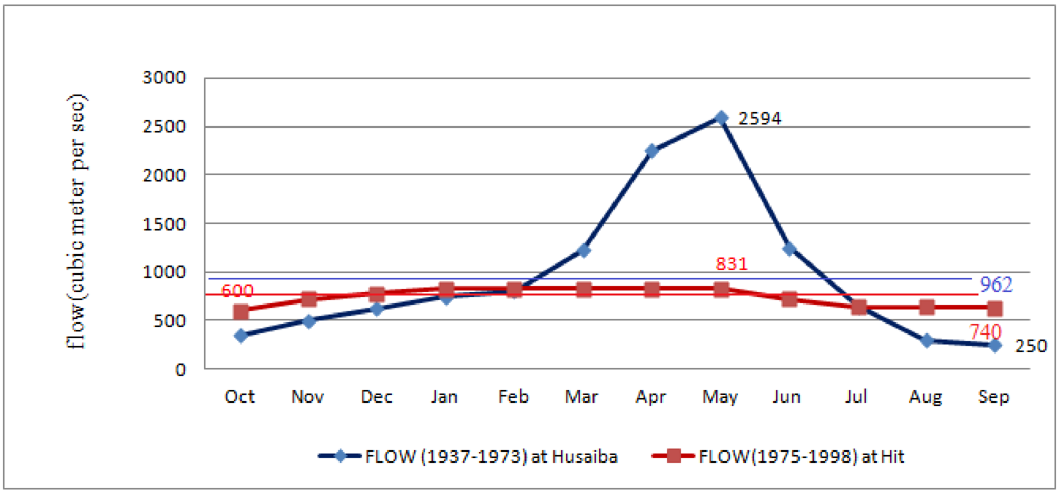


Figure 4.9 Monthly flows through Euphrates before and after dams' construction (flow numbers extracted and averaged from Jawad (2003) and other studies)

The peak flow for the pre-dam construction period recorded at the Syria-Iraqi border was 7510 m^3/s, while after the river flow had been completely regulated by a series of dams and reservoirs was only 2514 m^3/s. Measurements show that no major changes have occurred in the minimum flow through Euphrates, and it ranges from 55 m^3/s to 58 m^3/s for the aforementioned periods (Isaev and Mikhailova, 2009). The "water year" in Iraq basically depends on the annual flow volume through Iraq's rivers. It is classified according to how much flow passes through the rivers during a year, and whether the flow is much larger or smaller than the average annual flow. The year is classified as a **wet year** when a large flow volume passes through the river during this year, and an **average year** or **dry** year if the quantity is normal or smaller, respectively.

Euphrates enters Iraq at Al Qaim city. During its passage through Iraq, the river crosses more than 1000 km. The river elevation starts at 57 m above sea level and ends at zero when it reaches Shat Al Arab. The river loses a major portion of its water to irrigation canals along its course. The remaining portion of Euphrates is joined with the Tigris River near the Qurna city in southern Iraq and forms Shat Al Arab, which has a length of 190 km before the combined water is discharged into the Arabian Gulf (Dagan, 2004).

4.3.2 Tigris-Euphrates allocation processes and system flow

A schematic description of the hydrologic and water allocation schemes for Euphrates River and its relationship with Tigris River within Iraq is shown in figure 4.10 and figure 4.11. The management and operation of the whole system is done in accordance with the water balance, the climatic conditions (dry-wet year), and the dam operation policies (storage- release) in the upstream countries.

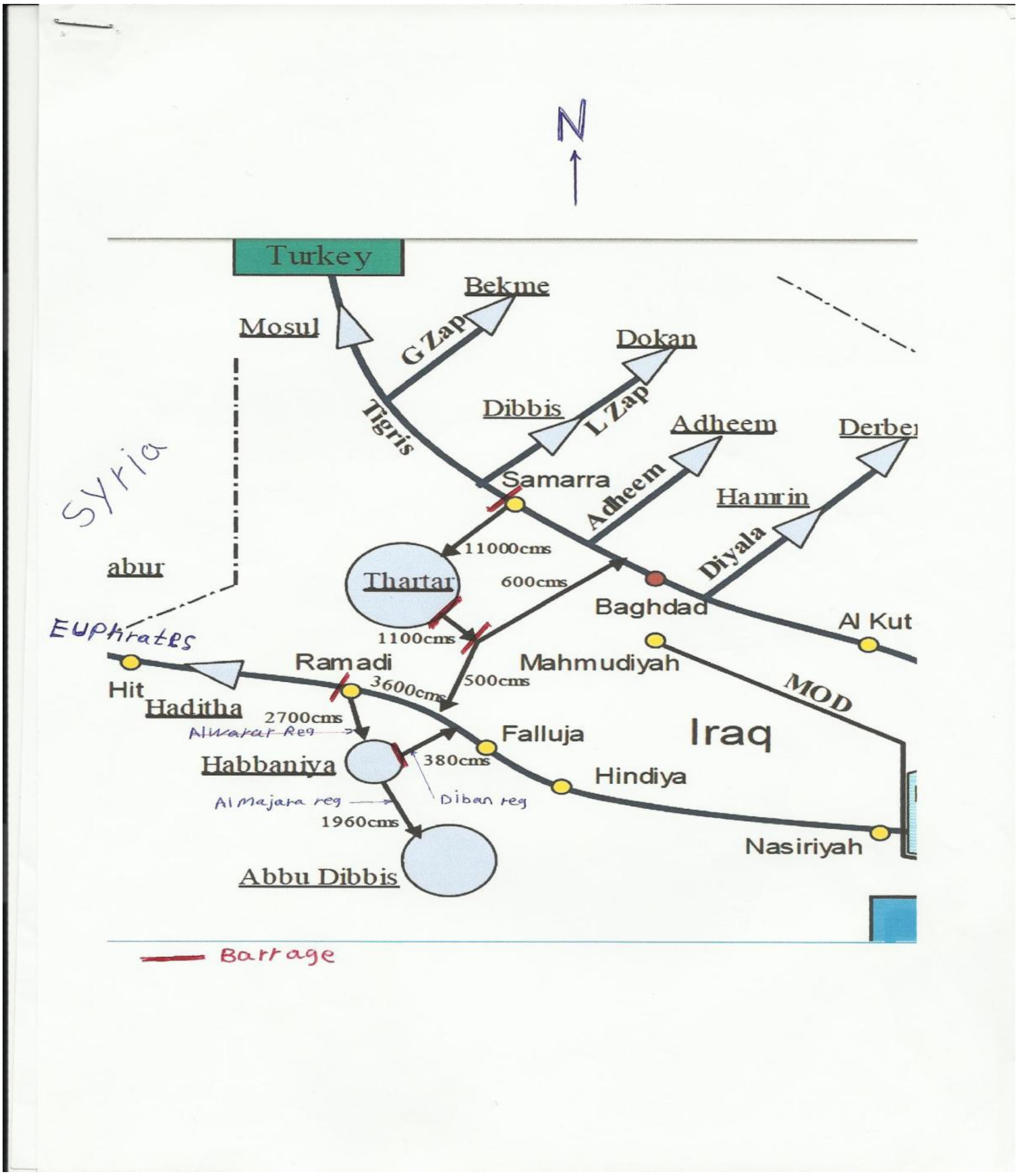


Figure 4.10 Major reservoir systems in the Tigris-Euphrates watershed (improved from Kavvas et al 2006)

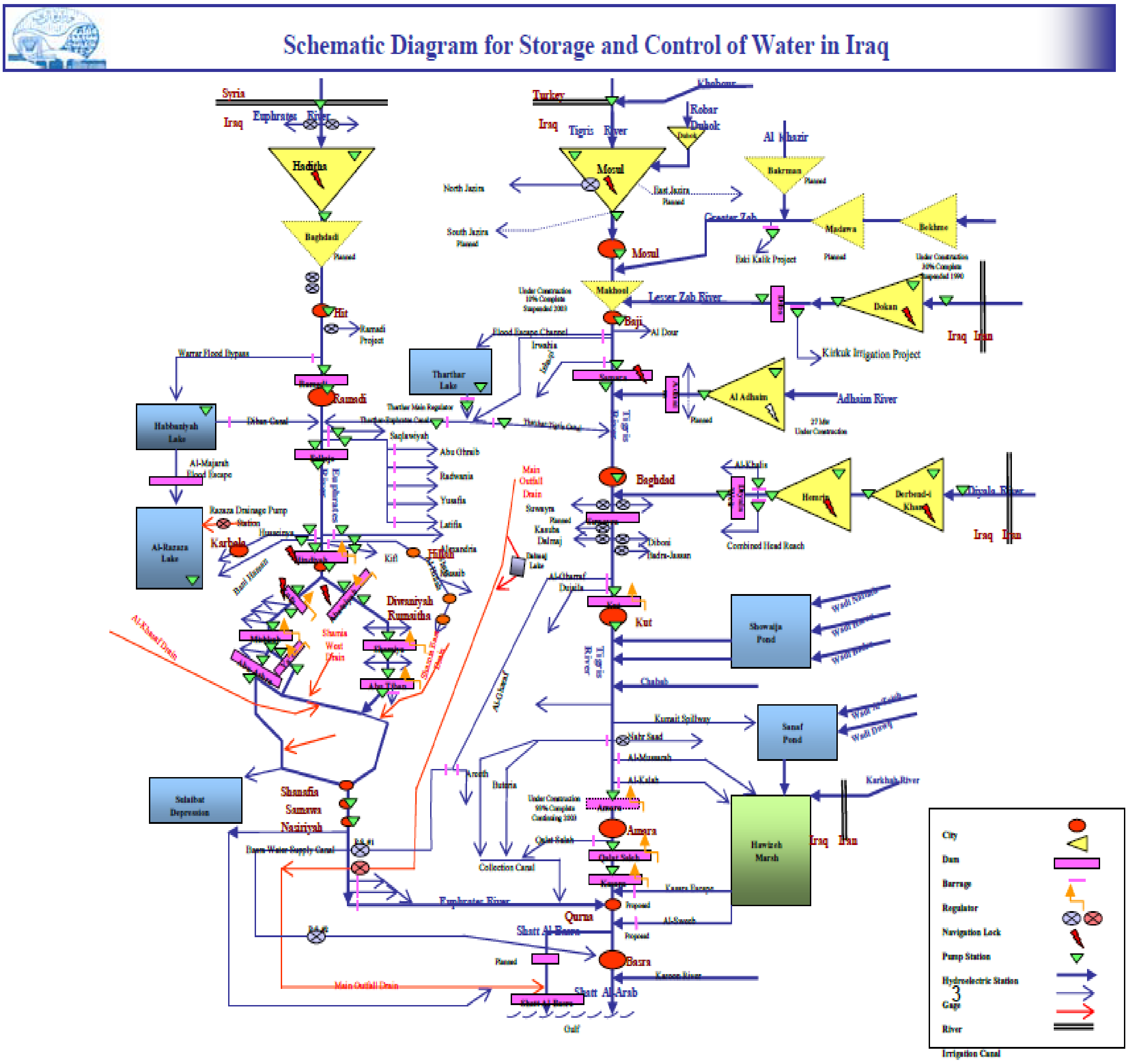


Figure 4.11 Scheme of the Iraq hydraulic network (web reference 32)

<u>The most important water management projects in Iraq water system:-</u>

As demonstrated in the figures 4.10 and 4.11 above, the Tigris and Euphrates rivers are completely controlled by a series of dams, barrages, reservoirs, and regulators located along the river stretches. The three depressions ***<u>Tharthar</u>***, ***<u>Al Habbaniya</u>*** and ***<u>al Razaza</u>*** give a good protection against floods and they can store large quantities of water. The regulators ***<u>Tigris arm</u>***, ***<u>Al Tharthar canal, warar</u>*** and ***<u>Diban</u>*** organize the flow and they give flexibility to transfer the storage water from the depressions to Tigris or to Euphrates rivers.

The ***<u>Al Hindiah Barrage</u>*** was the first modern water diversion structure built on the Tigris-Euphrates river system. It was designed by the British civil engineer William

Willcocks, and the work started in 1911 and was finished in 1913 (Qadir, 2007). It plays a major role in the river water allocation downstream, where it distributes the water flow among four branches. The largest is the main channel of the Euphrates which flows towards southern Iraq, whereas the second is the Shatt Al-Hillah branch which flows through the Babylon province. The third branch is the Al Musiab Canal, which is used to irrigate the agricultural land within Al Musaiab district. Finally, the last branch is al Hussiniah Canal, which is used to irrigate the agricultural land within Karbala province in the middle of Iraq.

Al Ramadi barrage and the nearby ***Abo Dibbis regulator*** have as main purpose to regulate the discharge to the Warar Regulator, which was constructed in the 1950s and serves to regulate the flow regime of the Euphrates and to discharge excess flood water into the depression that is now lake Habbaniya.

Haditha dam is Iraq's largest dam on the Euphrates and it was completed in 1985 with ***lake Qadisiya***, which works as a reservoir with a storage capacity from 6.2BCM (Awash, 2001) to 11.3 BCM (Juhmani, 1999).

Al Tharthar lake has been used from 1954 as a flood control basin for the Tigris river. It provides a storage capacity of 30BCM. The outlet was constructed in 1975, and the outlet canal from the Tharthar lake feeds into the Euphrates via Hakka canal with a maximum flow capacity of 500m^3/s. A second canal is a branch from the outlet canal to the Tigris with a maximum flow capacity of 600m^3/s (Al-Saadi 1983).

Al Warrar Regulator channels divert flood waters from Euphrates into Habbaniya reservoir and the Abo Dibis depression. ***Habbaniya reservoir*** is used to store excess water through these two projects, but it might be used for irrigation during the summer time by releasing back the water into the Euphrates during dry seasons via the ***Diban Regulator*** or passed on to Razaza lake through the ***Mujarah escape*** channel during very wet seasons. However, studies have revealed that large quantities of water that evaporate from the surfaces of these depressions, together with the dissolution of salts from bed and banks of the depressions, worked to increase the salinity in the storage water and rendered it unsuitable for many purposes.

Al Fallujah barrage constructed on Euphrates raises the water level upstream to allow gravity irrigation of the fertile agricultural lands around Abu Ghraib, Yousifia, Latifia, and Iskandaria. The maximum discharge capacity is 3,600m^3/s. The building of ***al-Kut barrage*** began in 1934 and was completed in 1943, while on the Diyla (a tributary of Tigris) a weir was constructed in 1927 (Jehad 1984). ***The Samarra barrage*** was constructed on the Tigris River with the objective of diverting flood waters during very wet year into the Tharthar depression. In conjunction with all these barrages on Tigris and Euphrates, many major dams were constructed on tributaries of Tigris.

4.4 Water use

The agriculture sector is by far the most demanding in terms of water withdrawal in all riparian countries compared to the industrial and domestic sector, see figure 4.12.

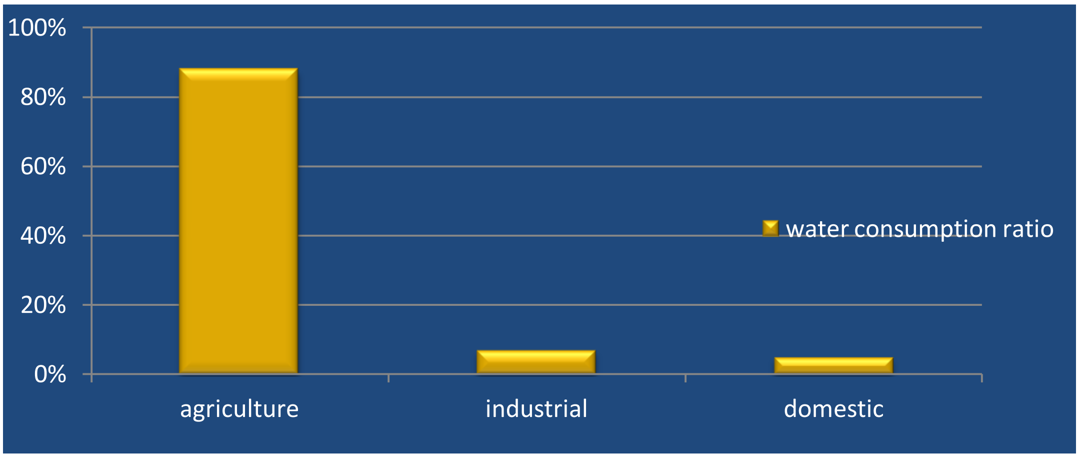


Figure 4.12 Water consumption ratios in Euphrates riparian countries (Behnam, 2003)

Turkey developed the South-Eastern Greater Anatolia Project and it consists of 22 dams. Some of the dams are in operation, which restricts the water flow through the Tigris and Euphrates. The key project within GAP is the Ataturk dam on the Euphrates River, which is located approximately 80 km upstream from the Turkish-Syrian border. It has a capacity of about 48.7 BCM (Beaumont, 1996). Turkey, through these dams, especially the Ataturk dam, has a stranglehold and complete ability to control flow towards the downstream countries (Syria and Iraq). What gives Turkey this strong position, is that more than 88% of river flow is generated in the highlands of Turkey. Furthermore, it has the ability to store a water volume equivalent to 1.38 times the average annual flow river flow.

Syria and Iraq are highly dependent on the inflow from the Euphrates River, and they have presented objections to Turkey's water use plans. These plans have direct effects on their own plans to use the water from Euphrates. In this situation, and with the absence of any water sharing agreement between riparian countries, they find it difficult to get what they need to meet their water needs. Consequently, they cannot apply these plans, see table 4.4.

Table 4.4 Water consumption in riparian countries (numbers from different sources)

Country	**%need from total river flow**	**Consumption Target BCM/year**
Turkey	52	16.64
Syria	31	9.92
Iraq	65	20.80
SUM	148	47.37

All three countries need water from Euphrates River for various purposes, and their plans involve water demand that outstrips the existing annual water supply by 15 BCM (for all countries), where the average annual flow is about 32 BCM. It is worth to note that the difference between available water and the target quantity has caused many crises in the riparian countries.

Chapter 5

Water Quality Data

5.1 Data sampling and temporal resolution

Data on water quality for years 2009 and 2010* were obtained from two river sampling areas (second and third station), which are located in the middle stretch and in mid-downstream stretch of Euphrates River, see figure 5.1. The first sampling area is located in the upper reaches of Euphrates River and it represents the base water quality of the river (the baseline), and the water from this area was examined during 2002 and 2003.

*It should be noted that there is information on page 7 and 8 in this report about sample stations and the difference in sampling date period etc.

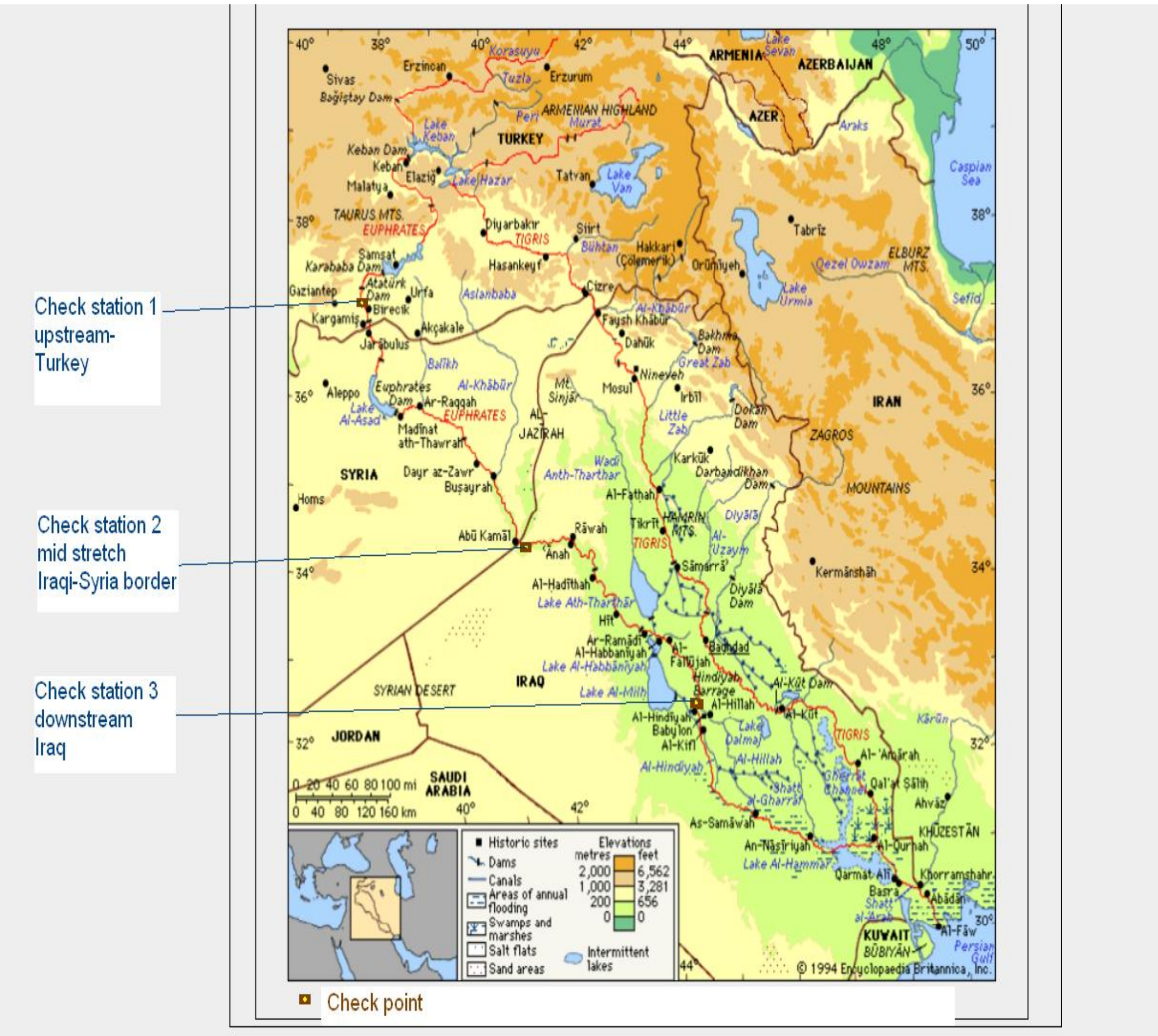


Figure 5.1: Location of sampling area stations over Euphrates River

A large number of water quality parameters of the Euphrates surface water were investigated. The results derived for these parameters were compared, first between the two downstream stations and second with the previous result from the first sampling station. Thus, changes in the water quality could be detected by analyzing the change in the concentration of these parameters. The flow through the river over the years was also monitored, and the correlation between the quantity of flow and the water quality was examined. In order to provide more background to these changes in quantity and quality, an extensive comparison with previous studies were performed.

The water samples from the river were taken by an official team under the monitoring of specialist staff from the Iraqi ministries of Environment and Water Resources and from the municipality and public works, see figure 5.2.

Figure 5.2 Specialist team in charge of taking water samples and the analysis processes

5.2 Sampling area stations and water quality parameters investigated

Three sampling area stations were chosen along Euphrates River, the **first one** is in the upstream part within Turkey and this represents the baseline water quality. It is the nearest station to the head of the river, so the results from this station were used as a baseline for the water quality. Several water parameters were examined with regard to the quality of the water using a sampling period of eight months during 2002 and 2003. This sampling station, including 500 samples from 13 locations (position where sample taken), which have similar climatic and geographic properties (as illustrated in appendix 3) and for 19 parameters, see figure 5.3, displayed good water quality. Thus, the result of the sample analysis from this station showed very low concentration of pollutants, and more information found in page 8 within this report.

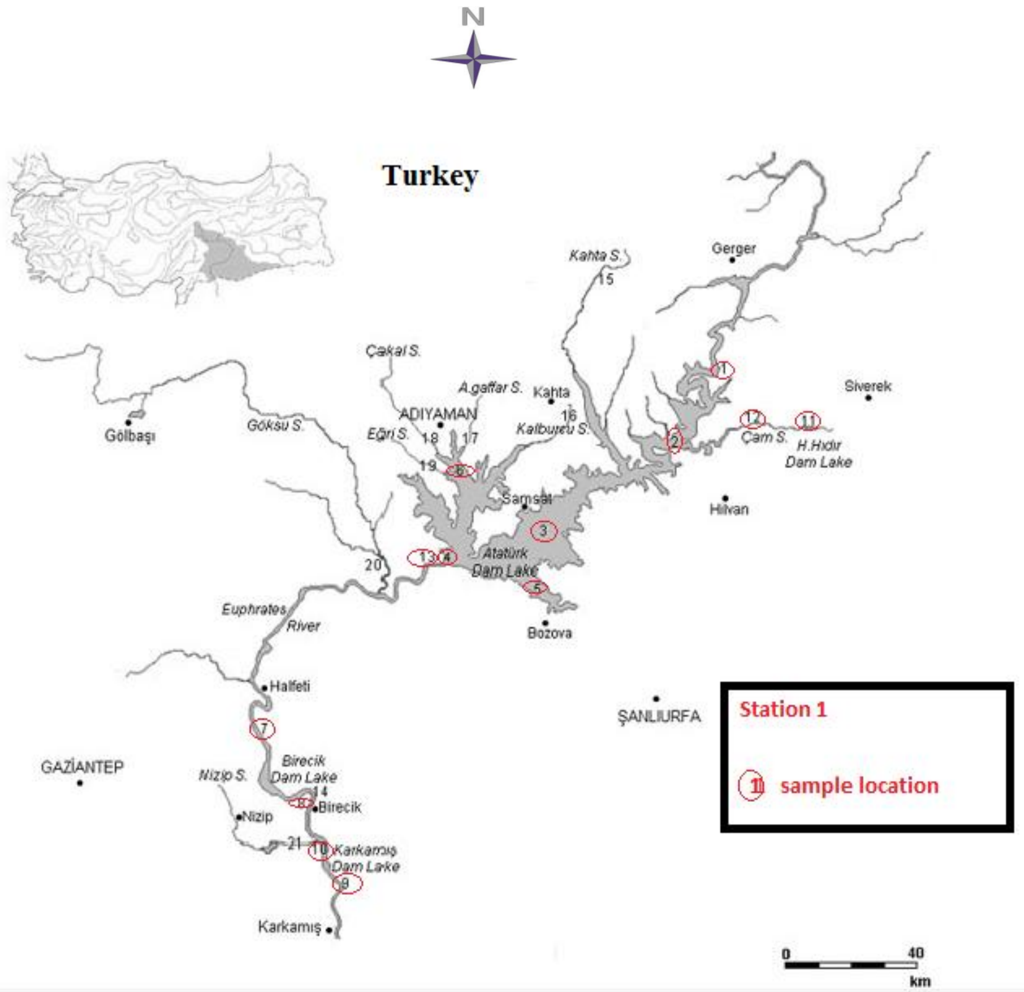


Figure 5.3 First sampling station and individual sample locations (original from Mehmet et al, 2010)

The mean annual temperature at this station ranged from 16.7 deg C to 18.8 deg C, whereas the mean annual precipitation is between 460 and 798 mm. The main rock in this district is the calcareous type, which means that the level of calcium carbonate is more than 15%. The other common rock type within this district is the basaltic soils. The main activity within this district is agriculture (Mehmet et al, 2010).

Samples were analyzed for 19 parameters including: Hydrogen power (pH), Electrical conductivity (EC), Dissolved oxygen (DO), Turbidity (Turb), Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Biochemical Oxygen Demand over 5 days, Total Hardness (Hard). Alkalinity (Alk), Calcium (Ca), Magnesium (Mg), sodium (Na), Potassium (K), Chloride (Cl), Florid (F), sulphate (SO_4), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N) and reactive phosphorus (PO_4-P).

The **second sampling station** is located in the middle stretch of Euphrates; it is near the Syria–Iraqi border. The stretch chosen for the sampling is located between Husaibah (50 km from border) and Hit (200 km from border), and the stretch is located entirely within Iraq.

Several parameters were investigated to detect changes in the water quality based on a sampling period that extended from December 2009 to November 2010. This sample station included 200 samples from 7 locations (sample positions) along the stretch chosen (which have similar climatic and geographic properties; location 1 represents the upstream, location 7 the downstream, and the other locations are in between) and for 18 parameters, see figure 5.4. The data from this stretch displayed changes in the water quality parameters; the result of the sample analysis from this station showed increases in the concentration of pollutants due to many reasons, to be discussed later.

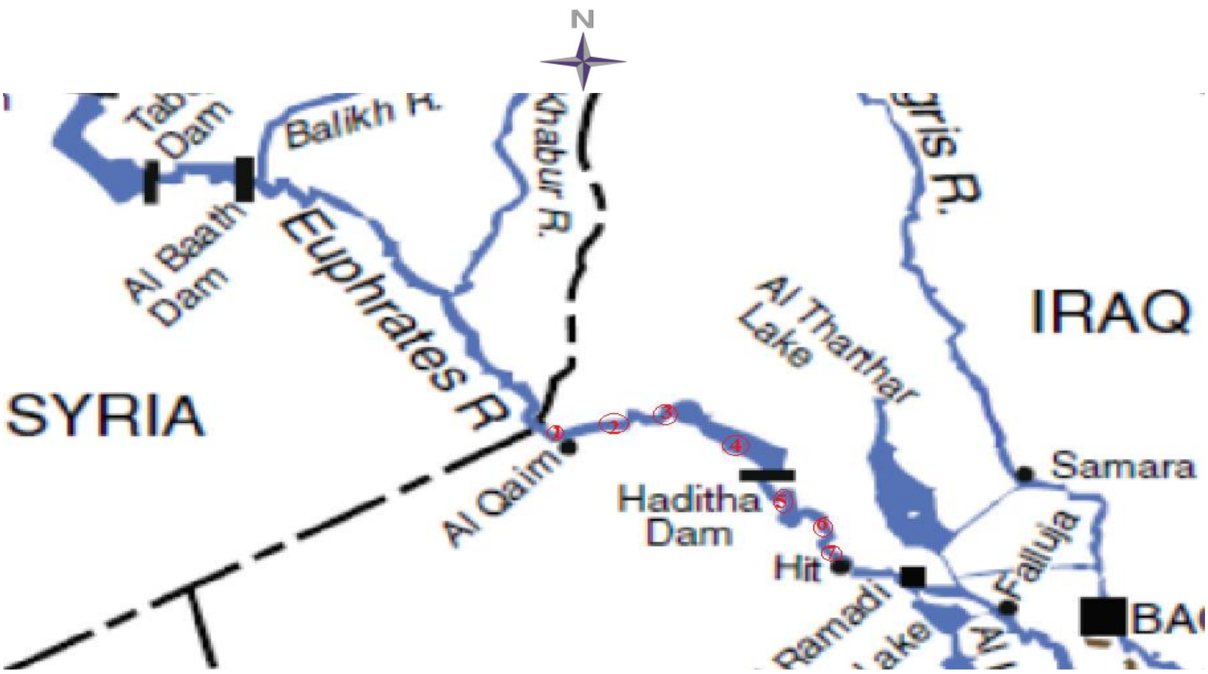


Figure 5.4 Second Sample station and sample locations

The mean annual temperature at this station ranges between 24 deg C and 26 deg C, and the mean annual precipitation is from 150 to 200 mm. The main rock in this district is the calcareous and gypsum type. The other common type within this district is the sandy soil. The main activity in the district and near the river is agriculture, but many cities and villages are also located on the river banks as well as several factories, which take their water from the Euphrates and discharge their wastewater into the river.

Samples were analyzed for 18 parameters including: water and air temperature, Hydrogen power (pH), Electrical conductivity (EC), Dissolved oxygen (DO), Turbidity (Turb), Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Biochemical Oxygen Demand over 5 days, Total Hardness (Hard), Alkalinity (Alk), Calcium (Ca), Magnesium (Mg), Potassium (K), sulphate (SO_4), Nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N) and reactive phosphorus (PO_4-P).

The **third sampling station** is located in the mid downstream stretch of Euphrates. It is in the middle of Iraq, about 532 km from Iraq Syria border, where the Al Hindiah barrage plays a main role in Euphrates water river allocation among the downstream stake holders (more information about Al Hindiah barrage may be found on pages 57 and 58 in this report). The Euphrates flows through four branches (main Euphrates and three branches), illustrated in figure 5.5, and the largest is the main channel of Euphrates, the second is the Shatt Al Hillah, the third is Al Musaiab, and the last one is Al- Hussiniah, which is utilized to irrigate the agricultural land and for domestic purposes within the Karbala province.

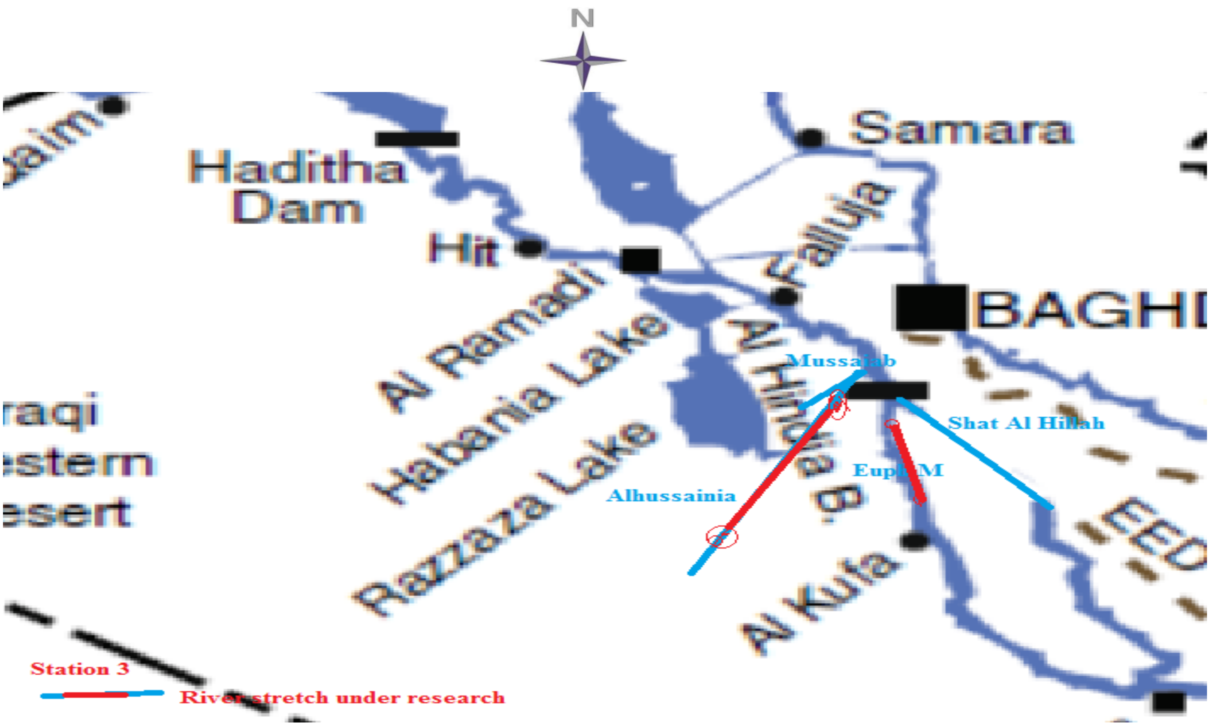


Figure 5.5 Third sampling station and sample locations

Several water parameters were investigated to examine the changes in water quality based on a sampling period from September 2009 to November 2010. This station included 650 samples from more than 39 locations (for analysis purposes, 6 out of 39 were chosen), which were located on two branches (main Euphrates and Al- Hussiniah canal; see figure 5.5). The result of the sample analysis from this sampling station showed an increase in the concentration of pollutants due to many reasons affecting the river and the deterioration in the water quality.

Samples were analyzed for 16 parameters including: water temperature, Hydrogen power (pH), Electrical conductivity (EC), Turbidity (Turb), Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Total Hardness (Hard), Alkalinity (Alk), Calcium (Ca), Magnesium (Mg), Potassium (K), sulphate (SO_{4}), DO, NO_3-N and sodium (Na).

5.3 Sample collection and equipment used

The team took the samples in running water from the river banks by filling 2 litres of surface water in pre-cleaned plastic bottle by hand or from a boat. Several samples were taken from each location to avoid point effects. Most of the samples were transported to the laboratory on the sampling day. Analysis of samples at the first station was carried out in the laboratory of XV Regional Directorate of State Hydraulic Works (Mehmet et el 2010: web reference 29), whereas for the second and third station they were performed in laboratories of GWD, belonging to MOMPW.

Figure 5.6 Procedure for taking samples

Temperature, pH, EC and DO were measured in the field by using the special equipments class YSI 63, and YSI 55, thermometer, pH meter model HANNA and EC-meter model Bischof L17, respectively. The parameters DO, Alk, Hard, Ca, Mg and sulphate were estimate following APHA (American Public Health Association), whereas Nitrite, nitrate and phosphate were estimated following Parson (a manual of chemical and biological method for seawater analysis Pergamone press, Oxford, 1984).

5.4 Data analysis and results

Several methods, such as gravimetric, titrimetric and colorimetric methods, approved by Turkish Standards Institution and the Iraqi Bureau for Environmental Improvement and Protection, were used to analyze the water samples.

For spatial-temporal analysis, multivariate statistical techniques were used to segregate and examine the water quality data obtained from the samples. Multivariate statistics is considered one of the best and efficient tools to analyse the spatial and temporal variation in the water quality of a river, as well as the variation in water quantity among different stations along the river (Quadir, 2007). A summary of the sample analysis for the three stations is given in tables 5.1A and B, 5.2A and B, 5.3A and B, and figures 5.7, 5.8 and 5.9.

Table 5.1 Summary of analysis results for water quality parameters at first station (for more information about the name of locations 1 to 13, see appendix 3). Concentration in mg/l which is equal to ppm, (Mehmet et el 2010: web reference 29)*.

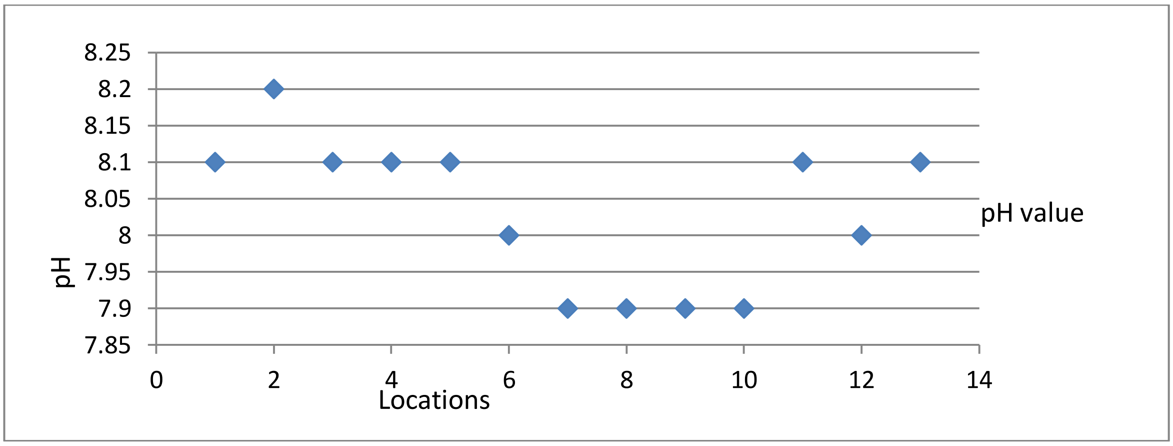
*These numbers represent the mean values over the period of study within this sample station (eight months); the relatively high values in some locations, such as location 6, could be due to agriculture or human activities within this stream basin which discharged their wastewater into river.

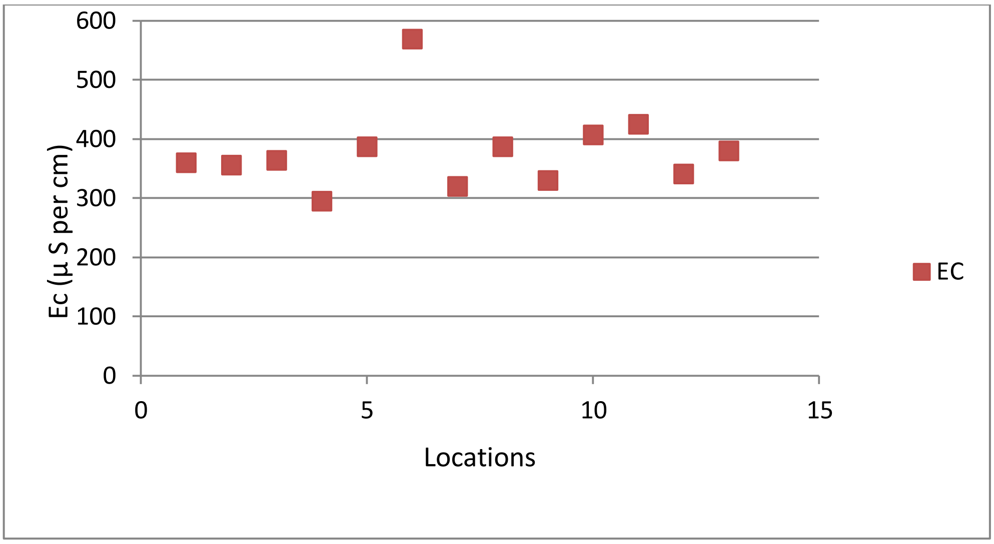
A

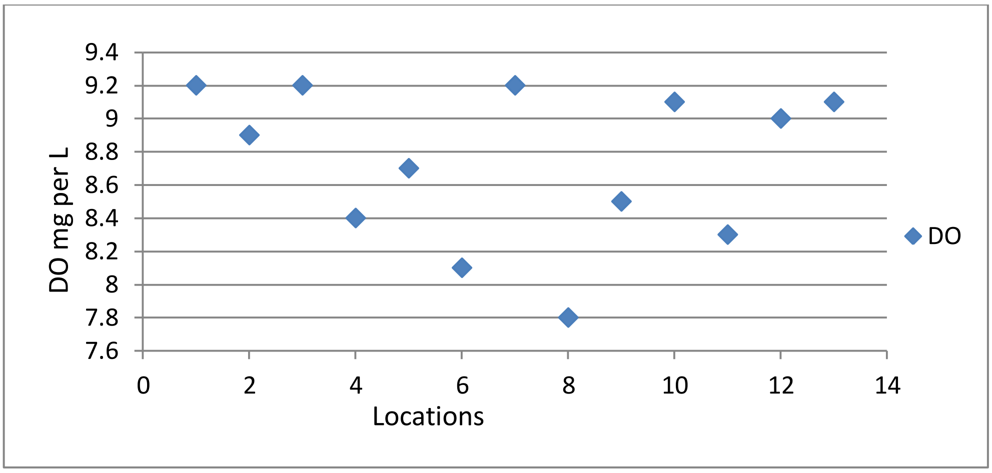
Location	**pH**	**EC**	**DO**	**BOD**	**Turb.**	**TSS**	**TDS**	**Alk.**	**Hard.**
1	8.1	360	9.2	1.3	7.1	8.6	227	127	165
2	8.2	356	8.9	1.1	7.5	9.4	227	135	175
3	8.1	364	9.2	1.6	6.3	8.6	230	137	175
4	8.1	295	8.4	3.9	7.5	13	183	118	138
5	8.1	387	8.7	1.4	5	13	250	145	180
6	8	569*	8.1	1.1	5	6.4	338*	205	274
7	7.9	320	9.2	1	5	5.2	204	128	155
8	7.9	387	7.8	0.9	5	4.8	248	140	183
9	7.9	330	8.5	1.3	5	4.6	202	120	160
10	7.9	407	9.1	1.2	5	6.8	256	155	200
11	8.1	425	8.3	2.3	5	5.2	272	180	176
12	8	341	9	1.5	5	6.6	218	135	175
13	8.1	380	9.1	1.4	5	5.6	230	149	185
Ave.	8.0	378.5	8.73	1.54	5.65	7.5	237	144	180

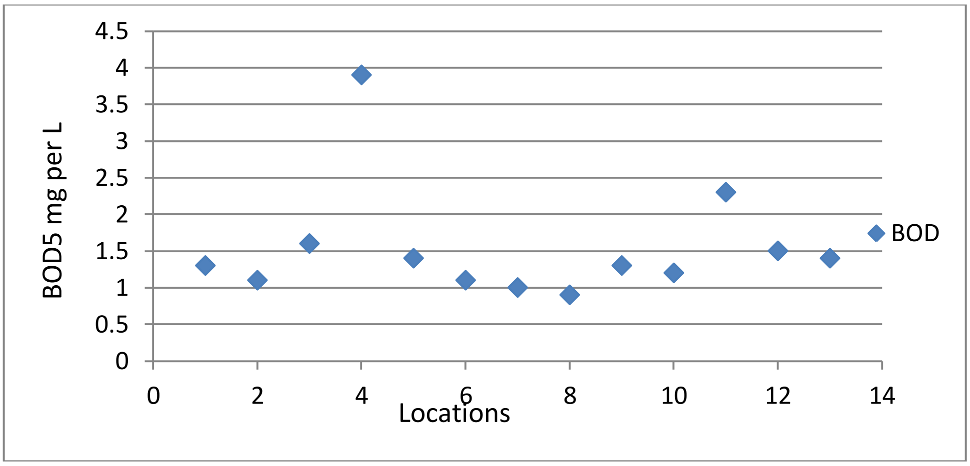
B

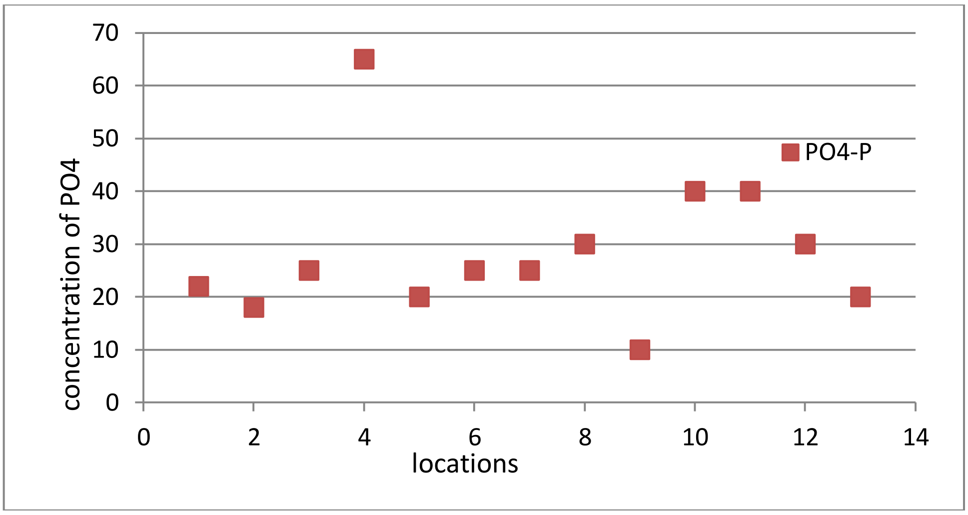
Location	Ca	Mg	K	Na	Cl	F	SO4	NH3-N	NO3-N	PO4-P *1000
1	45	13	1.7	13	22	0.4	33	0.32	3.7	22
2	48	13	1.6	12	24	0.1	33	0.3	3.9	18
3	43	13	1.7	14	23	0.2	33	0.31	4.1	25
4	40	12	5.2	13	21	0.1	24	0.51	4.4	65
5	52	12	1.7	14	24	0.2	34	0.31	3.6	20
6	72	18	1.6	8.2	36	0.2	25	0.47	4.8	25
7	40	13	0.5	3.1	16	0.1	23	0.29	4.1	25
8	48	17	0.8	3.7	21	0.2	27	0.33	4.5	30
9	40	15	1	2.9	18	0.1	23	0.34	3.5	10
10	58	13	0.6	3	18	0.1	15	0.24	3.9	40
11	60	15	1.4	7.4	24	0.1	26	0.41	4	40
12	50	12	1.2	9.4	15	0.1	23	0.33	3.2	30
13	53	12	1.1	4.5	17	0.1	21	0.51	3.6	20
Ave.	50	14	1.5	8.3	21	0.2	26	0.36	3.94	28.46

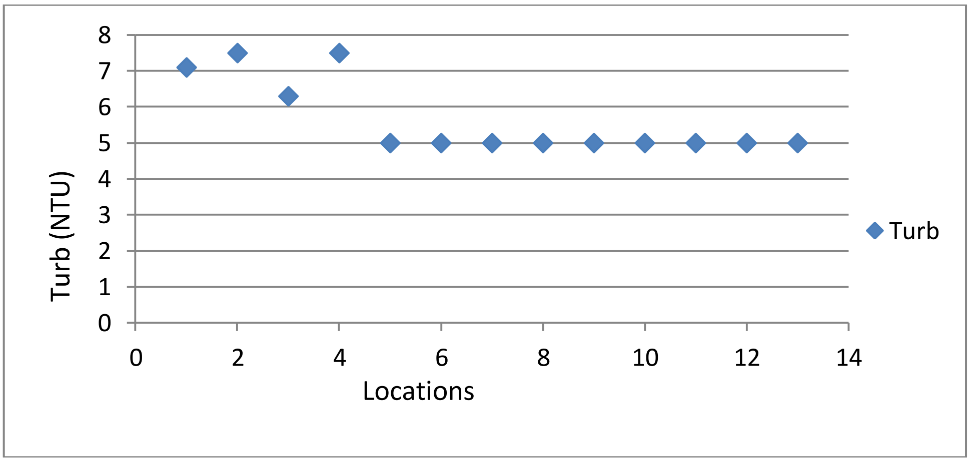


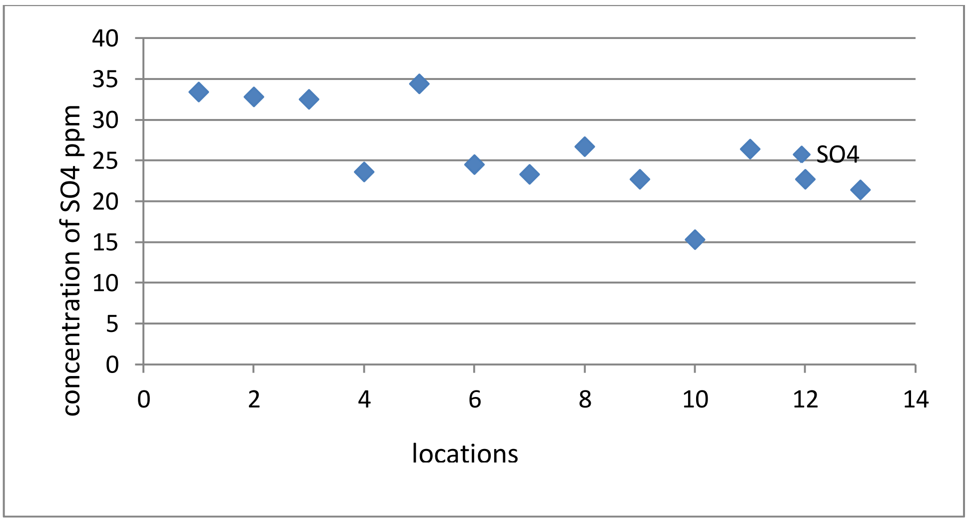

600
500
400
300
200
100
0
Ec (µ S per cm)
0
5
10
15
Locations
EC

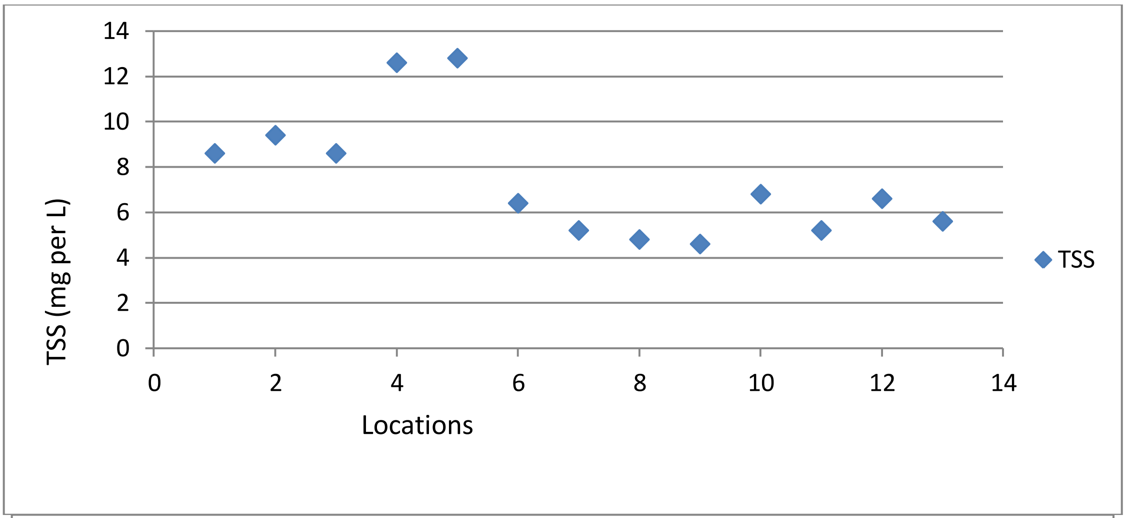

9.4
9.2
9
8.8
8.6
8.4
8.2
8
7.8
7.6
DO mg per L
0
2
4
6
8
10
12
14
Locations
DO

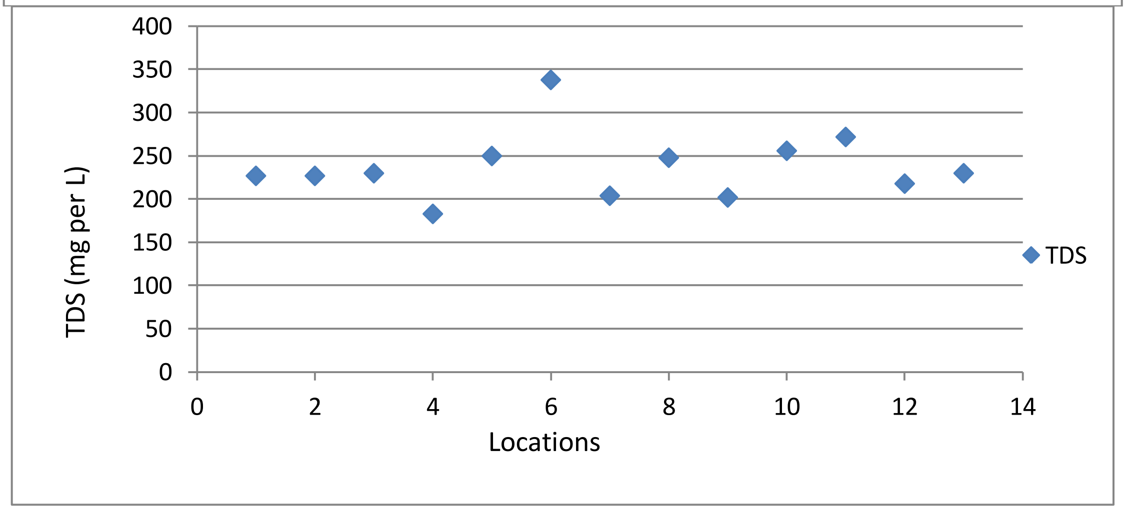

4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
BOD5 mg per L
0
2
4
6
8
10
12
14
Locations
BOD

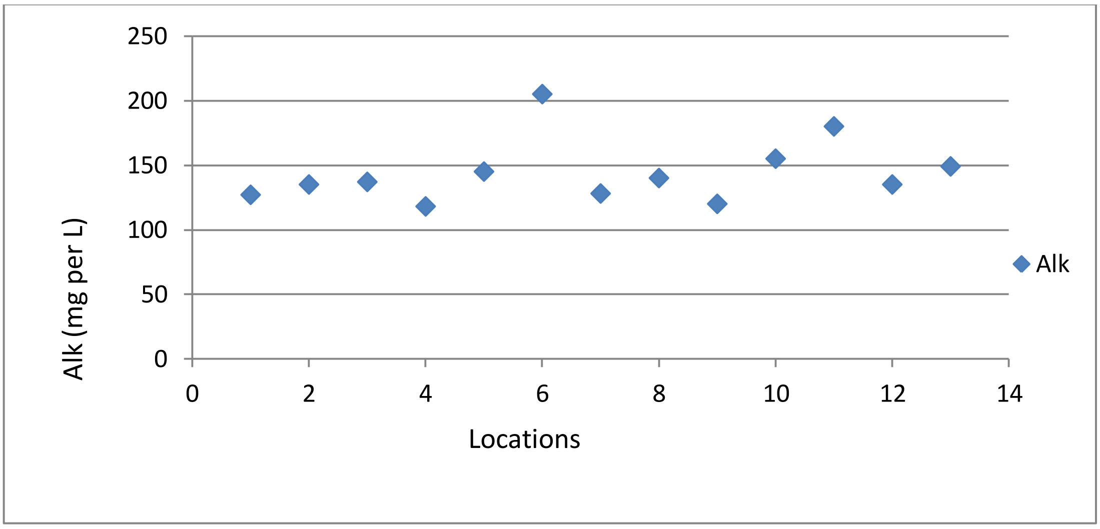

PO4-P
concentration of PO4
locations

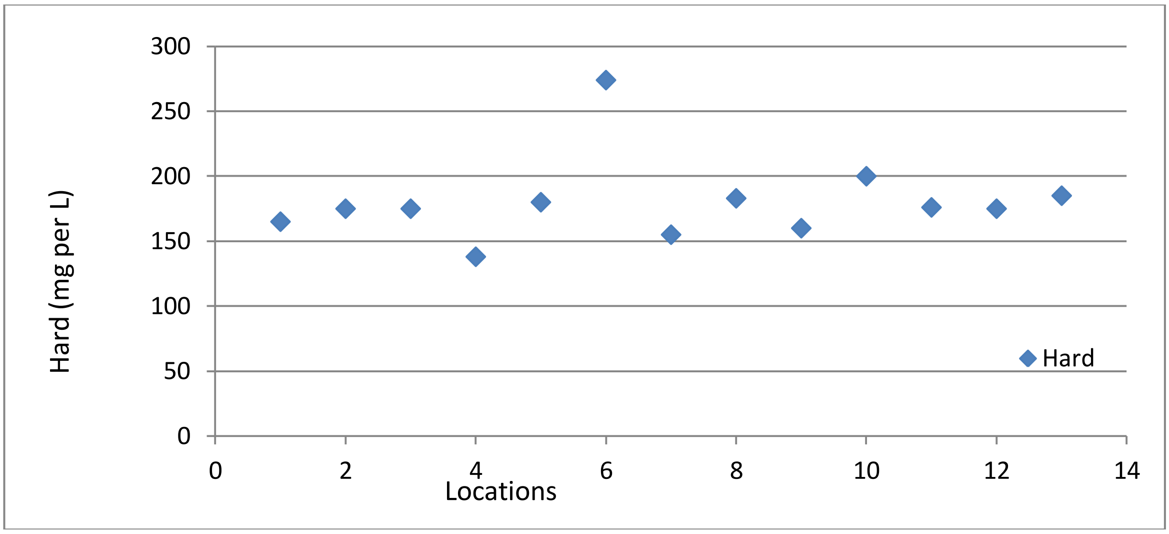

Turb
Turb (NTU)
Locations


SO4
concentration of SO4 ppm
locations

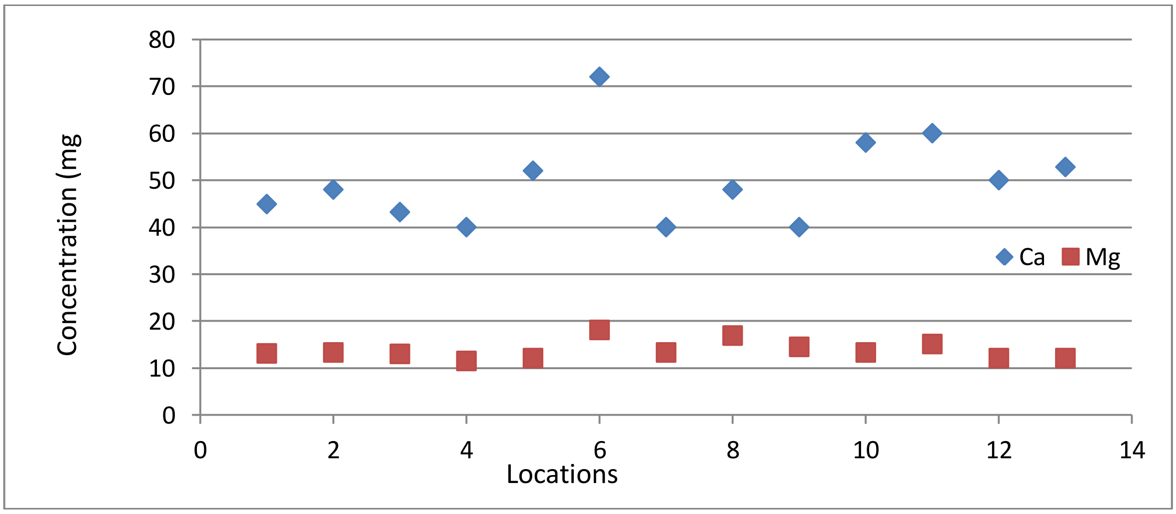

TSS (mg per L)
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
Locations
TSS


TDS (mg per L)
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
Locations
TDS

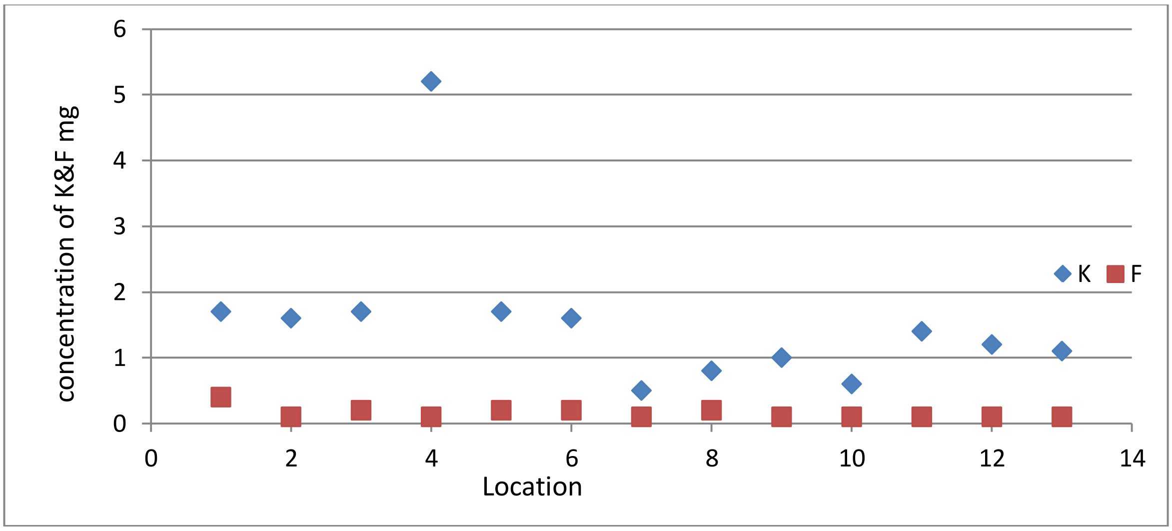

Alk (mg per L)
250
200
150
100
50
0
0
2
4
6
8
10
12
14
Locations
Alk



Hard (mg per L)
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
Locations
Hard



Concentration (mg
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
Locations
Ca
Mg



concentration of K&F mg
6
5
4
3
2
1
0
0
2
4
6
8
10
12
14
Location
K
F

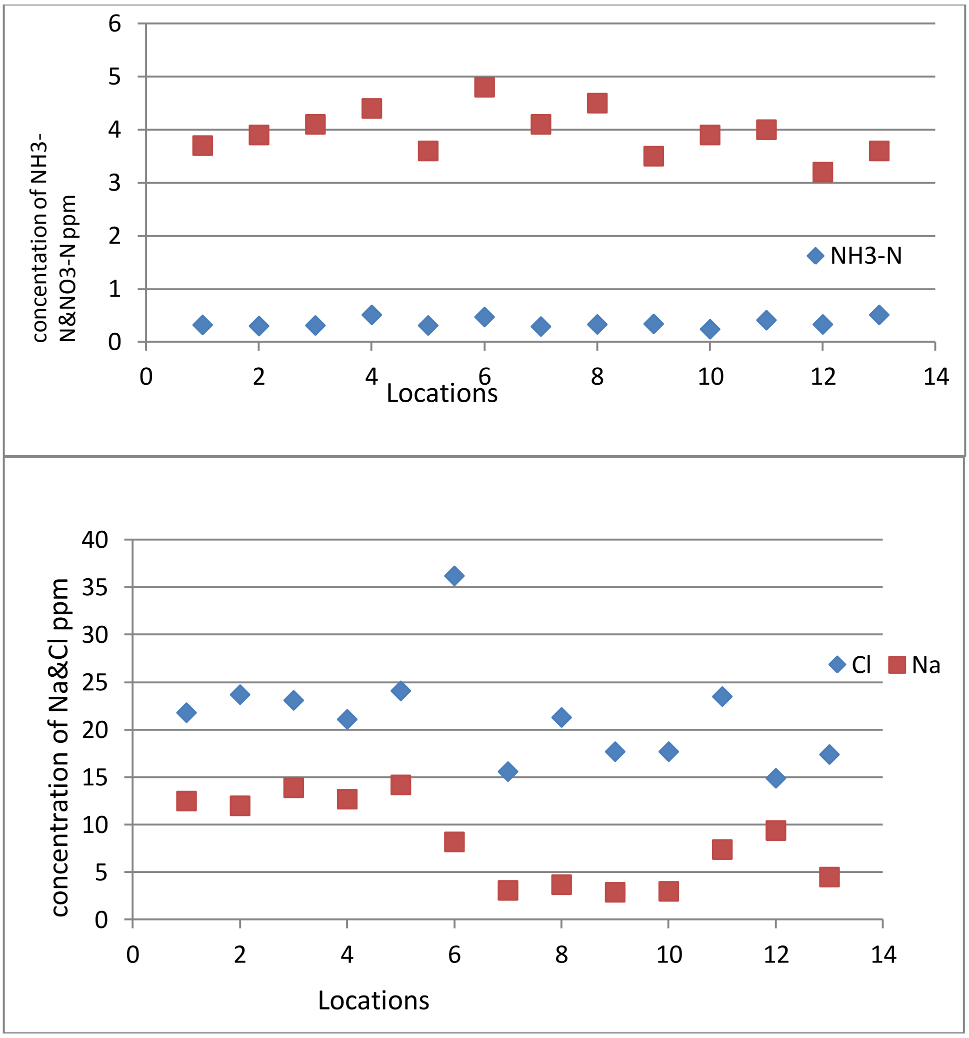


Figure 5.7: The change in water quality parameter value with location for first station

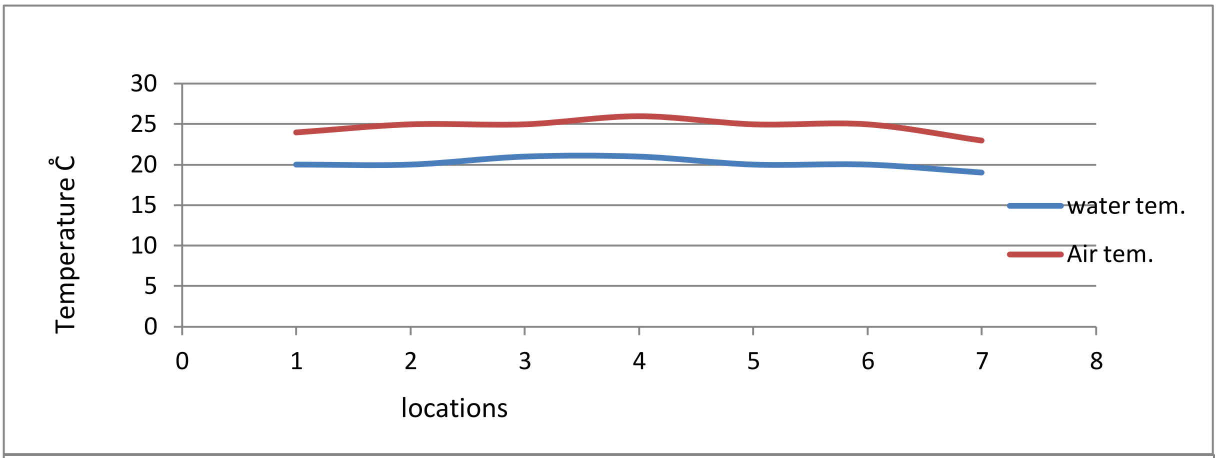
Table 5.2 Summary of analysis results for water quality parameters at second station, concentration in mg/l or ppm, and the numbers represent the mean value over time period.

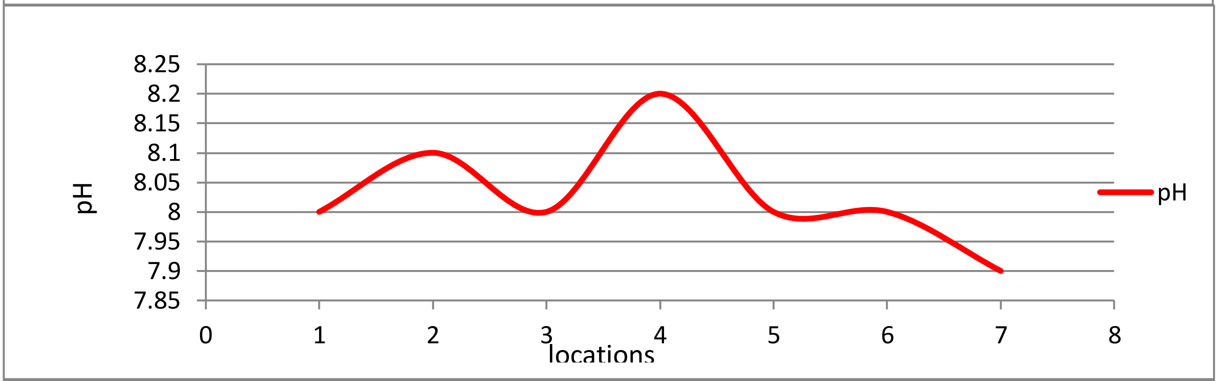
A

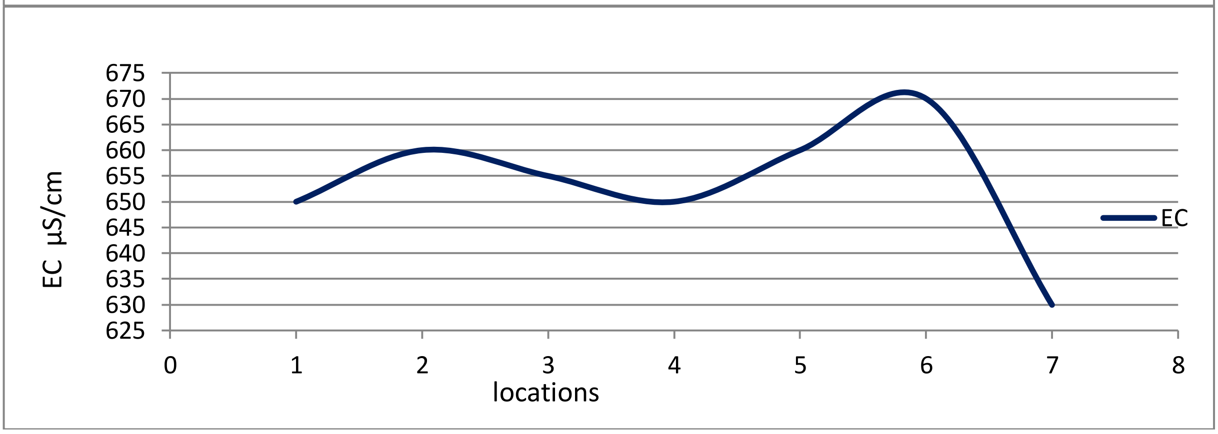
Location	**Water tem.**	**Air tem.**	**pH**	**EC**	**TDS**	**TSS**	**DO**	**Turb.**	**BOD_5**
1	20	24	8	650	500	12.5	6	13	3.5
2	20	25	8.1	660	480	13	6	13	3.7
3	21	25	8	655	490	12	6.25	12.5	4.2
4	21	26	8.2	650	500	13	6.5	13	4.4
5	20	25	8	660	520	12.5	6.7	12.75	4
6	20	25	8	670	510	12	6.4	12.5	3.8
7	19	23	7.9	630	505	12.3	5.5	12.5	4.5
Ave. mean	20.1	24.7	8.0	654	500.	12.5	6.19	12.7	4.01

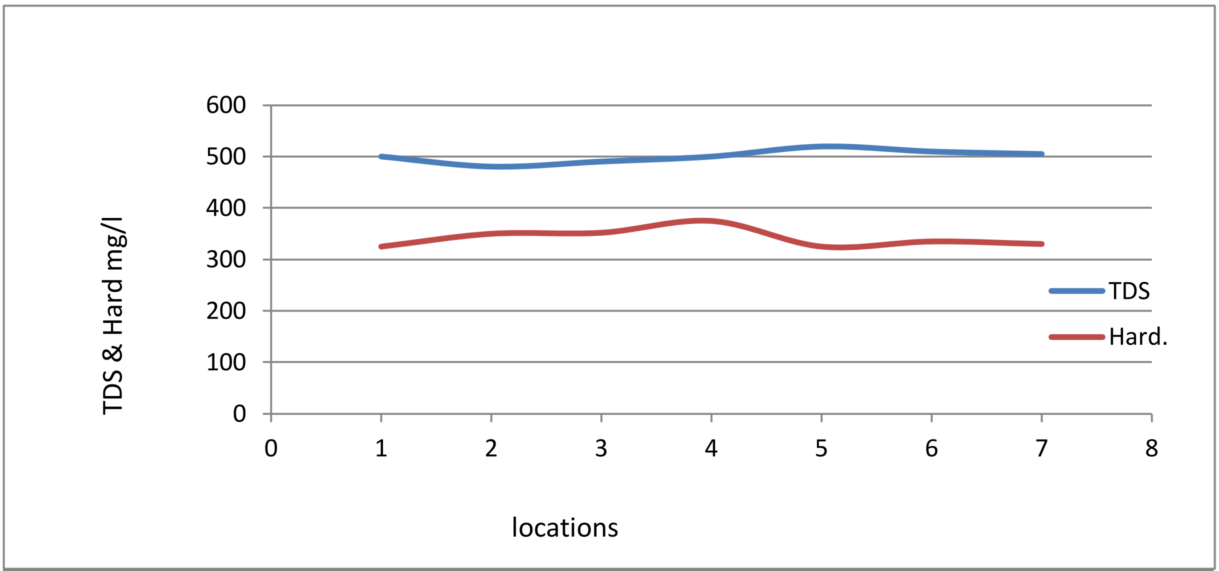
B

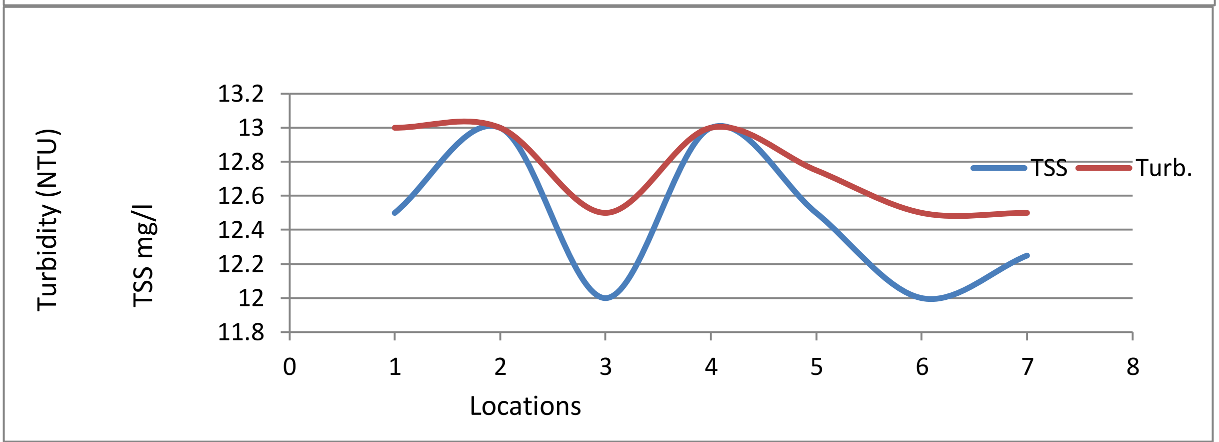
Location	**Alk.**	**Hard.**	**Ca**	**Mg**	**NO_3-N**	**NO_2-N**	**PO_4 -P *1000**	**SO_4**	**K**
1	120	325	80	20	4.5	< 0.2	35	170	2.1
2	125	350	75	22	5.7	< 0.2	37	175	2
3	122	352	80	23	6.5	< 0.2	40	180	2
4	124	375	95	25	7.4	< 0.2	42	175	1.9
5	110	325	90	24	6.5	< 0.2	45	170	2.2
6	120	335	85	22	6.4	< 0.2	45	165	2.3
7	125	330	90	23	7.7	< 0.2	46	155	2.4
Ave. mean	120.9	341.7	85	22.7	6.38	< 0.2	41.42	170	2.13

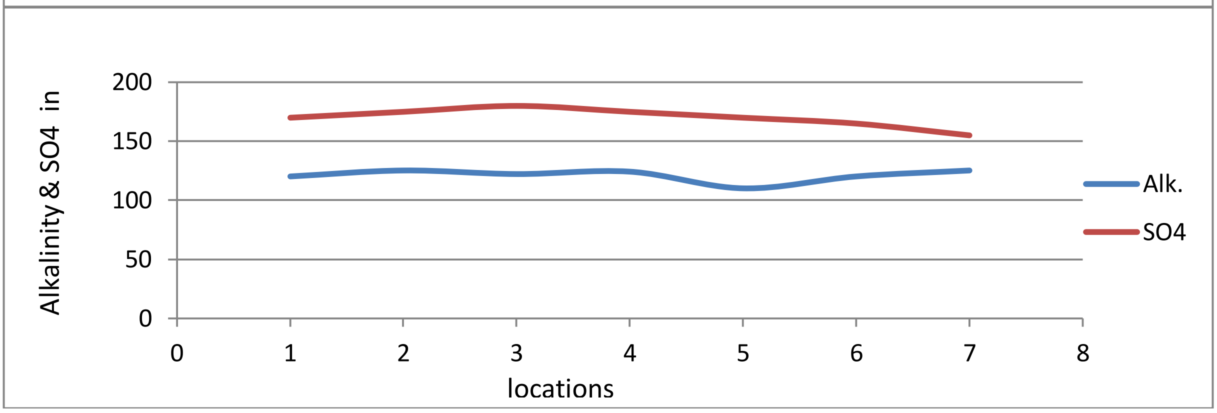

30
25
20
15
10
5
0
Temperature C̊
0
1
2
3
4
5
6
7
8
locations
water tem.
Air tem.


8.25
8.2
8.15
8.1
8.05
8
7.95
7.9
7.85
pH
0
1
2
3
4
5
6
7
8
locations
pH


675
670
665
660
655
650
645
640
635
630
625
EC µS/cm
0
1
2
3
4
5
6
7
8
locations
EC


600
500
400
300
200
100
0
TDS & Hard mg/l
0 1 2 3 4 5 6 7 8
locations
TDS
Hard.


13.2
13
12.8
12.6
12.4
12.2
12
11.8
Turbidity (NTU)
TSS mg/l
0 1 2 3 4 5 6 7 8
Locations
TSS
Turb.


200
150
100
50
0
Alkalinity & SO4 in
0 1 2 3 4 5 6 7 8
locations
Alk.
SO4

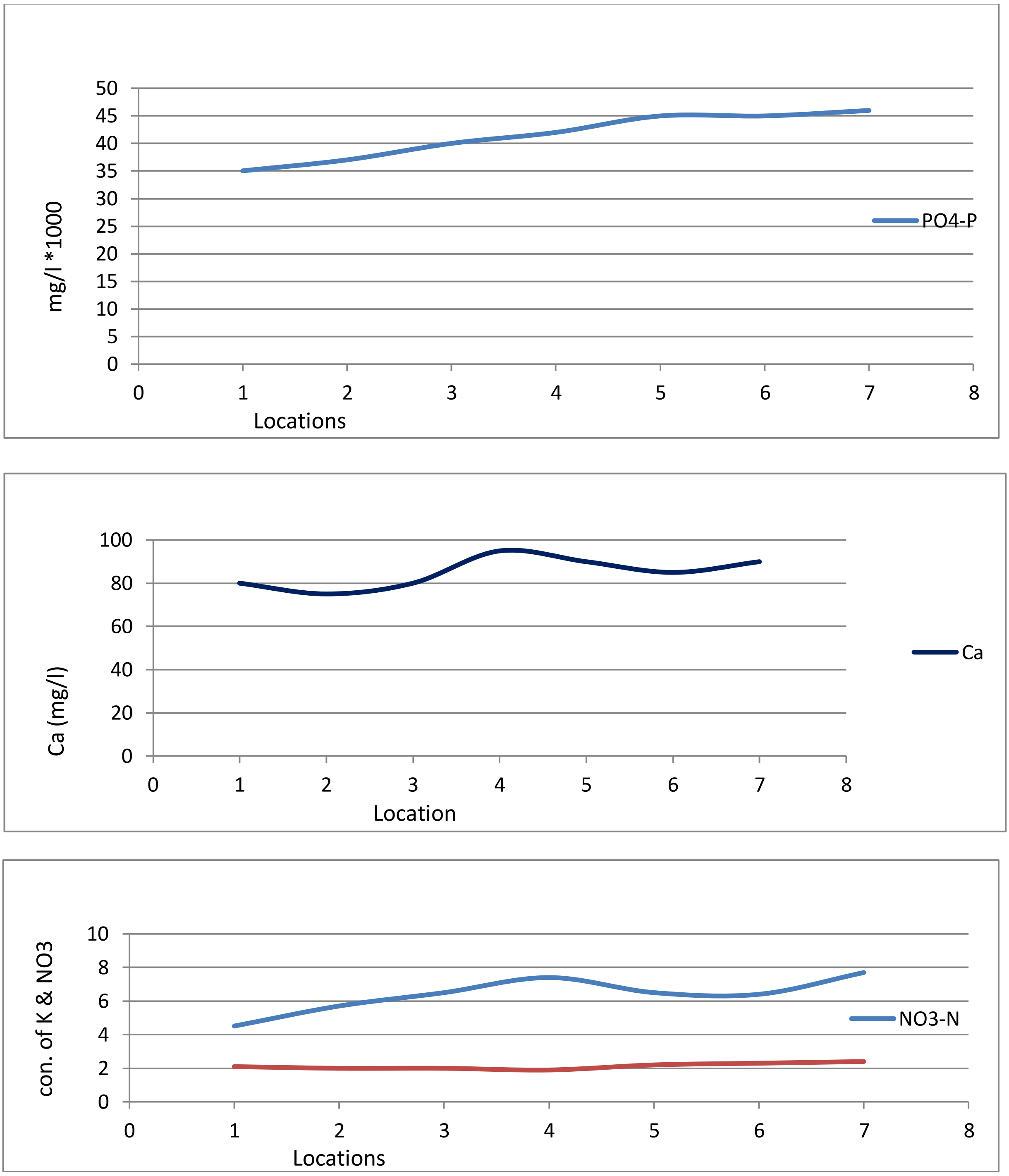


Figure 5.8: The change in water quality parameter value with location for second station

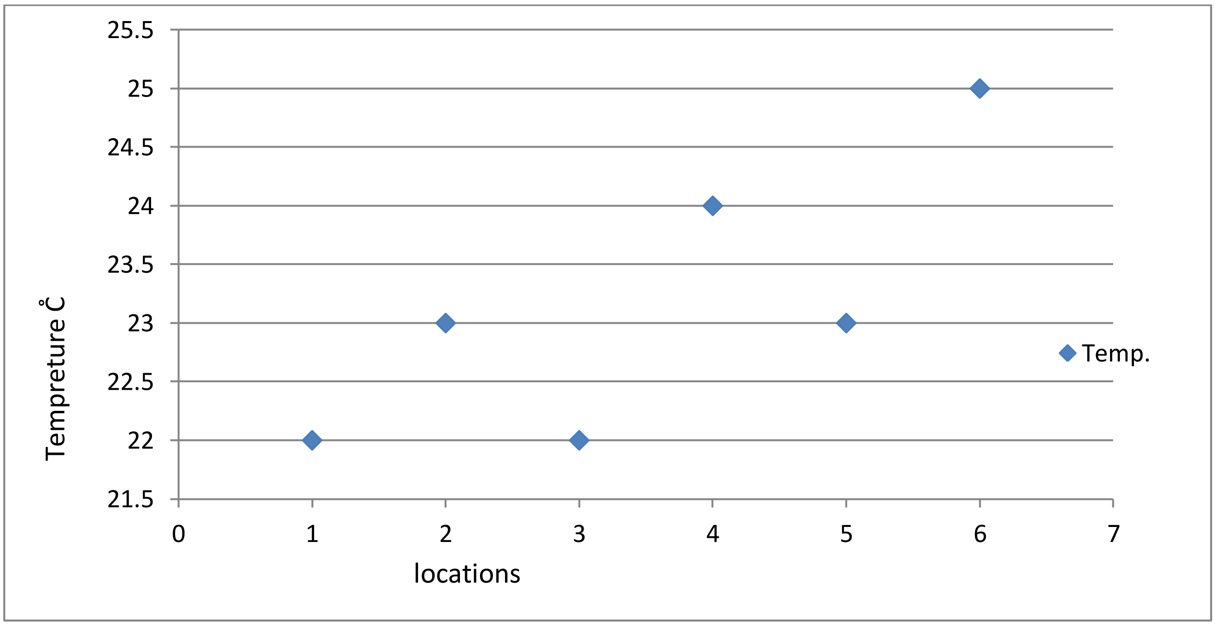
Table 5.3 Summary of analysis results for water quality parameters at third station, concentration in mg/l or ppm. Numbers represent the mean value over study period.

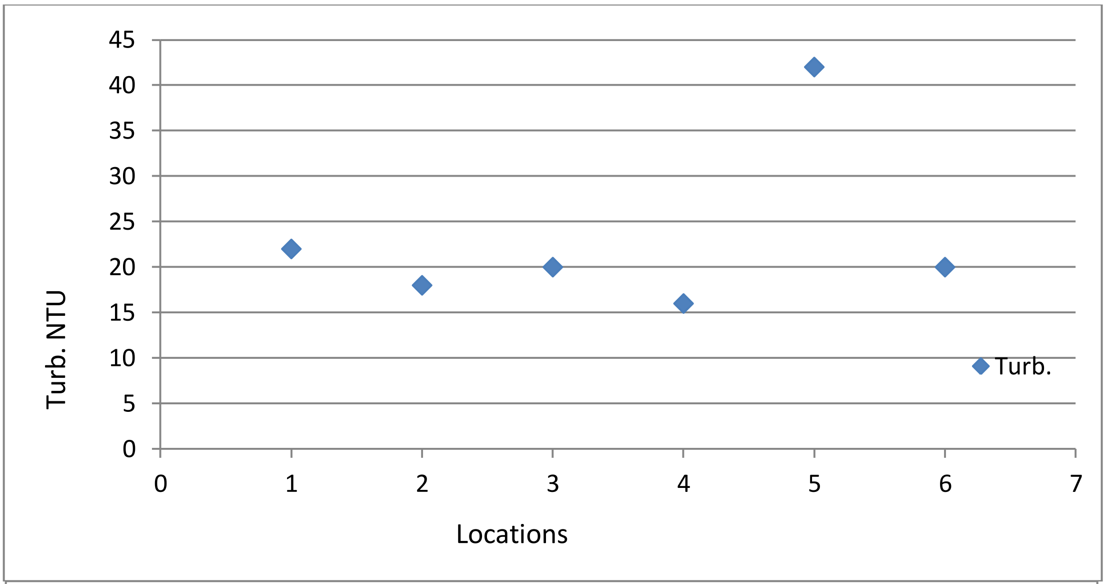
A

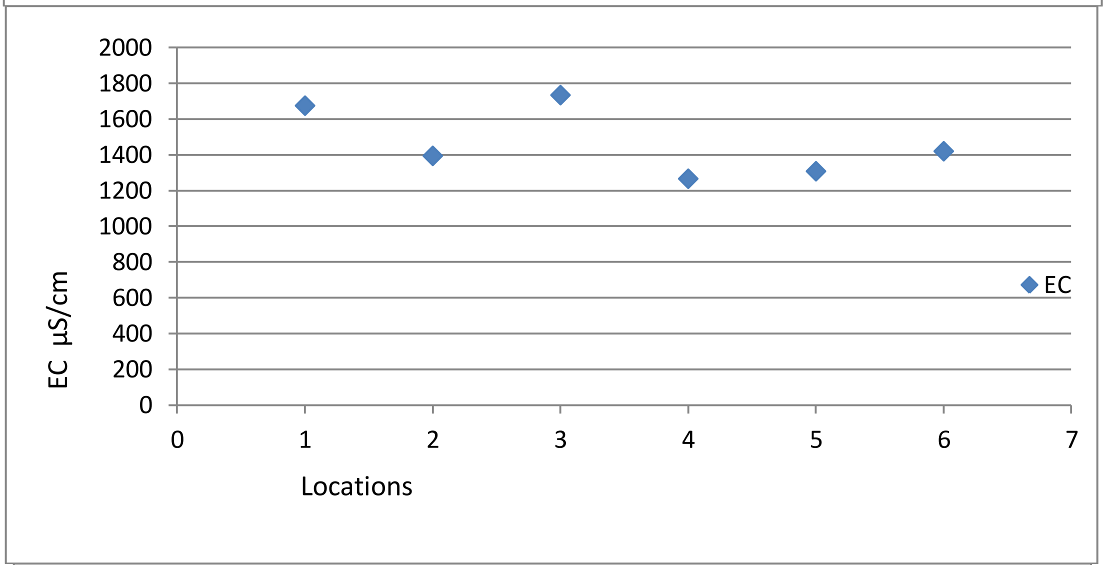
Location	Temp.	Turb.	pH	EC	Alk.	Hard.
1	22	22	8.4	1675	130	560
2	23	18	8.2	1394	132	520
3	22	20	8	1734	128	430
4	24	16	8.2	1266	158	494
5	23	42	8.1	1308	130	500
6	25	20	8	1420	132	510
Ave. mean	23.16	23	8.15	1466	135	502

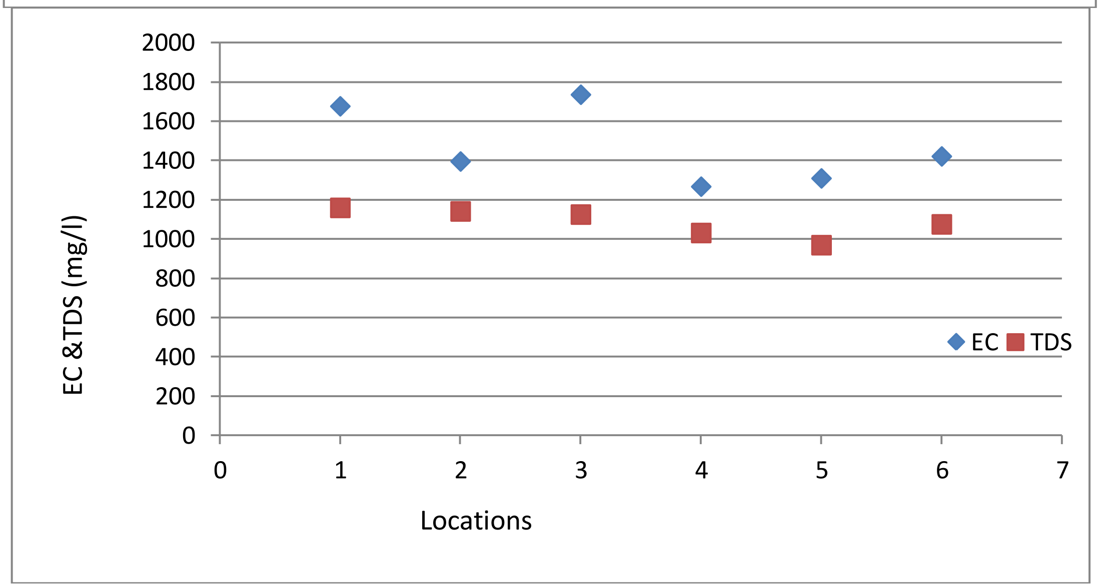
B

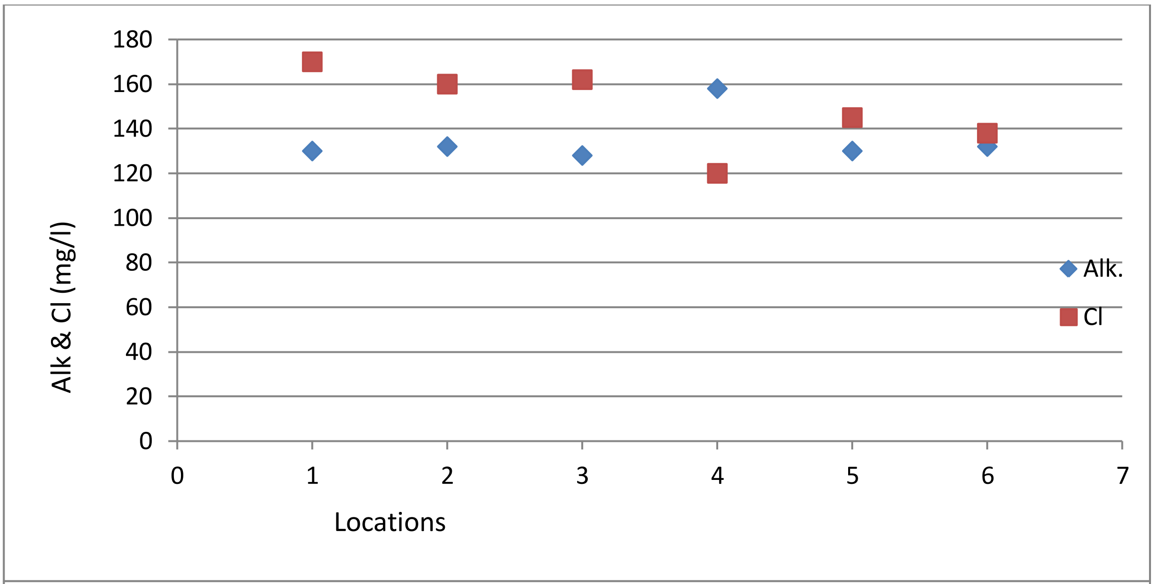
Location	Ca	Mg	Cl	SO_4	TDS	TSS	Na	K	DO	NO_3
1	176	49	170	388	1158	38	122	4.3	2.5	30
2	156	27	160	387	1140	26	112	4.1	1.1	45
3	150	37	162	376	1124	42	121	5.3	1.3	65
4	112	47	120	348	1030	32	97	5.2	0.9	70
5	128	44	145	390	968	52	102	4.7	5.4	86
6	138	38	138	380	1074	48	110	4.5	5.7	80
Ave. mean	143	40	149	378	1082	40	111	4.7	2.8	62.7

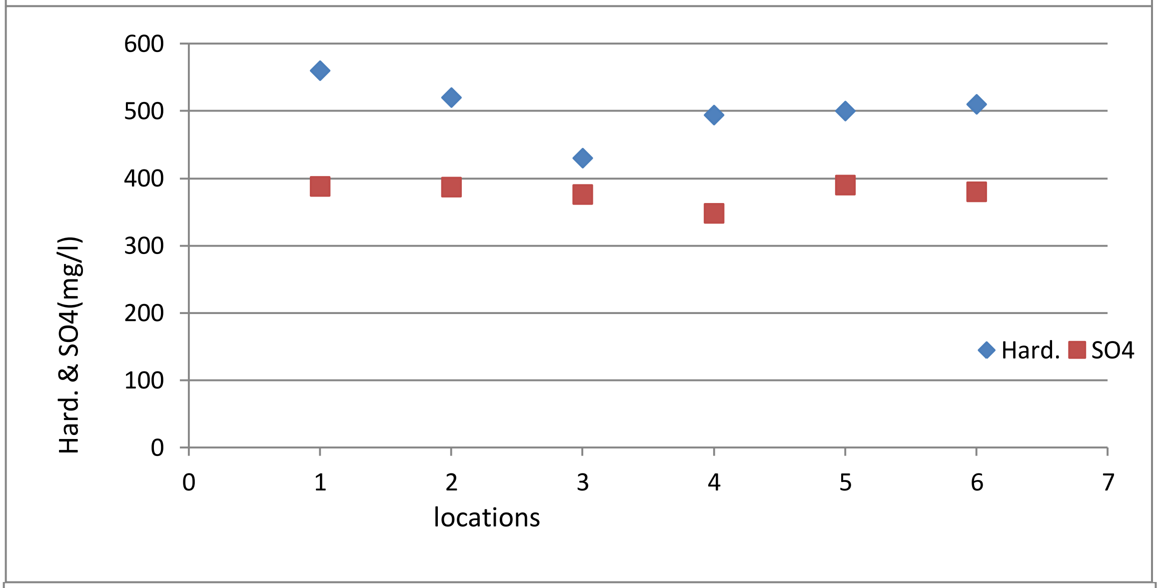


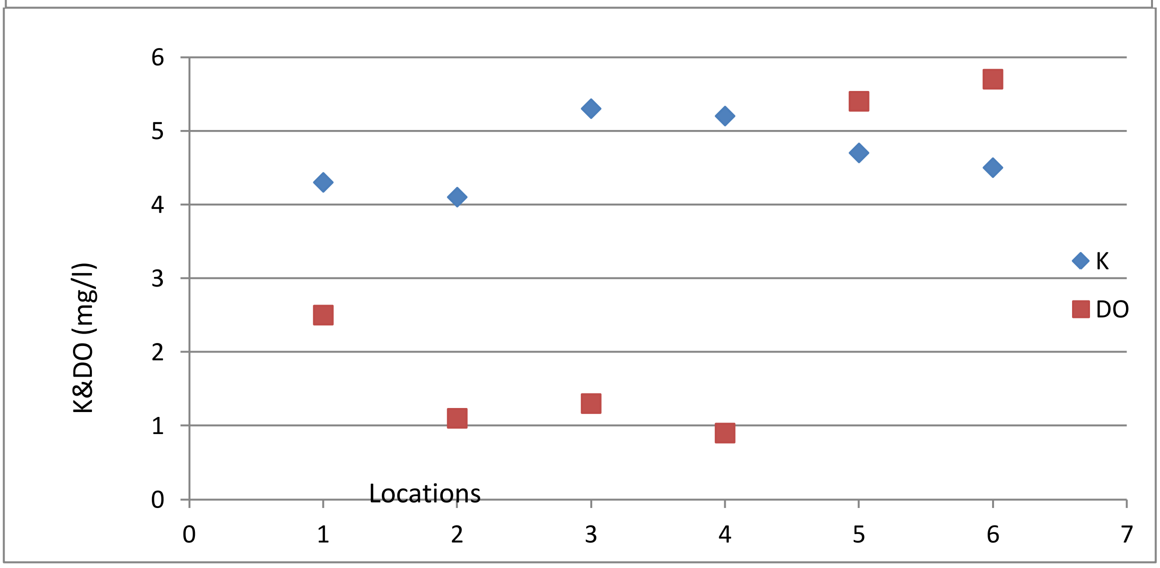

45
40
35
30
25
20
15
10
5
0
Turb. NTU
0
1
2
3
4
5
6
7
Locations
Turb.


2000
1800
1600
1400
1200
1000
800
600
400
200
0
EC µS/cm
0
1
2
3
4
5
6
7
Locations
EC


2000
1800
1600
1400
1200
1000
800
600
400
200
0
EC &TDS (mg/l)
0
1
2
3
4
5
6
7
Locations
EC
TDS


Alk & Cl (mg/l)
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
Locations
Alk.
Cl


Hard. & SO4(mg/l)
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
locations
Hard.
SO4


K&DO (mg/l)
6
5
4
3
2
1
0
0
1
2
3
4
5
6
7
Locations
K
DO

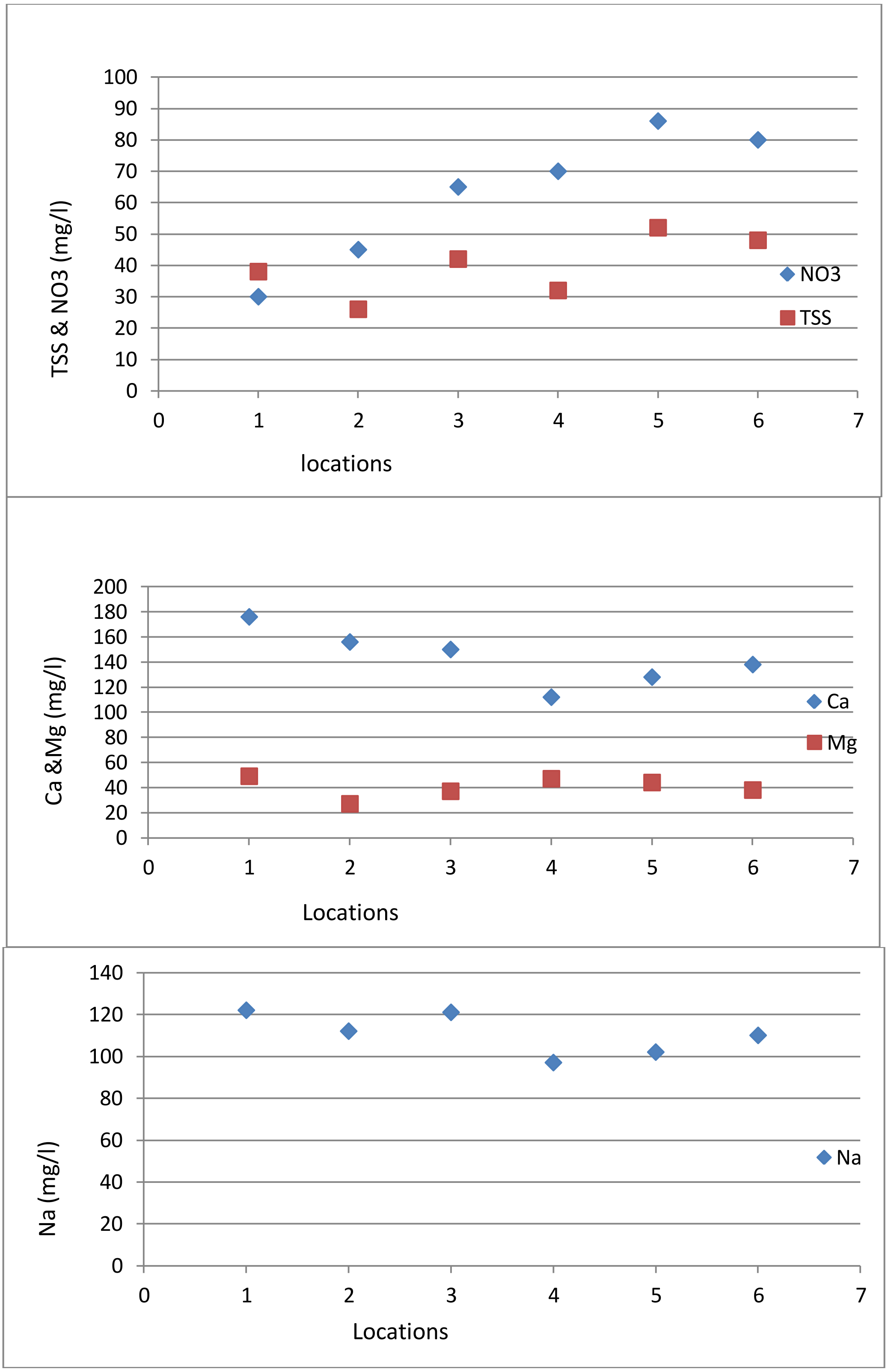


Figure 5.9: The change in water quality parameter with location for third station

Chapter 6

Statistical analysis of water quantity and quality data

6.1 Strategy of data analysis and hypotheses

There is a wide range of changes in the water quantity and quality of Euphrates throughout its course over the riparian countries. For example, increasing deterioration in water quality along the course of the river is manifested in the increase in the concentration of all elements, particles, ions, and components which reach or already exist in the water of the river in all riparian countries. This deterioration is due to several factors, which will be discussed in detail later in this report.

The main factors which affect water quality are the base quality and base quantity of the river flow and the quantity of pollutants that reaches the river. The water in the Euphrates starts with having a relatively good quality, implying low concentrations of pollutants. During its journey, this initially good water is mixed with polluted water that comes from different sources, supplied with pollutants that are picked up from the bedrock or river banks, or exposed to some natural or artificial factors that alter the quality.

6.2 Basic data properties and discussion

It is quite clear from figures 5.7, 5.8, 5.9 and tables 5.1a and b, 5.2a and b, 5.3a and b in the previous chapter that:

- In the first sampling station (first check point), the value of pH ranged between 7.4 and 8.4 for all locations, the mean of pH was in a narrow range (7.9-8.2), and the average of the mean values was 8.0 for all locations within this station. In the second sampling station the value ranged between 7.5 and 8.8, and the mean of pH were (7.9-8.1), and the average mean was the same as for station one. For the third station, the value ranged between 7.6 and 8.4, with a mean having a range (8-8.4) and the average mean was 8.2.

- In the first sampling station, the value of DO ranged between 6.6 mg/l and 10.2 mg/l for all locations, the mean of DO was in a narrow range (7.8-9.2) mg/l, and the average mean was 8.7mg/l for all locations within this station. It is worth to note that the DO of surface water was mainly dependent on temperature and elevation. In the second station the value was in the range (2-9.5) mg/l, the range of the mean was (5.5-6.7) mg/l, and the average mean was 6.2 mg/l. For the third station, the value ranged between 0.5 mg/l and 11 mg/l with the mean having a range (2.5-5.7) mg/l and the average mean was 3.8 mg/l.

- In the first sampling station, the value of BOD_5 ranged between 0.5mg/l and 6.8mg/l for all locations, the mean of BOD_5 was in a range (0.9-3.9) mg/l, and the average mean was 1.5mg/l for all locations within this station. In the second station the value was in the range (1.2-6.7) mg/l, the range of mean was (3.5-4.5) mg/l, and the average mean was 4 mg/l. No value was available for the third sampling station.

- In the first sampling station, the value of EC ranged between (250-635) µS/cm for all locations, the mean of EC was in a narrow range (295-569) µS/cm, and the average mean was 378µS/cm for all locations within this station. In the second station the value was in the range (450-870) µS/cm, the range of mean (630-670) µS/cm, and the average mean was 654µS/cm. In third station, the value ranged between 1166 µS/cm and 1790 µS/cm with the mean having a range (1266-1734) µS/cm and the average mean was 1466 µS/cm.

- In the first sampling station, the value of Turbidity ranged between (5 and 20) NTU for all locations, the mean of Turbidity was in a narrow range (5-7.5) NTU, and the average mean was 5.6 NTU for all locations within this station. In the second station the value was in the range (5-24) NTU, the range of the mean (12.5-13) NTU, and the average mean was 12.8 NTU. In the third sampling station, the value ranged (11-45) NTU, the mean had a range (16-42) NTU, and the average mean was 23 NTU.

- In the first sampling station, the value of TSS ranged between (2.2-24) mg/l for all locations, the mean of TSS was in a narrow range (5.2-12.8) mg/l, and the average mean was 7.5 mg/l for all locations within this station. There is a close correlation between turbidity and TSS. In the second station the value was in the range (5-24) mg/l, the range of the mean (12-13) mg/l, and the average mean was 12.5 mg/l. For the third station, the value ranged from (24-52) mg/l, the mean had the range (26-56) mg/l, and the average mean was 40 mg/l.

- In the first sampling station, the value of TDS ranged between (160-406) mg/l for all locations, the mean of TDS was in a narrow range (183-338) mg/l, and the average mean was 237 mg/l for all locations within this station. In the second station the value was in the range (400-675) mg/l, the range of the mean (400-520) mg/l, and the average mean was 500 mg/l. For the third station, the value was in the range (896-1298) mg/l, the mean range was (968-1158) mg/l, and the average mean was 1082 mg/l.

- In the first sampling station, the value of Alkalinity ranged between (85-265) mg/l for all locations, the median of Alkalinity was in a narrow range (120-205) mg/l, and the average mean was 144mg/l for all locations within this station. In the second station the value was in the range (102-145) mg/l, the range of the mean was (110-125) mg/l, and the average median was 120 mg/l. For the third station, the value was in the range (51-168) mg/l, the mean had a range (128-158) mg/l, and the average mean was 135 mg/l.

- In the first sampling station, the value of Hardness ranged between (95-290) mg/l for all locations, the mean of Hardness was in a narrow range (138-274) mg/l, and the average mean was 180mg/l for all locations within this station. In the second station the value was in the range (200-475) mg/l, the range of the mean was (325-375) mg/l, and the average mean 341 mg/l. For the third station, the value ranged between (356-1060) mg/l, the mean had a range of (430-560) mg/l, and the average mean was 502 mg/l.

- In the first sampling station, the value of Ca^{+2} ranged between (24-86) mg/l for all locations, the mean of Ca^{+2} was in a narrow range (40.1-72.1) mg/l, and the average mean was 50mg/l for all locations within this station. In the second station the value was in the range (50-140) mg/l, the range of the mean was (75-95) mg/l, and the average median was 85 mg/l. For the third station, the value ranged between (48-225) mg/l, the mean had a range (112-176) mg/l, and the average mean was143 mg/l.

- In the first sampling station, the value of Mg^{+2} ranged between (6.1-28) mg/l for all locations, the mean of Mg^{+2} was in a narrow range (11.6-18.2) mg/l, and the average mean was 14mg/l for all locations within this station. In the second station the value was in a range (15-30) mg/l, the range of the mean was (20-25) mg/l, and the average mean was 22.7 mg/l. For the third station, the value ranged between (17-170) mg/l, the mean had a range (27-49) mg/l, and the average mean was 40 mg/l in the third station.

- In the first sampling station, the value of K^{+1} ranged between (0.4-6.1) mg/l for all locations, the mean of K^{+1} was in a narrow range (0.6-5.2) mg/l, and the average mean was 1.5 mg/l for all locations within this station. In the second station the value was in the range (1.5-2.7) mg/l, the range of the mean was (1.9-2.4) mg/l, and the average mean was 2.1 mg/l. For the third station, the value ranged from (3.9-5.1) mg/l, the mean had a range of (4.1-5.3) mg/l, and the average mean was 4.7 mg/l.

- In the first sampling station, the value of Na^{+1} ranged between (2.1-21.4) mg/l for all locations, the mean of Na^{+1} was in a range (2.9-14.2) mg/l, and the average mean was 8.3mg/l for all locations within this station. For the second station no data were available. In the third station the range was between (90-130) mg/l, the mean had a range (97-122) mg/l, and the average mean was 111 mg/l.

- In the first sampling station, the value of Cl^{-1} ranged between (9.4-49.6) mg/l for all locations, the mean of Cl^{-1} was in a narrow range (14.9-36.2) mg/l, and the average mean was 21mg/l for all locations within this station. No values were available for the second station. In the third station the range was (130-180) mg/l, the mean had a range (120-170) mg/l, and the average mean was 149 mg/l.

- The value of F ranged between (0.7-1.0) mg/l for all locations, the mean of F were in a narrow range (0.1-0.4) mg/l, and the average mean was 0.2mg/l for all locations within this station. Values for second and third station were not available.

- In the first sampling station, the value of SO_4^{-2} ranged between (8.5-44.1) mg/l for all locations, the mean of SO_4^{-2} was in a narrow range (15.3-33.4) mg/l, and the average mean was 26mg/l for all locations within this station. In the second station the value was in the range (60-300) mg/l, the mean had a range (155-180) mg/l, and average mean was 170 mg/l. For the third station, the value ranged between (309-400) mg/l, the mean was in the range (348-390) mg/l, and the average mean was 378 mg/l.

- In the first sampling station, the value of NH_3-N ranged between (0.06-1.6) mg/l for all locations, the mean of NH_3-N was in a narrow range (0.24-0.47) mg/l, and the average mean was 0.36 mg/l for all locations within this station. Values for the second and third station were not available.

- In the first sampling station, the value of NO_3-N ranged between (1.6-6.7) mg/l for all locations, the mean of NO_3-N was in a narrow range (3.2-4.8) mg/l, and the average mean was 3.9 mg/l for all locations within this station. In the second station the value range between (3.5-9.7) mg/l, the mean had a range (4.5-7.7) mg/l, and the average mean was 6.4 mg/l. For the third station, the range was (20 - 90) mg/l, the mean had a range (30-86) mg/l, and the average mean was 62.7 mg/l.

- In the first sampling station, the value of PO_4-P ranged between (5-300) µmg/l for all locations, the mean of PO_4-P was in a range (18-65) µmg/l, the average mean value was 28.5 µmg/l for all locations within this sample station. In the second station the value was in a range (20-70) µmg/l, the mean ranged from (35-46) µmg/l, and the average mean was 41.4 µmg/l. No values were available for the third station.

The results of the sample analysis can be summarized for all three sampling stations in the table 6.1a and b and figure 6.1.

Table 6.1: Changes in parameter values between the sampling stations, concentration in mg/L or ppm.

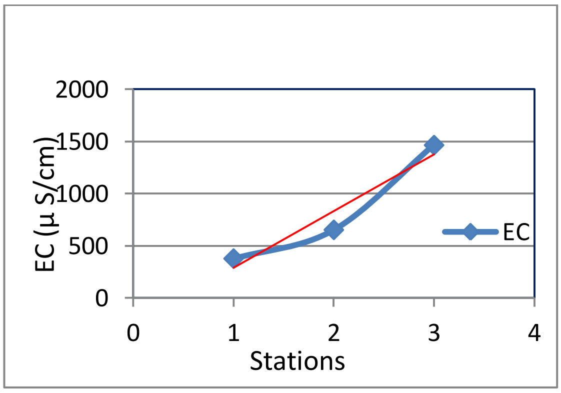
a

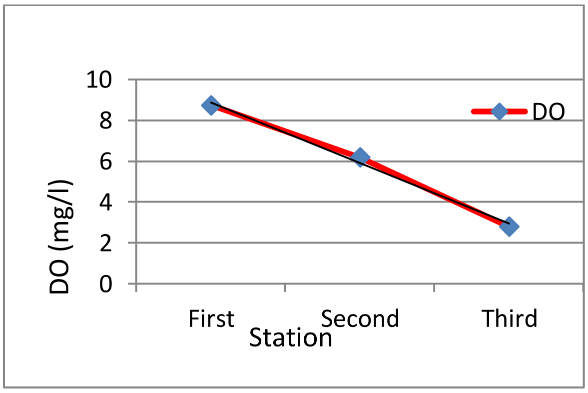
S. station	**pH**	**EC**	**DO**	**BOD**	**Turb**	**TSS**	**TDS**	**Alk**	**Hard**
First	8.0	378.5	8.73	1.54	5.65	7.5	237	144	180
Second	8.0	654	6.19	4.01	12.75	12.5	500.7	121	341.7
Third	8.1	1466	2.8	-	23	40	1082	135	502

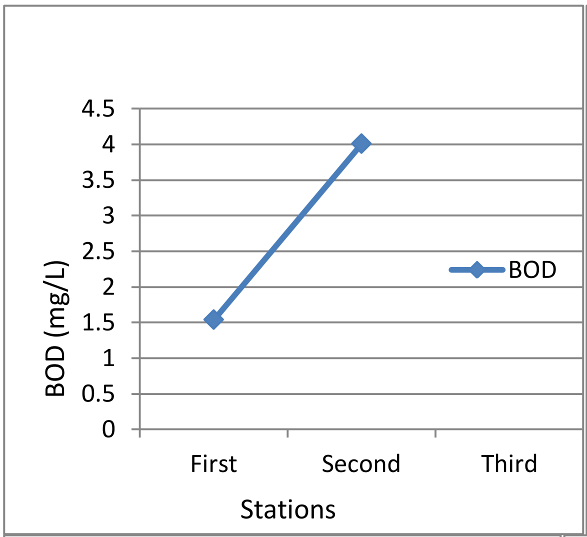
b

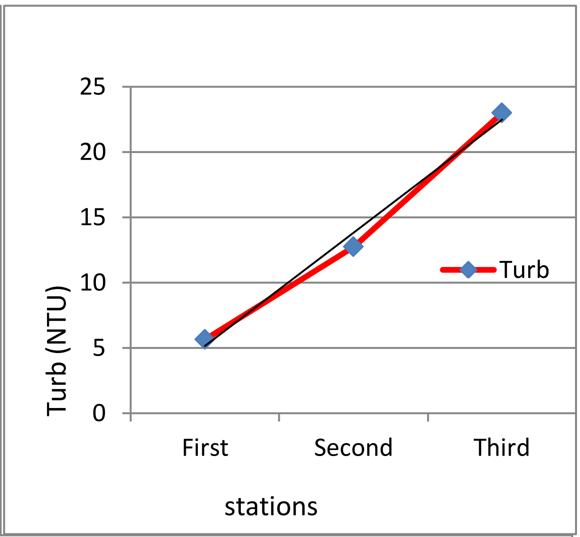
S. station	**Ca**	**Mg**	**K**	**Na**	**Cl**	**F**	**SO_4**	**NH_3-N**	**NO_3-N**	**PO4-P*1000**
First	50	14	1.5	8.3	21	0.2	26	0.36	3.94	28.46
Second	85	22.7	2.13	-	-	-	170	-	6.38	41.43
Third	143	40	4.7	111	149	-	378	-	62.7	-

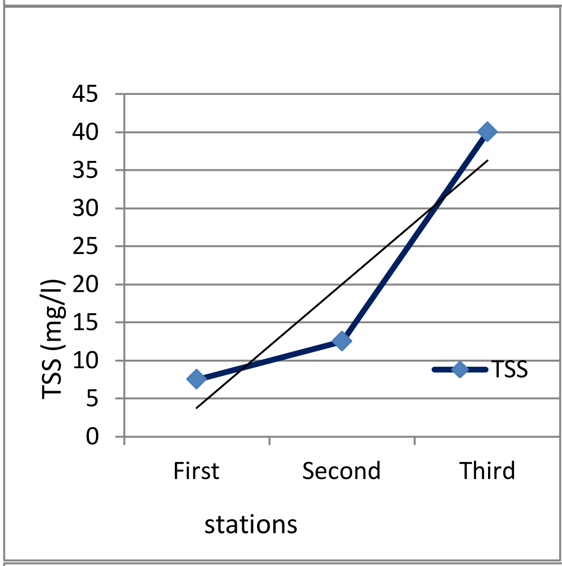
Figure 6.1: The change in parameter over sampling stations

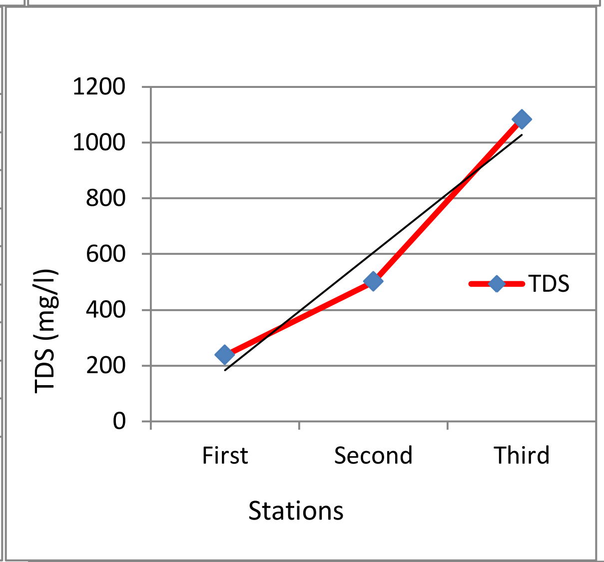


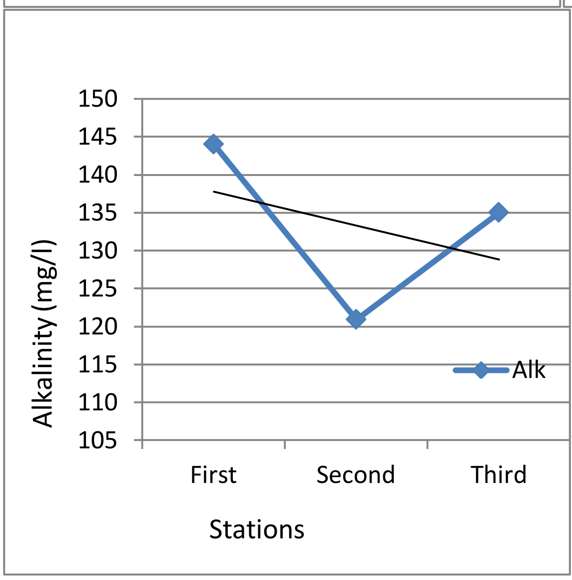


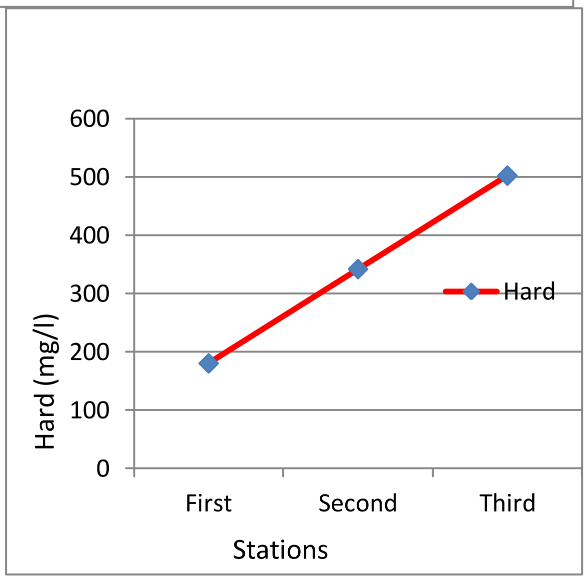

BOD (mg/L)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
BOD
First
Second
Third
Stations

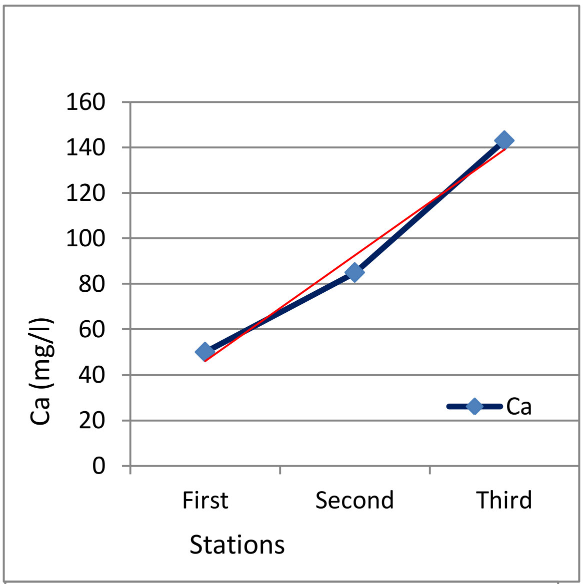

Turb (NTU)
25
20
15
10
5
0
Turb
First
Second
Third
stations

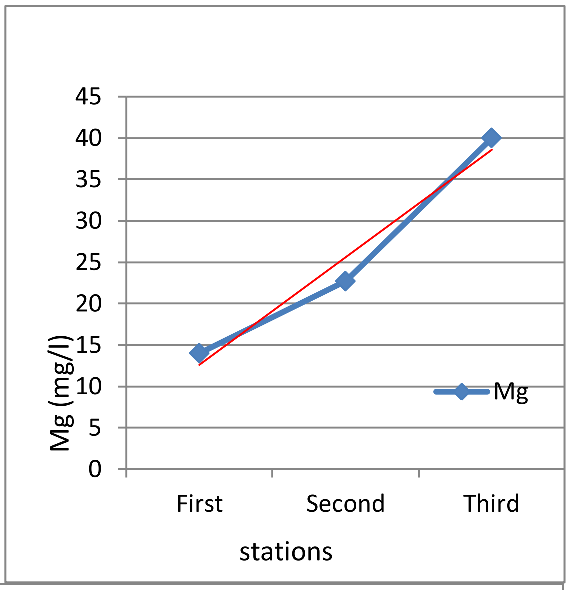

TSS (mg/l)
45
40
35
30
25
20
15
10
5
0
TSS
First
Second
Third
stations

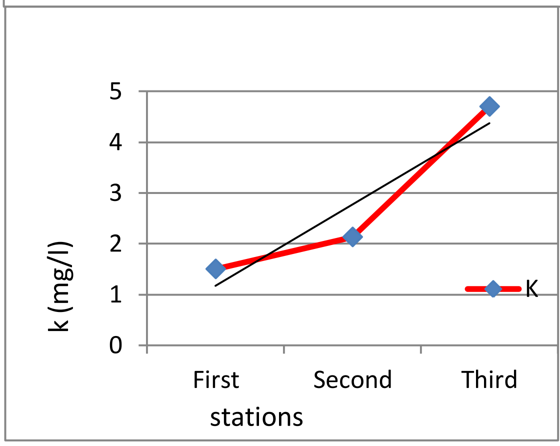

TDS (mg/l)
1200
1000
800
600
400
200
0
TDS
First
Second
Third
Stations

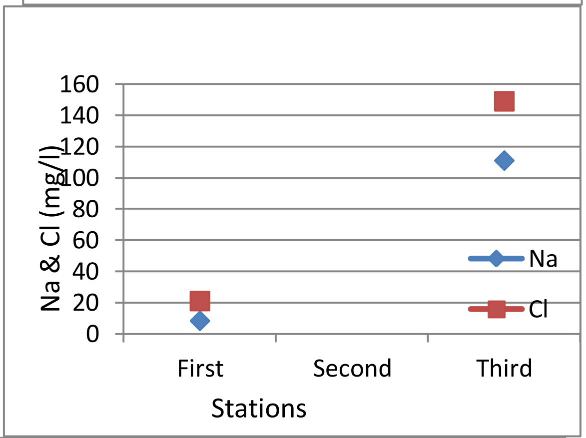

Alkalinity (mg/l)
150
145
140
135
130
125
120
115
110
105
Alk
First
Second
Third
Stations

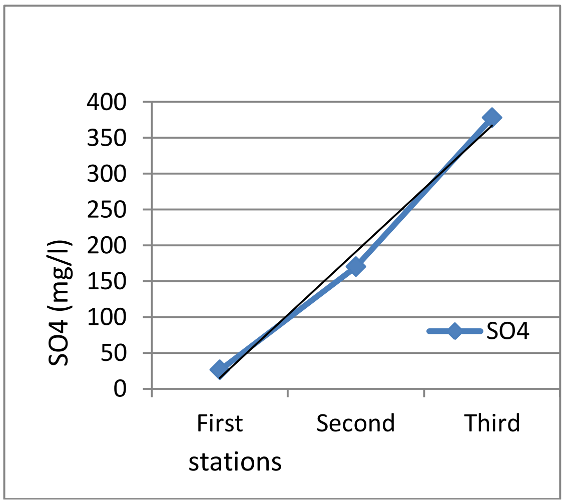

Hard (mg/l)
600
500
400
300
200
100
0
Hard
First
Second
Third
Stations

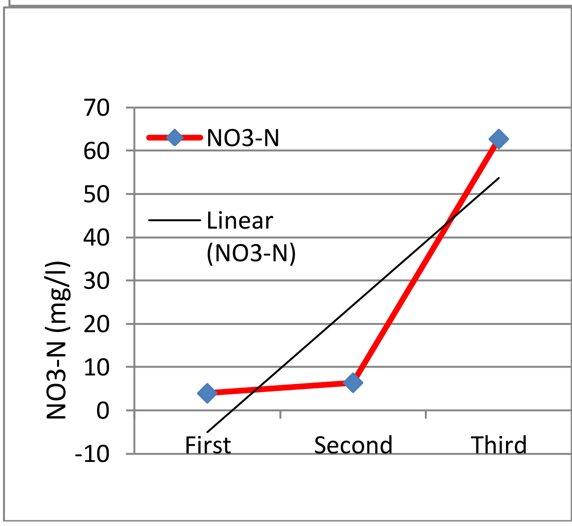

160
140
120
100
80
60
40
20
0
Ca (mg/l)
Ca
First
Second
Third
Stations

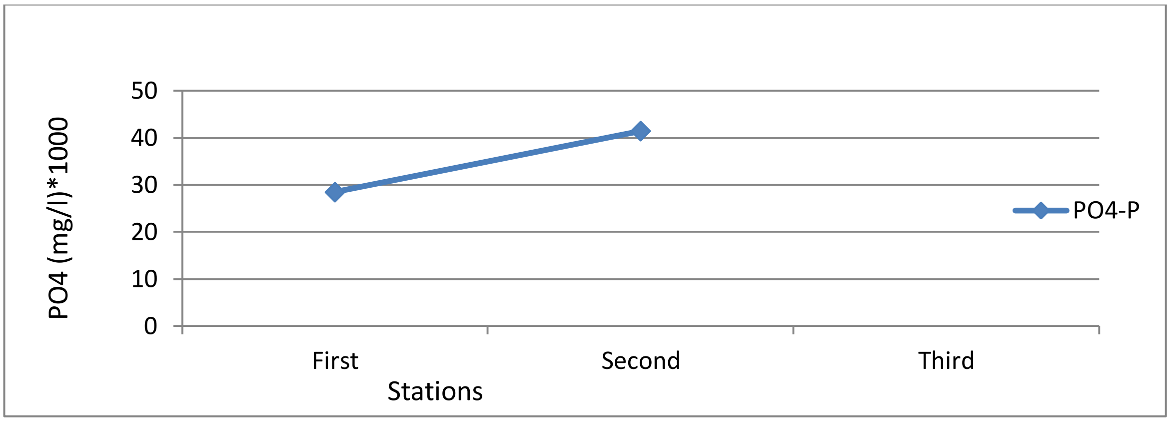

45
40
35
30
25
20
15
10
5
0
Mg (mg/l)
Mg
First
Second
Third
stations


5
4
3
2
1
0
k (mg/l)
K
First
Second
Third
stations


160
140
120
100
80
60
40
20
0
Na & Cl (mg/l)
Na
Cl
First
Second
Third
Stations


400
350
300
250
200
150
100
50
0
SO4 (mg/l)
SO4
First
Second
Third
stations


70
60
50
40
30
20
10
0
-10
NO3-N (mg/l)
NO3-N
Linear
(NO3-N)
First
Second
Third



6.3 Spatial changes and their relation to previous studies

It is quite clear from the previous tables and the figures for the different parameters that there is a wide range of changes in the water quality of the Euphrates throughout its course in the riparian countries. The river starts with good water quality in the upstream part (the first sampling station in Turkey), where the water has low concentration of pollutants.

During its journey downstream, the clean river water is mixed with polluted water or it picks up pollutants from bedrock or river banks. Also, evaporation may lead to the concentration of pollutants.

Table 6.1a and b illustrate the results of the analysis at all stations and for all parameters. It shows that there is an increase in the concentration of all elements, particles, ions, and components (except DO and Alkalinity) throughout the course of the river in all riparian countries. Accompanying this increase, significant changes in the water quality occur.

Air and water temperature over the study area during the study period were in the range 4-46 deg C and 6-26 deg C, respectively. These values followed almost identical seasonal cycles. A significant variation was found in temperature among the stations and over time, which directly affects the evaporation rate, especially for the reservoirs within Iraq. This leads to a concentration of pollutants in the storage water and it decreases the concentration of DO. No significant variation was found between pH values among the sites and over times. The electric conductivity value measured as the average median was (378.5 µS/cm) at first sample station and (654 µS/cm) at second station, and it increased to (1466 µS/cm) at the third station. The results for dissolved oxygen showed significant differences among the sample stations. The DO values changed from 8.7 mg/l at the first sampling station to 6.2 mg/l at the second station, and decreasing to 2.8 mg/l at third station.

The results of BOD_5, which was available at the first and second station, are 1.5 mg/l for the first station, and it increased to 4.0mg/l at the second station (the value is expected to be higher at the third station).

The results for TSS showed significant differences among the stations, where the TSS values changed from 7.5 mg/l at the first station to 12.5 mg/l at the second station, and increasing to 40 mg/l at the third station.

The results for Turbidity showed significant differences among the sample stations. The Turbidity values changed from 5.65 NTU at the first sampling station to 12.75 NTU at the second station, increasing to 23 NTU at the third station.

The results for Hardness showed significant differences among the stations, where the Hardness values changed from 180 mg Ca CO_3/l in the first station to 341.7 mg Ca CO_3 /l at the second station, and increased further to 502 mg Ca CO_3 /l at the third station.

The results for Ca^{+2} showed significant differences among the stations, and the Ca^{+2} values changed from 50 mg/l in the first station to 85 mg/l at the second station, and increased to 143 mg/l at the third station.

The results for Mg^{+2} showed significant differences among the stations, where the Mg^{+2} values changed from 14 mg/l at the first station to 22.7 mg/l at the second station, and to 40 mg/lat at the third station.

The results for K^{+1} showed significant differences among the stations, and the K^{+1} values changed from 1.5 mg/l at the first station to 2.1 mg/l at the second station, and to 4.7 mg/lat the third station.

The results for Na^{+1} were only available for the first and third station with the values 8.3 and 111 mg/l, respectively. Thus, these two measurements showed significant differences between each other. The second station could indicate transition properties.

The results for Cl^{-1} were available for the first and third station, and concentration was 21 and 149 mg/l, respectively. Again, the second station could indicate transition properties.

The results of SO_4 showed significant differences among sample stations, where the SO_4 values changed from 26 mg/l at the first station to 170 mg/l at the second station, and to 378 mg/l at the third station.

The results of NO_3-N showed significant differences among sample stations, the NO_3-N values changed from 3.94 mg/l at the first station to 6.38 mg/l at the second station, and to 62.7 mg/l at the third station.

The results of PO_4-P were available for the first and second station, yielding concentrations of 28.46 µmg/l and µ41.43, respectively.

The results of TDS showed significant differences among the stations, the TDS values changed from 237 mg/l at the first station to 500 mg/l at the second station, and, to 1082 mg/l at the third station. The spatial changes along the river are shown in figure 6.2.

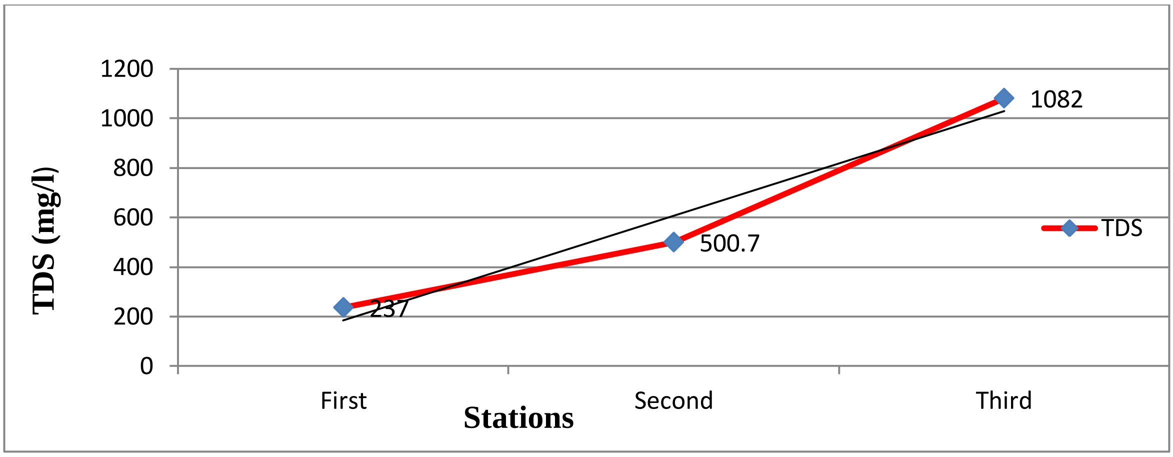


Figure 6.2: The change in TDS over stations

It is worth to refer to chapter 3.1 and 3.3 and the discussion about water quality. The most important parameter in this study is TDS, since it provides a good overall assessment of the water quality. It is considered to be a good indicator for water salinity, and it gives general information about the sum of ions in the water. This explains why the focus is on this parameter here.

According to the result of the present analysis, it is found that the TDS changes with increasing distance from upstream, and that it is negatively correlated with the flow. These conclusions coincide with the results of previous investigations, e.g., Rahi and Halihan (2009) and other similar studies (see table 6.2 and figure 6.3).

Table 6.2 The TDS (ppm) in Euphrates along the river stretch within Iraq (Rahi &Halihan 2009)

Location	**Dist. from the Syrian Border (km)**	**TDS (ppm) pre Dam construction period (1946-1974)**	**TDS (ppm)post Dam construction period (1991-2007)**
Al Qaim	50	467	1000
Fallujah	385	485	1100
Hindiah	532	495	1150
AlKufa	650	510	1200
Al Samawa	770	525	2000
Al Nassriah	905	1000	3450

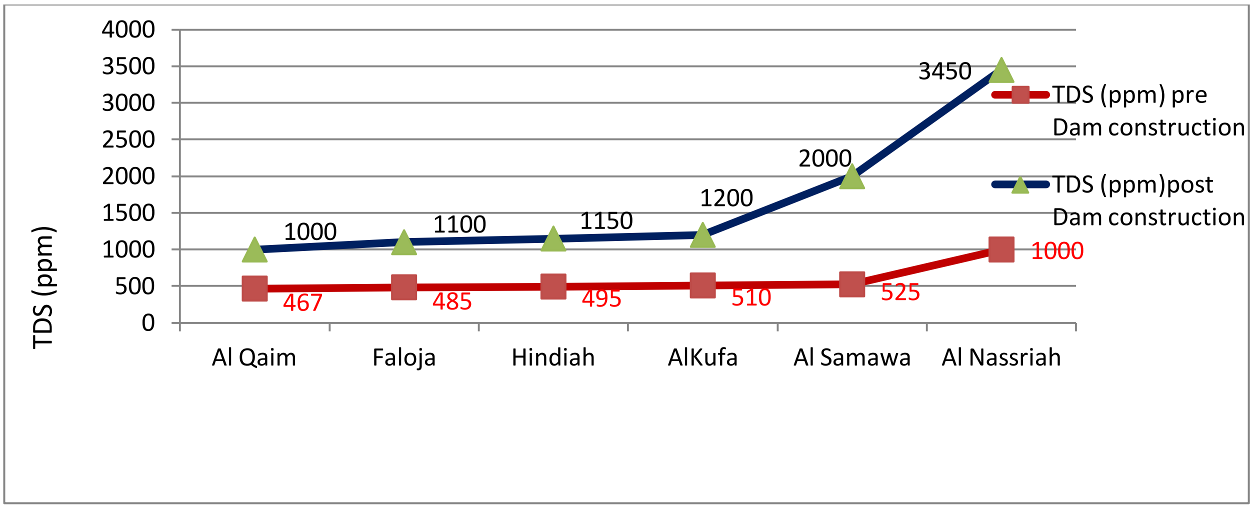


Figure 6.3: The change in TDS along part of Euphrates river stretch within Iraq; numbers extracted from Al-Hadithi (1978) and Partow (2001).

6.4 Temporal changes and their relation to previous studies

There are also temporal changes in water quality parameters over the years and these changes are highly correlated with the flow released from Turkey and Syria through Euphrates into Iraq, see table 6.3 and figure 6.4. The flow rate here represents the situation in Iraq when Syria did not use significant quantities of water from Euphrates (during the time 1959-1973). Syria started using water from Euphrates River after 1974.

Table 6.3 The TDS in Euphrates River at Fallujah over the years; numbers are extracted from Rahi and Halihan (2009),

Year	**Average annual flow of the Euphrates river at Turkish-Syria border BCM**	**TDS at Fallujah (ppm)**
1959	19	645
1960	26	585
1961	14	725
1962	19	635
1963	41	500
1964	27	640
1965	27	585
1966	35.75	490
1967	38	440
1968	49	440
1969	57	440
1970	27.9	605
1971	29.9	590
1972	20.5	600
1973	19	660

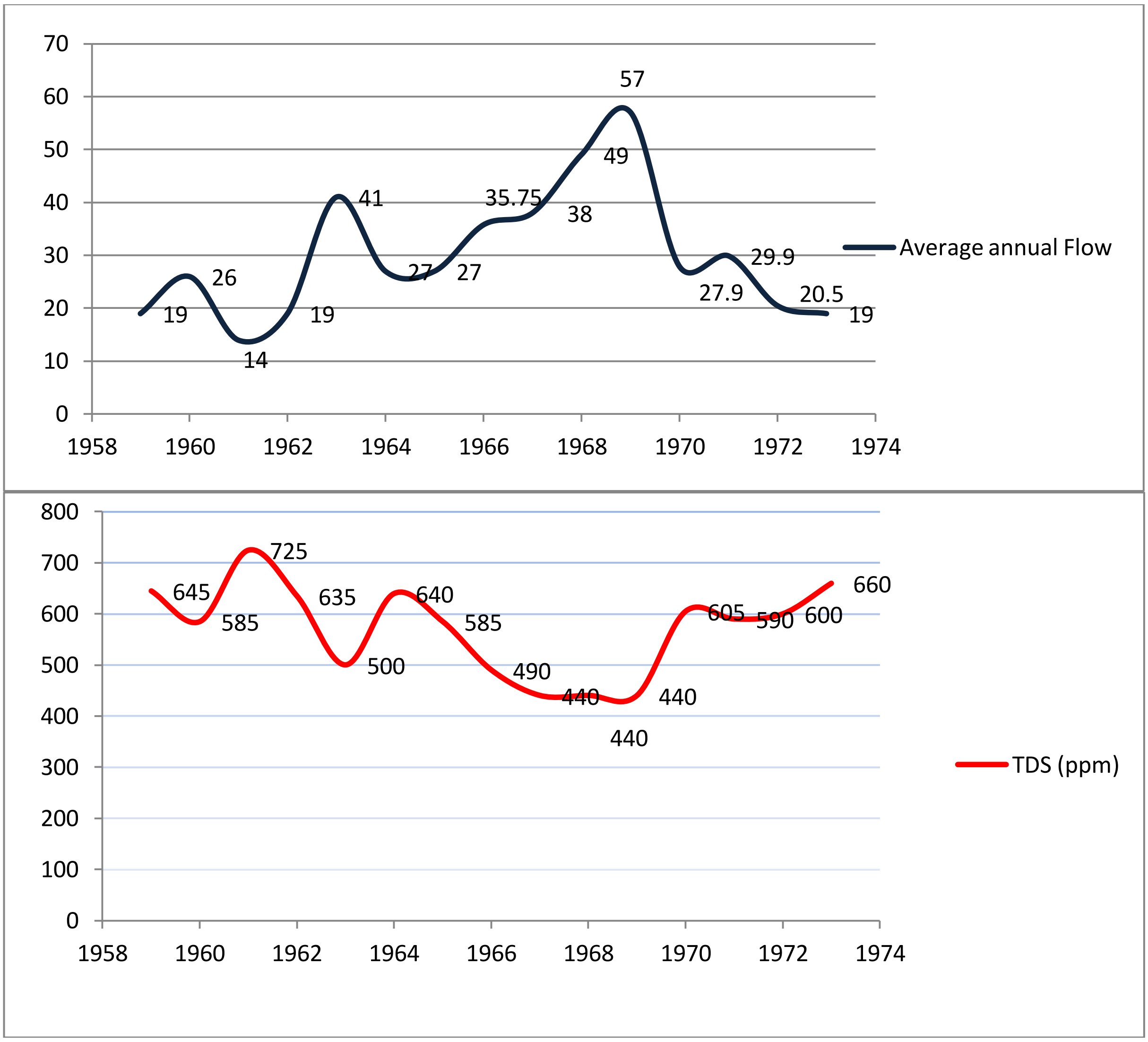


Figure 6.4 Correlation between TDS and average annual flow of Euphrates River at Al-Fallujah station over years; (numbers are extracted from Rahi & Halihan 2009)

In addition to the yearly spatial and temporal changes in flow rate through the river, there are also seasonal variations and monthly fluctuations, as illustrated in table 6.4 and figure 6.5.

Table 6.4 Mean monthly flow in Euphrates at the Syria-Iraq border for two periods; numbers extracted and modified from Aljanabi (2010), the average mean for period after dam construction is lower 30% than the value for period before dam construction.

Month	**Mean monthly flow pre-dam construction(1937-1973) cubic meter per sec**	**Mean monthly flow after dam construction(1975-2009) cubic meter per sec**
Mar	1150	800
Apr	2200	750
May	2440	785
Jun	1350	710
July	670	615
Aug	400	550
Sep	360	550
Oct	400	600
Nov	500	715
Dec	600	800
Jan	900	970
Feb	950	990
Average	993.33	736.25

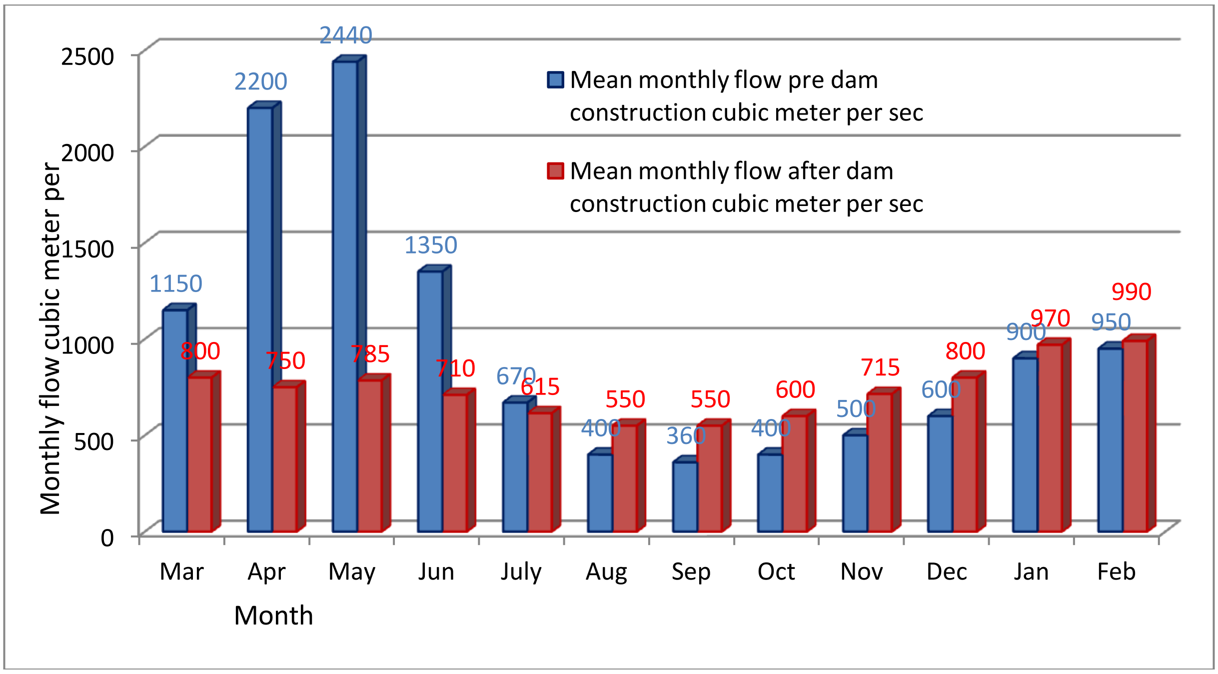


Figure 6.5 Monthly flow fluctuations in Euphrates River; numbers extracted from Aljanabi (2010)

Another study (Jawad, 2003) about the monthly variation in flow rate for Euphrates River indicates similar results, see table 6.5 and figure 6.6.

Table 6.5 Monthly average flow through Euphrates River; numbers are extracted, modified and averaged from Jawad (2003) and other studies

Month	Flow (1937-1973) at Husaibah	Flow(1975-1998) at Hit
Oct	350	600
Nov	500	725
Dec	625	775
Jan	750	825
Feb	800	830
Mar	1225	830
Apr	2250	830
May	2594	831
Jun	1250	725
Jul	650	640
Aug	300	640
Sep	250	630

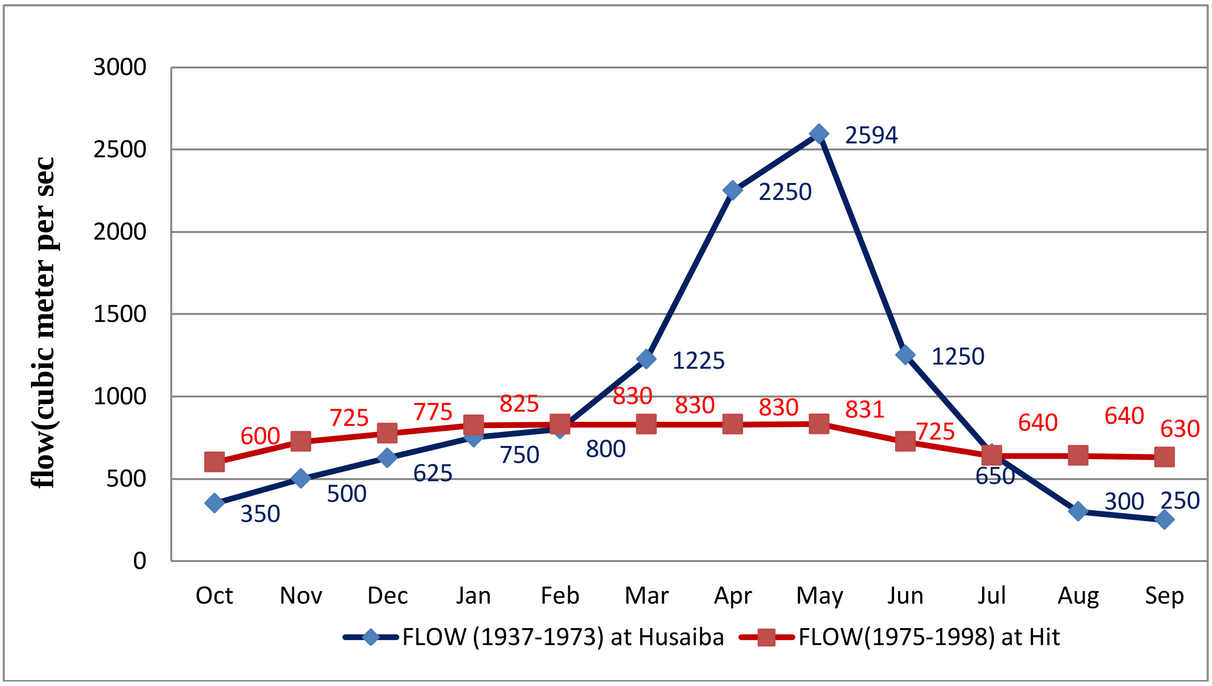


Figure 6.6: The monthly average discharge (m^3/s) through Euphrates River at Iraq; numbers extracted from Jawad (2003) and other studies

There are also temporal changes in annual peak (maximum) flow in Euphrates River over the years, as illustrated in table 6.6 and figure 6.7.

Table 6.6: The peak flow in Euphrates at Hit (Iraq) over the years; numbers extracted from several sources

year	**peak flow**	**Year**	**Peak flow**	**Year**	**Peak flow**	**Year**	**Peak flow**
1969	7390	1956	4430	1928	3240	1925	1750
1968	6654	1957	4420	1935	3200	1961	1732
1967	6072	1941	4220	1949	2950	1934	1730
1929	4980	1960	4080	1947	2900	1932	1630
1963	4816	1942	4040	1959	2770	1930	850
1972	4810	1943	3900	1955	2600		
1954	4730	1939	3850	1970	2550		
1948	4670	1946	3750	1945	2510		
1940	4660	1950	3690	1958	2480		
1952	4610	1931	3630	1951	2470		
1953	4540	1964	3548	1962	2224		
1944	4530	1936	3450	1933	2170		
1938	4500	1965	3422	1924	2120		
1966	4484	1926	3320	1973	2055		
1971	4435	1937	3320	1927	1850		

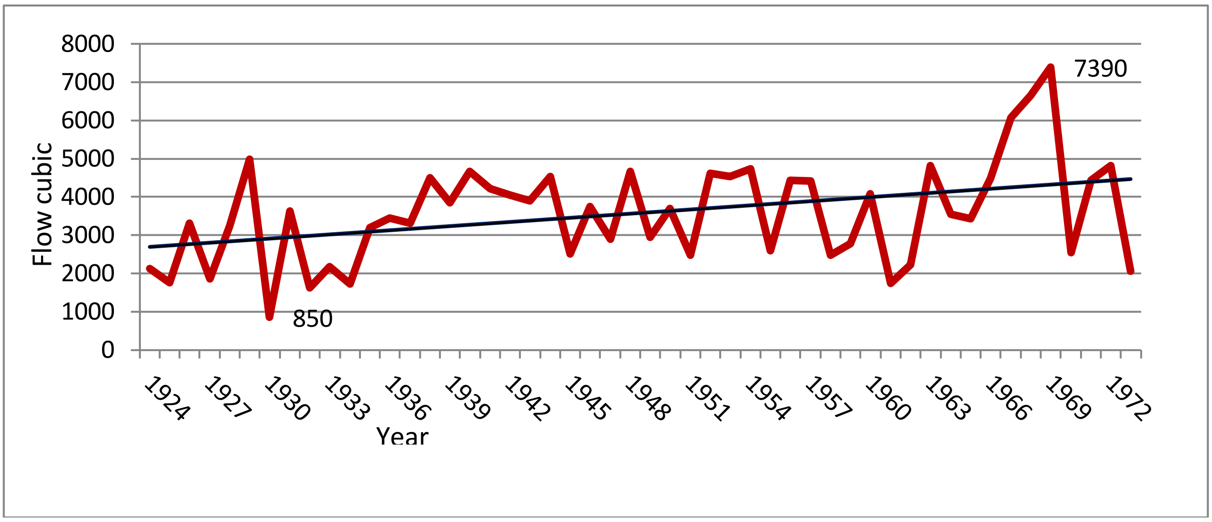


Figure 6.7: Peak flow through Euphrates River at Hit (Iraq) over the years; extracted from several references

Also there are temporal changes in the average annual flow value for Euphrates River, see table 6.7 and figure 6.8.

Table 6.7: The average annual flow values for Euphrates River at Turkey-Syria border; extracted from several sources

Year	**average annual flow of Euphrates BCM**	**Year**	**average annual flow of Euphrates BCM**	**Year**	**average annual flow of Euphrates BCM**
1946	30	1963	41	1980	38
1947	25	1964	27	1981	33
1948	34	1965	27	1982	33
1949	22.5	1966	35.75	1983	24
1950	25	1967	38.5	1984	27.5
1951	25	1968	49	1985	23.9
1952	31.5	1969	57	1986	23.9
1953	30	1970	27.9	1987	45
1954	32	1971	29.9	1988	55
1955	19	1972	20.5	1989	25
1956	27.5	1973	19	1990	27.5
1957	27.5	1974	21	1991	26.5
1958	21	1975	21.25	1992	34
1959	19	1976	35.8	1993	28.75
1960	26	1977	32.9	1994	26.75
1961	14	1978	32.95		
1962	19	1979	28		

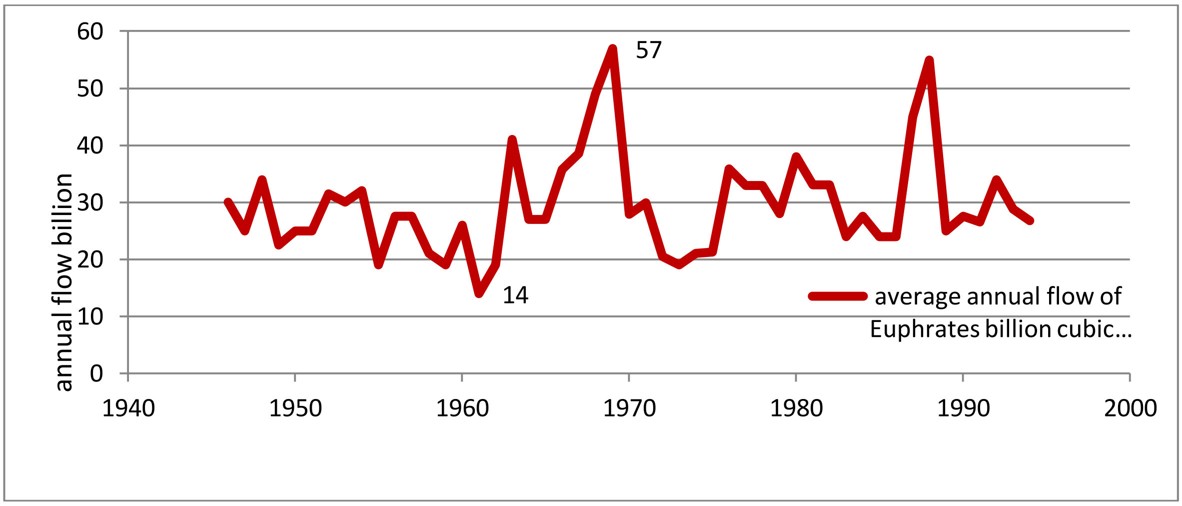


Figure 6.8: The average annual flow through Euphrates at Turkey-Syria border over years; numbers extracted from several sources

The same changes in flow discharge occurred in the Euphrates river flow at the Syria-Iraq border, see table 6.8 and figure 6.9.

Table 6.8: The Euphrates average annual flow at Syria-Iraq border; data were extracted and averaged from several sources

Year	Euphrates Annual flow BCM
1990-1991	12.42
1991-1992	12.15
1992-1993	12.37
1993-1994	15.33
1994-1995	23.9
1995-1996	30
1996-1997	27.46
1997-1998	28.91
1998-1999	18.61
1999-2000	17.23
2000-2001	9.56
2001-2002	10.67
2002-2003	15.71
2003-2004	20.54
2004-2005	17.57
2005-2006	20.6
2006-2007	19.3

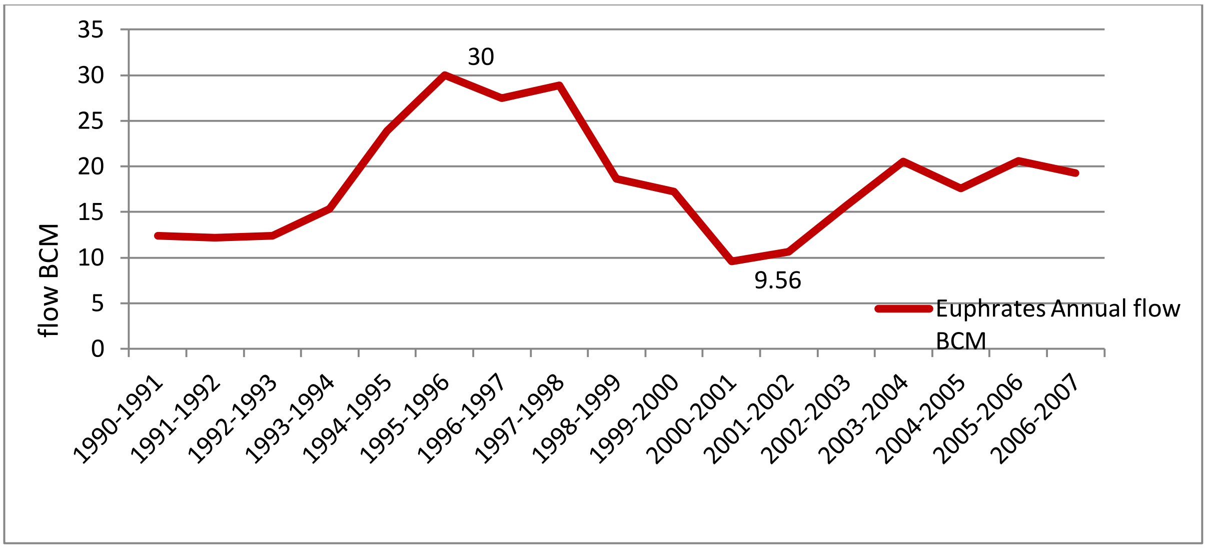


Figure 6.9: The Euphrates average annual flow over years at Syria-Iraq border; extracted from several sources

6.5 Discussion of water quality and relation to pollution sources

According to the analysis results and comparing with the results for the same parameters from previous studies, the Euphrates water quality has degraded and the pollution in the river has increased over the last decades. This is mainly because of the decrease in flow volume that enters into Iraq (in response to the increase in water demand in all riparian countries) and the increase in pollution load to the river. A significant difference in results was recorded between the first sampling station (baseline station) and the other sampling stations. It was found that the decrease in the quantity of water released from Turkey through Euphrates, the decrease in precipitation rates, the run-off from agricultural waste, which returns back to the river, storing water in reservoirs, the water diversion from Al Tharthar depression to Euphrates river, the nature of bedrock and bank soil of the river and depressions, some illegal practices, throwing solid waste into river and untreated wastewater either from the industrial or domestic sectors are the main reasons for the high values of some parameters at the second and third sampling stations.

An increasing trend in major ions (Ca, Mg, Na, K, Cl and SO_4) and related variables (EC, TDS, Alk, Hard) was observed along the river. This increase originated from effects of pollutants discharges into the river (see app 1). The study indicates that pH was not correlated with alkalinity, calcium, or magnesium concentrations. The highest values of Dissolved Oxygen concentration were recorded at the first station (8.7 mg/l), which indicates a good quality of the water (the clean river is characterized by high concentration of dissolved oxygen), and this value decreased to 6.2 mg/l at second station because of increase in pollutants in the river that deplete the dissolved oxygen. Due to the increase in pollutants along the river, the concentration decreased 2.8 mg/l. High values of dissolved oxygen were recorded in the winter time, with the lowest values in the summer time at all sampling stations. Negative correlation between temperature and dissolved oxygen was recorded, as expected. Dissolved salts also influenced the solubility of oxygen. Untreated wastewater and return irrigation flow could cause oxygen depletion. The organic matter in the soil could reach waterways in case runoff and heavy rain. It can be decomposed by natural aquatic bacteria, which can severely deplete dissolved oxygen concentrations.

The results for BOD_5 were available for the first and second station (1.5 mg/l for the first station, increasing to 4.0 mg/l for the second station). High values of BOD_5 were recorded at most sites of the second station, and it is expected the values become even higher at the third station. This is because direct discharge of untreated sewage into the river occurs along this river stretch.

The results for Cl^{-1} were available for the first and third station (21 and 149 mg/l, respectively). Chloride (Cl^{-1}) is one of the major anions found in water and are generally combined with calcium, magnesium, or sodium. Almost all chloride salts are highly soluble in water and they give an indication of salinity if the concentration is more than 250 mg/l. There are several possible sources for the increase in chloride concentration along the river, for example, anthropogenic sources such as septic waste, wastewater treatment plant effluent, industrial waste, animal waste, fertilizer and de-icing activities, and natural sources of chloride such as precipitation, salt water intrusion, and geologic weathering.

The results for SO_4^{-2} showed significant differences among the stations, and the SO_4^{-2} value changed from 26 mg/l at the first station to 170 mg/l at the second station and 378 mg/l at the third station. The maximum level of sulphate suggested by the WHO in the guidelines for drinking water quality, set up in Geneva in 1993, is 500 mg/l. EU standards are more recent (from 1998) and stricter than the WHO standards, suggesting a maximum of 250 mg/l of sulphate in water intended for human consumption (Mehmet et al, 2010). The origin of most sulphate compounds is the oxidation of sulphite ores, the presence of shale, or industrial waste. It could also come from dissolved components in rain or in minerals that exist in bed rock. Some minerals that contain sulphate are sodium sulphate (Glauber's salt), magnesium sulphate (Epsom salt), and calcium sulphate (gypsum). Some of the sulphate may dissolve into the water, when the water moves over these rocks, or it can come from ground water or springs that have a content of SO_4. Bacteria play a role in forming (H_2S) from sulphates. These bacteria chemically change natural sulphates (SO_4) in water to hydrogen sulphide.

The results for Ca^{+2} showed that the Ca^{+2} values changed from 50 mg/l at the first station to 85 mg/l at the second station and 143 mg/l at the third station. The results for Mg^{+2} changed from 14 mg/l at the first station to 22.7 mg/l at the second station and 40 mg/l at the third station. High Mg values may be a result of soil erosion (Hassan, 2008). The concentration of Ca^{+2} for all stations were higher than the Mg^{+2} concentration, which is probably due to the high ability of Ca^{+2} to react with dioxide carbon more than for Mg^{+2} (Al-Saadi and Antoin, 1983). The results showed that the Ca^{+2} is the main dissolved ion at the three stations, which may be due to nature of the bedrock geology.

Hardness values changed from 180 mg Ca CO_3/l at the first station to 342 mg Ca CO_3/l at the second station and 502 mg Ca CO_3 /l at the third station. Hardness in water is defined as the concentration of multivalent cations (Ca^{2+} and Mg^{2+}). These ions enter the river water by leaching from minerals like Calcite, gypsum and Dolomite, which exist throughout the course of the river. The study indicates a high concentration of total hardness at the second and third stations. Total hardness is mainly a reflection of major ions, e.g., Ca^{+2}, Mg^{+2}, CO_3^{-1} and HCO_3^{-1}, being present in the water. It was also well correlated with EC and TDS.

The results for Na^{+1} available for the first and third station were 8.3 and 111 mg/l, respectively. It can be tasted by most people at concentrations of 200 (mg/l) or more. All water samples from all stations contained some sodium, because most bed rocks and banks soil contain sodium compounds, which are easily dissolved. The most common sources of sodium in river water are by erosion of salt deposits and sodium bearing rock minerals, irrigation and precipitation leaching through soils with high content in sodium components, from sewage effluent or brackish water, and infiltration of leachate from landfills or industrial sites into river water.

The results for TSS showed values that changed from 7.5 mg/l at the first station to 12.5 mg/l at the second station and 40 mg/l at the third station. This increase throughout the course of the river could originate from mineral or organic sources. High concentrations of particulate matter can cause increased sedimentation and siltation in the river, which in turn can ruin important habitat areas for fish and other aquatic life. Suspended particles also provide attachment places for other pollutants, such as metals and bacteria. In general, the TSS increase in winter time and decrease in summer time, although heavy rainfall may cause a temporary increase in TSS concentrations, and run-off can pick up and carry enough dirt and debris to pollute a stream. There was a close correlation between turbidity and TSS.

The results for Turbidity showed values that changed from 5.65 NTU at the first station to 12.75 NTU at the second station and 23 NTU at the third station. Many factors could explain this increase: it may be caused by growth of phytoplankton or human activities that disturb land. Areas prone to high bank erosion rates as well as urbanized areas also contribute large amounts of turbidity to nearby waters (Wikipedia, 2011). Certain industries such as quarrying, mining and coal recovery can generate very high levels of turbidity from colloidal rock particles (Wikipedia, 2011). The higher the turbidity level, the higher the health risk. High turbidity levels can also reduce the amount of light reaching lower depths, which can inhibit growth of aquatic organisms. It can also affect the ability of fish gills to absorb dissolved oxygen.

The results for K^{+1} showed values that changed from 1.5 mg/l at the first station to 2.1 mg/l at the second station and 4.7 mg/l at the third station. High concentration of K^{+1} may be related to the use of potassium fertilizers which are regarded as an essential nutrient for boll and fiber growth of cotton plant. A number of potassium compounds, mainly potassium nitrate, are popular synthetic fertilizers. About 95% of commercially applied potassium is added to synthetic fertilizers. Potassium occurs in various minerals such as feldspars, which may be dissolved through weathering processes; some clay minerals also contain potassium. Potassium could come from wastewater through urine, it is found on detergents, and softeners. Other potassium compounds are applied in fluid soap production or could come from glass industry, or from landfill leachate.

The Electric Conductivity values ranged from 378 µS/cm at the first station, recorded as an average median, to 654 µS/cm at the second station and 1466 µS/cm at the third station. The Iraqi standard does not include limits for EC value. Meanwhile, the WHO and the European standards recommend a value of 250 µS/cm for drinking water. The EC values were highly correlated with TDS. Electrical conductivity measures the total amount of dissolved salts (TDS), or the total amount of dissolved ions in the water. All dissolved solids and ionized salt increased in the water throughout the course of the river, being particularly high when SO_4^{-2} and Cl^{-1} were present at high concentration. The main natural source of EC is limestone, which leads to higher EC because of the dissolution of carbonate minerals in the river basin. Untreated wastewater from sewage treatment plants, waste water from drain fields, urban runoff from roads, nutrients and pesticides are other main reasons for an increase in EC values. Evaporation of water from the surfaces of lakes and reservoirs concentrates the dissolved solids in the remaining water – leading to higher EC values.

The results for NO_3-N values changed from 3.9 mg/l at the first station to 6.4 mg/l at the second station and 62.7 mg/l at the third station. The increase in NO_3-N after the first station throughout the course of the river might be due to sewage discharge from cities, land drainage, and urban run-off. However, agricultural discharges may also contribute with high nitrate levels resulting from excessive fertilizer use in agriculture, when microorganisms break down fertilizers, decaying plants, manures, animal feedlots or other organic residues.

The results for PO_4-P were available at first and second station (28.5 and 41.4 mg/l, respectively). The increase in PO_4-P after the first station throughout the course of the river may be due to the inflow from city sewage discharge. Untreated sewage from inefficient treatment plants is one source of phosphorus in rivers. Sewage effluent should not contain more than 1 mg/l phosphorus according to the U.S. Environmental Protection Agency, but wastewater treatment plants often fail to meet this standard because most of the plants are outdated. High values of PO_4-P could result from excessive fertilizer use in agriculture or home gardens; much of the phosphorus in these fertilizers eventually finds its way into lakes and rivers. PO_4-P could also come from other sources such as land drainage, urban run-off, human wastes, animal wastes, industrial wastes, and human disturbance of the land and its vegetation. All these sources generate particles that could be washed into waterways leading to higher phosphorus concentration in the water.

6.6 Data accuracy and limitations

Most of the derived results from the sample analysis in the present study agreed with results from previous studies carried out on the Euphrates River. The main restrictions and limitations which faced the present study are:

- It is very difficult to find sufficient statistical information related to either the water quality or the water quantity for the Euphrates River especially over Syria and Iraq. There are a limited numbers of studies on water quality of surface water over Iraq river basin. Crucial information, reliable and trusted databases related to water and land resources of the region are not exchanged on a regular basis among the riparian countries, may be due to political issues that generate an absence of confidence among these countries. A variety of figures concerning the availability of irrigable land and soil water requirements in each riparian country are available depending on the origin of the data and the inclination of the experts. For more benefits of water sharing, to solve the pollution problems, and to support better decision making, it is necessary to obtain reliable historical stream flow data at all locations within the river basin.

- Not all parameters investigated at first station are available at second and third station, and this is due to the fact that not all equipment is available at all sampling stations.

- The number of samples is not equal for the different sampling stations. The security situation in Iraq is still is not safe enough in the areas where the second and third stations are located, which has affected especially the number of samples taken at the second station.

- There is no available information about exactly how much water is withdrawn throughout the course of the river; thus, the information about quantities of return irrigation water is lacking.

- Sewage water could contain high concentrations of heavy metals (Cd, Zn, Cu, Ni, Pb, and Cr) that have high toxicity, but reliable information about these elements could not be obtained.

Chapter 7

Conclusions and Recommendations

7.1 Conclusions

This study identified and quantified the spatial variation in water chemistry, the spatial and temporal variation in the water discharge, the deterioration in water quality, and the increasing elemental load throughout the course of the Euphrates River. Point and non-point sources of pollution are widespread along the investigated stretch. This is particularly apparent at the second and third sampling stations, both of them located within Iraq.

The Euphrates River, like any other major water body, is subject to numerous sources of pollution. It was found that the run-off from excessive irrigation and excessive fertilization used in agriculture activities, the water diversion from Al Tharthar depression, the nature of bedrock geology and bank soil of the river and reservoirs, the waste of some military factories, solid waste, illegal practices, untreated wastewater either from industrial or domestic, and construction of dams and reservoirs on the river are the main reasons responsible for the high concentration values on most parameters. All these reasons severely affect the Euphrates water quality and lead to adverse consequences as well as health risks. The increase in pollutant concentrations have lessened the river water use, and rendered the water unfit for different beneficial uses. What makes the pollution issue even more pressing is the limited self purification processes in the river and the expected effects of climate change (increase in temperature rate and decrease in precipitation rate).

The major portion of the increase in concentration of pollutants within stretch investigated is between the second and the third station which mean within Iraq. The average longitudinal gradient of concentration of TDS is 1.1 ppm/km, whereas the second major increase in concentration is between the first and the second station with an average longitudinal gradient of TDS 0.22 ppm/km.

7.2 Recommendations

- Establish a dialogue among the three riparian countries based on the environment impact assessment and convening an acceptable agreement among all riparian countries for river water sharing, as well as pollution prevention based on integrated water resources and sustainable principals. This agreement should include different fields such as economical, industrial, agricultural, environmental and educational sectors.

- Establish a permanent commission committee, consisting of specialist members from all riparian countries, tasked with monitoring and oversight, wide information exchange, setting standards and water conservation policies (multi-sector conversation) to support both water quantity and quality management concerns for household, agriculture, and industrial uses. This will satisfy broader benefits of integration and will avoid several bad effects resulting from unilateral projects.

- Foster the cooperation between governorates among all riparian countries through sectors (agriculture, irrigation, hydropower, industry, construction, and domestic). Strengthen operational management and exchange information between official ministries and NGO.

- Expedite the issuance of a unified water law, which covers all activities using water resources such as agriculture, hydropower, municipal, and industry. It has to establishing Public water utilities and a national pricing policy in Iraq, to support cost recovery and enhance water conservation.

- Improve strategic water resources management by adopting the sustainable management principal of land and water resources. All projects should be based on sustainability and participatory approach in the decision-making process among all stockholders in all riparian countries at all stages. The implementation of a sustainable land water strategy will have a direct effect on the mitigation of water pollution.

- Create environmental awareness through environmental education at all levels in all riparian countries. It is important for success almost all plane. All types of media should contribute to improve the public awareness of the pollution prevention measures and create effective monitoring systems.

- Encourage research at all levels within ministries, research centers as well as in the universities to improve the water use efficiency, water management, reuse wastewater for industry and irrigation after proper treatment.

- Create a special office that will be responsible for water pollution monitoring, in charge of strengthen water quality monitoring measures, management and set ecosystem conservation priorities.

- Promote the official authorities to play an effective role in preventing unlawful discharging into rivers or water bodies and reducing the hydraulic pollution loads received by the rivers. It should be given also the adequately power to enforce the law against illegal practices.

- Manage irrigation return flow upstream of Iraq, diverting the irrigation return discharge away from the river, and connecting the drains with MOD and EOD within Iraq. Thus, the return irrigation water will be prevented from mixing with river water, and the irrigated lands will be kept free from salinization and water logging problems. Application of modern technology in agriculture and irrigation systems in all riparian countries. Utilization of industrial sprinklers or other demand rationalization methods to rationed controlled water quantities for irrigation which led to reduce back irrigation water, choosing crops that depend on smaller quantities of irrigation water. Reducing the use of fertilizer in agriculture will limit the amount of nutrients that reaches the river. It is better to use natural pesticides and insecticides which are made of organic products, and to plant native crops instead of hybrid ones, since they may require a lot of pesticides and chemicals for their protection. When it rains, these chemicals reach the river, thus polluting the water.

- Stop the release of water from al Tharthar Lake and eliminate the flow diversion from the Tigris River to the Euphrates River via Al-Tharthar depression. This will reduce the supply of river with water stored in Al-Tharthar depression which holds high concentration of different pollutants due to evapotranspiration.

- Use treatment plant units in factories and industrial plants, study the possibility of reusing wastewater (recycling) in theses plant and factories.

- Treat the domestic wastewater completely before release it into river. Efficient wastewater treatment is considered an important way to preserve water quality in rivers.

- Use a detergent that has low phosphate levels. Reducing the use of detergent will decrease the quantity of nutrients that reaches to the water course through domestic waste water.

- Assess the amount of hazardous, medical, chemical and industrial wastes (locations, composition, volumes, and disposal routes). At any rate, it must be not possible to throw out such waste into river.

- Limit and ration the usage of water, for example, people should not keep the water running when they are brushing their teeth, washing their hands, and washing their dishes et cetera. An appropriate quantity of water should be used for watering lawns. Other forms of wastes, such as tissue papers and the odd trash, must be removed by putting them in trash bins rather than flushing them down the drain. Executing these simple procedure like these are extremely important to preventing water losses, thereby the wastewater quantity that reaches to the waterway will decrease significantly, finally, limiting the pollutant load that may reach to river.

- Avoid flushing chemicals and hazardous liquid waste into domestic sewage and do not allow household wastes like pet waste or other waste like petroleum materials, exchanged motor oil, paint, chemicals, and other such items to be discarded in the trash or be thrown into the sewer.

- Segregate solid waste and encourage recycling by setting up a compost unit, and use products which can be easily recycled so that all the household waste can be converted into manure or compost rather than being disposed off in the wrong manner or reach the river.

- Avoid littering in water bodies by increase awareness and install river equipment protection. Each person need to take up the responsibility and do something at an everyday level to prevent or mitigate pollution. More than this, voluntary activities to clean rivers must be encouraged. This will ensure that pollution is prevented or minimized.

- Stop quarrying of sand in river beds, and protect the banks of the river to prevent erosion.

At any rate, these measures could be implemented without extreme difficulties, but require the mutual collaboration of the riparian countries. The condition could be even worse if the proper actions are not urgently taken by all riparian countries at all levels. To reach a trilateral agreements on how the flow discharge will be distributed among the riparian countries, like these agreements should take into account the projected hydraulic works, agricultural and irrigation systems, food needs, electricity needs, and other activities.

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Appendix

Note: Because most of this text (appendix 1) contains scientific definitions, specifications, and certain numbers, it is situated here. Direct quotations from other authors have been put between citation markers (“) and written with Italics font together with the original source at the end.

1. Water quality parameters

1.1(pH)

It is a measure of the amount of acidity in the water. A low pH indicates more acidity and pH is considered an important parameter for water usage and aquatic life. This term was originally derived from a French phrase “pouvoir hydrogene” (Klontz, 1993), which means “hydrogen power”. Thus, it is a measure of the concentration of hydrogen ions in a sample of water. The pH level indicates if the water is acidic or basic at a logarithmic scale, which means that each integer value is ten times greater or lesser than the previous or following value. It ranges from 1 (high concentration of positive hydrogen ion, implying strongly acidic conditions) to 14 (high concentration of negative hydroxide ions, which means strongly basic conditions), while the value 7 refers to equilibrium concentration which represent the pure or neutral water (web reference 40), see figure 1.

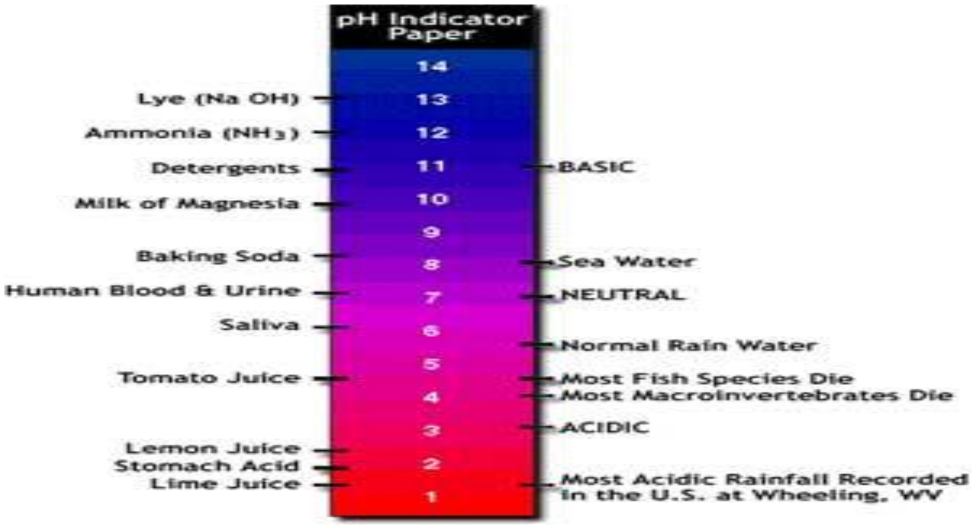

Figure 1: The range of pH value (web reference 15)

Any change in pH value from 7 may indicate the presence of pollutants in the water, and changes in the river pH directly affect the environmental chemistry of the river, thus affecting aquatic organisms (web reference 47).

Most aquatic organisms prefer a range of pH between 5.5 and 9.5 (EPA, 1976), and they are stressed if the pH falls too much above or below this range.

The pH value of clean water depends on several factors such as the types of rock (released acidic or alkaline components) and vegetation within the river watershed. *"Stream draining forests and marshes are often slightly acidic due to the presence of humic acids produced by decaying vegetation in the soil. On the other hand, streams in watersheds situated on limestone ($CaCO_3$) contain high concentration of bicarbonate ions, this result in alkaline waters"* (web reference 39).

Low pH levels could increase the solubility of certain heavy metals and some chemicals, making them more toxic than what is normal, implying increased concentrations of pollutants in the river water (web reference 41). Acid water will allow metals and other components to be more easily absorbed by aquatic organisms. In this study table 1 was used for classifying the water according to its pH.

Table 1 Classification of water according pH

pH value	**From 1 to 2**	**From 4 to 6**	**7**	**From 8 to 10**	**From 11 to 14**
Water Quality class	Acidic water	Moderate acid	Moderate water	Moderate basic	Basic water

1.2 Alkalinity

The Alkalinity refers to the buffering capacity of a river and indicates the ability of river water to neutralize acidic pollution (which may come from acid rain or other sources) and resist changes in pH. It encompasses the total amount of base substances that release hydroxide ion when dissolved in water expressed in mg/l. It measures the amount of some chemical compounds such as CO_3^-, HCO_3^- and OH^-. "*These compounds are natural buffers that can remove excess hydrogen* (H^+)"(web reference 36).

Waters that have adequate buffering capacity are able to keep a relatively constant pH, preventing rapid changes. High alkalinity makes the river and water bodies less vulnerable to acid rain or increases in other chemicals (web reference 40).

Water with Alkalinity values within the range 20-200 ppm is considered to have good ability for resisting changes in pH, whereas water with alkalinity values below 10 ppm means poor ability to resist changes in pH (web reference 39).

Rocks, such as borates, silicates and limestone, which are rich with carbonate, are the main sources of alkalinity components (web reference 47) which increased buffering capacity, that mean rivers that flow through areas rich with granite has low alkalinity, thereby, they have weak buffering capacity. Rivers that flows through limestone regions react with $CaCO_3$, the carbon dioxide (CO_2) is released from the calcium carbonate during the equilibrium reaction, resulting in water with high alkalinity and strong buffer capacity:

$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow 2H^+ + CO_3^{2-}$ (web reference 35)

It is clear from the above the reaction equation that the carbonate (CO_3^{2-}) and bicarbonate (HCO_3^{2-}) ions act as hydrogen ion absorbers. "*This causes the reaction of the bicarbonate buffering system to shift left or right while maintaining a relatively constant pH, in this way an alkaline stream with a large buffering capacity is able to "hold" more acidic pollutant without displaying a significant decrease in pH"* (web reference 39).

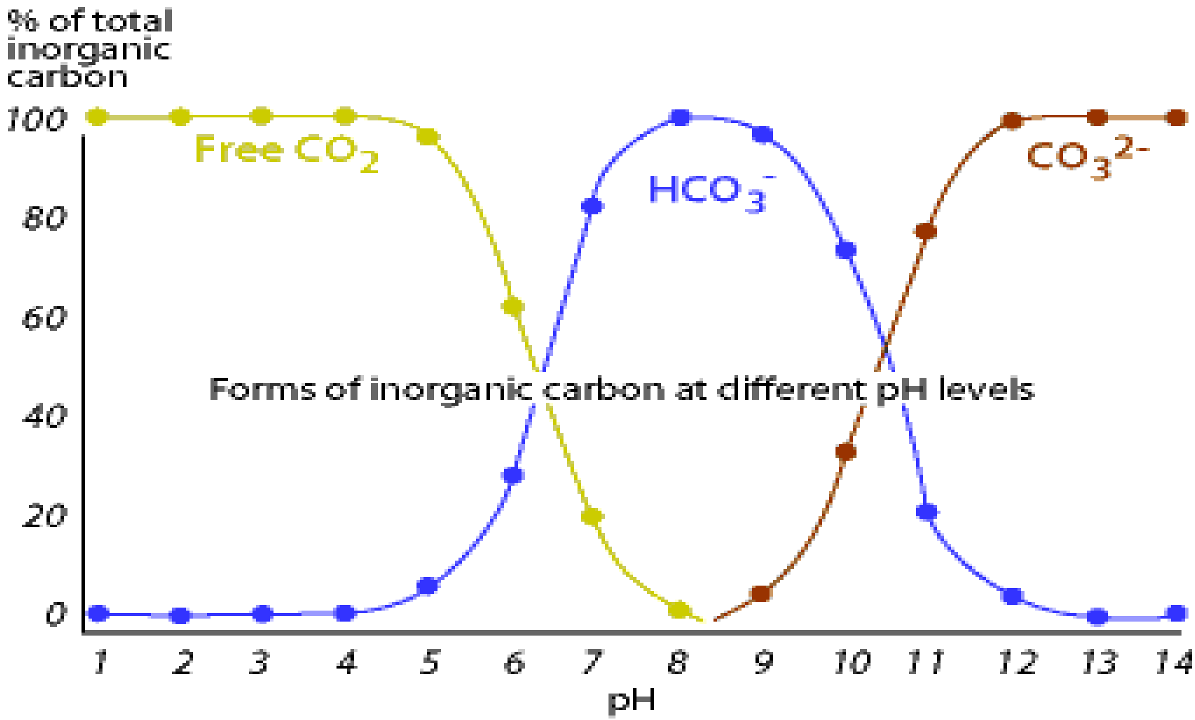

Figure 2: Forms of inorganic carbon at different pH levels (web reference 39)

1.3 Nitrogen components: Ammonia, Nitrite and Nitrate

Nitrogen, along with carbon, hydrogen, phosphorus, and oxygen, is considered one of the most important elements for biological life and it is present in the atmosphere and in the soil. Nitrogen gas forms about 78.08% by volume of the Earth's atmosphere (Furans, 1992), being one of the limiting nutrients during photosynthesis (web reference 36). It can be combined with many materials to product basic components for biological organisms and plants, and finally return back to the soil or air naturally by assistance of some kind of organisms in a nitrogen cycle. It is an important nutrient for plant growth and a key component of organisms. Nitrogen plays a large role in formation of amino acid.

To be useful for aquatic life Nitrogen as an element must be converted to one of its components through several processes such as ammonification, nitrification, and dentrification. Nitrogen occurs in natural waters in various forms, including nitrate (NO_3), nitrate (NO_2), and ammonia (NH_3). The chemical term (NO_3-N) refers to the concentration of nitrogen in form of nitrate. Ammonia is another Nitrogen component manufactured from nitrogen and hydrogen; it is regarded as the least stable form among other forms. It is one of the most important pollutants in the aquatic environment because it is highly toxic to the life of aquatic organisms. When it is converted to nitrite by specific types of bacteria it has strong smell. Ammonia salts are a major source of fertilizers but they speed up the process of eutrophication in water bodies, if the return irrigation water reaches to the waterway. Also, it is toxic to fish and aquatic organisms. Elevated concentrations of ammonia greater than 0.1 mg/l indicate polluted water (Knepp& Arkin, 1973).

The danger of ammonia for aquatic organisms depends on water temperature, pH, DO, and carbon dioxide. The toxicity of ammonia to aquatic life is positively correlated with CO_2, pH of water and temperature also, and negatively correlated with DO (Knepp& Arkin, 1973).

Total Ammonia Nitrogen (TAN) is a parameter that measures the sum of un-ionized (NH_3) and ionized (NH_4^+) form of ammonia present in the aquaculture system.

If pH of the solution increases either naturally or by addition of a base, the concentration of unionized NH_3 increases. This will impede the conversion of nitrite to nitrate, causing nitrite to accumulate (web reference 40).

Nitrite (NO_2^-) is extremely toxic to aquatic life, and it is another Nitrogen component that is less stable and usually present in much lower amounts than nitrate (web reference 40). Usually the concentration of Nitrite in most rivers and water bodies is tiny, because it is rapidly oxidized to nitrate.

NO_2 is an intermediate product in the conversion of NH_3 or NH_4^+ into NO_3 (Lawson, 1995). This process is affected by several factors, such as pH, DO, and temperature nitrifying bacteria, and reversely affected by inhibiting factors. The toxicity of nitrite is dependent on chemical factors such as the reduction of calcium, chloride, bromide and bicarbonate ions, and the level of Ph, DO and ammonia (web reference 40).

Nitrate (NO_3^-) occurs in tiny quantities in river and water bodies, where it is formed through the nitrification process, i.e., oxidation of NO_2 into NO_3 by the action of aerobic bacteria. It is a stable form of Nitrogen, considered to be highly soluble and the least toxic material, but in high concentration it increases eutrophication (Lawson, 1995).

The most common sources of excessive nitrogen in water bodies are wastewater from domestic, industrial, and return irrigation water. High concentration of nitrogen in river water may indicate the presence of one or both of these forms of pollution. Under normal conditions, the environmental effectively recycles most of its nitrogen.

The resulting decay of organic matter rapidly depletes available dissolved oxygen supplies in the water, causing the death of other organisms, such as fish. In addition, excess nitrate increases algal blooms, which may block light penetration, affecting underwater plants and adding to the organic decay. Low- or no-oxygen environments can support few aquatic organisms and may produce methane, hydrogen sulphide and other noxious gases besides its ability for self-purification.

The term Organic Nitrogen refer to component of nitrogen that had its origin in living organisms such as proteins and peptides, nucleic acids and urea, and numerous synthetic organic materials.

1.4 Phosphates P

Phosphate along with carbon, hydrogen, and oxygen is considered as one of the most important elements to all biological life in the form of ions PO_4^{3-} and HPO_4^{2-} . Inorganic orthophosphate (PO_4^{3-}) is the only form available to organisms (web reference 40), and it is regarded as the key energy for all organisms and the limiting nutrient for plant growth. There are two forms of Phosphate, organic (which associated with plants and organisms) and inorganic which found in, rocks and minerals. Organic and inorganic phosphates are present in soil, sediments, rivers and water bodies, in dissolved form or suspended particles.

Phosphorus exist in various forms, such as, orthophosphate, metaphoshate, and organically bound phosphate, the first form comes from detergents that exist in the wastewater, while the other forms come as result from the breakdown of organic pesticides.

The most sources of phosphorus are return irrigation wastewater which contains high concentration of fertilizers, pesticides, phosphorus mining, rocks weathering, industry wastewater, cleaning compounds and detergent, and untreated sewage, or waste water from inefficient wastewater treatment plant. Phosphorus could come also from human and animal waste. Typically, the human body releases about 0.453 kg of phosphorus per year (EPA, 1976).

High concentration of Phosphorus in rivers or water bodies could cause damage to people and animals. A classification for water bodies is available in table 2.

Table 2 Classification of water body according P concentration, (Muller and Helsel, 1999)

Concentration of phosphorus mg/l	**Class**
Below 0.01	Oligotrophic
0.010 to 0.020	Mesotrophic
More than 0.020	Eutrophic

If the phosphorous concentration is very high in river or water bodies, it will stimulate the growth of plankton and water plants that provide food for fish. Thus, a large quantity of algae and plants will grow, which lead to poor oxygen concentration in the river. It could also affect the drinking water plants (web reference 40).

1.5 Turbidity

Measuring the turbidity of water is considered to provide a key test of the overall water quality and the main way to identify the clarity of water river and water bodies. Turbidity measures the amount of suspended solids in a sample that causes cloudiness of the water. It is defined by (APHA) as ”*the optical property of a water sample that causes to be scattered and absorbed rather than transmitted in straight lines through the sample*” (EPA 1974).

When water has a lot of suspend solid in the water column, less sunlight will be able to penetrate inside, which may lead to a decrease in the quantity of dissolved oxygen in river water that is produced by plants during the photosynthesis process. The suspended material which exists in the water has another effect: it absorbs the heat from sunlight leading to an increase in water temperature, which will decrease the concentration of dissolved oxygen in river water (web reference 47).

Suspended solids causes the turbidity (see figure 3) and they include mud, algae, detritus, and fecal material, microorganisms, plant fibbers sawdust, wood ashes. Thus, any substance that makes the water cloudy leads to turbidity.

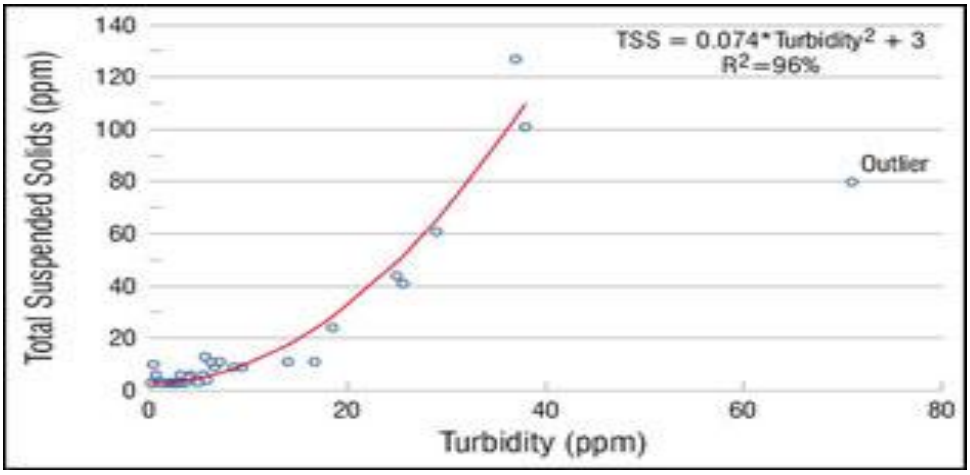

Figure 3: Example of a relationship between turbidity and total suspended (EPA, 1976)

Other factors contributing to water turbidity include soil erosion, elevated nutrient inputs that stimulate algal blooms, waste discharge, and existing of bottom feeders in large quantity that stir up particles and impurities, mining processes, and dredging operation.

The most accurate method to measures turbidity is through an electronic turbid meter, the units used in this method are the NTU units, which stands for Nephlometric Turbidity Units or JTU units which stands for Jackson Turbidity Units. For both of these methods, the smaller the value obtained, the less turbid the water.

The turbidity value of drinking water according to the (WHO) requirements should not be more than 5 NTU and not to be less than 1 NTU, whereas value more than 40 NTU indicates pollution in water (WHO, 1997).

There are many unwanted effects related to turbidity, and these effects range from aesthetic to health hazards. Turbidity also has economic impacts, where it is essential to eliminate the turbidity of water in order to effectively disinfect it for drinking purposes. Another unwanted effect occurs on filters; thus, turbidity will reduce the efficiency of filters and reduce the water production, making unit price higher. There is also environmental impact for high turbidity since the suspended particles provide a transport path for heavy metals and other toxic components.

1.6 Dissolved oxygen (DO)

DO is a measure of the amount of oxygen that is dissolved in water. Along with water, oxygen is essential for the survival of every living thing, and it is considered as one of the most important aspects of aquaculture. Oxygen is necessary for all aquatic life.

As illustrated in figure 4 and table 4 the ability of water to hold oxygen is inversely proportional to the temperature of the water, the lower the water temperature is the more dissolved oxygen it can hold. The velocity and depth of the flow also affect the concentration of DO. The presence of aquatic plants in a stream influences the dissolved oxygen content, as well as the altitude (DO is correlated reversely with altitudes) and suspended and dissolved solids.

The unit measure of dissolved oxygen in water is often given by the parts of oxygen per million parts of water (ppm) or by calculating the saturation degree by oxygen. Because the temperature of the stream can vary widely over day, it is important to referring to the effect of temperature when examining the DO levels in a sample of water. This could be achieved by measuring the saturation degree. Saturation degree is the "*maximum level of DO that would be present in the water at a specific temperature, in the absence of other influences"* (web reference 40). River and water bodies which have degree of saturation with ranged 90-100 percent and dissolved oxygen concentrations greater than 8 mg/L regard healthy and free of pollution and indicate good water quality (web reference 40).

Table 3: The feature of water according to its dissolved oxygen content (web reference 36 and 40)

Concentration of DO	Feature
greater than 8 mg/L	good water quality
More than 5mg/l	high production yield
Less than 5 mg/l	indicate poor water quality
less than 3 mg/L	stressful to most aquatic organisms
Less than 2 mg/l	will not support fish at all
From 1 to 2 mg/l	Most fish die
From 0.5 to 1 mg/l	considered hypoxic
less than 0.5 mg/L	Considered anoxic

Table 4: Maximum Dissolved Oxygen Concentration Saturation Table, (web reference 35)

Temperature (degrees C)	**DO mg/L**	**Temperature (degrees C)**	**DO mg/L**	**Temperature (degrees C)**	**DO mg/L**	**Temperature (degrees C)**	**DO mg/L**
0	14.60	13	10.52	26	8.09	39	6.51
1	14.19	14	10.29	27	7.95	40	6.41
2	13.81	15	10.07	28	7.81	41	6.31
3	13.44	16	9.85	29	7.67	42	6.22
4	13.09	17	9.65	30	7.54	43	6.13
5	12.75	18	9.45	31	7.41	44	6.04
6	12.43	19	9.26	32	7.28	45	5.95
7	12.12	20	9.07	33	7.16		
8	11.83	21	8.90	34	7.05		
9	11.55	22	8.72	35	6.93		
10	11.27	23	8.56	36	6.82		
11	11.01	24	8.40	37	6.71		
12	10.76	25	8.24	38	6.61		

Atmosphere is the main source of dissolved oxygen in river water and water bodies through direct transfer through the water surface (the gas comprises about 20% of our atmosphere) and through aquatic plants as by-product of photosynthesis in the presence of light and chlorophyll (Boyd 1999):

$6\ CO_2 + 6H_20 \rightarrow 6O2 + C_6\ H_{12}\ O_6$ (carbon-rich foods)

Wind and wave action, water that goes over falls and rapids, boat movement and mechanical aeration increase the concentration of dissolved oxygen in river water.

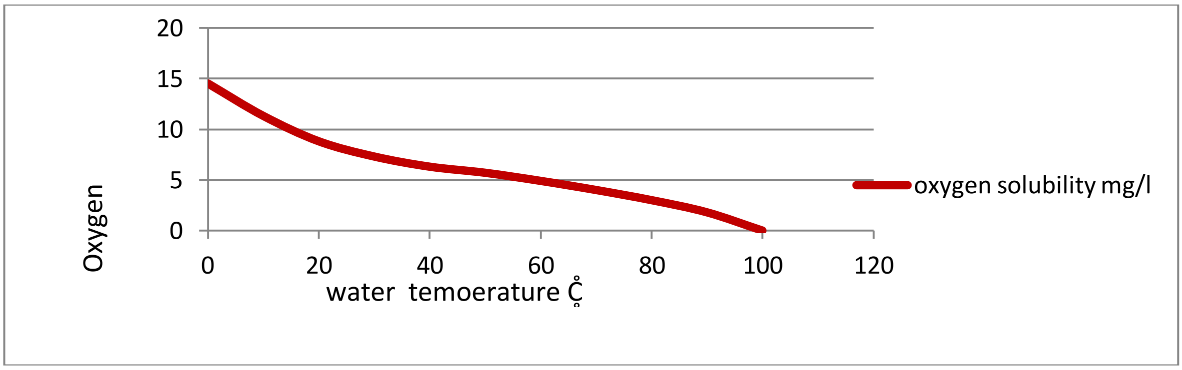

Figure 4: Dissolved oxygen concentration in a water sample taken from first sample area (at constant atmospheric pressure).

The presence of pollutants can reduce the oxygen carrying capacity and the concentration value of dissolved oxygen in river water. Pollutants consume dissolved oxygen and the rate is quantified by such measures as the chemical (COD) or microbial (BOD) decomposition in the case of sewage pollutants. Dissolved oxygen is needed by many organisms that live in rivers and water bodies such as fish, bacteria, phytoplankton and zooplankton.

The number and size of plants in a river will increase, if the waterway receives run-off from agricultural land after using intensive fertilizer. Then, if the water becomes cloudy for several days or during dark times, plants will use dissolved oxygen to metabolize food through the process of respiration and release carbon dioxide. In this case the plants will use much dissolved oxygen. Also, when these plants die, bacteria will use a great amount of dissolved oxygen during decay of these plants (EPA, 1976).

1.7 BOD Biochemical Oxygen Demand and COD

BOD is defined as the "*amount of oxygen consumed by bacteria in the decomposition of organic material in the streams*" (web reference 40). From this definition, it can be surmised that the quantity of oxygen that is used for aerobic oxidation is positively correlated with the quantity of organic material which exist in a water body.

BOD measurement is obtained by counting the decrease in quantity of dissolved oxygen in mg/l after five days. It also "*includes the oxygen required for the oxidation of various chemical in the water, such as sulphides, ferrous iron and ammonia*. *Unpolluted, natural waters should have a BOD of 5 mg/L or less. Raw sewage may have BOD levels ranging from 150 – 300 mg/L* (web reference 40).

This term COD refers to "*chemical oxygen demand (COD) is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant*" (web reference 40).

1.8 Conductivity

Conductivity is the ability of the water to conduct or transmit an electrical current, it is considered an indirect measure of the content of ionic material dissolved in the water such as chloride, nitrate, sulphate, phosphate, sodium, magnesium, calcium, iron, and aluminium. Seawater usually has high and freshwater low conductivity. The more ions present, the more electricity can be conducted by the water (web reference 47).

Measurements are expressed in micro-Siemens per centimetre (µS/cm) at temperature 25 degrees Celsius (web reference 35). In general, a higher conductivity indicates that more material exists as dissolved material in the water, which may contain more contaminants. Conductivity in water is influenced by several factors, such as rainwater conductivity value, road salt, fertilizer used in farmland, and evaporation rate.

1.10 Fecal Coliform Bacteria

"*Fecal coliform bacteria are microscopic organisms that live in the intestines of all warm blooded animals, and in animal wastes or faeces eliminated from the intestinal tract*"(web reference 41).

Besides fecal coliform there are several types of bacteria that are used as indicator factors in sample analysis. These types are enterococci, and E. coli bacteria, which are used as indicator organisms ("*they indicated the probability of finding pathogenic organisms in a stream*"; web reference 40). "*Fecal coliform bacteria may indicate the presence of disease carrying organisms which live in the same environment as the fecal coliform bacteria*" (web reference 41). The measurement is expressed as the number of organisms per 100 mL sample of water (#/100mL) (web reference 35). "*Human and animal wastes carried to stream systems are sources of pathogenic or disease-causing, bacteria and viruses*"(web reference 40).

Appendix

2. Monthly water samples analysis results for station 3 (Karbala)

Physical Turb - temp TDS - TSS - color - odor - [illegible]

chemical EC - PH - Alk - TH - Cl - SO4 - Mg - Ca - Na - K Al

Biological Bacterial counts - chlorphyll

From Date: 2010/01/01

To Date: 2010/01/31

اسم المحافظة كربلاء المقدسة

Al	K	Na	T.S.S	T.D.S	SO4	Cl	Mg	Ca	T.H	Alk	E.C	PH	Turb	Temp	تاريخ الفحص	تاريخ الجمع	طبيعة النموذج	اسم المشروع او المجمع	ت
0	5.5	140	36	924	335	174	38	130	480	154	1190	8.3	12	20	1/5/2010	1/4/2010	RAW	مشروع مدينة الحسين	1
0	5.6	154	56	996	335	190	44	120	480	164	1355	8.3	20	20	1/5/2010	1/4/2010	RAW	مشروع حي الحسين	2
0	5.4	142	52	948	346	170	40	125	480	158	1258	8.3	18	20	1/5/2010	1/4/2010	RAW	مشروع الصافي القديم	3
0	4.4	108	62	920	355	160	50	110	480	130	1236	8	22	17	1/5/2010	1/4/2010	RAW	مجمع الحي العسكري/ناحية الجدول	4
0	5.2	132	36	1012	316	174	45	120	480	126	1428	7.9	24	20	1/7/2010	1/6/2010	RAW	مشروع الهندية الموحد	5
0	5.8	126	44	998	308	188	42	120	492	134	1398	8.1	22	20	1/7/2010	1/6/2010	RAW	مشروع الهندية القديم	6
0	5.2	128	54	1024	348	172	42	126	488	132	1414	7.8	20	20	1/11/2010	1/10/2010	RAW	مشروع حي الحسين	7
0	7.2	100	40	1025	302	160	40	125	476	148	1442	8.2	12	20	1/13/2010	1/12/2010	RAW	مجمع الطبر/قضاء الهندية	8
0	7	106	24	1018	317	202	43	125	488	132	1486	8.1	18	20	1/13/2010	1/12/2010	RAW	مجمع ام طوب/قضاء الهندية	9
0	6.2	126	28	992	394	176	40	128	486	144	1376	8.2	16	20	1/13/2010	1/12/2010	RAW	مجمع الكريزات/قضاء الهندية	10
0	6.8	112	26	944	338	170	44	120	480	140	1272	8.4	15	22	1/13/2010	1/12/2010	RAW	مجمع الحكمة/ناحية الجدول الغربي	11
0	6.5	124	32	910	344	170	29	144	480	140	1340	8.1	16	22	1/13/2010	1/13/2010	RAW	مجمع العبدعونيات/ناحية الجدول	12
0	6.5	122	38	1004	352	165	26	148	480	150	1366	8.3	17	22	1/13/2010	1/12/2010	RAW	المجمع الفرنسي/ناحية الجدول	13
0	6.8	110	42	870	370	160	28	150	490	145	1348	8.4	17	22	1/13/2010	1/13/2010	RAW	مجمع الدويهية/ناحية الجدول	14
0	6	85	32	958	294	150	36	125	460	140	1274	8.3	10.2	20	1/13/2010	1/12/2010	RAW	مشروع مدينة الحسين	15
0	10.1	176	66	1035	400	338	56	148	600	160	2172	8.3	13	18	1/14/2010	1/13/2010	RAW	مجمع الفيضة/ناحية الحسينية	16
0	5.4	131	26	896	368	176	34	132	472	138	1493	8.3	12	18	1/14/2010	1/13/2010	RAW	مجمع عون الجديد/ناحية الحسينية	17
0	5.2	118	18	857	332	128	26	140	460	138	1317	8.3	10	18	1/14/2010	1/13/2010	RAW	مجمع حصوة عون الاول/ناحية	18
0	5.3	126	22	930	338	158	31	140	480	140	1342	8.3	10	18	1/14/2010	1/13/2010	RAW	مجمع الابراهيمية/ناحية الحسينية	19
0	5.3	118	38	853	302	188	37	139	506	136	1280	8.3	26	18	1/14/2010	1/13/2010	RAW	مجمع خديدان/ناحية الحسينية	20
0	5.5	138	22	900	385	186	34	139	488	138	1394	8.4	16	18	1/14/2010	1/13/2010	RAW	مجمع ناحية الحسينية	21
0	5.6	116	30	994	344	178	29	144	478	150	1486	7.9	28	20	1/18/2010	1/17/2010	RAW	مشروع الصافي القديم	22
0	5.8	148	18	1072	320	200	25	154	490	144	1511	8.1	7	17	1/18/2010	1/17/2010	RAW	مجمع العبودة/ناحية الحر	23
0	5.6	184	22	1180	450	195	24	150	474	138	1458	7.9	8	17	1/18/2010	1/17/2010	RAW	مجمع الكاظي/ناحية الحر	24
0	5.6	174	26	1216	427	200	34	144	500	130	1378	8	5	17	1/18/2010	1/17/2010	RAW	مجمع الحصوة/ناحية الحر	25
0	5.3	128	18	968	395	155	36	124	460	130	1324	8.4	5	22	1/19/2010	1/18/2010	RAW	مجمع ام جمل/ناحية الجدول الغربي	26
0	5.5	128	26	948	335	150	28	130	440	135	1292	8.2	7	20	1/19/2010	1/18/2010	RAW	مجمع الشوجية/ناحية الجدول الغربي	27
0	5.3	124	22	940	380	150	34	120	440	130	1308	8.3	6	22	1/18/2010	1/18/2010	RAW	مجمع ابوسفن/ناحية الجدول الغربي	28
0	5.4	124	20	934	345	140	44	120	480	130	1278	8.3	6	20	1/19/2010	1/18/2010	RAW	مجمع ابوبغال/ناحية الجدول الغربي	29
0	6	168	22	966	395	200	34	128	460	144	1485	8.3	9	17	1/20/2010	1/19/2010	RAW	مشروع الخيرات	30
0	5	140	36	1036	329	160	32	124	440	136	1289	8.6	11.4	17	1/20/2010	1/19/2010	RAW	مجمع المقدوني/ناحية الخيرات	31
0	6.5	172	28	1072	399	205	32	132	460	136	1513	8	11	17	1/20/2010	1/19/2010	RAW	مجمع القيادة/ناحية الخيرات	32
0	5.5	136	36	956	363	175	36	124	460	140	1400	8.4	18	16	1/21/2010	1/20/2010	RAW	مشروع الهندية الموحد	33
0	5.2	132	28	972	363	190	36	124	460	140	1462	8.3	14	16	1/21/2010	1/20/2010	RAW	مشروع الهندية القديم	34
0	6.7	158	24	960	369	166	32	131	460	150	1339	8.3	11	17	1/25/2010	1/24/2010	RAW	مجمع الصلامية الشرقي/ناحية الحسينية	35
0	6	142	22	980	368	166	37	132	480	148	1358	8.3	11	16	1/25/2010	1/24/2010	RAW	مجمع الصلامية الغربي/ناحية الحسينية	36
0	6.7	168	20	960	378	168	36	125	460	150	1356	8.4	10	16	1/25/2010	1/24/2010	RAW	مجمع ناحية الحسينية	37

From Date: 2010/02/01
To Date: 2010/02/28

اسم المحافظة كربلاء المقدسة

Al	K	Na	T.S.S	T.D.S	SO4	Cl	Mg	Ca	T.H	Alk	E.C	PH	Turb	Temp	تاريخ الفحص	تاريخ الجمع	طبيعة النموذج	اسم المشروع او المجمع	ت
0	6.6	152	16	894	372	150	34	128	460	140	1072	8.2	18	21	2/2/2010	2/1/2010	RAW	مشروع مدينة الحسين	1
0	6.8	172	22	957	369	160	34	128	460	130	1245	8.4	15	20	2/2/2010	2/1/2010	RAW	مشروع حي الحسين	2
0	4.4	112	50	944	348	130	40	118	460	124	1465	7.9	18	22	2/2/2010	2/1/2010	RAW	مشروع الصافي القديم	3
0	5.8	156	38	870	369	166	39	128	480	134	1242	8.2	5	20	2/2/2010	2/1/2010	RAW	المجمع الفرنسي/ناحية الحر	4
0	5.6	156	36	878	375	178	40	128	480	126	1255	6.8	12	20	2/2/2010	2/1/2010	RAW	مجمع مصيليخ/ناحية الحر	5
0	6.3	128	34	968	380	170	25	158	500	120	1331	8.1	13	20	2/9/2010	2/8/2010	RAW	مجمع ناحية الحسينية	6
0	6.3	130	28	988	370	170	29	160	500	120	1263	8.4	12	20	2/9/2010	2/8/2010	RAW	مجمع الصلامية الشرقي/الحسينية	7
0	6.2	130	32	976	370	158	32	150	500	140	1366	8.3	12	20	2/9/2010	2/8/2010	RAW	مجمع الابراهيمية/الحسينية	8
0	6.2	133	26	1000	355	168	28	152	495	148	1258	8.3	15	20	2/9/2010	2/8/2010	RAW	مجمع مرغز/الحسينية	9
0	6.2	122	32	800	355	160	46	124	500	138	1473	8.3	16	22	2/10/2010	2/9/2010	RAW	مشروع مدينة الحسين	10
0	6.1	122	42	912	337	150	31	141	480	170	1298	8.3	20	21	2/11/2010	2/10/2010	RAW	مشروع الهندية الموحد	11
0	5.2	136	48	989	340	160	28	146	480	180	1364	8.3	21	21	2/11/2010	2/10/2010	RAW	مشروع الهندية القديم	12
0	5.1	128	38	862	370	155	29	152	500	130	1492	8.3	17	20	2/15/2010	2/14/2010	RAW	مشروع مدينة الحسين	13
0	4.8	120	22	936	399	125	32	147	500	150	1521	8.4	6	22	2/16/2010	2/15/2010	RAW	مجمع الكراكشة/الجدول الغربي	14
0	4.4	114	20	972	350	130	29	144	480	160	1521	8.2	5	22	2/16/2010	2/15/2010	RAW	مجمع ابو بغال/الجدول الغربي	15
0	4.5	114	28	988	372	118	44	152	485	162	1432	8.4	9	22	2/16/2010	2/15/2010	RAW	مجمع الحكمة /الجدول الغربي	16
0	4.4	122	16	1030	392	143	32	148	500	142	1290	8.3	5	21	2/17/2010	2/16/2010	RAW	مجمع ماء الحسين/المركز	17
0	44	126	20	1072	371	146	28	154	500	132	1288	7.8	9	21	2/17/2010	2/16/2010	RAW	مجمع سيد اسماعيل/المركز	18
0	4.8	120	14	1050	390	142	36	152	528	140	1380	7.4	5	21	2/17/2010	2/16/2010	RAW	مجمع الشبانات/المركز	19
0	5	112	42	886	380	120	34	144	500	150	1232	8.5	13	21	2/17/2010	2/16/2010	RAW	مجمع البو كريدة القديم/الهندية	20
0	4.8	120	38	984	369	125	37	140	500	150	1246	8.4	10	21	2/17/2010	2/16/2010	RAW	مجمع ابن الكاظم/الهندية	21
0	4.9	118	18	996	360	116	29	144	480	152	1360	8.5	5	21	2/17/2010	2/16/2010	RAW	مجمع البو كريدة الجديد/الهندية	22
0	4.9	120	0	1066	340	127	32	140	480	156	1336	8.4	39	21	2/17/2010	2/16/2010	RAW	مجمع ام طوب/الهندية	23
0	5.6	88	36	1054	366	152	54	138	568	122	1446	8.3	28	20	2/17/2010	2/17/2010	RAW	مشروع الصافي القديم	24
0	5.4	92	42	1170	369	166	57	146	590	128	1488	8.1	10	20	2/18/2010	2/17/2010	RAW	مجمع العبودة /الحر	25
0	5.4	100	38	1094	380	155	48	150	572	132	1414	8.2	5	20	2/18/2010	2/17/2010	RAW	مجمع الحصوة /الحر	26
0	5.4	92	50	1066	370	142	52	148	584	128	1478	8.2	7	21	2/18/2010	2/17/2010	RAW	مجمع الكاضي /الحر	27
0	5.3	125	46	986	348	160	34	136	480	120	1346	8.2	12	22	2/18/2010	2/17/2010	RAW	مشروع حي الحسين	28
0	5	105	18	998	370	150	37	140	500	130	1396	8.3	5	21	2/22/2010	2/21/2010	RAW	مشروع الصافي القديم	29
0	5.1	112	38	1060	382	140	32	148	500	122	1435	8.3	9	20	2/22/2010	2/21/2010	RAW	مجمع ماء الحسين /المركز	30
0	5.2	116	42	1084	380	155	32	148	500	130	1552	8	9	20	2/22/2010	2/21/2010	RAW	مجمع سيد اسماعيل/المركز	31
0	4.9	104	48	1032	382	145	29	144	480	130	1450	8.2	9.7	20	2/22/2010	2/21/2010	RAW	مجمع الحافظ/الحسينية	32
0	5.6	114	42	1061	375	160	68	104	540	130	1343	8.5	16	20	2/23/2010	2/22/2010	RAW	مشروع الهندية الموحد	33
0	5.5	108	50	998	378	150	68	104	540	120	1272	8.3	16	20	2/23/2010	2/22/2010	RAW	مجمع الكريزات/الهندية	34
0	4.8	112	28	1022	387	160	44	136	520	126	1514	8.4	15	21	2/24/2010	2/23/2010	RAW	مجمع خديدان/الحسينية	35
0	5	136	32	1190	398	180	44	148	550	140	1610	8.4	17	21	2/24/2010	2/23/2010	RAW	مجمع الصلامية الغربي/الحسينية	36
0	4.8	113	48	1005	355	140	37	148	500	130	1403	8.2	16	20	2/24/2010	2/24/2010	RAW	مشروع حي الحسين	37
0	4.4	104	58	998	340	160	39	138	505	128	1388	8.1	15	20	2/25/2010	2/25/2010	RAW	مشروع مدينة الحسين	38

From Date: 2010/03/01

To Date: 2010/03/31

اسم المحافظة كربلاء المقدسة

Al	K	Na	T.S.S	T.D.S	SO4	Cl	Mg	Ca	T.H	Alk	E.C	PH	Turb	Temp	تاريخ الفحص	تاريخ الجمع	طبيعة النموذج	اسم المشروع او المجمع	ت
0.07	5.1	108	8	958	400	146	39	128	482	140	1470	7.9	2.8	20	3/2/2010	3/1/2010	TREATED	مشروع مدينة الحسين	1
0.03	5.9	147	4	1088	400	172	34	144	500	130	1630	8	0	18	3/2/2010	3/1/2010	TREATED	مشروع الخيرات	2
0.01	5.3	144	8	1100	400	148	31	140	480	140	1635	8.3	0	18	3/2/2010	3/1/2010	TREATED	مجمع ناحية الخيرات	3
0.01	5.2	142	10	1086	389	150	29	152	500	140	1460	8.3	0	18	3/2/2010	3/1/2010	TREATED	مجمع ابو عويجيلة/ناحية الخيرات	4
0.02	4.6	124	2	1090	406	166	39	144	520	150	1408	8.2	0	18	3/3/2010	3/2/2010	TREATED	مشروع حي الحسين	5
0.06	5	98	6	976	398	136	32	138	478	136	1520	7.9	0.8	18	3/2/2010	3/2/2010	TREATED	مشروع الصافي القديم	6
0.07	4.2	108	2	1200	416	165	34	144	500	130	1564	8	0	24	3/10/2010	3/9/2010	TREATED	مجمع حصوة عون الثاني/ناحية الحسينية	7
0.01	4.4	112	22	1152	413	165	29	152	500	142	1612	7.8	10	24	3/10/2010	3/9/2010	TREATED	مجمع عون الجديد/ناحية الحسينية	8
0.01	4.6	122	12	1100	390	176	49	132	530	130	1646	8.3	4.1	25	3/11/2010	3/10/2010	TREATED	مشروع مدينة الحسين	9
0.02	4.8	124	8	1160	414	170	36	148	520	120	1604	7.9	1	24	3/14/2010	3/14/2010	TREATED	مشروع حي الحسين	10
0.03	4.8	124	16	1010	426	160	34	136	480	130	1385	8.4	23	25	3/15/2010	3/14/2010	TREATED	مجمع الصلامية الغربي/ناحية الحسينية	11
0	4.2	128	28	852	446	160	34	128	460	130	1427	8.2	24	25	3/15/2010	3/14/2010	TREATED	مجمع الصلامية الشرقي/ناحية الحسينية	12
0	4.2	128	12	848	446	136	30	135	460	140	1615	8.4	1.4	24	3/17/2010	3/16/2010	TREATED	مجمع البو كريدة الجديد/قضاء الهندية	13
0	4.3	128	12	848	426	140	34	133	472	144	1822	8.3	2.5	24	3/17/2010	3/16/2010	TREATED	مجمع البو كريدة القديم/قضاء الهندية	14
0.06	4.6	120	16	952	356	162	44	128	500	150	1810	8.4	1.4	24	3/17/2010	3/16/2010	TREATED	مجمع ابن الكاظم/قضاء الهندية	15
0	4.3	126	16	1016	459	140	40	135	500	150	1820	7.3	3.4	24	3/17/2010	3/16/2010	TREATED	مجمع الابراهيمية/قضاء الهندية	16
0	4.4	122	6	1150	400	160	37	136	492	160	1820	7.9	0	24	3/17/2010	3/16/2010	TREATED	مجمع خديدان/ناحية الحسينية	17
0.05	5.2	106	20	966	375	160	40	135	500	148	1711	7.9	15	24	3/17/2010	3/16/2010	TREATED	مجمع ابو زرنت/ناحية الحسينية	18
0.05	5.2	106	20	966	375	150	26	134	440	120	1510	8.2	14	20	3/18/2010	3/16/2010	TREATED	مشروع جرف البو عامر/ناحية الجدول	19
0	5.4	104	4	1006	425	150	31	134	460	120	1484	7.9	3	22	3/18/2010	3/16/2010	TREATED	مجمع البو سفن/ناحية الجدول الغربي	20
0.01	4.8	82	8	998	410	150	34	136	480	120	1452	8.3	4	22	3/18/2010	3/16/2010	TREATED	مجمع الشوجية/ناحية الجول الغربي	21
0.08	5	118	8	1020	410	160	31	141	480	130	1492	8	0.27	22	3/18/2010	3/17/2010	TREATED	مشروع الصافي القديم	22
0.05	4.6	106	16	1018	405	160	34	136	480	120	1528	7.8	5	22	3/18/2010	3/17/2010	TREATED	مشروع مدينة الحسين	23
0	4.2	124	14	1008	477	140	29	160	520	152	1308	8.2	1.7	20	3/23/2010	3/22/2010	TREATED	مجمع الكاضي/ناحية الحر	24
0	4.4	126	6	1010	411	140	10	192	520	144	1384	8.1	0.4	20	3/23/2010	3/22/2010	TREATED	مجمع الحصوة/ناحية الحر	25
0	4.4	120	8	1020	468	145	29	160	520	144	1361	8.1	1.9	20	3/23/2010	3/22/2010	TREATED	مجمع العبودة/ناحية الحر	26
0.01	4.4	120	6	1108	420	138	24	168	520	128	1572	8.1	0	20	3/24/2010	3/23/2010	TREATED	مشروع الصافي القديم	27
0.04	4.6	120	6	1108	400	150	24	168	520	120	1634	8	1.2	20	3/24/2010	3/23/2010	TREATED	مشروع مدينة الحسين	28
0.05	4.2	128	6	1136	451	140	24	168	520	120	1558	7.9	2.7	20	3/24/2010	3/24/2010	TREATED	مشروع حي الحسين	29
0.01	4.2	120	6	950	400	142	34	144	500	144	1724	7.6	0	20	3/29/2010	3/28/2010	TREATED	مشروع الهندية الموحد	30
0	4.2	128	4	980	400	150	27	148	480	140	1678	7.9	0	20	3/29/2010	3/28/2010	TREATED	مشروع الهندية القديم	31
0.09	4.6	130	12	1148	420	160	29	160	520	140	1657	7.9	2.7	20	3/29/2010	3/28/2010	TREATED	المجمع الفرنسي/ناحية الحر	32
0	4.2	118	16	1220	400	175	26	166	520	130	1546	8	3	22	3/30/2010	3/29/2010	TREATED	مجمع ماء الحسين /المركز	33
0.01	4.4	98	12	1200	400	175	29	176	560	140	1675	7.6	1.1	22	3/30/2010	3/29/2010	TREATED	مجمع ماء سيداسماعيل/المركز	34
0.11	4.4	114	6	1122	400	160	20	160	480	142	1516	7.6	0	22	3/30/2010	3/29/2010	TREATED	مجمع الشبانات/المركز	35
	4.2→5.9	100→150	4→22	1010-1100	400-450	140-175	34-49	128-160	440-550		1470-1675	7.8→8.3	1-10	18—24					

From Date: 2010/04/01

To Date: 2010/05/01

كربلاء المقدسة

اسم المحافظة:

ت	اسم المشروع او المجمع	طبيعة النموذج	تاريخ الجمع	تاريخ الفحص	Temp	Turb	PH	E.C	Alk	T.H	Ca	Mg	Cl	SO4					
1	مشروع مدينة الحسين	RAW	4/1/2010	4/1/2010	22	20	8.4	1675	130	560	176	49	170	388	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	مشروع الصافي القديم	RAW	4/1/2010	4/1/2010	22	16	8.4	1694	132	520	156	31	160	387	1140	[illegible]	[illegible]	[illegible]	[illegible]
3	مشروع حي الحسين	RAW	4/1/2010	4/1/2010	22	22	8.2	1734	128	530	150	37	162	376	1158	[illegible]	[illegible]	[illegible]	[illegible]
4	مجمع البو كريدة الجديد/ الهندية	RAW	4/4/2010	4/5/2010	22	5	8	1420	140	480	148	26	120	393	890	38	[illegible]	[illegible]	[illegible]
5	مجمع الكريزات/ الهندية	RAW	4/4/2010	4/5/2010	22	7.5	8.2	1472	148	500	176	14	128	390	890	38	108	[illegible]	[illegible]
6	مجمع ابن الكاظم/ الهندية	RAW	4/4/2010	4/5/2010	22	7	8.4	1476	146	500	148	31	138	400	1014	40	108	[illegible]	[illegible]
7	مجمع المنفهان/الهندية	RAW	4/4/2010	4/5/2010	22	7	8.2	1272	140	480	152	24	140	390	966	36	102	4.3	[illegible]
8	مشروع الهندية الموحد	RAW	4/4/2010	4/5/2010	25	18	8.2	1266	128	494	112	47	140	348	924	32	90	5.2	0
9	مشروع الهندية القديم	RAW	4/4/2010	4/5/2010	25	20	8.4	1308	130	500	128	44	140	325	948	52	92	4.2	0
10	مجمع الصلامية الشرقي/الحسينية	RAW	4/5/2010	4/6/2010	22	6	8.4	1396	140	500	152	29	145	359	1098	42	112	4.2	0
11	مجمع الصلامية الغربي/الحسينية	RAW	4/5/2010	4/6/2010	22	8	8.2	1686	140	500	155	27	145	382	1114	16	104	5	0
12	مجمع الامام عون/الحسينية	RAW	4/5/2010	4/6/2010	22	8	8.2	1560	146	500	152	30	150	385	1050	24	118	5.2	0
13	مجمع بدعة شريف/الحسينية	RAW	4/5/2010	4/6/2010	22	6	8.4	1560	142	500	154	28	140	376	1180	30	108	4.8	0
14	مجمع الحافظ/الحسينية	RAW	4/5/2010	4/6/2010	22	18	8.4	1670	136	520	154	35	160	400	1180	30	121	4.3	0
15	مجمع العبودة/ناحية الحر	RAW	4/6/2010	4/7/2010	22	6.7	8.4	1840	160	540	169	53	180	400	1522	32	133	5.1	0
16	مجمع الحصوة/ناحية الحر	RAW	4/6/2010	4/7/2010	22	8.5	7.8	1880	145	520	172	37	182	398	1500	48	133	5.1	0
17	مجمع الكمالية/ناحية الحر	RAW	4/6/2010	4/7/2010	22	8	8.3	1900	152	520	160	68	180	400	1410	44	132	5.3	0
18	مجمع مصليخ/ناحية الحر	RAW	4/6/2010	4/7/2010	22	5	8.3	1690	140	520	152	44	172	400	1140	38	143	5.1	0
19	مجمع المقدوني/ناحية الحر	RAW	4/6/2010	4/7/2010	25	11	8.3	1654	120	480	136	31	135	390	1106	48	92	4.7	0
20	مجمع الفرنسي/ناحية الحر	RAW	4/6/2010	4/7/2010	25	16	8.1	1668	120	480	136	31	150	400	1132	62	94	4.2	0
21	مجمع الابراهيمية/الحسينية	RAW	4/11/2010	4/12/2010	25	23	8.4	1403	150	440	128	26	150	388	990	30	126	4.7	0
22	مجمع الصلامية الشرقي/الحسينية	RAW	4/11/2010	4/12/2010	25	30	8.3	1432	142	480	146	25	148	380	1098	28	122	4.9	0
23	مجمع العكابات/الحسينية	RAW	4/11/2010	4/12/2010	25	26	8.4	1428	148	500	138	38	146	392	1064	32	112	5.1	0
24	مجمع ناحية الحسينية	RAW	4/11/2010	4/12/2010	25	38	8	1410	150	480	128	35	156	375	1048	0	122	4.2	0
25	مشروع الصافي القديم	RAW	4/12/2010	4/13/2010	25	20	8.1	1364	124	480	138	33	145	390	1030	48	118	4.3	0
26	مشروع حي الحسين	RAW	4/12/2010	4/12/2010	25	22	7.9	1298	132	510	146	35	134	380	1018	48	108	4.7	0
27	مشروع مدينة الحسين	RAW	4/12/2010	4/13/2010	25	22	8	1338	132	505	138	39	136	380	1002	42	102	4.5	0
28	مجمع الحكمة/الجدول الغربي	RAW	4/13/2010	4/14/2010	25	10	8.5	1264	155	480	132	37	130	360	900	38	110	4.2	0
29	مجمع الجذار/الجدول الغربي	RAW	4/13/2010	4/14/2010	25	5	8.5	1235	160	472	128	37	130	366	896	20	102	4.4	0
30	مشروع الهندية الموحد	RAW	4/14/2010	4/15/2010	25	14	8.2	1322	122	468	130	35	138	379	1068	38	102	4.1	0
31	مشروع الهندية القديم	RAW	4/14/2010	4/15/2010	25	10	8.2	1328	128	472	132	35	140	380	926	32	110	4.1	0
32	مجمع البو زكم/الهندية	RAW	4/18/2010	4/19/2010	25	8	8.7	1270	80	420	116	32	135	315	902	22	110	3.9	0
33	مشروع مدينة الحسين	RAW	4/19/2010	4/20/2010	23	30	8.4	1420	130	520	136	44	145	340	1090	66	100	4.5	0
34	مشروع الصافي القديم	RAW	4/19/2010	4/20/2010	23	20	8.1	1428	130	500	138	38	145	340	1074	48	102	4.6	0
35	مجمع بدعة اسود الشرقي/الحسينية	RAW	4/21/2010	4/22/2010	25	25	7.6	1428	120	520	136	44	145	350	1136	66	78	3.9	0
36	مجمع بدعة اسود الغربي/الحسينية	RAW	4/21/2010	4/22/2010	25	20	8	1410	120	520	136	44	140	328	936	30	80	4.2	0
37	مشروع مدينة الحسين	RAW	4/25/2010	4/26/2010	25	11	8.3	1389	122	488	133	38	148	309	936	30	110	4.2	0

From Date: 2010/05/01

To Date: 2010/06/01

كربلاء المقدسة

لمحافظة:

Al	K	Na	T.S.S	T.D.S	SO4	Cl	Mg	Ca	T.H	Alk	E.C	PH	Turb	Temp	تاريخ الفحص	تاريخ الجمع	طبيعة النموذج	اسم المشروع او المجمع
0	4.2	98	38	1036	365	125	38	115	460	120	1245	7.8	45	25	5/3/2010	5/2/2010	RAW	مشروع حي الحسين
0	4.8	114	30	962	337	134	30	116	420	92	1221	7.8	10	25	5/3/2010	5/2/2010	RAW	مجمع الحصوة/ناحية الحر
0	4.4	110	22	988	388	140	30	118	432	96	1230	7.9	13	24	5/2/2010	5/2/2010	RAW	مجمع العبودة/ناحية الحر
0	4	104	24	958	330	132	30	116	428	90	1194	7.6	15	24	5/3/2010	5/2/2010	RAW	مجمع الكاضي/ناحية الحر
0	4.8	98	22	896	380	140	44	124	508	164	1294	8.3	18	24	5/4/2010	5/3/2010	RAW	مشروع الهندية الموحد
0	4.4	100	16	874	349	138	47	118	500	168	1246	8.4	13	24	5/4/2010	5/3/2010	RAW	مشروع الهندية القديم
0	4.4	80	20	850	300	130	25	122	420	120	1242	7.8	10.3	25	5/5/2010	5/4/2010	RAW	مجمع الكريزات/الهندية
0	5.2	90	30	858	330	130	27	122	428	116	1266	7.8	12.4	25	5/5/2010	5/4/2010	RAW	مجمع المنفهان/الهندية
0	5.1	108	38	824	340	120	28	120	428	124	1168	8	14	25	5/5/2010	5/4/2010	RAW	مجمع البو كريدة الجديد/الهندية
0	5.6	118	40	926	345	125	31	119	440	126	1270	8.1	8.5	25	5/5/2010	5/4/2010	RAW	مجمع ابن الكاظم/الهندية
0	4.3	130	48	900	350	146	38	122	460	160	1184	7.7	21	25	5/6/2010	5/5/2010	RAW	مشروع مدينة الحسين
0	4.2	136	20	950	320	146	29	123	428	162	1164	8	8	25	5/6/2010	5/5/2010	RAW	مشروع الصافي القديم
0	4.9	120	20	918	291	178	33	106	416	168	1405	8.5	5	25	5/11/2010	5/10/2010	RAW	مجمع العبد عونيات/الجدول الغربي
0	4.4	104	22	1040	271	180	47	106	448	160	1454	8.5	5	25	5/11/2010	5/10/2010	RAW	مجمع مسيعيدة/الجدول الغربي
0	4.4	156	14	1010	344	170	33	101	400	166	1300	8.5	5	25	5/11/2010	5/10/2010	RAW	مجمع شط الله/الجدول الغربي
0	4.3	106	28	1010	264	160	42	92	420	130	1472	7.6	8	25	5/12/2010	5/11/2010	RAW	مشروع حي الحسين
0	5	114	18	938	312	158	43	100	425	128	1312	7.8	12	24	5/12/2010	5/11/2010	RAW	مشروع مدينة الحسين
0	5.2	98	18	938	324	148	36	130	486	126	1258	7.9	44	25	5/13/2010	5/12/2010	RAW	مجمع الابراهيمية/الحسينية
0	4.4	94	20	898	310	138	25	140	462	130	1250	8.2	54	25	5/13/2010	5/12/2010	RAW	مجمع العكابات/الحسينية
0	4.3	132	36	862	370	160	31	111	416	124	1363	8.3	6	25	5/18/2010	5/17/2010	RAW	مجمع المقدوني/الخيرات
0	4.2	90	30	968	371	140	2	200	508	110	1317	8.1	6	25	5/18/2010	5/17/2010	RAW	مجمع ال جباس/الجدول الغربي
0	3.9	98	32	1400	310	145	43	115	480	134	1781	8.1	5	25	5/18/2010	5/17/2010	RAW	مجمع مصليخ/ناحية الحر
0	5.2	135	38	872	370	150	34	120	440	160	1385	8.4	25	24	5/19/2010	5/18/2010	RAW	مشروع الهندية القديم
0	4.6	122	42	1070	350	160	37	116	440	160	1488	8.4	25	24	5/19/2010	5/18/2010	RAW	مشروع الهندية الموحد
0	4.3	116	38	1000	330	145	34	120	440	164	1357	8.4	20	24	5/19/2010	5/18/2010	RAW	مجمع الكريزات/الهندية
0	4.2	116	26	984	360	140	37	116	440	170	1365	8.1	18	24	5/19/2010	5/18/2010	RAW	مجمع المنفهان/الهندية
0	5.2	138	28	1000	338	140	34	120	440	170	1387	8.3	16	24	5/19/2010	5/18/2010	RAW	مجمع ابن الكاظم/الهندية
0	4.3	90	30	910	304	132	39	122	480	140	1282	7.9	32	25	5/19/2010	5/18/2010	RAW	مشروع الصافي القديم
0	4.1	112	56	1120	322	145	34	128	460	140	1478	8.1	30	24	5/25/2010	5/24/2010	RAW	مجمع الصلامية الشرقي/الحسينية
0	4.6	116	28	1150	300	155	34	136	480	160	1465	8.2	18	25	5/25/2010	5/24/2010	RAW	مجمع مرغز/الحسينية
0	4.3	122	24	960	313	160	34	136	480	145	1369	8.4	15	25	5/25/2010	5/24/2010	RAW	مشروع مدينة الحسين
0	4.5	126	26	1110	380	150	34	136	480	150	1388	8.4	14	25	5/25/2010	5/24/2010	RAW	مشروع الصافي القديم
0	4.6	92	30	890	304	134	40	114	462	120	1176	8.2	40	24	5/27/2010	5/26/2010	RAW	مجمع ناحية الحسينية
0	5.2	112	52	1010	349	160	26	150	480	116	1425	8.3	20	25	5/27/2010	5/26/2010	RAW	مجمع الدويهية/الجدول الغربي
0	4	86	42	852	348	136	33	128	476	148	1210	8.1	18	25	5/27/2010	5/26/2010	RAW	مجمع البو زكم/الجدول الغربي
0	4.2	116	28	994	387	170	24	160	500	120	1344	7.8	16	25	5/27/2010	5/26/2010	RAW	مشروع حي الحسين
	4–5.6	90 110	30→40	450 1010	290 365	125 170	25 47	100 140	420 510	90 120	1200 1400	7.8 8.3	5 45	24				

mg/L

From Date: 2010/06/01
To Date: 2010/07/01

اسم المحافظة: كربلاء المقدسة

Al	K	Na	T.S.S	T.D.S	SO4	Cl	Mg	Ca	T.H	Alk	E.C	PH	Turb	Temp	تاريخ الفحص	تاريخ الجمع	طبيعة النموذج	اسم المشروع او المجمع	ت
0	4	98	40	996	390	145	34	140	500	150	1545	7.8	45	24	6/2/2010	6/1/2010	RAW	مشروع مدينة الحسين	1
0	45	116	28	972	395	140	26	152	500	148	1492	8	11	24	6/2/2010	6/1/2010	RAW	مجمع الرشيدة/الهندية	2
0	5	118	32	1076	375	170	23	150	480	150	1674	8.1	13	24	6/2/2010	6/1/2010	RAW	مجمع ام طوب/الهندية	3
0	4.8	122	14	1020	380	170	30	150	496	154	1686	8.3	13	24	6/2/2010	6/1/2010	RAW	مجمع الطبر/الهندية	4
0	4.2	110	44	1010	385	150	40	152	560	146	1536	8.4	24	25	6/2/2010	6/1/2010	RAW	مشروع جرف البو عامر	5
0	4.6	116	32	1040	396	145	20	147	460	146	1558	8.3	12	25	6/2/2010	6/1/2010	RAW	مجمع ام جمل/الجدول الغربي	6
0	4.2	126	6	1090	380	145	17	142	440	154	1681	8.4	7	25	6/2/2010	6/1/2010	RAW	مجمع ابو بغال/الجدول الغربي	7
0	4.4	122	22	950	387	135	26	144	480	148	1568	8	10	25	6/2/2010	6/1/2010	RAW	مجمع البو سفن/الجدول الغربي	8
0	4.9	118	30	950	370	140	22	144	460	160	1425	8.2	20	25	6/3/2010	6/2/2010	RAW	مشروع حي الحسين	9
0	4.4	110	38	936	380	144	21	152	468	160	1545	8.2	22	25	6/3/2010	6/2/2010	RAW	مشروع الصافي القديم	10
0	3.7	122	42	930	380	150	39	120	460	160	1440	8.4	44	25	6/7/2010	6/6/2010	RAW	مجمع المقدوني /الحر	11
0	3.5	132	38	917	393	150	24	128	420	142	1449	8.3	38	25	6/7/2010	6/6/2010	RAW	مجمع الكاضي /الحر	12
0	3.9	130	44	956	366	150	34	128	460	156	1478	8.4	37	25	6/7/2010	6/6/2010	RAW	مجمع الفرنسي /الحر	13
0	4.5	94	52	820	354	135	36	128	480	124	1266	8.3	97	24	6/8/2010	6/7/2010	RAW	مشروع مدينة الحسين	14
0	4.3	123	48	834	398	148	39	128	480	160	1420	7.7	32	25	6/10/2010	6/9/2010	RAW	مشروع الصافي القديم	15
0	5.1	126	44	1020	395	140	29	148	488	140	1520	7.7	30	25	6/10/2010	6/9/2010	RAW	مجمع الشريعة/الحر	16
0	3.5	108	52	868	355	130	39	120	460	120	1483	8.3	40	25	6/14/2010	6/13/2010	RAW	مشروع مدينة الحسين	17
0	4.1	112	64	996	383	130	44	120	480	120	1498	8.3	45	25	6/14/2010	6/13/2010	RAW	مشروع الهندية القديم	18
0	5	102	36	916	380	112	27	136	460	124	1440	7.9	26	25	6/15/2010	6/14/2010	RAW	مشروع حي الحسين	19
0	4	130	54	1140	390	140	33	132	480	146	1689	8.2	30	25	6/16/2010	6/15/2010	RAW	مجمع الفيضة/الحسينية	20
0	4.4	122	34	1070	370	130	29	132	460	150	1580	8.3	26	25	6/16/2010	6/15/2010	RAW	مجمع جصوة عون /الحسينية	21
0	4.6	120	48	1130	377	128	34	136	490	140	1710	8.5	30	25	6/16/2010	6/15/2010	RAW	مجمع بذعة اسود الشرقي/الحسينية	22
0	4.1	72	26	914	284	120	38	132	446	148	1492	8	28	25	6/16/2010	6/15/2010	RAW	مجمع الابراهيمية/الحسينية	23
0	4.2	86	40	878	266	122	27	136	452	142	1530	8.1	30	25	6/16/2010	6/15/2010	RAW	مجمع ناحية الحسينية	24
0	4.3	128	16	906	398	110	29	120	430	130	1446	7.7	27	25	6/17/2010	6/16/2010	RAW	مشروع الهندية الموحد	25
0	4.2	110	16	1084	394	114	31	130	466	134	1492	7.8	28	25	6/17/2010	6/16/2010	RAW	مشروع الهندية القديم	26
0	4.4	136	28	1126	390	112	38	124	480	126	1448	8	14	25	6/17/2010	6/16/2010	RAW	مجمع ام جمل/الجدول الغربي	27
0	3.9	121	48	1056	389	122	32	132	460	160	1688	8.3	19	24	6/21/2010	6/20/2010	RAW	مجمع ناحية الخيرات	28
0	4.1	127	52	1024	357	122	32	124	440	154	1733	8.1	22	24	6/21/2010	6/20/2010	RAW	مجمع ابو عويجيلة/الخيرات	29
0	4	124	22	1004	337	132	24	120	400	156	1520	8.1	10	24	6/21/2010	6/20/2010	RAW	مجمع ابو روية/الخيرات	30
0	3.9	112	66	1018	327	132	24	152	480	156	1511	8.2	71	25	6/22/2010	6/21/2010	RAW	مشروع مدينة الحسين	31
0	4.1	112	58	1000	371	132	32	140	480	154	1468	8.1	51	25	6/22/2010	6/21/2010	RAW	مشروع الصافي القديم	32
0	3.9	122	52	836	385	120	37	132	480	120	1326	8.4	25	25	6/23/2010	6/22/2010	RAW	مشروع حي الحسين	33
0	3.9	100	28	996	350	116	38	130	480	156	1430	8.3	15	25	6/28/2010	6/27/2010	RAW	مجمع العبودة /الحر	34
0	4.2	112	22	972	366	124	32	132	460	156	1500	8.3	10	25	6/28/2010	6/27/2010	RAW	مجمع مصليخ /الحر	35
	4.2→5.1	98→126	22→40	900 1071	360 380	120→145	26→34	120→152	450→500	120→160	1440 1670	8→8.3	10→45	24					

From Date: 2010/07/01

To Date: 2010/08/01

اسم المحافظة: كربلاء المقدسة

Al	K	Na	T.S.S	T.D.S	SO4	Cl	Mg	Ca	T.H	Alk	E.C	PH	Turb	Temp	تاريخ الفحص	تاريخ الجمع	طبيعة النموذج	اسم المشروع او المجمع	ت
0	3.3	80	58	782	370	134	34	144	500	150	1176	8.3	60	25	7/5/2010	7/4/2010	RAW	مشروع مدينة الحسين	1
0	4	50	66	850	255	126	34	144	500	160	1329	8.3	62	25	7/5/2010	7/4/2010	RAW	مشروع الصافي القديم	2
0	3.8	90	52	806	380	130	35	147	512	124	1242	8.2	44	25	7/6/2010	7/5/2010	RAW	مجمع بدعة اسودالشرقي/الحسينية	3
0	3.4	87	66	810	360	128	35	143	500	128	1266	8.3	62	25	7/6/2010	7/5/2010	RAW	مجمع بدعة اسودالغربي/الحسينية	4
0	4	92	52	878	388	134	33	151	512	120	1372	8.3	46	25	7/6/2010	7/5/2010	RAW	مجمع حصوة عون الاول/الحسينية	5
0	3.2	83	48	900	366	132	35	150	520	116	1398	8.3	45	25	7/6/2010	7/5/2010	RAW	مجمع حصوة عون الثاني/الحسينية	6
0	3.2	84	50	848	354	126	39	136	500	150	1329	8.3	30	25	7/8/2010	7/7/2010	RAW	مجمع ام جمل/الجدول الغربي	7
0	3.5	88	48	894	373	124	37	140	500	136	1398	8.3	41	25	7/8/2010	7/7/2010	RAW	مجمع البوسفن/الجدول الغربي	8
0	3.8	90	36	866	364	126	34	144	500	138	1352	8.3	30	25	7/8/2010	7/7/2010	RAW	مجمع شط الله/الجدول الغربي	9
0	4	98	72	900	361	130	31	128	448	140	1395	8.5	65	25	7/13/2010	7/12/2010	RAW	مجمع الصلامية الشرقي/الحسينية	10
0	4.2	92	76	876	367	130	44	124	490	134	1366	8.4	68	25	7/13/2010	7/12/2010	RAW	مجمع الصلامية الغربي/الحسينية	11
0	4.2	98	48	860	347	130	33	131	464	138	1335	8	52	25	7/12/2010	7/12/2010	RAW	مجمع المقدوني/الحسينية	12
0	4.2	104	48	880	386	140	37	124	460	130	1367	8.4	37	25	7/19/2010	7/18/2010	RAW	مشروع حي الحسين	13
0	4	94	34	864	347	145	62	88	476	130	1350	8	31	25	7/20/2010	7/15/2010	RAW	مجمع ام طوب/الهندية	14
0	3.8	90	38	896	320	135	53	92	448	120	1398	8.4	33	25	7/20/2010	7/19/2010	RAW	مجمع المقدوني/الخيرات	15
0	4	74	74	790	342	148	48	122	500	148	1238	8.4	66	25	7/21/2010	7/20/2010	RAW	مشروع الصافي القديم	16
0	4.8	92	62	806	333	140	33	130	460	140	1260	8.4	54	25	7/21/2010	7/20/2010	RAW	مجمع الكريزات/ الهندية	17
0	4.6	114	52	816	367	142	31	128	448	142	1272	8.3	45	25	7/21/2010	7/20/2010	RAW	مجمع ابن الكاظم/الهندية	18
0	4.6	116	54	816	370	140	41	116	460	140	1275	8.4	52	25	7/20/2010	7/20/2010	RAW	مجمع المنفهان/الهندية	19
0	5	102	58	776	360	160	41	124	480	150	1208	8.3	52	25	7/22/2010	7/21/2010	RAW	مشروع مدينة الحسين	20
0	4.1	112	48	818	370	160	43	124	488	140	1278	8.4	50	25	7/22/2010	7/21/2010	RAW	مشروع حي الحسين	21
0	4.2	116	42	810	367	156	40	126	480	150	1263	8.3	46	25	7/22/2010	7/21/2010	RAW	مشروع الهندية القديم	22
0	4.2	116	44	810	360	162	37	130	480	152	1262	7.9	52	25	7/22/2010	7/21/2010	RAW	مجمع خير الدين/الحسينية	23
0	4.2	120	48	806	377	160	35	130	472	154	1260	7.8	54	25	7/22/2010	7/21/2010	RAW	مجمع المقدوني/الحسينية	24
0	5.1	116	62	834	380	155	29	140	472	130	1278	8	56	25	7/22/2010	7/21/2010	RAW	مجمع الصلامية الشرقي/الحسينية	25
0	5.4	124	54	816	370	170	37	130	480	156	1268	8	52	25	7/22/2010	7/21/2010	RAW	مجمع بدعة اسود الشرقي/الحسينية	26
0	4.2	112	54	868	378	152	37	130	460	150	1357	8.1	54	25	7/22/2010	7/21/2010	Raw	مجمع حصوة عون الاول/الحسينية	27
0	4.1	112	56	810	378	150	37	130	478	150	1278	8.2	54	25	7/22/2010	7/21/2010	RAW	مجمع الناحية الجديد/الحسينية	28
0	4.8	112	62	870	366	160	46	124	500	155	1363	8	54	25	7/22/2010	7/21/2010	RAW	مجمع ام جمل/الجدول الغربي	29
0	5	100	66	880	370	160	43	130	500	155	1372	8	57	25	7/22/2010	7/21/2010	RAW	مجمع الفرنسي/الجدول الغربي	30
0	5	108	72	876	360	160	46	116	480	155	1365	8.2	60	25	7/22/2010	7/21/2010	RAW	مجمع العبد عونيات/الجدول الغربي	31
0	5	130	56	884	366	160	48	106	460	144	1382	8	50	25	7/22/2010	7/21/2010	RAW	مجمع الكراكشة/الجدول الغربي	32
0	5.1	96	44	746	364	172	39	128	480	108	1165	8.3	45	25	7/26/2010	7/25/2010	RAW	مشروع مدينة الحسين	33
0	5	90	48	732	354	170	46	124	500	108	1144	8.3	50	25	7/26/2010	7/25/2010	RAW	مشروع الصافي القديم	34
0	4.8	92	38	806	367	135	44	120	480	124	1256	8.3	40	25	7/26/2010	7/25/2010	RAW	مشروع حي الحسين	35

From Date: 2010/08/01

To Date: 2010/09/01

اسم المحافظة: كربلاء المقدسة

Al	K	Na	T.S.S	T.D.S	SO4	Cl	Mg	Ca	T.H	Alk	E.C	PH	Turb	Temp	تاريخ الفحص	تاريخ الجمع	طبيعة النموذج	اسم المشروع او المجمع	ت
0	4.2	128	38	842	388	165	41	128	488	160	1303	8.3	30	24	8/2/2010	8/1/2010	RAW	مشروع مدينة الحسين	1
0	4.6	122	54	1150	410	164	44	115	468	120	1600	8.1	40	24	8/3/2010	8/2/2010	RAW	مجمعات الحر	2
0	4.6	92	50	1118	380	155	40	134	500	120	1662	8.2	38	24	8/3/2010	8/2/2010	RAW	مجمع العبودة/الحر	3
0	5	108	66	1134	406	166	43	130	500	120	1688	8	60	24	8/3/2010	8/2/2010	RAW	مجمع الكاضي/الحر	4
0	4.8	113	62	1156	390	165	40	135	500	120	1618	8.3	56	24	8/2/2010	8/2/2010	RAW	مجمع الحصوة/الحر	5
0	5.1	122	56	1130	392	168	36	128	469	130	1686	8.2	32	25	8/4/2010	8/3/2010	RAW	مجمع ابو بغال/الجدول الغربي	6
0	4.5	82	42	1170	300	164	38	125	468	138	1693	8.1	34	25	8/4/2010	8/3/2010	RAW	مجمع البو سفن/الجدول الغربي	7
0	5	88	58	1120	306	164	34	128	460	150	1694	8.2	45	25	8/4/2010	8/3/2010	RAW	مجمع الكراكشة/الجدول الغربي	8
0	5	100	44	1110	366	166	39	128	480	142	1600	7.8	27	25	8/5/2010	8/4/2010	RAW	مشروع الصافي القديم	9
0	4.6	110	40	1180	371	170	39	128	480	138	1579	7.9	28	25	8/5/2010	8/4/2010	RAW	مجمع خديدان/الحسينية	10
0	4.8	122	56	1078	367	172	37	124	460	134	1544	8	32	25	8/5/2010	8/4/2010	RAW	مجمع الصلامية الغربي/الحسينية	11
0	4.9	120	60	924	391	170	54	120	520	144	1448	8.2	45	24	8/9/2010	8/8/2010	RAW	مشروع الهندية القديم	12
0	4.4	112	70	1076	370	170	54	120	520	140	1537	8.2	62	24	8/9/2010	8/8/2010	RAW	مشروع الهندية الموحد	13
0	4.6	113	38	1120	395	184	27	152	490	108	1540	7.8	26	24	8/10/2010	8/9/2010	RAW	مشروع مدينة الحسين	14
0	4.8	115	78	1142	392	186	37	136	492	106	1574	8.1	85	24	8/10/2010	8/9/2010	RAW	مشروع حي الحسين	15
0	5	120	28	1150	395	180	37	139	500	116	1708	8.2	14	24	8/10/2010	8/9/2010	RAW	مجمع ابو بغال/الجدول الغربي	16
0	4.9	122	48	1050	381	172	40	134	500	125	1536	8.2	20	25	8/11/2010	8/10/2010	RAW	مشروع ماء الخيرات	17
0	5.1	118	54	1134	395	160	27	156	500	120	1546	8	36	25	8/11/2010	8/10/2010	RAW	مجمع ناحية الخيرات	18
0	4.7	88	22	1220	300	185	36	152	528	150	1704	8.5	7	25	8/12/2010	8/11/2010	RAW	مجمع مصليخ/الحر	19
0	4.6	98	58	1190	350	178	49	131	528	140	1732	8.2	32	25	8/12/2010	8/11/2010	RAW	مجمع العبودة/الحر	20
0	4.8	102	48	1184	380	160	39	142	515	124	1532	8.2	30	25	8/12/2010	8/11/2010	RAW	مشروع مدينة الحسين	21
0	4.6	94	38	1028	389	174	42	140	524	114	1447	7.9	24	24	8/16/2010	8/15/2010	RAW	مشروع الصافي القديم	22
0	4.8	94	40	1150	350	168	34	148	510	120	1522	7.8	30	24	8/16/2010	8/15/2010	RAW	مشروع حي الحسين	23
0	4.6	70	32	1176	386	174	36	153	528	110	1642	7.8	18	24	8/16/2010	8/15/2010	RAW	مجمع ابو روية/الخيرات	24
0	4.8	118	74	1048	380	176	39	132	490	136	1672	8.1	62	25	8/16/2010	8/16/2010	RAW	مجمع الصليب/الحسينية	25
0	4.6	120	26	1180	370	205	31	149	500	104	1802	8.1	10	25	8/17/2010	8/16/2010	RAW	مجمع سيد اسماعيل/المركز	26
0	4.9	118	48	1170	379	200	41	133	500	100	1706	8.1	37	25	8/17/2010	8/16/2010	RAW	مجمع الشبانات/المركز	27
0	4.2	116	52	1080	370	170	34	152	520	136	1559	8.1	45	25	8/19/2010	8/18/2010	RAW	مجمع خديدان/الحسينية	28
0	4.4	114	50	1070	390	155	37	148	520	136	1560	8	42	25	8/19/2010	8/18/2010	RAW	مجمع الابراهيمية/الحسينية	29
0	4.6	112	54	1160	391	168	37	148	520	136	1619	8.2	42	25	8/19/2010	8/18/2010	RAW	مجمع خير الدين/الحسينية	30
0	4.6	116	42	1190	389	160	39	144	520	148	1692	7.8	30	24	8/23/2010	8/22/2010	RAW	مشروع مدينة الحسين	31
0	4.8	109	68	1060	383	165	39	144	520	152	1662	7.8	42	24	8/23/2010	8/22/2010	RAW	مشروع الصافي القديم	32
0	5	107	68	1080	380	170	38	146	520	148	1634	8	40	24	8/23/2010	8/23/2010	RAW	مشروع حي الحسين	33
0	4.8	102	46	1098	339	170	36	133	480	150	1662	7.8	28	25	8/23/2010	8/23/2010	RAW	مجمع المقدوني /الحسينية	34
0	4.9	120	56	1120	392	168	34	144	500	125	1533	8.1	38	25	8/11/2010	8/10/2010	RAW	مجمع ابوعويجيلة/الخيرات	35
	4.2 4.8	92→128	42→78	890 1170	380 400	155 180	34 41	115→144	480 520	120 160	1305 1690	7.8 8.3	10→50	24					

From Date: 2010/09/01

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اسم المحافظة: كربلاء المقدسة

Al	K	Na	T.S.S	T.D.S	SO4	Cl	Mg	Ca	T.H	Alk	E.C	PH	Turb	Temp	تاريخ الفحص	تاريخ الجمع	طبيعة النموذج	اسم المشروع او المجمع	ت
0	4.1	108	32	1130	387	170	34	144	500	110	1691	8.2	22	25	9/6/2010	9/5/2010	RAW	مشروع مدينة الحسين	1
0	4.2	108	52	1160	330	160	41	132	500	120	1632	8.2	35	25	9/6/2010	9/5/2010	RAW	مشروع الصافي القديم	2
0	4.1	98	48	1150	380	165	48	142	550	120	1392	7.8	33	25	9/7/2010	9/6/2010	RAW	مشروع حي الحسين	3
0	4.5	92	22	1146	380	175	49	144	560	126	1474	7.6	8	25	9/7/2010	9/6/2010	RAW	مجمع سيد اسماعيل/المركز	4
0	4.1	84	78	1166	368	165	48	145	560	120	1434	7.8	80	25	9/7/2010	9/6/2010	RAW	مجمع الشبانات/المركز	5
0	4.3	112	46	1100	392	165	37	140	500	140	1600	8.3	42	25	9/8/2010	9/7/2010	RAW	مجمع الفرنسي/الحر	6
0	4.3	102	42	1120	400	160	41	140	520	150	1612	8.3	41	25	9/8/2010	9/7/2010	RAW	مجمع الفارس/الحر	7
0	4.3	102	50	1110	380	165	41	140	520	150	1610	8.3	40	25	9/8/2010	9/7/2010	RAW	مجمع المقدوني /الحر	8
0	4.3	102	48	1280	386	165	38	145	520	146	1722	8.1	35	25	9/8/2010	9/7/2010	RAW	مجمع العبودة/الحر	9
0	4	102	20	1020	370	150	39	128	480	144	1452	8.4	35	25	9/15/2010	9/14/2010	RAW	مجمع خديدان/الحسينية	10
0	4.4	116	18	1010	410	145	39	128	480	144	1472	8.4	38	25	9/15/2010	9/14/2010	RAW	مجمع خير الدين/الحسينية	11
0	4.5	120	16	1010	460	145	40	127	480	140	1468	8.4	37	25	9/15/2010	9/14/2010	RAW	مجمع الابراهيمية/الحسينية	12
0	4	112	28	1000	370	160	43	122	480	150	1454	8.4	35	25	9/16/2010	9/15/2010	RAW	مجمع ابو بغال/الجدول الغربي	13
0	4.4	116	22	1040	392	155	48	116	488	150	1446	8.4	20	25	9/16/2010	9/15/2010	RAW	مجمع البو سفن/الجدول الغربي	14
0	4.1	96	38	1050	290	155	48	122	500	150	1428	8.3	30	25	9/16/2010	9/15/2010	RAW	مجمع الدويهية/الجدول الغربي	15
0	4.2	104	26	1060	377	160	41	124	480	120	1478	7.8	56	25	9/20/2010	9/19/2010	RAW	مشروع الهندية القديم	16
0	4.2	102	32	1040	370	160	41	124	480	120	1414	8.2	20	25	9/20/2010	9/19/2010	RAW	مجمع ابن الكاظم/الهندية	17
0	4.5	118	12	1112	400	170	39	128	480	110	1459	8.2	15	25	9/20/2010	9/19/2010	RAW	مجمع ام طوب/الهندية	18
0	4.5	118	16	1010	400	160	49	112	480	100	1360	8.4	15	25	9/20/2010	9/19/2010	RAW	مجمع البو كريدة/الهندية	19
0	4.5	116	42	1148	392	170	41	133	500	120	1572	8.2	42	25	9/20/2010	9/19/2010	RAW	مجمع حصوة عون الاول/الحسينية	20
0	4.5	116	48	1130	392	170	40	134	500	120	1595	7.9	50	25	9/20/2010	9/19/2010	RAW	مجمع حصوة عون الثاني/الحسينية	21
0	4.6	115	48	1134	400	152	46	120	490	110	1495	8.2	48	25	9/20/2010	9/19/2010	RAW	مجمع عون/الحسينية	22
0	4.7	118	62	1010	393	165	41	124	480	120	1436	8.4	30	25	9/21/2010	9/20/2010	RAW	مشروع الهندية الموحد	23
0	3.9	100	26	1208	337	170	44	120	480	124	1464	8.1	26	25	9/22/2010	9/21/2010	RAW	مشروع مدينة الحسين	24
0	4.1	100	38	1182	320	170	43	122	480	124	1470	8.2	28	25	9/22/2010	9/21/2010	RAW	مشروع الصافي القديم	25
0	3.9	106	52	1062	360	165	44	120	480	130	1400	8	25	25	9/22/2010	9/21/2010	RAW	مشروع حي الحسين	26
0	4.6	120	44	1160	390	173	46	124	500	110	1484	8.3	28	25	9/22/2010	9/21/2010	RAW	مجمع بدعة اسود الشرقي/الحسينية	27
0	4.1	108	52	1194	380	168	44	128	500	120	1464	8.2	28	25	9/22/2010	9/21/2010	RAW	مجمع بدعة اسود الغربي/الحسينية	28
0	4.1	112	20	1020	330	160	34	136	480	120	1502	8.2	10	25	9/22/2010	9/21/2010	RAW	مجمع مصليخ/الحر	29
0	4	114	28	1110	360	150	44	128	500	120	1500	8.1	24	25	9/22/2010	9/21/2010	RAW	مجمع الكاضي/الحر	30
0	4.1	114	18	1140	367	150	39	136	500	124	1468	8	12	25	9/22/2010	9/21/2010	RAW	مجمع الحصوة /الحر	31
0	4.2	118	22	1120	390	165	46	120	490	120	1458	7.8	12	25	9/22/2010	9/21/2010	RAW	مجمع ناحية الخيرات	32
0	4.2	108	22	1120	382	168	44	120	480	112	1536	7.9	28	25	9/27/2010	9/26/2010	RAW	مشروع مدينة الحسين	33
0	4.3	112	26	1200	371	168	44	120	480	112	1542	8	26	25	9/27/2010	9/26/2010	RAW	مشروع الصافي القديم	34
0	4.3	114	32	1210	360	170	46	124	500	120	1554	7.9	30	25	9/27/2010	9/26/2010	RAW	مشروع حي الحسين	35
0	4.2	118	40	1112	381	152	39	120	460	116	1484	8.2	35	25	9/27/2010	9/26/2010	RAW	مشروع الهندية القديم	36

From Date: 2010/10/01
To Date: 2010/11/01

اسم المحافظة: كربلاء المقدسة

Al	K	Na	T.S.S	T.D.S	SO4	Cl	Mg	Ca	T.H	Alk	E.C	PH	Turb	Temp	تاريخ الفحص	تاريخ الجمع	طبيعة	اسم المشروع او المجمع	ت
0	4.2	116	48	1060	375	150	39	120	460	120	1513	8.3	30	25	10/4/2010	10/3/2010	RAW	مشروع مدينة الحسين	1
0	4.3	118	50	970	375	150	39	120	460	120	1498	8.3	31	25	10/4/2010	10/3/2010	RAW	مشروع الصافي القديم	2
0	4.6	118	44	1030	396	150	38	122	460	120	1409	8.3	30	25	10/4/2010	10/3/2010	RAW	مشروع حي الحسين	3
0	4.5	79	26	972	310	150	41	116	460	100	1410	8.3	12	25	10/5/2010	10/4/2010	RAW	مجمع ام جمل/الجدول الغربي	4
0	4.6	98	30	1010	356	155	41	124	480	130	1398	8.4	20	25	10/5/2010	10/4/2010	RAW	مجمع مسيعيدة/الجدول الغربي	5
0	4.3	105	28	1070	370	160	44	112	460	100	1430	8.2	15	25	10/5/2010	10/4/2010	RAW	مجمع الحي العسكري/الجدول الغربي	6
0	4.1	78	62	918	330	145	44	120	480	120	1322	8.3	52	25	10/7/2010	10/6/2010	RAW	مجمع العبودة/الحر	7
0	4.2	109	58	942	380	140	33	130	460	120	1326	8.2	50	25	10/7/2010	10/6/2010	RAW	مجمع الكاضمي/الحر	8
0	4.4	108	52	956	360	143	44	120	480	134	1332	8.2	50	25	10/7/2010	10/6/2010	RAW	مجمع الحصوة/الحر	9
0	4.1	113	38	830	307	116	34	112	420	148	1170	8.4	28	25	10/11/2010	10/10/2010	RAW	مشروع مدينة الحسين	10
0	3.6	102	60	900	319	120	46	96	428	122	1144	7.7	50	25	10/13/2010	10/12/2010	RAW	مجمع الصليب/الحسينية	11
0	3.6	102	48	896	351	122	48	92	428	122	1179	7.8	45	25	10/13/2010	10/12/2010	RAW	مجمع المقدوني/الحسينية	12
0	4.4	106	42	948	266	145	29	128	440	150	1197	8.2	12	25	10/13/2010	10/12/2010	RAW	مجمع ماء الحسين/المركز	13
0	3.4	98	46	798	345	116	37	104	410	110	1080	8.5	28	25	10/13/2010	10/12/2010	RAW	مشروع الهندية الموحد	14
0	3.4	99	48	892	310	114	38	106	420	118	1078	8.2	30	25	10/13/2010	10/12/2010	RAW	مشروع الهندية القديم	15
0	4.2	102	72	876	322	132	38	102	410	132	1168	8.4	55	25	10/13/2010	10/12/2010	RAW	مجمع بدعة اسود الشرقي/الحسينية	16
0	4.2	106	68	928	350	128	43	104	435	132	1166	8.3	55	25	10/13/2010	10/12/2010	RAW	مجمع بدعة اسود الغربي/الحسينية	17
0	3.9	98	28	846	333	118	39	112	440	136	1090	8	18	25	10/14/2010	10/13/2010	RAW	مشروع حي الحسين	18
0	4.2	102	20	886	250	128	35	116	432	150	1104	8.1	12	25	10/14/2010	10/13/2010	RAW	مجمع ماء العباس/المركز	19
0	3.9	98	38	860	392	120	44	116	470	130	1290	7.8	20	25	10/18/2010	10/17/2010	RAW	مجمع البو سفن/الجدول الغربي	20
0	4	98	40	856	385	130	46	100	440	156	1228	7.9	28	25	10/18/2010	10/17/2010	RAW	مجمع النبهانية/الجدول الغربي	21
0	3.6	96	32	906	350	125	24	136	440	150	1092	8.2	20	25	10/18/2010	10/17/2010	RAW	مشروع الهندية القديم	22
0	3.9	106	26	890	370	120	32	124	440	150	1122	8.3	12	25	10/18/2010	10/17/2010	RAW	مجمع ام طوب/الهندية	23
0	3.4	108	32	830	375	125	40	127	480	150	1140	8.1	16	25	10/21/2010	10/20/2010	RAW	مشروع مدينة الحسين	24
0	3.6	107	38	900	350	120	44	120	480	150	1126	7.9	20	25	10/21/2010	10/20/2010	RAW	مشروع الصافي القديم	25
0	3.9	112	42	836	377	125	38	130	480	150	1152	8.1	22	25	10/21/2010	10/20/2010	RAW	مشرووع حي الحسين	26
0	4.1	118	48	908	390	128	38	116	445	130	1242	8.3	30	25	10/25/2010	10/24/2010	RAW	مجمع حصوة عون الاول/الحسينية	27
0	4.1	110	52	946	400	132	35	122	450	132	1208	8.3	33	25	10/25/2010	10/24/2010	RAW	مجمع حصوة عون الثاني/الحسينية	28
0	4.1	102	60	988	385	130	37	132	480	128	1278	8.1	40	25	10/25/2010	10/24/2010	RAW	مجمع عون/الحسينية	29
0	4.2	108	56	840	351	125	24	128	420	130	1158	8.4	20	25	10/26/2010	10/25/2010	RAW	مجمع ابو عويجيلة/الخيرات	30
0	4.3	112	38	950	351	130	29	120	420	130	1196	8.2	10	25	10/26/2010	10/25/2010	RAW	مجمع المقدوني /الخيرات	31
0	4	92	42	850	340	120	29	128	440	130	1200	8.4	25	25	10/26/2010	10/26/2010	RAW	مشروع مدينة الحسين	32
0	3.9	90	32	868	348	124	29	128	440	120	1160	8	12	25	10/27/2010	10/26/2010	RAW	مشروع الصافي القديم	33
0	3.4	86	26	970	335	134	27	124	420	120	1120	8.2	8	25	10/27/2010	10/26/2010	RAW	مجمع الصلامية الغربي/الحسينية	34
0	4	102	30	1006	389	130	22	124	420	110	1190	7.6	12	25	10/27/2010	10/26/2010	RAW	مجمع ناحية الحسينية	35
0	3.9	99	48	860	331	136	29	128	440	120	1184	7.6	20	25	10/27/2010	10/26/2010	RAW	مجمع الكريزات/الهندية	36
0	3.8	102	18	886	355	130	32	124	440	130	1154	8	6	25	10/27/2010	10/26/2010	RAW	مجمع المنفهان/الهندية	37

3. The full names and symbols for all location in first sample station

No	Symbol	Full name
1	ADL	Ataturk dam lake
2	BDL	Birercik dam lake
3	KDL	Karakmis dam lake
4	HDL	Haci Hidir dam lake
5	EPH	Euphrates River
6	NZP	Nizip stream
7	GKS	Goksn stream
8	KLB	Kalburcu stream
9	KHT	Kahta stream
10	CKL	Cakal stream
11	EGR	Egri stream
12	CAN	Cakal stream
13	AGF	Abuzergaffar stream