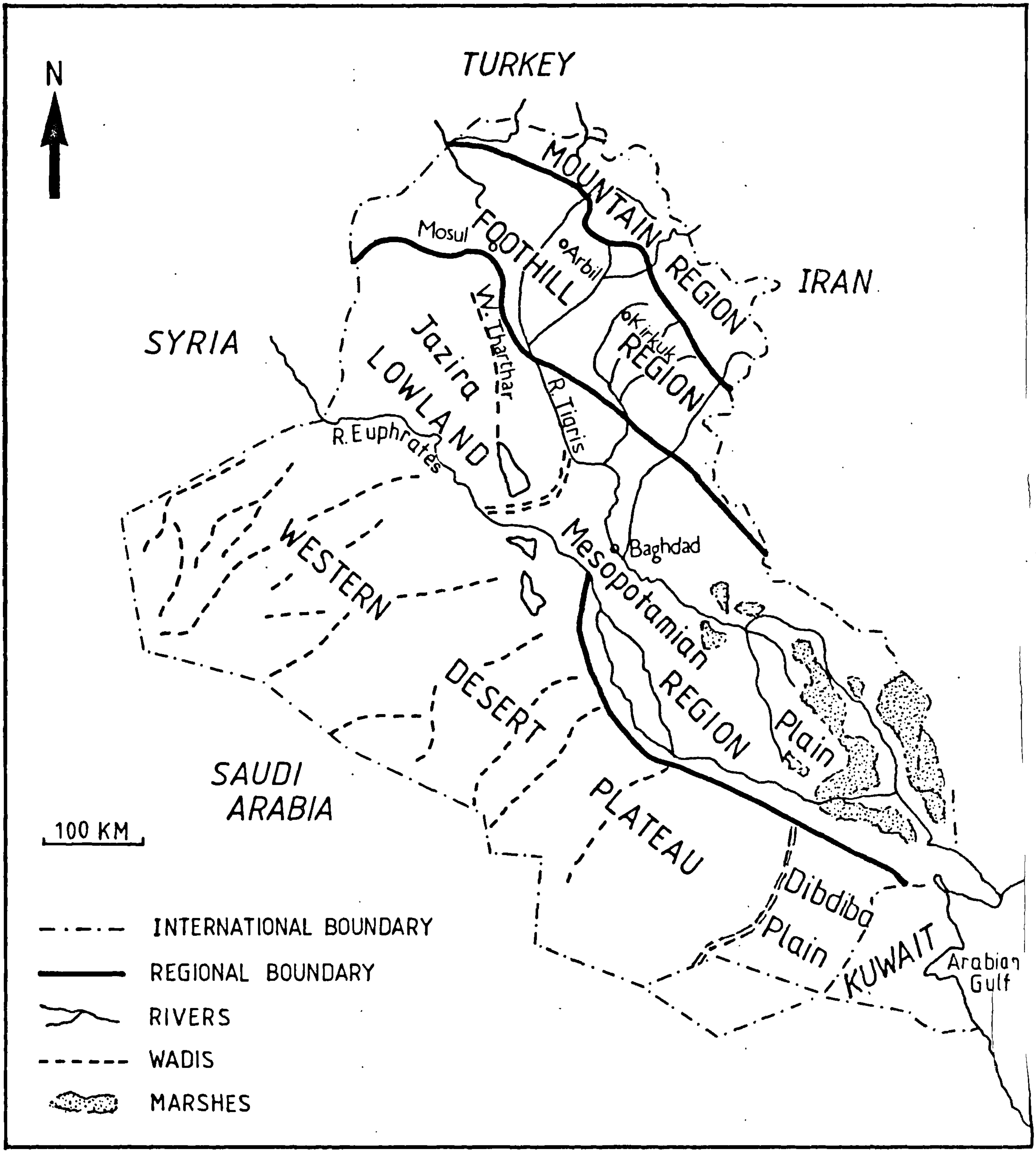
FRONTISPIECE : TOPOGRAPHICAL REGIONS OF IRAQ



THE WATER RESOURCES OF IRAQ:

AN ASSESSMENT

By

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To

My parents

ABSTRACT

The Euphrates and Tigris are international rivers with renewable but finite resources, shared by four riparian states, Turkey, Syria, Iraq and Iran. At present, only Iraq is a major water user and, due to the dominant arid to semi-arid climate, relies almost entirely upon this drainage system. Therefore, the present government has given high priority to water resources as a key element in present and prospective economic development. In recent decades, the upstream riparian states have planned for large scale irrigation and hydroelectric power developments. These will certainly affect water availability and quality in the lower riparian state, Iraq, if they are fully implemented as planned. Thus, the objective of this study is to emphasize the Euphrates and Tigris as an integrated crucial shared resource and to determine the whole aspect of the present and prospective water development situations. Therefore, it is important first to evaluate the influence of the physical aspects upon water resource, the availability and quality of the surface and the potential groundwater resources. Subsequently, the basins' development have been examined, their water requirements analyzed and the water balance evaluated. The result of water balance assessment indicates that a large scale potential problem of water shortage, both in quantity and

quality will definitely arise in Iraq if all the developments come to fruition.

The main solution to the problem is achieving a mutual international agreement to secure the appropriate share for each state in terms of water quantity and quality. This will enable each state to design its development more realistically. So far, the co-operation among the riparian states is progressing well and there is already an existing agreement between Iraq and Turkey (1946). Furthermore, the establishment of the 1980 Joint Technical Committee between Turkey, Syria and Iraq, the existing economic links, the comparatively long time available before the upstream development is fully implemented, and the available international co-operative experiences all bode well for the future. It is hoped that the riparian states will promote these co-operative efforts to achieve lasting agreements in order to avoid potential conflict.

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CHAPTER 1

INTRODUCTION

Water is a precious substance and is essential for sustaining life. It is exploited in many ways, for example, for irrigation, hydroelectric power generation, industrial production, recreation. It needs to be controlled, regulated and protected in order to achieve effective and efficient utilization and to avoid disastrous hazards such as large scale pollution or floods.

In the Middle East, the Euphrates and Tigris rivers constitute a major water supply system which is vitally important due to the dominant arid to semi-arid climate of the region. A major part of the basin receives rainfall average under 300mm annually. Therefore, dry farming cultivation, which requires at least 400mm, is impossible under such conditions(1). The remaining small portion of the basin located in the north and north-eastern highland areas of Turkey, Syria, Iraq and Iran, receives annual rainfall average ranges from 300 to more than 1000mm. Thus, the rivers mainly have their sources in this part of the basin.

The most important riparian states, in terms of water production, are Turkey and Iraq which contribute to 66.8% and 22.5% respectively of the total annual river waters, which is 84.4bcm. The other two riparian states, Syria and Iran, are less effective as they contribute 4.7% and 5.8% respectively of the total annual river waters. Thus, the

Euphrates and Tigris waters are shared by four riparian states. The Euphrates is shared by Turkey, Syria and Iraq, while the Tigris is shared by Turkey, Iraq and Iran. In recent decades, the upstream riparian states, particularly Turkey and Syria, have formulated plans for extensive irrigation developments covering 2004890 and 640000ha respectively. While that in Iran will be 80000ha. Three major storage projects (Keban, Karakaya and Tabqa) to control river flow for irrigation and hydroelectric power generation have been constructed and several others are under construction or planned.

Unlike the upstream riparian states, Iraq has a very long history of utilizing the Euphrates and Tigris waters dating back some 6000 years, to the beginning of the human civilization. In addition, Iraq was the first riparian state to construct modern water development structures(2). According to Allan (1985)(3) Iraq is the one Middle Eastern country which, based on irrigated farming, is potentially self-sufficient in agriculture. Given the planned future developments in the Tigris-Euphrates basin, this conclusion will be disputed in this thesis.

The Hindiya barrage, completed in 1913, made it possible to divert the Euphrates water into reconstructed irrigation canals dating from ancient and medieval times. In the 1950's the Ramadi barrage was built to divert the Euphrates flood water to the Habbaniya and Abu-Dibbis depressions, permitting a measure of flood control(4). In 1984, the Qadisiya multi-purpose dam was constructed. On the Tigris, the Kut barrage (1939), the Samarra barrage (1956), the Dokhan dam (1959), the Derbendi Khan dam (1961), the Hamrian dam (1985) and the Saddam dam (1985) were constructed to regulate the river water for irrigation, flood control and hydroelectric power generation. In addition, approximately 2700km of drainage network was completed in the Mesopotamian Plain(5).

Successive Iraqi governments have contributed to the development of water and land resources with great energy and financial support. Indeed, the present government has given the highest priority to the development of these resources to achieve self-sufficiency. Thus, substantial investment and effort have been allocated to storage (dams and reservoirs), irrigation and drainage projects. For instance, in the development plan (1976-80) the amount allocated to these developments was ID (619.470)* million(6). The completion of the major storage projects, Qadisiya (1984), Saddam (1985), Hamrian (1985) and the initiation of the Bekme project (the second largest reservoir, costing 1.6 billion US $), despite the war, are clear evidence of the government's determination in this field.

* 1 Iraqi Dinar = 3.4 US $

So far, the war with Iran has had little effect upon the water system. There has been no significant damage but, owing to the expense of the war, there has been a certain delay in implementing development schemes.

The high priority given to water development in government policy is justified by the fact that water resources are the key element for national economic development. The reality is recognized that water and land are renewable resources in contrast to oil, gas and other mineral resources which are exhaustible. Another fact which justifies the importance afforded water resources is that the whole country, with the exception of the mountain region which constitutes only 5% of the total area, enjoys an arid to semi-arid climate. Therefore, water is vitally required for irrigation.

It is the main objective of this study to emphasize the vital nature of water in the present and prospective economic developments of the country. To identify this and the associated problems, it is necessary to deal not only with the river basins of Iraq, but because these resources are shared, to make an integrated study of the entire Euphrates and Tigris basin. It is essential to determine the totality of present and future development.

The present study therefore deals with the Euphrates and

Tigris basin as an integrated shared resource. Firstly, it deals with the physical aspects and their influence on water availability. These include geology, topography, climate, soil and vegetation. Secondly, it determines the hydrological characteristics of the rivers in terms of water quantity, water regime, suspended sediment, hydraulic structures, the marshes and their effect on water quantity and quality and the river water quality. Chapter 4 evaluates the groundwater from the viewpoint of quantity and quality and the potential for future resources. Chapter 5 investigates the upstream riparian states' present and prospective multi-purpose developments and their water requirements. The effects of such changes on the availability and quality of Iraqi water resources, the development implementation schedule, organizations responsible for the development and the problems encountered in development construction are assessed. Chapter 6 deals with present and future water utilization and the water balance for each river basin with regard to the total water requirement and the water losses of the co-riparian states. Then an integrated water balance for the combined Euphrates and Tigris basins is considered in order to identify whether the rivers are able to satisfy present and prospective water requirements. Finally, Chapter 7 examines the management problems of the finite shared resource. It focuses on international law and the legal principles involved, evaluates the previous agreements among the co-riparian states, examines the conflict/ co-operation potential and details the global co-operative experiences in international river basins.

It should be indicated that the Euphrates and Tigris basin has never before been subjected to such a detailed integrated study. Therefore, this study can be regarded as the first comprehensive geographical attempt in this field. Some studies have concentrated on the water resources, but most of these have dealt with a single aspect of an individual river in part of the basin, usually in Iraq. Of these, a dissertation by Al-Khashab (1958) was concerned almost entirely with evaluation of the total water potential of the Euphrates and Tigris on the basis of theoretical estimates. Al-Hakeem (1981) investigated the hydrology of the Iraqi part of the Tigris basin. In 1984, a dissertation by Al-Himyari dealt with the water management of the Euphrates and Tigris basin. It is entirely focused on international law and the right of the co-riparian states in shared resources. In addition, there are several government reports, mostly concerned with the hydrological aspects of the rivers in the Iraqi part of the basin. The most recent of these are dated 1975 and 1978. The first one is concerned with all aspects of Iraq and the second with the Shatt Al-Arab region. All of these studies have been considered in this work.

To complete the study, fieldwork was vitally important, due to the inadequacy or total lack of available data. Therefore, a visit to the study area was made in 1983-84 to collect data and discuss the problems with the planners and engineers. The data were collected from several government offices and from libraries. In addition, field visits were made to a number of projects and gauging stations. Furthermore, the author is familiar with water and land resources through having lived in the countryside until 1974 and as a result, made several visits to almost all parts of Iraq. His knowledge was further developed during eight years (1975-82) as an undergraduate student and afterwards as a research assistant in Basrah University.

Several major problems were encountered during the research. Of these, the most significant was the unavailability of data for the study. Those found in the government offices are mostly confidential and restricted. Thus, it is impossible to collect such data. However, the data obtained for this work are both important and substantial. With only minor limitations, they cover all aspects of the study. These data have been analyzed and results of significance have been deduced. It is hoped that this study will contribute to the wise and optimum utilization of water for the benefit of all the nations of the Euphrates and Tigris basin.

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CHAPTER 2

PHYSICAL BACKGROUND

2.1 INTRODUCTION

The aim of this chapter is to examine the influence of the physical characteristics of the drainage basin upon water resources. Key characteristics are: geology, topography, climate, soil and vegetation. The geology of the basin affects the rate of runoff, the losses or gains along the channels and especially the low-flow characteristics. Knowledge of the geology as it affects the water resources may be very useful even though it is only qualitative.

Basin topography influences runoff in several ways. For example, steep slopes concentrate the rainfall quickly and result in high flood discharges. Gentle slopes result in slow runoff, increased groundwater recharge, increased evapotranspiration and consequently in decreased total runoff. An additional index is the percentage of lakes, swamps and marshes in the basin (see Frontispiece).

The climatic factors, mainly precipitation and temperature, provide the major influence on runoff regimes. Soil characteristics determine the rate of infiltration and thus affect the rate and amount of runoff(1). Basin vegetation also affects runoff as it increases infiltration and evapotranspiration rates. It decreases flood peaks and soil erosion(2). Soil deposition affects river channels and reservoir capacities.

There is an interrelationship between drainage basin physical characteristics and the processes which they influence and determine. It exists at several levels. Firstly, because certain attributes of the drainage basin may be expressed in different ways, there will be relationships between these alternative parameters. Thus, a broad correlation should exist between the various indices proposed to express basin shape or basin relief. Secondly, due to the size of different drainage basin units, certain associations will exist, for instance, between basin area and total length of stream channels. Thirdly, because it is unrealistic to separate the drainage basin system arbitrarily into components, there will be an association between different basin measurements. Therefore, on a single rock type, a particular kind of network or basin shape may be produced according to the local relief and so a correlation may exist between network shape and basin relief, or relative relief. Fourthly, certain relationships may occur between the drainage basin characteristics, due to their interaction with the basin process. Thus, particular rock types may be associated with certain types of stream network pattern as a result of weaknesses in the rock and, equally, certain rock types may be associated with particular densities of streams. This may arise because of the effect of rock type upon soil character and hence upon infiltration and runoff, which in turn is related to stream density. Fifthly, this introduces the possibility that strong associations apparent between characteristics may merely reflect dependence upon a third or fourth intermediate characteristic. For example, a measure of relief could be related to drainage density, but it may be rainfall, which is related to relief and also to drainage density, which accounts for the association. Numerous relationships exist between drainage basin variables and the nature and extent of the influence of several independent variables, upon one dependent variable, which in turn influence and determine the drainage basin process[3].

2.2 GEOLOGY

Under the same climatic influences, greatly different streamflow regimes are produced from drainage basins having different soils and rocks. The soil or other surficial material determines how much and at what rate the precipitation will infiltrate and thus what proportion will become overland runoff. Some of the infiltrated water will be evaporated and the rest will move through the rocks, either to a stream channel or, in some arid regions, to a zone of saturation below any stream channel. The character of rocks determines how the water moves underground and at what rates.

Rapid surface runoff and little base flow are associated with low infiltration rates. Conversely, the streamflow is much less variable from a basin with a high infiltration rate.

Basins with similar infiltration characteristics may have very different outflow regimes, due to differences in the rate of movement through the ground and in the amount of storage in the aquifer.

Basin geology may permit substantial amounts of groundwater to move across topographic boundaries, causing an unequal distribution of runoff with respect to surface-water drainage areas.

In arid and semi-arid regions where the water table is below stream channels, the permeability of the stream bed determines the rate at which streamflow seeps into the ground. Transfer of water between the surface and the ground also may occur at geological faults[4].

Table 2.1 shows a brief summary of the geological formations of the country and their hydrological characteristics. Since only the younger formations, mainly from the Miocene up to the Recent, are generally close enough to the surface to be of hydrological importance, formations older than these are only summarized briefly in the table.

The Miocene form three main series:

1. The Euphrates Limestones;
2. The Lower Fars;
3. The Upper Fars.

The Euphrates limestones are the oldest rock. They are common on the right bank of the Euphrates river and consist of limestones, varying in colour, density and structure. They frequently produce karst scenery and sometimes appear in a bituminous form. In the foothill region, they are represented by the Jariba series which is composed of brownish-grey fine

Table 2.1 Geological Formations of Iraq and Their Hydrological Characteristics

AGE	FORMATION	THICKNESS(metres)	DESCRIPTION	HYDROLOGICAL REMARKS
RECENT	Younger Alluvium	0-10 Of unknown and perhaps great thickness in Mesopotamia Valley	River silt, lacustrine clay, loess, sand dunes, stream gravel	Stream gravels of most of the larger streams (both perennial and intermittent) carry an important underflow at least locally. Frequently too thin elsewhere to reach to the water table. Not yet distinguished from Older Alluvium in the Mesopotamia Valley.
PLEISTOCENE	Older Alluvium	0-100	Coarse, poorly sorted, locally derived (generally is) gravel, boulder conglomerate; lacustrine clay and silt. Frequently exposed as terrace gravel and conglomerate in fold zone.	Better sorted beds are good aquifers but many deposits are poorly sorted. The source of water in many dug wells and in some irrigation wells. Sometimes difficult to distinguish from Younger Alluvium in wells. Locally derived gravels generally distinguishable from distantly derived Bakhtiari gravel.
PLIOCENE	Upper Bakhtiari)) Lower Bakhtiari)	0-4,000	Conglomerate, gravel and sandstone interbedded with siltstone mudstone and clay. Generally not well sorted, cementation variable and irregular. Pebbles chiefly siliceous.	Gravel and sandstone beds are important aquifers. Probably most important water-bearing formation in Iraq. Source of water in wells of Arbil Plain and other valleys of the fold zone. Dibdiba beds are correlatives in S.W. Iraq. Possible but undeveloped, artesian aquifer in Mesopotamia Valley.

Contd.

AGE		FORMATION	THICKNESS (metres)	DESCRIPTION	HYDROLOGICAL REMARKS
MIOCENE	Upper	Upper Fars	0-5,000	Interbedded mudstone and sandstone. Also much siltstone. Generally red or brown in colour.	Sandstone beds are important aquifers locally as in the Sinjar area. Aquifers generally of low permeability.
		Lower Fars	300-600*	Marine limestone, anhydrite, gypsum, grey shale, local salt beds.	Secondary permeability developed along bedding planes and solution channels.
	Middle	Chama limestone		Reef limestone present only locally in N.E. Iraq.	Hydrologic properties not known.
	Lower	Euphrates limestone	0-200	Foraminiferal and reef limestone passing basinward into anhydrite and shale.	Source of many mountain springs in fold zone. Probable source of springs of West desert. Possible source of artesian wells.
OLIGOCENE		Chilou marl	0-143		Generally impermeable.
EOCENE	Upper and Middle	Pila Spi limestone Jaddala marl	0-690	Thin-bedded, fine-grained dolomitic limestone and dolomite.	Generally impermeable.
	Lower	Gercus(Dohuk) red beds	0-500	Red marl, sandstone and conglomerate, local gypsum.	Possible local aquifer.
		Sinjar limestone (Kashti limestone)		Reef limestone.	Springs issue from this formation in Jabal Sinjar. Possible aquifer where not too deeply buried.
CRETACEOUS	Upper	Hadiena limestone	0-600+	Sandy and fragmented limestone, hematite breccia. Locally developed formation.	Possible local aquifer between Ora and the Khabour River
		Germav formation	0-2,600	Sandstone and conglomerate alternating with marl and shale, occasional roof tongues of massive limestone.	Permeable beds generally deeply covered in valleys. Of possible local importance as an aquifer.
		Shiranish marl	200-300	Thin-bedded globigerinal marls and marly limestones weathering.	Generally impermeable.
		Bekhme limestone	200-300	Reef limestone.	Possible aquifer but not known to be of hydrologic importance.

Contd.

AGE		FORMATION	THICKNESS (metres)	DESCRIPTION	HYDROLOGICAL REMARKS
CRETACEOUS	Middle	Qamchuqa limestone	1,000	Massive reef and foraminiferal limestone.	Possible aquifer but not known to be of hydrologic importance.
		Sarmord formation	1,000	Globigerinal marl and limestone grading into reef facets on the one hand and bathyal limestone on the other.	Generally impermeable.
	Lower	Garagu member	20-50	Sandstone and ferruginous oolite.	Possible aquifer but not known to be of hydrologic importance.

<u>Source</u>: Dennis,P.E.,Report to the Government of Iraq on the Investigation and Development of Groundwater Resources, F.A.O., Rep. No.189, 1953,Table III and p9.

* According to the Ministry of Irrigation (see p20)

crystalline limestone beds, intermixed with thin layers of gypsum or chalk-like rocks. In the Dibdiba Plain, Ghar rock fragments are of a similar age. The thickness of the Euphrates limestones ranges from about 200m in the north to 100m in the Dibdiba at the southern part of the country.

The groundwater aquifer in the Euphrates formations is developed in different parts of the country. On the right bank of the Euphrates, the water-bearing rocks are represented by fractured cavernous limestones with clay and marl bands within a strip several kilometres wide. On the Dibdiba Plain, replacement of limestones by terrigene rocks of the Ghar series takes place. The water table occurs generally at 20-75m and the maximum depth is not more than 100m. The aquifers recharge by precipitation and water coming from the underlying aquifers. They discharge into the Euphrates river valley, in the northern portion of the western plateau, along the zone of the Abu-Jir fault and in the Hammar lake vicinity. It has to be noted that the greater part of the spring yield in the discharge zone (Euphrates right bank) probably comes from aquifers more ancient than that of the Euphrates which, in this case, is a transit aquifer. (A transit aquifer allows passage, but does not hold water.) This is confirmed by the small area of the Euphrates limestones extension.

The Lower Fars consists of limestones, anhydrite, gypsum, grey shale and local salt beds (Table 2.1). It is predominantly developed in the Jazira Plain to the west and south-west of Wadi Tharthar. In the eastern portion of the Western Plateau, the Lower Fars formations overlie the Euphrates limestones. They are formed from alternating layers of clay, marl, limestone, gypsum and anhydrite. The presence of sulphur and bitumen is characteristic of the stratum. There is an increase of gypsum content generally to the top of the profile, while terrigenous formations are typical of the lower part series. In the foothill region, the Lower Fars outcrops to the west and north-west of Mosul. In the mountain region, the Lower Fars deposit includes a mature breccia-like limestone bed 25m thick which divides the stratum into two parts. The thickness of the Lower Fars formations varies from 300m to 600m. They are mainly impermeable formations, but secondary permeability is generally developed along bedding planes and solution channels. The aquifer yields highly mineralized water. It recharges by precipitation and partially from the underlying aquifers and dischargse in the Tigris-Euphrates valleys as well as Wadi Tharthar.

The Upper Fars formations occupy a vast area to the east of Wadi Tharthar and are frequently found on the Euphrates river right bank. They are not continuous and rarely occur in the central parts of the folded region low structures. They consist of clays, oblique laminated sandstones, agrillites and siltstones, alternating vertically and horizontally. The thickness of the layers is from 2m-3m to 10m-15m. Concurrent with this, the Upper Fars stratum comprises thin gypsum bands and rarely conglomerate lenses. The total thickness of the Upper Fars formations ranges from several metres in the south of the Mesopotamian Plain to 700m-1200m in the foothill region. In the southern part of the country, the Dibdiba gravel sand deposits, slightly cemented and concentrated with gypsum, are referred to as the Upper Fars. These formations are highly permeable. Their thickness increases from 30m in the west to 300m in the east.

The groundwater aquifer in the Upper Fars is contained in the sandy clay layers in the foothill region and in the Dibdiba weakly cemented conglomerates. The aquifer recharges by seepage precipitations and from the underlying aquifers and it discharges in the Tigris and Euphrates river valleys as well as in local runoff zones, such as Wadi Tharthar. Due to the high permeability of the sandstone water-bearing layers, artesian water can be found, particularly in the foothill region. Generally, the groundwater depth ranges from 5m-20m and only in the Dibdiba central part does it increase to 70m-100m(5).

The Bakhtiari (Pliocene) formation consists mainly of gravel and conglomerate, interbedded with siltstone and mudstone, which are generally poorly sorted. The pebbles of the conglomerate and gravel consist almost exclusively of hard siliceous rocks such as jasper, flint, chert, quartzite and andesite. Pebbles derived from the nappe zone are especially common. The formation thickness is over 3000m in the folded region, but thins rapidly and becomes finer grained south-westward. Similar beds of sand and gravel in the Dibdiba area were derived from the south-west. The upper parts of these beds are referred to as the Bakhtiari formation, while the lower beds are much older and referred to as the Upper Fars formation.

The Bakhtiari formation outcrops extensively in the Arbil Plain, in most of the synclinal valleys of the folded region and in the area north-west of Baghdad, between Wadi Tharthar and the Tigris river. It presumably underlies much of all the Mesopotamian Plain, but its extent, character and depth beneath the surface remain undetermined. The Bakhtiari formation is highly permeable; therefore it is an important water-bearing formation in the foothill region, particularly in the Arbil, Kirkuk, Samarra and Badra-Mandly areas[6] (Chapter 4). The aquifer is recharged by precipitation and discharged as natural flow in valleys of the Tigris and its tributaries. The groundwater depth is about 40m.

The Pleistocene and Recent are represented by the alluvial deposits. The most ancient alluvium, referred to as the

Pleistocene, is found in high terraces of large rivers. Such deposits are often observed in the Tigris valley as well as in the Greater Zab, Lesser Zab and Diyala river valleys. In the Euphrates river valley, on the other hand, they compose part of the preserved high terrace on the left bank. In all areas, the deposits consist of well rolled gravel and pebbles in sand and loamy-sand matrix. Rocks are cemented into weak conglomerate which is analogous to the Bakhtiari deposits. The thickness of the layer is generally 10m-15m, though in the deeper valleys it can reach 40m-50m.

Alluvium of low terraces forms from two layers: the first one consists of loam and loamy sand, while the second one is composed of sand and gravel. Both influence the terracing of large rivers. This combination is typical of stretches in the Tigris and Euphrates river valleys as well as for the part of the Mesopotamian Plain located to the north of the latitude of Baghdad. The low terraces of the Tigris tributaries (G. Zab, L. Zab, Diyala and partially Adhaim rivers) are of a similar character. The total thickness of the deposits ranges from 5m-10m in the upper reaches to 15m-30m at the latitude of Baghdad.

Alluvial deposits, together with irrigation deposits in the Tigris-Euphrates interfluve, consist mainly of a stratum of evenly alternating loams, loamy-sands, sands and clays.

Facial replacements horizontally and vertically are sharp and frequent and this fact permits the stratum to be treated as uniform. Sands are generally fine and clayey, loams and clays are limey, silty and macroporous. The thickness of the deposits is not determined precisely, although it supposedly increases from the Euphrates river (12m-15m) to the Tigris (80m-100m).

Alluvial-lacustrine formations are common in the southern and eastern parts of the Mesopotamian Plain and are characterized by the presence of organic inclusions and sometimes rather thick layers of peat. The composition of the mineral part of the deposits remains approximately similar to alluvial sediments. However, the peculiar feature of the stratum structure as a whole is the presence of a presumed clay layer of great thickness at a depth of 7m. This condition is characteristic for the region of development of alluvial-marine and sand clay sediments in the extreme southern portion of the plain.

Alluvial-proluvial deposits generally belong to wadi channels and they are also typical of the profile in the upper part of Dibdiba Plain. These deposits are composed of gravel-sand, sometimes covered either by loamy sand or loam soil. The average thickness is from 1m-2m to 10m-15m.

Proluvial and talus-proluvial rocks, typical in the northern and western parts of the country where silty-clay compositions prevail, are characterized by the presence of gravel inclusions with a high carbonate and a gypsiferous content. The overall thickness is 5m-10m and rarely 15m-25m.

Loamy-silty talus deposits with semi-solid fragments cover low slopes, valleys and depressions in the Tigris river basin and are rarely observed near the western border of the country. The thickness of deposits is about 10m.

Alluvium in the Western Plateau and the mountainous regions is represented by shallow loamy sands and loams augmented with gypsum and crushed stones of country rock.

The groundwater aquifer within the Tigris and Euphrates valleys to the north of the latitude of Baghdad is formed in sand-gravel deposits of alluvial channels and in loam and loamy sand formations of the flood plain. Its depth does not exceed 5m. Its recharge and discharge are closely related to the regimes of the rivers.

In the lower part of the Mesopotamian Plain, the water-bearing formation is represented by sand-clay deposits. The groundwater depth ranges from 1m-3m and rarely reaches 5m. It recharges mainly from irrigation water in addition to the Tigris and Euphrates rivers and possibly from underlying aquifers. The discharge takes place in the form of evaporation as underground outflow is absent, due to the extreme flatness of the area[7].

From the foregoing, it should be noted that the oldest geological formations outcrop only in the mountain and Western Plateau and dip under the younger formations in the central part of the country. These are generally of low permeability. The younger Miocene to Recent rocks, of differing permeabilities, form the dominant outcrops which occur irregularly. Generally, surface runoff is limited or absent in the Western Plateau, lowland and foothill regions. This is due to prevalent permeable formations and low rainfall. In the mountainous region, runoff occurs as a result of dominant impermeable formations and high precipitation.

2.3 TOPOGRAPHY

Topographic features such as elevation and slope influence runoff characteristics. For instance, in the mountainous basins, land slopes are steep, stream gradients are high and thus precipitation reaches the channels quickly. This results in increased flood peaks. Conversely, in basins where land slopes are gentle, precipitation reaches the channels more slowly and consequently streams take longer to rise to a peak and the peaks tend to be flattened. A flood peak may move downstream two or three times as fast on a high gradient stream as on one of low gradient. Low gradient channels tend to be in wide valleys where large riparian areas are inundated by significant floods. The resulting channel storage reduces the peak discharge, although much of the overflow is returned to the stream rather promptly. Overflows of some channels in very flat topography may never return to the main channel. This natural diversion reduces both the flood peak and the yield downstream.

Lakes, swamps and marshes are common in basins of low relief. The natural storage in these areas generally reduces the downstream flood peaks. Evaporation from the water surfaces and evapotranspiration from the perimeters of the wetland areas and from the shallow groundwater reduce basin runoff substantially at times. The variability in storage due to weather patterns results in a high variability of annual low flows downstream.

Topography controls stream pattern which in turn affects flood characteristics along the main channel. Tributaries entering a channel at regular intervals will produce a flood that increases downstream if their peaks are substantial and more or less concurrent with the peak of the main channel. Double or multiple flood peaks will occur if the tributaries have different regimes from the main channel. In a long channel reach without tributaries, or with tributaries that do not contribute at the same time as the headwaters, a flood generated upstream will be attenuated[8].

Land-surface topography affects the localization of ground-water movement into and out of the ground. It also indirectly influences precipitation, temperature, vegetation and soil type which affect water resources[9].

Topographically, the country can be divided into three major regions. These are the mountain, foothill, lowland and western desert plateau (Table 2.2 and Fig.2.1).

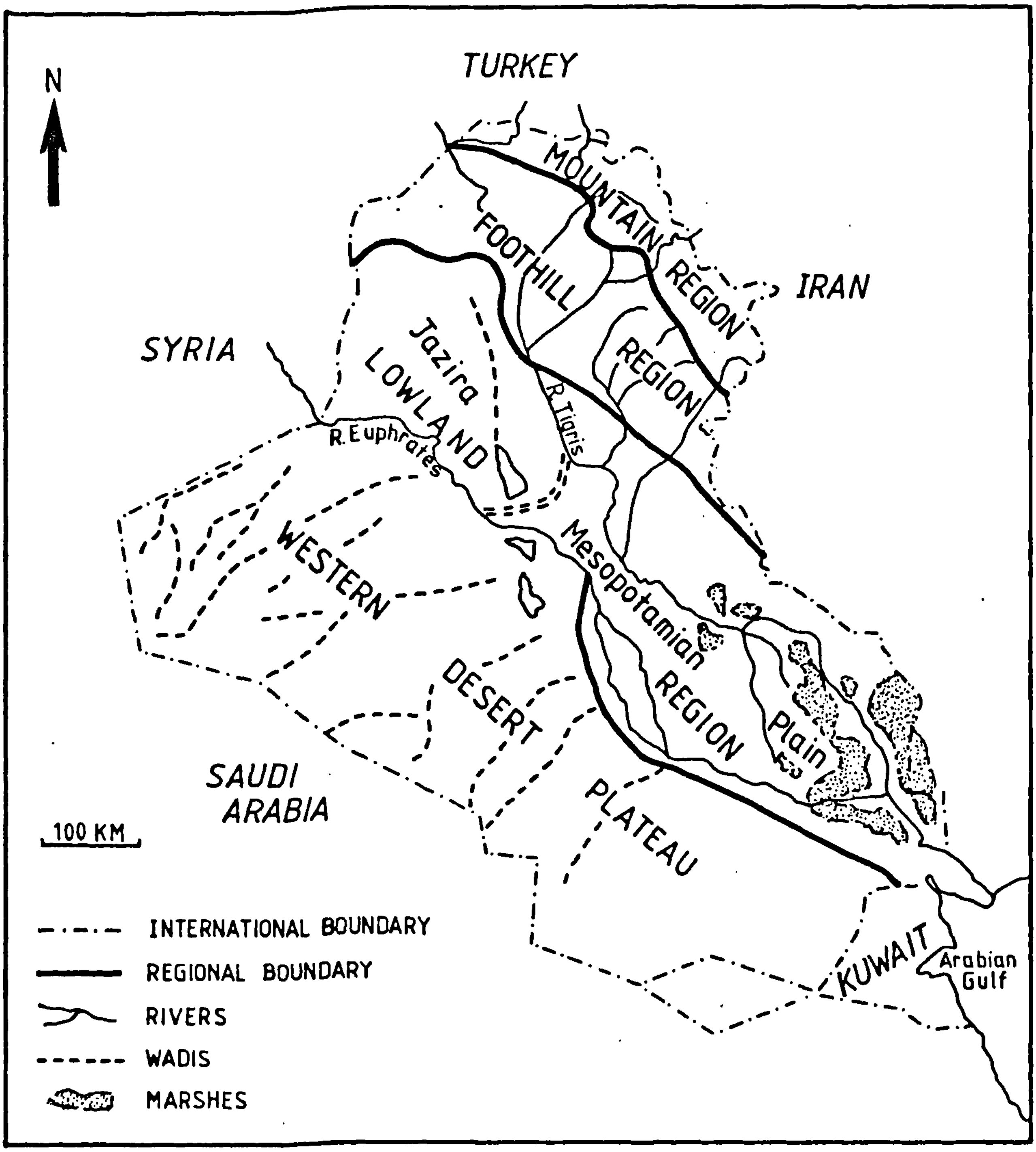
Table 2.2 Topographic Regions of Iraq; Type and Proportion

Region	Area km^2	% of Country's Area
1. The Mountain	23500	5.3
2. The Foothill	67000	15.0
3. The Lowland:		
The Jazira	31000	6.9
The Mesopotamia	93000	20.8
4. The Western Desert Plateau	232000	52.0
Total Area of Iraq	446500	100%

Source: Sousa A. The Floods of Baghdad in History, Vol.1, Baghdad, Al-Adib Press, 1965 pp130-141 (in Arabic).

Faugere Y. and Hawa A.J. Hydrological Study of the Jazira-Singar Area, Institute for Applied Research on Natural Resources, Technical Bulletin, No.90, Baghdad, February 1976 p7.

Fig. 2.1 : The Topographical Regions of Iraq



2.3.1 THE MOUNTAIN REGION

This occupies the northern and north-eastern part of the country and occurs between the Taurus mountain in Turkey and the Zagros in Iran. The region forms 5.3% of the country's area or 23500km^2 (Table 2.2). It consists of a series of parallel mountain ranges with a general trend from the north-west to south-east and an elevation ranging from 3600m in the north-east to 1000m in the south-west. Consequently, the Tigris tributaries follow the general slope towards the south-west, form a trellised drainage pattern and cross the mountain ranges through gaps or gorges (antecedent drainage). These are of great hydrological importance in that several dams are constructed here.

The region contains three main plains which are rich in surface and groundwater resources. These are:

1. The Sandy Plain which is situated in the northern part and through which the Khabour cuts its channel, draining towards the Tigris river.
2. The Ranya Plain which locates in the middle of the region and is drained by the Lesser Zab river.
3. The Shahrazor Plain in the south-eastern part, which is traversed by the Diyala and Lesser Zab rivers[10].

The higher mountains are snow-covered throughout the year.

In addition, the annual rainfall ranges from 600mm-1000mm (Fig.2.2) and increases in total towards Turkey and Iran. Therefore, this region and its extension in Turkey and Iran is the main source of the Euphrates and Tigris rivers.

2.3.2 THE FOOTHILL REGION

This is a transition region between the mountain and lowland regions. It extends from the north-west to south-east with an area of 67000km^2, or 15% of the total area of the country. It forms from a series of hill ranges which generally trend from north-west to south-east with an elevation ranging from 200m-1000m. The highest elevation occurs near the mountain region. Between the foothill ranges a number of broad flat plains with good potential of ground-water resources occurs. These are the Hamrian, Arbil, Kirkuk and Mosul plains.

The region is traversed by the Tigris and its tributaries (the Greater Zab, Lesser Zab, Adhaim and Diyala) which flow from north to south and north-east to south-west in accordance with the general slope of the region crossing the foothill ranges through gorges[(11)], in which several dams are constructed and others planned. As stated earlier, the Tigris and its tributaries are fed from the mountain region, while the contribution of the foothill region is limited, due to low rainfall which ranges from 300mm-600mm.

2.3.3 THE LOWLAND REGION

This region occupies the middle part of the country with a total area of $124000km^2$, or 27.8% of the total area of the country. It consists of two sub-regions, the Jazira and Mesopotamian plains.

2.3.3.1 The Jazira

This is an undulating plain, located between the Euphrates and Tigris rivers. Its total area is $31000km^2$, or 6.9% of the total area of the country. It extends northward far beyond the international boundary, through Syria and Turkey to areas in which the recently planned irrigation developments are located (Chapter 5).

The Jazira is dissected by numerous wadis of which Wadi Al-Tharthar is the most prominent (A wadi is a valley cut by a river, but at the present time having flow only seasonally or less regularly). This starts from Jabal Singar in the north, runs parallel to the Tigris river and ends in the Tharthar depression in the south. Its total length is about 300km with an average width of 45km. Its elevation ranges from 225m in the north to about 3m below sea level at the depression in the south. It is the major drainage valley in the area, as the land generally slopes from north, west and east towards the middle and south, i.e. towards the Tharthar valley. Thus, interior drainage is characteristic of this area(12) and therefore it provides no surface water contribution. Furthermore, its groundwater resources cannot be used as a result of the high salinity.

2.3.3.2 The Mesopotamian Plain

This extends from the Jazira and foothills in the north to the Arabian Gulf in the south-east. It forms 20.8% of the country's area, or $93000km^2$. It is a flat plain with low altitudes and uniform relief when compared with the surrounding regions. It slopes gently from north to south with an average of 1 : 17500[13] and thus the maximum fall of the Euphrates and Tigris rivers within the area is 10.5cm/km and 6.9cm/km respectively[14]. This causes a decrease in flow which in turn promotes wide, meandering and braiding river channels, with the associated occurrence of lakes and marshes. These all increase water loss through evaporation (Chapter 6).

The Mesopotamian Plain is the most important part of the country in which much of the irrigated land is situated, and depends entirely on the Euphrates and Tigris waters. This is due to low rainfall which ranges from 100mm-200mm and unexploited groundwater resources because of high salinity (Chapter 4).

2.3.4 THE WESTERN DESERT PLATEAU

This is the largest region as it comprises a total area of 232000km^2, or 52% of the total area of the country. It occupies the whole area to the west of the Euphrates river and extends into Syria, Jordan and Saudi Arabia. Its altitude is about 1000m in the west, decreasing gently eastward to 100m. The region is traversed by numerous wadis, which run from west to east in accordance with the general slope[(15)]. Thus, the regional drainage is towards the Euphrates river. Also, the region consists of several depressions. The most important of these are the Habbaniya and Abu Dibbis on the eastern margin, which are used as reservoirs to control the Euphrates flood water (Chapter 3).

However, there is no regional contribution in surface water, due to low rainfall, which is about 100mm. Furthermore, its groundwater is limited to small quantities in depressions, valleys and the eastern spring zone.

Thus, Iraq as a whole is broadly synclinal in shape, bordered by the mountain and foothill in the north and north-east and the desert plateau in the west. In the mountain region, runoff occurs due to steep land slopes and high precipitation. Therefore, this region and its extension in Turkey and Iran is the main source of surface and ground-water. It provides the bulk of the Euphrates and Tigris river waters. The contribution of the other regions is limited or absent and thus, they vitally depend on the river waters.

Topographic characteristics influence the surface and groundwater drainage system as it follows the general slope of the land from north, north-east, east and west, towards the central and southern part of the country. In the mountain and foothill regions, land slopes are steep and therefore, the river valleys and channels are narrow and deep. In the central and southern part, as a result of the flatness of the basin, the river valleys and channels are wider, meandering and braiding. In addition, lakes and marshes are characteristic of the southern part of the basin, influencing water quality and quantity.

2.4 CLIMATE

The climatic factors of precipitation, temperature, sunshine, humidity and wind all affect stream runoff to some extent, but only precipitation and temperature account for major differences among runoff regimes in regions of similar geology and topography. Precipitation, the source of runoff, is disposed of in several ways; some is evaporated from the surfaces on which it falls, some infiltrates into the soil and some moves directly to stream channels. Of the water that infiltrates into the soil, some will be removed later by evaporation and transpiration and some may reach a groundwater body which maintains stream runoff. The seasonal and annual distribution of the basin precipitation account for considerable variation in monthly and annual runoff, in flood peaks and in low flows.

Temperature influences runoff in two principal ways:

1. High temperatures increase evapotranspiration and thus reduce the amount of runoff from precipitation.
2. Freezing and thawing change the timing of runoff by delaying the response of runoff to precipitation and by modifying the winter runoff because of ice formation(16).

The climate of the country varies considerably in temperature, pressure and winds, precipitation, relative humidity and evaporation. This is due to the effect of several factors:

1. latitude;
2. position relative to the neighbouring water bodies;
3. relief;
4. vegetation cover.

To identify the climate characteristics, data have been adopted from four climatic stations which are well distributed over the country (Fig.2.2):

1. Mosul in the north;
2. Baghdad in the centre;
3. Rutba in the west;
4. Basrah in the south.

2.4.1 TEMPERATURE

Temperatures throughout the country are characterized by large seasonal and monthly ranges as shown in Table 2.3. The mean annual temperatures gradually increase from the north towards the centre, west and south. The figures are: 19.8°C at Mosul; 22.9°C at Baghdad; 19.3°C at Rutba ; and 24°C at Basrah.

There are two main seasons, a cool winter (December-February) and very hot summer (May-September). Spring (March-April) and autumn (October-November) are only short transitional

Table 2.3 Mean Monthly and Annual Temperatures ($0^{o}C$) 1941-1970

Mean Temperature

Stations	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mosul	7.0	8.7	12.3	17.4	24.1	30.5	34.0	33.0	27.7	20.5	13.5	8.3	19.8
Baghdad	10.0	12.3	16.3	21.9	28.4	33.0	34.8	34.4	30.6	24.6	17.1	11.0	22.9
Rutba	7.4	9.4	13.0	18.2	23.8	28.4	30.6	30.3	26.7	21.3	14.2	8.9	19.3
Basrah	12.4	14.6	18.7	24.1	29.7	32.7	34.0	33.6	30.6	25.9	19.3	13.6	24.1

Maximum Temperature

Mosul	12.8	15.3	19.0	25.4	32.9	39.6	43.4	43.0	38.7	31.2	22.3	15.0	28.2
Baghdad	15.8	18.7	22.7	28.7	35.8	41.0	43.4	43.3	39.8	33.4	24.6	17.7	30.4
Rutba	13.8	16.1	19.8	25.4	31.5	36.1	38.5	38.7	35.5	29.6	21.6	15.4	26.8
Basrah	18.6	21.0	25.3	30.8	36.1	38.8	40.5	41.3	39.7	35.0	26.7	20.0	31.2

Minimum Temperature

Mosul	2.5	3.5	6.3	10.2	15.0	19.5	22.9	21.8	16.6	11.4	7.0	3.3	11.7
Baghdad	4.3	5.9	9.6	14.6	20.0	23.4	25.3	24.6	21.0	16.2	10.3	5.2	15.1
Rutba	1.7	2.9	6.0	10.7	15.8	19.3	21.7	21.4	17.6	12.9	7.1	3.2	11.7
Basrah	7.0	8.7	12.6	18.0	23.7	26.9	27.7	26.3	22.6	18.3	13.2	8.0	17.8

Source: Iraqi Meteorological Organization, Baghdad (unpublished data) seasons with moderate temperatures.

During the winter season, the average monthly temperature falls to 8°C at Mosul; 11°C at Baghdad; 9°C at Rutba ; and 14°C at Basrah. The coldest month is January with a minimum temperature of 2.5°C; 4.3°C; 1.7°C; and 7°C at the above stations, respectively.

In summer, the average monthly temperature increases to 30°C at Mosul; 32°C at Baghdad; 28°C at Rutba ; and 32°C at Basrah. July is the hottest month with a maximum temperature of 43.4°C; 43.4°C; 38.5°C; and 40°C at the same stations, respectively.

The large seasonal ranges between winter and summer are related to the fact that during summer the completely cloudless skies, the long day and hot-dry CT (continental tropical) air masses in association with the latitudinal location, intensify the high temperatures. While during winter the relatively short days, the predominant cold-dry CP (continental polar) air, bring low temperatures to almost every part of the country.

2.4.2 PRESSURE AND WINDS

There are two main pressure systems affecting the climate of the country. In winter, the low pressure concentrates over the Mediterranean Sea, Black Sea, Caspian Sea and the

Arabian Gulf. At the same time, the high pressure centres dominate the Anatolian, Iranian and the Arabian Plateaux. Thus, during this season the country is affected by cold air masses from the inland high pressure centres and warm rainy Mediterranean depressions as well as from the Arabian Gulf during the development of cyclonic storms over the eastern Mediterranean.

In summer, the low pressure dominates the north-western Indian subcontinent and extends westward to Afghanistan, Iran, the southern part of Iraq and the Arabian Plateau. The high pressure is concentrated over the high Zagros mountains and Asia Minor.

In accordance with the pressure systems, different winds blow to the country from different directions. In winter, there are four prevailing winds. These are westerly, north-westerly, easterly and south-easterly. The westerly and north-westerly winds bring warm and dry weather to the country. The easterly and north-easterly winds are usually associated with cold, dry weather and clear skies. The south-easterly winds are relatively cold and damp and bring clouds and rain to almost the entire country.

In summer, the hot, dry north-westerly wind is dominant, comprising 75% of all winds. This results from the effect of the Indian low pressure centre(17).

2.4.3 PRECIPITATION

Precipitation occurs almost always in the form of rainfall, while snow is confined only to the highest mountain peaks. The main sources of rainfall are depressions from the Mediterranean Sea and Arabian Gulf. These are only effective during winter, autumn and spring, while they are completely absent in summer. The mean annual precipitation decreases from north to south and from east to west (Table 2.4 and Figure 2.2), with 388.8mm at Mosul; 144.9mm at Baghdad; 108.3mm at Rutba ; and 140mm at Basrah. The maximum precipitation occurs during January and December with an average of 66mm; 24mm; 15mm; and 27mm respectively at the above stations. While the minimum occurs in October and May with an average of 18mm; 6mm; 10mm; and 4mm respectively.

2.4.4 RELATIVE HUMIDITY

The mean annual relative humidity is generally high in the north and south with 54% at Mosul and 60% at Basrah, while it decreases towards the centre and west with 43% and 42% at Baghdad and Rutba respectively (Table 2.5). This generally results from rainfall distribution. In the case of Basrah, however, there is low rainfall with high relative humidity, due to the influences from the Arabian Gulf and the marshes.

The highest monthly relative humidity occurs during the rainy season (October-May) with an average of 66.6% at Mosul; 53%

Table 2.4 Mean Monthly and Annual Rainfall in mm - 1941-1970

Stations	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mosul	67.2	63.4	69.3	50.8	25.3	0.7	0.1	0.0	0.7	9.9	36.1	65.3	388.8
Baghdad	24.8	24.0	23.1	21.5	7.3	0.1	0.0	0.0	0.3	3.7	17.4	22.7	144.9
Rutba	13.1	13.7	15.4	16.0	14.5	0.1	0.0	0.0	0.6	5.6	12.6	16.7	108.3
Basrah	24.2	14.3	20.3	20.9	7.8	0.0	0.0	0.0	0.0	0.8	22.5	29.3	140.1

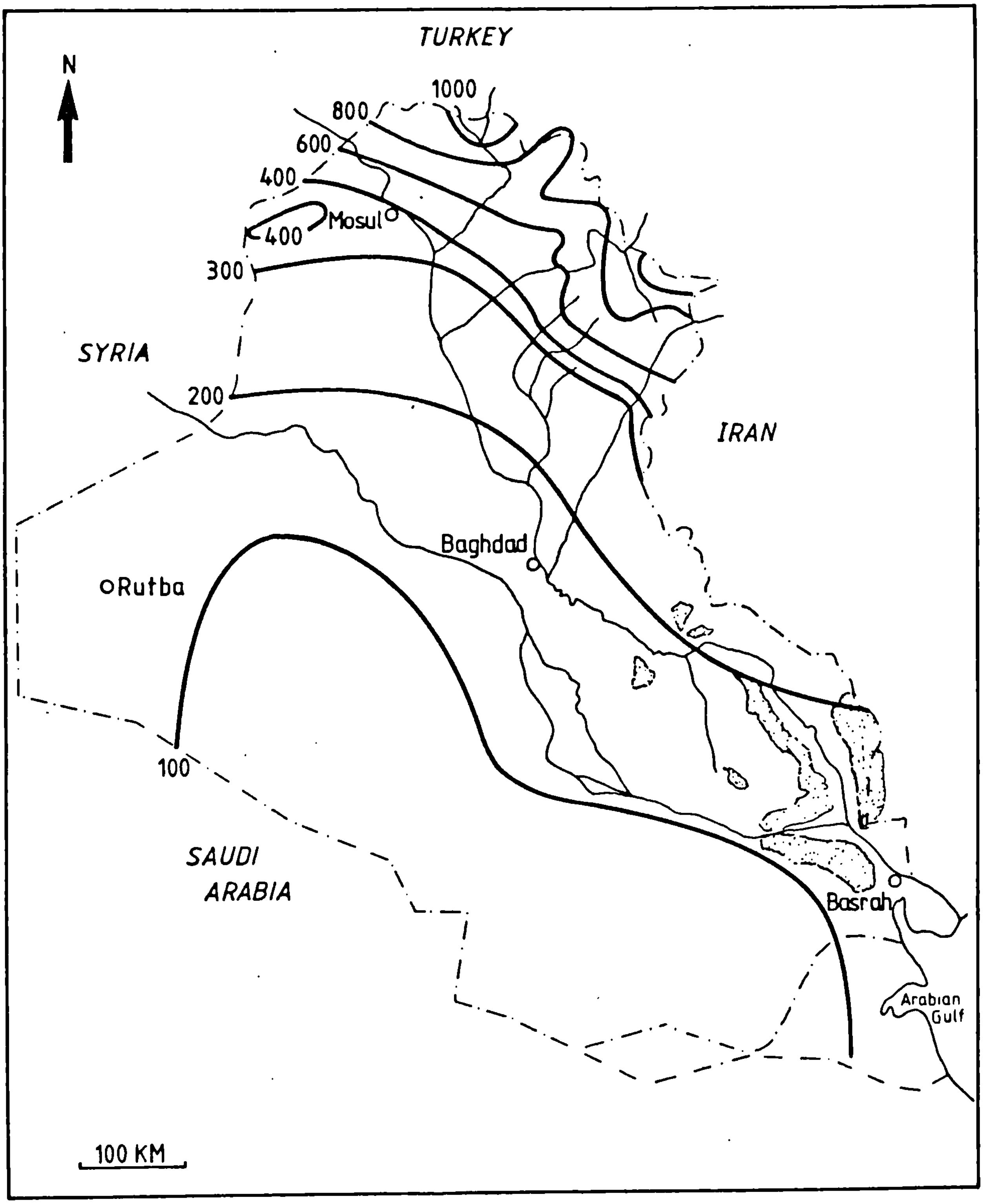
Source: Iraqi Meteorological Organization, Baghdad (unpublished data)

Table 2.5 Mean Monthly and Annual Relative Humidity (%) - 1941-1970

Stations	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mosul	82	76	70	62	44	30	26	29	34	49	67	83	54
Baghdad	71	62	52	44	31	22	23	24	27	36	56	71	43
Rutba	68	57	48	40	33	25	24	23	27	34	53	67	42
Basrah	78	70	64	58	53	49	49	48	50	56	69	78	60

Source: Iraqi Meteorological Organization, Baghdad (unpublished data)

Fig. 2.2 : Mean Annual Rainfall (mm)



Source : Iraqi Meteorological Organization at Baghdad; 50% at Rutba ; and 66% at Basrah. December and January have the maximum as a result of high rainfall and cloudy skies. The lowest monthly relative humidity is observed during summer (June-September inclusive), with an average of 30%; 24%; 25%; and 49% at the preceding stations, respectively. This is due to the absence of rainfall, cloudless skies and the dominant hot, dry north-westerly winds.

2.4.5 FREE-WATER SURFACE EVAPORATION

As a result of high air temperatures, low humidity and rather strong, dry winds, free-water surface evaporation from the Euphrates and Tigris river basins in Iraq, is substantial. Thus, the mean annual free-water surface evaporation at Mosul, Baghdad, Rutba and Basrah is 2279mm; 2598mm; 2089mm; and 2241mm respectively (Table 2.6). The mean monthly evaporation increases in summer to 72.4%; 68.2%; 67.5%; and 62.3% of the annual rate at the previous stations, respectively. This is due to hot, dry winds, cloudless skies and low relative humidity. In other seasons, the mean monthly evaporation forms only 27.6%; 31.8%; 32.5%; and 37.7% of the annual rate at the same stations respectively. The low evaporation during these seasons results from the relatively short days, predominantly cold winds, cloudiness and high relative humidity.

The mean monthly and annual values of free-water surface

Table 2.6 Mean Monthly and Annual Values of Free-Water Surface Evaporation (mm)

Station	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Annual
Mosul	146.9	86.6	48.3	46.8	62.9	98.4	145.3	225.4	330.1	434.1	396.3	263.9	2279
%	6.45	3.8	2.12	2.05	2.76	4.32	6.38	9.9	14.5	19.05	17.4	11.58	100
Baghdad	182.6	102.7	53.1	61	82.6	148.1	197.8	292.8	377.8	438.3	390.7	270.5	2598
%	7.03	4.0	2.04	2.35	3.2	5.7	7.61	11.3	14.54	16.9	15.04	10.41	100
Rutba	167.8	82.3	49.1	40.6	60	111.1	168.5	205.6	298.9	360.7	288.9	254.8	2089
%	8.03	3.94	2.35	1.94	2.9	5.32	8.07	9.84	14.31	17.27	13.83	12.2	100
Basrah	171.3	97.1	70.6	59.5	84.4	154.3	198.9	268.8	286.8	313.3	295.3	229.6	2241
%	7.64	4.33	3.15	2.66	3.77	6.9	8.9	12	12.8	14	13.2	10.25	100

Source: Kettaneh M.S. et al Evaporation Losses from Free-Water Surface Within the Watersheds of the Tigris and Euphrates Rivers, Institute for Applied Research on National Resources, Technical Bulletin, No.103, Baghdad, December 1976 Table 4a evaporation at these and other stations (Appendix 50) are applied in evaluation of evaporation water losses from the Euphrates, Tigris river channels and reservoirs (Chapter 6).

2.4.6 CLIMATE CLASSIFICATION

To identify the climatic types within the country, the most widely used classification[18], that of Koppen, modified by Trewartha, is applied. Trewartha classified the climate of the country (Plate 1) as follows:

1. Arid or desert (BWh);
2. Semi-arid or steppe (BSh);
3. Dry-summer Mediterranean (Csb).

Where:

B = evaporation exceeds precipitation;

C = coldest month between 18°C (64.4°F) and 0°C (32°F);

S,W = degrees of dryness as defined by formula 2;

s = summer dry; at least 3 times as much rain in wettest month of winter as in driest month of summer; driest month less than 3cm (1.2 ins);

h = temperature of the coldest month; greater than 0°C (32°F). Less than that is k (cold, dry climate);

a = warmest month over 22°C (71.6°F);

b = warmest month below 22°C (71.6°F).

The boundary between BS and humid climates when rainfall is concentrated in winter is expressed by the following formula:

1) $r = 0.44t - 14$

where:

r = mean annual rainfall in inches;

t = mean annual temperature in degrees Fahrenheit.

If r is over the calculated amount, the climate is humid and if it is less than the calculated amount, the climate is dry or BS.

The boundary between C and D climates is defined by $0^{\circ}C$ ($32^{\circ}F$) for the coldest month.

The boundary between BS and BW is defined by the following formula:

2) $r = \frac{0.44t - 14}{2}$

If r is over the calculated amount, the climate is BS and if it less than the calculated amount, the climate is BW.

However, by applying the available climatic data (Tables 2.3, 2.4 and 2.7), it appears that Mosul, Baghdad, Basrah and Rutba are situated in climatic types BSh; BWh; BWh; and BWh respectively. These are similar to the classification produced by Trewartha. However, the mountain area is of a Mediterranean climatic type (Csa) rather than of a Csb type as stated by Trewartha.

From what has been stated, the following conclusions can be drawn:

Table 2.7 <u>Mean Monthly and Annual Precipitation (mm) and Temperature (^{o}C) of the Mountain Region</u>

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Salahddin:													
Precip. (41-70)	109.7	92.5	106.2	89.3	53.2	0.4	0.0	0.0	0.0	13.5	90.1	96.5	651.4
Temp. (67-73)	3.7	5.2	9.2	14.4	21.2	27.3	30.9	30.9	26.7	19.4	12.2	5.7	17.2
Sulaimaniya:													
Precip. (71-73)	114.4	84.3	100.3	138	66.4	1.3	0.3	0.1	0.0	2.0	46.1	102.2	655.4
Temp. (71-73)	3.6	5.6	11.3	15.6	21.8	28	31.3	31.7	27.8	2.4	12.3	5.4	18.1

<u>Source</u>: Iraqi Meteorological Organization, Baghdad (unpublished data)

1. Arid - semi-arid climates prevail over 95% of the country.
2. Only the mountain region which occupies 5% of the country is of a humid climatic type. Therefore, this region and its extension in Turkey and Iran is the main source of water supply for the Euphrates and Tigris rivers.
3. Climatic variations promote seasonal and annual variations in the river discharges (Chapter 3).
4. Due to the arid - semi-arid climate, evaporation water loss from the rivers is extremely high (Chapter 6).
5. The arid - semi-arid climate of the country results in the vital need for the Euphrates and Tigris waters for irrigation and other purposes.

2.5 SOILS

Soil characteristics determine the rate of infiltration and thus affect the rate and amount of runoff. There is a variety of soils resulting from variations in:

a) soil parent material;

b) climate;

c) vegetation.

Thus, the country can be divided into four major regions:

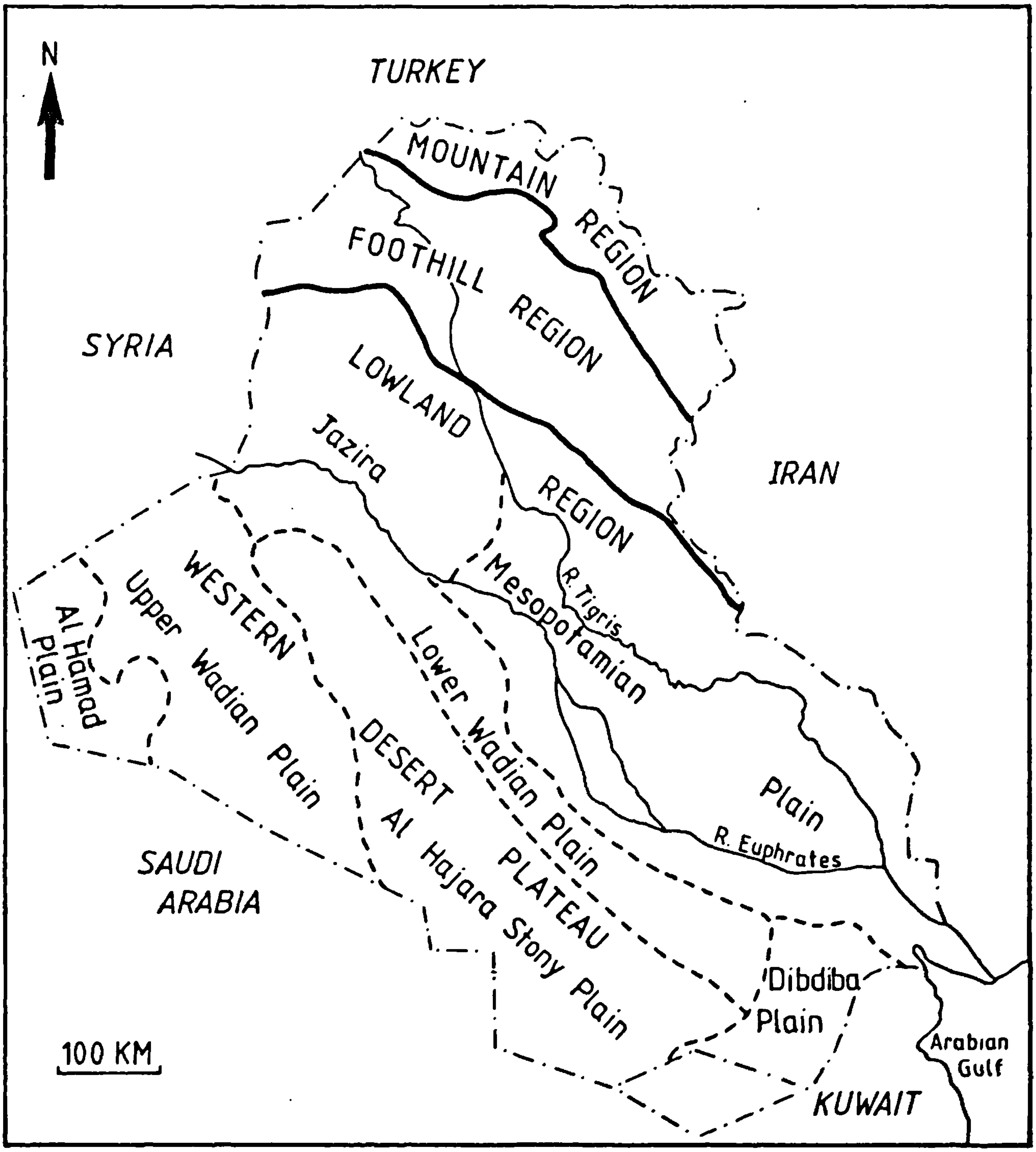
1. mountain;
2. foothill;
3. lowland;
4. western desert plateau (Fig.2.3).

2.5.1 THE MOUNTAIN REGION

The mountain region mainly consists of a rough, broken, stony surface of various kinds of limestone. Most of the soils are lithosols and are gravelly and shallow. Other different soil groups such as rendzinas and brown rendzinas, chestnut, reddish-chestnut, brown and chernozems also occur in this region.

The valleys, for example near Rania, are filled with gravel and conglomerate belonging to the Bakhtiari formations. The surface of these gravel deposits is erosional and has been covered by 2m-3m of fine textured silty clay and clay soil

Fig. 2.3 : Soil Regions.



Source : Buringh, P., Soils and Soil Conditions in Iraq, Ministry of Agriculture, Baghdad, 1960,pp.34 and 192.

materials, belonging to the chestnut soils. Some gravel fans and the highest terrace have a very thin layer or no soil layer at all. The alluvial soils form strips along the rivers. They are of light texture with gravel substrata and riverwash material. Drainage in this region is good, due to the high topographical position and general relief. Therefore, saline or alkali soils do not occur in this region[19].

Generally, soil infiltration rates are low as the largest part of the region is stony without soil or with shallow soil. This condition, together with steep land slopes and high precipitation result in occurrence of surface runoff.

2.5.2 THE FOOTHILL REGION

The foothill region mainly consists of gravel of the Bakhtiari formation. The gravel and conglomerate layers alternate with narrow layers of reddish loam and clay. The strata are often folded and in places these red layers are at the surface, mostly forming deeply gullied land. The hills are rounded and the soils generally shallow, sloping and gravelly. In some areas, older rock formations, i.e. limestone, sometimes sandstone and shale, are at or near the surface. Deeply eroded and gullied areas also occur locally. There are some broader valleys with medium and deep brown soils, sometimes graduating into weak chestnut soils. At the bottom of these valleys, strips of dark coloured hydromorphic soils with rust and gley are observed. On convex hill slopes, approximately 15% of the soil has a rather dark brown surface, which consists of silt loam mixed with some gravels, grading into brown silt loam at 14cm, with lime accumulation beginning at a depth of 30cm. This soil has been classified as brown soil. On some other hill slopes, soils are reddish-brown and lime accumulation begins at a depth of 15cm.

The region consists of three main extensive plains: the Kirkuk, Arbuil and Mosul. These have an undulating to rolling relief. The deeper strata of the plains consist of Bakhtiari gravel and limestone, which are covered by a soil layer of 2m-4m thick. There are a number of limestone hills with shallow brown soils or lithosols. The brown soils are well developed over the whole plain. In shallow valleys, chestnut soils are also observed, for example in the north-west of Dohuk. A layer of lime accumulation generally occurs in the horizon of these soils at a depth of 30cm-40cm and at a maximum of 40cm-50cm. Gypsum accumulation is absent from these areas. The soils are generally non-saline.

The soils of the area west of the Tigris river are mainly derived from gypsum, particularly in the southern section. In the east and north, soils are derived from limestone and sandstone. The soils of the southern half mainly belong to the reddish brown group, while those of the northern half belong to the brown soil group. There are many areas with lithosols on gypsum and limestone. Crust soils (lime and gypsum crusts) particularly occur in hilltops and slopes[20]. Soil infiltration rates are generally high with a lowest average of 6mm/h (Fig.2.4). This, with low rainfall, results in limited surface runoff.

2.5.3 THE LOWLAND REGION

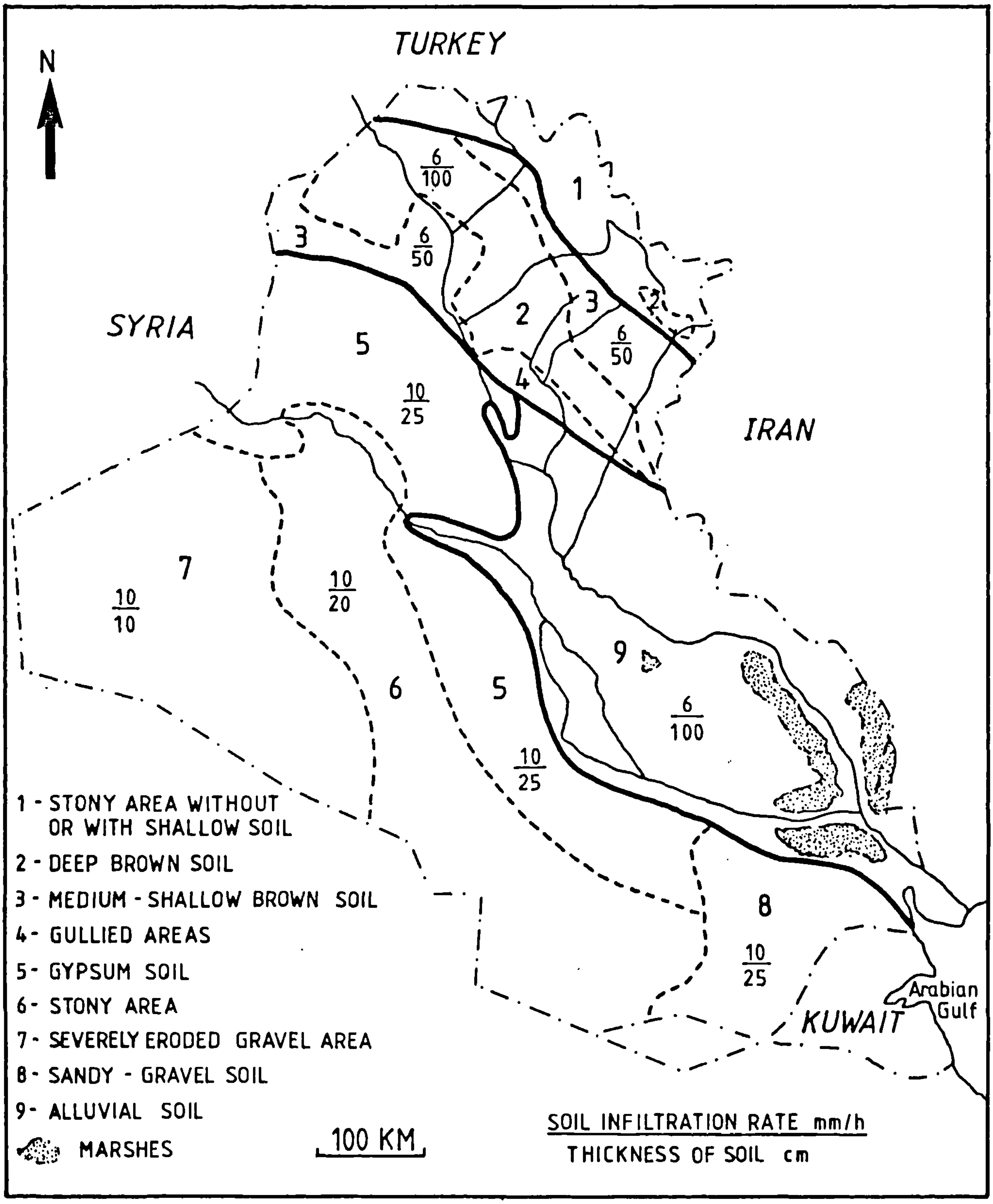
2.5.3.1 The Jazira

The soils of this area are mainly derived from gypsum. They mostly consist of weathered gypsum material with a depth of a few decimetres only and a high salt content. In some areas, gypsum material accumulates on the surface. In the central and southern part, some areas where the gypsum is not directly on the surface have somewhat reddish coloured silt and clay soils. In the west and north-west portion, aeolian sands occur in small dunes. They are derived from sand and siltstone outcrops of the Upper Fars. In the north-eastern portion, greyish or reddish-brown soils of loamy sand, loam and silty clay occur in the shallow valleys. In the depressions, hydromorphic clay and silty clay soils with a high salt content are found[21].

2.5.3.2 The Mesopotamian Plain

The soils of the lower Mesopotamian Plain consist mainly of fluviatile river sediments which have been deposited by the

Fig. 2.4 : Soil Types and Their Average Lowest Infiltration Rates



Source : Ministry of Agriculture, A climatological Study of Daily Rainfall and Overland Flow in Iraq, Tech. Paper No. 79, Baghdad, 1975, Fig.5.

Tigris and Euphrates rivers. The fluviatile sediments are covered by a recent layer of flood material and, in particular, irrigation sediment, often several metres thick. In addition, some material of aeolian origin has been blown out of the deserts and mixed with the fluviatile deposits. In some areas, river sediment has been subject to wind erosion and new aeolian deposits have been formed. The sediments in and around lakes and in large depressions are lacustrine in origin.

Almost all of the Lower Mesopotamian Plain has deep alluvial soils with extremely low natural fertility as the organic matter content is only 0.5% or less. The lime content ($CaCO_3$ and $MgCO_3$) of all soils is extremely high with an average of 20%-30%, while the gypsum ($CaSO_4$) content is generally low with a few percent only[22].

Salinity in the soils of the Mesopotamian Plain is a serious problem which affects large areas. This is attributed to the following factors:

1. The absence of natural drainage due to the extreme flatness of the area.
2. The prolonged use of irrigation water in the area.
3. The effect of saline groundwater, ranging in depth from 1m-3m (occasionally 5m) and almost at the surface in the southern portion (Section 1).

Thus, the drainage network which is under construction is vitally important to protect the soils of this area, in which is found all irrigated agricultural land.

Surface runoff in the lowland region is absent due to low rainfall and high infiltration rates with a lowest average ranging from 6mm/h-10mm/h (Fig.2.4).

2.5.4 THE WESTERN DESERT PLATEAU

This region forms more than half of the land surface of the country. The largest part of this region consists of barren rocks or stony plains or surface covered by desert pavement (surface accumulation of gravel). Thus, well developed soils are not observed in this region. This is attributed to severe wind as well as water erosion, enhanced by the absence of vegetation cover.

In detail, the soils in this region are discussed according to physiographic units from west to east (Fig.2.3) as follows:

1. The Al Hamad Plain: this is almost level and featureless. Soils consist mainly of stones and pebbles which are derived from limestone background.
2. The Upper Wadian Plain: soils are developed on limestone. They are generally shallow and stony everywhere, due to severe erosion. The largest depressions, such as Gaara, north of Rutba , are filled with

lacustrine and fluviatile material.

3. The Al Hajara Stony Plain: this is a flat stony desert area. Its surface is covered with pebbles and cobbles of limestone, flint and chert, which are dark coloured on the surface due to desert varnish. Generally, soils in this area are shallow, stony and poorly developed.
4. The Lower Wadian Plain: soils are developed on limestone and gypsum. In the wadi beds, soils contain subrounded cobbles and pebbles of limestone and siliceous rocks, mixed with brownish calcareous sand, silt and clay. The areas between the wadis have a shallow or very shallow soil layer, often mixed with or covered by cobbles and pebbles. The large Abu Dibbis depression is mainly filled with fluviatile and lacustrine sediments.
5. The Dibdiba Plain: this is an undulating to flat area. Almost all the plain consists of sandy to gravelly soils. For example, in the Zubair areas sand forms 87%-96% of the soil material. In the largest depressions, soils consist of clay and silty clay. Sand dunes occur to the east of this area, bordering the Lower Mesopotamian Plain. The dunes are up to 35m high[23].

Surface runoff in this region is absent as a result of very low rainfall and high soil infiltration rates with a lowest average of 10mm/h.

Thus, soil infiltration rates are generally low in the mountain region. This, together with steep land slopes and high precipitation leads to increases in surface runoff. In the foothill region, surface runoff is limited as soil infiltration rates increase, while precipitation and land slopes decrease. Surface runoff is absent in the lowland and western desert regions, due to high infiltration rates and low precipitation.

As a result of insufficient precipitation, due to arid climate, supplementary irrigation from the river waters is vitally required.

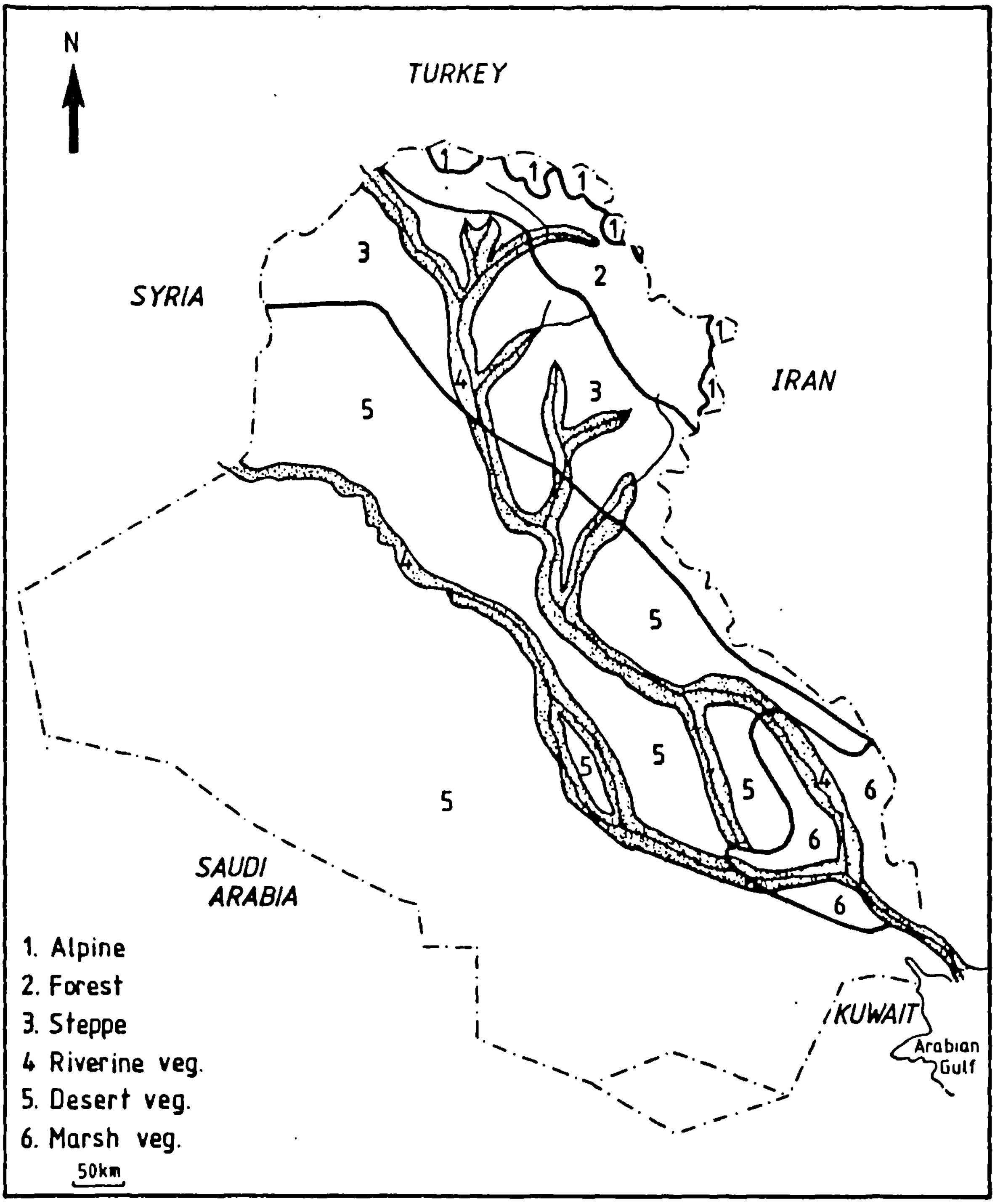
2.6 VEGETATION

Vegetation cover influences surface runoff as it increases infiltration and evapotranspiration rates. It is estimated that a mature forest reduces the annual water yield by 100mm-200mm[24]. Therefore, vegetation reduces flood peaks and controls soil erosion. Soil deposition causes sedimentation problems affecting river channels and reservoir capacities.

The distribution of vegetation is strongly controlled by temperature and rainfall and there is a very close relationship between the climatic and vegetation patterns in the country. The climatic conditions as well as the vegetation distribution are determined to a considerable extent by topography. Accordingly, the natural vegetation of the country shows a transition from the colder, wetter forested areas of the mountains, through the areas of low-land steppes, with moderate temperature and less rainfall, and to the hot, dry, desert areas. Thus, two vegetation regions can be identified. These are:

1. The mountain and
2. The foothill, lowland and desert region (Fig.2.5).

Fig. 2.5 : Vegetation Types



Source : Al-Khalaf, J.M., Physical, Economic and Human Geography of Iraq, 2nd Ed., Al-Bayan Al-Araby Press, Cairo, 1961, Fig.22.

2.6.1 THE MOUNTAIN REGION

The vegetation types in this region differ according to elevation. In the higher parts of the region, above 3400m, alpine vegetation is dominant. It is mainly in the form of grasses, mosses, lichens and shrubs. The forest prevails below the alpine covering areas with elevation up to 800m. It is principally in the form of oak trees and coarse shrubs. The larger part of the forest has been destroyed by cutting and overgrazing and, as a result, these regions are subjected to erosion.

2.6.2 THE FOOTHILL, LOWLAND AND DESERT REGION

Here the rainfall decreases rapidly and the length of the dry summer season increases. In consequence, the vegetation is of a steppe and desert type, although there are different grasses and palm trees in the irrigated land along the river banks and irrigated canals. In the northern part of the lowland region (Jazira), the vegetation consists principally of different kinds of grasses and bulbous plants and several varieties of thistle. In the southern area of the lowlands, the Mesopotamian Plain, in which the marshes occur, there is a heavy vegetation of common reeds, sedges, tube grasses and water-lilies[25].

Thus, vegetation cover is vitally important to water-soil conservation. Unfortunately, the whole area of the country is covered by sparse steppe and desert types of vegetation.

In addition, the largest part of the vegetation has been affected by excessive cutting, shifting cultivation and heavy grazing. These result in a serious increase in soil erosion which in turn results in high turbidity of the Euphrates and Tigris rivers (Chapter 3). This is affecting the river channels, irrigation canals and the reservoir capacities. It was estimated that the sediments accumulation in the Dokhan reservoir for the period of 1959-73 and Derbendi Khan (1962-73), reduced the net storage capacities of the reservoirs by 228 mcm and 78 mcm respectively[26].

2.7 CONCLUSION

Finally, the influence of the physical characteristics on water resources of the country can be summarized as follows:

1. Surface runoff is confined only to the mountain region. This is due to the high precipitation, low infiltration rate and steep land slopes. Therefore, this region and its extensions in Turkey and Iran are the main water supply of the Euphrates and Tigris rivers. Surface runoff, in the other part of the country, is limited or absent as a result of high infiltration rates and low precipitation.
2. The drainage system of the surface and groundwater is influenced by topographic characteristics since it follows the general slope of the land from north, north-east, east and west, towards the central and southern parts of the country. Furthermore, steep land slopes in the mountains and foothills result in narrow valleys and deep channels. In the central and southern parts, the flat basin accounts for wide river valleys and channels, meandering and braiding. In addition, lakes and marshes are common in the southern part. These increase evaporation losses.
3. The seasonal and annual climatic variations promote seasonal and annual variations in river water discharges.

4. As a result of arid - semi-arid climate evaporation water loss from the Euphrates and Tigris river basins is substantial.
5. Vegetation influences on surface runoff are limited as the vegetation cover consists of sparse steppe and desert plant types. However, lack of vegetation cover, strong winds and heavy rain storms during winter account for serious soil erosion which in turn results in the high sedimentation of the Euphrates and Tigris rivers, affecting river channels, irrigation canals and reservoir capacities.
6. The arid - semi-arid climate results in the vital need for the Euphrates and Tigris waters for irrigation and other purposes.

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CHAPTER 3

HYDROLOGICAL CHARACTERISTICS OF THE SURFACE WATER RESOURCES

3.1 INTRODUCTION

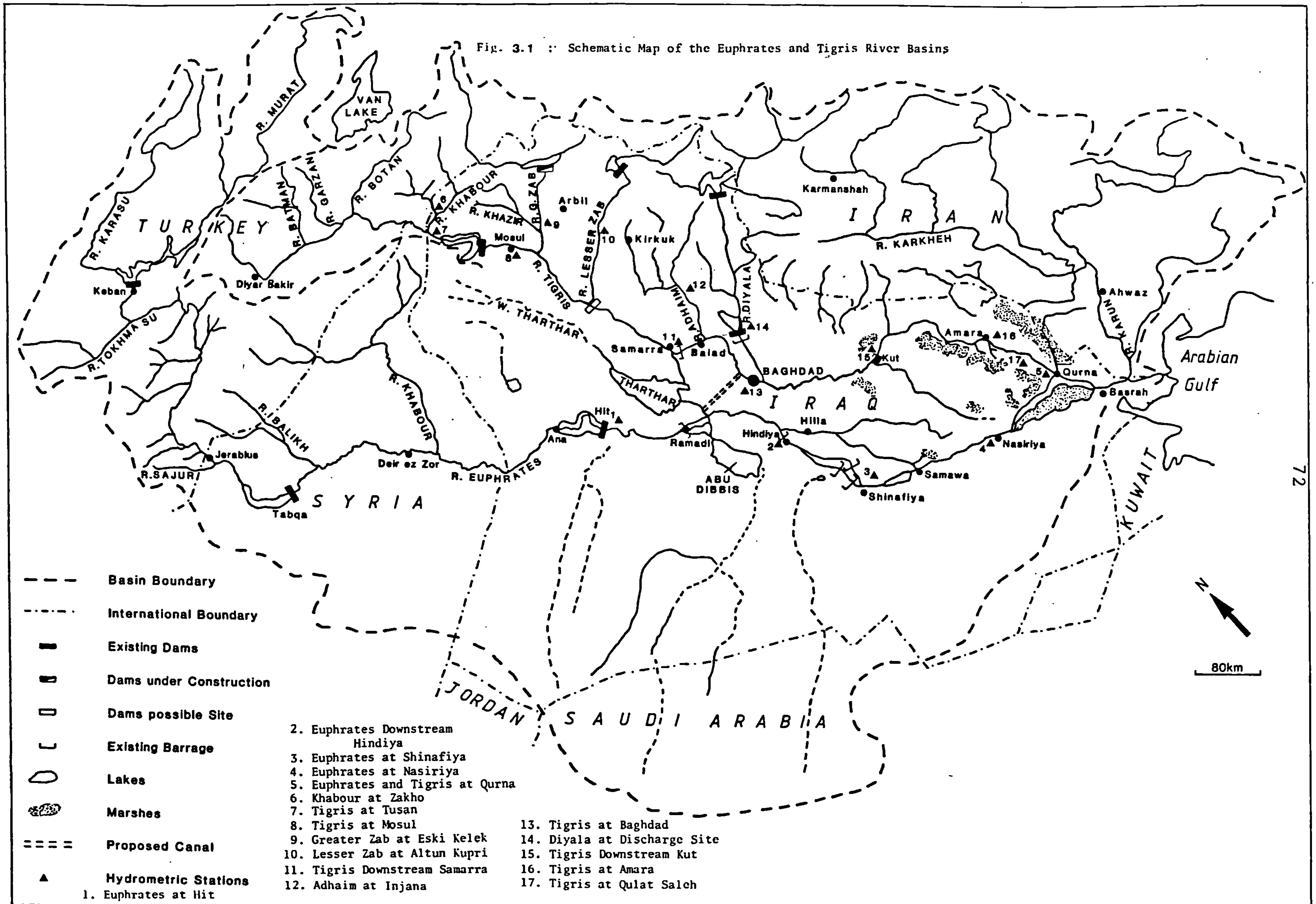
Before considering water utilization, it is important to determine the hydrological characteristics of the Euphrates, Tigris and Shatt Al-Arab rivers. Thus, this chapter is divided into five main sections. Of these sections, 3.2, 3.3 and 3.4 deal with each river individually. Each considers water discharge and its source according to the riparian states, together with water regime to show the effect of the seasonal and annual variations on water quantity and quality which in turn influence water demands. The river water turbidity and its effects on river channels, irrigation canals and reservoir capacities are also described. The hydraulic structures and their importance to combat the variability problem of the river flows is discussed. Section 3.5 focuses on the effect of the marshes on water quantity and quality. Finally, section 3.6 analyzes the river water quality in order to determine its suitability for utilization, particularly for irrigation purposes.

3.2 THE EUPHRATES RIVER

The source of the Euphrates river is in the mountainous area of eastern Turkey which rises to heights of more than 3000m. It is formed from four tributaries, the Karasu, the Murat, the Munzur and the Peri. Of these, the Karasu and the Murat are the main tributaries. The former originates north of Erzurum city and flows westwards for more than 300km before it turns to the south. The Murat rises west of Mount Ararat (at 5165m it is Turkey's highest peak) and flows westwards for more than 500km before joining the Karasu at Keban, forming the Euphrates river (Fig.3.1). Downstream of the confluence of these tributaries the Keban dam has been constructed (Chapter 5).

Below Keban, the river flows south-westwards through a narrow valley which finally widens and swings to the south-east when Malatya plains are reached. The river then enters a deep, 120km long canyon which it has eroded through the Taurus mountains. After this stretch, the river valley widens somewhat, but remains deep and steep-sided, guiding the river in a generally south-western direction through foothill regions and hilly plateaux, where several dams are either constructed or planned or under construction (Chapter 5). Also in this stretch, several streams join the river. Further downstream, the river turns slowly to the south, entering the plains and approaching the Syrian border[(1)].

Fig. 3.1 : Schematic Map of the Euphrates and Tigris River Basins



In Syria, the river swings to the south-east and traverses the Jazira, undulating steppe plain, where the river valley then widens. Here, the last three smallest tributaries, which have their head water in Turkey, join the Euphrates. The Sajur joins upstream of Tabqa dam. The Balikh and Khabour join the river downstream of Tabqa. Downstream of the Khabour confluence, the river continues to flow south-eastwards, crossing the Iraqi border at Husaiba village.

In Iraq, the river continues to flow south-eastwards through arid desert area and therefore receives no tributaries.

Along the stretch from the border to the town of Hit, the width of the river valley varies from 1-4km. The banks are steep, sometimes abrupt, with a height ranging between 20-40m. In some sections, especially at Rawa and Ana , the valley becomes only 0.5km wide, forming narrow passes with rocky, abrupt banks. The Qadisiya dam is constructed upstream from Hit (section 3.2.4).

In the section from Hit to Ramadi, the river valley widens as the river enters the Mesopotamian Plain. The height of the river banks ranges from 2.5 to 3.5m above low-water levels. Thus, the river channel is leveed to prevent the flooding of cultivated lands. The natural depressions of

Habbaniya and Abu-Dibbis, which are located south-east of Ramadi, are used for flood control regulation(2).

The average stream gradient upstream of Ramadi is 20.5cm/km, falling downstream to 7cm/km. This promotes meandering and braiding of the river on the Mesopotamian Plain(3).

From the Ramadi barrage to the Hindiya barrage, several irrigation canals have been constructed from both sides of the river. Of these, the Saqlawiya, the Abu-Ghuraib, the Yusufiya, the Latifiya, the Eskendariya, the Mussaib, the Hilla and the Kufel leave from the left bank and flow east and south-eastward. The Hussainiya and the Beni-Hassan are right bank canals. The Hindiya barrage was constructed to lift water to these canals(4).

Downstream of Hindiya barrage, the river bifurcates into two channels; the Kufah (right) and the Shamiya (left) which rejoin at Shinafiya. About 24km further downstream, the river splits again into two channels; the Abu-Rifoosh (left) and the Shatt Al-Atshan (right). The Abu-Rifoosh is the main channel taking the entire Euphrates low-water flow. Water flow in the Shatt Al-Atshan is observed only during flood period. These channels rejoin a few km north of the city of Samawa. The Swear channel branches off from the Abu-Rifoosh 9km above its confluence with Shatt Al-Atshan and rejoins the Euphrates river downstream of Samawa.

In the stretch from Shinafiya to Nasiriya, the average width of the main Euphrates channel is 170m. The height of its banks above the mean low-water level is 3.0-5.5m, reaching 6.0-8.0m at Samawa and Shinafiya. Therefore, the river is leveed to prevent the flooding of cultivated land(5).

Downstream of the town of Suk-Al-Shuyuk, the river splits into five branches, flowing mainly into the Hammar lake. The main channel runs northwards of the lake and joins the Tigris river at the town of Qurna. The other four branches cut their way through the Hammar lake, forming the main channel, named Garmat Ali which joins the Shatt Al-Arab at the town of Garmat Ali, 10km upstream of Basrah(6).

The total basin area of the Euphrates is 444000km^2, distributed between Turkey (125000km^2), Syria (76000km^2), Iraq (177000km^2) and Saudi Arabia (66000km^2). These comprise 28%, 17%, 40% and 15% respectively of the total basin area. The total effective area (the area which produces water) is 201000km^2, of which 125000km^2, or 62% is located in Turkey and the remaining portion (76000km^2, or 38%) in Syria. The total length of the river from the confluence of Karasu and Murat to its junction with the Shatt Al-Arab at Garmat Ali, is 2330km, of which 445km is in Turkey, 675km in Syria and 1200km in Iraq (Table 3.1).

Table 3.1 Physical Characteristics of the Euphrates and Tigris River Basins

River Basin	Characteristics	Basin States					
		Turkey	Syria	Iraq	Saudi Arabia	Iran	Total
Euphrates	Basin Area(km^2)	125000	76000	177000	66000	-	444000
	% Of Total Area	28	17	40	15	-	100
	Effective Area(km^2)	125000	76000	-	-	-	201000
	% Of Effective Area	62	38	-	-	-	100
	Contribution to Annual Water Potential (bcm) *	31.4	4.0	-	-	-	35.4
	% Of Annual Water Potential	89	11	-	-	-	100
	Length(km)	455	675	1200	-	-	2330
	% Of Length	20	29	51	-	-	100
Tigris	Basin Area(km^2)	57614	834	253000	-	160158	471606
	% Of Total Area	12	0.2	54	-	34	100
	Effective Area(km^2)	57614	834	83237	-	130158	271843
	% Of Effective Area	21	0.3	31	-	48	100
	Contribution to Annual Water potential (bcm)	25	-	19	-	4.9	49**
	% Of Annual Water Potential	51	-	39	-	10	100
	Length(km)	300	-	1358	-	-	1658
	% Of Length	18	-	82	-	-	100

Sources: Kettaneh M.S. et al, Water Budget of Iraq, Higher Agricultural Council, Study No.1-1, Baghdad, 1979, p33

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* Billion Cubic Metre

** Including mean water discharges of the Tigris at Tusan; Greater Zab at Eski Kelek; Lesser Zab at Altun Kupri; Adhaim at Injana and Diyala at discharge site (Tables 3.5 and 3.6)

3.2.1 WATER DISCHARGE

Table 3.1 shows that the area within Turkey is the most important part of the Euphrates river basin. It provides the river with 996 cumecs (31.4bcm) or 89% of the total annual water potential. In Syria, the mean annual discharge slightly increases to 1122.5 cumecs (35.4bcm). This can be attributed to the water discharges of the Sajur, the Balikh, the Khabour and other periodical streams. Further downstream the mean annual discharge falls to 909 cumecs (28.6bcm) at Hit in Iraq (Table 3.2). This is due to water withdrawal for irrigation and losses in Syria (Chapter 5). Downstream of Hindiya barrage, the mean annual discharge decreases to 524 cumecs (16.5bcm), about 57.6% of that at Hit. This results from abstraction into irrigation canals as well as water diversion to the Habbaniya reservoir.

In the lower sections, the mean annual discharge decreases considerably as a result of:

1. Intensive water withdrawal for irrigation.
2. Water losses through seepage and evaporation. These are evaluated as 153.85 cumecs (4.85bcm) and 16.24 cumecs (0.512bcm) respectively (Chapter 6).
3. Water dispersion at Qurna marsh (section 3.5).

Thus, the mean annual discharge decreases to 473 cumecs (14.9bcm) and 475 cumecs (15.0bcm) at Shinafiya and

Table 3.2 Mean Monthly and Annual Water Discharge of the Euphrates River at Selected Gauges in Cumecs

Period of Observation	Characteristic Year	Months												Mean Annual	
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	cumecs	(bcm)
	At Hit														
1932-75	Mean for period	343	465	596	699	787	1150	2150	2390	1220	530	310	270	909	28.6
	Wet year (1969)	478	650	1540	2450	1660	2760	4660	5790	2320	875	454	404	2003	63.0
	Dry year (1961)	331	390	383	462	537	434	1300	1170	443	192	86	93	485	15.3
	Downstream Hindiya														
1956-75	Mean for period	198	178	294	415	446	612	1086	1434	821	336	245	217	524	16.5
	Wet year (1969)	376	334	908	1210	1250	1250	2640	3380	1830	826	666	603	1270	40.0
	Dry year (1961)	144	130	114	285	322	236	342	888	265	106	77	67	248	7.8
	At Shinafiya														
1954-71	Mean for period	158	164	263	443	461	606	877	1210	848	307	155	227	473	14.9
	Wet year (1969)	245	226	722	964	1113	1024	1354	1586	1306	549	318	284	808	25.5
	Dry year (1961)	112	96	83	226	307	201	240	740	230	63	34	31	197	6.2
	At Nasiriya														
1930-71	Mean for period	174	208	273	370	429	537	821	1178	1047	353	159	145	475	15.0
	Wet year (1969)	372	361	762	1004	1425	1312	1430	1853	1674	721	448	411	981	30.9
	Dry year (1961)	198	207	216	267	303	255	254	567	241	92	65	76	228	7.2
	At Qurna														
1977-78	Mean for period	124	129	170	231	279	322	378	423	445	396	268	194	280	8.8

Table 3.2

Sources: Ministry of Irrigation, Directorate General of Irrigation, Discharges for Selected Gauging Stations in Iraq, Baghdad, 1976, pp48-52

Selkhozpromexport Co. General Scheme of Water Resources and Land Development in Iraq, Vol.1, Book 1, Baghdad, 1975 pp43-44

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Nasiriya respectively. These are equivalent to 52% and 52.4% of the mean annual discharge at Hit. At Qurna, the mean annual discharge falls to 280 cumecs (8.8bcm), although a large amount flows back from Qurna marsh through 46 canals. The largest of these canals is the Nahr Al-Huwair with a discharge of up to 80 cumecs (2.52bcm)(7). Qurna marsh has an adverse effect on both the quantity and quality of water in the lower section of the Euphrates and the Shatt Al-Arab (sections 3.5 and 3.6).

3.2.2 ANNUAL WATER REGIME

The annual water regime of the Euphrates river can be divided into two periods:

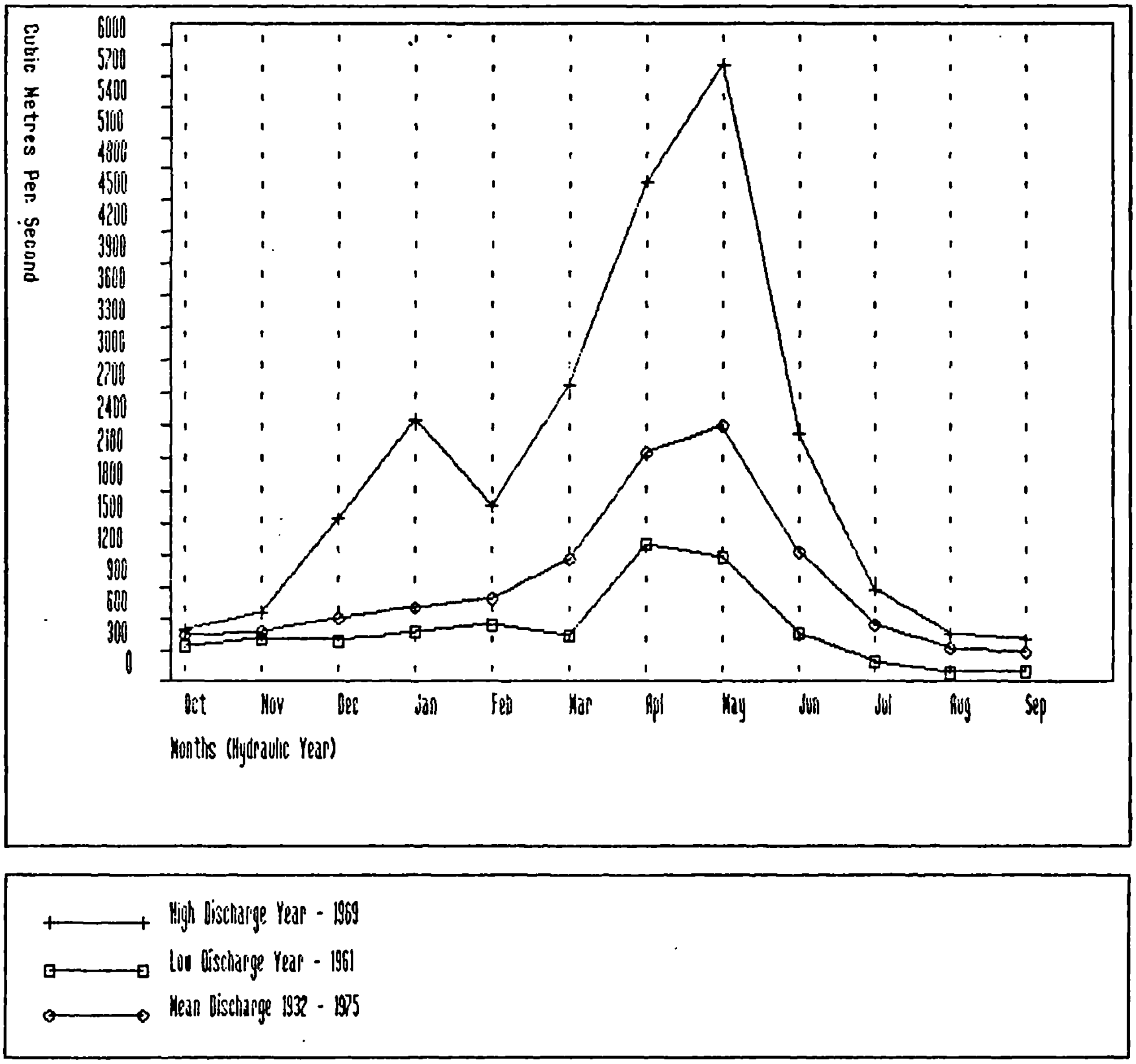
a) the winter-spring flood period (December-July inclusive) which results from high rainfall and snow melt in the high mountainous area of the basin; and

b) the summer-autumn low-water period (August-November inclusive) which is marked by low runoff due to low rainfall.

Thus, during the summer-autumn period, river runoff depends almost entirely upon the melting of the remaining snow in the Turkish mountains and also upon groundwater throughout the basin.

Table 3.2 and Fig.3.2 show that the river runoff is considerably increased from December-July (inclusive) with

Fig. 3.2 : Mean Monthly Discharge Variations for the Euphrates River at Hit (Selected Years)



a mean monthly value of 1190 cumecs (25.0bcm) or 87.4% of the total annual runoff based on the mean period (1932-75) at Hit gauge. The flood hydrograph during this period has a multi-peaked character. The greatest runoff occurs during April-May with a mean of 2270 cumecs (12.0bcm) or 42% of the total annual runoff. Further downstream from this gauge the flood runoff is greatly distorted as a result of intensive water withdrawal for irrigation and runoff regulation by the Habbaniya and Abu-Dibbis reservoirs. Thus, the mean monthly flood runoff downstream of Hindiya, Shinafiya and Nasiriya falls to 681 cumecs (14.3bcm), 627 cumecs (13.2bcm) and 626 cumecs (130bcm) respectively. These are equivalent to 57.2%, 52.8% and 52% of the total flood runoff at Hit. The greatest runoff at downstream Hindiya and Shinafiya is also observed during April-May with a mean of 1260 cumecs (6.64bcm) and 1044 cumecs (5.5bcm) respectively, equivalent to 40.2% and 37% of the total annual runoff at these gauges. At Nasiriya the greatest runoff occurs in May-June with a mean of 1113 cumecs (5.9bcm) or 39.3% of the total annual runoff. At Qurna the flood runoff is clearly distorted at Qurna marsh. Therefore, the mean monthly flood runoff falls to 331 cumecs (7.0bcm) (1978) or 28% of the total flood runoff at Hit. The flood peaks take place in May-June, with a mean of 434 cumecs (2.3bcm), equivalent to 26% of the total annual runoff at this gauge.

During the low-water period (August-November inclusive) the mean monthly discharge falls to 347 cumecs (3.7bcm) at Hit, 210 cumecs (2.2bcm) at downstream Hindiya, 176 cumecs (1.9bcm) at Shinafiya, 172 cumecs (1.8bcm) at Nasiriya and 179 cumecs (1.9bcm) at Qurna. These equate to 12.9%, 13.3%, 12.8%, 12% and 21.6% of the total annual runoff at these gauges respectively. The extreme lowest discharge occurs in September, with a mean of 270 cumecs (0.7bcm) at Hit, decreasing to 145 cumecs (0.4bcm) at Nasiriya.

Besides the seasonal variations there is the annual variation. For instance, in 1969 the mean annual discharge at Hit was 2003 cumecs (63.0bcm) or about double the average long term discharge (1932-75) at this gauge. In 1961, the mean annual discharge fell to 485 cumecs (15.3bcm), about half of the average long term discharge. Other years in which the annual discharge fell a long way below the average long term were 1974, 286 cumecs (9.0bcm) and 1975, 299 cumecs (9.4bcm)[8]. This is due to the filling of the Tabqa reservoir in Syria which severely affected flow into Iraq (Chapter 7).

Thus, seasonal and annual variations influence the river water quantity and quality. Therefore, several dams and reservoirs have been constructed or planned particularly for the purpose of regulation.

3.2.3 SUSPENDED SEDIMENT

Lack of vegetation cover results in high water turbidity in both the Euphrates and Tigris rivers. This in turn affects river channels, irrigation canals and reservoir capacities.

Table 3.3 indicates that the total annual suspended load of the Euphrates at Hit is 55 million tons, with a mean runoff of 1744kg/sec. This decreases southwards as a result of the deposition along the river course, in irrigation canals and at Habbaniya reservoir. Thus, the total annual load falls to 11.6 million tons, with a mean runoff of 368kg/sec at Nasiriya. The suspended runoff varies seasonally in accordance with the seasonal variations of the river water discharge. Thus, the total suspended load during the flood period (December-July inclusive) is 52.84 million tons at Hit, decreasing to 11.06 million tons at Nasiriya. These amount to 96% and 95.3% of the total annual amounts at these gauges respectively. The greatest amount passes in April with 22.4 and 5.1 million tons at Hit and Nasiriya respectively, equivalent to 40.73% and 44.0% of the total annual amounts. In the low-water period (August-November inclusive) the total suspended load falls to 2.16 and 0.54 million tons at Hit and Nasiriya respectively, equal to 4% and 4.7% of the total annual amounts respectively.

In future, the suspended load will decrease due to deposition in the Turkish and Syrian reservoirs.

Table 3.3 Annual Distribution of the Euphrates Suspended Sediment for the Year with Annual Runoff Close to its Mean Value in Million Tons

Site	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total Annual	Mean Runoff kg/sec
Hit	0.94	0.88	0.33	4.07	2.64	5.39	22.40	15.70	1.76	0.55	0.22	0.06	55	1744
%	1.71	1.6	0.6	7.4	4.8	9.8	40.73	28.55	3.2	1.0	0.4	0.11	100	
Nasiriya	0.16	0.21	0.07	0.09	0.10	1.98	5.10	1.50	0.96	1.26	0.11	0.06	11.6	368
%	1.38	1.81	0.6	0.78	0.86	17.1	44.0	12.93	8.3	10.86	0.95	0.52	100	

Source: Selkhozpromexport Co., Op. Cit. Vol.1, Book 1, p64

3.2.4 HYDRAULIC STRUCTURES

As a result of discharge variations, several dams and reservoirs have been constructed, are under construction or planned on the Euphrates and Tigris rivers for regulation purposes.

3.2.4.1 The Qadisiya Dam and Reservoir

This is located upstream of Haditha (Fig.3.1). It was operated first in 1984. The total storage capacity is 8.2bcm, of which 0.7bcm is a dead storage* and 1.137bcm is accounted for by evaporation losses (Chapter 6). The surface area of the reservoir is 500km^2.

3.2.4.2 The Habbaniya Reservoir

The reservoir is a natural depression located to the south-east of Ramadi. It is used as a reservoir to regulate the flow of the Euphrates. Its total storage capacity at a water level of 51.0m is 3.28bcm, of which 0.58bcm is a dead storage and 1.09bcm potential evaporation losses. The total surface area is 426km^2. The hydraulic structures of the reservoir include three main canals, the Warrar, Dhibban and Mujarah. The Warrar canal, upstream of Ramadi barrage, is used to direct the flood water from the Euphrates to the reservoir. The Dhibban canal links the reservoir with the river to feed it during low-water period. As a result of limited storage capacity of the reservoir, the Mujarah canal was excavated to divert the surplus flood water into Abu-Dibbis

* Dead storage includes seepage losses and the amount of water which cannot be extracted from reservoirs.

depression which is located to the south-west of Habbaniya. Its total storage capacity at a water level of 40.5m is 26bcm. This is not utilized due to its very high salinity which ranges from 5640-7400PPM*(9), or an EC value of 8.8-11.54mmhos/cm (section 3.6).

* 1g/L = 1000mg/L = 1000PPM = 1.56mmhos/cm (at 25°C).
(In the case of water, specific conductance is related to the concentration of ions and the prevailing temperature.)

3.3 THE TIGRIS RIVER

The Tigris river rises in the mountainous area of south-eastern Turkey where the elevation ranges from 1000 to 1500m. It flows southwards and at a short distance from Diyar Bakir it turns to the east where it is joined by three main tributaries, the Batman, the Garzan and the Botan (Fig.3.1). These flow from a mountainous area where the elevation ranges from 2000 to 4000m. After the Botan confluence, the river swings to the south-east, approaching the Iraqi border at the village of Faish-Khabour(10).

In Iraq, the river continues to flow south-eastwards, traversing the foothill ranges through gaps or gorges, where the Saddam dam has been constructed and the Fatha dam has been proposed. Here the river valley is narrow and deep, but it finally widens when it enters the Mesopotamian Plain at Balad. The average stream gradient upstream of Balad is 65cm/km, decreasing downstream to 6cm/km(11). Therefore, meandering and braiding is characteristic of the river in this area. Its average channel width is about 160m.

Five main tributaries join the Tigris river from the left bank between the Turkish-Iraqi border and 31km downstream of Baghdad. These are, the Khabour, Greater Zab, Lesser Zab, Adhaim and Diyala (Fig.3.1).

The Khabour flows from the mountainous area along the border between Turkey and Iraq where the elevation reaches more than 3350m. It runs south-west and joins the Tigris near the village of Faish-Khabour(12). Its total basin area is 6438km^2 (3718km^2 in Turkey and 2720km^2 in Iraq). Its total length is 160km (Table 3.4). The mean annual long term discharge is 68 cumecs (2.14bcm), of which 88% passes during the flood period (December-July inclusive) and 12% during the low-water period (August-November inclusive). In addition to the seasonal variations, there is also variation from year to year. The discharge increased to 121 cumecs (3.81bcm) in 1969 and fell to 38 cumecs (1.2bcm) in 1961 (Table 3.5 and Fig.3.3).

The Greater Zab tributary has its source in the Turkish-Iraqi mountainous area which rises to an altitude of 4636m. It is formed from five main streams which join upstream of Bekme gorge (Iraq), where Bekme dam is under construction. Further downstream the river flows south-westward and is joined by several other streams. The largest of these are, the Bastora and Khazir which join the river from the left and right banks respectively. The total length of the river from its source to its junction with the Tigris 49km downstream of Mosul(13) is 392km. Its total basin area is 25810km^2, of which 9210km^2 is located in Turkey and 16600km^2 in Iraq. Its mean annual long term discharge at Eski-Kelek is 424 cumecs (13.4bcm), of which 87.3% flows in the flood period and 12.7% in the

Table 3.4 Distribution of the Basin Areas and Lengths of the Tigris Tributaries

River	Basin Area(km^2)(1)				Length(km)(2)
	Turkey	Iraq	Iran	Total	
The Khabour	3718	2720	-	6438	160
The Greater Zab	9210	16600	-	25810	392
The Lesser Zab	-	15975	5500	21475	400
The Adhaim	-	13000	-	13000	230
The Diyala	-	24072	7824	31896	386

Sources: (1) Kettaneh, M.S., et al, Op. Cit., pp17-19

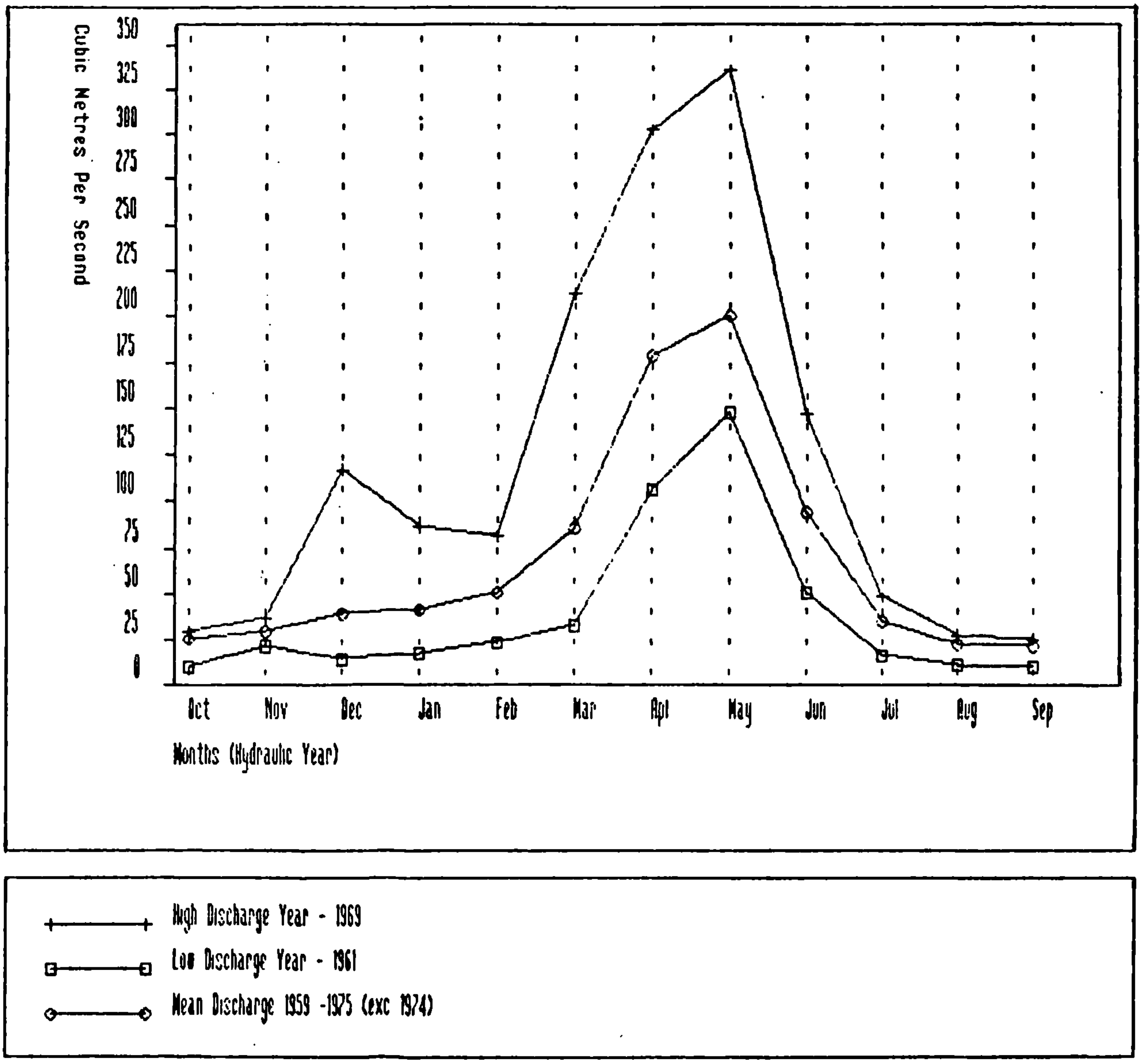
(2) Al-Kholy, F.H., Op. Cit., pp108-145

Table 3.5 Mean Monthly and Annual Water Discharges of the Tigris Tributaries in Cumecs

River Site	Period of Observation	Characteristic Year	Months												Mean Annual	
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Cumecs	(bcm)
Khabour at	1959-73 & 75	Mean for period	25	29	39	41	50	85	178	199	93	34	22	21	68	2.144
Zakho	1969	Wet year	29	37	116	86	81	212	302	335	146	48	27	25	121	3.81
	1961	Dry year	10	21	14	17	23	32	106	147	50	16	11	10	38	1.2
Greater Zab at	1944-75	Mean for period	141	171	216	258	371	654	1011	1019	609	313	183	140	424	13.4
Eski-Kelek	1969	Wet year	169	308	836	604	554	1650	1780	1630	698	352	228	180	749	23.6
	1961	Dry year	84	191	146	175	278	348	834	877	462	192	102	91	315	9.93
Lesser Zab at	1960-75	Mean for period	299	194	212	210	230	238	228	200	164	211	301	287	231	7.3
Altun Kupri	1969	Wet year	263	232	292	359	572	820	1110	772	421	573	640	478	544	17.14
	1961	Dry year	230	243	119	155	176	117	107	75	83	168	204	239	160	5.0
Adhaim at	1945-75	Mean for period	2	17	29	48	46	75	56	21	4	2	1	1	25	0.8
Injana	1969	Wet year	0	19	64	168	71	109	170	45	6	3	1	2	55	1.73
	1960	Dry year	2	1	2	27	6	8	10	1	1	1	0	1	5	0.16
Diyala at	1962-75	Mean for period	133	145	150	179	188	325	414	288	154	144	151	150	202	6.4
Discharge Site	1969	Wet year	145	170	191	316	330	839	1500	844	307	277	293	196	450	14.2
	1960	Dry year	38	53	58	90	69	73	115	86	33	14	14	14	55	1.73

Source: Ministry of Irrigation, Directorate General of Irrigation, Discharges for Selected Gauging Stations in Iraq, 1976, Op. Cit., pp9, 22-23, 26-28, 32-33, 40-41

Fig.3.3:Mean Monthly Discharge Variations for the Khabour River at Zakho (Selected Years)



low-water period. Furthermore, the annual discharge varies from year to year. Examples occurred in 1969 and 1961, amounting to 749 cumecs (23.6bcm) and 315 cumecs (9.93bcm) respectively (Table 3.5 and Fig.3.4).

The Lesser Zab rises in the western mountainous area of Iran at an altitude of about 3200m. It is formed from several streams which join together upstream of Dokhan gorge in Iraq, where the Dokhan dam has been constructed. Downstream of this point the river flows south-westwards and joins the Tigris river 35km downstream of Shargat[14]. Its total basin area is 21475km^2 (15975km^2 in Iraq and 5500km^2 in Iran). Its total length is 400km (Table 3.4). The mean annual long term discharge, regulated by the Dokhan reservoir, is 231 cumecs (7.3bcm), increasing in wet years such as 1969 to 544 cumecs (17.14bcm) and falling in dry years such as 1961 to 160 cumecs (5.0bcm) (Tables 3.5 and Fig.3.5).

The Adhaim tributary rises from the foothill region in Iraq. It forms from three main streams which are joined upstream of Injana. Further downstream it flows south-westwards and joins the Tigris 15km downstream of Balad[15]. Its total basin area is 13000km^2 and its length is 230km. The mean annual long term discharge at Injana is 25 cumecs (0.8bcm). This fluctuates from year to year. For instance, it increased to 55 cumecs (1.73bcm) in 1969 and decreased to 5 cumecs (0.16bcm) in 1960 (Table 3.5 and Fig.3.6).

Fig.3.4: Mean Monthly Discharge Variations for the Greater Zab at Eski Kelek (Selected Years)

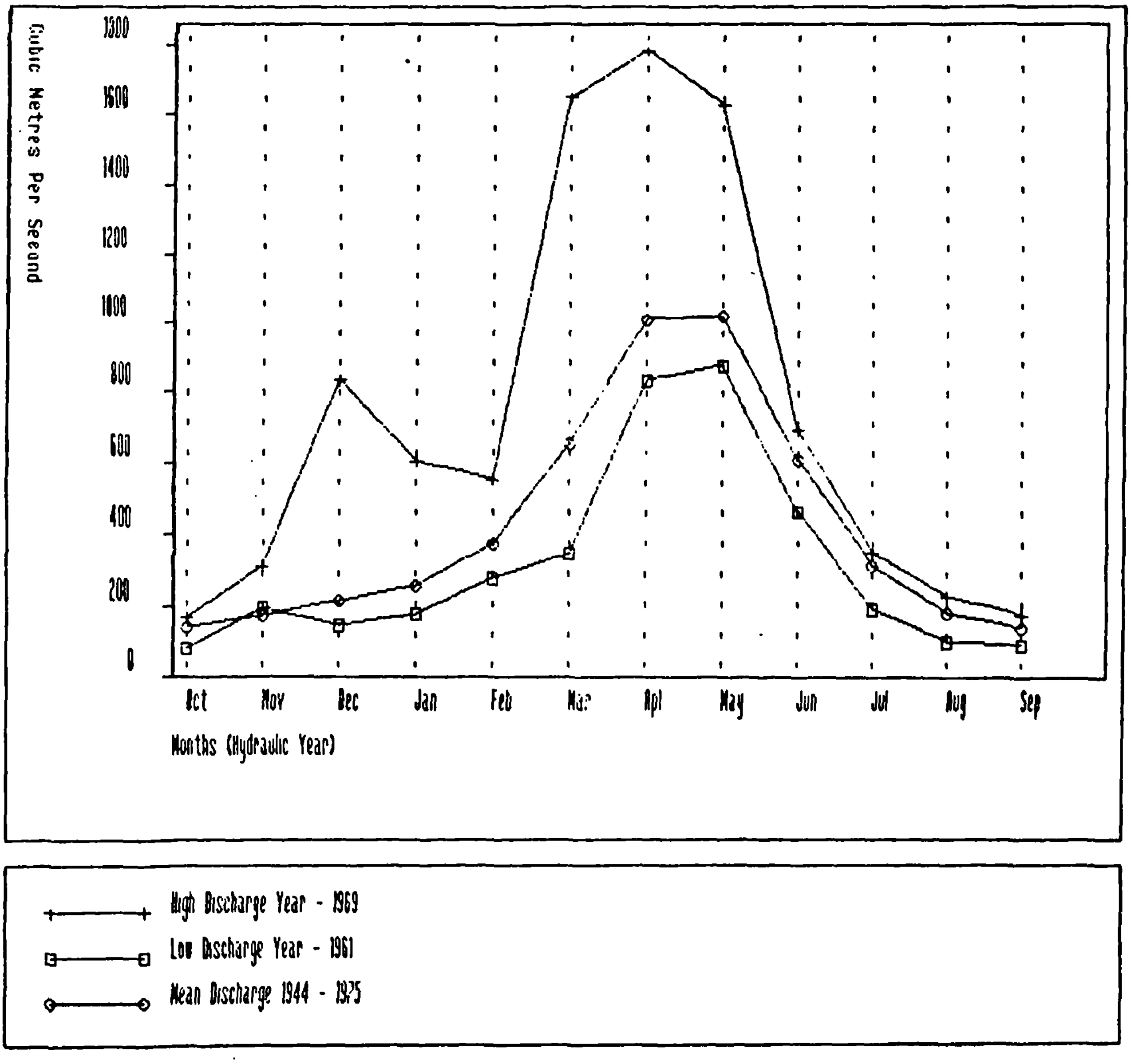


Fig.3.5: Mean Monthly Discharge Variations for the Lesser Zab River at Altun Kupri (Selected Years)

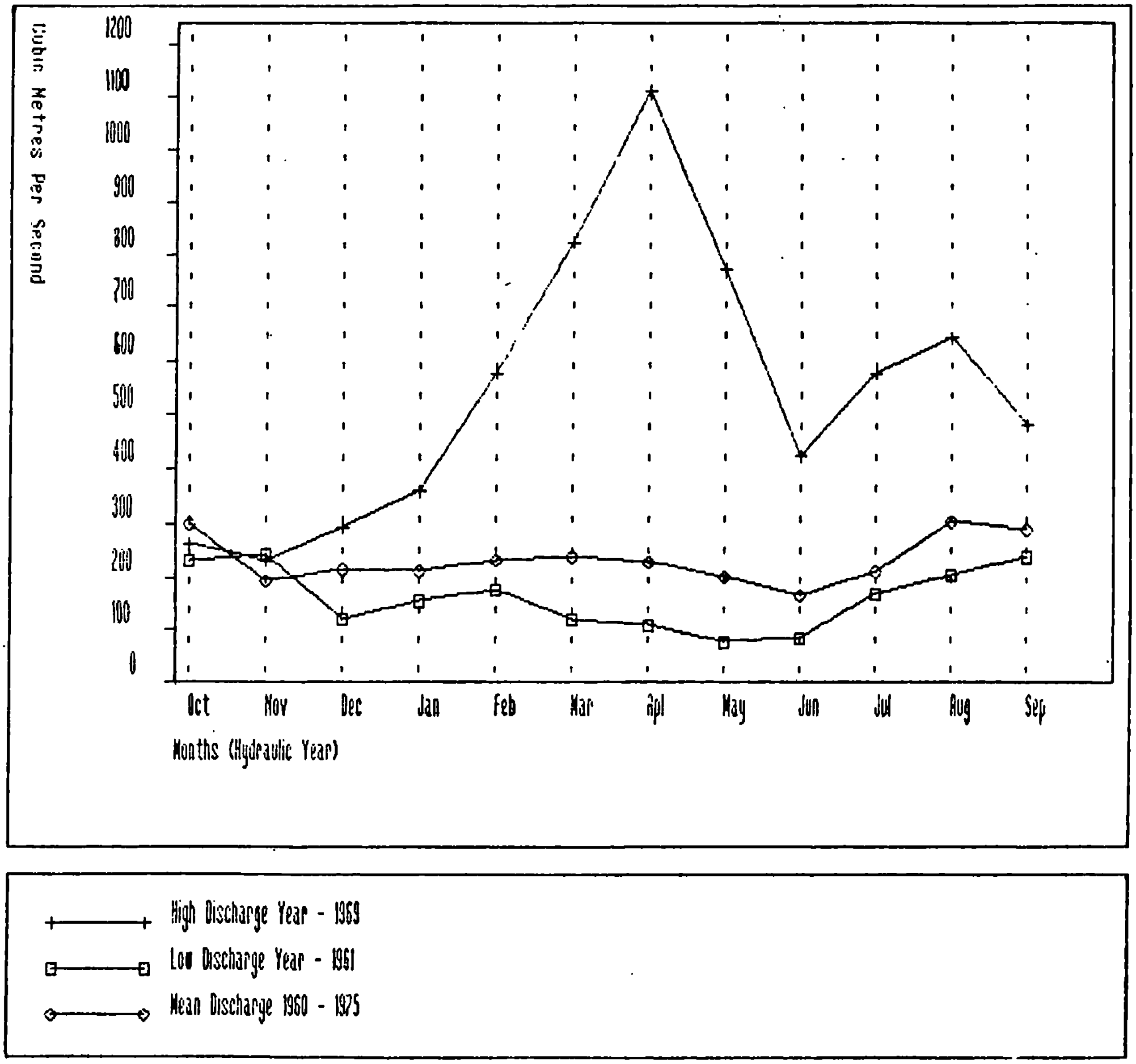
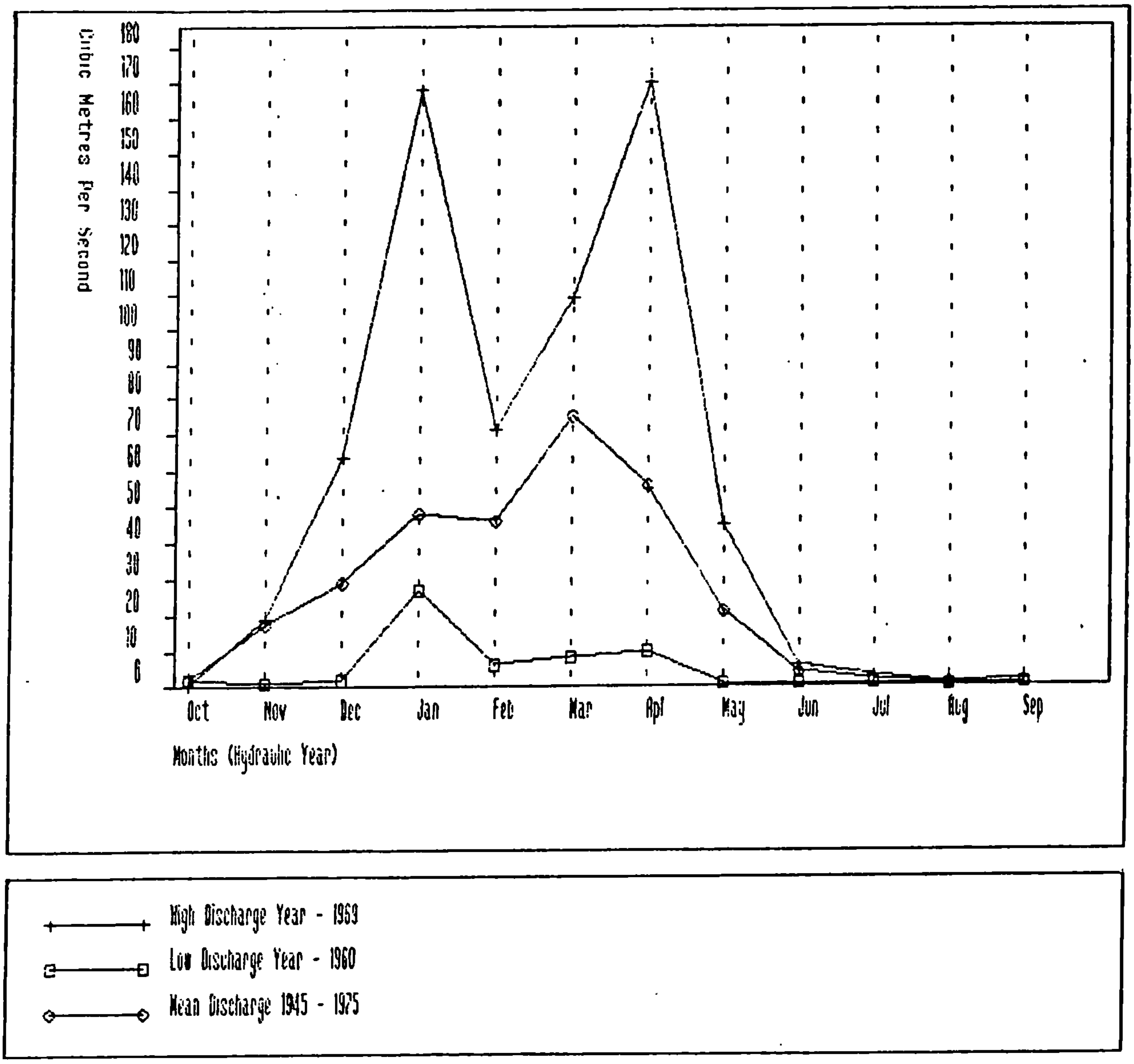


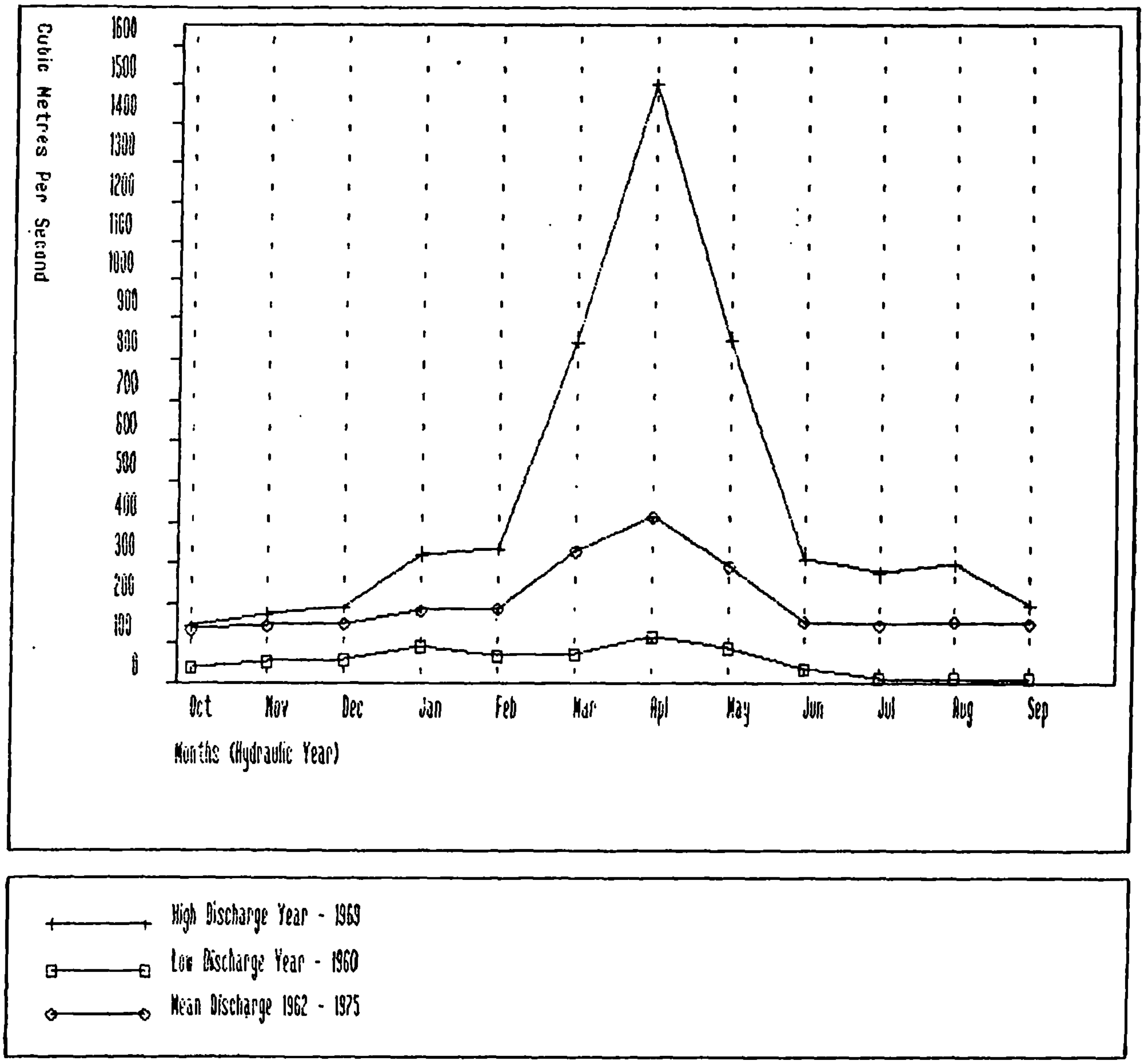
Fig.3.6: <u>Mean Monthly Discharge Variations for the Adhaim River at Injana (Selected Years)</u>



The Diyala forms from two main streams, the Serwan and Tangrow. The first rises from the western mountainous area in Iran at an altitude ranging from 2500-3000m. The Tangrow originates in Iraq and joins the Serwan just upstream of Derbendi Khan gorge (Iraq), where Derbendi Khan dam has been constructed. Further downstream the river flows south-westwards and joins several other streams. In the lower stretch six irrigation canals have been constructed at the head of the Diyala barrage[16]. The total length of the river from its source to its confluence with the Tigris 31km downstream of Baghdad is 386km. Its basin area is 31896km^2 (24072km^2 in Iraq and 7824km^2 in Iran). Its mean annual long term discharge, regulated by the Derbendi Khan reservoir, is 202 cumecs (6.4bcm), increasing in wet years such as 1969 to 450 cumecs (14.2bcm) and decreasing in dry years such as 1960 to 55 cumecs (1.73bcm) (Table 3.5 and Fig.3.7).

At a point 308km downstream of Baghdad the Kut barrage has been constructed to lift water for Gharraf and Dujaila irrigation canals which leave the right bank of the river. Some 85km downstream of Kut the Musandak Escape is located on the right bank to divert surplus flood water into the Qurna marsh. Further downstream in the Amara area, several irrigation canals branch from the river. These are the Butara, Tabar, Mujar Al-Kabir from the right bank and Sa'ad, Musharah, Kahla and Machriya from the left bank. In this

Fig.3.7: Mean Monthly Discharge Variations for the Diyala River at Discharge Site (Selected Years)



section of the river, these canals take the largest amount of flow and terminate at the Qurna and Huwaiza marshes. Therefore, the river is reduced to its smallest size at Qulat Saleh. Further downstream several streams from the Qurna and Huwaiza marshes join the river. At Qurna the Tigris joins the Euphrates river forming the Shatt Al-Arab(17).

The total basin area of the Tigris river is 471606km^2, of which 57614km^2 is located in Turkey, 834km^2 in Syria, 253000km^2 in Iraq and 160158km^2 in Iran. These areas account for 12%, 0.2%, 54% and 34% of the total basin area respectively. The total effective area is 271843km^2. This is distributed as follows: 57614km^2 (21%) in Turkey; 834km^2 (0.3%) in Syria; 83237km^2 (31%) in Iraq; and 130158km^2 (48%) in Iran. The total length of the river from its source at Diyar Bakir in Turkey to Qurna is 1658km, of which 300km is in Turkey and 1358km in Iraq (Table 3.1).

3.3.1 <u>WATER DISCHARGE</u>

Table 3.1 indicates that the most effective areas for the production of water in the Tigris river basin are located in Turkey and Iraq. These provide the river with 51% and 39% respectively of the total annual water potential 1541 cumecs (49.0bcm)). Iran is less important as it contributes only 10% of the total annual water potential. However, the mean annual water discharge of the Tigris river at Tusan, close to the Turkish-Iraqi border, is 659 cumecs (20.8bcm). This almost all comes from Turkey. Further downstream, the mean annual discharge increases to 1314 cumecs (41.5bcm), due to additional water from the largest tributaries, the Greater Zab which provides 424 cumecs (13.4bcm) and the Lesser Zab which contributes 231 cumecs (7.3bcm) (Tables 3.5 and 3.6). These aggregate to 42.2% of the total annual water potential. Downstream of Samarra the mean annual discharge falls to 1036 cumecs (32.63bcm) as a result of water diversion to the Tharthar reservoir and that extracted for irrigation. A further increase to 1224 cumecs (38.6bcm) occurs downstream of Baghdad. This results from input from the Adhaim, 25 cumecs (0.8bcm) and Diyala, 202 cumecs (6.4bcm). Thus, the main Tigris tributaries, the Greater Zab, Lesser Zab, Adhaim and Diyala contribute 882 cumecs (27.9bcm) or 57% of the total annual water potential.

Downstream of Baghdad, the mean annual discharge decreases considerably to 837 cumecs (26.4bcm) below Kut, 105 cumecs (3.31bcm) at Amara and 26 cumecs (0.82bcm) at Qulat Saleh. These are equivalent to 54%, 6.8% and 1.7% respectively of the total annual water potential. This is attributed to the following:

1. Water intake by several irrigation canals.
2. Water losses through seepage and evaporation along the river course. These are evaluated at 221.2

Table 3.6 Mean Monthly and Annual Water Discharges of the Tigris River at Selected Gauges in Cumecs

Period of Observation	Characteristic Year	Months												Mean Annual	
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Cumecs	(bcm)
	At Tusan														
1959-75	Mean for period	180	269	483	563	676	1200	1700	1540	691	302	167	131	659	20.8
	Wet year (1969)	234	388	1440	1580	1110	3010	2840	2620	928	516	291	248	1267	39.9
	Dry year (1961)	129	192	174	321	374	479	1040	1020	416	166	112	98	377	11.9
	Downstream Samarra														
1956-78	Mean for period	450	524	742	840	1135	1592	2052	2056	1342	731	525	442	1036	32.63
	Wet year (1969)	478	602	1473	1291	1474	1594	1375	2059	2234	1176	888	642	1273	40.1
	Dry year (1961)	331	529	444	547	727	759	1580	1859	761	452	345	352	724	22.81
	Downstream Baghdad														
1956-80	Mean for period*	525	624	886	1027	1297	1922	2515	2377	1505	837	630	545	1224	38.6
	Wet year (1969)**	561	734	1881	1996	2210	2939	3710	3494	2927	1707	1303	941	2034	64.0
	Dry year (1961)***	398	706	550	764	828	805	1565	1966	822	454	325	336	792	25.0
	Downstream Kut														
1956-78	Mean for period	284	261	376	525	840	1451	2022	2142	1144	447	301	250	837	26.4
	Wet year (1969)	376	326	1150	1260	1510	1800	2370	2430	2120	1050	751	592	1311	41.3
	Dry year (1961)	281	474	237	449	420	355	1100	1660	477	154	170	200	498	15.7

Contd.

Table 3.6 Contd.

Period of Observation	Characteristic Year	Months												Mean Annual	
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Cumecs	(bcm)
	At Amara														
1950-78	Mean for period	53	49	62	85	114	161	205	211	146	72	50	46	105	3.31
	Wet year (1969)	53	49	144	174	186	196	235	224	213	142	103	79	150	4.73
	Dry year (1961)	59	80	50	71	65	57	140	196	80	32	36	39	75	2.4
	At Qulat Saleh														
1950-78	Mean for period	16	15	18	22	27	36	45	47	35	20	15	14	26	0.82
	Wet year (1969)	14	13	41	54	62	67	105	98	80	46	31	24	49	1.54
	Dry year (1961)	15	18	13	18	17	16	32	50	20	11	11	11	19	0.6
	At Qurna														
1977-78	Mean for period	71	75	106	158	200	241	297	342	362	315	190	126	207	6.5

Sources: Ministry of Irrigation,Discharges for Selected Gauging Stations in Iraq, 1976,Op. Cit.,pp11, 35-36, 40-41, 45-46
Ministry of Irrigation (unpublished data)
Selkhozpromexport Co.,Op. Cit.,Vol.1, Book 1, 1975 pp55-56
Polservice Co.,Op. Cit.,Vol.VII, Part A, 1980, p57

* Including the Tigris mean water discharge at Baghdad (1956-80), plus the Diyala at discharge site (1962-75)

** Including the Tigris mean water discharge (1969), plus the Diyala (1969)

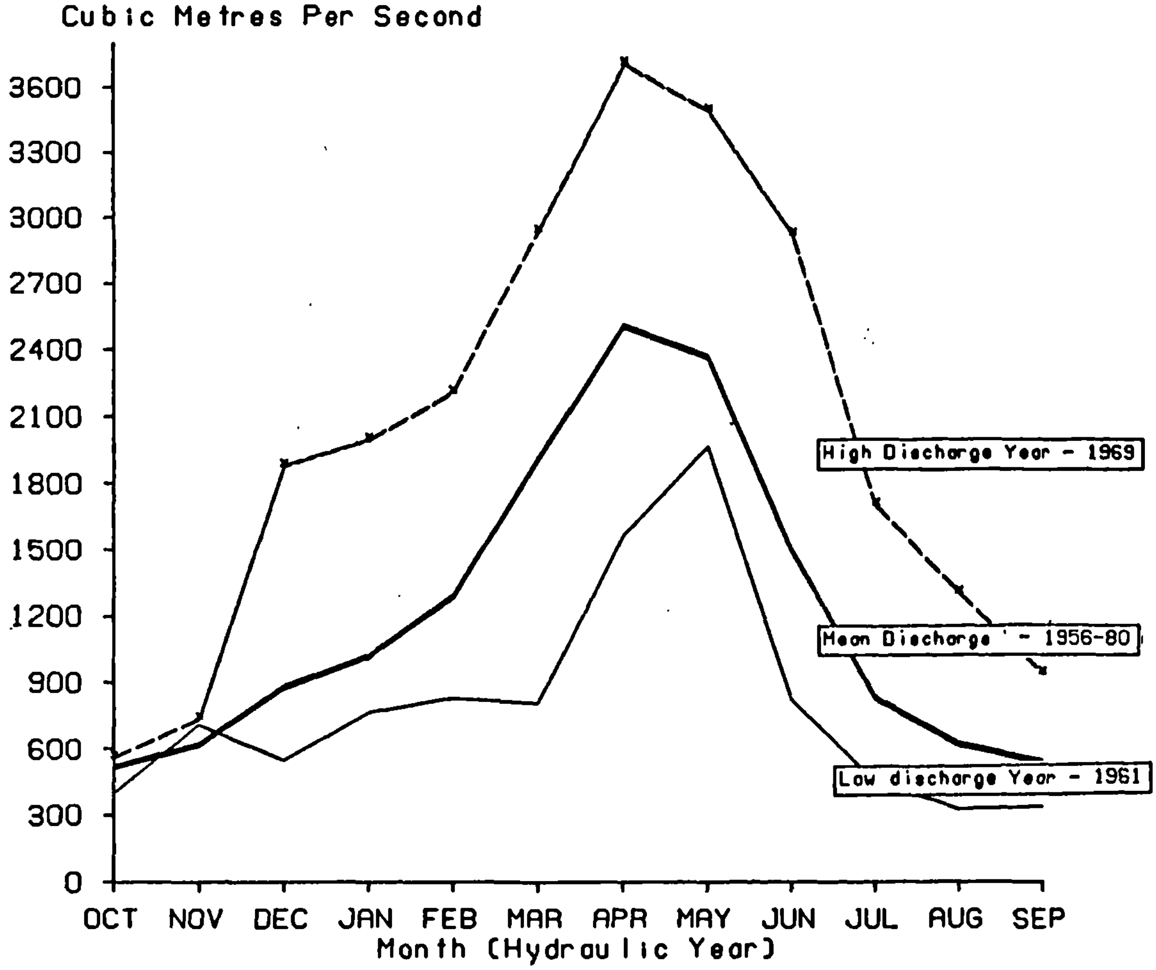
*** Including the Tigris mean water discharge (1961), plus the Diyala (1960) cumecs (6.97bcm) and 17.4 cumecs (0.55bcm) respectively (Chapter 6).

At Qurna the mean annual discharge increases to 207 cumecs (6.5bcm). This is due to water received from Qurna marsh through eight canals with a total annual discharge of 57 cumecs (1.8bcm) and from the Huwaiza marsh through the Rotah and Kassara streams with a total discharge of 122 cumecs (3.8bcm)[18]. Thus, the annual water discharge from the marshes provides 87% of the Tigris mean annual discharge at Qurna. This affects considerably the water quality of the Tigris and Shatt Al-Arab, resulting in very high salinity (section 3.5).

3.3.2 ANNUAL WATER REGIME

The annual water regime of the Tigris is similar to that of the Euphrates river. Thus, the flood period (December-July inclusive) mean monthly water discharge downstream of Baghdad is 1546 cumecs (32.5bcm) or 84% of the total annual runoff based on the period (1956-80). This is 1224 cumecs (38.6bcm) Table 3.6 and Fig.3.8. The greatest runoff occurs in April-May, with a mean of 2446 cumecs (12.9bcm), 33.4% of the total annual discharge. Further downstream the flood runoff is considerably decreased as a result of water intake by several irrigation canals along the Kut-Amara stretch. Thus, the mean monthly runoff falls to 1118.4 cumecs (23.5bcm) downstream of Kut, 132 cumecs (2.8bcm) at Amara and 31.3 cumecs

Fig.3.8: Mean Monthly Discharge Variations for the Tigris River Downstream of Baghdad



(0.7bcm) at Qulat Saleh. These represent 72.3%, 8.6% and 2.2% of the total flood runoff downstream of Baghdad respectively. The highest runoff at these gauges occurs in April-May, with a mean of 2082 cumecs (11.0bcm) downstream of Kut, 208 cumecs (1.0bcm) at Amara and 46 cumecs (0.24bcm) at Qulat Saleh. These constitute 41.7%, 30.2% and 29.3% of the total annual runoff at these gauges respectively.

At Qurna, the mean monthly flood discharge rises to 253 cumecs (5.3bcm) or 16.3% of the total flood discharge downstream of Baghdad. This results from water received from Qurna and Huwaiza marshes. The highest runoff takes place in May-June, with a mean of 352 cumecs (1.9bcm), equivalent to 29.2% of the total annual discharge at this gauge.

The low-water period (August-November inclusive) mean monthly discharge downstream of Baghdad is 581 cumecs (6.0bcm), or 15.5% of the total annual discharge. This decreases southwards to 274 cumecs (2.9bcm) downstream of Kut, 49.5 cumecs (0.5bcm) at Amara and 15 cumecs (0.2bcm) at Qulat Saleh. These account for 11%, 15% and 24.4% of the total annual discharge at these gauges respectively. The extreme lowest discharge downstream of Kut, Amara and Qulat Saleh occurs in September with a mean of 250 cumecs (0.65bcm), 46 cumecs (0.12bcm) and 14 cumecs (0.04bcm) respectively.

At Qurna the low-water mean monthly discharge increases to

116 cumecs (1.2bcm) or 18.5% of the total annual discharge. This is due to water received from the marshes. The lowest discharge occurs in October with a mean of 71 cumecs (0.2bcm).

In addition to seasonal changes, there are also variations from year to year. For example, in 1969 the mean annual discharge downstream of Baghdad rose to 2034 cumecs (64.0bcm), compared to the mean long term discharge (1956-80) which is 1224 cumecs (38.6bcm). While in 1961 the mean annual discharge fell to 792 cumecs (25bcm). As a result of that, several dams and reservoirs were constructed to combat the problem.

3.3.3 SUSPENDED SEDIMENT

Table 3.7 shows that the total annual suspended load of the Tigris river at Mosul is 51 million tons, with a mean runoff of 1617kg/sec. This increases considerably downstream and reaches 107.4 million tons, with a mean of 3406kg/sec at Fatha. This results from the additional suspended load brought by the Greater Zab and Lesser Zab tributaries, with a total annual load of 54 million tons, or 50.3% of the total annual amount at Fatha (Table 3.8). Downstream of Baghdad, the total annual load falls to 45.82 million tons[19], or 42.7% of that at Fatha. This decreases considerably southwards to a few million tons at its confluence with the Euphrates at Qurna.

Table 3.7 Annual Distribution of the Tigris River Suspended Sediment for the Year with Annual Runoff Close to its Mean Value in Million Tons

Site	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total Annual	Mean Runoff kg/sec
Mosul	0.04	0.95	0.58	1.32	3.12	7.59	20.6	15.7	1.06	0.12	0.04	0.02	51	1617
%	0.08	1.86	1.14	2.59	6.12	14.9	40.4	30.8	2.1	0.24	0.08	0.04	100	
Fatha	0.08	0.91	0.74	1.79	6.02	18.2	45.7	30.6	2.59	0.50	0.18	0.06	107.4	3406
%	0.07	0.85	0.69	1.67	5.61	16.95	42.6	28.5	2.41	0.47	0.17	0.06	100	

Source: Selkhozpromexport Co. Op. Cit. Vol.1, Book 1 pp66

Table 3.8 Annual Sediment Runoff Of the Tigris Tributaries for the Year with Annual Runoff Close to Their Mean Value in Million Tons

River	Total Annual	Mean Runoff kg/sec
Greater Zab at Eski Kelek	35.0	1100
Lesser Zab at Altun Kupri	19.0	602
Diyala at Derbendi Khan	10.5	333

Sources: Al-Sahaf M. Pollution Control and Water Resources of Iraq, Baghdad, Al-Hurria Printing House, 1976 p129

Selkhozpromexport Co. Op. Cit. Vol.1, Book 1 p67

The suspended load varies seasonally according to the seasonal variations of the river water discharge. Therefore, the total suspended load during the flood period (December-July inclusive) at Fatha is 106.14 million tons, equivalent to 98.83% of the total annual amount. The greater quantity passing during April and May is 76.3 million tons, or 71% of the total annual load at this gauge. During the low-water period, the suspended load falls to 1.26 million tons, about 1.2% of the total annual amount. The lowest amount, 0.06 million tons, occurs in September.

3.3.4 HYDRAULIC STRUCTURES

3.3.4.1 Saddam Dam and Reservoir

This was constructed upstream of Mosul city and became operational in 1985 (Fig.3.1). Its total storage capacity at normal water level of 329m is 10.74bcm, of which 1.07bcm is dead storage and potential evaporation losses account for 0.7bcm (Chapter 6). The reservoir water surface area is 371km^2[20].

3.3.4.2 The Bekme Dam and Reservoir

This is under construction on the Greater Zab. The seven year contract, worth $1,600 million, has been undertaken in a joint venture by Enka of Turkey and Hidrogradnja of Yugoslavia. The contract was signed 29 September 1986. It will be the second largest reservoir in the country after the Tharthar, with a total storage capacity of 33.0bcm[21].

3.3.4.3 The Bakerman Dam and Reservoir

This is planned for the Khazir (Greater Zab tributary). Its total storage capacity will be 0.375bcm, of which 0.0195bcm will be a dead storage. The water surface area will be 150km^2.

3.3.4.4 The Dokhan Dam and Reservoir

This has been constructed on the Lesser Zab tributary. Its total storage capacity at water level of 511m is 6.8bcm; of this 0.7bcm is a dead storage, while potential evaporation losses amount to 0.332bcm. The reservoir water surface area is 270km^2.

3.3.4.5 The Dibbis Dam

The dam was constructed on Lesser Zab tributary, downstream of Altun Kupri, to divert water through Kirkuk canal to the Kirkuk irrigation project. The total storage capacity is only 0.05bcm.

3.3.4.6 The Adhaim Dams and Reservoirs

The Damer gobow and Basra dams, with a total storage capacity of 1.35bcm, are planned to be constructed on the Adhaim tributary.

3.3.4.7 The Derbendi Khan Dam and Reservoir

This has been constructed on the Diyala tributary and has a total storage capacity at water level of 485m of 3.0bcm, 0.5bcm of which is a dead storage and 0.149bcm potential evaporation losses. Its surface area is 121km^2.

3.3.4.8 The Hamrian Dam and Reservoir

This has a total storage capacity of 3.95bcm at water level of 107.5m and is constructed on the Diyala tributary. Of the total amount, 1.5bcm is dead storage and 1.0bcm comprises potential evaporation losses. The reservoir surface water area is 440km^2.

3.3.4.9 The Fatha Dam and Reservoir

This is proposed for the Tigris at Fatha gorge. Its total storage capacity at water level of 169m will be 14.0bcm, of which 4.0bcm is a dead storage(22).

3.3.4.10 The Tharthar Reservoir

It occupies a natural depression located to the north-west of Baghdad. It was initially used in 1956 to control Tigris flood water through a diversion canal upstream of the Samarra barrage. Its total storage capacity at a water level of 60m is 72.8bcm, of which 29.3bcm is a dead storage(23) and 6.4bcm evaporation losses. The total surface area is 2710km^2. The reservoir water has a very high salinity of 1600PPM (an EC value of 2.5mmhos/cm) (section 3.6).

In future, after improving water quality, the reservoir will be used to augment the Euphrates and Tigris rivers. It is connected with the Euphrates through the Tharthar-Euphrates canal. A second Tharthar-Tigris canal is under construction(24).

3.4 THE SHATT AL-ARAB

The Shatt Al-Arab begins at Qurna at the confluence point of the Euphrates and Tigris rivers. It runs south-eastwards and flows into the Arabian Gulf downstream of Fao (Fig.3.9).

In the stretch from Qurna to Maqil (69.3km), three tributaries flow from the Qurna and Huwaiza marshes to join the river. These are the Swaib from the left bank and the Shafi and Garmat Ali from the right bank. The average river channel width in this section is about 200m.

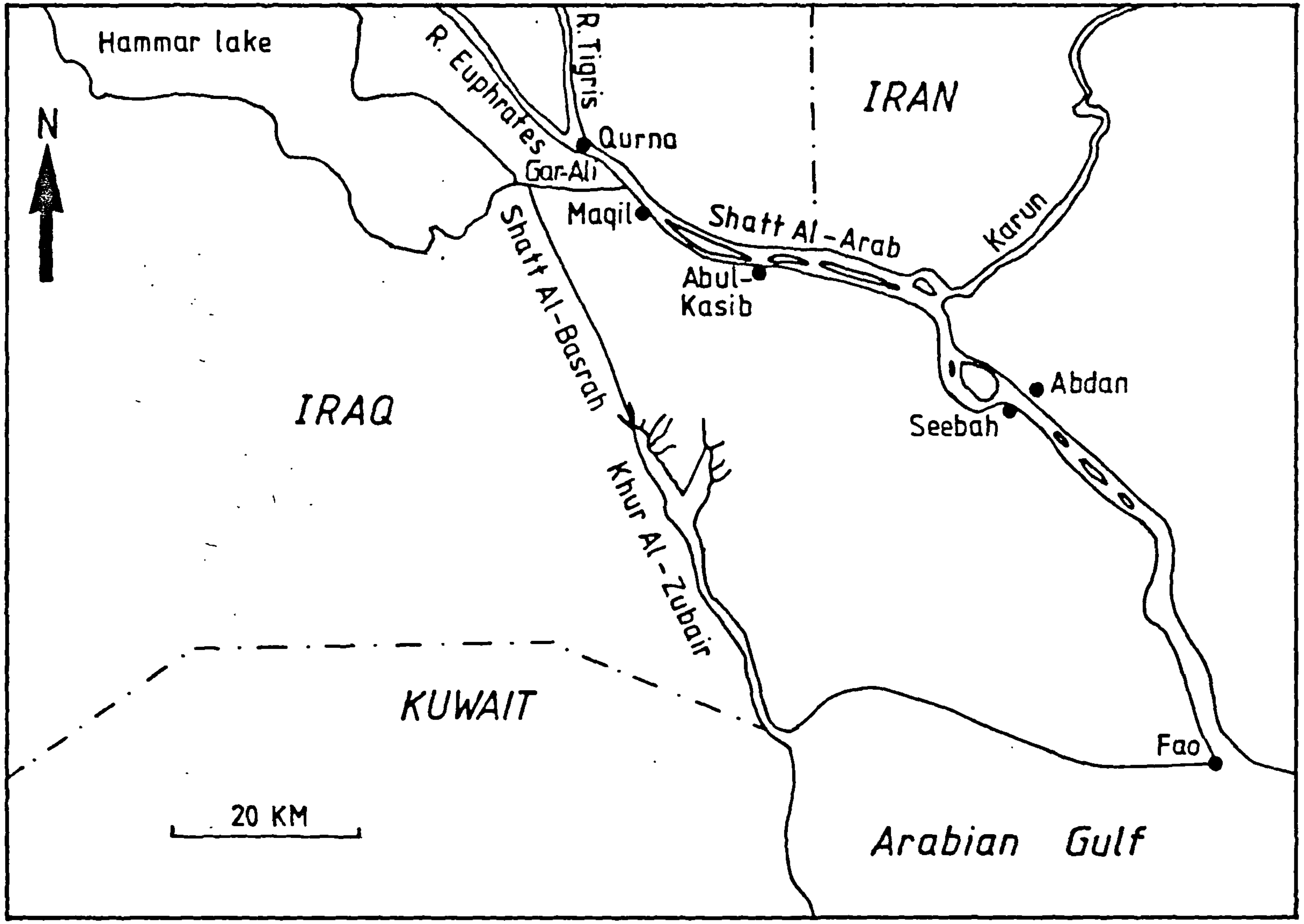
In the Maqil-Fao section (108km), the Karun tributary joins the river from the left bank 70km upstream of Fao. It flows from the Zagros mountains. Its total basin area of 63200km^2 lies entirely in Iran. Downstream of the Karun, the Shatt Al-Arab becomes wider. Its width ranges from 260 to 700m.

The total length of the river from Qurna to Fao is 177.3km. It is tidal throughout its length. The total basin area is 808000km^2(25).

3.4.1 WATER DISCHARGE

The mean annual discharge of the river at Qurna (1977-78) is 487 cumecs (15.3bcm), 57.5% from the Euphrates and 42.5% from the Tigris (Table 3.9). Downstream, at Maqil, the mean

Fig. 3.9 : Schematic Map of the Shatt Al-Arab



Source : Razoska, J., Euphrates and Tigris, Mesopotamian Ecology and Destiny, London, 1980, p.83.

Table 3.9 Mean Monthly and Annual Water Discharge of the Shatt Al-Arab and its Tributaries in Cumecs

Rivers and Gauges	Months												Annual	Average
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Cumecs	(bcm)
Tigris River at Qurna (1977-78)(1)	71	75	106	158	200	241	297	342	362	315	190	126	207	6.5
Euphrates River at Qurna (1977-78)(1)	124	129	170	231	279	322	378	423	445	396	268	194	280	8.8
Swaib River (1977-78)(1)	23	24	41	73	99	125	157	185	197	171	95	57	104	3.3
Shatt Al-Arab downstream Swaib River (1977-78)(1)	224	228	315	463	577	674	815	924	969	862	562	392	584	18.4
Shafi River (1977-78)(1)	17	17	29	54	72	93	112	137	160	142	73	45	79	2.5
Garmat Ali River (1977-78)(1)	93	75	123	196	246	297	317	364	433	435	240	186	250	7.9
Shatt Al-Arab at Maqil (1977-78)(1)	330	317	495	797	916	1082	1191	1313	1506	1463	963	653	919	29.0
Karun River at the confluence with the Shatt Al-Arab (1948-60)(2)	130	170	370	410	490	910	1060	880	480	300	180	170	458	14.4

Sources: (1) Polservice Co. Op. Cit. Vol.VIII, Part A Text, Table 5.1-5.2

(2) Ibid Vol.VII, Part A p38

annual discharge increases to 919 cumecs (29.0bcm), as a result of water received from the Swaib, Garmat Ali and Shafi tributaries, with a total mean discharge of 433 cumecs (13.7bcm), or 47% of the mean annual discharge at this gauge. Further downstream, the Shatt Al-Arab is joined by its last tributary, the Karun, and the mean annual discharge rises to 1377 cumecs (43.4bcm), of which 33.3%, or 458 cumecs (14.4bcm) is supplied by this tributary.

In future, the Shatt Al-Arab water quantity and quality will be considerably affected as a result of the extensive planned irrigation projects in Turkey, Syria and Iraq (Chapters 5 and 6). In addition, Iran has planned nine dams to be constructed on the Karun for irrigation and power production. The total effective storage capacity of these will reach 19.0bcm(26).

3.4.2 ANNUAL WATER REGIME

The annual water regime of the Shatt Al-Arab is influenced by that of the Euphrates, Tigris and Karun rivers. Thus, the annual cycle of the river is similar to that of its tributaries, with a slight time lag. In other words, the flood and low-water periods take place one month later, January-August (inclusive) and September-December (inclusive) respectively.

Table 3.9 and Fig.3.10 show that the mean monthly flood runoff at Maqil is 1154 cumecs (24.2bcm), or 83.4% of the total annual discharge at this gauge. The greatest runoff occurs in June-July, with a mean of 1485 cumecs (7.8bcm), equivalent to 27% of the total annual discharge. Further downstream from Maqil, the flood water is considerably increased due to the additional water of the Karun. The mean monthly runoff rises to 1743 cumecs (36.6bcm), or 84.3% of the total annual discharge downstream of the Karun. The highest runoff occurs early in April-May, with a mean of 2222 cumecs (11.7bcm), equivalent to 27% of the total annual runoff at this point. This results from the Karun flood peak which takes place during these months.

The low-water period mean monthly discharge at Maqil is 449 cumecs (4.7bcm), or 16.2% of the total annual discharge. The lowest runoff passes in November, with a mean of 317 cumecs (0.82bcm), equivalent to 2.8% of the total annual discharge. Downstream of the Karun confluence, the mean monthly discharge during this period increases to 659 cumecs (6.9bcm), or 15.9% of the total annual discharge. The lowest runoff occurs in October, with a mean of 460 cumecs (1.23bcm), about 2.83% of the total annual discharge. Moreover, the annual river discharge varies. For example, in 1967 the mean annual discharge at Maqil rose to 1017 cumecs (32.0bcm). In 1961 the mean annual discharge fell to 398 cumecs (12.55bcm) (Table 3.10). The seasonal and annual

Fig.3.10: Mean Monthly Discharge Variations for the Shat Al-Arab at Maqil

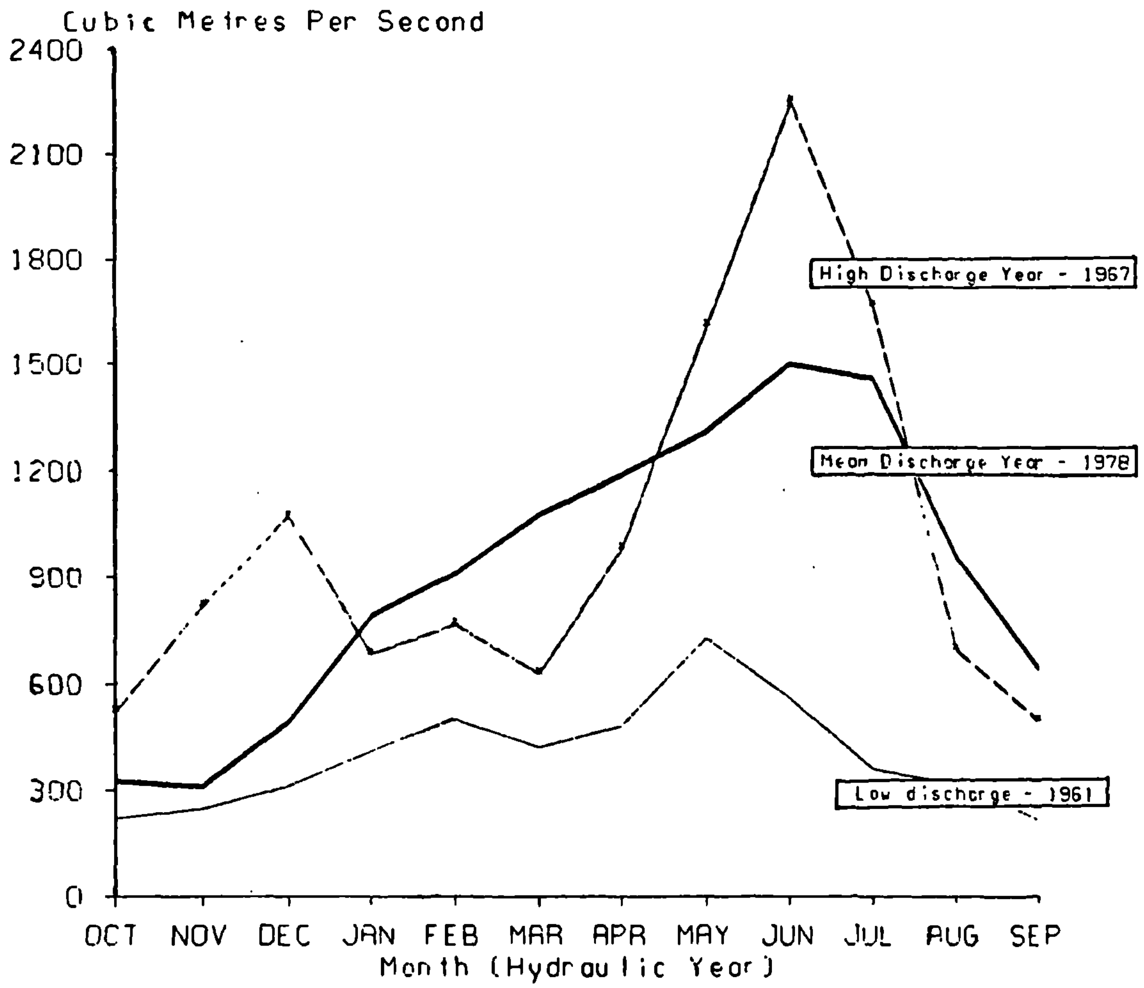


Table 3.10 Mean Monthly and Annual Water Discharge of the Shatt Al-Arab at Maqil During Wet and Dry Years in Cumecs

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean Cumecs	Annual (bcm)
Wet year 1967	520	820	1070	685	770	630	980	1610	2250	1670	700	500	1017	32.0
Dry year 1961	220	250	310	410	500	420	480	730	560	360	320	220	398	12.55

Source: Ministry of Agrarian Reform Study Report on the Shatt Al-Arab Project, Nippon Koei Co. Ltd., Tokyo, June 1972 variations affect water quality and quantity. For instance, the length of the Gulf saline wedge on the Shatt Al-Arab decreases during the flood period and increases in the low-water period. Therefore, on 27 April 1978, when the water discharge at Maqil was 1461 cumecs, a wedge of the Gulf saline water penetrated 9km upstream of Fao. On 30 August, when the water discharge was 722 cumecs, the saline wedge reached about 22km upstream of Fao[27]. This indicates that in future when the major irrigation projects in Turkey, Syria, Iraq and Iran are completed, the water quantity will considerably decrease and Gulf saline water will penetrate further upstream of Fao, influencing the river water quality.

3.4.3 SUSPENDED SEDIMENT

The suspended load of the Shatt Al-Arab is small, due to settlement in the upper reaches of the Euphrates and Tigris and also in the Qurna-Huwaiza marshes. Thus, the total annual suspended sediment load of the river at Maqil is about 4 million tons, with a mean of 123kg/sec[28]. This increases to 35 million tons downstream of the Karun confluence, with a mean of 1100kg/sec. As a result, several longitudinal islands and sedimentary bars occur in this stretch[29].

3.5 THE MARSHES

The southern part of the country, particularly in the areas of Amara, Nasiriya and Basrah, is traversed by a series of swamps and shallow lakes known by the general term of marshes. These are divided into two parts, the Qurna marsh to the west of the Tigris river and the Huwaiza to the east (Fig.3.1).

3.5.1 THE QURNA MARSH

The Qurna marsh occurs in the vicinity of Amara, Nasiriya and Basrah. It is fed by surplus water from the Euphrates and Tigris canals such as Butara, Tabar, Mujar Al-Kabir and Musandak escape canals. It discharges part of its water back to the Tigris through eight outlets at Uzair-Qurna reach, to the Euphrates through 46 culverts and to the Shatt Al-Arab by the Shafi, Omaitsh and Garmat Ali tributaries. The area and water volume fluctuate seasonally in accordance with the river discharge variations. Thus, the total area and water volume during the flood period are 9278km^2 and 11.637bcm respectively, falling, in the low-water period, to 2514km^2 and 1.212bcm respectively (Table 3.11). The total annual evaporation loss from this system is assessed as 11.2bcm, with a mean of 355 cumecs.

3.5.2 THE HUWAIZA MARSH

This marsh lies in the Amara Basrah areas. It is supplied by

Table 3.11 The Areas and Water Volumes of the Qurna and Huwaiza Marshes

Marsh	Maximum Area & Water Volume(flood period)		Minimum Area & Water Volume(low-water period)	
	Area km^2	Water Volume (bcm)	Area km^2	Water Volume (bcm)
The Qurna Marsh	9278	11.637	2514	1.212
The Huwaiza Marsh	3590	2.428	648	0.234
Total	12868	14.065	3162	1.446

Source: Polservice Co. Op. Cit., Vol.VIII, Part A, Basrah, 1979, Table 6-3 the surplus water from the Tigris left bank canals such as Musharah, Kahla and Machriya as well as from the Iranian rivers, namely the Tib and Karkheh. The outflow from this system goes to the Tigris through the Kassara and Rotah, and to the Shatt Al-Arab by the Swaib. The total area and water volume of this marsh during the flood period are 3590km^2 and 2.428bcm respectively, decreasing in low-water period to 648km^2 and 0.234bcm respectively (Table 3.11). Its total annual evaporation loss is evaluated at 3.2bcm, with a mean of 101.5 cumecs[30].

However, high evaporation losses and the disposal of the drainage saline water cause a considerable increase in salinity of the marshes, reaching an average annual figure of 2.54 at Qurna and 2.13mmhos/cm (EC value) at Huwaiza (Table 3.12). These are classified as very high or class (C4)and high (C3) respectively (Fig.3.11). This has affected the water quality of the Tigris, Euphrates lower sections and Shatt Al-Arab. Thus, it is important to control the outflow from the rivers to the marshes and from the marshes to the rivers in order to improve and maintain water quality. This will certainly take place in future as a result of increasing water demands which will diminish the outflow to the marshes. Thus, a large part of this system will dry up and only be used for flood control during wet years.

Table 3.12 Mean Monthly and Annual Water Salinity of the Qurna and Huwaiza Marshes in EC mmhos/cm at 25^{O}C (1977–78)

Outflow from the marsh	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
The Shafi River (from the Qurna marsh)	3.18	2.32	2.53	1.72	2.18	2.26	2.11	3.15	2.81	2.65	2.45	2.98	2.53
The Garmat Ali River (from the Qurna marsh)	3.07	2.81	2.71	2.42	2.65	2.26	2.34	2.65	2.04	2.51	2.31	2.82	2.55
The Rotah River (from the Huwaiza marsh)	1.51	1.51	2.59	2.7	2.42	2.18	1.72	1.25	1.05	1.06	1.23	1.47	1.72
The Swaib River (from the Huwaiza marsh)	2.11	3.62	3.4	3.34	3.28	2.81	2.18	1.95	1.72	1.84	2.0	2.03	2.52

Source: Polservice Co. Op. Cit., Vol.VIII, Part A Text Table 2.2

3.6 WATER QUALITY

The quality of irrigation water refers to its suitability for use. Good quality water has the potential to allow maximum yield under optimum soil and water management practices. However, with poor quality water, soil and cropping problems can develop and will reduce yields unless special management practices are adopted to maintain or restore maximum production capability[31]. The parameters which are used for evaluating water quality for irrigation purposes are salinity, which is measured as electrical conductivity (EC), or total dissolved solids (TDS), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), pH*, chloride and sulphate concentrations.

3.6.1 THE EUPHRATES WATER QUALITY

Table 3.13 shows the mean annual EC values (1967-69) of the Euphrates water increase southward from 0.575mmhos/cm at Al-Qaim close to the border, to 0.6 at Hit, 0.984 at Samawa, 0.976 at Nasiriya and 0.959mmhos/cm at Qurna. More recent data (1977-78) indicate that the mean EC value at Qurna increases to 1.587mmhos/cm (Table 3.14). These increases can be attributed to the following factors:

1. The increasing number of irrigation projects in the upper and middle sections of the river, which return some of their saline drainage water back to the river (Table 3.15).

* Scale which measures the concentration of hydrogen ions.

Table 3.13 Seasonal and Annual Variations of the Euphrates Water Salinity at Selected Gauges, 1967–69

Gauge	EC mmhos/cm at 25°C			1967		1968		1969	
	Low-water period	Flood period	Mean Annual	Mean Annual Discharge(bcm)	EC	Mean Annual Discharge(bcm)	EC	Mean Annual Discharge(bcm)	EC
Al-Qaim	0.731	0.444	0.575						
Hit	0.776	0.470	0.600	45.0	0.621	53.0	0.592	63.0	0.583
Samawa	1.440	0.631	0.984						
Nasiriya	1.386	0.640	0.976						
Qurna	1.276	0.765	0.959						

Source: Al-Sahaf M. Op. Cit. p194

Table 3.14 Mean Monthly and Annual Water Salinity of the Euphrates River at Qurna, 1977–78

Quality factor	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean Annual
EC mmhos/cm at 25°C	2.262	2.636	2.480	2.028	1.950	1.404	1.061	0.827	0.686	0.811	1.264	1.638	1.587

Source: Polservice Co. Op. Cit., Vol.1 Summary, Part A Table 1-9-1

Table 3.15 Water Salinity of the Existing Drainage Networks which Discharge to the Euphrates River

Drainage Canal	Discharge(cumecs)	EC mmhos/cm at 25°C
Al-Ramadi	1.5	no data
Habbaniya	1.5	no data
Towariech	0.5	14.565
Rumaitha	16.0	13.101
Hilla-Kufel	6.0	27.125
Hussainiya-Beni-Hassan	3.7	4.500
Azraqiya-Abu Akash	0.3	no data
Total	29.5	

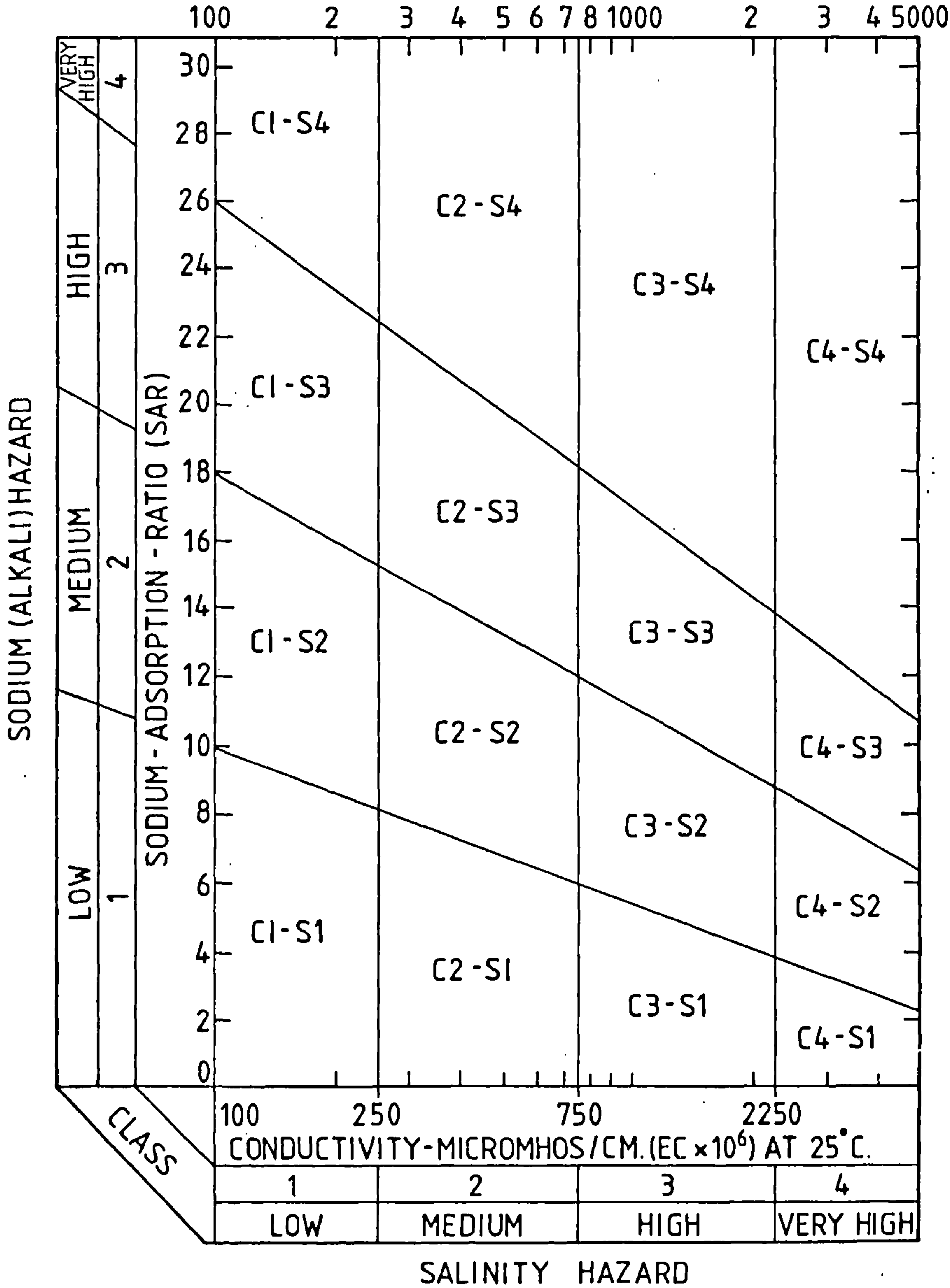
Source: Al-Mashadany M. et al Completion of the Main Drainage Network in Iraq, Higher Agricultural Council, Study No.2-2, Baghdad, Al-Ershad Press, 1978 pp16, 49-53

2. The influence of a very high saline groundwater discharge with an EC value of 15.600mmhos/cm[32].
3. High evaporation water losses along the river course.
4. The effect of very high saline water outflow from Qurna marsh (section 3.5).

According to the US irrigation water classification referenced in Todd (1970), the Euphrates water at Hit is classified to have medium salinity (C2) (Fig.3.11). This water can be used for irrigation if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control. Further downstream, at Samawa, Nasiriya and Qurna, the river water is classified as having high salinity (C3). This can be used for irrigation with adequate drainage. Special management for salinity control may be required and plants with good salt tolerance should be selected.

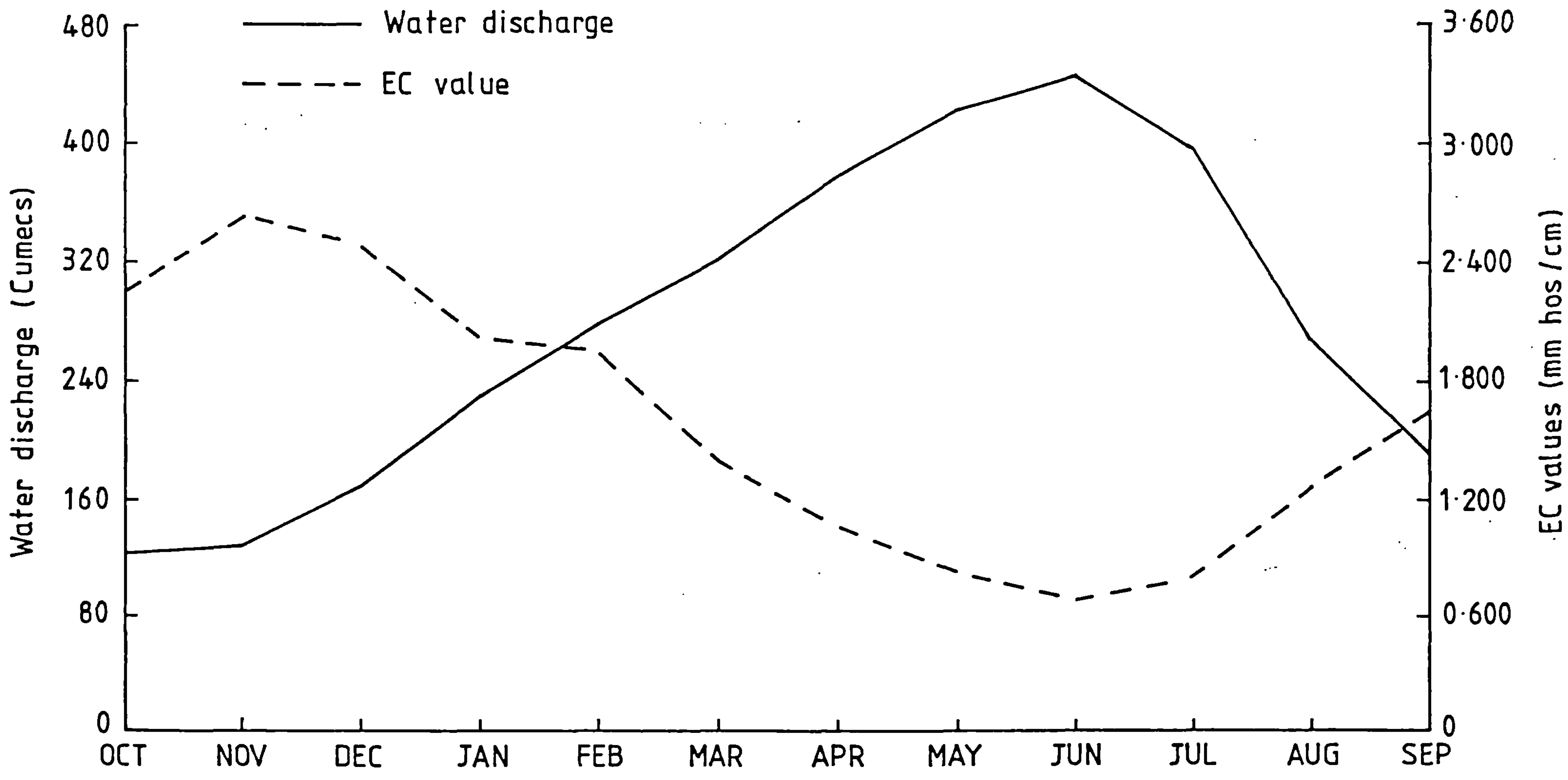
The EC values vary seasonally in accordance with the seasonal variations of the river discharge. Thus, the mean value increases in the low-water period to 0.776 at Hit, 1.440 at Samawa, 1.386 at Nasiriya and 1.276mmhos/cm at Qurna. These fall in the flood period to 0.470, 0.631, 0.640 and 0.765mmhos/cm respectively (Table 3.13 and Fig.3.12). There is also an annual variation, for instance, in 1967, when the mean

Fig.3.11: Quality Classification of Irrigation Waters



Source: U.S. Salinity Laboratory Staff, Diagnosis and Improvement of Saline and Alkali Soils, U.S.D.A. Agriculture Handbook No.60 Washington D.C., Aug., 1969, p.80.

Fig. 3.12 : Monthly Water Discharge and EC Value of the Euphrates River at Qurna (1977-78)



discharge at Hit was 45.0bcm, the mean EC value was 0.621mmhos/cm. While in 1968 and 1969, when the mean discharges were 53.0bcm and 63.0bcm respectively, the mean EC values fell to 0.592 and 0.583mmhos/cm respectively.

The sodium adsorption ratio (SAR) (Table 3.16) is assessed through the combination of sodium, calcium and magnesium salts concentration. The values are 1.3 at Al-Qaim, 1.2 at Ramadi, 1.2 at Hindiya, 2.5 at Nasiriya and 1.9me/L (milliequivalents per litre) at Qurna (Table 3.17). According to US criteria (Todd, 1970), the Euphrates water is considered to have a low sodium hazard (SI) (Fig.3.11). This water is suitable for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium which, in any case, can be avoided by adequate drainage(33).

Water quality from the viewpoint of residual sodium carbonate (RSC) (Table 3.16) which is evaluated through the combination of carbonate, bicarbonate, calcium and magnesium, is considered to be safe for irrigation of almost all crops and any arable soil as its value is less than 1.25me/L (Table 3.17).

Chloride concentration in the Euphrates water is 2.0me/L at Al-Qaim and Hit, increasing southward to 2.8, 8.7 and 3.6me/L at Ramadi, Nasiriya and Qurna respectively

Table 3.16 <u>Guides for Evaluating the Quality of Water Used for Irrigation</u>

Quality factors	Threshold concentration[1]	Limiting concentration[2]
Total dissolved solids (TDS), mg/L	500	1500
Electrical conductivity, mmhos/cm	0.750	2.250
Range of pH	7.0-8.5	6.0-9.0
Sodium adsorption ratio (SAR)[3] me/L	6.0	15
Residual sodium carbonate (RSC)[4] me/L	1.25	2.5
Chloride me/L	2.8	10.0
Sulphate me/L	4.2	21.0

Notes: (1) Threshold values at which irrigator might become concerned about water quality and might consider using additional water for leaching. Below these values, water should be satisfactory for almost all crops and almost any arable soil.

(2) Limiting values at which the yield of high-value crops might be reduced drastically, or at which an irrigator might be forced to less valuable crops.

(3) Sodium adsorption ratio is defined by the formula $SAR=Na/\sqrt{Ca+Mg/2}$ where the concentrations are expressed in milliequivalents per litre (me/L).

(4) Residual sodium carbonate is defined by the formula $(RSC)=(CO_3+HCO_3)-(Ca+Mg)$ where concentrations are expressed in me /litre. When $RSC>2.5$ probably not suitable for irrigation; 1.25-2.5 marginal; <1.25 probably safe for irrigation.

<u>Source</u>: USA, California State Water Quality Control Board, 1963: In Todd D.K. The Water Encyclopedia, Water Information Center Inc, USA, 1970 p333

Table 3.17 <u>Chemical Analysis of the Euphrates Water (1978)</u>

Site	Cations				Total	Anions				Total	Total	Total	
	Na	K	Ca	Mg	Cations	Cl	SO_4	HCO_3	CO_3	Anions	Cations & Anions	Hardness mg/L	pH
Al-Qaim	2.2/50	0.1/3.1	3.0/60	2.5/30	7.8/143.1	2.0/70	2.9/140	2.9/180	0.3/9.0	8.1/399	15.9/542.1	320	8.0
Hit	2.2/50	0.1/3.6	3.1/62	2.5/30	7.9/145.6	2.0/70	2.6/125	2.9/180	0.3/9.0	7.8/384	15.7/529.6	340	7.9
Ramadi	2.2/50	0.1/3.1	3.0/60	4.0/50	9.3/163.1	2.8/100	2.7/130	3.1/186	0.3/9.0	8.9/425	18.2/588.1	300	8.0
Hindiya	3.0/70	0.1/3.4	6.0/120	5.8/70	14.9/263.4	3.5/125	5.8/280	4.3/260	0.3/9.0	13.9/674	28.8/937.4	390	8.0
Nasiriya	7.8/180	0.1/3.6	7.0/140	12.3/150	27.2/473.6	8.7/310	10.2/490	6.9/420	0.3/9.0	26.1/1229	53.3/1702.6	650	7.9
Qurna	3.7/85.1	0.1/4.3	3.7/74	3.6/43.8	11.1/207.2	3.6/127.6	3.3/158.5	3.4/207.5	0.3/9.0	10.6/502.6	21.7/709.8	365	8.0

Notes: Measurement units of the figures presented above: numerator - me/L; denominator - mg/L

<u>Source:</u> Selkhozpromexport Co. Problems of Water Resources Conservation in Iraq, Interim Report, Baghdad, 1979 Table 12

(Table 3.17). Thus, water quality from this point is considered to be satisfactory for irrigation at Hit. Downstream of Hit, the chloride value is well below the guideline limit (Table 3.16).

The sulphate value upstream of Ramadi is regarded as satisfactory for irrigation as it ranges between 2.6-2.9me/L. Further downstream, the value ranges from 3.3 to 10.2me/L (Table 3.17). This is well below the index limit (Table 3.16) of irrigation water.

The pH concentration in the Euphrates water is regarded as satisfactory since its value ranges between 7.9-8 (Tables 3.16 and 3.17).

The total hardness* of the Euphrates water is 320mg/L at Al-Qaim, increasing southward to 340, 650 and 365mg/L at Hit, Nasiriya and Qurna respectively.

The predominant cation in the Euphrates water at Hit is calcium with a value of 3.1me/L, with subsidiary magnesium and sodium having values of 2.5 and 2.2me/L respectively. The predominant anion is bicarbonate (2.9me/L) with subsidiary sulphate and chloride (2.6 and 2.0me/L respectively). At Hindiya, calcium remains the dominant cation (6.0me/L), while magnesium and sodium also remain as subsidiary cations (5.8 and 3.0me/L respectively).

* Water hardness refers to the weight of dissolved magnesium and calcium salts.

Bicarbonate is replaced by sulphate as the dominant anion (5.8me/L) compared with values of 4.3 and 3.5me/L for bicarbonate and chloride. At Qurna, sodium, calcium and magnesium are the dominant cations with values of 3.7, 3.7 and 3.6me/L respectively. Chloride is the dominant anion (3.6me/L), while bicarbonate and sulphate remain as subsidiary with values of 3.4 and 3.3me/L respectively (Table 3.17).

3.6.2 THE TIGRIS WATER QUALITY

The salinity of Tigris water follows a similar trend to that of the Euphrates. Thus, the mean EC value at Mosul is 0.404mmhos/cm (1967-69), decreasing slightly to 0.373mmhos/cm at Fatha, due to the fresh water received from the Greater Zab and Lesser Zab tributaries. Further downstream, the mean EC value increases gradually to 0.507 at Baghdad, 0.573 at Kut, 0.650 at Amara and 0.880mmhos/cm at Qurna (Table 3.18). Recent observations (1977-78) show that the mean EC value increases to 1.313mmhos/cm at Qurna (Table 3.19). These gradual increases result from the following factors:

1. The effect of the high saline discharge of the Diyala with a mean annual EC value of 1.058mmhos/cm at Diyala barrage.
2. The very high saline groundwater discharge with an EC value of 15.600mmhos/cm[34].
3. The influence of the large irrigation projects in the middle and lower sections which return some of their

Table 3.18 Seasonal and Annual Variations of the Tigris Water Salinity at Selected Gauges, 1967-69

Gauge	EC mmhos/cm at 25°C			1967		1968		1969	
	Low-water period	Flood period	Mean Annual	Mean Annual Discharge(bcm)	EC	Mean Annual Discharge(bcm)	EC	Mean Annual Discharge(bcm)	EC
Mosul	0.455	0.350	0.404						
Fatha	0.440	0.352	0.373	46.0	0.402	56.0	0.391	93.0	0.385
Baghdad	0.674	0.422	0.507						
Kut	0.670	0.441	0.573						
Amara	0.992	0.475	0.650						
Qurna	1.137	0.773	0.880						

Source: Al-Sahaf M. Op. Cit. p180

Table 3.19 Mean Monthly and Annual Water Salinity of the Tigris River at Qurna, 1977-78

Quality factor	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean Annual
EC mmhos/cm	1.404	2.122	2.621	1.638	1.638	1.092	0.827	0.780	0.702	0.827	0.936	1.170	1.313

Source: Polservice Co. Op. Cit., Vol.1 Summary, Part A, Table 1-9-1 high saline drainage water back to the river (Table 3.20).

4. The high evaporation losses along the river course.
5. The effect of very high saline water outflows from the marshes (section 3.5).

According to the US irrigation water classification, the Tigris water is considered of medium salinity, or class C2, upstream of Amara and high salinity, or C3 further downstream of this point. These values are similar to those of the Euphrates.

The EC value fluctuates seasonally, due to seasonal variation in the river discharge (Table 3.18 and Fig.3.13). Thus, its value increases in the low-water period to 0.455 at Mosul, 0.674 at Baghdad, 0.670 at Kut and 1.137mmhos/cm at Qurna. These figures fall in the flood period to 0.350, 0.422. 0.441 and 0.773mmhos/cm respectively. Furthermore, there is an annual variation. For example, in 1967, when the mean annual discharge at Fatha was 46.0bcm, the mean EC value was 0.402mmhos/cm. In 1968 and 1969, when the mean discharges were 56.0bcm and 93.0bcm respectively, the mean EC values fell to 0.391 and 0.385mmhos/cm respectively.

The SAR ranges from 0.3 to 0.9me/L. Therefore, the Tigris is considered to have low sodium hazard or SI (Table 3.21 and Fig.3.11). Also, water quality from the viewpoint of RSC

Table 3.20 Water Salinity of the Existing Drainage Networks Which Discharge to the Tigris River

Drainage Canal	Discharge (cumecs)	EC mmhos/cm at 25°C
Saqlawiya-Abu-Ghuraib	12.0	17.580
Khalis-Dawoody	4.0	6.549
Ishaqi	1.0	no data
Salman Pak	1.0	no data
Washash	1.1	no data
Total	19.1	

Sources: Al-Mashadany M. et al Completion of the Main Drainage Network in Iraq, Op. Cit. pp16, 49

Al-Sahaf M. Op. Cit. pp182

Fig. 3.13 : Monthly Water Discharge and EC Value of the Tigris River at Qurna (1977-78)

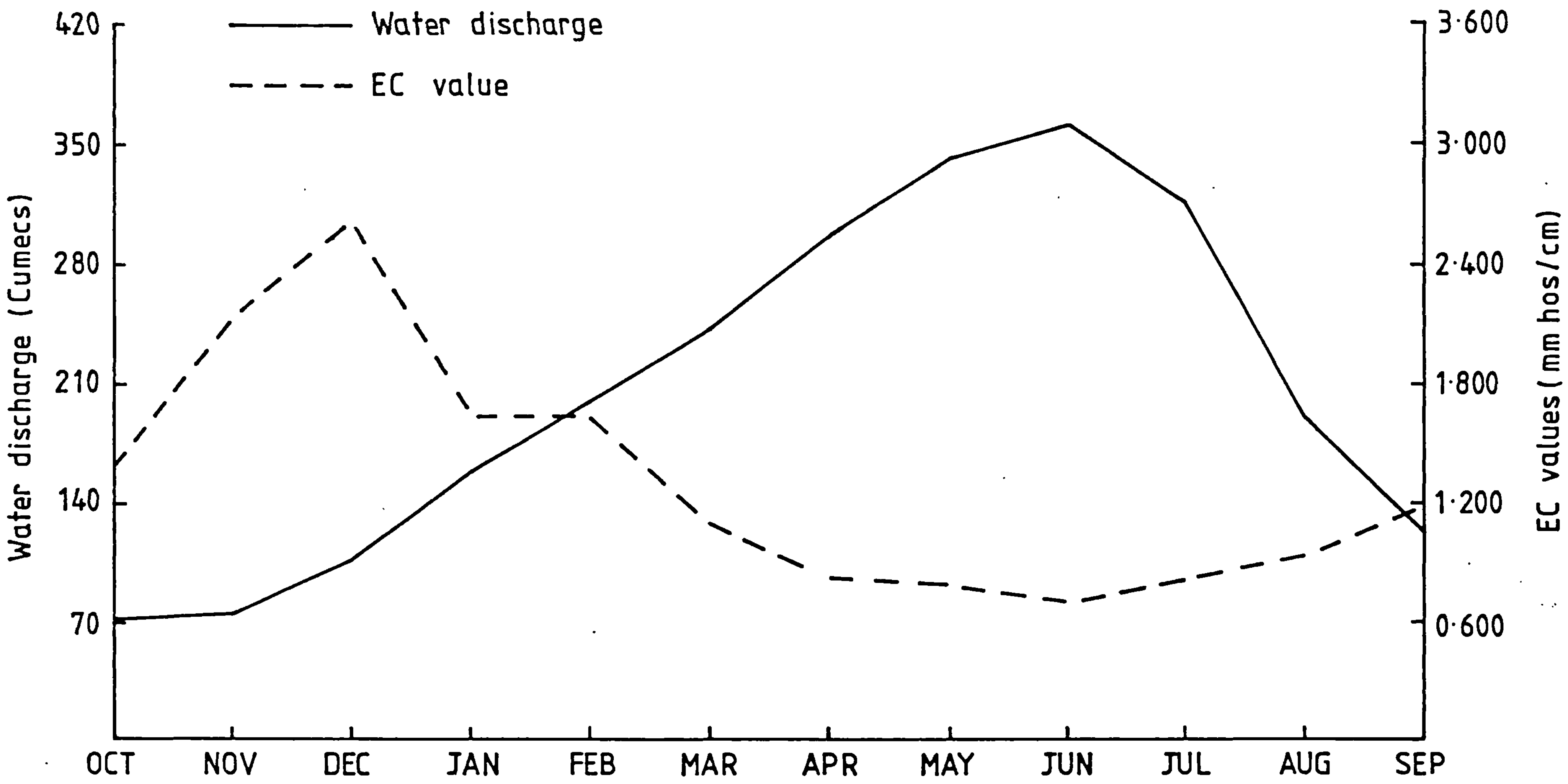


Table 3.21 Chemical Analysis of the Tigris Water (1978)

Site	Cations				Total	Anions				Total	Total	Total	
	Na	K	Ca	Mg	Cations	Cl	SO_4	HCO_3	CO_3	Anions	Cations & Anions	Hardness mg/L	pH
Mosul	0.6/13.2	0.1/2.8	3.1/62.1	2.4/28.9	6.2/107	0.8/30.1	1.5/74.5	3.1/192	0.3/9.1	5.7/305.7	11.9/412.7	235	8.0
Fatha	0.6/14.7	0.1/2.1	3.2/64.2	2.2/27.6	6.1/108.6	0.9/32.1	1.6/78.4	3.5/215.4	0.3/9.0	6.3/334.9	12.4/443.5	240	8.0
Samarra	0.5/12.6	0.1/3.0	2.6/52.6	2.3/22.4	5.5/90.5	0.9/32.8	1.1/54.2	2.9/180	0.3/9.0	5.2/276	10.7/366.5	220	8.1
Baghdad	1.5/33.8	0.1/3.1	3.0/59.6	2.2/27.1	6.8/123.6	1.7/60.8	1.9/85.3	3.0/185	0.3/9.4	6.9/350.6	13.7/474.1	296	8.0
Kut	1.5/34.1	0.1/3.3	3.0/60.3	3.0/36.1	7.6/133.7	1.8/65.5	2.2/105	3.5/215	0.3/9.4	7.8/394.9	15.4/528.6	325	8.1
Amara	2.2/50.1	0.1/3.3	3.6/71.5	2.8/34	8.7/158.9	2.7/96.1	3.1/150	3.6/220	0.3/9.5	9.7/475.6	18.4/634.5	358	8.2
Qurna	3.0/70	0.1/4.4	4.2/84.5	3.3/41	10.6/200	3.9/140	5.0/242	3.8/232	0.3/9.5	13.0/623.5	23.6/823.5	396	8.2

Note: Measurement units of the figures presented above: numerator - me/L; denominator - mg/L

Source: Selkhozpromexport Co. Problems of Water Resources Conservation in Iraq, Op. Cit. Table 11 is safe as its value is negative (Tables 3.21 and 3.16).

Chloride content ranges between 0.8 and 3.9me/L, while sulphate ranges from 1.1 to 5.0me/L (Table 3.21). These values are still well below the guideline limit (Table 3.16) for irrigation water.

The pH is considered to be satisfactory for irrigation as its maximum value is 8.2 (Tables 3.21 and 3.16).

The total hardness of the Tigris water is 235mg/L at Mosul, increasing southwards to 296 and 396mg/L at Baghdad and Qurna respectively.

The predominant cations in the Tigris water are calcium and magnesium, with respective figures of 3.1, 2.4me/L at Mosul, 3.0, 2.2me/L at Baghdad and 4.2, 3.3me/L at Qurna. The predominant anions are bicarbonate and sulphate with respective values of 3.1, 1.5me/L at Mosul and 3.0, 1.9me/L at Baghdad. At Qurna, bicarbonate is replaced by sulphate as the dominant anion, 5.0me/L, compared with 3.9 and 3.8me/L for chloride and bicarbonate respectively.

3.6.3 THE SHATT AL-ARAB WATER QUALITY

The Shatt Al-Arab water quality is influenced by that of its tributaries (the Euphrates, Tigris and Karun), the marshes and the saline water intrusion from the Arabian Gulf. Thus, the mean EC value downstream of the Swaib confluence is 1.475mmhos/cm, increasing southwards to 2.328mmhos/cm at Maqil (Tables 3.22 and 3,23). This is due to very high saline water received from Qurna marsh through the Garmat Ali and Shafi tributaries, with a mean EC value of 2.54 mmhos/cm (section 3.5). A further increase to 2.947mmhos/cm occurs at Fao (Table 3.24). According to the US classification, Shatt Al-Arab water downstream of Swaib is regarded as having high salinity (C3), similar to that of the lower sections of the Euphrates and Tigris. That of the lower section (Maqil to Fao) is considered to be of very high salinity (C4). This water is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances, ie. the soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide leaching and very salt-tolerant crops should be selected(35).

The EC value fluctuates seasonally according to the river water discharge variations. Thus, its mean value rises in the low-water period to 2.644mmhos/cm at Maqil, while it falls to 2.171mmhos/cm during the flood period. Its highest and lowest values occur in October and March with values of 2.773 and 1.762mmhos/cm respectively (Table 3.23 and Fig.3.14).

Table 3.22[1] Chemical Analysis of the Shatt Al-Arab Water Downstream Swaib Confluence, 1977-78

Date	EC mmhos/cm at 25°C	pH	Cations			Anions				Total Hardness
			Na me/L	Ca me/L	Mg me/L	Cl me/L	HCO_3 me/L	CO_3 me/L	SO_4 me/L	mg/L
2.11.1977	2.202	8.0	14.7	4.4	7.7	10.7	3.2	0.6	10.0	181
27.12.1977	2.464	7.5	9.5	6.1	5.4	12.4	3.5	0.2	11.8	189
7. 1.1978	1.811	7.9	6.9	4.6	7.7	8.8	3.7	0.2	8.5	146
1. 2.1978	2.008	7.7	7.3	4.8	2.8	8.5	4.5	nil	7.9	130
7. 3.1978	1.321	7.6	5.1	4.2	5.4	5.7	3.6	0.6	8.5	150
19. 4.1978	1.080	8.5	3.7	4.1	2.4	4.0	4.3	nil	8.0	111
9. 5.1978	0.900	8.4	3.5	4.7	4.0	3.5	4.2	nil	7.5	144
7. 6.1978	0.822	8.4	2.7	1.4	6.4	2.2	4.0	nil	6.4	106
10. 7.1978	0.818	8.3	2.5	2.0	3.2	2.7	3.5	nil	1.9	79
7. 8.1978	0.941	7.6	3.8	5.5	3.3	4.3	4.0	nil	6.4	150
6. 9.1978	1.392	8.0	5.3	4.1	4.3	6.3	4.6	nil	5.7	134
3.10.1978	1.888	7.8	7.8	5.5	6.7	8.7	3.9	nil	9.7	191
Mean*	1.475	8.0	$\frac{6.0}{138.0}$	$\frac{4.3}{86.2}$	$\frac{4.9}{59.5}$	$\frac{4.5}{159.5}$	$\frac{3.9}{238.0}$	$\frac{0.1}{3.0}$	$\frac{7.7}{370.0}$	142

Table 3.23[1] Chemical Analysis of the Shatt Al-Arab Water at Maqil, 1977-78

Date	EC mmhos/cm at 25°C	pH	Cations Na me/L	Cations Ca me/L	Cations Mg me/L	Anions Cl me/L	Anions HCO_3 me/L	Anions CO_3 me/L	Anions SO_4 me/L	Total Hardness mg/L
29.11.1977	2.659	7.8	11.0	6.5	8.7	12.5	3.0	0.2	13.1	236
29.12.1977	2.399	7.7	9.5	6.0	4.7	12.2	3.3	0.2	13.8	177
14. 1.1978	2.481	7.7	10.0	4.9	4.4	14.4	3.2	nil	13.8	152
12. 2.1978	2.429	7.8	9.1	5.1	5.2	13.5	2.5	0.2	10.6	165
11. 3.1978	1.762	7.5	7.6	5.1	0.4	9.0	3.7	nil	9.5	108
12. 4.1978	2.180	8.4	9.2	5.0	6.6	11.8	2.7	nil	12.0	180
16. 5.1978	2.270	8.3	13.4	7.8	9.5	16.4	2.8	nil	12.9	273
15. 6.1978	1.932	7.8	8.3	4.7	6.6	8.9	2.4	nil	12.5	174
18. 7.1978	2.127	8.4	3.8	3.2	6.0	10.4	3.6	nil	5.4	138
15. 8.1978	2.186	7.7	10.4	4.4	9.0	12.0	2.4	nil	10.6	197
13. 9.1978	2.743	8.2	8.2	4.8	5.8	9.3	5.2	nil	7.3	167
10.10.1978	2.773	7.8	11.8	5.8	10.9	11.8	2.5	nil	13.8	249
Mean	2.328	7.9	$\frac{9.4}{216.0}$	$\frac{5.3}{106.2}$	$\frac{6.5}{79.0}$	$\frac{11.8}{418.3}$	$\frac{3.1}{189.2}$	$\frac{0.04}{1.2}$	$\frac{11.3}{543.0}$	184

Table 3.24[2] Chemical Analysis of the Shatt Al-Arab at Fao, 1967-69

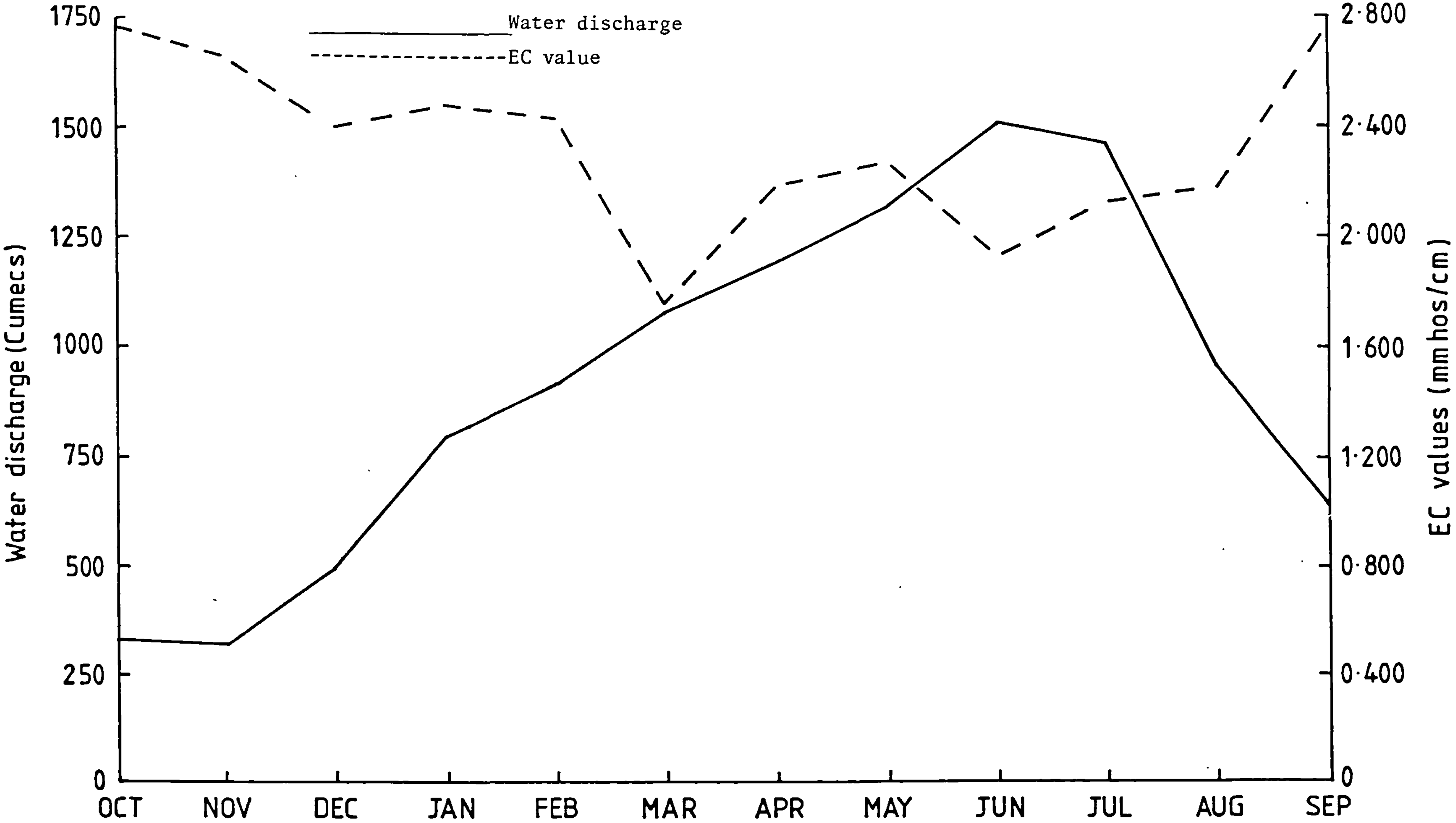
EC mmhos/cm at 25°C	pH	Cations Na me/L	Cations Ca me/L	Cations Mg me/L	Anions Cl me/L	Anions HCO_3 me/L	Anions CO_3 me/L	Anions SO_4 me/L	Total Hardness mg/L
2.947	8.0	$\frac{21.4}{492.0}$	$\frac{4.0}{80.2}$	$\frac{7.2}{87.5}$	$\frac{23.0}{815.4}$	$\frac{3.2}{195.3}$	$\frac{0.3}{9.0}$	$\frac{4.9}{235.3}$	560

* Measurement units = $\frac{me/L}{mg/L}$

Sources: (1) Polservice Co. Op. Cit., Vol.11, Part B Water Quality Appendix

(2) Al-Sahaf Op. Cit. p209

Fig. 3.14 : Monthly Water Discharge and EC. Value of the Shatt Al-Arab at Maqil (1977-78)



The SAR values downstream of Swaib, Maqil and Fao are 2.8, 3.9 and 9.0me/L respectively. This is below 10me/L and therefore the water is classified as having a low sodium hazard or SI, which is good for irrigation purposes.

The RSC concentration is regarded as safe for irrigation as its value is below 1.26me/L (Table 3.16).

The pH value downstream of Swaib, Maqil and Fao is 8.0. Therefore, irrigation with such water is satisfactory (Table 3.16).

The chloride concentration of 11.8me/L at Maqil exceeds the index limit of irrigation water and therefore irrigation with such water may necessitate the cultivation of less valuable crops. The sulphate content is well below the guideline limit as its value is 11.3me/L (Tables 3.23 and 3.16).

Tables 3.22, 3.23 and 3.24 show that the predominant cation downstream of Swaib is sodium (6.0me/L), with subsidiary magnesium and calcium (4.9 and 4.3me/L respectively). Sulphate is the predominant anion (7.7me/L), with subsidiary chloride and bicarbonate (4.5 and 3.9me/L respectively). At Maqil, sodium remains the dominant cation (9.4me/L), with subsidiary magnesium and calcium (6.5 and 5.3me/L respectively). Chloride is the dominant anion (11.8me/L), with subsidiary sulphate and bicarbonate (11.3 and 3.1me/L respectively). At Fao, sodium remains the dominant cation (21.4me/L), while the dominant anion is chloride (23.0me/L).

3.7 CONCLUSION

The Euphrates and Tigris rivers have their sources in Turkey. Their total annual water potential is 84.4bcm, with a mean of 2676.3 cumecs. The most effective parts of the basin for water production are located in Turkey and Iraq which contribute 66.8% and 22.5% of the total annual water potential respectively. The remaining parts of the basin in Syria and Iran are less effective as they contribute 4.7% and 5.8% of the total annual water potential respectively (Table 3.1).

There are several problems affecting water quantity and quality which in turn influence water requirements. Of these, the seasonal discharge variations are the most significant. For instance, the Euphrates mean annual discharge at Hit is 909 cumecs (28.6bcm) of which 87.4% passes during the flood period (December-July inclusive) and only 12.6% during the low-water period (August-November inclusive). The mean annual discharge of the Tigris downstream of Baghdad is 1224 cumecs (38.6bcm), 84% and 16% passing respectively during the flood and low-water periods. The mean annual discharge of the Shatt Al-Arab at Maqil is 919 cumecs (29.0bcm), of which 83.4% flows during the flood period and 16.6% during the low-water period. Furthermore, the river water discharges fluctuate annually. For example, the Euphrates and Tigris discharges increased to 2003 cumecs

(63.0bcm) and 2034 cumecs (64.0bcm) respectively during the wet year (1969), falling to 485 cumecs (15.3bcm) and 792 cumecs (25.0bcm) respectively in the dry year (1961). The Shatt Al-Arab discharge rose to 1017 cumecs (32.0bcm) in 1967 and fell to 398 cumecs (12.5bcm) in 1961. As a result, several dams and reservoirs have been constructed or planned, in order to regulate the river flow.

The present water quality of the upper and middle sections of the Euphrates and Tigris has proved to be satisfactory for irrigation. It is less suitable in the lower sections and the Shatt Al-Arab, due to the effect of the large up-stream irrigation projects which return some of their saline drainage water back to the rivers and also to the influence of very high saline outflows from the marshes. Therefore, it is vitally important to complete the drainage network to the Arabian Gulf via Shatt Al-Basrah, avoiding the rivers, controlling the river flow to the marshes and the marsh flow to the rivers. This will improve water quality and maintain water quantity.

Future water quantity and quality will be affected as a result of large scale planned irrigation developments in the upstream riparian states, Turkey, Syria and Iran (Chapter 5). Therefore, negotiations to achieve an international agreement to secure the appropriate share for each country with regard to quantity and quality is essential (Chapter 7).

In addition, monitoring of water quantity and quality should be strengthened in order to identify the future changes and to increase present knowledge.

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CHAPTER 4

GROUNDWATER RESOURCES

4.1 INTRODUCTION

As a result of the large scale planned irrigation developments in the upstream riparian states, Turkey, Syria, Iran and increasing demand in Iraq, a shortage of surface water resources will be certain. Thus, groundwater is an important resource which must be significantly considered parallel to the surface water resources in order to satisfy increasing demands. At present, groundwater development, compared with the surface water, receives little attention. Moreover, studies in this field are insufficient for specific evaluation. Most of these have been carried out at a time when there was a lack of meteorological data and therefore, they were only given an initial evaluation. Best known of these is The Subsurface Water Resources of Iraq (Noble, 1926).

From the 1930s, the Groundwater Division of the Ministry of Municipalities has been carrying out drilling works for irrigation and other purposes. A later report, Water Supplies in Iraq (Macfadyen, 1938), was completed. The Ralph M. Parsons Engineering Company, 1955, carried out a regional hydrogeological study for most of the country. It was a more useful study than those completed previously. The Institute for Applied Research on Natural Resources has been carrying out research, mostly in the northern part of the country. However, future development of the groundwater resources requires further quantitative studies regarding the hydrogeological aspects of the aquifers, including the aquifer system, annual recharge, annual storage, groundwater depth, flow and safe yield. These, together with the quality evaluation, will identify whether or not the potential groundwater resources are economically feasible for future development.

The objective of this chapter is to evaluate the potential groundwater resources of the country regarding water quantity and quality. Thus, it includes two main sections; the first one deals with the groundwater hydrogeological aspects, ie. the aquifer system, annual recharge, annual storage, depth, flow and safe yield. The second analyzes water quality, particularly for irrigation, to determine whether the groundwater resources are suitable to be developed.

4.2 THE HYDROGEOLOGICAL ASPECTS

The groundwater hydrogeological aspects are determined according to the physiographical regions of the country as follows.

4.2.1 THE MOUNTAIN REGION

This forms a strip occupying the extreme north and north-east part of the country. It comprises 5.3% of the area of the country. Its climate is typically Mediterranean, characterized by a dry, hot summer and moderately rainy, cold winter. Its mean annual rainfall ranges between 600 and 1000mm (Chapter 2 Fig.2.2).

4.2.1.1 The Aquifer System

The aquifer system underlying the region is formed by the Pliocene-Pleistocene formations. Generally, the region can be divided into three groundwater areas. Firstly, the mountain areas, which are composed of limestones, dolomites and other hard rocks. Here, the aquifer is distributed in the form of extensive elongated mountain ridges. Water is stored in fissures, fractures and joints at very variable depths and is unconfined. Secondly, the valley areas which consist of soft clastic sedimentary rocks - marls and shales. The aquifer is distributed in elongated areas, following valleys and valley slopes. Individual aquifers are often lenticular, at greatly varying depths. The water is contained in a porous aquifer which is often confined, producing semi-artesian rises in boreholes. Thirdly, the alluvium areas, which consist of deposits of a limited thickness. These occur in some valley regions where groundwater is found at shallow depths[1].

In both the mountain and foothill regions, the groundwater flow coincides with surface drainage patterns which follow the general slope from north and north-east to south and south-west (Fig.4.1). The groundwater depth varies throughout the regions. It generally ranges from 5 to 50m[2]. These regions have the largest number of springs in the country, approximately 143, and their total water discharge is about 25.7 cubic metres per second, with an average of 0.18 cumecs, ranging from 0.1 to 8000 litres per second[3].

4.2.1.2 Groundwater Recharge and Safe Yield

To determine groundwater recharge and safe yield in this region, the Shahrazor Plain has been chosen. The area covers $675km^2$[4] and is located in the south-eastern part of the region (Fig.4.2). Runoff (taken to include recharge) is equal to precipitation minus interception, evaporation and evapo-transpiration. 90% of this runoff facilitates groundwater recharge (this percentage is based on data for arid and semi-arid regions in the U.S.A.). The resulting figure, multiplied by the area involved[5] gives the total recharge. In this case, the relevant total annual groundwater recharge is 119.5mcm* (Table 4.1).

* million cubic metre

Fig. 4.1 : Groundwater Flow

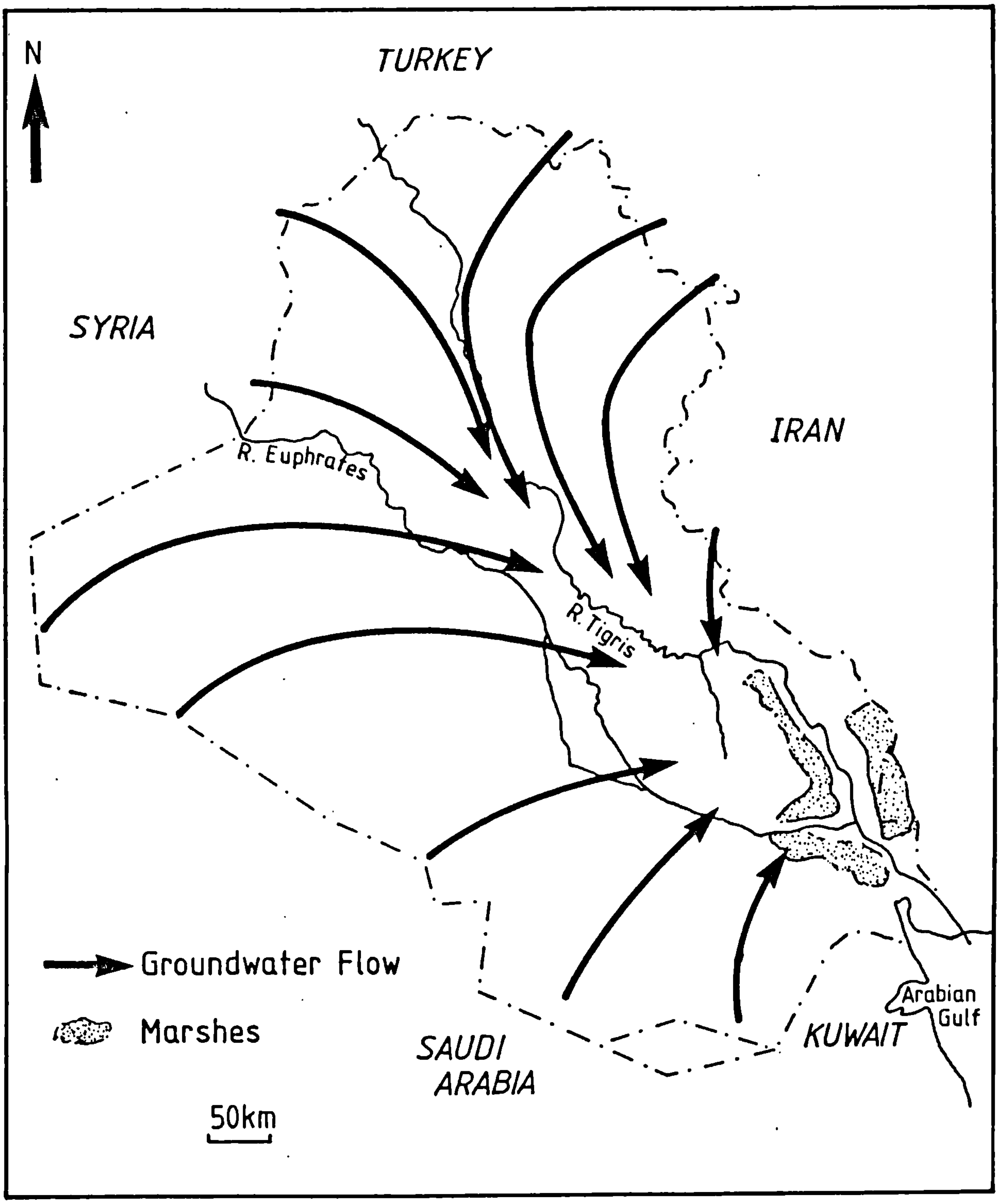

Fig. 4.2 : Regional Location of Selected Drainage Areas

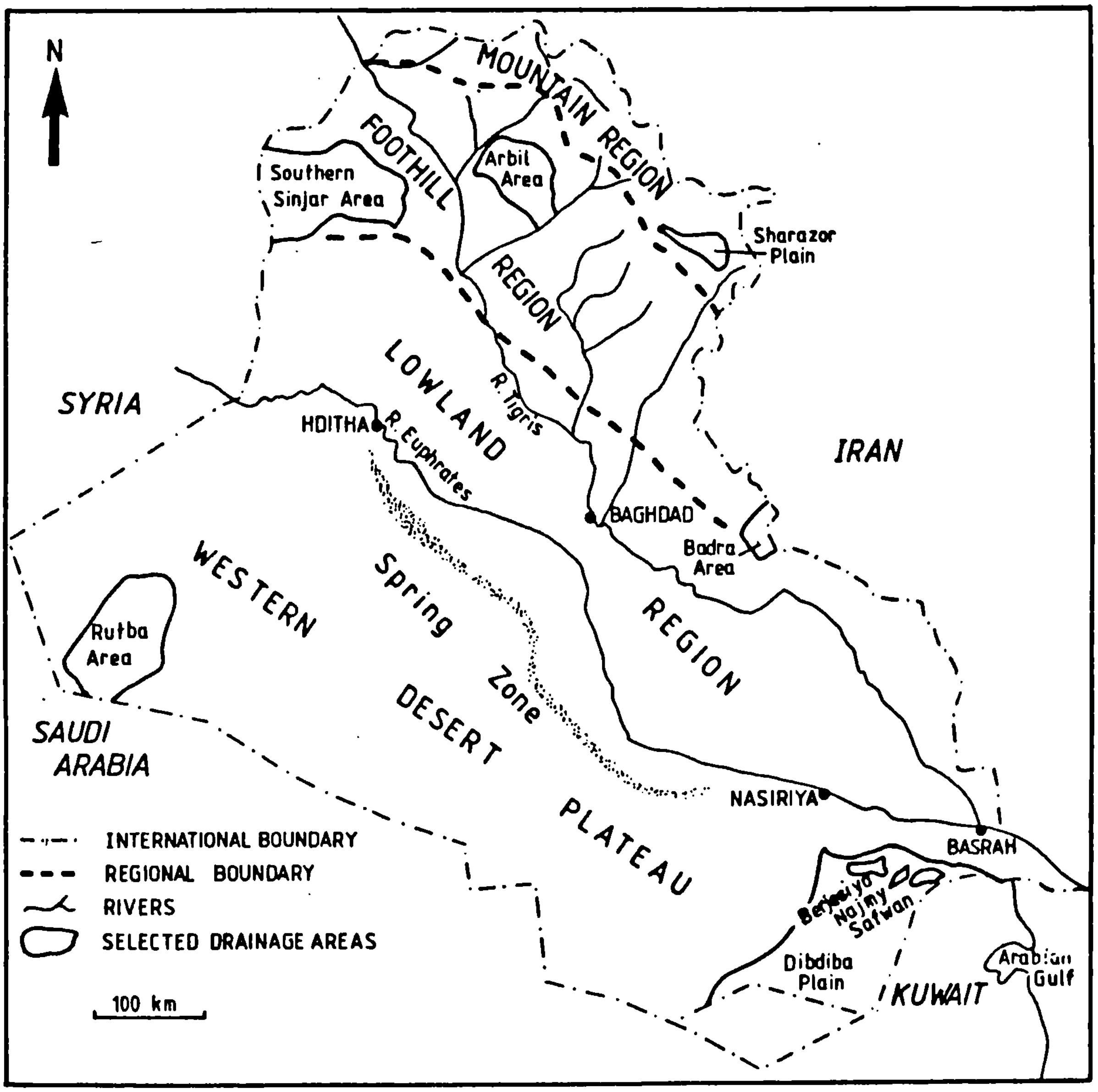

Table 4.1 Evaluation of Annual Groundwater Recharge in the Mountain, Foothill and Western Desert Regions, Through Selected Areas

Region	Selected Area (km^2)		Mean Ann. Precipitation (mm)	Mean Ann. Loss (mm)	Mean Ann. Runoff (mm)	Mean Ann. Recharge (mm)	Total Ann. Recharge (mcm)
1) Mountain R.	Shahrazor Plain	(675)	655	458*	197	177	119.5
2) Foothill R.	Southern Singar Area	(8350)					
	Foothill	(350)	610	480	130	117	41
	Plain	(8000)	290	286	4	3.6	29
	Arbil Area	(3050)					
	Foothill	(280)	570	480	90	81	23
	Plain	(2770)	440	418	22	20	55
	Badra Area	(500)	175	157	18	16.2	8.1
3) Western Desert							
	Rutba Area	(6200)	119	117	2	1.8	11.2

Sources: Ministry of Development, Development Board, Groundwater Resources of Iraq Vol.9, Hydrologic Aspects of Selected Areas, The Ralph and Parsons Company, Baghdad, Nov. 1955 pp51, 101, 105

Institute for Applied Research on Natural Resources, Galal Badra Project Area, Part 1, Geological and Hydrological Investigations, Tech. Bull. No. 106, Baghdad , April 1977, ppiii-1

* Evaluated to be 70% of the annual precipitation.

Safe yield is the average groundwater quantity which can be extracted without lowering water levels to an uneconomical pumping depth, or causing the quality to become unsuitable(6). The total annual groundwater recharge of the area is 119.5mcm. If the consumptive use is 60% of pumpage, the remaining 40% returns to groundwater as deep seepage. If recharge is entirely recoverable, the total annual safe yield is equivalent to 119.5mcm divided by 0.6(7) which is equal to 199mcm, with a mean of 379 cubic metres per minute, or 56cm/min per 100km^2. Thus, safe yield of 379cm/min can be withdrawn from 473 wells, each producing at a continuous rate of 0.8cm/min.

4.2.2 THE FOOTHILL REGION

This region forms 15% of the total area of the country. Its climate is semi-arid or steppe. The mean annual rainfall over the region ranges from 300 to 600mm. In general, the geology is characterized by extensive gravel terraces of Pliocene and Pleistocene age. These formations comprise the main groundwater aquifer in the region (Chapter 2). To evaluate the groundwater condition in this region, three areas have been chosen. These are:

1. The Southern Singar Area in the north-west.
2. The Arbil Area in the centre.
3. The Badra Area in the south-east (Fig.4.2).

4.2.2.1 The Southern Singar Area

This area covers 8350km^2 and occupies the north-western part of the region. It is divided into foothills in the north and plain in the south. The foothill area consists of the Cretaceous and Eocene limestones, which are overlain by the Middle Eocene marls and marly limestone, then by the Lower Miocene which consists of massive white limestone, chert beds, sandstones, shale and anhydrite. These formations are deeply buried beneath younger sediments in the synclinal basins. They are mostly impervious when fissures and caverns are absent. Their occurrence is tectonically predisposed close to the anticlinal structures. The springs which flow along Jabal Singar have their source in the Singar limestones. The Lower Miocene limestone, with a thickness of about 150-200m, is also a potential aquifer with good quality water.

The Singar Plain is located to the south of the foothill area. Here, the Lower Fars, which outcrops irregularly along Singar mountain range, thickens in depth, reaching between 500 and 600m. It consists of interbedded gypsum, anhydrite, limestone and the occasional strata of siltstones and marls. Conformably, it is overlain by the Upper Fars deposits (Upper Miocene) which are composed of interbedded sands, silts and clays, with a thickness of about 300m. Alternating layers of gravels, calcareous concretions and fragments of gypsum are also present in these strata. In the Lower Fars formation, secondary permeability is generally developed along faults, cracks or solution channels in calcareous and evaporitic layers, while in the

Upper Fars, it is dependent on the thickness and nature of the detrital deposits such as sands, gravels and silts[8].

4.2.2.1.1 <u>Groundwater Recharge and Safe Yield</u>

The total annual groundwater recharge from direct precipitation is evaluated as 70.0mcm, distributed between the foothill and the plain (41.0mcm and 29.0mcm respectively) (Table 4.1).

Using the calculations described, the total annual safe yield of the whole area is 117.0mcm, with a mean of 223cm/min, or 2.7cm/min per $100km^2$. Thus, safe yield of 223cm/min can be withdrawn from 279 wells, each producing at a continuous rate of 0.8cm/min.

4.2.2.2 <u>The Arbil Area</u>

This area is located in the central part of the region and covers $3050km^2$. The aquifer system underlying the region is composed of the Pliocene Bakhtiari formation, the Pleistocene residual alluvial deposits and the Recent alluvial deposits.

The Bakhtiari formation consists of mainly gravel and conglomerate layers interbedded with sands, clays and silts. This is the thickest (more than 330m) and the most important aquifer of the area. In the foothill part of the area, where this formation outcrops, perched water tables occur, due to the presence of clay beds. Springs occur where the beds of gravel and sand overlie the poorly permeable clay layers. There are about 40 springs in the region, having their source in this formation, with discharge rates ranging from 3 to 30L/S during and after the rainy season. Generally, the depth to the groundwater table in the outcropping Bakhtiari formation is less than 10m.

The Pleistocene residual alluvial deposits vary in lithology, comprising of gravels, sands, clays and silts layers. These generally outcrop in the undulating terrain which constitutes about 47% of the area. The thickness of the deposits is also variable, but generally less than 120m. Several wells in the region have their sources in this deposit and the underlying Bakhtiari formation. The depth to the groundwater table ranges from 10 to more than 50m.

The Recent alluvial deposits mainly outcrop in the plain which forms about 16% of the total area. The deposits consist generally of sands, silts, clays with underlying lenses and beds of gravels. The thickness of deposits varies, but it is usually less than 150m. Drilled wells generally pass this deposit on route to the location of their source in the Bakhtiari formation. The groundwater depth ranges from 10 to 30m, but sometimes it is less[9].

4.2.2.2.1 Groundwater Recharge and Safe Yield

The total annual groundwater recharge amounts to 78.0mcm, of which 23.0mcm originates in the foothill area and 55.0mcm in the plain (Table 4.1).

The total annual safe yield of the whole area is equivalent to 130.0mcm, with a mean of 247cm/min, or 8cm/min per $100km^2$. Hence, safe yield of 247cm/min can be withdrawn from 309 wells, each producing at a rate of 0.8cm/min.

4.2.2.3 The Badra Area

The Badra area occupies the extreme south-eastern part of the region (Fig.4.2) and covers $500km^2$. The aquifer system underlying the area is composed of the Bakhtiari formation (Pliocene) and alluvial deposits of the Pleistocene and Recent.

The Bakhtiari formation consists of interbedded clays, sands and gravels. It generally outcrops in the foothill part of the area in the east. The Bakhtiari and the underlying formations are separated from the overlying older alluvium formation by a regional clay layer, which is inclined westward. As an impervious layer, this safeguards the older alluvium aquifer against the upward movement of the sodium-chloride water of the deeper formations. It becomes more sandy and silty towards the west and forms only a semi-pervious boundary, less effective in preventing the upwards movement of the sodium-chloride water.

The Older alluvium outcrops in the plain area and constitutes fan deposits which gradually change from gravels to pebbly sands and sands related to the westerly direction of flow. The thickness of this gravelly portion of aquifer is about 35m and it is considered the main source of water as a result of good natural recharge.

The Older alluvium is separated from the Younger alluvium by an impervious clay layer. Thus, the Older alluvium aquifer is considered as confined.

The Recent alluvium also occurs in the plain part of the area and is composed of different deposits of silts, sands and clays. The aquifer thickness increases from 2-10m in the east, to 30m in the west. It is not an important aquifer due to its low storage capacity[10].

4.2.2.3.1 <u>Groundwater Recharge and Safe Yield</u>

The total annual groundwater recharge of the area is evaluated as 8.1mcm (Table 4.1).

Its total annual safe yield is equivalent to 13.5mcm, with a mean of 26cm/min, or 5.2cm/min per $100km^2$ of drainage area. Thus, a safe yield of 26cm/min can be withdrawn from 33 wells, each producing at a rate of 0.8cm/min.

4.2.3 THE LOWLAND REGION

This region forms 27.8% of the total area of the country. It is considered a discharge zone for the surrounding groundwater regions, in addition to one of recharge from the Tigris, Euphrates, the Shatt Al-Arab and rainfall. The groundwater discharge takes place as evaporation because underground outflow is absent (Fig.4.1) there being no extensive groundwater flow, due to the flatness of the region (Chapter 2).

The groundwater level in most of the region is less than 5m. Only in small areas in the north and north-west does the groundwater level range from 5 to 10m. It falls to 1-3m and is sometimes close to the surface in the lower portion of the region. The groundwater level fluctuates seasonally, with a tendency to rise in the wet season and fall in the dry, in accordance with the seasonal fluctuations of the rivers and rainfall.

Generally, the groundwater in the region is abundant, but it is unusable as a result of its extremely high salinity (the mean EC value ranges from 4.68 to 62.4mmhos/cm)(11). These values exceed the irrigation water guideline limit, based on the US evaluation (Chapter 3, Table 3.16).

As a result of unsuitable groundwater and arid climate, the surface water resources from the Euphrates, Tigris and

Shatt Al-Arab are the main and vital sources for irrigation and other purposes.

4.2.4 THE WESTERN DESERT PLATEAU

This plateau occupies the whole area to the west of the Euphrates river and comprises 52% of the total area of the country. The climate is arid with a mean annual rainfall of 110.7mm, ranging between 108.3mm in the north to 113mm[12] in the south. Generally, the region consists of the oldest formations of the Triassic up to rocks of Pleistocene and Recent age. Groundwater depth is 50m in the eastern margin, increasing westwards to 300 m[13]. The flow coincides with the general slope which trends to the north-east and east directions. Thus, the regional drainage is toward the Euphrates river (Fig.4.1).

To determine the groundwater condition in this region, three areas have been chosen:

1. The Rutba Area in the north-west.
2. The Spring Zone at the eastern margin of the region.
3. The Dibdiba Plain in the south-eastern part (Fig.4.2).

4.2.4.1 The Rutba Area

This occupies the north-western part of the region and covers 6200km^2. The aquifer system underlying the area is formed by flat beds of limestone and sandstone. Most of the recharge occurs as infiltration through the limestone, silts, sands and gravels of the wadi beds. Much of this recharge percolates downstream through the alluvial materials and solution openings underlying the wadis. During percolation, some of the recharge is lost to adjoining basins and some water from adjoining basins is gained, the net gain or loss being indeterminate. However, the material underlying the wadis is much more permeable than that between the wadis and thus, the exchange between basins is small[14].

4.2.4.1.1 Groundwater Recharge and Safe Yield

Table 4.1 shows that the total annual groundwater recharge is equal to 11.2mcm.

The total annual safe yield amounted to 18.7mcm, with a mean of 36cm/min, or 0.6cm/min per 100km^2 of drainage area. Thus, safe yield of 36cm/min can be withdrawn from 45 wells, each producing at a continuous rate of 0.8cm/min. As safe yield of the area is rather low, therefore the most favourable locations for groundwater development are mainly in wadis and depressions, where recharge tends to concentrate.

4.2.4.2 The Spring Zone

This zone appears along the eastern boundaries of the region, from Haditha in the north to Nasiriya in the south (Fig.4.2). Springs are distributed over an area about 488km in length. There appear to be some 20 springs or major groups of springs as, for instance, Rahaliya and Shithatha.

4.2.4.2.1 Groundwater Recharge and Safe Yield

There are three possibilities for the recharge of the springs zone. Firstly, the rainfall in the northern part of the country makes its way beneath the Mesopotamian Plain in the Euphrates limestone towards this area. Secondly, the rainfall over this region drains underground towards the Euphrates river, down the slope.
Thirdly, water of the Euphrates river seeps towards this area, along the strike of porous strata in the Euphrates limestone or Lower Fars beds(15).

The total surface yield of all the springs is 9.4 cumecs, and this appears to be a permanent and slightly fluctuating supply. The total is unequally distributed, over 3.7, 3.2 and 1.5 cumecs being yielded by Hajlan, Shithatha groups and Al Ruhba respectively, while the other springs are very small(16).

The springs zone is of considerable importance, since its water is extensively utilized for irrigation and other purposes.

4.2.4.3 The Dibdiba Plain

The Plain is situated in the south-eastern part of the region (Fig.4.2). The aquifer system underlying the area is mainly formed by sands and gravels of the Miocene-Pliocene formations. Its thickness is about 350m. Water is unconfined and depth to the water table increases from about 50m in the east to 200m in the west. The thickness of the aquifer increases from zero in the south-west to an unknown maximum in the east[(17)]. This can be attributed to the effect of the general slope of the area from the south-west and west to the north-east and east, with the elevation ranging from 289.6m in the west to 12.2m in the east[(18)]. However, wadis and surface depressions which occupy the eastern margin of the area are the most favourable locations for groundwater development as a result of the greater quantity of water available from surrounding areas for recharge. The most important depressions in the area are:

1. Safwan;
2. Al-Berjesiya; and
3. Al-Najmy.

The total area of these depressions is 472km^2 (Safwan 150km^2, Al-Berjesiya 198km^2 and Al-Najmy 124km^2[(19)].

The surfaces of the depressions are mostly composed of sandy layers with grits and gravels, occasional pebbly beds, locally intercalated with thin clayey or silty beds and sometimes containing an argillaceous or gypsiferous component. These formations are derived from the underlying Dibdiba formation (Pliocene)[20]. This formation creates favourable conditions for the free infiltration of rain water into the sandy-gravel sediments of these depressions and the Dibdiba area as a whole. The infiltration rate for the entire Dibdiba formations is about 8 to 10m a day, but near Zubair it amounts to about 15m a day[21]. Therefore, the Dibdiba formations provide good conditions for the storage and exploitation of groundwater.

4.2.4.3.1 Groundwater Recharge and Safe Yield

The groundwater recharge provides 90% of the surface runoff which is equal to 1% of the mean annual rainfall over the area (113mm)[22]. Thus, the total annual recharge to the depressions is equivalent to 481000cm, or individually 153000cm at Safwan, 202000cm at Al-Berjesiya and 127000cm at Al-Najmy. The total annual recharge to the depressions includes the above amounts, plus the additional amounts which recharge from the adjoining areas. The groundwater recharge of the depressions and the Dibdiba area as a whole varies annually, according to the large fluctuations in the annual rainfall.

The average groundwater discharge into the wells in the depressions is about 0.8cm/min. This falls to about 0.4cm/min in the surrounding areas to the west and south-west. This phenomenon indicates that the groundwater storage in the depressions is more than that in the surrounding areas.

Groundwater depth in the depressions is shallower than that in the surrounding areas due to groundwater concentration in the depressions. The depth ranges from 10 to 16m at Safwan, 15 to 25m at Al-Berjesiya and 15 to 20m at Al-Najmy. These increase in the surrounding areas and attain measured depths of 172 and 198m[23].

The total annual safe yield from direct rainfall is 255000cm at Safwan, 337000cm at Al-Berjesiya and 212000cm at Al-Najmy, with a mean of 0.5, 0.64 and 0.4cm/min respectively.

4.3 THE GROUNDWATER QUALITY

In order to determine whether or not exploitation is feasible, this section analyzes groundwater quality, particularly in the mountain, foothill and western desert regions from the viewpoint of its suitability for irrigation.

4.3.1 THE MOUNTAIN REGION

Table 4.2 shows that the EC value of the groundwater varies throughout the region. Its average is 0.54mmhos/cm, ranging between 0.22 to 0.63mmhos/cm. According to the US classification of irrigation water (Chapter 3, Fig.3.11), this water can be classified as having medium salinity (C2).

The average value of the sodium adsorption ratio (SAR) of the groundwater in this region is 0.2me/L (Table 4.2). According to the US classification, the groundwater quality from this point is regarded as providing a low sodium hazard (S1) and can be considered as satisfactory for irrigation (Chapter 3, Fig.3.11 and Table 3.16).

Groundwater quality from the viewpoint of the residual sodium carbonate (RSC), is satisfactory for irrigation as its mean value is negative (Chapter 3, Table 3.16).

Table 4.2 Chemical Analysis of the Groundwater at the Mountain Region

Sample	pH	EC mmhos/cm	Cation meq/L			Anion meq/L		
			Na	Ca	Mg	Cl	SO_4	HCO_3
1	7.4	0.51	0.2	3.4	1.9	0.2	0.8	5.1
2	7.8	0.47	0.1	1.8	2.4	0.3	1.4	4.1
3	7.3	0.63	0.1	3.2	3.8	0.3	0.8	6.3
4	7.4	0.55	0.1	3.4	2.3	0.2	0.8	5.9
5	7.5	0.4	0.05	3.0	0.8	0.2	Nil	4.4
6	7.4	0.42	0.08	3.4	1.3	0.1	"	6.1
7	7.5	0.45	0.1	3.0	2.0	0.2	0.2	4.7
8	7.7	0.56	0.04	3.2	2.5	0.2	0.8	5.5
9	7.6	0.5	0.06	3.8	1.8	0.2	0.2	6.3
10	7.2	2.44	0.6	29.3	8.0	0.5	32.5	3.1
11	7.5	0.57	0.1	2.6	3.9	0.3	1.4	6.4
12	7.5	0.36	0.3	2.3	1.3	0.3	1.4	4.0
13	7.7	0.29	0.05	2.5	1.3	0.3	2.2	3.8
14	7.3	0.56	0.1	4.0	2.5	0.2	Nil	6.6
15	8.1	0.22	0.2	1.7	0.4	0.2	"	2.4
16	7.5	1.42	9.0	4.1	3.3	7.9	3.3	6.9
17	7.5	0.47	0.06	3.7	1.7	0.2	Nil	5.2
18	7.4	0.47	0.3	3.4	1.6	0.3	"	4.7
19	7.2	0.48	0.1	3.4	1.5	0.2	"	4.9
20	7.4	0.36	0.07	3.3	0.6	0.2	"	3.7
21	7.6	0.51	0.3	33.8	1.3	0.2	"	5.0
22	7.5	0.62	0.3	4.3	0.4	0.3	"	6.0
23	7.3	0.45	0.1	4.2	0.3	0.2	"	4.3
24	8.2	0.40	0.04	1.0	3.5	0.2	"	4.4
25	7.2	0.55	0.1	4.5	1.3	0.2	"	5.8
26	8.0	0.35	0.03	1.2	2.6	0.2	"	3.9
27	7.4	0.37	0.1	3.2	0.4	0.2	"	3.4
28	7.7	0.38	0.1	3.5	0.4	0.2	"	4.0
29	7.5	0.40	0.08	3.7	0.6	0.2	"	4.2
30	7.8	0.29	0.06	2.9	0.4	0.2	"	3.2
31	7.3	0.52	0.05	4.2	0.6	0.2	"	5.4
Average	7.5	0.54	0.4	5.0	1.8	0.5	1.5	4.8

Source : Institute For Applied Research on Natural Resources, Utilization of Mineral and Thermal Springs in Iraq, Tech. Bull. No.58, Baghdad, March, 1974, pp.105-115 and Annex 1.

Chloride and sulphate average concentrations are 0.5 and 1.5me/L respectively. These values are well below the guideline limit for irrigation water and are therefore deemed to be satisfactory (Chapter 3, Table 3.16).

The average pH value is 7.5, ranging from 7.2 to 8.2. This is regarded as suitable for irrigation.

Table 4.2 shows that the predominant cation in most of the groundwater samples is calcium at an average of 5.0me/L. This can be attributed to the presence of significant quantities of minerals rich in gypsum, anhydrite, calcite and dolomite, which are dissolved in various degrees throughout the groundwater flow. The subsidiary cation is magnesium, with an average of 1.8me/L. This results from its association with calcium in most of the minerals listed above. Sodium occurs in small amounts with an average of 0.4me/L. The predominant anion is bicarbonate, with an average of 4.8me/L. This is due to the existence of the principal soluble material of carbonates (mainly of calcium), which is present in the sedimentary rocks[24]. Sulphate and chloride are the subsidiary anions at an average of 1.5 and 0.5me/L respectively, while the carbonate ion is almost absent.

4.3.2 THE FOOTHILL REGION

The groundwater salinity varies from place to place in this region. However, groundwater with an average EC value of less than 1.56mmhos/cm is confined to the central and north-west parts of the region. This increases considerably towards the south and the south-east and ranges from 1.56-4.68 to 4.68-9.36mmhos/cm[25]. According to the US irrigation water classification, the groundwater quality of the region is classified as a high (C3) to very high (C4) salinity (Chapter 3, Fig.3.11).

The SAR average value is 1.3me/L (Table 4.3). Therefore, the groundwater of the region is regarded as having low sodium hazards (SI).

Water quality regarding the RSC is considered to be safe for irrigation as its value is negative (Table 4.3).

The mean chloride value of 2.5me/L is regarded as satisfactory for irrigation. While the average sulphate value of 7.8me/L is still well below the index limit of irrigation water (Chapter 3, Table 3.16).

The average pH concentration is equal to 7.5. Thus, irrigation with such water is considered to be suitable.
The predominant groundwater cation is calcium, with an average value of 8.8me/L. Magnesium and sodium are the subsidiary cations with an average of 4.6 and 3.3me/L respectively.
The predominant anion is sulphate with an average of 7.8me/L,

Table 4.3 Chemical Analysis of the Groundwater at the Foothill Region

Sample No.	pH	EC mmhos/ cm	Cation meq/L			Anion meq/L		
			Na	Ca	Mg	Cl	SO_4	HCO_3
1	7.5	2.45	7.2	14.4	6.6	7.3	15.3	4.9
2	7.2	3.84	16.5	22.2	18.3	11.2	42.7	2.0
3	7.5	1.25	6.3	3.3	3.5	3.0	7.1	2.0
4	7.3	1.47	7.4	4.7	2.0	4.7	7.0	4.2
5	7.6	0.51	0.3	3.6	1.8	0.4	1.6	3.4
6	7.4	0.44	0.2	3.3	1.3	0.3	Nil	4.4
7	7.5	0.48	0.2	3.0	1.3	0.3	"	4.4
8	6.7	1.33	1.1	14.4	4.4	0.5	15.8	3.2
9	6.9	0.15	0.3	3.6	1.1	0.3	0.4	4.0
10	6.5	3.2	1.7	8.0	2.3	0.3	33.9	8.8
11	7.7	0.38	0.1	2.6	1.5	0.2	2.7	3.9
12	7.4	1.64	1.9	11.9	8.5	2.8	0.2	5.0
13	7.6	2.18	2.3	21.3	7.7	1.5	28.5	3.0
14	7.2	3.25	22.0	68.2	35.7	26.5	5.0	3.3
15	7.0	1.7	5.0	7.1	4.7	0.3	5.4	11.1
16	6.9	1.41	13.0	5.6	2.8	5.7	5.4	8.6
17	7.0	3.9	8.0	30.2	16.0	0.3	35.2	7.3
18	6.7	7.5	40.0	24.7	14.2	49.7	33.2	9.2
19	7.2	2.85	3.3	30.2	5.9	2.5	33.9	2.0
20	7.5	0.77	0.3	5.8	2.6	0.4	4.8	3.4
21	7.7	0.56	0.1	3.0	2.4	0.3	1.4	6.2
22	7.5	1.1	2.7	6.6	2.7	2.0	6.7	5.2
23	7.2	1.76	4.3	9.4	4.2	4.5	11.2	6.7
24	7.6	2.6	1.3	29.6	6.1	1.0	31.6	2.0
25	7.7	2.43	0.9	29.9	3.6	0.6	33.9	1.5
26	7.8	2.58	1.3	30.6	5.8	0.9	31.6	2.9
27(1)	7.5	0.4	0.6	3.2	0.5	0.5	0.4	3.8
28	7.2	0.44	0.6	3.3	0.6	0.5	0.6	2.9
29	7.0	0.46	0.3	3.6	1.1	0.3	0.3	4.6
30	7.2	0.55	0.8	3.4	1.7	0.5	0.4	5.0
31	7.2	0.46	0.6	2.8	1.1	0.5	0.6	3.5
32	7.3	0.64	0.5	4.2	1.6	0.8	0.3	4.5
33	7.5	0.9	1.9	4.1	3.4	0.6	2.8	5.4

Table 4.3 (cont.)

Sample No.	pH	EC mmhos/cm	Cation meq/L			Anion meq/L		
			Na	Ca	Mg	Cl	SO_4	HCO_3
34	7.9	0.97	2.5	4.7	3.7	0.9	4.6	4.6
35	7.5	0.66	1.1	3.2	2.5	0.4	0.6	5.1
36	7.0	0.51	0.8	2.8	1.7	0.3	0.3	4.2
37	7.9	0.54	0.8	3.1	1.7	0.4	0.7	4.6
38	7.7	0.54	1.4	2.2	1.8	0.4	0.4	3.0
39	7.4	0.41	0.7	2.4	1.3	0.3	0.7	3.2
40 (2)	7.3	0.91	1.2	4.9	3.6	0.5	6.0	3.6
41	7.7	0.49	0.6	2.7	1.7	0.3	0.8	4.5
42	7.6	0.53	0.9	3.0	1.8	0.3	1.2	5.0
43	7.7	0.46	0.6	2.4	1.8	0.3	0.5	4.4
44	7.8	0.43	0.2	2.9	1.3	0.3	0.4	3.9
45	7.5	0.67	1.0	3.8	2.5	0.5	1.1	6.5
46	7.9	0.47	0.3	3.3	1.1	0.4	1.5	3.4
47	8.3	1.24	5.8	2.0	4.4	2.0	5.8	5.0
48	8.1	0.60	0.7	1.8	2.9	0.4	1.2	4.6
49	7.9	0.50	0.6	2.9	1.5	0.3	1.0	4.6
50	7.5	0.98	2.5	4.0	3.4	0.6	1.5	9.0
51	7.9	0.52	0.5	2.9	1.0	0.5	0.8	4.2
52	7.6	1.0	2.1	7.4	4.1	0.9	2.3	7.1
53	7.3	0.89	1.5	4.5	4.2	0.6	3.3	5.8
54	7.4	2.81	11.2	8.2	13.7	3.7	18.3	8.3
55 (3)	7.6	0.48	0.3	3.4	1.2	0.3	0.6	4.3
56	7.7	0.68	0.3	4.3	1.2	0.3	2.3	2.9
57	7.8	0.74	1.9	3.6	2.1	1.2	2.9	3.5
58	7.3	0.7	0.9	7.3	26.1	1.0	2.5	1.7
59 (4)	7.9	0.37	0.8	2.1	1.5	1.0	1.2	1.6
Average	7.5	1.3	3.3	8.8	4.6	2.5	7.8	4.6

Sources:

(1) Institute for Applied Research on Natural Resources, Utilization of Mineral and Thermal Springs in Iraq, op cit., pp.105-115 and Annex 1.

(2) Institute for Applied Research on Natural Resources, Hydrogeological Investigations in Jolak Basin of the Altun-Kupri Project Area, Tech. Rep. No.25, Baghdad, 1971, Annex 4 and Institute for Applied Research on Natural Resources, Groundwater Resources of Altun-Kupri Area, Tech. Bull. No.69, Baghdad, 1974, Annex 1.

(3) Institute for Applied Research on Natural Resources, Groundwater Survey of the Arbil Project Area, Tech. Bull. 50, Baghdad, May, 1973, Table 2 and Institute for Applied Research on Natural Resources, Groundwater Resources of Arbil Area, Tech. Bull.70, Baghdad, Sep., 1975, Annex 1.

(4) Faugere, Y. Hawa, A.J., et al, Hydrogeological Study of the Jazira-Singar Area, Institute for Applied Research on Natural Resources, Tech. Bull. 90, Baghdad, Feb. 1976, Annex 5.

followed by bicarbonate and chloride at average values of 4.6 and 2.5me/L respectively (Table 4.3).

4.3.3 THE WESTERN DESERT PLATEAU

Groundwater salinity differs throughout the region. Groundwater, with an average EC value of less than 1.56mmhos/cm occupies the north-western part of the region. This value rapidly increases in the southern and eastern parts in which it ranges from 1.56-4.68 to 4.68-9.36 mmhos/cm[26]. Regarding the US irrigation water classification, the groundwater quality is classified to have high (C3) to very high (C4) salinity. The second value (C4) exceeds the guideline limit for irrigation water (Chapter 3, Table 3.16).

In the previous section, it has already been explained that groundwater utilization for irrigation purposes is confined to the eastern and south-eastern limits of the region; namely, in the spring zone and in the Dibdiba depressions. Groundwater quality for irrigation purposes has been determined in these areas as follows.

4.3.3.1 The Spring Zone

Table 4.4 shows that the EC values vary from spring to spring. The average is 4.56mmhos/cm, ranging between 2.8 to 9.4mmhos/cm. Thus, the groundwater quality of all springs is classified to have very high salinity hazard (C4), but

Table 4.4 Chemical Analysis of the Spring Zone at the Western Desert Region

Sample No.	pH	EC mmhos cm	Cation meq/L				Anion meq/L		
			Na	K	Ca	Mg	Cl	SO_4	HCO_3
1	7.3	5.1	31.5	1.2	13.7	10.5	37.3	13.3	4.0
2	7.2	5.0	31.5	1.2	13.9	10.5	37.3	13.3	12.9
3	7.5	4.2	29.5	1.1	12.3	7.6	32.3	5.0	4.9
4	7.3	5.9	39.0	1.3	14.7	9.7	43.5	5.0	5.0
5	7.0	5.95	42.5	1.4	12.9	10.3	47.2	8.0	6.7
6	7.7	4.3	31.5	1.1	11.5	8.7	34.8	5.0	4.8
7	7.1	5.0	35.0	1.2	12.3	7.9	37.3	5.0	5.3
8	7.3	2.82	11.3	0.8	10.8	9.2	16.1	16.1	3.8
9	7.4	2.9	11.6	0.8	10.3	9.0	16.1	16.1	3.6
10	7.5	3.32	10.0	0.5	19.0	11.1	12.4	12.4	3.1
11	8.0	3.3	9.8	0.5	18.8	12.1	12.4	12.4	2.6
12	7.7	3.85	12.0	0.6	20.6	12.4	15.5	15.5	2.7
13	7.4	3.88	12.0	0.5	20.6	13.4	15.5	15.5	2.8
14	7.5	4.15	13.3	0.5	22.7	21.0	15.5	16.1	2.3
15	7.5	4.17	13.3	0.5	24.0	17.8	16.1	16.1	2.3
16	7.6	9.4	53.0	1.1	30.9	20.1	63.3	63.2	2.2
17	7.8	4.28	15.0	0.5	24.7	16.0	17.4	17.3	2.2
Average	7.5	4.56	23.6	0.9	17.3	12.2	27.6	15.0	4.2

Source : Institute for Applied Research on Natural Resources, Utilization of Mineral and Thermal Springs in Iraq, op.cit., pp.105-115 and Annex 1.

in spite of that, it is used for irrigation purposes. This is related to the soil, which is characterized by a coarse texture with rapid permeability as it is formed mainly from sand and gravel. Irrigation with such water is possible under such conditions.

The average value (SAR) is 6.1me/L. Thus, groundwater quality is classified as having low sodium hazard (S1). Water can therefore be used for irrigation with little danger of development of harmful levels of exchangeable levels of sodium.

The RSC value of all springs is negative. Therefore, irrigation with such water is regarded as safe. The average chloride value of 27.6me/L exceeds the irrigation guideline limit, although the average sulphate value of 15.0me/L is still below the guideline limit (Chapter 3, Table 3.16).

The average pH value is 7.5, ranging between 7.0 and 8.0 (Table 4.4). This is classified as satisfactory.

The predominant cation is sodium, at an average of 23.6me/L. Calcium, magnesium and potassium are the subsidiary cations, with average values of 17.3, 12.2 and 0.9me/L respectively. Chloride is the predominant anoin with an average of 27.6me/L, followed by sulphate and bicarbonate, with averages of 15.0 and 4.2me/L respectively. Carbonate and nitrate anions are absent (Table 4.4).

4.3.3.2 The Dibdiba Depressions

The average EC values of the groundwater varies in these depressions. Its average at Safwan is 5.5mmhos/cm, ranging from 3.6 to 7.8mmhos/cm (Table 4.5). This increases in the Zubair-Berjesiya depressions, where it ranges from 5.5 to 12.8mmhos/cm. Most of the EC values in these depressions are concentrated between 5.5 and 8.0mmhos/cm. The EC value, however, shows a tendency to increase from the depression centres towards the marginal limit, where it reaches 10.4 and 15.9mmhos/cm[27]. According to the US irrigation water classification, the groundwater salinity in all depressions exceeds the irrigation guideline limit and therefore is classified as unsuitable for irrigation (Chapter 3, Table 3.16). In spite of this, it is utilized for irrigation. This can be attributed to the soil, which has a coarse texture with high permeability. As a result, irrigation with such water is possible and currently occurs.

It is clear from Fig.4.2 that the depressions are located in the south-eastern part of the Dibdiba area and are formed from the same geological formations. Therefore, the other groundwater analyses, which represent the Safwan depression, have been applied from Table 4.5. Accordingly, the average value (SAR) is 7.4me/L. This water is classified as having low sodium hazard (S1). The RSC value

Table 4.5 Chemical Analysis of the Groundwater at Safwan Depression (Dibdiba Area)

Sample No	EC mmhos cm	Cation meq/L			Anion meq/L		
		Na	Ca	Mg	Cl	SO_4	HCO_3
1	5.4	34.0	30.7	6.8	19.9	42.5	0.9
2	4.2	23.7	28.6	7.0	11.8	38.5	0.9
3	4.6	36.5	18.0	8.0	11.2	42.5	1.1
4	4.4	19.0	33.7	5.6	15.0	37.7	1.0
5	3.6	17.7	25.9	6.7	6.0	37.2	0.9
6	5.9	29.0	34.4	8.0	25.5	40.6	1.6
7	5.9	34.0	29.1	9.4	22.7	44.6	1.5
8	4.9	26.0	28.1	7.5	17.0	22.0	0.3
9	7.8	48.0	32.3	12.5	38.2	53.3	1.4
10	3.7	11.8	30.4	5.3	5.2	38.0	1.6
11	7.1	38.0	32.8	9.8	32.2	47.0	1.7
12	6.1	43.6	28.4	8.3	24.5	46.5	1.4
13	6.8	48.0	27.1	7.7	25.0	52.8	1.3
14	5.9	38.0	28.9	8.1	23.0	44.1	1.4
Average	5.5	32.0	29.2	7.9	19.8	42.0	1.2

Source : Lageman, R., Haddad, W. and Hawa, A.J. Results of Geoelectrical Survey Near Safwan, Institute for Applied Research on Natural Resources, Tech. Bull. 89, Baghdad, Dec. 1975, Tab. 2b.

is negative and therefore the groundwater of the depressions is considered to be satisfactory for irrigation.

The chloride and sulphate concentrations exceed the irrigation index limit as their average values are 19.8 and 42.0me/L respectively.

An earlier study has proved that the mean pH value is 7.2[28]. Thus, irrigation with such water is regarded as satisfactory.

The predominant groundwater cation is sodium, with an average value of 32.0me/L, with subsidiary calcium (29.2me/L) and magnesium (7.9me/L). The predominant anion is sulphate with an average of 42.0me/L, followed by chloride and bicarbonate with average values of 19.8 and 1.2me/L respectively.

4.4 CONCLUSION

From the foregoing review of the groundwater resources, it should be pointed out that the most important potential aquifers are confined to the mountain and foothill regions. These are mainly represented by the Pliocene and Pleistocene formations. The recharge, storage and safe yield of the aquifers are generally promising. In addition, the groundwater depth ranges from 5-50m. Moreover, water quality is generally acceptable for irrigation purposes.

In the lowland region, the groundwater is unsuitable for use, due to its very poor quality.

Regarding the western desert region, the groundwater condition is characterized by low recharge which results in low storage and safe yields. Furthermore, the groundwater is generally deep as it ranges from 50-300m. The most important locations for groundwater development are mainly confined to the wadis, depressions and the eastern margin of the region. The groundwater quality of the region is classified as having a high to very high salinity hazard.

Finally, optimum groundwater development requires quantitative evaluation which can be achieved by a consideration of the following:

1. Long term observations of such basic hydrological data as water level and its fluctuations, infiltration rates, stream flow records, direction and velocity of water movement are required to determine groundwater storage.
2. A systematic and wide groundwater sampling from the existing wells and springs in the mountain, foothill and western desert is needed for the purposes of water quality analyses.
3. Regular discharge measurements of the existing wells and springs should be carried out to determine specific safe yield.
4. Hydrogeological surveys should be undertaken in the important groundwater regions, to explore the groundwater bodies, their relationships and the groundwater table.
5. Research by the Institute for Applied Research on Natural Resources should be encouraged and supported.
6. A continuous recording of meteorological data: temperature, rainfall, evaporation etc. is required. Furthermore, the installation of additional meteorological stations will benefit the development of the ground and surface water resources.

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CHAPTER 5

THE DEVELOPMENT OF THE EUPHRATES AND TIGRIS RIVER BASINS IN TURKEY, SYRIA AND IRAN

5.1 INTRODUCTION

This chapter focuses on the present and future development of the Euphrates and Tigris river basins outside Iraq, in Turkey, Syria and Iran. Most of these, particularly the planned future developments, are located in Turkey and Syria, while those in Iran are of marginal importance. However, the main objectives of this chapter are to determine the effects of these developments on the availability and quality of Iraq's water resources. Thus, it mainly considers the development scale, implementation schedule and the existing problems facing the government organizations which are responsible for these developments. In the light of these problems, it will be possible to examine how successful are the governments in the establishment of the large scale planned irrigation and hydroelectric power developments in the Euphrates and Tigris river basins.

5.2 THE DEVELOPMENT OF THE EUPHRATES BASIN IN TURKEY

5.2.1 THE RIVER HYDRAULIC ASPECTS

The Euphrates river flows from the mountainous area of eastern Turkey which rises to a height of more than 3000m. It is formed from four main tributaries; the Karasu, the Murat, the Munzur and the Peri. The total length of the Euphrates river in Turkey is about 455km and its drainage area is 125000km^2, or 28% of the whole drainage basin (Chapter 3). The average long term river water discharge at Karkamis, close to the Syrian border, is 996 cumecs (31.4bcm). This comes entirely from Turkey and forms 89% of the total annual water potential which is 1123 cumecs (35.4bcm). It represents 17.44% of the total annual Turkish water potential which is 180bcm.

5.2.2 THE DEVELOPMENT BACKGROUND

The Turkish interest in the large scale development of the Euphrates river, with a prior objective of hydroelectric power generation, started in the 1930s after the establishment of the Electrical Works Survey Authority (EIE). In 1958, the EIE prepared the first exploration report which suggested, downstream of the key project at Keban, a three-dam system (Bilalusagi, Sarsap and Halfeti) for hydro-electric purposes only. In 1967, another reconnaissance report by the State Hydraulic Works Authority (DSI), laid special emphasis on irrigation and foresaw a two-dam system (High Tasustu and Hisarkoy), where irrigation water would be diverted from the first reservoir and conveyed by gravity and pumping. Garbrecht (1968) suggested a two-dam system (Karakaya and Karababa), with gravity irrigation diverted from both dams.

The feasibility report prepared for DSI by the co-operative group, Electrowatt-Tipton Kalmbach-SGI-Gizbili (1970), foresaw a three-dam system (Karakaya-Golkoy and Middle Karababa), where irrigation water would be diverted from the third reservoir and conveyed mainly by pumping.

As a result of high increases in energy prices due to the oil crisis of 1974, the feasibility study was revised again. This revision showed that the difference in economic parameters between the selected three-dam alternative (Karakaya-Golkoy and Middle Karababa) and the next best two-dam alternative (Karakaya and High Karababa) had greatly diminished, because the High Karababa dam enables gravity irrigation for a significant part of the area and greatly decreases the pumping energy requirements. As a result, in early 1978, the DSI finally settled for the two-dam system (Karakaya and High Karababa). The High Karababa, which will be the largest dam in Turkey, was named the Ataturk Scheme (relating to the founder of the modern Turkish Republic)(1).

5.2.3 THE DEVELOPMENT OF THE UPPER EUPHRATES

This comprises the Keban dam and all the other upstream small dams, top priority of which is hydroelectric power generation.

5.2.3.1 The Keban Project

Keban is a rockfill dam, with a height of 206m above its foundations. The dam creates an artificial lake with a surface area of 680km^2 and a total storage capacity of 30.7bcm (Table 5.1). The construction work began in 1966 and was completed and filled in 1973, with two main objectives:

1. to regulate the river flow; and
2. to generate hydroelectrical power with an installed capacity of 1240MW.

The estimated cost of Keban, including electrical power transmission lines, was US $300 million, of which half was in foreign currency, financed by loans obtained from the World Bank, the European Investment Bank, the US Agency for International Development (AID), West Germany, Italy and France(2).

Furthermore, the development includes eight small dams on the tributaries. Four of these are complete. The total storage capacity of all will be 0.381bcm (Table 5.1).

Table 5.1 <u>Hydraulic Structures of the Upper Euphrates in Turkey</u>

Dam	Status	Total storage (mcm)
Keban	completed	30700.0
Tercan	completed	178.0
Medik	completed	22.0
Kalecik	completed	12.5
Cip	completed	7.0
Kale	planned	67.6
Sultansuyu	planned	53.3
Gayt	planned	23.0
Mursal	planned	17.6
Total		31081.0

<u>Sources</u>: Doluca K. and Pircher W. Development of the Euphrates River Basin in Turkey (1971): In Water Power Vol. 23, No. 2 p48

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Uskay S. et al GAP, DSI General Directorate, Ankara, 1980 ppv3-v26

Besides the energy generation, the scheme will provide irrigation water for a total planning area of 300000ha (Table 5.2).

5.2.4 THE PLANNED DEVELOPMENT OF THE LOWER EUPHRATES

According to the State Hydraulic Works (DSI, 1980), quoted by Ozis (1982)[3], this includes all the projects downstream of the Keban dam (Tables 5.2, 5.3 and Fig.5.1), together with that of the Tigris river, known as the South-east Anatolia Project.

5.2.4.1 The Karakaya Project

Karakaya is an arched gravity dam, completed in 1986, with a height of 169m above the river bed and total storage capacity of 9.58bcm, of which 5.58bcm is useful storage (Table 5.3). The main purpose of the project is hydro-electric power production, with an installed capacity of 1800MW. The scheme greatly benefits from the regulation effect of the upstream Keban reservoir.

5.2.4.2 The Adiyaman-Kahta Project

The project is at the reconnaissance level and comprises two earth fill dams (Adiyaman and Kahta), which are scheduled to be constructed on the two western tributaries of the Euphrates (Fig.5.1). The heights of the dams will be 90 and 125m above the river bed respectively. The total storage capacity will be 2.504bcm, of which 0.918bcm will be

Table 5.2 The Euphrates : Existing and Planned Irrigation Projects and Their Water Demands, In Turkey

Project	Annual Irrigation Water Req. m³/ha.	Irrigation Area ha. by gravity	Irrigation Area ha. by pumping	Total ann. irrigation water req. (bcm)
1) Existing irrigation projects of the whole river	9100*	23480		0.21
2) Planned irrigation projects				
A) The Upper Euphrates projects	8333	300000		2.5
B) The Lower Euphrates projects:				
Kahta	7630	-	80000	0.61
Adiyaman	7630	-	80000	0.61
Ataturk Harran	8900	180000	-	1.6
Ataturk Mardin	10000	120000	192000	3.12
Ataturk Hilvan	10460	-	180300	1.89
Ataturk Bozova	10460	-	55300	0.58
Ataturk Suruc	8900	30000	116500	1.3
Birecik Araban	7225	-	23300	0.17
Birecik Gaziantep	8750	-	88900	0.78
Total Planned Irrigation Land		1446300		13.2

Sources: Devlet Su Isleri (DSI), Statistical Abstract 1983, DSI General Directorate, Ankara, 1984, pp. 82-85.

Ozis, U., The Development Plan for the Lower Euphrates Basin in Turkey (1982): In Natural Resources and Development, Vol. 16, pp. 78-79.

* Based on the Average Annual Irrigation Water Requirement of the Planned Development.

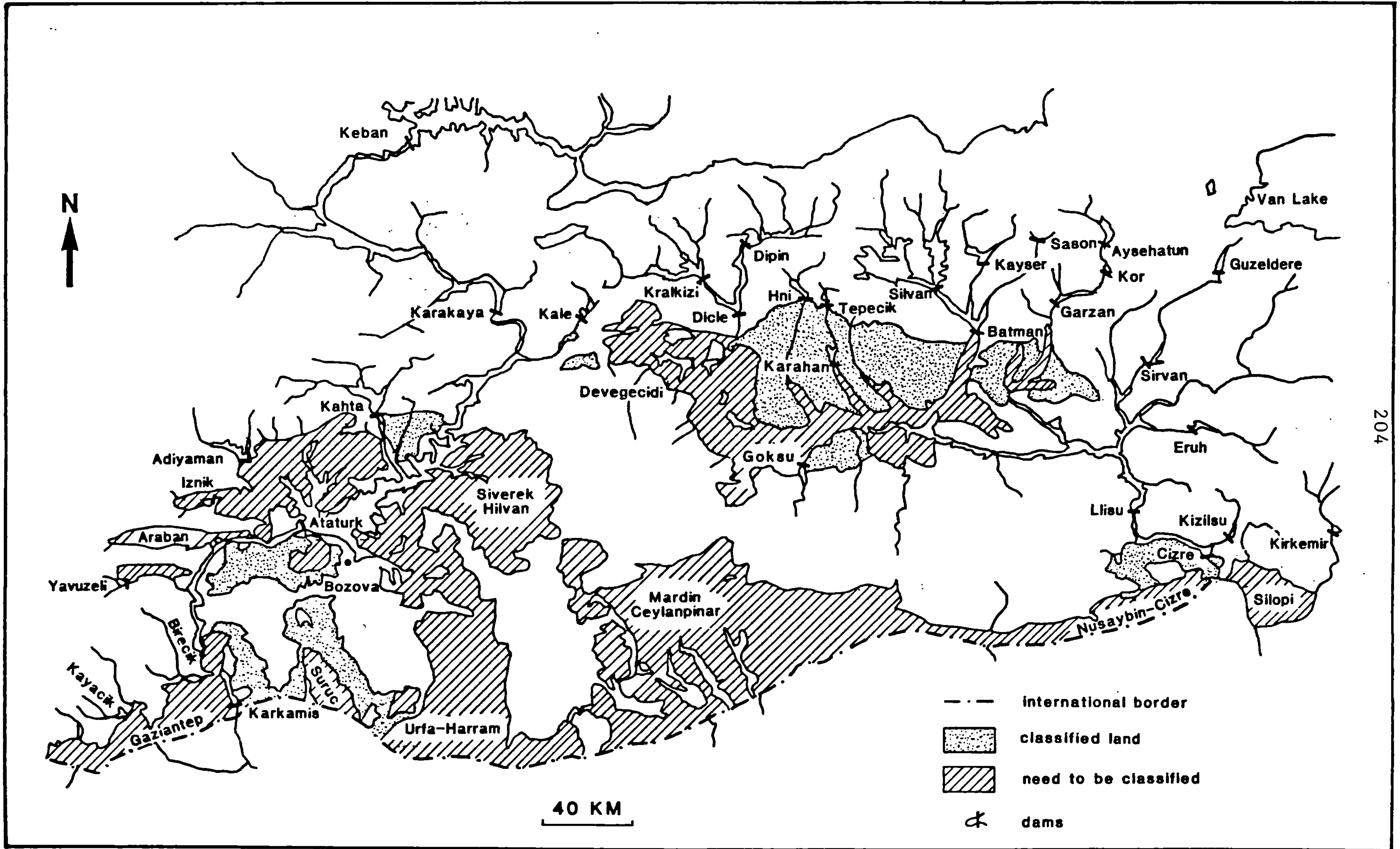
Table 5.3 Hydraulic Structures of the Lower Euphrates Basin

Project	Height above river bed(m)	Total storage (mcm)	Useful storage* (mcm)	Annual natural inflow(mcm)
Karakaya	169	9580.0	5580.0	23550.0
Kahta	125	1887.0	661.0	1000.0
Adiyaman	90	617.0	257.0	2000.0
Ataturk	166	48500.0	12000.0	26650.0
Ataturk/Mardin	23	335.0	261.0	negl.
Ataturk/Derik	35	345.0	318.0	negl.
Ataturk/Hilvan (17 dams)	22-52	470.0	344.0	negl.
Ataturk/Suruc (3 dams)	17-27	40.0	27.0	negl.
Birecik	49	1314.0	972.0	30970.0
Birecik/Gaziantep (3 dams)	33-47	130.0	110.0	150.0
Karkamis	23	271.0	86.0	31380.0
Total		63489.0	20616.0	

Source: Ozis U. The Development Plan for the Lower Euphrates Basin in Turkey (1982), Ibid, pp76

* useful storage is: total storage-(seepage plus evaporation loss, plus the amount of water which cannot be extracted from the reservoir)

Fig. 5.1 : Planned Irrigation Developments on the Euphrates and Tigris Basins in Turkey



Source: DSI (Devlet Su Isleri), the Kralkizi Dam and Hydroelectricity Plant, 10th Regional Directorate of DSI, Diyarbakir, 1985, (Pamphlet in Turkish).

useful storage (Table 5.3). The project will provide irrigation water to an area of 160000ha (Table 5.2), on the right bank of the Ataturk reservoir. The irrigation water has to be pumped to a height of 130m from Kahta and to 210m from the Adiyaman reservoirs. In addition, the project includes hydroelectric power plant at the foot of the Adiyaman dam with an installed capacity of 75MW.

5.2.4.3 The Ataturk Project

This multi-purpose project is considered the heart of the Lower Euphrates basin development plan. The main feature is the rockfill Ataturk dam, under construction. It will be the largest dam in Turkey. The total storage capacity of the total Ataturk scheme will be 49.69bcm, of which 12.95bcm will be useful storage (Table 5.3).

The Ataturk reservoir will provide irrigation water to four major irrigation systems. The largest system will irrigate 492000ha by gravity through the Urfa twin tunnel (under construction), which will have a total length of 26.4km and an interior diameter of 7.6m. After the tunnel, the conveyance canal branches off into two subsystems. The first subsystem includes the Urfa hydroelectric power plant and offers irrigation water for an area of 160000ha by gravity at the Harran Plain. The second subsystem irrigates an additional area of 20000ha by gravity at Harran and 120000ha in the Mardin Plains. Also, it irrigates the remaining part of the Mardin Plain by pumping, with the help of two intermediate reservoirs; Mardin and Derik. About 15000ha at Akcakale and 60000ha at Ceylanpinar, close to the irrigation area of the first system, are planned to be irrigated from groundwater; of that there are 9000ha already under operation.

The other three systems are at the reconnaissance level. The second system will irrigate 180300ha in the Hilvan-Siverek region by pumping water to 75m and, with the help of 17 small dams, forming intermediate reservoirs. The third system will irrigate 55300ha in the Bozova region by pumping water to 144m. The fourth system will irrigate 30000ha by gravity in the Yaylak Plain, on the left bank of the Ataturk reservoir, and the remaining area of 116500ha at Suruc by pumping water up to 74m. In addition, three small dams and four small hydroelectrical power plants are planned along the main conveyance system.

Besides the irrigation, the project will generate hydro-electric power with a total installed capacity for the whole scheme of 2500MW.

5.2.4.4 The Birecik Project

The main feature of this project is the Birecik rockfill dam which will be constructed on the main river, with a height of 49m above the river bed. Its total storage capacity will be 1.314bcm, out of which 0.972bcm will be useful storage. The project will provide water for two irrigation systems on the right bank of the river. The first system will irrigate 23300ha in the Araban region by pumping water from the Birecik reservoir to 70m. 1600ha of the total will be irrigated by the Karasu tributary. The second system includes all the irrigated land in the Gaziantep region, with a total of 88900ha, which will be pumped from the Birecik reservoir to 67m. Three small dams will provide support during the peak irrigation season and 6600ha will be irrigated by pumping returning water. In addition, the project will generate hydroelectric power with an installed capacity of 800MW.

5.2.4.5 The Karkamis Project

This last project on the Euphrates river, close to the Syrian border, encompasses a rockfill dam, 23m in height above the river bed. Its total storage capacity will be 0.271bcm, of which 0.086bcm will be useful storage (Table 5.3). At this point, the total annual water potential of the Euphrates is 31.4bcm. The main objective of the project is hydroelectric power generation with an installed capacity of 350MW.

5.2.5 EVALUATION OF THE EUPHRATES WATER BALANCE

Table 5.2 shows that the present total irrigated area of the whole Euphrates river is about 23480ha and the total annual irrigation water demand is evaluated at 0.21bcm. The total future irrigated land will be 1446300ha and the total annual irrigation water requirement will amount to 13.2bcm. This, together with evaporation water loss, will reach 17.4bcm, or 49.2% of the river's total annual water potential which is 35.4bcm (Table 5.4). In this instance, the remaining annual water flow to Syria and Iraq will be only 18.0bcm, or 50.8% of the river's total annual water potential.

If the same experience of the Lower Seyhan Project (section 5.6) is repeated in the Euphrates projects, by applying flood irrigation methods, the amount of water reaching the lower riparian states will be definitely less than 50.8%. This situation will not only affect the amount of water, but also the quality of the water will be seriously impaired.

5.2.6 THE INVESTMENT COSTS AND BENEFITS OF THE PROJECTS

The total estimated investment cost of the lower Euphrates projects alone, based on 1979 rates, is US $11.2 billion, 34.7% of that being in foreign currency (Table 5.5).

After final development (section 5.4), the total annual irrigation benefit is expected to be US $0.7 billion. This is calculated from the production increase which is estimated to be in the order of US $600/ha. Furthermore, the annual energy benefit will be worth US $1.6 billion. Thus, the total annual benefit will be US $2.3 billion.

Table 5.4 <u>Evaluation of the Euphrates Water Balance in Turkey</u>

Status	Annual water volume(bcm)
Potential River Flow	+35.4*
Existing Irrigation Projects	- 0.21
Keban Reservoir Evaporation Loss	- 1.0
Present Outflow to Syria and Iraq	+34.2
Potential River Flow	+35.4
Upper Euphrates Planned Irrigation Projects	- 2.5
Upper Euphrates Reservoirs Evaporation Loss	- 0.7
Upper Euphrates (Keban Reservoir Evaporation Loss)	- 1.0
Lower Euphrates Planned Irrigation Projects	-10.7
Lower Euphrates Reservoirs Evaporation Loss	- 2.5
Future Outflow to Syria and Iraq	+18.0

<u>Source</u>: Ozis U. Op. Cit. p79

* Derived from Chapter 3 (Table 3.1)

Table 5.5 Investment Estimates of the Lower Euphrates Basin Development Projects

Project	Items	Foreign exchange (m US$)	Total investment (m US$)
Karakaya	Dam + Power plant	600.0	1470.0
Adiyaman	Dam + Power plant	75.0	230.0
Adiyaman	Irrigation	170.0	475.0
Kahta	Dam + Irrigation	196.0	600.0
Ataturk	Dam + Power plant	800.0	1780.0
Urfa	Irrigation + Power plants	720.0	3000.0
Hilvan	Irrigation + Dams	330.0	1220.0
Bozova	Irrigation	96.0	330.0
Suruc	Irrigation + Dams + Power plants	227.0	820.0
Birecik Karkamis	Dam + Power plant	420.0	715.0
Araban	Irrigation	38.0	70.0
Gaziantep	Irrigation + Dams	212.0	490.0
Total		3884.0	11200.0

Source: Ozis U. The Development Plan of the Lower Euphrates Basin in Turkey, Op. Cit., p81

5.3 THE DEVELOPMENT OF THE TIGRIS BASIN IN TURKEY

5.3.1 THE HYDRAULIC ASPECTS OF THE RIVER

The Tigris river rises in the south-east mountain area of Turkey, where the elevation ranges from 1000 to 1500m. It is joined by three main tributaries; the Batman, the Garzan and the Botan. The total length of the Tigris river in Turkey is about 300km and its basin area is 57614km, or 12% of the whole basin. Its elevation ranges from 1000 to 4000m. The average long term water discharge at Tusan in Iraq, close to the Turkish border, is 659 cumecs (20.8bcm). This comprises 42.4% of the total annual water potential which is 1554 cumecs (49bcm) (Chapter 3). It represents 11.6% of the annual Turkish water potential which is 180bcm.

5.3.2 THE DEVELOPMENT BACKGROUND

The development background of the Tigris river started in 1940s, with the beginning of regular hydrometric observations. The first report prepared by EIE in 1958, suggested five dams, three of which would be on the main river and two on the Batman and Garzan tributaries. These were to provide irrigation water for 20000ha and to generate hydroelectic power, with an installed capacity of 800MW. In 1968, another report prepared by DSI, placed the emphasis on irrigation and proposed the development of 190000ha as well as the generation of 3.6 billion KWh, through 20 dams of variable size. Later studies by DSI and EIE planned to develop 560000ha of irrigated land and to generate hydroelectric power with an installed capacity of 2200MW[4].

5.3.3 THE PLANNED DEVELOPMENT

According to DSI, 1980, based on Ozis (1983)[5], the planned development projects are as follows.

5.3.3.1 The Kralkizi-Dicle Project

This project encompasses five complex dams with a total storage capacity of 3.505bcm, of which 3.07bcm is useful storage. It will offer water for an irrigated area of 140000ha on the right bank of the Upper Tigris (Tables 5.6, 5.7 and Fig.5.1). The existing Devegecidi dam will supply irrigation water for 9000ha. The Goksu dam will serve 4000ha. The remaining large portion of 126000ha will be irrigated by pumping water to 80m from the reservoir of Dicle dam. While the Kralkizi dam will primarily serve as a reserve supply.

In addition, the project will generate hydroelectric power from three plants, with an installed capacity of 209MW.

5.3.3.2 The Silvan Project

The main feature of this project will be the Silvan dam and five other small dams, with a total storage capacity of

Table 5.6: <u>Hydraulic Structures of the Tigris Basin</u>

Project	Height above river bed (m)	Total storage (mcm)	Useful storage (mcm)	Annual natural inflow (mcm)
Dicle/Dipni	90	1020.0	855.0	990.0
Kralkizi	112	1920.0	1712.0	760.0
Dicle	62	305.0	255.0	1900.0
Dicle/Devegecidi	33	195.0	187.0	175.0
Dicle/Goksu	50	65.0	57.0	55.0
Silvan/Hani	58	130.0	124.0	75.0
Silvan/Tepecik	58	31.0	29.0	30.0
Silvan/Karahan	45	71.0	67.0	55.0
Silvan	185	8735.0	4700.0	3770.0
Silvan/Kayser	125			
Silvan/Sason	80	(included in the fig. of Silvan)		
Batman	74	1175.0	737.0	4270.0
Garzan	170	500.0	435.0	1290.0
Garzan/Aysehatun	68	409.0	331.0	255.0
Garzan/Kor	83	74.0	59.0	135.0
Ilisu	130	10410.0	7460.0	15545.0
Cizre	53	522.0	201.0	15800.0
Total		25562.0	17209.0	

<u>Source</u>: Ozis U. Development Plan of the Western Tigris Basin in Turkey (1983): In Water Resources Development, Vol.1, No.4, p345

Table 5.7 The Tigris : Existing and Planned Irrigation Projects and Their Water Demands, In Turkey

Project	Annual Irrigation Water Req. m^3/ha.	Irrigation Area ha.		Total ann. irrigation water req. (bcm)
		by gravity	by pumping	
1) Existing irrigation projects	9581	10100		0.1
2) Planned irrigation projects				
Dicle Kralkizi	11700	-	126080	1.475
Dicle Devegecidi	11430	8960	-	0.102
Dicle Göksu	11000	4350	-	0.05
Silvan	8680	198500	-	1.73
Silvan Hani	8680	7000	-	0.06
Silvan Tepecik	8680	2500	-	0.022
Silvan Karahan	8680	5000	-	0.043
Batman	8680	27900	9800	0.327
Garzan	8440	30600	29400	0.51
Garzan Kozluk	8440	4100	-	0.035
Cizre Idil	9800	-	70000	0.686
Cizre Silopi	9020	-	32000	0.29
Cizre Silopi (Nerdüs)	9020	2400	-	0.022
Total Planned Irrigation Land		558590		5.4

Sources : Devlet Su Isleri (DSI), Statistical Abstract 1983, op. cit., p.84.

Ozis, U., ibid, p.347.

8.97bcm, of which 4.92bcm is useful storage. The project will supply irrigation water by gravity to 213000ha, located on the left bank of the Upper Tigris. The Silvan reservoir will supply irrigation water for an area of 198500ha and the remaining 14500ha will be served by three small dams (Hani, Tepecik and Karahan). A part of the Batman tributary flow will be diverted by two small dams (Sason and Kayser) towards the Silvan reservoir, where basic flow regulation will occur (Tables 5.6, 5.7 and Fig.5.1).

Furthermore, the project will generate hydroelectric power with an installed capacity of 300MW from a power plant which will be constructed at the foot of the 185m high Silvan dam.

5.3.3.3 The Batman Project

The Batman reservoir, with a total storage capacity of 1.175bcm (0.737bcm is useful storage), will serve an irrigated area of 38000ha and will generate hydroelectric power with an installed capacity of 130MW from the power plant at the foot of the dam. There will be 19000ha on the right bank of the Batman tributary and 9000ha on the left bank, irrigated by gravity. The remaining 10000ha on the left bank will be irrigated by pumping water to 55m.

5.3.3.4 The Garzan Project

The project will supply irrigation water for 60000ha of land, situated on both banks of the Garzan tributary. Almost one-half of this land will be irrigated by gravity and the other half by pumping water to 55m.

A further 4100ha will be irrigated by water diverted through the Kozluk weir. This system will be supported in July, the driest month, by the reservoir regulation of a small dam.

Two high-head diversion plants are planned to be constructed upstream from the Garzan dam, supplied from the reservoirs of two dams (Aysehatun and Kor).

The project also aims to generate hydroelectric power with an installed capacity of 90MW from the power plant at the foot of the 170m high Garzan rockfill dam and an additional 54MW from the two dams upstream of Garzan.

5.3.3.5 The Ilisu Project

The main Ilisu dam and reservoir has a total storage capacity of 10.41bcm, of which 7.46bcm is useful storage. The main objective of this project is hydroelectric power production, with an installed capacity of 1200MW, which will be generated from the power plant at the foot of the 130m high Ilisu dam.

5.3.3.6 The Cizre Project

This last project on the Tigris in Turkey (Fig.5.1) encompasses the Cizre dam, with a height of 53m above the river bed. The total storage capacity of the reservoir behind the dam will be 0.522bcm, of which 0.201bcm will be useful storage. The project will provide irrigation water for 104400ha of land (Tables 5.6 and 5.7). Of this, 70000ha on the right bank of the Tigris will be irrigated by pumping water to 200m from this reservoir. A previous planning indicated that a large part of this subproject, called Idil-Nusaybin, had to be irrigated by the Lower Euphrates system through canals with a total length of about 400km. At present, there is 7800ha at Nusaybin under irrigation by water diverted through the Cagcag weir from the Euphrates tributary of the same name. A further 19000ha may be irrigated after the construction of the Nusaybin dam.

The remaining 32000ha on the left bank of the Tigris, forming the Silopi subproject, will be irrigated by pumping water to 100m from the Cizre reservoir. Another 2400ha are to be irrigated through the Nerdus weir on a small tributary and conveyed by gravity.

The project will also generate hydroelectric power with an installed capacity of 210MW, from the power plant at the foot of 53m high Cizre dam.

5.3.4 EVALUATION OF THE TIGRIS WATER BALANCE

Table 5.7 illustrates that the total existing irrigated land of the Tigris river in Turkey is 10100ha. Its annual irrigation water requirement is in the order of 0.1bcm. This is based on the average annual irrigation water demand for the planned irrigation projects which is 9581m^3/ha. In future, the total irrigated area will rise to 558590ha and will require an annual water volume of 5.4bcm. This, together with the water evaporation loss, will amount to 6.4bcm (Table 5.8). This comprises 30.8% of the annual river water discharge at Tusan in Iraq, close to the Turkish border, and 13.1% of the river's total annual water potential downstream of Baghdad which is 49bcm (Chapter 3, Table 3.1). Consequently, Iraq will receive an annual amount of 42.6bcm, or 86.9% of the total annual water potential of the river. However, this amount will be reduced further if the irrigation methods in the Lower Seyhan project are also practised in the Tigris projects. There will be a further reduction due to water consumption in Iran (section 5.8).

5.3.5 THE INVESTMENT COSTS AND BENEFITS OF THE PROJECTS

The total estimated investment cost for the Tigris development, based on 1979 rates, is US $6.04 billion, 39% of it in foreign exchange (Table 5.9).

After final development (section 5.4), the total annual

Table 5.8 Evaluation of the Tigris Water Balance in Turkey

Status	Annual Water Volume(bcm)
Natural Flow of the River at Tüsan in Iraq (close to the Turkish border)	+20.8*
Existing Irrigation Projects	- 0.1
Present Outflow to Iraq (Excluding Tributaries in Iraq)	+20.7
Natural Flow of the River at Tusan	+20.8
Planned Irrigation Projects	- 5.4
Evaporation Water Loss from the Reservoirs	- 1.0
Future Outflow to Iraq (Excluding Tributaries in Iraq)	+14.4

Source: Ozis U. The Development Plan of the Western Tigris Basin in Turkey (1983), Op. Cit., p351

* Derived from Chapter 3 (Table 3.6)

Table 5.9 Investment Estimates of the Tigris Basin Development Projects

Project	Items	Foreign exchange (m US$)	Total investment (m US$)
Kralkizi	Dam + Power plant	60.0	240.0
Dicle	Dam + Power plant	35.0	150.0
Dicle	Irrigation	250.0	710.0
Silvan	Dam + Power plant	375.0	830.0
Silvan	Irrigation	363.0	1180.0
Batman	Dam + Power plant	54.0	100.0
Batman	Irrigation	60.0	200.0
Garzan	Dam + Power plant	105.0	290.0
Garzan	Irrigation	106.0	310.0
Ilisu	Dam + Power plant	550.0	1100.0
Cizre	Dam + Power plant	120.0	230.0
Cizre/Idil	Irrigation	197.0	490.0
Cizre/Silopi	Irrigation	74.0	210.0
Total		2349.0	6040.0

Source: Ozis U. Development Plan of the Western Tigris Basin in Turkey, Op. Cit., .p351 irrigation benefit is estimated to be US $0.3 billion. This results from the production increase which is expected to be in the order of US $550/ha. In addition, the annual energy benefit will be US $0.6 billion. Hence, the total annual benefit will be US $0.9 billion.

5.4 THE EUPHRATES AND TIGRIS DEVELOPMENT IMPLEMENTATION SCHEDULE

As mentioned previously, most of the Euphrates and Tigris projects are either under construction or in the planning stage. At present, the Turkish government has given high priority to the major civil engineering works, the dams and the irrigation systems which are under the responsibility of the State Hydraulic Works (DSI). Only Keban, Karakaya and five other small dams are completed (Table 5.1). The remaining major works are scheduled to be completed either before or in the year 2001, as shown in Table 5.10.

This schedule differs from the earlier published schedules and takes into consideration a number of delays. The general opinion within DSI and in the universities is that, barring unforeseen problems, this schedule will be achieved. There are no financial constraints on DSI and the civil engineering works for which they are responsible are seemingly well designed.

The other agronomic aspects of the development are currently receiving less attention from Turkish government agencies. For instance, the General Directorate of Rural Services which is responsible for irrigation management and drainage is receiving very little money from the government,

Table 5.10 Major Civil Engineering Works

1. The Euphrates Project

Sub-Project	Completion Date
Ataturk Dam	1992
Urfa Tunnel	1990
Urfa HEP Station	1991
Harran Plain Irrigation	1990
Sivrek-Hilvan Irrigation	2001
Bosova Irrigation	1993
Mardin-Ceylanpinar Irrigation	1999
Karakaya Dam	1989 (Filling commenced 1986)
Birecik Dam	1992
Karkamis Dam	1992
Suruc-Baziki Irrigation	1999
Adiyaman Khata Dam	1999
Adiyaman Plains Irrigation	1993
Adiyaman Goksu Dam	1997
Hancagis Dam and Irrigation	1990
Kayacik and Kemlin Dams and Irrigation	1996

Continued

2. The Tigris Project

Sub-Project	Completion Date
Kralkizi Dam	1991
Tigris Dam	1991
Tigris Right Bank Irrigation	1993
Batman Dam	1990
Batman Right Bank Irrigation	1992
Batman Left Bank Irrigation	1992
Garzan Dam and Irrigation	2000
Ilisu Dam	1994
Cizre Dam	1994
Silopi Plain Irrigation	2001
Nusaybin-Cizre Irrigation	2001

Source: Devlet Su Isleri (State Hydraulic Works), March 1986: In Mitchell J.K.M. The South East Anatolia Project - Commercial Opportunities, Preliminary Report, British Embassy, Ankara, and Department of Trade and Industry, London, August 1986, p3 compared with the amount allocated to DSI. Overall, other aspects of the development such as the question of how irrigation water will be applied to the land, together with the problems of drainage, agro-education, agricultural extension, crop types, marketing and the communications structure, are at present being examined, primarily by Turkish universities and not by the government agencies concerned with their implementation. This is despite warnings from analysts of previous projects that such considerations must be dealt with in parallel with the civil engineering works, in order to achieve the rapid completion of the whole development. Officially, all other aspects of development structure are scheduled to be completed within 25-30 years. This seems to be over-optimistic.

If lessons have been learnt from previous projects, especially the Lower Seyham Project, then the Euphrates and Tigris Projects should be fully implemented by about the year 2020. If not, it could be argued that a further 15-20 years will be needed to complete the projects[6].

5.5 ORGANIZATIONS RESPONSIBLE FOR IRRIGATION DEVELOPMENT

This section deals with organizations which are responsible for irrigation development in order to examine their capability to implement the future planned developments of the Euphrates and Tigris rivers.

Thus, Turkey has 28000000ha for agriculture, of which 8500000ha constitute the irrigable lands. Irrigation works relating to 2320000ha of land have already been completed; 1000000ha of land are held by the private sector, the remaining 1320000ha have been irrigated by the General Directorate of State Hydraulic Works (DSI) and General Directorate of Soil and Water Conservation Service (TOPRAKSU) - two state organizations, with 1005000 and 315000ha respectively. The development of irrigation projects for the total irrigable land is under the government's long term basic investment programmes, under the responsibility of the DSI, TOPRAKSU, the Ministry of Food, Agriculture and Animal Husbandry and Agricultural Bank.

5.5.1 GENERAL DIRECTORATE OF STATE HYDRAULIC WORKS (DSI)

This is an agency with a legal entity and a supplementary budget organized in 1953 to develop water resources, to drain marshlands, to protect residential and agricultural lands from flood and to build hydroelectric power plants. Until 1976, the DSI controlled an irrigated area of 1005000ha.

The General Directorate of DSI consists of nine central divisions at the headquarters, 21 regional directorates and more than 50 sub-regional directorate branches in rural areas.

All the investments made for the irrigation construction, operation and maintenance expenditures are legally subject to repayment to DSI. This excludes those investments made for flood control work in the cause of public safety.

In the DSI sponsored irrigation networks, the conveyance and distribution systems are constructed as either the classical type (open canal) or canalet or piped systems. There are 523000ha, 177000ha and 11000ha (a total of 711000ha) of lands which have been installed respectively with classical, canalet and pipe networks. Canal systems in surface irrigation methods have shown a rapidly changing character in the past. The transition from unlined to lined canals has only been completed on a small scale in this modern development.

In the DSI constructed irrigation projects, various irrigation application methods are exercised by farmers. Farmers' knowledge and experience play an important role in the selection of the most economical and efficient irrigation methods. So far, the inadequate field development practices, the adoption of unsuitable crop patterns and the lack of farmer training have affected the development of the most suitable and most efficient irrigation methods. In most irrigation projects, farmers apply in general flood, furrow and border irrigation methods. In coastal strips, furrow and border methods are widely applied. From the viewpoint of water economy, the DSI is concerned deeply with modern irrigation methods which may be utilized by farmers, so that irrigation water may be used more efficiently. For this reason, DSI is trying to establish close co-operation with the local irrigation groups and other government agencies.

The construction and maintenance of drainage works in the irrigation projects is carried out by DSI and TOPRAKSU. The DSI is responsible for main collector, collector and interceptor drainage canal systems. TOPRAKSU is responsible for in-farm irrigation and drainage works.

5.5.2 GENERAL DIRECTORATE OF SOIL AND WATER CONSERVATION SERVICE (TOPRAKSU)

This is an agency organized in the Ministry of Village Affairs, responsible for the development of soil and water resources (up to 500L/s of flow rates) and the training of farmers in conservation, irrigation, drainage, soil fertility, salinity control methods and farm management. It controls a total irrigated area of 315000ha.

The General Directorate of TOPRAKSU consists of eight divisional offices at the headquarters, 18 regional directorates and a number of field divisions scattered around the country.

5.5.3 MINISTRY OF FOOD, AGRICULTURE AND ANIMAL HUSBANDRY

This is responsible for supplying all the agricultural inputs and for conducting farmer training programmes in irrigation projects. It consists of several general directorates which conduct all these services.

5.5.4 AGRICULTURAL BANK

It provides installation and operation credits to the agricultural businesses and individual farmers who are involved in irrigation projects.

Besides the above institutions, there are several other organizations such as farming co-operatives, associations and unions which are engaged in agricultural activities to supply various agricultural inputs and establish marketing facilities in irrigation projects.

The responsibility of the stated organizations cannot be fulfilled without co-operation. For instance, the DSI is responsible for the supply and conveyance of irrigation water to irrigation projects, down to the end of tertiary irrigation canals. The responsibility of the TOPRAKSU organization is to deliver irrigation water from the last point of the tertiary canals to the farm turnouts. The Ministry of Food, Agriculture and Animal Husbandry has the responsibility of supplying all the required agricultural inputs, in addition to conducting training programmes for farmers. The joint responsibilities of these three organizations support the establishment of research centres, land development, irrigation projects and initiation of Cukurova Farmer Training Organization Service (CES) by means of financial aid of the World Bank[7].

It is clear from the agricultural problems which have been discussed that the above organizations, especially DSI, TOPRAKSU, the Ministry of Food, Agriculture and Animal Husbandry, are unable to control their existing irrigation projects. As a result, all other works (excluding engineering) in the new irrigation projects of the Euphrates and Tigris rivers are receiving scant attention from these agencies and responsibility has devolved on to the universities. This has happened, despite warnings from analysts that such works must be dealt with in parallel to the civil engineering works, in order to achieve rapid completion of entire projects. Thus, the inability of these organizations to be involved in the planned projects will result in the extension of the projects' implementation schedule and, it could be argued, in the reduction of the projects' size.

5.6 PROBLEMS AFFECTING PRESENT DEVELOPMENT AND THEIR EFFECTS ON FUTURE DEVELOPMENT

To evaluate the present situation of the existing irrigation projects in Turkey, the Lower Seyhan project in Adana province has been chosen. In the light of this project, it will be possible to anticipate how successful the establishment of the large irrigation projects in the Euphrates and Tigris rivers might be.

The Lower Seyhan is one of the most important irrigation projects in Turkey built by DSI. The main feature of the project is the Seyhan dam which was completed in 1956 on the river of the same name. The project occupies the Seyhan Plain, which is the largest and most important deltaic plain in Southern Anatolia. Its whole area is about 210000ha, of which 181000ha are irrigable. Irrigation works on the Seyhan Plain have been planned to be completed in three stages. The works of the first and second stages were completed in 1968 and 1978 respectively. The construction of the third stage has not yet started, due to financial problems. As yet, there are only 108582ha of land under irrigation. In addition, there is an average annual energy generation of 300MWh from the hydroelectric power plant of the dam.

This modern project has been affected by serious irrigation, drainage and financial problems:

1. The first stages planning land utilization pattern was proposed as 35% cotton, 15% wheat, 12% citrus, 8% vegetables, 20% forage crops and 10% rice. However, the proposed optimum land utilization pattern has not been achieved. Although the cultivated area of cotton changes from one year to the next, generally the cultivated area varies from 75-90% of the total land. Another important crop of the region is wheat. Under the present land cultivation pattern of the farmers, the majority of land is only single cropped. Furthermore, market value and the high cash values encourage farmers to cultivate the land with the same crop each year. Thus, they do not follow a rotation.
2. In most irrigated areas of the region, farmers have traditionally practised furrow and flood irrigation methods. It is a usual and well known fact that when dry farming is replaced by irrigated farming, the majority of farmers provide excessive water to the field in the common misbelief that more water would result in higher yields. This problem is clearly observed in this project. For example, the dam is designed to supply water for the irrigation of 181000ha of land. The allocated water for irrigation is totally used at the end of each irrigation season

in spite of only 108582ha of land being irrigated at present. This flood irrigation method results in an increase in soil salinity and enhanced drainage problems on the project area.

3. Another factor causing an over-irrigation problem is attributed to the present land utilization pattern. For instance, the capacity of the Seyhan dam is designed with regard to the proposed land cultivation pattern in which cotton was only 35% of the total area. At present, cotton crops utilize 75% to 90% of the land. Together with the farmers' habit of over-irrigating cotton, the result has been unexpectedly high water consumption. This over-consumption in the upstream section has left farmers in the lower section with a water shortage problem. As a result, short water supply has been forcing southern farmers to use water from drainage canals which also contains industrial wastes. This misuse of drainage water has created salinity and toxic element problems in the project area.
4. In the existing irrigation system, measuring devices have been installed at the heads of all main and most secondary and tertiary canals. While turnouts and individual farmers were excluded, in spite of their importance, from the provision of adequate and equal division of water among users and its controlled application, the absence of these control structures

encourages farmers to over-consume irrigation water by obtaining it directly from canals with siphons. Additionally, the water cost is billed to farmers according to the crop grown and size of area irrigated. This factor, together with low cost of water also leads to over-consumption of irrigation water.

5. The over-irrigation problem has also resulted from:
   a) an inadequate number of technical personnel who would maintain controlled water distribution; and
   b) the farmers' unwillingness towards night irrigation.

   Traditionally, farmers have practised only daytime irrigation. The result of this practice is that about one-third of water released from the dam is lost due to neglect and dumping of irrigation water into drainage canals during night hours.

6. Despite the enormous investments made towards implementation of the project, in recent years it has been noted that farmers in some areas have switched back to dry farming. For instance, in 1968 irrigation facilities were brought to 57322ha of land, of which 91% was actually irrigated. In 1978, irrigation facilities were extended to 108582ha of land, but the area actually irrigated dropped to 67%. The unexpected outcome is therefore the usage of irrigated lands to far below their potential. The

annually decreasing trend of actual irrigated land might be related to government price policy, high labour costs, problems faced concerning pesticides and insecticides, fertilizers and seeds, insufficient credits, lack of rotation and the fuel crisis.

7. To practise surface irrigation in the project area, land levelling is required before irrigation. This work was completed in all places within stages 1 and 2. However, the farmers' customary way of preparing land for irrigation and seeding, without using a rotary tiller, has been deforming the original land levels, starting from the second year of tillage. This results in a steady decrease of the yield.
8. The drainage problems have resulted from the relative flatness of the major portion of the plain, the high winter rainfall, the excessive irrigation water application and seepage from irrigation water conveyance canals. These have caused high year round water table levels and therefore have created serious drainage problems for optimum crop production.

Also, the main drainage problem is attributed to inefficiency of the tile drainage system. A considerable portion of the system has been working under submerged conditions year round, indicating the inaccurate layout of the system. The incapability of the tile drainage to drain excess water effectively could be related to an over-calculation of the lateral spacings of the tile drains. The over-calculation is thought to have resulted from the use of classical drain spacing formulae without regarding the unique hydrogeological features of the plain.

The drainage problems have occurred in the early stages of the project as the drainage system was not developed in parallel with the irrigation system. For instance, the irrigation works were started in the 1950s, while the construction of tile drainage systems was begun in 1966 after serious drainage problems in the project. This delay has caused a sharp decrease in yield in some areas and consequently has resulted in considerable loss of income to the farmers.

9. Lack of machinery - the agricultural machinery which was imported to carry out maintenance works on about 70000ha in 1968 is still in service, despite the fact that the area increased to 180582ha in 1978. Within this period, no additional equipment has been purchased. Hence, only 40% of the annual required maintenance work is being carried out at present. In particular, the inability to clean the open drain ditches on time has reduced the effectiveness of tile drainage systems considerably.

10. Urban areas and industrial establishments have been

steadily expanding on very fertile first class agricultural lands in the project area. This means that lands on which about $4000 per hectare were spent for development of soil and water resources are lost for ever. This situation firstly results in the loss of high value agricultural land and secondly, creates serious environmental pollution problems in the region as a result of industrial pollution dumping in drainage canals and the atmosphere.

11. As a result of financial difficulties, the extension services for irrigated farming to the farmers of the region, which are carried out by the Extension Service Agency (CES), have suffered problems in recent years. In addition, the discontinuation of stage 3 is also related to the financial problems.

Some of the stated problems were taken into consideration in the planning and application stages of the project, but unfortunately no special efforts have been made toward overcoming them. The required attention has still not been given to the majority of the problems. The project has not reached its real potential yet, despite the fact that large amounts of money have been invested. Optimum benefit from the project would be obtained if the solution of these problems were considered as vital as the engineering works[8].

It is not only the Lower Seyhan project that has suffered from these problems, but all the Turkey irrigation projects are affected by deficient installations, inadequate field development services, insufficient agricultural credits, lack of machinery and equipment, high labour costs, insufficient supplies (of improved seed, pesticide, insecticide and fertilizer), limited and insufficient legislation and, above all, inadequate farmer training programmes(9). Therefore, improving the existing irrigation project by attacking these problems will affect the planned irrigation development of the Euphrates and Tigris rivers by shifting some of the investments from these developments. This will, in turn, force Turkey either to reduce the project areas or to extend the development schedules.

5.7 THE DEVELOPMENT OF THE EUPHRATES BASIN IN SYRIA

5.7.1 THE RIVER HYDRAULIC ASPECTS

The Euphrates river flows from Turkey, with a mean annual discharge of 996 cumecs (31.4bcm) at Karkamis, close to the Syrian border. In Syria, the river receives about 127 cumecs (4.0bcm) from the last tributaries, the Sajur, Balikh and Khabour, as well as from other periodic streams. The total length of the Euphrates in Syria is 675km and its basin area is 76000km^2, or 17% of the total river basin (Chapter 3).

5.7.2 THE DEVELOPMENT BACKGROUND

Syria has given the highest priority to the Euphrates river from the mid 20th century. The objectives are to develop new irrigated lands and hydroelectric power generation. Before the involvement of the government, there were only 150000ha irrigated privately. This has remained constant during 1975-80 (section 5.7.3), although several thousand hectares have been abandoned due to salinity and replaced by bringing new land under cultivation[10]. These lands already require rehabilitation, including flood control and control of water-logging and salinity in order to enhance their productivity. However, the first government step in the development of the river took place in 1957, when Syria signed an agreement with the Soviet Union to carry out survey and research work on the river. The Soviets submitted their report at the end of

1960, proposing to build a 75m dam on the river at Tabqa. After an interlude in the early 1960s, the Syrians sought West German aid to build the dam. The Germans offered a loan of only US $87.5 million and recommended reducing the scale of the Euphrates project. Syria was unable to secure additional funding from the West and so turned to the Soviet Union and signed an accord in April 1966 to finance and construct the project with a fund of US $132 million for the first stage of the plan(11).

5.7.2.1 The Tabqa Dam and Reservoir

The dam construction was started by the Soviet Union after the 1966 agreement and was completed and filled in 1974-75. It is an earth filled dam, with an impervious clay core. The construction was done by hydraulic filling. The dam is 4500m long and 60m high above the foundation. It has created a lake with a gross storage capacity of 11.7bcm, of which 0.63bcm is lost through evaporation. The dam is the key element in the Euphrates development, with two main objectives:

1. to provide irrigation water for a total area of 640000ha; and
2. it will generate hydroelectric power with an installed capacity of 800MW.

As yet, three generators, each with the capacity of 100MW, have been installed and space has been provided for future installation of another five generators, each with 100MW.

5.7.3 IRRIGATION DEVELOPMENT AND PLANNING POLICIES

The Euphrates dam is planned to increase the future irrigated land to 640000ha. This may take as long as 30 years to be attained(12). Table 5.11 and Fig.5.2 show the breakdown of the above figure into six possible irrigated regions, according to the Ministry of the Euphrates Dam, quoted by the World Bank in 1978. This indicates that the total planned irrigated land will range between 497000-507000ha. This means a reduction of 143000 to 133000ha has already taken place. However, to examine how successful is the government's plan to achieve its target, three government plans (the Third, Fourth and Fifth) have been studied. The study of these plans reveals that there was a big gap between the plans of the government and what has been achieved. For instance, in the Third Plan period (1971-75) only 20000ha of new irrigated lands were brought under cultivation as a pilot project. The private irrigated land remained at 150000ha (Table 5.12). However, the problems of this plan relate to its poor conceptualization, the effect of the 1973 war with Israel and the events in the Lebanon(13).

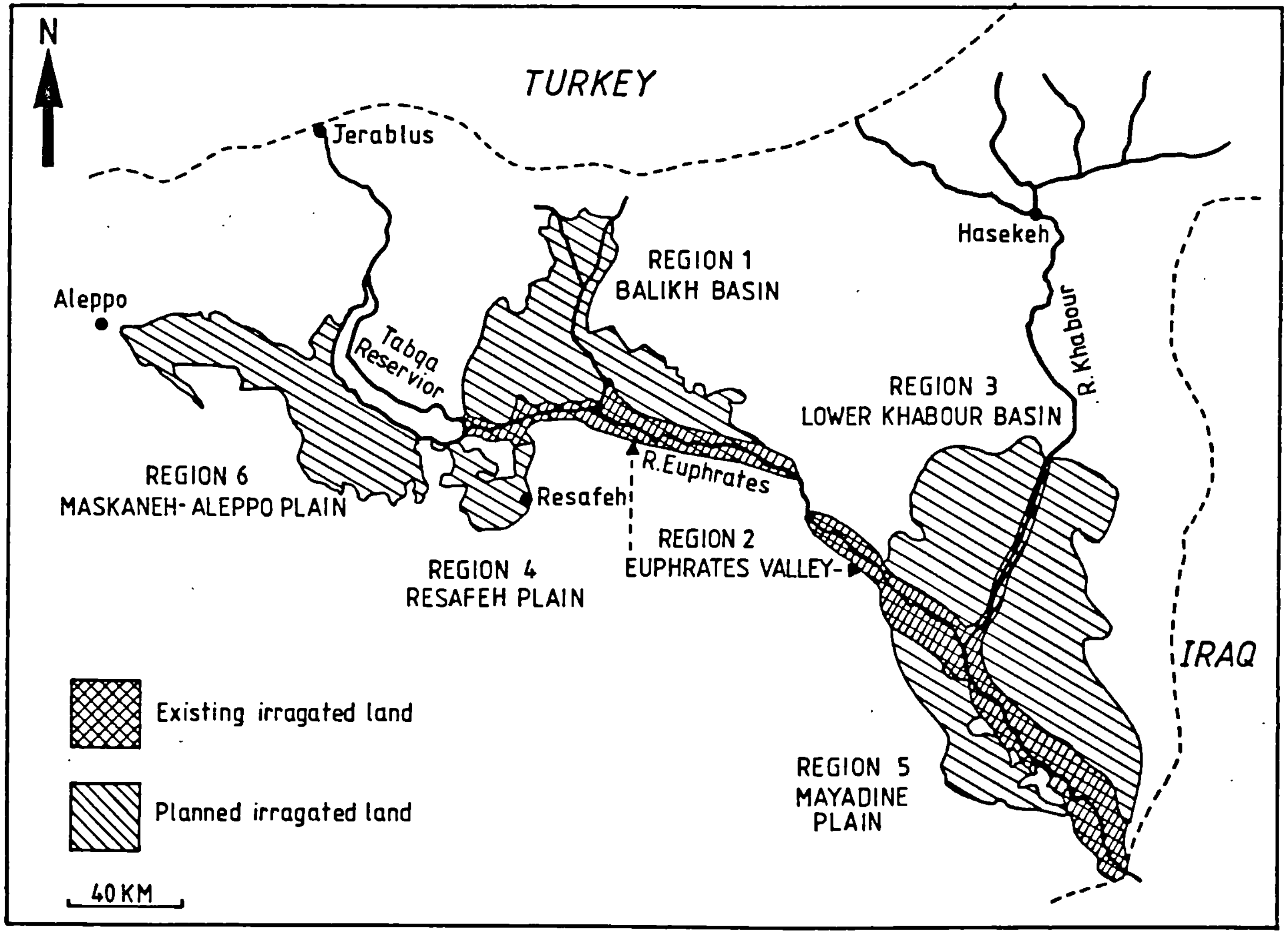
The Fourth Plan for the period (1976-80) was supposed to seek an answer to the disappointing performance of the previous plan in an attempt to improve the situation by comprehensive and realistic planning. Thus, the goal of this plan was to bring 240000ha of newly irrigated land into cultivation. This goal proved unattainable. By 1978, only

Table 5.11 : Irrigation Development in the Euphrates Basin Completed, In progress and Planned by the Ministry of the Euphrates Dam, 1976-77

Sub-Project	Area ha Completed	In Progress	Planned	Status
Balikh Basin (Region 1)				
Pilot Project	20000	—	—	Completed and irrigated by temporary pump station until gravity supply from Tabqa reservoir available through lower main canal.
Location 1				
1. Bir al Hashim	—	10000	—	Contracts awarded and work in progress on lower main canal, irrigation system and Bir al Hashim pump station.
2.	—	11000	—	Site being evaluated for irrigation system and second reach of main canal. Award due end 1976.
Location 2	—	—	24000	Studies and design completed. Negotiations underway with US A.I.D. for additional financing and bidding delayed.
Location 3				
1.	—	—	11000	Study and detailed design by FAO/SOGREAH in progress.
2.	—	—	11000	Negotiations in progress for Yugoslav financing of detailed design and construction.
Locations 4,5 and 6	—	—	60000	Studies financed by Romania and being undertaken by Romagrimex.
Sub Total	20000	21000	106000	
Euphrates Valley (Region 2)				
Middle Euphrates	—	27000	—	Studies and implementation of drainage and irrigation rehabilitation financed by Romania. Construction began July 1974 and expected to complete in 1979
Lower Euphrates				
1.	—	—	50000	Feasibility study for drainage, leaching and irrigation improvement nearing completion. Construction likely to begin 1978 and take six years.
2.	—	—	71000	Preliminary study completed.
Sub Total	—	27000	121000	
Lower Khabour Basin (Region 3)	—	—	70000	No studies undertaken.
Resafeh Plain (Region 4)	—	—	18000	Studies by AGROCOMPLECT (Bulgaria) and final design due end 1977. Irrigation supply would be pumped from Tabqa Reservoir.
Mayadine Plain (Region 5)	—	—	40000	No studies undertaken. Irrigation supply would be pumped from Lower Euphrates.
Maskaneh Plain (Region 6)				
East Maskaneh Project				
1.	—	—	14000	Loan from Japan for studies and con. Final design due in 1977. Supply pumped from Tabqa Res.(80 m lift).
2.	—	—	18000	Preliminary studies completed.
West Maskaneh Project				
1.	4000	—	—	Pilot project con. with loan from USSR for machinery and technical assistance. Model State farm.
2.	—	17000	—	Extension to model State farm. Designs completed and approved. Con. began in Jan.1977 financed by USSR loan as for part one. Completion scheduled by 1980.
3.	—	—	50000	Prel.studies completed by USSR and designs due mid-1977.
4.	—	—	30000	Prel. report being prepared.
Sub Total	4000	17000	112000	
Aleppo Plain	—	—	30000-40000	To be added to Maskaneh Plain irrig. area
Total	24000	65000	497000-507000	

Source : Ministry of the Euphrates Dam : In World Bank, Syrian Development, Annex II (Draft) Re. No. 1975-SYR, 13 March, 1978, Table 31.

Fig. 5.2 : Existing and Planned Irrigation Developments on the Euphrates in Syria



Source : Samman, N., Cost-Benefit Analysis of the Euphrates Dam : In Water Supply and Management, Vol. 5 No. 4/5, Pergamon Press Ltd., Great Britain, 1981, Fig. 1.

Table 5.12 The Euphrates Irrigated Land, 1975 (ha)

Public Perimeters	20000
Private Pumped Irrigated Land:	
Middle Euphrates	30000
Lower Euphrates	120000
Total	170000

Source: World Bank, Syrian Development, Annexe II (Draft) Report No.1975-SYR, 13 March 1978, Table 6

7400ha of land had actually been prepared and the 1980 target for land preparation had been revised downwards to 43200ha[14]. According to the World Bank study (1978), the situation and the prospects for irrigation in the Euphrates basin by 1980 can be summarized by the following projects:

1. The pilot project in Balikh was to irrigate 20000ha. By 1975-76, there were 16080ha under irrigation and by 1980 the remaining 4000ha were expected to be developed. However, severe gypsum problems have arisen with the local collapse of canals, which may make necessary the withdrawal of some land.
2. The model state farm in Maskaneh has 2000ha under irrigation. Another 2000ha were to be added by 1980. Furthermore, 17000ha were expected to be developed by 1980 for other state farms.
3. A Romanian project (by Rumagrimex) in the Middle Euphrates, involving irrigation of 27000ha, was expected to be finished by 1980.
4. In the Balikh basin, Section 1 financing had been obtained for 10000ha and this area was expected to be under irrigation by 1979.
5. In the Lower Euphrates valley and East Maskaneh studies have been completed by French and Japanese consultants for areas of 30000 and 15000ha respectively. These projects had not been financed at that time and they were not finished by 1980.

The study had concluded that under the most propitious circumstances the maximum new irrigated land in the Euphrates basin (by 1980) was not expected to exceed 60000ha. A more realistic estimate was to be 40000ha[15]. This meant that the 1976-80 plan had brought only 20000ha of new irrigated land and thus it was also disappointing.

The Fifth Plan for the period 1981-85 had, as one of its goals, the development of 201000ha of newly irrigated land in the Euphrates basin, a goal that seemed unrealistic in view of previous progress. Thus, it was estimated that only a relatively modest 20000ha would be actually brought under irrigation by 1985. Accordingly, the total newly irrigated land brought under cultivation for the period 1971-85 was to be 60000ha and if the total private irrigated land (147000ha) (Table 5.13) was fully rehabilitated, then the general total of irrigated land was to be 207000ha by 1985.

It seems from what has been stated that the Syrian government has opted to build the agriculture development on points of strength and political expediency rather than technical feasibility. As a result, the development has proceeded more slowly than planned due to unrealistic planning, associated with several serious problems, which have been affecting the present construction and will make the future target impossible.

Table 5.13 Private Irrigated Land in the Euphrates Basin, 1980 (ha)

Middle Euphrates	27000*
Lower Euphrates	120000**
Total	147000

Source: World Bank, Syrian Development, Annexe II (Draft) Report No.1975-SYR, Op. Cit., Table 30

* Including rehabilitation of the whole existing area

** Including a start to rehabilitate 60000ha

5.7.4 MAJOR PROBLEMS AFFECTING PRESENT DEVELOPMENT AND THEIR EFFECTS ON FUTURE DEVELOPMENT

5.7.4.1 Technical Problems

These are related to the soil salinity and gypsiferous soils.

5.7.4.1.1 Soil and Soil Salinity Problem

The alluvial soils with textures ranging from clay to sandy loam occur in a narrow band along the Euphrates river and its tributaries. The higher lands bordering the Euphrates valley, downstream of the Tabqa dam, comprise medium to fine-textured soils frequently, with a moderate to high gypsum content and, in places, overlying gypsum rock. Internal drainage ranges from good to locally poor[(16)].

It has been estimated that up to 1981, about 50% of the irrigated land in the Euphrates valley was seriously affected by salinity and water-logging[(17)]. As a result, up to 1978, some 3000ha per year of private irrigated lands of the Lower Euphrates valley were abandoned to salinity[(18)].

Soil salinity problems in the Euphrates basin are due to poor irrigation management practices, mainly the flood irrigation methods which have been traditionally practised and seepage from irrigation canals. These cause a rapid rise in the water table, bringing to the surface salts present in the deep subsoil through capillary action and resulting in salt accumulation which, in turn, affects productivity. It also slows the growth in total irrigated acreage, due to the abandoning of some lands and it creates the necessity for reclamation and rehabilitation which require time and investment. To combat the problem, several intensive studies are vital. These should include the following:

1. The determination of water requirements of crops by means of meteorological calculations and direct measurements.
2. Experiments with different systems of irrigation, including studies of the amount of water and frequency of irrigation.
3. Studies of soil properties and, in particular, soil-water relationships, to obtain data for the improvement of irrigation practices and the reclamation of saline soils.
4. Trials with different crop rotations with a view to maintaining favourable soil conditions and ensuring the maximum possible sustained benefit.
5. Trials on gypsiferous soils to determine the effect of gypsum on plant growth and the maximum permissible percentage of gypsum in the soil.
6. Studies of the reclamation of saline soils to be carried out on a pilot area of $1\text{-}2km^2$. The studies should include the determination of the optimum

level of the water table and the optimum depth and arrangement of drains, as well as the amount of water needed for leaching and the effect of leaching on soil properties. These studies should involve the determination of the nature and distribution of salts, soil texture and structure, infiltration rates and hydraulic conductivity by means of the auger hole method. After reclamation, improved soil management practices should be applied in order to ensure the maximum possible benefit and to prevent resalinization[19].

5.7.4.1.2 The Gypsiferous Soils Problem

Another serious problem which has been encountered in bringing the land into production is related to the difficulty of constructing irrigation canals in the existing gypsiferous soils of the Euphrates basin. Major sections of concrete canal lining have collapsed when minor seepage resulted in progressive solution of gypsum in the underlying soil, which then created extensive subsidence. Measures to combat the problem include the following:

1. The avoidance of high gypsum soils in designing canal alignments.
2. The use of waterproof plastic material in conjunction with concrete lining.
3. The use of a better sealant for joints in concrete

canal linings.

4. The excavation of high gypsum soils along canal alignments, replacing them with compacted low gypsum fill before re-excavating the canal sections.

5.7.4.2 Expensive Reclamation

Prospects for large new irrigation development are not encouraging due to high investment costs. For instance, in the Balikh basin, the cost of reclaiming the new irrigated land which it was planned to develop in the first stage was estimated at US $11000/ha for section 1 and an estimated US $7500/ha at 1974 prices for sections 4, 5 and 6. Additional investments will be required for farm machinery and buildings. Expected return rates are low, ranging from 3% to 4% for sections 1 and 2. US AID, which was involved in the finance pulled out because of the high costs and low anticipated returns. The high costs of new reclamation land results from the presence of gypsiferous soils which are dominant in the Euphrates basin. Therefore, it is realistic to anticipate a similar high cost in the other parts of the basin and even higher costs in the marginal lands, far from the rivers.

This is one of several serious problems which face the General Administration for the Development of the Euphrates Basin (GADEB), which may restrict future development progress. GADEB has admitted that it is becoming increasingly difficult to ensure finance for the remaining irrigation projects and to maintain the scheduled rate of development. In addition, there are not sufficient well trained staff to organize, administer and operate the ambitious development programme[20].

According to a report in the Quarterly Economic Review of Syria, Jordan, 4th Quarter 1979 (Economist Intelligence Unit), quoted by the US Bureau of Science and Technology in 1981, several foreign-sponsored projects for land reclamation in the Euphrates basin have failed and Syrian officials are now advocating the diversion of some of the Tabqa reservoir water to agricultural lands in the Aleppo area (Fig.5.2), instead of using it to reclaim saline lands in the Euphrates basin[21].

5.7.4.3 Rehabilitation of the Existing Irrigated Lands

Soil problems cause a substantial loss of the Euphrates irrigated lands with an average of 3000ha annually. Therefore, high priority should be assigned to the rehabilitation of these existing irrigated lands where salinity, water-logging, flooding and poor on-farm distribution systems are at present seriously limiting land productivity. On these lands, investment costs per hectare will be generally lower than the equivalent cost of reclaiming new irrigated lands, since some of the investment required already exists.

Thus, rehabilitation work started in 1978, when a Romanian contractor planned to rehabilitate 9000ha on the left bank of the Middle Euphrates area (section 7 of Balikh) and 18000ha on the right bank, have been studied.

In the beginning of 1979, it was planned to control water-logging and salinity of 35000ha out of 60000ha on the right bank of the Lower Euphrates valley through tubewell drainage. Another area of 35000ha out of 60000ha on the left bank was planned for 1981. A phased investment is being considered:

1. Provision of a sufficient number of tubewells to provide control of the water table under the present agricultural system, at a rough estimated cost of about US $500/ha, or alternatively,
2. Installation of a greater density of tubewells to control the water table, allowing for leaching, at a rough estimated cost of US $1000/ha,
3. Followed by full agricultural development after including a new irrigation system as well as tube-wells for groundwater control at a cost of up to US $8000/ha.

It is clear from what has been stated, that rehabilitation is reversing the development as it shifts the investment from reclamation of new irrigated land. Furthermore, rehabilitation is needed elsewhere such as in the Ghap project on the Orontes river in which 60000ha was studied in 1978 with a view to rehabilitation[22]. This will shift further investment from rehabilitation and reclamation in the Euphrates development.

5.7.4.4 Financial Problems

Syria is unable to offer the whole bulk of the capital investment for the agricultural development due to its weak economy, with an annual rate of inflation, based upon official figures, ranging from 15% to 20% (1980). Unofficial sources put the annual rate at about 30%[23]. The foreign debt totals US $2.5 billion (1983) and is another indication of weakness[24]. As a result, the development depends almost entirely on foreign capital, mainly from USSR, the World Bank, the Arab countries and funds from the European Economic Community (EEC). In 1981 and 1982, Syria received US $195.9 and 84.7 million respectively[25]. Thus, the present and future development will be at the mercy of the foreign aid which, in turn, will depend on Syria's relationship and its foreign policy.

Thus, these problems in combination will paralyze the future planned development.

5.7.5 EVALUATION OF THE EUPHRATES WATER BALANCE

The total present irrigated land of the Euphrates basin in Syria is about 207000ha. Its total annual water demand amounts to 2.2bcm. This, added to evaporation water loss from Tabqa reservoir, brings the total annual to 2.83bcm, or 8.3% of the total annual available water of the river in Syria, which is 34.2bcm (Table 5.14). The maximum future irrigated land will be 640000ha and will require an annual water volume of 6.7bcm. This, together with evaporation water loss from Tabqa reservoir will amount to 7.33bcm, or 40.7% of the total outflow from Turkey, which is 18.0bcm. Thus, the future outflow from Syria to Iraq will be only 10.7bcm, or 59.4% of the future outflow from Turkey to Syria and 30.2% of the total annual water potential of the river, which is 35.4bcm. The future annual outflow of 10.7bcm from Syria to Iraq will be less if the traditional flood irrigation methods are applied and thus, a shortage in water quantity and quality will definitely occur in Iraq.

5.7.6 GENERAL ORGANIZATIONS RESPONSIBLE FOR DEVELOPMENT

The Ministry of the Euphrates Dam is in overall charge of all development in the Euphrates project. It is divided into two major entities: (a) The Government Organization for the Development of the Euphrates Dam (GOED). This had the responsibility for the construction of the Euphrates Dam and it has to act as a competing contractor for other major works. (b) The General Administration for the Development of the Euphrates Basin (GADEB). To this is assigned all other aspects of the development of the Euphrates basin. It has separate offices for planning and statistics, and

Table 5.14 Evaluation of the Euphrates Present and Future Water Balance in Syria

1. Present Water Balance

Status	Annual Water Volume(bcm)
Present River Flow in Syria	34.2*
Present Irrigation Water Demand in Syria (207000ha)	- 2.2**
Tabqa Evaporation Water Loss	- 0.63
Present Outflow from Syria to Iraq	+31.4

2. Future Water Balance

Status	Annual Water Volume(bcm
Future Outflow from Turkey	+18.0
Future Irrigation Water Demand in Syria (640000ha)	- 6.7**
Tabqa Evaporation Water Loss	- 0.63
Future Outflow from Syria to Iraq	+10.7

* Derived from Table 5.4

** Based on the maximim demand in Turkey which is 10460m^3/ha (Table 5.2) acquisition, public relations and procurement. Its technical functions are divided among four sectors: irrigation, agriculture, social affairs, and finance and administration. Each of these sectors is headed by a deputy director general. The office of planning and statistics is concerned with overall, intersectoral planning and logistics; that of land acquisition with the purchase of land for right of way and government farms; and the office of procurement is responsible for final approval and the award of civil works contracts and purchase of materials, machinery and equipment. GADEB is regarded as the most important organization in implementing future development. It has already been involved in the establishment of the pilot irrigation project, the planning and supervision of construction and studies in the remainder of the project.

As the government agency responsible for the project networks construction, therefore it claims a water tax ranging from SP*70 to 250 per hectare. This may be misallocated as it is based on the amortization cost of the waterworks rather than on the basis of usage and marginal productivity of the water. A similar case involves the rental of land, which varies from a minimal 5% of total output for state lands to 20% for private non-irrigated lands and 25% for irrigated lands(26).

* SP = Syrian Pounds = US $1. Official exchange rate US $1 = 3.925 SP, Economist Intelligence Unit (EIU), Country Report on Syria, No.4, 1987, p2

5.7.7 FARM PRODUCTION SECTORS

For the Syrian cultivated lands as a whole, there are three main agriculture sectors: the private, co-operative and state farms. In 1978, the private sector was regarded as the most important as it occupied over 80% of the total cultivated lands. It is still the dominating sector at present (section 5.7.9). The co-operative is the second most important sector as it occupies 16% of the total cultivated lands. However, it includes about one-half of the irrigated lands, partly as a result of land redistribution carried out under the agrarian reform law. The state farm sector is very small, occupying less than 2% of the total cultivated lands[27].

5.7.8 CROPPING INTENSITY

According to the Syrian authorities, the irrigated land cropping intensity was planned to be 160% by 1985. However, this was unlikely to be attained, since the Syrian irrigation planning had never reached the target during the period of 1971-85. Thus, the present cropping intensity is without doubt less than 160%. The future intensity is planned to be 175% by the year 2000. It was also planned to attain cropping intensity of 100% by 1985 in non-irrigated land, especially Region I (1-2)[28] (Table 5.15 and Fig.5.3).

5.7.9 FARMING COSTS AND BENEFITS

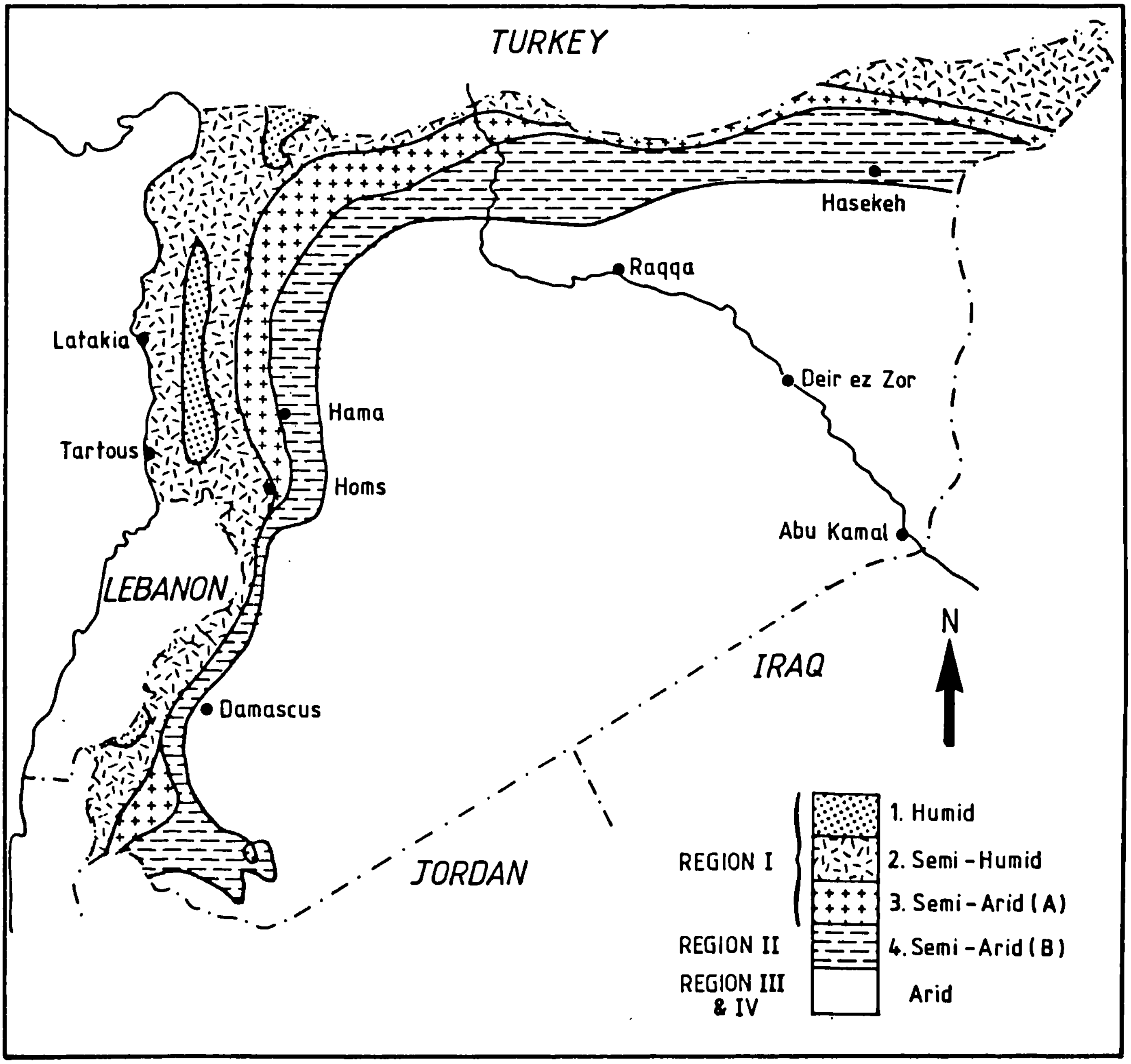
The present level of farming management can be identified

Table 5.15 Syria's Major Agroclimatic Regions and Subregions

Region	Sub-region	Mean annual rainfall Millimeters	Inches	Area cult. 000 ha.	Characteristics
I	1.Humid	over 800	over 32	76	Topography of gently rolling to mountainous; deciduous fruits, vegetables grown with terracing, difficult terrain but substantial improvements in management and marketing possible.
	2.Semi-humid	500-800	20-32	602	Coastal region, northern Syria; has high potential along coast for vegetables and fruits. Northern areas easily convertible to continuous cropping. Yields well below potential, higher fertilizer applications on all crops possible. Opportunities for the construction of small-scale catchment reservoirs; some additional well irrigation also feasible.
	3.Semi-arid (A)	350-500	14-20	828	Area of high potential for traditional dryland crops; continuous cropping possible in much of the area; modest fertilizer dosages profitable
Total, stability Region I				1,506	
II	4.Semi-arid (B)	250-350	10-14	1,945	Area will probably remain under crop-fallow rotation; herbicides likely to be profitable on wheat.
III, IV	Arid	under 250	under 10	2,035	Grazing areas will need regulation if productivity is to be improved; it is primarily devoted to livestock grazing.

Source : World Bank, Vol. 2, ibid, Table 8.1 and pp.159-162.

Fig.5.3 : Syria : Agroclimatic Regions and Subregions



Source : World Bank, Syrian Development, Vol. 2 Main Report (Draft) No. 1975-SYR, 13 March, 1978, Fig. 8.1.

through the crop yields. The wheat crop which is one of the most important irrigated crops has been chosen for this purpose. According to Table 5.16 the cultivation costs per hectare of irrigated wheat during 1978, 1979 and 1980 were US $474.21, 515.72 and 497.33 respectively. The machinery, fertilizers and seeds represented 73.4%, 74.7% and 74.6% of the above total cost respectively. The total yields in tons per hectare during these years were 2.17, 2.39 and 2.75 respectively (Table 5.17). By comparing the cultivation cost with price per ton, the results are negative (ie. the cultivation cost is more than the sale price) in spite of the government subsidies for this crop. For a good quality product this was US $12.2/T in 1976 and became US $17.8/T in 1980(29). This in turn means that irrigated wheat is not beneficial, due to the cost of cultivation. As a result, the farmers prefer dry farming which accounted for 88.4%, 88.2% and 88% of the total cultivated wheat lands during 1978, 1979 and 1980 respectively. This is a result of the lower cultivation cost and less effort required than for irrigated land (Tables 5.16 and 5.17).

The following conclusions can be drawn:

1. Farm productivity is very low. It was 2.75T/ha of irrigated wheat and 1.4T/ha of dry farming in 1980, compared with 5.9T/ha in UK(30). This results from the small scale use of farm machinery, low rates of fertilizer application, less use of improved seeds,

Table 5.16 Wheat Cultivation Costs in US$/ha. and its Prices in US$/T during 1978-80

Cultivation costs	1978		1979		1980	
	Irrigated Mexican wheat	Non-irrigated local wheat	Irrigated wheat	Non-irrigated wheat	Irrigated wheat	Non-irrigated wheat
Machinery costs	182.21	63.05	208.86	64.81	190.06	120.26
Agricultural material (fertilizers, seeds etc.)	165.83	34.94	176.2	34.68	180.89	66.24
Land rent	83.55	30.38	83.55	30.38	83.55	30.38
Investment interest	19.49	3.8	21.78	3.8	16.56	8.66
Others	22.53	6.58	25.33	6.33	25.73	13.5
Total	474.21	138.75	515.72	140	497.33	239.04
Wheat prices US$/T	195.93		193.4		221.4	

Source: Rihawi, D., Cereal and its Future Cultivation in Syrian Arab Republic, Diploma Dissertation, The Arab Planning Institute - Kuwait, 1982-83, Tables 10 and 11.

Table 5.17 Wheat Area, Production and Yield for the period 1974-80

Years	Irrigated wheat				Non-irrigated wheat				Area under Co-operative
	Area 000ha	Area %	Tot. Prod. 000 T	Yield T/ha	Area 000ha	Area %	Tot. Prod. 000 T	Yield T/ha	%
1974	165	10.7	364	2.210	1373	89.3	1266	0.922	14.4
75	174	10.3	362	2.074	1518	89.7	1188	0.788	16.3
76	162	10.4	444	2.307	1398	89.6	1347	0.963	25.0
77	178	11.7	334	1.873	1349	88.3	883	0.654	25.7
78	180	11.6	391	2.169	1375	88.4	1260	0.916	25.7
79	170	11.8	405	2.386	1275	88.2	915	0.718	30.0
80*	174	12.0	480	2.752	1275	88.0	1759	1.379	30.4

* The State Farms form 0.02% of the total cereal cultivated lands and 0.011% of the total cereal product

Source: Rihawi, D., Ibid, Tables 5,8 and p.37.

inadequate weed and pest control practices.

2. Low productivity can be related to flood irrigation methods which have been traditionally practised on most of the irrigated lands. Here, the majority of farmers apply more than enough water to the field due to the common misconception that more water would result in higher yields. This has not increased the crop yields and has created soil salinity problems. It also distorts the water resources which are vital to the lower riparian state, Iraq.
3. Lack or low effectiveness of drainage systems in irrigated lands.
4. Expensive machinery, fertilizers, improved seeds and other farm irrigation equipment discourage the farmers in the expansion of irrigated farming as it is unprofitable. As a result, dry farming still dominates Syrian agriculture. It accounted for 88% of the cultivated wheat lands (1980). In spite of the low yields, it is still profitable compared with irrigated farming.
5. The co-operative and public sectors are still ineffective, for instance the co-operatives occupied only 30.4% of the total cultivated wheat lands, while the public sector occupied only 0.02% of the total cereal cultivated lands during 1980 (Table 5.17). This relates to the farmers' misunderstanding of the new system, compared with the independent traditional system.

Thus, the study of the irrigation development in the Euphrates basin reveals that the total planned area of 640000ha is unrealistic in the light of the project problems which are not only hindering the expansion of irrigation, but even reversing it. Therefore, this figure has already been reduced to 507000ha, according to Syrian sources (Table 5.11). Even so, most of that area has still not been studied finally. Hence, this figure may also be revised downwards. However, if the Syrians have learned from the past experiences that large scale irrigation development in the Euphrates basin is unsuccessful, due to technical and financial difficulties, their ambition to attain self-sufficiency may still possibly be achieved by vertical rather than horizontal expansion. In this scheme, the technical and financial problems can be controlled and the new reclamation lands can be protected. The successful achievement of vertical development requires the following:

1. Intensive land use necessitates further large scale soils classification studies. This will enhance the knowledge to assist in the selection of the best productive land which is suitable for intensive use. Detailed soil surveys will identify the soil problems in advance and will facilitate their treatment. Therefore, these studies must be regarded as continuous, not ending when a given piece of land has been surveyed to the scale required and

the soil map has been prepared.

2. Crop water requirements should be determined by means of meteorological calculations and direct field measurements.
3. Farm management practices should be improved by means of intensive farmer education and supervision in:
   a) irrigation and drainage practices;
   b) machinery and fertilizer use; and
   c) control of weeds, pests and diseases.
4. Intensive use of machinery, fertilizers and improved seeds.
5. Managers well trained in different fields of agriculture must be considered.
6. Effective irrigation systems should be applied, using mainly sprinkler and drip irrigation, which are the most suitable irrigation systems for the Euphrates project, in order to avoid salinity and other technical problems.
7. Trials with different crop rotations, so that favourable soil conditions may be maintained and maximum possible benefit ensured.

Thus, priority should be assigned to improve the existing irrigation projects, not only in the Euphrates basin, but also in the other parts of the country, mainly in the Orontes river valley. Here, the Ghab irrigation project, which covers an area of 72000ha is regarded as the most important project in Syria. This project has encountered several difficulties such as:

1. the annual flooding of large areas because the principal drainage canals are unable to handle the heavy volume of winter flood water; and
2. water-logging caused by rising groundwater and alterations in physical and chemical characteristics, resulting in detrimental effects on the crop productivity[31].

The cost of improving the existing irrigation projects and increasing their productivity is lower than that entailed in developing new irrigated lands (section 5.7.4). Also, high returns may come from developing small irrigation projects through controlling other small rivers in other parts of the country.

Moreover, dry farming practices, especially in the stable region I (1-2) should be improved by applying modern technology in order to increase the land productivity. Here, the problems and the costs of cultivation are rather simple, compared with those in irrigated lands.

The groundwater resources should be developed and existing irrigation projects should be intensified.

Finally, self-sufficiency can be attained by vertical intensive development rather than horizontal expansion.

5.8 THE DEVELOPMENT OF THE TIGRIS BASIN IN IRAN

Iran is a marginal riparian state, sharing only part of the Tigris river basin and, in particular, those of the Lesser Zab and Diyala tributaries. It contains about 34% of the whole drainage basin of the Tigris river and 10% of the total annual water potential (Chapter 3). Its present and future planned irrigation developments respectively are small, 50000 and 80000ha, and located on the mountain region. The present irrigation water demand is evaluated at 0.5bcm. This will rise to 0.8bcm in future. These figures are based on the average annual water requirement of $10000m^3/ha$[32].

5.9 CONCLUSION

Thus, the upstream states, particularly Turkey and Syria, are planning for large scale irrigation developments of 2004890 and 640000ha respectively. Iran is a marginal riparian state with a limited planned development of only 80000ha. However, water balance evaluation indicates that, if these developments are fully implemented within three decades, as planned, Iraq will be vulnerable in terms of water quantity and quality. Syria will also become vulnerable with regard to water quality.

In the light of the existing problems, it could be argued that the full scale planned development will not be an easy task. For example, since 1966 Turkey has paid maximum attention to major engineering works such as dams and irrigation canals. Of these, only the Keban and Karakaya dams are completed. The rest are planned to be completed either before or in the year 2001. The other agronomic aspects of the development are at present receiving scant attention from the government and are being examined primarily by the Turkish universities. These programmes are officially scheduled to be completed within 25-30 years. If lessons have been learned from the previous projects such as the Lower Seyhan, then the development should be completed by about the year 2020. If not, it could be anticipated that either a reduction in the development scale or an extension in the implementation schedule will prolong the period, at least until the years 2035-2040.

In Syria, the development has proceeded more slowly than planned, due to several serious technical and financial problems. For instance, the programme was begun in 1966, but by 1975 only the Tabqa dam was completed and 20000ha of new land irrigated. Up to 1985, the total of new irrigated land has been increased only to about 60000ha. As stated earlier, several land reclamation projects have failed and Syrian officials are now advocating the idea of diversifying some of the Tabqa water into Aleppo area, instead of using it to reclaim saline lands in the Euphrates basin.

Finally, it is vital that the riparian states of the Euphrates and Tigris basins benefit from the available time by searching for an early solution to the problem of water allocation through a peaceful international agreement, to achieve a fair and optimum share for each state in order to avoid future conflict (Chapter 7).

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CHAPTER 6

WATER UTILIZATION AND WATER BALANCE

6.1 INTRODUCTION

Chapters 2 and 3 have considered the hydrological aspects of water resources from the viewpoint of quantity, quality, annual and seasonal variations and river control systems for regulation and other purposes. This chapter deals with water utilization for such purposes as irrigation, population, industry and fisheries. These water requirements and water losses are compared with the available river water resources for each river by means of water balance calculations. The purpose of the water balance evaluation is to identify if there is enough available water to satisfy the present and prospective water requirements. Finally, an integrated water balance for the complete Euphrates and Tigris basins has been determined, considering the effect of future large scale planned irrigation developments on the upstream riparian states (Turkey, Syria and Iran).

6.2 IRRIGATION RATES FOR AGRICULTURAL CROPS

Table 6.1 represents the actual amount of water required by the crops, reduced by the amount of available precipitation and increased by the amount of losses which are calculated according to the climate and soil conditions of the country as follows:

1. Water losses through evaporation and seepage from main and distributory canals with concrete lining are evaluated to be 4% of the discharge at the head of canals (efficiency 0.96).
2. Water losses from unlined farm ditches 5% (efficiency 0.95) and in water courses 5% (efficiency 0.95). Thus, the irrigation efficiency coefficient, excluding field evaporation losses and leaching, water requirements will be:
   $0.96 \times 0.95 \times 0.95 = 0.866$.
3. Field evaporation losses are calculated for three soil groups ie. heavy silty clay loam, silty clay loam and light clay soil. As a result of these calculations, the mean values of 3.7% for winter and 10.2% for summer are adopted.
4. Leaching water requirements for normal irrigation rates have been calculated in relation to existing soil conditions, applying to deep (2.4-2.7m) and permanent drainage systems. The mean values of 23%

Table 6.1 Monthly and Annual Irrigation Rates for Agricultural Crops (mm) and (L/s/ha)

Crops		Monthly irrigation rates*												Annual rate (mm)
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	
Winter crops	mm	147.62	178	130.7	113.4	127.6	166.93	231.5						1095.75
L/s/ha		0.551	0.69	0.49	0.423	0.53	0.623	0.893						
Summer crops	mm						78.74	215.75	404.8	533.3	611.1	549.2	204.8	2597.7
L/s/ha							0.294	0.832	1.511	2.1	2.282	2.05	0.79	
Rice	mm**	199.8							691.8	623.61	448.8	430.8	374.61	2769.42
L/s/ha		0.746							2.583	2.406	1.676	1.608	1.445	
Orchards	(peren.)	176.2	80.32	29.92	33.1	69.3	118.1	170.1	265.1	361.9	338.1	320.6	246	2208.74
L/s/ha		0.66	0.31	0.11	0.124	0.29	0.441	0.66	1.0	1.4	1.262	1.2	0.95	
Alfalfa	(peren.)	201.6	107.1	45.7	48.82	74	122.84	170.1	260.32	366.7	377.8	352.4	288.9	2416.3
L/s/ha		0.753	0.413	0.171	0.182	0.31	0.46	0.66	0.972	1.42	1.41	1.32	1.12	

* Total irrigation rates comprise the irrigation efficiency coefficients of 0.635 for winter (Nov. - Apr.) and 0.63 for summer (May - Oct.) excluding rice.

** Including water losses through evaporation and seepage from the field and irrigation canals plus leaching requirement which is evaluated to be 2.187 mm/day according to item 4, pp. 276-278.

Sources:

Ministry of Irrigation : In Kienitz, G. Introduction of Methods of Planning Water Resources Management in Iraq, Institute for Applied Research on Natural Resources, Tech Rep. No. 36, Baghdad, 1971, pp.51-54.
Al-Sahaf, M., op.cit., pp.142-144.
Polservice Co., op.cit., Vol. IX, Part A Text, pp.5-9 and Table IX-2-2.

for winter and 17% for summer seasons are applied. The idea of using deep and permanent drainage systems is that most of the irrigated lands are situated in the Mesopotamian Plain in which the salinity problem is serious (Chapter 2).

Thus, during cultivation some of the irrigation water will be stored in the upper part of the soil, where it will be partly consumed by the crops and partly evaporated from the soil surface, leaving behind its load of salt. A certain amount of this irrigation water will infiltrate below the root zone and eventually will reach the groundwater table which is usually close to the soil surface. Due to the topographical condition of the Mesopotamian Plain, there is practically no natural drainage. Consequently, the groundwater table will rise rapidly during the cultivation period. During the fallow period, it drops back again. The drop in the level of water table is mainly caused by the upward movement of water by capillary action and its eventual evaporation from the soil surface, leaving salt content in the upper part of the soil profile. The higher the water table, the greater will be the rate of upward movement of saline groundwater and hence the faster will be the process of soil salinisation. Therefore, under this condition, deep and permanent drainage associated with an adequate drainage network is the main solution to avoid the soil salinity process in the Mesopotamian Plain.

However, the irrigation efficiency coefficients for normal leaching water requirements and field evaporation losses are[1]:

For winter season (November-April) = $\frac{100-(23.0+3.7)}{100}$ = 73.3%

For summer season (May-October) = $\frac{100-(17.0+10.2)}{100}$ = 72.8%

Thus, the total irrigation efficiency coefficients are:

For winter season = 0.866 x 0.733 = 0.635

For summer season = 0.866 x 0.728 = 0.630.

Finally, Table 6.1 represents the actual monthly and annual irrigation rates for agricultural crops, using the irrigation efficiency coefficients of 0.635 and 0.630 for winter and summer crops respectively. This table is adapted to evaluate national irrigation water balance.

6.3 IRRIGATION WATER BALANCE

As the largest amount of water is devoted to irrigation purposes, this section will deal only with the present and prospective irrigation water balances of the country, according to the particular river basin, adopting the relationship between four variables. These are:

1. the average long term river water discharge and the discharge in the driest year, usually 1961;
2. the crop water consumption;
3. irrigated land; and
4. land use including cropping pattern and cropping intensity regarding two alternatives (A and B). These are:

   A) The Ministry of irrigation cropping intensity which are as follows:

   1. The present Euphrates basin (1985) cropping intensity is 117%*and it will be 115% in future (2000) (Appendices 1 and 3).
   2. The Tigris basin: 102% at present and will be 116% in future (Appendices 9 and 11).
   3. The Shatt Al-Arab: 173% at present and will be 144% in future (Appendices 41 and 43).

   B) The Higher Agricultural Council cropping intensity which is designed according to the Ministry of Planning and FAO co-operative study. According to

*117% = area irrigated in winter + area irrigated in summer that, the present (1985) intensity is 108% of the total irrigated land and will be 128% in future (Appendices 5, 7, 13, 15, 45 and 47).

The aim of applying the above two alternatives is to testify whether there is enough available water to satisfy their requirements. Thus, irrigation water requirements of these alternatives have been evaluated and compared with the available river water resources as follows:

6.3.1 THE EUPHRATES IRRIGATION WATER BALANCE

The only source for irrigation water within the Iraqi part of the Euphrates basin is the river itself. This is the result of two factors. Firstly, the area lies beyond the 200mm isohyet, rendering dry farming impossible (Chapter 2, Fig.2.2). Secondly, groundwater, though underlying the basin, is entirely unsuitable for irrigation. This is due to its high salinity with an average EC value, ranging from 4.68 to 9.36mmhos/cm (Chapter 4, p171). Furthermore, the water table is generally considerably less than 5m below the ground surface, leading to water-logging and consequent soil salinisation. This suggests that adequate drainage is vital. Large supplies of fresh water are necessary to flush the salts out of the soil, once sufficient drainage has been established.

6.3.1.1 Alternative (A)

The total present irrigated land of the Euphrates river is 1650869ha. This will increase to 1801524ha in the future (Appendices 1 and 3). To evaluate the irrigation water balance, the average length of time (1956-80) and the driest year (1961) water discharges at Hit gauge, regulated by the Habbaniya reservoir, are adopted (Table 6.2).

According to this alternative (Table 6.3), the present annual irrigation water demand is in the order of 866.92 cumecs (27.31bcm). In this instance, the annual balance is negative, with a mean deficit of 42.1 cumecs (1.31bcm), regarding the average long term discharge, which is 824.83 cumecs (26.0bcm). The monthly balance is positive for six months (December-May inclusive), with a mean surplus of 259.5 cumecs (4.1bcm). The greatest surplus of 554 cumecs (1.44bcm) occurs in April, while the lowest, 92 cumecs (0.25bcm) occurs in December. The balance is negative during the other six months (June-November inclusive), with a mean deficit of 343.7 cumecs (5.43bcm). The most serious deficits arise in July, August and October, with a mean of 507 cumecs (4.1bcm).

The future predicted annual irrigation water requirements will rise to 934.42 cumecs (29.43bcm), increasing the present annual deficit to 109.59 cumecs (3.43bcm), as compared with the average long term discharge previously indicated. There

Table 6.2 Average Long Term and Driest Year Water Discharges of the Euphrates River at Hit, Regulated by the Habbaniya Reservoir

Status	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	Mean annual (bcm)
Average water discharge (1956-80)	399	494	632	728	770	1114	1919	2152	1236	527	341	325	886.42	27.95
Water diversion to Habbaniya reservoir								989	66				87.92	2.8
Water releases from Habbaniya reservoir										101	157	58	26.33	0.83
Regulated flow	399	494	632	728	770	1114	1919	1163	1170	628	498	383	824.83	26.0
Driest year water discharge (1961)	331	390	383	462	537	434	1300	1170	443	192	86	93	483	15.23
Water diversion to Habbaniya reservoir								535	36				47.6	1.5 *
Water releases from Habbaniya reservoir										55	85	32	14.3	0.45*
Regulated flow	331	390	383	462	537	434	1300	635	407	247	171	125	449.7	14.2

Sources:

Ministry of Irrigation, Directorate General of Irrigation, Discharges for Selected Gauging Stations in Iraq, Baghdad, 1976,pp.48-49

Ministry of Irrigation (Unpublished Data)

Selkhozpromexport Co., op.cit., vol.1, Book 2, p.271.

* Water diversions and releases in the dry year are defined on the bases of percentage relationship between average long term discharge their water diversions and releases and dry year discharge.

Table 6.3 Present and Future Monthly and Annual Irrigation Water Balances of the Euphrates River (Alternative A), in cumecs

Status	MONTHS Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	(bcm)
Euphrates average dis. at Hit (1956-80)(1)	399	494	632	728	770	1114	1919	1163	1170	628	498	383	824.83	26.0
Present water requirement(2)	789	799	540	474	624	854	1365	912	1193	1177	1080	596	866.92	27.31
Present water balance	-390	-305	92	254	146	260	554	251	- 23	-549	-582	-213	- 42.1	- 1.31
Future water requirement(2)	853	856	579	508	668	913	1458	999	1295	1269	1165	650	934.42	29.43
Future water balance	-454	-362	53	220	102	201	461	164	-125	-641	-667	-267	-109.59	- 3.43
Driest year dis. at Hit (1961)(1)	331	390	383	462	537	434	1300	635	407	247	171	125	449.7	14.2
Present water balance	-458	-409	-157	-12	-87	-420	- 65	-277	-786	-930	-909	-471	-417.22	-13.11
Future water balance	-522	-466	-196	-46	-131	-479	-158	-364	-888	-1022	-994	-525	-484.72	-15.23

(1) Derived from Table 6.2

(2) Derived from Appendix 2 and 4

will be enough water available for six months (December-May inclusive), with a mean monthly surplus of 200.2 cumecs (3.15bcm). The lowest surplus, with a mean of 53 cumecs (0.142bcm) will occur in December, while the highest of 461 cumecs (1.2bcm) will arise in April. During the other six months (June-November inclusive), there will be a deficit, with a mean of 419.33 cumecs (6.63bcm). Again, the greatest deficit will occur in July, August and October, with a mean of 587.33 cumecs (4.72bcm).

In the driest year, such as 1961, the river is unable to cope with the irrigation water requirements. In this instance, the present and future balances are negative for the whole year, with annual deficits of 417.22 cumecs (13.11bcm) and 484.72 cumecs (15.23bcm) respectively. The period of June to August exhibits the most serious deficit with a mean of 875 cumecs (6.96bcm) at present, which will increase to 968 cumecs (7.7bcm) in the future.

6.3.1.2 Alternative (B)

According to this alternative (Table 6.4), the present annual irrigation water demand is evaluated to be 818.42 cumecs (25.78bcm). By comparing this with the available average long term discharge at Hit, which is 824.83 cumecs (26.0bcm), the result is positive, with a surplus of only 6.41 cumecs (0.22bcm). Moreover, there is sufficient water for seven months, December-June inclusive, with a mean

Table 6.4 Present and Future Monthly and Annual Irrigation Water Balances of the Euphrates River (Alternative B), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Euphrates average dis. at Hit (1956-80)	399	494	632	728	770	1114	1919	1163	1170	628	498	383	824.83	26.0
Present water requirement(1)	772	821	568	494	634	851	1351	818	1043	1028	940	501	818.42	25.78
Present water balance	-373	-327	64	234	136	263	568	345	127	-400	-442	-118	6.41	0.22
Future water requirement(1)	1015	1094	761	661	845	1124	1776	1021	1295	1276	1166	615	1054.1	33.2
Future water balance	-616	-600	-129	67	-75	- 10	143	142	-125	-648	-668	-232	-229.3	- 7.2
Driest year dis. at Hit (1961)	331	390	383	462	537	434	1300	635	407	247	171	125	449.7	14.2
Present water balance	-441	-431	-185	- 32	- 97	-417	- 51	-183	-636	-781	-769	-376	-368.72	-11.58
Future water balance	-684	-704	-378	-199	-308	-690	-476	-386	-888	-1029	-995	-490	-604.4	-19.0

(1) Derived from Appendix 6 and 8.

surplus of 248.14 cumecs (4.55bcm). The lowest surplus occurs in December, with a mean of 64 cumecs (0.17bcm). The balance is negative through the other five months, July to November inclusive, with a mean deficit of 332 cumecs (4.39bcm). The greatest deficit, with a mean of 405 cumecs (3.25bcm), occurs in July, August and October.

The future annual predicted irrigation water requirement will be 1054.1 cumecs (33.2bcm), compared with the available average long term discharge at Hit, which is 824.83 cumecs (26.0bcm). Therefore, the annual deficit will be 229.3 cumecs (7.2bcm). The monthly balance will be negative for nine months, June-December inclusive, February and March, with a mean deficit of 344.78 cumecs (8.13bcm). The most serious deficit will occur in July, August, October and November, with a mean of 633 cumecs (6.73bcm). Only January, April and May will exhibit a positive balance with a mean surplus of 117.33 cumecs (0.933bcm).

Considering the driest year discharge, based on 1961 figures, the present and future water balances are completely negative for the whole year as there is insufficient water in the river to meet their water demands. Thus, the present and future annual deficits are 368.72 cumecs (11.58bcm) and 604.4 cumecs (19.0bcm) respectively. Again, as in the first alternative, the serious deficit occurs in June-August, with a mean of 728.67 cumecs

(5.8bcm) at present and will increase to 970.67 cumecs (7.72bcm) in the future.

It should be pointed out that the future water deficit in both alternatives will be increased greatly, due to the extensive planned irrigation development in the upstream states, Turkey and Syria, which will require a total annual volume of 784.4 cumecs (24.73bcm). Thus, the future available water to Iraq during a normal year will be only 338.6 cumecs (10.7bcm). This, together with the Tharthar supply, can only satisfy the minimum total water requirement of the Euphrates river. In dry years, the river water balance will be in extreme deficit (section 6.5.1).

6.3.2 THE TIGRIS IRRIGATION WATER BALANCE

The total present and future irrigated areas of the Tigris river (including its tributaries) are 2059965 and 3663810ha respectively (Appendices 9 and 11). The irrigation water balances result from the comparison of the irrigation water demands with the average long term river discharge (1956-78) and the driest year discharge of the main river downstream of Samarra barrage, plus that of the Adhain and Diyala tributaries as follows:

6.3.2.1 Alternative (A)

Regarding this alternative, the present annual irrigation water requirement is 975 cumecs (30.75bcm) (Table 6.5).

Table 6.5 Present and Future Monthly and Annual Irrigation Water Balances of the Tigris River (Alternative A), in cumecs

Status	MONTHS Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	(bcm)
Tigris average dis. downstream Samarra (1956-78)(1)	585	686	921	1067	1369	1992	2522	2365	1500	877	677	593	1263	39.83
Present water requirement(2)	872	950	657	572	734	1004	1618	968	1273	1289	1174	589	975	30.75
Present water balance	-287	-264	264	495	635	988	904	1397	227	-412	-497	4	288	9.1
Future water requirement(2)	1705	1748	1180	1035	1365	1885	3030	1991	2649	2647	2424	1306	1913.8	60.35
Future water balance	-1120	-1062	-259	32	4	107	-508	374	-1149	-1770	-1747	-713	-650.8	-20.52
Driest year dis. downstream Samarra (1961)(3)	371	583	504	664	802	840	1705	1946	795	467	359	367	784	24.72
Present water balance	-501	-367	-153	92	68	-164	87	978	-478	-822	-815	-222	-191	- 6.03
Future water balance	-1334	-1165	-676	-371	-563	-1045	-1325	-45	-1854	-2180	-2065	-939	-1129.8	-35.63

(1) Including (Tigris average discharge downstream Samarra 1956-78 (excluding water diversion to Tharthar reservoir) + Adhaim at Injana 1945-75 + Diyala at the Discharge Site 1962-75) Chapter 3 (Tables 3.5 and 3.6)

(2) Derived from Appendix 10 and 12

(3) Including Tigris discharge downstream Samarra 1961 + Adhaim at Injana 1960 + Diyala at the Discharge Site 1960) Chapter 3 (Tables 3.5 and 3.6).

This forms 77.2% of the average long term river discharge, which is 1263 cumecs (39.83bcm). Furthermore, the monthly balance is positive for eight months, December-June inclusive and September, with a mean surplus of 614.25 cumecs (12.843bcm). September exhibits a critical balance with a surplus of 4 cumecs (0.01bcm). The period of the other four months, October-November and July-August, shows a negative balance, with a mean deficit of 365 cumecs (3.88bcm). The greatest deficit, with a mean of 454.5 cumecs (2.435bcm) occurs in July and August.

In the driest year, there is insufficient water in the river to satisfy its present water demand. Consequently, the annual balance is negative, with a mean deficit of 191 cumecs (6.03bcm). In addition, the monthly balance is negative for eight months, June-December inclusive and March, with a mean deficit of 440.25 cumecs (9.32bcm). The greatest deficit occurs in July and August, with a mean of 818.5 cumecs (4.385bcm). Only the period of the remaining four months, January, February, April and May exhibits a positive balance, with a mean surplus of 306.25 cumecs (3.175bcm).

The predicted water requirement will be double that at present, or 1913.8 cumecs (60.35bcm). In this instance, the river's normal water discharge will be insufficient to meet its water demand. As a result, the annual balance will be negative, with a mean deficit of 650.8 cumecs (20.52bcm). The monthly balance will be in deficit for eight months, June-December inclusive and April, with a mean of 1041 cumecs (21.95bcm). Only the period of January to March inclusive and May shows a positive balance, with a mean surplus of 129.25 cumecs (1.4bcm). February will exhibit a critical balance, with a surplus of 4 cumecs.

Regarding the driest year discharge, the river is unable to meet its extremely high predicted future water requirement. Thus, the balance will be completely negative for the whole year, with an overall annual deficit of 1129.8 cumecs (35.63bcm).

6.3.2.2 Alternative (B)

In this alternative (Table 6.6), the present annual irrigation water requirement is evaluated to be 1021.25 cumecs (32.21bcm). This comprises 80.86% of the average long term river water discharge, which is 1263 cumecs (39.83bcm). The monthly positive balance is reduced to seven months, December-June inclusive, with a mean surplus of 649.86 cumecs (11.903bcm), compared with eight months at the alternative (A). The lowest surplus, with a mean of 205.5 cumecs (1.083bcm) occurs in December and June, while the highest of 1344 cumecs (3.6bcm) occurs in May. The period of July-November inclusive, exhibits a negative balance with a mean deficit of 330 cumecs (4.362bcm). The greatest deficit occurs in July and

Table 6.6 Present and Future Monthly and Annual Irrigation Water Balances of the Tigris River (Alternative B), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Tigris average dis. downstream Samarra (1956-78)	585	686	921	1067	1369	1992	2522	2365	1500	877	677	593	1263	39.83
Present water requirement(1)	963	1024	708	617	792	1062	1685	1021	1302	1283	1173	625	1021.25	32.21
Present water balance	-378	-338	213	450	577	930	837	1344	198	-406	-496	- 32	241.75	7.62
Future water requirement(1)	2064	2226	1547	1345	1718	2286	3612	2076	2634	2594	2371	1252	2143.75	67.61
Future water balance	-1479	-1540	-626	-278	-349	-294	-1090	289	-1134	-1717	-1694	-659	-880.75	-27.8
Driest year dis. downstream Samarra(1961)	371	583	504	664	802	840	1705	1946	795	467	359	367	784	24.72
Present water balance	-592	-441	-204	47	10	-222	20	925	-507	-816	-814	-258	-237.25	- 7.5
Future water balance	-1693	-1643	-1043	-681	-916	-1446	-1907	-130	-1839	-2127	-2012	-885	-1360	-42.9

(1) Derived from Appendix 14 and 16

August, with a mean of 451 cumecs (2.416bcm).

Considering the driest year water discharge, the present water balance shows an increase of the annual deficit to 237.25 cumecs (7.5bcm), compared with 191 cumecs (6.03bcm) at the alternative (A). Again, a period of eight months, June-December inclusive and March, is in deficit, with a mean of 481.75 cumecs (10.2bcm). The greatest deficit, with a mean of 815 cumecs (4.366bcm) occurs in July and August. Only a period of four months, January-February, April and May, exhibits a positive balance with a mean surplus of 250.5 cumecs (2.6bcm). The lowest surplus with a mean of 15 cumecs (0.075bcm) occurs in February and April.

The future annual expected water requirement will rise to about double that at present, or 2143.75 cumecs (67.61bcm). Again, this forms about double the available mean annual normal river water discharge. This indicates that there is insufficient water in the river to satisfy its water demands. Thus, the annual deficit will reach 880.75 cumecs (27.8bcm). The monthly balance will be negative for 11 months, June-April inclusive, with extremely high mean deficit of 987.273 cumecs (28.49bcm). May will be the only month with a positive balance of 289 cumecs (0.774bcm).

Regarding the driest year, the future balance will be completely negative for the whole year, with an overall annual deficit of 1360 cumecs (42.9bcm).

From what has been stated, the following can be concluded:

1. The present irrigation water deficits during normal and driest years will be further increased regarding other water requirements and losses of the country, which will have priority (section 6.4).
2. The future irrigation water deficits will increase, bearing in mind water demands of the planned irrigation development in the upstream riparian states, Turkey and Iran, which will require a total annual volume of 212.51 cumecs (6.7bcm), as well as the prior satisfaction of the country's other water requirements and losses (section 6.5.2).
3. The future deficit will be slightly reduced, due to the effect of the Tharthar, Bekme reservoirs and the potential groundwater aquifers attached to the irrigated land, if developed. These are relatively few, as follows:
   a) the lower section of the Khabour tributary;
   b) the middle and lower sections of the Greater Zab tributary;
   c) the middle section of the Lesser Zab tributary;
   d) the middle section of the Adhaim tributary; and
   e) the upper and middle sections of the Diyala tributary.

   Generally, the groundwater depth of these aquifers ranges from 10 to 50m, with an average EC value between less than 1.56 to 4.68mmhos/cm[2].

6.3.3 IRRIGATION WATER BALANCE OF THE TIGRIS TRIBUTARIES

The irrigation water balances of the Tigris tributaries are individually evaluated according to the moderate alternative (A), to investigate whether they are able to cope with the water requirements of this alternative. They are already included in the irrigation water balance evaluation of the Tigris river basin as a whole in alternatives (A) and (B).

6.3.3.1 The Khabour River

The total irrigated land of this tributary is 3000ha (Appendix 17). The present and future water requirements (Table 6.7) are relatively small, compared with the available average long term water discharge. Thus, the mean monthly irrigation water demands for seven months, July-January, are 1.289 for the present and 1.279 cumecs for the future. These form only 4.28% and 4.244% of the mean low water discharge, which is 30.14 cumecs. The present and future annual water demands form only 2.12% and 2.1% of the mean annual water discharge, which is 68 cumecs (2.144bcm).

In accordance with the driest year for water discharge (1961), the river is also capable of satisfying its present and future monthly and annual irrigation water demands. For example, the present and future mean monthly water requirements during the low water period, July-January, form only 9.12% and 9.05% respectively of the mean water discharge during this period, which is 14.14 cumecs. While

Table 6.7 Present and Future Monthly and Annual Irrigation Water Balances of the Khabour River (Alternative A), in cumecs

	MONTHS												Mean annual	
Status	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Khabour average dis. at Zakho (1959-73 and 75)(1)	25	29	39	41	50	85	178	199	93	34	22	21	68	2.144
Present water requirement (2)	1.32	1.4	0.97	0.84	1.07	1.46	2.33	1.49	1.9	1.87	1.71	0.91	1.44	0.045
Future water requirement (2)	1.33	1.37	0.95	0.83	1.06	1.43	2.27	1.53	1.9	1.85	1.69	0.93	1.43	0.045
Driest year dis. at Zakho (1961) (1)	10	21	14	17	23	32	106	147	50	16	11	10	38	1.2

(1) Derived from Chapter 3 (Table 3.5)

(2) Derived from Appendix 18 and 20

the annual water demands form 3.79% and 3.76% respectively of the mean annual discharge, which is 38 cumecs (1.2bcm).

It is clear from Table 6.7 that the river water discharge is unregulated at present, ie. the highest mean discharge of 121 cumecs occurs during the period, February-June, while the lowest mean of 30.14 cumecs appears during the period July-January. Nevertheless, the river is capable of meeting its present and future water demands, even in the driest year, such as 1961. Thus, regulation of the river water discharge will enable the river to offer water for further irrigation development, which is necessary in summer. While that in winter should depend on rainfed irrigation as there is enough rainfall, with an annual of 731.7mm at Zakho station (Appendix 49).

6.3.3.2 <u>The Greater Zab River</u>

The total present and future irrigated lands of this tributary are 93715 and 133000ha respectively (Appendices 21 and 23). The river irrigation water balance (Table 6.8) indicates that there is sufficient water to satisfy the present and future water requirements regarding the average long term and driest year water discharges. Thus, the present annual demand forms 10.72% of the average long term discharge, which is 424 cumecs (13.4bcm). The monthly balance is completely positive, with a mean surplus of 378.55 cumecs (11.97bcm). The greatest monthly demands

Table 6.8 Present and Future Monthly and Annual Irrigation Water Balances of the Greater Zab River (Alternative A), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Greater Zab average dis. at Eski-Kelek (1944-75)(1)	141	171	216	258	371	654	1011	1019	609	313	183	140	424	13.4
Present water requirement(2)	40	44	30	26.2	34	47	75.3	45	60	61	55.4	27.5	45.45	1.433
Present water balance	101	127	186	231.8	337	607	935.7	974	549	252	127.6	112.5	378.55	11.97
Future water requirement(2)	67	67	44	39	53	74.2	120	80	111	112	103	56	77.183	2.434
Future water balance	74	104	172	219	318	579.8	891	939	498	201	80	84	346.817	10.97
Driest year dis. at Eski-Kelek (1961)(1)	84	191	146	175	278	348	834	877	462	192	102	91	315	9.93
Present water balance	44	147	116	148.8	244	301	758.7	832	402	131	46.6	63.5	269.55	8.5
Future water balance	17	124	102	136	225	273.8	714	797	351	80	-1	35	237.817	7.5

(1) Derived from Chapter 3 (Table 3.5)
(2) Derived from Appendix 22 and 24.

occur in April and June-August inclusive, with a mean of 62.93 cumecs.

In a dry year, and taking 1961 as an example, the annual water requirement forms only 14.43% of the mean annual discharge, which is 315 cumecs (9.93bcm). The monthly balance is positive, with a mean surplus of 269.55 cumecs (8.5bcm). The lowest surplus of 46.6 and 44 cumecs occur in August and October respectively.

The future water requirements will be completely satisfied regarding the average long term discharge stated previously. Thus, the annual demand forms only 18.2% of the mean annual discharge. The monthly balance will be positive, with a mean surplus of 346.82 cumecs (10.97bcm). The greatest demands will arise in April and June-August inclusive, with a mean of 111.5 cumecs.

Regarding the driest year for water discharge (1961), the future annual irrigation water demand forms 24.5% of the mean annual discharge. The monthly balance will be positive for 11 months, September-July inclusive, with a mean surplus of 259.5 cumecs. The October balance will be critical, with a surplus of 17 cumecs. The balance will only be negative in August, with a deficit of 1 cumec.

It should be noted that the river is unregulated, ie. the highest mean discharge of 823.3 cumecs occurs during the period March-June, while the lowest mean discharge of 224.13 cumecs occurs during the period July-February (Table 6.8). Despite this, the river is capable of meeting its present and future irrigation water demands, even in the driest year, such as 1961. In future, the river will be regulated by the Bekme reservoir, which has a total storage capacity of 33.0bcm, of which 28.0bcm* will be useful storage. Consequently, it will be able to offer water for further irrigated land and to provide water for the Tigris lower basin, especially in dry years.

Furthermore, the groundwater resources at the middle and lower sections of the river, as previously stated, should be utilized in order to offer the surface water to the Lower Tigris basin.

6.3.3.2.1 The Khazir

This is one of the most important Greater Zab tributaries (Chapter 3, Fig.3.1) from the viewpoint of irrigation developments. Its total irrigated land is 26950ha (Appendix 25). However, the evaluation of irrigation water balance indicates that the river is capable of fulfilling its present annual water requirement regarding the average long term water discharge, which is 29 cumecs (0.914bcm), with a mean surplus of 16.09 cumecs (0.507bcm) (Table 6.9). In addition, the monthly balance is positive for seven months,

* This is evaluated on the basis of the previous plan based in: Higher Agricultural Council, Op. cit. Studies Nos. 1-2, 1-3 and 1-4, pp34.

Table 6.9 Present and Future Monthly and Annual Irrigation Water Balances of the Khazir River (Alternative A), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Khazir average dis.at Manquba (1944-75)(1)	10	15	29	36	53	74	59	31	13	10	9	8	29	0.914
Present water requirement (2)	11.9	12.5	8.6	7.5	9.6	13.1	20.9	13.4	17	16.8	15.4	8.2	12.91	0.407
Present water balance	- 1.9	2.5	20.4	28.5	43.4	60.9	38.1	17.6	- 4	- 6.8	- 6.4	-0.2	16.09	0.507
Future water requirement (2)	11.9	12.3	8.5	7.4	9.5	12.8	20.4	13.7	17.1	16.6	15.2	8.4	12.82	0.404
Future water balance	- 1.9	2.7	20.5	28.6	43.5	61.2	38.6	17.3	- 4.1	- 6.6	- 6.2	-0.4	16.18	0.51
Driest year dis. at Manquba (1961)(1)	6	20	11	18	29	22	25	14	6	6	6	6	14.1	0.444
Present water balance	- 5.9	7.5	2.4	10.5	19.4	8.9	4.1	0.6	-11	-10.8	- 9.4	-2.2	1.19	0.037
Future water balance	- 5.9	7.7	2.5	10.6	19.5	9.2	4.6	0.3	-11.1	-10.6	- 9.2	-2.4	1.28	0.04

(1) Ministry of Irrigation, Directorate General of Irrigation, Discharges for Selected Gauging Stations in Iraq, 1976, op.cit., p.20.

(2) Derived from Appendix 26 and 28.

November-May inclusive, with a mean surplus of 30.2 cumecs (0.553bcm). During the other five months, June-October inclusive, the balance is negative, with a mean deficit of 3.9 cumecs (0.052bcm). The highest deficit, with a mean of 6.6 cumecs (0.04bcm) occurs in July and August.

Regarding the driest year discharge (based on 1961 figures), the present annual demand forms 91.6% of the mean annual water discharge, which is 14.1 cumecs (0.444bcm). The monthly balance is positive for seven months, November-May inclusive, with a mean surplus of 7.63 cumecs (0.14bcm). The balance in May is critical, with a surplus of 0.6 cumecs. The other five months, June-October inclusive, exhibit a negative balance, with a mean deficit of 7.86 cumecs (0.104bcm).

The future annual irrigation balance based on the average long term water discharge, stated before, will be positive, with a mean surplus of 16.18 cumecs (0.51bcm). Furthermore, the monthly balance will be positive for seven months, November-May inclusive, with a mean surplus of 30.34 cumecs (0.56bcm), while it will be negative during the other five months, June-October inclusive, with a mean deficit of 3.84 cumecs (0.051bcm).

During a dry year, such as 1961, the river will be able to satisfy its annual irrigation water demand, with a mean surplus of 1.28 cumecs (0.04bcm). Its monthly requirements during the period, November-May inclusive, will also be met, with a mean surplus of 7.77 cumecs (0.142bcm). The period of June-October inclusive, will exhibit a negative balance, with a mean deficit of 7.84 cumecs (0.104bcm).

Thus, it would seem from the water balance analysis that the river is able to satisfy its present and future annual water demands, as well as the monthly needs, especially during the period, November-May, regarding the average long term and driest year water discharges. It is however, unable to cope with demand during the period of June-October. As there is sufficient of an annual water surplus, the regulation of the river discharge by the planned Bakerman dam, which has a total storage capacity of 0.375bcm (Chapter 3, section 3.3.4) will certainly remove the deficit.

6.3.3.3 The Lesser Zab River

At present, the total irrigated land of this tributary is 63240ha, which will increase to 256250ha in the future (Appendices 29 and 31). The present irrigation water balance (Table 6.10) indicates that the river contains sufficient water to fulfil its present annual and monthly water requirements regarding the average long term discharge (1960-75), which was regulated by the Dokhan reservoir. Thus, the annual demand forms only 14.8% of the mean annual discharge, which is 231 cumecs (7.3bcm). The monthly balance is

Table 6.10

Present and Future Monthly and Annual Irrigation Water Balances of the Lesser Zab River (Alternative A), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Cumecs	(bcm)
Lesser Zab aver.dis.at Altun Kupri(1960-75)(1)	299	194	212	210	230	238	228	200	164	211	301	287	231	7.3
Present water requirement(2)	31	31	21	18.4	24.3	33.4	53.4	36	47.4	47	43	24	34.16	1.08
Present water balance	268	163	191	191.6	205.7	204.6	174.6	164	116.6	164	258	263	196.84	6.22
Future water requirement(2)	129	129	85	75	102	143	230.2	154	213	215	197	108	148.35	4.673
Future water balance	170	65	127	135	128	95	- 2.2	46	-49	- 4	104	179	82.65	2.627
Driest year dis.at Altun Kupri (1961)(1)	230	243	119	155	176	117	107	75	83	168	204	239	160	5.0
Present water balance	199	212	98	136.6	151.7	83.6	53.6	39	35.6	121	161	215	125.84	3.92
Future water balance	101	114	34	80	74	-26	-123.2	-79	-130	-47	7	131	11.65	0.327

(1) Derived from Chapter 3 (Table 3.5).

(2) Derived from Appendix 30 and 32.

completely positive, with a mean surplus of 196.84 cumecs (6.22bcm).

Considering the driest year (1961) water discharge, which is 160 cumecs (5.0bcm), the present balance is positive for the whole year, with an annual surplus of 125.84 cumecs (3.92bcm).

The future annual balance, based on the average long term discharge stated before, will be positive, with a mean surplus of 82.65 cumecs (2.627bcm). In addition, the monthly balance will be positive for nine months, August-March inclusive and May, with a mean surplus of 116.56 cumecs (2.76bcm), while it will be negative for the other three months, April, June and July, with a mean deficit of 18.4 cumecs (0.145bcm).

In the driest year, such as 1961, the future annual balance will still be positive, with a mean surplus of only 11.65 cumecs (0.327bcm), while the positive monthly balance will be reduced to seven months, August-February inclusive, with a mean surplus of 77.29 cumecs (1.416bcm). The remaining five months, March-July inclusive, will exhibit a negative balance, with a mean deficit of 81.04 cumecs (1.07bcm).

From the preceding analysis, it seems that the river is capable of meeting its present monthly and annual water demands regarding the average long term and driest year water discharges. The future annual balance will be positive during normal and dry years, with a mean surplus of 82.65 cumecs (2.627bcm) and 11.65 cumecs (0.327bcm) respectively. The monthly balance will be negative for three months, April, June and July, regarding the normal water discharge. This will extend to five months (March-July inclusive) in the driest year. However, this situation is completely different when compared with other rivers and indicates that the operating scheme of the Dokhan reservoir is inaccurate. Therefore, the shortage stated before can be removed, as there will be enough annual water surplus, if the reservoir operating scheme is re-regulated.

Moreover, the groundwater aquifers in the middle section of the river, previously indicated, should be developed in order to offer some of the surface water to the Lower Tigris basin.

6.3.3.4 The Adhaim River

The total present and future irrigated lands of this tributary are 22600ha and 143100ha respectively (Appendices 33 and 35). At present, the annual water requirement forms 44.12% of the mean annual long term discharge which is 25 cumecs (0.8bcm). Thus, the annual balance is positive, with a mean surplus of 13.97 cumecs (0.453bcm) (Table 6.11).

Table 6.11 Present and Future Monthly and Annual Irrigation Water Balances of the Adhaim River (Alternative A), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Cumecs	(bcm)
Adhaim average dis, at Injana (1945-75) (1)	2	17	29	48	46	75	56	21	4	2	1	1	25	0.8
Present water requirement(2)	10.9	10.5	7.3	6.3	8.2	10.8	16.7	12.6	14.9	13.7	12.6	7.8	11.03	0.347
Present water balance	- 8.9	6.5	21.7	41.7	37.8	64.2	39.3	8.4	-10.9	-11.7	-11.6	-6.8	13.97	0.453
Future water requirement(2)	68.9	70.9	47	41.5	55.7	78.6	127.4	81.5	113.7	116.5	106.5	56	8 0.35	2.531
Future water balance	-66.9	-53.9	-18	6.5	- 9.7	- 3.6	-71.4	-60.5	-109.7	-114.5	-105.5	-55	-55.35	-1.731
Driest year dis. at Injana (1960)(1)	2	1	2	27	6	8	10	1	1	1	0	1	5.0	0.16
Present water balance	- 8.9	- 9.5	-5.3	20.7	- 2.2	- 2.8	- 6.7	-11.6	-13.9	-12.7	-12.6	- 6.8	-6.03	-0.187
Future water balance	-66.9	-69.9	-45	-14.5	-49.7	-70.6	-117.4	-80.5	-112.7	-115.5	-106.5	--55	-75.35	-2.371

(1) Derived from Chapter 3 (Table 3.5).

(2) Derived from Appendix 34 and 36.

The monthly balance is positive for seven months, November-May inclusive, with a mean surplus of 31.4 cumecs (0.58bcm), while during the other five months, June-October inclusive, a negative balance is exhibited, with a mean deficit of 9.98 cumecs (0.132bcm).

In future, the river will be unable to meet its water requirements regarding the average long term discharge. In this instance, there will be a mean annual deficit of 55.35 cumecs (1.731bcm). The monthly balance will be negative for 11 months, February-December inclusive, with a mean deficit of 60.8 cumecs (1.76bcm). The greatest deficit of 114.5 cumecs will occur in July and the lowest of 3.6 cumecs will occur in March. Only the January balance will be positive, with a surplus of 6.5 cumecs (0.02bcm).

For the lowest discharge, using prediction based on the 1960 figures, the present and future balances are completely negative, with annual deficits of 6.03 cumecs (0.187bcm) and 75.35 cumecs (2.371bcm) respectively. Only January exhibits a positive balance at present, with a surplus of 20.7 cumecs.

It has already been pointed out that the present water balance, based on the average long term discharge, is in deficit for five months, June-October inclusive. However, this can be removed as there is enough annual water surplus after the regulation of the river discharge by the planned dams, Damer gabow and Basara, with a total storage capacity of 1.35bcm (Chapter 3, section 3.3.4). The present deficit during a dry year can be only slightly reduced by the development of the groundwater aquifers in the middle section.

In future, the river water will be insufficient to satisfy its high requirements. Thus, the balance is predicted to be negative, with annual deficits of 55.35 cumecs (1.731bcm) and 75.35 cumecs (2.371bcm) during normal and dry year discharges respectively.

6.3.3.5 The Diyala River

This is the most important of the Tigris tributaries with regard to its irrigation development. Its present irrigated land is 415670ha. This will expand to 555350ha in future (Appendices 37 and 39). At present, the annual irrigation water requirement is in the order of 198.42 cumecs (6.25bcm). This represents 98.2% of the average long term water discharge (1962-75)*, which is 202 cumecs (6.4bcm) (Table 6.12). In this instance, the annual balance is positive, with a surplus of only 3.58 cumecs (0.15bcm). In addition, the monthly balance is positive for seven months, December-May inclusive and September, with a mean surplus of 64.43 cumecs (1.18bcm), while it is negative through the other five months, June-August inclusive, October and November, with a

* This is regulated by the Derbendi Khan reservoir.

Table 6.12 Present and Future Monthly and Annual Irrigation Water Balances of the Diyala River (Alternative A), in cumecs

Status	MONTHS Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	(bcm)
Diyala average dis. at the Discharge Site (1962-75) (1)	133	145	150	179	188	325	414	288	154	144	151	150	202	6.4
Present water requirement (2)	168	193	133	116	149	208	340	184	257	273	247	113	198.42	6.25
Present water balance	- 35	- 48	17	63	39	117	74	104	-103	-129	- 96	37	3.58	0.15
Future water requirement (2)	237	261	177	155	203	285	464	270	377	394	359	174	279.67	8.81
Future water balance	-104	-116	- 27	24	- 15	40	- 50	18	-223	-250	-208	- 24	- 77.67	-2.41
Driest year dis. at the Dis.Site (1960)(1)	38	53	58	90	69	73	115	86	33	14	14	14	55.0	1.73
Present water balance	-130	-140	-75	-26	-80	-135	-225	-98	-224	-259	-233	-99	-143.42	-4.52
Future water balance	-199	-208	-119	-65	-134	-212	-349	-184	-344	-380	-345	-160	-224.67	-7.08

(1) Derived from Chapter 3 (Table 3.5).

(2) Derived from Appendix 38 and 40.

mean deficit of 82.2 cumecs (1.09bcm). The period of June-August inclusive, exhibits the extreme highest deficit with a mean of 109.33 cumecs (0.87bcm).

In future, the river will be unable to deal with its increasing irrigation water requirement, bearing in mind its average long term discharge, previously stated. As a result, the annual water deficit will be 77.67 cumecs (2.41bcm). In addition, the monthly balance will be negative for nine months, June-December inclusive, February and April, with a mean deficit of 113 cumecs (2.66bcm). The highest deficit, with a mean of 227 cumecs (1.8bcm) will occur during the period June-August inclusive. The balance will only be positive in January, March and May, with a mean surplus of 27.33 cumecs (0.22bcm).

In a dry year and taking 1960 as an example, the present and future water balances are completely negative for the whole year, with annual deficits of 143.42 cumecs (4.52bcm) and 224.67 (7.08bcm) respectively.

From this evaluation, the following points have been concluded:

1. The present deficit during a normal year, based on the average long term discharge, will be removed as there is enough annual water surplus, due to the regulating effect of the Hamrian reservoir, which

became operational in 1985. The deficit during the driest year will be slightly reduced, if the groundwater aquifers at the river's upper and middle sections are developed.

2. The river will be unable to meet its future monthly and annual irrigation water requirements during normal and driest years.

6.3.4 THE SHATT AL-ARAB IRRIGATION WATER BALANCE

As stated in Chapter 3, section 3.6.3, the Shatt Al-Arab water quality downstream of Maqil is unsuitable for irrigation and other uses, due to the effect of the salt water intrusion from the Arabian Gulf, as well as the highly saline drainage water from the existing irrigation projects of the Karun river. Therefore, future irrigation, industrial and municipal water requirements in the region of the Shatt Al-Arab, should be covered by the available fresh surface water resources from the water intake located in the upper reach of the river (upstream of the proposed Maqil barrage). Its function would be to separate the inland fresh water from the saline sea water intrusion, which is severely affecting the water quality in the lower section of the river. The irrigation water for the land downstream of that barrage should be conveyed along both sides of the river, through the system of main and secondary distributory canals, accompanied by a good drainage system. In this instance, the lower section of the river will serve for drainage purposes as it is considered unsuitable for irrigation or other purposes.

6.3.4.1 Alternative (A)

To evaluate the present and future water balances, the river's average water discharges at Maqil during a normal year (1978) and the driest year (1961) are adopted.

The river's total present and future irrigated lands are 9850ha and 70676ha respectively (Appendices 41 and 43). However, the irrigation water balance (Table 6.13) indicates that the river is highly capable of satisfying its present and future water demands, regarding the available normal discharge of 1978. Thus, the present and future annual water requirements form only 0.71% and 4.4% of the mean annual discharge which is 919 cumecs (29.0bcm). The monthly balances are positive, with a mean surplus of 912.5 and 879 cumecs respectively. The greatest water demand occurs in June and July, with a mean of 10.8 cumecs at present and 61.8 cumecs in the future.

Considering the lowest discharge, based on 1961 figures, the river is still able to meet its present and future water requirements. Therefore, the present and future annual demands represent 1.633% and 10.1% respectively of the mean annual discharge, which is 398 cumecs (12.55bcm). The present and future monthly balances are positive, with a mean surplus

Table 6.13 Present and Future Monthly and Annual Irrigation Water Balances of the Shatt Al-Arab (Alternative A), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Shatt Al-Arab normal dis.at Maqil(1978)(1)	330	317	495	797	916	1082	1191	1313	1506	1463	963	653	919	29.0
Present water requirement(2)	6.1	4.2	2.2	2.1	3.5	5.2	7.9	8.0	11.1	10.4	9.8	7.0	6.5	0.205
Present water balance	323.9	312.8	492.8	794.9	912.5	1076.8	1183.1	1305	1494.9	1452.6	953.2	646	912.5	28.795
Future water requirement(2)	37.4	30.2	18.0	16.4	24.7	34.7	54.0	45.0	63.0	60.6	56.5	38.0	40.0	1.26
Future water balance	292.6	286.8	477	780.6	891.3	1047.3	1137	1268	1443	1402.4	906.5	615	879	27.74
Driest year dis. at Maqil (1961)(1)	220	250	310	410	500	420	480	730	560	360	320	220	398	12.55
Present water balance	213.9	245.8	307.8	407.9	496.5	414.8	472.1	722	548.9	349.6	310.2	213	391.5	12.345
Future water balance	182.6	219.8	292	393.6	475.3	385.3	426	685	497	299.4	263.5	182	358	11.29

(1) Derived from Chapter 3 (Tables 3.9 and 3.10).

(2) Derived from Appendix 42 and 44.

of 391.5 and 358 cumecs respectively. The greatest present mean monthly surplus of 635.5 cumecs occurs during May-June, compared with 591 cumecs in future, while the lowest surplus occurs in October and September, with a mean of 213.5 cumecs at present and 182.3 cumecs in future.

6.3.4.2 Alternative (B)

The previous alternative (A), indicates that available river discharge during the normal and driest years are highly capable of satisfying the present and future irrigation water requirements. In this alternative (Table 6.14), the present and future expected irrigation water demands are changed only slightly and are still small compared with the available normal and driest year water discharges. Thus, the present annual water demand forms only 0.54% of the normal mean annual discharge of 1978 which is 919 cumecs (29.0bcm). This will rise to 4.5% in future. Both the present and future monthly balances are positive, with a mean surplus of 914.05 and 877.683 cumecs respectively. The highest monthly demand occurs in April and June-August inclusive, with a mean of 6.75 cumecs (0.071bcm) at present, which will increase to 56.08 cumecs (0.591bcm) in the future.

In the driest year (1961), the present and future annual water requirements represent only 1.244% and 10.4% of the mean annual water discharge, which is 398 cumecs (12.55bcm).

Table 6.14 Present and Future Monthly and Annual Irrigation Water Balances of the Shatt Al-Arab (Alternative B), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Shatt Al-Arab normal dis. at Maqil (1978)	330	317	495	797	916	1082	1191	1313	1506	1463	963	653	919	29.0
Present water requirement (1)	4.3	5	3.4	3	4	5.3	8.5	4.4	6.1	6.4	6	3	4.95	0.156
Present water balance	325.7	312	491.6	794	912	1076.7	1182.5	1308.6	1499.9	1456.6	957	650	914.05	28.844
Future water requirement (1)	37	43	30	26	33.2	45.4	73.3	35.5	50	53	48	21.4	41.317	1.301
Future water balance	293	274	465	771	882.8	1036.6	1117.7	1277.5	1456	1410	915	631.6	877.683	27.699
Driest year dis. at Maqil (1961)	220	250	310	410	500	420	480	730	560	360	320	220	398	12.55
Present water balance	215.7	245	306.6	407	496	414.7	471.5	725.6	553.9	353.6	314	217	393.05	12.394
Future water balance	183	207	280	384	466.8	374.6	406.7	694.5	510	307	272	198.6	356.683	11.249

(1) Derived from Appendix 46 and 48.

Furthermore, both the monthly balances are positive, with a mean surplus of 393.05 and 356.683 cumecs respectively. The greatest monthly surplus occurs in May and June, with a mean of 639.8 cumecs (3.372bcm) at present and 602.3 cumecs (3.174bcm) in future, while the lowest occurs in October and September, with a mean of 216.4 (1.14bcm) and 190.8 cumecs (1.01bcm) respectively.

The preceding water balance analysis of both alternatives indicates that the available river water is sufficient for satisfying its present and future irrigation water requirements. However, the large scale planned irrigation development upstream in Turkey, Syria and Iraq will severely affect the available water quantity and quality in the Shatt Al-Arab region.

6.4 THE OTHER WATER REQUIREMENTS AND LOSSES

This section evaluates the other present and future water requirements of the country, such as population, industry, fisheries and minimum acceptable flow. It also deals with water losses, which include evaporation and seepage from river channels and reservoirs. These are calculated according to the river basins and adopted in the river water balance (section 6.5). However, while these requirements and losses are small compared with the irrigation requirements, they are vitally important and their satisfaction has priority.

6.4.1 POPULATION WATER REQUIREMENTS

Table 6.15 summarizes the predicted present and future population of the country according to the river basins. This is calculated by using the final results of the 1965 and 1977 censuses on the average annual national growth rate for urban and rural areas, which yields the following formula(3):

$$Pt = Po\ (1 + r)^a$$

or

$$r = \left(\sqrt[a]{\frac{Pt}{Po}} - 1\right)$$

where:

Po = the population size according to the earlier census (1965)

Pt = the population size according to the later census (1977)

Table 6.15 Present and Future Predicted Population of Iraq and its Annual Water Requirements According to the River Basins

	1965 (1)		1977 (2)		1985		2000		Total Annual Water Demand (bcm)	
	Tot.Urban	Tot.Rural	Tot.Urban	Tot.Rural	Tot.Urban	Tot.Rural	Tot.Urban	Tot.Rural	1985	2000
(1) The Euphrates*	853138	1283974	1508915	1470284	2163737	1393062	4694941	1569924		
Annual Water Demand (bcm)					0.216	0.061	0.785	0.115	0.277	0.9
(2) The Tigris R**	2843405	2397419	5352326	2660346	8227267	3083673	17851766	3475172		
Annual Water Demand (bcm)					0.82	0.135	2.984	0.254	0.955	3.238
(3) The Shatt Al-Arab***	415748	253731	800453	208173	1190147	147651	2582416	166397		
Annual Water Demand (bcm)					0.119	0.0065	0.432	0.012	0.1255	0.444

Sources : (1) Ministry of Planning, Central Statistical Organization, Population Census of 1965, Baghdad, 1973, pp.3-28.

(2) Ministry of Planning, Central Statistical Organization, Annual Statistical Abstract, Baghdad, 1979, p.34.

Population of the Euphrates, Tigris and Shatt Al-Arab Rivers at the years of 1985 and 2000 are represented by the following Provinces:-

* Including Anbar, Kerbela, Babylon, Najaf, Qadisiya, Muthanna, Thi-Qar and Mudayna Nahia and excluding Rifa'i and Shatra Qadha.

** Including D'hok, Nineveh, Arbil, Sulaimaniya, Ta'meem, Salahddin, Baghdad, Diyala, Wasit, Maysan and (Qurna Qadha Center, Swaib Nahia, Rifa'i and Shatra Qadha)

*** Including Basrah and excluding Qurna Qadha Center, Swaib and Mudayna Nahia).

r = the average annual rate of growth .

a = the number of years between the two censuses.

As a result, the average annual national growth rates (r) for the urban and rural populations are 0.053 and 0.008 respectively.

After evaluating the average annual national growth rates, the future urban and rural populations of the country are estimated by applying the formula as follows:

$$Pt = Po\ (1 + r)^a$$

where:

Pt = population in 1985 or 2000

Po = population in the later census (1977)

r = the average annual national growth rate for the urban (0.053) and the rural (0.008)

a = the number of years between the basic year (1977) and the years at which the population are estimated ie. 1985 or 2000.

Thus, the total annual predicted present population water requirements from the Euphrates, Tigris and Shatt Al-Arab are 0.277bcm, 0.955bcm and 0.1255bcm respectively. These will increase in future to 0.9bcm, 3.238bcm and 0.444bcm respectively, as illustrated in Tables 6.15 and 6.16.

Table 6.16 Present and Future Mean Monthly and Annual Population Water Requirements from the Euphrates, Tigris and Shatt Al-Arab Rivers (cumecs)

River	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
(1) The Euphrates														
a. Present	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	0.277
b. Future	28.54	28.54	28.54	28.54	28.54	28.54	28.54	28.54	28.54	28.54	28.54	28.54	28.54	0.9
(2) The Tigris														
a. Present	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	0.955
b. Future	102.7	102.7	102.7	102.7	102.7	102.7	102.7	102.7	102.7	102.7	102.7	102.7	102.7	3.238
(3) The Shatt Al-Arab														
a. Present	4	4	4	4	4	4	4	4	4	4	4	4	4	0.1255
b. Future	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	0.444

The above annual requirements are based on average annual rates of 99.645m^3 per urban person* and 43.8m^3 per rural person at present. These will increase in the future to 167.17* and 73m^3 respectively[(4)].

6.4.2 INDUSTRIAL WATER REQUIREMENTS

The present mean annual industrial water demands from the Euphrates, Tigris and its tributaries and Shatt Al-Arab rivers are 0.37 cumecs (0.012bcm), 1.94 cumecs (0.061bcm) and 0.66 cumecs (0.021bcm) respectively. These are predicted to increase in the future to 0.74 cumecs (0.023bcm), 3.54 cumecs (0.112bcm) and 1.73 cumecs (0.054bcm)[(5)]. These values are distributed equally over the months of the year as demonstrated in Table 6.17.

6.4.3 FISHERIES WATER REQUIREMENTS

The present mean annual fisheries water demands from the Euphrates, Tigris and Shatt Al-Arab rivers are 6.532 cumecs (0.206bcm), 7.515 cumecs (0.237bcm) and 0.634 cumecs (0.02bcm) respectively. These will increase in the future to 24.797 cumecs (0.782bcm), 39.257 cumecs (1.238bcm) and 0.888 cumecs (0.028bcm) respectively[(6)]. These figures are distributed over the months of the year, according to the fisheries monthly water demand in percentage terms[(7)] (Tables 6.18 and 6.19).

* Urban water demand including: 1. domestic utility; 2. commercial use for stores, hotels etc; 3. public services ie. administrative buildings, schools, hospitals etc.; 4. light industries; and 5. water losses.

Table 6.17 Present and Future Mean Monthly and Annual Industrial Water Requirements from the Euphrates, Tigris and Shatt Al-Arab Rivers (cumecs)

River	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Cumecs	(bcm)
(1) The Euphrates														
a. Present	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.012
b. Future	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.023
(2) The Tigris														
a. Present	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	0.061
b. Future	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	0.112
(3) The Shatt Al-Arab														
a. Present	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.021
b. Future	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	0.054

Table 6.18 Monthly and Annual Fisheries Water Demands (%)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total annual
	7.7	3.85	3.85	3.85	3.85	3.85	15.4	15.4	11.54	11.54	11.54	7.7	100%

Table 6.19 Present and Future Mean Monthly and Annual Fisheries Water Demands from the Euphrates, Tigris and Shatt Al-Arab Rivers (cumecs)

River	MONTHS Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	(bcm)
(1) The Euphrates														
a. Present	6.04	3.02	3.02	3.02	3.02	3.02	12.07	12.07	9.05	9.05	9.05	6.04	6.532	0.206
b. Future	22.91	11.46	11.46	11.46	11.46	11.46	45.82	45.82	34.34	34.34	34.34	22.91	24.797	0.782
(2) The Tigris														
a. Present	6.94	3.47	3.47	3.47	3.47	3.47	13.89	13.89	10.41	10.41	10.41	6.94	7.515	0.237
b. Future	36.27	18.14	18.14	18.14	18.14	18.14	72.55	72.55	54.36	54.36	54.36	36.27	39.257	1.238
(3) The Shatt Al-Arab														
a. Present	0.586	0.293	0.293	0.293	0.293	0.293	1.172	1.172	0.88	0.88	0 .88	0.586	0.634	0.02
b. Future	0.821	0.41	0.41	0.41	0.41	0.41	1.64	1.64	1.23	1.23	1.23	0.821	0.888	0.028

6.4.4 MINIMUM ACCEPTABLE FLOW IN THE RIVER WATERCOURSES

This is generally considered as the discharge which must be maintained in the river watercourses to satisfy the quantitative and qualitative requirements, which, on the whole, cannot be measured, or are very difficult to assess. These requirements are as follows:

1. A satisfactory flow in the river bed to prevent the stagnation of water, formation of swampy zones and centres of infection which may be dangerous to public health.
2. To ensure sufficient dilution of dispersed pollutants due to disorganized discharges, riparian dwellings, or to the pollution of other media, like air and soil.
3. This will maintain the biological balance of the natural aquatic environment.
4. To ensure the necessary flows for uncontrolled water supplies, including the watering of livestock.
5. To prevent sedimentation and other flow phenomena, which could change the morphology of the watercourse bed.
6. To preserve natural beauty spots; waterfalls, tourist sites etc.

In this evaluation, the water balance is calculated on the assumption that the available water resources must previously be reduced by the volume of water required for public health and life, in other words, by the minimum acceptable flow which is measured by the following formula[8]:

$Qm = A\ Qd$

where:

Qm = minimum acceptable flow in cumecs

A = an empirical coefficient equal to 0.85

Qd = the minimum daily river discharge observed over a long period.

The Qd of the rivers in the period of 16 years are[9]:

1. The Euphrates at Hit (65 cumecs on 6th Sept. 1961).
2. The Tigris at Tusan (53 cumecs on 7th-30th Sept. 1971).
3. The Khabour and Zakho (8 cumecs on 7th Nov. 1958).
4. The Greater Zab at Eski Kelek (60 cumecs on 22nd Nov.-4th Dec. 1958).
5. The Lesser Zab at Goma Zerdala (6 cumecs on 14th May 1964).
6. The Diyala at Discharge Site (12 cumecs on 7th Sept. 1960).
7. The Shatt Al-Arab at Maqil (65 cumecs on 6th Oct. 1977).

According to the previous formula, the mean monthly minimum acceptable flows of the rivers (Table 6.20) are :

1. - The Euphrates at Hit 55.3 cumecs
2. - The Tigris main river at Tusan 45 cumecs (including the Khabour minimum acceptable flow).

Table 6.20 Mean Monthly And Annual Minimum Acceptable Flow for the Euphrates, Tigris, Tigris Tributaries and Shatt Al-Arab Rivers (cumecs)

River	MONTHS Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	(bcm)
1. The Euphrates R. at Hit	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	1.742
2. The Tigris main R. at Tusan*	45	45	45	45	45	45	45	45	45	45	45	45	45	1.42
2.1 The Khabour	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	0.214
2.2 The Greater Zab	51	51	51	51	51	51	51	51	51	51	51	51	51	1.61
2.3 The Lesser Zab	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	0.161
2.4 The Diyala	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	0.321
Total for the Tigris R. downstream of Baghdad**	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.3	3.51
3. The Shatt Al-Arab at Maqil	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	1.742

Minimum acceptable flow of the Adhaim River is zero as the minimum daily discharge zero

* Including the Khabour minimum acceptable flow

** Excluding the Khabour minimum acceptable flow

2.1- The Khabour at Zakho 6.8 cumecs.

2.2- The Greater Zab at Eski Kelek 51 cumecs.

2.3- The Lesser Zab at Goma Zerdala 5.1 cumecs.

2.4- The Diyala at Discharge Site 10.2 cumecs.

3. - The Shatt Al-Arab at Maqil 55.3 cumecs.

6.4.5 EVAPORATION WATER LOSSES FROM THE RIVER CHANNELS

The monthly evaporation water losses are calculated by applying the following formula:[(10)]

$$R = \frac{(t \times a) \times d}{S}$$

Where:

R = The monthly surface evaporation water losses from the river channel in cumecs.

t = The river length in (m)*

a = The average river width in (m)*

d = The climatic station monthly evaporation in (m) as shown in (Table 6.21 and Appendix 50)

S = The month in seconds

As a result, the mean annual evaporation water losses from the river channels are evaluated (Table 6.22) to be 46.716 cumecs

	*River	Length (km)	Average Width (m)
1.	The Euphrates	1200	170
2.	The Tigris	1358	160
	The Tigris Tributaries		
2.1	The Khabour	160	30
2.2	The Greater Zab	392	127
2.3	The Lesser Zab	400	163
2.4	The Adhaim	230	38
2.5	The Diyala	386	46
3.1	The Shatt Al-Arab upstream Maqil	69.3	200
3.2	The Shatt Al-Arab downstream Maqil	108	480

Derived from Chapter 3 (Tables 3.1, 3.4) and pp. 75 89, and 113.
The Tigris Tributaries' width are evaluated.

Table 6.21 Mean Monthly and Annual Values of Free-Water Surface Evaporation from the Euphrates and Tigris Climatic Stations (mm) and (m)*

River	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total annual
1. The Euphrates (mm)	184.9	102.8	60.3	55.9	80.9	142.6	188.5	282.8	344.7	404.3	379.5	284.5	2513.8
(m)	0.1849	0.1028	0.0603	0.0559	0.0809	0.1426	0.1885	0.2828	0.3447	0.4043	0.3795	0.2845	2.5138
2. The Tigris main R (mm)	183.6	106.5	60.3	59.7	77.5	134.8	178.6	276.9	362.1	414.1	376.9	289.3	2520
(m)	0.1836	0.1065	0.0603	0.0597	0.0775	0.1348	0.1786	0.2769	0.3621	0.4141	0.3769	0.2893	2.520

* Derived from Chapter 2 (Table 2.6) and Appendix 50.

1. The Euphrates River is represented by the average evaporation of the following stations: (Haditha, Habbaniya, Diwaniya, Nasiriya and Basrah)

2. The Tigris main River is represented by the average evaporation of the following stations: (Mosul, Baghdad, Hai, Amara and Basrah)

3. The Tigris Tributaries: (1) The Khabour and Greater Zab are represented by Salahddin Station (2) The Lesser Zab is represented by Sulaimaniya Station (3) The Adhaim is represented by Kirkuk Station (4) The Diyala is represented by Khanaqin Station.

4. The Shatt Al-Arab is represented by Basrah Station.

Table 6.22 Mean Monthly and Annual Surface Evaporation Water Losses from the Euphrates, Tigris, Tigris Tributaries and Shatt Al-Arab River Channels (cumecs)

River	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual Cumecs	Mean annual (bcm)
1. The Euphrates R	14.1	8.1	4.6	4.3	6.82	10.9	14.84	21.54	27.13	30.8	28.9	22.4	16.24	0.512
2. The Tigris Main R.	14.9	8.93	4.9	4.84	7.0	10.94	15.0	22.5	30.4	33.6	30.6	24.3	17.4	0.55
3. The Tigris Tributaries														
3.1 The Khabour	0.22	0.094	0.04	0.06	0.07	0.1	0.15	0.2	0.36	0.5	0.412	0.34	0.21	0.0066
3.2 The Greater Zab	2.23	0.98	0.41	0.595	0.72	1.02	1.52	2.05	3.75	4.94	4.28	3.5	2.174	0.068
3.3 The Lesser Zab	4.33	1.74	0.68	0.95	0.89	1.51	2.57	3.72	7.17	8.62	7.35	7.07	3.9	0.123
3.4 The Adhaim	0.654	0.235	0.15	0.156	0.23	0.36	0.5	0.914	0.96	1.46	1.33	1.034	0.668	0.021
3.5 The Diyala	1.54	0.75	0.292	0.38	0.543	0.822	1.16	1.88	2.21	3.0	2.63	2.213	1.455	0.046
Total for the Tigris and its tributaries	23.874	12.729	6.472	6.981	9.453	14.752	20.9	31.264	44.85	52.12	46.602	38.457	25.807	0.815
4. Shatt Al-Arab upstream Maqil	0.89	0.52	0.37	0.31	0.484	0.8	1.064	1.4	1.534	1.621	1.53	1.23	0.985	0.031
4.1 Shatt Al-Arab downstream Maqil	3.32	1.94	1.37	1.15	1.81	2.99	3.98	5.2	5.74	6.1	5.72	4.6	3.684	0.116
Total for the Shatt Al-Arab	4.21	2.46	1.74	1.46	2.294	3.79	5.044	6.6	7.274	7.721	7.25	5.83	4.669	0.147

(1.474bcm), out of which 16.24 cumecs (0.512bcm) from the Euphrates, 25.807 cumecs (0.815bcm) from the Tigris and its tributaries and 4.669 cumecs (0.147bcm) from the Shatt Al-Arab.

6.4.6 EVAPORATION WATER LOSSES FROM THE MAIN RESERVOIRS OF THE EUPHRATES, TIGRIS, AND ITS TRIBUTARIES

The annual water losses from the reservoirs are calculated according to the formula:

$$R = (d - a) \times S$$

where:

R = net annual evaporation water losses from the reservoir in cubic metres (cm)

d = the total annual evaporation from the climatic station in metres (m)

a = the total annual rainfall from the climatic station in metres (m)

S = the reservoir area in metres^2 (m^2).

The result (R) is distributed over the months according to the monthly evaporation percentage of the climatic station which represents the reservoir.

Thus, the mean annual evaporation water losses from all the main operational reservoirs is calculated to be 139.821 cumecs (4.405bcm), out of which 70.593 cumecs (2.224bcm) is from the Euphrates reservoirs and 69.228 cumecs (2.181bcm) is from the Tigris and its tributaries reservoirs as illustrated in Table 6.23.

Table 6.23 : Mean Monthly and Annual Surface Evaporation Water Losses from the Main Reservoirs of the Euphrates, Tigris and its Tributaries (cumecs)

Reservoir	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	Mean annual (bcm)
A. The Euphrates Reservoirs:														
(1) Qadisiya	31.9	16.5	7.82	8.16	14.53	20.39	31.87	46.43	64.65	72.47	67.33	49.47	36.08	1.137
(2) Habbaniya	24.544	17.22	7.15	7.924	13.81	23.0	28.18	43.11	58.58	71.93	67.5	49.76	34.513	1.087
Total Euphrates Reservoirs Evaporation	56.444	33.72	14.97	16.084	28.34	43.39	60.05	89.54	123.23	144.4	134.83	99.23	70.593	2.224
B. The Tigris and its Tributaries Reservoirs:														
(3) Saddam	16.89	10.28	5.55	5.37	8.0	11.31	17.26	25.92	39.23	49.88	45.56	31.33	22.237	0.7
(4) Dokhan	11.71	4.692	1.86	2.61	2.4	4.081	6.935	10.06	19.37	23.285	19.85	19.1	10.536	0.332
(5) Derbendi Khan	5.25	2.1	0.834	1.17	1.08	1.83	3.11	4.51	8.68	10.435	8.9	8.56	4.722	0.149
(6) Hamrian	33.63	16.29	6.35	8.26	12.0	17.93	25.25	40.91	48.26	65.39	57.24	48.26	31.733	1.0
(7) Tharthar	173.7	95.4	46.65	51.2	83.16	126.1	183.9	265.8	361.63	405.7	369.1	267.45	203.16	6.4
Total Tigris Reservoirs Evaporation Excluding Tharthar (unoperated)	67.48	33.362	14.594	17.41	23.48	35.151	52.555	81.4	115.54	148.99	131.55	107.25	69.228	2.181

The reservoirs above are represented by the following climatic stations:

(1) Haditha annual evaporation mince Ana annual rainfall in (m) (2.397 - 0.1216 = 2.2754 Net Evapor. Water losses)
(2) Habbaniya annual evaporation mince its annual rainfall in (m) (2.667-0.1121 = 2.5549)
(3) Mosul annual evaporation mince its annual rainfall in (m) (2.279-0.3888 = 1.8902)
(4-5) Sulaimaniya annual evaporation mince its annual rainfall in (m) (1.886-0.6554 = 1.2306)
(6) Khanaqin annual evaporation mince its annual rainfall in (m) (2.585-0.3106 = 2.2744)
(7) Average Baghdad and Haditha evaporation mince average annual rainfall of Baghdad and Ana in (m) (2.4975-0.1333 = 2.3642)

Chapter 2 (Tables 2.4, 2.6 and 2.7) and (Appendix 49 and 50)

The reservoir areas (km^2) are:
(1) 500 (2) 426 (3) 371 (4) 270 (5) 121 (6) 440 (7) 2710 Chapter 3 (Section 3.2.4 and 3.3.4)

6.4.7 DEAD STORAGE* WATER LOSSES FROM THE MAIN OPERATED RESERVOIRS OF THE EUPHRATES, TIGRIS AND ITS TRIBUTARIES

Table 6.24 illustrates that the mean annual dead storage water losses from the operated reservoirs of the Euphrates, Tigris and its tributaries are 40.6 cumecs (1.28bcm)** and 119.55 cumecs (3.77bcm)*** respectively.

6.4.8 SEEPAGE WATER LOSSES FROM THE RIVER CHANNELS

These losses are calculated by using the following empirical formula(11):

$$S = c\sqrt{Q}$$

where:

S = seepage in cumecs/km

Q = the river discharge in cumecs

c = an empirical coefficient equal to 0.01 in the case of medium and 0.015 in the case of maximum high flows.

As a result, the mean annual seepage water losses from the Euphrates and Tigris rivers**** are evaluated to be 153.85 cumecs (4.85bcm) and 221.2 cumecs (6.97bcm) respectively as shown in Tables 6.25 and 6.26.

* This term is defined in Chapter 3 p 87

** Including Qadisiya 0.7bcm and Habbaniya 0.58bcm

*** Including Saddam 1.07bcm, Dokhan 0.7bcm, Derbendi Khan 0.5bcm and Hamrian 1.5bcm (Chapter 3, section 3.2.4 and 3.3.4.)

**** Seepage water losses from the Shatt Al-Arab and the lower section of the Tigris river are not considered as a result of the tidal phenomena effect from the Arabian Gulf

Table 6.24 Mean Monthly and Annual Dead Storage Water Losses from the Main Operated Reservoirs of the Euphrates, Tigris and its Tributaries (cumecs)

Status	Months												Mean	Annual
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	cumecs	(bcm)
1. The Euphrates														
Reservoirs	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	1.28
2. The Tigris and its														
Tributaries Reservoirs	119.55	119.55	119.55	119.55	119.55	119.55	119.55	119.55	119.55	119.55	119.55	119.55	119.55	3.77

Table 6.25 Mean Monthly and Annual Seepage Water Losses From the Euphrates River Channel (cumecs)

	MONTH												Mean annual	
Status	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Euphrates mean water discharge at Hit (1956-80)*	399	494	632	728	770	1114	1919	2152	1236	527	341	325	886.42	27.95
Seepage water losses from Ramadi to Hindiya (207 km)			52.0	55.9	57.4	103.6	136.0	144.0	109.2	47.5				
Euphrates mean water dis.downstream Hindiya (1956-75)**	193	178	294	415	446	612	1086	1434	821	336	245	217	524	16.5
Seepage water losses from Hindiya to Shinafiya (158 km)			27.1	32.2	33.4	58.6	78.1	89.7	67.9	29.0				
Euphrates mean water discharge at Shinafiya (1954-71)**	158	164	263	443	461	606	877	1210	848	307	155	227	473	14.9
Seepage water losses from Shinafiya to Nasiriya (252 km)			40.9	53.0	54.1	93.0	111.9	131.5	110.1	44.2				
Euphrates water dis. at Nasiriya (1930-71)**	174	208	273	370	429	537	821	1178	1047	353	159	145	475	15.0
Seepage water losses from Nasiriya to Hamar (34 km)			5.6	6.5	7.0	11.8	14.6	17.5	16.5	6.4				
Total seepage water losses			125.6	147.6	151.9	267.0	340.6	382.7	303.7	127.1			153.85	4.85

* Derived from Table 6.2

** Derived from Chapter 3 (Table 3.2)

Distances (km) derived from: Sousa, A., op.cit., Part 1, pp.102-111.

Table 6.26 : Mean Monthly and Annual Seepage Water Losses from the Tigris River Channel (cumecs)

Status	MONTHS Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	(bcm)
Tigris mean water discharge downstream Samarra (including Adhaim) (1956-78)*	452	541	771	888	1181	1667	2108	2077	1346	733	526	443	1061	33.4
Seepage water losses from Balad to Baghdad (127 km)			35.3	37.8	65.5	77.8	87.5	86.8	69.9	34.4				
Tigris mean water discharge downstream Baghdad (1956-80)*	525	624	886	1027	1297	1922	2515	2377	1505	837	630	545	1224	38.6
Seepage water losses from Baghdad to Kut (308 km)			91.7	98.7	166.4	202.5	231.7	225.2	179.2	89.1				
Tigris mean water discharge downstream Kut (1956-78)*	284	261	376	525	840	1451	2022	2142	1144	447	301	250	837	26.4
Seepage water losses from Kut to Amara (236 km)			45.8	54.1	68.4	134.8	159.2	163.8	119.7	49.9				
Tigris mean water discharge at Amara (1950-78)*	53	49	62	85	114	161	205	211	146	72	50	46	105	3.31
Seepage water losses from Amara to Qulat Saleh (47 km)			3.7	4.3	7.5	8.9	10.1	10.2	8.5	4.0				
Tigris mean water discharge at Qulat Saleh (1950-78)*	16	15	18	22	27	36	45	47	35	20	15	14	26	0.82
Seepage water losses from Qulat Saleh to Kasara (38 km)			1.6	1.8	2.0	3.4	3.8	3.9	3.4	1.7				
Total seepage water losses			178.1	196.7	309.8	427.4	492.3	489.9	380.7	179.1			221.2	6.97

* Derived from Chapter 3 (Tables 3.5 and 3.6)

Distances (km) derived from : Al-Kholy, F.H., op.cit., Appendix No.2.

6.5 THE RIVERS WATER BALANCE IN RELATION TO THE WHOLE WATER REQUIREMENTS AND LOSSES

The present and future water balances of the Euphrates, Tigris and Shatt Al-Arab rivers are evaluated individually in relation to the irrigation water requirement, according to Alternatives (A) and (B), other water demands and water losses. These are as a total, compared with the available average long term and driest year rivers water discharges. The effect of the planned irrigation of the upstream states (Turkey, Syria and Iran) have been considered in the evaluation of future water balances.

6.5.1 THE EUPHRATES WATER BALANCE

6.5.1.1 Alternative (A)

According to this alternative (Table 6.27), the river is unable to satisfy its water requirements, neither at present, nor in the future. Therefore, the present annual balance regarding the available average long term water discharge, which is 824.83 cumecs (26.0bcm), is negative, with a mean deficit of 394.1 cumecs (12.4bcm). The monthly balance is negative for 11 months, May-March inclusive, with a mean deficit of 431.82 cumecs (12.5bcm). The period June-August exhibits the greatest deficit, with a mean of 805.33 cumecs (6.4bcm). Only April shows a positive balance, with a mean surplus of 21 cumecs (0.054bcm).

Table 6.27 Present and Future Monthly and Annual Water Balances of the Euphrates River Regarding the Whole Water Requirement and losses (Alternative A), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Euphrates average dis. at Hit (1956-80)	399	494	632	728	770	1114	1919	1163	1170	628	498	383	824.83	26.0
Present water requirement and losses(1)	971	949	793	750	919	1283	1898	1523	1761	1593	1358	829	1218.92	38.4
Present water balance	-572	-455	-161	-22	-149	-169	21	-360	-591	-965	-860	-446	-394.1	-12.4
Future water requirement and losses(1)	1072	1035	861	813	992	1371	2045	1664	1909	1731	1488	920	1325.1	41.74
Future water balance	-673	-541	-229	-85	-222	-257	-126	-501	-739	-1103	-990	-537	-500.27	-15.74
Driest year dis. at Hit (1961)	331	390	383	462	537	434	1300	635	407	247	171	125	449.7	14.2
Present water balance	-640	-559	-410	-288	-382	-849	-598	-888	-1354	-1346	-1187	-704	-769.22	-24.2
Future water balance	-741	-645	-478	-351	-455	-937	-745	-1029	-1502	-1484	-1317	-795	-875.4	-27.54

(1) Including (Irrigation alternative (A) + Population + Industry + Fisheries + Minimum acceptable flow + Evaporation losses from the river channel and reservoirs + Reservoirs dead storage + Seepage water losses from the river channel) Tables 6.3, 6.16, 6.17, 6.19, 6.20, 6.22, 6.23, 6.24 and 6.25.

In a dry year and taking 1961 as an example, the present balance is negative for the whole year, with an annual deficit of 769.22 cumecs (24.2bcm).

The future predicted balance, based on the available average long term discharge previously stated, will be negative for the whole year, with a mean annual deficit of 500.3 cumecs (15.74bcm). The most extreme monthly deficit will occur during the period June-August inclusive and in October, with a mean deficit of 876.3 cumecs (9.31bcm). The period of November-May inclusive and September shows the lowest deficit with a mean of 312.3 cumecs (6.53bcm).

However, the available normal discharge is expected to fall to 338.6 cumecs (10.7bcm) as a consequence of the upstream future irrigation development in Turkey and Syria, which will require a total annual of 784.4 cumecs (24.73bcm). In this instance, the future annual deficit in Iraq will rise to 986.4 cumecs (31.04bcm) (Table 6.28). This will be reduced to a certain extent due to the effect of part of Tharthar (total useful storage 37.0bcm) (Chapter 3, section 3.3.4).

Taking into consideration the available driest year water discharge, based on 1961 figures, the future balance will be negative for the whole year, with an annual deficit of 875.4 cumecs (27.54bcm). This deficit is expected to

Table 6.28 Future Water Balance of the Whole Euphrates Basin, Regarding the Average Long Term River Discharge

Status	Annual Water Volume cumecs	(bcm)
Potential River discharge(1)	+1123	+35.4
Future irrigation water requirements and evaporation losses in Turkey. (1)	- 552	-17.4
Outflow to Syria	+ 571	+18
Future irrigation water requirements and Tabqa evaporation losses in Syria (1)	- 232.4	- 7.33
Outflow from Syria to Iraq	+338.6	+10.7
Future water requirements(2) of Iraq:		
(Alternative A)	-1325	-41.74
(Alternative B)	-1444.8	-45.5
Future water deficit in Iraq		
(Alternative A)	-986.4	-31.04
(Alternative B)	-1106.2	-34.8

(1) Derived from Chapter 5 (Tables 5.4 and 5.14)

(2) Derived from Tables 6.27 and 6.30.

increase to 1325 cumecs (41.74bcm), as a result of the up-stream future irrigation water requirements in Turkey and Syria (Table 6.29).

This means that the only available water for Iraq during such a year is from the Tharthar reservoir as previously indicated.

6.5.1.2 Alternative (B)

This alternative (Table 6.30) indicates that the river contains insufficient water to satisfy its extremely high present and future water requirements. Therefore, the present balance regarding the available average long term water discharge previously mentioned is negative, with an annual deficit of 345.59 cumecs (10.9bcm). As in the previous alternative, the monthly balance is negative for 11 months, May-March inclusive, with a mean deficit of 380.2 cumecs (11.0bcm). The greatest deficits arise in July and August, with a mean of 768 cumecs (4.11bcm). Only April exhibits a positive balance, with a mean surplus of 35 cumecs (0.091bcm).

In the driest year (1961), the present balance is negative for the whole year, with annual deficit of 720.72 cumecs (22.7bcm).

The future predicted balance regarding the available average

Table 6.29 Future Water Balance of the Whole Euphrates Basin, Regarding the Driest Year Discharge*

Status	Annual Water Volume cumecs	(bcm)
Driest year discharge at Hit in Iraq (1961) (1)	+ 449.7	+14.2
Future irrigation water requirements and evaporation losses in Turkey (2)	- 552	-17.4
Future irrigation water requirements and Tabqa evaporation losses in Syria (excluding present) (2)	- 163.6	- 5.16
Annual water deficit outside Iraq	- 265.9	- 8.36
Future water deficit in Iraq:(1)		
(Alternative A)	-1325	-41.74
(Alternative B)	-1444.8	-45.5

(1) Derived from Tables 6.27 and 6.30.

(2) Derived from Chapter 5 (Tables 5.4 and 5.14).

* In the calculations for this table,it is assumed that the present water requirements in the upstream states have been satisfied.

Table 6.30 Present and Future Monthly and Annual Water Balances of the Euphrates River Regarding the Whole Water Requirement and Losses (Alternative B), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Euphrates av. dis. at Hit (1956-80)	399	494	632	728	770	1114	1919	1163	1170	628	498	383	824.83	26.0
Present water req. and losses (1)	954	971	821	770	929	1280	1884	1429	1611	1444	1218	734	1170.42	36.9
Present water balance	-555	-477	-189	- 42	-159	-166	35	-266	-441	-816	-720	-351	-345.59	-10.9
Future water req. and losses (1)	1234	1273	1043	966	1169	1582	2363	1686	1909	1738	1489	885	1444.77	45.51
Future water balance	-835	-779	-411	-238	-399	-468	-444	-523	-739	-1110	-991	-502	-619.94	-19.51
Driest year dis. at Hit (1961)	331	390	383	462	537	434	1300	635	407	247	171	125	449.7	14.2
Present water balance	-623	-581	-438	-308	-392	-846	-584	-794	-1204	-1197	-1047	-609	-720.72	-22.7
Future water balance	-903	-883	-660	-504	-632	-1148	-1063	-1051	-1502	-1491	-1318	-760	-995.1	- 31.31

(1) Including (Irrigation alternative (B) + Population + Industry + Fisheries + Minimum acceptable flow + Evaporation losses from the river channel and reservoirs + Reservoirs dead storage + seepage water losses from the river channel)
Tables 6.4, 6.16, 6.17, 6.19, 6.20, 6.22, 6.23, 6.24 and 6.25.

long term discharge, already stated, will be negative for the whole year, with annual deficit of 619.94 cumecs (19.51bcm). Regarding the planned development in Turkey and Syria, the available water discharge will decrease to 338.6 cumecs (10.7bcm). Consequently, the annual deficit in Iraq will rise to 1106.2 cumecs (34.8bcm) (Table 6.28). This will be reduced to a certain extent, due to the effect of part of Tharthar reservoir (total useful storage 37.0bcm).

Regarding the driest year available discharge, based on 1961 figures, the future balance is predicted to be negative for the whole year, with annual deficit of 995.1 cumecs (31.31bcm). This will increase to 1444.8 cumecs (45.5bcm), when the planned upstream development in Turkey and Syria is fully developed (Table 6.29). In this instance, the only available water for the Euphrates development in Iraq will be from the Tharthar reservoir.

6.5.2 THE TIGRIS WATER BALANCE

6.5.2.1 Alternative (A)

According to this alternative (Table 6.31) there is insufficient water in the river to meet its present and future water requirements. Thus, the present annual balance regarding the available average long term discharge which is 1263 cumecs (39.83bcm) is negative, with a deficit of 298.8 cumecs (9.4bcm). The monthly balance is negative for seven months, June-December inclusive, with a mean deficit of

Table 6.31 Present and Future Monthly and Annual Water Balances of the Tigris River Regarding the Whole Water requirement and Losses (Alternative A), in cumecs

Status	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	Mean annual (bcm)
Tigris average dis. downstream Samarra (1956-78)	585	686	921	1067	1369	1992	2522	2365	1500	877	677	593	1263	39.83
Present water requirement and losses(1)	1233	1263	1123	1060	1343	1748	2461	1848	2088	1943	1626	1005	1561.8	49.2
Present water balance	-648	-577	-202	7	26	244	61	517	-588	-1066	-949	-412	-298.8	- 9.4
Future water requirement and losses(1)	2170	2149	1734	1611	2063	2718	4005	3003	3582	3419	2994	1825	2606.1	82.1
Future water balance	-1585	-1463	-813	-544	-694	-726	-1483	-638	-2082	-2542	-2317	-1232	-1343.1	-42.3
Driest year dis. downstream Samarra (1961)	371	583	504	664	802	840	1705	1946	795	467	359	367	784	24.72
Present water balance	-862	-680	-619	-396	-541	-908	-756	98	-1293	-1476	-1267	-638	-777.8	-24.5
Future water balance	-1799	-1566	-1230	-947	-1261	-1878	-2300	-1057	-2787	-2952	-2635	-1458	-1822.1	-57.4

(1) Including (Irrigation alternative (A) + Population + Industry + Fisheries + Minimum acceptable flow + Evaporation losses from the river channel and operated reservoirs + Dead storage of operated reservoirs + Seepage losses from the river channel) Tables 6.5, 6.16, 6.17, 6.19, 6.20, 6.22, 6.23, 6.24 and 6.26.

634.6 cumecs (11.73bcm). The most serious deficits occur in July and August, with a mean of 1007.5 cumecs (5.4bcm). Only the period of five months, January-May inclusive, shows a positive balance, with a mean surplus of 171 cumecs (2.23bcm). The January balance is critical as its surplus is only 7 cumecs (0.02bcm).

With regard to the driest year available water discharge, which is 784 cumecs (24.72bcm), the present balance is negative, with annual deficit of 777.8 cumecs (24.5bcm). Only May shows a positive balance, with a mean surplus of 98 cumecs (0.26bcm).

The future predicted balance, based on the available average long term water discharge previously indicated, will be negative for the whole year, with an overall annual deficit of 1343.1 cumecs (42.3bcm). However, the planned upstream development in Turkey and Iran will reduce the available normal discharge to 1050.5 cumecs (33.13bcm) (Table 6.32). Consequently, the annual deficit in Iraq will increase to 1555.5 cumecs (49.0bcm). This will be reduced, due to the effect of the Bekme reservoir, which has a useful storage of 28.0bcm, part of the Tharthar total useful storage of 37.0bcm and potential groundwater if it is utilized.

Considering the driest year available water discharge, the future balance will be negative, with annual deficit of 1822.1 cumecs (57.4bcm). This is predicted to increase to

Table 6.32 Future Water Balance of the Whole Tigris Basin, Regarding the Average Long Term River Discharge*

Status	Annual Water cumecs	Volume (bcm)
The river average long term discharge in Iraq (1)	+1263	+39.83
Future irrigation water requirements and evaporation losses in Turkey(2)	- 203	- 6.4
Future irrigation warer requirements of Iran (excluding present)(2)	- 9.51	- 0.3
The remaining outflow to Iraq	+1050.5	+33.13
Future water requirements of Iraq:(1)		
(Alternative A)	-2606	-82.1
(Alternative B)	-2836	-89.3
Future water deficit in Iraq		
(Alternative A)	-1555.5	-49.0
(Alternative B)	-1785.5	-56.2

(1) Derived from Tables 6.31 and 6.34.

(2) Derived from Chapter 5 (Tables 5.8 and Section 5.8)

* In the calculations for this table, it is assumed that the present water requirements in the upstream states have been satisfied.

2034.5 cumecs (64.1bcm), due to the effect of the planned upstream development in Turkey and Iran, which will require a total annual amount of 212.5 cumecs (6.7bcm) (Table 6.33). However, the deficit could be slightly reduced, bearing in mind the previous considerations.

6.5.2.2 Alternative (B)

According to this alternative (Table 6.34). the river is unable to meet its present and future water requirements. Therefore, the present annual balance, based on the average long term discharge, is negative, with a mean deficit of 345.1 cumecs (10.9bcm). The monthly balance is negative for 10 months, June-February inclusive and April, with a mean deficit of 479.2 cumecs (12.55bcm). The greatest deficit occurs in June-August, October and November, with a mean of 803 cumecs (10.62bcm). Only the period of two months, March and May, exhibits a positive balance, with a mean surplus of 325 cumecs (1.74bcm).

The present balance regarding the available driest year discharge is negative, with an annual deficit of 824.1 cumecs (26.0bcm). May is the only month which exhibits a positive balance, with a mean surplus of 45 cumecs (0.12bcm).

Considering the available average long term river discharge, the future predicted balance will be negative for the whole

Table 6.33 Future Water Balance of the Whole Tigris Basin, Regarding the Driest Year Discharge*

Status	Annual Water Volume cumecs	(bcm)
Driest year discharge in Iraq(1)	+ 784	+24.72
Future irrigation water requirements and evaporation losses in Turkey(2)	- 203	- 6.4
Future irrigation water requirements of Iran (excluding present)(2)	- 9.51	- 0.3
The remaining outflow to Iraq	+ 571.5	+18.0
Future water requirements of Iraq:(1)		
(Alternative A)	-2606	-82.1
(Alternative B)	-2836	-89.3
Future water deficit in Iraq:		
(Alternative A)	-2034.5	-64.1
(Alternative B)	-2264.5	-71.3

(1) Derived from Tables 6.31 and 6.34.

(2) Derived from Chapter 5 (Table 5.8 and Section 5.8)

* In the calculations for this table, it is assumed that the present water requirements in the upstream states have been satisfied.

Table 6.34 Present and Future Monthly and Annual Water Balances of the Tigris River Regarding the Whole Water Requirement and Losses (Alternative B), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Tigris average dis. downstream Samarra (1956-78)	585	686	921	1067	1369	1992	2522	2365	1500	877	677	593	1263	39.83
Present water requirement and losses(1)	1324	1337	1174	1105	1401	1806	2528	1901	2117	1937	1625	1041	1608.1	50.7
Present water balance	-739	-651	-253	- 38	- 32	186	- 6	464	- 617	-1060	-948	-448	-345.1	-10.9
Future water requirement and losses(1)	2529	2627	2101	1921	2416	3119	4587	3088	3567	3366	2941	1771	2836.1	89.34
Future water balance	-1944	-1941	-1180	-854	-1047	-1127	-2065	-723	-2067	-2489	-2264	-1178	-1573.1	-49.5
Driest year dis.downstream Samarra (1961)	371	583	504	664	802	840	1705	1946	795	467	359	367	784	24.72
Present water balance	-953	-754	-670	-441	-599	-966	-823	45	-1322	-1470	-1266	-674	-824.1	-26.0
Future water balance	-2158	-2044	-1597	-1257	-1614	-2279	-2882	-1142	-2772	-2899	-2582	-1404	-2052.1	-64.62

(1) Including (Irrigation alternative (B) + Population + Industry + Fisheries + Minimum acceptable flow + Evaporation losses from the river channel and operated reservoirs + Dead storage of operated reservoirs + Seepage losses from the river channel) Tables 6.6, 6.16, 6.17, 6.19, 6.20, 6.22, 6.23, 6.24 and 6.26.

year, with an annual deficit of 1573.1 cumecs (49.5bcm). This will rise further to 1785.5 cumecs (56.2bcm), taking into account the future irrigation water demands of the upstream riparian states, Turkey and Iran, which will require a total annual volume of 212.5 cumecs (6.7bcm) (Table 6.32). The deficit will be reduced, bearing in mind the previous considerations.

The future water balance, based on the available driest year discharge previously noted, is predicted to be negative, with an annual deficit of 20521.1 cumecs (64.62bcm). This deficit will increase further to 2264.5 cumecs (71.3bcm), as a result of the future irrigation water demands of Turkey and Iran, which is evaluated to be 212.5 cumecs (6.7bcm) (Table 6.33). The deficit will be reduced by the effect of the Bekme and Tharthar reservoirs and the development of potential groundwater resources.

6.5.3 THE SHATT AL-ARAB WATER BALANCE

6.5.3.1 Alternative (A)

In accordance with this alternative (Table 6.35), the river is able to satisfy its present and future water demands, regarding the available normal and driest year water discharges. Thus, the present and future annual water demands range from only 7.41% to 12.3% of the mean annual normal discharge, based on 1978 figures, which is 919 cumecs (29bcm).

Table 6.35 Present and Future Monthly and Annual Water Balances of the Shatt Al-Arab Regarding the Whole Water Requirement and Losses (Alternative A), in cumecs

Status	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	Mean annual (bcm)
Shatt Al-Arab normal dis. at Maqil (1978)	330	317	495	797	916	1082	1191	1313	1506	1463	963	653	919	29
Present water requirement and losses(1)	68	65	63	63	64	66	70	71	74	73	72	69	68.1	2.145
Present water balance	262	252	432	734	852	1016	1121	1242	1432	1390	891	584	850.9	26.86
Future water requirement and losses(1)	110	102	90	88	97	107	128	119	137	135	130	111	113	3.56
Future water balance	220	215	405	709	819	975	1063	1194	1369	1328	833	542	806	25.44
Driest year dis. at Maqil (1961)	220	250	310	410	500	420	480	730	560	360	320	220	398	12.55
Present water balance	152	185	247	347	436	354	410	659	486	287	248	151	329.9	10.4
Future water balance	110	148	220	322	403	313	352	611	423	225	190	109	285	9.0

(1) Including (Irrigation alternative (A) + Population + Industry + Fisheries + Minimum acceptable flow + Evaporation losses from the river channel upstream Maqil) Tables 6.13, 6.16, 6.17, 6.19, 6.20 and 6.22.

The highest monthly requirement occurs during the period April to October inclusive, with a mean of 71 cumecs (1.31bcm) at present, which will increase to 124.3 cumecs (2.3bcm) in the future. The period, November-March inclusive, exhibits the lowest demand, with a mean of 64.2 cumecs (0.84bcm) at present, which will increase to 96.8 cumecs (1.3bcm) in the future.

In the driest year water discharge, based on 1961 figures, the present and future water requirements are completely satisfied. Thus, the present and future annual demands comprise only 17.11% and 28.4% of the mean annual available discharge, which is 398 cumecs (12.55bcm).

6.5.3.2 Alternative (B)

This alternative (Table 6.36) indicates a similar situation to that of the former, with a slight change. This means the river is able to fulfil its present and future water requirements. Hence, the present annual demand comprises only 7.24% of the annual available normal discharge previously stated. This is predicted to increase to 12.44% in the future. The highest monthly demand occurs between April-August inclusive, with a mean of 68.8 cumecs (0.91bcm) at present and will rise to 126 cumecs (1.67bcm) in the future. The lowest demand occurs during the period September-March inclusive, with a mean of 65.14 cumecs (1.2bcm) and 106.14 cumecs (1.94bcm) respectively.

Table 6.36 Present and Future Monthly and Annual Water Balances of the Shatt Al-Arab Regarding the Whole Water Requirement and Losses (Alternative B), in cumecs

Status	MONTHS												Mean annual	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	cumecs	(bcm)
Shatt Al-Arab normal dis. at Maqil (1978)	330	317	495	797	916	1082	1191	1313	1506	1463	963	653	919	29
Present water requirement and losses(1)	66	66	64	64	65	66	71	67	69	69	68	65	66.55	2.1
Present water balance	264	251	431	733	851	1016	1120	1246	1437	1394	895	588	852.45	26.9
Future water requirement and losses(1)	110	115	102	98	105	118	147	110	124	127	122	95	114.32	3.6
Future water balance	220	202	393	699	811	964	1044	1203	1382	1336	841	558	804.68	25.4
Driest year dis. at Maqil (1961)	220	250	310	410	500	420	480	730	560	360	320	220	398	12.55
Present water balance	154	184	246	346	435	354	409	663	491	291	252	155	331.45	10.45
Future water balance	110	135	208	312	395	302	333	620	436	233	198	125	283.68	8.95

(1) Including (Irrigation alternative (B) + Population + Industry + Fisheries + Minimum acceptable flow + Evaporation losses from the river channel upstream Maqil) Tables 6.14, 6.16, 6.17, 6.19, 6.20 and 6.22.

The present and future water requirements are fully met, regarding the available driest year discharge. Thus, the present and future annual demands form only 16.72% and 28.72% respectively of the annual discharge which is 398 cumecs (12.55bcm).

The preceding water balance evaluation indicates that the available river discharge, based on the normal and driest year figures, are sufficient to satisfy the present and future water requirements. However, the planned upstream irrigation development in Turkey, Syria, Iran and Iraq will seriously affect the available water quantity and quality of the Shatt Al-Arab region.

6.6 GENERAL WATER BALANCE OF IRAQ

In this section, the present and future water balances of the country are calculated from a comparison of the whole water requirements and losses from the Euphrates, Tigris and Shatt Al-Arab rivers, according to alternative (A) and (B), with the available average long term and driest years water discharges of the Euphrates and Tigris rivers. The effects of the planned irrigation developments in the up-stream riparian states (Turkey, Syria and Iran) have been considered.

6.6.1 ALTERNATIVE (A)

This alternative (Table 6.37) illustrates that there is insufficient water in the country to satisfy present and future water requirements. Thus, the present annual balance regarding the available average long term water discharge, which is 2088 cumecs (65.85bcm) is negative, with a deficit of 705.8 cumecs (22.2bcm). The monthly balance is negative for nine months, June-February inclusive, with a mean deficit of 971.8 cumecs (22.92bcm). Only a three month period, March-May inclusive, shows a positive balance with a mean surplus of 90.7 cumecs (0.72bcm).

Considering the available driest year discharge, which is 1234 cumecs (38.92bcm), the present balance is negative for

Table 6.37 Present and Future Monthly & Annual Water Balances of Iraq Regarding the Whole Water Requirement and Losses (Alternative A), in cumecs

Status	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	(bcm)
Total average long term river discharges(1)	984	1180	1553	1795	2139	3106	4441	3528	2670	1505	1175	976	2088	65.85
Present water requirement and losses (2)	2217	2222	1924	1818	2271	3042	4374	3387	3868	3554	3001	1848	2793.8	88.0
Present water balance	-1233	-1042	-371	- 23	-132	64	67	141	-1198	-2049	-1826	-872	-705.8	-22.2
Future water requirement and losses(2)	3297	3231	2630	2457	3097	4141	6123	4731	5573	5230	4557	2801	3989	125.7
Future water balance	-2313	-2051	-1077	-662	-958	-1035	-1682	-1203	-2903	-3725	-3382	-1825	-1901	-59.9
Total driest year river discharges(3)	702	973	887	1126	1339	1274	3005	2581	1202	714	530	492	1234	38.92
Present water balance	-1515	-1249	-1037	-692	-932	-1768	-1369	-806	-2666	-2840	-2471	-1356	-1559.8	-49.1
Future water balance	-2595	-2258	-1743	-1331	-1758	-2867	-3118	-2150	-4371	-4516	-4027	-2309	-2755	-86.8

(1) Including The Euphrates average discharge at Hit 1956-80 + Tigris average discharge downstream Samarra 1956-78 (Tables 6.27 and 6.31).
(2) Including full water requirement and losses of the Euphrates + Tigris + Shatt Al-Arab excluding its minimum acceptable flow (Tables 6.27, 6.31, 6.35 and 6.20.
(3) Including The Euphrates driest year discharge at Hit 1961 + Tigris driest year discharge downstream Samarra 1961 (Tables 6.27 and 6.31).

the whole year, with an annual deficit of 1559.8 cumecs (49.1bcm).

The future predicted balance, based on the available average long term water discharge previously indicated will be completely negative, with an annual deficit of 1901 cumecs (59.9bcm). However, the available water discharge will decrease to 1160 cumecs (36.6bcm), as a consequence of the planned upstream irrigation developments in Turkey, Syria and Iran, which will require a total annual volume of 928 cumecs (29.3bcm) (Table 6.38). In this instance, the annual deficit in Iraq will rise to 2829 cumecs (89.1bcm). This will be reduced by the effects of Bekme reservoir (total useful storage 28.0bcm), the Tharthar (total useful storage 37.0bcm) and the potential groundwater resources if they are fully developed.

Regarding the available driest year discharge, which is 1234 cumecs (38.92bcm), the future balance will be negative for the whole year, with an annual deficit of 2755 cumecs (86.8bcm). It should be noted that the available water discharge during such a year will also be reduced to 306 cumecs (9.7bcm), due to the future irrigation water demand in the upstream states previously mentioned. This will require a total annual of 928 cumecs (29.3bcm) (Table 6.39). As a result, the annual deficit in Iraq will rise to 3683 cumecs (116bcm). However, this could be slightly reduced owing to the considerations stated before.

Table 6.38 Future Water Balance of the Euphrates and Tigris River Basins, Regarding the Average Long Term Discharge*

Status	Annual Water cumecs	Volume (bcm)
Total average long term discharge of the Euphrates and Tigris in Iraq(1)	+2088	+65.85
Future irrigation water requirements and evaporation losses in Turkey (2)		
From the Euphrates River	- 552	-17.4
From the Tigris River	- 203	- 6.4
Future irrigation water requirements and Tabqa evaporation losses in Syria from the Euphrates (excluding present). (2)	-163.6	- 5.16
Future irrigation water requirements of Iran from Tigris (excluding present). (2)	- 9.51	- 0.3
The remaining outflow to Iraq	+1160	+36.6
Future water requirement of Iraq: (1)		
(Alternative A)	-3989	-125.7
(Alternative B)	-4340	-136.7
Future water deficit in Iraq:		
(Alternative A)	-2829	-89.1
(Alternative B)	-3180	-100.1

(1) Derived from Tables 6.37 and 6.40.

(2) Derived from Chapter 5 (Tables 5.4, 5.8, 5.14 and Section 5.8)

* In the calculations for this table, it is assumed that the present water requirements in the upstream states have been satisfied.

Table 6.39 Future Water Balance of the Euphrates and Tigris River Basins, Regarding the Driest Year Discharge*

Status	Annual Water Volume cumecs	(bcm)
Total driest year discharge of the Euphrates and Tigris in Iraq (1)	+1234	+38.92
Future irrigation water requirements and evaporation losses in Turkey (from the Euphrates and Tigris) (2)	- 755	-23.8
Future irrigation water requirements and Tabqa evaporation losses in Syria (excluding present)(2)	-163.6	- 5.16
Future irrigation water requirements of Iran from Tigris (excluding present)(2)	- 9.51	- 0.3
The remaining outflow to Iraq	+306	+ 9.7
Future water requirement of Iraq:(1)		
(Alternative A)	-3989	-125.7
(Alternative B)	-4340	-136.7
Future water deficit in Iraq:		
(Alternative A)	-3683	-116.0
(Alternative B)	-4034	-127.0

(1) Derived from Tables 6.37 and 6.40

(2) Derived from Chapter 5 (Tables 5.4, 5.8, 5.14 and Section 5.8).

* In the calculations for this table, it is assumed that the present water requirements in the upstream states have bee- satisfied.

6.6.2 ALTERNATIVE (B)

This alternative (Table 6.40) indicates that the available water resources are unable to meet the extremely high present and future water requirements. Thus, the present annual balance regarding the available average long term water discharge, which is 2088 cumecs (65.85bcm), is negative, with a deficit of 702 cumecs (22.2bcm). This is similar to the previous alternative, with a slight change in monthly balance. The monthly balance is negative for nine months, June-February inclusive, with a mean deficit of 959.7 cumecs (22.64bcm). Only a three month period, March-May inclusive, exhibits a positive balance, with a mean surplus of 69.33 cumecs (0.55bcm).

The present balance, based on the available driest year discharge stated before, is negative for the whole year, with an overall annual deficit of 1556 cumecs (49.1bcm).

The future predicted balance, regarding the available average long term discharge previously indicated, will be completely negative, with an annual deficit of 2252.2 cumecs (70.9bcm). This is 351.2 cumecs (11.0bcm) higher than that in the previous alternative. As previously indicated, the available water discharge will decrease to 1160 cumecs (36.6bcm), due to the effect of the planned irrigation development in the upstream states, which will require a total annual volume of 928 cumecs (29.3bcm).

Table 6.40 Present and Future Monthly and Annual Water Balances of Iraq Regarding the Whole Water Requirement and Losses (Alternative B), in cumecs

Status	MONTHS Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean annual cumecs	(bcm)
Total average long term river discharges	984	1180	1553	1795	2139	3106	4441	3528	2670	1505	1175	976	2088	65.85
Present water requirement and losses(1)	2289	2319	2004	1884	2340	3097	4428	3342	3742	3395	2856	1785	2790	88.0
Present water balance	-1305	-1139	-451	- 89	-201	9	13	186	-1072	-1890	-1681	-809	-702	-22.2
Future water requirement and losses(1)	3818	3960	3191	2930	3635	4764	7042	4829	5545	5176	4497	2696	4340.2	136.7
Future water balance	-2834	-2780	-1638	-1135	-1496	-1658	-2601	-1301	-2875	-3671	-3322	-1720	-2252.2	-70.9
Total driest year river discharges	702	973	887	1126	1339	1274	3005	2581	1202	714	530	492	1234	38.92
Present water balance	-1587	-1346	-1117	-758	-1001	-1823	-1423	-761	-2540	-2681	-2326	-1293	-1556	-49.1
Future water balance	-3116	-2987	-2304	-1804	-2296	-3490	-4037	-2248	-4343	-4462	-3967	-2204	-3106.2	-97.8

(1) Including full water requirement and losses of the Euphrates + Tigris + Shatt Al-Arab excluding its minimum acceptable flow (Tables 6.30, 6.34, 6.36 and 6.20).

Therefore, the deficit in Iraq will increase to 3180 cumecs (100bcm) (Table 6.38). This will be slightly reduced as a result of the effect of the Bekme-Tharthar reservoirs and the development of potential groundwater resources, stated earlier.

In accordance with the available driest year discharge, the future balance will be negative for the whole year, with an annual deficit of 3106.2 cumecs (97.8bcm). This is predicted to increase to 4034 cumecs (127bcm), considering water demand of the planned irrigation development in Turkey, Syria and Iran (Table 6.39). The deficit will be only slightly reduced regarding the previous considerations.

6.7 CONCLUSION

This water balance evaluation with respect to present and prospective long term developments indicates that it is impossible to satisfy water requirements if these developments come to fruition. The problem of water shortage will be more acute in future, as a result of the effects of the upstream large scale planned irrigation developments, particularly in Turkey and Syria. However, the present and future water shortage in Iraq must be seen in the context of the large scale irrigated land (3.721 million hectares) at present (and 5.536 million hectares in future). Thus, on the basis of the limited water resources, a priority should be established towards intensive farming with an average cropping intensity ranging from 130% to 150%. This will in turn lead to a reduction in the large scale irrigated land which will automatically result in a reduction of water loss from:

a) the farms;

b) the main and secondary canals; and

c) as a result of leaching water requirements.

The most important point which should be considered is negotiations with the co-riparian states of the Euphrates and Tigris basins to achieve an international agreement regarding water allocation (Chapter 7). This would secure the appropriate share for each country and in turn would provide a reliable basis for the planners to design the irrigation and drainage schemes more realistically.

It is also vital to make use of the most effective irrigation methods such as sprinkler, drip and furrow irrigation, which would reduce seepage loss from farms and therefore water requirements. In addition, land levelling practices and lining canals would also reduce water loss. Furthermore, these reductions would result in the control of soil salinisation.

Finally, extensive studies should be carried out to evaluate the potential groundwater resources, so that they could be developed in parallel with the surface water resources.

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CHAPTER 7

MANAGING A FINITE BUT RENEWABLE RESOURCE

7.1 INTRODUCTION

The Euphrates and Tigris are international rivers with renewable, but finite water resources, shared by four riparian states, Turkey, Syria, Iraq and Iran. Of these, only Iraq is a major water user at present. While the other riparian states, especially Turkey and Syria, are planning for large scale irrigation and hydroelectric power developments, Iran is only a minor riparian state as it holds a marginal position in the Tigris basin, with limited future irrigation development (Chapters 5 and 6).

However, water management problems in the basins have arisen in recent decades when the upstream states, Turkey and Syria have planned extensive developments. If these are completed within about three decades, Iraq will be vulnerable in terms of water quantity and quality. Syria will be the second most vulnerable state in terms of water quality. Thus, the riparian states should work together for an early solution to the problem, through a peaceful agreement to allocate the available water resources, in order to avoid the future catastrophe.

To examine the problems, this chapter, firstly, looks at international law and the legal principles involved; secondly, it examines the previous agreements among the riparian states; thirdly, it evaluates the conflict/ co-operation potential; and, fourthly, it focuses on the global co-operation experiences in international river basins.

7.2 THE LAW OF INTERNATIONAL RIVER BASINS

According to Utton (1973)(1) there are four major traditional alternative theories governing the rights and obligations of co-riparian nations in international river basins. These are as follows.

1. The Theory of Absolute Territorial Sovereignty.
2. The Theory of Absolute Territorial Integrity.
3. The Theory of Community, or The Drainage Basin Integrated Development.
4. The Theory of Limited Territorial Sovereignty, or Equitable Utilization.

1. The Theory of Absolute Territorial Sovereignty

This is the oldest theory in international law. It was originally defined in 1895 by Harmon, the US Attorney General, in connection with the dispute with Mexico over the utilization of the Rio Grande river. He stated that:

> .... the rules, principles, and precedents of international law impose no liability or obligation upon the United States.
> (quoted by Berber, 1959)

Fenwick (1948) indicated that:

> .... conscious of the possession of the traditional right of sovereignty, states in possession of the upper waters of a river have not recognised any general obligation to refrain from diverting its waters and thereby denying to the states in possession of the lower waters the benefits of its full flow. Such restrictions as have been recognised have been in every case the result of treaty stipulations.
> (quoted by Berber, 1959)(2)

Hence, this theory is completely in favour of the upper riparian state of the international river basin. In this instance, Turkey is the most advantaged riparian state in the Euphrates and Tigris basins as it holds the upper position, but its attitude towards the lower riparian states, Syria and Iraq, is positive and tends toward co-operation (section 7.5.2).

2. <u>The Theory of Absolute Territorial Integrity</u>

This theory is completely opposite to the first one and operates for the advantage of the lower riparian states, as explained by Berber (1959)(3):

> A state has the right to demand the continuation of the natural flow of waters coming from other countries, but may not for its part restrict the natural flow of waters flowing through its territory into other countries.

Oppenheim (1955) indicates that:

> .... it is a rule of international law that no state is allowed to alter the natural conditions of its own territory to the disadvantage of the natural conditions of the territory of a neighbouring state. For this reason, a state is not only forbidden to stop or divert the flow of a river which runs from its own to a neighbouring state, but likewise to make such use of the water of the river as either causes danger to the neighbouring state or prevents it from making proper use of the flow of the river on its part .... (quoted by Utton, 1973) (4)

Thus, this theory is in favour of Syria and Iraq as lower riparian states in the Euphrates and Tigris basins. As yet, neither of them advocates this theory, but it may be claimed, if Turkey, the upper riparian state, advocates the first theory.

3. The Theory of Community, or The Drainage Basin Integrated Development

This theory, adopted by the International Law Association (ILA) at its conferences in Dubrovnik (1956) and New York (1958), regarded it as an agreed principle of international law pertaining to the utilization of international river basins, as stated by the 1956 conference[5]:

> .... riparian states should join with each other to make full utilization of the waters of a river, both from the viewpoint of the river basin as an integrated whole, and from the viewpoint of the widest variety of uses of the water, so as to assure the greatest benefit to all.

Lemarquand (1976)[6], indicates that this theory is typically applicable to the developments of flood control and hydroelectric power production. However, this theory opposes the other two and is more equitable as it regards the right of all riparian nations of international river basins.

4. The Theory of Limited Territorial Sovereignty, or Equitable Utilization

This theory stresses that a state may make use of international river waters insofar as it does not interfere with their reasonable use by other riparian states. It is the most common and widely advocated by the international community, as evidenced by treaties, judicial decisions, the statements of individual scholars and private and international bodies[7]. For instance, the ILA, at its conferences of 1956 and 1958, adopted this theory and considered it as an agreed principle of international law, governing the use of international river basins[8]. Again, at its Helsinki conference (1966), the ILA developed this theory more broadly into the so-called 'Helsinki rules', which are considered the most definitive expression of the international law pertaining to the management of international river basins[9].

Besides these theories, there is an extensive study being carried out by the UN to formulate widely acceptable and applicable principles concerning the legal aspects of the use and management of international watercourses. This is being undertaken by the UN International Law Commission, in accordance with General Assembly resolution 2669 (XXV) of 8 December 1970, which recommended that the Commission should

> take up the study of the law of the non-navigational uses of international watercourses with a view to its progressive development and codification ....

The study is still in progress and can be considered as an important step forwards promoting peaceful co-operation between co-riparian states in the management of international river basins[10].

The preceding discussion illustrates the fact that international law has been developing in favour of the community and equitable utilization theories and can be regarded as a set of agreed principles of international law pertaining to the management of international river basins. As yet, none of the co-riparian states of the Euphrates and Tigris basins proclaims the first two theories and to examine their attitude towards adherence to the common international law, it is important next to look at the previous agreements between these co-riparian states of the basins.

7.3 EVALUATION OF THE PREVIOUS AGREEMENTS IN THE EUPHRATES AND TIGRIS BASINS

As yet, there are only a few agreements between the co-riparian states, dealing only marginally with water management of the Euphrates and Tigris rivers.

1. The Protocol of Constantinople (1913), between Turkey and Iran, provides for equal shares of the small frontier streams between Turkey (Iraq) and Iran. However, Iran is violating this accord in several cases such as the Al-Wand (Diyala Tributary), Ganguir and Gunjan Jim rivers, by taking the greater share and leaving the Iraqi side with shortages (in spite of repeated protests from Iraq). The dispute over the water of these streams continues at the present time.

2. The Franco-British Convention (1920), which dealt with water allocation between their respective mandates, Syria and Iraq, provided a commission to study any plan of irrigation in Syria which might diminish considerably the Euphrates and Tigris waters, at the point of entry into Iraq. This convention dealt only with the Euphrates river and it was unspecific about quantities of water.

3. The Treaty of Lausanne (1932) concluded that the Euphrates and Tigris are international rivers between Turkey, Syria and Iraq. Article 109 of this treaty indicated that:

> In default of any provisions to the contrary, when at the result of the fixing of a new frontier the hydraulic system (canalisation, irrigation, drainage, or similar matters) in a state is dependent on works executed within the territory of another state, or when usage is made on the territory of a state in virtue of pre-war usage, of water or hydraulic power, the source of which is on the territory of another state, an agreement shall be made between the states concerned, to safeguard the interests and rights acquired by each of them. Failing an agreement, the matter shall be regulated through arbitration. (11)

4. The Friendship Treaty (1946), between Turkey and Iraq, is the most important as compared with the previous agreements. The key part of it provides that:

> Turkey shall keep Iraq informed of her plans for the construction of conservation works on either of the two rivers or their tributaries, in order that these works may as far as possible be adapted, by common agreement, to the interests of both Iraq and Turkey.(12)

Thus, the previous agreements between the co-riparian states, regarding the water resources of the Euphrates and Tigris rivers are limited, mostly imprecise, vague and uncertain with regard to the future water allocation. Of these, only the agreement between Turkey and Iraq (1946) can be considered as an important step forward and this provides a basic background for further co-operative actions between the co-riparian states of the basins. To evaluate the situation within the basins, it is important to deal with the conflict-co-operation potential.

7.4 MODELLING OF WATER CONFLICT POTENTIAL IN INTERNATIONAL RIVER BASINS (NAFF AND MATSON)

Naff and Matson (1984)[13] in their study of the Euphrates, Orontes, Nile and Jordan rivers, indicate that the conflict potential among the co-riparian states can be shaped by three major factors:

1. interests and issues;
2. riparian position; and
3. external and internal power.

They state that the model is exploratory and requires further rectification. However, regarding the interests and issues factor, they indicate that:

> Felt interests and perceived issues define the motivations and cognitions of the participants, channelling them toward collision or co-operation. If interests are perceived as fostered or complemented by other actors, the pressure will be toward co-operation; if they are perceived as blocked by others, the drive will be toward conflict. If the blockage is seen as deliberate, avoidable, illegitimate, and occurs close to goal realization, the thrust toward conflict is increased.

However, interests as a conflict factor is adjusted by a third factor (power), as they stated:

> Blockage does not always lead to conflict. It is frequently constrained or suppressed by considerations of power. In the simplest cases, either the aroused actor does not see itself as possessing the power to reduce or eliminate the blockage, or, although it believes it possesses the power, it finds that the cost of exercising

> it exceeds the benefits anticipated from the elimination or reduction of blockage.

Riparian position is considered as a powerful factor in this model as follows:

> In general, upstream position confers power advantages. From this position one can usually take actions that can be contested or countered by a downstream opponent only with considerably increased difficulty or cost.

To show how the model works, the authors have aggregated a weighting for each conflict factor, ranging from one (weak) to five (strong) and applied each to each riparian state. From the totals, they reached the following conclusions:

> In general, conflict potential is high when there is relative equality in the overall rankings of the parties, relatively high interest by the parties, and no higher ranked actor with a strong interest.

In this instance, as shown in Table 7.1, Syria and Iraq are in high conflict potential over the Euphrates water. Turkey is the dominant among the riparians, but its lower degree of interest is an inhibiting factor.

It should be noted that this model is extremely negative as it looks only on conflict potential factors and completely neglects the effect of other factors such as that of the good relationship between Turkey and Iraq. This will tend to offset the effect of Turkish dominance of the basin on the one hand and will serve to offset the Iraqi-Syrian tension on the other. It is important next to consider the Nizim and Al-Himyari approach.

Table 7.1 Conflict Matrix for the Euphrates River Basin

Co-riparian States	Conflict factors: Interests and issues	Riparian position	External and internal power	Total
Turkey	3	5	5	13
Syria	4	3	3	10
Iraq	4	1	4	9

Source: Naff T. and Matson R.C. Middle East Water: The Potential for Conflict or Co-operation: In Water in the Middle East: Conflict or Co-operation, Westview Press, Boulder, Colorado, 1984 pp194

7.5 CONFLICT-CO-OPERATION POTENTIAL IN INTERNATIONAL RIVER BASINS (NIZIM-AL HIMYARI APPROACH)

This is a more comprehensive approach as it focuses on both negative and positive facets, of conflict/co-operation potential. The approach was designed by Nizim (1968) for a study of the Indus, Nile and Jordan as international drainage basins. It mainly concentrated on the negative side, or conflict potential (Table 7.2). In 1985(14), Al-Himyari adopted the approach and broadened it. In particular, he modified this approach to focus on the positive side or co-operation potential in the Euphrates and Tigris as international drainage basins. The factors are almost the same (Table 7.3). Mitchell (1988 forthcoming)(15) has applied the original Nizim approach to the Euphrates and Tigris basins (Table 7.4) and his analysis of the basin situation concentrates almost exclusively on the conflict potential. However, to explain the basins' development, this table is adapted here, with slight modifications of both conflict/co-operation potential.

7.5.1 CONFLICT POTENTIAL IN THE EUPHRATES AND TIGRIS BASINS

Table 7.4 shows that the conflict potential among the co-riparian states of the Euphrates and Tigris basins is almost solely based on physical and future water needs factors. These and other factors are discussed:

Table 7.2 Conflictual Factors In International Drainage Basins

Factors	Conflict Potential	
	Low	High
Location of Surface and Ground water		
Type of International River	Contiguous	Successive
No. of Riparian States	2	>2
Climatic and Water Use Conditions		
Climatic Type	Humid	Arid
Type of Water Use	Non Consumptive	Consumptive
Pollution	In Humid Regions	In Arid Regions
Surface Features		
Region Type	Mountain Barren	Arable
Physical Interdependance	High	Low
Population		
Density	Low	High
Diversity	Homogeneous	Heterogeneous
Level of Development	Low	High
Political Boundaries		
Terrain at Frontier	Mountain Desert	Fertile
Boundary Issues	Settled	Unsettled
International Conditions		
Riparian's Political Ideologies	Similar	Opposite
Riparian's Political Stability	Stable	Unstable
Legal and Admin. Structures for Water	Similar	Dissimilar
Perceptions of Future Water Needs	Small Increase	Large Increase
Foreign Relations		
Riparians Political Perceptions	Friendly	Unfriendly
Attitudes Towards International Law	Acceptable	Rejection
History of Relations with Co-Riparians	Amicable	Hostile
Riparians Membership of Alliances	Same Coalition	Different Coaltion

Source: Al-Himyari, A.H., Managing Water Resources in the Tigris and Euphrates Drainage Basins, Ph.D. North Texas State Univ., 1984, (Univ. Microfilms International, Ann Arbor, Michigan, 1985),p.212 based on Nizim, B.K., The Indus, Nile and Jordan : International Rivers and Factors in Conflict Potential, Ph.D (Unpublished), Univ. Indiana, 1968, p.24.

Table 7.3 Co-operation Potential In International Drainage Basins

Factors	Willingness to Cooperate Less	More
Physical Characteristics		
Type of River	Successive	Contiguous and Important to all
Navigation	Non Navigable	Navigable
Seasonal and Climatic Variation	Small	Great
Physical Definition of Political Borders	Badly Defined	Well Defined
Economic Factors		
Benefits from Water Resource Development Projects	Some Riparians Benefit	All Riparians Benefit
Trade and Technological Exchange	Small	Amount
Technical and Administrative Factors		
Riparian Perception of the Technical Aspects of Water Projects	Divergent	Similar
Availability of Hydrological and Technical data	Scarce	Abundant
Structure of Riparian Water Institutions and Water Use Codes	Different	Similar
Cultural Factors		
Riparians Cultural Heritage	Different	Common
Communications and Relations between Riparians	Limited Difficult	Extensive and freely carried on
Political Factors		
Relations Between Leaders	Unfriendly	Friendly
Riparians Political and Economic Ideologies	Divergent	Similar Non Competitive
Membership of Alliences	Different	Same
Riparians International Images	Little Concern	Great Concern
Riparians Stability	History of Instability	History of Stability
Support from Interest Groups	In Opposition or Weak Support	Strong Support

Source : Al-Himyari, A.H., Ibid, p.261.

Table 7.4 The Nizim Approach as Applied to the Euphrates and Tigris Basins

Factors	Conflict Potential Low	Medium	High
Surface and Ground Water			
Type of International Rivers			Successive (Shatt al Arab is contiguous but with high conflict potential)
Number of Riparian States			4
Climatic and Water Use Factors			
Climate			Semi Arid-Arid
Water Use			Consumptive
Pollution			Arid Region
Surface Features			
Region Type		Desert	Arable
Physical Interdependance			Low
Population			
Density	Varies Throughout Basins		
Diversity			Heterogeneous
Level of Development		Medium	
Political Boundaries			
Type of Land Crossed by Frontiers	Mountain Desert		
Boundary Issues	Settled Except for Iraq-Iran War zone		
International Conditions			
Riparian's Political Ideologies			Opposite
Riparian's Political Stability	Stable		
Riparian's Legal and Administrative Systems for Water	Similar		
Riparian's Perception of Water Need			Huge Increase
Foreign Relations			
Riparian's Political Perceptions	Varies from Pairs of States to pairs of States		
Riparian's History of Relations	Varies from Pairs of States to pairs of States		
Memberships of Alliances			Different Coalitions,but some Groups of States same

Source : Mitchell, J.K.M., The Future Impact of the Tigris and Euphrates Rivers on the Socio-Economic Development of South Eastern Turkey, PhD. (forthcoming) University of Durham, Department of Geography, 1988.

7.5.1.1 Location of Surface Water

The total annual water potential of the Euphrates and Tigris rivers is 84.4bcm. The most effective parts of the basins for water production are located in Turkey and Iraq, which contribute 66.8% and 22.5% respectively, of the total annual water potential. The other parts of the basins in Syria and Iran are less important from this point of view as they contribute 4.7% and 5.8% respectively, of the total annual water potential (Chapter 3, Table 3.1). However, Turkey is in the most advantageous position as an upstream state. Iran is also an upstream state, but with less importance as it holds a marginal position only on small streams of the Lesser Zab and Diyala (Tigris tributaries). Syria and Iraq are the most vulnerable as downstream riparian states, particularly in the case of the Euphrates river. Thus, conflict potential could arise from this point, when Turkey claims as much water as it needs, neglecting the right of the lower riparian states, Syria and Iraq. This situation does not yet prevail, as none of the riparian states advocates the theories of Absolute Territorial Sovereignty and Integrity. Furthermore, their attitude towards co-operation is positive (section 7.5.2).

7.5.1.2 Climate and Relief

The climatic condition of the basin is generally semi-arid to arid. Only a small area of the basin includes the mountains and part of the foothill regions is relatively humid. Here, dry farming cultivation is possible, especially in winter. Most of the land suitable for cultivation is confined to the arid lowland region (Mesopotamia and Jazira) which is mostly located in Iraq, extending into Syria and Turkey. Here, surface water is the main source for cultivation. This is especially the case in Iraq, in which most of its irrigated land in this region is beyond the 200mm isohyet, rendering dry farming impossible (Chapter 2).

Thus, the arid climate and vast available suitable land for cultivation, which almost all depends on irrigation, will increase the conflict potential among the co-riparian states about the limited available water resources of the Euphrates and Tigris rivers.

7.5.1.3 Population Characteristics

The Euphrates and Tigris basins are dominated by three main races: the Turkish, Arab, Persian and other minorities. The population is increasing rapidly. For instance, Turkey's population has grown from 27.7 million (1960) to 50.7 million (1985)[16], with an average annual increase of 2.44%. The total population of the Euphrates and Tigris river basins (1983) are 4.93 and 1.8 million respectively[17].

The Syrian population* has increased from 4.5 million (1960) to 10.6 million (1986)[18], with an average annual growth of 3.33%.

The whole Iraqi population is concentrated in the Euphrates and Tigris basins. It has grown from 8 million (1965) to 16.2 million (1985), with an average annual growth of 3.56% (Chapter 6, Table 6.1).

The population* of Iran has increased from 25.7 million (1966) to about 45 million (1986)(19), with an average annual growth of 2.82%.

Thus, populations are a potential conflict factor because, firstly, they are heterogeneous and, secondly, their rapid increase will lead to rapid irrigation and hydroelectric power developments in the basins to satisfy their demands.

7.5.1.4 Relations Among the Co-Riparian States

Relations among the four co-riparian states vary from one pair of states to another. For example, Turkish-Iraqi relations are historically friendly and stable. The countries have a friendship treaty (1946) and an economic link as Iraq exports part of its oil through Turkey, by a pipeline to the Mediterranean Sea. Also, Turkey has a stable relationship with Syria. Relations between Iraq and Iran are historically unstable. This is a result of territorial disputes. The relations between Iraq and Syria are unstable, due to ideological differences and the dispute over the Euphrates river. They have deteriorated in recent years as a result of the Syrian government's support to Iran in its war with Iraq.

* There are no available data for the populations of Syria and Iran in the Euphrates and Tigris basins.

Furthermore, the unfriendly relations between Iraq and Syria can be clearly demonstrated by the events surrounding the filling of the Syrian Tabqa reservoir. When the reservoir began to fill in 1974, the annual discharge of the Euphrates at Hit in Iraq was reduced to 286 cumecs and 299 cumecs in 1975 (compared with the average long term discharge at the same gauge which is 909 cumecs) (Chapter 3, Table 3.2). As a result, in mid 1974 Iraq requested that Syria should release an additional 200mcm of water from the reservoir. Syria complied and the problem was avoided. In 1975, tension increased again, but the conflict was circumvented when Syria agreed to release an additional amount of water from the reservoir[20]. This was a temporary problem in which only Syria and Iraq were involved. This type of problem is not yet over, since Turkey will become involved as a result of its reservoirs filling which will affect both Syria and Iraq.

7.5.1.5 <u>The Future Water Problems</u>

Future problems over water resources can be classified into two patterns. Firstly, the problem which will arise due to the filling of the Turkish reservoirs and secondly, the problem over water use, particularly for the planned irrigation developments of the co-riparian states.

The problem which will result from the reservoir filling programme is confined to the Euphrates river. The projects on the Tigris are too small to affect the river flow.

This time, the problem will arise in Turkey, the upstream state. The downstream reservoirs in Syria have already been filled. However, the total storage capacity of the Turkish Euphrates reservoirs is 94.6bcm (Chapter 5). Of the largest, only Keban, with a total storage capacity of 30.7bcm, has been filled. The filling of the remaining, especially the Karakaya and Ataturk reservoirs, with a total storage capacity of 9.58bcm and 48.5bcm respectively, will certainly affect the lower riparian states, Syria and Iraq, by diminishing the river flow. This is clearly demonstrated in Tables 7.5 and 7.6 in which are represented the scheduled filling events and the annual rate of filling as planned by the DSI (State Hydraulic Works).

According to Table 7.6, the filling years of the Karakaya reservoir, 1986 to 1988 will reduce the river mean annual discharge at the Turkish-Syrian border (which is 31.4bcm) by 9% each year. This will be followed by the most serious years of the Ataturk filling which will continue from 1989 to 1992. The first filling year, 1989, will diminish the river flow by 47%. The following three years will reduce the river flow by 40%. Thus, the filling period, 1989-92, will severely affect the downstream riparian states, unless the period of filling is extended.

Table 7.5* Probable Filling Scenario for the Turkish Euphrates Reservoirs

Dam	Fill Rate (years)	Water Requirement per year (mcm)	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01
Karakaya	3½	2737.0	----	----	----	--												
Hancagiz	3	14.8			----	----	----											
Ataturk	4	12125.0				----	----	----	----									
Birecik	3	164.6					----	----	----									
Karkamis	3	245.0					----	----	----									
Kayacik	3	17.3									----	----	----					
Goksu	3	205.0										----	----	----				
Kahta	3	629.0												----	----	----		
Mardin-Derik	3	226.6												----	----	----		
Surut	3	13.1												----	----	----		
Siverek-H'n	3	156.6														----	----	----
			86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01

Table 7.6* Annual Water Requirement for Filling of Turkish Euphrates Reservoirs 1986-2001

Year	Water Requirement (mcm)	Percentage Reduction in mean annual discharge
1986	2737.0	9
1987	2737.0	9
1988	2751.0	9
1989	14877.0	47
1990	12550.0	40
1991	12535.0	40
1992	12535.0	40
1993	-------	0
1994	17.0	0.05
1995	222.0	1
1996	222.0	1
1997	1074.0	3
1998	869.0	3
1999	1025.0	3
2000	157.0	0.5
2001	157.0	0.5

Source*: DSI Implementation Schedule, 1986 (unpublished)
Uskay S. et al GAP (DSI General Directorate), Ankara. 1980

Based in Mitchell J.K.M. The Future Impact of the Tigris and Euphrates Rivers on the Socio-Economic Development of South Eastern Turkey, PhD (Forthcoming), University of Durham, Dept. of Geography, 1988

The problem over water use for irrigation developments is the dominant problem between the co-riparian states of the Euphrates and Tigris basins, as explained in Chapters 5 and 6. The four riparian states have been planning for extensive irrigation developments. Turkey, Syria and Iraq have planned to irrigate 1446300ha, 640000ha and 1801524ha respectively in the Euphrates basin. While in the Tigris basin, Turkey, Iraq and Iran have planned to irrigate 558590ha, 3663810ha and 80000ha respectively. To these areas to be irrigated from the Euphrates and Tigris in Iraq should be added a further 70676ha to be irrigated from the Shatt Al-Arab. It is impossible to satisfy the water requirements of all these developments, given the available water resources of the rivers. The problem will have subsided after about three decades, when these developments are fully implemented as planned. Should the co-riparian states wait for that to happen, or should they make use of the available time to promote the existing co-operation actions in order to reach a mutual international agreement to allocate their potential water resources with a fair and optimum benefit to each state?

From what has been stated, it seems that the Euphrates river is potentially vulnerable, compared with the Tigris river, as it is shared by three riparian states, Turkey, Syria and Iraq. All have planned for extensive irrigation and hydro-electric power developments. In addition, Syria and Iraq are hostile. At the same time, both are vulnerable as a result of their downstream position.

The Tigris river is less vulnerable as it is shared by only two main riparian states, Turkey and Iraq and both are friendly. Also, Turkey is less dominant here with small planned irrigation developments. The third state, Iran, is only a minor riparian state with small planned future irrigation developments.

7.5.2 CO-OPERATION POTENTIAL IN THE EUPHRATES AND TIGRIS BASINS

The conflict potential among the co-riparian states of the basin is almost exclusively based on the physical variables. The other variables show a tendency toward higher co-operation potential (Table 7.4). Thus, co-operation among the co-riparian states of the Euphrates and Tigris basins is possible and there is already an existing background for this.

As yet, none of the co-riparian states embraces the common international law, which is in favour of equitable utilization. None advocates the theory of Absolute Territorial Sovereignty and Integrity. Furthermore, there is a tendency towards co-operation. For instance, the Turkish attitude towards the lower riparian states is positive as stated by Volkan Vural (1986)[(21)], the Deputy

Director General for Bilateral Economic Relations in the Turkish Foreign Ministry:

> As a result of our friendly relations with the neighbouring countries, we have taken measures to increase our co-operation and establish a pattern for peaceful collaboration regarding the management of their water resources. It is with this concern that in 1980, Turkey, Iraq and Syria established a Joint Technical Committee to exchange all available information on regional waters and determine the most rational and optimal methods for the better utilization of these resources. In this way, we regularly exchange data regarding the flow and the use of waters, as well as forecasts on snow and rain conditions in the basin.
>
> We feel that matters relating to the management of common waters can only be solved through the co-operation of the countries concerned. These matters should not be subject to political exploitation or interference from outside. The countries utilizing common waters must try to devise criteria which would allow for a fair and optimum utilization.

In addition, Turkey and Iraq already have a friendship treaty and their relations have been good. An example is shown by the involvement of the Turkish Enka Construction Company (on an equal share basis with a Yugoslavian company, Hidrogradnja) in construction of the Bekme dam, the second largest in Iraq (total storage capacity 33.0bcm). The contract is worth $1,600 million and was signed in September 1986 (Chapter 3). Another co-operative action between the two riparian states is that Iraq planned to supply Turkey with electric power of 570MW. According to the Iraqi authorities (November 1987), the first stage of this, with a total capacity of 70MW has been completed[22].

Thus, the establishment of the Joint Technical Committee in 1980 and the 1946 treaty are important steps forward which will encourage the co-riparian states to work for further co-operation. As Fox (1978) stated[23]:

> ....continuing communication and exchange of information at the technical as well as at the political level should be encouraged as a means of building mutual trust among co-riparian nations.

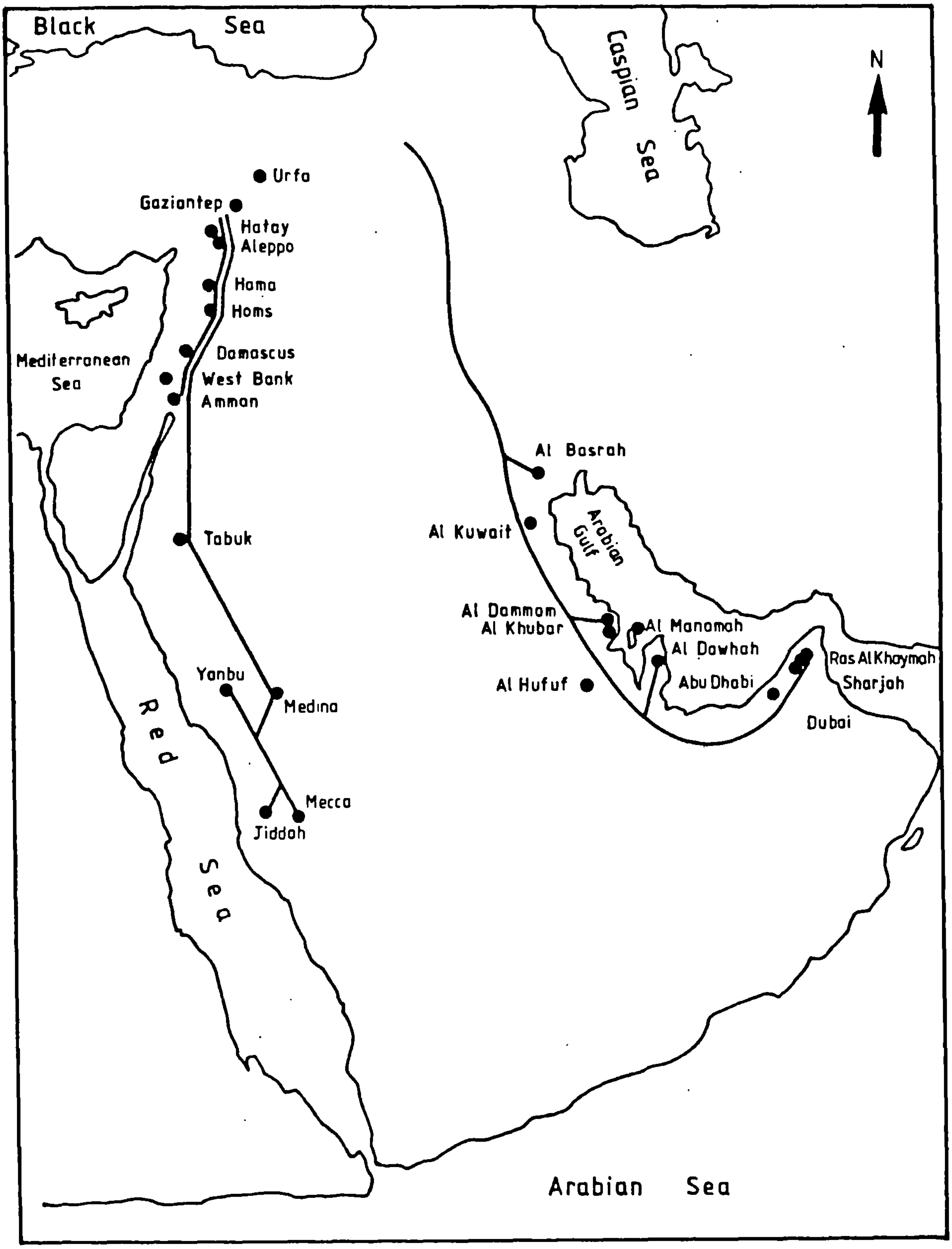
Also, the similar water administration systems of the co-riparian states regarding the hydrological, climatical data and water use, will make communications more effective and the assessment of the data easier in the evaluation of a framework for an international agreement between the co-riparians.

Another factor which will result in the co-riparian states, especially Turkey and Syria, taking further co-operative actions is the need for international investment for water developments (Chapter 5). Investment is difficult to obtain because the Euphrates and Tigris are international rivers and there are unresolved problems regarding water allocation between the states. For instance, the Turkish Euphrates project has been slowed as a result of the refusal of the World Bank and other agencies to make sufficient loans available in the absence of an international agreement with Syria and Iraq[24].

Furthermore, Turkey has potential surface water resources of 180bcm annually (Chapter 5). Thus, if Turkey is determined to maintain co-operation as it demonstrated, it is possible to transfer water from other river basins to the Euphrates and Tigris rivers to the benefit of the lower riparian states, Syria and Iraq. A recent plan (1987) by Turkey indicates that it proposes to supply water to other states outside the Euphrates and Tigris basins through two pipelines (Fig.7.1). The western pipeline will convey an annual amount of 1.3bcm from the Ceyhan and Seyhan rivers to Syria, Jordan and Saudi Arabia. Its cost has been estimated at $8500 million. The eastern one will transfer an annual amount of 0.91bcm from the Tigris to Iraq, Kuwait, Saudi Arabia, Bahrain, Qatar and the United Arab Emirates. Its cost has been evaluated at $11000 million[25]. However, to promote co-operation between the co-riparians of the Euphrates and Tigris basin, such a plan should be only for the benefit of the lower riparian states, Syria and Iraq and not for the benefit of non-riparian states. This is only a draft plan and is unlikely to come to fruition because the Gulf states prefer not to rely on outside water sources, for political reasons. It can also be regarded as a part of normal trade to obtain some of the investment required for the planned developments of the Euphrates and Tigris basins.

Another potentially co-operative factor is that the four riparian states of the basins have a similar faith based on

Fig. 7.1 : Turkish Water Supply Plan (1987)



Source : Government of Turkey, The Peace Pipeline, Water from Source to Consumer, Ankara, 1987, (Pamphlet).

the Islamic religion. Its basic tenets are in favour of equitable utilization as Mohammed indicated that free access to water is the right of the Muslim community[26]. This completely opposes the first two theories and provides a basis for mutual co-operation to the benefit of all the riparian states.

To mitigate the problems over the utilization of the surface water resources, the riparian states of the basins should give maximum attention to the developments of the available groundwater resources. These have received scant attention in the present and planned irrigation developments.

The most important riparian states, Turkey, Syria and Iraq have stable governments. This, together with the time available, should encourage these governments to negotiate and develop the existing co-operative actions. They should seek to achieve a peaceful agreement with a fair and optimum utilization to each state in order to avoid future conflict.

Use must be made of the United Nations (UN) and its various agencies. They can provide considerable technical help and assistance and guidance on the legal principles of international river basin water utilization. The UN can play an important role as a mediator to help the co-riparian states in the development of their legal frameworks for water, in order to achieve a mutual international agreement.

It is also vital to benefit from global co-operation experiences in international river basins. These can provide solutions to the management problems as some of these are applicable to the Euphrates and Tigris basins.

7.6 CO-OPERATIVE EXPERIENCES IN INTERNATIONAL RIVER BASINS: WAYS OF FOSTERING CO-OPERATIVE ACTIONS

Peaceful co-operation through an international agreement has been successfully achieved in many international river basins[27]. Of these, four examples have been chosen:

1. The USA and Mexico.
2. Egypt and Sudan.
3. The Soviet Union and Turkey.
4. Argentina and Uruguay.

7.6.1 THE USA AND MEXICO

The two riparian nations have been amicably co-operative regarding the utilization of the Rio Grande river, in spite of the differences in political-economic ideologies, culture, race and power. The first international treaty between them was signed in 1906. This was followed by the existing 1944 treaty, which allocates the average annual flow equally between the two riparians. The treaty has been operated by the International Boundary and Water Commission, which has the duty to apply the treaty, to carry out observation studies, to maintain measuring stations and to plan for flood control works and hydroelectric power plants with approval of the riparian governments and to settle all the disputes which may arise between the riparians[28].

7.6.2 EGYPT AND SUDAN

The Nile is an international river, shared by nine riparian states: Tanzania, Zaire, Uganda, Kenya, Ethiopia, Rwanda, Burundi, Sudan and Egypt. Of these, only Egypt and Sudan are major water users at present. The two riparian states have effectively co-operated to manage the river water resources. In 1929, the two riparian signed the first co-operative agreement. This was followed by the existing 1959 agreement; the most important provisions of which are:

1. The agreement firstly established the right of the two riparians to satisfy their need prior to the agreement. This was fixed at an annual share of 48bcm for Egypt and 4bcm for Sudan. It was also agreed that the Aswan Dam net storage which is 22bcm out of the total 32bcm, will be apportioned between the two states at 7.5bcm for Egypt and 14.5bcm for Sudan. Hence, the total water allocation, according to this agreement, is equal to 55.5bcm for Egypt and 18.5bcm for Sudan. In addition, the agreement indicated that any increase in the mean annual flow (84bcm at Aswan) should be shared equally between the two states.
2. The two riparian states agreed to establish a permanent Joint Technical Committee, comprising an equal number of representatives from each state.
3. Sudan agreed to carry out projects in the basin for the purpose of increasing the available river waters by controlling waste water in the marshes

and the river tributaries.

4. Regarding the future negotiations in matters concerning claims which may come from the other riparian states, the two major riparians agreed to adopt a unified view, based on the studies of the problem by the Technical Committee. If such claims arise from other riparian states such as Ethiopia, the two states, Egypt and Sudan, agreed that the amount of the claim should be deducted in equal shares from each of their shares(29).

7.6.3 THE SOVIET UNION AND TURKEY

A convention between the two countries regarding the use of frontier waters and a protocol concerning the Araxe river was signed in Kars, 8 January 1927 and both came into force on 26 June 1928. They provide that:

> Article 1: The two Contracting Parties shall have the use of one half of the water from the rivers, streams and springs which coincide with the frontier line between the Turkish Republic and the Union of Soviet Socialist Republics.

7.6.4 ARGENTINA AND URUGUAY

The 1946 agreement between the two states concerning the utilization of the Uruguay river provides that:

> Article 1: The High Contracting Parties declare that, for the purposes of this agreement, the waters of the Uruguay river shall be utilized jointly and shared equally.
>
> Article 2: The High Contracting Parties agree to appoint and maintain a Mixed Technical Commission

> composed of an equal number of delegates from each country which shall deal with all matters relating to the utilization, damming and diversion of the waters of the Uruguay river. (30)

It is hoped that the co-riparian states of the Euphrates and Tigris basins can learn and benefit from these and many other amicable co-operative experiences in international river basins, to promote the existing co-operative efforts, in order to achieve a mutual international agreement and avoid future conflict.

7.7 CONCLUSION

The preceding evaluation of the Euphrates and Tigris water management situation indicates that the conflict potential relates to the long term future and is only confined to the Euphrates basin. The river discharge is shared by Turkey, Syria and Iraq. Of these, Iraq is the major water user at present, while the other two states are planning for large scale future irrigation developments, which will take about three decades to be completed. These developments all together will certainly result in large scale water shortage and will stimulate conflict among the co-riparian states. However, there are hopes that the problem will be solved through a mutual international agreement. This is due to the stable relations between Turkey and Syria and good, friendly relations between Turkey and Iraq which will help to offset the tension between Iraq and Syria and will bring the latter to negotiation. In addition, Syria and Iraq are both vulnerable with regard to water supplies and they are Arabic states, so the problem between them can be solved through the Arab league. Also, the three co-riparian states have stable governments. This, together with the available time, will help them revise the future planning developments on a scale which will offer a fair and optimum benefit to each state. Furthermore, Turkey and Syria need international investment which is difficult to obtain without resolving the problems over water allocation between these states and Iraq.

The case of the Tigris basin is completely positive, with a tendency towards co-operation potential. Here, the river is shared by two main riparians, Turkey and Iraq. They have stable, friendly relations. Turkey is less dominant in this basin, with only small scale planned irrigation developments. The third riparian, Iran, is less important as it holds only a marginal position, with small developments. Thus, agreement between Turkey and Iraq can be achieved in the near future.

Finally, it is hoped that the co-riparian states could benefit from global co-operation experiences and take advantage of the available time to promote the existing co-operative effort, in order to achieve an early, peaceful solution to the problems, through a mutual international agreement, which will stimulate peace and settlement for the benefit of the whole community in the Euphrates and Tigris basins.

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CHAPTER 8

CONCLUSION

This study has evaluated and analyzed the Euphrates and Tigris basin as a crucial, integrated and shared resource. It has considered the impact of the physical characteristics of geology, topography, climate, soil and vegetation upon water resources and includes the evaluation of water quantity and quality of surface and groundwater resources, basin developments, water requirement and loss analyses, water balance calculations and water management, together with the associated problems, consequences and possible solutions.

The physical characteristics of the basin, both individual or as a complex, largely influence water quantity. For instance, geology (rocks and surficial material) affect the rate of surface runoff, the amount and rate of seepage water losses along the river channels and reservoirs and, as a result, the amount and rate of recharge to the groundwater. Surface runoff occurs in the highland areas due to the dominant impermeable outcrop rocks and high precipitation. It is limited or absent in other parts of the basin as a result of the highly permeable geological formations, low precipitation and high evaporation. The seepage losses from the river channels are assessed as 11.82bcm annually. The annual groundwater recharge from direct precipitation is evaluated as 17.7mcm per 100km^2 in the mountain region and in the foothill region ranges from 0.84mcm to 2.6mcm per

$100km^2$. It is considerably lower in the other parts despite the dominant permeable formations because of low precipitation and high evaporation.

Topographically, the Euphrates and Tigris basin is a broad syncline in shape, bordered by the mountain and foothill regions in the north and north-east and the desert plateau in the south-west. The lowland region (Mesopotamia and Jazira) occupies the central and southern part of the basin. Most of the present and planned irrigation developments are concentrated here. The mountain and foothill regions are the most important sources of water supply in the basin as a result of:

a) the high rate of precipitation ranging from 300 to more than 1000mm annually;

b) the low infiltration rate due to the impermeable outcropping rocks and steep land slopes; and

c) the low average annual temperature (17.2°C at Salahddin, 19.8°C at Mosul, 18.1°C at Urfa*, 13.6°C at Malatya*, 10.6°C at Erzincan* and 15.9°C at Siirt*).

The contribution of other parts of the basin to water supply is limited through low precipitation which ranges from 200 to 300mm, high evaporation and high infiltration rates. Therefore, irrigation developments, particularly in the lowland region, depend almost entirely on the water from the rivers.

* Derived from Prime Ministry State Institute of Statistics, Statistical Yearbook of Turkey 1985 p18

The climate of the basin is generally arid to semi-arid with an annual precipitation range of 200 to 300mm. A humid climate with an annual precipitation ranging from 300 to more than 1000mm prevails over a small portion of the basin in the mountain and foothill regions where the rivers have their sources. However, the dominant arid to semi-arid climate results in a vital need for the river waters for irrigation and other utilizations. It also results in a high application rate of irrigation water and high surface evaporation losses. In addition, climatic variations promote seasonal and annual variations in the river water discharges, affecting water demand.

The basin vegetation cover is generally of sparse steppe and desert types. The forest prevails only in the mountain region below the alpine, covering areas with an elevation of up to 800m. It mainly consists of oak trees and coarse shrubs. Lack of vegetation cover promotes serious soil erosion which in turn results in high river sedimentation, affecting channels, irrigation canals and reservoir capacities.

The total available surface water resource of the Euphrates and Tigris river basins is 2676.3 cumecs (84.4bcm). This is mostly supplied from the mountain and foothill regions in Turkey, Syria, Iraq and Iran with respective contributions to the annual total of 66.8%, 4.7%, 22.5% and 5.8%.

There are several problems affecting water quantity and quality and consequently water demand. The most significant of these is seasonal discharge variations. For example, the mean annual discharge of the Euphrates at Hit (Iraq) is 909 cumecs (28.6bcm), of which 87.4% flows during the flood period, December-July inclusive, and only 12.6% during the low water period, August-November inclusive. The mean annual discharge of the Tigris downstream of Baghdad is 1224 cumecs (38.6bcm), 84% and 16% respectively passing during the flood and low water periods. Moreover, there are also annual fluctuations. For instance, the Euphrates and Tigris discharges may increase to as much as 2003 cumecs (63.0bcm) and 2034 cumecs (64.0bcm) respectively during a wet year (eg. 1969), falling to 485 cumecs (15.3bcm) and 792 cumecs (25.0bcm) respectively in a dry year (eg. 1961). To combat the problem, several dams and reservoirs have been constructed, while others are under construction or are planned.

The present water quality analyses indicate that the water of the upper and middle sections of the Euphrates and Tigris is satisfactory for irrigation. The quality, however, becomes less suitable in the lower sections and in the Shatt Al-Arab. This is attributed to the influence of large scale upstream irrigation projects which return some of their very highly saline water to the rivers, the effect of very highly saline water outflow from the marshes and the highly saline groundwater discharge.

Groundwater evaluation shows that the most important potential aquifers are confined to the mountain and foot-hill regions and are mainly represented in the Pliocene and Pleistocene formations. The recharge, storage and safe yield of the aquifers are generally promising. The ground-water depth ranges from 5 to 50m and the quality is generally acceptable for irrigation. So far, groundwater development, compared with the surface water development, receives little attention.

Evaluation of the developments in the upstream riparian states illustrates that most of these are based on the long term future and cover 2004890ha in Turkey, 640000ha in Syria and 80000ha in Iran. If these developments are fully implemented within three decades as planned or take longer, as seems likely from the present progress and the associated problems, their annual water demands, together with the evaporation losses from the reservoirs, will be 784.4 cumecs (24.73bcm) from the Euphrates and 212.51 cumecs (6.7bcm) from the Tigris. Thus, the future water balance calculation with respect to these developments and that of Iraq (based on Alternative A and B) indicates a serious water shortage in Iraq, if all developments come to fruition. For example, the future annual water balance of the Euphrates during a normal year (based on the average long term discharge which is 1123 cumecs or 35.4bcm) will be in deficit by 1043 cumecs (32.82bcm) and 1163.4 cumecs (36.6bcm) respectively in

Alternative (A)* and (B)* (Table 6.28). Considering the dry year discharge based on the 1961 figure which is 449.7 cumecs (14.2bcm), the deficit will rise to 1381.5 cumecs (43.52bcm) in Alternative (A)* and 1502 cumecs (47.3 bcm) in Alternative (B)* (Table 6.29). The deficits will be reduced to a certain extent due to the effect of part of the Tharthar total useful storage which is 37.0bcm.

The future annual water balance of the Tigris during normal water discharge which is 1263 cumecs (39.83bcm), will be in deficit by 1612 cumecs (50.8 bcm) and 1842.7 cumecs (58.0bcm) according to Alternative (A)* and (B)* respectively (Table 6.32). The water shortage will be extremely high, increasing to 2091 cumecs (65.88bcm) and 2321.7 cumecs (73.1bcm) respectively in Alternative (A)* and (B)*, given the dry year (1961) discharge which is 784 cumecs (24.72bcm) (Table 6.33). The deficits will be reduced due to the effect of the Bekme reservoir which has a useful storage of 28.0bcm, part of the Tharthar total useful storage (37.0bcm) and if the potential groundwater is developed.

The future integrated water balance of the total Euphrates and Tigris river basins' water requirements, compared with the total average long term river discharge, which is 2088 cumecs (65.85bcm), assuming that all the development will be implemented, indicates that there is insufficient water to satisfy prospective water demand. Thus, the annual shortage

* Including 50% of the future Shatt Al-Arab water requirement which is:
Alternative (A) 113 cumecs (3.56bcm) Table 6.35; and
Alternative (B) 114.32 cumecs (3.6bcm) Table 6.36

in Iraq will be 2829 cumecs (89bcm) in Alternative (A), increasing to 3180 cumecs (100bcm) in Alternative (B), Table 6.38. The deficit will be reduced by the effect of the Bekme and Tharthar reservoirs' useful storage which is 28bcm and 37bcm respectively and also by potential groundwater resources if they are fully developed.

Considering the driest year available discharge, based on the 1961 figure which is 1234 cumecs (38.92bcm), the future annual deficit will be extremely high. It will be 3683 cumecs (116bcm) in Alternative (A) and will rise to 4034 cumecs (127bcm) in Alternative (B), Table 6.39. The actual deficit will be slightly reduced owing to the considerations discussed previously.

Thus, the key problem in the Euphrates and Tigris basins is a serious potential future water shortage. To avoid that and its consequences, it is vitally important for the riparian states to promote the existing co-operative effort which is represented by:

1) The establishment of the 1980 Joint Technical Committee between Turkey, Syria and Iraq.
2) The 1946 agreement between the important riparian states Turkey and Iraq.
3) The existing economic links.
4) The advantage of the available time and the stability of the riparian governments.

5) The international co-operative experiences available in international river basins.

These, together with improving relations, communications, exchanging of hydrological, meteorological, geological, topographical, soil and vegetation data, goodwill and trust will pave the way for an early peaceful solution to the problem, through a mutual international agreement to secure the appropriate share for each state, with respect to water quantity and quality. This in turn will provide a reliable basis for the planners and engineers to design the irrigation and drainage schemes more realistically.

Furthermore, to attain optimum utilization of the available water resources in the basin, the following are recommended:

1. As a result of limited available water resources the deployment of modern technology is essential. In particular, the following are needed:
   a) Intensive farming on the most productive land rather than extensive large scale development which has heavy water requirements and a heavy investment in marginal land reclamation.
   b) The application of the most effective irrigation methods such as sprinklers, drip irrigation and furrow irrigation. These, together with lining canals and land levelling would reduce water requirements, seepage losses from farms, main and secondary canals and in turn would control the soil salinity problem.

c) Farm management practices should be improved by means of intensive farmer education and supervision, particularly in (i) irrigation and drainage practices, (ii) machinery and fertilizer use and (iii) the control of diseases.

2. Controlling the river waste waters in the marshes through the irrigation canals.

3. The groundwater resources in the mountain and foothill regions should be quantitatively defined for such factors as quantity and quality. These are required long term basic hydrological, meteorological and hydrochemical data. Also an evaluation must be made of previous studies.

4. A continuous recording of hydrological, meteorological and hydrochemical data is vitally important to identify potential future changes and to enhance present knowledge.

5. Studies concerned with the evaluation of the Tharthar reservoir water quality, quantity, water diversion and water supply should be enlarged and a mixing with the Euphrates water should be undertaken to improve water quality before the river flow is reduced by the upstream planned storage and irrigation developments.

6. The proposed Fatha dam should be constructed in the foreseeable future as a major storage reservoir in order to increase the total effective storage to deal with future demands.

7. An evaluation of the Abu-Dibbis reservoir water quality, quantity, diversion and supply should be considered for future utilization.

8. A plan should be considered regarding the development of artificial sources such as desalination of drainage water and sewage treatment.

9. On water conservation the following measures are recommended:
   a) Monitoring of water quality should be continued and intensified, particularly that near the frontiers to identify precisely the natural conditions of the river water quality before the implementation of the large scale upstream irrigation developments in Turkey and Syria. Furthermore, in future Iraq should request the upstream states, particularly Turkey, to carry out quality observation on the head waters of the Euphrates at Keban and near the frontier with Syria at Karakaya and on the Tigris at Diyar Bakir. These, together with the monitoring at the frontiers will identify the individual future influence of the upstream developments in Turkey and Syria.

b) The drainage network to the Arabian Gulf via the Shatt Al-Basrah should be completed avoiding the rivers and marshes.

c) Sewage water should be treated by installing treatment facilities throughout the country. This in turn will maintain water quality and provide an additional source for future utilization.

d) The highly saline outflow from the marshes to the rivers should be controlled.

e) Public understanding should be reinforced on the importance of water and water conservation through the available media.

10. Finally, highly skilled and well trained staff in different fields of land and water resources are required to deal with these problems, continuous assessment of the country's available surface and groundwater resources, water quality, land and water requirements and the economic feasibility of the development as they are changing in time and with changing technology.

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APPENDIX 1 : Present Irrigated Land, its Cropping Intensity and Patterns in the Euphrates Basin (Alternative A)*

Total irrigated land : 1650869 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	63.1[2]	1041698
Summer crops	19.951[2]	329365
Rice	4.049	66850[3]
Orchards (perennial)	11.706	193243[1]
Alfalfa (perennial)	3.0 [4]	49526
Total irrigated in winter	77.806	1284467
Total irrigated in summer	38.706	638984
Total	116.512	1923451

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2. Ministry of Irrigation, G.E.S.D., Proposals on the agricultural development in Iraq up to the year 2000, Baghdad, 1979, pp.4-5.
3. Selkhozpromexport Co., op.cit., Vol.1, Book2, Table IV, 2.3-3.
4. Kettaneh, M.S., et al., op.cit., pp.65-67.

* This term is defined in pages 280-281.

APPENDIX 2 : Present Monthly Irrigation Water Requirement of the Euphrates River (Alternative A), in cumecs

Crop type	Monthly irrigation needs*											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	574	718.8	510.43	440.64	552.1	649	930.24					
Summer crops						96.83	274.03	497.7	691.7	751.61	675.2	260.2
Rice	49.9							172.7	160.84	112.04	107.5	96.6
Orchards (perennial)	127.54	59.91	21.26	24	56.04	85.22	127.54	193.24	270.54	243.9	231.9	183.6
Alfalfa (perennial)	37.3	20.45	8.47	9.01	15.35	22.8	32.7	48.14	70.33	69.83	65.4	55.47
Total	788.74	799.16	540.16	473.65	623.49	853.85	1364.51	911.78	1193.41	1177.38	1080.00	595.87

* These values are derived from the relationship between the irrigated area of a crop and the rate of irrigation for that crop (Table 6.1).

APPENDIX 3 : Future Irrigated Land, its Cropping Intensity and Patterns in the Euphrates Basin (Alternative A)

Total irrigated land : 1801524 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	62.0 [2]	1116945
Summer crops	19.37[2]	348955
Rice	4.635	83500[3]
Orchards (perennial)	11.273	203093[1]
Alfalfa (perennial)	3.0 [4]	54046
Total irrigated in winter	76.273	1374084
Total irrigated in summer	38.278	689594
Total	114.551	2063678

Sources:

1. Higher Agricultural Council, Study No. 3-1, op.cit., pp.37-65. Ministry of Irrigation : In Kienitz, G., op.cit., pp.55-61.

2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.

3. Selkhozpromexport Co., op. cit., Vol.1, Book 3, pp.27-28.

4. Kettaneh, M.S., et al., op. cit., pp.59-61.

APPENDIX 4 : Future Monthly Irrigation Water Requirement of the Euphrates River (Alternative A), in cumecs.

Crop Type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	615.44	770.7	547.3	472.5	592	695.9	997.43					
Summer crops						102.6	290.33	527.3	732.81	796.32	715.36	275.7
Rice	62.3							215.7	200.9	139.95	134.3	120.7
Orchards (perennial)	134.04	63	22.34	25.2	58.9	89.6	134.04	203.1	284.33	256.3	243.71	192.94
Alfalfa (perennial)	40.7	22.32	9.24	9.84	16.8	24.9	35.7	52.53	76.75	76.2	71.34	60.53
Total	852.48	856.02	578.88	507.54	667.7	913	1457.5	998.63	1294.79	1268.77	1164.71	649.87

APPENDIX 5 : Present Irrigated Land, its Cropping Intensity and Patterns in the Euphrates Basin (Alternative B)*

Total irrigated land : 1650869 (ha.)**

Type of crops	Cropping intensity (1) (% of the total land)	Annual irrigated land (ha.)
Winter crops	68	1122591
Summer crops	19	313665
Rice	5	82544
Orchards (perennial)	5	82544
Alfalfa (perennial)	3	49526
Total irrigated in winter	76	1254661
Total irrigated in summer	32	528279
Total	108	1782940

Source:

1. Kettaneh, M.S., et al., op.cit., pp.51-67.

* This term is defined in pages 280-281.

** Derived from Appendix 1.

APPENDIX 6 : Present Monthly Irrigation Water Requirement of the Euphrates River (Alternative B), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	618.55	774.6	550.1	474.9	595	699.4	1002.5					
Summer crops						92.22	261	473.95	658.7	715.8	643.01	247.8
Rice	61.6							213.21	198.6	138.34	132.73	119.3
Orchards (perennial)	54.5	25.6	9.08	10.24	23.94	36.4	54.5	82.54	115.6	104.2	99.05	78.42
Alfalfa (perennial)	37.3	20.45	8.47	9.01	15.35	22.8	32.7	48.14	70.33	69.83	65.4	55.47
Total	771.95	820.65	567.65	494.15	634.29	850.82	1350.7	817.84	1043.23	1028.17	940.19	500.99

APPENDIX 7 : Future Irrigated Land, its Cropping Intensity and Patterns in the Euphrates Basin (Alternative B)

Total irrigated land : 1801524 (ha.)*

Type of crops	Cropping intensity(1) (% of the total land)	Annual irrigated land (ha.)
Winter crops	84	1513280
Summer crops	22	396335
Rice	6	108091
Orchards (perennial)	5	90076
Alfalfa (perennial)	3	54046
Total irrigated in winter	92	1657402
Total irrigated in summer	36	648548
Total	128	2305950

Source :

1. Kettaneh, M.S., et al., op.cit., pp.51-61.

* Derived from Appendix 3.

APPENDIX 8 : Future Monthly Irrigation Water Requirement of the Euphrates River (Alternative B), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	833.82	1044.2	741.51	640.12	802.04	942.8	1351.4					
Summer crops						116.52	329.8	598.9	832.3	904.44	812.5	313.1
Rice	80.64							279.2	260.1	181.2	173.81	156.2
Orchards (perennial)	59.45	27.92	9.91	11.17	26.12	39.72	59.45	90.1	126.11	113.7	108.1	85.6
Alfalfa (perennial)	40.7	22.32	9.24	9.84	16.8	24.9	35.7	52.53	76.75	76.2	71.34	60.53
Total	1014.61	1094.44	760.66	661.13	844.96	1123.94	1776.35	1020.73	1295.26	1275.54	1165.75	615.43

APPENDIX 9 : Present Irrigated Land, its Cropping Intensity and Patterns in the Tigris Basin (Alternative A)

Total irrigated land : 2059965 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	63.1[2]	1299838
Summer crops	20.8[2]	428473
Rice	3.205	66021[3]
Orchards (perennial)	4.376	90148[1]
Alfalfa (perennial)	3.0[4]	61799
Total irrigated in winter	70.476	1451785
Total irrigated in summer	31.381	646441
Total	101.857	2098226

Sources :

1. Higher Agricultural Council, op.cit., Study No.3-1, pp. 162-165, 172-173, 184-190, 235-253, 207-210, 270-306, 314-355, 197-200, 218-221, 363-388, 396-399, 404-423.
   Higher Agricultural Council, The Large and Medium Irrigation Projects in Iraq, Study No. 3-5, Baghdad, 1977, pp.251-260, 489-491, 512-517.
   Ministry of Irrigation : In Kienitz, G. op.cit., pp.55-61.
   Higher Agricultural Council, The Large, Medium and Small Dams, Studies No.1-2, 1-3 and 1-4, Baghdad, 1978, pp.33.
   University of Basrah, Scientific and Economic Study of the State Farm in the Swaib, Basrah, 1979, pp.51-63.
   Selkhozpromexport Co., op.cit., Vol.1, Book 2, Table IV 2.3-3.
2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.
3. Selkhozpromexport Co., op.cit., Vol.1, Book 2, Table IV 2.3-3.
   University of Basrah, op.cit., pp.51-63.
   Higher Agricultural Council, op.cit., Study No.3-1, pp.396-399, 415-423.
   Kettaneh, M.S. et al., op.cit., pp.65-67.
4. Kettaneh, M.S., et al., ibid, pp.65-67.

APPENDIX 10 : Present Monthly Irrigation Water Requirement of the Tigris River (Alternative A) in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	716.21	896.9	636.92	549.83	688.91	809.8	1160.8					
Summer crops						126	356.5	647.42	899.8	977.8	878.4	338.5
Rice	49.25							170.53	158.85	110.7	106.16	95.4
Orchards (perennial)	59.5	27.95	9.92	11.2	26.14	39.8	59.5	90.15	126.21	113.8	108.2	85.64
Alfalfa (perennial)	46.53	25.52	10.6	11.25	19.16	28.43	40.8	60.07	87.8	87.14	81.6	69.21
Total	871.49	950.37	657.44	572.28	734.21	1004.03	1617.6	968.17	1272.66	1289.44	1174.36	588.75

APPENDIX 11 : Future Irrigated Land, its Cropping Intensity and Patterns in the Tigris Basin (Alternative A)

Total irrigated land : 3663810 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	62.0[2]	2271562
Summer crops	21.0[2]	769400
Rice	3.003	110013[3]
Orchards (perennial)	11.942	437528[1]
Alfalfa (perennial)	3.0[4]	109914
Total irrigated in winter	76.942	2819004
Total irrigated in summer	38.945	1426855
Total	115.887	4245859

Sources:

1. Ministry of Irrigation : In Kienitz, G., op.cit., pp.55-61.
   Higher Agricultural Council, op.cit., Study No.3-1, pp.172-173.
   Higher Agricultural Council, op.cit., Studies No.1-2, 1-3 and 1-4, pp.33.
2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.
3. Selkhozpromexport Co., op.cit., Vol.1, Book 3, pp.25-28.
   Kettaneh, M.S., op.cit., pp.59-61.
4. Kettaneh, M.S., et al., ibid., pp.59-61.

APPENDIX 12 : Future Monthly Irrigation Water Requirement of the Tigris River (Alternative A), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	1251.63	1567.4	1113.07	960.9	1203.93	1415.2	2028.5					
Summer crops						226.2	640.14	1162.6	1615.74	1755.8	1577.3	607.83
Rice	82.07							284.2	264.7	184.4	176.9	159
Orchards (perennial)	288.8	135.63	48.13	54.25	126.9	192.95	288.8	437.53	612.54	552.16	525.03	415.7
Alfalfa (perennial)	82.8	45.4	18.8	20	34.07	50.6	72.54	106.84	156.1	155	145.1	123.1
Total	1705.3	1748.43	1180	1035.15	1364.9	1884.95	3029.98	1991.17	2649.08	2647.36	2424.33	1305.63

APPENDIX 13 : Present Irrigated Land, its Cropping Intensity and Patterns in the Tigris Basin (Alternative B)

Total irrigated land : 2059965 (ha.)*

Type of crops	Cropping intensity[1] (% of the total land)	Annual irrigated land (ha.)
Winter crops	68	1400776
Summer crops	19	391393
Rice	5	102998
Orchards (perennial)	5	102998
Alfalfa (perennial)	3	61799
Total irrigated in winter	76	1565573
Total irrigated in summer	32	659188
Total	108	2224761

Source:

1. Kettaneh, M.S., et al., op cit., pp.51-67.

* Derived from Appendix 9.

APPENDIX 14 : Present Monthly Irrigation Water Requirement of the Tigris River (Alternative B), in cumecs

	Monthly irrigation needs											
Crop type	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	771.83	966.54	686.4	592.53	742.41	872.7	1250.9					
Summer crops						115.07	325.64	591.4	821.93	893.16	802.36	309.2
Rice	76.84							266.04	247.81	172.62	165.62	148.83
Orchards (perennial)	68	31.93	11.33	12.8	29.9	45.42	68	103	144.2	130	123.6	97.85
Alfalfa (perennial)	46.53	25.52	10.6	11.25	19.16	28.43	40.8	60.07	87.8	87.14	81.6	69.21
Total	963.2	1023.99	708.33	616.58	791.47	1061.62	1685.34	1020.51	1301.74	1282.92	1173.18	625.09

APPENDIX 15 : Future Irrigated Land, its Cropping Intensity and Patterns in the Tigris Basin (Alternative B)

Total irrigated land : 3663810 (ha.)*

Type of crops	Cropping intensity[1] (% of the total land)	Annual irrigated land (ha.)
Winter crops	84	3077600
Summer crops	22	806038
Rice	6	219829
Orchards (perennial)	5	183191
Alfalfa (perennial)	3	109914
Total irrigated in winter	92	3370705
Total irrigated in summer	36	1318972
Total	128	4689677

Source:

1. Kettaneh, M.S., et al., op. cit., pp.51-61.

* Derived from Appendix 11.

APPENDIX 16 : Future Monthly Irrigation Water Requirement of the Tigris River (Alternative B), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	1695.8	2123.54	1508.02	1301.82	1631.13	1917.34	2748.3					
Summer crops						237	670.62	1217.92	1692.7	1839.4	1652.4	636.8
Rice	164							567.82	528.91	368.43	353.5	317.7
Orchards (perennial)	120.91	56.8	20.15	22.72	53.13	80.8	120.91	183.2	256.47	231.2	219.83	174.03
Alfalfa (perennial)	82.8	45.4	18.8	20	34.07	50.6	72.54	106.84	156.1	155	145.1	123.1
Total	2063.51	2225.74	1546.97	1344.54	1718.33	2285.74	3612.37	2075.78	2634.18	2594.03	2370.83	1251.63

APPENDIX 17 : Present Irrigated Land, its Cropping Intensity and Patterns in the Khabour Basin (Alternative A)

Total irrigated land : 3000 (ha.)[(1)]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	63.1[(2)]	1893
Summer crops	19.0[(2)]	570
Rice	5.0[(3)]	150
Orchards (perennial)	5.0[(3)]	150
Alfalfa (perennial)	3.0[(3)]	90
Total irrigated in winter	71.1	2133
Total irrigated in summer	32.0	960
Total	103.1	3093

Sources:

1. Higher Agricultural Council, op. cit., Study No.3-1, pp.172-173.

2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.

3. Kettaneh, M.S., et al., op.cit., pp. 65-67.

APPENDIX 18 : Present Monthly Irrigation Water Requirement of the Khabour River (Alternative A), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	1.04	1.31	0.93	0.8	1	1.18	1.69					
Summer crops						0.17	0.48	0.86	1.2	1.3	1.17	0.45
Rice	0.11							0.39	0.36	0.25	0.24	0.22
Orchards (perennial)	0.1	0.05	0.02	0.02	0.04	0.07	0.1	0.15	0.21	0.19	0.18	0.14
Alfalfa (perennial)	0.07	0.04	0.02	0.02	0.03	0.04	0.06	0.09	0.13	0.13	0.12	0.1
Total	1.32	1.4	0.97	0.84	1.07	1.46	2.33	1.49	1.9	1.87	1.71	0.91

APPENDIX 19 : Future Irrigated Land, its Cropping Intensity and Patterns in the Khabour Basin (Alternative A)

Total irrigated land : 3000 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	62[2]	1860
Summer crops	18[2]	540
Rice	6[3]	180
Orchards (perennial)	5[3]	150
Alfalfa (perennial)	3[3]	90
Total irrigated in winter	70	2100
Total irrigated in summer	32	960
Total	102	3060

Sources:

1. Higher Agricultural Council, op.cit., Study No.3-1, pp.172-173.

2. Ministry of Irrigation, G.E.S.D., opcit., pp.4-5.

3. Kettaneh, M.S., et al., op.cit., pp.59-61.

APPENDIX 20 : Future Monthly Irrigation Water Requirements of the Khabour River (Alternative A), in cumecs

Crop type	Monthly irrigarion nwwsa											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	1.03	1.28	0.91	0.79	0.99	1.16	1.66					
Summer crops						0.16	0.45	0.82	1.13	1.23	1.1	0.43
Rice	0.13							0.47	0.43	0.3	0.29	0.26
Orchards (perennial)	0.1	0.05	0.02	0.02	0.04	0.07	0.1	0.15	0.21	0.19	0.18	0.14
Alfalfa (perennial)	0.07	0.04	0.02	0.02	0.03	0.04	0.06	0.09	0.13	0.13	0.12	0.1
Total	1.33	1.37	0.95	0.83	1.06	1.43	2.27	1.53	1.9	1.85	1.69	0.93

APPENDIX 21 : Present Irrigated Land, its Cropping Intensity and Patterns in the Greater Zab Basin Excluding the Khazir (Alternative A)

Total irrigated land : 93715 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	63.1 [2]	59134
Summer crops	21.66[2]	20299
Rice	2.341	2194[3]
Orchards (perennial)	5.76	5397[1]
Alfalfa (perennial)	3.0 [4]	2812
Total irrigated in winter	71.86	67343
Total irrigated in summer	32.761	30702
Total	104.621	98045

Sources:

1. Higher Agricultural Council, op.cit., Study No.3-1, pp. 184-190, 207-210, 235-253.

   Higher Agricultural Council, op.cit., Study No.3-5, pp.512-517.

   Ministry of Irrigation : In Kienitz, G., op.cit., pp.55-61.

2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.
3. Selkhozpromexport Co. op.cit., Vol.1, Book 2, Table IV 2.3-3.
4. Kettaneh, M.S., et al., op cit., pp.65-67.

APPENDIX 22 : Present Monthly Irrigation Water Requirement of the Greater Zab River (Alternative A), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	32.6	40.8	29	25	31.34	36.84	52.81					
Summer crops						6	17	30.7	42.63	46.32	41.61	16.04
Rice	1.64							5.67	5.28	3.68	3.53	3.17
Orchards (perennial)	3.6	1.7	0.6	0.7	1.6	2.4	3.6	5.4	7.6	6.81	6.5	5.13
Alfalfa (perennial)	2.12	1.2	0.48	0.51	0.9	1.3	1.9	2.73	4	4	3.71	3.15
Total	39.96	43.7	30.08	26.21	33.84	46.54	75.31	44.5	59.51	60.81	55.35	27.49

APPENDIX 23 : Future Irrigated Land, its Cropping Intensity and Patterns in the Greater Zab Basin Excluding the Khazir (Alternative A)

Total irrigated land : 133000 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	62 [2]	82460
Summer crops	23.25[2]	30923
Rice	0.752	1000[3]
Orchards (perennial)	20.226	26900[1]
Alfalfa (perennial)	3.0 [4]	3990
Total irrigated in winter	85.226	113350
Total irrigated in summer	47.228	62813
Total	132.454	176163

Sources:

1. Ministry of Irrigation : In Kienitz, G. op.cit., pp.55-61.

2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.

3. Selkhozpromexport Co., op.cit., Vol.1, Book 3, pp.27-28.

4. Kettaneh, M.S., et al., op.cit., pp.59-61.

APPENDIX 24 : Future Monthly Irrigation Water Requirement of the Greater Zab River (Alternative A), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	45.44	56.9	40.41	34.9	43.7	51.4	73.64					
Summer crops						9.1	25.73	46.73	64.94	70.57	63.4	24.43
Rice	0.75							2.58	2.41	1.68	1.61	1.45
Orchards (perennial)	17.8	8.34	3	3.34	7.8	11.9	17.8	26.9	37.7	33.95	32.28	25.56
Alfalfa (perennial)	3	1.65	0.68	0.73	1.24	1.84	2.63	3.9	5.67	5.63	5.27	4.47
Total	66.99	66.89	44.09	38.97	52.74	74.24	119.8	80.11	110.72	111.83	102.56	55.91

APPENDIX 25 : Present Irrigated Land, its Cropping Intensity and Patterns in the Khazir Basin (Alternative A)

Total irrigated land : 26950 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated irrigated land (ha.)
Winter crops	63.1[2]	17006
Summer crops	19.0[2]	5121
Rice	5.0[3]	1348
Orchards (perennial)	5.0[3]	1348
Alfalfa (perennial)	3.0[3]	809
Total irrigated in winter	71.1	19163
Total irrigated in summer	32.0	8626
Total	103.1	27789

Sources:

1. Higher Agricultural Council, op.cit., Studies No.1-2, 1-3, and 1-4, pp.33.

2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.

3. Kettaneh, M.S., et al., op.cit., pp.65-67.

APPENDIX 26 : Present Monthly Irrigation Water Requirement of the Khazir River (Alternative A), in cumecs

	Monthly irrigation needs											
Crop type	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	9.37	11.73	8.33	7.19	9.0	10.6	15.19					
Summer crops						1.51	4.26	7.74	10.75	11.69	10.5	4.05
Rice	1.0							3.48	3.24	2.26	2.17	1.95
Orchards (perennial)	0.89	0.42	0.15	0.17	0.39	0.59	0.89	1.35	1.89	1.7	1.62	1.28
Alfalfa (perennial)	0.61	0.33	0.14	0.15	0.25	0.37	0.53	0.79	1.15	1.14	1.07	0.91
Total	11.87	12.48	8.62	7.51	9.64	13.07	20.87	13.36	17.03	16.79	15.36	8.19

APPENDIX 27 : Future Irrigated Land, its Cropping Intensity and Patterns in the Khazir Basin (Alternative A)

Total irrigated land : 26950 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	62[2]	16709
Summer crops	18[2]	4851
Rice	6[3]	1617
Orchard (perennial)	5[3]	1348
Alfalfa (perennial)	3[3]	809
Total irrigated in winter	70	18866
Total irrigated in summer	32	8625
Total	102	27491

Sources:

1. Higher Agricultural Council, op.cit., Studies No.1-2, 1-3 and 1-4, p.33.

2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.

3. Kettaneh, M.S., et al., op.cit., pp.59-61.

APPENDIX 28 : Future Monthly Irrigation Water Requirement of the Khazir River (Alternative A), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	9.21	11.53	8.19	7.07	8.86	10.41	14.92					
Summer crops						1.43	4.04	7.33	10.19	11.07	9.95	3.83
Rice	1.21							4.18	3.89	2.71	2.6	2.34
Orchards (perennial)	0.89	0.42	0.15	0.17	0.39	0.59	0.89	1.35	1.89	1.7	1.62	1.28
Alfalfa (perennial)	0.61	0.33	0.14	0.15	0.25	0.37	0.53	0.79	1.15	1.14	1.07	0.91
Total	11.92	12.28	8.48	7.39	9.5	12.8	20.38	13.65	17.12	16.62	15.24	8.36

APPENDIX 29 : Present Irrigated Land, its Cropping Intensity and Patterns in the Lesser Zab Basin (Alternative A)

Total irrigated land : 63240 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	63.1 [2]	39904
Summer crops	20.53[2]	12983
Rice	3.47	2194[3]
Orchards (perennial)	13.69	8658[1]
Alfalfa (perennial)	3.0 [4]	1897
Total irrigated in winter	79.79	50459
Total irrigated in summer	40.69	25732
Total	120.48	76191

Sources:

1. Higher Agricultural Council, op.cit., Study No.3-1, pp.270-306. Ministry of Irrigation : In Kienitz, G., op.cit., pp.55-61.
2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.
3. Selkhozpromexport Co., op.cit., Vol.1, Book 2, Table IV 2.3-3.
4. Kettaneh, M.S., et al., op.cit., pp.65-67.

APPENDIX 30 : Present Monthly Irrigation Water Requirement of the Lesser Zab River (Alternative A), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	22	27.53	19.6	16.9	21.15	24.9	35.63					
Summer crops						3.82	10.8	19.62	27.3	29.63	26.62	10.3
Rice	1.64							5.7	5.3	3.7	3.53	3.2
Orchards (perennial)	5.71	2.7	0.95	1.1	2.51	3.82	5.71	8.7	12.12	10.93	10.4	8.23
Alfalfa (perennial)	1.43	0.78	0.32	0.35	0.6	0.9	1.3	1.84	2.7	2.7	2.5	2.12
Total	30.78	31.01	20.87	18.35	24.26	33.44	53.44	35.86	47.42	46.96	43.05	23.85

APPENDIX 31 : Future Irrigated Land, its Cropping Intensity and Patterns in the Lesser Zab Basin (Alternative A)

Total irrigated land : 256250 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	62.0 [2]	158875
Summer crops	23.12[2]	59245
Rice	0.878	2250[3]
Orchards (perennial)	20.02	51300[1]
Alfalfa (perennial)	3.0 [4]	7688
Total irrigated in winter	85.02	217863
Total irrigated in summer	47.018	120483
Total	132.038	338346

<u>Sources</u>:

1. Ministry of Irrigation : In Kienitz, G., op.cit., pp.55-61.

2. Ministry of Irrigation, G.E.S.D., op cit., pp.4-5.

3. Selkhozpromexport Co., op.cit., Vol.1, Book 3, pp.25-28.

4. Kettaneh, M.S. et al., op.cit., pp.59-61.

APPENDIX 32 : Future Monthly Irrigation Water Requirement of the Lesser Zab River (Alternative A), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	87.54	109.62	77.85	67.2	84.2	99	141.9					
Summer crops						17.42	49.3	89.52	124.41	135.2	121.5	46.8
Rice	1.7							5.81	5.41	3.8	3.62	3.3
Orchards (perennial)	33.9	15.9	5.64	6.4	14.9	22.62	33.9	51.3	71.82	64.74	61.6	48.74
Alfalfa (perennial)	5.8	3.2	1.31	1.4	2.4	3.54	5.1	7.5	10.92	10.84	10.15	8.61
Total	128.94	128.72	84.8	75	101.5	142.58	230.2	154.13	212.56	214.58	196.87	107.45

APPENDIX 33 : Present Irrigated Land, its Cropping Intensity and Patterns in the Adhaim Basin (Alternative A).

Total irrigated land : 22600 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	63.1[2]	14261
Summer crops	14.3[2]	3232
Rice	9.7	2194[3]
Orchards (perennial)	5.53	1250[1]
Alfalfa (perennial)	3.0[4]	678
Total irrigated in winter	71.63	16189
Total irrigated in summer	32.53	7354
Total	104.16	23543

Sources:

1. Ministry of Irrigation : In Kienitz, G., op.cit., pp.55-61.

2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.

3. Selkhozpromexport Co., op.cit., Vol.1, Book 2, Table IV.2.3-3.

4. Kettaneh, M.S., op.cit., pp.65-67.

APPENDIX 34 : Present Monthly Irrigation Water Requirement of the Adhaim River (Alternative A), in cumecs.

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	7.9	9.84	7	6	7.6	8.9	12.74					
Summer crops						0.95	2.7	4.9	6.8	7.4	6.63	2.6
Rice	1.64							5.7	5.3	3.7	3.53	3.2
Orchards (perennial)	0.83	0.4	0.14	0.16	0.4	0.6	0.83	1.3	1.8	1.6	1.5	1.2
Alfalfa (perennial)	0.51	0.28	0.12	0.123	0.21	0.31	0.45	0.66	0.96	0.96	0.9	0.8
Total	10.88	10.52	7.26	6.283	8.21	10.76	16.72	12.56	14.86	13.66	12.56	7.8

APPENDIX 35 : Future Irrigated Land, its Cropping Intensity and Patterns in the Adhaim Basin (Alternative A)

Total irrigated land : 143100 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	62.0[2]	88722
Summer crops	24.0[2]	34344
Orchards (perennial)	17.714	25350[1]
Alfalfa (perennial)	3.0[3]	4293
Total irrigated in winter	82.714	118365
Total irrigated in summer	44.714	63987
Total	127.428	182352

Sources:

1. Ministry of Irrigation : In Kienitz, G., op.cit., pp.55-61.

2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.

3. Kettaneh, M.S., et al., op.cit., pp.59-61.

APPENDIX 36 : Future Monthly Irrigation Water Requirement of the Adhaim River (Alternative A), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	48.9	61.22	43.5	37.53	47	55.3	79.23					
Summer crops						10.1	28.6	51.9	72.12	78.4	70.41	27.13
Rice												
Orchards (perennial)	16.73	7.9	2.8	3.14	7.4	11.18	16.73	25.4	35.5	32	30.42	24.1
Alfalfa (perennial)	3.23	1.8	0.73	0.78	1.33	2	2.83	4.2	6.1	6.1	5.7	4.81
Total	68.86	70.92	47.03	41.45	55.73	78.58	127.39	81.5	113.72	116.5	106.53	56.04

APPENDIX 37 : Present Irrigated Land, its Cropping Intensity and Patterns in the Diyala Basin (Alternative A)

Total irrigated land : 415670 (ha.) [1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	63.1 [2]	262288
Summer crops	24.0 [2]	99761
Orchards (perennial)	5.18	21530 [1]
Alfalfa (perennial)	3.0 [3]	12470
Total irrigated in winter	71.28	296288
Total irrigated in summer	32.18	133761
Total	103.46	430049

Sources:

1. Higher Agricultural Council, op.cit., Study No.3-1, pp.314-355.
   Higher Agricultural Council, op.cit., Study No.3-5, pp.251-260.
   Ministry of Irrigation : In Kienitz, G., op.cit., pp. 55-61.

2. Ministry of Irrigation, G.E.S.D., op.cit., pp.4-5.

3. Kettaneh, M.S., et al., op.cit., pp.65-67.

APPENDIX 38 : Present Monthly Irrigation Water Requirement of the Diyala River (Alternative A), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	144.52	181	128.52	111	139	163.41	234.22					
Summer crops						29.33	83	150.74	209.5	227.7	204.51	78.81
Orchards (perennial)	14.21	6.7	2.4	2.7	6.24	9.5	14.21	21.53	30.14	27.17	25.84	20.45
Alfalfa (perennial)	9.4	5.15	2.13	2.3	3.9	5.74	8.23	12.12	17.71	17.6	16.5	14
Total	168.13	192.85	133.05	116	149.14	207.98	339.66	184.39	257.35	272.47	246.85	113.26

APPENDIX 39 : Future Irrigated Land, its Cropping Intensity and Patterns in the Diyala Basin (Alternative A)

Total irrigated land : 555350 (ha.)[1]

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	62.0[2]	344317
Summer crops	24.0[2]	133284
Orchards (perennial)	9.495	52730[1]
Alfalfa (perennial)	3.0[3]	16661
Total irrigated in winter	74.495	413708
Total irrigated in summer	36.495	202675
Total	110.99	616383

Sources:

1. Ministry of Irrigation : In Kienitz, G., op.cit., pp.55-61.

2. Ministry of Irrigation, G.E.S.D., op.cit.,pp.4-5.

3. Kettaneh, M.S., et al., op cit., pp.59-61.

APPENDIX 40 : Future Monthly Irrigation Water Requirement of the Diyala River (Alternative A), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	189.72	237.6	168.72	145.65	182.5	214.51	307.5					
Summer crops						39.2	110.9	201.4	279.9	304.2	273.23	105.3
Orchards (perennial)	34.8	16.35	5.8	6.54	15.3	23.3	34.8	52.73	73.82	66.55	63.3	50.1
Alfalfa (perennial)	12.55	6.9	2.85	3.03	5.2	7.7	11	16.2	23.7	23.5	22	18.7
Total	237.07	260.85	177.37	155.22	203	284.71	464.2	270.33	377.42	394.25	358.53	174.1

APPENDIX 41 : Present Irrigated Land, its Cropping Intensity and Patterns in the Shatt Al-Arab (Alternative A)

Total irrigated land : 9850 (ha.)[1]*

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	31.1	3060[1]
Summer crops	9.14	900[1]
Orchards (perennial)	63.5	6250[1]
Alfalfa (Perennial)	3.0[2]	296
Total irrigated in winter	97.6	9606
Total irrigated in summer	75.64	7446
Total	173.24	17052

Sources:

1. Polservice Co., op.cit., Vol.VIII, Part A Text, Table 5.7.

2. Kettaneh, M.S., et al., op.cit., pp.65-67.

* Excluding 17720 ha downstream of Maqil which is under tidal irrigation.

APPENDIX 42 : Present Monthly Irrigation Water Requirement of the Shatt Al-Arab (Alternative A), in cumecs

	Monthly irrigation needs											
Crop type	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	1.7	2.11	1.5	1.3	1.622	1.91	2.733					
Summer crops						0.3	0.8	1.4	1.9	2.1	1.85	0.711
Orchards (perennial)	4.13	1.94	0.69	0.78	1.813	2.8	4.13	6.3	8.8	7.9	7.5	5.94
Alfalfa (perennial)	0.223	0.122	0.051	0.054	0.092	0.14	0.2	0.3	0.42	0.42	0.4	0.332
Total	6.053	4.172	2.24	2.134	3.527	5.15	7.863	8.0	11.12	10.42	9.75	6.983

APPENDIX 43 : Future Irrigated Land, its Cropping Intensity and Patterns in the Shatt Al-Arab (Alternative A)

Total irrigated land : 70676 (ha.)*

Type of crops	Cropping intensity (% of the total land)	Annual irrigated land (ha.)
Winter crops	40.62	28709
Summer crops	12.0	8481
Orchards (perennial)	40.25	28448
Alfalfa (perennial)	5.3	3746
Total irrigated in winter	86.17	60903
Total irrigated in summer	57.55	40675
Total	143.72	101578

Source:

Polservice Co., op.cit., Vol. IX, Part A Text, pp.1-3, Tables 1.1 and 2.5

* This is the whole irrigated land of the Shatt Al-Arab region

APPENDIX 44 : Future Monthly Irrigation Water Requirement of the Shatt Al-Arab (Alternative A), in Cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	15.82	19.81	14.1	12.14	15.22	17.9	25.64					
Summer crops						2.5	7.1	12.82	17.81	19.4	17.4	6.7
Orchards (perennial)	18.8	8.82	3.13	3.53	8.25	12.55	18.8	28.45	39.83	35.9	34.14	27.03
Alfalfa (perennial)	2.82	1.55	0.64	0.7	1.2	1.72	2.5	3.64	5.32	5.3	4.94	4.2
Total	37.44	30.18	17.87	16.37	24.67	34.67	54.04	44.91	62.96	60.6	56.48	37.93

APPENDIX 45 : Present Irrigated Land, its Cropping Intensity and Patterns in the Shatt Al-Arab (Alternative B)

Total irrigated land : 9850 (ha.)*

Type of crops	Cropping intensity[1] (% of the total land)	Annual irrigated land (ha.)
Winter crops	68	6698
Summer crops	24	2364
Orchards (perennial)	5	493
Alfalfa (perennial)	3	296
Total irrigated in winter	76	7487
Total irrigated in summer	32	3153
Total	108	10640

Source:

1. Kettaneh, M.S.,et al., op.cit., pp.65-67.

* Derived from Appendix 41.

APPENDIX 46 : Present Monthly Irrigation Water Requirement of the Shatt Al-Arab (Alternative B), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	3.7	4.62	3.3	2.83	3.55	4.2	6					
Summer crops						0.7	2	3.6	5	5.4	4.85	1.9
Orchards (perennial)	0.33	0.153	0.054	0.061	0.143	0.22	0.33	0.5	0.7	0.622	0.6	0.47
Alfalfa (perennial)	0.223	0.122	0.051	0.054	0.092	0.14	0.2	0.3	0.42	0.42	0.4	0.332
Total	4.253	4.895	3.405	2.945	3.785	5.26	8.53	4.4	6.12	6.442	5.85	2.702

APPENDIX 47 : Future Irrigated Land, its Cropping Intensity and Patterns in the Shatt Al-Arab (Alternative B)

Total irrigated land : 70676 (ha.)*

Type of crops	Cropping intensity[1] (% of the total land)	Annual irrigated land (ha.)
Winter crops	84	59368
Summer crops	28	19789
Orchards (perennial)	5	3534
Alfalfa (perennial)	3	2120
Total irrigated in winter	92	65022
Total irrigated in summer	36	25443
Total	128	90465

Source:

1. Kettaneh, M.S.,et al., op.cit., pp.59-61.

* Derived from Appendix 43.

APPENDIX 48 : Future Monthly Irrigation Water Requirement of the Shatt Al-Arab (Alternative B), in cumecs

Crop type	Monthly irrigation needs											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Winter crops	32.71	41	29.1	25.11	31.47	37	53.02					
Summer crops						5.82	16.5	29.9	41.56	45.16	40.57	15.63
Orchards (perennial)	2.33	1.1	0.39	0.44	1.025	1.56	2.33	3.534	4.95	4.46	4.24	3.36
Alfalfa (perennial)	1.6	0.88	0.363	0.386	0.657	0.975	1.4	2.061	3.01	2.99	2.8	2.374
Total	36.64	42.98	29.853	25.936	33.152	45.355	73.25	35.495	49.52	52.61	47.61	21.364

APPENDIX 49 : Mean Monthly and Annual Rainfall for Selected Stations in Iraq (mm) 1941 - 70

Station	M O N T H S												Annual
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Zakho	148.3	106.2	128.8	93.4	41.2	0.0	0.0	0.0	0.3	20.6	71.5	121.4	731.7
Khanaqin	62.0	43.7	66.4	37.0	18.2	0.3	0.2	0.1	0.0	4.3	30.6	47.8	310.6
Ana	18.8	16.9	20.4	22.2	5.7	0.0	0.0	0.0	0.0	5.3	9.8	22.5	121.6
Habbaniya	27.9	12.0	10.5	19.9	6.2	0.0	0.0	0.0	0.2	2.3	20.0	13.1	112.1

Source : Iraqi Meteorological Organization, op cit., (Unpublished data)

APPENDIX 50 : Mean Monthly and Annual Values of Free-Water Surface Evaporation for Selected Stations in Iraq (mm)

Station	MONTHS												Annual
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	
Salahddin	120	51	22	32	35	55	79	110	195	266	230	182	1377
%	8.71	3.7	1.6	2.32	2.54	4.0	5.74	8.0	14.16	19.32	16.7	13.22	100
Sulaimaniya	178	69	28	39	33	62	102	153	285	354	302	281	1886
%	9.44	3.66	1.5	2.1	1.75	3.29	5.41	8.11	15.11	18.77	16.0	14.9	100
Kirkuk	200.4	69.6	46.1	47.7	63.5	109.7	147.5	280.2	284.6	446	407	306.6	2409
%	8.32	2.9	1.91	2.0	2.64	4.55	6.12	11.63	11.81	18.51	16.9	12.73	100
Khanaqin	232	109	44	57	74	124	169	283	322	452	396	323	2585
%	9.0	4.22	1.7	2.21	2.9	4.8	6.54	10.95	12.5	17.5	15.32	12.5	100
Haditha	180	90	44	46	74	115	174	262	353	409	380	270	2397
%	7.51	3.76	1.84	1.92	3.09	4.8	7.26	10.93	14.73	17.06	15.85	11.27	100
Habbaniya	161	109	47	52	82	151	179	283	372	472	443	316	2667
%	6.04	4.1	1.76	1.95	3.07	5.66	6.71	10.61	13.95	17.7	16.61	11.85	100
Diwaniya	205.8	111.4	73.6	60.2	80.5	138.3	186	280.8	361.8	419.4	384.7	296	2598
%	7.92	4.29	2.83	2.32	3.1	5.32	7.16	10.81	13.93	16.14	14.81	11.4	100
Nasiriya	206.2	106.6	66.3	61.7	83.8	154.3	204.4	319.5	349.7	407.9	394.5	310.7	2666
%	7.73	4.0	2.5	2.31	3.14	5.8	7.67	12.0	13.12	15.3	14.8	11.65	100
Hai	220	125	64	68	80	136	170	295	380	420	410	350	2718
%	8.1	4.6	2.35	2.5	2.94	5.0	6.25	10.85	14.0	15.45	15.1	12.9	100
Amara	197.4	121.3	65.5	63.3	77.5	137.2	180.8	302.6	435.6	464.8	392.3	332.3	2764
%	7.14	4.39	2.37	2.29	2.8	5.0	6.54	10.95	15.76	16.82	14.2	12.02	100

Source : Kettaneh, M.S., et al., op cit., Tables 4a and 4b.