

Water Resources of the Tigris River Catchment

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Abstract

The Tigris River is one of the longest rivers in western Asia. Its length is about 1800 km. It drains a catchment area of 473103 km² divided in 4 countries (Turkey, Syria, Iran and Iraq). About 23 million people live within this catchment. The flow of the River Tigris is decreasing with time due to the construction of dams and climate change. The discharge of the Tigris River at Baghdad was 1,207 m³/s for the period 1931-1960 and since 2000 onward it is 522m³/s. Riparian countries (mainly Iraq and Iran) are facing water shortage problems. This requires prudent regional and national cooperation and management to overcome this problem.

Keywords: Tigris River, Basin, Climate change, Turkey, Iraq

1 Introduction

The Tigris River's basin is about 1800 km in length and covers a total area of 473103 km² shared by 4 countries (Figure 1 and Table 1). About 24.5% of the area of the Tigris River's catchment lies in Turkey, while 0.4%, 19% and 56.1% lies in Syria, Iran and Iraq, respectively. The total population within the Tigris River basin reaches about 23.4 million inhabitants (ESCWA, 2013) of which 18, 3.5, 1.5 million live in Iraq, Turkey and Iran, respectively and the remainder 0.05 million live in Syria.

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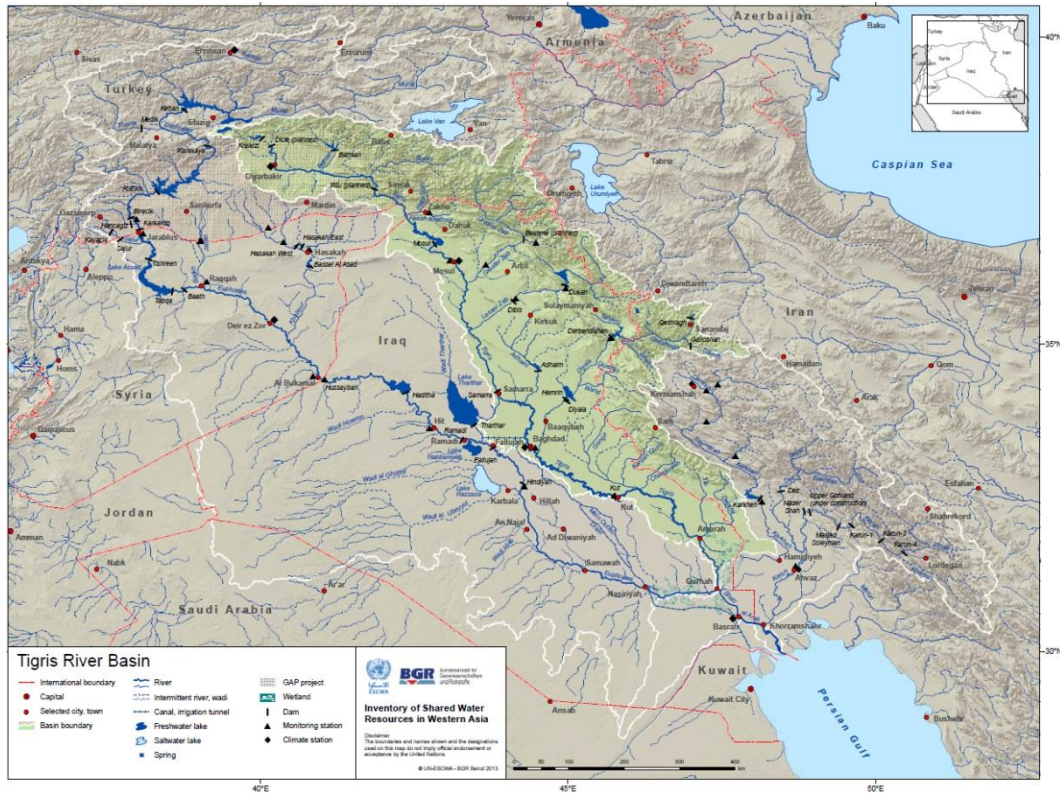


Figure 1: The Tigris River Basin (After ESCWA, 2013).

Table 1: The area of Tigris River Basin.

Countries	Tigris River	
	Catchment area (km ²)	Catchment area (%)
Turkey	57614	12.2
Syria	834	0.2
Iraq	253000	58
Iran	140180	29.6
Total	473103	100

Tigris and Euphrates Rivers are well known through history. This is due to the fact that the water of these rivers had witnessed the dawn of the civilization in Mesopotamia. Irrigation and agricultural practices started in this area thousands of years ago where system of canals, dikes, weirs, and reservoirs were constructed (Kramer, 1963, Sousa, 1981, Tamnurrino, 2010). This was reflected in their historic achievements (Figures 2, 3 and 4). Canals were dug and maintained continuously and hydraulic structures were constructed, and even sanitary engineering works were performed as early as 6500B.C. (Tamnurrino, 2010). Despite the prosperity and wealth of the region, there were waves of conflicts during the history of the region, which was reflected through myths, legends and historical accounts, e.g. Epic of Gilgamesh, and attacks on water supply systems during wars was very common (Gleick, 1994; George, 2000). After this period and until the nineteenth century, the area showed more and more dependence on irrigated agriculture for its survival and more rural society was noticed.



Fig 2: The Goddess “Boa” holding two stalks of wheat with three bearded attendants the last of them in stalks of wheat (after Sousa, 1981).



Fig 3: Sumerian women-peasant holding a winnowing pitchfork as depicted on a marble slab dating from the middle of the third millennium B.C. discovered at Nippur, Iraq (after Sousa, 1981).



Fig 4: Seals with the representation of the water god Enki – Ea. Upper image: Old Babylonian seal (ca. 1700 B.C.). The god with water flowing from his shoulders. Lower image: Akkadian cylinder seal (ca. 2300 B.C.). The god seated on a stool and holding up a jar from which waterspouts and falls (after Tamnurrino, A., 2010).

Recently, the Middle East area has been experiencing water shortage problems. Most of the countries of this region have acute water scarcity problem and the allocation per capita is less than 500 m³ (Roger and Lydon, 1994; Biswas, 1994; Allan, 2001; Al-Ansari, 1998, 2013, 2016; Cherfance and Kim, 2012; Barr et al., 2012). This is due to several reasons which includes:

- a. High population growth rate.
- b. Improved standard of living.
- c. Effect of climate change.
- d. Construction of huge hydraulic structures on the rivers' water courses.

For these reasons, the conflict and friction among neighboring countries had risen at different times related to water sharing.

In this work, hydrological conditions of the Tigris River's catchment area will be addressed. This will give a good insight on the present conditions and can be used to solve ongoing problems.

2 Climate

In the headwater area of the Tigris basin, the weather in summer is dry; while it is cold and wet during winter. Precipitation dominates during autumn, winter and spring seasons and snow fall takes place during winter. The climate in Turkey is of Mediterranean type and gradually changes toward the south to hot and dry arid climate (Turkish Ministry of Environment, 2012; Sen et al., 2012). At the south, the precipitation hardly exceeds 1000 mm/year (Figure 5) (Al-Ansari and Knutsson, 2011; ESCWA, 2013; Al-Ansari, 2013; Al-Ansari et al., 2014a). The temperature varies from -35° C in winter at the northern parts of the basin and goes up to 50° C during summer at the southern part of the basin (Figure 6).

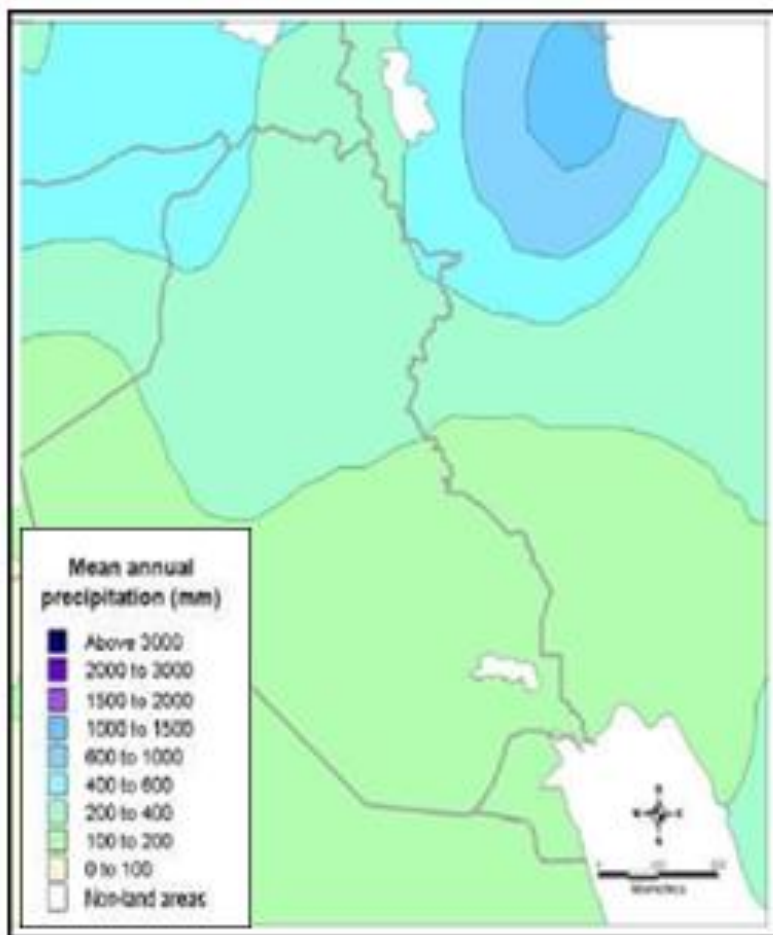


Figure 5: Mean annual precipitation in the Tigris and Euphrates Basins
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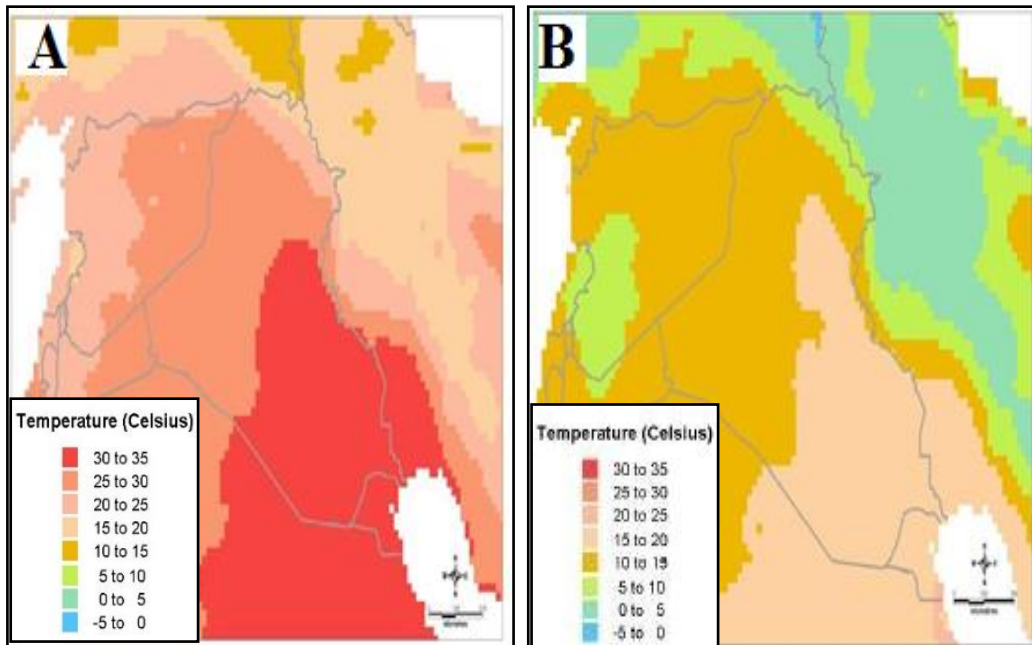


Figure 6: Maximum, A and minimum B, daily temperature in the Tigris and Euphrates basins.

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3 Course of the Tigris River

The Tigris River rises at Taurus Mountains near the city of Elazig at the Armenian Highlands. It is 1800 km long, which makes it the second longest river in Western Asia. The river starts with small tributaries that join together to form two main tributaries. These are:

- Batman Su or Dijla Su. This tributary rises at altitude up to 4500 m (a.s.l.) and it runs from the west toward the east.
- Botan Su: It rises at altitude up to 1500 m (a.s.l.) and it is comprised of several small tributaries that originate near Van lake.

Table 2: Main tributaries of the River Tigris

River	Catchment (km ²)				Length (km)	Flow (BCM)		
	Total	Turkey	Iran	Iraq		Mean Annual	Minimum	Maximum
Feesh Khabur	6143	57%	-	43%	181	2.0	0.9	4.3
Greater Zab	26310	35%		65%	462	12.7	3.7	23.6
Lesser Zab	19,780	-	24%	76%	456	6.0	1.7	15.1
Al-Adhaim	13,000	-	-	100%	330	0.79	0.08	1.85
Diyala	33,240	-	25%	75%	445	4.6	1.2	14.4
Source of data: ESCWA, 2013; Mahmoud, 2010 ; Ministry of Water Resources in Iraq, 2012; USGS, 2012								

The river runs 400 km in Turkey and it forms the Turkish- Syrian border for about 47 km, then it flows inside Iraq for about 1400 km. The mean annual flow of the river in Turkey reaches 20.3×10^9 m³/y (Kliot, 1994; Kolars, 1994; Kurdish Human Rights Project, 2002; Biedler, 2004; ESCWA, 2013). The rivers enter Iraq near Zakho town. Inside Iraq, the first tributary “Feesh Khabour” joins the River Tigris near the city Zakho. Al-Khabur catchment area reaches 6143 km² shared between Turkey (3477 km²) and Iraq (2666 km²). The total length of the river is 181 km with a mean annual flow of 2 billion cubic meters (BCM) (Table 2), while the minimum and maximum flows reach 0.9 and 4.3 BCM, respectively. It originates at Sirnak in the eastern Turkey. The river flows south towards Iraq and is joined by its main tributary Hezil Suyu, which forms the Turkish- Iraqi border for about 20 km and then merges with the Tigris at the tripoint of the three countries (Turkey, Syria, Iraq) (ESCWA, 2013).

After the confluence with the Khabur, the River Tigris runs south for about 188 km and it reaches one of the main cities “Mosul”. At Mosul, the average, maximum and minimum discharges of the river is 668 m³/s, 7,740 m³/s, 2/5/1972, and 85 m³/s, October, 1935, respectively and the elevation of the channel bed is 225 m (a.s.l.). Further south for about 50 km, the Tigris joins its largest tributary “Greater Zab” near the city of Shirqat. This tributary has a total length of 462 km and it originates in Turkey and drains a catchment area of 26310 km² of which 9209 km² (35%) lies in Turkey and the remainder in Iraq. This tributary contributes about 33% of the Tigris flow. The Tigris River then flows south, and 30 km before it reaches Al-Fatha gorge, the Lesser Zab (Little Zab) joins the river. This tributary is 456 km in length and drains an area of 19,780 km² of which 24% lies in Iran and the remainder 76% lies in Iraq.

The mean, minimum and maximum annual flows of the river are 6.0, 1.7 and

15.1 BCM, respectively. Two dams were constructed on this tributary. The first one is referred to as Dokan Dam, which is located in the upper part of the catchment in Iraq; approximately 60 km north-west of the city of Sulaimaniyah. It is a concrete arch multipurpose dam. This dam was put into operation in 1959. The second is known as Dibis Dam, is an embankment dam located about 130 km upstream of the confluence of the Lesser Zab with the River Tigris and it was put into operation in 1965. Its main function is to divert the Lesser Zab water to Kirkuk irrigation scheme.

South of Al-Fatha gorge, the River Tigris enters the Mesopotamian Plain. When the river reaches Samara city, a barrage was constructed in 1956. The main purpose of this barrage is flood control by diverting excess water from the Tigris River to Tharthar Lake and generate electricity. Further downstream, Al-Adhaim tributary joins the Tigris River 15 km south of Balad city. This tributary is about 330 km long and drains an area of 13000 km² which lies entirely in Iraq. It is an intermittent river having mean, minimum and maximum annual flows of 0.79, 0.08 and 1.85 BCM, respectively. An embankment dam was constructed on this tributary for flood control, hydro-power and irrigation and it started operating in 2000.

The Tigris River flows further south till it reaches the capital Baghdad. At Baghdad the mean, maximum and minimum discharges are 1,140m³/s, 7,640 m³/s on 12/2/1941 and 163m³/s in October, 1955, respectively. South of Baghdad (about 30 km), the Diyala tributary joins the Tigris River. This tributary is about 445 km long and drains an area of 33,240 km². About 20% of its drainage area lies in Iran and the remainder in Iraq. The mean, minimum and maximum flows of this tributary are 4.6, 1.2 and 14.4 BCM, respectively.

Downstream of this confluence, the Tigris River channel is characterized by its large number of meanders and its discharge decreases downstream due to different kind of losses which include evaporation, infiltration and mainly water withdrawal through irrigation canals. Several irrigation canals are supplied by the Tigris River. These are Gharraf, Dujalia and Hussaynia south of Kut city, Great Majar south of Emarah city, Mushrah, Kahlaa and Mejariah South of Qalaat Salih. Large marshes used to be on both sides of the Tigris channel in its southern stretch. Nowadays, these marshes occupy relatively small areas due to water scarcity. Several small streams running from Iran discharge their water to the Tigris River during rainy periods. The most important streams are Tib (or Teeb), Dewarege and Shehabi. These streams drain an area of about 8000 km² and they provide 1.0 BCM of water annually, which ends into the marshes (Abdullah, 2016). South of Amarah city, the Tigris River reaches its minimum with at Kasarah area. The River joins the Euphrates River at Qurnah city and its mean daily discharge before this confluence reaches 80 m³/s at Amrah.

4 Flow Characteristics of the Tigris River

Flow of the River Tigris can be considered as natural before 1973 where no dams were constructed within the northern part of the catchment. After that, a number of dams were built in the Turkish part of the catchment as well as in Iraq. ESCWA (2013) analyzed the annual flow volume of the Tigris River at two stations (Table 3). One of the stations (Mosul), which is located northern part of Iraq and the second station (Kut) located in the southern part of Iraq (Figure 1). The flow of the Tigris River at Mosul station for the period 1931-1973 represents natural flow because no dams were constructed on the river upstream this station. The flow for the period 1974-2005 was affected by the construction of dams after the 1990's. The overall mean annual flow for the period of the record was 20 and 25.7 BCM at Mosul and Kut stations, respectively (Table 3). The maximum and minimum flows at Mosul were 43.1 BCM (1969) and 6.5 BCM (1999), respectively, while it was at Kut station 59.2 BCM (1946) and 4.2 BCM (2001), respectively. It should be mentioned; however, that the tributaries of the Tigris River downstream Mosul station contribute about 50% of the Tigris flow at Baghdad (ACSAD and UNEP-ROWA, 2001 and Shahin, 2007). Taking this into consideration, then it can be noticed that, the flow of the river is decreasing downstream toward Kut. This is due to large scale extraction for municipal, industrial and agricultural purposes.

The mean annual discharge of the Tigris River at Mosul station for the period 1931 to 2011 does not show any trend while a negative trend is recognized at Kut station (Figure 7). A negative trend can be recognized at Baghdad station (Figure 8). The records indicate that the discharge of the Tigris River for the period 1931-1960 where no dams were constructed on the river reached 1,207 m³/s. Following that period (1961-2000), some dams were constructed on the river and its tributaries, which caused decrease of the discharge to 927 m³/s (Al-Ansari et al., 2015). The annual water flow of the river decreased by 2.8% between the 1950's and 1960's and this trend continued where the flow of the river reached 715 m³/s from 1980 onwards. This is mainly due to the construction of dams and climate change (Al-Ansari et al., 2015). Further reduction in the flow was noticed after the year 2000, where the discharge of the river at Baghdad reached 522 m³/s; due to the construction of dams in Turkey and Iraq, and diversion water coming from the valleys in Iran to the river inside Iranian borders. Analysis of the records for the past 60 years suggest that the annual flow of the river was reduced by 59.3% (Al-Ansari et al., 2015).

Table 3: Summary of annual flow of the River Tigris at Mosul and Kut stations (modified after ESCWA, 2013).

Station (Drainage area, km ²)	Period	Annual Flow (BCM)		
		Mean	Minimum	Maximum
Mosul (56000)	1931-2011	20.0	6.5	43.1
	1931-1973	21.3	11.7	43.1
	1931-1952	19.4	12.2	27.6
	1953-1984	22.0	11.7	43.1
	1974-2005	19.5	6.5	41.7
	1985-2005	19.1	6.5	41.7
Kut (173000)	1931-2005	25.7	4.2	59.2
	1931-1973	32.0	15.2	59.2
	1931-1952	36.8	15.2	59.2
	1953-1984	24.5	13.2	50.3
	1974-2005	16.7	4.2	47.5
	1985-2005	13.9	4.2	47.5

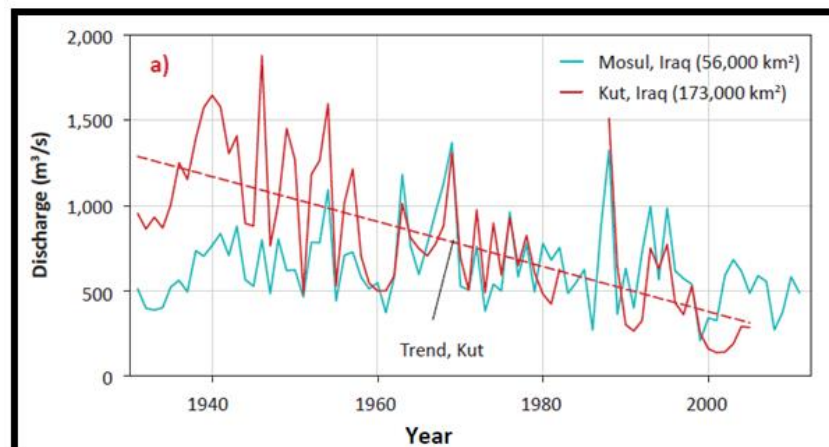


Figure 7: Mean annual discharge of the Tigris River at Mosul and Kut stations (modified after ESCWA, 2013).

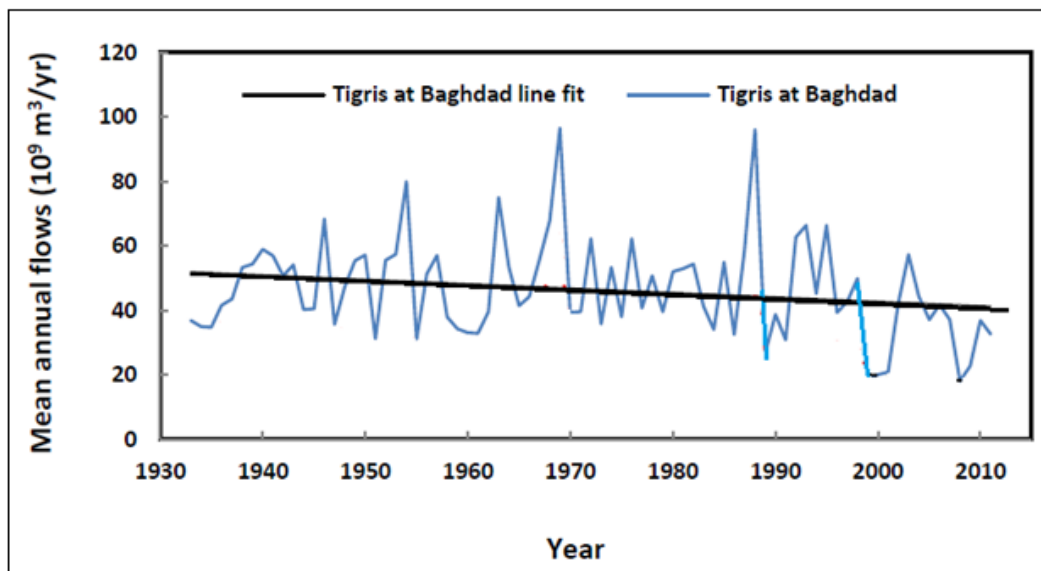


Figure 8: Mean annual flow variation of the Tigris River at Baghdad station for the period 1933 to 2011 (modified after Abdullah, 2016)

The maximum flow of the Tigris River takes place during April - May period (Figure 9). The discharge varies according to the meteorological conditions mainly the intensity and duration of rainfall events during the period October to February and is known as variable flood period. The following period (March – April) is characterized by relatively steady discharge due to snow melt in the upper catchment area in Turkey and northern Iraq, and is known as steady flood period. It is clear that the hydrograph of the river is becoming flatter with time (Figure 9). This reflects the effect of dams' construction in the upper parts of the catchment and draught that is affecting the Middle East area due to climate change (Al-Ansari et al., 2014a).

5 Water Schemes and Projects

Projects in the upper parts of the Tigris River basin started in the early 1930's in Turkey mainly for flow regulations. In the 1940's; however, projects for the production of electricity using hydroelectric power mainly in addition to limited irrigation practices were developed (Ozis, 1983; ESCWA, 2013). Later, during the 1970's, the Turkish Government started what is known as Southeastern Anatolia Project (GAP). According to this project, 22 dams and 19 hydraulic power plants which are supposed to irrigate 17,000 km² of land are to be constructed (Olcay Unver, 1997; GAP, 2006). According to this project, some of the dams are to be constructed on the Tigris River (Table 4) to irrigate about 600000 ha using 5.6 BCM (ESCWA, 2013).

One of the biggest dams within the GAP project on the Tigris River is Ilisu

Dam. When this dam operates, then, Iraq will receive only 9.7 BCM of water (Alalaf, 2009), which means that the decrease of flow will be 47% (Al-Ansari, 2016). As a consequence, and due to water scarcity, 696000 ha of agricultural land will be abandoned (Al-Ansari and Knutsson, 2011). EsCWA (2013) stated that Turkey controls about 33% of the Tigris River total flow and its utilization of water is increasing with time and it can theoretically use the Greater Zab River water also.

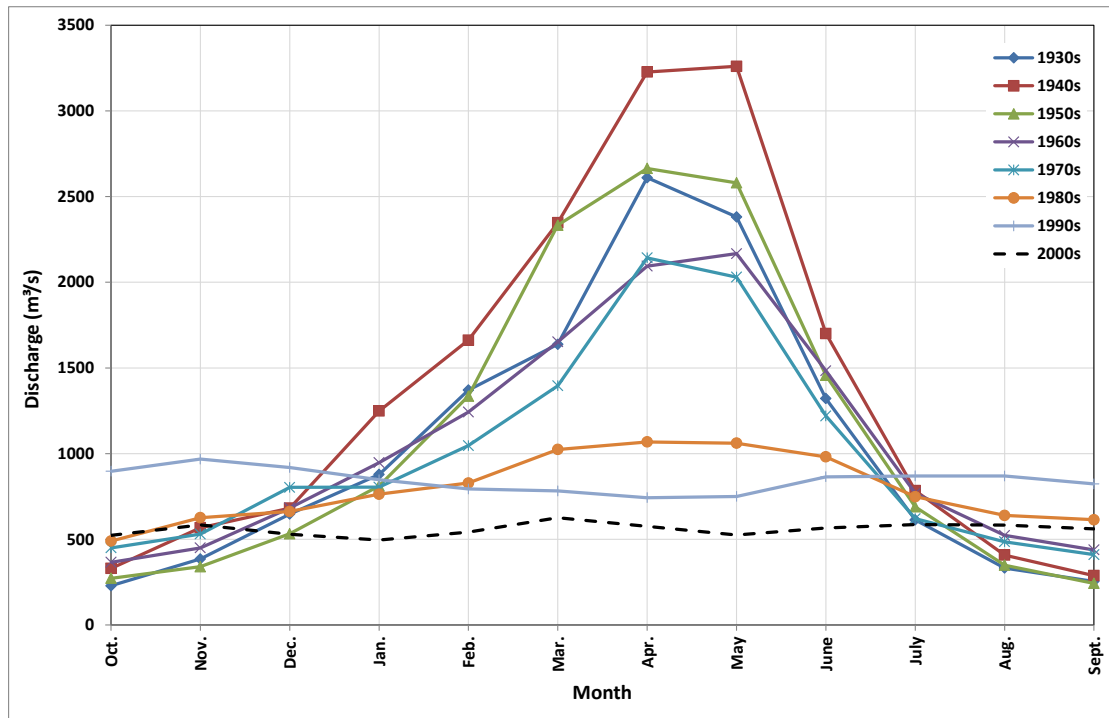


Figure 9: Decadal hydrographs of the Tigris River at Sarai Baghdad for the period 1930-2013 (source of data: Al-Shahrabaly, 2008).

Table 4: The constructed dams in the basin of the Tigris River (modified after ESCWA, 2013 and Issa et al., 2014).

Name of dam	Use	Date of operation	Height (m)	Storage capacity (km ³)	Water surface area (km ²)	Hydro power (MW)
TURKEY						
Cag-cag	HP,	1968				14
Devegeci	I	1972	33	0.2	32.1	-----
Goksu	I	1991	46	0.06	3.9	-----
Kralkizi	HP	1997	113	1.92	57.5	90
Dicle	HP,	1997	75	0.60	24	110
Batman	HP,	1998	71	1.18	49.2	198
IRAQ						
Kut	I	1939				
Samarra Thartha	FD, I,	1956	-----	72.8	2170	87
Dokan,	HP,I	1959	116.5	6.8	270	400
Derbend ikhan	I	1961	128	3	114	-----
Dibbis,	I	1965	22	0.05	32	-----
Diyala	I	1969	12	-----	-----	-----
Hamrin	I,	1981	40	3.56	450	50
Mosul	HP,I	1986	113	11.1	380	750
Al-Adhi	HP,I	1999	-----	1.5	-----	-----
IRAN						
Dez	HP,I	1962	203	3.46		520
Karun	HP,I	1977	200	3.14	54.8	1000
Marun	HP,I	1998	165	1.2	25	145
Karkhe	HP,I	2001	128	7.8		400
I: Irrigation HP: Hydropower FC: Flood Control						

The use of the Tigris water is very limited in Syria. This is due to the fact that the Tigris River forms a small stretch of the Turkish- Syrian border. Syria is using 1.25 BCM annually to irrigate 15000 ha of land in Hasakah Governorate based on an agreement with Iraq in 2002 (ESCWA, 2013).

Iran is suffering from drought where plenty of villages have no water supply and some of the lakes became dry (Sharifikia, 2013, Al-Shaab, 2017, Proyect, 2018). For this reason, Iran diverted most of the valleys supplying water to the Tigris River and its tributaries and constructed several dams for the same purpose (Table 4). Recently, Karkha and Karun Rivers had been almost completely diverted inside the Iranian borders.

Iraq was the first riparian country to use the water of the Tigris River by constructing barrages and dams since 1939 (Table 4). Regulation of flow and flood control was the main goal of the early projects. One of the earlier projects is Tharthar barrage and canal, which is located north-west of Baghdad. This project, which was completed in 1977, is to divert excess water from the Tigris River to Tharthar Depression (Figure 10). This project helped in overcoming the water shortage problems in the flow of the Euphrates River; where water from the Tigris River was diverted to the Euphrates River via Tharthar Lake. In addition, Iraq constructed what is known as the Third River to collect drainage water from 1.5 million ha of agricultural land (FAO, 2003). Other projects were constructed on the Tigris River and its tributaries (Table 4 and Figure 10) to irrigate about 4 million ha (ESCWA, 2013).

Spring flood of the Tigris River and its tributaries normally causes plenty of problems for the agricultural practices due to the large quantities of carried silt and clay (Al-Ansari, 2013 and 2016; Al-Ansari et al., 2014b and 2015). The nature of the topography in the lower parts of the Tigris basin in Iraq is very flat and poorly drained which has caused number of problems including flooding, siltion and soil salinity. For these reasons, the focus of the Iraqi authorities concerned was directed towards land reclamation where 1 million ha of land was reclaimed and another 1.5 million ha was semi-reclaimed (Ministry of Planning in Iraq, 2010). New reclamation projects were planned for 920000 ha and irrigation of 134000 ha (FAO, 2008).

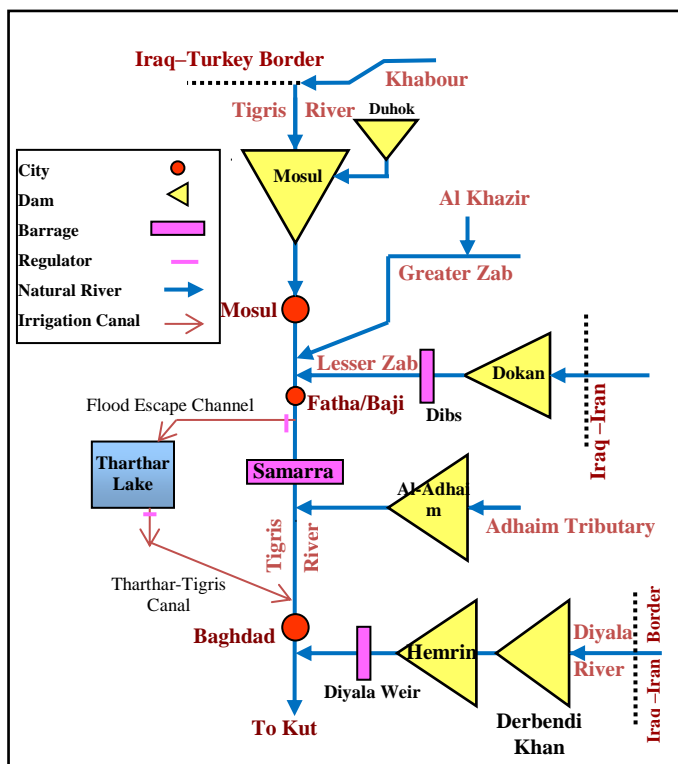


Figure 10: Schematic Diagram of the Tigris River Hydrological Scheme (MWR, 2005).

6 Discussion

Most of the Middle East considered as arid to semi-arid area. The countries in this region suffer from water shortage problems for a long time (Al-Ansari, 1998, 2013; Shahin, 2007; Roger and Lydon, 1994; Biswas, 1994). The Middle East is experiencing drought problems due to climate change. Most of the countries of the region, which suffer are vulnerable to the impact of this change (IPCC, 2007; Arab Forum for Environment and Development; AFED, 2009). The problem is intensifying with time due to high rate of population growth and development (Shahin, 2007). Future expectations are more negative where the region is to suffer from high temperatures and lower rainfall (Al-Ansari and Baban, 2005; Al-Ansari et al., 1999, 2006). Such conditions will enhance drought and flooding. As a result of such meteorological conditions, agricultural life and water supply will be highly affected (Medany, 2008), where most of the areas in this region are rain fed. In addition, groundwater resources will be depleting due to low recharge (Voss et al., 2013).

The high rate of population growth and droughts forced the riparian countries to use all possible ways and means to augment their water resources. To achieve this goal, new dams were planned and constructed (Table 5). Many

irrigation projects were implemented so that they can attain food self-sufficiency. As a consequence, water quantity of the Tigris River available to Iraq is decreasing with time. The increase in salinity caused soil degradation due to intensive irrigation and high rates of evaporation. It should be mentioned; however, that in the upper parts of the catchment (Turkey) the salinity is still acceptable (Odemis and Evrendilek, 2007). Other sources of pollution in the Tigris River is the untreated wastewater that is dumped directly in the river (Al-Hamdani, 2013; Varol et al., 2011). The salinity of the river reaches 300 ppm when the river enters Iraq and it increases gradually downstream where it reaches 1318 pp in Amarah city (see Al-Shujairi, 2013; ESCWA, 2013). Iraq is highly affected where 98% of the population in this part of the basin depends on the Tigris water for drinking and irrigation. Furthermore, in case Turkey and Syria keep implementing irrigation projects and dams to meet the growing demand for water, this will lead to dry up the Tigris and Euphrates Rivers by 2040 (UN, 2010).

It is a clear fact that, water resources represent an extremely important factor in the stability of the region and an integral element in its economic development and prosperity (Naff, 1993; Al-Ansari, 1998; 2005; 2016). Recently, Iraq has been experiencing very hard water shortage problems where the Tigris flow drastically has decreased and there is almost no flow in the river at Amarah city in the south (Figure 11). Such a situation will definitely lead to human and environmental crises. To solve this conflict, it requires plenty of regional cooperation as well as prudent water managem.

7 Conclusions

The Tigris River flow is decreasing with time. This is due to the effect of various variables. Among these are: climate change, which is causing droughts, depletion of groundwater resources and floods, and the large scale development in the upper catchment in the form of constructing new dams and irrigation projects. High population growth rates and these developments in the region caused more need for water resources. Riparian countries planned and constructed various dams and irrigation projects. Intensive irrigation and high rates of evaporation caused increase in the salinity of the Tigris water downstream. In addition, dumping wastewater directly to the river caused water pollution. Iraq is the most affected country because it is the downstream riparian country.

To overcome these problems, it requires intensive regional and national cooperation and work. Agreements for cooperation and agreement on water quotas should be reached by the riparian countries and cooperation is also needed to preserve and improve the quality of the Tigris River water. On national level, public awareness program is to be implemented as well as prudent water management planning. New water conservation irrigation techniques are to be adopted.

Table 5: Planned dams on the River Tigris (modified After ESCWA, 2013)

Name	Capacity (BCM)	Purpose	Status	Information
TURKEY				
Ilisu	10.41	HP	Construction started in 2006, but was suspended in 2008. Work resumed in March 2010.	Planned hydropower capacity: 1,200 MW Projected irrigated area: 313,000 ha
Cizre	0.36	HP	Construction was to begin in June 2008. Completion scheduled: 2017.	The downstream Cizre Dam will work in parallel with the Ilisu Dam. Planned hydropower capacity: 240 MW Projected irrigated area: 121,000 ha
Silvan	..	HP	Construction started in 2012.	Planned hydropower capacity: 150 MW
Kayseri	..	HP	Master plan completed.	Planned hydropower capacity: 90 MW
IRAQ				
Badush	10,000	HP	Partially constructed.	Planned hydropower capacity: 170 MW
Bekhme Dam (Greater Zab)	17,000	HP	Partially constructed	Planned hydropower capacity: 150 MW
Mandawa (Greater Zab)	..	HP, I
Taq Taq (Lesser Zab)	..	HP, I
HP: Hydropower I: Irrigation				



Figure 11: Tigris River at Amara City (February, 2018)

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