Journal of Water Resources and Geosciences

Vol. 4, No.2, 2025

Impacts of Climate Change and Dam Construction on Tigris River Stream flow: A Case Study at Baghdad Sarai Station

Qais AL-Shahrabale* and Suha Q. AL-Shahrabalee

Ministry of Water Resource/ National Center for Water Resource Management

*Corresponding author's E-mail: Alshahrabaly@yahoo.com

Abstract

Baghdad Sarai gauging station is a hydrological gaging station started from 1906 to record surface water level for Tigris River at Baghdad capital, after this date, discharge measurements and other information recorded from automatic level recorder, sediment samplers, and meteorological equipment. This station recorded the highest discharge 7100m^3/s from the flood of 1954 at water level 36m A.S.L, but the cross section of Tigris River at Baghdad Sarai was deterioration due to sedimentation and other causes. The recorded maximum flood discharge for 1988 was 3050m^3/s at level 35m A.S.L., the expected capability of river cross section for year 2022 will not exceed 3000m^3/sec for the same level. This study deals with the historical information of Baghdad Sarai station, analysis of discharge formulas, and analysis of water flows for the period 1930-2022. Impact of climatic changes on river flows for the period 1999-2022, impact of dams' construction on Tigris River tributaries for the period 1954-2000 and the expected Tigris River drought flows in the future.

Keywords: Baghdad Sarai, Climatic changes, river flow, discharge, water level.

تأثيرات تغير المناخ وبناء السدود على تدفق مياه نهر دجلة: دراسة حالة محطة سراي بغداد

قيس الشهربلي*، سهى قيس الشهربلي

وزارة الموارد المائية/ المركز الوطني لادارة الموارد المائية

*البريد الالكتروني للمؤلف المراسل: Alshahrabaly@yahoo.com

الخلاصة

محطة قياس سراي بغداد هي محطة قياس هيدرولوجية بدأت من عام 1906 لتسجيل منسوب المياه السطحية لنهر دجلة في العاصمة بغداد. بعد هذا التاريخ، تم تسجيل قياسات التصريف ومعلومات أخرى من مسجل المستوى الآلي، وأجهزة أخذ عينات الرواسب، والمعدات المترولوجية. سجلت هذه المحطة أعلى تصريف 7100 م^3/ثا من فيضان عام 1954 عند منسوب المياه 36م فوق مستوى سطح البحر، ولكن المقطع العرضي لنهر دجلة في سراي بغداد كان متدهورًا بسبب الترسيب وأسباب أخرى. كان أقصى تصريف فيضاني مسجل لعام 1988 هو 3050 م^3/ثا عند منسوب 35.0 فوق مستوى سطح البحر، ولم تتجاوز القدرة المتوقعة لمقطع النهر العرضي لعام 2022 مقدار 3000 م^3/ثا لنفس المستوى. تتناول هذه الدراسة المعلومات التاريخية لمحطة سراي بغداد، وتحليل صيغ التصريف، وتحليل تدفقات المياه للفترة 1930-2022. بالاضافة الى تأثير التغيرات المناخية على تدفقات الأنهار للفترة 1999-2022، تأثير بناء السدود على روافد نهر دجلة للفترة 1954-2000 وتوقعات جفاف نهر دجلة المتوقعة في المستقبل.

الكلمات المفتاحية: سراي بغداد، التغيرات المناخية، جريان النهر، التصريف، منسوب المياه.

1. Introduction

Baghdad Sarai site was selected in 1981 for military and river navigation purposes (Susa, 1963).

The importance of this study helps in recording and analyzing all available hydrological data including water level, river discharge, changes in river cross section, recording droughts and fluids. In addition to that, the results can be used for future projects design which depends on historical information such as irrigation projects, water supply pumping station, navigation, municipality project and many other projects.

This station was selected due to its importance to all projects depending on the river upstream and downstream. Especially, to regulate the flow from Samarra barrage and Adhaim Dam. Also this station includes along historical information since 1930.

1.1.Baghdad Sarai gauging station

In 1906 sir William Willcocks (A British engineer came to Iraq to study Irrigation management in Iraq) (Susa., 1965), Willcocks established a staff gauge at the wall of the British council house, at the left bank of Tigris River to get Tigris River water level at Baghdad.

In 1930 at 1.8km upstream this gauge, Baghdad Sarai was selected for hydrological managements located at Lat. 33° 18´ N, long. 44° 23´ E, Baghdad Iraq.

At the Sarai wall of the river retaining wall, staff gauges were installed (enameled iron strips of one meter length) (Figure 1) and water level had been read at least once daily (Harza et al., 1958).

The gauge was set to G.T.S. and more than one reading is taken during flood waves. The gauge starts from level 30.2 up to level 36, A.S.L.

Automatic water level recorder was placed on a well to record river level. Discharge measurements were made frequently from a steel boat attached to a permanent over head steel cable connected between two steel towers placed at the left and right banks of the river (Qais A., 2008).

In 1983 a new automatic discharge and gauge height recording station was constructed at left bank of Tigris River 14km upstream Baghdad Sarai. In 2007 a new method of discharge measurement carried out using ADCP equipment (Figure 2). However in 2008 a master station was put into operation at the building of National center for water resources management. The station records the data from a network via a satellite system (Qais A., 2009). Received from the hydrological and metrological station along Iraqi rivers.

Figure 1: Staff gauges at Baghdad Sari station, **Figure 2:** ADCP equipment.

1.2.Tigris River main resources

The main source of the Tigris River is the highlands of southeastern Turkey. The river flows towards the Iraqi-Turkish border after crossing Syrian border to join faysh Khabur river tributary in Iraqi lands. Tigris River total length 1900km. about 1419km inside Iraq, total catchment area of Tigris river is 235000km^2. This catchment includes four countries, Iraq, Iran, Syria, and Turkey. Many tributaries joining Tigris River at its eastern side the major ones are Khabur, Greater Zab, Lesser Zab, Adhaim, Diyala and many other tributaries and rivers flowing to the south marshes. Mean annual water inflows of Tigris River for the period (1930 – 2004) is 48.0*10^3 m^3 (World bank, 2006). Catchment area of Tigris River at Faysh Khabur 46700km (Harza et al., 1958), catchment area at Baghdad Sarai 134,290km^2 (Susa, 1963).

1.3. Baghdad Sarai inflows

Baghdad Sarai inflows depending on Tigris River upstream and downstream Samarra (Figure 3).

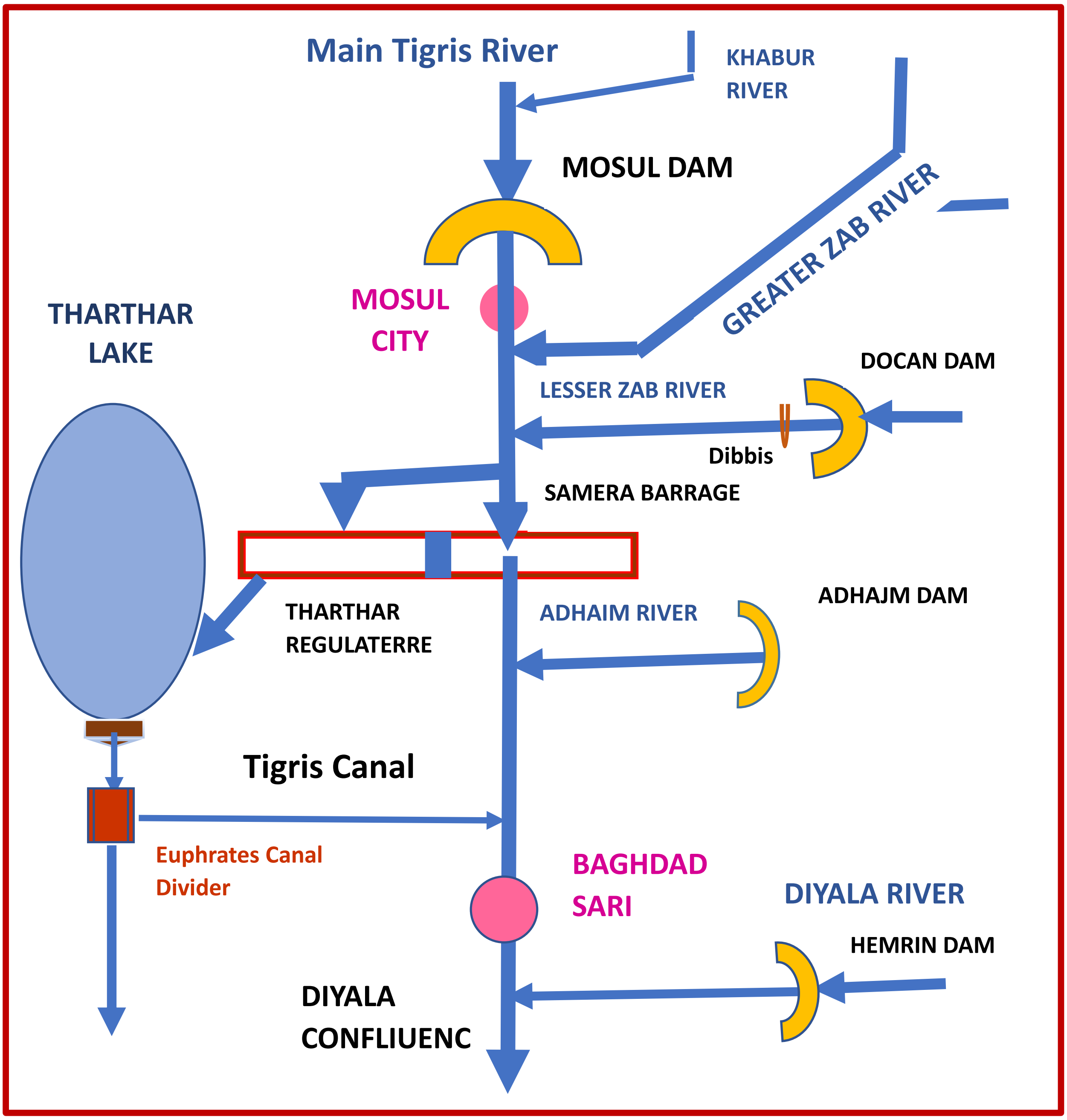

Figure 3: Schematic diagram for Tigris River inflows to Baghdad Sari station

1.3.1. Inflows downstream Samarra, includes downstream Samarra flows, (downstream Samarra barrage after 1956) (M. Abdulridha et al,. 2017), Adhaim River flows before 1999, (Adhaim dam releases after 1999) and Tigris – Euphrates canal (added after 1977).

1.3.2. Inflows upstream Samarra, includes inflows before 1954 (before Samarra complex were operatored), were natural flows coming from Tigris river and tributaries catchment area, after 1954 (Samarra barrage put into operation), the inflows were regulated by the dams water releases of Tigris tributaries at Turkish water-shed catchment area, out flows of Mosul dam after 1986, inflow of greater Zab river (Qais A., 2009), out flows downstream Docan Dam after 1959 (A. Susa, 1966), part of the upstream Samarra flows diverted to tharthar lake.

1.4.Dam construction on Tigris River and tributaries

1.4.1. Major hydraulic infrastructure, in Iraq.

A series of dams and barrages, completed before 1986, (Docan dam, derbendikan dam, and Samarra barrage).

Dams put into operation after 1986 were Mosul, Hemrin, and Adhaim dams. Dams construction located in the left side of Tigris River and tributaries are from Iranian catchment area.

1.4.2. Dams' construction eastern side of Tigris River and tributaries (from Iranian catchment area).

Dams' construction are still in progress for all rivers flowing to Iraq areas at the eastern side of Tigris river to cover all the rivers crossing the Iraqi-Iran common border and divert the rivers water to inlands area, most of the planed dams and structures were completed causing a catastrophic impact on agriculture projects and migration of the population living in the water shed in Iraq areas of the tributaries, Lower Zab river areas (Iraqi Civil Society S.I, 2021), Diyala River areas (Iraqi civil society S.I, 2021), dryness of lack Hemrin Dam areas (Rudaw, 2022). Dryness of most marshes south Iraq region (W. CRISP, 2023), dryness of all agricultural areas, loss of biodiversity and aquatic life besides the migrating of international birds to another countries.

1.4.3. Historical development of the Turkish GAP project

The investigation commenced in Euphrates River in 1936 by directives of Mustafa Kemal Ataturk, the founder of Turkish Republic, flow monitoring stations were established for Euphrates and Tigris River in 1935-1936, respectively.

In 1954 "Basin Preliminary Survey Report" involving whole basin were prepared. In 1966 Keban Dam funded and put into service in 1974.

The Gap Project become one of the most ambitious regional development project in the country encompassing all related sectors including power generation. The GAP was initially as a program to develop water and land resources of the region and consequently planed as a package compressing projects envisaging irrigation schemes and hydraulic power plants in the Tigris and Euphrates basins, the package includes 22 Dams (13 Dams on Euphrates and 9 on Tigris River branched) (M. Kankal et al., 2016).

Concerning Tigris River, 7 dams are put into operation (Figure 4), the largest dam is Ilisu dam, with live storage (7.46 BCM), total storage (10.4 BCM), and 135m high with 6 generators, the first was commissioned on 19 May 2020 (Nakoeniz & Nural company, 2015). The Ilisu dam operates with the diversion Cizra Dam (located 45km downstream).

The Turkish retention capacity, operative and under construction is approximately 14 BCM from large dams, sufficient to consume all the river water from Turkey (H.A. Hussein & A.H., 2022).

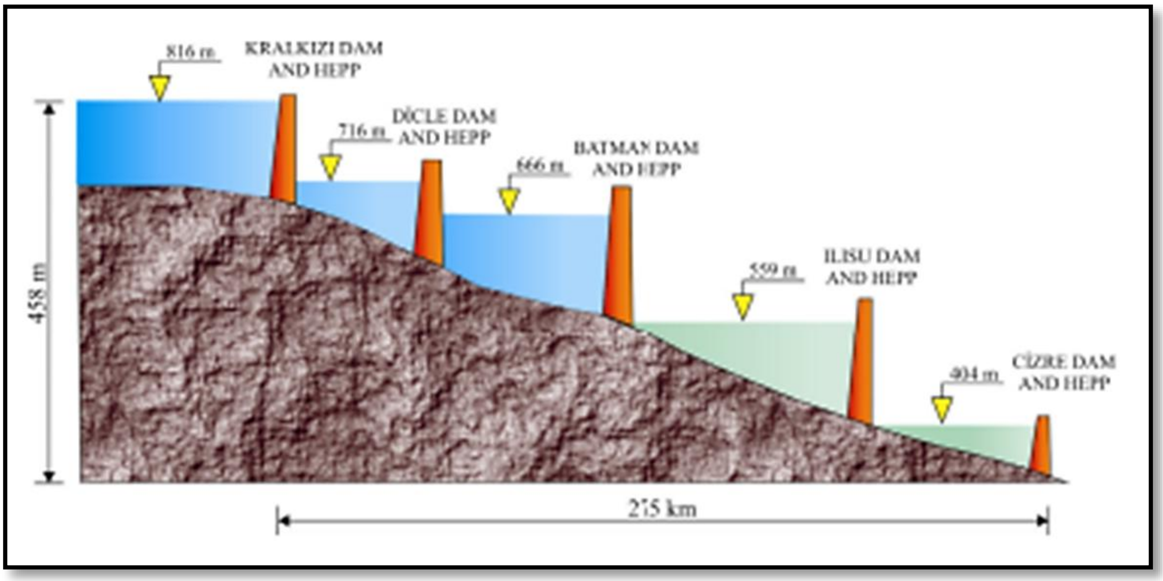

Figure 4: Tigris main dams in Turkey.

1.4.4. Morphology of Tigris River downstream Baghdad Sarai.

In recent years, substantial changes have occurred to Tigris River morphology upstream and downstream Baghdad Sarai formation of large islands, falling debris of bridges during the wars after 1991, structures erected inside the river for bridge maintenance, sunk of steel boats during high flood seasons, which causes a back water curve downstream Baghdad Sarai and poor estimation of discharge measurements (Ministry of irrigation, 1976). Also, during high flows a whirlpool is formed at the left side of the river with 20m in diameter next to Baghdad Sarai wall, forming an opposite flow direction which must be consider when the flow is calculated, Diyala River floods usually gives arise in Tigris water level causes extra back water curve downstream Baghdad Sarai gauging station (Figure 5).

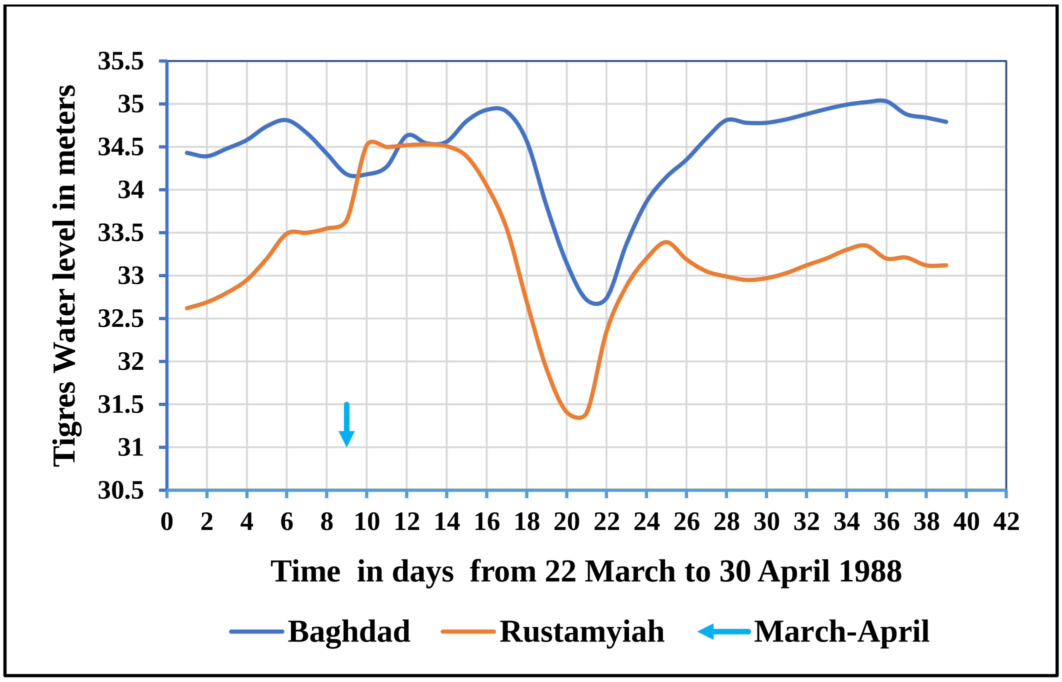

Figure 5: Sarai - Rustamiya Tigres water level 1988 flood.

1.4.5. Climatic changes

Climatic changes have a major impact on water resources (Jasim et al., 2025) (Fouad H. Saeed, 2025) and due to that, Tigris River at Baghdad Sarai station during the period between year 2000 and the following years recorded the minimum stream inflows and minimum gage water levels, these observed never recorded after 1986 (date of Mosul dam put into operation) (A. A. Ali et al., 2012). Table 1 includes the recorded values.

Table 1: Minimum water level and discharge for Tigris River at Baghdad Sarai station (1986-2023)

Year	Water level (m ASL)	Discharge (m^3/s)
2000	27.36	310
2001	27.26	290
2002	27.16	280

2. Materials and methods

2.1. Tigris river bed level and discharge estimation at Bagdad Sarai

Tigris River cross sections at Baghdad Sarai were measured for the period (1974-2008) (A. A. Ali et al., 2012), year 2020 is added (Natural center for water resources management, 2023) as shown in Figure 6. Tigris river bed level is always rising due to continuous sedimentation during flood seasons, which indicate a decrease of the capability to pass high flows for future probability floods (1954, level 36.0 discharge 7100m^2/sec level 35.0 discharge 3050 for 1988.

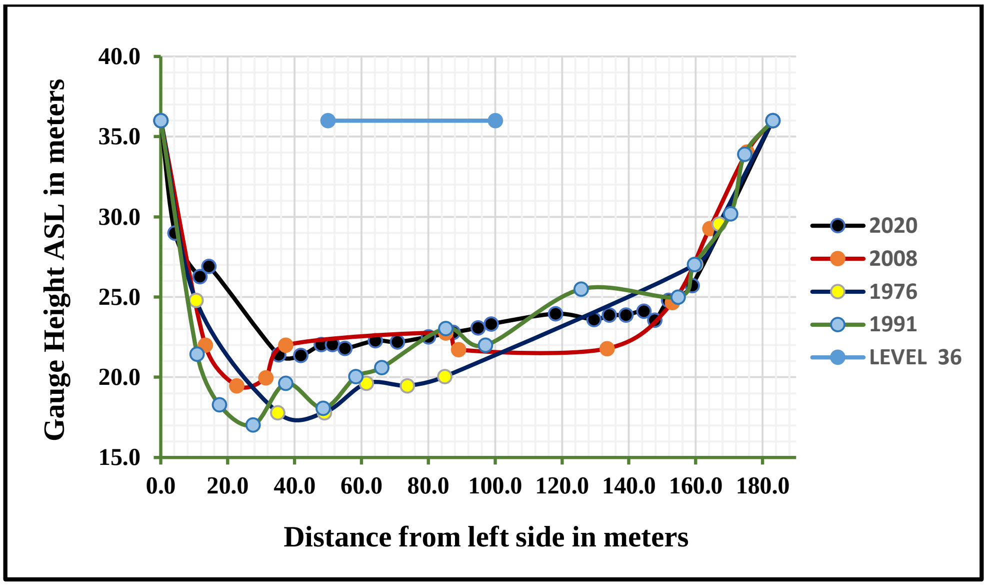

Figure 6: Tigres River cross sections at Baghdad Sari.

2.2. Discharge calculation from Manning's formula

Discharge measurements during Diyala river floods requires to install staff gauges between diyala river confluence with tigris river at Rustamiya city, and downstream Baghdad sari station. Surface water level between two gages will represent the slop of Tigris River. Discharge estimation is calculated from Manning's formula (Ven Te Chow, 1959).

$$Q = \frac{1}{n} R^{2/3} S^{1/2} A \qquad \text{(SI units)}$$

Where: Q = Discharge (m^3/s)

n = Manning coefficient ≈ 0.034 for natural rivers.

P = Welted parameter* of the cross section (m)

S = Surface water slope (Average reading between two gage levels)

A = Average cross section area of Tigris river between the selected gauge heights.

R = hydraulic radius = A/P

2.3. Rating curve discharge estimation

To estimate river flow for a given gauge, level of Tigris River it is required to get a rating curve formula for any selected period, the recommended formula usually used is:

$$Q = c(H - a)^n$$

Where: Q = Discharge (m^3/s)

H = Water level in meters.

c, a, n = Coefficient to be estimate.

Procedure to get a rating curve:

a. Field discharge measurements for different gauge levels as many as possible.

b. Plotting the discharges and the related gauge height on a sheet of graph paper.

c. Estimation of the rating curve formula:

There are many regression equations to be selected to fit the relation between measured discharge and related water level gauge height the familiar formula,

$$Q = c(H - a)^n$$

Where: Q = measured discharge

H = Gage high of river water level.

c, a, n = Coefficient to be estimate.

The recommended procedure will be explained as follows (Q. AL-Shahrabaly, 1971) (Figure 7):

$$Q = c(H - a)^n$$

$$\log Q = n \log(H - a) + \log c$$

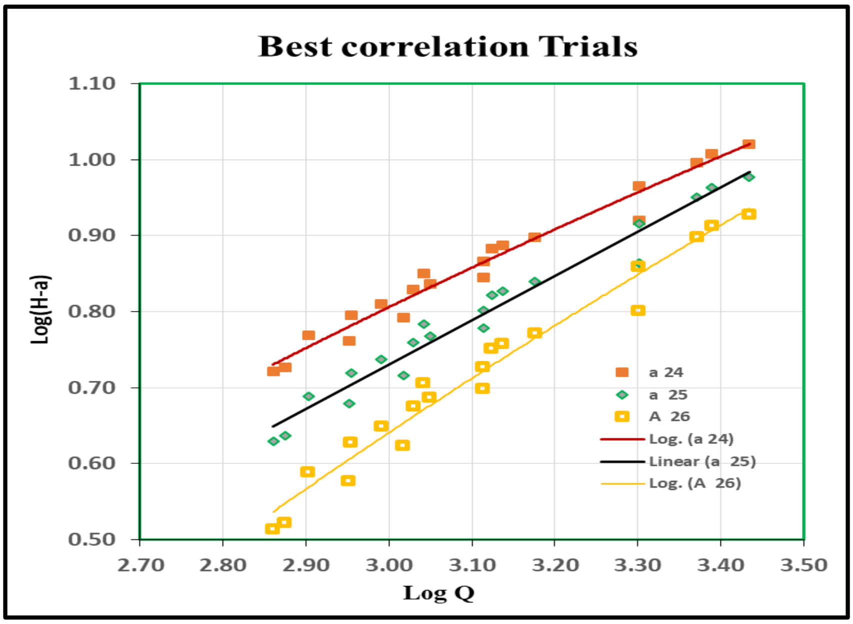

Figure 7: Baghdad correlation curves year 1988.

Plotting log $(H - a)$ on vertical X-axis and $\log(Q)$ on horizontal axis with ordinary graph sheet for all measured discharges and related gauge height some trial values for (a) is required depending on the lowest probable bed level (Fig 8). The selected trial values (for a = 24, 25, 26). Each trial will give a graph. From these graphs it is clear that the lower part of the curves, a = 24 concaved upward, for a = 26 concaved downward for value of a = 25 the curve is forming a straight line, a straight line is fitted through the points for best fit.

d. Selecting two points on the trend line for $\log(Q)$ $(H - a)$, (a = 25). The coefficient value are n = 2.25 and c = 23.2

$$Q = 23.2(H - a)^{2.25}$$

(Note: This equation depending on discharge measurement for year 1988)

(Max. recorded measured in March 1988 2819m^3/s at level 34.43m).

2.4. Analysis of Tigris River inflows

2.4.1. Tigris river average yearly total inflows Tigris river to all inflows includes all Tigris River tributaries inflows to its main river valley which includes upstream flows at Mosul city, greater Zab river, lesser Zab river, adhaim river, and Diyala river (Figure 8). A trend line is drawn which shows a negative rotation* decreasing from the left side of the graph to the wright side. Also a hydrograph for Baghdad sari is presented in (Figure 9). The hydrograph is divided into four period, Table 2, the first period is the average yearly inflows before construction of large dams at Tigris River and its trituration.

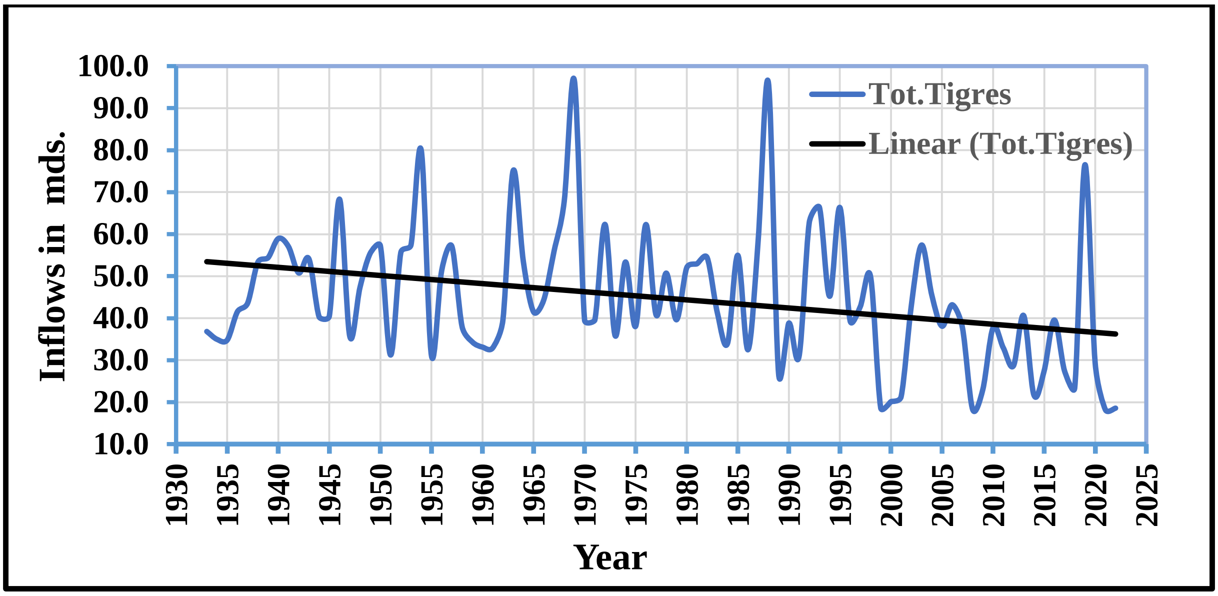

Figure 8: Total yearly inflows for Tigres River.

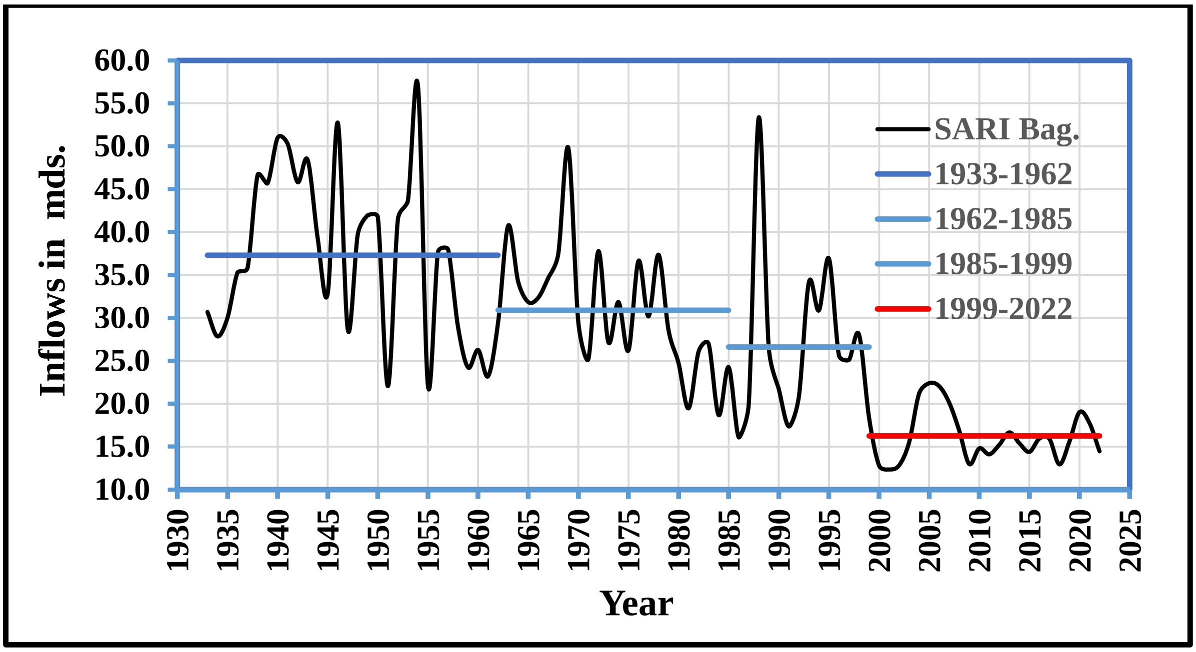

Figure 9: Yearly inflows for Tigris River at Baghdad Sari.

Table (2): average yearly inflows of Tigris River at Baghdad Sarai for selected periods from 1933-2022.

Period	years	Average inflow ($10^9 m^3$)
1	1933-1962	37.28
2	1962-1985	30.88
3	1985-1999	26.62
4	1999-2022	16.24

The second period is after construction of samara Barrage, Docan dam and derbendikan dam. The third period is after completion of Mosul Dam and Adhaim Dam. The fourth period is period of climatic impact changes on Tigris river before putting Ilisu Dam into operation.

Impact of climatic changes includes part of the 3rd period for years 1991 and 1992, after the flood of 1988 (with peak discharge 3150m^3/sec at Baghdad sarai station) (Qais A., 2008).

Yearly average flow for 1991 and 1992 were 18.98mds. and 20.84mds. both years are below two third of grand mean yearly inflow of Tigris river at Baghdad sarai. The decrease in mean yearly flows for the 2nd and 3rd period and part of the fourth period come from the storage of river flow upstream, Iraqi dams for Tigris River and tributaries.

3. Climatic changes impact on river flows

3.1. Global climatic changes

Climatic change describes a change in the average conditions - such as temperature and rainfall – in a region over along period of time NASA scientists observed earth's surface is warning and many of the warmest years on record have happened in past 20 years (Susan callery, 2023). The hottest on record 2016.

The current warming trend is started since mid- 1805, it is clearly the result of human activities to produce atmospheric gases that have trapped in the earth system. This extra has warmed the atmosphere, ocean, and land. Most of the warming occurred in the past 40 years with seven most resent years being the warmest, the years 2016-2020.

Global temperature are likely to surge to record levels in the next five years, there is 60% likelihood that the annual average near-surface global temperature between 2023 and 2027 will be more than 1.5°C above pre-industrial levels for at least one year as indicated in Figure 10). There is 98% likelihood that at least one of the next five years period will be the warmest on record (WMO, 2023).

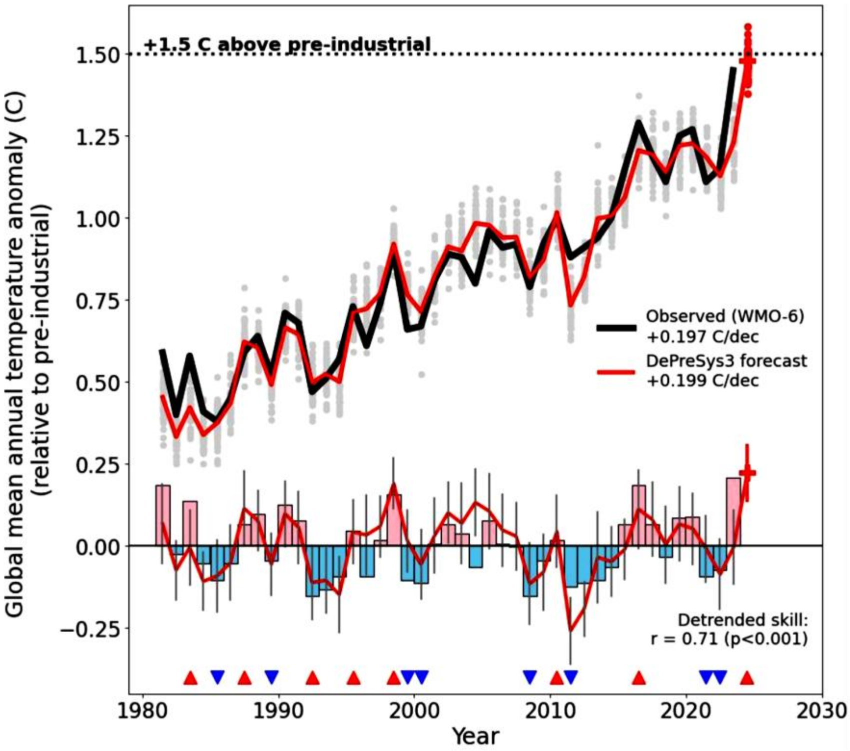

Figure 10: Variability of the global mean annual temperature (1981–2023) (Dunstone et al., 2024).

3.2. Impact of climatic changes on Tigress River at Baghdad Sarai

According to the PCI, Iraq's rainfall concentration is highly erratic, as the studies demonstrate. In the 40-year span from 1980 to 2019, RVI notes that 2017 and 1983 were exceptionally dry years, whereas 2018 was a particularly wet year. (Aleedani et al., 2024) which can be predicated, Tigris River flows at Baghdad Sarai will continue with drought conditions for the next coming years.

3.3. Probability of Future River flows at Baghdad Sarai

Estimation of future river flows for the available recorded data for Tigris River at Baghdad Sarai period for the 1999-2022, Gumbel EVE III distribution is selected for this estimation (Ven Te Chow, 1964).

Gumbel and Pearson selected 34 streams at U. S. areas, they found Gumbel III distribution equally well and more representative of the probability distribution of low flows than either 3 parameter Log-Normal or Pearson type V distribution, cumulative probability (N. C. Matalas, 1963) (a plot* were made for the flows of the rivers on Gumbel extreemal* probability paper and the result were vary suitable) (S. Kotz, S. Nadarajah, 2000).

3.3.1. Type III extreme value distribution

The type III extreme value distribution (EV3 or Gumbel III or Log Gumbel) describing the distribution of smallest value can be written as:

$$p\ (\underline{X} \geq X) = \text{Exp}\ (-\left(\frac{X-Ɣ}{β-Ɣ}\right)^{\alpha}) \qquad \ldots\ldots\ldots\ldots (1)$$

And its Density Function as

$$p'\ (\underline{X}) = \frac{α}{β-Ɣ}\left(\frac{X-Ɣ}{β-Ɣ}\right)^{\alpha-1} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where β, Ɣ, and α are parameters to be estimated.

In these two equations the recorded events are arranged in order of decreasing magnitude with m being 1, for the maximum event.

The probability of accidence* is given as

$$1-\ \frac{1}{T_r} = \frac{m}{n+1} \qquad \ldots\ldots\ldots.. (3)$$

Where: m = event order.

n = number of events.

T_r = return period in years.

The mean μ and variance $σ^2$ are given by

$$μ = Ɣ + (β - Ɣ)Γ\ (1 - \frac{1}{α}) \quad \ldots\ldots\ldots.. (4)$$

$$σ^2 = (β - Ɣ)^2\ \left(Γ\left(1 + \frac{1}{\alpha}\right)\right) + Γ^2(1 + \frac{1}{\alpha}) \ldots\ldots\ldots\ldots (5)$$

Where: β = location parameter.

α = scale parameter.

Ɣ = lower bound vale.

3.3.2. Probability estimation for future Baghdad Sarai minimum flow to estimate minimum probable flows at Baghdad Sarai, two methods are proposed:

3.3.2.1. External Gumbel probity paper.

A plot of the event value on the (Y) axis and the probability on the (X) axis, equation (3), gives a line its lower part shall be concaved up warred on down warred. Several trials required to adjust this line by selecting a value proposed* subtracted from the event values to release the lower part curve Cher, the best value of C is when we get a straight line.

3.3.2.2. Using frequency factor table of Gumbel type III external distribution.

The formula to be used to estimate the external value of an event as follow:

$$X_{tr} = \bar{x} + K_{tr} \cdot S$$

X_{tr} = event estimate value for drought tr value (m^3/s).

$\bar{x}$ = mean value for the given data (m^3/s).

S = standard deviation for the data.

K_{tr} = is frequency factor for type III external distribution selected from Gumbel external tables for each tr value.

tr = return period of time in years.

3.3.2.3. Baghdad Sari probable draught estimation.

The main parameters of the recorded discharge data at Baghdad Sari for the period 1999-2022 as follow:

Coefficient of skewness* = 0.73 m^3/s.

Standard deviation = 94.28 m^3/s.

Mean = 516 m^3/s.

n = number of years of the data = 24 years.

Estimation of drought values for selected return periods are presented in table (3), these estimation of the drought data in this table are suitable for the Tigris River flow data recorded before Ilisu Dam put into operation at year 2022. After this data the expected drought values will be less than what is estimated in Table 3.

Table 3: Probable drought flow of Tigris River at Baghdad Sarai station

Return period in years	Frequency factor	Draught value (m^3/s)
2	-0.1275	503
5	-0.8921	431
10	-1.1989	402
20	-1.3992	384
50	-1.568	368
100	-1.651	360

4. Conclusion

1. Discharge measurements made from a steel boat connected to a steel cable connect to towers erected* on both sides of Tigris River and water level read from staff gauges and from water level recorder above water level 30.2 GTS. The boat sunk in Tigris River during the flood of 1988 and no discharge measurement were made until 2007, ADCP equipment used for Tigris River flow measurement at Baghdad Sarai and other station.
2. Rating curves of Baghdad Sarai station are unstable during all years even in the same year during flood years. The rating curve are based on least – square statistical analysis of the form $Q = C\,(H\text{-}a)^b$.

   Also, the cross section of the river is unstable due to sedimentation during flood years at river bed and erosion during other years, besides formation of many island. There are many other causes, such as falling structure and sunk steel boats which caused a decrease in cross section capability to pass a high flood flows, the estimated maximum permissible discharge in the future does not exceeds $3000m^3/s$ at Baghdad Sarai water level 35.0GTS.
3. Tigris river yearly flows at Baghdad Sarai are in a continuous decrease starting from 1954 down to 2023 due to:
   a) Continuous construction of dams on Tigris river tributaries within Turkish and Iranian catchment areas.
   b) Climatic changes for the period 1999 – 2022 which caused a lowest flows for the recorded data.

   The Tigress river flows will continue in a drought condition for the next 5 years. According to NASA and other world* metrological organizations global temperature between 2023 and 2027 will be more than 1.5°C above pre-industrial* levels for at least one year of the next five years period will be the warmest on record.

4. The probable future flows at Baghdad Sarai (considering Gumbel type III extreme value distribution), for 5 years return period estimated 431m^3/s and with 10 years return* period equal to 402m^3/s.

5. Recommendations

The cross-section of the Tigris River is highly altered due to coving resulting from high flows in some months and deposition in other months. Thus, the recommendation:

1. Regional cooperation for managing the Tigris River waters
2. Adopting drought adaptation plans
3. The necessity and importance of enhancing meteorological and climate monitoring
4. It is necessary to use advance programs including the regulated of all upstream Samarra and downstream flows to predicts the possible flows at Sarai Baghdad.
5. The probable flood and drought flows and water level cannot predict for future years depending on classical methods. Thus, it is necessary to use the real programed flows from all upstream dams to predict the expected flows at Baghdad Sarai flows.
6. Evaluating the accuracy of information related to water released from all dams and the recorded data taken from hydrological data of the Tigris River and its tributaries to be used in an advanced program of related hydrological studies.

Reference

Abdulridha, M., & Hyder, A. (2017). Hydraulic analysis of the Samara Al-Tharthar system. *Journal of Engineer*, November 2017.

Aleedani, F. Y., Albattat, M. Q., & Badr, J. M. (2024). Rainfall repercussions: Assessing climate change influence on Iraq precipitation patterns. *Al-Kitab Journal for Pure Sciences, 8*(01), 92-103.

Ali, A. A., & Al-Ansari, N. (2012, October). Morphology of Tigris River within Baghdad city. *Hydrology and Earth System Sciences*.

Al-Shahrabaly, Q. (1971). The accuracy of stream flow data. Southampton University.

Callery, S. (2023). *Annual global temperature change*. NASA, Jet Propulsion Laboratory, California.

Chow, V. T. (1959). *Open channel hydraulics*. McGraw Hill Book Company, Inc.

Chow, V. T. (1964). *Handbook of applied hydrology*. McGraw Hill Book Company, New York, Sec. 8.

Crisp, W. (2023, January). After come back, southern Iraq marshes are now drying up. *Yale Environment*.
Dunstone, N. J., Smith, D. M., Atkinson, C., Colman, A., Folland, C., Hermanson, L., & Scaife, A. A. (2024). Will 2024 be the first year that global temperature exceeds 1.5°C? *Atmospheric Science Letters, 25*(9), e1254.
Harza, B. (1958). *Discharges for selected gaging station. Iraq*. May 1958.
Hussein, H. A., & Alshami, A. H. (2022, June). Hydrological characteristics of the Tigris River at Baghdad Sarai station. *Hydrological Characteristics Journal*.
Iraqi Civil Society S.I. (2021). Diyala in catastrophic situation, most farmers leave their farmland due to drought. *Sulaimanyah Conference*, July 2021.
Iraqi Civil Society S.I. (2021). Fears of disappearance of lower Zab. *Sulaimanyiah Conference*, July 13, 2021.
Jasim, M., & Kareem, I. R. (2025). Estimate the actual evaporation of Lake Habbaniyah under conditions of changing climatic conditions. *Journal of Water Resources and Geosciences, 4*(1), 45-57.
Kankal, M., & Nacar, S. (2016). Status of hydropower and water resources in southeastern Anatolia project (GAP) of Turkey. *Energy Reports*. Elsevier.
Kotz, S., & Nadarajah, S. (2000). *Extreme value distribution*. Imperial College Press, London.
Matalas, N. C. (1963). Probability distribution of low flows. U.S. Department of the Interior, P.P. 434-A, P. 6132.
Ministry of Irrigation, Directorate General of Irrigation. (1976, August). Discharges for selected gaging station in Iraq. *Ministry of Irrigation Reports*.
Nakoeniz, N. (2020, May). 1st turbine of Ilisu dam has been commissioned. *Nural Company*.
Natural Center for Water Resources Management, Water Control Section. (2023, June). *Water Resources Management Report*.
Qais, A. (2008). *River discharges for Tigris and Euphrates gaging station. Ministry of Water Resources*. March 2008.
Qais, A. (2009). *Water resources management study. World Bank, Middle East and North Africa region*. March 2009.
Rudaw. (2022, May). Lake Hemrin in Iraq dries up threatening lives. *Rudaw*.
Saeed, F. H. (2025). Forecasting of irrigation water requirements in Wasit Province under climate change conditions using LARS-WG and CROPWAT-8 models. *Journal of Water Resources and Geosciences, 4*(1), 204-216.
Susa, A. (1963). *Baghdad floods in history (Part 1).* Al-Adeeb Press.
Susa, A. (1966). *Baghdad floods in history (Part 3).* Al-Adeeb Press.
Susu, A. (1965). *Baghdad flood in history (Part 2).* Al-Adeeb Press.
World Bank. (2006). *Iraq country water resources assistance strategy*. Middle East and North Africa. April 2006.
World Meteorological Organization. (2023). *Issues of World Meteorological Organization*. Geneva.