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Minimum Instream Environmental Flow in Shatt Al-Hillah River

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ABSTRACT

To maintain river flows necessary to meet social and ecological objectives, instream environmental flows are frequently used as a strategy. The capability of three alternative historical flow approaches to protect against low flows is shown in this study using gage stations in the Shatt Al-Hillah River in Iraq. The extension of the Shatt al-Hillah River is the focus of this research discussion on environmental flow assessment. The available data on discharge in this research were adopted for ten years from 2012-2021. Different flow methods were adopted to establish a minimum environmental flow in the Shatt Al-Hillah River. Three hydrological-based approaches: Tennant, modified Tennant, and low-flow metrics like 7Q10, were used to compare the results of the methods with the provision of a minimal environmental flow. The Tennant method relies on 30 % of the annual discharge rate as the minimum environmental instream flow. The modified Tennant method is based on 30% of the monthly average discharge rate as a minimum environmental instream flow. The 7Q10 method is based on the lowest daily discharge rate in 7 consecutive days for ten years. The results showed that the minimum instream environmental flow given by the Tennant method is 42.26 m^3/s while the lowest value of the minimum instream environmental flow obtained from modified Tennant was 37.2 m^3/s in January, and the largest value was 47.22 m^3/s in August. The one obtained by the 7Q10 method was 50 m^3/s in this research.

Keywords: Historical flow, Environmental Flow, Shatt Al-Hillah River.

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الحد الأدنى من التدفق البيئي لنهر شط الحلة

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الخلاصة

من أجل الحفاظ على تدفقات الأنهار الضرورية لتلبية الأهداف الاجتماعية والبيئية ، كثيرًا ما تستخدم التدفقات البيئية أثناء التدفق كاستراتيجية. تم توضيح قدرة ثلاثة مناهج تدفق تاريخية بديلة للحماية من التدفقات المنخفضة في هذه الدراسة باستخدام محطات القياس في نهر شط الحلة في العراق. امتداد نهر شط الحلة هو محور هذا البحث حول تقييم التدفق البيئي. تم اعتماد البيانات المتوفرة عن التصريف في هذا البحث لمدة عشر سنوات من 2012−2021 تم اعتماد طرق تدفق مختلفة لإنشاء الحد الأدنى من التدفق البيئي في نهر شط الحله. ثلاثة مناهج هيدرولوجية: Tennant، Tennant المعدلة ، ومقاييس التدفق المنخفض مثل 7Q10 ، تم استخدام طرق لمقارنة نتائج الطرق مع توفير الحد الأدنى من التدفق البيئي. تعتمد طريقة Tennant على 30٪ من معدل التفريغ السنوي باعتباره الحد الأدنى لتدفق التدفق البيئي ، وتعتمد طريقة Tennant المعدلة على 30٪ من متوسط معدل التفريغ الشهري كحد أدنى للتدفق البيئي أثناء التدفق ، وتستند طريقة 7Q10 على أدنى مستوى يومي. معدل التفريغ في 7 أيام متتالية ولمدة عشر سنوات.أظهرت النتائج أن الحد الأدنى للتدفق البيئي الناتج عن طريقة Tennant هو 42.26 م^3 / ثانية بينما أقل قيمة للحد الأدنى للتدفق البيئي الناتج من Tennant المعدلة كانت 37.2 م^3 / ثانية في كانون الثاني وأكبر قيمة كانت 47.22 م^3 / ثانية في آب ، والذي تم الحصول عليه بطريقه 7Q10 كان 50 م 3 / ثانية في هذا البحث.

الكلمات المفتاحية: التدفق التاريخي ، التدفق البيئي ، نهر شط الحلة.

1. INTRODUCTION

Rivers offer various crucial ecosystem services to society, including the advantages humans derive from ecosystems, such as supplying, controlling, sustaining, and cultural services **(Assessment, 2005; AL-Zaidy and AL-Thamiry, 2020)**. The necessity to maintain stream flow became apparent during naturally low flow or after human activity (e.g., consumption for personal or business use, irrigation diversions, or energy production).On the other hand, there is a growing public awareness of the need to conserve and maintain aquatic resources and a growing water demand, particularly during dry spells similar to those in numerous New Brunswick neighborhoods in the summer of 1994. On the other hand, they have mandated that water managers exercise caution while determining and allocating the stream flow that is available the idea of a minimum or maintenance flow was developed by hydrologists, engineers, biologists, and managers of water resources to solve this problem **(Wesche and Rechard, 1980)**. The most advanced techniques for determining the instream flow needs of aquatic species are thought to be the habitat preference approaches.

With regard to the impacted and/or researched species, these methodologies take into account some biological variables in addition to assessing hydraulic and hydrologic aspects **(Caissie and El-Jabi, 1995b)**. Instream environmental flow criteria can be chosen using a wide range of techniques, such as those that are depending on the physical environment, hydraulic conditions, or historical flow **(Jowett, 1997).** Nevertheless, instream environmental flow regulations are employed as a tool for management throughout the world and in the United States, there have not been many studies looking at how well the different standards prevent low flows. An innovative method of assessing how well such criteria protect low flows is to compare actual flow data to imaginary instream environment flow thresholds. Since minimum flow guidelines are only based on historical flow **(Praskievicz et al., 2018, Abbas et al., 2019)**. Many states, including several of Alabama's neighboring states, have set their instream environmental flow criteria using historical flow techniques. Instream environmental flow requirements in Georgia give applicants for permits the option of a monthly 7Q10 (low flow of seven days with a ten-year recurrence interval), a site-specific flow analysis, or a temporary modification of the Tennant strategy based on percentages of mean monthly Georgia has a rather strict withdrawal regulation regime, therefore these limits are enforceable **(Praskievicz et al., 2018).**

This work aims to compare three popular instream flow models with hydrological foundations. Measurement methods and the purpose of this research are to:

1) Use three hydrologically based approaches to determine the minimum instream environmental flows in the Shatt Al-Hillah River.
2) Contrast the outcomes of the various approaches investigated.
3) Suggest new methods based on the findings of the current study.

2. METHODS

This part includes clarifying the description of the study area, the historical methods used to calculate the minimum instream of environmental flow, and the results obtained and discussing those results. The research area is located between longitudes (43º 42'E: 45º 50'E) and latitudes (32º 7' N: 33 º 8'N) in Babylon Governorate, Central Iraq, as depicted in **Fig. 1**. The Babylon Governorate covers a total area of 5119 km^2, about 1.3% of Iraq's total land area **(ALZubaidi, 1974, Mosawi and Al Thamiry, 2022)**. Waterway Shatt Al-Hillah is 100 km long in the Babylon Governorate. It flows southeast through the province of Babylon and into the province of Al Diwaniyah **(Al-Ibrahimi and Ghalib, 2018)**. Shatt Al-Hillah is a crucial water supply in Babylon, where it flows through a huge area and is separated into various rivers and streams **(Manea et al., 2019, Alsaadi and AL-Thamiry, 2022).** Daily, monthly, and annual discharge data for Shatt Al-Hillah were provided by the Water Resources Department within Babylon Governorate for ten consecutive years from 2012-2021.

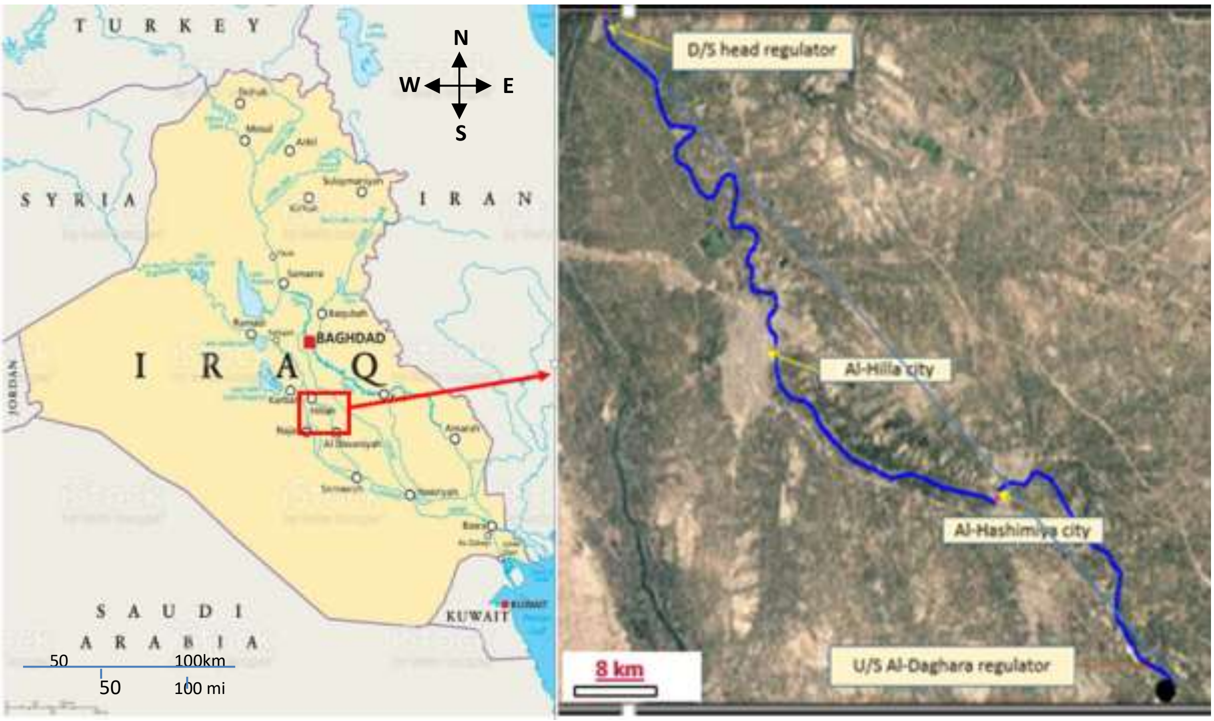

Figure 1. Location of the study area along Shatt Al-Hillah River.

3. HISTORIC METHODS

Three techniques were employed to compare hydrologically based approaches for assessing instream environmental flow in Shatt Al-Hillah River: (1) the Tennant Method; (2) a modified Tennant (based on a 30% monthly average flow), and 3) the statistically low flow frequency approach (7Q10 - a 7-day low flow with a 10-year repetition interval). As the name suggests, historical flow methods only use the river's estimated or recorded flow regime.

3.1 Tennant (1976) Method

Also called the "Montana method," it is arguably the most well-known. 16 states use or recognize it, making it the second-most widespread technique in the USA **(Caissie and El-Jabi, 1995a).** According to the Tennant technique, a certain amount of mean flow is required to maintain a healthy stream environment, as indicated in **Table 1**. Tennant looked analyzed cross-section data from 11 Montana streams. **(Orth, 1981)** believed a stream's width, depth, and velocity would be adequate for a "base flow regime" at 30% of the average flow. Tennant evaluated the physical habitat that each level of flow supplied to determine the environmental quality of each level. Fraser (1978) proposed that by expressing monthly minimum flows as a proportion of monthly mean flows, the Tennant approach might be expanded to encompass seasonal variation **(Fraser, 1978).** A minimum flow has been recommended in Denmark as a part of the median of the annual minima **(Jowett, 1997; Ubertini et al., 1996)**.

3.2 Low Flow Frequency Statistical Method (7Q10)

The minimum mean daily flow over a defined sample period of seven days is studied statistically using low-flow frequency in this method. The 7Q10 instream flow approach, employed for this investigation, was applied using values that matched the minimal flow established using a 10-year repetition time across an average of 7 days in a row. **(Chiang and Johnson, 1976; Ubertini, et al., 1996)**. The minimum 7-day low flows for each year of records were calculated to estimate the low flow with a 10-year return period. For each year of records, the minimum 7-day low flows were calculated. These values were then fitted to a low-flow distribution model **(Caissie and El-Jabi, 1995a)**. Problems with stream water quality typically necessitate using this **(Reiser et al., 1989)**.

3.3 Modified Tennant Method

This method has been used when it uses only one instream flow value, such as 30% MAF **(Annear and Conder, 1983)**. In the current investigation, the application of Tennant using only the 30% MAF is considered. To account for seasonal hydrologic variability, the modified Tennant technique, instead of annual flows, determines the 30% flow threshold for mean monthly flows **(Fraser, 1978).** The modified Tennant approach is used because instream environmental flows represent one of the choices in Georgia. The conventional Tennant technique using the exception of 30% of the mean monthly flow for the recording period is used to determine the minimum flow threshold for that month (creating twelve minimum-flow limits, one for each month), as opposed to 30% of mean yearly flow.

Table 1. The Natural flow percentages following the Montana technique ensure varying protection for fish, aquatic life, recreational purposes, and environmental aspects.

Suggested flow (% of mean annual flow)		
Flow Descriptions	Low Flow	High Flow
Flushing or maximum	200	200
Optimum range	60–100	60–100
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair or degrading	10	30
Poor or minimum	10	10

4. RESULTS AND DISCUSSION

4.1 Analysis of the Tennant Method

An environmental flow (EF) was offered following Tennant's advice. Time series data of the annual discharge were the primary factors driving the environmental flow data used to compute the annual average discharge (AAF), defined as a discharge of 140.87 m^3/s.

The available ambient flow ranges between 10% AAF and 60% to 100% AAF as ideal values. In Shatt Al-Hillah River the AAF, the ideal environmental flow the interval of 84.52 m^3/s to AAF (140.87 m^3/s) was also provided. The middle reach of Shatt AL-Hillah River's minimum discharge requirement for environmental flow is 14.09 m^3/s (10% AAF). (**Fig. 2** and **Table 2.**) lists the additional environmental benefit as categorized by Tennant.

Table 2. Environmental flow for the reach of Shatt Al-Hillah River.

Description of discharges	Recommended base	Flow regime (%)	Discharge (m^3/s)	
	Oct.-Mar	Apr.-Sept.	Oct.-Mar.	Apr.-Sept.
Average annual flow	100% average flow		140.87	
Flushing or maximum	200% average flow		281.74	
Optimum range	60% - 100%	average flow	84.522-140.87	
Outstanding	40%	60%	56.35	84.52
Excellent	30%	50%	42.26	70.44
Good	20%	40%	28.17	56.35
Fair or degrading	10%	30%	14.09	42.26
Poor or minimum	10%	10%	14.09	14.09
Severe degradation	10% average flow	to zero flow	14.09-0.00	

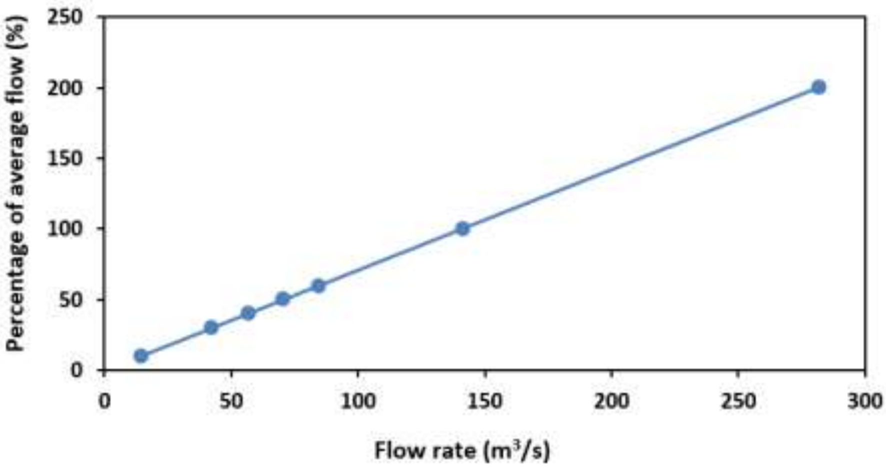

Figure 2. Variation of average flow percentage with flow rate using Tennant method.

4.2 Analysis of Modified Tennant Method

An environmental flow (EF) was offered in accordance with modified Tennant's. Time series data of the monthly discharge were the primary factors driving the environmental flow data used to compute the average monthly Flow (AMF) (After multiplying the discharge values 30% AMF). It was founded that the lowest value of the minimum instream environmental flow is 37.2 m^3/s in January and the largest value of minimum instream environmental flow is 47.22 m^3/s in August. (**Fig. 3** and **Table 3**) lists the additional environmental benefit as categorized by modified Tennant.

Table 3. Monthly average flow values for discharge by modified Tennant during 10 years (2012-2021).

Months	Average monthly flow
January	37.2
February	38.67
March	45.39
April	37.23
May	37.63
June	44.31
July	47.04
August	47.22
September	42.84
October	42.21
November	46.59
December	40.98

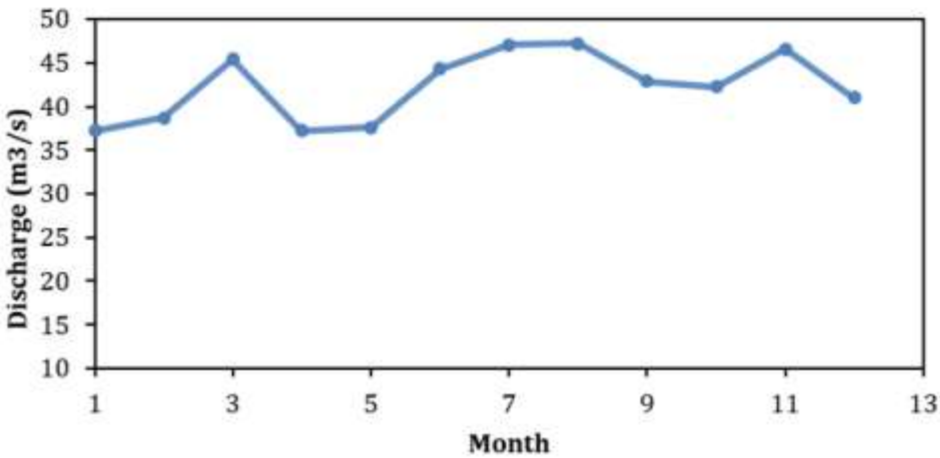

Figure 3. Variation of monthly average discharges using modified Tennant method.

4.3 Analysis of the 7Q10 Method:

An environmental flow (EF) was offered in accordance with the 7Q10 method. Time series data of the daily discharge were the primary factors driving the environmental flow data were used to compute minimal average daily flow throughout a specified sample period of 7 consecutive days with constant discharge for 10 years. It found the minimum value was 50 m^3/s in 2013 and 2014. **Fig. 4** shows the values of discharge in 7Q10.

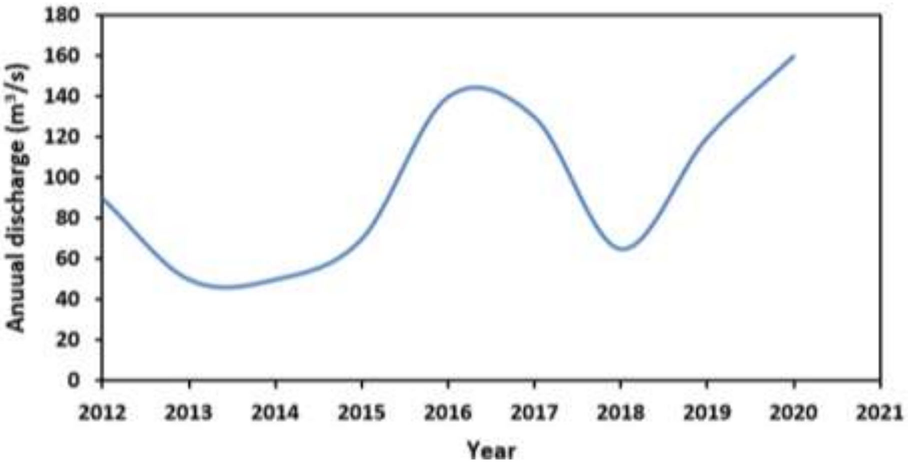

Figure 4. Variation of the annual average discharges using 7Q10 method.

5. CONCLUSIONS AND RECOMMENDATIONS

Although the Shatt Al-Hillah River has significant ecological importance, its biodiversity is in danger due to the unknown future water supply, rising habitat changes, low flow rates, and water demand. To maintain and restore aquatic life, the instream environmental flow limitations must be updated for Shatt Al-Hillah River, which was established in accordance with the country's water policy. The following conclusions can be drawn from this study:

1- The three methods used to find the minimum instream environmental flow found that the Modified Montana method gives the lowest value of the flow, which is 37.2 m3/s in January within 30% AMF is considered the worst case. As for the Tennant method, it was found that the lowest discharge value was 42.27 m^3/s within 30% AAF. In the 7Q10 method, the least 7 consecutive days of discharge were 50 m^3/s in 2013 and 2014.

2- The modified Tennant method was used based on the monthly discharge rate. It was found that during the summer, the minimum value of instream environmental flow ranged from 44.31 to 47.22 m^3/s, while for the winter, it ranged from 37.2 to 40.98 m^3/s. It was also found that the critical value of the minimum instream environmental flow in January is 37.2 m^3/s. The Tennant method was calculated based on the annual discharge rate, and the critical value was 42.27 m^3/s.

3- The minimal stream flows necessary to prevent degradation should be regarded as 30% of the monthly average flow. Higher proportions of the average annual flow might be advised for streams that are more valuable as fisheries resources. Additionally, higher percentages might have to be advised for more significant, permanent streams.

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