https://doi.org/10.26682/csjuod.2023.26.2.28
Journal of University of Duhok., Vol. 26, No.2 (Pure and Engineering Sciences), Pp 298-313, 2023
4th International Conference on Recent Innovations in Engineering (ICRIE 2023) (Special issue)

DAILY AND ANNUAL DAILY TREND ANALYSIS FOR GREATER ZAB RIVER FLOW AT DERALOK STATION

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(Accepted for Publication: November 27, 2023)

ABSTRACT

This study examines the trends in daily and annual discharge data from the Deralok station in northern Iraq over a 16-year period (2004-2019). To analyze these trends, several statistical methods were employed, including the innovative trend approach, the non-parametric Mann-Kendall test (MK), and Sen's slope estimator. Linear regression was also used to establish relationships between variables. The results of the annual discharge analysis reveal a clear increasing trend. The innovative trend method indicated positive slopes, with a value of B = 12.37, which is greater than 0. This positive trend was further supported by the Mann-Kendall test, where both tau values were positive, measuring 0.574 and 4.6, respectively, for Sen's slope estimator. Additionally, the linear regression analysis demonstrated a positive slope, amounting to 4.306 m³/year, indicating a consistent increase in annual discharge. Furthermore, this positive trend was observed across all months, from January to December. These findings collectively suggest a notable upward trend in discharge over the study period, with statistical evidence supporting the observed increases.

KEYWORDS: Innovative Trend Method; Mann- Kendall (MK); Estimator of Sen’s slope; Trend Analysis; Linear Regression.

1. INTRODUCTION

Water is a fundamental element for different environments which means the natural and artificial ones. These environments are provided by rivers to supply the generating fuel for different sectors life (Md. Saiful Islam et al., 2016), so study and analysing of the river flow data is one of the essential matters in water resources engineering. Because as it's known that the water resources in the world are influenced by climate changes. This means that the hydrological recorded data for long periods and many regions show significant non-stationarity under the impact of change of global climate and the activities of humans on water resources systems (A. J. Adebayo et al., 2002) and this that it's noted in most region of Iraq, so this issues must be taken under different studies especially because the rivers is the essential resource in Iraq. So, it can be said that planning and expansion of projects such as the projects of agricultural and food-producing, management of water resource mechanism, flood estimation and control methodologies, etc. (Fiaz et al., 2015) are related directly to water resources. Because the agriculture sector, pastures, livestock, and electricity generation in Deralok District is essential for peoples ' s life, therefore it's important to study the hydrological characteristics of Great Zab observed data in Deralok Station. Trend analysis is one of the hydrological characteristics that should be studied and in it is important to remember that data being analysed are uniform and free of the trend which means stationary (Adebayo et al., 2002) to build the suitable stochastic model to forecast the future flow data to control the problems of flow scarcity or flood that may be facing this region. Great Zab River at Deralok station is one of the major rivers in the north of Iraq which has good discharge along all the seasons of the year, so the availability of this good discharge is the reason behind constructing the hydropower project. This study is dealing with examining the possible trends in daily and annual time series flow of Deralok station on the Great Zab River in the north of Iraq.

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Some many studies and researches preceded this study, where they used the innovation trend approach, non-parametric test Mann-kendall test, and Sen's slope estimator that shown some of them in the literature review.

2. LITERATURE REVIEW

There exist numerous earlier studies that have employed the same trend analysis techniques, including:

(Ihsan and Younis, 2020) preformed an evaluation of the hydrological drought in the North-Eastern region of Iraq. The researchers used the stream-flow drought index (SDI) to analyze mean monthly stream-flow data, gathered from three specific gauging stations at the Greater Zab River, Lesser Zab River, and Khazir River. Utilizing the Mann-Kendall non-parametric method, they explored the trend analysis of hydrological drought, assessing the significance of the trends. Sen's slope method was applied to ascertain the slope's magnitude of these trends over a period of 47 years. The findings from the M-K method revealed diminishing trends in SDI values in the basins of the Greater Zab River and Lesser Zab River, while an increasing trend in SDI values was found to be not significant. The results suggest a growing occurrence of hydrological drought in the area under study. In the research conducted by (Veysel et al. 2022), they examined the patterns in monthly and annual stream flow values from 16 stream flow gauge stations situated within the Tigris basin, which accounts for 13% of Turkey's water resources. The investigators employed the non-parametric Mann-Kendall (MK) test to compute the monotonic trends and utilized Sen's slope method to assess the trend gradients. Additionally, they applied the innovative trend analysis (ITA) method to determine the trends in stream flow values within low, medium, and high ranges. (Mohammad et al. 2021) investigated the patterns in the Ganga River concerning the annual maximum and minimum discharges, as well as water and sediment yield during the monsoon season. To analyze these trends, the researchers employed the Mann-Kendall (M-K) test, Sen's slope method, and innovative trend analysis at various measuring sites along the river during the monsoon period. The results were subjected to significance testing at a 5% level. The findings indicated a decreasing trend in the annual maximum discharge at almost all selected locations, while conversely, the annual minimum discharge exhibited an upward trend at these measurement sites. (Özgür et al. 2017), various analytical methods, including the Mann Kendall (MK) test, Sen's method, and Şen's innovative trend method (ITM), were employed to explore potential trends in monthly stream flows. Data for this analysis was collected from nine monitoring stations situated in three basins, specifically in the regions of Yakabasi and Derecikviran within the Western Black Sea Basin. Through the application of Sen's trend analysis, the study identified a significant declining trend at the Durucasu, Sütlüce, Yakabasi, and Derecikviran stations. In contrast, the Tozköy station exhibited a noteworthy upward trend. In accordance with the ITM analysis, Tozköy Station's values in the low to medium range displayed a minor upward trend, while the same value range at Yakabasi, Derecikviran, Durucasu, and Sütlüce stations exhibited a declining trend. (Rawshan and Shadan 2019) examined the flow patterns within the Yangtze River, with a specific focus on both seasonal and annual fluctuations. They utilized analytical tools such as the Mann-Kendall (MK) test, Sen's slope estimator, and the innovative trend method (ITM). Their investigation revealed significant regional disparities in the magnitudes of both seasonal and annual temperature increases. More precisely, a more pronounced warming trend was observed in the eastern YRB (Yangtze River Basin) and the area of the Yangtze River's origin on the Qinghai-Tibetan Plateau (QTP). The study emphasized a trend characterized by increasing warmth and humidity in the southeastern and northwestern regions of the YRB, in contrast to a trend of warming accompanied by decreased moisture in the central region. (Fawaz et al. 2020) employed the non-parametric Mann-Kendall test in conjunction with Sen's slope estimator to identify trends and quantify the steepness of those trends in a 70-year dataset of rainfall data from the Sinjar District. Their analysis of the annual trend indicated an overall decline, although variations in the trend were observed across different rainy months. Specifically, their findings showed an upward trend in rainfall data for the months of October and April, while a contrasting downward trend was evident in the remaining months. (Rawshan et al. 2019) conducted a study to examine potential trends in the flow of the Yangtze River. They considered annual, seasonal, maximum, and minimum flow levels at the Cuntan and Zhutuo stations in China. Their analysis covered data from the years 1980 to 2015, utilizing the Mann-Kendall trend test and innovative trend analysis for evaluation, and employing Sen's slope method to assess the magnitude of these changes.The research findings revealed a combination of upward and downward trends in different months at the Cuntan and Zhutuo stations. To be specific, the average annual flow decreased at rates of -26.76 m^3/s and -17.37 m^3/s at the two stations, respectively. Conversely, there was a significant increase in the minimum flow, with rates of 30.57 m^3/s and 16.37 m^3/s observed. Furthermore, the maximum annual flows showed an upward trend in both areas of the Yangtze River. Additionally, the analysis of seasonal patterns indicated that these stations exhibited greater responsiveness to changes in seasonal flow. The goals of this study are understanding seasonal patterns, resources management and planning and development.

3. STUDY AREA

The current research is based on flow measurements taken at the Deralok station, which is situated in the upper part of the Great Zab River in Northern Iraq, depicted in Figure 1 at coordinates approximately 37.055° latitude and 43.646° longitude. The station records an average annual discharge of approximately 78.185 m3/sec, as reported by Ismaiel in 2018. The historical records of the daily discharge data series were sourced from the Irrigation Directorate in Duhok, within the Kurdistan region of Iraq. Specifically, the dataset covers a span of 16 years, encompassing the period from 2004 to 2019, which was chosen as a representative timeframe for forecasting changes in the discharge time series.

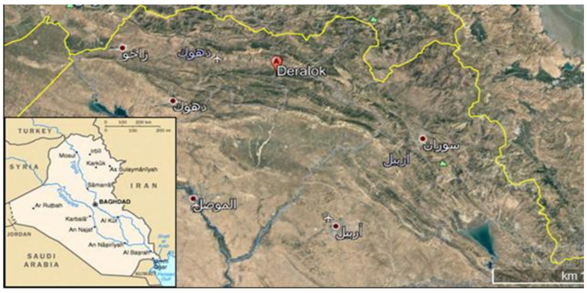

Fig.(1):-Study area location determined by GIS

4. MATERIALS AND APPLYING THE TESTS

4.1 Innovative Trend Method

The Innovative Trend Analysis (ITA) was the final method utilized in this study. ITA has previously been employed in other research to analyze hydrological, climatological, and meteorological time series data, with its reliability confirmed through comparisons with results obtained using the Mann-Kendall (MK) method. The procedure for employing ITA involves several key steps.First, the hydro-meteorological time series data is divided into two equal parts. Subsequently, both of these subseries are organized in ascending order, ensuring that both the vertical and horizontal axes have the same range. Following this, the first subseries is plotted along the X-axis, while the second subseries is plotted on the Y-axis using a two-dimensional Cartesian coordinate system (2DCCS). When the data points on the scatter plot align along the 45° line (i.e., the 1:1 line), it signifies the absence of a trend. In contrast, when the data points cluster below the 1:1 line, it indicates a negative trend within the presented data series. Conversely, if the data points accumulate above the 1:1 line, it suggests a positive trend within the series (Sen, 2012). To quantify the magnitudes of both declining and growing trends, the averages between the values of Xi and Xj at each point are computed. This trend estimator is standardized to the same scale as the MK and Sen's slope tests by multiplying it by ten. The mathematical representation is as follows in the equations:

$$B = \frac{1}{n} \sum_{i=1}^{n} \frac{10(X_j - X_i)}{\mu} \qquad (1)$$

Xi and Xj represent the observed data values in both sub-series individually, with B serving as the trend indicator, and n denoting the length of each part. In the end, the symbol represents the average of the first part. A positive or negative value of B signifies either a declining or growing trend. In cases where the observed data values in the time series are uneven (i.e., odd), the initial observation is excluded, and the series is then divided into two parts. For trend analysis of daily and annual daily discharge data at the Deralok Station, Sen's slope estimator and the Mann-Kendall method were employed. These analyses were carried out using XLSTAT version 20. Additionally, regression analysis was utilized to establish a linear relationship between the recorded discharge data and the time period over which they were recorded.

4.2 Mann-Kendall Test

The Mann-Kendall test, an non-parametric method, is commonly utilized for trend detection in time series data. Kendall extensively documented this test in 1962, while Mann did so in 1945, establishing it as a dependable approach for trend analysis. Both Mann-Kendall and Spearman's rho are non-parametric tests, offering more robust and reliable results compared to parametric tests. One notable advantage of non-parametric tests is their ability to function without strict assumptions about the data's distribution. Consequently, the test evaluates the data's relative orderings rather than focusing on their specific values, a point highlighted by Gilbert in 1987. The formula for this test is as follows:

$$S = \sum_{i=1}^{n-1} \sum_{k=i+1}^{n} \mathrm{sgn}\,(X_k - X_i) \qquad (2)$$

The xi is time series,
i = 1, 2….., n-1,
xk is from k

$$Sign(X_j - X_i) = \begin{cases} -1 \text{ for } (X_j - X_i) < 0 \\ 0 \text{ for } (X_j - X_i) = 0 \\ +1 \text{ for } (X_j - X_i) > 0 \end{cases} \qquad (3)$$

The following equation computes the Normalized test statistic:

$$Z_{mk} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, \text{ if } S < 0 \\ 0 \quad \text{if } S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, \text{ if } S > 0 \end{cases} \qquad (4)$$

In this context, the test statistic Zc is crucial, and if the absolute value of Zc is greater than the critical value Z1–α/2, where Z1–α/2 represents the standard normal variables and α denotes the significance level of the test, then the null hypothesis (H0) is disproved. The equation below provides the trend values:

$$\beta = \mathrm{Median}\left(\frac{X_i - X_j}{i-j}\right), \forall_j < i, \text{where } 1 < j < I < n \qquad (5)$$

When β is negative, it indicates a decreasing trend, and when it has a positive value, it signifies an increasing trend

4.3 Sen's Slope Estimator

Most hydrological variables observed marked partly skewness in the right as a result of the natural phenomena effect and they are not adopting a normal distribution. Moreover, (Sen, 1968) slope estimator is good to improve the linear relationships. This estimator has a benefit upon the regression slope as it does not widely affect by the gross data errors as well as the outliers. It is found to be as the whole pairwise slopes median between all pairs of points in each dataset (Helsel et al., 2002).

Any individual slope estimation is observed in the equation as shown:

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$$m_{ij} = \frac{Y_{j-} \; Y_i}{j-1} \quad (6)$$

First, estimate the slope of each (n) pair of the data series using the equation below:

$$m = m_{\left[\frac{N+1}{2}\right]} \quad if n \text{ is odd} \quad (7a)$$

$$m = \frac{1}{2}\left(m_{\frac{N}{2}} + m_{\left[\frac{N+2}{2}\right]}\right) \quad if n \text{ is even} \quad (7b)$$

Where:
i: from 1 to n-1, j: from 2 to n. and mij: The slope

When j is greater than i, the data values at times j and i are denoted as Yj and Yi. If there are n values of Yj identified in the time series, there will be a total of N slope estimates, where N equals n(n-1)/2. Sen's slope is computed as the median slope among these N slope values. A positive Sen's slope indicates an increasing trend, whereas a negative Sen's slope signifies a declining trend.

5. RESULTS AND DISCUSSION

5.1 Innovative Trend Method

The daily and annual daily discharges were tested to an innovative trend approach. For the Deralok stations, the ITM findings are displayed in Fig. 2. Figure 1 shows an increasing trend in annual daily discharge which the value of all points is above the 1:1 line and that can consider as indictor to the positive trend in the data. From value of B = 12.37, which is more than 0 can say the trend is positive. The value of B for the daily and annual daily discharge is shown in Table 1.

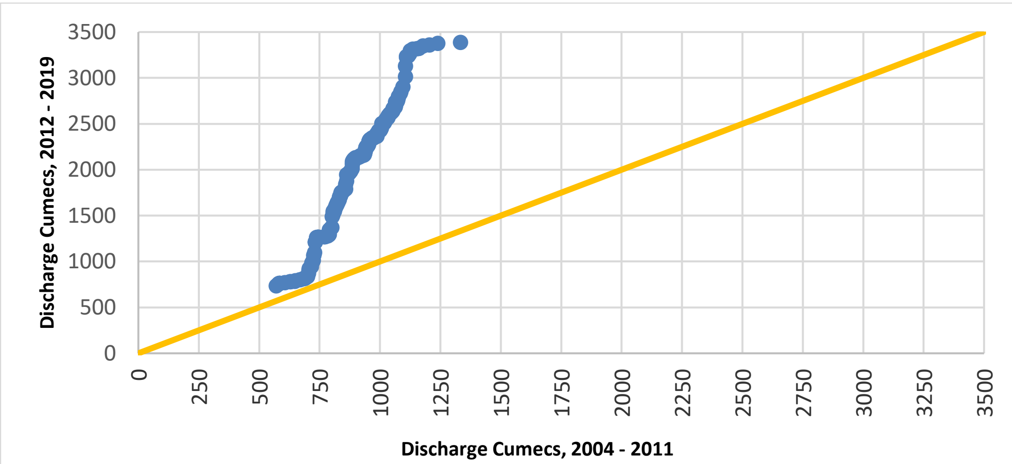

Fig.(2):-The results of innovative trend method for the Annual Data

Table (1):- The Value of B for the daily and annual data

Month	Jan.	Feb.	Mar.	Apr	May	Jun.	Jul	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
B	15.2	11.06	9.15	7.81	8.35	12.61	9.04	19.81	18.76	19.84	24.9	23.53	12.37

For the months of January to December, table depicts the daily discharge trends of Deralok stations. The trend for all months is increasing, and the value of the B inductor is more than zero for all months. Figures 3 to 14 are the daily discharge variation for the period 2004 to 2019 from January to December. From figures below, for all months the points are above the 1:1 line

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and that lead to say there is positive trend in the data.

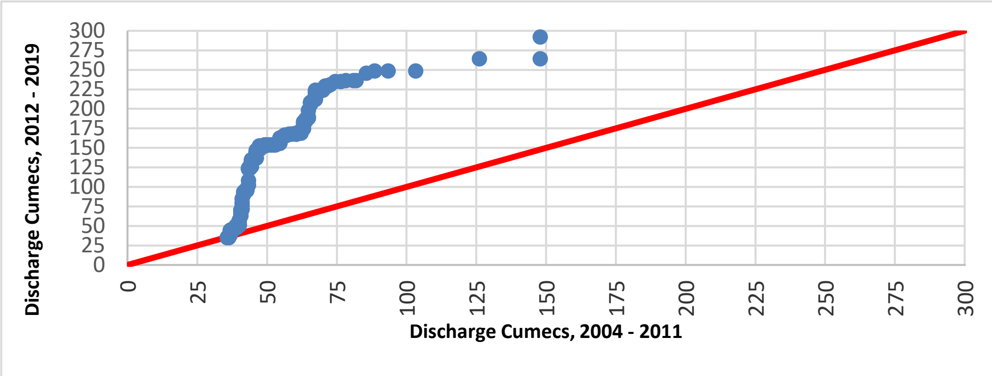
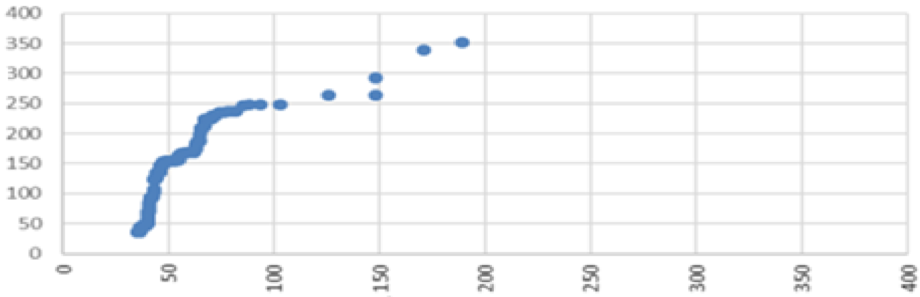


Fig.(3):-Innovation trend analysis for the daily discharge for month of January



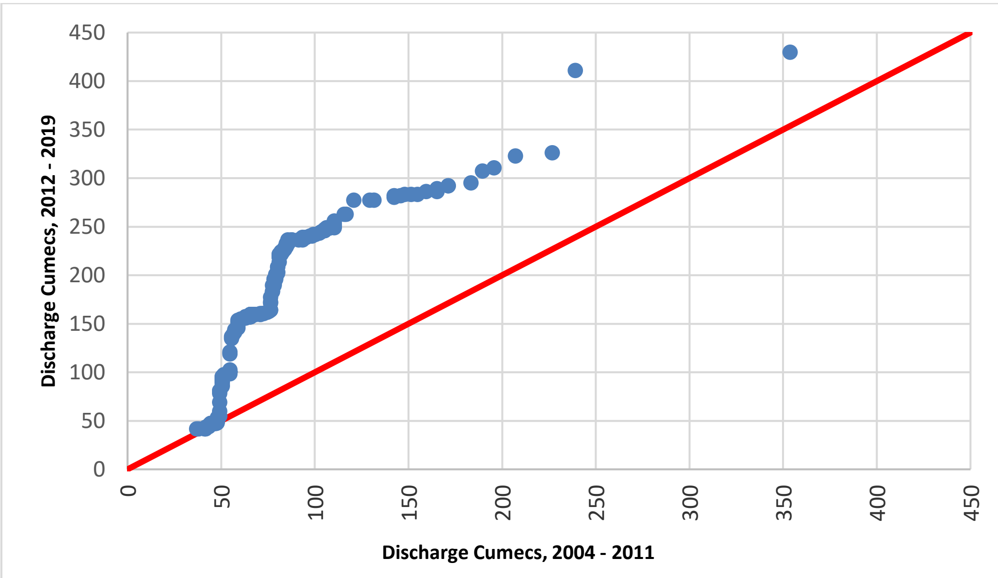


Fig.(4):-Innovation trend analysis for the daily discharge for month of February

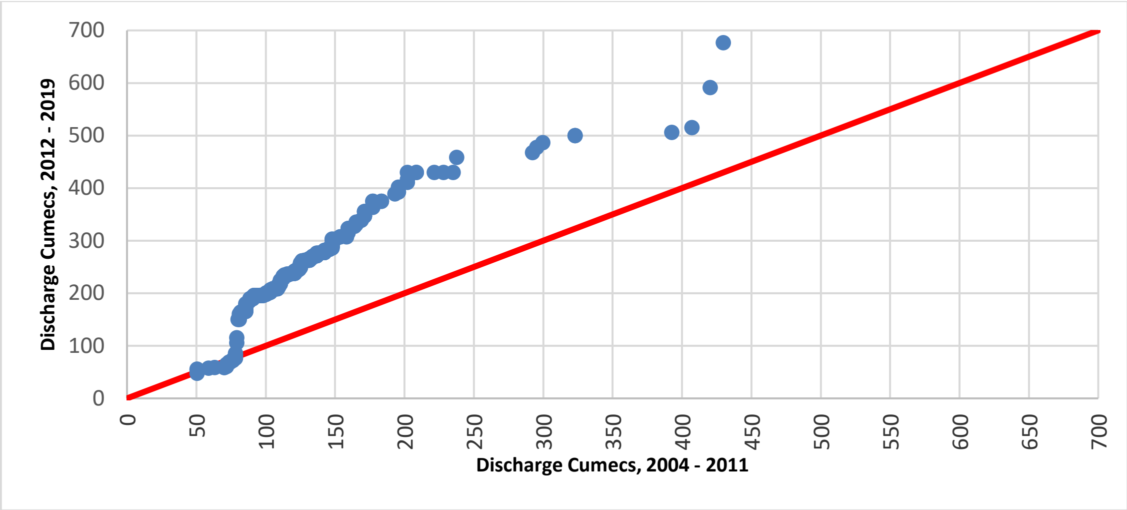


Fig.(5):-Innovation trend analysis for the daily discharge for month of March

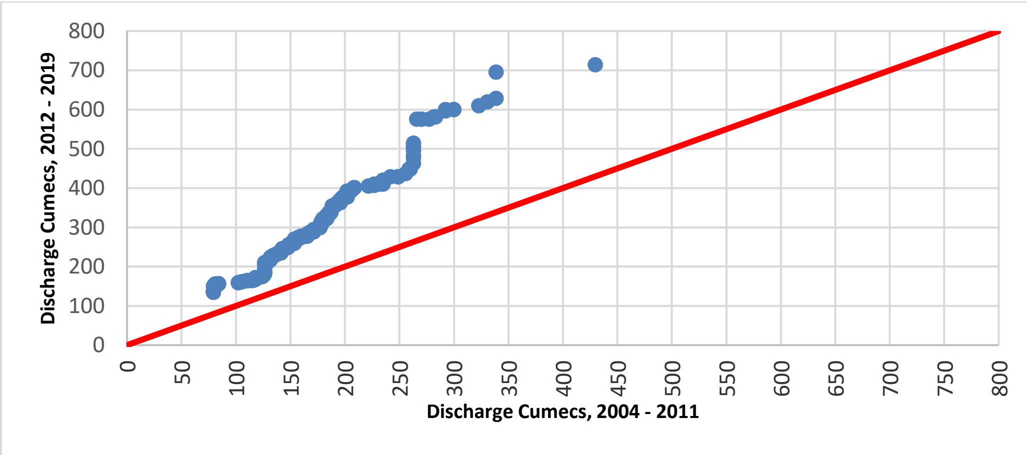


Fig.(6):-Innovation trend analysis for the daily discharge for month of April

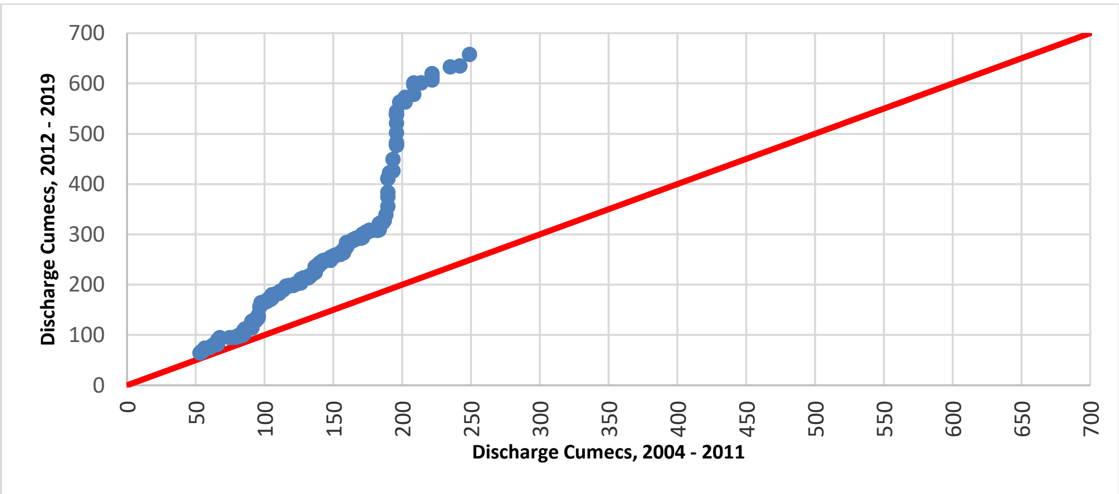


Fig.(7):-Innovation trend analysis for the daily discharge for month of May

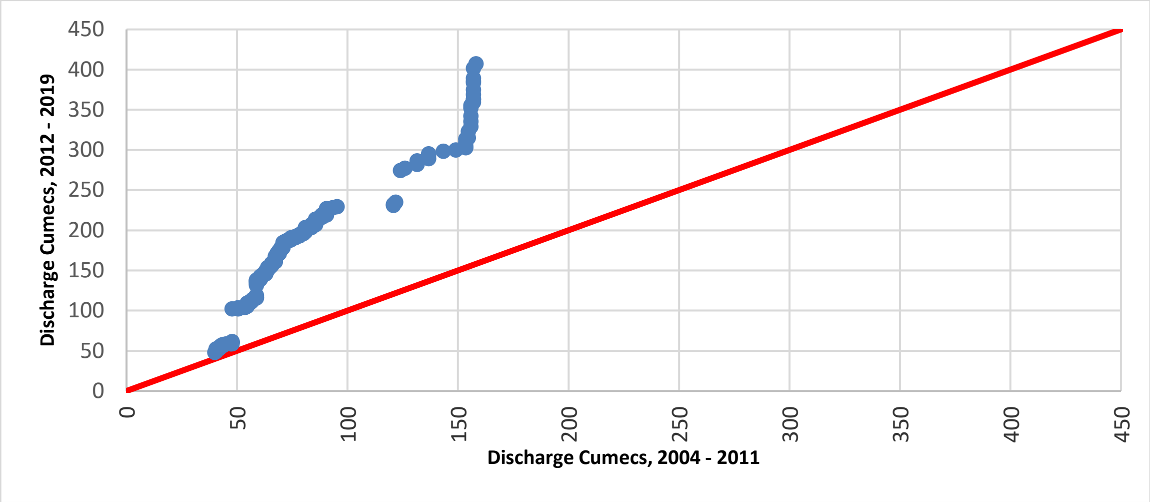


Fig.(8):-. Innovation trend analysis for the daily discharge for month of June

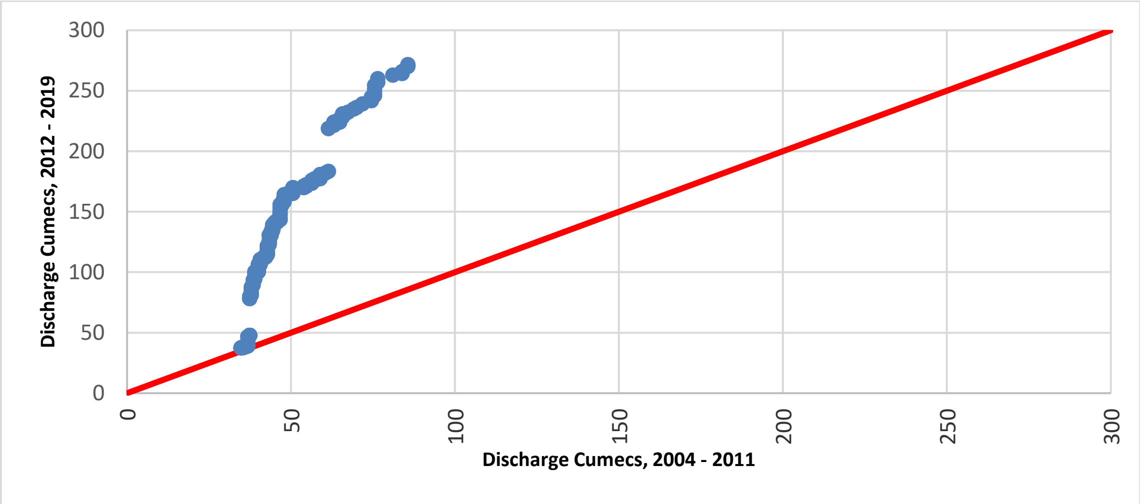


Fig.(9):-Innovation trend analysis for the daily discharge for month of July

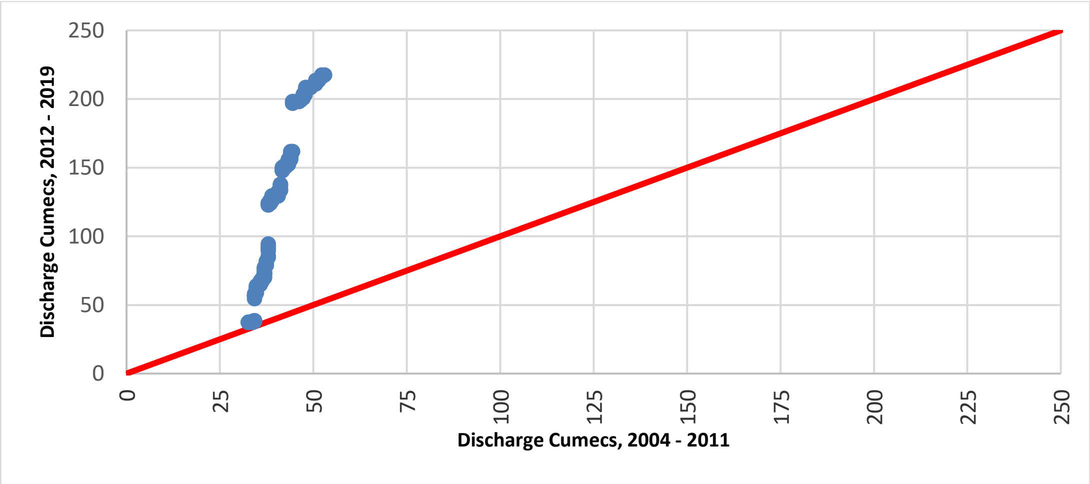


Fig.(10):-Innovation trend analysis for the daily discharge for month August

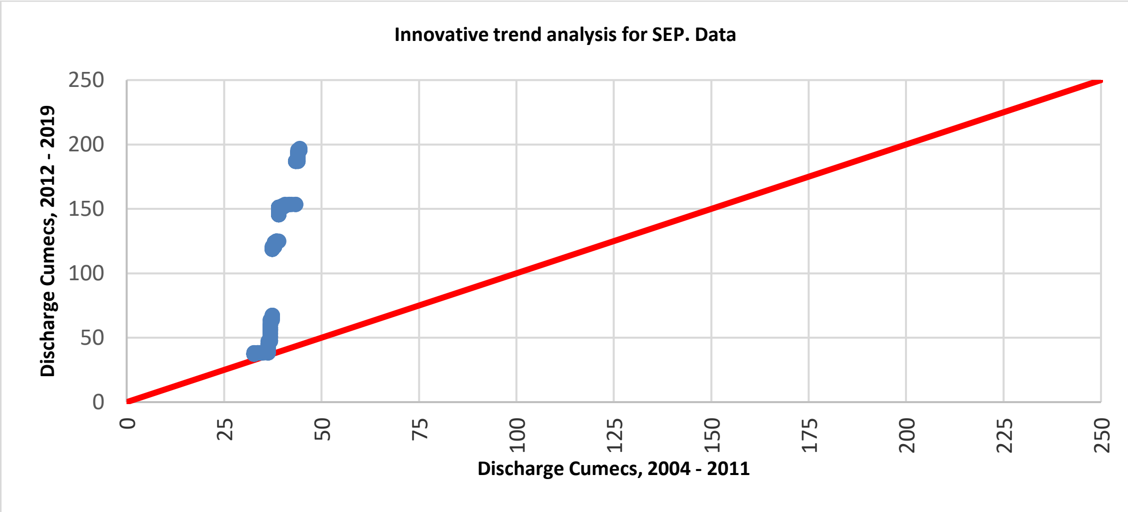


Fig.(11):-Innovation trend analysis for the daily discharge for month of September

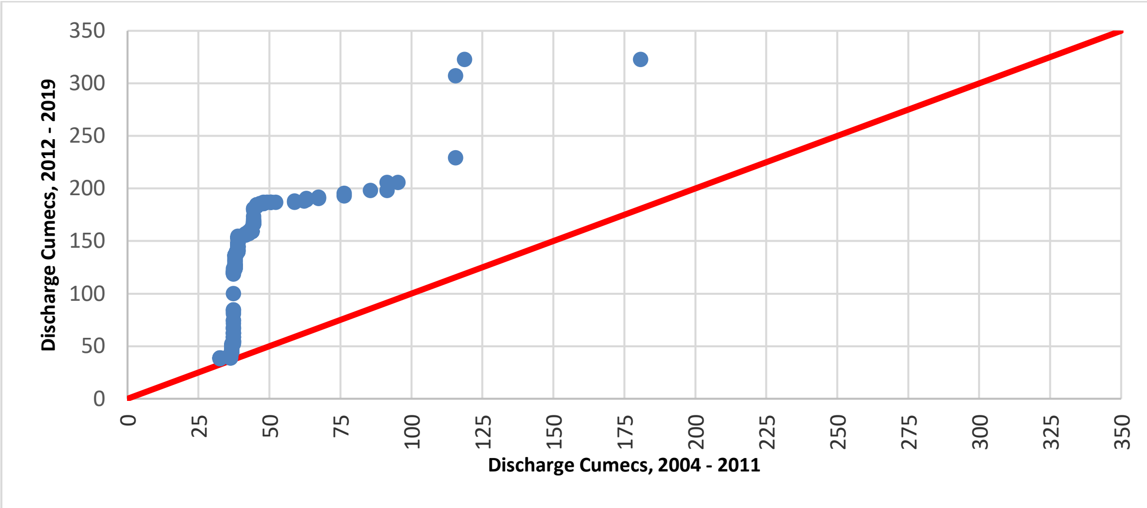


Fig.(12):-. Innovation trend analysis for the daily discharge for month of October

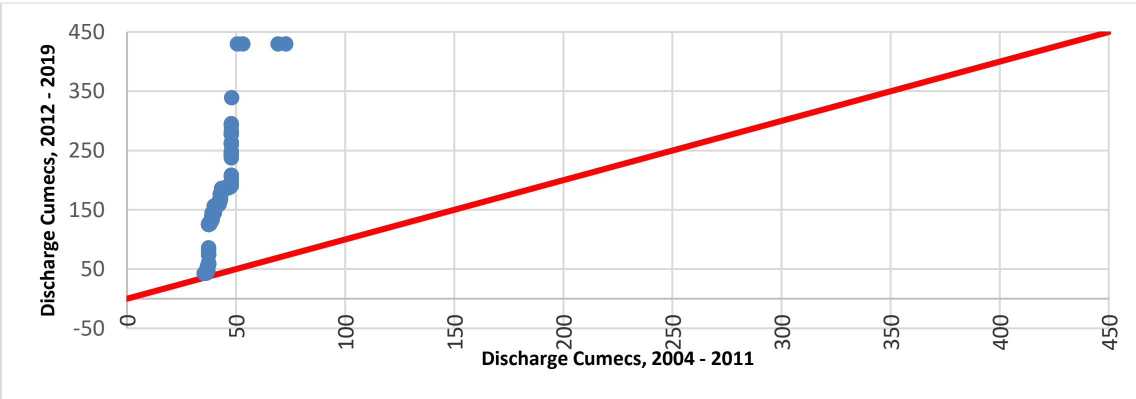


Fig.(13):-Innovation trend analysis for the daily discharge for month of November

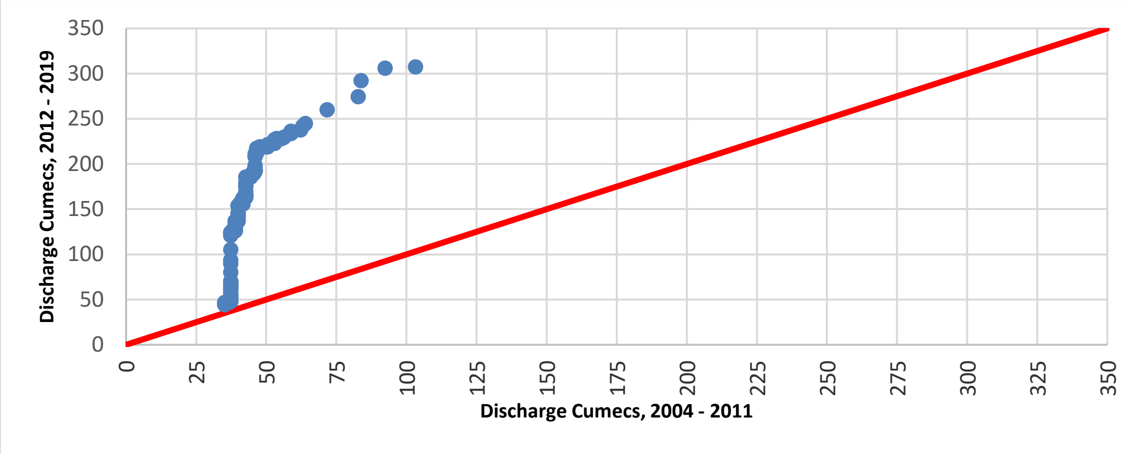


Fig.(14):-Innovation trend analysis for the daily discharge for month of December

From comparing between results in the figures 3 to 14, the trend of November is more than all the other months, because the points in November is far from 1:1 line more than other months which is indictor the trend in this month is creates trend in data.

5.2 Mann-Kendall's Test & Sen's Slope

Table 2 shows the statistical analyses of the time series data for the years 2004 to 2019. The average yearly data for 16 years was 1459.05 m^3/sec mm, with the lowest and highest daily annual data of 571.22 m^3/sec and 3387.20 m^3/sec, respectively. In April and September, the maximum and minimum average daily readings for the same period were 239.93 m^3/sec and 74.14 m^3/sec, respectively.

Table (2):- Statistical Parameters for the Data of selected (Daily and Annual Data).

Stat. Parameter	Avg. m^3/sec	SD.	Max. m^3/sec	Min m^3/sec
Jan.	91.92	63.16	351.98	35.25
Feb.	122.14	77.72	429.65	36.83
Mar.	191.06	97.94	676.65	47.90
Apr.	239.93	114.62	714.65	79.15
May	198.88	112.17	657.65	53.01
Jun.	126.18	76.96	407.24	40.05
Jul.	93.51	60.71	271.51	34.72
Aug.	79.13	53.90	217.50	32.63
Sept.	74.17	51.44	196.91	32.63
Oct.	85.86	58.29	322.86	32.63
Nov.	91.63	71.61	429.65	35.25
Dec.	92.63	66.16	307.34	35.25
Annual	1459.05	729.95	3387.20	571.22

Table 3 displays the outcomes derived from the Mann-Kendall test and Sen's slope estimator. Examining the annual results in Table 3 reveals an upward trend, as both the Sen's slope estimator and Kendall's tau (Z) values exhibit positive figures, measuring 4.16 and 0.574, respectively. Upon comparing the results for individual months (using Sen's slope and Kendall's tau (Z) values) for the daily data, Table 3 indicates that the most pronounced trend is observed in the month of April. In this particular month, Sen's value is at its highest with a score of 0.572, and Kendall's tau (Z) values also reach a peak at 0.594.

Table (3):- Annual daily and daily data trend analysis outcomes with α =5%

Statistic Parameters	Kendall's tau	Sen's Slop
January	0.457	0.307
February	0.44	0.38
March	0.53	0.456
April	0.594	0.572
May	0.491	0.45
June	0.473	0.375
Juley	0.42	0.317
August	0.497	0.268
September	0.556	0.254
October	0.532	0.299
November	0.501	0.321
December	0.523	0.326
Annual daily	0.574	4.16

As depicted in Table 3, there are no negative values in either Sen's slope or Kendall's tau (Z). This indicates a positive trend for all months, spanning from January to December, as both the values of Sen's slope and Kendall's tau (Z) are positively oriented.

In Figure 15, the analysis of annual daily data reveals an upward trend, mirroring the flow trends identified by the Sen Slope estimator and the Mann-Kendall test, both of which indicate a positive trend.

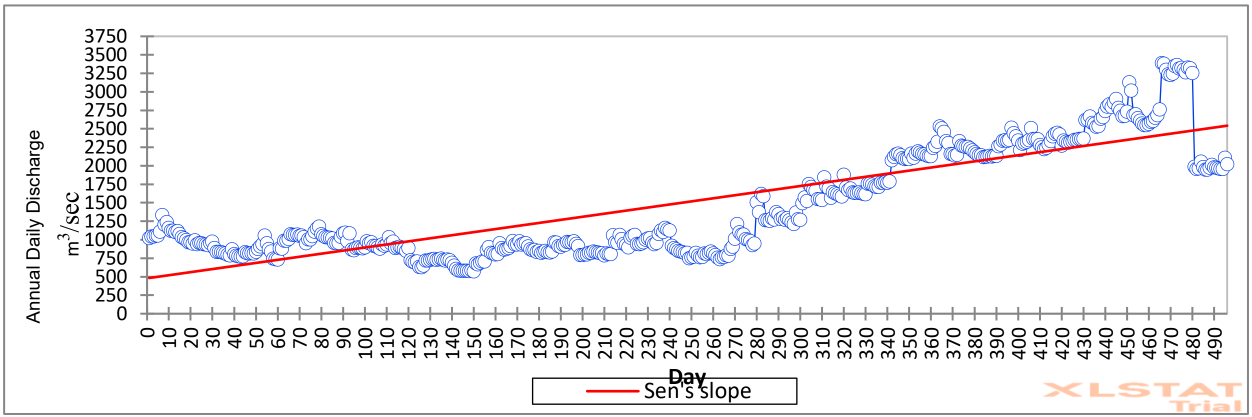


Fig.(15):-Annual daily discharge variation for the period 2004 to 2019

Figures 16 to 24 shows the analysis daily data for all months. This slope represents the monthly rate of increase in precipitation per year. The result was similar to daily flow trends found by Mann Kendall's test and Sen's slope estimator. The trend for daily data in all months January to December is increasing. The values of Mann Kendall's test and Sen's slope estimator for all months are positive. The positive value for Mann Kendall's test and Sen's slope estimator considers as indicator to the positive value of trend.

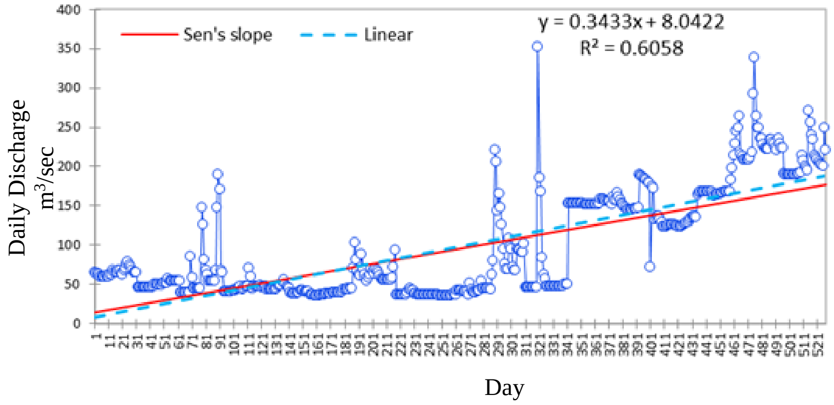


Fig.(16):-Trend analysis and Sen Slope for the month of January

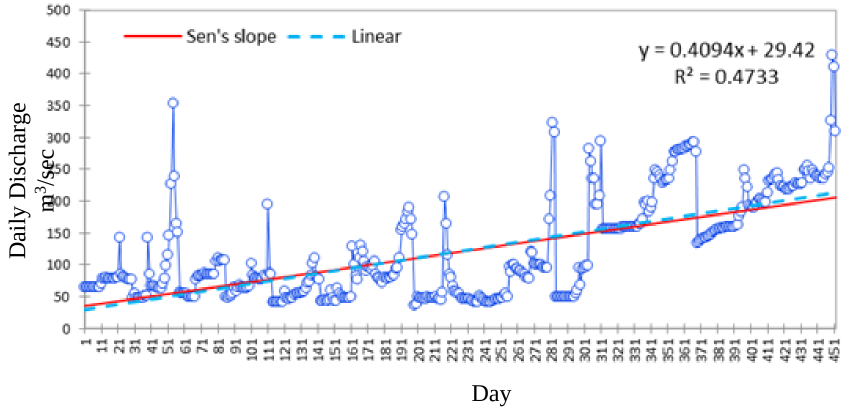


Fig.(17):-Trend analysis and Sen Slope for the month of February

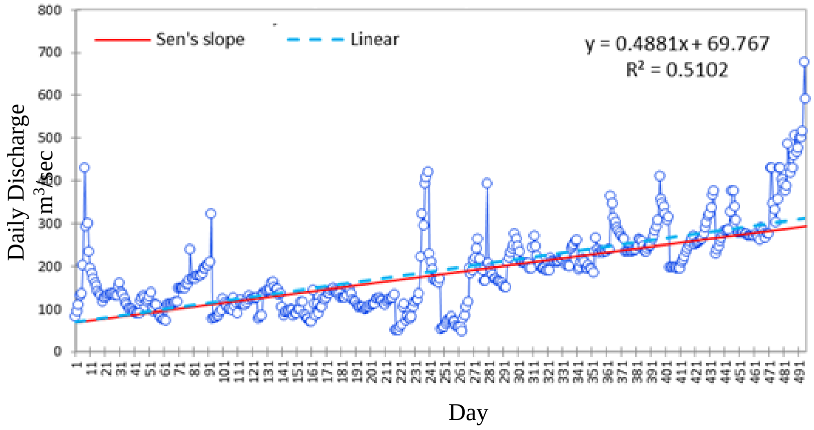


Fig.(18):-Trend analysis and Sen Slope for the month of March

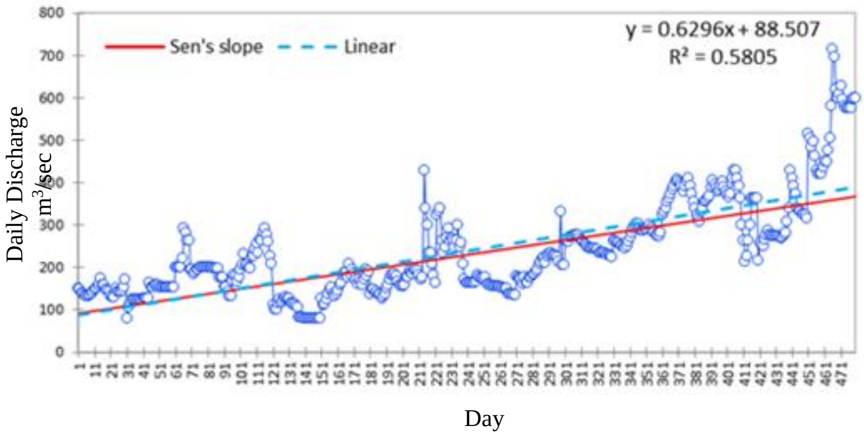


Fig.(19):-Trend analysis and Sen Slope for the month of April

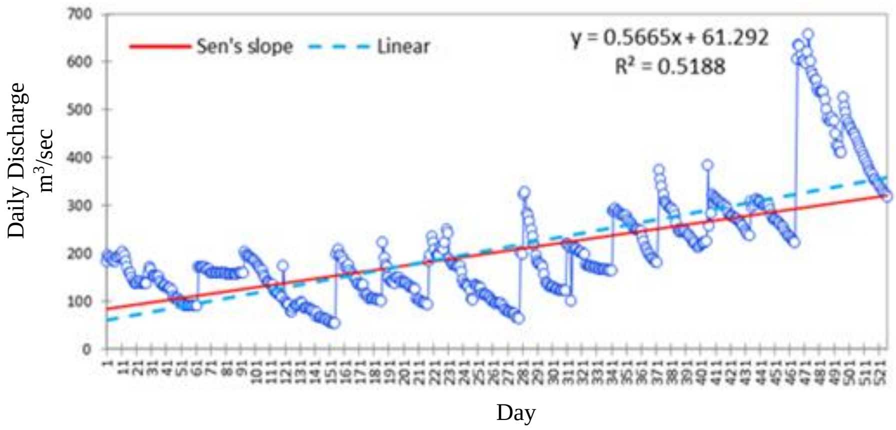


Fig.(20):-Trend analysis and Sen Slope for the month of May

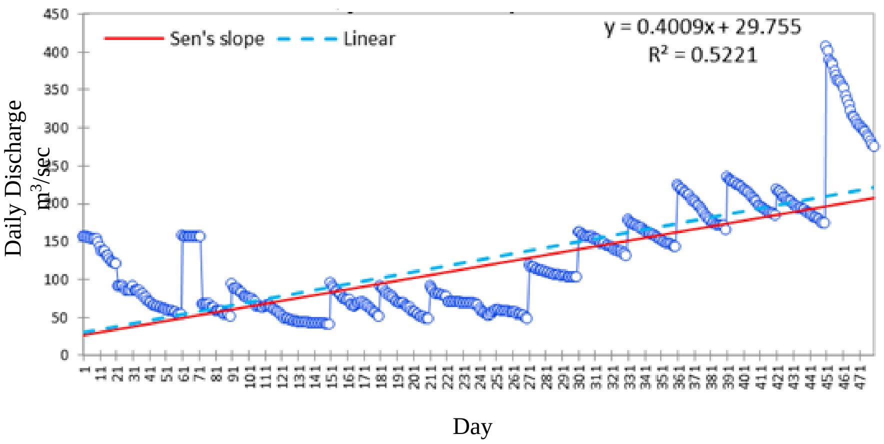


Fig.(21):-Trend analysis and Sen Slope for the month of Jun

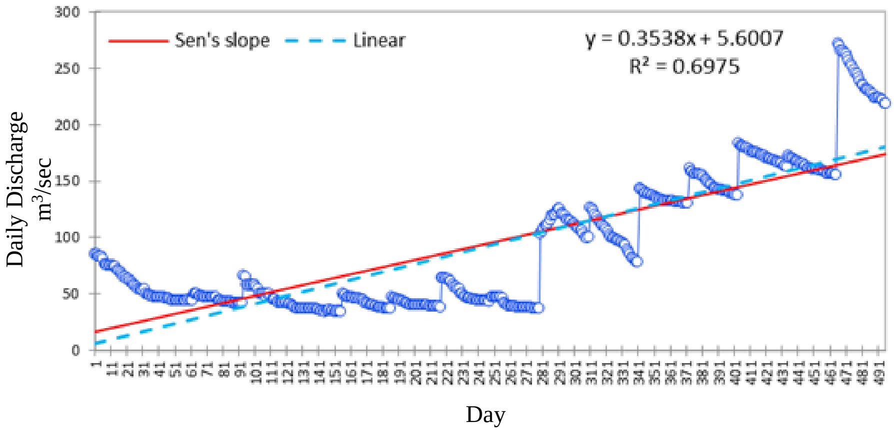


Fig.(22):-Trend analysis and Sen Slope for the month of July

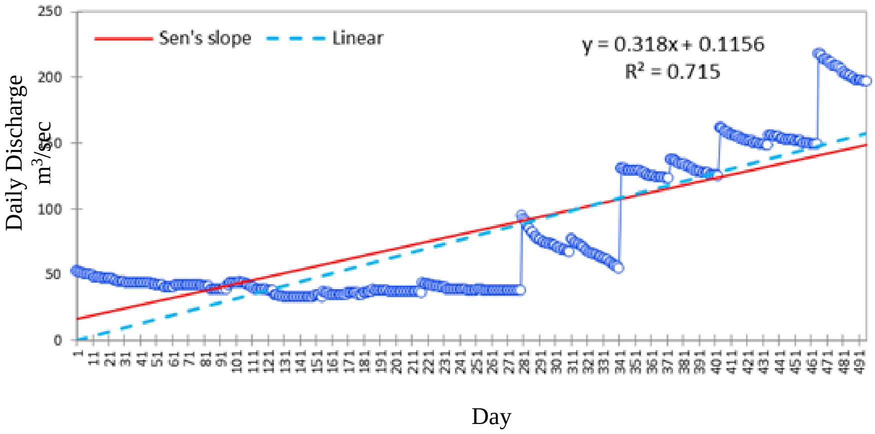


Fig.(23):-Trend analysis and Sen Slope for the month of August

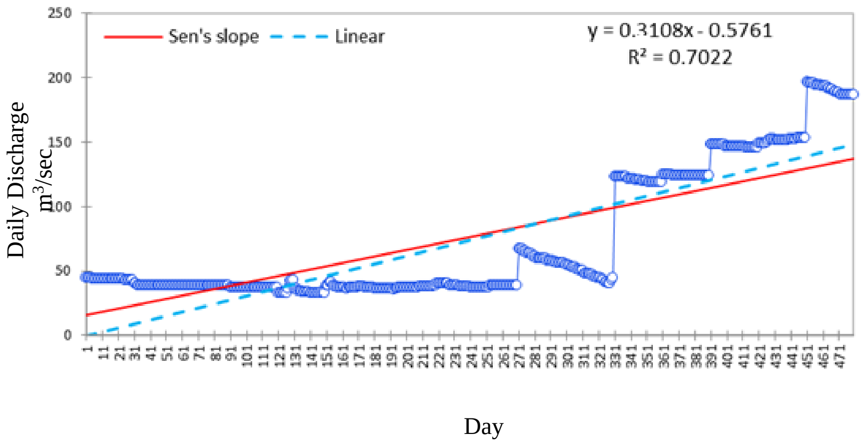


Fig.(24):-Trend analysis and Sen Slope for the month of September

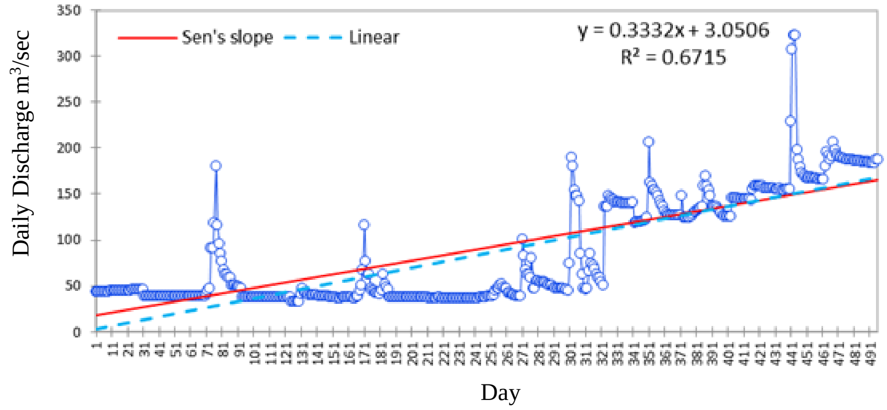


Fig.(25):-Trend analysis and Sen Slope for the month of October

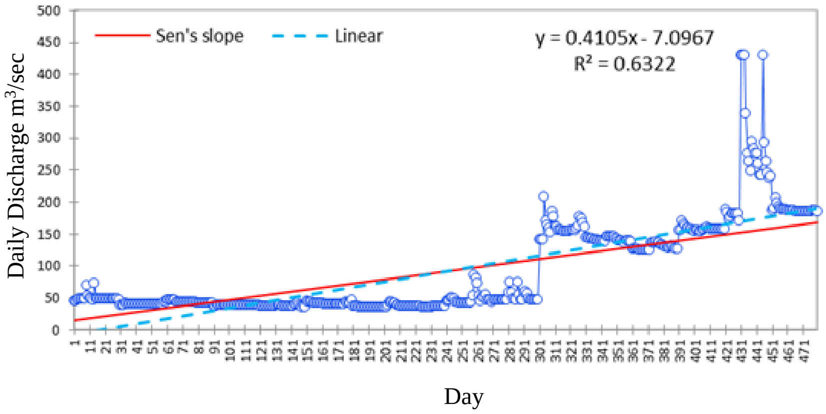


Fig.(26):-Trend analysis and Sen Slope for the month of November

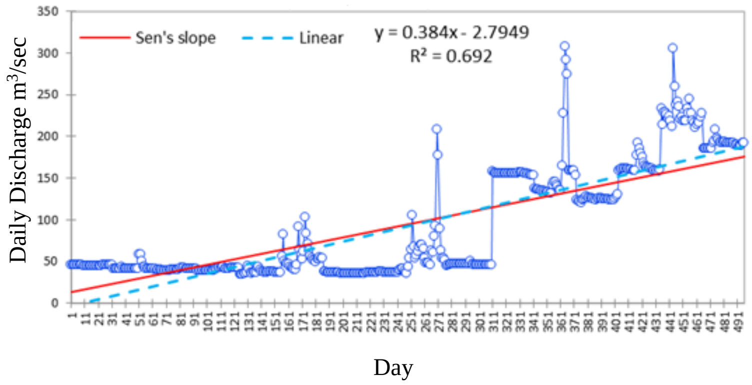


Fig.(26):-Trend analysis and Sen Slope for the month of December

Figures 15 to 26, shows there is a jump in the data of station (daily and annual daily data). The jump is considering a component in the Time series (Jump, Trent, Periodic & Random). Jump occur in the data due to the activities of the human in the catchment area of the river. This activates lead to positive jump or negative jump. By looking to the jump of data can say it's a most of the jumps are positive by moving upward through the time, also there some negative jump in the data.

6. CONCLUSION

The findings indicate a statistically significant increase in the annual flow data trend at the 95% confidence level. Specifically, the annual daily data reveals a rising trend with an increase rate of 4.306 m³/year (equivalent to

0.011797 m^3/day). The analysis of daily flow data shows an increasing trend for all months, spanning from January to December. This trend is consistently confirmed by the linear regression analysis, which yields similar results. The rate of increase for daily flow in January is 0.343 m^3/year, while for the remaining months (February to December), the rates are as follows: 0.409, 0.488, 0.629, 0.567, 0.401, 0.354, 0.318, 0.311, 0.333, 0.411, and 0.348, respectively. These study results can offer valuable insights to engineers regarding water resource management and the construction of essential structures in areas where they are needed. The findings also have practical implications for optimizing water distribution within the crucial agricultural sector of this district and for the development of hydropower plant projects.

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