EVALUATION OF THE HYDROLOGICAL BEHAVIOR IN THE GREATER ZAB RIVER BASIN

Haitham A. Hussein
Civil engineering department, Al-Nahrain University, Baghdad-Iraq

Alaa H. Alshami
Civil Engineering department, AL-FARABI University Coll. Eng., Baghdad Iraq

ABSTRACT

The Greater Zab river originating in Turkey and is a major and greater tributary of Tigris river (in Iraq). The Greater Zab confluence with Tigris river at south of Mosul city. The mean annual water volume of Greater Zab river is about 13.6 milliard M³ (BCM) (FAO, 2006). The aim of this research is to find the recession of water in the Greater Zab river for period (1975-1995) and (1996-2007). This study analyzed the discharges data of the Greater Zab river at Eskiulek station to find the maximum flood for different return period by using different distribution methods. The first method is empirical relative frequency relation and the second method is analytical probability distribution which consist of Normal distribution, Log normal distribution, log-person type 3 distribution, Gumble distribution. From the analysis, the Log normal distribution will give greater discharge comparing than other methods for different period of return (10, 50, 100) years. The results showed decrease in the inflow discharges with about 14%. The recession of water in the Greater Zab river are checked by using program (ERDAS-image 8.5) with Satellite Image between 1990 and 2000 and the results illustrated the recession validation of land cover/use classes (Water, Bare, and Green) for Greater Zab river. The flood discharges that found from log normal distribution are tested. The flow in the river channel from confluence of Khazer river with Greater Zab river to confluence with Tigris river (length 31.96 Km) are conducted using HEC-RAS version 4 (River analysis system). The results found that the river flow in the channel be over flow in some critical sections.

Keywords: Greater Zab river, Tigris River, Discharges measurement, Statically model.

http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=13
1. INTRODUCTION

The greater Zab river is the largest tributary of the Tigris river from the left bank. The length of the river is about 462 Km and run in Turkey and Iraqi region and it is source of water from Van Lake in Turkish area and joined with Tigris river about 50 Km south of Mosul city. The estimated drainage basin of the river about 26470 Km$^2$ (ACSAD) The Arab center for studies of arid zone and dry land and (UNEP) united nation Environment program. The percent of the river inside Iraq area equal to 62% and the mean annual volume water inside Iraq estimated 5.7 BCM and the total mean annual volume equal to 13.6BCM according the hydrological study by (FAO) 2006. This river consist of seven tributaries flowing toward the south west which the most of them is AlKhazer river. Bakhma Dam is under construction on the Greater Zab river with storage capacity up to 14.5 BCM is under way on normal operation level and 17.16 BCM on flood level. The northern region of Iraq heavily depends on rivers, such as the Greater Zab river, for water supply and irrigation. Thus, river water management in light of future climate change is of paramount importance in the region(Osman, Al-Ansari, & Abdellatif, 2017). (Hassan & Jalut, 2018) studied mathematical model to estimate surface runoff amount during flood seasons for a selected unengaged area in Diyala governorate near the Iraqi-Iranian border. (Hussein, 2010) investigated different probabilities (95%,80% and 50%) of water year (Oct-Sep) for the period (1989-2007) by using the empirical Wei Bull probability equation. The results showed that the probability of 50% can be considered the suitable probability for the water requirement to upper and middle Diyala basins.

This study is focusing on two periods of measurement for discharge and volume of water in BCM for greater Zab River at EskiKelek station and Khazer river which the main tributary of greater zab river at Manquba station. These periods is between (1975-1996) and (1996-2007) in order to find the following

- The difference in the rate of flow and the volume of water between the two periods.
- Analysis the discharge to find the maximum probable discharge by using the different methods of the statically models (Wurbs & James, 2002).
- Determine maximum discharge, then test the flow along the river channel from confluence of Khazer river with Zab river up to the join with Tigris river south of Mosul city by using HEC-RAS version 4 program in order to find critical section of the over flow through the side banks
- Using Erdas Imagine 8.5 program with satellite image for different periods in order to check the recession of the water during these two periods.

2. HYDROLOGICAL CONSIDERATION

The estimated drainage basin of Greater Zab river equal to 26470 Km$^2$ (see Figure 1) which represent about 35% of the area under annual rain fall between 350 mm to 1000 mm and the maximum discharge will be in May and will supply the Tigris river with water with mean annual volume at EskiKelek station about 12.6 BCM. The EskiKelek station can consider the main station at Greater zab river than other stations. Al Khazer river is one of the tributary of the greater Zab river and the discharges are measured by Munquba station. The greater Zab river supply Tigris river with about 33% from the total annual volume of Tigris river (Harza, 1959). The greater Zab river is uncontrolled and they proposed to construct two dams which are Bahkma and Mendawa dams in the Iraqi side while in Turkish area are Kokorka, Hakary for power production. The proposed dams on Al Khazer river are Bakerman and Khalekan.
3. MEASUREMENT STATION

3.1. EskiKelek station

EskiKelek station established in 1925 located Lat 36°16'N long 43°39' and 12 Km downstream Gridmamukh station and by using staff gauge on pier bridge and was calibrated in 1940 according to G.T.S. (Greater Trigonometric survey base for leveling in Iraq which is the mean level of Basra gulf at FAO at Shatt- el Arab) and the zero reading equal to 240.58m. The relation between elevation and discharge for greater Zab river at EskiKelek for previous reading (30 September 1956) is presented by the following mathematical relation constructed from gauge height and discharges in m³/s as shown in the Figure 2.

\[ H = 240.1Q^{0.004} \]
\[ R^2 = 0.994 \]

Figure 1. Greater Zab river basin

Figure 2. Relation discharge and elevation at Greater Zab river
3.2. Munquba station at Khazer river

One of the Greater Zab river tributary is AlKhazer river, a measurement station established at al Khazer river called Munquba station which is located at Lat 36°18' N, Long 43°33'E, the staff gauge is calibrated according to GTS datum. The estimated drainage basin for the station equal to 2900 Km², the relation between discharge and elevation is shown in the Figure 3.

![Figure 3 Relation discharge and elevation at Al-Khazer river](image)

4. MATERIALS AND METHODS

The analysis of maximum discharges find by two Statically models (Raghunath, 2006)

4.1. Empirical relative frequency equation

The general form of most plotting position formula which called Weiball formula and most commonly written as

\[ P_m = \frac{m}{N+1} \]  

(1)

The Weiball formula may expressed in terms of either annual exceedance probability or recurrence interval \( T \) for rank \( m \) and number of years of observation \( N \)

\[ P = \frac{m}{N+1} \]  

(2)

and

\[ T = \frac{N+1}{m} \]  

(3)

4.2. Distribution of analytical analysis

4.2.1. Gamble distribution

The theory of extreme values consider the distribution of the largest of smaller observation occurring on each group of repeated sample based on extreme value theory treating each year as sample. Cumble applied the extreme value, Type I function, the probability distribution.

\[ P = 1 - e^{-e^{-y}} \]  

(4)

Where
\[ y = \frac{1}{0.779\sigma}(X - \bar{X} + 0.45 \times \sigma) \]  
\[ y = \text{reduced variant} \]  
\[ \bar{X} = \text{arithmetic mean} = \frac{1}{N} \sum_{i=1}^{n} X_i \]  
\[ \sigma = \text{Standard Deviation} = \left( \frac{\sum_{i=1}^{n}(x_i - \bar{X})^2}{n-1} \right) \]  
Skew coefficient \( C_s = \sum (x_i - \bar{X})^3 \)  
Coefficient of variation \( C_v = \sigma / \bar{X} \)  

4.2.2. Normal and Log normal Distribution

The normal distribution has two parameters, the mean and standard deviation for purpose of practical application, the normal distribution is represented by the equation

\[ X = \bar{X} + k \sigma \]

With frequency factor, \( K \) can find from table. The log normal distribution is transformed random variable log \( x \)

4.2.3. Person Type III and Log person type III

Have three parameters that are include the Skew coefficient as well the mean and standard deviation and if \( C_s \) has value of zero the person type III distribution reduces to the normal distribution.

5. RESULTS OF CALCULATIONS

5.1. Al-Khazer River

Al-Khazer river at Manquba station for the period (1975-1995) the following graph represent a mean monthly annual discharge and volume of water for khazer river at Manquba station for the period (1975-1995) as shown in Figure 4. In addition the probability of annual discharge for recurrence intervals (50, 80, 95\%) by using Weiball formula for the period (1975-1995) is shown in Figure 5

![Figure 4: Relation of annual mean discharge and annual volume 10^7 at khazer River for the period (1975-1995)](http://www.iaeme.com/IJCIET/index.asp)
Figure 5. Annual discharge for recurrence intervals (50, 80, 95%) by using Weiball formula for the period (1975-1995)

Al-Khazer River at Munquba station for the period (1975-1995) by using probability analysis for recurrence intervals (10, 50, 100) years

- Maximum discharges for different recurrence by using Normal Distribution is shown in Figure 6(a).
- Maximum discharges for different recurrence interval by using log Normal Distribution is shown in Figure 6(b).
- Figure 6(c) shows the maximum discharges for different recurrence interval by using Log Person Distribution Method.
- Maximum discharges for different recurrence interval by using Gumble distributing method is shown in Figure 6(d).
Figure 6. Maximum discharges for different recurrence interval by using Distributions a) Normal b)log Normal c) Log Person d) Gumble Distributions for Khazer River at Munquba station for the period (1975-1995)

5.2. Greater Zab River at EskiKelek station for the periods (1975-1995)
Mean annual discharges for the periods (1975-1995) Greater Zab river at EskiKelek station is shown in Figure 7. The maximum probability discharge by using Weiball formula for the periods (1975-1995) for recurrence intervals (50, 80, 95%) is shown in Figure 8.
Figure 7. Relation of annual mean discharge and annual volume $10^7$ at EskiKelek station for the period (1975-1995)

Figure 8. Annual discharge for recurrence intervals (50, 80, 95%) by using Weiball formula for the period (1975-1995) at EskiKelek station

Maximum probability discharge for Greater river at Eskikelk station for different recurrence intervals by using normal distribution, Log normal, log person type III and Gumble distributions are shown in Figure 9(a,b,c,d).

(a)
Figure 9 Maximum discharges for different recurrence interval by using Distributions a) Normal b) log Normal c) Log Person d) Gumble Distributions for Greater Zab river at Eskikelek station for the periods (1975-1995)

5.3 Greater Zab River at Eskikelek station for the periods (1996-2007)
Maximum discharges for Greater river at Eskikelek station for the period (1996-2007) by using Welball formula the mean and average annual discharges for Greater Zab river at Eskikelek station for the Period 1996-2007 can be seen in Figure 10. In addition the maximum probability discharge of Greater Zab river at Eskikelk station for the periods (1996-2007) by using the Weiball formula is shown in Figure 11 for recurrence intervals (50, 80, 95%).
Figure 10. Relation of annual mean discharge and annual volume $10^7$ at EskiKelek station for the period (1996-2007)

Figure 11. Annual discharge for recurrence intervals (50, 80, 95%) by using Weiball formula for the period (1996-2007) at EskiKelek station

The maximum probability discharges for different recurrence interval (50, 80, 95%) by using the Normal distribution, log normal, Log person type III and Gumble distribution methods are shown in Figure 12(a,b,c,d).
Figure 12. Maximum discharges for different recurrence interval by using Distributions a) Normal b) log Normal c) Log Person d) Gumble Distributions for Greater Zab river at Eskikelk station for the periods (1996-2007)

5.4. Evaluation of the reduction in the volume of water

Total volume of water for annual mean of the period 1975-1996 equal to 12.59 BCM and for the period 1996-2007 equal to 10.83 and the percent of reduction equal to 14% Figure 13 shows the difference in volume between the two periods.
5.5. Satellite Image Processing Using ERDAS Imagine

To check the reduction of mean volume flow at the basin, the ERDAS image 12 is used to analysis the data of satellite images specially the land cover. The steps for processing and analysis the satellite image are Stack image, Subset Image, Classification/Supervised, and map composer. All satellite information was investigated by assigning per-pixel signature and differentiating the watershed into four classes. The classes were Green Area, Bare area 1, Bare Area 2, and water class (Butt, Shabbir, Ahmad, & Aziz, 2015). The satellite images is used for

- The satellite images are provided from electronic site (Earth Explorer US Geological survey / USGS)
- The satellite image investigated are 4-3 1990 the sample of period 1975-1995 and the other satellite image investigated on 16-4- 2000 as sample of the period 1996- 2007

The detail of the photograph are shown in the Figure 14. The results of classification for 1990 and 2000 are summarized in Table 1. Figure 15 shows the validation and analysis of land cover/use classes (Water, Bare 2,Bare 1, and Green) for Greater Zab in time period 1990 and 2000. Figure 15 illustrated that the area covers by water reduced by 0.479 percent. Furthermore the agricultural area reduced by 6.048 percent and the Bare area (not agricultural) increased by 6.527 percent

![Figure 13. Difference of mean volume flow for period (1975-1995) and (1996-2007)](image)

![Figure 14. Satellite Image Processing Using ERDAS Imagine](image)

![Figure 15. Validation and analysis of land cover/use classes](image)
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Figure 14. Classified maps of Greater Zab watershed (1990 and 2000)

Table 1. Land cover/land use classes and areas in hectares

<table>
<thead>
<tr>
<th>Land cover/use classes</th>
<th>Greater Zab 1990</th>
<th>Greater Zab 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area(ha)</td>
<td>Ratio %</td>
</tr>
<tr>
<td>Water</td>
<td>0.47</td>
<td>0.966</td>
</tr>
<tr>
<td>Bare 2</td>
<td>18.57</td>
<td>38.17</td>
</tr>
<tr>
<td>Bare 1</td>
<td>21.61</td>
<td>44.4</td>
</tr>
<tr>
<td>Green</td>
<td>8</td>
<td>16.44</td>
</tr>
<tr>
<td>Total</td>
<td>48.65</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 15. validation of land cover/use classes (Water, Bare, and Green) for Greater Zab

5.6. Hydraulic flow condition for Greater Zab River

HEC- RAS is a program used for the Greater Zab river for distance 31 Km. The distance from the confluence of greater zab river with Tigris river south Mosul city to the confluence of Khazer river with Greater Zab river at EskiKelek station by using the cross section of the river. The purpose of finding critical sections which the over flow will exist, the program was used for different discharges:
The discharges which obtained from log normal distribution which gives maximum discharges comparing than other methods for recurrence intervals of 10,50,100 years.

Mean annual flow at Manquba and EskiKelek stations for the period (1975-1995) which gives mean annual flow more than the periods (1996-2007) for the same stations.

The results from the above scenarios

- The over flow will exist at distances of 0, 1.5, 5, 15 Km along the river with respect to the discharge at (a).
- The over flow will exist at distance 0,1.5,5, 15 Km along the Greater Zab river with respect to the flow at (b).

The following Figure 16,17,18,19 represent the discharges of (a) and (b) for Greater Zab river from Khazer river Confluence to the confluence of Tigris river as follows

- Sectional plan for the river
- One of the cross section
- Longitudinal section for the river
- The critical over flow sections are shown in the Figures as red points as indication.
Figure 16 log Normal distribution maximum discharge of 10 years recurrence (1735 m$^3$/sec) of Greater Zab river (plan, cross section, and profile)
Figure 17 log Normal distribution maximum discharge of 50 years recurrence (2720 m$^3$/sec) of Greater Zab river (plan, cross section, and profile)
Figure 18 log Normal distribution maximum discharge of 100 years recurrence (3187 m$^3$/sec) of Greater Zab river (plan, cross section, and profile)
6. CONCLUSIONS

• The total annual volume of water for Greater Zab river at EskiKelek station for the period (1996-2007) equal to 10.83 BCM and the total annual volume for the period (1975-1995) equal to 12.59 BCM, the difference between the two periods equal 13.9%.

• The total annual volume of the Greater Zab River for the period (1996-2007) at EskiKelek and Manquba stations equal to 10.83 BCM + 1 BCM = 11.83 BCM and if compare with FAO study equal to 13.6 BCM, then the difference equal to 13% which close to the percent study.

• The reduction in the annual volume of water are checked by using Erdas program and two satellite images for the two periods.

• The maximum discharge is obtained from Log normal distribution than other methods.

• The maximum discharge obtained by Log normal distribution are used in the channel of the Greater Zab to find the suitability of the flow by using HEC-RAS model (hydrological engineering Center- River analysis system). The cross section is used between confluence of greater Zab River with Tigris and Khazer River total distance of 31 Km.

• The critical section are indicated as red points as shown in the Figures (16,17,18,19).

REFERENCES


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