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Innovated Method to Estimate the Water Income in the Section of Tharthar Valley near the Site of Hatra Proposed Dam

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Abstract

Innovated method applied to adapt Hatra Bridge on Tharthar valley as discharge monitoring station, to estimate the water income of the valley near the site of proposed dam. The section of the valley was geometrically surveyed before the first rainfall storm to build the equation of relationship between water level and area of flow section which required for the discharge estimation.

Six flood waves were monitored along the period of raining season of 2012-2013, the flow velocity were measured on the surface of flow section, with 30 minutes time interval, the same time interval used for the measurements of water level.

The average velocity estimated by innovated method according to the measurements of surface velocity, the equation of the relationship between average velocity and water level were derived and applied with the cross sectional area of flow to estimate the discharge, then the accumulated discharge measurements converted to the total volume of water income for each flood wave.

The total volume of water income in the studied section reached to 141719509 m^3.

Key words: Tharthar valley, Hatra dam, water income, flow velocity

Introduction

The water resources one of the main economic and social constituent, the cover of quality and quantity of water needed represent the biggest challenge in many countries. And by 2025, 1.4 milliard people in about 48 countries will suffer from the water scarcity, mostly from developing countries; historically the water was a controlling factor of population attraction, where the ancient human civilizations grew up on the banks of rivers, such as Hatra Kingdom which located on the Tharthar Valley under study. It is difficult to access sufficient water, in the absence of integrated management of water resources, which required detailed strategic studies for encouraging seasonal valleys for storage and investment such as Tharthar Valley, and explain the possibility of recycling the water to the dry period, the study will discuss the ways to invest and develop the water resources.

Tharthar Valley basin located at northwestern of Iraq, and passes through the Hatra town in the province of Nineveh, within the arid and semi-arid region, it is one of the promise basins for water harvesting, by construction of engineering project such as small dam, to control the water resources in the valley north of Hatra town [1].

The valley extended from the slopes of Sinjar Mount on the northwestern border of Iraq and descended toward the south with slight slope towards the east, and after passing the old Hatra on the west side, it passes near Makhoul Mount which recharge the valley by rain water, then continue the slope towards the south until end on Tharthar Lake that away about 125Km from Baghdad, the average length of Tharthar basin more than 300Km and the average width about (95Km), either the length of the valley is more than (225Km), while the level of the stream is about (400m.a.s.l) at its source, then the level of bottom of the valley down gradually to reaches (160m.a.s.l) at Hatra and about (3m.b.s.l) at the lowest point of the bottom of Tharthar depression, the region between the Tharthar beginning to the proposed dam site characterized by simple terrain in general, with some scattered hills, due to the lack of impact of tectonic movements [2].

Innovative monitoring point for calculate the water income, located on (70Km) southwest of Mosul city, and about (125Km) northwest of Baiji and distance (40Km) west of Sharqat, at Hatra bridge (Figure 1).

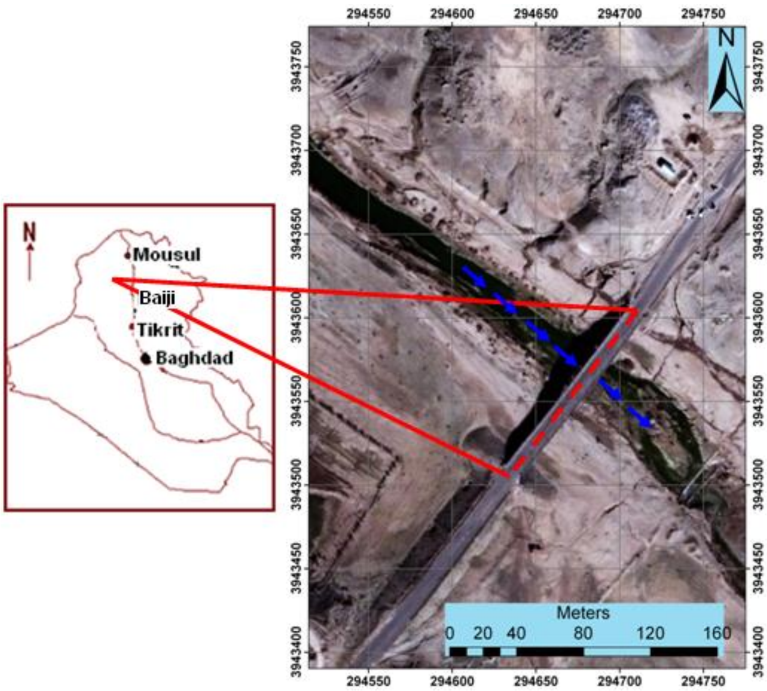

Figure (1). Map of Iraq indicating the location of the study area at Hatra Bridge

There are no detailed hydrological studies to estimate the water income in the proposed dam site, and everything wrote about it, focus on some preliminary information dispersed within reports and regional studies, including a study [3], which stated some preliminary data on the annual discharge in several locations on the valley, [4] determine the reservoir of groundwater, and subdivided the basin to hydrological sub basins, [5] achieve a study on the investment of groundwater in Tharthar upstream area and its impacts on human activities, the morphometric properties of Tharthar upstream area studied by [6], the results used for the selection of proposed sites for the establishment of small dam.

The mathematical model build by [7] to simulate the upper groundwater in the northern part of Tharthar basin, [8], divide the northern part of Tharthar valley basin to six subasins, and use the climate data to estimate the annual discharge of the basin, while [9] studied the hydrogeology and hydrochemistry of groundwater in Tharthar basin near Hatra area, and develop a mathematical model to simulate the hydrogeological conditions after the construction of the proposed dam, [10] studied the geotechnical properties of the rocks in the valley near Hatra city to evaluate their suitability for the construction of Hatra proposed dam, hydrochemistry of the valley studied by [1] and used as a criterion for the selection of suitable sites for the storage of water in the valley by small dams.

These studies were unanimous on the existence of huge amounts of water that takes place during the rainfall season in the Tharthar valley near Hatra Bridge and go without the benefit of them.

One of the justification for this study that the region is suffering from the decline of the agricultural areas because of the scarcity of water income, and that these studies represent a database to convince the design makers of the possibility and feasibility of storing water through the establishment of small dam (bridging the urban proposal) on Tharthar valley, especially the region is one of the attractions for tourism because the presence of archaeological Hatra Kingdom dating back to the (3000 years BC.).

The present study aims to:

1. Survey section of the valley at Hatra bridge site and analyze its geometric characteristics to determine its hydrology and hydraulic.
2. Measure the water levels and flow velocity periodically, during the flood waves of study season and thus analyze the water Hydrographs and calculate the discharge for each flood.
3. Calculate the annual water income of Tharthar valley at Hatra Bridge.
4. Create hydrological database of the site to take its advantage by the designer and decision-makers and implementing companies for the proposed dam.

Geology of the Study Area

The geology of the region is great significance to locate large engineering installations such as dams, and reflected on the qualitative properties of the water. The area covered by sediment outcrops of (Middle Miocene – Recent) represented by Fat'ha and Injana formations and Quaternary deposits.

The age of Fat'ha Formation is the Middle Miocene, it covers wide areas of the region along the banks of the Tharthar valley began from Tel Abtah to the east of the Hatra city, and consists of successive layers of Gypsum, Limestone, Marl and clastic sediments of clay and silt [11], characterized by the rocks of weak resistance to erosion and high solubility deposits.

Injana Formation goes back to the cycle (Upper

Miocene-Pliocene) [12] and consists of rocks clay, silt, layers of sandstone (Medium Sand) to (Coarse Sand) and clastic material increases to upwards, either in the lower part soft clastic materials appears with limestone and shale, this formation has an important composition in the region to contain the water because of the high permeability layers of sand and silt in addition to the large thickness [13].

Quaternary deposits extended widely in the study area by the processes of weathering and erosion which occurred in the region by water current and wind movement, these sediments consisting of mixture of gravel, sand, silt, and clay, The rates of these components varying between one region and another [14], usually these sediments friable, which leads to find a good layer for water penetration into groundwater reservoirs. It include deposits of Pleistocene Holocene [15], and there are several types of Quaternary deposits such as River Terraces, Flood plain, Polygenetic deposits, Aeolian Deposits, Sabkha, [16].

Tharthar valley is the deepest and longest one in the region, and beyond the limits of the study area is extending from Mount Sinjar, north to TharThar Lake south [17], several notably valleys flows to Tharthar such as Althrether, Al-Amer and Qaiberah, Ibdan and Ibrah [5], as shown in (Figure 2).

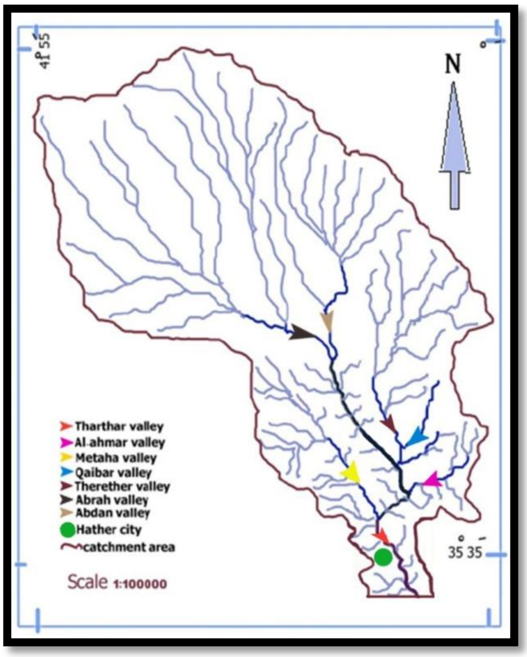

Figure (2). Shows the drainage system into the Tharthar valley

The pattern of discharge in the Tharthar basin is a dendritic which reflect the hardness of rock porosity and climate of the region [18], it is characterized by quick arrival of water from upstream to downstream, in addition to the existence of some deep and long valleys within the catchment area of Tharthar valley, the rain water played a key role in the formation of the valleys, where rains fall for several times in the season and as a result of surface slope towards the Tharthar valley, which divides the study area into two parts, this rain will be torrential floods have a large-capacity to the erosion.

Field work:

The objectives of the field work are the formulation and finalize, and conclude the information that contributes in achieving the objectives of the research. Field work began in April 2012, where the complete survey was conducted on the section of valley and documenting some of the phenomena by photographs as evidence on the accuracy of the hypotheses presented in the search, and then the tours repeated to measure water levels and flow velocity at each level and each flooding during 2012-2013 season.

Floods predicted in the site of monitoring and measurement point, by early warning of rainfall in three locations within the recharge basin of Tharthar valley (Sinjar, TelAbtah and Hatra).

Metering station was created on Tharthar valley at Hatra bridge to calculate the area of valley section, monitor the floods, measure the velocity of flow and water levels, then to calculate the total discharge of water for each flood, to create a database to do the calculations in a computer program (Excel) to complete the calculation of water income for each flood and thus annual water income, and the sampling for water quality studies, as shown in the following steps:

1- Measuring points determined in horizontal level at 120-point with interval of one meter using a measuring tape, every point was marked, Plate No. (1).

2- Measuring the height of the monitoring stage (the bridge fence) from the bottom of the valley at every point mediated by a measuring tape, Plate (1).

3- The vertical differences between the reference point (zero point), on the western end of the bridge and other points, were measured by Boif All32 Automatic Level.

4- The coordinates of reference point defined by GPS-GARMIN-12, then, these coordinates used to determine the elevation of this point in m.a.s.l. from the Digital Elevation Model (DEM).

5- The deepest point in the valley (point no. 82), was chosen to measure the difference between the stage of measurement and the water level during the observed floods by water level detector type (BGS) which produced by Bourne Geotechnical Supplies.

6- Water levels and flow velocity were measured periodically for each flooding from the beginning to the end, with time interval one hour during the first flood and the beginning of the second one, but then reduce the measuring time interval to half an hour during the subsequent floods to increase accuracy.

7- Flow velocity were measured periodically in the same time interval by (FP311 Global Water Flow Probe Hand-held Flow meter) as shown in plate (1)

8- Field observations were recorded for the secondary valleys which flow in the Tharthar valley

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after the rainstorms in Hatra area, and its neighboring areas.

9- 6 samples were collected from the valley water (1 sample from each flood), as in plate (1). Plastic containers of 2.25 liters where used to collect the water samples from the same location, the containers closed to prevent the exit of the water, then the containers labeled by date and time of the flood, and taken to the laboratory for tests of chemical properties.

Plate (1). describes how to measure the flow velocity by flow meter (bottom left), and sampling of the valley water (right) and survey the observation station on Tharthar valley / Hatra bridge (top-left).

Result and Discussion

The study of the annual water income in Tharthar valley basin at Hatra Bridge aims to estimate the total discharge of the valley, as one of the requirements for construction of the proposed dam. The planning for the storage of water in the seasonal valleys requires a completion of series of studies in several axes, including spatial and geometric analysis for topographic depression which represents the proposed reservoir, evaluation of geotechnical characteristics of soil and rocks of the selected site, study the reality of groundwater in the region to predict its future after the construction of the dam, study of the quality and hydrochemical characteristics of water in the valley, and estimate annual water income of the proposed site.

Several studies were concluded on the site by a group of researchers, they covered most of the mentioned themes. But there is no detailed study to estimate the water income to be a database for the designer and decision makers, to knew the adequacy of such income to the actual annual need of the reservoir, there are several conventional and innovative methods to estimate the water income, but the most important and accurate method is the periodical monitoring of discharge in the measuring stations which installed in sites of special specifications, where the valley section unified (non-divided), can be reached easily for transfer of survey devices, velocity measurement and sampling, and can be install the levels and speed measuring equipment, and can carry out a section survey smoothly, without topographic complexes.

Geometry of Section

The geometric study of the valley section is important to know the geometric properties with the fluctuation of water level. The of water level, cross sectional area, discharge and size of water income, represent the most important information relied upon by the designer to construct the dam, it represents the basics to evaluate the ability of reservoir to contain the water at every level, which explain the changes that will occur on the land use after storage at every level, as well as variation of outcrops of formations which will be submersed with raising of level.

Surveys have been conducted on the section of valley at Hatra Bridge, the bridge adapted to be measuring and observation station before the first rainfall for the water year 2012-2013, some devices and instruments was used in the survey:

1. GPS System.
2. Leveling instrument type- Boif All32 Automatic.
3. Measuring tape.

The survey was in accordance with the following steps:

1- Use the bridge fence as stage of measurement, and identified the measurement points (120 point) with interval of one meter in the horizontal level, every point labeled and tabulated in the 1st column in Table (1), Figure (3).

2- Stage (fence of the bridge) height was measured from the bottom of the valley at every point and tabulated in the 2nd column in Table (1), Figure (3).

3- The zero point on the western end of the bridge adopted as a reference point for measuring the elevations, the height differences between the zero point and the other 120 points were determined and tabulated in the 3rd column in Table (1), Figure (3).

4- The height of the bridge fence was measured, it was constant (1.10m) along the bridge, then tabulated in the 4th column in Table (1), Figure (3).

5- The height difference between the reference point

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(zero-point) and the bottom of the valley at every measurement point (after subtracting the height difference for each point to the reference point listed in the 3rd column and the height of bridge fence listed in the 4th column, from the stage (fence bridge) height to the bottom of the valley which listed in the 2nd column), the difference listed in the 5th column in Table (1), as in the equation.

$5^{th}=2^{nd}-3^{rd}-4^{th}$

6- The coordinates of reference point determine, and then projected on Digital Elevation Model (DEM) to determine the height of this point above sea level; it was 162.55m as in the 6th column in Table (1).

7- The height of the valley bottom calculated in m.a.s.l. at each point, by subtracting the value of 5th column from the high of reference point (162.55m) as in the equation below, it listed in the 7th column in Table (1).

$7^{th}=162.55-5^{th}$

8- The section of valley was plotted, as that the distance to reference point (5th column) on the X-axis, and high of points to sea level (7th column) on the Y-axis, Figure (3).

9- The point no. (82) adopted later for measuring of water levels in the valley, because it is the deepest point in the valley and it can be used to monitor the lowest level, to convert the measured levels to discharge (m^3/sec), Figure (3).

Table (1). Part of the measurements of topographic section survey at the innovative metering station at Hatra Bridge on Tharthar valley

1st	2nd	3rd	4th	5th	6th	7th
0	2.85	0	1.1	1.75	162.55	160.8
1	3.25	0	1.1	2.15		160.4
2	3.4	0	1.1	2.3		160.25
3	3.6	0	1.1	2.5		160.05
4	3.95	0	1.1	2.85		159.7
5	4.47	0.01	1.1	3.36		159.19
6	4.68	0.01	1.1	3.57		158.98
119						

1st: Measurement point number
2nd: Elevation between fence edge to bottom of the valley
3rd: Elevation between the points to reference one
4th: Height of fence= 1.1m
5th: Difference between reference point to bottom of valley
6th: Elevation of reference point above sea level =162.55m
7th: Elevation of bottom of the valley above sea level (m).

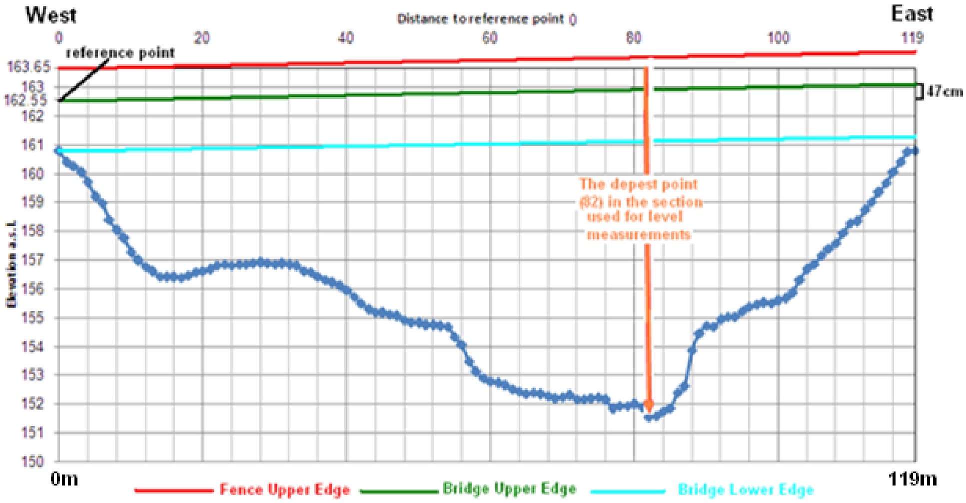

Figure (3). Survey of flow section of Tharthar valley at the Hatra Bridge

Relationship of Level and Area

The relationship between the water level and the area of section one of the important basics in the modeling to simulate reality, to know the corresponding area of the valley section for each level, and through the comprehension of the area and flow velocity, can be calculated the corresponding discharge, and thus calculating the water income from the total cumulative discharge during the time of the flood. The section of flow was graphed, from the lowest level (151.54m) to the highest one (161m) on the vertical axis, and the horizontal distance to the reference point on the horizontal axis, using (Excel) program, and then the drawing modified to equal the scale in both horizontal and vertical directions with interval of one meter, and then the graph of this relationship added to Arc GIS, and then georeferenced to the reference point, it was dealt with as the flat plan (like a map) to calculate the flow section area at every level, 20 level between (151m) and (161m) were chosen with 0.5m interval, as shown in Table (2).

Table (2). Shows the elevations of selected levels for calculating the flow section area

Water level in the valley m.a.s.l.	Flow section area m^2	Water level in the valley m.a.s.l.	Flow section area m^2
151.58	0	156.5	173.6993
152	4.48497	157	209.916
152.5	11.34443	157.5	250.2243
153	20.8024	158	294.789
153.5	33.02488	158.5	343.7774
154	48.1776	159	397.354
154.5	66.42634	159.5	455.6852
155	87.9371	160	518.937
155.5	112.8756	160.5	587.2745
156	141.408	161	660.864

The values of corresponding calculated areas for each level treated using the program (Grapher 4) and then derive the equation that correlate the two variables, it was third class as follows:

$Y=665841.76+13858.79*X-95.97*X^2+0.22*X^3$

Where:

Y: cross section area (m^2).

X: water level (m).

Then equation was generalized to calculate the cross sectional areas that corresponding to measured levels during subsequent floods, as in Figure 4.

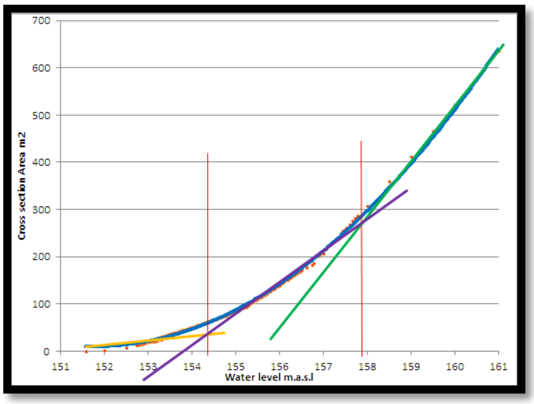

Figure (4). Represents the relationship between water levels and cross sectional areas

Figure (4) explain that there is more than one direction in this relationship as a reflection of the shape of the section, it was noted that there are three trends in this relationship, the first trend represents the submersed of limited area of flow section under water levels, and he second trend of the curve, reflects the submersing of the major parts of the bottom of valley.

The final trend represents the submersing of all the section area of the valley under water levels, which reach to the shoulders of the valley due to the raising of water levels, that caused by the quantity and size of flood discharge passes through the flow section.

Relationship of Level and Velocity

The relationship between the water level and flow velocity is important in the calculation of discharge, and then to find the corresponding discharge for each level, the discharge is constant when the constancy of level at specific point on the section of the valley, the discharge calculated according to equation Q=A*V when:

Q: discharge (m^3 / sec).

V: Velocity (m/sec).

A: area of the valley section (m^2).

Surface flow velocity was measured for the water of Tharthar valley by the current meter at different levels, on the basis that the flow velocity is constant when the constancy of level at specific point on the section of the valley.

Relationship has been found between the flow velocity and the level, the equation devised using all measurements of flow velocity, which reached (1178 reads) during the floods of the observed year from the lowest to the highest level, it was a linear relationship as shown in Figure 5:

Velocity = 0.429 Level -64.73

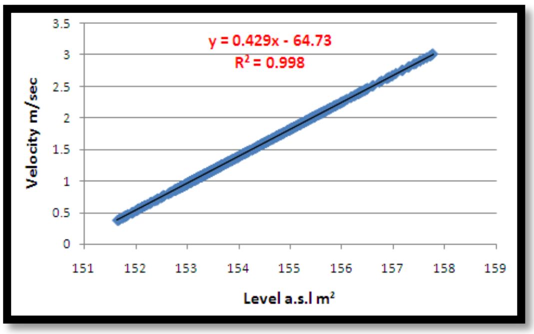

Figure (5). Represents the relationship between the water level and surface flow velocity

This relationship was generalized to calculate the flow velocity corresponding each of the water levels which measured in the field, this velocity is the velocity of flow on water surface and do not represent the average velocity in all the area of flow section, where the velocity at the bottom of the valley is equal to zero, it was used in the calculation of discharge, while the value of velocity in the surface be higher, accordingly, must be found the correlation relationship between the level - average velocity in the section of the valley.

Calculation of Mean Velocity

The adoption of the flow velocity which measured in the field on the surface of the water does not simulates the actual reality of the flow velocity, due to the speed is decreased towards the bottom and shoulders of the valley, and vary from one section to another depending on cross sectional area (A), and wetted perimeter (P), and hydraulic radius (R = A /

P), [19], the speed became zero on the bottom of the section (the valley bottom), so, the average velocity must be calculated and adopted in the calculations of discharge, the experimental studies suggested that the average flow velocity is on 0.6 of the total depth at the deepest point in a flow section [20]; [21], figure (6).

The method that described in [20]; [19], modified to calculate the average velocity, 10 levels were selected to calculate the average velocity, the flow sections of these levels plotted, the value of the surface velocity used as velocity of upper contour line, and the zero value for the contour that in contact with the bottom of the valley (wetted perimeter), and then insert intra-contour lines (between the lowest and highest contours), the values of flow velocity distributed between the contour lines, as in figures (7, 8, 9, 10, 11, 12, 13, 14, 15, 16).

Then the partial areas between each two successive contour lines were measured, and the percentages of these areas to the total area of flow section were calculated using ARC GIS and thus the average velocity calculated according to the following equation:

$$\text{Average Velocity} = \frac{V1+V2}{2} * \frac{A1}{A} + \frac{V2+V3}{2} * \frac{A2}{A} \ldots\ldots\ldots\ldots\ldots \frac{(Vn-1)+Vn}{2} * \frac{An-1}{A}$$

V_1, V_2, V_n: is the flow velocity of each contour line in the flow section.

A_1, A_2, A_{n-1}: is the partial area (intra) between two contour lines.

A: The total area of the flow section for the selected level.

This process was repeated for ten selected levels as in table (3), the linear relationship graphed between the water levels on the X-axis and average velocity on the Y-axis, the equation of correlation between them, and the coefficient of determination (R^2 = 0.995) inserted as shown in Figure (17) .

Table (3). Average velocity of selected water levels

Level	Mean Velocity	Level	Mean Velocity
152	0.382	157	1.787
153	0.663	158	2.068
154	0.944	159	2.349
155	1.225	160	2.63
156	1.506	161	2.911

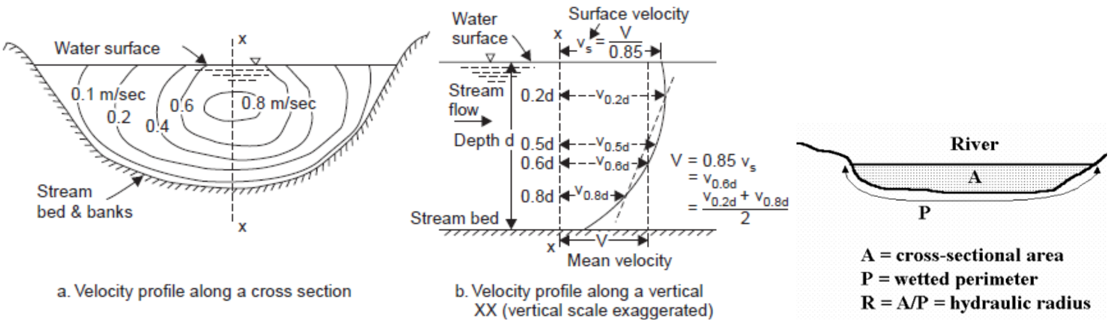

Figure (6). Velocity contour (Left), velocity profile along a vertical xx, vertical scale exaggerated (middle) [20], and cross section of the river (Right) [19].

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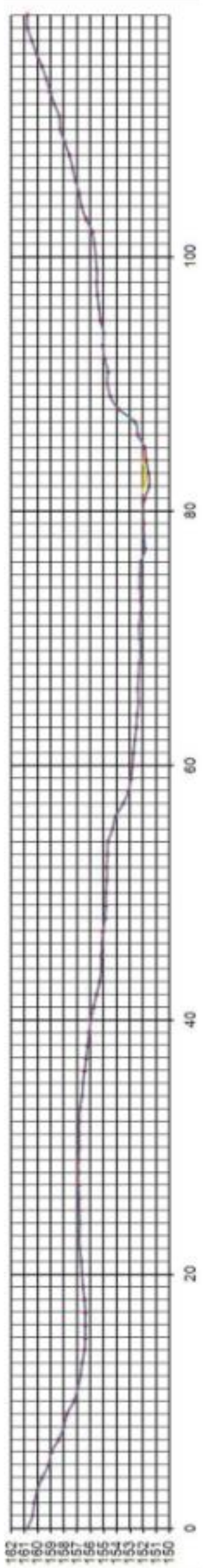

Figure (7). Represent the flow section with contour lines of flow velocity, at the level 152, the horizontal scale equal to the vertical.

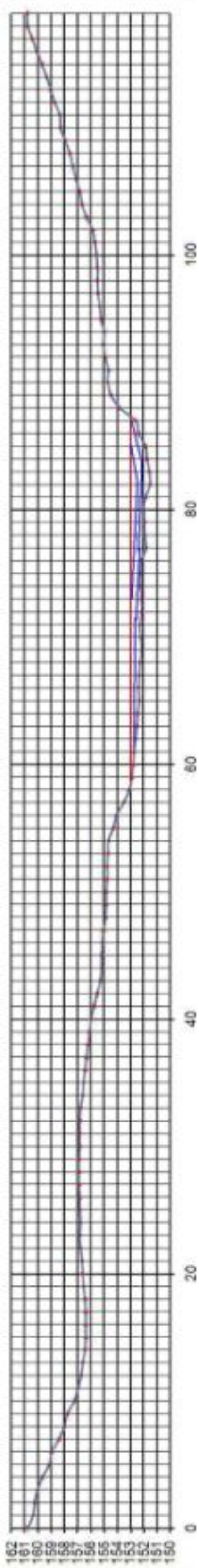

Figure (8). Represent the flow section with contour lines of flow velocity, at the level 153, the horizontal scale equal to the vertical.

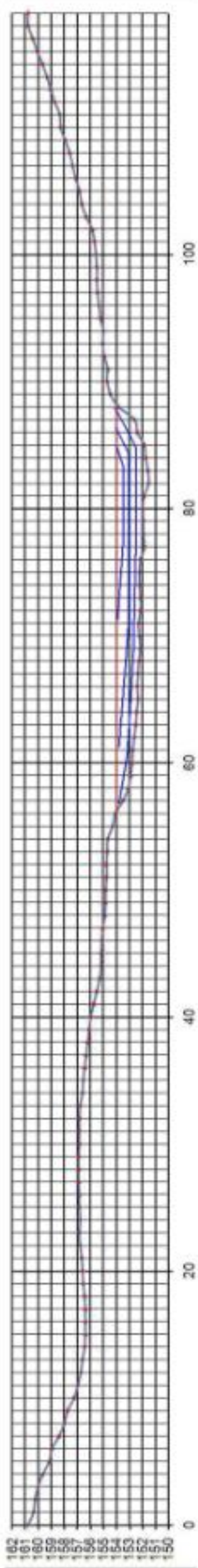

Figure (9). Represent the flow section with contour lines of flow velocity, at the level 154, the horizontal scale equal to the vertical

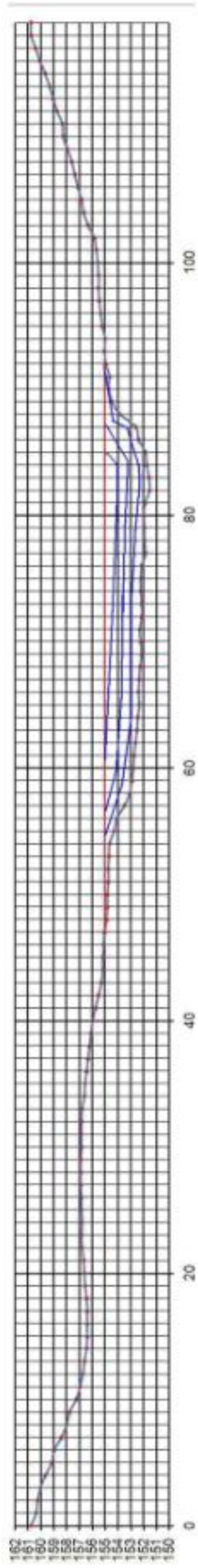

Figure (10). Represent the flow section with contour lines of flow velocity, at level 155, the horizontal scale equal to the vertical.

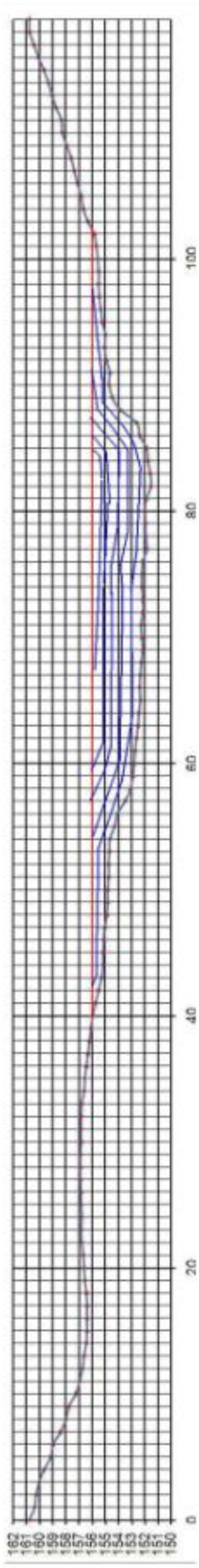

Figure (11). Represent the flow section with contour lines of flow velocity, at level 156, the horizontal scale equal to the vertical.

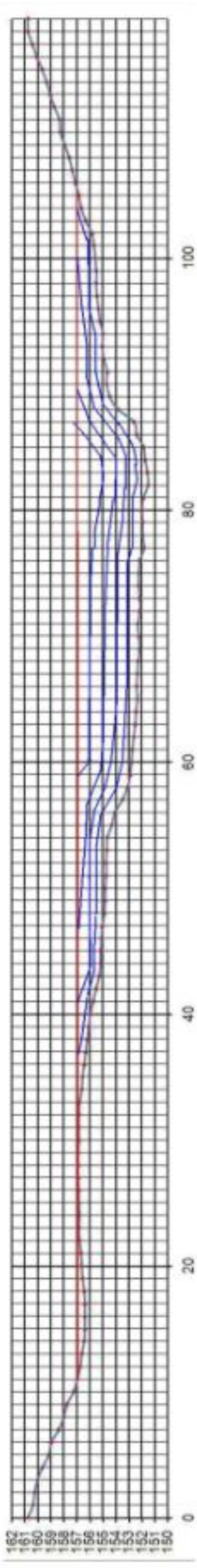

Figure (12). Represent the flow section with contour lines of flow velocity, at level 157, the horizontal scale equal to the vertical

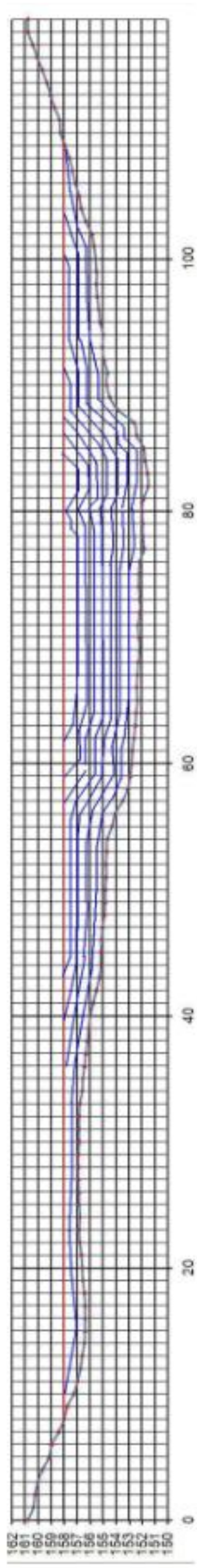

Figure (13). Represent the flow section with contour lines of flow velocity, at level 158, the horizontal scale equal to the vertical

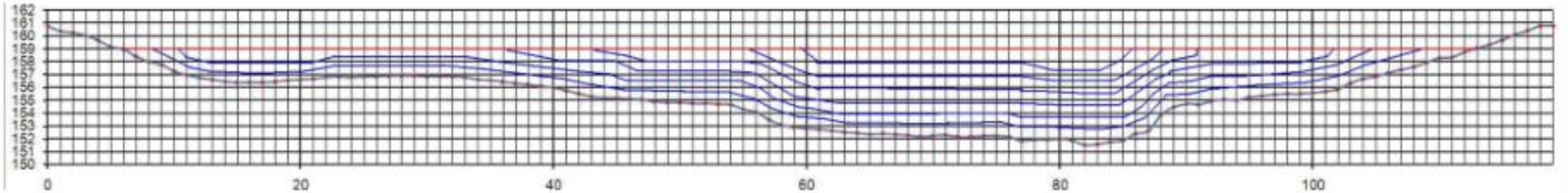

Figure (14). Represent the flow section with contour lines of flow velocity, at level 159, the horizontal scale equal to the vertical.

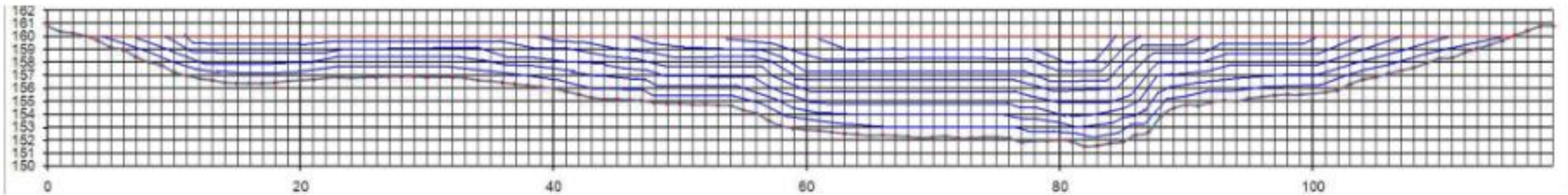

Figure (15). Represent the flow section with contour lines of flow velocity, at level 160, the horizontal scale equal to the vertical.

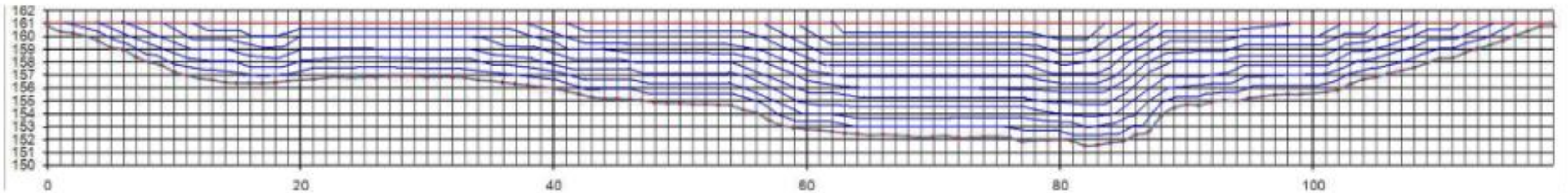

Figure (16). Represent the flow section with contour lines of flow velocity, at level 161, the horizontal scale equal to the vertical.

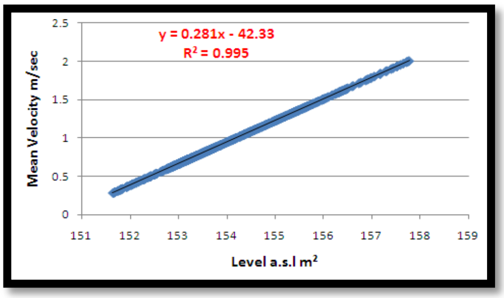

Figure (17). Represents the relationship between the average velocity and water level

This relationship was generalized in the calculations of the floods that have been monitored, in order to calculate the average velocity depending on the water levels which measured during the flood, as in the table (4).

Table (4). Shows part of the calculation of average velocity depending on the water levels which measured during the flood

Water surface Level (m.a.s.l.)	Surface velocity (m/sec)	Average velocity (m/sec)
154.33	1.680	1.03673
154.36	1.681	1.04516
154.38	1.710	1.05078
154.41	1.711	1.05921

Calculations of discharge during floods:

The aim of this part of the study to calculate the variation of discharge in Tharthar valley at Hatra bridge during the observed floods within the study period, the discharge calculated for each flood using multiply the average flow velocity by the corresponding area of flow section, 1 hour time interval used for the first flood and part of second flood and a half hours for the other floods, the interval decreased to increase the accuracy, then time was converted to (seconds) to unify the units, and calculate the total water income along the period of the flood, as in tables (5, 6, 7, 8, and 9). Discharge of each period calculated individually by the following equation:

Q = Velocity * Cross Section Area

Where:

Q: Discharge (m^3/sec).

Velocity: Velocity (m/sec)

Cross Section Area: Valley section of the unity of space (m^2).

The discharge of Tharthar valley characterized by the instability between flood to another, and during the flood itself depending on the intensity of the rainstorm, and the area that covered by the rainstorm, the sustainability of rainfall (Duration), as well as difference in the time of arrival of flood wave (travel time) from the different locations of catchment area.

The importance of hydrograph analyses for surface drainage basins, to know the rainfall density within the recharge area of the valley basin, to invest the water by water harvesting projects which contribute in the development of land use and land cover in the areas which suffer from shortages in this field [6].

The first flood wave began on (13/11/2012) and receded on (17/11/2012), and the data tabulated in table (5).

Table (5). Shows examples of how to calculate the first flood discharge

1	2	3	4	5	6	7	8	9	10	11	12
13/11	2	0.00	0	12.44	11.01	151.54	0.00	0	0	0	0
	3	1.00	3600	11.99	10.56	151.99	4.37	0.38	1.658254	3600	5969.714517
	4	2.00	7200	11.55	10.12	152.43	10.23	0.50	5.144686	3600	18520.87129
	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	∑=33352998.71

The columns in the tables (5, 6, 7, 8, and 9) represent:

1- History
2- Time (hr)
3- Cumulative time
4- Time (sec)
5- The levels referenced to the point 82 (m).
6- The levels referenced to the point 0 (m).
7- Height of the water surface above sea level (m)
8- Sectional area (m^2)
9- Average velocity (m/sec)
10- Discharge (m^3 / sec)
11- Time – Previous Time.
12- Volume during the period between the two measuring times (m^3).

The hydrographs of the valley graphed between each of the discharge (m/sec) on the Y-axis, and the time (sec) on the X-axis.

The hydrograph of the first flood started the raising to marking the beginning of the wave at (02:00 am), of (13/11/2012), to record the highest discharge of the valley (216.92m^3/sec), at (20:00 pm), of the day (14/11/2012), then the hydrograph start the recession in time (21:00 pm), of the day (14/11/2012), and continued to go down to the end of the wave at the time (03:00 am) of the day (17/11/2012), as shown in the figure (18).

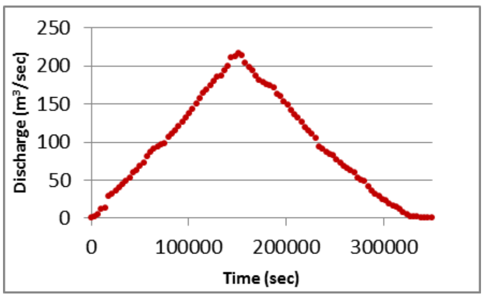

Figure (18). Shows the hydrograph analysis of the first flood on (13/11/2012)

As for the second wave of flood at (25/11/2012), which receded at (28/11/2012), and the data tabulated in (Table 6).

Table (6). Shows an example of how to calculate the second flood discharge

1	2	3	4	5	6	7	8	9	10	11	12
25	12	0.00	0	12.44	11.01	151.54	0.00	0	0	0	0
	1	1.00	3600	12.21	10.78	151.77	4.71	0.32	1.495	3600.00	5383.0818
	2	2.00	7200	11.96	10.53	152.02	7.88	0.39	3.053	3600.00	10990.924
	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	∑=11164003.90

The hydrograph of the second flood on (25/11/2012) reflect that there are two peaks, indicating that the rainfall was not homogeneous on the basin and that the arrival of rain water was not coincident from all parts of the basin, but the water arrive in two waves the first, occurred at (00:00 am), on the day (11/26/2012), and reach the highest discharge (111.34m³ / sec), due to the high rainfall intensity.
Then the hydrograph start the recession in the time (01:00 am), of the day (11/26/2012), and continued to occurrence of the second peak at the time (8:00 am), of the day (11/28/2012), it is record the highest discharge on the second peak (15.47 m³/sec) due to the increase of rain intensity within the basin, the recession started at (08:30 am), of the day (28/11/2012) and continued to the end flood wave at (20:30 pm) of the same day as shown in Figure (19).

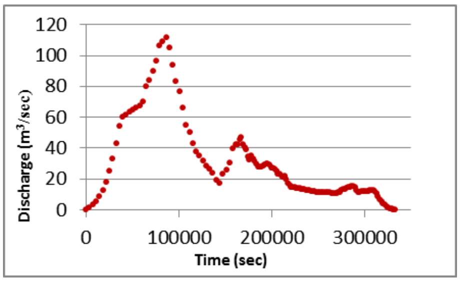

Figure (19). Shows the hydrograph analysis of the second flood on (25/11/2012)

The third flood wave has begun on (21/12/2012) and the receded in the time (22:30 pm), of the same day, the data tabulated in the table (7).

Table (7). Shows examples of how to calculate the third flood discharge

1	2	3	4	5	6	7	8	9	10	11	12
21/12	02:30	0.00	0	12.44	11.01	151.54	0.00	0	0	0	0
	03:00	0.50	1800	12.24	10.81	151.74	1.89	0.31	0.583	1800.0	1050.987085
	03:30	1.00	3600	12.05	10.62	151.93	3.72	0.36	1.348	1800.0	2427.83916
	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	∑=6686904.49

The hydrograph of the third flood started the raising of the wave beginning at (02:30 am), of (21/12/2012), to record the highest discharge of the wave (173.79m³/sec), at (13:30 pm), of the same day, then the hydrograph start the recession in time (14:30 pm), of the same day, and continued the recession to the end of the wave at the time (22:30 pm) of the day (22/ 12/2012), as shown in the figure (20).
The fourth flood wave, which began at (10/2/2013) and receded at the next day (11/02/2013), the data tabulated in the table (8).

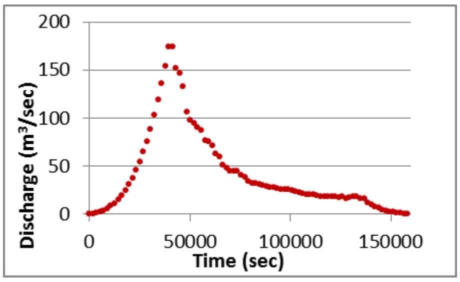

Figure (20). Shows the hydrograph analysis of the third flood wave on (21/12/2012)

Table (8). Shows examples of how to calculate the fourth flood discharge

1	2	3	4	5	6	7	8	9	10	11	12
10/2	10:00	0.00	0	12.44	11.01	151.54	0.00	0	0	0	0
	10:30	0.50	1800	12.15	10.72	151.83	2.72	0.34	0.934	1800.0	1682.401451
	11:00	1.00	3600	11.86	10.43	152.12	5.90	0.43	2.513	1800.0	4523.540638
	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	∑=3462829.09

The hydrograph of the forth flood reflect the raising of the wave beginning at (10:00 am), of (10/2/2013), to record the highest discharge of the wave (36.70m³/sec), at (22:00 pm), of the same day, then the hydrograph start the recession in time (22:30 pm), of the same day, and continued the recession to the end of the wave at the time (15:30 pm) of the day (12/2/2013), as shown in the figure (21).

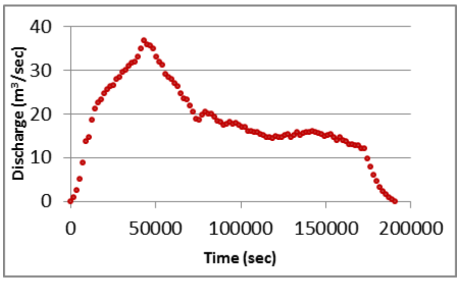

Figure (21). Shows the hydrograph analysis of the fourth flood wave on (10/02/2013)

The data of this flood compared with the discharge of previous waves, especially with the maximum discharge, it was found that the amount of discharge for the fourth flood wave, is the lowest discharge, due to the reservation of the water in the area of Tel Abtah which located within the recharge area of Tharthar valley basin by building temporary earthy dam on the valley to irrigate crops on the shoulders of the valley, which lead to the fluctuation of discharge during the fourth flood wave, this idea was confirmed by the discharge calculations.

Regarding the hydrographs of the fifth and sixth connected waves, their discharge not recedes to zero, the reason for separating them into two waves is that they resulted from two separated rainstorms which cover all the feeding basin of the valley, the fifth wave began on (28/02/2013), the discharge decreased to the lowest limit on (31/02/2013), (but the discharge did not fall to zero, as in previous waves), then the sixth wave of (8/3/2013) was started, as shown in the table (9).

Table (9). Shows examples of how to calculate the discharge of the fifth and sixth flood

1	2	3	4	5	6	7	8	9	10	11	12
28	01:30	0.00	0	12.44	11.01	151.54	0.00	0	0	0	0
	02:00	0.50	1800	12.19	10.76	151.79	2.34	0.32	0.755	1800.0	1359.851375
	02:30	1.00	3600	11.95	10.52	152.03	4.83	0.39	1.884	1800.0	3391.786224
	-	-	-	-	-	-	-	-	-	-	-
	-	-	-		-	-	-	-	-	-	∑=87052773.67

The hydrographs of the fifth and sixth waves on (28/12/2013) indicate that there are three peaks recorded the highest discharge during the time of the two waves, the fifth wave began in time (01:30 am) on (28/2/2013), the hydrograph started the raise to record the first discharge peak of fifth flood (550.99m³/sec) at (3:00 am) on (30/2/2013), in comparison of the discharge of other floods, the discharge of the fifth flood is the highest, due to the high intensity and duration of rainstorm which cover all of the catchment area of the valley, in addition to the saturation of the surface soil of the basin, which increases the chance of surface runoff and decrease the penetration into the soil and unsaturated zone, this results has been confirmed by hydrographs.

The recession of the fifth wave hydrograph began at (03:30 am) on (30/12/2013), and continued to the beginning of the second peak within the fifth wave at the time (16:00 pm) on (01/03/2013) to record the second highest discharge in the fifth wave (170.4 m³ / sec) then start the recession again in the time (16:30 pm) on (1/3/2013), and continued to descend to the beginning of sixth wave in the time (07:00 am) on (8/3/2013 pm) to record the peak of discharge within this wave (153.0875 m³/sec) the recession of hydrograph started at (07:30 am) on (8/3/2013), the recession continued to the end of flood wave at (19:00 pm) on (12/3/2013), as shown in Figure (22).

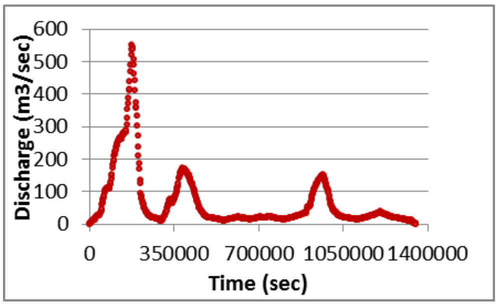

Figure (22). Shows the hydrograph analysis of the fifth and sixth waves on 28/2/2013.

Annual Water Income Calculations:

The values of levels, sectional areas and velocities which measured in the valley used for each flood waves during the rainy season, from the first wave on (13/11/2012) to last one on (07/03/2013), the data of each flood wave processed by EXCEL software to calculate the annual water income of Tharthar valley.

Size of water income was calculated for each time period in specific wave (interval-water income within an hour for the first wave and part of the second wave, and half an hour interval for the other flood waves) by the following equation as in the last fields of the tables (5, 6, 7, 8, 9), subsequently, finding the cumulative water size of each wave, which represents the last cell of the last column in each of these tables:

$V = Q * T$

Where:

V: water income volume (m³).

Q: time-interval discharge (m³/sec).

T: the time interval (sec).

The equation of water income volume applied to calculate the cumulative volume for the first flood wave on (13/11/2012), which is equal to (33352998.71 m³).

The water income of the second wave on (25/11/2012), equals (11164003.90 m³) while for the third wave on (21/12/2012), it is equal to (6686904.49 m³), the fluctuation of water income assigned to the amount of rainfall, intensity and sustainability and the area which covered by the rainstorm in the recharge basin of Thathar valley.

The total water income calculated for the fourth flood wave on (10/02/2013), it was equal to (3462829.09 m³), the lack of water income for this flood wave is due to reserve of water in Tel Abtah located within the area of recharge of the valley on the upstream of the proposed dam site, the farmers were built on an earthy dam to reserve water for irrigation of the plants on the shoulders of the valley.

Regarding to the total water income volume for the fifth and sixth flood waves on (28/02/2013), which reached the highest water income compared with the other flood waves, it was equal to (87052773.67 m³), the causes of the high water income in these waves are to the falling of heavy rain covered the recharge area of the valley basin and fully saturation of the surface soil which increase the surface runoff relative to the percolation.

After completing the calculations of water income for each wave, the annual volume of water income was calculated for all the flooding waves, by summation of total volumes by the program EXCEL, it was equal to (141719509.86 m^3), as shown in the table (10).

Table (10). Shows the annual volume of water income of the Tharthar valley at the Hatra Bridge

Flood waves	Date	Water income volume (m^3)
1st wave	13/Nov/2012	33352998.71
2nd wave	25/Nov/2012	11164003.90
3rd wave	21/ Dec/2012	6686904.49
4th wave	10/Jan/2013	3462829.09
5th and 6th waves	28/Jan/ 2013	87052773.67
		∑=141719509.86

Through the results that obtained, the basin of Tharthar valley is an important water resource, the calculated volume of water income indicates that the water can be exploited by one of the methods of water harvesting, such as the small dams and assembly of water in small artificial water tanks during the season of rainfall to recycled for use in the dry season, which would plays a major role in providing additional water for irrigation and other uses for the region's development.

Conclusion

1- The innovative station greatly served the objectives of this study, through the easy access, and accurate and easy measurements of level variance, flow velocity and flow section areas.

2- The innovative method to calculate the average flow velocity, which gives the weight to the inter-area between the successive contour lines of velocity, is more accurate than all the other methods, the method take into account the geometric characteristics of the section, and depends on the measurement more than the estimation.

3- The basin of Tharthar valley is an important water resource, the volume of water income which calculated during the monitoring season, indicates that there are a significant water resources can be exploited by small dams.

4- The fluctuation of rainfall on the recharge basin reflected on the water income of flood waves, the extent of the basin area and presence of secondary basins in the upstream of the valley lead to the presence of multiple peaks in some flooding waves due to non-coincidence of the travel time of rainstorms causing the floods.

Recommendations

1- Installation of typical registering permanent measuring station for the levels of valley for subsequent periodic monitoring.

2- Repeating the procedure which was adopted in this study on other sections on the Thathar valley towards the downstream of the valley, especially in the sections of Bagga and Sukkariah, and on the other seasonal valleys within other water catchments.

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تخمين الإيراد المائي ودراسة الخصائص الهيدرولوجية عند موقع سد الحضر المقترح قرب جسر الحضر/شمال العراق

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المخلص

تم ابتكار طريقة لتحويل جسر الحضر إلى منصة لقياس تصاريف وادي الثرثار الموسمي، إذ تم انتخاب نقطة مرجعية للارتفاعات عند رأس الجسر، ونقطة أخرى لقياس المنسوب الفيضاني في وسط الجسر، ثم تم مسح 119 نقطة على الجسر بفاصلة 1متر، استخدمت هذه النقاط لقياس ارتفاع قاع الوادي عن مستوى سطح البحر. وبالتالي تم حساب مساحة مقطع الجريان المقابل للمناسيب الفيضانية للوادي من 152م – 162م فوق مستوى سطح البحر وبفاصلة 0.25 م، وقياس سرعة الجريان السطحية عند مناسيب فيضانية مختلفة.

استنبطت العلاقات الرياضية بين المنسوب ومساحة مقطع الجريان، وبين المنسوب وسرعة الجريان السطحي، وبين المنسوب ومعدل سرعة الجريان، ومن هذه العلاقات تم حساب التصريف في الوادي مع الزمن خلال ستة فيضانات جرت خلال موسم شتاء 2012–2013، ومنها تم تخمين الإيراد المائي لهذا الموسم، كما تم تقييم تغاير الخصائص الهيدروكيميائية للماء خلال الفيضانات التي تم رصدها. ان هذه المعلومات أساسية و مهمة جدا لدى المهندس المصمم للسد المقرح ولصناع القرار الذين سيشرفون على تنفيذ المشروع.

الكلمات المفتاحية: وادي الثرثار، سد الحضر، الايراد المائي، سرعة الجريان