Hydraulic Analysis of the Samarra-Al Tharthar System

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ABSTRACT

Low incoming discharge upstream of Samarra-Al Tharthar System leads to sediment accumulation and forming islands, especially an island upstream of Al Tharthar Regulator. This island and the sedimentation threaten the stability of the structure and reduce the efficiency of the system. This study aims to hydraulically identify the sedimentation problem mentioned above, to find solutions of how to control the sediment problems, and to develop the capacity of the system for 500 years return period flood of 15060 m^3/s. Surface Water Modeling System (SMS10.1) with two dimensional depth average models (RMA-2) software were used to simulate and analyze the system. The results of analysis showed that the maximum permissible discharge through the system was 8250 m^3/s where the discharge from Samarra Barrage was 2400 m^3/s to avoid flooding in Baghdad city. The water surface level could be lowered during constructing; the new Al Tharthar Regulator expansion capacity of 7000 m^3/s in the case of peak flood (15060 m^3/s) to 68.51 m.a.m.s.l. upstream of Samarra Barrage by dredging the island and channel. On the other hand, during constructing the guide bank, and dredging the island and channel, the water surface elevation was 68.91 m.a.m.s.l. upstream of Samarra Barrage.

Key words: Tigris River, Simulation, Flow analysis, SMS, RMA2

التحليل الهيدروليكي لمنظومة سامراء – الثرثار

الخلاصة

تسبب انخفاض الايرادات المائية مقدم منظومة سامراء- ثرثار في تراكم الترسبات وتكون الجزرات وخصوصا الجزرة المقابلة للناظم وهذه الجزر والترسبات تهدد استقرار هذا الهيكل وتقلل من كفاءة المنظومة. تمت دراسة استيعاب المنظومة وفقا لواقع الحال وكذلك الاعتماد على ثلاثة سيناريوهات اساسية في دراسة المنظومة وهي سنوات الجافة والفيضانية. وتم توظيف برنامج نظام نمذجة المياه السطحية (SMS10.1) والموديل ثنائي البعد RMA2 لإعداد نموذج رياضي ثنائي البعد يحاكي المنظومة من اجل دراسة الاداء الهيدروليكي للمنظومة خلال السنوات الفيضانية والجافة وتحري السعة الفعلية لها وايجاد الحلول اللازمة لتحسين سعة المنظومة وتطويرها لإمرار موجة فيضانية بتصريف 15060 م^3/ ثا لفترة عودة 500 سنة . من نتائج المحاكاة استنتج ان الحد الاقصى المسموح لاستيعاب المنظومة هو 8250 م^3/ ثا حيث ان التصريف المطلق من سدة سامراء 2400 م^3/ ثا لضمان عدم فيضان مدينة بغداد. وأوطأ منسوب ممكن تحققه عند انشاء ناظم توسعة الثرثار الجديد ذو سعة 7000 م^3/ ثا في حالة فيضان 15060م^3/ ثا كان 68.51 م فوق مستوى سطح البحر مقدم سدة سامراء مع كري الجزرة والقناة. وعند انشاء السدة الموجهة وكري الجزرة والقناة تعطي منسوب المياه مقدم سدة سامراء 68.91م فوق مستوى سطح البحر و 66.6م فوق مستوى سطح البحر مقدم ناظم الثرثار.

كلمات مفتاحية: نهر دجلة ، محاكاة ، تحليل الجريان ، SMS ، RMA2

1. INTRODUCTION

Iraqi rivers are considered non regime channels according to the fluctuation in their discharges and the reduction in the inflow, especially in the recent years. Low discharges cause harmful effects on the rivers, morphology through the accumulated sediment in low velocity regions, capacity of the rivers, and changing the flow pattern.

Samarra Barrage and Al Tharthar Regulator system is a multi-purpose barrage on Tigris River adjacent (West) to Samarra City and north of Baghdad, Iraq. Reduced discharges of Tigris River, the draught seasons, and the lack of rainfall with an increased need to water led to serious problems in the river. Problems like sedimentation upstream of the system and formation of islands resulted upstream of system. These islands and the sedimentation threaten the stability of this structure and reduce the efficiency of the system.

The main purpose of the system is to divert floodwater in Tigris River to Lake Tharthar through Al Tharthar Regulator, control irrigation, and power generation of 84 MW.

This system consists of Samarra Barrage, which consists of 17 gates and passes 7000 m^3/s and Al Tharthar Regulator which can divert 9000 m^3/s across 36 gates. The design capacity of the reservoir is 150,000,000 m^3 but most of that is filled with sediment.

It was built in 1956 by the German company "Zeblin" to control 16000 m^3/s peak flood flow rate. During 1969, Tigris witnessed a high flood of 15000 m^3/s at Begi City.

This study aims to identify the problem, find the required solutions, how to control the sediment problems, and also to predict the capacity of the system at 500 years return period flood of 15060 m^3/s.

Outcomes are expected to improve the flow upstream of the system, occupy flood discharge and reduce the accumulation of sediment.

Simulation will be done by using Surface Water Modeling System (SMS) with the two dimensional depth average models (RMA-2) software.

The preparation of a two-dimensional mathematical model simulates the system in order to evaluate the hydraulic performance of the system during flood, dry years, and actual capacity of the system, define the required treatments to improve the capacity of the system, develop capacity of the system to the expected 500 year return period discharge of 15060 m^3/s capacity, and define the best scenario to avoid sedimentation during dry seasons.

2. HYDROLOGY OF TIGRIS RIVER BETWEEN SAMARRA BARRAGE AND BAGHDAD CITY.

Al-Samuraie, 2004, studied the hydraulic behavior of Tigris River between Samarra Barrage Station and Sarai Station in Baghdad City. This study used discharges between 300 and 7000 cumecs. The main results of the study showed that the bank full discharge is 3175 cumecs, when released from Samara Barrage is the maximum possible discharge that could be passed through the river. Recently, the capacity of Tigris River capacity within Baghdad city is limited to 2500 m^3/s (**National Center for Water Resources Management**).

3. STUDY AREA

After the flood of 1954 which, apart from inflicting economic disaster, threatened to be a national tragedy when many cities were subjected to flood, the Ministry of development (at that time) invited consulting engineers in order to make the necessary investigations and studies for a flood control project, **Figure (1-A)**. The work at the first stage of the present Samarra–Al Tharthar scheme was inaugurated in 1956, **Figure (1-B)** with an estimated Al Tharthar lake storage capacity of 73 billion cumecs, comprising of Samarra Barrage, by which the river level can be raised sufficiently to divert flood water over the west bank of the river; a spillway formed by the construction of a dyke to prevent the water from returning to the river through which the water will flow to the depression; and a regulator to control flow onto the spillway. It is the policy of the government of Iraq to develop the water resources to the extent that all water available for irrigation will be actually used for that purpose. After the 1969 flood, Al Tharthar Project has been developed by raising the surrounding embankments in order to hold large quantities of water to prevent flood hazards ,**Ministry of Water Resource, 2003.**

3.1 Samarra-Al Tharthar System

The system is consisting of the following facilities as shown in **Fig. 2** Samarra Barrage, Al Tharthar Regulator, Tigris-Al Tharthar channel and Al Tharthar irrigation project channel. The first facility includes the irrigation gates, fish path, hydroelectric station and Al- Ishaqi regulator. The second facility includes head regulator for Al Tharthar irrigation system and Al Tharthar escape regulator. This system starts from the end of the closing dyke till the middle dyke with 252 m length from the right shoulder to the left of the facility. There are 17 vertical gates, 12*5.5 m dimensions in Samarra Barrage, power gates 14 gates, 10*12 m dimensions. 6 of them are used for the hydro-electric system now and Al Ishaqi 4 gates, 2.5*2.5 m dimensions.

3.2 The Guide Bank

In the original design of SOGREAH, there was a guide bank to direct the flow into hydroelectric station and separate Al Tharthar Regulator from Samarra Barrage. In the basic design of Samarra-Al Tharthar System there supposed to set up a barrage to guide the flow and separate Al Tharthar Regulator from Samarra Barrage. The guide bank closes the small dyke channel and determines the direction of the Tigris and the section that feeds the flow of flood to Al Tharthar Regulator. At that time, the guide bank was not build, as shown in **Fig.3**

3.3 Suggested New Expansion Regulator

It is expected that there will be flood of 500-year return period upstream Samarra Barrage with a discharge of 15060 m^3/s. For this reason, the Ministry of Water Resources decided to expand the capacity of Al Tharthar canal to attain the maximum benefit of this project by controlling flood of Tigris River. Expanding Al Tharthar Regulator is a suggestion made by the Alphurate Center for the Study and Designs Irrigation Facilities/ Ministry of Agriculture and Irrigation in 1988. It was built near Al Tharthar Regulator that exists now. It passes a discharge of 7000 m^3/s. It consists of 28 openings about 396.6 m long and about 392.7 m away from Al-Tharthar. In the case of its execution it would be with the same characteristics, **Fig4.**

4. MESH GENERATIONS

The finite element mesh was generated by using the SMS software package for the case study of Samarra-Al Tharthar System. All regions in the domain were represented by two-dimensional, depth-averaged elements. The mesh was built by using an adaptive tessellation technique for triangular elements and a patch technique for rectangular ones; the mesh consists of nodes, from which elements are generated. Each node in the mesh is described by an XYZ coordinate system. The value of X and Y indicate the position of the node with respect to some point of reference, while the Z value indicates the ground elevation (bathymetry) at that particular node.

The finite element mesh was generated to represent the case of dry year as shown in **figure (5)**. **Figures (6)** and **(7)** represent the finite element mesh for the case of flood year.

5. TOPOGRAPHY

Bathymetry data for the study site was collected in the form of XYZ coordinates by using a Leica TC 600 total station **,Center of Studies and Engineering Designs/ Ministry of Water Resources, 2013.** In order to create a numerical model, information about the topography in the study area is needed. The topography for the area upstream of Samarra-Al Tharthar System was surveyed in advance with a total station by the Ministry of Water Resource. From this survey, around 3583 scatter points were obtained with x, y, and z-coordinates. For the pre-construction situation, these points were simply converted into contour lines by using the scatter module within SMS as can be seen in **Fig.8**

6. INPUT PARAMETERS AND BOUNDARY CONDITIONS

In order to receive reliable results from the RMA2 computations, input parameter values have to be properly assigned. The input parameters in this model include the upstream boundary conditions (flow from river 1, flow from river 2, and flow from river 3), as shown is **Fig.9**, the downstream boundary condition (water surface elevation at Samarra Barrage and outflow at Al Tharthar Regulator), Manning's roughness coefficient, n, and the eddy viscosity, E, as was previously mentioned.

A summary of the boundary condition for dry and flood seasons is shown in **Tables 1.** and **(2)**, respectively. Discharge rates were recorded by the National Center for Water Resources Management in the case of dry season. The water surface elevation was considered as 67.4 m.a.m.s.l. at Al Tharthar Regulator as an operation water level upstream of the control structures in all scenarios for dry year and 69 m.a.m.s.l. for flood year.

7. SCENARIOS OF THE SYSTEM

The study was divided into three main categories according to inflow as:

A- Dry season.
B- Flood season with discharges of 10400 and 11400 m^3/s according to actual situation.
C- Flood season with a discharge of 15060 m^3/s, according to 500-year return period flood.

The adopted treatments for each of the above categories are based on the following items:

1. Dredging of the channel and total or partial dredging of the island upstream of Al Tharthar Regulator to elevation 60 m.a.m.s.l. for the island area and a level of 62 m.a.m.s.l. for Al Tharthar channel, or without dredging.
2. Constructing a Guide Bank.
3. Constructing the expansion of Al Tharthar Regulator.

The first category consists of four cases that were based on the release from the control structures. Then they were identified as Samarra Barrage only, Samarra Barrage with Al Tharthar Regulator, Samarra Barrage with hydroelectric station, and Samarra Barrage with both hydroelectric station and Al Tharthar Regulator.

8. RESULTS AND DISCUSSIONS

In this research, the flow of Tigris River upstream the system was simulated by using a mathematical model RMA2 within SMS10.1 system for dry and flood seasons and because the results of the model are in the form of a digital map it was not possible to present the maps of all scenarios that were used in the mathematical simulation. So, it the result of one of the scenarios will be presented in the dry season and in the case of operating hydroelectric station, Samarra

Barrage and Al Tharthar Regulator, and operating the system in the existing situation with a discharge of 492 m^3/s.

The distribution of the velocities in the study area was identified as a digital contour map as shown in **Fig. 10 and 11**. It is obvious that the flow velocity upstream of Samarra Barrage ranges between 0 and 0.3 m/s while the flow velocity upstream of Al Tharthar Regulator is close to zero because of the lack of discharge that passes from Al Tharthar Regulator. When constructing the guide bank the flow will be directed towards the hydroelectric power station and Samarra Barrage.

On the other hand, the results of the flood season presented to pass the flood peak with a discharge of 15060 m^3/s for a return period of 500 years when constructing the expansion of Al Tharthar Regulator with a capacity of 7000 m^3/s. **Fig. 12.** shows the distribution of velocity for four cases ranging between 0 and 0.75 m/s upstream of Al Tharthar Regulator and 0 to 1.5 m/s upstream of Samarra Barrage in the existing situation. **Table3.** shows that the water depth ranges between 14 and 17 m upstream of Al Tharthar Regulator and reaches 20.4 m upstream of Samarra Barrage.

Fig. 13 shows the water levels for four operational cases; the water surface elevation upstream of Samarra Barrage would be 68.5 and 68.9 in case of island and canal dredging and in case of constructing the guide bank، and island and canal dredging upstream of Al Tharthar Regulator. Thus, flow over will happen and the level of water surface reaches 78.4 and 79.19 m for the two other cases as shown in **Table4**.

9. CONCLUSIONS

The maximum permissible discharge through the system is 8250 m^3/s while the discharge from Samarra Barrage is 2400 m^3/s. Guide bank improves the flow towards the hydroelectric station and Samarra Barrage. When operating the system with a discharge of 15060 m^3/s and constructing new Al Tharthar Regulator expansion capacity of 4000 m^3/s, water surface elevation will be higher than the allowable limit by 1.51, 0.70, 3.70, and 0.60 m upstream Samarra Barrage for all cases overtopping and overtopping will occur. While operating the system with a discharge of 15060 m^3/s and constructing new Al Tharthar Regulator expansion capacity of 7000 m^3/s, water surface elevation will be lower than the allowable limit by 0.50 and 0.10 m upstream Samarra Barrage in case of dredging the island and channel and constructing a guide bank with dredging the island and channel upstream Al Tharthar Regulator consequently. Water surface elevation will be higher than the allowable limit by 9.40 and 4.19 m upstream Samarra Barrage in other cases and overtopping will occur. The expansion regulator of 7000 m^3/s is the solution for the 500-years return period flood since the water level upstream of Samarra Barrage is within the maximum allowable limit of 69 m.a.m.s.l.

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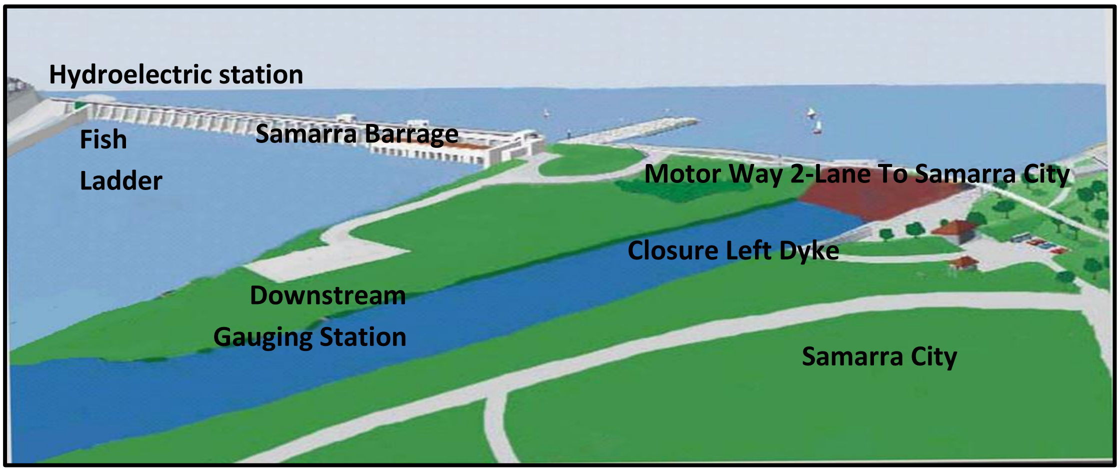
A- Layout of Head Works of Samarra Barrage as it was planned.



B- Layout of head works of Samarra Barrage as it was built**.**

Figure 1 . Layout of head works of Samarra Barrage, General Establishment of Dams and Reservoirs, Unpublished Report, Baghdad. Ministry of Water Resources,2003.

Figure 2. Satellite image of Samarra-Al Tharthar System**.**

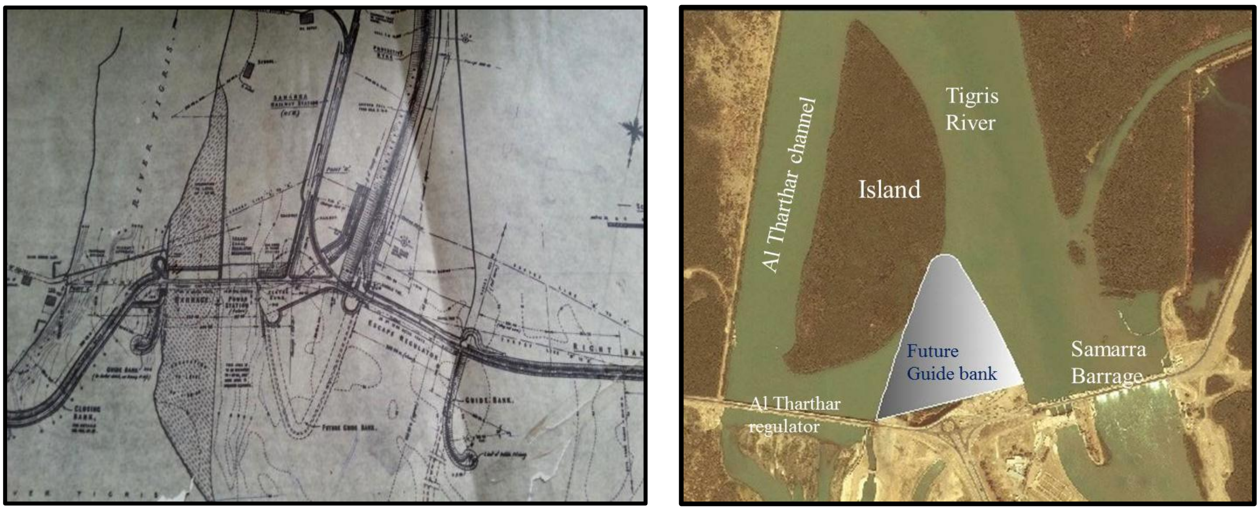


Figure 3. Layout of the future guide bank, Wadi Tharthar Project by Coode and Partners S.W.T, 1954.

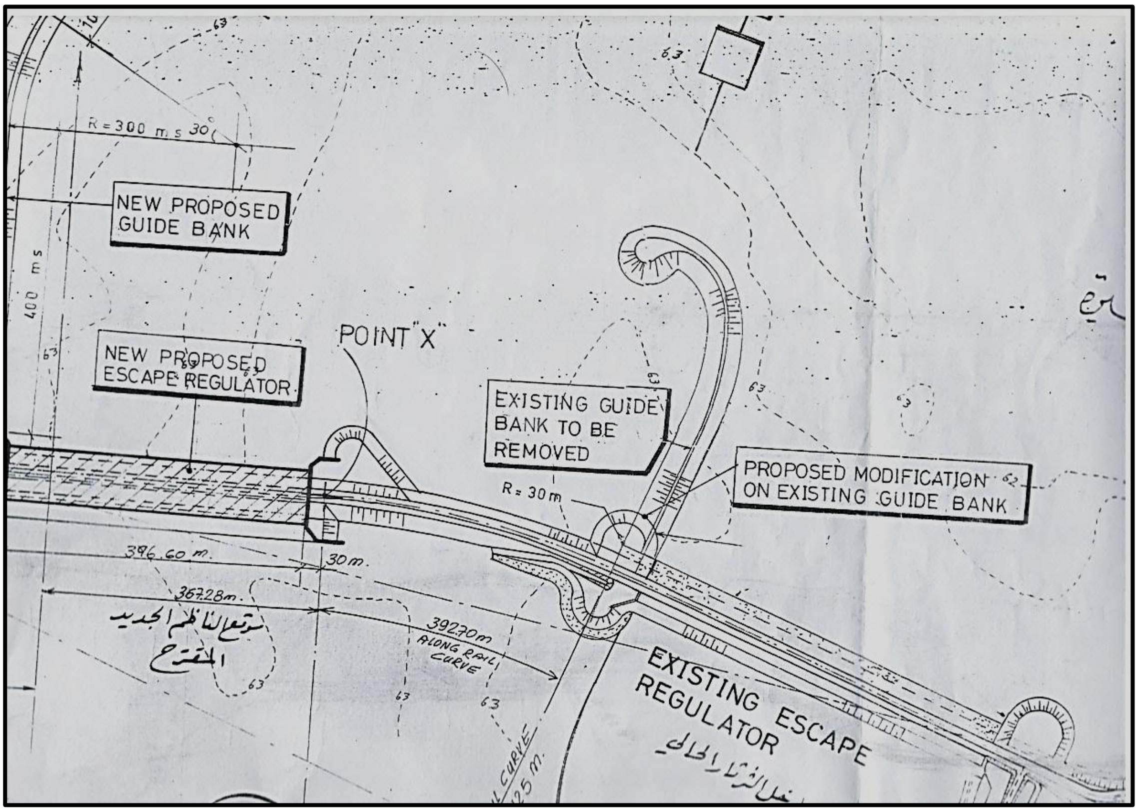
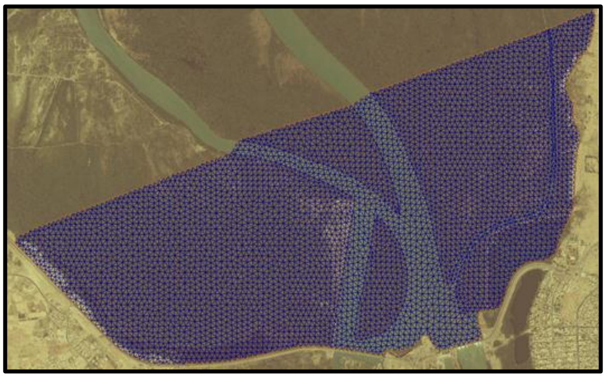
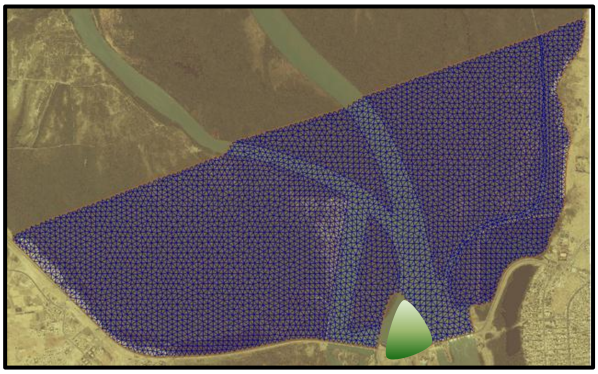


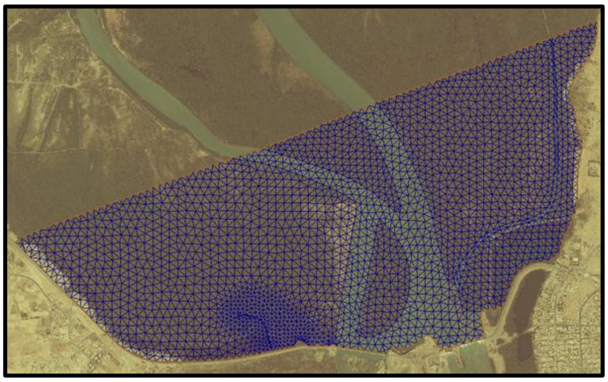
Figure 4. Layout of the expansion of Al Tharthar Regulator. Alphurate Center for the Study and designs irrigation facilities,1988.

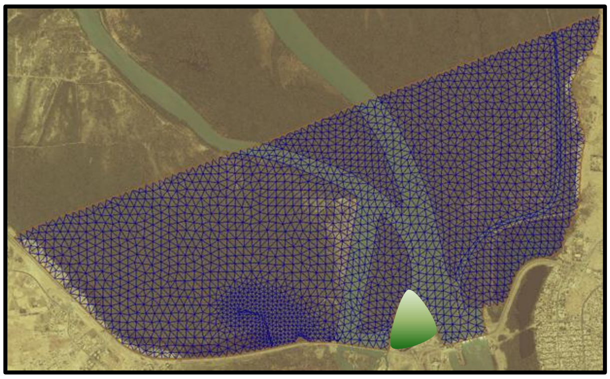




A- Without construction of guide bank . **B-** With construction of guide bank.

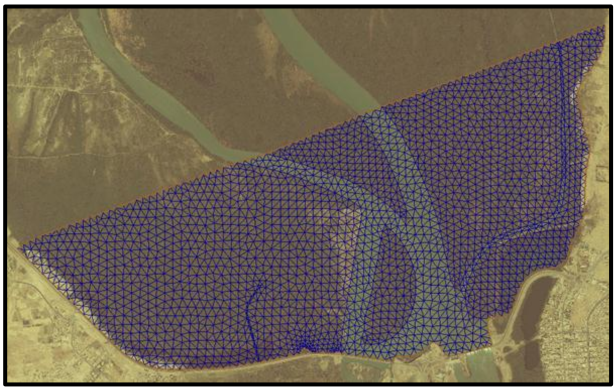
Figure 5. Finite elements of the type adaptive tessellation in the mathematical model of the study area for actual situation in dry year.



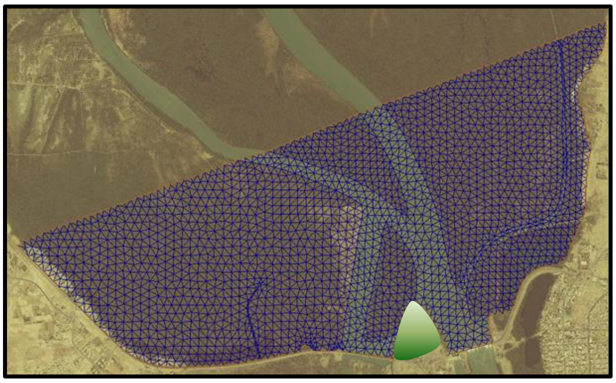


A- Without construction of guide bank **B-** With construction of guide bank

Figure 6. Finite elements of the type adaptive tessellation in the mathematical model of the study area for actual situation with discharge 15060 m^3/s, with new expansion of Al Tharthar Regulator for 4000 m^3/s.



A- Without construction of guide bank



B- With construction of guide bank

Figure 7. Finite elements of the type adaptive tessellation in the mathematical model of the study area for actual situation with discharge 15060 m^3/s, with new expansion of Al Tharthar Regulator for 7000 m^3/s.

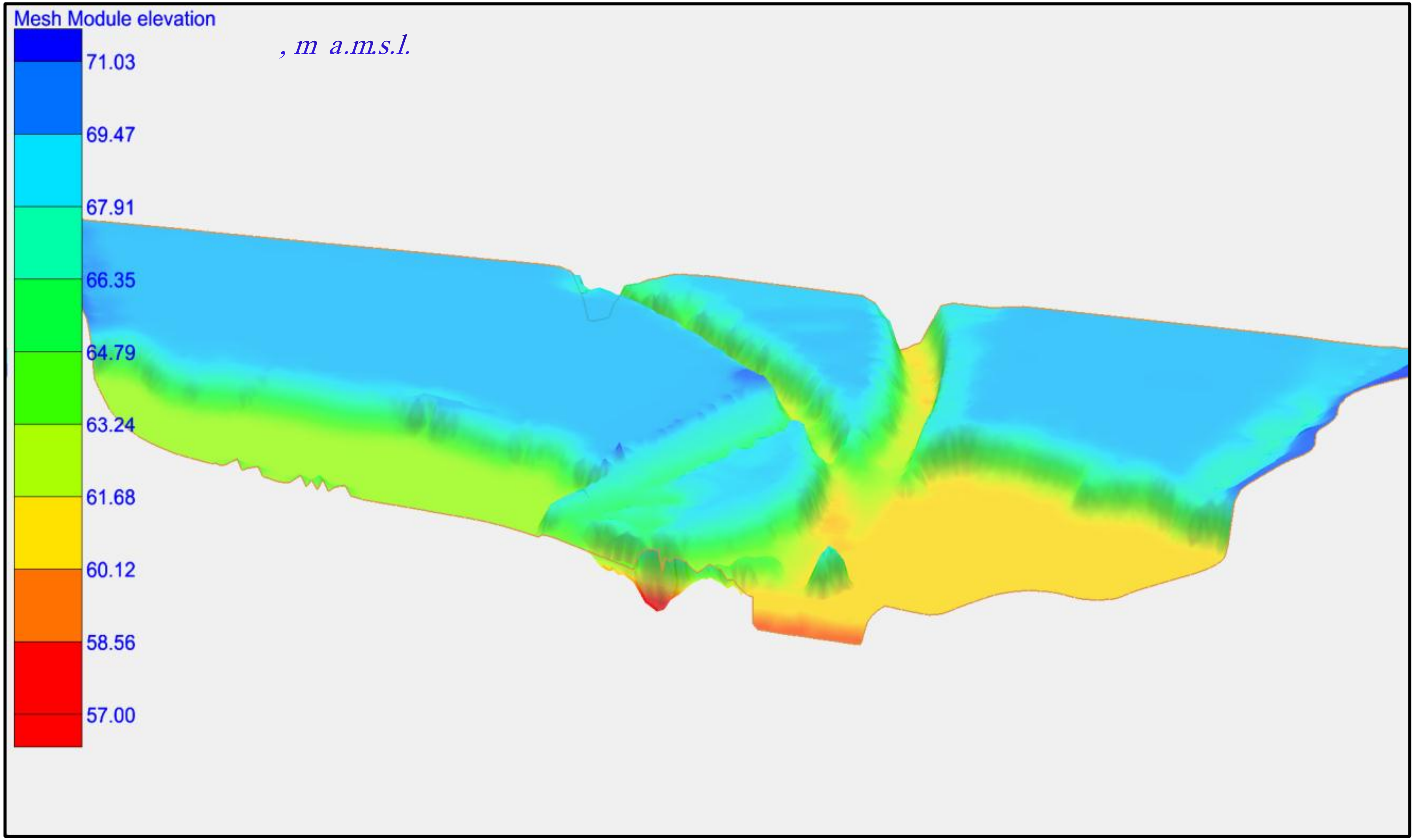


Figure8. Digital elevation model (DEM) of Samarra Tharthar system, Center of studies and Engineering Designs/ Ministry of Water Resources(2013).

A. Layout input parameters at dry year   B. Layout input parameters at flood year

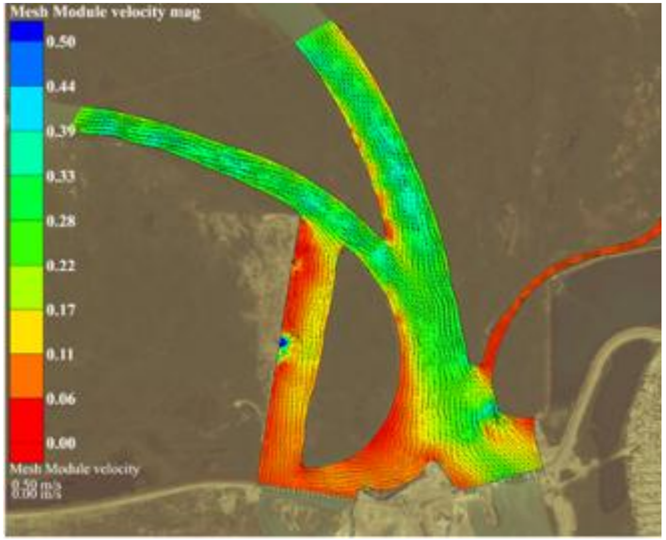
Figure 9. Layout of boundary conditions for the study area.

Table 1. Input parameters and boundary conditions for dry year.

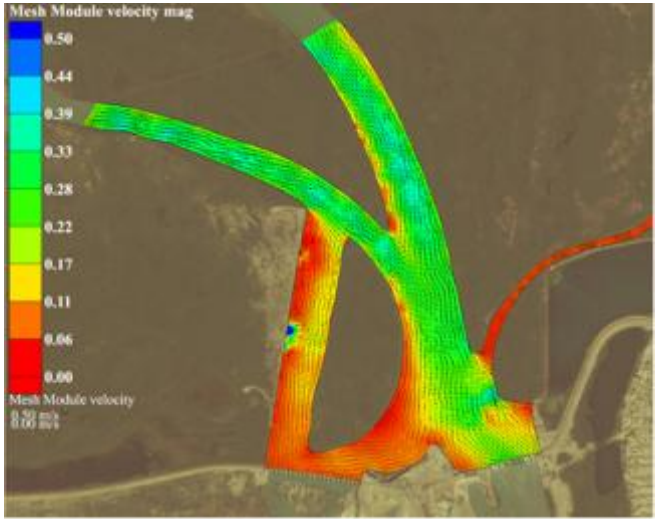
Operation case	River 1, (m^3/s)	River 2, (m^3/s)	River 3, (m^3/s)	Al Tharthar Regulator, (m^3/s)	Water level at Samarra Barrage, (m)
Samarra Barrage	193	289	10	---	67.4
Samarra Barrage with hydroelectric station	193	289	10	---	
Samarra Barrage with Al Tharthar Regulator	193	289	10	72	
Samarra Barrage with hydroelectric station and Al Tharthar Regulator	193	289	10	72	

Table 2. Input parameters and boundary conditions for flood year.

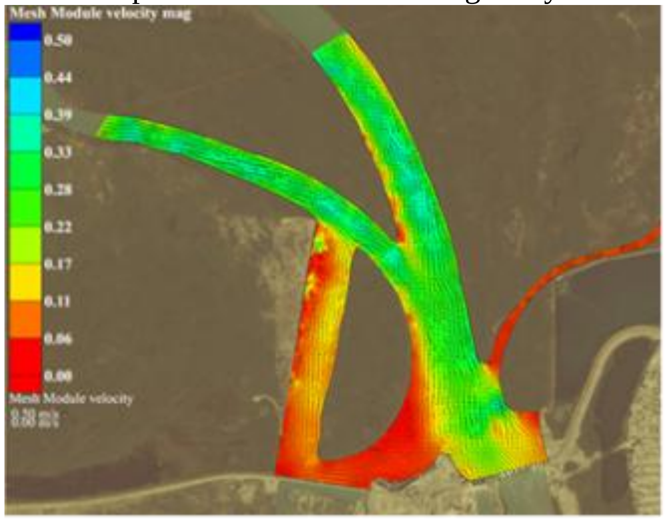
Discharge combination	Inlet Discharge, (m^3/s)	Water level at Al Tharthar Regulator, (m)	New Al Tharthar Regulator, (m^3/s)	Water level at Samarra Barrage, (m^3/s)
10400	10400	W.L	---	2400
11400	11400	W.L	---	
15060	15060		3660	



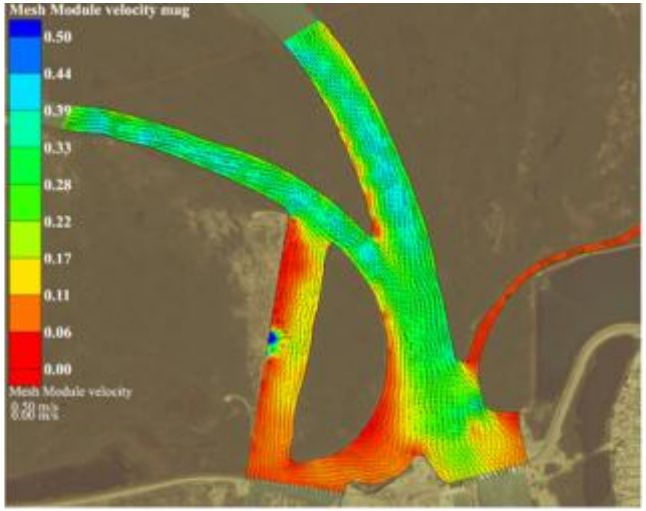
Operation of Samarra Barrage only



Operation of Samarra Barrage and Al Tharthar Regulator

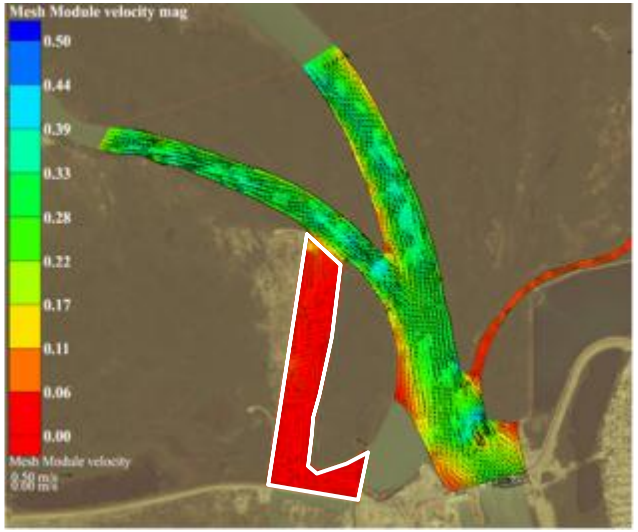


Operation of Samarra Barrage with Hydroelectric station

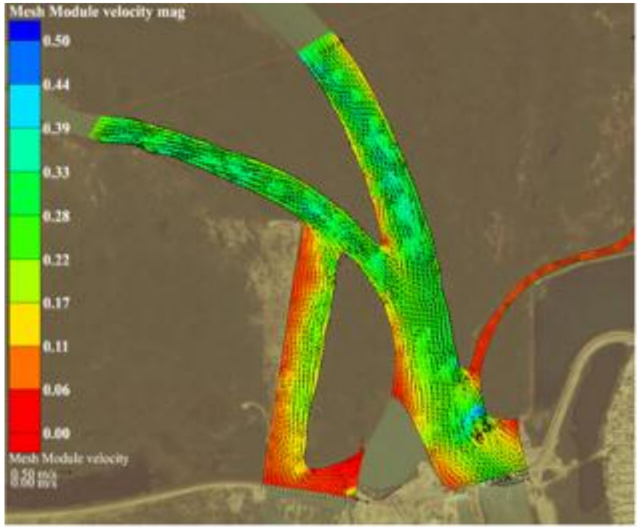


Operation of Samarra Barrage with Al Tharthar Regulator with Hydroelectric station

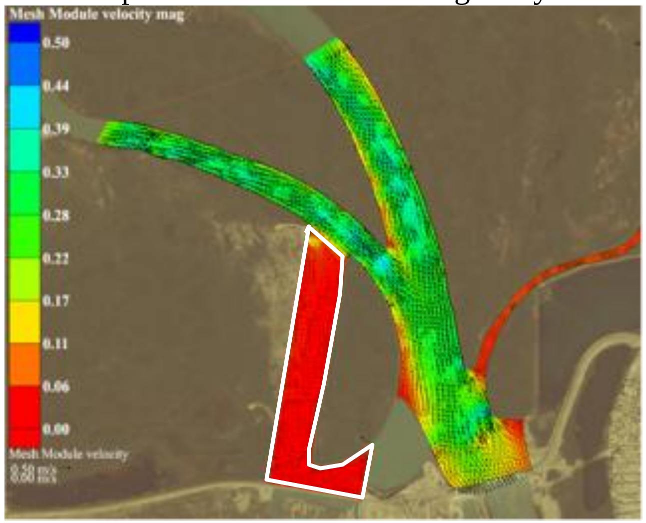
Figure 10. Velocity distribution upstream of Samarra-Al Tharthar system for first scenario in case existing situation.



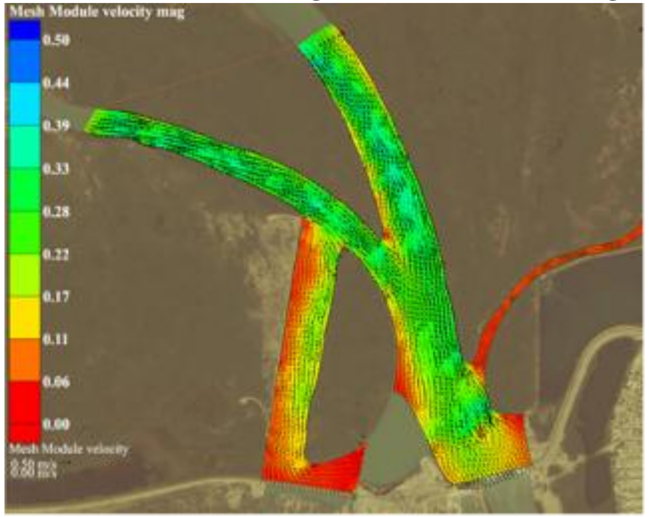
Operation of Samarra Barrage only



Operation of Samarra Barrage with Al Tharthar Regulator

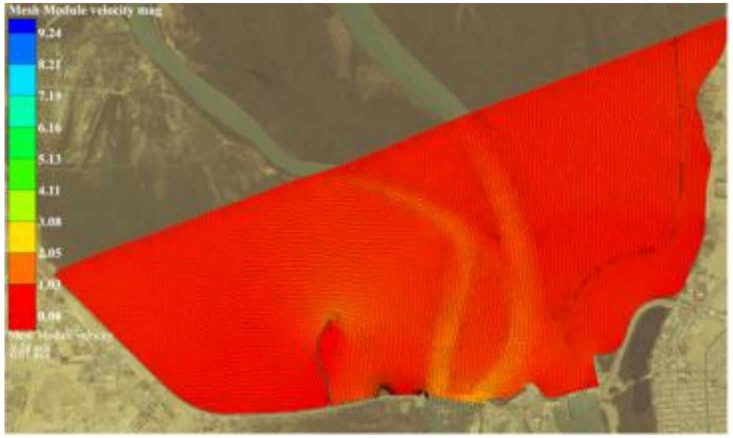


Operation of Samarra Barrage with Hydroelectric station

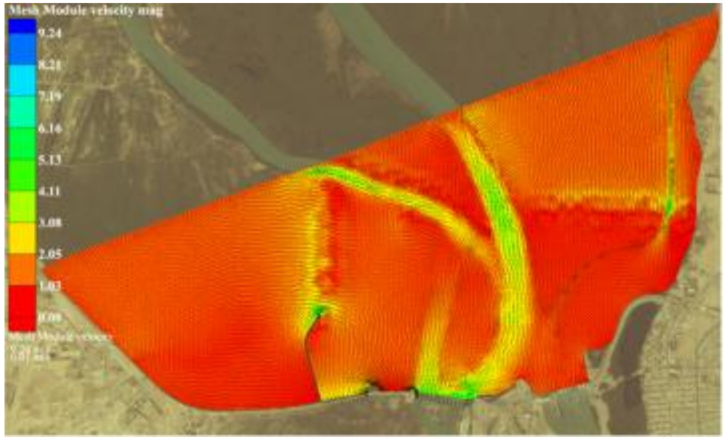


Operation of Samarra Barrage with Al Tharthar Regulator with Hydroelectric station

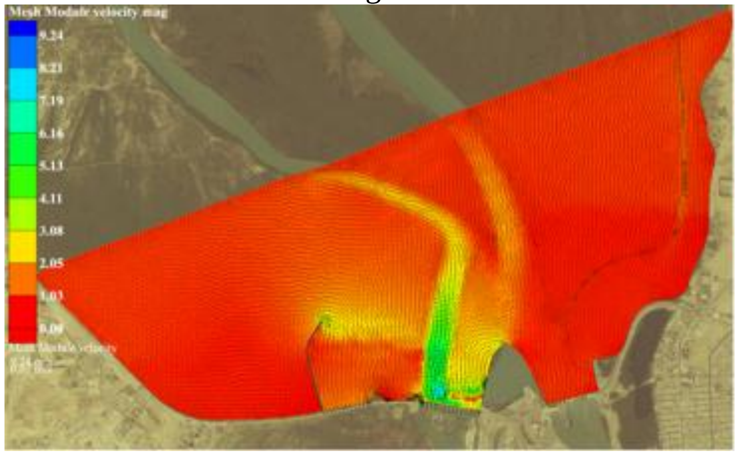
Figure 11. Velocity distribution upstream of Samarra-Al Tharthar system for first scenario in case existing situation with guide bank.



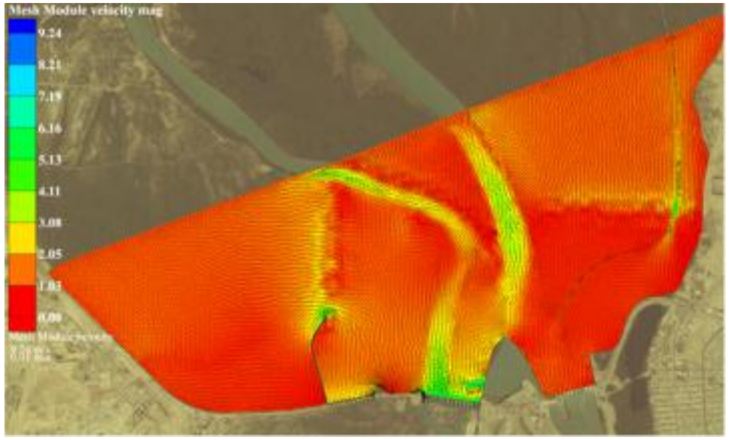
1- Existing situation



2- Existing situation with dredging channel and island

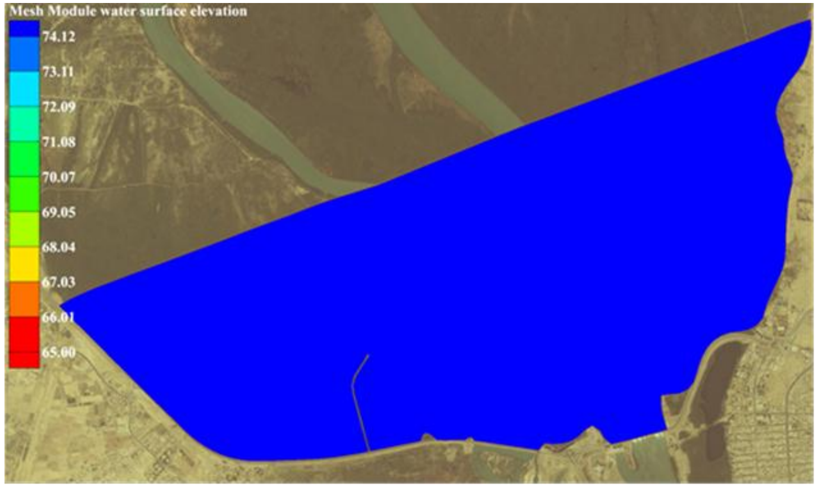


3-Constructing future guide bank

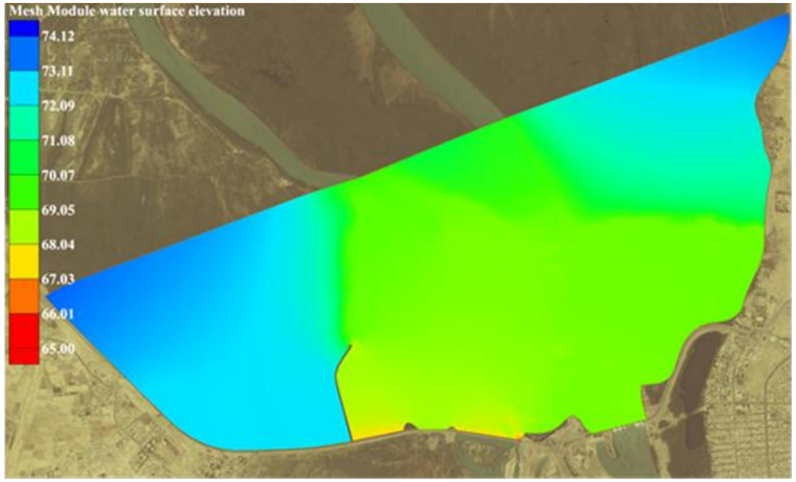


4-Constructing future guide bank with dredging channel and island

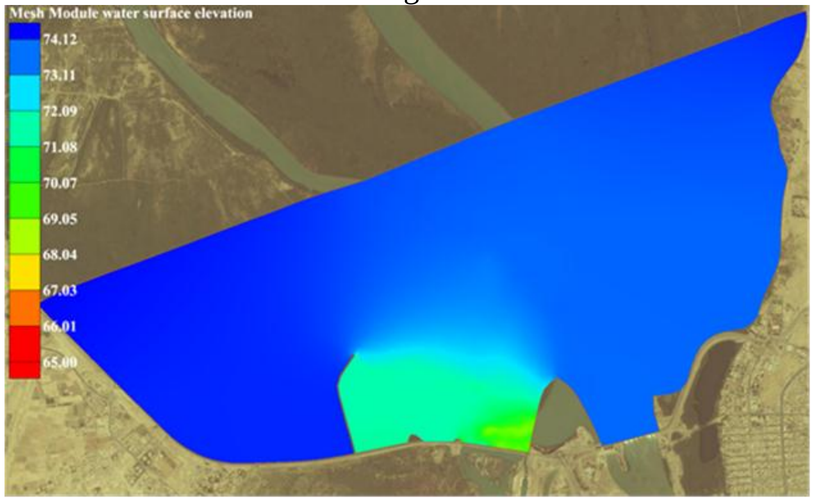
Figure 12. Distribution of velocities upstream of Samarra-Al Tharthar system for third scenario with discharge of 15060 m^3/s and new expansion Regulator of 7000 m^3/s.



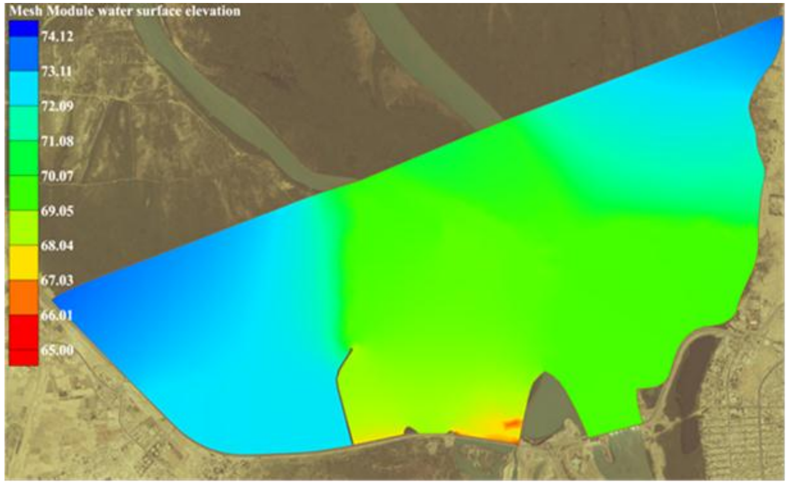
1- Existing situation



2- Existing situation with dredging channel and island



3- Constructing future guide bank



4- Constructing future guide bank with dredging channel and island

Figure 13. Water surface elevation upstream of Samarra-Al Tharthar system for third scenario.

Table 3. Summary of the RMA-2 software results of velocity distribution and water depth for Samarra-Al Tharthar System of the adopted cases in the third scenario with a discharge of 15060 m^3/s.

case	Upstream Samarra Barrage	Upstream Al Tharthar Regulator	Upstream Expansion of Al Tharthar Regulator
	Velocity, m/s		
	Depth of water, m		
Existing situation	0.00-0.75	0.50-1.50	0.50-0.80
	20.40	14.00-17.00	15.60
Existing situation with channel and island dredging.	**0.17-0.80**	**0.50-1.50**	**2.00-2.40**
	10.00-10.50	**5.50-7.40**	**6.25**
Constructing of future guide bank	0.14-1.50	2.00-7.40	1.00-1.16
	10.00-15.00	2.00-10.00	8.00-10.00
Constructing of future guide bank , dredging channel and Island	0.20-1.00	1.00-5.00	1.40-2.00
	7.50-11.00	4.00-8.00	4.00-6.00

Table 4. Summary of the RMA-2 software results of water surface elevation for Samarra-Al Tharthar System of the adopted cases in the 3rd scenario with a discharge of 15060 m^3/s for new regulator of capacity 4000 and 7000 m^3/s.

S	Description	Capacity of the new regulator, m^3/s	Water surface elevation, m.a.m.s.l.		
			Upstream New Al Tharthar Regulator	Upstream Al Tharthar Regulator	Upstream Samarra Barrage
3-5	Existing situation	7000	78.30	78.26	78.40
3-6	Existing situation with dredging channel and Island.		**66.90**	**67.10**	**68.50**
3-7	Constructing of future guide bank		70.95	69.00	73.19
3-8	Constructing of future guide bank with dredging channel and Island		**67.10**	**66.60**	**68.90**