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Original Research

BUILDING A HYDRAULIC MODEL TO RAISE THE LEVEL OF THE TIGRIS RIVER IN THE SCARCITY PERIOD

***Ali Dhafer Abed[1]** **Md. Azlin Md. Said[2]**

1) Water Resources Engineering Department, College of Engineering, Mustansiryah University, Baghdad 10052, Iraq
2) School of Civil Engineering, Engineering Campus, Universiti SainsMalaysia, 14300 Nibong Tebal, Penang, Malaysia

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Abstract: Due to the flow's lack from Turkey and Iran, the Tigris River has recently been suffering from a decrease in water elevations and the emergence of dry areas in some parts of the river. This drought impacts the water levels needed by the liquefaction station and agricultural area, making it a research problem. Therefore, the Tigris River needs to find an effective technical means to increase its water level to a level that does not cause dry areas to appear in any part of the river and does not lead to water flooding in neighboring areas, to be considered a research objective. The research followed the simulation methodology, in which a hydraulic model was built to simulate the river's water levels to detect critical levels. Another hydraulic model was designed and gated weirs were proposed that increased the water level to reach the required levels. The most important finding is that the design of a weir with dimensions of 10 * 3 m of the gated Inline type and in the shape of the Ogee Spillway Crest downstream of the river can contribute to raising the water level in times of scarcity by 1.92 m from its original level. In times of flood, the design of a 5-gate weir of dimensions of 10 * 4 m will maintain a water level between 26.8- 35.2 m along the course of the river and will contribute to raising the water level by 2.23 m from its original level in the estuary.

Keywords: *River Simulation; liquefaction Station; Tigris River; water level; gated weirs.*

1. Introduction

Flow modeling in rivers is performed using computer simulation programs primarily to determine where and when floods occur and simulate water flow and velocity, sediment transport, and all river flow characteristics. There are many computer programs used to model water flows. The most important water modeling programs are HEC-RAS, HEC-6, MIKE II, and CHARIMA. To test one of these programs, several factors must be taken into consideration, the most critical of which are: the price of the product, ease of use, input and output factors, the graphic and digital interfaces of the program, and the source code [1]. CHARIMA is one of the programs that need programming language proficiency because it is written in Fortran. HEC-6 requires additional software for storage and operation, and MIKE II is a model produced by the Danish Hydraulic Institute it is considered expensive due to the price of the source code. The HEC-RAS simulates the hydraulics of water flow in natural rivers and other waterways, modeling capabilities for flow and sediment transfer.

The United States Army Corps of Engineers created the HEC-RAS to manage the rivers, harbors, and other public works under their jurisdiction. It has gained widespread approval since its public release in 1995 [2]. The HEC-RAS program has a more complex graphical user interface than other software, which makes it easier to work because the user can view the inputs and local mistakes before starting the simulation process. Furthermore, the program

**Corresponding Author*:
ali.dhafer@uomustansiriyah.edu.iq

does not require any additional software to display the findings because it already contains all of the necessary tools to present the results as graphs or tables. It includes a variety of data entering options, hydraulic analysis components, data storage, and management, as well as graphing and reporting.

Therefore, in this paper, the main objective will be to raise the levels of the river in the study area by building a one-dimensional numerical model using the HEC-RAS program to simulate the actual reality of the river in the study area in times of scarcity. Simulating the actual reality will lead to showing results related to the levels, velocities, and water flows of the river. Then, the results of simulating the reality of the actual situation will be exploited in designing another model to raise the river level to the required levels by suggesting gated weirs in locations that achieve the research objective [3].

For the HEC-RAS program to run on the river of the study area, the program needs to define the following inputs:

a) geometric data for the river :

Geometric data include Manning roughness coefficient values and watercourse shape data, which involved cross-section shape data along each river, the distance between every two cross-sections, reach lengths, and stream junction information.

b) initial condition for river flows:

The values of water level and discharge at zero time. Where zero time means; the time when the user enters the start time of the simulation to condense the 2D boundary conditions and give them the first value as a level or flow [4]. Applying Manning's equation according to the boundary conditions, the HEC-RAS program uses the back-water curve approach to the steady flow to estimate the initial conditions [3].

c) boundary conditions for river flows:

To determine the initial condition of the surface level at the upstream and downstream. The discharge at the upstream end of the river represents the upstream boundary condition, while the upstream water surface is the downstream boundary condition [4].

d) Manning's roughness:

It describes the flow resistance or relative roughness of a channel and is a function of the type of riverbed material [5]. It depends on the amount of drainage, the cross-section shape, the obstructions to the flow, the density and thickness of the bottom vegetation, and the degree of channel bends. This parameter is used to determine a quantitative value that represents the collective effect of these factors [6].

2. Case Study and Methods

2.1. Study Area

The study area is represented by the Tigris River within the boundaries of the municipality of Baghdad City, Iraq. In the City of Baghdad, the slope of the Tigris River is very small (6.9 cm/km) [7]. The river enters the city of Baghdad from its north at the Al-Muthanna Bridge and ends at its confluence with the Diyala River, south of the city of Baghdad, with a length of approximately 48 km [8] as in Figure 1. The Samarra Dam and the Azim Dam are among the most important dams affecting the waters of the Tigris River since 1990. The average daily discharge of the Tigris River inside the city of Baghdad is 833 m^3/s [9].

The Tigris River has experienced drops in water levels due to the effects of the dams in Turkey and Iran which had reduced the flow to half [10].

The establishment of huge projects by the neighboring countries and the weakness of coordination and agreements with them in a way that guarantees Iraqi interests; Exceeding the water quota from neighboring governorates also contribute to the reduction in water flows. The flow of approximately 20 million tons of silt sediments to the bottom of the Tigris River inside the city of Baghdad, caused the bottom to rise [9], [11]; The increased demand for water for agricultural and industrial purposes, the failure of irrigation methods, and the use of primitive methods for irrigating crops [12]. One major factor is also due to climate change, which has reduced the amount of rainfall, and in some cases droughts in areas in Iraq. All of these factors contributed to the exacerbation of the Tigris River water scarcity crisis inside the city of Baghdad in particular and in Iraq in general [12]. Water scarcity is defined as a failure to meet human and environmental requirements of freshwater resources. Water scarcity is linked to many factors that face most countries of the world, such as increased water pollution, overuse, and extreme climatic changes [13]. The Tigris River is considered one of the most important rivers in Iraq, whose water scarcity must be addressed before causing an environmental disaster that could affect all residents of Baghdad and the governorates of Iraq [14].

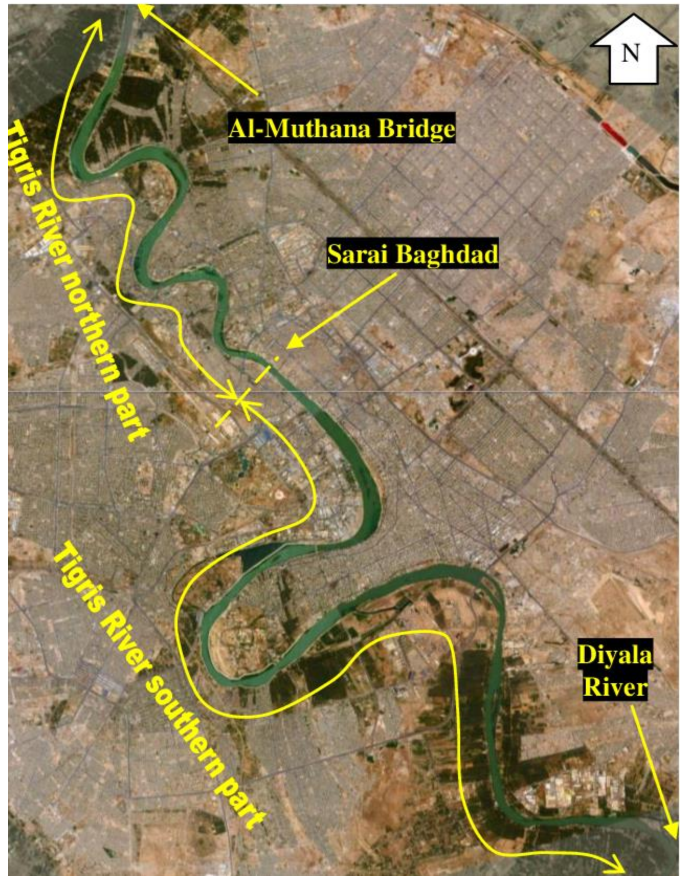


Figure 1. The Reach of the Tigris River within Baghdad City [7]

2.2. Building a model that simulates the reality of the river

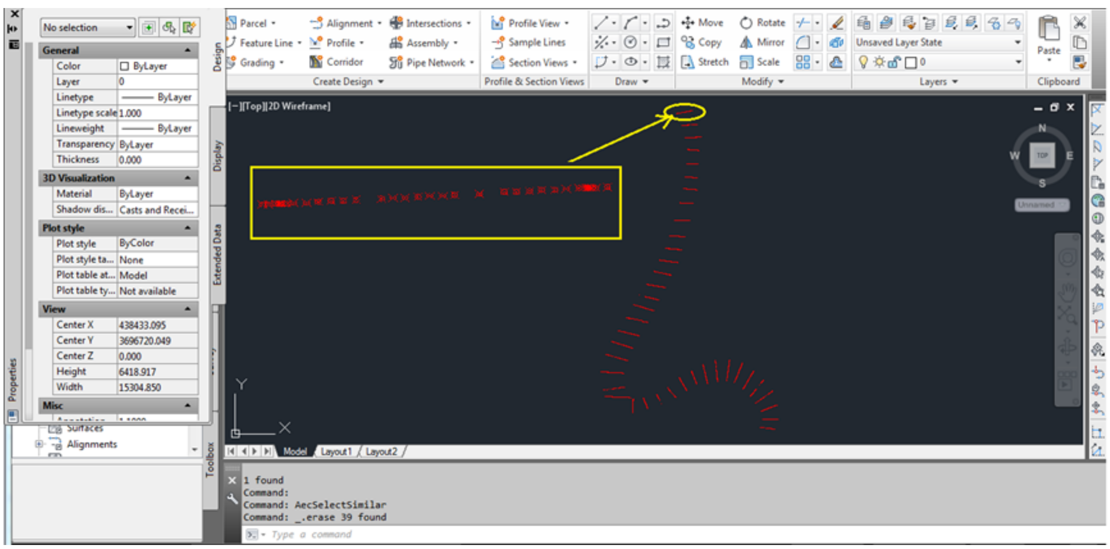
For the purpose of building a numerical simulation model that simulates the reality of the river in the study area, inputs to the simulation program must be defined, as follows:

2.2.1. *Definition of Geometric data*

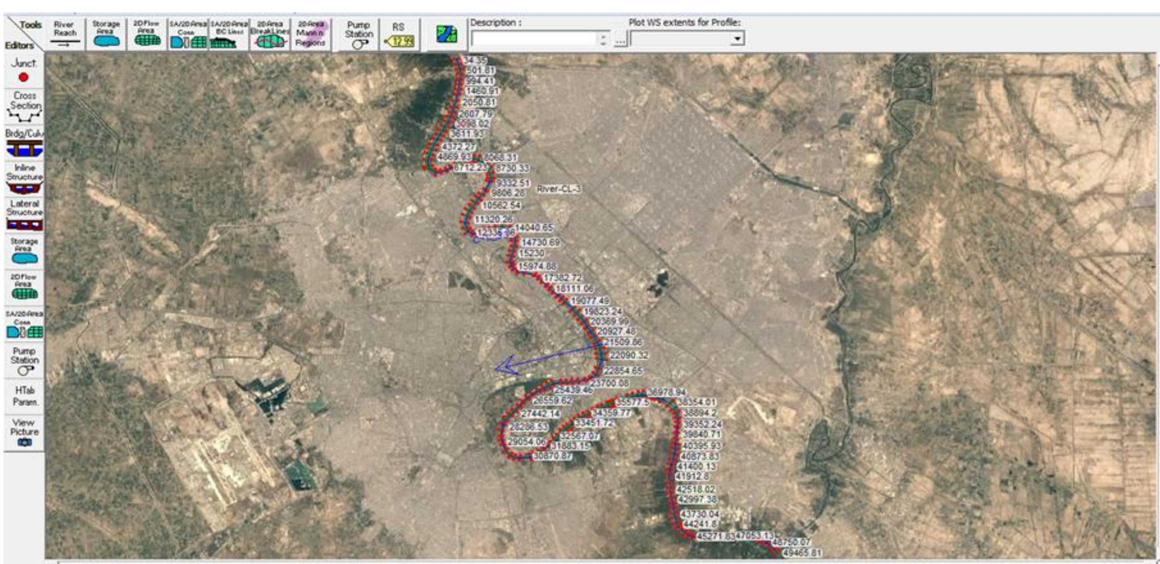
It was based on the topographical survey points for the course of the river, which were obtained from the Ministry of Municipalities and Public Works. The data included three-dimensional coordinates of the cross-sections distributed along the river for every 250 meters. The data was processed based on the Civil 3D 2021 program, where the definition of the river's course, banks, and cross-sections were defined and then exported to the HEC-RAS program to represent the geometric data. Note Figure 2, Figure 3, and Figure 4.

The model that was built in the HEC-RAS program was calibrated by comparing the levels calculated by the program at the upstream and downstream with field-observed data for the same cross-section. It turned out that the difference between the calculated level and the real level ranged between 0.02 to 0.04 m, which is a high accuracy percentage on the basis of which the results of the model can be adopted.

By presenting the results, the minimum elevation of the riverbed is 25.9 m, and 26.3 m for the maximum, so the lowest elevation that does not cause the emergence of dry areas in the middle of the river should be more than 25.9 m. As for the highest elevation that does not cause damage to the banks or the exit of water to the neighboring areas, it ranges from 35.2 m in the north of Baghdad to 32.1 m in the south. Therefore, the water elevations of the Tigris River must range between 26-32.1 m as a minimum in order to achieve the desired goal of the research.



.Figure 2. Ground survey points of river's cross sections in Civil 3D



.Figure 3. Geometric data in the HEC-RAS program

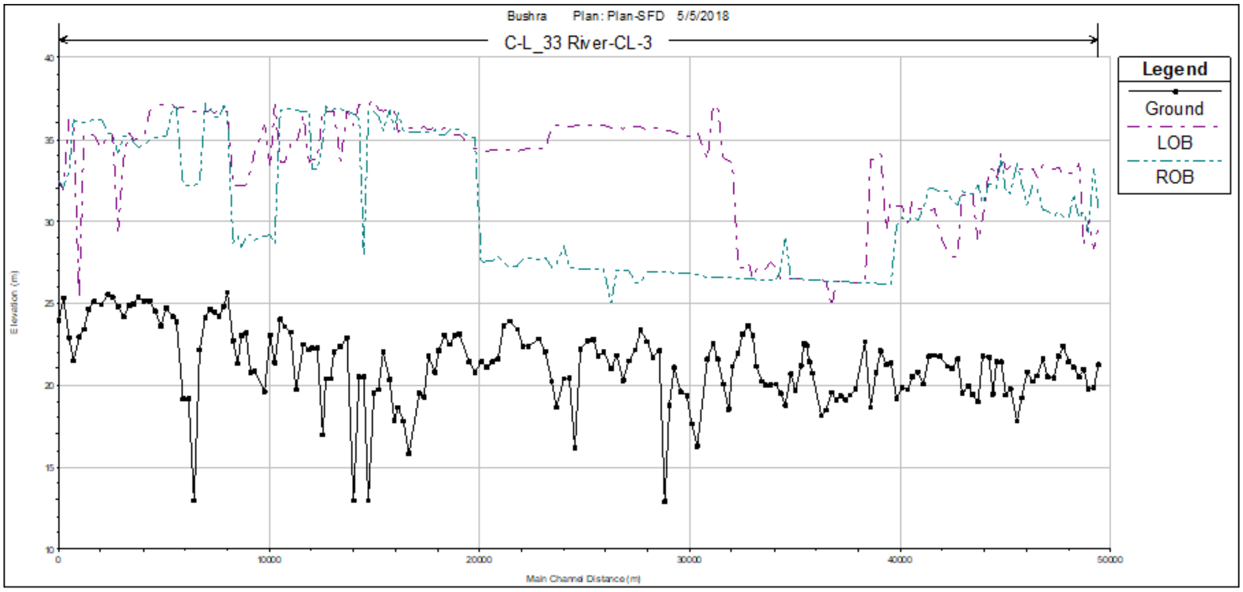


Figure 4. Definition of the longitudinal section of the river course and its banks (LOB-Left of Banks and ROB-Right of Banks).

2.2.2. *Define initial and boundary conditions*

For the purpose of raising the level of the Tigris River in times of scarcity to a level that does not cause the emergence of dry areas in the middle of the river, ~~and does~~ not cause flooding and the exit of river water from the banks, a simulation model will be built based on two periods. The first period is represented by the low flow that occurred in 2014 from November to December. The lowest level was 27.6 m and the lowest discharge was 332 m^3/s, according to the forecasts of the North Baghdad station. The second period was represented by the flood that occurred in 2013 between February and March, which represents the period during which the Tigris River reached its highest level. Where the highest level and discharge of the river reached between 30.34 m and 1210 m^3/s, respectively. These two months will be used as variables for the initial and boundary conditions for the purpose of running the model.

2.3. Building a hydraulic model that raises the river level

To raise the river level, two scenarios were proposed and the model was run according to them. These scenarios can be summarized as follows:

2.3.1 . *A scenario that proposes the establishment of an (Ungated Inline Weir) south of Baghdad, according to the scarcity of data*

It was proposed to construct a weir near the confluence of the Tigris River with the Diyala River at Station 480 so that the river level would not be less than 25.9 m and not more than 32.1 m.

The proposed weir is of the gated Inline weirs type and has the shape of (Ogee Spillway Crest). This shape needs to enter (the spillway approach height and the ogee's design energy head) in order to calculate the dam's coefficient by the program (weir coefficient) according to the (weir equation).

In the Inline Structure Weir Station Elevation Editor window for HEC-RAS, the weir

Table 1. Definition of weir parameters.

weir parameters	***Value***
Weir Station	480
Width of Weir (Road Width)	20 m
Spillway Approach Height	3.67m
Design Energy Head = energy grade line elevation (at the design discharge) - elevation of spillway crest= 25.9-23.17	2.73 m
Weir Coefficient	1.99

parameters are defined in Table 1, note Figures 5 and 6:

When Q = 322 m^3/s and the water level is 27.6 m, with the number of gates 5 and the dimensions of the gate are Width=10m, Height= 3m, the gate opening should not exceed 0.46 m to achieve a level of not less than 25.9 m, and raise the elevation 1.92 m at downstream, as shown in Figure 5 and Figure 6 below.

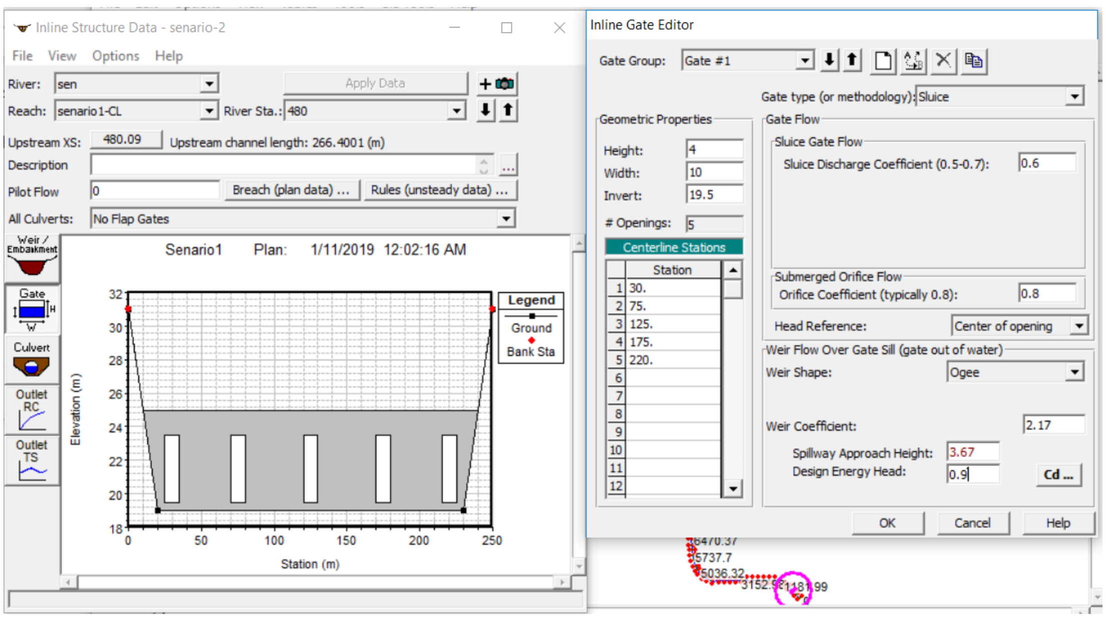


Figure 5. identify Gated Spillway inline weir station, elevation and its parameters.

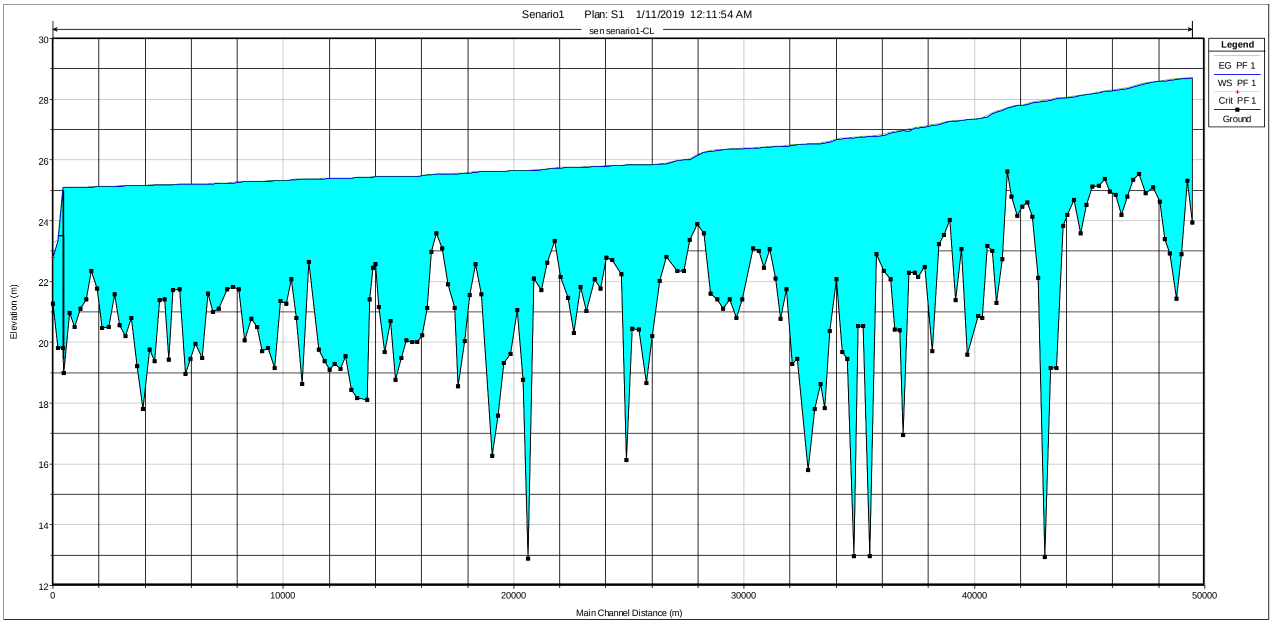


Figure 6. Longitudinal section of the water level change along the river during the scarcity period after the weir proposal and the definition of the gates.

2.3.2 . *A scenario that proposes the construction of an (Ungated Inline weir) south of Baghdad, according to the flood data*

When Q = 1210 m^3/s, the water level is 30.34 m, the number of gates is 5, and the dimensions are Width= 10 m, Height= 4 m, and the entire gate opening (4 m) provides us with a level of no more than 35.2 m and no less than 25.9 m to achieve this required level. The gates will also raise the water level at the estuary by 2.23 m above its original level, as shown in Figure 7 and Figure 8.

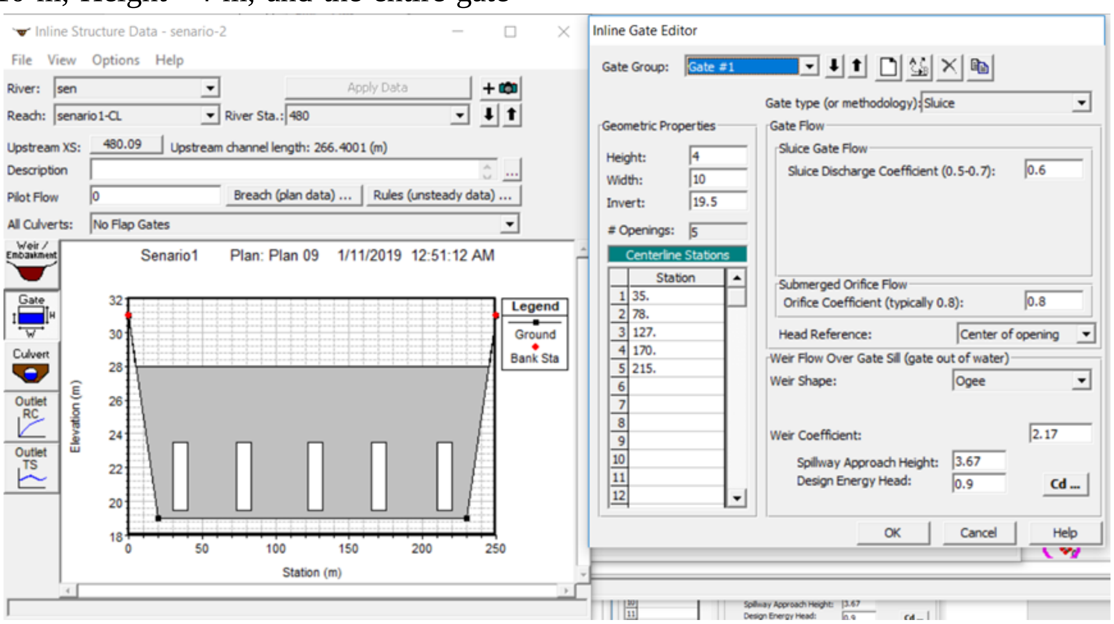


Figure 7. Identify the Gated Spillway inline weir station, elevation and its parameters.

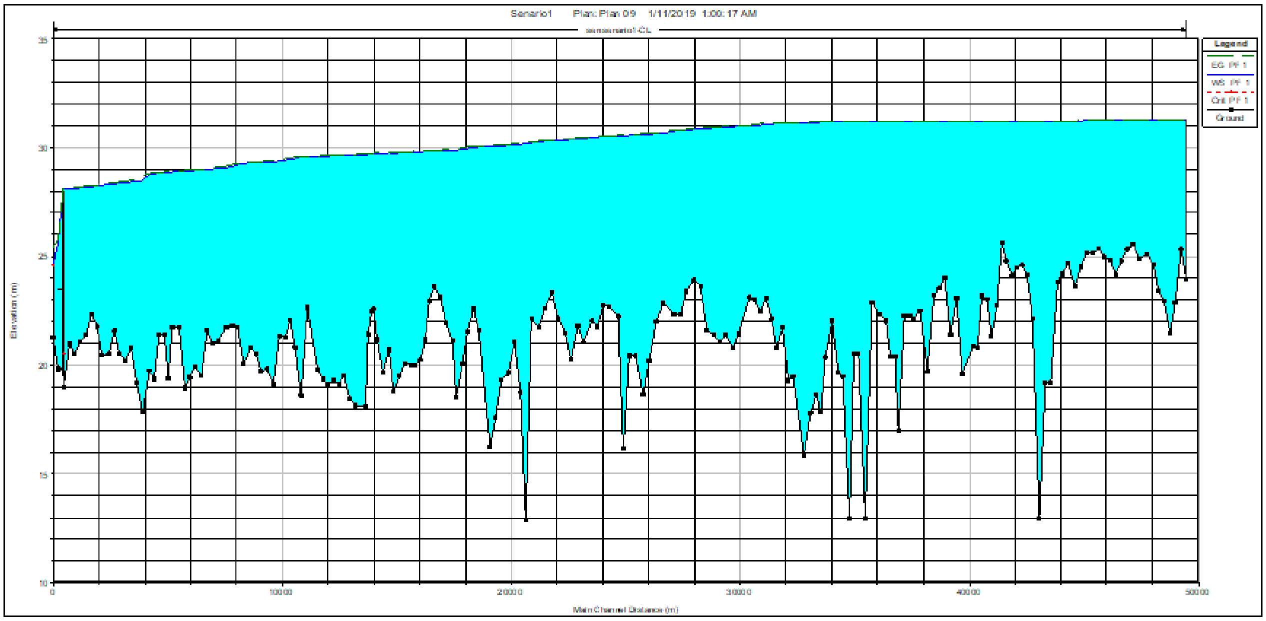


Figure 8. Longitudinal section of the water level change along the river during the flood period after the proposal of the weir and the definition of the gates.

4. Conclusions and Recommendations

Depending on the river's path model, the lowest level of the Tigris River bed was 25.9 m, which does not provide the levels needed by the liquefaction stations. Therefore, the lowest water level should be no less than 26.5m in order to not show dry areas in the middle of the river and not hinder the navigation of riverboats. The design of a gated Inline weir with the shape of an Ogee Spillway Crest near its confluence with the Diyala River contributes to raising the water level in times of scarcity by 1.92 m from its original level downstream. In times of flood, a 5-gate weir design of 10 x 4 m will maintain a water level between 26.8 and 35.2 m along the river path. It will also raise the water level by 2.23 m above its original level downstream. The water level should not exceed 35.2 m in the north of Baghdad, and not exceed 32.1 m in the south of the city, so as not to cause the water to flood in neighboring lands.

The research suggests conducting a study on sediment transport in the Tigris River and determining the cross-sections in which the largest amount of silt is deposited. As well as studying the areas where erosion of the banks occurs in the areas of the river bends. Whereas, determining the areas of sedimentation and erosion within the river with high accuracy can result in the treatment of all flow characteristics within the river.

5. Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

6. Author Contribution Statement

The author, Ali Dhafer Abed, proposed the research problem and developed a simulation model to solve the problem and achieve the research goal.

The author Md. Azlin Md. Said supervised and developed the final results of the research.

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