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MODELING OF LOCAL SCOUR AROUND AL-KUFA BRIDGE PIERS

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Al-Kufa bridge, bridge piers, field measurements, HEC-RAS, local scour, model, scour.

ABSTRACT

Bridges are critical structures that require a substantial investment to construct and serve an important role in economic development. There is need to protect these assets by continuous monitoring, maintenance, proposing any required repair works. Al-Kufa bridge is an important and old structure in Al-Najaf city in Iraq, so computing and monitoring the scour around its piers is a significant thing to know if the bridge is safe from failure. HEC-RAS program was used, and from the collected data field measurements and laboratory results analysis, the maximum local scour depth around Al-Kufa bridge piers was evaluated. Where found that the computed scour depth from HEC-RAS program compares well with the observed value. It was found that the HEC-RAS model is a good tool for predicting local scour depth for bridge piers. And the study showed that the piers of Al-Kufa bridge are safe against the scouring in the present time.

1 Introduction

The most common cause of bridge failures is from floods scouring bed material from around bridge foundations. Scour is the engineering term for the erosion of streambed sediment around an obstruction in a flow field (Chang, 1988 is cited from Alabi, 2006).

Local scour at bridge piers caused worry for hydraulic engineers for a long time. To avoid a failure in the bridge, the pier foundation is to be constructed to a depth deeper than the maximum possible scour depth in its life time, and the old bridges must be evaluated from time to time to estimate the maximum scour depth around piers to avoid the failure.

Because of complexity of evaluating flow pattern around piers and shear forces generated by flow pattern, most of the estimates of scour depth have been obtained by experimental work..

In this study, provide a description of the methodology used to develop the hydraulic model of Al-Kufa bridge in Al-Najaf city in Iraq. The hydraulic modeling was performed using the one-dimensional U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System, HEC-RAS version (4.1.0, 2010). Al-Kufa bridge model was developed to evaluate the maximum local scour depth which formed around its single piers.

2 Site Description

The case that will be studied is single piers for Al-Kufa bridge at Shatt Al-Kufa in Al-Najaf city. The bridge was built through the period (1954- 1957), It consists of four openings separated by three single piers with a total length of 166 m. The width of each pier is two meters and the space between each pier is 44.5 m and the abutment of the bridge is built away from the section of the river, figure (1) show Al-Kufa bridge.



Figure (1): Al-Kufa bridge in Iraq

3 Field Measurements

The present study involves collecting field data for Shatt Al-Kufa and Al-Kufa bridge, these data were made during the research in March of 2013 and including the measurements of :

- 1) Data on cross section from which one can determine the cross sectional area and the depth of water at each point along the cross section.
- 2) Water discharge and velocity of river at all reach sections.
- 3) A representative sample of the bed sediments.
- 4) Geometric data for the bridge.

3.1 Cross Section Measurements

Ten cross sections located in the river, seven at the upstream and three at the downstream of Al-Kufa bridge were selected at the reach. The cross sections of Shatt Al-Kufa were measured by using Acoustic Doppler Current Profiler (ADCP) device with technique of river surveyor measurement as shown in figure (2). Where cross section area, velocity and water depth are determined by passing Acoustic Doppler Current Profiler (ADCP) device along transect lines which was operated from an anchored boat. After proceeding appropriate calibration for this device, the (ADCP) device measures the depth at each point when the device passes on. Also the device (ADCP) measures the average velocity of entire cross section.



Figure (2): Acoustic Doppler Current Profiler (ADCP) device

3.2 Bed Material Sampling

Three samples from the bed material were taken from the section near piers, at location 0.25, 0.5 and 0.75 the width of the river in the cross section in order to conduct the grain size analysis. These samples finally mixed well to reduce the error of measurement and get a homogenous sample.

3.3 Geometric Bridge Data

For representation a bridge model in HEC-RAS many of needed measurements had done by using the measuring tape as shown in figure (3), the measurements are : the length of pier along the direction of flow which is equal to (12.70 m), the width of the pier is (2 m), the distance between the piers is (44.5 m), the height of bridge from the water surface level is (8m).



Figure (3): Measuring the geometric bridge data

4 Laboratory Measurements

It involves collecting of laboratory data including measurements of

A- specific gravity

B- Mechanical analysis of the bed sample from which the size distribution curve can be constructed.

Where the experiments was conducted in the laboratories of Engineering Faculty in Al-Kufa University.

4.1 Specific Gravity Determination

The specific gravity is defined as the ratio of the weight of a given volume of soil at a given temperature to the weight of an equal volume of distilled water at The same temperature. The procedure followed to obtain the specific gravity of bed sediment materials was according to (Apparao and Roa, 1995).

Calculations showed that the specific gravity of the section near Al – Kufa bridge is equal to 2.68.

4.2 Grain Size Analysis

The process of obtaining the size distribution which is essentially the separation of sample into a number of size classes, is known as the mechanical analysis. The results of such analysis of sediment are usually presented as cumulative size – frequency curve.

The sieve analysis was used for sediment of the section near Al – Kufa bridge and hydrometer analysis was used for particles finer than 0.075 mm.

Figure (4) shows the grain size distribution of the bed material, where the result of test showed that the median particle size (D50) equal to (0.19 mm) and the size fraction (D95) equal to (0.58 mm).

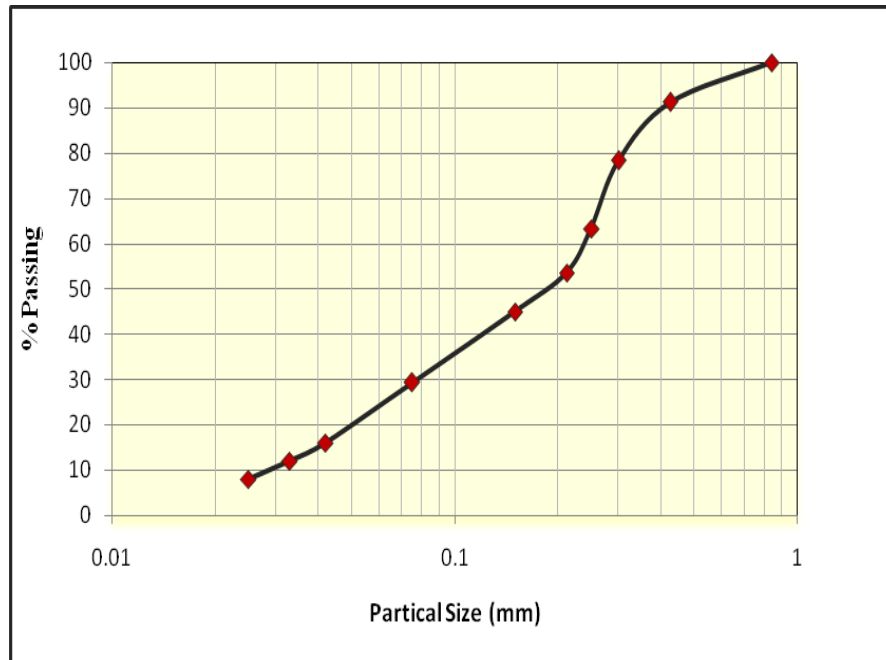
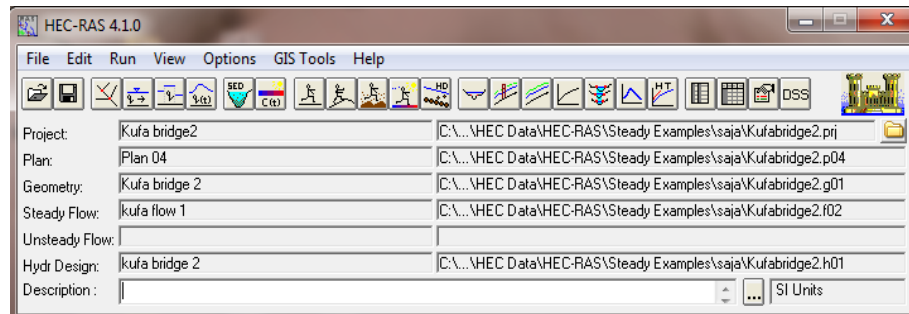


Figure (4): Grain size distribution curve of bed material

5 Al-Kufa Bridge Scour Modeling Using Hec-Ras Program

For this study, hydraulic model was developed using HEC-RAS [Version 4.1.0,(2010)]. The HEC-RAS model allows to perform simulation steady and unsteady flow evaluation in single or networked channels. It is an integrated system of software, designed for interactive use in multitasking, multi-user network environment.

The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management graphics and reporting facilities(HEC-RAS, 2010). Figure (5) showing the main window when you first start HEC-RAS model.



Figure(5): Main menu of HEC-RAS model

To apply a bridge for a steady flow hydraulic model and to find the magnitude of maximum scour at bridge piers, two necessary file types are required:

- 1) The geometry file contains the necessary physical description for the stream reach and the bridge.
- 2) The flow file describes all the flow inputs and relates reach boundary conditions needed for the steady flow analyses.

The data required to represent the bridge model are roadway data, piers data and sloping abutment data, these data were measured. For steady flow hydraulic model are flow regime, boundary conditions and peak discharge information are taken from Najaf Water Resources Department (NWRD).

From these data, the model is applied using HEC-RAS one dimensional analysis to calculate the maximum scour at bridge piers.

All the input data required to run a bridge HEC-RAS model are presented in the following sections.

5.1 The Geometric Data

The first step to develop HEC-RAS model is to create a HEC-RAS geometric file. The basic geometric data consists of establishing how the various river reaches are connected (River System Schematic); cross section data; reach lengths; energy loss coefficients (function losses, contraction and expansion losses); and stream junction information. These data were inputted to the model through the menu of cross section geometrical data as shown in figure (6).

Whereas, the bridge location on the river is specified and its detail has entered to the model using bridge geometrical data menu, as shown in figure (7).

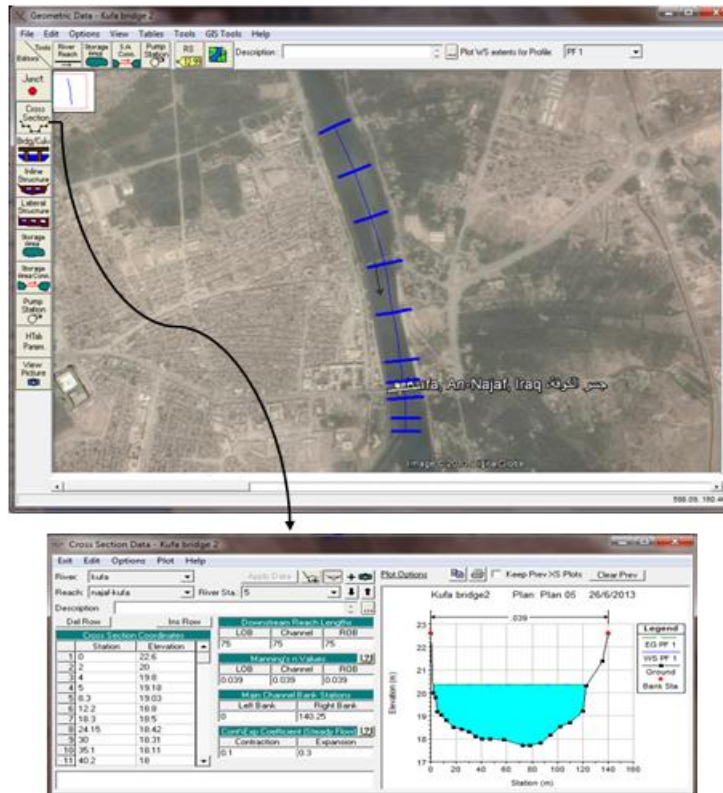


Figure (6): Input menu of cross section geometrical data

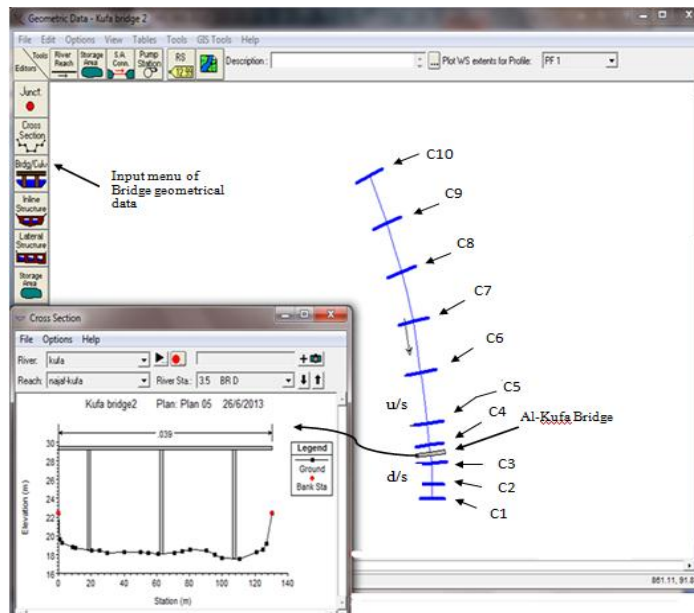


Figure (7): Input menu of bridge data

5.1.1 The River System Schematic

The schematic defines how the various river reaches are connected. The model can handle simple single reach modules or complex networks. The river system schematic is developed by drawing and connecting the various reaches of the system within the geometric data editor. This schematic data must be the first input into the HEC-RAS model. For this study, the model of river system schematic is single reach.

A schematic diagram of the river system is drawn as shown in Figure (7). The reach is drawn from upstream to downstream (in the flow direction), because the HEC-RAS model assumes this to be true.

5.1.2 Cross Section Geometry

Boundary geometry for the analysis the flow in river stream is specified in terms of ground surface profiles (cross sections) .The measured distance between any two cross sections is referred to a reach length. Cross sections should be perpendicular to the anticipated flow lines and extend across the entire flood plain (these cross sections may be curved or bent).

The cross section is described by entering the stations and their elevations (x-y) data from left to right. When numbering River Station Identifiers were being taken; it was assumed that the higher numbers are upstream and the lower numbers are downstream within a reach. All of the required information is displayed on the cross section data editor, figure(8) shows some of cross sections at upstream and downstream

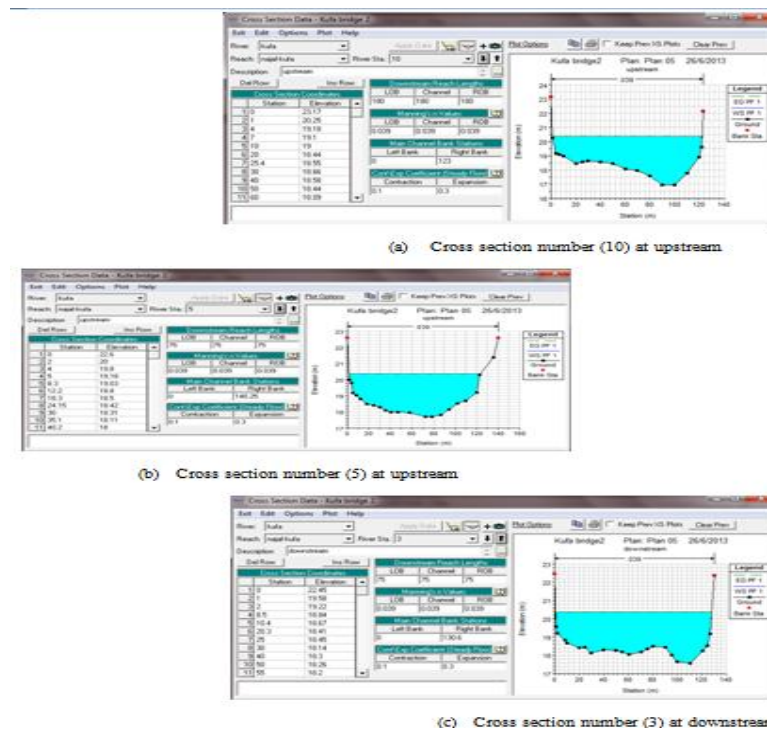


Figure (8): Some of cross sections

5.1.3 Energy Loss Coefficients

Energy losses are represented by channel expansion, contraction and by friction losses. Explaining these losses are in the following sections.

- Manning’s Coefficient (n)

The value of n depends on: surface roughness, vegetation, channel irregularities, channel alignment, scour and deposition, obstructions, size and shape of the channel, stage and discharge, seasonal change, temperature, and suspended material and bed load (Chow, 1959; Henderson, 1966). One value of n will be selected for all cross sections as shown in figure (8), for the reach in this study Manning’s coefficient was taken 0.039 (Sahib, 2013).

- Contraction and Expansion Coefficients

Contraction or expansion of flow due to changes in the cross section is a cause of energy loss between cross sections. The loss may be computed from the contraction and expansion coefficients were input manually using the HEC-RAS cross section data editor, figure (8). Typical coefficients used in the model are values 0.1 and 0.3 for Contraction and Expansion Coefficients, respectively.

5.1.4 Bridge Geometry

Bridge geometry consists of the necessary data that related to the bridge:

The location of the bridge by entering new river station for the bridge in the reach.

Roadway data that include the distance between the upstream cross section and bridge, the width of bridge in direction of flow and the thickness of bridge is described by entering the stations and elevations of bridge (x-y) data from left to right.

Pier data that include the distance from the left to the centerline of each pier, the width of the pier and the height of the pier represented by elevations.

These data are entered to the model through the menu of bridge data as shown in figure (9).

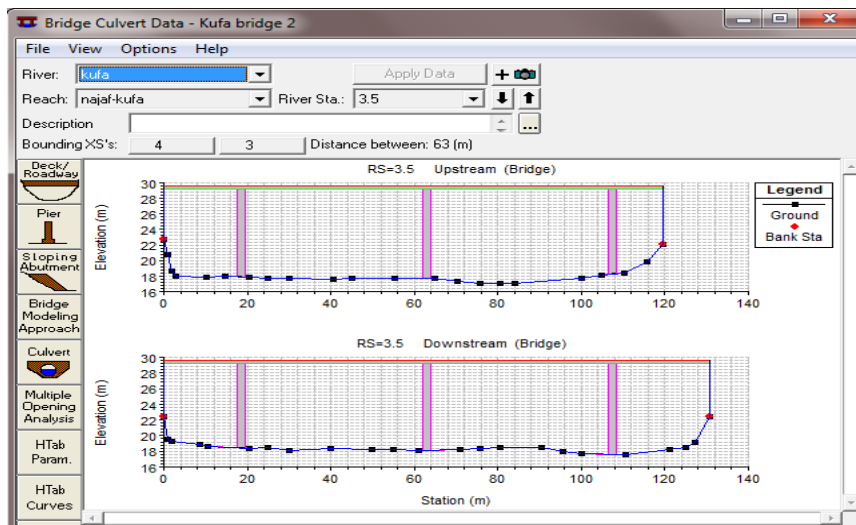


Figure (9): Bridge data menu

5.2 Steady Flow Data

Steady flow data are required in order to perform a steady water surface profile calculation. Steady flow data contain details on flow regime, boundary conditions and peak discharge information.

Flow regime (subcritical, supercritical or mixed flow regime) is specified on the steady flow analysis window of the user interface as shown in figure (10).

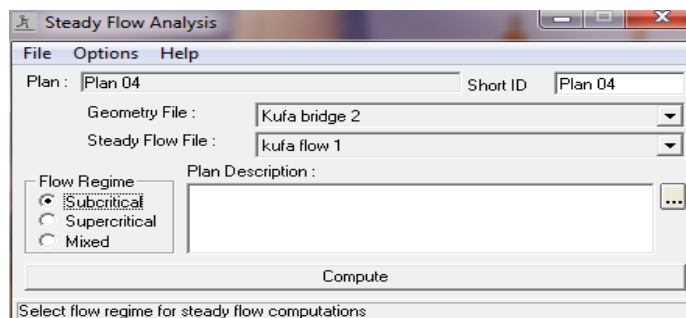


Figure (10): Steady flow analysis window

Boundary conditions are necessary to establish the starting water surface at the ends of the river system (upstream and downstream). A starting water surface is necessary for the program to begin the calculations. For this case, boundary condition in downstream is the slope of reach for normal depth computation and it equals to (0.00013) (NWRD, 2013). Discharge for the reach that measured by Acoustic Doppler Current Profiler (ADCP) device in (march, 2013) is equal to (40 m³/s). These data are put to the model through the menu of steady flow data as shown in figure (11).

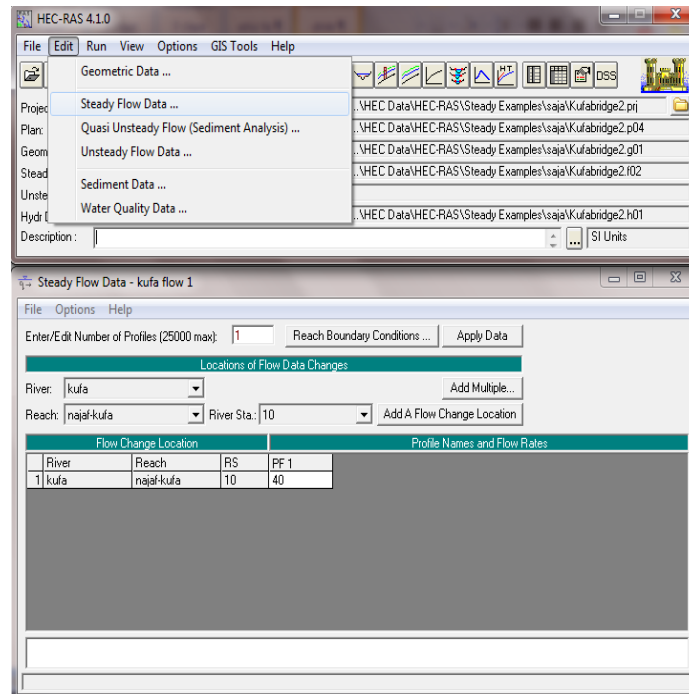


Figure (11): Input menu of steady flow data

5.3 Bridge Scour

The bridge scour computations are performed from the hydraulic design functions window and selecting the scour at bridge function as shown in figure (12)

The scour at bridges window contains the input data, a graphic and a window for summary results. From this window pier scour can be computed by either Colorado State University (CSU) equation or the Froehlich equation, for this study the CSU equation is considered as shown in figure (12).

The data that required to be entered are a D50 size fraction for the bed material which is equal to (0.19 mm) from the grain size distribution curve of bed material, the pier nose shape (K1) which is equal to (0.9) for sharp nose, the angle of attack for flow hitting the piers (K2) which is determined by entering the angle of attack, the condition of the bed (K3) and a D95 size fraction for the bed material which is equal to (0.58 mm) from the grain size distribution curve of bed material.

For determined whether the flow condition is either clear-water or live-bed, then the channel velocity (V1) that which equal to (0.13 m/s) is compared to the critical velocity of the D50 size for sediment movement (Vc) by using this formula:

$$V_c = 6.19 (y_1)^{1/6} (D_{50})^{1/3} \quad (1)$$

Where found that Vc is (0.417 m/s), then V1 < Vc, that mean the flow condition is clear-water (Richardson and Davis, 2001; Barbhuiya and Dey, 2004), therefore selected clear-water scour in bridge scour window.

The result of scour at piers can be computed from this window which appears below the graph, the scour for this case is equal to (0.91 m).

From field measurement when the scour measured found that the maximum scour equals to (0.74 m) and its find the computed scour from HEC-RAS program is (0.91), that is a good indicator. Through the results showed that the bridge is safely against the scour, this is because the scour depth is fewer than footing depth.

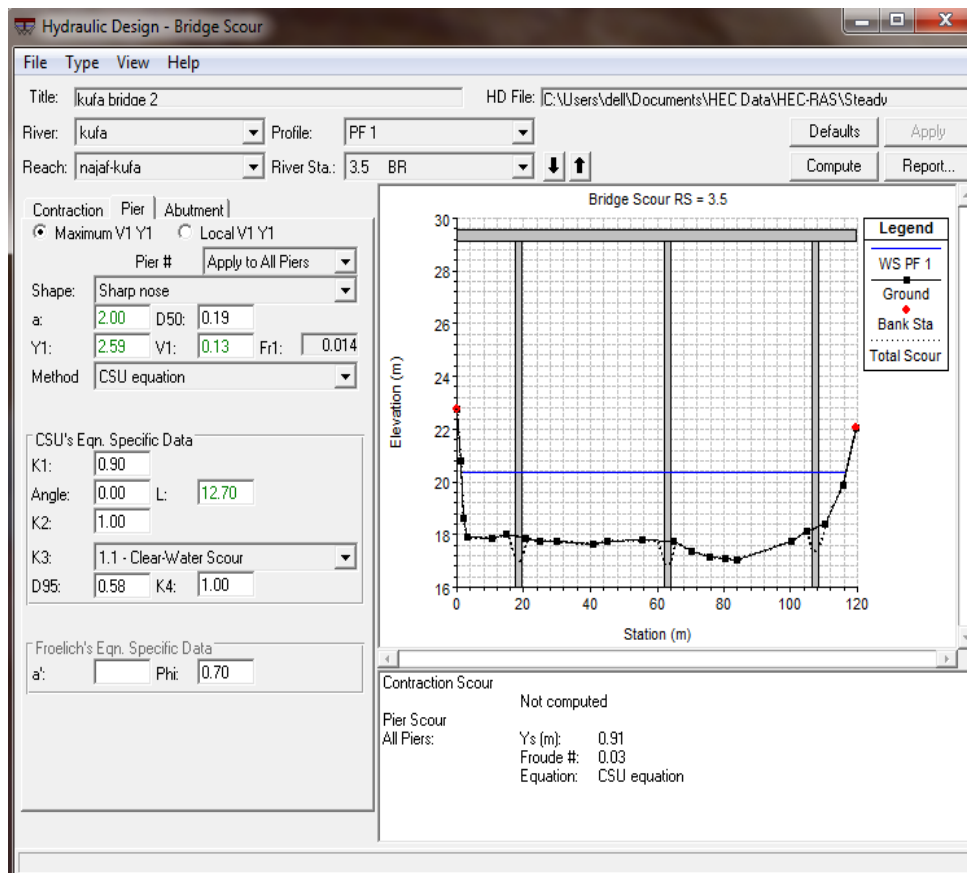


Figure (12): Scour at bridges window

6 Conclusion

When the discharge equal to (40 m³/s) that measured during the period of measuring the field data , the maximum local scour depth that measured was found equal to (0.74m) and the evaluated maximum local scour depth is 0.91m at Al-Kufa bridge piers by HEC-RAS program.

The difference between the computed and measured local scour depth showed that the HEC-RAS model is a good tool for predicting local scour for bridge piers. Hence, it could be used to determine the type of bridge pier foundations before constructing.

The study showed that the piers of Al-Kufa bridges is safe against scouring because the depth of the equilibrium scour is less than the depth of foundation of the bridge .The scouring around the piers should be evaluated from time to time because the local scour could be a major cause of bridge failures which the hydraulic conditions may change.

References

- [1] Alabi, P.D., (2006), "Time Development Of Local Scour At A Bridge Pier Fitted With A Collar", M.Sc. Thesis, University of Saskatchewan.
- [2] Appararo, K.V.S. and Rao, V.C.S, (1995), " Laboratory Manual And Question Bank ", Mehra Offset Press, New Delhi
- [3] Barbhuiya, A.K., and Dey, S., (2004), "Local Scour At Abutments: A Review", Sadhana Vol. 29, Part 5, pp. 449-476.
- [4] Bowels, J.E., (1970), " Engineering Properties Of Soil And Their Measurement ", McGraw-Hill Book company, New York, USA.
- [5] Chow, V.T, (1959), " Open-Channel Hydraulics ", McGraw-Hill Book, , New York, USA.
- [6] Henderson, F.M., (1966), " Open Channel Flow ", Macmillan Publishing company, New York.
- [7] NWRD (2013), (Najaf Water Resources Department), Al-Najaf city, Iraq.
- [8] Richardson, E.V. and Davis, S.R., (May 2001), " Evaluating Scour At Bridges", Hydraulic Engineering Circular No.18, Fourth Edition.
- [9] Sahib, J.H., (2013), "Inverse Method For Operation And Control Of Gates Stroke For Downstream Discharge" M.Sc. Thesis, University of Kufa.
- [10] U.S. Army Corps of Engineers,(2010), HEC-RAS, River Analysis System User's Manual ", Hydraulic Engineering Center ,New York.