Simulation of Sediment Transport in Al- Hilla River in Iraq Using the HEC-RAS Software

محاكاة نقل الرواسب نهر الحله في العراق بإستخدام برنامج HEC-RAS

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Abstract

Sedimentation of canals is a big problem where the feeding rivers contain a large amount of sediments. Hec-Ras 5.0, 2016 program is an applied software package for simulation of river network in steady and unsteady flow regime. The aim of this paper is to verify the model simulation with field survey for Al-Hilla river, depending on the bed material and other characteristics. For transport function, Meyer Peter Muller method was used, and Ruby method is used for calculating the fall velocity, with the active layer as a sorting method. In this paper different types of outputs resulted in both tabular and graphical of Al-Hilla river were showed using different effective elements like discharge, velocity, elevation (bed level changes). The results showed that the change in river's bed differed according to the river sections and sediment material type and the concentration of sediment increased in the part of river when pass the center of Al-Hilla city, this concentration reach to 125 mg/L.

الخلاصة

الترسيب في القنوات يعتبر من اكبر المشاكل من حيث ان مجاري الانهار تحتوي على كميات كبيرة من الرسوبيات. ان برنامج Hec-Ras 5.0, 2016 هو برنامج تطبيقي يمكنه محاكاة شبكة جريان الانهار في حالتي الجريان المستقر و غير المستقر. ان الهدف من هذا البحث لتحقيق موديل يمثل محاكاة مع المسح الموقعي لنهر الحلة بحسب مكونات قاع النهر و الخصائص الاخرى للنهر و بالاعتماد على معادلة Meyer Peter Muller لانتقال الرسوبيات و معادلة Ruby لسرعة الترسيب و باستخدام طريقة الطبقة الفعالة. في هذا البحث تم التوصل الى مختلف المخرجات المجدولة و الرسومات لنهر الحلة حيث عرضت باستخدام العناصر المؤثرة مثل التصريف و السرعة والمنسوب . ان النتائج بينت ان تركيز الرسوبيات يزداد في جزء المقطع الطولي للنهر المار في مركز المدينة ويصل الى 125 mg/L.

1. Introduction

In many countries there is a significant problem of sediment transport of sediments in canals and rivers. When water flows in a channel, the water velocity is reduced due to sediments so the suspended sediments being deposited. As the sediments accumulate in the canal, the canal gradually loses its ability to transport water and high water velocities lead to more sediments being picked up, when water velocity are lowered, the heaviest sediments will settle. Over time this deposition leads to a reduced volume in the channel **[1].** Sometimes the rate of sedimentation is higher than the rate at which revenue required for maintenance of the canal is submitted by the users. Canal sedimentation is the most series technical problem facing irrigation systems **[2].** Effective management of sediment in river is becoming increasingly important from an economic, social and environmental perspective. Sediment carried by rivers is an important component of the global geochemical cycle. Depending on local factors, sediment can prove either beneficial or detrimental to society or the environment **[3].** In Iraq and other countries, many hydrologist and other experts have studies the effect of sediment. Kheder et al. (2014) used three dimensional numerical modeling in a large Canal:Marala Ravi Link Canal (Pakistan) for investigate sediment transport. In this paper, provide a description of the methodology used to develop sediment simulation of Al-Hilla river in Al-Hilla city in Iraq, sediment simulation was performed using HEC-RAS version (5.0, 2016).

2. The Case Study

The selected river is Al-Hilla River, in Al-hilla city in Iraq, which is the river passes inside the middle city of Al-hilla the center of Babylon governorate, the cross section of the river not constant as the river move inside the city, The problem of sediment transport according to erosion of Al-hilla river is one of the major reasons of contamination in this river. See Figures from (1) to (3)

3.Methodology

3.1 Determination of Input Parameters which into HEC–RAS (5.0, 2016) model

Table 1 shows the input parameters which were used in the program. The value of each parameter was either measured directly or computed from hydrologic equations or was already engraved in the model.

Table 1: HEC-RAS input parameters and how they were determined.

Symbol	Description	Determination
n	Manning coefficient (Constant depends on type of channel and description)	(0.025) for straight, full no rifts or deep pool.
Q(m^3/s)	Discharge of water	From " Iraqi Meteorological Office of Water Source, Babylon governorate "
T(C^0)	Water temperature	Measured used a thermometer
d (mm)	Particle diameter	Measured from sieving sediment samples in field
g (m/s^2)	Acceleration due to gravity	Constant provided in Hec-Ras user manual (9.81 m/s^2)
V(m/s)	Average flow velocity	From " Iraqi Meteorological Office of Water Source, Babylon governorate "
υ (m^2/s)	Kinematic viscosity (depend on temperature and quality of water)	Provided by HEC-RAS user manual as being computed from measured water temperature

3.2: Surveying:

This stage contained the collection of all available information for supporting the simulation, Its important step to calculation the difference in cross sections along the specific longitudinal part of the river, this step had completed by using of famous satellite websites like Google earth and by using information of the river from Iraqi Meteorological Office of Water Source, Babylon governorate **[4].**

The difference in cross sections of the river can be obviously noticed by the Google earth website as shown in Fig.1 below:

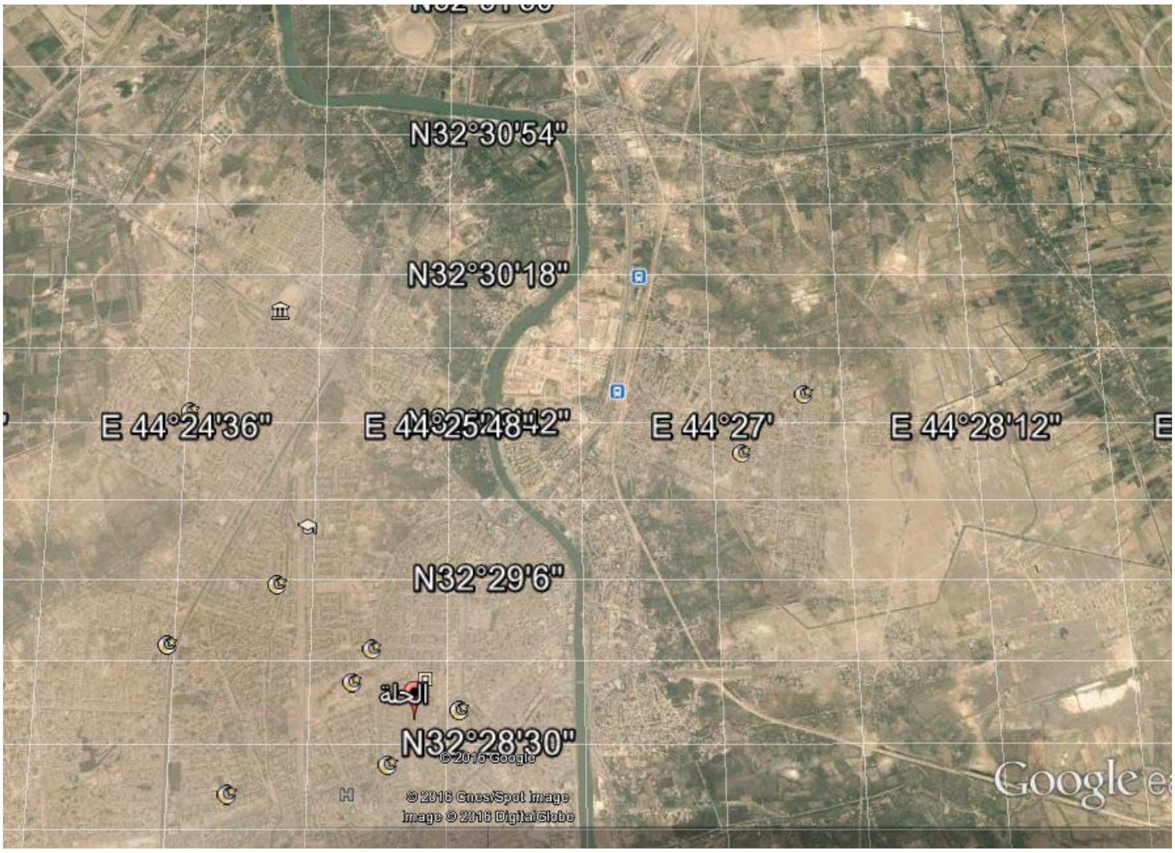


Fig (1): The cross sections of Al-hilla river by google earth website

For the simulation of the sediment transport in the river, data for each cross section in the research's area must be available, this data related to the shape of the cross section and elevation of water surface as shown in Figure (2)

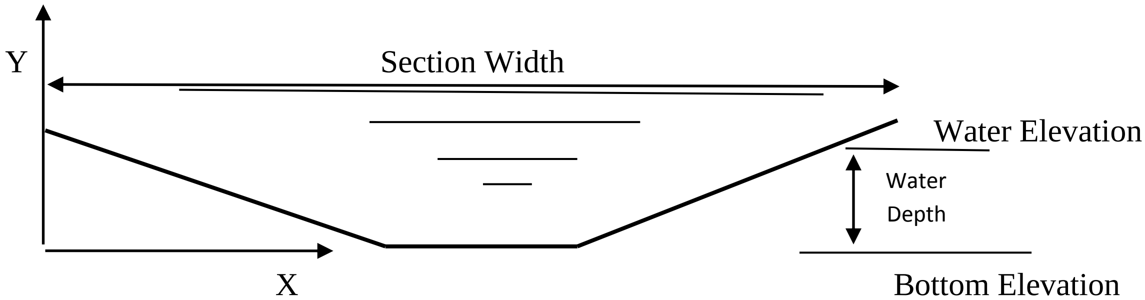


Fig (2): Cross section of Al-hilla river

The surveying results about the cross sections of Al-hilla River in the researched area were summarized in the following table:

Table 2: Summarized of surveying results (Data of Al-hilla cross section from Office of Water Source, Babylon governorate **[4]**)

Latitude	section width	Bottom elevation (meter)	Water elevation (meter)	Water depth (meter)	(x1)	(y1)	(x2)	(y2)	(x3)	(y3)	(x4)	(y4)
N32̊ 30' 54"	68.7	24.86	29.46	4.60	0	4.60	13.80	0	54.89	0	68.7	4.60
N32̊ 30' 36"	78.3	24.74	29.38	4.63	0	4.63	13.90	0	64.39	0	78.3	4.63
N32̊ 30' 18"	84.7	24.62	29.29	4.67	0	4.67	14.00	0	70.66	0	84.7	4.67
N32̊ 30' 0"	95.6	24.51	29.21	4.70	0	4.70	14.10	0	81.47	0	95.6	4.70
N32̊ 29' 42"	67.8	24.39	29.12	4.73	0	4.73	14.20	0	53.57	0	67.8	4.73
N32̊ 29' 24"	47.9	24.27	29.04	4.77	0	4.77	14.30	0	33.63	0	47.9	4.77
N32̊ 29' 6"	50.1	24.15	28.95	4.80	0	4.80	14.40	0	35.68	0	50.1	4.80
N32̊ 28' 48"	72.0	24.04	28.87	4.83	0	4.83	14.50	0	57.52	0	72.0	4.83
N32̊ 28' 30"	75.0	23.92	28.78	4.87	0	4.87	14.60	0	60.40	0	75.0	4.87
N32̊ 28' 12"	103.7	23.80	28.70	4.90	0	4.90	14.70	0	88.99	0	103.7	4.90

The cross section includes the slope of 1:3 as shown in the Figure below

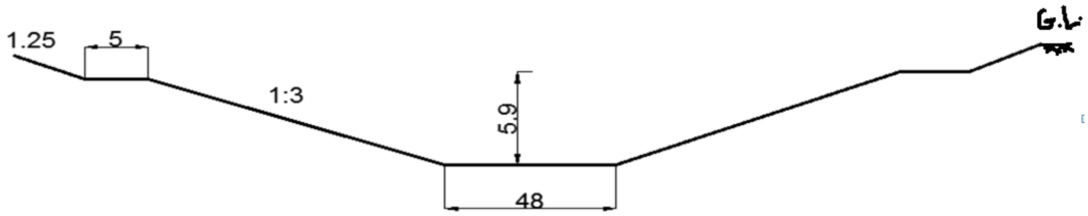


Fig (3): Lateral slope of Al-hilla River

For simulation, its necessary to provide information about the river discharge and bed's soil gradation, according to Iraqi Meteorological Office of Water Source, Babylon governorate, the maximum and minimum discharge in the research's area is 303 m^3/sec and 116 m^3/sec respectively. Table below contained soil type and grading in the bottom of the river.

Table 3: Soil type and grading in the bottom of the river from field.

Soil class	Particle Size (mm)	% Pass
Fine Silt	0.008 - 0.016	5
Medium Silt	0.016 - 0.032	10
Coarse Silt	0.032 - 0.0625	19
V. Fine Sand	0.0625 - 0.125	30
Fine Sand	0.125 - 0.25	40
Medium Sand	0.25 - 0.5	55
Coarse Sand	0.5 - 1	82
V. Coarse Sand	1 - 2	90
V. Fine Gravel	2 - 4	100

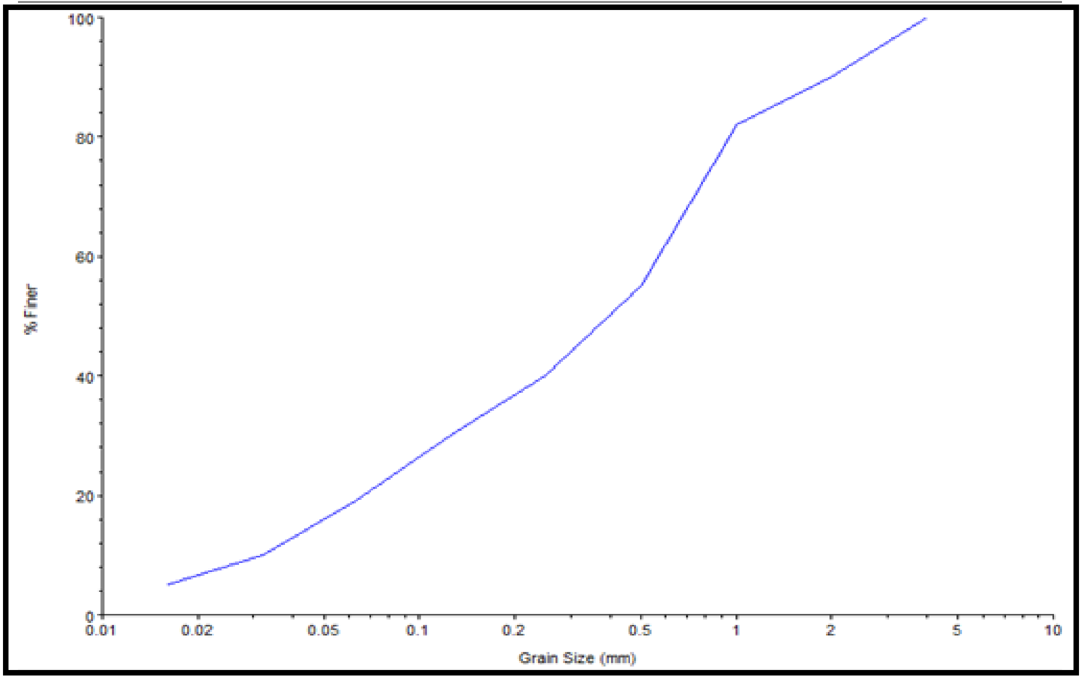


Fig (4): The gradient of soil particles in the bottom of Al-hilla River

3.3 Simulation using HEC-RAS Model

For this paper, sediment model was developed using HEC-RAS [Version 5.0,(2016)]. Figure (5) showing the main window when you first start HEC-RAS model.

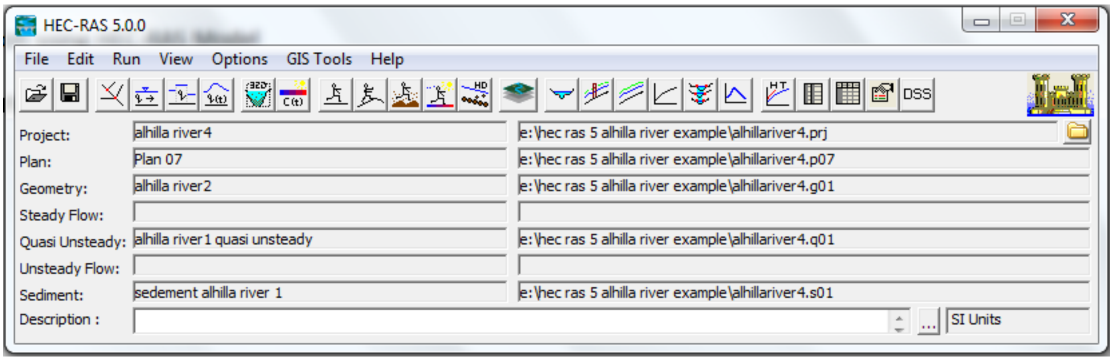


Fig (5): Main menu of HEC-RAS Model

To make a sediment simulation two necessary file types are required:

1) The geometry file contains the necessary physical description for the stream reach and the cross section of the river.

2) The flow file describes all the flow inputs and reach boundary conditions needed for the steady flow analyses.

The data required to represent the sediment simulation are the method for transport function, and method to calculate the fall velocity, with the active layer as a sorting method, for steady flow hydraulic model are flow regime, boundary conditions and peak discharge information are taken from Al- hilla river. From these data, the model is applied using HEC-RAS one dimensional analysis to develop a sediment model. All the input data required to run a sediment HEC-RAS model are presented in the following sections.

3.3.1.The Geometric File

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 length; 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).

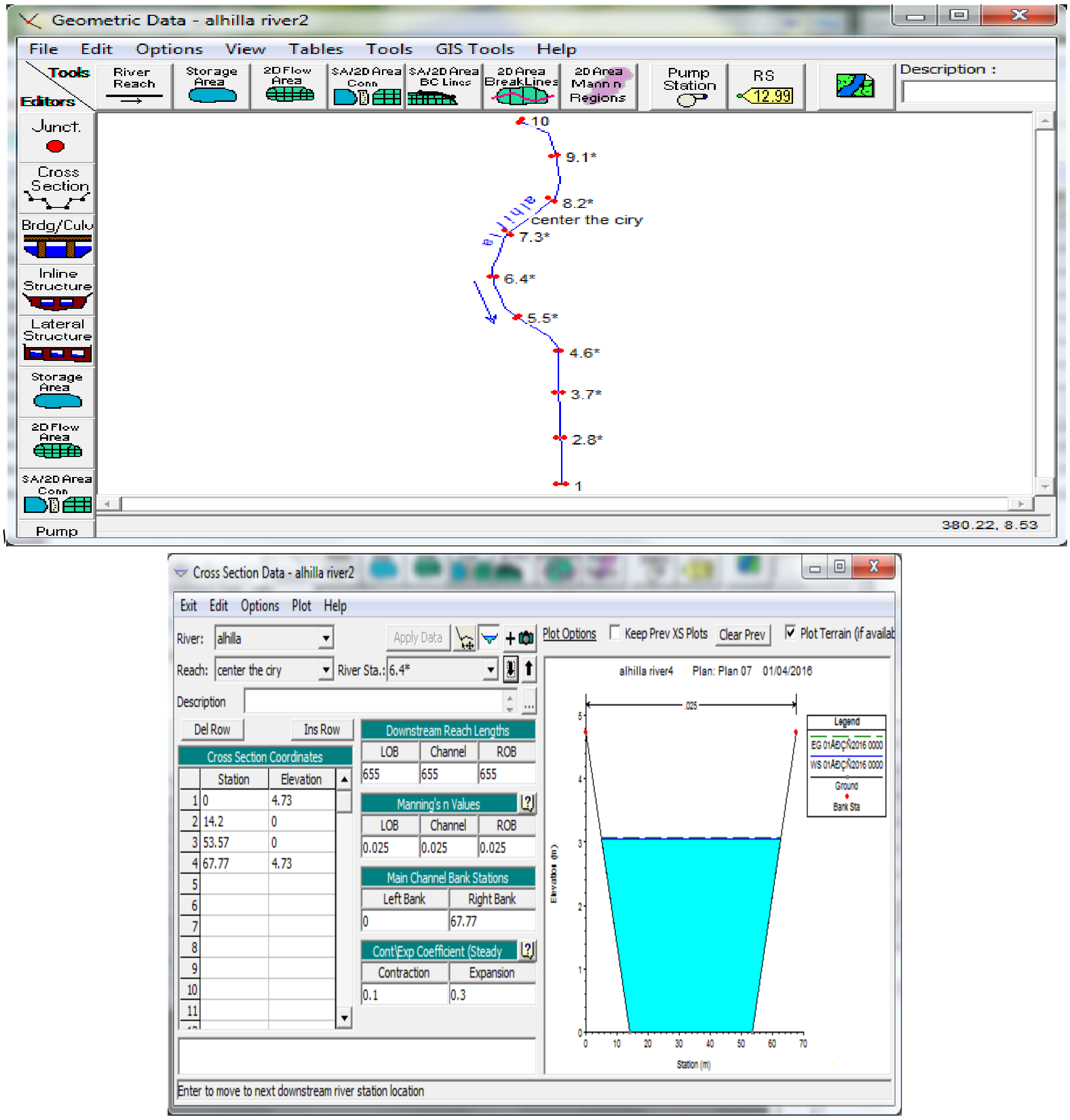


Fig (6): Input menu of cross section data for Al-hilla river

3.3.2: Cross Section Geometry

Boundary geometry for the analysis of the flow in river stream is specified in terms of ground surface profiles (cross sections). Reach length is the distance measured between any two cross sections. Cross sections should be perpendicular to the anticipated flow lines and extend across the entire flood plain (these cross sections may be curve or bent). The cross section is described by entering the stations and their elevations (x-y) data from left to the 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 the required information is displayed on the cross section data editor, Figure (7) shows some of cross sections at upstream and downstream.

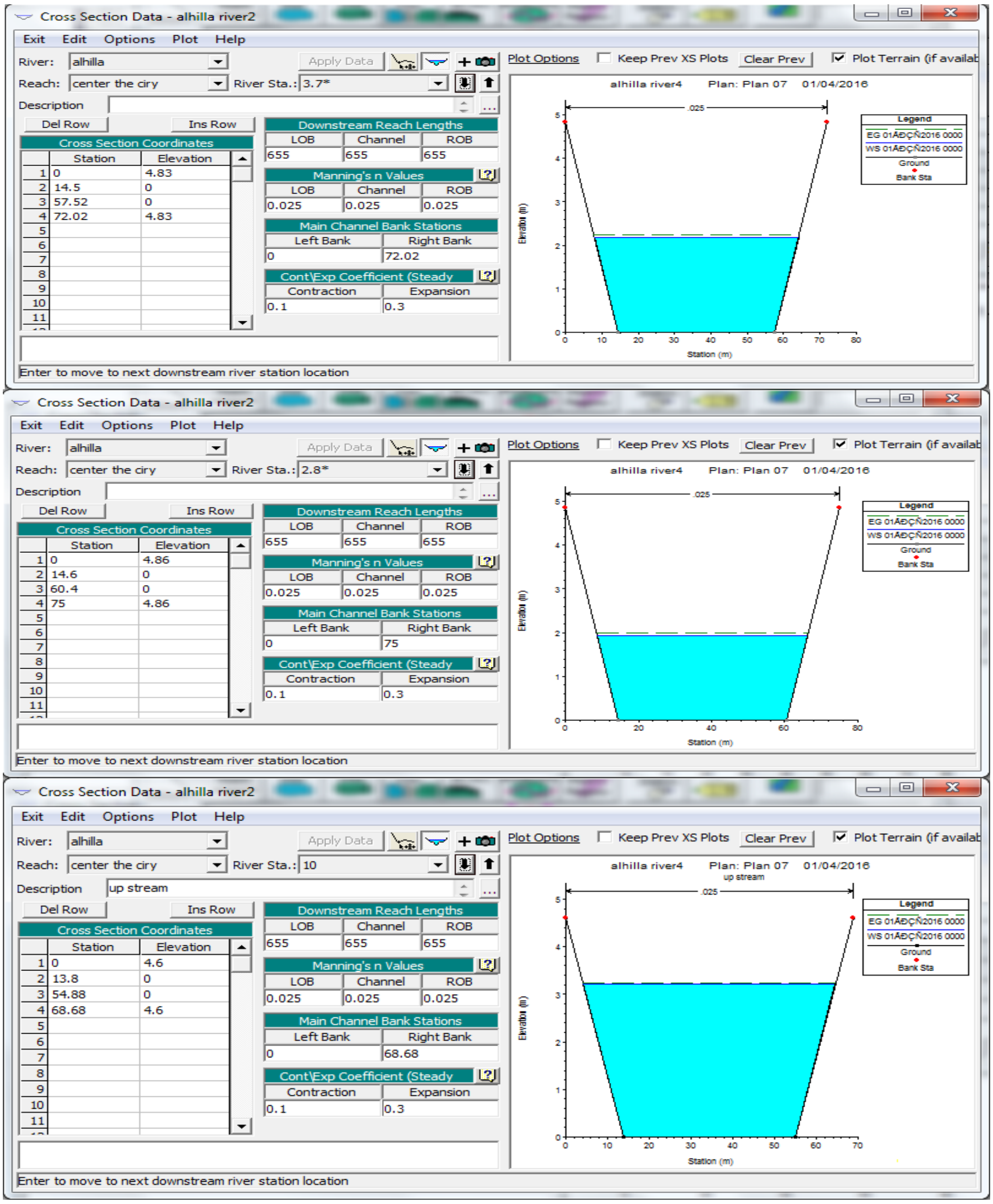


Fig (7): Some of different cross sections.

3.3.3.Sediment Data

Sediment data consists of the necessary data that related to the sediment simulation: Transport function: using Meyer Peter Muller (1948) method, the formula of this method shown in Equation below **[5].**

$$q^* = 8(\tau^* - \tau^*_{crit})^{3/2} \quad \cdots (1)$$

Dimensionless Quantities

$$q^* = \frac{q_b}{\sqrt{(s-1)gd^3}} \quad \text{(dimensionless bed flux)} \quad \cdots (2)$$

$$\tau^* = \frac{\tau_b}{\rho(s-1)gd} \quad \text{(dimensionless shear stress; or } \textit{Shields stress}\text{)} \quad \cdots (3)$$

$$d^* = d\left[\frac{(s-1)g}{\nu^2}\right]^{1/3} \quad \text{(dimensionless particle diameter)} \quad \cdots (4)$$

Where

q_b = bed flux (volume rate of transport per unit length of surface)

τ_b = bed shear stress

d = particle diameter

ρ_s = sediment density

ρ = fluid density

s (= ρ_s/ρ) = relative density

g = acceleration due to gravity

ν = kinematic viscosity

is critical shear stress and $\tau_{cr.}$\

3.3.4: Bed sorting method

In most of the river systems, the full bed gradation is covered by a layer of coarse material called an armor layer. This layer can be formed by static armoring or the differential transport of the finer materials. In order to model this armor layer, two algorithms have been included in HEC-RAS to simulate bed sorting and armoring , both methods are based on dividing the bed material into an active layer and an inactive layer.

Exner 5: A three layer active bed model (see Figure 8) that includes the capability of forming a course surface layer that will limit erosion of deeper material thereby simulating bed armoring.

Active layer method: This is a simplified two layer active bed approach (see Figure 8). The active layer thickness is equal to d90 of the layer Based on the existing conditions and chosen sediment transport equation, active layer method has been selected for the model **[6].**

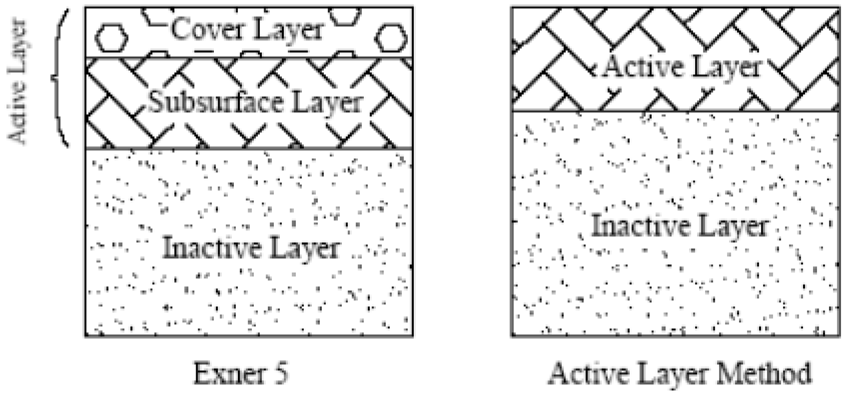


Fig (8): Schematic of the mixing layers in HEC-RAS sorting methods

3.3.5:Fall velocity method

There are currently four methods for computing fall velocity in HEC-RAS, Ruby, Toffaleti, Van Rijn and Report 12. The employed method is Ruby, these data ae entered to the model through the menu of sediment data as shown in Figure (9)

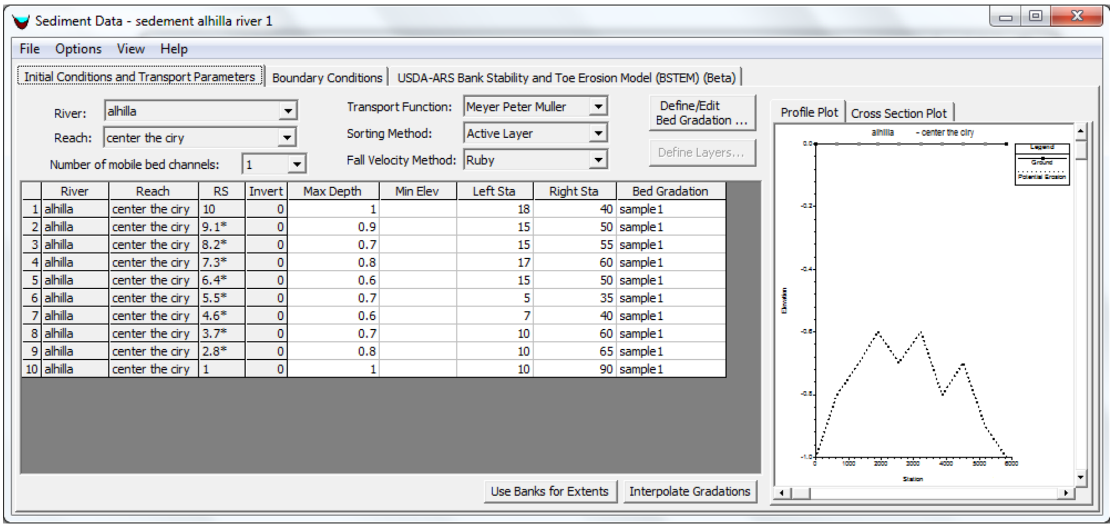


Fig (9): Sediment data menua for Al-Hilla river

4. Results and Conclusions

In this paper, after completed inserting sediment data in the suitable places and clicked on "Run" button in the Sediment Analysis, the program completed simulating the sediment transport data and showed the result in View/ Sediment Output. The results of simulation appeared that:

- The change in river's bed differed according to the river sections and sediment material type as shown in Figure below:

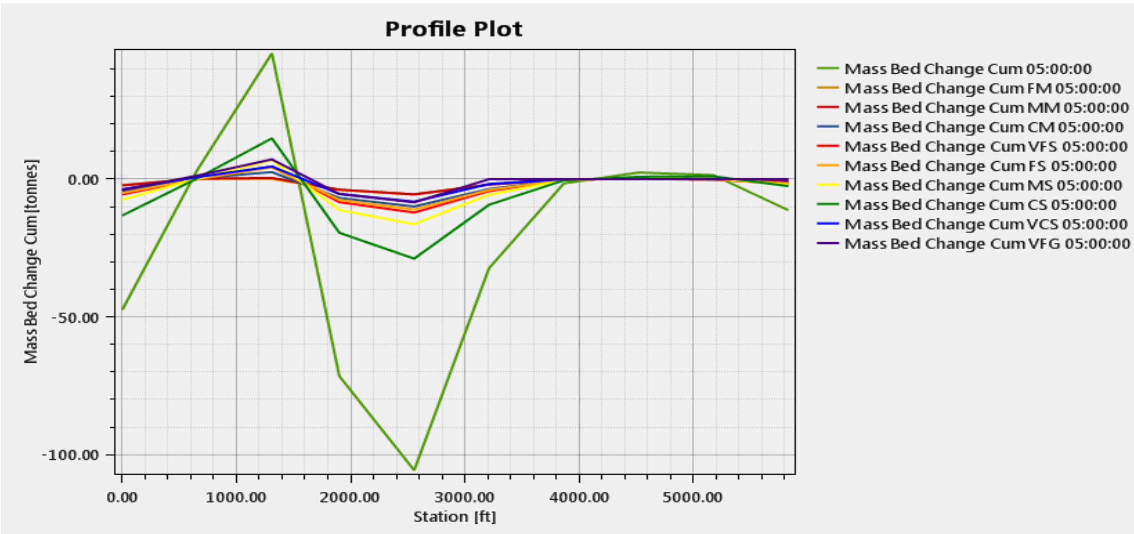


Fig (10): The relationship between mass bed change and its station

- Velocity of the river changes according to the cross section and can be noticed that the velocity increased when the river pass inside center of Al-hilla city at distance about 2000 m from the beginning of the specific researched area.

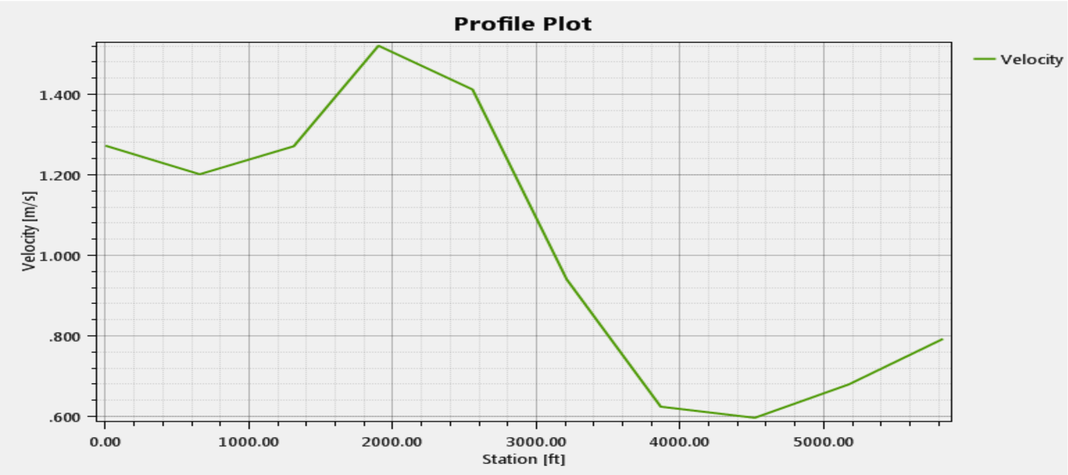
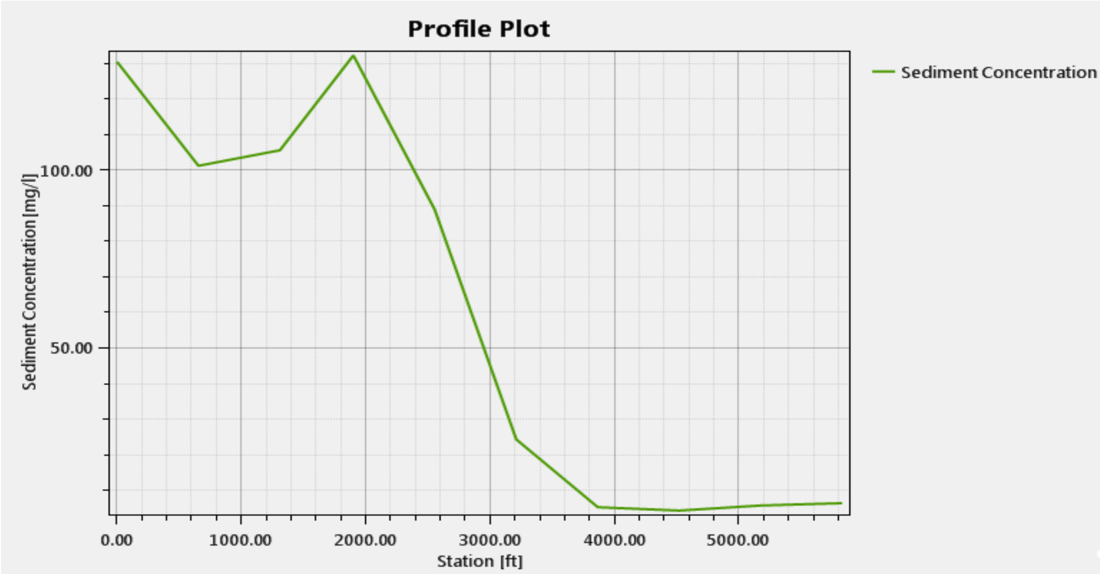
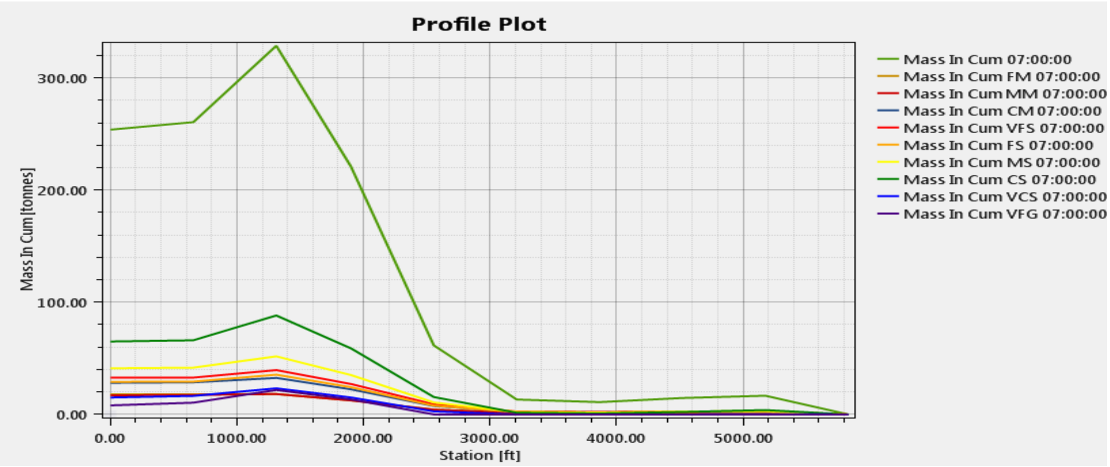


Fig (11): The relationship between velocity and its station

- The concentration of sediment increased in the part of river when pass the center of Al-hilla city, this concentration reach to125 mg/L and this mean that any illegal disposal could cause increasing in sediment load up to 300 or 400 mg/L and this could make the problem of contamination very huge and needed heavy cost for treatment and effect negatively on human life and activates. See Figures (12) and (13).



Fig(12): The relationship between sediment concentration and its station.



Fig(13): The relationship between mass and its station

The results showed that the change in river's bed differed according to the river sections and sediment material type and the concentration of sediment increased in the part of river when pass the center of Al-Hilla city, this concentration reach to 125 mg/L.

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