DRAINAGE DESIGN MANAGEMENT SYSTEM FOR WINDOWS

VERSION 6.0.5

TUTORIAL # 11

TOTAL SCOUR ANALYSIS FOR BRIDGE PIERS

K · V · L

KVL Consultants, Inc.

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TOTAL SCOUR ANALYSIS FOR BRIDGE PIERS

<u>DATE UPDATED</u>: APRIL 20, 2022
<u>TUTORIAL TIME</u>: 40 MINUTES

1.0 PROBLEM STATEMENT

To estimate the total scour depth for a bridge pier (use *"Equilibrium Slope for Sediment-Laden Flow"* method for long-term scour, use *"Neil"* method for general scour including a moderate bend, and use the local scour at the piers) with the following given conditions:

- The Cross Section "*BRIDGECROSSSECTION*"
  - Parameters for Hydraulics and Geometry:
    - **Design Flow Rate (cfs):** *3200*
    - **Dominant Flow Rates (cfs):** *800*
    - **Channel Slope** for **Design Flow (ft/ft):** *0.015*
    - **Channel Slope** for **Dominant Flow (ft/ft):** *0.015*
    - **Channel Manning's n** for **Design Flow:** *0.035*
    - **LOB Manning's n** for **Design Flow:** *0.035*
    - **ROB Manning's n** for **Design Flow:** *0.035*
    - **Channel Manning's n** for **Dominant Flow:** *0.030*
    - **LOB Manning's n** for **Dominant Flow:** *0.030*
    - **ROB Manning's n** for **Dominant Flow:** *0.030*
    - **The geometric data (station and elevation) of the cross section:**

Station (X)	Elevation (Y)	Notes
100	*100*	
106	*98*	
131	*98*	*Left Bank Station*
141	*95*	
166	*95*	
176	*98*	*Right Bank Station*
201	*98*	
207	*100*	

- The Cross Section "*STUDYREACHCROSSSECTION*"

➢ Parameters for Hydraulics and Geometry:

- **Design Flow Rate (cfs):** *3200*
- **Dominant Flow Rates (cfs):** *800*
- **Channel Slope** for **Design Flow (ft/ft):** *0.015*
- **Channel Slope** for **Dominant Flow (ft/ft):** *0.015*
- **Channel Manning's n** for **Design Flow:** *0.035*
- **LOB Manning's n** for **Design Flow:** *0.035*
- **ROB Manning's n** for **Design Flow:** *0.035*
- **Channel Manning's n** for **Dominant Flow:** *0.030*
- **LOB Manning's n** for **Dominant Flow:** *0.030*
- **ROB Manning's n** for **Dominant Flow:** *0.030*
- **Length to Pivot Point (ft):** *800*
- **The geometric data (station and elevation) of the cross section:**

Station (X)	Elevation (Y)	Notes
100	*100*	
106	*98*	
156	*98*	*Left Bank Station*
166	*95*	
191	*95*	
201	*98*	*Right Bank Station*
251	*98*	
257	*100*	

❖ The Cross Section "*SUPPLYREACHCROSSSECTION*"

➢ Parameters for Hydraulics and Geometry:

- **Design Flow Rate (cfs):** *3200*
- **Dominant Flow Rates (cfs):** *800*
- **Channel Slope** for **Design Flow (ft/ft):** *0.010*
- **Channel Slope** for **Dominant Flow (ft/ft):** *0.010*
- **Channel Manning's n** for **Design Flow**: *0.035*
- **LOB Manning's n** for **Design Flow:** *0.035*
- **ROB Manning's n** for **Design Flow:** *0.035*
- **Channel Manning's n** for **Dominant Flow:** *0.030*
- **LOB Manning's n** for **Dominant Flow:** *0.030*
- **ROB Manning's n** for **Dominant Flow:** *0.030*

- **The geometric data (station and elevation) of the cross section:**

Station (X)	Elevation (Y)	Notes
100	*100*	
106	*98*	
181	*98*	*Left Bank Station*
191	*95*	
216	*95*	
226	*98*	*Right Bank Station*
301	*98*	
307	*100*	

❖ Parameters for the ***Long Term*** *Scour* :

- **D50 (mm)** for Study Reach: *1.50*
- **D84 (mm)** for Study Reach: *10.00*
- **D16 (mm)** for Study Reach: *0.50*
- **D50 (mm)** for Supply Reach: *1.50*
- **D84 (mm)** for Supply Reach: *12.00*
- **D16 (mm)** for Supply Reach: *1.00*

❖ Parameters for the **General** Scour:

- **Exponent m:** *Coarse Gravel (0.85)*
- **Bend Factor, z:** *Moderate Bend (0.60)*
- **D50 (mm):** *1.50*
- **Bend Angle (Degrees):** *45.00*

❖ Parameters for the **Low Flow** Scour:

- **Low Flow Rate (cfs):** *100.00*
- **Channel Material** *Medium Sand*

❖ Parameters for the **Local** Scour:

- **Pier Width, a (ft):** *2.50*
- **Pier Length, L (ft):** *60.00*
- **Angle of Attack (Degrees):** *30.00*
- **D50 (mm):** *1.50*
- **D95 (mm):** *20.00*
- **Nose Shape Factor, K1:** *1.0 (Round Nose)*

- **Bed Condition Factor, K3:** *1.2 (Medium Dune)*

2.0 STEP-BY-STEP PROCEDURES

Step 1: Establish a New Project and Defaults Set-up

Step 2: Prepare the Cross Section Hydraulics

Step 3: Import Cross Section and Hydraulic Data

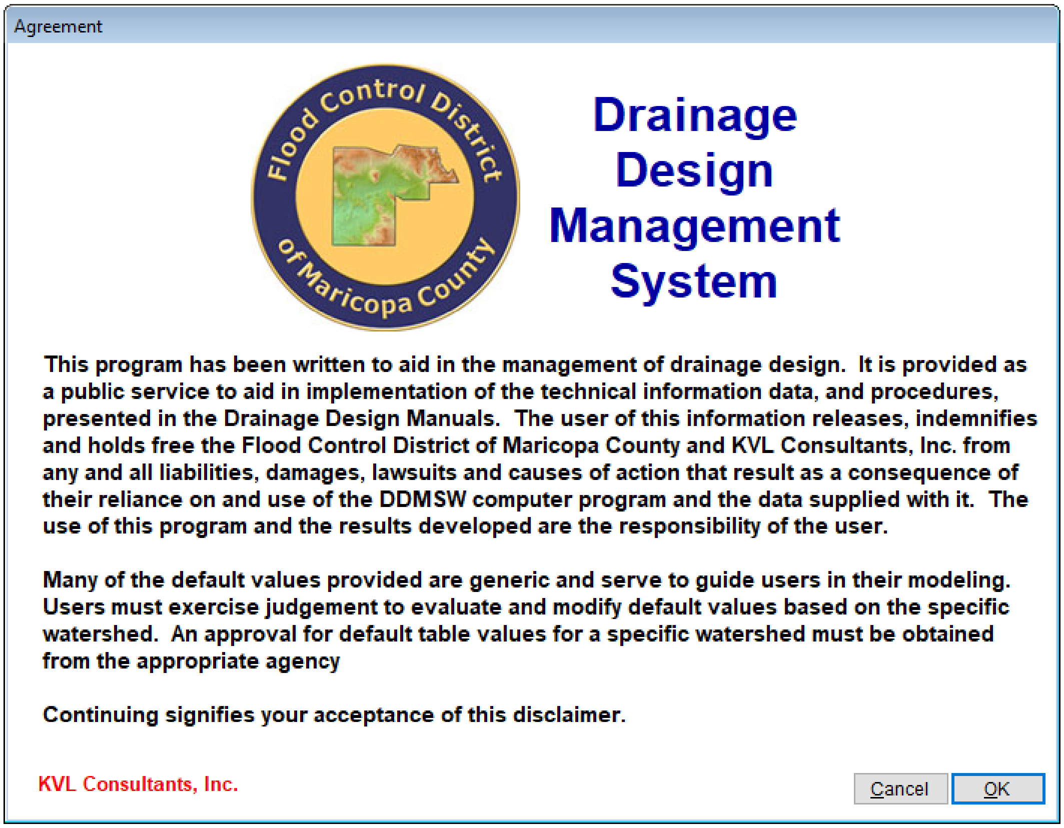
Step 4: Calculate Total Scour at Bridge Piers

- Step 4.1: Set up Total Scour Basic Data
- Step 4.2: Calculate the Long Term Scour
- Step 4.3: Calculate the General Scour
- Step 4.4: Calculate the Local Scour
- Step 4.5: Calculate the Low Flow Scour
- Step 4.6: Calculate the Total Scour

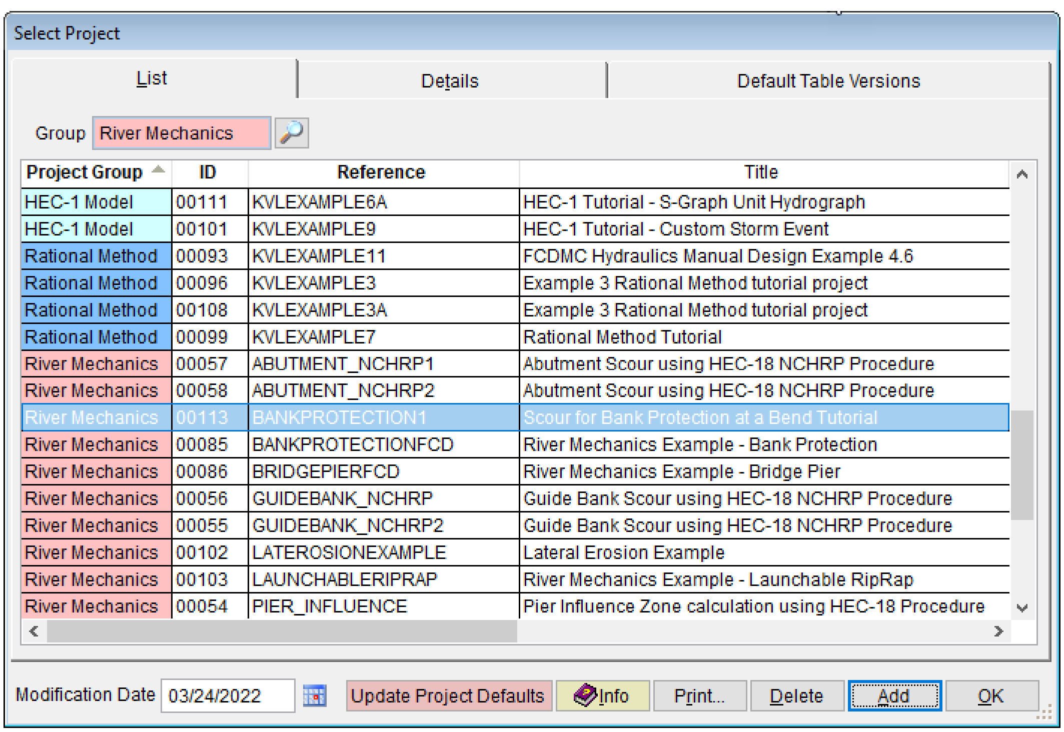
Step 5: Report and Document the Results

2.1 Step 1 - Establish a New Project and Defaults Set-up

(a) Click the **DDMSW** icon on the Desktop or Program menu to launch the **DDMSW.** Click the **OK** button to accept the software disclaimer as shown in the following figure.



After the **DDMSW** is launched, the **SELECT PROJECT** window is automatically opened as shown in the following figure.



~~(a)~~(b) Click the **Add** button on the **SELECT PROJECT** window to start a new project (Or **File ➔ New Project ➔ Add**).

~~(b)~~(c) Select **River Mechanics** checkbox and click the **OK** button on the **NEW PROJECT OPTIONS** form.

~~(c)~~(d) Type "*BRIDGEPIER1*" into the **Reference** textbox. This is the name of this newly created project. Users can choose any name for the Reference textbox as long as it does not exist in the current **DDMSW** project database.

~~(d)~~(e) Type into the **Title** textbox a brief descriptive title for this project. ***(Optional)***

~~(e)~~(f) Type into the **Location** textbox the location of this project. ***(Optional)***

~~(f)~~(g) Type into the **Agency** textbox the agency or company name**.** ***(Optional)***

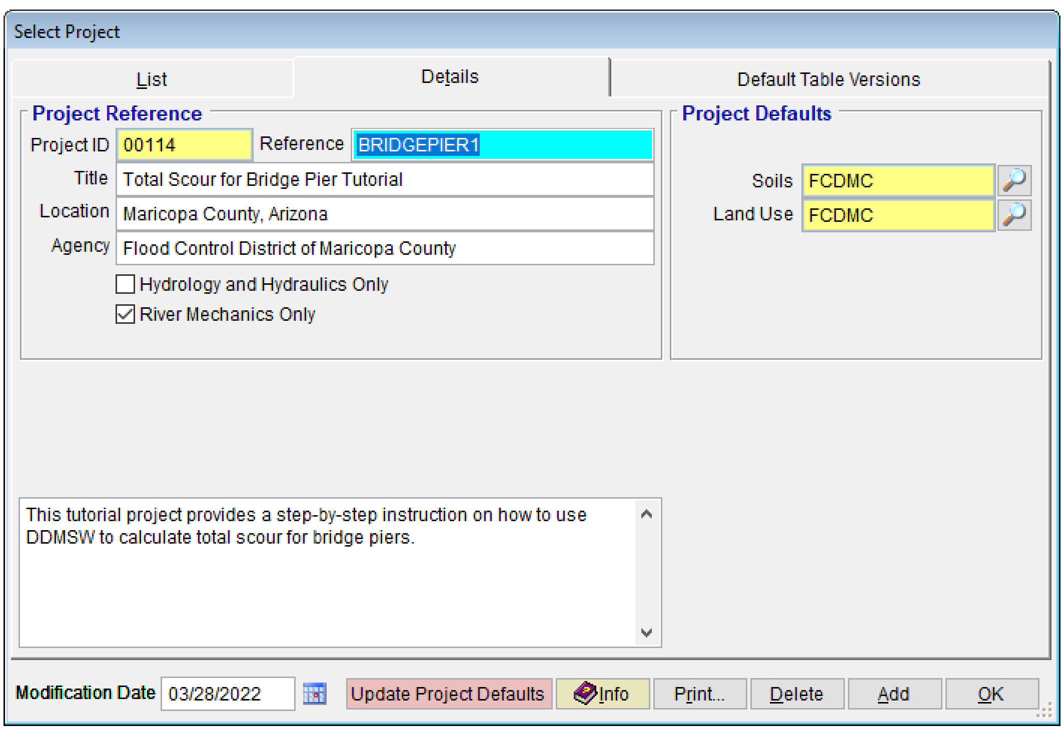
~~(g)~~(h) Check **River Mechanics Only** checkbox for this project.

~~(h)~~(i) Type a detailed description of this project into the comment area under the **Project Reference** frame. ***(Optional)***

~~(i)~~(j) Set the Modification Date using today's date by clicking on the Calendar icon.

~~(j)~~(k) Click the **Save** button to save the entered data.

~~(k)~~(l) Click the **OK** button on the **SELECT PROJECT** window and click the **OK** button on the pop-up message box. The following figure shows what the window looks like.



Note: the **Project ID** *"00114"* in the above figure is the unique database record identifier for the project, which is automatically generated by the program when a new project is created. When users create a new project, the **Project ID** of the new project will not be the same as the **Project ID** shown in the above figure.

2.2 Step 2 - Prepare the Cross Section Hydraulics

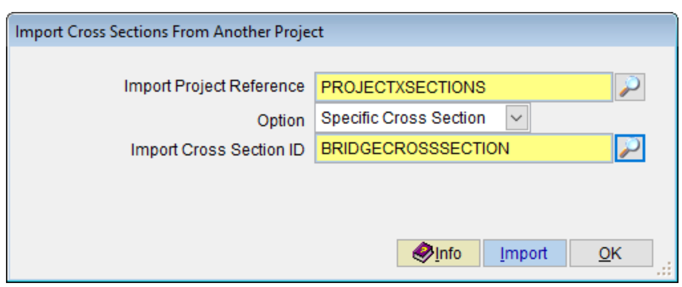
All the three (3) cross section data that will be used for this tutorial will be imported from another project. These cross section data are:

- Bridge Cross Section Data *"BRIDGECROSSSECTION"*
- Study Reach Cross Section Data *"STUDYREACHROSSSECTION"*
- Supply Reach Cross Section Data *"SUPPLYREACHCROSSSECTION"*

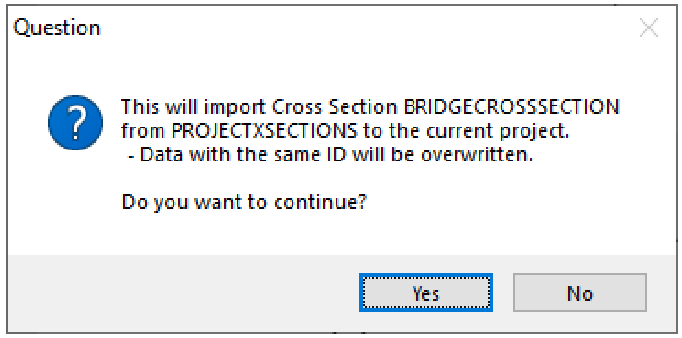
a. Import the Bridge Cross Section Data

(a) To import the first cross section data (Bridge Cross Section Data), open the **IMPORT CROSS SECTIONS FROM ANOTHER PROJECT** form (**River Mechanics → Import Cross Sections from Another Project**). Use the following data on the form.

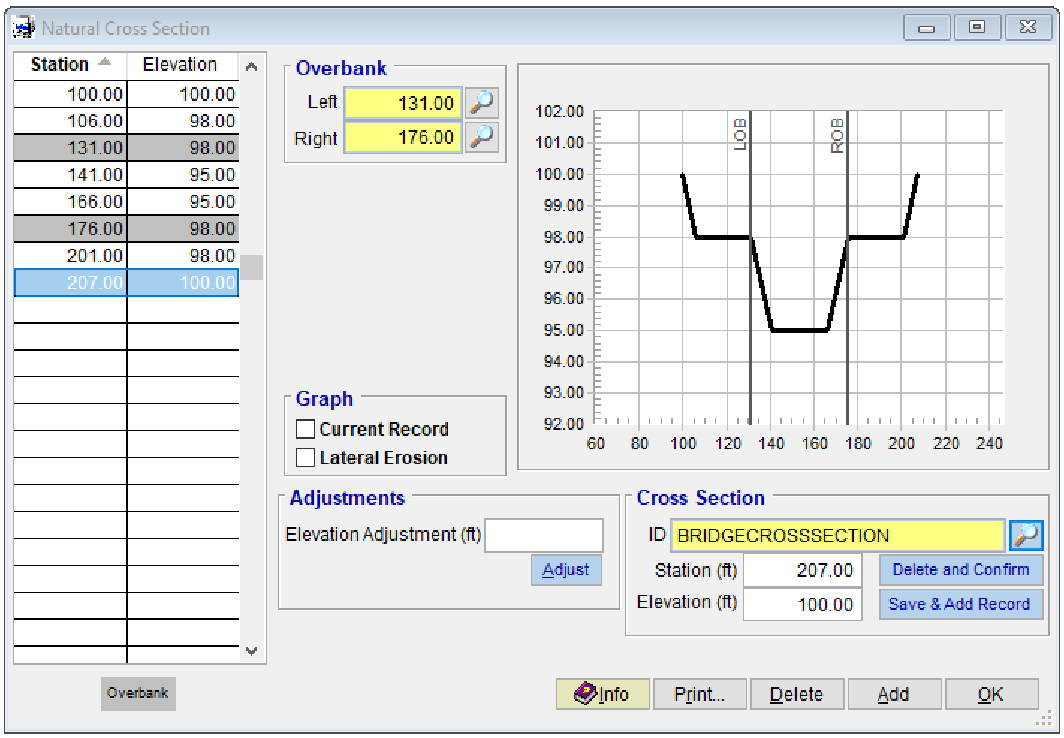
- **Import Project Reference:** *PROJECTXSECTIONS*
- **Option:** *Specific Cross section*
- **Import Cross Section ID:** *BRIDGECROSSSECTION*



(b) Once the specified data have been selected, click the **Import** button. Select **Yes** to proceed, and hit **OK** to close the **IMPORT CROSS SECTION FROM ANOTHER PROJECT** form.



(c) To check if the bridge cross section data has been successfully imported, open the **Natural Cross Sections** form (**River Mechanics ➔ Cross Section Geometry**). For the **Cross Section ID**, select *"BRIDGECROSSSECTION"* by clicking the Selector button at the right side of the **ID** textbox.



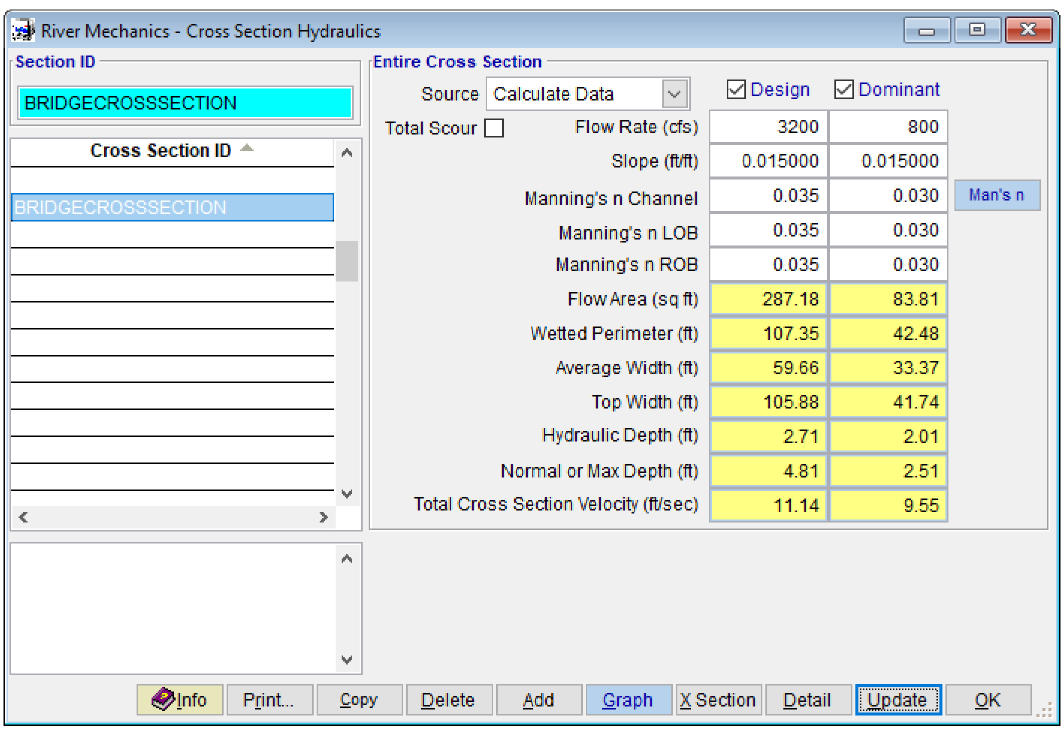
Compare the geometric data on the **Natural Cross Sections** form against the tabulated data listed below. Make necessary data edits or adjustments on the form, if necessary. Click **OK** to close the form.

Station (X)	Elevation (Y)	Notes
100	*100*	
106	*98*	
131	*98*	*Left Bank Station*
141	*95*	

166	*95*	
176	*98*	*Right Bank Station*
201	*98*	
207	*100*	

(d) To check if the imported hydraulic data has all the correct **Flow Rates (cfs)**, **Slopes (ft/ft)**, and **Manning's n (Channel, LOB, and ROB)** data, open the **CROSS SECTION HYDRAULICS** form (**River mechanics → Cross Section Hydraulics**). Make sure that the **Cross Section ID** is set to *"BRIDGECROSSSECTION"* and compare the data on the form and the following data:

- **Cross Section ID:** *BRIDGECROSSSECTION*
- **Design Flow Rate (cfs):** *3200*
- **Dominant Flow Rate (cfs):** *800*
- **Design Slope (ft/ft):** *0.015*
- **Dominant Slope (ft/ft):** *0.015*
- **Design Manning's n (Channel, LOB, and ROB):** *0.035*
- **Dominant Manning's n (Channel, LOB, and ROB):** *0.030*



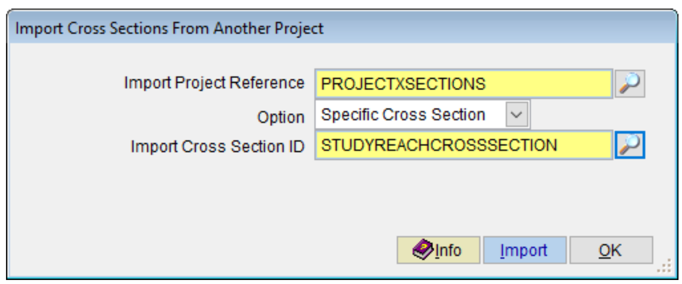
(e) If everything checks out, click the **Update** button to update the hydraulic analysis results. If not, edit the data to match the above figure. On the **SELECT OPTION** form, select *"This Record"* and click **OK**. Hit **Yes** to continue.

(f) Click **OK** to close the **RIVER MECHANICS – CROSS SECTION HYDRAULICS** form.

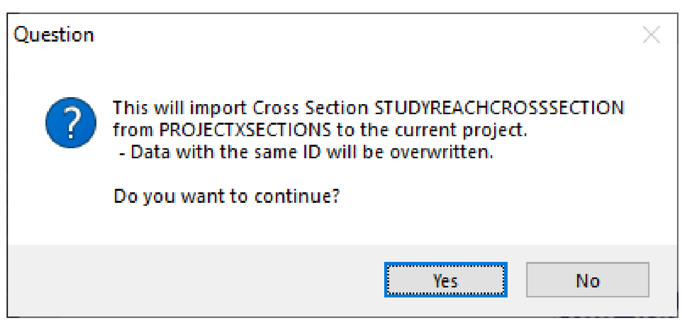
b. Import the Study Reach Cross Section Data

(a) To import the second cross section data (Study Reach Cross Section Data), open the **IMPORT CROSS SECTIONS FROM ANOTHER PROJECT** form (**River Mechanics ➔ Import Cross Sections from Another Project**). Use the following data on the form.

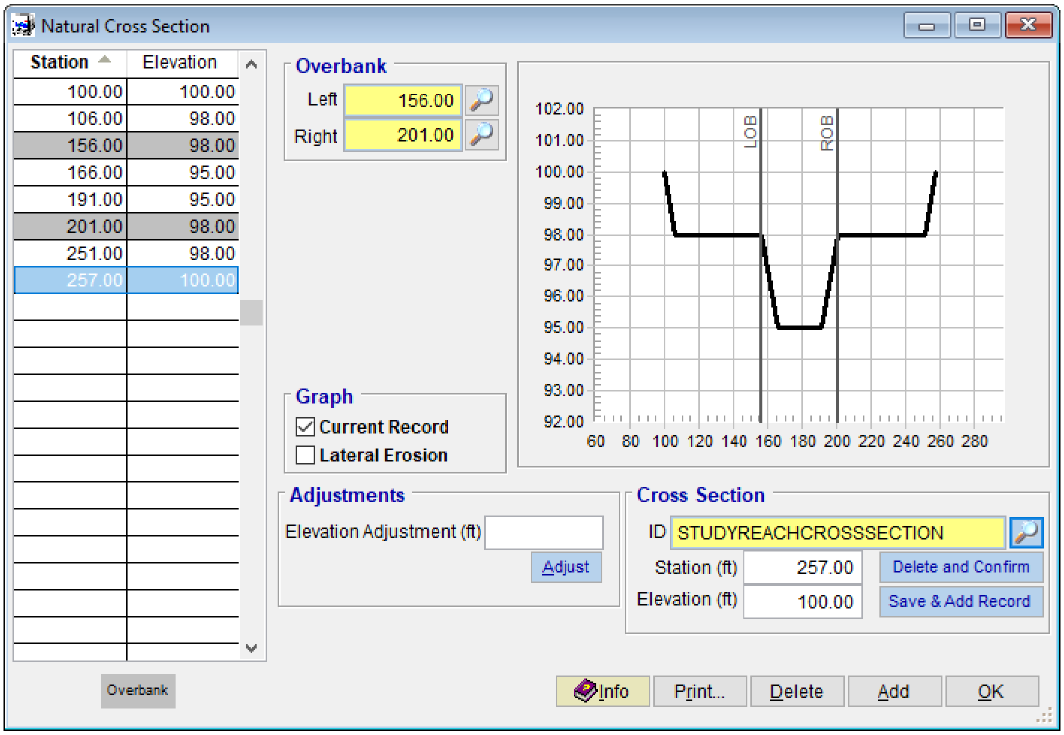
- **Import Project Reference:** *PROJECTXSECTIONS*
- **Option:** *Specific Cross section*
- **Import Cross Section ID:** *STUDYREACHCROSSSECTION*



(b) Once the specified data have been selected, click the **Import** button. Select **Yes** to continue and hit **OK** to close the **IMPORT CROSS SECTION FROM ANOTHER PROJECT** form.



(c) To check if the study reach cross section data has been successfully imported, open the **NATURAL CROSS SECTIONS** form (**River Mechanics ➔ Cross Section Geometry**). For the **Cross Section ID**, select *"STUDYREACHROSSSECTION"* by clicking the Selector button at the right side of the **ID** textbox.



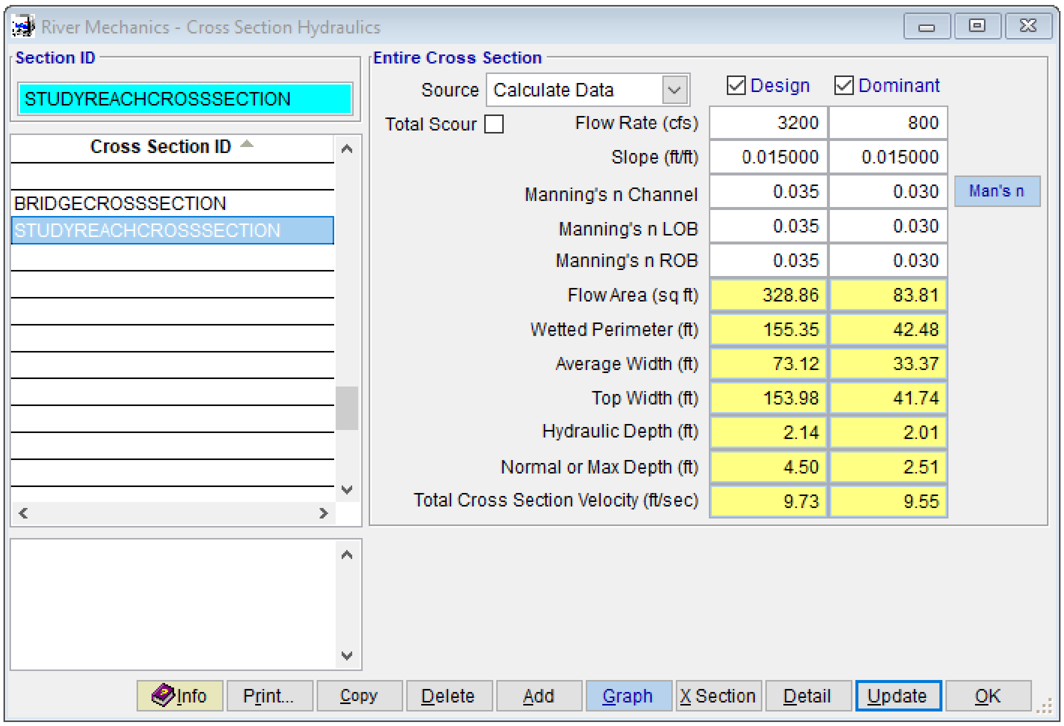
Compare the geometric data on the **NATURAL CROSS SECTIONS** form against the tabulated data listed below. Make necessary data edits or adjustments on the form, if necessary. Click **OK** to close the form.

Station (X)	Elevation (Y)	Notes
100	*100*	
106	*98*	
156	*98*	*Left Bank Station*
166	*95*	
191	*95*	
201	*98*	*Right Bank Station*
251	*98*	
257	*100*	

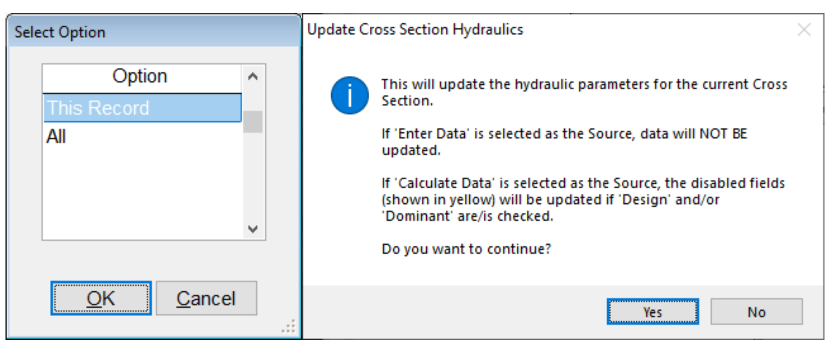
(d) To check if the imported hydraulic data has all the correct **Flow Rates (cfs)**, **Slopes (ft/ft)**, and **Manning's n (Channel, LOB, and ROB)** data, open the **CROSS SECTION HYDRAULICS** form (**River mechanics → Cross Section Hydraulics**). Make sure that the **Cross Section ID** is set to *"STUDYREACHCROSSSECTION"* and compare the data on the form and the following data:

- **Cross Section ID:** *STUDYREACHCROSSSECTION*

- **Design Flow Rate (cfs):** *3200*
- **Dominant Flow Rate (cfs):** *800*
- **Design Slope (ft/ft):** *0.015*
- **Dominant Slope (ft/ft):** *0.015*
- **Design Manning's n (Channel, LOB, and ROB):** *0.035*
- **Dominant Manning's n (Channel, LOB, and ROB):** *0.030*



(e) If everything checks out, click the **Update** button to update the hydraulic analysis results. If not, edit the data to match the above figure. On the **Select Option** form, select *"This Record"* and click **OK**. Hit **Yes** to continue.



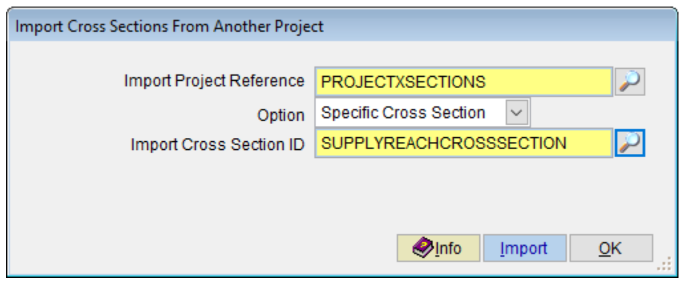
(f) Click **OK** to close the **River Mechanics – Cross Section Hydraulics** form.

a. Import the Supply Reach Cross Section Data

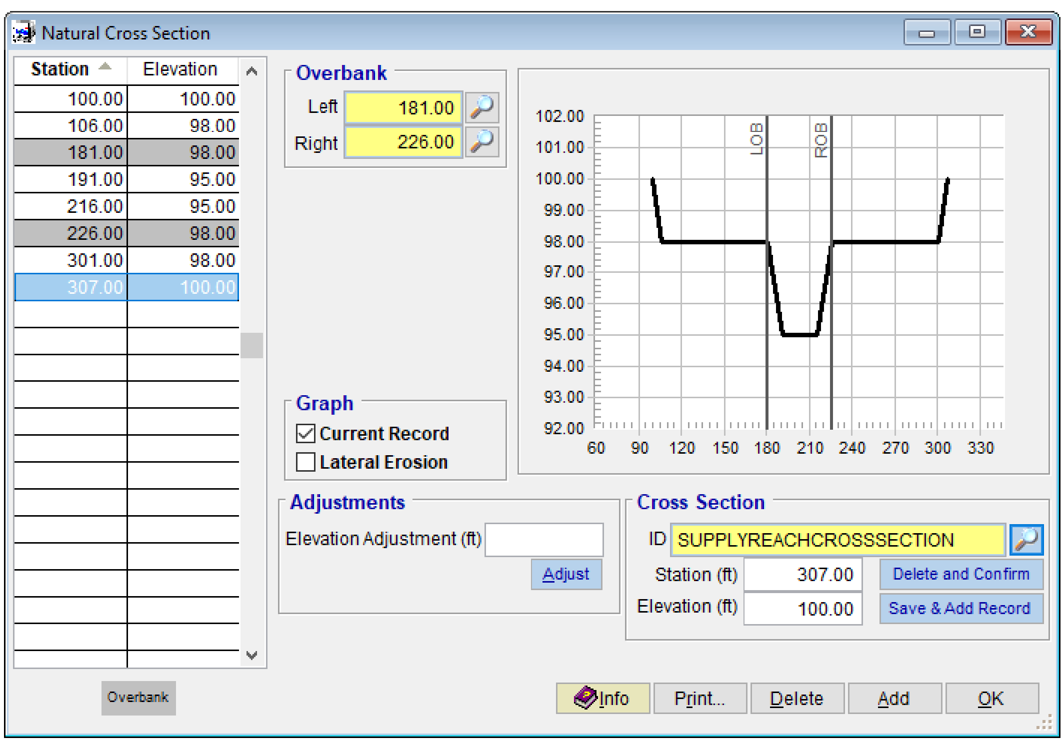
(a) To import the *"SUPPLYREACHCROSSSECTION"* dataset, open the **IMPORT CROSS SECTIONS FROM ANOTHER PROJECT** form **(River mechanics → Import Cross Sections from Another Project**).

(b) On the **IMPORT CROSS SECTIONS FROM ANOTHER PROJECT** form, use the data provided below. Click **Import** to import the cross section data into the project. Select **Yes** to continue and hit **OK** to close the form.

- **Import Project Reference:** *PROJECTXSECTIONS*
- **Option:** *Specific Cross section*
- **Import Cross Section ID:** *SUPPLYREACHCROSSSECTION*



(c) To check if the cross section data has been successfully imported, open the **NATURAL CROSS SECTIONS** form (**River Mechanics → Cross Section Geometry**).

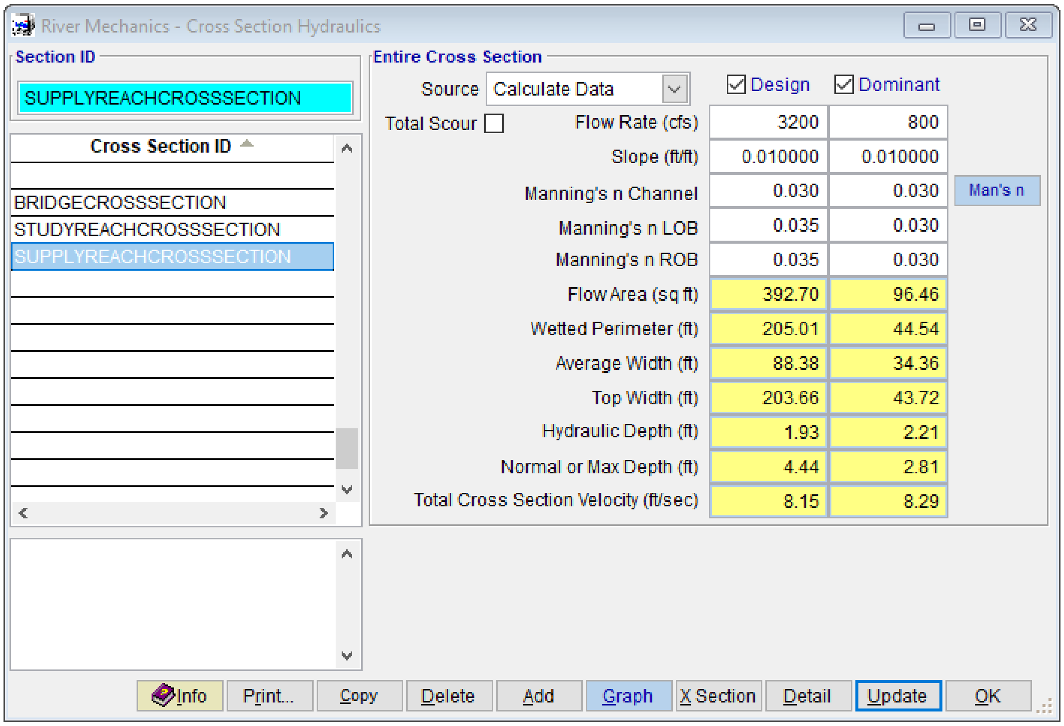


Compare the geometric data on the **NATURAL CROSS SECTIONS** form against the tabulated data listed below. Make necessary data edits or adjustments on the form, if necessary. Click **OK** to close the form.

Station (X)	Elevation (Y)	Notes
100	*100*	
106	*98*	
181	*98*	*Left Bank Station*
191	*95*	
216	*95*	
226	*98*	*Right Bank Station*
301	*98*	
307	*100*	

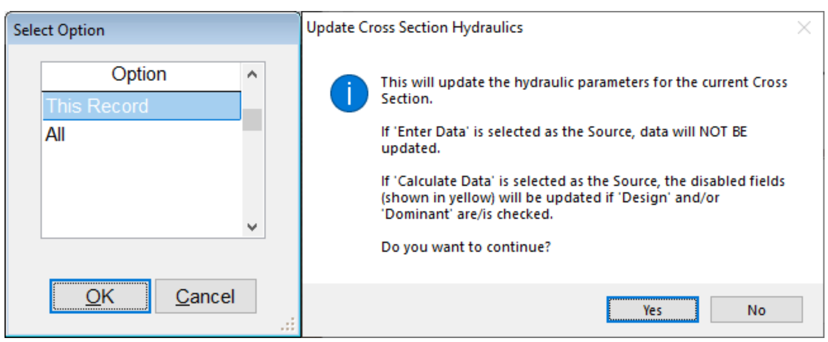
(d) To check if the imported data has all the correct **Flow Rates (cfs)**, **Slopes (ft/ft)**, and **Manning's n (Channel, LOB, and ROB)** data, open the **CROSS SECTION HYDRAULICS** form (**River mechanics ➔ Cross Section Hydraulics**). To compare, make sure that the **Cross Section ID** is set to *"SUPPLYREACHCROSSSECTION".*

- **Cross Section ID:** *SUPPLYREACHCROSSSECTION*
- **Design Flow Rate (cfs):** *3200*
- **Dominant Flow Rate (cfs):** *800*
- **Design Slope (ft/ft):** *0.010*
- **Dominant Slope (ft/ft):** *0.010*
- **Design Manning's n (Channel, LOB, and ROB):** *0.035*
- **Dominant Manning's n (Channel, LOB, and ROB):** *0.030*



(e) If everything checks out, click the **Update** button to update the hydraulic analysis results. If not, edit the data to match the above figure.

(f) On the **Select Option** form, select *"This Record"* and click **OK**. Hit **Yes** to continue.



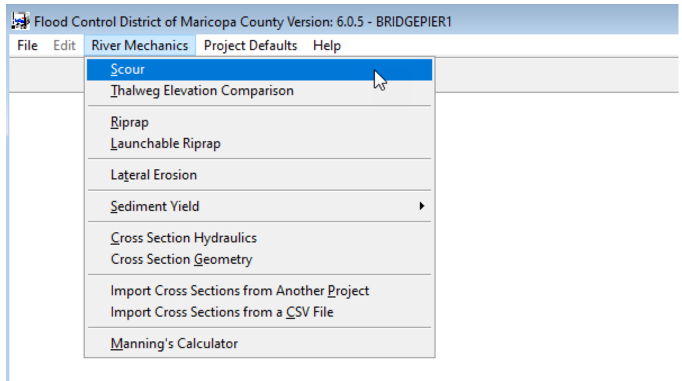
(g) Click OK to close the **River Mechanics – Cross Section Hydraulics** form.

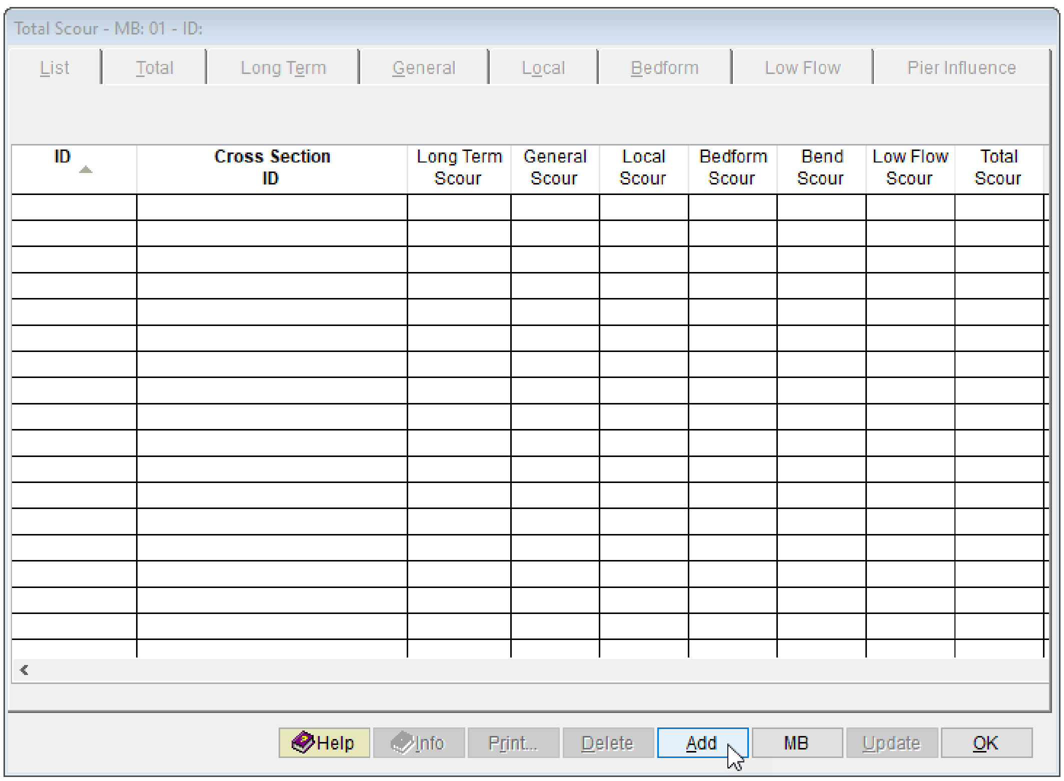
Creating the three cross sections and evaluating their respective hydraulics in **Step 2** are essential steps before proceeding to **Step 3** of this tutorial.

2.3 Step 3 - Calculate Total Scour

a. Set up Total Scour Basic Data

(a) From the menu bar of main application window, click **River Mechanics ➔ Scour**, to open the **TOTAL SCOUR** form.



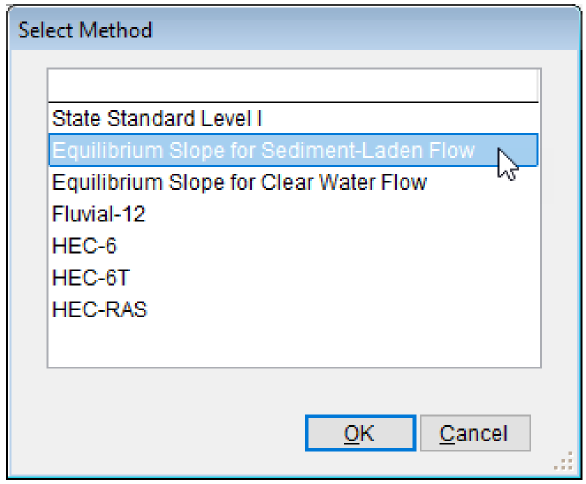


(b) Click the **Add** button to activate the necessary data entry fields.

(c) Type "*PIERNO1*" into the **ID** textbox (this **ID** indicates that it is for Pier No.1).

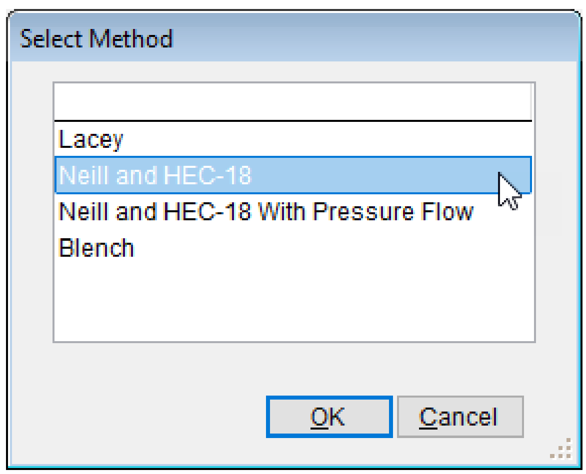
(d) Check the checkboxes **Long Term**, **General**, **Local**, and **Low Flow** (**Bed Form** is not computed because it will be part of pier local scour computation where the K3 factor, the *Bed Condition Factor*, will be used).

(e) Click the browse button in the **Method** column across **Long Term** check box to launch long term scour method select menu.



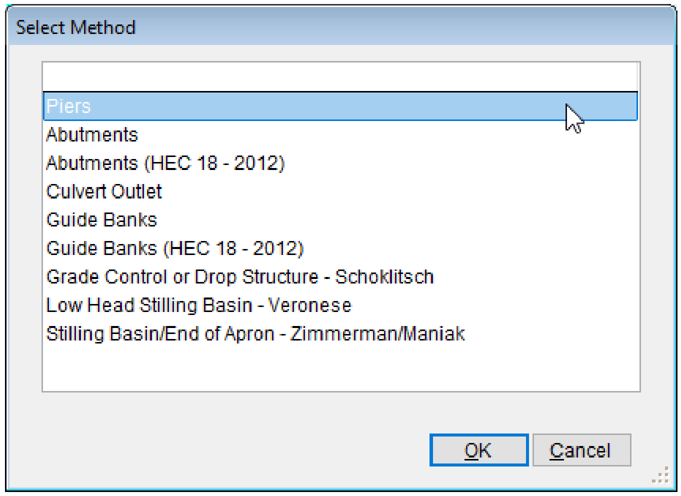
Select the "*Equilibrium Slope for Sediment-Laden Flow*" from the **SELECT METHOD** window, and click **OK** to close the **SELECT METHOD** window.

(f) Click the browse button in the **Method** column across **General** check box to launch general scour method select menu.



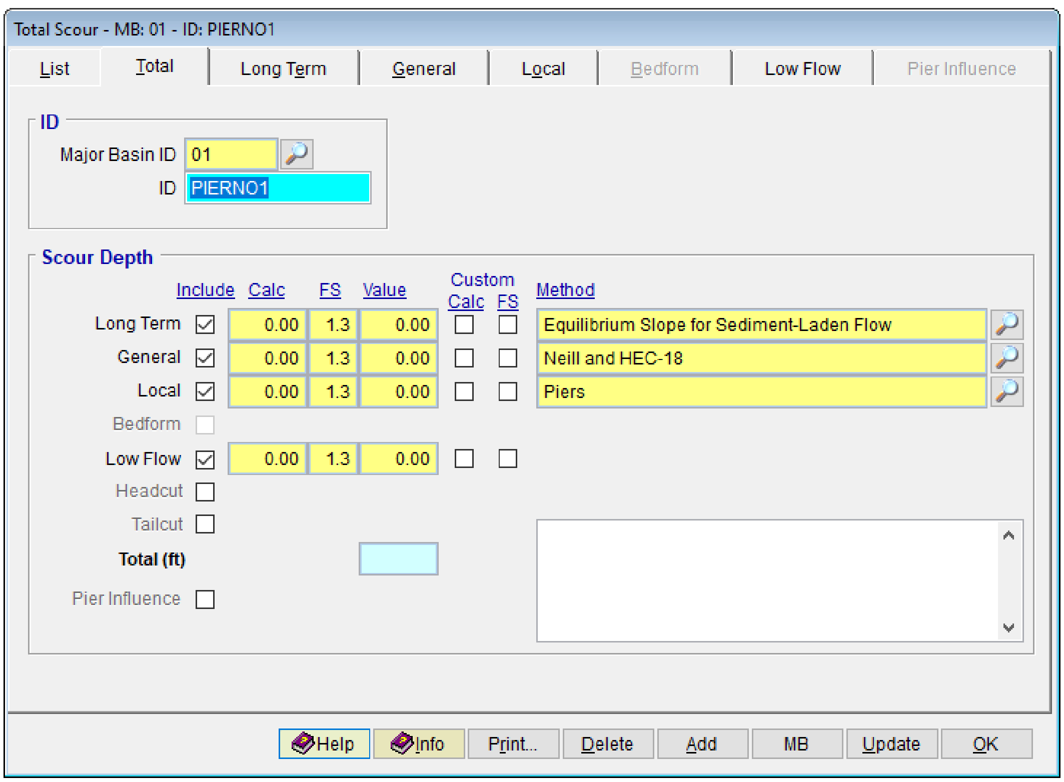
(g) Select the "*Neil and HEC-18*" from the **SELECT METHOD** window and click **OK** to close the **SELECT METHOD** window.

(h) Click the browse button in the **Method** column across **Local** check box to launch local scour method select menu.



(i) Select the "*Piers*" from the **SELECT METHOD** window and click **OK** to close the **SELECT METHOD** window.

(j) Click the **Save** button to save the entered data. The **TOTAL SCOUR – MB: 01 – ID: PIERNO1** window shows up like following figure.



a. Calculate the Long Term Scour

(a) Click the **Long Term** tab.

(b) Click browse button beside the **Study Reach Cross Section ID** to select the cross section **ID** "*STUDYREACHCROSSSECTION*", and click **OK** to close the **SELECT CROSS SECTION ID** window.

(c) Click browse button beside the **Supply Reach Cross Section ID** to select the cross section **ID** "*SUPPLYREACHCROSSSECTION*", and click **OK** to close the **SELECT CROSS SECTION ID** window.

(d) Enter the **D50 (mm)** values *"1.5"* and *"1.5"* for **Study** and **Supply**, respectively.

(e) Enter the **D84 (mm)** values *"10"* and *"12"* for **Study** and **Supply**, respectively.

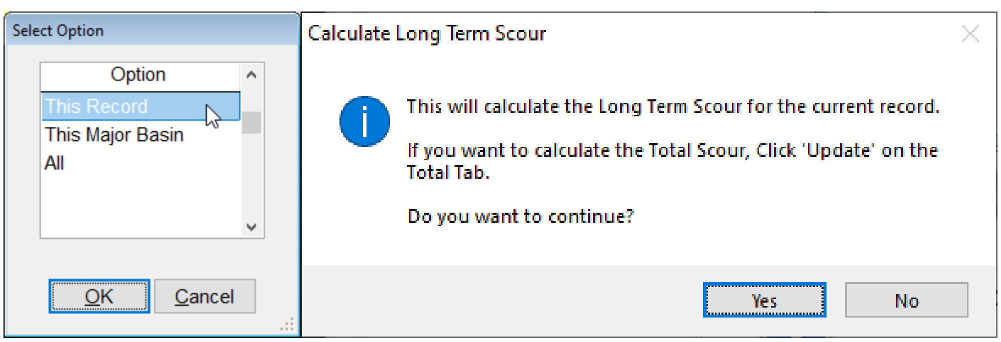
(f) Enter the **D16 (mm)** values *"0.5"* and *"1.0"* for **Study** and **Supply**, respectively.

(g) Enter *"800"* into **Length to Pivot Pt (ft)**.

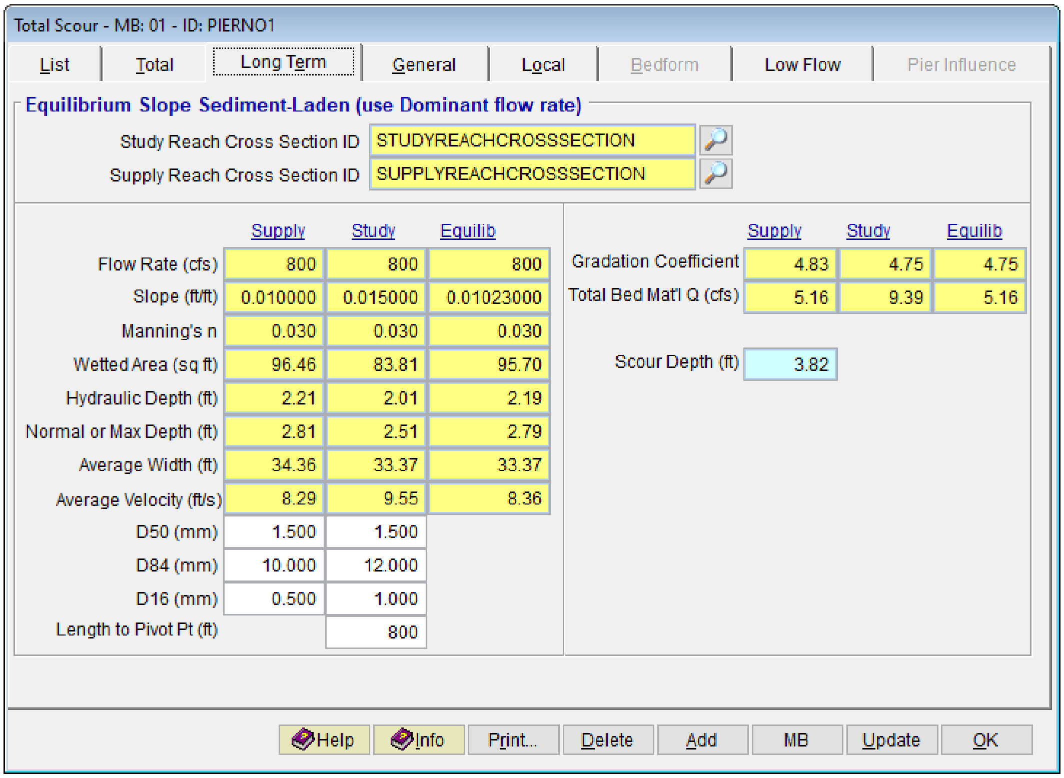
(h) Click the **Save** button to save the entered data.

(i) Click the **Update** button to update the data.

(j) Select *"This Record"* from the **SELECTION OPTION** window and click the **Yes** button on the **CALCULATE LONG TERM SCOUR** dialog box to proceed.



After the update, the result of the long term scour calculation shows in the following figure.



Calculate the General Scour

(a) Click the **General** tab.

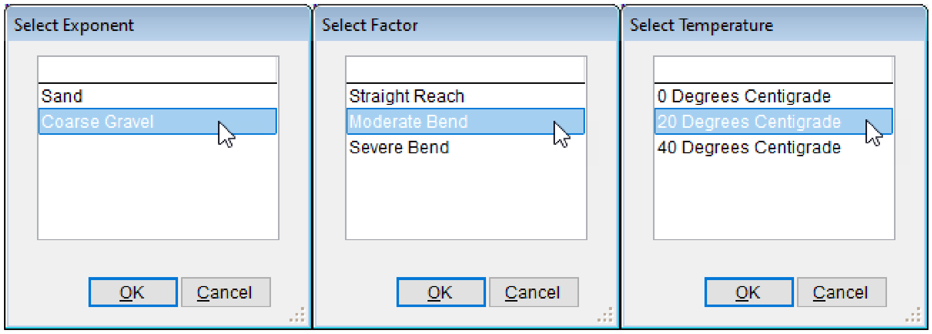
(b) Click the browse button beside the **Bridge Section ID** textbox to open the **SELECT CROSS SECTION ID** window. Select the "*BRIDGECROSSSECTION*" and click **OK** to close the window.

(c) Click the browse button beside the **Upstream Section ID** textbox to open the **SELECT CROSS SECTION ID** window. Select the "*STUDYREACHCROSSSECTION*" and click **OK** to close the window (Note: Upstream section is for the area upstream of the bridge contraction. It can be generally represented by the study reach cross-section. The supply reach cross-section is not used as the upstream section because it is upstream of the study reach and is generally far away upstream from the bridge).

(d) Click the browse button beside the **Exponent m** textbox to open the **SELECT EXPONENT** window. Select the "*Coarse Gravel*", and click **OK** to close the window.

(e) Click the browse button beside the **Bend Factor, Z** textbox to open the **SELECT FACTOR** window. Select the "*Moderate Bend*" bend factor and click **OK** to close the window.

(f) Click the browse  button beside the **Water Temp (C)** textbox to open the **Select Temperature** window. Select the *"20 Degrees Centigrade"* and click **OK** to close the window.



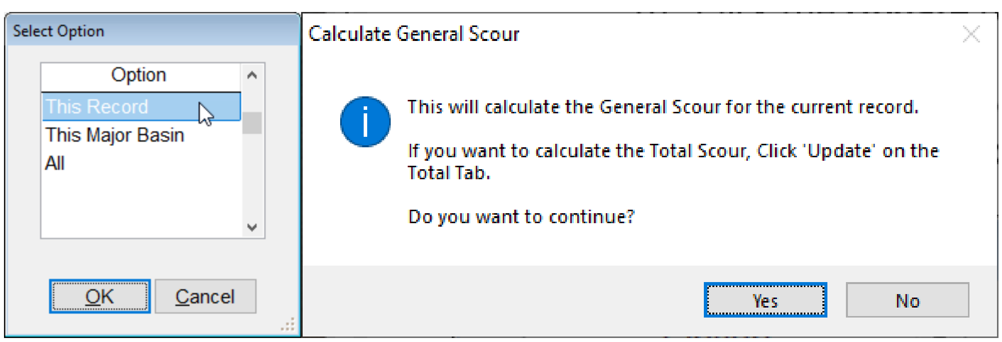
(g) **D50 (mm)**: Use the default value of *"1.5"* in the textbox (the default value is from the D50 value entered in study reach under Long Term scour menu for **Supply**). Or enter a value directly in this box. (Note: if a different value is entered here, the D50 value in Long Term for **Supply** will be changed).

(h) Enter *"45"* into the **Bend Angle (Degrees)** textbox

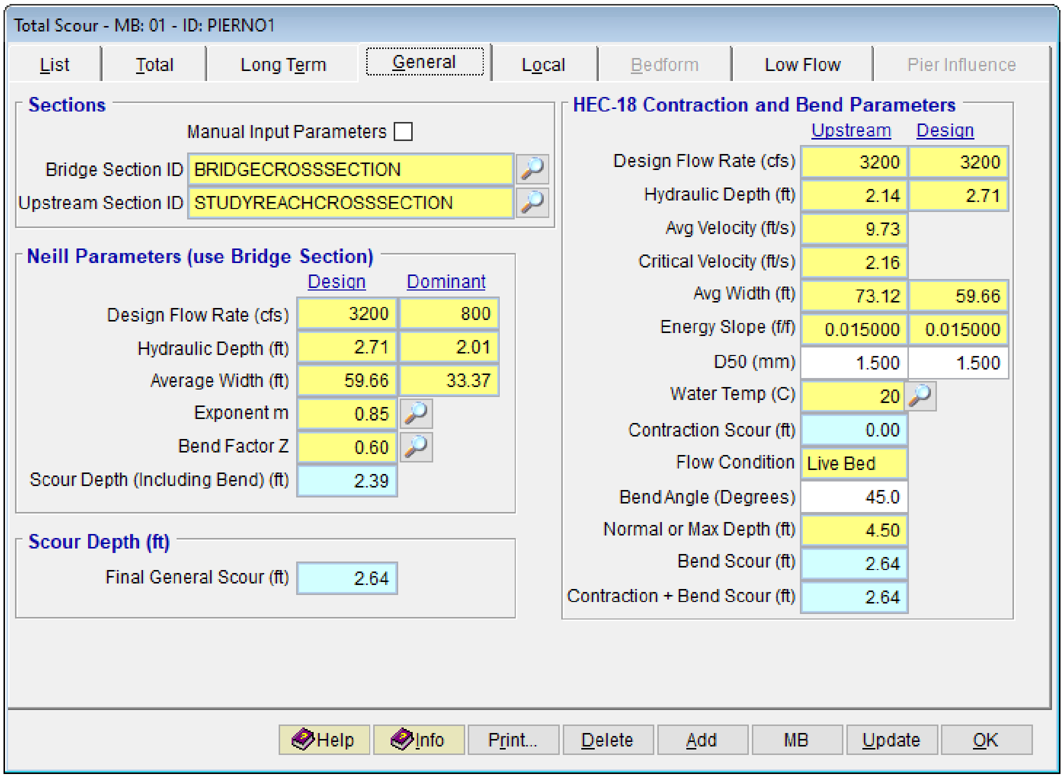
(i) Click the **Save** button to save the entered data.

(j) Click the **Update** button on the **General** tab to update the data.

(k) Select *"This Record"* from the **Selection Option** window and click the **Yes** button on the **Calculate General Scour** dialog box to proceed.



The following figure shows what the window looks like after the data entry.



a. Calculate the Local Scour

(a) Click the **Local** tab.

(b) Click the browse button  beside the **Bridge Section ID** textbox to open the **SELECT CROSS SECTION ID** widow. Select the "*BRIDGECROSSSECTION*" and click the **OK** button to close the window.

(c) Enter "*2.5*" into the **Pier Width, (ft)** textbox.

(d) Enter "*60*" into the **Pier Length, L (ft)** textbox.

(e) Enter "*30*" into the **Angle of Attack (Degree)** textbox.

(f) Enter "*1.5*" into the **D50 (mm)** textbox.

(g) Enter "*20.0*" into the **D95 (mm)** textbox.

(h) Click the browse button  beside the **Nose Shape Factor, K1** textbox to open the **NOSE SHAPE** window. Select "*Round Nose*" item, and click **OK** button to close it.

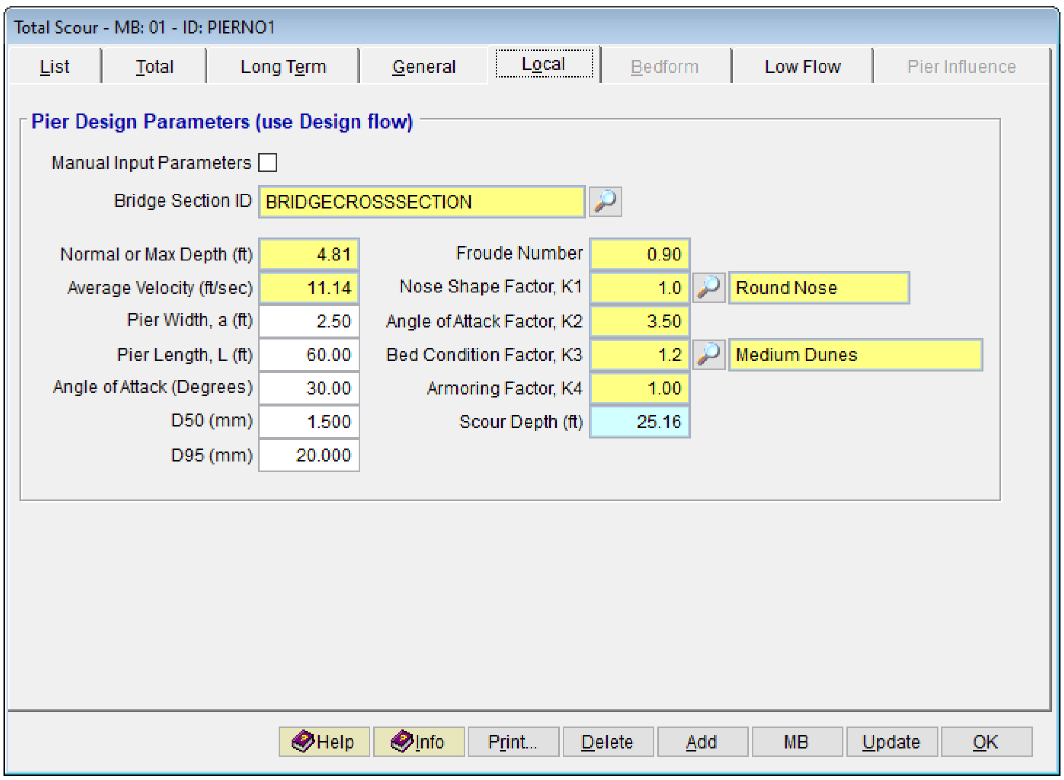
(i) Click the browse button beside the **Bed Condition Factor, K3** textbox to open the **Bed Condition** window. Select "*Medium Dunes*" item and click **OK** button to close the window.

(j) Click the **Save** button to save the entered data.

(k) Click the **Update** button to update the data.

(l) Select "*This Record*" from the **Selection Option** window and click **Yes** from the confirmation message to proceed.

After the update the window looks like what is shown in the following figure.



b. Calculate the Low Flow Scour

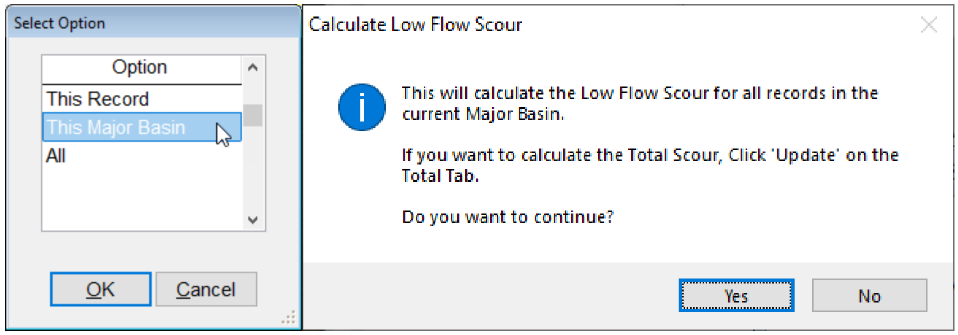
On the **Total Scour** form, select the **Low Flow** tab. The following figure shows what the window looks like before data entry.

(a) Enter *"100"* into the **Low Flow Rate (cfs)** textbox.

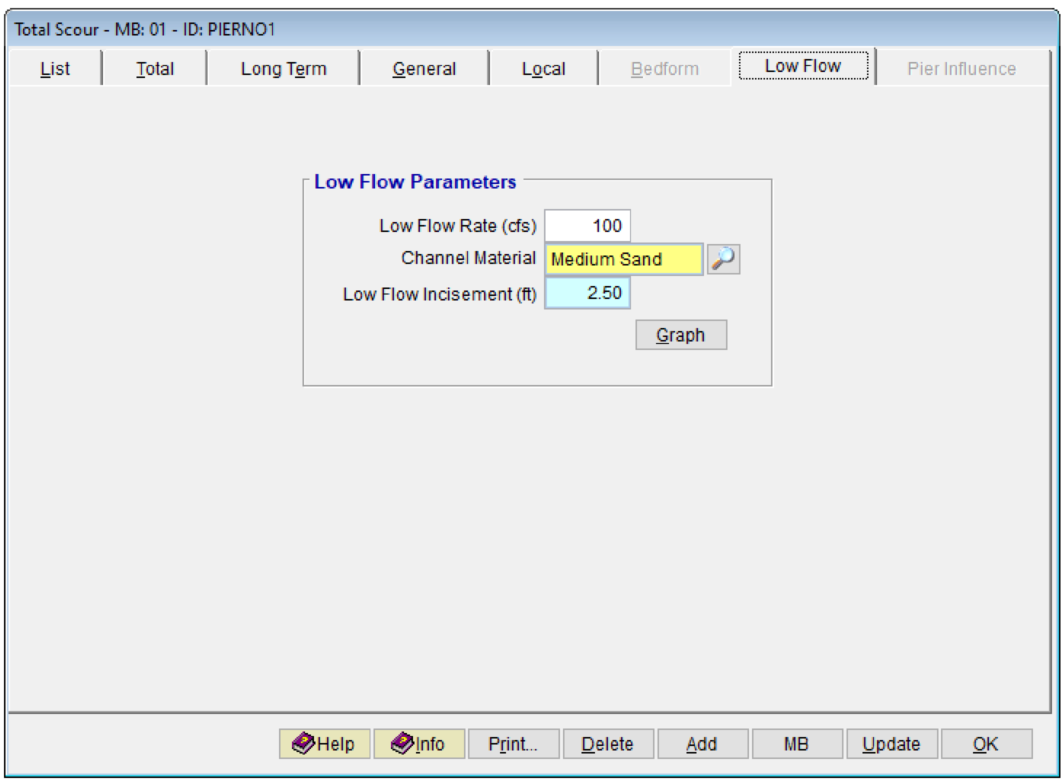
(b) Click browse button beside the **Channel Material** to select the channel material data. Choose *"Medium Sand"* and click **OK** to exit the **Select Channel Material** window.

(c) Click the **Save** button to save the data just entered.

(d) Click the **Update** button and select "*This Major Basin*" from the **SELECTION OPTION** window. Click **Yes** to continue.



After the update the final result of the low flow scour calculation result shows in the following figure

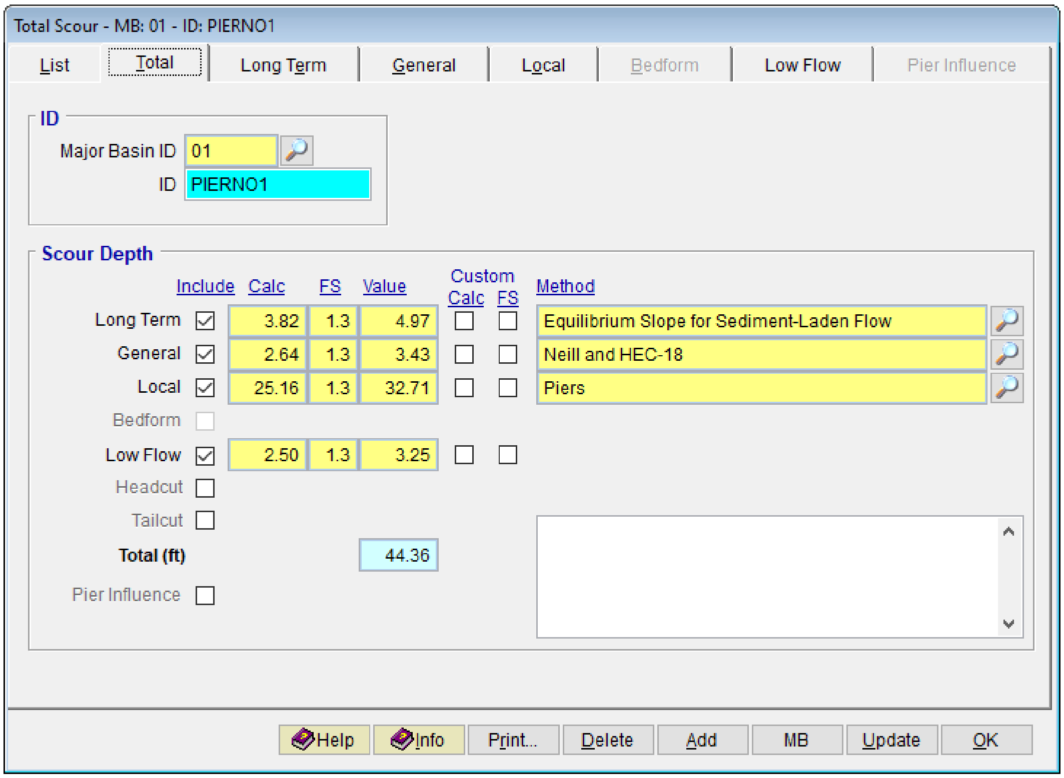


c. Calculate the Total Scour

(a) Click the **Update** button to compute the total scour and individual scour components.

(b) Select "*This Record*" from the **Selection Option** window to proceed.

After the update the window, the total scour results and individual scour components are displayed as shown in the following figure.



2.4 Step 4 - Report and Document the Results

In this section, the instruction will be given on how to view, print, and export the calculation results of the total scour.

The total scour is the sum of the long term scour, general scour, local scour, bedform scour and low flow scour. In this tutorial, these scour components are covered.

(a) To view the results on the screen, click the **Print…** button on the **Total Scour – MB: 01 – ID: PIERNO1** window, a report will be generated as is shown in the following figure.

Flood Control District of Maricopa County
Drainage Design Management System
RIVER MECHANICS - TOTAL SCOUR
Page 1 Project Reference: BRIDGEPIER1 3/28/2022

Major Basin: 01
ID: PIERNO1 Cross Section ID: STUDYREACHCROSSSECTION

Type	Calc (ft)	F S	Value (ft)	Method
Long Term	3.82	1.30	4.97	Equilibrium Slope for Sediment-Laden Flow
General	2.64	1.30	3.43	Neill and HEC-18
Local	25.16	1.30	32.71	Piers
Bedform		1.30		Comments
Low Flow	2.50	1.30	3.25	
Pressure Flow	0.00	1.30	0.00	
Headcut	-	1.30	-	
Tailcut	-	1.30	-	
Total			**44.36**	

(b) To print out the results on a printer, click the printer symbol ( ).

(c) To export the results in PDF format or other formats, click the export symbol ( )

(d) The individual scour components results and cross section hydraulics results can also be viewed, printed, and exported by clicking the **Print…** button under individual component scour menus and **Cross Section Hydraulics** menu.

This concludes this tutorial for bridge pier scour evaluation.