MARICOPA COUNTY
FLOOD CONTROL DISTRICT

DRAINAGE DESIGN MANAGEMENT SYSTEM FOR WINDOWS

VERSION 6.8.0

TUTORIAL # 21

PRESSURE FLOW SCOUR ANALYSIS HEC-18 PROCEDURE

K · V · L

KVL Consultants, Inc.

PRESSURE FLOW SCOUR ANALYSIS
[HEC-18 PROCEDURE]

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PRESSURE FLOW SCOUR ANALYSIS
[HEC-18 PROCEDURE]
DATE UPDATED: MAY 7, 2024
TUTORIAL TIME: 40 MINUTES

1.0 INTRODUCTION

Evaluation of pressure flow scour underneath a bridge structure from significant flood events is critical for safe bridge design and for assessing bridge stability. **FIGURE 1** below shows a typical bridge condition where pressure flow impacts the transport and stability of the bed materials giving rise to bed degradation and the formation of scour. FHWA (2012) has developed a number of useful procedures to evaluate such scour depth. The analysis procedure for predicting scour depths have been established for the following conditions:

(a) Live-bed with overtopping (or submerged) condition;
(b) Live-bed with no overtopping (or not submerged) condition;
(c) Clear-water with overtopping condition; and,
(d) Clear-water with no overtopping condition.

For a more thorough coverage on this topic, please refer to the following reference materials:

(a) River Mechanics Manual for DDMSW by FCDMC (April 30, 2021)
(b) HEC-18 – Evaluating Scour at Bridges by FHWA (April 2012).

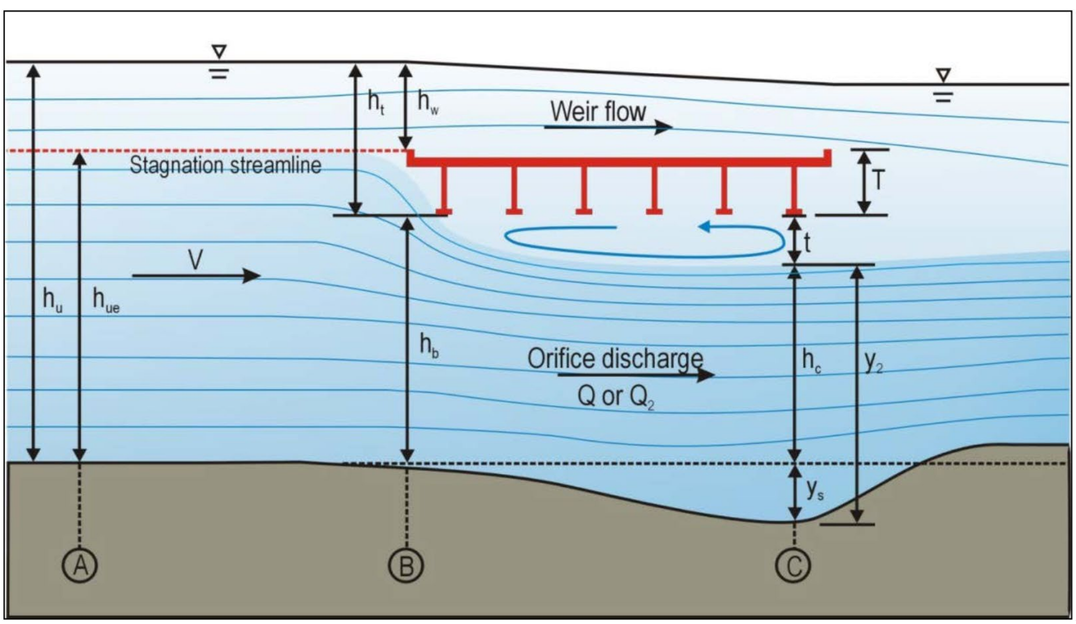


FIGURE 1: Vertical contraction under the bridge (FHWA, 2012)

2.0 SYMBOLS AND DEFINITION OF TERMS

The different symbols used to describe the parameters presented in **FIGURE 1** associated with pressure flow scour are defined below.

No.	Symbol	Definition
1	D_{50}	Average size of the bed material upstream of the bridge. It is the sediment particle size in which 50% are smaller (mm).
2	h_b	Vertical height of the bridge opening prior to scour (ft),
3	h_c	Vertical flow height in ft.
4	h_t	Distance from the water surface to the lower face of the bridge girders in ft, i.e., $h_t = h_u - h_b$;
5	h_u, y_a	Average depth of flow upstream of the bridge (ft),
6	h_{ue}	Effective upstream channel flow depth for live-bed conditions and bridge overtopping in ft.
7	h_w	Weir flow height in ft. $h_w = h_t - T$ for $h_t > T$ $h_w = 0$ for $h_t < T$;
8	Q_1	Flow in the upstream channel transporting sediment (cfs),
9	Q_2	Flow in the contracted channel section (cfs),
10	t	Maximum thickness of the flow separation zone (ft),
11	T	Height of obstruction that includes girders, deck, and parapet, ft.
12	Vc	Critical velocity (ft/s),
13	W_1	Bottom width of the upstream channel that is transporting bed material (ft).
14	W_2	Bottom width of the main channel in the contracted section less pier widths (ft).
15	y_1	Average depth of flow in the upstream main channel (ft), (hydraulic depth),
16	y_2	Average depth of flow in the contracted section (ft), (hydraulic depth),
17	y_s	Pressure flow scour depth, ft.

3.0 PROBLEM STATEMENT

This tutorial document was developed to show how scour analysis is performed for bridge structures involving pressure flow conditions with live-bed and no bridge overtopping. The conditions are described below:

- All the flow is through the bridge with no overtopping.
- There are no piers (clear span)
- Upstream channel width (W_1) and bridge opening width (W_2) = 40 ft;
- Total discharge (Q_2) = 5000 cfs;
- Upstream channel discharge (Q_1) = 4000 cfs;
- Upstream floodplain discharge = 1000 cfs
- Upstream channel flow depth ($y_1 = h_u$) = 10.14 ft
- Bridge opening height (h_b) = 8.0 ft;
- Deck thickness (T) = 3 ft;
- Bed material, D_{50} = 20 mm (V_c = 6.63 fps)
- Upstream channel velocity ($V = Q_1/(W_1h_u)$ = 5000/(40 x 10.14) = 9.86 fps;

Determine the magnitude of live-bed contraction scour for pressure flow conditions.

4.0 REQUIRED DATA

The following data are the basic data that will be used for the pressure flow scour analysis.

(a) Data at the Bridge Cross-Section

i. Bridge Cross-Section Data – The cross-section geometry where the bridge is located is provided below:

No	Station (X)	Elevation (Y)	Notes
1	*0*	*20*	
2	*20*	*19*	*Left Bank Station*
3	*20.01*	*4*	
4	*40.01*	*4*	
5	*60.01*	*4*	
6	*60.02*	*19*	*Right Bank Station*
7	*80.02*	*20*	

- *No piers (Clear Span)*
- *Height of obstruction/ Deck thickness, T (ft):* 3.0
- *Bridge opening width, W_2 (ft)* 40
- *Bridge opening height, h_b (ft):* 8.00

ii. Flow Rates and Related Data:

- *Design Flow Rate (cfs):* 5000
- *Dominant Flow Rate (cfs):* 1000
- *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:* 0.035
- *LOB Manning's n for Dominant Flow:* 0.035
- *ROB Manning's n for Dominant Flow:* 0.035

(b) Data at the Upstream Cross-Section

i. Upstream Cross-Section Data – The representative geometry of the upstream cross-section is provided below:

No	Station (X)	Elevation (Y)	Notes
1	0	20	
2	20	19	Left Bank Station
3	20.01	4	
4	40.01	4	
5	60.01	4	
6	60.02	19	Right Bank Station
7	80.02	20	

ii. Flow Rates and Related Data:

- *Design Flow Rate (cfs):* 4000
- *Channel Slope (ft/ft):* 0.0070
- *Channel Manning's n:* 0.045
- *LOB Manning's n:* 0.045
- *ROB Manning's n:* 0.045
- *Bottom width of upstream channel, W_1 (ft):* 40.00

iii. Sediment Data:

- *Bed material, D_{50} (mm):* 20.00

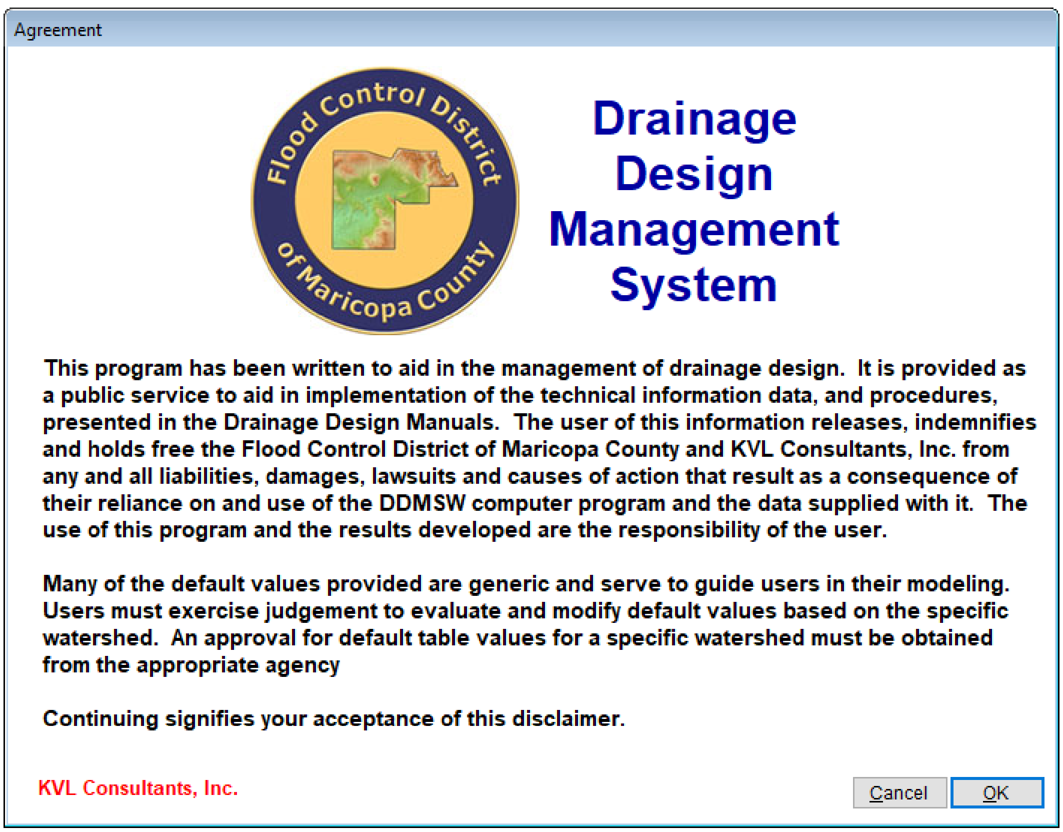
5.0 STEP-BY-STEP PROCEDURE

The general procedure for evaluating scour involving pressure flows at bridges is as follows:

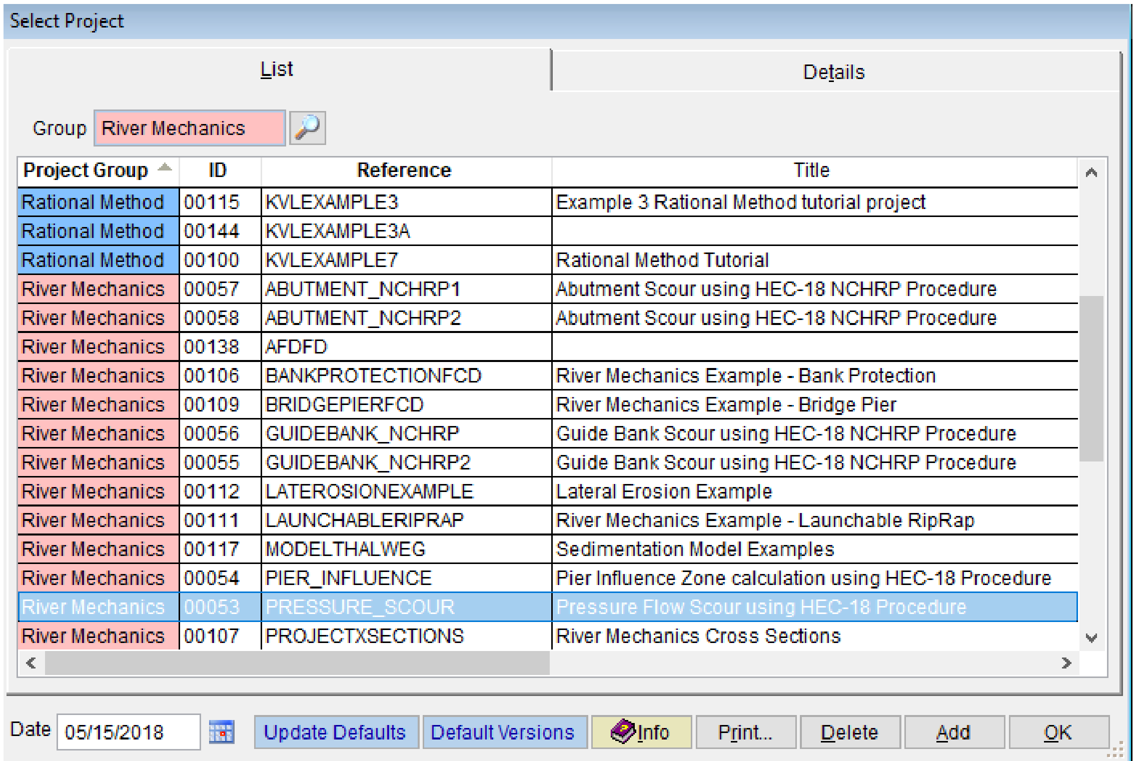
(i) Create a new river mechanics project and set-up project defaults
(ii) Prepare the cross-section geometry and evaluate the hydraulics
(iii) Calculate the pressure flow scour
(iv) Reporting and documentation of results

5.1 STEP 1 - CREATE A NEW PROJECT AND SET-UP PROJECT DEFAULTS

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



After **DDMSW** is launched, the **SELECT PROJECT** window is automatically opened.



(b) Click the ***Add*** button on the **Select Project** form to start a new project (Alternatively, ***File*** ➔ ***New Project***).

(c) Select ***River Mechanics*** checkbox, then click the ***OK*** button on the **New Project Options** form.

(d) On the **Select Project** form, enter "*V680_PRESSURE_SCOUR*" into the ***Reference*** textbox. This is the name of the new project. Users can choose any project name to be entered on the ***Reference*** textbox as long as it does not already exist in the **DDMSW** project database.

(e) Type into the ***Title*** textbox a brief descriptive title of this project. *(Optional) (e.g., 'Pressure Flow Scour using HEC-18 NCHRP Procedure').*

(f) Type into the ***Location*** textbox the location of this project. *(Optional) (e.g., 'Maricopa County, Arizona')*

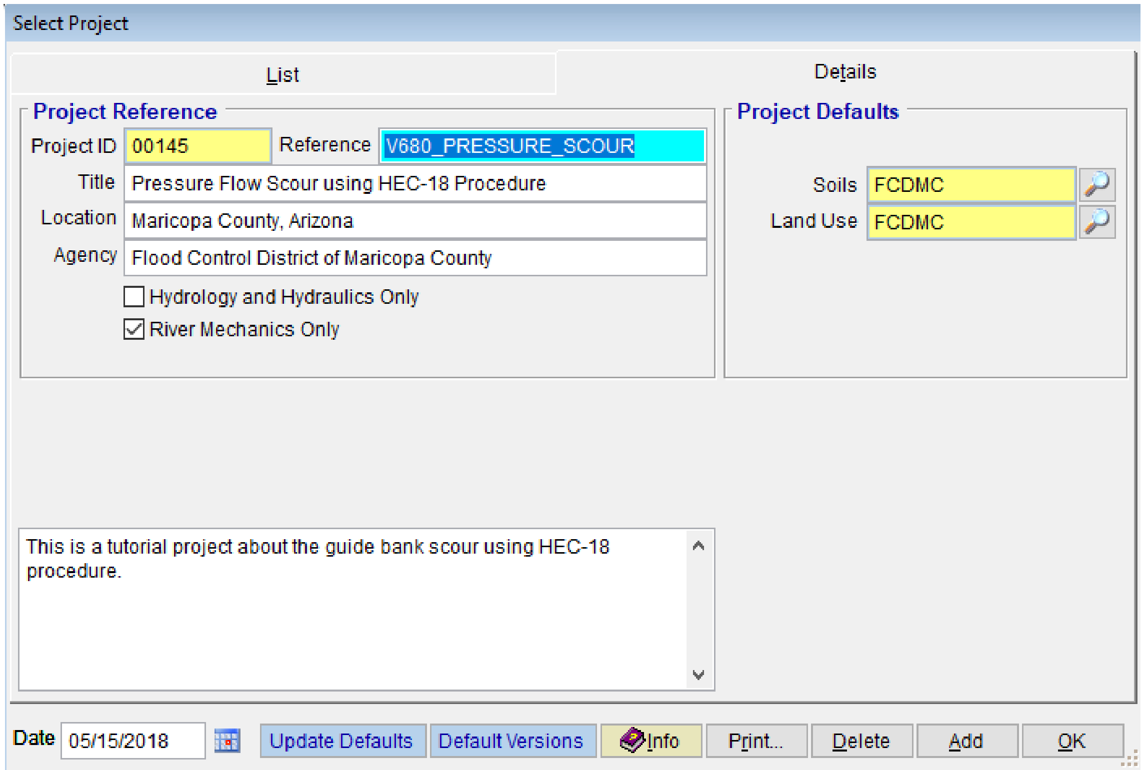
(g) Type into the ***Agency*** textbox the agency or company name. *(Optional) (e.g., 'Flood Control District of Maricopa County').*

(h) Check the ***River Mechanics Only*** checkbox.

(i) Type a detailed description of this project into the comment area under the ***Project Reference*** frame. *(Optional) (e.g., 'This is a tutorial project for evaluating Pressure Flow Scour using HEC-18 NCHRP Procedure').*

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

The following figure shows what the form should look like.



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

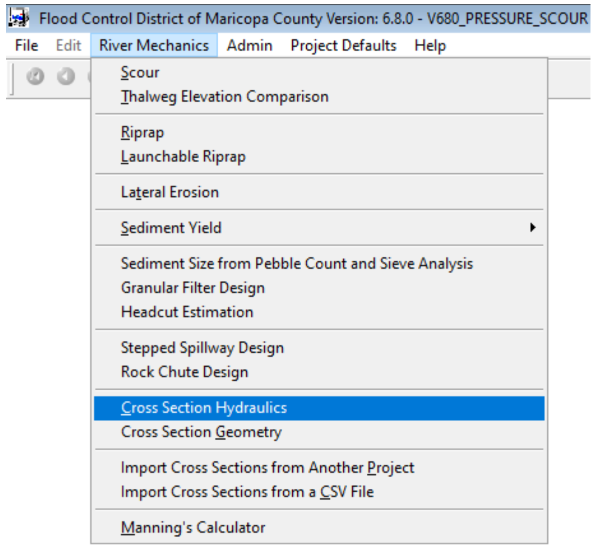
Note: The ***Project ID*** *"00145"* in the above figure is the unique database record identifier for the project, which is automatically generated by the program. Each time a new project is created, a ***Project ID*** is assigned by the program. The ***Project ID*** assigned to your project will not necessary be the same as the ***Project ID*** shown in the above figure.

(l) Click the ***OK*** button to exit/close the **Select Project** form.

5.2 Step 2 - Prepare the Cross-Section Data and Evaluate the Section Hydraulics

Two channel section data are considered in the analysis where hydraulics information would be evaluated. They are the cross-section data of: (a) upper channel reach; and, (b) bridge channel. Geometric and relevant data are entered in DDMSW to evaluate relevant flow hydraulics to be used by the program in evaluating the Pressure Flow scour depth.

From the menu bar of the main application window, open the **Cross Section Hydraulics** form (***River Mechanics*** ➔ ***Cross Section Hydraulics***).



5.2.1 Create the Bridge Cross-Section Data and Evaluate the Hydraulics

(a) On the **CROSS SECTION HYDRAULICS** form, click the ***Add*** button.

(b) Enter "*BRIDGEXS*" into the ***Section ID*** textbox, then click the ***Save*** button.

(c) Check both the ***Design*** and the ***Dominant*** checkboxes.

(d) Enter *"5000"* into the ***Design Flow Rate (cfs)*** textbox.

(e) Enter "*0.01"* into the ***Design Slope (ft/ft)*** textbox.

(f) Enter *"0.035"* into the ***Design Manning's n Channel*** textbox.

(g) Enter *"0.035"* into the ***Design Manning's n LOB*** textbox.

(h) Enter *"0.035"* into the ***Design Manning's n ROB*** textbox.

(i) Enter *"1000"* into the ***Dominant Flow Rate (cfs)*** textbox.

(j) Enter "*0.01"* into the ***Dominant Slope (ft/ft)*** textbox.

(k) Enter *"0.035"* into the ***Dominant Manning's n Channel*** textbox.

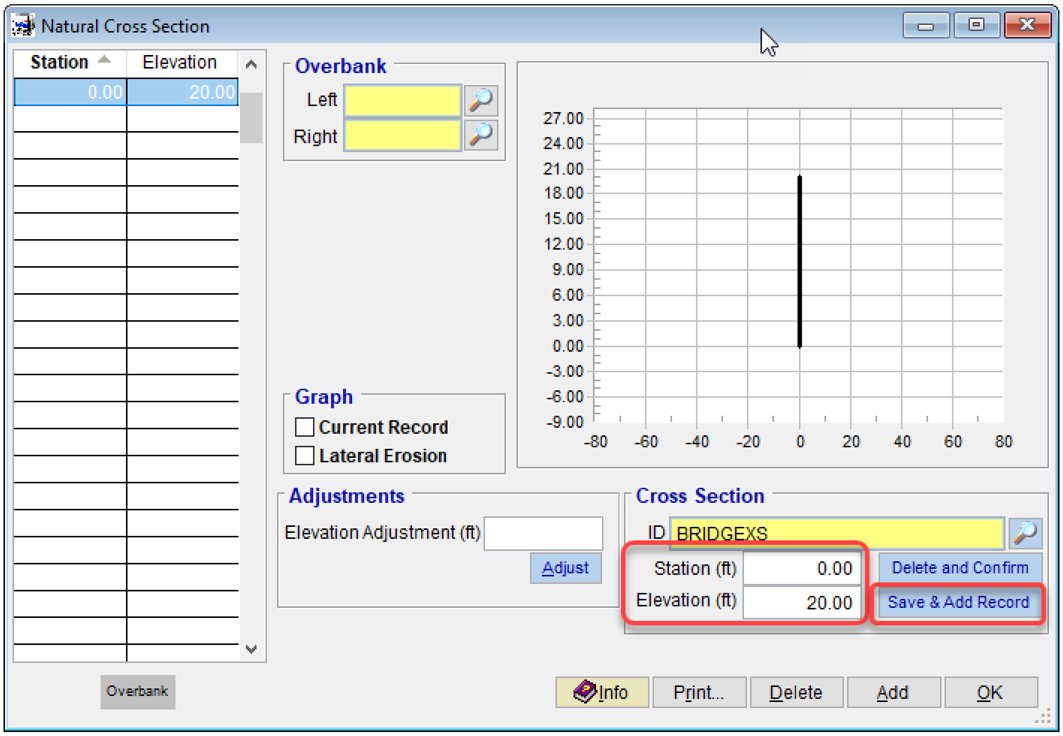
(l) Enter *"0.035"* into the ***Dominant Manning's n LOB*** textbox.

(m) Enter *"0.035"* into the ***Dominant Manning's n ROB*** textbox.

(n) Click the ***Save*** button to save the entered data for the Bridge Section.

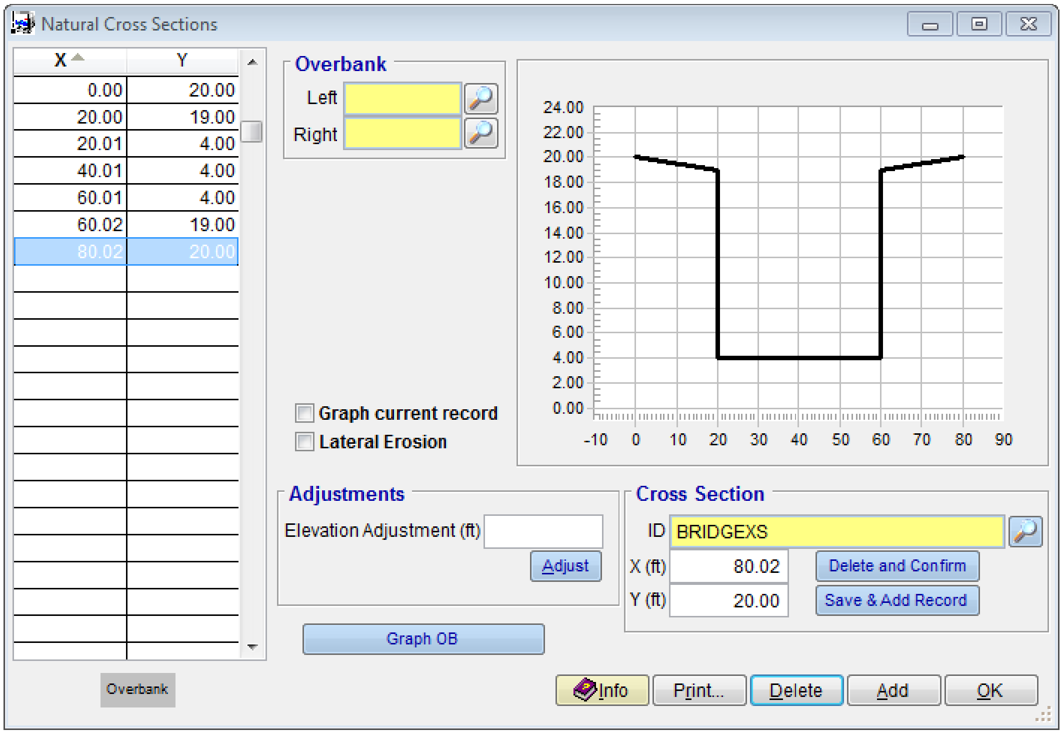
(o) Click the **X Section** button at the bottom of the **CROSS SECTION HYDRAULICS** form to enter the X and Y coordinates of the Bridge Section.

(p) On the **NATURAL CROSS SECTION** form, enter the first X and Y values (i.e., X= *"0.00"* and Y = *"20.00"*) from the Bridge Cross Section data table into the ***Station (ft)*** and ***Elevation (ft)*** text boxes shown below. Click the ***Save & Add Record*** button when done to continue with the next XY dataset.

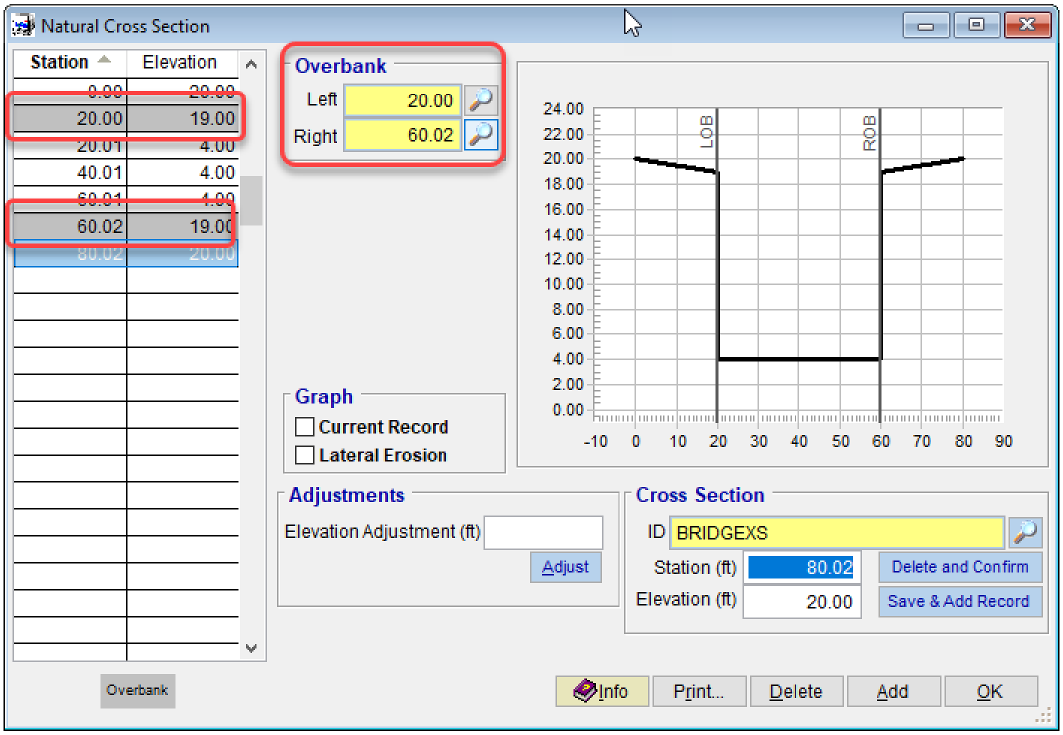


(q) Follow the same procedure until all the ***Station*** (X) and ***Elevation*** (Y) data pairs are entered.

The completed form should look like the figure below.



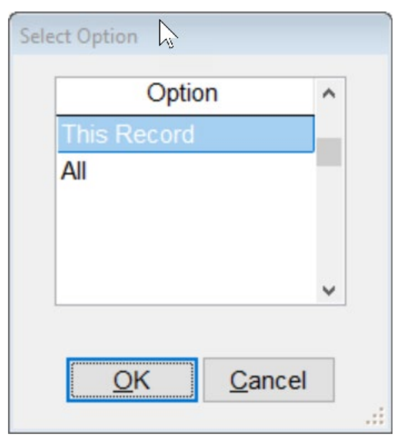
(r) After entering all the ***Station*** (X) and ***Elevation*** (Y) data, set the left and right overbank stations. The left overbank station is set by selecting the row with ***Station*** value of *"20.00"* and then clicking the "Selection" button on the right side of the ***Left Overbank*** textbox. Similarly, the right overbank station is set by selecting the row with ***Station*** value of *"60.02"* and then clicking the "Selection" button on the right side of the ***Right Overbank*** textbox.

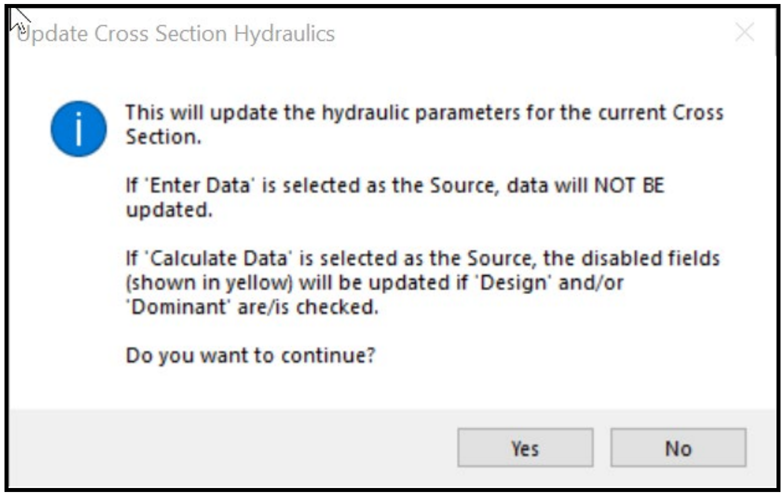


(s) Once the data entry is complete, close the **NATURAL CROSS SECTION** form by clicking the ***OK*** button.

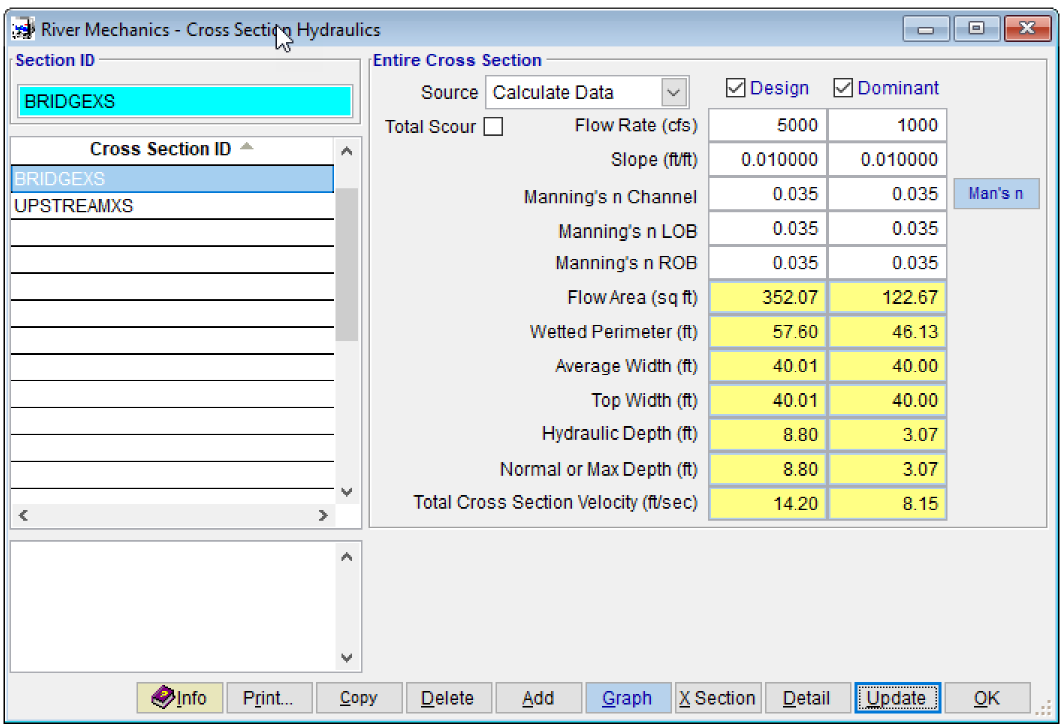
(t) On the **RIVER MECHANICS - CROSS SECTION HYDRAULICS** form, click the ***Update*** button to update the hydraulic analysis at the Bridge Section, *BRIDGEXS,* for both the ***Design*** and ***Dominant*** flow conditions.

(u) On the **SELECT OPTION** dialog box, select *"This Record"*, then click ***OK*** to close. When the **UPDATE CROSS SECTION HYDRAULICS** dialog box appears, click ***Yes*** to continue.





(v) After successful analysis update, the **River Mechanics - Cross Section Hydraulics** form should look like the figure below:



5.2.2 Create the Upstream Cross Section Data and Evaluate the Hydraulics

(a) On the **River Mechanics - Cross Section Hydraulics** form, click the ***Add*** button.

(b) Enter "*UPSTREAMXS*" into the **Section ID** textbox, then click the ***Save*** button.

(c) In the ***Entire Cross Section*** data frame, check the ***Design*** checkbox and uncheck the ***Dominant*** checkbox.

(d) Enter *"4000"* into the ***Design Flow Rate (cfs)*** textbox.

(e) Enter *"0.007"* into the ***Design Slope (ft/ft)*** textbox.

(f) Enter *"0.045"* into the ***Design Manning's n Channel*** textbox.

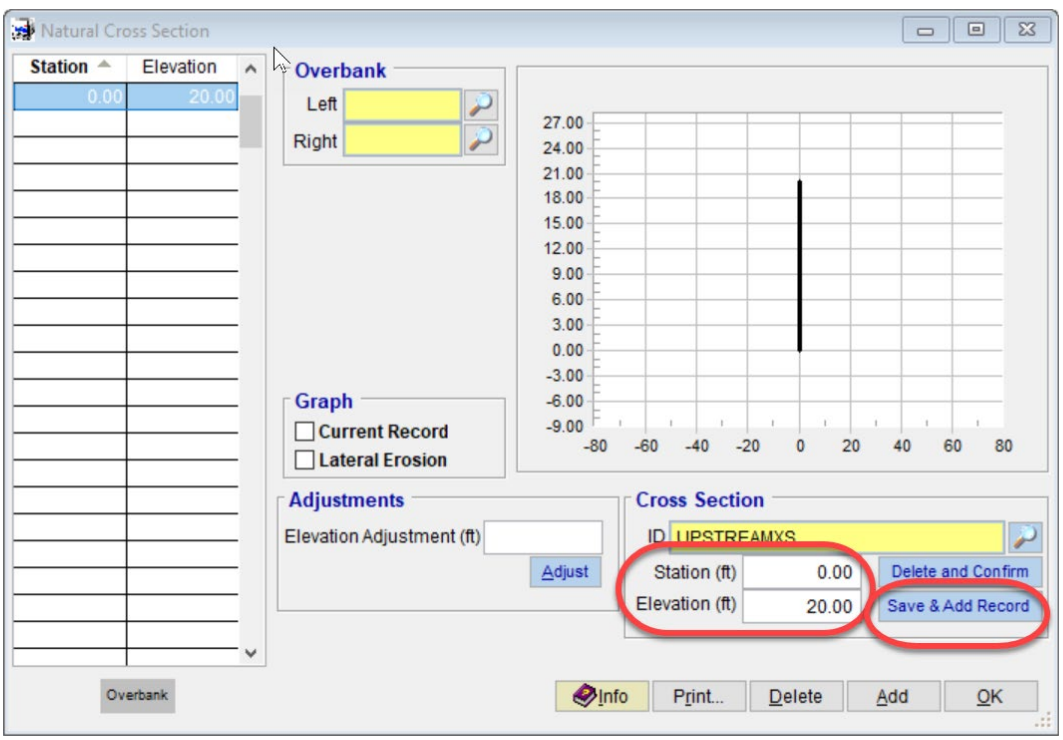
(g) Enter *"0.045"* into the ***Design Manning's n LOB*** textbox.

(h) Enter *"0.045"* into the ***Design Manning's n ROB*** textbox.

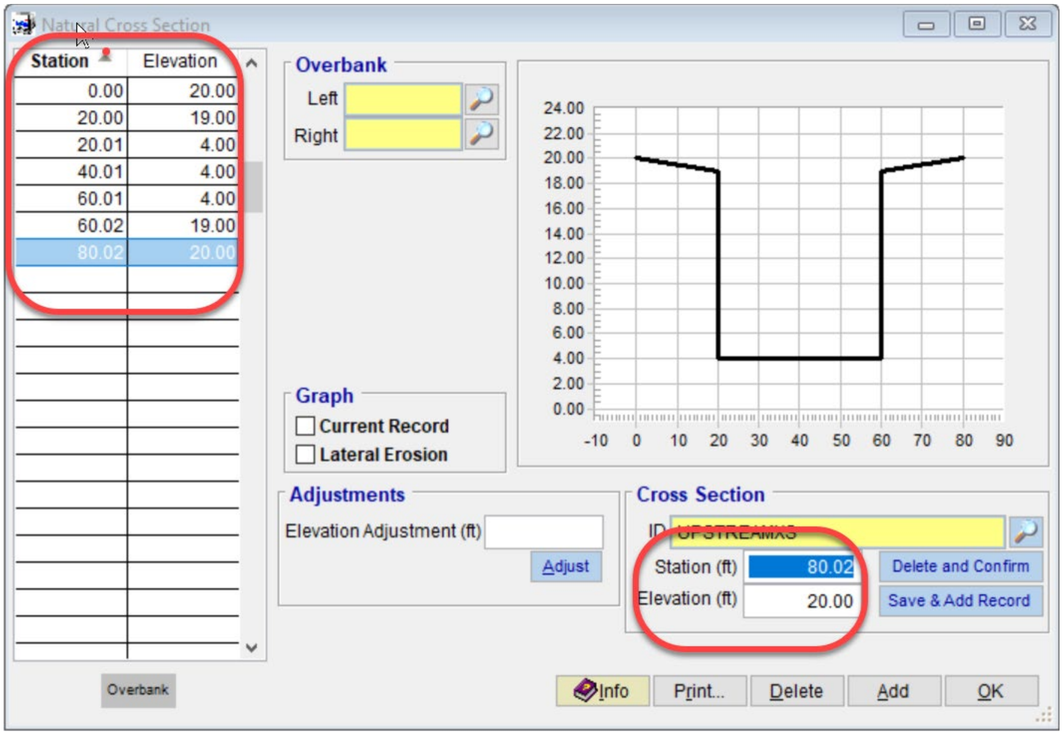
(i) Click the ***Save*** button to save the entered data.

(j) Click the ***X Section*** button at the bottom of the form to enter the X and Y coordinates of the Upstream cross section.

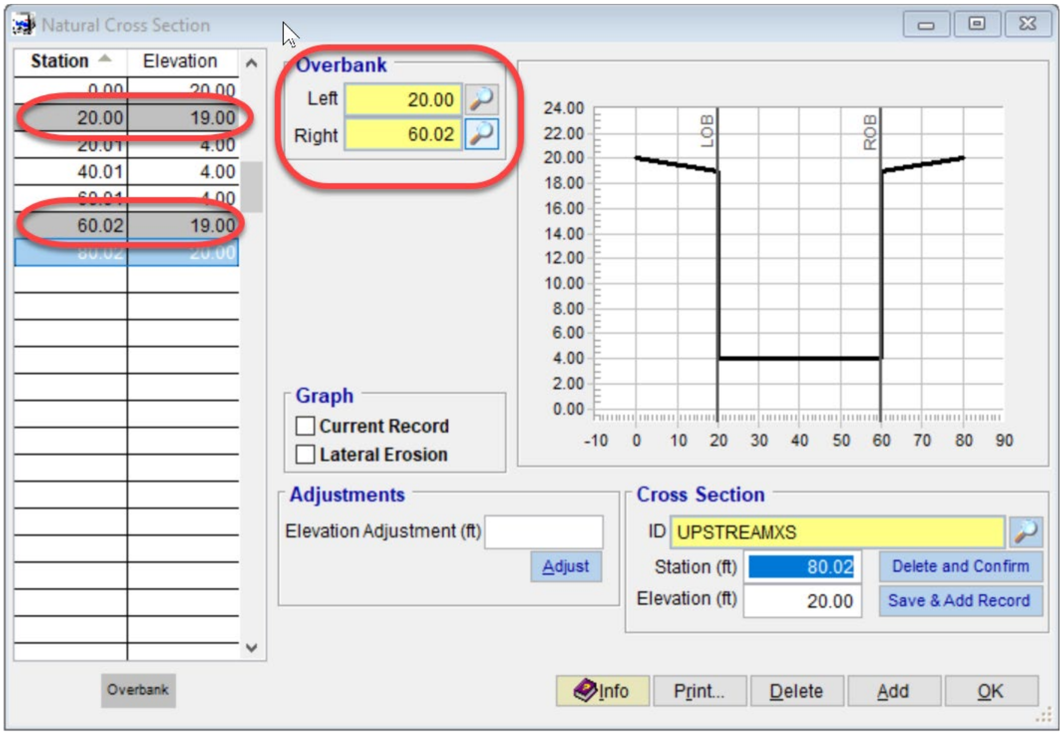
(k) On the **NATURAL CROSS SECTION** form, enter the first X and Y values (i.e., X = *"0.00"* and Y = *"20.00"*) from the Upstream Cross Section data table into the ***Station (ft)*** and ***Elevation (ft)*** text boxes as shown below. Click the ***Save & Add Record*** button when done to continue with the next XY dataset.



(l) Follow the same procedure until all the ***Station*** and ***Elevation*** data pairs are entered.



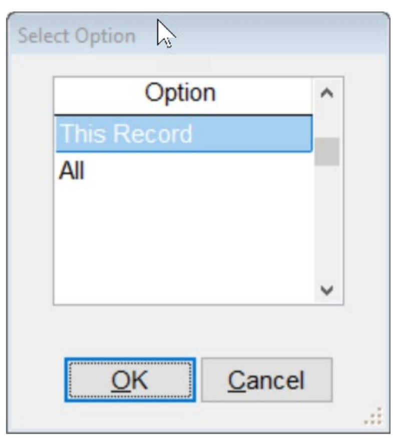
(m) After entering all the ***Station*** and ***Elevation*** dataset, define the left and right over bank stations. The left bank station is set by selecting the row with ***Station*** value of *"20"* and then clicking the "Selection" button on the right side of the ***Left Overbank*** textbox. Similarly, the right bank station is set by selecting the row with ***Station*** value of *"60.02"* and then clicking the "Selection" button on the right side of the ***Right Overbank*** textbox.

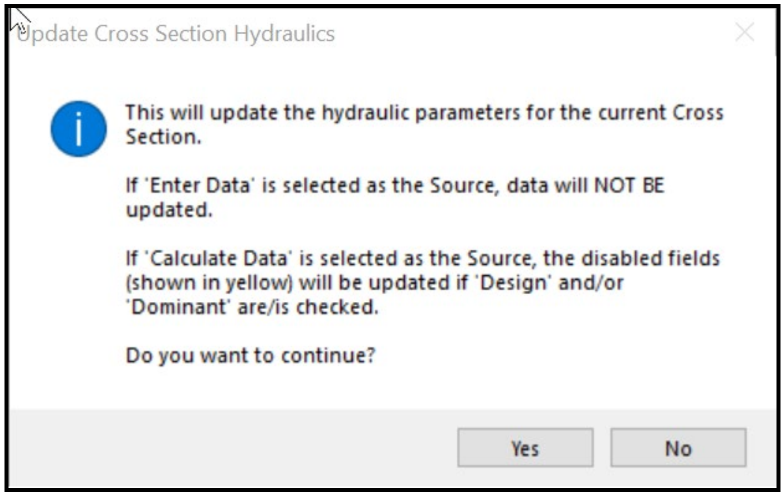


(n) To close the **NATURAL CROSS SECTION** form, click the ***OK*** button.

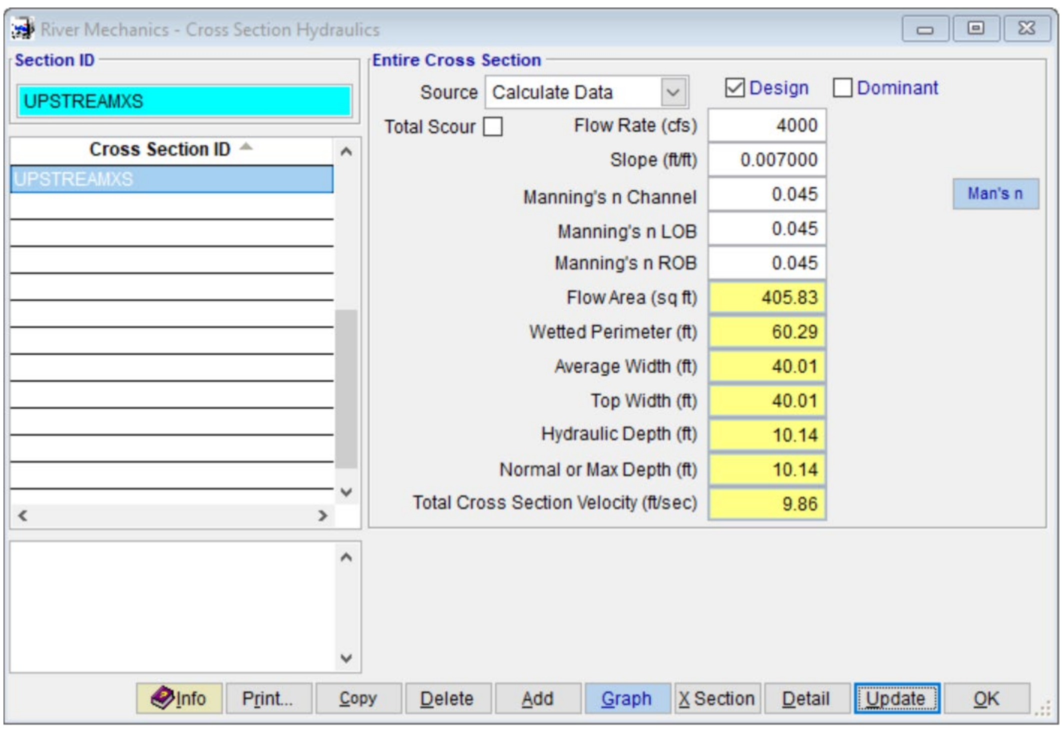
(o) On the **RIVER MECHANICS - CROSS SECTION HYDRAULICS** form, click the ***Update*** button to update the hydraulics analysis at the upstream cross section, *UPSTREAMXS.*

(p) On the **SELECT OPTION** dialog box, select *"This Record"*, then click ***OK*** to close. When the **UPDATE CROSS SECTION HYDRAULICS** dialog box appears, click ***Yes*** to continue.





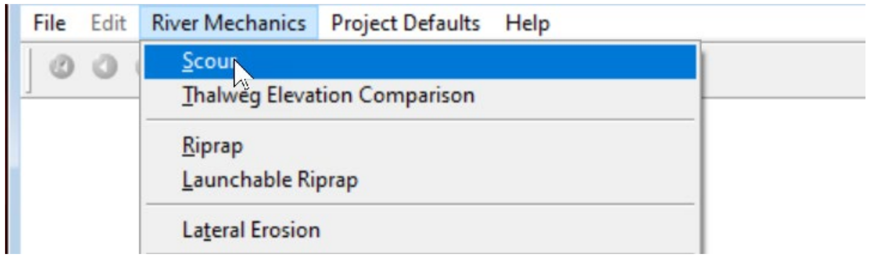
(q) The **River Mechanics - Cross Section Hydraulics** form should now look like the following figure:

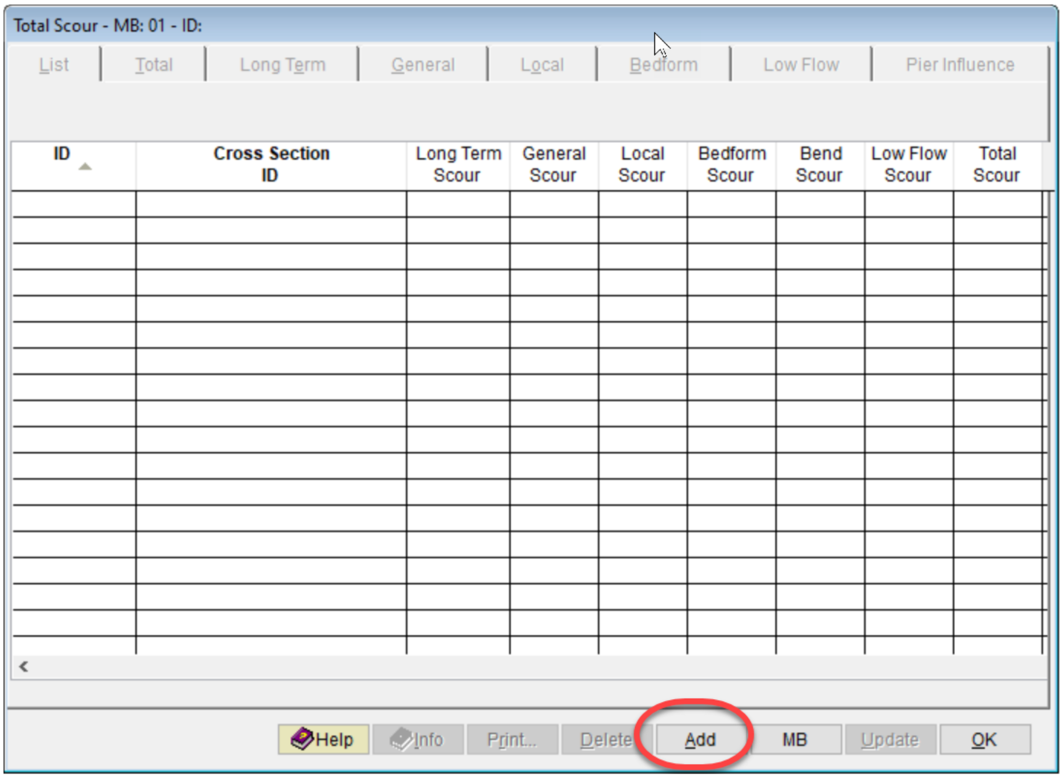


(r) Click the ***OK*** button to close the form.

5.3 Step 3 - Calculate the Pressure Flow Scour

(a) From the menu bar of the main application window, open the **Total Scour** form (i.e., **River Mechanics → Scour**).

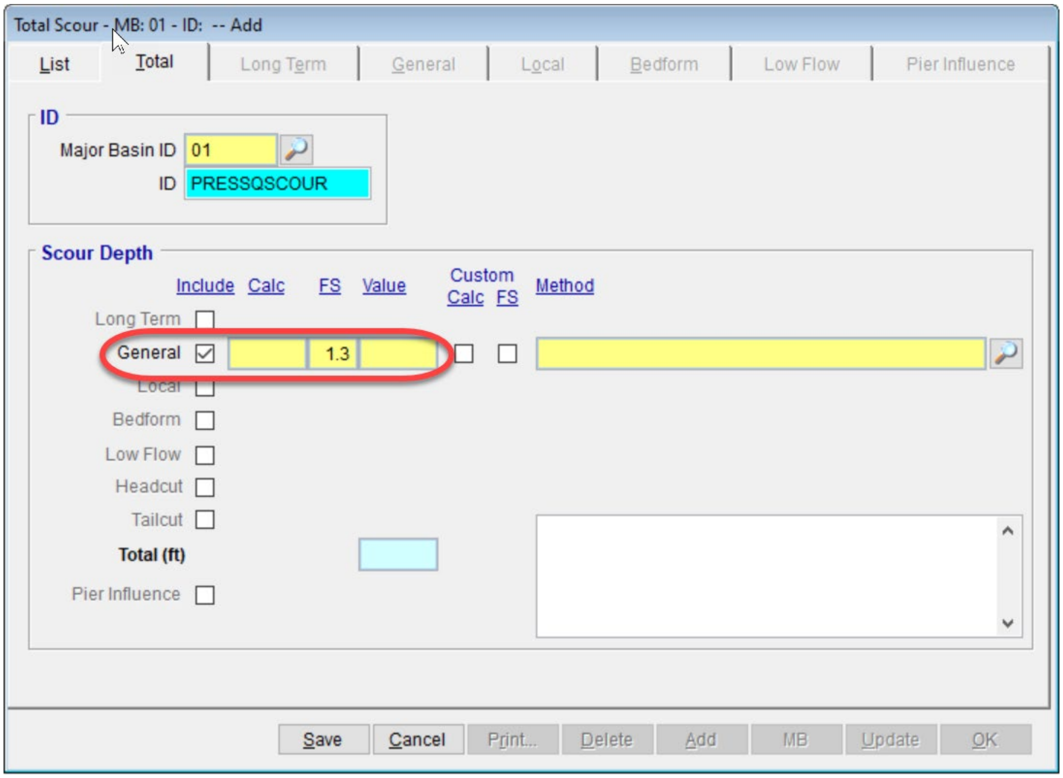




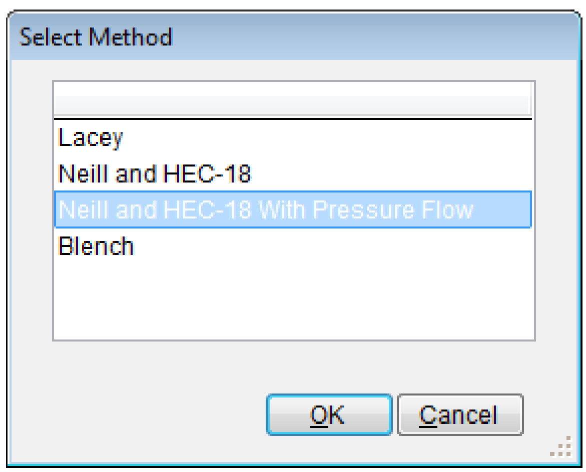
(b) Click the ***Add*** button to activate the necessary data entry fields

(c) On the ***Total*** tab of the **TOTAL SCOUR** form, enter "*PRESSQSCOUR*" into the ***ID*** textbox

(d) Check the ***General*** check box only.



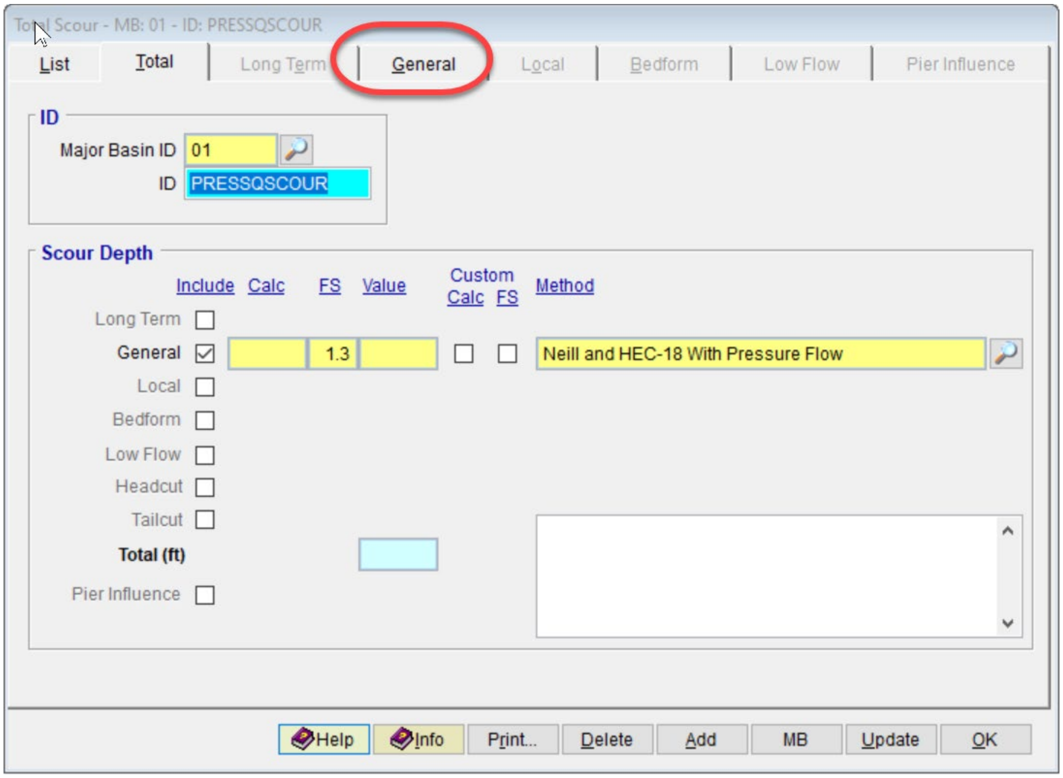
(e) Click the browse button under the ***Method*** column across the ***General*** checkbox to launch **SELECT METHOD** dialog box.



(f) Select *"Neill and HEC-18 With Pressure Flow"* from the **SELECT METHOD** dialog box, then click ***OK*** to exit.

(g) On the **TOTAL SCOUR** form, click the ***Save*** button to save the entered data.

(h) To perform the pressure flow scour analysis, click the ***General*** tab



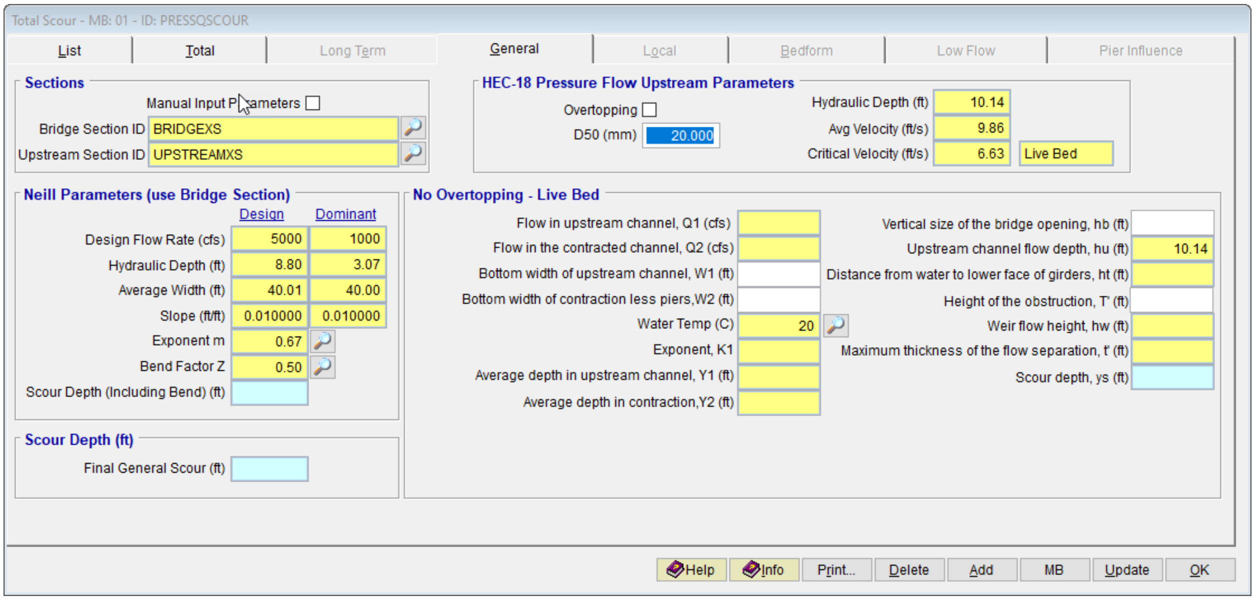
(i) On the ***General*** tab of the **TOTAL SCOUR** form, select *"BRIDGEXS"* for the ***Bridge Section ID.***

(j) Select *"UPSTREAMXS"* for the ***Upstream Section ID.***

(k) In the ***Neill Parameters (use Bridge Section)*** frame, select *"Sand"* for ***Exponent m*** textbox and select *"Straight Reach"* for ***Bend Factor Z*** textbox.

(l) In the ***HEC-18 Pressure Flow Upstream Parameters*** frame, enter *"20"* into the ***D50 (mm)*** textbox.

(m) Check the Manual Input Parameters checkbox and enter "10.14" into the Hydraulic Depth (ft) textbox, and "9.86" into the Avg Velocity (ft/s) textbox. After entering the data, uncheck the Manual Input Parameters checkbox.



(n) Enter *"40"* into the ***Bottom width of upstream channel, W_1 (ft)*** textbox.

(o) Enter *"40"* into the ***Bottom width of contraction less piers, W_2 (ft)*** textbox.

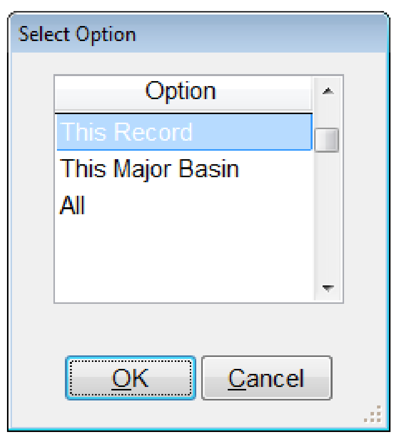
(p) Enter *"8"* into the ***Vertical size of the bridge opening, h_b (ft)*** textbox.

(q) Enter "*3*" into the ***Height of the obstruction, T (ft)*** textbox.

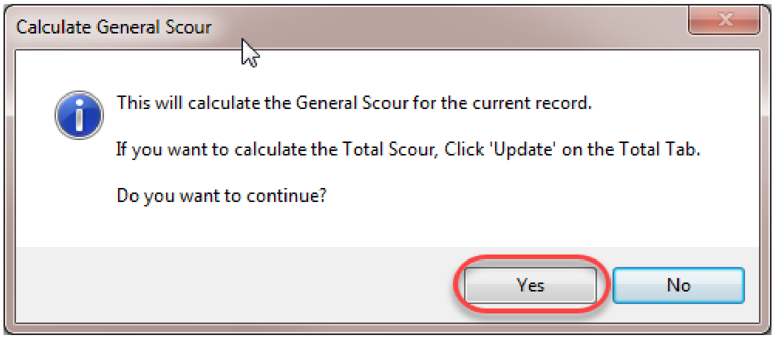
(r) Click the ***Save*** button to save the entered data.

(s) Click the ***Update*** button to perform / update the analysis.

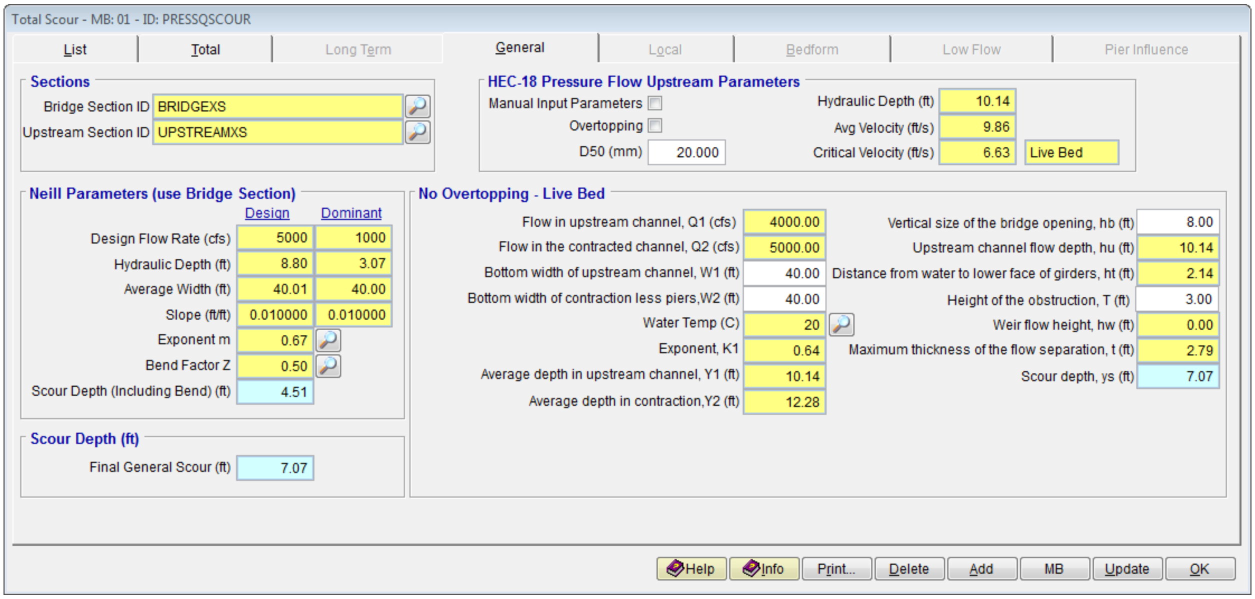
(t) Select "*This Record*" from the **SELECT OPTION** window, then click ***OK*** to exit.



(u) When the **CALCULATE GENERAL SCOUR** dialog box shows up, click ***Yes*** to continue.

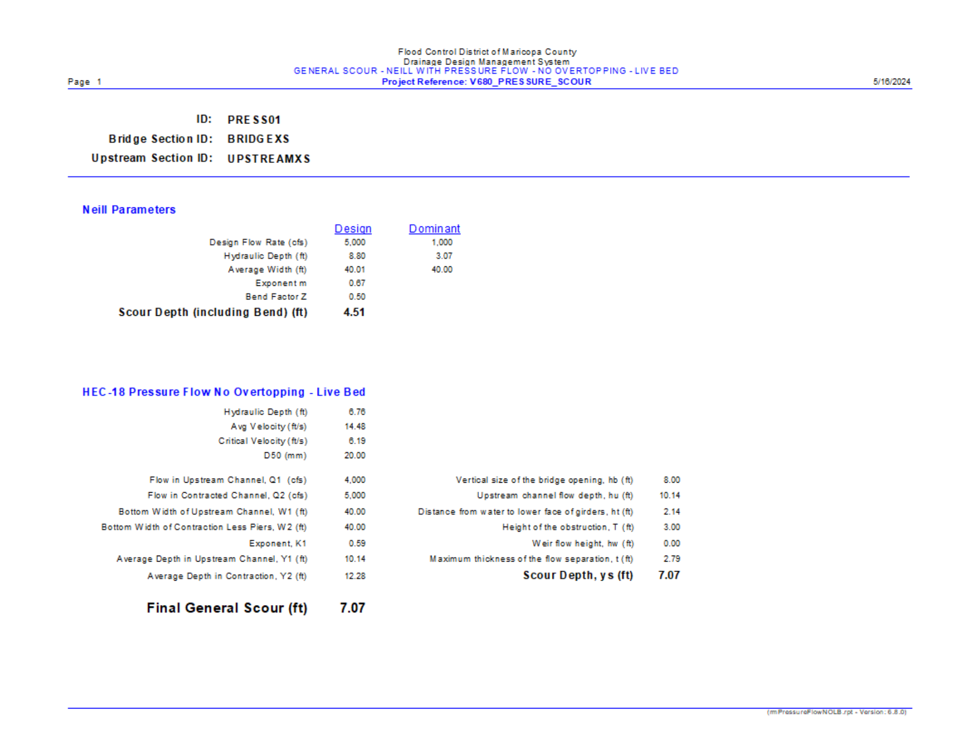


(v) After the update, the general scour analysis results form should look like the screen shot shown below:



5.4 STEP 4 - REPORTING AND DOCUMENTATION OF RESULTS

(a) To view the analysis results on the screen, click the ***Print …*** button on the ***General*** tab of the **TOTAL SCOUR** form.


Flood Control District of Maricopa County
Drainage Design Management System
GENERAL SCOUR - NEILL WITH PRESSURE FLOW - NO OVERTOPPING - LIVE BED
Page 1 | Project Reference: V680_PRESSURE_SCOUR | 5/16/2024

ID:	PRESS01
Bridge Section ID:	BRIDGEXS
Upstream Section ID:	UPSTREAMXS

Neill Parameters

	Design	Dominant
Design Flow Rate (cfs)	5,000	1,000
Hydraulic Depth (ft)	8.80	3.07
Average Width (ft)	40.01	40.00
Exponent m	0.67	
Bend Factor Z	0.50	
Scour Depth (including Bend) (ft)	**4.51**	

HEC-18 Pressure Flow No Overtopping - Live Bed

Hydraulic Depth (ft)	6.76
Avg Velocity (ft/s)	14.48
Critical Velocity (ft/s)	6.19
D50 (mm)	20.00

Flow in Upstream Channel, Q1 (cfs)	4,000	Vertical size of the bridge opening, hb (ft)	8.00
Flow in Contracted Channel, Q2 (cfs)	5,000	Upstream channel flow depth, hu (ft)	10.14
Bottom Width of Upstream Channel, W1 (ft)	40.00	Distance from water to lower face of girders, ht (ft)	2.14
Bottom Width of Contraction Less Piers, W2 (ft)	40.00	Height of the obstruction, T (ft)	3.00
Exponent, K1	0.59	Weir flow height, hw (ft)	0.00
Average Depth in Upstream Channel, Y1 (ft)	10.14	Maximum thickness of the flow separation, t (ft)	2.79
Average Depth in Contraction, Y2 (ft)	12.28	**Scour Depth, ys (ft)**	**7.07**

Final General Scour (ft) 7.07

(rnPressureFlowNOLB.rpt - Version: 6.8.0)

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

(c) To export the results into a PDF file or other file formats, click the export symbol ( ) and select the preferred file format

This concludes this tutorial for Pressure Flow Scour Analysis based on HEC-18 procedure.