Tips & Tools

for

Fluvial-12

A basic reviewer's and modeler's guide to Fluvial-12 and other helpful programs

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Table of Contents

Introduction

Fluvial-12 is a mathematical model for erodible channels. It was developed and has been maintained by Howard H. Chang. Fluvial-12 is similar to HEC-6 in the structure of the input file, but uses different methods. This model is used to develop sediment transport models for studies and Floodplain Use Permits such as Sand & Gravel permits. The purpose of this document is to give a brief overview of some of the tips and tools currently available for the Fluvial-12 model. This document is based on the version of Fluvial-12 named "FL12.exe" compiled on 05/08/2012, the "Fluvial 12 GUI.exe" used in this document was compiled on 04/10/2009. The Plot program "Plot.exe" was compiled on 02/07/2009 and "PLOT2012.exe" was compiled on 06/28/2012.

Fluvial-12 has a similar input file structure to HEC-6, HEC-6T and HEC-2. The input file is based on cards, that is the first 2 positions of each line in the file are used as an identifier of what records are stored in that line. The basic format for the file is each line contains records composed of 11 fields, the first as was already mentioned is the identifier and is 2 characters long. The next 10 fields contain the data for that identifier, not all 10 fields are used for each identifier. These data fields are 6 characters long. The figure below shows an input file with the fields outlined and labeled in red.

```
G2  6400   309.2    7466   309.5    8000   309.8    7466   310.2    6400   310.8
G2  4266   312.0    2133   313.7    1066   315.4     640   316.7     192   320.0
C
C     1       2       3       4       5       6       7       8       9      10
G3 .0036                                                        6
G4 10000                                                 1
G5                                                                           50
GQ     5
GQ1150.8      50  1151.5    1400  1152.9    3333  1155.3   19140  1156.9   37800
GS  0.14    0.04    0.42    0.12    1.10    0.25    4.47    0.18    17.3    0.20
GS  45.8    0.20
X119.066      51      57    1381       0       0  100660
XF                                   900
GR1167.1       0  1166.1      16  1164.1      22  1162.1      28  1160.1      34
GR1158.1      40  1156.1      46  1154.1      52  1152.1      57  1150.3     128
GR1152.1     185  1153.8     211  1152.1     241  1152.1     288  1152.1     343
GR1152.1     356  1154.1     505  1152.1     578  1150.1     596  1149.8     626
```

A list of the Records or Cards (the identifiers) and a basic description of them is in APPENDIX B. USERS INSTRUCTIONS FOR THE FLUVIAL MODEL of the Fluvial-12 User's Manual. This document will not cover all of them since most are fairly common and are explained sufficiently in the Fluvial-12 User's Manual, also since the model's input file is similar to HEC-6 some user's problems might be solved by consulting HEC-6 documentation. The focus of this manual will be on the methods most commonly used in reviewing Fluvial-12 models to determine their correctness and demonstrated impacts.

Minimum Bed Elevation

In most cases the important output from a sediment transport model is the minimum bed elevations for each cross section during the simulation. This is important, because from this the maximum scour can be calculated. The maximum scour is an important factor in most designs; it also demonstrates the impact of adding a bridge or a sand and gravel pit on the surrounding areas. The minimum bed elevations are not automatically reported by Fluvial-12, but it has the capability of reporting these results. This section deals with how to have Fluvial-12 output minimum bed elevations.

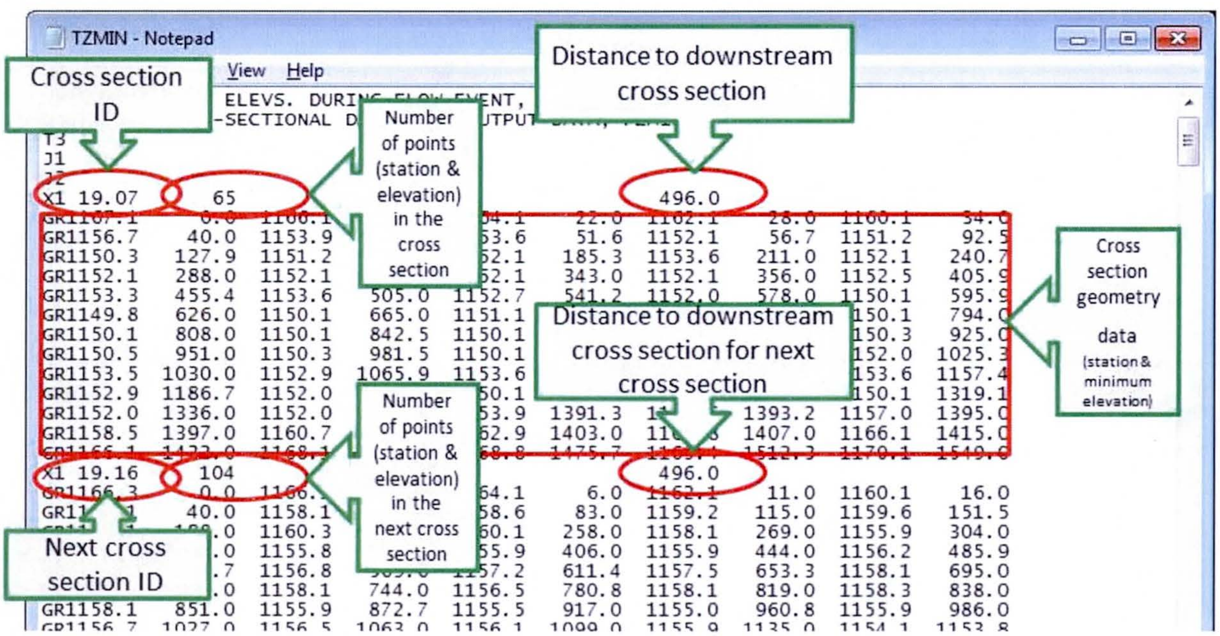
To obtain the minimum bed elevations the correct data must be entered into the input file. The G4 card which is described as "General Use Record for Selected Cross-Sectional Output" is used to tell the model that the minimum bed elevations results are needed. The G4 card can use fields 1-7 and 10 but we are only interested in field number 7 to obtain the minimum bed elevations during the simulation. Most of the fields for G4 are or can be left blank including field 7, this default of blank or zero for field 7 does not report the minimum bed elevations. The figure below shows the G4 Record of an input file with field 7 blank which is how the model is usually run.

```
G2   373    291.2    1120    291.6    1866    292.0    3733    292.2    7466    292.8
G2 11200    293.2   13066    293.5   14000    293.8   13066    294.2   11200    294.8
G2  7466    296.0    3733    297.7    1866    299.4    1120    300.7     336    304.0
G2   213    307.2     640    307.6    1066    308.0    2133    308.2    4266    308.8
G2  6400    309.2    7466    309.5    8000    309.8    7466    310.2    6400    310.8
G2  4266    312.0    2133    313.7    1066    315.4     640    316.7     192    320.0
C
C     1        2        3        4        5        6        7        8        9       10
G3  0036                                                             6
G4 10000
G5                                                                                    50
GQ     5
GQ1150.8       50  1151.5     1400  1152.9     3333  1155.3    19140  1156.9    37800
GS  0.14     0.04    0.42     0.12    1.10     0.25    4.47     0.18    17.3     0.20
GS  45.8     0.20
X119.066       51      57     1381       0        0  100660
XF                                     900
GR1167.1        0  1166.1       16  1164.1       22  1162.1       28  1160.1       34
GR1158.1       40  1156.1       46  1154.1       52  1152.1       57  1150.3      128
GR1152.1      185  1153.8      211  1152.1      241  1152.1      288  1152.1      343
```

To report the minimum bed elevations, enter "1" into field number 7 of G4. Below is shown the same input file with a "1" placed in field 7.

```
G2  6400    309.2     7466    309.5     8000    309.8     7466    310.2     6400    310.8
G2  4266    312.0     2133    313.7     1066    315.4      640    316.7      192    320.0
C
C    1        2         3         4         5         6         7         8         9        10
G3  .0036                                                                   6
G4  10000                                                         1
G5                                                                                       50
GQ     5
GQ1150.8       50   1151.5     1400   1152.9     3333   1155.3    19140   1156.9     37800
GS   0.14    0.04     0.42     0.12     1.10     0.25     4.47     0.18     17.3      0.20
GS   45.8    0.20
X119.066       51       57     1381        0        0   100660
XF                                       900
GR1167.1        0   1166.1       16   1164.1       22   1162.1       28   1160.1        34
GR1158.1       40   1156.1       46   1154.1       52   1152.1       57   1150.3       128
GR1152.1      185   1153.8      211   1152.1      241   1152.1      288   1152.1       343
GR1152.1      356   1154.1      505   1152.1      578   1150.1      596   1149.8       626
```

Now when this input file is run the program should produce an additional output file named TZMIN that contains the minimum bed elevations for every cross section in the model. The way that Fluvial-12 reports the minimum elevations, is to report the cross section geometry for each cross section, which is station and elevation for the cross section and the elevation is the minimum elevation for that station during the simulation. This geometry can then be compared to the original input geometry to compare them or they can be subtracted to determine the scour at each point. The maximum scour for each cross section can then be determined. Shown below is an example TZMIN file with the main components of the file labeled.



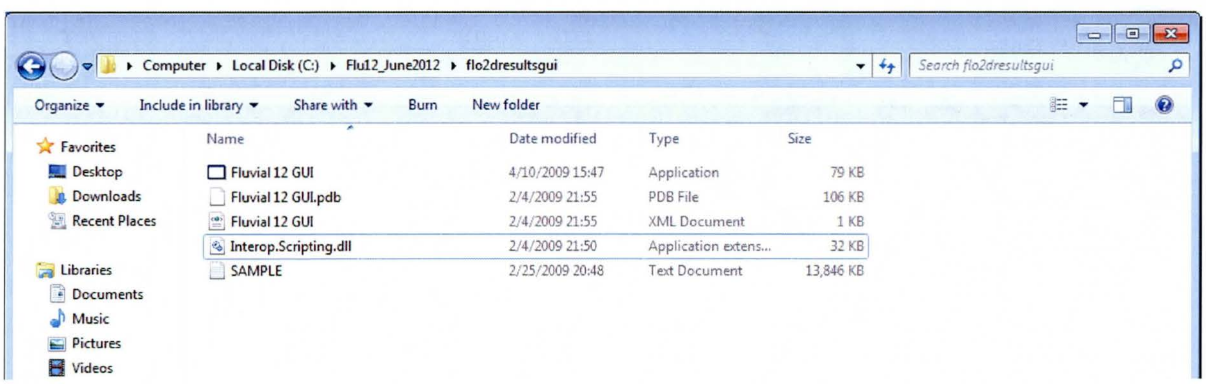
Fluvial 12 GUI

Introduction

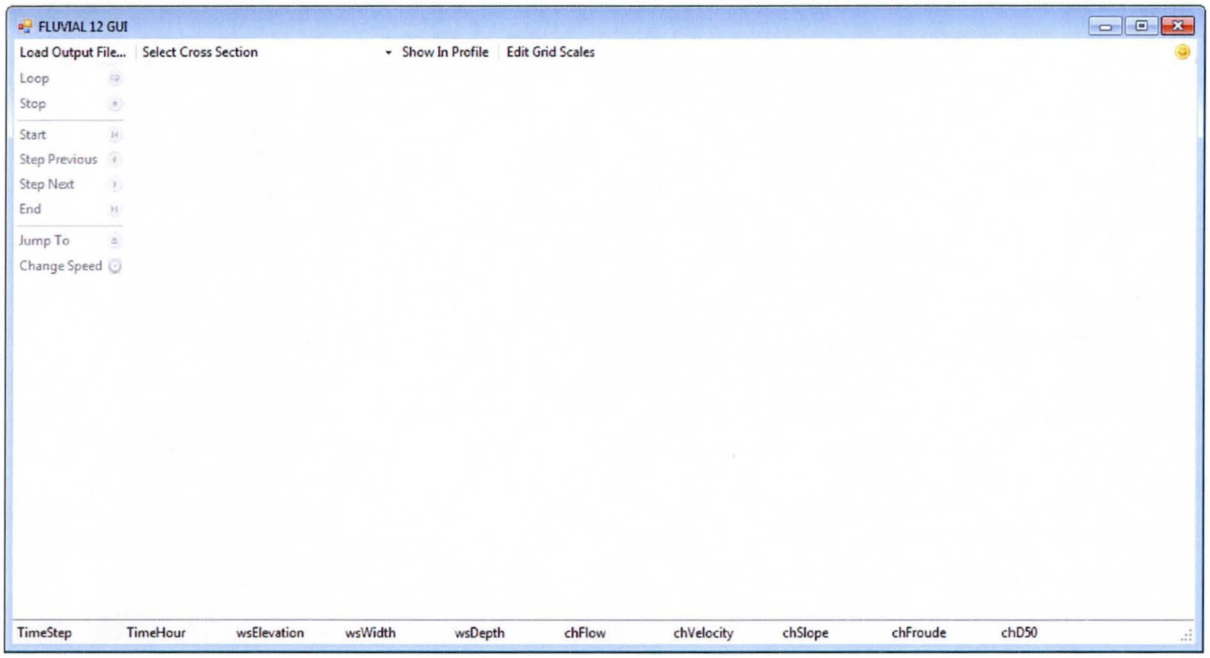
One of the tools that has been developed to help with displaying the results from Fluvial-12 is the Fluvial-12 GUI. This program allows the user to view the results in a graphical manner. The application allows the user to view both profile and cross section views of the model extents. The window shows the initial bed conditions with the bed conditions and water surface at the current time step. This allows the user to see the progression of the model. It should be noted that the Fluvial-12 GUI does not really present the results in enough detail for review or submittal. The consultants should supply tables containing the numerical results and not just graphics. The graphics and animation help the user to ensure that the model makes sense and that it is showing similar results to what one would expect from previous results and intuition. The Fluvial-12 GUI can be used to determine approximately what time the maximum scour or water surface elevation occurs, this can then be used to retrieve the numerical data from the output file or the Plot program.

Using the GUI

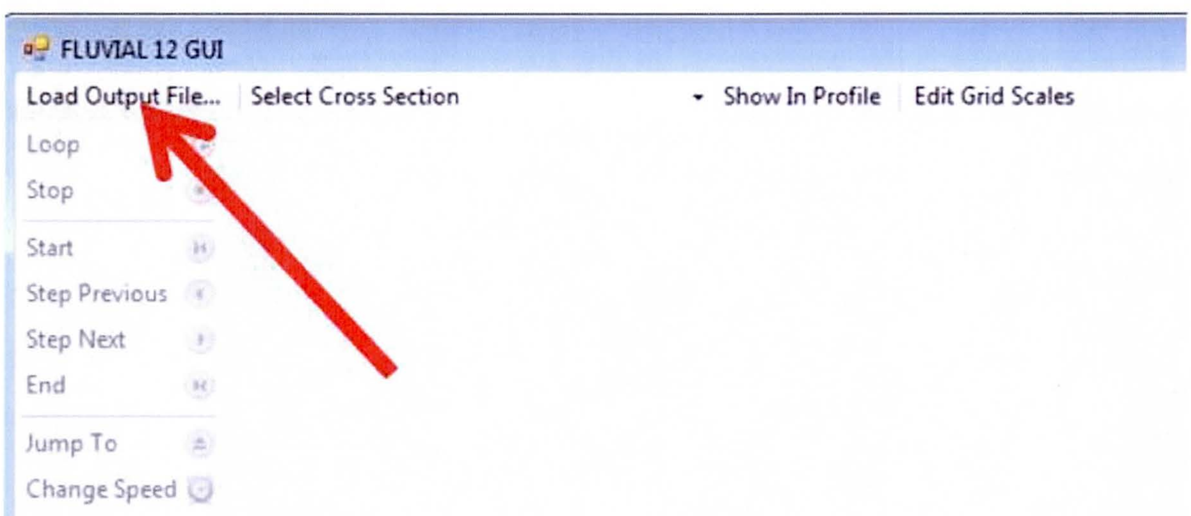
The Fluvial-12 GUI takes a text file and reads the geometry data for each cross section at each time step. It is important to note that only text files can be input into the Fluvial-12 GUI, that is files with *.txt extension. Thus the usual *.out or any other extension for the output file will not be accepted. However, the Fluvial-12 model allows the user to specify the name and extension for the output file, thus if the user has Fluvial-12 write the results to a text file no further preparation is needed. If there is an existing output file that is not saved as a text file, then simply open the file in a text editor and save a copy as a text file. The output file can then be loaded by the Fluvial-12 GUI. It is very important when obtaining or installing the Fluvial-12 GUI that all of the files are present otherwise the program will not function properly. In the folder where the application is located should have all of the following files: "Fluvial 12 GUI.exe", "Fluvial 12 GUI.pdb", "Fluvial 12 GUI.xml" and "Interop.Scripting.dll". The folder should look similar to the folder in the figure below.

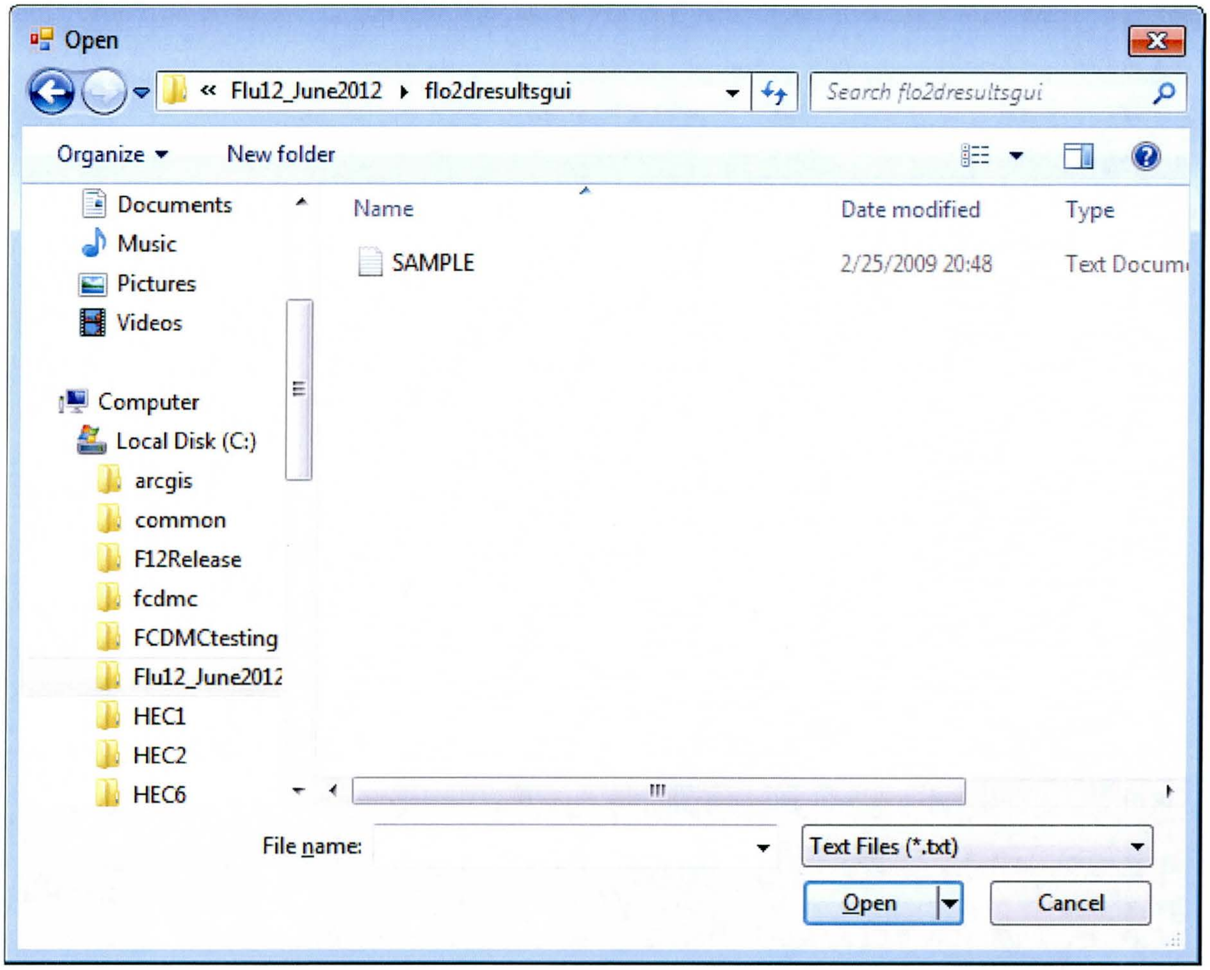


To start the program double click on the Fluvial 12 GUI application, the figure below shows the Fluvial 12 GUI window.

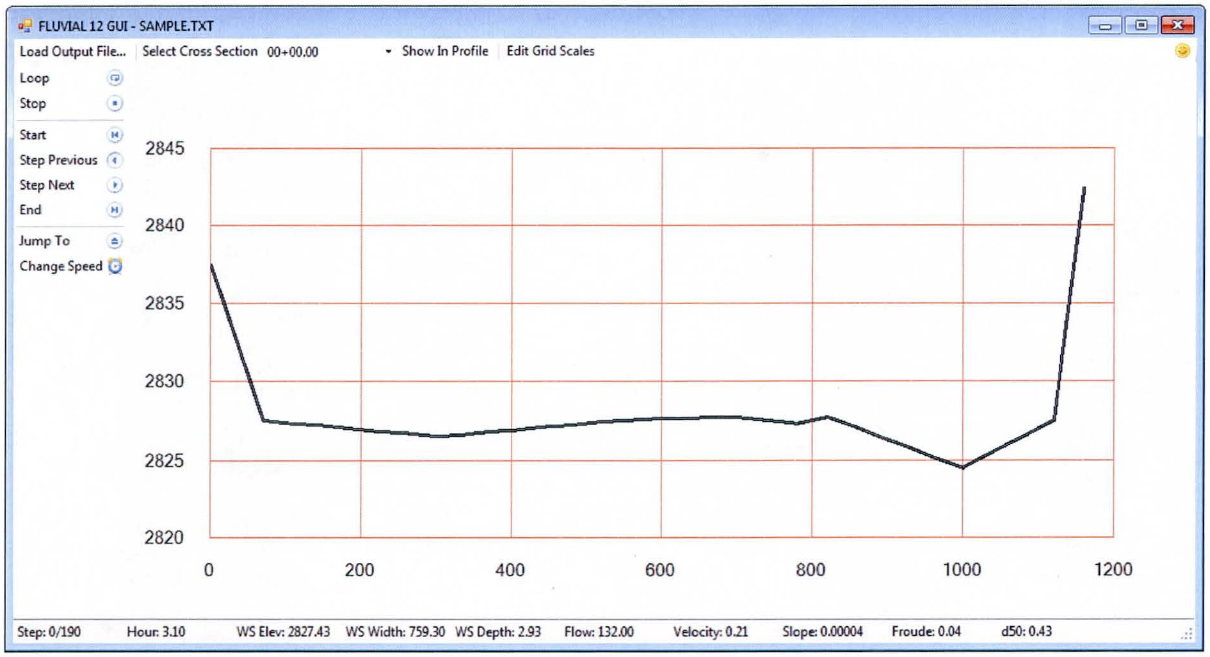


To load an output file, click on the "Load Output File..." button and then navigate to the file location.

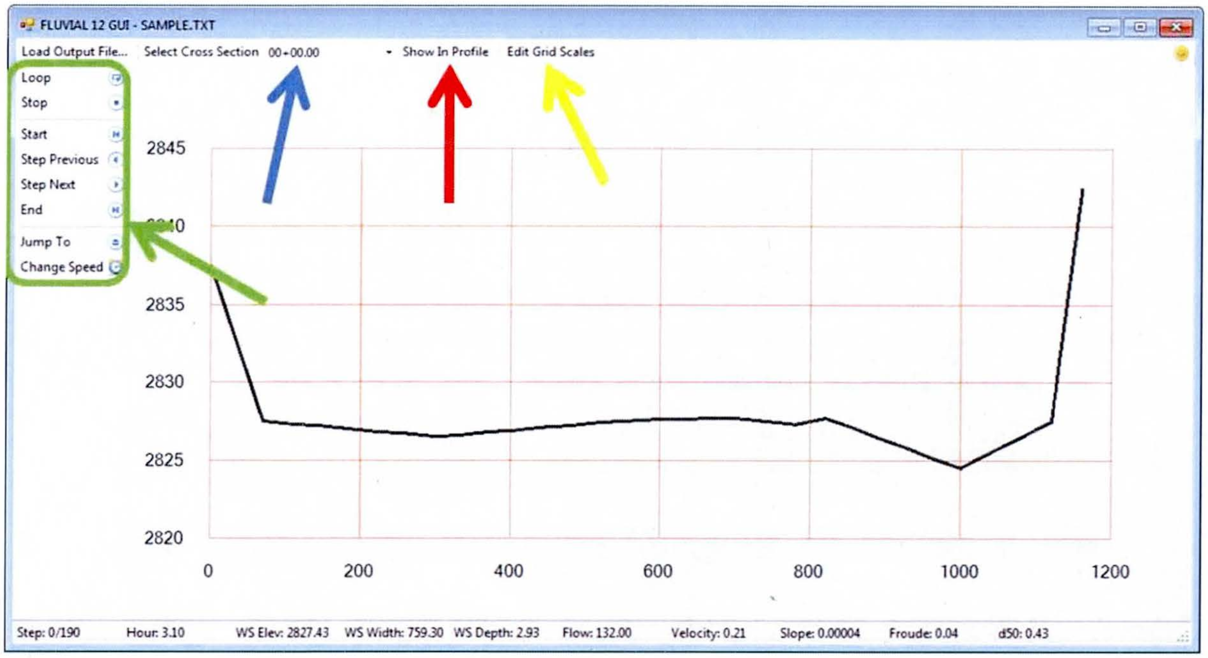




After opening this file in the Fluvial 12 GUI it will display the first cross section in the window.



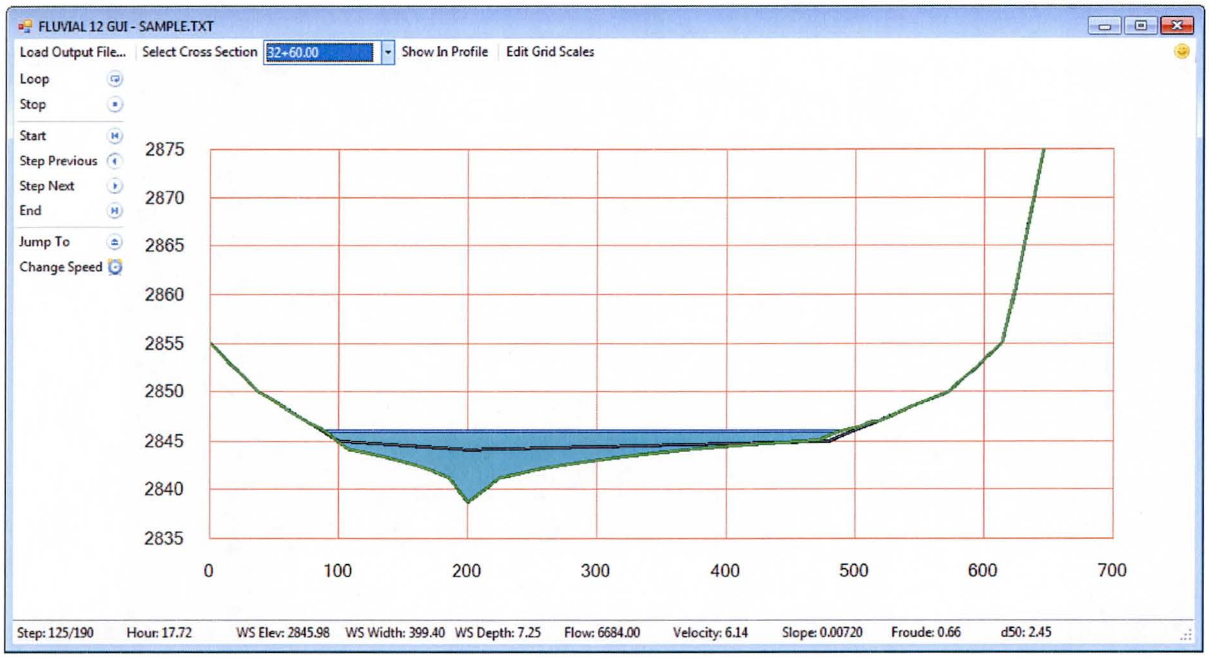
To change the cross section click on the "Select Cross Section" pull down menu indicated by the blue arrow and to change to profile view click on the "Show In Profile" button indicated by the red arrow. If the default window extents do not contain the plot then click on the "Edit Grid Scales" button indicated by the yellow arrow, this will allow the user to enter extents. The buttons indicated by the green arrow and box can be used to run and control an animation of the model results or to step through each time step, this can be run for every cross section as well as the profile.



When the "Show In Profile" button is clicked the window should show the results in profile as shown below, if the window does not change automatically then try clicking on it again, clicking in the plot area or resizing the window.

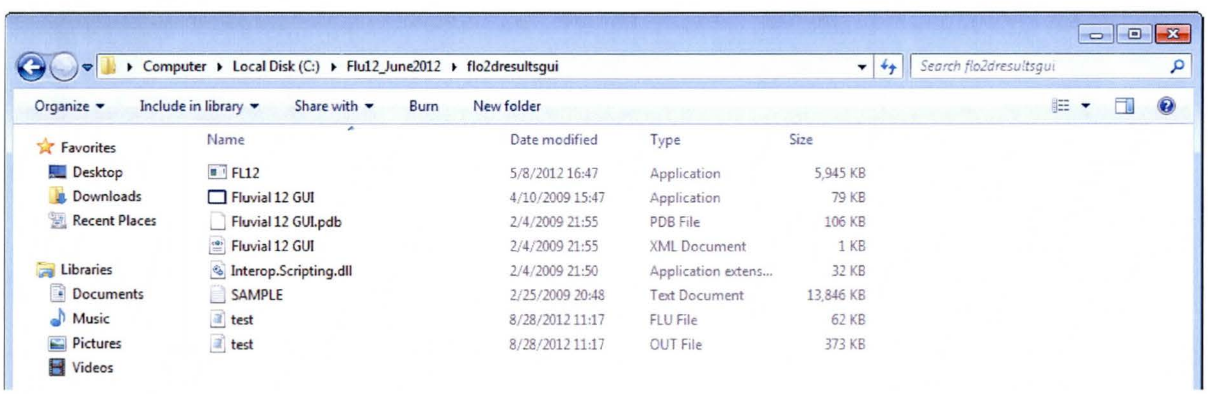
In the animation, the changes in the bed are illustrated by color. In the window the black line indicates the initial, or input bed conditions. The green line shows the bed condition at the current time step.

The blue line and aqua shaded area indicate the water surface and flow area during that time step. This is illustrated in the figure below.

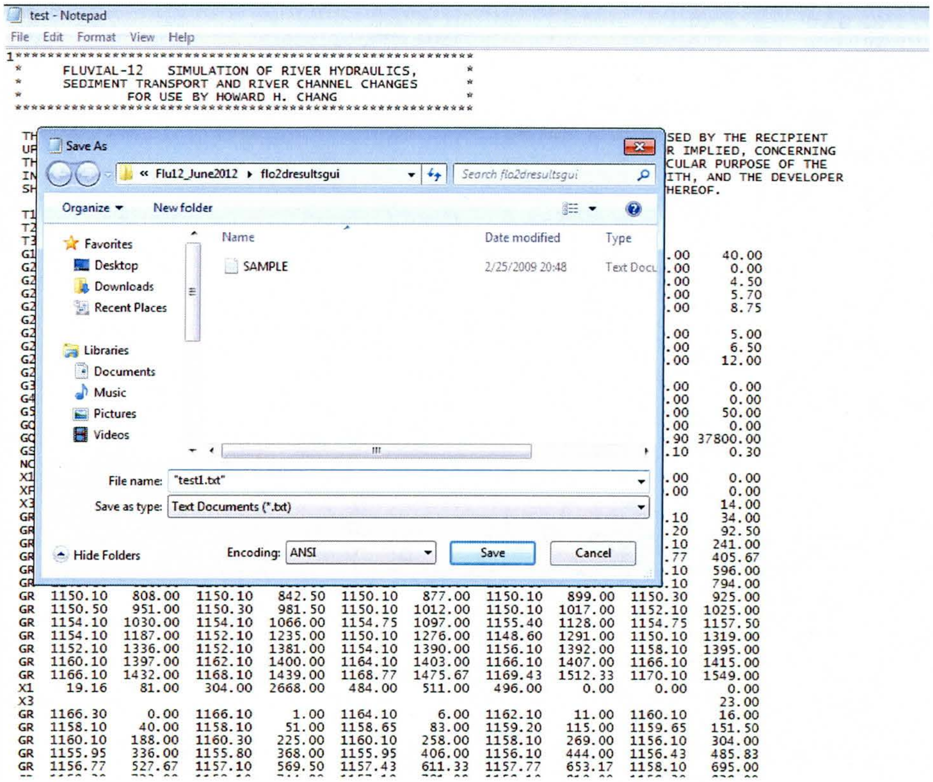


Example

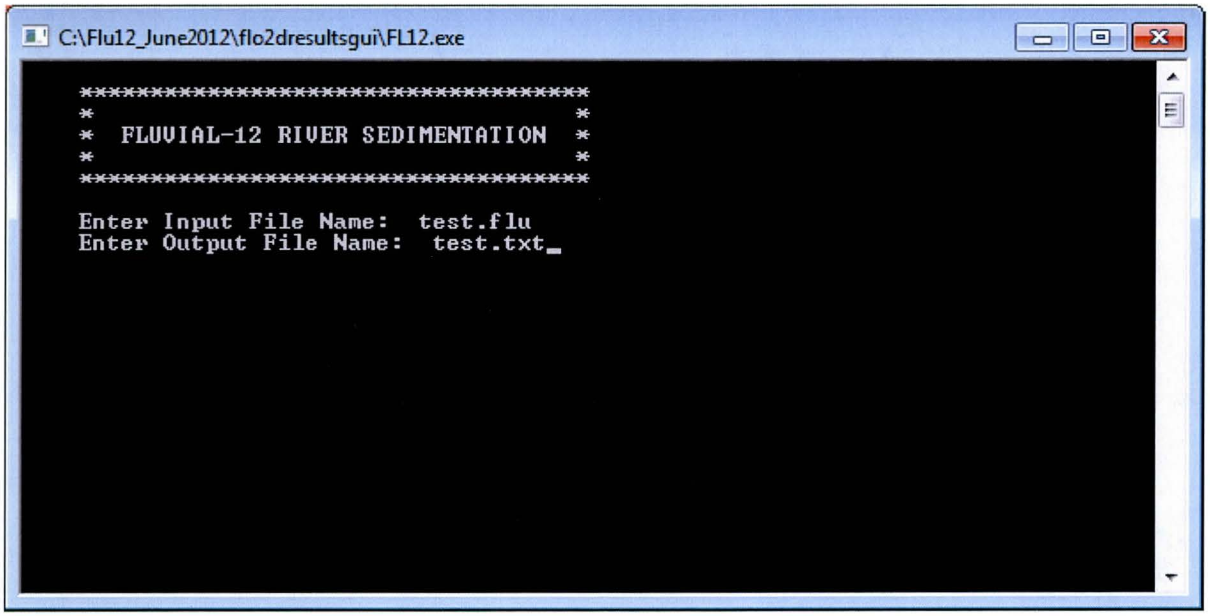
In this example we will start with an input file "test.flu" and an output file "test.out" to demonstrate how to use the application. To begin, ensure that the folder contains all of the required files. In this case the FL12.exe has been copied into the folder along with the test files. The GUI files mentioned previously are all located in the folder, this is shown below.



First we will show how to save the existing "test.out" file as a text file. Open the file with Notepad or another text editor.



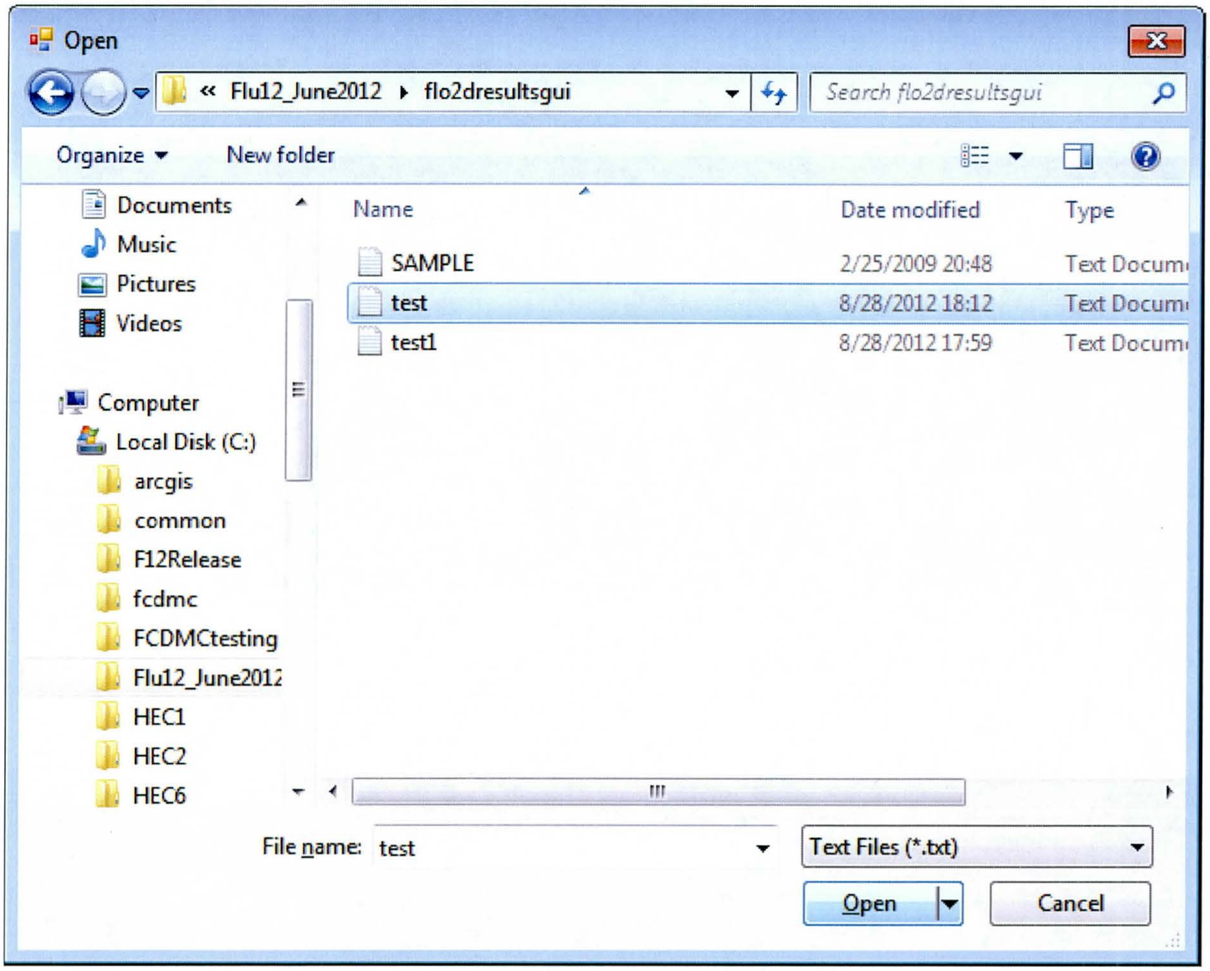
After the file has been opened go to "File" then "Save As" and in this case "test1.txt" is entered to ensure that it is saved as a text file. This file could now be input to the Fluvial 12 GUI. The other option is to have Fluvial-12 create the output file as a text file. To do this click on and open the FL12 application, Fluvial-12 is a DOS based application, so this will open a DOS window. In the window it prompts the user for the input file name, enter "test.flu" and press enter. It will then prompt the user for the output file name, enter "test.txt" and press enter. The window is shown in the figure below.



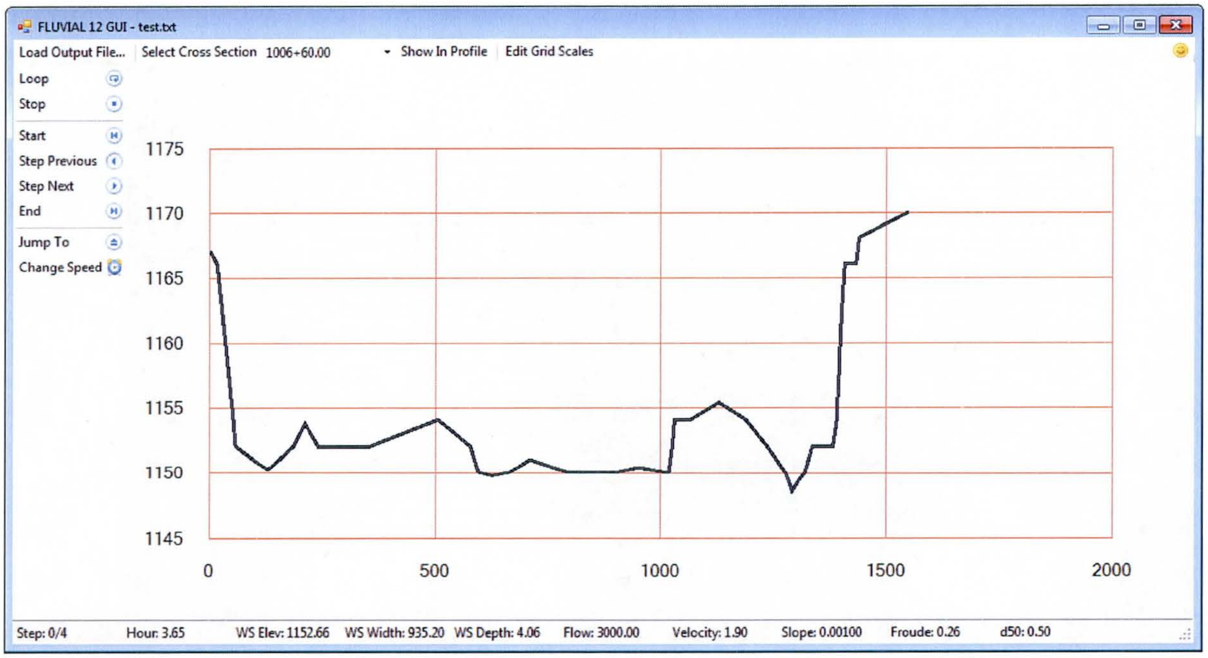
The model will then run and generate the text output file "test.txt" in the folder.

Now open the Fluvial 12 GUI application.

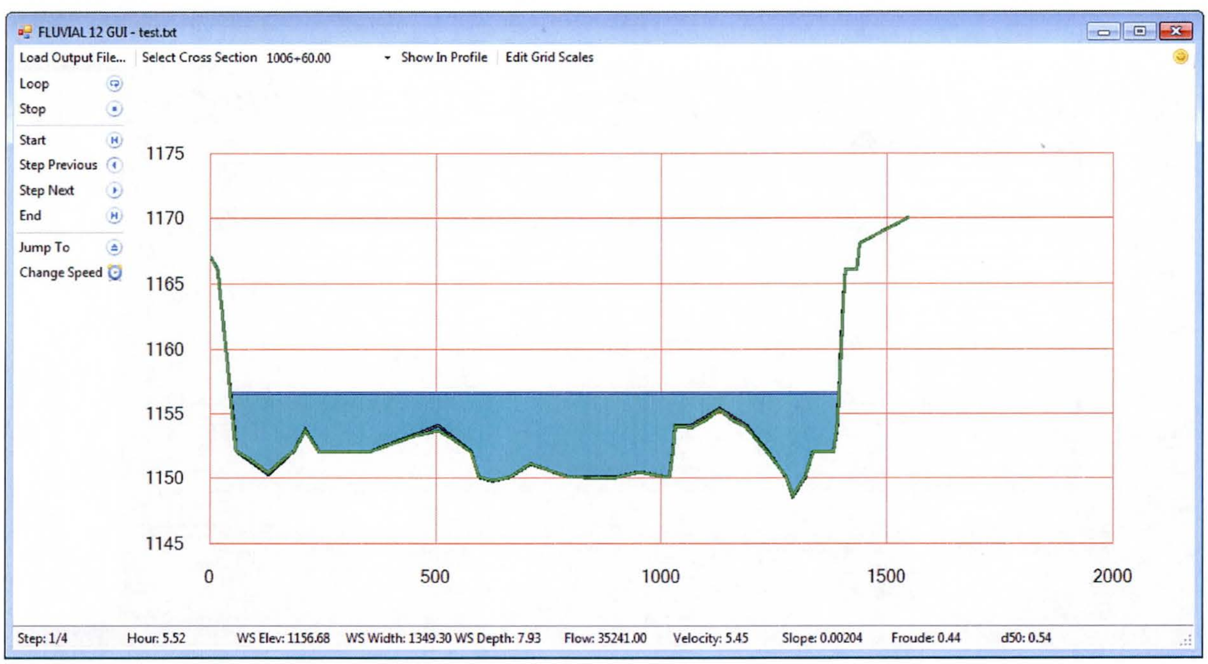
Then load the "test.txt" file into the GUI.



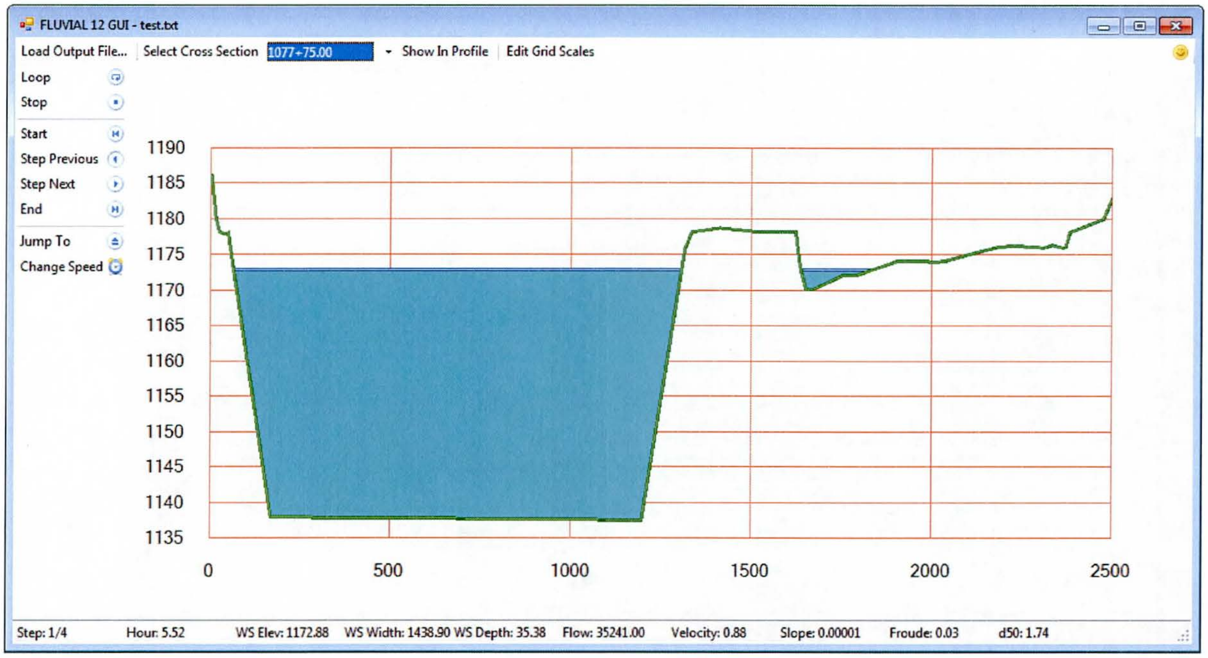
The first cross section is then displayed in the window.



Now click on the "Loop" button on the left side of the window near the top. This will begin the animation of the model results.

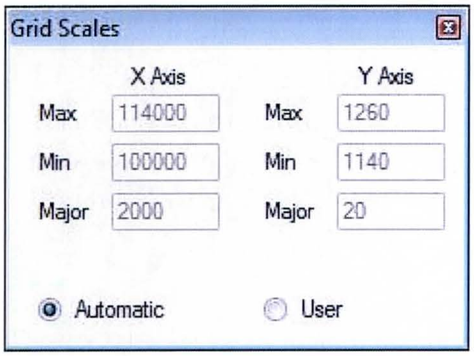


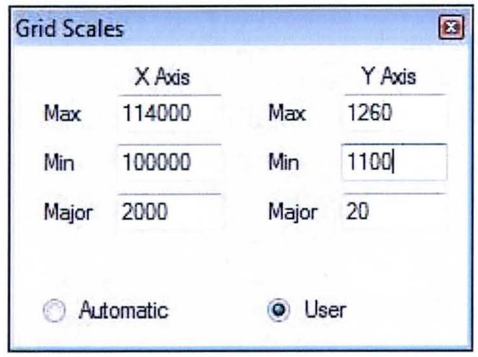
Now go to the "select Cross Section" pull down menu and select cross section 1077+75.00 from the list, you can do this while the animation is still running. You can also change cross section by scrolling with the mouse. This is shown below.



Now click on the “Show In Profile” button at the top of the window in the middle. This changes the view to profile, the graphics might not refresh immediately. If the graphics do not change to the profile view try clicking around the window or resizing the window. The window with the profile view is shown below.

As can be seen the extents being shown on the plot are not sufficient, thus the default plot extents must be changed. To do this click on the "Edit Grid Scales" button on the top right side of the window, that will open the window shown below.





Click on the user control button and change the extents so that the entire profile can be seen, the new plot is shown below.

The animation can also be run in the profile view. The yellow and red area highlighted in the profile is the selected cross section from the pull down menu or the last selected cross section. The other controls on the left of the screen can be used to stop and start the animation, step through the time steps manually or adjust the speed of the animation. On the bottom of the window is a bar, this bar displays the results at the current time step for the selected cross section.

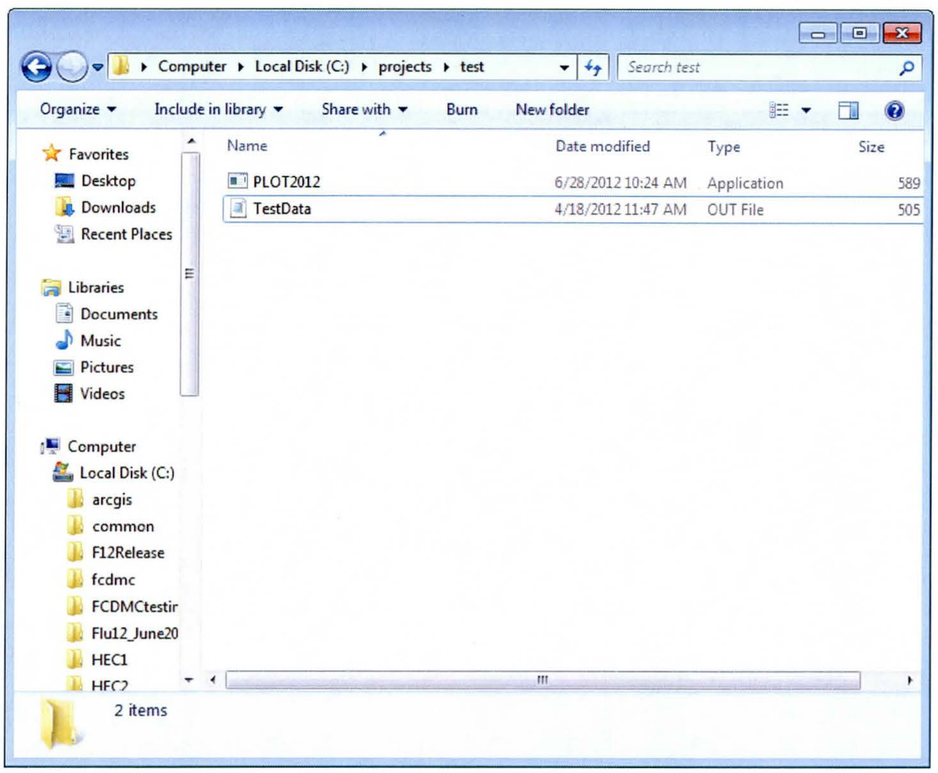
Fluvial- 12 Plot Program

Introduction

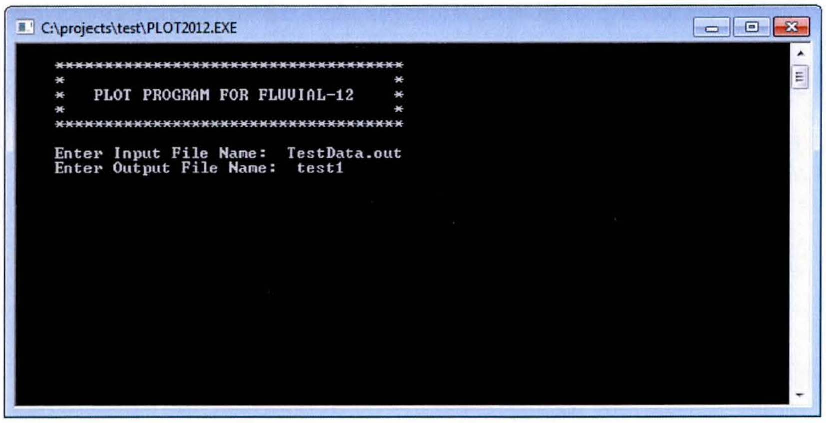
The Plot or PLOT2012 programs are a tool developed by Howard Chang that aids in retrieving data/results from the Fluvial-12 output files. It allows the user to specify what data is needed and at what time(s) during the simulation. The program then retrieves this data from the output file and creates new files that contain the data in tabular text files. These files can then be copied into Excel or other programs for easier manipulation and presentation of the data. There are a few other capabilities of this program but this document focuses on extracting data from the output file. Given below is brief tutorial on how to use this program.

Running the Program

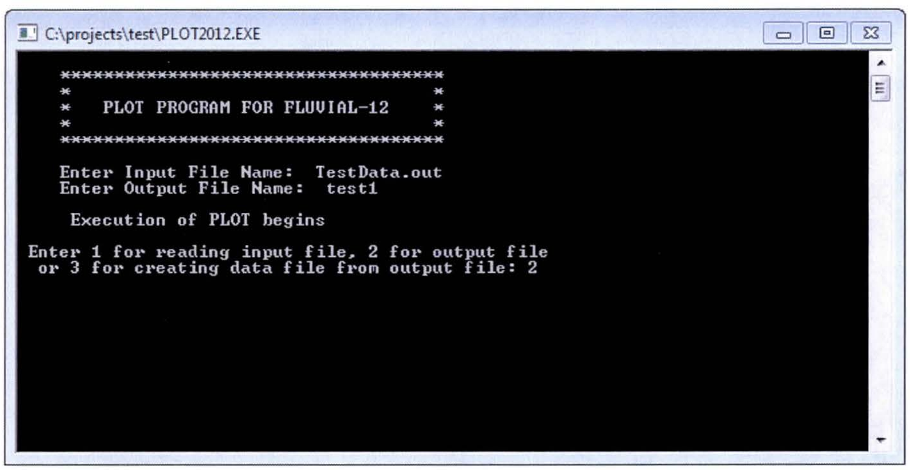
To setup the program, first copy the PLOT program into a new folder and then copy the *.out file for the model.



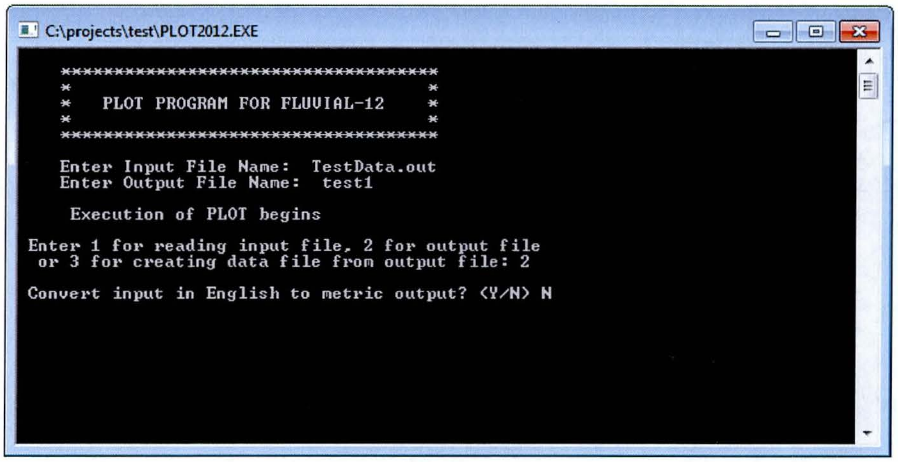
Double click on the PLOT application to launch the program; this will open a DOS window. In this window the user must first specify the name of the file being input into the program, this is the file copied into the folder, please note that the file extension (ex. *.out) must also be specified. Then specify a name for the output from the PLOT program.



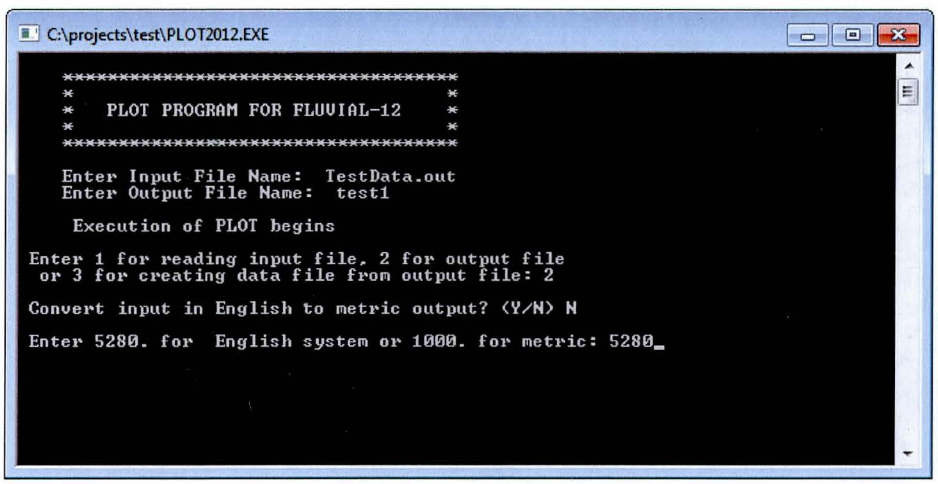
The next prompt allows the user to choose the type of input file being given to the PLOT program, in this case type 2 into the window since an output file is being input.



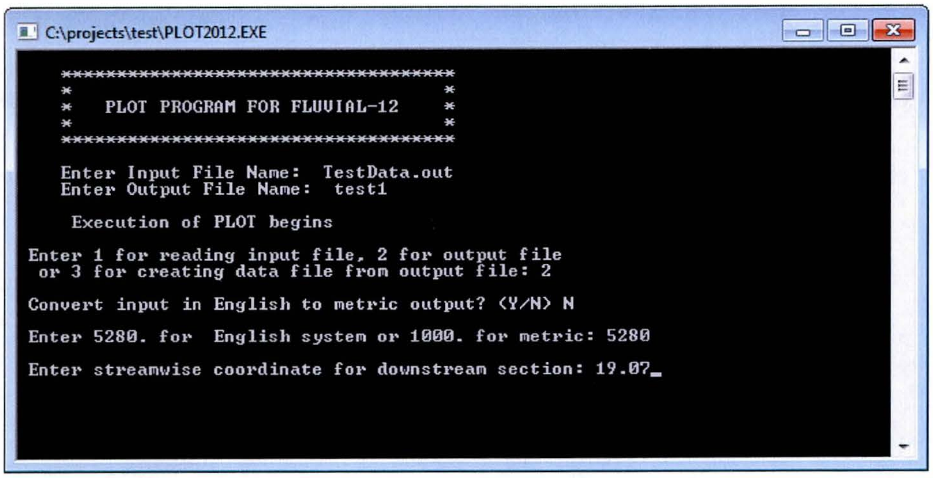
Next the program asks if the user wants to convert English to metric output, enter N into the window unless the user wishes to convert the output.



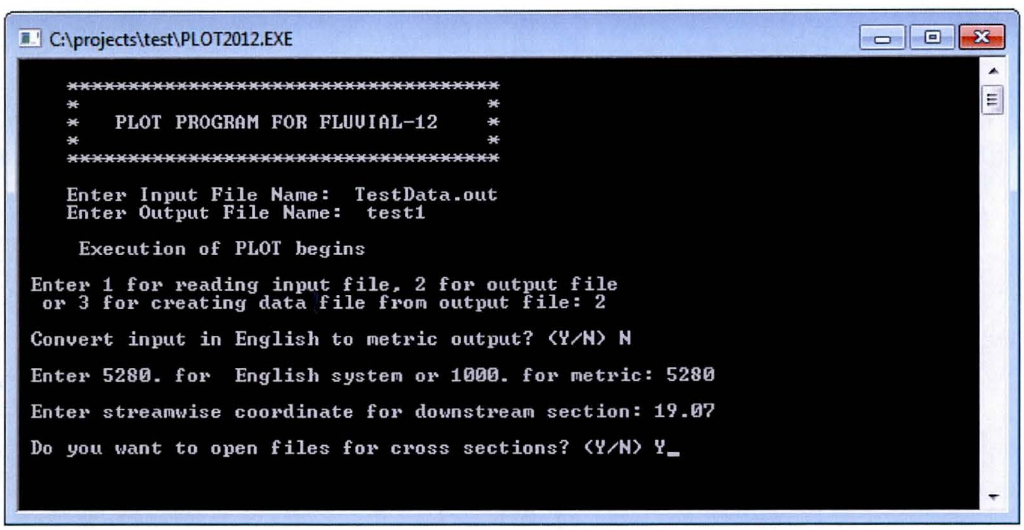
The program then asks for the river stationing multiplier, enter 5280 for English unit system or 1000 for metric.



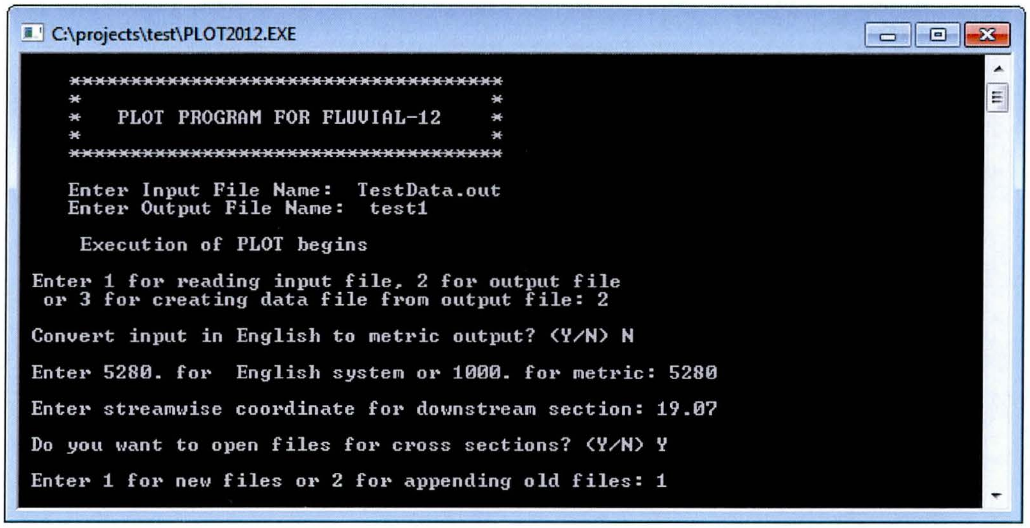
The next input is the station of the most downstream cross section, it should be noted that in the newest version of this program (PLOT2012) that the program copies the stations from the file input into the program, previously the program used this river station as a starting point and added the reach lengths from the model instead of copying the stationing.



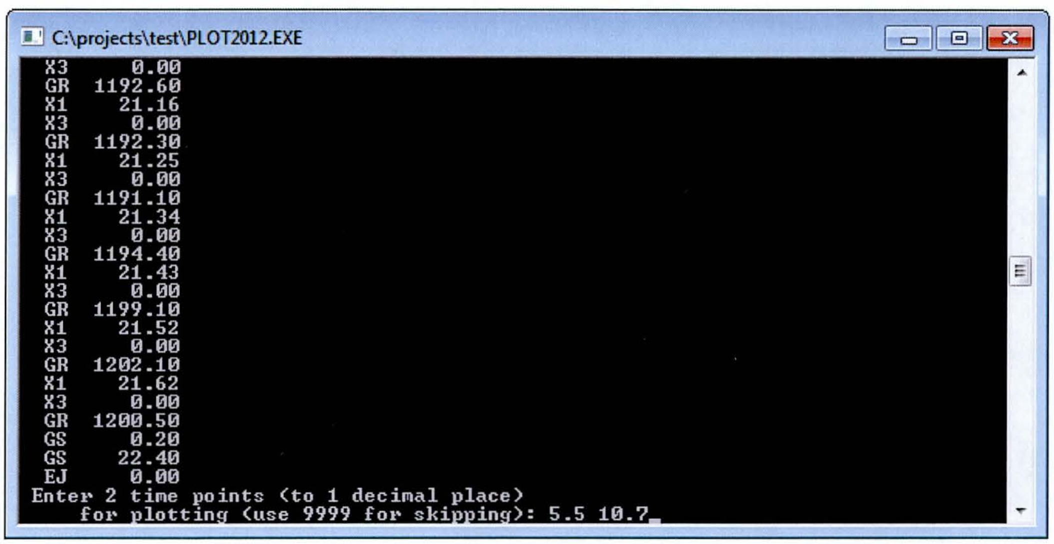
The program then asks if the user wishes to open the files for the cross sections, unless otherwise desired enter Y. It should be noted that the Y or N must be capitalized; a lower case y may cause the program to malfunction.



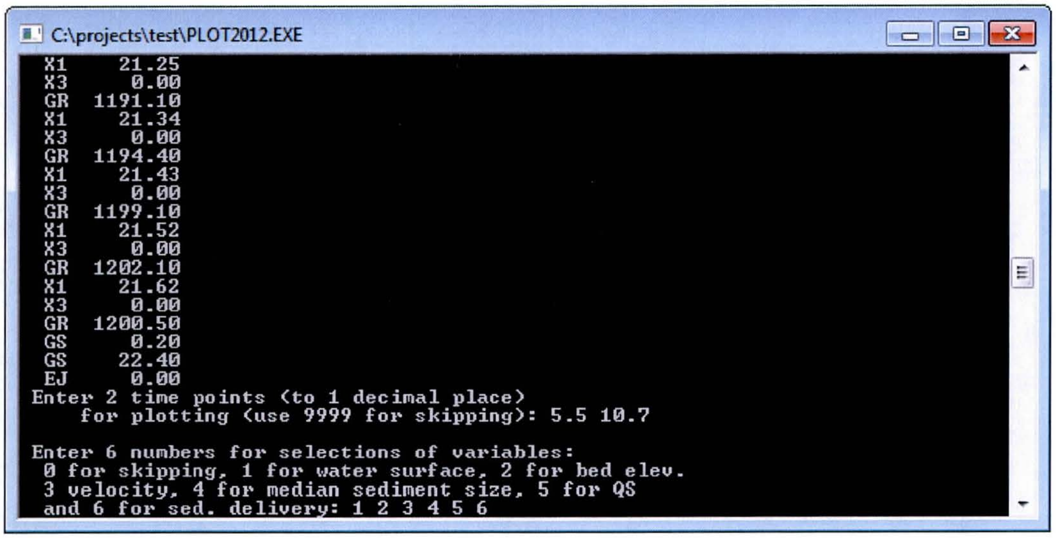
The next prompt asks the user if they want to generate new files or append to old files, enter 1 to generate new files unless otherwise desired.



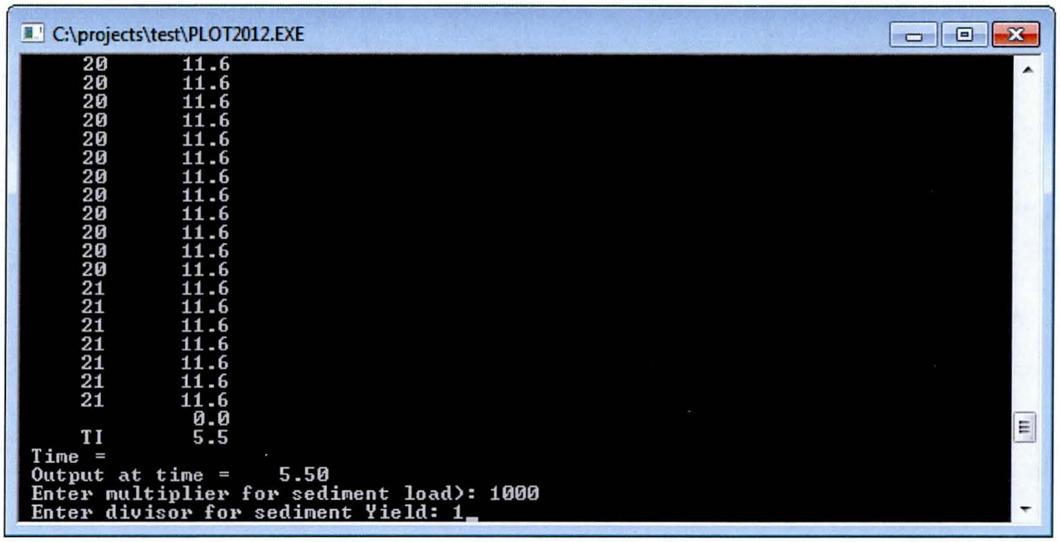
The next prompt allows the user to enter two points in time during the simulation to report the results besides the initial conditions; these should be the same as time steps reported in the output file.



The program then allows the user to choose which variables the user wishes the program to report.



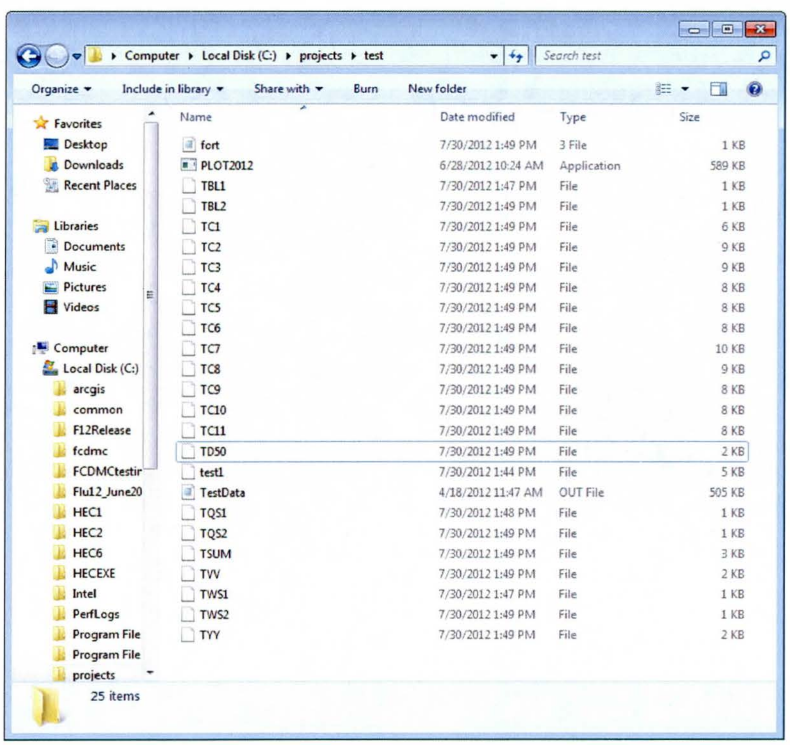
If the sediment parameters are selected then the program will prompt the user to enter the multiplier for the sediment load and divisor for the sediment yeild for the time steps selected.



When user has entered this data the program will then complete its run, no other input is needed.

Results/Output Files

After these have all been entered the program will finish its run. Then the user can check the project folder to see the files generated by the PLOT program.



Shown above are most of the files generated by the program. The TSUM file contains a summary of the data requested in multiple columns. This file does not contain any labels for the table. In this file the first column is the river stationing. The next column is the max water surface elevation. The next column is the initial channel bed elevation. The forth column contains the channel bed elevation at the first time specified and the fifth column contains the channel bed elevation at the last time specified.

TSUM - Notepad

File Edit Format View Help

19.0700	1156.6700	1148.6000	1148.6300	1149.1300
19.1600	1158.0300	1150.2000	1150.5000	1150.5000
19.2600	1159.6400	1152.0000	1152.6700	1153.0200
19.3500	1161.8300	1154.9000	1152.8600	1151.9000
19.4500	1164.2800	1155.6000	1155.6300	1155.6500
19.5400	1165.5699	1157.1000	1157.2300	1157.5000
19.6400	1166.6600	1159.4000	1159.5901	1159.8800
19.7300	1167.8800	1160.2000	1159.6500	1159.3800
19.8300	1169.7400	1162.0000	1161.7200	1161.2700
19.9200	1171.2800	1163.1000	1163.2200	1163.0200
20.0000	1172.3300	1164.1000	1163.1100	1162.5199
20.0200	1172.8700	1131.0000	1131.0000	1131.0000
20.1100	1172.8700	1132.4000	1132.4000	1132.4000
20.2100	1172.8700	1133.9000	1133.9000	1133.9000
20.2900	1172.8700	1135.3000	1135.3000	1135.3000
20.3400	1172.8800	1136.0000	1136.0000	1136.0000
20.3900	1172.8800	1136.7000	1136.7000	1136.7001
20.4000	1172.8800	1136.8000	1136.8000	1136.8000
20.4500	1172.8800	1137.5000	1137.5000	1137.5000
20.4800	1172.8800	1138.0000	1138.0000	1138.0000
20.5800	1172.8800	1139.4000	1139.4000	1139.4000
20.6700	1172.8800	1140.9000	1140.9000	1140.9000
20.7700	1172.8800	1142.3000	1142.3000	1142.3000
20.8600	1172.8900	1143.6000	1143.6000	1143.6000
20.9600	1172.9000	1144.7000	1144.7001	1144.7001
21.0600	1172.8900	1139.1000	1139.1000	1139.1000
21.1600	1172.9100	1148.7000	1148.7001	1148.7001
21.2500	1172.9200	1126.1000	1126.1001	1126.1000
21.3400	1172.9200	1139.2000	1139.2001	1139.2001
21.4300	1172.9200	1137.9000	1137.9000	1137.9100
21.5200	1172.9100	1145.4000	1145.4000	1145.4000
21.6200	1172.9301	1149.5000	1149.5000	1149.5000

The TBL1 and TBL2 files show the stationing and requested data, in this case the bed elevation, at the times requested. This file actually included headings unlike most of the files generated by this program. TBL1 is shown below, the first column is the river stationing and the second column is the bed elevation.

TBL1 - Notepad

File Edit Format View Help

TIME = 5.50	X	BED ELEV.
	19.0700	1148.6300
	19.1600	1150.5000
	19.2600	1152.6700
	19.3500	1152.8600
	19.4500	1155.6300
	19.5400	1157.2300
	19.6400	1159.5901
	19.7300	1159.6500
	19.8300	1161.7200
	19.9200	1163.2200
	20.0000	1163.1100
	20.0200	1131.0000
	20.1100	1132.4000
	20.2100	1133.9000
	20.2900	1135.3000
	20.3400	1136.0000
	20.3900	1136.7000
	20.4000	1136.8000
	20.4500	1137.5000
	20.4800	1138.0000
	20.5800	1139.4000
	20.6700	1140.9000
	20.7700	1142.3000
	20.8600	1143.6000
	20.9600	1144.7001
	21.0600	1139.1000
	21.1600	1148.7001
	21.2500	1126.1001
	21.3400	1139.2001
	21.4300	1137.9000
	21.5200	1145.4000
	21.6200	1149.5000

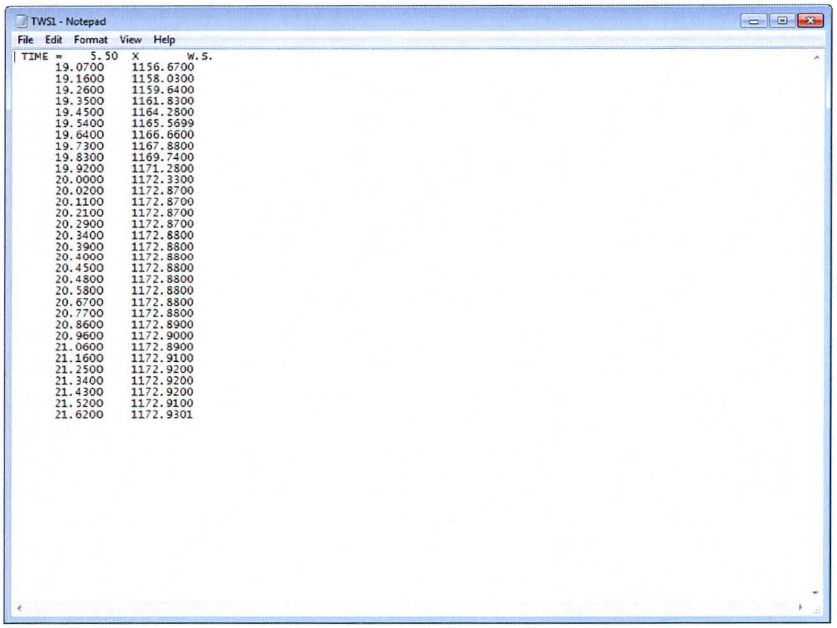
The TC1, TC2, … TC# files contain data for each cross section in the model, there were generated because yes was selected for the cross section files. The cross section data files have the results for three time periods the initial and the two requested. They are all shown in the same file, the first pair of columns is the initial values so the first column is the cross sectional stationing and the second column is the elevation. The second pair of columns follows the same format (station and elevation) and is for the first time specified. The last pair of columns is for the last specified time. There are no labels in the file itself.

TC1 - Notepad

File Edit Format View Help

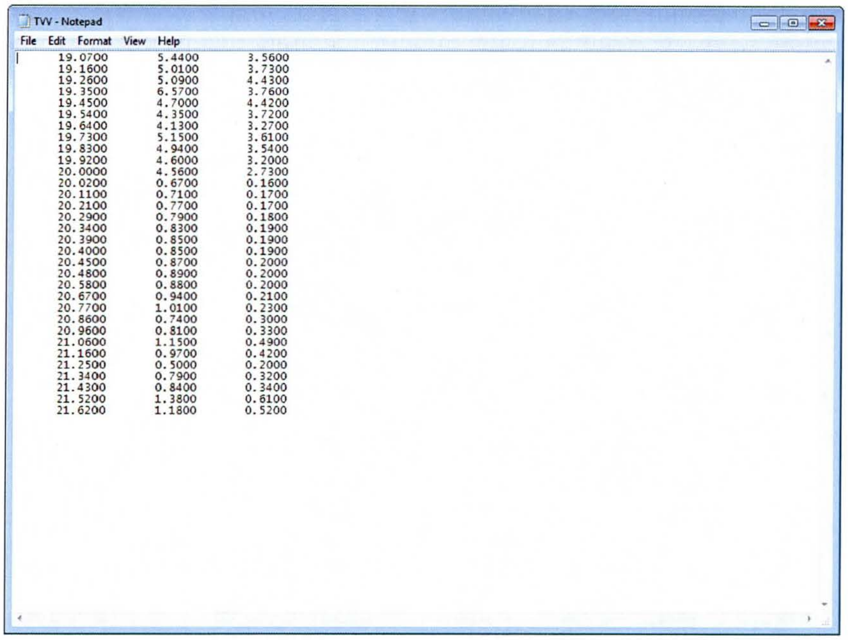
0.0000	1167.1000	0.0000	1167.1000	0.0000	1167.1000
16.0000	1166.1000	16.0000	1166.1000	16.0000	1166.1000
22.0000	1164.1000	22.0000	1164.1000	22.0000	1164.1000
28.0000	1162.1000	28.0000	1162.1000	28.0000	1162.1000
34.0000	1160.1000	34.0000	1160.1000	34.0000	1160.1000
40.0000	1158.1000	40.0000	1158.1000	40.0000	1158.1000
46.0000	1156.1000	46.0000	1156.0601	45.8000	1155.8700
52.0000	1154.1000	52.0000	1154.0601	51.8000	1154.0699
57.0000	1152.1000	57.0000	1152.1200	57.0000	1152.4200
92.5000	1151.2000	92.5000	1151.2300	92.5000	1151.6400
128.0000	1150.3000	128.0000	1150.3300	128.0000	1150.7800
156.5000	1151.2000	156.5000	1151.2300	156.5000	1151.6400
185.0000	1152.1000	185.0000	1152.1200	185.0000	1152.4200
211.0000	1153.8000	211.0000	1153.8199	211.0000	1154.0400
241.0000	1152.1000	241.0000	1152.1200	241.0000	1152.4200
288.0000	1152.1000	288.0000	1152.1200	288.0000	1152.4200
315.5000	1152.1000	315.5000	1152.1200	315.5000	1152.4200
343.0000	1152.1000	343.0000	1152.1200	343.0000	1152.4200
356.0000	1152.1000	356.0000	1152.1200	356.0000	1152.4200
405.6700	1152.7700	405.7000	1152.7800	405.7000	1153.0200
455.3300	1153.4301	455.3000	1153.4500	455.4000	1153.6400
505.0000	1154.1000	505.0000	1154.0601	505.0000	1154.0699
541.5000	1153.1000	541.5000	1153.1100	541.5000	1153.2800
578.0000	1152.1000	578.0000	1152.1200	578.0000	1152.4200
596.0000	1150.1000	596.0000	1150.1300	596.0000	1150.5800
626.0000	1149.8000	626.0000	1149.8300	626.0000	1150.3000
665.0000	1150.1000	665.0000	1150.1300	665.0000	1150.5800
710.0000	1151.1000	710.0000	1151.1300	710.0000	1151.5500
752.0000	1150.6000	752.0000	1150.6300	752.0000	1151.0699
794.0000	1150.1000	794.0000	1150.1300	794.0000	1150.5800
808.0000	1150.1000	808.0000	1150.1300	808.0000	1150.5800
842.5000	1150.1000	842.5000	1150.1300	842.5000	1150.5800
877.0000	1150.1000	877.0000	1150.1300	877.0000	1150.5800
899.0000	1150.1000	899.0000	1150.1300	899.0000	1150.5800
925.0000	1150.3000	925.0000	1150.3300	925.0000	1150.7800
951.0000	1150.5000	951.0000	1150.5300	951.0000	1150.9700
981.5000	1150.3000	981.5000	1150.3300	981.5000	1150.7800
1012.0000	1150.1000	1012.0000	1150.1300	1012.0000	1150.5800
1017.0000	1150.1000	1017.0000	1150.1300	1017.0000	1150.5800
1025.0000	1152.1000	1025.0000	1152.1100	1025.1000	1152.3600
1030.0000	1154.1000	1030.0000	1154.1100	1030.0000	1154.3199
1066.0000	1154.1000	1066.0000	1154.1000	1066.0000	1154.2700
1097.0000	1154.7500	1097.0000	1154.7300	1097.1000	1154.6200
1128.0000	1155.4000	1128.0000	1155.3900	1128.0000	1155.3700
1157.5000	1154.7500	1157.5000	1154.7300	1157.4000	1154.6200
1187.0000	1154.1000	1187.0000	1154.1000	1187.0000	1154.2700
1235.0000	1152.1000	1235.0000	1152.1100	1234.9000	1152.3600
1276.0000	1150.1000	1276.0000	1150.1300	1276.0000	1150.5800
1291.0000	1148.6000	1291.0000	1148.6300	1291.0000	1149.1300

The TWS1 and TWS2 files show the water surface elevations at the times requested for every cross section. The first column shows the river mile stationing and the second column gives the water surface elevation at the time specified. This file contains labels in the file.



```
TWS1 - Notepad
File  Edit  Format  View  Help
TIME =      5.50   X          W.S.
       19.0700     1156.6700
       19.1600     1158.0300
       19.2600     1159.6400
       19.3500     1161.8300
       19.4500     1164.2800
       19.5400     1165.5699
       19.6400     1166.6600
       19.7300     1167.8800
       19.8300     1169.7400
       19.9200     1171.2800
       20.0000     1172.3300
       20.0200     1172.8700
       20.1100     1172.8700
       20.2100     1172.8700
       20.2900     1172.8700
       20.3400     1172.8800
       20.3900     1172.8800
       20.4000     1172.8800
       20.4500     1172.8800
       20.4800     1172.8800
       20.5800     1172.8800
       20.6700     1172.8800
       20.7700     1172.8800
       20.8600     1172.8900
       20.9600     1172.9000
       21.0600     1172.8900
       21.1600     1172.9100
       21.2500     1172.9200
       21.3400     1172.9200
       21.4300     1172.9200
       21.5200     1172.9100
       21.6200     1172.9301
```

The TVV file contains velocity data at the times requested. In this file there are no labels. The first column is the river mile stationing. The second column is the velocity at the first time specified at each station and the last column is the velocity at each station for the last time specified.

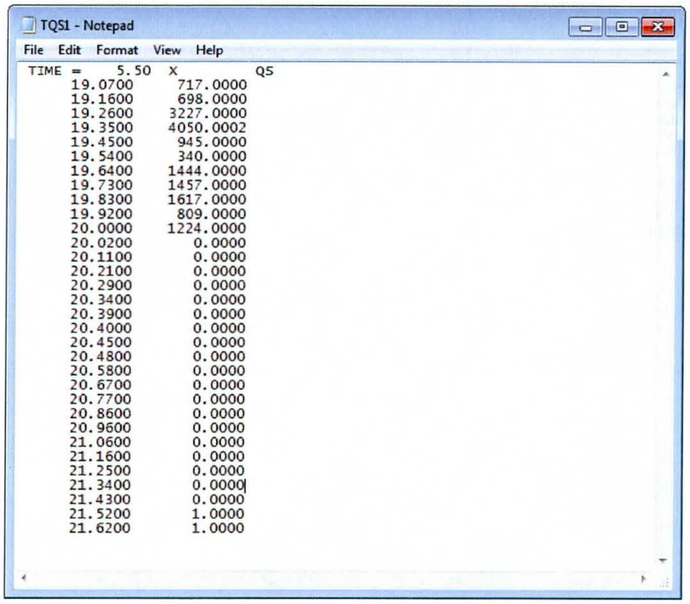

TVV - Notepad
File Edit Format View Help

19.0700	5.4400	3.5600
19.1600	5.0100	3.7300
19.2600	5.0900	4.4300
19.3500	6.5700	3.7600
19.4500	4.7000	4.4200
19.5400	4.3500	3.7200
19.6400	4.1300	3.2700
19.7300	5.1500	3.6100
19.8300	4.9400	3.5400
19.9200	4.6000	3.2000
20.0000	4.5600	2.7300
20.0200	0.6700	0.1600
20.1100	0.7100	0.1700
20.2100	0.7700	0.1700
20.2900	0.7900	0.1800
20.3400	0.8300	0.1900
20.3900	0.8500	0.1900
20.4000	0.8500	0.1900
20.4500	0.8700	0.2000
20.4800	0.8900	0.2000
20.5800	0.8800	0.2000
20.6700	0.9400	0.2100
20.7700	1.0100	0.2300
20.8600	0.7400	0.3000
20.9600	0.8100	0.3300
21.0600	1.1500	0.4900
21.1600	0.9700	0.4200
21.2500	0.5000	0.2000
21.3400	0.7900	0.3200
21.4300	0.8400	0.3400
21.5200	1.3800	0.6100
21.6200	1.1800	0.5200

The TYY file is the sediment yield at the times requested for each cross section. There are no labels in this file. The first column gives the river stationing. The second column gives the sediment yield at the first time specified for every cross section and the third column gives the sediment yield for the last time specified, sediment yield is in tons.

19.0700	1970.0000	8850.0000
19.1600	2520.0000	19700.0000
19.2600	12800.0000	31900.0000
19.3500	17500.0000	39400.0000
19.4500	2620.0000	16000.0000
19.5400	1770.0000	10600.0000
19.6400	3690.0000	14800.0000
19.7300	7970.0000	24400.0000
19.8300	6250.0000	21100.0000
19.9200	2140.0000	12400.0000
20.0000	4350.0000	12900.0000
20.0200	0.0388	0.1810
20.1100	0.0500	0.2220
20.2100	0.0523	0.2490
20.2900	0.0708	0.3320
20.3400	0.0780	0.3740
20.3900	0.0786	0.3690
20.4000	0.0698	0.3390
20.4500	0.0930	0.4240
20.4800	0.0610	0.3200
20.5800	0.1510	0.6480
20.6700	0.1940	0.8880
20.7700	0.2830	1.2900
20.8600	0.0707	1.9100
20.9600	0.1320	3.5800
21.0600	0.3000	8.3100
21.1600	0.1590	4.4500
21.2500	0.0171	0.4600
21.3400	0.1240	3.3500
21.4300	0.1660	4.5100
21.5200	0.4850	14.0000
21.6200	1.2700	34.8000

The TQS1 and TQS2 contain sediment results at each time period requested. The first column is the river mile stationing and the second column is the bed material discharge at each cross section at the time specified. This file contains labels for the table.


TQS1 - Notepad

File Edit Format View Help

```
TIME =      5.50  X         QS
      19.0700      717.0000
      19.1600      698.0000
      19.2600     3227.0000
      19.3500     4050.0002
      19.4500      945.0000
      19.5400      340.0000
      19.6400     1444.0000
      19.7300     1457.0000
      19.8300     1617.0000
      19.9200      809.0000
      20.0000     1224.0000
      20.0200        0.0000
      20.1100        0.0000
      20.2100        0.0000
      20.2900        0.0000
      20.3400        0.0000
      20.3900        0.0000
      20.4000        0.0000
      20.4500        0.0000
      20.4800        0.0000
      20.5800        0.0000
      20.6700        0.0000
      20.7700        0.0000
      20.8600        0.0000
      20.9600        0.0000
      21.0600        0.0000
      21.1600        0.0000
      21.2500        0.0000
      21.3400        0.0000
      21.4300        0.0000
      21.5200        1.0000
      21.6200        1.0000
```

The TD50 file contains the D50 at each time requested for each cross section. There are no labels in this file. The first column contains the river stationing. The second column contains the D50 for each cross section at the first time specified. The third column contains the D50 for each cross section at the last time period specified.

19.0700	4.3300	2.9500
19.1600	2.5600	2.8600
19.2600	3.6600	4.2900
19.3500	5.0100	5.6500
19.4500	2.9800	3.2900
19.5400	2.4000	2.1800
19.6400	2.2700	2.4100
19.7300	2.1400	2.2500
19.8300	1.9900	2.1200
19.9200	1.5800	1.6100
20.0000	1.7800	2.0300
20.0200	1.6600	1.6600
20.1100	1.6800	1.6800
20.2100	1.7000	1.7000
20.2900	1.7100	1.7100
20.3400	1.7200	1.7200
20.3900	1.7300	1.7300
20.4000	1.7300	1.7300
20.4500	1.7400	1.7400
20.4800	1.7500	1.7500
20.5800	1.7600	1.7600
20.6700	1.7800	1.7800
20.7700	1.8000	1.8000
20.8600	1.8100	1.8100
20.9600	1.8300	1.8300
21.0600	1.9400	1.9400
21.1600	2.0300	2.0300
21.2500	2.1100	2.1100
21.3400	2.1500	2.1500
21.4300	2.1500	2.1500
21.5200	2.1000	2.1000
21.6200	2.0200	2.0200

Difference between Plot and PLOT2012

The only differnce between the two Plot programs (Plot and PLOT2012) is that in the Plot program the river stationing is computed based on the downstream station that the user gives the program and the reach lengths in the output file. Where as the PLOT2012 copies the station data from the file input to the program. The figure below shows the TSUM file for both the PLOT2012 (on the left) and the Plot (on the right) programs. As can be seen the stationing does not match, this is because the reach lengths in the input file are incorrect.

TSUM - Notepad

File Edit Format View Help

19.0700	1156.6700	1148.6000	1148.6300	1149.1300
19.1600	1158.0300	1150.2000	1150.5000	1150.5000
19.2600	1159.6400	1152.0000	1152.6700	1153.0200
19.3500	1161.8300	1154.9000	1152.8600	1151.9000
19.4500	1164.2800	1155.6000	1155.6300	1155.6500
19.5400	1165.5699	1157.1000	1157.2300	1157.5000
19.6400	1166.6600	1159.4000	1159.5901	1159.8800
19.7300	1167.8800	1160.2000	1159.6500	1159.3800
19.8300	1169.7400	1162.0000	1161.7200	1161.2700
19.9200	1171.2800	1163.1000	1163.2200	1163.0200
20.0000	1172.3300	1164.1000	1163.1100	1162.5199
20.0200	1172.8700	1131.0000	1131.0000	1131.0000
20.1100	1172.8700	1132.4000	1132.4000	1132.4000
20.2100	1172.8700	1133.9000	1133.9000	1133.9000
20.2900	1172.8700	1135.3000	1135.3000	1135.3000
20.3400	1172.8800	1136.0000	1136.0000	1136.0000
20.3900	1172.8800	1136.7000	1136.7000	1136.7001
20.4000	1172.8800	1136.8000	1136.8000	1136.8000
20.4500	1172.8800	1137.5000	1137.5000	1137.5000
20.4800	1172.8800	1138.0000	1138.0000	1138.0000
20.5800	1172.8800	1139.4000	1139.4000	1139.4000
20.6700	1172.8800	1140.9000	1140.9000	1140.9000
20.7700	1172.8800	1142.3000	1142.3000	1142.3000
20.8600	1172.8900	1143.6000	1143.6000	1143.6000
20.9600	1172.9000	1144.7000	1144.7001	1144.7001
21.0600	1172.8900	1139.1000	1139.1000	1139.1000
21.1600	1172.9100	1148.7000	1148.7001	1148.7001
21.2500	1172.9200	1126.1000	1126.1001	1126.1000
21.3400	1172.9200	1139.2000	1139.2001	1139.2001
21.4300	1172.9200	1137.9000	1137.9000	1137.9100
21.5200	1172.9100	1145.4000	1145.4000	1145.4000
21.6200	1172.9301	1149.5000	1149.5000	1149.5000

TSUM - Notepad

File Edit Format View Help

19.070	1156.67	1148.60	1148.63	1149.13
19.164	1158.03	1150.20	1150.50	1150.50
19.255	1159.64	1152.00	1152.67	1153.02
19.347	1161.83	1154.90	1152.86	1151.90
19.437	1164.28	1155.60	1155.63	1155.65
19.531	1165.57	1157.10	1157.23	1157.50
19.625	1166.66	1159.40	1159.59	1159.88
19.719	1167.88	1160.20	1159.65	1159.38
19.814	1169.74	1162.00	1161.72	1161.27
19.907	1171.28	1163.10	1163.22	1163.02
19.984	1172.33	1164.10	1163.11	1162.52
20.007	1172.87	1131.00	1131.00	1131.00
20.094	1172.87	1132.40	1132.40	1132.40
20.186	1172.87	1133.90	1133.90	1133.90
20.268	1172.87	1135.30	1135.30	1135.30
20.316	1172.88	1136.00	1136.00	1136.00
20.357	1172.88	1136.70	1136.70	1136.70
20.370	1172.88	1136.80	1136.80	1136.80
20.418	1172.88	1137.50	1137.50	1137.50
20.464	1172.88	1138.00	1138.00	1138.00
20.560	1172.88	1139.40	1139.40	1139.40
20.655	1172.88	1140.90	1140.90	1140.90
20.748	1172.88	1142.30	1142.30	1142.30
20.840	1172.89	1143.60	1143.60	1143.60
20.935	1172.90	1144.70	1144.70	1144.70
21.041	1172.89	1139.10	1139.10	1139.10
21.138	1172.91	1148.70	1148.70	1148.70
21.227	1172.92	1126.10	1126.10	1126.10
21.317	1172.92	1139.20	1139.20	1139.20
21.405	1172.92	1137.90	1137.90	1137.91
21.486	1172.91	1145.40	1145.40	1145.40
21.568	1172.93	1149.50	1149.50	1149.50

Apart from this one item the programs are the same, all of the inputs are the same. This can be used to check the reach lengths against the stationing. But the PLOT2012 should be used to maintain consistent station IDs.

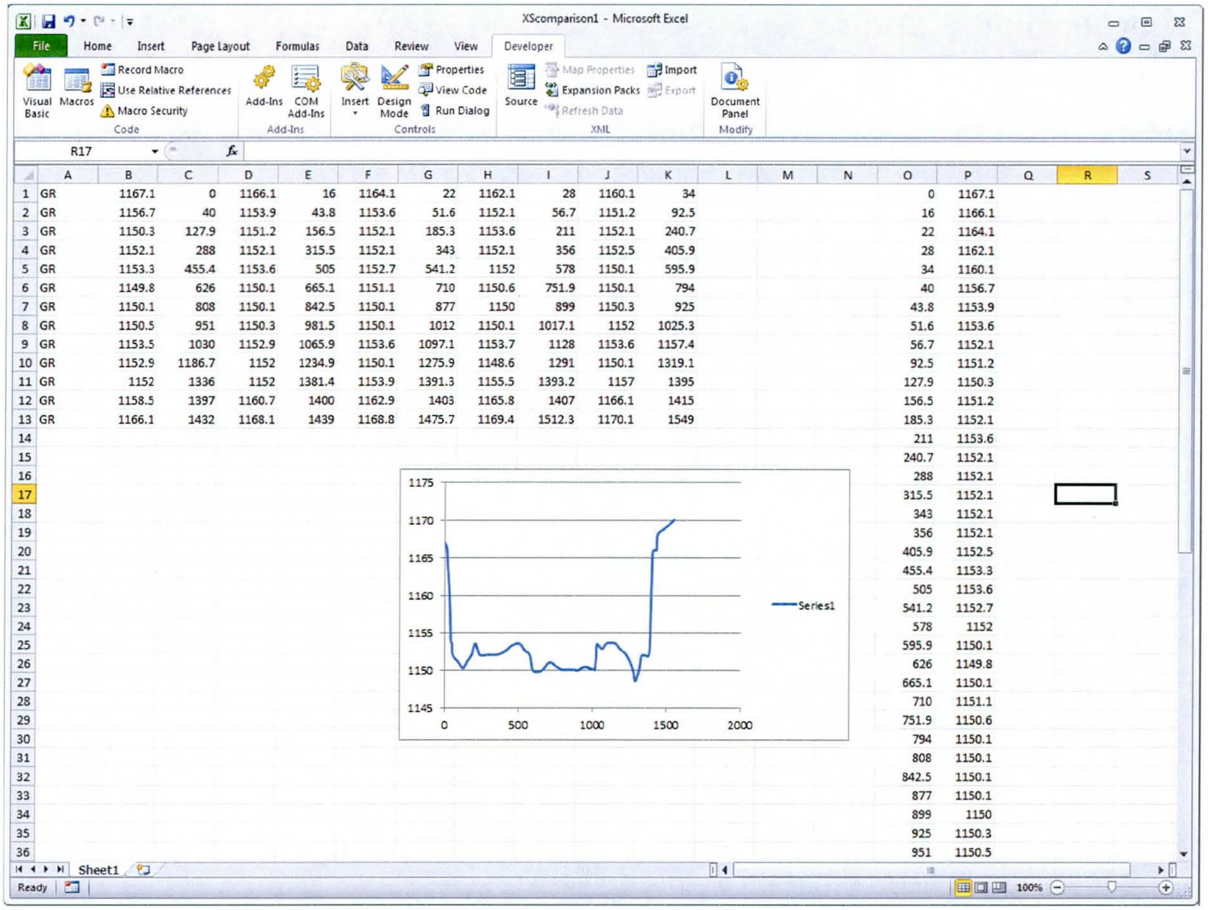
Other Reviewing Tools

It should be noted that the tools listed here were developed using Macros inside Microsoft Excel 2010 and that they might not be compatible with other versions. They were created on Microsoft Excel 2010, Version: 14.0.6129.5000 (32-bit) with Windows 7 Service Pack 1.

Cross Section Comparison Tool

This tool was developed using Microsoft Excel. The purpose of this tool is to obtain cross section data in columns for station and elevation instead of the format used in Fluvial-12 input and output files. To use this tool, open the Excel file named XScomparison.xltm. Below is a basic set of instructions for the program.

1. Open the XScomparison.xltm Excel file
2. Ensure that macros are enabled in Excel for your computer
3. Copy the data into a new sheet in Excel
    a. The data should be copied into cell A1
    b. If Excel does not automatically convert the text then use the convert to text option under the Data tab in Excel
4. This program handles data in the following format:
    a. First column = blank or ID card (ex. GR)
    b. Second column = elevation
    c. Third column = station
    d. Repeat second and third column out to eleven
    e. The program will read until there is a blank row
    f. The program only reads the first 11 columns in the spreadsheet
5. To run the program:
    a. Go to the Developer tab and select Macros or use Alt+F8
    b. In the Macros window that appears select, orginizeData then click on run
    c. The Macro will now organize the data into columns
6. The program will produce two columns of data in columns O and P, O contains the station data and P contains the elevation data, a chart is also created which plots the cross section
7. This program can also be used to obtain columnized data for other parameters, as long as it follows the same format



	A	B	C	D	E	F	G	H	I	J	K
1	GR	1167.1	0	1166.1	16	1164.1	22	1162.1	28	1160.1	34
2	GR	1156.7	40	1153.9	43.8	1153.6	51.6	1152.1	56.7	1151.2	92.5
3	GR	1150.3	127.9	1151.2	156.5	1152.1	185.3	1153.6	211	1152.1	240.7
4	GR	1152.1	288	1152.1	315.5	1152.1	343	1152.1	356	1152.5	405.9
5	GR	1153.3	455.4	1153.6	505	1152.7	541.2	1152	578	1150.1	595.9
6	GR	1149.8	626	1150.1	665.1	1151.1	710	1150.6	751.9	1150.1	794
7	GR	1150.1	808	1150.1	842.5	1150.1	877	1150	899	1150.3	925
8	GR	1150.5	951	1150.3	981.5	1150.1	1012	1150.1	1017.1	1152	1025.3
9	GR	1153.5	1030	1152.9	1065.9	1153.6	1097.1	1153.7	1128	1153.6	1157.4
10	GR	1152.9	1186.7	1152	1234.9	1150.1	1275.9	1148.6	1291	1150.1	1319.1
11	GR	1152	1336	1152	1381.4	1153.9	1391.3	1155.5	1393.2	1157	1395
12	GR	1158.5	1397	1160.7	1400	1162.9	1403	1165.8	1407	1166.1	1415
13	GR	1166.1	1432	1168.1	1439	1168.8	1475.7	1169.4	1512.3	1170.1	1549

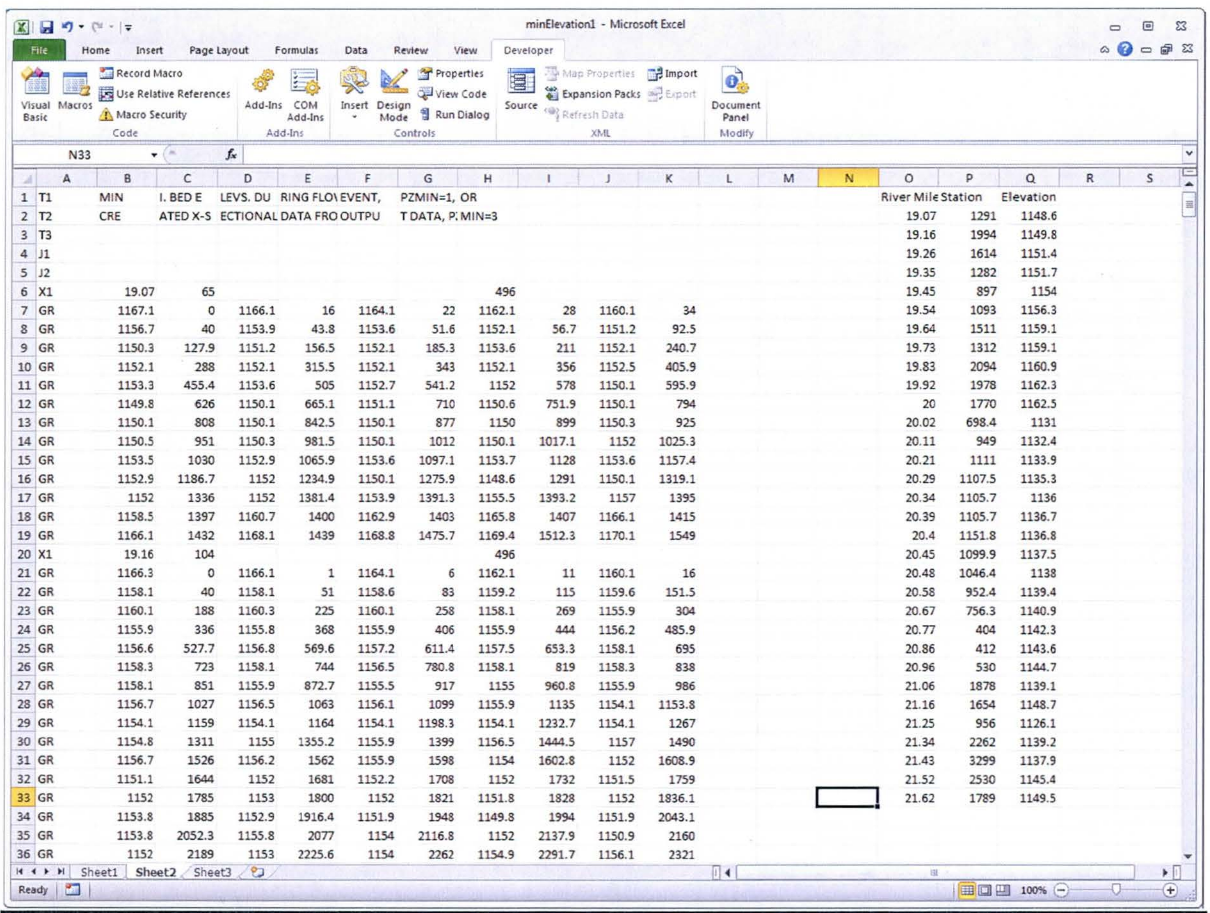
	O	P
1	0	1167.1
2	16	1166.1
3	22	1164.1
4	28	1162.1
5	34	1160.1
6	40	1156.7
7	43.8	1153.9
8	51.6	1153.6
9	56.7	1152.1
10	92.5	1151.2
11	127.9	1150.3
12	156.5	1151.2
13	185.3	1152.1
14	211	1153.6
15	240.7	1152.1
16	288	1152.1
17	315.5	1152.1
18	343	1152.1
19	356	1152.1
20	405.9	1152.5
21	455.4	1153.3
22	505	1153.6
23	541.2	1152.7
24	578	1152
25	595.9	1150.1
26	626	1149.8
27	665.1	1150.1
28	710	1151.1
29	751.9	1150.6
30	794	1150.1
31	808	1150.1
32	842.5	1150.1
33	877	1150.1
34	899	1150
35	925	1150.3
36	951	1150.5

Get Thalweg Elevation

This tool takes the TZMIN file (that is the file that contains the minimum bed elevations) and finds and reports the lowest point on each cross section. This tool is very similar to Cross Section Comparison tool mentioned above. For this tool it takes all of the cross section from the TZMIN file, so the entire file can be copied into the Excel workbook. Below are basic instructions for using this tool.

1. Open the minElevation.xltm Excel file
2. Ensure that macros are enabled in Excel for your computer
3. Copy the data into a new sheet in Excel
    a. The data should be copied into cell A1
    b. Copy as many cross sections as needed, it is best to copy the entire TZMIN file into the workbook
    c. If Excel does not automatically convert the text then use the convert to text option under the Data tab in Excel
4. This program handles data in the following format:

   a. First column = ID card, the program looks for X1 and GR records, the X1 records is used to label the results
   b. Second column = elevation (if it is a GR record or river mile if it is an X1 record, otherwise this data is not looked at)
   c. Third column = station (if it is a GR record otherwise this data is not looked at)
   d. Repeat second and third column out to eleven
   e. The program will read until there is a blank row
   f. The program only reads the first 11 columns in the spreadsheet
5. To run the program:
   a. Go to the Developer tab and select Macros or use Alt+F8
   b. In the Macros window that appears select, getThalweg then click on run
   c. The Macro will now find the low point of each cross section and report the cross section ID or river mile, station and elevation of the low point
6. The program will produce three columns of data in columns O, P, and Q
   a. O contains the river mile or cross section identifiers
   b. P contains the Station that the low point occurs at in that cross section
   c. Q contains the elevation of the low point for that cross section

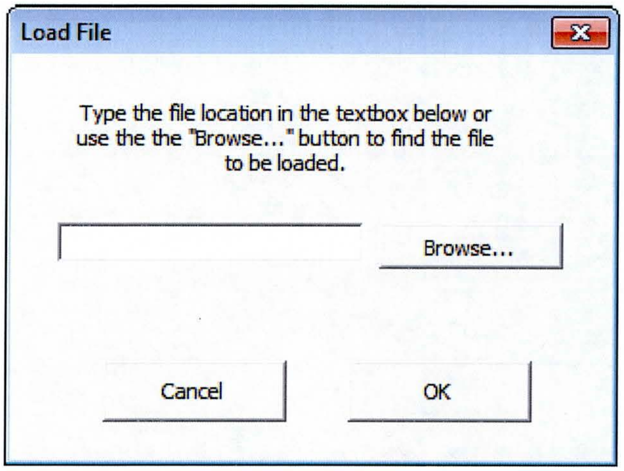


	A	B	C	D	E	F	G	H	I	J	K	O	P	Q
1	T1	MIN	I. BED E	LEVS. DU	RING FLO\	EVENT,	PZMIN=1,	OR				River Mile	Station	Elevation
2	T2	CRE	ATED X-S	ECTIONAL	DATA FRO	OUTPU	T DATA, P:	MIN=3				19.07	1291	1148.6
3	T3											19.16	1994	1149.8
4	J1											19.26	1614	1151.4
5	J2											19.35	1282	1151.7
6	X1	19.07	65					496				19.45	897	1154
7	GR	1167.1	0	1166.1	16	1164.1	22	1162.1	28	1160.1	34	19.54	1093	1156.3
8	GR	1156.7	40	1153.9	43.8	1153.6	51.6	1152.1	56.7	1151.2	92.5	19.64	1511	1159.1
9	GR	1150.3	127.9	1151.2	156.5	1152.1	185.3	1153.6	211	1152.1	240.7	19.73	1312	1159.1
10	GR	1152.1	288	1152.1	315.5	1152.1	343	1152.1	356	1152.5	405.9	19.83	2094	1160.9
11	GR	1153.3	455.4	1153.6	505	1152.7	541.2	1152	578	1150.1	595.9	19.92	1978	1162.3
12	GR	1149.8	626	1150.1	665.1	1151.1	710	1150.6	751.9	1150.1	794	20	1770	1162.5
13	GR	1150.1	808	1150.1	842.5	1150.1	877	1150	899	1150.3	925	20.02	698.4	1131
14	GR	1150.5	951	1150.3	981.5	1150.1	1012	1150.1	1017.1	1152	1025.3	20.11	949	1132.4
15	GR	1153.5	1030	1152.9	1065.9	1153.6	1097.1	1153.7	1128	1153.6	1157.4	20.21	1111	1133.9
16	GR	1152.9	1186.7	1152	1234.9	1150.1	1275.9	1148.6	1291	1150.1	1319.1	20.29	1107.5	1135.3
17	GR	1152	1336	1152	1381.4	1153.9	1391.3	1155.5	1393.2	1157	1395	20.34	1105.7	1136
18	GR	1158.5	1397	1160.7	1400	1162.9	1403	1165.8	1407	1166.1	1415	20.39	1105.7	1136.7
19	GR	1166.1	1432	1168.1	1439	1168.8	1475.7	1169.4	1512.3	1170.1	1549	20.4	1151.8	1136.8
20	X1	19.16	104					496				20.45	1099.9	1137.5
21	GR	1166.3	0	1166.1	1	1164.1	6	1162.1	11	1160.1	16	20.48	1046.4	1138
22	GR	1158.1	40	1158.1	51	1158.6	83	1159.2	115	1159.6	151.5	20.58	952.4	1139.4
23	GR	1160.1	188	1160.3	225	1160.1	258	1158.1	269	1155.9	304	20.67	756.3	1140.9
24	GR	1155.9	336	1155.8	368	1155.9	406	1155.9	444	1156.2	485.9	20.77	404	1142.3
25	GR	1156.6	527.7	1156.8	569.6	1157.2	611.4	1157.5	653.3	1158.1	695	20.86	412	1143.6
26	GR	1158.3	723	1158.1	744	1156.5	780.8	1158.1	819	1158.3	838	20.96	530	1144.7
27	GR	1158.1	851	1155.9	872.7	1155.5	917	1155	960.8	1155.9	986	21.06	1878	1139.1
28	GR	1156.7	1027	1156.5	1063	1156.1	1099	1155.9	1135	1154.1	1153.8	21.16	1654	1148.7
29	GR	1154.1	1159	1154.1	1164	1154.1	1198.3	1154.1	1232.7	1154.1	1267	21.25	956	1126.1
30	GR	1154.8	1311	1155	1355.2	1155.9	1399	1156.5	1444.5	1157	1490	21.34	2262	1139.2
31	GR	1156.7	1526	1156.2	1562	1155.9	1598	1154	1602.8	1152	1608.9	21.43	3299	1137.9
32	GR	1151.1	1644	1152	1681	1152.2	1708	1152	1732	1151.5	1759	21.52	2530	1145.4
33	GR	1152	1785	1153	1800	1152	1821	1151.8	1828	1152	1836.1	21.62	1789	1149.5
34	GR	1153.8	1885	1152.9	1916.4	1151.9	1948	1149.8	1994	1151.9	2043.1			
35	GR	1153.8	2052.3	1155.8	2077	1154	2116.8	1152	2137.9	1150.9	2160			
36	GR	1152	2189	1153	2225.6	1154	2262	1154.9	2291.7	1156.1	2321			

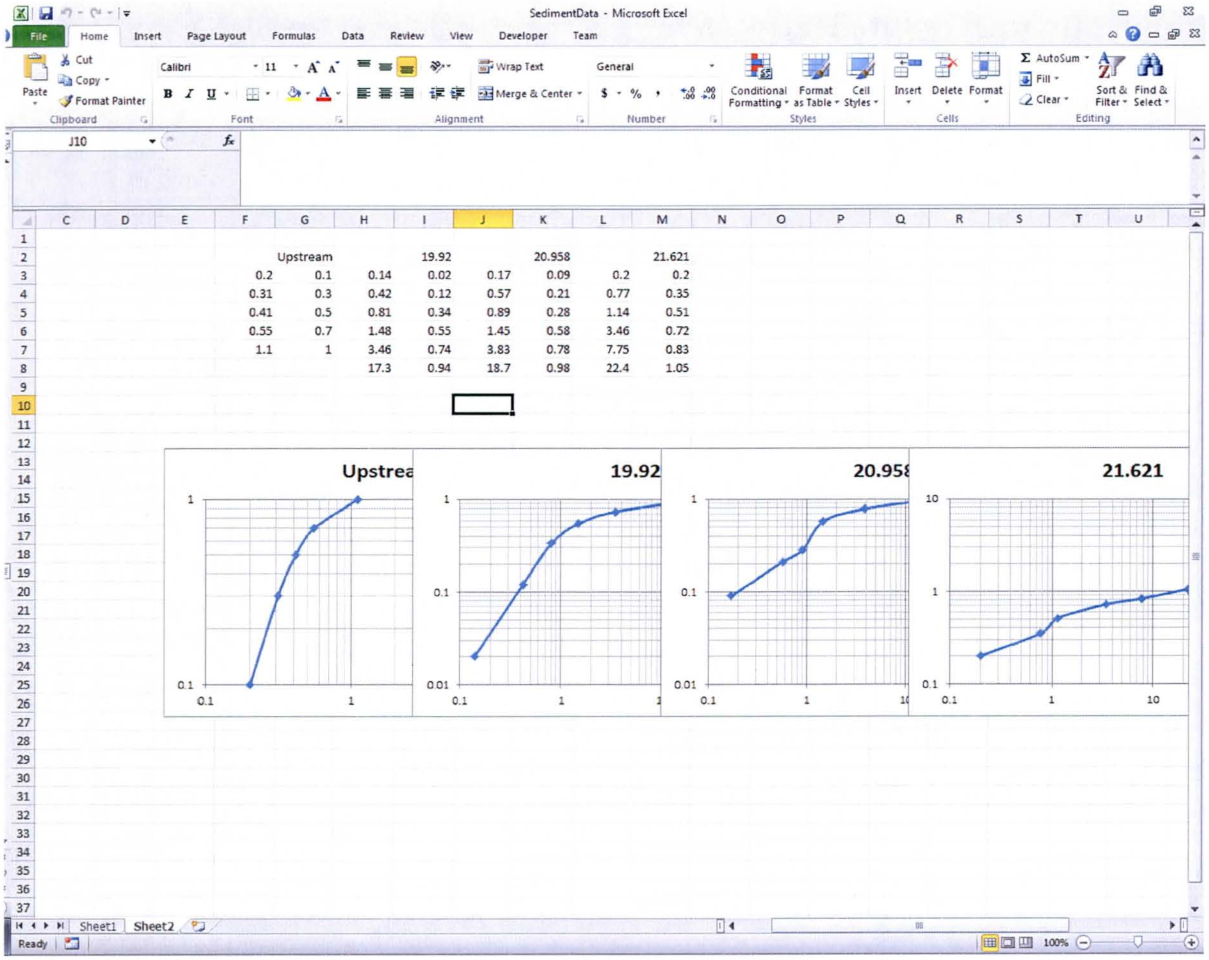
Sediment Conversion Tool

This tool converts the initial bed material composition in Fluvial-12 to a comparable percent finer data used in HEC-6. Fluvial-12 has the user break the bed composition into fractions and the user enters the geometric mean of each fraction. Most sediment data is presented as soil gradation curves as percent finer or percent passing. This tool allows the user to compare Fluvial-12 data to these curves easily. Below are the basic instructions for this tool.

1. Open the SedimentData.xltm Excel file
2. Ensure that macros are enabled in Excel for your computer
3. Go to the Developer tab in Excel or press Alt+F8 to view the Macros
4. Select "CovertSediment" from the list of macro names
5. This will open the "Load File" textbox
    a. Type in the file location and name of the *.FLU file to extract the data from
    b. Or use the "Browse..." button to search for *.FLU file to extract the data from



6. Click the OK button
7. The data will be displayed in tabular form at the top of the sheet
8. Plots will also be made of the data as shown below


SedimentData - Microsoft Excel
Upstream 19.92 20.958 21.621
0.2 0.1 0.14 0.02 0.17 0.09 0.2 0.2
0.31 0.3 0.42 0.12 0.57 0.21 0.77 0.35
0.41 0.5 0.81 0.34 0.89 0.28 1.14 0.51
0.55 0.7 1.48 0.55 1.45 0.58 3.46 0.72
1.1 1 3.46 0.74 3.83 0.78 7.75 0.83
17.3 0.94 18.7 0.98 22.4 1.05
Upstrea
19.92
20.95
21.621
Sheet1
Sheet2
Ready

Import Geometry into HEC-RAS

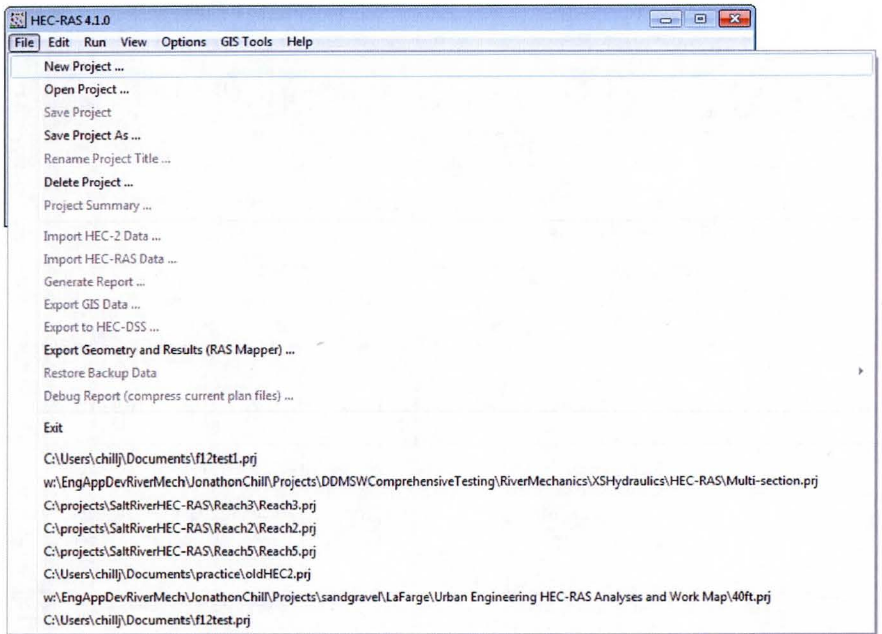
Introduction

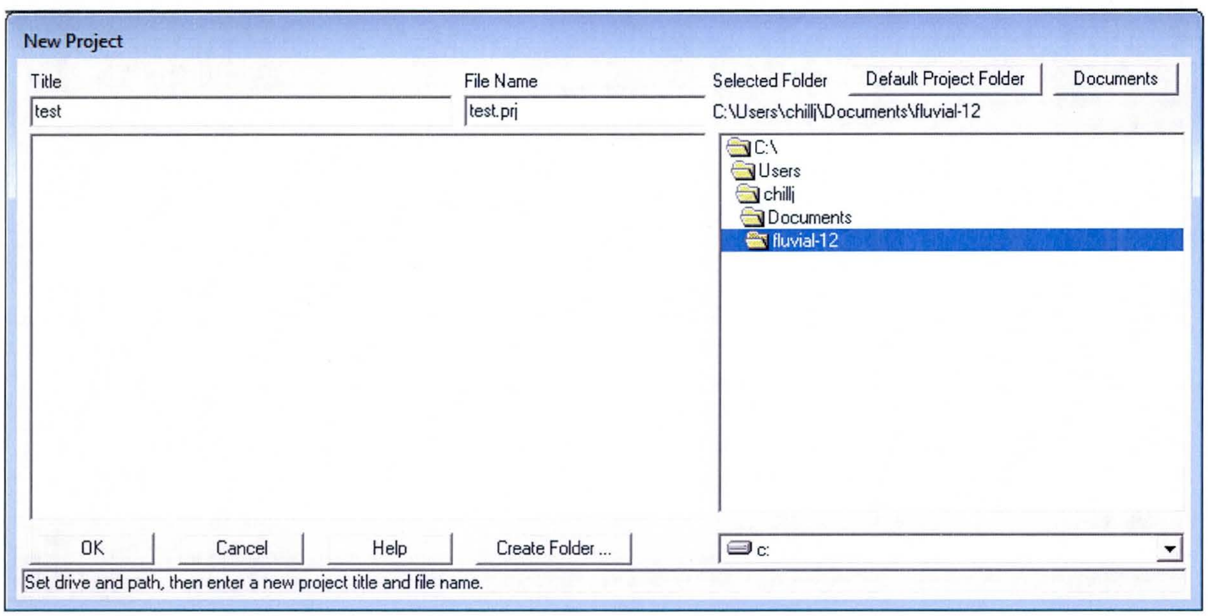
One method to view the cross section geometry from a Fluvial-12 model is to use HEC-RAS. HEC-RAS has the capability to import geometry data in the format of HEC-2, which is the same format as the geometry in Fluvial-12. A HEC-RAS model could also be created using this geometry, which is the majority of the data input, to check water surface elevation or other parameters.

Importing Geometry

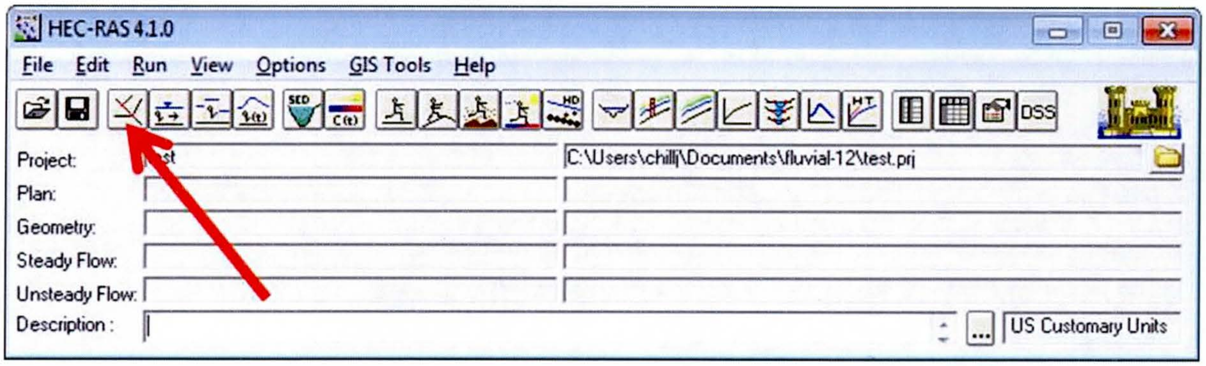
There are a few important things to note about importing the Fluvial-12 files into HEC-RAS. The file extension must be "*.dat" for HEC-RAS to recognize it. So the text file must be saved as a *.dat file before being imported. Only the input file can be viewed, the output file has the input data offset two spaces so HEC-RAS cannot parse the data in. There is not really any need to import the data from the output file for viewing in HEC-RAS because the results are not stored in a format that can be imported into HEC-RAS. If the results from the model need to be compared then the minimum bed elevations from the simulation duration can be imported into HEC-RAS. These are obtained by requesting them in the input file, this is done in the "G4" field in the input file. See the Fluvial-12 User's Manual and other documentation for more information on this. The minimum bed elevation are written to a separate file when the model is run, this file is called TZMIN. It already has the file extension of *.dat so it can be imported into HEC-RAS.

After the file is in the correct format it can be imported into HEC-RAS. To import the file, open HEC-RAS and then create a new project.

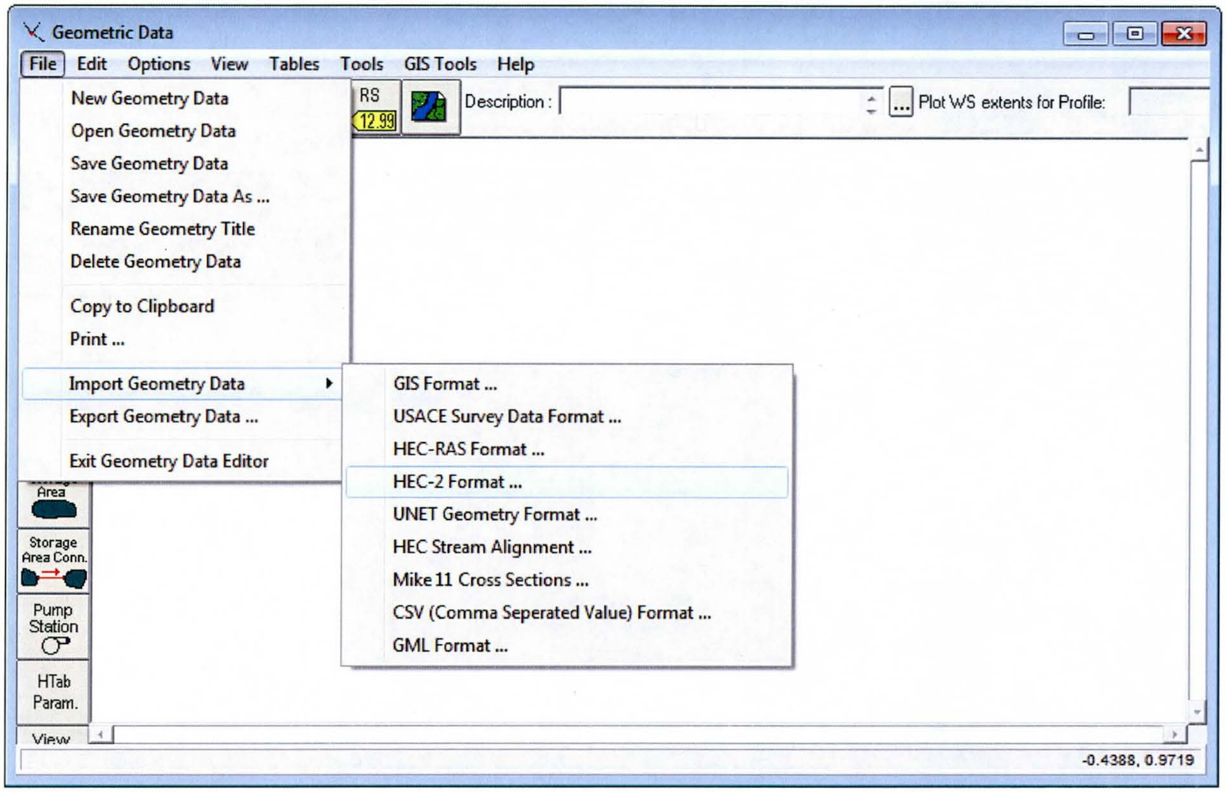




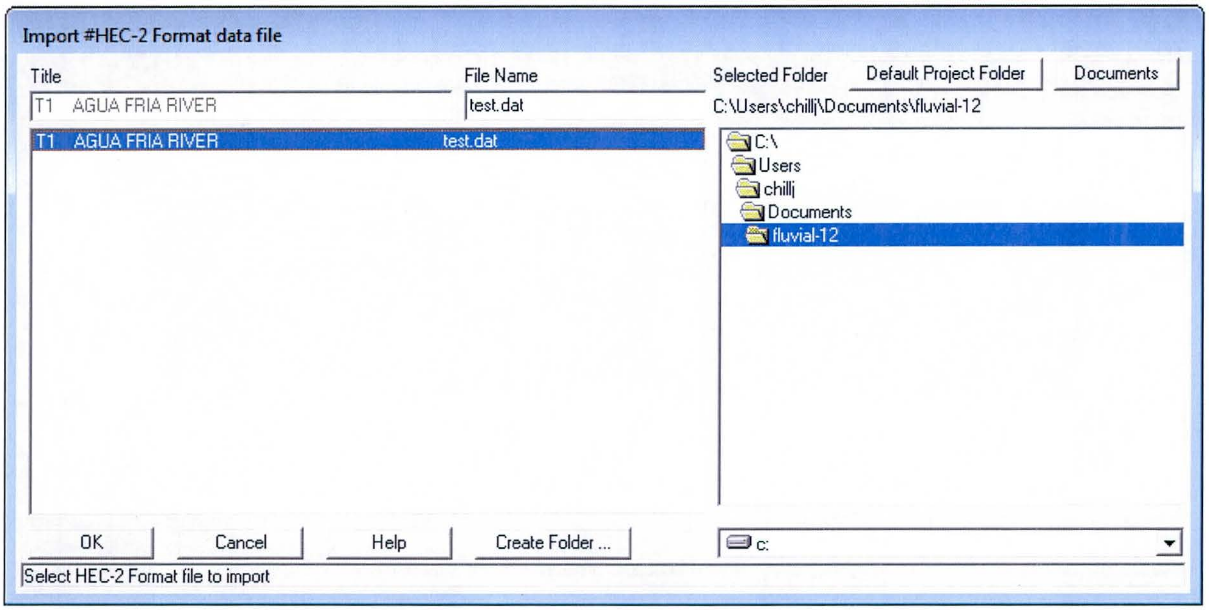
Then open the geometry data, the button to open the geometry data is indicated by the red arrow below.



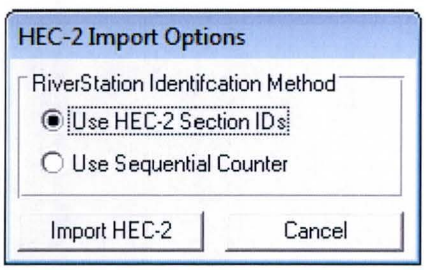
In the geometry window click on "File" then select "Import Geometry Data" from the pull down menu and then select "HEC-2 Format..." from the menu.



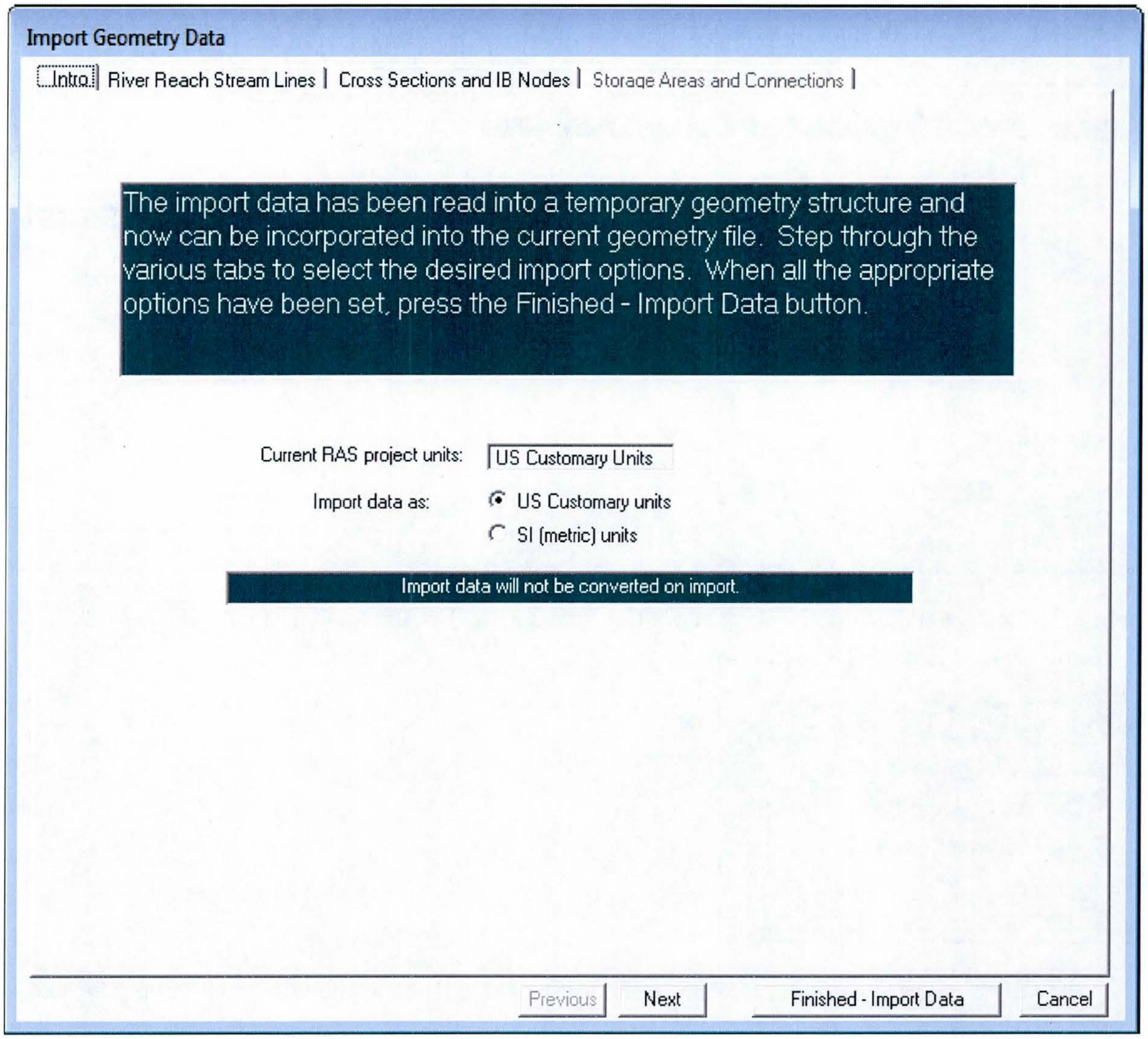
This opens the import window, here browse to find the *.dat file that contains the geometry data from the model. Select the file and open it.

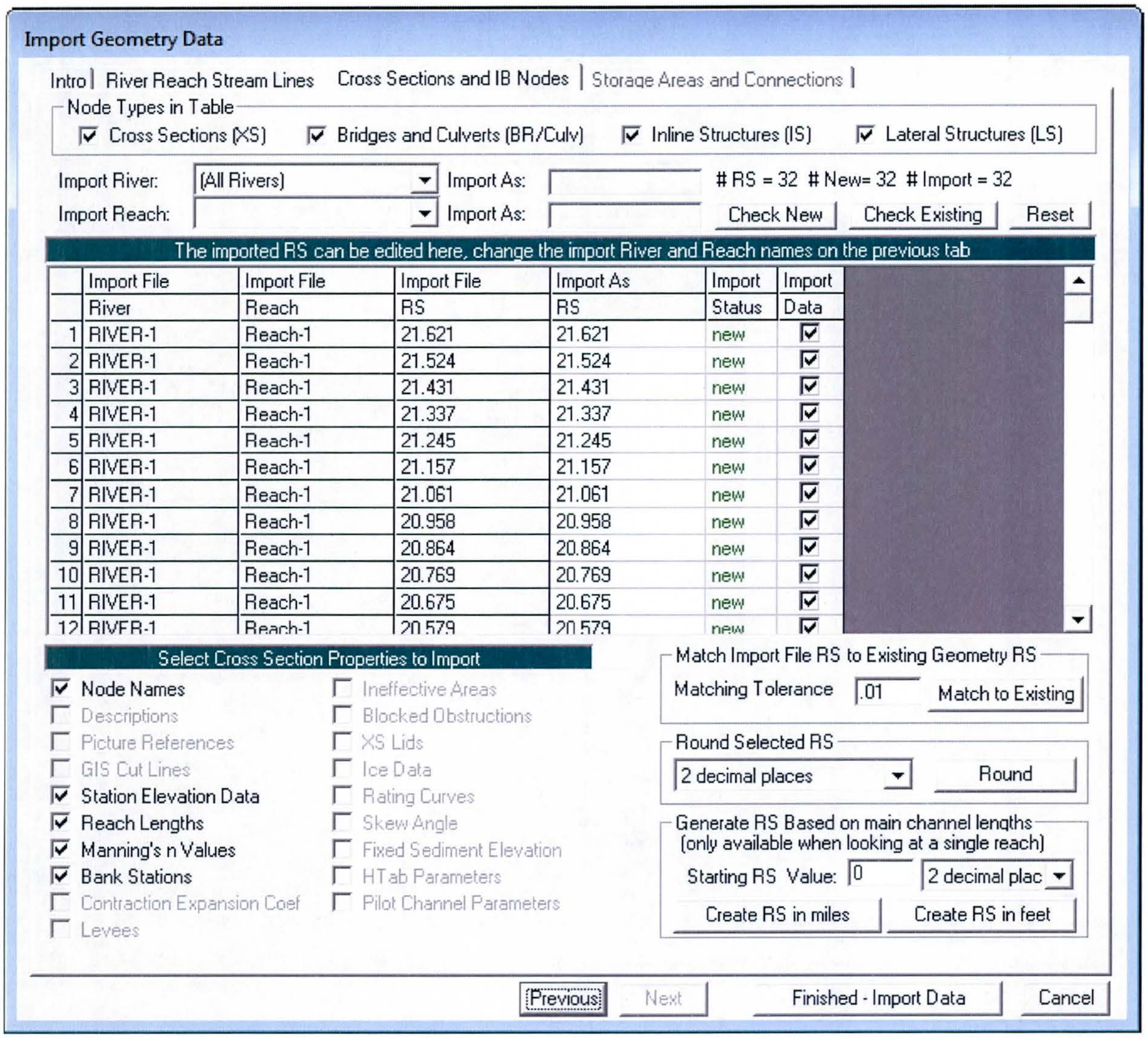


Another window will then open, asking about the cross section IDs, to maintain the IDs in Fluvial-12 select "Use HEC-2 Section IDs" as shown below.

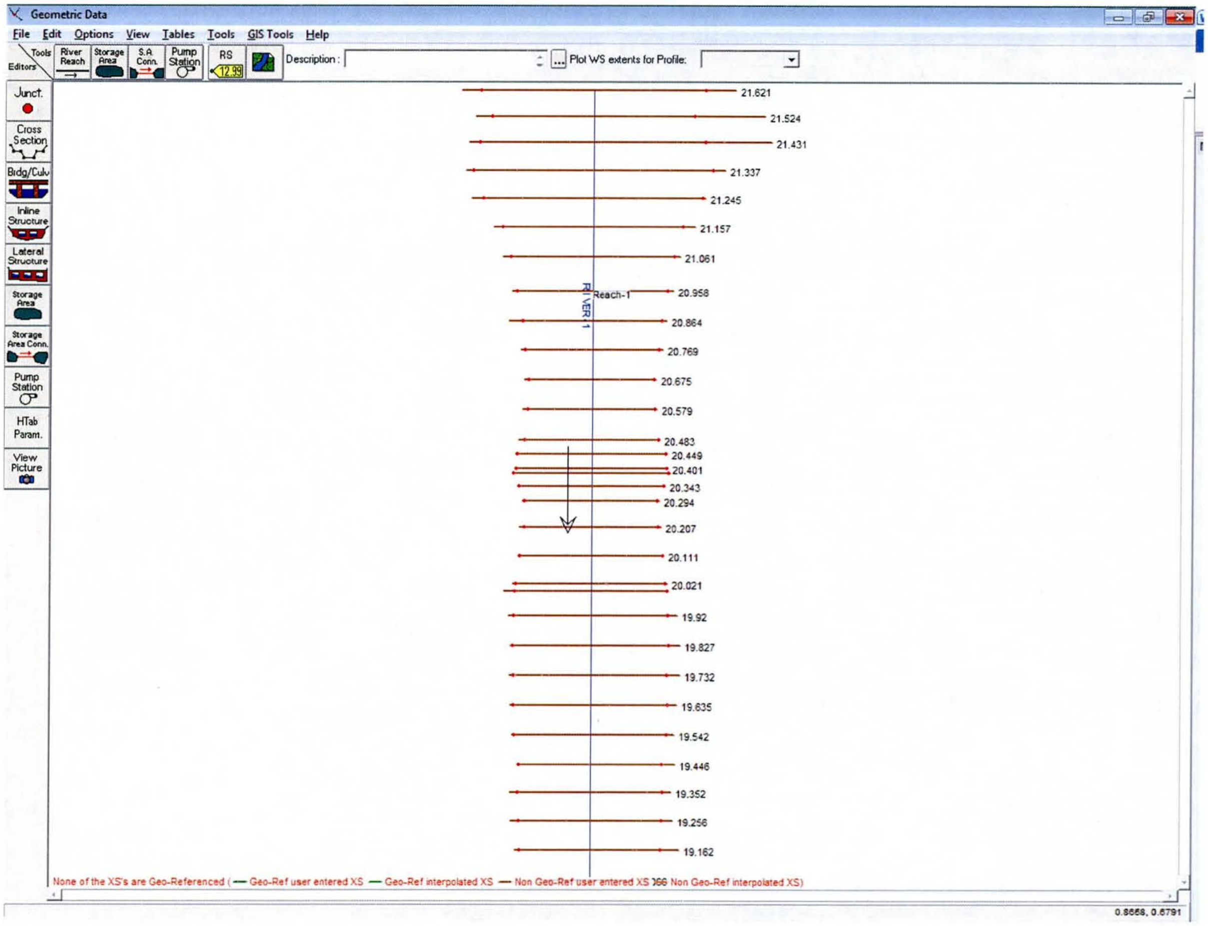


Then the last "Import Geometry Data" opens, check the data in these windows then click the "Finished – Import Data" to finish the import.

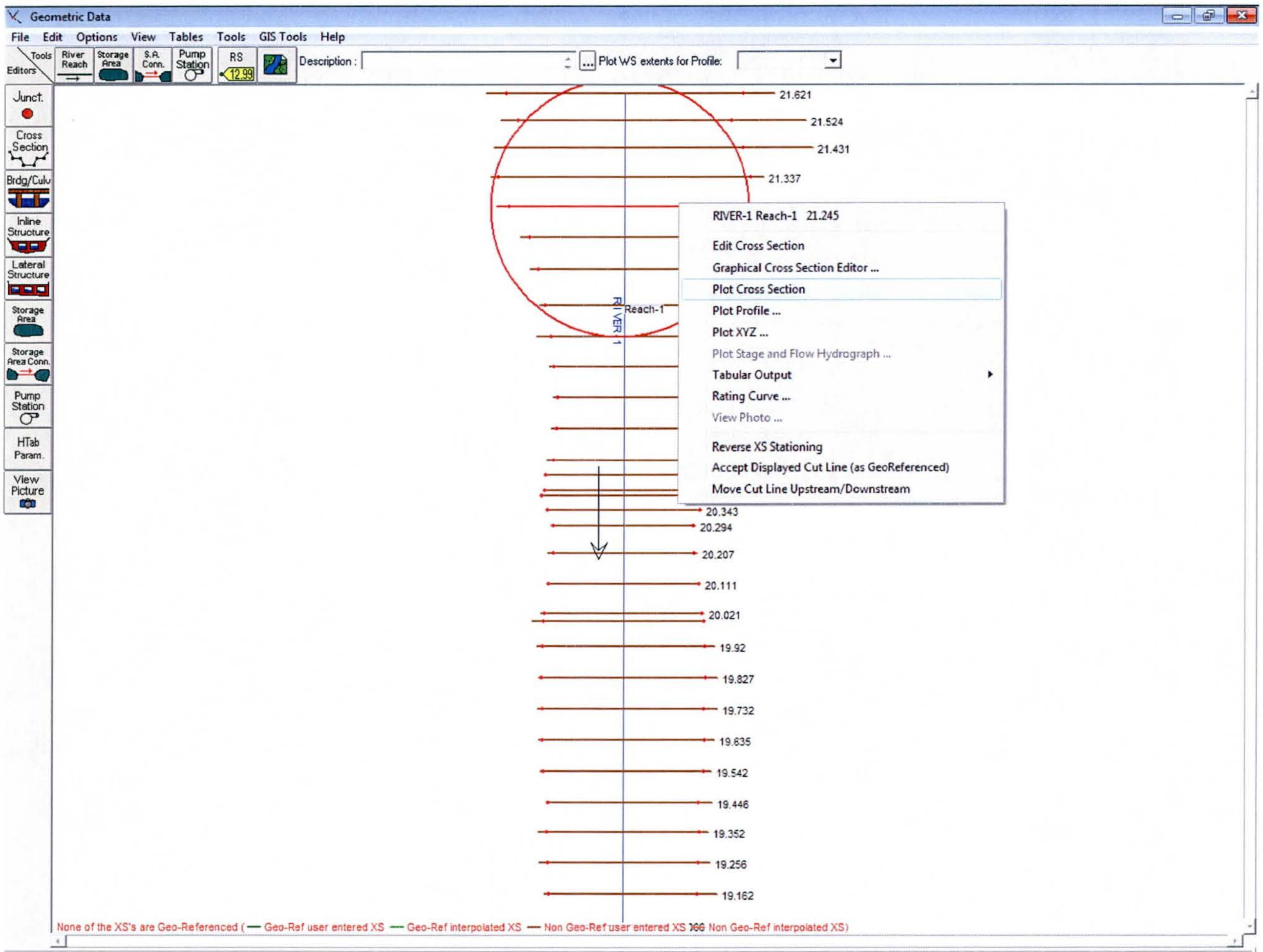

Import Geometry Data
Intro
River Reach Stream Lines
Cross Sections and IB Nodes
Storage Areas and Connections
The import data has been read into a temporary geometry structure and now can be incorporated into the current geometry file. Step through the various tabs to select the desired import options. When all the appropriate options have been set, press the Finished - Import Data button.
Current RAS project units:
US Customary Units
Import data as:
US Customary units
SI (metric) units
Import data will not be converted on import.
Previous
Next
Finished - Import Data
Cancel



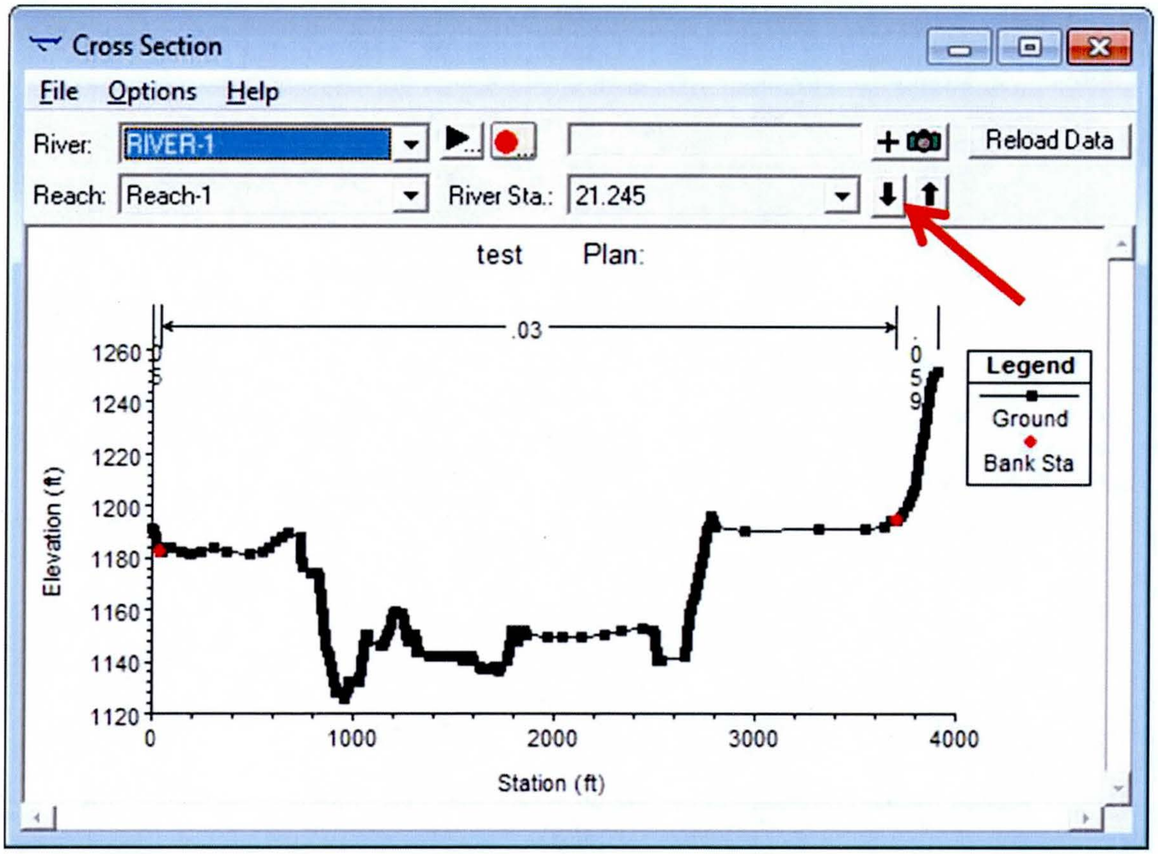
The cross sections are then shown in the “Geometric Data” window.



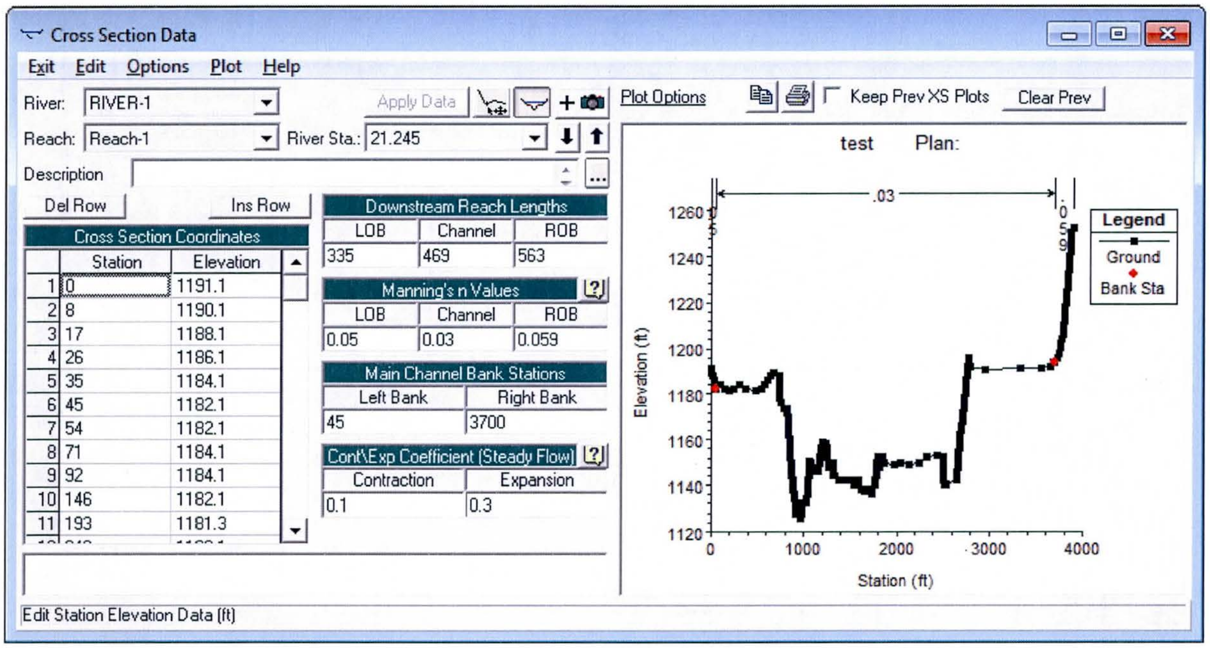
To view an individual cross section the user can either select the cross section and select "Plot Cross Section" from the menu that appears or click on the "Cross Section" button on the left side of the "Geometric Data" window.



If the first method is used then the following window will appear. The red arrow indicates the buttons that allow the user to scroll through the cross section in the model, or a cross section can be selected from the pull down menu to the left of the scroll button.

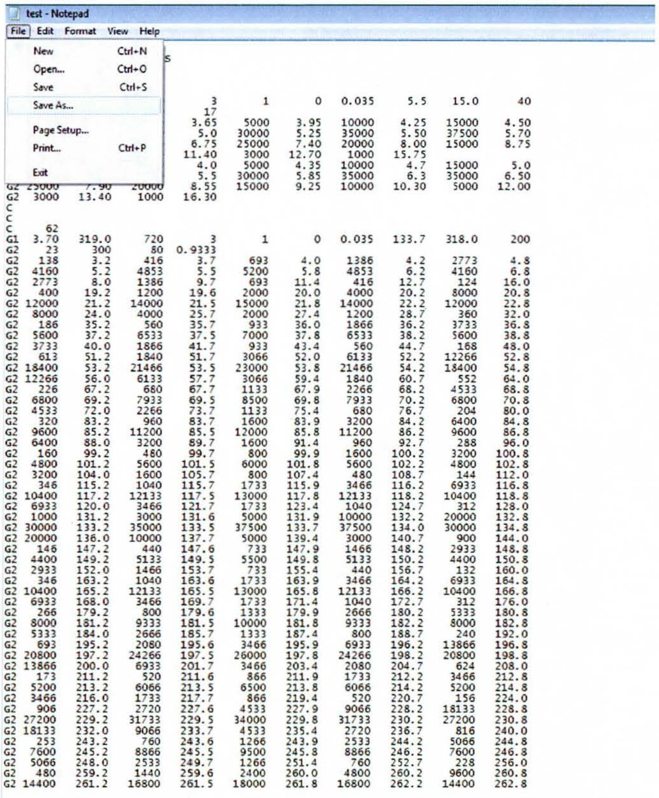


If the "Cross Section" button is clicked then the following window appears which allows the data to be edited.

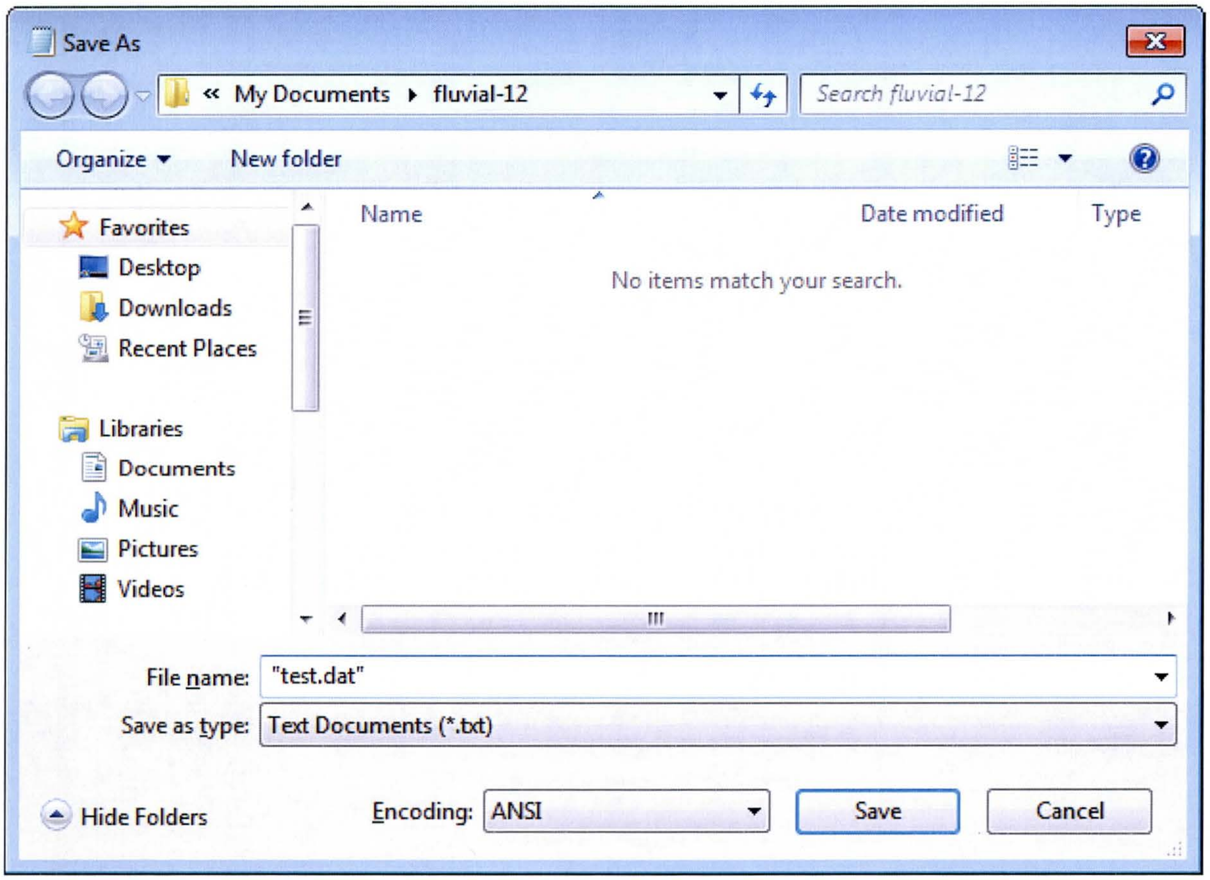


Example

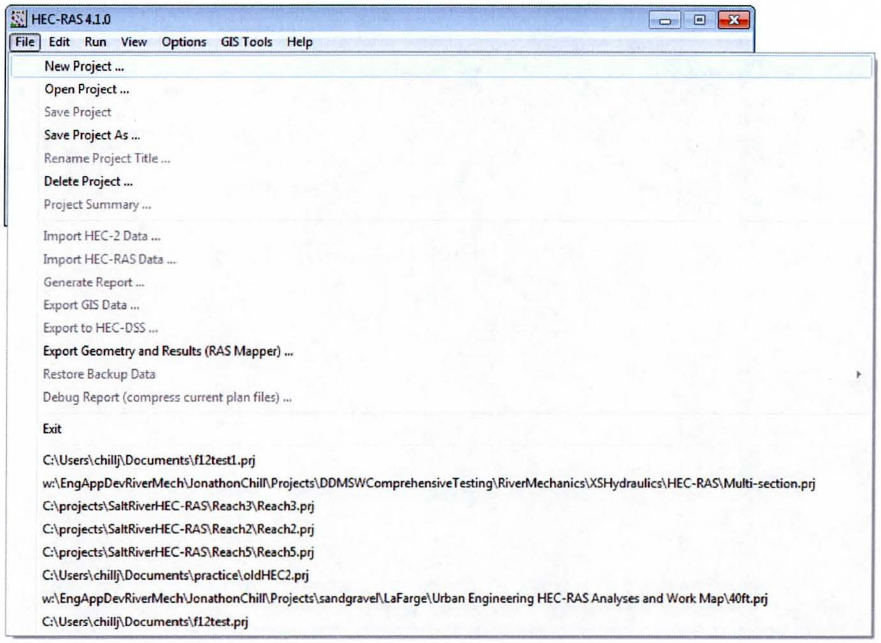
To begin obtain an input file for Fluvial-12 or a TZMIN.dat file. In this example an input file name test.flu will be used. The first step then is to convert this file to a *.dat file. To do this the file is opened in a text editor. Then select "File" and then "Save As…" to create the new file.

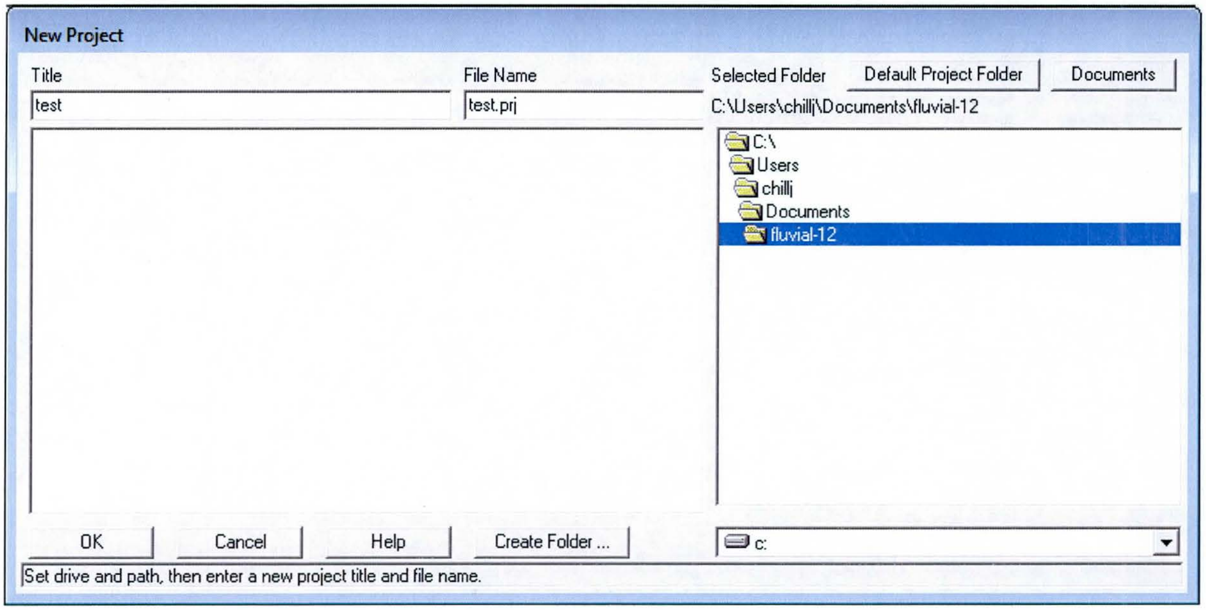


In the window that opens enter "test.dat" in the File name filed to ensure that the file is saved as a *.dat as shown below.

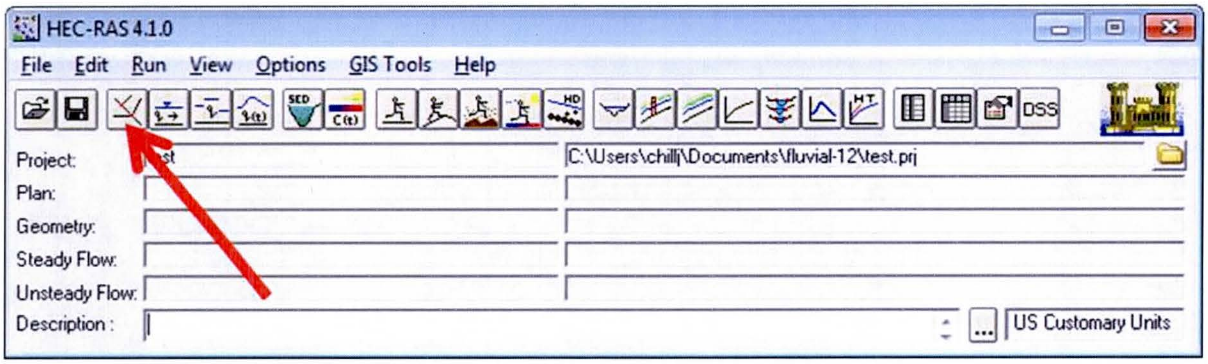


Then open HEC-RAS and create a new project, in this case the project was named test.prj this is shown in the figures below.

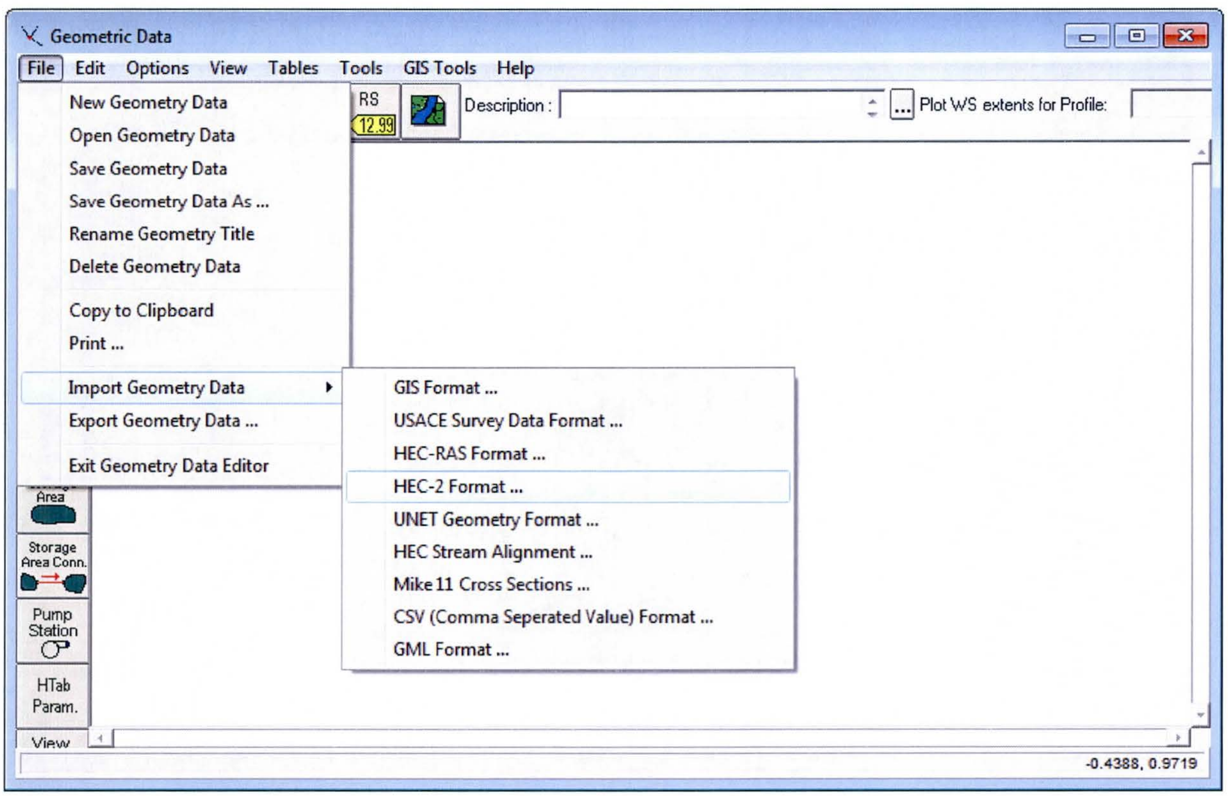




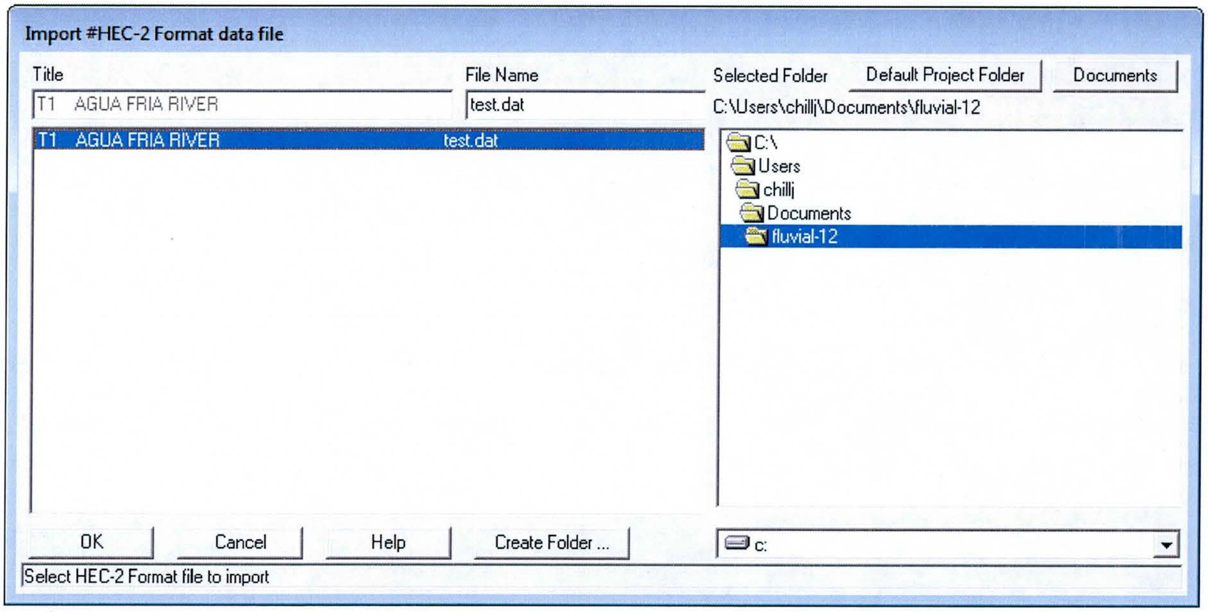
Then open the geometry data, the button to open the geometry data is indicated by the red arrow below.



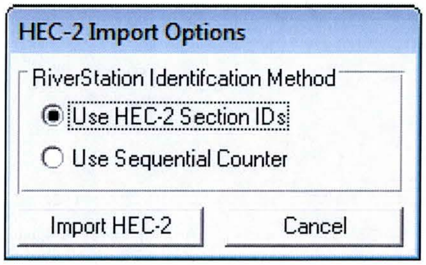
In the geometry window click on "File" then select "Import Geometry Data" from the pull down menu and then select "HEC-2 Format..." from the menu.



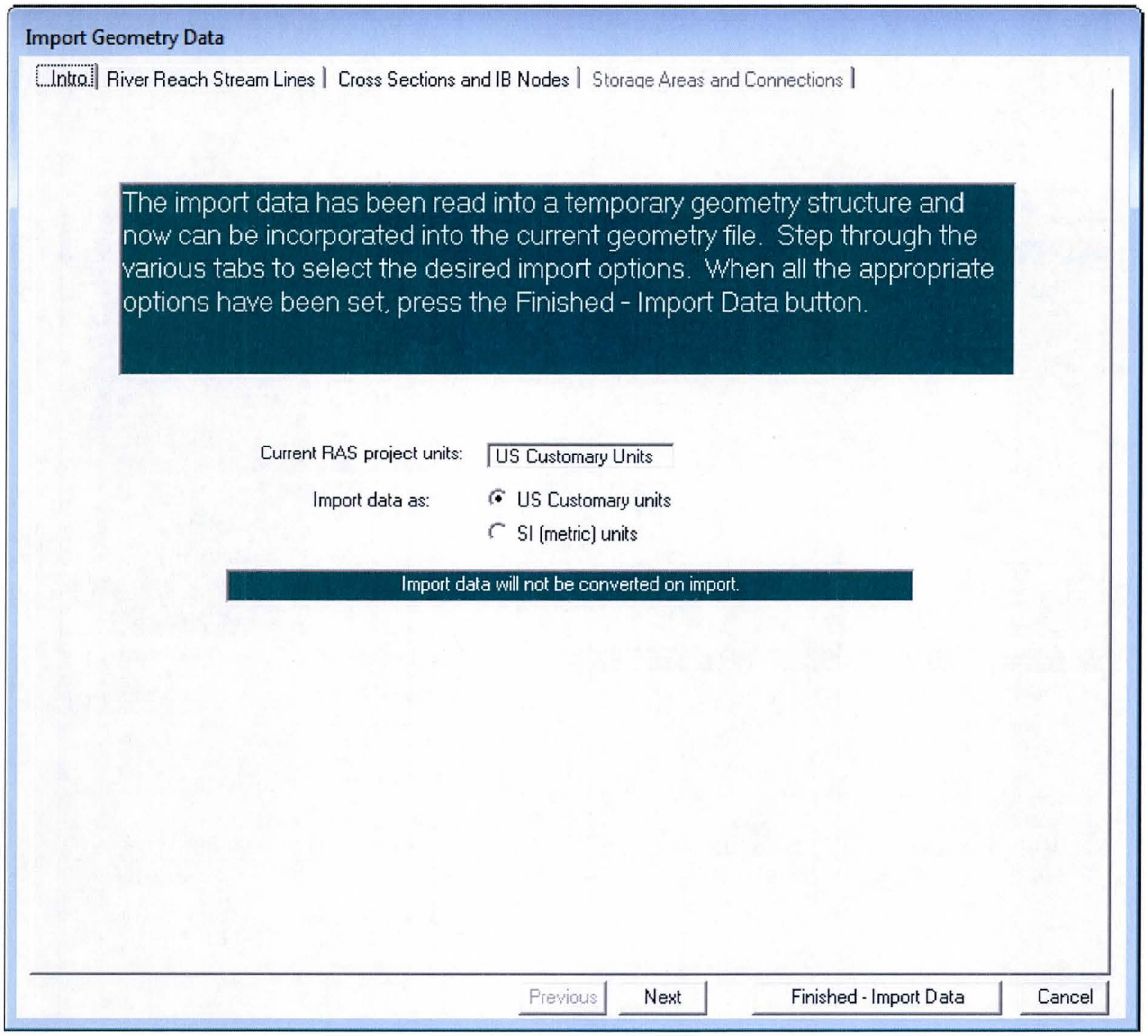
This opens the import window; here browse to find the test.dat file that contains the geometry data from the model. Select the file and open it.



Another window will then open, asking about the cross section IDs, to maintain the IDs in Fluvial-12 select "Use HEC-2 Section IDs" as shown below.



Then the last "Import Geometry Data" opens, check the data in these windows then click the "Finished – Import Data" to finish the import.


Import Geometry Data
Intro
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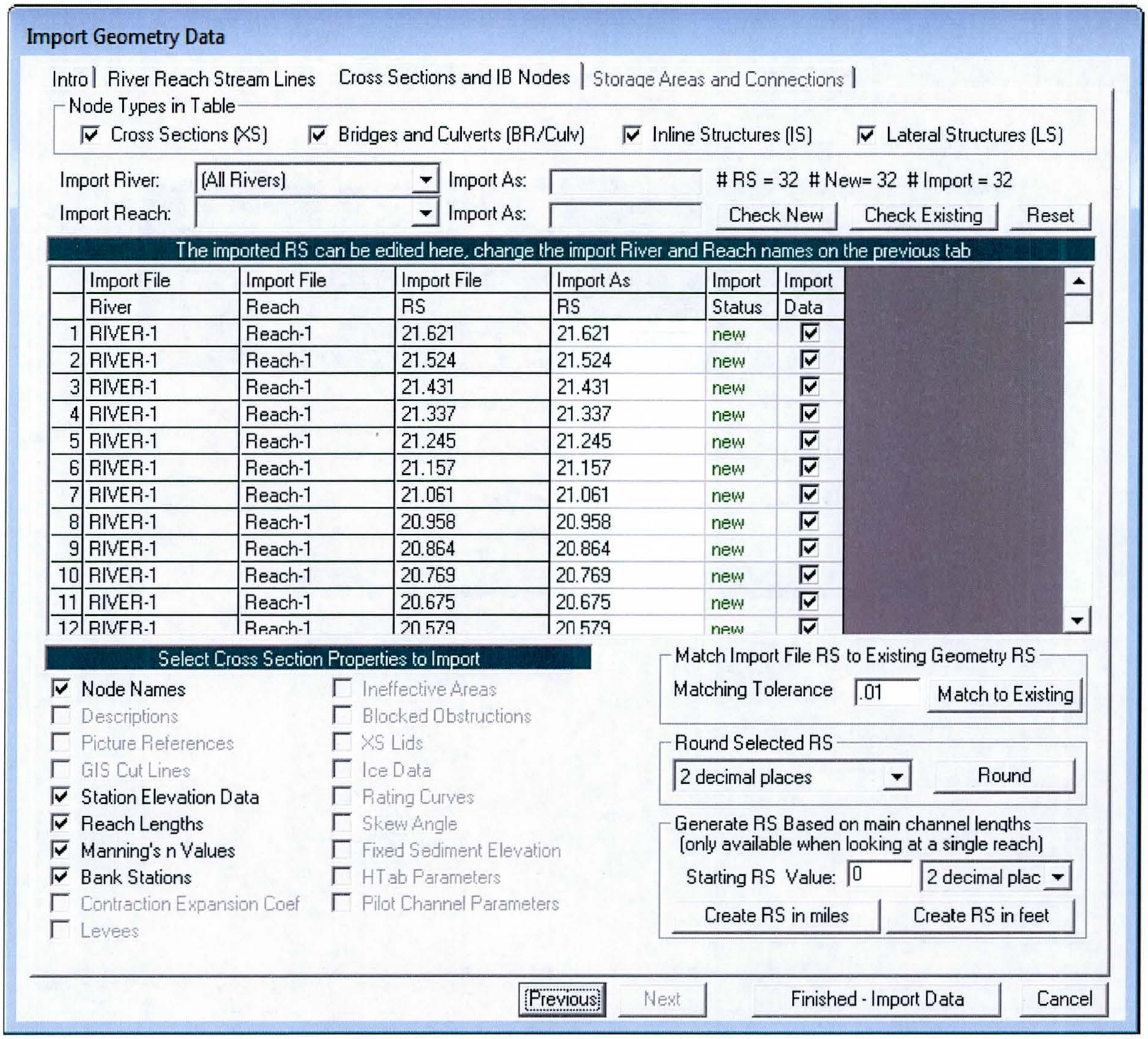
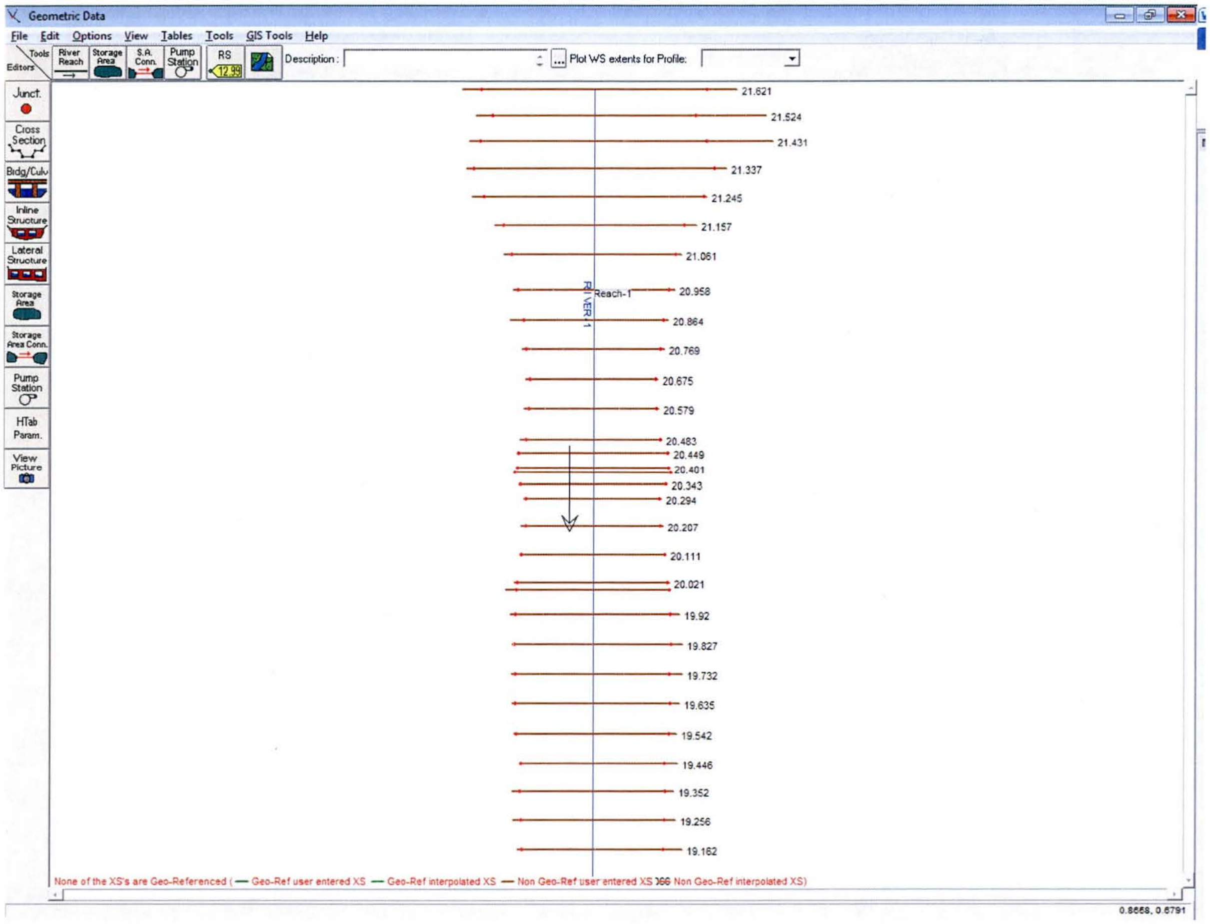
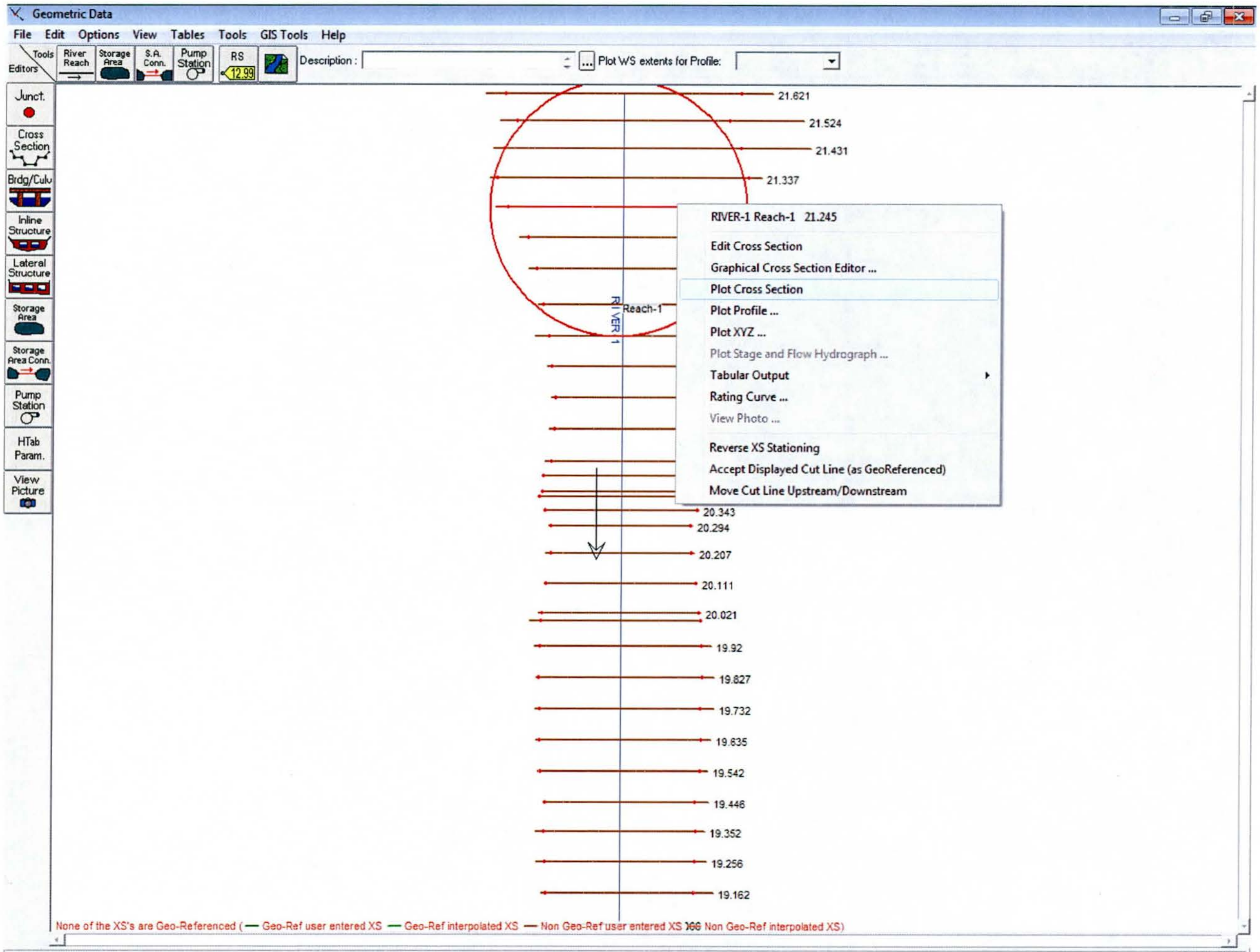
The import data has been read into a temporary geometry structure and now can be incorporated into the current geometry file. Step through the various tabs to select the desired import options. When all the appropriate options have been set, press the Finished - Import Data button.
Current RAS project units:
US Customary Units
Import data as:
US Customary units
SI (metric) units
Import data will not be converted on import.
Previous
Next
Finished - Import Data
Cancel

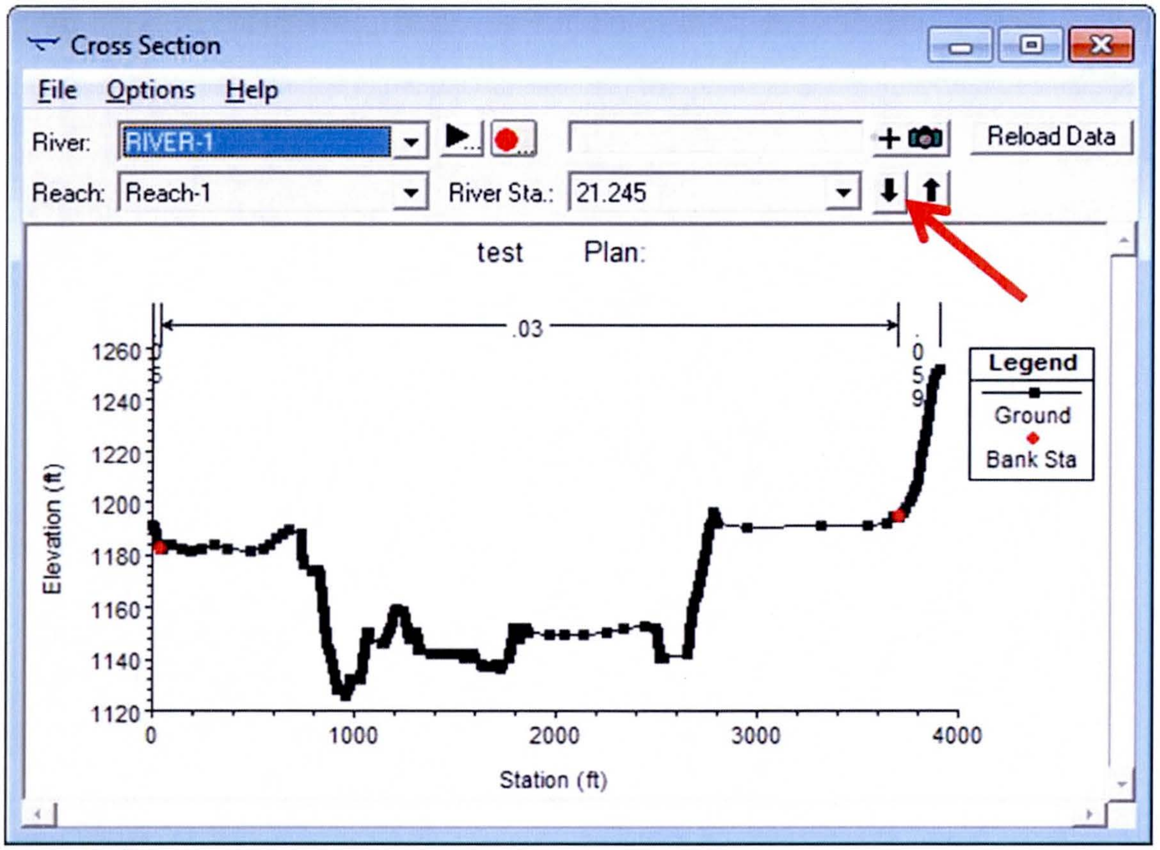


The cross sections are then shown in the "Geometric Data" window.



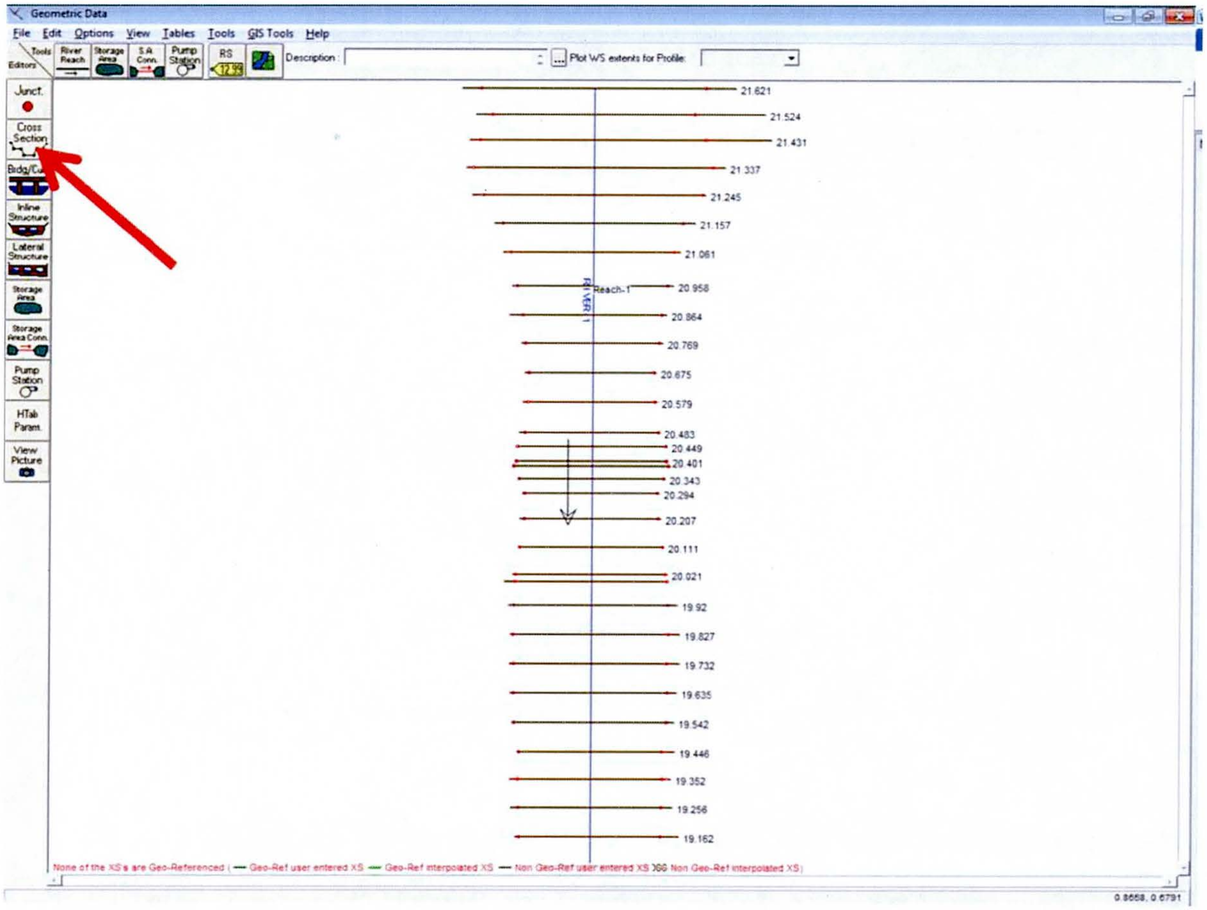
To view an individual cross section the user can either select the cross section and select "Plot Cross Section" from the menu that appears or click on the "Cross Section" button on the left side of the "Geometric Data" window. First select cross section number 21.245 in the window, then select "Plot Cross Section" this is shown below.


Geometric Data
File Edit Options View Tables Tools GIS Tools Help
Description :
Plot WS extents for Profile:
21.621
21.524
21.431
21.337
RIVER-1 Reach-1 21.245
Edit Cross Section
Graphical Cross Section Editor ...
Plot Cross Section
Plot Profile ...
Plot XYZ ...
Plot Stage and Flow Hydrograph ...
Tabular Output
Rating Curve ...
View Photo ...
Reverse XS Stationing
Accept Displayed Cut Line (as GeoReferenced)
Move Cut Line Upstream/Downstream
20.343
20.294
20.207
20.111
20.021
19.92
19.827
19.732
19.635
19.542
19.446
19.352
19.256
19.162
None of the XS's are Geo-Referenced (— Geo-Ref user entered XS — Geo-Ref interpolated XS — Non Geo-Ref user entered XS — Non Geo-Ref interpolated XS)

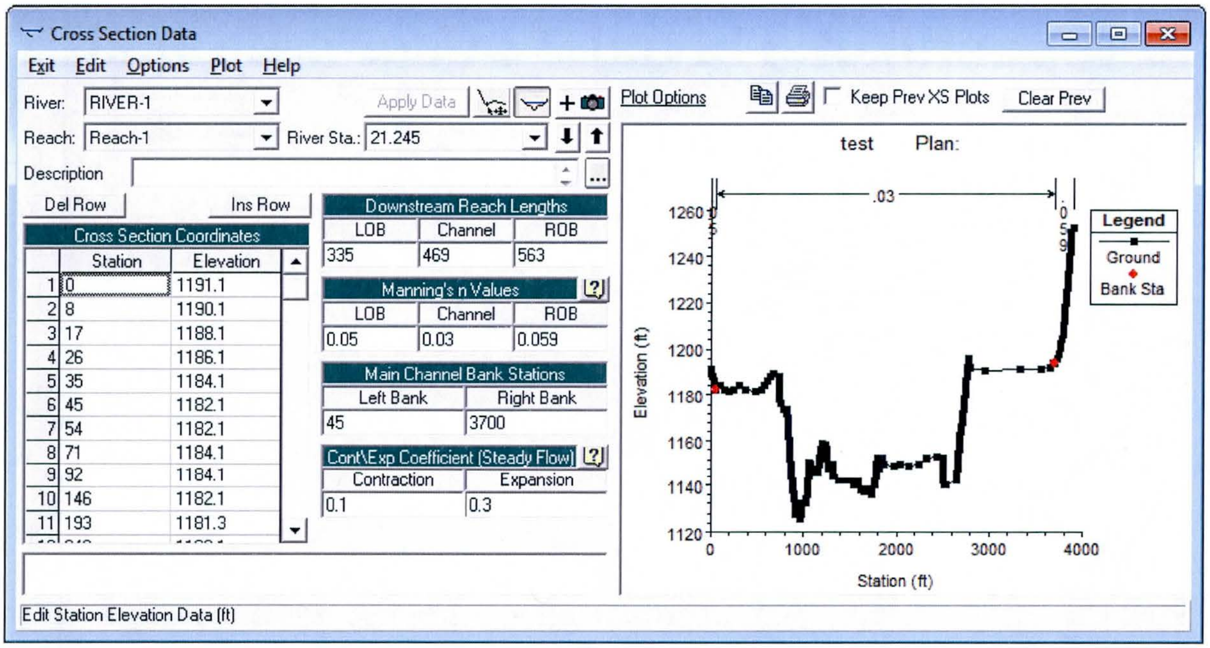


The red arrow indicates the buttons that allow the user to scroll through the cross section in the model, or a cross section can be selected from the pull down menu to the left of the scroll button.

Now close the "Cross Section" window that contains the plot of the cross section. Next click on the "Cross Section" button on the left side of the "Geometric Data" window indicated below by the red arrow.



Now the "Cross Section Data" window will open, this also plots the cross section and shows the data.


Cross Section Data
Exit Edit Options Plot Help
River: RIVER-1
Reach: Reach-1
River Sta.: 21.245
Apply Data
Plot Options
Keep Prev XS Plots
Clear Prev
Description
Del Row
Ins Row
Cross Section Coordinates
Station Elevation
1 0 1191.1
2 8 1190.1
3 17 1188.1
4 26 1186.1
5 35 1184.1
6 45 1182.1
7 54 1182.1
8 71 1184.1
9 92 1184.1
10 146 1182.1
11 193 1181.3
Downstream Reach Lengths
LOB Channel ROB
335 469 563
Manning's n Values
LOB Channel ROB
0.05 0.03 0.059
Main Channel Bank Stations
Left Bank Right Bank
45 3700
Cont\Exp Coefficient (Steady Flow)
Contraction Expansion
0.1 0.3
test Plan:
.03
Legend
Ground
Bank Sta
Elevation (ft)
Station (ft)
1260
1240
1220
1200
1180
1160
1140
1120
0
1000
2000
3000
4000
Edit Station Elevation Data (ft)

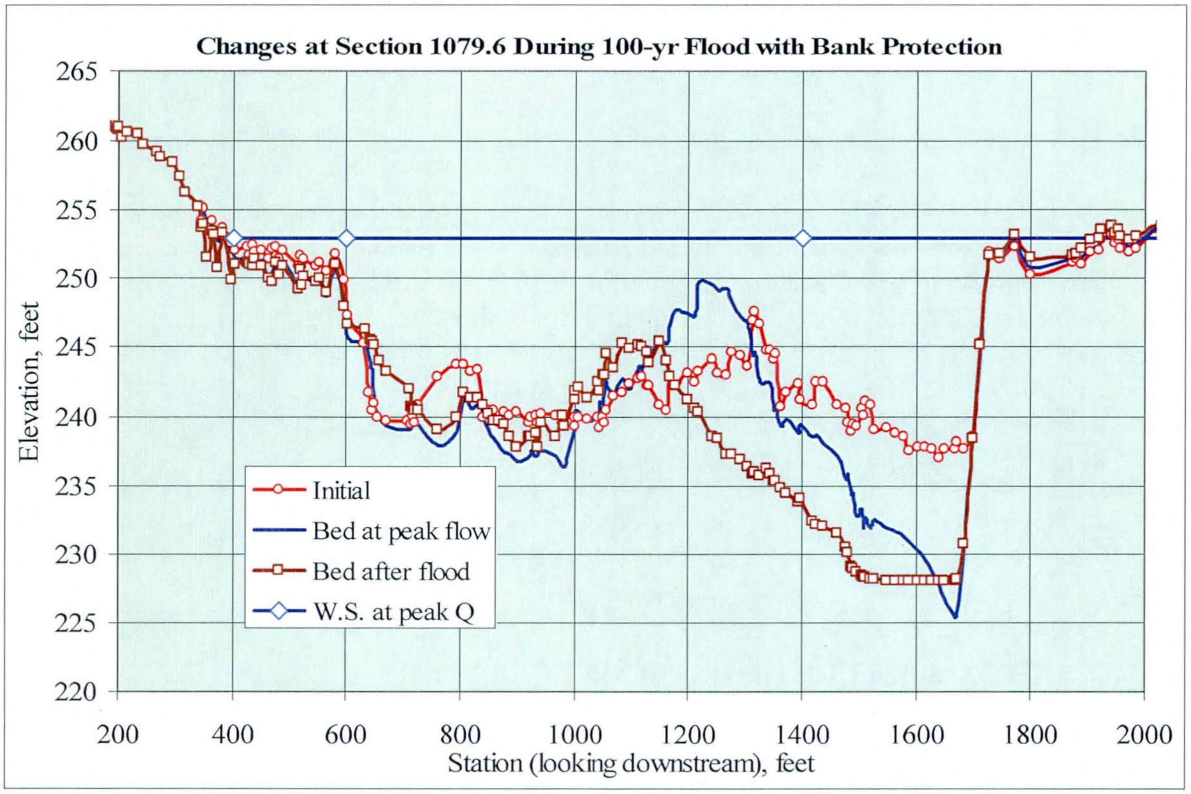
Appendix A: Fluvial-12 User's Manual

Generalized Computer Program

FLUVIAL-12

Mathematical Model for Erodible Channels

Users Manual



Updated In January 2006

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TABLE OF CONTENTS

This program is developed and furnished by Howard H. Chang and is accepted and used by the recipient upon the express understanding that the developer makes no warranties, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the information and data contained in this program or furnished in connection therewith, and the developer shall be under no liability whatsoever to any person by reason of any use made thereof.

PROGRAM SUMMARY FOR FLUVIAL-12

River channel behavior often needs to be studied for its natural state and response to human regulation. Studies of river hydraulics, sediment transport, and river channel changes may be through physical modeling, or mathematical modeling, or both. Physical modeling has been relied upon traditionally for river projects, but mathematical modeling is becoming more popular as its capabilities expand rapidly. The computer program FLUVIAL-12 is a mathematical model that is formulated and developed for water and sediment routing in natural and man-made channels. The combined effects of flow hydraulics, sediment transport and river channel changes are simulated for a given flow period.

River channels changes simulated by the model include channel bed scour and fill (or aggradation and degradation), width variation, and changes in bed topography induced by the curvature effect. These inter-related changes are coupled in the model for each time step. While this model is for erodible channels, physical constraints, such as bank protection, grade-control structures and bedrock outcroppings, may also be specified. Applications of this model include evaluations of general scour at bridge crossings, sediment delivery, channel responses to sand and gravel mining, channelization, etc. It has been applied to many designs for bank protection and grade-control structures which must extended below the potential channel bed scour and withstand the design flood.

This model is applicable to ephemeral rivers as well as rivers with long-term flow; it has also been tested and calibrated with field data from several rivers, in both semi-arid and humid regions. Because of the transient behavior in dynamic changes, ephemeral rivers require more complicated techniques in model formulation. This model may be used on any main frame computer; it may be used on a personal computer with adequate capacity.

The FLUVIAL-12 model is an *erodible-boundary model*; it simulated inter-related changes in channel-bed profile, channel width and bed topography induced by the channel curvature. The erodible-boundary model is different from an *erodible-bed model* in the following ways.

(1) An erodible-bed model does not simulate changes in channel width. Since changes in channel-bed profile is closely related to changes in width, these changes may not be separated.

(2) The change in bed profile in an erodible-bed model is assumed to be uniform in the erodible zone. All points adjust up and down by an equal amount during aggradation and degradation. Actual bed changes are by no means uniform and therefore they may not be simulated by an erodible-bed model.

(3) An erodible-bed model does not consider the channel curvature. In reality, the bed topography is highly non-uniform in a curved channel, especially during a high flow.

(4) The erodible zone needs to be specified at all cross sections in an erodible-bed model. This means the model does not provide the extent of erosion in the channel, but the user has to inform the model about the erodible part of the channel bed. The boundary of erosion is computed and provided by the FLUVIAL-12 model, this boundary changes with the discharge and time.
(5) Sediment inflow into the channel reaches needs to be specified for many other models. This

requires the sediment rating curve which is usually not available for stream channels. In the FLUVIAL-12 model, the sediment inflow may be specified and it may also be computed based on the hydraulics of flow at the upstream section at every time step.

(6) The FLUVIAL-12 has been calibrated using many sets of river data (see Section XI). An erodible-bed model may not be calibrated with field data of natural streams.

Development of the FLUVIAL computer model dates back to 1972. Several publications describing the physical foundation, analytical background, and applications are included in this manual. Publications documenting the successive stages of development and calibration of the model are listed below.

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Chang, H. H., 1987, "Modeling Fluvial Processes in Streams with Gravel Mining," in *Sediment Transport in Gravel-Bed Rivers*, Thorne, et al. editors, John Wiley & Sons, pp. 977-988. Also presented at the Intern. Workshop on Problems of Sediment Transport in Gravel-Bed River, Colorado State University, August 12-17, 1985.

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Chang, H. H., 1988, "Simulation of River Channel Changes Induced by Sand Mining", *Proceedings* of Intern. Conf. on Fluvial Hydraulics, IAHR, May 30-June 3, Budapest, Hungary.

Chang, H. H. and Stow, D., 1988, "Sediment Transport Characteristics of a Coastal Stream", *Journal of Hydrology*, Elsevier Science Publishers B. V., Amsterdam, 99, 201-214.

Yang, X-Q. and Chang, H. H., 1988, "Mathematical Modeling of Compound Channel with High Sediment Concentration", *Proceedings* of the National Conference on Hydraulic Engrg., August 8-12, Colorado Springs, Colo.

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Engineering, ASCE, 116(1).
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I. INTRODUCTION

Alluvial rivers are self-regulatory in that they adjust their characteristics in response to any change in the environment. These environmental changes may occur naturally, as in the case of climatic variation or changes in vegetative cover, or may be a result of such human activities as damming, river training, diversion, sand and gravel mining, channelization, bank protection, and bridge and highway construction. Such changes distort the natural quasi-equilibrium of a river; in the process of restoring the equilibrium, the river will adjust to the new conditions by changing its slope, roughness, bed-material size, cross-sectional shape, or meandering pattern. Within the existing constraints, any one or a combination of these characteristics may adjust as the river seeks to maintain the balance between its ability to transport and the load provided.

River channel behavior often needs to be studied for its natural state and responses to the aforementioned human activities. Studies of river hydraulics, sediment transport and river channel changes may be through physical modeling or mathematical modeling, or both. Physical modeling has been relied upon traditionally to obtain the essential design information. It nevertheless often involves large expenditure and is time consuming in model construction and experimentation. What limits the accuracy of physical modeling is the scale distortion which is almost unavoidable whenever it involves sedimentation.

Mathematical modeling of erodible channels has been advanced with the progress in the physics of fluvial processes and computer techniques. An evaluation of existing models was made by the National Academy of Sciences (1983). Recommendations in this report have been beneficial for subsequent model development. Since the actual size of a river is employed in mathematical modeling, there is no scale distortion. The applicability and accuracy of a model depend on the physical foundation and numerical techniques employed.

The traditional regime analyses of rivers are limited to regime rivers and their long-term adjustments in equilibrium. The hydraulic geometry, flow and sediment transport processes exhibited in the process of adjustments are outside the scope of regime approach but they are included in the mathematical modeling. This manual addresses the more rapid process-response or the transient behavior of alluvial rivers. The subject is on unsteady flow and sediment transport in river channels with a changing boundary under given physical constraints. In the following, the physical foundation and numerical techniques for the transient process-response of the FLUVIAL model are described. Users' instructions are provided. Applications of the FLUVIAL model are illustrated by examples given in the appendixes.

II. PHYSICAL FOUNDATION OF FLUVIAL PROCESS-RESPONSE

Mathematical modeling of river channel changes requires adequate and sufficient physical relationships for the fluvial processes. While the processes are governed by the principles of continuity, flow resistance, sediment transport and bank stability, such relations are insufficient to explain the time and spatial variations of channel width in an alluvial river. Generally, width adjustment occurs concurrently with changes in river bed profile, slope, channel pattern, roughness, etc. These changes are closely interrelated; they are delicately adjusted to establish or to maintain the dynamic state of equilibrium. While any factor imposed upon the river is usually absorbed by a combination of the above responses. The extent of each type of response is inversely related to the resistance to change.

The dynamic equilibrium is the direction toward which each river channel evolves. The transient behavior of an alluvial river undergoing changes must reflect its constant adjustment toward dynamic equilibrium, although, under the changing discharge, the true equilibrium may never be attained. For a short river reach of uniform discharge, the conditions for dynamic equilibrium are: (1) Equal sediment discharge along the channel, and (2) uniformity in power expenditure γQS, where γ is the unit weight of the water-sediment mixture, Q is the discharge, and S is the energy gradient. If the energy gradient is approximated by the water-surface slope, then uniform power expenditure or energy gradient is equivalent to the linear (straight-line) water-surface profile along the channel. A river channel undergoing changes usually does not have a linear water-surface profile or uniform sediment discharge, but river channel adjustments are such that the non- uniformities in water-surface profile and sediment discharge are effectively reduced. The rate of adjustment is limited by the rate of sediment movement and subject to the rigid constraints such as grade-control structures, bank protection, abutments, bedrock, etc.

The energy gradient at a river cross section varies wildly. This variable is usually included in a hydraulic computation such as that of a HEC-2 study. The output of any HEC-2 study, even if it is for a fairly uniform river channel, usually exhibits non-uniformity in energy gradient along the channel. This variation is much more pronounced in disturbed rivers. A mathematical modeler realizes that a river channel will change in order to attain stream wise uniformity in sediment load. It is equally important to perceive that it will also adjust toward equal energy gradient along the channel. Because sediment discharge is a direct function of γQS, channel adjustment in the direction of equal power expenditure also favors the uniformity in sediment discharge. The sediment discharge in the reach will match the inflow rate when the equilibrium is reached.

III. CHANNEL WIDTH ADJUSTMENTS DURING SCOUR AND FILL

A stream channel's adjustment in the direction of equal power expenditure, or straight water-surface profile, provides the physical basis for the modeling of channel width changes. However, this adjustment does not necessarily mean movement toward uniformity in channel width. For one thing, the power expenditure is also affected by channel roughness and channel-bed elevation, in addition to the width. But, more importantly, the adjustment toward uniformity in power expenditure is frequently accomplished by significant streamwise variation in width. Such spatial width variation generally occurs concurrently with streambed scour or fills to be illustrated in the following by several examples.

The transient behavior can be more clearly demonstrated by more dramatic river channel changes in the short term. Field examples of this nature are selected herein to illustrate how the significant spatial variation in width is related to river channel's adjustment toward uniform power expenditure. This example will also show why the regime approach may not be employed to simulate river channel changes.

Figure 1 shows a short reach of the San Diego River at Lakeside, California on February 25, 1981 during the initial stage of a storm. The estimated discharge of 600 cfs persisted for several subsequent days. Prior to the storm, this sandy streambed was graded, because of sand mining, to a wavy profile. During the initial period of flow, the water-surface profile was not straight because its gradient was steeper over higher streambed areas than over lower areas. Gradually, these higher streambed areas were scoured while lower places were filled. Small widths formed with streambed scour, whereas large widths developed with fill as shown in the figure. The width development in this case was rapid in occurrence in the sandy material, its significant streamwise variation is depicted by the natural streamlines visible on the water surface. This pattern of significant spatial variation in width actually represents the stream's adjustment toward equal energy gradient, as explained in the following.

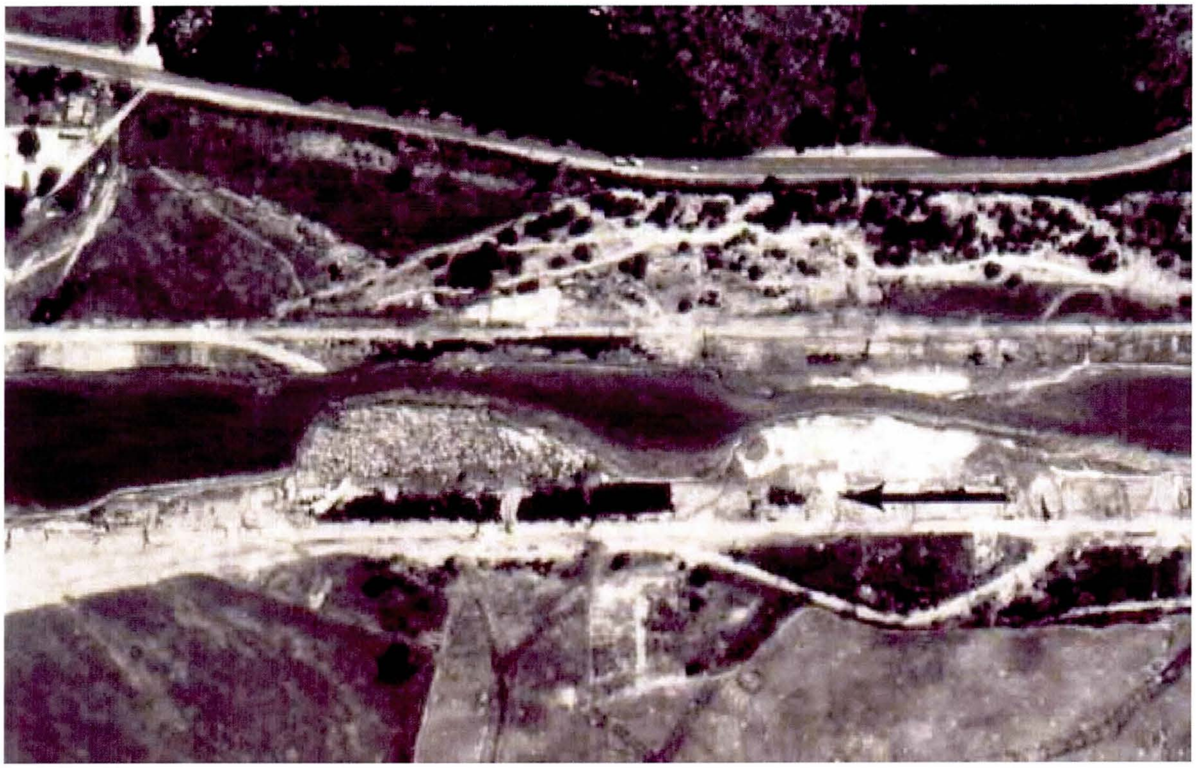

Fig. 1 Streamwise variation in width during stream channel adjustment toward establishing straight water-surface profile, San Diego River at Lakeside, California

The streambed area undergoing scour had a steeper energy gradient (or water-surface slope) than its adjacent areas. Formation of a narrower and deeper channel was effective to reduce the energy gradient due to decreased boundary resistance and lowered streambed elevation. In addition, the cross section developed a somewhat circular shape, which conserved power as a result of being closer to the best hydraulic section. On the other hand, the streambed area undergoing fill had a lower streambed elevation and a flatter energy gradient. Channel widening at this area was effective to steepen its energy gradient due to the increasing boundary resistance and rising streambed elevation. In summary, these adjustments in channel width effectively reduced the spatial variation in power expenditure or non-linearity in water-surface profile. Because sediment discharge is a direct function of stream power γQS, channel adjustment in the direction of equal power expenditure also favors the equilibrium, or uniformity, in sediment discharge.

The significant spatial width variation shown in Fig. 1 was temporary. The small width lasted while streambed scour continued and the large width persisted with sustained fill. At a later stage when scour and fill ceased, the energy gradient or water-surface slope associated with the small width became flatter than that for the large width. The new profile of energy gradient or water surface became a reversal of the initial profile. Then, the small width started to grow wider while the large width began to slide back into the channel, resulting in a more uniform width along the channel.

The above example illustrates that a regime relationship for channel width may not be used in simulating transient river channel changes. Under the regime relationship, the width is a direct function of the discharge, i.e., B % $Q^{0.5}$; but under transient changes, the channel can have very different widths even though the discharge is essentially uniform along the channel.

The characteristic changes in channel width during channel-bed scour and fill were also observed by Andrews (1982) on the East Fork River in Wyoming. This river was in its natural state, undisturbed by human activities. River channel changes were induced by the variation in discharge.

In 1906, the Associated Press filed a well-written report that seemed to end one of the world's most spectacular stories. In the story, the AP reported that the Colorado River flooded; the water moved from the All American Canal to the New River and poured down to the Salton Sea. The sea rose 7 in. per day. The water became a cascade and its force cut back the banks. Soon the bank was receding faster and faster, moving upstream into the valley at a pace of 4000 ft a day; widening the New River channel to a gorge of more than 1000 feet. This example also illustrates the dramatic widening of river channel associated with a rising bed elevation.

A field study by the U. S. Bureau of Reclamation (1963) upstream of Milburn Diversion Dam on the Middle Loup River, central Nebraska also exemplifies the aggradation of a channel and associated channel widening.

> The construction of Milburn Diversion Dam was completed in May, 1956 ... By May 1957, two months after the reservoir was impounded for the first irrigation season, the channel had aggraded an average of 1.6 feet, with a rise in the channel thalweg elevation of 2.2 feet; and by October of the same year, the total rise in the streambed averaged 2.2 feet. The cross section obtained in December 1957 shows a continued rise in the thalweg elevation. During the same period, the width of the channel had increased by 70 feet, from 475 feet in 1951 to 545 feet in 1957. One-third of this increase occurred during the June, 1956 - December, 1957 period.

For these two case histories, both alluvial rivers entered reservoirs with a rising base level. The transient changes are characterized by rising channel bed and increasing channel width. Although measurements of the discharge and other parameters are not available, it is possible to describe, at least in trend, the nature of power transformation in the river channel. At the river mouth, the base level was controlled in the reservoir. The rising base level first caused a lower velocity and energy gradient in the river channel near the mouth in relation to its upstream reach. In response to this change, channel adjustments through widening and aggradation near the mouth provided greater flow resistance and power expenditure at this location partly due to the increased boundary resistance. This process resulted in a more uniform power expenditure per unit channel length along the river.

A lowering base level, on the other hand, would result in a higher energy gradient in the river channel near the mouth. The higher energy gradient could be reduced through the development of a narrower and deeper channel at this location. This process would also result in a more uniform power expenditure along the channel. Such morphological features for deltas are also applicable to alluvial fans and hill slopes.

IV. ANALYTICAL BASIS OF THE FLUVIAL MODEL

The FLUVIAL model with different versions has been developed for water and sediment routing in rivers while simulating river channel changes as documented in a series of publications listed in Section I. River channel changes simulated by the model include channel-bed scour and fill (or aggradation and degradation), width variation, and changes caused by curvature effects. Because changes in channel width and channel-bed profile are closely inter-related, modeling of erodible channels must include both changes. In fact, width changes are usually greater than the concomitant scour and fill in the bed, particularly in ephemeral streams. The analytical background of the FLUVIAL model is described in the following.

The FLUVIAL model has the following five major components: (1) Water routing, (2) sediment routing, (3) changes in channel width, (4) changes in channel-bed profile, and (5) changes in geometry due to curvature effect. These inter-related components are described in the following sections. A flow chart showing the major steps of the computation is given in Fig. 2.

This model employs a space-time domain in which the space domain is represented by the discrete cross sections along the channel; the time domain is represented by discrete time increments. Temporal and spatial variations in flow, sediment transport and channel geometry are computed following an iterative procedure. Water routing, which is coupled with the changing curvature, is assumed to be uncoupled from the sediment processes because sediment movement and changes in channel geometry are slow in comparison to the flow hydraulics.

V. WATER ROUTING

Water routing provides temporal and spatial variations of the stage, discharge, energy gradient and other hydraulic parameters in the channel. The water routing component has the following three major features: (1) Numerical solution of the continuity and momentum equations for longitudinal flow, (2) evaluation of flow resistance due to longitudinal and transverse flows, and (3) upstream and downstream boundary conditions. The continuity and momentum equations in the longitudinal direction are

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial s} - q = 0 \tag{1}$$

$$\frac{1}{A}\frac{\partial Q}{\partial t} + g\frac{\partial H}{\partial s} + \frac{1}{A}\frac{\partial}{\partial s}\frac{Q^2}{A} + gS - \frac{Q}{A^2}q = 0 \tag{2}$$

where Q is the discharge, A is the cross-sectional area of flow, t is the time, s is the curvilinear coordinate along discharge centerline measured from the upstream entrance, q is the lateral inflow rate per unit length, H is the stage or water-surface elevation, and S is the energy gradient. The upstream boundary condition for water routing is the inflow hydrographs; the downstream condition is the stage-discharge relation or the base-level variation. Techniques for numerical solution of Eqs. 1 and 2 are described by Chen (1973) and Fread (1971, 1974), among others.

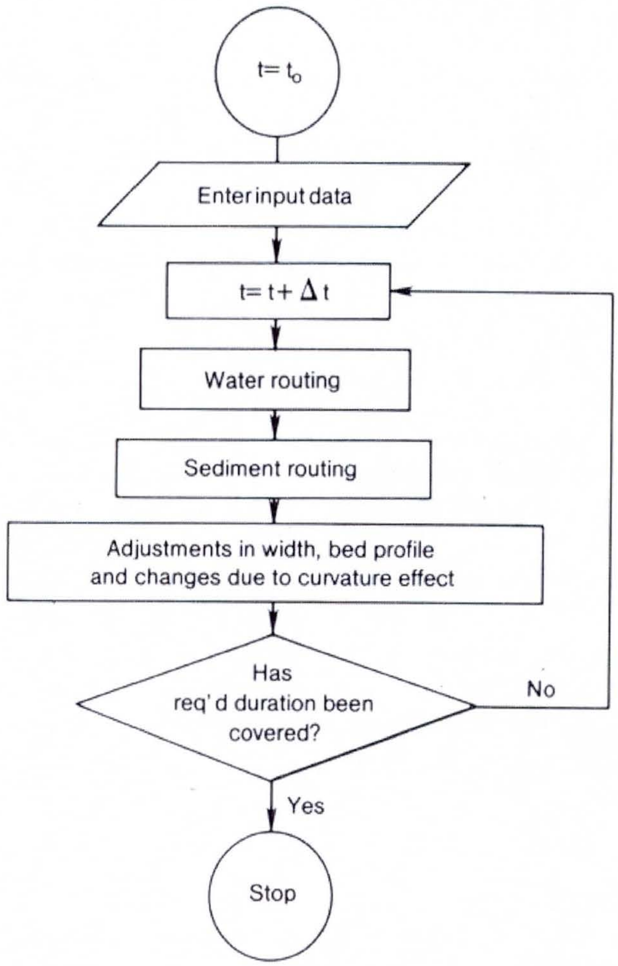

Fig. 2 Flow chart showing major steps of computation for FLUVIAL model

In a curved channel, the total energy gradient, S, in Eq. 2 is partitioned into the longitudinal energy gradient, S', and the transverse energy gradient, S'', due to secondary currents, i.e.

$$S = S' + S'' \tag{3}$$

The longitudinal energy gradient can be evaluated using any valid flow resistance relationship. If Manning's formula is employed, the roughness coefficient n must be selected by the modeler. However, if a formula for alluvial bed roughness (e.g., Brownlie's formula, 1983) is used, the roughness coefficient is predicted by the formula.

Method for evaluating the transverse energy gradient by Chang (1983) is used in the model. Because of the streamwise changing curvature, the transverse energy loss varies with the growth and decay of secondary currents. Analytical relationships pertaining to curved channels are often based upon the mean channel radius, r_c. Under the streamwise changing curvature, the application of such relationships is limited to fully-developed transverse flow for which the curvature is defined. Streamwise variation of transverse flow, over much of the channel length, is characterized by its growth and decay. In order to describe this spatial variation, the mean flow curvature defined as the flow curvature along the discharge centerline is employed. It is assumed that analytical relationships for developed transverse flows are applicable for developing transverse flows when the mean channel curvature, r_c, is replaced by the mean flow curvature, r_f. Upon entering a bend, the mean flow curvature increases with the growth in transverse circulation. In a bend, the transverse flow becomes fully developed if the flow curvature approaches the channel curvature. In the case of exiting from a bend to the downstream tangent in which the channel curvature is zero, the flow curvature decreases with the decay of transverse circulation.

The reason that the flow curvature lags behind the channel curvature during circulation growth and decay is attributed to the internal turbulent shear that the flow has to overcome in transforming from parallel flow into the spiral pattern and vice versa. From the dynamic equation for the transverse velocity, an equation governing the streamwise variation in transverse surface velocity, v, was derived (Chang, 1984). In finite difference form, the change in v over the distance Δs is given by

$$v_{i+1} = \left\{ v_i + F_1(f) \frac{U}{r_c} \exp[F_2(f)\ \Delta s]\ \Delta s \right\} \exp[-F_2(f)\ \Delta s] \qquad (4)$$

where v is the transverse surface velocity along discharge centerline, U is the average velocity of a cross section, i and i+1 are s-coordinate indices, F_1 and F_2 are functions of f (friction factor) and depth, and the overbar denotes averaging over the incremental distance between i and i+1. Eq. 4 provides the spatial variation in v, from which the mean flow curvature may be obtained using the transverse velocity profile. From the transverse velocity profile by Kikkawa, et al. (1976), the mean flow curvature, r_f, is related to the transverse surface velocity as

$$r_f = \frac{D_c}{\kappa} \frac{U}{v} \left\{ \frac{10}{3} - \frac{1}{\kappa} \frac{5}{9} \left(\frac{f}{2} \right)^{1/2} \right\} \qquad (5)$$

where D_c is the flow depth at discharge centerline (thalweg) and κ is the Karman constant. At each time step, the mean flow curvature at each cross section is obtained using Eqs. 4 and 5. Accuracy of computation for the finite-difference equation (Eq. 4) is maintained if the step size $\Delta s \leq 2D_c$. For this reason, the distance between two adjacent cross sections is divided into smaller increments if necessary. Flow parameters for these increments are interpolated from values known at adjacent cross sections.

If the temporal terms in Eqs. 1 and 2 are ignored, water routing may be simplified by computing water-surface profiles at successive time steps. This option is available in the model. Computation of the water-surface profile at each time step is based upon the standard-step method (see Chow, 1957) using techniques similar to the HEC-2 computer model (U. S. Army Corps of

Engineers, 1982). For many cases, spatial variation in discharge due to channel storage is small and this technique produces closely similar results as the unsteady routing.

VI. SEDIMENT ROUTING

The sediment routing component for the FLUVIAL model has the following major features: (1) Computation of sediment transport capacity using a suitable formula for the physical conditions, (2) determination of actual sediment discharge by making corrections for sorting and diffusion, (3) upstream conditions for sediment inflow, and (4) numerical solution of the continuity equation for sediment. These features are evaluated at each time step, the results so obtained are used in determining the changes in channel configuration.

Determination of Sediment Discharge

To treat the time-dependent and non-equilibrium sediment transport, the bed material at each section is divided into several, say five, size fractions; the size for each fraction is represented by its geometric mean. For each size fraction, sediment transport capacity is first computed using a sediment-transport formula. The FLUVIAL model currently provides the choices of the following six sediment formulas: (1) Engelund-Hansen formula (1967), (2) Yang's unit stream power formula (1972, 1986), (3) Graf's formula (1970), (4) Ackers-White formula, (5) Parker, et al. formula for gravel (1982), and (6) Meyer-Peter and Muller bedload formula. The actual sediment rate is obtained by considering sediment material of all size fractions already in the flow as well as the exchange of sediment load with the bed using the method by Borah et al. (1982). If the stream carries a load in excess of its capacity, it will deposit the excess material on the bed. In the case of erosion, any size fraction available for entrainment at the bed surface will be removed by the flow and added to the sediment already in transport. During sediment removal, the exchange between the flow and the bed is assumed to take place in the active layer at the surface. Thickness of the active layer is based upon the relation defined by Borah, et al. This thickness is a function of the material size and composition, but also reflects the flow condition. During degradation, several of these layers may be scoured away, resulting in the coarsening of the bed material and formation of an armor coat. However, new active layers may be deposited on the bed in the process of aggradation. Materials eroded from the channel banks, excluding that portion in the wash load size range, are included in the accounting. Bed armoring develops if bed shear stress is too low to transport any available size.

The non-equilibrium sediment transport is also affected by diffusion, particularly for finer sediments. Because of diffusion, the deposition or entrainment of sediment is a gradual process and it takes certain travel time or distance to reach the transport capacity for a flow condition. Therefore, the actual sediment discharge at a section depends not only on the transport capacity at the section but also on the supply from upstream and its gradual adjustment toward the flow condition of this section. In the model, the sediment discharge is corrected for the diffusion effects on deposition and entrainment using the method by Zhang, et al. (1983). The procedures for computing sediment transport rate, sediment sorting and diffusion are applied to the longitudinal and transverse directions. They are also coupled with bed-profile evolution, which is described later in this section.

Sediment discharge may be limited by availability, as exemplified by the flow over a grade-control structure or bed rock. The very high transport capacity at such a section, associated with the high velocity, is limited by the supply rate from upstream; that is, the sediment discharge at such a section is under upstream control.

Upstream Boundary Conditions for Sediment Inflow

The rate of sediment inflow into the study reach is provided by the upstream boundary condition for sediment. If this rate is known, it may be included as a part of the input and used in the simulation. Unfortunately, sediment rating data are rarely very reliable or simply not available. For such cases, it is assumed that the river channel remains unchanged above the study reach, and sediment inflow rate is computed at the upstream section at each time step, the same way they are computed at other cross sections. For this reason, the study reach should extend far enough upstream so that the channel beyond may be considered basically stable. Factors that may induce river channel changes must be included in the study reach.

Numerical Solution of Continuity Equation for Sediment

Changes in cross-sectional area, due to longitudinal and transverse imbalances in sediment discharge, are obtained based upon numerical solution of continuity equations for sediment in the respective directions. First, the continuity equation for sediment in the longitudinal direction is

$$(1 - \lambda)\frac{\partial A_b}{\partial t} + \frac{\partial Q_s}{\partial s} - q_s = 0 \qquad (6)$$

where λ is the porosity of bed material, A_b is the cross-sectional area of channel within some arbitrary frame, Q_s is the bed-material discharge, and q_s is the lateral inflow rate of sediment per unit length. According to this equation, the time change of cross-sectional area $\partial A_b/\partial t$ is related to the longitudinal gradient in sediment discharge $\partial Q_s/\partial s$ and lateral sediment inflow q_s. In the absence of q_s, longitudinal imbalance in Q_s is absorbed by channel adjustments toward establishing uniformity in Q_s.

The change in cross-sectional area ΔA_b for each section at each time step is obtained through numerical solution of Eq. 6. This area change will be applied to the bed and banks following correction techniques for channel width and channel-bed profile.

From Eq. 6, the correction in cross-sectional area of channel bed for a time increment can be written as

$$\Delta A_b = - \frac{\Delta t}{1 - \lambda}\left(\frac{\partial Q_s}{\partial s} - q_s\right) \qquad (7)$$

At a section i, the lateral sediment inflow may be written as

$$q_{s_i} = \frac{1}{2}\left(q_{s_i}^{j} + q_{s_i}^{j+1} \right) \qquad (8)$$

where superscripts j and j+1 are the times at t and $t+\Delta t$, respectively. This model employs an upstream difference in s and a centered difference in t for the partial derivative, $\partial Q_s/\partial s$, in Eq. 6, i.e.

$$\left(\frac{\partial Q_s}{\partial s}\right)_i = \frac{2}{\Delta s_i + \Delta s_{i-1}} \left(\frac{Q_{s_i}^{j} + Q_{s_i}^{j+1}}{2} - \frac{Q_{s_{i-1}}^{j} + Q_{s_{i-1}}^{j+1}}{2} \right) \tag{9}$$

where Δs_i is the distance between sections i and i+1, Δs_{i-1} is the distance between i-1 and i. With this upstream difference for $\partial Q_s/\partial s$, the change in bed area at a section i depends on sediment rates at this section and its upstream section i-1; it is independent of the sediment rate at the downstream section. In other words, it is under upstream control. Contrary to this, the stage at a section in subcritical flow depends on the downstream stage and is independent of the upstream stage; i.e., the stage is under downstream control in a subcritical flow.

VII. SIMULATION OF CHANGES IN CHANNEL WIDTH

The change in cross-sectional area ΔA_b obtained in sediment routing represents the correction for a time increment Δt that needs to be applied to the bed and banks. With ΔA_b being the total correction, it is possible for both the bed and banks to have deposition or erosion; it is also possible to have deposition along the banks but erosion in the bed and vice versa. The direction of width adjustment is determined following the stream power approach and the rate of change is based upon bank erodibility and sediment transport described in the following.

Direction of Width Adjustment

For a time step, width corrections at all cross sections are such that the streamwise distribution of stream power for the reach moves toward uniformity; these corrections are subject to the physical constraint of rigid banks and limited by the amount of sediment removal or deposition along the banks within the time step. A river channel undergoing changes usually has nonuniform spatial distribution in power expenditure or γQS. Usually the spatial variation in Q is small, but that in S is pronounced. An adjustment in width reflects the river's adjustment in flow resistance, that is, in power expenditure. A reduction in width at a cross section is usually associated with a decrease in energy gradient for the section, whereas an increase in width is accompanied by an increase in energy gradient. To determine the direction of width change at a section I, the energy gradient at this section, S_i, is compared with the weighted average of its adjacent sections, S_i. Here

$$S_i = \frac{S_{i+1}\,\Delta s_{i-1} + S_{i-1}\,\Delta s_i}{\Delta s_i + \Delta s_{i-1}} \tag{10}$$

If the energy gradient S_i is greater than S_i, channel width at this section is reduced so as to decrease the energy gradient. On the other hand, if S_i is lower, channel width is increased in order to raise the energy gradient. These changes are subject to the rate of width adjustment and physical constraints.

Width changes in alluvial rivers are characterized by widening during channel-bed aggradation (or fill) and reduction in width at the time of degradation (or scour). Such river channel changes represent the river's adjustments in resistance to seek equal power expenditure along its course. A degrading reach usually has a higher channel-bed elevation and energy gradient than do its adjacent sections. Formation of a narrower and deeper channel at the degrading reach decreases its energy gradient due to reduced boundary resistance. On the other hand, an aggrading reach is usually lower in channel-bed elevation and energy gradient. Widening at the aggrading reach increases its energy gradient due to increasing boundary resistance. These adjustments in channel width reduce the spatial variation in energy gradient and total power expenditure of the channel.

Rate of Width Adjustment

For a time increment, the amount of width change depends on the sediment rate, bank configuration and bank erodibility. The slope of an erodible bank is limited by the angle of repose of the material. The rate of width change depends on the rate at which sediment material is removed or deposited along the banks. For the same sediment rate, width adjustment at a tall bank is not as rapid as that at a low bank. The rates of width adjustment for cases of width increase and decrease are somewhat different as described below separately.

An increase in width at a channel section depends on sediment removal along the banks. The maximum rate of widening occurs when sediment inflow from the upstream section does not reach the banks of this section while bank material at this section is being removed. River banks have different degrees of resistance to erosion; therefore, the rate of sediment removal along a bank needs to be modified by a coefficient. For this purpose, the bank erodibility factor is introduced as an index for the erosion of bank material and the four bank types reflecting the variation in erodibility are classified as follows

(1) Non-erodible banks.

(2) Erosion-resistant banks, characterized by highly cohesive material or substantial vegetation, or both.

(3) Moderately erodible banks having medium bank cohesion.

(4) Easily erodible banks with noncohesive material.

Values of the bank erodibility factor vary from 0 for the first type to 1 for the last type of banks. The values of 0.2 and 0.5 have been empirically determined for the second and third types, respectively, based upon test and calibration of the model using field data from rivers in the western U. S. However, the bank erodibility factor should still be calibrated whenever data on width changes are available.

A decrease in channel width is accomplished by sediment deposition along the banks or by a decrease in stage, or both. For practical reasons, deposition does not exceed the stage in the model. The maximum amount of width reduction at a section occurs when sediment inflow from the upstream section is spread out at this section and the sediment removal from the bank areas at this section is zero. Within the limit of width adjustment, changes in width are made at all cross sections in the study reach toward establishing uniformity in power expenditure.

VIII. SIMULATION OF CHANGES IN CHANNEL-BED PROFILE

After the banks are adjusted, the remaining correction for ΔA_b is applied to the bed.

Distributions of erosion and deposition, or scour and fill, at a cross section are usually not uniform. Generally speaking, deposition tends to start from the low point and is more uniformly distributed because it tends to build up the channel bed in nearly horizontal layers. This process of deposition is often accompanied by channel widening. On the other hand, channel-bed erosion tends to be more confined with greater erosion in the thalweg. This process is usually associated with a reduction in width as the banks slip back into the channel. Such characteristic channel adjustments are effective in reducing the streamwise variation in stream power as the river seeks to establish a new equilibrium. In the model, the allocation of scour and fill across a section during each time step is assumed to be a power function of the effective tractive force $\tau_o - \tau_c$, i.e.

$$\Delta z = \frac{(\tau_o - \tau_c)^m}{\sum_B (\tau_o - \tau_c)^m \Delta y} \Delta A_b \tag{11}$$

where Δz is the local correction in channel-bed elevation, τ_o (given by γDS) is the local tractive force, τ_c is the critical tractive force, m is an exponent, and y is the horizontal coordinate, and B is the channel width. The value of τ_c is zero in the case of fill.

The m value in Eq. 11 is generally between 0 and 1; it affects the pattern of scour-fill allocation. For the schematic cross section shown in Fig. 3, a small value of m, say 0.1, would mean a fairly uniform distribution of Δz across the section; a larger value, say 1, will give a less uniform distribution of Δz and the local change will vary with the local tractive force or roughly the depth. The value of m is determined at each time step such that the correction in channel-bed profile will result in the most rapid movement toward uniformity in power expenditure, or linear water-surface profile, along the channel.

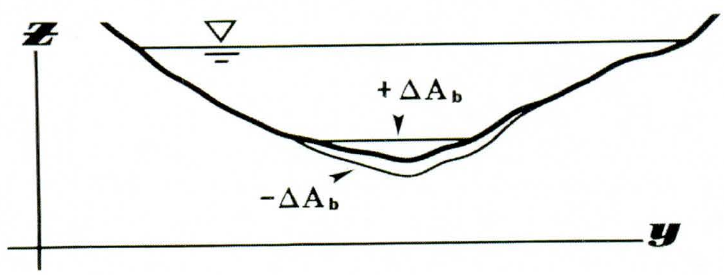

Fig. 3. Corrections of bed profile for aggradation and degradation. They are made in such ways that water-surface profile or power expenditure moves toward uniformity.

Equation 11 may only be used in the absence of channel curvature. The change in bed area at a cross section in a curved reach is

$$\Delta A_b = \frac{1}{r_f} \int r dz\, dr \tag{12}$$

where r_f is the radius of curvature at the discharge centerline or thalweg. Because of the curvature, adjacent cross sections are not parallel and the spacing Δs between them varies across the width. Therefore, the distribution of Δz given in Eq. 11 needs to be weighted according to the r-coordinate with respect to the thalweg radius, r_f/r, i.e.

$$\Delta z = \frac{(\tau_o - \tau_c)^m/r}{\sum_B (\tau_o - \tau_c)^m/r \, \Delta r} \Delta A_b \tag{13}$$

IX. SIMULATION OF CHANGES DUE TO CURVATURE EFFECT

Simulation of curvature-induced scour and deposition is based upon the flow curvature for which the streamwise variation is given by Eq. 4. The major features of transverse sediment transport and changes in bed topography are described below.

Sediment transport, in the presence of transverse flow, has a component in that direction. Sediment movement in the transverse direction contributes to the adjustment of transverse bed profile. In an unsteady flow, the transverse bed profile varies with time, and it is constantly adjusted toward equilibrium through scour and deposition. The transverse bed load per unit channel length q_b' can be related to the streamwise transport q_b. Such a relationship by Ikeda (1982) can be written in parametric form as

$$\frac{q_b'}{q_b} = F\left(\tan\delta, \frac{\partial z}{\partial r}\right) \tag{14}$$

where δ is the angle of deviation of bottom currents from the streamwise direction. The near-bed transverse velocity is a function of the curvature, and it is computed using the flow curvature.

Equation 14 relates the direction of bed-load movement to the direction of near-bed velocity and transverse bed slope $\partial z/\partial r$. As transverse velocity starts to move sediment away from the concave bank, it creates a transverse bed slope that counters the transverse sediment movement. An equilibrium is reached, i.e., $q_b' = 0$, when the effects of these opposing tendencies are in balance. Transverse bed-profile evolution is related to the variation in bed-material load. Ikeda and Nishimura (1986) developed a method for estimating transport and diffusion of fine sediments in the transverse direction by vertical integration of suspended load over the depth. Their model for predicting the transverse bed slope is also employed.

Changes in channel-bed elevation at a point due to transverse sediment movement are computed using the transverse continuity equation for sediment

$$\frac{\partial z}{\partial t} + \frac{1}{1-\lambda}\frac{1}{r}\frac{\partial}{\partial r}(r\, q_s') = 0 \tag{15}$$

Written in finite difference form with a forward difference for q_s', this equation becomes

$$\Delta z_k = \frac{\Delta t}{1 - \lambda} \frac{2}{r_k} \frac{r_{k+1}\, q'_{s\,k+1} - r_k\, q'_{s\,k}}{r_{k+1} - r_{k-1}} \tag{16}$$

where k is the radial (transverse) coordinate index measured from the center of radius. Equation 16 provides the changes in channel-bed elevation for a time step due to transverse sediment movement. These transverse changes, as well as the longitudinal changes, are applied to the stream bed at each time step. Bed-profile evolution is simulated by repeated iteration along successive time steps.

X. TEST AND CALIBRATION OF FLUVIAL-12

The accuracy of a mathematical model depends on the physical foundation, numerical techniques, and physical relations for momentum, flow resistance and sediment transport. Test and calibration are important steps to be taken for more effective use of a model. Because of the difference in sensitivity of simulated results to each relation or empirical coefficient, more attention needs to be paid to those that generate sensitive results. Major items that require calibration include the roughness coefficient, sediment transport equation, bank erodibility factor, bed erodibility factor, and so on.

To determine the sensitivity of flow, the sediment transport, and the channel changes caused by the variation of each variable, different values of the variable need to be used in simulation runs and the results so obtained are compared. Generally speaking, the rate of channel changes is more sensitive to the sediment rate computed from a sediment equation but the equilibrium channel configuration is less sensitive. For example, the constriction scour at a bridge crossing, or the equilibrium local scour at a bridge pier, is found to be more or less independent of the sediment equation, or sediment size, since both inflow and outflow rates of sediment are affected by about the same proportion. It may also be stated that the rate of widening is sensitive to the bank erodibility factor but that the equilibrium width is not nearly as sensitive.

Field data are generally used for test and calibration of a model. The required information includes channel configuration before and after the changes, a flow record, and sediment characteristics. Data sets with more complete information are also more useful. The FLUVIAL-12 has undergone test and calibration using many data sets. Such studies together with their respective references are given below. Many such data sets are also useful for the test and calibration of other models.

(1) Test and Calibration Study Using Data from the San Diego River in Southern California. Chang, H. H., 1982, "Mathematical Model for Erodible Channels", *Journal of the Hydraulics Division*, ASCE, 108(HY5), 678-689. Closure in 109(HY4), 655-656.

(2) Test and Calibration Study Using Data from the Inlet Channel of San Elijo Lagoon in Southern California. Chang, H. H., and Hill, J. C., 1977, "Minimum Stream Power for Rivers and Deltas," *Journal of the Hydraulics Division*, ASCE, 103(HY12), 1375-89.

(3) Test and Calibration Study Using Data from the San Dieguito River in Southern California.

Chang, H. H., 1984, "Modeling of River Channel Changes", *Journal of Hydraulic Engineering*, ASCE, 110(2), 157-172. Closure in 113(2), 1987, 265-267.

(4) Test and Calibration Study Using Data from the San Lorenzo River in Northern California. Chang, H. H., 1985, "Water and Sediment Routing through Curved Channels", *Journal of Hydraulic Engineering*, ASCE, 111(4), 644-658.

(5) Test and Calibration Study Using Data from San Juan Creek in Southern California. Chang, H. H., 1987, "Modeling Fluvial Processes in Streams with Gravel Mining," in *Sediment Transport in Gravel-Bed Rivers*, Thorne, et al. editors, John Wiley & Sons, pp. 977-988. Also presented at the International Workshop on Problems of Sediment Transport in Gravel-Bed River, Colorado State University, August 12-17, 1985.

(6) Test and Calibration Using the Missouri River Data in Iowa. Chang, H. H., 1988, "Test and Calibration Study of the FLUVIAL Model Using the Missouri River Data", Prepared for the Waterways Experiment Station, U.S. Army Corps of Engineers, Under Contract "Computer-Based Design of River Bank Protection", No. DACW39-87-0039.

(7) Test and Calibration Study Using Data from the Santa Clara River in Southern California. Chang, H. H. and Stow, D., 1989, "Mathematical Modeling of Fluvial Sediment Delivery", *Journal of Waterway, Port, Coastal, and Ocean Engineering*, ASCE, 115(3), 311-326.

(8) Test and Calibration Study Using Data from the Fall River in Colorado. Chang, H. H., 1991, "Simulation of Bed Topography in a Meandering River", *Proceedings* of the Fifth Interagency Sedimentation Conference, Las Vegas, NV, March 21-28.

(9) Test and Calibration Study Using Data from the San Luis Rey River in Southern California. Chang, H. H., 1991, "Computer Simulation of River Channel Changes Induced by Sand Mining", *Proceedings* of International Conference on Computer Applications in Water Resources, July 3-6, Taipei, Taiwan, Vol. 1, 226-234.

(10) Test and Calibration Study Using Data from Stony Creek in Northern California. Chang, H. H., Harris, C., Lindsay, W., Nakao, S. S., and Kia, R., 1993, "Selecting Sediment Transport Equation for Scour Simulation at Bridge Crossing", *Proceedings* of the 1993 National Conference on Hydraulic Engineering, San Francisco, CA, July 25-30, pp. 1744-1949. Chang, H. H., 1994, "Selection of Gravel-Transport Formula for Stream Modeling", *Journal of Hydraulic Engineering*, ASCE, Vol. 120, No. 5, May, pp. 646-651.

(11) Test and Calibration Study Using Data from the Feather River in Northern California. Chang, H. H., 1993, "Numerical Modeling for Sediment-Pass-Through Operations of Reservoirs on North Fork Feather River", prepared for Pacific Gas & Electric Company, San Francisco. Chang, H. H., Harrison, L., Lee, W., and Tu, S., 1996, "Numerical Modeling for Sediment-Pass-Through Reservoirs", *Journal of Hydraulic Engineering*, ASCE, Vol. 122, No. 7, pp. 381-388.

(12) Test and Calibration Study Using Data from the San Dieguito River in Southern California for the 1993 Floods. Chang, H. H., Grove, R., and Pearson, D., 2001, "Modeling Changes in an Ephemeral Coastal River", *Journal of Floodplain Management*, Floodplain Management

Association, Vol. 2, No. 2, April, pp. 17-28.

(13) Test and Calibration Study Using Data from a Tidal Inlet with Oscillating Tidal Flow. Chang, H. H., 1997, "Modeling Fluvial Processes in Tidal Inlet", *Journal of Hydraulic Engineering*, ASCE, Vol. 123, No. 12, pp. 1161-1165.

(14) Correlation Study of FLUVIAL-12 Model Using Flume Data from National Taiwan University, Master's Thesis by Thomas Macchiarella, San Diego State University, May 2001.

(15) Chang, H.H., "A Case Study of Fluvial Modeling of River Responses to Dam Removal", *Journal of Hydraulic Engineering*, ASCE, 2006.

APPENDIX A. REFERENCES

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APPENDIX B. USERS INSTRUCTIONS FOR THE FLUVIAL MODEL

I. INPUT DESCRIPTION

The basic data requirements for a modeling study include (1) topographic maps of the river reach from the downstream end to the upstream end of study, (2) digitized data for cross sections in the HEC-2 format with cross-sectional locations shown on the accompanying topographic maps, (3) flow records or flood hydrographs and their variations along the study stream reach, it any, and (4) size distributions of sediment samples along the study reach. Additional data are required for special features of a study river reach.

The HEC-2 format for input data is used in all versions of the FLUVIAL model. Data records for HEC-2 pertaining to cross-sectional geometry (X1 and GR), job title (T1, T2, and T3), and end of job (EJ), are used in the FLUVIAL model. If a HEC-2 data file is available, it is not necessary to delete the unused records except that the information they contain are not used in the computation. For the purpose of water- and sediment-routing, additional data pertaining to sediment characteristics, flood hydrograph, etc., are required and supplied by other data records. Sequential arrangement of data records are given in the following.

Records	**Description of Record Type**
T1,T2,T3	Title Records
G1	General Use Record
G2	General Use Records for Hydrographs
G3	General Use Record
G4	General Use Record for Selected Cross-Sectional Output
G5	General Use Record
G6	General Use Record for Selecting Times for Summary Output
G7	General Use Record for Specifying Erosion Resistant Bed Layer
GS	General Use Records for Initial Sediment Compositions
GB	General Use Records for Time Variation of Base-Level
GQ	General Use Records for Stage-Discharge Relation of Downstream Section
GI	General Use Records for Time Variation of Sediment Inflow
X1	Cross-Sectional Record
XF	Record for Specifying Special Features of a Cross Section
GR	Record for Ground Profile of a Cross Section
SB	Record for Special Bridge Routine
BT	Record for Bridge Deck Definition
EJ	End of Job Record

Variable locations for each input record are shown by the field number. Each record has an input format of (A2, F6.0, 9F8.0). Field 0 occupying columns 1 and 2 is reserved for the required record identification characters. Field 1 occupies columns 3 to 8; Fields 2 to 10 occupy 8 columns each. The data records are tabulated and described in the following.

T1, T2, T3 Records - These three records are title records that are required for each job.

Field	Variable	Value	Description
0	IA	T1	Record identification characters
1-10	None		Numbers and alphanumeric characters for title

G1 Record - This record is required for each job, used to enter the general parameters listed below. This record is placed right after the T1, T2, and T3 records.

Field	Variable	Value	Description
0	IA	G1	Record identification characters
1	TYME	+	Starting time of computation on the hydrograph, in hours
2	ETIME	+	Ending time of computation on the hydrograph, in hours
3	DTMAX	+	Maximum time increment Δt allowed, in seconds
4	ISED	1	Select Graf's sediment transport equation.
		2	Select Yang's unit stream power equation. The sediment size is between 0.063 and 10 mm.
		3	Select Engelund-Hansen sediment equation.
		4	Select Parker gravel equation.
		5	Select Ackers-White sediment equation.
		6	Select Meyer-Peter Muller equation for bed load.
5	BEF	+	Bank erodibility factor for the study reach. This value is used for each section unless otherwise specified in Field 9 of the XF record. Use 1 for highly erodible banks; 0.5 for moderately erodible banks; and 0.2 for erosion-resistant banks. Any value between 0 and 1 may be used.
6	IUC	0	English units are used in input and output.
		1	Metric units are used in input and output.
7	CNN	+	Manning's *n* value for the study reach. This value is used for a section unless otherwise specified in Field 4 of the XF record. If bed roughness is computed based upon alluvial bedforms as specified in Field 5 of the G3 record, only an approximate *n* value needs to be entered here.
8	PTM1	+	First time point in hours on the hydrograph at which summary output and complete cross-sectional output are requested. It is usually

			the peak time, but it may be left blank if no output is requested.
9	PTM2	+	Second time point on the hydrograph in hours at which summary output and complete cross-sectional output are requested. It is usually the time just before the end of the simulation. This field may be left blank if no output is needed.
10	KPF	+	Frequency of printing summary output, in number of time steps. The default value is 1.

G2 Records - These records are required for each job, used to define the flow hydrograph(s) in the channel reach. The first one (or two) G2 records are used to define the spatial variation in water discharge along the reach; the succeeding ones are employed to define the time variation(s) of the discharge. Up to 10 hydrographs, with a maximum of 120 points for each, are currently dimensioned. See section II for tributaries. These records are placed after the G1 record.

Field	**Variable**	**Value**	**Description**
First G2			
0	IA	G2	Record identification characters
1	IHP1	+	Number of last cross section using the first (downstream most) hydrograph. The number of section is counted from downstream to upstream with the downstream section number being one. See also section II.
2	NP1	+	Number of points connected by straight segments used to define the first hydrograph.
3	IHP2	+	Number of last section using the second hydrograph if any. Otherwise leave it blank.
4	NP2	+	Number of points used to define the second hydrograph if any. Otherwise leave it blank.
5	IHP3	+	Number of last section using the third hydrograph if any. Otherwise leave it blank.
6	NP3	+	Number of points used to define the third hydrograph if any. Otherwise leave it blank.
7	IHP4	+	Number of last section using the fourth hydrograph if any. Otherwise leave it blank.
8	NP4	+	Number of points used to define the fourth hydrograph if any. Otherwise leave it blank.

9	IHP5	+	Number of last section using the fifth hydrograph if any. Otherwise leave it blank.
10	NP5	+	Number of points used to define the fifth hydrograph if any. Otherwise leave it blank.

Second G2: Note that this record is used only if more than 5 hydrographs are used for the job. It is necessary to place a negative sign in front of NP5 located in the 10th field of the first G2 record as a means to specify that more than 5 hydrographs are used.

0	IA	G2	Record identification characters
1	IHP6	+	Number of last cross section using the sixth hydrograph if any. Otherwise leave it blank.
2	NP6	+	Number of points connected by straight segments used to define the sixth hydrograph if any. Otherwise leave it blank.
3	IHP7	+	Number of last section using the seventh hydrograph if any. Otherwise leave it blank.
4	NP7	+	Number of points used to define the seventh hydrograph
5	IHP8	+	Number of last section using the eighth hydrograph if any. Otherwise leave it blank.
6	NP8	+	Number of points used to define the eighth hydrograph
7	IHP9	+	Number of last section using the ninth hydrograph if any. Otherwise leave it blank.
8	NP9	+	Number of points used to define the ninth hydrograph
9	IHP10	+	Number of last section using the tenth hydrograph if any. Otherwise leave it blank.
10	NP10	+	Number of points used to define the tenth hydrograph

Succeeding G2 Record(s)

1	Q11, Q21 Q31	+	Discharge coordinate of point 1 for each hydrograph, in ft^3/sec or m^3/sec
2	TM11,TM21 TM31	+	Time coordinate of point 1 for each hydrograph, in hours
3	Q12, Q22 Q32	+	Discharge coordinate of point 2 for each hydrograph, in cfs or cms

4	TM12,TM22 TM32	+	Time coordinate of point 2 for each hydrograph, in hours

Continue with additional discharge and time coordinates. Note that time coordinates must be in increasing order.

G3 Record - This record is used to define required and optional river channel features for a job as listed below. This record is placed after the G2 records.

Field	Variable	Value	Description
0	IA	G3	Record identification characters
1	S11	+	Slope of the downstream section, required for a job
2	BSP	0	One-on-one slope for rigid bank or bank protection
		+	Slope of bank protection in BSP horizontal units on 1 vertical unit. In the case of vertical bank, use 0.05 for BSP. This value is used for all cross sections unless otherwise specified in Field 8 of the XF record for a section.
3	DSOP	0	Downstream slope is allowed to vary during simulation.
		1	Downstream slope is fixed at S11 given in Field 1.
4	TEMP	0	Water temperature is 15°C.
		+	Water temperature in degrees Celsius
5	ICNN	0	Manning's n defined in Field 7 of the G1 record or those in Field 4 of the XF records are used.
		1	Brownlie's formula for alluvial bed roughness is used to calculate Manning's n in the simulation.
6	TDZAMA	0	Thickness of erodible bed layer is 100 ft (30.5 m).
		+	Thickness of erodible bed layer in ft or m. This value is applied to the entire channel reach but it may be redefined for a section using Field 10 of the XF record.
7	SPGV	0	Specific gravity of sediment is 2.65.
		+	A value between 1 and 10 is for the specific gravity of sediment
	QMIN	+	A value greater that 10 is the minimum discharge in cfs included in modeling. Discharges lower than QMIN carrying no bed sediment are ignored in modeling.
8	KGS	0	The number of size fractions for bed material is 5.
		+	The number of size fractions for bed material. It maximum value is

			8.
9	PHI	0	The angle of repose for bed material is 36^o.
		+	Angle of repose for bed material

G4 Record - This is an optional record used to select cross sections (up to 4) to be included at each summary output. Each cross section is identified by its number which is counted from the downstream section. This record also contains other options; it is placed after the G3 record.

Field	Variable	Value	Description
0	IA	G4	Record identification characters
1	IPLT1	+	Number of cross section
2	IPLT2	+	Number of cross section
3	IPLT3	+	Number of cross section
4	IPLT4	+	Number of cross section
5	IEXCAV	+	A positive integer indicates number of cross section where sand/gravel excavation occurs.
6	GIFAC	+	A non-zero constant is used to modify sediment inflow at the upstream section.
7	PZMIN	0	Minimum bed profile during simulation run is not requested.
		1	Output file entitled TZMIN for minimum bed profile is requested.
10	REXCAV	+	A non-zero value specifies rate of sand/gravel excavation at Section IEXCAV.

G5 Record - This is an optional record used to specify miscellaneous options, including unsteady-flow routing for the job based upon the dynamic wave, bend flow characteristics. If the unsteady flow option is not used, the water-surface profile for each time step is computed using the standard-step method. When the unsteady flow option is used, the downstream water-surface elevation must be specified using the GB records.

Field	Variable	Value	Description
0	IA	G5	Record identification characters
1	DT	0	The first time step is 100 seconds.
		+	Size of the first time step in seconds.

2	IROUT	0	Unsteady water routing is not used; water-surface profiles are computed using standard-step method.
		1	Unsteady water-routing based upon the dynamic wave is used to compute stages and water discharges at all cross sections for each time step.
3	PQSS	0	No output of gradation of sediment load
		3	Gradation of sediment load is included in output in 1,000 ppm by weight.
5	TSED	0	Rate of tributary sediment inflow is 1 times the discharge ratio.
		+	Rate of tributary sediment inflow is TSED times the discharge ratio.
6	PTV	0	No output of transverse distribution of depth-averaged velocity
		1	Transverse distribution of depth-averaged velocity is printed. The velocity distribution is for bends with fully developed transverse flow.
10	DYMAX	0	No GR points are inserted for cross sections.
		+	Maximum value of spacing between adjacent points at a cross section (ft or m). If this value is exceeded, intermediate points will be inserted by interpolation. The number of points inserted is given in Field 10 of the X3 record in output.

G6 Record - This is an optional record used to select time points for summary output. Up to 30 time points may be specified. The printing frequency (KPF) in Field 10 of the G1 Record may be suppressed by using a large number such as 9999.

Field	Variable	Value	Description
First G6 Record			
0	IA	G6	Record identification characters
1	NKPS	+	Number of time points
Succeeding G6 Record(s)			
0	IA	G6	Record identification characters
1	SPTM(1)	+	First time point, in hours
2	SPTM(2)	+	Second time point, in hours

Continue with additional time points.

G7 Record - This is an optional record used to specify erosion resistant bed layer, such as a caliche layer, that has a lower rate of erosion.

Field	Variable	Value	Description
First G7 Record			
0	IA	G7	Record identification characters
1	KG7	+	Number of time points used to define the known erosion rate in relation to flow velocity
2	THICK	+	Thickness of erosion resistant layer, in feet
Succeeding G7 Record(s)			
0	IA	G7	Record identification characters
1	ERATE(1)	+	Erosion rate, in feet per hour
2	G7V(2)	+	Velocity, in feet per second

Continue with additional time points.

GS Record - At least two GS records are required for each job, used to specify initial bed-material compositions in the channel at the downstream and upstream cross sections. The first GS record is for the downstream section; it should be placed before the first X1 record and after the G4 record, if any. The second GS record is for the upstream section; it should be placed after all cross-sectional data and just before the EJ record. Additional GS records may be inserted between two cross sections within the stream reach, with the total number of GS records not to exceed 15. Each GS record specifies the sediment composition at the cross section located before the record. From upstream to downstream, exponential decay in sediment size is assumed for the initial distribution. Sediment composition at each section is represented by five size fractions.

Field	Variable	Value	Description
0	IA	GS	Record identification characters
1	DFF	+	Geometric mean diameter of the smallest size fraction in mm
2	PC	+	Fraction of bed material in this size range

Continue with other DFF's and PC's in the increasing order of sediment diameter.

GB Records - These optional records are used to define time variation of stage (water-surface elevation) at a cross section. The first set of GB records is placed before all cross section records (X1); it specifies the downstream stage. When the GB option is used, it supersedes other methods for determining the downstream stage. Other sets of GB records may be placed in other parts of the data set; each specifies the time variation of stage for the cross section immediately following the GB records.

Field	Variable	Value	Description
First GB Record			
0	IA	GB	Record identification characters
1	KBL	+	Number of points used to define base-level changes
Succeeding GB Record(s)			
0	IA	GB	Record identification characters
1	BSLL(1)	+	Base level of point 1, in ft or m
2	TMBL(1)	+	Time coordinate of point 1, in hours
3	BSLL(2)	+	Base level of point 2, in ft or m
4	TMBL(2)	+	Time coordinate of point 2, in hours

Continue with additional elevations and time coordinates, in the increasing order of time.

GQ Records - These optional records are used to define stage-discharge relation at the downstream section. The GQ input data may not used together with the GB records.

Field	Variable	Value	Description
First GQ Record			
0	IA	GQ	Record identification characters
1	KQL	+	Number of points used to define base-level changes
Succeeding GQ Record(s)			
0	IA	GQ	Record identification characters
1	BSLL(1)	+	Base level of point 1, in ft or m
2	TMQ(1)	+	Discharge of point 1, in cfs or cms
3	BSLL(2)	+	Base level of point 2, in ft or m
4	TMQ(2)	+	Discharge of point 2, in cfs or cms

Continue with additional elevations and discharges, in the increasing order of discharge.

GI Records - These optional records are used to define time variation of sediment discharge entering the study reach through the upstream cross section. The GI input data, if included, will supersede other methods for determining sediment inflow. The sediment inflow is classified into the two following cases: (1) specified inflow at the upstream section, such as by a rating curve; and (2) sediment feeding, such as from a dam breach or from a sediment feeder. These two cases are distinguished. For the first case, the upstream section has a set of GS records for its bed material composition, placed right after the GR Records. The geometry of this section does not change. For the second case, the upstream section has a set of the GS records for its bed material composition. An additional imaginary section needs to be added placed after the upstream section, located at the distance of DX upstream from the upstream section. A set of GS records must be placed after the GR records to specify the sediment composition of the inflow sediment. The imaginary section does not change in geometry but the upstream section may undergo geometry changes.

Field	Variable	Value	Description
First GI Record			
0	IA	GI	Record identification characters
1	KGI	+	Number of points used to define time variation of sediment inflow.
Succeeding GI Record(s)			
0	IA	GI	Record identification characters
1	QSU(1)	+	Sediment discharge of point 1, in cubic ft or m (net volume) per second
2	TMGI(1)	+	Time coordinate of point 1, in hours
3	QSO(2)	+	Sediment discharge of point 2
4	TMGI(2)	+	Time coordinate of point 2.

Continue with additional sediment discharges and time coordinates, in the increasing order of time coordinates.

X1 Record - This record is required for each cross section (175 cross sections can be used for the study reach); it is used to specify the cross-sectional geometry and program options applicable to that cross-section. Cross sections are arranged in sequential order starting from downstream.

Field	Variable	Value	Description
0	IA	X1	Record identification characters
1	SECNO	+	Original section number from the map
2	NP	+	Total number of stations or points on the next GR records for current cross section
3-6			These fields (Fields 3 to 6) are not used in the model. Numbers in

			these fields are ignored.
7	DX	+	Length of reach between current cross section and the next downstream section along the thalweg, in feet or meters
8	YFAC	0	Cross-section stations are not modified by the factor YFAC.
		+	Factor by which all cross-section stations are multiplied to increase or decrease area. It also multiplies YC1, YC2 and CPC in the XF record, and applies to the CI record.
9	PXSECE	0	Vertical or Z coordinate of GR points are not modified.
		±	Constant by which all cross-section elevations are raised or lowered
10	NODA	0	Cross section is subject to change.
		1	Cross section is not subject to change.

XF Record - This is an optional record used to specify special features of a cross section.

Field	Variable	Value	Description
0	IA	XF	Record identification characters
1	YC1	0	Regular erodible left bank
		+	Station of rigid left bank in ft or m, to the left of which channel is nonerodible. Note: This station is located at toe of rigid bank; its value must be non-zero and must be equal to one of the Y coordinates in GR records but not the first Y coordinate.
2	YC2	0	Regular erodible right bank
		+	Station of rigid right bank, to the right of which channel is nonerodible. Note: This station is located at toe of rigid bank; its value must be equal to one of the Y coordinates in GR records but not the last Y coordinate.
3	RAD	0	Straight channel with zero curvature
		+	Radius of curvature at channel centerline in ft or m. Center of radius is on same side of channel where the station (Y-coordinate) starts.
		-	Radius of curvature at channel centerline in ft or m. Center of radius is on opposite side of zero station. Note: RAD is used only if concave bank is rigid and so specified using the XF record. RAD produces a transverse bed scour due to curvature.
4	CN	0	Roughness of this section is the same as that given in Field 7 of the G1 record.
		+	Manning's *n* value for this section

Field	Variable	Value	Description
5	CPC	0	Center of thalweg coincides with channel invert at this section.
		+	Station (Y-coordinate) of the thalweg in ft or m
6	IRC	0	Regular erodible cross section
		1	Rigid or nonerodible cross section such as drop structure or road crossing. There is no limit on the total number of such cross sections.
8	BSP	0	Slope of bank protection is the same as that given in Field 2 of the G3 record.
		+	Slope of bank protection at this section in BSP horizontal units on 1 vertical unit. Use 0.05 for vertical bank.
		5	Slope of rigid bank is defined by the GR coordinates.
9	BEFX	0	Bank erodibility factor is defined in Field 5 of the G1 record.
		+	A value between 0.1 and 1.0 for BEFX specifies the bank erodibility factor at this section.
	RWD	+	RWD is the width of bank protection of a small channel in the floodplain. Areas outside this zone remains erodible. RWD is specified by a value greater than 1 (ft or m) in this field. When RWD is used, BEFX is not specified.
10	TDZAM	0	Erodible bed layer at this section is defined by TDZAMA in Field 6 of the G3 record.
		+	Thickness of erodible bed layer in ft or m. Only one decimal place is allowed for this number.
	ENEB	$\pm$	Elevation of non-erodible bed, used to define the crest elevation of a grade-control structure which may be above or below the existing channel bed. In order to distinguish it from TDZAM, ENEB must have the value of 1 at the second decimal place. For example, the ENEB value of 365 should be inputted as 365.01 and the ENEB value of -5.2 should be inputted as -5.21. When ENEB is specified, it supersedes TDZAM and TDZAMA

CI Record - This is an optional record used to specify channel improvement options due to excavation or fill. The excavation option modifies the cross-sectional geometry by trapezoidal excavation. Those points lower than the excavation level are not filled. The fill option modifies the cross-sectional geometry by raising the bed elevations to a prescribed level. Those points higher than the fill level are not lowered. Excavation and fill can not be used at the same time. This record should be placed after the X1 and XF records but before the GR records. The variable ADDVOL in Field 10 of this record is used to keep track of the total volume of excavation or fill along a channel reach. ADDVOL specifies the initial volume of fill or excavation. A value greater or less than 0.1 needs to be entered in this field to keep track of the total volume of fill or excavation until another ADDVOL is defined.

Field Variable Value Description

0	IA	G5	Record identification characters
1	CLSTA	+	Station of the centerline of the trapezoidal excavation, expressed according to the stations in the GR records, in feet or meter.
2	CELCH	+	Elevation of channel invert for trapezoidal channel, in feet or meters.
4	XLSS	+	Side slope of trapezoidal excavation, in XLSS horizontal units for 1 vertical unit.
5	ELFIL	+	Fill elevation on channel bed, in feet or meters.
6	BW	+	Bed width of trapezoidal channel, in feet or meters. This width is measured along the cross section line; therefore, a larger value should be used if a section is skewed.
10	ADDVOL	0	Volume of excavation or fill, if any, is added to the total volume already defined.
		+	Initial volume of fill on channel bed, in cubic feet or cubic meters.
		-	Initial volume of excavation from channel bed, in cubic feet or meters.

GR Record - This record specifies the elevation and station of each point for a digitized cross section; it is required for each X1 record.

Field	Variable	Value	Description
0	IA	GR	Record identification characters
1	Z1	"	Elevation of point 1, in ft or m. It may be positive or negative.
2	Y1	"	Station of point 1, in ft or m
3	Z2	"	Elevation of point 2, in ft or m
4	Y2	"	Station of point 2, in ft or m

Continue with additional GR records using up to 399 points to describe the cross section. Stations should be in increasing order.

SB Record - This special bridge record is used to specify data in the special bridge routine. This record is used together with the BT and GR records for bridge hydraulics. This record is placed between cross sections that are upstream and downstream of the bridge.

Field Variable Value Description

0	IA	SB	Record identification characters
1	XK	+	Pier shape coefficient for pier loss
2	XKOR	+	Total loss coefficient for orifice flow through bridge opening
3	COFQ	+	Discharge coefficient for weir flow overtopping bridge roadway
4	IB	+	Bridge index, starting with 1 from downstream toward upstream
5	BWC	+	Bottom width of bridge opening including any obstruction
6	BWP	0	No obstruction (pier) in the bridge
		i	Total width of obstruction (piers)
7	BAREA	+	Net area of bridge opening below the low chord in square feet
9	ELLC	+	Elevation of horizontal low chord for the bridge
10	ELTRD	+	Elevation of horizontal top-of-roadway for the bridge

BT Record - This record is used to compute conveyance in the bridge section. The BT data defines the top-of -roadway and the low chord profiles of bridge. The program uses the BT, SB and GR data to distinguish and to compute low flow, orifice flow and weir flow.

Field	Variable	Value	Description
0	IA	BT	Record identification characters
1	NRD	+	Number of points defining the bridge roadway and bridge low chord to be read on the BT records
2	RDST(1)	+	Roadway station corresponding to RDEL(1) and XLCEL(1)
3	RDEL(1)	+	Top of roadway elevation at station RDST(1)
4	XLCEL(1)	+	Low chord elevation at station RDST(1)
5	RDST(2)	+	Roadway station corresponding to RDEL(2) and XLCEL(2)
6	RDEL(2)	+	Top of roadway elevation at station RDST(2)
7	XLCEL(2)	+	Low chord elevation at station RDST(2)

Continue with additional sets of RDST, RDEL, and XLCEL.

EJ Record - This record is required following the last cross section for each job. Each group of records beginning with the T1 record is considered as a job.

Field	Variable	Value	Description
0	IA	EJ	Record identification characters
1-10			Not used

II. INPUT PREPARATION FOR TRIBUTARIES

Tributaries may be included in the simulation following either a simplified approach or a detailed approach. Mixed usage of these two approaches is not currently permitted.

In the simplified approach, cross-sectional data for a tributary are not required; the tributary water discharge is specified in the G2 record; and tributary inflow of sediment is related to the water inflow.

Cross-sectional data are required in the detailed approach. Such cross sections are arranged in sequence from the confluence toward upstream just as for the main channel cross sections. They are placed in the input file after the main channel cross sections. In addition, the following input specifications are required:

(1) Use a negative sign for the first tributary section number, SECNO, in Field 1 of the X1 record. This section number is designated as ITR in the model.

(2) Use a negative sign for a section number IHP1, IHP2, etc. in the G2 record. This section number in the main channel is designated as ITM in the model.

(3) Include a GS record just after the cross-sectional data of the main stream. Place another GS record after the cross-sectional data of the tributary and just before the EJ record. This GS record is used to specify the bed-material composition at the upstream section of the tributary.

Nine tributaries for detailed analysis are currently allowed for a job. When selecting this option, unsteady routing may not used.

III. OUTPUT DESCRIPTION

Output of the model include initial bed-material compositions, time and spatial variations of the water-surface profile, channel width, flow depth, water discharge, velocity, energy gradient, median sediment size, and bed-material discharge. In addition, cross-sectional profiles are printed at different time intervals.

Symbols used in the output are generally descriptive, some of them are defined below:

SECTION	Cross section
TIME	Time on the hydrograph
DT	Size of the time step or Δt in sec
W.S.ELEV	Water-surface elevation in ft or m
WIDTH	Surface width of channel flow in ft or m
DEPTH	Depth of flow measured from channel invert to water surface in ft or m
Q	Discharge of flow in cfs or cms
V	Mean velocity of a cross-section in fps or mps
SLOPE	Energy gradient
D50	Median size or d_{50} of sediment load in mm
QS	Bed-material discharge for all size fractions in cfs or cms
FR	Froude number at a cross section
N	Manning's roughness coefficient
SED.YIELD	Bulk volume or weight of sediment having passed a cross section since beginning of simulation, in cubic yards or tons.
WSEL	Water-surface elevation, in ft or m
Z	Vertical coordinate (elevation) of a point on channel boundary at a cross-section, in ft or m
Y	Horizontal coordinate (station) of a point on channel boundary at a cross-section, in ft or m
DZ	Change in elevation during the current time step, in ft or m
TDZ	Total or accumulated change in elevation, in ft or m

IV. RUNNING THE MODEL

The executable file of FLUVIAL-12, FL12.EXE, may be run on a Personal Computer or a main-frame computer. To run it on a PC, just type the command FL12. The computer will respond by requesting the input file name and then the output file name. A math coprocessor is required for the PC.

The device codes for running this program on a main-frame computer are as follows: 1 for READ, 3 for WRITE into an output file, and 5 for WRITE at the terminal.

V. IMPORTANT MESSAGES FOR INPUT PREPARATION

1. The computing time of this program is sensitive to the reach length between two adjacent cross sections, DX. Very small reach lengths which may result in excessive computing time should be avoided. In HEC-2, a downstream section and an upstream section are usually used at each bridge crossing, but these two sections should be combined into one, if possible, for the FLUVIAL application.

2. The GR points used to define the ground profile should be selected to provide an accurate definition of the initial profile. As such, sufficient points should be used for each cross section. Also, large spacing between adjacent points should be avoided even if there is no difference in initial elevation. Detailed results rely upon the adequate number of points used. Use Field 10 of G5 record

to insert points by interpolation.

3. The number of GR points used in defining the ground profile also affects the computing time because these points are executed a great number of times for each job. Points that are definitely outside the flow boundary level should be deleted during initial editing. However, because of the possibility for bank erosion, there should be sufficient points to cover any such potential changes.

4. Ineffective flow areas should be specified, either by excluding them from the GR points or by raising the GR elevations above the water level.

5. Very fine sediments with a grain size less than 0.0625 mm constitute the wash load and should normally be excluded from the size-fraction data on GS records.

6. The bank erodibility factor, BEF, in Field 5 of Record G1, is a control for the rate of channel widening. A small value slows down widening. This value should be calibrated against field data whenever possible.

7. The radius of curvature, RAD, in Field 3 of the XF record should be specified if lateral migration is simulated. The rate of lateral migration is controlled by RAD and the bank erodibility factor BEFX in Field 9 of the G3 record. In using this option, YC1 or YC2 should not be specified.

8. The radius of curvature r_c (or RAD) along a reach between two adjacent cross sections is computed by interpolating those defined at the cross sections. Since r_c has infinite value at a straight section, its adjacent reaches also have infinite r_c. For this reason, a curved reach must be between cross sections with finite r_c values.

APPENDIX C. SAMPLE INPUT LISTINGS

```
T1      UPPER SAN DIEGO RIVER NEAR CHANNEL ROAD
T2      FOR SCOUR PREDICTION AT CHANNEL ROAD AFFECTED BY SAND MINING
T3      100-YEAR FLOOD, PEAK Q = 32000 CFS
G1   5.1  190.20     720       3     0.5             0.04   19.98  189.00    12.0
G2    11      40
G2  1250       0    1800       2    3200     8.5   10880      14   32000    19.8
G2 32000    20.1   22400      26    9600      34    7540      38    3200      50
G2  1400    50.1    4760      54   14000      60    9800      66    2800      70
G2  1250    70.1    3040      73    3800      75    2800      80    1250      90
G2  1250    90.1    3040      93    3800      95    2800     100    1250     120
G2  1250   120.1    3040     123    3800     125    2800     130    1250     140
G2  1400   140.1    4760     144   14000     150    9800     156    2800     170
G2  1250   170.1    3040     173    3800     175    2800     180    1250     190
G3 0.005
GS   0.2     0.2    0.75     0.2    1.50     0.2    2.80     0.2     6.5     0.2
GQ     5
GQ   365     500     367    1400     368    2500     374    7000     378   34000
NC  0.04    0.04   0.050     0.1     0.3
ET           5.1     7.1     5.1    1480    2200    1480    2050
X1   730      33  1442.0  2506.4     770     670    889.
XF                         0.045
GR 381.4  1240.4   385.5  1248.9   385.1  1281.3   381.9  1287.2   381.8  1344.2
GR 380.9  1418.1   383.3  1423.8   383.7  1442.0   380.2  1450.2   373.6  1462.3
GR 371.3  1477.7   370.2  1538.5   369.6  1639.5   369.1  1690.7   367.9  1700.8
GR 366.9  1768.1   364.9  1794.5   363.8  1813.3   364.7  1867.4   368.5  1881.3
GR 369.2  1928.7   368.9  1962.0   366.4  1972.1   364.5  1981.5   366.1  1987.1
GR 365.8  2005.0   365.2  2006.3   365.2  2164.4   367.0  2167.6   380.0  2214.7
GR 380.0  2264.0   380.0    2300   380.0    2400
ET           5.1     7.1     9.1  1167.7    1800  1167.7    1700  1167.7    1850
X1   734      23  1167.7  1880.1     470     695     550     .95
GR 383.7  1100.0   383.7  1167.8   375.2  1179.4   371.2  1192.3     372  1221.7
GR 370.6  1266.5   370.9  1297.9   372.2  1314.7   371.1  1333.6   367.8  1347.4
GR 366.0  1382.7   367.4  1394.9   369.7  1408.6   371.2  1440.4   370.6  1523.1
GR 370.7  1629.9   371.8  1700.0   386.0  1735.0   386.4  1794.7   386.8  1821.3
GR 387.0  1900.0   387.4    1950   387.8    2000
NC                            .3      .5
ET           5.1     7.1     5.1     820    1575     820    1470    1000    1350
X1   738      30     785  1773.9     300     255     298     .82
GR 393.6     785   393.6   785.1   392.4   793.5     387     810   382.3   823.8
GR   371     860     371   967.1     371  1006.6     371  1028.3     371  1040.8
GR 371.0  1059.7     371  1074.3     371  1101.2   369.5  1112.6   367.3  1144.7
GR 368.5  1158.1   368.7  1175.8   370.0  1187.1   372.7  1203.2   372.3  1268.1
GR 373.7  1297.5   373.3  1372.5   371.9  1382.6   371.6  1417.4   369.6  1441.5
GR 369.6  1470.0   388.0  1507.0   388.5  1597.4   389.0  1694.1   390.0  1800.3
QT     3   32000   32000    3200
NC  .060    .050    .035
ET           5.1     7.1     5.1     720    1475     720    1370     315    1150
X1   740      30     680  1751.8     130     130     172     .82
```

XF					750					
GR	390	680	390	680.05	390	680.1	375	731.3	375	813.5
GR	375	840.4	374.7	856.6	372.7	867.8	372.6	982.3	372.7	1028.6
GR	373.6	1063.3	374.8	1074.1	373.8	1084.6	373.6	1101.5	376.3	1116.0
GR	373.6	1132.8	373.6	1157.4	373.6	1184.7	373.6	1197.2	373.2	1210.1
GR	373.0	1224.9	373.7	1261.1	372.3	1294.9	374.4	1318.2	372.9	1370.8
GR	389.0	1403.0	389.6	1540.3	390.0	1629.5	390.3	1674.2	390.5	1750.0
ET		5.1	7.1	5.1	680	950	680	905	550	800
X1	741	18	680	905	0	875	350			
XF					800					
GR	390	680	385	720	380	770	375	790	373	800
GR	373	810	373	860	373	870	375	880	380	900
GR	385	905	385	950	385	1175	391	1187	391.5	1250
GR	391.5	1300	391.7	1400	392	1500				
ET		5.1	7.1	5.1	420	700	420	700		
X1	744	44	420	655.0	195	205	315			
XF				0.035						
GR	401.6	0.0	399.9	40.8	395.7	62.5	394.4	95.7	394.6	151.7
GR	394.4	206.1	392.8	272.1	392.5	356.9	392.3	420	390	430
GR	385	455	380	480	375	490	373	500	373	581.8
GR	373.0	600	373	610	375	620.0	380.0	630.0	385.0	640
GR	390.0	655	391.0	700	391.6	835.7	389.6	1194.5	389.9	1316.4
GR	390.6	1407.6	392.6	1454.4	392.7	1537.6	393.8	1614.2	393.5	1656.5
GR	391.9	1705.9	392.7	1792.7	392.9	1881.6	393.5	1973.0	394.0	2089.8
GR	393.6	2185.3	393.5	2206.6	393.0	2216.3	393.7	2228.0	394.5	2288.3
GR	403.0	2315.7	413.5	2335.4	414.8	2337.6	416.2	2358.3		
NC	.050	.050	.045							
ET		5.1	7.1	5.1	50	870	300	730		
X1	750	45	115.6	629.2	245	250	307			
GR	400.8	0.0	401.0	16.9	399.1	29.3	396.5	35.6	394.6	59.4
GR	394.7	86.3	390.9	99.6	389.6	115.6	385.9	123.9	381.4	133.0
GR	380.0	182.8	379.6	255.9	377.3	281.8	377.3	415.2	377.3	527.8
GR	379.0	532.9	379.1	584.9	377.5	595.6	377.5	605.7	380.0	616.1
GR	390.7	629.2	391.7	691.1	393.2	760.5	409.3	763.4	409.3	834.1
GR	393.8	837.5	393.8	908.5	392.3	919.5	393.2	926.6	393.6	1040.7
GR	393.2	1152.6	393.1	1222.8	393.8	1320.3	393.3	1416.1	393.9	1526.0
GR	394.8	1646.2	396.9	1679.0	397.4	1735.9	398.3	1810.4	398.1	1885.5
GR	396.6	1908.9	399.2	1926.1	402.8	1940.8	406.2	1974.6	407.0	1998.3
NC	.035	.050	.070	.1	.3					
ET		5.1	7.1	5.1	1	744.6	70	620		
X1	760	44	73.3	620.7	415	715	547			
GR	406.1	0.0	406.5	29.9	399.9	41.2	398.6	57.7	394.3	73.3
GR	386.7	87.9	381.9	95.6	382.3	129.4	378.3	136.2	377.9	186.8
GR	377.4	258.2	377.8	283.5	380.1	294.7	381.2	335.6	380.9	401.8
GR	383.3	426.0	383.3	480.5	380.8	498.6	383.1	508.7	384.2	539.1
GR	382.3	554.2	382.9	583.2	385.4	601.0	392.4	620.7	394.0	641.7
GR	395.6	705.1	396.8	744.6	394.4	792.8	395.2	835.2	397.0	880.1
GR	398.9	987.4	398.3	1025.7	397.6	1086.3	397.9	1156.8	399.7	1168.8
GR	404.9	1187.5	408.2	1203.4	408.6	1266.0	409.3	1311.5	402.5	1325.9
GR	397.4	1341.7	397.9	1405.0	399.3	1476.3	398.3	1612.4		

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ET                7.1                               220   897.3
X1    764      29   246.4   703.8     770     690     731
GR  407.6     0.0   405.9    23.8   403.8    30.8   402.6    76.3   401.6   122.8
GR  402.4   204.5   395.4   216.4   386.7   233.6   388.9   246.4   386.3   272.7
GR  386.1   280.7   381.6   291.0   380.4   322.9   380.1   390.3   379.5   440.7
GR  380.4   469.4   381.7   532.9   381.4   556.4   379.6   569.3   379.3   620.9
GR  379.9   638.2   381.3   677.0   383.7   684.6   389.8   692.1   393.9   703.8
GR  395.6   731.1   395.9   793.7   396.9   850.8   396.7   897.3
ET            5.1     7.1     5.1     380    1335     400    1335
X1    765      42   493.7  1228.6     660     160     604
GR  411.6     0.0   411.7    64.8   406.3    79.3   398.4    98.1   396.5   106.6
GR  396.4   191.7   397.2   285.4   395.9   335.7   396.2   444.8   395.7   493.7
GR  392.5   515.9   390.1   528.0   391.1   537.3   390.2   569.5   388.7   624.2
GR  385.4   630.8   384.3   653.4   383.2   658.0   384.9   663.7   387.9   668.6
GR  387.6   708.6   386.9   732.1   386.1   769.8   385.2   834.1   383.7   851.4
GR  383.9   875.9   385.6   894.3   388.9   959.4   388.7  1040.4   386.3  1054.1
GR  389.1  1065.0   390.3  1122.2   393.1  1186.4   395.5  1228.6   395.7  1312.3
GR  396.5  1369.3   399.1  1472.8   399.1  1582.3   400.0  1666.6   399.9  1791.8
GR  399.4  1905.3   399.6  2008.9
X1    770      35   493.7  1228.6     400     400     400               1
GR  396.4   191.7   397.2   285.4   395.9   335.7   396.2   444.8   395.7   493.7
GR  392.5   515.9   390.1   528.0   391.1   537.3   390.2   569.5   388.7   624.2
GR  385.4   630.8   384.3   653.4   383.2   658.0   384.9   663.7   387.9   668.6
GR  387.6   708.6   386.9   732.1   386.1   769.8   385.2   834.1   383.7   851.4
GR  383.9   875.9   385.6   894.3   388.9   959.4   388.7  1040.4   386.3  1054.1
GR  389.1  1065.0   390.3  1122.2   393.1  1186.4   395.5  1228.6   395.7  1312.3
GR  396.5  1369.3   399.1  1472.8   399.1  1582.3   400.0  1666.6   399.9  1791.8
GS    0.2     0.2    0.75     0.2    1.50     0.2    2.80     0.2     6.5     0.2
EJ
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APPENDIX D. SAMPLE OUTPUT LISTINGS

INITIAL BED MATERIAL COMPOSITION

SECTION	SIZE MM	FRACTION	SIZE MM	FRACTION	SIZE MM	FRACTION	SIZE MM	FRACTION	SIZE MM	FRACTION
730.00	0.20	0.200	0.75	0.200	1.50	0.200	2.80	0.200	6.50	0.200
734.00	0.20	0.200	0.75	0.200	1.50	0.200	2.80	0.200	6.50	0.200
738.00	0.20	0.200	0.75	0.200	1.50	0.200	2.80	0.200	6.50	0.200
740.00	0.20	0.200	0.75	0.200	1.50	0.200	2.80	0.200	6.50	0.200
741.00	0.20	0.200	0.75	0.200	1.50	0.200	2.80	0.200	6.50	0.200
744.00	0.20	0.200	0.75	0.200	1.50	0.200	2.80	0.200	6.50	0.200
750.00	0.20	0.200	0.75	0.200	1.50	0.200	2.80	0.200	6.50	0.200
760.00	0.20	0.200	0.75	0.200	1.50	0.200	2.80	0.200	6.50	0.200
764.00	0.20	0.200	0.75	0.200	1.50	0.200	2.80	0.200	6.50	0.200
765.00	0.20	0.200	0.75	0.200	1.50	0.200	2.80	0.200	6.50	0.200
770.00	0.20	0.200	0.75	0.200	1.50	0.200	2.80	0.200	6.50	0.200

THE ENGELUND-HANSEN SEDIMENT FORMULA IS USED

TIME = 5.10 HRS DT = 100 SECS TIME STEP = 0

SECTION	W.S.ELEV. FT	WIDTH FT	DEPTH FT	Q CFS	V FPS	SLOPE	D50 MM	QS/Q 1000 PPM	FR	SED. YIELD C. Y.
730.00	367.97	384.5	4.17	2467	2.71	0.00215	1.39	1.62	0.31	0.903E+01
734.00	371.32	384.6	5.32	2467	5.75	0.02074	1.67	32.80	0.96	0.182E+03
738.00	373.40	461.6	6.10	2467	2.23	0.00113	1.32	0.54	0.25	0.300E+01
740.00	374.29	390.6	1.99	2467	5.62	0.01967	1.69	29.81	0.94	0.166E+03
741.00	377.53	110.2	4.53	2467	5.98	0.00450	1.54	6.57	0.54	0.366E+02
744.00	378.60	144.4	5.60	2467	3.36	0.00073	1.45	0.61	0.26	0.339E+01
750.00	379.24	352.9	1.94	2467	4.52	0.00826	1.54	7.84	0.64	0.436E+02
760.00	381.81	292.5	4.41	2467	3.33	0.00234	1.50	1.35	0.37	0.752E+01
764.00	383.07	395.0	3.77	2467	2.33	0.00106	1.39	0.52	0.25	0.287E+01
765.00	386.95	236.0	3.75	2467	6.74	0.01854	1.67	38.42	0.95	0.214E+03
770.00	389.87	432.7	5.67	2467	2.56	0.00164	1.50	0.99	0.30	0.553E+01

TIME = 9.96 HRS DT = 395 SECS TIME STEP = 60

SECTION	W.S.ELEV. FT	WIDTH FT	DEPTH FT	Q CFS	V FPS	SLOPE	D50 MM	QS/Q 1000 PPM	FR	SED. YIELD C. Y.
730.00	371.65	706.9	6.55	5239	2.09	0.00075	0.54	0.58	0.20	0.349E+04
734.00	372.51	487.6	8.73	5239	4.43	0.00440	1.52	7.73	0.50	0.135E+05
738.00	374.04	512.6	4.87	5239	4.89	0.00649	1.93	11.97	0.60	0.104E+05
740.00	375.19	514.5	4.94	5239	5.13	0.00768	2.74	12.76	0.64	0.137E+05
741.00	376.90	117.4	6.10	5239	8.07	0.00500	2.94	12.69	0.60	0.121E+05
744.00	378.48	146.4	4.92	5239	7.63	0.00423	2.77	10.11	0.62	0.802E+04
750.00	380.56	452.5	3.80	5239	4.45	0.00403	1.49	8.22	0.49	0.825E+04
760.00	382.82	381.6	4.98	5239	4.97	0.00464	1.22	9.24	0.53	0.670E+04
764.00	385.35	404.2	4.06	5239	3.89	0.00221	0.57	5.23	0.38	0.716E+04
765.00	387.37	287.5	6.06	5239	6.09	0.00632	1.76	16.18	0.62	0.230E+05
770.00	390.07	454.1	5.87	5239	4.97	0.00586	1.50	13.30	0.57	0.151E+05

TIME = 16.80 HRS DT = 720 SECS TIME STEP = 96

SECTION	W.S.ELEV. FT	WIDTH FT	DEPTH FT	Q CFS	V FPS	SLOPE	D50 MM	QS/Q 1000 PPM	FR	SED. YIELD C. Y.
730.00	376.08	735.7	7.75	21069	5.57	0.00322	0.88	12.01	0.43	0.362E+05
734.00	377.83	509.3	7.88	21069	7.65	0.00449	1.85	19.44	0.58	0.870E+05
738.00	379.18	509.8	10.27	21069	7.56	0.00432	1.44	15.02	0.57	0.100E+06
740.00	379.93	536.2	9.40	21069	8.05	0.00571	2.36	22.21	0.64	0.114E+06
741.00	381.02	210.2	11.29	21069	10.25	0.00374	2.22	19.74	0.58	0.121E+06
744.00	381.97	203.0	11.12	21069	10.77	0.00323	1.95	18.50	0.61	0.104E+06
750.00	384.27	488.6	7.52	21069	7.39	0.00379	1.40	16.65	0.54	0.921E+05

760.00	386.40	514.5	9.31	21069	7.32	0.00393	1.50	16.66	0.54	0.925E+05
764.00	389.22	469.7	6.61	21069	7.56	0.00391	1.59	16.68	0.55	0.912E+05
765.00	391.88	639.3	10.49	21069	6.85	0.00422	1.50	16.17	0.55	0.112E+06
770.00	393.59	659.4	9.39	21069	6.80	0.00429	1.50	16.21	0.55	0.104E+06

TIME = 19.99 HRS DT = 720 SECS TIME STEP = 117

SECTION	W.S.ELEV. FT	WIDTH FT	DEPTH FT	Q CFS	V FPS	SLOPE	D50 MM	QS/Q 1000 PPM	FR	SED. YIELD C. Y.
730.00	377.70	745.4	8.27	32000	7.46	0.00495	1.80	19.75	0.55	0.161E+06
734.00	379.97	516.5	9.49	32000	8.99	0.00450	2.02	19.80	0.60	0.224E+06
738.00	381.35	531.7	8.92	32000	9.02	0.00472	2.04	22.86	0.62	0.244E+06
740.00	382.13	543.9	9.73	32000	9.47	0.00574	2.57	25.55	0.67	0.260E+06
741.00	383.83	413.5	14.37	32000	9.18	0.00362	1.95	18.76	0.56	0.271E+06
744.00	384.35	265.7	12.52	32000	11.08	0.00292	1.65	19.85	0.59	0.240E+06
750.00	386.33	500.1	9.44	32000	8.50	0.00358	1.41	19.72	0.55	0.218E+06
760.00	388.34	522.5	10.69	32000	8.33	0.00355	1.48	18.99	0.54	0.220E+06
764.00	390.87	475.3	8.66	32000	8.68	0.00361	1.62	19.25	0.55	0.220E+06
765.00	393.47	683.6	12.04	32000	7.78	0.00405	1.49	19.34	0.56	0.238E+06
770.00	395.11	699.4	10.91	32000	7.75	0.00410	1.50	19.34	0.56	0.230E+06

ID
10 SECTION 765.00 TIME = 19.99 HRS WS = 393.47 WIDTH = 683.6

Z	DZ	TDZ	Y	Z	DZ	TDZ	Y	Z	DZ	TDZ	Y
411.60	0.00	0.00	0.0	411.70	0.00	0.00	64.8	406.30	0.00	0.00	79.3
398.40	0.00	0.00	98.1	396.50	0.00	0.00	106.6	396.40	0.00	0.00	191.7
397.20	0.00	0.00	285.4	395.90	0.00	0.00	335.7	396.20	0.00	0.00	444.8
395.70	0.00	0.00	493.7	392.50	0.00	0.00	515.9	390.12	0.00	0.02	528.0
391.12	0.00	0.02	537.3	390.22	0.00	0.02	569.5	388.09	0.00	-0.61	624.2
383.34	0.00	-2.06	630.8	381.43	0.00	-2.87	653.4	381.43	0.00	-1.77	658.0
383.66	0.00	-1.24	663.7	387.18	0.00	-0.72	668.6	387.61	0.00	0.01	708.6
386.85	0.00	-0.05	732.1	384.32	0.00	-1.78	769.8	383.09	0.00	-2.11	834.1
381.49	0.00	-2.21	851.4	381.80	0.00	-2.10	875.9	384.54	0.00	-1.06	894.3
388.93	0.00	0.03	959.4	388.74	0.00	0.04	1040.4	386.40	0.00	0.10	1054.1
389.13	0.00	0.03	1065.0	390.32	0.00	0.02	1122.2	393.10	0.00	0.00	1186.4
395.50	0.00	0.00	1228.6	395.70	0.00	0.00	1312.3	396.50	0.00	0.00	1369.3
399.10	0.00	0.00	1472.8	399.10	0.00	0.00	1582.3	400.00	0.00	0.00	1666.6
399.90	0.00	0.00	1791.8	399.40	0.00	0.00	1905.3	399.60	0.00	0.00	2008.9

ID
9 SECTION 764.00 TIME = 19.99 HRS WS = 390.87 WIDTH = 475.3

Z	DZ	TDZ	Y	Z	DZ	TDZ	Y	Z	DZ	TDZ	Y
407.60	0.00	0.00	0.0	405.90	0.00	0.00	23.8	403.80	0.00	0.00	30.8
402.60	0.00	0.00	76.3	401.60	0.00	0.00	122.8	402.40	0.00	0.00	204.5

395.40	0.00	0.00	216.4	384.79	0.00	-1.91	232.4	388.88	0.00	-0.02	246.4
383.82	0.00	-2.48	271.2	384.70	0.00	-1.40	280.5	382.67	0.00	1.07	289.6
382.60	0.00	2.20	322.9	382.51	0.00	2.41	390.3	382.41	0.00	2.91	440.7
382.40	0.00	2.00	469.4	382.34	0.00	0.64	532.9	382.29	0.00	0.89	556.4
382.26	0.00	2.66	569.3	382.21	0.00	2.91	620.9	382.87	0.00	2.97	638.2
383.24	0.00	1.94	677.6	383.52	0.00	-0.18	687.0	387.25	0.00	-2.55	692.2
393.90	0.00	0.00	703.8	395.60	0.00	0.00	731.1	395.90	0.00	0.00	793.7
396.90	0.00	0.00	850.8	396.70	0.00	0.00	897.3				

ID
8 SECTION 760.00 TIME = 19.99 HRS WS = 388.34 WIDTH = 522.5

Z	DZ	TDZ	Y	Z	DZ	TDZ	Y	Z	DZ	TDZ	Y
406.10	0.00	0.00	0.0	406.50	0.00	0.00	29.9	399.90	0.00	0.00	41.2
398.60	0.00	0.00	57.7	394.30	0.00	0.00	73.3	387.06	0.00	0.36	88.1
383.88	0.00	1.98	96.8	382.05	0.00	-0.25	129.4	377.81	0.00	-0.49	136.0
377.67	0.02	-0.23	186.8	377.67	0.02	0.27	258.2	377.67	0.02	-0.13	283.5
379.65	0.00	-0.45	294.7	380.53	0.00	-0.67	335.6	380.14	0.00	-0.76	402.1
383.28	0.00	-0.02	426.0	383.29	0.00	-0.01	480.5	380.34	0.00	-0.46	498.3
383.09	0.00	-0.01	508.7	384.23	0.00	0.03	539.1	382.30	0.00	0.00	554.1
384.82	0.00	1.92	582.1	385.99	0.00	0.59	600.7	392.40	0.00	0.00	620.7
394.00	0.00	0.00	641.7	395.60	0.00	0.00	705.1	396.80	0.00	0.00	744.6
394.40	0.00	0.00	792.8	395.20	0.00	0.00	835.2	397.00	0.00	0.00	880.1
398.90	0.00	0.00	987.4	398.30	0.00	0.00	1025.7	397.60	0.00	0.00	1086.3
397.90	0.00	0.00	1156.8	399.70	0.00	0.00	1168.8	404.90	0.00	0.00	1187.5
408.20	0.00	0.00	1203.4	408.60	0.00	0.00	1266.0	409.30	0.00	0.00	1311.5
402.50	0.00	0.00	1325.9	397.40	0.00	0.00	1341.7	397.90	0.00	0.00	1405.0
399.30	0.00	0.00	1476.3	398.30	0.00	0.00	1612.4				

ID
7 SECTION 750.00 TIME = 19.99 HRS WS = 386.33 WIDTH = 500.1

Z	DZ	TDZ	Y	Z	DZ	TDZ	Y	Z	DZ	TDZ	Y
400.80	0.00	0.00	0.0	401.00	0.00	0.00	16.9	399.10	0.00	0.00	29.3
396.50	0.00	0.00	35.6	394.60	0.00	0.00	59.4	394.70	0.00	0.00	86.3
390.90	0.00	0.00	99.6	389.60	0.00	0.00	115.6	385.63	0.62	-0.27	123.7
383.82	-0.01	2.42	134.2	380.50	-0.02	0.50	182.8	380.18	-0.03	0.58	255.9
377.67	-0.04	0.37	281.9	376.82	-0.07	-0.48	415.2	376.82	-0.07	-0.48	527.8
379.05	-0.05	0.05	532.9	379.28	-0.05	0.18	584.9	377.45	-0.06	-0.05	595.6
378.05	-0.05	0.55	605.4	383.53	0.29	3.53	614.9	390.36	0.00	-0.34	629.2
391.70	0.00	0.00	691.1	400.26	0.00	7.06	760.5	402.37	0.00	-6.94	763.4
402.77	0.00	-6.53	834.1	400.30	0.00	6.50	837.5	393.80	0.00	0.00	908.5
392.30	0.00	0.00	919.5	393.20	0.00	0.00	926.6	393.60	0.00	0.00	1040.7
393.20	0.00	0.00	1152.6	393.10	0.00	0.00	1222.8	393.80	0.00	0.00	1320.3
393.30	0.00	0.00	1416.1	393.90	0.00	0.00	1526.0	394.80	0.00	0.00	1646.2
396.90	0.00	0.00	1679.0	397.40	0.00	0.00	1735.9	398.30	0.00	0.00	1810.4
398.10	0.00	0.00	1885.5	396.60	0.00	0.00	1908.9	399.20	0.00	0.00	1926.1
402.80	0.00	0.00	1940.8	406.20	0.00	0.00	1974.6	407.00	0.00	0.00	1998.3

ID
6 SECTION 744.00 TIME = 19.99 HRS WS = 384.35 WIDTH = 265.7

Z	DZ	TDZ	Y	Z	DZ	TDZ	Y	Z	DZ	TDZ	Y
401.60	0.00	0.00	0.0	399.90	0.00	0.00	40.8	395.70	0.00	0.00	62.5
394.40	0.00	0.00	95.7	394.60	0.00	0.00	151.7	394.40	0.00	0.00	206.1
392.80	0.00	0.00	272.1	392.50	0.00	0.00	356.9	386.14	-0.42	-6.16	420.0
384.03	0.07	-5.97	422.9	372.89	0.00	-12.11	442.6	372.89	0.00	-7.11	469.9
372.89	0.00	-2.11	487.2	372.89	0.00	-0.11	500.0	372.89	0.00	-0.11	581.8
372.89	0.00	-0.11	600.0	372.10	0.27	-0.90	610.0	372.10	0.27	-2.90	622.3
372.10	0.27	-7.90	634.9	372.10	0.27	-12.90	652.0	372.10	0.27	-17.90	668.1
391.00	0.00	0.00	700.0	391.60	0.00	0.00	835.7	389.60	0.00	0.00	1194.5
389.90	0.00	0.00	1316.4	390.60	0.00	0.00	1407.6	392.60	0.00	0.00	1454.4
392.70	0.00	0.00	1537.6	393.80	0.00	0.00	1614.2	393.50	0.00	0.00	1656.5
391.90	0.00	0.00	1705.9	392.70	0.00	0.00	1792.7	392.90	0.00	0.00	1881.6
393.50	0.00	0.00	1973.0	394.00	0.00	0.00	2089.8	393.60	0.00	0.00	2185.3
393.50	0.00	0.00	2206.6	393.00	0.00	0.00	2216.3	393.70	0.00	0.00	2228.0
394.50	0.00	0.00	2288.3	403.00	0.00	0.00	2315.7	413.50	0.00	0.00	2335.4
414.80	0.00	0.00	2337.6	416.20	0.00	0.00	2358.3				

ID
5 SECTION 741.00 TIME = 19.99 HRS WS = 383.83 WIDTH = 413.5

Z	DZ	TDZ	Y	Z	DZ	TDZ	Y	Z	DZ	TDZ	Y
390.00	0.00	0.00	680.0	373.57	-1.20	-11.43	715.3	370.65	1.00	-9.35	739.2
370.65	1.13	-4.35	781.6	370.65	1.19	-2.35	800.0	370.65	1.16	-2.35	810.0
370.65	1.00	-2.35	860.0	370.65	0.97	-2.35	870.0	370.65	0.91	-4.35	889.1
370.65	0.86	-9.35	904.3	370.65	0.76	-14.35	933.6	379.88	-1.20	-5.12	951.5
385.00	0.00	0.00	1175.0	391.00	0.00	0.00	1187.0	391.50	0.00	0.00	1250.0
391.50	0.00	0.00	1300.0	391.70	0.00	0.00	1400.0	392.00	0.00	0.00	1500.0

ID
4 SECTION 740.00 TIME = 19.99 HRS WS = 382.13 WIDTH = 543.9

Z	DZ	TDZ	Y	Z	DZ	TDZ	Y	Z	DZ	TDZ	Y
390.00	0.00	0.00	557.6	390.00	0.00	0.00	557.8	390.00	0.00	0.00	558.0
371.78	-0.65	-3.22	596.8	374.89	-0.70	-0.11	667.1	375.22	-0.64	0.22	689.1
375.26	-0.61	0.56	702.6	371.85	-0.55	-0.85	711.8	372.43	-0.62	-0.17	805.5
373.61	-0.52	0.91	843.5	375.88	-0.35	2.28	872.0	377.27	-0.26	2.47	880.8
376.45	-0.29	2.65	889.3	376.26	-0.29	2.66	903.4	378.59	-0.16	2.29	915.1
376.73	-0.23	3.13	928.7	377.28	-0.19	3.68	949.1	377.56	-0.16	3.96	971.5
377.67	-0.14	4.07	981.7	377.56	-0.14	4.36	992.3	377.56	-0.12	4.56	1004.4
378.18	-0.08	4.48	1034.1	377.73	-0.06	5.43	1061.8	379.60	0.90	5.20	1080.4
382.17	0.00	9.27	1119.7	389.00	0.00	0.00	1150.5	389.60	0.00	0.00	1263.0
390.00	0.00	0.00	1336.2	390.30	0.00	0.00	1372.8	390.50	0.00	0.00	1435.0

ID
3 SECTION 738.00 TIME = 19.99 HRS WS = 381.35 WIDTH = 531.7

Z	DZ	TDZ	Y	Z	DZ	TDZ	Y	Z	DZ	TDZ	Y
393.60	0.00	0.00	643.7	393.60	0.00	0.00	643.9	392.40	0.00	0.00	650.7
387.00	0.00	0.00	664.2	382.30	0.00	0.00	675.5	375.05	0.15	4.05	701.6
373.55	0.16	2.55	793.0	374.38	0.16	3.38	825.4	374.05	0.16	3.05	843.2
373.90	0.16	2.90	853.5	373.68	0.16	2.68	869.0	373.50	0.17	2.50	880.9
373.17	0.17	2.17	903.0	373.02	0.17	3.52	912.3	372.60	0.17	5.30	938.7
372.78	0.17	4.28	949.6	373.01	0.17	4.31	964.2	373.16	0.17	3.16	973.4
373.92	0.16	1.21	986.6	374.14	0.16	1.84	1040.8	376.55	0.13	2.85	1063.9
375.54	0.14	2.24	1124.5	376.50	0.13	4.60	1133.7	376.74	0.13	5.14	1162.3
375.87	0.14	6.27	1182.0	379.79	0.08	10.19	1204.4	388.00	0.00	0.00	1235.7
388.50	0.00	0.00	1309.9	389.00	0.00	0.00	1389.2	390.00	0.00	0.00	1476.2

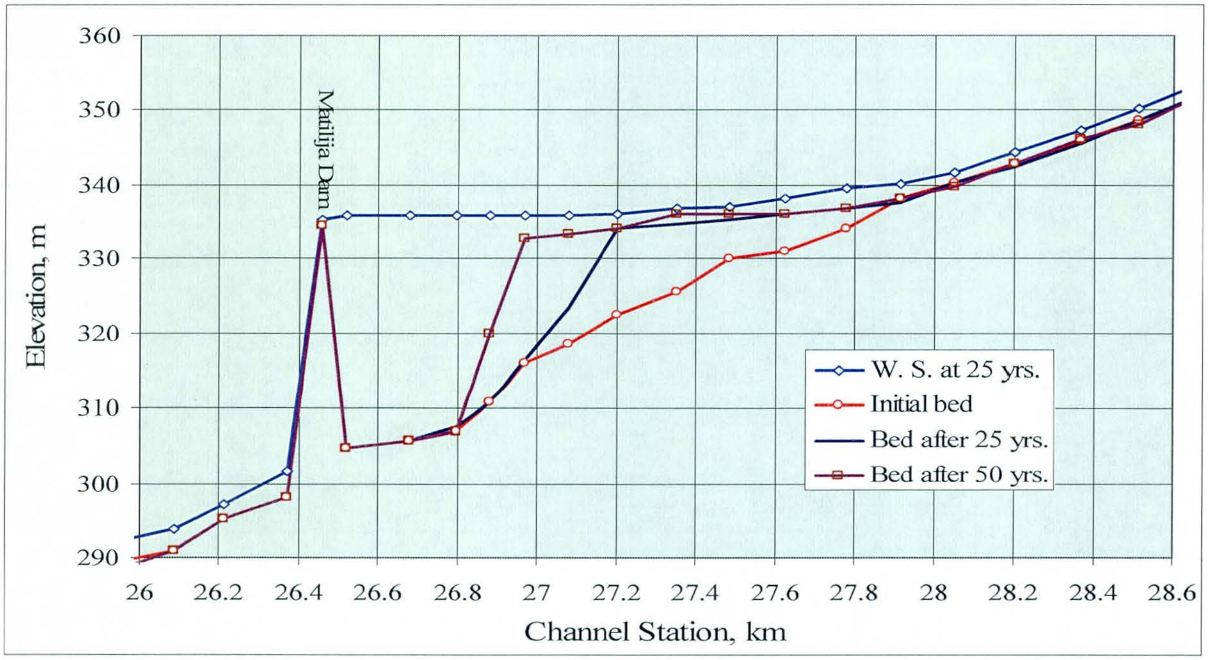
ID
2 SECTION 734.00 TIME = 19.99 HRS WS = 379.97 WIDTH = 516.5

Z	DZ	TDZ	Y	Z	DZ	TDZ	Y	Z	DZ	TDZ	Y
383.70	0.00	0.00	1045.0	383.58	0.00	-0.12	1109.4	376.35	0.07	1.15	1120.4
373.59	0.09	2.39	1132.7	374.07	0.09	2.07	1160.6	372.86	0.10	2.26	1203.2
373.09	0.10	2.19	1233.0	374.06	0.09	1.86	1249.0	373.24	0.10	2.14	1266.9
370.64	0.12	2.84	1280.0	370.59	0.12	4.59	1313.6	370.61	0.12	3.21	1325.2
371.49	0.11	1.79	1338.2	373.36	0.10	2.16	1368.4	372.93	0.10	2.33	1446.9
373.30	0.10	2.60	1548.4	374.18	0.09	2.38	1615.0	386.00	0.00	0.00	1648.2
386.40	0.00	0.00	1705.0	386.80	0.00	0.00	1730.2	387.00	0.00	0.00	1805.0
387.40	0.00	0.00	1852.5	387.80	0.00	0.00	1900.0				

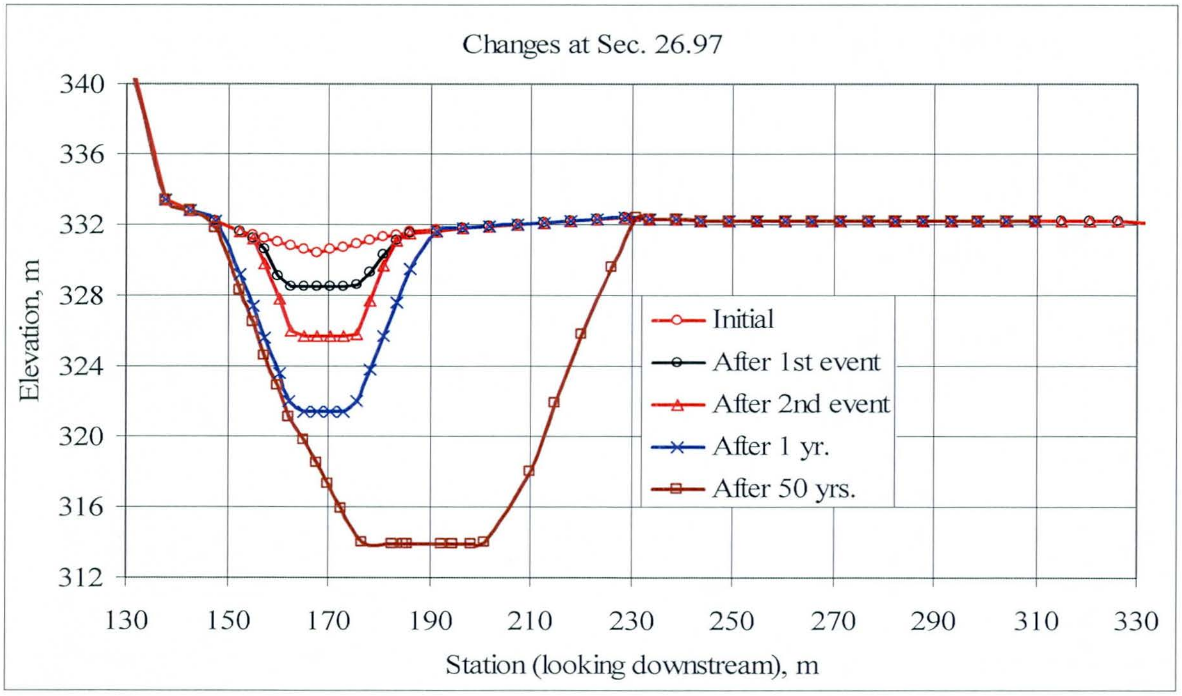
ID
1 SECTION 730.00 TIME = 19.99 HRS WS = 377.70 WIDTH = 745.4

Z	DZ	TDZ	Y	Z	DZ	TDZ	Y	Z	DZ	TDZ	Y
381.40	0.00	0.00	1240.4	385.50	0.00	0.00	1248.9	385.10	0.00	0.00	1281.3
381.90	0.00	0.00	1287.2	381.80	0.00	0.00	1344.2	380.90	0.00	0.00	1418.1
383.30	0.00	0.00	1423.8	383.70	0.00	0.00	1442.0	380.20	0.00	0.00	1450.2
375.30	0.00	1.70	1462.3	374.03	0.00	2.73	1477.7	373.35	0.00	3.15	1538.5
372.97	0.00	3.37	1639.5	372.65	0.00	3.55	1690.7	372.09	0.00	4.19	1700.8
371.55	0.00	4.65	1768.1	370.22	0.00	5.32	1794.5	369.44	0.00	5.64	1813.3
370.08	0.00	5.38	1867.4	372.32	0.00	3.82	1881.3	372.71	0.00	3.51	1928.7
372.52	0.00	3.62	1962.0	371.23	0.00	4.83	1972.1	369.94	0.00	5.44	1981.5
371.04	0.00	4.94	1987.1	370.84	0.00	5.04	2005.0	370.43	0.00	5.23	2006.3
370.43	0.00	5.23	2164.4	371.61	0.00	4.61	2167.6	380.00	0.00	0.00	2214.7
380.00	0.00	0.00	2264.0	380.00	0.00	0.00	2300.0	380.00	0.00	0.00	2400.0

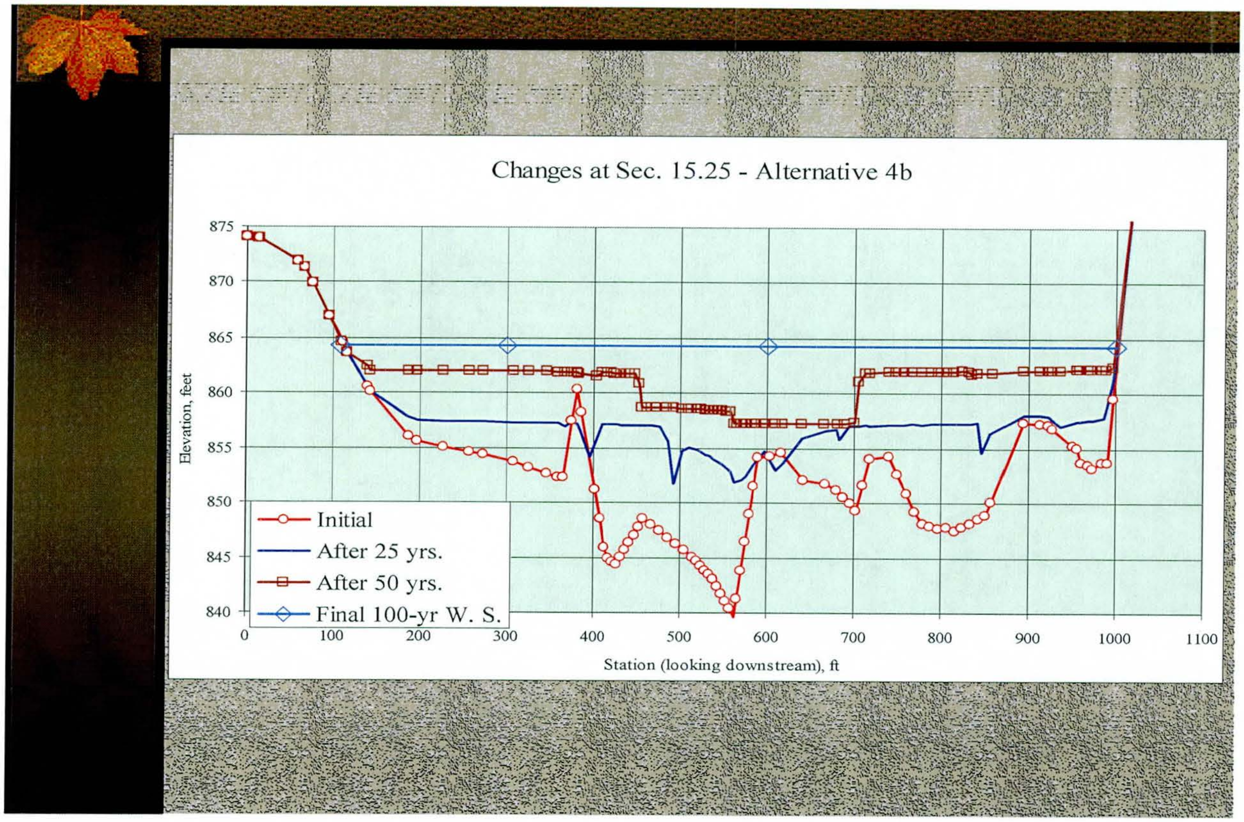
SAMPLE GRAPHICAL RESULTS



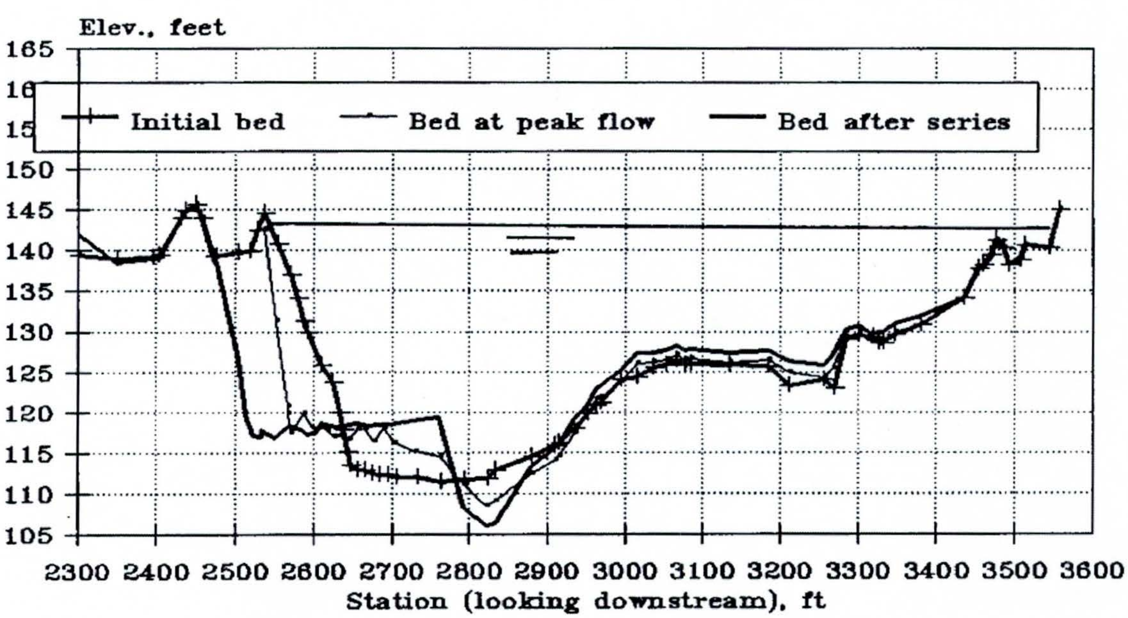
Longitudinal profiles of water surface and channel bed for sediment deposition in reservoir



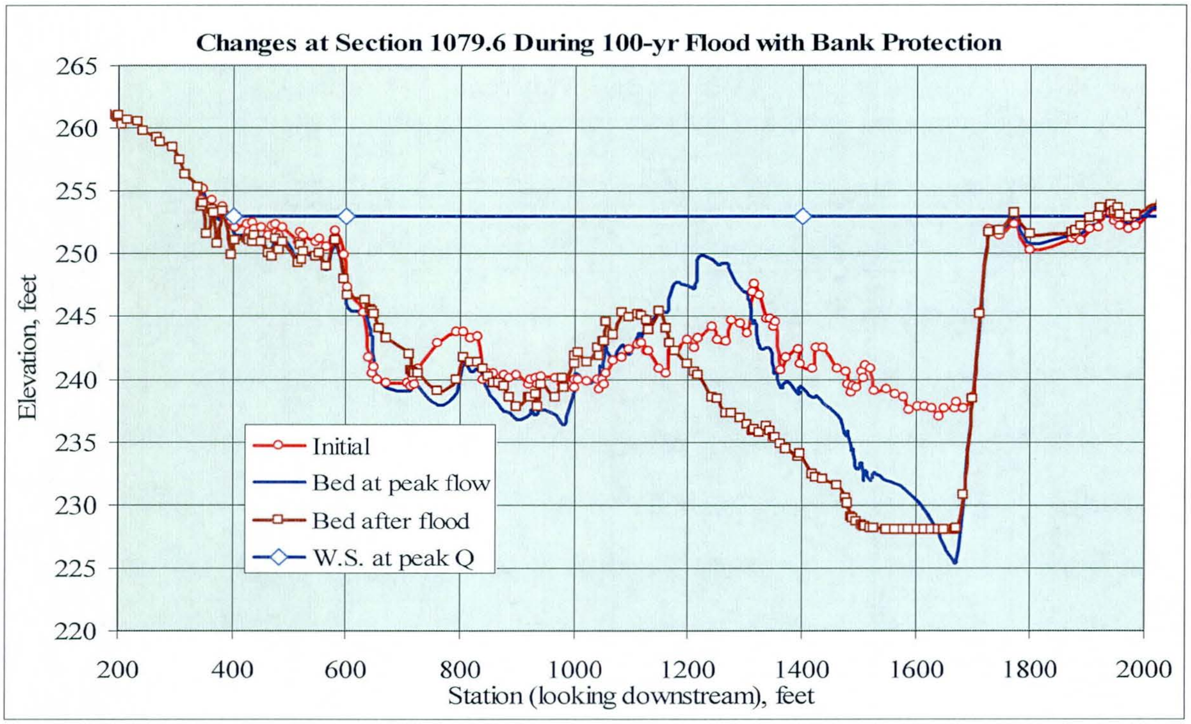
Changes in cross sectional profile during erosion of delta in reservoir after dam removal



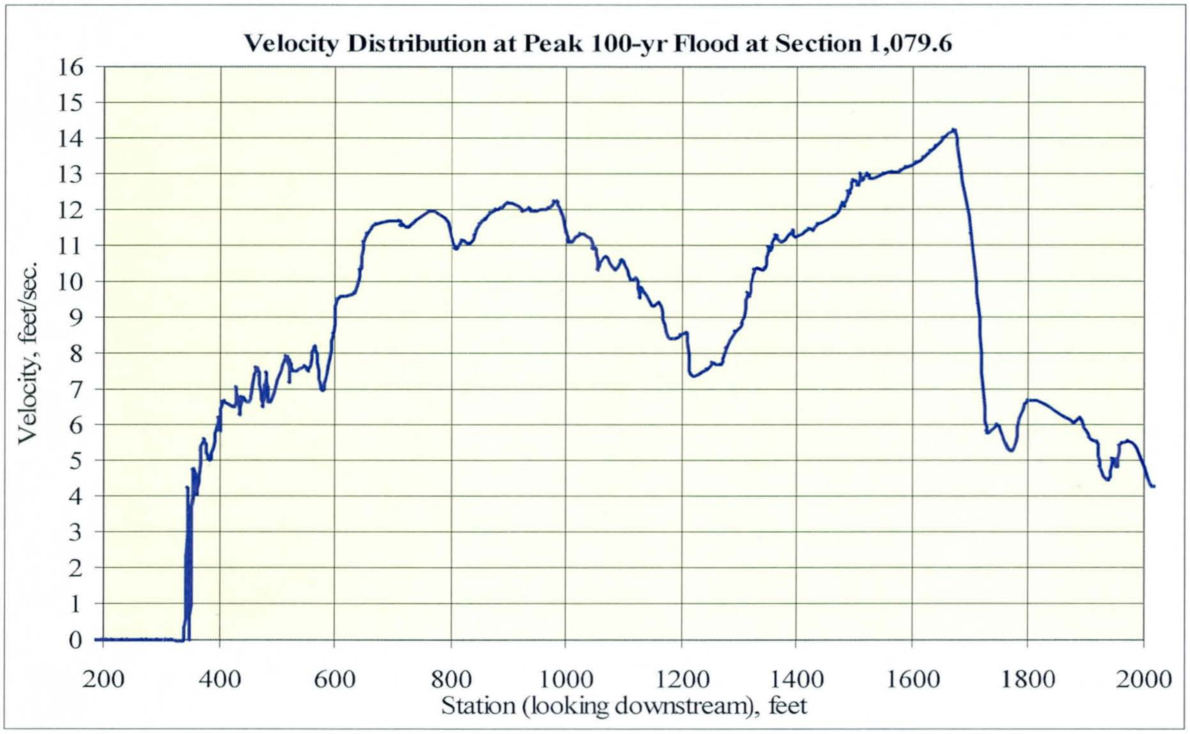
Sediment deposition in channel induced by check dam on downstream side



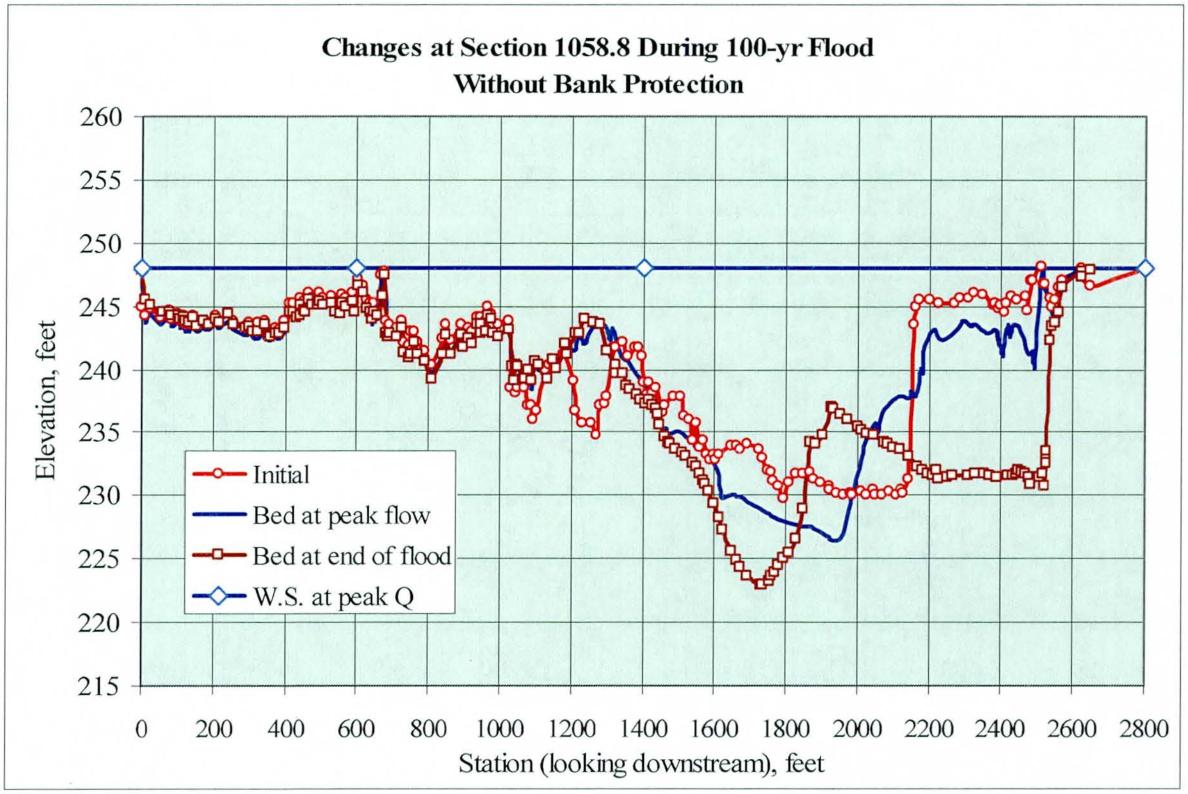
Cross sectional changes during lateral migration



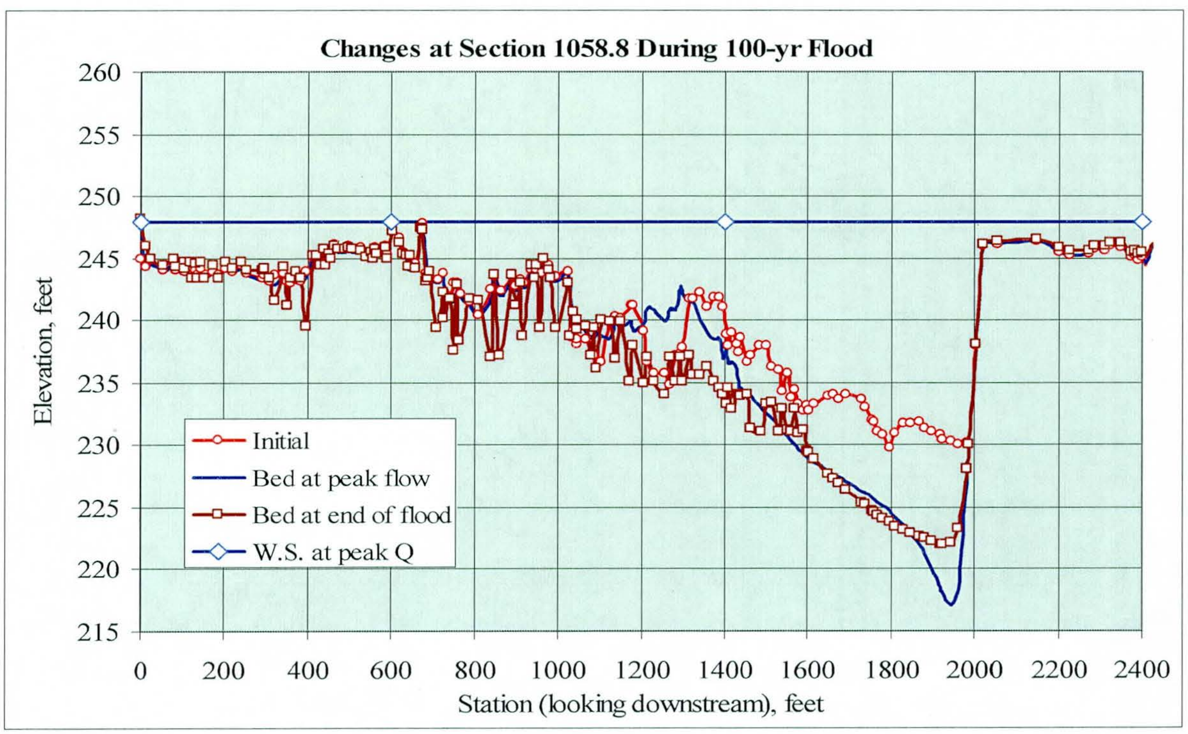
Bank protection along concave bank in curved channel



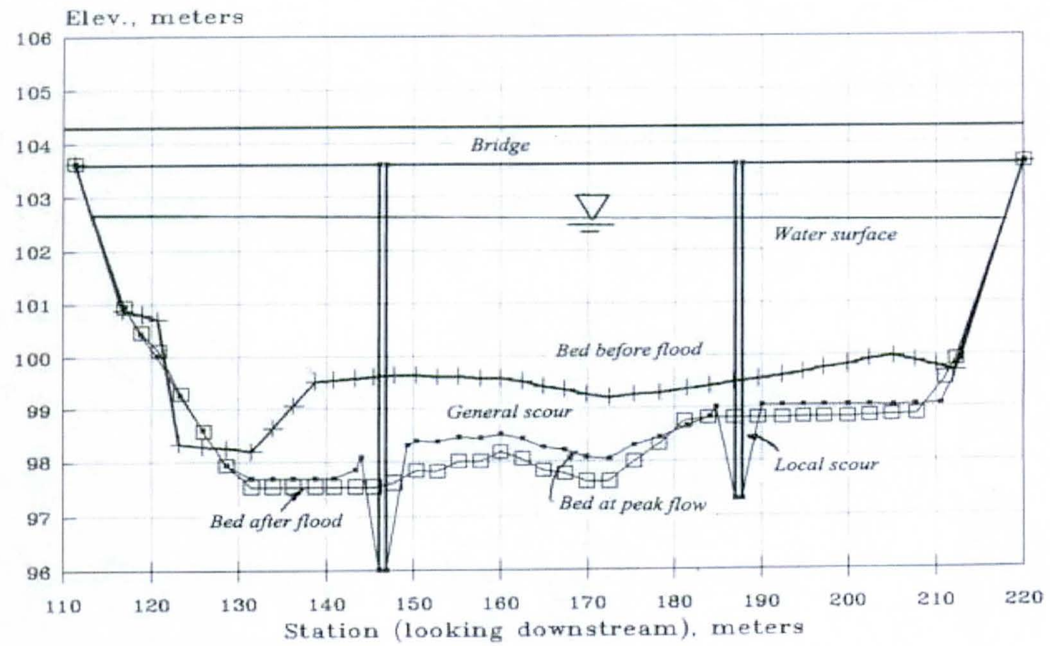
Velocity distribution at peak flow at the same cross section



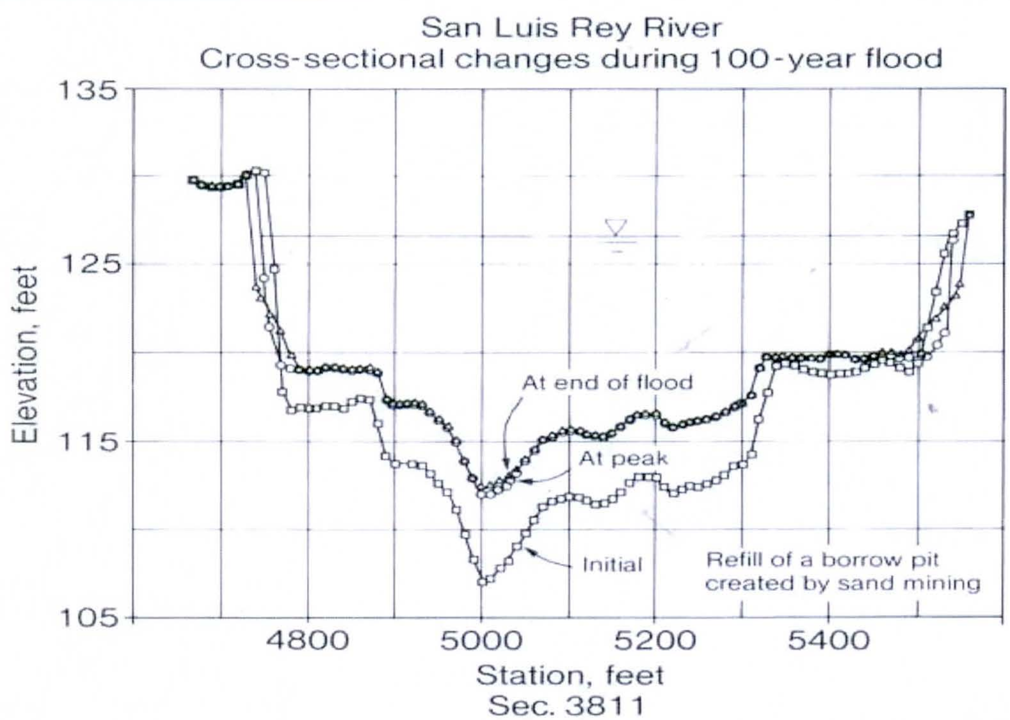
Cross-sectional changes with lateral migration



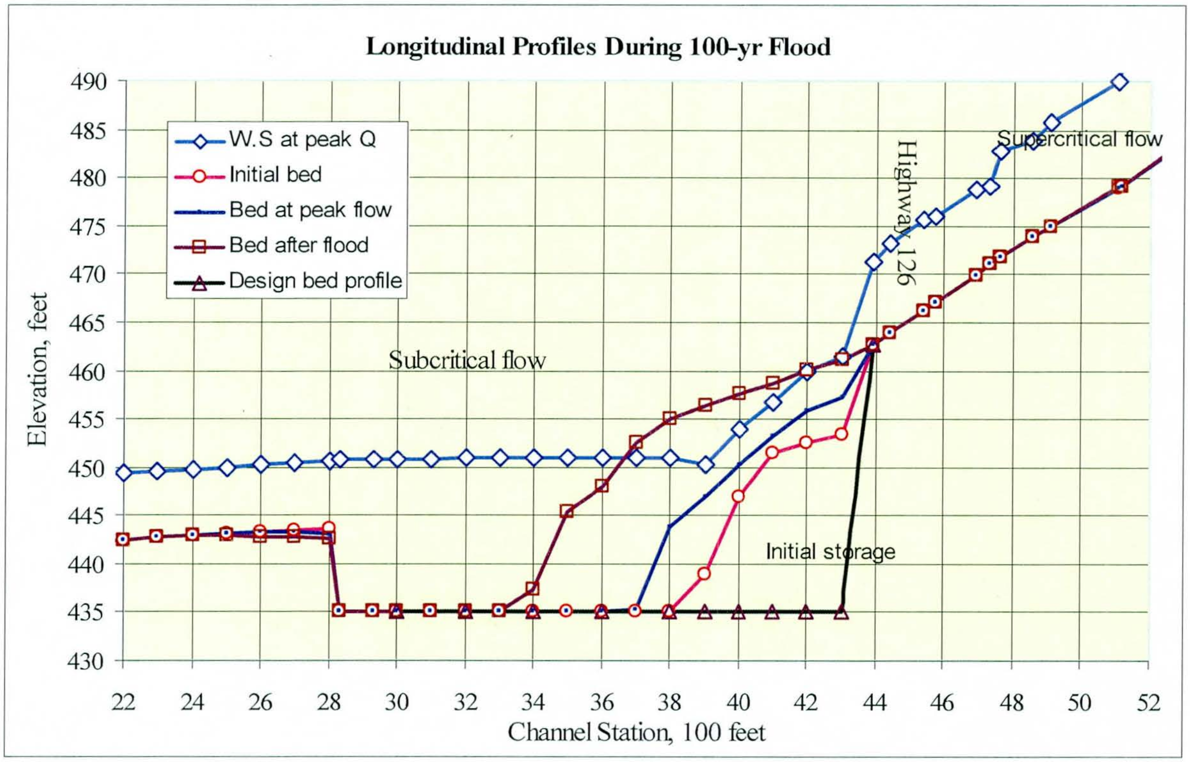
Bank protection along concave bank in curved channel



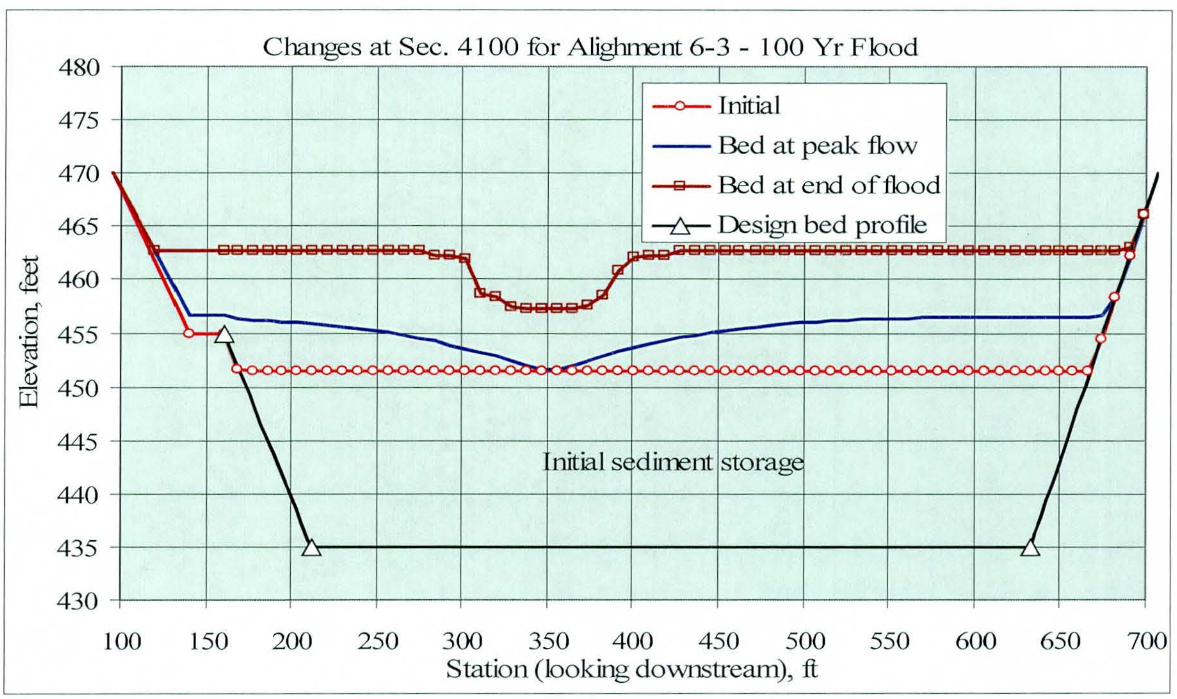
Scour prediction for bridge design



Refill of a sand pit by sediment deposition



Simulation of sediment deposition in a sediment basin



Cross sectional changes during deposition in sediment basin

SELECTION OF MATHEMATICAL MODELS FOR RIVER AND RESERVOIR SEDIMENTATION

River channel behavior often needs to be studied for its natural state and response to human regulation. Studies of river hydraulics, sediment transport, and river channel changes may be through physical modeling, or mathematical modeling, or both. Physical modeling has been relied upon traditionally for river projects, but mathematical modeling is becoming more popular as its capabilities expand rapidly.

Mathematical models are developed based on convoluted physical relationships. The five most important relations are: continuity equation of flow, momentum equation of flow, continuity equation of sediment, sediment transport equation, and relations for channel deformation. These equations are applied at successive time steps to simulate the time-dependent processes. In selecting a model for application, the user should consider the necessary model feathers described below.

(1) The model should have sound mathematical and physical bases. The allocation of scour and fill at a time step should be based on physical principles that can be verified using field data. Empirical relationships are considered in adequate for modeling river dynamics.

(2) A mathematical model applicable to natural streams should be an *erodible boundary model* rather than an *erodible bed model*. The channel boundary changes are by no means uniformly distributed on the bed. The changes in channel width and bed profile are closely inter-related. For these reasons, the model must consider all boundaries of a river channel as free surfaces. These changes must be coupled at each time step.

(3) The curvature effect on bed topography is an important feature for river morphology. Natural streams are seldom straight over a length longer than a few channel widths. The channel curvature, with its inherent secondary currents, has important effects on channel morphology; therefore, a mathematical model should possess this capability.

(4) A model should allow the user to specify non-erodible parts of a channel, such as bank protection, grade control structures, check dams, etc.

(5) The applicability of a model must be substantiated by adequate number of test and calibration studies using field data.

COMPARISON OF FLUVIAL-12 AND HEC-6 MODELS

The FLUVIAL-12 model is an *erodible-boundary model*; it simulated inter-related changes in channel-bed profile, channel width and bed topography induced by the channel curvature. The erodible boundary model is different from an *erodible-bed model*, such as HEC-6 in the following ways.

(1) The HEC-6 model does not simulate changes in channel width. Since changes in channel-bed profile is closely related to changes in width, these changes may not be separated.

(2) The change in bed profile in HEC-6 is assumed to be uniform in the erodible zone. All points adjust up and down by the equal amount during aggradation and degradation. Actual bed changes are by no means uniform and therefore they may not be simulated by an erodible bed model.

(3) An erodible bed model does not consider the channel curvature. In reality, the bed topography is highly non-uniform in a curved channel, especially during a high flow.

(4) The erodible zone needs to be specified at all cross sections in the HEC-6 model. This means the model does not provide the extent of erosion in the channel, but the user has to inform the model about the erodible part of the channel bed. The boundary of erosion is computed and provided by the FLUVIAL-12 model, this boundary changes with the discharge and time.

(5) The sediment inflow into the channel reach needs to be specified in the HEC-6 input. This requires the sediment rating curve which is usually not available for stream channels. In the FLUVIAL-12 model, the sediment inflow may be specified and it may also be computed based on the hydraulics of flow at the upstream section at every time step.

(6) The FLUVIAL-12 model has been calibrated using 12 sets of river data. An erodible-bed model may not be calibrated with field data of natural streams.

Data Requirements for Fluvial Study

Prepared by Howard H. Chang

(1) Topographic maps of the Sacramento River for a channel reach at least two miles in length, with one mile minimum on each side of the intake structure. These maps should show locations of cross sections used for the HEC-2 study, if any.

(2) Available digitized cross-sectional data used for HEC-2 studies for the stream reach from the downstream end to the upstream end of study. The locations of cross sections should be shown on the accompanying topographic maps. For stream reaches without such data, the consultant will prepare cross-sectional data based on the topographic maps.

(3) Peak discharges of 10-, 50- and 100-yr floods and their variations along the study stream reach. The hydrographs for 100-yr floods are also required.

(4) Exiting mining sites and proposed mining plans, if any.

(5) Plans for the proposed structure.

(5) Plans for existing bridges and hydraulic structures, such as drop structures, bank protection, levees, etc. on the stream, if any.

(6) At least two sediment samples along the study reach of each stream. Size distributions of such samples are normally determined based on the sieve analysis.

USE AGREEMENT

An Agreement between Chang Consultants, Located at Rancho Santa Fe, California 92067-4492, U.S.A., hereinafter referred to as the "Developer" and __________________ in California hereafter referred to as the "User."

WHEREAS the parties agree that subject to the following terms and conditions, the Developer shall deliver to the User in a machine-readable form FLUVIAL-12, a computer model hereinafter referred to as the "Product."

I. Definitions

A. The term "copy" shall mean any transfer in whole or in part of the product onto transportable machine-readable media.

B. The term "use" shall mean any use whatsoever of the Product whether in whole or in part in its original mode or in any mode.

II. Use of Product

A. User agrees that the product shall be used only at the User's place of business or its contracted Computer Service Bureau.

B. User agrees not to copy, release, disclose or otherwise make the Product available, in its original form, as received from the Developer.

C. User agrees not to include the Product in an online commercially available terminal service established to offer service to people who are not a part of the User's organization. However, the User may use the product as a part of an online service offered wholly for the use of the User's employees.

D. User agrees to notify the Developer of any physical defects in the Product within sixty (60) days following delivery of the Product by the Developer.

Developer:	User:
______________________________	______________________________
Signature and Date	Signature and Date
	______________________________
	Name
	______________________________
	Title

Return to: Howard H. Chang, P.O. Box 9492, 6001 Avenida Alteras, Rancho Santa Fe, CA 92067-4492, U.S.A.

The FLUVIAL-12 model contains special and unique features, making it the most suitable model for the Salt River project as described below:

(1) The model simulates river hydraulics, sediment delivery, and river channel changes, which include channel bed scour and fill, width changes and lateral migration. The Salt River, as an ephemeral river undergoes changes during floods, not only in the bed but also along the banks. Changes in channel bed and banks are interrelated, and thus they must be considered at the same time in a simulation study. The FLUVIAL-12 model is unique in that these changes are coupled at every time step. Other models are limited to changes of the bed (i.e., scour and fill) but not the banks.

(2) The model includes the effects of secondary currents inherent in river channels. For this reason, the hydraulics, sediment transport and channel changes related to the channel curvature may be computed using the model. Bank erosion evaluation is an important task for the Salt River project, and it is specifically called out in the scope of work. Reaches of bank erosion are evident along the river and they need to be identified in the project. Continued erosion of concave banks will result in lateral migration of the channel. Lateral migration is an important concern for channel stability. The FLUVIAL-12 model is unique, as it is the only model that contains the features for curved channels.

(3) Rivers in the arid western U. S. are highly dynamic as they may undergo rather rapid and significant changes in comparison to the eastern rivers. The FLUVIAL-12 model has been developed in the west, adopted to the dynamic nature of the western rivers. Most importantly, the model has been tested and calibrated based on more than five sets of river data. The simulation results by the model have been confirmed by field data.