1D HEC-RAS Model Development using RAS-Mapper

Prepared by

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Introduction

The objective of this exercise is learn the basic functions of RAS Mapper in HEC-RAS to create a 1D model of a river system. Students are expected to have a basic understanding of hydraulics, open channel flow and GIS functions. A small reach of the Wabash River in Tippecanoe County, Indiana is created using the RAS Mapper in HEC-RAS.

Computer Requirements

You must have a computer with HEC-RAS version 5.0.3 or higher. The latest version of HEC-RAS can be downloaded from the link below:

http://www.hec.usace.army.mil/software/hec-ras/downloads.aspx

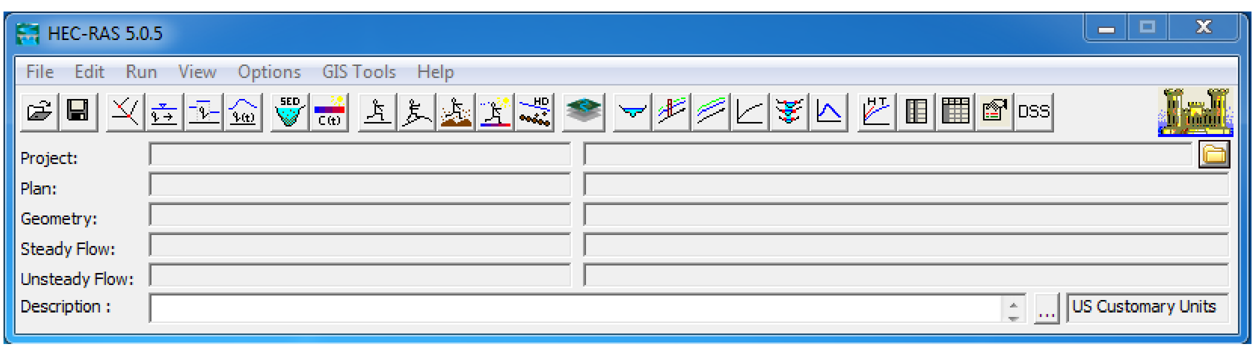
Data Requirements

The key data required to create a hydraulic model is the terrain data (TIN or DEM or surveyed cross-sections). Additional datasets that may be useful are aerial photograph (s) and land use information. The dataset supplied to you includes a small portion of the Wabash River and its tributary, the Tippecanoe River, located in Indiana, US.

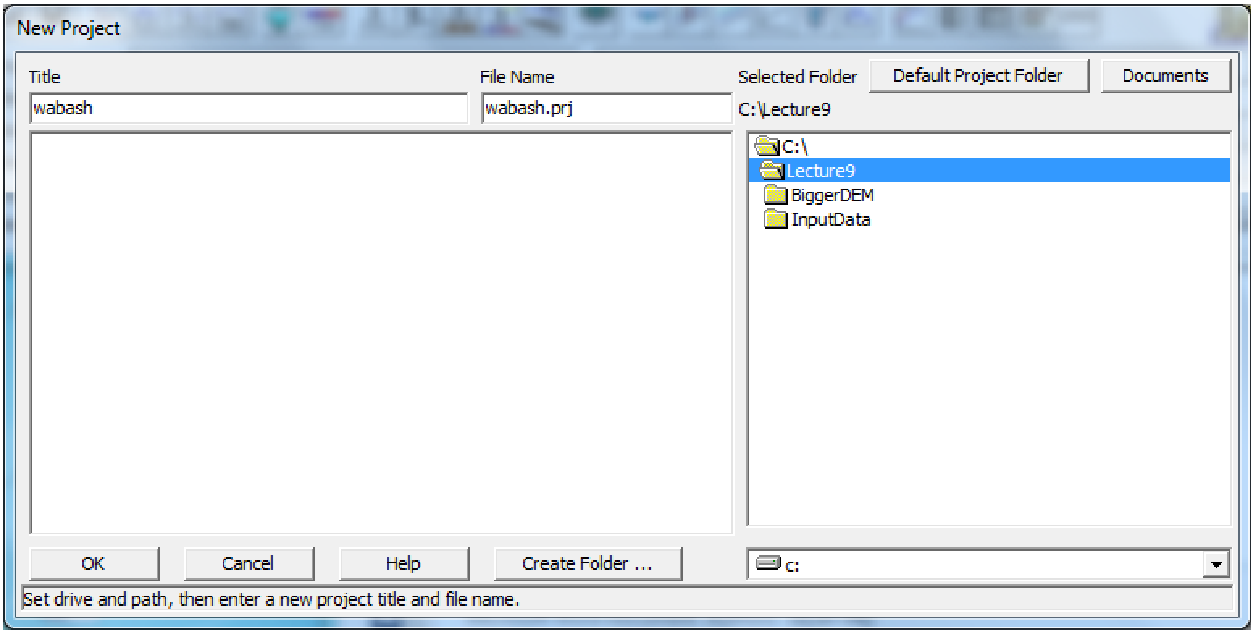
Download the zip file from ftp://ftp.ecn.purdue.edu/vmerwade/download/data/rasmapper.zip on your local drive, and **unzip** its contents in your working folder. It contains a polygon shapefile depicting the study area extents and a DEM of the study area in raster format.

Getting Started

Start HEC-RAS from the *Start* menu by **clicking** on *Start >> HEC-RAS 5.0.5*. The following window should open.

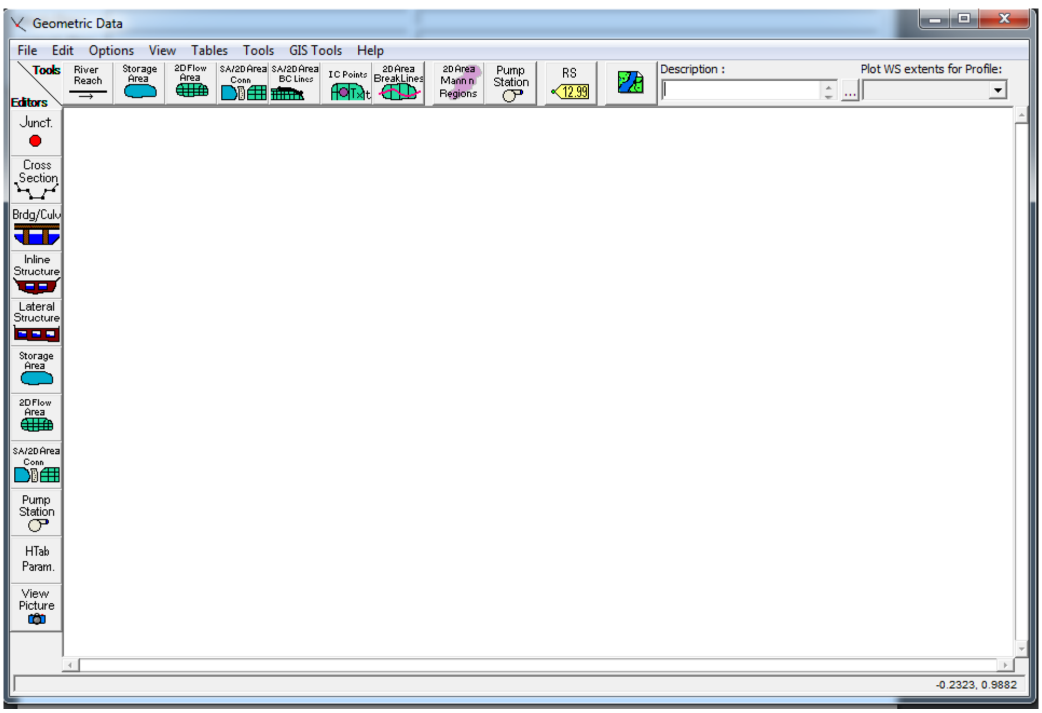


Next, **Click** on *File >> New Project*. **Navigate** to your working folder on the right pane, **specify** a name (Wabash) for the project in the "*Title*" box and **click** *OK*.



A new window appears confirming the project details and the units system (default is US Customary units). **Click** *OK.*

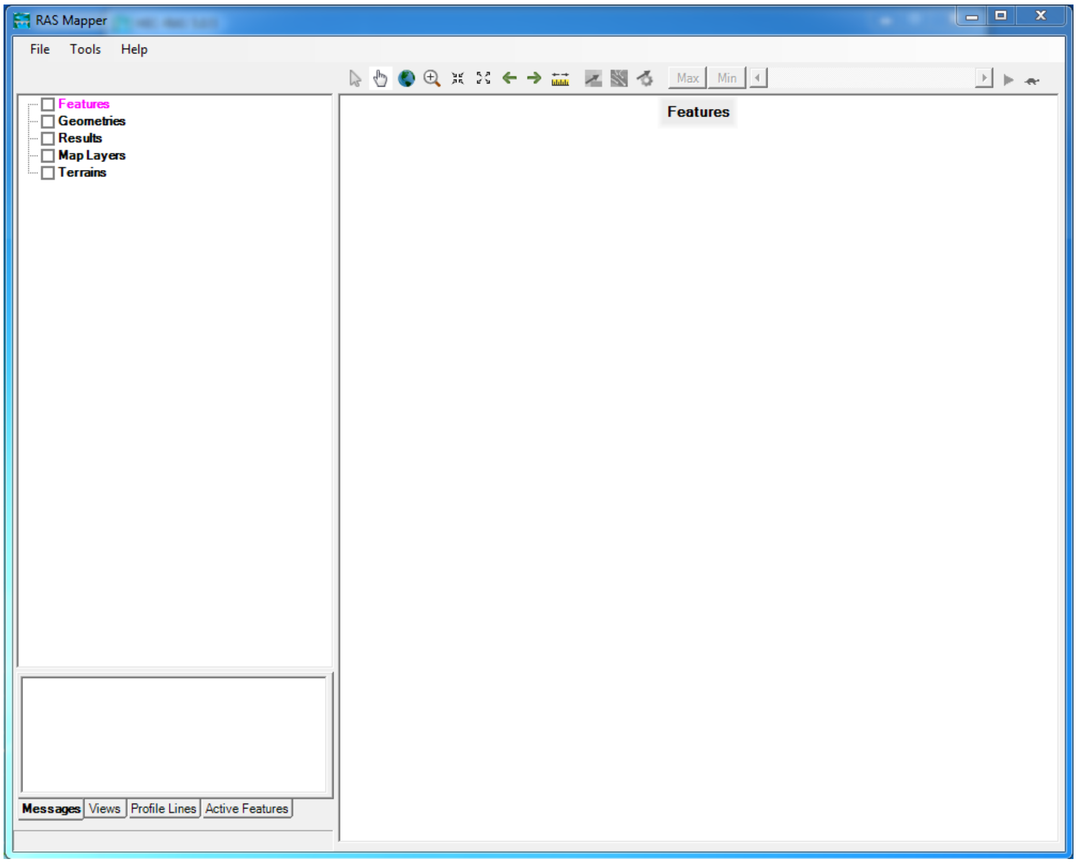
In the HEC-RAS window, **click** on *Edit >> Geometric Data…* The following window opens.



Click on *File >> Save Geometry Data as.* **Specify** a name (Wabash), and save it in the same folder as the project file, and **click** "OK". This file contains all the geometric information that HEC-RAS will use for its computations. Close the geometry editor.

From the main HEC-RAS window, **open** RAS Mapper by **clicking** on the RAS Mapper button shown in the figure below. You can also open the RAS Mapper by **clicking** on *GIS Tools >> RAS Mapper*.

The RAS Mapper interface opens as shown in the figure below.



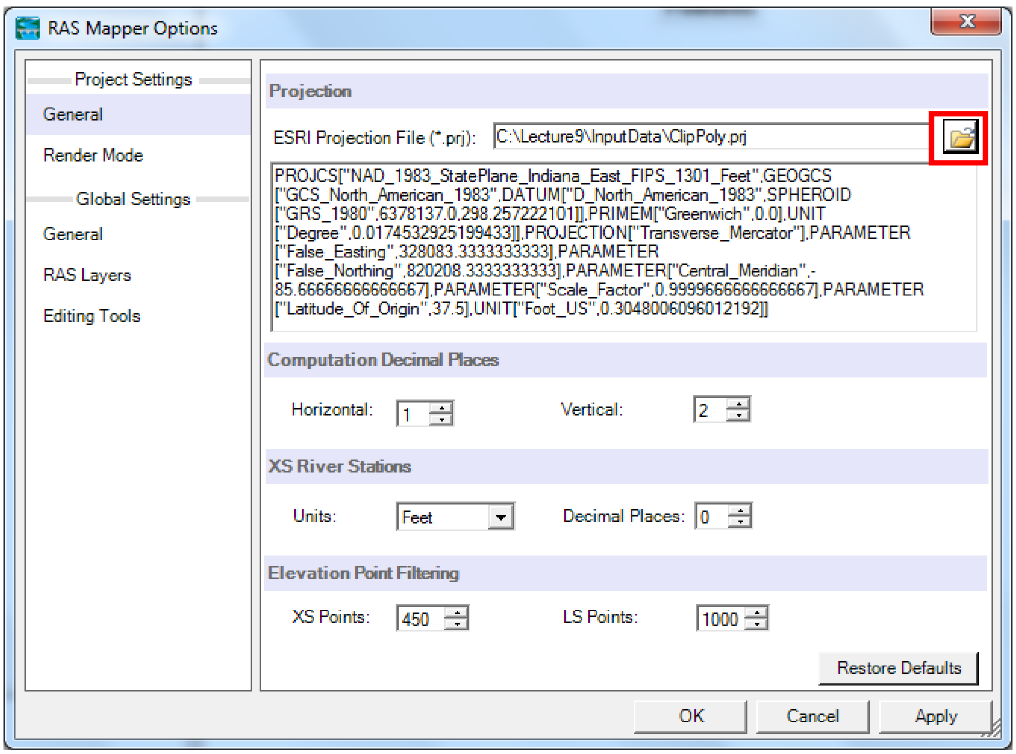
The upper left pane is called the *Data Layer Window*. It contains a tree structure of all the available layers and associated data. The layers are grouped as per the HEC-RAS layer structure. The right pane is called the *Display Window*. It displays geospatial data corresponding to the HEC-RAS inputs, outputs (results) and imported datasets. The pane on the bottom left is called the *Status Window*. It displays the status messages for RAS Mapper operations. For more detailed information, you can refer to the RAS Mapper User Manual (later!) which can be accessed by **clicking** on *Help >> RAS Mapper Help…* in the RAS Mapper interface.

5.0 Importing Data into RAS Mapper

Before importing data, it is important to set the coordinate system in RAS Mapper. All datasets should be in this coordinate system. **Click** on *Tools >> Set Projection for Project…* A new window (RAS Mapper Options window) opens as shown below. RAS Mapper uses an ESRI projection file to import the coordinate system. **Click** on the browse button (highlighted in red border in the figure below). The shapefile for the study area, "*ClipPoly.shp*" has an associated .prj file that can be used for setting the coordinate system. Navigate to your working folder where you have unzipped the downloaded data. **Select** the "*ClipPoly.prj*" file from the InputData folder and **click** OK.

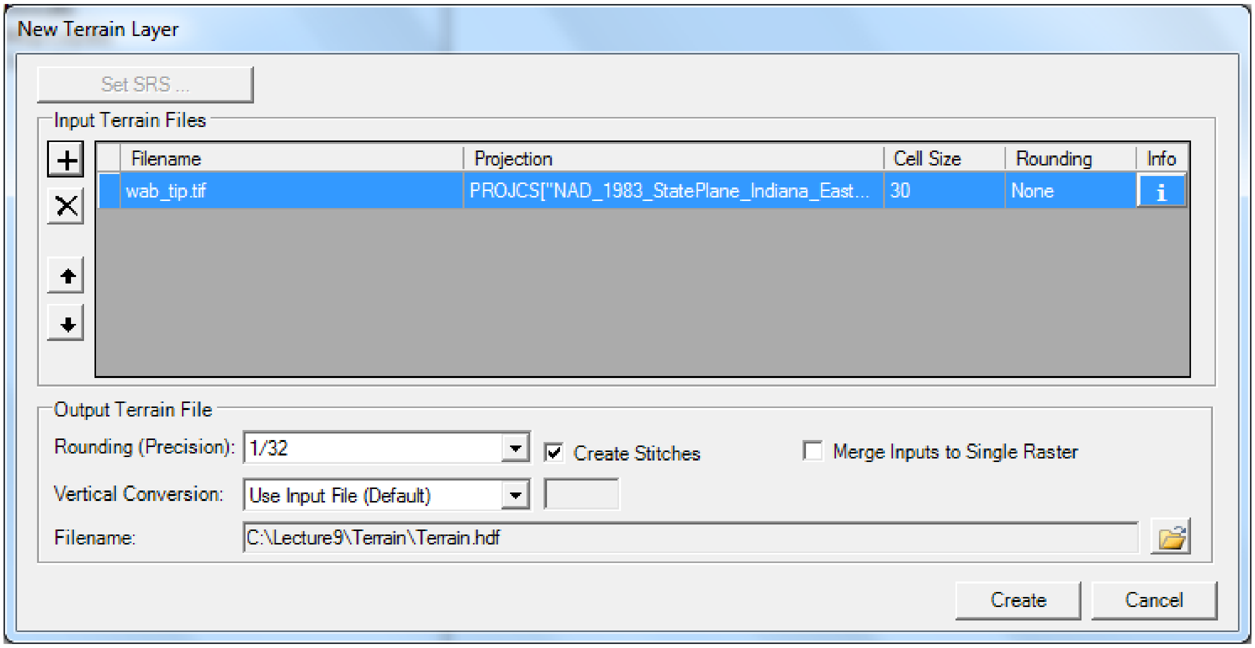
Note that a HEC-RAS project file, such as the one created earlier, also has the same extension (.prj). Do not confuse the GEC-RAS .prj file with the ESRI .prj file associated with the shapefile.

The details of the coordinate system are extracted automatically from the .prj file and populated in the "RAS Mapper Options" window. **Click** *Apply* and then *OK*.

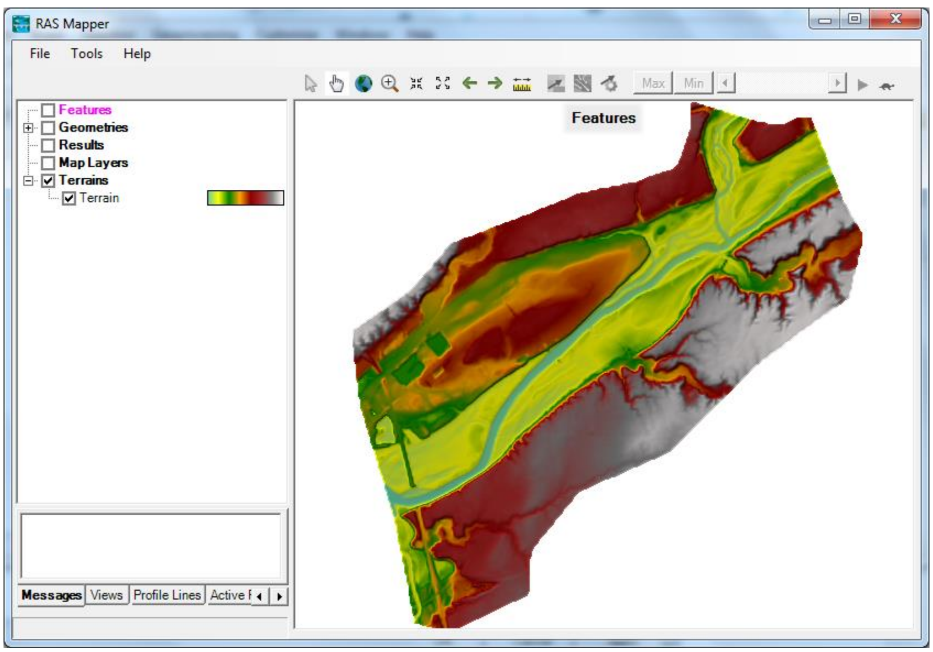


Next we will import the terrain or DEM into the RAS Mapper. **Click** on *Tools >> New Terrain…* The "New Terrain Layer" window opens as shown below.

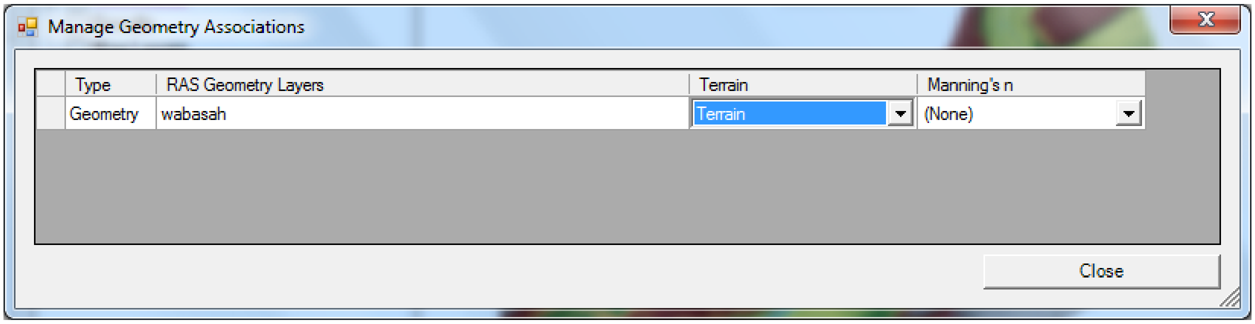
Click on the "+" button, and navigate to wab_tip.tif file containing the raster inside the InputData folder. **Click** *Open*. You will see that the file is added to the *Input Terrain Files* list. **Click** on *Create*. A new window open showing the progress of terrain import. Once the import is complete, **click** *Close*.



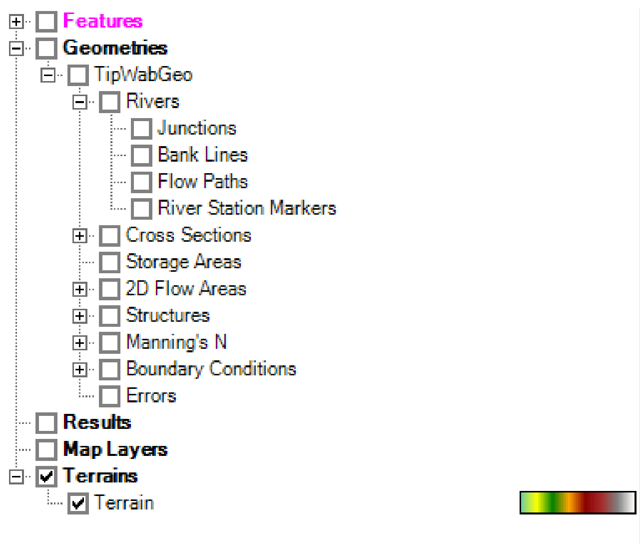
You should be able to see the DEM in the RAS Mapper Display window. **Click** on *File >> Save* in the RAS Mapper window to save the progress.



In the *Data Layer Window* (upper left pane), **right click** on *Geometries* and then **click** on *Manage Geometry Associations*. A new window opens up as shown below. Make sure that under the Terrain column, the correct terrain file is chosen. In this case, we used the default name. So select *Terrain* from the drop down menu. **Click** on *Close*.

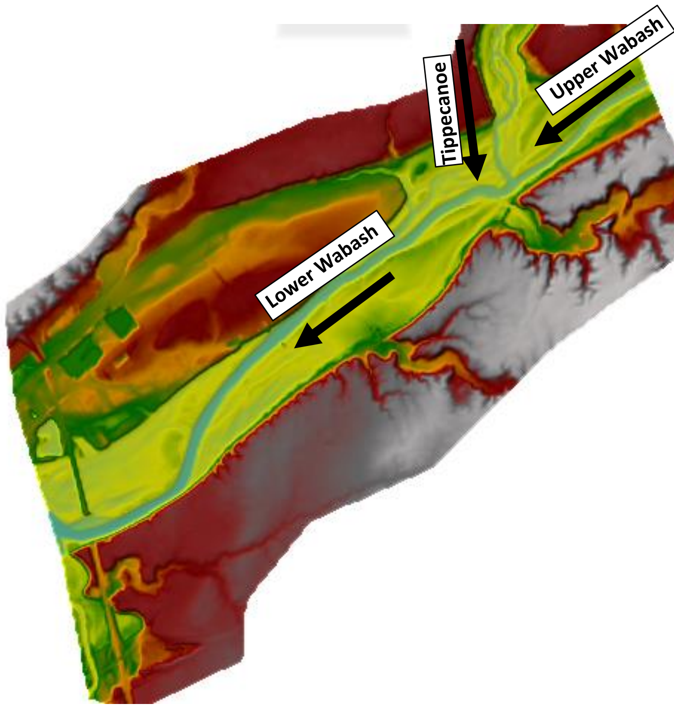


Expand the *Geometries* group by **clicking** on the plus sign next to it. Next, **expand** the River group. This group contains the various datasets depicting the river and its floodplains that are needed by HEC-RAS to perform hydraulic simulation. We need to populate these before performing a hydraulic simulation.



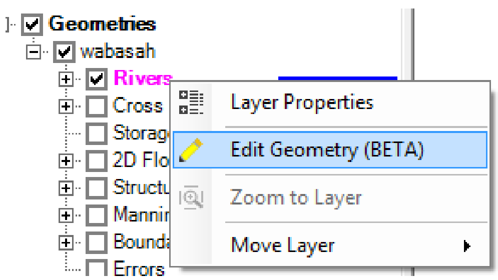
Creating River Centerline

First, we will create a centerline to define the overall extent of the model. River centerline is also used to establish the river reach network for HEC-RAS. The example dataset has Wabash River flowing from northeast to southwest (upper right to lower left) and Tippecanoe River meeting it as a tributary. So there are three reaches as shown in the figure below: upper Wabash River, lower Wabash River and Tippecanoe River (tributary).

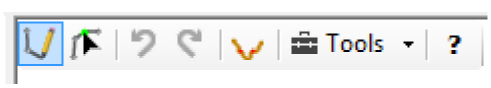


We will create/digitize one feature for each reach approximately following the center of the river, and aligned in the direction of flow. Zoom-in to the most upstream part of the upper Wabash River to see the main channel (blue outline shown in the above figure).

In the *Data Layer Window*, **right click** on *Rivers*, and **click** on *Edit Geometry (BETA)*.

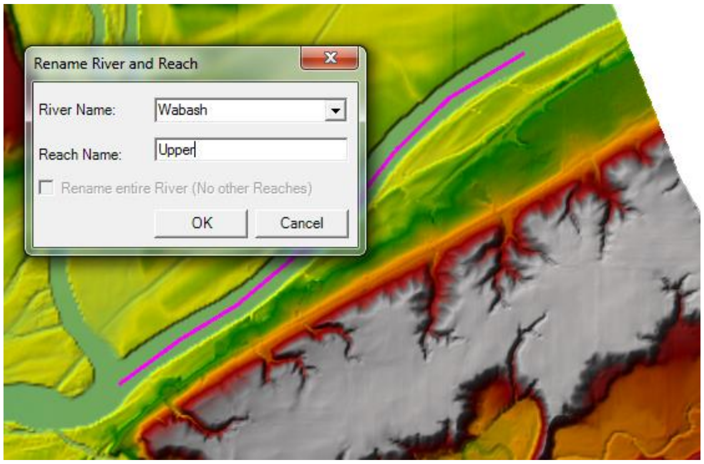


A toolbar is displayed at the top left corner of the *Display window* as shown below:



Make sure the first button (Add New Feature) is selected. Leave some space from the boundary, and start **digitizing** the river centerline from the upstream end of the upper Wabash River reach towards the downstream until you reach the intersection/junction with the Tippecanoe River. Once you reach the junction, double click to stop. You can push down on the scroll button to pan through the map as you move downstream.

When you reach the junction of the two rivers, **double click** to finish digitizing. An input box pops up asking you to specify the River and reach name. **Specify** "*Wabash*" for River Name and "Upper" for the reach name as shown below. **Click** *OK*. Each river in HEC-RAS must have a unique river name, and each reach within a river must have a unique reach name.

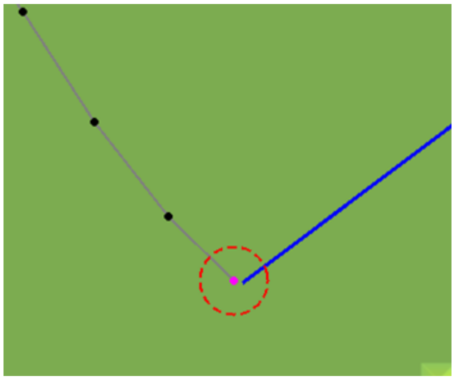


[Note: In case you make a mistake, such as clicking at the wrong location, continue digitizing till the end. One digitization is over, you can always edit the lines by going to edit geometry mode, and **right clicking** the feature (such as the centerline) you want to edit. There are option such as *Split Line*, *View/Edit Points*, *Reverse Selected Lines* etc. In case you need to edit the location of one of the vertices, **click** on *View/Edit Points,* and then manually change the coordinates of the point you want to shift to the desired location. You can get the coordinate of any point in the Display Window by clicking in the Display window. The coordinates are displayed on the lower left corner. To shift the entire feature **select** the "*Edit Feature*" button on the top (second button on the picture above), then **select** the feature and drag to its desired location.]

Right Click on *Rivers* layer in the *Data Layer Window* and **click** on *Stop Editing*. A message box pops up asking you to save the edits. **Click** *Yes*.

Start editing the river layer again (Right click→Edit geometry..) to start **digitizing** the Tippecanoe River (Tributary) from its upstream end towards the junction with the Upper Wabash River reach (start after the braided section to keep it simple). When you come close to the junction, zoom-in, and you will notice a dashed red circle (figure below). You might need to zoom in a lot till you see the circle. Make sure that the final point of the tributary centerline is at a location such that the ends of both the centerlines lie within this red circle. **Double click** at this point to finish digitizing the Tippecanoe Tributary. **Assign** the river and reach name as *Tippecanoe* and Tributary, respectively and **press** *OK*.

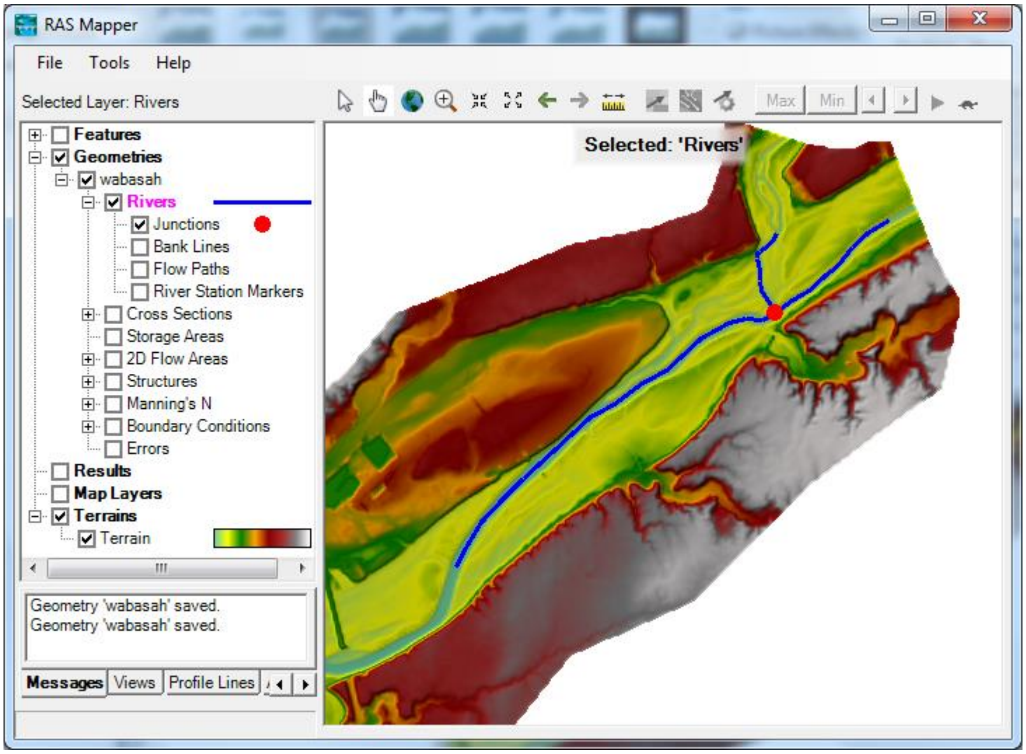
Note that there is no snapping feature in RAS Mapper (at least not yet!). So the ends of the rivers cannot be snapped. However, RAS Mapper automatically finds the ends of the centerlines that are within that "buffer" region denoted by the red dashed circle and connects them using a junction.



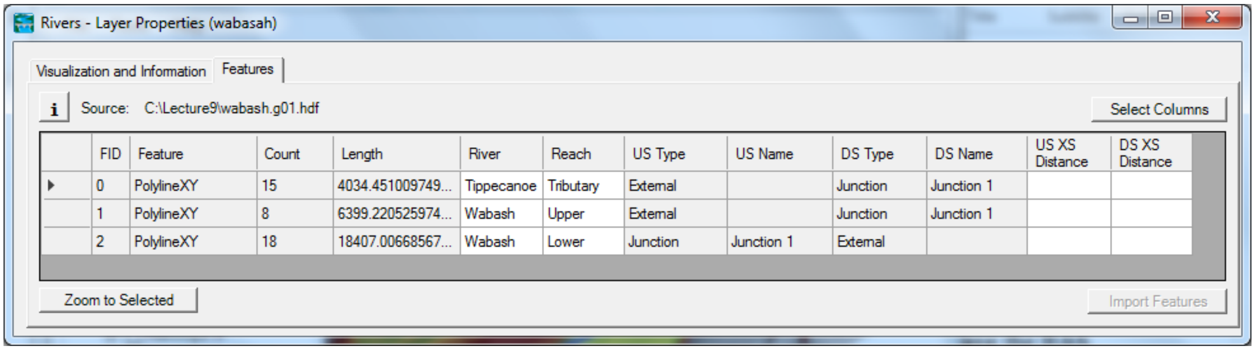
Save your edits.

Finally, **digitize** the lower Wabash River reach from junction with the Tippecanoe River (Tributary) to the most downstream end of the Wabash River (again leave some space from the edge at the downstream!). Make sure the starting point is placed such that the ends of Upper Wabash and Tippecanoe are within the red dashed circle. When you reach the downstream end, **double click** to finish digitizing and **specify** the river and reach names as "*Wabash*" and *"Lower"*, respectively.

Note that HEC-RAS has automatically created a junction (*Junction1*) connecting the three centerlines. Make sure the *Junctions* layer is checked. You will see red dot showing the location of the junction. (Expand the *River* group to show its content if you cannot see the *Junction* feature)



Now, **open** the attribute table of the *River* dataset by **right clicking** on *Rivers* and **clicking** on *Open Attribute Table*, and you will see that the information you just provided on river and reach names is entered as feature attributes as shown below.



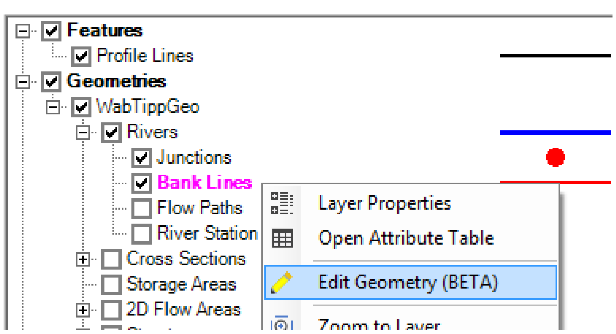
FID is a unique number for a given feature in a geodatabase. *Count* refers to the number of vertices (digitized points) in each of these lines. This will vary based on how you digitize your centerline. *Length* refers to the total length of that centerline. *US Type* and *DS Type* refers to the type of boundary condition at each end of the reaches. "External" means that an external flow or stage can be provided at those locations. We will be specifying these later in this tutorial. "Junction" is self-explanatory. Also, there are some unpopulated attributes such as *US XS Distance* and *DS XS Distance*. These will get populated later when we digitize the cross-sections. **Close** the attribute table, and **save** the RAS Mapper by **clicking** on *File >> Save.*

[Important points to remember about creating river centerlines: (i) always digitize from upstream to downstream; (ii) make sure two more centerlines are connected through a junction]

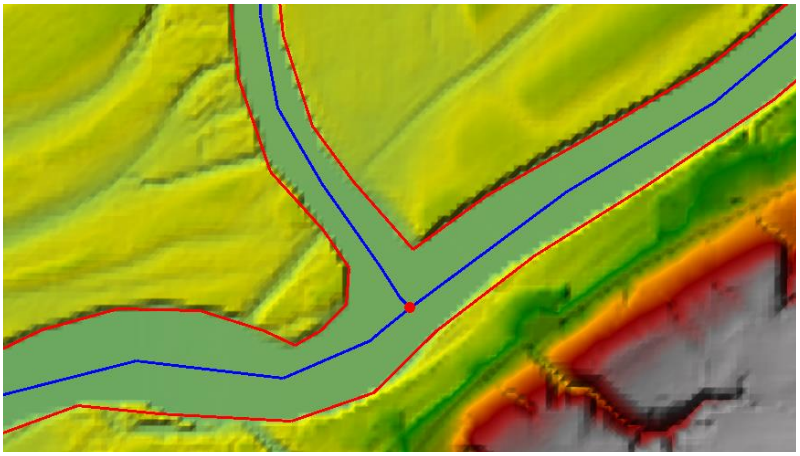
Creating Bank Lines

Bank lines are used to distinguish the main channel from the overbank floodplain areas. Information related to bank locations is used to assign different properties for cross-sections. For example, compared to the main channel, overbank areas are assigned higher values of Manning's n to account for more roughness caused by vegetation. Creating bank lines is similar to creating the channel centerline, but there are no specific guideless with regard to line orientation and connectivity - they can be digitized either along the flow direction or against the flow direction, or may be continuous or broken.

To create bank lines, **right click** on *Bank Lines* (under *Rivers*) and select *Edit Geometry (BETA)* as shown in the figure below.



Follow the same digitization procedure as centerline. Although there are no specific guidelines for digitizing banks, to be consistent, follow these guidelines: 1) start from the upstream end; 2) looking downstream, digitize the left bank first and then the right bank. When digitizing the left bank, you do not have to stop at the intersection, you can have a single bank for the whole reach. One the right hand side, however, you cannot cross the centerline for Tippecanoe River, so you will need two separate lines for the right bank of the Wabash River – one each for upper and lower reach. The bank lines need not be snapped at their ends to the other bank lines. See figure below at the junction.



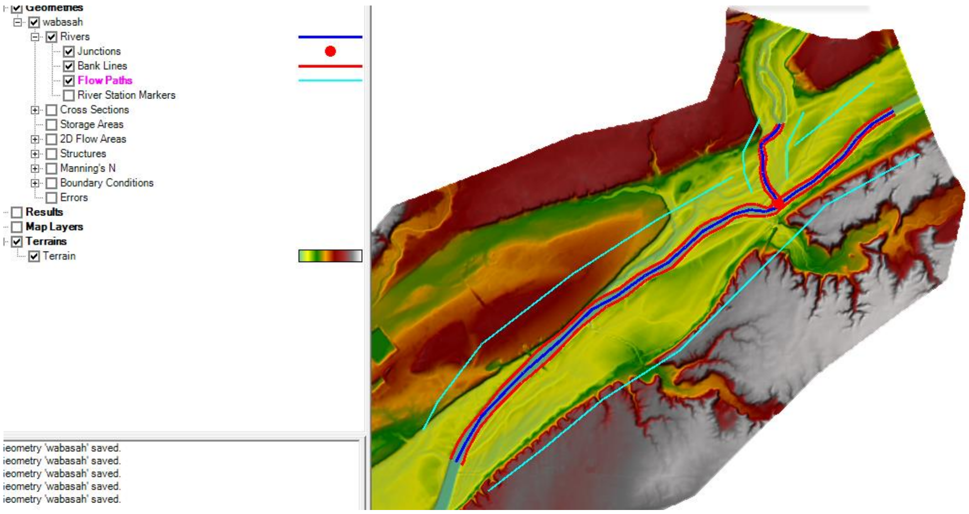
Digitize banks for all three reaches and **save** the edits by **right clicking** on the *Bank Lines* layer and **clicking** on *Stop Editing*, and then selecting *yes* when prompted to save. **Save** the RAS Mapper by **clicking** on *File >> Save.*

Open the attribute table for the Banks layer and you will see that it only stores the geometry without any attributes compared to what we saw for the centerline features.

<u>Creating Flow Paths</u>

The flow paths are used to determine the downstream reach lengths along the left over bank, the main channel and the right over bank. The reach length along the main channel can be extracted using the centerline since it lies approximately at the center of the main channel and run parallel to the main channel. For the left and right over bank, we need to digitize the left and right flow paths respectively.

Digitize flow paths using the same digitization procedure as before, that is, **right clicking** on *Flow Paths* layer and selecting "*Edit Geometry (BETA)".* The left and right flow paths must be digitized within the floodplain. Look at the DEM to try and estimate the boundaries of the floodplain. These lines are used to compute distances between cross-sections in the over bank areas. So digitize the flow paths at the boundary of the floodplains. Again, to be consistent, looking downstream, first digitize the left flow path followed by the right flow path for each reach. After digitizing, **right click** on *Flow Paths* layer to **click** on *Stop Editing* and **select** *yes* when asked to save. Make you digitize right and left flow path separately for each individual reach. Do not use a common flow path line for multiple reaches. Also, make sure a flow path does not intersect with another flow path, centerline or bank line. An example is shown below.



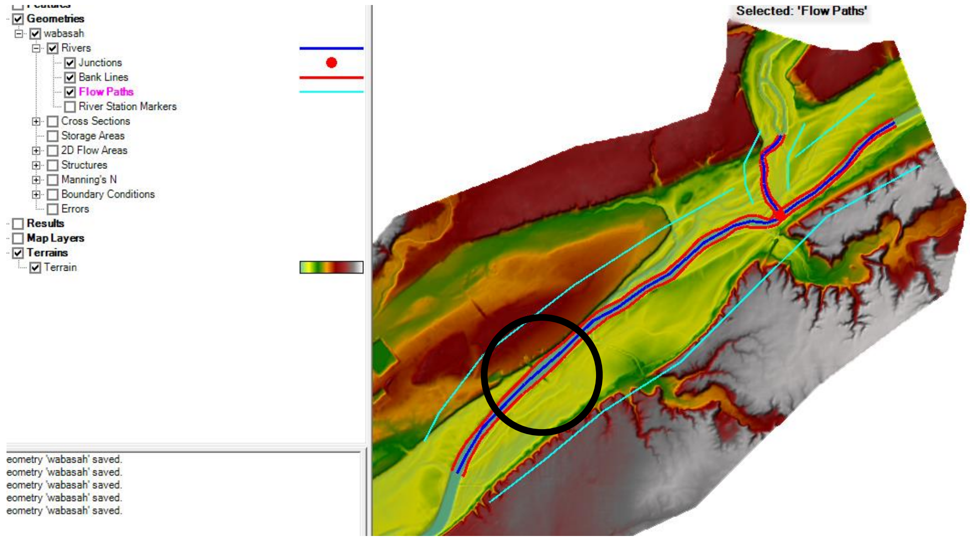
Once you are finished digitizing the flow paths, **open** the attribute table of *Flow Paths* layer. You will see that the attribute table lists the point count (*Count*) and length of the flow paths (*Length).* It does not specify the reach or direction (left or right) of the flow paths. HEC-RAS automatically decides which flow path to use based on the points at which a flow path intersects the cross-section. **Close** the attribute table and **save** RAS Mapper.

Creating Cross-sections

Cross-sections are one of the key inputs to HEC-RAS. Cross-sections are used to extract the elevation data from the terrain to create a ground profile across channel flow. The intersection of cross-sections with other RAS layers such as centerline and flow path lines are used to compute HEC-RAS attributes such as bank stations (locations that separate main channel from the floodplain), downstream reach lengths (distance between cross-sections) and Manning's n. Therefore, creating adequate number of cross-sections to produce a good representation of channel bed and floodplain is critical. Certain guidelines must be followed in creating cross-sections:

1) They are digitized perpendicular to the direction of flow.
2) They must span over the entire flood extent to be modeled.
3) They are always digitized from left to right (looking downstream).
4) Each Cross-Section should intersect the centerline, both bank lines and both flow paths once.

Even though it is not required, but it is a good practice to maintain a consistent spacing between cross-sections. In this exercise, let us use an approximate spacing of 300 meters (1000 feet) for all cross-sections. In addition, if you come across a structure (eg. bridge/culvert) along the channel, make sure you define one cross-section each on the upstream and downstream of this structure. The upstream and downstream cross-sections must be no farther than 100 – 200 feet from the structure. Structures can be identified by using the aerial photograph or by looking at the DEM. For example, we will use one bridge location in this exercise at the downstream end of the lower Wabash River reach as shown below (bridge location is shown in circle; there is one downstream too):



To create cross-sections, **right click** on the *Cross-Sections* layer and **select** *Edit Geometry (BETA)".* **Digitize** cross-sections by using the same digitization procedure as before, but follow the guidelines outlined in the previous paragraph.

While digitizing, make sure that each cross-section is wide enough to cover the floodplain. One way to do this is make sure that the cross-section ends at relatively high locations such as the top of the valley. One way to check this is to use the profile plot. After digitizing a cross-section**, right click** on the cross-section and **click** on *Plot Terrain Profile.* If you cross-sections looks like Figure A below, you should be fine. However, if it looks like Figure B, you might need to extend the cross-section further. As a general rule of thumb, make sure your cross-section is at least four to five times wider than the channel banks. The terrain profile gives an idea about the extent as well.

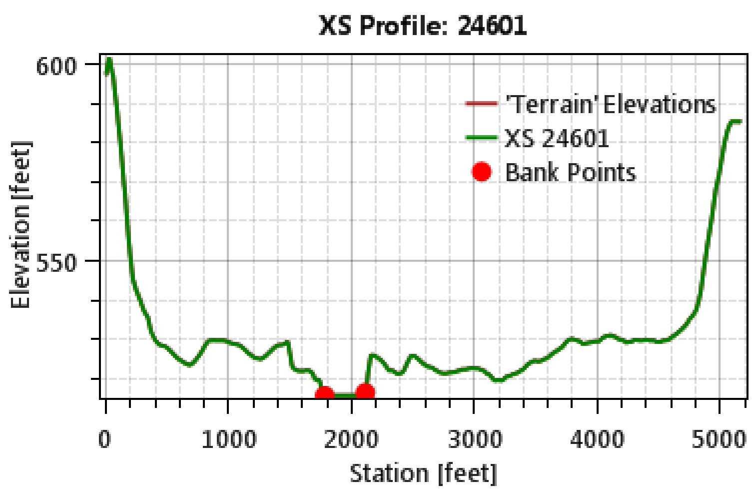


Figure A: Proper Cross-section

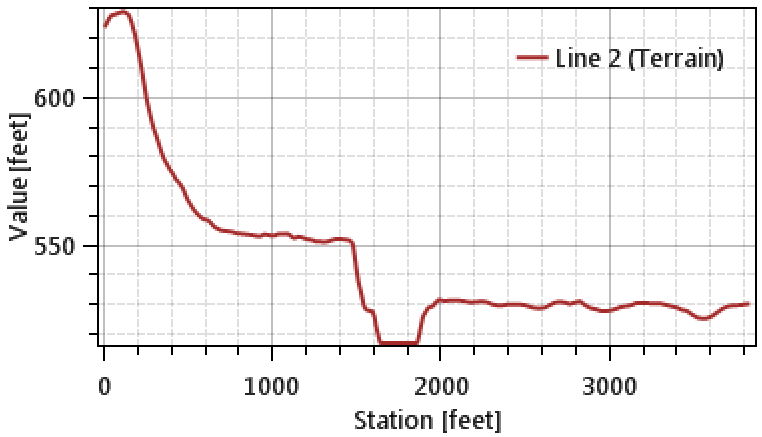
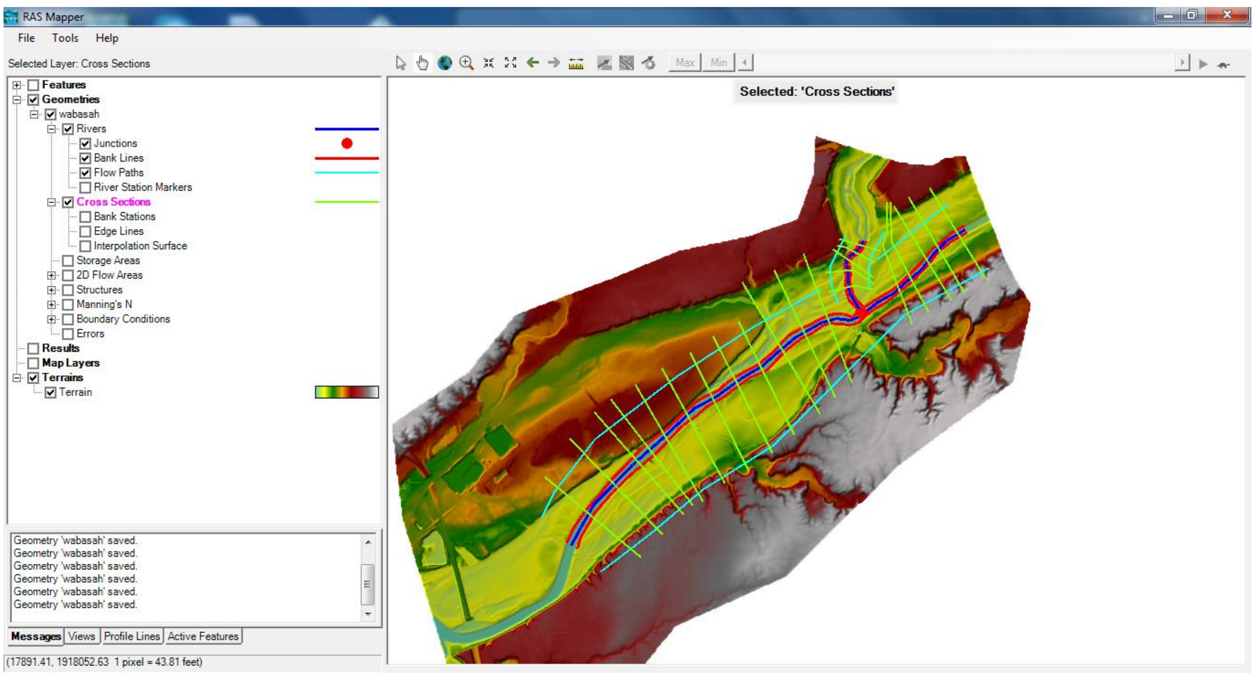
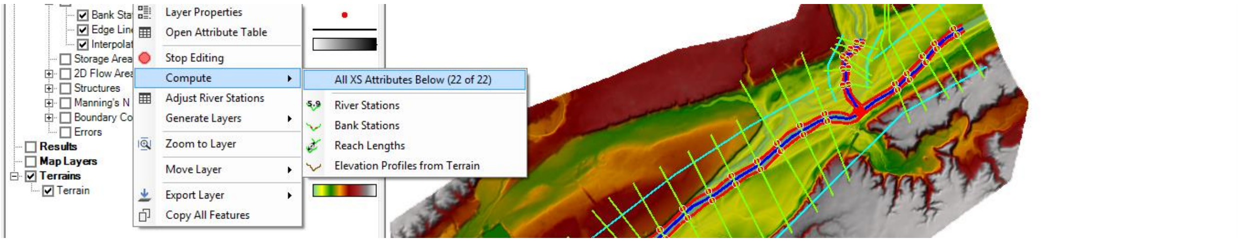


Figure B: Incomplete Cross-section that might need to be extended

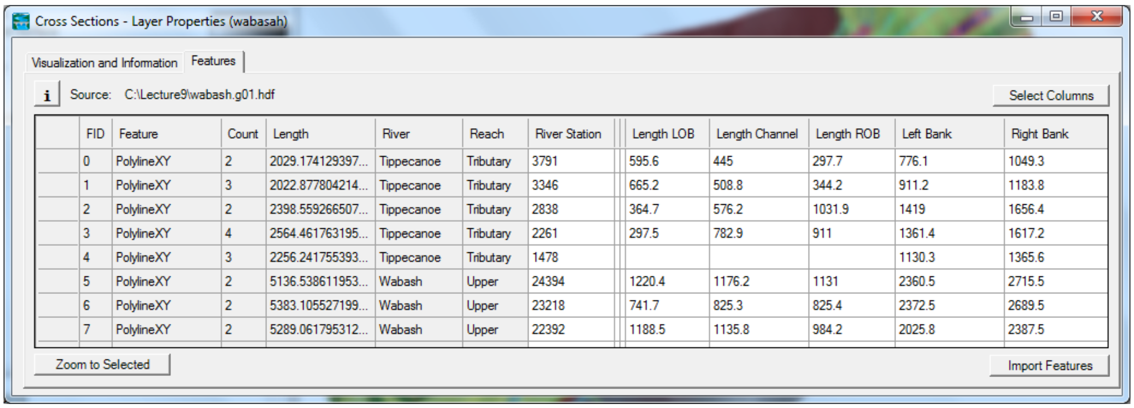
An example cross-sectional configuration is shown below. Some of the cross-sections on the Tippecanoe river may seem to have incomplete profile, but that region is already covered through the Wabash cross-sections so lets not worry about them.



After digitizing the cross-sections, **save** the edits. The next step is to add HEC-RAS attributes to these cross-sections. Go back to the edit mode by **selecting** the *Edit Geometry (BETA)* option. **Right click** on *Cross- Sections* layer and **select** *Compute >> All Xs Attributes Below* as shown in the figure below. **Save** your edits and **stop** editing.



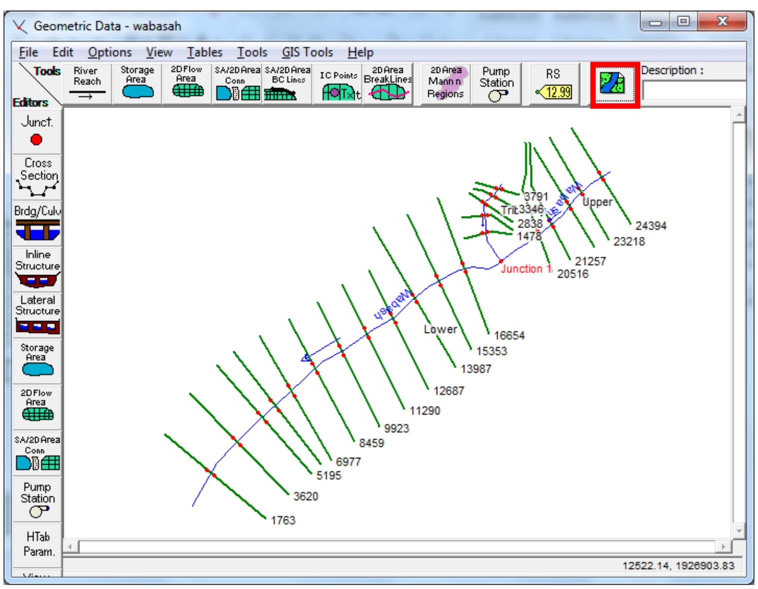
Open the attribute table of *Cross Section* by **right clicking** on the layer and **selecting** *Open Attribute Table.* You will see that the attributes Length LOB, Length Channel, Length ROB, and bank stations have been computed by HEC-RAS. This step also extracts the cross-section elevation from the DEM and populates it in the geometry file.



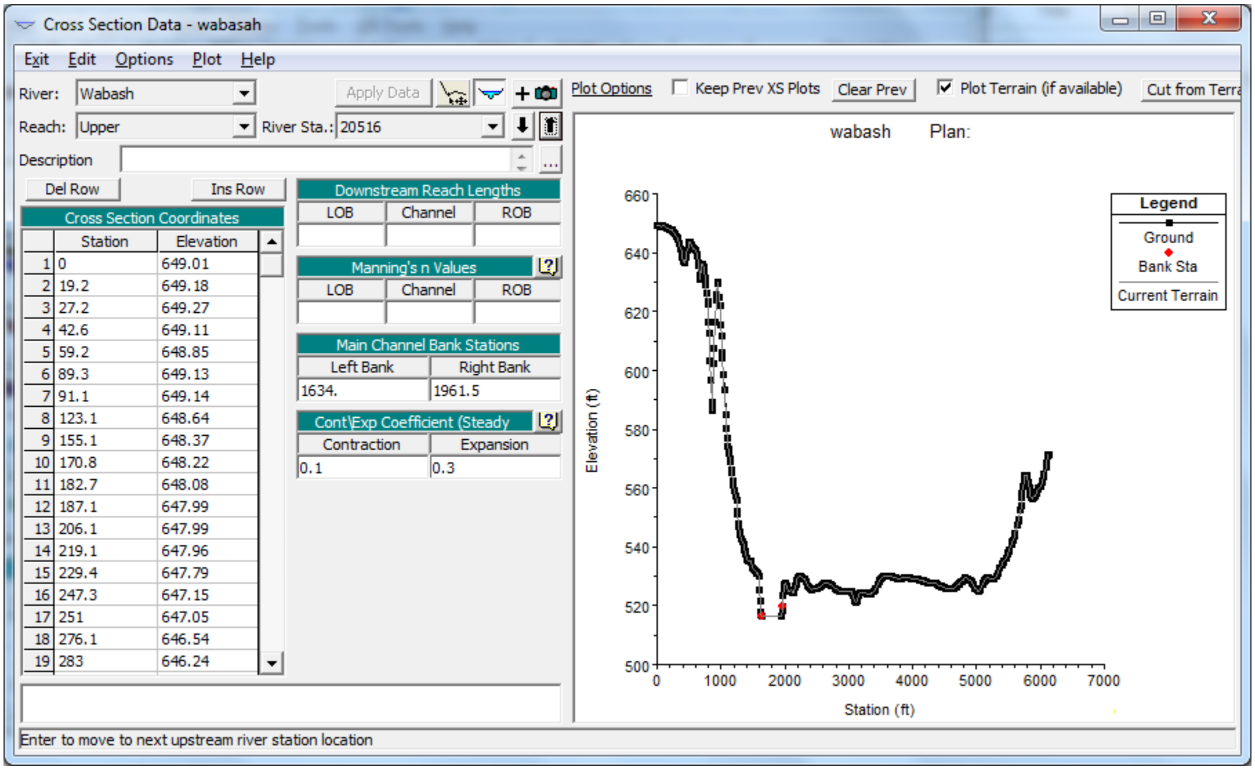
FID	Feature	Count	Length	River	Reach	River Station	Length LOB	Length Channel	Length ROB	Left Bank	Right Bank
0	PolylineXY	2	2029.174129397...	Tippecanoe	Tributary	3791	595.6	445	297.7	776.1	1049.3
1	PolylineXY	3	2022.877804214...	Tippecanoe	Tributary	3346	665.2	508.8	344.2	911.2	1183.8
2	PolylineXY	2	2398.559266507...	Tippecanoe	Tributary	2838	364.7	576.2	1031.9	1419	1656.4
3	PolylineXY	4	2564.461763195...	Tippecanoe	Tributary	2261	297.5	782.9	911	1361.4	1617.2
4	PolylineXY	3	2256.241755393...	Tippecanoe	Tributary	1478				1130.3	1365.6
5	PolylineXY	2	5136.538611953...	Wabash	Upper	24394	1220.4	1176.2	1131	2360.5	2715.5
6	PolylineXY	2	5383.105527199...	Wabash	Upper	23218	741.7	825.3	825.4	2372.5	2689.5
7	PolylineXY	2	5289.061795312...	Wabash	Upper	22392	1188.5	1135.8	984.2	2025.8	2387.5

Save the Mapper and **close** it.

Go to the geometry file you created at the beginning of the tutorial by **clicking** on *Edit >> Geometric Data…* in the main HEC-RAS window. The river centerline and cross-sections have been imported automatically from the RAS Mapper and should be visible as shown below. If you also see the terrain in the background, it is okay. If you want to turn it off, you can use the background layers button (red box) to uncheck the terrain layer.



Next, **click** on the geometry editor and **select** any cross-section. You should see the cross-section window as shown below.



Each cross-section in HEC-RAS has the following information:

<u>Location</u>: This is described by using three pieces of information: River, Reach and River Station. The cross-section in Figure is located at a distance of 5996 ft (River Sta.) on the lower reach from the most downstream end of the Wabash River.

<u>Elevation Profile</u>: This is the profile view that you see on the right hand side in the cross-section window. This profile is created by using the information from the station and elevation columns in the Cross Section Coordinates table on the left. The numbers in the station column shows the distance along the cross-section from left to right (looking downstream along the flow direction), and the elevation column shows the elevation at each station point. You can think of Station and Elevation as the (x,z) attributes for the cross-section line. Each station/elevation point is represented by a black dot on the cross-section profile.

<u>Bank locations</u>: These are represented by two red dots on the cross-section profile. The location of these red dots is dictated by the station numbers for Left and Right Banks in the "Main Channel Bank Stations" table in the cross-section window.

Roughness (Manning's n Values): Each cross-section is assigned 3 Manning's n value – left overbank, main channel and right overbank. These have not been populated yet. We will discuss this in more details later.

Distance to the next downstream cross-section: This information is presented in the Downstream Reach Lengths table. The numbers for LOB, ROB and Channel represent the distances to the next downstream cross-section along the left over bank, right over bank and channel, respectively. These distances are computed by using the flow path features that are digitized in RAS Mapper.

The basic construction of a HEC-RAS model is now complete. Save your project. The next step is to create a simulation.

Save your project. You are done for now!

1D HEC-RAS Simulation and Flood Inundation Mapping in HEC-RAS

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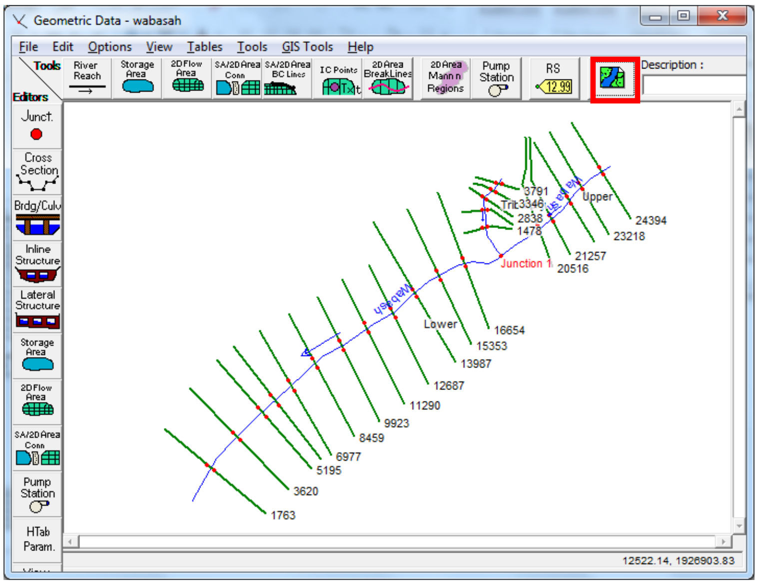
Introduction

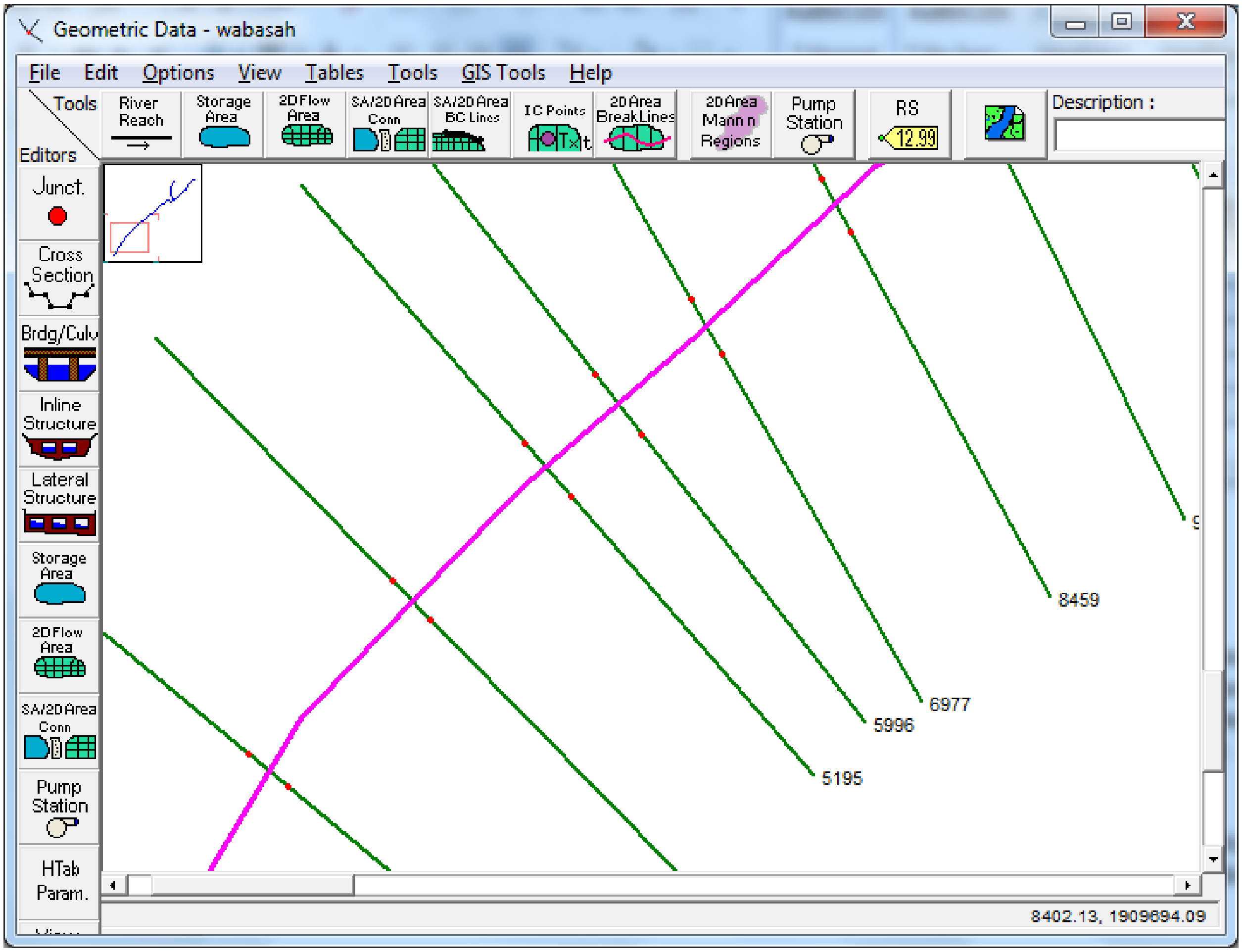
The objective of this exercise is to learn how to run a 1D simulation using HEC-RAS and use the results for mapping the inundation extent using RAS Mapper.

Open the HEC-RAS project that you previously created for the Wabash reach. Before we run the simulation, lets go ahead and add the bridge details in the model.

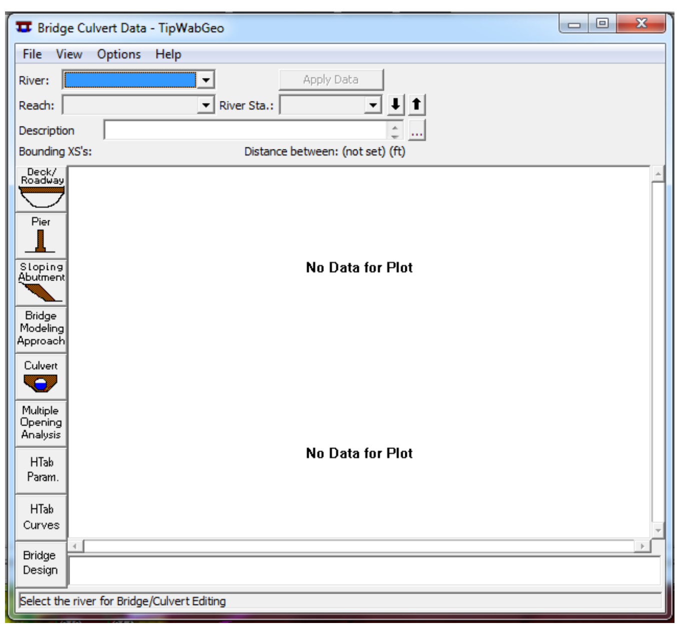


Creating Bridges and Culverts

Cross-section can be added using the geometry editor in HEC-RAS. In the geometry editor, zoom in on the location of the bridge. For the image below, the bridge is between cross-sections 5195 and 5996. These numbers will be different for your model, which is not critical. Just make sure that you know the location of the upstream and downstream cross-section for the bridge.

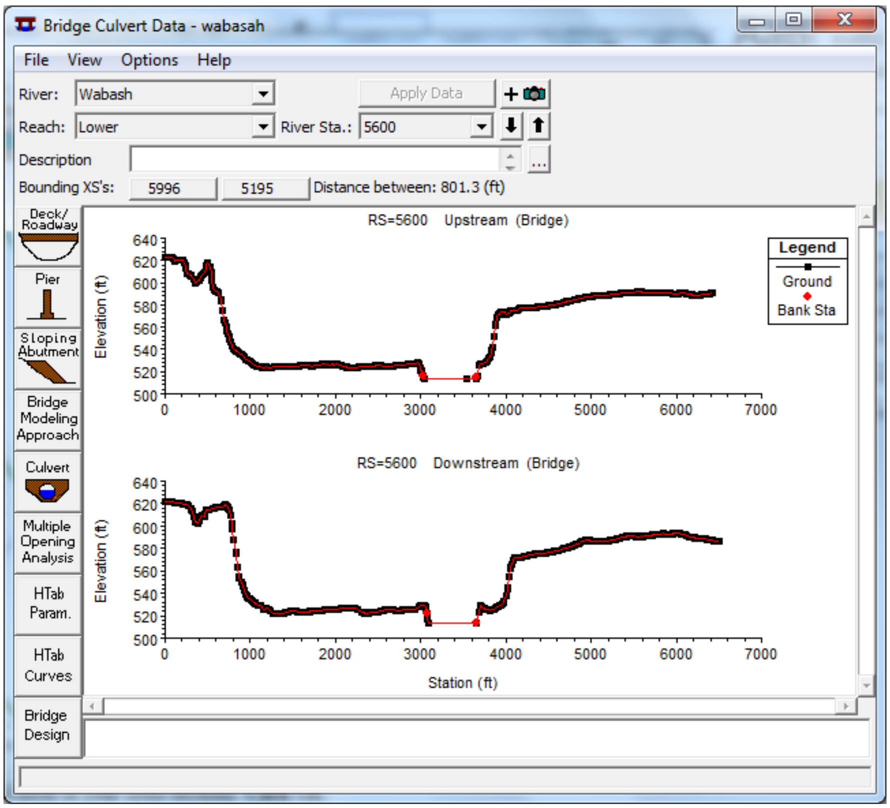


Note the river station of the cross-sections just upstream and downstream of the bridge. Now **click** on *Brdg/Culv* button on the left pane. The *Bridge Culvert Data Editor* opens as show below.

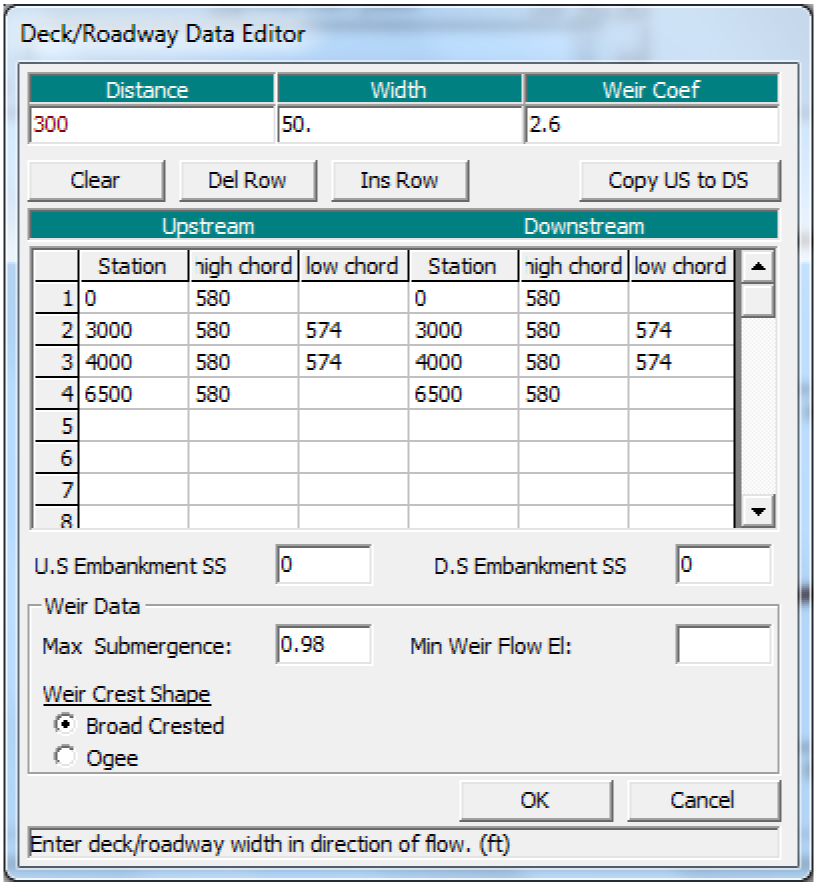


Change the River and Reach to Wabash and Lower, respectively (the reach on which the bridge is located). **Click** on *Options >> Add a bridge and/or culvert.* A message box opens up, asking for the river station of the structure. **Specify** a number that lie between the river station of the upstream and downstream cross-sections. The river stations are only used to position the structure, as such the exact value is not important. For example, for this case we will use 5600 that is between 5195 and 5996. As mentioned earlier, you will have you use a different value depending on the location of your cross-sections. **Click** *OK*.

You will see the cross-section profile (black dots and black line) of the upstream and downstream cross-sections.



Generally, bridges are not captured in a DEM, which is a 2D representation of topography. What we need to do here is define the elevation of the road and the opening through which the water will flow. First we need to find out what is the top elevation of the bridge. From the figure above, we are going to assume it to be around 580 ft as seen along the profile (this will be different for your data). Next, we need to know the opening for the bridge. In this case, we are going to assume that the opening is between 3000 ft and 4000 ft along the station (x-axis) axis. We will also assume that the road is around 6 ft thick, which means the elevation of the lower chord of the bridge is 574 ft where the bridge is open. Once we have this information, we can then use the Deck/Roadway editor (first button on the left menu) and enter this information as shown below (this information will change for each model depending on the exact location of the cross-section).

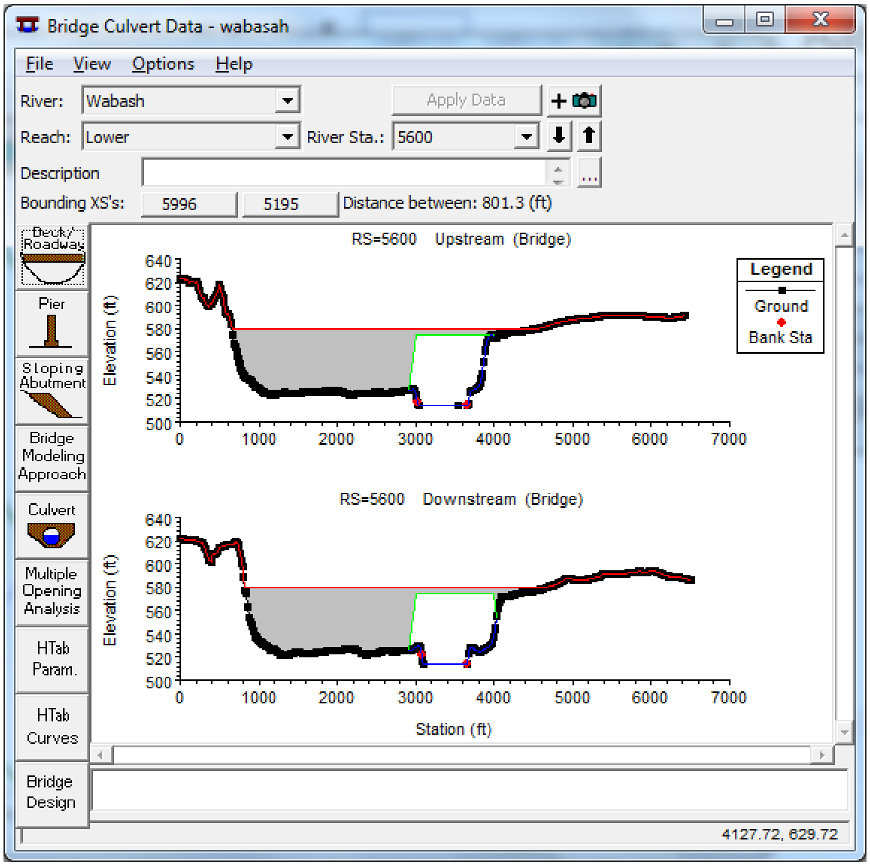


	Station	high chord	low chord	Station	high chord	low chord
1	0	580		0	580	
2	3000	580	574	3000	580	574
3	4000	580	574	4000	580	574
4	6500	580		6500	580	
5						
6						
7						
8						

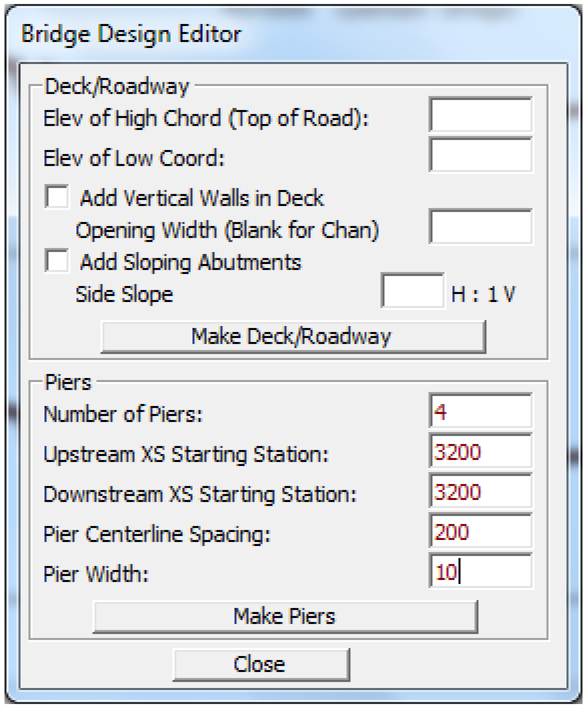
In addition to providing the station and elevation information, o provide the position of the bridge relative to the cross-sections. The *Distance* field shows the distance between the upstream cross-section and the upstream face of the bridge. The width is the width of the deck/roadway. In this case, we used a bridge that is 50 ft wide. Typically, you would fill the distance field by measuring the distance between the cross-section and the approximate upstream face of the bridge in the DEM or aerial photograph. The width is usually extracted from field surveys. **Click** on the *Copy US to DS* button to copy the information from upstream to downstream, and **click** *OK*.

(**Note**: The figures and the numbers need to be interpreted appropriately based on your cross-section profile. Do not blindly use the same numbers that are presented here. They may not work for you). The high chord column in the above figure basically defines the top elevation of the bridge, and the low chord defines the elevation of the bottom of the bridge deck. In the absence of any values for low chord, the deck will extend to the ground surface.)

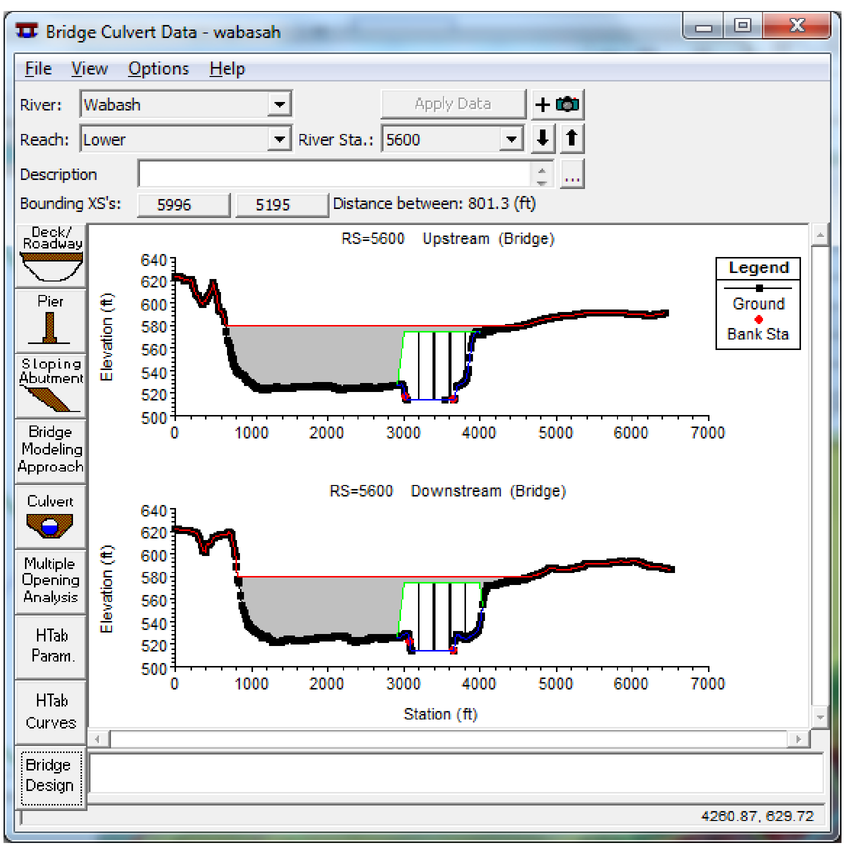
After the high and low chord values are defined, the new cross-section with the bridge opening is shown in the *Bridge Culvert Data Editor*.



Try to understand how the information we entered for high chord/low chord in the Deck/Roadway editor got translated into the opening. Once the opening is defined, the next step is to use the Bridge Design tool to enter pier information. We will assume four piers of 10ft width and a spacing of 200ft. Piers information can be specified easily using the *Bridge Design Editor*, which can be accessed by **clicking** on the *Bridge Design* button (last button on the left menu) in the left pane of *Bridge Culvert Data Editor*. Enter the information as shown below. The Upstream and Downtream XS starting position will depend on your cross-section.



Click on *Make Piers*, and then **click** *Close*. The bridge opening will look as shown in the figure below.

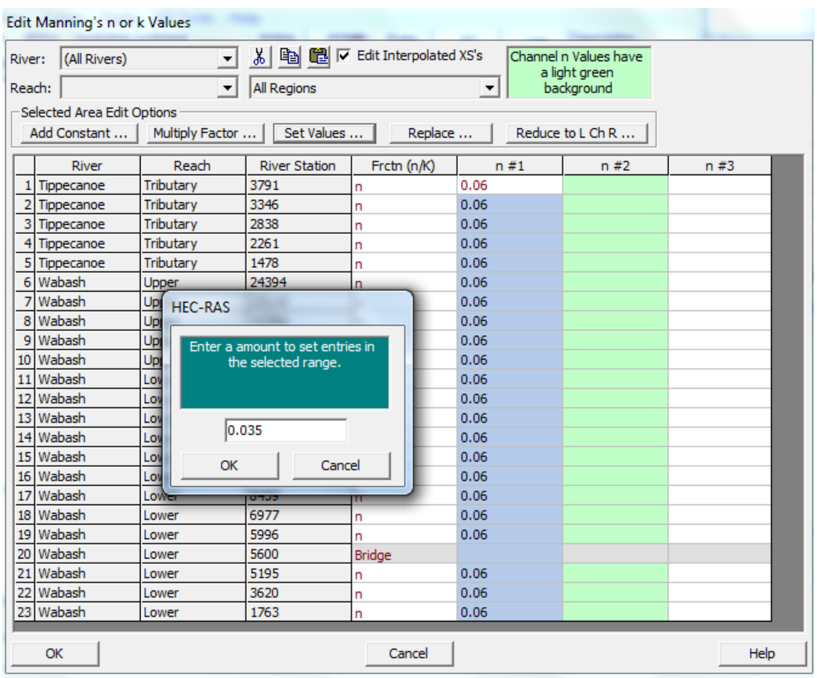


You need to know the actual bridge condition to be able to accurately enter this information, but for this tutorial we have used our intuition (and creativity!) in designing the bridge. After you are done editing the bridge data, **close** the *bridge/culvert editor*, and **save** geometry data.

The next step is to assign Manning's n values.

Assigning Manning's n values to cross-sections

The final task in the *Geometric Data Editor* is assigning Manning's n values to individual cross-sections. You can enter it for each cross-section individually in the cross-section editor but that can be cumbersome and time taking when the number of cross-sections is large. **Click** on *Table >> Manning's n or k values (Horizontally varied).* Make sure the *(All Rivers)* option is selected for *Rivers.* Now **click** on the column head *n #1*. The entire column is selected. **Click** on *Set Values…* and enter the value of 0.06 (for floodplain) and **click** *OK.* Similarly set a value of 0.035 for n #2 (main channel) and 0.06 for n#3 (floodplain).



(Note: A good practice is to extract these from landuse maps, but the currently RAS Mapper cannot do that for 1D flow. That option is only available for 2D in the current RAS Mapper version.) **Click** *OK*.

Save the geometry file by clicking *File >> Save Geometry Data*. Before you proceed, it is a good practice to perform a quality check on the data to make sure no erroneous information is imported from the RAS Mapper. You can use the tools in Geometric editor to perform the quality check. One of the best tools for editing cross-sections in HEC-RAS is the graphical cross-section editor. In the geometric editor, go to *Tools >> Graphical Cross-Section Edit*.

You can use the editor to move bank stations, change the distribution of Manning's n, add/move/delete ground points, edit structure, etc. You can play around with these tools and learn more about the functions. The horizontal line at the top of the cross-section profile shows the distribution of Manning's n value along the cross-section.

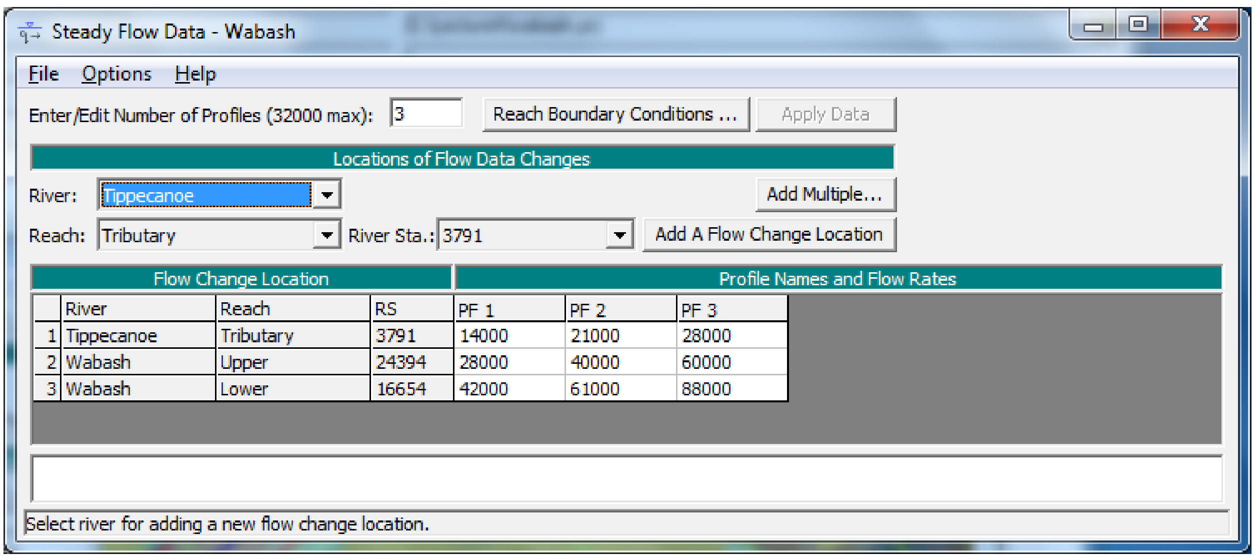
We are done with geometric data! The next step is to enter flow data. For this tutorial we will run the model in steady state condition

Entering Flow Data and Boundary Conditions

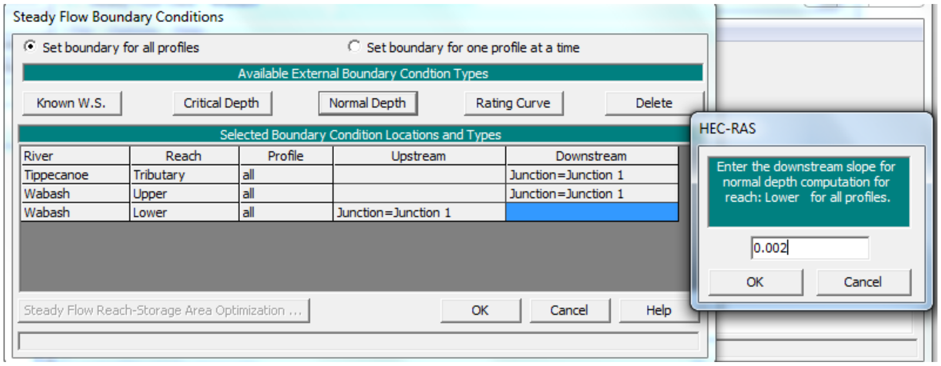
Flows are typically defined at the most upstream location of each river/tributary, and at junctions. There are situations where you need to define flows at additional locations, but for this tutorial we will use a simple case. Each flow that needs to be simulated is called a profile in HEC-RAS. For this exercise, we will create three hypothetical profiles.

In the main HEC-RAS window, **click** on *Edit >> Steady Flow Data*. First save the flow data by going to Flow→Save Data as.. and save it as wabash in the same folder where your project and geometry is stored.

Enter *3* for number of profiles, and **click** *Apply Data*. **Enter** hypothetical flow conditions for these profiles as shown below:



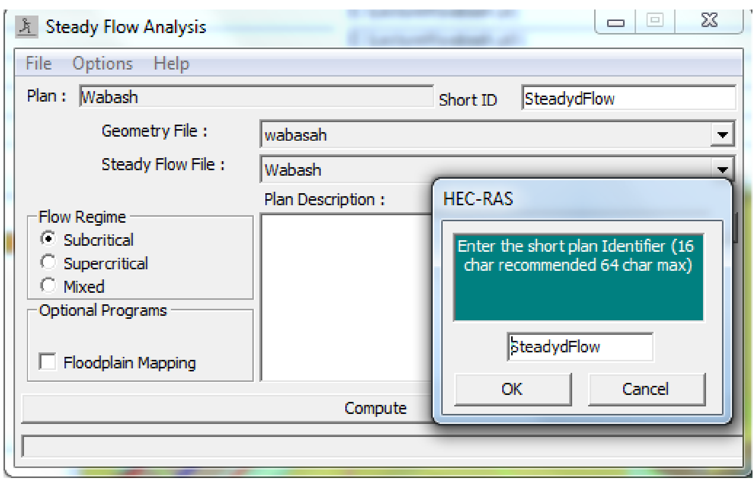
The flow conditions defined in the above window are upstream conditions. To define downstream boundary, **click** on *Reach Boundary Conditions*. Then **select** *Downstream* for Wabash Lower Reach, **click** on *Normal Depth*, and **enter** *0.002* as shown below.



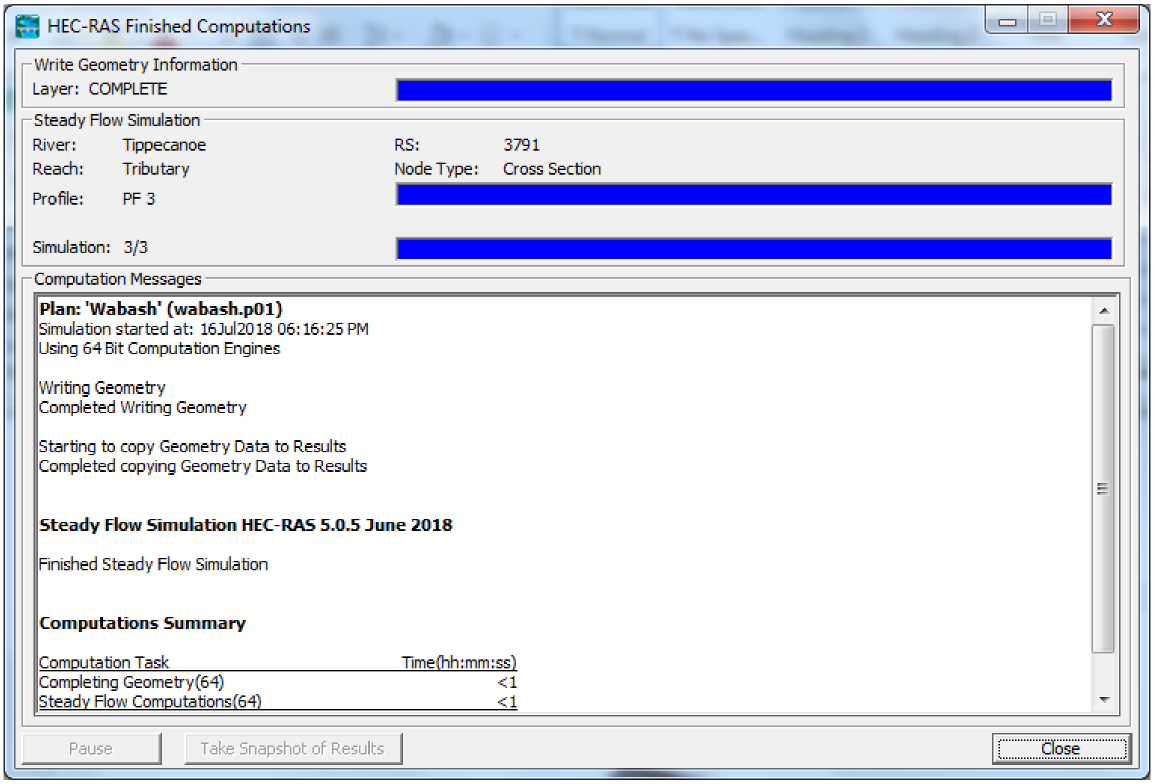
Click *OK*. **Save** the flow data. **Close** the *Steady Flow editor*. Now we are ready to run HEC-RAS!

Running HEC-RAS

In the main HEC-RAS window, **click** on *Run >> Steady Flow Analysis*. First, save the file by giving a title and give a name to the plan as SteadyFlow as shown below.



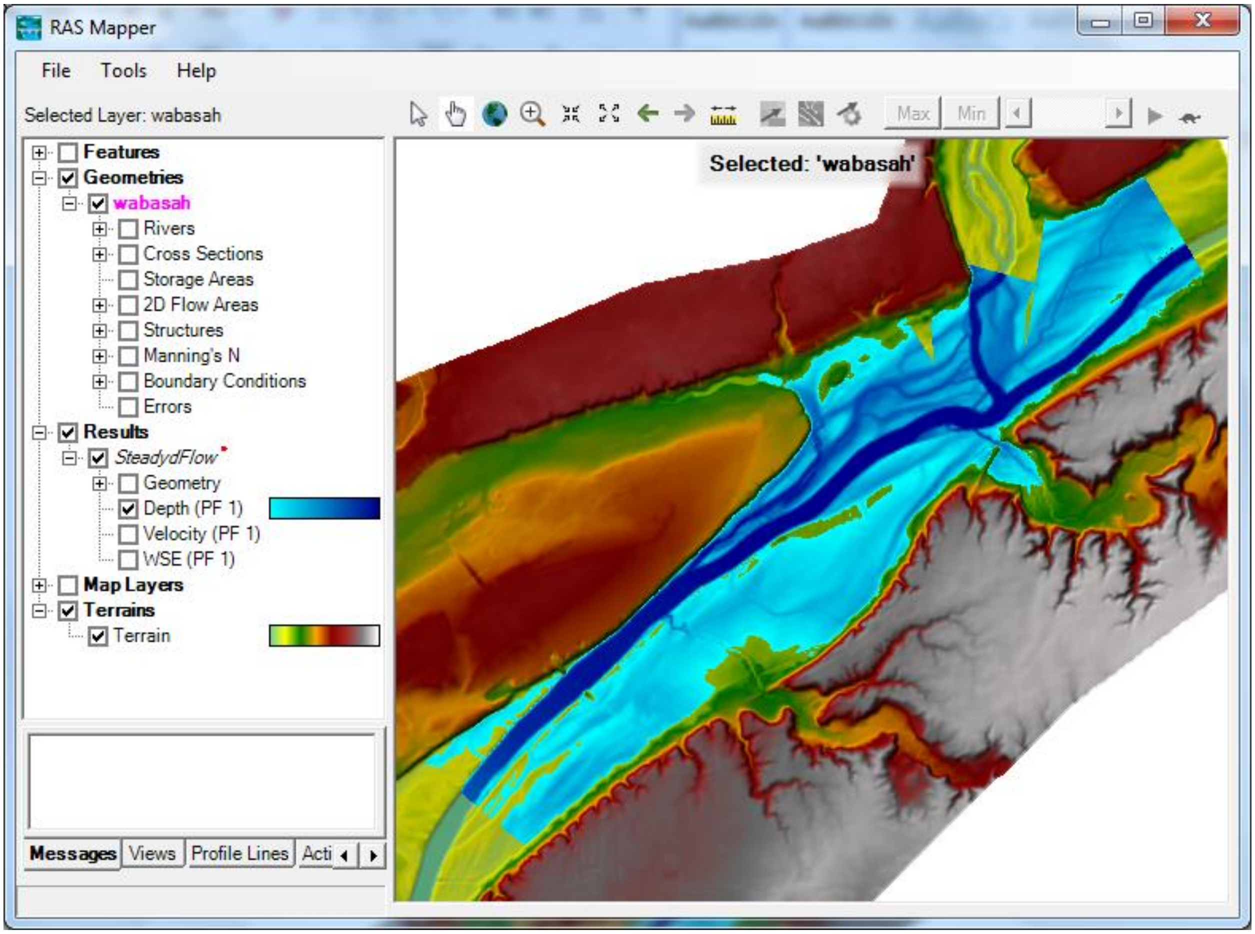
Next, **select** the *Subcritical* Flow Regime, and **click** on the *Compute* button. The simulation run should not take more than a minute. (Note: If you get an error, you will need to modify geometry or flow data based on error messages to run the simulation successfully).



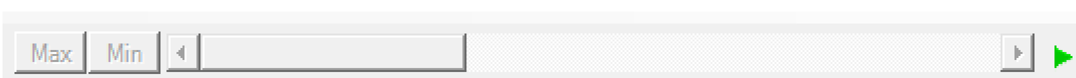
After successful simulation, close the computation window and the steady flow window. We will now view the results in the RAS Mapper.

Flood Inundation Mapping in RAS Mapper

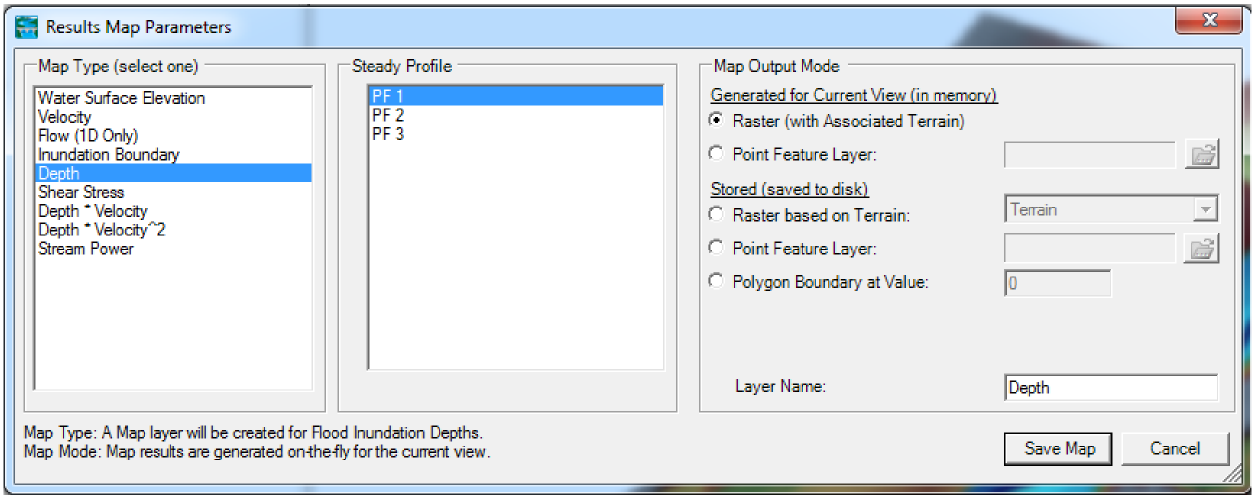
Open RAS Mapper from the main HEC-RAS window. In the *Data Layer Window* (left pane), you will see that under the *Results* group, there are new layers namely SteadyFlow (or whatever name you gave to your plan when running the steady flow analysis). Under SteadyFlow, there are four more groups namely *Geometry*, *Depth*, *Velocity* and *WSE*. **Click** on the *Depth* layer. Make sure the box next to it is checked. The inundation depths will appear as shown below. The profile corresponding to the depths are shown beside the *Depth* layer.



You can toggle between the different profiles using the slider at the top of the window.



You can also change the profiles by **right clicking** on the *Depth layer >> Edit Map Parameters*. **Select** the profile under *Steady Profile* and **click** on *Save Map.*



If you need to view a different output, **right click** on SteadyFlow and **click** on *Add New Result Map Layer*. The same form as shown above opens. **Select** the variable under *Map Type*, select the profile under *Steady Profile*, and **click** on *Save Map*. A new layer is created. **Right click** on the new layer and **click** on *Compute/Update Stored Map* and the new variable will be mapped in the *Display Window*.

(Note: Only those variables are mapped that have been calculated under 1D steady state condition. Some of the variables may not be for 1D steady state flow and may not be mapped onto the Display Window!)

Once the depth is mapped, you must check the inundated region for its quality. You will have to look at the inundation map and the underlying terrain to correct errors in the flood inundation map. Sometimes you will realize (at the end!) that your terrain has errors, which you need to fix in the HEC-RAS geometry file. The refinement of flood inundation results to create a hydraulically correct output is not covered in this tutorial - this is an iterative process requiring several iterations in HEC-RAS. The ability to judge the quality of terrain and flood inundation map comes with the knowledge of the study area and experience.

Save the RAS Mapper and the HEC-RAS project. Congratulations, you have successfully finished the RAS Mapper tutorial!