Tutorial on using HEC-GeoRAS with ArcGIS 9.3

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Introduction

This tutorial is designed to expose you to basic functions in HEC-GeoRAS for pre- and/or post-processing of GIS data and HEC-RAS results for flood inundation mapping using ArcGIS. It is expected that you are familiar with HEC-RAS and ArcGIS. If you want to get into details of HEC-GeoRAS that are not covered in this tutorial please refer to the HEC-GeoRAS users manual.

Computer Requirements

You must have a computer with windows operating system, and the following programs installed:

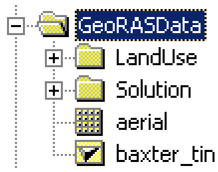
1. ArcGIS 9.3
2. HEC-GeoRAS version 4
3. HEC-RAS version 4.0

You can download HEC-RAS and HEC-GeoRAS for free from the US Army Corps of Engineers Hydrologic Engineering Center website http://www.hec.usace.army.mil/software/

Data Requirement

The only essential dataset required for HEC-GeoRAS is the terrain data (TIN or DEM). Additional datasets that may be useful are aerial photograph (s) and land use information. The dataset supplied with this tutorial includes a small portion of the fictional Baxter River available with HEC-GeoRAS users manual.

The data (11.1 MB) required for this tutorial is available at ftp://ftp.ecn.purdue.edu/vmerwade/download/data/georasdata.zip. **Download** the zip file on your local drive, and **unzip** its contents. The GeoRASData folder contains two sub-folders, one TIN dataset, and one aerial image (as raster grid) as shown below (ArcCatalog view):

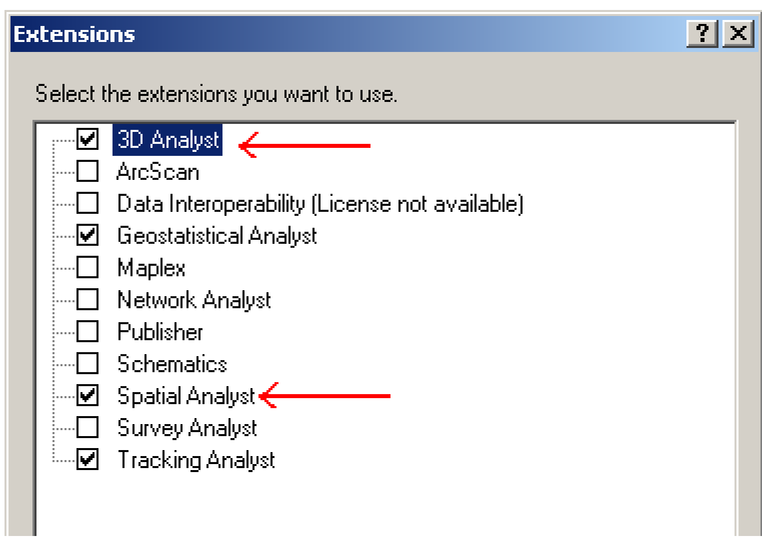


The *LandUse* folder contains a shapefile with land use data, the *Solution* folder contains results for this tutorial, *aerial* is the aerial image of the study area, and *baxter_tin* is the TIN dataset for the study area. Please use the results provided in the solution folder as a GUIDE only.

Getting Started

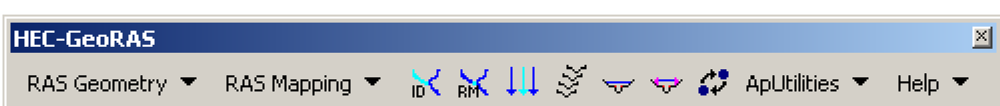
Start ArcMap by **clicking** *Start*→ *Programs*→*ArcGIS*→*ArcMap*. Save the ArcMap document (by **clicking** *File*→*Save As.*.) as *baxter_georas.mxd* in your working folder.

Since Hec-GeoRAS uses functions associated with ArcGIS *Spatial Analyst* and *3D Analyst* extensions, make sure these extensions are available, and are enabled. You can check this by **clicking** on *Tool*→*Extensions.*., and **checking** the boxes (if they are unchecked) next to *3D Analyst* and *Spatial Analyst* as shown below:



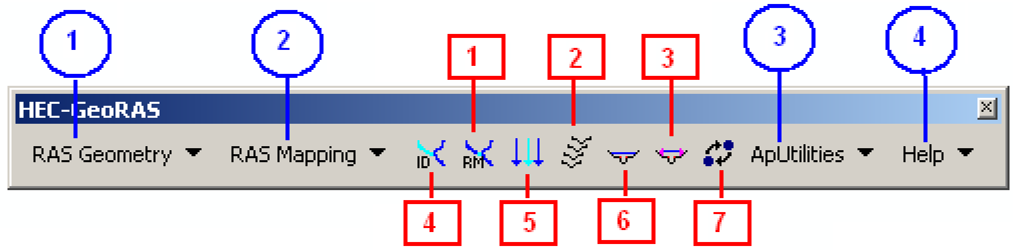
Close the Extensions window.

Now load the HEC-GeoRAS toolbar into ArcGIS by **clicking** on *View*→*Toolbars*→*HEC-GeoRAS* to see the toolbar as shown below:



You can either leave the HEC-GeoRAS toolbar on the map or dock it with other toolbars as desired.

The HEC-GeoRAS toolbar has four menus (RAS Geometry, RAS Mapping, ApUtilities, Help) and seven tools/buttons (Assign RiverCode/ReachCode, Assign FromStation/ToStation, Assign LineType, Construct XS Cutlines, Plot Cross Section, and Assign Levee Elevation) as shown in circles and boxes, respectively in the figure below.



The *RAS Geometry* menu contains functions for pre-processing of GIS data for input to HEC-RAS. The *RAS Mapping* menu contains functions for post-processing of HEC-RAS results to produce flood inundation map. The *ApUtilites* menu contains functions mainly for data management. The *Help* menu is self-explanatory. You will learn about functions associated with these menus and buttons in the following sections.

Setting up Analysis Environment for HEC-GeoRAS

Using GIS for hydrologic/hydraulic modeling usually involves three steps: 1) pre-processing of data, 2) model execution, and 3) post-processing/visualization of results. It is common to use a single map document to handle a single project, but this ends up with too many feature classes/layers in a single map. It is then cumbersome to find out which feature classes were used during pre-processing, and which feature classes contain results for visualization. To avoid this confusion, HEC-GeoRAS uses separate data frames to organize pre- and post-processing data. In the HEC-GeoRAS toolbar, **click** on *ApUtilities→ Add New Map* to create a new data frame as shown below (in ArcMap, you can add a new data frame by **clicking** on *Insert→Data Frame*):

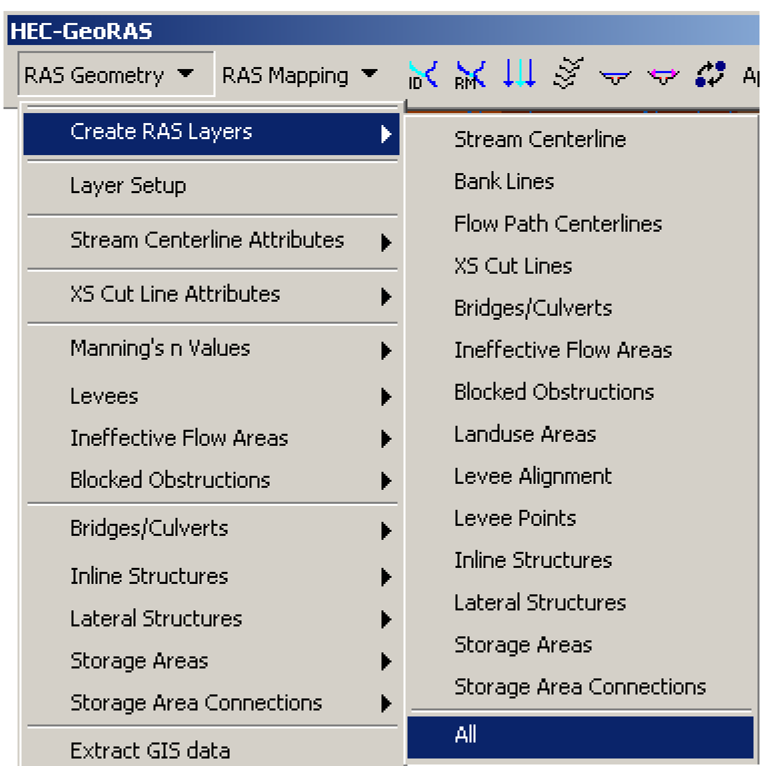
Since the outcome of pre-processing in HEC-GeoRAS is the creation of HEC-RAS geometry file, name the new data frame as BaxterGeometry and **click** *OK*.

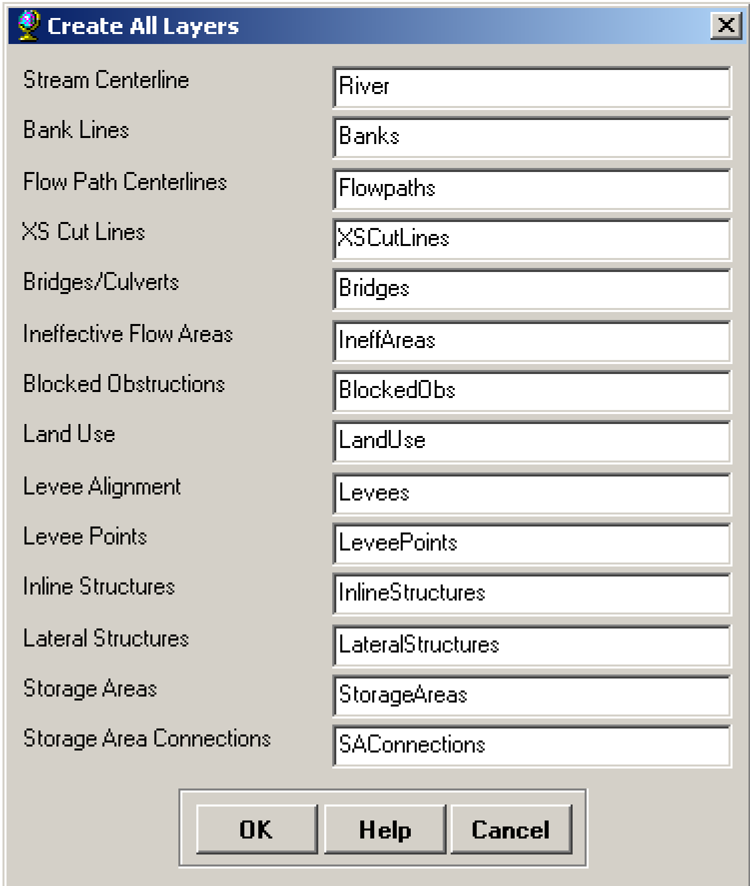
Notice the new data frame (BaxterGeometry) is added to the ArcMap table of contents. If you **right click** on the BaxterGeometry data frame, and then click on *Properties*…, you will see No Projection in the Coordinate System tab. **Close** the data frame properties window.

To create a geometry file, you need terrain (elevation) data. **Click** on Add  button in ArcMap, and **browse** to *baxter_tin* to add the terrain to the map document. You must have the same coordinate system for all the data and data frames used for this tutorial (or any GeoRAS project). Because *baxter_tin* already has a projected coordinate system, it is applied to the BaxterGeometry data frame. You can check this by right-clicking on the data frame and looking at its properties.

Creating RAS Layers

The geometry file for HEC-RAS contains information on cross-sections, hydraulic structures, river banks and other physical attributes of river channels. The pre-processing using HEC-GeoRAS involves creating these attributes in GIS, and then exporting them to the HEC-RAS geometry file. In HEC-GeoRAS, each attribute is stored in a separate feature class called as RAS Layer. So before creating river attributes in GIS, let us first create empty GIS layers using the RAS Geometry menu on the HEC-GeoRAS toolbar. **Click** on *RAS Geometry→Create RAS Layers*. You will see a list of all the possible attributes that you can have in the HEC-RAS geometry file. If you wish, you can click on individual attribute to create a single layer at a time, or you can click on All to create all layers. For this tutorial, **click** on *ALL* to create all layers.



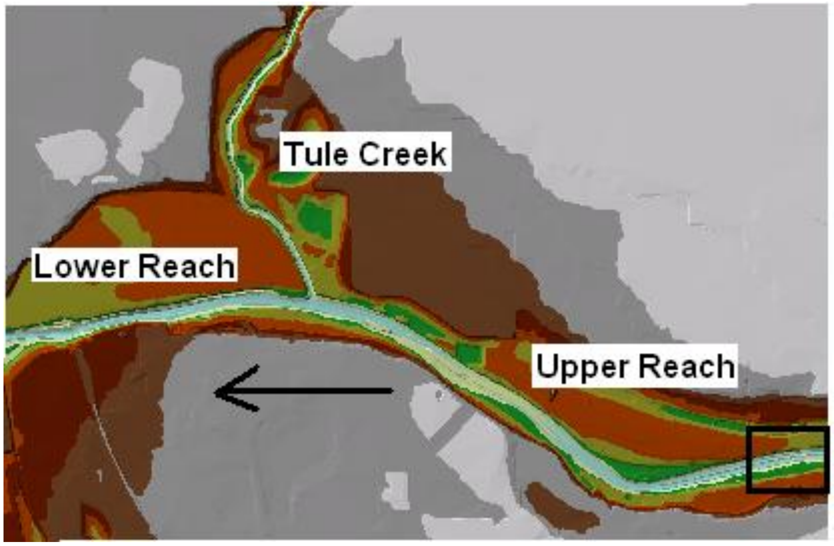


In the *Create All Layers* window, accept the default names, and **click** *OK*. HEC-GeoRAS creates a geodatabase in the same folder where the map document is saved, gives the name of the map document to the geodatabase (Baxter_georas.mdb, in this case), and stores all the feature classes/RAS layers in this geodatabase.

After creating RAS layers, these are added to the map document with a pre-assigned symbology. Since these layers are empty, our task is to populate some or all of these layers depending on our project needs, and then create a HEC-RAS geometry file.

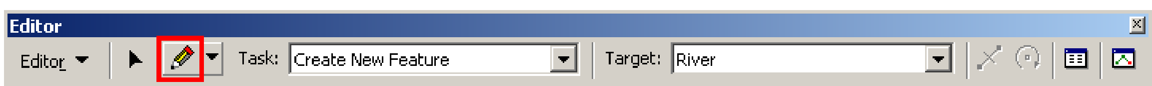
Creating River Centerline

Let us first start with river centerline. The river centerline is used to establish the river reach network for HEC-RAS. The baxter_tin dataset has the Baxter River flowing from east to west with Tule Creek as a tributary. So there are three reaches: upper Baxter River, lower Baxter River and Tule Creek Tributary as shown below:



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 Baxter reach to see the main channel (black outline shown in the above figure).

To create the river centerline (in River feature class), **start editing**, and choose *Create New Feature* as the *Task*, and *River* as the *Target* as shown below:

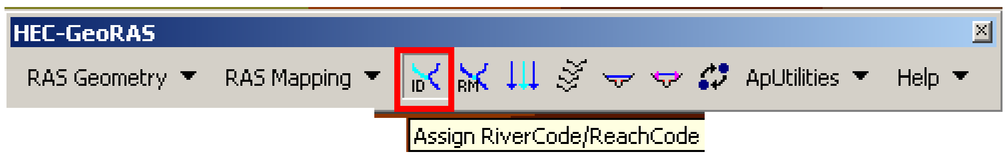


Using the Sketch tool (highlighted above), **start digitizing** the river centerline from upstream to downstream until you reach the intersection with Tule Creek tributary. To digitize the upper Baxter River reach, click in the direction of flow and double click when done (at intersection with Tule Tributary). If you need to pan, click the pan tool, pan through the map and then continue by clicking the sketch tool (do not double-click until you reach the junction). After finishing digitizing the upper Baxter Reach, **save the edits**. Before you start digitizing the Tule Creek tributary, modify some editing options. **Click** on *Editor*→ *Snapping*, and check the *End* box next to *River* as shown below:

Layer	Vertex	Edge	End
SAConnections	☐	☐	☐
StorageAreas	☐	☐	☐
LateralStructures	☐	☐	☐
InlineStructures	☐	☐	☐
LeveePoints	☐	☐	☐
Levees	☐	☐	☐
BlockedObs	☐	☐	☐
IneffAreas	☐	☐	☐
Bridges	☐	☐	☐
XSCutLines	☐	☐	☐
Flowpaths	☐	☐	☐
Banks	☐	☐	☐
River	☐	☐	☑

We are modifying the editing environment because when we digitize the Tule tributary we want its downstream end coincide with the downstream end of the upper Baxter Reach. **Close** the snapping box, and then **start digitizing** the Tule Tributary from its upstream end towards the junction with the Baxter River. When you come close to the junction, **zoom-in,** and you will notice that the tool will automatically try to snap (or hug!) to the downstream end of the upper Baxter Reach. **Double click** at this point to finish digitizing the Tule Tributary. **Save edits**. Finally, **digitize** the lower Baxter reach from junction with the Tule Tributary to the most downstream end of the Baxter River. Again make sure you snap the starting point with the common end points of Upper Baxter Reach and Tule Tributary. **Save edits**, and **stop editing**. (Snapping of all the reaches at the junction is necessary for connectivity and creating HEC-RAS junction so make sure the three reaches are snapped correctly).

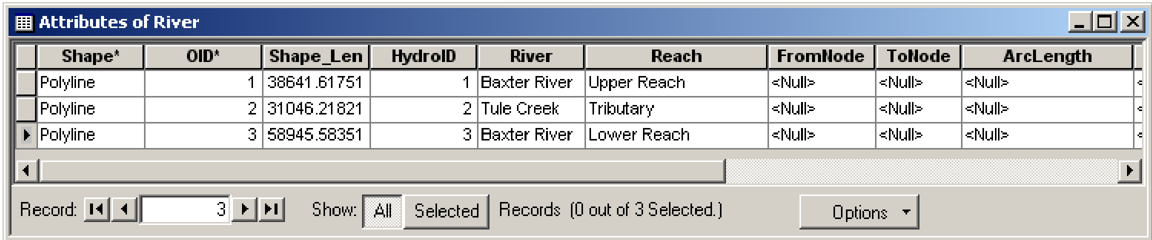
After the reaches are digitized, the next task is to name them. Each river in HEC-RAS must have a unique river name, and each reach within a river must have a unique reach name. We can treat the main stem of the Baxter River as one river and the Tributary as the second river. To assign names to reaches, **click** on *Assign RiverCode/ReachCode* button to activate it as shown below:



With the button active, **click** on the upper Baxter River reach. You will see the reach will get selected, invoking the following window:

Assign the River and Reach name as *Baxter River* and *Upper Reach*, respectively, and **click** *OK*. **Click** on the tributary reach, and use *Tule Creek* and *Tributary* for River and Reach name, respectively. For lower Baxter river, use *Baxter River* and *Lower Reach* for River and Reach name, respectively.

Now open the attribute table of River featureclass, and you will see that the information you just provided on river and reach names is entered as feature attributes as shown below:

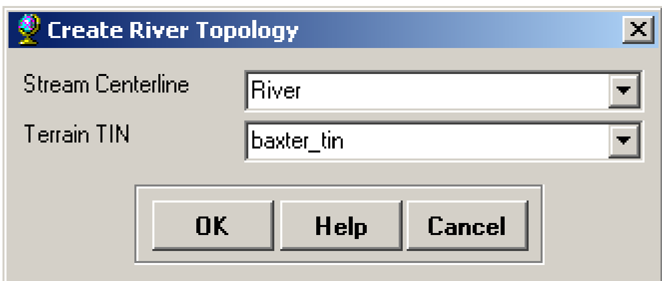

Attributes of River

Shape*	OID*	Shape_Len	HydroID	River	Reach	FromNode	ToNode	ArcLength
Polyline	1	38641.61751	1	Baxter River	Upper Reach	<Null>	<Null>	<Null>
Polyline	2	31046.21821	2	Tule Creek	Tributary	<Null>	<Null>	<Null>
Polyline	3	58945.58351	3	Baxter River	Lower Reach	<Null>	<Null>	<Null>

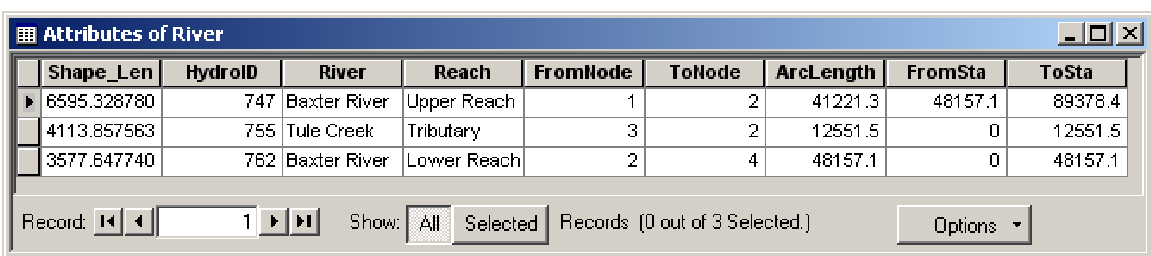
Record: 3 Show: All Selected Records (0 out of 3 Selected.) Options

Also note that there are still some unpopulated attributes in the River feature class (FromNode, ToNode, etc.).

Before we move forward let us make sure that the reaches we just created are connected, and populate the remaining attributes of the River feature class. **Click** on *RAS Geometry→ Stream Centerline Attributes→ Topology*



Confirm *River* for *Stream Centerline* and *baxter_tin* for *Terrian TIN*, and **click** *OK*. This function will populate the FromNode and ToNode attribute of the River feature class. Next, **click** on *RAS Geometry→Stream Centerline Attributes→Lengths/Stations*. This will populate the remaining attributes. Now open the attribute table for River, and understand the meaning of each attribute.


Attributes of River

Shape_Len	HydroID	River	Reach	FromNode	ToNode	ArcLength	FromSta	ToSta
6595.328780	747	Baxter River	Upper Reach	1	2	41221.3	48157.1	89378.4
4113.857563	755	Tule Creek	Tributary	3	2	12551.5	0	12551.5
3577.647740	762	Baxter River	Lower Reach	2	4	48157.1	0	48157.1

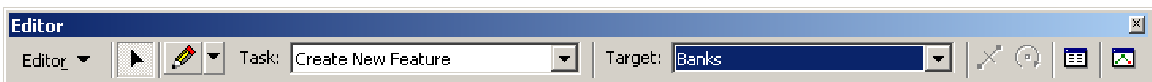
Record: 1 Show: All Selected Records (0 out of 3 Selected.) Options

HydroID is a unique number for a given feature in a geodatabase. The *River* and *Reach* attributes contain unique names for rivers and reaches, respectively. The *FromNode* and *ToNode* attributes define the connectivity between reaches. *ArcLength* is the actual length of the reach in map units, and is equal to Shape_Length. In HEC-RAS, distances are represented using station numbers measured from downstream to upstream. For example, each river has a station number of zero at the downstream end, and is equal to the length of the river at the upstream end. Since we have only one reach for Tule Creek tributary the *FromSta* attribute is zero and the *ToSta* attribute is equal to the *ArcLength*. Since the Baxter River has two reaches, the *FromSta* attribute for Upper Reach = *ToSta* attribute of lower reach, and the *ToSta* attribute for upper reach is the sum of *ArcLengths* for the upper and lower reach. **Close** the attribute table, and **save** the map document.

Creating River Banks

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 the channel centerline (in Banks feature class), **start editing**, and **choose** *Create New Feature* as the *Task*, and *Banks* as the *Target* as shown below:



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.

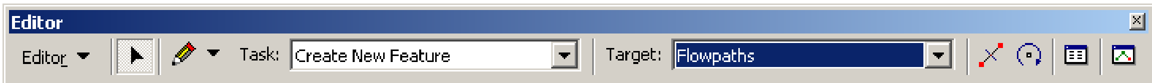
Digitize banks for all three reaches and **save** the edits and the map document.

Creating Flowpaths

The flowpath layer contains three types of lines: centerline, left overbank, and right overbank. The flowpath lines are used to determine the downstream reach lengths between cross-sections in the main channel and over bank areas. If the river centerline that we created earlier lie approximately in the center of the main channel (which it does), it can be used as the flow path centerline. **Click** on *RAS Geometry→Create RAS Layers→Flow Path Centerlines*

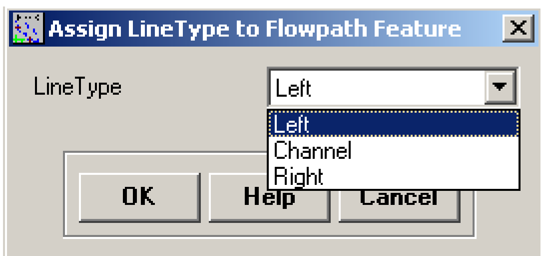
Click *Yes* on the message box that asks if you want to use the stream centerline to create the flow path centerline. Confirm *River* for *Stream Centerline* and *Flowpaths* for *Flow Path Centerlines*, and **click** *OK*.

To create the left and right flow paths (in Flowpaths feature class), **start editing**, and choose *Create New Feature* as the *Task*, and *Flowpaths* as the *Target* as shown below:

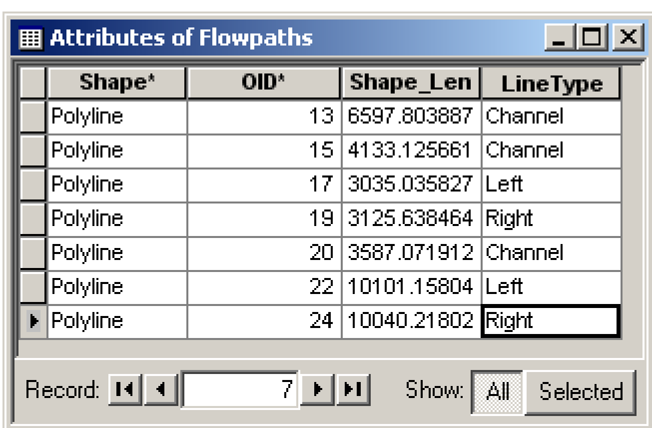


Use the sketch tool to create flowpaths. The left and right flowpaths must be digitized within the floodplain in the downstream direction. These lines are used to compute distances between cross-sections in the over bank areas. Again, to be consistent, looking downstream first digitize the left flowpath followed by the right flowpath for each reach. After digitizing, **save the edits** and **stop editing**.

Now label the flowpaths by using the Assign LineType button . **Click** on the button (notice the change in cursor), and then **click** on one of the flow paths (left or right, looking downstream), and name the flow path accordingly as shown below:



Label all flow paths, and confirm this by opening the attribute table of the Flowpaths feature class. The LineType field must have data for each row if all flowpaths are labeled.

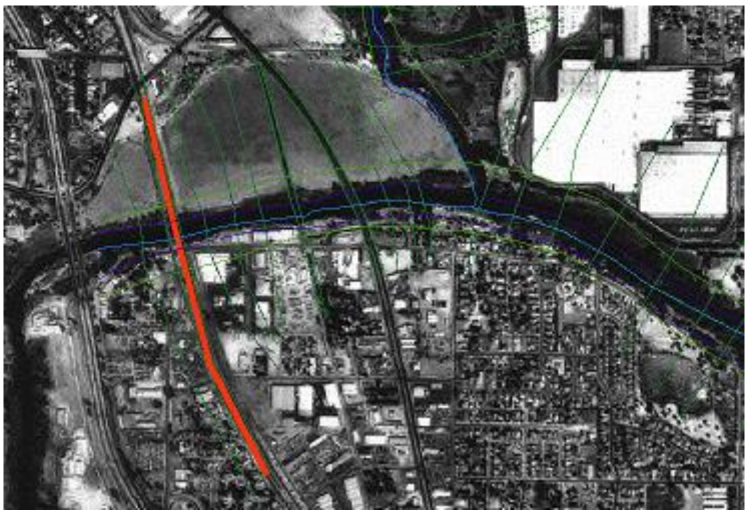

Attributes of Flowpaths

Shape*	OID*	Shape_Len	LineType
Polyline	13	6597.803887	Channel
Polyline	15	4133.125661	Channel
Polyline	17	3035.035827	Left
Polyline	19	3125.638464	Right
Polyline	20	3587.071912	Channel
Polyline	22	10101.15804	Left
Polyline	24	10040.21802	Right

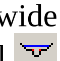
Record: 7 Show: All Selected

Creating Cross-sections

Cross-sections are one of the key inputs to HEC-RAS. Cross-section cutlines are used to extract the elevation data from the terrain to create a ground profile across channel flow. The intersection of cutlines 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 Mannings 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-section cutlines: (1) they are digitized perpendicular to the direction of flow; (2) must span over the entire flood extent to be modeled; and (3) always digitized from left to right (looking downstream). Even though it is not required, but it is a good practice to maintain a consistent spacing between 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. Structures can be identified by using the aerial photograph provided with the tutorial dataset. For example, we will use one bridge location in this exercise just downstream of the junction with tributary as shown below (bridge location is shown in red):



To create cross-section cutlines (in XSCutlines feature class), **start editing**, and choose *Create New Feature* as the *Task*, and *XSCutlines* as the *Target* as shown below:

Follow the above guidelines and digitize cross-sections using the sketch tool. While digitizing, make sure that each cross-section is wide enough to cover the floodplain. This can be done using the cross-sections profile tool . **Click** on the profile tool, and then **click** on the cross-section to view the profile. For example, if you get a cross-section profile shown in Figure A below, then there is no need to edit the cross-section, but if you get a cross-section as shown in Figure B below, then the cross-section needs editing. (Note: This tool stops the edit session so you will have to start the edit session every time after viewing the cross-section profile).

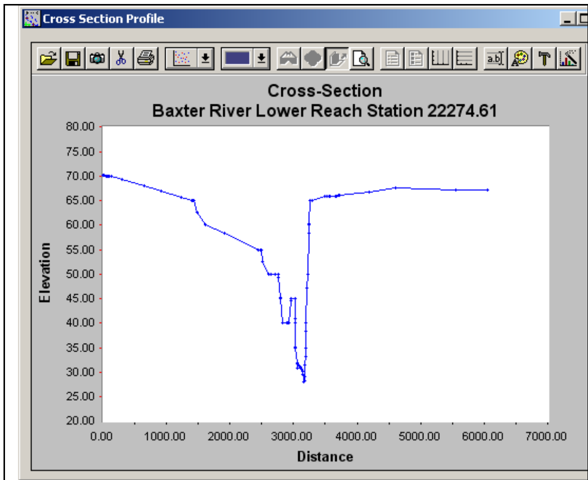


Figure A: adequate definition of cross-section

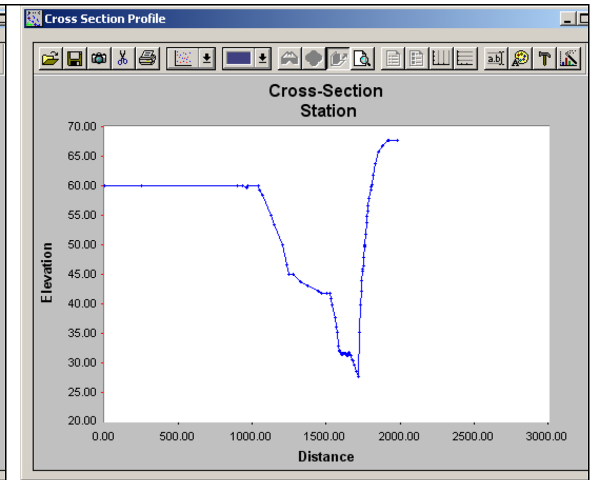
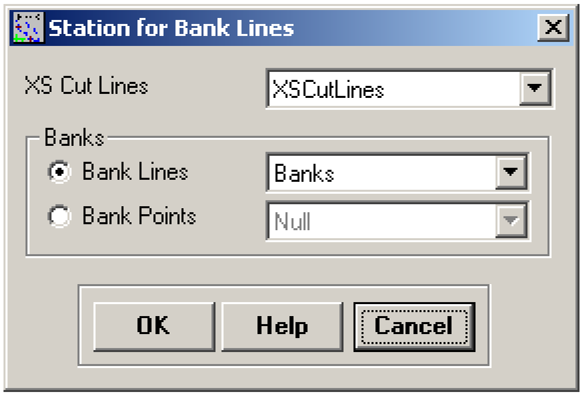


Figure b: inadequate definition of coss-section

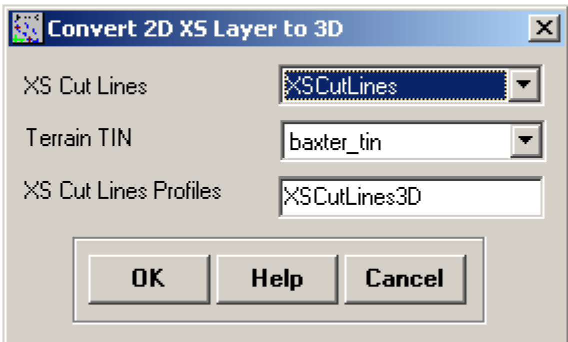
After digitizing the cross-sections, **save** the edits and **stop** editing. The next step is to add HEC-RAS attributes to these cutlines. We will add Reach/River name, station number along the centerline, bank stations and downstream reach lengths. Since all these attributes are based on the intersection of cross-sections with other layers, make sure each cross-section intersects with the centerline and overbank flow paths to avoid error messages.

Click on *RAS Geometry→ XS Cut Line Attributes→ River/Reach Names*. This tool uses the River and Reach attributes of the centerline, and copy them to the XS Cutlines. Next, **click** on *RAS Geometry→XS Cut Line Attributes→Stationing*. This tool will assign station number (distance from each cross-section to the downstream end of the river) to each cross-section cutline. Next, **click** on *RAS Geometry→XS Cut Line Attributes→ Bank Stations*. Confirm XSCutlines for XS Cut Lines, and Banks for Bank Lines, and **click** *OK*.



This tool assigns bank stations (distance from the starting point on the XS Cutline to the left and right bank, looking downstream) to each cross-section cutline. Finally, **click** on *RAS Geometry→XS Cut Line Attributes→Downstream Reach Lengths*. This tool assigns distances to the next downstream cross-section based on flow paths.

The cross-section cutlines are 2D lines with no elevation information associated with them (Polyline). When you used the profile tool earlier to view the cross-section profile, the program used the underlying terrain to extract the elevations along the cutline. You can convert 2D cutlines into 3D by **clicking** *RAS Geometry→XS Cut Line Attributes→Elevation*. Confirm *XSCutlines* for *XS Cut Lines*, and *baxter_tin* for *Terrian TIN*. The new 3D lines (XS Cut Lines Profiles) will be stored in the XSCutLines3D feature class. **Click** *OK*.



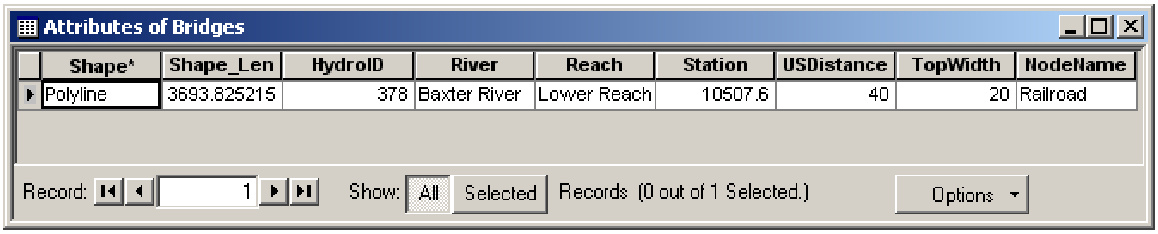
After this process is finished, open the attribute table of XSCutLines3D feature class and see that the shape of this feature class is now PolylineZ.

Creating Bridges and Culverts

After creating cross-sections, the next step is to define bridges, culverts and other structure along the river. Since we used aerial photograph while defining the cross-sections, our job of locating the bridge is done. To create bridges/culverts (in Bridges feature class), **start editing**, and choose *Create New Feature* as the *Task*, and *Bridges* as the *Target* as shown below:

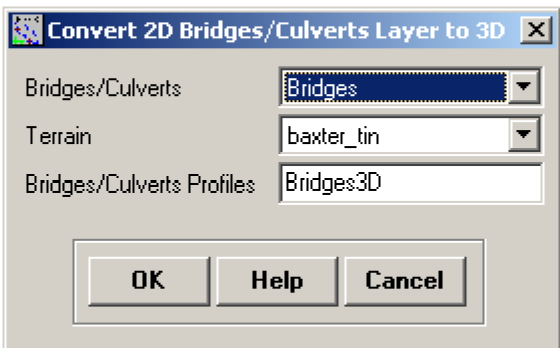
A bridge or culvert is treated similar to a cross-section so the same criteria used for creating cross-sections must be used for bridge/culverts. Using the sketch tool on the editor toolbar, the **digitize** bridge location just downstream of the tributary junction. While digitizing the bridge, make use of the terrain model to make sure the bridge/road centerline fall on the high ground. **Save** your edits and **stop** editing.

After digitizing bridges/culverts, you need to assign attributes such as River/Reach name and station number to these features. **Click** on *RAS Geometry→ Bridge/Culverts→ River/Reach Names* to assign river/reach names. Next **click** on *RAS Geometry→ Bridge/Culverts→Stationing* to assign station numbers. Besides these attributes, you must enter additional information about the bridge(s) such as the name and width in its attribute table as shown below.



Close the attribute table, **save** edits and **stop** editing.

Similar to cross-sections, the Bridges feature class stores 2D polylines, you can make them 3D by **clicking** *RAS Geometry→Bridge/Culverts→Elevations* to create a new 3DBridges feature class. Confirm *Bridges* for *Bridges/Culverts*, *baxter_tin* for *Terrain*, *Bridges3D* for *Bridges/Culverts Profiles*, and **Click** *OK*.



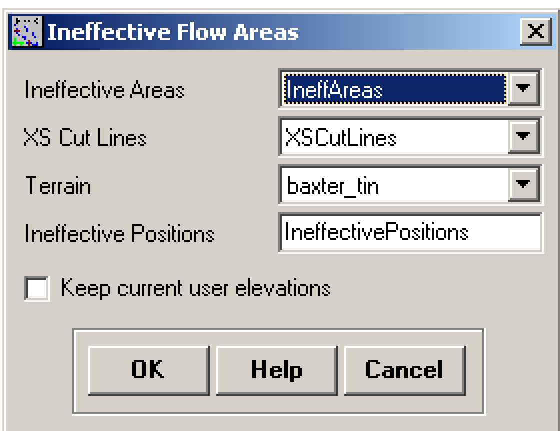
A new feature class (Bridges3D) will be created. You can check it is PolylineZ by opening its attribute table.

Creating ineffective flow areas

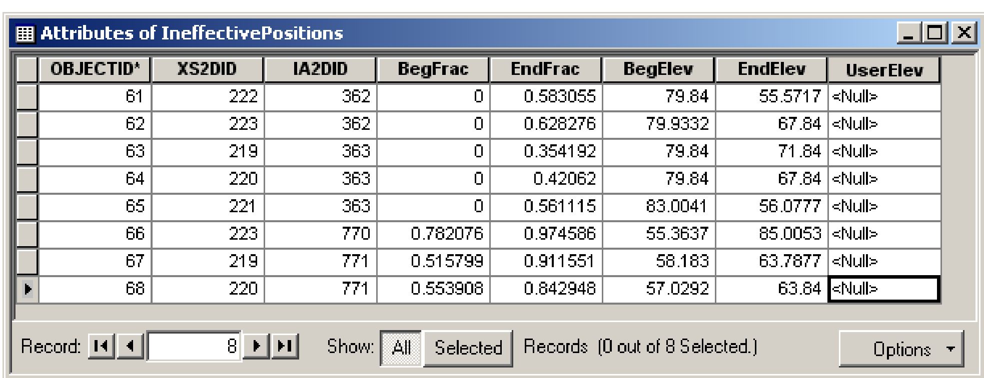
Ineffective flow areas are used to identify non-conveyance areas (areas with water but no flow/zero velocity) of the floodplain. For example, areas behind bridge abutments representing contraction and expansion zones can be considered as ineffective flow areas. To define ineffective areas (in IneffAreas feature class), **start editing**, and choose *Create New Feature* as the *Task*, and *IneffAreas* as the *Target* as shown below:

Use the sketch tool to define ineffective areas. The figure below shows an example of ineffective area for the bridge downstream of the tributary junction (Note: this is a polygon feature class).

HEC-RAS does not store all information about ineffective areas. Instead only the information where the ineffective area may interfere with cross-sections/flow is stored. To extract the position and elevation at points where these ineffective areas intersect with cross-sections, **click** on *RAS Geometry→Ineffective Flow Areas→Position*. Leave the default feature classes for *IneffectiveAreas*, *XS Cut Lines*, and *Terrain* unchanged. The position of ineffective areas will be stored in a new table named *IneffectivePositions*. Leave current user elevations **unchecked**, and **Click** *OK*.



Open the attributes of the *IneffectivePositions* table (shown below) to understand how this information is stored.



Attributes of IneffectivePositions

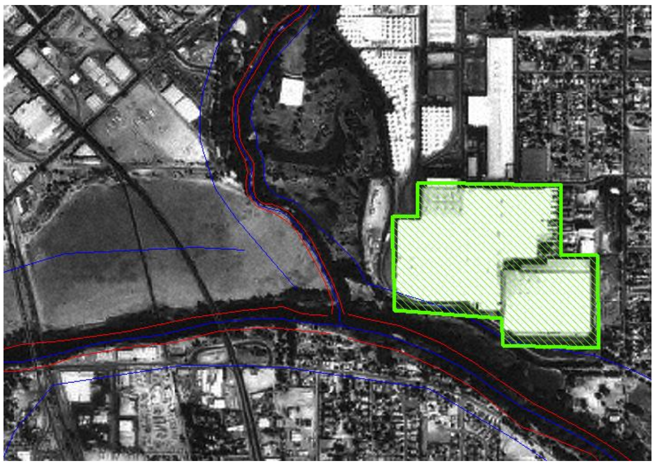
OBJECTID*	XS2DID	IA2DID	BegFrac	EndFrac	BegElev	EndElev	UserElev
61	222	362	0	0.583055	79.84	55.5717	<Null>
62	223	362	0	0.628276	79.9332	67.84	<Null>
63	219	363	0	0.354192	79.84	71.84	<Null>
64	220	363	0	0.42062	79.84	67.84	<Null>
65	221	363	0	0.561115	83.0041	56.0777	<Null>
66	223	770	0.782076	0.974586	55.3637	85.0053	<Null>
67	219	771	0.515799	0.911551	58.183	63.7877	<Null>
68	220	771	0.553908	0.842948	57.0292	63.84	<Null>

Record: 8 Show: All Selected Records (0 out of 8 Selected.) Options

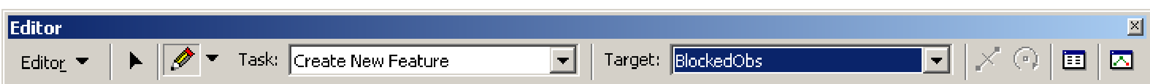
IA2DID is the HydroID of the ineffective flow area, *XS2DID* is the HydroID of the intersecting cross-section, *BeginFrac* and *EndFrac* are the relative positions of the first and last intersecting points (looking downstream) of the ineffective area with the cross-section. *BegElev* and *EndElev* are the elevations of the first and last intersecting points of the ineffective area with the cross-section. Since you left the *UserElev* box unchecked there are no values in this field.

Creating obstructions

Obstructions represent blocked flow areas (areas with no water and no flow). For example, buildings in the floodplain and levees are considered obstructions. We can add blocked obstructions to our study by using building locations in the aerial photograph. In the upper reach of the Baxter River just before Tule Creek, there are two building in the floodplain that can be considered as blocked obstructions.



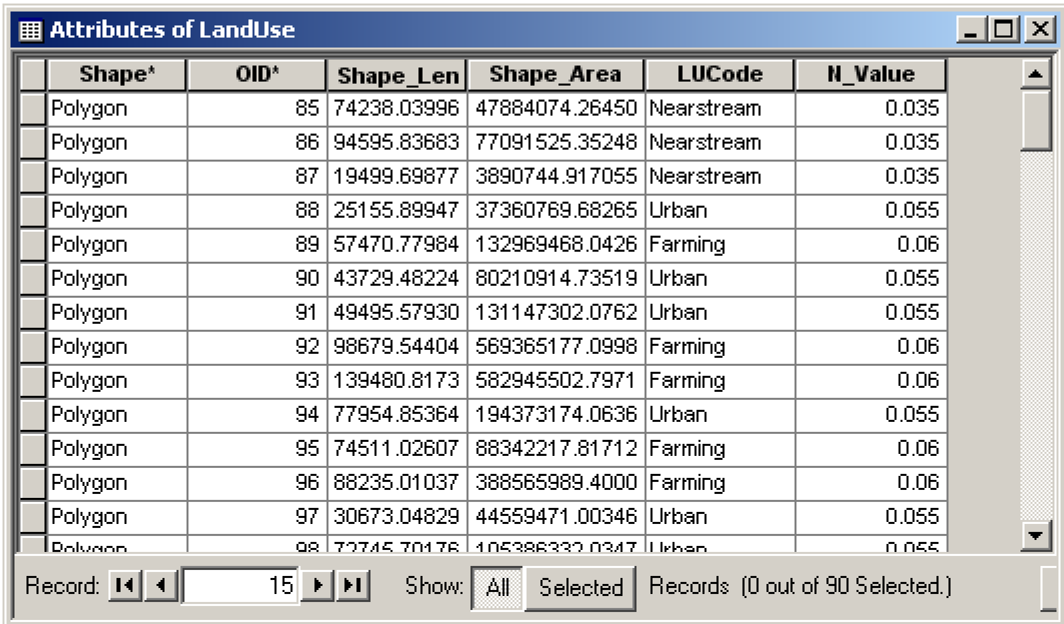
To define blocked obstructions (in BlockedObs feature class), **start editing**, and choose *Create New Feature* as the *Task*, and *BlockedObs* as the *Target* as shown below:



Use the Sketch tool to define the blocked obstruction, **save edits** and **stop editing**. Similar to Ineffective flow areas, the positions and elevations of the intersection of this obstruction with cross-sections needs to be stored in a table. Click on *RAS Geometry→ Blocked Obstructions→ Positions*. Leave the default values in the *Blocked Obstructions* window, and **click** *OK*. You will notice that a new table (*BlockedPositions*) will be added to the map document, and its content are identical to *IneffectivePositions* table.

Assigning Manning's n to cross-sections

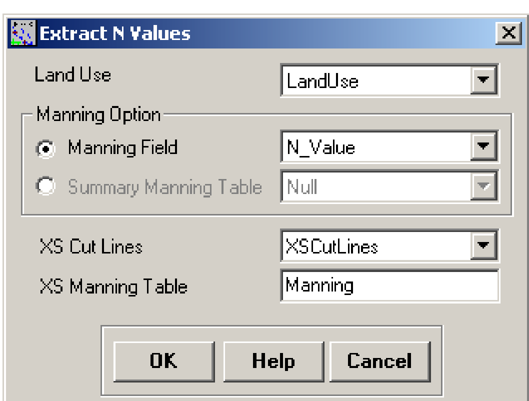
The final task before exporting the GIS data to HEC-RAS geometry file is assigning Manning's n value to individual cross-sections. In HEC-GeoRAS, this is accomplished by using a land use feature class with Manning's n stored for different land use types. Ideally you will store this information in the LandUse feature class added to the map document. Since we created empty feature classes at the beginning of the tutorial, we do not have this information. We will remove this empty LandUse feature class, and add LandUse shapefile (stored in LandUse folder) provided with the tutorial dataset. (Note: you can also replace the LandUse feature class in Baxter_georas.mdb with the shapefile in ArcCatalog)



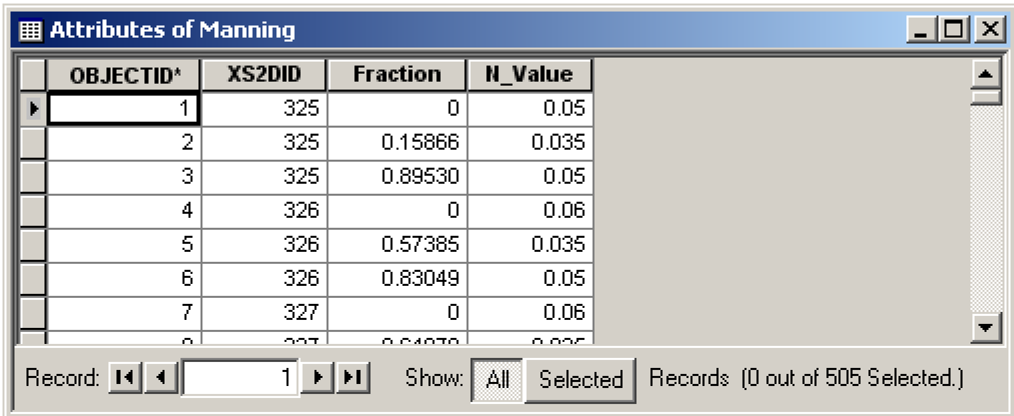
Shape*	OID*	Shape_Len	Shape_Area	LUCode	N_Value
Polygon	85	74238.03996	47884074.26450	Nearstream	0.035
Polygon	86	94595.83683	77091525.35248	Nearstream	0.035
Polygon	87	19499.69877	3890744.917055	Nearstream	0.035
Polygon	88	25155.89947	37360769.68265	Urban	0.055
Polygon	89	57470.77984	132969468.0426	Farming	0.06
Polygon	90	43729.48224	80210914.73519	Urban	0.055
Polygon	91	49495.57930	131147302.0762	Urban	0.055
Polygon	92	98679.54404	569365177.0998	Farming	0.06
Polygon	93	139480.8173	582945502.7971	Farming	0.06
Polygon	94	77954.85364	194373174.0636	Urban	0.055
Polygon	95	74511.02607	88342217.81712	Farming	0.06
Polygon	96	88235.01037	388565989.4000	Farming	0.06
Polygon	97	30673.04829	44559471.00346	Urban	0.055

The land use table must have a descriptive field identifying landuse type, which is *LUCode* in this case, and a field for corresponding Manning's n values. In addition, HEC-GeoRAS requires the land use polygons to be non multi-part features (a multipart feature has multiple geometries in the same feature). The issue of non multi-part features is taken care of for the tutorial dataset.

To assign Manning's n to cross-sections, **click** on *RAS Geometry→Manning's n Values→Extract n Values*. Confirm *LandUse* for *Land Use*, choose *N_Value* for *Manning Field*, *XSCutLines* for *XS Cut Lines*, leave the default name *Manning* for *XS Manning Table*, and **click** *OK*. (Note: Summary Manning Table is not required if n values already exist in the LandUse table.).

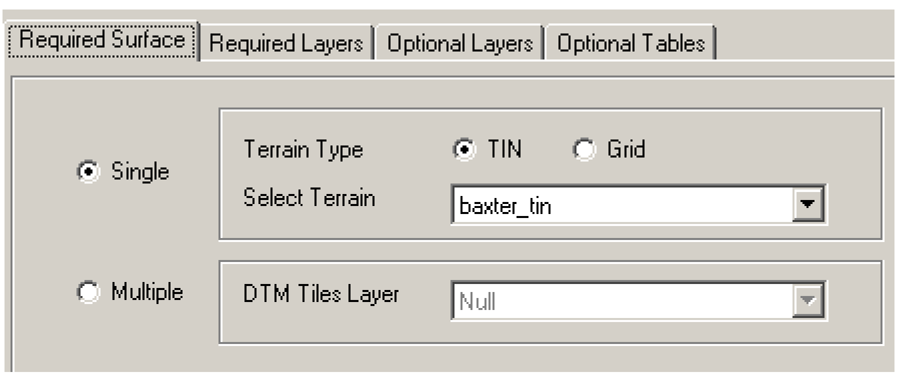


Depending on the intersection of cross-sections with landuse polygons, Manning's n are extracted for each cross-section, and reported in the XS Manning Table (*Manning*). **Open** the Manning table, and see how the values are stored. Similar to previous tables, the data are organized as the feature identifier (*XS2DID*), its relative station number and the corresponding n value as shown below:

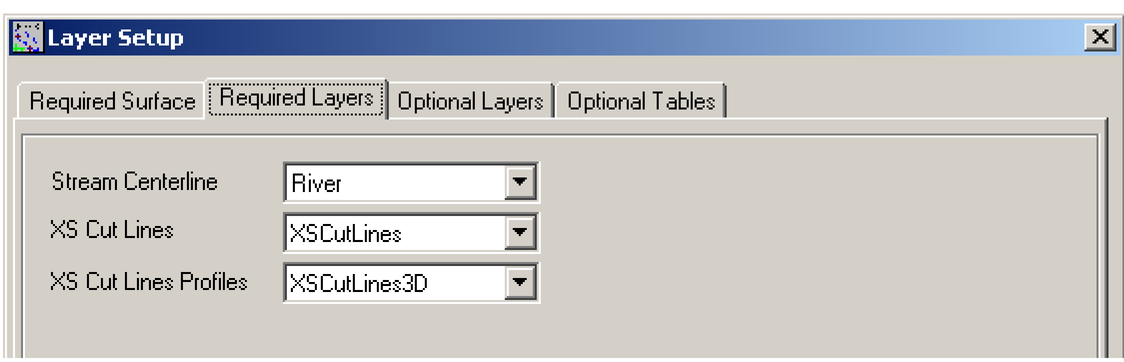


OBJECTID*	XS2DID	Fraction	N_Value
1	325	0	0.05
2	325	0.15866	0.035
3	325	0.89530	0.05
4	326	0	0.06
5	326	0.57385	0.035
6	326	0.83049	0.05
7	327	0	0.06

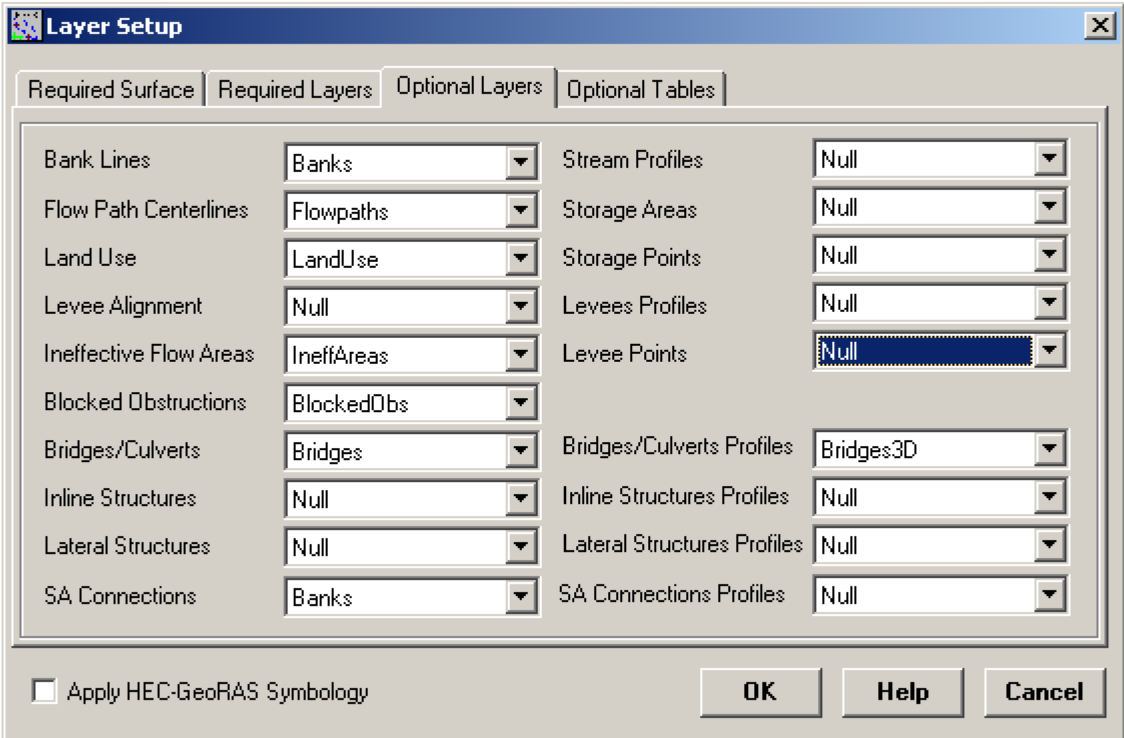
Close the table. We are almost done with GeoRAS pre-processing. The last step is to create a GIS import file for HEC-RAS so that it can import the GIS data to create the geometry file. Before creating an import file, make sure we are exporting the right layers. **Click** on *RAS Geometry*→ *Layer Setup*, and verify the layers in each tab. The required surface tab should have *baxter_tin* for *single Terrain* option.



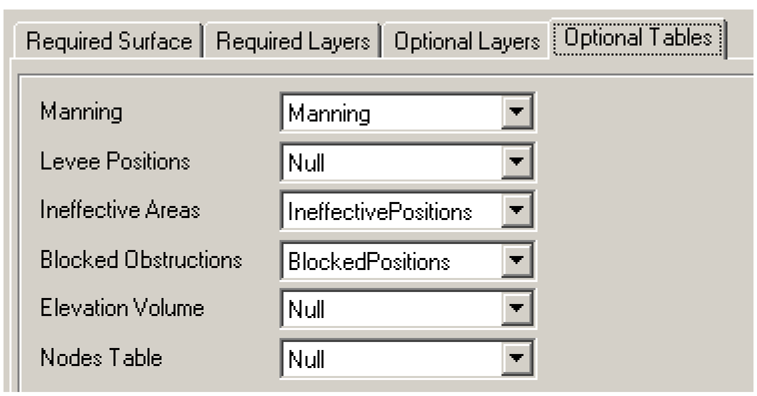
The *Required Layers* tab should have *River*, *XSCutLines* and *XSCutLines3D* for *Stream Centerline*, *XSCutmLines* and *XSCut Lines Profiles*, respectively.



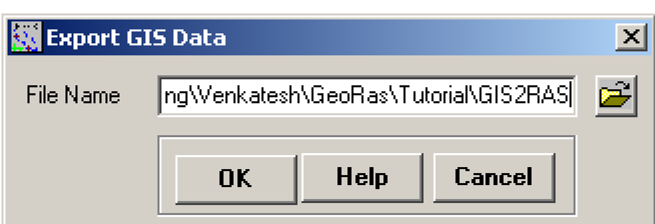
In the *Optional Layers* tab, make sure the layers that are empty are set to *Null*.



Finally, verify the tables and **Click** *OK*.



After verifying all layers and tables, **click** on *RAS Geometry*→*<u>Export GIS Data</u>*.



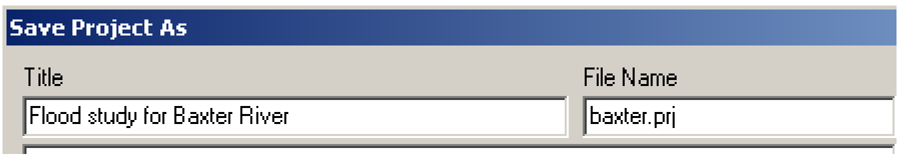
Confirm the location and the name of the export file (*GIS2RAS* in this case), and **click** *OK*. This process will create two files: *GIS2RAS.xml* and *GIS2RAS.RASImport.sdf*. **Click**

OK on the series of messages about computing times. You are done exporting the GIS data! The next step is to import these data into a HEC-RAS model.

Save the map document. You can either close the ArcMap session or leave it running.

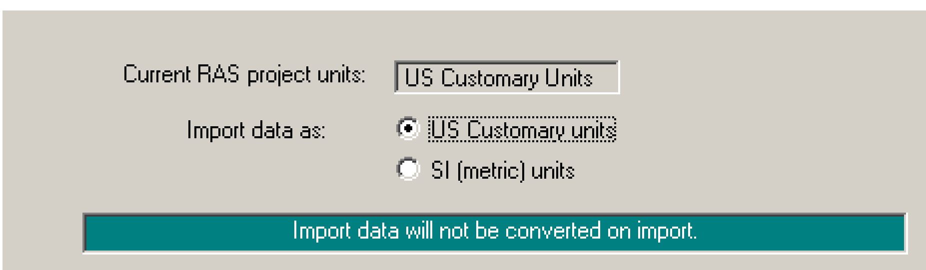
Importing Geometry data into HEC-RAS

Launch HEC-RAS by **clicking** on *Start→Programs→HEC→HEC-RAS→HEC-RAS 4.0*. **Save** the new project by going to *File→Save Project As..* and save as *baxter.prj* in your working folder as shown below:

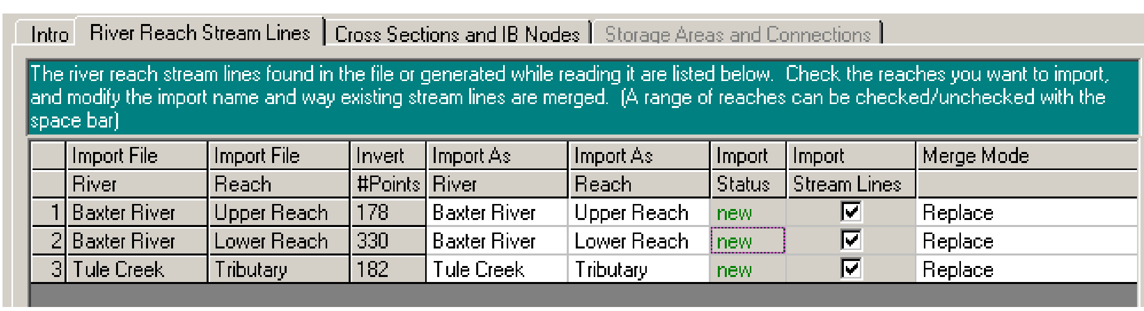


Click *OK*.

To import the GIS data into HEC-RAS, first go to geometric data editor by **clicking** on *Edit→Geometric Data…* In the geometric data editor, **click** on *File→Import Geometry Data→ GIS Format*. **Browse** to *BaxterRAS.RASImport.sdf* file created in GIS, and **click** *OK*. The import process will ask for your inputs to complete. In the Intro tab, confirm US Customary Units for Import data as and **click** *Next*.

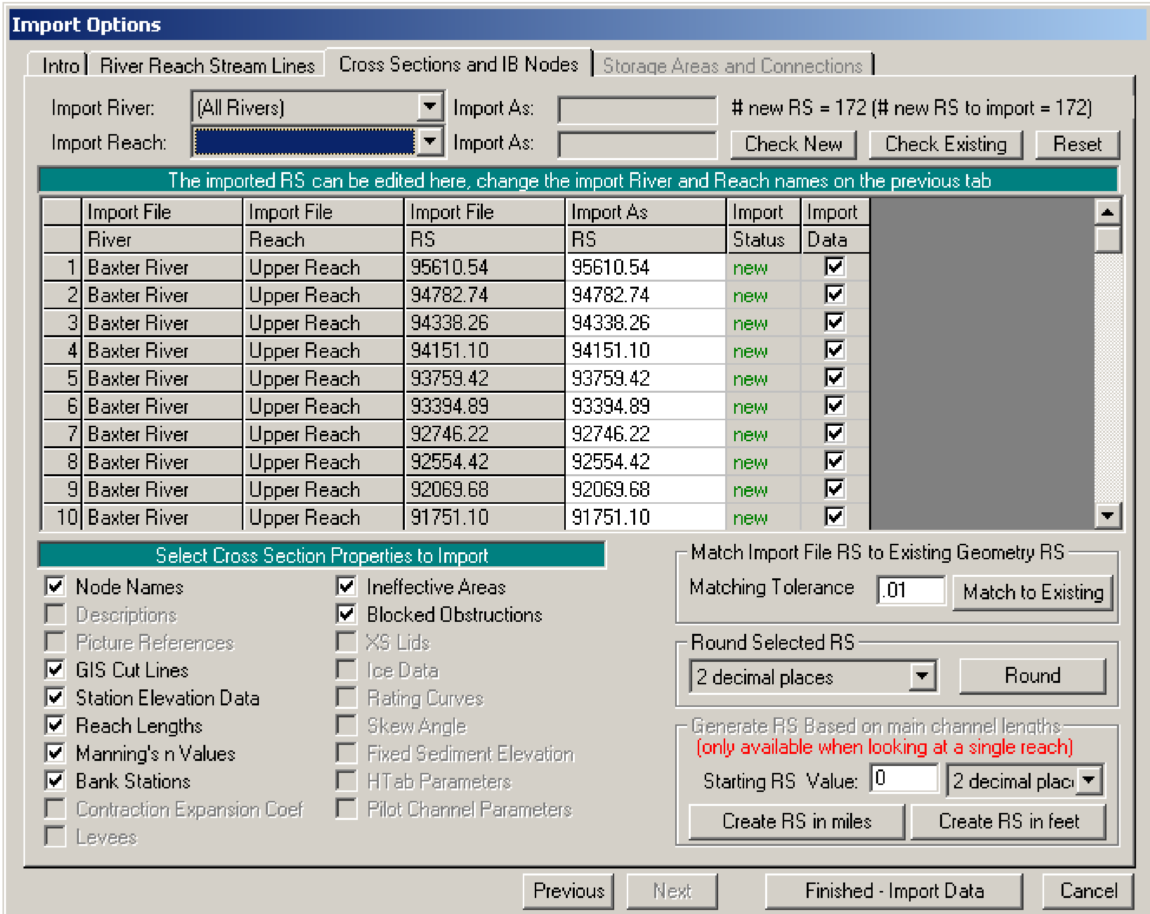


Confirm the River/Reach data, make sure all import stream lines boxes are checked, and **click** *Next*.

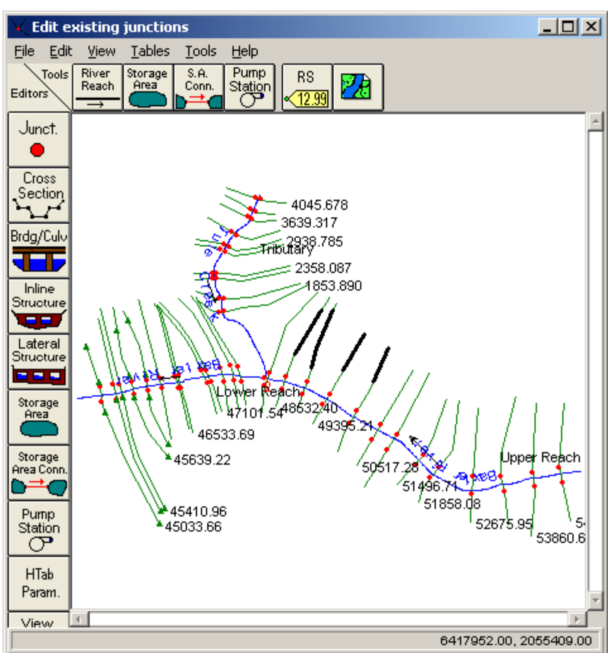


	Import File River	Import File Reach	Invert #Points	Import As River	Import As Reach	Import Status	Import Stream Lines	Merge Mode
1	Baxter River	Upper Reach	178	Baxter River	Upper Reach	new	☑	Replace
2	Baxter River	Lower Reach	330	Baxter River	Lower Reach	new	☑	Replace
3	Tule Creek	Tributary	182	Tule Creek	Tributary	new	☑	Replace

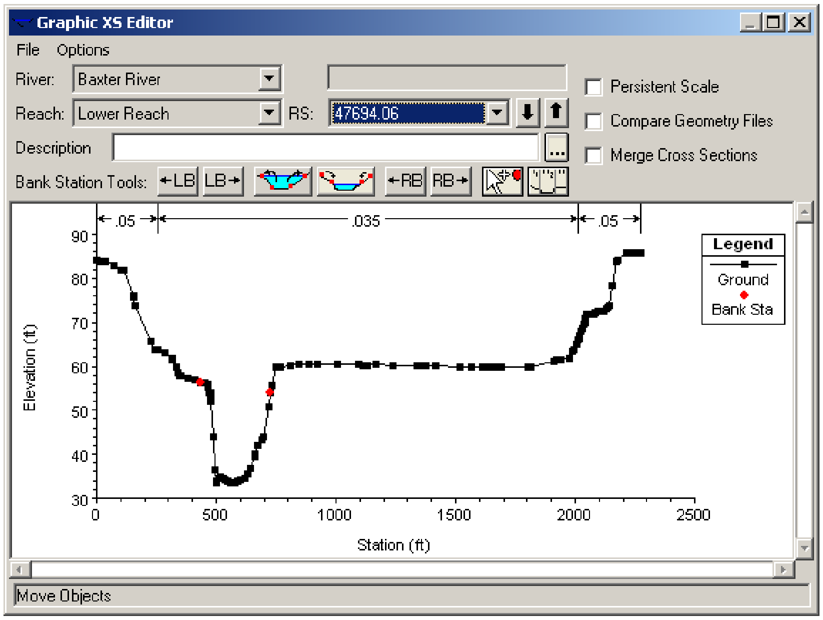
Confirm cross-sections data, make sure all Import Data boxes are **checked** for cross-sections, and **click** *OK* (accept default values for matching tolerance, round places, etc).



Since we do not have Storage areas, **click** *Finished-Import Data*. The data will then be imported to the HEC-RAS geometric editor as shown below:



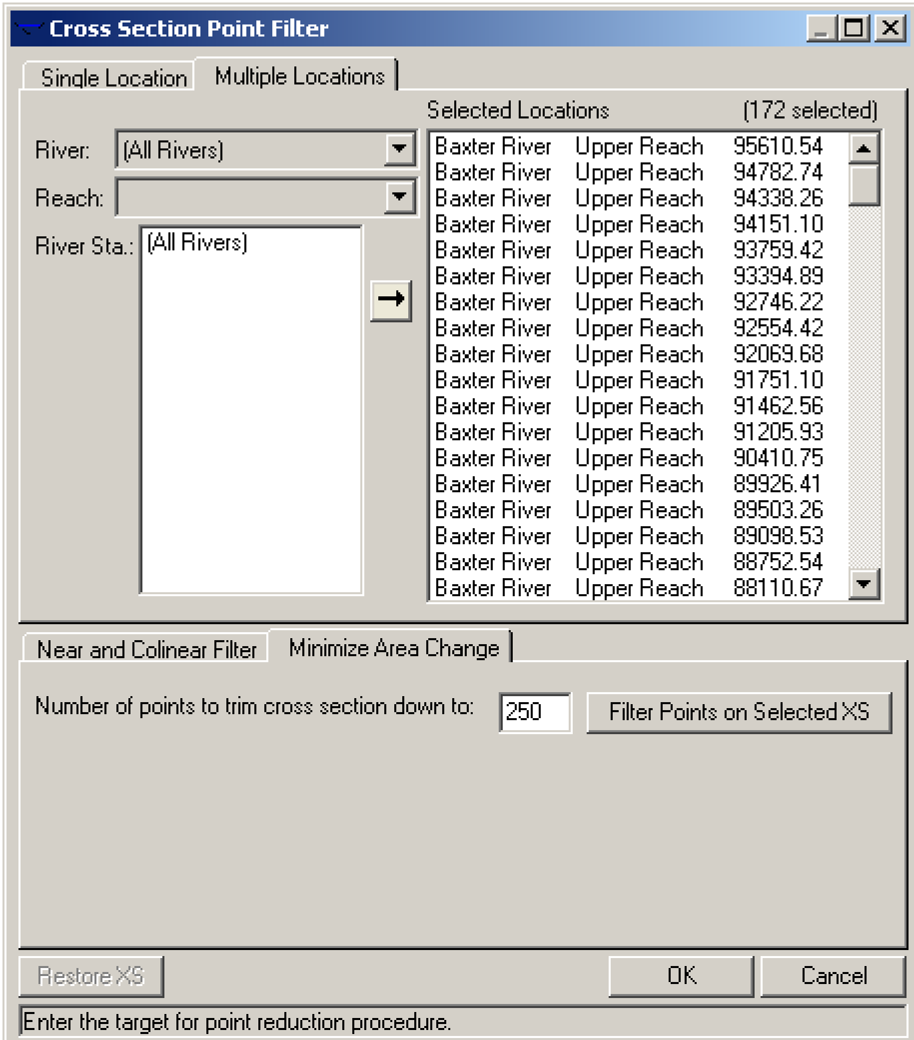
Save the geometry file by **clicking** *File→Save Geometry Data*. Before you proceed, it is a good practice to perform a quality check on the data to make sure no erroneous information is imported from GIS. You can use the tools in Geometric editor to perform the quality check. One of the best tools 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.

A cross-section in HEC-RAS can have up to 500 elevation points. Generally these many points are not required, and also when we extract cross-sections from a terrain using HEC-GeoRAS, we get a lot of redundant points. This issue can be handled by using the cross-section filter in HEC-RAS. In the Geometric data editor, click on *Tools→Cross Section Points Filter*.

In the Cross Section Point Filter, **select** the *Multiple Locations* tab. From the *River* drop down menu, **select** *(All Rivers)* option, and **click** on the select arrow button  to select all cross-sections for all reaches. Then **select** the *Minimize Area Change* tab at the bottom, and **enter** *250* for the number of points to trim cross-sections down to. The minimize area change will reduce the impact of change in cross-sectional area as a result of points removal. **Click** *Filter Points on Selected XS* button.

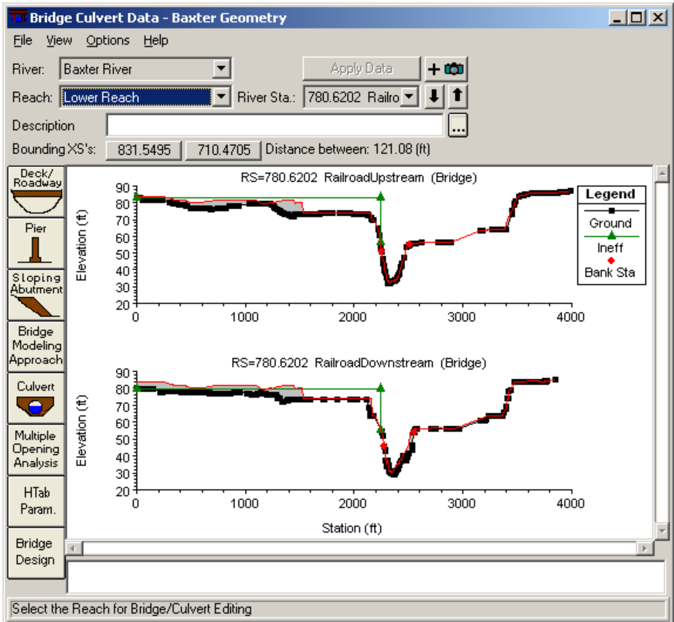


You will get a summary of number of points removed for the filtered cross-sections. You will notice that only a few cross-sections had points removal. **Close** the summary results box. You can select the Single Location tab to see the effect of points removal on the cross-sections.

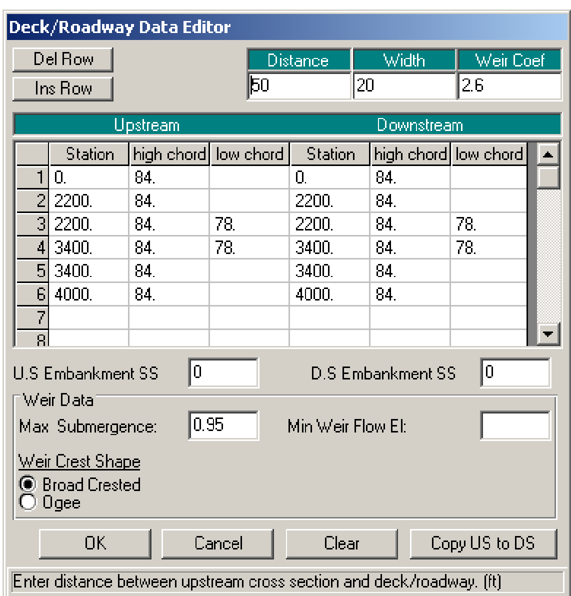
Another main task that we want to do is to edit data related to structures. Since we have only one bridge, we will edit its information because details such as deck elevation and number of piers are usually not exported by HEC-GeoRAS. **Click** on Bridge/Culvert editing button 

, and select the *Railroad* bridge on the *Lower Reach* of the *Baxter River*.

You will see that the deck elevation is not complete. The bridge does not even cross the river in this case! So we will edit this information.

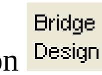


Click on Deck/Roadway editor, and delete all information (you can **select** the Cells and press **Delete** on the key board similar to an Excel operation). We will approximate the bridge width to about 1200 ft (station 2200 to 3400), deck elevation as 84 ft (high chord) and 6ft deep (low chord) as shown below:

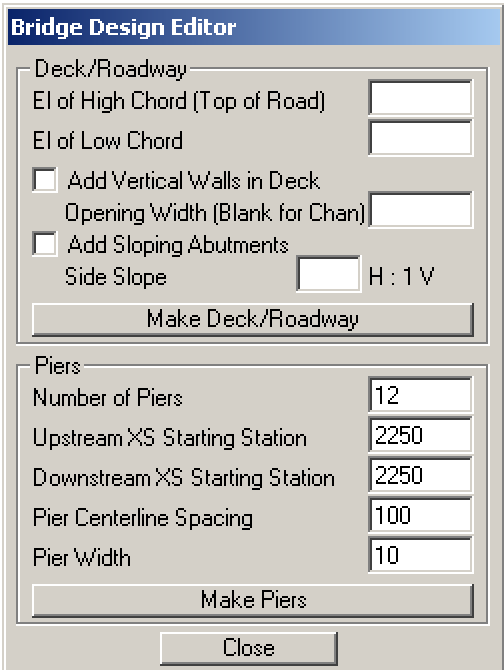


	Upstream			Downstream		
	Station	high chord	low chord	Station	high chord	low chord
1	0.	84.		0.	84.	
2	2200.	84.		2200.	84.	
3	2200.	84.	78.	2200.	84.	78.
4	3400.	84.	78.	3400.	84.	78.
5	3400.	84.		3400.	84.	
6	4000.	84.		4000.	84.	
7						
8						

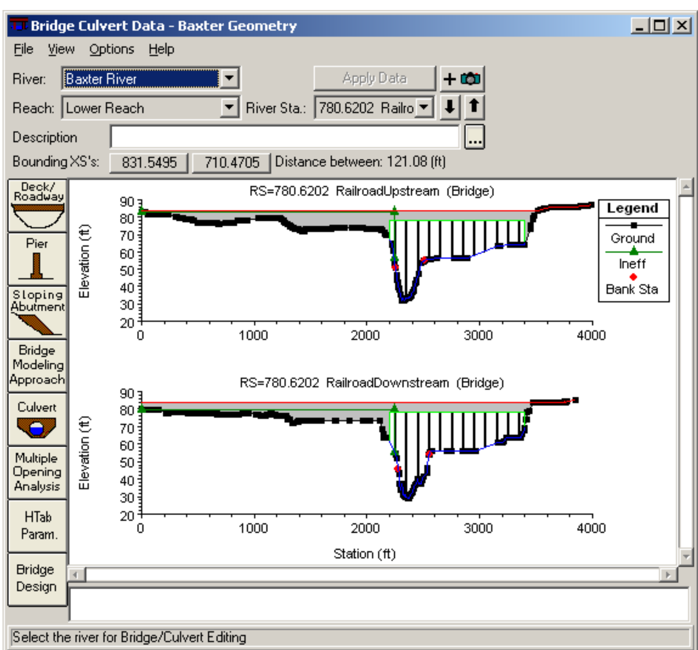
Click on the *Copy US to DS* button to copy the information from upstream to downstream, and **click** *OK*. Next, we will enter pier information. We will assume twelve

10 ft wide piers with a spacing of 100 ft. Click on Bridge Design button 

, and enter the information as shown below:



Click on *Make Piers*, and then **click** *Close*. The bridge should now look similar to the figure shown below:

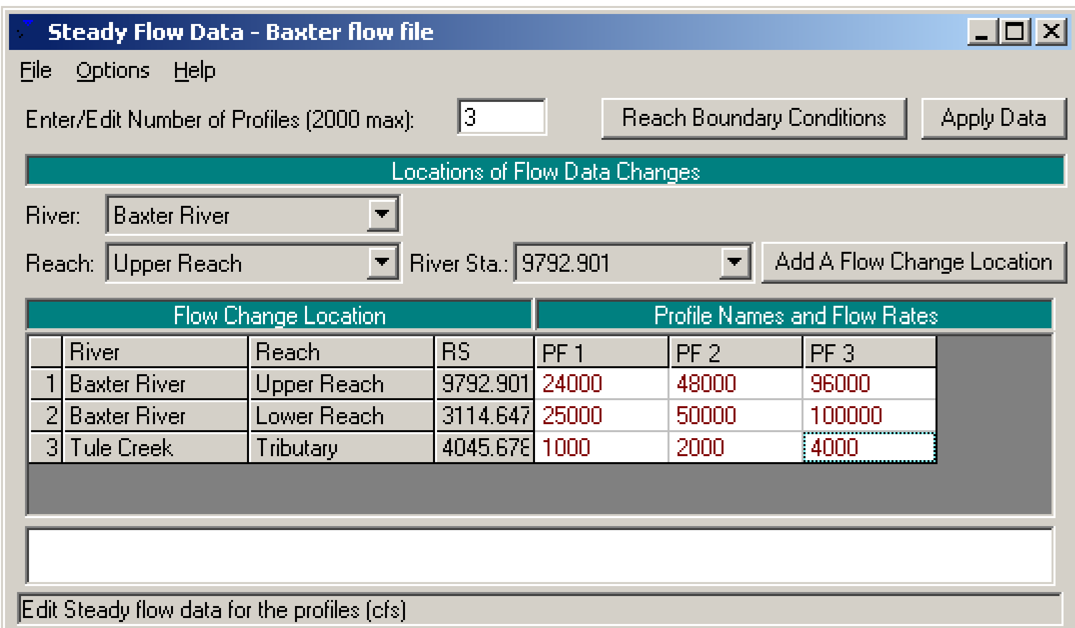


You need to know the actual bridge condition to be able to accurately enter this information, but for this tutorial we have used our intuition (and creativity!) in designing the bridge. After you are done editing the bridge data, **close** the bridge/culvert editor, **save** geometry data and **close**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

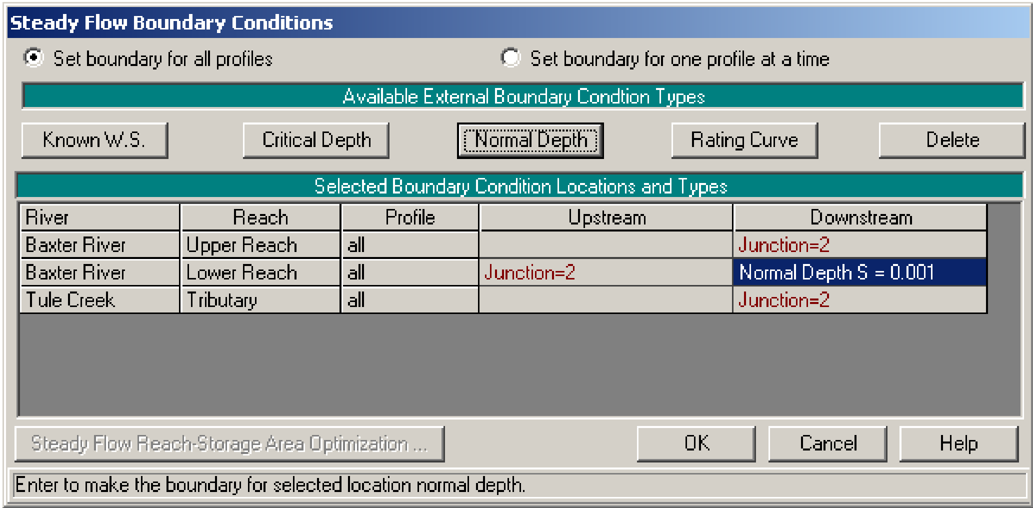
Entering Flow Data and Boundary Conditions

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



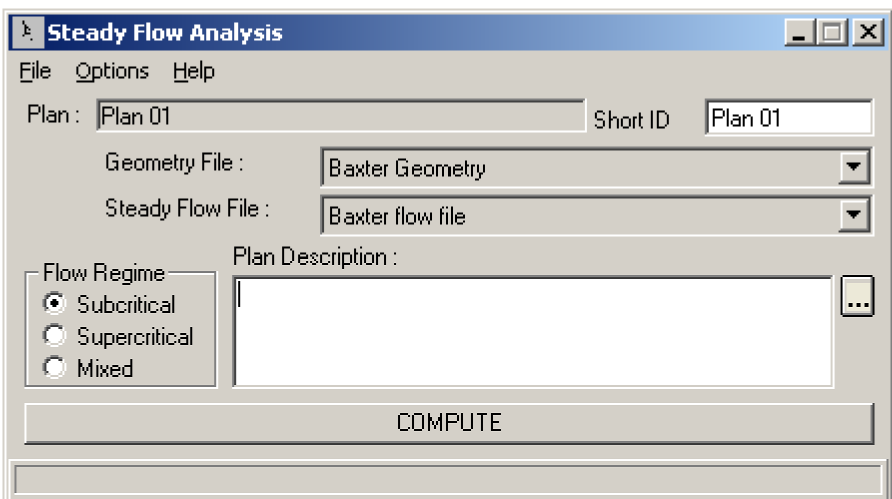
The flow conditions defined in the above window are upstream conditions. To define downstream boundary, **click** on *Reach Boundary Conditions*. Then **select** *Downstream* for *Baxter River Lower Reach*, **click** on *Normal Depth*, and **enter** *0.001*.



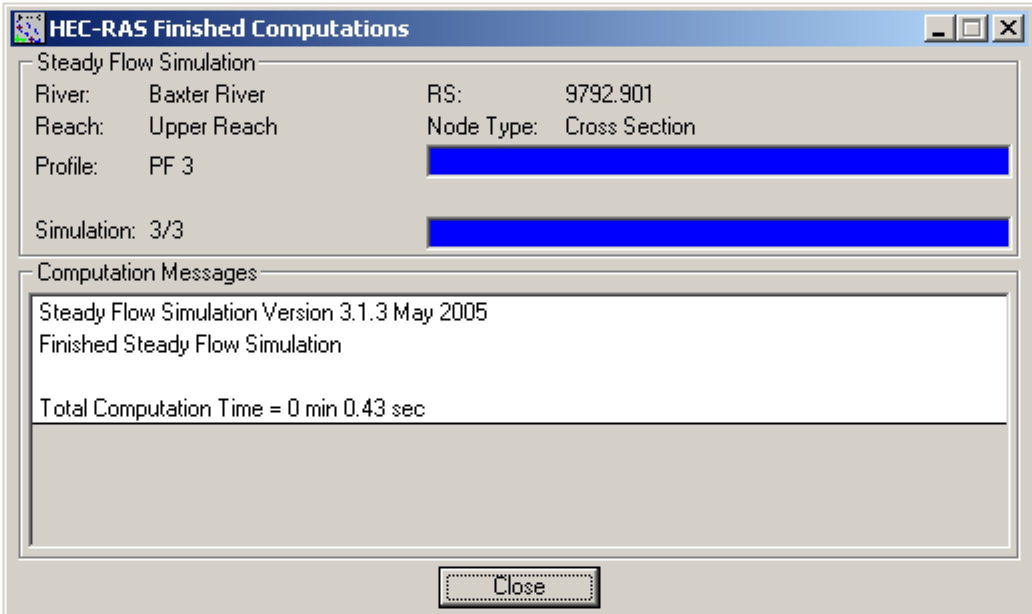
Click *OK*. **Save** the flow data (give whatever title you like), and **close** the *Steady Flow* editor. Now we are ready to run HEC-RAS!

Running HEC-RAS

In the main HEC-RAS window, **click** on *Run→Steady Flow Analysis*..



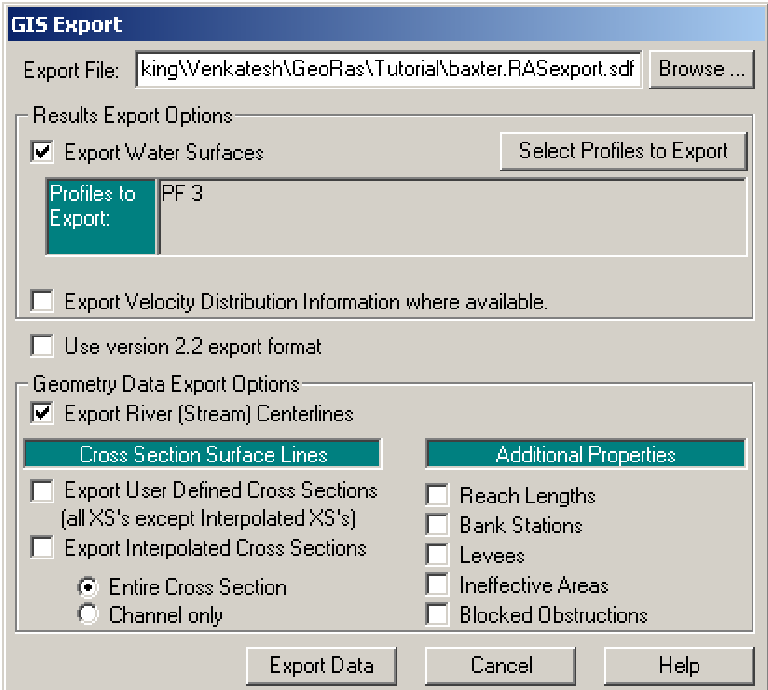
Select the *Subcritical Flow Regime*, and **click** on the *COMPUTE* button. (Note: If you get an error, you will need to modify geometry or flow data based on error messages to run the simulation successfully).



After successful simulation, **close** the computation window and the steady flow window. We will now export HEC-RAS results to ArcGIS to view the inundation extent, but before this step, you should look at the output results and verify them in HEC-RAS. This will help identify any errors in the input data and fix them, and run the simulation again, if necessary.

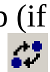
Exporing HEC-RAS Output

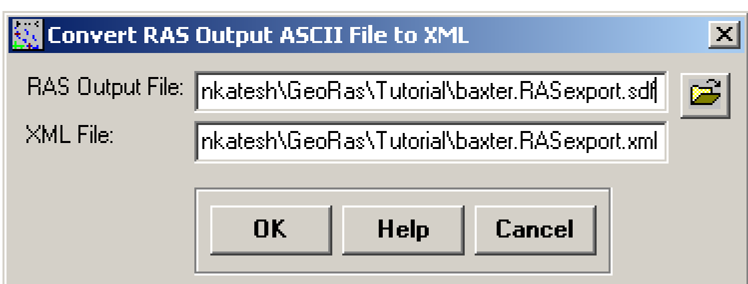
To export the data to ArcGIS **click** on *File→Export GIS Data…* in the main HEC-RAS window. Since we ran the model with three profiles, we can choose which profile we would like to export. **Click** on *Select Profiles to Export* button, and choose the profile you want to export. For this exercise we will choose the one with maximum flow (*PF3*), and accept the default export options.



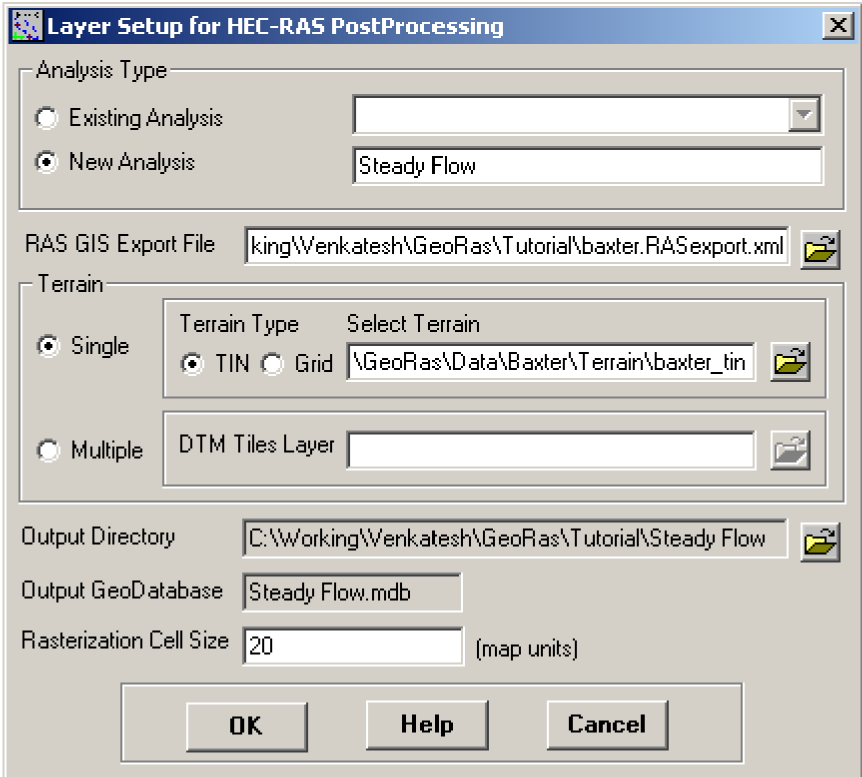
Click on *Export Data* button, which will create a SDF file in your working directory. **Save** the HEC-RAS project and **exit**. We will now return to ArcMap to create a flood inundation map.

Flood inundation mapping

In ArcMap (if you closed baxter_georas.mxd earlier, open it) **click** on *Import RAS SDF* file button  to convert the SDF file into an XML file. In the *Convert RAS Output ASCII File to XML* window, **browse** to *Baxter.RASexport.sdf*, and **click** *OK*. The XML file will be saved with the input file name in the same folder with an xml extension

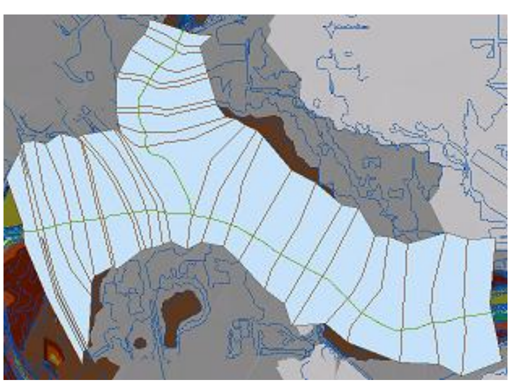


Now **click** on *RAS Mapping*→ *Layer Setup* to open the post processing layer menu as shown below:

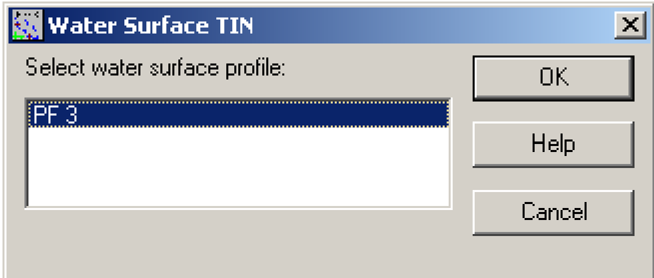


In the layer setup for post-processing, first **select** the *New Analysis* option, and **name** the new analysis as *Steady Flow*. **Browse** to *Baxter..RASexport.xml* for *RAS GIS Export File*. **Select** the *Single Terrain* Type, and **browse** to *baxter_tin*. **Browse** to your working folder for *Output Directory*. HEC-GeoRAS will create a geodatabase with the analysis name (*Steady Flow*) in your output directory. Accept the default *20* map units for *Rasterization Cell Size*. **Click** *OK*. A new map (data frame) with the analysis name (*Steady Flow*) will be added to ArcMap with the terrain data. At this stage the terrain TIN (*baxter_tin*) is also converted to a digital elevation model (DEM) and saved in the working folder (Steady Flow) as *dtmgrid*. The cell size of *dtmgrid* is equal to the *Rasterization Cell Size* you chose in the layer setup window.

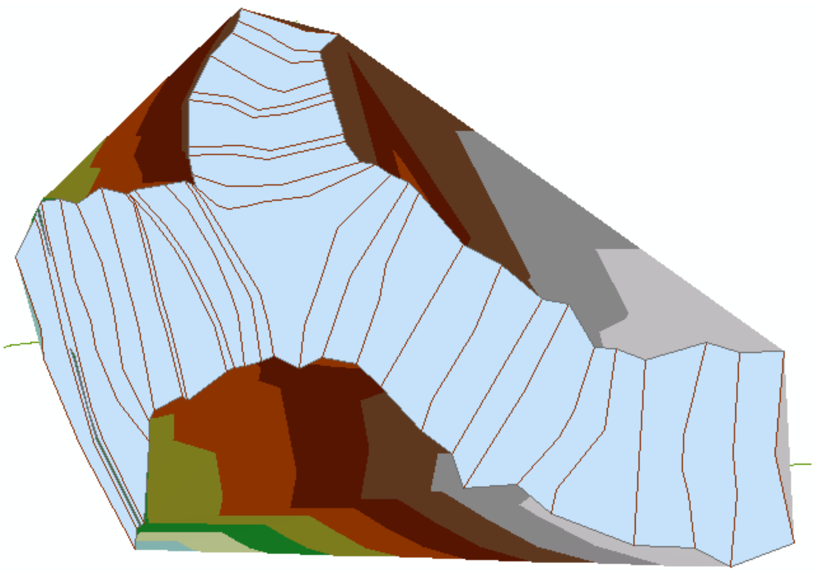
Next **click** on *RAS Mapping→ Read RAS GIS Export File*. This will create a bounding polygon, which basically defines the analysis extent for inundation mapping, by connecting the endpoints of XS Cut Lines.



After the analysis extent is defined, we are ready to map the inundation extent. **Click** on *RAS Mapping→Inundation Mapping→ Water Surface Generation*. **Select** *PF3* (profile with highest flow), and **click** *OK*.

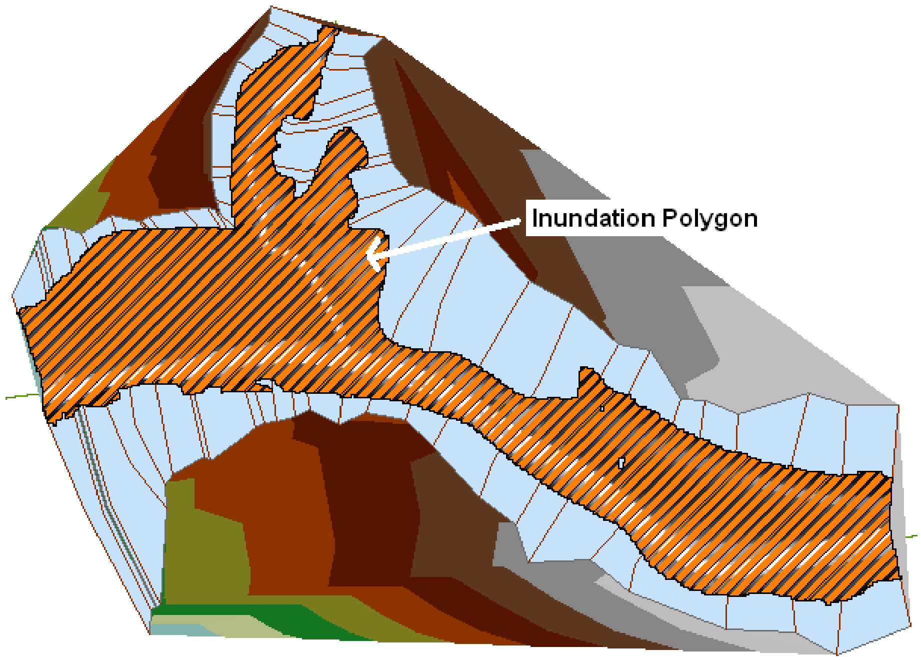


This will create a surface with water surface elevation for the selected profile. The TIN (*tP003*) that is created in this step will define a zone that will connect the outer points of the bounding polygon, which means the TIN will include area outside the possible inundation.



At this point we have a water surface (*tP003*) TIN, and we have an underlying terrain (*baxter_tin* and *dtmgrid*). Now we will subtract the terrain (*dtmgrid*) from the water surface TIN, by first converting the water surface TIN to a grid.

Click on *RAS Mapping→Inundation Mapping→Floodplain Delineation*. Again, **select** *PF3* (profile with highest flow), and **click** *OK*. At this stage the water surface TIN (*tP003*) is first converted to a GRID, and then *dtmgrid* is subtracted from the water surface grid. The area with positive results (meaning water surface is higher than the terrain) is flood area, and the area with negative results is dry. All the cells in water surface grid that result in positive values after subtraction are converted to a polygon, which is the final flood inundation polygon.



After the inundation map is created, you must check the inundation polygon for its quality. You will have to look at the inundation map and the underlying terrain to correct errors in the flood inundation polygon. 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 between GIS and HEC-RAS. The ability to judge the quality of terrain and flood inundation polygon comes with the knowledge of the study area and experience.

Save the ArcMap document. Congratulations, you have successfully finished the HEC-GeoRAS tutorial!