

Tutorial on using HEC-GeoRAS 10.6 with ArcGIS 10.6 and HEC-RAS 5.0.7 for flood inundation mapping in Steady and Unsteady Flow Conditions (1D and 2D)

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Objectives of this Tutorial: The objective of this tutorial is to give a brief introduction on the use of HEC-GeoRAS with ArcGIS and HEC-RAS for flood inundation mapping in **one-** and **two-dimensional steady** and **unsteady** flow conditions

Computer Requirements




1. HEC-GeoRAS version 10.6 or newer
2. ArcGIS 10.6 or newer (***if you use a newer version of ArcGIS 10.6**, install the same version of HEC-GeoRAS at <http://downloads.esri.com/archydro/>).
3. HEC-RAS version 5.0.7 or newer

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

Data Requirements

The data required for this tutorial is available at

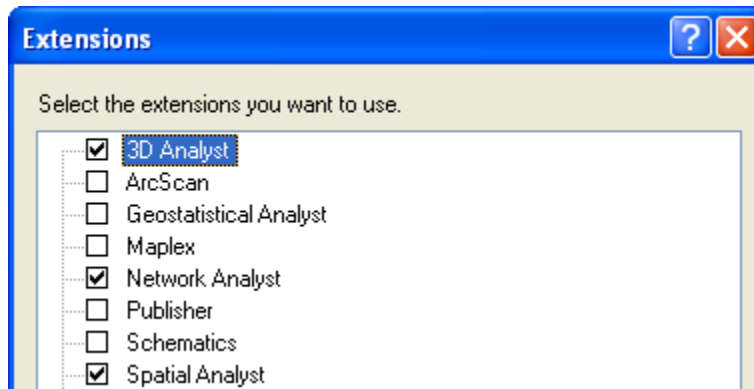
http://web.eng.fiu.edu/arleon/Teaching_unsteady_rivers.html. **Download** the zip file **on your local drive (e.g. C:\)** (**If you do not work in your local drive, you may have problems exporting HEC-RAS to Arc GIS**), and **unzip** its contents. The GeoRASData folder contains three sub-folders, one TIN dataset, a RASModel and one aerial image (as raster grid) as shown below (ArcCatalog view):

Name	Date modified	Type	Size
 Aerials	9/26/2013 8:59 PM	File folder	
 RASModel	9/26/2013 8:59 PM	File folder	
 Terrain	9/26/2013 8:59 PM	File folder	

Getting Started

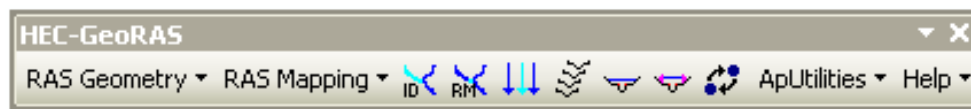
Start ArcGIS by **clicking** *Start*→ *Programs*→*ArcGIS*→*ArcGIS*. Save the ArcGIS document (by **clicking** *File*→*Save As*) as *baxter_georas.mxd* in your working folder.

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



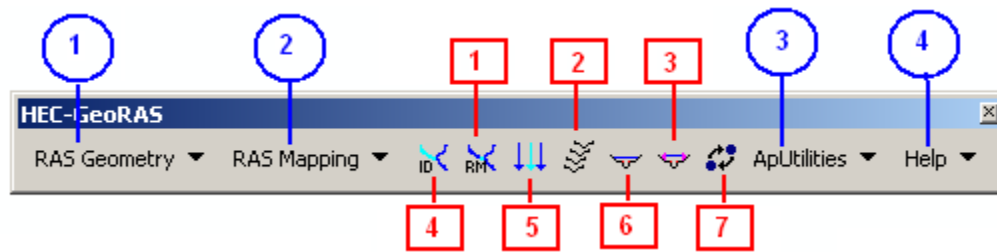
Close the Extensions window.

Now load the HEC-GeoRAS toolbar into ArcGIS by **clicking** on *Customize* → *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.

Running HEC-RAS

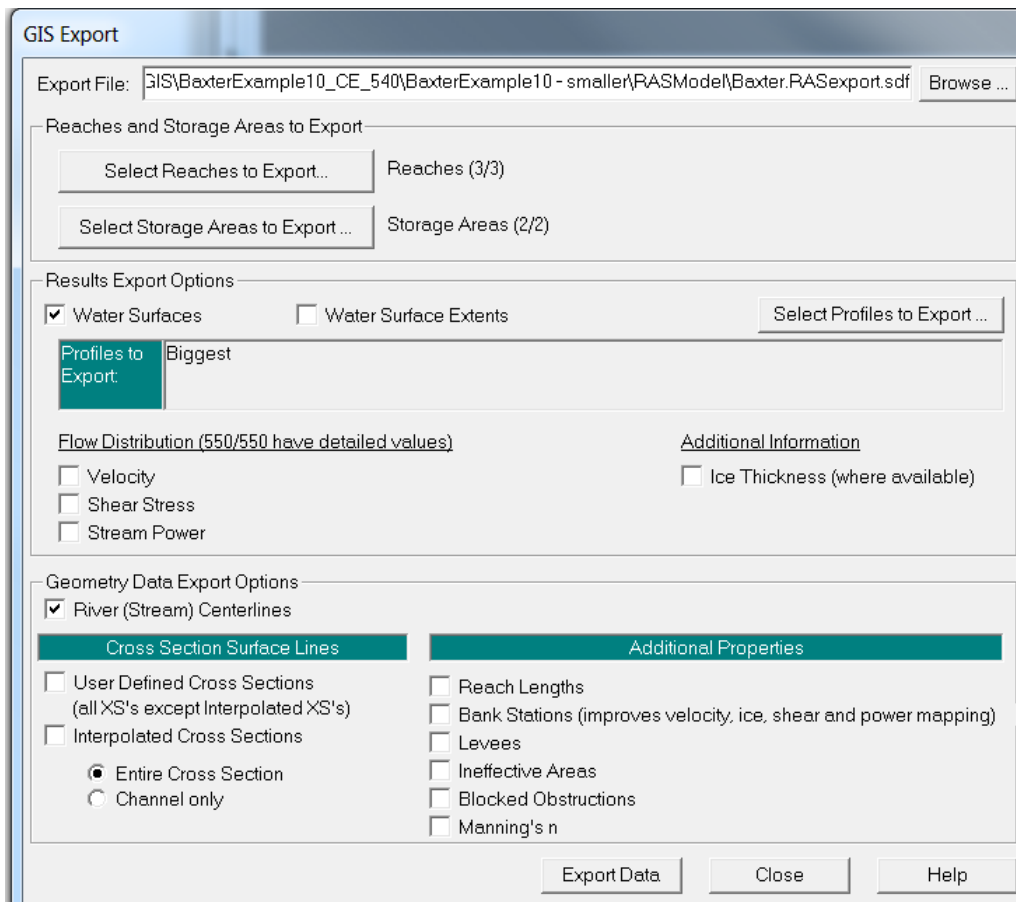
This hydraulics tutorial doesn't cover pre-processing of data. You can find multiple tutorials on pre-processing. In our class, will use the HEC-RAS model provided in the folder RASModel (see above).

Now launch HEC-RAS, open the RASModel and Run it for Subcritical flow conditions.

Exporting HEC-RAS Output (Before exporting HEC-RAS to ArcGIS, you need to run the HEC-RAS Model)


To export the HEC-RAS output data to ArcGIS **click** on *File* → *Export GIS Data...* in the main HEC-RAS window. **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 (*Biggest* profile), and accept

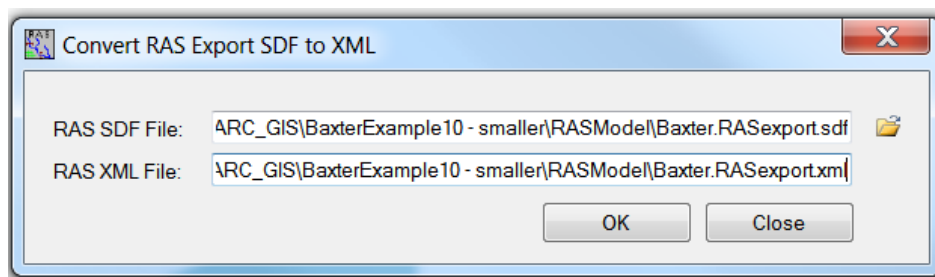
the default export options.



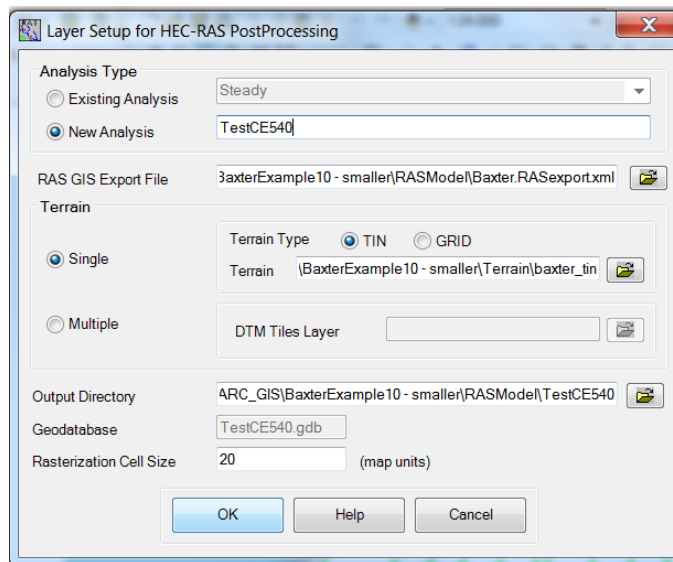
Click on *Export Data* button, which will create a SDF file in your working directory. **Save** the HEC-RAS project and **exit**. We will now return to ArcGIS to create a flood inundation map.

Flood inundation mapping

In ArcGIS (open *Baxter10.mxd*, which is provided in the data) **click** on *Import RAS SDF* file button  to convert the SDF file into an XML file. In the *Convert RAS Export RAS SDF to XML* window, **browse** to *Baxter.RASexport.sdf* (RASModel Folder), and **click OK**. The XML file will be saved with the input file name in the same folder with an xml extension

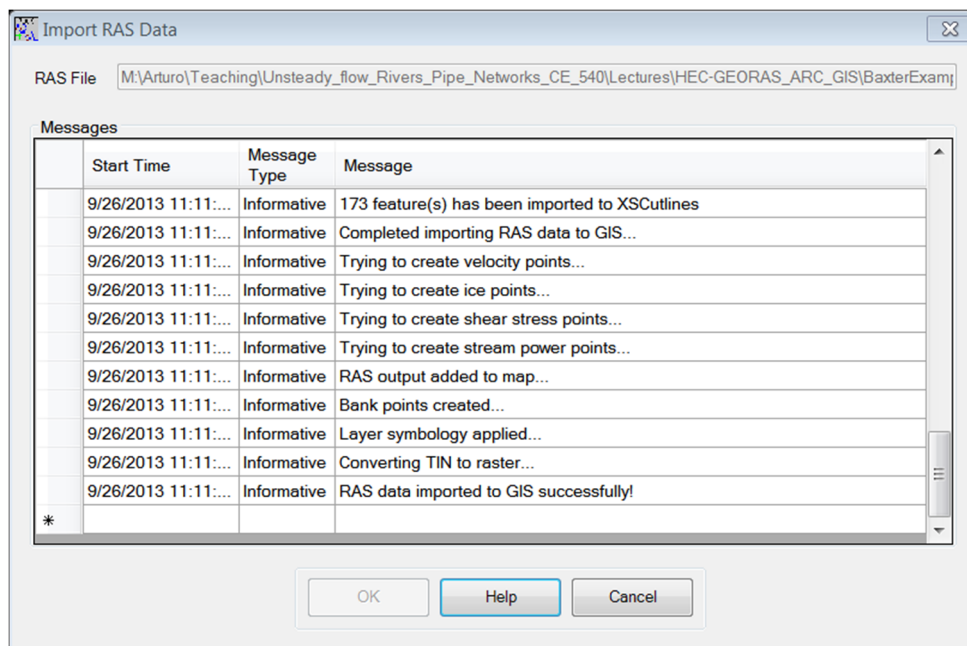


Now **click** on *RAS Mapping/Layer Setup* to open the post processing layer menu as shown below:

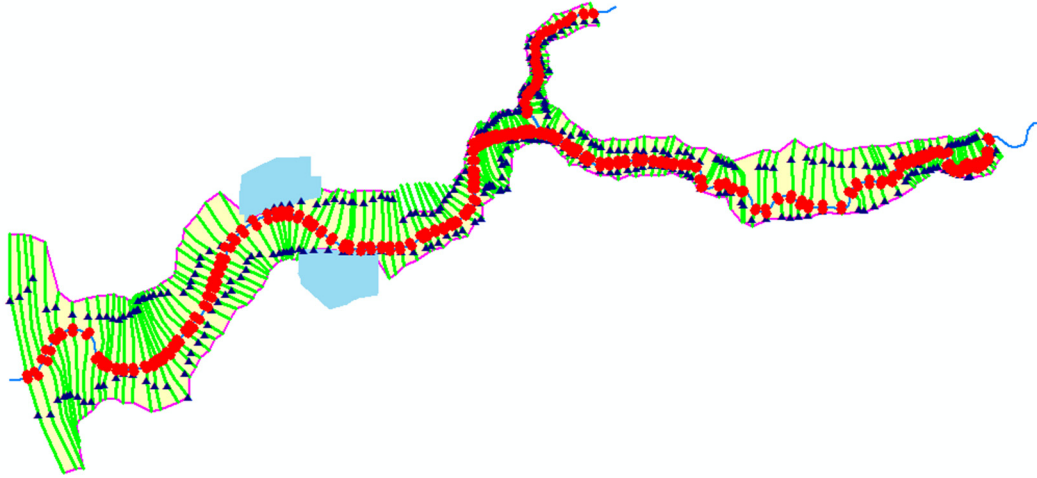


In the layer setup for post-processing, first **select** the *New Analysis* option, and **name** the new analysis as *Test_CE540*, or any name you like. **Browse** to *Baxter.RASexport.xml* for *RAS GIS Export File* (RASModel folder). **Select** the *Single Terrain* Type, and **browse** to *baxter_tin* in the Terrain folder. **Browse** to your working folder for *Output Directory* (e.g., RASModel/*Test_CE540*). HEC-GeoRAS will create a geodatabase with the analysis name (e.g., *Test_CE540*) 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 (e.g., *Test_CE540*) will be added to ArcGIS 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 (e.g., *Test_CE540*) 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* → *Import RAS Data* and then **click Ok**. Similar to during export, you will see a series of messages during the import as shown below.

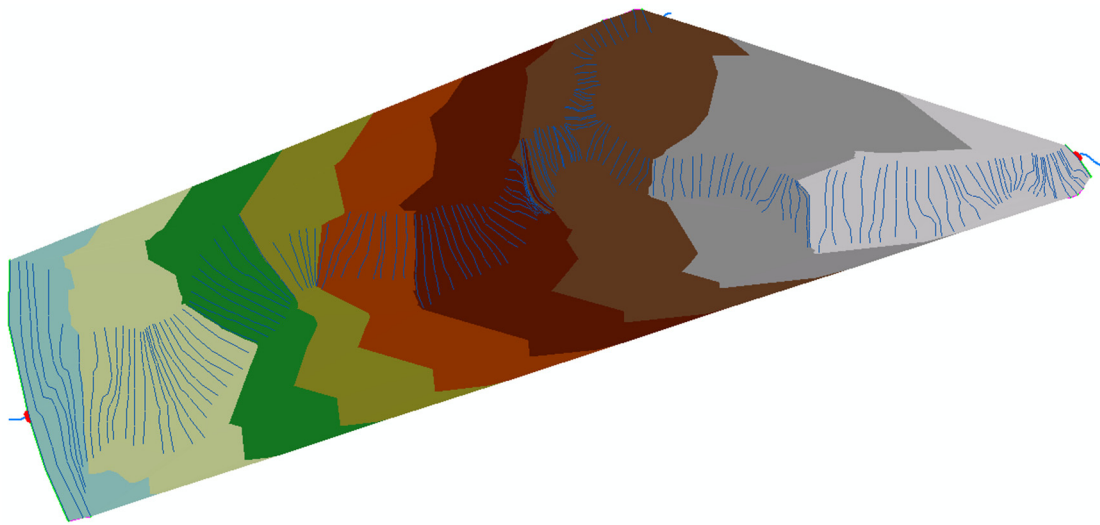


This will create a bounding polygon, which basically defines the analysis extent for inundation mapping, by connecting the endpoints of XS Cut Lines.



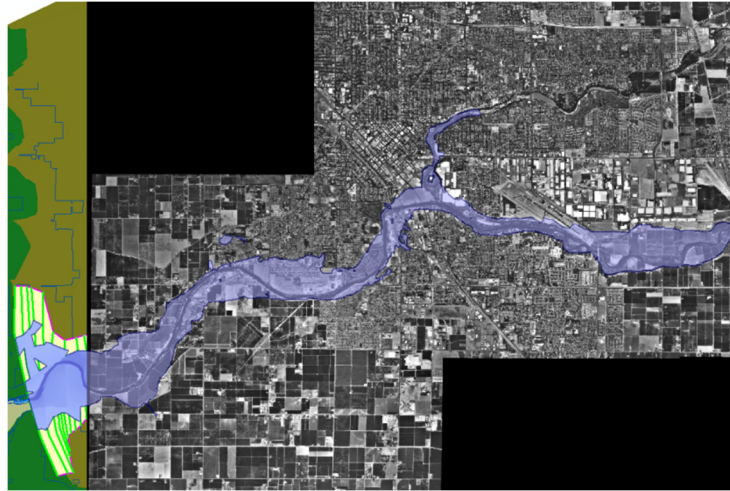
After the analysis extent is defined, we are ready to map the inundation extent. **Click** on *RAS Mapping/Inundation Mapping/Water Surface Generation*. **Select** *Biggest* (profile with highest flow), and **click OK**.

This will create a surface with water surface elevation for the selected profile. The TIN that is created in this step (*t Biggest*) 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 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 using Rasters*. Again, **select Biggest** (profile with highest flow), and **click OK**. You will see a series of messages during the execution. During this step, the water surface TIN 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 accuracy. You may want to superimpose your results with the aerial map, which is available in the *Aerials* folder in the working directory (Right click on your directory, then **Add data** and choose **Aerials** in your working folder). It is very common to find errors in the terrain. If you detect these errors, you need to fix it in the HEC-RAS geometry file. After the errors are fixed, you need to repeat the conversion process of HEC-RAS to HEC-GEO RAS again. Don't forget to **Save** the ArcGIS document.

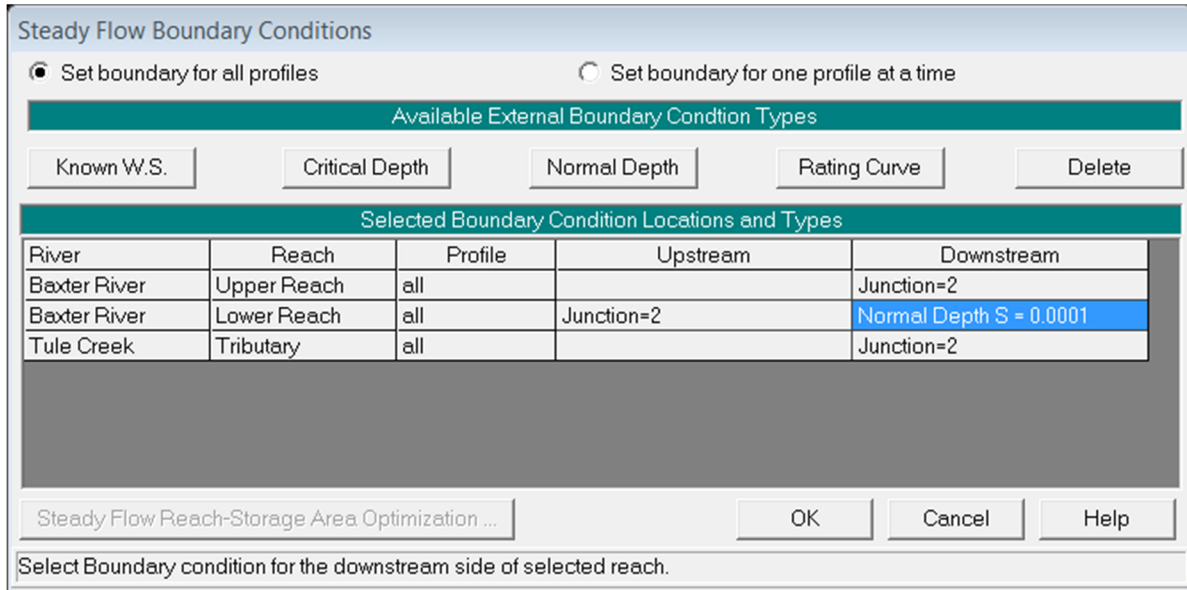
Hydraulic modeling

Now, let's play with the hydraulics of flooding.

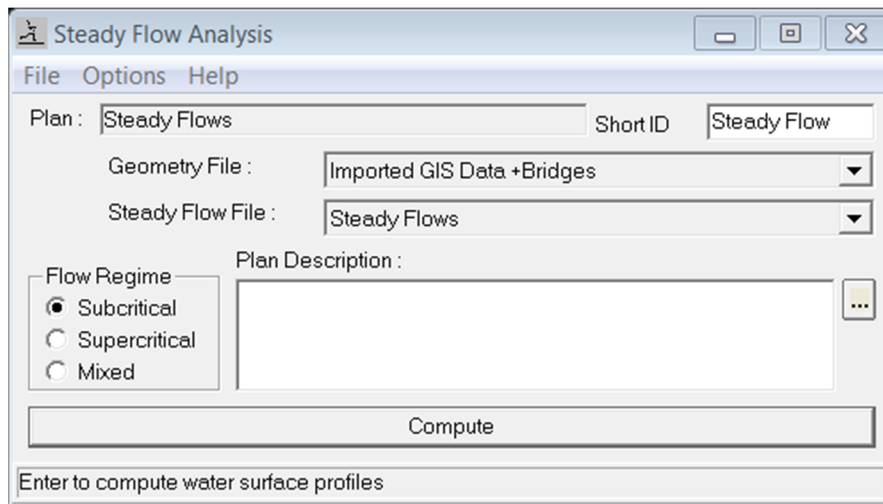
Flooding in Steady Flow Conditions (One-dimensional)

Open HEC-RAS and open the *Baxter.prj* project that is located in the RASModel folder. In the main HEC-RAS window, click on Edit/Steady Flow Data/Reach Boundary Conditions.

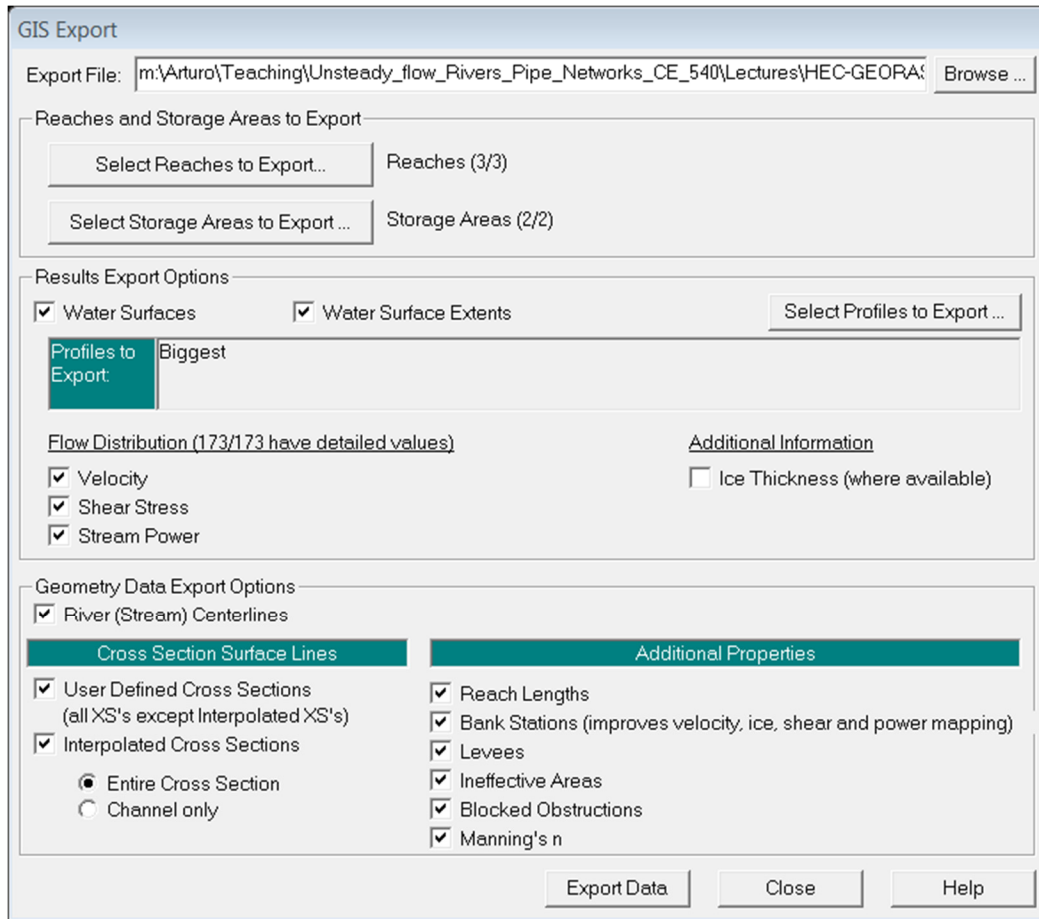
Then **select** *Downstream* for *Baxter River Lower Reach*, **click** on *Normal Depth*, and **enter** *0.0001* as follows:




Save the data and Run the HEC-RAS model (Subcritical flow).

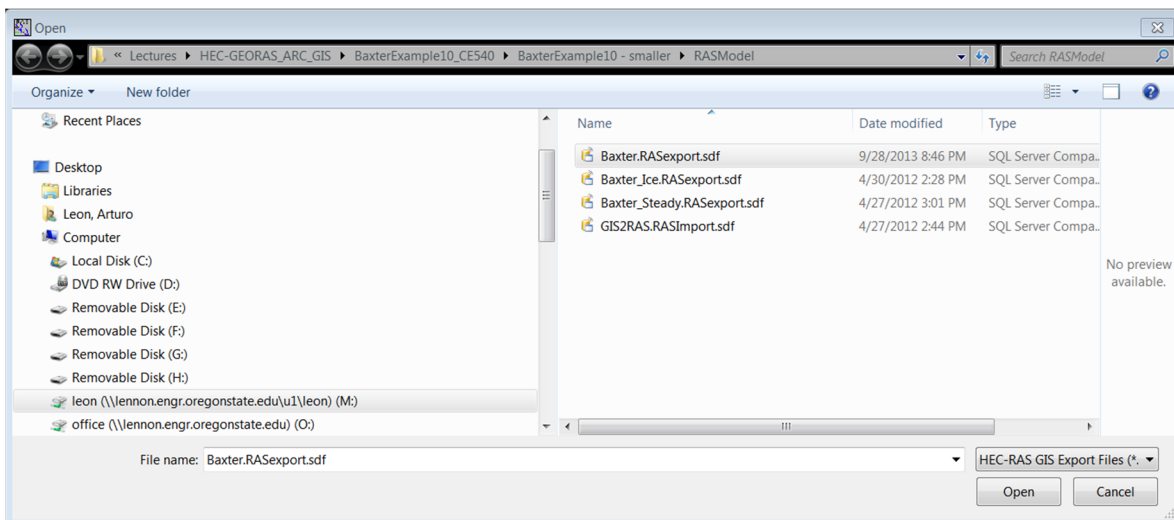


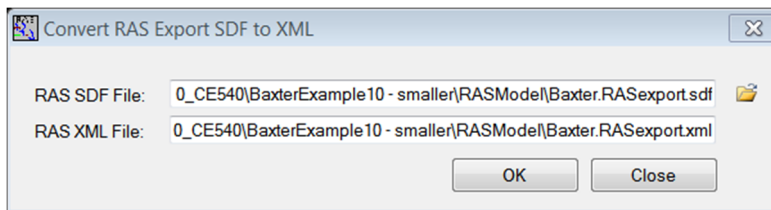
Then export the HEC-RAS output data to ArcGIS. **Click** on *File*→*Export GIS Data...* in the main HEC-RAS window. **Click** on *Select Profiles to Export* button, and choose the *Biggest* profile. Also, select the options shown below.



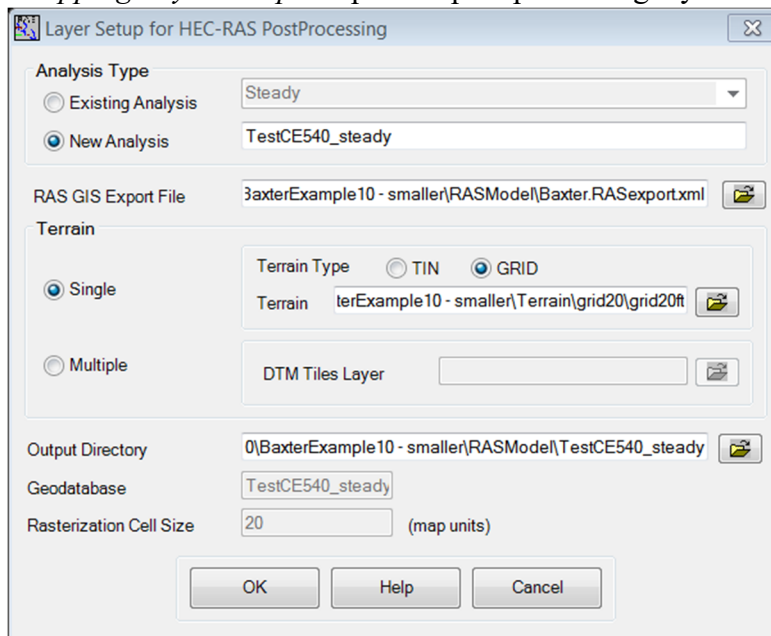
Click on *Export Data* button, which will create a SDF file in your working directory. **Save** the HEC-RAS project and **exit**. We will now open ArcGIS.

In ArcGIS (open *Baxter10.mxd*, which is located in the sub folder *BaxterExample10 - smaller*) **click** on *Import RAS SDF* file button  to convert the SDF file into an XML file. In the *Convert RAS Export RAS SDF to XML* window, **browse** to *Baxter.RASexport.sdf* (located in the sub folder RASModel), and **click OK**. The XML file will be saved with the input file name in the same folder with an xml extension

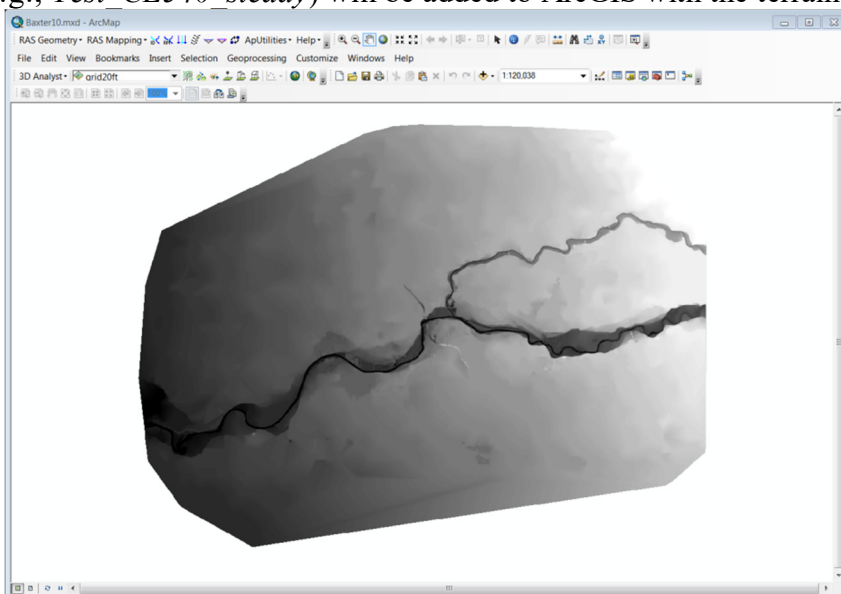




Now **click** on *RAS Mapping Layer Setup* to open the post processing layer menu as shown below:

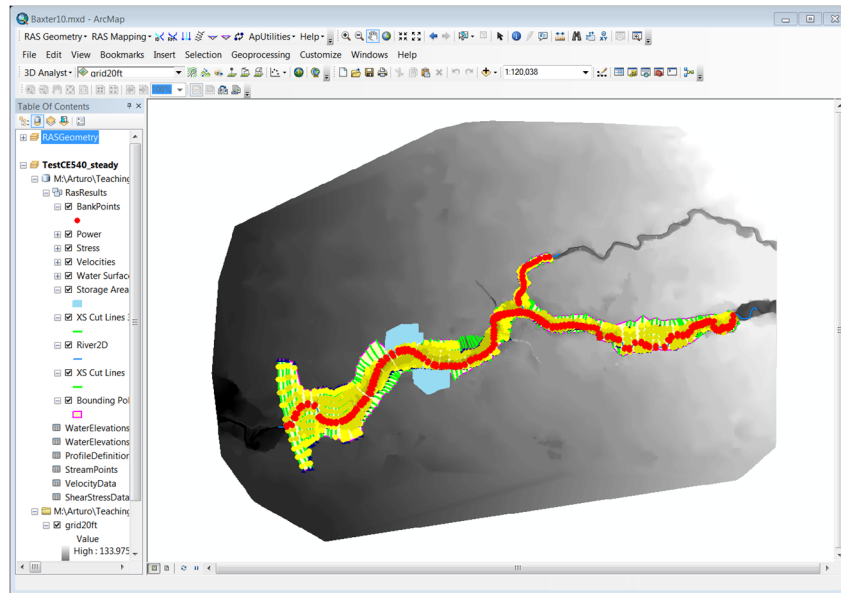


In the layer setup for post-processing, first **select** the *New Analysis* option, and **name** the new analysis as *Test_CE540_steady* or any other name you like. **Browse** to *Baxter.RASexport.xml* for *RAS GIS Export File*. **Select** the *Single Terrain Grid* Type, and **browse** to *grid20ft*. **Browse** to your working folder for *Output Directory* (*RASModel* in this case). HEC-GeoRAS will create a geodatabase with the analysis name (e.g., *Test_CE540_steady*) 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 (e.g., *Test_CE540_steady*) will be added to ArcGIS with the terrain data.

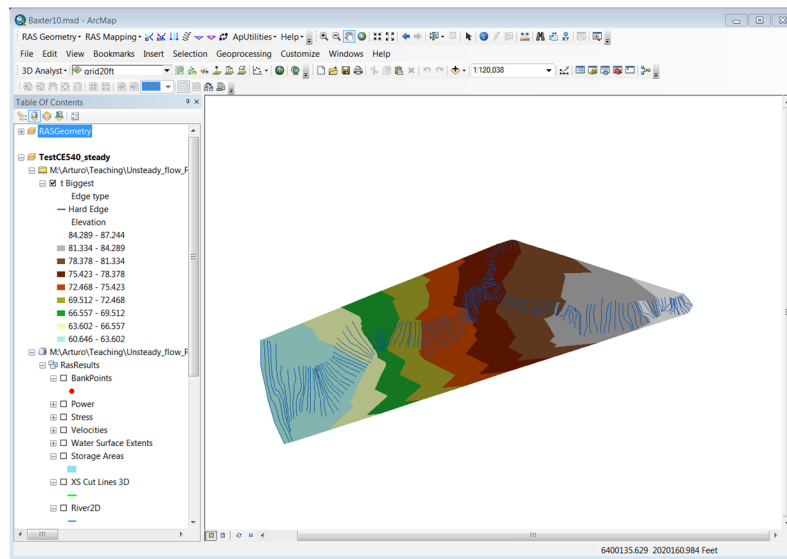


Next **click** on *RAS Mapping* → *Import RAS Data*. Similar to during export, you will see a series of

messages during the import. This will create a bounding polygon as follows.

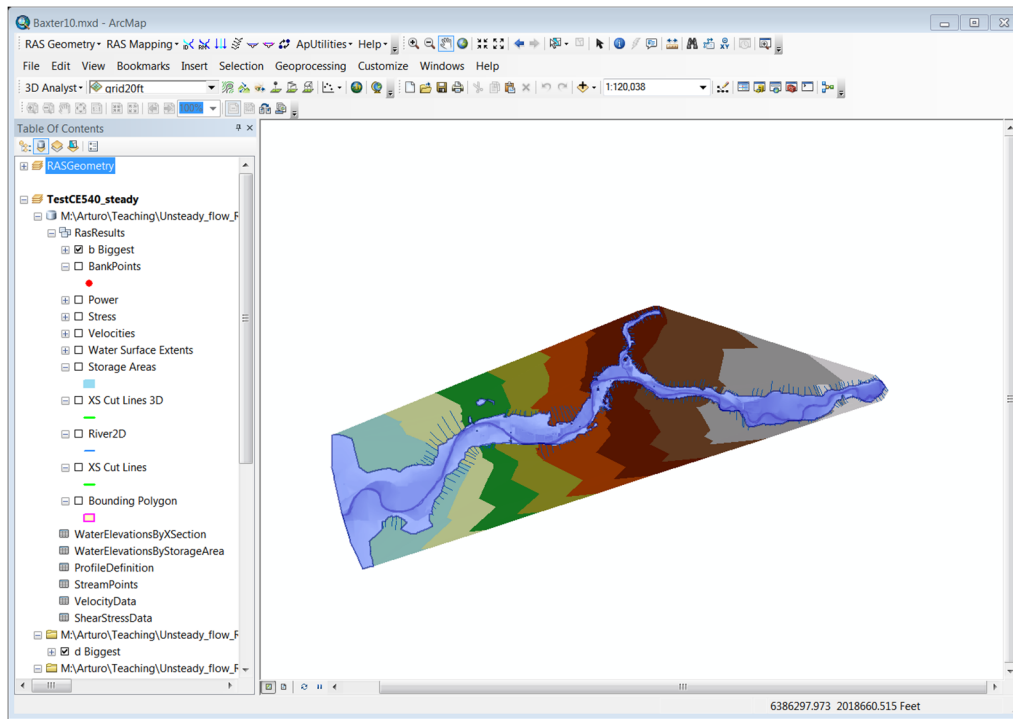


After the analysis extent is defined, we are ready to map the inundation extent. **Click** on *RAS Mapping/ Inundation Mapping/ Water Surface Generation*. **Select Biggest** (profile with highest flow), and **click OK**. This will create a surface with water surface elevation for the selected profile as follows.

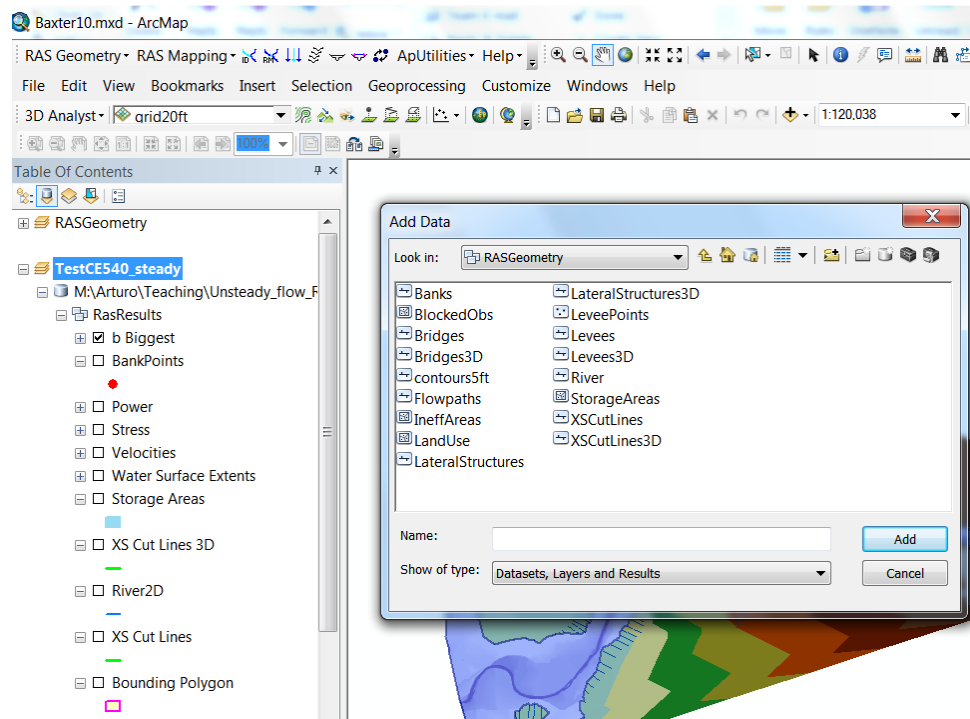


At this point we have a water surface and we have an underlying terrain. Now we will subtract the terrain from the water surface. Before this, for visualization purposes, I would suggest to add *Land Use* to the *Test_CE540_steady* data frame. To do this, right click on the *Test_CE540_steady* data frame. Then, Add data/Baxter10.mdb/ RASGeometry/LandUse.

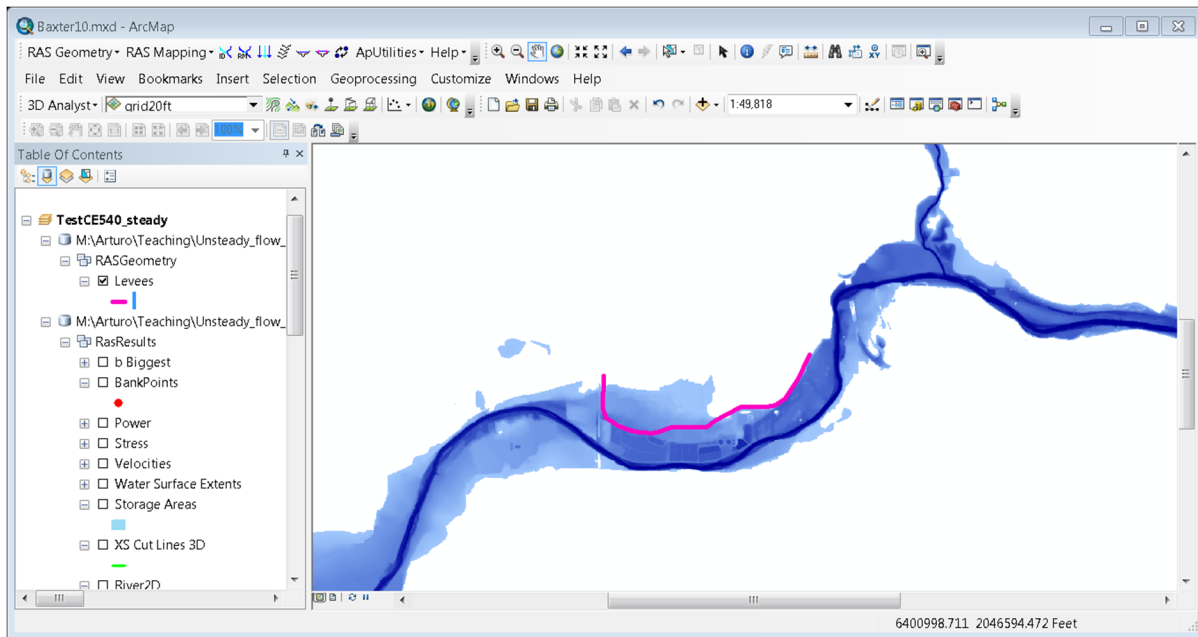
Next, **Click** on *RAS Mapping→Inundation Mapping→Floodplain Delineation using Rasters*. Again, **select Biggest** (profile with highest flow), and **click OK**. You will see a series of messages during the execution. Then, a polygon will be created that represents the flooded area.



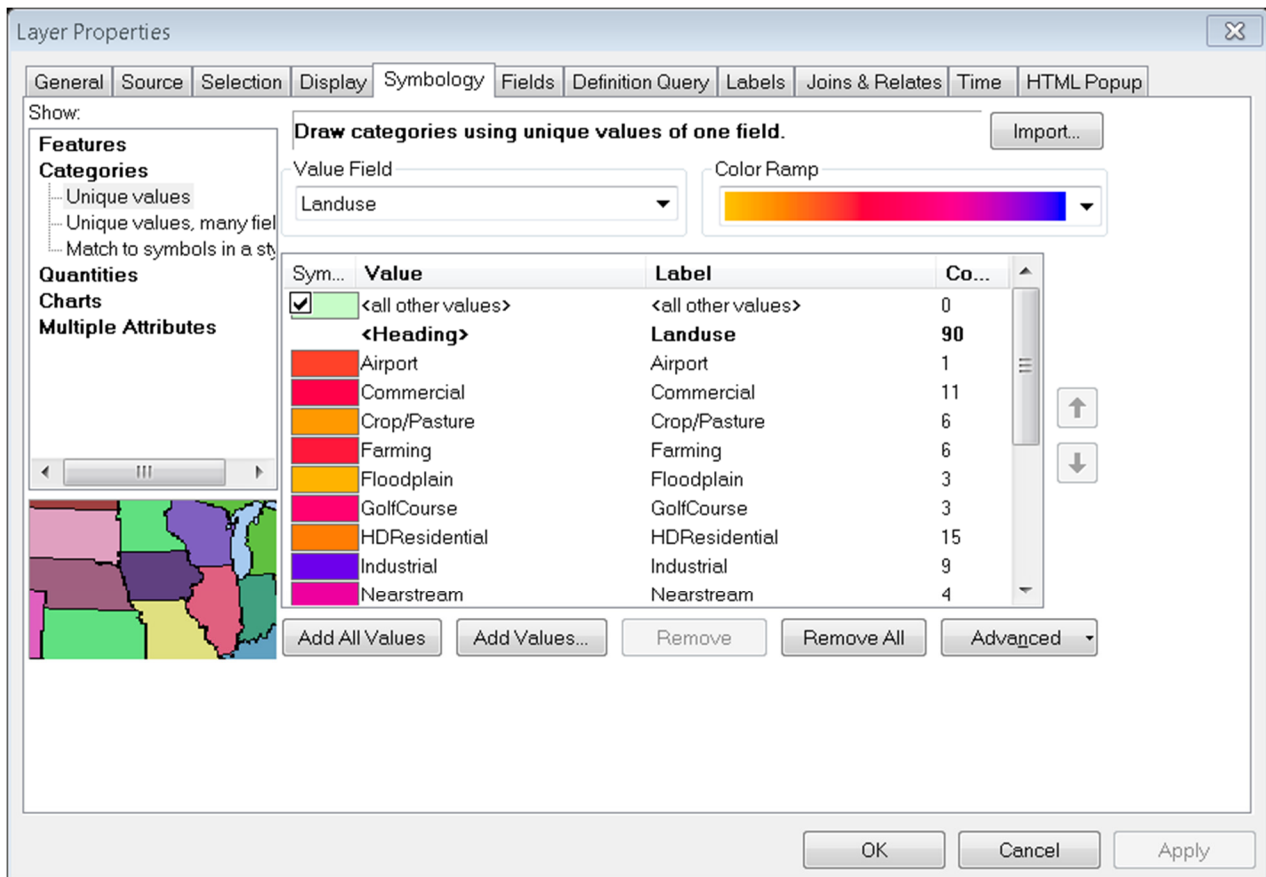
After the inundation map is created, you must check the inundation polygon for its accuracy. For this you may need to superimpose your results with the geometry of the river, aerial map, levee lines, etc. To do this for instance you can turn off all TINs except “d biggest” and insert various types of data to the *Test CE540_steady* data frame. To do this, right click on the *Test CE540_steady* data frame. Then, Add data/Baxter10.mdb/RASGeometry/



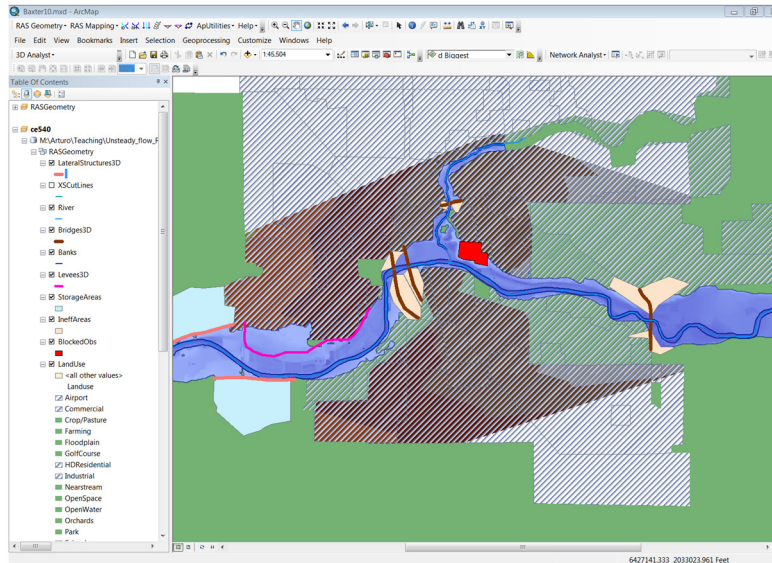
Then click for instance on *levees* and Add. This will result in a figure as shown below. You can edit the thickness of the levee line.



For LandUse you may want to edit the categories. To do this, double click on *LandUse*. Next click in *Categories* and enter *LandUse* in the Value Field. Then click on *Add All Values*. This will show all land uses in different colors.



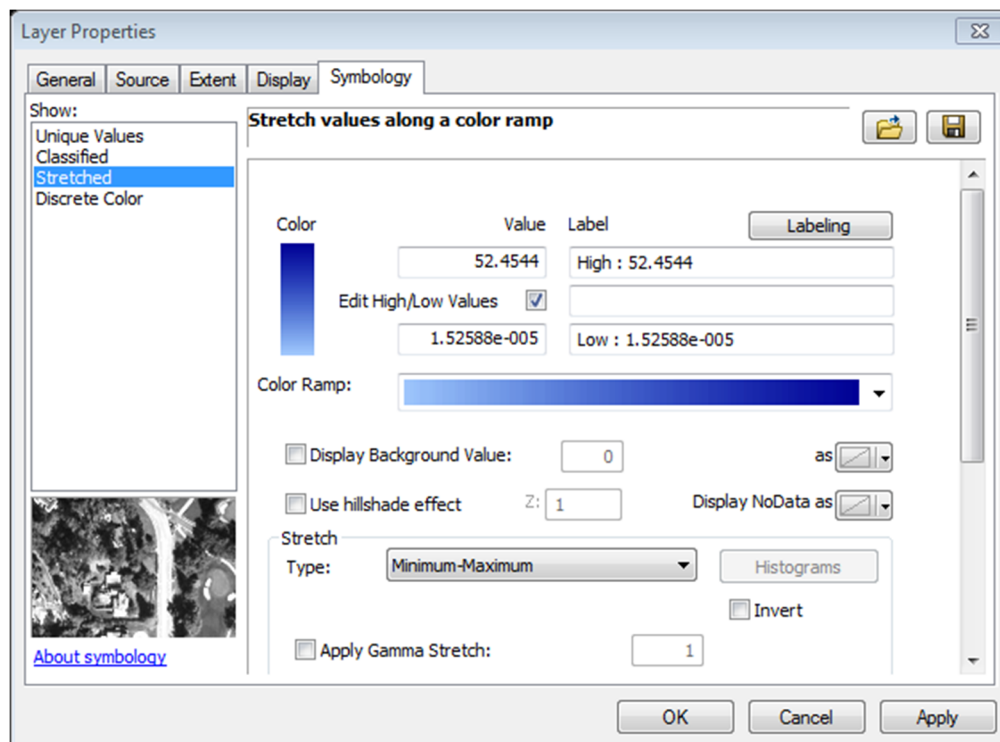
For Flooding in urban areas you may want to group the land uses in two or three regions [example: large losses (e.g., residential, commercial), and small losses (floodplain, farming, etc.)] To achieve this you will need to manually edit the colors for the various land uses. This will result in a plot like shown below:



In the figure above, the water exceeded the levee line and flooded part of the urban area. In the lab session, we will play with *levee* structures to protect urban areas. Also, we will discuss common external and internal boundary conditions and the input data for these boundaries. Finally, we will discuss **mixed flow** conditions, interpolation procedures and appropriate parameters for simulation.

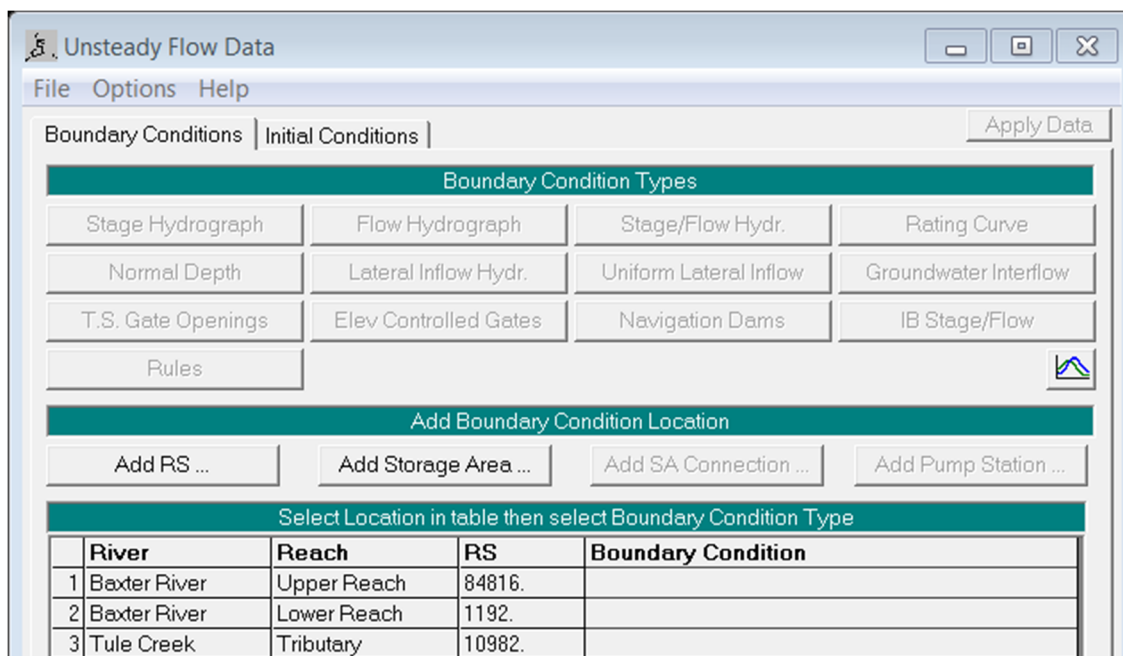
It is very common to find errors in the results. If you detect these errors, you need to fix them in HEC-RAS. Then you need to repeat the conversion process. Don't forget to **Save** the ArcGIS document. The common errors will be discussed in the computer lab session.

Furthermore, you may want to remove extremely low water depths (e.g., below 1 cm or 1/2 inch). To do this, double click in the water depth ("d") layer and select the *Symbology* tab. In this tab, select the *Minimum-Maximum* histogram in the lower region of the window. Then, check the *Edit High/Low Values* option. This will allow you to modify the minimum and maximum values of water depth that you want to show (see snapshot below).

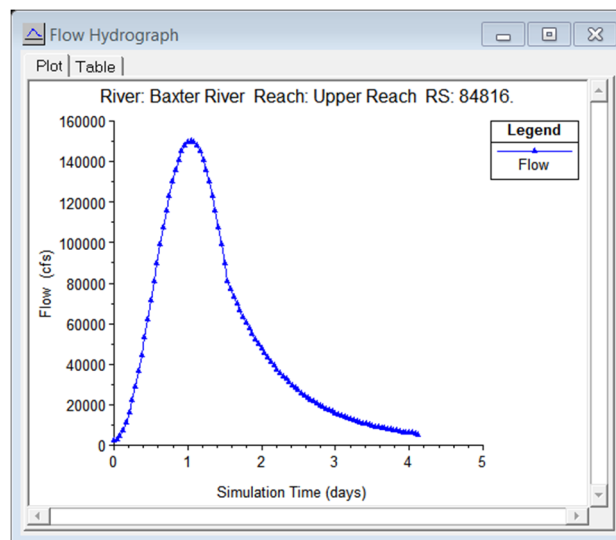
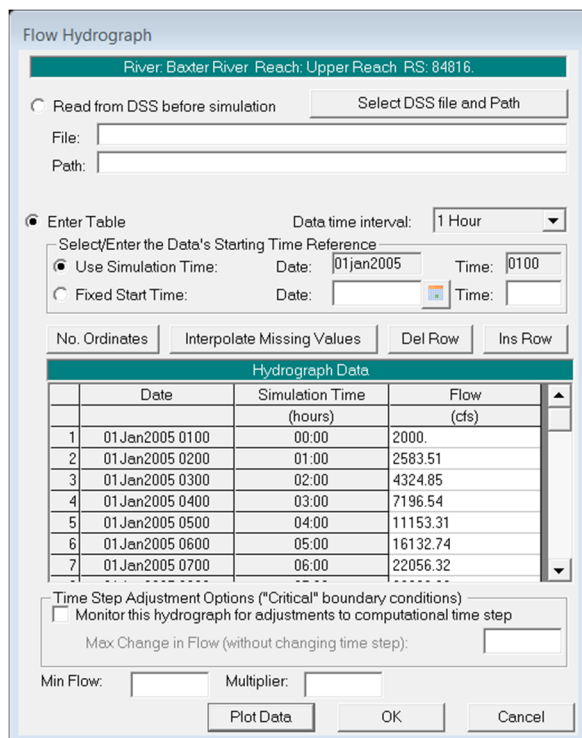


Flooding in Unsteady Flow Conditions (One-dimensional)

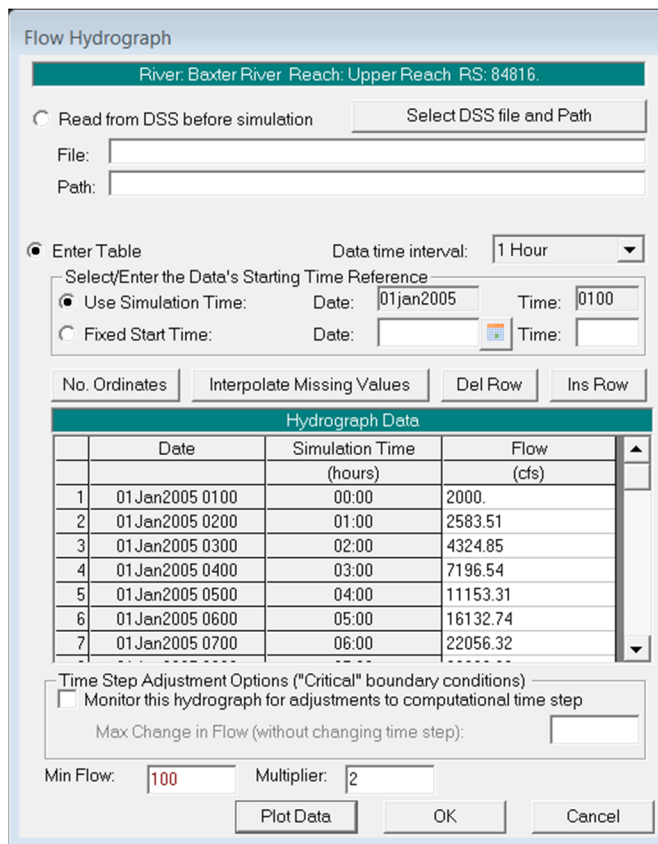
Open HEC-RAS and open the *Baxter.prj* project that is located in the RASModel folder. In the main HEC-RAS window, click on Edit/Unsteady Flow Data.



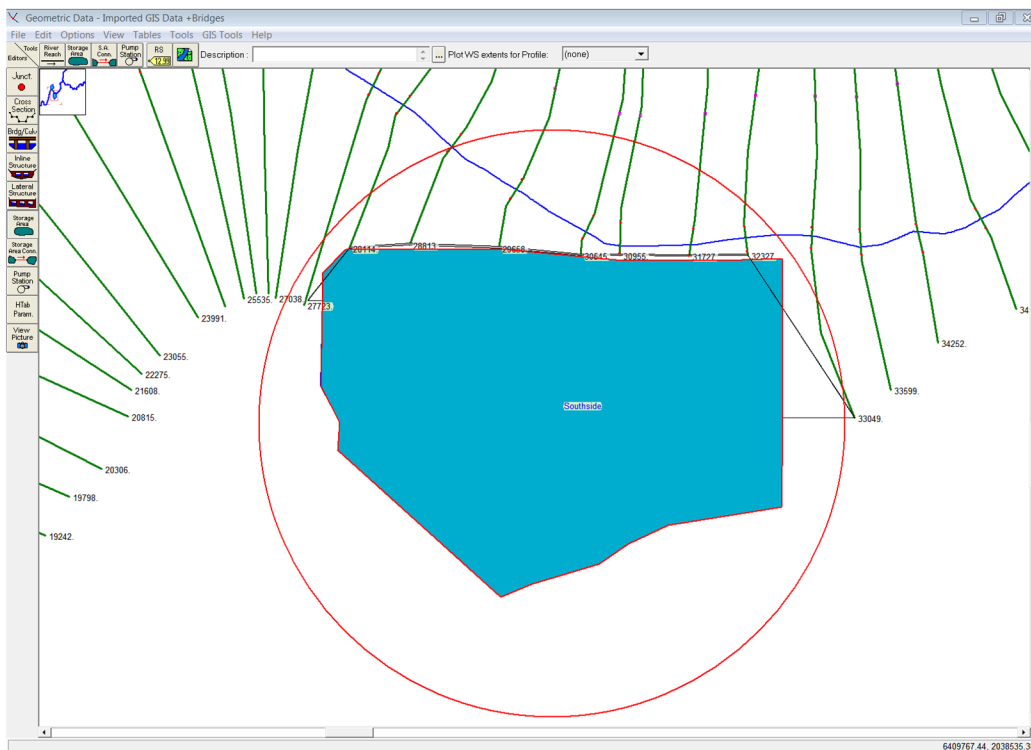
In the Unsteady Flow Data editor, open the *Flood Event* file. Double click on flood Hydrograph (Baxter River Upper Reach) to see the hydrograph data. You could also plot this data as follows.



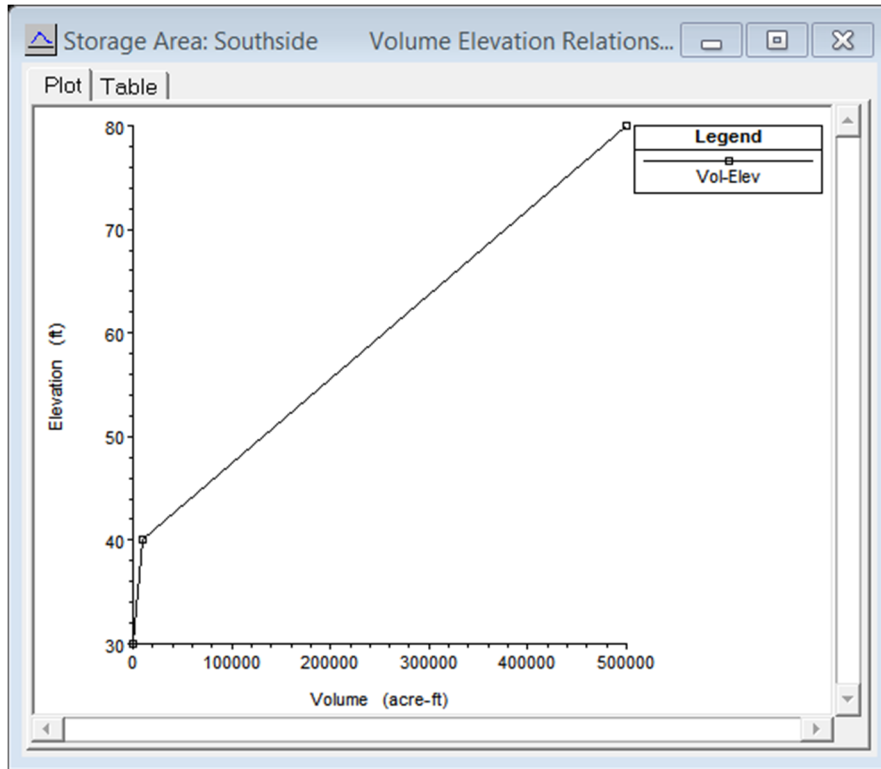
HEC-RAS provides the option to quickly scale the hydrograph. For instance, multiply the hydrograph ordinates by 2 as follows.



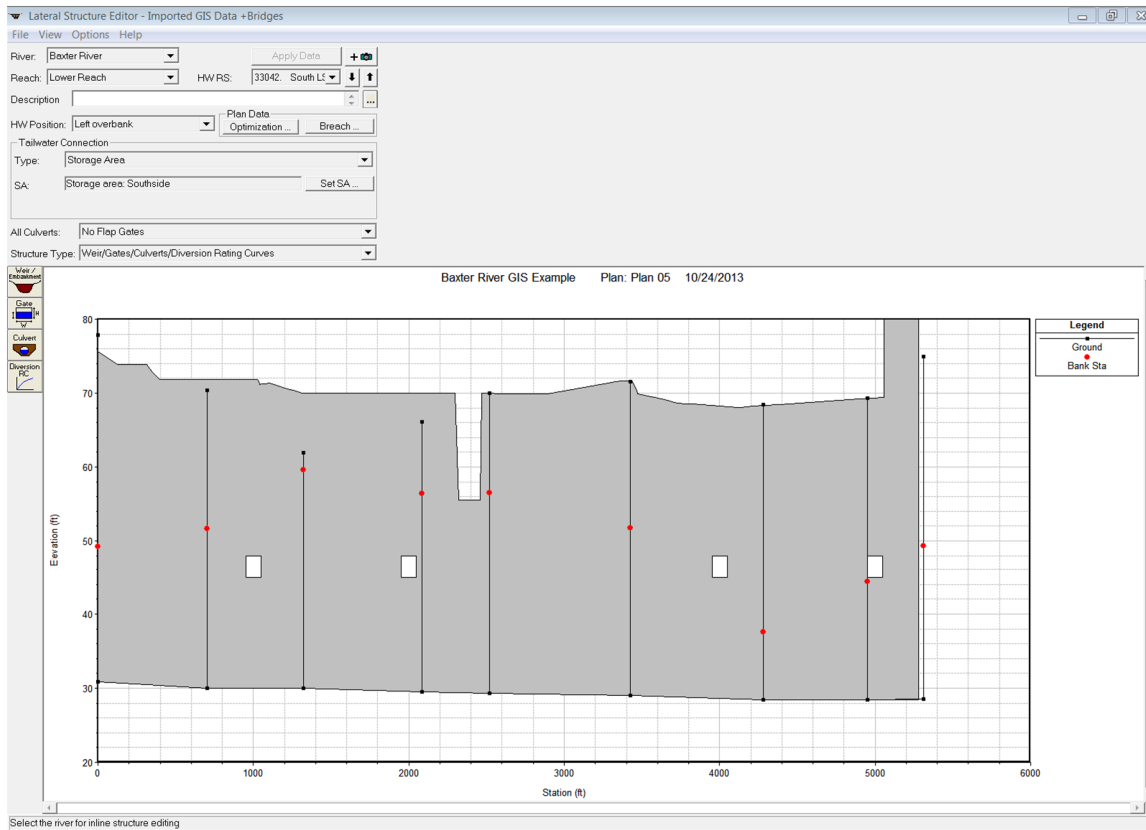
Now, let's work with Storage areas for temporal storage of water. First, you would need to add a *storage area* such as depicted below



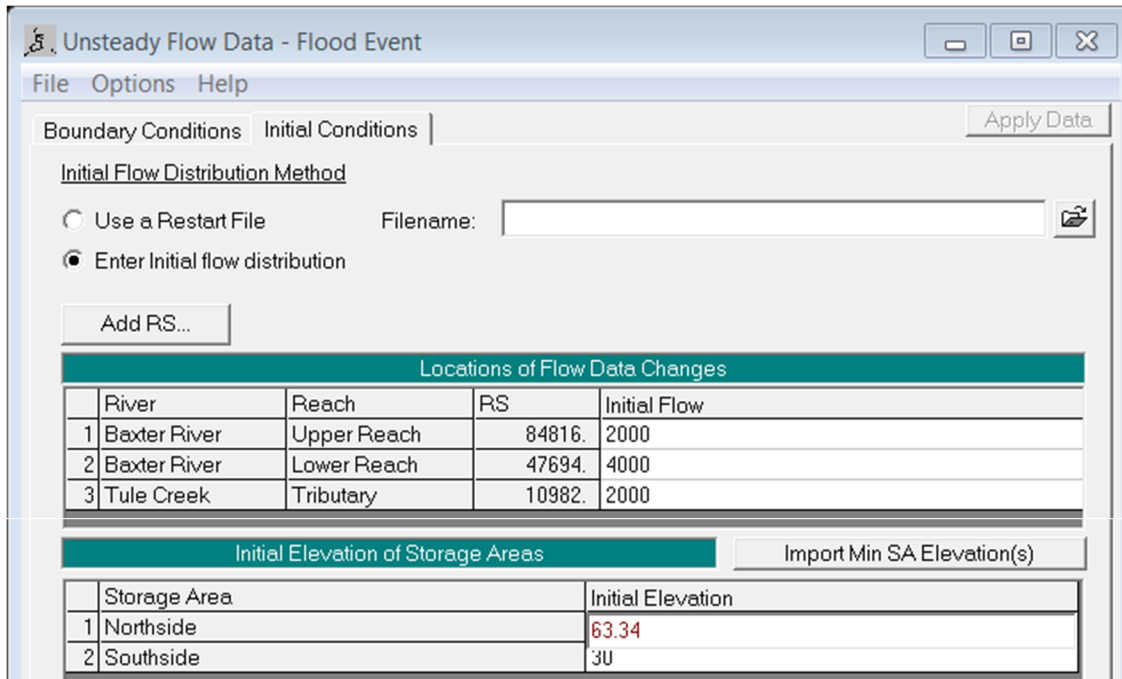
Then, a *Volume Elevation* curve for the reservoir is specified as shown below



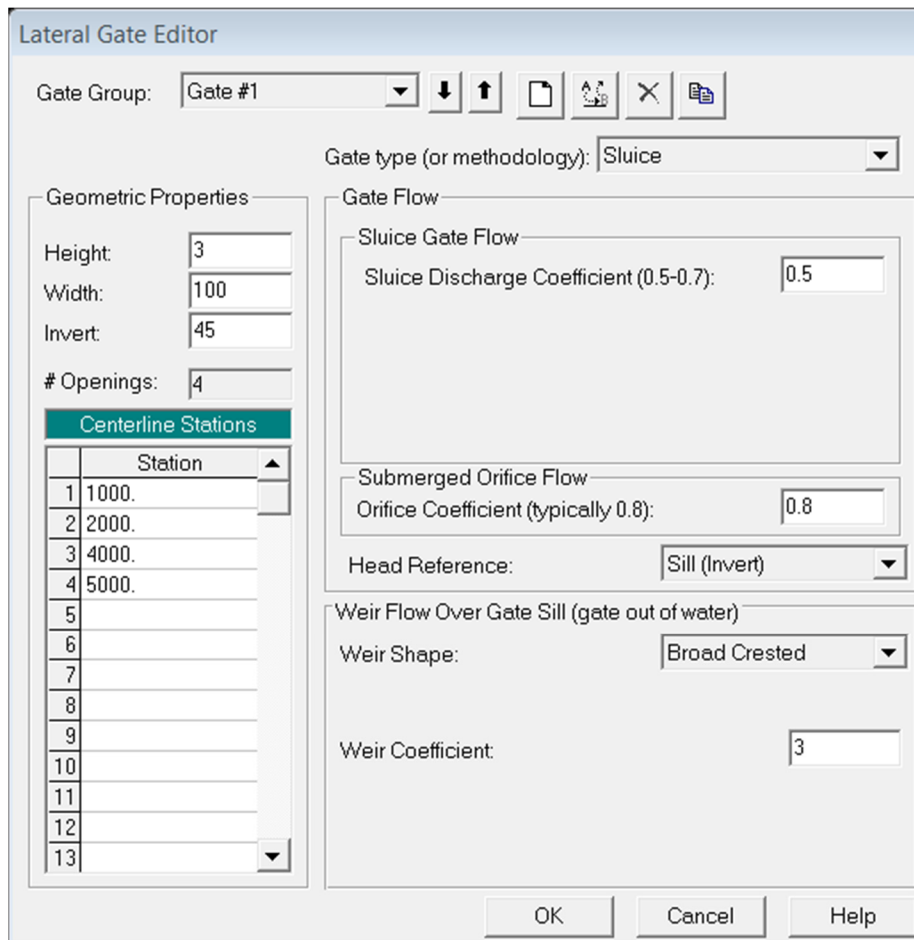
Also, it is necessary to add data of Station and Elevation for the lateral structure that connects the *Storage area* with the river as follows.



Do not forget to specify the initial water depth for the storage area. To do this, in the Unsteady Flow Data editor, select the *initial conditions* tab and then enter the initial water stage for the storage areas as depicted below.

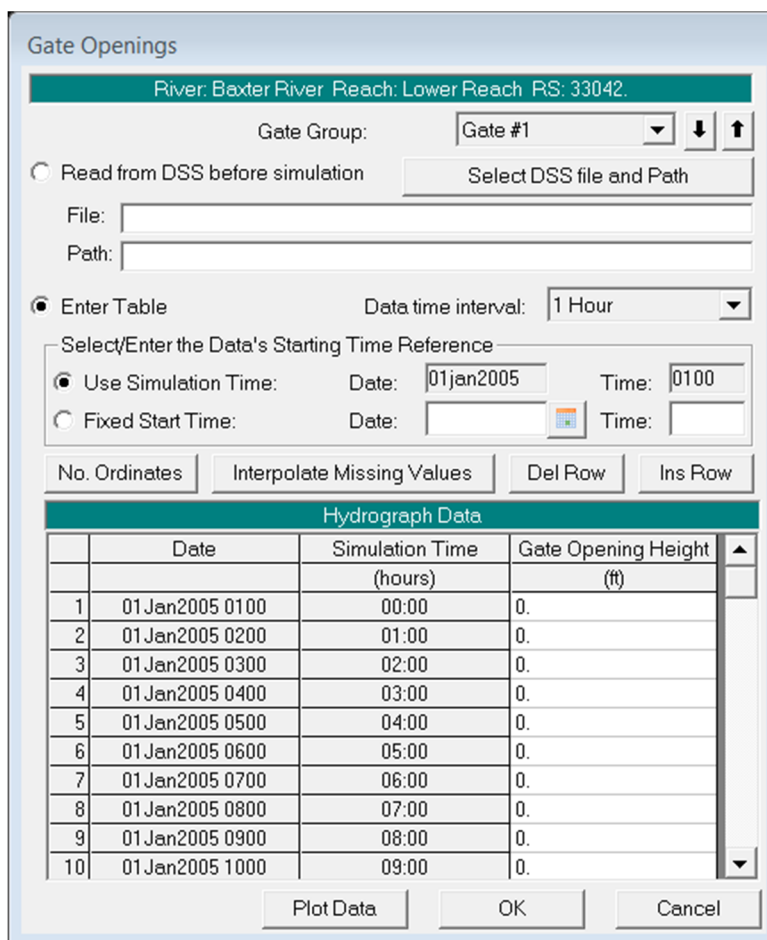
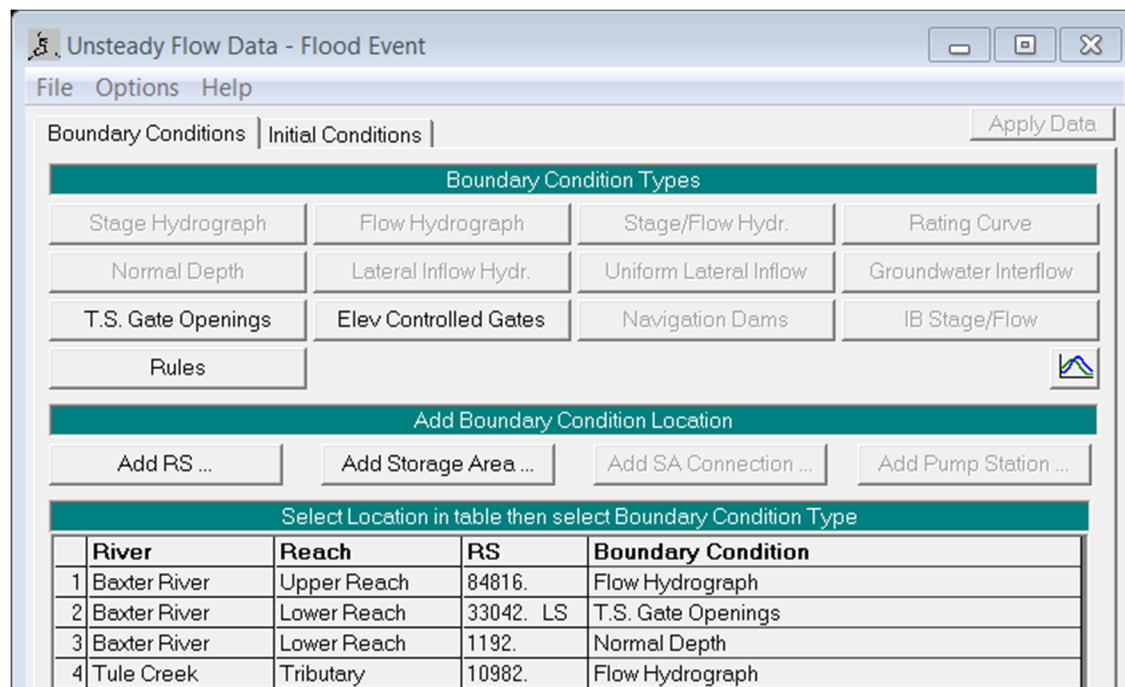


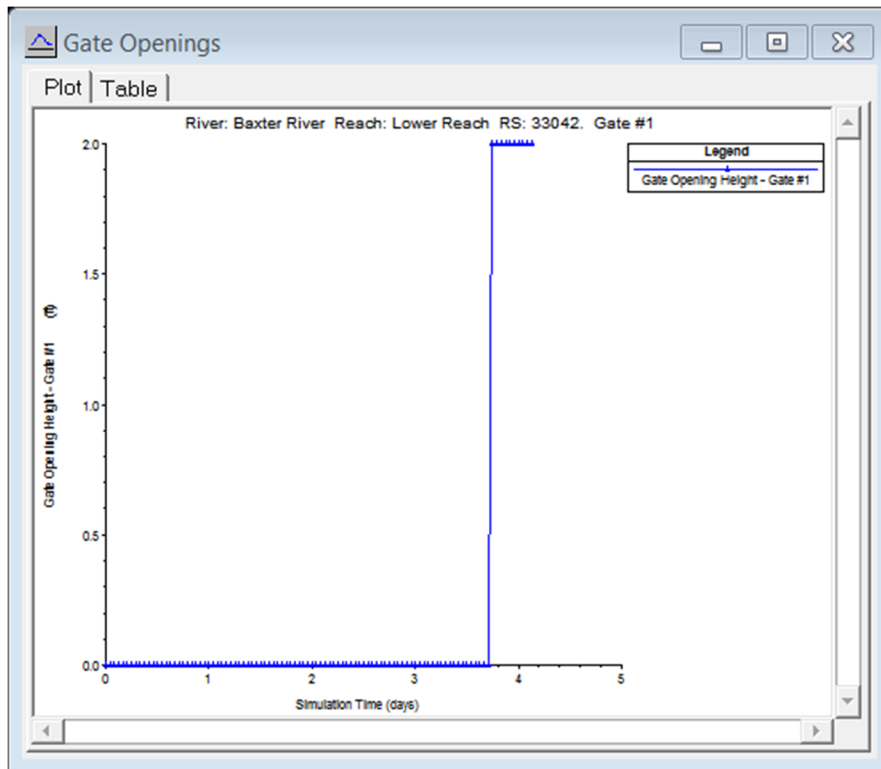
Now, let's add gates to the *lateral structure* as depicted below



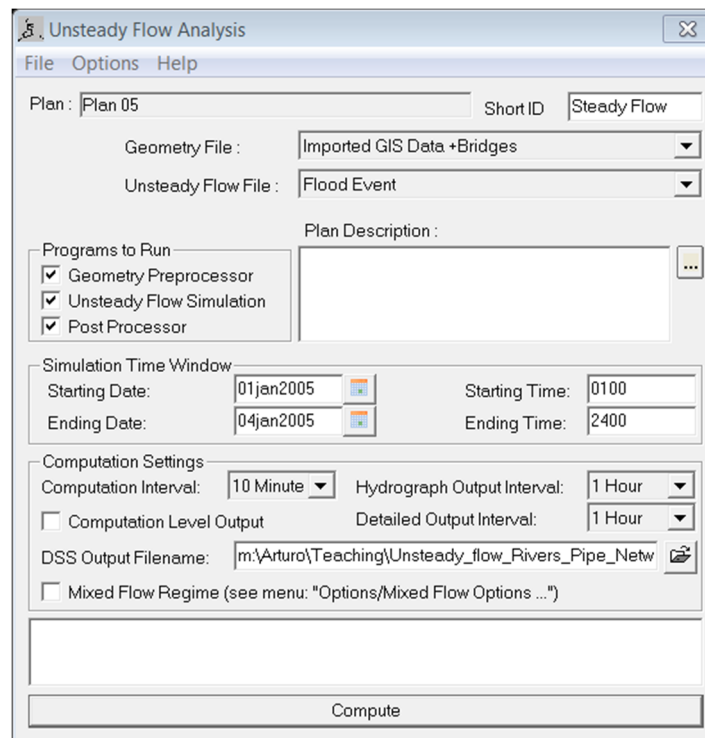
When using gates, it is necessary to specify how the gates will be operated. To do this, in the Unsteady Flow Data editor/*Boundary conditions* tab you would need to select the method of gate operation. For this application, choose *T.S Gate Openings*. Double click on the *T.S Gate Openings*

field and enter data of gate opening heights for all times of simulation. Do not forget to save the data.

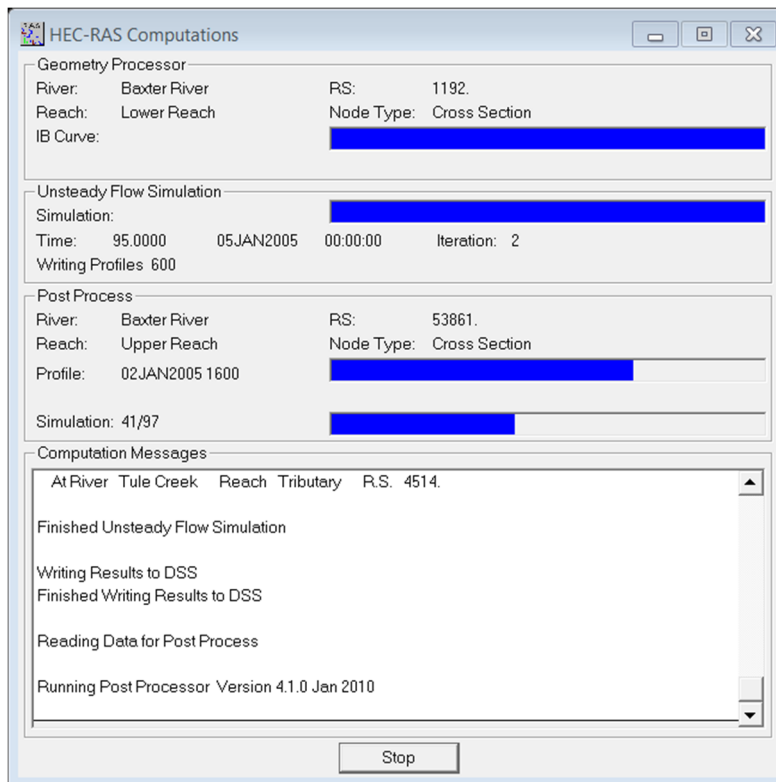





Now, Click on *Unsteady Flow Analysis* (main HEC-RAS window).

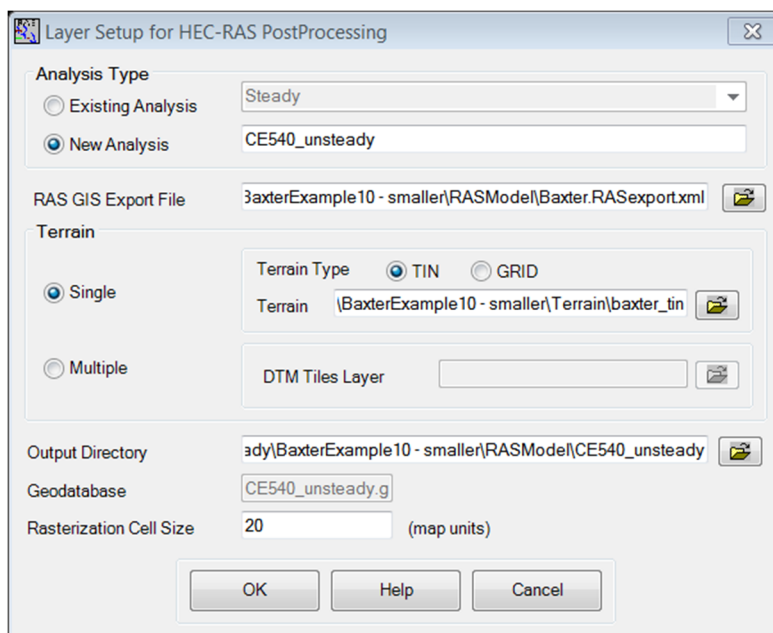


Click on *Compute* and *Save* the HEC-RAS model.



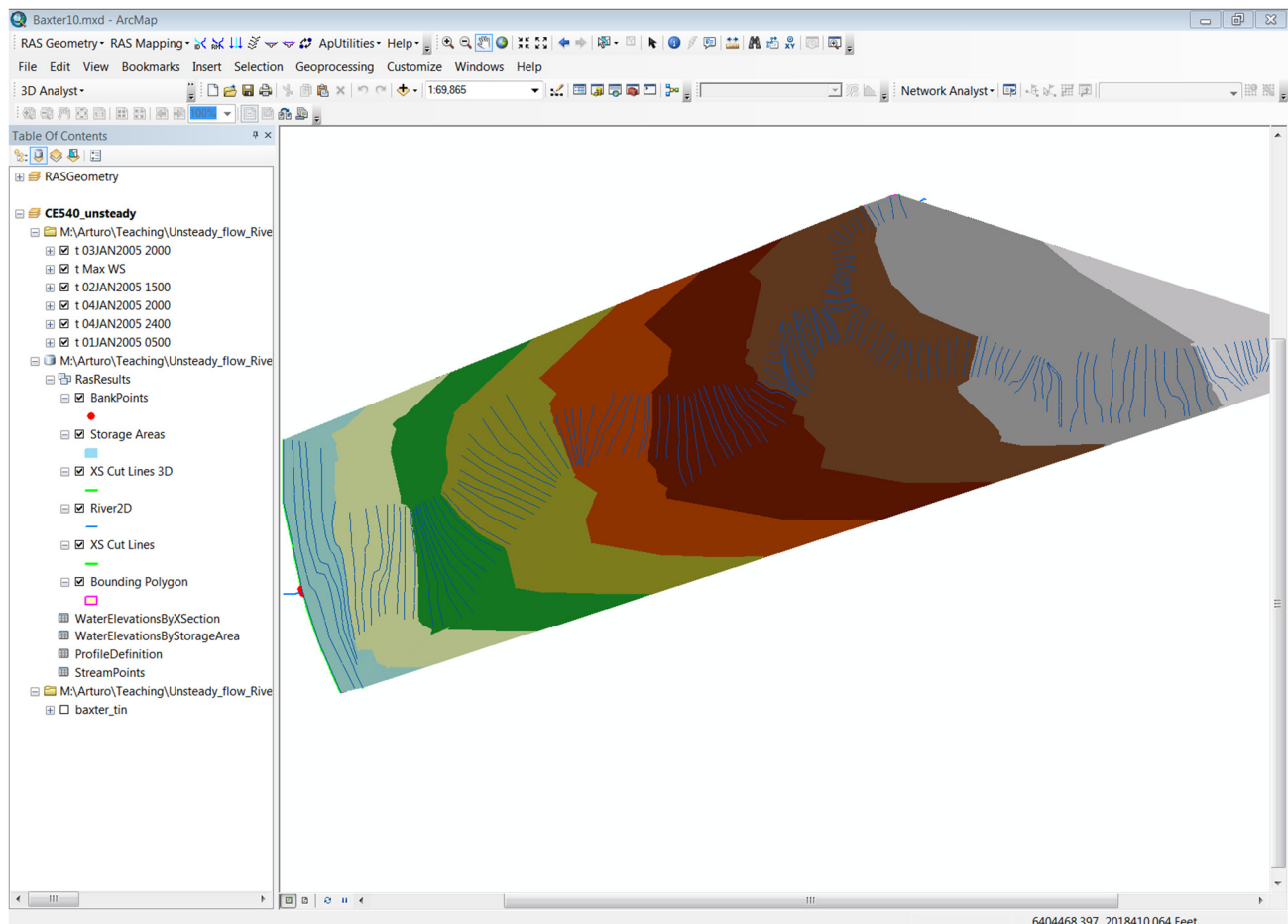
Then export the HEC-RAS output data to ArcGIS. **Click** on *File*→*Export GIS Data...* in the main HEC-RAS window. **Click** on *Select Profiles to Export* button, and select few profiles, including the maximum. **Click** on *Export Data* button, which will create a SDF file in your working directory. **Save** the HEC-RAS project and **exit**.

We will now open ArcGIS. In ArcGIS (open *Baxter10.mxd*, which is located in the sub folder *BaxterExample10 - smaller*) **click** on *Import RAS SDF* file button  to convert the SDF file into an XML file. In the *Convert RAS Export RAS SDF to XML* window, **browse** to *Baxter.RASexport.sdf* (located in the sub folder RASModel), 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:

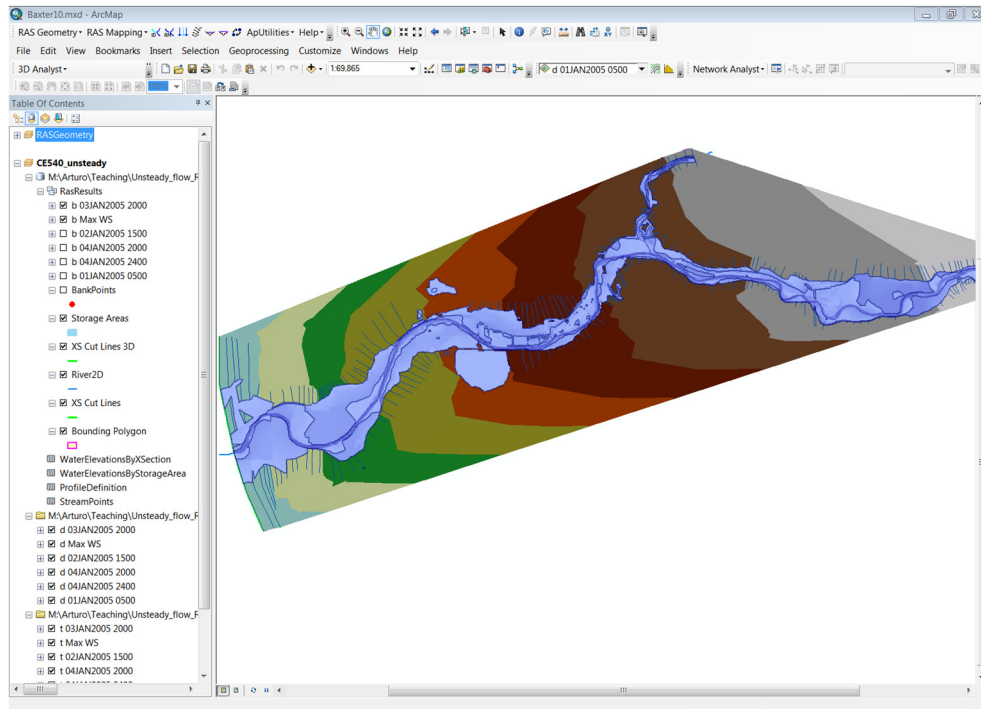


In the layer setup for post-processing, first **select** the *New Analysis* option, and **name** the new analysis as *CE540_unsteady* or any name you like. **Browse** to *Baxter.RASexport.xml* for *RAS GIS Export File*. **Select** the *Single Terrain TIN* Type, and **browse** to *Baxter_tin*. **Browse** to your working folder for *Output Directory* (*RASModel* in this case). Accept the default *20* map units for *Rasterization Cell Size*. **Click OK**. A new map (data frame) with the analysis name (e.g., *CE540_unsteady*) will be added to ArcGIS with the terrain data.

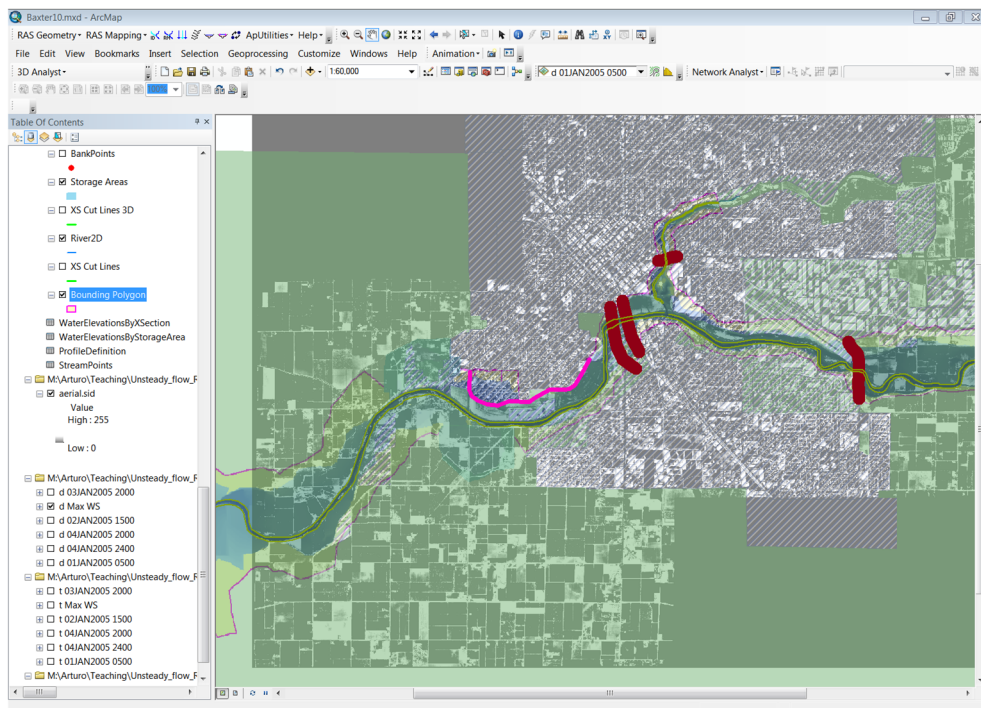
Next **click** on *RAS Mapping* → *Import RAS Data*. Similar to during export, you will see a series of messages during the import. This will create a bounding polygon. After the analysis extent is defined, we are ready to map the inundation extent. **Click** on *RAS Mapping/ Inundation Mapping/ Water Surface Generation*. **Select** All profiles, and **click OK**. This will create a surface with water surface elevation for the selected profiles as follows.



At this point we have a water surface and we have an underlying terrain. Now we will subtract the terrain from the water surface. Next, **Click** on *RAS Mapping* → *Inundation Mapping* → *Floodplain Delineation using Rasters*. Again, **select** All profiles, and **click OK**. You will see a series of messages during the execution. Then, a polygon will be created that represents the flooded area.

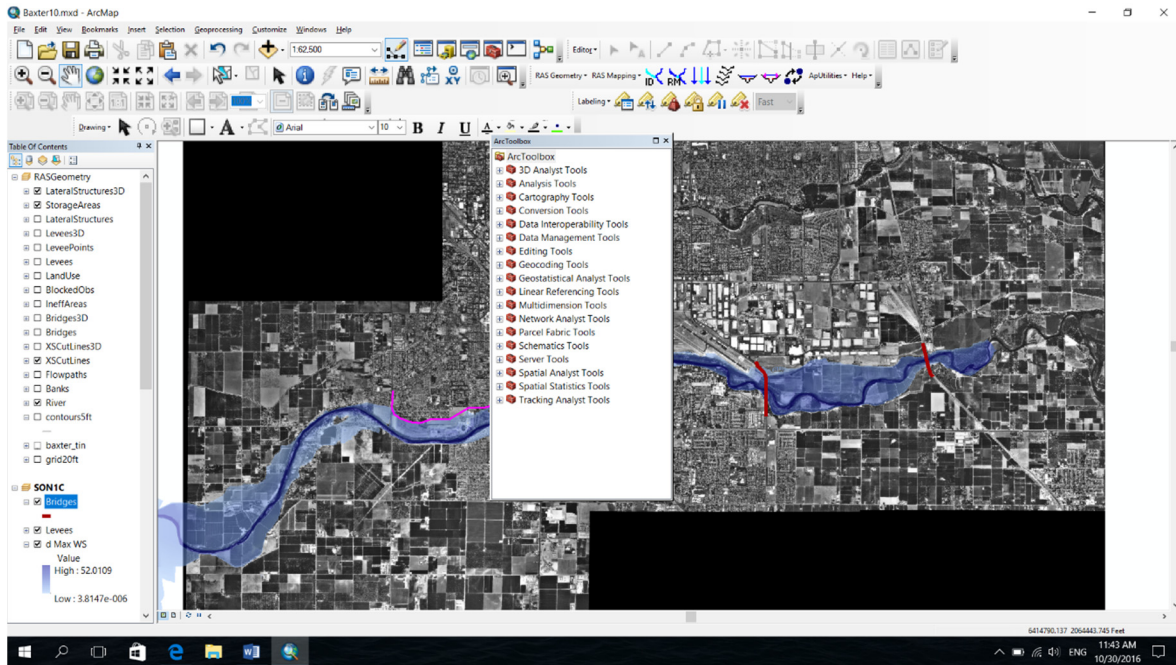


After the inundation map is created, you must check the inundation polygon for accuracy. For this you may need to superimpose your results with the geometry of the river, aerial map, levee lines, etc. (similar to the Steady Flow case). Notice in the plot above that there are unfeasible polders of water outside of the flooding area, meaning that the hydraulic simulation is not correct. Here you may need to add ineffective areas or blocked obstructions to avoid these unfeasible polders. Also, if the flooding extension is extending until the bounding polygon, this may mean that the bounding polygon needs to be extended to capture the full extension of flooding. In the computer lab session we will play with *levees* and other structures to protect urban areas. We will also learn how to check that your unsteady flow calculations make sense.

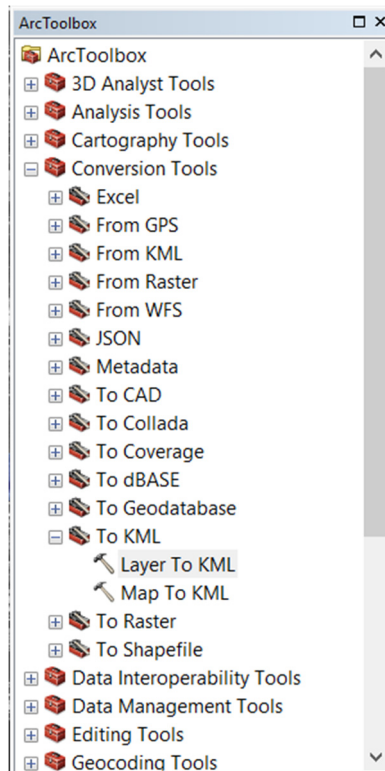


Visualization of HEC-RAS results in Google Earth

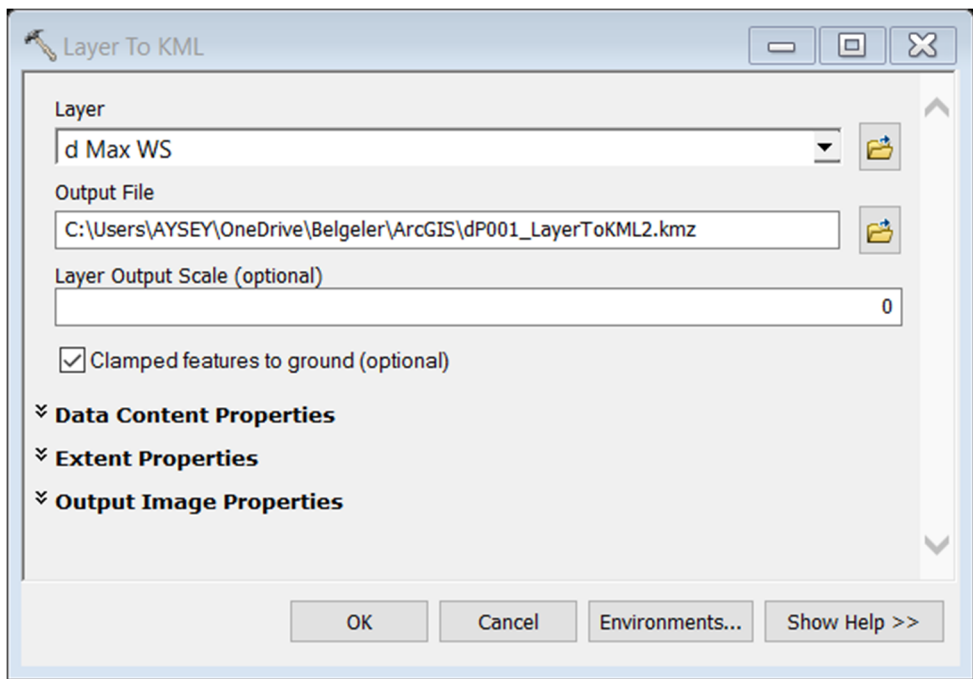
Start with clicking the ArcToolBox icon  [Geoprocessing/ ArcToolBox]



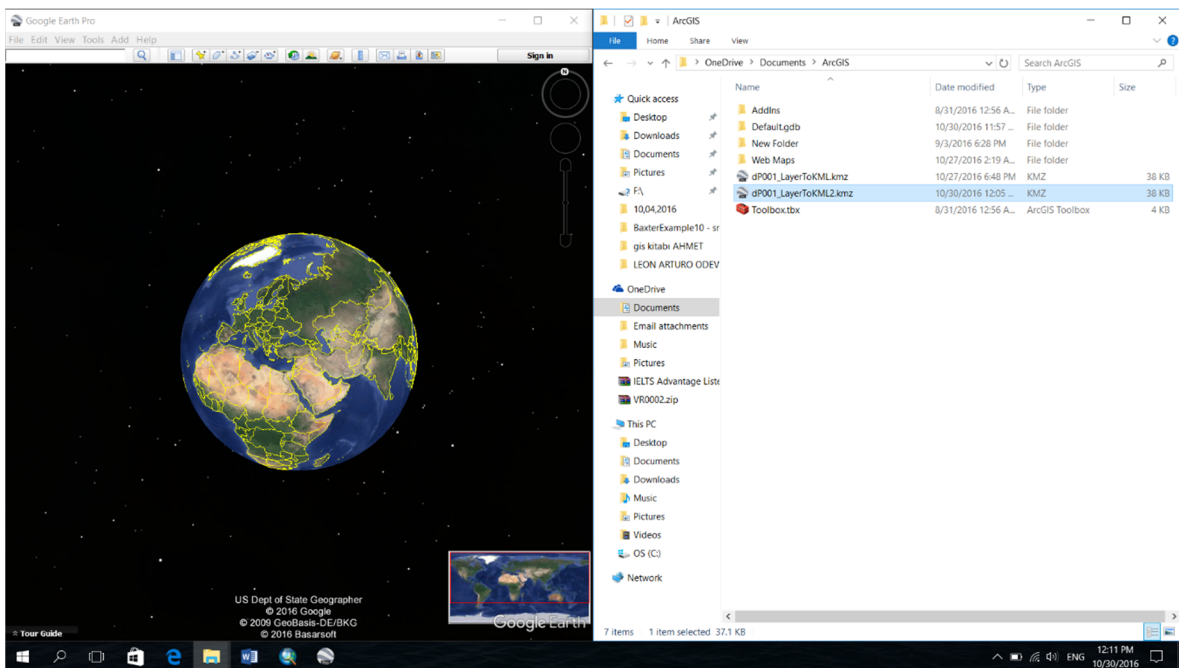
In the ArcToolBox list, select *Conversion Tools* → *To KML* → *Layer to KML* as follows



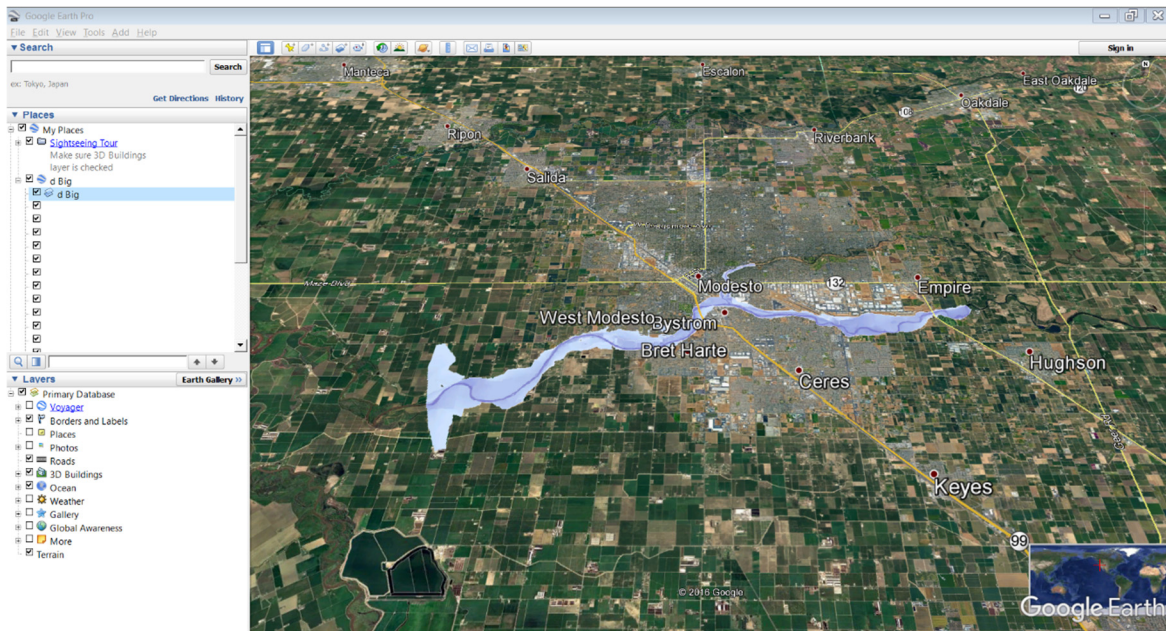
In the *Layer to KML* window, choose the layer that you would like to use (e.g., max water depth, maximum water surface elevation). In the figure below, the maximum water depth was used. The directory for the output file also needs to be specified.



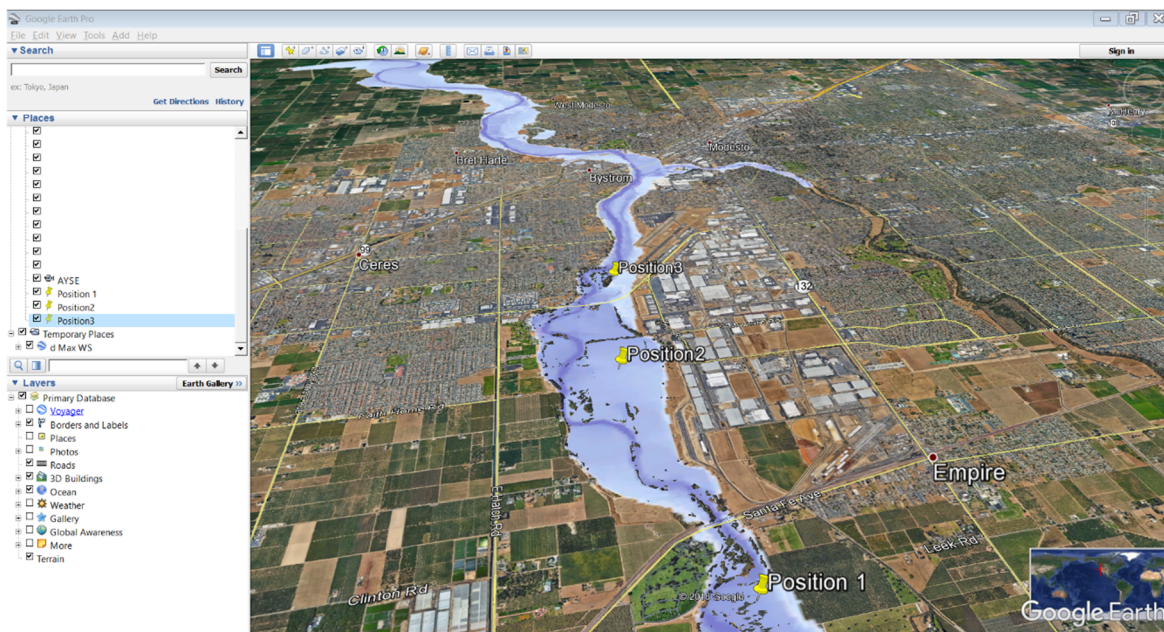
Click OK in the window above to create the KML file. Next, open Google Earth. Then, drag the created KML file to the Google Earth window.



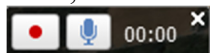
This will overlay the maximum water depth layer on Google Earth as shown below.



Before animating the inundation, you may want to adjust the perspective in Google Earth. In Google Earth select *Tools/Options/3D View* and then use the *maximum elevation exaggeration* (e.g., 3.0). Then Press *Shift* in the Keyboard and change the vertical angle with the mouse wheel. Play with this option until an appropriate view of the structures (e.g., bridges) is obtained.




Next, click on the *Record a Tour* icon . This will bring the following window

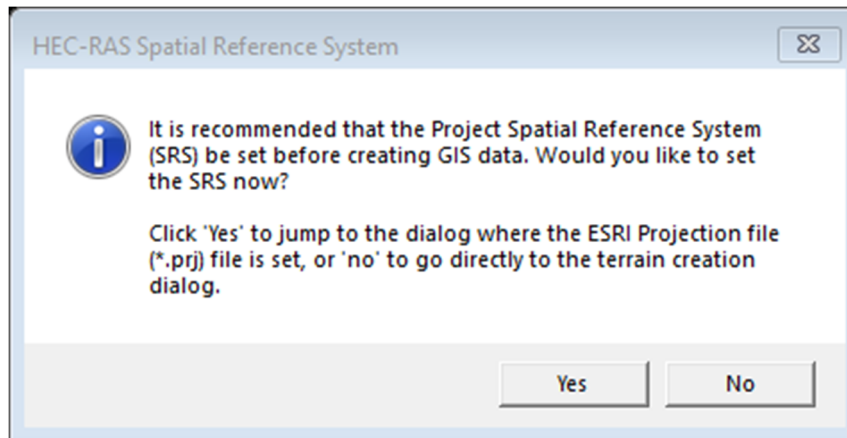


To start recording, click the red button. Then, using the mouse move and zoom-in along the river and structures as needed. To stop recording, click the red button again. To see the animation, click the play button.

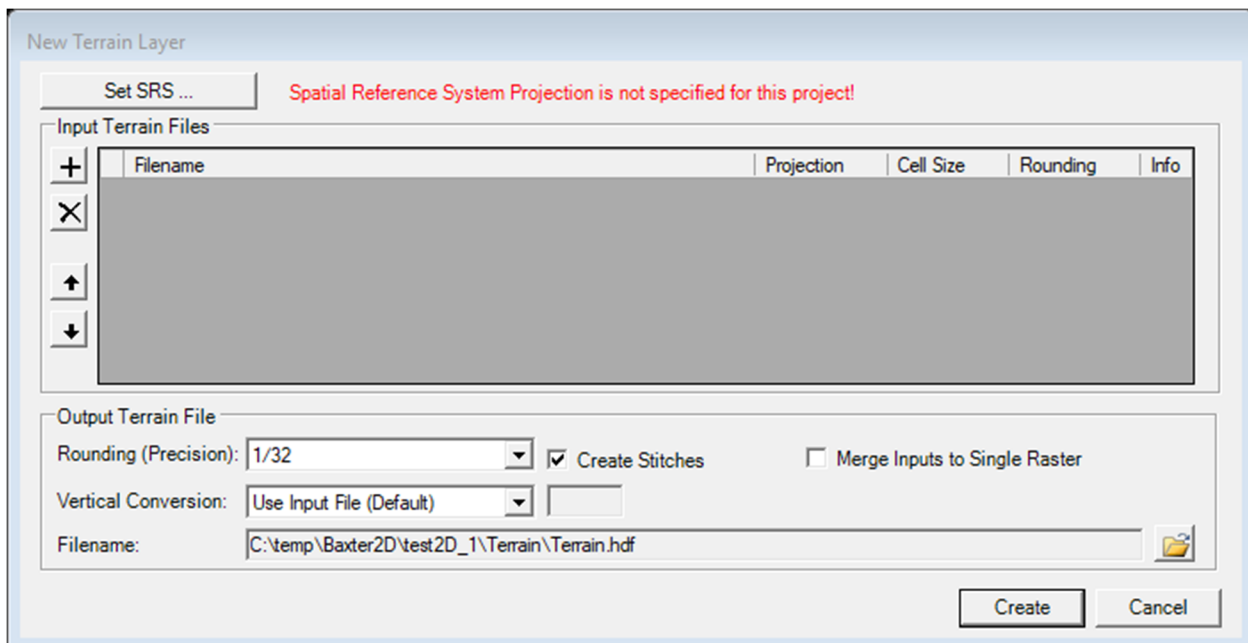


2D Flooding using HEC-RAS (with and without levees)

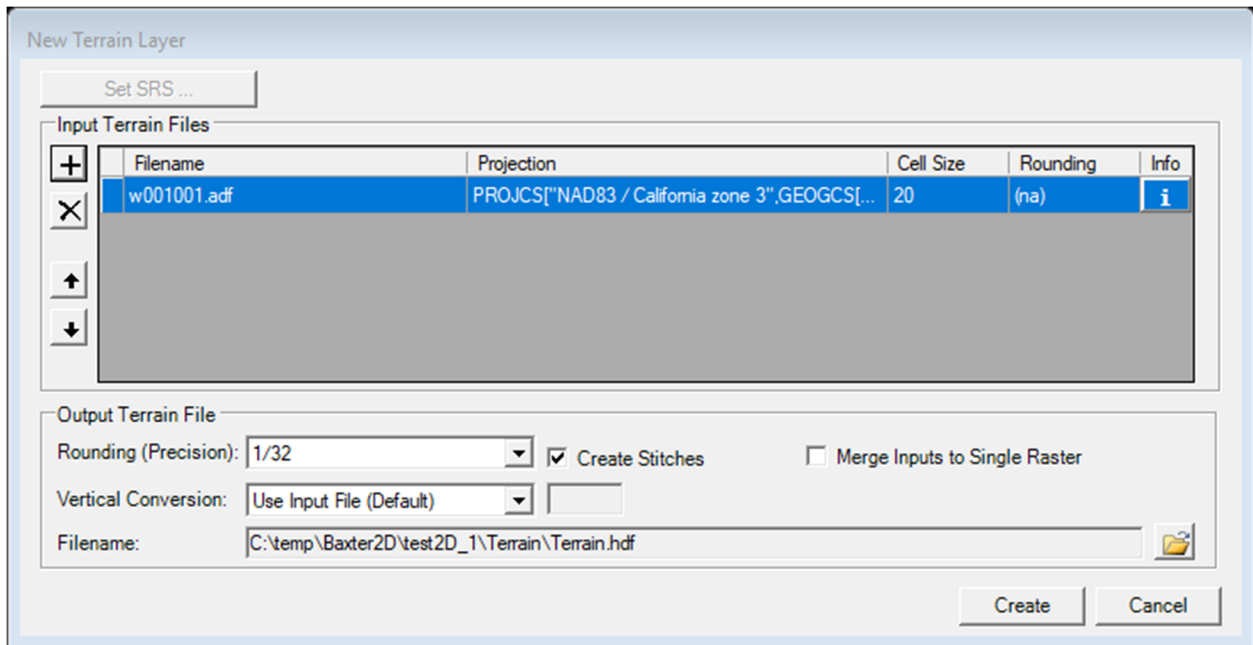
First, create a **new** HEC-RAS Project (File/New Project) and save it in a new Folder (Example: C:\temp\Baxter2D\test2D_1). Then click on the *RAS Mapper* icon . In the *RAS Mapper* window, highlight the *Terrains* option and right click on it. Then select the option *Create a new RAS terrain*. This will bring a window for creating a *Spatial Reference System* as follows



Select the **No** option because the Raster data of the Baxter River that we used in our previous tutorial has already a projection. This will result in the following window for a *New Terrain Layer*.

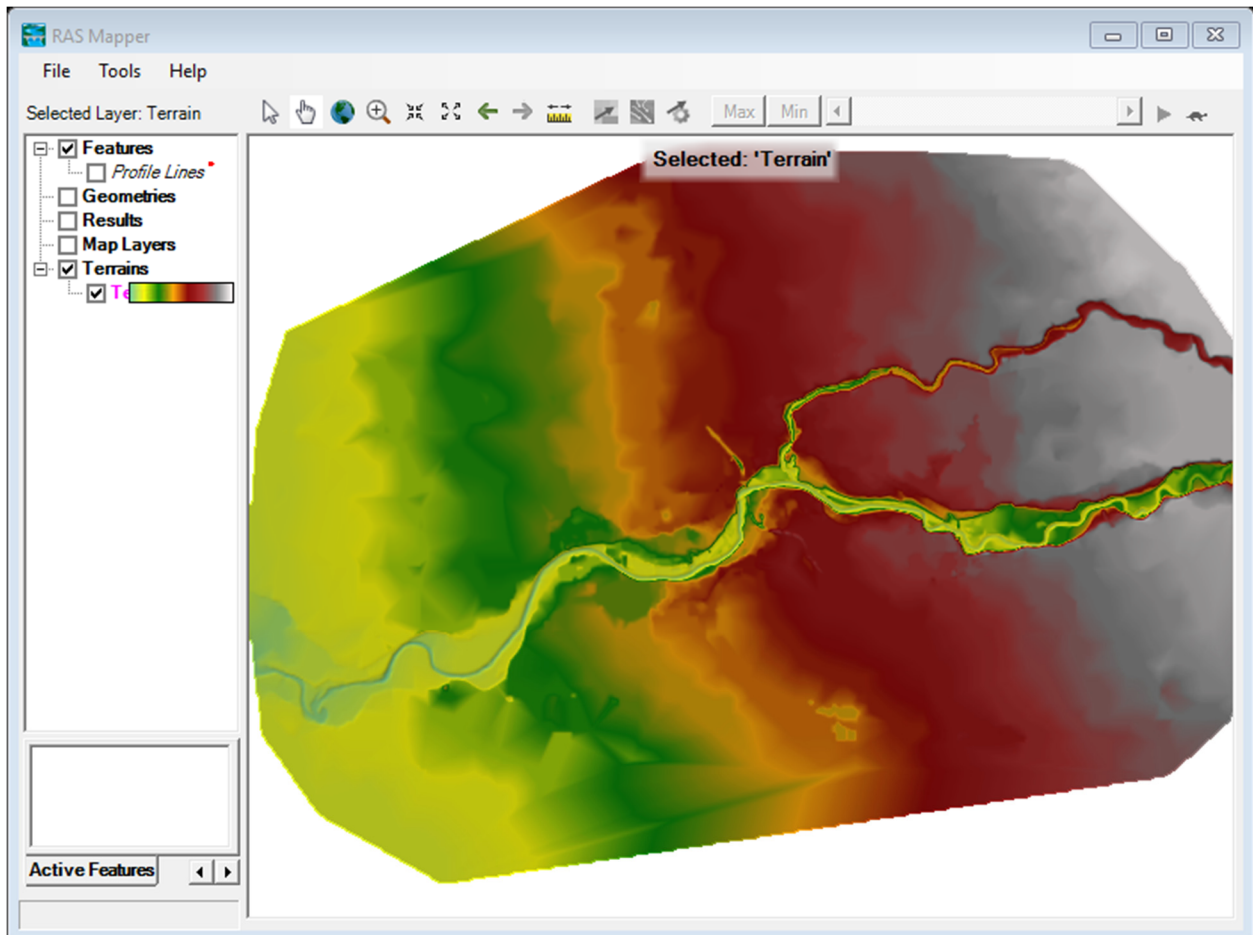


In the above window click on the plus icon (+) and open the raster data in the Directory you downloaded from the class website Terrain/grid20/grid20ft. The name of the file is w001001.adf. This again will bring a window for creating a *Spatial Reference System*. Now select **Yes**. Note in the window that this raster file has a projection associated with it. Now click on the button *Create* as follows



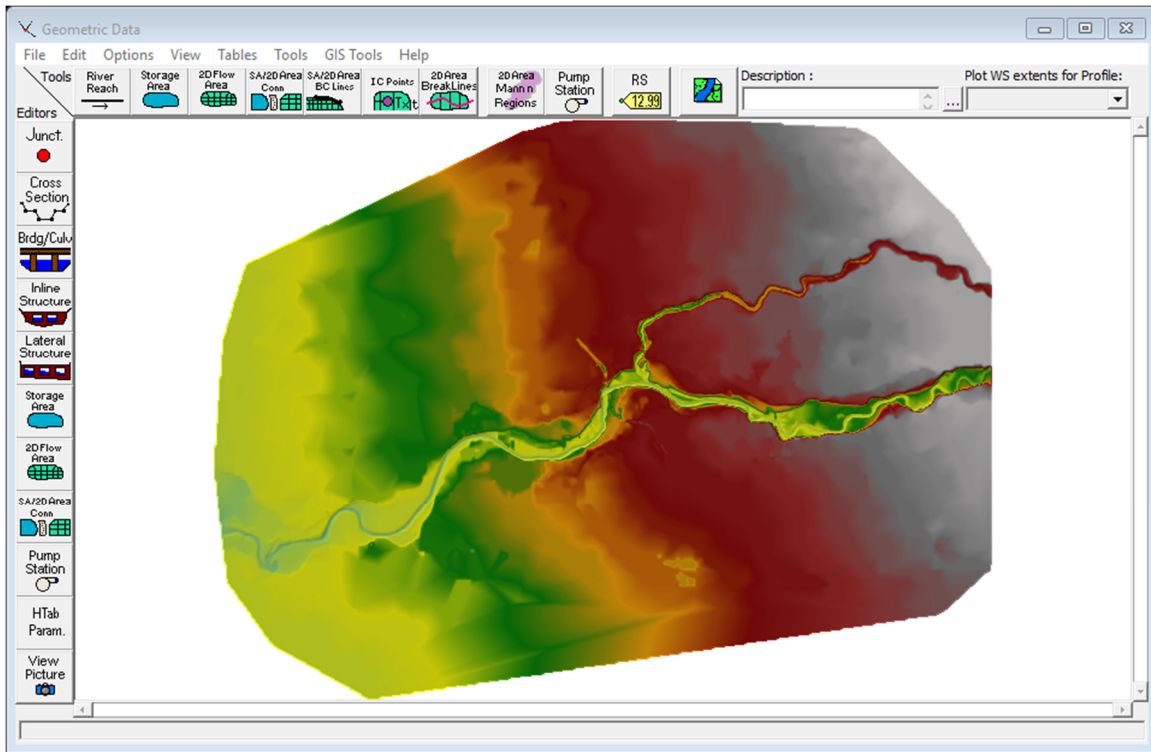
This will create the Terrain. Close the resulting window and save your HEC-RAS project.


Now open the *RAS Mapper* again and check the Terrain box to visualize the terrain. If the terrain is not displayed, highlight and check the terrain option and right click on it. Then, select the option *Zoom to Layer* and this should display the terrain as follows

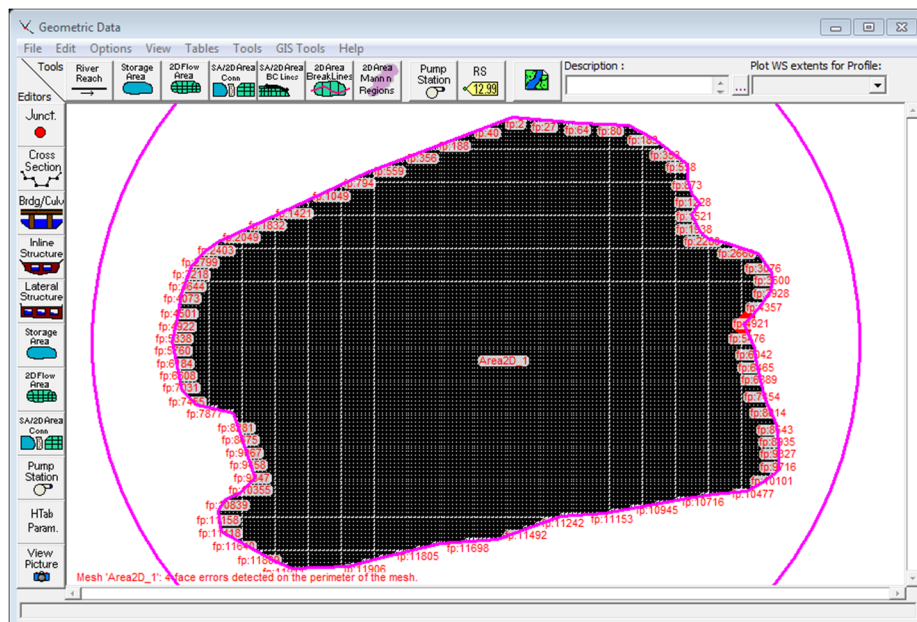


Save your HEC-RAS project and open the Geometry Tab  and you should be able to see the

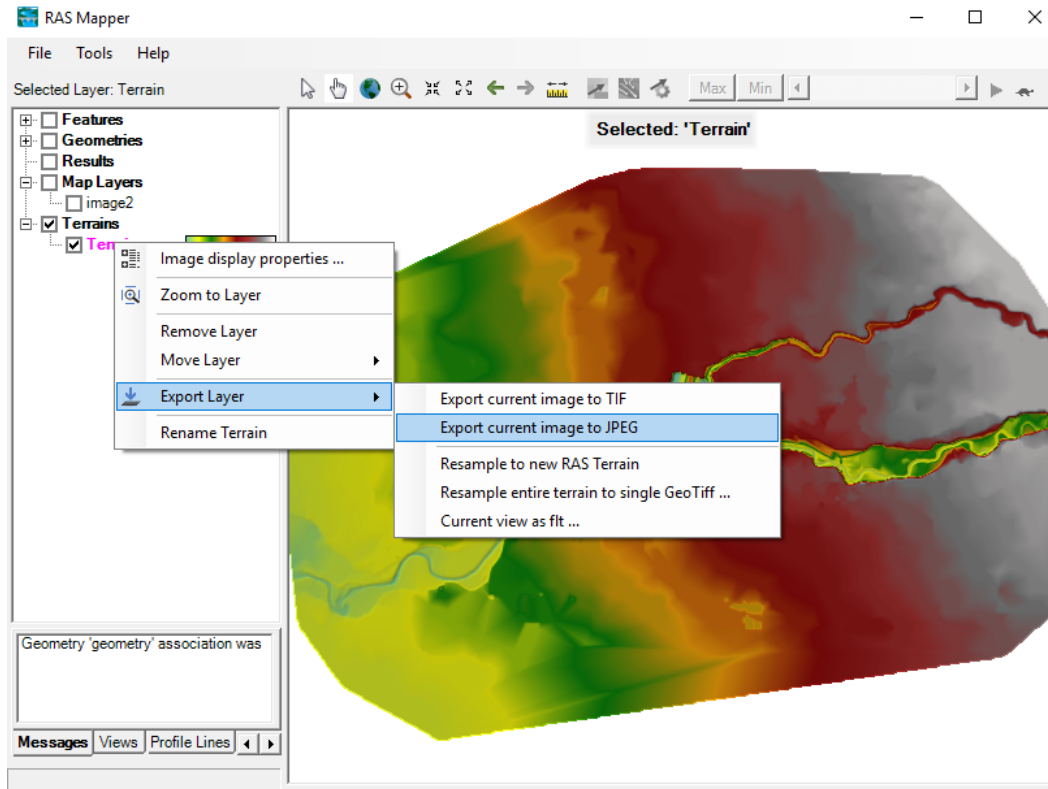
Terrain as follows:




Because this section is focused on 2D modeling, we will use the *2DFlow Area* icon, which is located at the top of the Geometry window (). Now select the Area of your domain and give a name to it. Click OK and now you have the *2DFlow Area* which will be the domain for the 2D simulation. Then select the 2D area you created and right click on it and select *Edit 2DFlow Area*. Then click on “*Generate Computation Points on regular Interval ...*” Then use a *Dx* and *Dy* equal to 10-200. Click on *Generate Points in 2D Flow Area* and the mesh will be created. **If your *Dx* and/or *Dy* are too small, HEC-RAS will not generate the mesh due to memory allocation issues.**





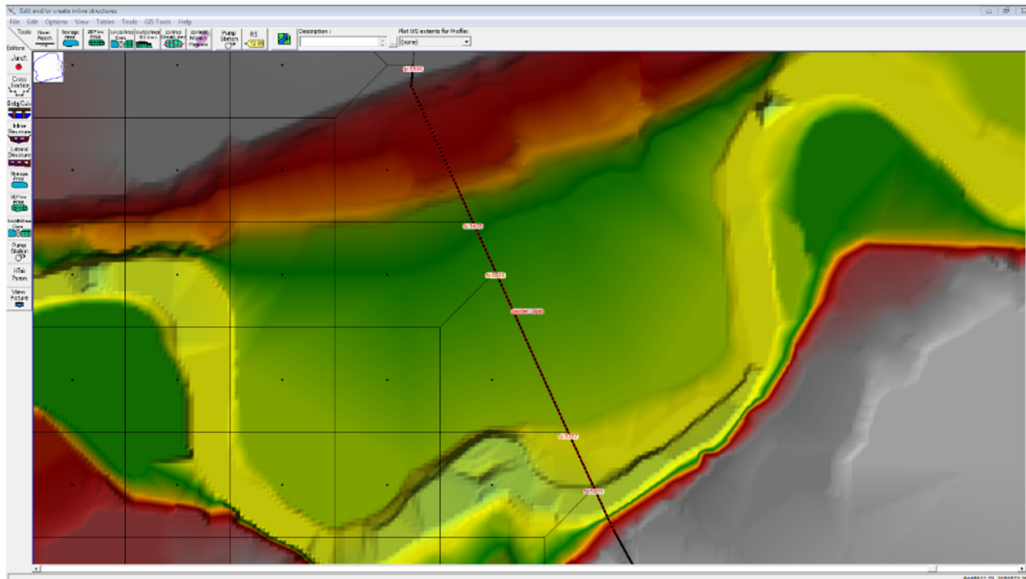
Once the mesh is generated, sometimes the DEM image is lost. To bring the DEM back, we need to export this from the *RAS Mapper* as follows



Assign a name to the *.jpg* image and save it. After you have exported the image you need to add it as a *Map Layer*. To do this, in *RAS Mapper* highlight and check the *Map Layers* option and right click on it. Then, select *Map data layers/Add existing layers* and search for the image you have exported. You can also add various existing *Map Layers* in *RAS Mapper*. For instance, the *Google Satellite Map* can be exported in *RAS Mapper* by selecting *Tools/Add Web Imagery/Google Satellite*. To select which background picture to show in the HEC-RAS *Geometry Data* window use the icon .

To hide the mesh, in the *Geometric Data* tab, select *View/View Options* and here uncheck the buttons *Fill in Storage Areas/2D Flow Areas*.

Before you create the boundary lines (Upstream Baxter River, Upstream Tule Creek, and Downstream Baxter River), it may be a good idea to edit you 2D Flow Area, especially along the boundaries. To do this, in the Geometry Tab  use the *Edit* option to *Add Points*, *Move points* and *Remove Points*. Now you can create the boundary lines using the icon  for Upstream Baxter River, Upstream Tule Creek, and Downstream Baxter River. The figure below is for Upstream Baxter River. **Please make sure that the upstream end boundary lines are not outside of the main channel of the river** as this will give an unrealistic inundation area. Also, make sure that the boundary lines are perpendicular to the flow direction. At the downstream boundaries, try to make the boundary line as large as possible to allow to pass the maximum flow rate without producing backwater due to the boundary.



Once you edited the boundary lines, you may want to rebuild your mesh (Use *Force Mesh Recomputation* and *Generate Computation Points on Regular Interval with all Breaklines*). Once this is complete save your geometry data and start to add the boundary conditions as usual (Edit/Unsteady Flow Data). You can use the same boundary conditions as the *1D Unsteady* flow data. To copy this data, you can open another instance of HEC-RAS and copy the data directly (use Ctrl “C” and Ctrl “V”). For each inflow hydrograph, at the bottom of the table, enter 0 for *EG Slope for distributing flow along BC Line*. Next, *save* the unsteady flow data. Next, create the Plan with the dates and parameters of the simulation in a similar way to the *1D Unsteady* case. Before running your model, as shown below, make sure that in the *Plan* you select *Options/Calculation Options and Tolerances/2D Flow Options* and in *Initial conditions Time*, you select the number of hours for the initial flow calculations. I would suggest to use a *steady flow* for the first “x” hours where x is at least two times the time period that it takes for the flow to travel from the most upstream end to the most downstream end.

HEC-RAS Unsteady Computation Options and Tolerances

General (1D Options) | 2D Flow Options | 1D/2D Options |

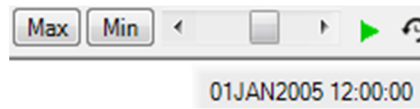
Use Coriolis Effects (only when using the momentum equation)

Number of cores to use in 2D computations: All Available

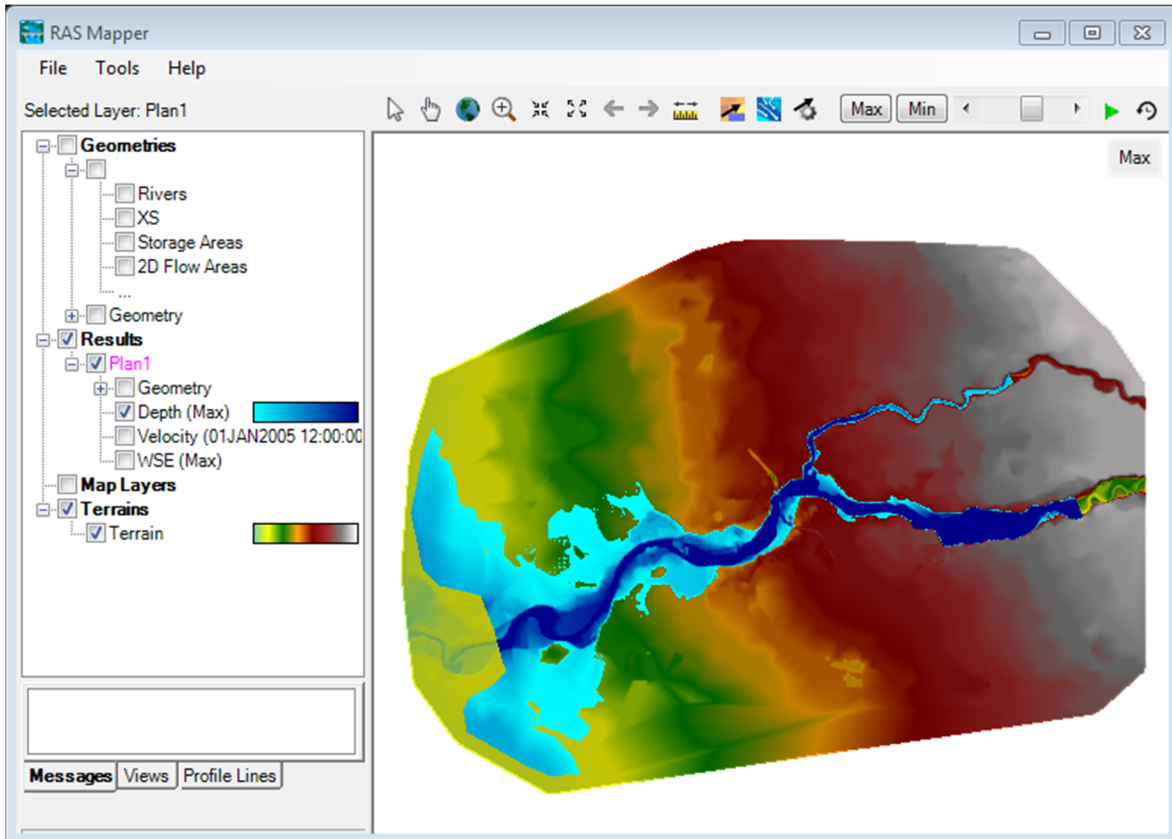
Parameter	(Default)	Area2D_1
1 Theta (0.6-1.0):	1	1
2 Theta Warmup (0.6-1.0):	1	1
3 Water Surface Tolerance [max=0.2](ft)	0.01	0.01
4 Volume Tolerance (ft)	0.01	0.01
5 Maximum Iterations	20	20
6 Equation Set	Diffusion Wave	Diffusion Wave
7 Initial Conditions Time (hrs)		200
8 Initial Conditions Ramp Up Fraction (0-1)	0.1	0.1
9 Number of Time Slices (Integer Value)	1	1
10 Eddy Viscosity Transverse Mixing Coefficient		
11 Boundary Condition Volume Check	<input type="checkbox"/>	<input type="checkbox"/>
12 Latitude for Coriolis (-90 to 90)		

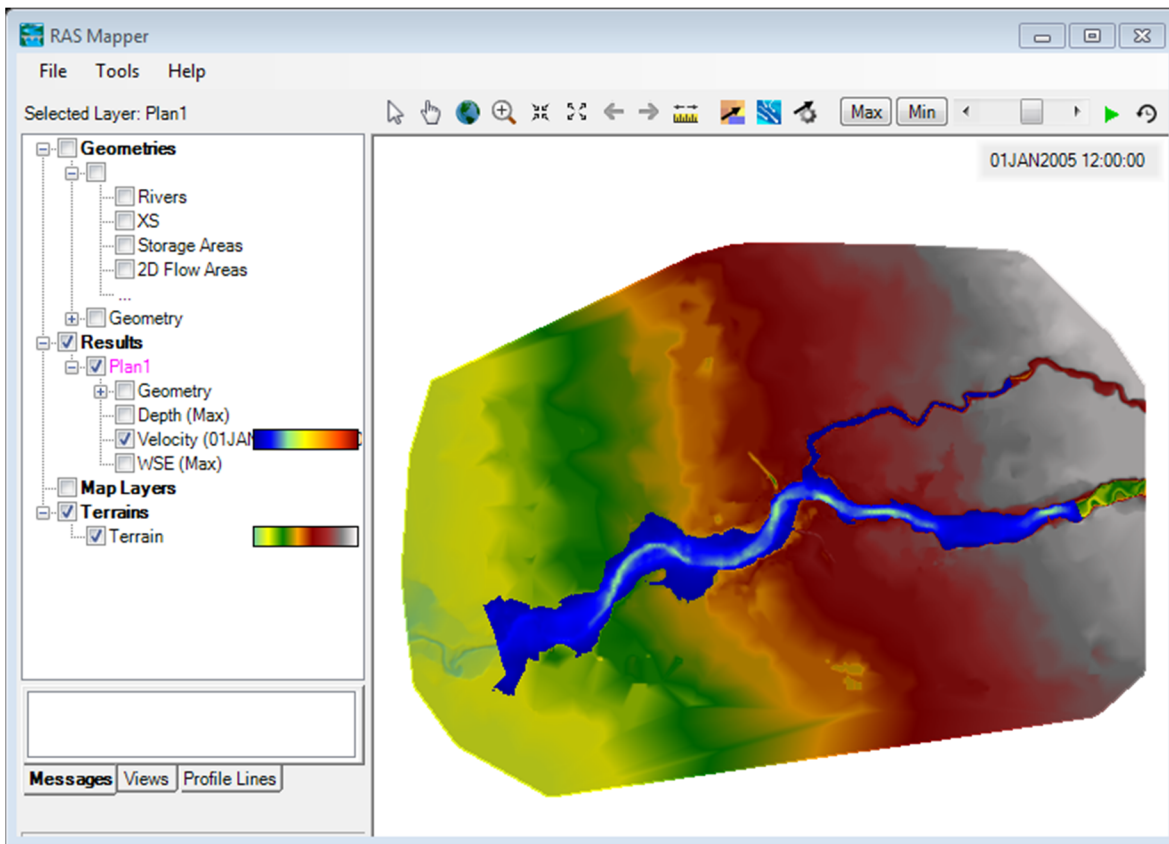
OK Cancel Defaults ...



Now you should be able to run the model. After the model is run, the visualization is done in *RAS Mapper* by checking the box *Results*. Here you may want to animate the water depth, velocity or the water surface elevation. The results at different times can be visualized by scrolling the following tab to the left or right.

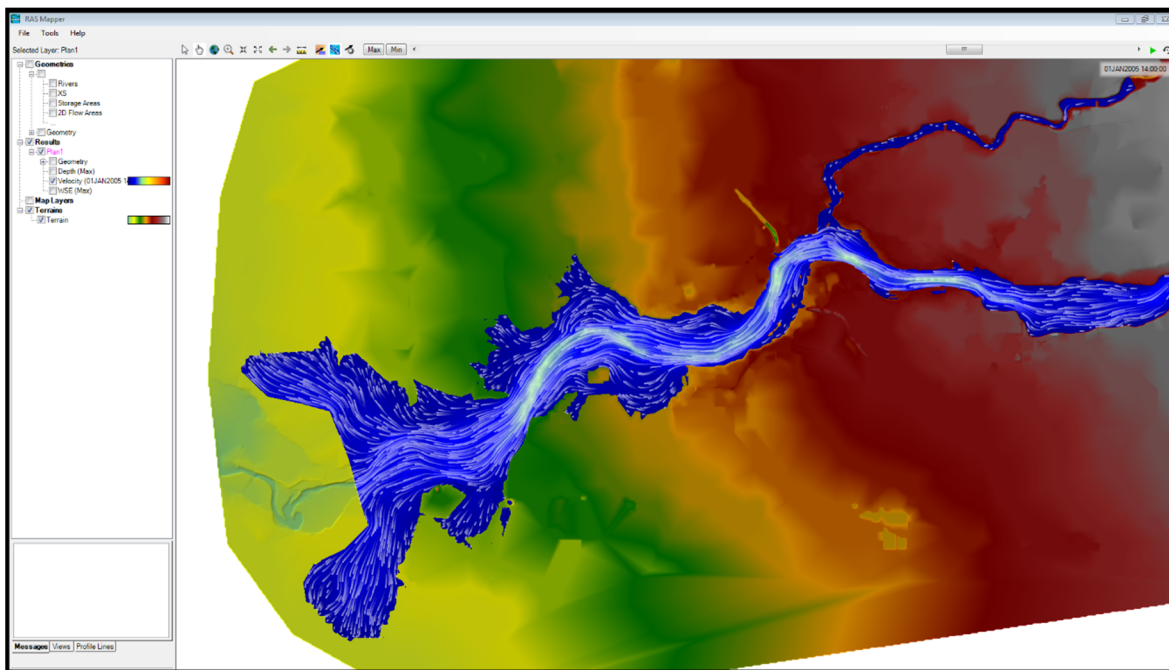


The above tab is located in the upper right corner of the *RAS Mapper* window. The two figures below show water depth and velocity snapshots, respectively.

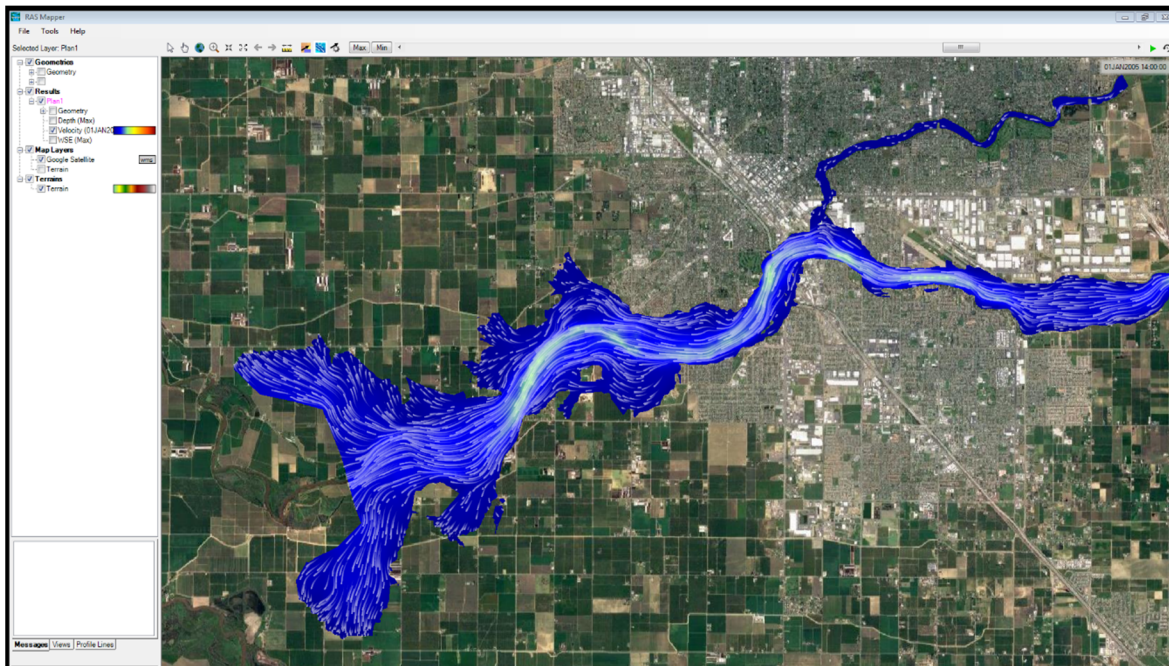






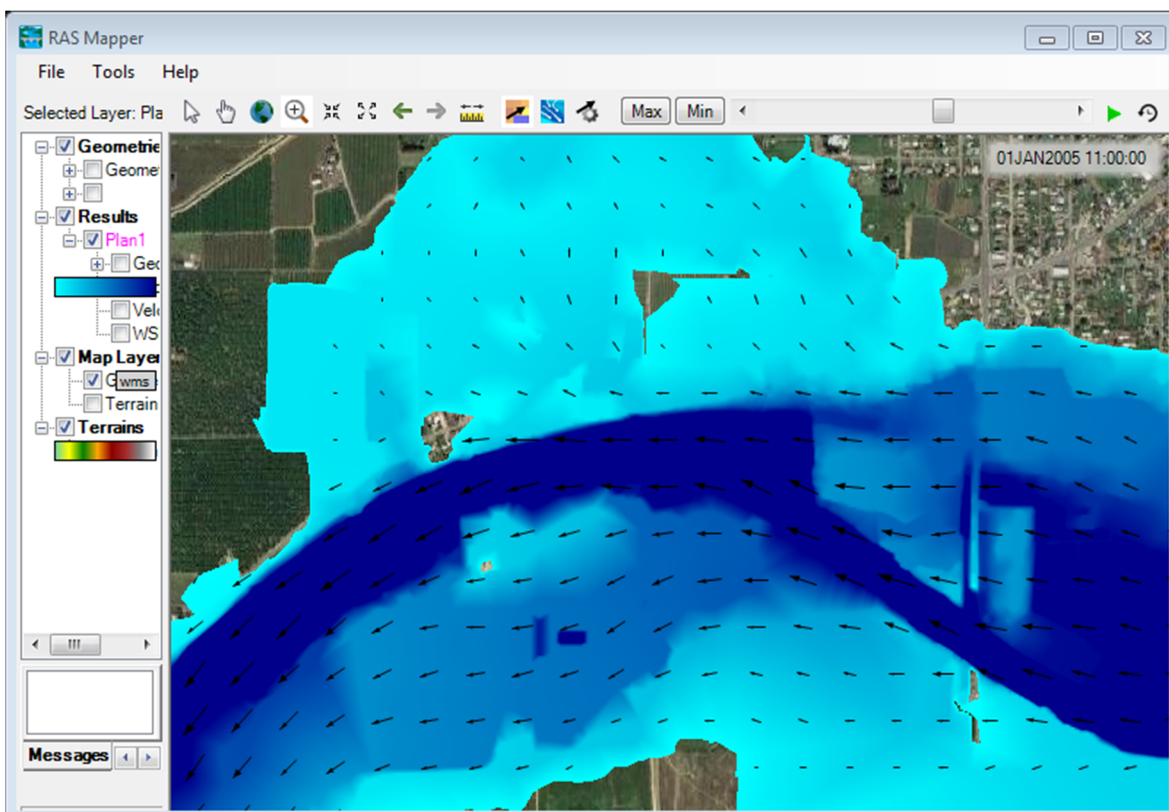
If you would like to visualize the particle tracing you can use the icon  and then click on the icon  to select the parameters of the tracing. Below is a snapshot of the particle tracing.



You can also add layers using *Tools/Add Map Layers* to show Aerial Maps available for the area (e.g., Google Satellite). One of this is shown below. Make sure that the appropriate Map layer is checked.



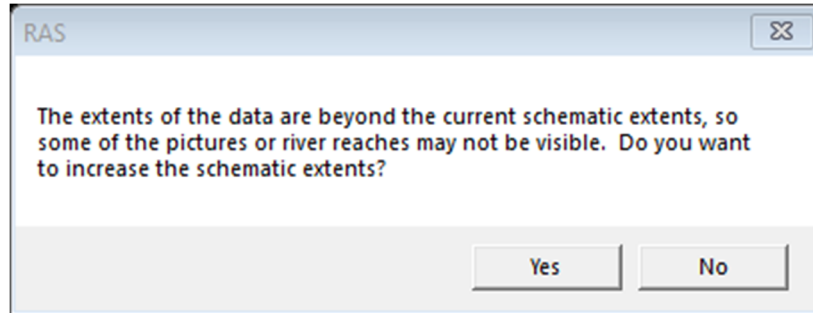
We can also visualize the velocity arrows at a given time. To do this use the icon  in *RAS Mapper*. To control the separation of the arrows, modify the *spacing* of *Static Arrows* using the icon . A snapshot of the velocity arrows at a given time is shown below:



As for the 1D case, you need to check if the results make sense. If they don't, we need to redo the simulations with the necessary corrections. This will be explained in the computer lab in more detail.

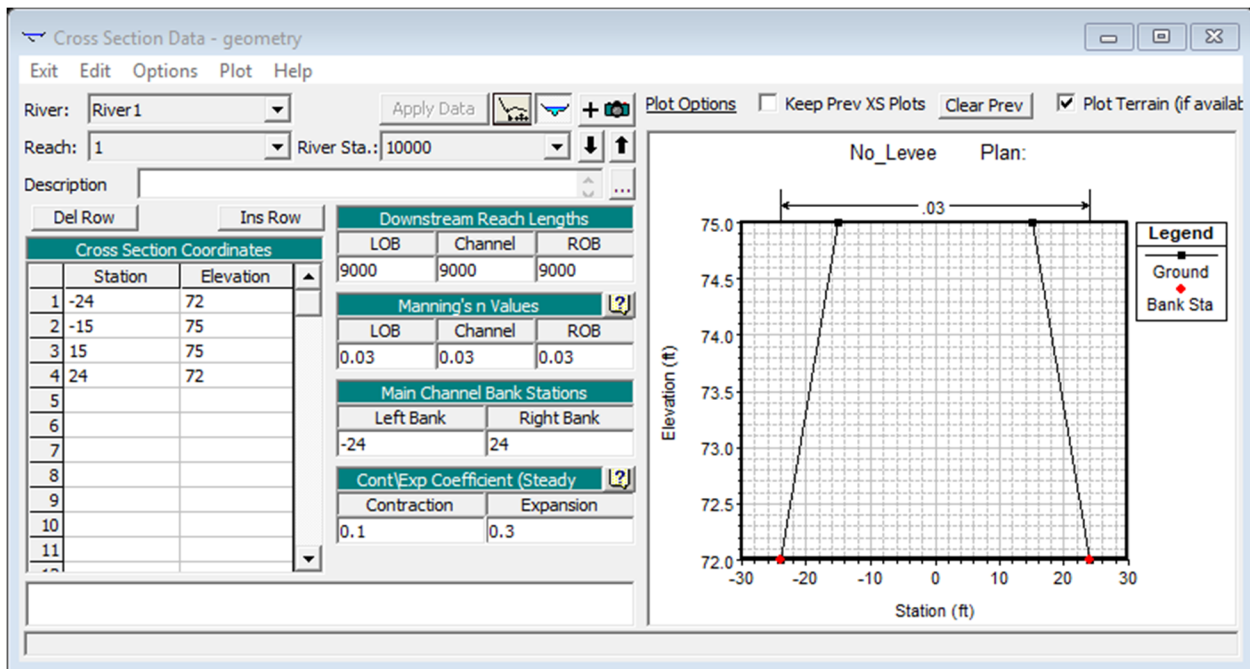
Adding Levees in 2D Modeling

To add levees, we can use the *lifting terrain* approach as described in <http://hecramodel.blogspot.com/2015/06/lifting-terrain-in-hec-ras-50.html>. Following this approach, we open the *Geometry* tab in HEC-RAS containing the terrain created previously. In the *Geometry* tab, we first define *breaklines* along existing or future levees (*2D Area Breaklines*), then we create a *river reach* along the *breakline* (from upstream to downstream). When creating the river reach we are asked the following question:

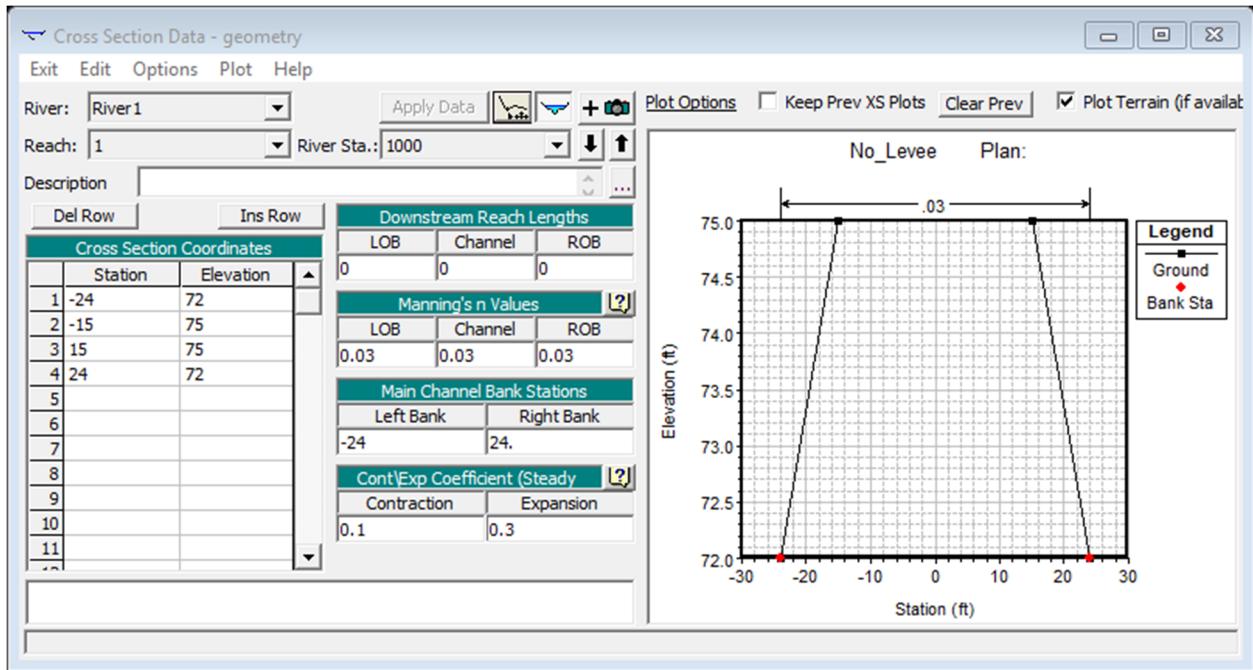


Select **No**. Then add two cross-sections representing the levees in the river reach. To make sure that the levee is wide enough to be well captured in the terrain model, I used a levee width of 30 ft. I also used a side slope of 3:1 ($z = 3$). There is no need to project the levee side slope to the ground as HEC-RAS will do it for you. The two created cross-sections are shown below.

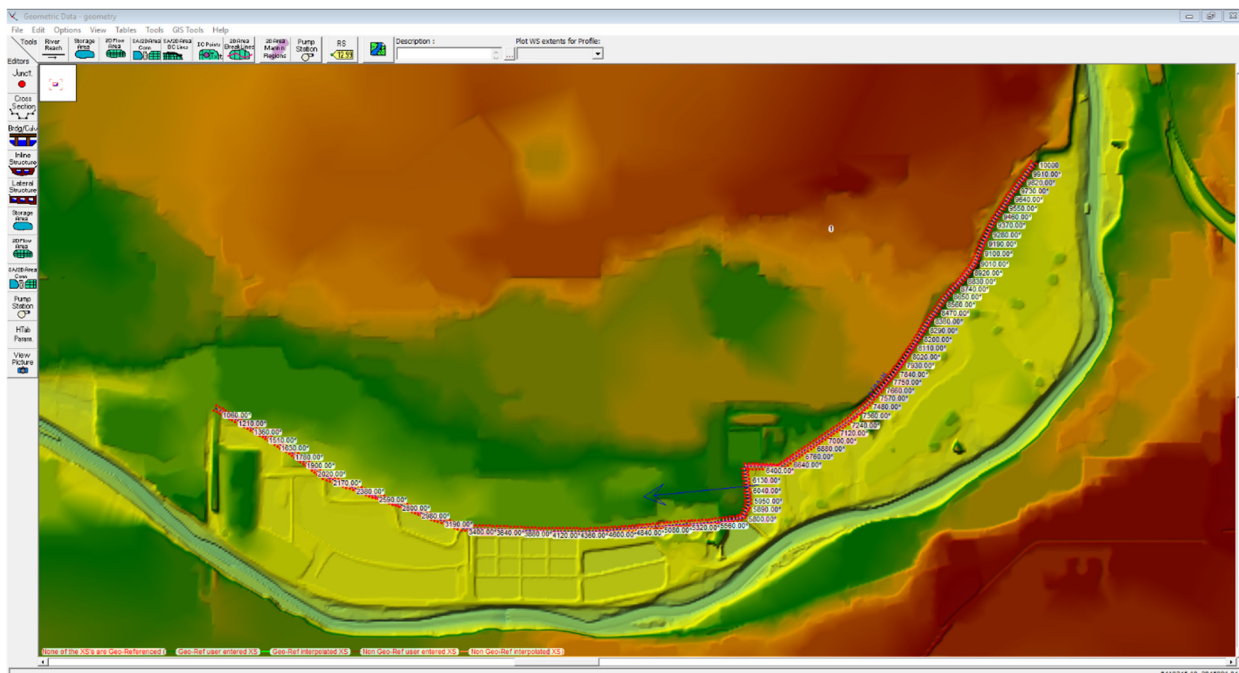
Upstream cross-section



Downstream cross-section

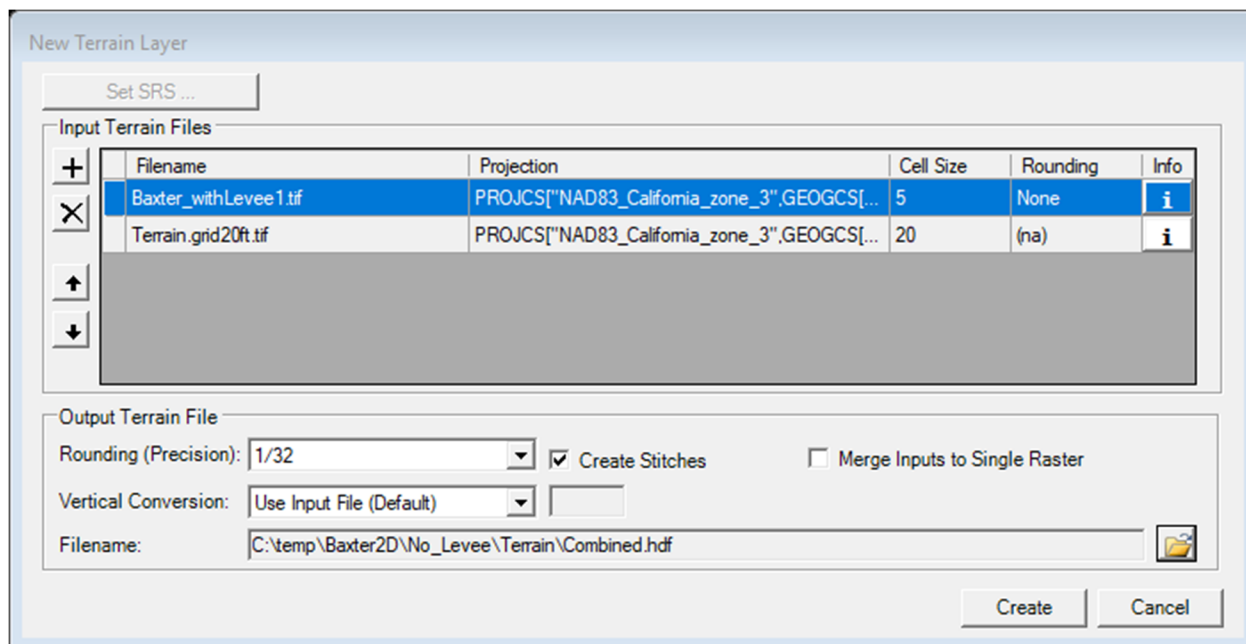


Then, I interpolated between the two cross-sections with a spacing of 30 ft, which resulted in the following plot.

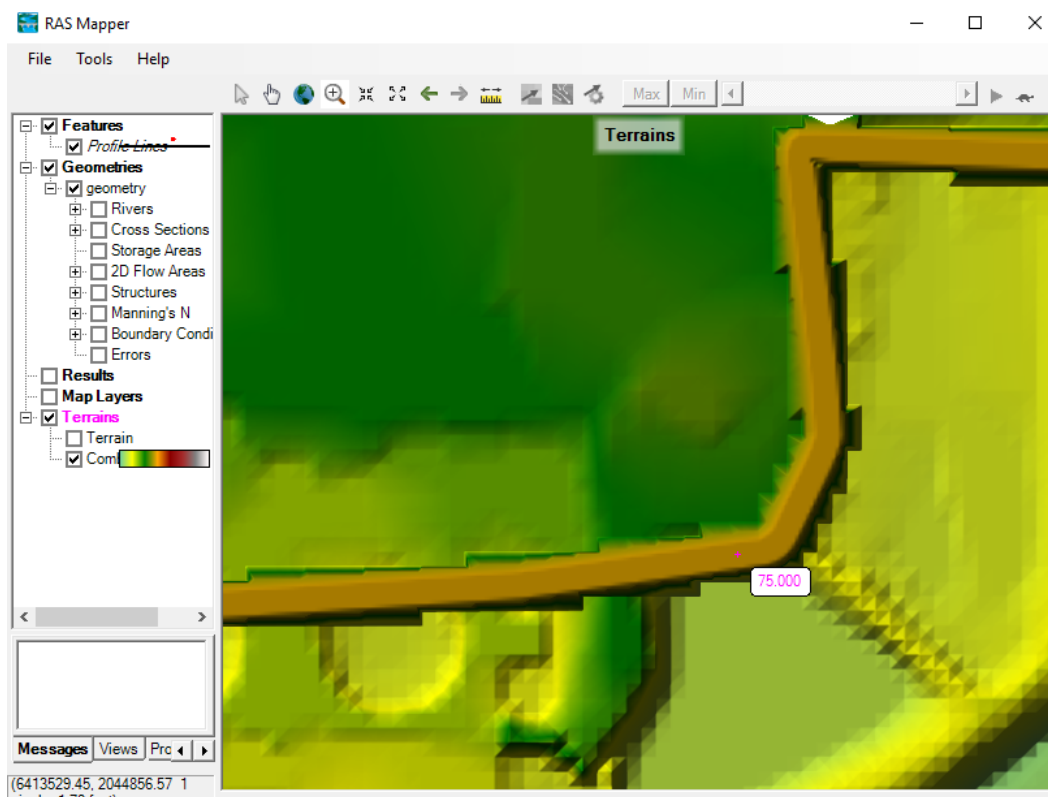


Then, export the levee as a terrain. To do this, *in RAS Mapper*, select the geometry you are using, right click on *Geometry* and select *Export Layer* and then *Create terrain GeoTiff from XS's (channel only)*. Save the terrain as for instance *Baxter_withLevee1* and use an appropriate raster size. I used 5 ft. **If you want to create a channelization (e.g., meandering for river restoration) instead of a levee**, you may use a similar approach. The only difference is that you would need to use the *Create terrain GeoTiff from XS's (overbanks and channel)* to account for the outer side slopes of the channel berms. This will be shown in the lab.

Now we need to combine both terrains (levee and original terrain). To do this, in *RAS Mapper/Tools* select the option "New terrain" and add the two terrain models. Also, give a name to the new terrain (e.g., Combined). Furthermore, make sure that the levee terrain is in the top of the list as this should have priority in the combination of terrains. Your new terrain layer, should look as follows:

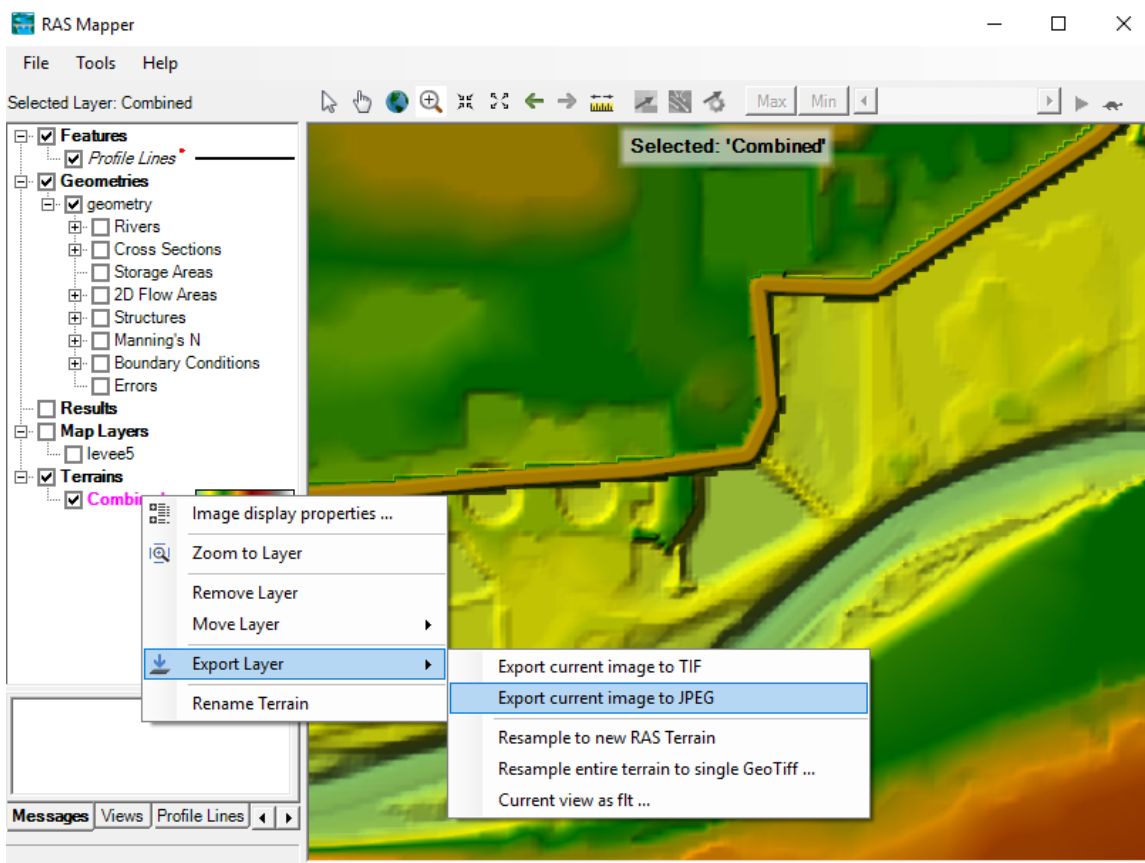



The combined terrain of my assumed levee and the original terrain is shown below.



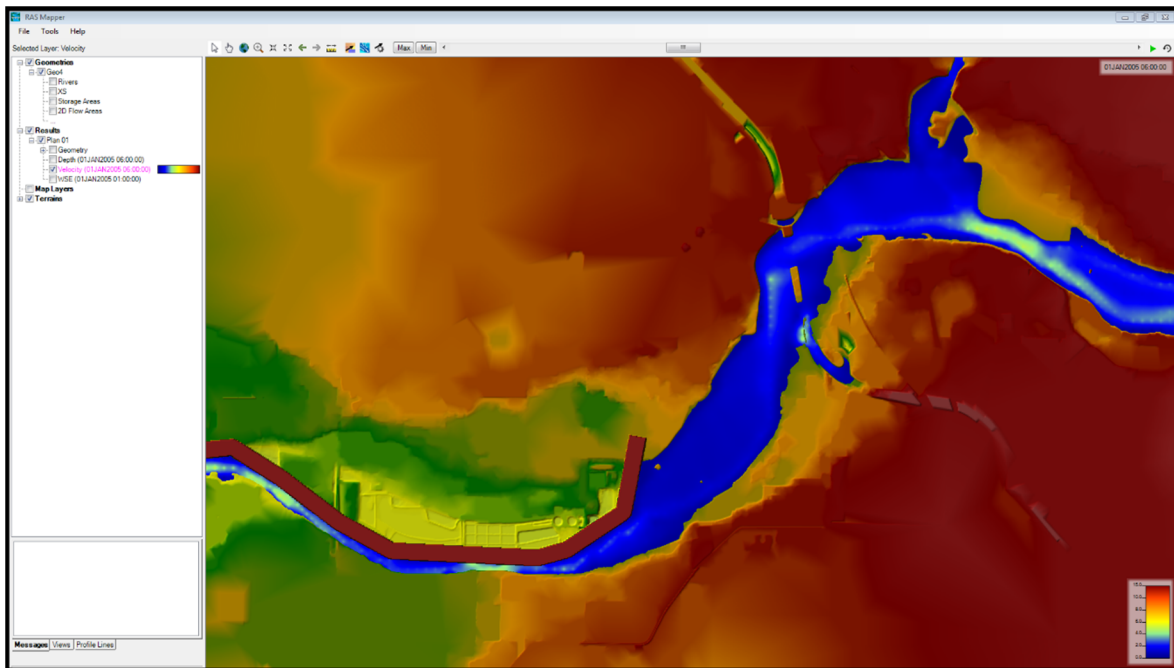
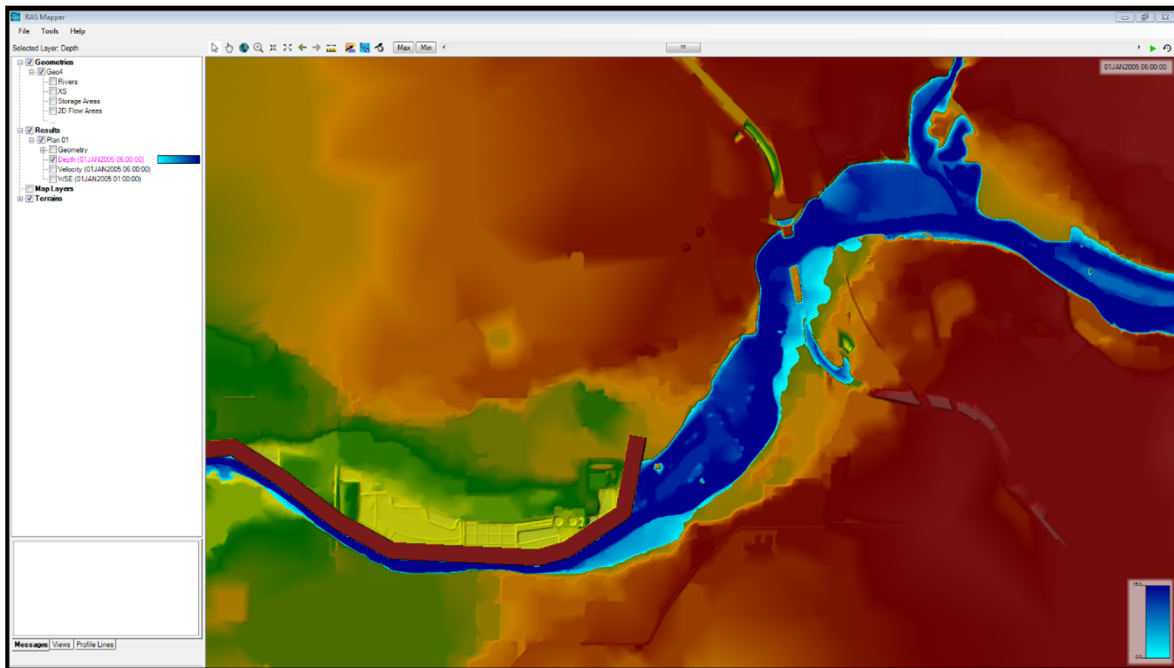
Please make sure that there is only one combined terrain in the RAS folder. If there are multiple terrains, the geometry file may not display the terrain you desire to show. If you have issues

showing the correct terrain in the *Geometry* Tab, you may want to remove all terrain other than the combined terrain in the *RAS Mapper*. Also, you may want to export the image of the combined terrain in *RAS Mapper* as follows



Assign a name to the *.jpg* image and save it. After you have exported the image you need to add it as a *Map Layer*. To do this, in *RAS Mapper* highlight and check the *Map Layers* option and right click on it. Then, select *Map data layers/Add existing layers* and search for the image you have exported. To select which background picture to show in the HEC-RAS *Geometry Data* window use the icon .

Once the combined terrain is displayed in the *Geometry* Tab, we follow the same approach described in the previous section to obtain flood inundation. Please make sure that the levee is wide enough to be well captured in the terrain model you create. At the same time, make sure that the number of cells don't exceed about 10'000,000 as the computer in the lab may ran out of memory. I used a mesh size of *Dx* and *Dy* equal to 10 ft. The two figures below show snapshots of water depth and velocity, respectively, when considering the assumed levee.



Finally, the figure below shows a snapshot of the particle tracing around the levee area.

