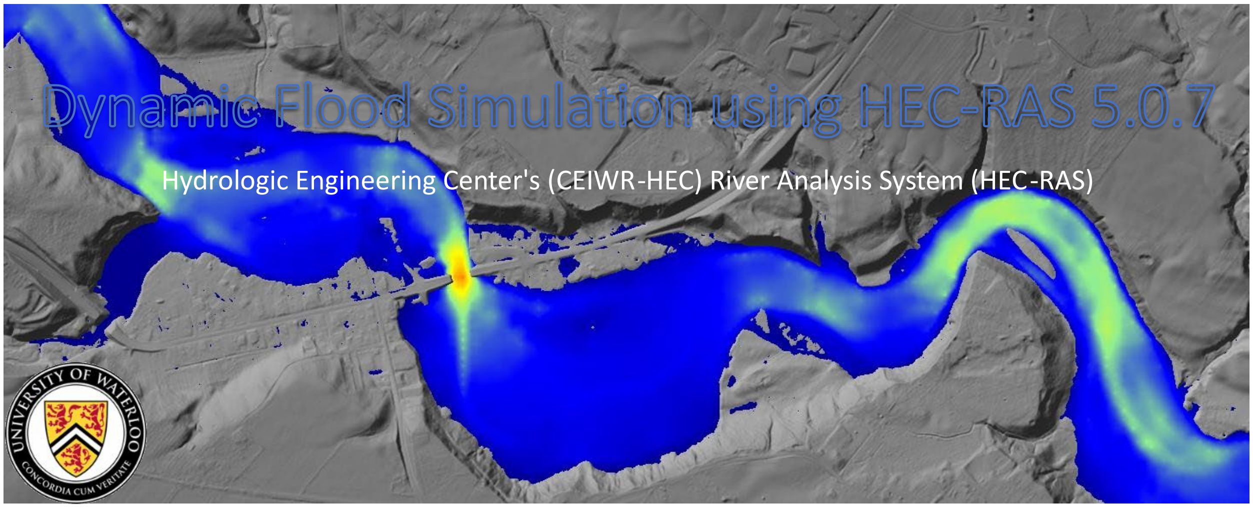

Dynamic Flood Simulation using HEC-RAS 5.0.7

Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System (HEC-RAS)

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

This tutorial is a primer for hydrological modeling using HEC- RAS. This software is exceptionally in-depth and covers many variables and types of modeling algorithms to adequately predict affected areas of a river system. This primer will cover the basics of Dynamic Flood Simulation (Unsteady Flow Modeling only) and assumes a mid-level understanding of GIS (Geographic Information System) files, file types and spatial modeling. By the end of this tutorial you will understand the basics of adding various volumes of simulated water over time to a DEM (assumes a river) to see what parts of said DEM are flooded, flow volume and visualize particle flow.

Setup

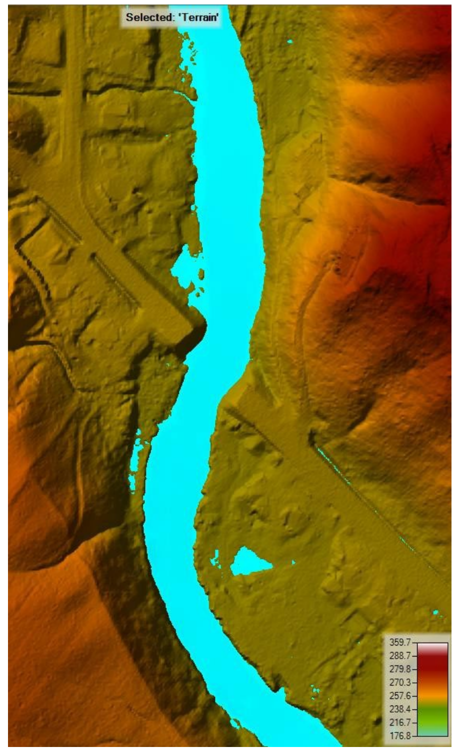
Download and install the HEC-RAS specific to your operating system. This software can be freely downloaded by anyone. While, the Hydrologic Engineering Center (HEC) has many different hydro analysis, simulation and GIS collaborative software we will only be looking at HEC-RAS.

In this guide, we are going to learn how to implement a few basic features of HEC-RAS, specifically creating a dynamic flood simulation using unsteady flow modeling only. This animated model will show depth, velocity, water surface elevation, particle tracing, and static velocity arrows on a terrain created from DEM.

Our start files are a DEM (tif with .tfw) of a river segment and a projection (.prj) file of the same river segment in the same units of measurement.

File Preparation

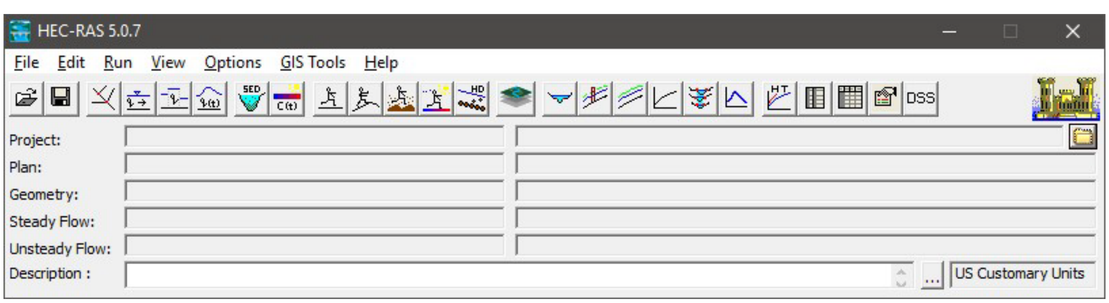
The files that are required to run a dynamic flood simulation are a "stream burned" DEM and an associated projection file. We won't be covering reaches, reach connectivity, river center lines, cut lines, banks, weirs, sediments, ice cover, etc. and their associated files.



1. A "stream burned" DEM is created as part of the process for Watershed and Stream Network Delineation. It is literally a set of bridge burning algorithms. Having this type of DEM is very important because the data collecting sensors that create the cloud point data that the DEM is based on just 'see' the tops of bridges and represent them as changes in elevation. This would block the simulated flow of water and create pools where there are none. Luckily "stream burned" DEM's are quite prevalent but first check to make sure your stream isn't blocked, if it is, there are various tools that can accomplish the required stream delineation within most GIS software.
2. The DEM being used should be of as high a resolution as possible.
3. The projection file must be of the same projection as the DEM as it sets all the measurements for the model. Unfortunately, HEC-RAS's project files have the same file extension as ESRI projection files (.prj). This is where good file management is key.

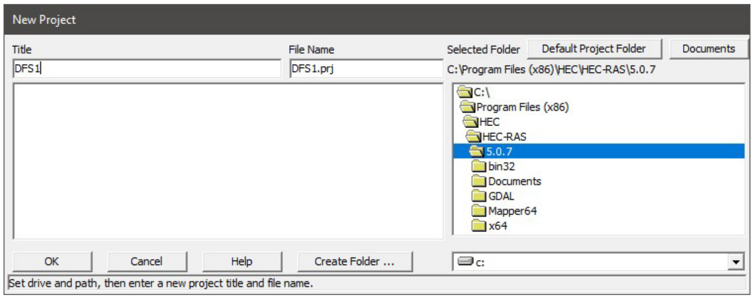
Getting Started

1. **Open HEC-RAS**

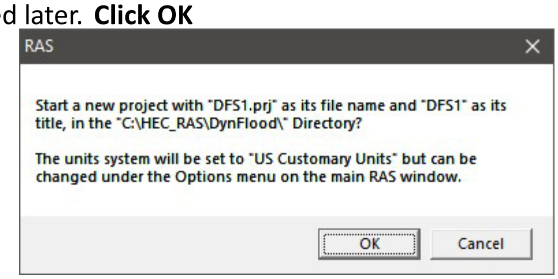


2. Select **File > New project…** on the start dialog box. Give it a title. (Be aware that the file extension is the same as a .prj projection file for a shapefile, you will have both in the project.)

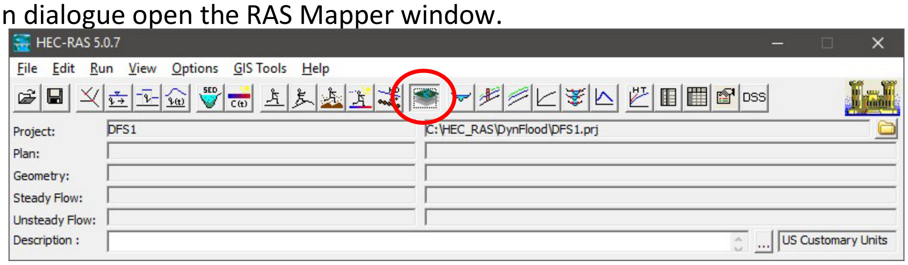
3.



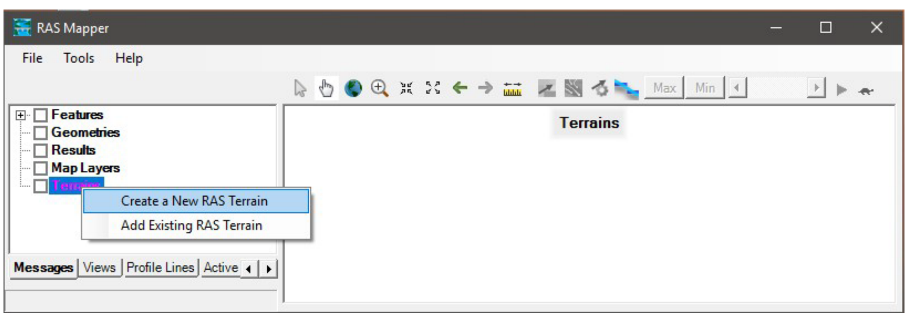
4. The Units can be changed later. **Click OK**



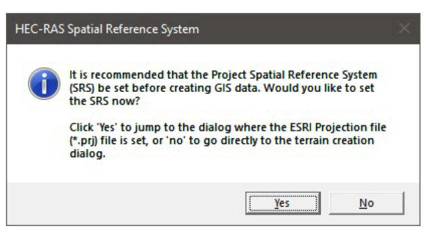
In the main dialogue open the RAS Mapper window.



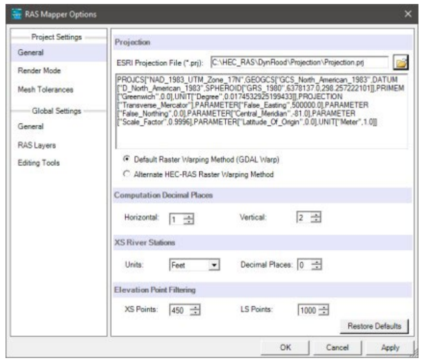
5. **Right click on Terrain > Create a New RAS Terrain.**



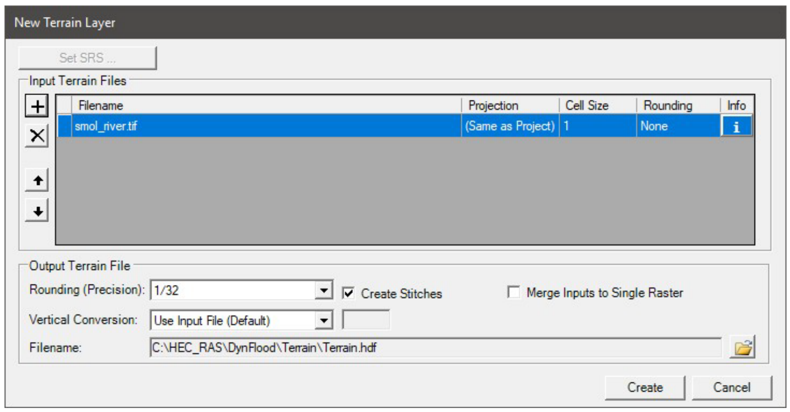
6. Click **Yes** to set the HEC-RAS Reference System



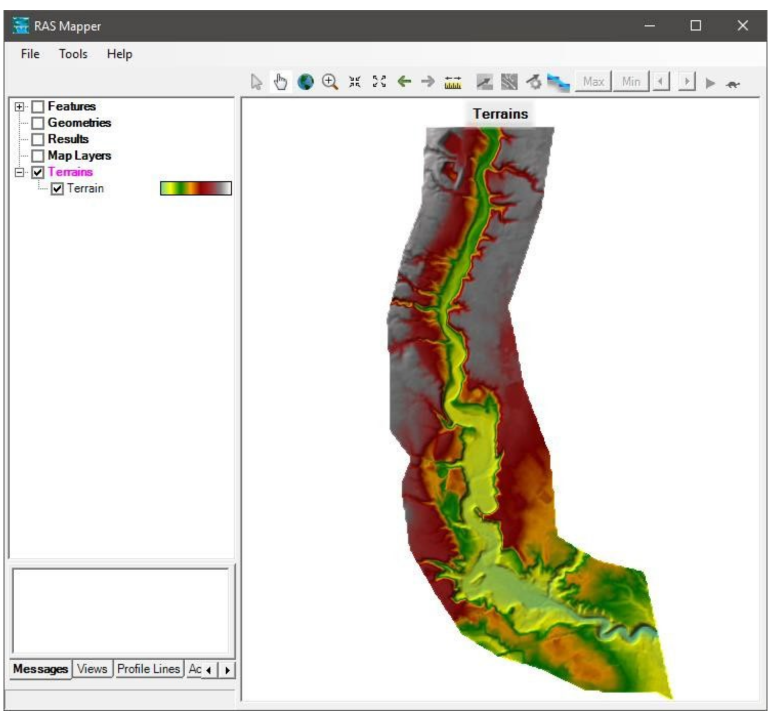
7. Select the projection (.prj) specific for the river study area (.tif)



8. Click **+** and select the river study area (.tif). Next be sure the Terrain file and folder are being created in a known location. Click **Create** – it may take some time.

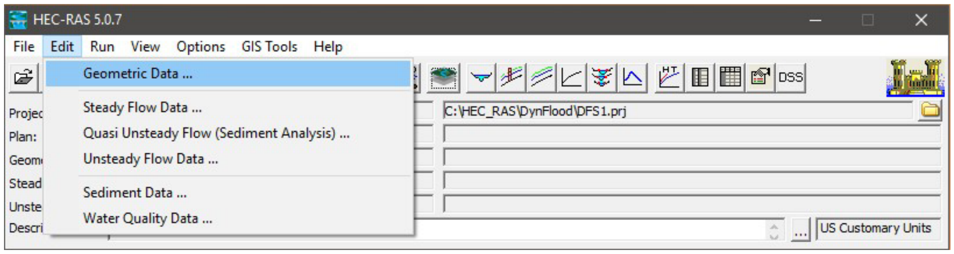


9. Result

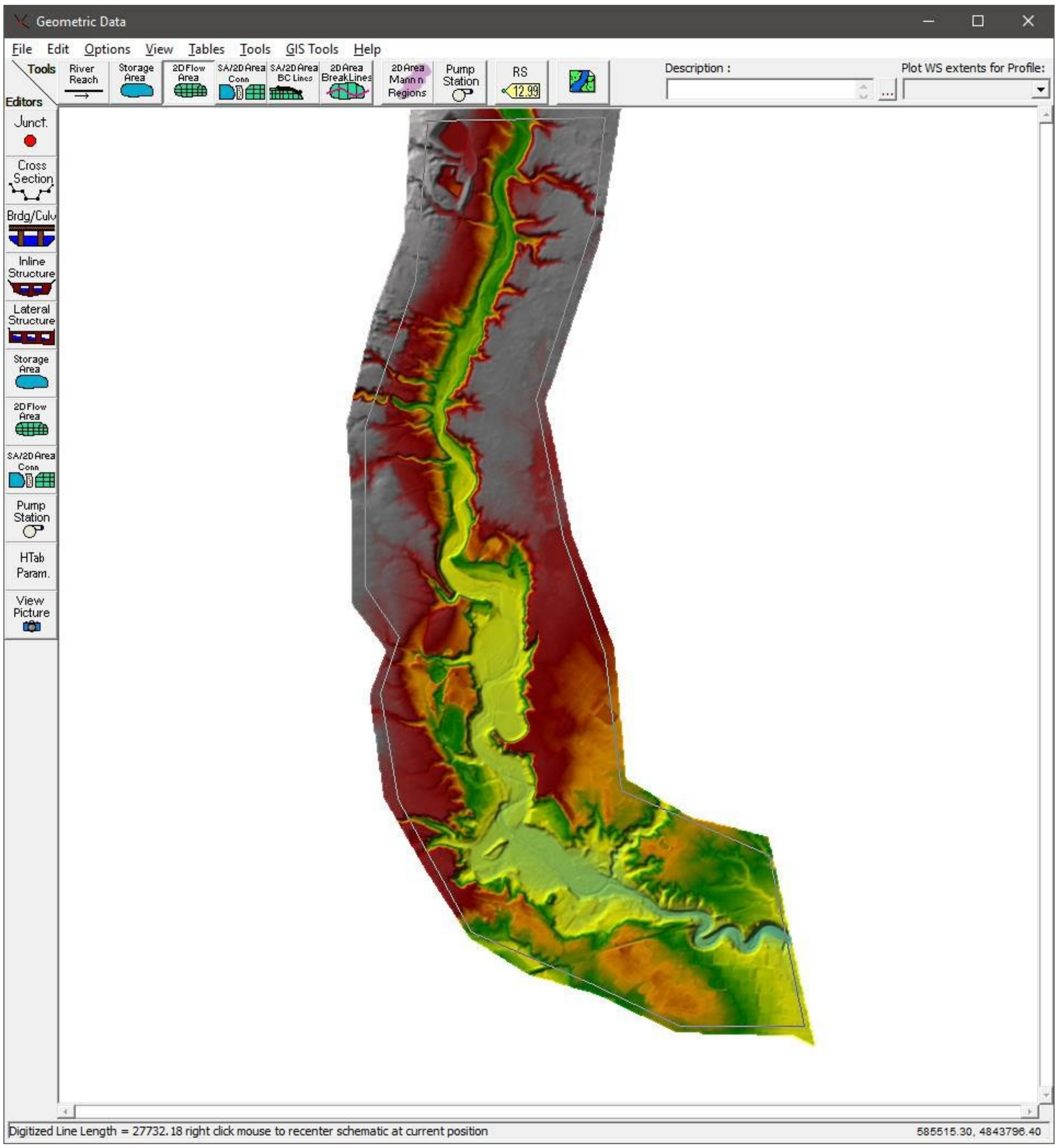


Calibrating/Creating the Model

10. Exit RAS Mapper and select **Edit > Geometric Data** on the main HEC-RAS window.



11. In the Geometric Data window is the newly created Terrain. Select the **2D Flow Area** and define the modeling area by drawing a polygon around the river within the Terrain (Ideally on the highest elevations). **Double Click** to finish the drawing and enter a name for the 2D Flow Area.

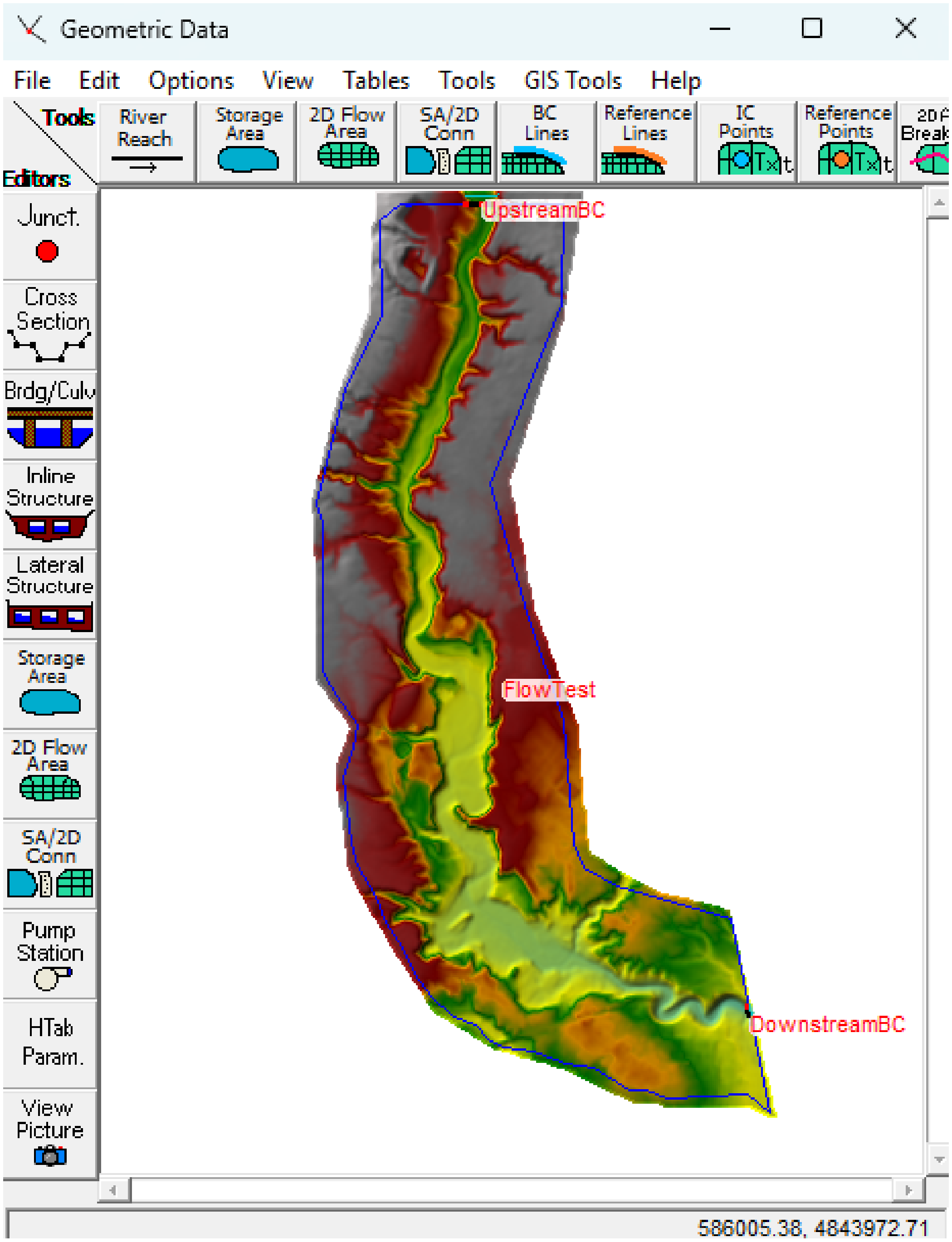


12. Remove the fill in the 2D Flow Area **Edit>Lines and Symbols…**

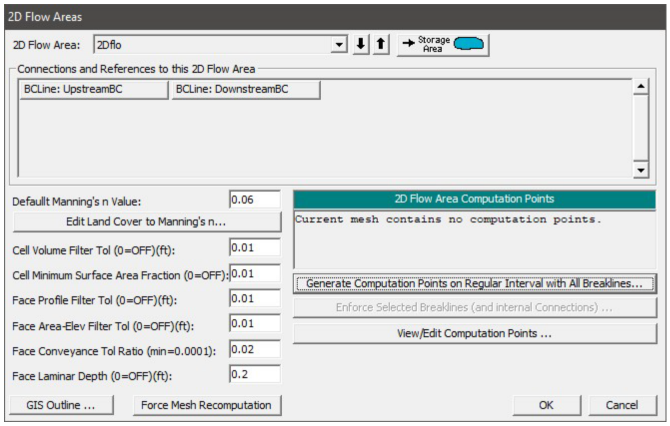
    Select the box Under the **Line/Fill** column of **Schem 2D** Row

    Click the outline box (top one) under the **Fill Pattern** column

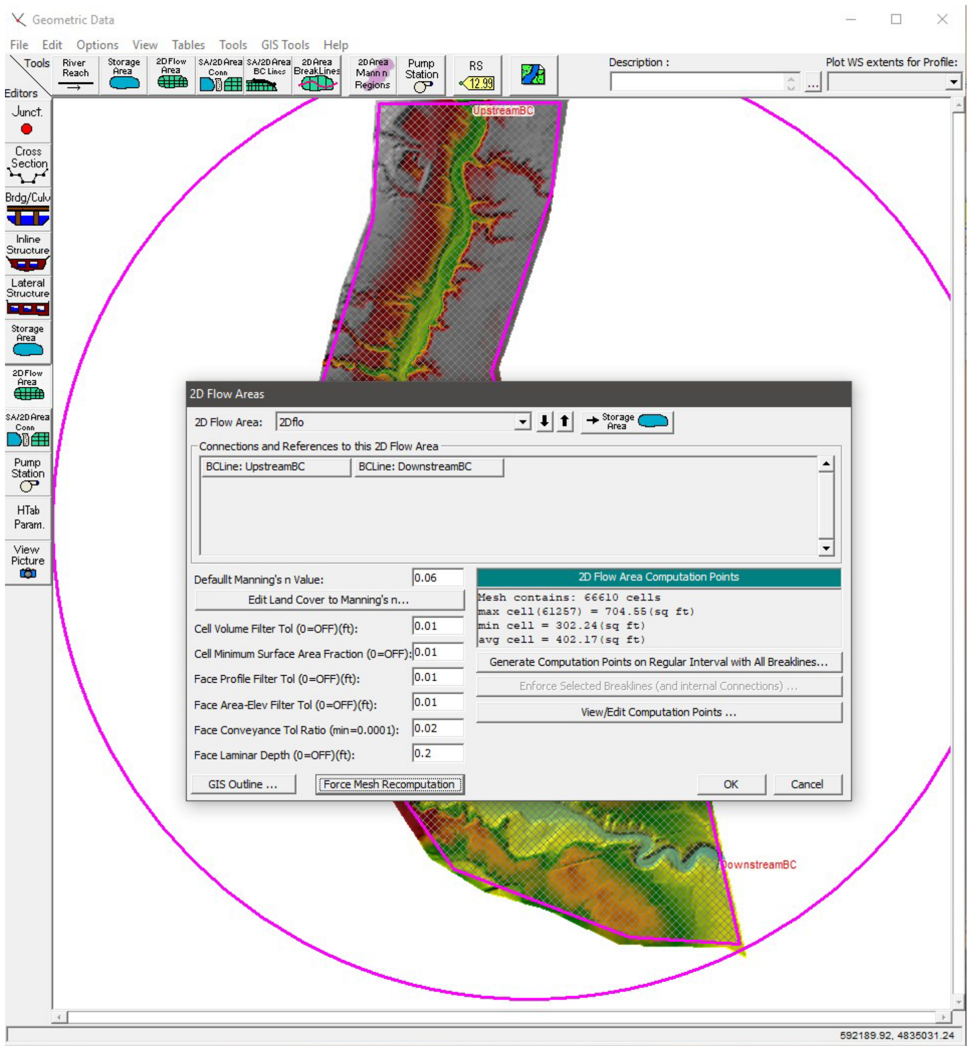
13. Select the **BC lines** option. **Boundary Conditions** are essentially telling the model what the start and end conditions are for the section of the river DEM being studied. Draw the first **Boundary Condition** (as a line) upstream on the DEM outside the 2D Flow Area and the second downstream (it will snap to the 2D Flow Area). Draw the BC bank to bank on top of water. **Dbl Click** to finish drawing. Name them both appropriately.



14. Click on the **2D Flow Area** (Magenta circle) > **Edit 2D Flow Area**.



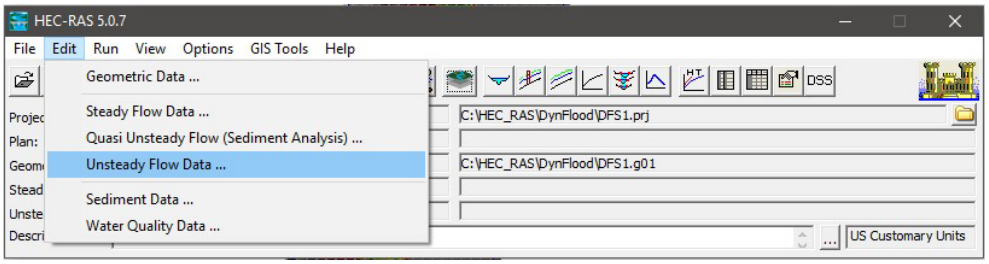
15. Click on the **Generate Computation Points on Regular Interval with All Breaklines**. **Enter** 50 in the **Spacing DX** and **Spacing DY** then **Click>Generate points in 2D flow area**. This is the size of the square mesh cells that will be created. The 2D Flow Areas dialog box will be updated with the number cells that will be created. Finally, **Click>Force Mesh Recomputation**.



16. **Click>OK**

    File > Save geometry Data As – Save in your main folder.

17. In the main HEC-RAS window, go to **Edit > Unsteady Flow Data**



18. This is where the Boundary Conditions are set. Boundary Conditions must be set as part of the model calibration. First **click the Boundary Condition box** beside **DownstreamBC**. Above, different Boundary Condition Types become available.

Brief Description:

Stage Hydrograph - flow gage data on the stream, or tidal cycle

Flow Hydrograph - gage data converted to flow

Stage & Flow - combined observed stage and forecasted flow

Rating Curve - rating at a gauged location, or steady-flow rating

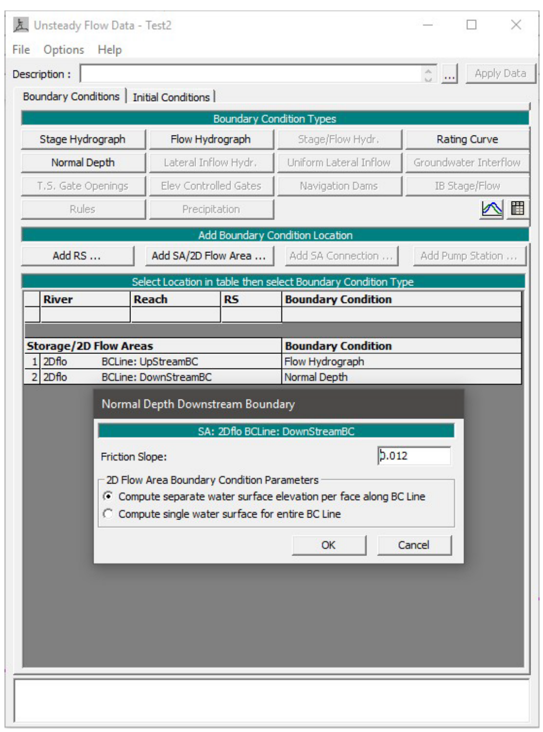
Normal Depth - average slope of stream to estimate energy slope

Since this is only a primer we are going to keep this simulation as straight forward as possible. For the **DownstreamBC select Normal Depth**. Set the Friction Slope to .012 it is derived from Slope Calculation: Rise/Run

(highest raster elevation) 252.71m – (lowest raster elevation) 211.71m = 41m

(rough length of river) 3400m

Slope: 41m/3400m = .012



19. Second **click the Boundary Condition box** beside **UpstreamBC** and **select Flow Hydrograph** This will be setting the volume (m^3/s) of “water” flowing into the model from up stream.

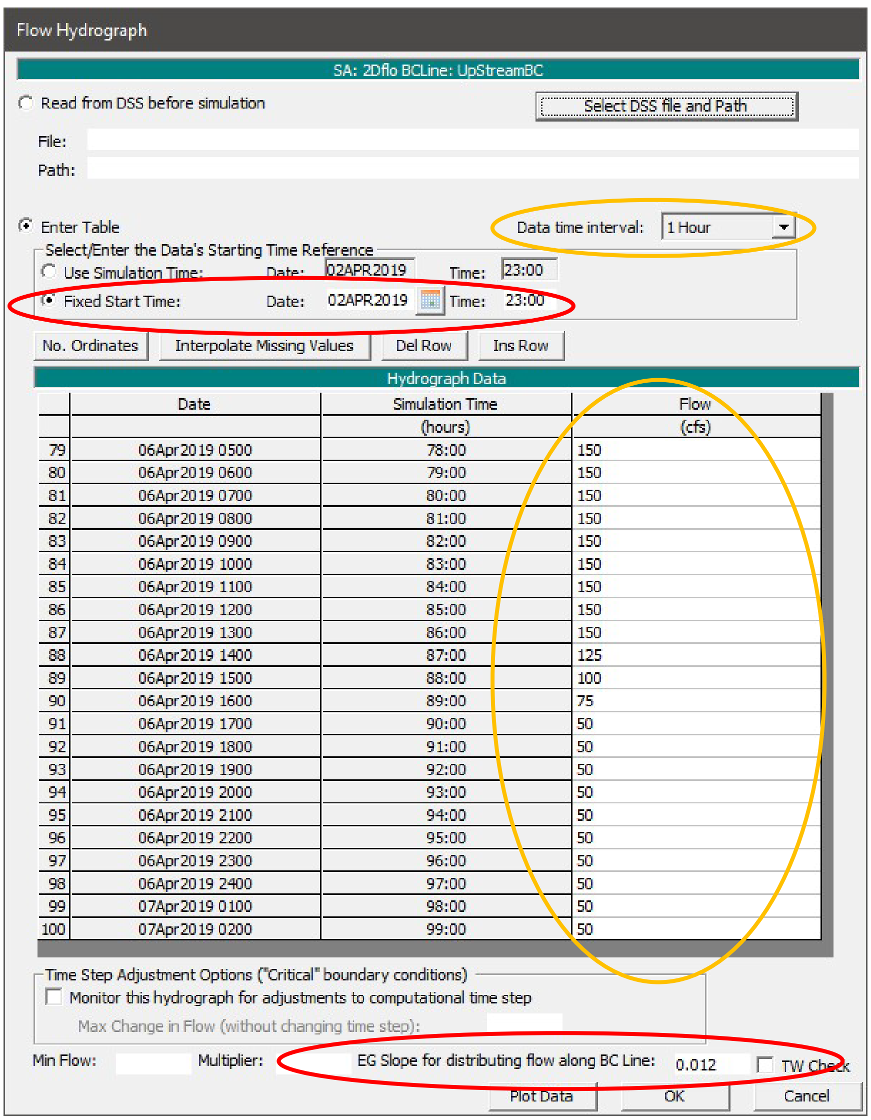
Select Fixed Start Time: Pick a date and time (24h) further than 5 days in the past as the **Hydrograph Data** chart is automatically filled in hourly (Data time interval: 1 Hour) 5 days forward of your chosen date.

In the **Hydrograph Data** chart start filling in the Flow (cfs) with real numbers or fun numbers.

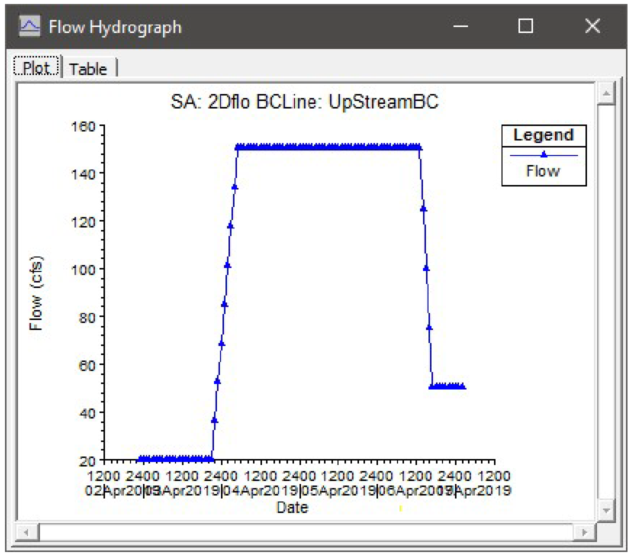
Row 1 – 20 is a good start to "fill" the river model
Row 24(?) – 20 to give the model time to "fill"
Row 31(?) – 150 start flooding…
Row 87(?) – 150
Row 91(?) – 50 ramp down the volume in the model
Row 100 – 50

Click Interpolate Missing Values. It will fill in the values in-between and ramp them to the different volume.

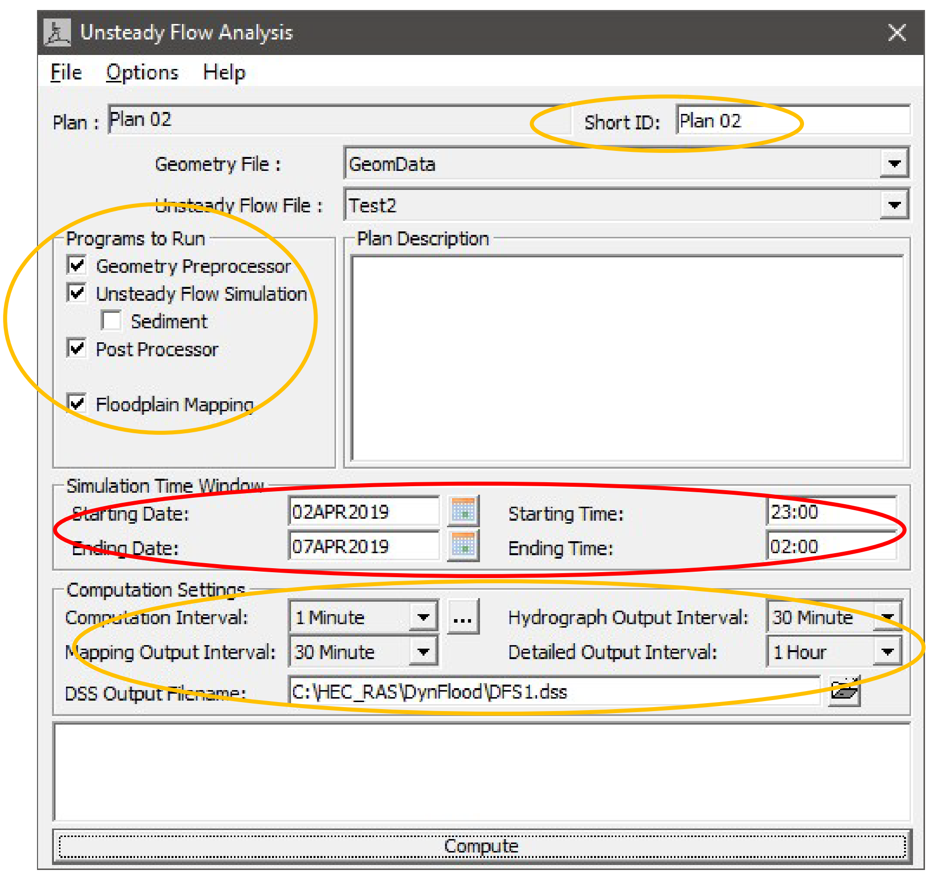
Be sure to set the **EG Slope for distributing flow along BC Line: 0.012** the same as our calculated slope.



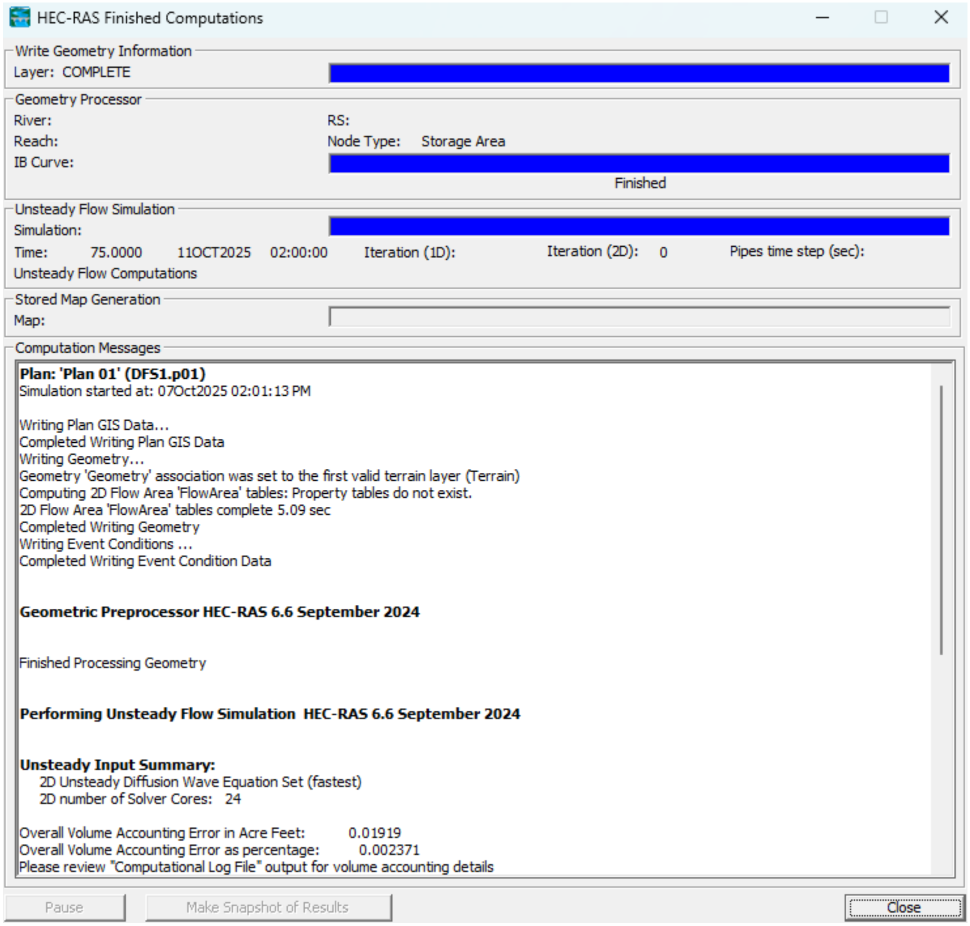
20. To see the flow curve **Click Plot Data**



21. Save the unsteady Flow created:
    Unsteady Flow Data dialog - File **> Save Unsteady Flow Data**
22. Back on the HEC-RAS main dialog **Select Run > Unsteady Flow Analysis**. Select the options as shown in the image below. Give the analysis a **Short ID**. Ensure the **Start Date** and **End Date** correspond with your **Flow Hygrograph** date time. To start **Click Compute**.



23. Success:



Running the Simulation

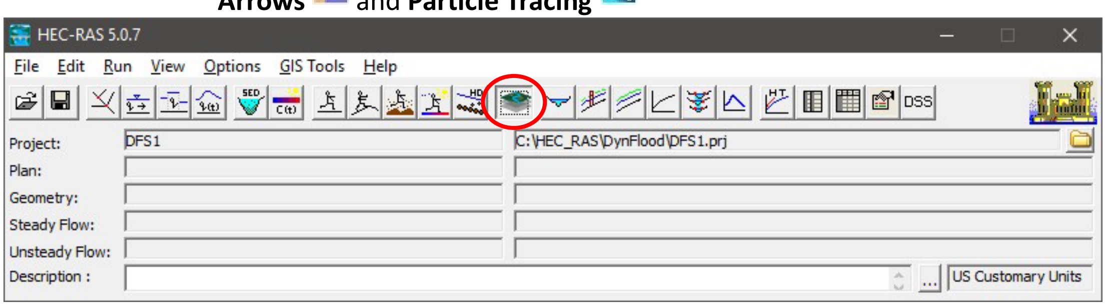
24. To visualize the results of the computations open the RAS Mapper window the main dialogue box.
    Under **Results> Check 'Your Plan'**

The simulations that can be run are Depth, Velocity and WSE (Water Surface Elevation)

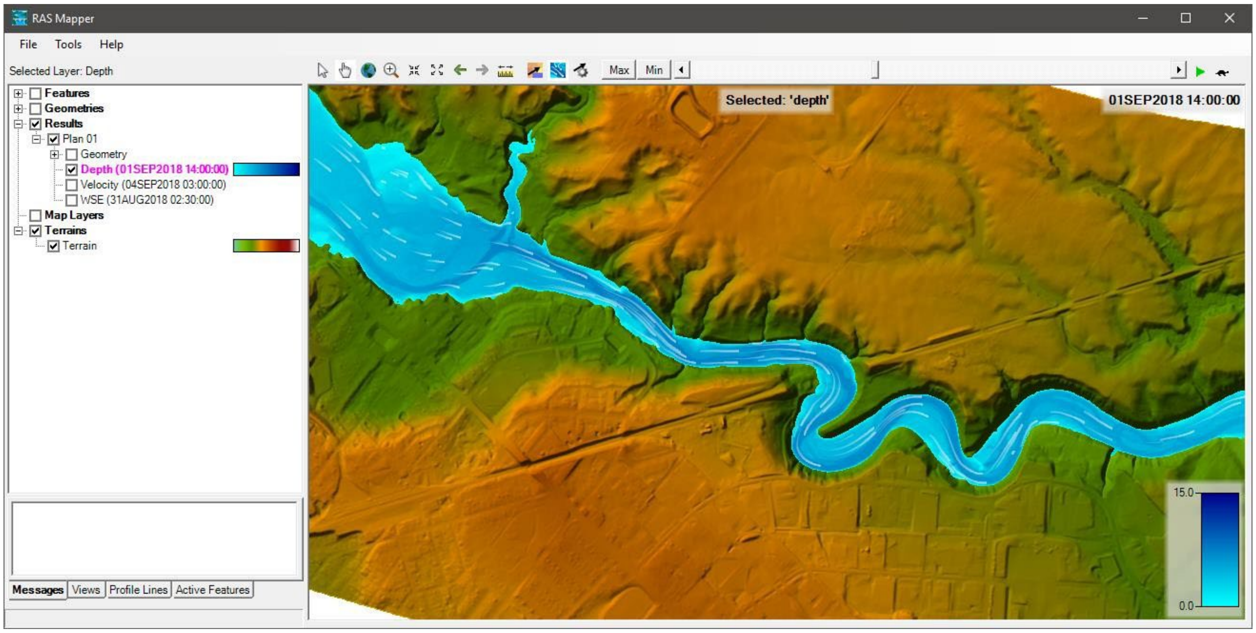
Just Press Play

The time can be adjusted with the slider.

With any of the simulations checked on can show the **Static Velocity Arrows** and **Particle Tracing**



Simulation running with Particle Tracing.



Wrapping Up

As mentioned in the introduction HEC RAS is computational hydrology software that can account for many variables. This tutorial has only covered one small part of HEC RAS. With your simulation up and running try changing some of the variables to see their effects. Start slow, and look into websites like 'HEC-RAS Help', NOAA's National Weather Service 'Hydrologic Science and Modeling Branch (HSMB)', 'researchgate.net' etc.

Trouble Shooting Hints

Check your **2D Flow Area** mesh for errors – The software will highlight problem areas after generation, right click to edit the mesh.

Force Mesh Re-computation again. This wills solve some 2D Flow Area mesh errors.

Try making the **2D Flow Area** mesh cells larger so there are less to render

Make sure the **BC**'s are drawn outside the **2D Flow Area** as the default is 'External'

Double check that your **Friction Slope** (Normal Depth Downstream Boundary) and **EG Slope for distributing flow along BC Line** (Bottom of Flow Hydrograph chart) – for this example they are the same number.

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