Bridge Hydraulics with the Hydrologic Engineering Center River Analysis System (HEC-RAS)

TRAINING MODULE 1A – WORKSHOP

PREPARED BY GERALD BLACKLER, PE, PHD

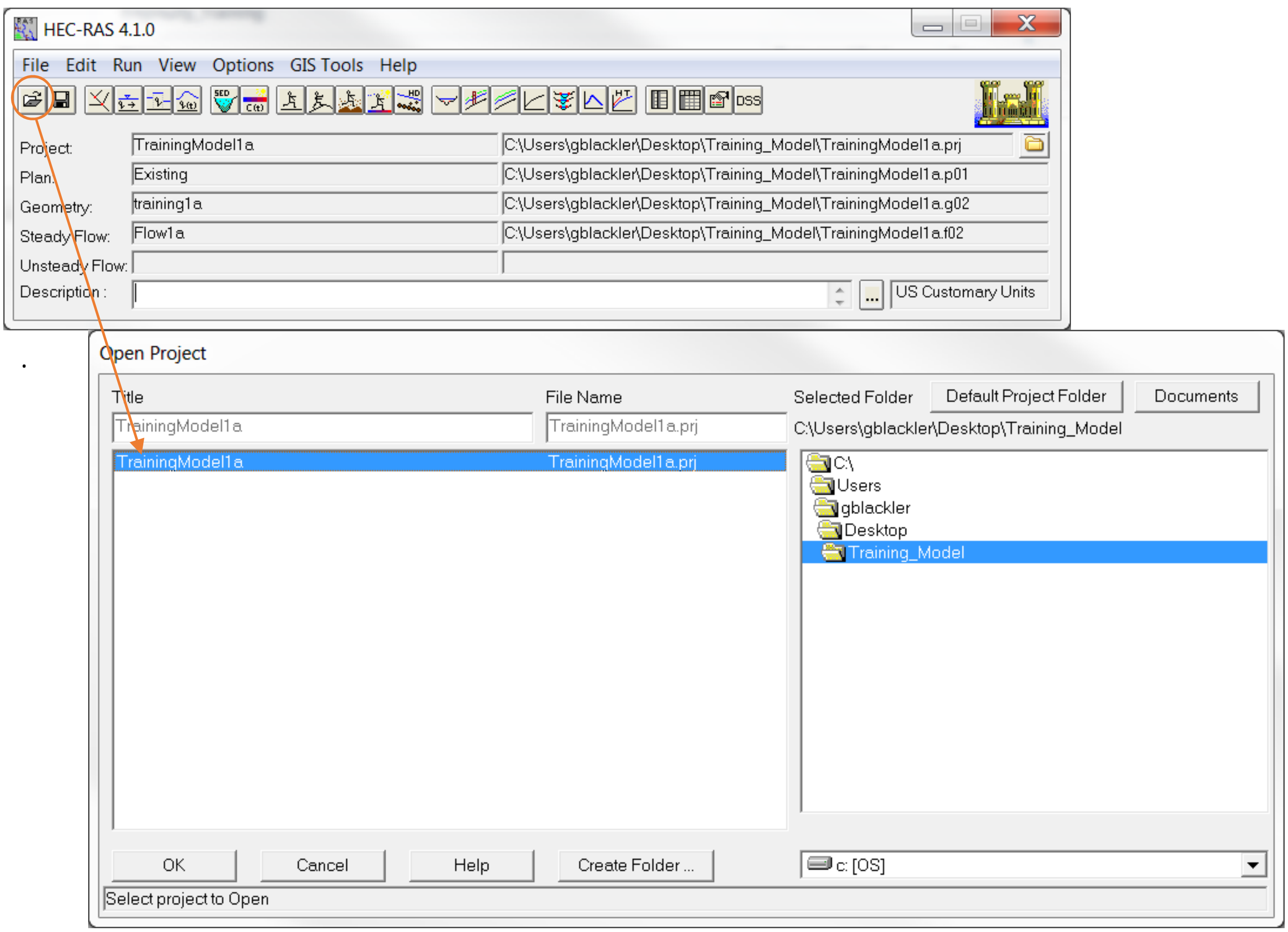
This training module focuses on correctly placing HEC-RAS Sections, coding in bridge deck and pier values, and how to select the appropriate bridge modeling approach. Original data used for this model was taken from a design project with Federal Highway Administration and has been modified to be strictly fictional.

1. LET'S GET STARTED

Download the Training folder provided and place in your Documents Folder. Then open HEC-RAS by going to:

Start menu → all programs → HEC→ HEC-RAS→HEC-RAS 4.1.0

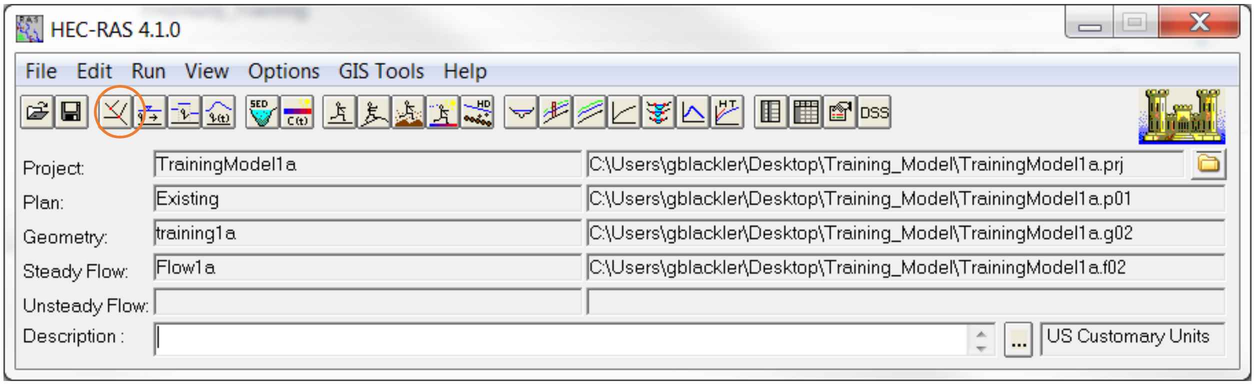
In HEC-RAS click the open folder in the upper left and navigate to your training folder. Then open the model **TrainingModel1a** and hit *OK*.



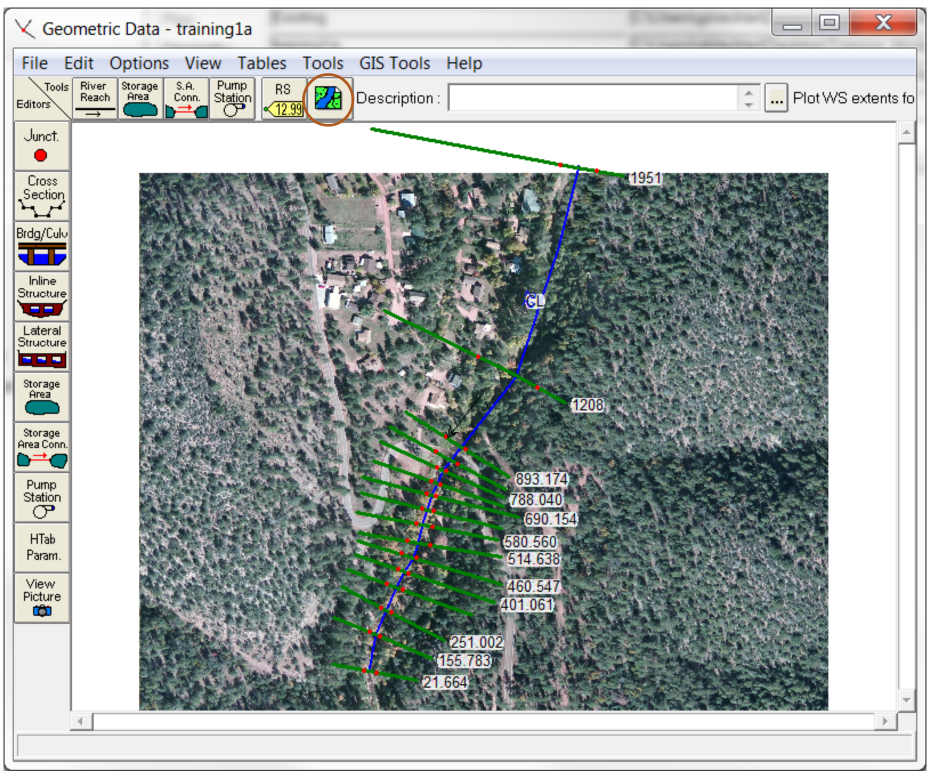
2. OPEN THE EXISTING HEC-RAS GEOMETRY FILE

When you open the HEC-RAS File, it should look like the image below.

- Click on the **enter/edit geometric data** button that is circled in the image below



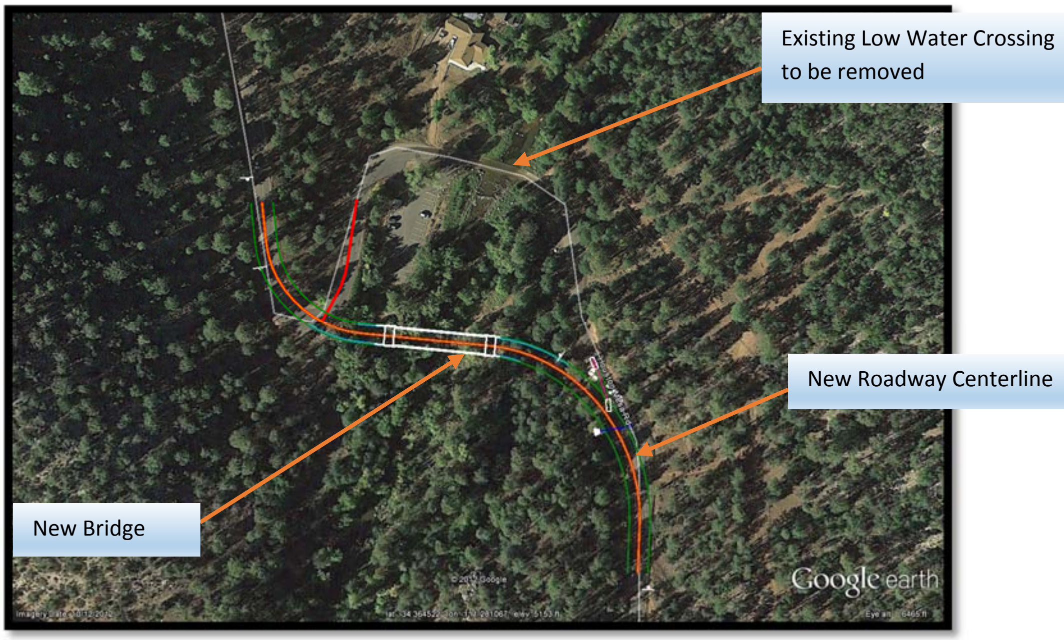
The existing geometry should open with a background photo like the image below.



If the background image does not appear, select **the Add edit background image** icon and select **Add→photo1.gm_w_imagery.web**. There should now be an image behind the cross sections and streamline.

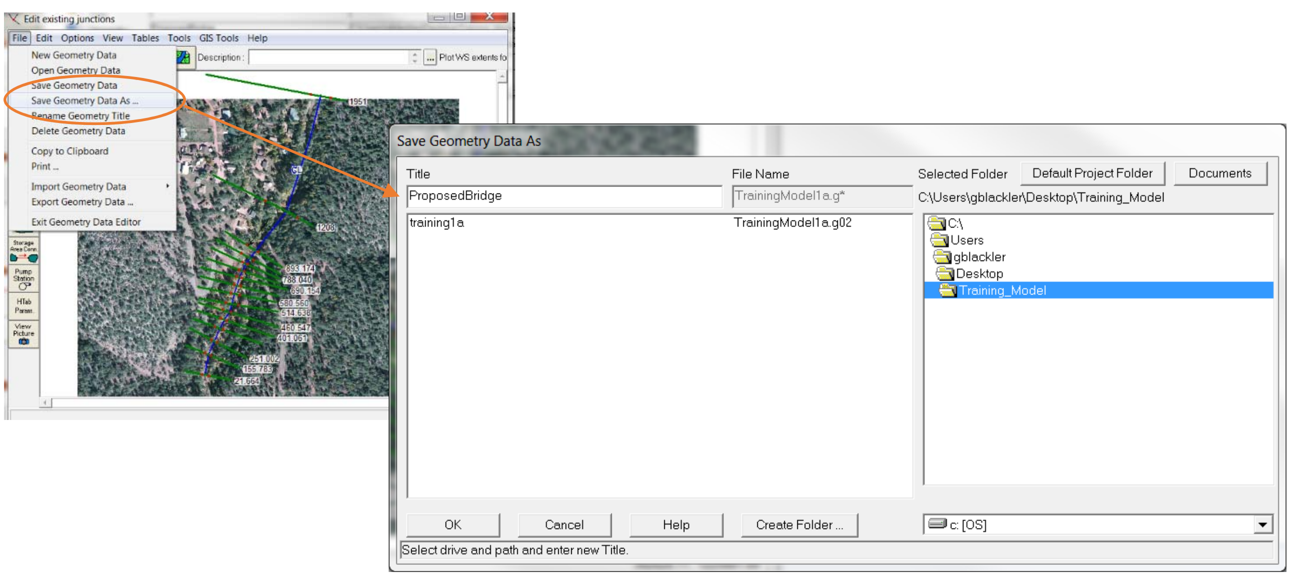
3. CREATE A BRIDGE DECK IN A NEW HEC-RAS GEOMETRY FILE

Our hypothetical project scope is to remove a low water crossing that has caused flooding to adjacent houses and remove hairpin turns that are slowing traffic during tourist season and are a safety hazard during the winter months. The image below shows the existing roadway along with our new roadway alignment and bridge location.

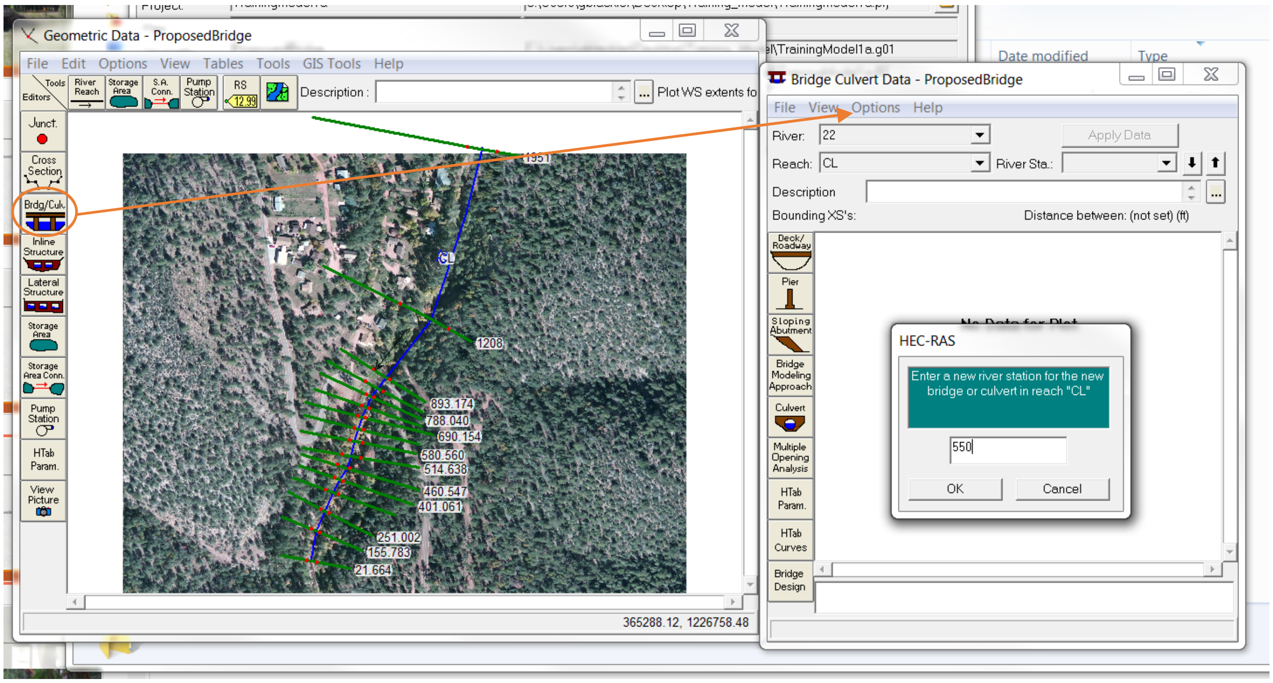


Now, let's create a proposed conditions model from our existing geometry:

1. In the geometric data editor go to **File→Save Geometry Data As** and save our new geometry as **ProposedBridge** and hit OK.

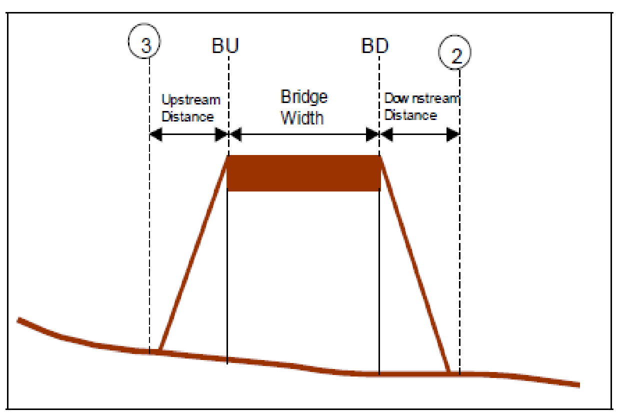


2. Add in a bridge by selecting the Bridge/Culvert icon in the left tool bar. When the bridge culvert data opens go to **options→add bridge or culvert**. Enter the station **550** for our bridge location.



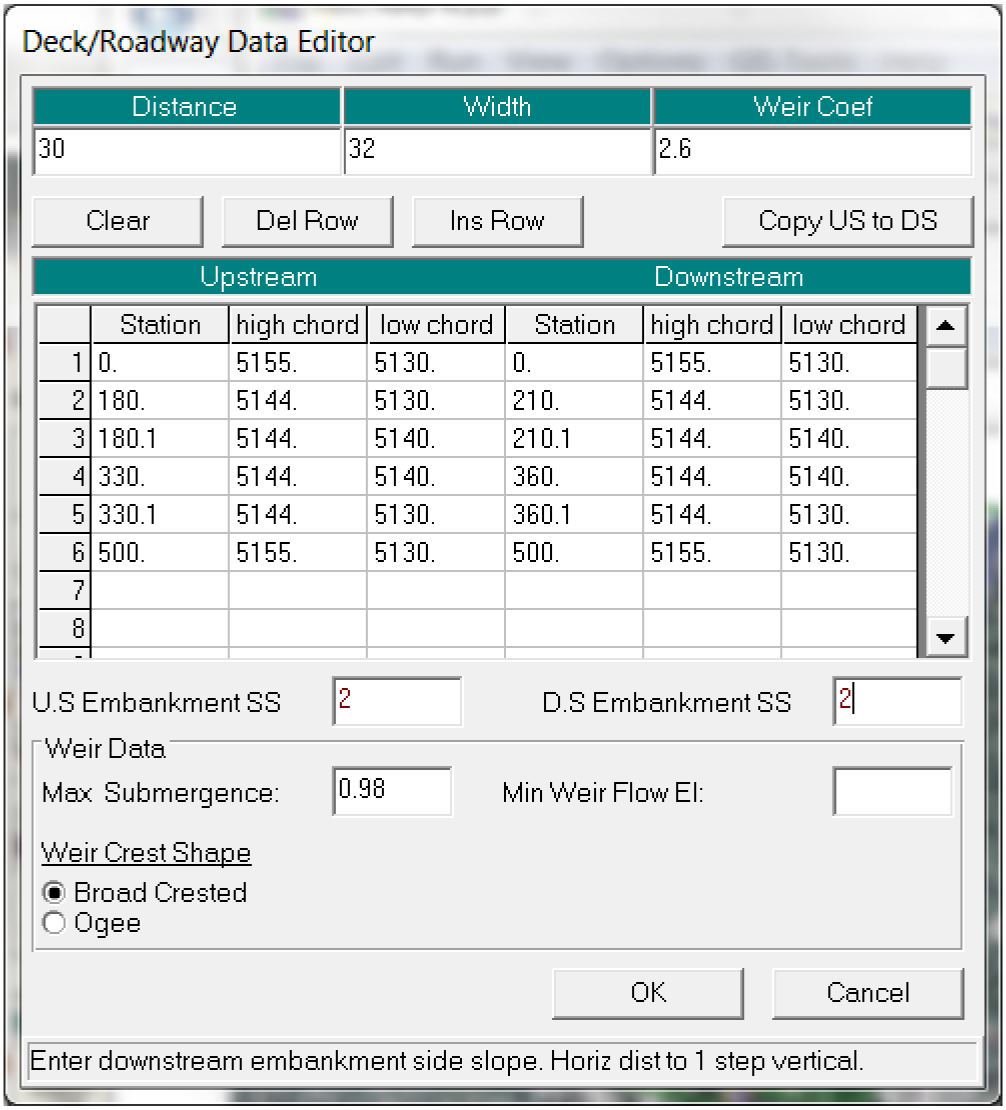
The bridge culvert data editor should now show your upstream and downstream cross sections (580, and 515). Now, let's add our deck/roadway information for our new alignment.

3. Select the Deck Roadway icon on the left tool bar and let's enter the following information:



   a. **Distance:** This is the distance from the *upstream* cross section to the new bridge deck. For this exercise, we know that it's approximately **30 feet**.
   b. **Width:** This is the bridge deck width in the direction of flow that would be determined by the roadway design standards for travel. For this exercise, we know it's **32 feet**.
   c. **Weir Coef:** This is the weir discharge coefficient for pressure/weir flow. Leave at a default of **2.60.**

d. **Deck Geometry:** This is where we enter the geometry of the new bridge by cross section stations (up and downstream) and by high and low chord (top of deck and bottom of stringers or beams) and by the upstream and downstream embankment side slopes. Complete the table per the caption below:



Select ***OK***

4. ADD PIERS TO BRIDGE MODEL

After examining the length of bridge required to pass the design flow, our structural engineers have stated that we cannot build a single span bridge and instead need it to be three sections at **50 foot** each: Piers that are **4 feet** wide and span the width of the deck (**32 feet**) will be constructed at each section. Below elevation **5130** the piers will be on piles that are **5 feet** wide and **10 feet** deep.

Let's begin to add piers to our hydraulic model:

a. Select the Pier icon 

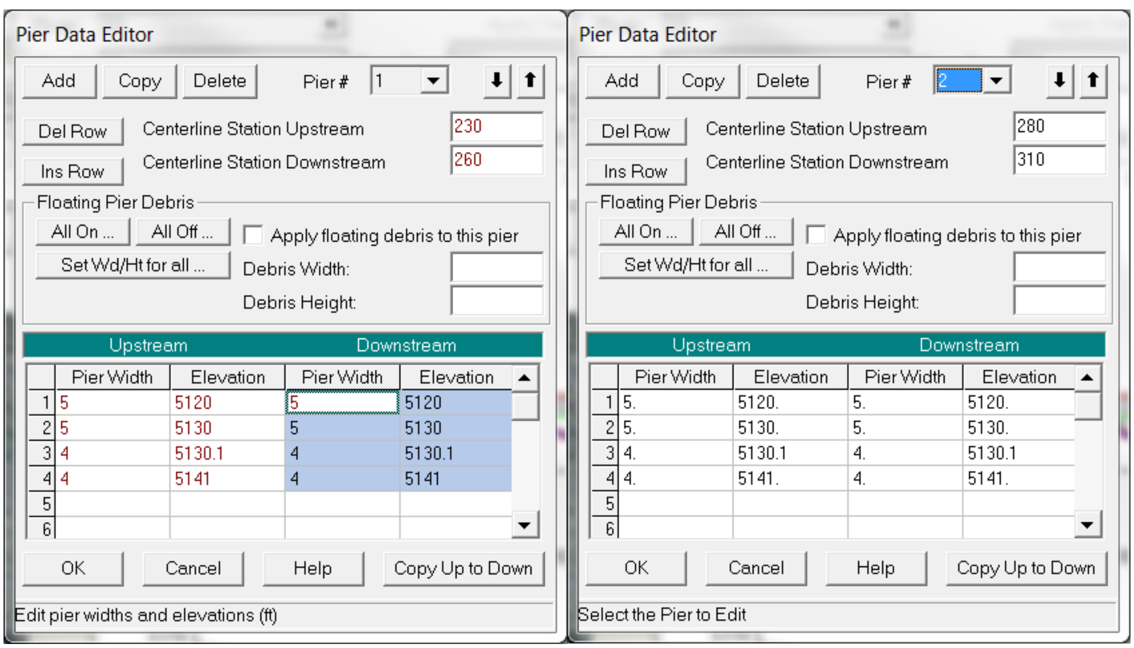
on the left of the Bridge Culvert Data Editor.

b. In the Pier Data Editor, begin to enter the pier stationing:

   a. Recall, our bridge is **150 feet** with three spans our piers will be at 50 and 100 feet from the start of the bridge.

c. Enter the bridge stationing of 230 and 260 for the Centerline Station Upstream and Downstream respectively, and the pier widths and elevations as shown for pier No. 1 below.

d. When done, select **Copy** and then change the Centerline Stations for Pier No. 2 to 280 and 310.



Select *OK*, and our Bridge Data Editor should now show two piers at 30 feet from the beginning and end of the new bridge.

Note: We won't see the 5 foot wide foundations because the ground level is higher than our piles. If the ground scoured away, we would then see the wider section of the piers.

5. ADD BRIDGE ABUTMENTS TO HEC-RAS MODEL

Abutments are designed to protect the bridge foundations from scour or failure during flood events. There are many types of abutments (See HEC-23 or HEC-18 published by the Federal Highway Administration), and some of the more common in water ways are spill through abutments and vertical wall abutments. A spill through abutment consists of sloping rock riprap and fill that protect the abutment foundation, while a vertical wall abutment is typically concrete or stone and stands vertically from the bridge deck to the stream bottom. Below are photographs of spill through (left) and vertical (right) abutments.

Spill through Abutment

Vertical Wall Abutment

*Left photo taken by Gerald Blackler in CA 2011 right taken by Gerald Blackler in AZ, 2013

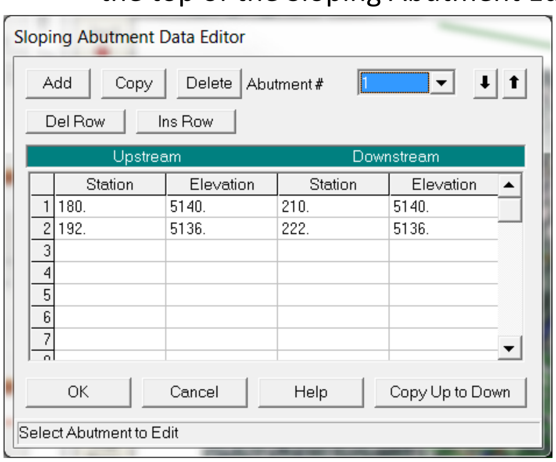
Sloping abutments can be added two ways, 1.) using the Sloping Abutment icon 

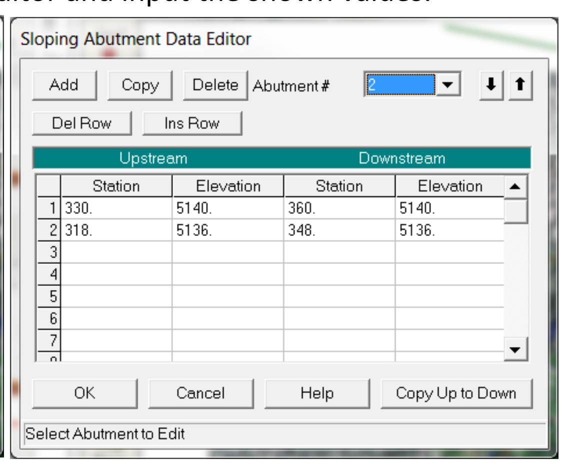
and 2.) by adjusting the internal cross sections under the **Options →Internal Bridge Cross Sections** editor.

We will input our sloping abutments using the Sloping Abutment Editor.

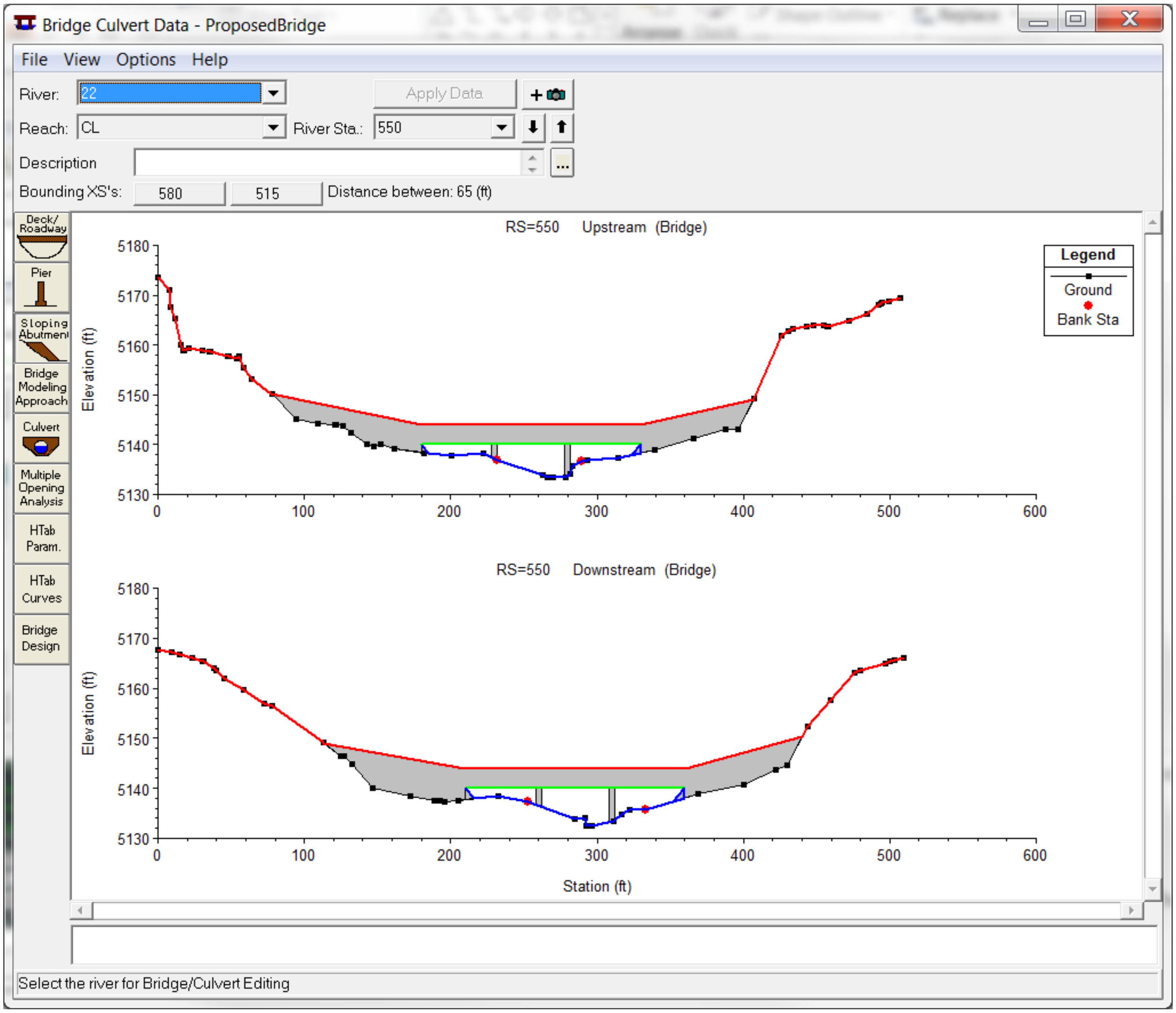
1. Click on the Sloping Abutment icon 

in the bridge editor.
2. Input the sloping abutment values as shown below, to add Abutment #2, click **Add** at the top of the Sloping Abutment Editor and input the shown values:

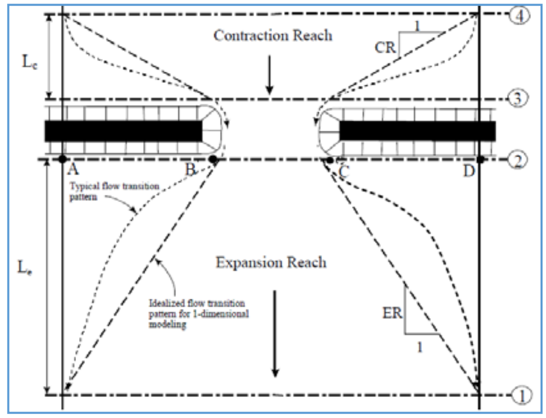




The bridge should now look like this with the deck, pier, and abutment information added:



6. ADDING INEFFECTIVE FLOW AREAS AND CONTRACTION AND EXPANSION COEFFICIENTS

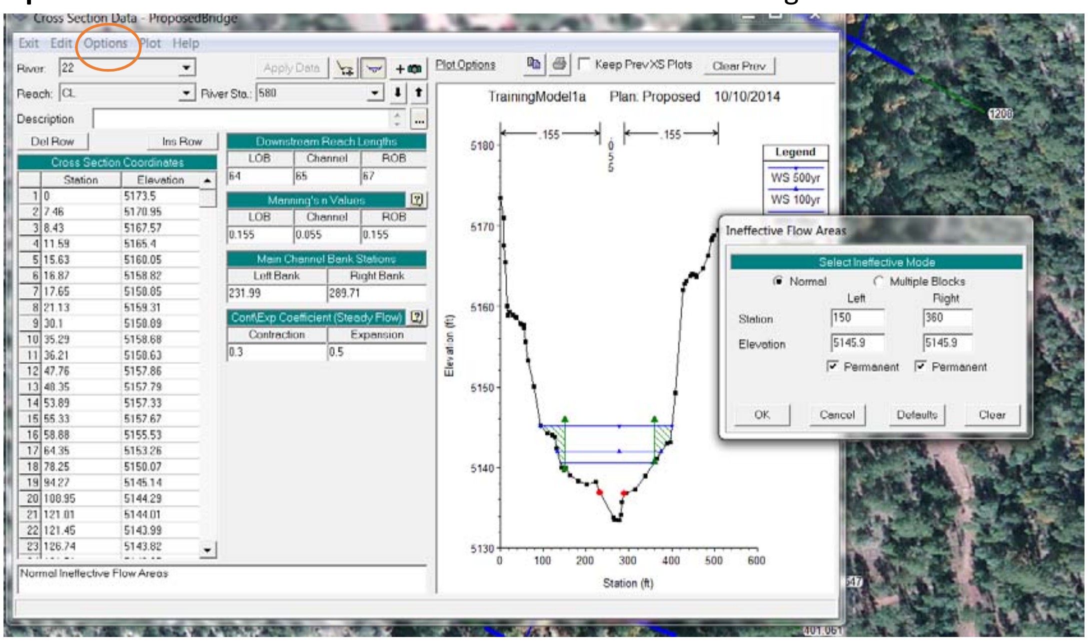


Recall our contraction and expansion diagram shown on the right. For this example, our model fits well within the typical range of expansion and contraction ratios, which are:

- Contraction Ratio (CR)=1
- Expansion Ratio (ER)=3
- Contraction and Expansion Coefficients =**0.5** and **0.3**, respectively.

1. Go into the cross section editor by clicking on the cross section editor icon 

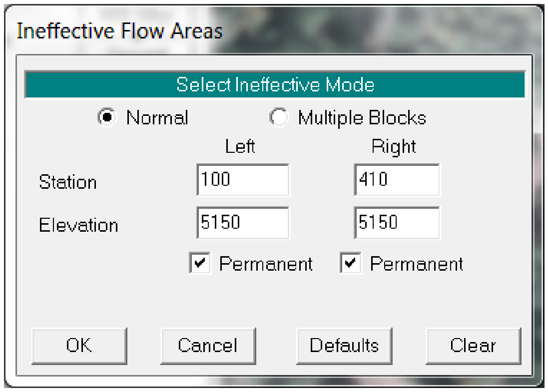
 in the geometric editor.
2. Go to the cross section immediately upstream of the bridge (River Station 580) and click **Options→ Select ineffective flow** areas as shown in the image below.



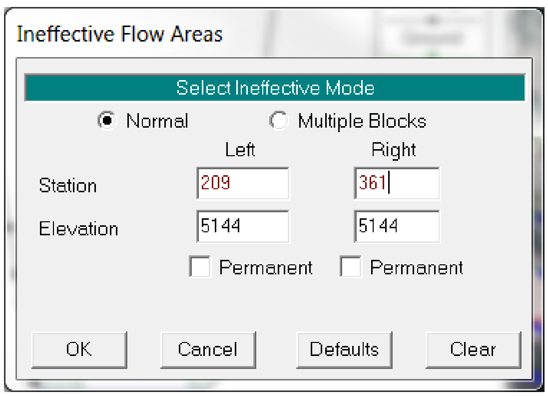
3. Within the ineffective flow editor select normal and permanent, and enter the appropriate left and right stations shown in the image above.

Click *OK.*

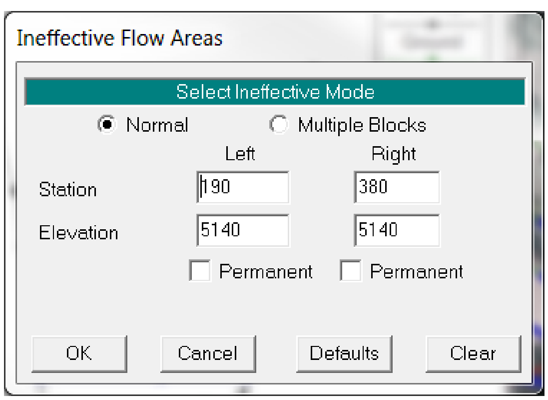
4. Move up to station 635.884 and enter the following left and right ineffective flow areas.



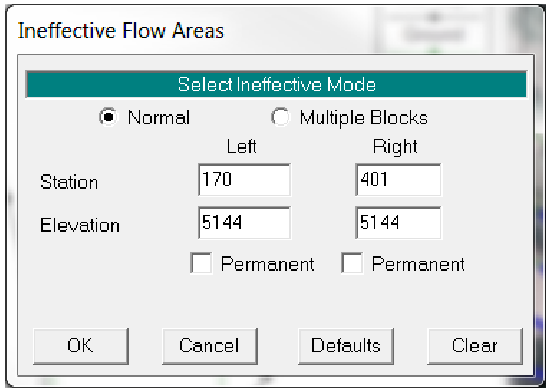
5. Go to Station 515 and enter the ineffective flow areas as shown below. How do we know? Well, we know the downstream length from Sta 580 is 65 feet. The bridge is 32 feet wide and 30 feet from that station, so the remainder length is **65-(30+32)=3 feet**. At a **3:1 ER**, this is a **1 foot adjustment** from the bridge opening. (Note: We do not select permanent on downstream sections).



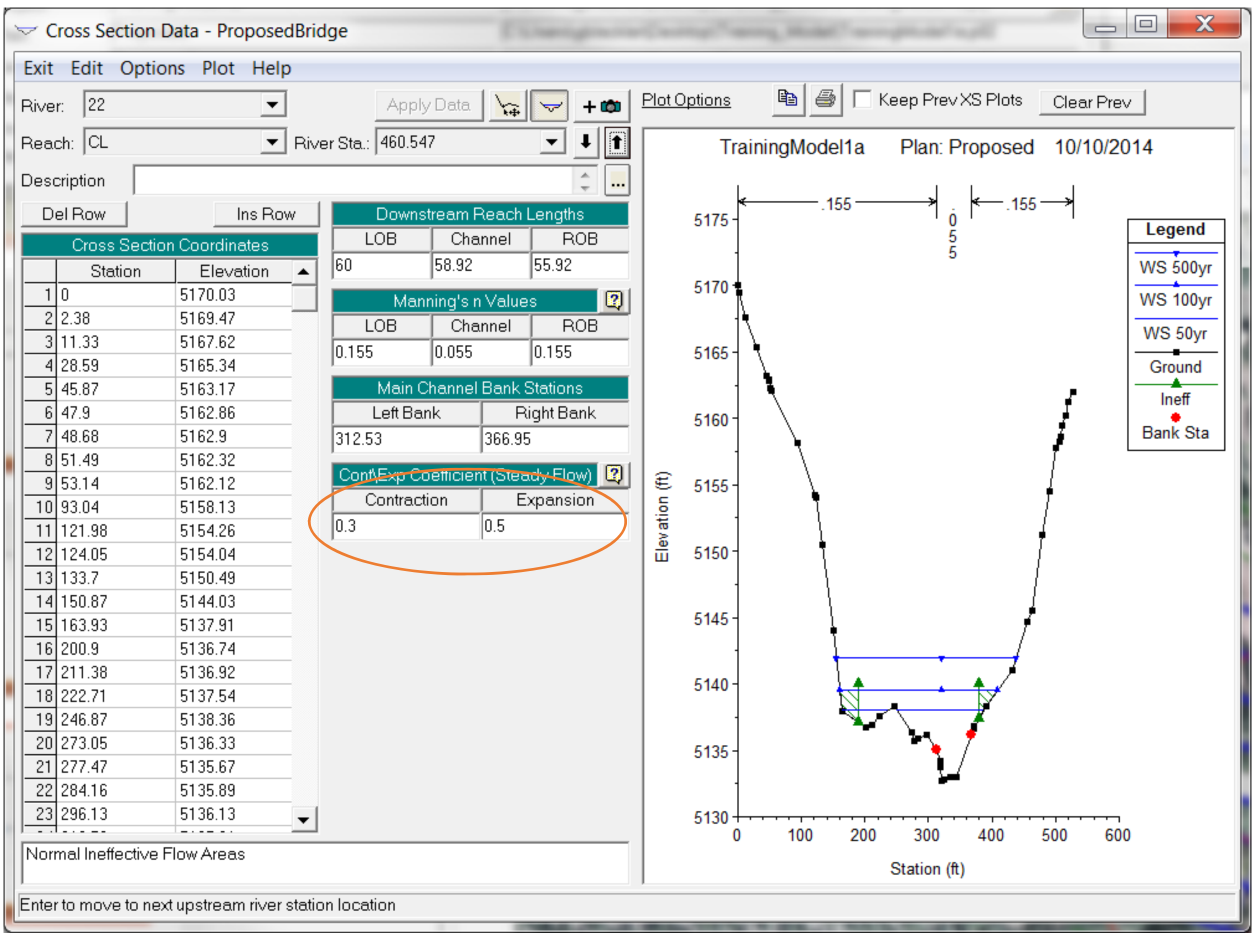
6. Go to the next downstream station (460.547) and enter the following ineffective flow areas.



7. Go to the next downstream station (401.061) and input the following:



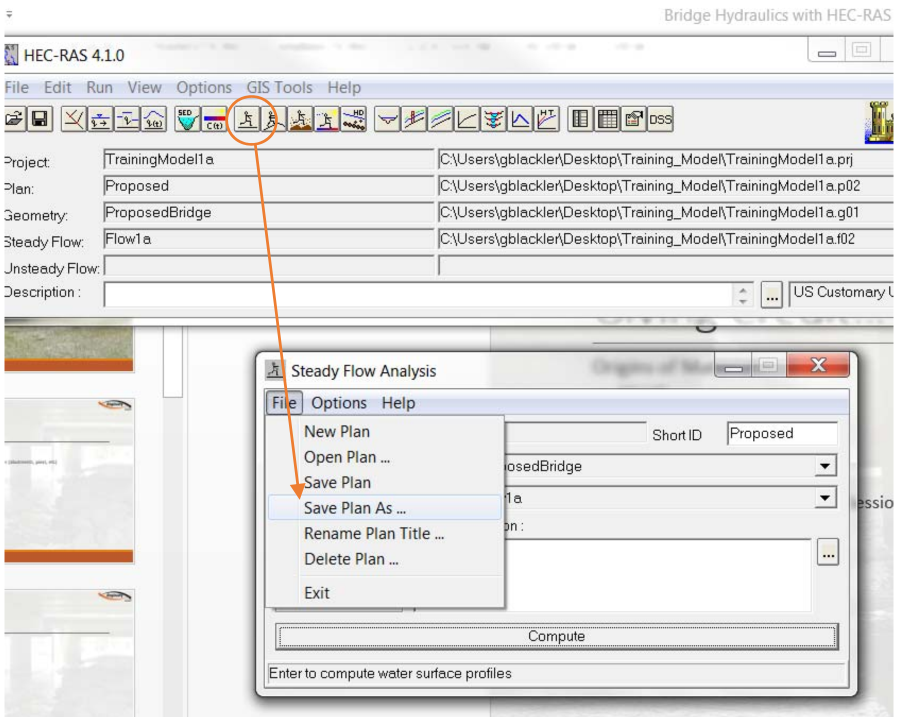
8. At each station where there are ineffective flows, be sure to enter contraction and expansion coefficients to accurately account for the head loss in sections that are influenced by the bridge.



7. MODELING BRIDGES IN HEC-RAS

Now that we have built our roadway section, input piers, sloping abutments, and our ineffective flow areas, we are now ready to run our model and observe the water surface profiles.

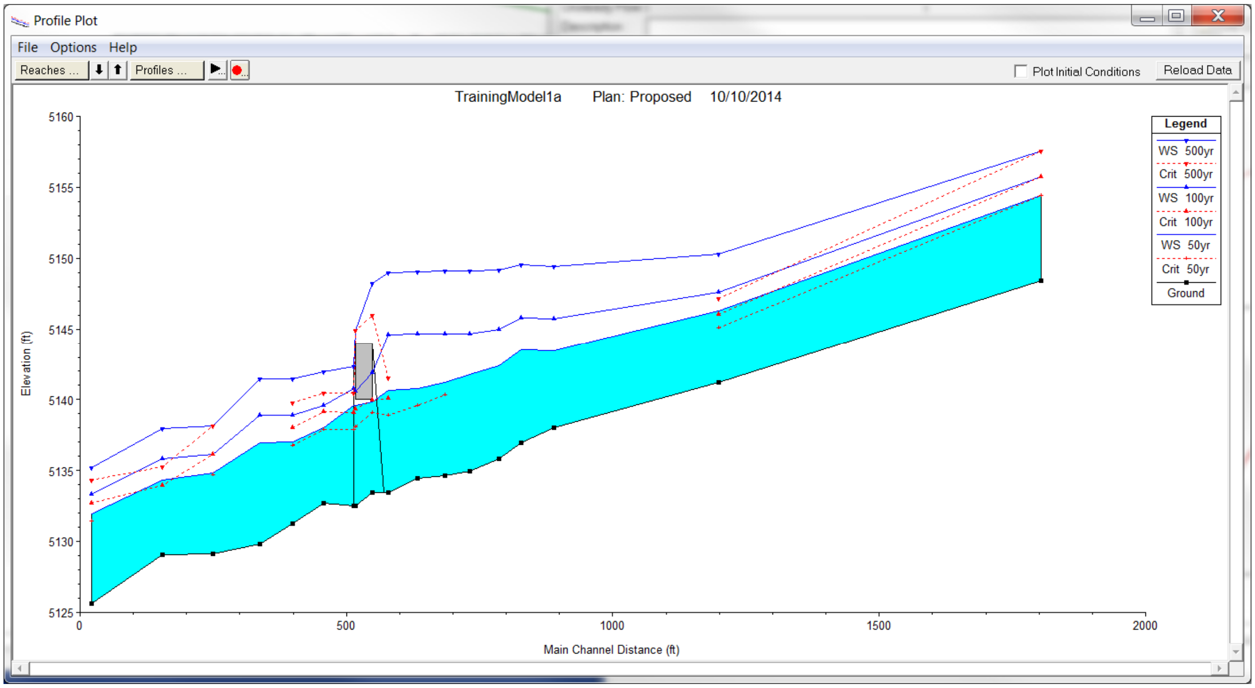
1. Save all your files and select the steady flow icon in the main HEC-RAS window.
2. In the steady flow analysis box select File→Save Plan as→ Proposed. Enter "Proposed" in the Short Plan Identifier window as well.



3. Now run the hydraulic model by selecting ***Compute***. Click **Close** once the computations are complete.

Now that we have coded and computed the hydraulics for our new bridge, we have some questions to ask. Profiles can be viewed by returning to the main HEC-RAS window, clicking **View**, and **Water Surface Profiles**.

- What type of water surface and flow profiles do you see?
- What method of computing flow through the bridge would you use for the 50 yr, the 100 yr, and the 500 yr flow rates?



In our next and final section, we will address the bridge modeling approaches.

8. SELECTING THE APPROPRIATE BRIDGE MODELING APPROACH

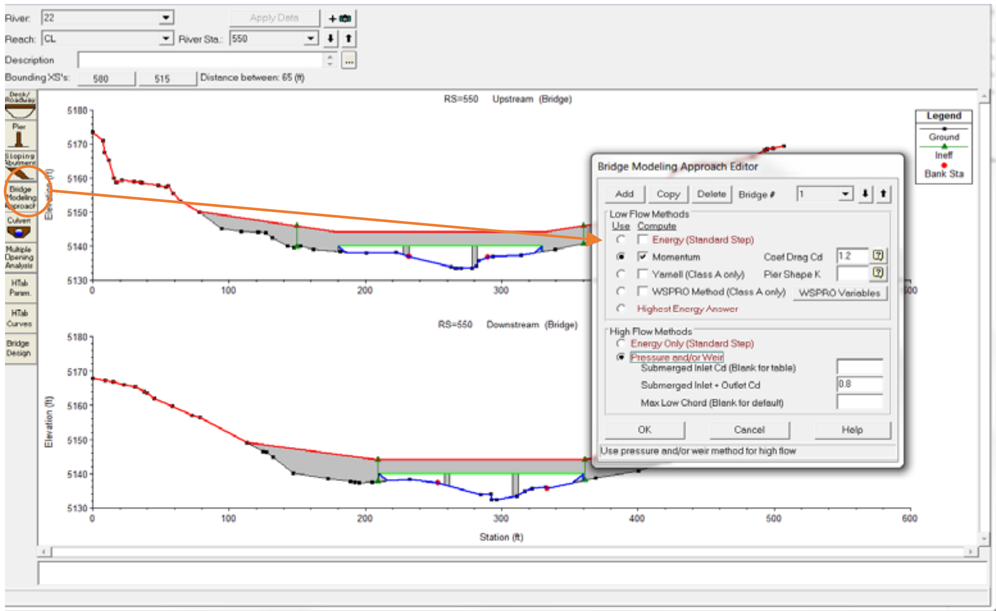
As we look at the water surface profiles, we can see that the 500 year is overtopping the roadway, the 100 year is up to the bridge deck, and the 50 year is going super critical through parts of the bridge constriction. This results in **submerged flow for the 500 year, pressure or sluice gate flow for the 100 year**, and **Class A flow for the 50 year** event (See Powerpoint Presentation and Notes Covered at Beginning of Class).

We need to adjust our bridge modeling approach!

1. In the Bridge Culvert Data Editor within the Geometric Data window, select the *bridge modeling approach* icon as shown below.
2. In the Bridge Modeling Approach Editor, adjust the low flow and high flow methods to the appropriate method.
    a. Recall that with Class B flow we should use the momentum equation (refer to technical presentation before) and anytime piers are in the flow field we should also use the momentum equation. Enter 0.6 for the drag coefficient (Coef Drag Cd) which is based on pier shape. Values can be found in the HEC-RAS v4.1 Reference Manual.

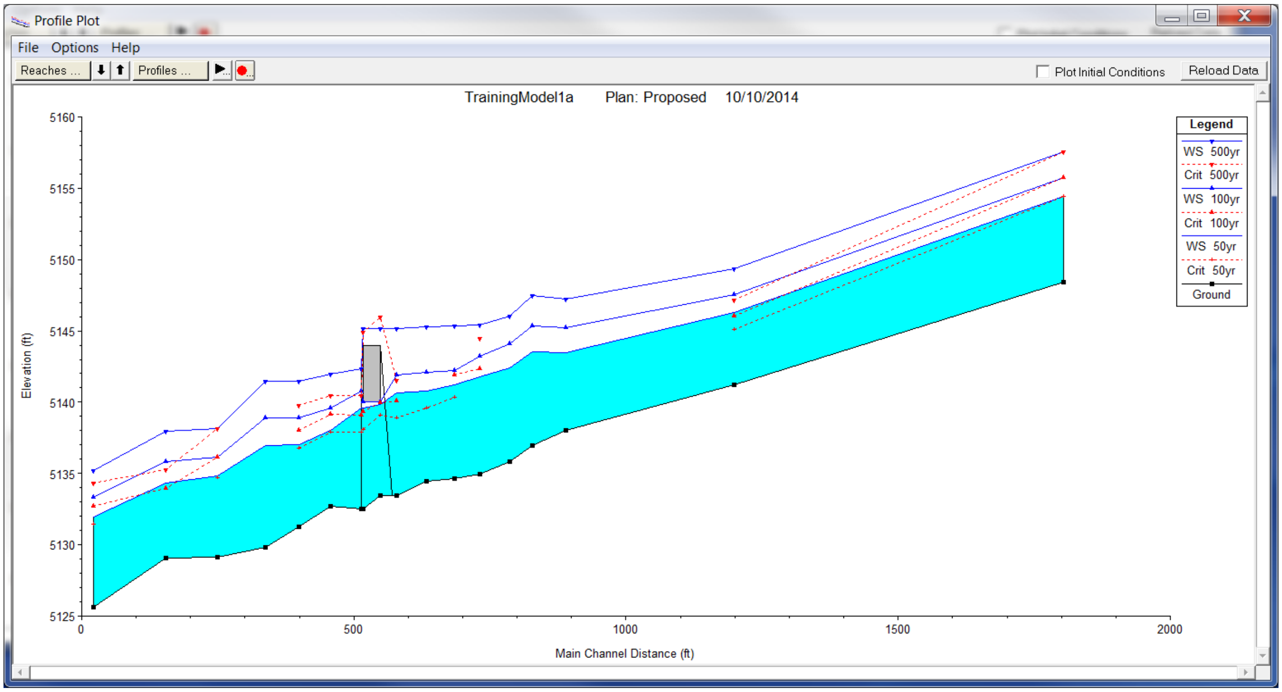
b. Our high flow methods are overtopping the roadway, but it is not completely submerged, therefore we should select the pressure/weir equation for high flow options.

c. Click OK.



3. After adjusting the bridge modeling approach, re-run the HEC-RAS Model.
4. Observe our before (top) and after (bottom) profiles below and notice that:
   a. The 500 year now behaves as it should as a broad crested weir flow.
   b. The 100 year acts like a sluice gate, and the water surface profile is not going through the deck of the bridge.

We have now appropriately modeled the new bridge structure in HEC-RAS.



Profile Plot
File Options Help
Reaches ...
Profiles ...
Plot Initial Conditions
Reload Data
TrainingModel1a Plan: Proposed 10/10/2014
Elevation (ft)
Main Channel Distance (ft)
5160
5155
5150
5145
5140
5135
5130
5125
0
500
1000
1500
2000
Legend
WS 500yr
Crit 500yr
WS 100yr
Crit 100yr
WS 50yr
Crit 50yr
Ground

Questions for HEC-RAS Lunch and Learn

Take a few minutes to answer the below questions to the best of your knowledge. After the course, return to this questioner and see if you have gained any knowledge.

What method does HEC-RAS use to compute flow depth?

a) St. Venant Equations
b) Manning's Equation
c) Energy Equation
d) Navier Stokes Equations

HEC-RAS only computes Uniform Flow (normal depth) water surface profiles when Steady Flow Regimes are used:

a) True
b) False

Critical depth occurs when,

a) Specific Energy is at a minimum
b) When there is only one depth value for any energy value
c) When Specific Energy is at a Maximum
d) Both a.) and b.)
e) None of the above

HEC-RAS does not compute rapidly varied flow conditions:

a) True
b) False

When modeling a bridge, the momentum equation should be used when:

a) There are piers or obstructions in the flow path
b) When the bridge is highly submerged
c) Low flow Classes B and C
d) Weir flow occurs over the deck
e) a), b), and c)
f) Both a) and c)
g) You should always use the momentum equation when modeling a bridge

By balancing the complete energy equation around structures, HEC-RAS fully handles weir, pressure, and flow obstructions correctly:

a) True
b) False