PAPE-DAWSON ENGINEERS
HDR
WALTER P MOORE

MAAPnext Program

Hydraulic Methods

Principal Author:

Lonnie Anderson, P.E., CFM
Pape-Dawson Engineers, Inc.

QC Reviewer(s):

Nick Irza, EIT
Walter P. Moore and Associates, Inc.

Carolina Molfetta, P.E., CFM
HDR Engineering, Inc.

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MAAPNext 1D/2D HEC-RAS Model Development

The 1D component MAAPNext models will build largely off of existing Harris County FEMA and Harris County Flood Control District model data sets. The existing 1D models will provide initial estimates for channel n-values, bridge/culvert structures and cross-section locations. Structures within these 1D models will likely require datum adjustments. Channel n-values will typically be simplified to a single n-value and channel geometry updated to 2018 Lidar data. The following is supplementary to the MAAPNext white papers and is intended to provide modeling guidance and recommendations for the primary components of the proposed 1D/2D HEC-RAS. This memo is not intended to dictate nor cover all modeling approaches that will be required. It is intended to provide guidance for the base level of model building and aide in the consistency of the hydraulic modeling across Harris County watersheds.

Section 1) Initial Unsteady Flow 1D HEC-RAS Model Development

While not a requirement it is recommended that initial 1D/2D model development begin with converting HCFCD provided base models to full 1D unsteady state models. This will provide valuable information to help guide 1D/2D model development. These 1D unsteady state models will use effective hydrology and allow for initial consideration of flow distribution as well as preliminary results that can provide validation during initial 1D/2D model development. This conversion can be simplified to some extent to provide model stability if needed such as adding or deleting structures/cross sections. Refer to the HCFCD HEC-RAS 1D UNSTEADY FLOW MODELING GUIDELINES for assistance in converting existing steady state models to unsteady flow models.

Section 2) Bathymetry

A number of channels will require modification to the 2018 LiDAR data to reflect bathymetry. This can be accomplished directly within HEC-RAS. It is anticipated that survey at major crossings or at approximately 1-mile spacing along the reaches will be sufficient for developing the bathymetry within the 1D portion of the models. The following provides a suggested approach within HEC-RAS for modifying the LiDAR data to reflect channel bathymetry. A separate HEC-RAS project, outside of the MAAPNext model, is to be used for the development of the bathymetry surface.

- In the Geometry Editor: Create a stand-alone geometry file with cross sections at locations where bathymetry survey data has been acquired.

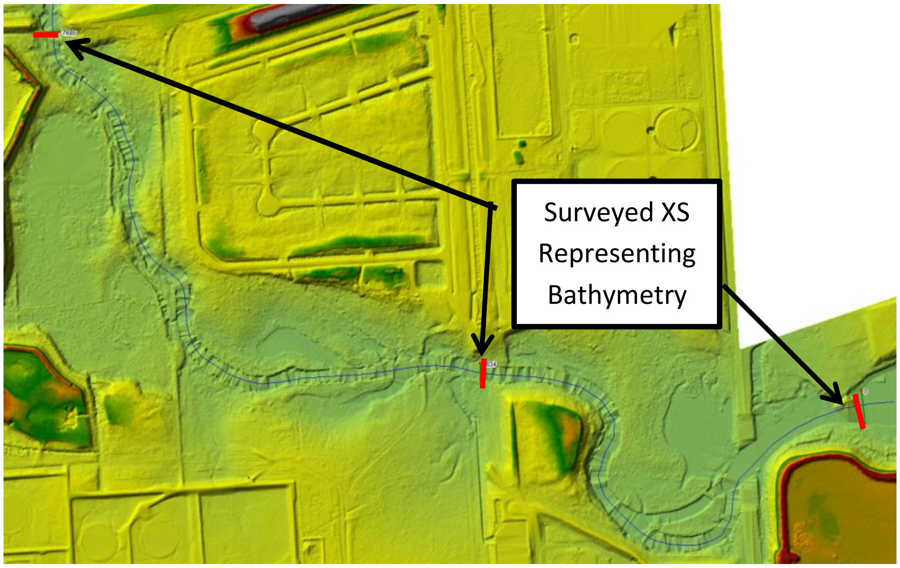


Figure 1 – Channel Bathymetry Survey Locations

- In Geometry Editor: Interpolate additional cross sections between the surveyed cross sections and graphically move end points of the interpolated cross sections to the LiDAR indicated "edge of water".

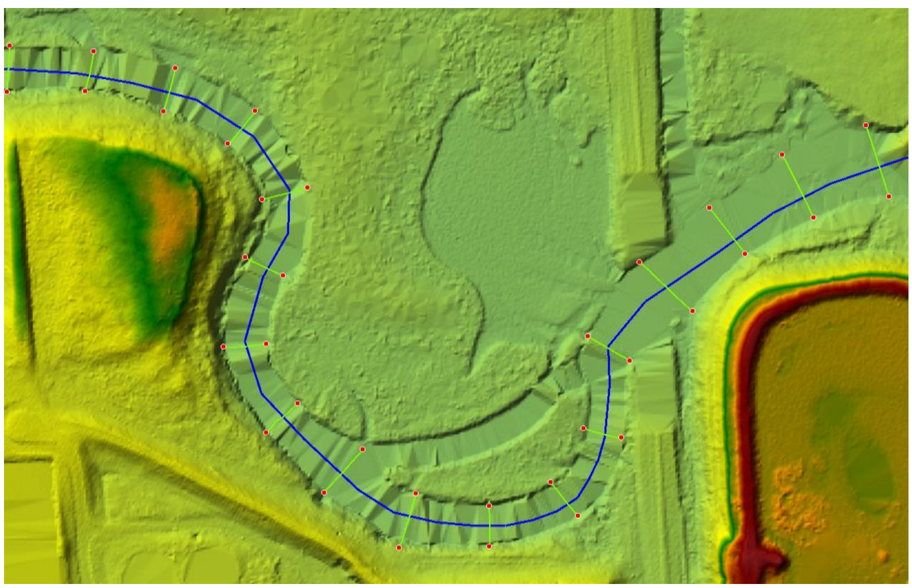


Figure 2 – Interpolated Cross Sections with end points located at "Edge of Water"

- In RAS-Mapper: Under Geometries/Geometry Name/Cross Sections, right click interpolation surface and edit geometry, right click again on interpolation surface and select Compute XS Interpolation Surface. Stop editing and save.

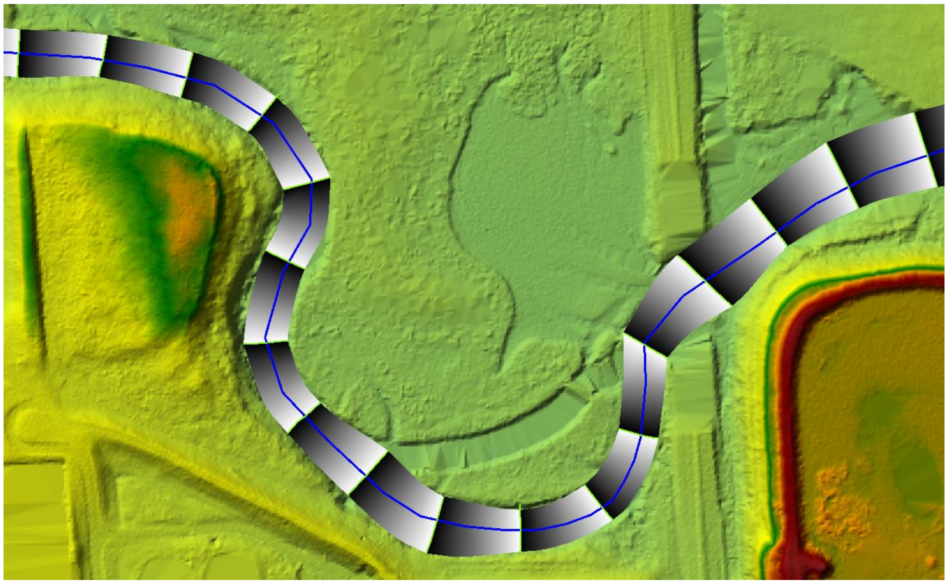


Figure 3 – Interpolation Surface within RAS-Mapper

- In RAS-Mapper: Right click the geometry name and select Export Layer/Create Terrain GeoTiff from XS's (Channel Only), select a cell resolution of 3 or value equal to base LiDAR data resolution.
- In RAS-Mapper: Add the exported GeoTiff to the base Lidar data using the Create New Terrain tool under Terrains.

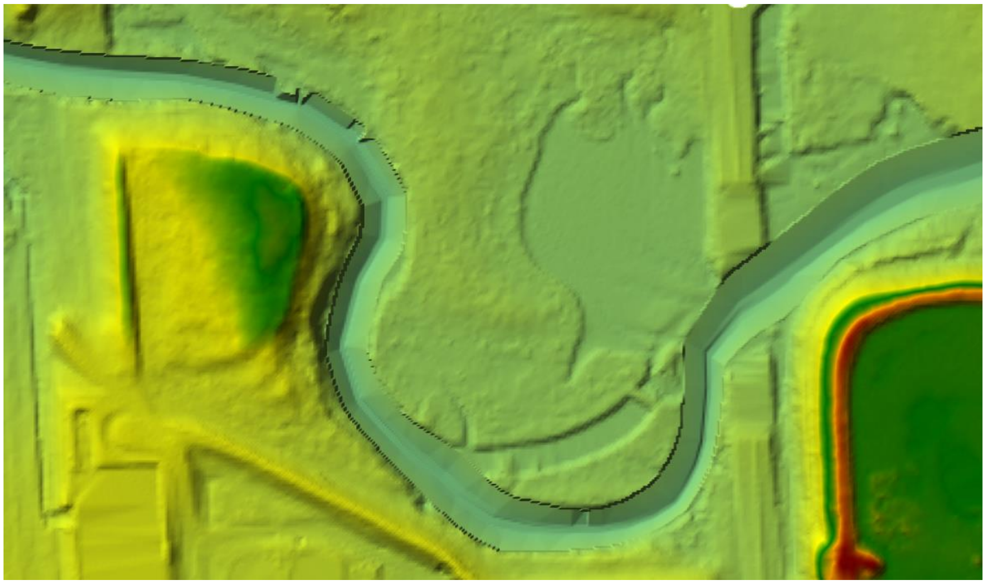


Figure 4 – Final Surface with Bathymetry within RAS-Mapper

Section 3) 1D/2D HEC-RAS Model Development

The MAAPNext modeling effort will likely result in different stationing along the 1D cross sections as compared to the previous FEMA studied channels. The following provides the recommended approach in developing the 1D portion of the 1D/2D models. Many of the following described edits can be accomplished both within the RAS Geometry Editor or RAS-Mapper. The guidance provided assumes they are performed within the Geometry Editor but does not preclude the use of RAS-Mapper if desired.

- In Geometry Editor: Establish channel centerline
    - Enable terrain contours in RAS-Mapper to assist with proper model setup.
    - Review channel centerline against LiDAR data and adjust river line as necessary to follow channel invert.

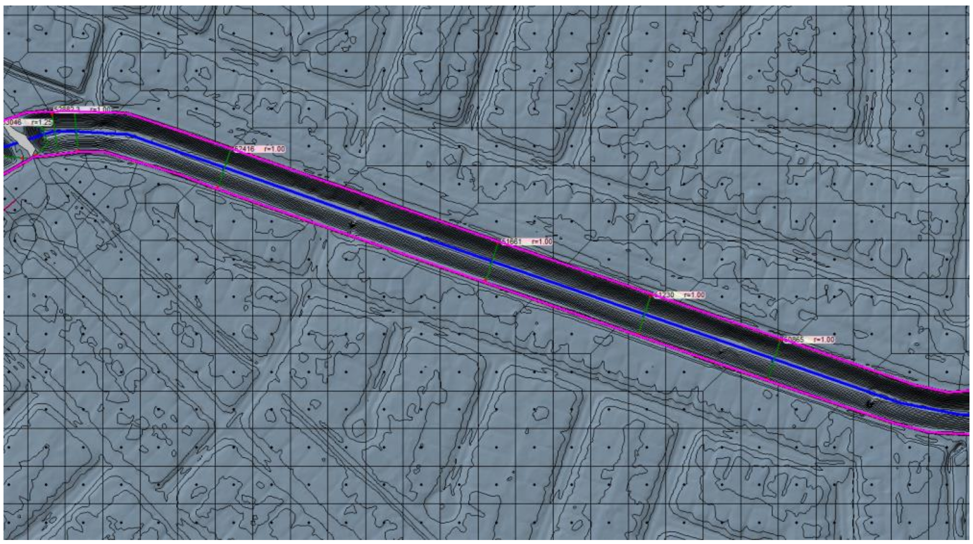


Figure 5 – Channel Centerline Alignment Set Along Invert

- In Geometry Editor: Revise existing cross section stations as necessary based on updated river centerline.
    - In the Geometry editor browse to “Tables” / “Names” / “River Stations” and select the GIS Cut Line Intersection tab.
    - Set decimal places to 0
    - Set the downstream Cross Section (XS) station to be in relation to the confluence station on receiving stream. For example, if the confluence station on the receiving stream is at station 102000 and the first XS on the tributary being modeled is located 229 feet upstream, the downstream-most cross section in the tributary model is assigned station 102229.
    - Set upstream station to the downstream station plus river reach length. For example, the downstream station is 102229 and the upstream most cross section measured along the updated channel invert line is 57,651.36 feet upstream, then the upstream cross section would be assigned station 159880.36.
    - With upstream and downstream River Stations (RS) set, click “Create RS” to populate new river stations for all existing cross sections.

- Use the updated cross section stations to update XS channel reach lengths by subtracting station numbers

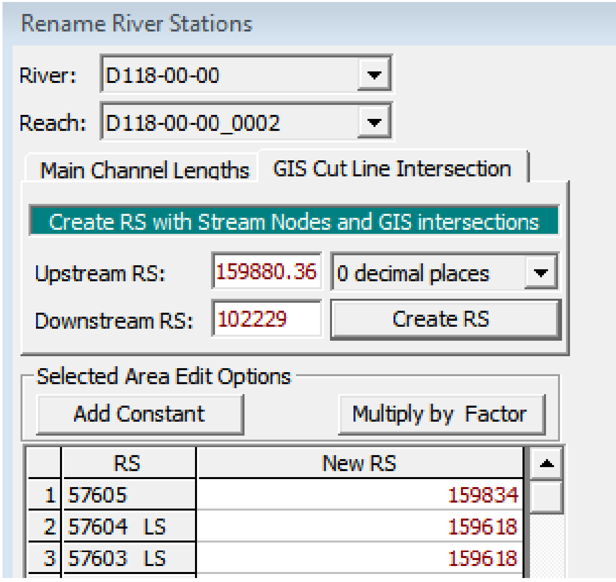


Figure 6 – Geometry editor “Tables” / “Names” / “River Stations” Interface Window

- Trim the existing 1D model cross sections to near top of bank high ground
  - Starting with effective model, convert channel to a single Manning n value (remove horizontal variation). Review the existing, effective model’s weighted Manning n-value table (Mann Wtd Chnl) for assistance in establishing the simplified channel n-value. Carefully review to identifiy cross sections with abrupt changes in n-value that may be indicative of errors in effective model. For example: Cross Section 20258 below n-value is nearly double that of adjacent cross sections. Review of aerial does not indicate this is accurate and value should be similar to that of adjacent cross sections.

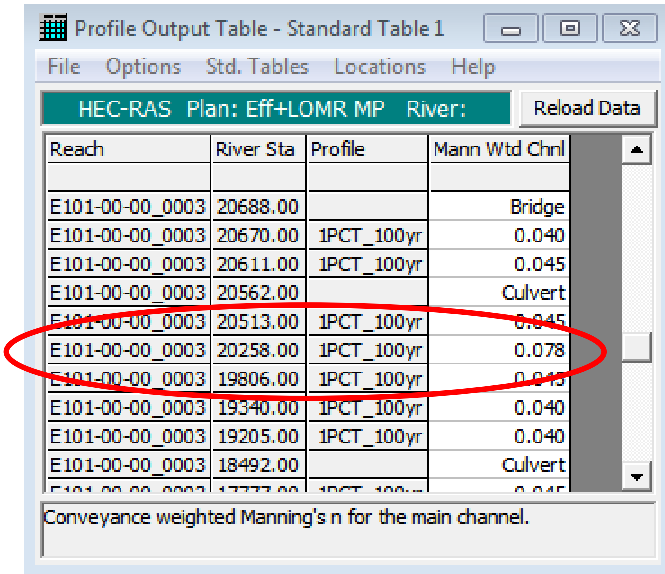


Figure 7 – Effective Model Mann WTD Chnl n-value

- Delete the effective model bank stations and ineffective/blocked obstructions station from the cross section. This is required as the effective cross sections typically have a 5000 station at the channel centerline. When using RAS to cut cross section from terrain the bank/ineffective/blocked obstructions stations will cause errors by retaining the station of these points.
- Suggest using graphical editor to delete cross section ground points (GR) point to near top of bank
  - Accept cut line length adjustment
  - Adjust XS cut line as needed to correctly align with channel. This can be done graphically in HEC-RAS using the edit move tool. Update river stationing as necessary
  - For structure bounding XS, review the bridge opening and if abutments are located outside of channel banks/high ground trim bounding XS to ~5' outside of abutment stations
  - For structures, trim deck elevations close to same extents as bounding XS
- Update XS GR by cutting from terrain within HEC-RAS
- Set new bank stations. These should be set at the top of bank elevation, likely near the end of the cross sections.
- Set overbank n-value. These overbank n-values can be determined from the effective model, by visual inspection of aerial photography or use of the 2D domain land classification.
- Set/adjust overbank reach lengths. Typically, these lengths will be similar or equal to the channel reach length since the 1D cross sections will largely cover only a small portion outside of the channel bank to bank. A useful option is to create "Bank Lines" and "Edge Lines" within RAS Mapper. The measured centroid length between these lines can then be determined as the overbank reach length. These lines can also be used to identify locations where additional cross sections are necessary to improve the location of the 1D/2D boundary. See Figure 8 below.

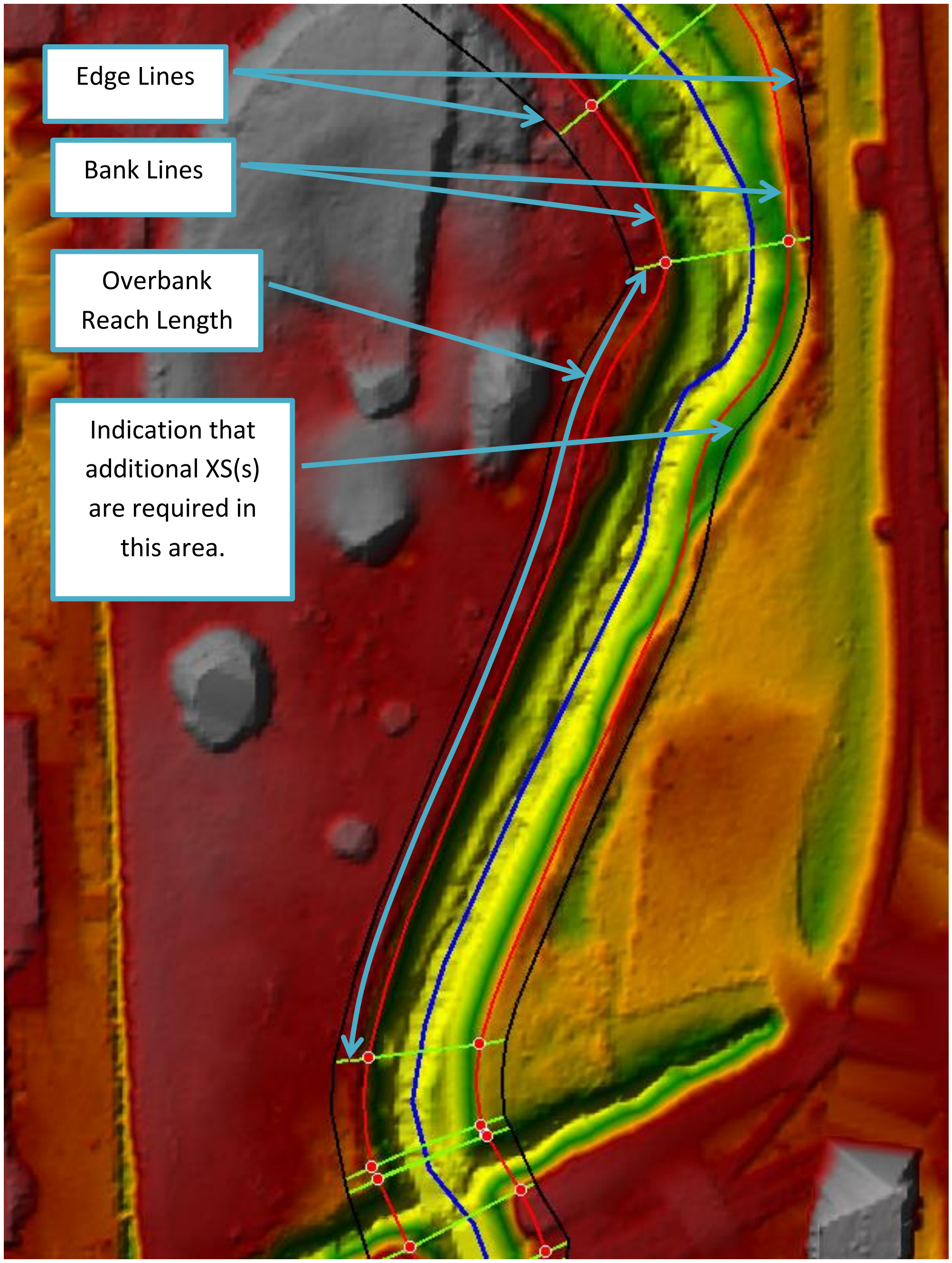


Figure 8 – Use of Edge and Bank Lines for Estimation of Overbank Reach Lengths

- Adjust or update bridge/culvert/inline structure deck stationing
- Avoid the use of internal XS on structures if possible. Will need to update internal XS through bridge/culvert editor interface if internal XS needs to be retained.
- Avoid the use of XS skew, if possible, by using properly-aligned XS. Skew is not required for cross sections with <20 degrees of skew.

- Create 2D boundary for main channel reach encompassing the entire watershed.
  - Strive to limit the number of 2D flow areas within a single watershed model. Attempt to model only a left and right 2D flow area per watershed. It is possible for there to be instances where more than a left and right 2D flow area is required.

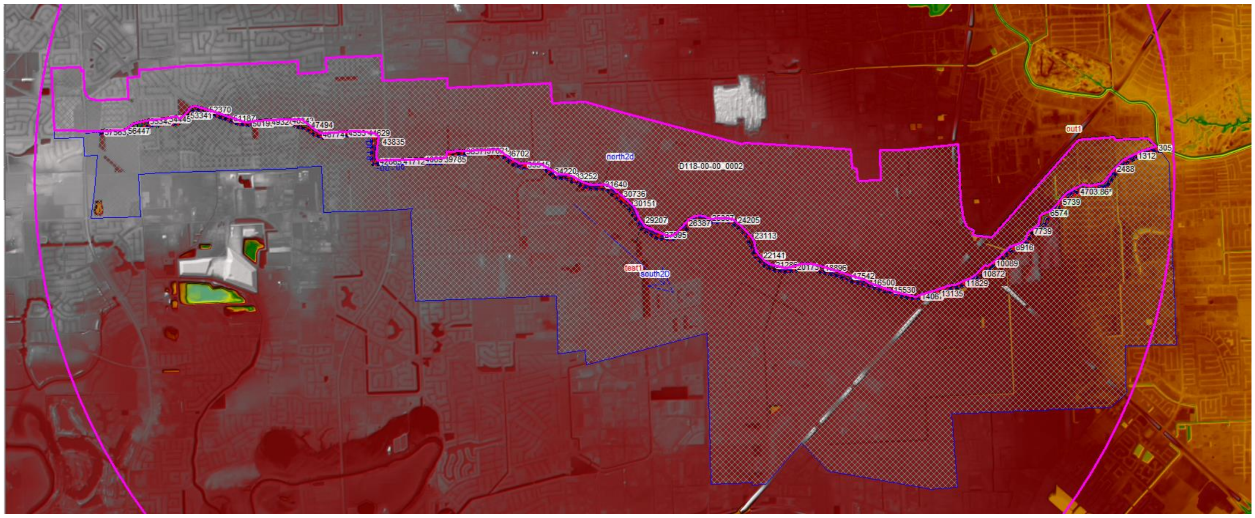


Figure 9 – Left Overbank 2D Domain

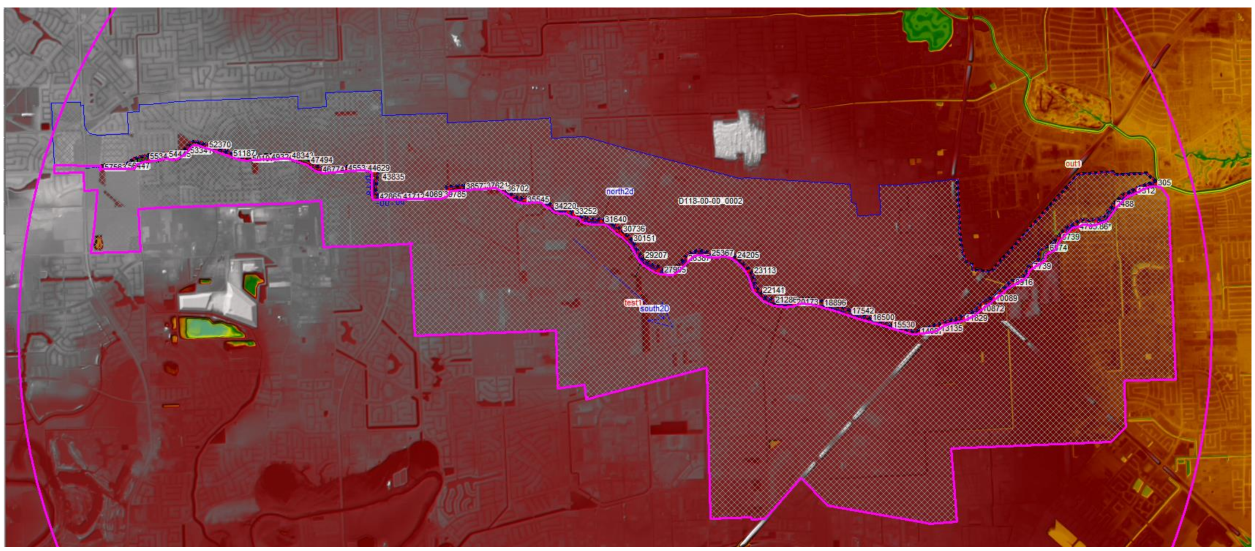


Figure 10 – Right Overbank 2D Domain

  - Permissible to split 2D areas if necessary but splits should be located such that overflow between the split 2D areas is unlikely or minimal.
  - Set 2D cell size to 100 x 100. This resolution will be acceptable for a vast majority of the MAAPNext modeling. It may be allowable in some areas to vary from this resolution if significant model stability or run time improvements can be documented and its use approved by HCFCD.
  - Set 2D boundary edge along 1D reaches at high ground near, or adjacent to, channel top of bank. Slight overlap of <5-feet with 1D is acceptable.

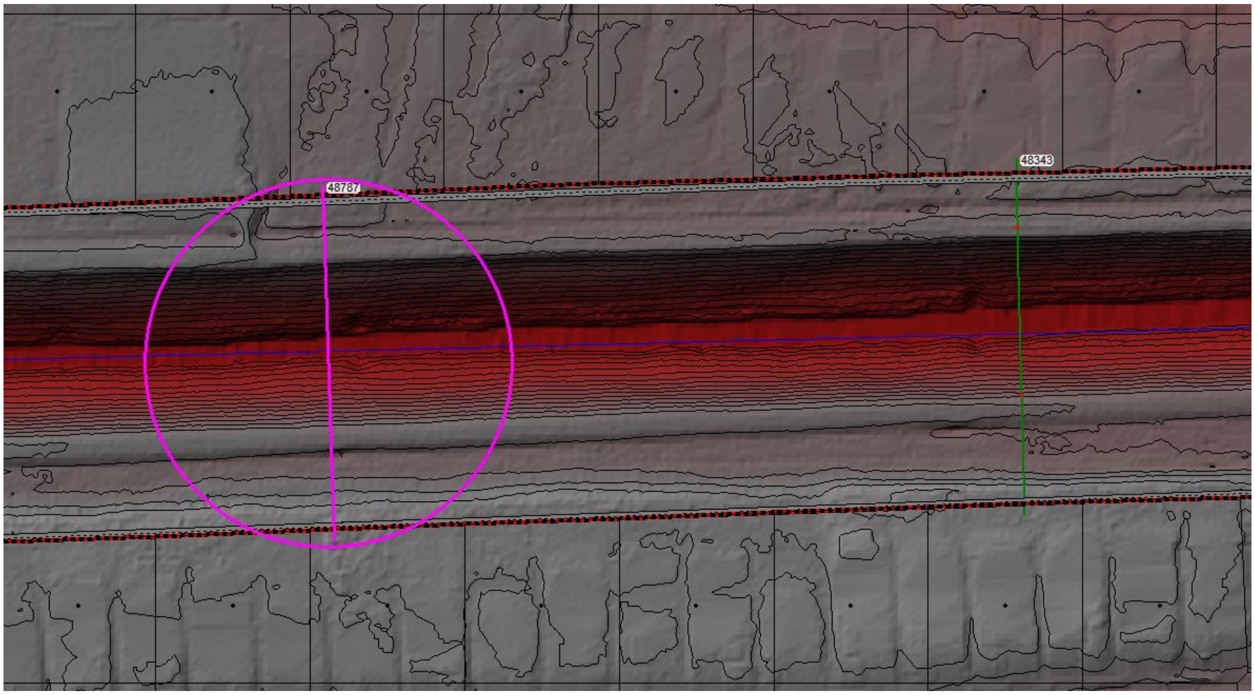


Figure 11 – Slight Overlap of 1D and 2D Domains

- Review in RAS-Mapper: Geometry / “Cross Sections” / “Edge Lines” to verify slight overlap of <5’ with 2D area. The “Slivers” between the 2D domain and the 1D edge line would result in no data being produced or mapped and must be avoided. Minimization of the overlap between 1D and 2D is to reduce double counting of storage/conveyance. However, with a slight overlap future model edits are enhanced by reducing the likelihood of the wrong point being modified as HEC-RAS does not include an “undo” option.

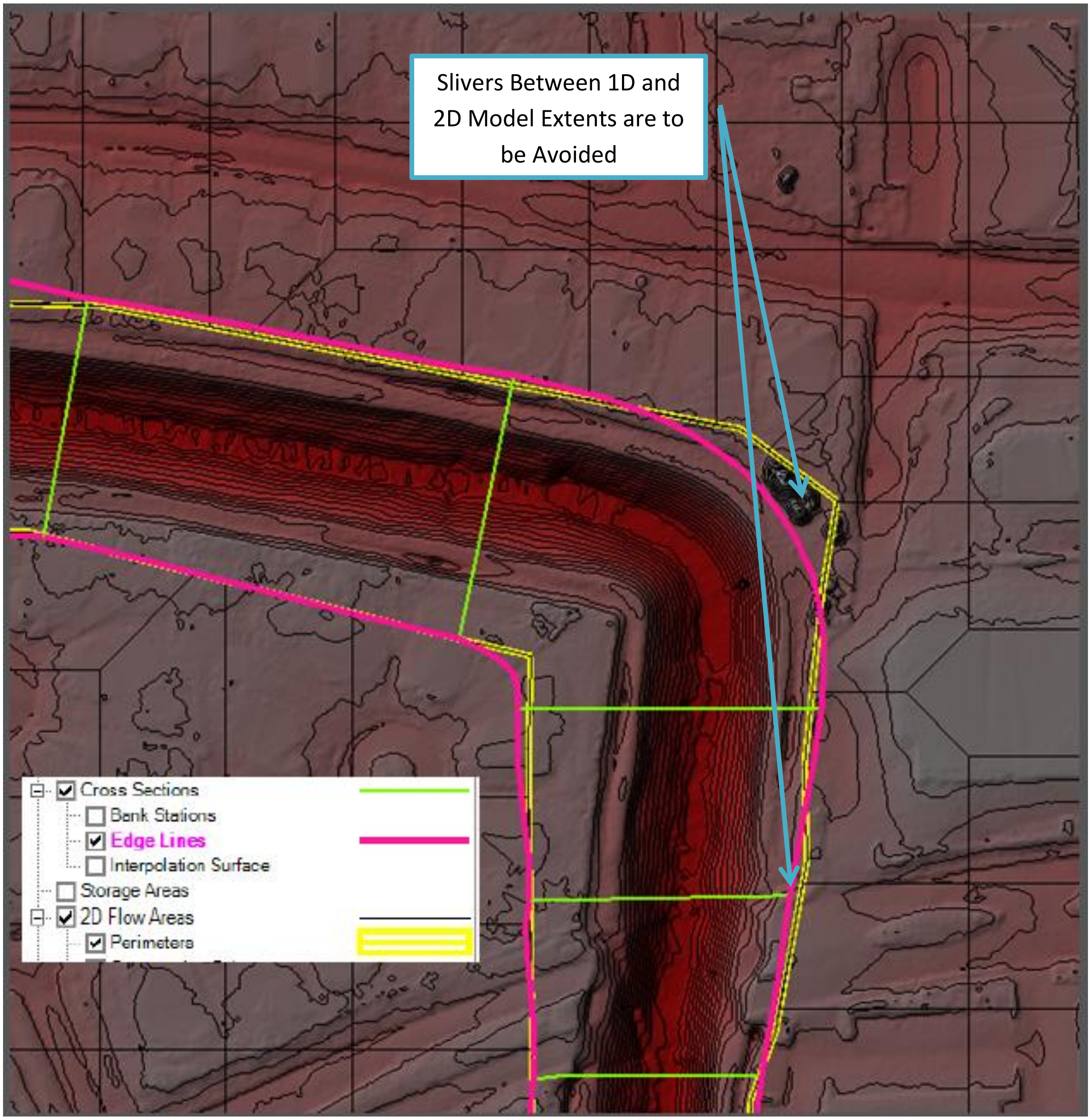


Figure 12 – Example of “Slivers” Between 1D and 2D Domains.

- Adjust 2D, 1D and/or add additional 1D XS to fix “slivers” between 1D and 2D

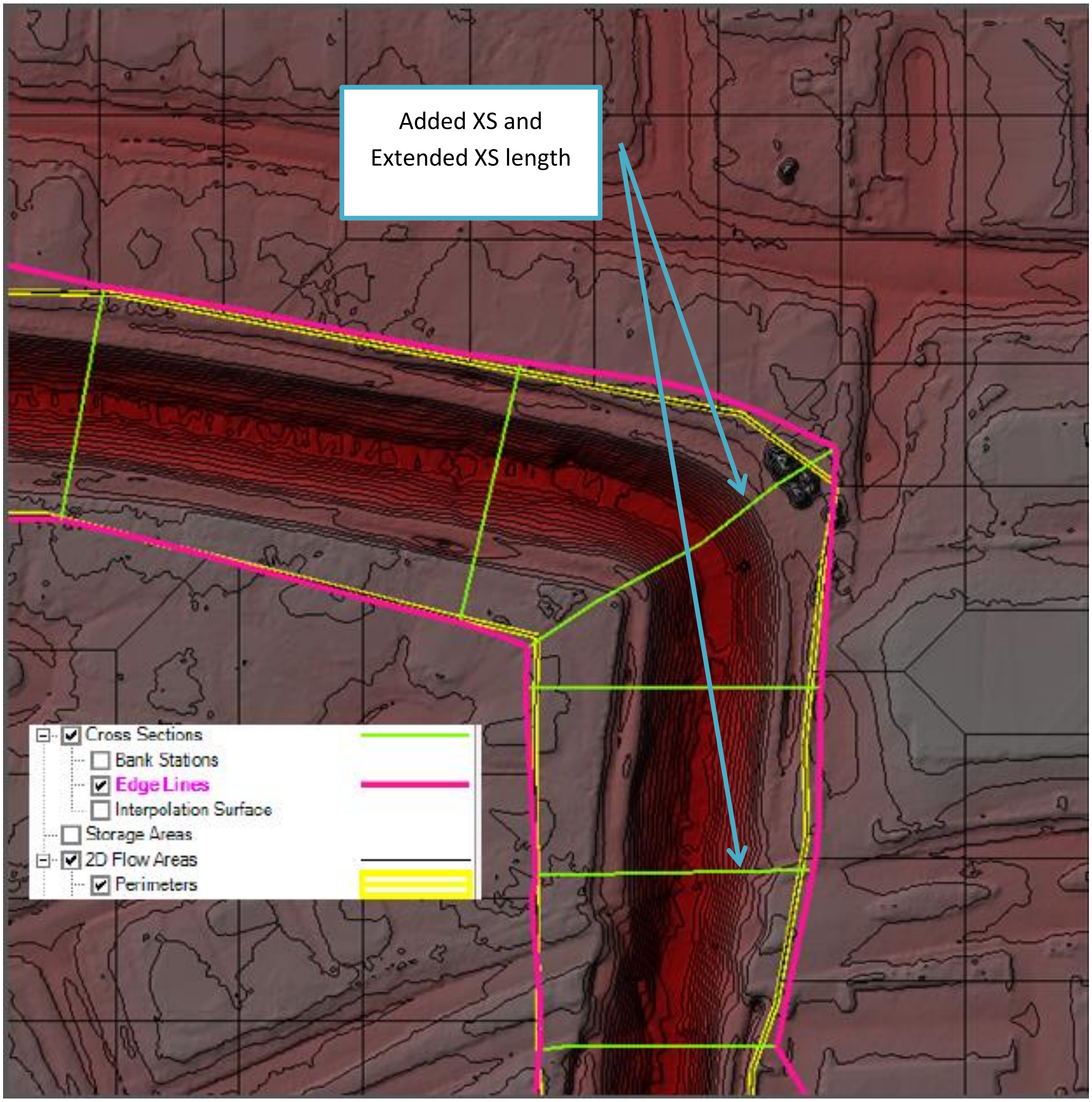


Figure 13 – Example of Added XS to Fix “Slivers” Between 1D and 2D Domains.

- Draw lateral structures and assign lateral structure stations
    - Laterals to be Geospatially delineation and located at high ground, near edge of 2D boundary. This can be accomplished by using the “measure” option in HEC-RAS to generate the Centerline GIS Coordinates and then pasted into the lateral structure coordinate table.

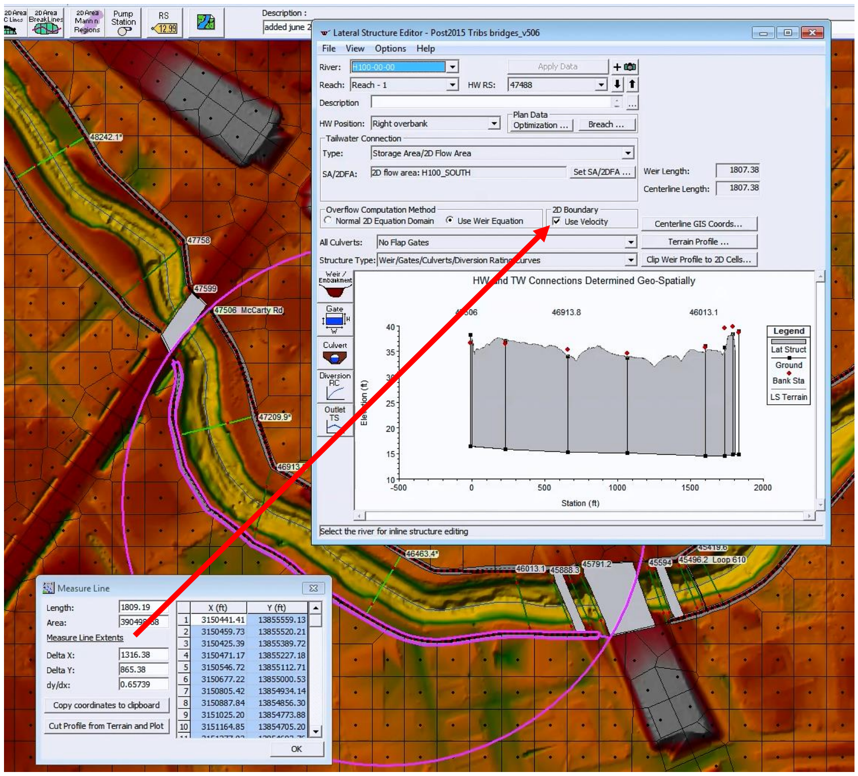


Figure 14 – Use of Measure Tool for GIS Coordinates of Structures/Boundary Conditions.

- Limit length of laterals to less than 1-mile
- Break laterals at logical divides such as structures in the 1D domain or embankments within the 2D Domain.
- When crossing tributaries with channel depths >6-feet divide lateral to model tributary from top of bank to top of bank as a single lateral to improve model stability and to allow for appropriate weir coefficient use at confluence. This also allows for improved quantification of flow at specific locations.
- Use weir equation as Overflow Computation Method (default) with typical coefficient of 0.5 along top of banks and 2.0 for tributaries.
- Assign elevations using copy/paste from the terrain profile option within the lateral structure editor.
    - Filter number of points to ~10% of the total number imported when number of points exceed 100.
    - Use Clip Weir Profile to 2D Cells with tolerance of 0.1 feet as necessary.

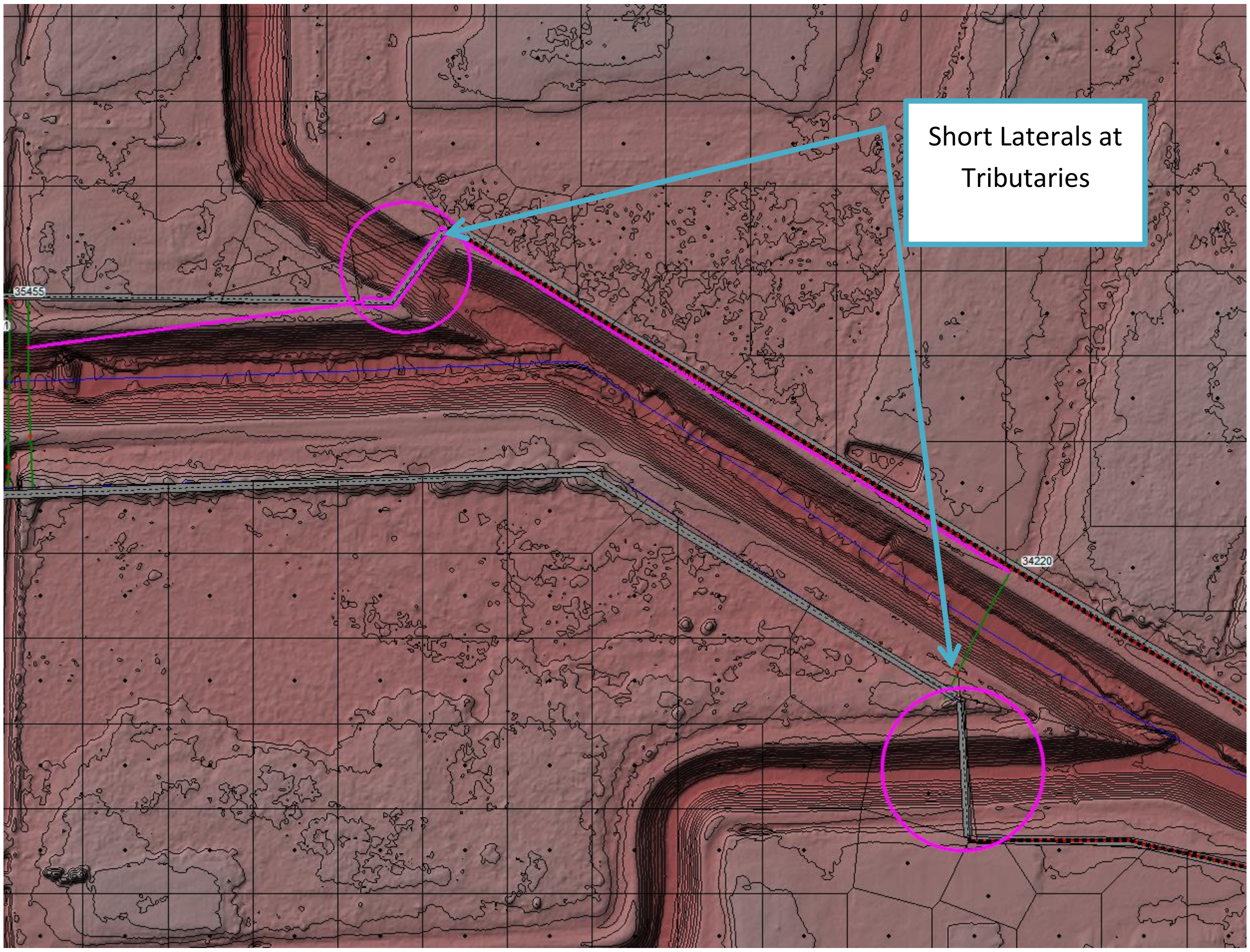


Figure 15 – Separate Laterals for Tributary Confluences >6-feet in depth.

- Adjust 2D boundary and 1D extents as needed to follow approximate lateral structure alignment
- Add/move cell centers to limit one lateral connection per cell face
- Additional attention to be paid where laterals span internal structures like bridge/culverts. RAS does not compute or transfer flow between bounding XS. See Figure 16
- If flow transfer between 1D/2D is anticipated between bounding XS:
  - XS may need to be adjusted graphically to minimize the end distance between bounding XS when Bounding XS distance is < 200-feet. Please note in description of XS if cutline geospatial points have been adjusted from the cutline used to generate the XS terrain points. See Figure 17.
  - Model area between bounding XS in 2D when bounding XS distance is >200-feet. See Figure 18.

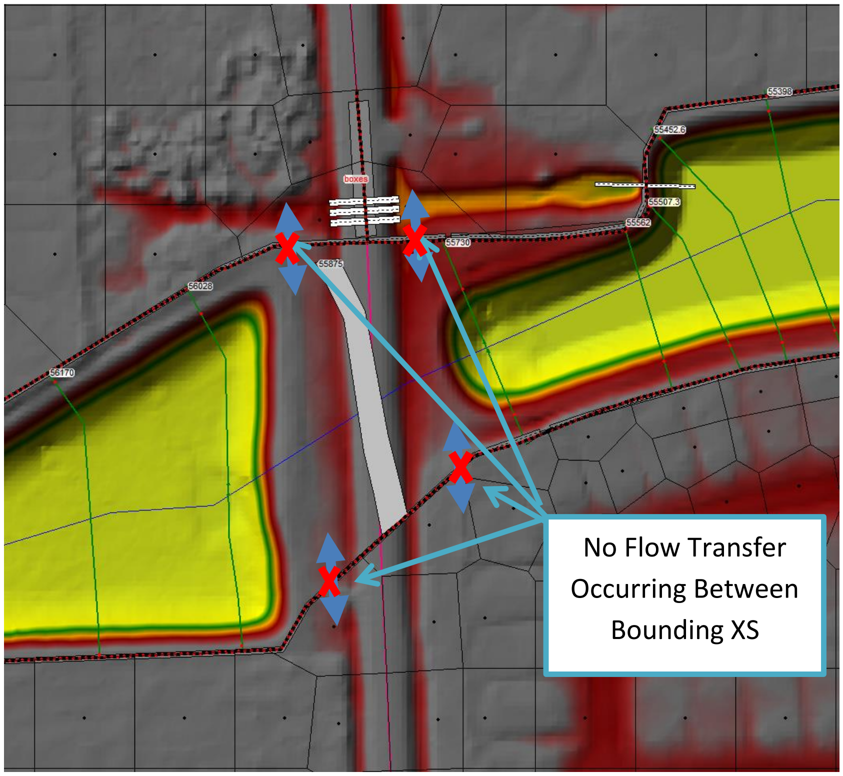


Figure 16 – Example Location Where Laterals do not Transfer Flow between 1D and 2D

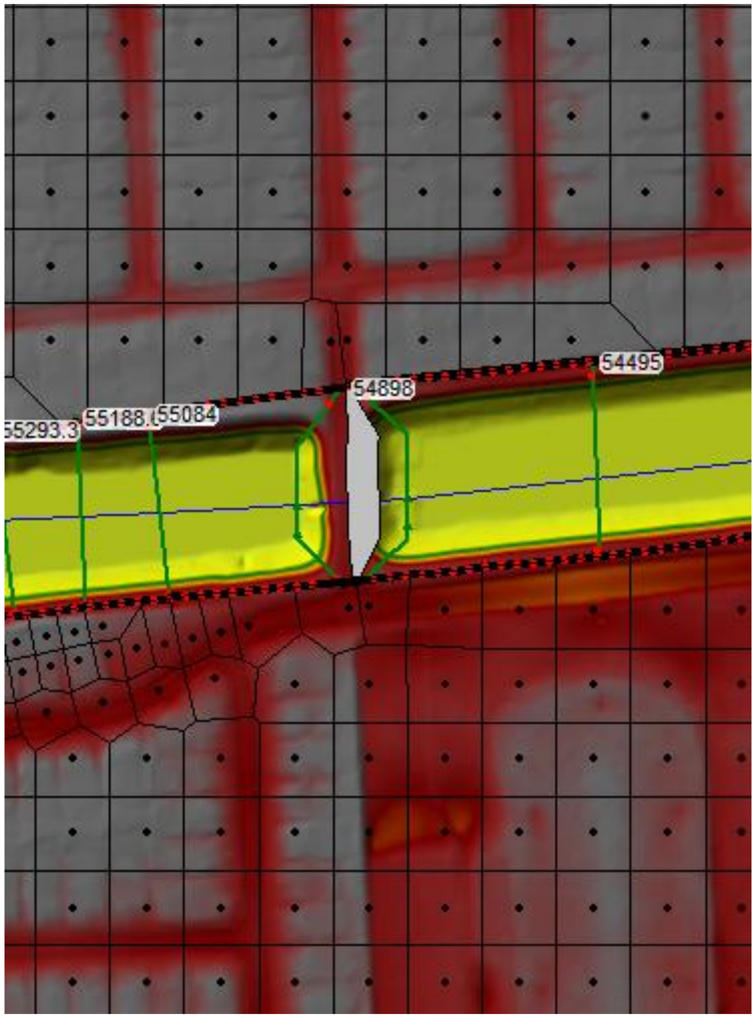


Figure 17 – Example of Bounding XS Ends Bent to Minimize Graphical Distance Between end point of bounding XS and Allow Flow Transfer to Occur Over Lateral Structures (Bounding XS < 200-feet)

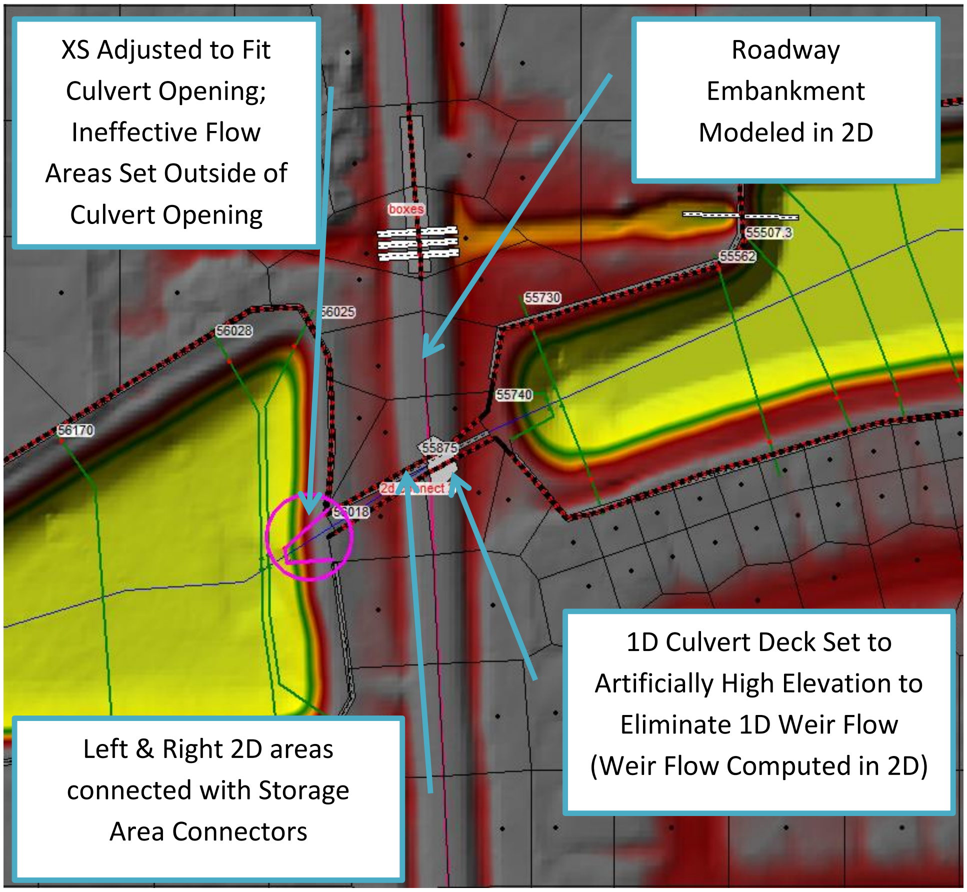


Figure 18 - Example of Area Between Bounding XS Modeled in 2D (Bounding XS >200-feet)

Section 4) Supplemental 1D reach modeling to be used for developing 1D reaches of previously unstudied streams.

- Draw 1D reach along channel to be modeled as described in Section 3.

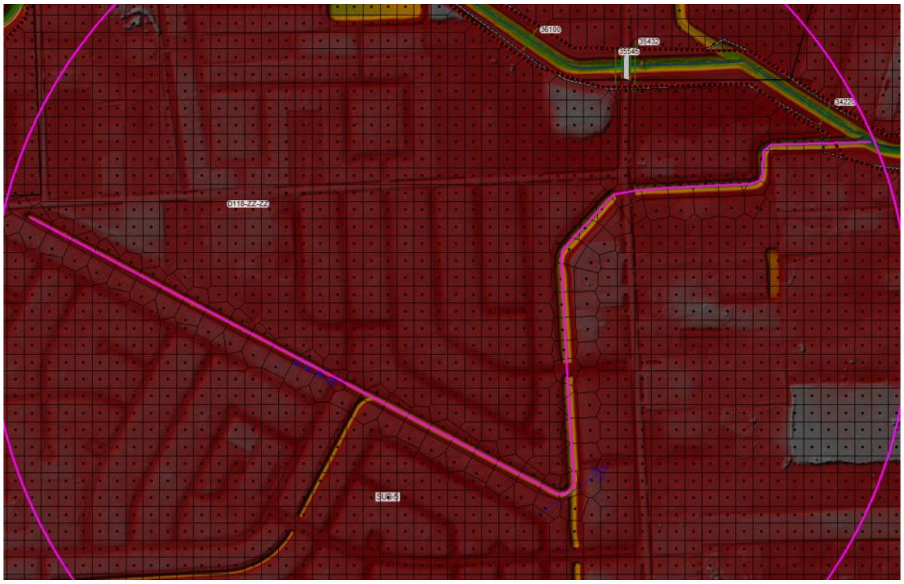


Figure 19 – Supplemental Reach Delineation

- Assign a downstream and upstream cross section. These do not initially need to be set geospatially. Use the channel invert length (see Figure 20) to assign the upstream and downstream stations as described in Section 3. The initial section geometry will be artificial with the width of cross-section being greater than channel top of bank to top of bank width. The cross section GR needs to only be 4 points and the elevation of the points is not important at this stage.

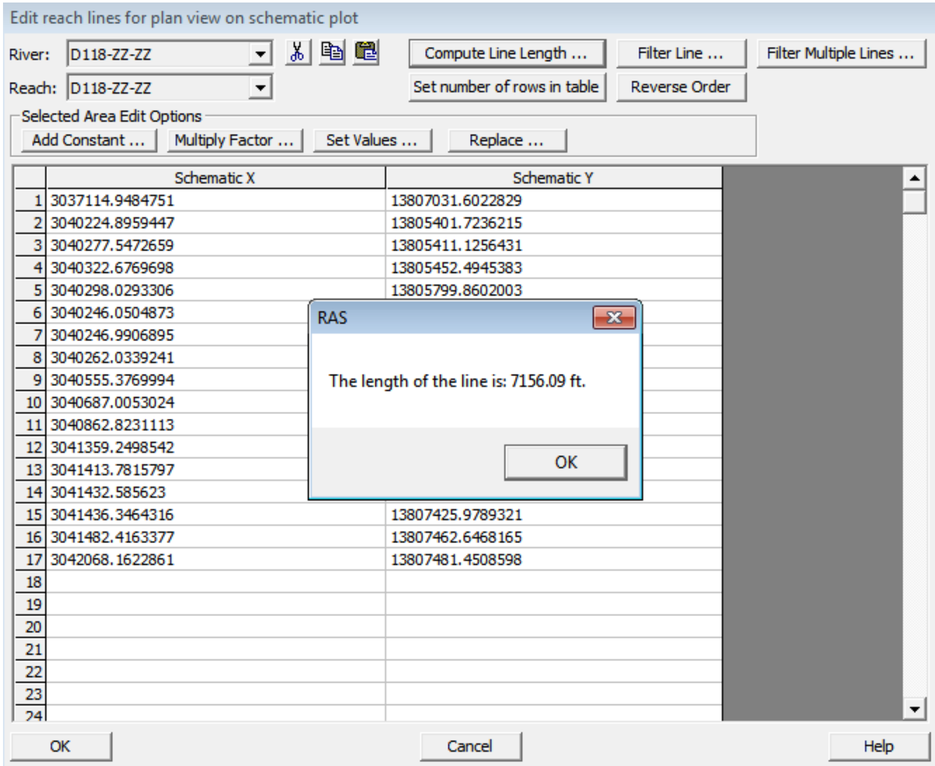
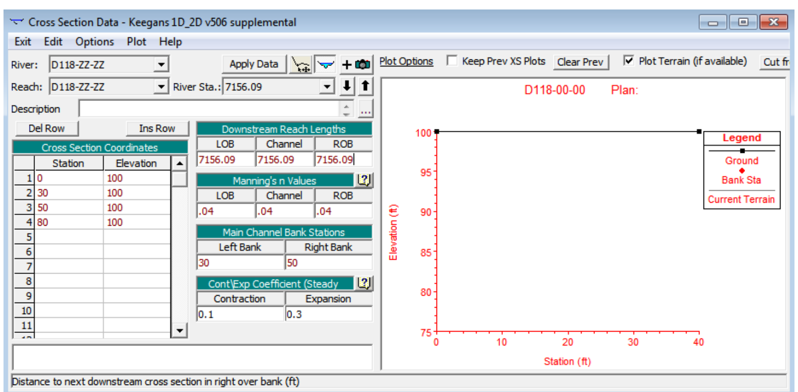


Figure 20 – Channel Centerline Length



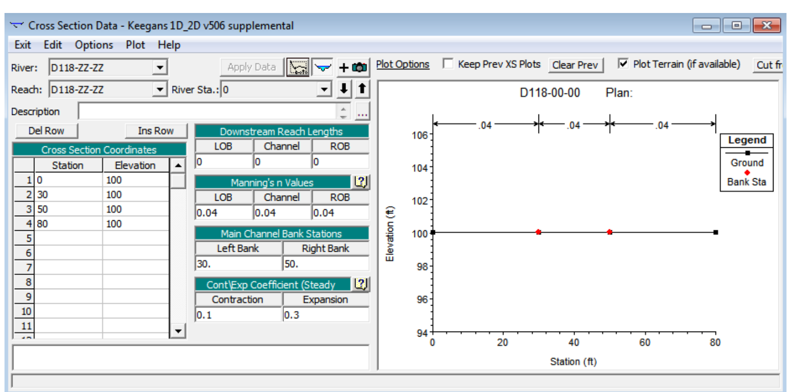


Figure 21 – Initial Upstream and Downstream Cross Section Assignments

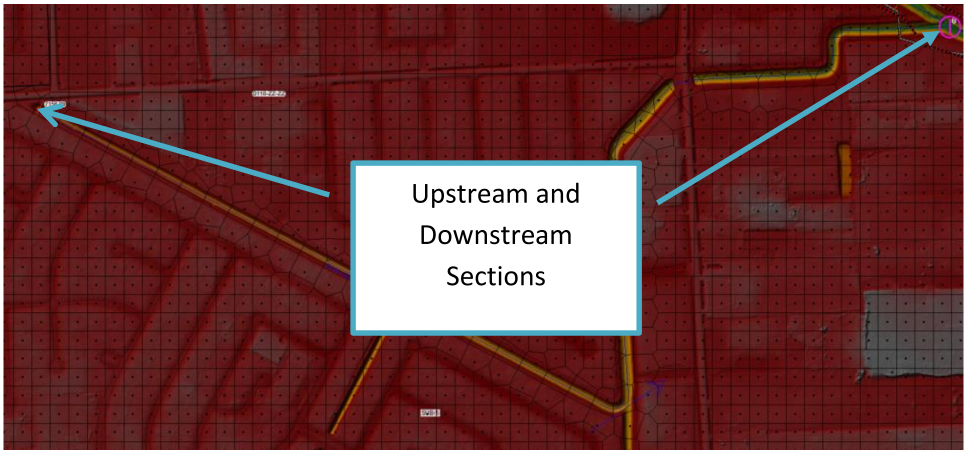


Figure 22 – RAS's Geospatial Assignment Based on Channel Reach Length

- Accept displayed location of Cut Lines as georeferenced. ("Geometry Editor" / "GIS Tools" / "GIS Cut Lines")
- Interpolate additional cross-sections at desired interval. Select the "Generate perpendicular to segments of reach invert" option.

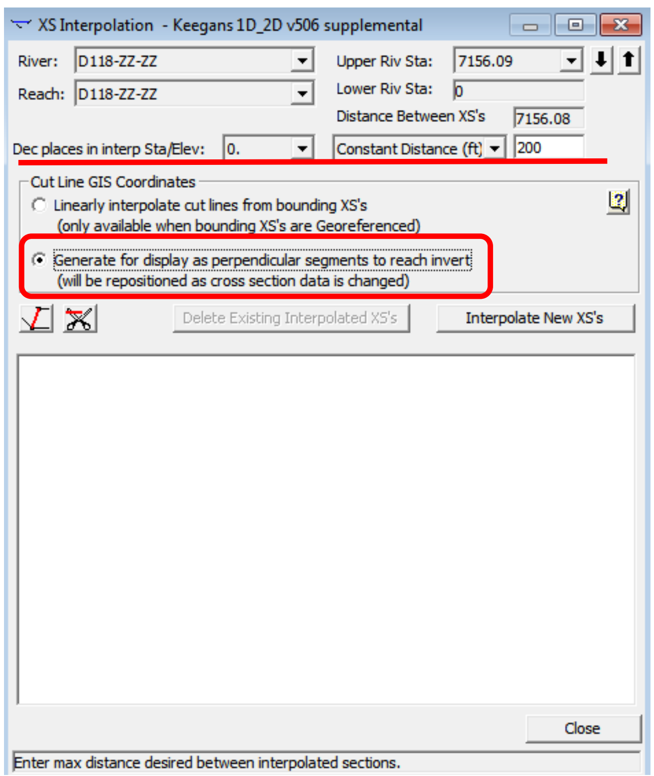


Figure 23 – Cross Section Interpolation Interface

Figure 24 – Cross Section Interpolations

- Accept displayed location of interpolated Cut Lines as georeferenced (“Geometry Editor” \ “GIS Tools” \ “GIS Cut Lines”)
- Cut cross-sections from terrain (“Geometry Editor” \ “GIS Tools” \ “Terrain”)

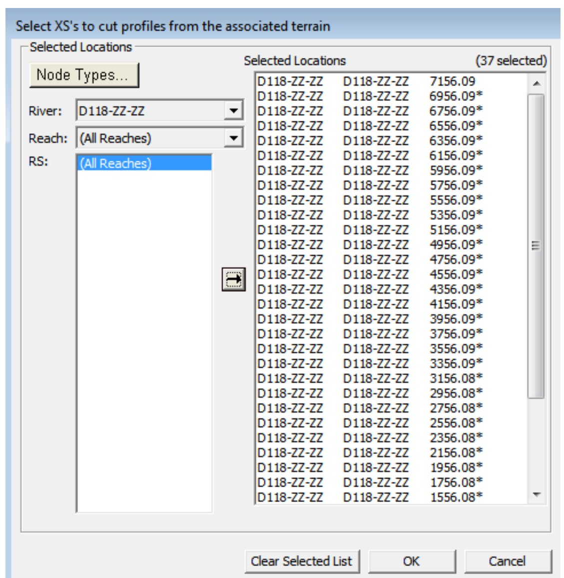


Figure 25 – Cross Section Cut Line Interface

- Set top of bank for cross sections based on terrain

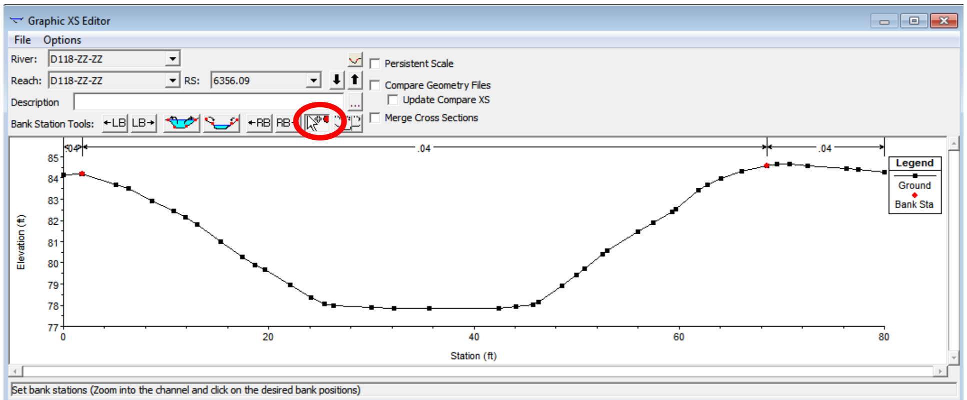


Figure 26 – Cross Section Graphic Editor Interface

If the added channel is within areas previously delineated as 2D flow areas, edit the 2D limits in RAS-Mapper to remove 2D flow area for 1D model extents.

- In RAS-Mapper right-click “Perimeters” under “Geometry” / “2D Flow Areas” and “Edit Geometry”

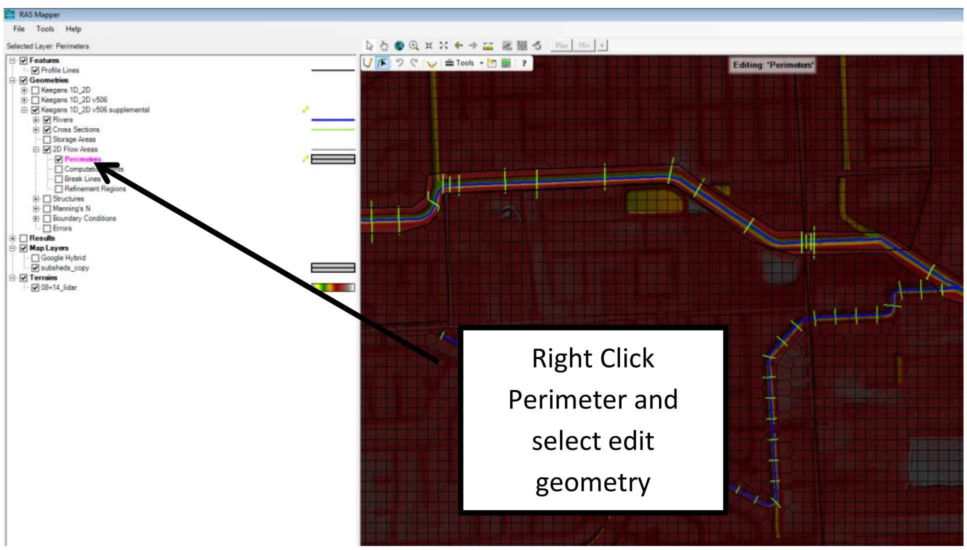


Figure 27 – RAS-Mapper Edit Perimeter

- Edit perimeter by drawing new area to be clipped from previously defined 2D flow area.

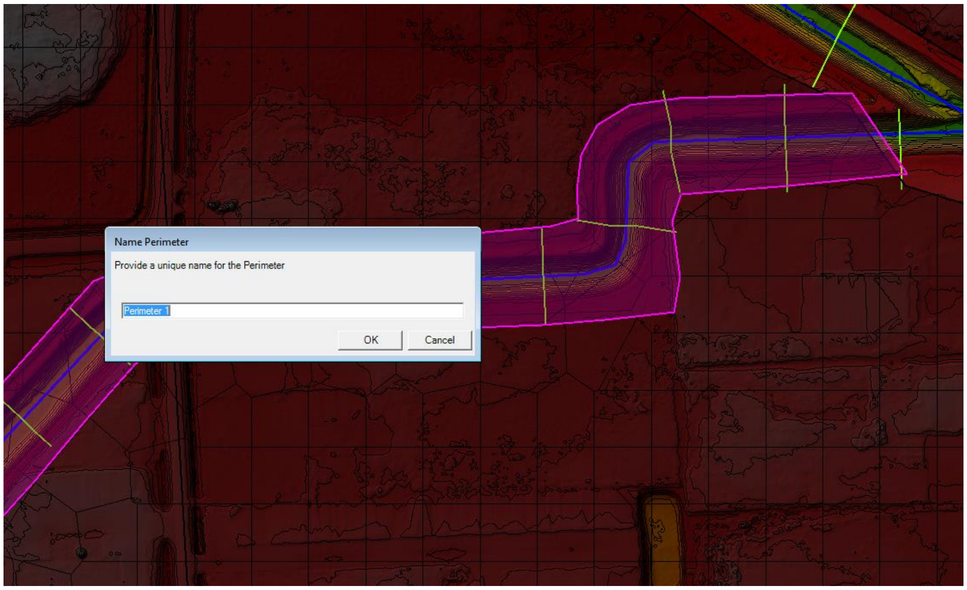


Figure 28 – Area To Be Clipped from 2D Flow Area

- Select the previously defined 2D domain and under “tools” select clip (discard)

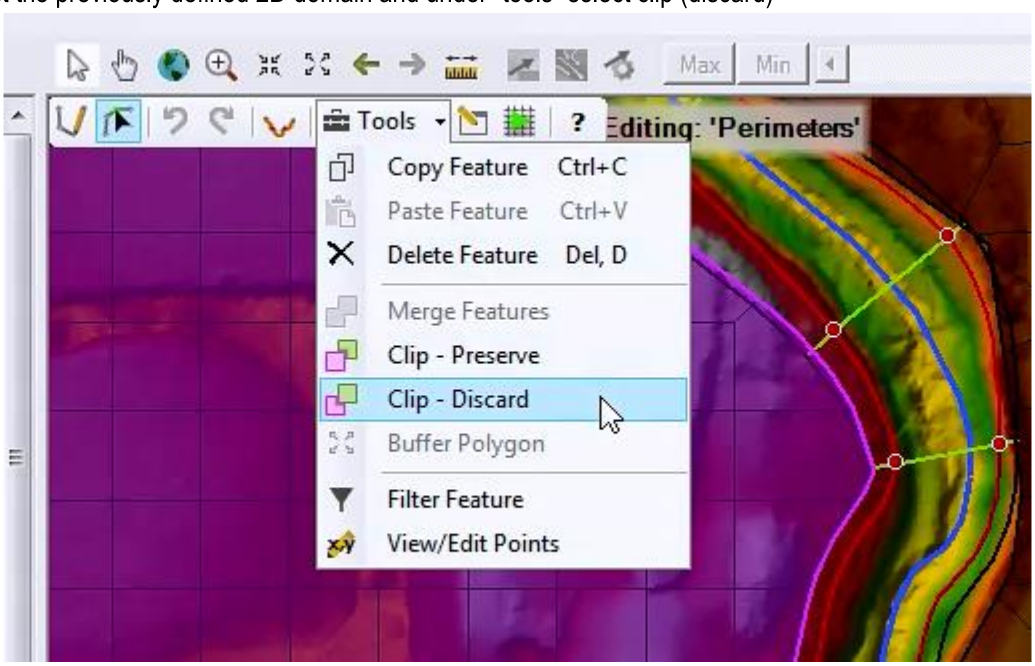


Figure 29 – Clip Discard Tool

The 2D domain will now be clipped to the supplemental channel limits delineated. Select the supplemental channel limits polygon and select delete under the Tools pull down, stop editing and return to the geometry editor.

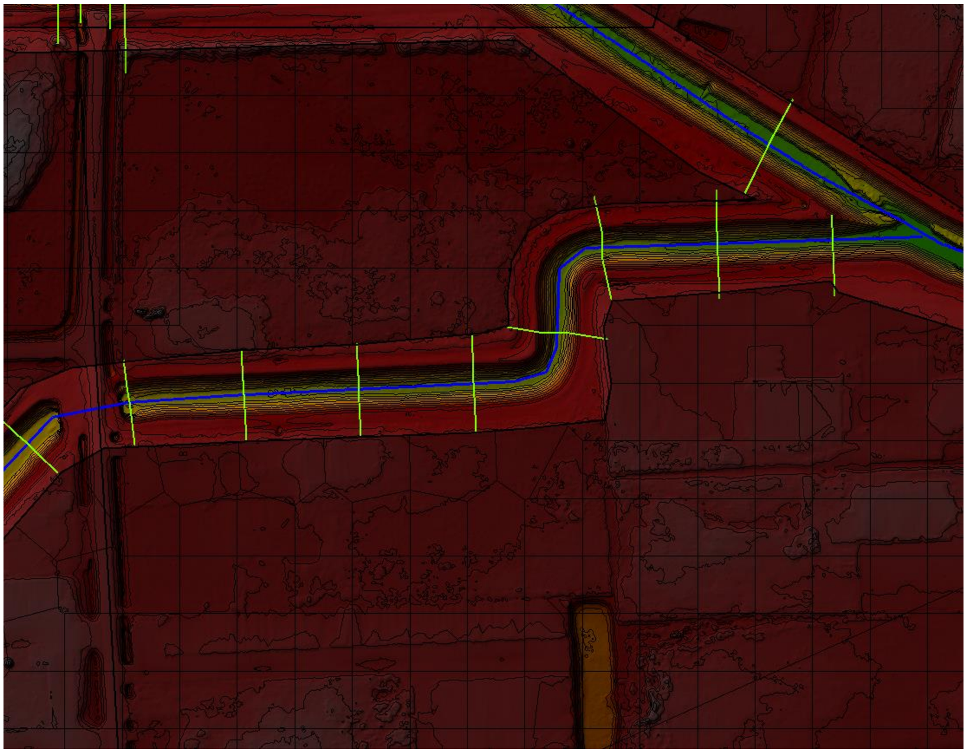


Figure 30 – Updated 2D Domain with Newly Added 1D Channel

- It is likely that some adjacent cells will need to be edited after this process has been completed. This typically requires moving cell centers that fall on or near the 2D perimeter.

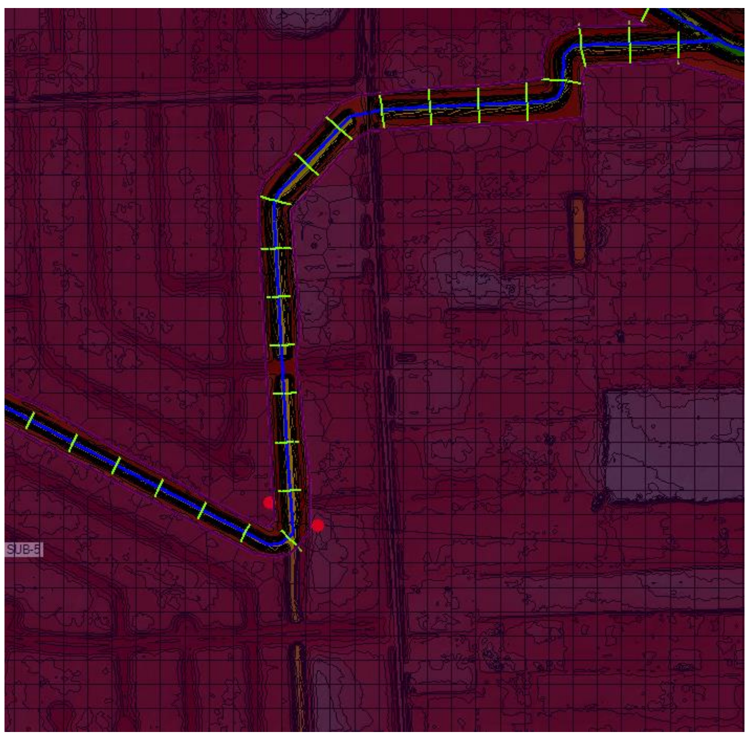


Figure 31 – Cells Requiring Edits

- Adjust 1D cut lines to match/overlap with 2D flow area as needed. Refer to Section 3 for adjusting 2D flow areas.
- Create lateral structures along supplemental reach and attach to 2D flow area. Refer to Section 3 for information on Lateral Structures.

Section 5) Storage Area Junctions for Joining 1D Model Reaches

Storage Area (SA) Junctions are recommended to be used for joining 1D portions of the models together, similar to traditional junctions. Prior to connecting the tributary reach to the SA Junction an initial condition run should be performed to provide an estimate of WSE in the receiving channel that can then be assigned as an initial stage elevation in the SA Junction. Edits to the 2D mesh faces will likely be required so that lateral structures and storage area connectors do not share a cell face. See Figure 32 below example of single face edits.

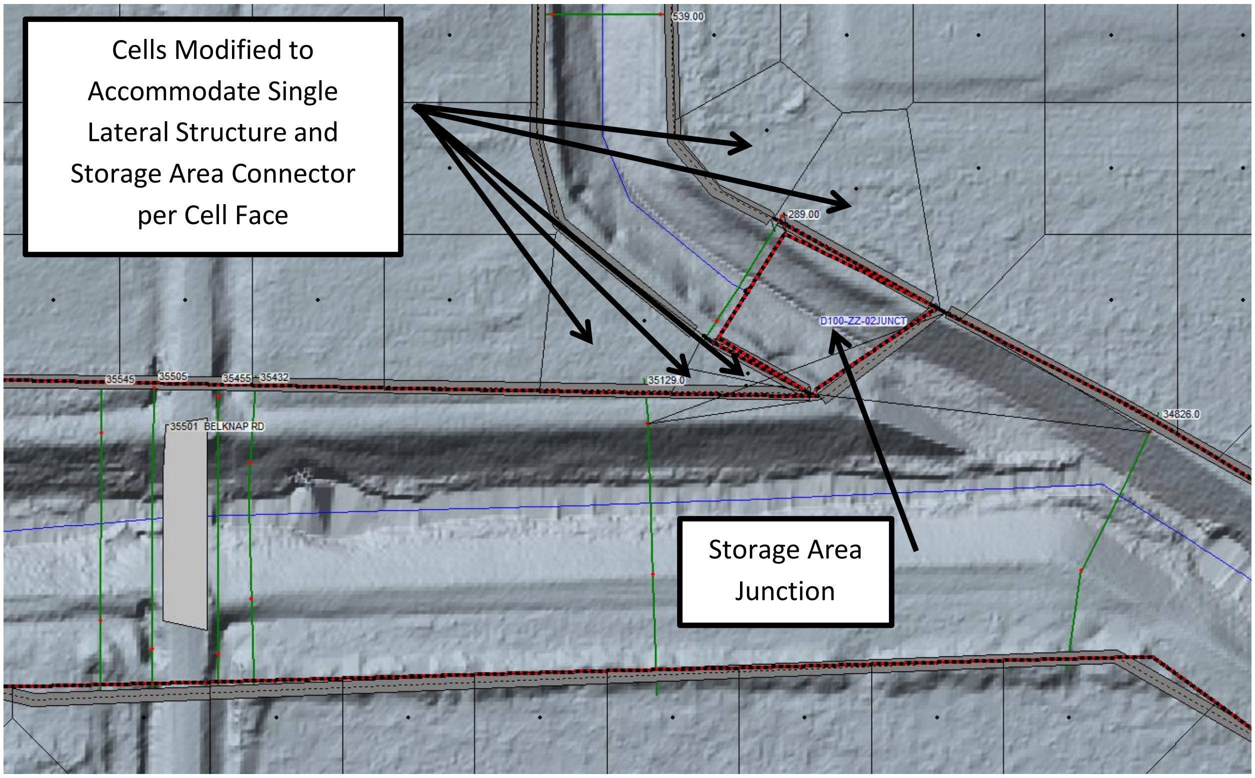


Figure 32 – Single Face Lateral/Storage Area Connector Assignments

Standard Tributary Connection

- Add a SA that covers the tributary portion of the channel entering the receiving channel. Populate the storage area curve using the "Compute E-V table from Terrain" tool in HEC-RAS's Storage Area Editor.
- Add Lateral Structure on receiving channel across tributary with tailwater location assigned to tributary SA using weir equation with discharge coefficient, C_d=2.0.
- Add Storage Area connector to join 2D area with SA Junction.
- Drag downstream point of tributary reach into SA Junction.
- Adjust SA Junction minimum elevation to be below minimum elevation of downstream tributary XS and lateral structure (if needed).

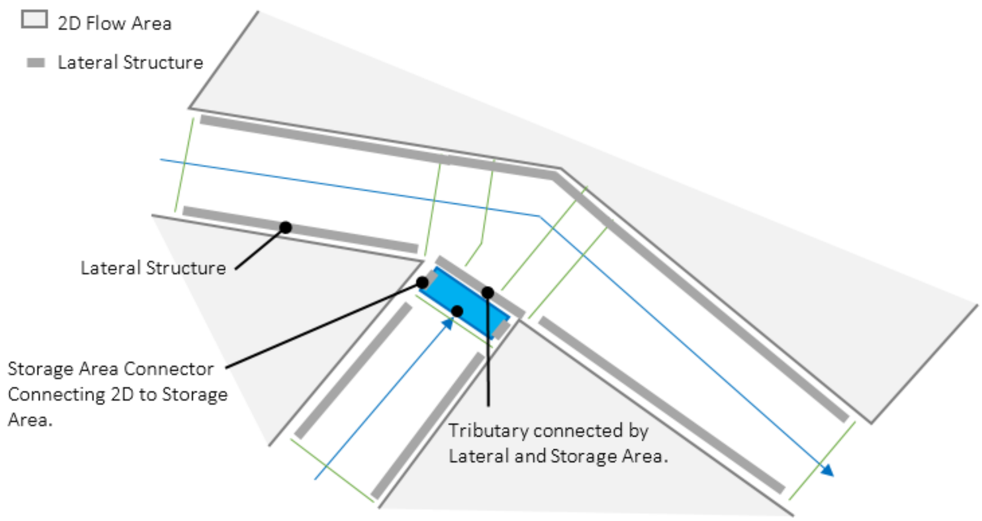


Figure 33 – Standard Storage Area Junction

Tributary Connection at Internal Boundary

- Similar to standard connection; however, due to no flow transfers being computed between bounding cross sections on internal boundaries, geospatial edits required to bounding XS to all for full flow transfer.
  - Add/Move points on bounding cross sections to have minimal distance between end points to allow full flow accounting across lateral structure.

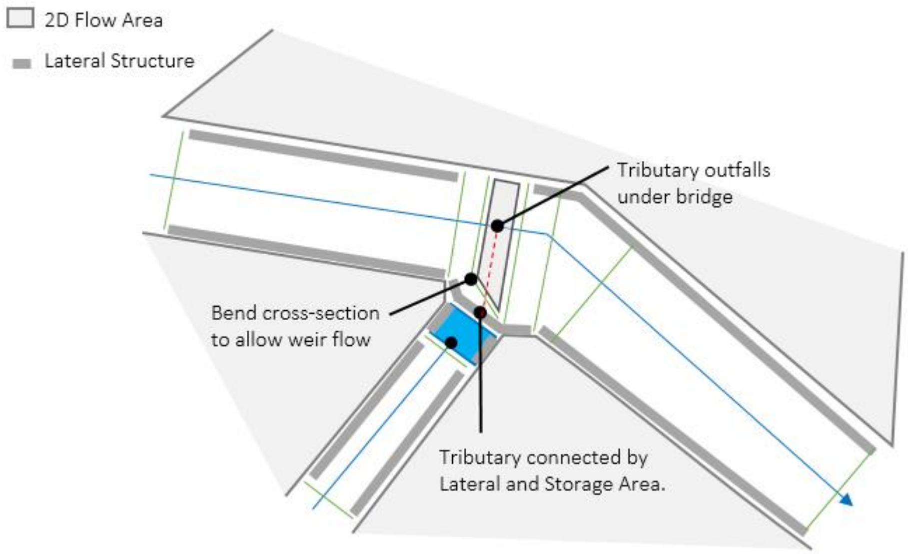


Figure 34 – Standard Storage Area Junction at Internal Boundary

Tributary Connection Through Culvert Structure

- Similar to standard connection with exception of weir Cd. Add Lateral Structure on receiving channel across tributary with tailwater location assigned to tributary SA using weir equation with Cd=0.5.

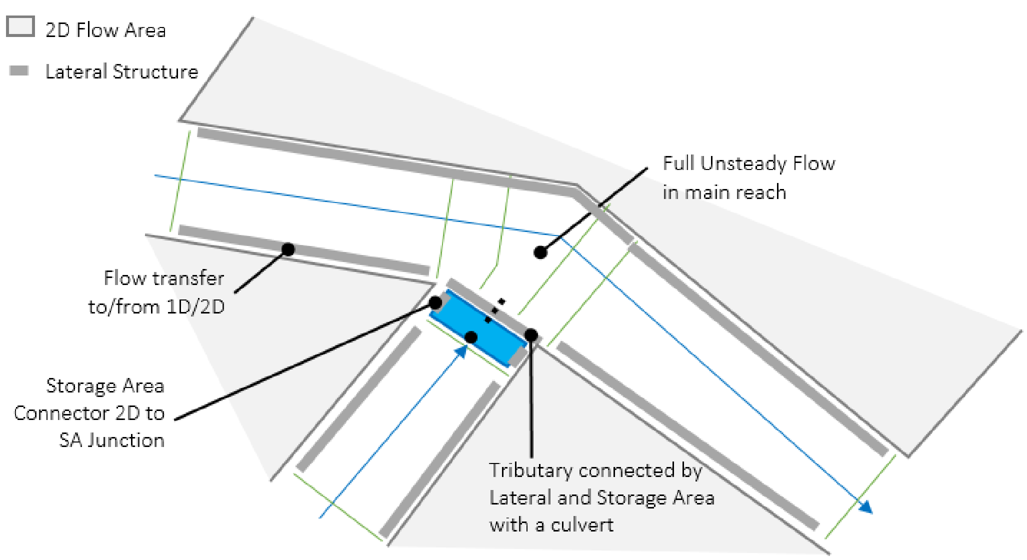


Figure 35 – Standard Storage Area Junction with Culvert Outfall

Tributary Connection to 2D Flow Area

- Connection to 2D flow area at the upstream end of the 1D reach can be accomplished similarly.
  - It is possible to connect directly to the 2D flow area by dragging end of reach line into the 2D area but stability improvements may be gained by using a SA Junction.

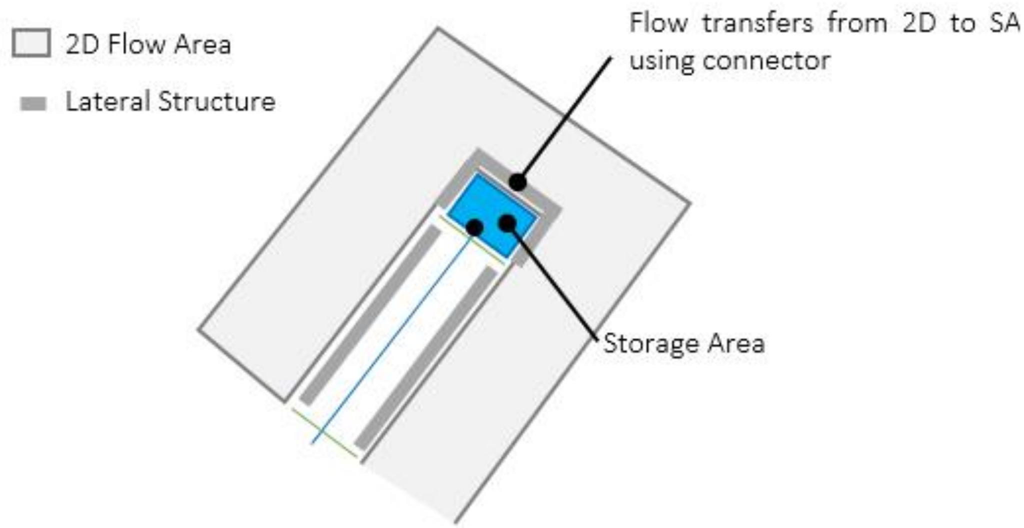


Figure 36 – Standard Storage Area Junction at 1D to 2D or 2D to 1D Interface

Section 6) Break Lines

- Add break lines through the Geometry Editor Interface. Enabling the terrain contour display in RAS-Mapper will assist in properly locating break lines. There will likely be areas where the need to revise cell spacing along break lines is required. Avoid cell spacing less than 50' if possible. Smaller cell sizes may require reduced time steps.
  - Break lines should be placed along the high break in grade along basins/roadway embankments within 0.2% floodplain for areas that may influence flow direction. Review 10% floodplain as well to identify lesser embankments that may need to be accounted for.

Figure 37 – Break Lines Along Roadway Embankments and Top of Basins/Channels

Section 7) Land Classification Assignment

- Associate provided land classification with terrain.
    - Manning's n Regions may be needed to provide additional detail. This will likely be necessary in areas where flow is assigned in the 2D flow area (done to reflect probable lower n values in minor channels than what the coarse land classification has). Attention needs to be paid to 2D mesh face delineation to verify proper n value assignment to cell face. A single n value is assigned to cell face based on what classification makes up largest percentage of coverage for each cell face. Figure 38 shows two channels that are modeled in 2D with internal flow assignments. Figure 39 shows the base Land Classification assignment. Note in Figure 39 that the channels are largely shown to have a Developed Low Intensity classification with a n-value of 0.016. These are grass lined channels and a n-value of 0.06 is to be assigned.

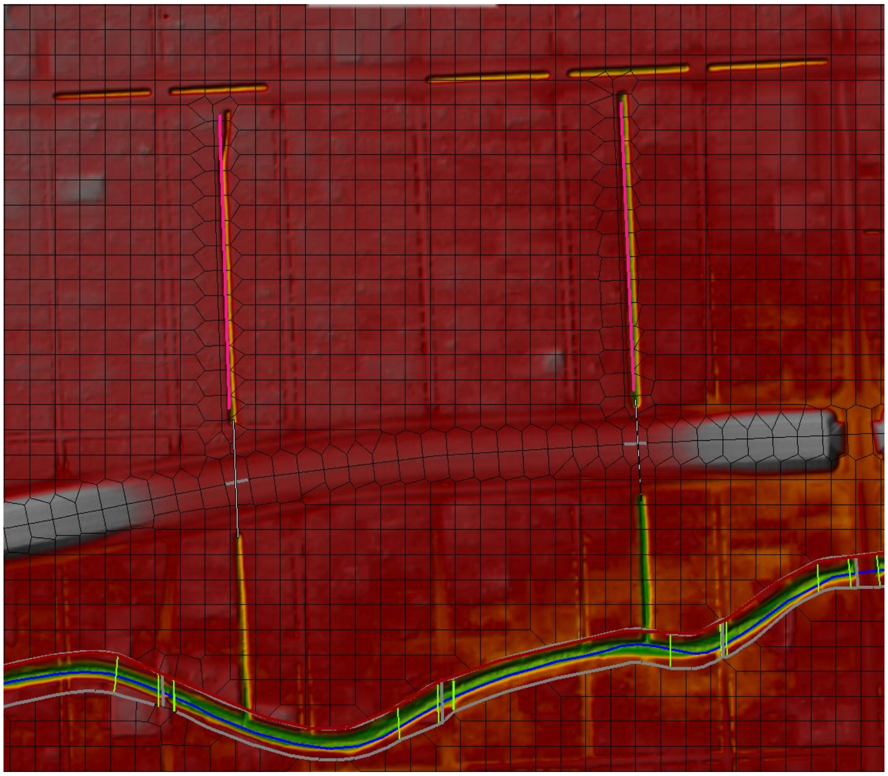


Figure 38 – Channels Modeled in 2D with Internal Flow Boundaries Assigned

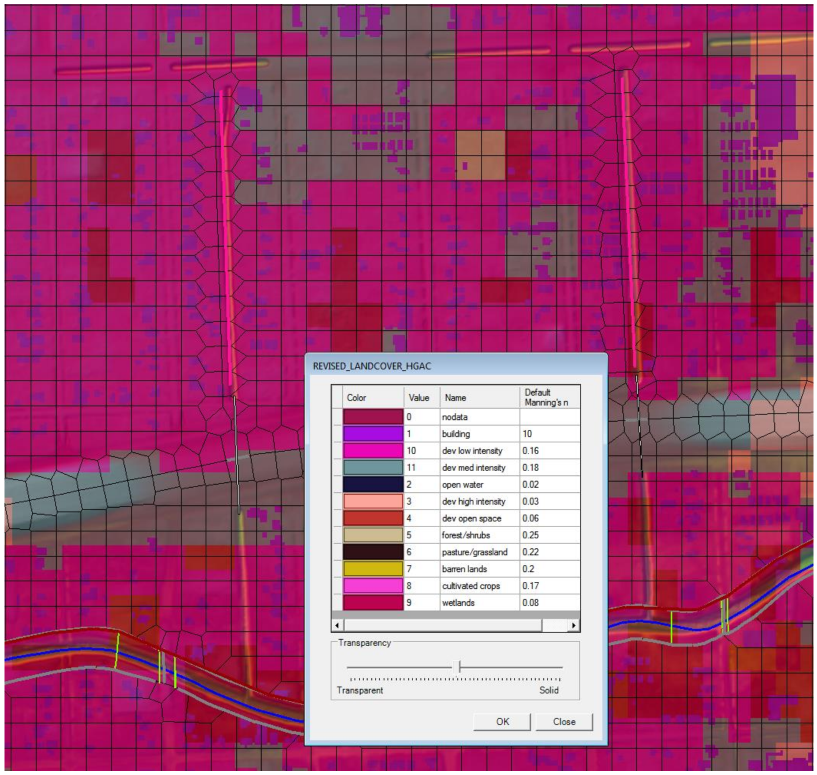


Figure 39 – Assigned Base Land Classification

- In the Geometry Editor select the n-regions tool and draw polygons around cells where n-value modifications are required. See Figure 40.

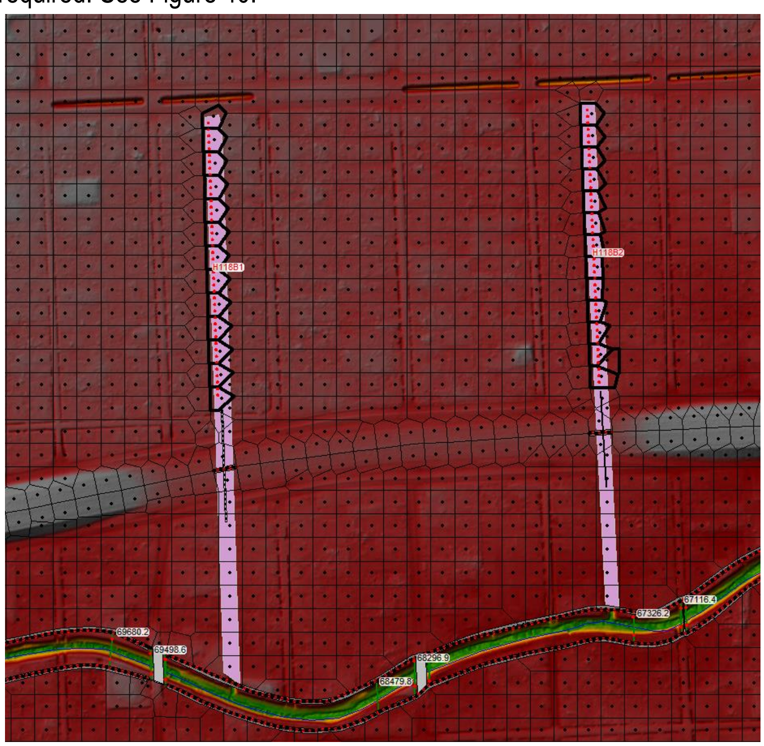


Figure 40 – 2D Area Manning's n-Regions Assigned to Channel Area

- Select the n-region polygon and select “Edit Manning’s n Values”. Assign n value to region that will replace underlying “base” n-value

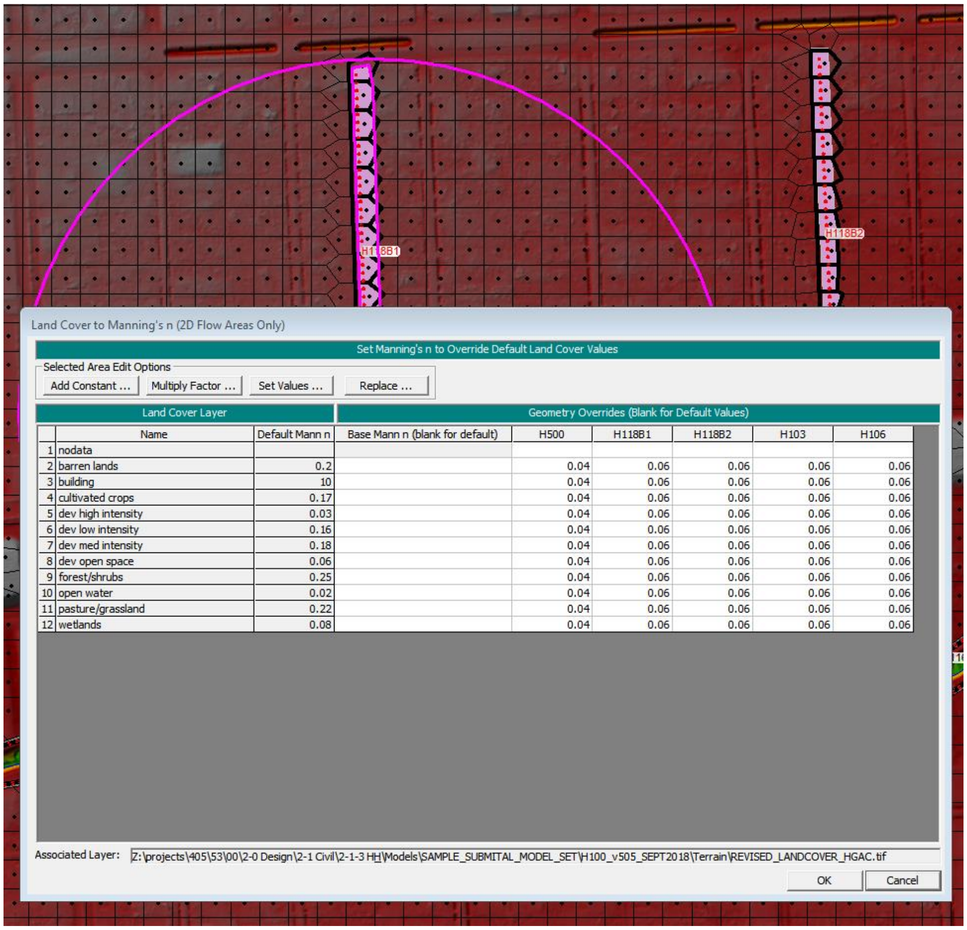


Figure 41 –n-Regions Assigned to Channel Area

- In RAS-Mapper under “Geometry” right click “2D Flow Area” select “Compute 2D Flow Areas Hydraulic Tables”
- After hydraulic tables have been updated review resulting n-value association in RAS-Mapper by selecting the check box next to “Final n values” under “Geometries” / “Geometry Name” / “Manning’s N”

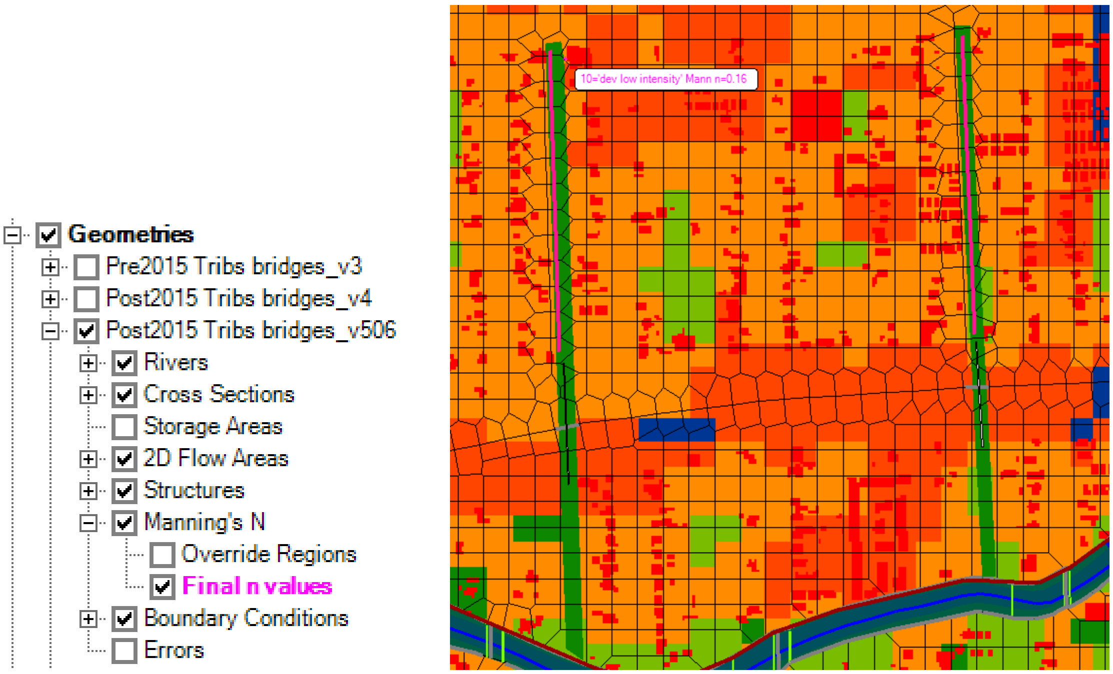


Figure 42 – Final n-value Assignments to 2D Domain

Section 8) Flow Boundary Assignments

- The most common flow assignments will be to the 1D portion of the models. Follow typical unsteady state assignment of hydrographs as detailed in the HCFCD Unsteady State Flow Guidance Manual.
- Flow assignments within the 2D domain may be occasionally required in order to capture flood risk in isolated flooding areas. Typical assignment would be to place an internal flow boundary within the cell or cells with the greatest flooding depths indicated by the rain on grid analysis. The modeler should test the sensitivity of the placement by varying the location of the hydrograph placement and inspection of the resulting aerial mapping extents.

The following is an example of varied internal flow assignments and comparison of the resulting aerial mapping extents. In this example it is found that location of flow assignment does not result in notable flooding extent differences. If differences were noted the modeler should compare calibration storm events against recorded flood damage records or high water marks and select the flow assignment location that most closely captures recorded flooding.

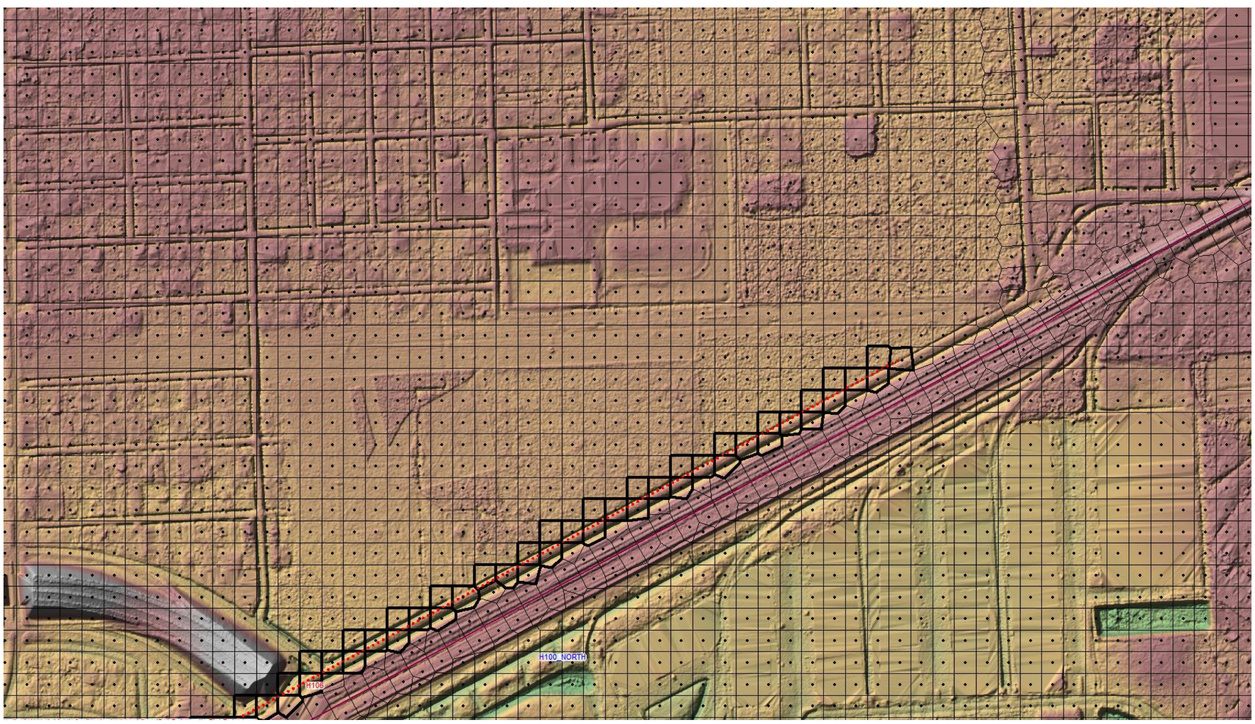


Figure 43 – Internal Boundary Flow Assignment #1

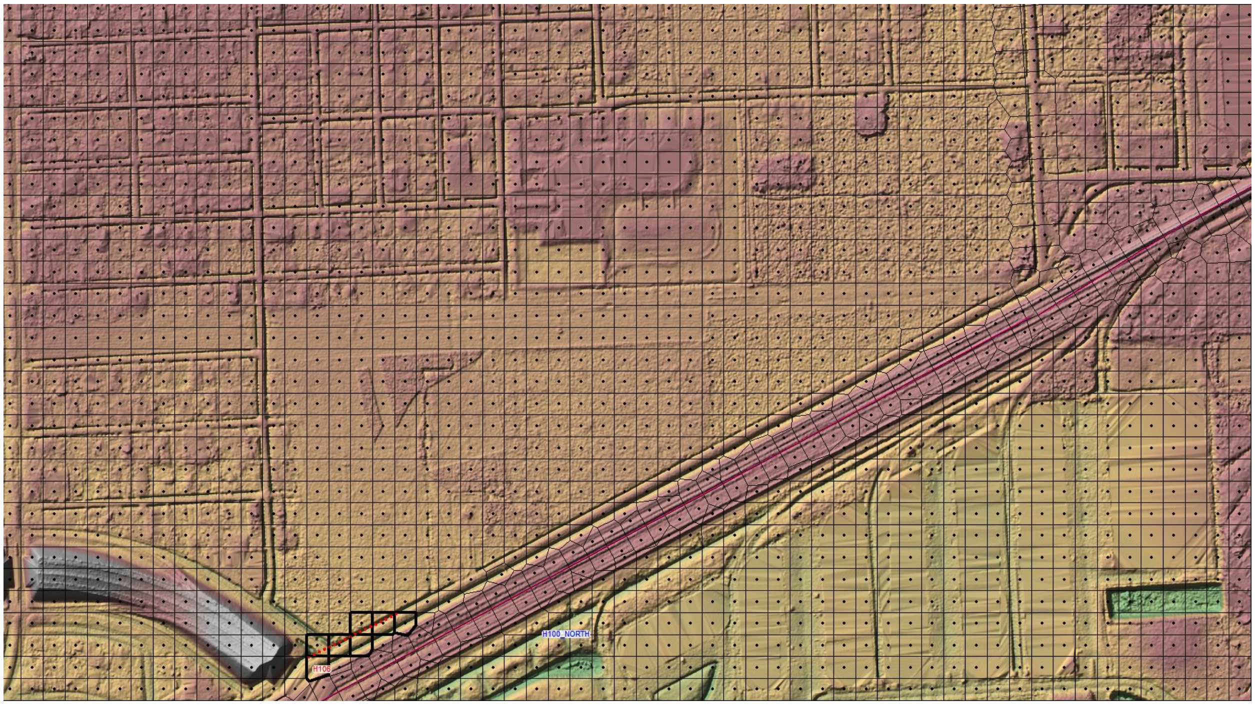


Figure 44 – Internal Boundary Flow Assignment #2

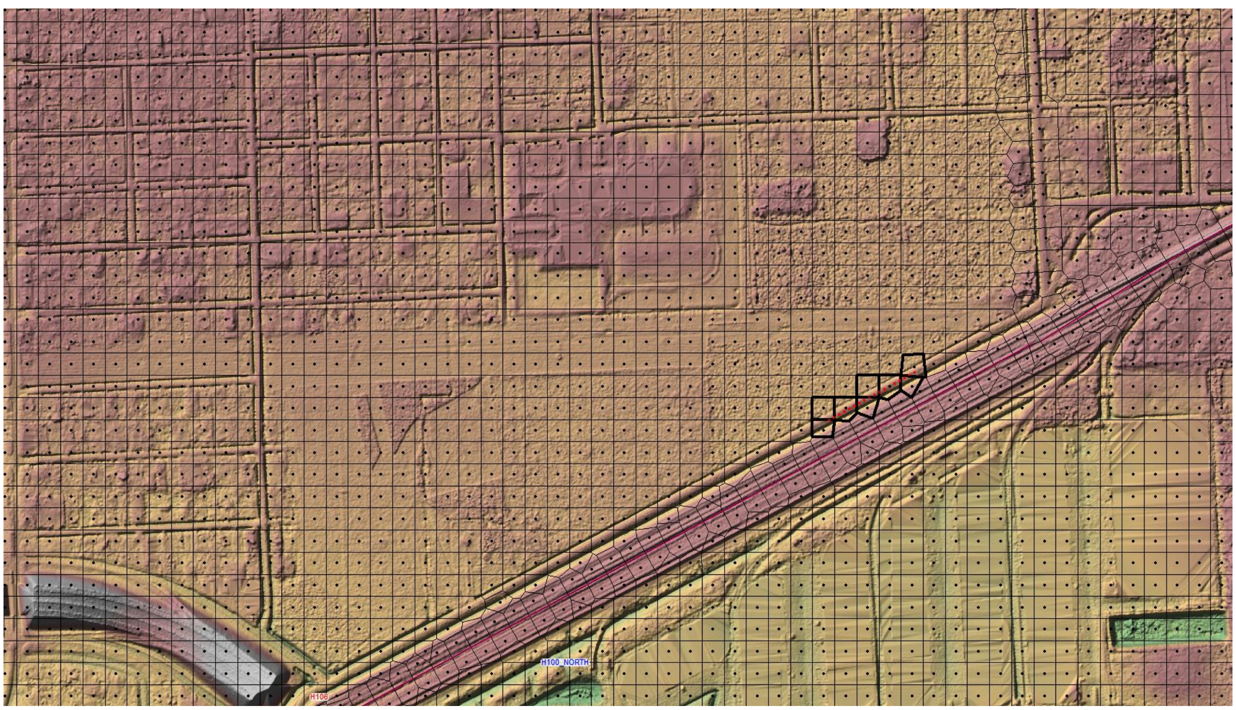


Figure 45 – Internal Boundary Flow Assignment #3

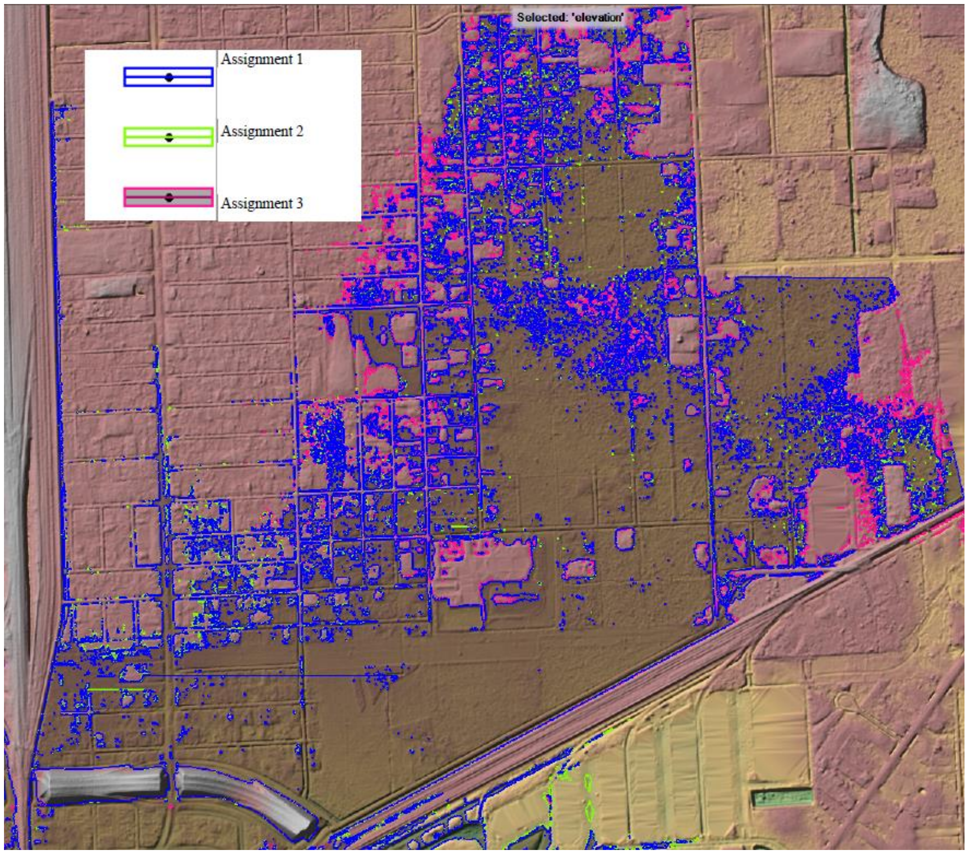


Figure 46 – Mapping Comparison Demonstrating Sensitivity of Flow Assignment Location

Section 9) Rain on Grid for Identification of Isolated Flooding

Once preliminary 1D/2D model set up has been made the model will be tested using a rain on grid boundary condition. This exercise is used to help identify areas of isolated flood risk that is not currently being captured in the 1D/2D modeling with hydrographs directly applied to the 1D portion of the model.

- Create copy of preliminary 1D/2D unsteady flow file. The initial conditions flow and starting WSE will be retained for the rain on grid analysis. Apply a "0" multiplier in the flow editor to all hydrographs assigned to the 1D and 2D domains.
- Review the HEC-HMS 1% event downstream node for total runoff volume in inches. Identify a sub-basin within HEC-HMS with a similar runoff volume. This sub-basin's excess precipitation will be used as the rain on grid input boundary condition assigned to all 2D flow area domains.
- Review the rain on grid mapping for depths greater than 18-inches against the preliminary 1D/2D mapping. Areas shown to have depths greater than 18-inches in the Rain on Grid run that are not reflected in the 1D/2D mapping should be reviewed to determine if hydraulic connections can be added to the modeling to allow for backwater conditions to enter these identified areas. Examples would be adding roadway cross culverts to allow backflow into

low lying areas. In some cases, internal 2D flow boundaries may be required to be assigned to the 2D flow area.

- The identified isolated flooding areas and proposed modeling approaches should be reviewed with HCFCD prior to their inclusion.

Section 10) RAS Data Used Directly in HEC-HMS

HEC-RAS output data will be used to develop routing information to be entered into HEC-HMS. After an initial 1D/2D HEC-RAS run has been completed for the 1-percent event routing information can be extracted from RAS-Mapper.

- Identify upstream and downstream reach limits as they pertain to the HEC-HMS model.
- In RAS-Mapper draw and save profile lines at the upstream and downstream limits of the reach.

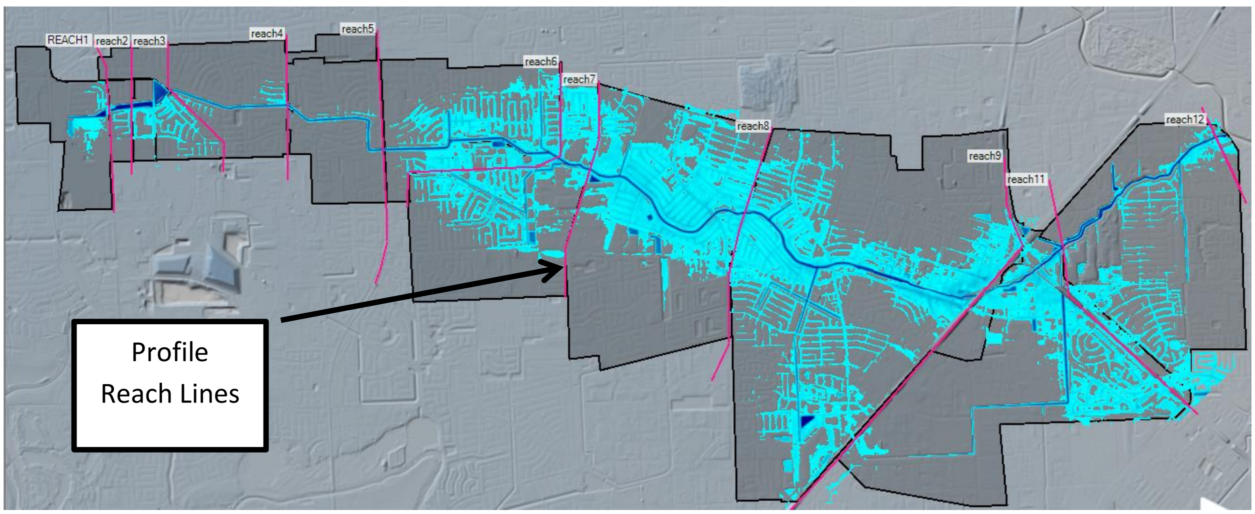
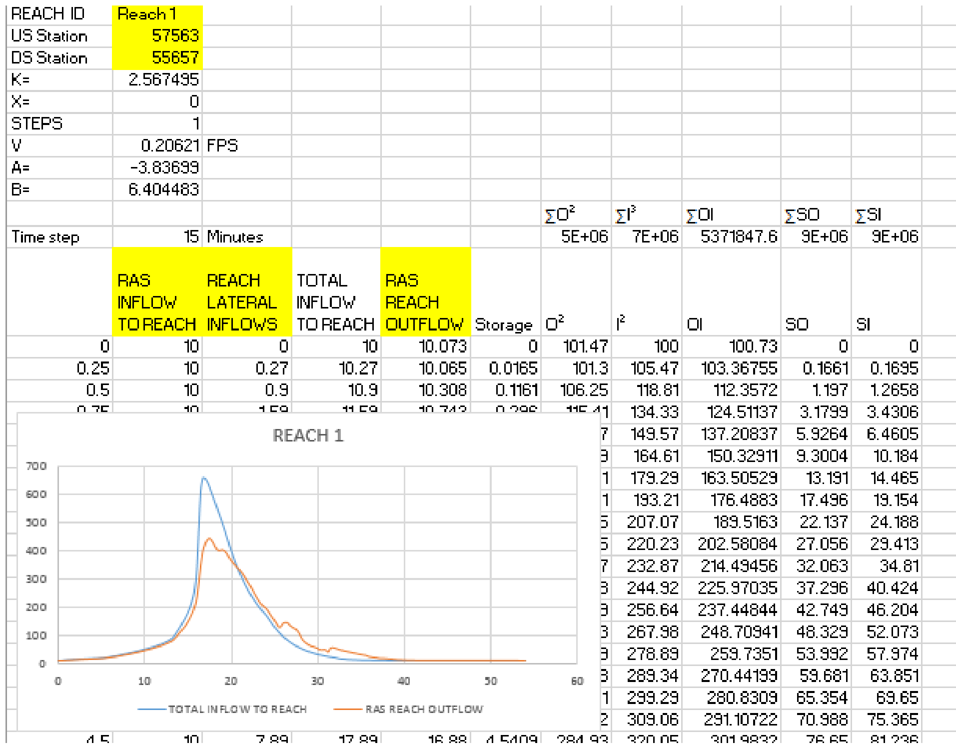


Figure 47 – Profile Reach Lines

Hydrograph information will be extracted from within RAS-Mapper for each profile line. These hydrographs will provide the inflow and outflow for each reach. Using this information, the timing and storage affect can be gathered and Muskingum K, X and number of routing steps derived in Excel using the Least Squares. A template spreadsheet will be provided allowing for copy and paste of data from HEC-RAS.

- In RAS-Mapper right-click the profile line and select plot time-series profile/flow. From the table, copy and paste the data into Excel. The reach inflow, outflow and all lateral inflows to the reach are required to be input into the spreadsheet.



REACH ID	Reach 1									
US Station	57563									
DS Station	55657									
K=	2.567495									
X=	0									
STEPS	1									
V	0.20621	FPS								
A=	-3.83699									
B=	6.404483									
						$\sum O^2$	$\sum I^3$	$\sum OI$	$\sum SO$	$\sum SI$
Time step	15	Minutes				5E+06	7E+06	5371847.6	9E+06	9E+06
	RAS INFLOW TO REACH	REACH LATERAL INFLOWS	TOTAL INFLOW TO REACH	RAS REACH OUTFLOW	Storage	O^2	I^2	OI	SO	SI
0	10	0	10	10.073	0	101.47	100	100.73	0	0
0.25	10	0.27	10.27	10.065	0.0165	101.3	105.47	103.36755	0.1661	0.1695
0.5	10	0.9	10.9	10.308	0.1161	106.25	118.81	112.3572	1.197	1.2658
							134.33	124.51137	3.1799	3.4306
							149.57	137.20837	5.9264	6.4605
							164.61	150.32911	9.3004	10.184
							179.29	163.50529	13.191	14.465
							193.21	176.4883	17.496	19.154
							207.07	189.5163	22.137	24.188
							220.23	202.58084	27.056	29.413
							232.87	214.49456	32.063	34.81
							244.92	225.97035	37.296	40.424
							256.64	237.44844	42.749	46.204
							267.98	248.70941	48.329	52.073
							278.89	259.7351	53.992	57.974
							289.34	270.44199	59.681	63.851
							299.29	280.8309	65.354	69.65
							309.06	291.10722	70.988	75.365

Figure 48 – Muskingum Reach Routing Template

Additional information that can be extracted from HEC-RAS for use in HEC-HMS is the generation of sub-catchment detention. The detention ratio of the catchment is required for generation of Clark Unit Hydrograph TC and R values.

- Create a “Storage Area” geometry file for the watershed being studied.
- Assign Terrain file and attach the watershed delineation shapefile for reference.
- Within the Geometry editor draw a “Storage Area” over basins identified in the terrain file.
  - The delineated basins are to exclude basins that are modeled in RAS directly with storage area connectors or shown to be inundated by the 1 percent event mapping.
    - Figure 49 illustrates basins delineated to be included in the catchment detention ratio. Basins D118B-2.1 and D118B-2.2 provide significant volume and serve a large drainage area. 1-percent mapping shows some flow enters these basins from overbank flooding but does not completely fill them. Because of the basins not being filled from overbank flooding they are included in the watershed detention ratio calculation. Alternatively, these basin’s outfall structures could be added to the modeling allowing for them to be backwatered from the 1D portion of the model. If this alternative modeling were to be done these basin volumes would be excluded from the watershed detention ratio.

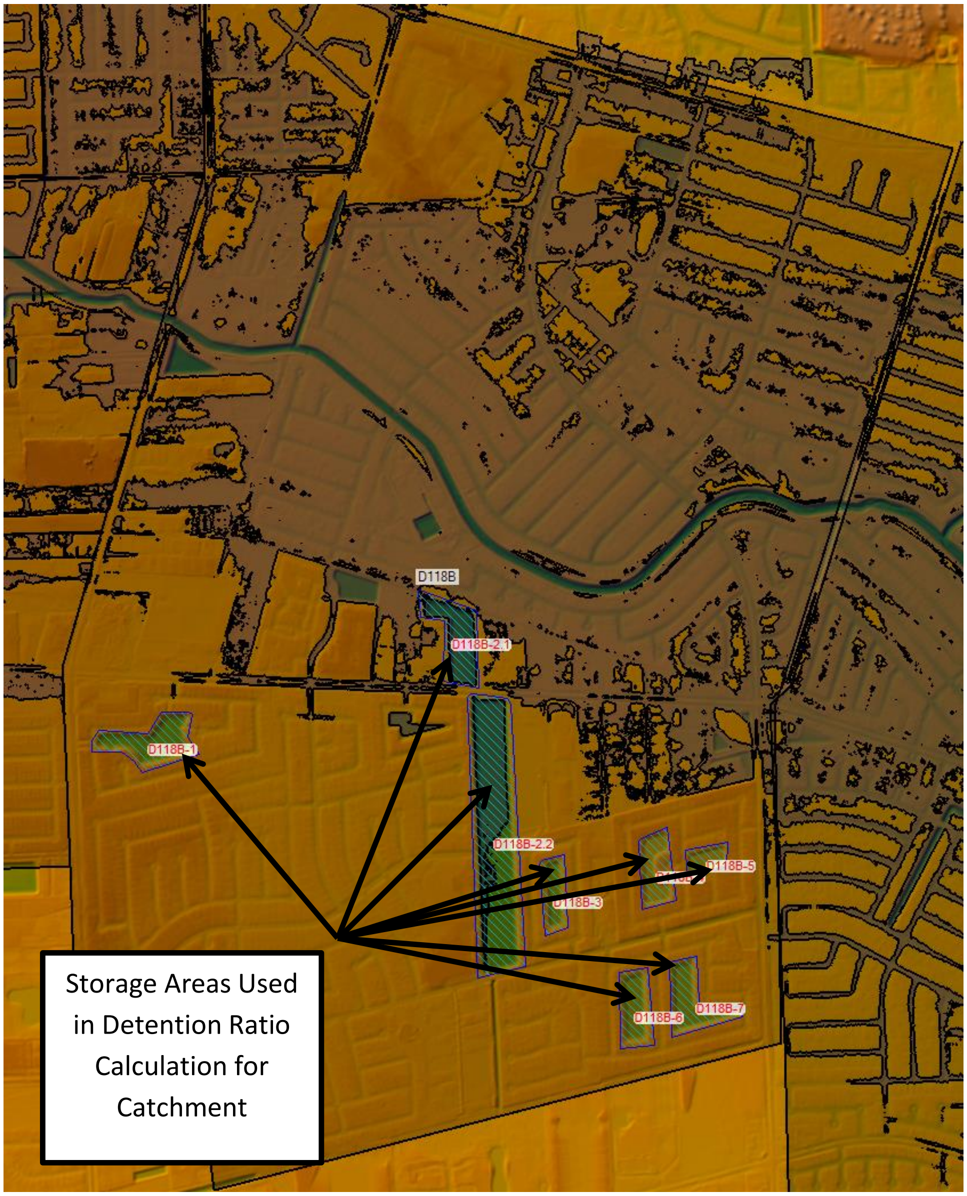


Figure 49 – Delineated Detention Basins for Detention Ratio Consideration

- Large basins such as gravel/sand pits that have minimal drainage area contributing to them should also be excluded from the calculation of the watershed detention ratio.
- Review the average top of bank elevation around the basins and compute peak storage volume at approximately 1-foot below the average top of bank. See Figures 50 and 51 for example volume estimation computed using HEC-RAS

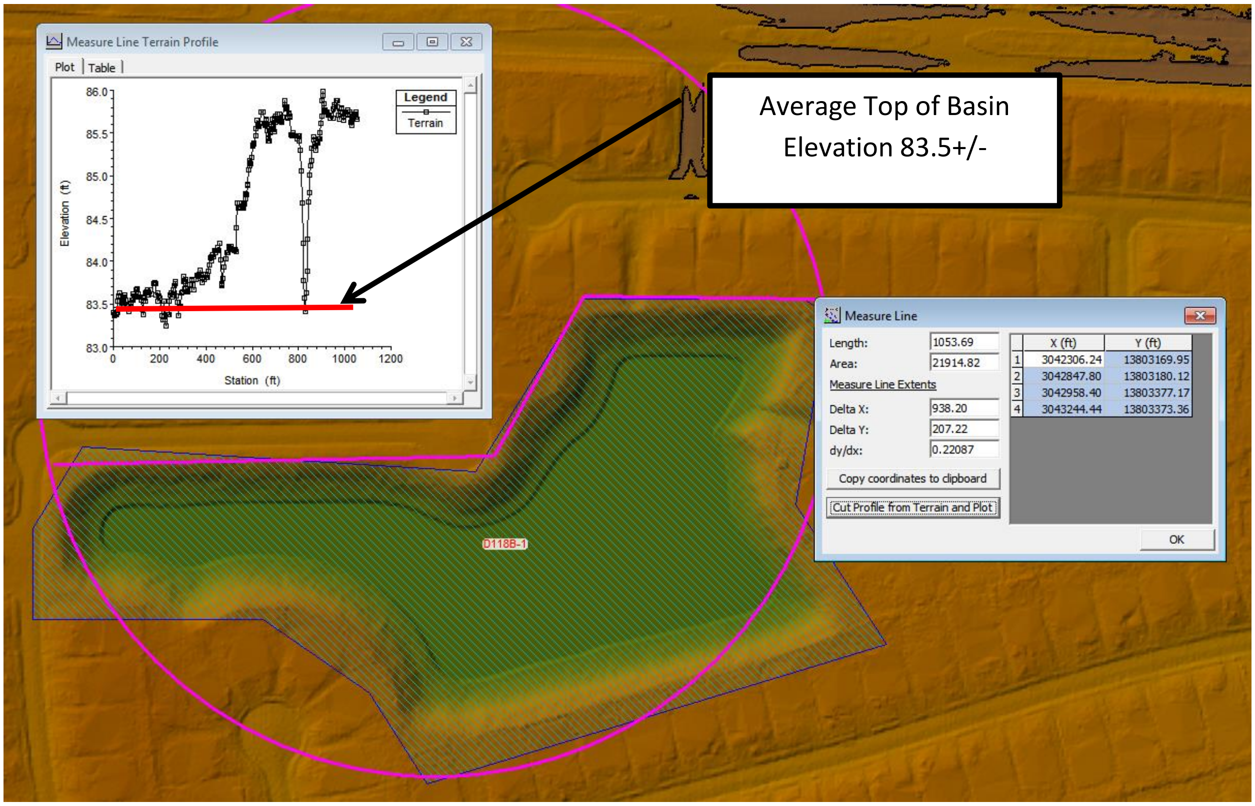


Figure 50 – Delineated Detention Average Top Elevation

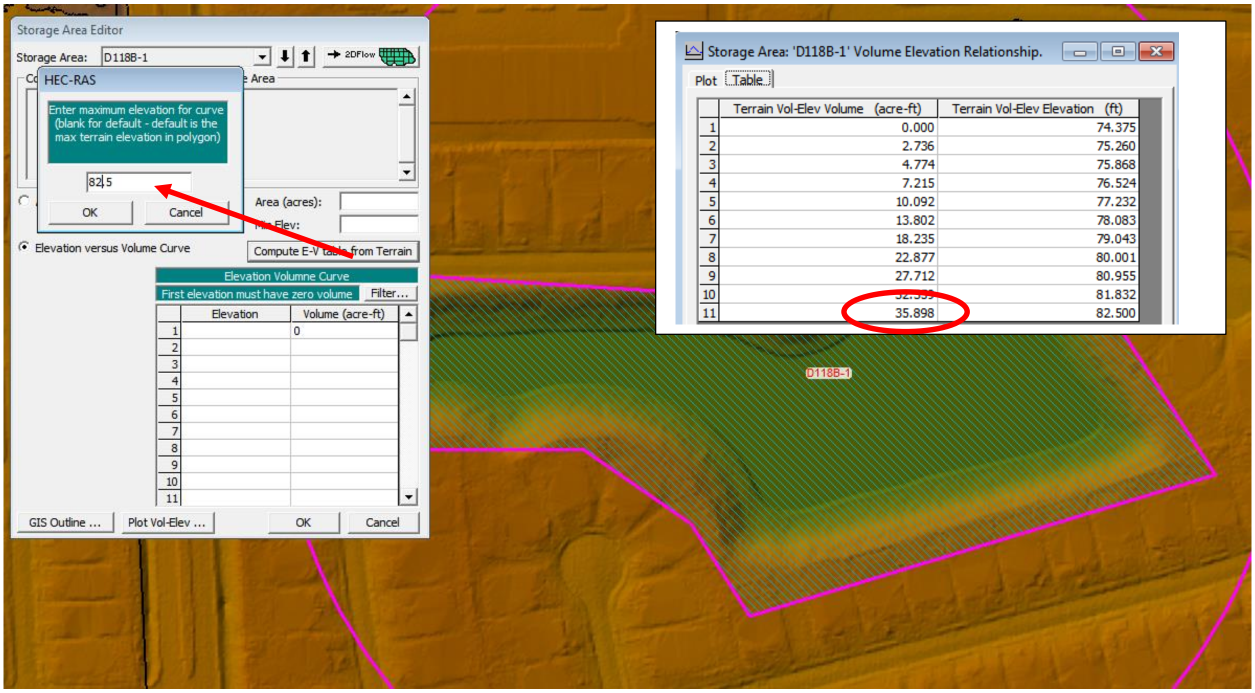


Figure 51 – Storage Area Editor Volume Calculation

- Sum total volume for delineated basins and compute watershed detention ratio (acre-feet/sq. mi.)