QUICK CHECK GUIDEBOOK

ILLINOIS DEPARTMENT OF TRANSPORTATION

BUREAU OF BRIDGES AND STRUCTURES

HYDRAULICS UNIT

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Quick Check Guidebook Forward

The purpose of this Quick Check Model Guidebook is to document a procedure for developing a 2D Quick Check report. This report will be used to: identify approximate flood levels and boundaries, estimate roadway overtopping conditions, determine the full 2D modeling domain, determine survey extents and needs, identify other structures that may impact the design and evaluation, and identify potential flood receptors. This report will be used to develop budgets and scopes of work for more detailed studies (prepared by either in-house IDOT staff or by a consultant). A secondary purpose of the Quick Check modeling is to engage IDOT Hydraulics staff in using SRH-2D and increase their comfort level with the software and 2D modeling in general.

The Quick Check Guide SMS files can be downloaded by clicking the link below.

Quick Check Guide SMS Models

INTRODUCTION

The purpose of this manual is to describe a methodology using SRH-2D to perform a preliminary evaluation of an existing or proposed waterway crossing. This preliminary evaluation is to inform IDOT District personnel of design considerations associated with the waterway crossing and assist in the development of the scope of work and budget for future design studies. This preliminary evaluation is not intended as a substitute for the detailed modeling required for design. These design considerations are potential roadway overtopping locations, flow directions and velocities in relation to the structure opening, additional floodplain opening requirements, and other nearby structures such as sensitive flood receptors, levees, bridges, etc. that may impact the waterway crossing design. The results of this evaluation will also assist in defining survey requirements for future design studies and permitting of any required structures.

The modeling and documentation methodologies cited in this guidebook are intended to leverage readily available data within the SRH-2D software, such as digital elevation data and aerial imagery, to minimize data collection and field survey requirements. This document has been developed to assist the engineer in performing this preliminary evaluation.

The following sections provide more detail on each of the recommended steps in this preliminary evaluation. Some steps are similar to existing design and analysis requirements. Each of these sections include descriptions and screen shots of the steps required when using SRH-2D.

The guidebook also includes example Quick Check evaluations of 15 sites located throughout Illinois for minor and major waterways as a supplement to this document to assist the modeler in understanding the issues that may be present at the site being evaluated. One complex site has been included to show the results of a more detailed evaluation of the existing conditions using SRH-2D. A comparison of the detailed modeling results to that of the Quick Check Model results shows how the results may vary given the differences in the level of detail between these studies.

SITE REVIEW

An initial site review by the engineer will assist the engineer in understanding the site constraints and problems when determining the model limits and data requirements. This site review may include the following items:

- District flood complaints in the vicinity of the crossing or nearby roads crossing the same waterway
- existing roadway and bridge plans
- previous hydraulic and scour reports for the waterway crossing
- current aerial imagery of the site
- existing FEMA floodplain mapping of the site

MODEL NAMING CONVENTION

A recommended naming convention for Quick Check model files and layers has been developed. The general format of the file/layer naming convention is:

QC_Route_Stream_Source_DataType.ext

All files and layers would start with QC denoting that this is a Quick Check model. The second part of the naming convention is the IDOT route or road name. The third part is the name of the watercourse. The fourth part is the source of the topographic data. If the topographic data came from SMS, this portion of the name would be SMS. If the aerial, LIDAR, etc. data came from another source, the name would be a descriptor of the source. For example, LIDAR data from the Illinois Geospatial Clearinghouse for IL 121 over the West Okaw River, the name would be:

QC_IL121_WestOkawRiver_IGC_LIDAR.las

This naming convention should be used for the model file name, layers that are imported such as aerial imagery, terrain data, etc., and created files such as terrain, scatter, and mesh files. The model file name would be:

QC_IL121_WestOkawRiver.sms

The other layers such as boundary conditions, material coverages, monitor lines, monitor points, and model simulations should be descriptive of the layer. It is recommended that they begin with "QC" to identify that this is a Quick Check model. Including the road and waterway name is recommended, but may be skipped if name lengths are excessive. For simulations and boundary conditions, this should include the flow frequency. For a boundary condition layer, the file name at a minimum would be:

QC_BoundaryCondition_100-yr

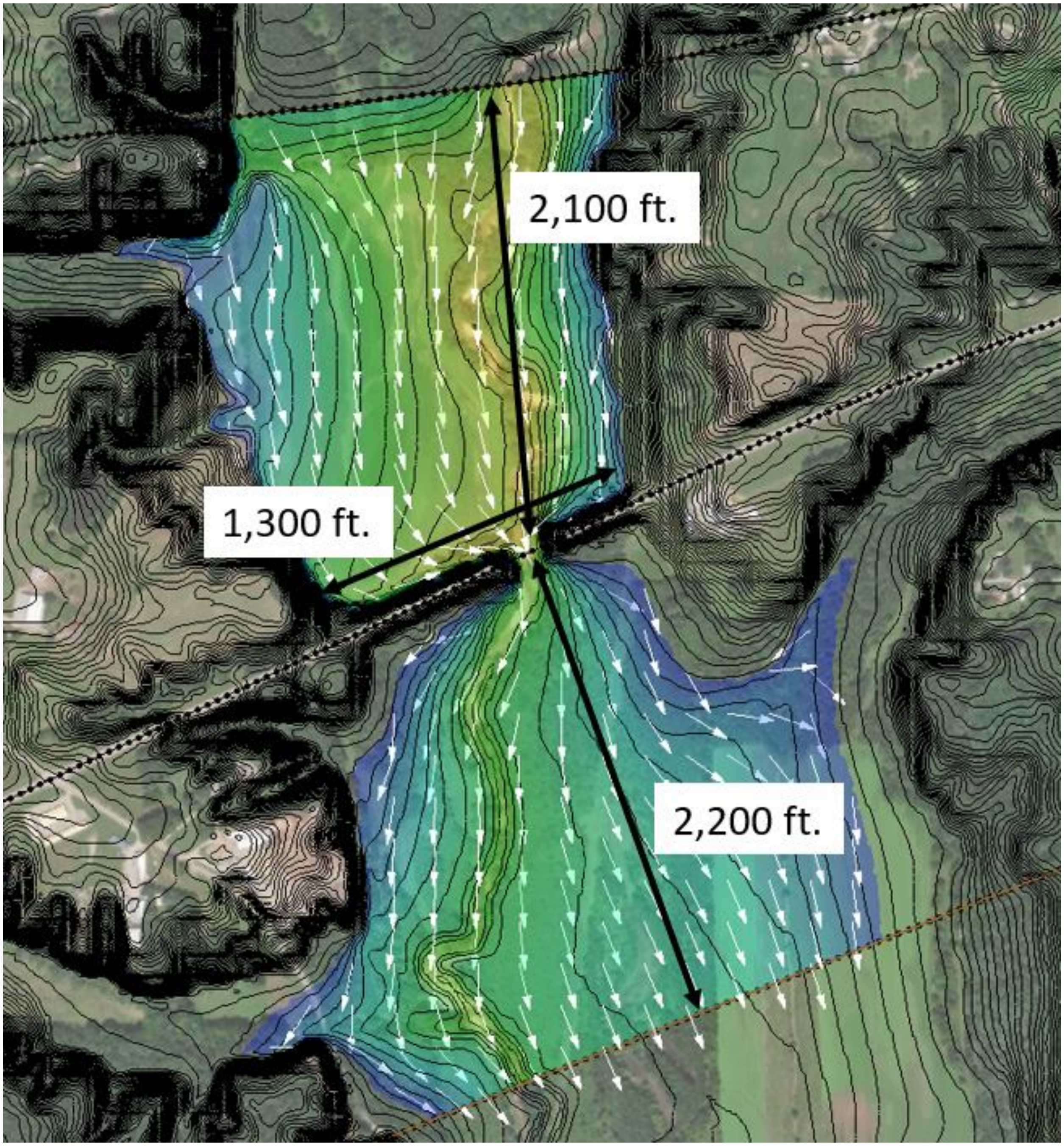
DETERMINATION OF MODEL LIMITS

The minimum Quick Check Model limits are consistent with Section 2-402 in the IDOT Drainage Manual. The upstream and downstream limits should extend a minimum of 1,000 feet upstream and downstream of the structure of interest.

The upstream and downstream model limits should be set at locations where the natural valley section is constricted. This would be where the flow lines are generally expected to be parallel to the floodplain limits and where the floodplain widths are anticipated to be reasonably uniform. The limits should also be set sufficiently far from the structure of interest so that the flow lines through the structure opening have expanded to the full width of the floodplain and are again generally parallel to the floodplain limits. Early guidance from FHWA/Aquaveo recommended that the upstream and downstream limits should be approximately twice the width of the floodplain at the structure of interest. The upstream and downstream limits should avoid locations where there is a significant change in valley width or tributary confluences. The upstream and downstream model limits should also generally be perpendicular to the flow direction.

See Figure 1 below for an example of the model limits for a site. The model limits in this example extend approximately 2,100 feet upstream and downstream of the bridge. The model limits are greater than the width of the floodplain at the upstream face. The floodplain width is fairly constant at the upstream and downstream boundaries. The flow direction is perpendicular to the upstream and downstream boundaries.

Figure 1 – Example Model Limits - US 40 over North Fork Embarras River



The horizontal model limits should include the entire floodplain valley. For structures with adjacent levees, the horizontal limits should include the areas behind the levee and extend to the entire floodplain valley as if no levee existed. This approach is needed to identify flow conditions in cases where the levee overtops and the results have an impact on flow conditions at the roadway and structure of interest.

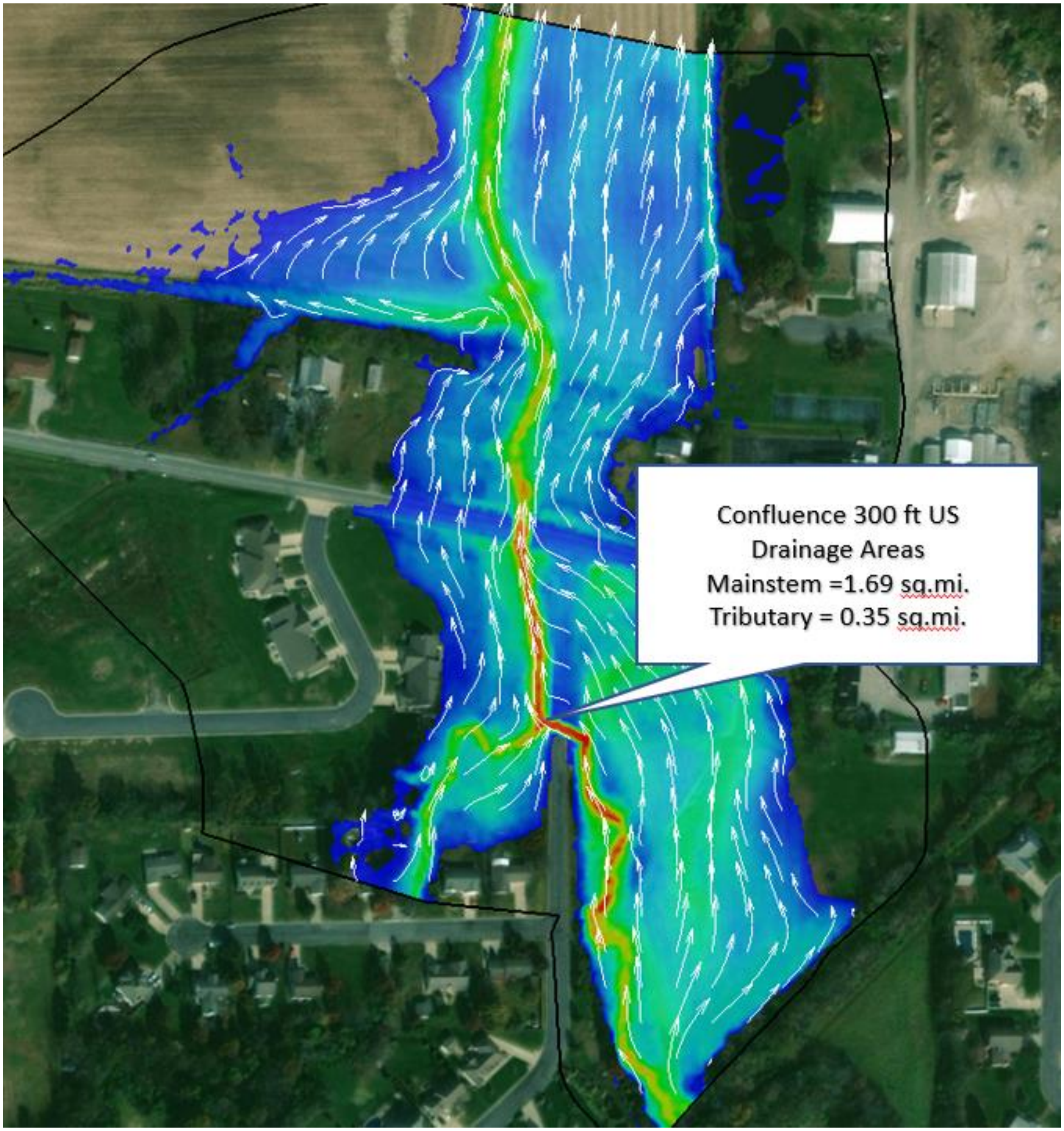
The model limits should also be adjusted when there are other nearby roadway embankments and bridges. Ideally, the model limits would extend similar distances upstream or downstream of these adjacent structures.

Model Limits with Tributary Inflows

Another factor in setting the model limits is presence of tributary inflows within the model limits described above. In cases where there are significant tributaries within the proposed model limits, it is recommended that discharges be computed at the bridge and for both the tributary and mainstem at at their confluence. See Figure 2 for an example of a tributary confluence within the model limits. An inlet flow boundary should be set for each of these tributaries to represent the flows into the model. The model limits on the tributary should be set at the tributary's naturally constricted valley section where the flow is not impacted by the mainstem flow patterns. This approach allows for flow directions to be identified in the model before entering the mainstem floodplain. If both streams have flow rates that are of similar magnitude, multiple Quick Check simulations should be developed to determine the peak flow distribution between the tributaries. This would generally require three Quick Check simulations to represent the conditions. One simulation would assume that the total flow at the bridge is distributed across both streams by calculating the ratio of the drainage areas of each tributary to that of the total drainage area at the structure. The other two cases would assume that one stream has a peak flow equal to the computed flow for that stream and the other stream would have the flow difference between the structure flow and the mainstem. This will allow the user to identify which flow condition is more critical in evaluating flood conditions at the structure.

Figure 2 shows an example of tributary within the proposed model limits. There is a confluence located approximately 300 feet upstream of the bridge. The tributary represents approximately 17% of the total drainage area. For this example, there would be two inflow boundaries. In this example, the 100-yr design flow at the bridge is 2,020 cfs. The inflow boundaries for the mainstem and tributary would have flow rates of 1,675 and 345 cfs, respectively.

Figure 2 – Model Limits for IL 15 over Nashville Creek



IMPORT MODELING SURFACE

The foundation of a 2D hydraulic model is the underlying terrain data. The SMS user interface includes access to a worldwide elevation dataset containing raster elevations of the conterminous United States, Alaska, Hawaii, and territorial islands. SMS uses a web-based map service tied to a Worldwide Elevation Dataset. The data has a variable resolution generally ranging from 10-meters to 30-meters. The SMS interface clips the worldwide elevation dataset to the users desired study extent and creates a new raster file, in TIF format, which is loaded directly into SMS. The raster elevations can be interpolated directly to the 2D model mesh and do not require any additional post processing or conversion.

It is recommended that the modeler carefully review of the worldwide elevation dataset terrain quality to ensure the terrain is of sufficient quality to capture the topographic detail of the structure, roadway embankment, waterway opening, channel, and appurtenant topographic features within the study reach. Information acquired during the site review including aerial imagery, FEMA floodplain mapping (where available), and existing bridge plans will assist in the review of the terrain quality. See Figure 3 for an example of a site where the SMS worldwide elevation dataset data from the SMS user interface is not adequate. At a minimum, the following detail should be identified in the modeling terrain:

- Discernable stream alignment and approximate channel banks.
- Roadway embankment of the study bridge and any relevant roadways in the model reach.
- Bridge waterway opening approximately equal in length to the opening documented in bridge plans or aerial imagery.
- Topographic features such as levees, river training structures and natural floodplain restrictions that may impact hydraulics of the study bridge.

Figure 3 – IL 23 over Tributary to Covel Creek with SMS Worldwide Elevation Dataset – 1 ft Contours

It is likely that as drainage area, channel widths, and structure size decreases, the detail captured in the terrain will also decrease. If the terrain lacks sufficient detail to capture critical hydraulic features, alternative higher resolution terrain data sources should be investigated. The Illinois Geospatial Data Clearinghouse (https://clearinghouse.isgs.illinois.edu/data/elevation/illinois-height-modernization-ilhmp) does provide a collection of alternative high-resolution topographic data in various formats for Illinois. Figure 4 shows the IL 23 over Tributary to Covel Creek with LIDAR data.

Figure 4 – IL 23 over Tributary to Covel Creek with LIDAR Data – 1 ft Contours

The intent of the worldwide elevation dataset used in SMS is to support a cursory analysis for identifying additional data requirements and survey needs. Low resolution topography from the SMS dataset is not recommended for a detailed hydraulic analysis.

Appendix A shows the steps to import SMS and LIDAR data from the Illinois Geospatial Data Clearinghouse.

HYDROLOGY

The preferred hydrologic method for the development of a Quick Check model is StreamStats. StreamStats is a web-based software package from the US Geologic Survey (USGS) which can be accessed at https://streamstats.usgs.gov/ss/. StreamStats will be used to compute the 10-, 50-, 100-, and 500-yr flows for the site. Where StreamStats computes flows according to different methodologies (i.e. rural, urban, etc.), the largest flows should be used for this analysis. The 200-yr flow will need to be interpolated for identifying hydraulic conditions at the scour design flow. A step-by-step example of the StreamStats analysis is included in Appendix B.

A comparison of the StreamStats results to any existing flow data will assist in determining which data is most representative of the conditions at the site. There are limitations on the applicability of the StreamStats regression methods to a given site that are described in the IDOT Drainage Manual and other USGS publications. Some of the limitations to the use of StreamStats are:

- Streams where peak discharges are appreciably affected by natural or reservoir storage;
- Man-made channel changes;
- Diversions;
- Karst terrain;
- Bluff-floodplain combinations;
- Streams listed in the IDOT Drainage Manual where the regression equations are not applicable.

In cases where the above limitations have an impact on the proper application of StreamStats and where FEMA FIS flows are available, the FIS flows may be used based on the engineer's judgement. See Section 3-201 of the IDOT Drainage Manual for how to obtain FEMA FIS flow information.

DEVELOP MODEL MESH

Most 2D models require the development of a computational mesh which is required to geospatially organize model flow elements. SRH-2D uses a flexible mesh which can contain both quadrilateral (patch) and triangular (pave) mesh cells. This is generally referred to as a hybrid mesh. For most Quick Check models, a uniform triangular or paving mesh is recommended. The modeler must carefully consider the appropriate spacing for the mesh. For most sites, a spacing of 50 feet can be used. This spacing may be decreased for locations where bridge openings are smaller or where other topographic features would not be represented correctly. In this scenario, mesh spacing that is equal to or less than the half the bridge opening may provide a better representation of the flow into and through the bridge opening. For some sites, a larger mesh spacing may be required when the number of cells is too great to allow for a reasonable solution time. According to FHWA guidance, the number of elements should be generally less than 150,000 for a standard bridge crossing. If the number of elements needs to be reduced, a larger mesh size should be used within the overall model limits, but a smaller mesh should be used in the vicinity of the bridge openings being evaluated.

It is recommended that feature arcs be used to define topographic breaks along roadways, levees, railroads, etc. A feature arc placed along these features will align the mesh element edges with the feature arc. This will provide a better representation of the overtopping flows at these features. The uniform mesh spacing along these feature arcs should be smaller than the bridge opening to allow for several cells to span the opening.

See Appendix C for the detailed steps required to develop a model mesh.

DEVELOP COVERAGES

For the Quick Check model, a land cover with a Manning's n-value of 0.06 for the entire model limits is recommended for most conditions. This n-value represents a typical average condition representative of both channel and overbank found in most modeling conditions for IDOT bridge projects. This will provide a quick estimate of approximate flood heights, velocities, and floodplain limits regardless of season.

Under certain conditions, a more detailed land use coverage may be more appropriate. Examples would include sites with widely varying land covers in the floodplain, very wide channels in relation to the floodplain, and widely varying land use in the overbank that may impact the flow distribution in the overbank areas.

See Appendix D for the detailed steps required to develop the model coverages.

DEVELOP BOUNDARY CONDITIONS

SRH-2D requires a minimum of two feature arcs within a boundary condition coverage – one for the upstream inflow and one for the downstream outflow. The upstream boundary condition (Inlet-Q) will require the user to input a flow rate. There may be more than one inflow location for more complex sites. If this is the case, each inflow location will require an Inlet-Q feature arc. This arc should be placed perpendicular to the anticipated stream flow line just outside of the limits of the mesh boundary. This will ensure that the flow into the model will occur only on mesh elements along the Inlet-Q feature arc. This Inlet-Q arc should be at a minimum the width of the channel and likely should be a similar width to the floodplain at this location to distribute the flow across the entire floodplain. The arc length will likely need to be adjusted in an iterative manner until the arc length and computed flow width reasonably agree. The computed flow directions at the boundary should be perpendicular to the boundary arc.

The downstream boundary condition for the Quick Check model should be a feature arc representing the Exit-H which will calculate the water surface elevation using a stage-flow rating curve. The Exit-H arc should be placed perpendicular to the anticipated flow line, similar to the feature arc for an Inlet-Q. However, unlike the feature arc for an Inlet-Q, the feature arc for the Exit-H should be placed just inside the mesh boundary. The arc should cover the entire floodplain or wherever the elevations of the mesh will allow water to exit. Typically, it will span the entire downstream outlet of the mesh boundary. This ensures that flow does not get “trapped” within mesh elements where it cannot be removed from the model. This is because the mesh boundaries are treated as a vertical walls.

The stage-flow rating curve for the Exit-H can be imported, if the user has the data available, or can be calculated within SRH-2D using the Channel Calculator. Within the Channel Calculator, the user will select the mesh elevations, input the composite Manning’s n-value, and the slope of the channel within the mesh. The channel slope can be estimated from measuring the start and stop elevations, and the length along the channel flow path within the mesh boundary. The measurement tool within SMS is sufficient for this task. The maximum flow entered should be equal to or greater than the maximum flow being analyzed to make sure the model is able to converge to a solution. An increment of flow must be entered to generate a range of points between the minimum and maximum flow in the curve. For most locations it is recommended that this be set to 10 cfs unless the maximum flow is small where a higher resolution will be required for the rating curve.

There will be one boundary condition coverage per flood frequency being analyzed. The Inlet-Q boundary condition for one flood frequency can be duplicated with updated flow rates for that frequency. The Exit-H boundary condition can remain the same for all storm frequencies as long as the total inlet flows for that event are less than the maximum value in the rating curve.

See Appendix E for the detailed steps for setting the boundary conditions.

RUN EXISTING CONDITIONS

One of the objectives of the Quick Check model simulation run is to reach a stable and reasonable hydraulic modeling solution which reaches equilibrium in a practical model runtime. The model simulation provides the link between the 2D modeling mesh, the monitor coverage, materials coverage, and boundary conditions. SRH-2D provides two methods for producing model results including an unsteady solution and steady solution. The final results of a steady or unsteady analysis will be the same; however, unsteady allows for more accurate intermediate results. The preferred method for the Quick Check model effort is steady flow output.

During the simulation, the modeler will review output from the monitor coverage using the Simulation Run Queue. The Simulation Run Queue provides live model results at specified time intervals allowing the user to evaluate model stability and adequacy without having to run the simulation to completion. The Simulation Run Queue should be reviewed to determine if:

- The simulation is producing stable output (i.e., the solution does not vary drastically from timestep to timestep, or the solution does not oscillate between high and low values).
- The Net Discharge (Outflow – Inflow) is approaching 0.0.
- The Monitor Points and Monitor Lines are approaching equilibrium (i.e., no change in monitor point water surface and monitor line discharge from the previous timestep to the current timestep)

It is recommended to begin with a model timestep between 1 and 5 seconds. If the simulation appears unstable, the timestep should be reduced. If the model does not achieve stability with a minimum timestep of 0.5 seconds it is recommended to increase the resolution and quality of the model mesh by increasing the total number of mesh cells and computational elements. This can be achieved through a blanket reduction in the mesh resolution or providing more detailed mesh generator linework to capture critical hydraulic features. Additionally, running the model with unsteady output may allow the model to work through stability issues.

The modeler will also need to specify an initial condition for the model simulation. The initial condition may have a significant impact on the stability of the model and the length of time required to reach equilibrium. For most Quick Check models, the “Automatic” initial condition is recommended. The Automatic initial condition assumes backwater from the downstream boundary to fill the model domain. While the model can start dry, the automatic boundary generally reduces computation time and improves model stability for a given steady discharge.

An initial simulation time of 12-hours is recommended to allow the model to reach equilibrium. If the model appears stable but equilibrium has not been reached the simulation length should be increased to allow for greater time to reach equilibrium. The user should gage how much longer to run the model based on the slope of the output from the monitor coverage and the proximity of the solution to any known target water surfaces. A step-by-step example of evaluating model stability is included in Appendix F.

REVIEWING RESULTS

This step is primarily a qualitative review by the modeler to determine if the results generally reasonable, consistent with the model assumptions, and comparable to independent modeling results identified in the initial site review. The modeler should compare the floodplain boundaries from the Quick Check model to FEMA studies where available. The water surface elevations should be compared to available IDOT or other studies of this site. The roadway overtopping results should be compared to District roadway maintenance records. The results of these comparisons should not be expected to agree exactly with the historic records, maps, or elevations, but the comparisons should not be unreasonable. For large discrepancies, the modeler should determine if there have been significant changes to conditions within the watershed since the original studies were prepared. The initial assumptions in the Quick Check model should be reviewed to determine if they were correct based on the results. Depending on the results of the comparisons, the Quick Check model may require changes to n-value coverages, mesh size, model limits, terrain data (SMS vs LIDAR), additional feature arcs, etc. to provide more reasonable model results.

The modeler should review the inundation area shown in the model results for the 100-yr to identify potential flood receptors located within the floodplain. This may have an impact on the permitting of any new or replacement structures.

DOCUMENTATION AND CONCLUSIONS

A Quick Check report format has been developed for documenting the results of the modeling effort for review and reporting purposes. A copy of a completed report format is included in Appendix G. This report will include a 1-page document in the form of a checklist that summarizes the site hydrology, surface topographic data source, model setup, and results. The report will also include several screen plots showing flow direction and magnitude versus water surface elevation and flow direction and magnitude versus depth, as well as the SRH-2D Solution Plots for Net Q, Mass Balance, Wet Elements, Monitor Points, and Monitor Lines to show that the model was stable and reached equilibrium. Plots will be done for a minimum of the 10-, 50-, 100-, 200-, and 500-yr flow events. A sample report is included in Appendix G.

This report will assist the modeler in identifying constraints at the site that should be examined in greater detail in future hydraulic modeling studies. It will also assist in identifying potential constraints on structure size, structure location, adjacent hydraulic features, and properties located within the floodplain.

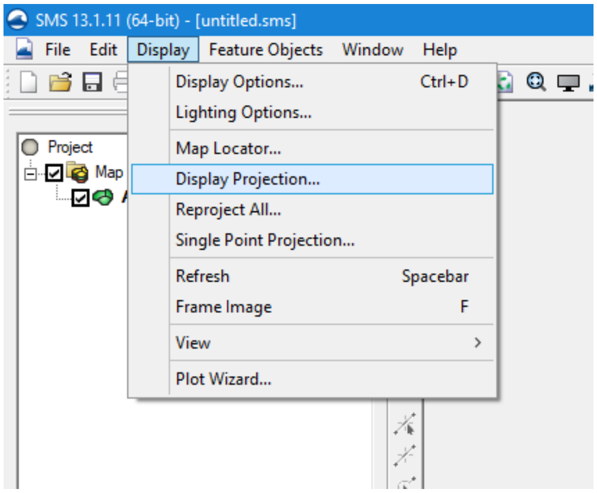
A summary of SMS & SRH-2D tutorials and guides is included in Appendix H .

APPENDIX A – IMPORT MODELING SURFACE

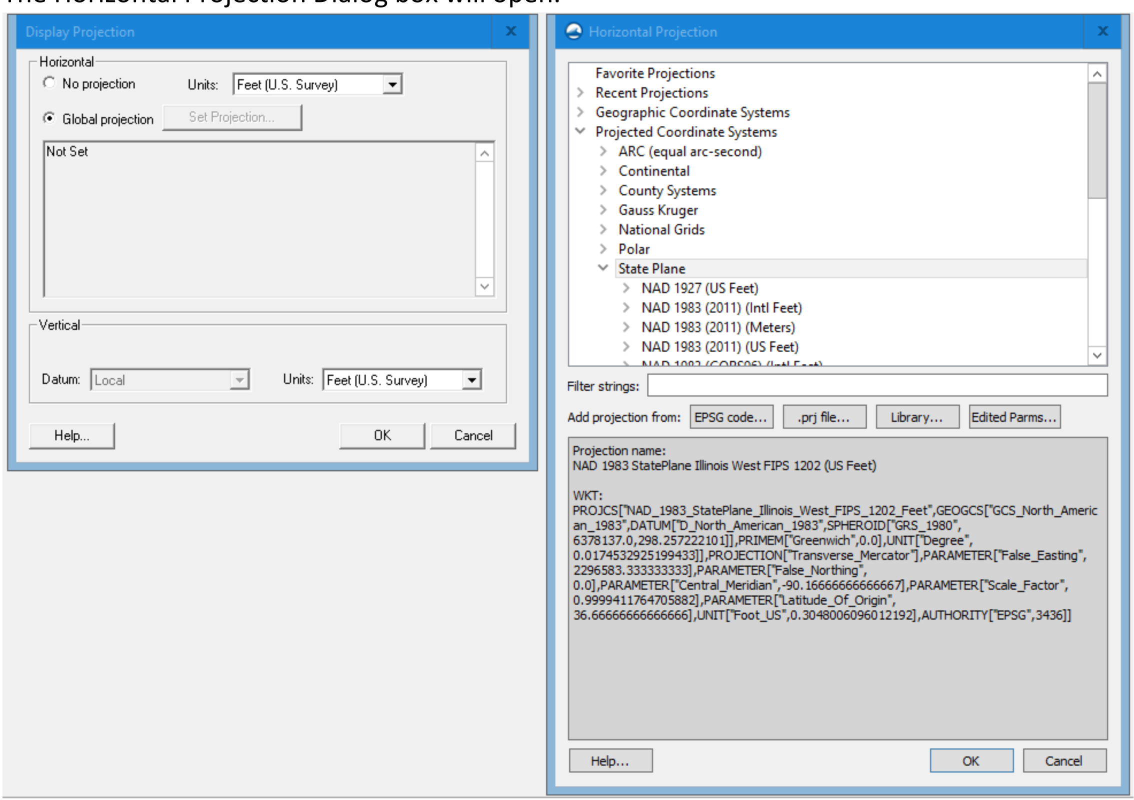
A horizontal projection must be defined to download web-based information through SMS.

To Set the Projection and Units:

1. Choose Display | Projection to open the Display Projection dialog.



2. In the Display Projection Dialog, change Horizontal from “No projection” to “Global Projection”.
3. The Horizontal Projection Dialog box will open.



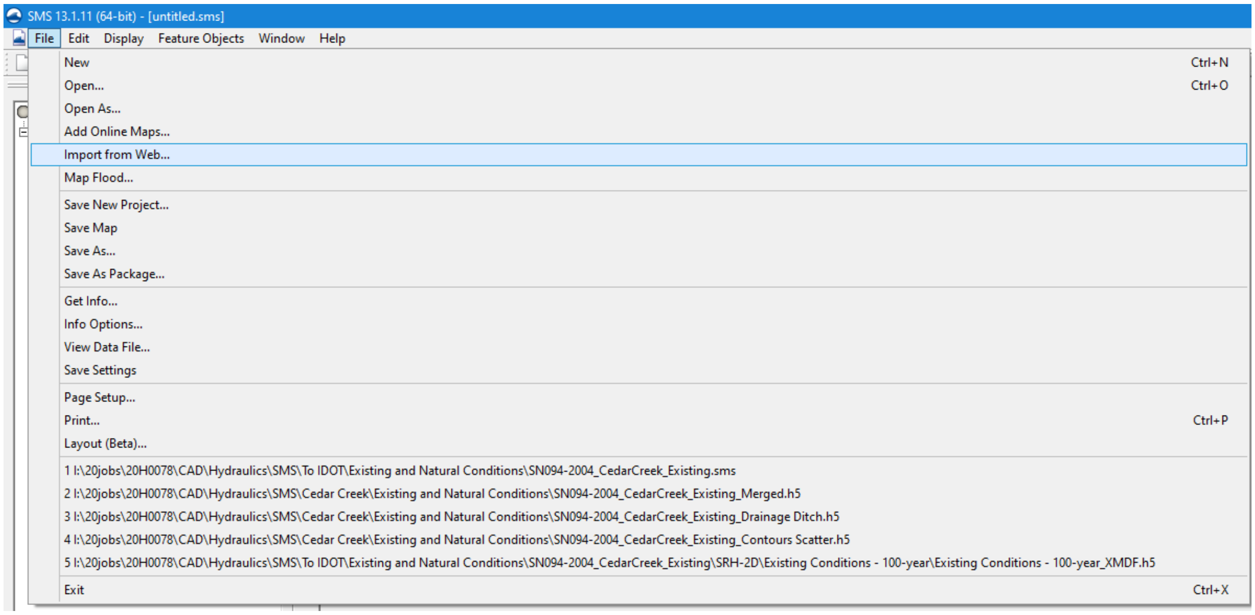
4. Navigate to the desired Projected Coordinate System and click OK.

5. In the Display Projection Dialog, change the Vertical Datum to NAVD 88(US) and the Units to Feet (U.S. Survey).

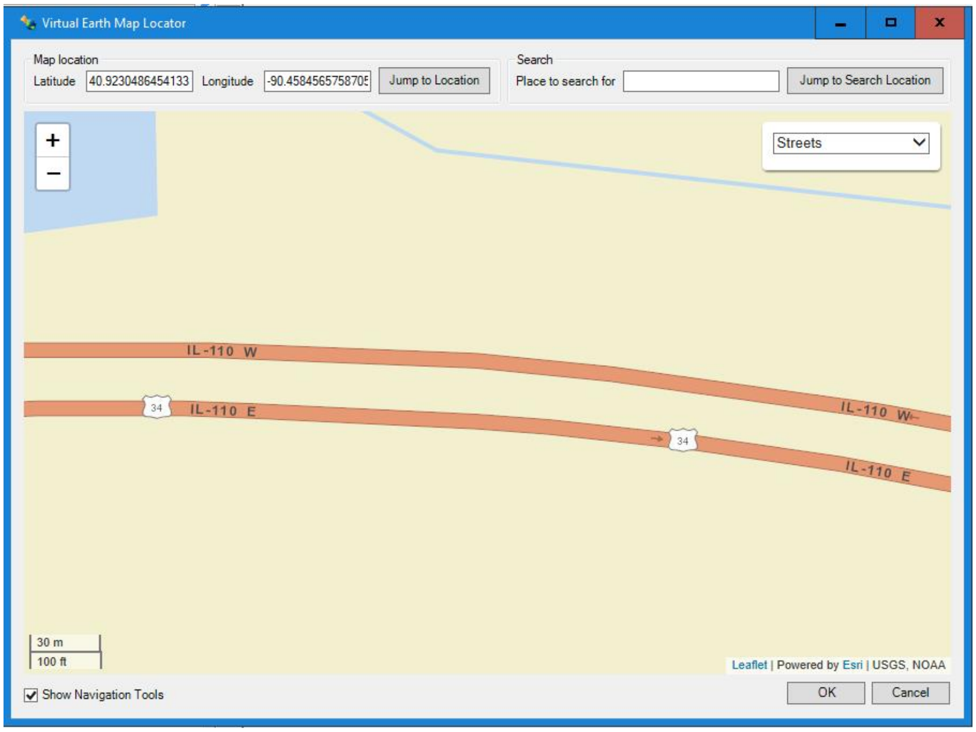
The project now has horizontal and vertical projection for referencing the SMS web-based map service.

To Download the Worldwide Elevation Dataset for the Modeling Surface:

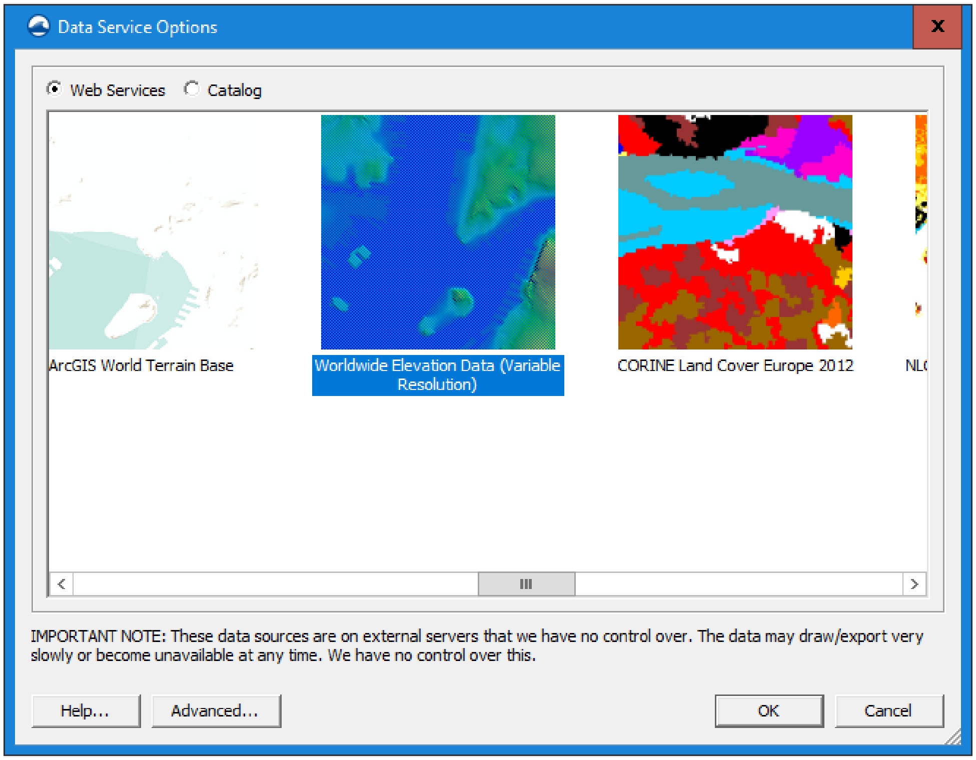
1. Zoom the project window to the model limits identified based on the initial site review. The extent should be large enough to capture the full floodplain and the entire anticipated study reach. Make sure to leave a buffer between the Modeling Surface Limits and the anticipated Model Limits.
2. Choose File | Import from Web… to open the Virtual Earth Map Locator dialog.



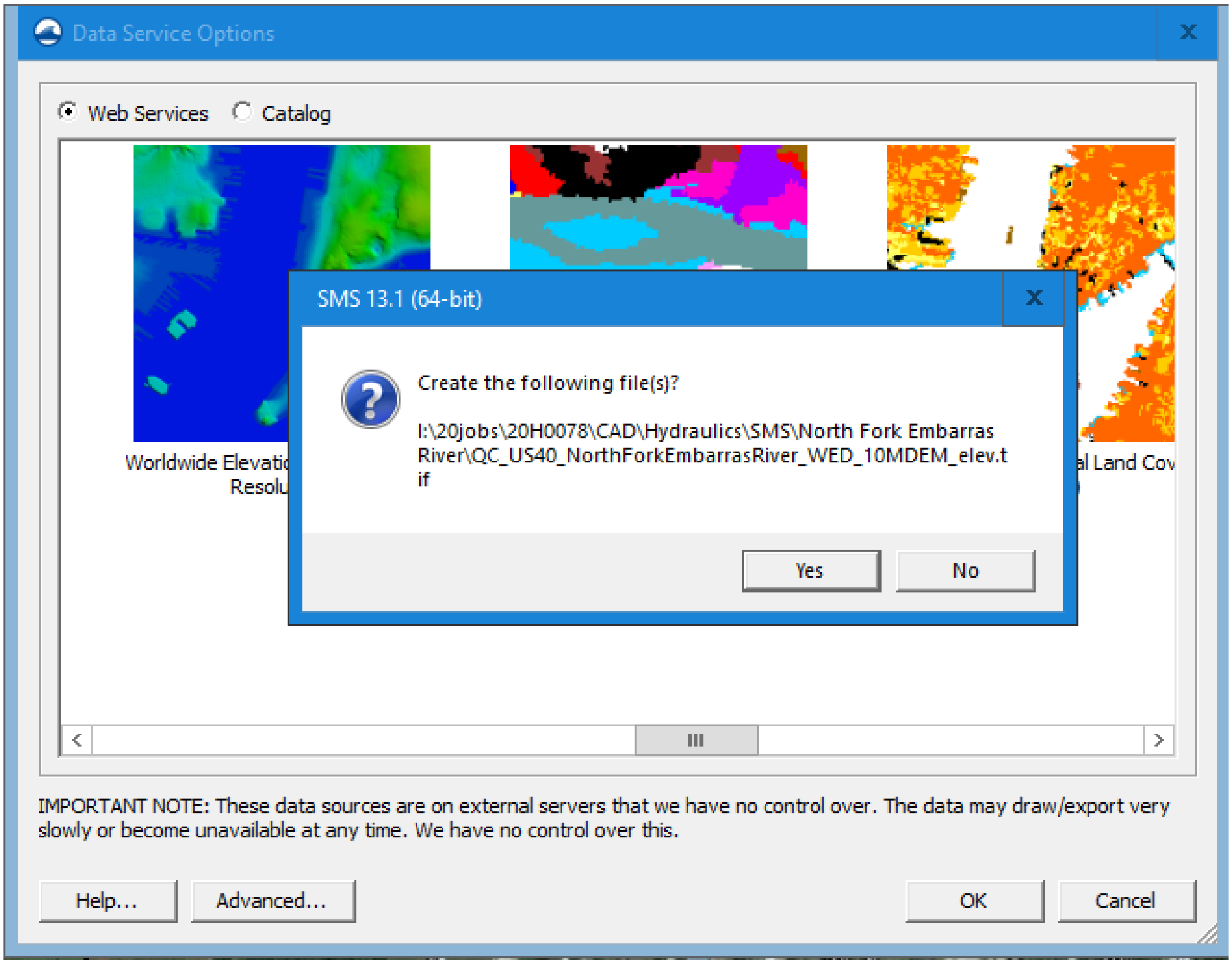
3. The location in the Virtual Earth Map Locator will already be focused on the map location set in step one. The map location can be changed by entering a latitude and longitude or by navigating to a desired location.



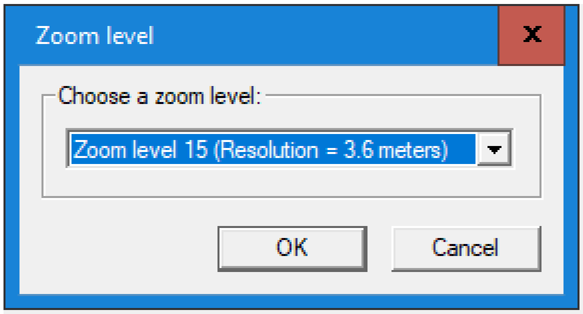
4. Select OK to open the Data Service Options.
5. Navigate to the Worldwide Elevation Data (Variable Resolution) and select OK.



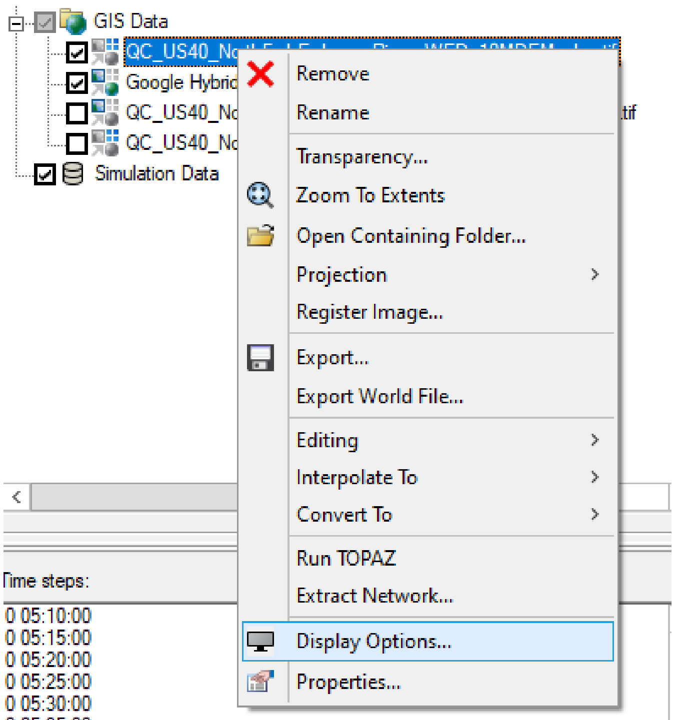
6. A dialog box will open to save the raster. Select the desired folder location and File name. The default file type is a .TIF. Follow the appropriate naming convention provided in the guidebook. Example: QC_US40_NorthForkEmbarrasRiver_WED_10MDEM.tif
7. A confirmation dialog box will open to confirm the file creation. Select Yes.



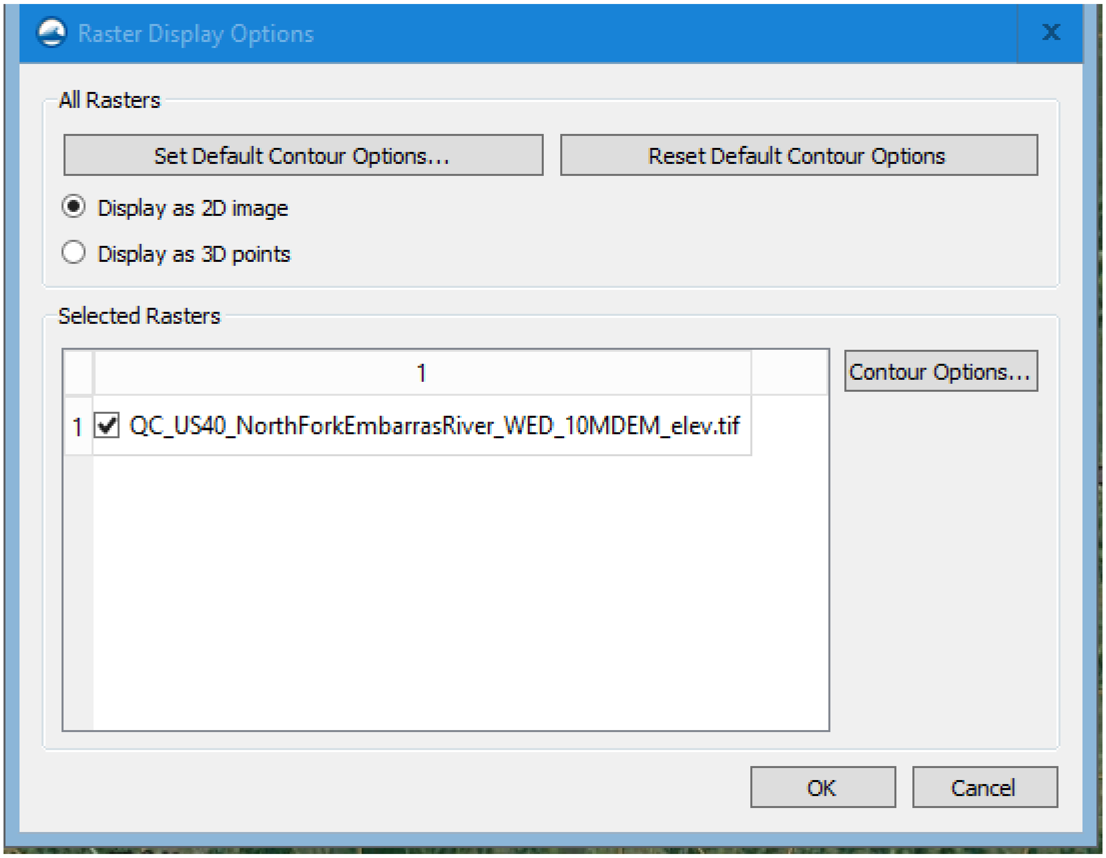
8. The user will be prompted to select a zoom level ranging from level 0 (117437.7 meters) to level 15 (3.6 meters). Note: The zoom level **does not** impact the resolution of the source data. The highest resolution of the Worldwide Elevation Data is 10-meters. The zoom level determines the cell size of the created SMS TIF file. If level 15 (3.6 meters) is selected the additional points will be interpolated from the 10-meter source data. It is not recommended to use a resolution coarser than level 14 (7.2 meters). Selecting a zoom level coarser than the worldwide dataset resolution of 10-meters will result in a loss of detail. Generally, zoom level 15 (3.6 meters) is recommended and will result in a manageable file size.



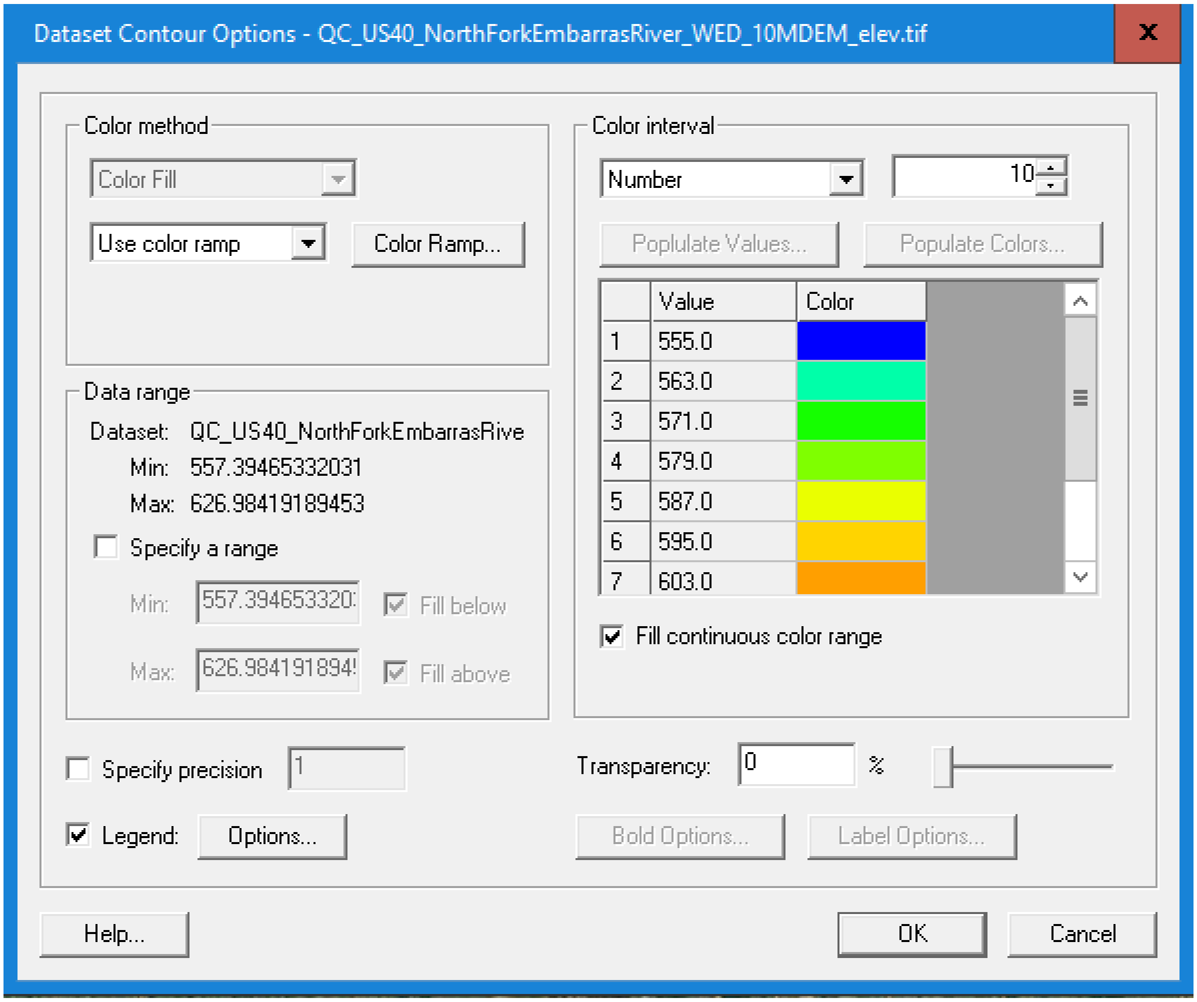
9. Selecting OK will load the raster to GIS Data in SMS.
10. The raster contours can be adjusted by right clicking on the terrain and selecting Display Options.



11. Select the desired raster in the dialogue box and click Contour Options…



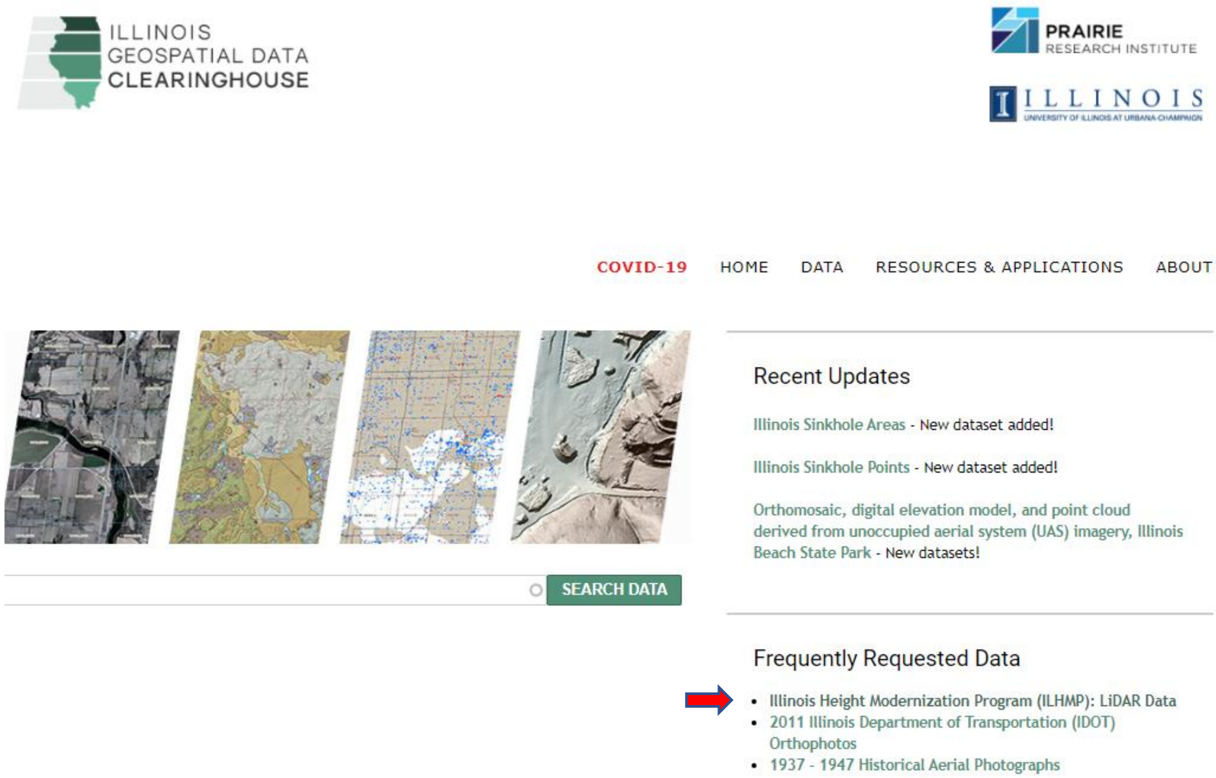
Adjust the contours as desired.



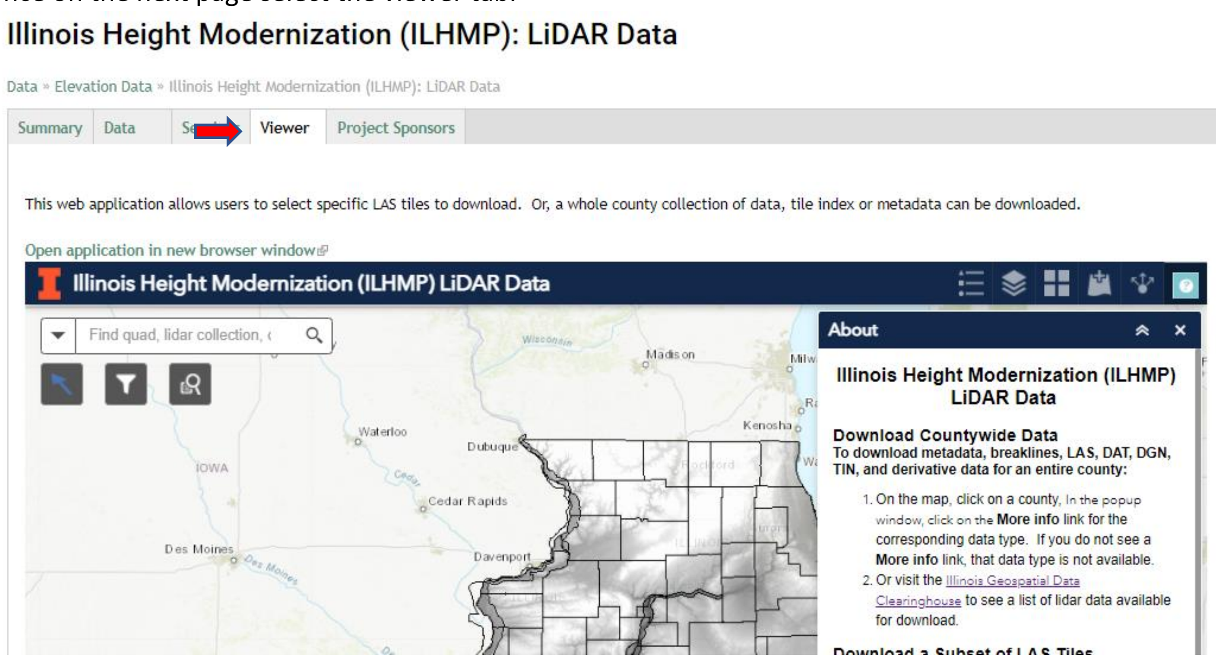
12. Review the raster to ensure the terrain is of sufficient quality to capture the topographic detail of the structure, roadway embankment, waterway opening, and appurtenant topographic features within the study reach. If the SMS terrain lacks sufficient detail to capture critical hydraulic features, alternative higher resolution terrain data sources should be investigated.

To Download Publicly available LiDAR and process using SMS (optional step)

1. Navigate to Illinois Geospatial Data Clearinghouse https://clearinghouse.isgs.illinois.edu/
2. Under Frequently Requested Data click "Illinois Height Modernization Program (ILHMP): LiDAR Data.

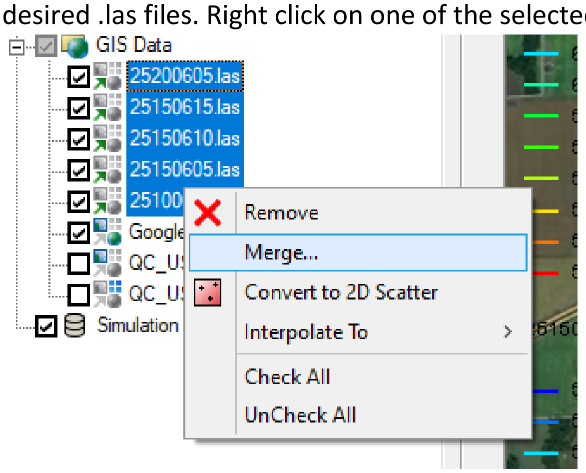


3. Once on the next page select the viewer tab.

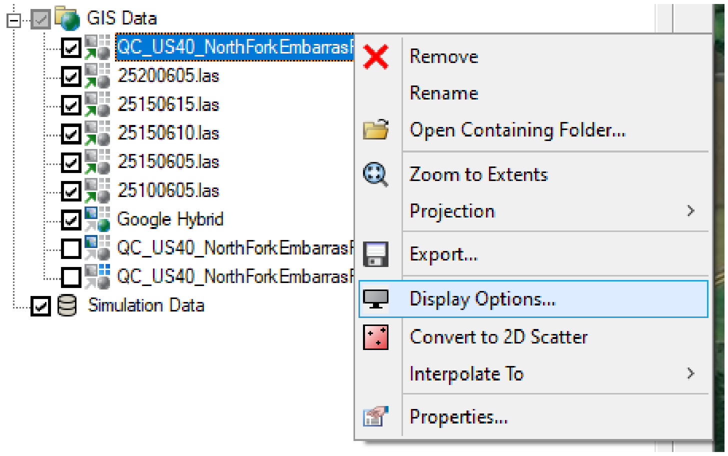


4. Zoom to the study reach and select LiDAR tiles for download that cover the desired surface extents.

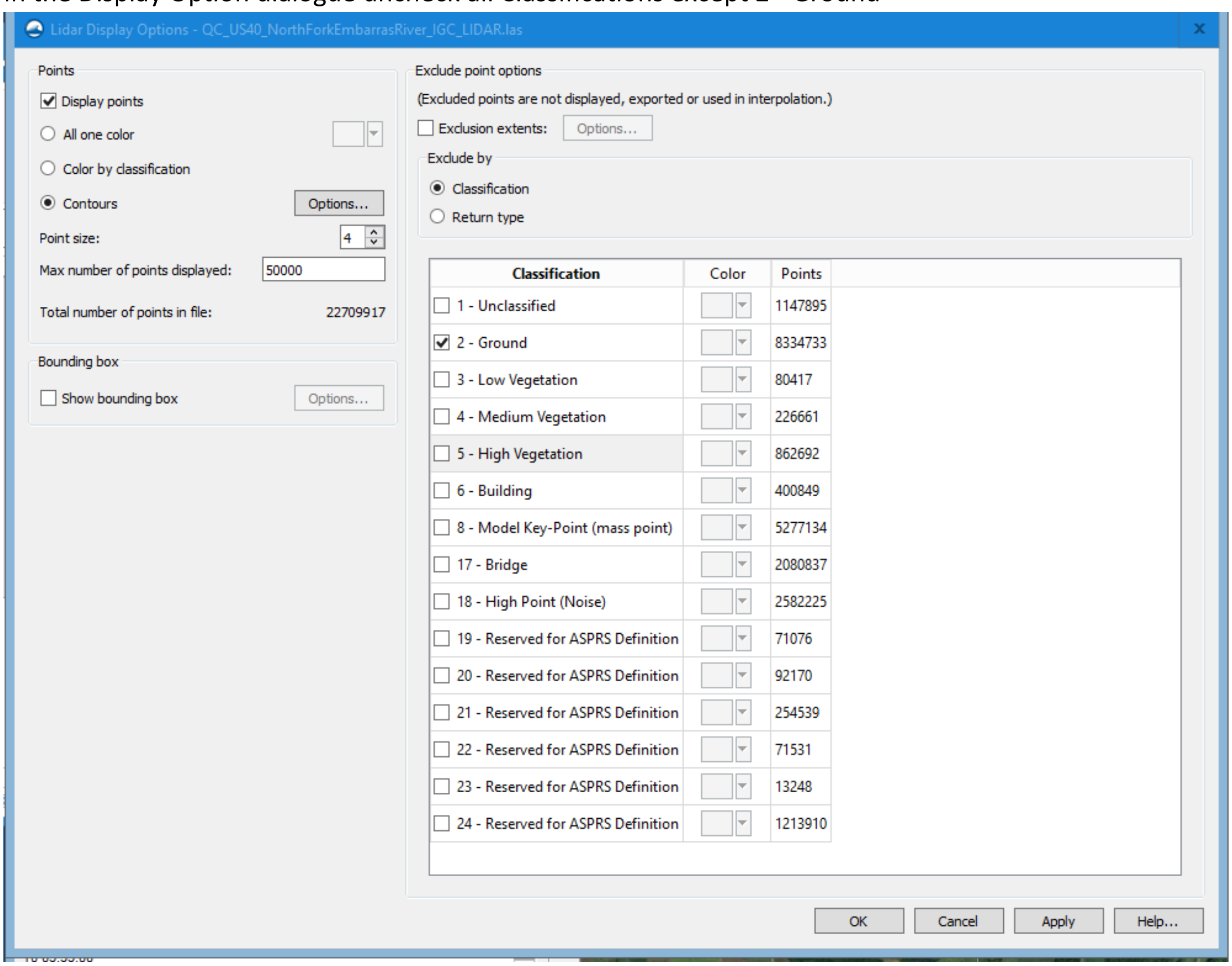
5. Las files may be directly opened using SMS. Select File | Open and select the .las files downloaded from the Data Clearinghouse. The .las files will open under the GIS Data module.
6. If multiple .las tiles were required, merge the tiles into a single .las. Using the shift key select all desired .las files. Right click on one of the selected tiles and select Merge…



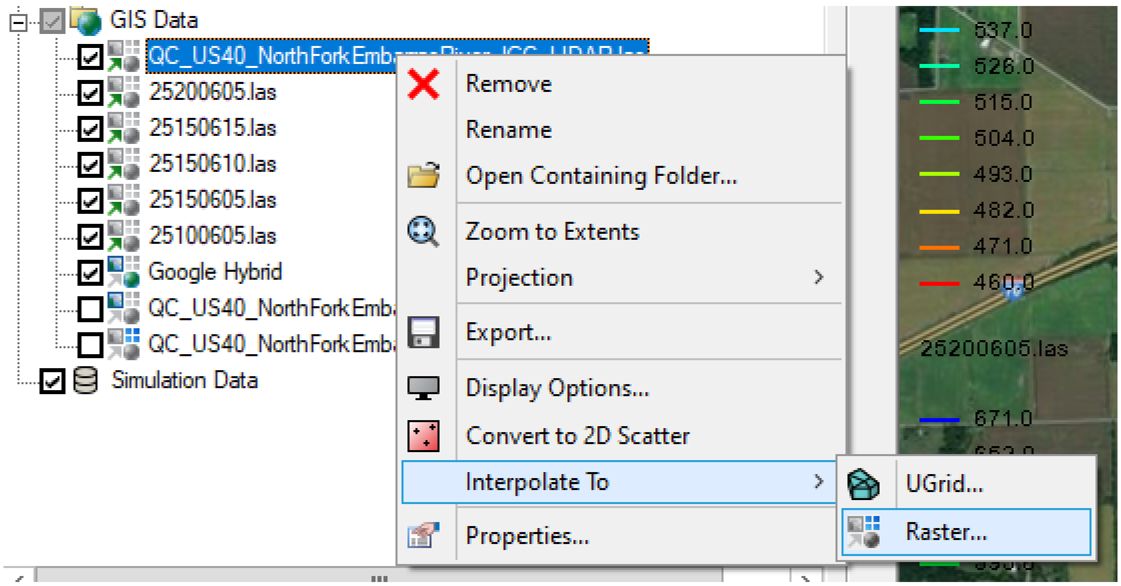
7. A window will open to select the save location and file name. Follow the appropriate naming convention provided in the guidebook. Example: QC_US40_NorthForkEmbarrasRiver_IGC_LIDAR.las
8. The generated .las will not automatically load in SMS. Select File | Open and navigate to the save location selected in step 7 to open the QC_US40_NorthForkEmbarrasRiver_IGC_LIDAR.las.
9. The .las file must now be filtered to generate a "Bare Earth" surface. Right click on QC_US40_NorthForkEmbarrasRiver_IGC_LIDAR.las and select Display Options…

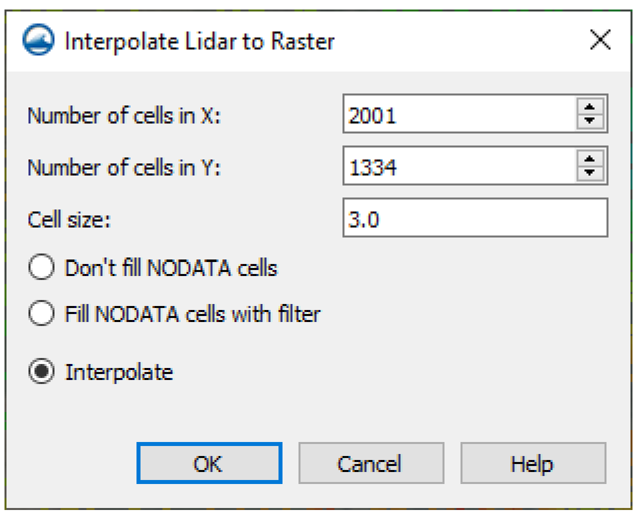


10. In the Display Option dialogue uncheck all Classifications except 2 - Ground



11. Select OK
12. Right click on QC_US40_NorthForkEmbarrasRiver_IGC_LIDAR.las and select Interpolate To | Raster... In the dialog box that appears, it is appropriate in most situations to enter a cell size of 3. This will update the output resolution. Select the Interpolate option to interpolate elevations for any gaps there may be in the LIDAR points.

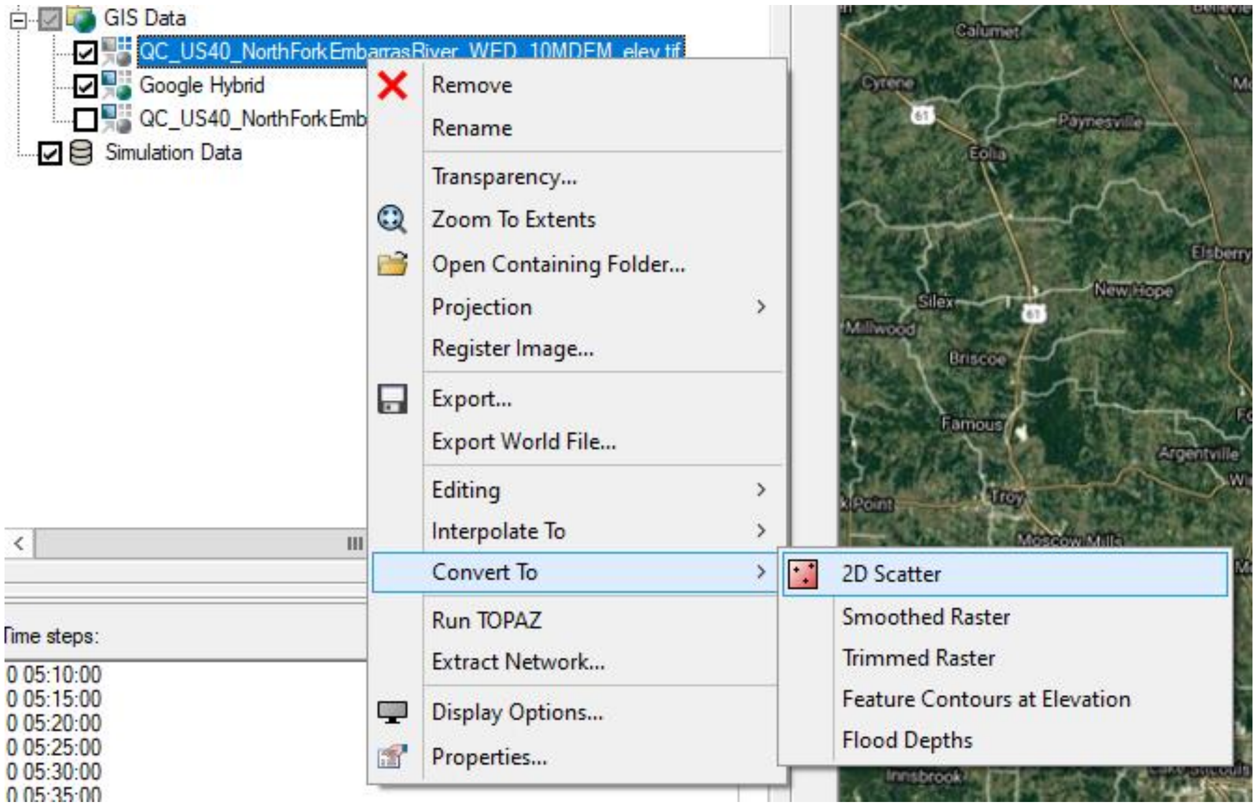




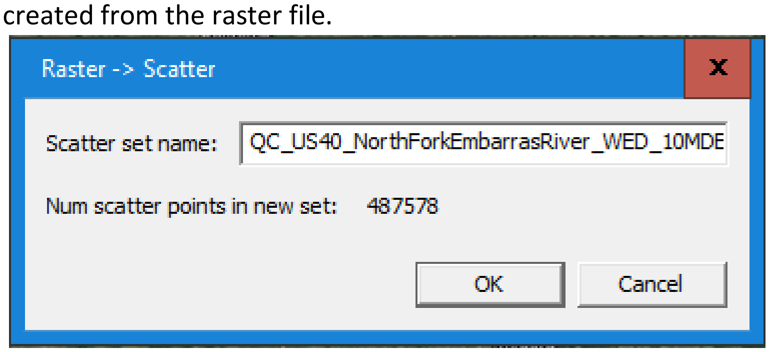
13. Alternatively the user may convert the .las file to a 2D Scatter by selecting Convert to 2D Scatter. Raster data can be interpolated directly to the model mesh and conversion to a scatter data set is not required. Due to their file size, scatter data sets can often become cumbersome to the model resulting in lagging model controls. Additionally, converting the raster to a scatter dataset requires a triangulation between the raster points and could result in discrepancies between the raster surface and converted scatter set. Converting the scatter set does provide additional surface display options including providing an option for scatter lines.

To Convert a Raster to Scatter (optional step)

1. Right click on the raster and select Convert To | 2D Scatter

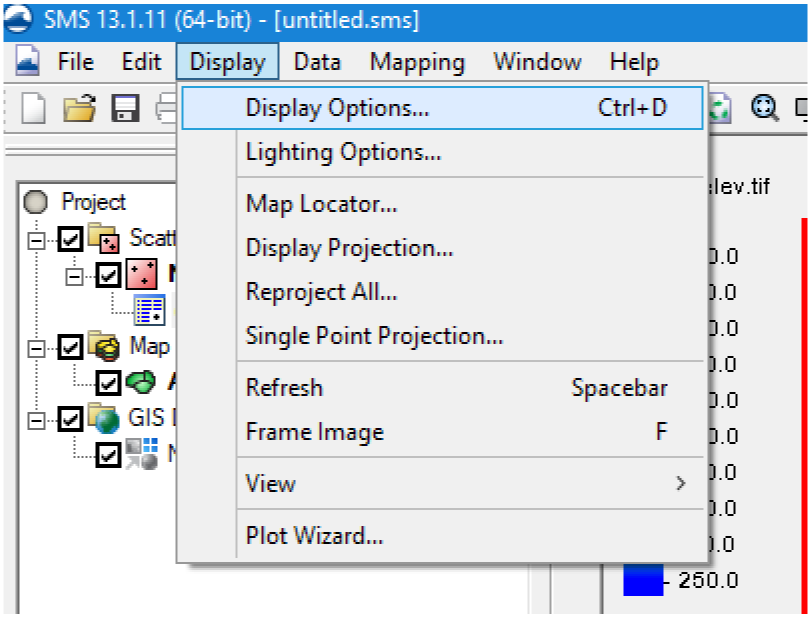


2. The user will be prompted to select a Scatter set name: By default, the name will be the same as the source raster. The dialogue includes a summary of the number of scatter points that will be created from the raster file.

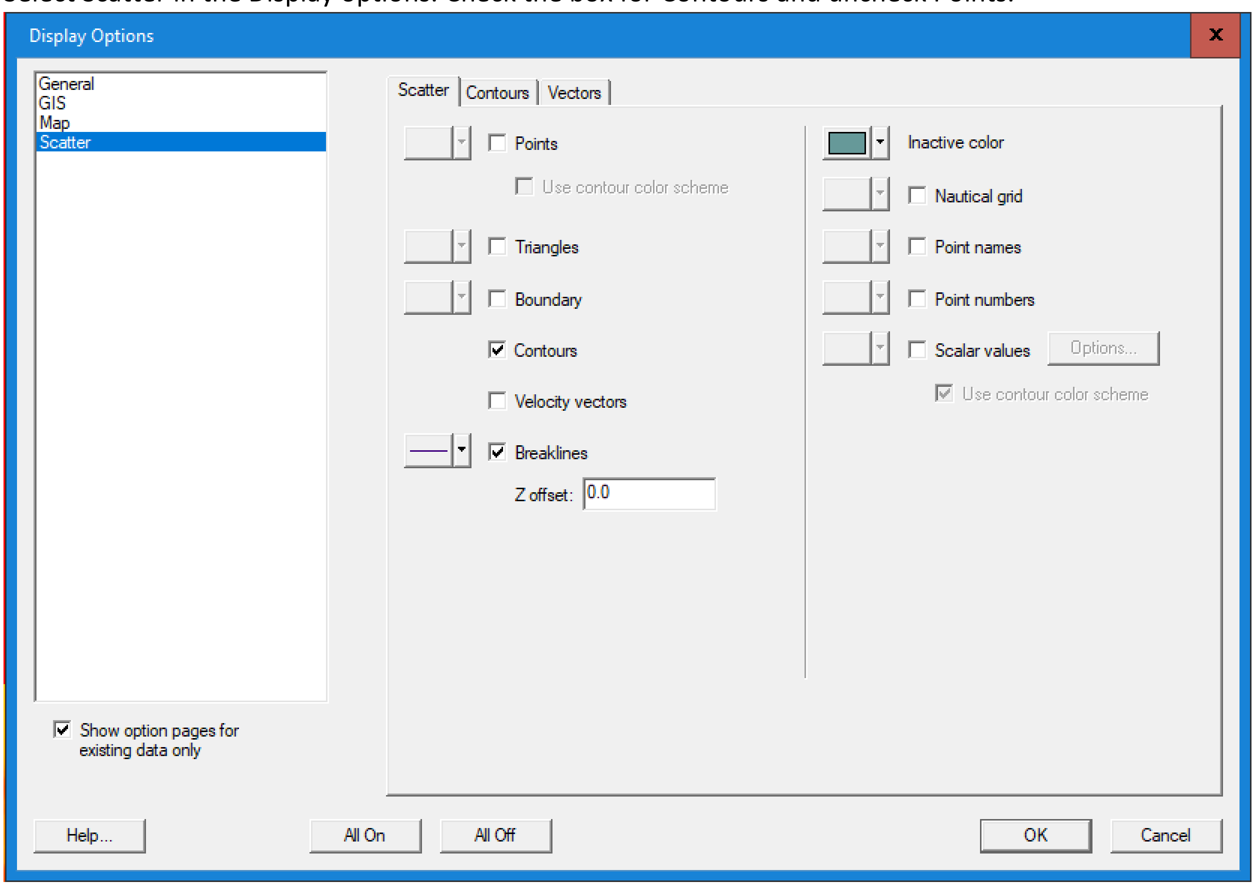


Note: By default, the maximum number of scatter points generated is 20-million.

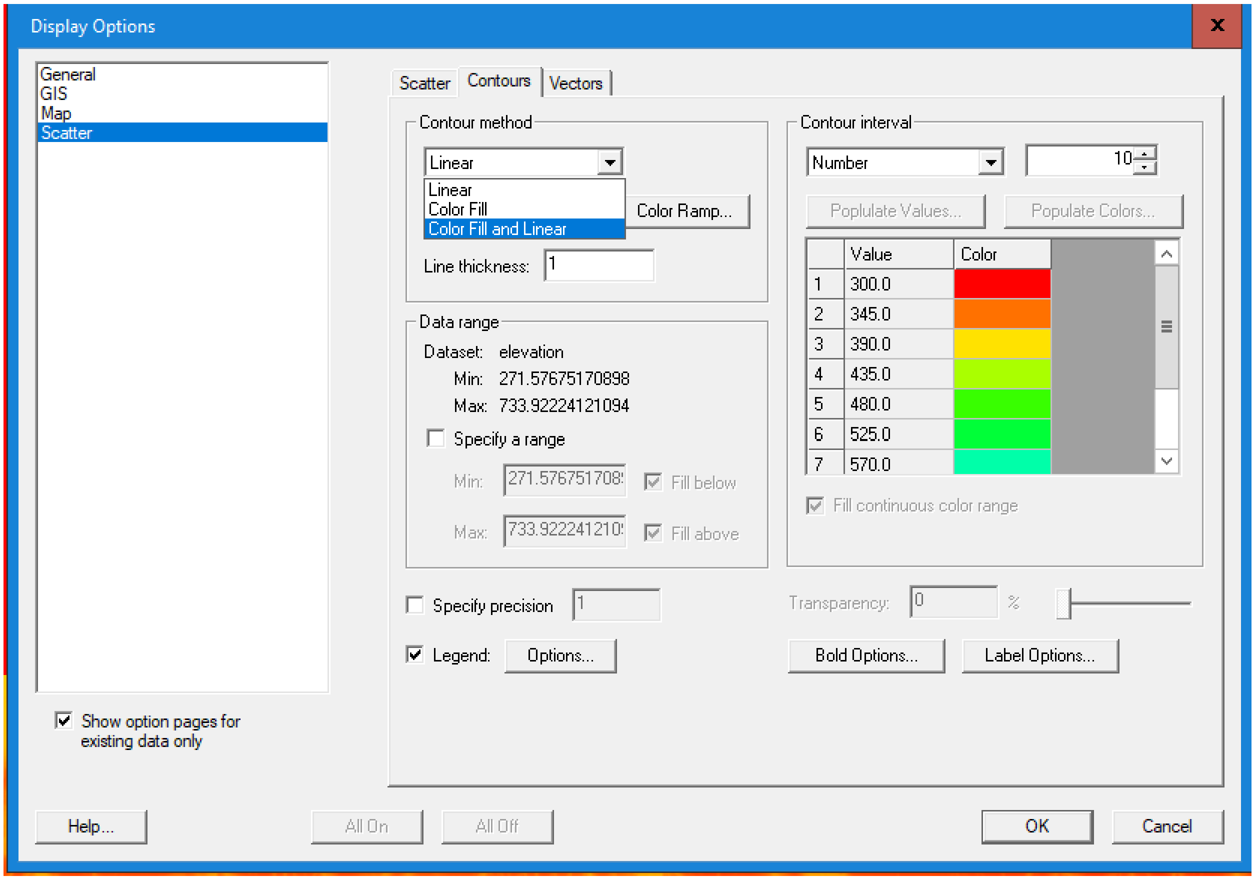
3. Click on Display| Display Option (Alternative shortcut Ctrl + D)



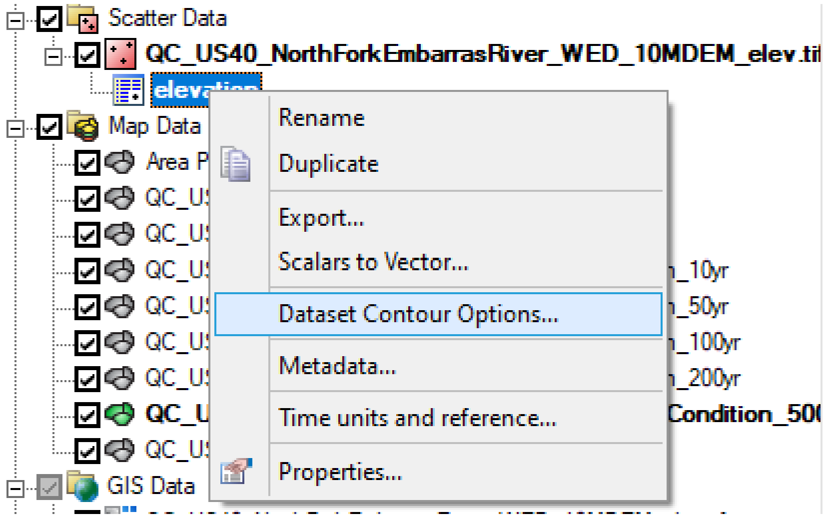
4. Select Scatter in the Display options. Check the box for Contours and uncheck Points.



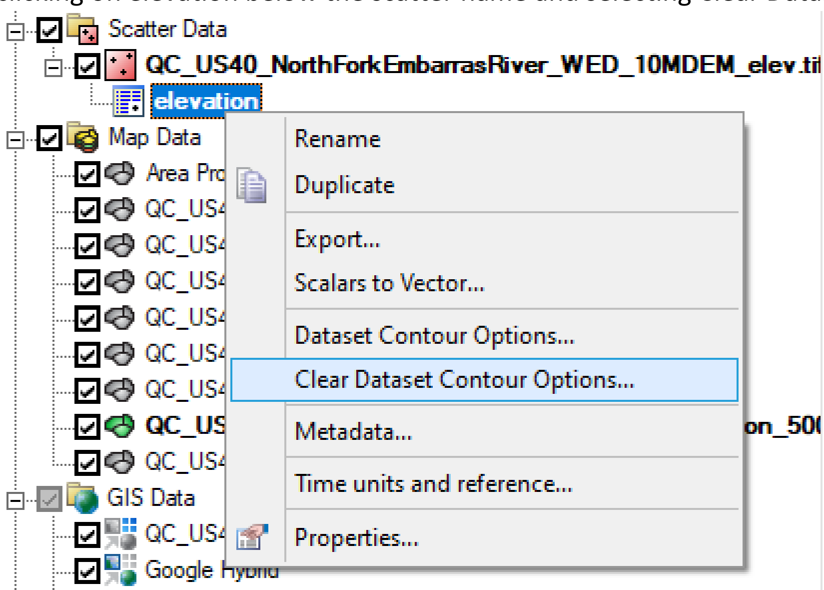
5. Click on the Contours tab and adjust the contours to the user preference. Under Contour method the user will find an additional option for Color Fill and Linear that allows the user to add contour lines in addition to color contours.



6. Adjusting the display options through Display| Display Option will adjust the contour preferences globally for all scatter sets included in the model. Alternatively, the user may set the display contours for a scatter individually by right clicking on elevation below the scatter name and selecting Dataset Contour Options. Setting display options through this window will override the global display from step 5.



7. Once contour options have been set for an individual scatter, they may be cleared by right clicking on elevation below the scatter name and selecting Clear Dataset Contour Options.



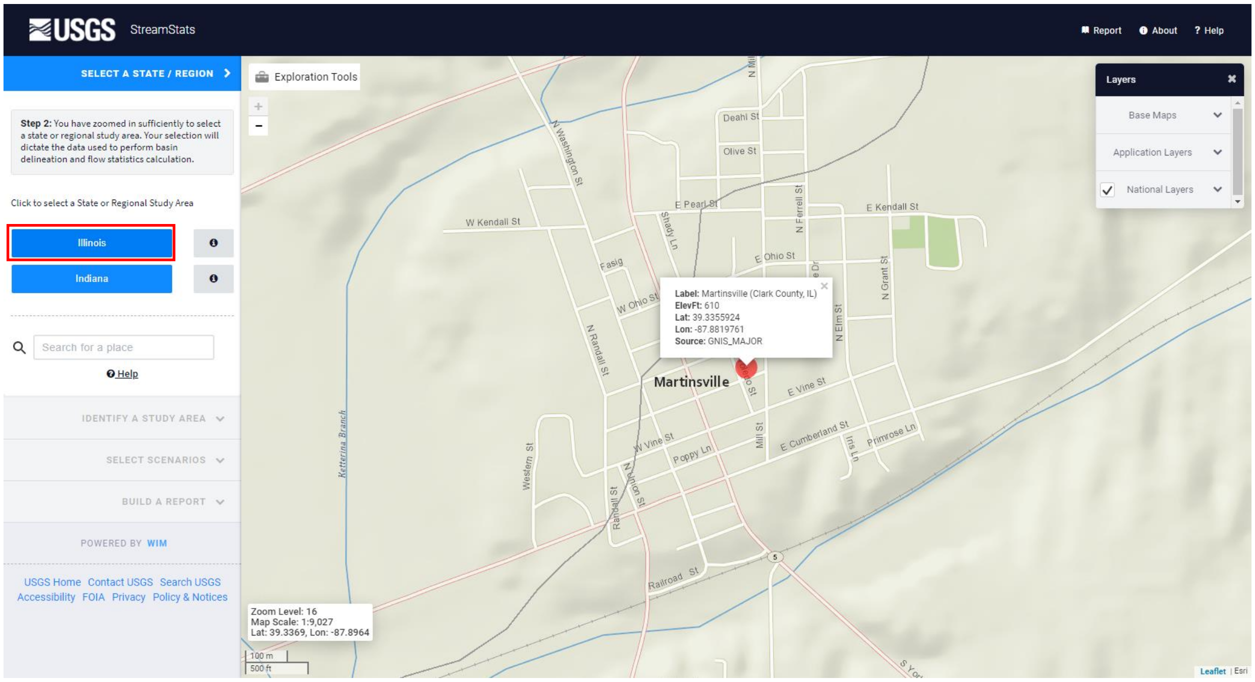
APPENDIX B - HYDROLOGY

Using StreamStats to determine model input flows:

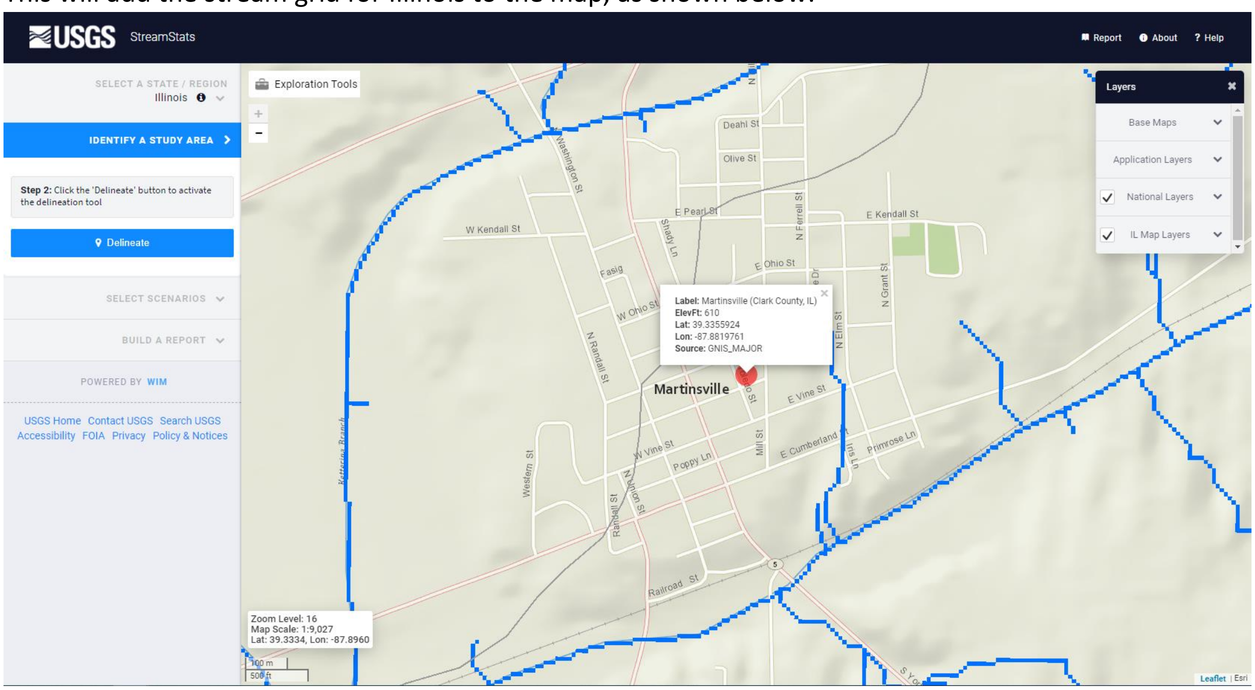
1. Go to https://streamstats.usgs.gov/ss/.

2. Search for the city or town nearest to the bridge, or zoom/pan into the area manually using the +/- tools at the top left of the map screen or by scrolling with your mouse.

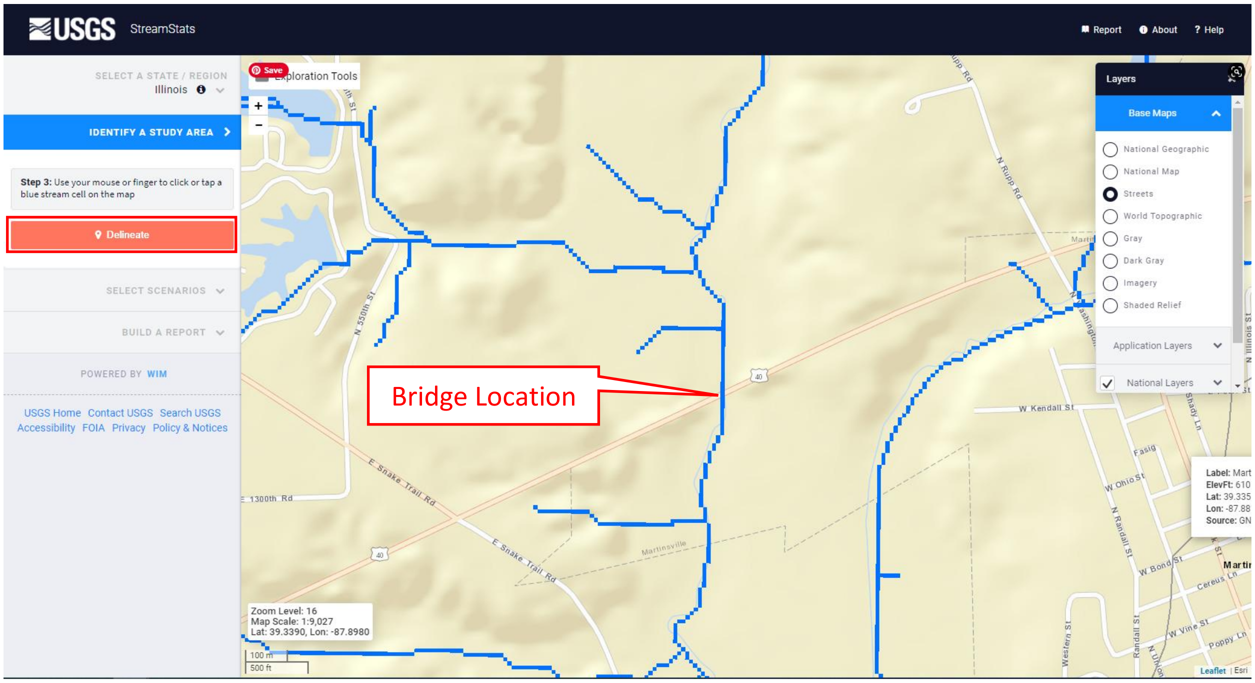
3. Select the Illinois as the state or regional study area.



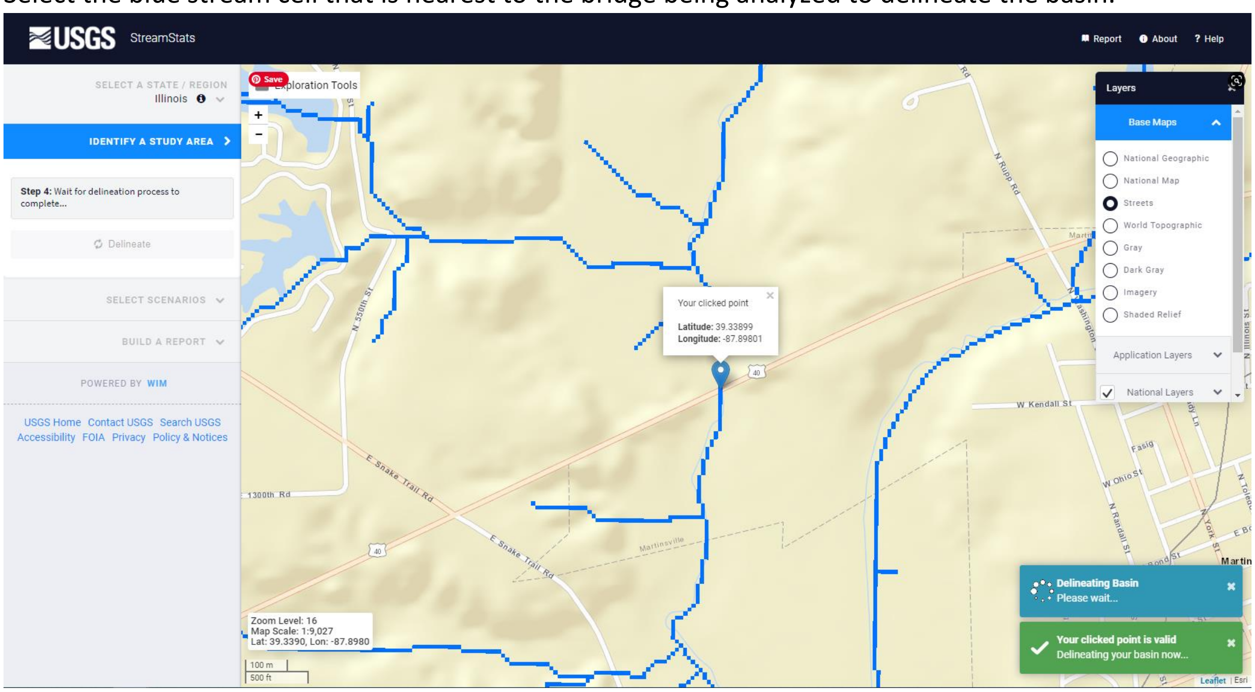
This will add the stream grid for Illinois to the map, as shown below.



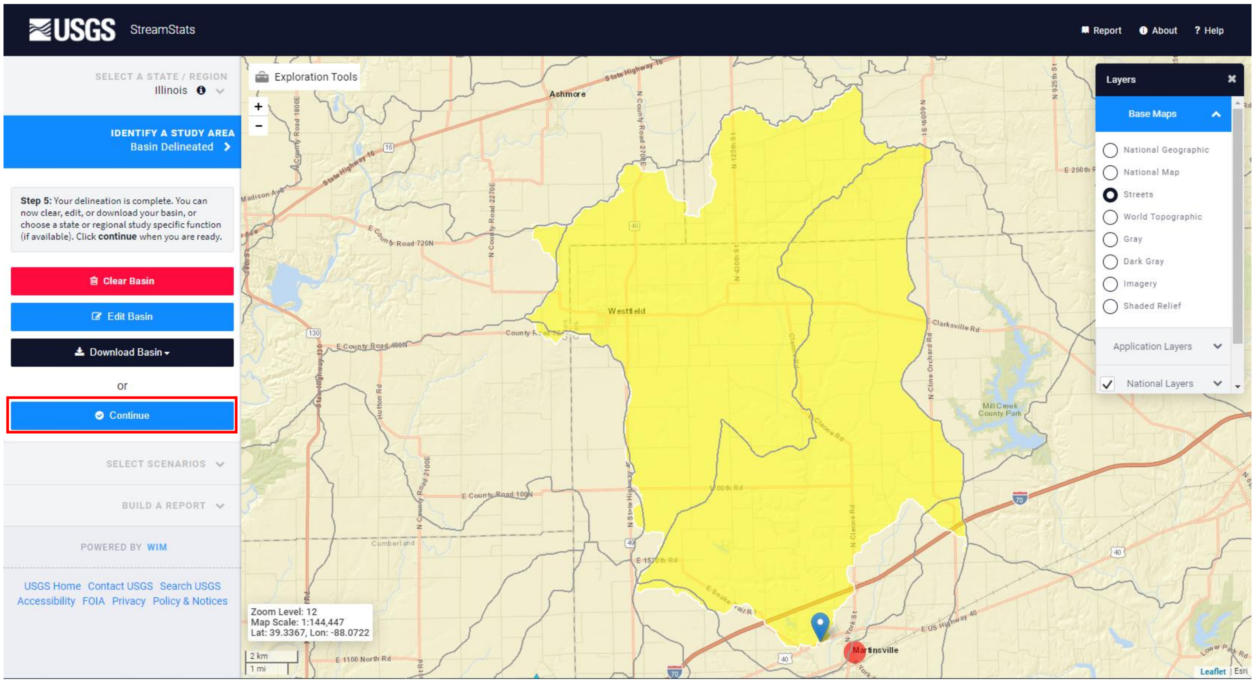
4. Navigate to the bridge location and select the "Delineate" button to activate the tool.



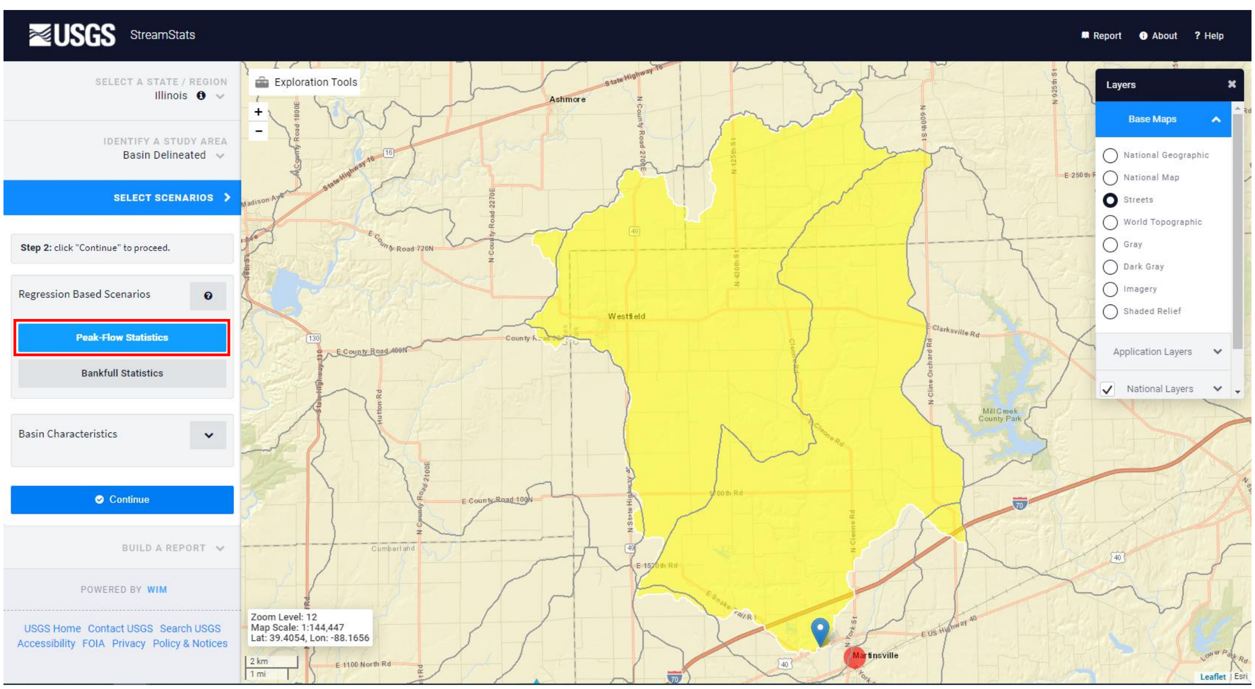
5. Select the blue stream cell that is nearest to the bridge being analyzed to delineate the basin.



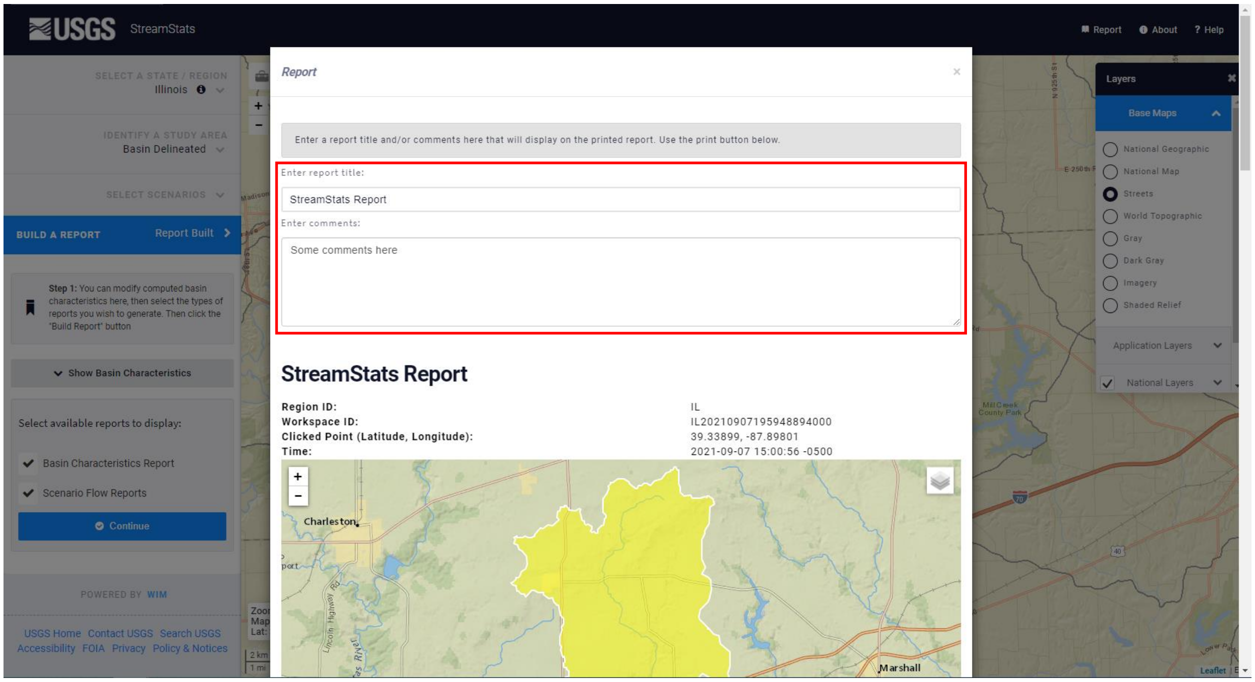
6. If there are obvious errors in the delineation given by StreamStats, areas can be added or subtracted from the basin using the “Edit Basin” button. If the delineation looks reasonable, select the “Continue” button.



7. Select the “Peak-Flow Statistics” button for the scenario and then select “Continue” to calculate the selected basin characteristics.



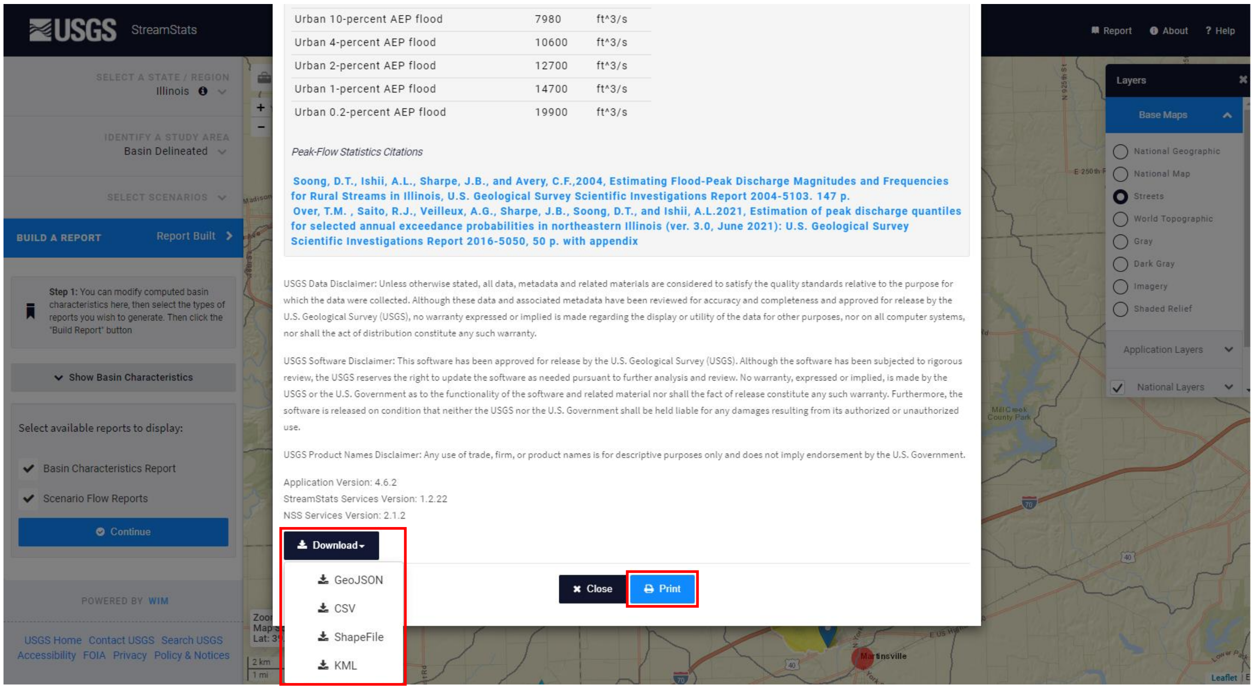
8. Select “Continue” once more to build the report. A report title and notes can be added to the top of the report if desired.



Scroll down through the report to view the information provided. The report will show two sets of discharges for the basin. It is up to the discretion of the engineer whether to use the urban flows or not.

Statistic	Value	Unit
50-percent AEP flood	3320	ft^3/s
20-percent AEP flood	5960	ft^3/s
10-percent AEP flood	7910	ft^3/s
4-percent AEP flood	10500	ft^3/s
2-percent AEP flood	12600	ft^3/s
1-percent AEP flood	14600	ft^3/s
0.2-percent AEP flood	19800	ft^3/s
Urban 50-percent AEP flood	3360	ft^3/s
Urban 20-Percent AEP flood	6020	ft^3/s
Urban 10-percent AEP flood	7980	ft^3/s
Urban 4-percent AEP flood	10600	ft^3/s
Urban 2-percent AEP flood	12700	ft^3/s
Urban 1-percent AEP flood	14700	ft^3/s
Urban 0.2-percent AEP flood	19900	ft^3/s

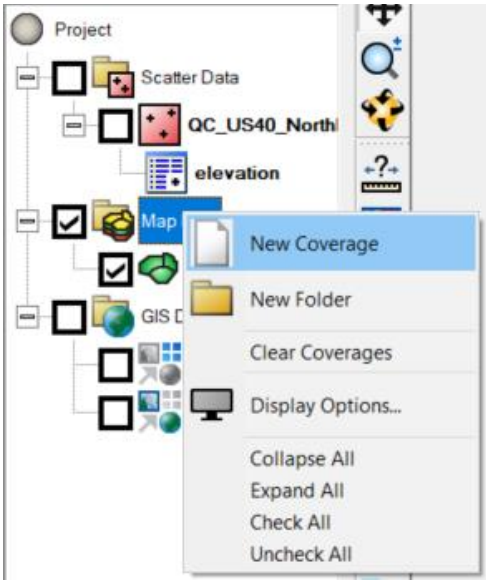
The report results can be printed to a PDF or printer, or downloaded to GeoJSON, CSV, ShapeFile, or KML formats.

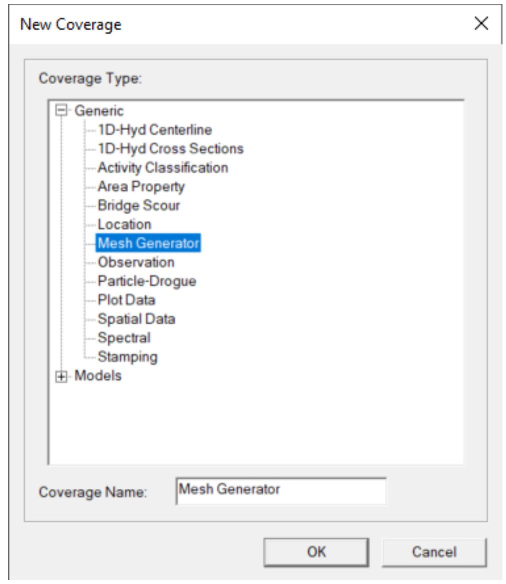


9. StreamStats provides flows for the 50% (2-year), 20% (5-year), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), and 0.2% (500-year) events. The 200-year flow will need to be interpolated for the model input.

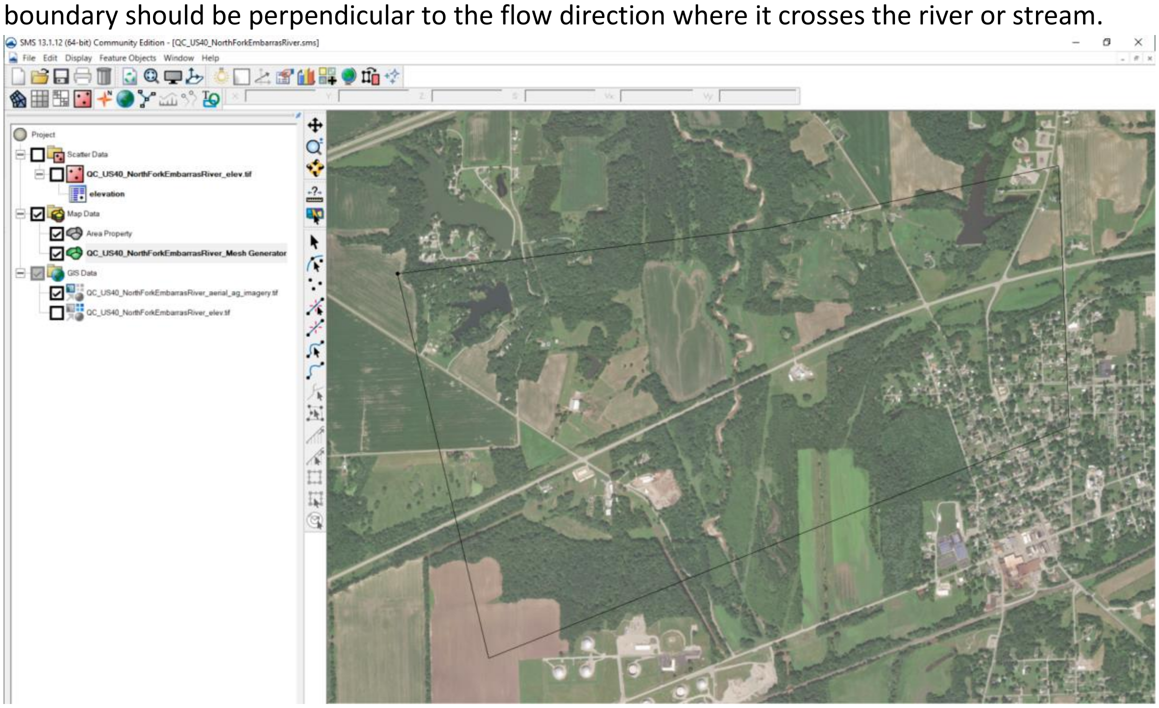
APPENDIX C – DEVELOP MODEL MESH

1. Create a new coverage by right clicking “Map Data” in the project organizer and selecting “New Coverage”. Select “Mesh Generator” from the generic coverage type.

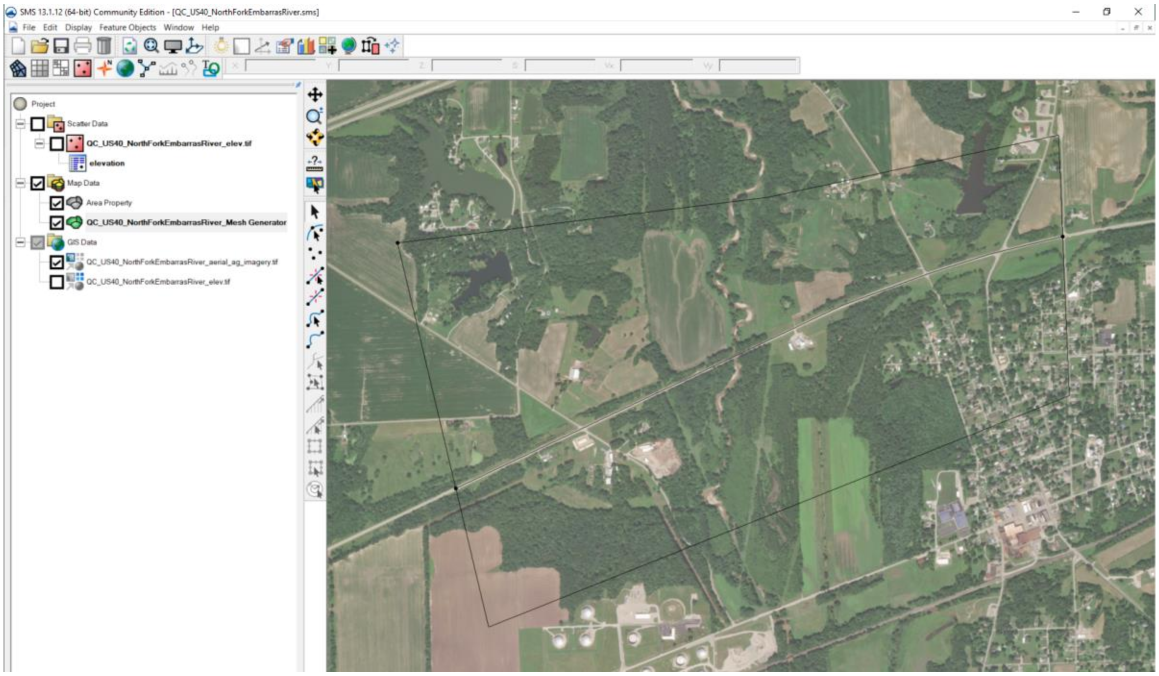




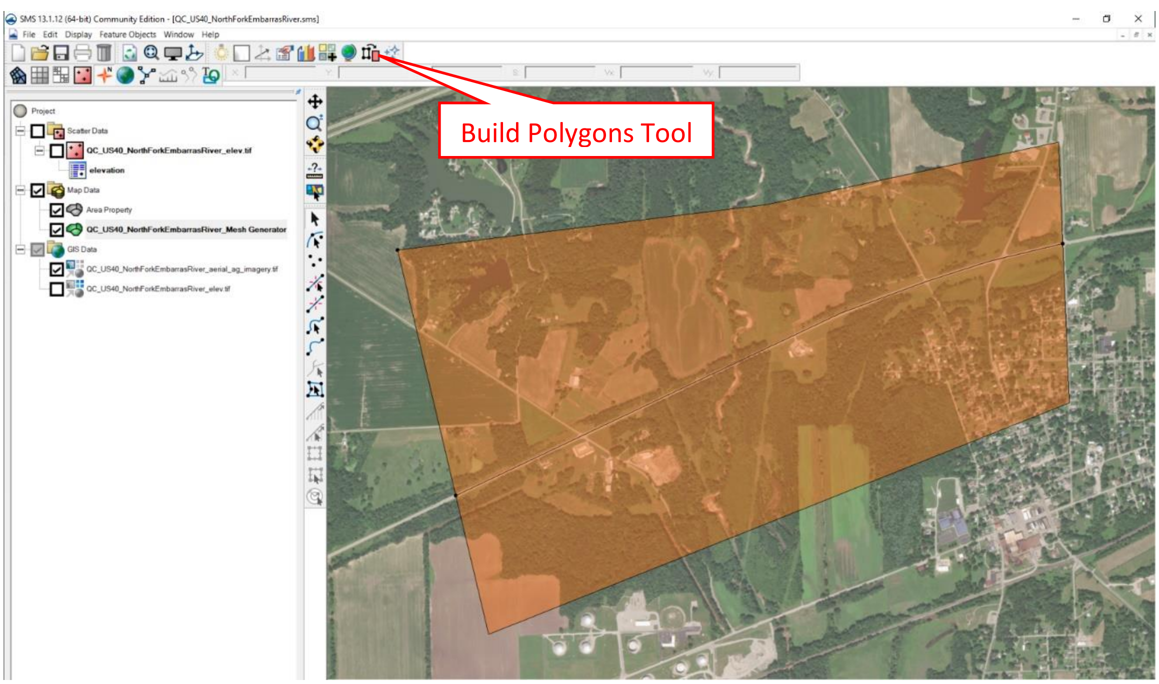
2. Select the Mesh Generator coverage that was just created in the project organizer window (as the active coverage it will be bold). Select the “Create Feature Arc” tool  and draw the boundary for the mesh. It should extend a few thousand feet upstream and downstream of the bridge being analyzed. The mesh boundary should span the width of the floodplain. The boundary should be perpendicular to the flow direction where it crosses the river or stream.



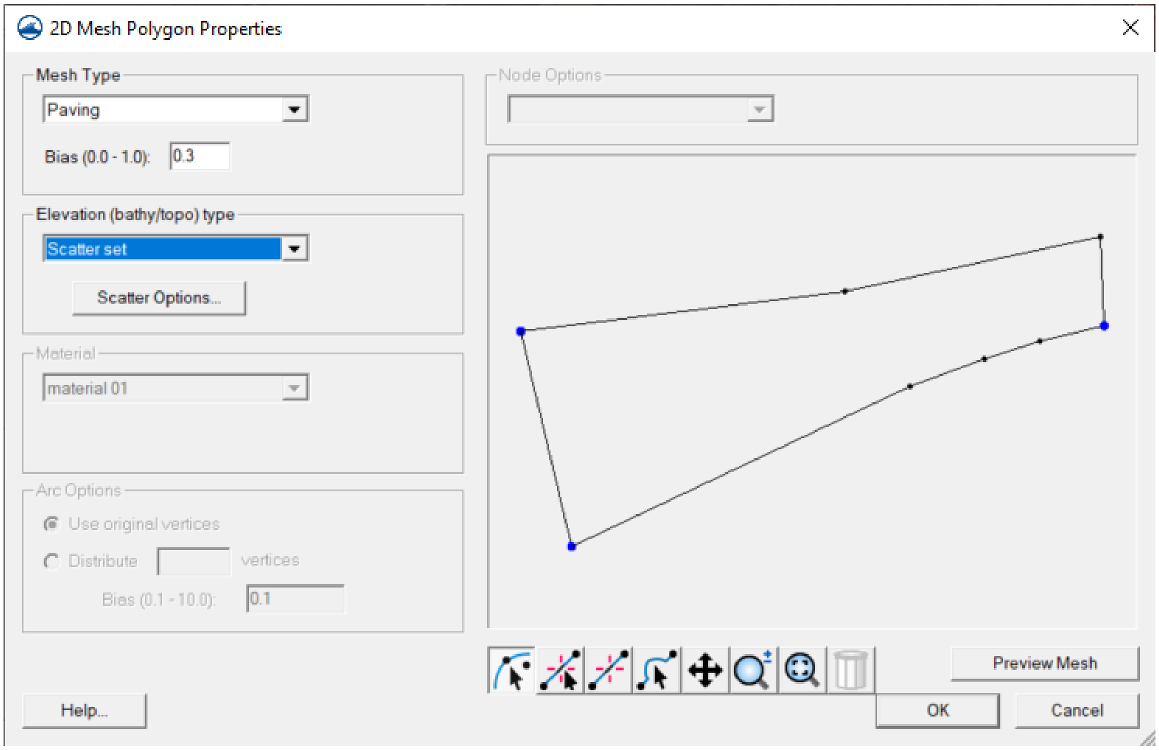
3. Create a feature arc along the centerline of the roadway to serve as a breakline. Each end of the feature arc should snap to the mesh boundary created in step 2.



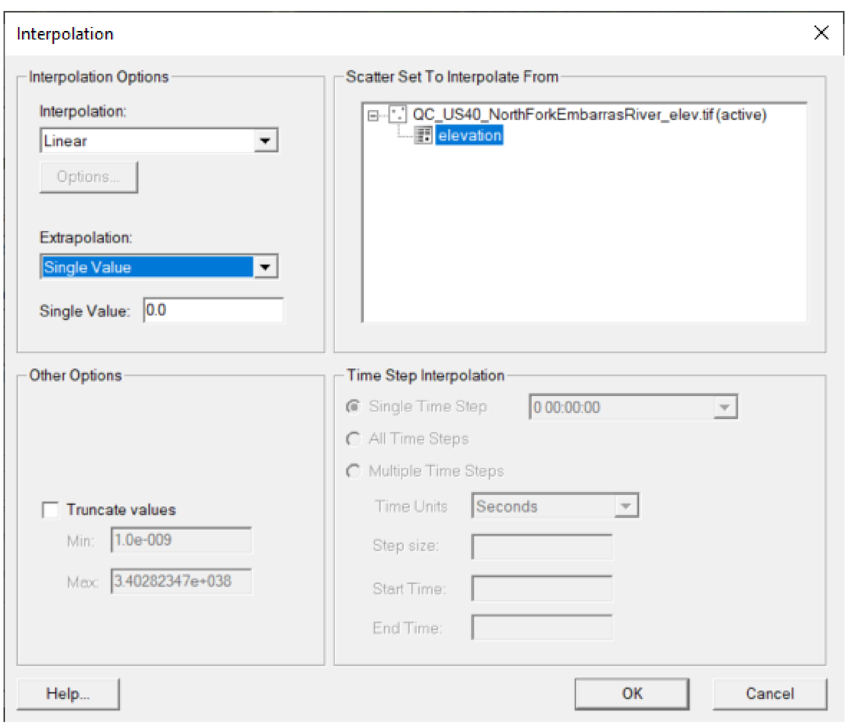
4. Polygon attributes cannot be applied until the polygons are built from the feature arcs created in the previous steps. To build polygons, make sure the mesh generator coverage is bold by clicking on it, and then click on the Build Polygons tool .



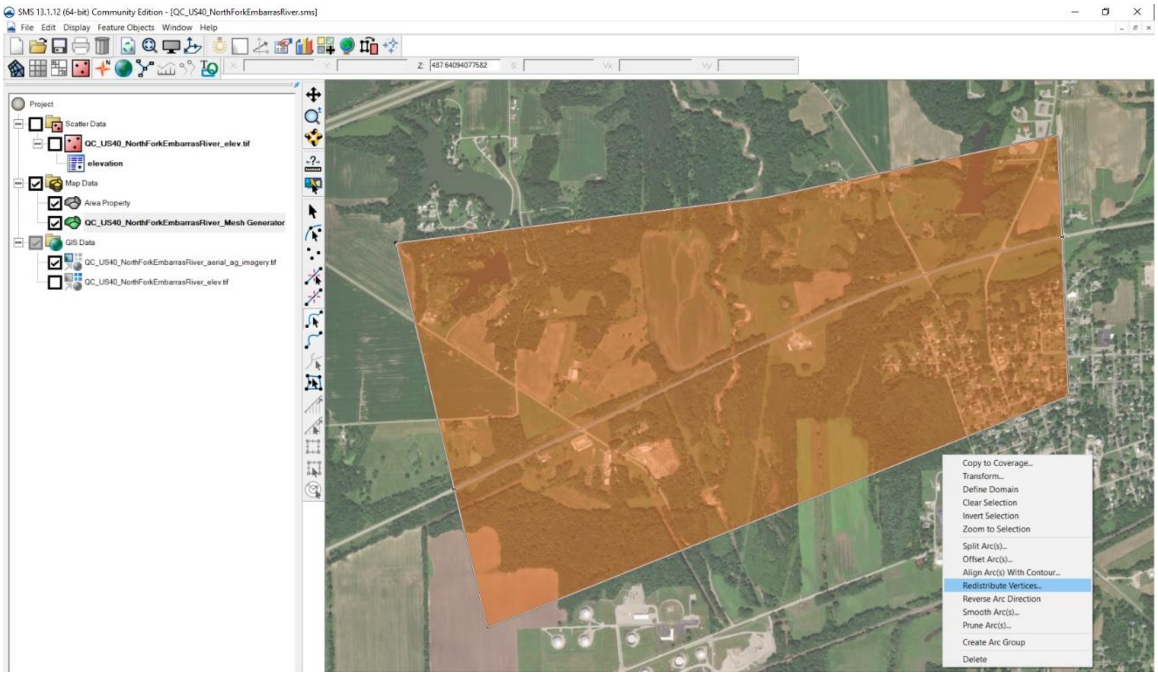
5. Select the "Select Feature Polygon" tool  and double click one of the polygons. Choose "Paving" for the mesh type. Choose "Scatter Set" for the Elevation (bathy/topo) type.



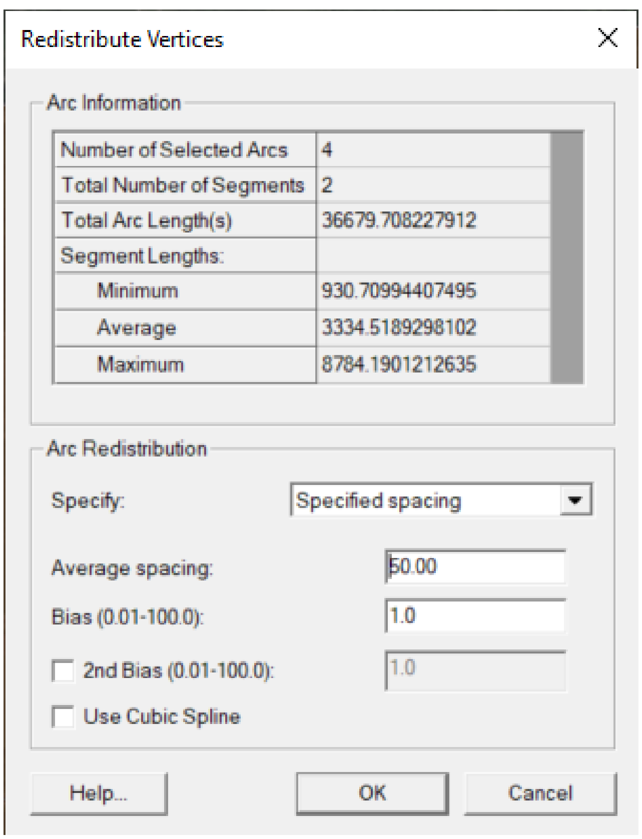
Select the "Scatter Options" button and select the scatter data. "Raster" can be selected if it was not converted to a scatter set. This will tie the mesh into the elevation data. Repeat this step for all polygons.



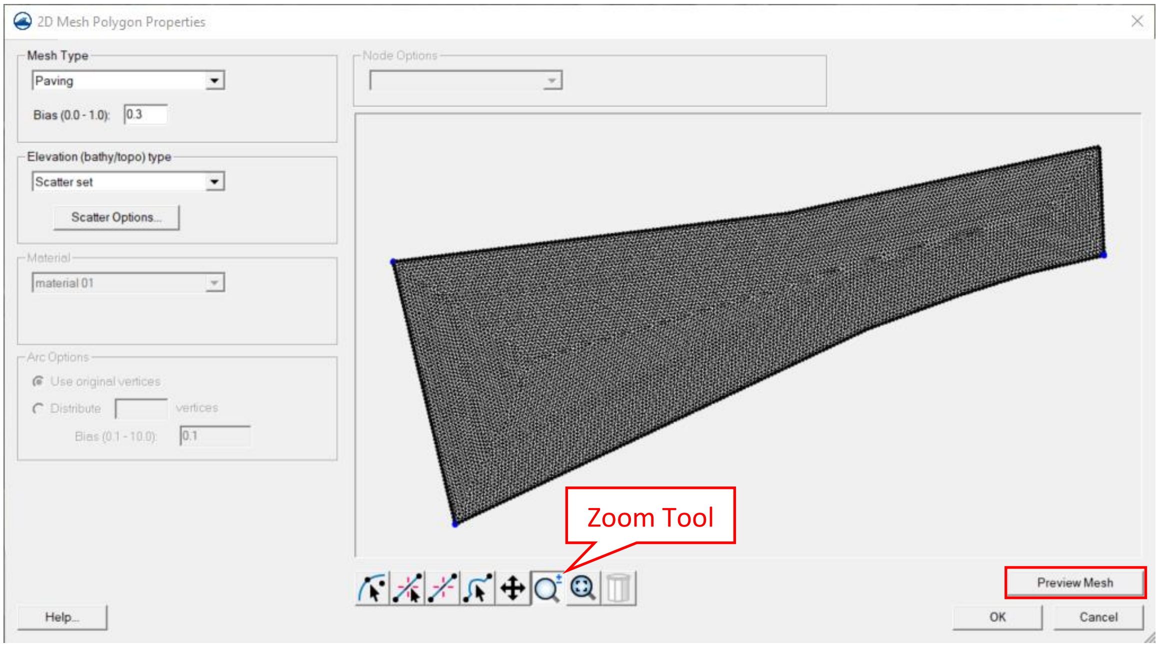
6. Select the “Select Feature Arc” tool. Hold shift and select all feature arcs. Right click anywhere on the screen and select “Redistribute Vertices”.



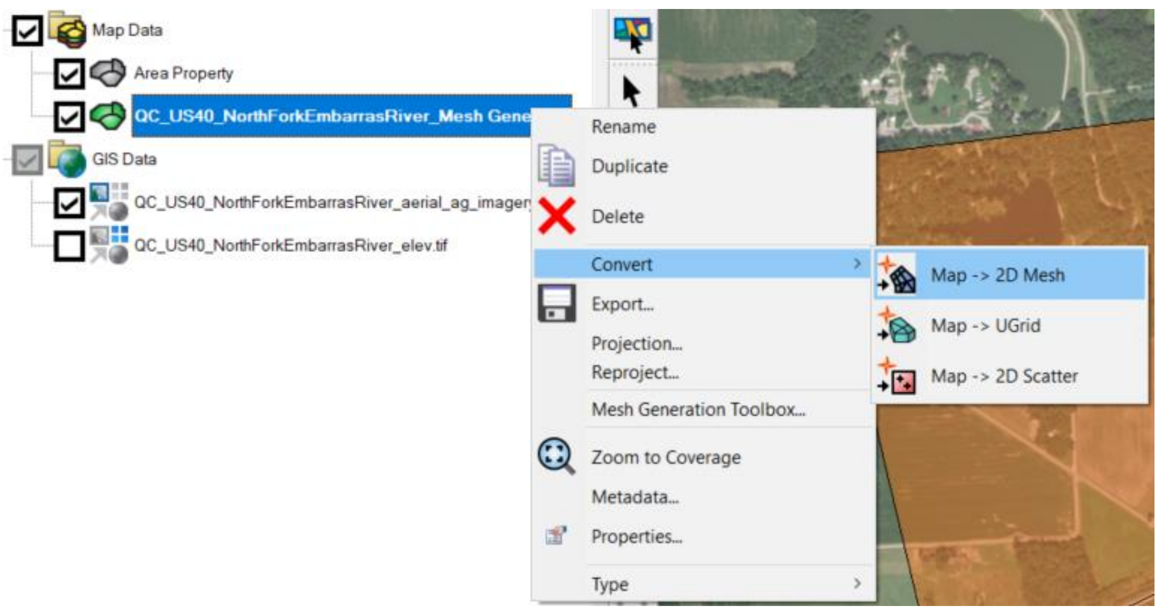
7. Choose “Specified spacing” and enter 50.00 for the average spacing. Spacing may be changed based on the size of the mesh.



8. The mesh can be previewed by double clicking a polygon using the “Select Feature Polygon” tool and selecting “Preview Mesh”. Ensure the elements are of similar size and continuous across the mesh. You can zoom in and out using the zoom tool.



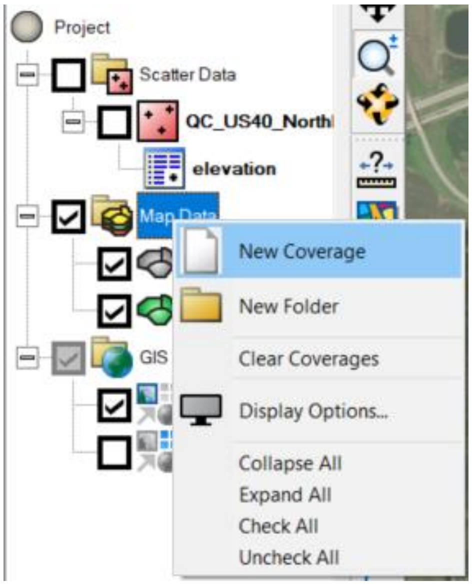
9. Convert the mesh generator coverage to a mesh on the 2D Map by right clicking the Mesh Generator in the project organizer and selecting “Convert” and then “Map->2D Mesh”. Adjustments to the mesh cannot occur in the converted “Mesh Data”. Adjustments must be made to the mesh generator coverage and then converted again to a 2D Mesh.

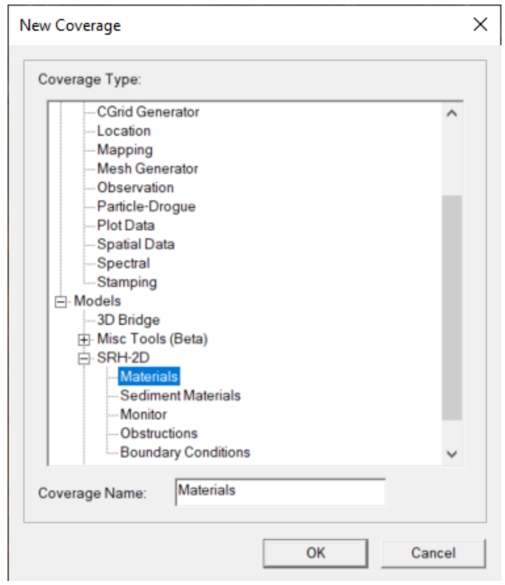


APPENDIX D – DEVELOP COVERAGES

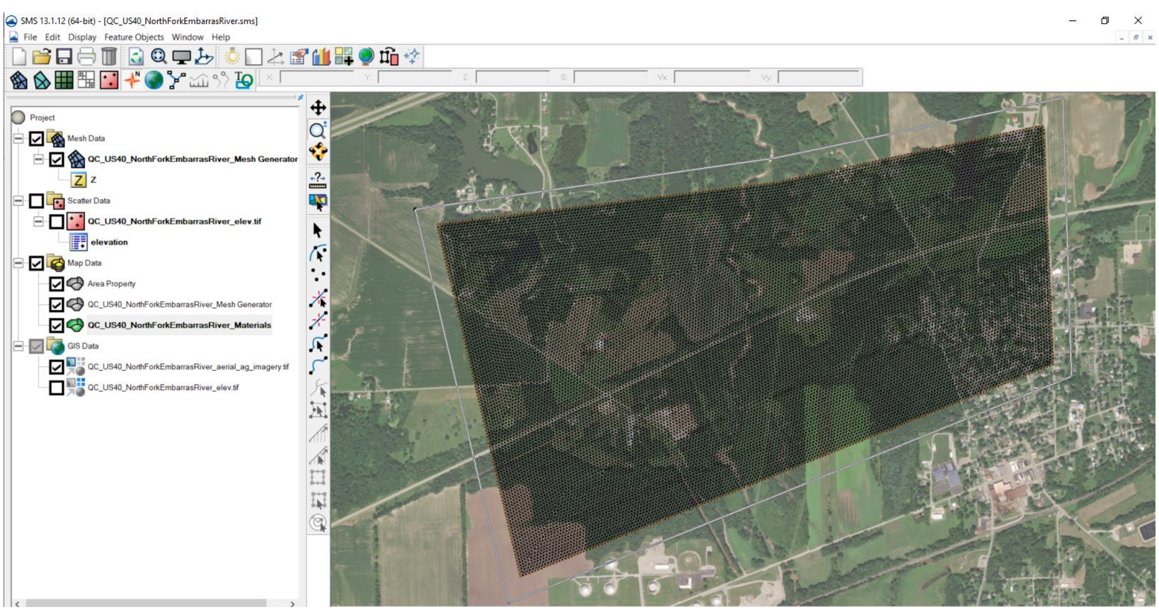
Materials Coverage

1. Right click “Map Data” in the project organizer window and select “New Coverage”. Select “Models” then “SRH-2D” then “Materials”.

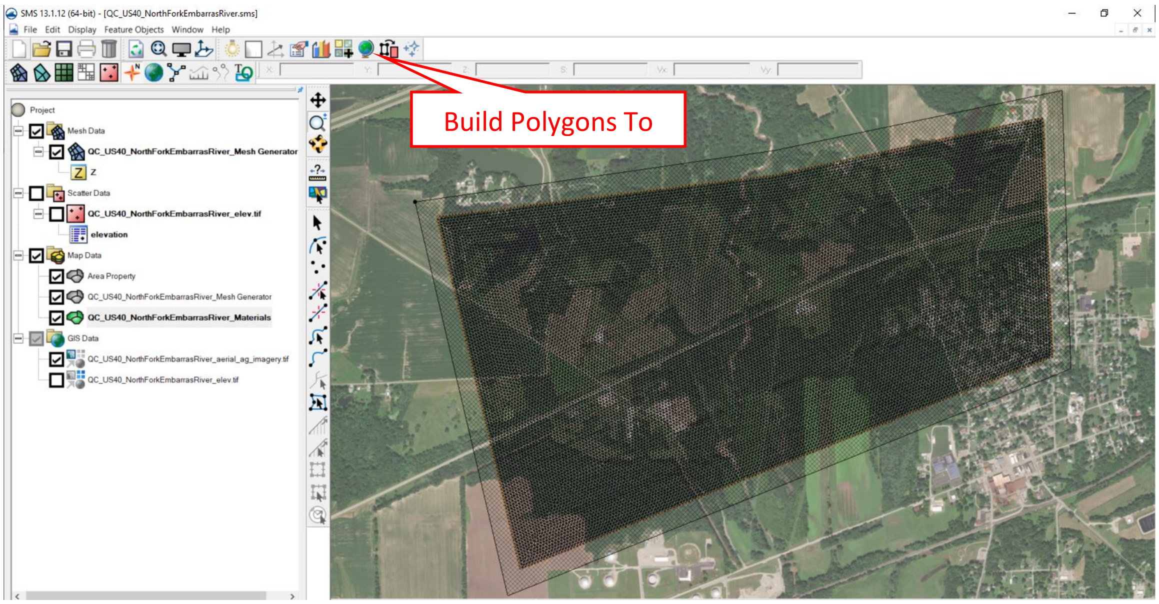




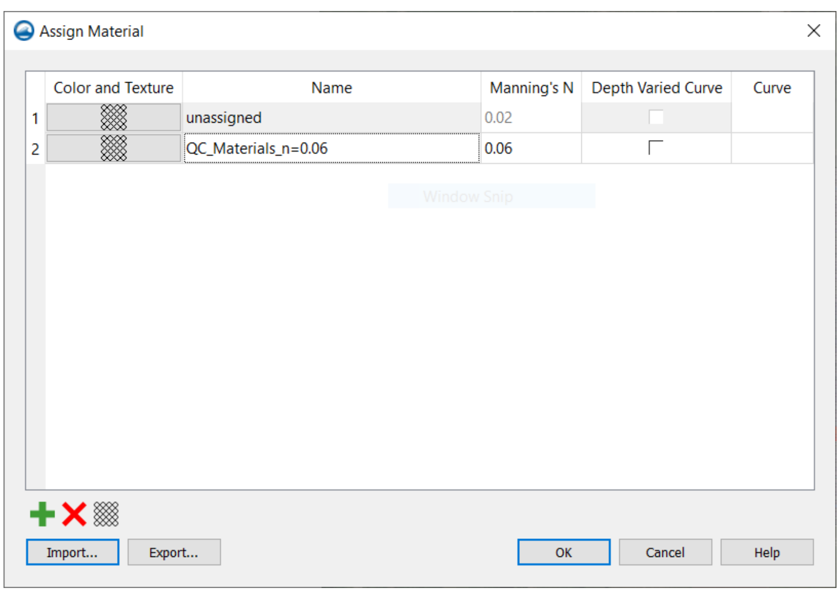
2. Make sure the Materials coverage that was just created is the active coverage (it should be bold). Select the “Create Feature Arc” tool and draw the boundary for the materials coverage. It is important to draw the materials coverage feature arcs so that they fully enclose the mesh. **At no point should there be mesh elements or nodes outside of the materials coverage**. Break lines within the outer boundary can be drawn to separate different land uses.



3. Select the “Build Polygons” tool. A material cannot be applied to the coverage until the polygons are built.

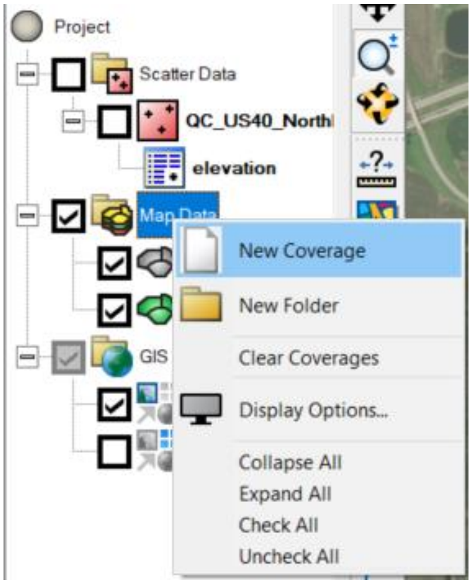


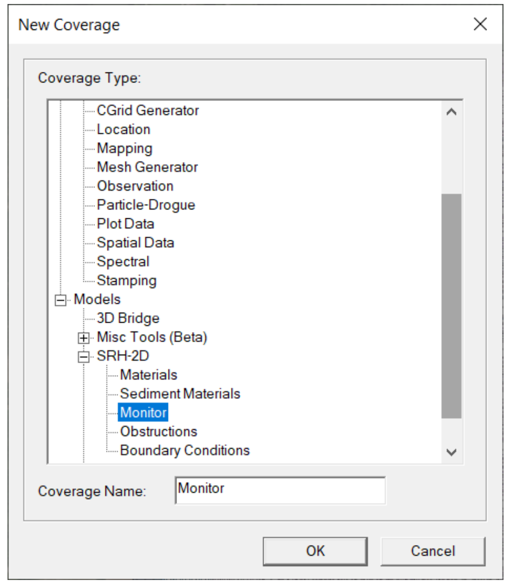
4. Select the “Select Feature Polygon” tool and double click one of the materials polygons. A window will open where the manning’s “n” value, name, and color/texture of the material can be assigned to the polygon that was selected. Materials can be added or deleted with the plus and “X” in the lower left corner of the window. Every polygon must have a material assigned to it.



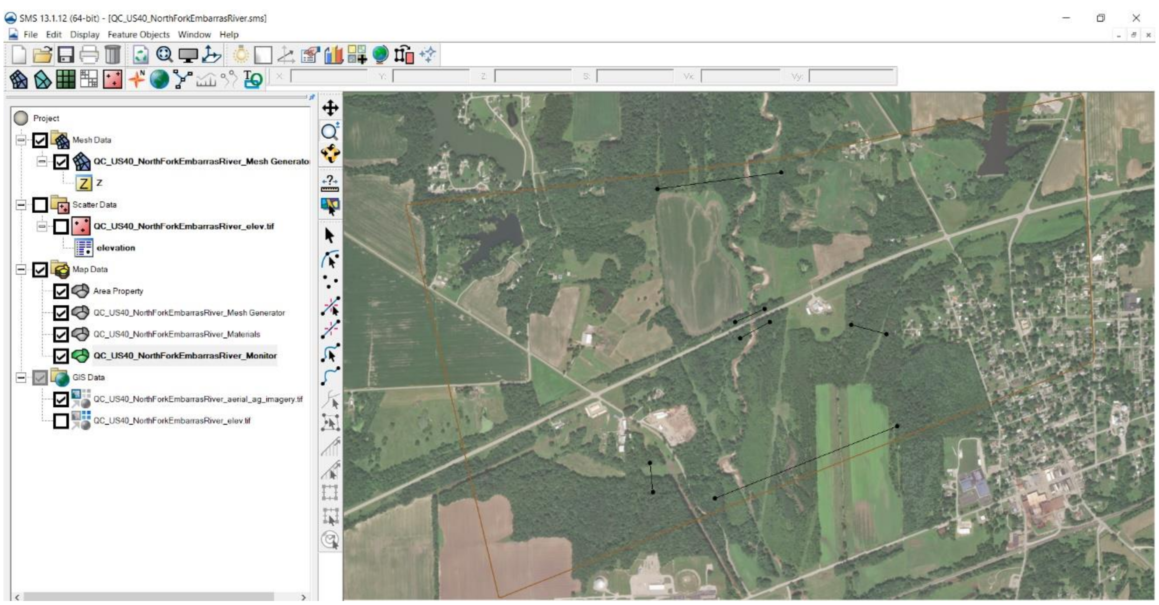
Monitor Coverage

1. Right click “Map Data” in the project organizer window and select “New Coverage”. Select “Models” then “SRH-2D” then “Monitor”.



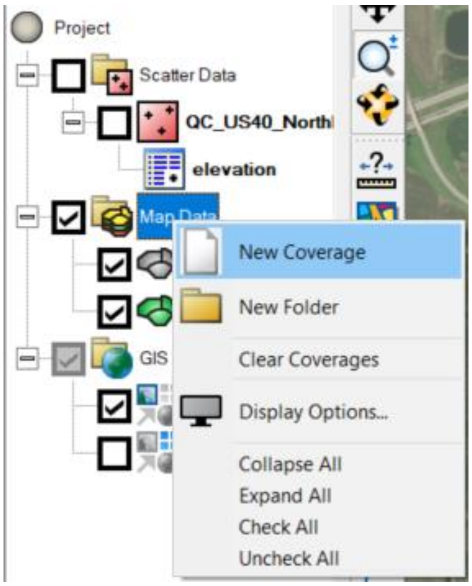


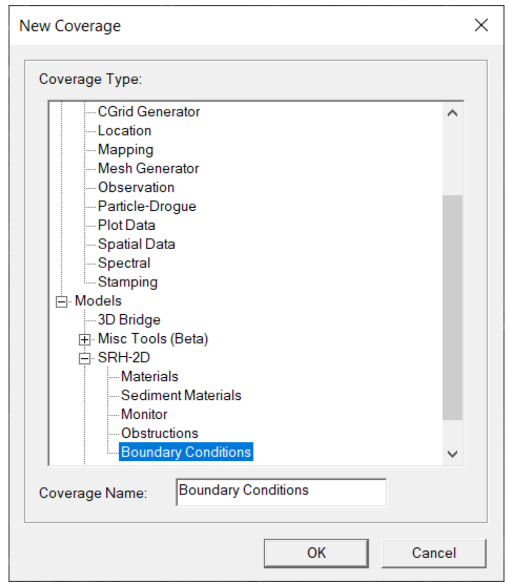
2. Select the “Create Feature Arc” tool. Monitor lines/points <u>do not</u> impact the calculations of the simulation. They serve as checks while the model is running to determine the stability of the model and when it reaches steady state. Monitor lines should be placed within the mesh.



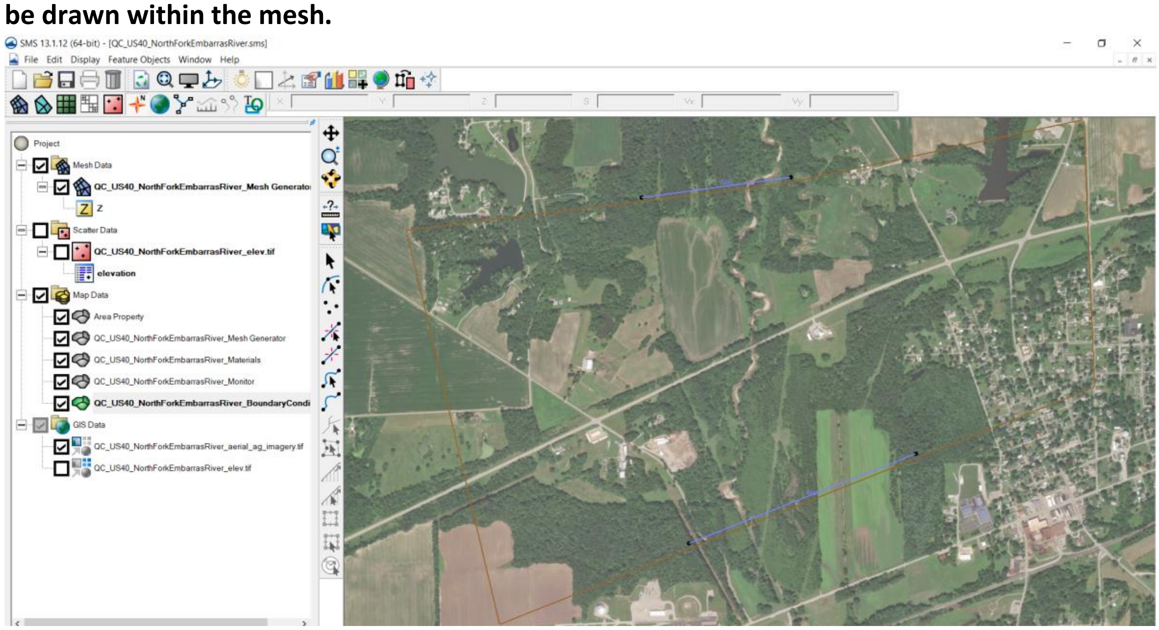
APPENDIX E – DEVELOP BOUNDARY CONDITIONS

1. Right click “Map Data” in the project organizer window and select “New Coverage”. Select “Models” then “SRH-2D” then “Boundary Conditions”. It is helpful to name the boundary condition in a way that represents the storm that the boundary conditions will represent.



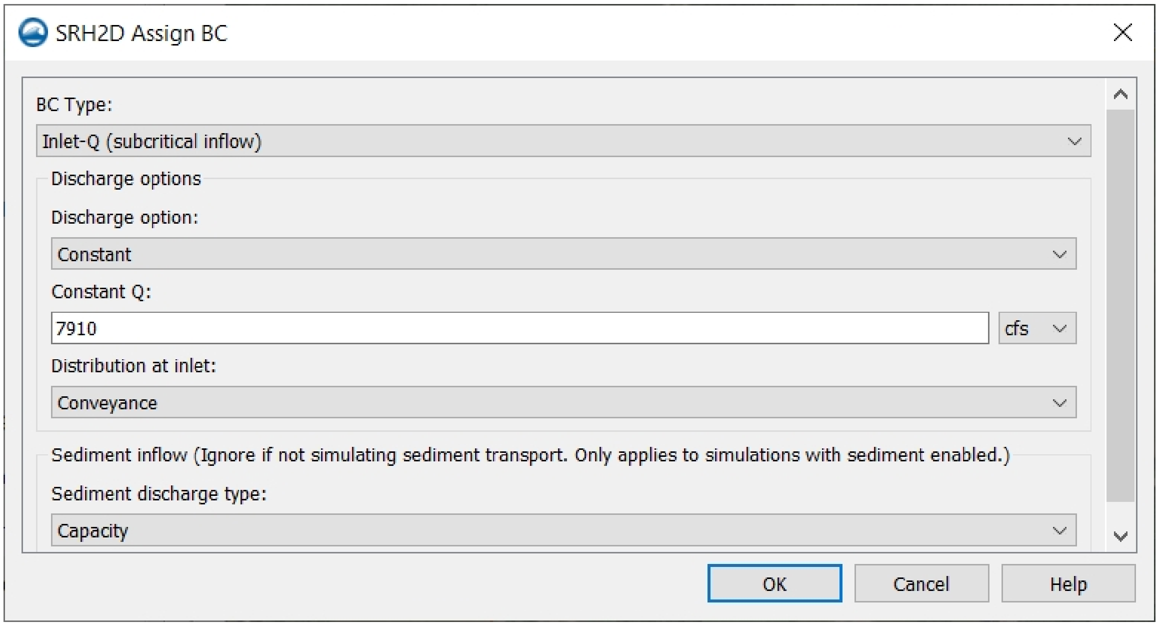


2. Make sure that the boundary condition that was just created is the active coverage (it should be bold). Select the “Create Feature Arc” tool and draw two lines: one at the upstream end where the flow will be entering the mesh and one at the downstream end where the flow will be leaving the mesh. **It is important to draw the upstream feature arc perpendicular to the flow and outside of the mesh but within the materials coverage. The downstream feature arc must be drawn within the mesh.**



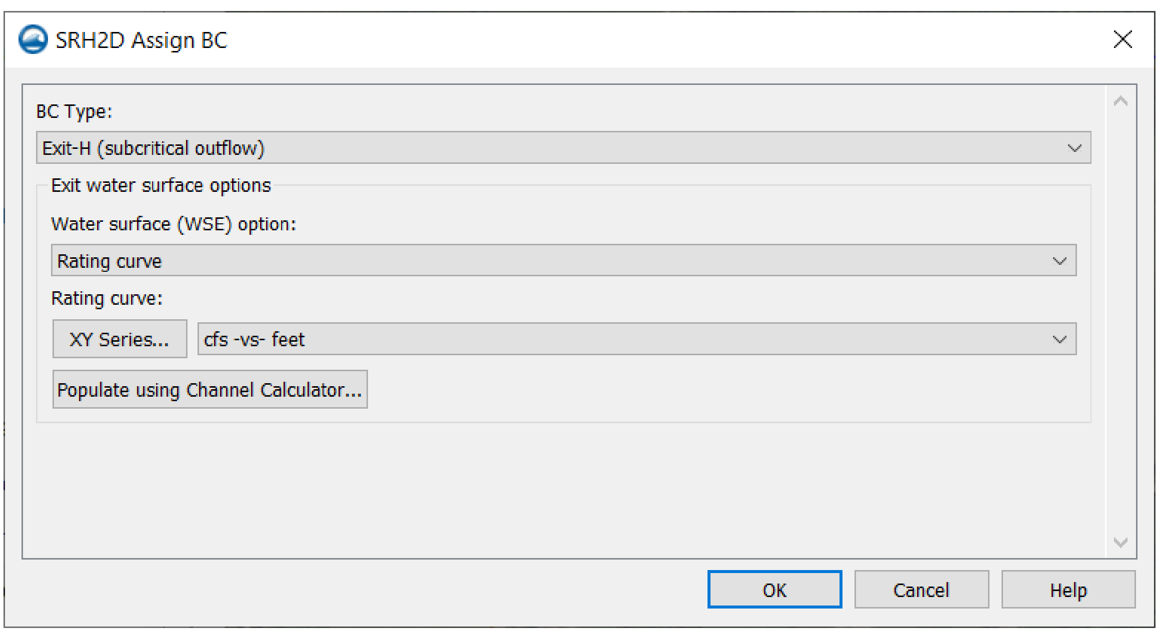
Inlet-Q Boundary Condition

3. Select the “Select Feature Arc” tool and double click on the upstream feature arc from the previous step. Change the BC Type to “Inlet-Q (subcritical inflow)”. Enter the flow for the appropriate storm given by StreamStats or by FEMA FIS. There will be one boundary condition coverage per storm frequency.

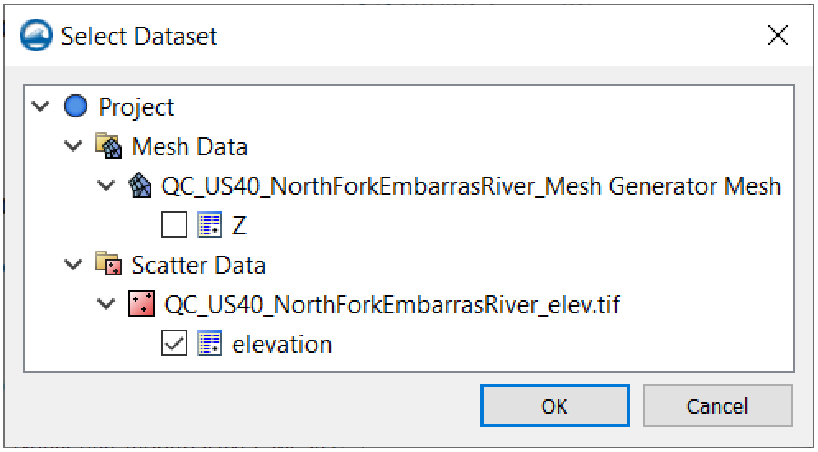


Exit-H Boundary Condition

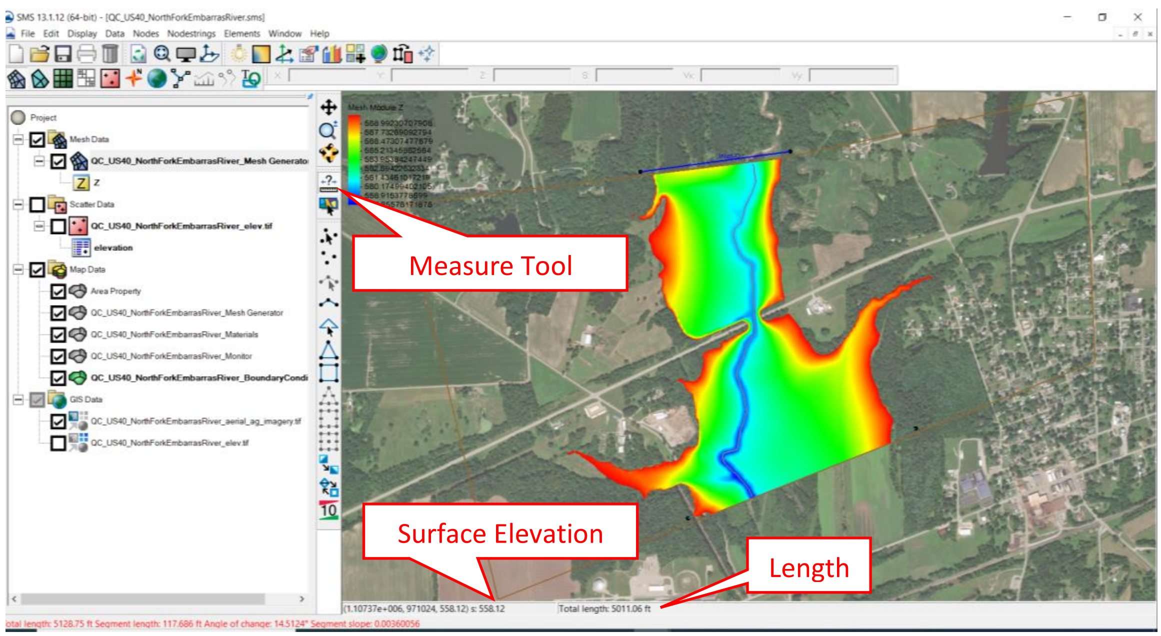
4. Select the “Select Feature Arc” tool and double click on the downstream feature arc. Change the BC Type to “Exit-H (subcritical outflow)”. Change the Water surface (WSE) option to “Rating Curve” and choose the correct units. Select the “Populate using Channel Calculator” button.



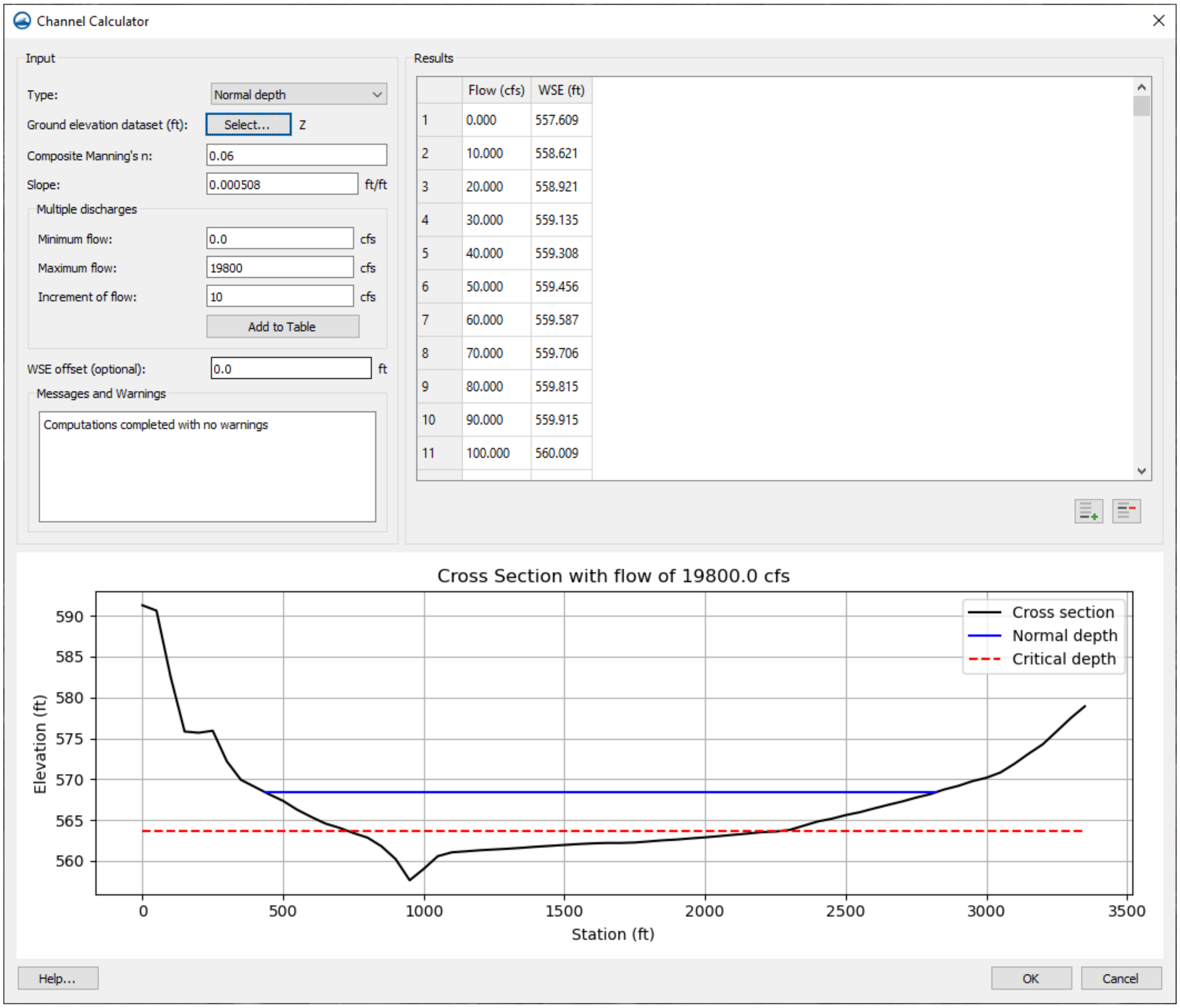
5. Select either the Raster or Scatter set as the Ground elevation dataset.



6. Enter the composite manning's "n" value for the site. To calculate the slope, make the mesh active in the project organizer. Choose the select objects tool and hover over the waterway at the most upstream portion of the mesh. The elevation will be shown at the bottom left of the window. Repeat the action for the most downstream portion of the waterway. To measure the length of the channel, use the "Measure Tool".



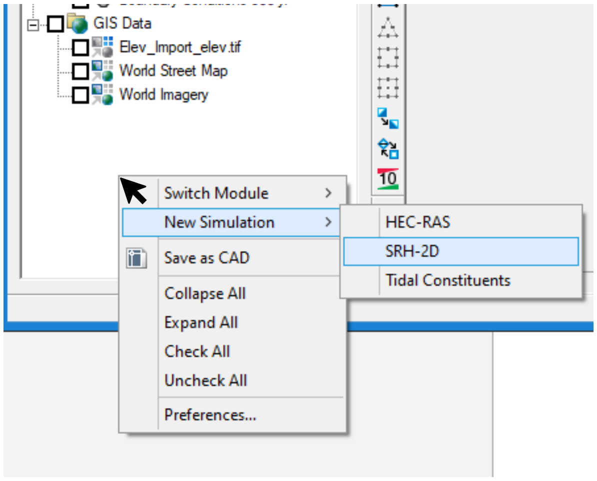
7. Enter zero for the minimum flow. Enter the 500-year flow from the hydrological analysis for the maximum flow. Enter an increment of flow that will give a good spread of tailwater conditions (typically 10 cfs). Click “Add to Table” to populate the table. Then click OK.



APPENDIX F – RUN EXISTING CONDITIONS AND REVIEW RESULTS

Create a Simulation.

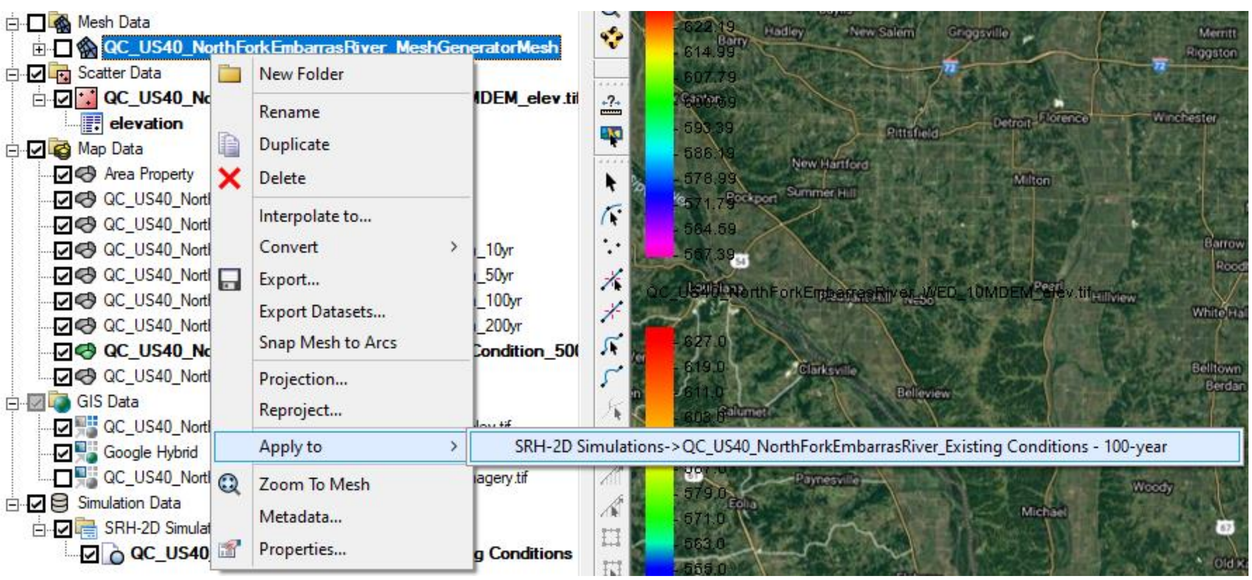
1. Right click in a blank space on the project explorer and select New Simulation | SRH-2D



2. By default, the simulation will be named Sim. Right click on Sim and select Rename.
3. Name the simulation **QC_US40_NorthForkEmbarrasRiver_Existing Conditions – 100-year.** The name of the simulation will determine the name of the simulation output folder.

Link Coverages to Simulation.

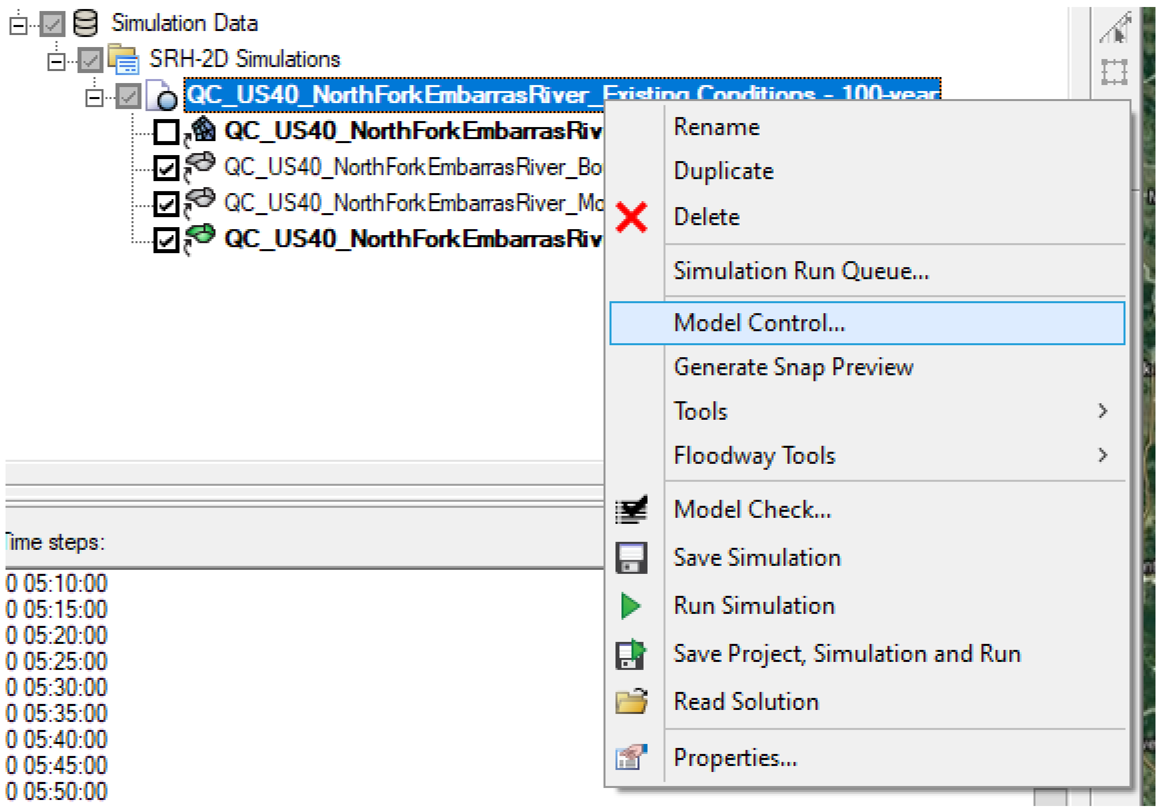
1. Four coverages will be linked to the simulation including the Mesh, Materials, Boundary Conditions, and Monitor. To link a coverage right click on the coverage and select Apply to | SRH-2D Simulations -> QC_US40_NorthForkEmbarrasRiver_Existing Conditions – 100-year



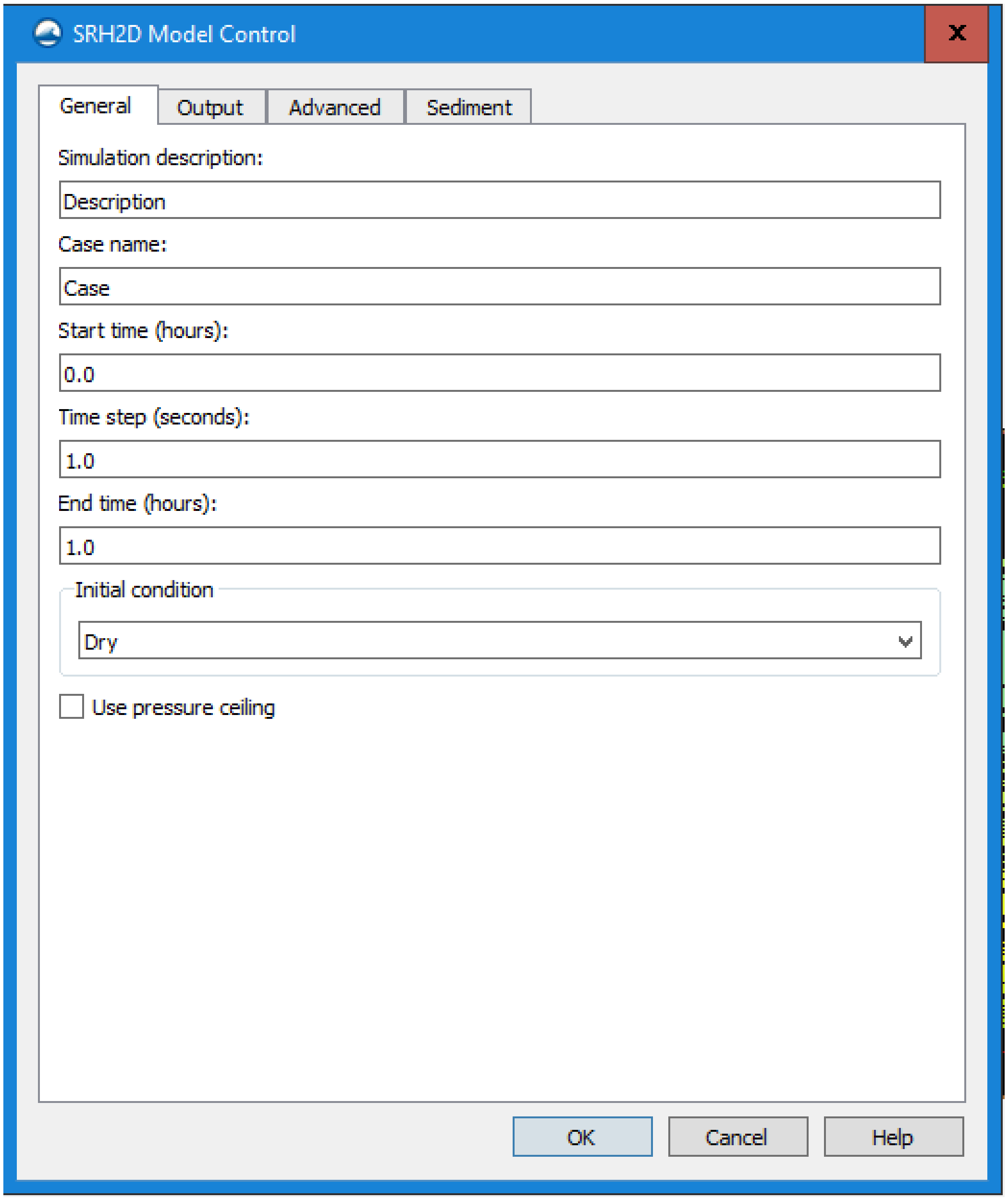
2. Repeat this step for the Mesh, Materials, Monitor, and Boundary Conditions. Once completed the coverages will appear below the linked SRH-2D simulation.

Specify Model Controls.

1. To access model controls right click on the simulation (Existing Conditions – 100-year) and select Model Control…

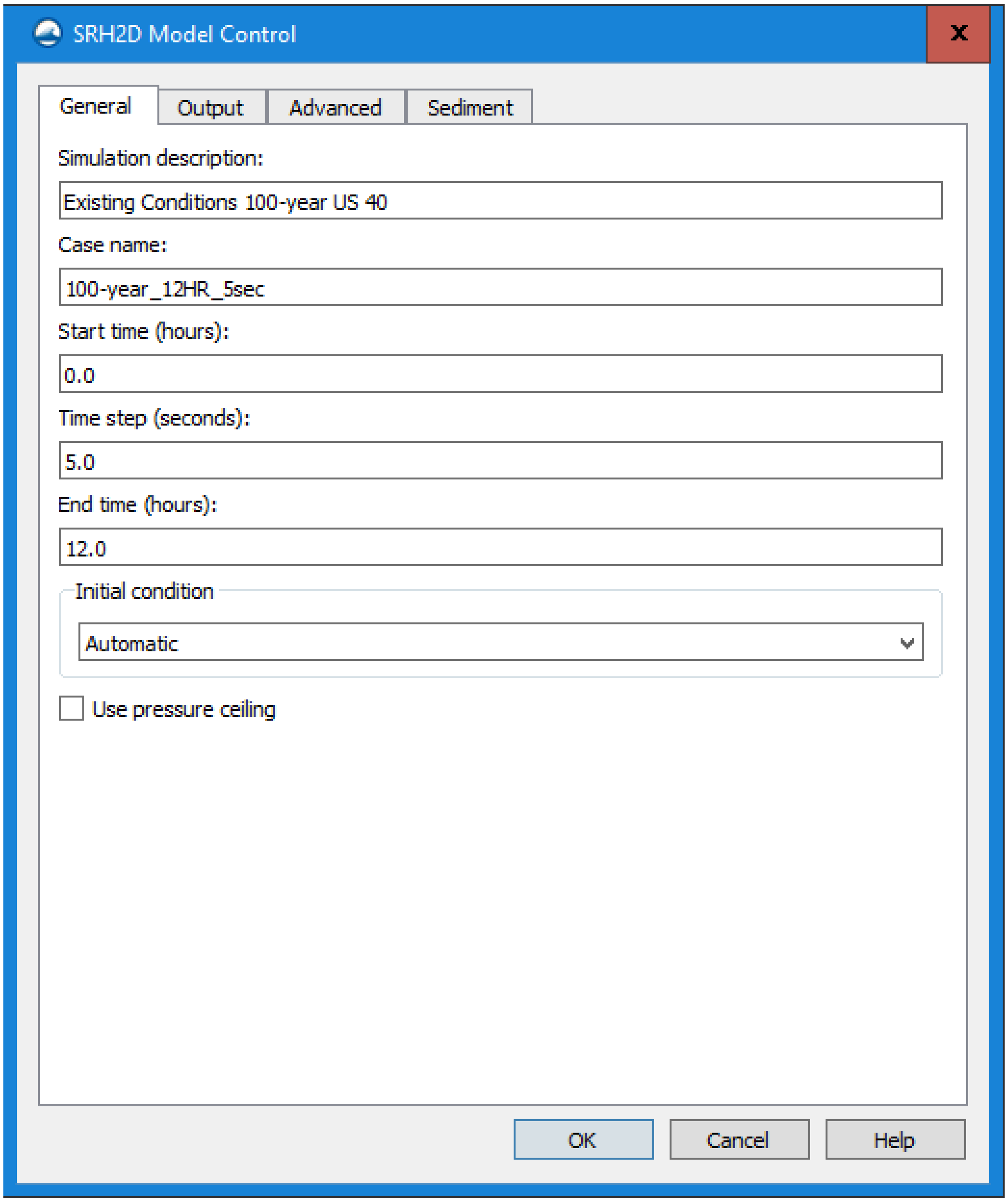


2. The model control dialogue will open with the following defaults.

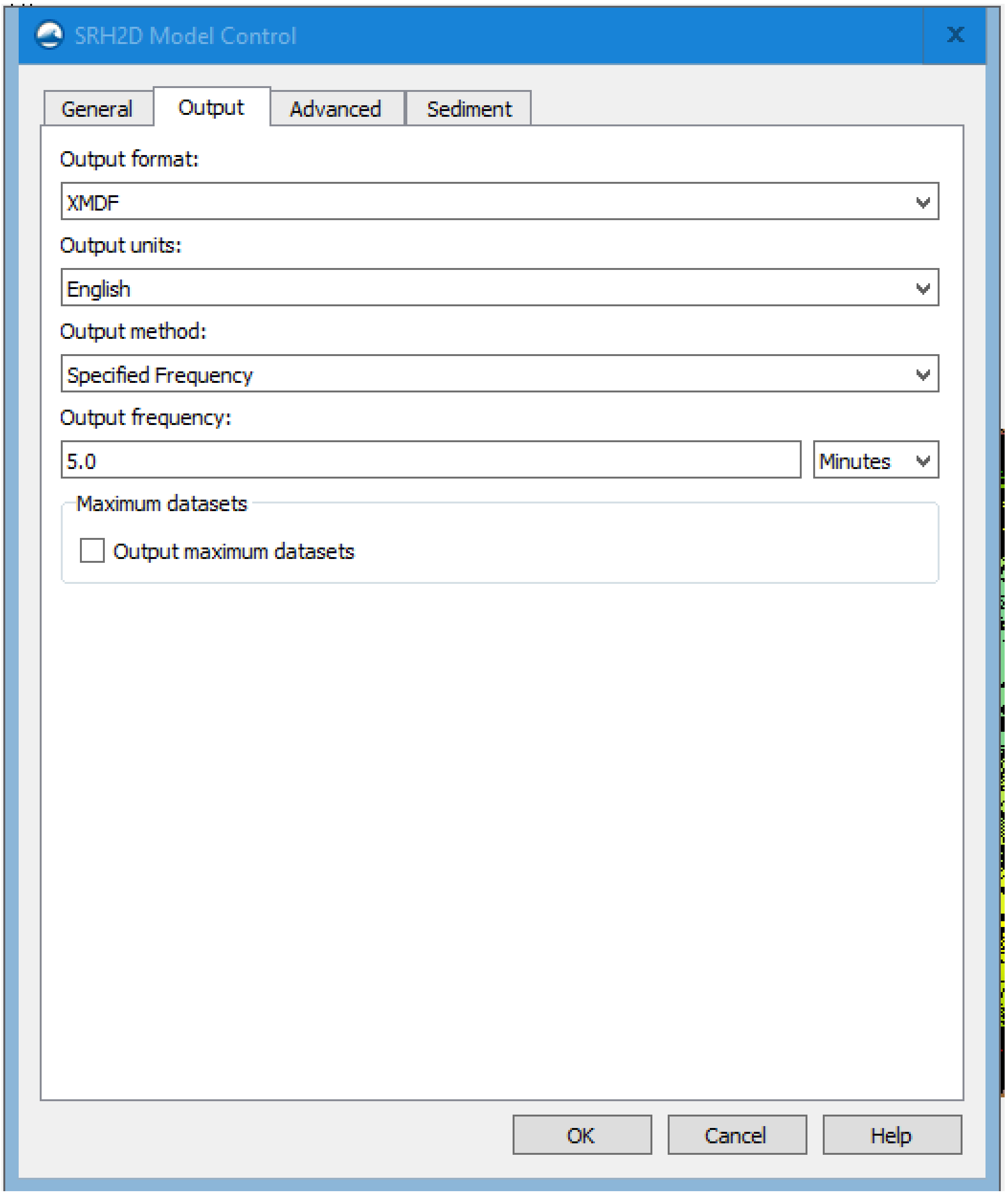


3. The General Model Control tab is where the user specifies the length of simulation, time step, and initial condition. The Simulation Description is optional and does not impact the naming convention of the model files. The description provides the modeler with an opportunity to elaborate on the details of the simulation. For this simulation the description will be **Existing Conditions 100-year US 40**.
4. The Case name will determine the file names of the simulation output files. This can be used as an opportunity to provide detail on parameters that may be iterated for the same simulation such as time step and simulation length. For this run the name will be **100-year_12HR_5sec** to note that the 100-year flood will be run with a simulation length of 12 hours at a timestep of 5 seconds.

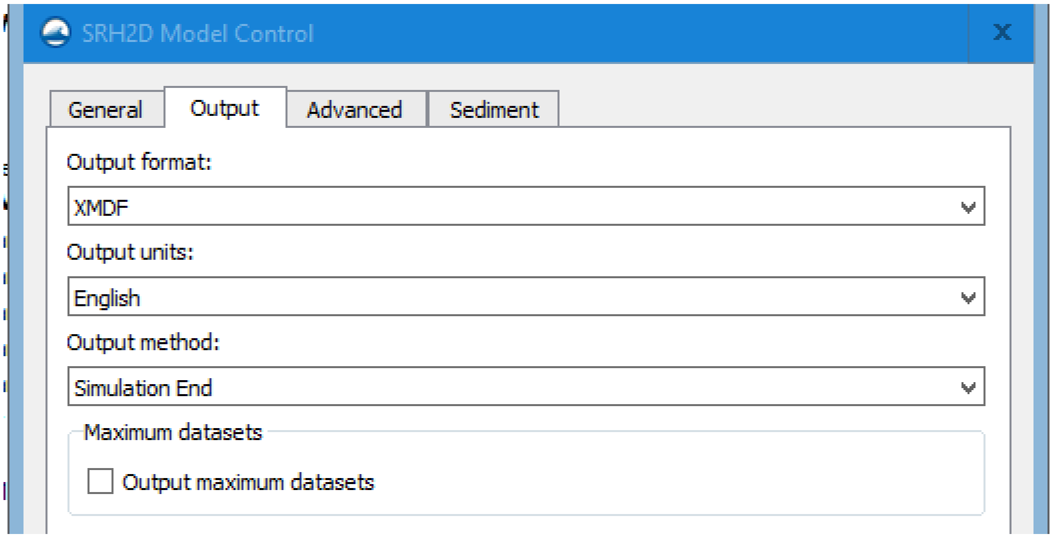
5. The start time of the simulation will be 0. The Time step will be 5 seconds and the end time will be 12. The Initial condition will be Automatic.



6. Select the Model Control Output Tab

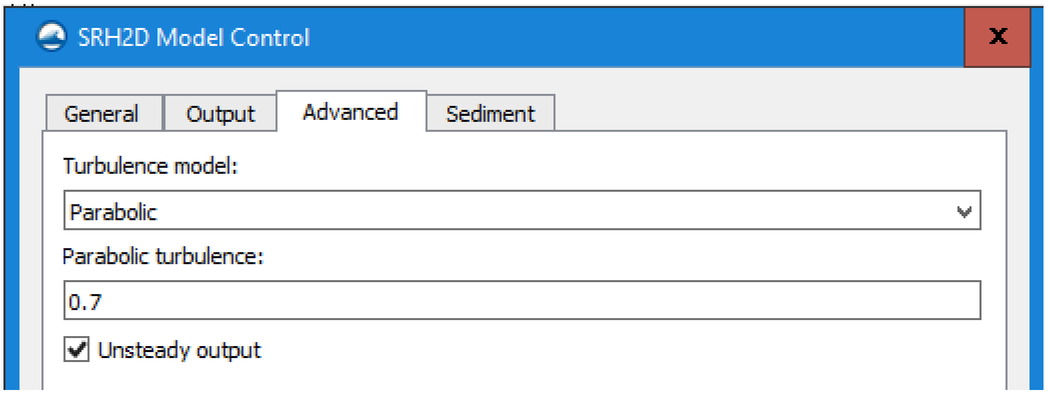


7. Output frequency determines how often the model will report output. For a steady state model, the desired output occurs at the final timestep. As such, the user should specify Simulation End for the Output method.

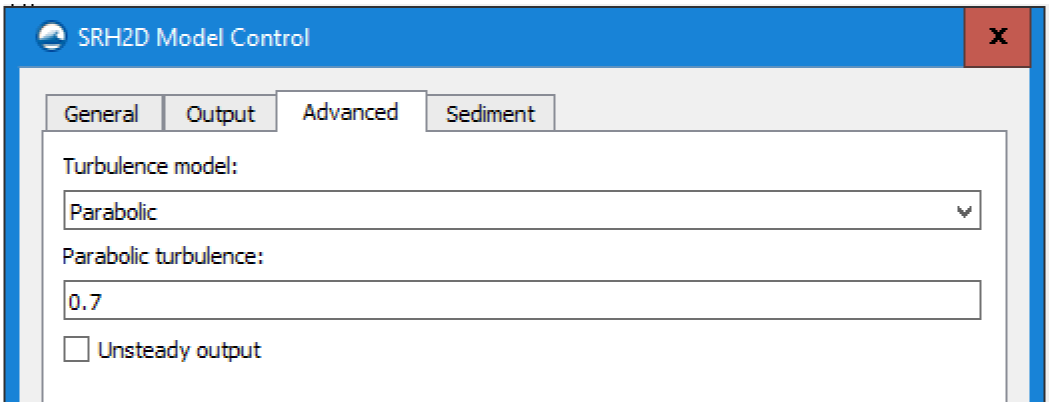


8. Select the Advanced Tab

9. By default, the Unsteady output is checked.

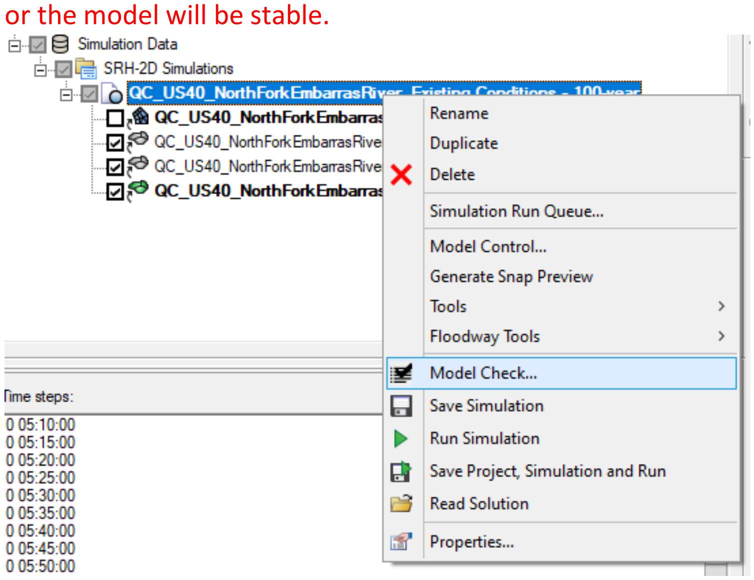


10. Uncheck the box for Unsteady output.

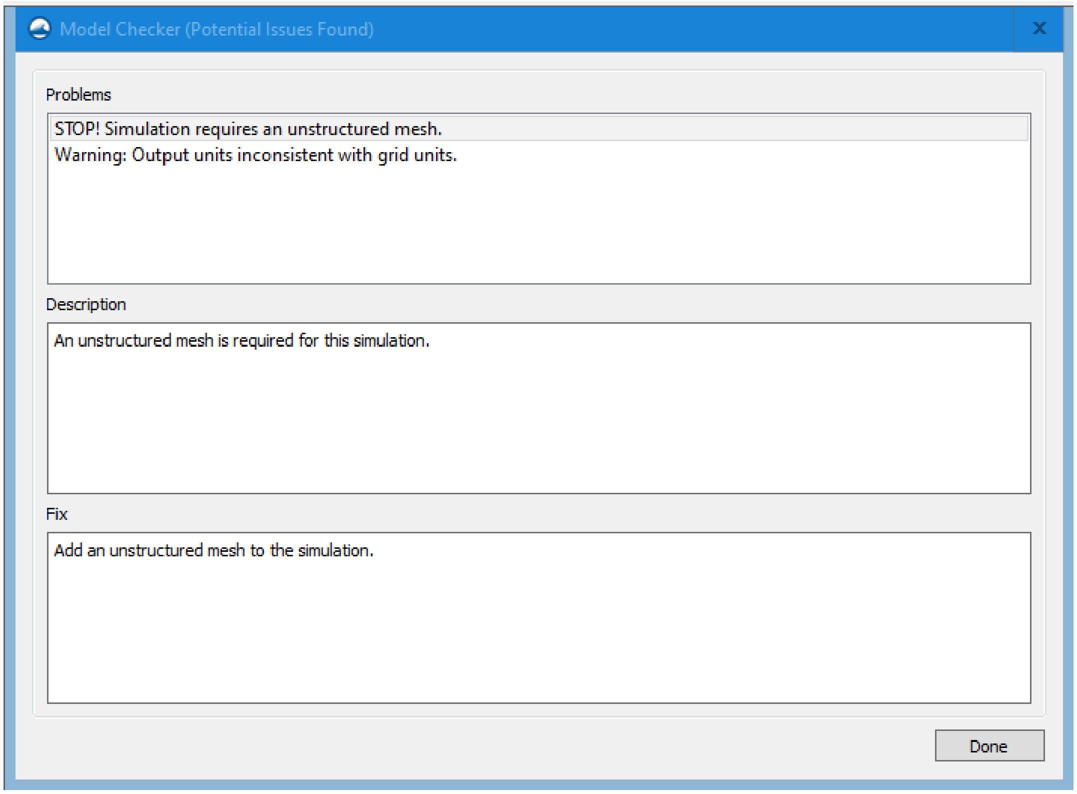


Saving and Running the Simulation

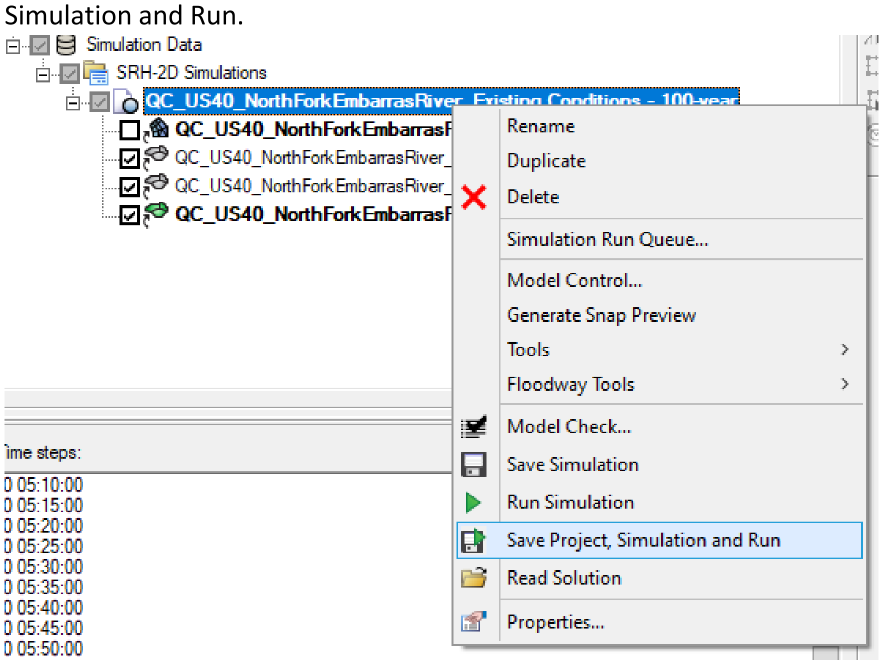
1. Right click on the simulation **QC_US40_NorthForkEmbarrasRiver_Existing Conditions - 100-year** and select Model Check. The model check looks for missing important data or inconsistent or incompatible options and parameters. Such errors will either cause the model to crash or to generate an erroneous solution. Note: The Model Check searches for obvious errors or potential problems. A successful model check does not guarantee that a solution will be correct or the model will be stable.



An example of a model check error is presented below. The error was generated by forgetting to connect the model mesh to the simulation.



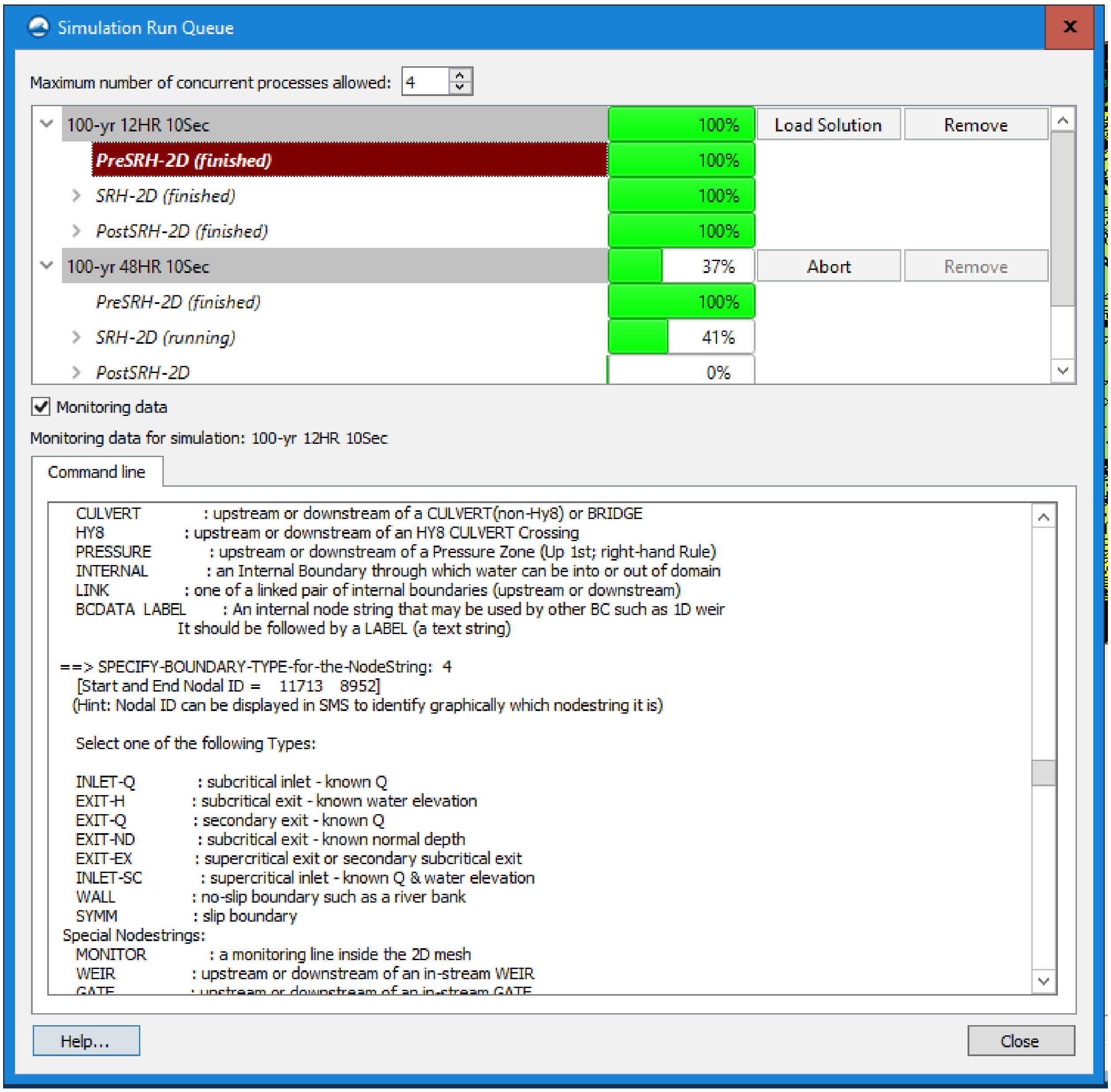
2. The model is now ready to save and run. Right click on the simulation and select Save Project, Simulation and Run.



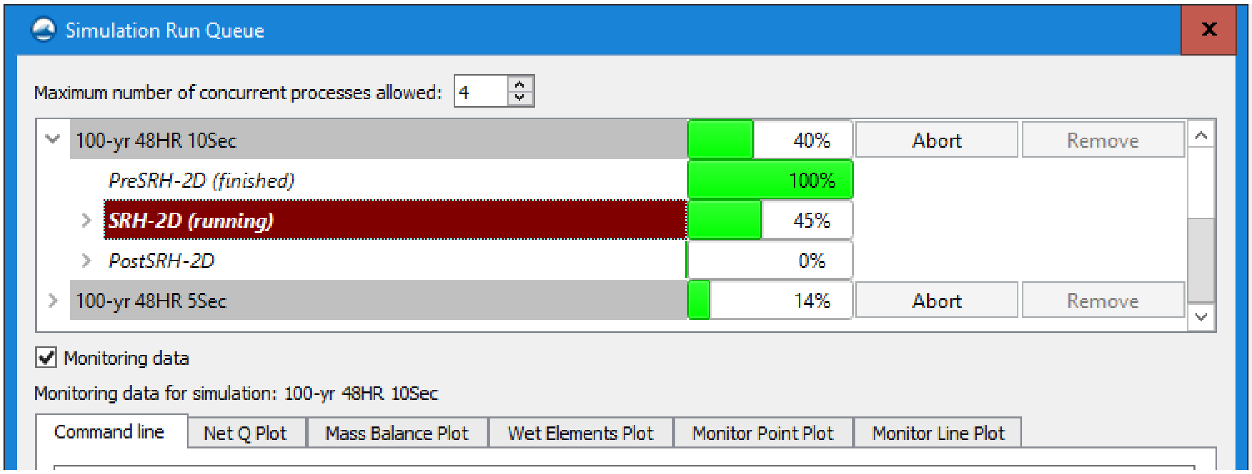
Note: This will save the SMS project file, the simulation file, and run the model. Alternatively, the modeler can select save simulation and run simulation individually. **If any edits are applied to the model control, the simulation must be saved for the edits to take effect when running the model.**

Monitoring the Output

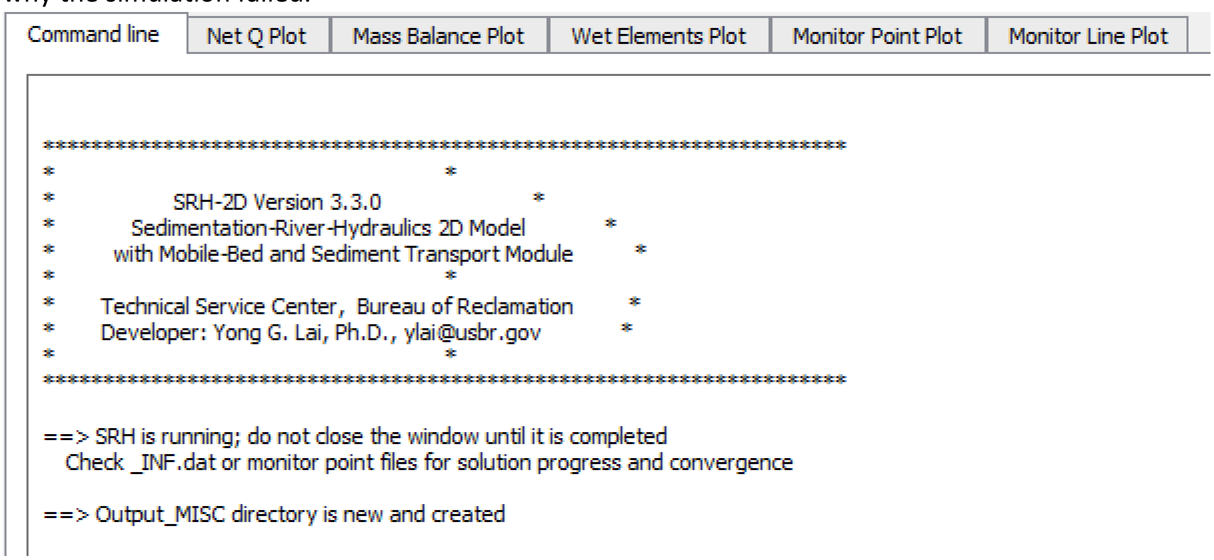
1. Running the model will activate the simulation run queue. The simulation run queue provides live results as solutions are completed. Results are updated at every output frequency specified in the model control. Note: If the modeler closes the simulation run queue the simulations will continue to run in the background if the SMS model is open. To reopen the queue, right click on SRH-2D Simulation and select Simulation Run Queue…
2. Click on PreSRH-2D. The simulation will first run PreSRH-2D. Pre-SRH reviews the model files generated by saving the simulation for any potential errors. Errors will be documented in the Command Line when PreSRH-2D is highlighted.



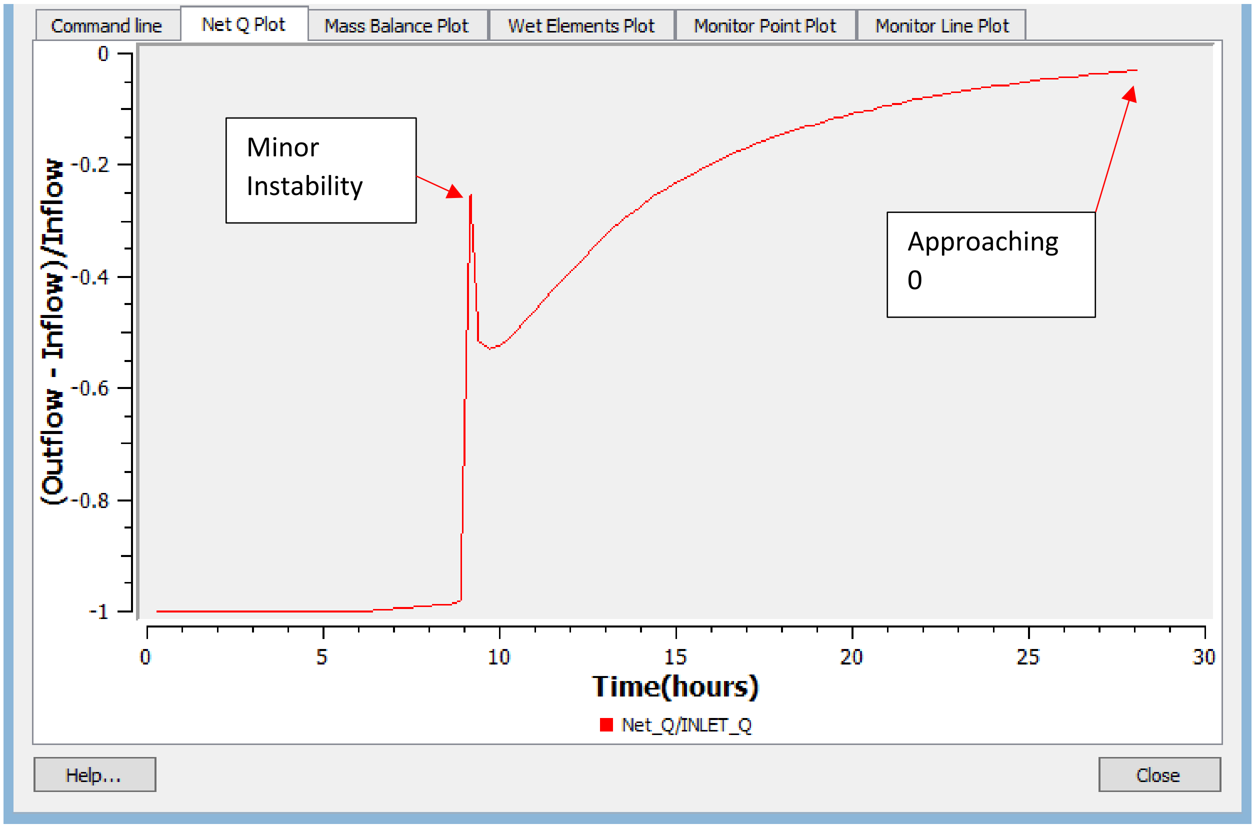
3. Click on SRH-2D. Once PreSRH is completed the model will begin SRH-2D computation. Selecting SRH-2D brings up 6 tabs for reviewing live data including the Command line, Net Q Plot, Mass Balance Plot, Wet Elements Plot, Monitor Point Plot, and Monitor Line Plot.



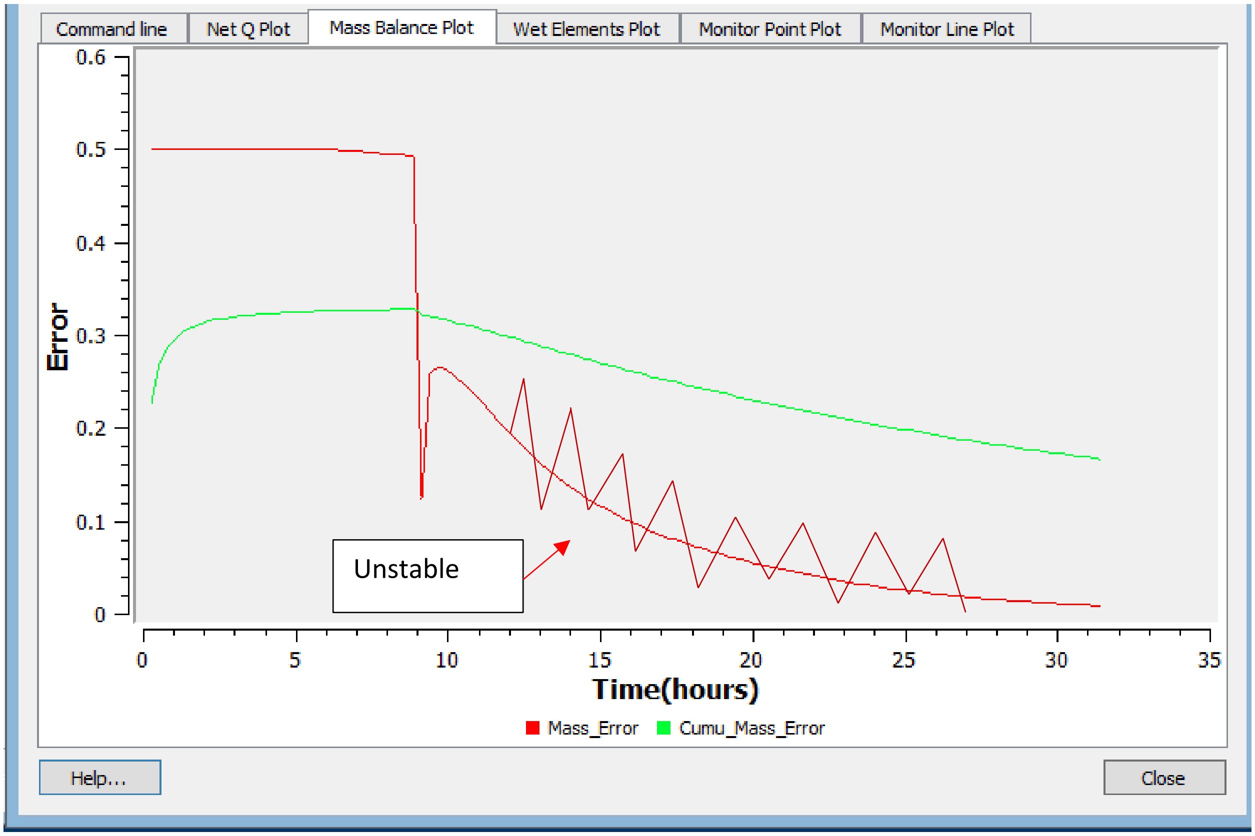
4. Select the Command line tab. The command line provides basic information on the model run. If the solution becomes unstable and fails the command line tab will provide a brief message on why the simulation failed.



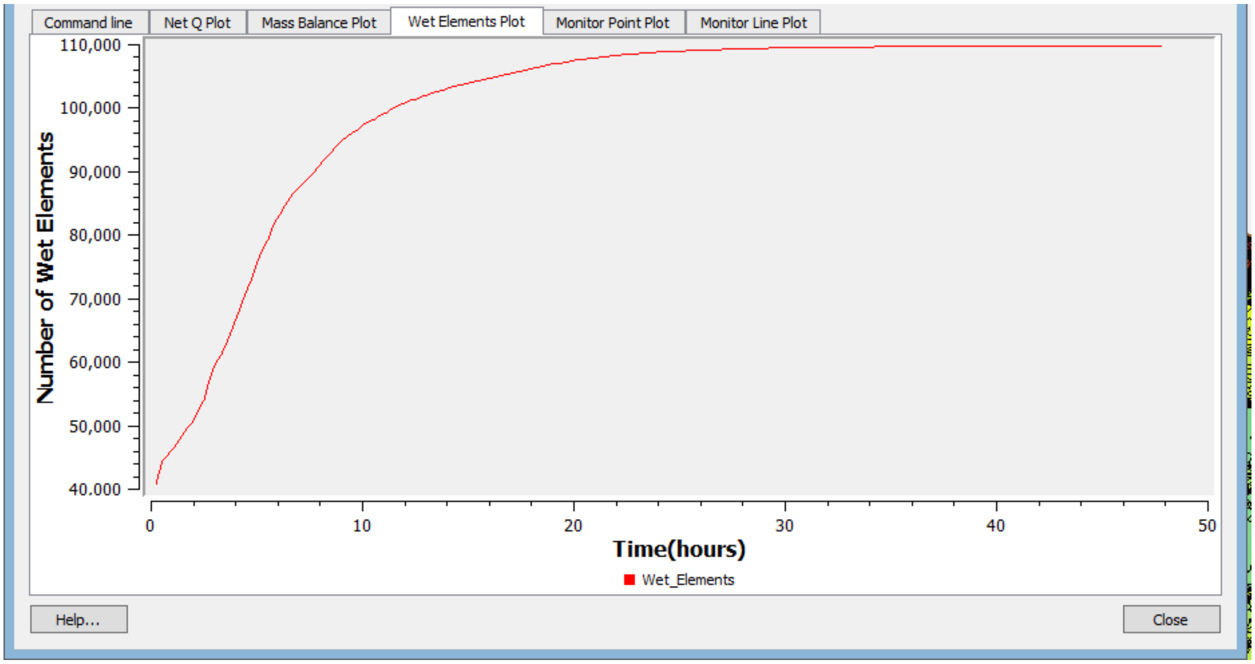
5. Select the Net Q Plot. The Net Q Plot should be reviewed to determine if the model is reaching equilibrium. The Net Q compares (Outflow-Inflow)/Inflow. As the outflow approaches a solution equal to inflow the graph will approach 0. The output line should be flat for multiple timesteps before the modeler can determine that the solution is reaching equilibrium. The Net Q plot can also assist the modeler in determining if the model is stable. If the solution varies drastically from timestep to timestep or the solution oscillates between high and low values the modeler should consider reducing the timestep in the model control or improving mesh quality.



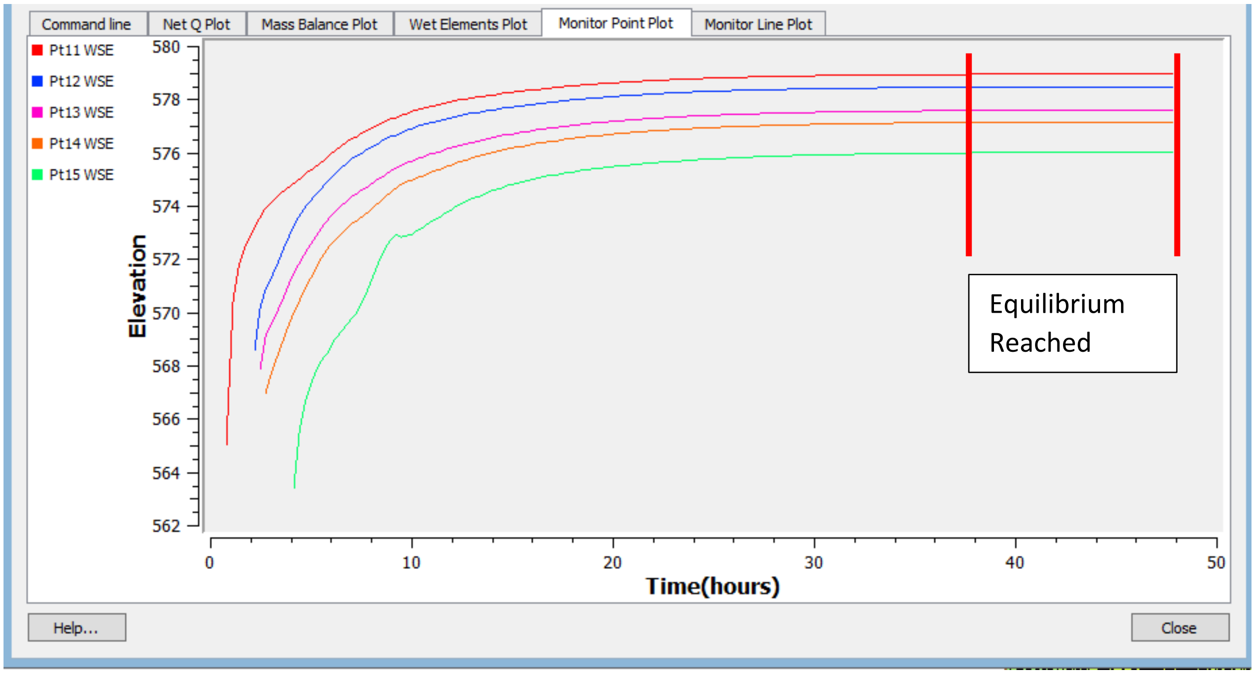
6. Select the mass balance plot. The mass balance plot is primarily used to determine if the model is unstable. If the solution varies drastically from timestep to timestep or the solution oscillates between high and low values the modeler should consider reducing the timestep in the model control or improving mesh quality.



7. Click the Wet Elements Plot. The wet elements plot displays how many of the model elements are in contact with water. The wet elements plots can also be used to help determine a model's stability and proximity to equilibrium. If the number of wet elements does not change over several timesteps it can be inferred that the solution is reaching equilibrium. Similar to the previous plots if the solution varies drastically from timestep to timestep or the solution oscillates between high and low values the modeler should consider reducing the timestep in the model control or improving mesh quality.



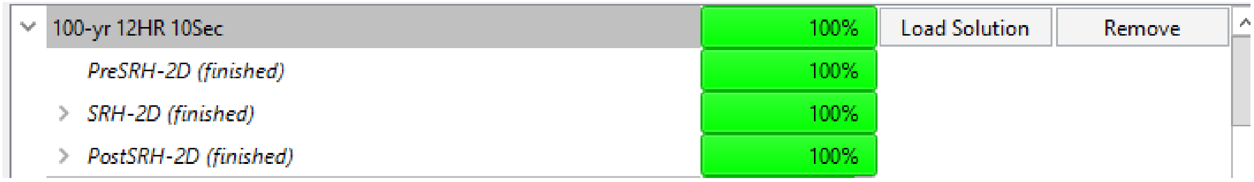
8. Click on the Monitor Point Plot. The monitor point plot provides water surface elevation at the monitor point locations in the model domain. The monitor point plot can be used to review equilibrium and model stability. If water surface elevations at each monitor point do not change over several timesteps it can be inferred that the solution is reaching equilibrium. Similar to the previous plots if the solution varies drastically from timestep to timestep or the solution oscillates between high and low values the modeler should consider reducing the timestep in the model control or improving mesh quality.



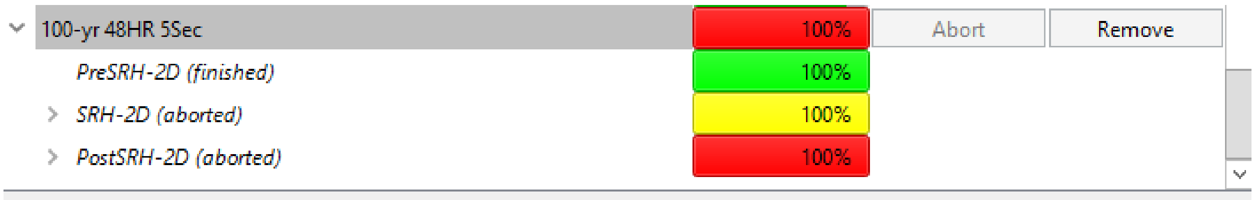
9. Click on the Monitor Line tab. The monitor line tab reports discharges at each monitor line placed in the model domain. The monitor line output can be used similar to the monitor point plot for reviewing equilibrium and stability.

Completed or Unstable Solution

1. Once a solution is complete select load solution to load the output into SMS.



2. If the solution appears unstable the user may select Abort while the simulation is running to cancel the simulation and restart with modified model controls. After selecting Abort the progress bar will highlight red and the option to remove the solution will become available. Make sure to Remove the solution. If remove is not selected the modeler will not be able to save the simulation once the model control is modified.

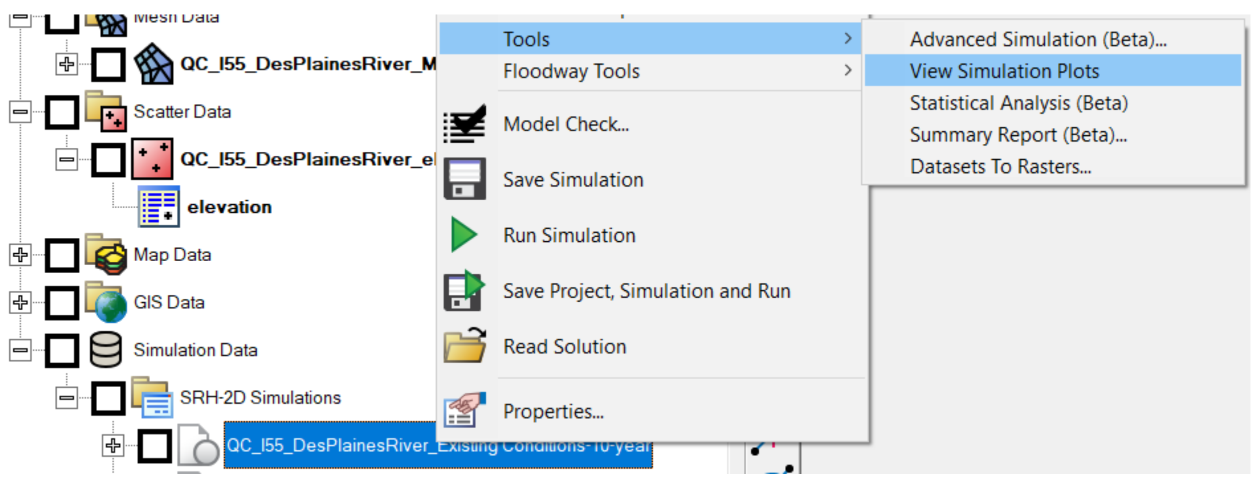


3. If the simulation does not appear to have reached equilibrium the user can modify the model control to lengthen the simulation and rerun.

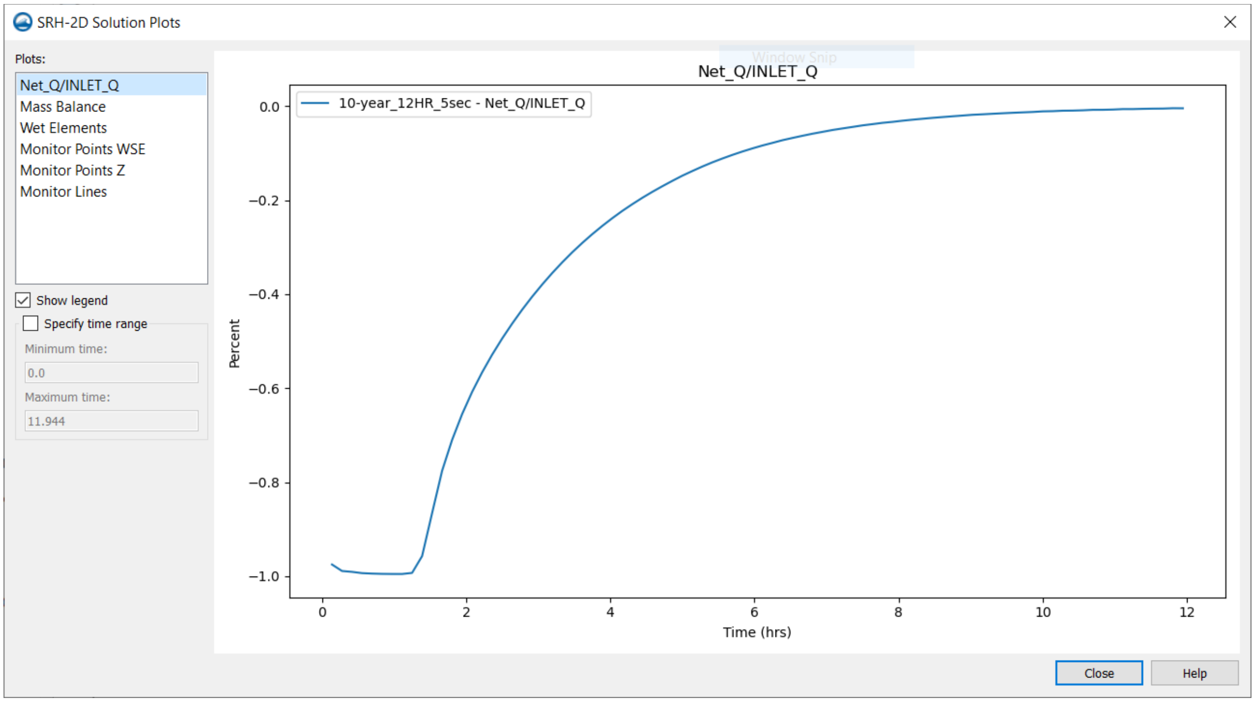
Note: Running a Simulation without changing either the Simulation Name or Case Name will overwrite the previous solution.

Adding Simulation Plots to the Quick Check Report

1. A screen capture of the Net Q, Mass Balance, Wet Elements, Monitor Points, and Monitor Lines Plots should be included in the Quick Check Report. To access the plots after the simulation has been run, right click on the simulation and select Tools → View Simulation Plots.



2. A window will pop up showing the various SRH-2D Solution Plots. Click on each type of plot shown in the top left corner of the window, one at a time, and create a separate screen capture for each plot to include in the report.



APPENDIX G – DOCUMENTATION

1. Sample completed Quick Check Report
2. Sample plot of flow direction and magnitude versus water surface elevation
3. Sample plot of flow direction and magnitude versus depth
4. SRH-2D Solution Plots

Date: 6/25/2021
County: Clark
Route: US 40
Watercourse: North Branch Embarras River
ESN: 012-0018 Structure Type: ☒ Bridge ☐ Culvert
Drainage Area: 88.2 Sq. Mi. (56,448 acres)

Hydrology Method (check all that apply):
☐FIS ☒StreamStats ☐HEC-HMS ☐TR-20 ☐Rational Method ☐Other:

Discharges/ Flows

Y	2	5	10	25	50	100	200	500	
Analyzed	☐	☐	☒	☐	☒	☒	☒	☒	☐
BC ID: 1	3,320	5,960	7,910	10,500	12,600	14,600	16,825	19,800	
BC ID:									
BC ID:									
BC ID:									

Source of Topography/ Surface Data (check all that apply):
☒SMS ☐LiDAR ☐Bathymetry ☐Cross Sections ☐Text File ☐LandXML

Mesh Generator Coverage:
Mesh Name: Mesh Generator Mesh
Mesh Type: ☒Paving ☐Patching
Vertices Spacing: Max: 50 ft.; Min: 50 ft.
Mesh Density (Elements/ Acre): 37,321 / 923 = 40.43

Monitor Lines & Points Coverage:
Number of Monitor Lines: 6 Number of Monitor Points: 0

Materials Coverage:
Manning's "n" Value used: 0.06

Boundary Conditions Coverage:
Number of BC Arcs: 2

BC ID: 1	Type:	☒Inlet-Q	☐Exit-H	Location: N
BC ID: 2	Type:	☐Inlet-Q	☒Exit-H	Location: S
BC ID:	Type:	☐Inlet-Q	☐Exit-H	Location:
BC ID:	Type:	☐Inlet-Q	☐Exit-H	Location:
BC ID:	Type:	☐Inlet-Q	☐Exit-H	Location:

Exit-H Channel Calculator Normal Depth Slope (ft/ft): 0.0005 Source: ☒DEM ☐FIS Profile

Model Control:
Time Step (sec.): 1 Simulations Length (hrs.): 6

Output Method: ☒Specified Frequency ☐Specified Times ☐Simulation End ☐Unsteady Output

Model Convergence:
Time of Convergence at (hrs.): 4

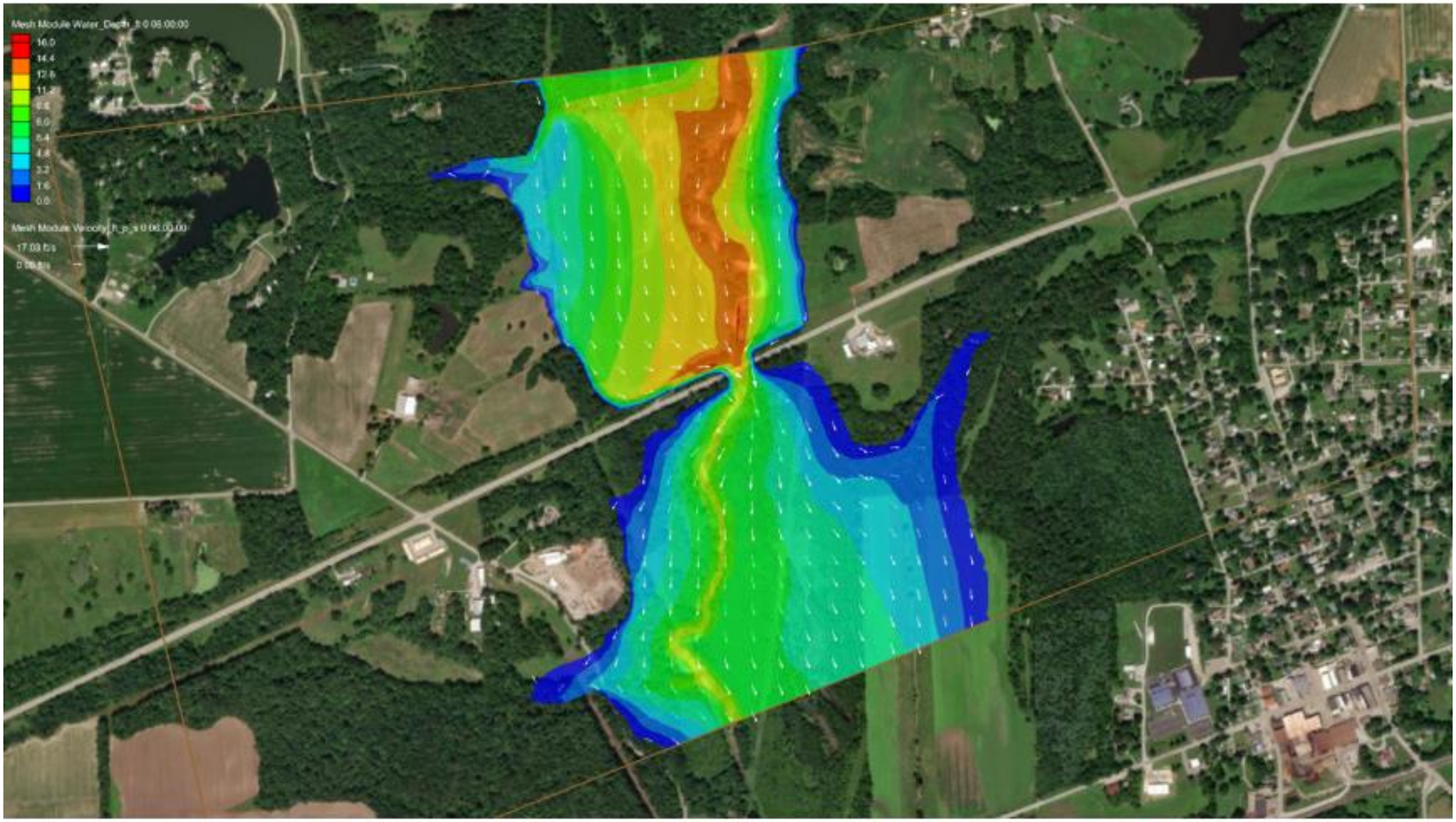
Results:
☒Roadway Overtopping occurs between the >500Y & Y
Ghere Ratio (Mesh Density/ Time of Convergence): 40.43 / 4 = 10

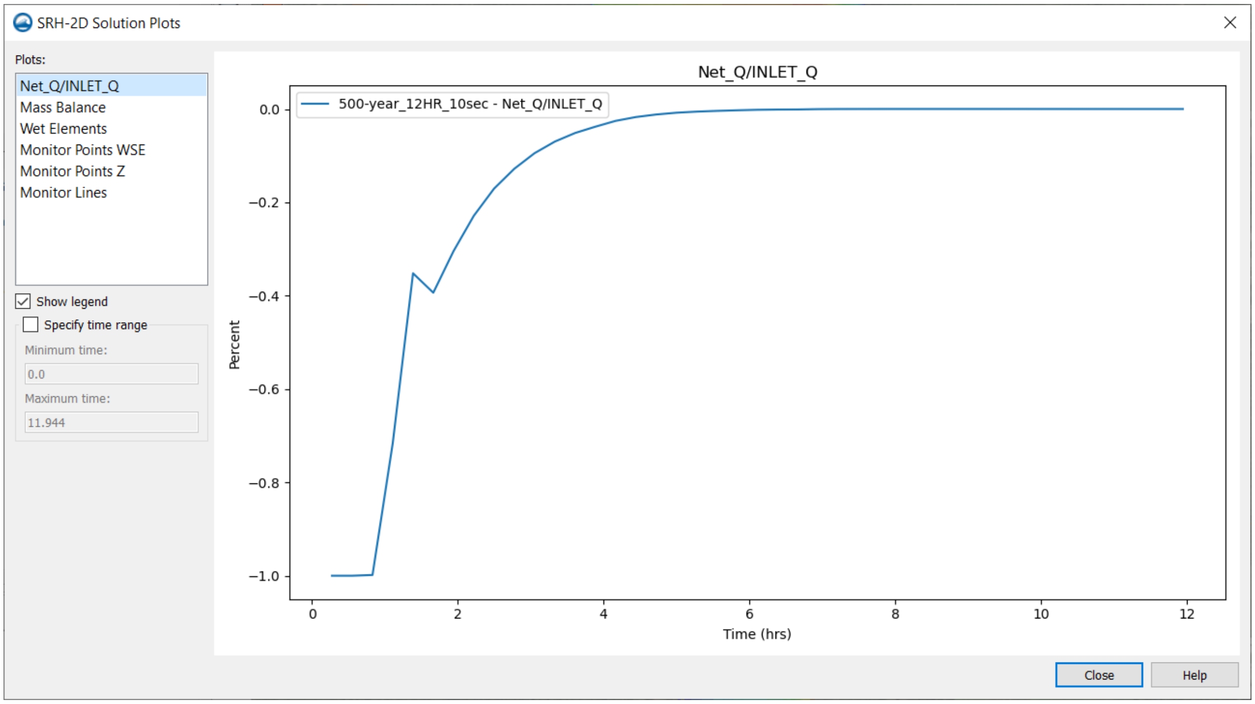
Notes:

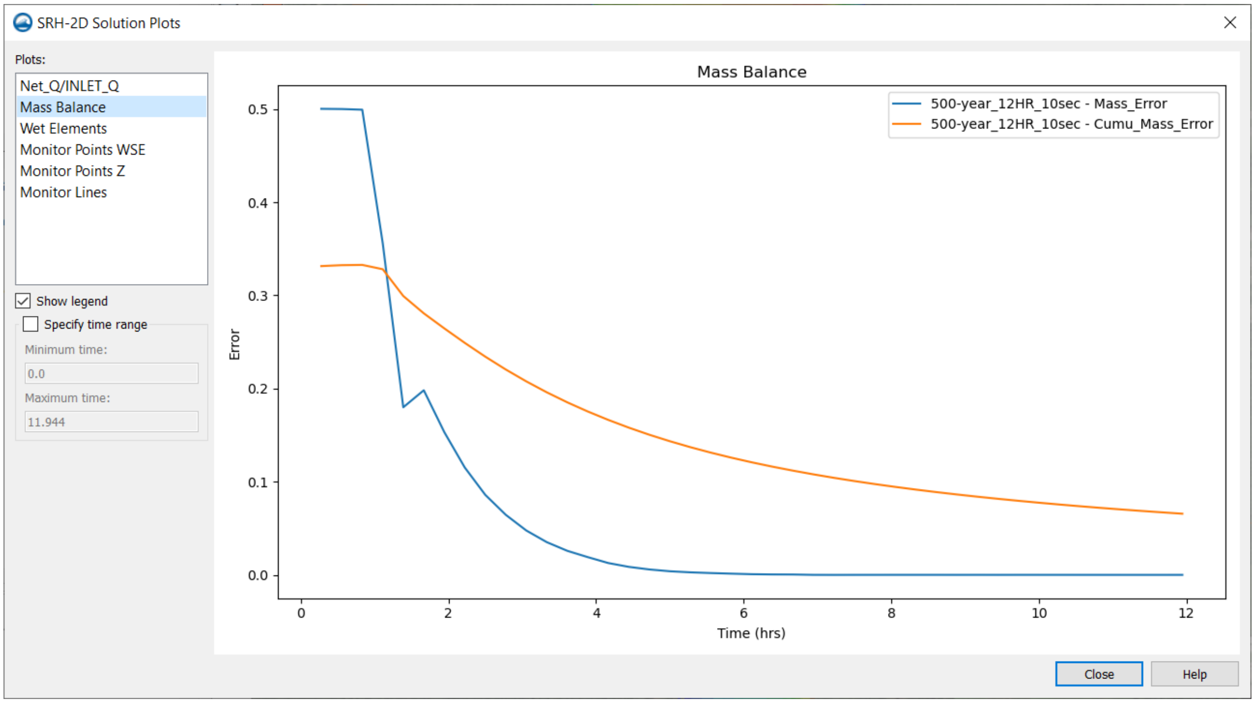
Revised: June 21, 2021

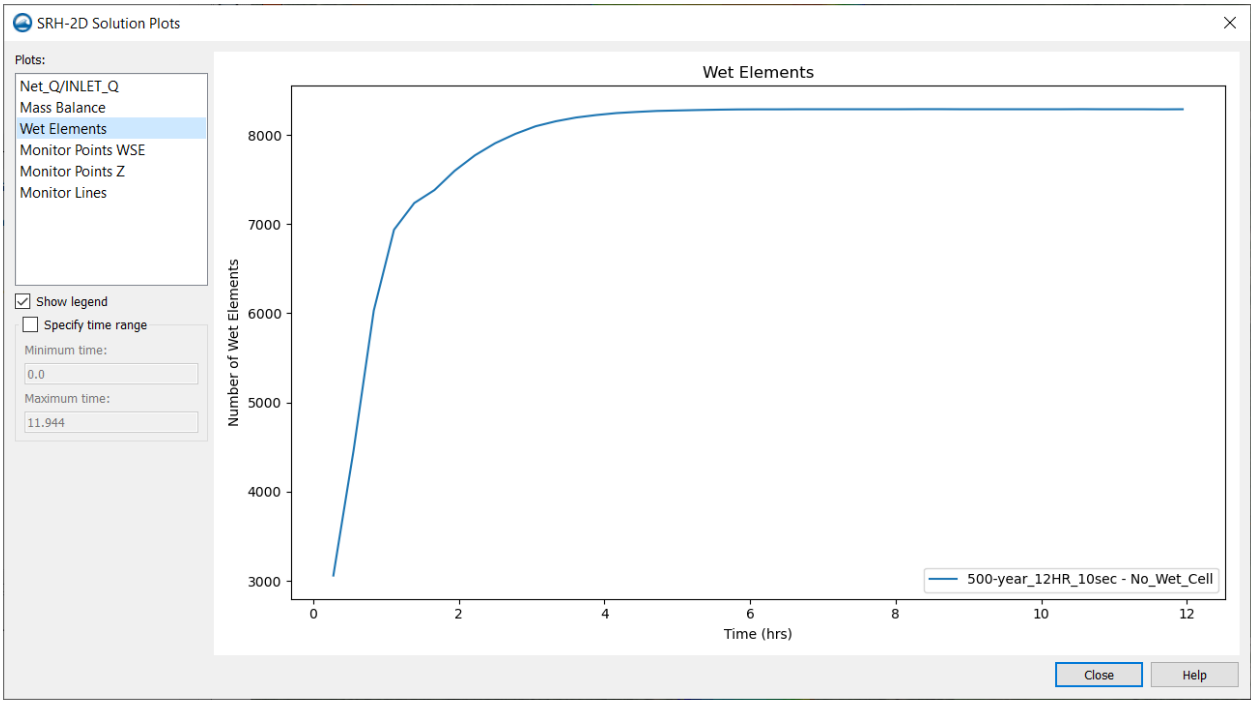
US-40 Over the North Branch Embarras River SMS Quick Check Model
500-Year Storm - Velocity/Elevation Results

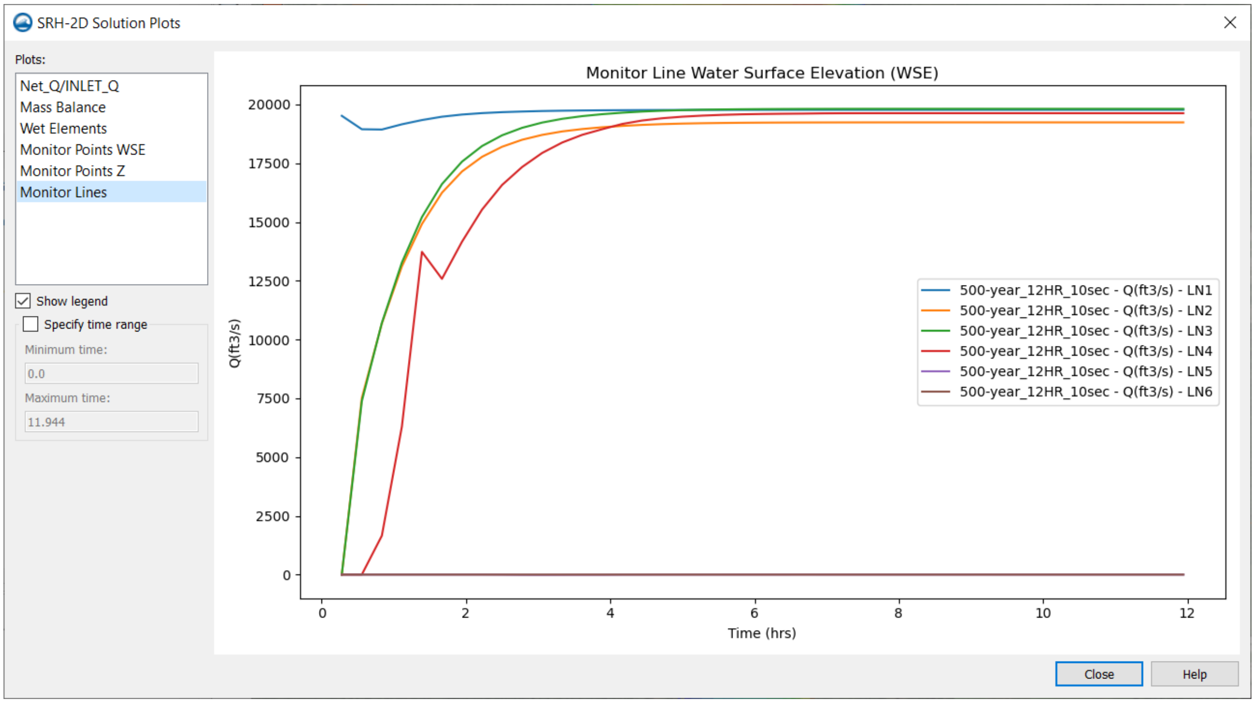
US-40 Over the North Branch Embarras River SMS Quick Check Model
500-Year Storm - Velocity/Depth Results




SRH-2D Solution Plots
Plots:
Net_Q/INLET_Q
Mass Balance
Wet Elements
Monitor Points WSE
Monitor Points Z
Monitor Lines
Show legend
Specify time range
Minimum time:
0.0
Maximum time:
11.944
Net_Q/INLET_Q
500-year_12HR_10sec - Net_Q/INLET_Q
Percent
Time (hrs)
Close
Help


SRH-2D Solution Plots
Plots:
Net_Q/INLET_Q
Mass Balance
Wet Elements
Monitor Points WSE
Monitor Points Z
Monitor Lines
Show legend
Specify time range
Minimum time:
0.0
Maximum time:
11.944
Mass Balance
500-year_12HR_10sec - Mass_Error
500-year_12HR_10sec - Cumu_Mass_Error
Error
Time (hrs)
Close
Help


SRH-2D Solution Plots
Plots:
Net_Q/INLET_Q
Mass Balance
Wet Elements
Monitor Points WSE
Monitor Points Z
Monitor Lines
Show legend
Specify time range
Minimum time:
0.0
Maximum time:
11.944
Wet Elements
Number of Wet Elements
Time (hrs)
500-year_12HR_10sec - No_Wet_Cell
Close
Help


SRH-2D Solution Plots
Plots:
Net_Q/INLET_Q
Mass Balance
Wet Elements
Monitor Points WSE
Monitor Points Z
Monitor Lines
Show legend
Specify time range
Minimum time:
0.0
Maximum time:
11.944
Monitor Line Water Surface Elevation (WSE)
Q(ft3/s)
Time (hrs)
500-year_12HR_10sec - Q(ft3/s) - LN1
500-year_12HR_10sec - Q(ft3/s) - LN2
500-year_12HR_10sec - Q(ft3/s) - LN3
500-year_12HR_10sec - Q(ft3/s) - LN4
500-year_12HR_10sec - Q(ft3/s) - LN5
500-year_12HR_10sec - Q(ft3/s) - LN6
Close
Help

APPENDIX H – SUMMARY OF SMS & SRH-2D TUTORIALS & GUIDES

Introduction

The resources available to the 2D modeling community have grown just as quickly as the interest in 2D hydraulic modeling. Technical reports, manuals, training videos, webinars, tutorials, informational webpages, blogs, and forums are all available to new and experienced users. The main provider of much of this content is the SMS software developer, Aquaveo. Aquaveo has its roots in engineering and computer software research and is development partners with the U.S. Department of Transportation's Federal Highway Administration (FHWA) for SRH-2D. But there are also other providers such as the U.S. Bureau of Reclamation (USBR) and IDOT.

As part of the Quick Check Guidebook, a list of websites and technical resources has been compiled which is intended to serve as a resource for users. This list is not intended to be comprehensive. However, most of these sites and resources are updated on a recurring basis and should serve as a technical resource for users as they become more and more familiar with SMS and SRH-2D.

1. U.S. Bureau of Reclamation (USBR) – Technical Service Center
   The USBR developed and maintains SRH-2D in collaboration with the Federal Highway Administration and the Water Resources Agency in Taiwan. The USBR website provides access to the SRH-2D software and technical papers funded by USBR.

   a. Computer Software – Sedimentation and River Hydraulics Group Numerical Models
      The latest version of the SRH-2D software can be found on the USBR Technical Service Center SRH-2D page at:

      https://www.usbr.gov/tsc/techreferences/computer%20software/models/srh2d/index.html

      New releases of SRH-2D are coordinated with the FHWA and the developers of Aquaveo SMS. The SRH-2D software comes pre-downloaded with Aquaveo SMS, and users are not typically required to download SRH-2D directly from the USBR web page.

   b. Manuals
      The USBR SRH-2D page includes links to both the SRH-2D Version 2 and 3 Model User's Manual. The Version 2 User's Manual highlights theories and processes for the SRH-2D surface water component. The Version 3 User's Manual focuses on SRH-2D's sediment transport and scour capabilities.

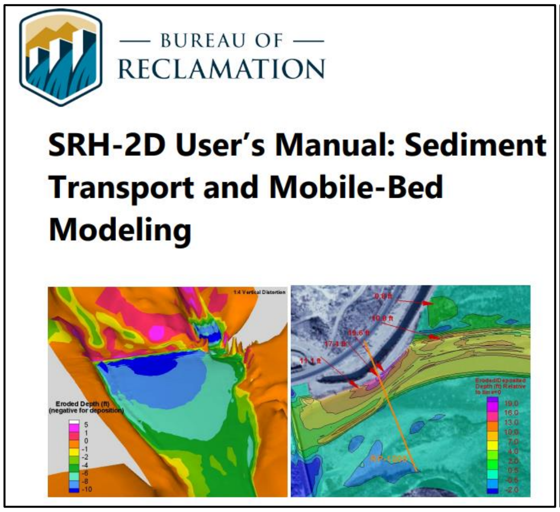
Downloads

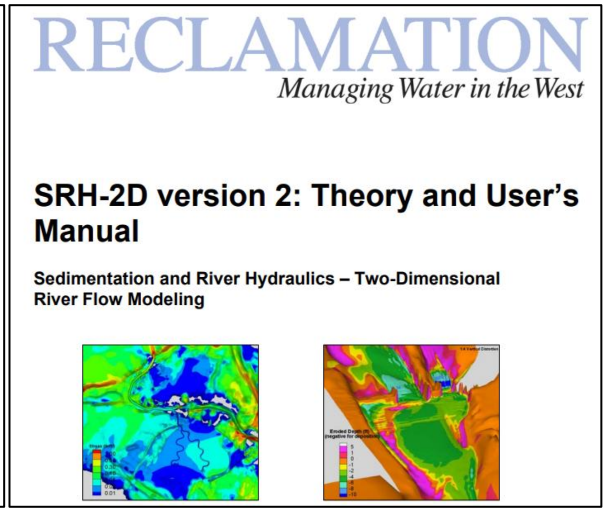
SRH-2D Version 3

- SRH-2D Version 3.3.1 Distribution Package (September 2020) (ZIP 19.4 MB)
- SRH-2D Sediment Transport Modeling User's Manual – Version 3.3 (June 2020) (PDF 5.5 MB)

SRH-2D Version 2

- SRH-2D Version 2.2 Distribution Package (February 2016) (ZIP 66 MB)
- "What's New With SRH-2D Version 2.2?" (August 2012) (DOC 16 KB)
- SRH-2D Version 2 Theory and User's Manual (November 2008) (PDF 2.4 MB)
- SRH-2D Version 2 Distribution Package (2009 [November 2008]) (ZIP 3.5 MB)
- Papers/Presentations:
  - Lai, Yong G. 2009. *Two-Dimensional Depth-Averaged Flow Modeling with an Unstructured Hybrid Mesh.* Paper/Presentation. (PDF 424 KB)
  - Lai, Yong G. 2007. *2D Flow Modeling With SRH-2D.* MS PowerPoint Training Presentation (PDF 9.9 MB)





c. Technical Reports

The USBR SRH-2D page also includes links to technical papers provided by Dr. Yong Lai.

Downloads

SRH-2D Version 3

- SRH-2D Version 3.3.1 Distribution Package (September 2020) (ZIP 19.4 MB)
- SRH-2D Sediment Transport Modeling User's Manual – Version 3.3 (June 2020) (PDF 5.5 MB)

SRH-2D Version 2

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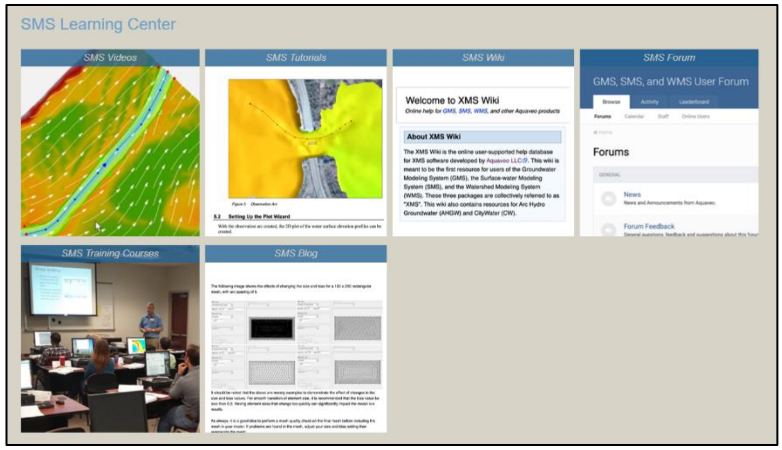
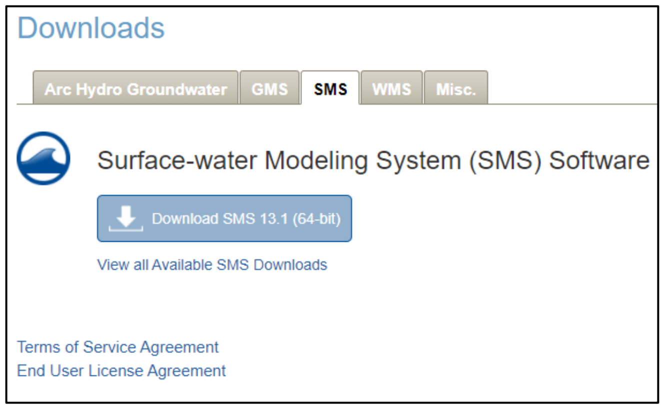
- Papers/Presentations:
  - Lai, Yong G. 2009. *Two-Dimensional Depth-Averaged Flow Modeling with an Unstructured Hybrid Mesh.* Paper/Presentation. (PDF 424 KB)
  - Lai, Yong G. 2007. *2D Flow Modeling With SRH-2D.* MS PowerPoint Training Presentation (PDF 9.9 MB)

2. Aquaveo SMS Learning Center
   The SMS Learning Center website provides a comprehensive list of links to training courses, a user's blog, a forum including a page for DOT employees to ask questions, a link to the SMS Wiki online manual, tutorials, and videos. The main learning center page can be accessed at:

   https://www.aquaveo.com/software/sms-learning



   a. SMS w/SRH-2D download
      The most recent version of SMS can be downloaded at https://www.aquaveo.com/downloads/sms. The download includes the SRH-2D program files and support files needed to run SRH-2D including the most up to date version of HY-8.



      Users can download past versions of SMS or Beta versions of future releases by clicking on "View all available SMS Downloads" or by following the link https://aquaveo.com/downloads-sms

General

Video	Description	Length	Watch
SMS: Flow Trace and Drogue Plot Animations	SMS supports creating animated videos that can be used to present a model's data outside of SMS. This video demonstrates flow trace and drogue plot animations, two methods for visualizing flow fields.	02:10	
SMS: Mesh Generation Using Scalar Paving Density	Demonstration of generating a finite element mesh for the ADCIRC model using the scalar paving density.	08:58	
SMS: Data Visualization with a Functional Surface	How to visualize data with a functional surface in SMS.	03:30	
SMS: Printing and Exporting	How to perform screen captures and export to Google Earth	02:37	
SMS: Creating Profile Plots	How to use the observation tools to create profile plots in SMS.	02:41	
SMS: Visualization Tools Introduction	SMS includes numerous tools and options for visualizing geometric and other quantitative data. This video demonstrates some of the features associated with contours, vectors, animations, and texture mapping.	08:05	
SMS: Export to Google Earth	SMS offers a wide array of options for exporting project data for use in other programs. This video shows how to export the contents of the SMS graphics window as a raster, vector, and transient data animation for use in Google Earth.	05:55	
SMS: Annotations Module	Surfacewater Modeling System (SMS) v10.1 New Feature Spotlight: The Annotations Module. Insert logos, text, shapes, North Arrows, and scale bars into a project.	07:30	

SMS Downloads

SMS Current Release

Software Title	Build Date	File Size
SMS 13.1.15 (64-bit) | Release Notes	11Nov21	634MB
SMS Tutorials	07Dec21	3.7GB

SMS Beta Release

Software Title	Build Date	File Size
There is currently no SMS Beta release.	-	-

Older SMS Versions

Software Title	Build Date	File Size
SMS 13.0.14 (64-bit)	24Jun20	455MB
SMS 12.3.5 (64-bit)	05Dec18	402MB
SMS 12.2.14 (32-bit)	08May18	303MB
SMS 12.2.14 (64-bit)	08May18	350MB
SMS 12.1.11 (32-bit)	14Mar17	273MB
SMS 12.1.11 (64-bit)	14Mar17	325MB
SMS 11.2.16 (32-bit)	03Mar16	305MB
SMS 11.2.16 (64-bit)	03Mar16	344MB

b. SMS Videos

SMS Videos are divided into two primary categories including General and Riverine Modeling. Videos can be accessed from https://www.aquaveo.com/software/sms-learning-videos

i. General SMS

The General SMS videos cover topics such as visualizing data, creating flow traces, and creating profiles.

ii. Riverine Modeling

The Riverine Modeling videos provide summaries of developing models for SRH-2D including modeling culverts and bridges, developing boundary conditions, creating materials coverages, and visualizing results.

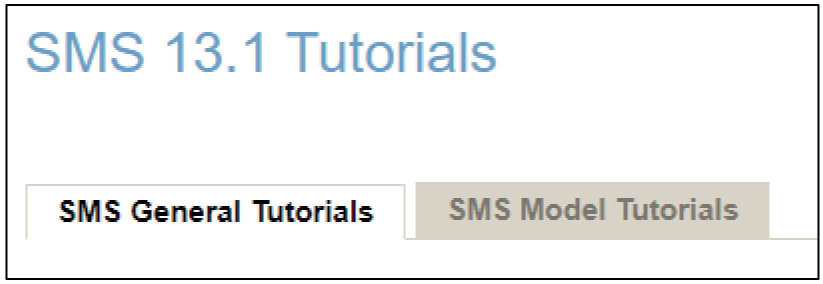
Riverine Modeling

Video	Description	Length	Watch
Modeling Culverts with SRH-2D	This video demonstrates one approach to incorporating a culvert structure into an SRH-2D Model. Additional tutorials and help resources: https://www.aquaveo.com/software/sms-learning	07:04	
Selecting SRH-2D Model Parameters	This video provides guidance for selecting SRH-2D model input parameters such as time step, model duration, initial conditions, and output options.	09:55	
Modeling Bridges in SRH-2D	This video shows how to incorporate a bridge structure into an existing SRH-2D hydraulic model.	09:18	
Importing LIDAR Data	This video demonstrates obtaining, importing, and processing LIDAR data in SMS for building SRH-2D models.	08:45	
Using Summary Tables for SRH-2D Models	This video shows how the Summary Table feature in SMS can be used to compare results from a 2D model with a 1D model.	08:14	
Using HEC-RAS Geometry to Create 2D Models	This video demonstrates the process of creating terrain for a 2D model from an existing 1D HEC-RAS Model.	08:15	
SRH-2D Depth Dependent Roughness	This videos shows how to implement depth-dependent roughness on an SRH-2D Model. More information about the Dataset Toolbox and Data Calculation tools can be found in this video: https://youtu.be/LTN9AypHhcs	05:31	
SRH-2D Visualization for Presentation of Results	This video demonstrates some of the available options for visualizing and presenting results from an SRH-2D model.	14:17	
How BC and Materials are Mapped to a Mesh for SRH-2D Models	This video describes the "Snap Preview" feature in SMS, which shows how feature objects are mapped to element edges in an SRH-2D mesh.	04:36	
Application of the SRH-2D Boundary Condition Types	This videos shows how to apply hydraulic boundary conditions to an SRH-2D model.	10:57	
Using the Dataset Toolbox to Evaluate SRH-2D Solutions	This video demonstrates how to use the tools available in the Dataset Toolbox to review and evaluate SRH-2D solution data. Additional Resources: www.fhwa.dot.gov/engineering/hydraulics/ www.xmswiki.com/wiki/SMS:Dataset_Toolbox www.aquaveo.com/software/sms-learning-tutorials	08:42	
SMS: Adding HY-8 Culverts to an SRH-2D Model	Beginning with SMS v12.0, SRH-2D models can include hydraulic structures such as culverts. SMS facilitates a link between SRH and HY-8 for incorporating culverts into an SRH-2D hydrodynamic model simulation.	03:04	
SMS: AdH Interface Introduction	A tutorial on how to build and run a basic AdH model in SMS.	14:54	

c. SMS Tutorials

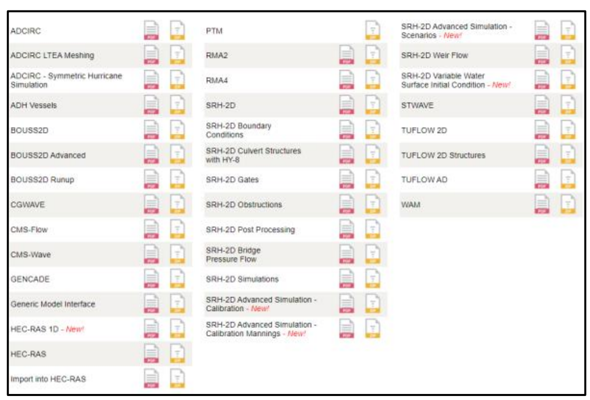
Aquaveo provides detailed step by step tutorials covering both use of the SMS interface and modeling with SRH-2D. The tutorials can be accessed from https://aquaveo.com/software/sms-learning-tutorials.

Each tutorial includes a pdf with the detailed steps and a .zip file with the necessary model files to complete the tutorials. The tutorials are divided into a General and Model Category.



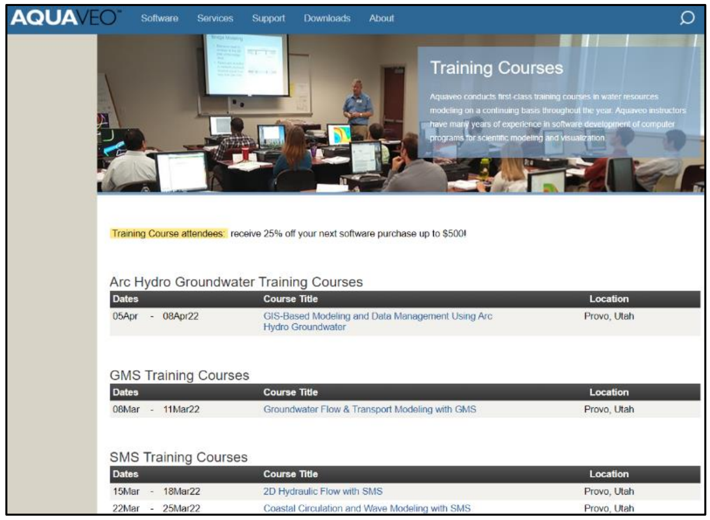
i. SMS General Tutorials
General tutorials focus of the use of the SMS user interface such as using the dataset toolbox, computing bridge scour, delineating floodways, mesh editing and generation, observation coverages, LiDAR, and working with Scatter datasets.

ii. SMS Model Tutorials (SRH-2D)
Model tutorials focus on the available hydraulic computation packages compatible with SMS including SRH-2D and HEC-RAS. SRH-2D tutorials are labeled accordingly and guide the user through creating an SRH-2D model and cover adding more advanced boundary conditions such as HY-8 culverts, gates, and bridge pressure flow.



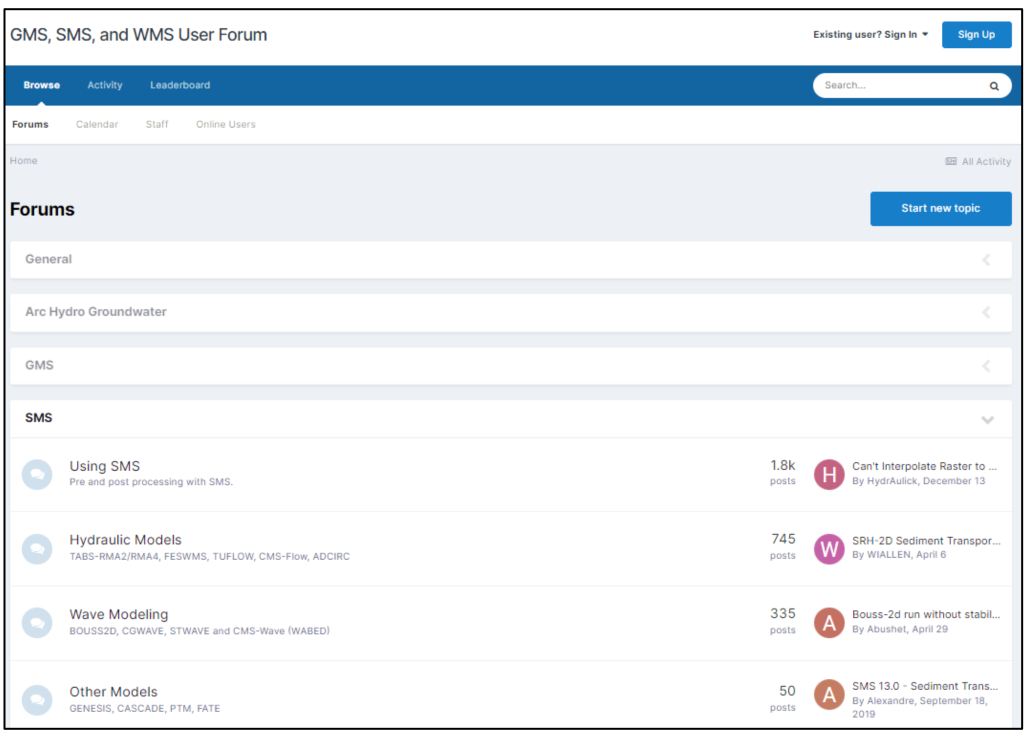
d. Training Courses

Available Aquaveo training courses can be found at https://aquaveo.com/training-courses. Aquaveo training courses cover a variety of compatible hydraulic software's and should be reviewed carefully to determine if they cover SRH-2D. SRH-2D specific courses are frequently provided by NHI and are discussed further in Section 5.

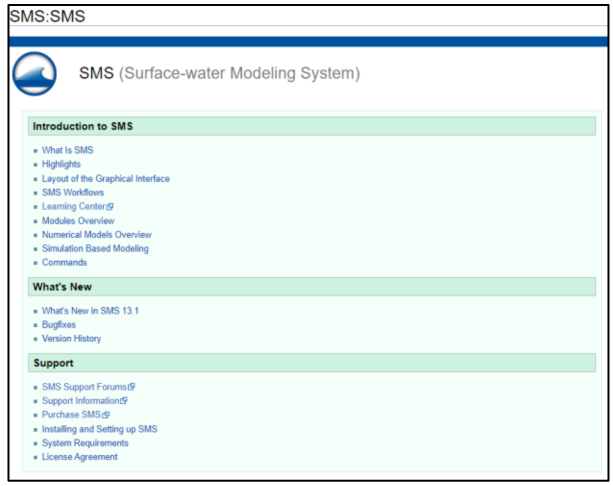


e. SMS Forum

The SMS user's forum provides a location for modelers to collaborate and discuss the SMS platform and hydraulic modeling software. The forum can be accessed from https://forum.aquaveo.com/.

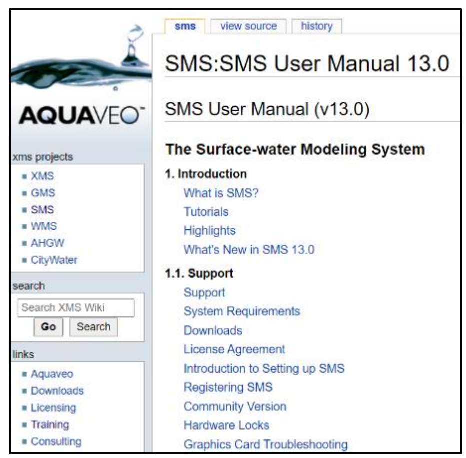


f. Wiki – SMS: SRH-2D
Aquaveo's XMS wiki page provides the most comprehensive source for the SMS User's Manual, Summary of Bug Fixes, and What's New and Version Histories. The SMS page can be accessed from https://www.xmswiki.com/wiki/SMS:SMS.



i. SMS User's Manual
The SMS User's Manual can be accessed from https://www.xmswiki.com/wiki/SMS:SMS_User_Manual_13.0.

This link is specific to the User Manual 13.0 available at the date of guidebook development. New and old versions of the manual can be found by using the search engine for "SMS User Manual".



ii. Workflows

Step by Step workflows for SMS and SRH-2D can be found at https://www.xmswiki.com/wiki/SMS:Workflows_Overview

SMS:Workflows Overview

Below is a list of Workflows for SMS tasks and projects. Each workflow gives basic needed.

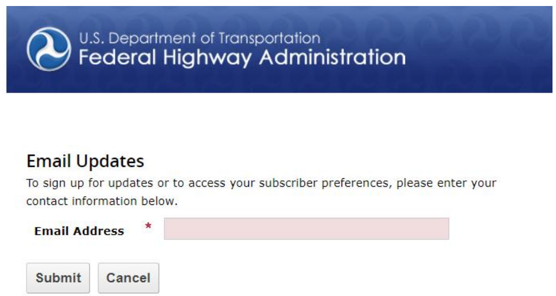
General Workflows	SRH-2D Workflows
3D Bridge	SRH-2D Project
Annotations	SRH-2D Boundary Conditions
Animation	SRH-2D Culvert
Breaklines	SRH-2D Gate
Bridge Scour	SRH-2D Monitor Points
CAD Data	SRH-2D Obstructions
Cartesian Grid Creation	SRH-2D Pressure Flow Bridge
Compute Volumes	SRH-2D Post-Processing
Cross Sections	SRH-2D Sediment Transport
Data Visualization	SRH-2D Simulation
Digitize	SRH-2D Summary Reports
Display Options	Summary Table
Element Patch Workflow	SRH-2D Weir
Export Data	SRH-2D Advanced Simulation Tools

iii. Wiki SMS:SRH-2D

The SRH-2D specific page can be accessed from https://www.xmswiki.com/wiki/SMS:SRH-2D. The SRH-2D home page gives a general overview of SRH-2D and includes additional links for Papers and Presentations.

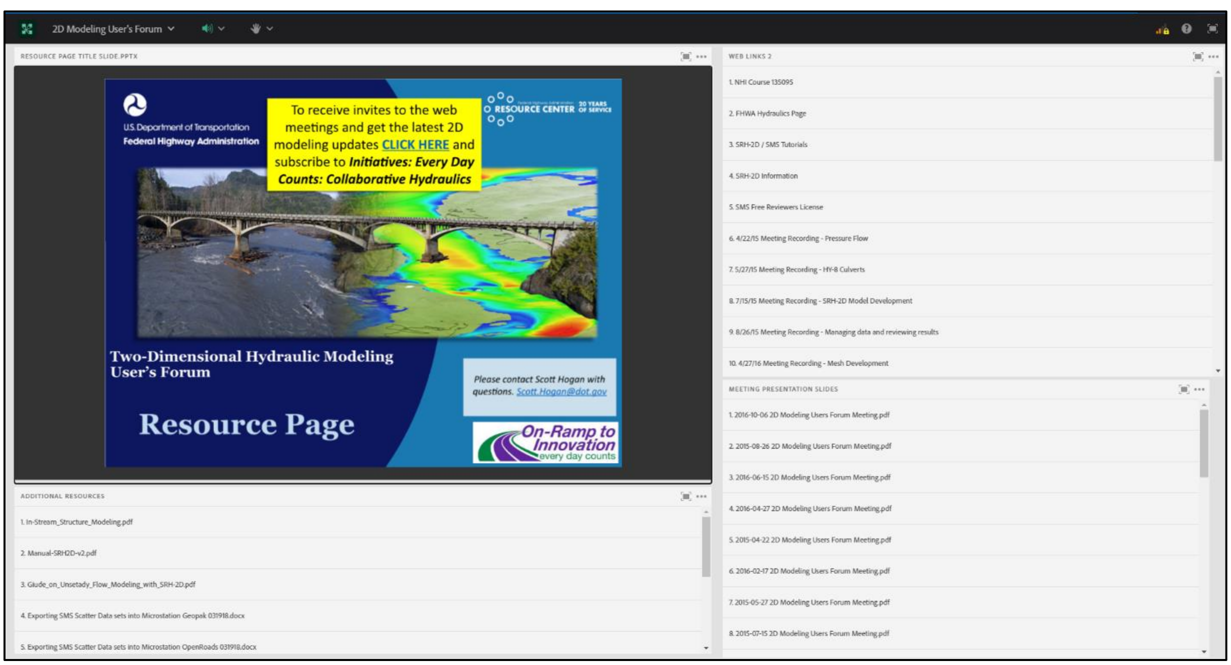
3. FHWA’s 2D Hydraulic Modeling User's Forum
    a. Bi-monthly technical presentations

    The 2D Hydraulics Modeling User’s Forum is sponsored by FHWA Every Day Counts. Bi-monthly presentations cover recent updates to SMS, SRH-2D, and summarize topics requested by the modeling community. A calendar invite and registration for the upcoming Bi-Monthly meeting can be found at https://www.fhwa.dot.gov/innovation/everydaycounts/2d-hydraulic-forum.cfm. Users can sign up for email alerts regarding upcoming User’s Forum webinars at https://public.govdelivery.com/accounts/USDOTFHWA/subscriber/new?topic_id=USDOTFHWA_97.



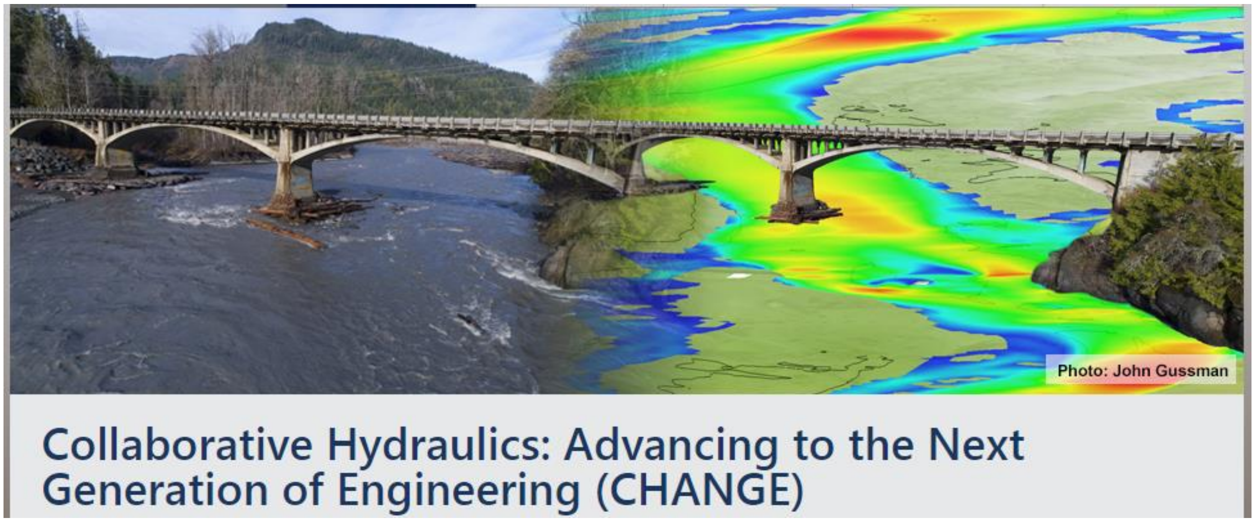
        i. Web Room

        The Web Room for Bi-monthly technical presentations can be accessed at any time and includes download links for past User’s Forum Webinars and additional 2D resources. The web room can be accessed from https://connectdot.connectsolutions.com/modelingusersforum/

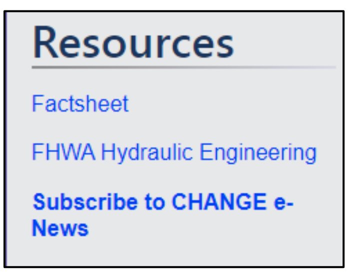


b. Technical guidance and best practices

FHWA provides ongoing technical guidance to DOTs through its Every Day Counts (CHANGE) program. The CHANGE webpage provides links to technical resources and FHWA modeling personnel to promote the continued advancement and application of 2D hydraulic software. The home page can be reached at:
https://www.fhwa.dot.gov/innovation/everydaycounts/edc_5/change2.cfm



The home page provides an option for users to subscribe to email's using the link pictured below.



4. Other Reference Materials
   a. Aquaveo provides SMS Technical Support Staff to answer questions. Representatives can be reached through the online portal at https://www.aquaveo.com/technical-support
   b. DOT/FHWA Licensing Instructions
   The FHWA bridges and structure hydraulics software page provides links to guidance documents supporting SRH-2D. The webpage also provides instruction for DOT staff to receive a no cost full license of the SMS software. The webpage can be reached at https://www.fhwa.dot.gov/engineering/hydraulics/software.cfm

Two-Dimensional Hydraulic Analysis	Surface-Water Modeling System (SMS)* Companion Resources: • DOT/FHWA Licensing Instructions (.pdf, 5 mb) • SRH-2D Modeling Instructions and Guidance • SRH-2D Tutorials (Basic Simulations, Bridge Pressure Flow, Culverts, Weirs, Diversions, etc.) • HDS 7 Hydraulic Design of Safe Bridges	2021	Scott Hogan

   c. National Highway Institute (NHI)
   NHI regularly provides training opportunities for 2D modeling including use of SMS and SRH-2D. A schedule of available training courses can be found at https://www.nhi.fhwa.dot.gov/course-search?tab=0

   d. XMS Wiki Summary of Papers/Presentations/Project Reports
   The Aquaveo XMS Wiki page provides access to technical papers and presentations with a focus on SRH-2D. Links for real world modeling projects using SRH-2D are also included. https://www.xmswiki.com/wiki/SMS:SRH-2D

Papers / Presentations

- SRH-2D Theory Paper
- SRH-2D Training Presentation
- 2006 FISC Paper on Savage Rapids Dam Removal Project "Comparison of Numerical Hydraulic Models Applied To The Removal of Savage Rapids Dam Near Grants Pass, Oregon"
- List of journal articles using SMS by Prof. Greg Pasternack, UC Davis
- Lai, Y. G. (2020). A Two-Dimensional Depth-Averaged Sediment Transport Mobile-Bed Model with Polygonal Meshes. Water, 12(4), 1032.

Project Reports

- Bountry J.A. and Lai, Y.G. (2006)."Numerical modeling of flow hydraulics in support of the Savage Rapids Dam removal."
- Lai, Y.G., Holburn, E.R., and Bauer, T.R. (2006)."Analysis of sediment transport following removal of the Sandy River Delta Dam."
- Lai, Y.G. and Bountry, J.A. (2006). "Numerical hydraulic modeling and assessment in support of Elwha Surface Diversion Project."
- Lai, Y.G. and Bountry, J.A. (2007). "Numerical modeling study of levee setback alternatives for lower Dungeness River, Washington"
- Lai, Y.G. and Greimann, B.P. (2011). "SRH Model Applications and Progress Report on Bank Erosion and Turbidity Current Models"

Additional References

- Launder, B. E., & Spalding, D. B. (1974). "The numerical computation of turbulent flows." *Computer Methods in Applied Mechanics and Engineering*, 3(2), 269-289.
- Seminara, G., Solari, L., & Parker, G. (2002). "Bed load at low Shields stress on arbitrarily sloping beds: Failure of the Bagnold hypothesis." *Water Resources Research*, 38(11).
- Greimann, B., Lai, Y., & Huang, J. (2008). "Two-dimensional total sediment load model equations." *Journal of Hydraulic Engineering*, 134(8), 1142-1146.
- Phillips, B. C., & Sutherland, A. J. (1989). "Spatial lag effects in bed load sediment transport." *Journal of Hydraulic Research*, 27(1), 115-133.
- Van Rijn, L. C. (1984). "Sediment transport, part I: Bed load transport." *Journal of Hydraulic Engineering*, 110(10), 1431-1456.
- Van Rijn, L. C. (1984). "Sediment transport, part II: Suspended load transport." *Journal of Hydraulic Engineering*, 110(10), 1613-1641.

In the News

- News article "Computer Modeling Smoothes a Dam Hard Job"
- Photos related to Wired.com article "Computer Modeling Smoothes a Dam Hard Job"