Build a large 1D/2D XPSWMM Model

Introduction

When working with very large models, the XPSWMM user interface sometimes can suffer from long opening and saving time and can feel unresponsive. To avoid these issues, in this workshop we'll learn the best practices of building large 2D models in XPSWMM.

The key is to reference large datasets from external sources rather than building them into the XPSWMM model database (*.xp) file and using the XPTIN file.

- Reference Landuse polygons for materials (manning's n) and soils (infiltration) from external shapefiles
- Reference DTM from external files (*.asc)
- Divide large background layers into tiles to speed up map rendering

You will learn the best practices through the following exercises,

1. Build a simple 2D model
2. Update manning's n
3. Update soil infiltration parameters
4. Add culverts
5. Add storm sewer system
6. Review results
7. Add 1D river
8. Use Quadtree and SGS

EX1: Build a simple 2D model

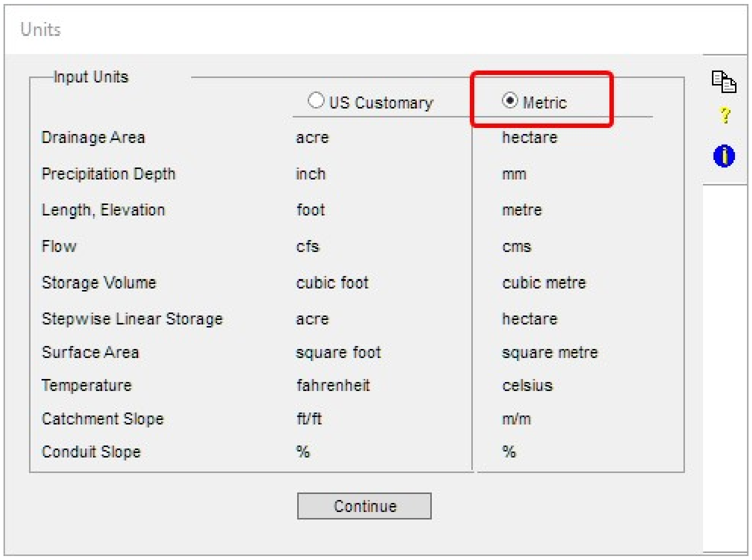
Building a 2D model can be simple, you only need a few things,

- The DTM (digital terrain model)
- A 2D grid
- Inflow boundary (how flow enters the 2D grid)
- Outflow boundary (how water leaves the 2D grid)
- Manning's n for the 2D grid

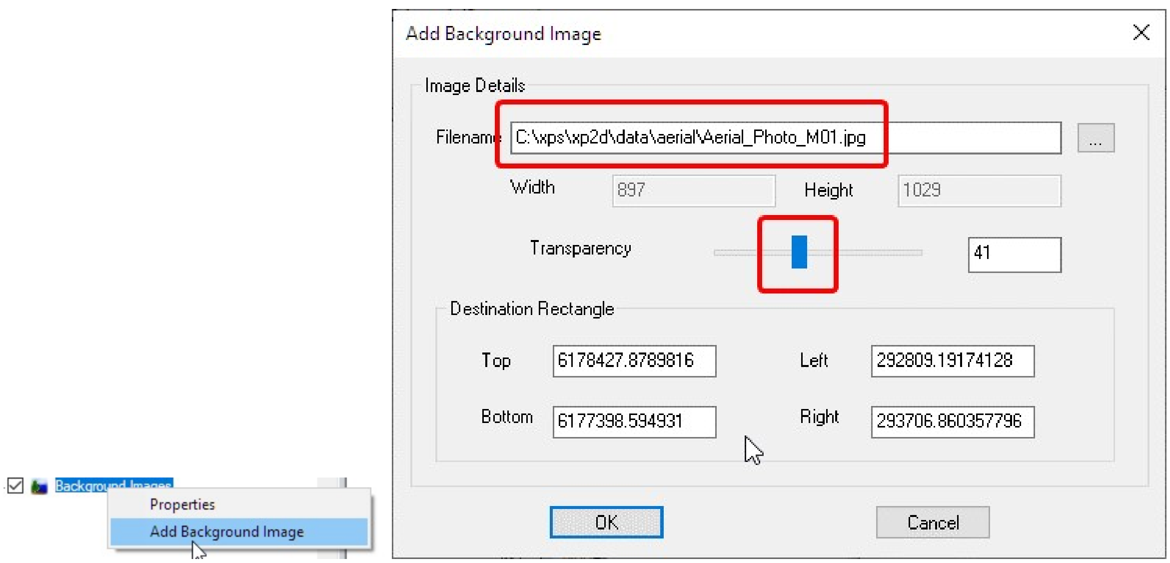
Note: The best practice is to organize all the files used by a model in the same folder, an example is shown below.

- Model.xp : save the model in the root folder
- GIS: GIS files referenced by the model
- Aerial: the aerial images
- DTM: the terrain data

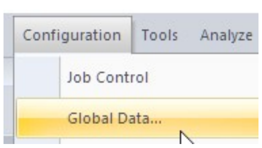
1. Create a new model in the workshop folder **2d model.xp**.

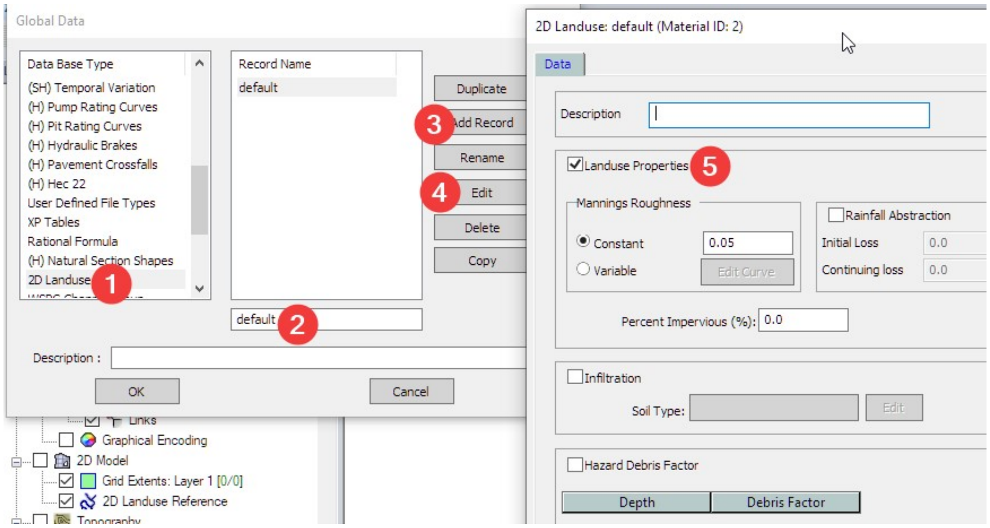


2. Load the background image

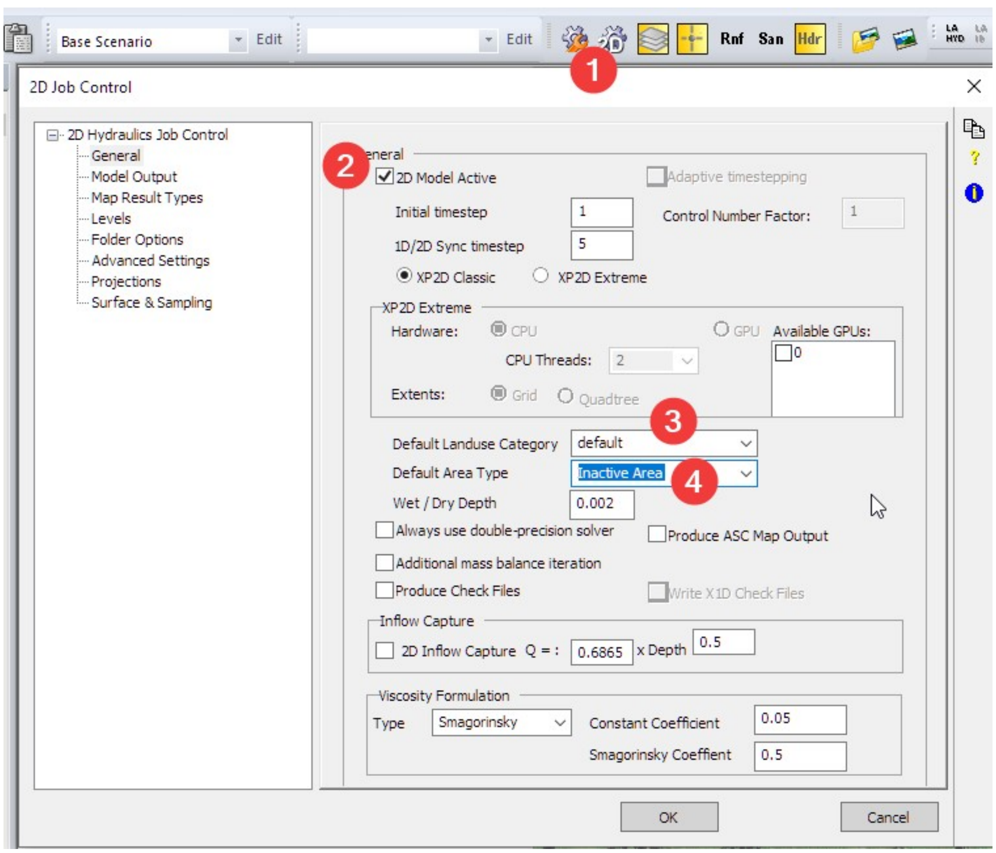


3. Add default landuse. For this simple 2D model, we'll assume the manning's n is 0.05 for the whole area.



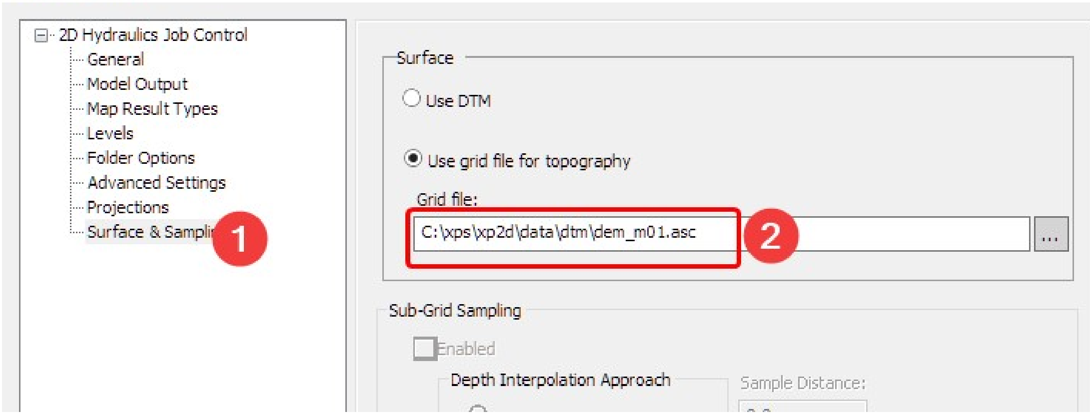


4. Set the 2D setting. (3) set the default manning's, (4) set the default area as inactive, which will not receive flow.

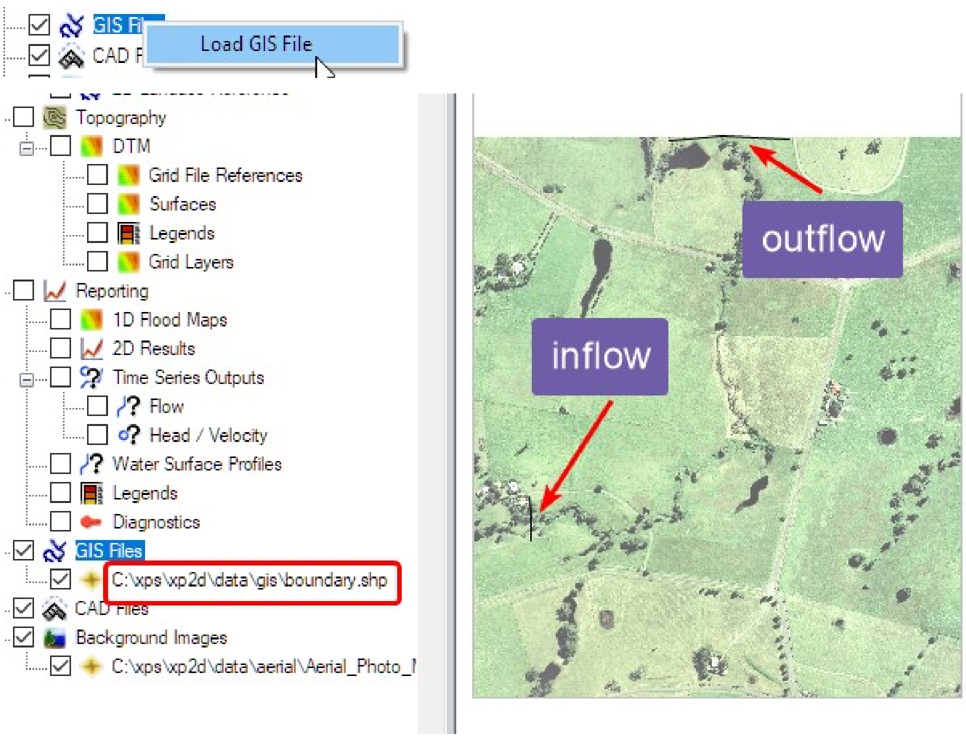


We'll reference the DTM from an external source instead to speed things up.

2D Job Control



5. Load background layers



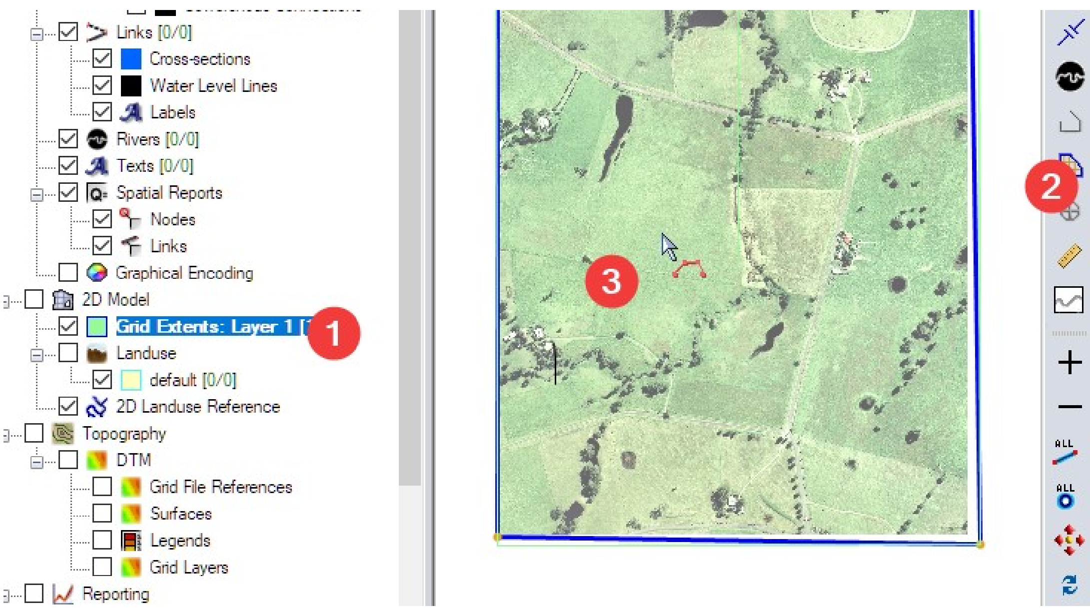
6. Add 2D grid roughly outside the boundaries, and the aerial photo. Set the cell size as 5m with no rotation since the river flows mostly south to north.

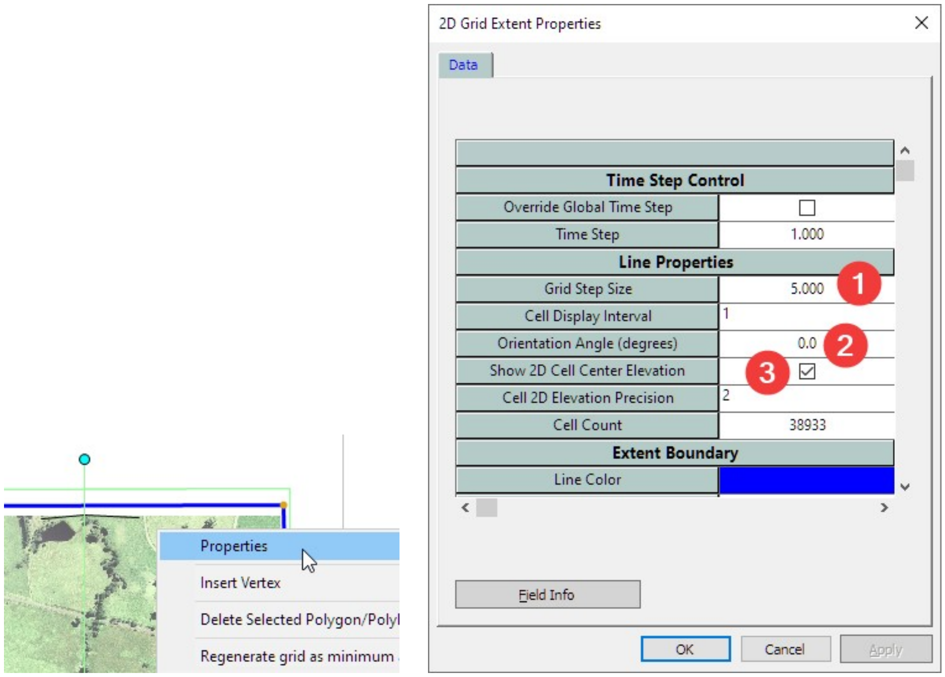
   Notes: The grid should be aligned with the direction of the flow. There are some guidelines on the grid size. For example, the CIWEM has the following recommendations (https://www.ciwem.org/special-interest-groups/urban-drainage-group).

Table 4-7 2D Requirements and parameters

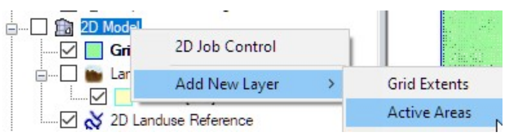
5m2?

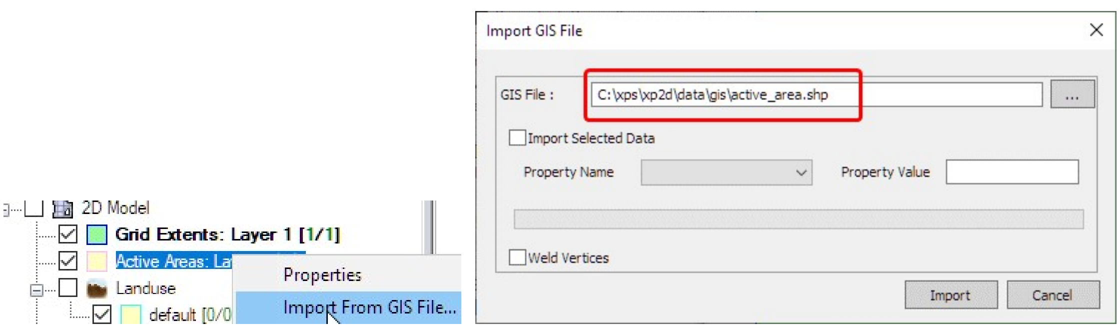
2D zone type		Coarse - Urban	Medium - Urban	Detailed - Urban	Rural
Max Source Data grid resolution		2 m	1 m	1 m	5 m
Element	Max.	250 m²	100 m²	25 m²	250 m²
	Min.	75 m²	25 m²	25 m²	75 m²
Road Element	Max.	No	25 m²	No	No
	Min.		10 m²	2.5 m²	
Lower Road areas		No	150mm	150mm	No
Buildings		>100 m² only	All buildings	All buildings	No
Walls, porous		No	Significant	All	No
Other Structures		No	Significant	All	Significant
Gullies		No	Significant	All	No
Site visit needed		No	Probably	Yes	No
Roughness zones min.		1	1	1	As required



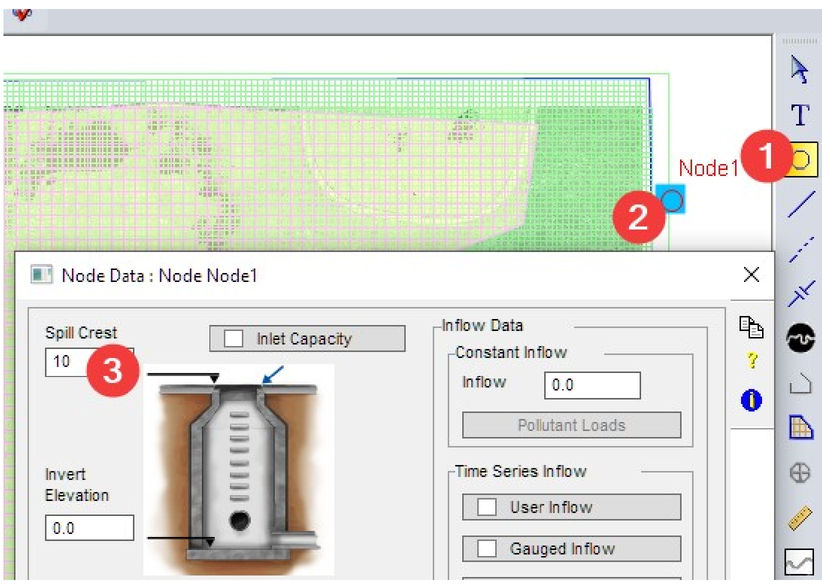


7. Add active area. Since the defaul area is inactive, we need to define the active area. (You can also set the default area as active area and only define inactive areas.)

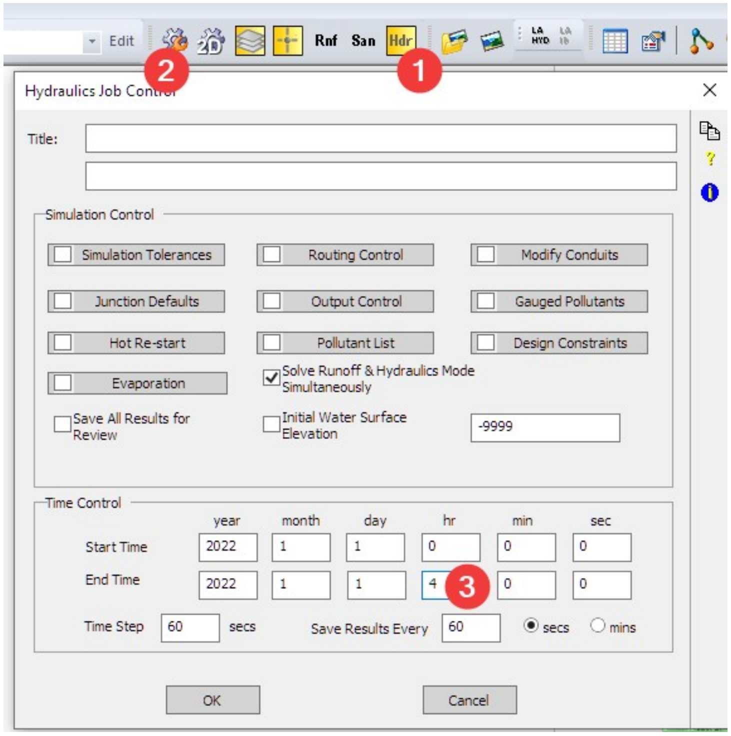




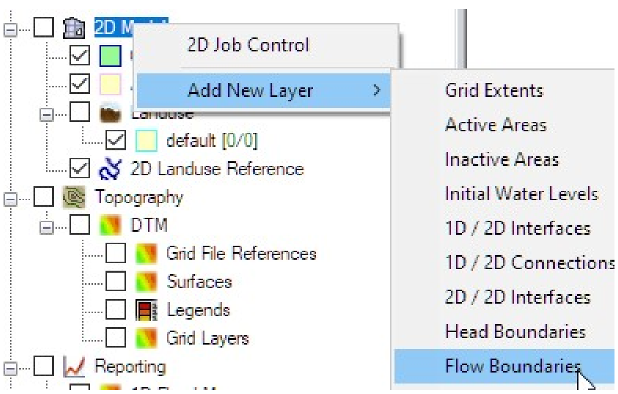
8. Add a dummy 1D node and setup the run time. To run a 2D model in XPSWMM, we need to have at least one node. Create a dummy node.



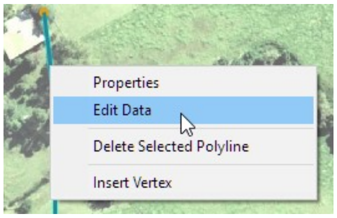
Then we can setup a 4hr simulation.



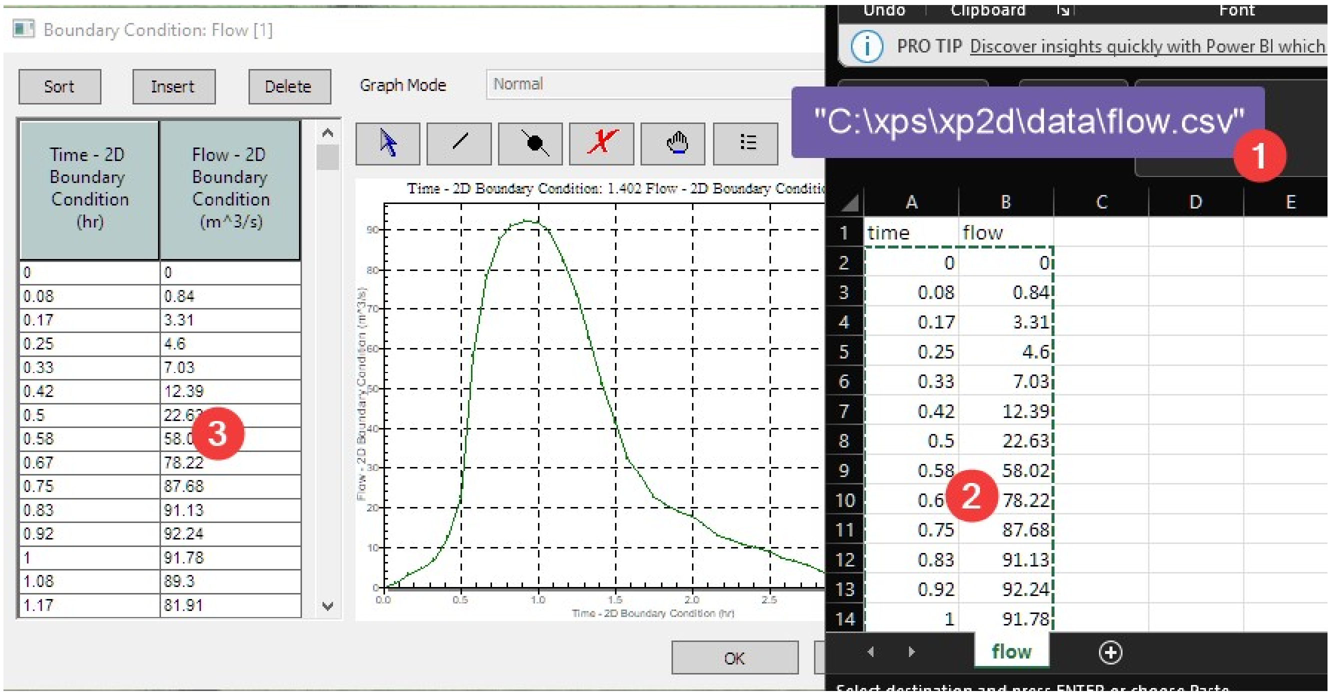
9. Add inflow boundary



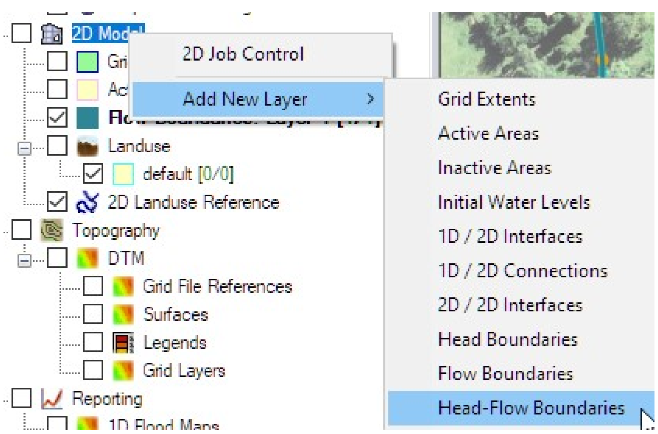
Digitize the inflow boundary



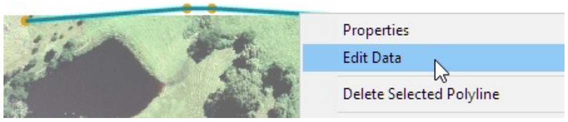
Copy the inflow from flow.csv to the inflow line.

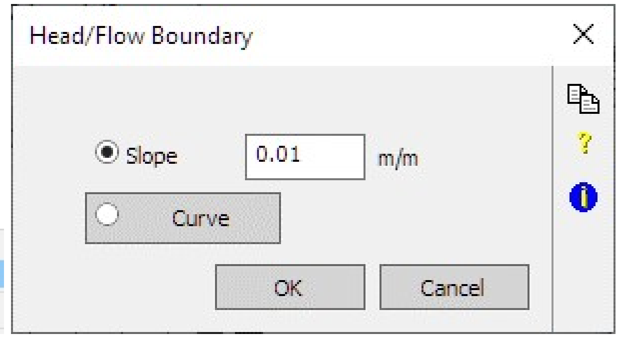


10. Add outflow boundary

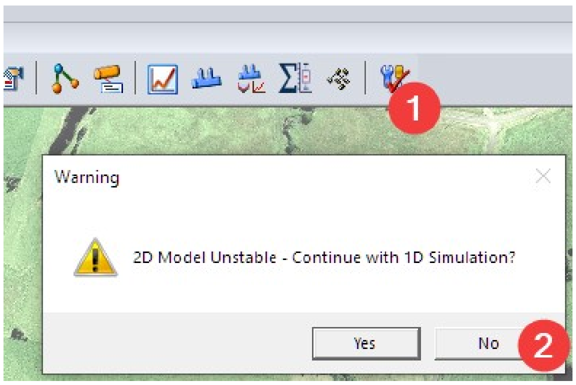


Digitize the outflow boundary, then set a slope.

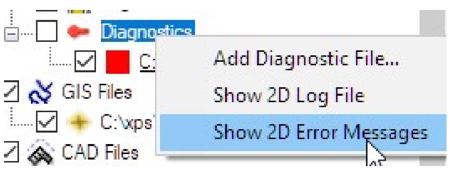


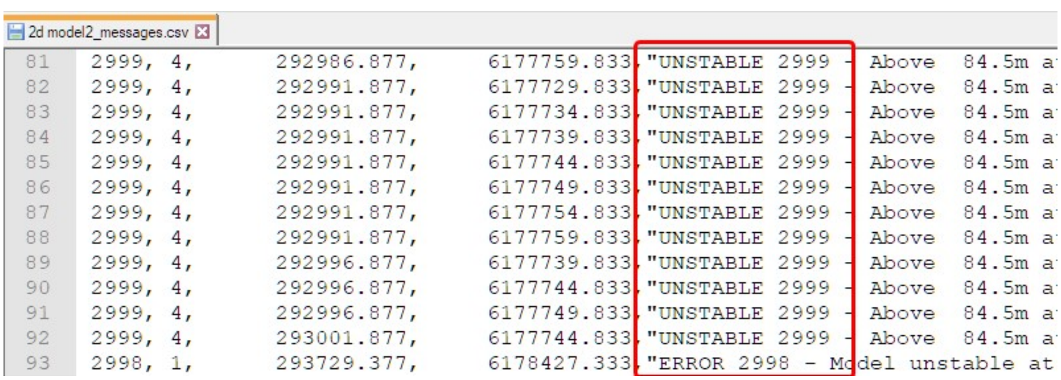


11. Run the model, you will get an error.

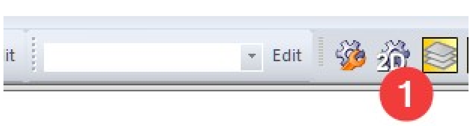


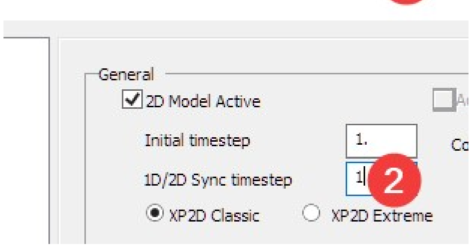
12. Troubleshooting diagnostics.



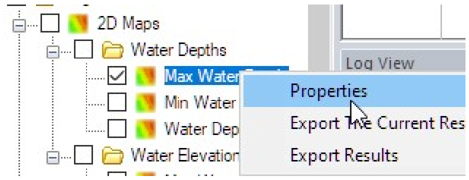


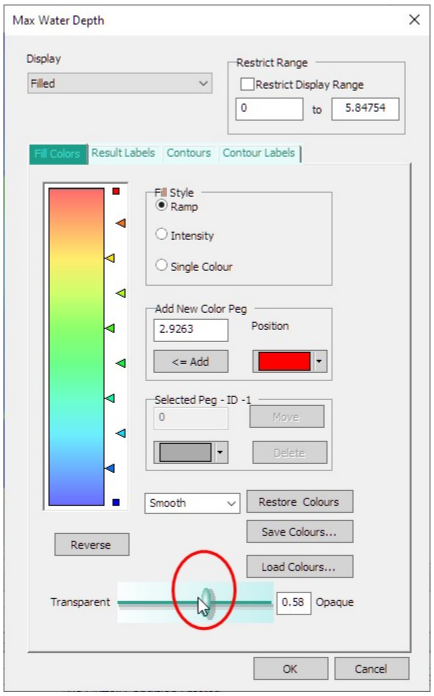
Unstable can usaully be addressed using smaller timesteps.

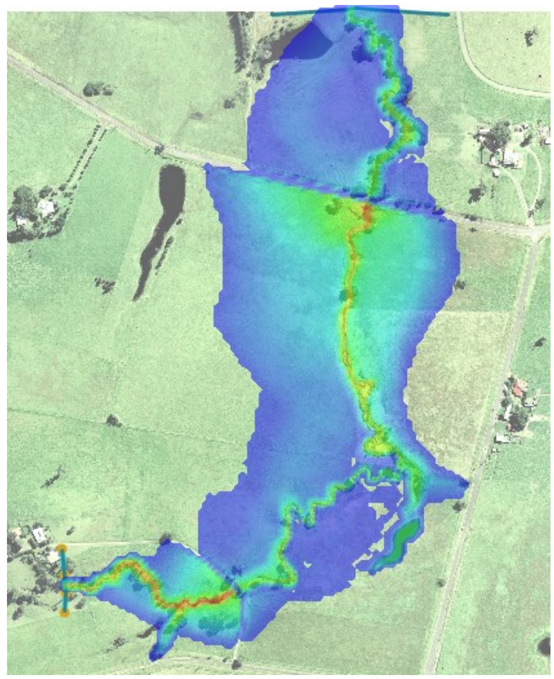




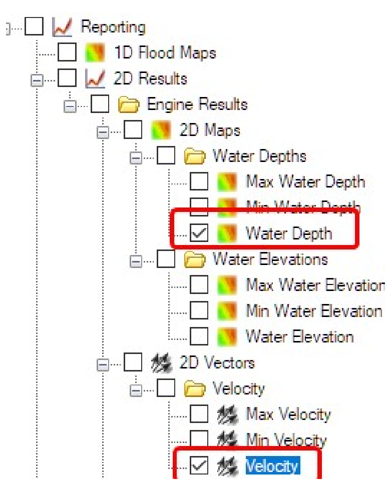
13. Review the max. depth results. This time the model should run, and you can review the modeling results.

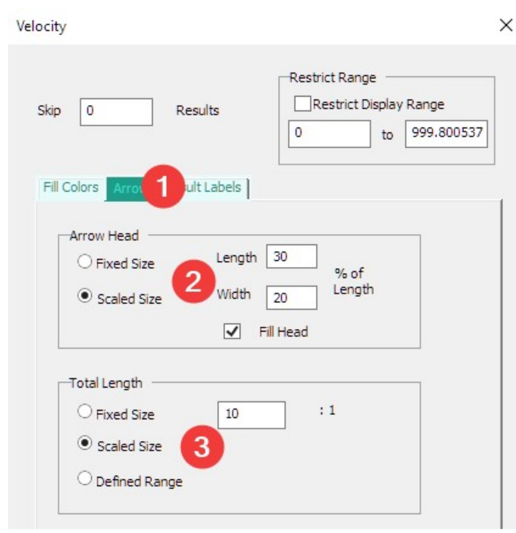


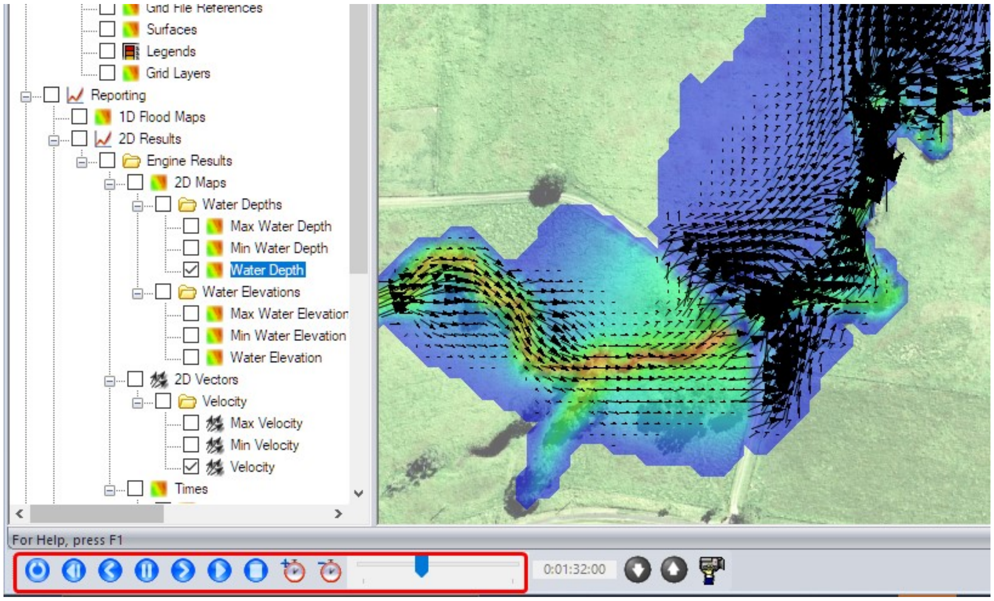




14. Play the animation







EX2: Update manning's n for different landcover

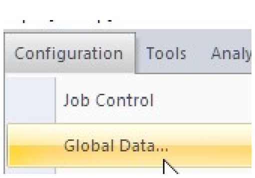
Once we have a rough initial model, we can use the preliminary results to guide our effort refining the models. You only need to add details in areas where there is flooding, adding details to dry cells will not add any value to the model.

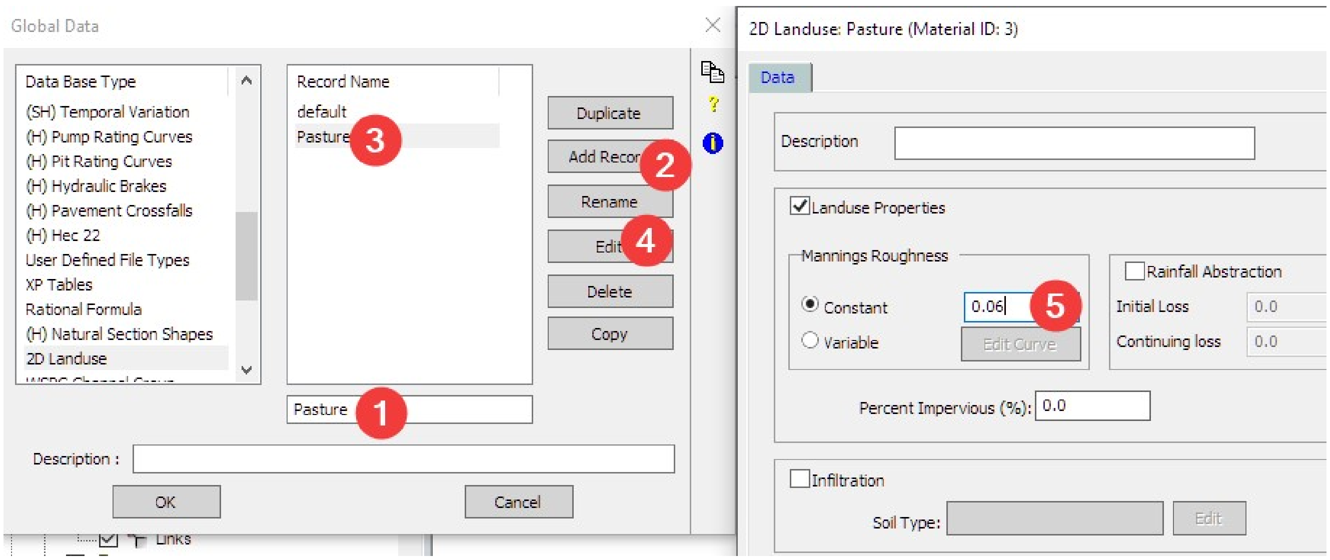
Getting the right manning's n value for the right land cover is important. For urban areas, land cover data are usually managed by regional government agencies. For areas without publicly available data, land cover can be digitized from aerial photos.

For large urban areas, we can have thousands of polygons representing different land covers. Saving these polygons inside the *.xp file can greatly slow down the open and save process of XPSWMM. Therefore, the best practice is to save the land cover polygon layer as a shapfile, and then reference the file to bring in the manning's n values.

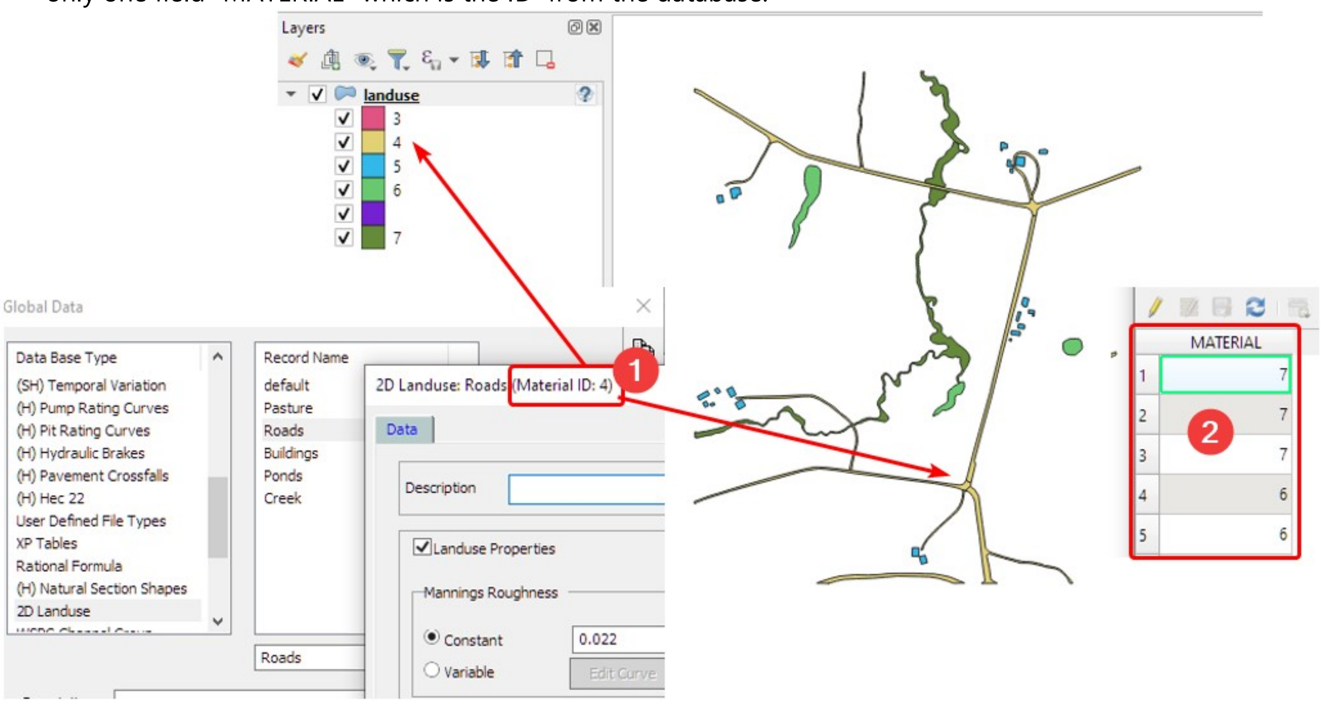
1. Create the landuse entries for manning's n using the table below,

Material I	Manning's n	Infiltratio	Land Use I	! Description
1	0.06			!Pasture
2	0.022			!Roads
3	3			!Buildings
4	0.03			!Ponds and other water
10	0.08			!Vegetated creek

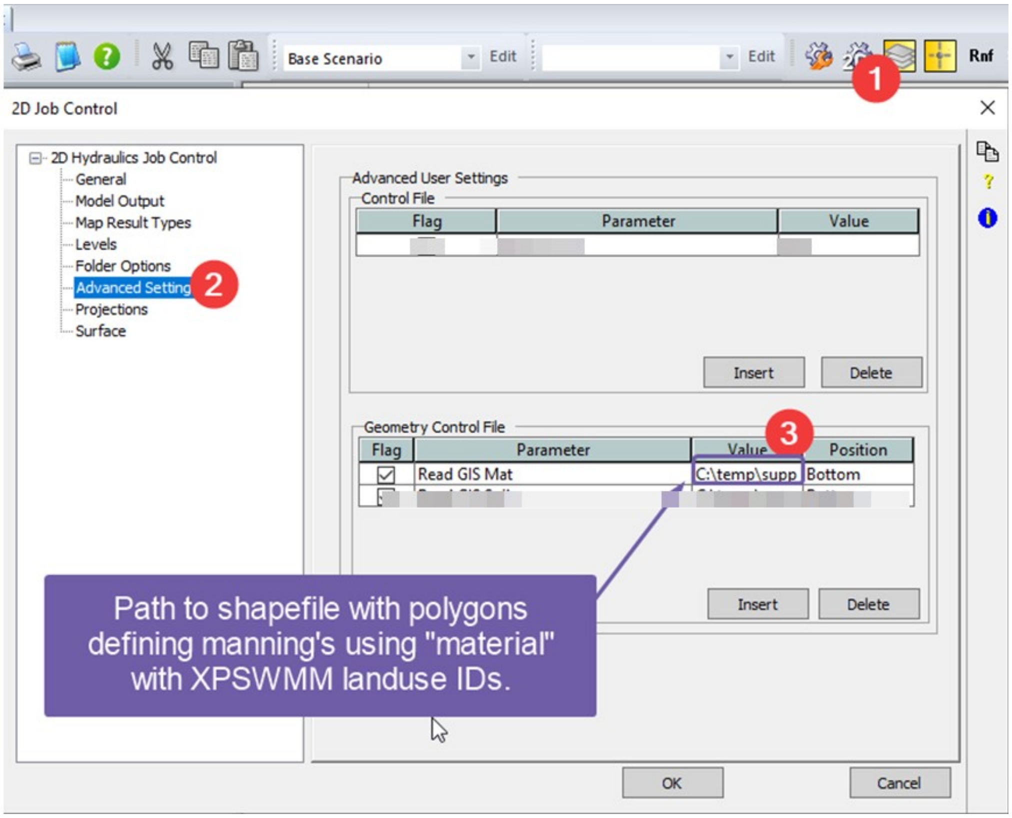




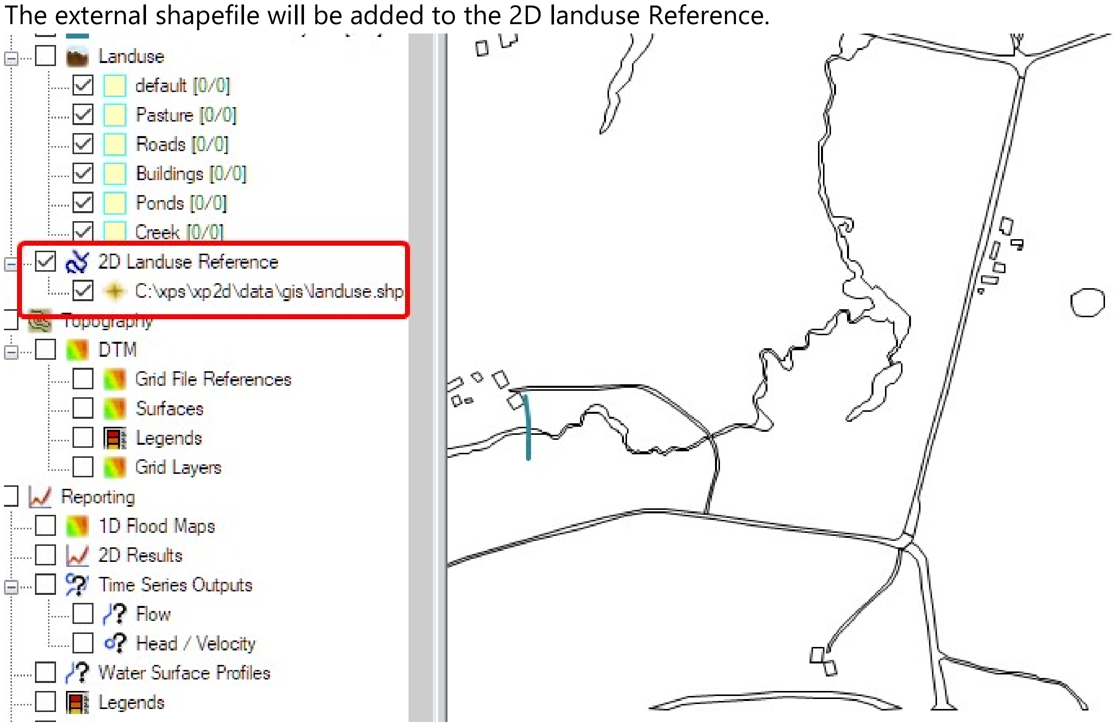
2. Update the material ID field of the land cover shapefile to match the model land use
   (1) Get the material ID from the global database (2) digitize the landuse in GIS, the shapfile should have only one field "MATERIAL" which is the ID from the database.



3. Add the command in 2D settings to reference external land use file
   (3) Read GIS Mat == <shapefile path>



The external shapefile will be added to the 2D landuse Reference.

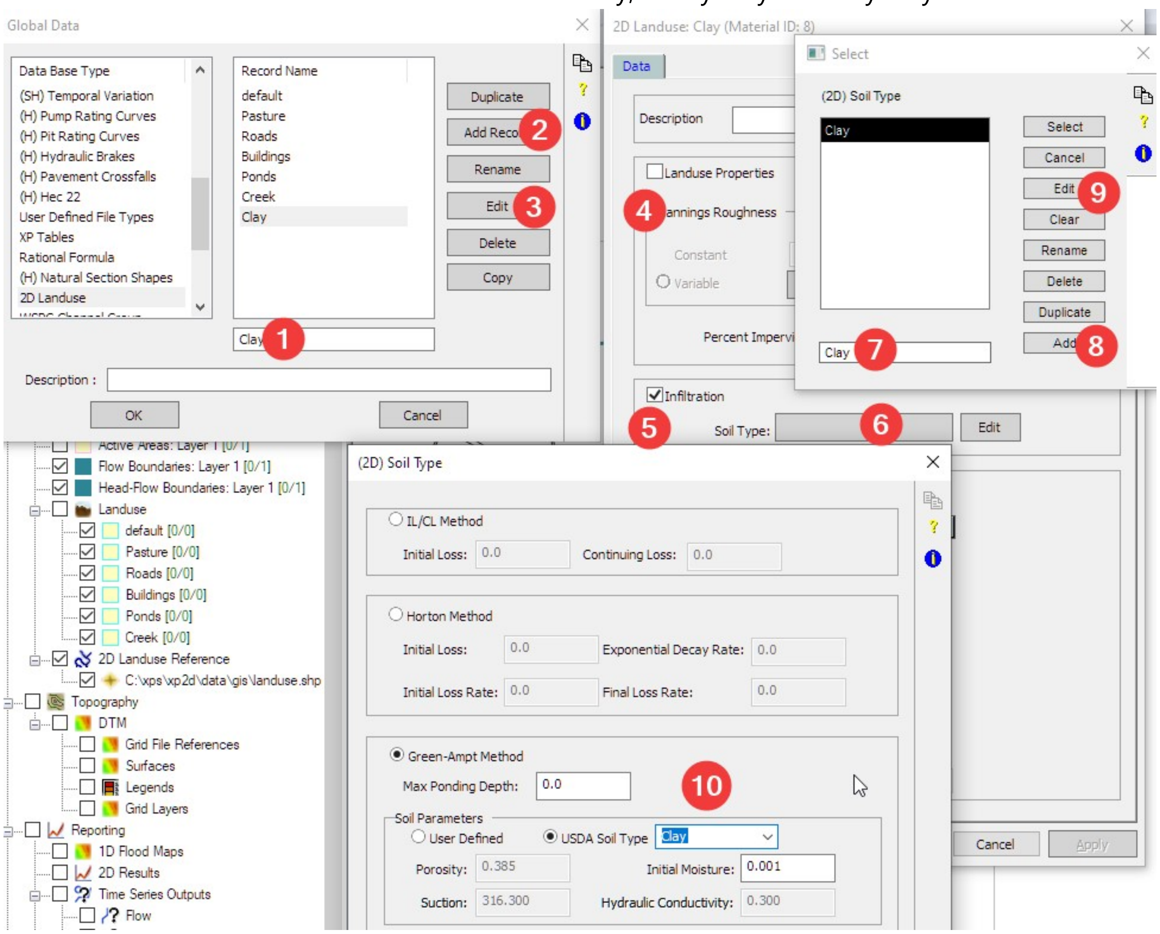


EX3: Update soil to account for infiltration

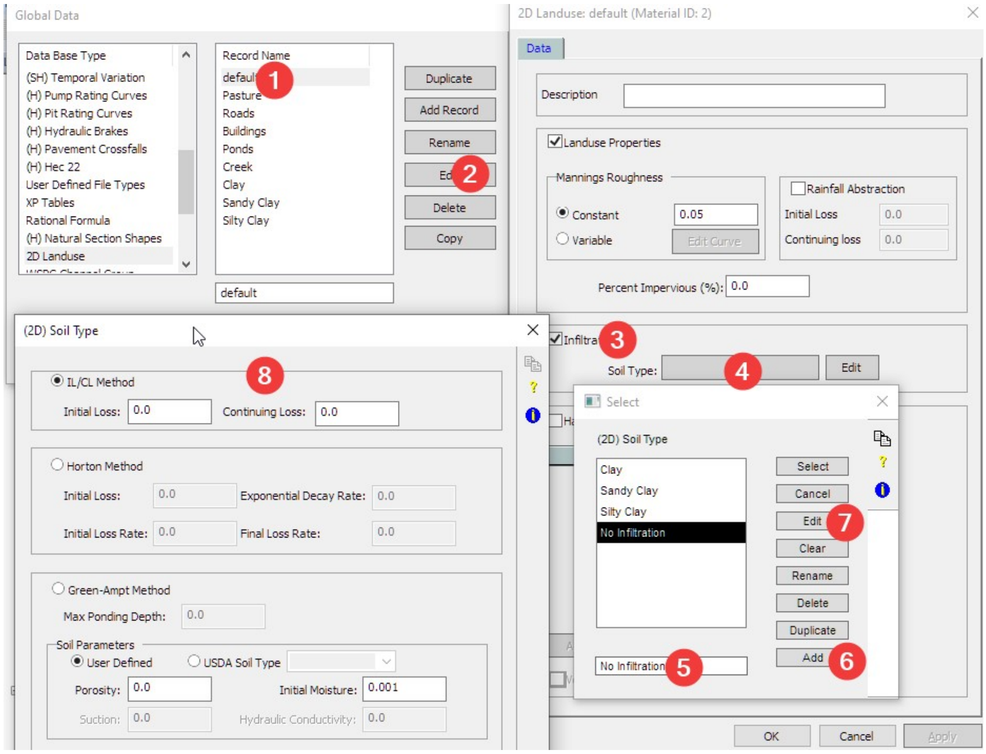
Modeling infiltration in the 2D grid can be especially important if the infiltration is not accounted for in the hydrology process. For example, flooding caused by a river instead of a local rainfall.

Although you can define both the manning's n and the soil type in a single landuse entry in XPSWMM. The best practice is to define them as separate entries, otherwise, you'll need to create landuse entries for all the combination of manning's and soil types. Soil types are available for most of the areas in the United States from the USDA website.

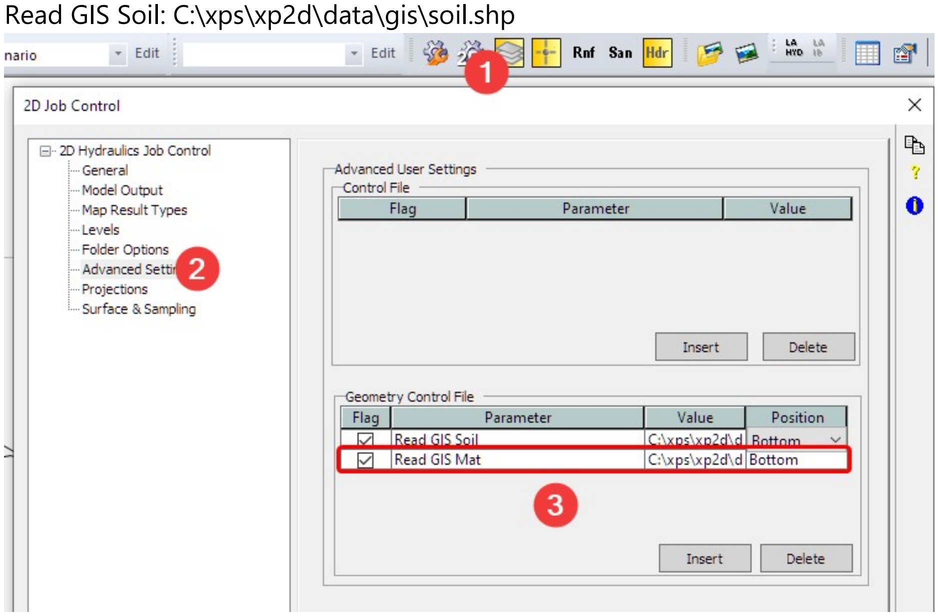
1. Create the soil landuse entries in XPSWMM. Add Clay, Sandy Clay and Silty Clay.



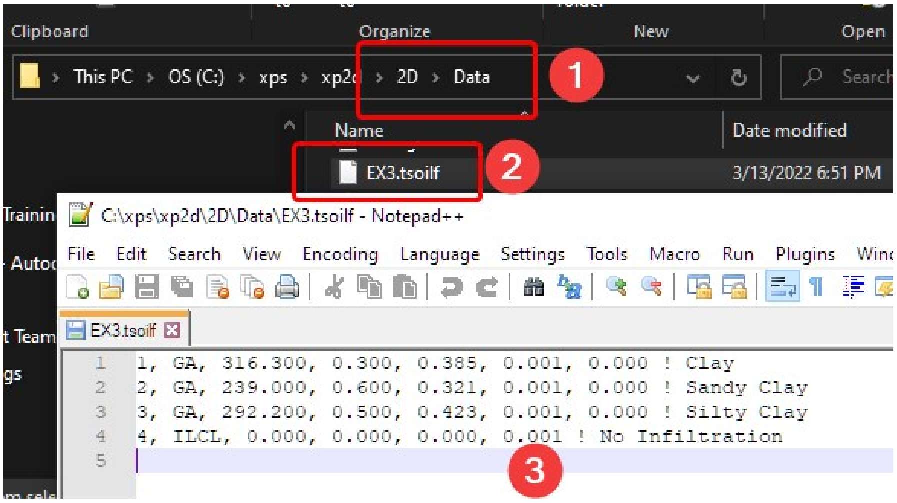
2. Update default landuse to include infiltration



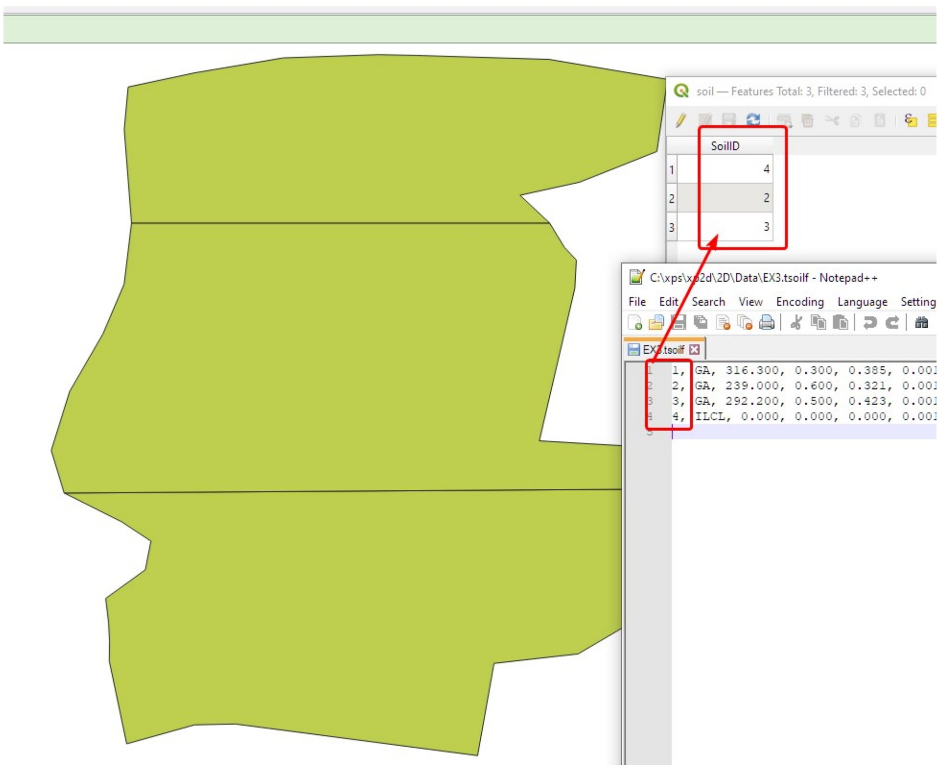
3. Update the 2D settings to reference the external shapefile
   Read GIS Soil: C:\xps\xp2d\data\gis\soil.shp



4. Run XPSWMM to generate the *.tsoilf file. Once the simulation starts, we can stop it. We need the soil ID from this file to update the shapefile for soil. It is in the model folder 2D/Data/<model>.tsoilf

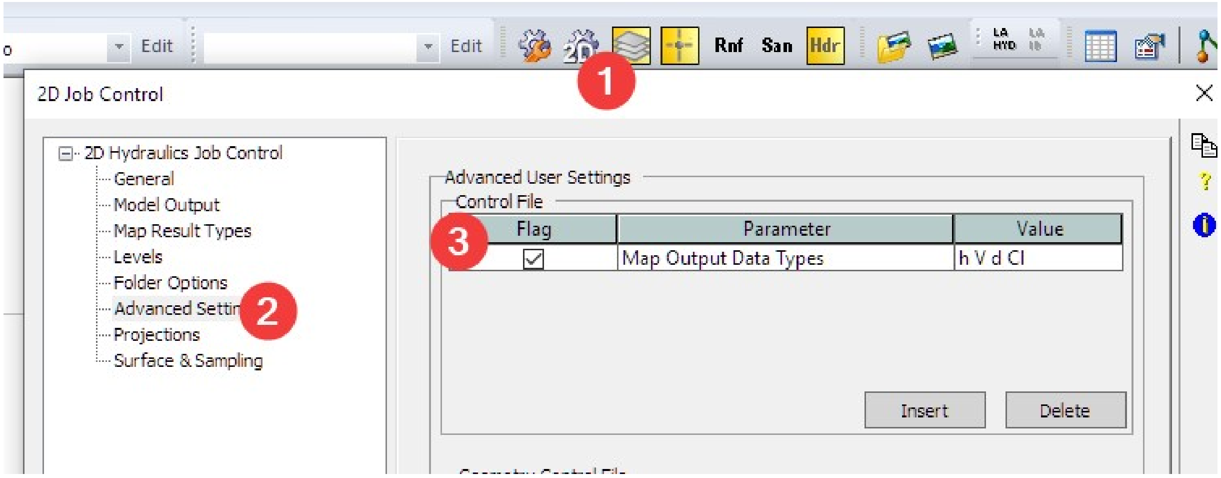


5. Update the soil layer ID field to match the *.soilf IDs. The shapefile should have a single field “SoilID” that matches the *.tsoilf. File IDs.



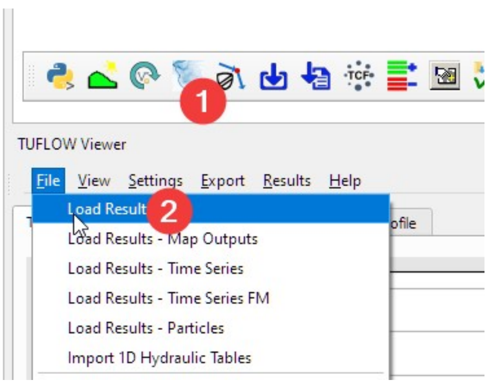
6. Review the cumulative infiltration. XPSWMM doesn’t support saving and showing inifiltration simulation results. To enable the infiltration results, we need a command.

   Map Output Data Types: h V d CI (CI: cumulative infiltration, h: elevation, V: velocity, d: depth)

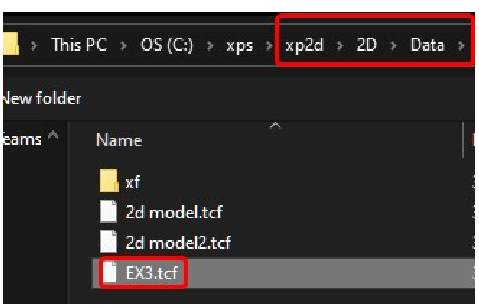


7. Run the model.

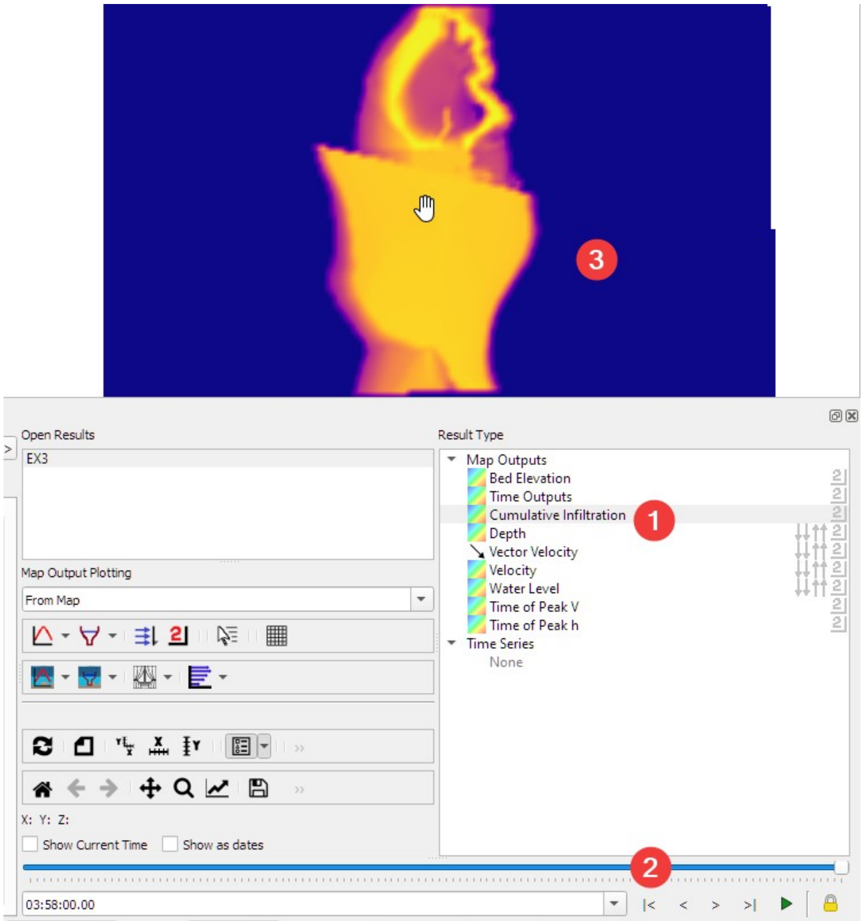
8. Review the Infiltration in QGIS Tuflow Plugin (https://wiki.tuflow.com/index.php?title=TUFLOW_QGIS_Plugin).



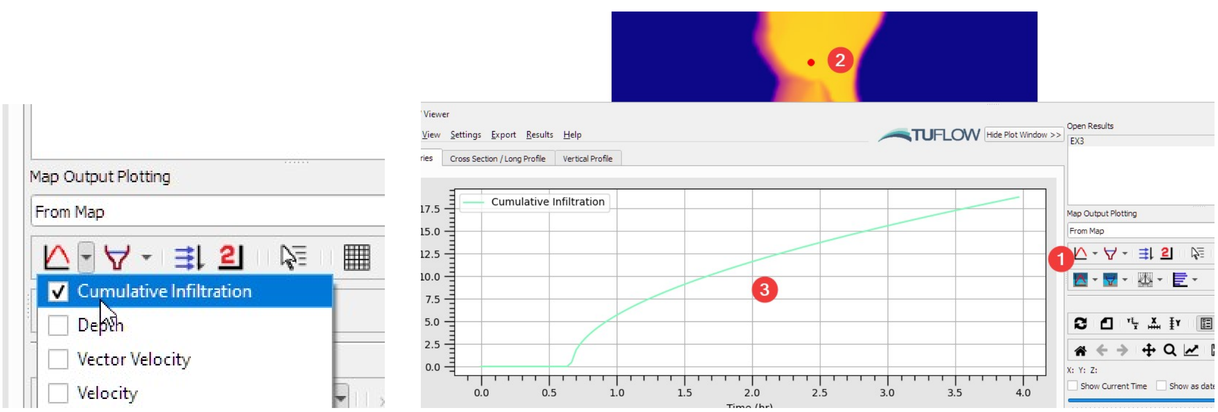
The tcf is in the model folder 2D/Data/<model>.tcf



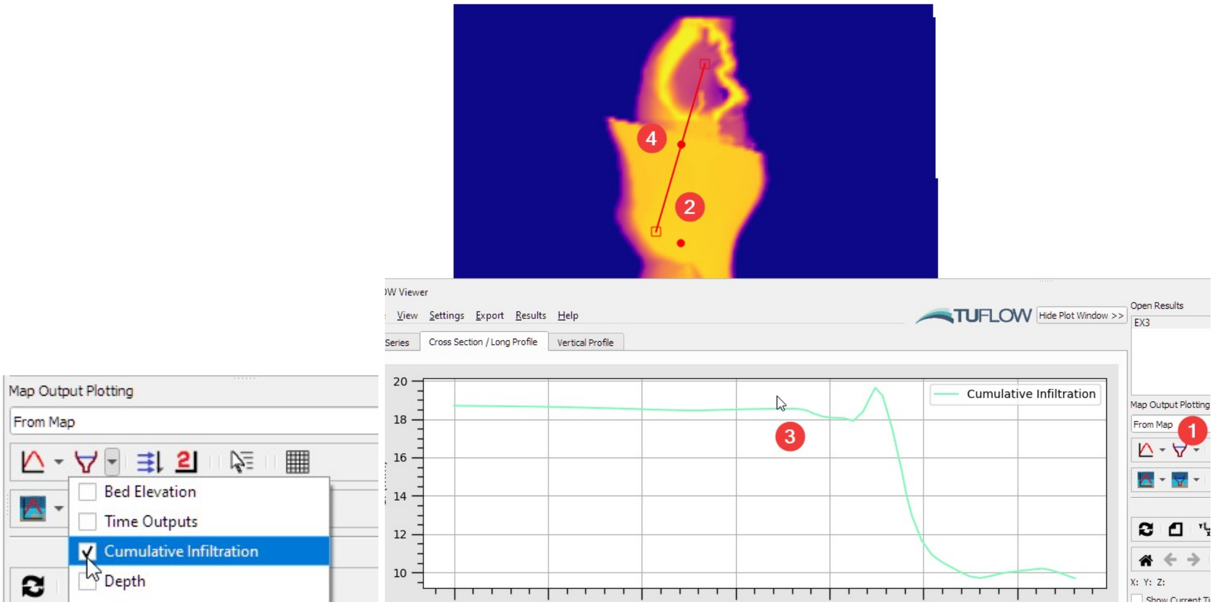
Play the animation



Plot the time series,



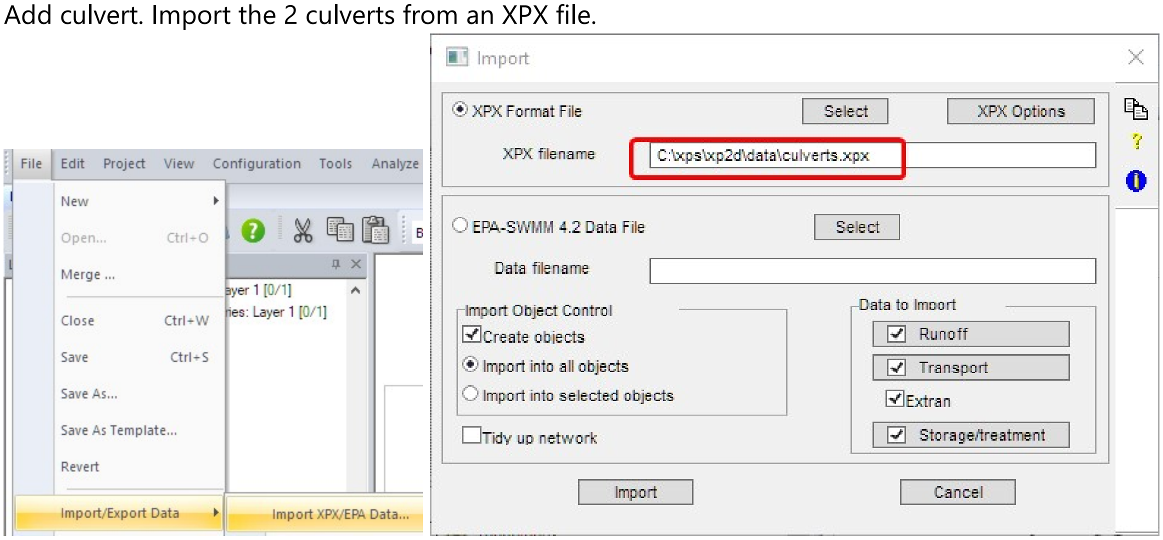
Plot the infiltration profile along a line,



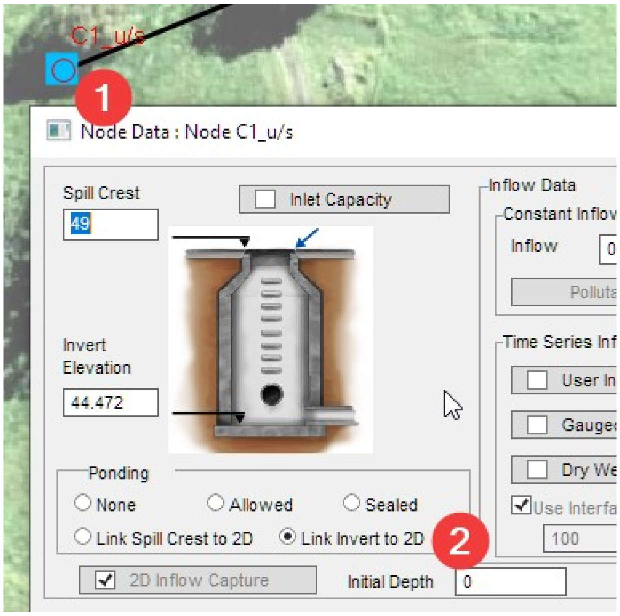
EX4: Add Culvert

Next, we'll add two culverts so that water can flow through the roads.

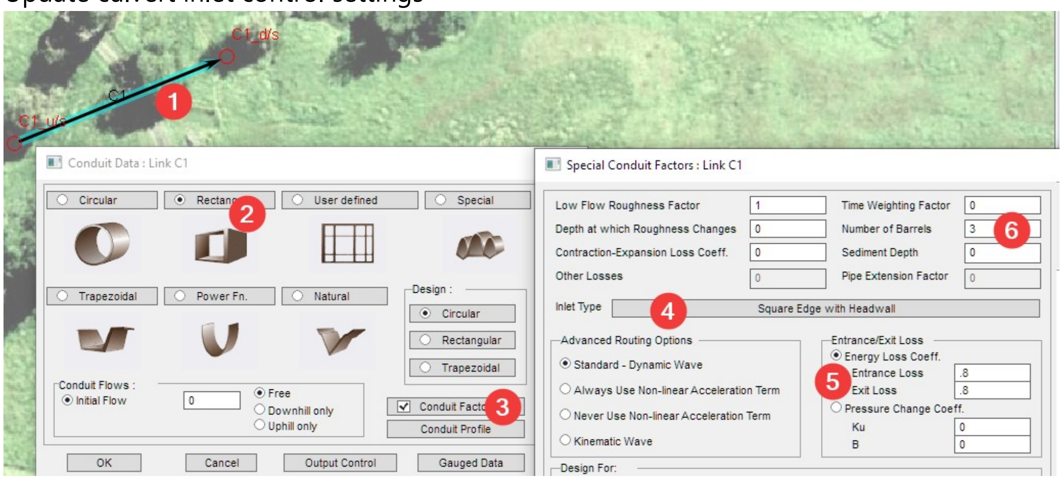
1. Add culvert. Import the 2 culverts from an XPX file.



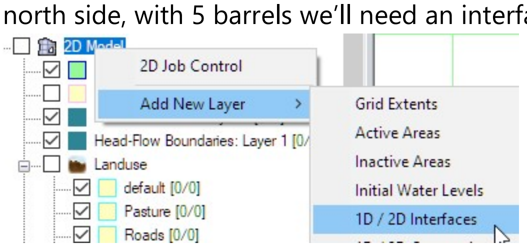
2. Link culvert to the 2D grid. For culverts without an "actual" manhole, we should choose the "link invert to 2D"

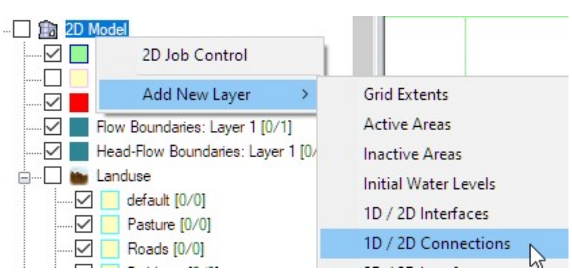


3. Update culvert inlet control settings

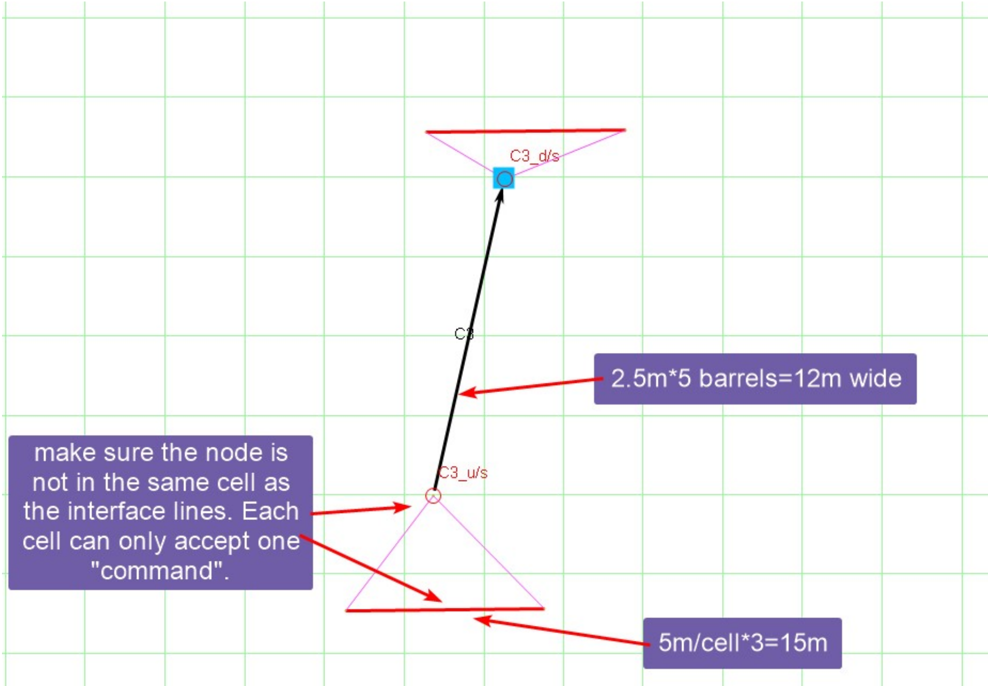


4. Add 1D/2D interface lines for wide culverts. For culverts that is wider than one cell, use a 1D/2D interface line to “force” the multiple cells to flow into the culvert. For the culvert on the south side, the cell size is about the same as the culvert size, there is no need for an interface line. For the culvert on the north side, with 5 barrels we’ll need an interface line.

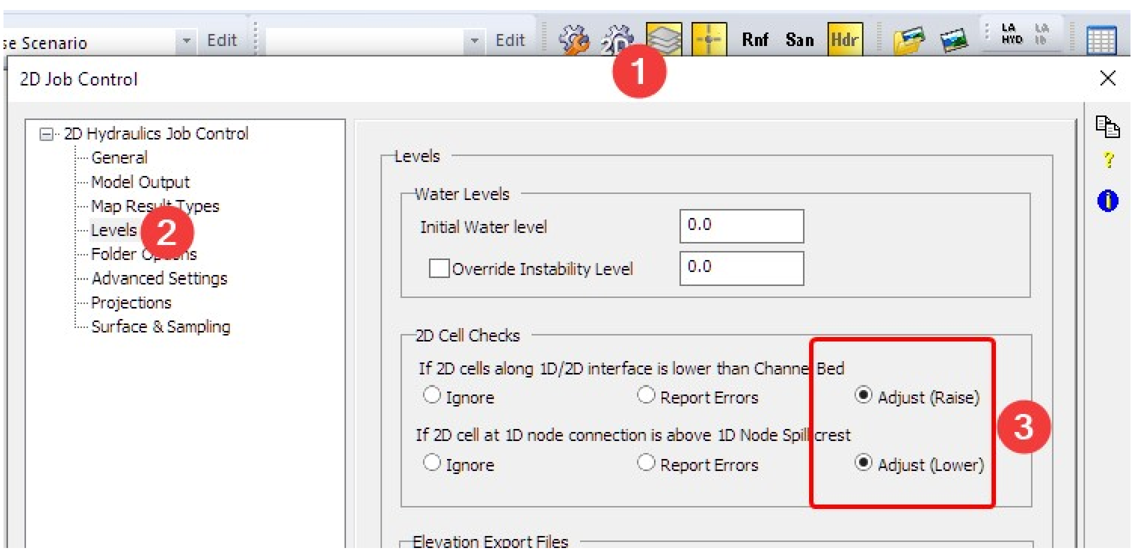


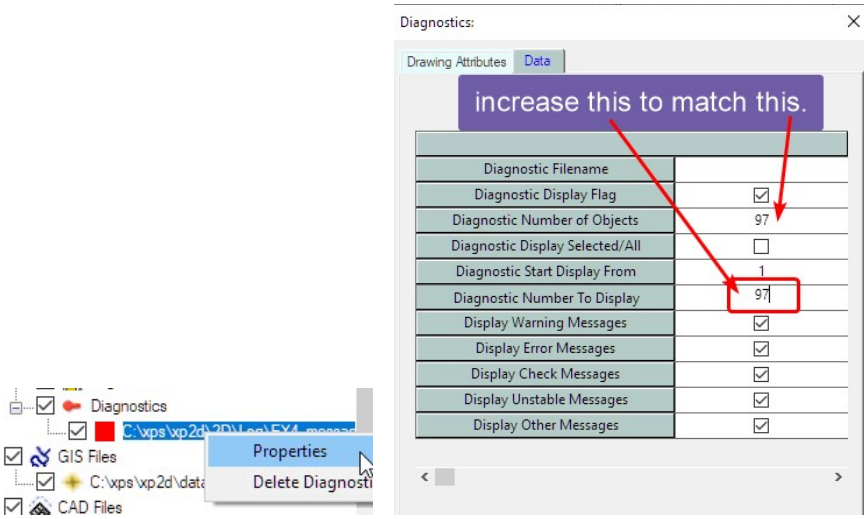


NOTE: everything we change will need to be converted to a 2D cell for the model to run. When drawing lines, go through the middle part of the cells, and make sure there is only one "command" for a cell, otherwise, move the lines or nodes to be in different cells.

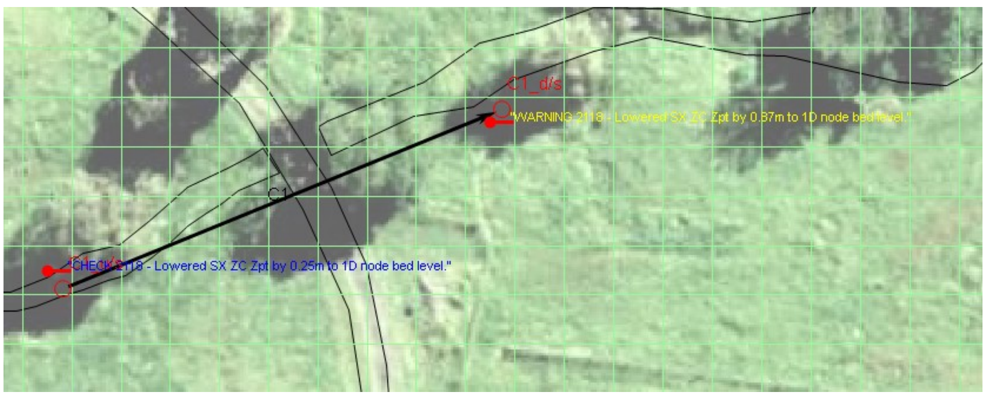


5. Adjust levels automatically. When building 1D/2D models, it is not guaranteed that the inverts or rim elevation of the 1D model will match the 2D surface correctly. XPSWMM can automatically adjust the 2D cell elevation to match these. Refer to the diagnostic information for warnings if the difference is too big.





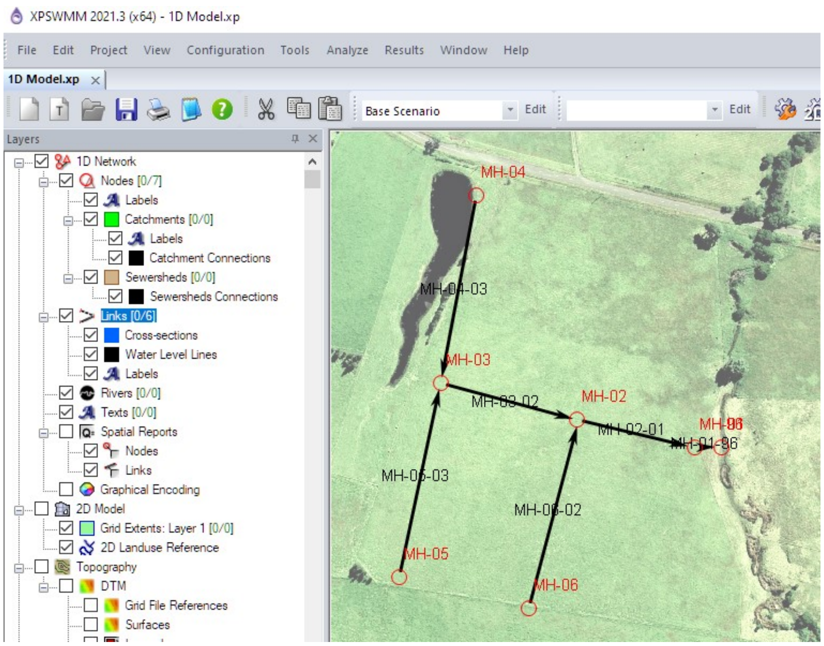
A check message is usually OK. A warning should be investigated because the mismatch might be too high.



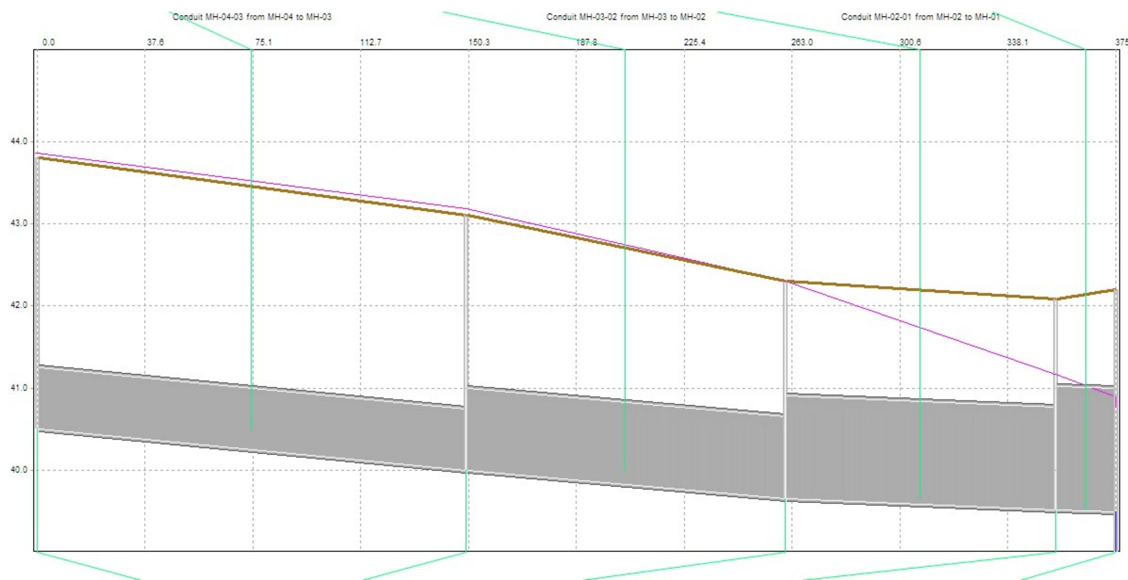
EX5: Add storm sewer system

Next, we'll add a 1D storm sewer system into the 2D model.

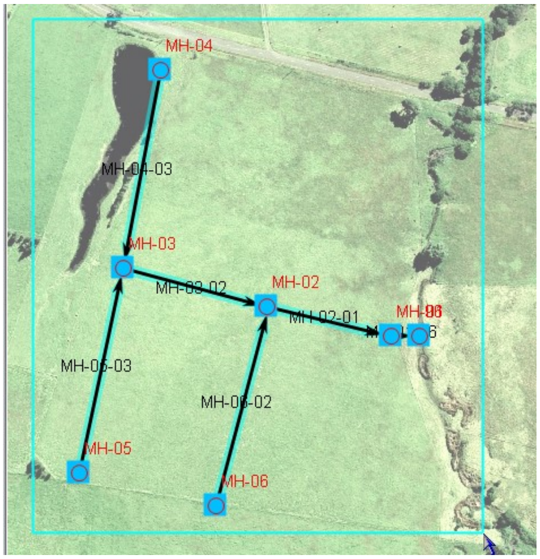
1. Open 1D **Model.xp** and run it.



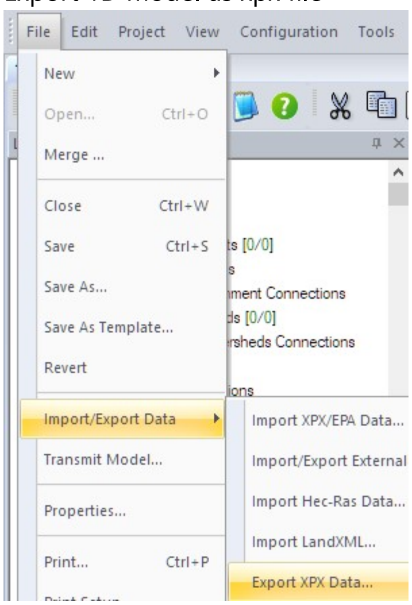
2. Run the model and review the results. It is good practice to run the 1D model and make sure it runs fine before adding to 2D. The 1D model runs fine and it is flooding.

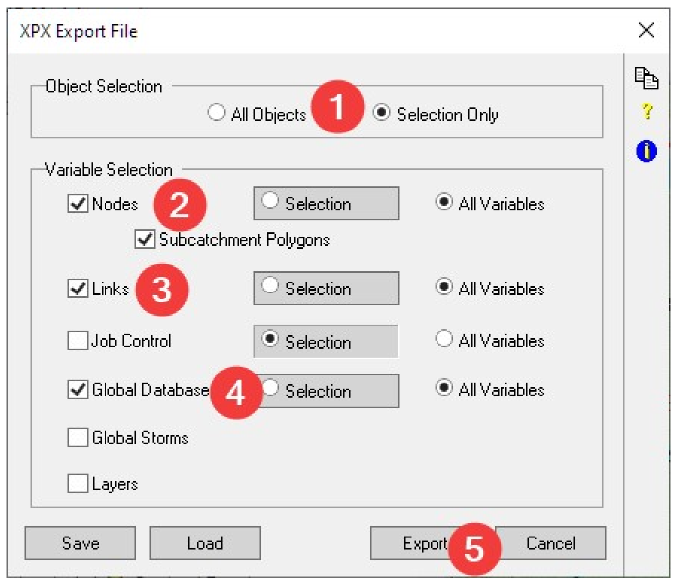


3. Export 1d model as XPX file. Select all the 1D elements



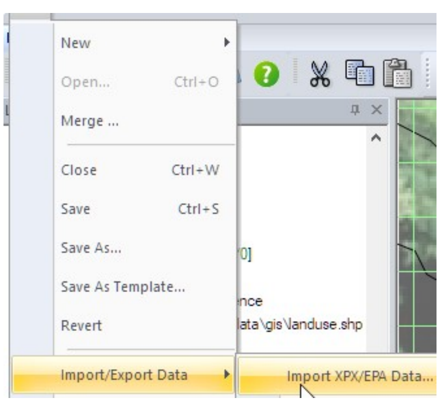
Export 1D model as xpx file

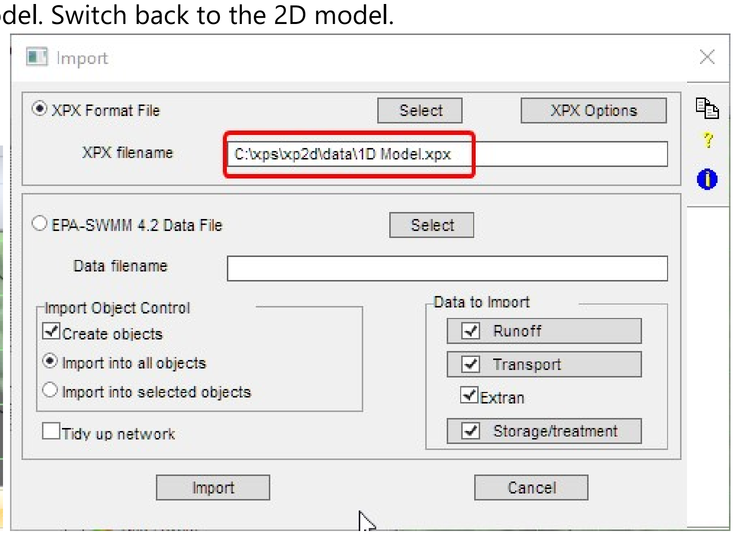




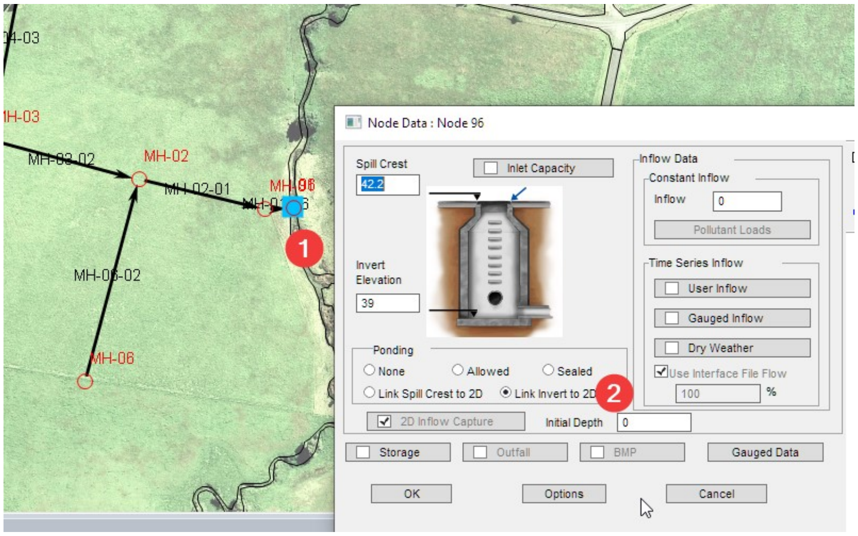
Save to **data\1D model.xpx**

4. Import the 1D model into the 2D model. Switch back to the 2D model.

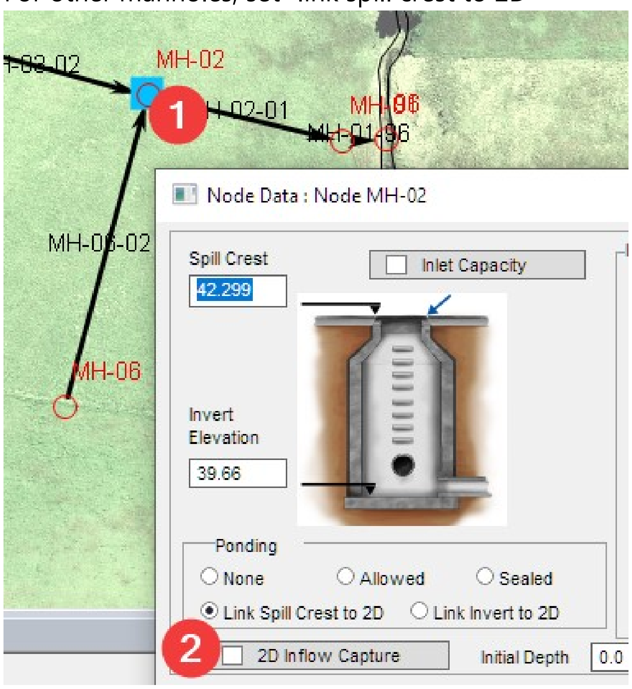




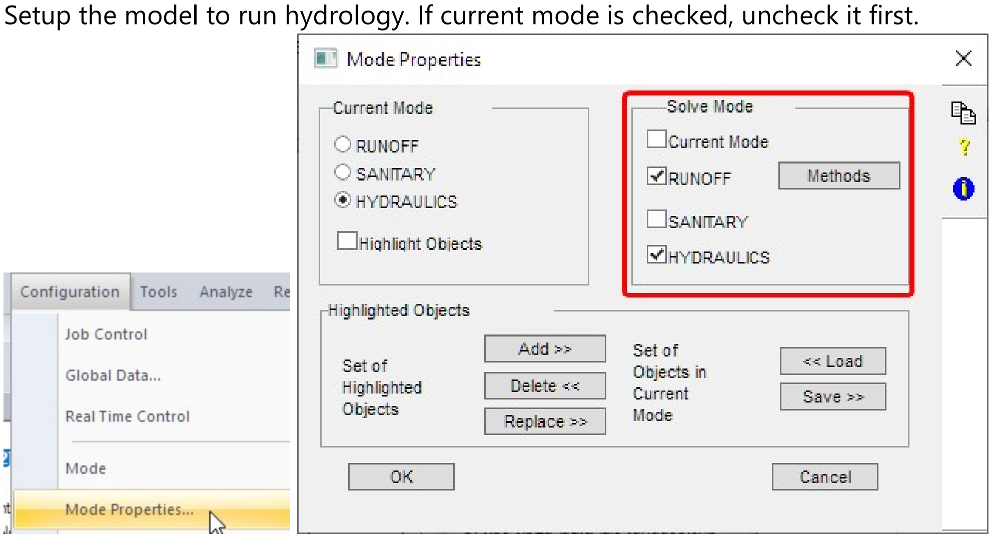
5. Connect 1D to 2D. For the outfall, "link invert to 2D"



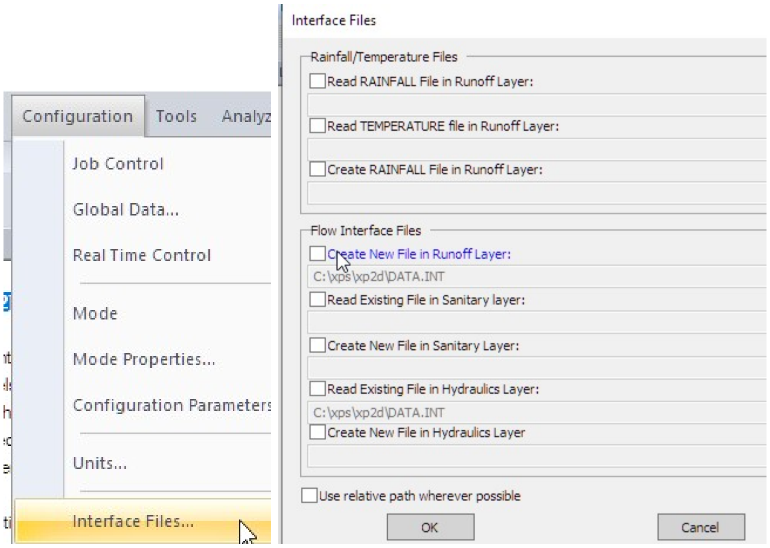
6. For other manholes, set “link spill crest to 2D”



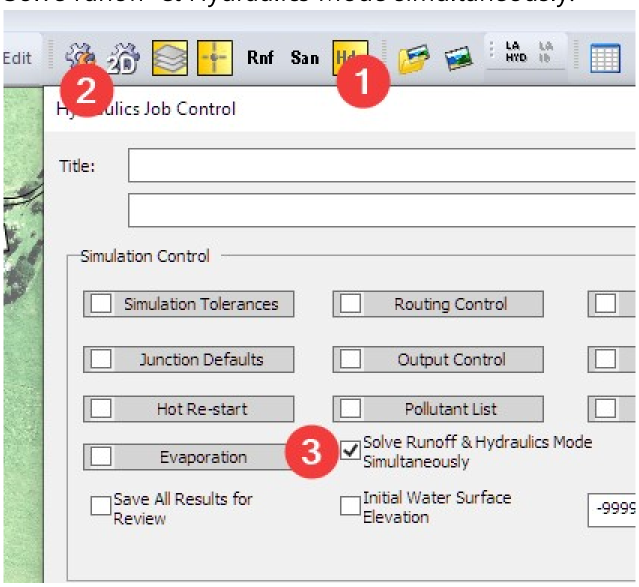
7. Setup the model to run hydrology. If current mode is checked, uncheck it first.



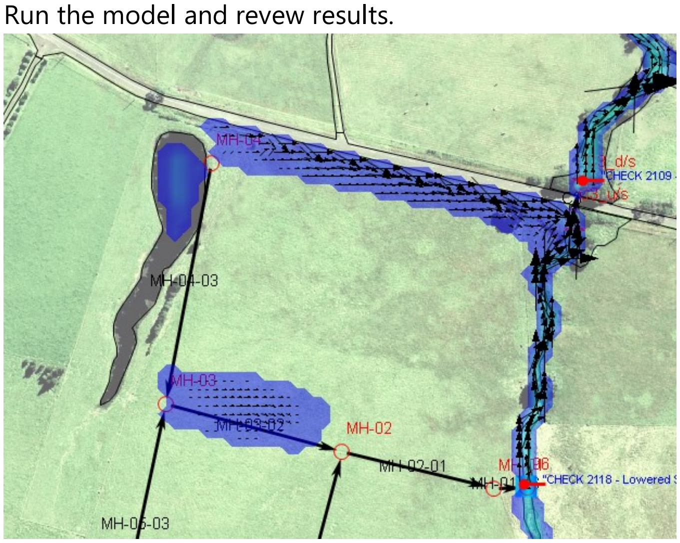
Uncheck all interface file.



Solve runoff & Hydraulics Mode simultaneously.



8. Run the model and revew results.



EX6: Add 1D river

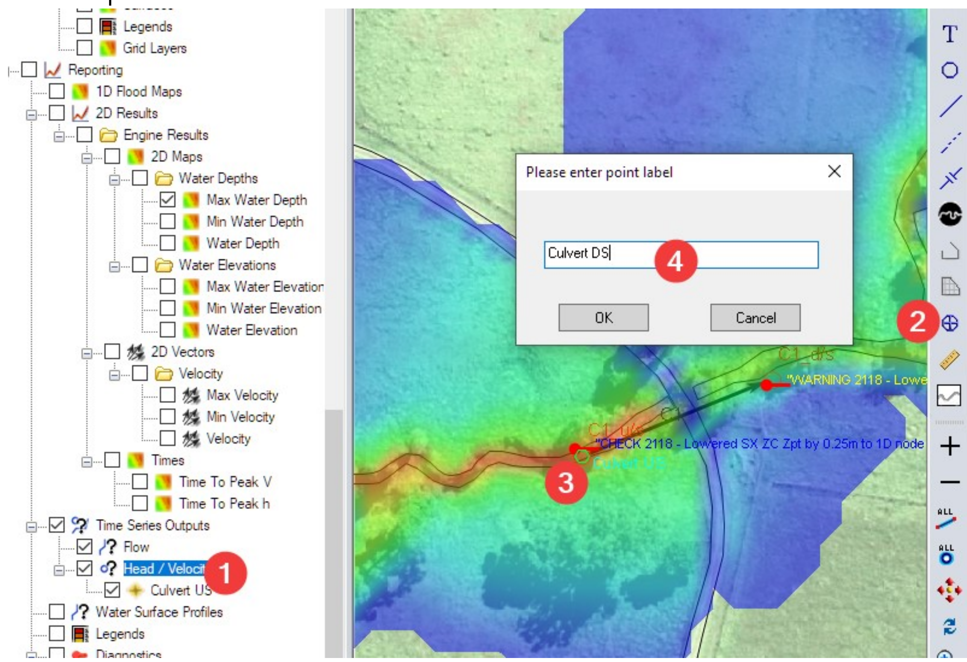
Watch the Youtube video (https://www.youtube.com/watch?v=fzZjJwqVolg).

EX7: Review Results

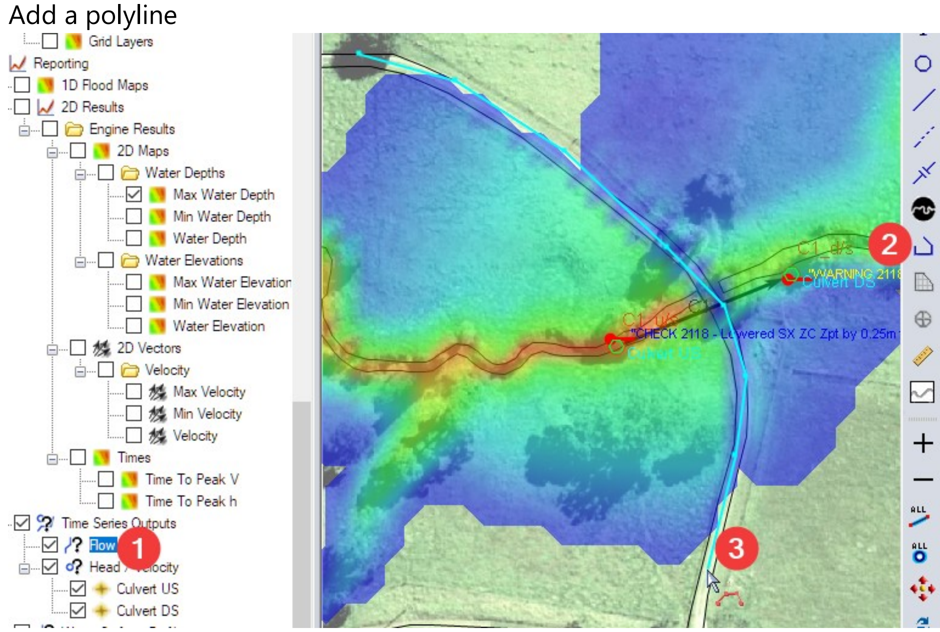
In addition to the 2D results, you can also extract results for point, lines, and polygon over the 2D cells.

For example, the water depth time series at a manhole, the flow through a road, and flow in and out of a pond.

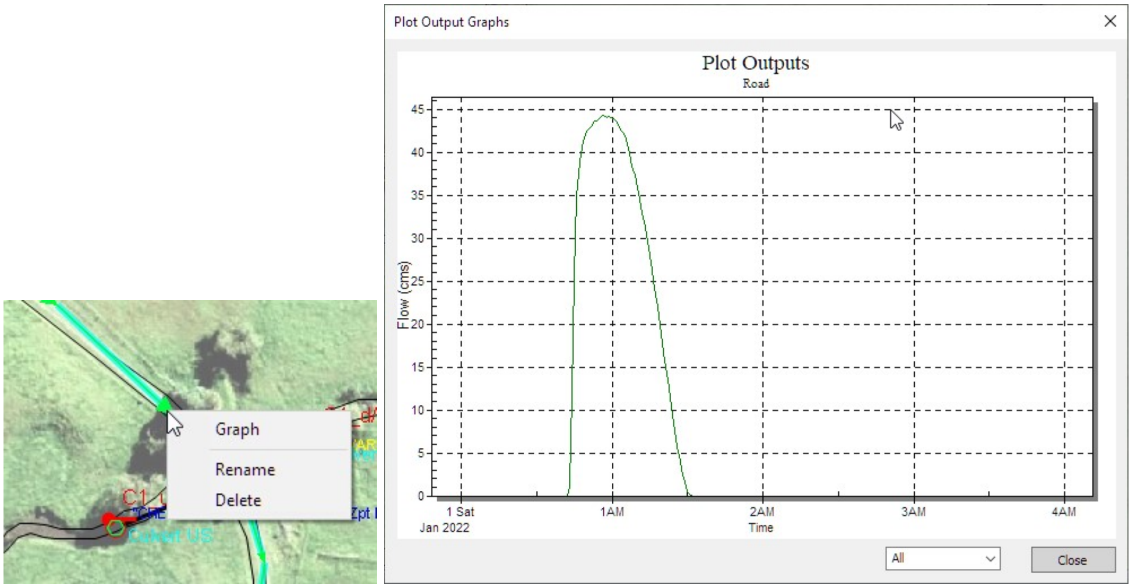
1. Add PO point

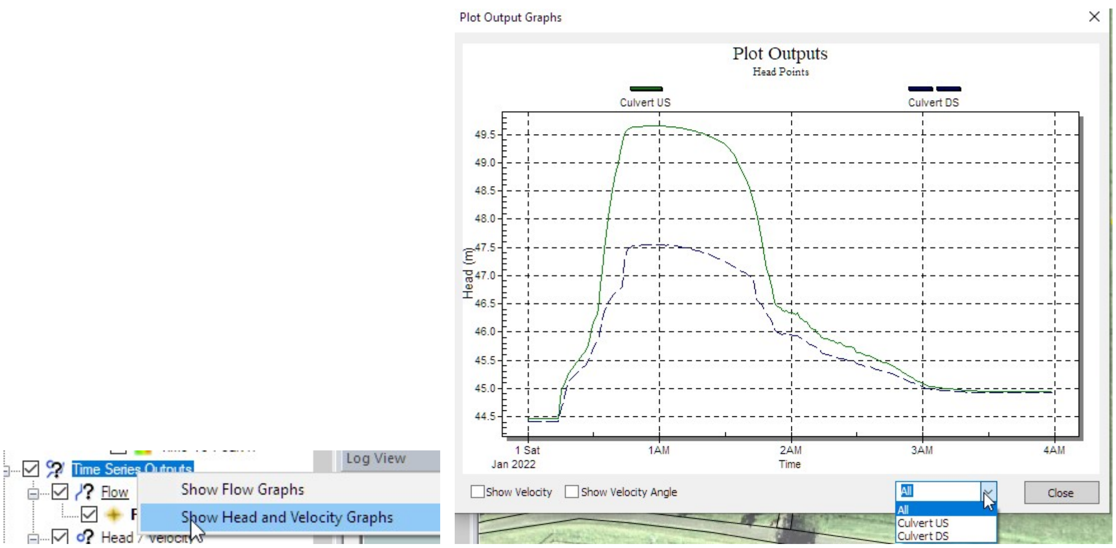


2. Add a polyline

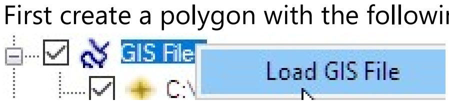


3. Re-run the model to extract the time series.

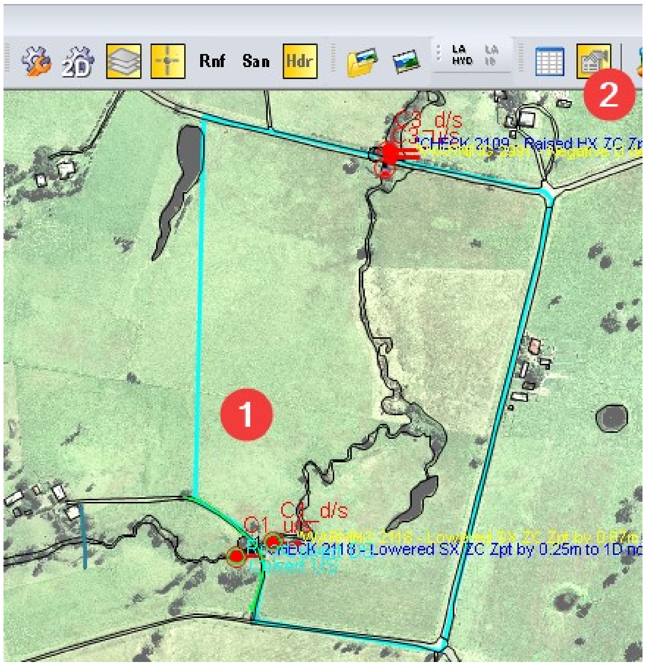


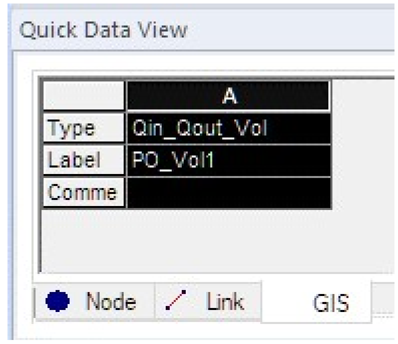


4. Add PO polygon. XPSWMM doesn't support extracting time series for polygons. You need to create a shapefile and then use the command to add it to the model.
   First create a polygon with the following attributes. Load the polygon: **\data\gis\2d_po_volume.shp**

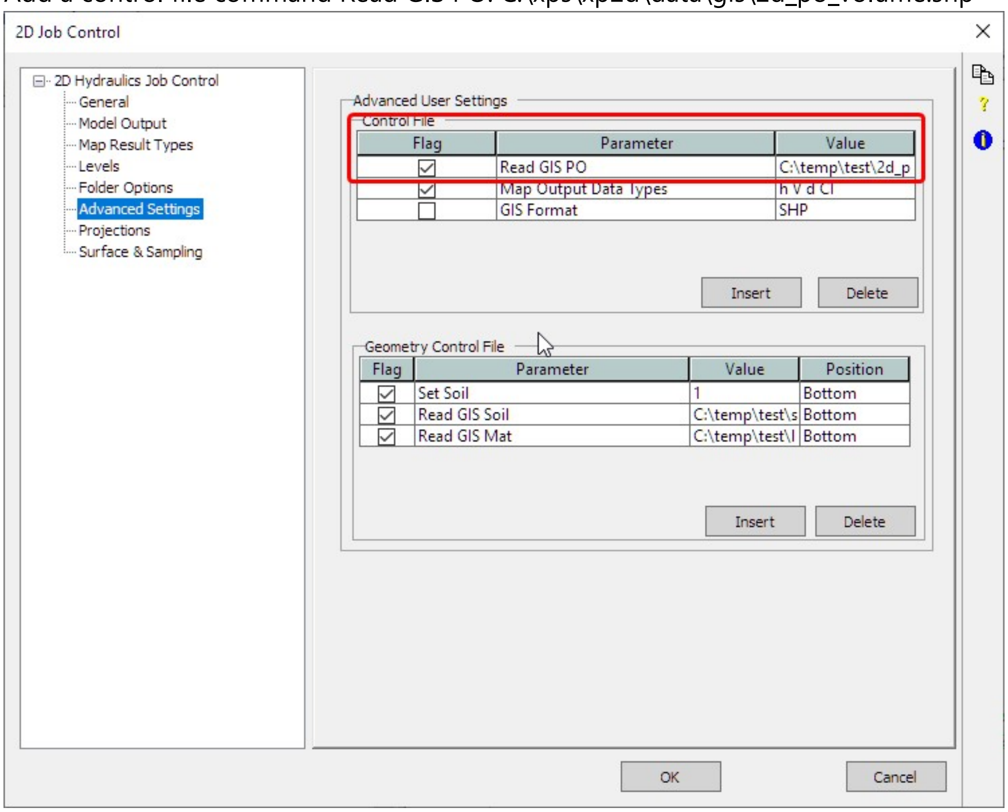
   

   The shapefile should have type: Qin_Qout_Vol (flow in and out, and volume time series), label: PO_Vol1 (the label for the time series)

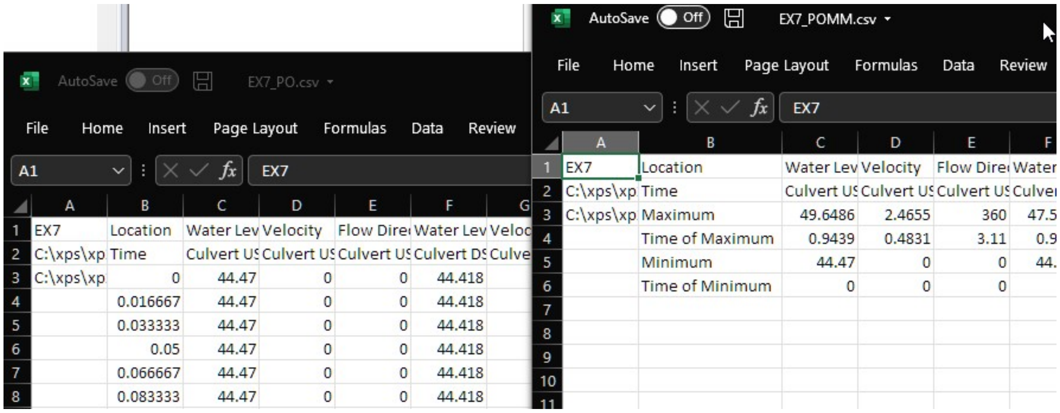




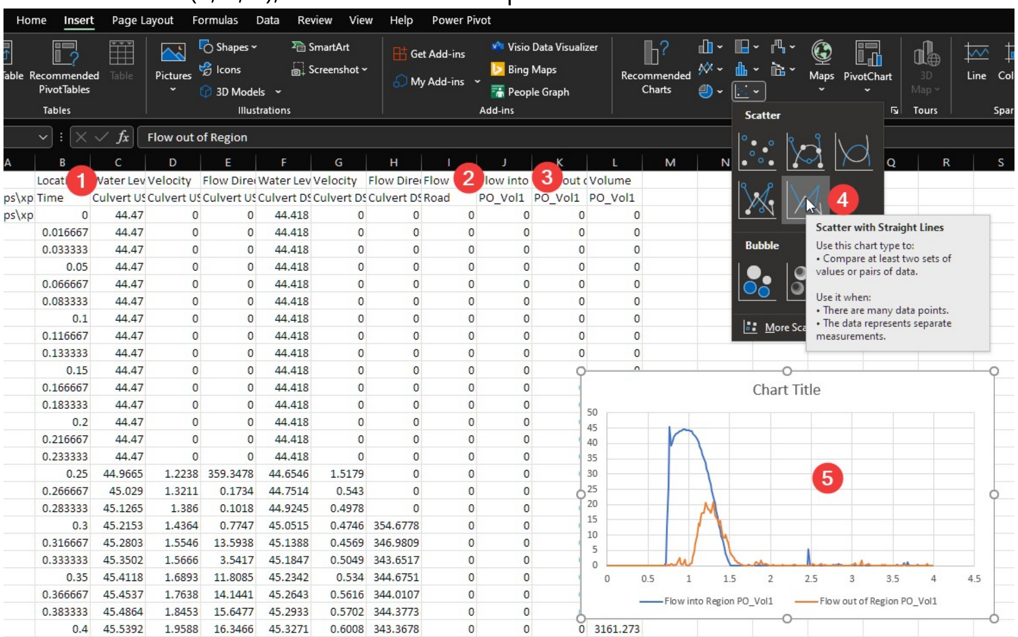
5. Add a control file command Read GIS PO: C:\xps\xp2d\data\gis\2d_po_volume.shp



6. Re-run the model and review the results.
The results for the time series are saved in 2D/Output/<model>_PO.csv and <model>_POMM.csv



7. For the polygon, you'll need to plot it in Excel.
   Select the rows (1, 2, 3), then add a scatter plot.

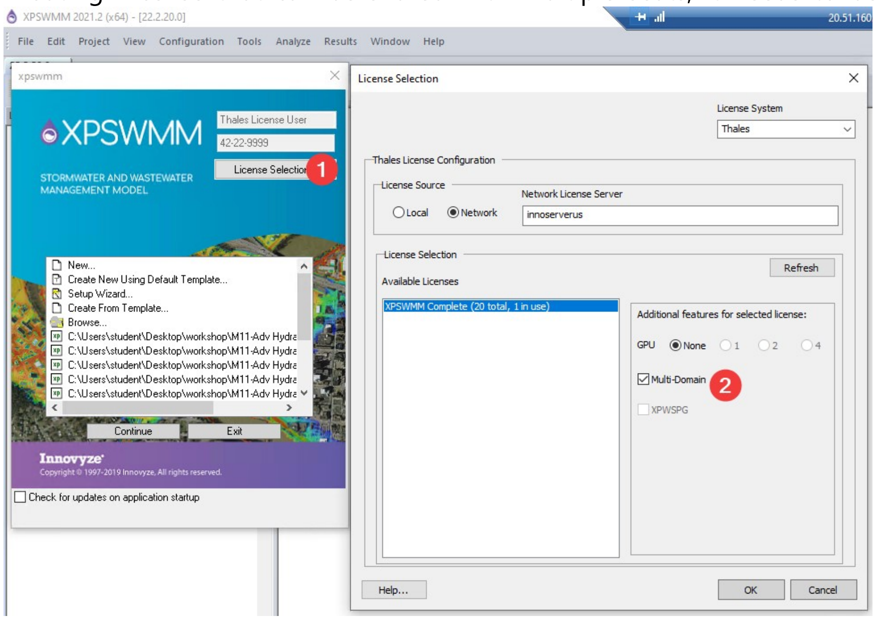


EX8: Quadtree and Subgrid Sampling

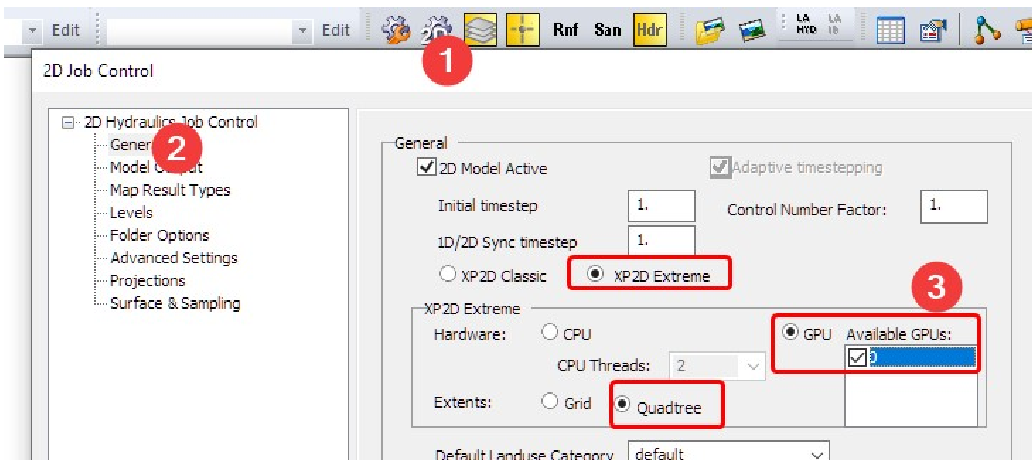
Tuflow added the Quadtree and SGS features in 2021, which has the potential to greatly improve the performance of a 2D model by two ideas,

- Use much bigger cell size in areas where details are not required using SGS. With SGS, much bigger cell size can be used without significantly reducing the model accuracy
- Use smaller cell size in areas where details are needed using Quadtree
- The net result is a model with a smaller number of cells while having more details than the current approach

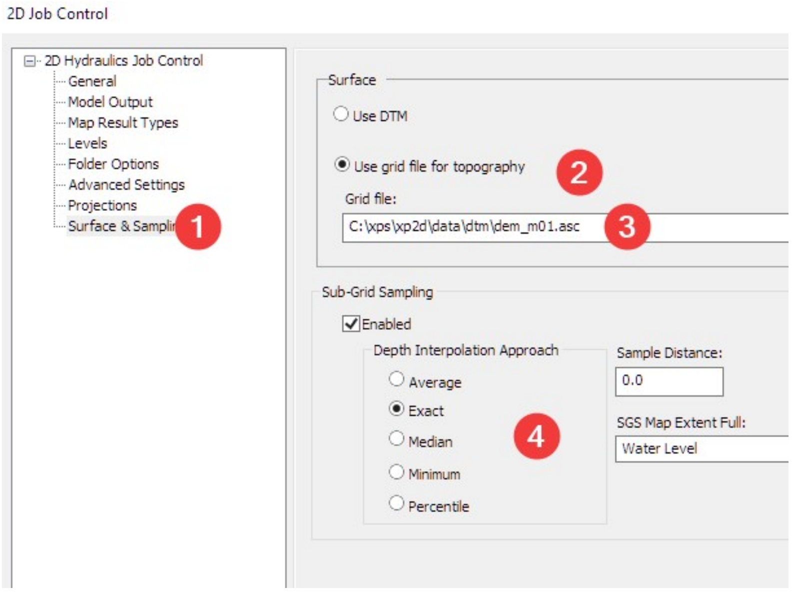
1. Enable quadtree. Start XPSWMM and check out the multi-domain license, since multi-domain is an optional "floating" license that can be shared with multiple seats, it needs to be enabled manually the first time.



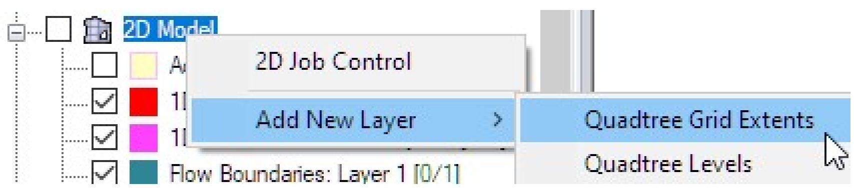
2. Open the model, and switch to Quadtree. You'll need to have GPU to take advantage of the Quadtree features, running on CPU will be very slow.



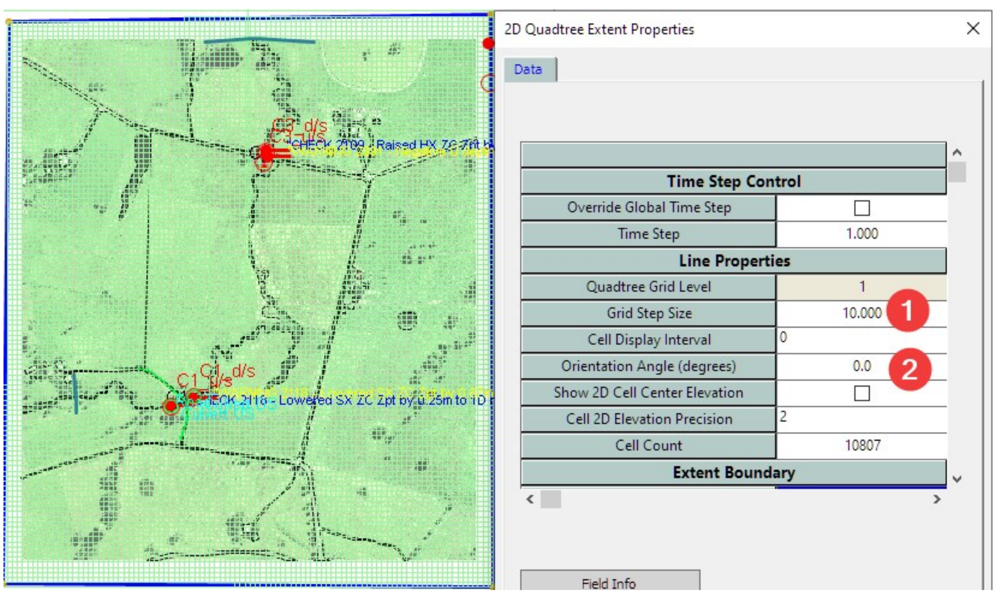
Currently XPSWMM only support external grid file for Quadtree simulation. Make sure you reference an asc file for DTM. Enable the SGS.



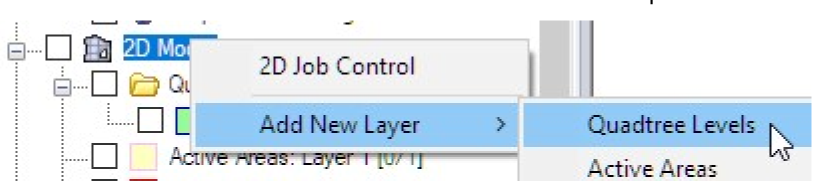
3. Create the 2D grids. You can easily convert an existing 2D model to use Quadtree, the only thing that will need to be recreated are the 2D grids.



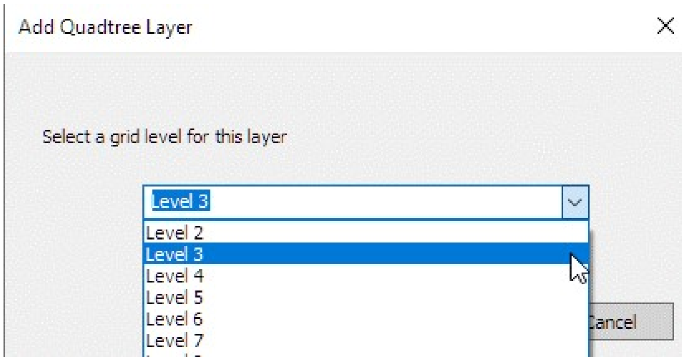
The 1st level is the same as the old 2D grid. Set up the cell size, extent and angle. You can use 10m instead of the 5 meter cell size in previous models.



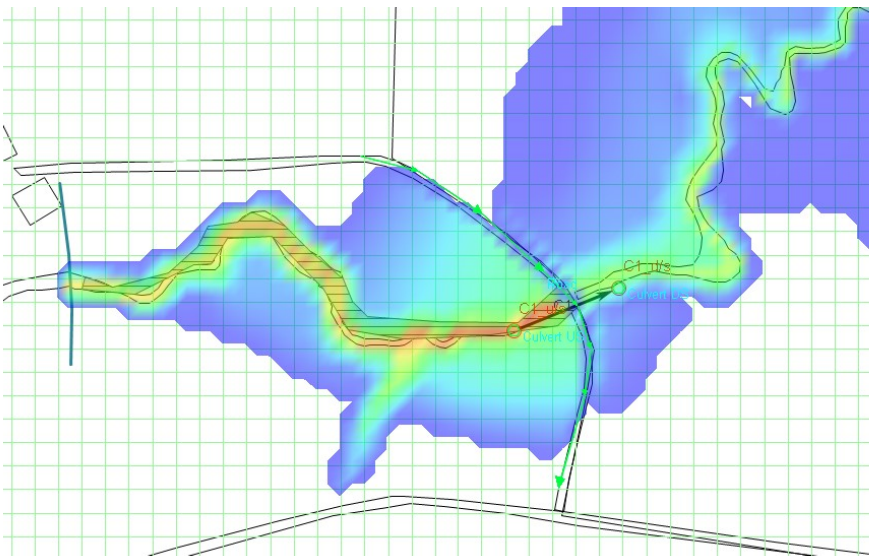
4. Add additional levels. Each level will half the size of the previous level.



We will skip level 2 (5m), and create a level 3 (2.5m) for where the river is. XPSWMM will figure out the transition from level 1 to level 3 in between.



You may run the model with the rough grid first to get some idea where more details will be needed.

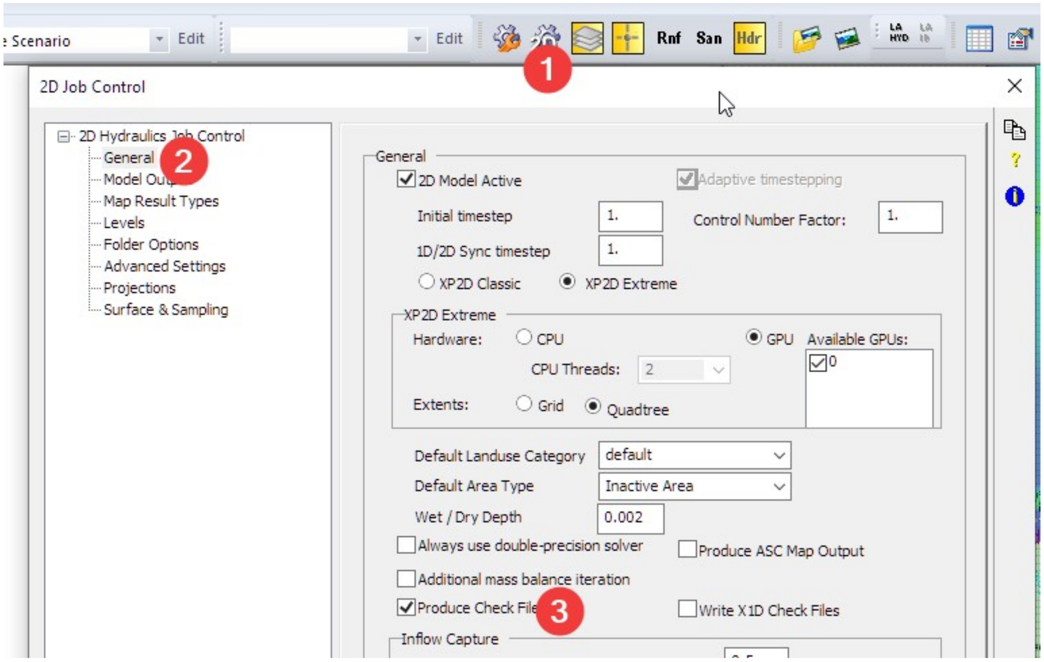


5. Run the model and review the results.

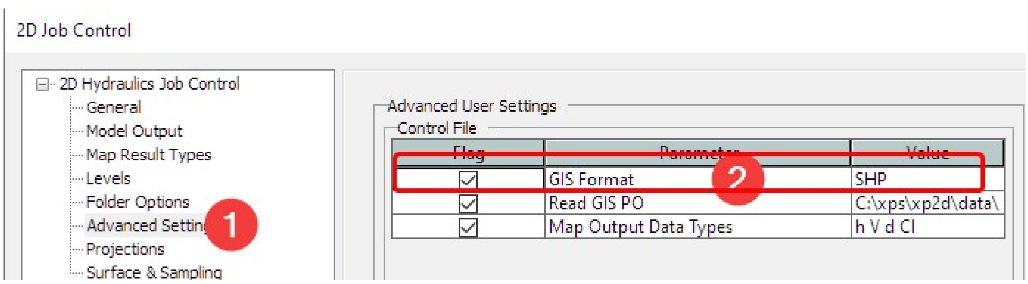
EX9: Review Input data with QGIS Plugin

Tuflow can generate check files for more close review of the input data. The most important file to review is the grid check file, which is the most important input for the 2D engine. With the Tuflow QGIS plugin, you can easily check the results.

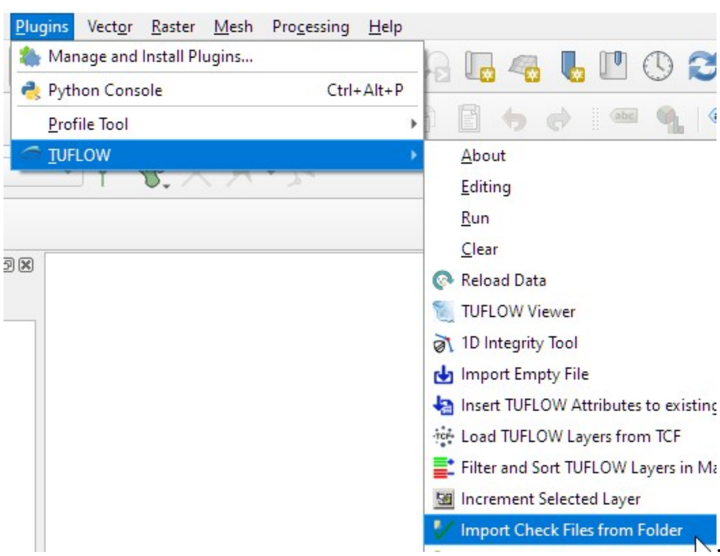
1. Install QGIS and the Tuflow Plugin (https://wiki.tuflow.com/index.php?title=TUFLOW_QGIS_Plugin)
2. Enable check files and change the file format to shapefiles



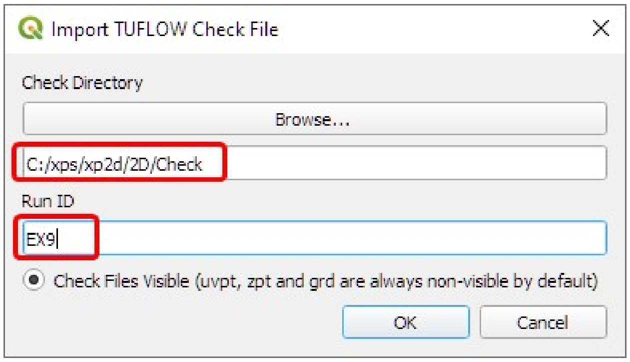
Add a control file command: GIS Format: SHP. This will break some of the functionalities of XPSWMM which assumes *.mif files are generated. For example, the diagnostics file will not load.

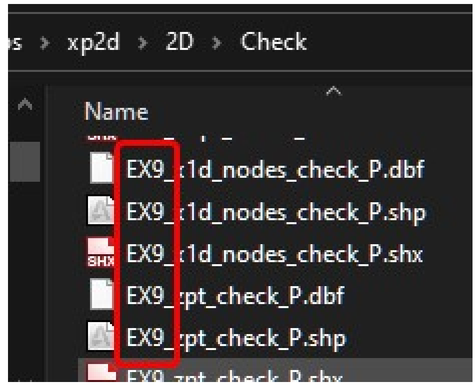


3. Re-run the model. The check files will be created in **/2D/Check**.
4. Start QGIS and Tuflow Plugin.

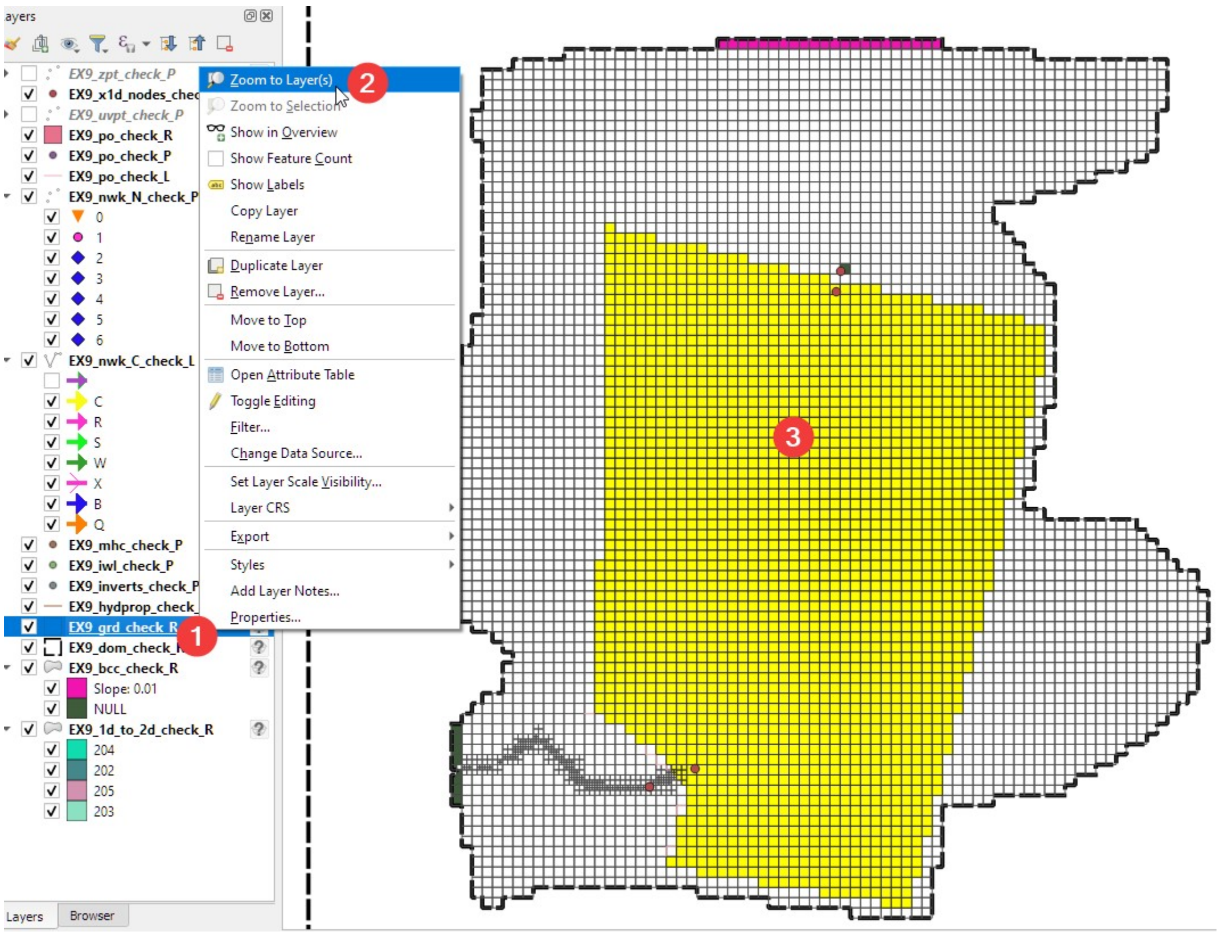


The Run ID is the model name. Go to the Check folder, it is the first part of the shapefile name.

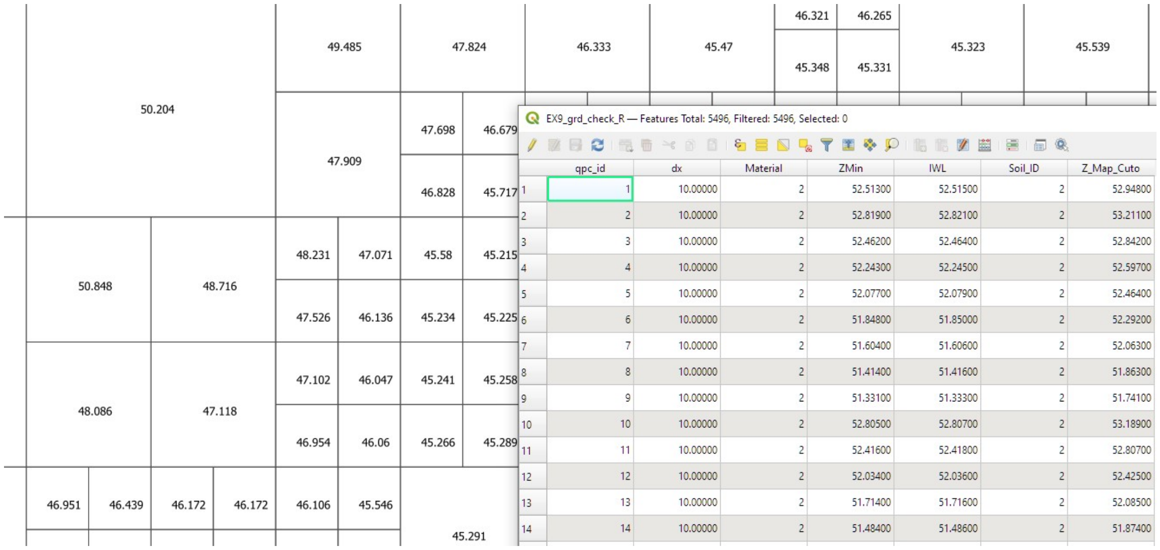




5. The layer we want to check is the XX_grd_check_R.shp file. It is the grid file.



You can easily check the input data from this shapefile. You can check if the Quadtree is correctly applied, the invert elevation of cells, the infiltration and manning's n values etc.



	qpc_id	dx	Material	ZMin	IWL	Soil_ID	Z_Map_Cuto
1	1	10.00000	2	52.51300	52.51500	2	52.94800
2	2	10.00000	2	52.81900	52.82100	2	53.21100
3	3	10.00000	2	52.46200	52.46400	2	52.84200
4	4	10.00000	2	52.24300	52.24500	2	52.59700
5	5	10.00000	2	52.07700	52.07900	2	52.46400
6	6	10.00000	2	51.84800	51.85000	2	52.29200
7	7	10.00000	2	51.60400	51.60600	2	52.06300
8	8	10.00000	2	51.41400	51.41600	2	51.86300
9	9	10.00000	2	51.33100	51.33300	2	51.74100
10	10	10.00000	2	52.80500	52.80700	2	53.18900
11	11	10.00000	2	52.41600	52.41800	2	52.80700
12	12	10.00000	2	52.03400	52.03600	2	52.42500
13	13	10.00000	2	51.71400	51.71600	2	52.08500
14	14	10.00000	2	51.48400	51.48600	2	51.87400