

Tips for a Good Meshing Experience

Meshes are very powerful and flexible for modeling 2D overland flows in a complex urban environment. However, complex geometries can be frustrating for many modelers to deal with. This is intended as a best practices guide to speed up the creation and setup of a high quality detailed 2D model in InfoWorks ICM. While this guide focuses on preliminary data cleanup in ArcGIS, where ICM has similar or identical tools these are noted.

1 – Where is it Flooding?

When I get a model that has a 1D network setup that has flooding, I typically do not know where the flooding will go. So my initial step is to draw a large 2D zone with large elements (typically 3000 sq. ft. for the maximum triangle area and 400 sq. ft. for minimum element area). Next I set nodes I want to integrate with 2D to a flood type 2D with the default flooding coefficient (this can be changed later, right now the idea is to get a general idea of the flooding extents).

With this done I run a model (If there are multiple storms, I run the biggest only), and do a theme on maxima flood depths to see the flooding extent. Now I can adjust the 2D zone so that it only covers the area I am interested in. There is no benefit to having elements that always stay dry under the largest event.

2 – Check / Simplify Geometries of Additional Files

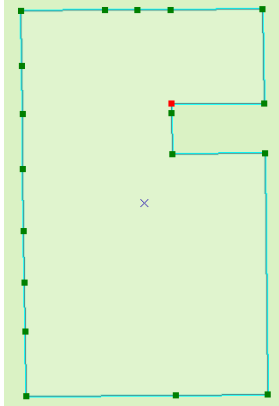
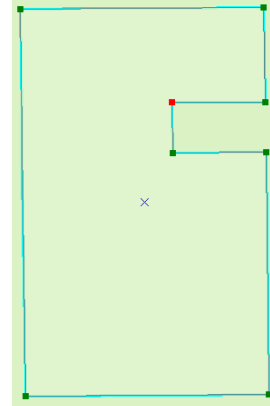
Often additional GIS files are used to add additional detail to the mesh. Examples are buildings (voids / porous polygons), curb lines (breaklines or porous polygons), walls (porous walls), land use (roughness polygons), etc. While much GIS data is great for mapping, it may not be adequate for geoprocessing or 2D modeling. Therefore, all additional data to be used should always be examined before running large detailed 2D models.

2.1 – Check and Repair Geometry

Any GIS dataset should have its geometry checked before it is ever imported into ICM. Common geometry problems of polygons include self-intersection, null geometry, and vertices stored out of order. If such files are used with geoprocessing in ArcGIS, the error in output may not be apparent. ICM specifically prevents a mesh from being created when there are such issues.

2.2 – Simplify Geometries as Reasonable

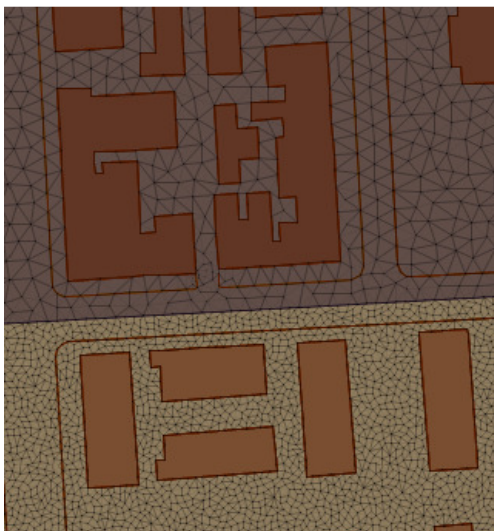
When building a mesh, each vertex in a background file = a triangle vertex. Complex geometries are at times unavoidable, but there are 4 main things that the user can have some control over. One is the number of vertices, as many times polylines and polygons have excessive vertices that do not add any benefit to 2D modeling. These can be greatly enhanced by removing vertices while maintaining the shape necessary. For this, the ArcGIS 'simplify line' and 'simplify' building tools are very beneficial. There is also a simplify tool in ICM. See below for an example.



Another are curves, that typically come from CAD, as curves are typically turned into many vertices for spatial analysis. Simplifying curves to a reasonable geometry can be a large benefit.

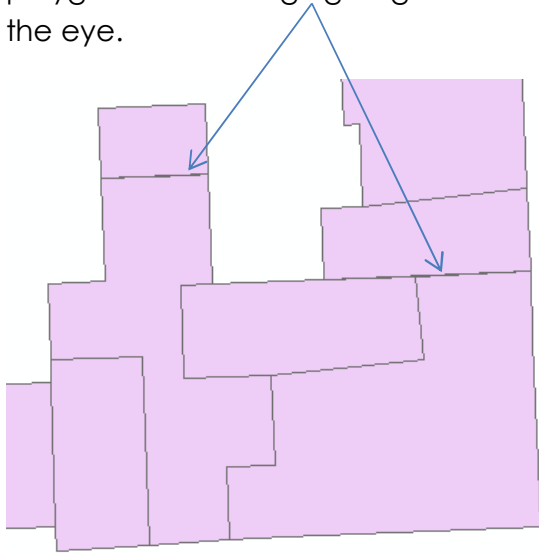
Donuts can be handled by ICM, but there are benefits to removing these (typically leaving the donut adds no benefit).

Finally, reducing the number of intersections where possible will greatly help. A good example is at mesh zones, where by simply not drawing these through buildings etc. the resultant mesh is much cleaner.



2.3 – Check for Slivers, Gaps, and Overlaps

Many GIS datasets have polygons that appear to have collinear polygons, but may not. There may be tiny gaps between polygons, or polygons that overlap, as well as polygons with diverging edges causing a sliver. Below is an example that is invisible to the eye.

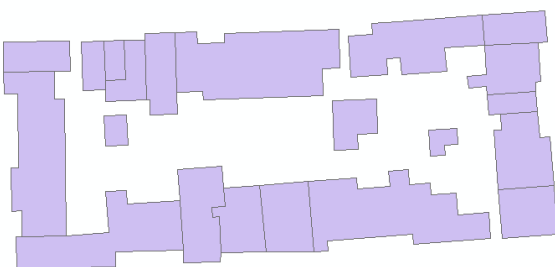
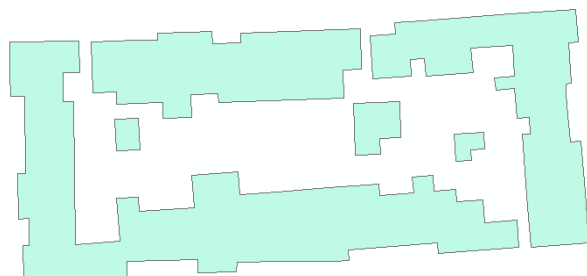


Such geometry problems cause massive issues when meshing, and they should be fixed up front. In ArcGIS, there is a tool named 'Integrate' that does this. In ICM, there is a tool called 'close gaps and overlaps' that does the same thing.

2.4 – Reduce the Number of Polygons and Layers

Sometimes adjacent polygons can be joined with zero consequence. One example is land use used for roughness zones. A city block may be 100% residential so the user wants to assign one roughness value for this land use. Perhaps the land use is broken down to the parcel level. Having 50 parcels as opposed to 1 adds no benefit to the model, but it adds much complexity to the geometry.

Another example is adjacent buildings. The buildings may have no gap for water to flow through, but yet the buildings are individual polygons as they have different owners. In such cases, using the ArcGIS 'dissolve' tool can greatly reduce the complexity as well as the number of polygons.



In addition, there may be some small polygons, or polygons located in areas of less interest in such datasets that could be deleted. Any polygon with an area less than say 10 sq. ft. may provide no benefit in keeping if the minimum element area is 10 sq. ft. In cases such as in the previous figure, the buildings isolated in the center of the block may provide little benefit in the scope of the analysis.

Finally consider grouping different surfaces together. For example, polygons for pavements (sidewalks) and roads may be in separate datasets, when in practice the roughness and infiltration characteristics are likely to be identical. Such datasets could be merged using the ArcGIS 'Merge' tool to reduce the number of datasets overlaid when creating a mesh.

2.5 – Restrict the background files to within the 2D Zone

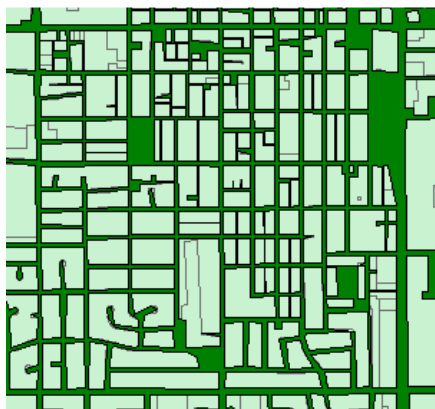
Having voids, breaklines, roughness zones, etc. outside the 2D zone does nothing for the 2D model. Restricting these datasets to within the 2D zone reduces intersections and simplifies everything. Using the ArcGIS 'clip' tool to reduce these files to the 2D extent is highly advised.

2.6 – Avoid Multi-Part Features

Always use single-part features when possible. Although ICM now supports multi-part features, multi-part features have zero benefit in ICM (unlike ArcGIS where there are other considerations). Since it is easy to get to single-part features, doing so is always recommended.

3 – Be Innovative

Sometimes thinking about the end goal and alternative solutions can be very helpful. One example applies to roughness zones. If roughness polygons are dissolved in ArcGIS, perhaps the following extremely complex geometry is created for roadways.



Instead of having this polygon be processed with a roughness representing pavement, the polygon can simply be deleted. In this case the 'default' roughness of the 2D zone

could be applied to these areas, without needing to process such a single complex polygon.

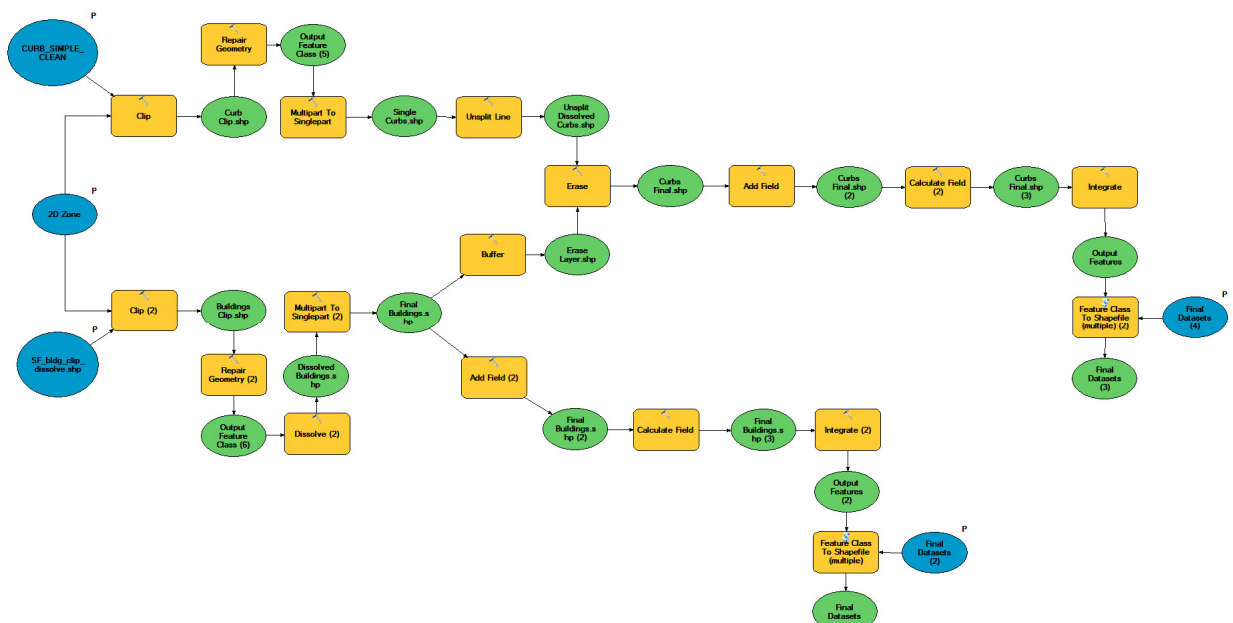
4 – Consider the Accuracy of the Elevation Model

Another thing to consider is the average LiDAR spacing (density) and the RMSE of the dataset. This can help determine the smallest element area that is ideal. If the LiDAR density is 3', having elements smaller than 10 sq. ft. will only add uncertainty to the model. Typically 1-3 times the density squared is a good minimum element area for anywhere in the system, although RMSE may impact the view of this.

The above is only for the minimum element area. There are other factors that may drive the minimum element area. Some areas being analyzed simply may not be as important so the element sizes can be larger. In flat open space, again the level of detail required may not be the same as for near important buildings. In steep areas, the element size can impact the surface volume available for ponding. Use of the terrain sensitive meshing can also help add detail where required. Refer to the ICM help file for more information on terrain sensitive meshing.

5 – Build Tools for Future Use

Below is a screenshot of a tool I made with esri ModelBuilder. I simply run my datasets through this (or a similar tool) before I ever try to bring them into ICM. This way I only have to consider 20% of the above.

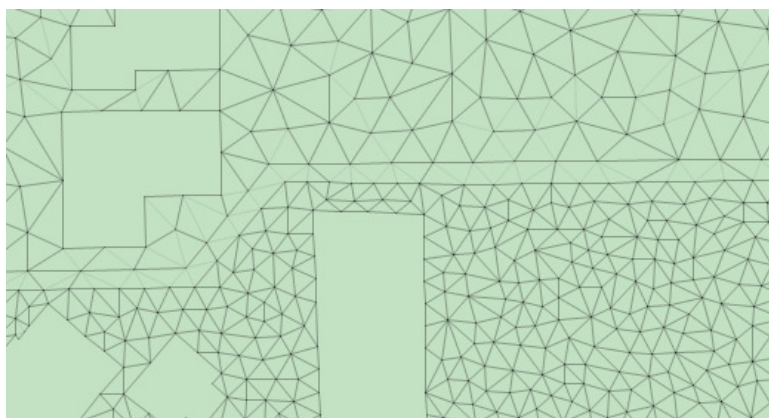


6 – Typically Exclude Zone Boundaries when Meshing

Unless there is a specific reason to enforce zone boundaries when meshing (for items such as roughness polygons and infiltration zones), excluding them is ideal. If the boundary is forced, it adds much complexity to the mesh, with likely little added benefit since the small amount of change in headloss or infiltration is likely negligible in most cases in the bigger picture. If a triangle centroid exists within the zone boundary then its parameter (roughness/infiltration etc...) will be determined by the zone properties. This is a similar approach to that taken in fixed gridded modelling software where the boundaries are not explicitly represented due to the fixed nature of the grid.

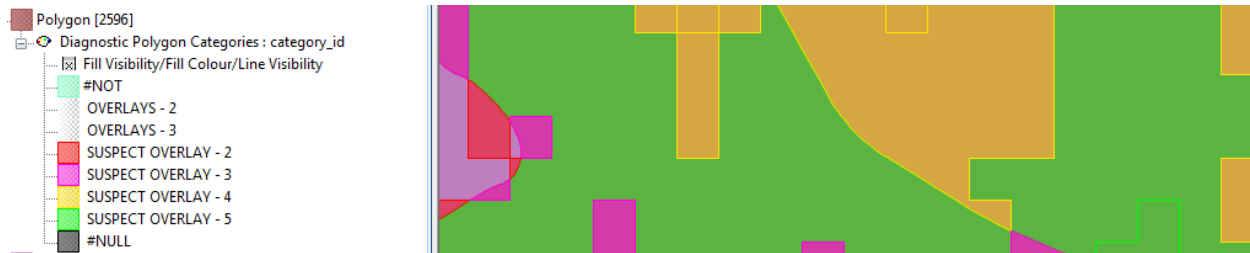
7 – Utilize Mesh Zones

Mesh zones allow the surface to be modified, and the triangle and element areas to vary from elsewhere in the 2D zone. Carefully inserting mesh zones can significantly benefit the simulation speed and create an optimal model for speed and accuracy. Remember to draw these zones with geometry in mind.



8 – Use Diagnostic Polygons

When the above have been finished, and everything is in ICM, there is a nice tool to see if there are any geometry errors. This tool is called 'create diagnostic polygons'. These are detailed in the ICM help file in more detail, but they are very useful for seeing which intersections are causing the problem. An example of themed diagnostic polygons is shown on the following page.



9 – Breakline / Porous Wall Considerations

Defined breaks can be very useful for adding detail of walls and streets. Porous walls and breaklines create barriers between both triangles and elements. When these are added to the mesh along with buildings they tend to control element size in areas with many voids, breaklines, and porous walls.

10 – After Meshing, Look for Small Elements

Small elements can really increase run time dramatically. After meshing, looking for small elements is highly recommended. The first indication of small elements is the validation warning w2285: 'Element XXX has an area (Xft2) less than 50% of the minimum element area (Xft2)'.

However this will only highlight the smallest element, there may be other small elements within the mesh (although usually the number of them is small, typically 1-10 in a mesh of 5 million). To find all small elements, first a simulation must be run, and then the mesh element area can be themed. I typically set something up like as shown below (arrows are easier to see).

Range

Continuous

☒ Use AutoRange

☐ Absolute Values

☐ Theme Nulls

Draw Style Preview

Properties

☒ Line Colour

☒ Line Visibility

☐ Line Style

☒ Line Width

☒ Arrow Length

☐ Fill Colour

☐ Fill Visibility

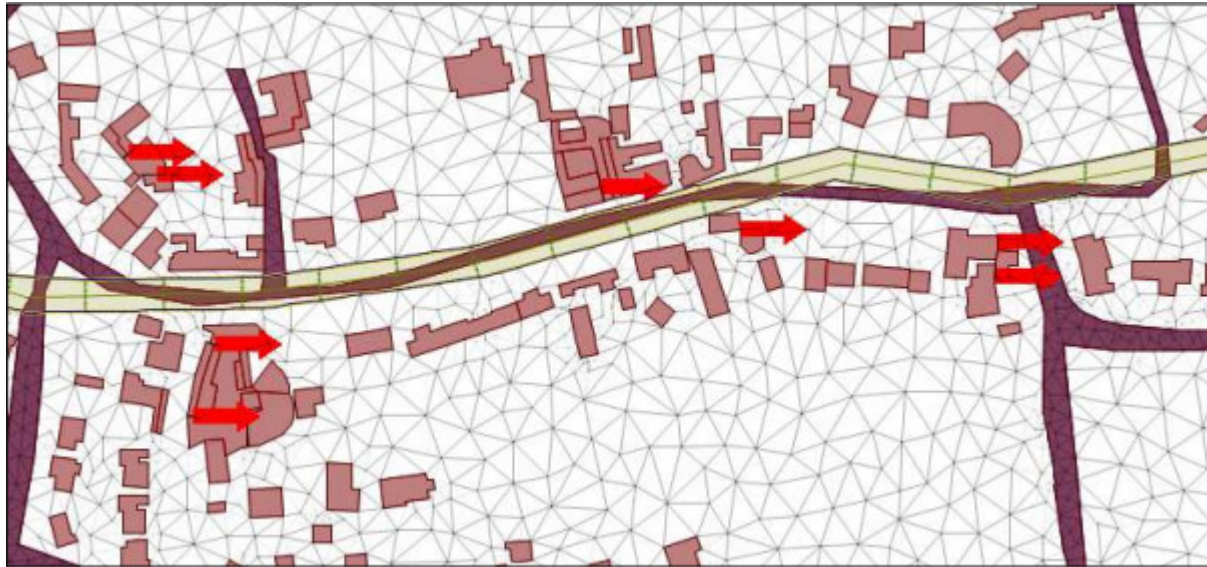
☐ Fill Style

Ranged Themes

Value count: 3

Value (ft2) [Linear]	Fix	Line Colour	Line Visibility	Line Width	Arrow Length
AutoScale	Toggle All	Auto-Theme	Auto-Theme	Auto-Theme	Auto-Theme
<	☒	Red	☒	5	100
10.0000002	☒	Orange	☒	1	100
13594.7111624	☐	Green	☒	1	100

It may be desirable to have a few sizes of elements colored. The main idea is it makes it very easy to see them since larger elements are invisible. An example is shown below.



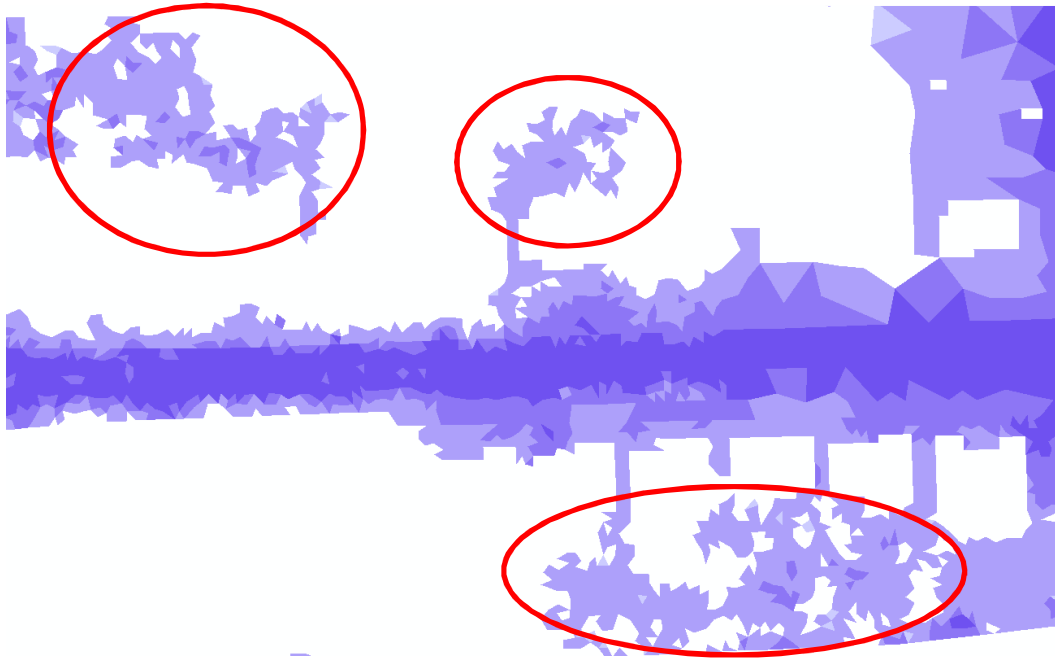
These cases are more of an art form. Sometimes the reason for small elements are obvious, sometimes they are not. The first things to look at are always geometries and the number of vertices in the background layers. There may be rare cases, but following these guidelines should generally remove 90-100% of potential issues before this theme is ever made on element area.

10 – Try a Sensitivity Analysis

From past studies, the relationship between mesh size and flooding extents can vary based on site conditions. Sometimes there is little to no difference between a coarse and fine mesh. Sometimes a coarse mesh can miss flow paths from generalizing and averaging the topography. However, sometimes coarse and fine meshes can show generally the same extent while intermediate meshes can miss the entire area. From a presentation given at the ASFPM conference in 2013, the flooding extents shown on the following pages demonstrate this (this is one site condition). Notice how the areas circled in red slowly disappear then reappear.

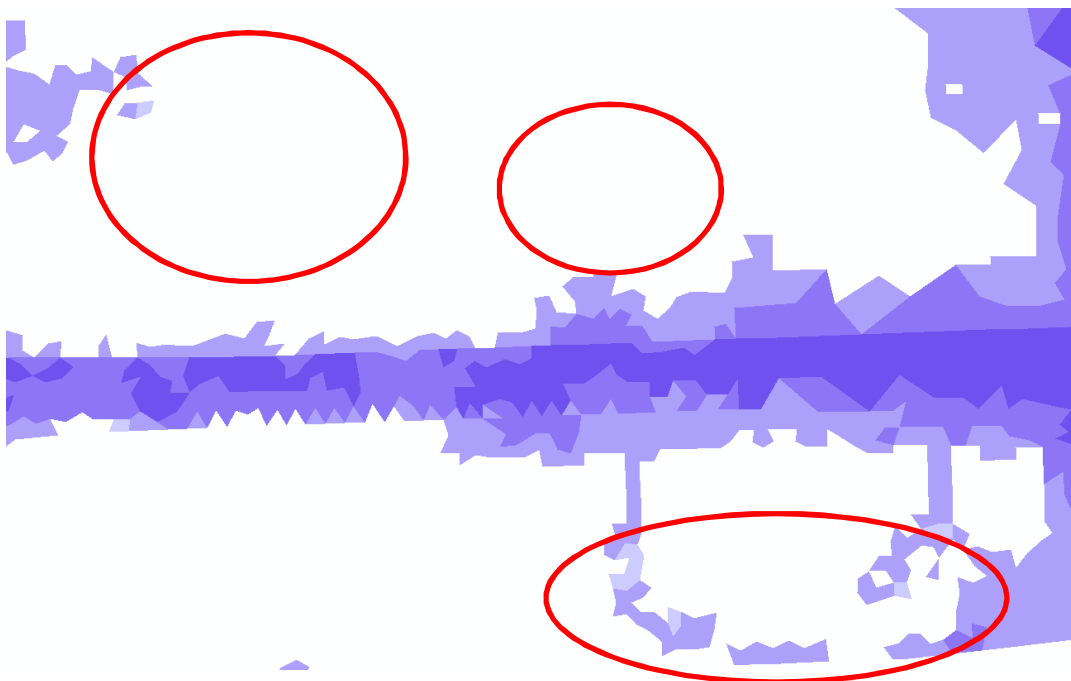
Maximum Triangle Size: 30

Minimum Element Area: 15



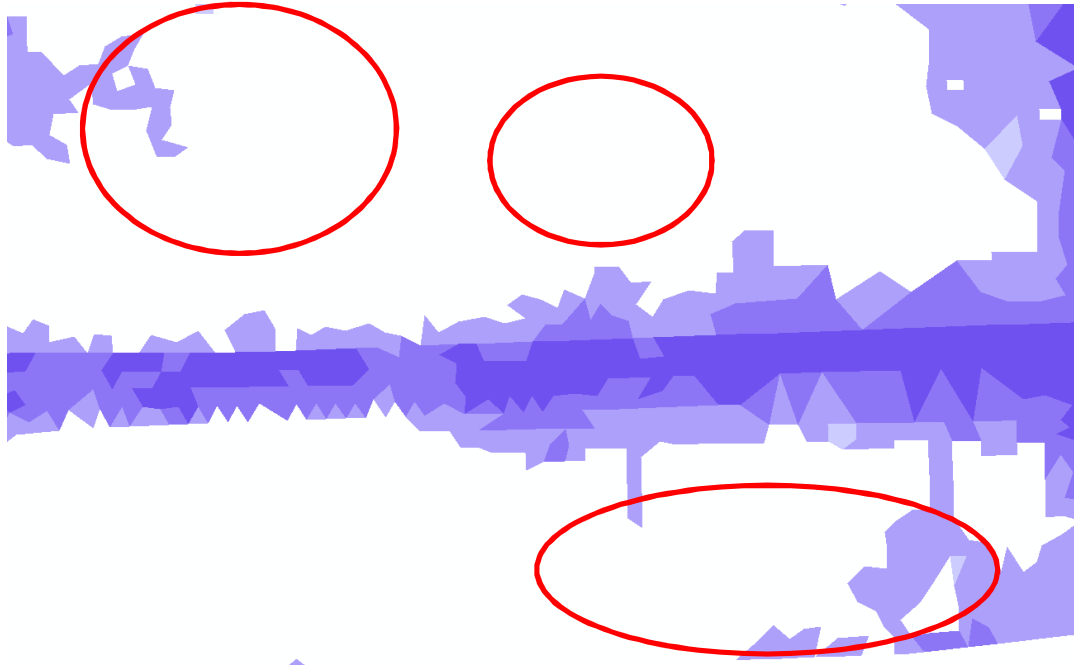
Maximum Triangle Size: 75

Minimum Element Area: 75



Maximum Triangle Size: 125

Minimum Element Area: 125



Maximum Triangle Size: 175

Minimum Element Area: 175



This happens because when elevation data is generalized there is so much going on that the size of the elements can impact flow paths. **One simple thing to do is to run a mesh with all large elements vs. one with all small elements. Then compare and use your engineering judgment to design mesh zones for an optimal 2D model. This mesh dependency is less significant to the grid dependency seen when using fixed grid schemes.**

11 – General Conclusions from Previous Analysis

The following were conclusions from the sensitivity analysis that was presented on at ASFPM in the summer of 2013:

- Resolution very important
 - Influences structure counts & ponding extents
- Global resolution less important with breaklines / areas with many voids
- Higher resolution potentially decreases ponding extents
 - Surface is better represented
 - More Storage
- Topographic surface accuracy
- Calibration data is extremely useful
- Mesh size obviously matters
 - Less in flat areas, more in varying areas
- Key Question
 - Does the modeling surface adequately represent reality?
- Utilize as high of resolution as possible
- Limiting factors
 - Computing power
 - Schedule
 - Iterations
 - Data resolution

Like all modeling, 2D modeling is often a trade-off between the level of detail that is desired and the computational effort to represent that detail.