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Arc Hydro: Stormwater Preprocessing and Analyses

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1.0 Executive Summary

Arc Hydro concept and base data model have supported stormwater analyses from the inception in 2002. Stormwater representation is combination of surface drainage and connectivity defined by built infrastructure that often redirects and alters surface drainage. Early development of Arc Hydro tools in cooperation with Southwest Florida Water Management District focused on detailed representation of such complex drainage systems based on availability of high-quality DEMs and asset inventory with ultimate goal of supporting detailed integrated hydrologic and hydraulic models operating on such systems.

The biggest problem with stormwater implementation was historically the level of detail that is needed to capture the intricacies in stormwater flow, both for the overland and built flow patterns. For a reasonable representation, high quality DEM and stormwater asset inventory is needed. Without both, attempts to build a viable stormwater system representation are not feasible.

Availability of high resolution DEMs (1m cell size or better) and better quality of stormwater infrastructure assets make automation and analysis more viable. The Arc Hydro team has supported several efforts in the past few years focusing on stormwater representation within Arc Hydro context focusing on representation of general flow patterns as opposed to detailed flow modeling. In a nutshell, the focus is on establishing the stormwater system representation that allows the user to perform basic upstream (watershed area) and downstream (flow path) analysis from any point in the landscape based on minimal stormwater and terrain informational content.

This document describes the implementation of stormwater representation within Arc Hydro framework based on these more general requirements and additional Arc Hydro tools and workflows that have been developed to handle stormwater special cases.

Document is organized around a normal processing workflow:

1. Data review and organization. In this step, the local data are organized into a consistent database structure containing only the pertinent data for the analyses.
2. Data evaluation and cleanup. Problems in original analytical data are identified and fixed (automatically and/or manually).
3. Data preprocessing. Establishing the necessary Arc Hydro analytical vector and raster infrastructure.
4. Analyses. Running two specific stormwater tools.
5. Tools and process automation. Location of the tools and workflow overview.
6. Database design. Basic description of layers created during data preprocessing.

The initial version of Arc Hydro software with all the stormwater tools implemented and documented here are versions past 1/4/2018 build (initially 10.6.0.27; 10.5.0.104; 10.4.0.49).

1.1 Document history

Table 1. Document Revision History

Version	Description	Date
1	First Version (CD)	10/03/2017
2	Additional review step after Create Sink Structure (CD)	11/10/2017
3	Complete update and rewrite (DD & CD). Inclusion of latest tools and updated workflows.	1/11/2019

2.0 Data review and organization

When establishing initial stormwater analytical dataset (network), the key is to identify stormwater infrastructure that participates in the water collection and conveyance. This includes:

1. Stormwater inlets that allow the surface water to enter the pipe system.
2. Pipe system that conveys water but does not collect it.
3. Open channel system that both collects and conveys water.

Often, stormwater infrastructure is not organized from this perspective. For example, a typical manhole feature class can include both manholes that are completely covered and do not allow water to enter the stormwater system as well as manholes with grated cover that do allow entry of the surface water. Similarly, inlet features that allow water to enter the system can be stored in multiple feature classes.

One of the first steps in building the representative Arc Hydro stormwater infrastructure is to identify which feature types play the three identified roles in Arc Hydro and organize those features into the three specific feature classes (part of the same feature dataset) for further use. This is performed to streamline the use of the tools and clearly separate data roles. The original infrastructure data will also be augmented during the terrain processing, so keeping the original infrastructure data separated from the “analysis” data is an important design consideration. It is important to note that this “duplicates” some of the infrastructure data, so appropriate data maintenance workflows need to put in place so that the data are in “sync” (through well-defined data editing and update procedures).

Initial infrastructure data are organized into three feature classes (and one optional one):

1. HydroJunction – combined inlet features.
2. Pipe – combined closed conveyance features.
3. StreamOrig – combined open conveyance features.
4. PipeOutlet (optional) – known structures that let water onto the surface

Note that at this point a single database design (attribute) structure was not enforced for these three feature classes – the attributes from individual contributing feature classes can be “combined” when the features are merged. This generates an inefficient data model that can be streamlined later. Once the improved data model is established, when moving original infrastructure data into this model a proper attribute transformation/population should be performed. The most important aspect of this attribute transformation is inclusion of key identifier that allows for linking of the data between the original infrastructure database and the Arc Hydro analytical geodatabase.

Naming of input and output layers (as presented in this document) is not critical – user can use their own naming conventions and specify those names when running the tools as long they are used consistently. Maintaining consistent and default names helps though with process quality control and tool use (as you do not have to explicitly specify inputs and outputs but just accept defaults when they are provided).

3.0 Data evaluation and cleanup

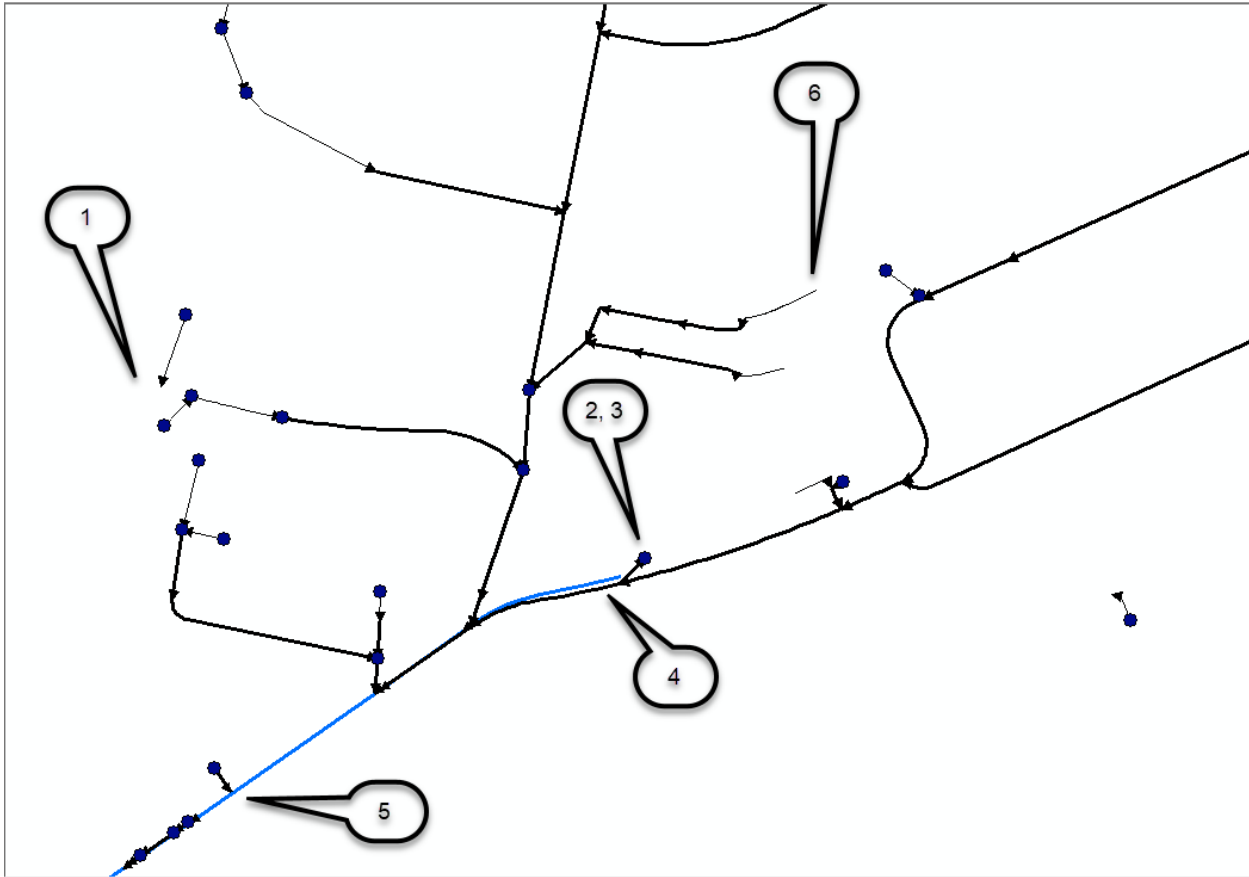
This section presents basic discussion of data quality requirements and some of the methods and tools for their evaluation and adjustments. While the requirements are not complicated, getting the typical data to conform to those requirements will represent the bulk of the effort in stormwater implementation and will require an iterative data development and review process. Experiences from this exercise should be incorporated in the data maintenance and collection workflows so that new data comply with the requirements and do not require additional adjustments.

Note that significant effort can go into snapping and orienting open channels, pipes, and inlets into a topologically “clean” dataset that can be used for tracing after the initial data are imported into the three basic stormwater feature classes. Even larger effort might be needed if complete infrastructure data are missing and fieldwork must be performed to collect them. The level of effort will also be end goal driven. For example, if the end requirement is to establish drainage areas draining to outfalls from 48” pipes or higher as opposed to hydraulic modeling of the full system for design purposes, a different data content design/evaluation/augmentation strategy can be implemented.

There are three key elements that must be correctly represented in the final stormwater system:

1. Feature content. Line and point features representing built infrastructure need to be in proper places (fill in the gap in missing features).
2. Connectivity.
 - a. Inlets need to be snapped on the from node of a pipe.
 - b. Pipes and streams need to be snapped onto each other.
3. Directionality. Pipes and streams need to be oriented “downstream” (for predominant flow direction in the system – disregard potential surcharging of the system).

Figure 1 presents some of the issues with the typical dataset. Thin black lines represent lateral pipes, thick black lines represent main pipes, blue lines represent open channels/streams, points represent inlets, and arrows are placed at the downstream end of the linear features indicating the direction of “flow”.



1. Potential lack of connectivity. Lateral is not connected to anything. This is not necessarily a problem if the pipe outlet is emerging onto the surface but is a problem if this is a completely underground pipe.
2. Incorrect direction of flow in the pipe.
3. Inlet placed at the outlet of the pipe.
4. Potentially misaligned pipe and open channel feature.
5. Simple connectivity not maintained between linear features (blue line should be split at the location of the confluence).
6. Potential lack of inlet at the top of the pipe. This is not necessarily a problem if the pipe inlet is at the surface but is a problem if this is a completely underground pipe.

Any standard data evaluation and editing tools can be used to build a topologically clean dataset. Ideally, these requirements would be introduced early in the data development cycle, so that the asset data brought into this system do not have “problems”. Following is a summary of types of issues addressed in this document (a 1m cell size DEM is assumed to be available to support the analysis, but this is not a “hard” requirement).

1. Remove all inlets that are not connected to a pipe (unless the inlet represents a known terrain sink).
2. Add inlets to all head pipes that do not already have an inlet.

3. Create outlets at stream ends and add them to inlets (they will be modeled as sinks). If disconnected streams are to be connected to the rest of the network by overland connectors, do not add the created stream outlets to inlets.
4. Create surface outlets at all pipe outlets (NDID = -1) that do not already have an outlet (isolated pipes will be connected to the network by overland connectors).
5. Check all inlets that are 3m from a stream. Manually adjust if necessary (no manual adjustment was done in the example).
6. Checks all inlets that are 3m from other inlets. Manually adjust if necessary (no manual adjustment was done in the example).
7. Delete all explicit outlets that are not connected to a pipe.
8. Build a network from pipes and streams and check for glaring gaps in connectivity and directionality. Note that additional connectivity will be established later on by creating the overland connectors that will be added as “streams”.

3.1 Initial database organization

Standard Arc Hydro database/project organization is used.

1. Select projection system to use in the project (usually based on DEM). Do not use unprojected coordinate system. Both raster and vector data must be in the same coordinate system, so if the original data are not (or are unprojected), decide which system to use based on broader project requirements.
2. A new folder is created to store the project data and mxd (project folder).
3. A subfolder “Layers” is created in the project folder. This will be used to store all the raster data.
4. A new geodatabase is created in the project folder. A feature dataset called “Layers” is created using selected spatial reference. The following data are imported from the original infrastructure geodatabase into the feature dataset:
 - a. Original open channel/surface drainage layers are consolidated and named “StreamOrig”.
 - b. Original pipe layers are consolidated and named “Pipe”.
 - c. Original inlet layers are consolidated and named “HydroJunction”.
5. DEM is clipped to rough outline (watershed) around the vector data and is named “DEMAOI”. It is stored in Esri GRID format and stored in the “Layers” folder under the parent folder. If necessary, it is projected in the project’s projection and if later used for landscape characterization, vertical units are adjusted to match the horizontal units.
6. A new ArcMap map is opened. The project DEM is added to it first, BEFORE any other layer (or base map).
7. The project is saved with the same name given to the geodatabase (without gdb extension).
8. Additional vector and base data can be added, and the project saved.

3.2 Data cleanup

A document focusing on typical stormwater data issues and fixes will be presented separately. This section presents a general overview of the process.

3.2.1 Checking for glaring issues in linear features

This is a quality control step that should be performed early on when the data are received, and their quality is uncertain. The final geometric network representing full stormwater system will be built later on after the overland connectors are built (if necessary), so this is performed here to do a “coarse” check on the stream and pipe data before detailed processing is started.

3.2.1.1 Build a QC network

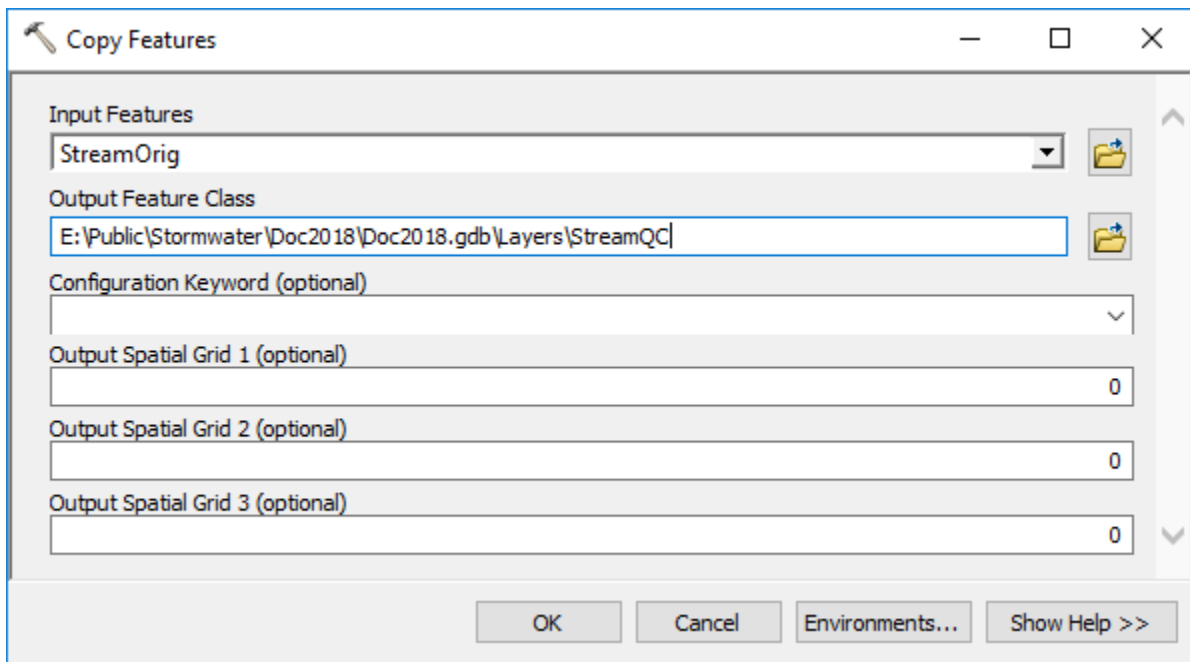
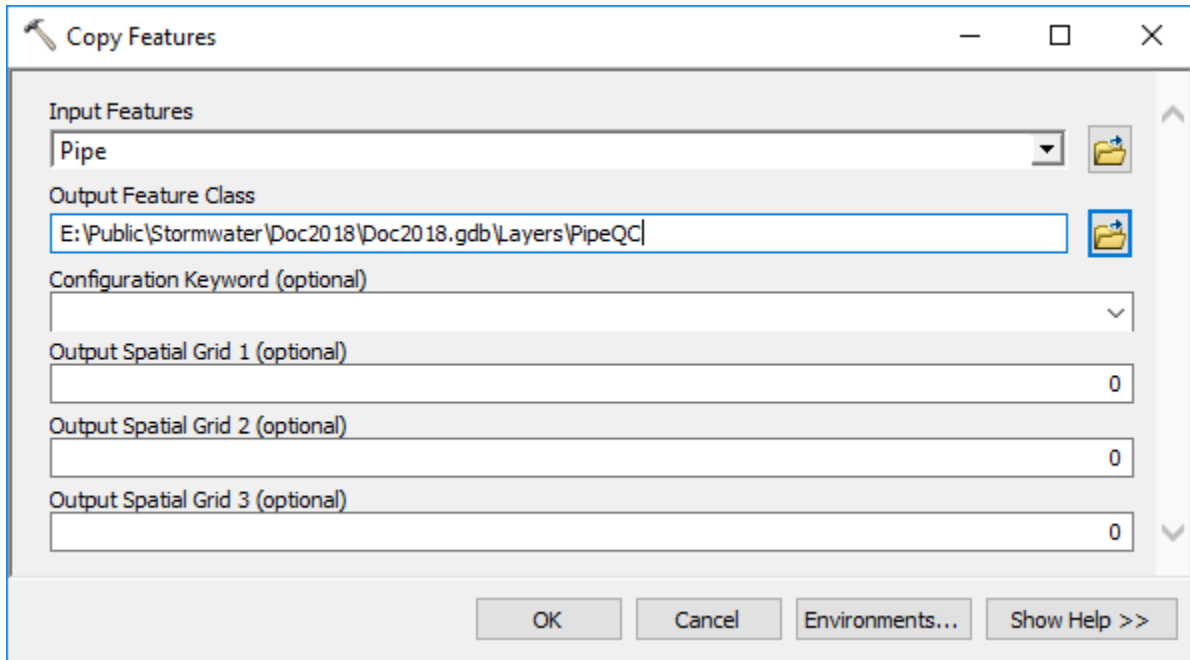
Note that building geometric network using snapping and simple features will modify geometry of the underlying input data. These changes CANNOT be reversed. It is strongly suggested that this operation is performed on the copy of the data until all the quality issues are resolved.

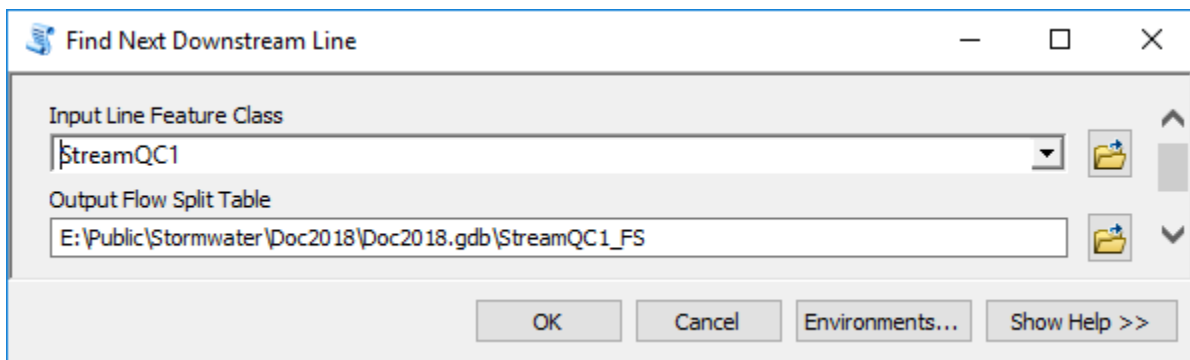
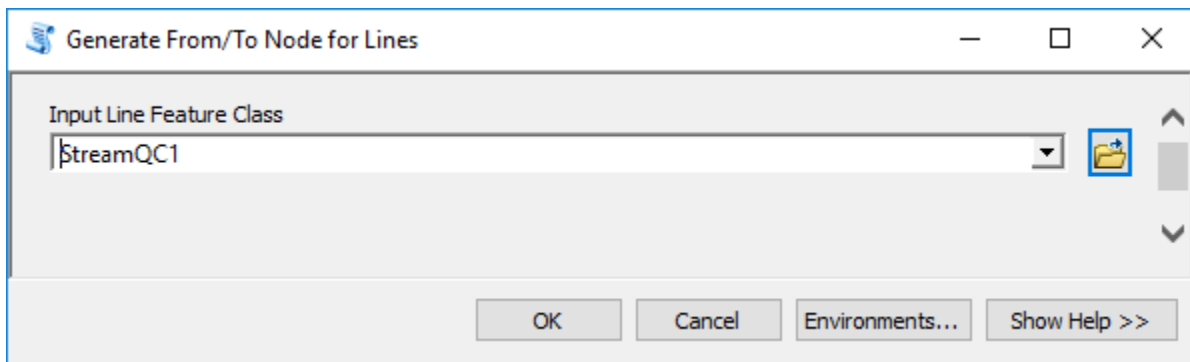
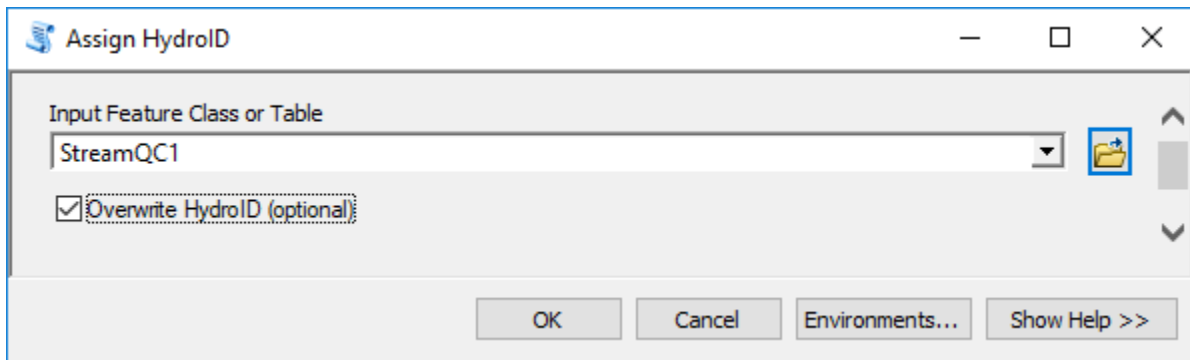
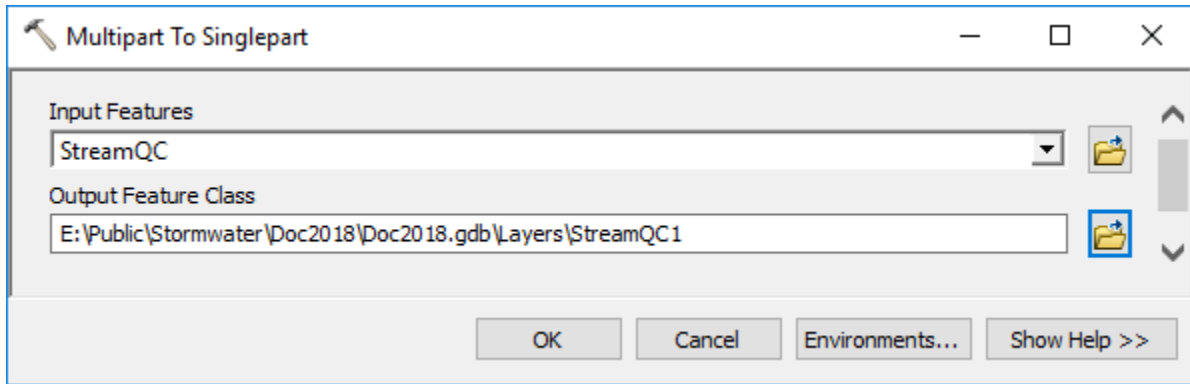
To build a good geometric network, initial data screening should be performed to eliminate known issues before building the network. Some of the more glaring issues include:

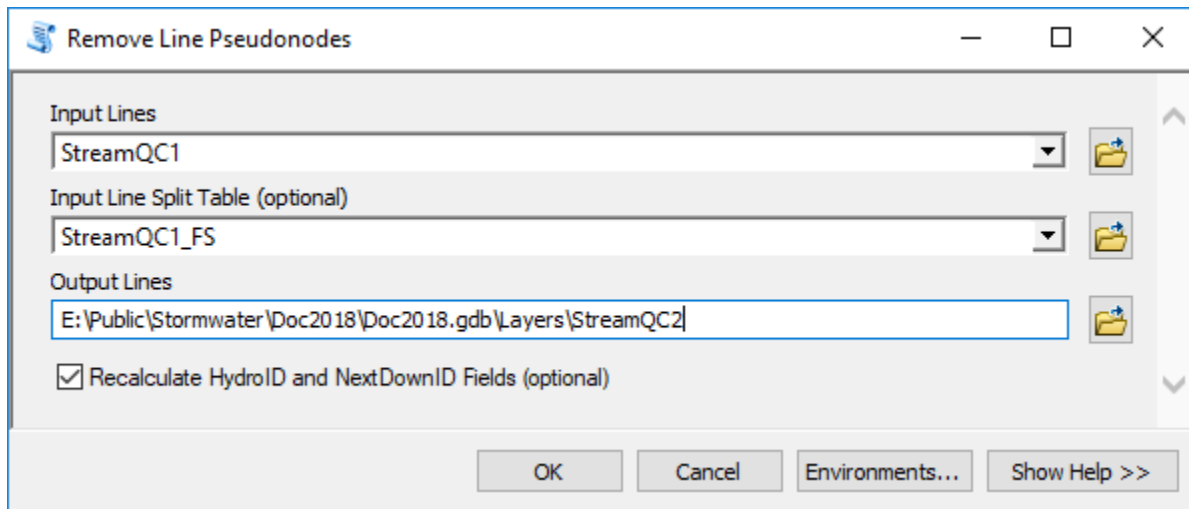
1. 0 (or very short) length features.
2. Multipart features.
3. Coincident/overlapping/duplicate features.

These issues should be reviewed and fixed using any editing means. The following steps are presented here as an example of what typical operations might include but are not exhaustive by any means and do not include any manual editing that might be required in a production situation. They include a mix of standard and Arc Hydro geoprocessing tools.

1. Multipart to singlepart conversion.
2. Removing of pseudonodes.
3. Splitting and connecting pipes and streams.







After running this tool, it is possible that fewer but longer stream segments remain. 0.1m snapping tolerance will be used when building the network to accommodate potential lack of enabled snapping when features were originally created. If snapping was enabled, network snapping tolerance can be skipped (0 by default).

Create Geometric Network

Feature Dataset

Geometric Network Name

Feature Classes

Feature Class Name	Role	Sources and Sinks
HydroJunction	SIMPLE_JUNCTION	NO
PipeQC	SIMPLE_EDGE	NO
StreamQC2	SIMPLE_EDGE	NO

Snap Tolerance (optional)

Weights (optional)

Weight Name	Type	Bitgate Size

Weight Associations (optional)

Feature Class Name	Field	Weight Name

Advanced Options

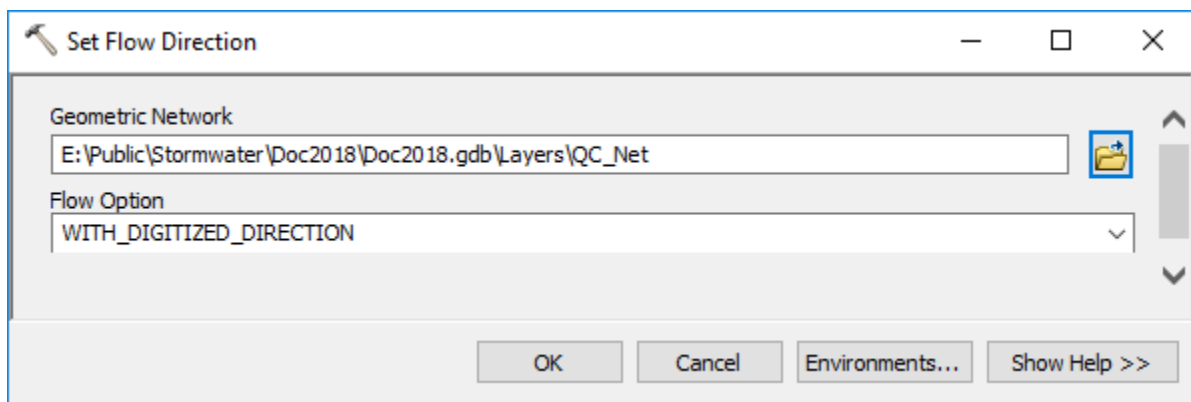
OK Cancel Environments... Show Help >>

Review the network build error table. Build error (ErrorType) 16 indicates that some junctions were not snapped to edges. That is an expected error that will be handled later.

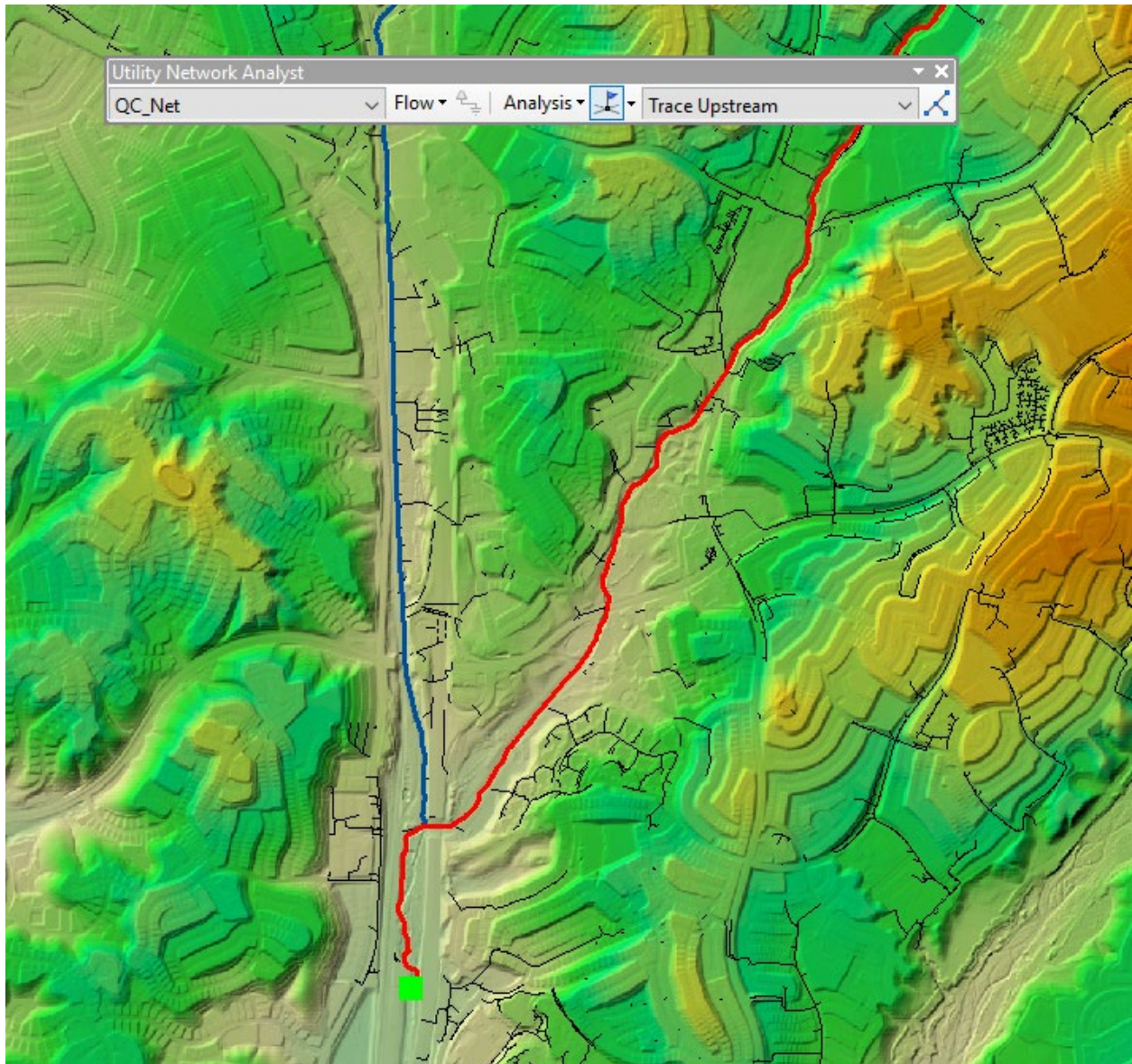
Review location of default junctions (QC_Net_Junctions). You will notice that they are placed at the ends of all the lines, but not at their intersections, indicating that the pipes are not splitting (connecting to) the streams.



You can verify that by tracing.

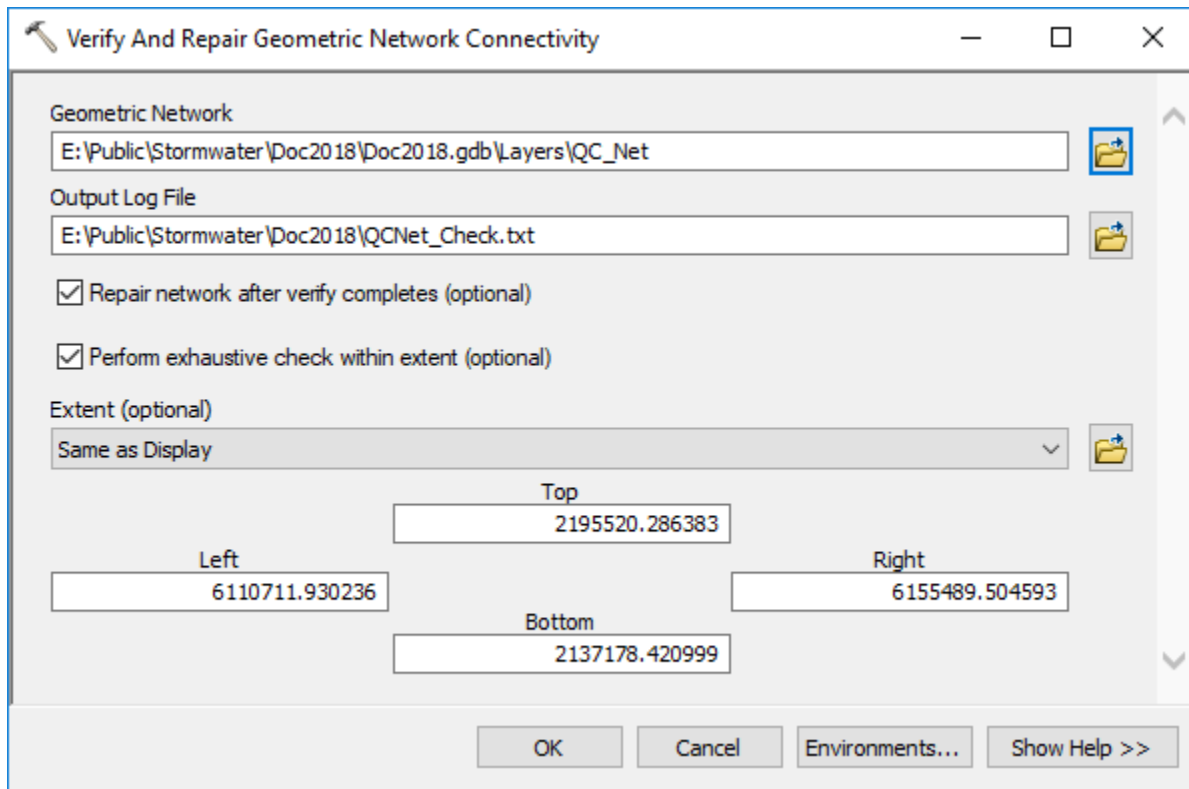


Place the network flag at the most downstream stream segment and trace upstream.



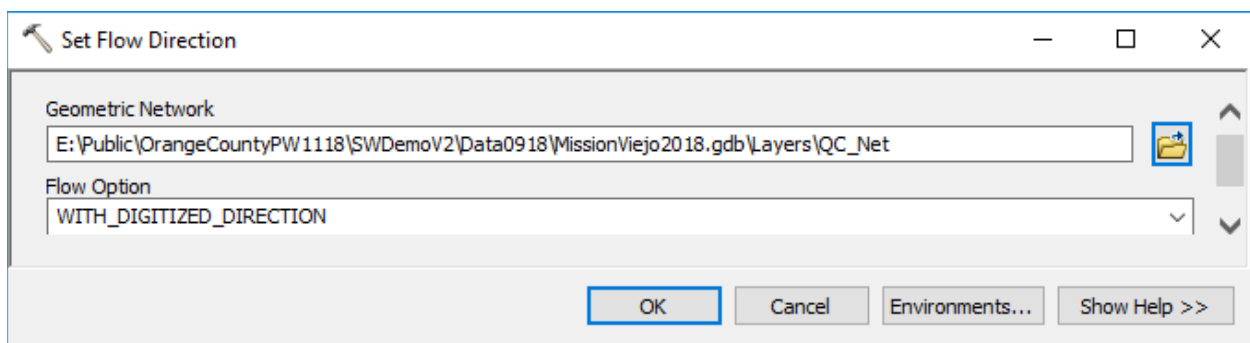
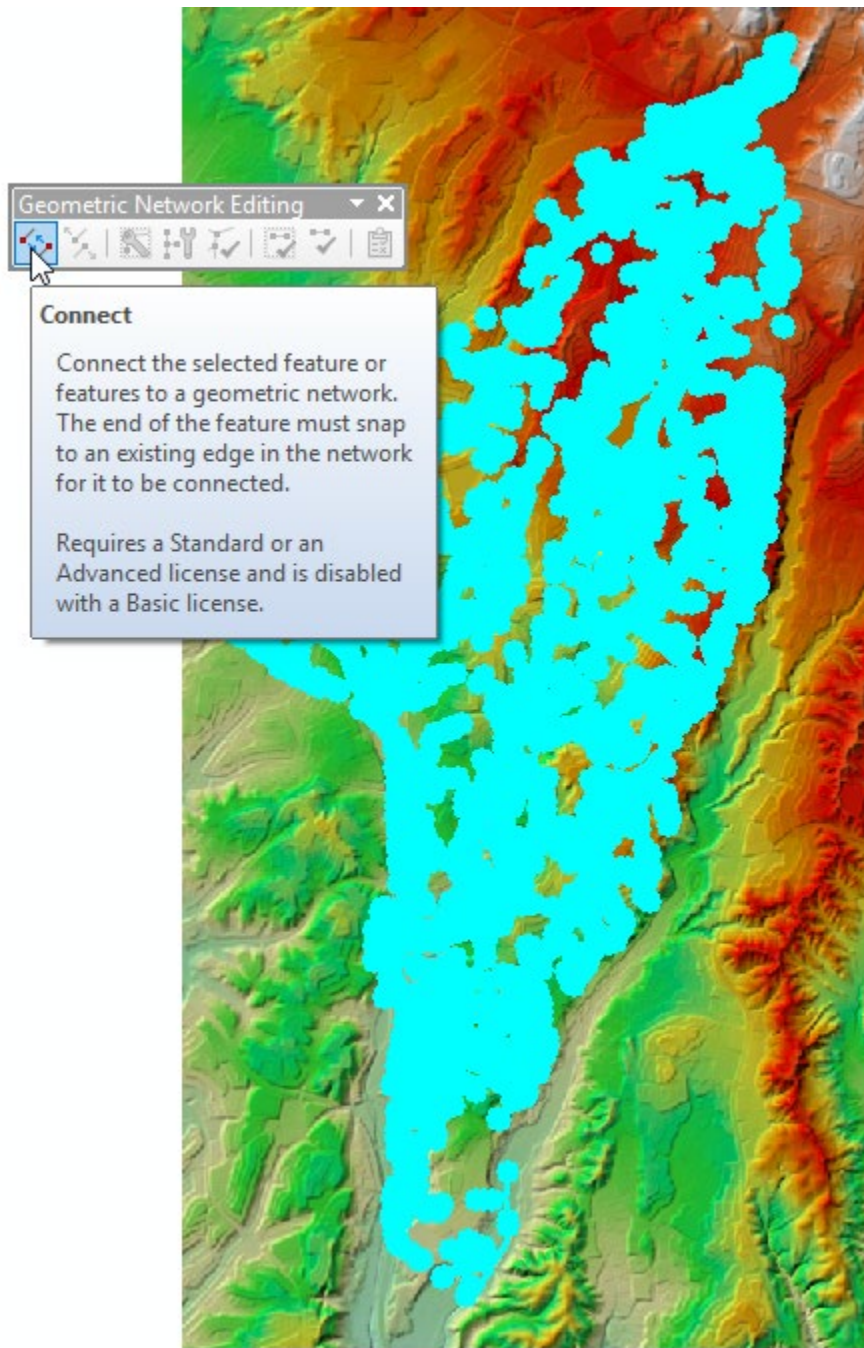
Only the main stem of the stream is highlighted (red) indicating that the pipes are not connected to the stream. This is because we built the network using simple edges that require the features to be directly snapped at end nodes before the trace will go through them.

Zoom out to the full extent of the data.



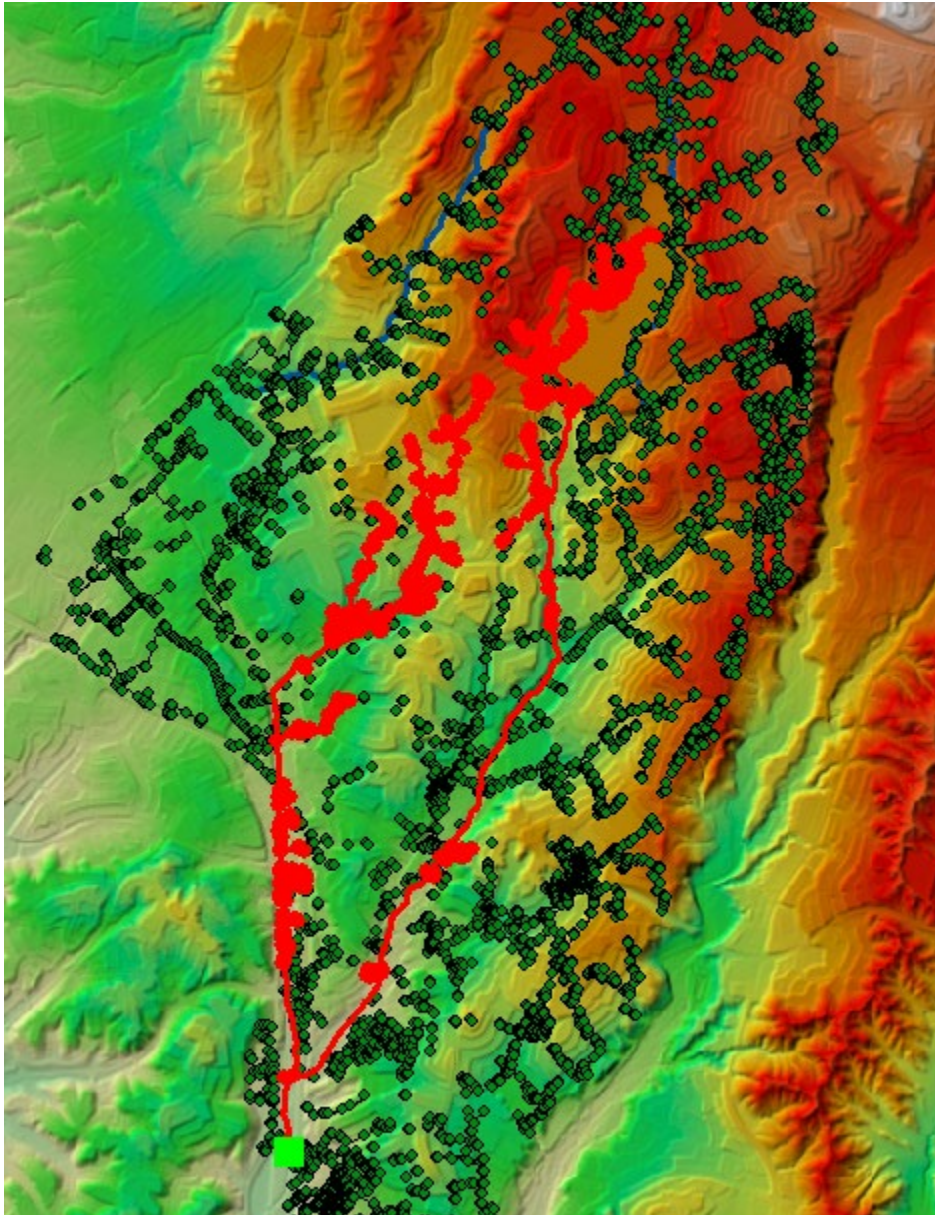
Review the report and fix any additional problems that might be reported. In order to intersect the two line feature classes that make the network, perform the following steps:

1. Add to the map the “Editor” toolbar.
2. Open the “Geometric Network Editing” toolbar (Editor → Editor -> More Editing Tools).
3. Start editing.
4. Select ALL features that participate in the GN.
5. Run the “Connect” tool from the Geometric Network Editing toolbar. This tool could run for several minutes depending on the number of features in the network.
6. Review the results. You will notice a significant number of new streams and pipes. Notice that this can also introduce undesired splits – for example, if the pipe is going over or under the stream, it should not be split as that will indicate that it flows into the stream. If there are places like that, the edits should be done locally and not globally. Also, note that if there is not a vertex on the two lines to intersect/split, they will not be split and connected, so the results of automated “Connect” vary greatly depending on the underlying data structure. While the most tedious, the best approach would be to review each case of missing connection individually and perform the edits manually.
7. Save edits.
8. Stop editing.
9. Unselect everything.
10. **Rerun flow direction assignment on the network** (for newly created features).



3.2.1.2 Use network for testing

Place a network “flag” on points of interest and trace upstream. This can be done interactively using the Utility Network Analyst toolbar or through geometric network GP tools. Typical points of interest should include major outfalls. Lack of connectivity indicates “missing” elements in the system (missing pipe/stream segment, elements not properly snapped, and wrong digitized direction). After the above fixes to the data, the same outlet point shows much larger connectivity and includes many pipe sub-systems contributing to the open channel flow.



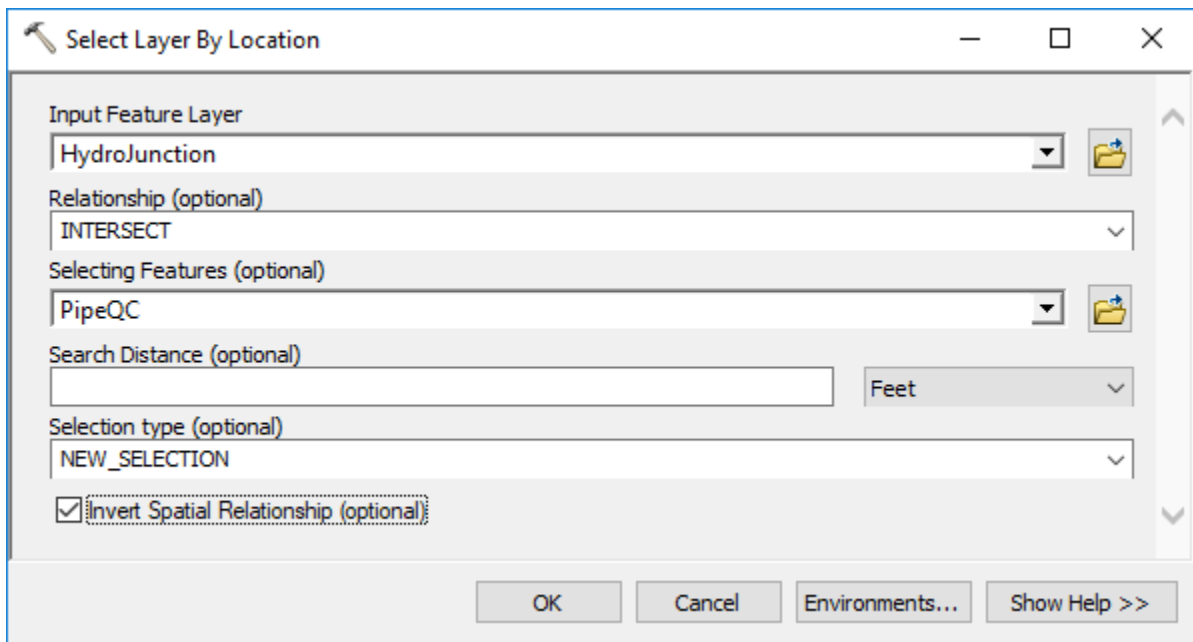
Note that later in the process we will generate “overland flow connectors” that will connect isolated subsystems into a connected system based on DEM-derived connectivity.

Once the initial network analyses are done, you can delete the geometric network. Note that will also delete the default junction feature class (end points of pipes and streams), so you should copy them into a different feature class (before deleting the GN) in case you think you might need those features later. In our workflow, they are not needed and are not saved.

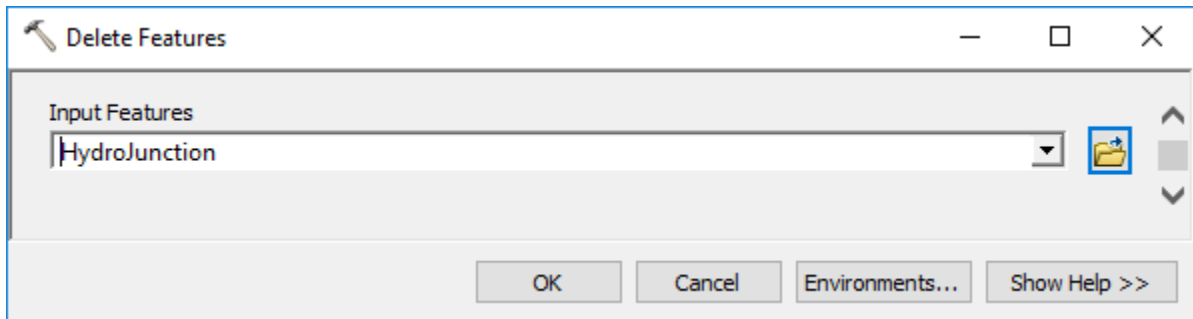
In the further processing, the edited linear features will be used.

3.2.2 Review and remove all inlets that are not connected to a pipe

Unconnected inlets will generate “sinks” that are not connected to anything and as a consequence that will exclude area contributing to those features to contribute anywhere in the system. That IS possible, so such inlets should not be deleted. In most cases though, these indicate missing pipe information.



In a typical data scenario, several inlet features might not be connected to a pipe. Note that some of the inlets are probably in a right place, but the connection pipes are missing. These instances should be investigated and fixed.

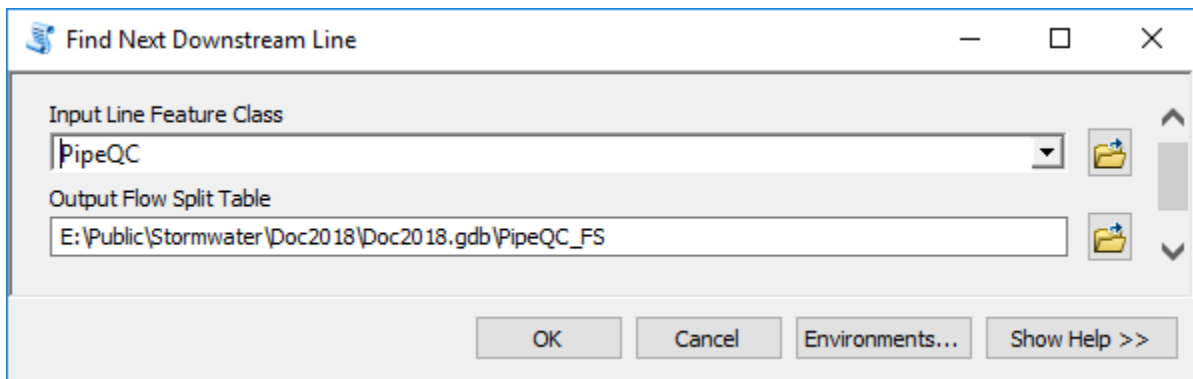
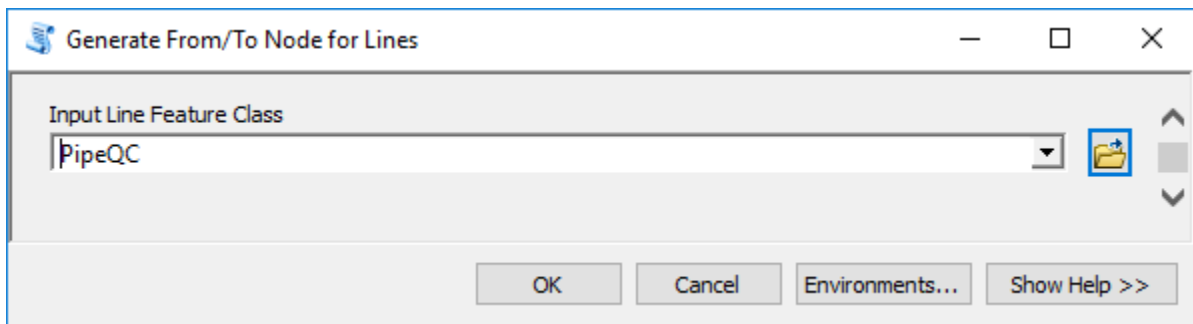
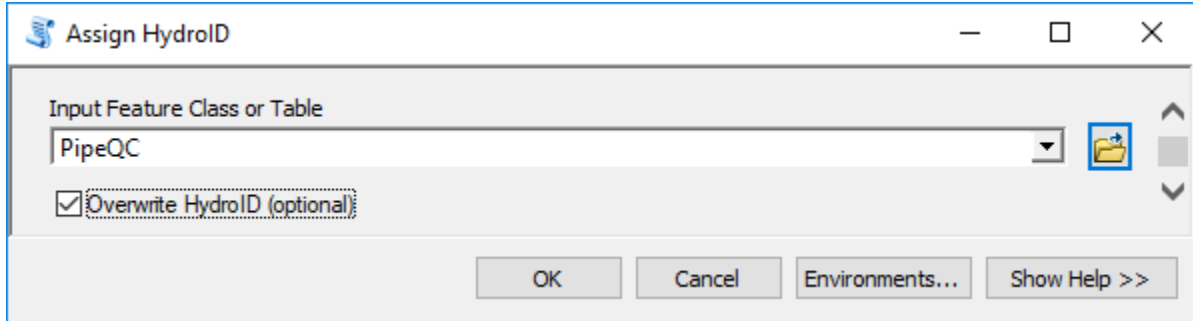


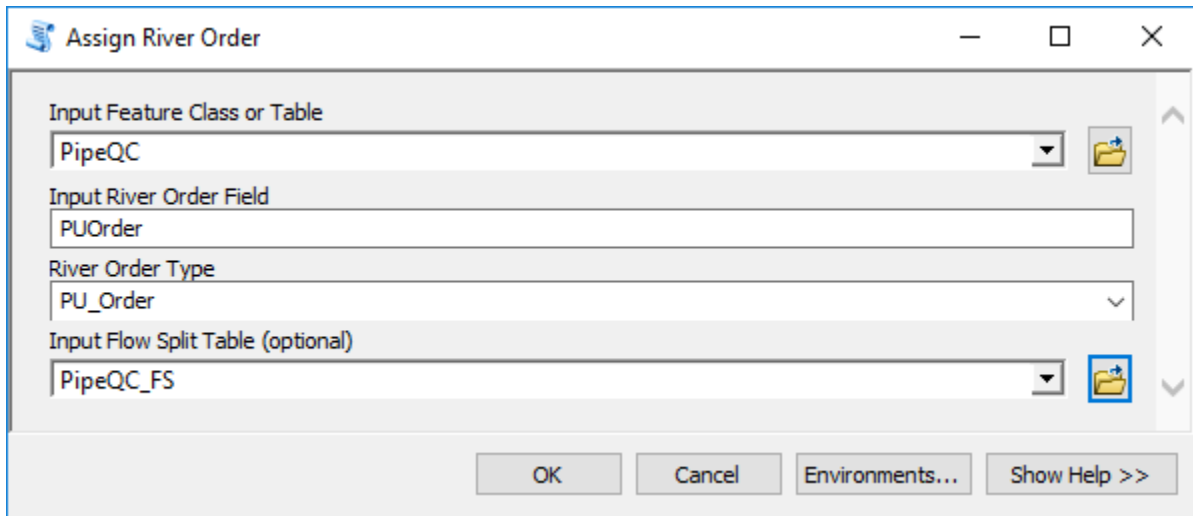
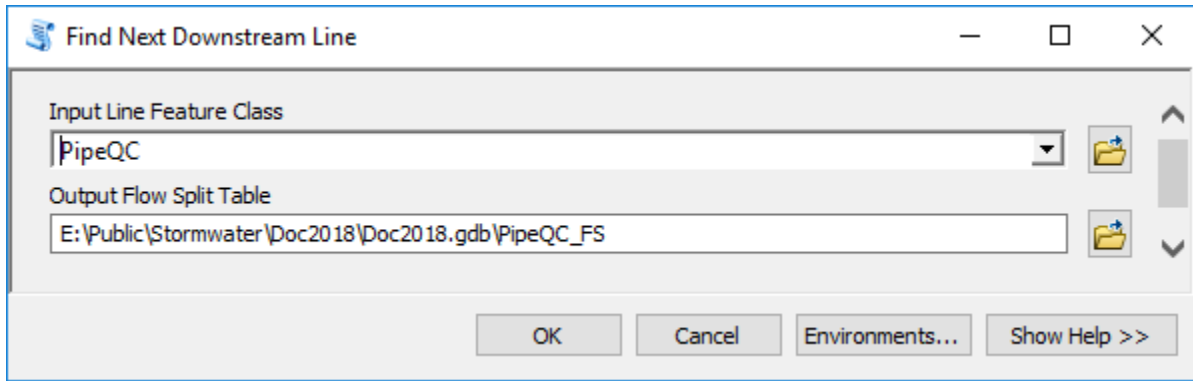
3.2.3 Add inlets to all head pipes that do not already have an inlet

This is a data augmentation step – if not performed, these pipes will not carry any flow (which might be correct, but makes them redundant in the analytical system).

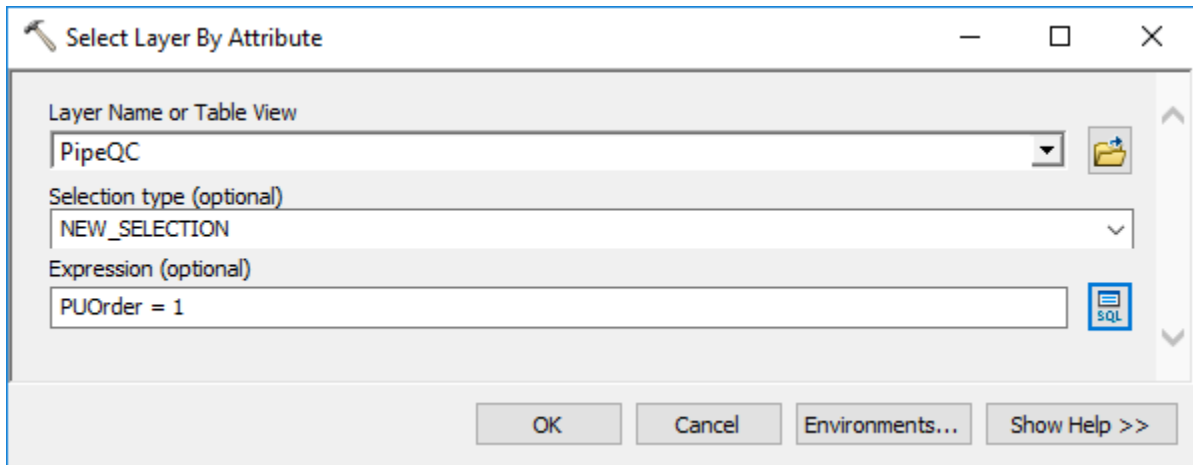
3.2.3.1 Characterize pipes

Assigning HydroID is needed only if not already performed as part of other data processing.

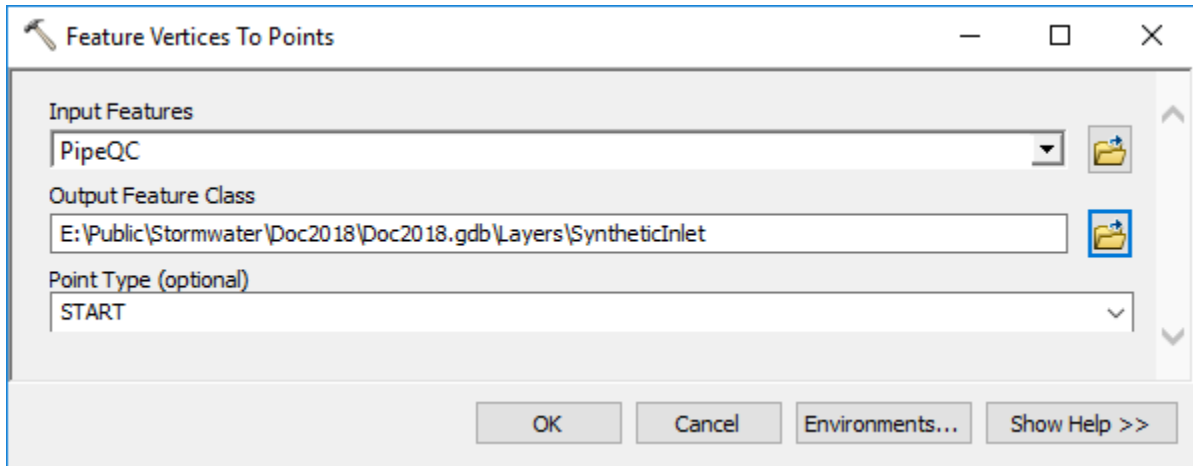




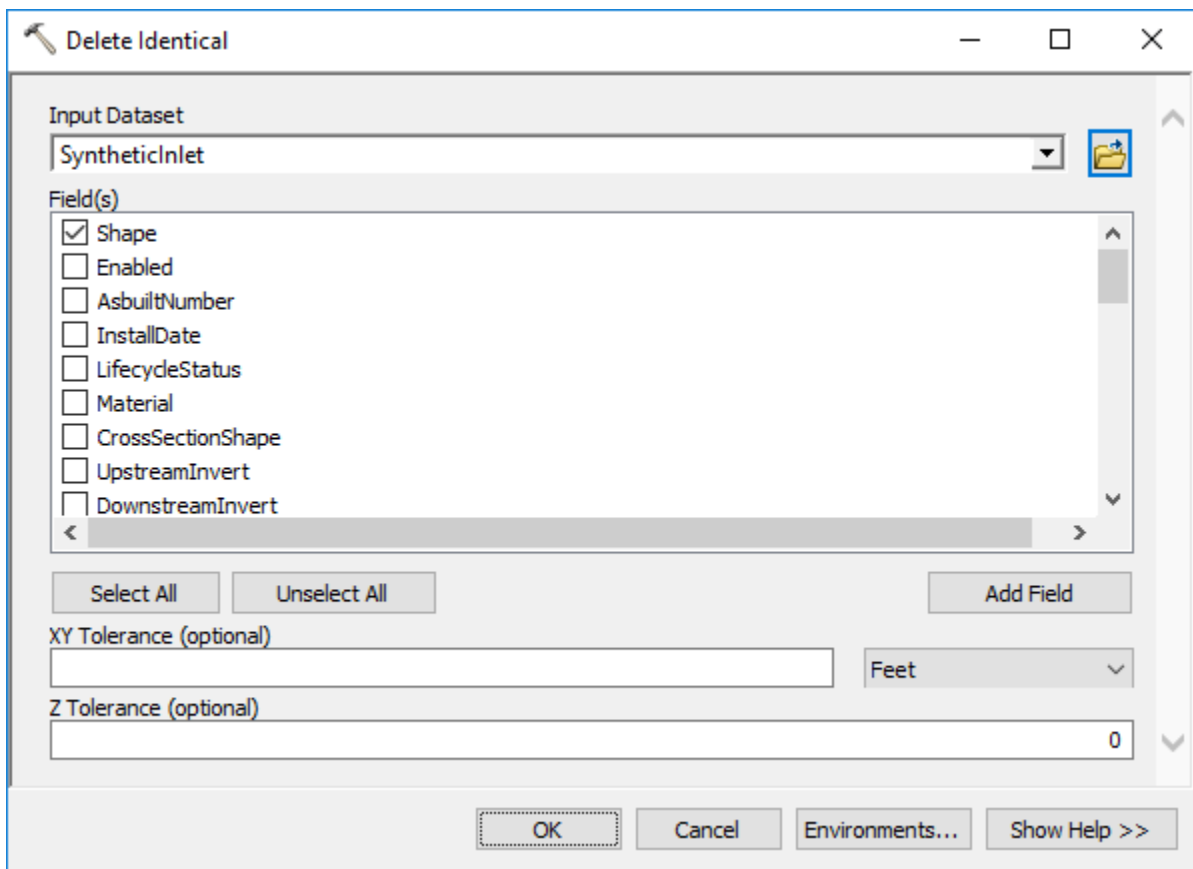
3.2.3.2 Select head pipes



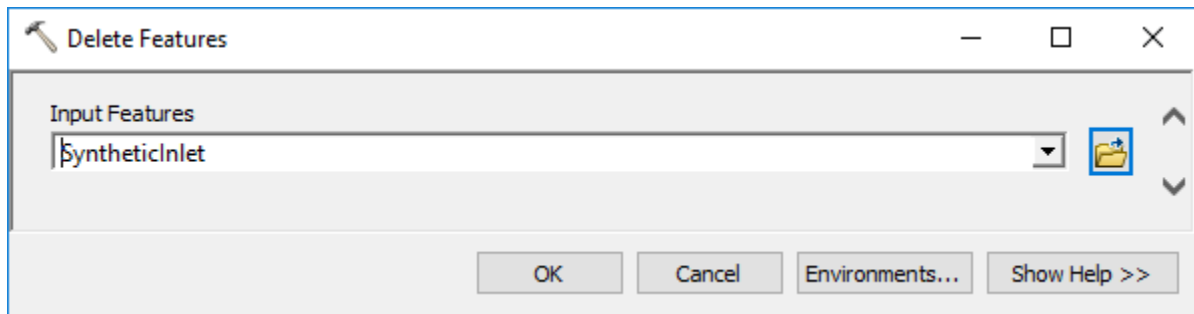
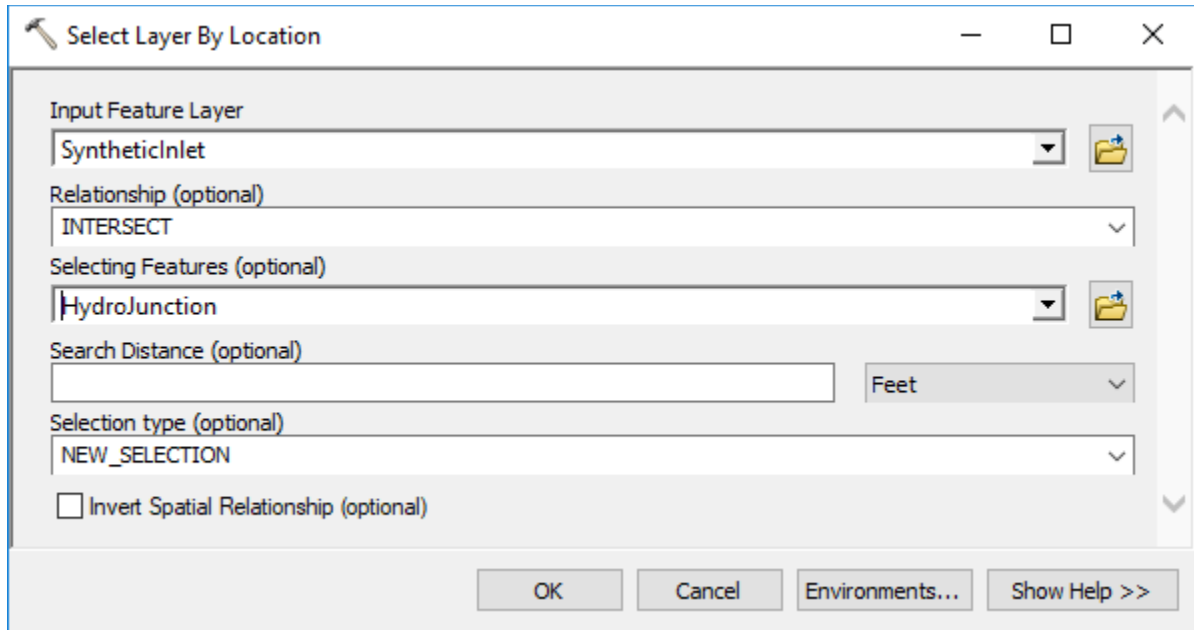
3.2.3.3 Create synthetic inlets



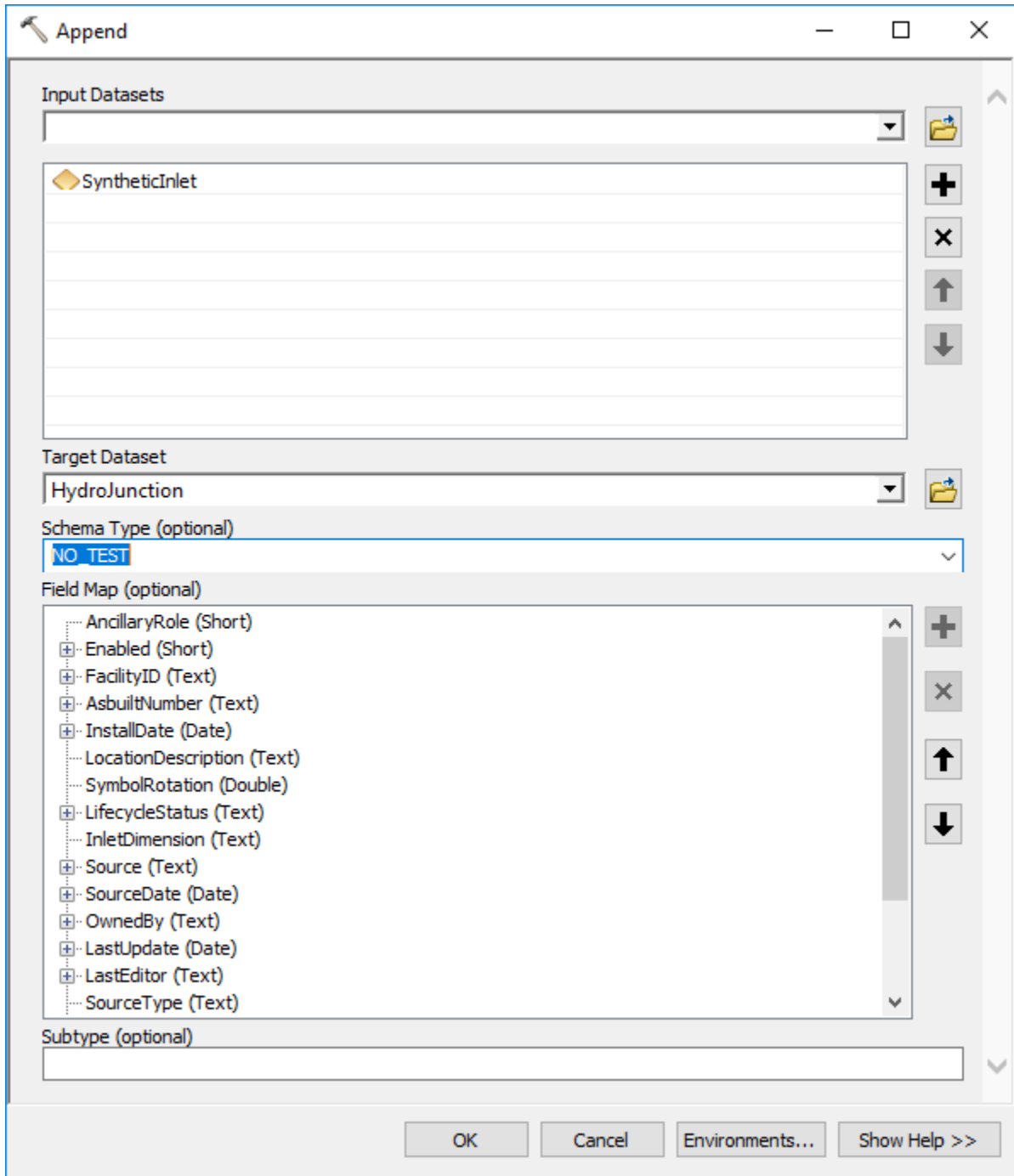
It is possible to generate coincident inlet features, so they will be deleted. These are cases where two pipes have the same origination point. In a normal data QC workflow, these cases should be identified (you can use tool “Find Identical” for that), reviewed, and edited manually if necessary.



Synthetic inlet points can already have inlet structures associated with them and are thus not needed. They will be deleted.



3.2.3.4 Append synthetic inlets to HydroJunction

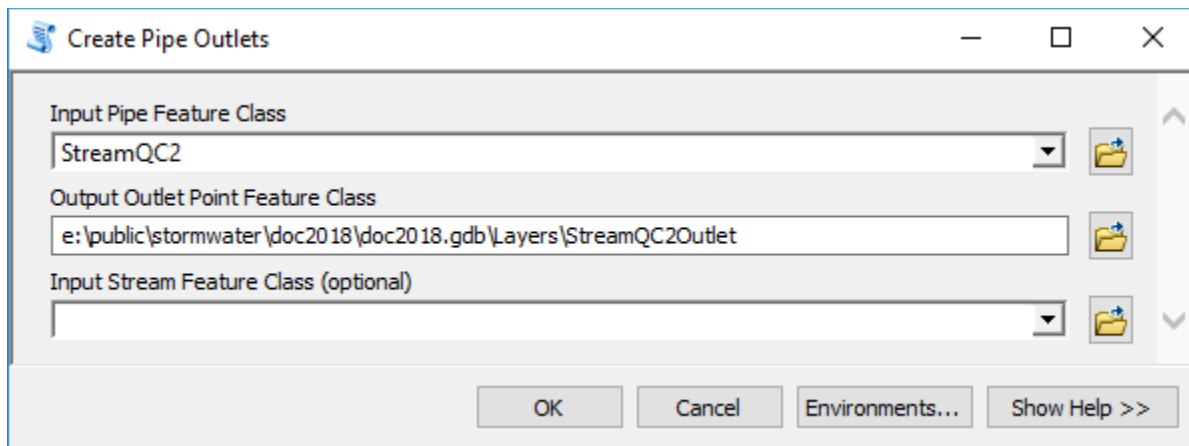


3.2.4 Create stream outlets and add them to HydroJunction

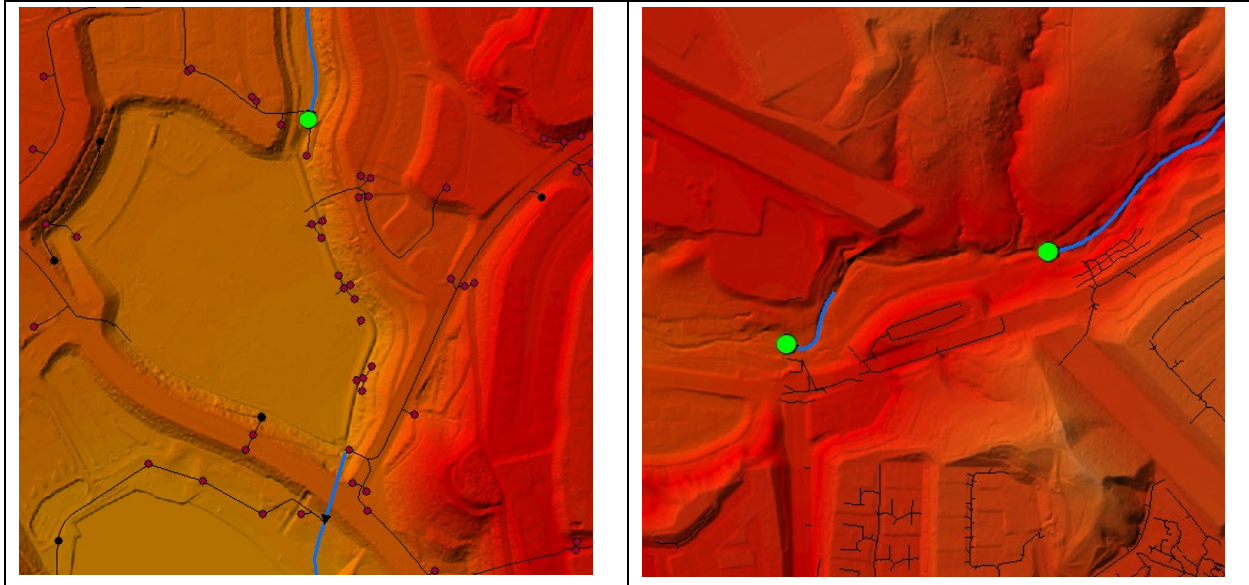
Stream outlets (end points of streams not connected to other streams) can happen in three circumstances:

1. Error in data – the connecting element is missing. If that is the case, it should be noted during initial quality control of linear features and fixed by digitizing the connector (see option for automated fixing discussion later on).
2. The stream segment actually ends in a sink (depression) and does not flow further downstream.
3. The stream segment ends in a pipe structure (e.g. culvert). In this case, the end of the stream is the beginning of a pipe, and those are modeled as sinks, so effectively, this is the same as case #2.

In this exercise, we will work under the assumption that these locations are represented as sinks in the system (case #2 or #3). See text inserts if case #1 is to be implemented.

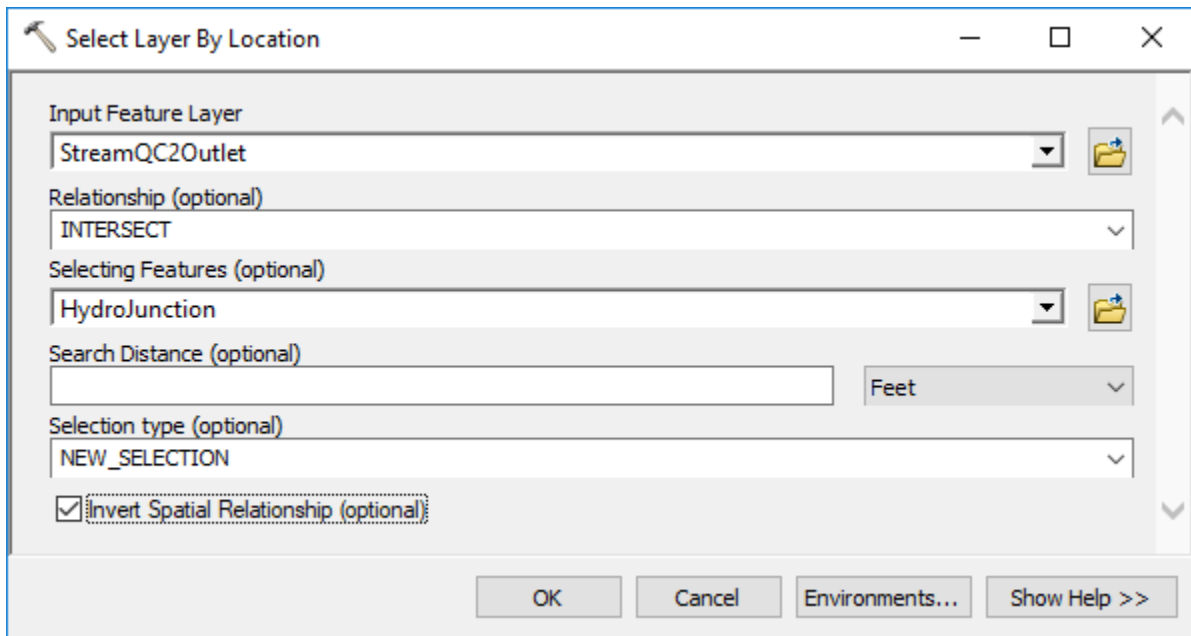


Several stream “outlets” are identified. They are at expected places. Few might require addition of overland paths but in this example, they will be treated as “real” sinks.

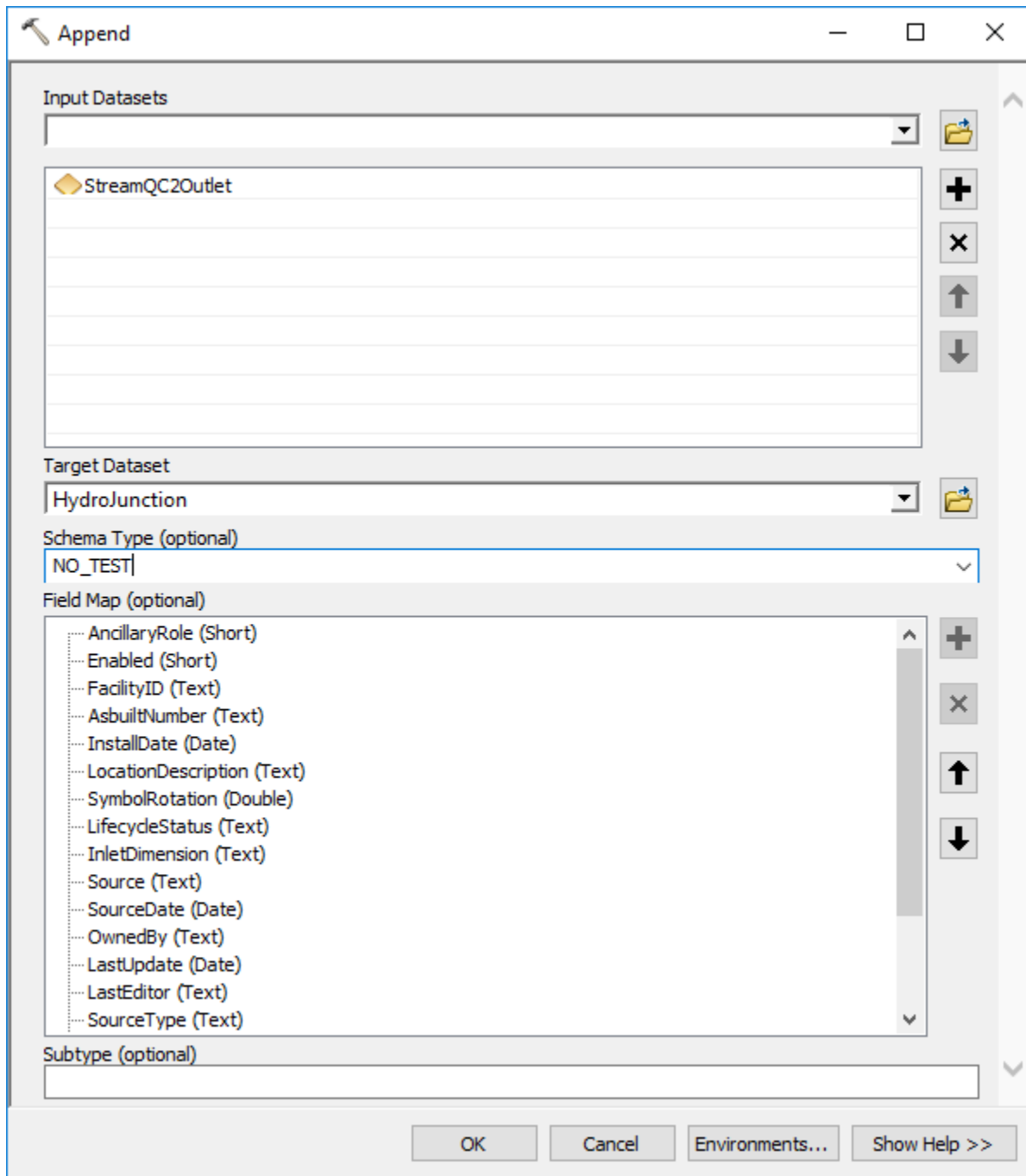


Do not do this if following case #1 (do not perform the next two steps).

Select stream outlets that are not represented in the HydroJunction feature class and add them to it.



In this case none of the outlets coincide with pipe inlets and all will be added to the HydroJunction feature class.



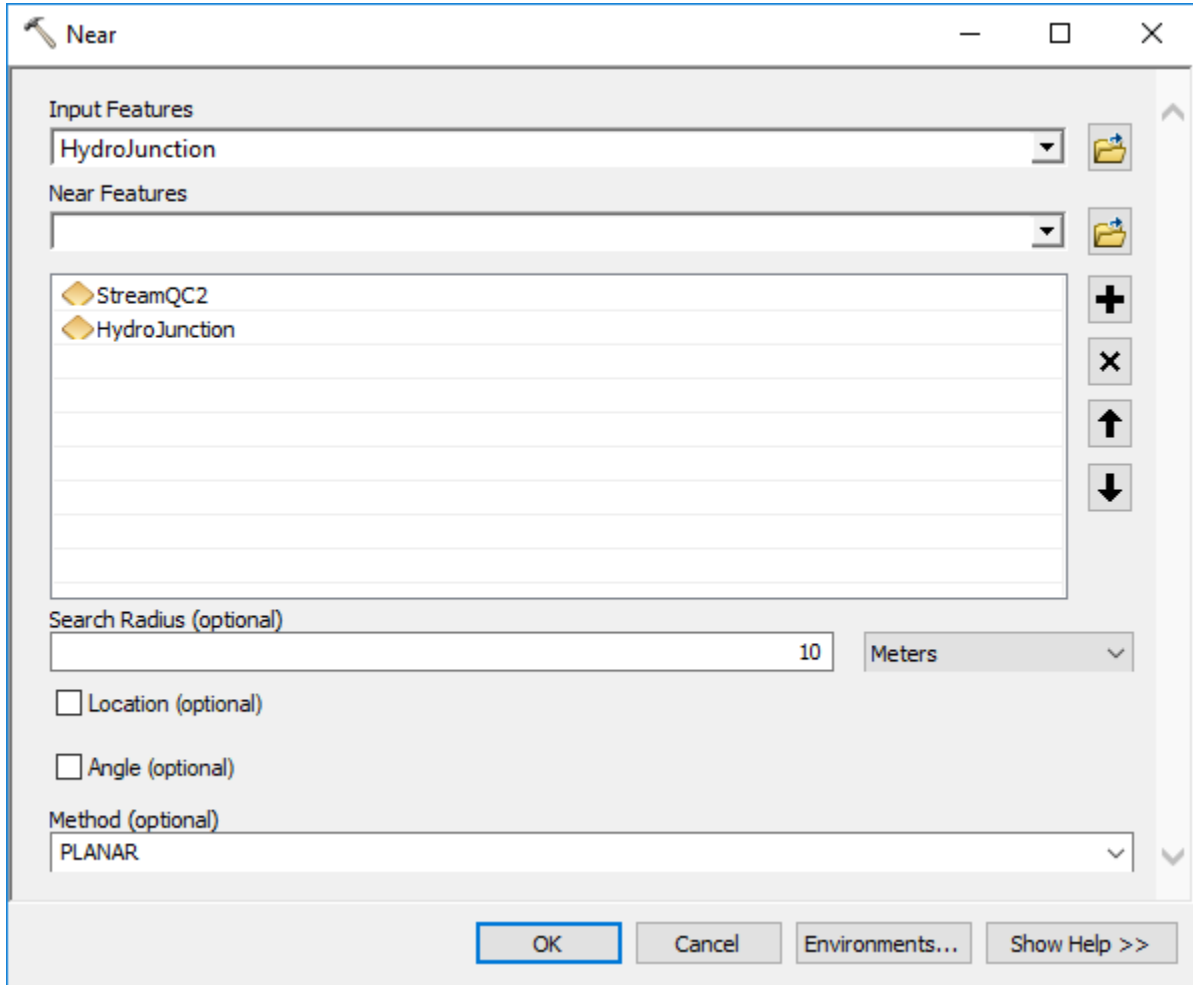
3.2.5 Check all inlets that are close to a stream or another inlet

Inlets in the current data processing workflow are modeled as sinks (to “attract” water to flow into them). Sinks are defined as polygons and constructed using a ~2-cell buffer around the inlet point. Proximity of inlets to a stream thus can generate unexpected behavior. The inlet that is in/too close to the stream will be treated as if the inlet defines a pipe divergence that is in the stream. The consequence will be that the “sink watershed” for that inlet will include upstream

surface area that is drained by the stream the inlet is in. If that is not the desired behavior, move the inlet point more than 2 cells away from the stream.

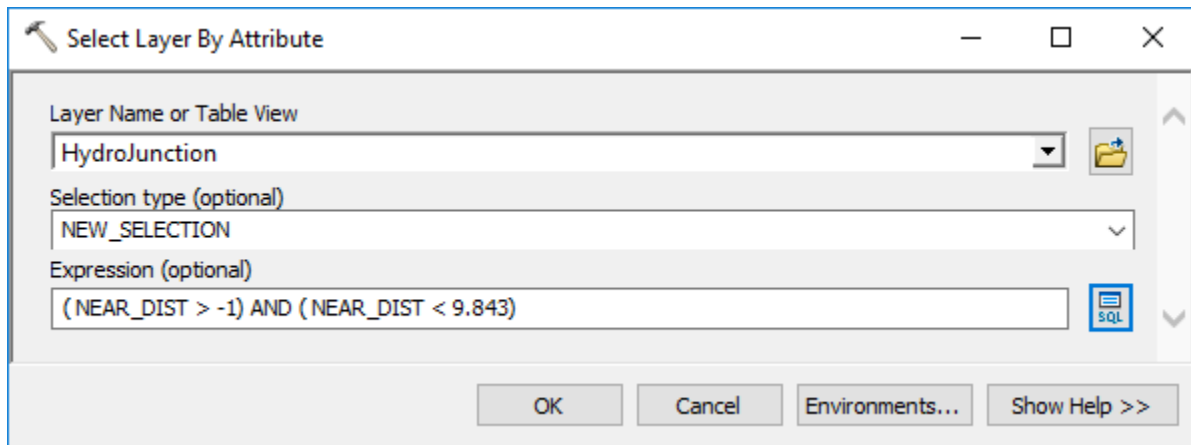
Similar issue exists when two inlets are close to each other since they will be collapsed into a single sink polygon.

Note that in the following example, the optional search distance is set to 10m to limit the operation time but also look at few more features than just the ones within the sink polygon buffer distance. This can be controlled based on QC requirements.



The result provides the fields with measurement of distance (NEAR_DIST) and proximity match layer name (NEAR_FC). Distance field will contain the distance to the closest stream or inlet feature (value of -1 indicates that the point is NOT within a search distance from any feature). Note that the distance is in layer units (e.g. feet), not in the “query” units (e.g. meters).

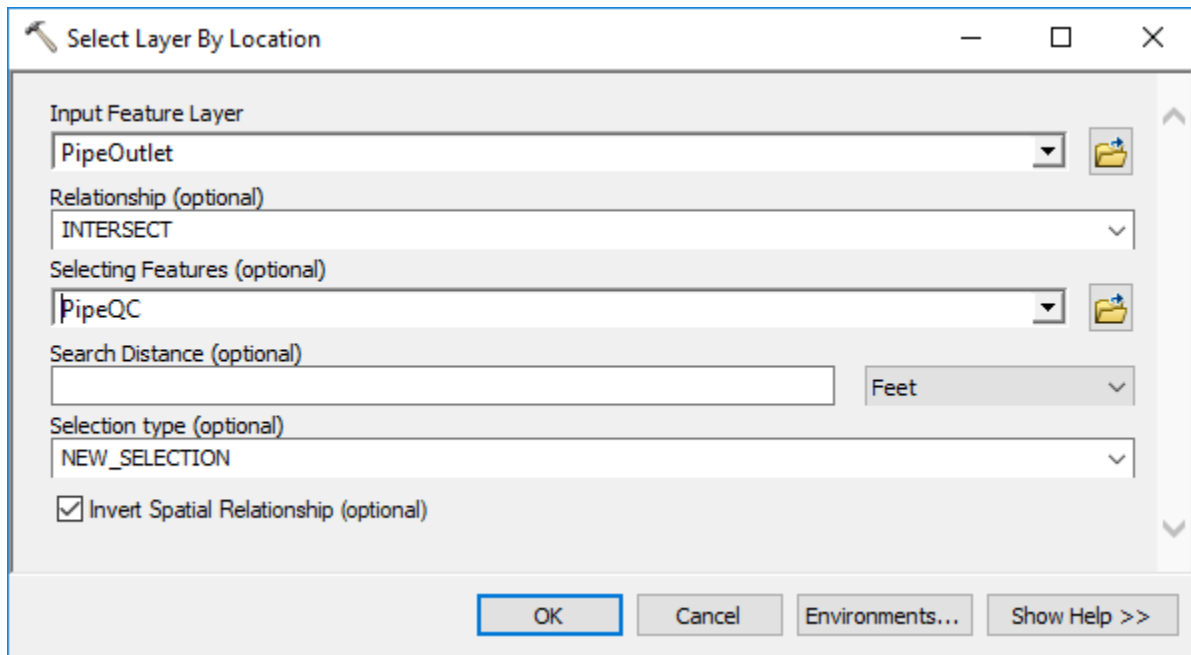
NEAR_FID	NEAR_DIST	NEAR_FC
568	2.001714	HydroJunction
7064	2.000427	HydroJunction
143	2.000427	HydroJunction
655	1.98763	HydroJunction
653	1.98763	HydroJunction
6313	1.956442	HydroJunction
7102	1.810145	HydroJunction
616	1.810145	HydroJunction
6498	1.745368	HydroJunction
6498	1.745279	HydroJunction
76	1.614625	StreamQC2
76	1.555445	StreamQC2
73	1.502553	StreamQC2
6374	1.489016	HydroJunction
6374	1.489016	HydroJunction
6468	1.414099	HydroJunction
2909	1.414099	HydroJunction
6719	1.405564	HydroJunction



Many inlets are selected based on proximity of 3 m. The results should be reviewed, and appropriate data editing performed to resolve any inlet distance issues.

3.2.6 Check all explicit outlets that are not connected to a pipe

This is just a quality control step to identify if the pipes that are supposed to end at those outlet locations are potentially missing. It is possible that the pipe outlet features are not explicitly known (pipe outlets is an optional feature class), so this check might not be possible to perform.

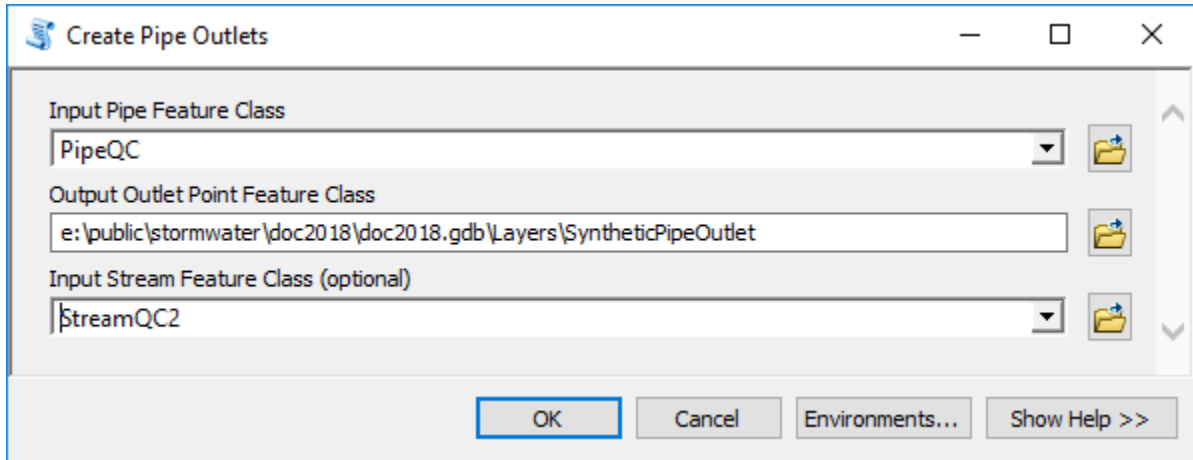


In this example, many discharge points are not connected to the pipes. Two are highlighted in the figure below. In this example, no additional pipes have been added based on this review.

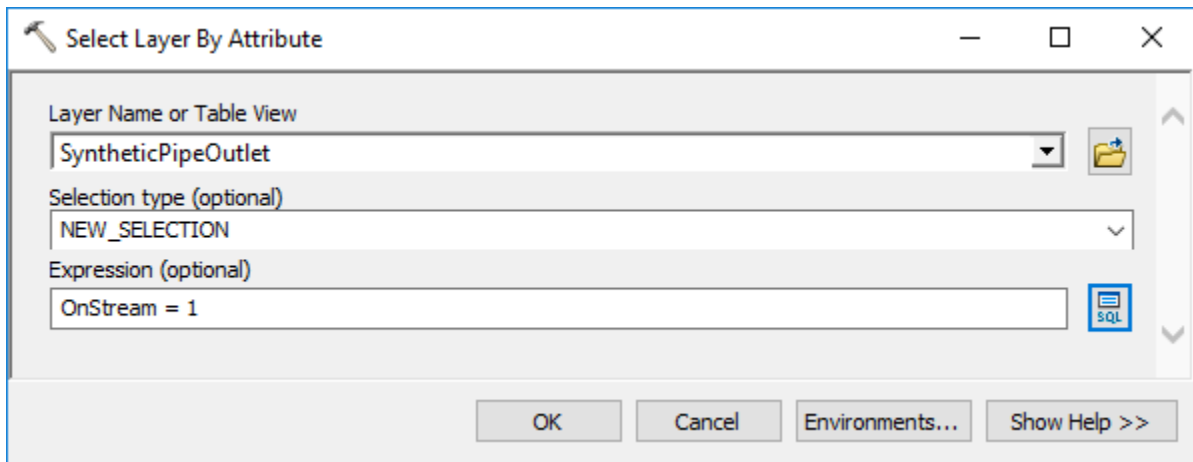


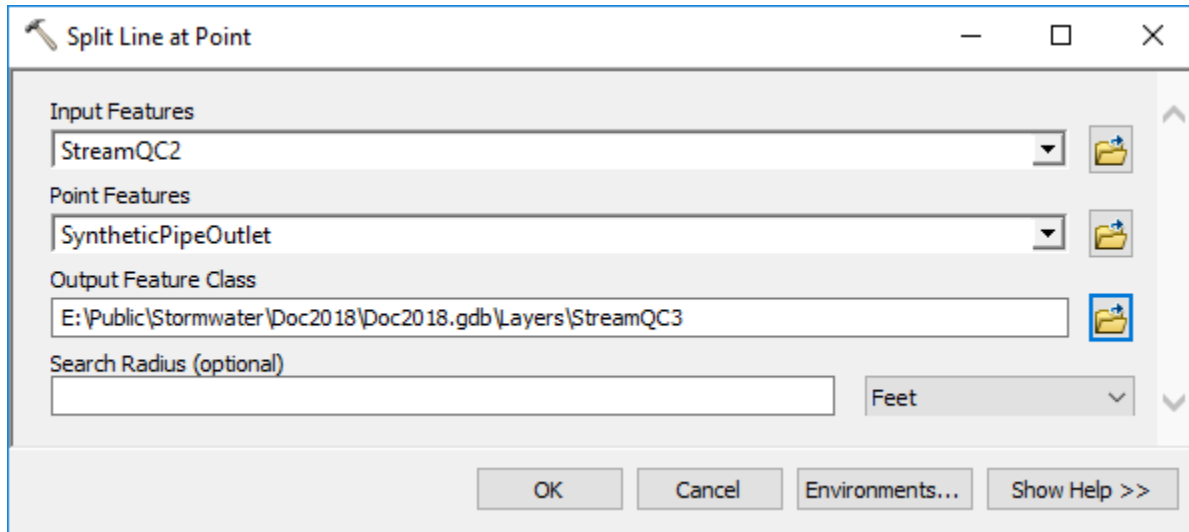
3.2.7 Create surface outlets at all pipe outlets that do not already have an outlet

Note that in this example we will not really review which end of pipes have and do not have an outlet structure. We will work under the assumption that any pipe outlet needs to be connected to the stream, either by already being on the stream or by creating an overland stream connector. In a normal QC process, a more thorough investigation and possibly manual editing should be performed.



The resulting feature class will have an attribute called “OnStream” where value 0 indicates that the outlet point is not on the stream and 1 indicates that it is. To ensure that the stream segments are split on the connection points with pipes (to ensure the consistency of the geometric network), the streams will be split at the connector points. In case you performed manual editing of the linear network elements, and you used “Connect” tool in geometric editing tools to “snap” stream and pipe network elements, the following two steps are not needed since the GN editing process will split the streams at pipe ends. Performing these two steps though will not do any “damage” so it does not hurt to include them into the process regardless of the previous editing effort.





Since in our case we did manual “connect” of pipes and streams, the return feature class does not have any additional streams split.

3.3 Final thoughts on data evaluation and cleanup

Steps presented in this chapter were just some of the possible techniques for data review, cleanup, and augmentation. They were presented here not as something that **MUST** be performed or the **ONLY** way of performing these activities, but rather as some of the viable options to perform them and to highlight Arc Hydro tools that were developed to support these activities. The actual work that will need to be performed on the data will vary greatly depending on the provenance of the data and the robustness of the data editing workflows used to develop them. Each local dataset is unique and specific steps will have to be developed to accommodate nuances of the specific dataset.

4.0 Data preprocessing

This section identifies individual terrain processing steps after the initial data QC, editing, and creating has been performed. The following layers are used in the process:

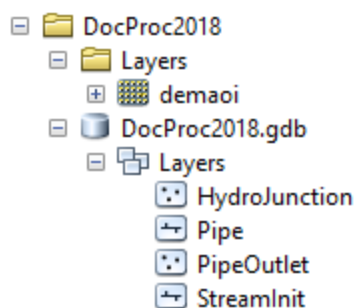
#	Description	QC process result name	Preprocessing workflow name
1	DEM		demaoui
2	Pipes	PipeQC	Pipe
3	Streams	StreamQC3	StreamInit
4	Inlets	HydroJunction	HydroJunction
5	Outlets	SyntheticPipeOutlet	PipeOutlet

Column “QC process result name” are names of the layers if you followed steps described in chapter 3. Column “Preprocessing workflow name” has the layer names that will be used as initial inputs in this chapter.

4.1 Processing data organization

To ensure consistency of the layer naming in the next steps, current layers that do not match “workflow name” in the table above will be renamed into it. While not necessary, a new folder and geodatabase is created that contains only the relevant renamed layers. To make this as generic as possible, there is not assumption that any previous Arc Hydro processing has been done with the data (so the layers do not need to have HydroID, etc.). Since no specific attributes, besides the ones generated during the process are used, all current attributes on the four feature classes can be deleted if desired. As discussed before, it is suggested that the original unique identifiers of the data elements are preserved to enable link back to the original feature if need arises.

The initial processing folder/data structure is as follows:



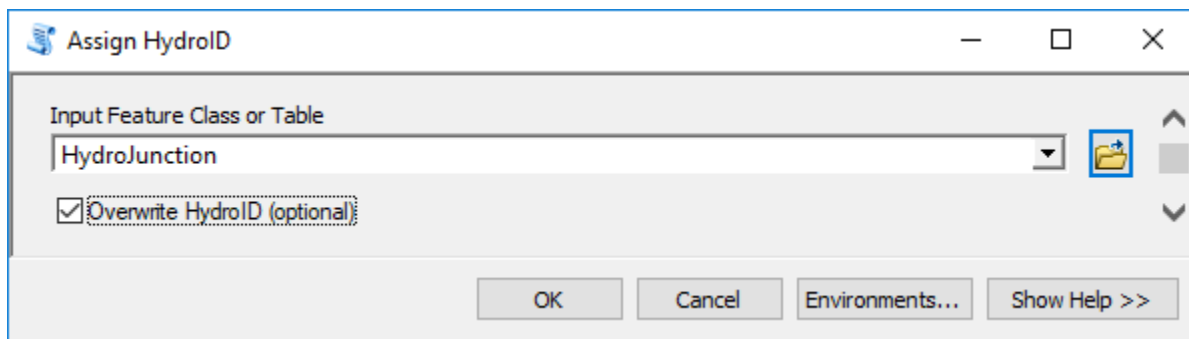
4.2 Create sink structures representing inlets

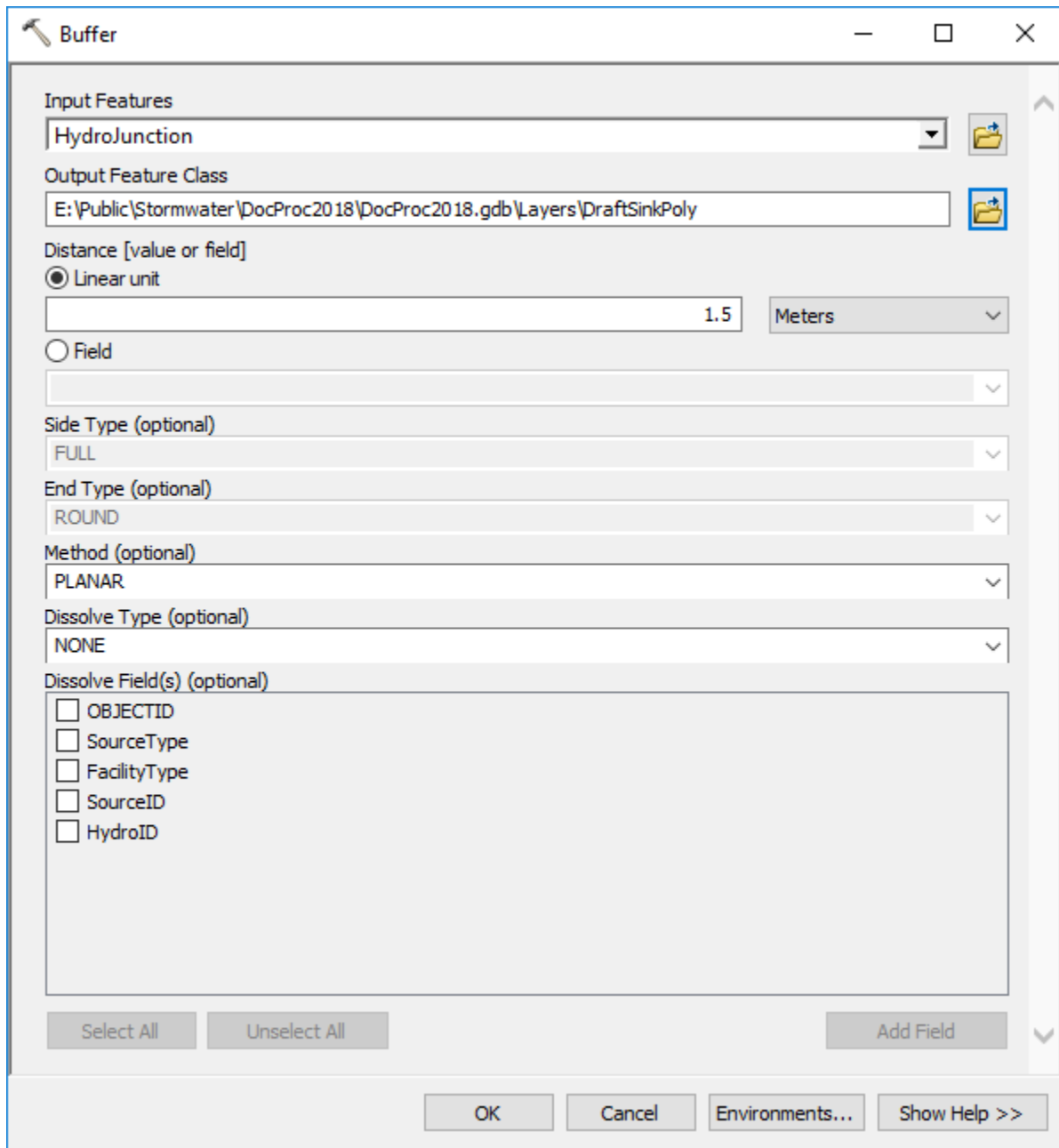
This step is used to generate artificial sinks at inlet locations to “force” the terrain to flow into the inlets.

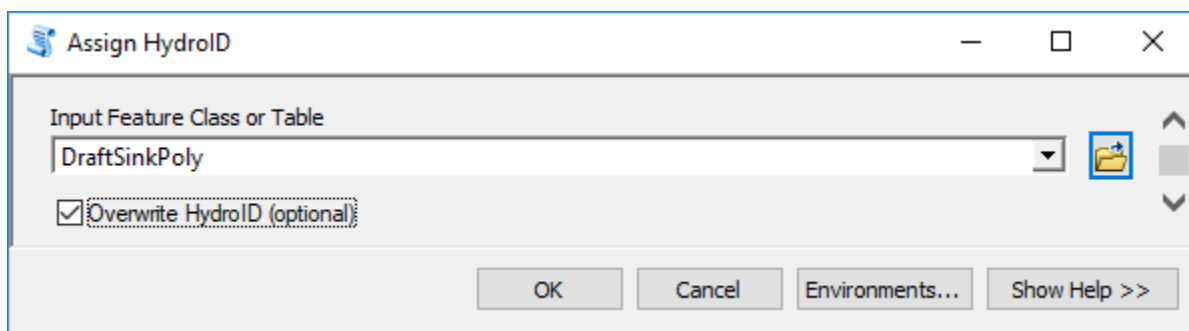
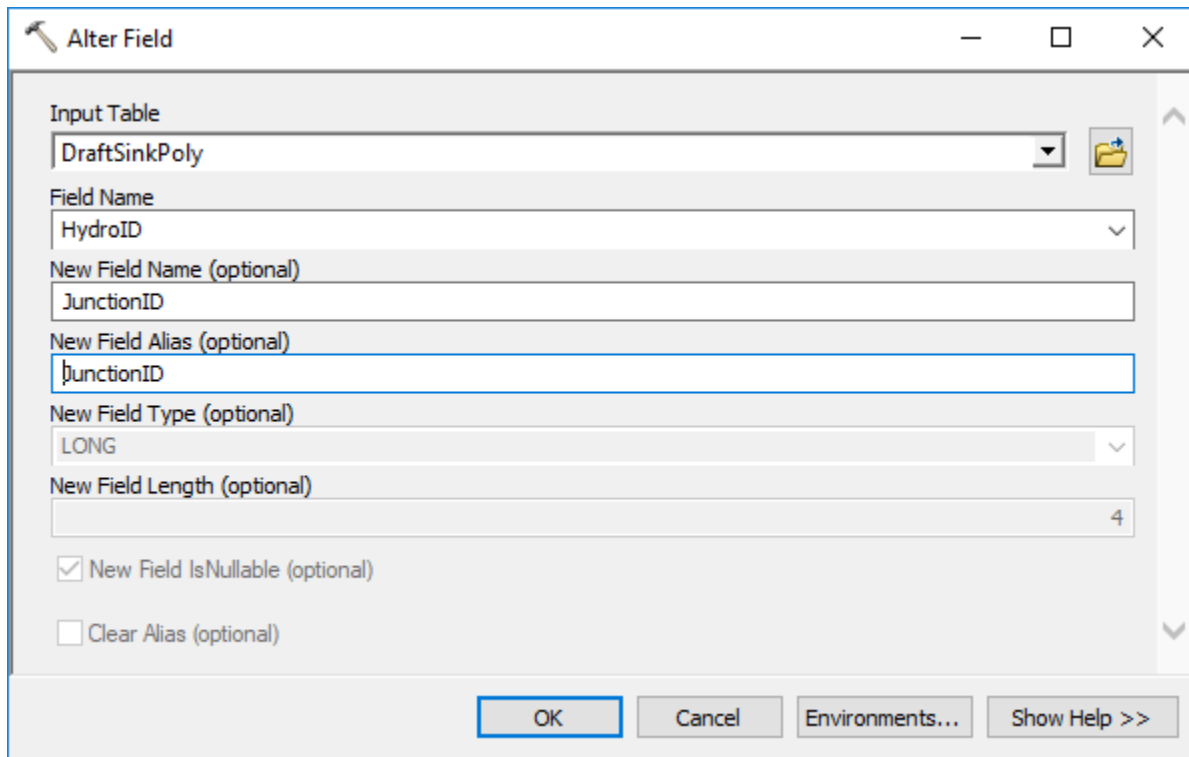
4.2.1 Create draft sink polygons

There are several ways to generate “sink polygons” associated with inlets. A buffer approach is presented here. A buffer of 1.5 the cell size around the inlet is used (in this case 1.5m). The presented buffer distance is a minimum that can be used. It is possible that such a small buffer will not generate a “sink” big enough to resolve DEM inaccuracies around inlets and a larger buffer might be appropriate. This can be evaluated once the sink watersheds are established. It is possible to have a point-specific buffer distance that varies throughout the system. In that case, establish a field in the HydroJunction feature class and populate it with the buffer distance to be used in the buffer function. Then use that field to define distance value in the “Buffer” function.

Assign HydroID to HydroJunction FC if necessary (if not performed somewhere earlier in the data development process).

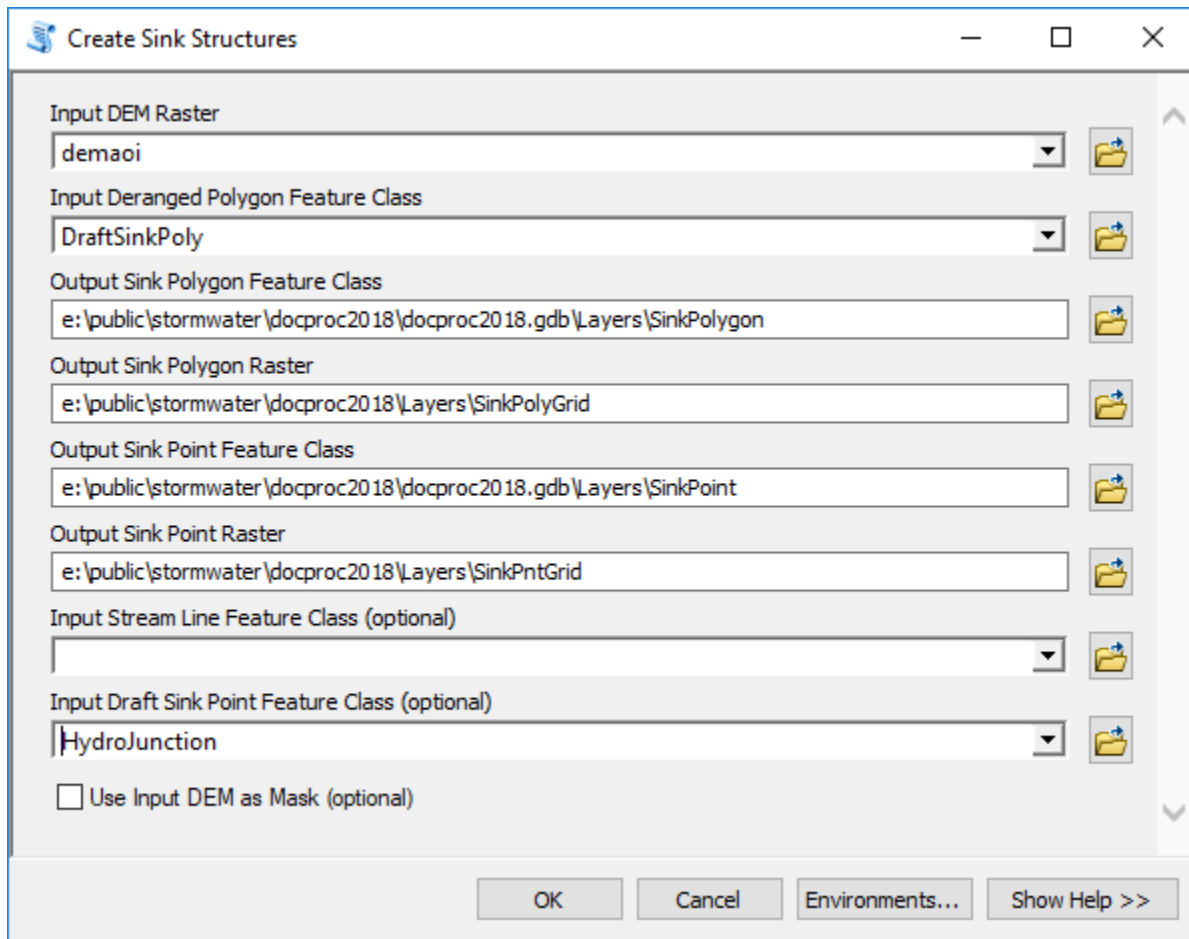






4.2.2 Create sink structures

This step generates sink representations (vector and raster) matching underlying DEM resolution that will be used in the processing.

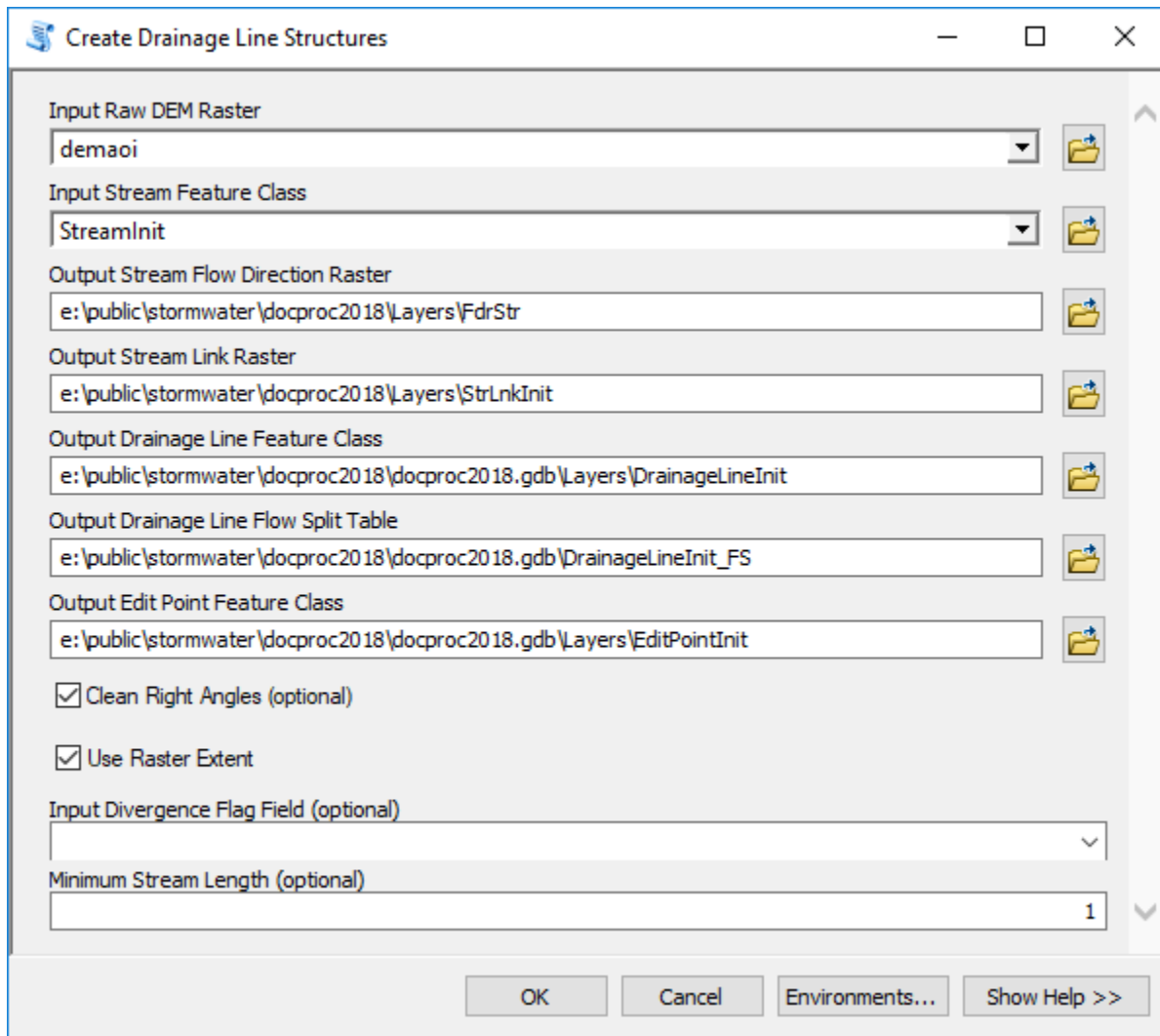


4.2.3 Sink point review #1

Notice that several points fall into a single sink polygon (the tool message will identify if multiple points fall within a single sink polygon and how many in total were deleted). This happens due to the point proximity with respect to the DEM cell size and buffer distance being used to generate sink polys. The tool will select one of the points within sink polygon and ignore the others. While not necessarily an error, this might generate unexpected results (e.g. one inlet collects all the water from the sink) and a detailed QC of those points is suggested (but not needed if the end results are acceptable).

4.3 Create drainage line structures representing open channels

This step generates stream representations (vector and raster) matching underlying DEM resolution that will be used in the processing.

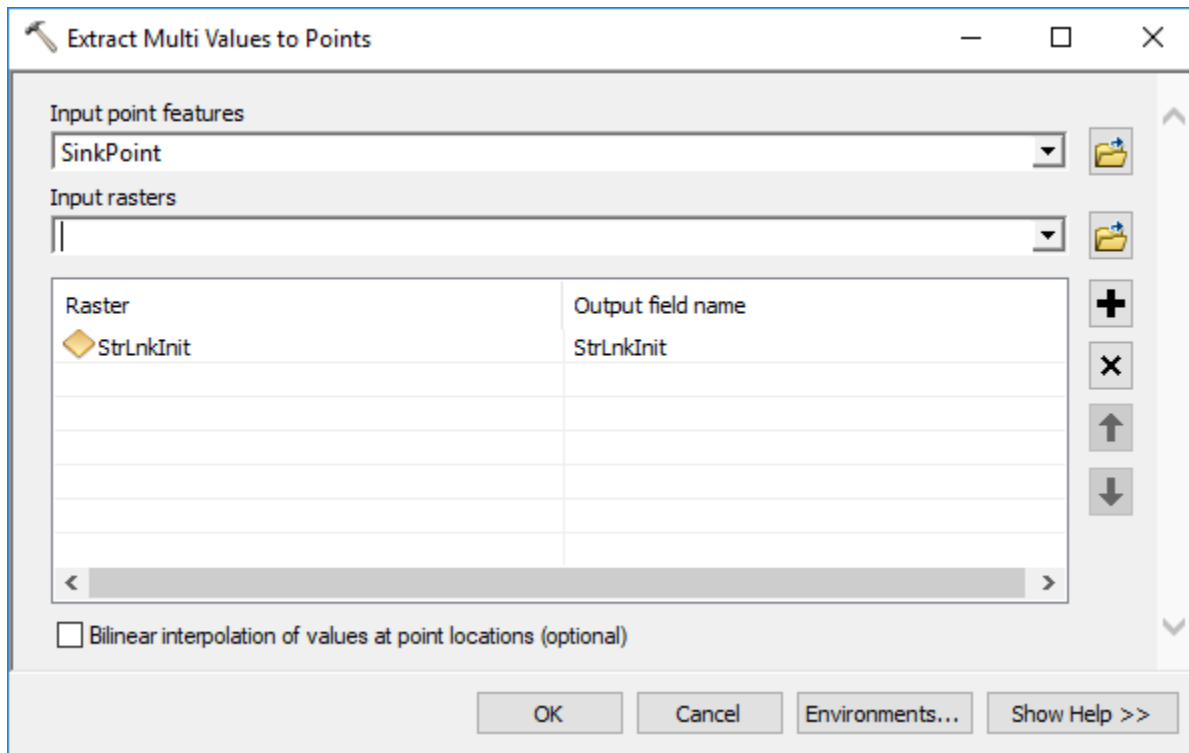


Note that:

1. HydroID field will be created and populated by the tool if one does not already exist.
2. Use of non-standard output names for some of the layers (“Init”).

4.3.1 Sink point review #2

The following section deals with evaluating the possibility that a sink point resides on a stream.



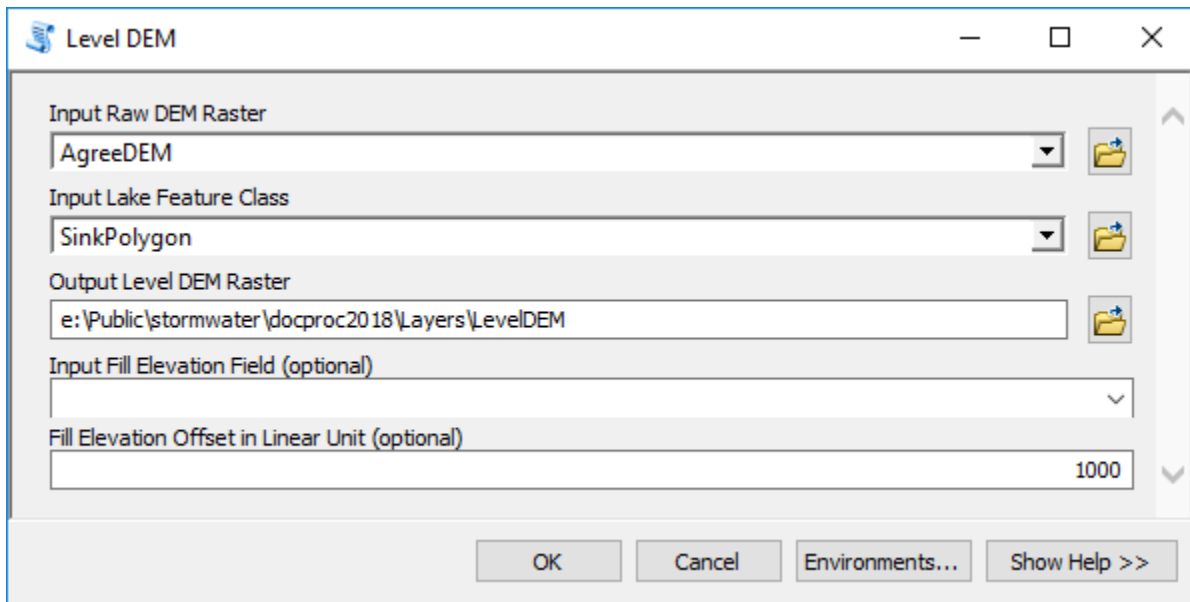
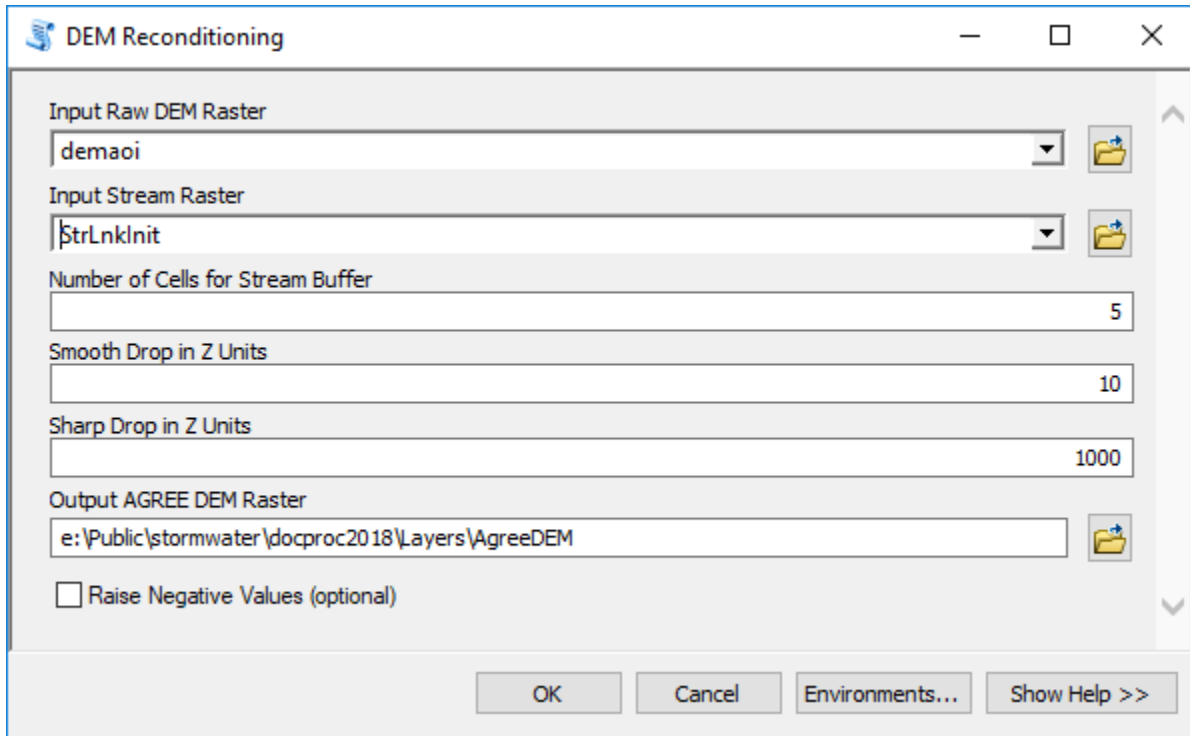
Review field “StrLnkInit” in the SinkPoint feature class. In this case, there are 12 points with a value. This indicates that an inlet point (sink) is located on a stream cell. By reviewing these points, three categories can be identified:

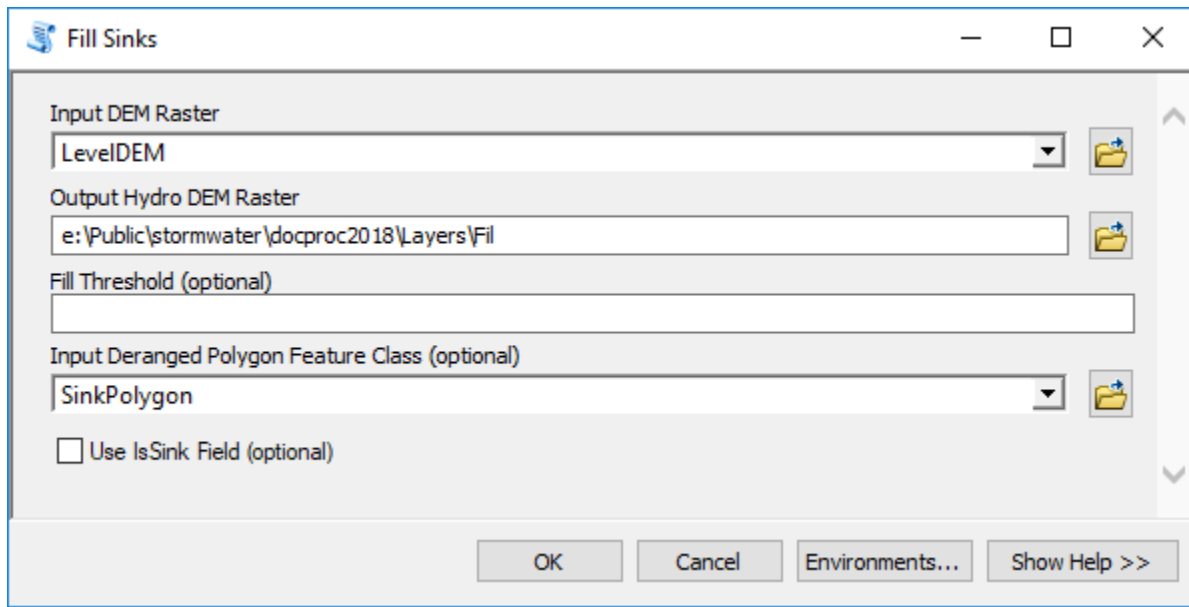
1. End of stream sinks. 9 of them. These were introduced on purpose and are correct.
2. Cross-pipe (divergence - inlet at the from node of the pipe). 1 of them. These are most likely data errors and need to be reviewed. Can potentially introduce unexpected behavior in the flow pattern.
3. Confluence (confluence – inlet at the to node of the pipe). 2 of them. No significant impact. Can potentially introduce unexpected behavior in the flow pattern.

Upon review, if data need to be fixed (e.g. remove the inlet point or stream), they should be fixed, and previous steps re-run. How many steps need to be re-run will depend on the changes made. In this example, no fixes were made.

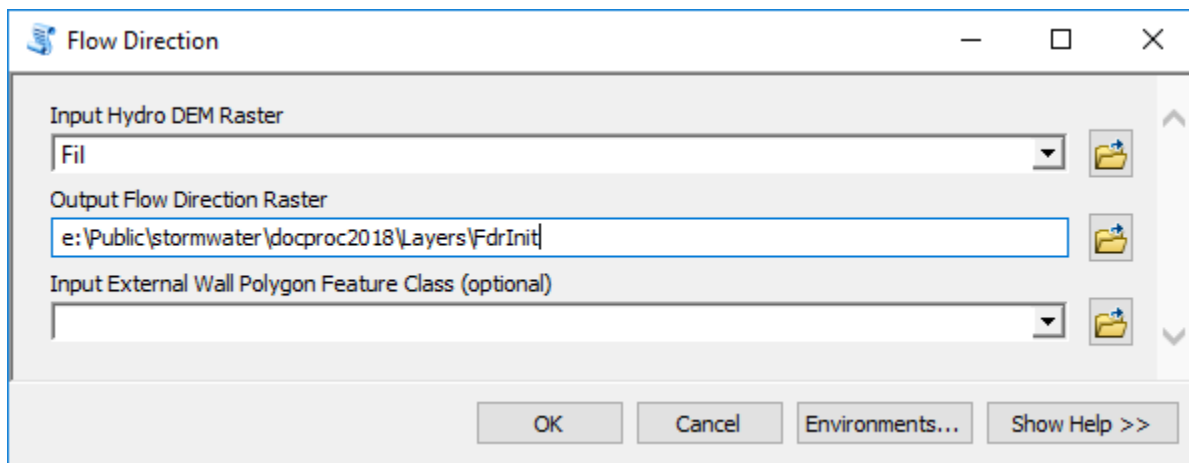
4.4 Adjusting DEM to enforce initial flow direction

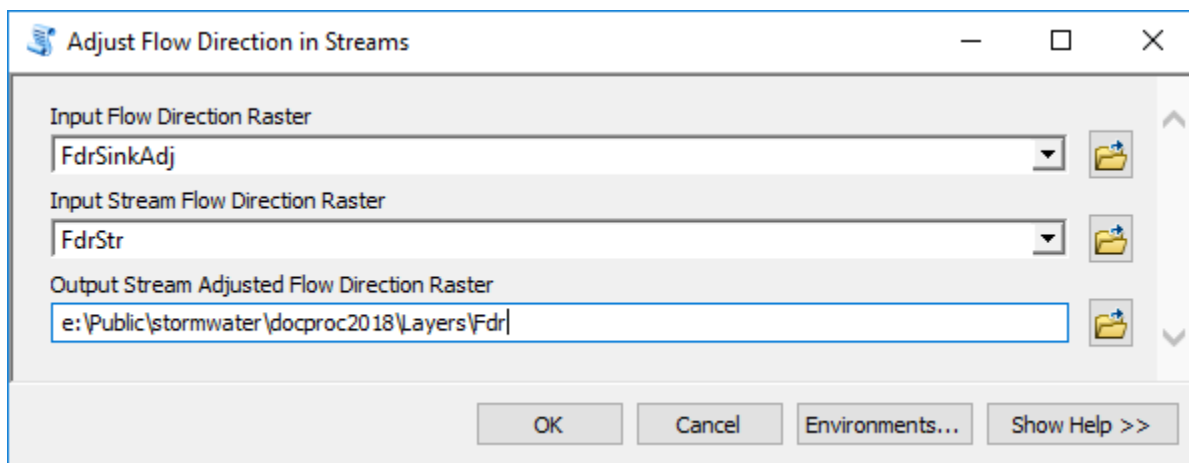
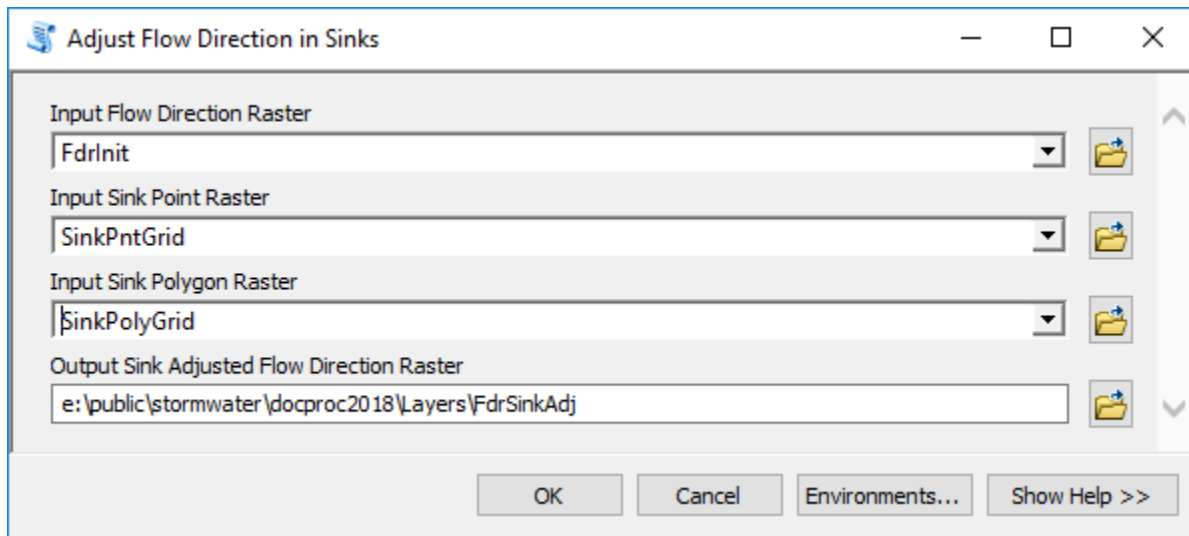
Note that “Input Stream Raster” is a result of the “Create Drainage Line Structure” function.





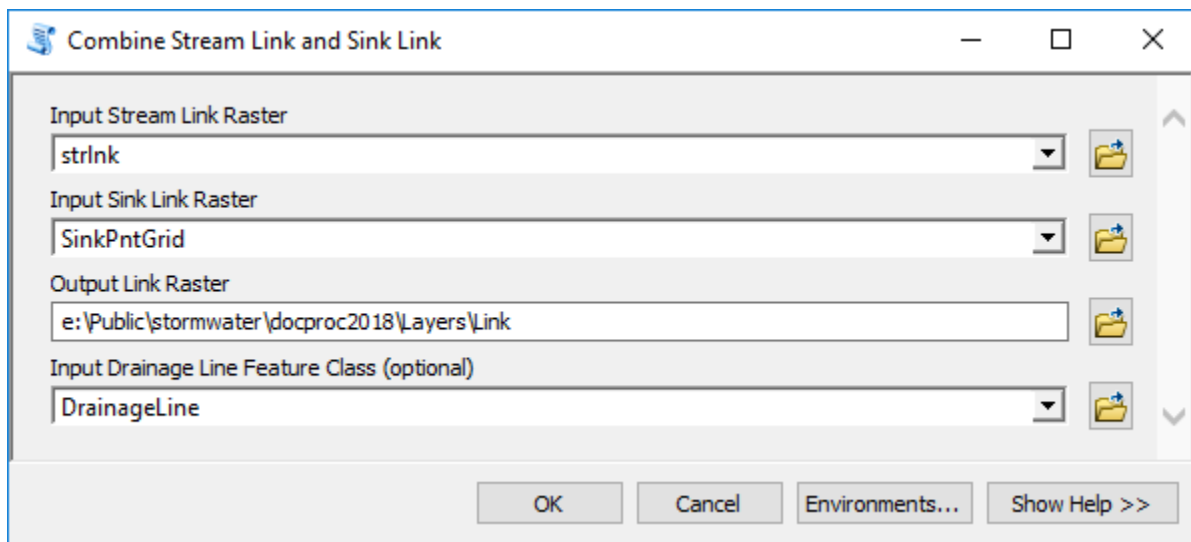
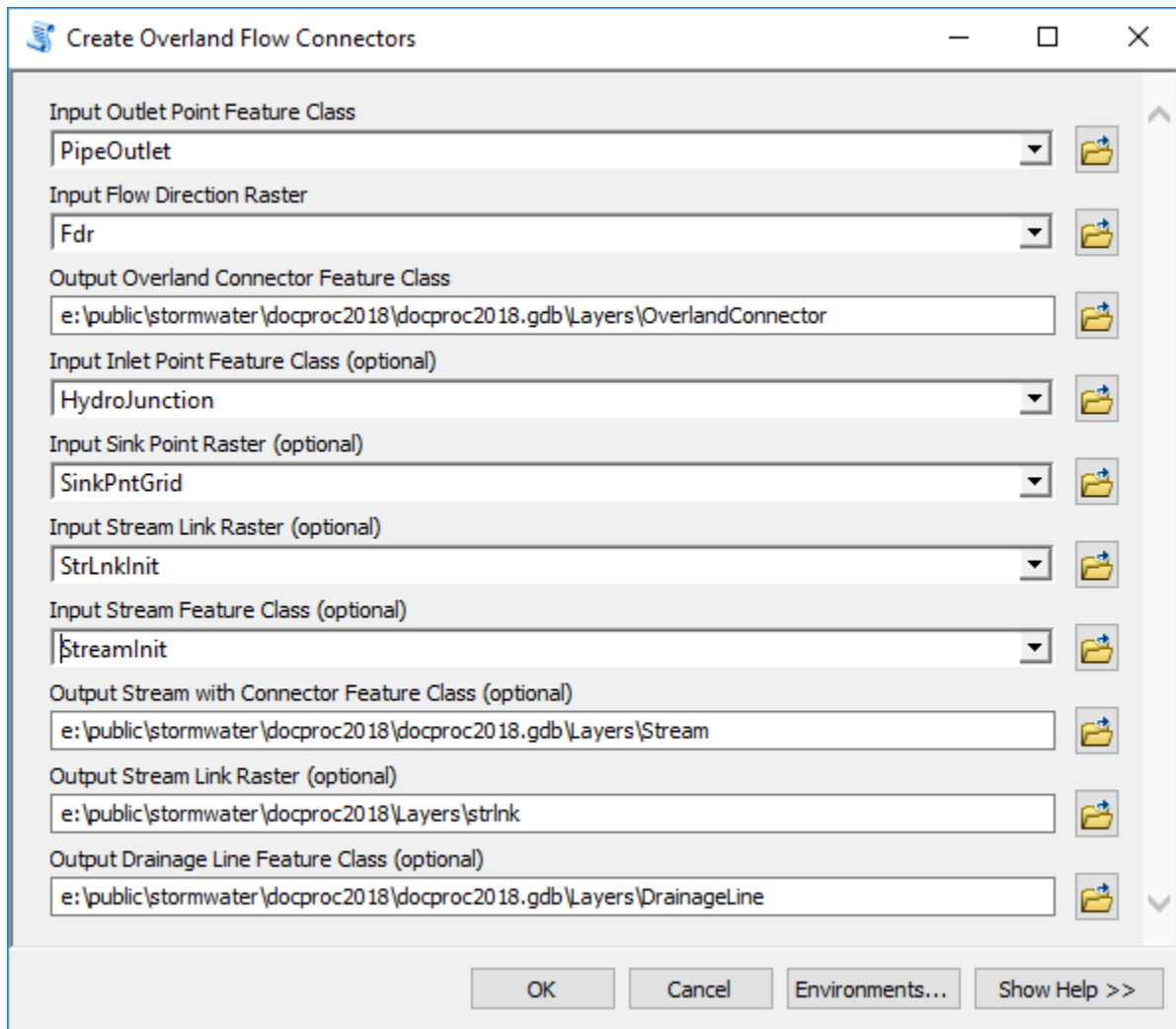
4.5 Establishing flow direction



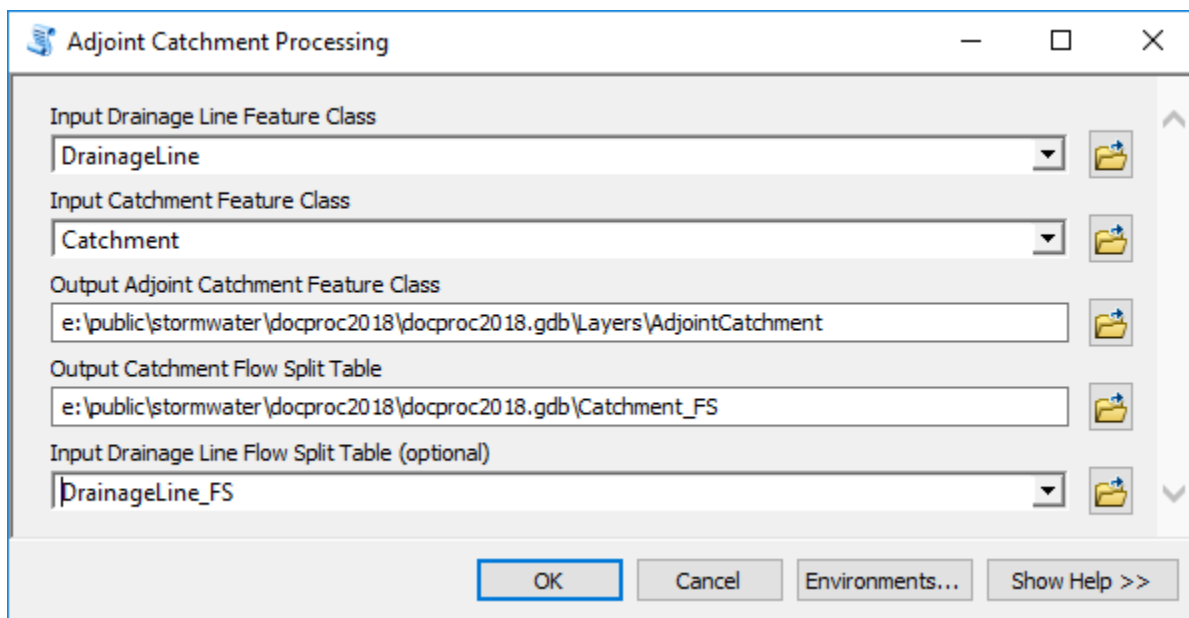
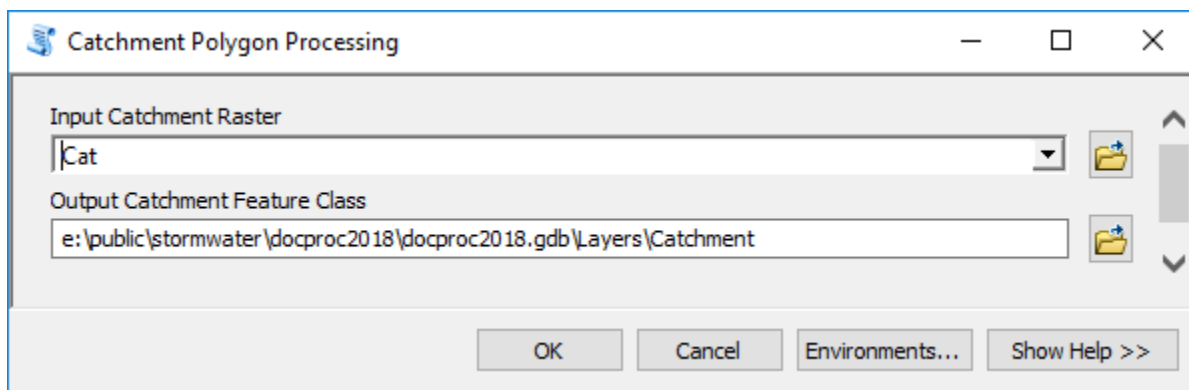
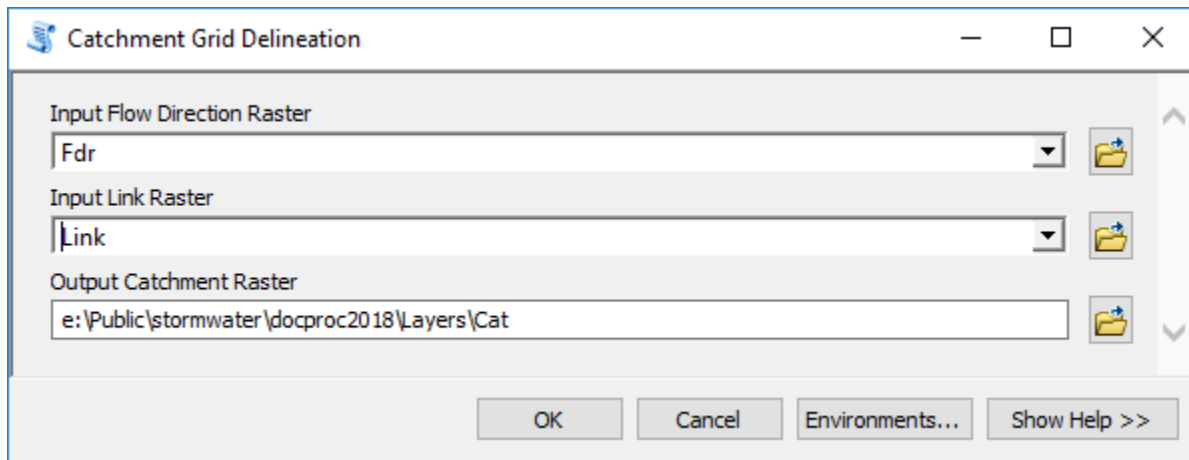


4.6 Create connected linear system

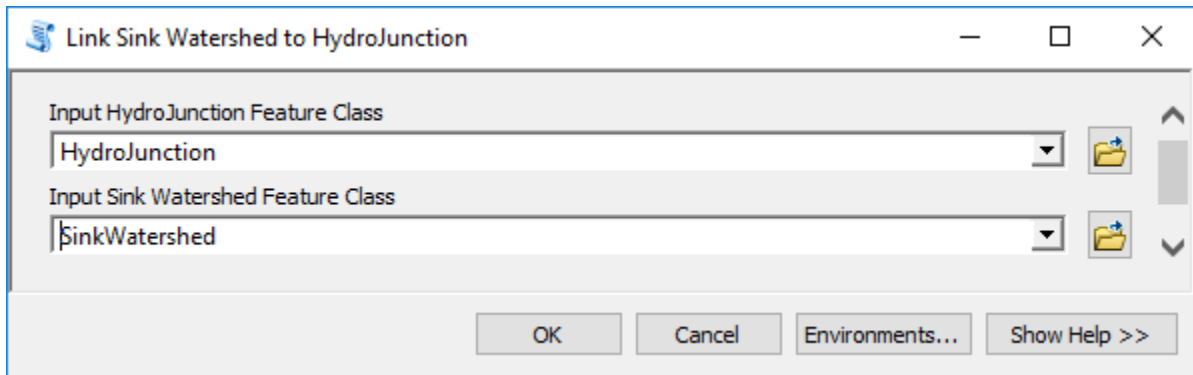
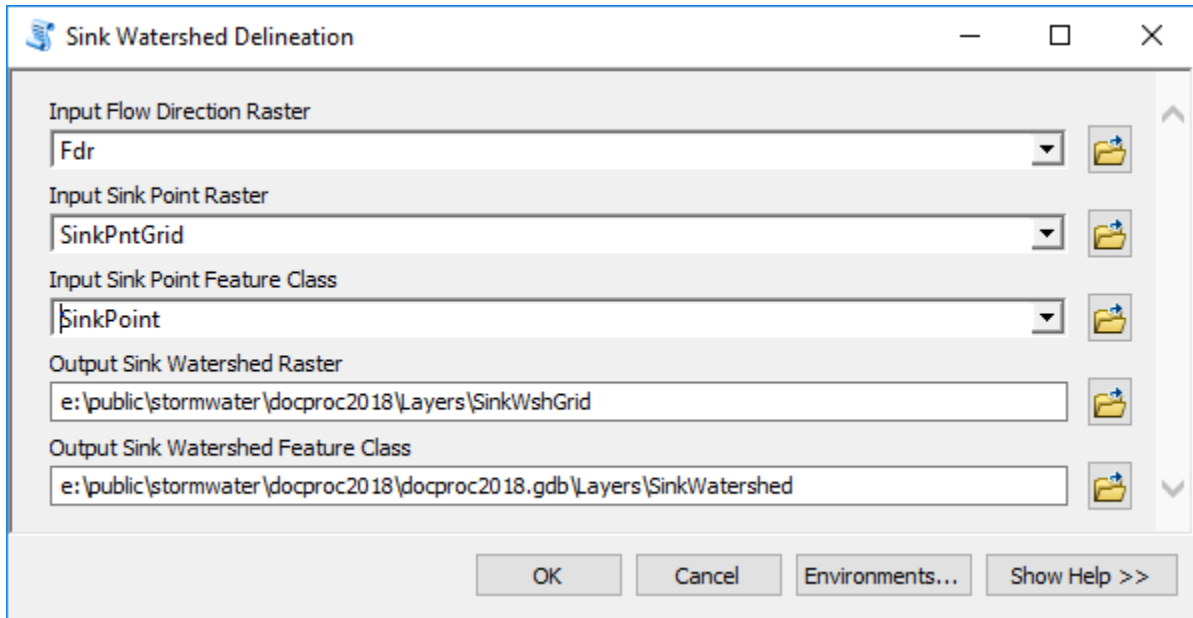
The following function is used to generate “missing” overland flow connectors (usually ends of pipes discharging onto a surface) and connect them to the existing stream features and/or downstream inlets/sinks.



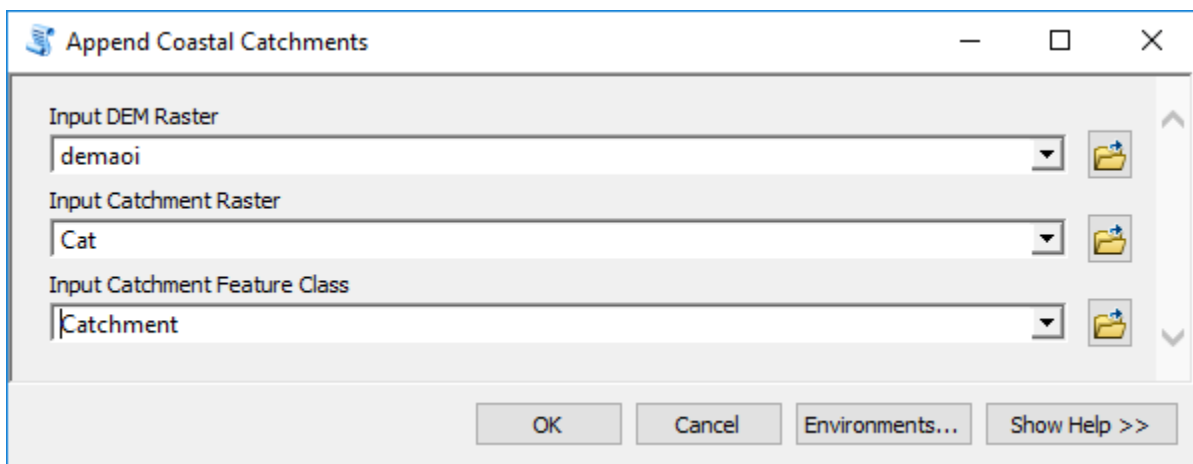
4.7 Create drainage area elements



Sink watersheds represent total directly contributing surface contributing area to a sink. They will be the same as the sink catchment unless there is a stream draining directly into the sink.

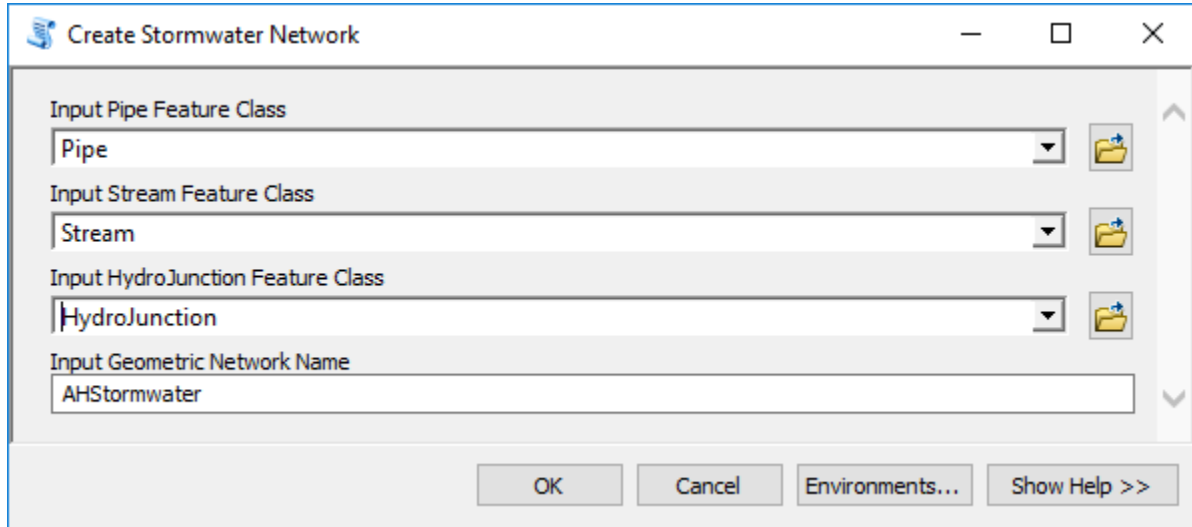


The following step is performed to ensure performance of the watershed delineation tool (even when processing inland areas). It is not needed if the DEM is clipped exactly along the major watershed boundary that defines AOI.

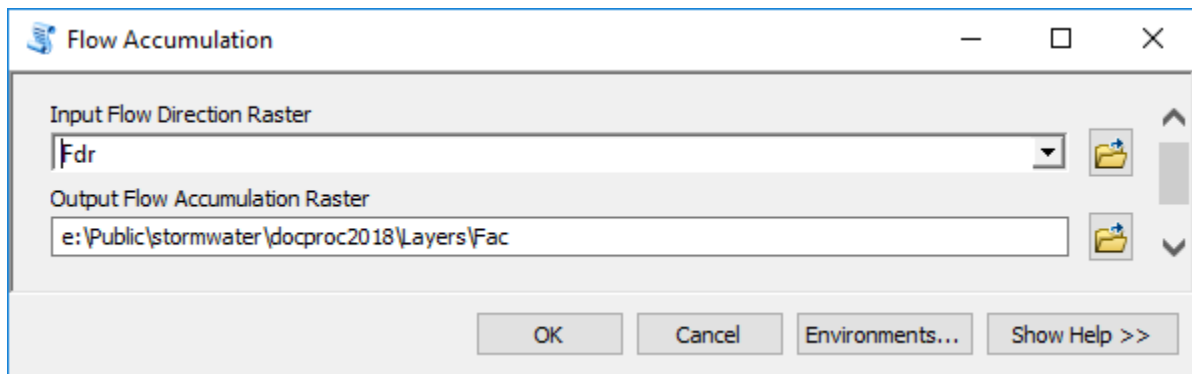


4.8 Build stormwater system

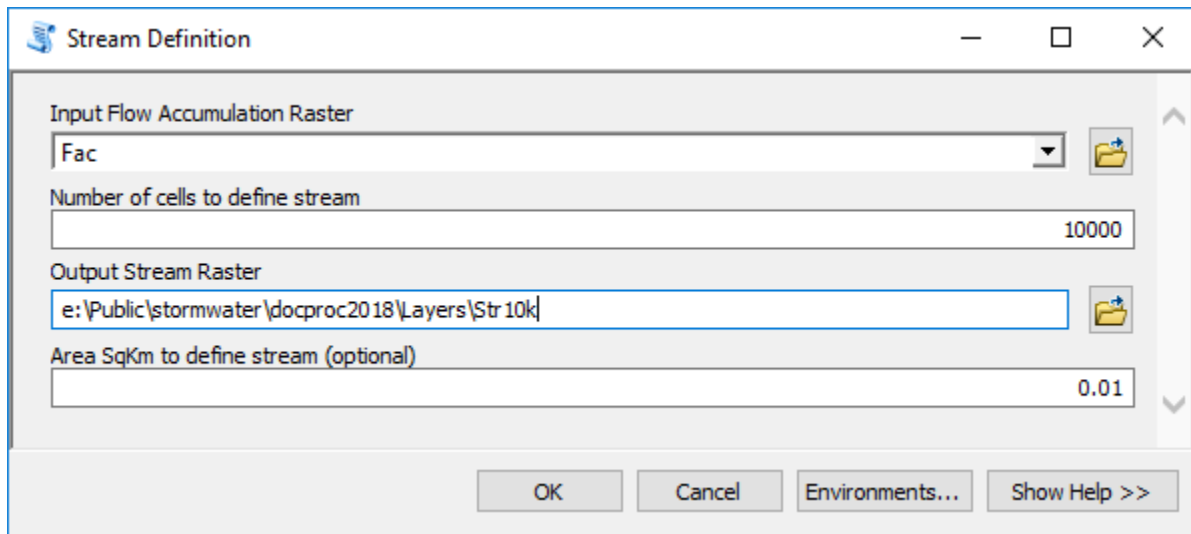
This section presents several steps for completing the stormwater system (building final connected network) and generating supplemental layers to facilitate stormwater delineation.



The following two steps are performed to establish a flow accumulation raster and a snap stream raster (to facilitate precise placement of points of interest when performing watershed delineation). These are optional steps but are recommended.



A threshold of 10,000 cells (10,000 m²) was used here. This can be changed to get more or less dense (bigger threshold) snap density.



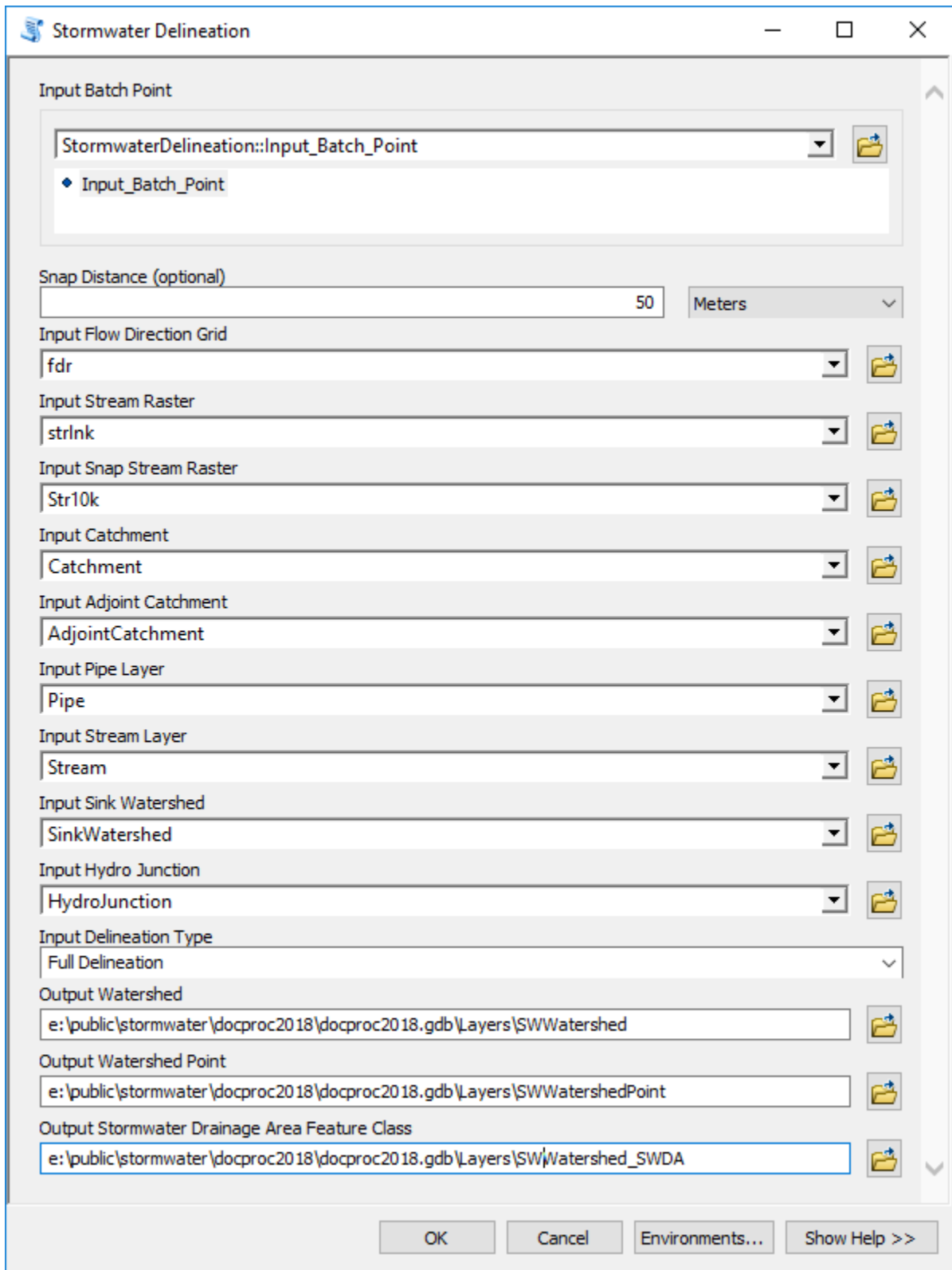
5.0 Analyses

Once the stormwater system is built, it can be used to support different analyses. Two specific tools are built to leverage the stormwater system data representation.

5.1 Stormwater delineation

This tool allows watershed delineation along the stormwater system. Three types of watershed delineation are possible: full delineation, direct surface contribution, and simulated inlet location (check tool help for detailed discussion on how each delineation type operates). To use the tool:

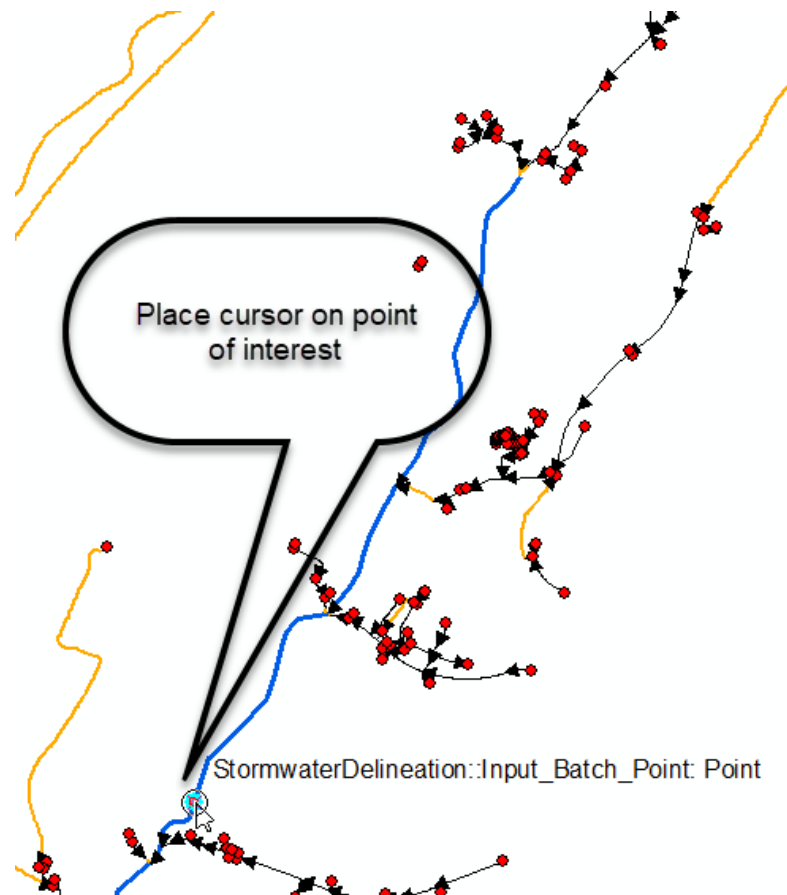
1. Open the “Stormwater Delineation” tool.



2. Check inputs and outputs. If you used standard naming conventions as presented in this document, default values will work, and you do not have to specify any of the input layers. If you created optional snap stream raster, set “Input Snap Stream Raster” to it. It

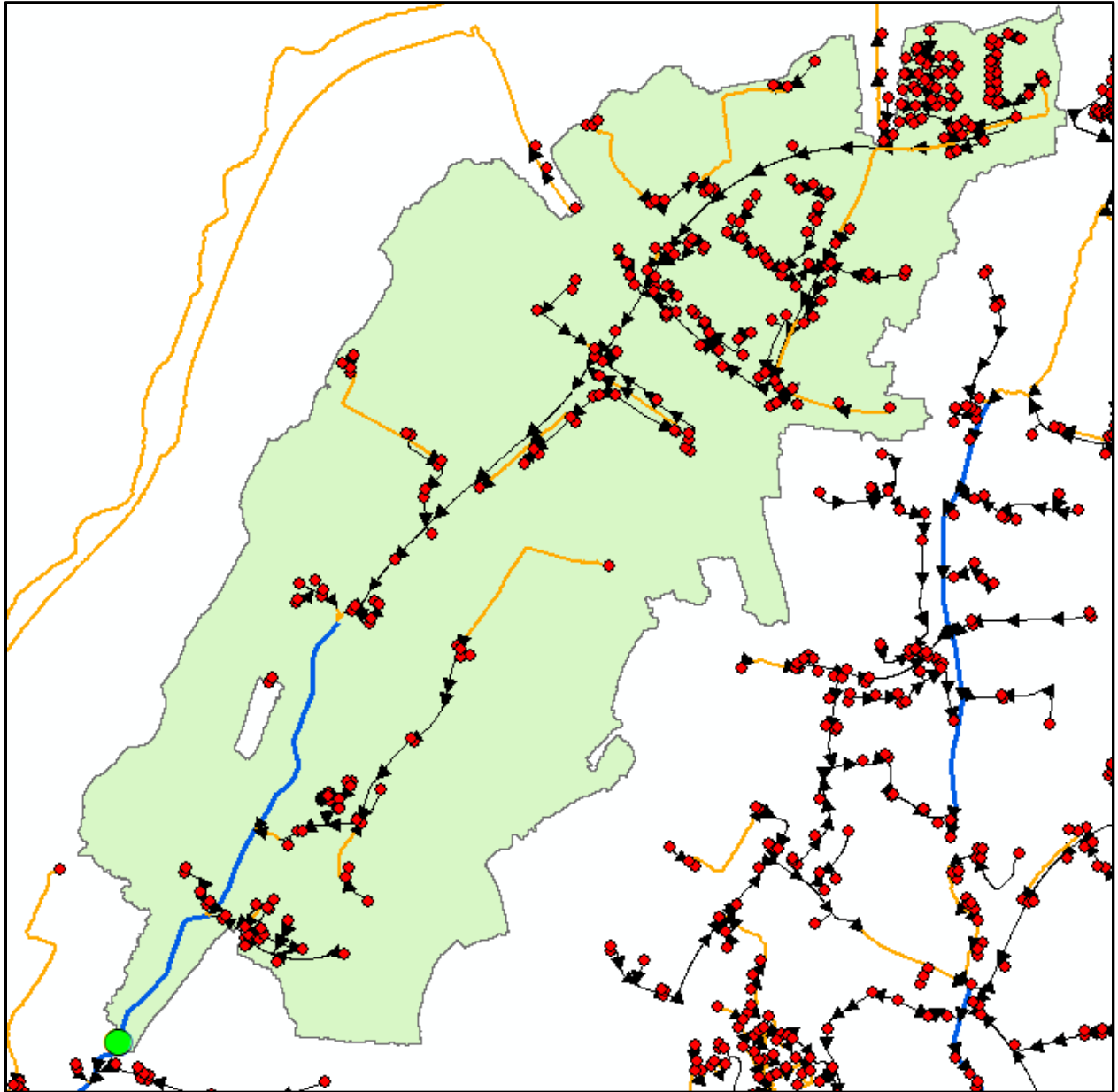
is suggested that you select non-default output names (e.g. in the example above, “SW” was placed before default output names). Note that each time a tool is run, new feature classes are generated. If the output feature classes already exist, they will be overwritten.

- a. Make sure you select the right type of delineation (“Input Delineation Type”).
3. Click on the point of interest in the map. Tool will place a point at the selected location. You can repeat this many times and generate several points before executing the tool. This can be used to run the tool as an interactive “batch” processor.



4. Click on “OK” in the tool interface. The tool will run and delineate the watershed. During the run, tool will generate an extensive log (message) on what it is doing. Review it to get the familiarity with the activities and processing times during delineation process. Process scales well, so if you pass multiple points, each point will take roughly the same time to delineate.

```
Executing: StormwaterDelineation "Feature Set" "50 Meters" fdr strlnk Str10k Catchment
AdjointCatchment Pipe Stream SinkWatershed HydroJunction "Full Delineation"
e:\public\stormwater\docproc2018\docproc2018.gdb\Layers\SWWatershed
e:\public\stormwater\docproc2018\docproc2018.gdb\Layers\SWWatershedPoint
e:\public\stormwater\docproc2018\docproc2018.gdb\Layers\SWWatershed_SWDA
Start Time: Thu Jan 10 20:30:05 2019
Running script StormwaterDelineation...
1 feature(s) to process.
    Finding network 0.58 seconds.
    After finding network 1.09 seconds.
    After copyfeatures 3.30 seconds.
    After delete fields 5.46 seconds.
    Starting loop 8.18 seconds.
Processing point 1: oid = 1
Number of Stream feature(s) within snapping distance: 1.
Distance to Stream: 0.000316052525144
Number of Pipe feature(s) within snapping distance: 0.
    After distance checks 9.84 seconds.
Performing local watershed delineation...
Using stream raster strlnk as snap raster.
snapdist 0
Distance snapped: -1
Number of intersecting catchment(s): 1
Delineating watershed
Appending Adjoint Catchment...
    After local delineation 23.06 seconds.
Performing network trace...
275 junction(s) traced.
    Storing results 24.96 seconds.
Copying new watershed
Copying new watershed point
Cleanup...
updating batchdone
    After storing results 34.03 seconds.
Results are stored in:
e:\public\stormwater\docproc2018\docproc2018.gdb\Layers\SWWatershed and
e:\public\stormwater\docproc2018\docproc2018.gdb\Layers\SWWatershedPoint
    GetWatershedViaNetTrace completed in 34.03 seconds.
Completed script StormwaterDelineation...
Succeeded at Thu Jan 10 20:30:41 2019 (Elapsed Time: 36.54 seconds)
```



Green dot is the point of interest while the green-ish polygon is the total upstream contributing stormwater watershed. Tool generates three output layers:

1. Outlet point (WatershedPoint).
2. Watershed draining to the point (Watershed). This is the total area draining to the outlet point.
3. Stormwater drainage areas created in the process (Watershed_SWDA). This includes three types of areas:
 - a. Total drainage area draining into the point (identified by “Total Upstream” value in the WshdType field). This is the polygon that is also stored in the watershed feature class.

- b. Local drainage area draining into the point (identified by “Local Upstream” value in the WshdType field). This is directly connected overland contribution to the point (does not include contribution through pipe system).
- c. Local area (within the catchment) downstream from the point (identified by “Local Downstream” value in the WshdType field). This area might be of use in specialized applications.

The features in the three feature classes are tied together through HydroID->DrainID (where DrainID is the HydroID of the watershed that other features are related to) relationship. Note that the key drainage area is the total watershed (its HydroID is used to tie all the pieces together).

The screenshot displays three tables in an ArcGIS interface, illustrating the relationship between a point, a watershed, and its sub-watersheds. Red circles highlight the HydroID and DrainID fields, and red arrows show the flow of data from the point to the watershed and then to the sub-watershed.

Table - SWWatershedPoint

OID *	Shape *	Name	Descript	SnapOn	SrcType	ORIGOID	HydroID	DrainID	SnapDist
1	Point	<Null>	<Null>	<Null>	<Null>	1	61371	61371	0.000316

SWWatershed

OBJECTID *	Shape *	Shape_Length	Shape_Area	HydroID	DrainID	WshdType
1	Polygon	60157.47286	30000128.62352	61371	61371	Total Upstream

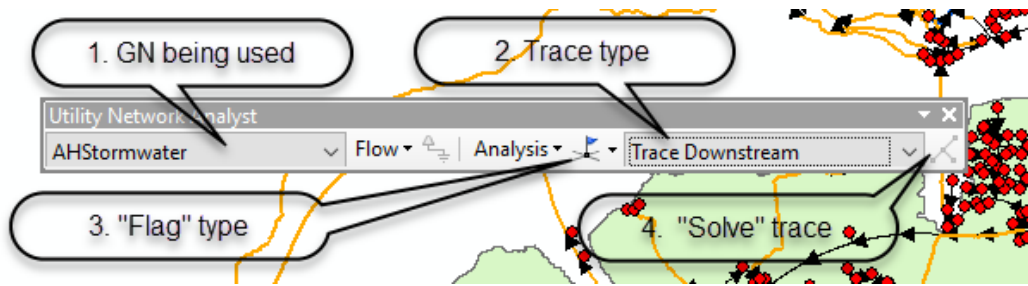
SWWatershed_SWDA

OBJECTID *	Shape *	Shape_Length	Shape_Area	HydroID	DrainID	WshdType
1	Polygon	60157.47286	30000128.62352	61371	61371	Total Upstream
2	Polygon	17788.711798	2254748.746723	61372	61371	Local Upstream
3	Polygon	2427.820932	108489.450765	61373	61371	Local Downstream

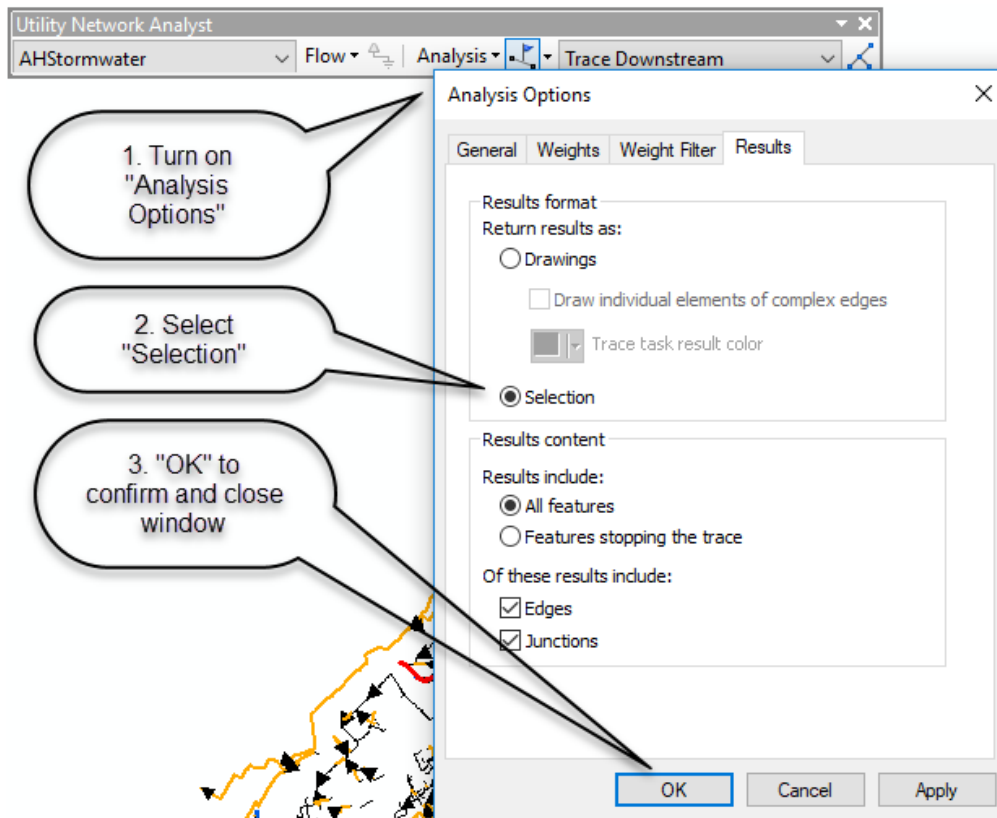
5.2 Downstream trace

A custom tool is not developed for this functionality. Standard geometric network tracing can be easily used to identify downstream path from a point of interest. Follow this procedure:

1. Turn on “Utility Network Analyst” toolbar if necessary. The “AHStormwater” network should already be active.



2. Select type of the trace to perform (“Trace Downstream” in this case, but other traces can be run as well).
3. Place junction or edge flag on the point of interest. A green square will appear and the ”Solve” button will become enabled.
4. Click on the “Solve” button to execute the analysis.
5. Graphics showing the result of the trace will appear.
6. If you want to get selected set as a return, change analysis options (“Analysis -> Options ...” from the Utility Network Analyst toolbar) and rerun the solver.



7. Use other tracing options and general ArcMap capabilities if needed, depending on your end requirements.
8. You can also use “Trace Geometric Network” gp tool to perform the trace.

5.3 Create network connectivity

This tool establishes network element connectivity in tabular form that can be useful for specific custom applications that need simpler connectivity representation. This form is also easy to export to formats that can be used by different network solvers operating outside of ArcGIS environment.

The screenshot shows the 'Create Network Connectivity' dialog box. It contains the following fields and values:

- Input Inlet Point Feature Class: HydroJunction
- Input Outlet Point Feature Class: PipeOutlet
- Input Stream Feature Class: Stream
- Input Pipe Feature Class: Pipe
- Input Catchment Feature Class: Catchment
- Output Node Feature Class: e:\public\stormwater\docproc2018\docproc2018.gdb\Layers\Node
- Output Link Feature Class: e:\public\stormwater\docproc2018\docproc2018.gdb\Layers\Link
- Output Catchment Connectivity Feature Class: e:\public\stormwater\docproc2018\docproc2018.gdb\Layers\CatchmentConn

Buttons at the bottom: OK, Cancel, Environments..., Show Help >>

Tool creates three outputs:

1. Nodes in the network (Node).
2. Connectors in the network (Link).
3. Drainage areas associated with the nodes in the network (CatchmentConn).

Node			CatchmentConn			Link			
NodeID	FeatureID	FType	NodeID	DrainID	FType	FeatureID	FType	From_Node *	To_Node *
1	24425	Inlet	9315	47840	Inlet	11756	Pipe	1	2
2	24424	Inlet	7910	47841	Inlet	11757	Pipe	3	4
3	27644	Inlet	1092	47842	Inlet	11758	Pipe	5	6
4	22321	Outlet	9331	47843	Inlet	11759	Pipe	7	8
5	26295	Inlet	9298	47844	Inlet	11760	Pipe	9	10
6	26294	Inlet	2008	47845	Inlet	11761	Pipe	11	12
7	<Null>	Network	1169	47846	Inlet	11762	Pipe	13	14
8	<Null>	Network	39	47847	Inlet	11763	Pipe	15	16
9	27391	Inlet	2041	47848	Inlet	11764	Pipe	17	18
10	27393	Inlet	9692	47849	Inlet	11765	Pipe	19	20
11	26607	Inlet	6662	47850	Inlet	11766	Pipe	21	22
12	<Null>	Network	9662	47851	Inlet	11767	Pipe	23	24
13	<Null>	Network	5789	47852	Inlet	11768	Pipe	25	26
14	<Null>	Network	4177	47853	Inlet	11769	Pipe	27	28
15	25529	Inlet	9167	47854	Inlet	11770	Pipe	29	30
16	<Null>	Network	1507	47855	Inlet	11771	Pipe	31	32
17	23122	Inlet	8208	47856	Inlet	11772	Pipe	33	34

The following attributes are used to connect the three feature sets:

- NodeID – unique identifier of a node.
- FeatureID – pointer to the HydroID of the feature that generated that network element.
- FType – type of the feature that generated that network element.
- From_Node – NodeID of the from node of the link.
- To_Node – NodeID of the to node of the link.

6.0 Tools and process automation

This section provides a list of tools used in the Arc Hydro stormwater data development and use workflow. Most of the tools used in the stormwater workflows have been part of Arc Hydro toolset for many years. The recent, stormwater specific tools are highlighted here.

6.1 Stormwater data development tools

Sample time of tool execution is provided for relative reference only (comparison of tool execution on a single dataset on a single computer). Actual time will vary depending on the complexity of the data (mostly DEM size) and the hardware used for processing. For reference, the sample dataset had:

1. DEM: 8,149 by 16,166 cells
2. Pipe: 8,721 features
3. StreamInit: 117 features
4. Stream: 1,333 features
5. HydroJunction: 5,515 features
6. PipeOutlet: 1,028 features

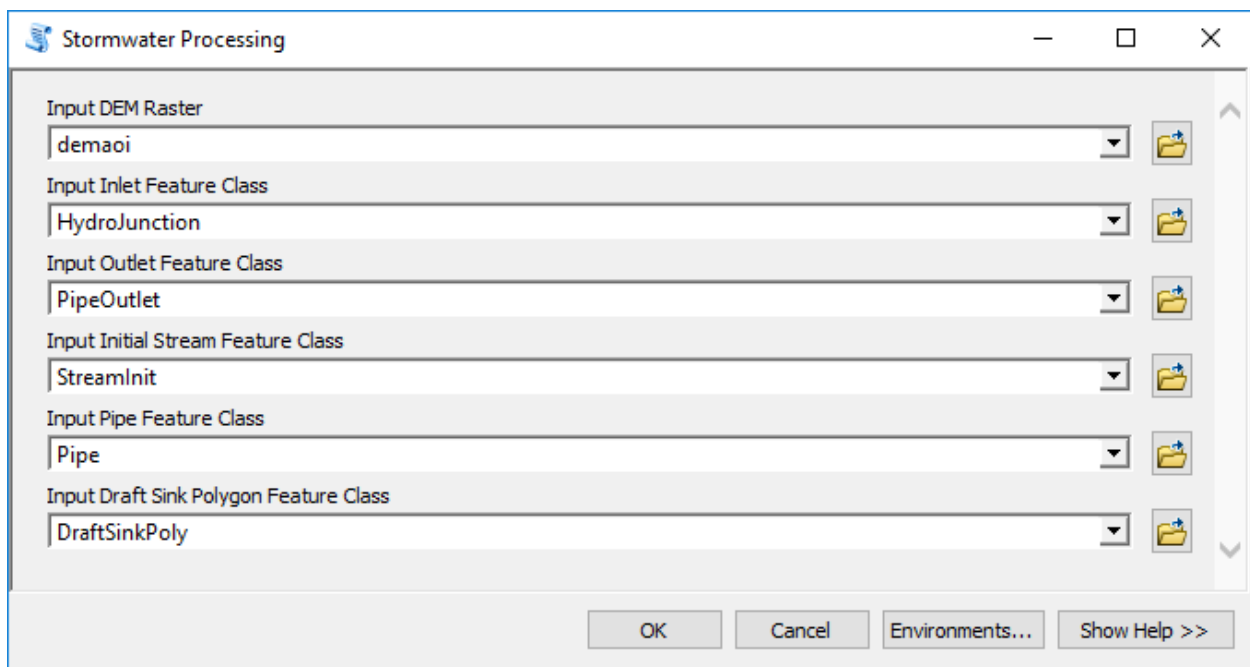
All of the tools used in the workflow are available in the Arc Hydro Tools Python toolbox (highlighted in green are the stormwater specific tools). The following toolset abbreviation is used:

- TP: Terrain Preprocessing
- TP-DM: Terrain Preprocessing -> DEM Manipulation

Step	Tool	Toolset	Sample time
1	Create Sink Structures	TP-DM	1' 21"
2	Create Drainage Line Structures	TP-DM	4' 15"
3	DEM Reconditioning	TP-DM	4' 17"
4	Level DEM	TP-DM	2' 23"
5	Fill Sinks	TP-DM	1' 42"
6	Flow Direction	TP	39"
7	Adjust Flow Direction in Sinks	TP	53"
8	Adjust Flow Direction in Streams	TP	28"
9	Create Overland Flow Connectors	TP	4' 19"

10	Combine Stream Link and Sink Link	TP	21''
11	Catchment Grid Delineation	TP	2' 44''
12	Catchment Polygon Processing	TP	14''
13	Adjoint Catchment Processing	TP	44''
14	Sink Watershed Delineation	TP	3' 32''
15	Link Sink Watershed to HydroJunction	TP	10''
16	Append Coastal Catchments	TP	56''
17	Create Stormwater Network	TP	14''
18	Flow Accumulation	TP	15' 49''
19	Stream Definition	TP	17''

The 19-step workflow is captured in tool “Stormwater Processing” (in Terrain Preprocessing Workflows -> Stormwater toolset). Output location (based on input data) and naming of all output layers is controlled by the tool and not accessible to the user.



Results are presented in Appendix 1. Run took about 37 minutes.

Location of the preprocessing tools is as follows:

- [-] Terrain Preprocessing
 - [+] DEM Manipulation
 - [+] Global
 - [+] Vector QC
 - Accumulate Shapes
 - Adjoint Catchment Processing
 - Adjust Flow Direction in Lakes
 - Adjust Flow Direction in Sinks
 - Adjust Flow Direction in Streams
 - Append Coastal Catchments
 - Assign CatType Attribute
 - Catchment Grid Delineation
 - Catchment Polygon Processing
 - Combine Stream Link and Sink Link
 - Create Overland Flow Connectors
 - Create Pipe Outlets
 - Create Snap Data
 - Create Stormwater Network
 - Drainage Line Processing
 - Drainage Point Processing
 - Flow Accumulation
 - Flow Direction
 - Link Sink Watershed to HydroJunction
 - Longest Flow Path for Adjoint Catchments
 - Sink Watershed Delineation
 - Stream Definition
 - Stream Segmentation
- [-] Terrain Preprocessing Workflows
 - [+] Combined
 - [+] Community Maps
 - [+] Dendritic
 - [+] Deranged
 - [-] Stormwater
 - Stormwater Processing

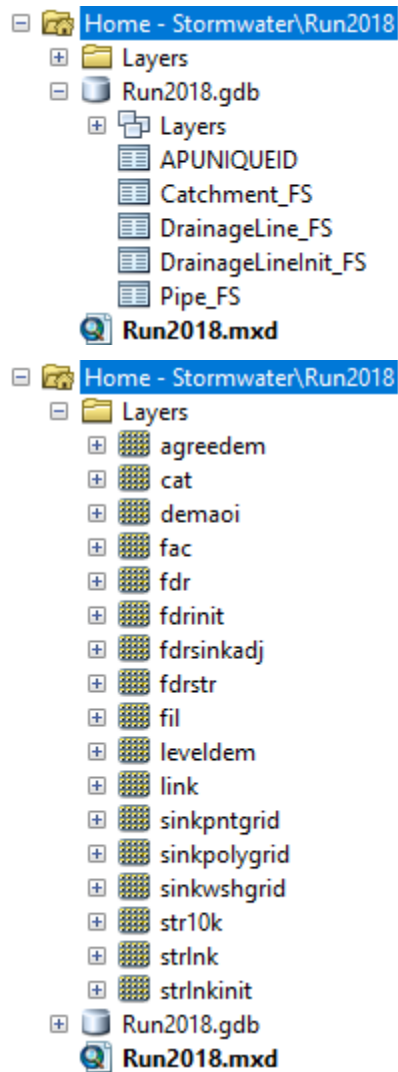
6.2 Stormwater analysis tools

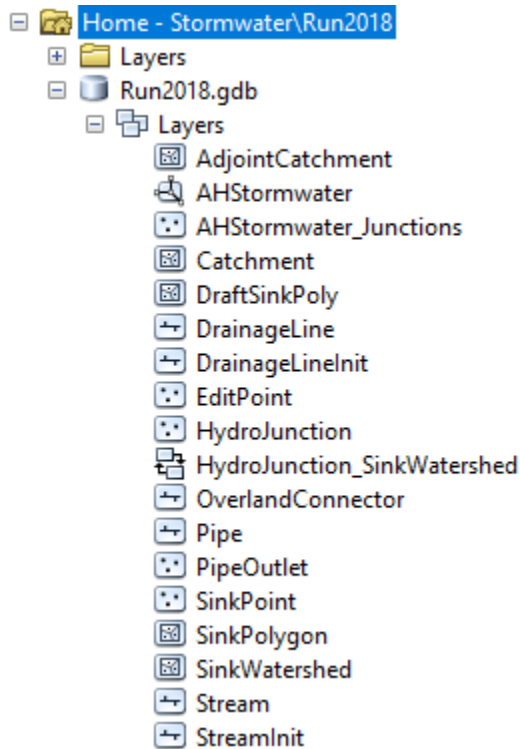
Location of the stormwater analysis tools is as follows:

- [-] Arc Hydro Tools Python.tbx
 - [+] Attribute Tools
 - [+] H & H Modeling
 - [-] Network Tools
 - Create Network Connectivity**
 - [+] Point Characterization
 - [+] Terrain Morphology
 - [+] Terrain Preprocessing
 - [+] Terrain Preprocessing Workflows
 - [+] Utility
 - [-] Watershed Processing
 - [+] Line Processing
 - Main Flow Path**
 - Stormwater Delineation**
 - TX Global Watershed Delineation
 - TX Watershed Delineation
 - Watershed Delineation

7.0 Database design

This section provides database structures generated during the process. It follows the standard Arc Hydro data organization and naming conventions.





7.1 Raster data structures

Layer name	Layer description	Output from Tool	Input to Tool	Used for
Agreedem	Reconditioned DEM with initial streams burnt in.	3	4	
Cat	Catchment raster associated to final streams.	11	12	
Demaoi	Input DEM.		1,2	
Fac	Flow accumulation raster based on final flow direction	18	19	
Fdr	Final flow direction (adjusted for direction in streams and sinks)	8	9,11,14,18	Delineation
Fdrinit	Initial flow direction based on reconditioned, leveled and filled DEM (not extending into sink polygon).	6	7	
Fdrsinkadj	Initial flow direction adjusted to extend into sink polygon.	7	8	

Fdrstr	Flow direction under input streaminit to ensure water follows the stream features.	2	8	
Fil	Reconditioned and leveled DEM filled outside of the sinks	5	6	
Leveldem	Sink-leveled reconditioned filled DEM	4	5	
Link	Link raster created by combining final stream link and sink link and used to delineate catchments.	10	11	
Sinkpntgrd	Sink point raster.	1	7,9,10,14	
Sinkpolygrid	Sink polygon raster.	1	7	
Sinkwshgrid	Sink watershed raster.	14		
Str10k	Cells draining at least 10k cells. Used for snapping. A different threshold may be used if more appropriate.	19		Delineation
Strlnk	Stream link raster created after splitting initial streams and adding overland flow connectors	9	10	Delineation
Strlnkinit	Initial stream link raster created based on the initial streams.	2	3,9	

7.2 Vector data structures/network/relationship

Layer name	Type	Layer description	Output from Tool	Input to Tool	Used for
AdjointCatchment	Poly	Adjoint catchments for final streams.	13		Delineation
AHStormwater	Network	Arc Hydro Stormwater Geometric Network.	17		
AHStormwater_Junctions	Point (Junction)	Default junctions for the geometric network. Deleted if the network is deleted.	17		

Catchment	Poly	Catchments for streams.	12	13,20	Delineation, Connectivity
DraftSinkPoly	Poly	Input draft sink polygons	1		
DrainageLine	Line	Final drainage lines after splitting streams and adding overland connectors.	9	13	Delineation
DrainageLineInit	Line	Drainage lines created based on initial streams.	2		
EditPoint	Point	Stream vertex points used to enforce streams.	2		
HydroJunction	Point	Input inlets to pipe or terrain.		1,9,15,17	Delineation
HydroJunction_Sink Watershed	Rel	Relationship between HydroJunction HydroID and SinkWatershed JunctionID.	15		Delineation
OverlandConnector	Line	Overland flow connector connecting PipeOutlet to stream, HydroJunction, PipeOutlet or other overland flow.	9		
Pipe	Line	Input closed pipes layer.		9,17	Delineation, Connectivity
PipeOutlet	Point	Input outlets from pipes to surface flow.		9	Delineation, Connectivity
SinkPoint	Point	Raster-snapped sink point	1		
SinkPolygon	Poly	Raster snapped sink polygon	1	4,5	

SinkWatershed	Poly	SinkWatershed associated to sinkpoint.	14		Delineation
Stream	Line	Final stream segments containing split streams and overland flow connectors.	2	17	Delineation
StreamInit	Line	Draft stream segments. input		2,9	

7.3 Tabular data structures

Layer name	Layer description	Output from Tool	Input to Tool	Used for
APUNIQUEID	HydroID dispenser			Delineation
Catchment_FS	Catchment flow split table storing flow split connectivity.	13	4	Delineation
DrainageLine_FS	Drainage line flow split table.		2	
DrainageLineInit_FS	Initial drainage line flow split table.	9	3	
Pipe_FS	Pipe flow split table.			
LAYERKEYTABLE	Not used. Related to HydroID dispenser.			

Appendix 1. Stormwater preprocessing automation results

```
Executing: Script demaoi HydroJunction PipeOutlet StreamInit Pipe
DraftSinkPoly
Start Time: Mon Dec 24 00:59:35 2018
Running script Script...
--Building sink structures...Mon Dec 24 00:59:35 2018
  Defining sink polygons in raster space...
--Copying input deranged polygon into temporary FC...
--Getting HIDs...
--Populating field TmpFeatID and HydroID in temporary FC...
----- Populating field TmpFeatID and HydroID in temporary FC completed in
0.78 seconds.
----- Converting temporary deranged polygon to raster completed in 0.78
seconds.
----- Defining sink polygons in raster space completed in 13.36 seconds.
--Defining sink polygons in vector space...
----- Calculating fields in sink polygons completed in 1.18 seconds.
----- Defining sink polygons in vector space completed in 9.72 seconds.
  Identifying sink points...
    Identifying user defined sink points...
5515 sink point(s) identified.
tmpDraftSinkPntFC
C:\Users\deand\Documents\ArcGIS\scratch\scratch.gdb\tmpdraftsinkpt
  Identifying all sink points...
    Some of the sink polygons contain multiple sink points.
    Deleting 84 duplicate sink point(s).
  Identifying sink points completed in 32.72 seconds.
  Defining sink points in raster space...
    Defining sink points in raster space completed in 5.69 seconds.
  Defining sink points in vector space...
----- Raster to Point conversion completed in 3.71 seconds.
----- Copy Features Management completed in 2.88 seconds.
----- Calculate field completed in 1.34 seconds.
    Defining sink points in vector space completed in 7.92 seconds.
Cleaning up temporary layers...
--Creating drainage line structures...Mon Dec 24 01:00:48 2018
--Creating drainage lines from input streams...
--Densifying lines using 2.46063 stepsize
117 record(s) updated on
E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinViejoPPAuto
.gdb\Layers\DrainageLineInit. The HydroID values ranged from 33104 to 33220.
Populating From_Node and To_Node fields...
Populating nextdownids...
inputline=E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinV
iejoPPAuto.gdb\Layers\DrainageLineInit
E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinViejoPPAuto
.gdb\Layers\DrainageLineInit_FS
```

```

('OK',
u'E:\\Public\\OrangeCountyPW1118\\SWDemoV2\\MissionViejoPPAuto\\MissioinViej
oPPAuto.gdb\\Layers\\DrainageLineInit',
u'E:\\Public\\OrangeCountyPW1118\\SWDemoV2\\MissionViejoPPAuto\\MissioinViej
oPPAuto.gdb\\Layers\\DrainageLineInit_FS')
Populating nextdownids completed.
--Adjusting Drainage Lines...
--Snapping vertices and removing points in the same cell...
Snapping vertices and removing points in same cell. 117 line(s) processed.
Points Processed:Removed=22567:0 TotalVertices=16.
--Snapping vertices and removing points in same cell completed.
Processing 126 confluences...
0 overlap(s) between lines successfully cleaned up.
--Cleaning overlapping lines completed.
--No zero length lines to cleanup.
--Fishnet: rows = 3, columns = 2
--Processing fishnet 1
3776 points created. Creating associated strlnk and strfdr grids. Iteration
1.
Total points added: 3776
Points processed during iteration 3776 Total point processed 3776
--Processing fishnet 2
1531 points created. Creating associated strlnk and strfdr grids. Iteration
1.
Total points added: 1531
Points processed during iteration 1531 Total point processed 5307
--Processing fishnet 3
6222 points created. Creating associated strlnk and strfdr grids. Iteration
1.
Total points added: 6222
Points processed during iteration 6222 Total point processed 11529
--Processing fishnet 4
4741 points created. Creating associated strlnk and strfdr grids. Iteration
1.
Total points added: 4741
Points processed during iteration 4741 Total point processed 16270
--Processing fishnet 5
3632 points created. Creating associated strlnk and strfdr grids. Iteration
1.
Total points added: 3632
Points processed during iteration 3632 Total point processed 19902
--Processing fishnet 6
7136 points created. Creating associated strlnk and strfdr grids. Iteration
1.
Total points added: 7136
Points processed during iteration 7136 Total point processed 27038
Total points added using fishnet cells: 7136
--Mosaicking stream link rasters...
--Mosaicking stream flow direction rasters...
--Defining projection for rasters...

```

```

--Building raster attribute tables...
--Cleaning up temporary layers...
--Burning streams into DEM...Mon Dec 24 01:03:26 2018
--Computing smooth drop/raise raster...
--Computing vector distance and allocation rasters...
--Computing elevation raster outside of the buffer...
--Computing buffer distance and allocation rasters...
--Computing sharp drop/raise raster...
--Leveling the DEM in sinks...Mon Dec 24 01:07:17 2018
Using zUnitFactor= 1
Elevation field not set.
Applying integer factor:1000.
Assigning Level Elevation to the lakes...
Identifying point inside...
Extracting values under points...
Calculating fields...
--Filling false sinks...Mon Dec 24 01:09:39 2018
--Identifying Deranged Polygons before filling...
--Filling the DEM...
--Updating the fill DEM with sink values of original DEM...
--Calculating flow direction...Mon Dec 24 01:11:28 2018
--Calculating Flow direction...
--Saving
E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\Layers\fdrintit...
--Adjusting flow direction in sinks...Mon Dec 24 01:12:07 2018
--Adjusting flow direction in sinks...
--Adjusting flow direction in streams...Mon Dec 24 01:12:55 2018
--Create Flow Overland Connectors...Mon Dec 24 01:13:20 2018
---- Replacing flow direction in sinks with 0...
---- Generating cost paths for 928 outlets.
        Completed: Generating cost paths for 928 outlets., dt=35.28s
---- Executing Stream to Feature
        Completed: Executing Stream to Feature, dt=15.01s
---- Snapping lines to outlets
---- Snapping lines to inlets
---- Snapping lines to stream
        Completed: Snapping lines to stream, dt=31.12s
---- Splitting streams at end point connectors and appending connectors.
Number of Split Point features: 92
Number of input lines: 117
Number of lines to split: 27
Number of lines not split: 90
Removing spatial index...
Adding spatial index...
1333 record(s) updated on
E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissionViejoPPAuto
.gdb\Layers\Stream. The HydroID values ranged from 33221 to 34553.
        Completed: Splitting streams at end point connectors and appending
connectors., dt=12.53s

```

```

---- Creating updated Stream Link.
---- Replacing flow direction in sinks with 0...
Executing Stream to Feature...
    - Stream to Feature completed in 5.2 seconds.
Copying C:\Users\deand\Documents\ArcGIS\scratch\scratch.gdb\tmpdl into
feature dataset...
    - Copying completed in 1.9 seconds.
Cleaning completed: 0 line(s) deleted.
    - Cleanup completed in 0.5 seconds.
--Adding GridID as a field...
--Adding and assigning HydroID...
1304 record(s) updated on
E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinViejoPPAuto
.gdb\Layers\DrainageLine. The HydroID values ranged from 34554 to 35857.
    - Adding and assigning HydroID completed in 1.0 seconds.
--Populating NextDownID...
inputline=E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinV
iejoPPAuto.gdb\Layers\DrainageLine
E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinViejoPPAuto
.gdb\DrainageLine_FS
('OK',
u'E:\\Public\\OrangeCountyPW1118\\SWDemoV2\\MissionViejoPPAuto\\MissioinViej
oPPAuto.gdb\\Layers\\DrainageLine',
u'E:\\Public\\OrangeCountyPW1118\\SWDemoV2\\MissionViejoPPAuto\\MissioinViej
oPPAuto.gdb\\DrainageLine_FS')
    - Populating NextDownID completed in 3.6 seconds.
Cleaning up...
    Completed: Executing Drainage Line Processing, dt=24.03s
---- Cleaning up...
--Combine Stream Link and Sink Link...Mon Dec 24 01:16:55 2018
max_sink_val 27594.0
Min GridID in DrainageLine:3, Minimum value in streamlink: 0
Increment: 27594
--Updating GridID in drainage lines...
--Updating link grid with sink links...
--Delineating catchment grid...Mon Dec 24 01:17:12 2018
--Creating catchment polygons...Mon Dec 24 01:19:52 2018
--Converting raster to polygons...
    - Conversion completed in 7.5 seconds.
Renaming field to GridID...
    - Renaming field completed in 0.2 seconds.
Assigning HydroIDs...
6811 record(s) updated on
E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinViejoPPAuto
.gdb\Layers\Catchment. The HydroID values ranged from 35858 to 42668.
    - Assigning HydroIDs completed in 2.5 seconds.
Adding attributes indices...
    - Adding attributes indices completed in 1.1 seconds.
Cleaning up...
--Adjoint catchment processing...Mon Dec 24 01:20:05 2018

```

Building dictionary to store connectivity...
Processing starts - reading 6811 records dt= 1.610 seconds.
Initial pass - identify head features and features having OmitUp=1...
Pass 1.1: Processed 1362 of 6811, 1362 records associated to head features or having OmitUp=1.
Pass 1.2: Processed 2724 of 6811, 2724 records associated to head features or having OmitUp=1.
Pass 1.3: Processed 4086 of 6811, 4086 records associated to head features or having OmitUp=1.
Pass 1.4: Processed 5448 of 6811, 5448 records associated to head features or having OmitUp=1.
Pass 1.5: Processed 6810 of 6811, 6280 records associated to head features or having OmitUp=1.
Pass 1: 6811 of 6811 records are processed, with 6280 records associated to head features or having OmitUp=1. dt= 7.906 seconds. dtTotal=9.516 seconds.
Pass 1 Done:NotDone=6280: 531 dt=7.906 seconds. dtTotal=9.516 seconds..
Head features assigned to 6280 feature(s).
Processing additional features...
Pass 2: 6583 features processed, 228 remaining. dt=5.863 seconds. dtTotal=15.402 seconds..
Pass 3: 6640 features processed, 171 remaining. dt=2.572 seconds. dtTotal=17.974 seconds..
Pass 4: 6669 features processed, 142 remaining. dt=1.450 seconds. dtTotal=19.425 seconds..
Pass 5: 6687 features processed, 124 remaining. dt=0.722 seconds. dtTotal=20.148 seconds..
Pass 6: 6703 features processed, 108 remaining. dt=0.798 seconds. dtTotal=20.947 seconds..
Pass 7: 6715 features processed, 96 remaining. dt=0.976 seconds. dtTotal=21.923 seconds..
Pass 8: 6760 features processed, 51 remaining. dt=2.274 seconds. dtTotal=24.198 seconds..
Pass 9: 6773 features processed, 38 remaining. dt=1.090 seconds. dtTotal=25.288 seconds..
Pass 10: 6785 features processed, 26 remaining. dt=1.626 seconds. dtTotal=26.914 seconds..
Pass 11: 6789 features processed, 22 remaining. dt=0.520 seconds. dtTotal=27.434 seconds..
Pass 12: 6791 features processed, 20 remaining. dt=0.145 seconds. dtTotal=27.580 seconds..
Pass 13: 6792 features processed, 19 remaining. dt=0.031 seconds. dtTotal=27.611 seconds..
Pass 14: 6793 features processed, 18 remaining. dt=0.046 seconds. dtTotal=27.658 seconds..
Pass 15: 6794 features processed, 17 remaining. dt=0.032 seconds. dtTotal=27.691 seconds..
Pass 16: 6795 features processed, 16 remaining. dt=0.032 seconds. dtTotal=27.724 seconds..
Pass 17: 6796 features processed, 15 remaining. dt=0.032 seconds. dtTotal=27.756 seconds..
Pass 18: 6797 features processed, 14 remaining. dt=0.033 seconds. dtTotal=27.790 seconds..

Pass 19: 6799 features processed, 12 remaining. dt=0.067 seconds.
dtTotal=27.857 seconds..
Pass 20: 6800 features processed, 11 remaining. dt=0.035 seconds.
dtTotal=27.892 seconds..
Pass 21: 6801 features processed, 10 remaining. dt=0.043 seconds.
dtTotal=27.935 seconds..
Pass 22: 6802 features processed, 9 remaining. dt=0.035 seconds.
dtTotal=27.971 seconds..
Pass 23: 6806 features processed, 5 remaining. dt=0.148 seconds.
dtTotal=28.120 seconds..
Pass 24: 6808 features processed, 3 remaining. dt=0.080 seconds.
dtTotal=28.200 seconds..
Pass 25: 6810 features processed, 1 remaining. dt=0.113 seconds.
dtTotal=28.313 seconds..
Pass 26: 6811 features processed, 0 remaining. dt=0.045 seconds.
dtTotal=28.358 seconds..
Accumulate shapes completed successfully.

Number of features processed: 6811

Number of loops: 26

Traced Layer:

E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinViejoPPAuto
.gdb\Layers\Catchment

Source

Layer:E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinViejo
PPAuto.gdb\Layers\Catchment

Target

Layer:E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinViejo
PPAuto.gdb\Layers\AdjointCatchment

Number of source features not aggregated: 0

Total merge processing Time: 28.413 seconds. 0.00789246631207 hrs.

531 record(s) updated on

E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinViejoPPAuto
.gdb\Layers\AdjointCatchment. The HydroID values ranged from 42669 to 43199.

--Delineating sink watersheds...Mon Dec 24 01:20:43 2018

Delineating sink watersheds...

Delineating sink watersheds completed in 167.53 seconds.

Vectorizing sink watersheds and populating attributes...

5509 record(s) updated on

E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissioinViejoPPAuto
.gdb\Layers\SinkWatershed. The HydroID values ranged from 43200 to 48708.

Vectorizing sink watersheds and populating attributes completed in
28.22 seconds.

Cleaning up...

--Link Sink Watershed to HydroJunctions...Mon Dec 24 01:24:00 2018

Creating relationship class between SinkWatershed's JunctionID and
HydroJunction's HydroID...

Cleaning up...

--Appending coastal catchments...Mon Dec 24 01:24:04 2018

Identifying coastal catchments in raster space...

Defining land areas covered by existing catchments...

```
    Defining coastal areas...
    Defining coastal catchments in raster space...
Identifying coastal catchments in raster space completed in 35.68
seconds.
    Converting coastal catchment grid into polygons...
    Populating attributes...
    Merging coastal catchments into catchments...
40 record(s) updated on
E:\Public\OrangeCountyPW1118\SWDemoV2\MissionViejoPPAuto\MissionViejoPPAuto
.gdb\Layers\Catchment. The HydroID values ranged from 48709 to 48748.
    Vectorizing coastal catchments and populating attributes completed in:
8.19 seconds.
Cleaning up...
--Create Stormwater Network...Mon Dec 24 01:24:49 2018
HydroJunction SIMPLE_JUNCTION NO;Pipe SIMPLE_EDGE NO;StreamInit SIMPLE_EDGE
NO
Creating geometric network...
Assigning flow direction to digitized direction...
Cleaning up...
--Calculating flow accumulation...Mon Dec 24 01:25:00 2018
Performing flow accumulation using INTEGER option.
Building raster attribute table.
--Calculating Stream Definition...Mon Dec 24 01:36:30 2018
Using threshold = 10000 cells.
---- Cleaning up...
Completed script Script...
Succeeded at Mon Dec 24 01:36:43 2018 (Elapsed Time: 37 minutes 7 seconds)
```