Arc Hydro Tools Process Paper #1

Quality Control for Vector Data Used in Arc Hydro Terrain Preprocessing

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1 Introduction

This document describes quality control (QC) processes for vector data used in Arc Hydro (AH) terrain preprocessing. They will also work when only vector preprocessing is performed (in which case only a subset of the QC processes will have to be performed).

The best way to fix data is not to have data problems in the first place. Using properly designed geodatabase and leveraging geometric networks and topology when the data are developed in house will go long ways in producing clean data from the get go. This document will explain why certain QC checks are being made and problems that can arise with Arc Hydro implementation if the data do not meet certain criteria. These explanations should help the reader in understanding the basic data requirements and their impact on Arc Hydro database development.

There are several important points to make:

- The QC processes presented here do NOT fix the data; they just identify known problems with the data that need to be reviewed and fixed before proceeding to Arc Hydro preprocessing. The users will have to perform data cleanup using standard ArcGIS data editing tools.
- Without clean input data, use of Arc Hydro tools will not generate correct and expected results and that effort should not be undertaken.
- Some of the QC processes are relative to the DEM resolution and parameters used in the preprocessing tools, so an iterative approach might have to be taken in the QC operations. The QC operations that are sensitive in this context are highlighted in the document.
- Not all the QC operations need to be performed. That will depend on the available data, terrain preprocessing workflows, and preprocessing tools to be used.
- The QC tools check for physical problems, not logical ones. That is still user's responsibility.
- Additional QC checks might be possible and needed and users are strongly encouraged to develop and capture them in more complex QC workflows that are specific to their data and data collection processes.

The Arc Hydro team is interested in learning about other possible QC checks, and if they are generic enough we will try to include them in the future releases of the tools. Please let us know what additional checks you find useful in your practice.

QC checks are implemented through a combination of Arc Hydro tools and processes and ArcGIS Data Reviewer extension (DR) checks. DR provides extensive and easy to configure data checking and result navigation capabilities. Use of DR also enables easy extension of the initial set of checks and was implemented with that particular approach in mind – the checks will grow over time and can be configured to meet specific user's data management and editing workflows. For those new to DR, there is a lot of online training and support documentation that can provide a quick start in its use.

- Using ArcGIS Data Reviewer to Assess Data Quality (ArcGIS Version 10.0): http://training.esri.com/gateway/index.cfm?fa=catalog.webCourseDetail&courseid=2099
- Introduction to GIS Data Reviewer (ArcGIS Version 9.3): http://training.esri.com/gateway/index.cfm?fa=catalog.webCourseDetail&courseid=1461
- ArcGIS Data Reviewer: An Introduction (video): http://video.arcgis.com/watch/1698/arcgis-data-reviewer-an-introduction

For those who want to understand and extend the QC processes embedded in the DR batch checks, they are presented in Appendix 1. The specific AH QC tools have been developed as python scripts and as such can be opened, reviewed, and modified if necessary. They are fairly simple scripts that should be easy to understand and extend. All AH QC tools and DR batch jobs are installed when AH is installed.

First chapter presents the overview of the QC checks. Second chapter presents the QC process in detail and presents individual steps in the process. The appendices present the configuration for each DR task/check, functionality of custom AH QC tools, and a worked out example.

1.1 Terrain preprocessing and need for clean data

Arc Hydro preprocessing establishes an Arc Hydro dataset that usually integrates raster and vector data into a single operational data system where Arc Hydro tools operate in fully optimized mode. Complexity of preprocessing depends on the available data and terrain morphology. In the simplest process, the only input into the preprocessing is the DEM and besides having a valid raster of the DEM, no other data are needed. For more complex processes where the user wants to impose known drainage structures into the DEM, additional vector data representing these structures are needed. The following vector data might be needed:

- Stream polylines representing known flow patterns.
- Sinks polygons representing known depressions collecting water.
- Waterbody polygons representing known areas collecting water that is drained out by a stream (as opposed to sinks that are not drained).
- Ridge polygons or lines representing know drainage divides.

These vector data will be inputs into the Arc Hydro tools for terrain preprocessing. For the tools to operate properly and produce expected results, the vector data have to have certain quality. Lack of that quality will result either in tools not working or producing unexpected results. Performing the quality control (QC) steps presented in this document will identify key input data problems that will make implementation of Arc Hydro preprocessing unpredictable. Data problems identified through the use of the presented QC check should be fixed before proceeding with Arc Hydro preprocessing.

1.2 Types of QC checks

There are two key types of checks:

1. Checks on the quality of geometry of the data within a single feature class. These could be considered as "physical" checks. They include basic checks such as checking for null geometry as well as more complex checks such as checking for pseudo-nodes and end edges.
2. Checks on the relationship of data across multiple feature classes. These could be considered as "process" checks.

In both cases, understanding the impact of identifying a "problem" identified through the check is important, as often, the identified "problem" is not a problem at all but a desired and necessary feature. DR identifies the potential problems, but the user ultimately decides what action to take, whether it is to fix a problem or keep the feature as is.

The following sections list physical and process checks currently implemented in the Arc Hydro QC tools. It is expected that these will grow over time. The current checks focus on four feature classes that are most often used in Arc Hydro terrain preprocessing. Using DR capabilities, these checks can be quickly adapted for other input data if need be.

1.2.1 Basic stream geometry checks

#	Check	AH issue/recommended fix
Physical check		
1.1	Zero geometry	Unnecessary features to process. Remove offending features.
1.2	Multipart	Unnecessary complexity, connectivity confusion. Split into individual features and/or merge into a single geometry.
1.3	Coincidence	Connectivity, order confusion. Remove all but one feature at each location.
1.4	Self-intersection including circular line	Connectivity confusion. Clean up geometry.
1.5	Short lines (not always a problem)	Connectivity confusion (lines can collapse when burning into DEM). Drainage line and catchment size issues. Merge into neighboring lines if possible.
1.6	Pseudo node (not always a problem)	Drainage line and catchment size issues. Merge into neighboring lines if possible.
1.7	• Outlets (not always a problem) • Overshoots (intersects) • Non-end node connections	Can produce sinks. Flow direction, drainage line issues. Clean-up geometry.
1.8	Flow splits (not always a problem)	Flow direction issues. If really existing require specific processing workflow. Remove if necessary.
Process check		
1.9	Directionality (digitized direction should be in flow direction)	Flow direction issue. Fix line orientation in downstream direction.
1.10	Braids (not always a problem)	Flow direction, short drainage line issues. Remove if necessary.

1.11	Looping sequence (not always a problem)	Flow direction, short drainage line issues. Remove if necessary.

Table 1. Basic stream geometry checks

If ridges are being applied as linear features (as opposed to implementing them as watersheds – polygonal features discussed in the next section), checks 1-4 above should be performed on them.

1.2.2 Basic polygon geometry checks

These checks apply to polygon type feature classes used in the Arc Hydro preprocessing. This includes:

- Sinks
- Water bodies (non-sinks)
- Watersheds

#	Check	AH issue/recommended fix
Physical check		
2.1	Zero geometry	Unnecessary features to process. Remove offending features.
2.2	Multipart	Unnecessary complexity, ID and order confusion. Split into individual features and/or merge into a single geometry.
2.3	Coincidence	ID and order confusion. Remove all but one feature at each location.
2.4	Overlaps/gaps	Precedence confusion, incompleteness. Clean up geometry.
2.5	Touching (not always a problem)	Unnecessary complexity, incompleteness. Clean up geometry.

Table 2. Basic polygon geometry checks

1.2.3 Stream geometry with respect to raster checks

These checks should be applied after all the issues identified in the basic checks have been resolved. It is important to note that results of these checks are a function of DEM cell size. Same vector geometry might have different issues (or none) depending on the DEM resolution.

#	Check	AH issue/recommended fix
Physical check		
3.1	Vertices within a single raster cell that form a loop	Flow direction issues. Clean up geometry.
3.2	Segments smaller than cell size (from and to nodes within the same cell)	Lost drainage lines. Adjust the segment length if possible or just note the mismatch between the

		resolution of vector and raster data.
3.3	Parallel lines within a single cell sequence Vertices from multiple lines occupying the same grid cell (confluences)	Lost drainage lines. Adjust distance between the lines if possible or just note the mismatch between the resolution of vector and raster data. Lost drainage lines and/or moved confluences. Adjust lines to enter a confluence from a single and different neighboring cell.
3.4	Identify lines that are extending over the DEM's "edge" (usually a good event)	Problem with "burning" streams. End streams that are fully contained within the processing area will generate internal drainage areas, which is valid only in fully deranged terrain morphology. Otherwise at least one end stream has to extend over the area (breach line).
3.5	Streams close to the edge of the DEM extent	Problem with "burning" streams. Streams within the AGREE buffer distance from the full extent boundary might "breach" the boundary. Move the streams away from the boundary or use a narrower AGREE buffer.

Table 3. Stream geometry with respect to raster checks

1.2.4 Polygon geometry with respect to raster checks

#	Check	AH issue/recommended fix
	Physical check	
4.1	All polygons have to be fully contained within the DEM extent	Unexpected results. Edit/remove geometry to fit within the DEM extent.

Table 4. Polygon geometry with respect to raster checks

1.2.5 Stream/boundary/water body interaction checks

#	Check	AH issue/recommended fix
	Physical check	
5.1	Water body (not sinks) polys that do not have streams going through them	These will not be used in "adjust flow direction in lakes" function. Extend the streams to "flow" through the water bodies.
5.2	Find if there are watershed boundary polygons (walls) that do not include either a sink poly or have a stream breaching its boundary (not always a problem)	Watersheds without a stream breach or a sink will generate an internal drainage area. Edit geometry if necessary, or just acknowledge internal drainage areas.
5.3	Streams close to watershed boundary (not always a problem)	Problem with "burning" streams. Streams within the AGREE buffer distance from the watershed boundary

		(not outlet) might “breach” the boundary. Move the streams away from the boundary or use a narrower AGREE buffer.

Table 5. Stream/boundary/water body interaction checks

2 QC process operation

2.1 Introduction

Quality control for vector data used in the Arc Hydro preprocessing is a process that involves a sequence of steps. It is a combination of data preparation and tool operations and involves knowledge of how the data will be used in preprocessing tools. The process outline is:

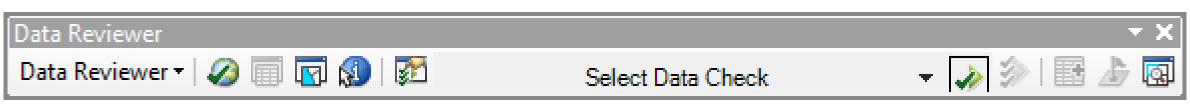
1. Prepare the initial geodatabase with vector data to be QC’ed.
2. Run basic QC checks (checks on individual layers).
3. Fix identified basic data problems.
4. Run steps 2-3 until all the data have been fixed.
5. Run advanced QC checks (checks across multiple layers).
6. Fix identified advanced data problems.
7. Run steps 5-6 until all the data have been fixed.

In case that the user has several other layers that are used in data development and maintenance workflows but are not used in Arc Hydro terrain preprocessing, a larger data processing workflow needs to be developed to integrate the presented QC techniques into the overall data processing methodology.

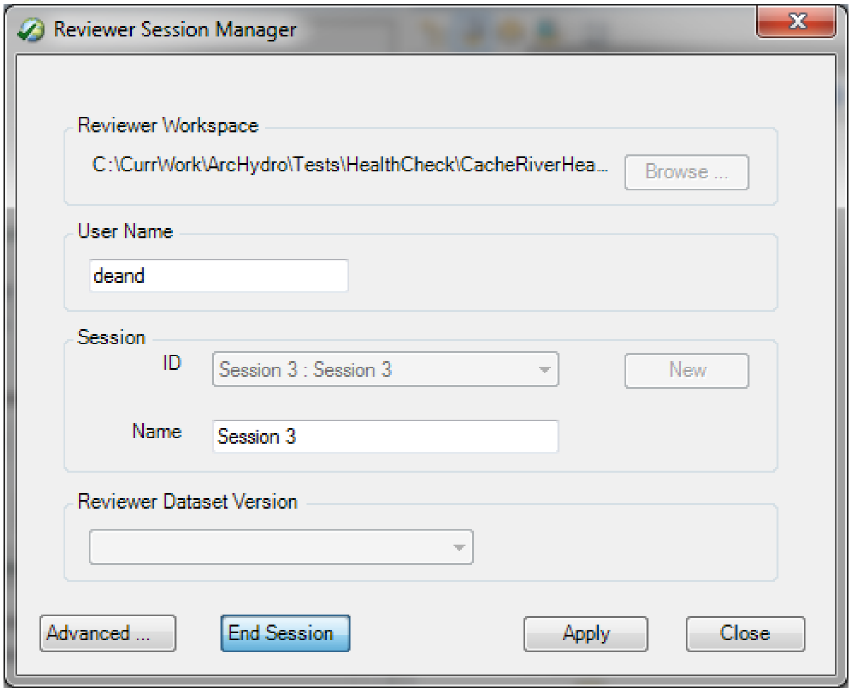
2.1.1 Overview of ArcGIS Data Reviewer batch job execution

All DR batch job runs are performed in the following way (ArcGIS Data Reviewer extension has to be installed and enabled on the computer where the checks are being performed):

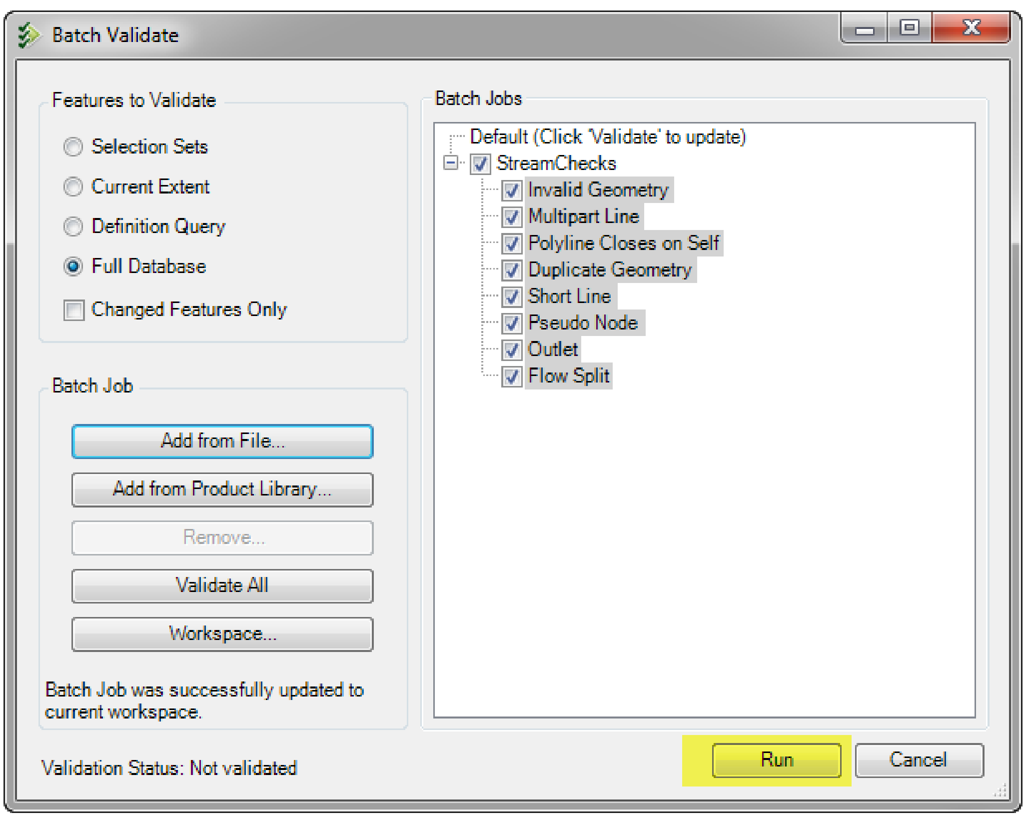
1. Make sure DR toolbar is visible.



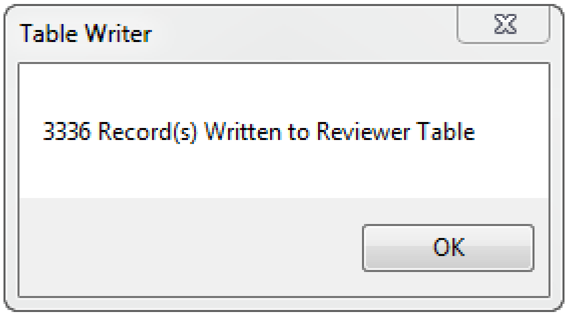
2. Start an existing or new DR session (click on the “Reviewer Session Manager” tool and open a session). Whether to start a new or an existing session and whether to store the records about anomalies in the data in the same or different geodatabase from where the data are stored depends on user’s overall data QC and editing strategy (e.g. if each layer is checked and fixed independently, generate a new session; if all are checked at once and then fixed, have all batch jobs reference the same session).



3. Run the batch job by clicking on the "Batch Validate". Select one of several available AH DR batch job definition files (in the AH tools installation directory, "rbjfiles" folder – usually at C:\Program Files (x86)\ESRI\WaterUtils\ArcHydro\rbjfiles). Click on "Run" to run the batch validation.



4. Upon completion, the validation process will provide a message about results being written to the reviewer table.



5. Review the results of the validation process and fix any problems (click on "Reviewer Table" to see all the identified issues and navigate to them).

2.2 Prepare initial geodatabase with vector data to be QC'ed

Arc Hydro data form an integrated analytical system. Both raster and vector data directly used by the Arc Hydro preprocessing tools have to be in the same spatial reference and vector data in the same geodatabase/feature dataset. The extent of the DEM dictates the area of interest and defines the extent of the vector data needed to support the development of the Arc Hydro preprocessed data system.

To automate the QC processes as much as possible, a fixed QC geodatabase structure has been defined and should be used to leverage the QC tools. Use of QC processes on non-structured data is possible but will require more manual work and thorough understanding of the implemented DR QC checks.

The following steps are performed to create the preformatted QC database. All QC jobs and data cleaning should be performed on that database.

1. Create an empty (file) geodatabase.
2. Create a feature dataset called "Layers" with spatial reference imported from the DEM that will be used in preprocessing. DEM should reside outside of the geodatabase and should cover at least the full extent of the area that will be preprocessed (or more).
3. Import vector layers to be QC'ed into the feature dataset created in #2. Which layers need to be imported depends on the available data and terrain preprocessing workflows to be executed. Some or all can be added. They will be given the following fixed names. These names facilitate easy application of batch QC jobs.
    a. "Stream" – line feature class with streams to be used for "DEM Reconditioning" and "Create Drainage Line Structures" functions.
    b. "Sink" – polygon feature class defining sinks to be used in the "Level DEM" and "Create Sink Structures" functions.
    c. "Waterbody" – polygon feature class of "non-sinks" to be used in the "Adjust Flow Direction in Lakes".

   d. "Watershed" – internal boundary polygon feature class to be used in "Build Walls" function.

4. Create "ProcessingArea" polygon feature class that defines the polygonal extent of DEM to be processed.
5. Create "ProcessingAreaOutline" polygon feature class that defines the extent of DEM to be processed as a linear feature set.

These steps are implemented in the "Create Initial QC GDB" AH QC tool (in "Vector QC" toolset within AH "Terrain Preprocessing" toolset).

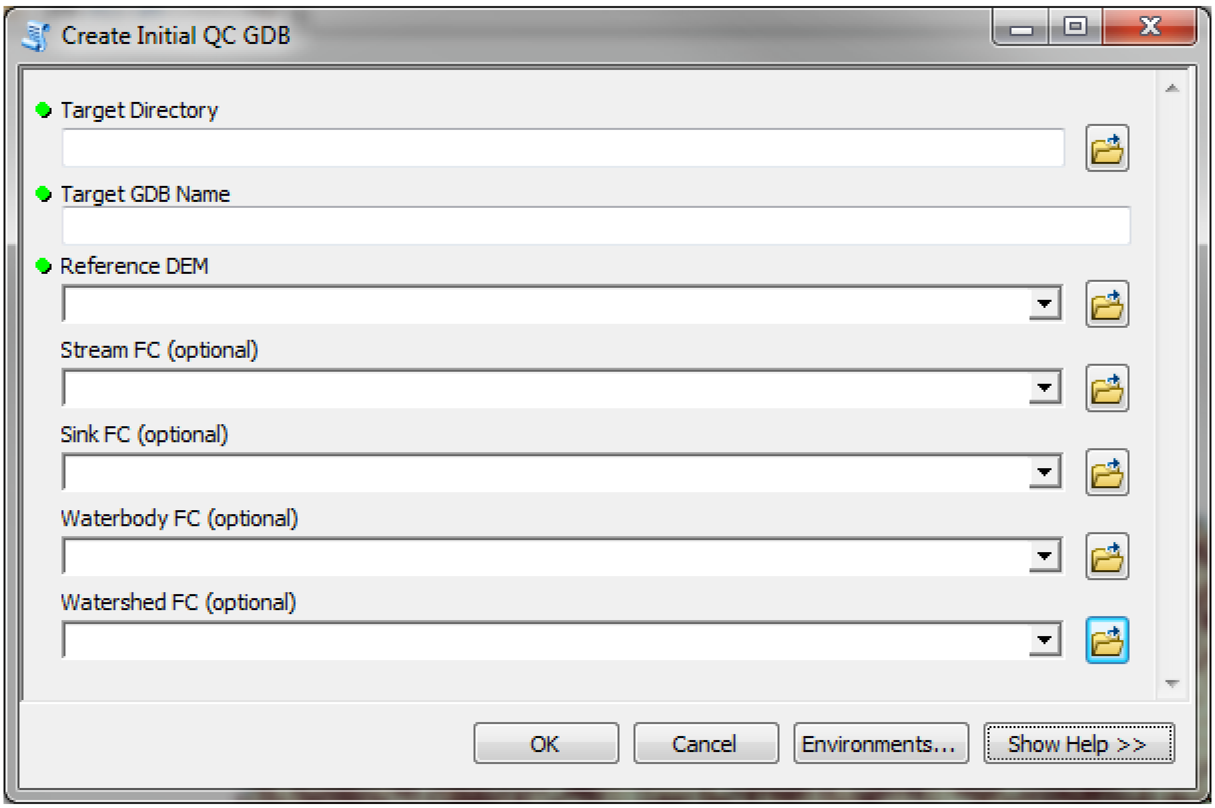


Figure 1. Create Initial QC GDB function user interface.

Additional linear and polygonal features can be added to the QC geodatabase if necessary. At this point, no QC batch jobs are established for these additional layers, but can be developed by the user based on the jobs developed for the first four layers.

2.3 Basic stream QC checks

This is the process that is performed on stream feature class. It involves two steps in this particular order:

1. Run stream connectivity AH QC function
2. Run DR basic stream QC check batch job

These two steps should be performed each time after stream data have been edited.

2.3.1 Stream connectivity definition

These operations (Appendix 2.2) prepare the stream connectivity data for the basic stream QC tasks. They should be executed after any edits to the stream layer are made and before executing the DR QC checks. These steps are implemented in the "Stream Connectivity Parameters" AH QC function (in "Vector QC" toolset within AH "Terrain Preprocessing" toolset).

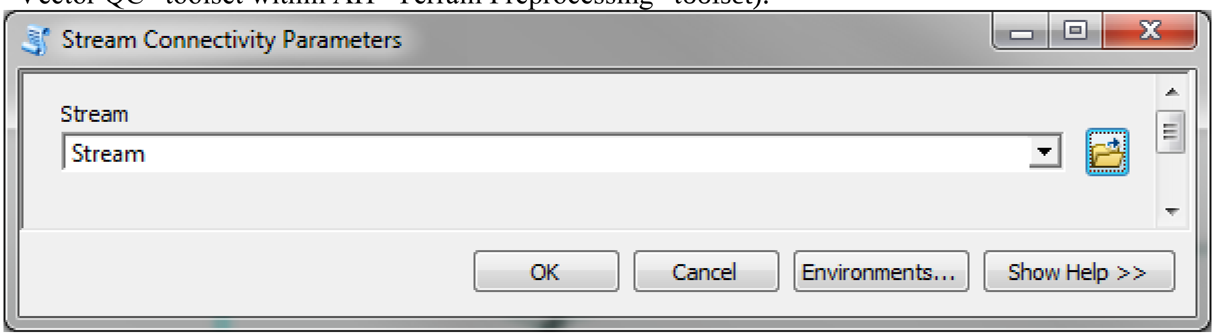


Figure 2. Stream Connectivity Parameters function user interface.

This function will create HydroID, From_Node, To_Node, NextDownID, and FlowSplitCnt fields in the Stream feature class as well as creating the Stream_FS table and Stream_AllEndPnt feature class.

2.3.2 Basic QC processes for streams

This section covers checks presented in Table 1. Checks 1.1-1.8 are performed through DR batch job while checks 1.9-1.11 are processes performed using standard ArcGIS tools. QC function "Stream Connectivity Parameters" should have been run before DR QC checks.

The DR batch job configuration file for basic stream QC checks is called "StreamBasicCheck.rbj" (configuration is provided in Appendix 1).

Check #1.9 deals with directionality of the stream lines. This is important for flow direction enforcement. This is a redundant check as if all fixes based on check #1.7 have been made, all stream segments will be oriented correctly in the downstream direction and this check will not identify any further issues. The check is performed using the following general procedure using standard ArcGIS tools (no specific AH QC tools are provided for this purpose):

1. Perform basic checks 1.1-1.8 and fix anything that needs to be fixed.
2. Build geometric network out of streams.
3. Use Arc hydro tool to assign flow direction in the network based on digitized direction.
4. For each true outlet edge, place a network flag at the downstream node(s).
5. Set tracing results to generate selected set.

6. Trace upstream - this will identify all edges that flow into the outlet(s). If this is the complete set of edges, then all the edges are oriented "downstream" and flow into the outlets. If not all edges are selected, it means that there is a "miss-oriented" edge that needs to be inspected and potentially "flipped".

Check #1.10 deals with braids in the system. Braids are not necessarily a data problem, but often present more detail than is needed. Braids will be identified through check #1.8 (flow splits). When inspecting identified flow splits, make a decision whether the braids will be represented explicitly or not. If not, remove the "minor" braid stream elements and just keep the main stream. If braids are to be modeled, make sure you use appropriate terrain preprocessing workflow (you cannot use synthetic streams as that workflow does not allow for flow splits in auto generated drainage lines).

Check #1.11 deals with loops in the system. As with braids, this is not necessarily a data problem and have to be treated in the same manner, that is, remove one ("minor") side of the loop if loop is not desired, or keep them both if they are explicitly modeled.

As fixes to the data are made, the QC process will have to be repeated until all the fixes are completed. If new lines are added or deleted, or directionality of the lines is changed (flipped), before running the DR batch job, you have to rerun "Stream Connectivity Parameters" tool to recalculate the stream connectivity attributes.

2.4 Basic QC processes for polygons

This covers checks presented in Table 2. These checks are performed through DR batch jobs. No other steps need to be performed before running the basic polygon checks. The following batch jobs should be used for each appropriate type of polygon geometry. Each of these batch jobs performs the same set of checks (configuration is provided in Appendix 1).

- Sinks – "SinkBasicCheck.rbj"
- Water bodies – "WaterbodyBasicCheck.rbj"
- Watershed – "WatershedBasicCheck.rbj"

It is best to fix any identified errors before proceeding to the advanced checks.

2.5 Advanced QC processes

The advanced QC processed deal with interaction of individual layers, for example interaction between the stream polylines and water body polygons. They should be performed after the basic checks and cleanup of data resulting from the basic checks have been completed.

2.5.1 Stream geometry with respect to raster QC checks

This covers checks presented in Table 3. These checks are performed through DR batch job ("StreamAreaCheck.rbj" - configuration is provided in Appendix 1). Before running this batch job, you first have to run:

1. "Stream QC" Arc Hydro QC tool.

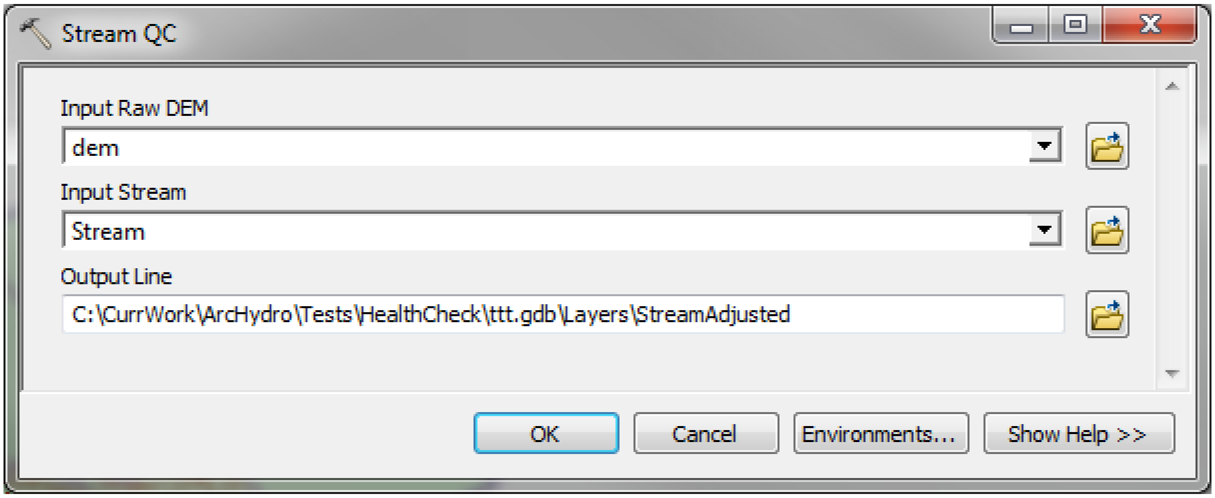


Figure 3. Stream QC function user interface.

2. "Streams Near Processing Area Boundary" Arc Hydro QC tool (Appendix 2.3).

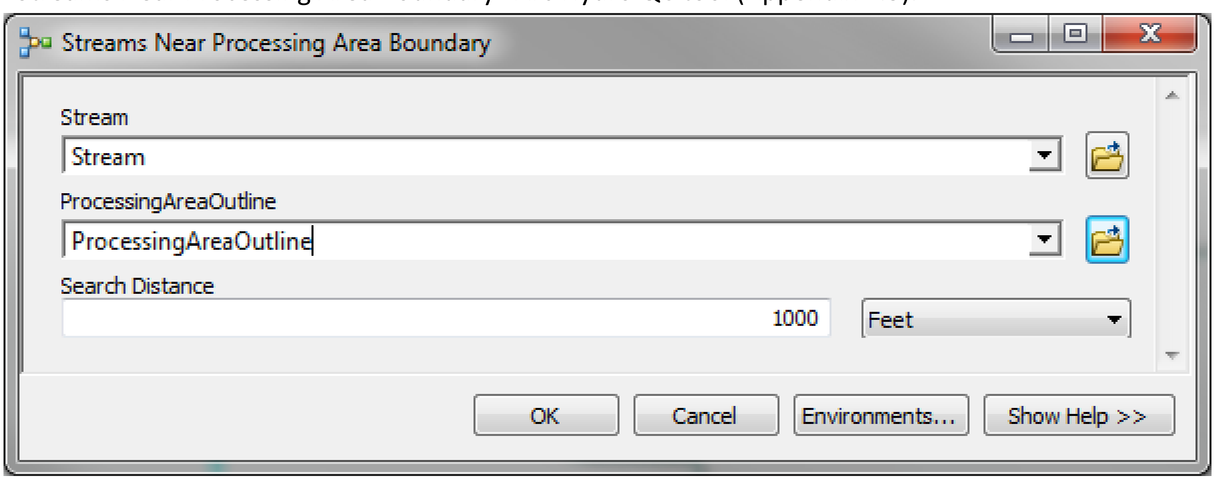


Figure 4. Streams Near Processing Area Boundary user interface.

The "Stream QC" Arc Hydro QC tool will populate attribute "QCVALUE" in the input stream feature class defining the type of the QC issues for checks #3.1-3.3. This value is then used in the DR batch job. The result of the Stream QC function is also a "jaggedized" version of the input stream line feature class (default name of that feature class is "StreamAdjusted"). This represents stream lines where vertices are snapped on the center of the DEM cell that the vertex is in. Any potential geometry issues due to the cell snapping will be documented in the QCVALUE field. The following values in the QCVALUE field correspond to the checks in table 3.

Check #	QCVALUE
3.1	1
3.2	2
3.3	4

Table 6. Advanced stream check vs. QCVALUE

QCVALUE can contain additional values besides 1, 2, and 4. These values are the sums of individual values indicating that more than one issue is present for that feature. For example, QCVALUE = 7 for a feature indicates issues 1, 2, and 3 (= 1 + 2 + 4) are present.

The DR batch task "Vertex Snap" will identify all features that have issues 3.1-3.3 in a single batch job task. By looking at the QCVALUE field, you can do further refinement of the issues. If desired, a single QC task for each of the issues can be established if that will facilitate data editing once the issues have been identified.

When evaluating results of check #3.4, there are two cases. One case is when the intersection of the stream line with the boundary is with a line that is "flowing" into the processing area. That can cause problems as this often indicates that after the streams are "burned" into the DEM, these lines will introduce additional area into the system (this of course might not be an issue if there is no DEM outside of the processing area polygon). The second case is when the intersection is with the line that is "flowing" out of the processing area. This is a desired situation for dendritic and combined terrains, but not for completely deranged terrains.

Check #3.5 is a general case of check #3.4. The "Streams Near Processing Area Boundary" Arc Hydro QC tool will populate attribute "NearBnd" in the input stream feature class defining whether the stream is within specified distance from the processing area boundary (=1 if it is and "Null" if it is not). The specified buffer distance should reflect the buffer distance that will be used in the "DEM Reconditioning" AH terrain preprocessing function (it should be the same or slightly bigger). When the streams are close to the boundary (whether external or internal), they can breach that boundary during the DEM reconditioning (buffer) process. If the streams are outlet streams, that is usually a good situation, while if they are not, then these streams need to be fixed.

2.5.2 Polygon geometry with respect to raster QC checks

This covers checks presented in Table 4. These checks are performed through DR batch job. The following batch jobs should be used for each appropriate type of polygon geometry. Each of these batch jobs performs the same check (configuration is provided in Appendix 1).

- Sinks – "SinkAreaCheck.rbj"
- Water bodies – "WaterbodyAreaCheck.rbj"
- Watershed – "WatershedAreaCheck.rbj"

No specific functions need to be run before performing these checks (so after edits to participating features, they can be immediately reapplied).

If the “Watershed” feature class is being used, after all the QC and cleaning is completed on it, the line representation of this feature class needs to be created for later QC tasks. Standard gp function “Polygon To Line” should be used. The resulting line feature class must be named “WatershedOutline” and has to reside in the same feature dataset where the input “Watershed” feature class is.

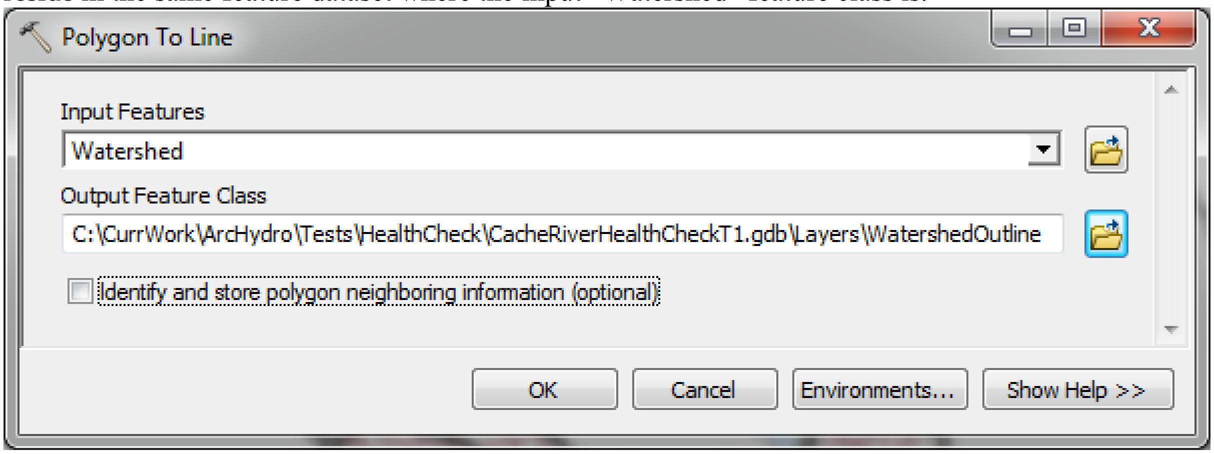


Figure 5. Polygon To Line function user interface.

2.5.3 Stream/boundary/water body interaction QC checks

This covers checks presented in Table 5. These checks are performed through several DR batch jobs (configuration is provided in Appendix 1).

- “WaterbodyAdvancedCheck.rbj” performs check #5.1.
- “WatershedAdvancedCheck.rbj” performs check #5.2.
- “StreamAdvancedCheck.rbj” performs check #5.3.

Check #5.1 does not require any specific functions to be run before performing it. It will identify water bodies that do not have a stream running through them. Such water bodies will be ignored when performing “adjust flow direction in lakes” function. User has three options:

1. Ignore these issues and keep those polygons in the feature class (they will just be ignored)
2. Remove the “offending” polygons – it results in a “cleaner” dataset (but the result on the preprocessed DEM will be the same as for option #1)
3. Extend the streams to “drain” (intersect) the offending polygons. This will then include these polygons in the flow direction adjustment.

Check #5.2 requires that “Non Draining Watersheds” Arc Hydro QC tool is run first. This tool will populate attribute “NonDraining” in the input watershed feature class defining whether the watershed is not drained (intersected by) neither by a stream nor a sink (=1 if it is not drained and “Null” if it is). Such watersheds might indicate a problem with any of participating datasets (watershed, stream, sink) and such cases need to be reviewed and problem data fixed. By not having a “draining” feature within a watershed, strange results might happen depending on the type of terrain preprocessing being used as these watersheds represent internal draining areas, and if they are truly such, a deranged processing needs to be used – in which case having a sink within that watershed is desired to explicitly direct the flow into it.

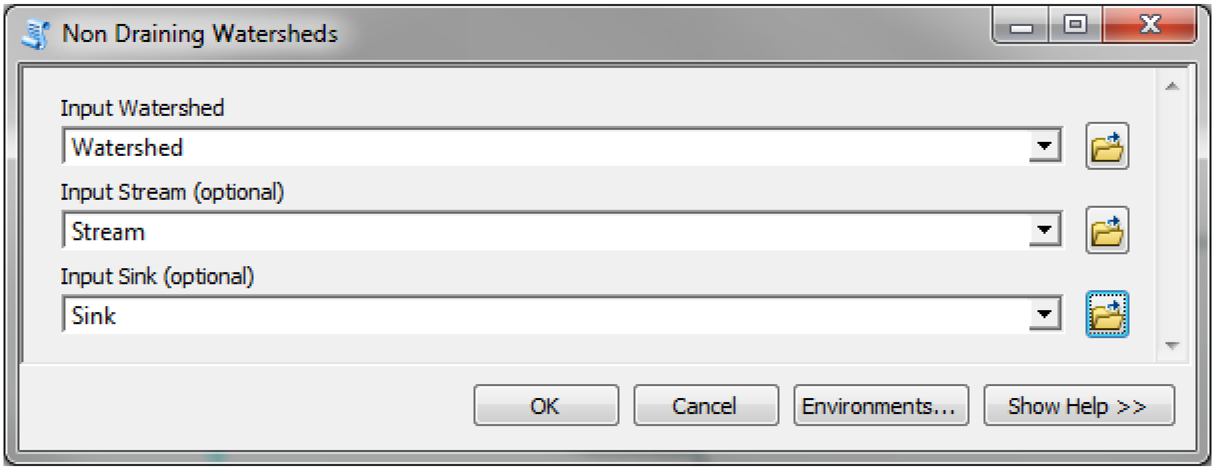


Figure 6. Non Draining Watersheds user interface.

Check #5.3 requires that "Streams Near Watershed Boundary" Arc Hydro QC tool is run first. This tool will populate attribute "NearWsh" in the input stream feature class defining whether the stream is within specified distance from the watershed boundary (=1 if it is and "Null" if it is not). The specified buffer distance should reflect the buffer distance that will be used in the "DEM Reconditioning" AH terrain preprocessing function. When the streams are close to the boundary, they can breach that boundary during the DEM reconditioning (buffer) process. If the streams are watershed outlet streams, that is usually a good situation, while if they are not, then these streams need to be fixed. This function requires a "WatershedOutline" polyline feature class to exist (section 2.5.2).

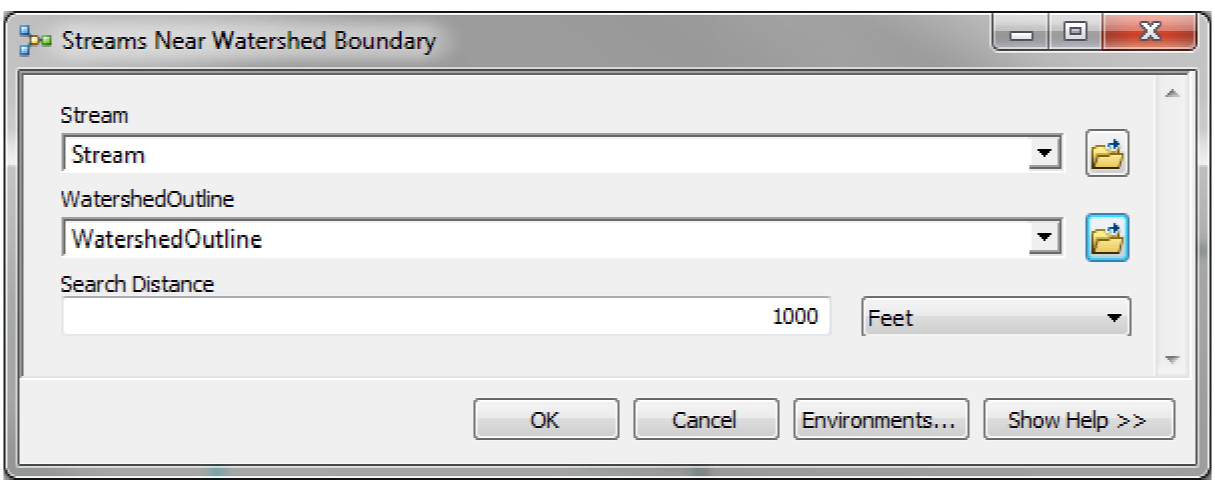


Figure 7. Streams Near Watershed Boundary user interface.

2.6 Loop through QC check and data fixes

After a set of checks is completed and data are fixed, the checks should be run again until no fixes are needed. Remember that some of the checks are dependent on the DEM that the vector data are being applied to. The process should always be such that the vector data are first cleaned on their own and only then they are checked in the context of the DEM and other data that they will be used in conjunction with. This ensures that the initial layer cleaning is not influenced by the later processing as that same layer might be used for other purposes or processing scales.

After the basic checks and data cleanup resulting from them have been completed and before performing advanced checks, it is advised to make a backup of all vector layers. Since advanced checks are related to interaction of different data layers, they might affect the individual layers in different ways that are not relevant to the dataset by itself. Having the backup will allow the user to go back to the original unaffected dataset if some of other vector layers in advanced checks are changed, or the data are applied to a different resolution DEM.

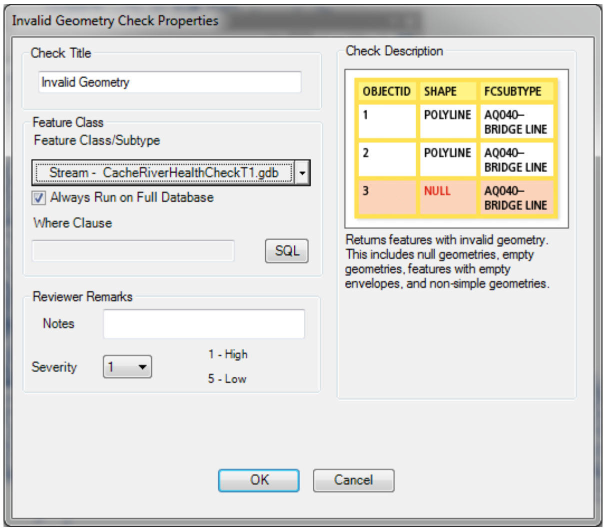
Appendix 1. QC Check Definitions

This appendix presents definitions of each DR check.

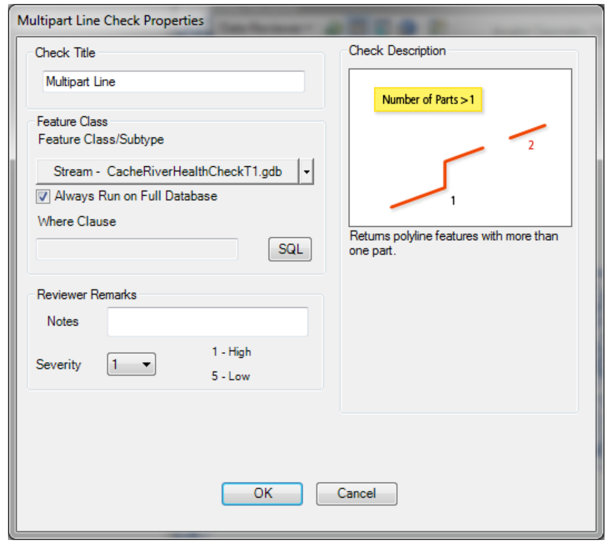
Checks	Batch job file	Batch job tasks
1.1 – 1.8	StreamBasicCheck.rbj	Stream Checks Invalid Geometry Multipart Line Polyline Closes on Self Duplicate Geometry Short Line Pseudo Node Outlet Flow Split
3.1 – 3.5	StreamAreaCheck.rbj	Stream Area Checks Breaching Processing Area Boundary Proximity Vertex Sanp
5.3	StreamAdvancedCheck.rbj	Stream Advanced Checks Watershed Boundary Proximity
2.1 – 2.5	SinkBasicCheck.rbj	Sink Checks Invalid Geometry Multipart Duplicate Geometry Overlap Touches Each Other
4.1	SinkAreaCheck.rbj	Sink Area Checks Not Within Processing Area
2.1 – 2.5	WaterbodyBasicCheck.rbj	Waterbody Checks Invalid Geometry Multipart Duplicate Geometry Overlap Touches Each Other
4.1	WaterbodyAreaCheck.rbj	Waterbody Area Checks Not Within Processing Area
5.1	WaterbodyAdvancedCheck.rbj	Waterbody Advanced Checks Non-Draining Waterbody
2.1 – 2.5	WatershedBasicCheck.rbj	Watershed Checks Invalid Geometry Multipart Duplicate Geometry Overlap Touches Each Other
4.1	WatershedAreaCheck.rbj	Watershed Area Checks Not Within Processing Area
5.2	WatershedAdvancedCheck.rbj	Watershed Advanced Checks Non-Draining Watershed

Appendix 1.1 Stream Basic Checks (StreamBasicCheck.rbj)

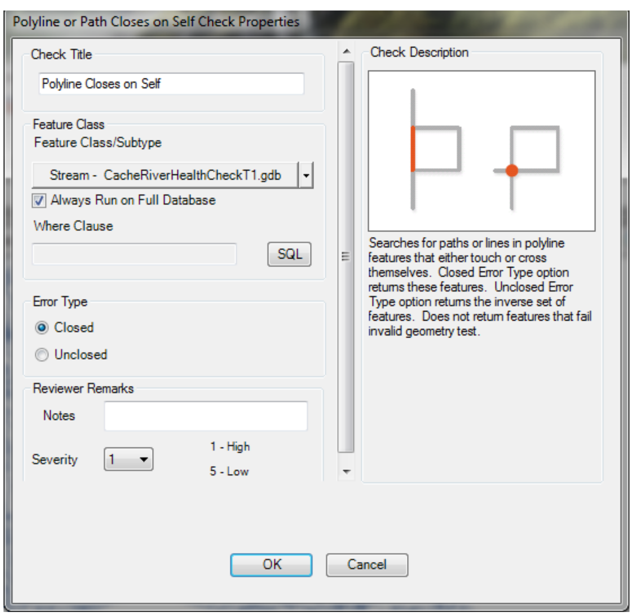
Invalid Geometry Check



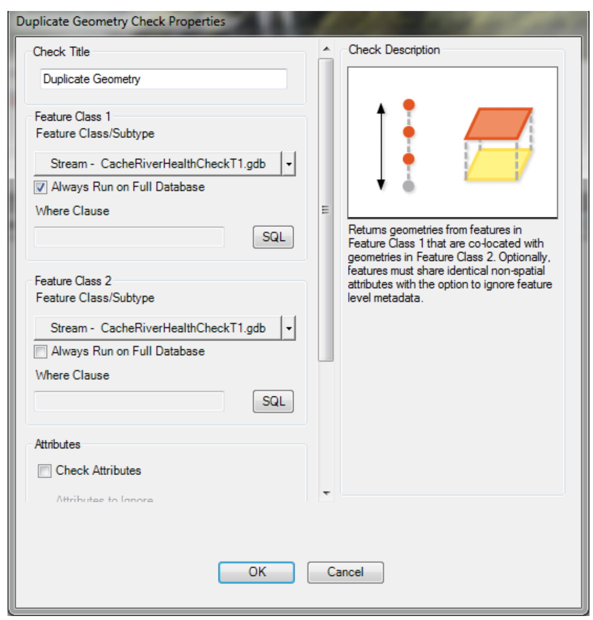
Multipart Line Check



Polyline Closes on Self Check

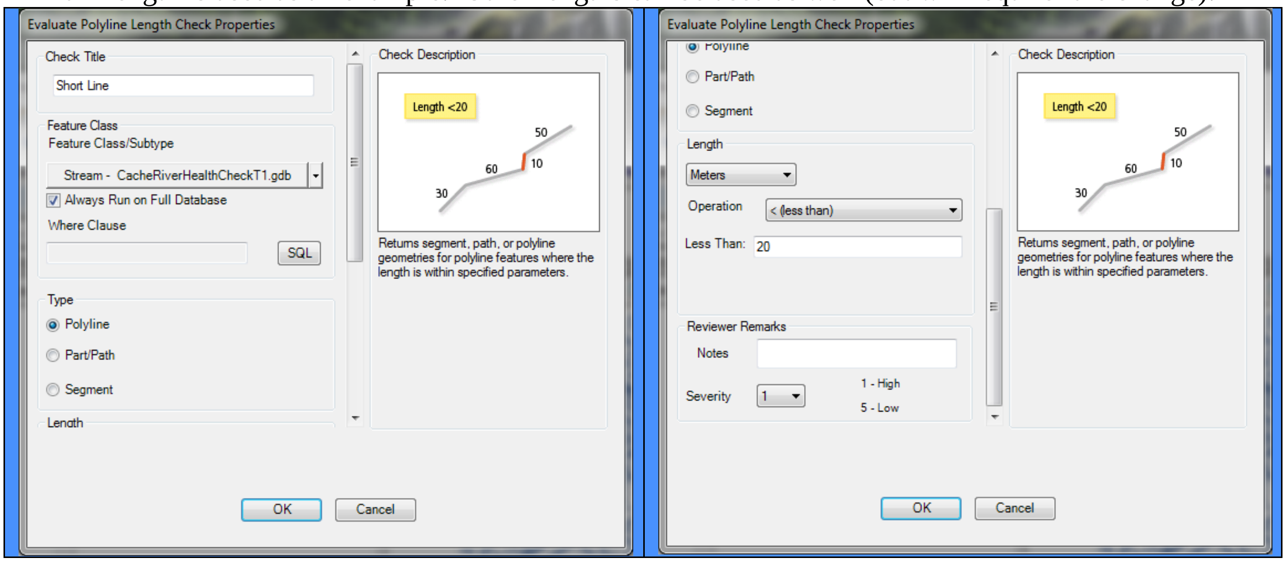


Duplicate Geometry Check



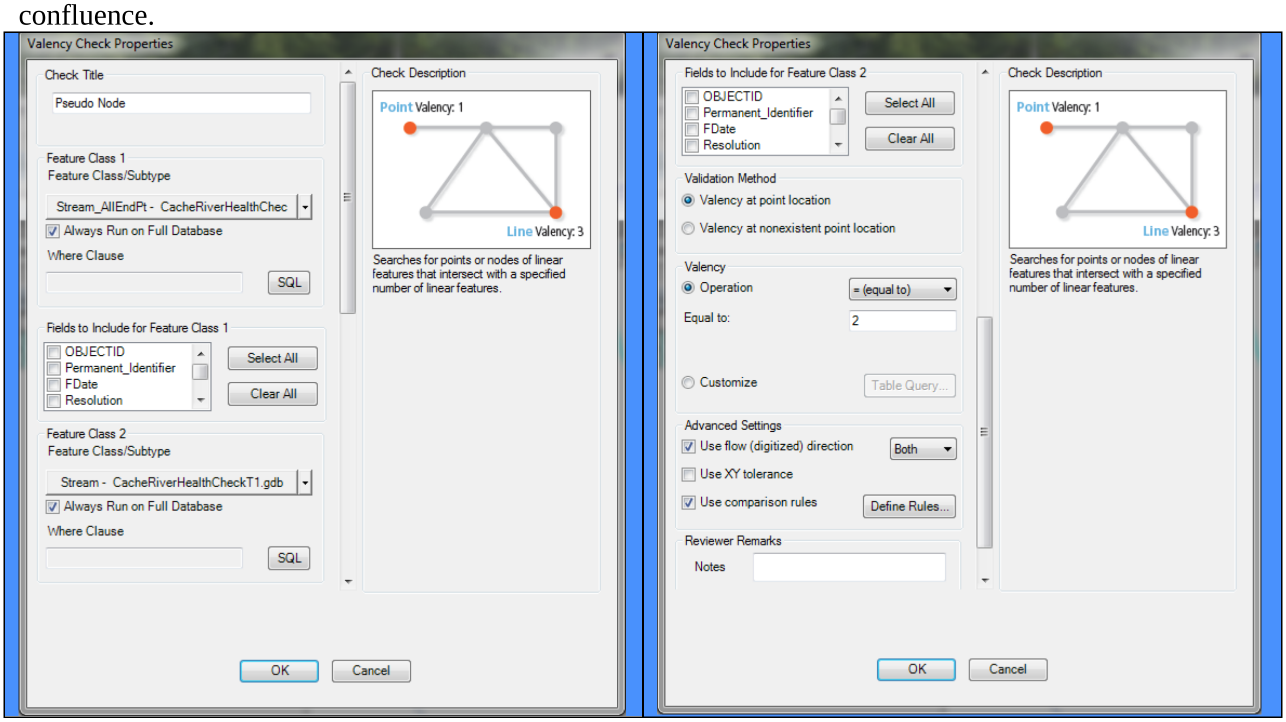
Short Line Check

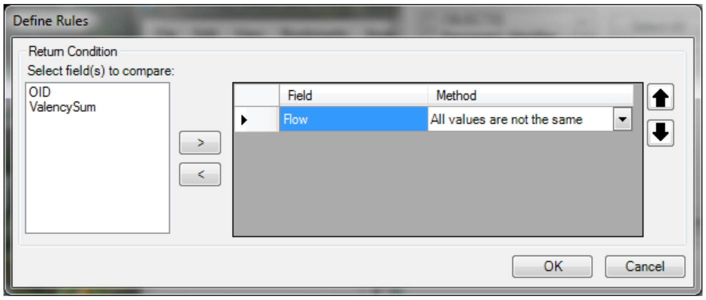
A 20m length is used as an example. Other lengths can be used as well (but will require rule change).



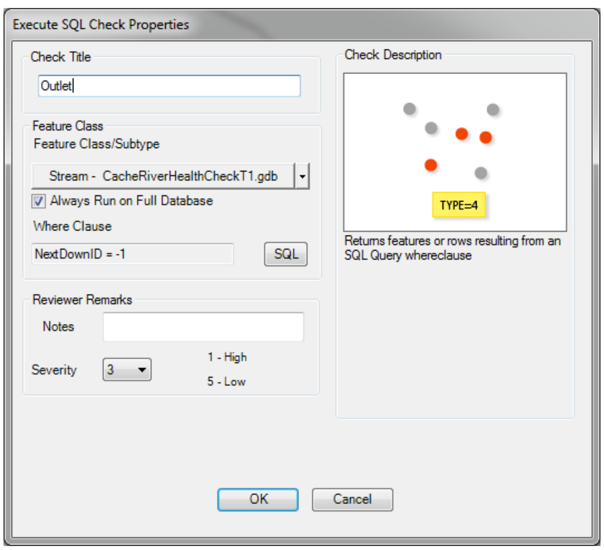
Pseudo Nodes Check

This will identify all two lines connected at a single end point. This will include valid case of a terminal confluence.

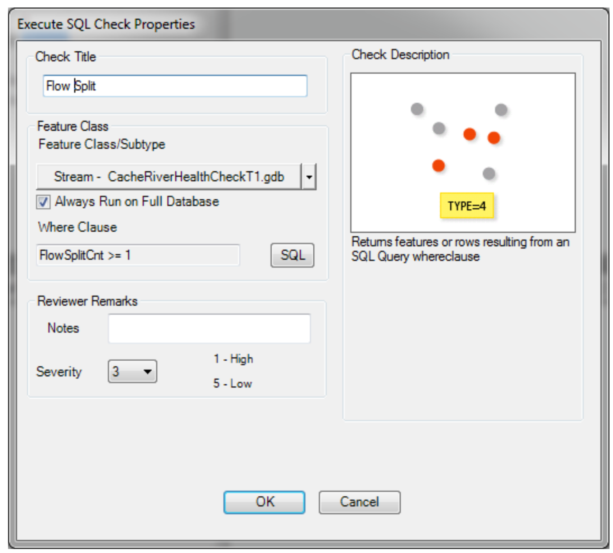




Outlets Check

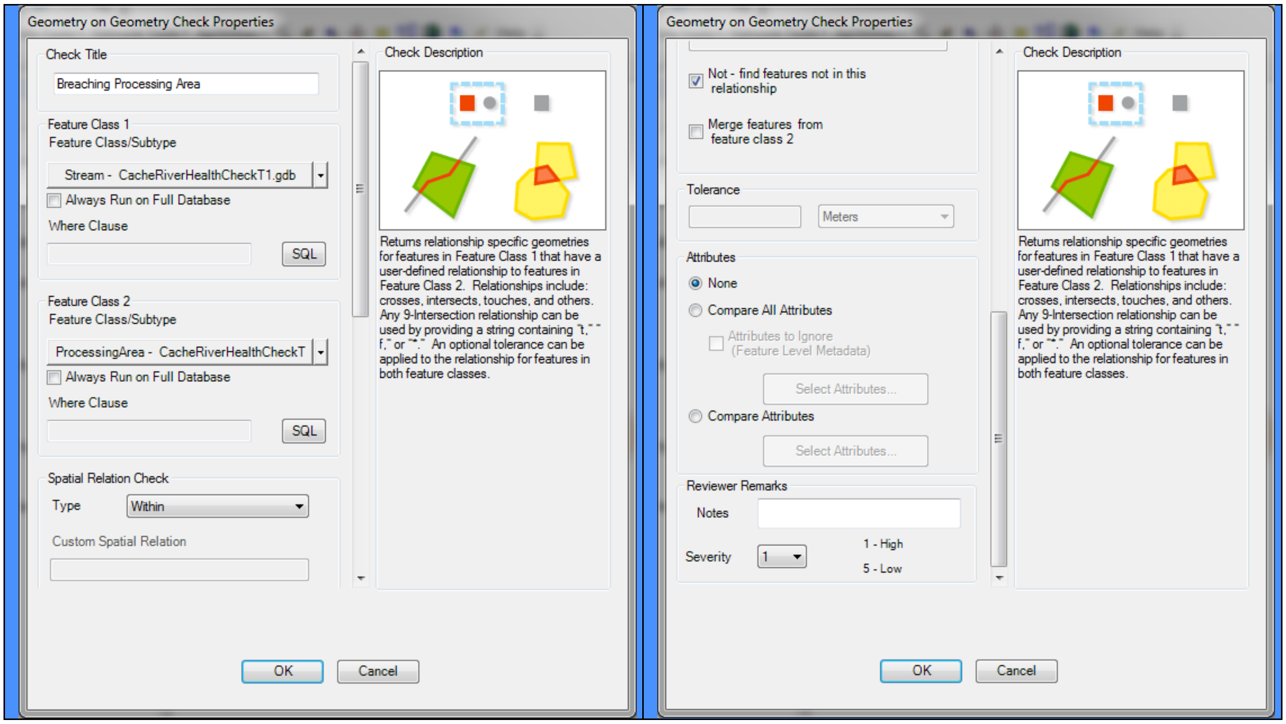


Flow Split Check

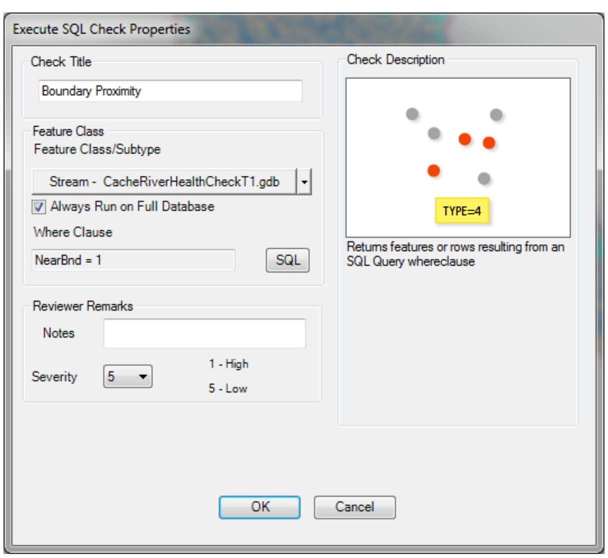


Appendix 1.2 Stream Area Checks (StreamAreaCheck.rbj)

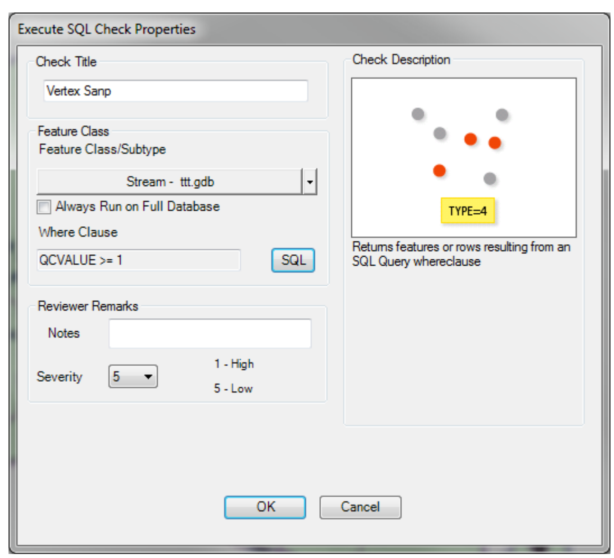
Breaching Processing Area Check



Stream Boundary Proximity Check

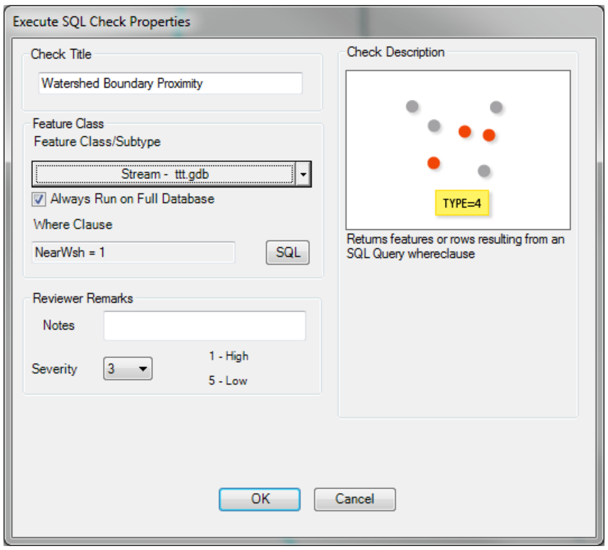


Vertex Snap Check



Appendix 1.3 Stream Advanced Checks (StreamAdvancedCheck.rbj)

Watershed Boundary Proximity Check



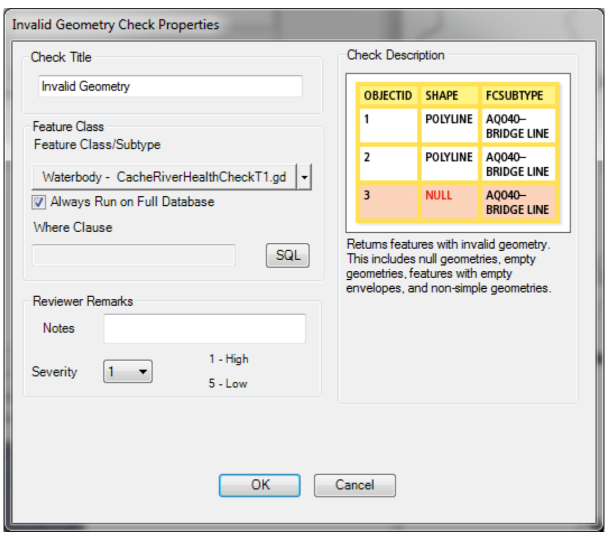
Appendix 1.4 Polygon Basic Checks

These checks apply to these three polygon geometries:

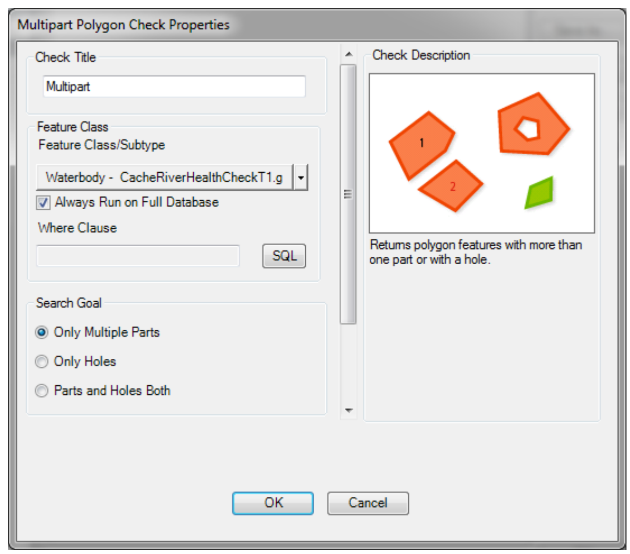
- Sink (SinkBasicCheck.rbj)
- Water body (WaterbodyBasicCheck.rbj)
- Watershed (WatershedBasicCheck.rbj)

The examples are presented for the water body, but they are exactly the same as for the other two feature classes (the feature class name will be pointing to the appropriate layer).

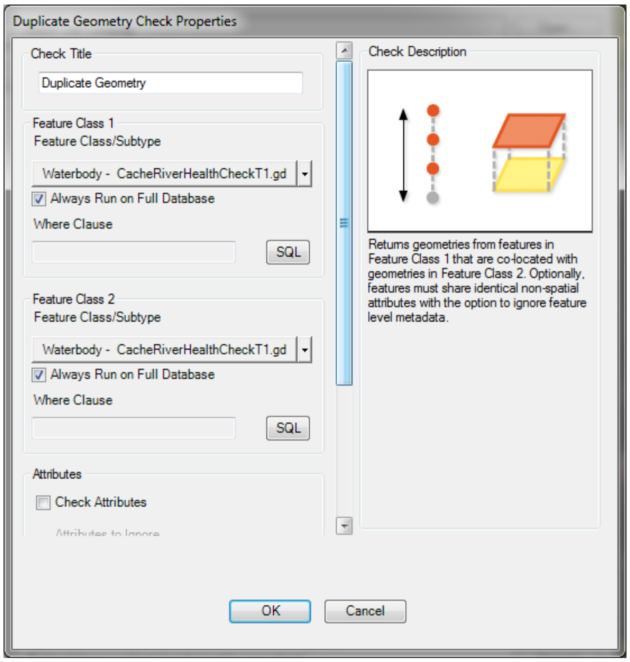
Invalid Geometry Check



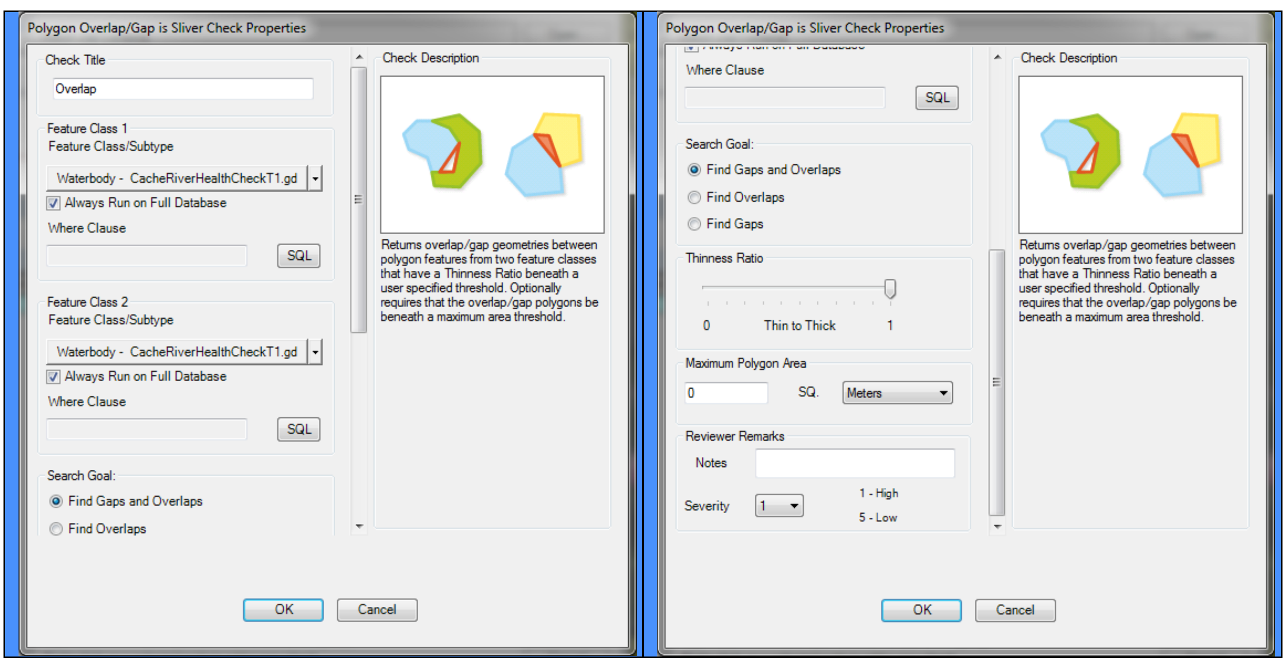
Multipart Geometry Check



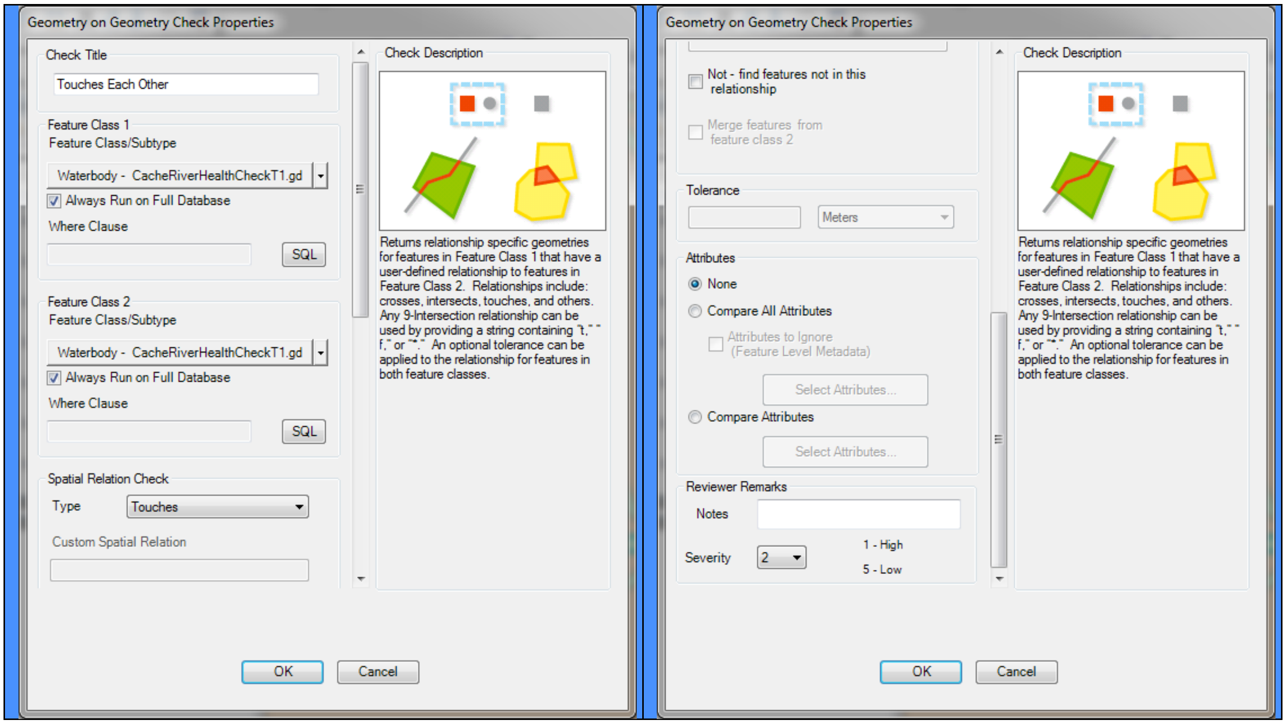
Duplicate Geometry Check



Polygon Overlap Check



Polygon Touches Each Other Check



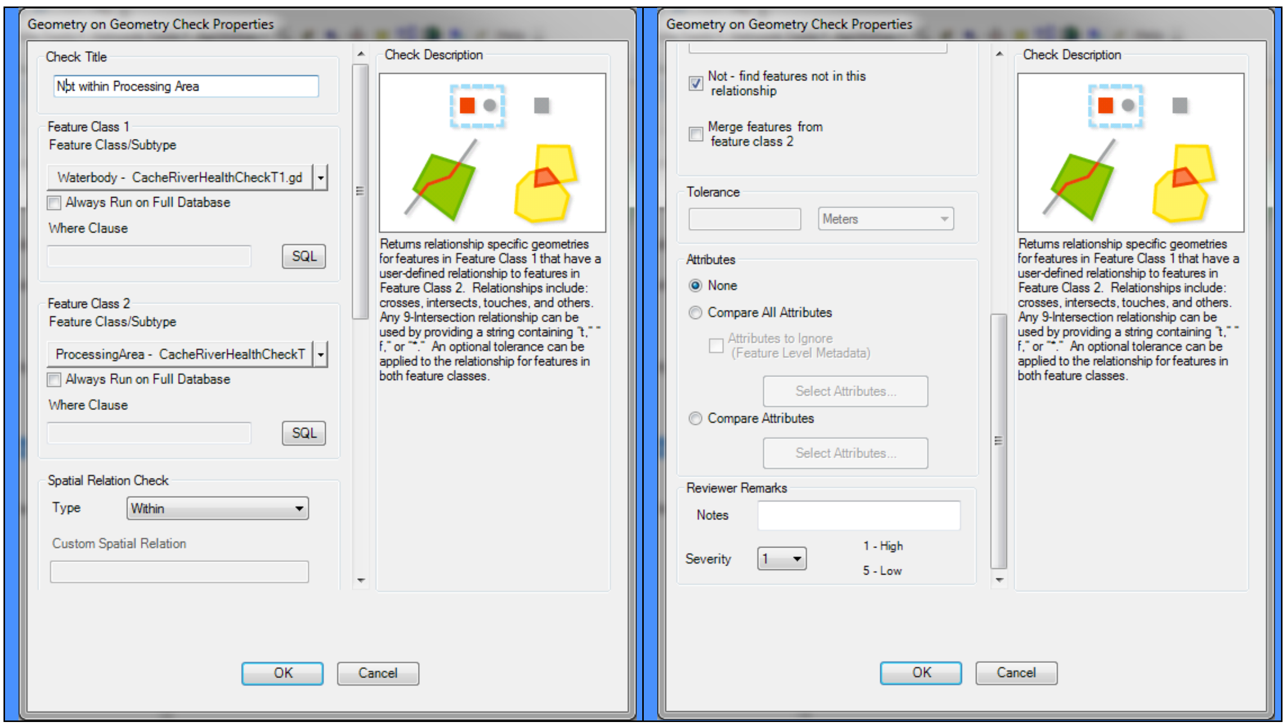
Appendix 1.5 Polygon Area Checks

These checks apply to these three polygon geometries:

- Sink (SinkAreaCheck.rbj)
- Water body (WaterbodyAreaCheck.rbj)
- Watershed (WatershedAreaCheck.rbj)

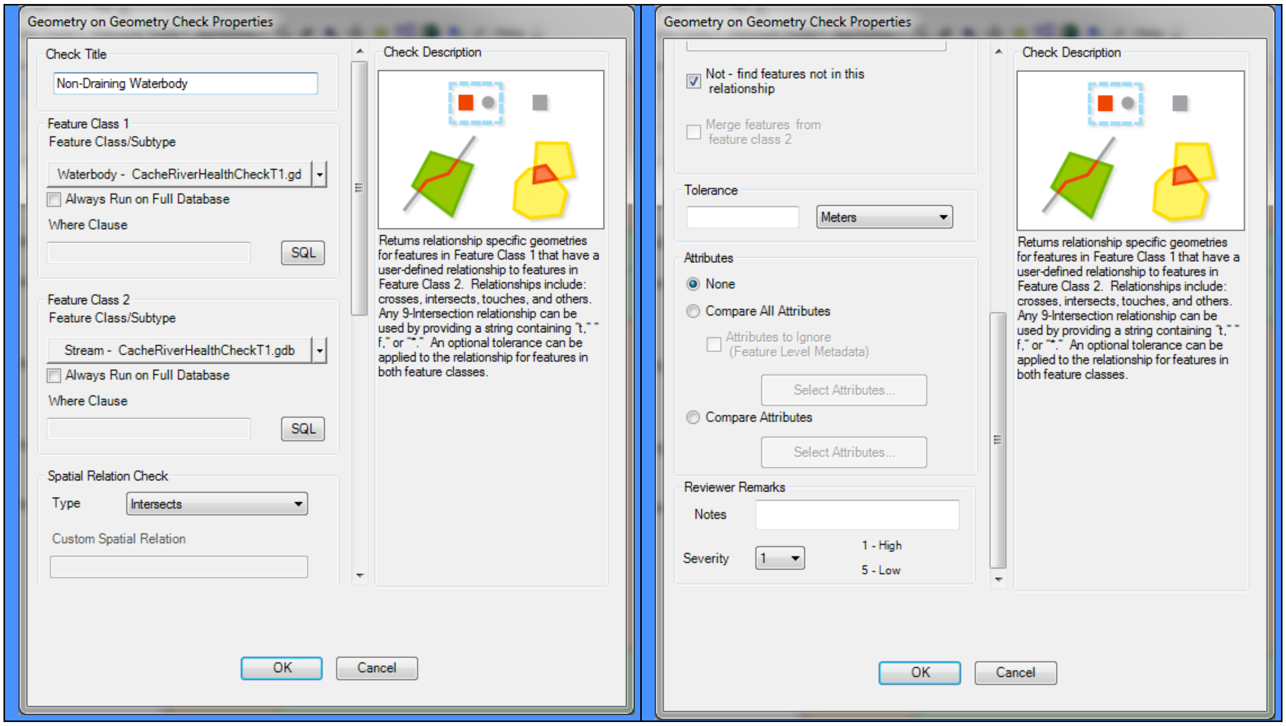
The examples are presented for the water body, but they are exactly the same as for the other two feature classes (the feature class name will be pointing to the appropriate layer).

Polygon Not Within Processing Area Check



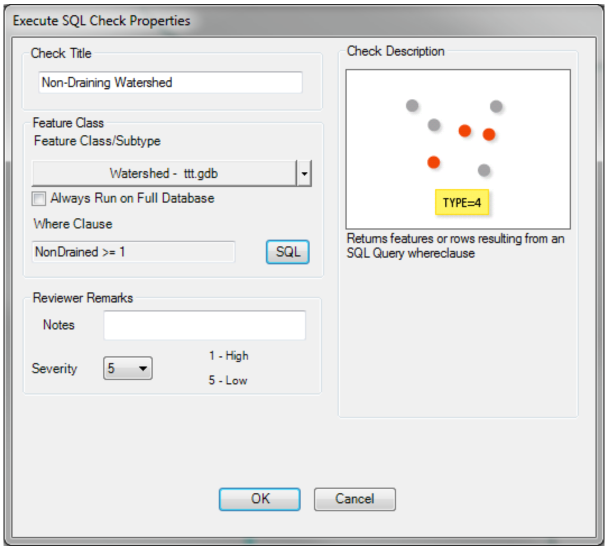
Appendix 1.6 Waterbody Advanced Checks (WaterbodyAdvancedCheck.rbj)

Non-Draining Waterbody Check



Appendix 1.7 Watershed Advanced Checks (WatershedAdvancedCheck.rbj)

Non-draining Watershed Check



Appendix 2. A worked out example

Initial data organization

The set of presented QC processes has been applied to the Cache watershed in Illinois. Cache is located at the southern tip of Illinois at the confluence of Mississippi and Ohio rivers. It is partially contained in subregion 07 (Mississippi) and 05 (Ohio). It covers all of 07140108 and portion north of Ohio River in 05140206 HUC-8. Red is the general area of the Cache watershed used in this example. Imagery shows Mississippi River (west boundary) and Ohio River (south boundary).

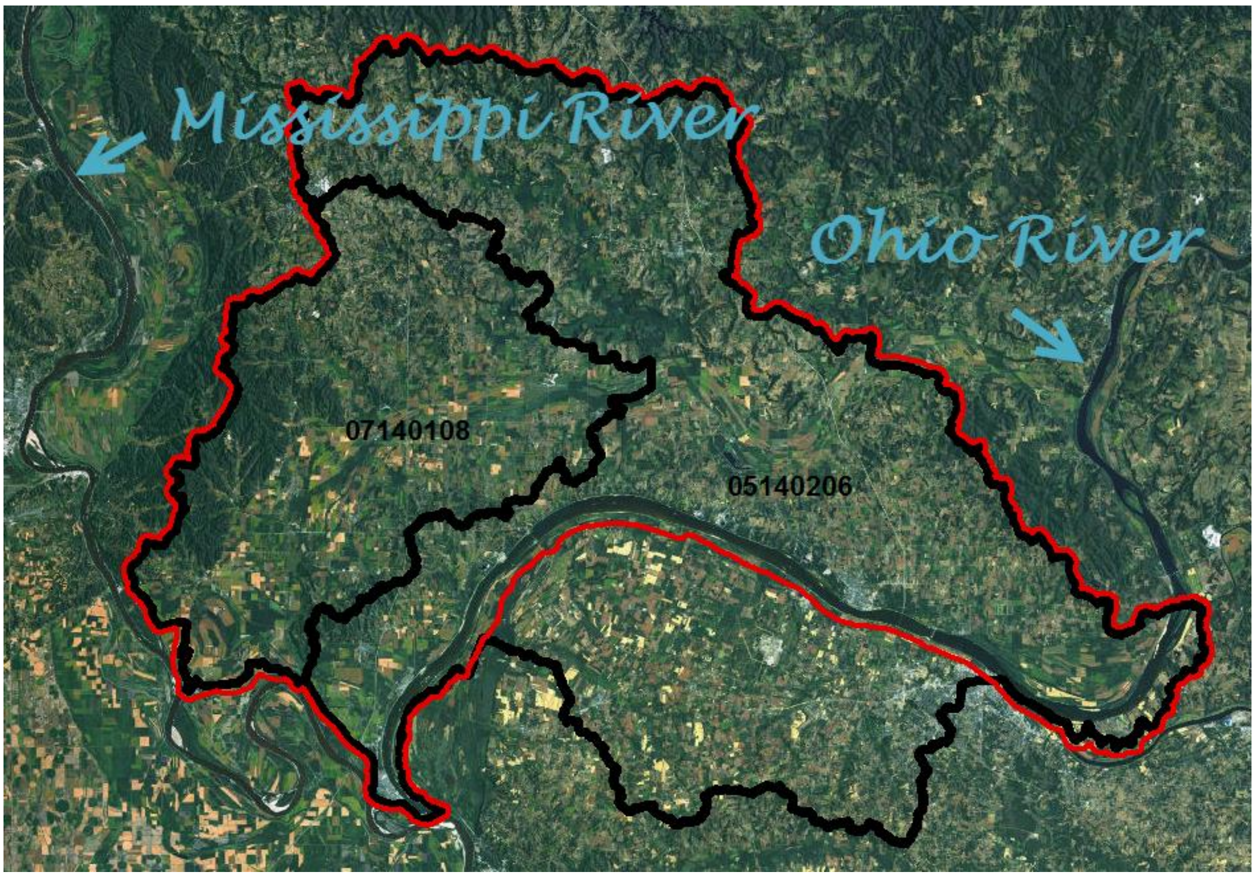


Figure 8. Cache area of interest. Black are the HUC-8 boundaries.

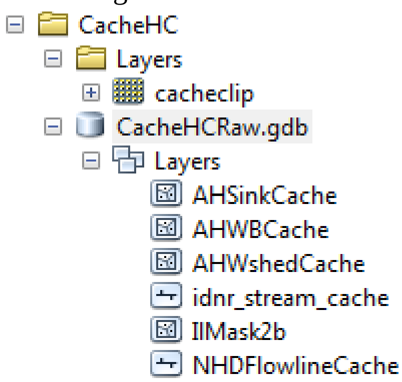
The vector data were put together from the NHD Hires (24K) dataset from USGS (ftp://nhdftp.usgs.gov/DataSets/Staged/SubRegions/FileGDB/HighResolution/). They were clipped based on the red Cache boundary (extent is slightly larger than the watershed boundary derived from the DEM) from the two subregion file geodatabases (05 and 07). NHDFlowline and NHDWaterbody feature classes were used as a source for streams, sinks, and water bodies for QC checks.

All NHDFlowlines were considered as streams (5465 features). NHDWaterbodys were split into sinks and water bodies based whether they were overlying the terminal (outlet) stream or not respectively. 42 sink and 8143 water body features were thus identified.

HUC12 that reside within Cache watershed were selected from the WBD dataset to represent the watershed boundaries.

The DEM is the 10m NED that was projected into Ill projection using bilinear interpolation and clipped to the red boundary.

The starting data were stored in the following data structure (top directory is called CacheHC):



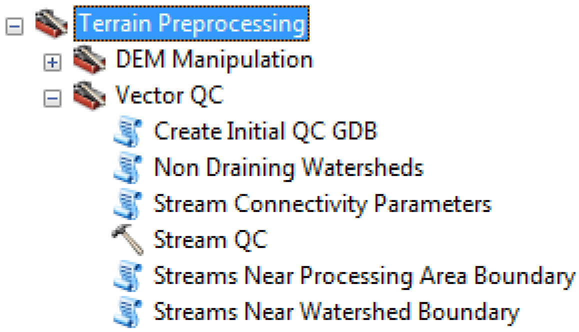
Folder “Layers” contains the DEMcalled “cacheclip” and the “raw” starting geodatabase (CacheHCRaw.gdb) with the following data structure:

- AHSinkCache – sinks
- AHWBCache – water bodies
- AHWshedCache – watersheds
- idnr_stream_cache – original IDNR streams used in the previous stream characterization project
- IlMask2b – Cache extent used for data clipping (“red” polygon)
- NHDFlowlineCache - streams

Naming of spatial layer for the “raw” data is arbitrary. It is important that the raster dataset is in projected system that will be used in the QC process. Vector data can be in any projection as they will be projected into the DEM projection during the initial processing step.

Performing operations

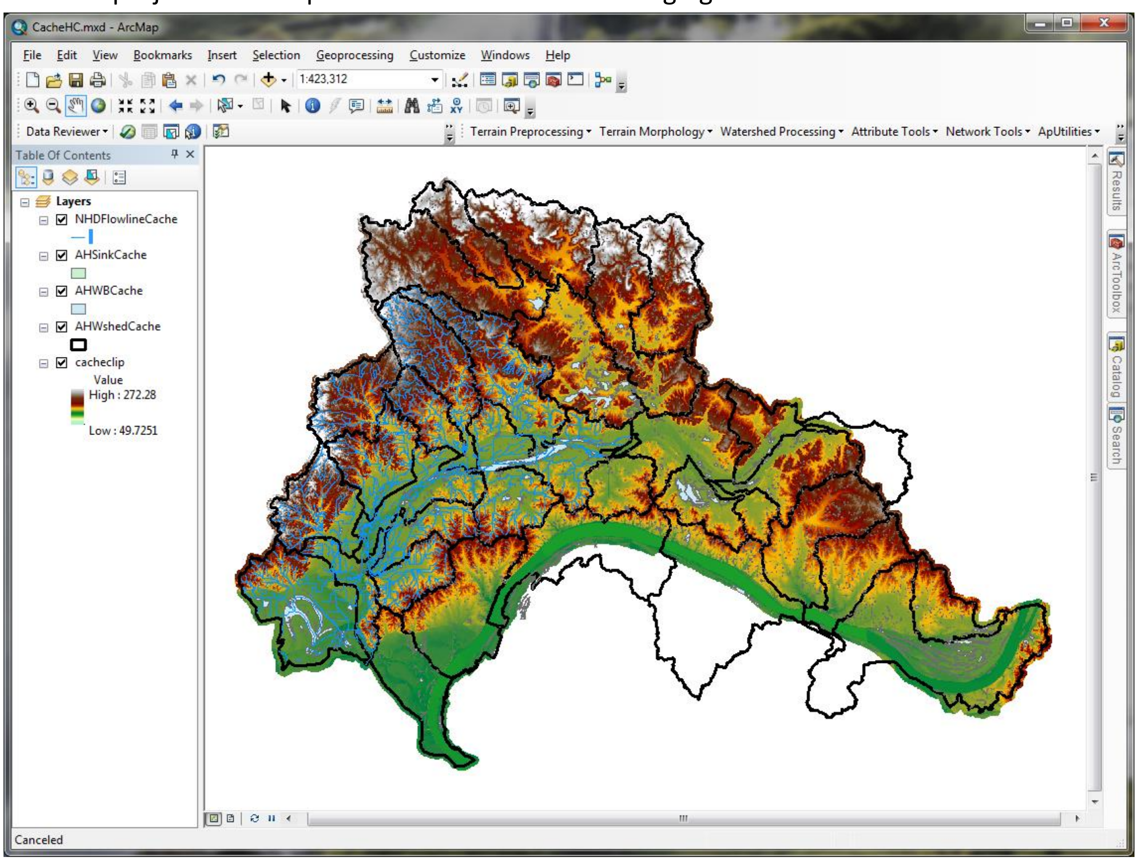
AH tools used in these operations are in the “Arc Hydro Tools -> Terrain Preprocessing -> Vector QC” toolset.



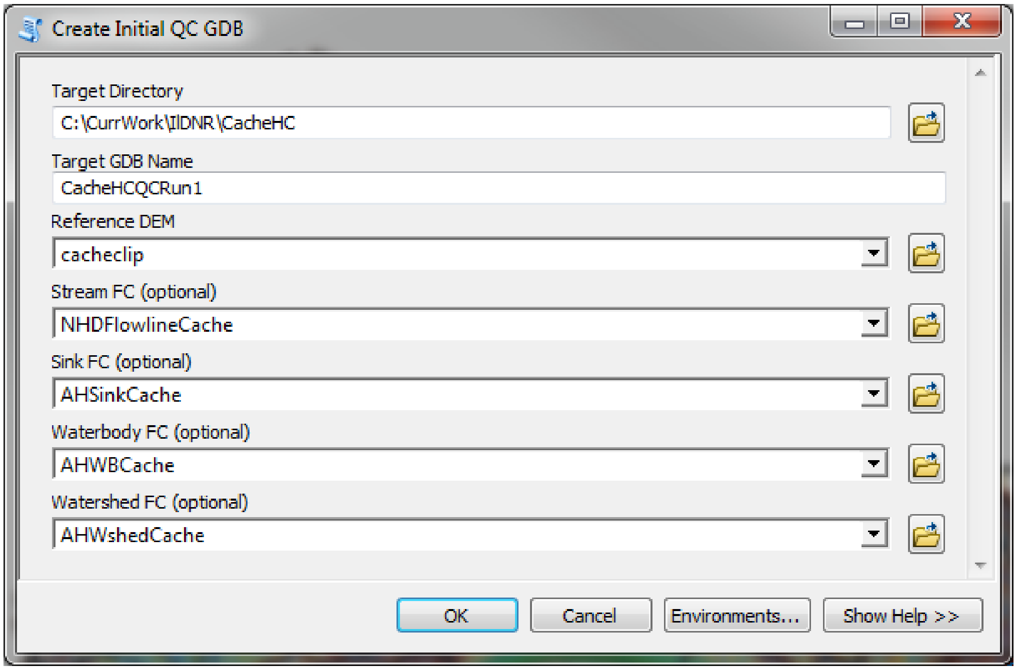
Initial project and database setup

Steps 1-4 are not required. You can jump into step 5 directly from an existing ArcMap project that has the required layers in it.

1. Open a new ArcMap project and add the DEM (cacheclip).
2. Save the project. It is recommended to save it in the directory one level above the directory containing the DEM. In this case it would be in the "CacheHC" directory. The name of the project can be anything. In this case it is "CacheHC.mxd".
3. Add vector data to be used in the QC process. Modify symbology as needed.
4. Save the project. The map should look like the following figure.



5. Run "Create Initial QC GDB" AH QC tool (make sure that Arc Hydro toolbox is available). Populate the form.

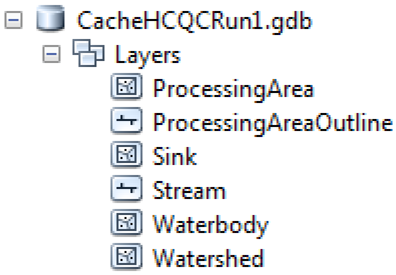


6. Run the tool to create the QC database.

```
Executing: CreateInitialQCGDB C:\CurrWork\IlDNR\CacheHC
CacheHCQCRun1 cacheclip NHDFlowlineCache AHSinkCache AHWBCache
AHWshedCache
Start Time: Tue Aug 06 15:57:27 2013
Running script CreateInitialQCGDB...
  Creating QC geodatabase...
      Creating QC geodatabase completed in 1.72 seconds.
  Defining processing area polygon and outline polyline...
      Defining processing area polygon and outline polyline
completed in 18.38 seconds.
  Importing optional vector layers...
          Importing optional stream layer ...
          Importing optional sink layer ...
          Importing optional waterbody layer ...
          Importing optional watershed layer ...
      Importing optional vector layers completed in 15.58 seconds.
Completed script CreateInitialQCGDB...
Succeeded at Tue Aug 06 15:58:03 2013 (Elapsed Time: 36.00 seconds)
```

7. This step creates a new geodatabase with processing area and its outline and loads the optional vector data into it if provided. The geodatabase structure is as follows (layer names are fixed). Note that any of the optional vector data will be copied (and projected if necessary) into the new geodatabase with all the fields as they are. If you want to simplify the data structure of the

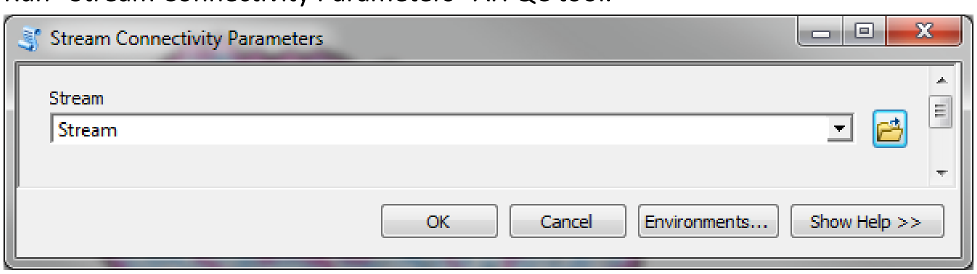
input layers, you can remove all unnecessary fields. QC tools do not require any fields to be present as they will create them on as needed basis.



8. Save the project.
9. Close ArcMap.

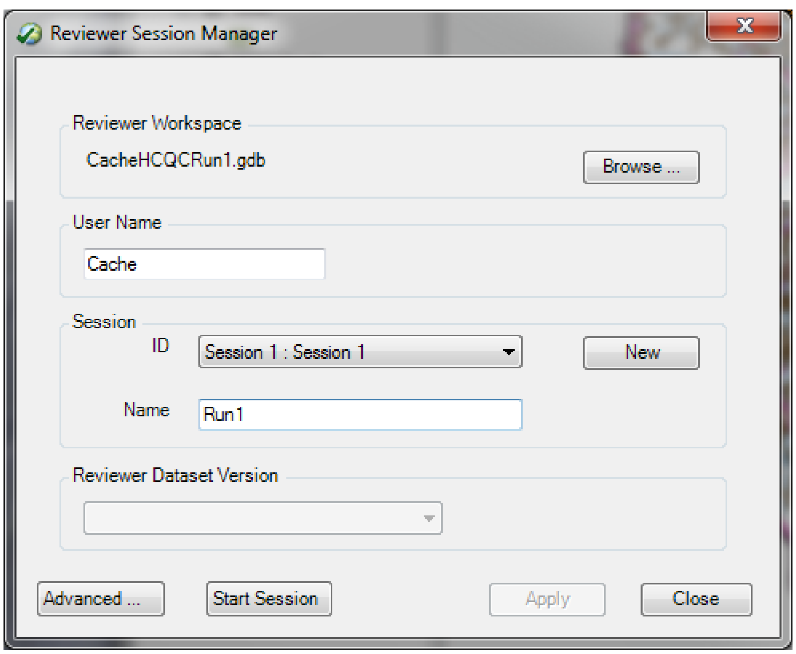
Running basic checks

1. Start a new ArcMap project. Make sure that DR toolbar is visible and extension is active. Make sure that Arc Hydro toolbox is available.
2. Add data from the geodatabase created in step 6 above.
3. Save the project with the same name as the geodatabase created in step 6 (in this case “CacheHCQCRun1”). This will ensure that the HydroID dispenser tables are created and managed in the proper place (QC geodatabase).
4. Run “Stream Connectivity Parameters” AH QC tool.



```
Executing: StreamConnectivityParameters Stream
Start Time: Tue Aug 06 16:52:15 2013
Running script StreamConnectivityParameters...
  Populating stream attributes...
          Populating HydroID ...
          Populating FROM_NODE and TO_NODE ...
          Populating NextDownID and generating Stream_FS table ...
          Populating FlowSplitCnt ...
      Populating stream attributes completed in 29.50 seconds.
  Defining stream line end points...
      Defining stream line end points completed in 4.59 seconds.
  Adding results to the map ...
  Cleaning up...
Completed script StreamConnectivityParameters...
Succeeded at Tue Aug 06 16:52:49 2013 (Elapsed Time: 34.00 seconds)
```

5. Start a new DR session. Specify the reviewer workspace to be the same as the geodatabase with the data to be QC'd (this can be pointing to a different gdb – it will depend on the user preferences and data editing workflows). Populate other fields in the form as desired and start the session.



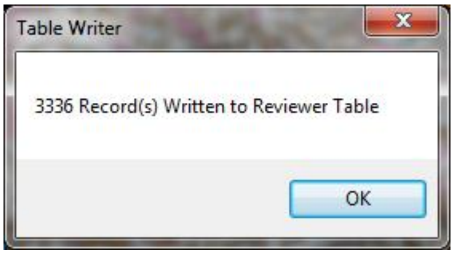
6. To run the basic stream checks, run "Batch Validate" from the DR menu.
   a. Once the form is presented, select "Add from File …" and navigate to the AH tools installation directory, "rbjfiles" folder (usually at C:\Program Files (x86)\ESRI\WaterUtils\ArcHydro\rbjfiles) where the AH HC rbj files are and select "StreamBasicCheck.rbj". You should see a message in the lower left corner of the form that "Batch Job was successfully updated to current workspace". This indicates that the

checks could recognize the current workspace and layer in it to which to apply the checks to. You can click on "Workspace …" to review the target layers.

b. Click on "Full Database" radio button to ensure that the checks will be performed on the full extent of the data.

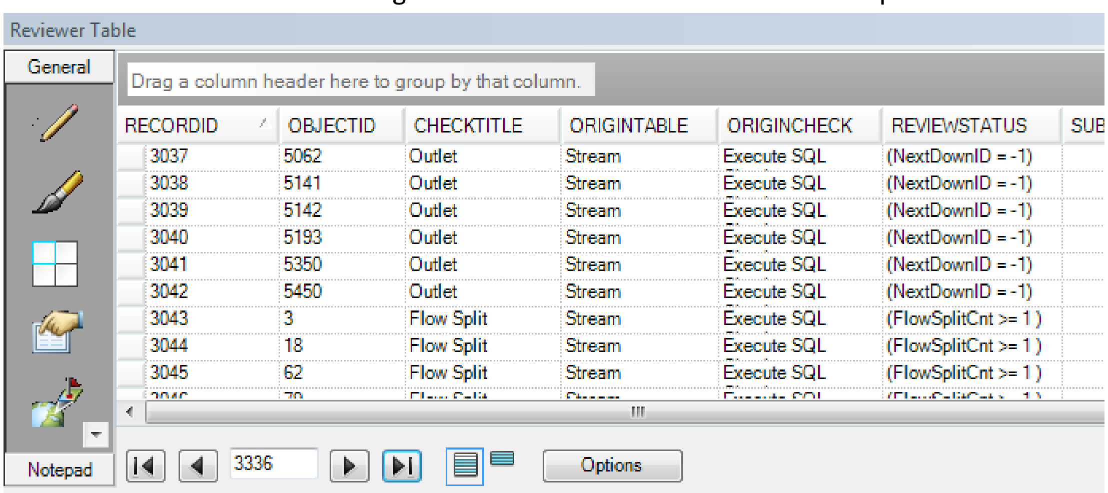
c. Click on "Run" to execute the checks.

d. After about one minute (performance will vary depending on the hardware) a message will appear stating that a number of records have been written to the reviewer table.

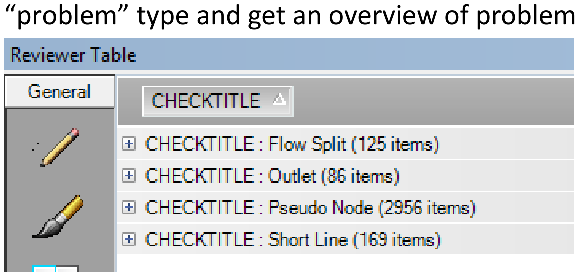


7. To review the records in the reviewer table, click on "Reviewer Table" on the DR menu. That will open the reviewer table and you will be able to navigate through identified records and use all DR capabilities. Following figures demonstrate few examples of reviewer table interface.

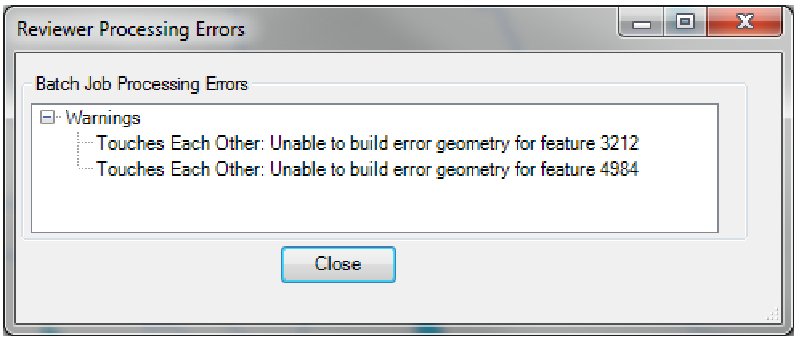
a. The "CHECKTITLE" shows which check "triggered" a feature. Clicking in the left-most box in each row will navigate and zoom to that feature on the map.



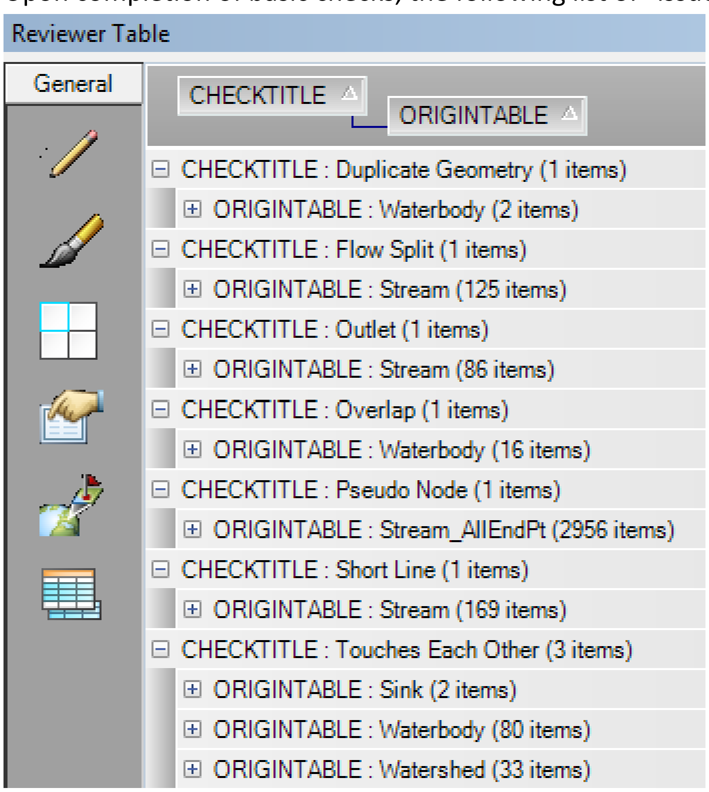
b. By moving the "CHECKTITLE" column header into the white box with "Drag a column header here to group by that column" text in it, you can group the records by the "problem" type and get an overview of problem types and their counts.



8. Run other basic checks following steps in #6. Depending on the desired editing workflows, you can start a new DR session (step #5) or keep current one active. In this example, all the checks will be done in a single session.
    a. Basic sink checks - SinkBasicCheck.rbj
    b. Basic water body checks - WaterbodyBasicCheck.rbj. This check produced the following errors:



    c. Basic watershed checks - WatershedBasicCheck.rbj
9. Upon completion of basic checks, the following list of “issues” can be produced.

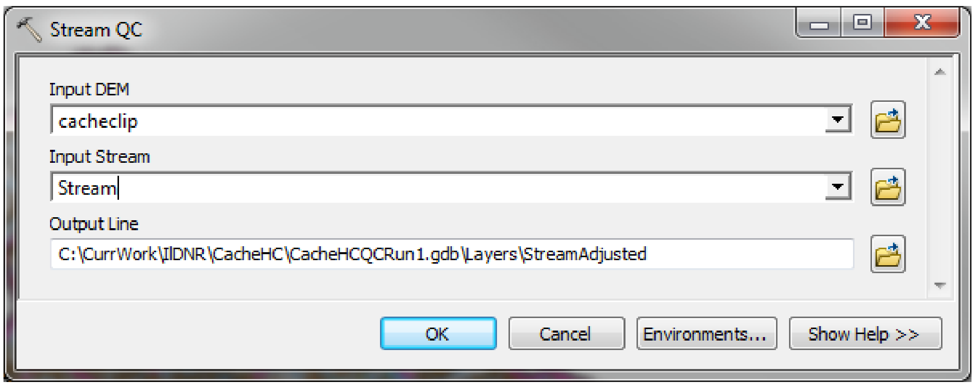


10. The identified problems can now be navigated and should be fixed before proceeding to the other checks.

Running other checks

Ideally, all real problems identified in basic checks should be fixed before proceeding to the advanced checks. In this example, that was not done and the checks are performed on "raw" data. If necessary, open ArcMap with the QC project and start the reviewer session (same or new one).

1. Stream geometry with respect to raster
    a. Add DEM to the map (if not already in it).
    b. Run "Stream QC" AH QC tool. This is a complex function that can take time to finish. It provides a lot of feedback on what is being performed while the function is running.

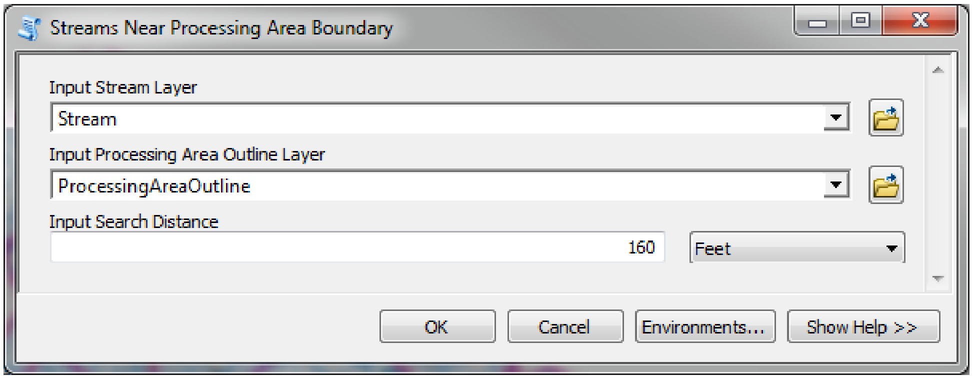



```
Executing: StreamQC cacheclip Stream
C:\CurrWork\IlDNR\CacheHC\CacheHCQCRun1.gdb\Layers\StreamAdjusted
Start Time: Wed Aug 07 12:05:13 2013

 ..............................  several skipped steps  ........................................

Snapping vertices and removing points in same cell completed. dt= 80.52s
Processing overlapping vertices of between lines, completed. dt= 74.80s
Check these lines for potential problems. FeatureClassName=StreamAdjusted
OBJECTID=56,1583,744,1587,2850,4058,3132,3288
Processing overlapping vertices of between lines, completed. dt= 74.80s
dt=0.00s
Succeeded at Wed Aug 07 12:08:34 2013 (Elapsed Time: 3 minutes 21 seconds)
```

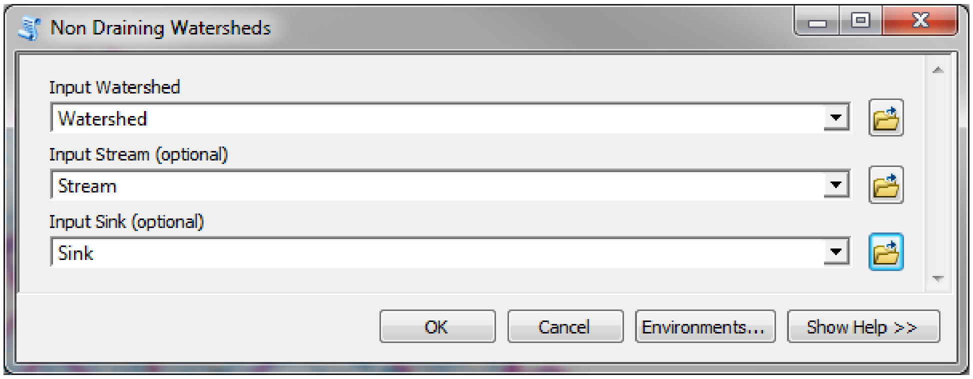
    c. Run "Streams Near Processing Area Boundary" AH QC tool. 160 ft search distance is used as a 5 cell buffer is being planned for use in the DEM Reconditioning function (so the search distance is slightly larger than 5 times the cell size).




```
Executing: StreamsNearProcessingAreaBoundary Stream ProcessingAreaOutline
"160 Feet"
Start Time: Wed Aug 07 13:15:50 2013
Running script StreamsNearProcessingAreaBoundary...
  Populating NearBnd stream attribute...
      Populating NearBnd stream attribute completed in 4.07 seconds.
  Cleaning up...
Completed script StreamsNearProcessingAreaBoundary...
Succeeded at Wed Aug 07 13:15:54 2013 (Elapsed Time: 4.00 seconds)
```

   d. To run the stream area checks, run “Batch Validate” from the DR menu with “StreamAreaCheck.rbj” file. (11 more records will be written to the Reviewer Table).

2. Polygon geometry with respect to raster.
   a. To run the sink area checks, run “Batch Validate” from the DR menu with “SinkAreaCheck.rbj” file. (No additional records will be written to the Reviewer Table).
   b. To run the water body area checks, run “Batch Validate” from the DR menu with “WaterbodyAreaCheck.rbj” file. (11 more records will be written to the Reviewer Table). Note that this check takes a long time to process if the number of water bodies is large (as in this case). It is possible to perform similar check using out of the box spatial selection and skipping use of DR for the task but that would then eliminate the benefits of using DR for management of all the checks. It would also be possible to modify the currently implemented DR check and implement a different technique while still using DR for the overall check management.
   c. To run the watershed area checks, run “Batch Validate” from the DR menu with “WatershedAreaCheck.rbj” file. (6 more records will be written to the Reviewer Table).
3. Advanced checks
   a. To run the water body advanced checks, run “Batch Validate” from the DR menu with “WaterbodyAdvancedCheck.rbj” file. (7564 more records will be written to the Reviewer Table).
   b. To run the watershed advanced checks:
      i. Run “Non Draining Watersheds” AH QC tool.

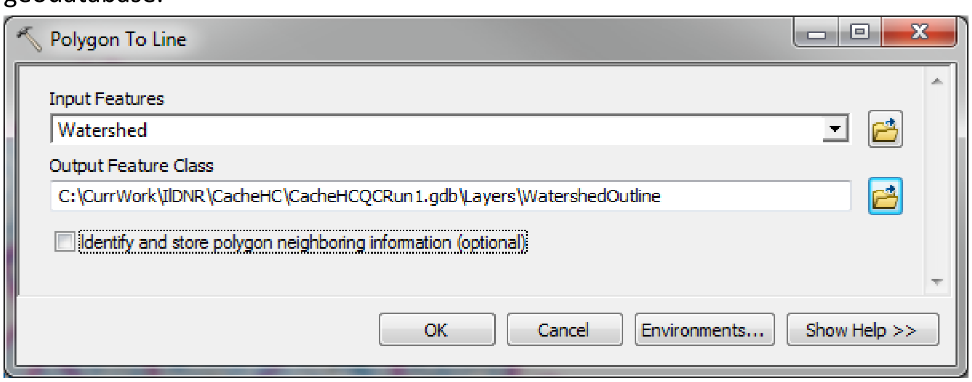



```
Executing: NonDrainingWatersheds Watershed Stream Sink
Start Time: Wed Aug 07 14:27:03 2013
Running script NonDrainingWatersheds...
  Populating NonDrained watershed attribute...
      Populating NonDrained watershed attribute completed in 1.50 seconds.
  Cleaning up...
Completed script NonDrainingWatersheds...
Succeeded at Wed Aug 07 14:27:05 2013 (Elapsed Time: 2.00 seconds)
```

ii. Run “Batch Validate” from the DR menu with “WatershedAdvancedCheck.rbj” file. (1 more records will be written to the Reviewer Table).

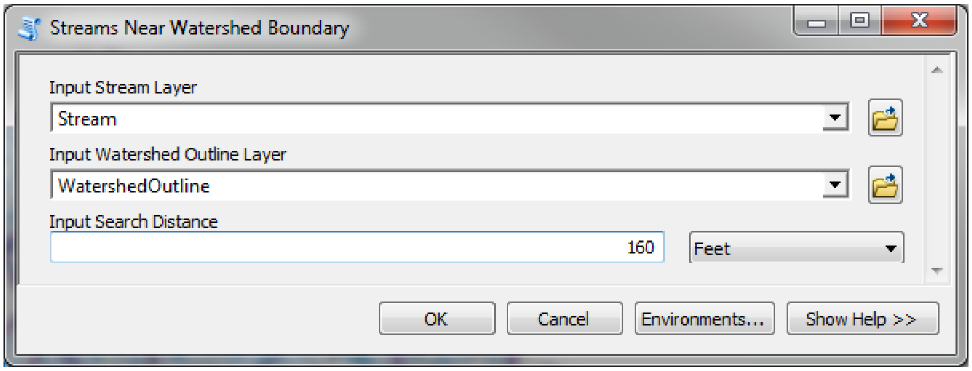
c. To run the stream advanced checks:

i. Run “Polygon To Line” standard geoprocessing function (Data Management Tools -> Features toolset) to create watershed outlines (as linear features). Make sure that the resulting feature class is saved in the proper (QC) geodatabase.




```
Executing: PolygonToLine Watershed
C:\CurrWork\IlDNR\CacheHC\CacheHCQCRun1.gdb\Layers\WatershedOutline
IGNORE_NEIGHBORS
Start Time: Wed Aug 07 14:57:35 2013
Succeeded at Wed Aug 07 14:57:35 2013 (Elapsed Time: 0.00 seconds)
```

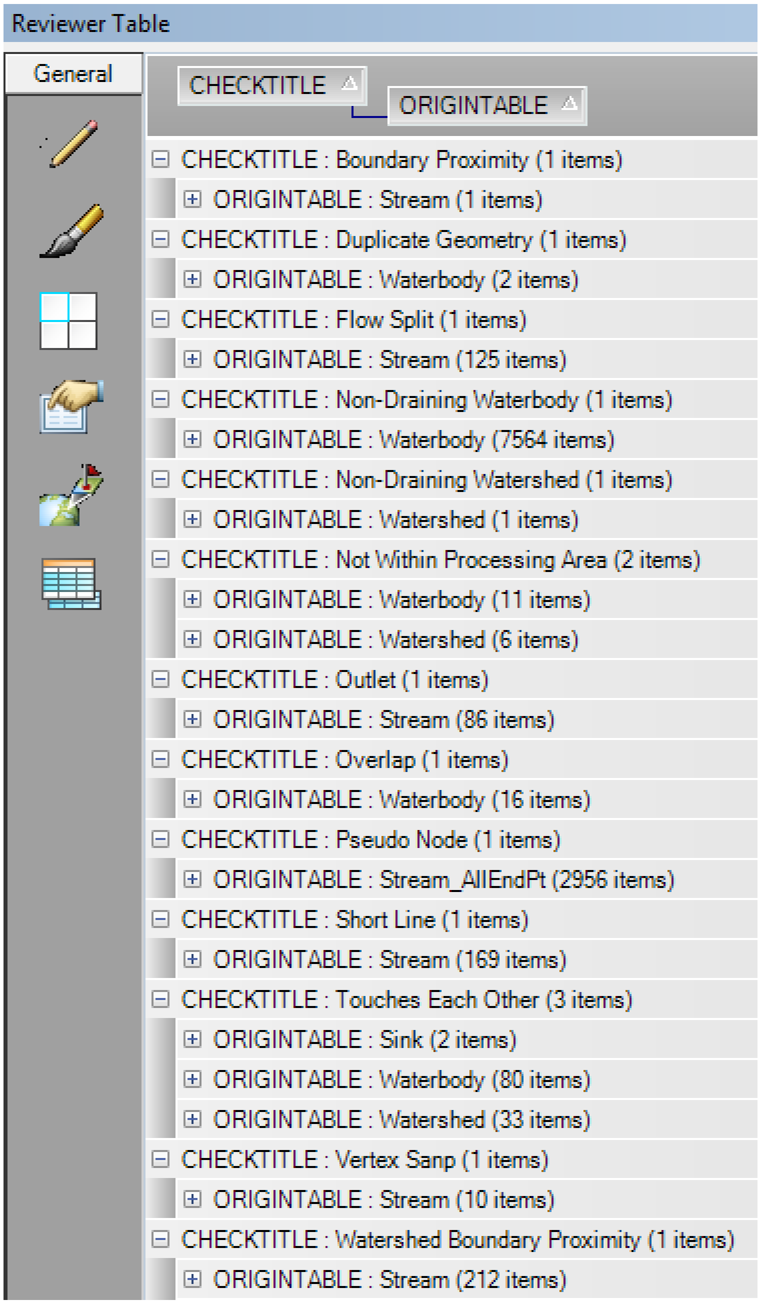
ii. Run “Streams Near Watershed Boundary” AH QC tool.




```
Executing: StreamsNearWatershedBoundary Stream WatershedOutline "160 Feet"
Start Time: Wed Aug 07 15:03:09 2013
Running script StreamsNearWatershedBoundary...
  Populating NearWsh stream attribute...
      Populating NearWsh stream attribute completed in 30.64 seconds.
  Cleaning up...
Completed script StreamsNearWatershedBoundary...
Succeeded at Wed Aug 07 15:03:40 2013 (Elapsed Time: 31.00 seconds)
```

iii. Run “Batch Validate” from the DR menu with “StreamAdvancedCheck.rbj” file. (212 more records will be written to the Reviewer Table).

Upon completion of all checks, the following list of “issues” can be produced.



DR now allows prioritization and navigation through the identified issues. Standard ArcGIS editing capabilities should be used to resolve any real issues. The most important issues to be resolved are the ones related to the flow patterns (stream connectivity, directionality, and flow splits, and existence and location of sink polygons). This is an iterative process. As features are edited, relevant checks have to be rerun.