

Independent Verification And Validation Of Elevation Data Using ArcGIS 9.0

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ABSTRACT

Large volumes of elevation data are being produced by Intermap Technologies globally using its advanced interferometric synthetic aperture radar technology. The Independent Verification and Validation (IV&V) group in the Customer Care division is responsible for, among other tasks, reviewing and reporting on samples of data prior to client delivery as the Production department completes project milestones. ArcGIS 9.0 with Spatial Analyst is instrumental in this review process. It provides all of the necessary tools to ensure that the elevation data is meeting product specifications consistently. Also, by taking advantage of ArcGIS Geoprocessing capabilities, many repetitive and time-consuming tasks are batch processed to increase the efficiency and consistency of IVV data reviews. From importing data to generating complex analysis masks, Geoprocessing tools are used to prepare layers for IVV data reviews. The increased efficiency using ArcGIS is resulting in faster turnaround of quality feedback to the Production department.

Intermap Technologies

Intermap Technologies is a data provider of high-accuracy, high-resolution digital elevation products. The data is acquired from an airborne platform using interferometric synthetic aperture radar (IFSAR) technology. Intermap produces three core mapping products: orthorectified radar imagery (ORIs), and two digital elevation models; digital surface models (DSMs) and digital terrain models (DTMs). ORIs and DSMs return the first surface on the ground identified by the radar, including natural and cultural features. The DTM is a "bare-earth" product that is generated from the DSM after trees, buildings and other cultural features have been digitally removed in the Production Department. Editors in the Production Department modify the elevation data using proprietary software according to tightly controlled specifications. Experienced editors in the Production Department perform quality control (QC) on all edited data using the same proprietary software. When data passes QC it is ready to be delivered to clients.

Introduction

The Independent Verification and Validation (IV&V) group in the Customer Care division is responsible for, among other tasks, reviewing and reporting on samples of edited data prior to client delivery as the Production Department completes project milestones. To maintain an independent point of view, commercial off the shelf software is used by the IV&V group to confirm that Intermap Core Products are meeting expectations. ArcGIS 9.0 has been instrumental in this review process. Combined with Spatial and 3D Analyst extensions, ArcGIS provides all of the necessary tools to ensure that specifications are being met consistently. IV&V is developing techniques to batch-process repetitive and time-consuming tasks. Taking advantage of ArcGIS geoprocessing capabilities increases efficiency and consistency of IV&V data reviews. This paper will focus on some methodologies IV&V uses in ArcGIS to confirm that Intermap Technologies Core Products are meeting specifications. Detailed information about these specifications can be found at <http://www.intermap.com/images/handbook/producthandbook.pdf>. Three specific checks will be examined in detail, including: quantifying instances of DTM elevations higher than DSM, analyzing target-editing and investigating DTM-derived stream networks.

DTM Higher Than DSM

The DTM is derived from the DSM and smoothed after most first surface features have been removed. The DTM elevations are expected to be lower than DSM elevations in obstructed areas (where the ground is not reflected) and should be about the same elevation in unobstructed areas. However, there are some exceptions. For example, large treed regions are not completely cleared in the DTM edit because underlying elevation changes cannot be measured. This is a radar data limitation. As a result, when the smoothing algorithm is applied to the DTM, forest edges ramp down from the

treetops to the ground and elevations in the DTM can be higher than those elevations in the DSM.

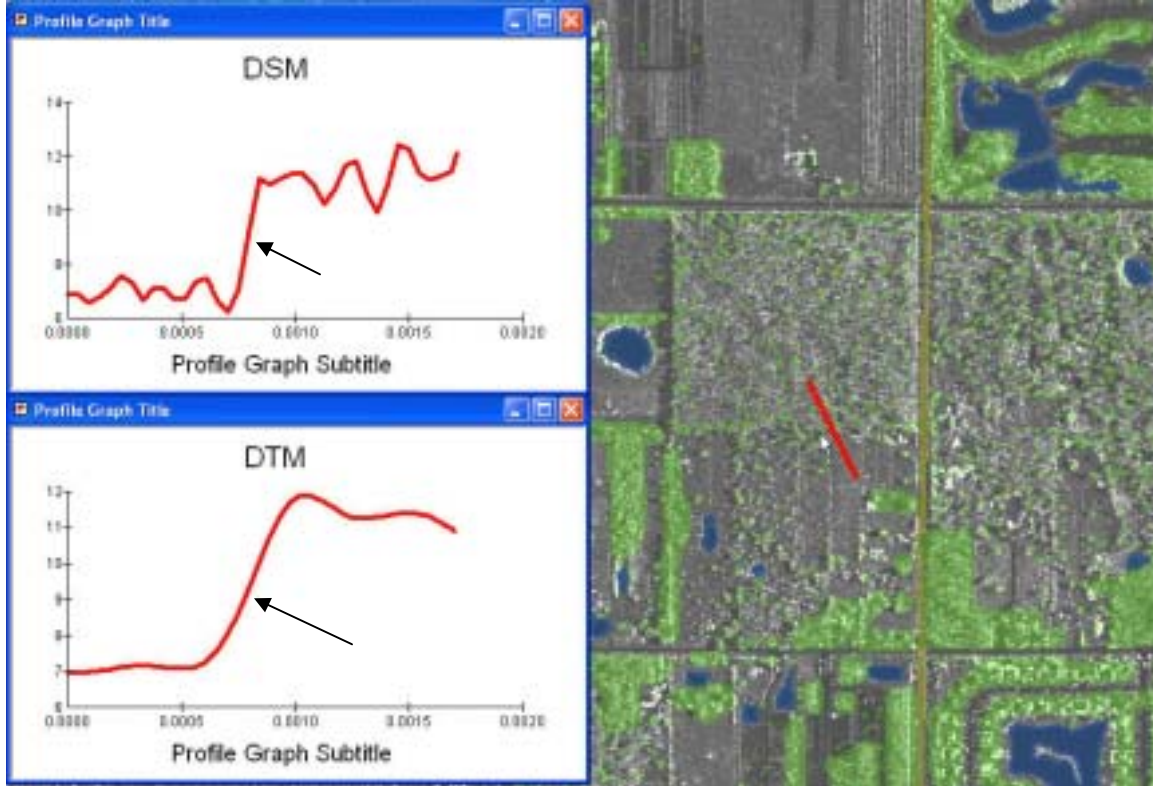


Figure 1. In the ORI above, semi-transparent green areas identify first surface features removed in the DTM. Profile graphs are displayed to show the differences in DSM and DTM elevations across the forest edge (highlighted by the red line). DTM elevations are higher than DSM elevations along the smooth slope from the treetops to the ground.

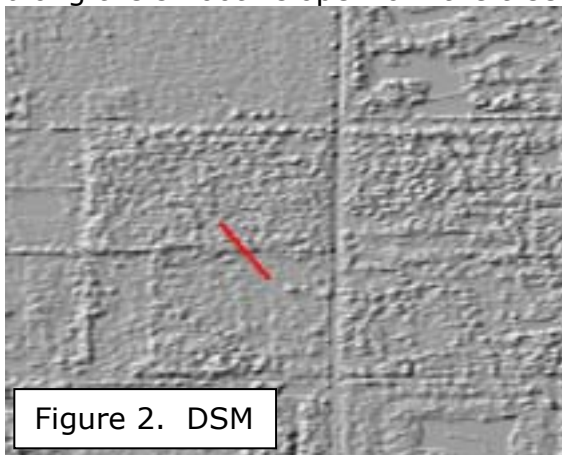


Figure 2. DSM

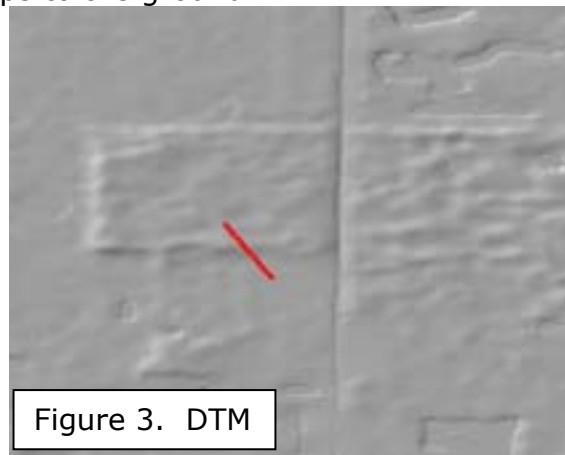


Figure 3. DTM

As seen in the hillshade views above, buildings and small tree regions are completely gone in the DTM. Notice the large forested areas are not completely removed in Figure 3. They remain in the DTM and are smoothed with a filtering process. This can cause DTM elevations to be higher than DSM elevations in certain areas, particularly where there are rapid elevation changes in obstructed areas.

Instances of DTM high are expected to be relatively low. Core product specifications state that in unobstructed slopes less than 10 degrees, less than 5% of the data will have DTM high elevations greater than 1m. The complex IV&V task of quantifying DTM high elevations becomes a fairly simple one using ArcGIS with Spatial Analyst. The task begins with combining slope and obstruction layers to isolate areas of interest. These steps can be automated using the following geoprocessing model:

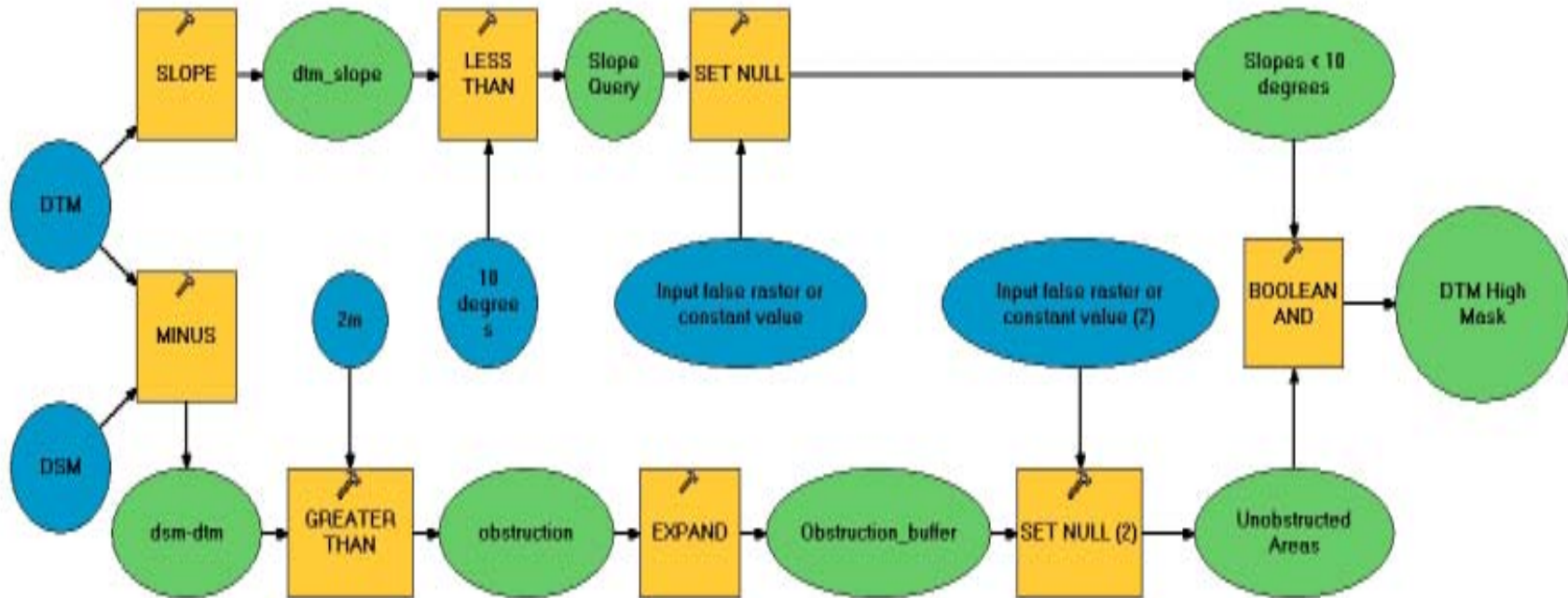


Figure 4. Stepping through the model, reading left to right, DSM and DTM inputs are used to create slope and identify obstruction. The top section of the model creates slope using the DTM. The slope layer is then queried for slopes less than 10 degrees. The Set Null command is then used on the output to isolate only those pixels where slopes are less than 10 degrees. Meanwhile, obstructed areas are defined by running the tools in the bottom section of the model. The Minus command is used to difference DSM and DTM. Differences greater than 2m clearly identify first surface features removed in the DTM and an obstruction layer is created with the Greater Than command. The obstructed areas are then expanded to ensure that the entire extents of obstructed areas are covered. The Set Null command is run on this "obstruction_buffer" layer to isolate unobstructed areas. Finally, the slopes less than 10 degrees and the unobstructed areas are combined to create a DTM High Mask.

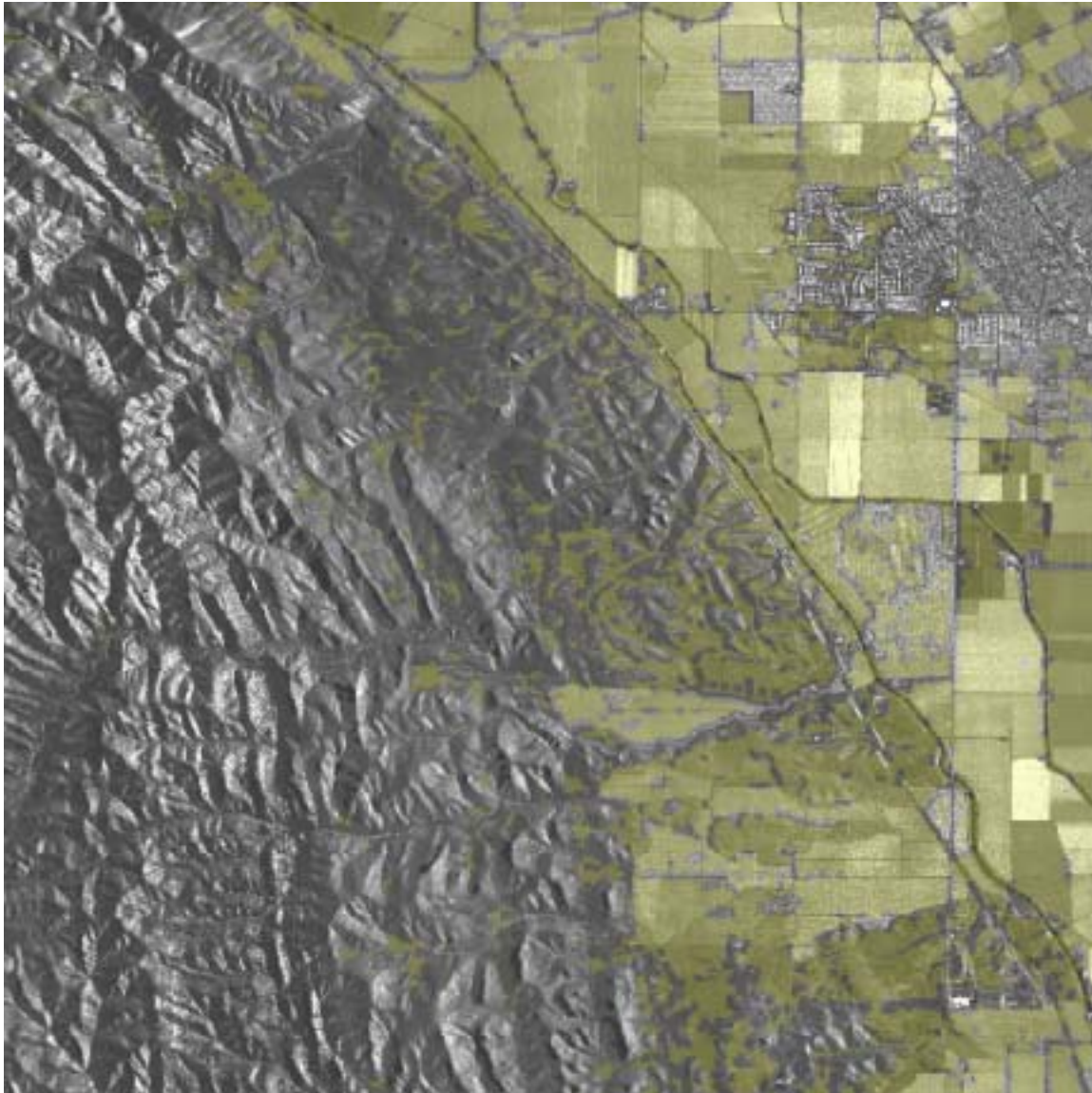


Figure 5. The semi-transparent DTM High Mask layer (yellow) is displayed over the ORI. This mask defines unobstructed slopes less than 10 degrees and is used as the Analysis mask in the Spatial Analyst Options settings. Intermap's data specifications state that the difference between DSM and DTM in the masked areas above must be within 1m with a 95% confidence level. With the Analysis mask defined, the "dsm-dtm" layer created in the geoprocessing model can be queried for values greater than 1m.

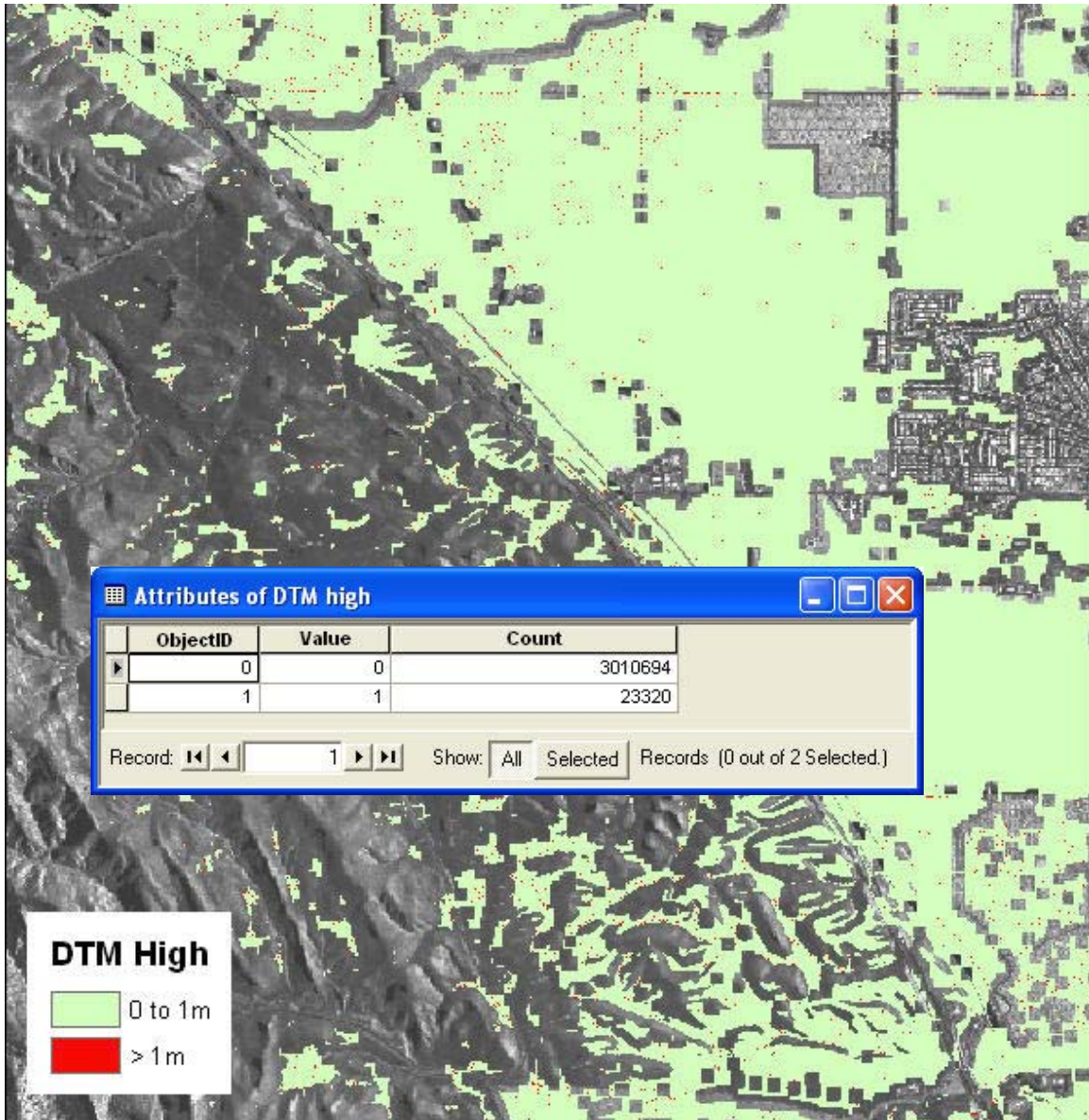


Figure 6. The DTM High layer is displayed on top of the ORI. The small red specs throughout the layer represents instances where the difference between DSM and DTM is greater than 1m. Opening the attribute table to read the pixel count provides the information necessary to determine if the data is within specifications. In the example above, the data meets DTM high specifications: $23320/(23320+3010694) = 0.0076 = \underline{0.8\%}$ (this is well under the allowable 5%).

Target-Editing

Intermap is in the middle of its NEXTMap USA program. This program involves mapping the entire continental United States in less than five years. The Production Department is facing the challenge of editing over 53,000 7.5' mapsheets, which amounts to approximately 8 million km². To be successful, it is crucial that editors work efficiently and focus their level of

effort appropriately. A "Target-Editing" strategy has been implemented as a result to assist in designating where to focus level of effort in each mapsheet. Using existing USGS Land Use/Land Cover (LULC) data and slope data derived from Shuttle Radar Topography Mission (SRTM) elevation models; target-editing masks are created and used as reference by editors in the Production Department while they edit DSM and DTMs. Example Target-Editing mask below (the semi-transparent mask is overlaid above the ORI - Targeted areas are green, non-targeted areas are red):



Figure 7. Specific editing guidelines exist for data in targeted versus non-targeted areas. These guidelines are in place so that a more extensive edit is completed in targeted areas. In this example, approximately 2/3 of the mapsheet designated targeted. IV&V uses ArcGIS to examine whether or not editors are editing appropriately throughout the mapsheet with regard to the Target-Editing mask. The first step involves locating where editors have actually modified the data. Subtracting the input or unedited DSM by the edited DSM and then querying all values not equal to 0 accomplishes this

task. The output is converted to polygon vector data and all features are selected to clearly display the locations of the differences (blue highlights below, 5511 polygon features selected):

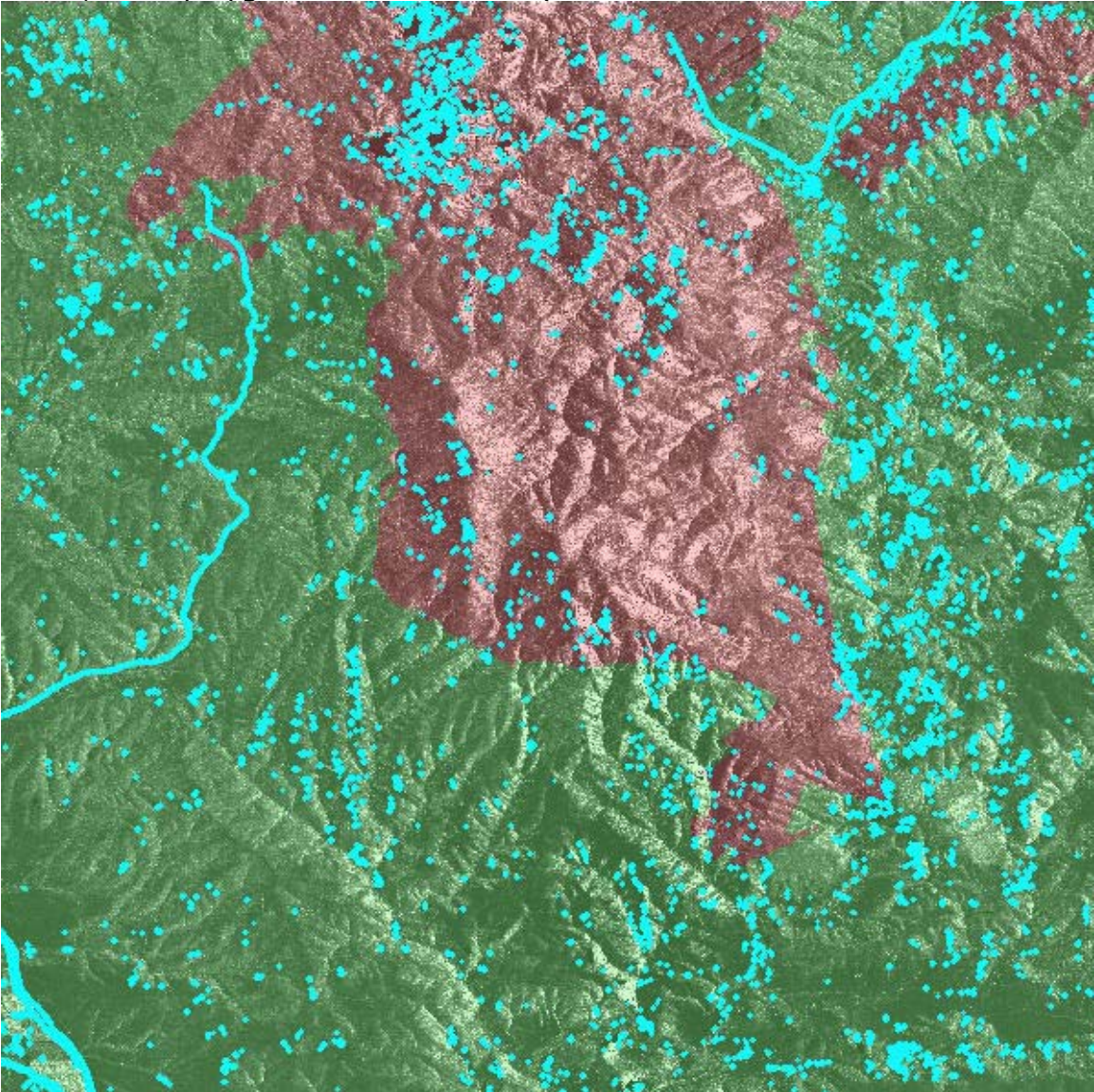


Figure 8. Unfortunately this task is more complicated because there are automated processes run on the data prior to manual editing in the Production Department. A “spike/well” tool is run on the data, which corrects obvious radar artifacts in the input DSM. Simply examining the differences between the input and edited DSM does not isolate the locations of manual editing by editors in the Production Department. Fortunately, the spike/well tool creates a log file with x/y coordinates of all automated edits. This log file is imported into ArcMap where it is used to help identify automated edits in the polygon layer that shows the differences between the input and edited DSM. After identifying and then excluding the automated edits, the locations of manual edits can be isolated.

The x/y coordinates (yellow points below) from the spike/well log file identify the most offending pixel of the radar artifacts.

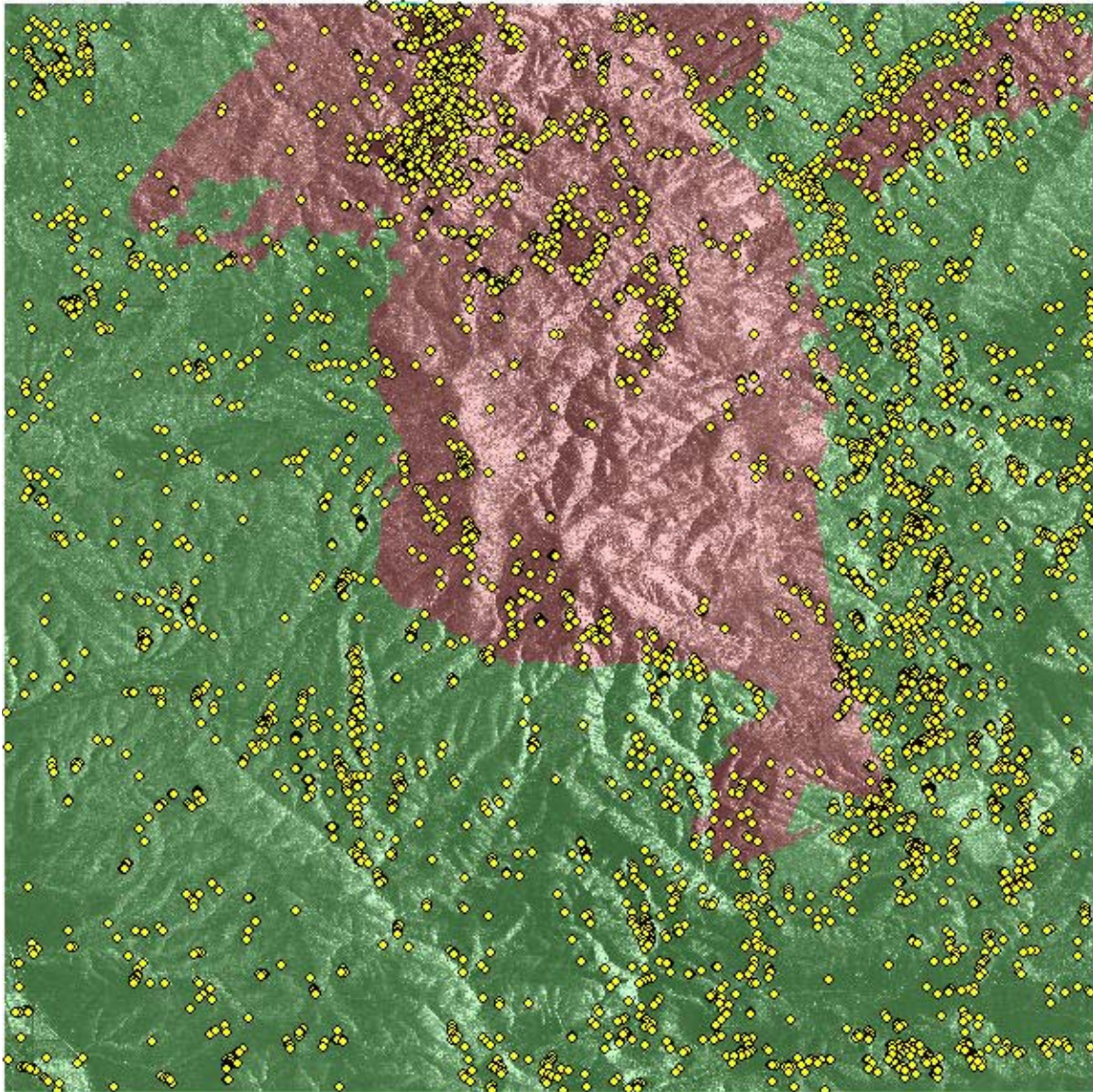


Figure 9. Using a Select-By-Location query, intersecting this point layer with the polygon layer showing the differences between input and edited DSM, only the differences generated by the automated spike/well tool are selected. With the automated differences selected, the Switch Selection tool is run, isolating manual edits. The newly selected features are saved as a separate "manual_edits" shapefile. The next step is to add the DTM manual-edits to the shapefile. This step is easy because the software used by editors in the Production Department tracks DTM edit locations in a raster edit mask. IV&V can import and query the edit mask to isolate manual DTM edits. The manual DTM edits are converted to polygons, copied and pasted into the "manual_edits" shapefile. All features are selected to visualize the location of all DSM and DTM manual-edits (blue highlights below, 426 features selected):

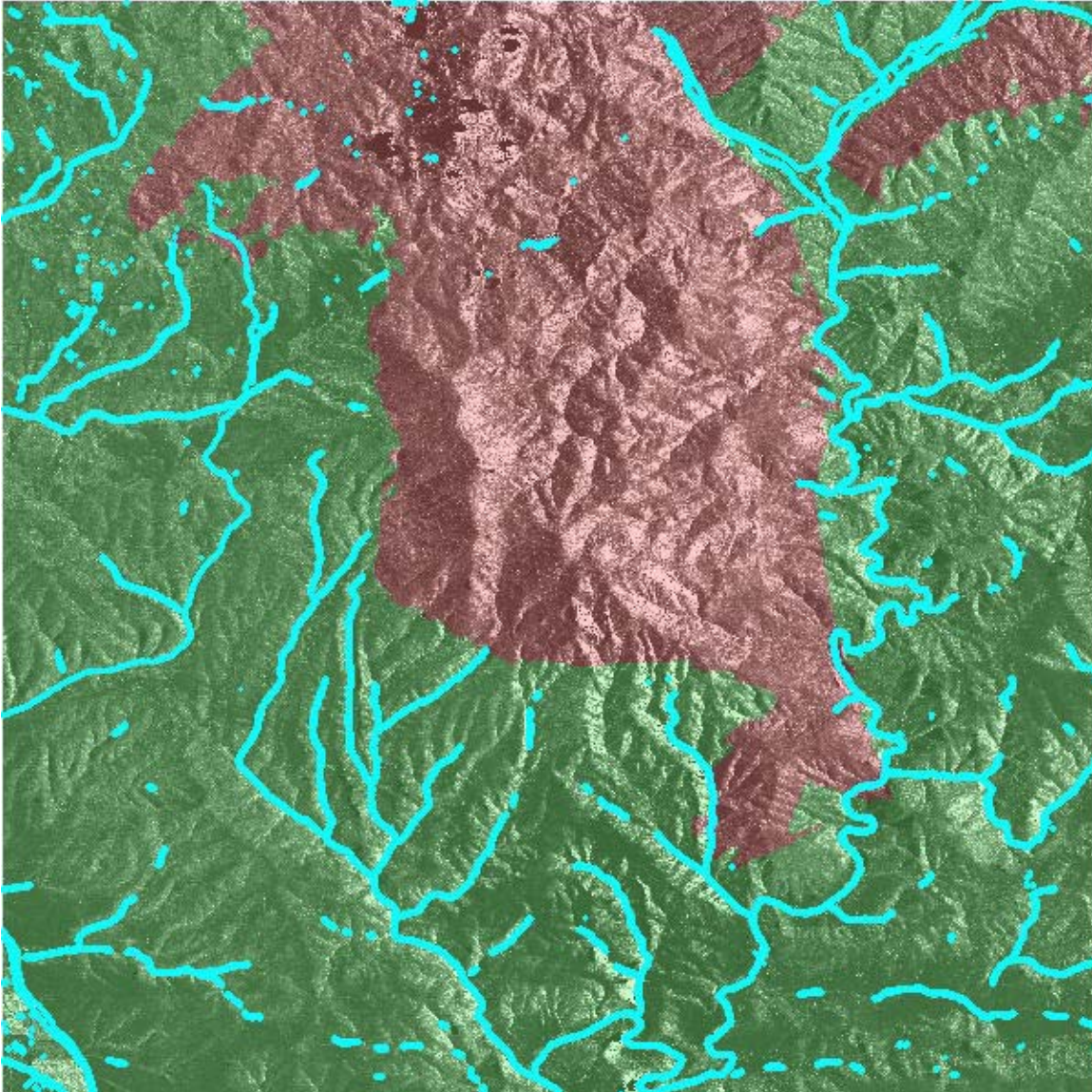


Figure 10. Another simple Select-By-Location query can help to quantify the results; in this case, there are 387 manual-edits in targeted areas and 39 in non-targeted. This process, as seen in the image above, helps to confirm that editing is being concentrated in appropriate locations and that Target-Editing is also reducing overall interactive editing time.

Stream Networks

While editing elevation data, the Production Department uses US Census Bureau TIGER data as an ancillary source of information to help identify the level of interactive editing required in defining drainage networks. Since the ORI displays first surface features, sections of single line streams can be obstructed the editor's view. Core product specifications state that hydrography features in TIGER data will be edited in the DTM.

Exceptions to these specifications stipulate that TIGER hydrography features may be omitted if the stream is in a non-targeted area (as described previously) or if the ORI clearly shows that the feature no longer exists. IV&V creates a stream network from the edited DTM and ensures that the elevations along the streams maintain monotonic flow within a 2-meter range in accuracy. This process involves running a series of commands and generating several intermediate files. To simplify the process, IV&V takes advantage of using Model Builder to automate most of the work.

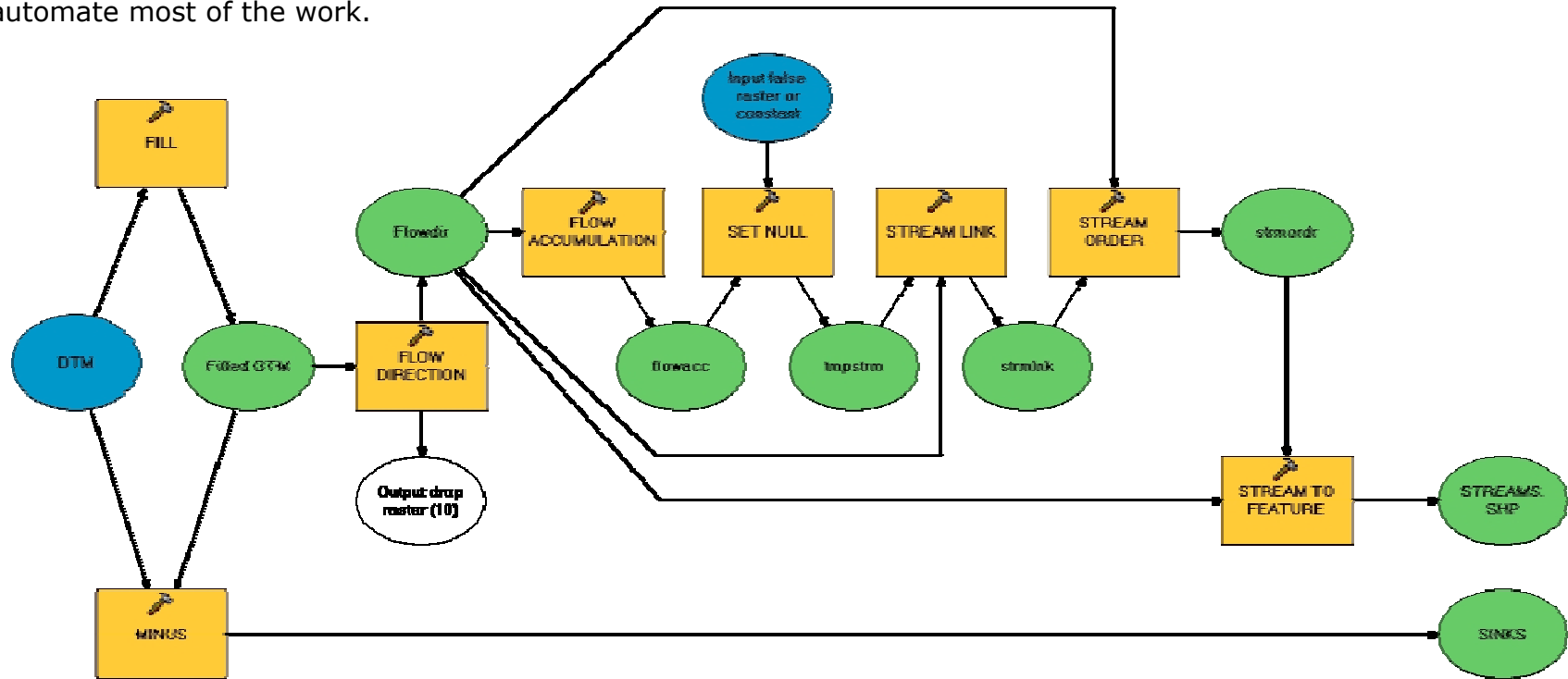


Figure 11. Stepping through the model, reading left to right, the DTM is used as the input to the Fill command. The filled DTM and the input DTM are subtracted to create the “sinks” output. The “sinks” layer will display where and by how much the DTM was filled to ensure water would continue to flow and not accumulate. Meanwhile, commands from the Hydrology toolset are run on the filled DTM (Flow Direction, Flow Accumulation, Stream Link, Stream Order). The Stream To Feature command is run on the output creating a streams shapefile. Streams and Sinks are automatically loaded into ArcMap where the interactive analysis begins.

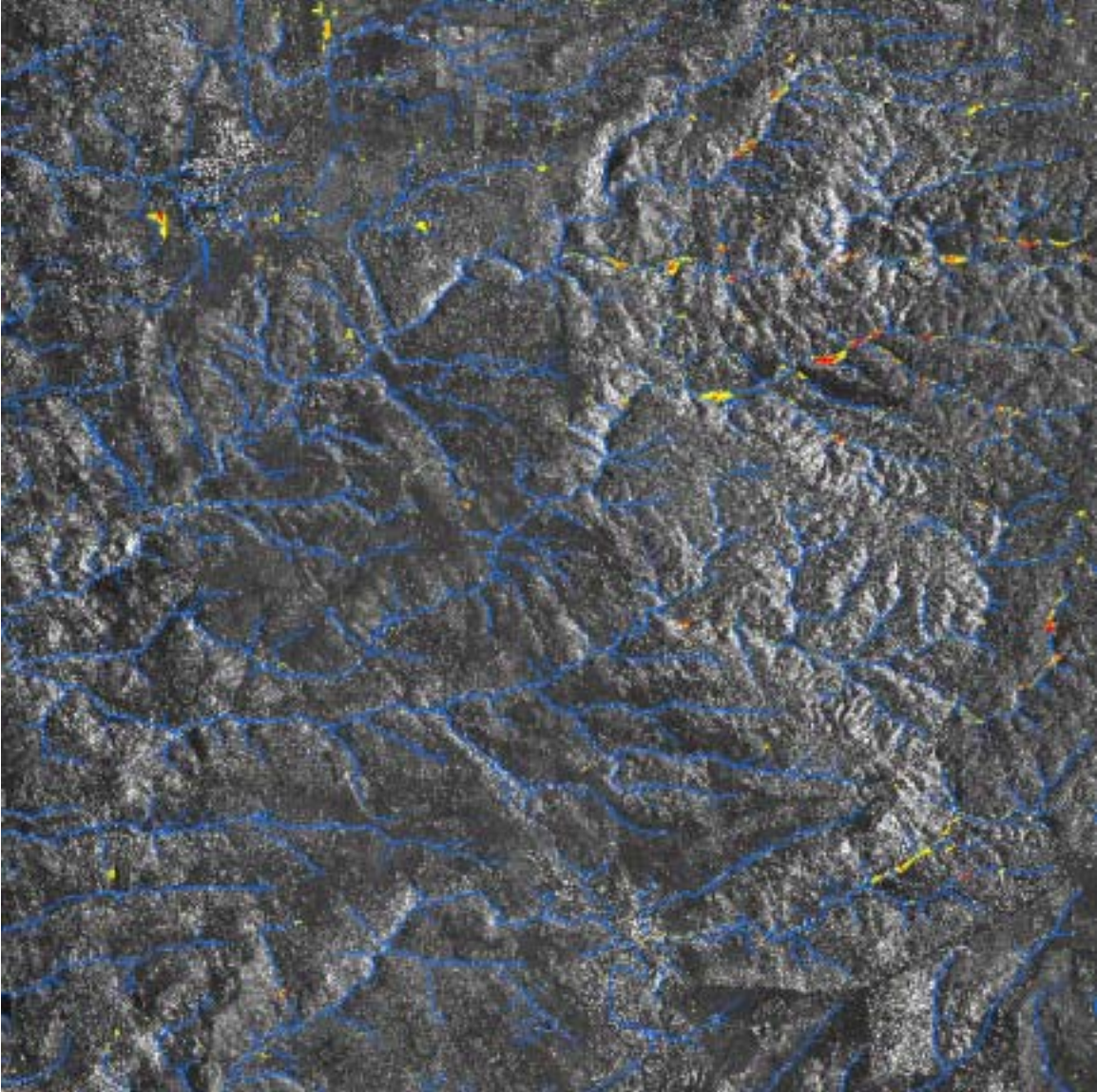


Figure 12. The stream network above is colored blue. The sinks are classified and colored by the elevation difference between the edited and filled DTM (yellow shows sinks greater than 2m and red shows sinks greater than 5m). Sinks will often identify the locations of lakes and/or natural depressions. IV&V investigates the sinks to determine if monotonicity along edited streams is within Intermap specifications. Notice most sinks along the stream network are located in the northeast section of the mapsheet. Checking the Target-Editing mask confirms that most of these sinks are located in non-target edited areas where the Production Department is not required to edit for stream monotonicity.

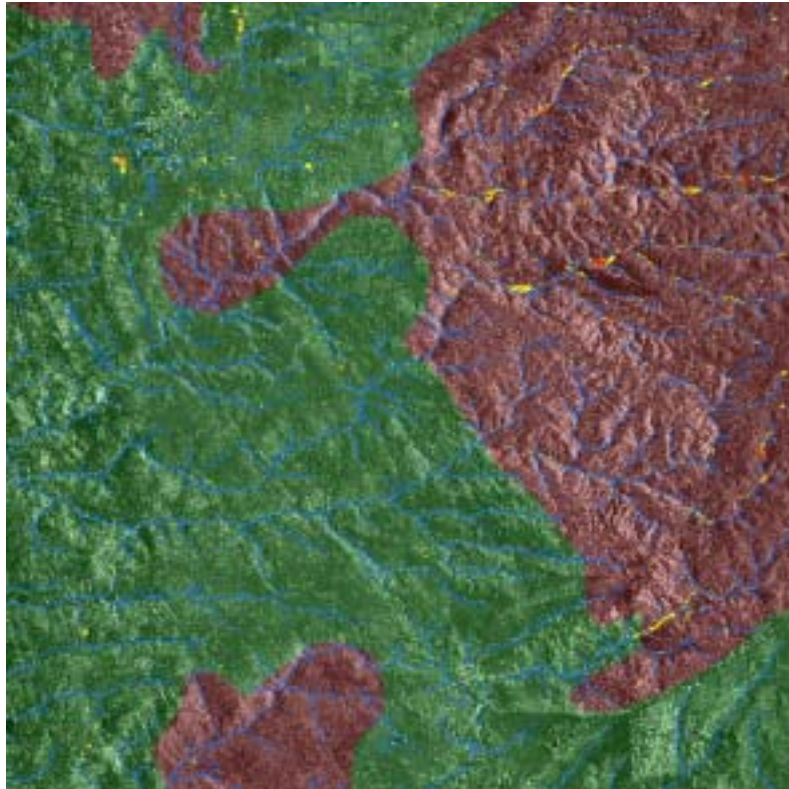


Figure 13. The target-editing mask is overlaid to focus attention on only those areas in the DEM where the Production Department is required to edit stream monotonicity. The sinks that must be investigated by IV&V are limited to those in the green or targeted areas that intersect a stream. Any sinks greater than the specification tolerance found intersecting an edited stream in a targeted area are reported to the Production Department if they do not reflect a natural accumulation of water (lake).

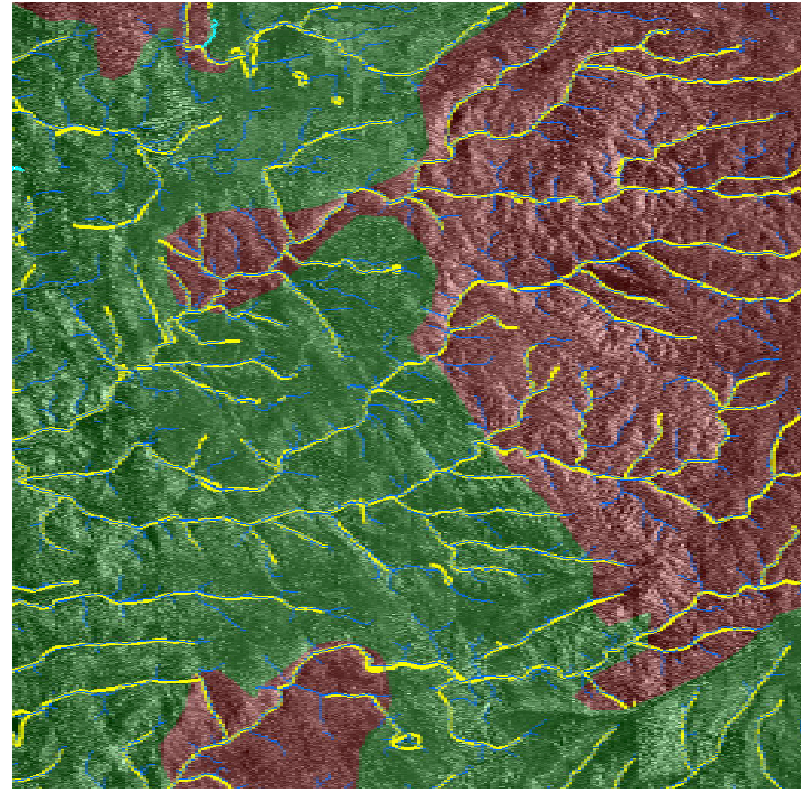


Figure 14. The TIGER hydrology layer is turned on (thick yellow lines) and the DTM stream network is compared to ensure that all TIGER streams are represented in the data. Any missing drainage lines in the DTM stream network are investigated to determine if the exclusion is valid. Any omitted streams identified as invalid are reported to the Production Department where the problem is fixed and communicated to editors.

Conclusion

ArcGIS is used on a daily basis by the IV&V group. It has become an instrumental tool for verifying and validating core product expectations. While the IV&V group has just begun to scratch the surface of its capabilities, the geoprocessing functionality in ArcGIS has already impacted the efficiency and consistency of IV&V core product data reviews. The time saved by batch processing many processes has permitted the IV&V group to keep up a mandate of reviewing 5 to 10% of edited data output from the Production Department. The increased efficiency using ArcGIS is resulting in faster turnaround of valuable feedback to the Production Department. This in turn translates into focused re-training and continued improvement in data quality.

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