Getting OS Digital Terrain Models into CAESAR

This tutorial will guide you through the process of preparing an Ordnance Survey (OS) digital terrain model (DTM) for use in CAESAR, the following software will be utilized:

- ESRI ArcGIS 9.1
- Arc Hydro Toolset (http://www.crwr.utexas.edu/archydrotools/tools.html)
- NTF2MIF (http://www.bodley.ox.ac.uk/guides/maps/translat.htm)
- RasterEdit (http://www.coulthard.org.uk/downloads/downloads.htm)

Part 1: Getting OS Digital Terrain Models into ArcGIS

DTM Acquisition
If you have a subscription to Digimap (http://edina.ac.uk/digimap/), you can freely download DTMs covering the UK. The OS offers two types of DTMs, the OS Land-Form PROFILE DTM, 1:10000 (10m resolution) and the OS Land-Form PANORAMA DTM, 1:50000 (50m resolution). In this example a 10m DTM will be processed, note that this data is available in NTF format. Proceed to download the DTM tiles of your interest.

Importing OS DTM into ArcGIS
Currently ArcGIS can not directly import NTF files without a built-in conversion tool (MapManager 9.1) which is not freely available. Therefore, files in NTF format must be converted into a file format that can be imported into ArcGIS. The following steps guide you through the process of converting NTF files into MIF files, MIF files into ArcGIS shapefiles and lastly converting the shapefile point features into an ArcGIS raster.

1. Download, install, and run NTFMIF. This freeware converts NTF files into MIF files.
2. Load all your NTF files into the translator at once, and select **separate tiles** as your output option (fig. 1). For some reason merging your data into a single tile produces errors in the final outcome.

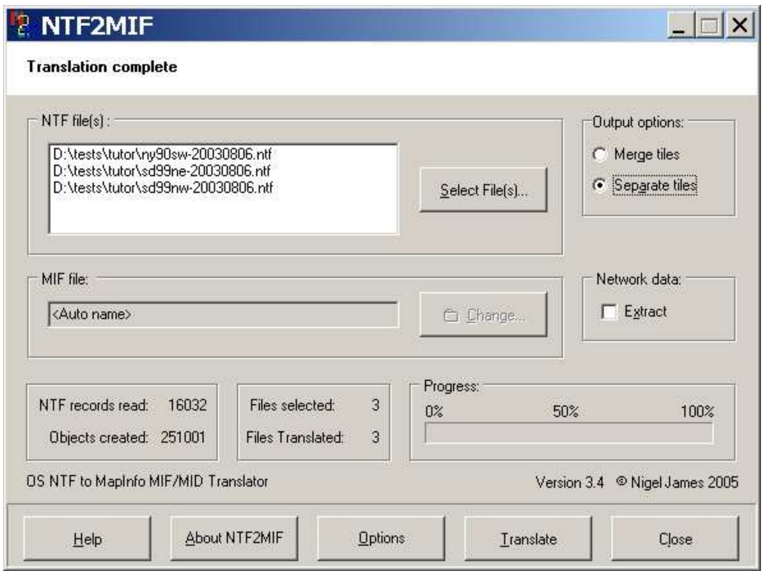


Fig. 1 NTF2MIF interface

3. Click on **translate**, your NTF files will be converted into MIF files which are stored in the same directory as the NTF files.
4. Open ArcGIS ArcCatalog, on the toolbar located at the top of the window, click on **View->Toolbars->Customize**. You will now place a check mark next to **ArcView 8x Tools** (fig. 2). Return to ArcCatalog's main window and notice that a **Conversion Tools** button has been added.

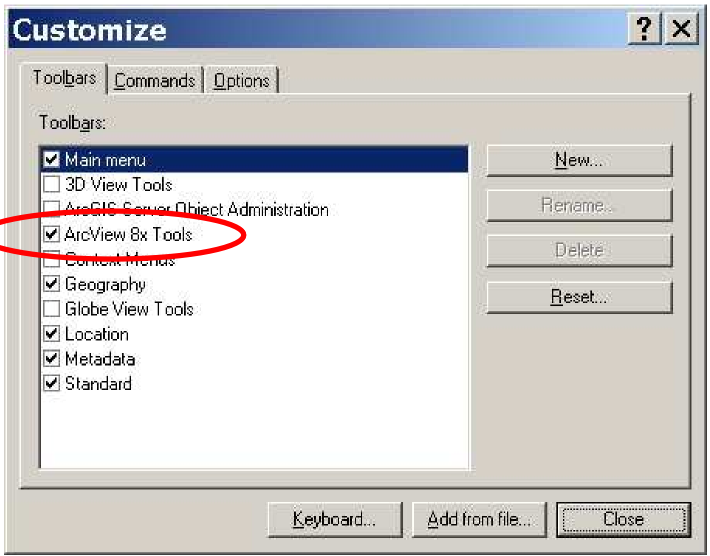


Fig. 2 Panel to add ArcView 8x conversion tools

5. Click on the new **Conversion Tools** button and select **MIF to Shapefile**. Fill in the textboxes appropriately, selecting the MIF file as the input, creating a point feature class, and naming the resulting shapefile in a directory without spaces in the name (fig. 3). Repeat this process for all of your MIF files.

Fig. 3 Panel for MIF to shapefile conversion

6. Open ArcGIS ArcMap, and add all the point shapefiles that you have created. Open the attribute table of one of the point shapefiles and notice that each point has a height value.

7. Make sure that ArcToolbox is open by pressing the ArcToolbox button . Navigate to the **Merge** tool by opening the **Data Management Tools** toolbox->**General** toolset. You should now merge all of your shapefiles into a single shapefile.

8. The resulting merged shapefile can now be converted into an ArcGIS raster. In the ArcToolbox tree open the **Conversion Tools** toolbox->**To Raster** toolset->**Feature to Raster** tool. The merged shapefile will serve as input and the **height** field will supply the raster cell values. Output cell size should be set to 10m, although ArcGIS may recommend something different.

9. The resulting DTM's height values need to be rescaled into meters. Make sure that your Spatial Analyst toolbar is visible and the extension is activated. Open the **Spatial Analyst Raster Calculator** and construct the following expression, substituting "Your_Raster_File" with the name of your raster:

[DTM] = Float([Your_Raster_File]) / 10

10. To make the DTM permanent, right click on DTM in the table of contents window, and select **Make Permanent…**
11. Return to ArcCatalog and navigate to the newly created DTM's directory, if the DTM does not appear, within ArcCatalog right click on the folder containing the DTM and select **Refresh**. Right click on the DTM and select **Properties…** Scroll down to **Spatial Reference**, notice that it is undefined; you will now define the coordinate system for the DTM.
12. Click the **Edit…** button next to **Spatial Reference**, select to define the coordinate system interactively.
13. Select the **Great Britain Grid** as your projection and click next, on the next form accept the default values and click next.
14. Select **ORDNANCE SURVEY OF GREAT BRITAIN 1936** from the list of datums and finally click on finish.

Part 2: OS DTM Preparation for CAESAR

Hopefully you have successfully imported your OS DTM into ArcGIS, but the DTM may require spatial adjustments, editing and hydrological conditioning before it can be loaded into CAESER. The next section will guide you through theses processes.

Rotation

CAESAR is set up so the main direction of flow is from left to right, so the catchment exit point has to be on the right hand end of the DTM. If the main flow of your DTM is in any other direction (fig. 4a) you will have to re-orient your DTM (fig. 4b). Follow these steps to rotate your DTM:

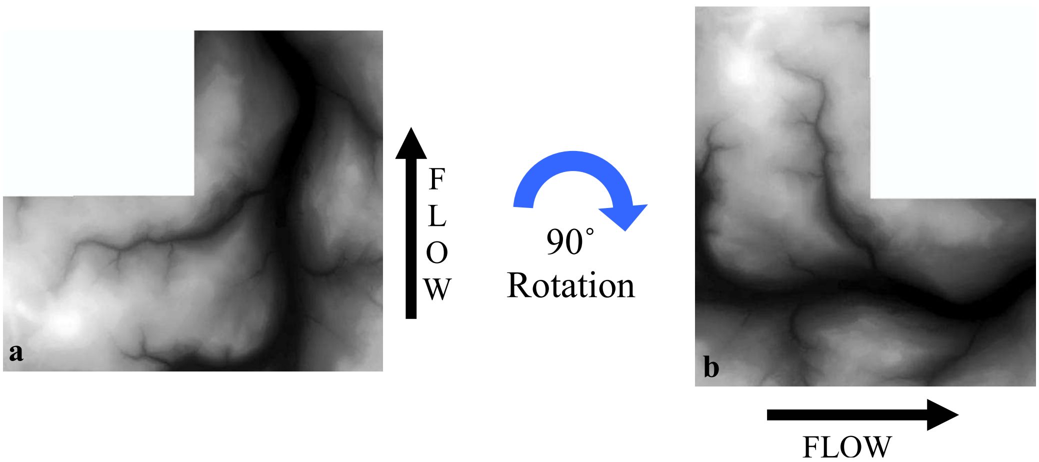


Fig. 4 (a) DTM with flow bottom to top. (b) Same DTM rotated 90˚, flow is now left to right

1. Open ArcMap and add your DTM.

2. In ArcToolbox navigate to the **Data Management Tools** toolbox->**Projections and Transformations** toolset->**Raster** toolset->**Rotate** tool.

3. Rotate your DTM accordingly so the river's main flow is from left to right, note that the default pivot point is the lower left corner of your DTM. Furthermore, rotate your DTM only in multiples of 90˚, not doing so will result in resampling, and will change your DTM values.

Resampling

CAESAR can run with up to 2 million grid cells, but is probably best suited to applications with 250 000 to 500 000 cells. Quite simply, the smaller the number of grid cells, the faster the model will operate. One way to reduce the number of grid cells is to resample your DTM to a coarser spatial resolution.

1. Within ArcMap, add your DTM , and within ArcToolbox navigate to the **Data Management** toolbox->**Raster** toolset->**Resample** tool.
2. Set the input and output rasters, new cellsize and select **bilinear** as the resampling technique which is useful for continuous data. Be aware that this resampling technique will cause some smoothing of the data. Also, set your cellsize to an integer value type, CEASAR will not accept cellsizes with decimal places.

DTM Editing

Sometimes you will find that your DTM has major obstacles across the channel which will block the downstream flow of your river within CEASAR (fig. 5). If you need to remove obstacles from your DTM use the freeware tool RasterEdit.

Fig 5 DTM with bridge blocking the river channel

1. Within ArcMap, add your DTM, and within the ArcToolbox navigate to the **Conversion Tools** toolbox ->**From Raster** toolset->**Raster to ASCII** tool. This tool will convert your DTM into an ASCII file which you can load into RasterEdit.
2. Open RasterEdit, and load your DTM in ASCII format (e.g. DTM.asc or DTM.txt).
3. To find the obstacle you wish to remove change the zoom level in the **Display Options** tab and use the scrollbars to navigate.
4. Once you've located the obstacle, click on **Reach Edit Mode** and make sure that **Mark interpolation points is selected.**

5. You will now click on the cells that are within the river channel and adjacent to your obstacle (fig. 6).

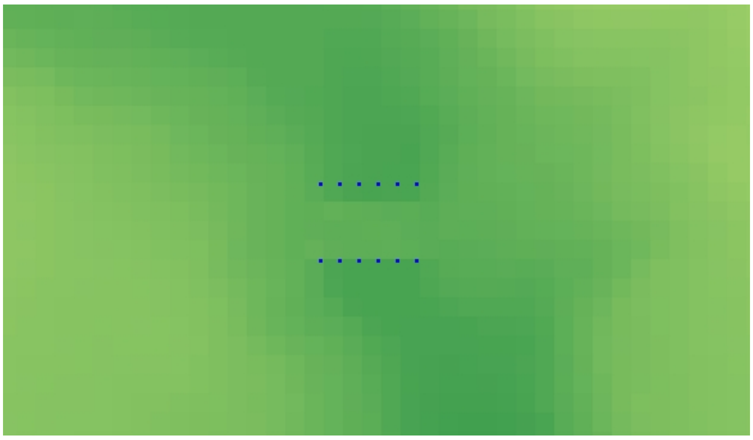


Fig. 6 DTM in RasterEdit with interpolation points marked above and below an obstacle.

6. Return to the **Display Options** tab and click on **Interpolate new point values**. Proceed to click on the cells that represent the obstacle, notice how the cells change color, indicating the newly interpolated height value (fig.7).

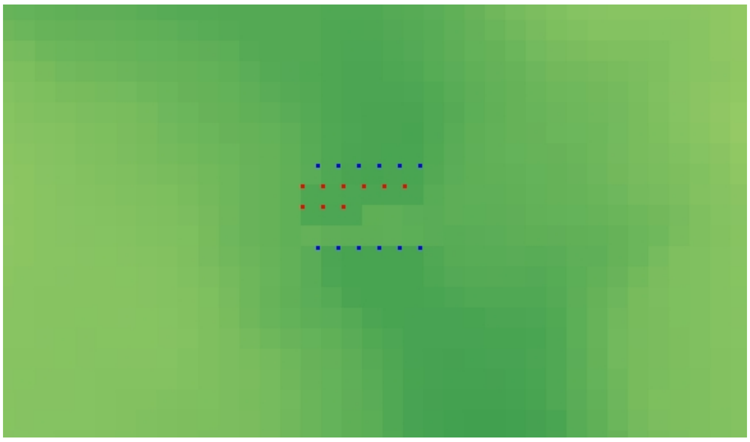


Fig. 7 DTM in RasterEdit with interpolation points marked above and below an obstacle (blue) and interpolated point values (red)

7. Once you've finished removing the obstacle, close RasterEdit, and click the **Save Changes** button on the **File** tab. Save your results with a .txt or .asc extension and close RasterEdit.
8. Open ArcMap, and within the ArcToolbox navigate to the **Conversion Tools** toolbox ->**To Raster** toolset->**ASCII to Raster** tool. This tool will convert your RasterEdit ASCII file into an ArcGIS raster.
9. As input enter the .asc or.txt you created with RasterEdit, set the output raster file name, and select **float** as the **Output data type**. Setting the data type to float will ensure that decimal height values in your DTM are retained.

Hydrological Conditioning
In this section you will fill sinks, extract the main drainage network, delineate the river catchment, edit the river catchment, clip the DTM to the river catchment and burn the main drainage network into the DTM.

Installing ArcHydo Tools

1. Download and install Arc Hydro Tools.
2. Open ArcMap and click on **View->Toolbars**. Check off **Arc Hydro Tools**. Dock the toolbar.

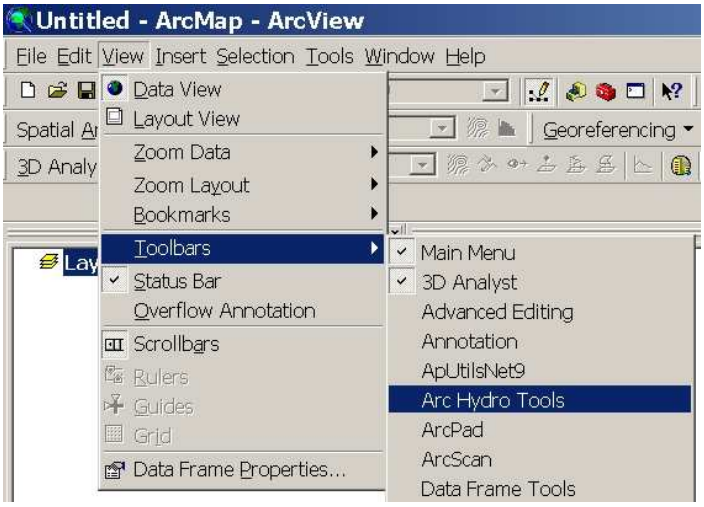


Fig. 8 Adding the ArcHydro Toolbar

Filling Sinks

1. Add your DTM to ArcMap and save the current project .
2. Click on the **Terrain Preprocessing** button, and click on **Fill Sinks**. This process will fill sinks in your DTM and fix small imperfection in the data. Input your DTM and click OK.

Extracting the Main Drainage Network

1. Next, using Arc Hydro tools, calculate the **Flow Direction** (Fdr) and **Flow Accumulation** (Fac) of your filled DTM. Inspect the resulting flow accumulation layer (Fac), and make sure that the flow of the river is not interrupted. Below, the flow accumulation of the DTM on the left (a), illustrates uninterrupted flow, while the same section of river on the right (B) illustrates interrupted flow. If you have interrupted flow, repeating the **Fill Sinks** step may correct this problem.

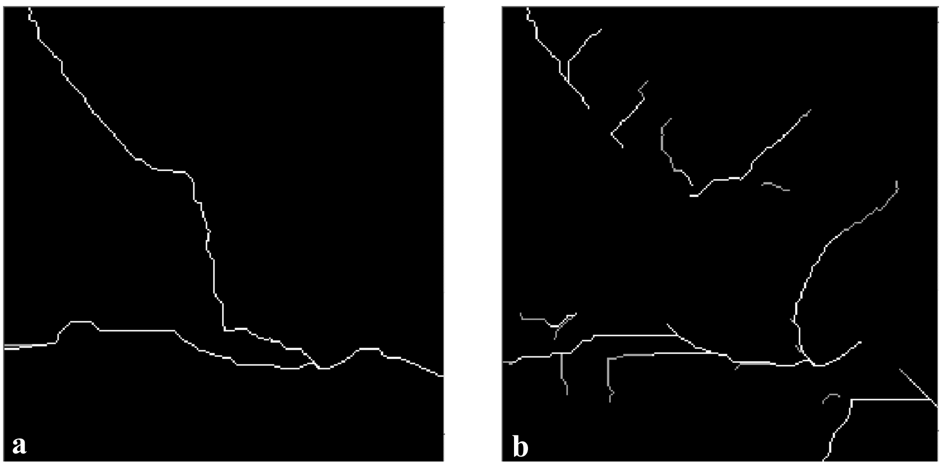


Fig. 9 River channel with uninterrupted flow (a) and interrupted flow (b).

2. The flow accumulation raster (Fac) contains values of accumulated flow to each cell. Cells with greater values tend to represent the river's main drainage pattern. If you are interested in extracting the main drainage pattern re-symbolize your DTM by right clicking on Fac in the table of contents, selecting **Properties…**, clicking on the **Symbology** tab and clicking on the **classified** option. Click on the **Classify**… button and change the classification method to standard deviation. Click OK.
3. Drag the flow accumulation raster's **Layer Properties** window to the upper left hand corner of your screen to make your map visible. You will now visually determine a threshold value for Fac that represents the main drainage network by individually changing the color of your classes.
4. Double click on the white symbol box (fig. 10a) and choose a different color (e.g. red), click **Apply**. Notice that cells representing the main river channel are now a different color (fig. 10b). Continue to re-symbolize your DTM until the main drainage pattern is clearly visible.
5. Write down the first value of the lowest classification range which you re-symbolized (e.g. 2996). This value will be used to extract the main drainage network.

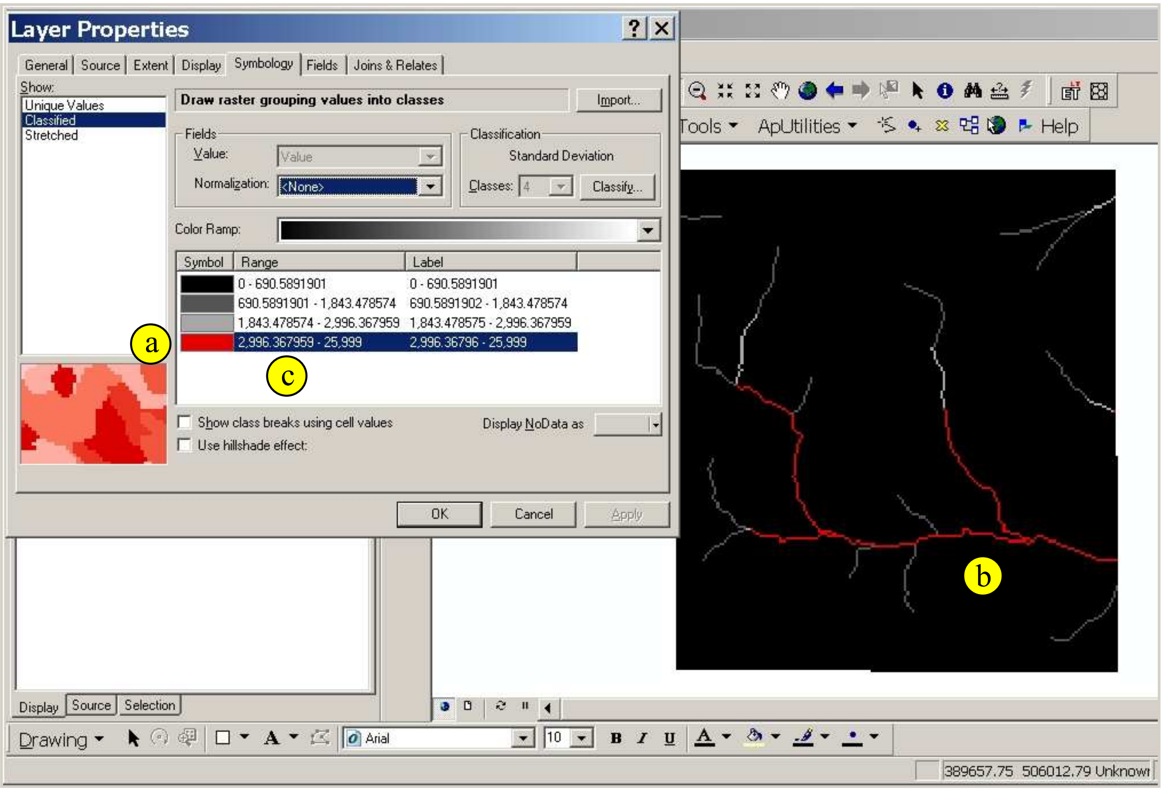


Fig. 10 Visually extracting the main drainage pattern.

6. Close the **Layer Properties** window, and click on the **Terrain Preprocessing** button. Select **Stream Definition** and click OK, in the following dialog enter the value you previously recorded in the **Number of cells** textbox and click OK.

7. Proceed with the remaing terrain preprocessing steps until you complete **Drainage Line Processing**.

This section has produced the following layers that will be used to finalize the conditioning of your DTM:

- Catchment (polygon): catchment for each stream segement
- DraingaeLine (polyline): river's main drainage network
- fil (grid): DTM with sinks filled

DEM Clipping

1. Display the follwing three layers within ArcMap: fil, Catchment and DrainageLine, remove all other layers (fig.11a). You will now clip your DTM to your area of interest by editing the Catchment layer.
2. Display the Catchment layer with a hollow fill and a red outline.
3. Make sure that your **Editor** toolbar is visible, and click on **Editor**->**Start Editing**. Make sure that the Catchment layer is the target layer.
4. Holding the shift key down proceed to click on the sub catchmnets that are not in your area of interest. When you have completed your selection press the delete key on your keyboard (fig. 11b). The remainng sub catchmnets will be used to clip your DEM.

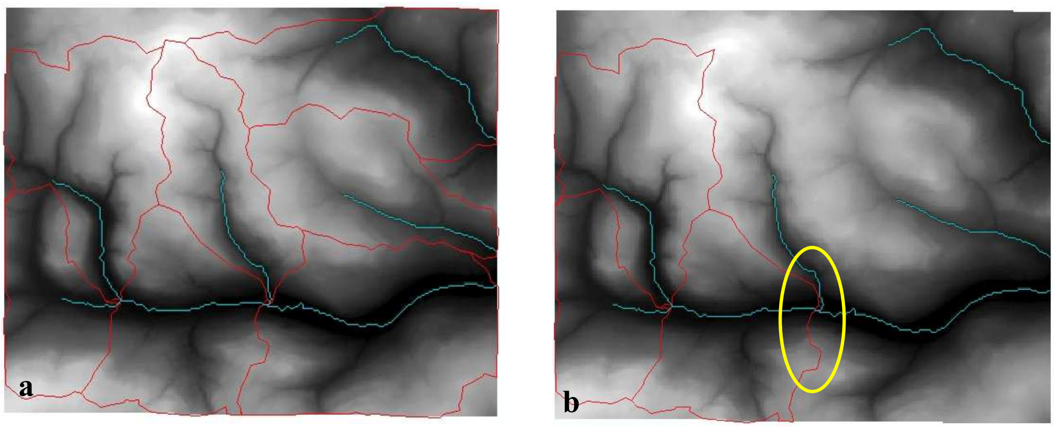
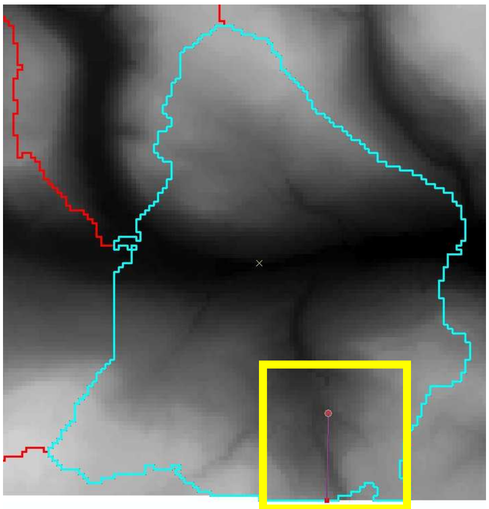


Fig. 11 Catchment, DrainageLine, and Fil, before (a) and after editing (b).

5. Your resulting Catchment layer may have an uneven right hand edge, as marked in fig. 11b. If this is the case, continue editing the Catchment layer to produce a flush right hand edge by clipping. If the right hand edge of your catchment is flush, save your edits, stop editting, and proceed to step 12 in this section.
6. Zoom into the right hand edge of your Catchmnet layer. On the **Editor** toolbar, click on the **edit task** button, select **Cut Polygon Features**, and close the drop down menu.
7. On the **Editor** toolbar, select **Snapping…,** and check off **edge** for the Catchment layer. Close the snapping window.
8. Using the Edit Tool, click once on the sub catchment that contains the uneven right hand edge. Click on the Sketch Tool.
9. You will now clip the sub catchment so the the right hand edge is flush. First, click on the boundary of the polygon where you would like to begin your cut (fig. 12). Notice that, as previously set, the crosshairs snap to the catchment boundary. Next, double click on the boundary of the polygon

where you would like to complete your cut, make sure that the cut is perfectly flush (fig. 13a).



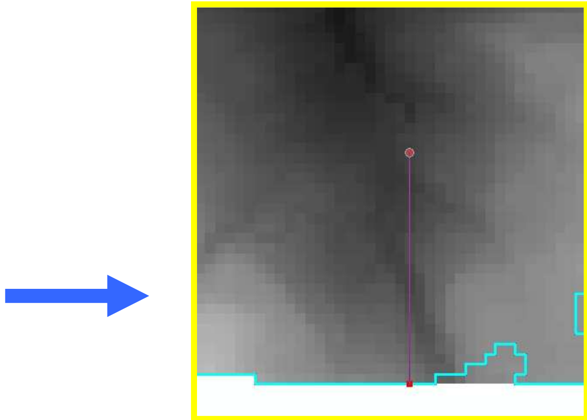


Fig. 12 Cutting the easternmost sub catchment.

10. Your sub catchment should now be sub-divided, you will now delete the eastern portion to produce a flush edge for your river's exit point (fig. 13b).
11. Clear all the selected features by clicking on the **Main Menu** toolbar->**Selection->Clear Selected Features**. Proceed to select the easternmost polygon in your sub catchment and press the delete key. Click on the **Editor** button, save your edits and stop editting.

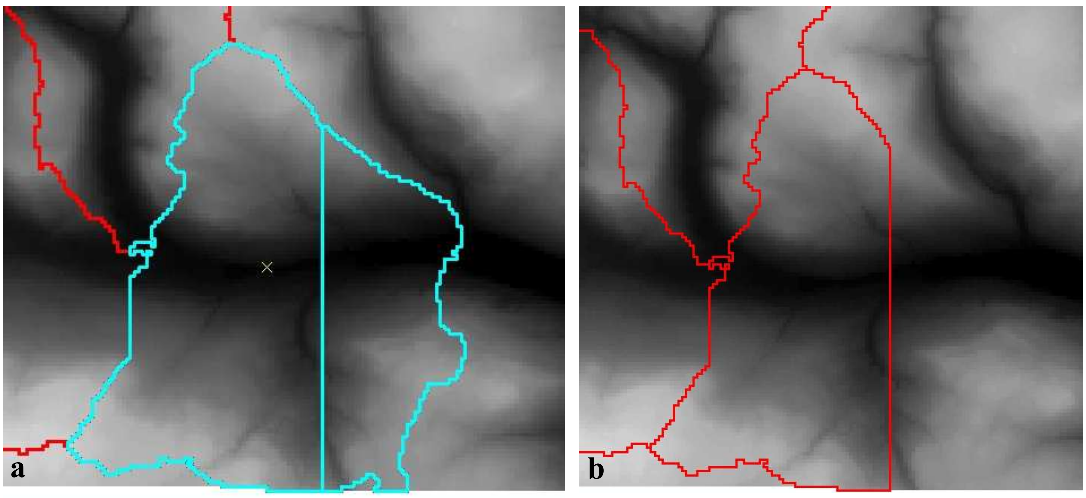


Fig. 13 Easternmost sub catchment subdivided into two polygons (a), rightmost portion deleted to produce flush edge.

12. It is necessary to recalculate the extent of your edited Catchment layer, the extent is important in clipping the DTM correctly. To recalculate the extent right click on the Catchment heading in the table of contents and select **Data->Export Data…** Name the output shapefile Catchment_Clip and add it to ArcMap.
13. You will now clip your filled DTM (fil) to the catchment of your river. Click on **Spatial Analyst** and select **Options…**, on the **General** tab set the Analysis Mask to the Catchment_Clip layer and on the Extent tab set the Analysis Extent to the Catchment_Clip layer, click OK. Now any

operation performed on a raster, using Spatial Analyst, will be clipped to your Catchment_Clip layer.

14. Clip your DTM by typing the following expression into Spatial Analyst's Raster Calculator:

[DTM_clip] = [fil]

15. Turn off the fil layer, open the **Properties…** of your DTM_clip layer. On the **Symbology** tab display the NoData values with a color. Your DTM should not have any NoData values blocking the exit point of your river (fig. 14).

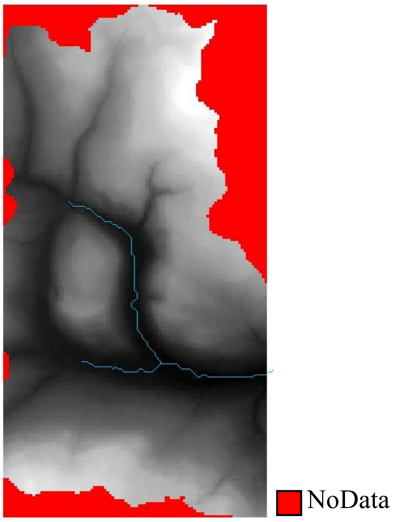


Fig. 14 Clipped DTM without NoData values blocking the river's exit point.

16. In the table of contents right click on your clipped DTM and make it permanent.

DEM Reconditioning

1. Using ArcHydro tool's **DEM Reconditioning** feature, you will "burn" the existing drainage network into your clipped DEM. Click on the **Terrain Preprocessing** menu and select **DEM Reconditioning**.
2. The **Raw DEM** is your clipped DTM, **Agree Stream** is the DrainageLine layer you produced earlier and **AgreeDEM** is the output of this process.
3. In the next dialog enter the value 1 as the **vector buffer**, and 0 as the **smooth drop/raise**, and 1 as the **sharp drop/raise**. These parameters will decrease the values of the clipped DTM intersecting the stream network by approximately 1 vertical unit (meter) and the width of 1 cell.
4. AgreeDEM can now be exported to ASCII using the **Conversion Tools** toolbox->**To Raster** toolset->**ASCII to Raster** tool. Make sure that your output data type is float so you don't lose the decimal places in your elevation values.
5. Lastly, use a text editor (e.g. wordpad) to open and inspect your DTM in ascii format.

Your DTM in ascii format is now ready for CAESAR.