Work book

ArcView Watershed Delineator

GIS Exercise - October 2007

Information Products for Nile Basin Water Resources Management
www.faonile.org

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Introduction

Requirements

This exercise requires a PC running Windows 95/98, NT/2000/XP, with ArcView 3.x including Spatial Analyst, and the projection extension. Internet access is needed. The necessary data are provided.

Objectives

The main objective of this exercise is to demonstrate how a Digital Elevation Model (DEM) can be employed for determining hydrologic terrain features. The exercise also aims at showing how internet resources can expand the functionality of ArcView.

At the end of the exercise, the trainees will be able to:

- Delineate drainage areas for any point on a Digital Elevation Model;
- Determine stream networks;
- Determine flow path and associated longitudinal profile;
- Clip grid layers
- Locate useful ArcView scripts for water resources purposes on the internet, and add these functions to the software;
- Use ArcView to edit a vector data layer..

Task

Use the Watershed Delineator to determine basic hydrologic terrain features like drainage area, stream network, flow path, and profile.

Procedure

The 'Watershed Delineator' is a set of procedures, tools, and utilities that allow interactive watershed delineation of a GRID terrain representation, for any given point, segment, or polygon. The extension was developed by for the Texas Natural Resources Conservation Commission.

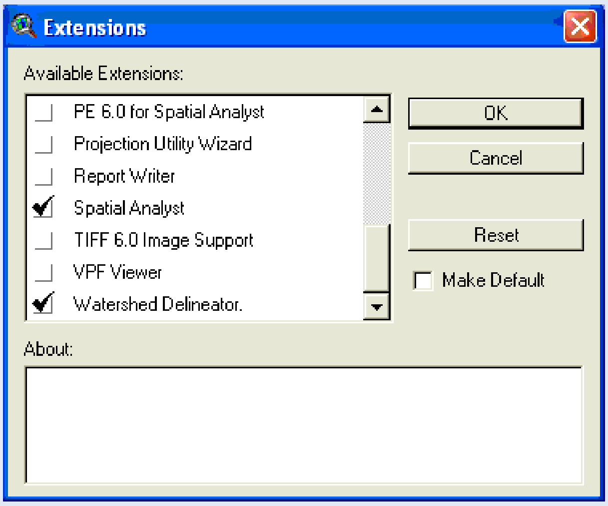
Install the Watershed Delineator.

The Watershed Delineator is located in the folder "Software\Wshedelin\Code\Install" on the workshop CD. Browse to this folder, and double click "setup" setup . Follow the instruction on screen.

Navigate to the folder C:\ESRI\AV_GIS30\ARCVIEW\EXT32, and check if the Watershed Delineator (stored in the "WshdDel.avx extension") has been added.

Open ArcView Select "File" => "Extensions..." to activate the Extension dialog box.

Check "Spatial Analyst" and "Watershed Delineator". Click OK OK .



The Watershed Delineator consists of two distinct operations: data development and watershed delineation. The former needs to be completed before the latter can be performed.

Create a Standard Directory Structure

Data development for the Watershed Delineator is essentially a one-time operation. Only when the basic Digital Elevation Model (DEM) is changed, will it necessary to redo this work. Preprocessing, however, can require quite some time and computer resources and it is therefore advised to store the preprocessed data layers in a standard directory structure. This will make it much easier to re-use and locate the data layers at a future occasion.

Create the following directory structure in the main sub folder "C:\GIS_Work\workshop\ExWshDel"

\usrdata	for all user files generated during the delineation process
\demdata	for all preprocessed GRID data
\prepdata	for all preprocessed vector data
\tmp	for all temporary work files generated by the Watershed Delineator

Please note that all folder names are limited to 8 or less characters. GRID files in ArcView do not work if their folder or file names exceed 8 characters.

Prepare DEM for Lake Victoria Region

We will use the Lake Victoria region to demonstrate how to use the Watershed Delineator. To reduce the file size, we will first extract a DEM for a Lake Victoria window bounded by:

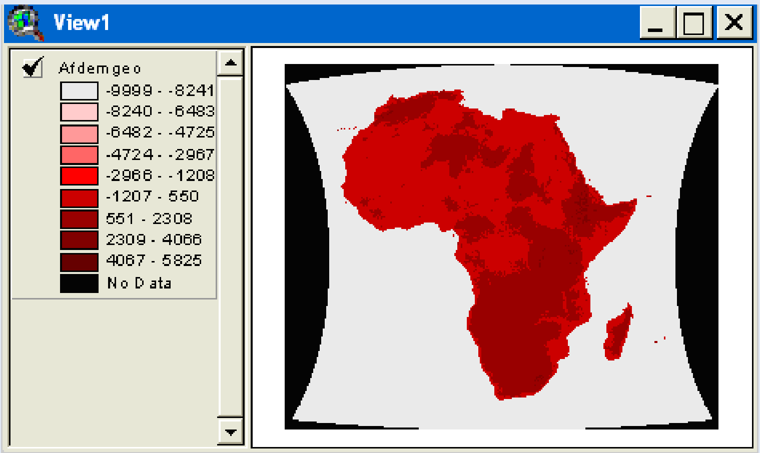
- upper latitude: 2 degrees north
- lower latitude: 5 degrees south
- western longitude: 28 degrees east
- eastern longitude: 36 degrees east

Click New [New] to open a new view in ArcView . Click to add a data layer. Navigate to the "Data\Afdem\Afdemgeo" folder on the workshop CD. This directory contains the GTOPO30 digital elevation model for Africa in geographic coordinate system (latitude – longitude). This grid has a resolution of approximately 1 x 1 square kilometers.

Select "GRID Data Sources" from the "Data Source Type" drop down list.

Chose "afdemgeo" afdemgeo and click OK [OK]

After switching on the theme, the view on the left-hand side appears.



The "afdemgeo" file has a size of 50.5 Mb, which too large to handle on a regular basis. We will now extract a window for the Lake Victoria region.

Select "Properties" from the "Analysis" menu.

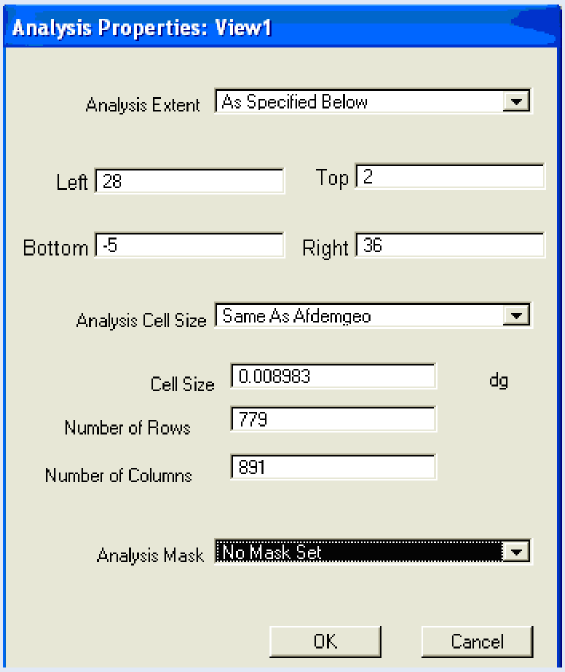
Chose "As Specified Below" from the "Analysis Extent" drop down list.

Set "Left" to 28, "Top" to 2, "Bottom| to –5, and "Right" to 36.

Set "Analysis Cell Size" to "Same As Afdemgeo" from the drop down list.

This will automatically set the right values for the cell size and number of rows and columns.

Click OK [OK].



Use the Map Calculator to create a new layer for the specified window.

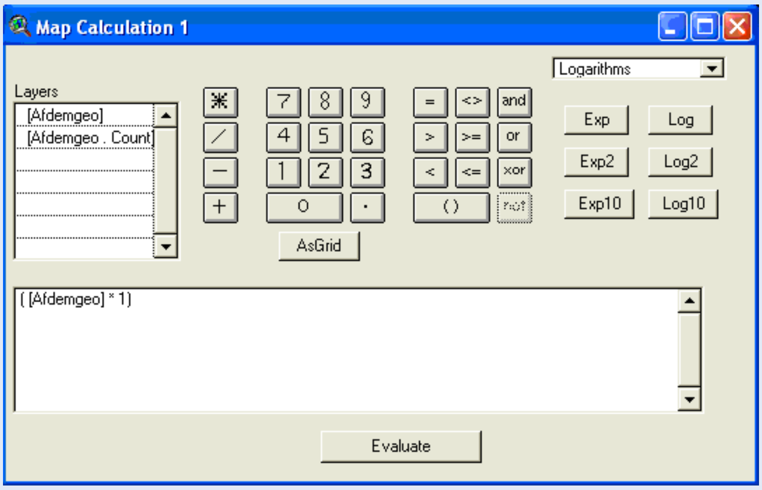
Select "Map Calculator" from the "Analysis" menu.

Use the dialog box to create the following calculation:

{[Afdemgeo] x 1}

Click Evaluate 

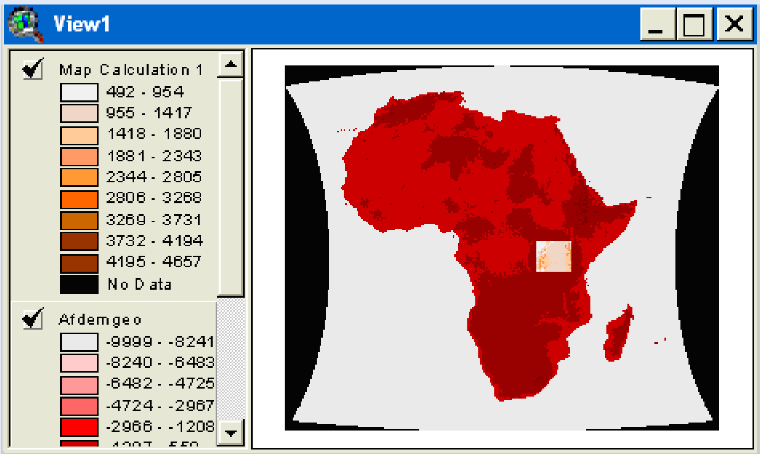
Close the "Map Calculator" window.



Switch on the new theme. The view now looks like in the left hand panel.

Notice how much the file size has been reduced.

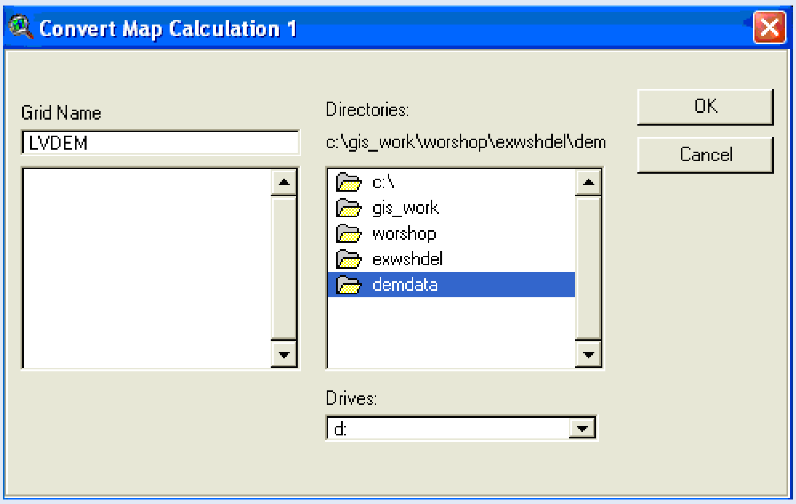
Click the "Map Calculation 1" theme, and select "Convert to GRID..." from the "Theme" menu.



Navigate to the folder: "C:\gis_work\workshop\Exwshdel\demdata" and type "LVDEM" in the Grid Name text box. Click OK. 

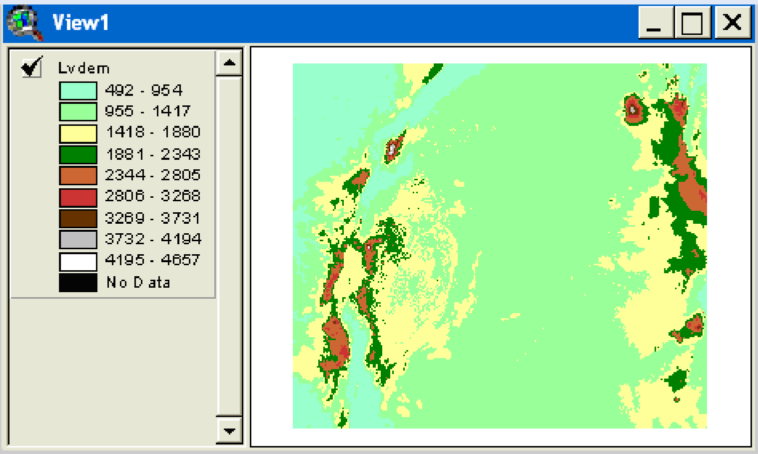
Add the theme to the view, and remove both "Map Calculation 1" and "Afdemgeo" (using "Delete Themes" from the "Edit" menu).

The new layer has a size of only 1.4 Mb.



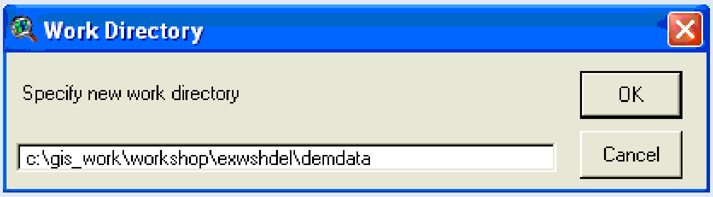
Zoom to the active theme . Then use the “Legend Editor” to select the “Elevation #1” color ramp.

This is the unprocessed DEM for the Lake Victoria region.



We will use this layer to prepare the data sets for the “Watershed Delineator”. However, before we continue, we have to set the proper working directory.

Select “Set Working Directory” from the “File” menu. Then enter the folder as indicated on the left. Click OK.



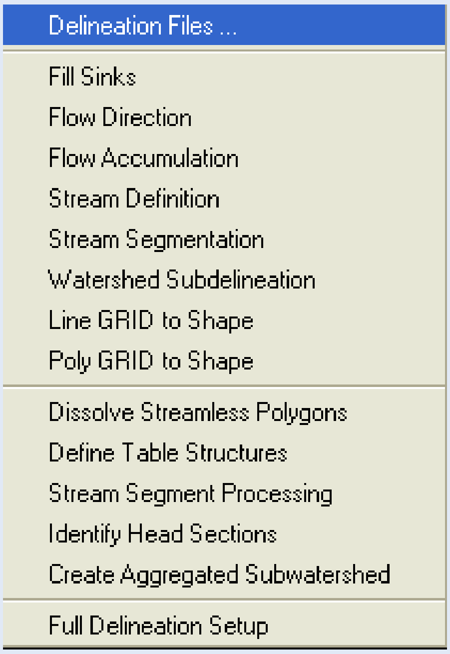
Raster Data Preparation

The GRID preprocessing includes the following operations:

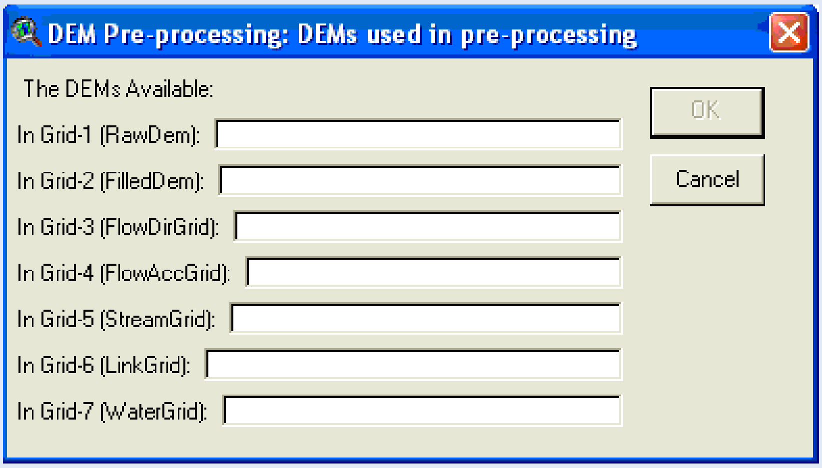
- Fill internal sinks
- Determine flow direction for each grid cell
- Determine flow accumulation value for each grid cell
- Define streams
- Determine stream segmentation
- Delineate sub watersheds

The Watershed Delineator performs all the above tasks. It has added two menu items to the main menu bar: "Hydro" and "Hydro-Utility".

The "Hydro" menu deals with data preparation. The various sub menus are shown on the left. The user has to go through all these steps before he can use the automated watershed delineation tools.



Select "Delineation Files..." from the "Hydro" menu. The right-hand window appears. It asks for the following seven input grids.



Grid 1: The original DEM, in this case the LVDEM prepared in the previous section.

Grid 2: The Filled DEM; the data preparation process starts with filling internal sinks in the DEM. This will remove small pits and imperfections in the DEM layer, and ensures that each grid cell has an outlet cell.

Grid 3: The Flow Direction grid; the flow-direction routine determines the direction in which water flows out of a cell. Of the 8 possible directions, the one with the maximum downward slope is selected. Rules are included for dealing with equal slopes in multiple directions.

Grid 4: The Flow Accumulation grid; it contains the contributing drainage area for every grid cell. For example, the value of the flow accumulation matrix at the catchment outlet will represent the total catchment area. Cells having a flow accumulation area of one, which means no inflow, will correspond to ridges or hilltops.

Grid 5: Stream grid; by applying a threshold value to the accumulation grid, a drainage network grid is produced.

Grid 6: Link grid; each cell between stream junctions, or in a head segment, is assigned a unique identifier.

Grid 7: Sub-watershed grid; each cell draining to a unique stream segment is assigned an identical value, corresponding to the value of the segment to which it drains.

Start producing grids 2 to 7. Step 1: select "Fill Sinks" from the "Hydro" menu.

Enter "lvdem" in the "Input Theme 1 field".
Enter "lvdem_f1" in the "Output Theme 1" field.
Click OK OK

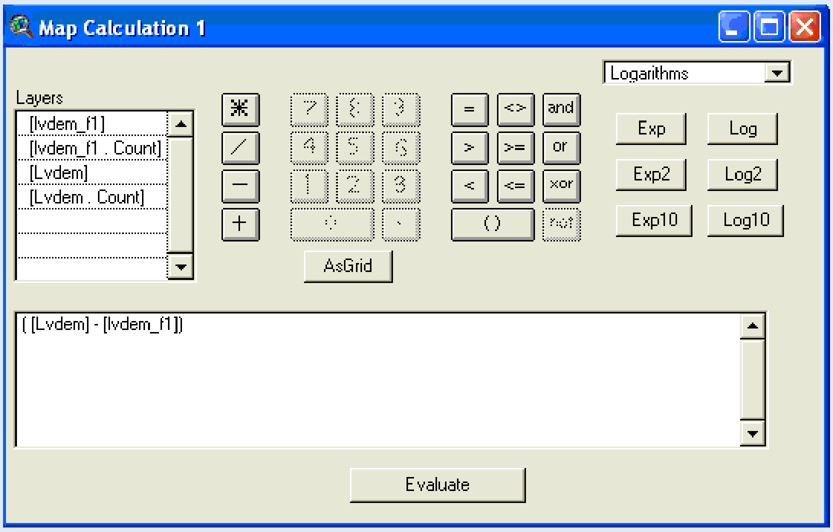
The filling process will take a few minutes. Save the Filled-DEM as "lvdem_f1" in the "demdata" folder. Add the new layer to the view.

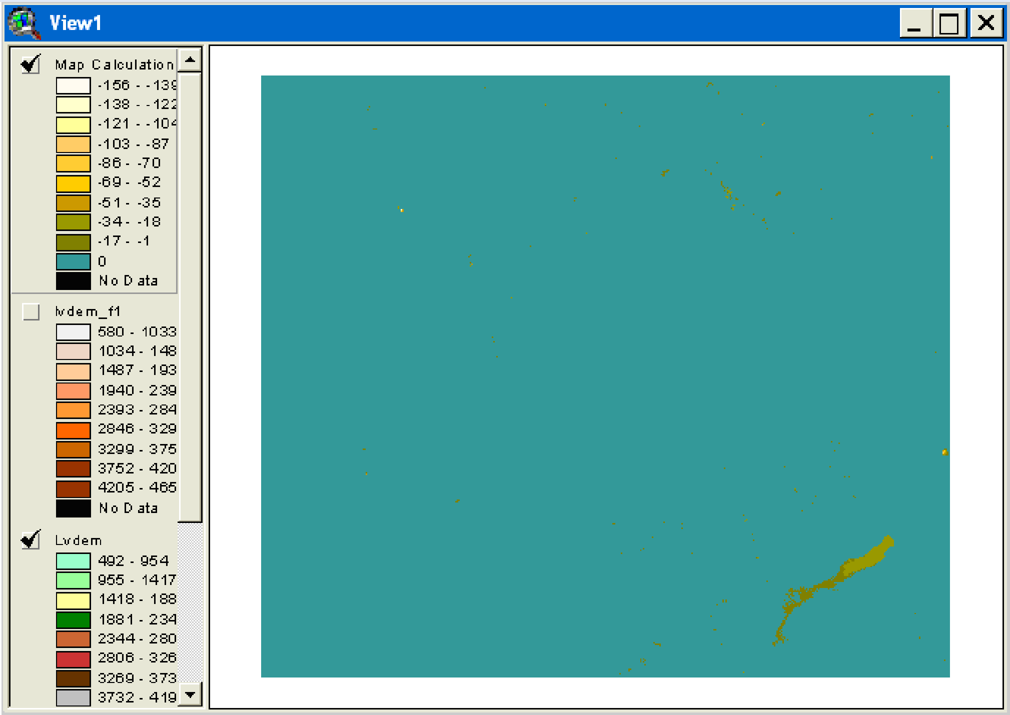
Check the changes by performing a map calculation in which the new filled DEM is subtracted from the original DEM. To this end, select "Map Calculator..." from the "Analysis" menu.

Build the map equation shown in the left panel.

Click Evaluate Evaluate

Add the calculated theme to the view and spend some time examining the results. It shows that no significant changes were made apart from an area in the lower right-hand corner, which is actually a lake. This view is presented below.

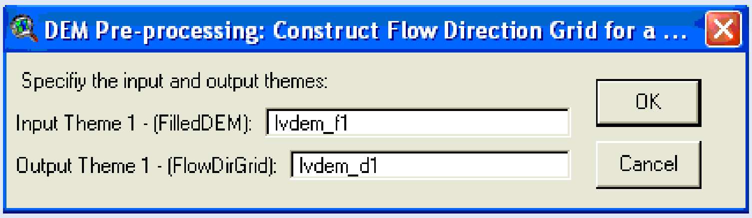




Delete the "Map Calculation 1" theme from the view and proceed with step 2: determining flow direction.

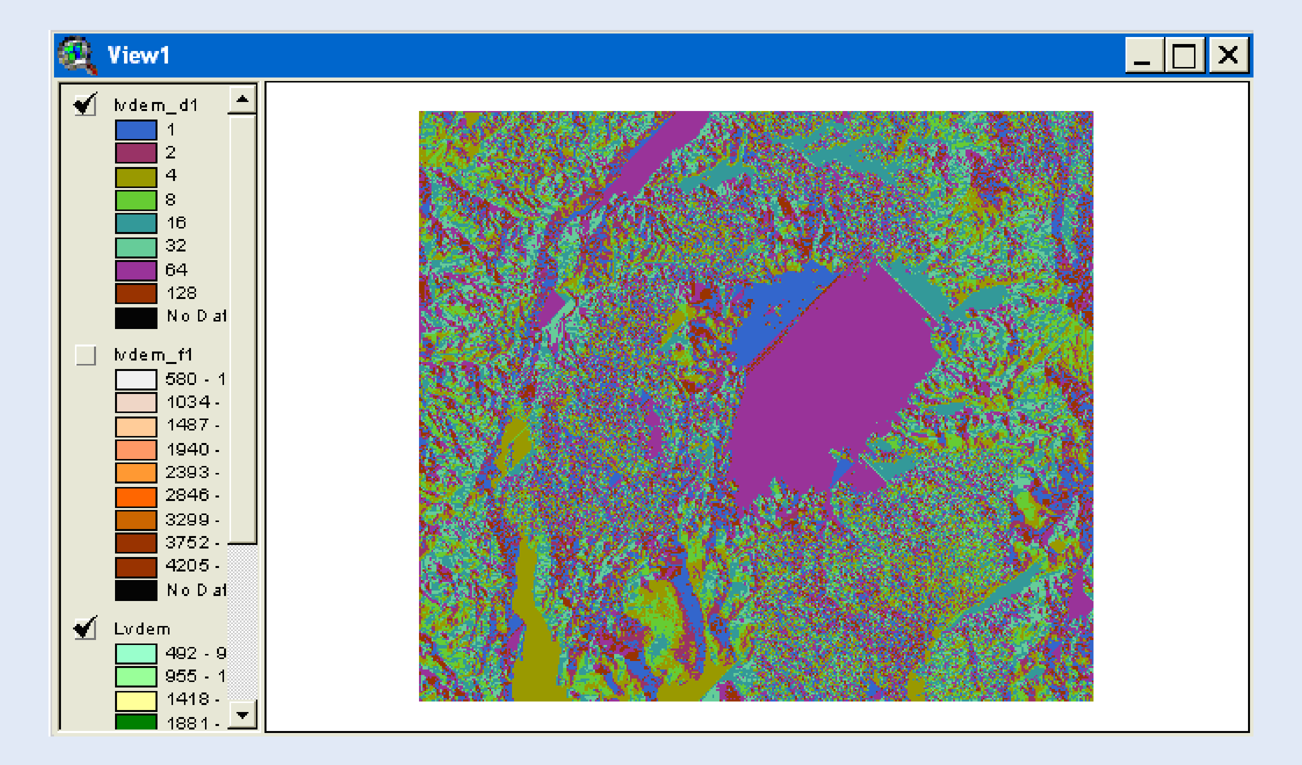
Select "Flow Direction" from the "Hydro" menu.

Enter "lvdem_f1" in the "Input Theme 1 field".
Enter "lvdem_d1" in the "Output Theme 1" field.
Click OK [OK]



We continue with the last projection class: Conical.

Two important members of this family are "Normal Conical" and "Secant Normal Conical", both presented below.



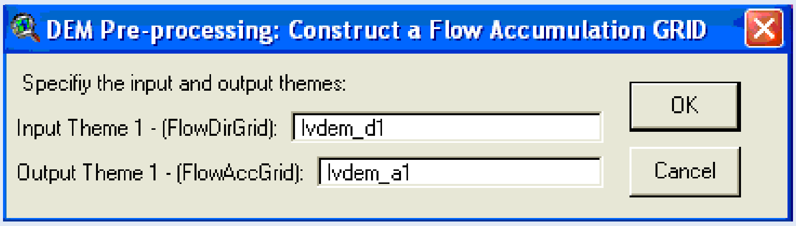
Note that the new layer holds 8 different values, each representing a different flow direction. It is possible to identify the rough feature of the lakes Victoria and Albert.

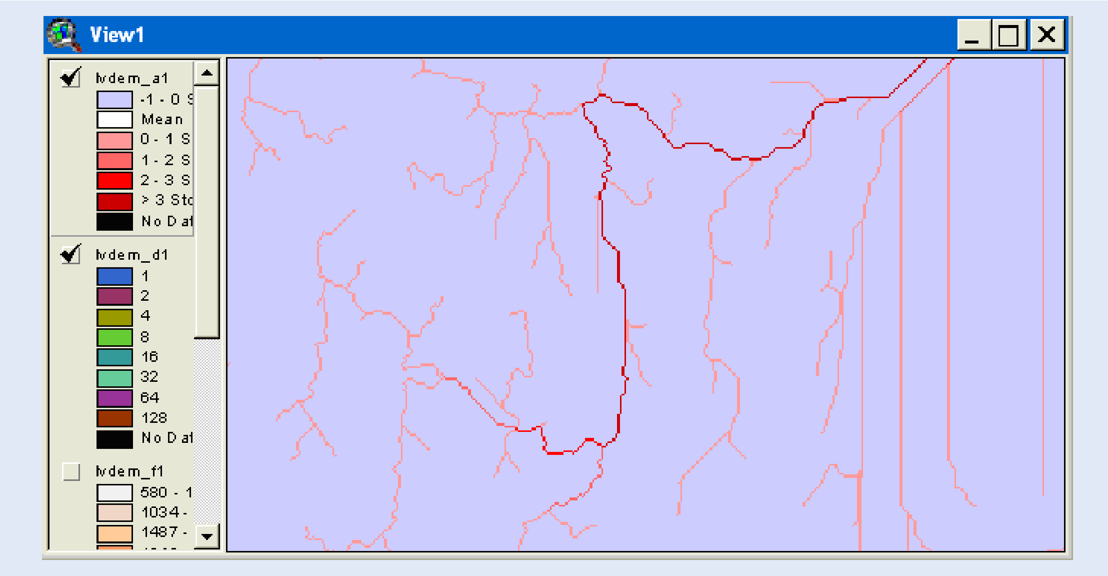
Continue by constructing the flow accumulation grid. Select "Flow Accumulation" from the "Hydro" menu.

Enter "lvdem_d1" in the "Input Theme 1 field".

Enter "lvdem_a1" in the "Output Theme 1" field.

Click OK 



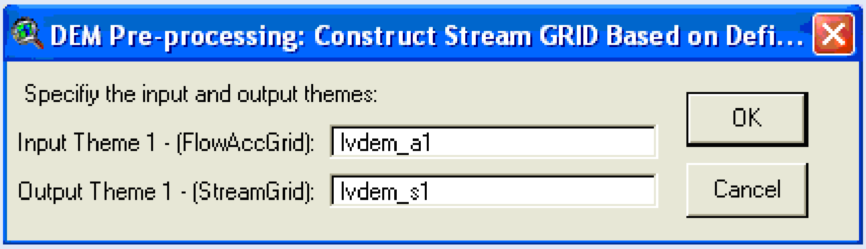


The next step is to calculate the stream network. Select "Stream Definition" from the "Hydro" menu.

Enter "lvdem_a1" in the "Input Theme 1 field".

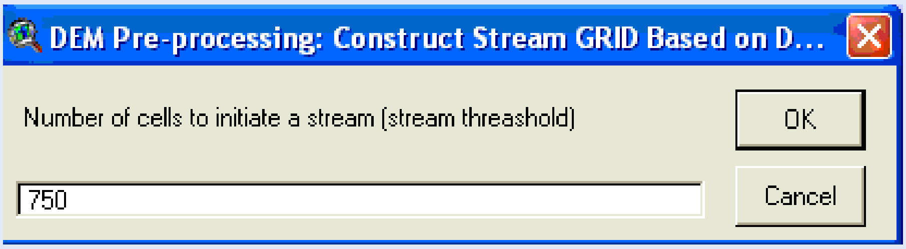
Enter "lvdem_s1" in the "Output Theme 1" field.

Click OK



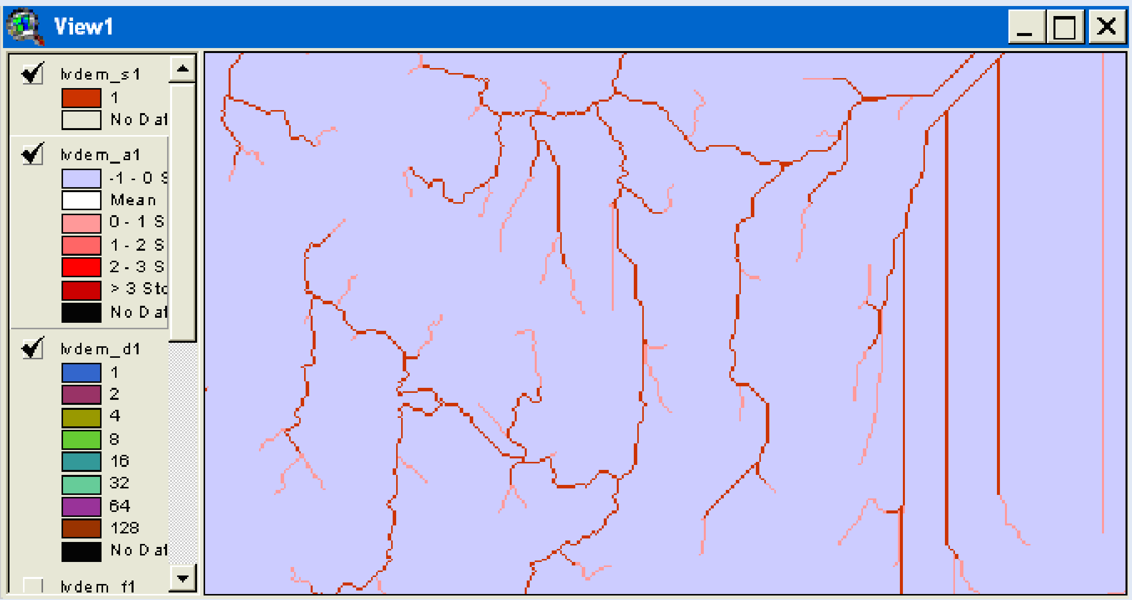
Set the threshold to 750. Click OK.

Save the new grid as "lvdem_s1" in the "demdata" folder



The threshold determines the size, and thus the number of the sub watersheds. The Watershed Delineator will not function properly if this number falls outside the range 100 – 450. This is because of a programming limitation of the tool.

Add the new theme to the view. The result, presented below, is very similar to the previous view. However, the new grid holds two values only: 1 for a stream cell, and "No Data" for a non-stream cell.

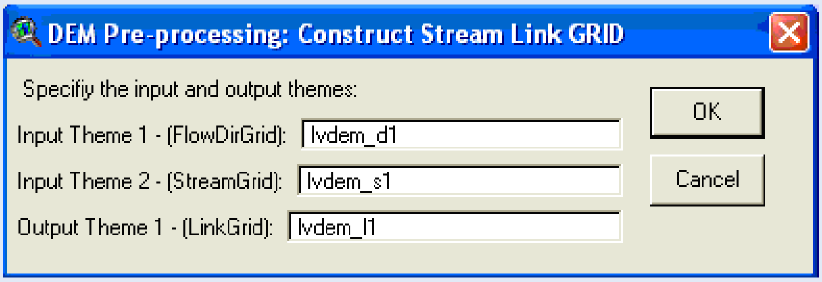


The next step involves building the segment raster. Select "Stream Segmentation" from the "Hydro" menu.

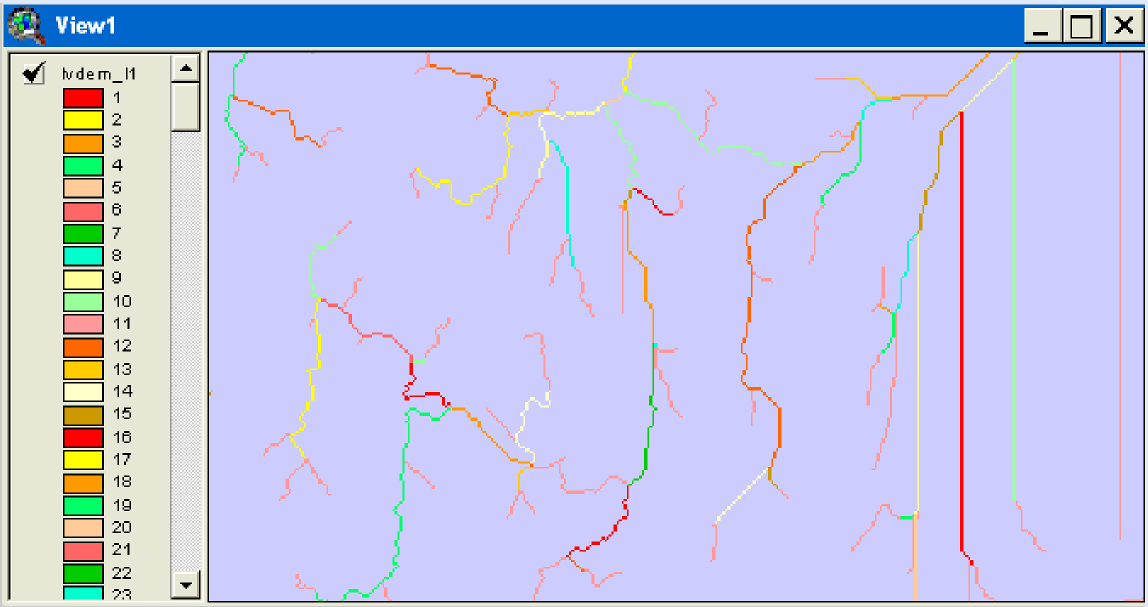
Enter “lvdem_d1” in the “Input Theme 1 field”.

Enter “lvdem_l1” in the “Input Theme 2” field.

Enter “lvdem_w1” in the “Output Theme 1” field. Click OK.



The new grid is automatically added to the view. Switch on the new theme, and change the Legend Type and Value Field as for the segmentation grid. The result is shown below.



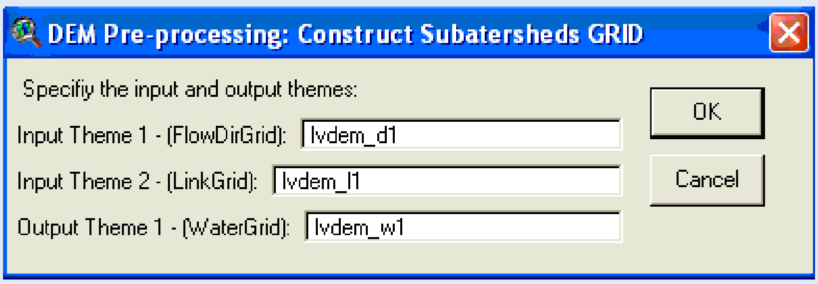
Each segment now has a unique identifier.

The final grid that needs to be prepared is the sub-watershed grid. Select “Watershed Subdelineation” from the “Hydro” menu.

Enter “lvdem_d1” in the “Input Theme 1 field”.

Enter “lvdem_l1” in the “Input Theme 2” field.

Enter “lvdem_w1” in the “Output Theme 1” field. Click OK.

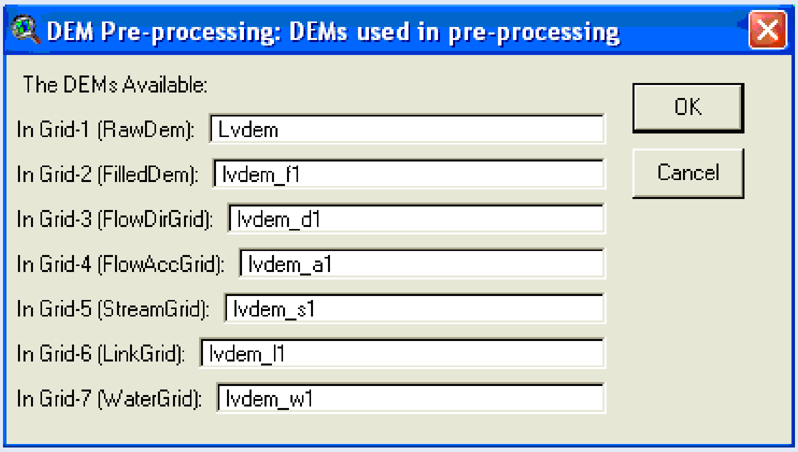


The new grid is automatically added to the view. Switch on the new theme, and change the Legend Type and Value Field as for the segmentation grid. The result is shown below.

All grids have now been prepared.

Check this by selecting "Delineation Files..." from the "Hydro" menu.

All grids have are present.



Stream Burning

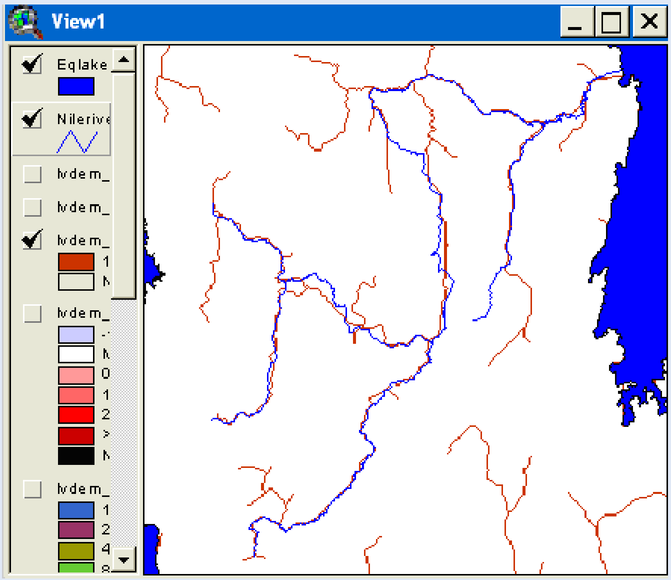
The accuracy of the drainage network just determined by the Watershed Delineator depends on the quality and resolution of the digital elevation model. Experience has shown mixed results. For topologically diverse portions of a basin, one generally finds a close agreement between the delineated stream network and the hydrographic maps. By contrast, in flat areas, and especially in alluvial planes, drainage paths tend to be distorted or short-circuit the known locations of streams and tributaries.

We will check this for the Stream grid derived in the previous section.

Switch off all themes except "lvdem_s1". Add the vector themes "EqLakes.shp" and "NileRivers.shp" from the Data\Vector folder on the workshop CD.

Switch on the new themes and zoom in to the Kagera basin. This is shown in the right-hand panel.

Notice the distortion in the areas characterized by flat slopes (and wetlands) in the middle regions of the Kagera.

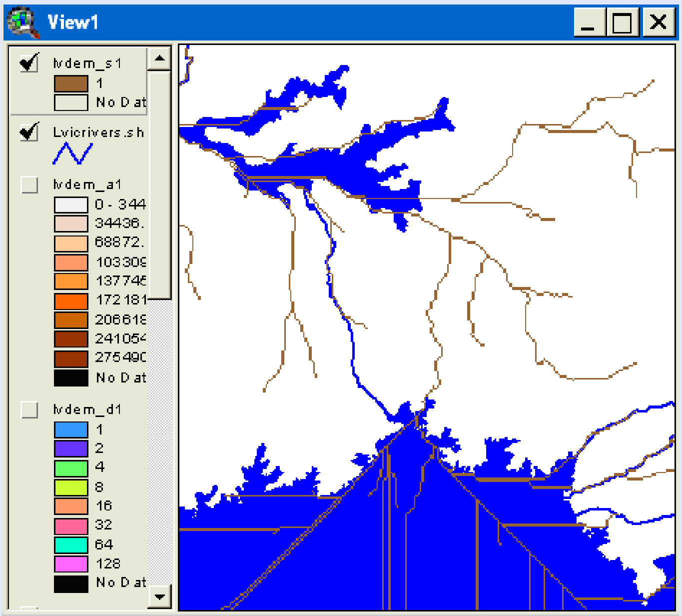


Exercise: check for other irregularities in the Lake Victoria window.

The problem is particularly bad for the Victoria Nile, the downstream reaches of Yala, and the upper parts of Simiyu and Mbaragethi.

As shown on the right-hand panel, the Watershed Delineator has selected an erroneous outlet point for Lake Victoria.

We will examine why this has happened later in this exercise.



It is clear that the quality of the DEM does not facilitate highly accurate stream delineation. This is a common problem. A widely accepted solution for this problem involves modifying the DEM to force flow through the grid cells corresponding to the streamline network. This process is called stream burning.

First convert the stream network to a grid comprising of single cell strings. Next, assign a certain value to all stream cells, and 0 to all non-stream cells. Then subtract the new grid from the old DEM.

We will now perform this exercise, in which we will also include the other water bodies (lakes).

However, we will first edit the "Nilerivers.shp" file.

Exercise: Edit NileRivers.shp, and remove all rivers north of 2 degrees latitude.

Select "Manage Data Sources..." from the "File" menu. Pick the "Nilerivers.shp" and click Copy 

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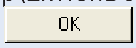
Navigate to the folder C:\GIS_Work\Workshop\ExWshDel\usrdata

Click OK 

Cancel the Data Manager by clicking Cancel 

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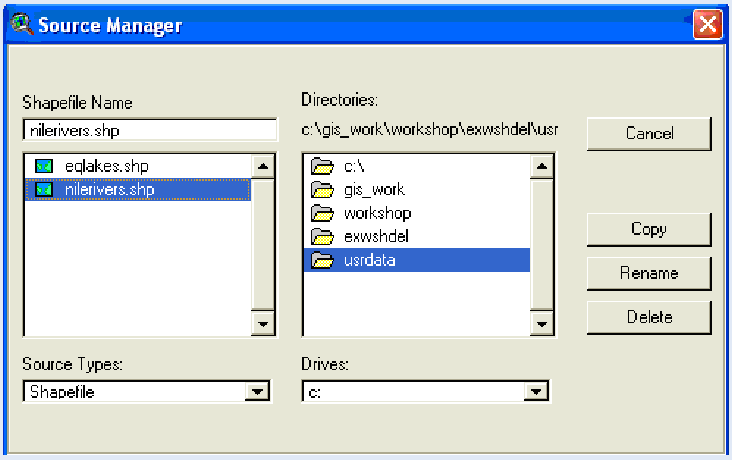


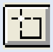
Repeat this exercise for the "EqLakes.shp" file. Next, copy "NileRivers.shp" to "LvicRivers.shp".

Use "Delete Themes" from the "Edit" menu to remove the "NileRivers.shp" from the View. Add the "LvicRivers.shp".

Switch off all themes except "LvicRivers"

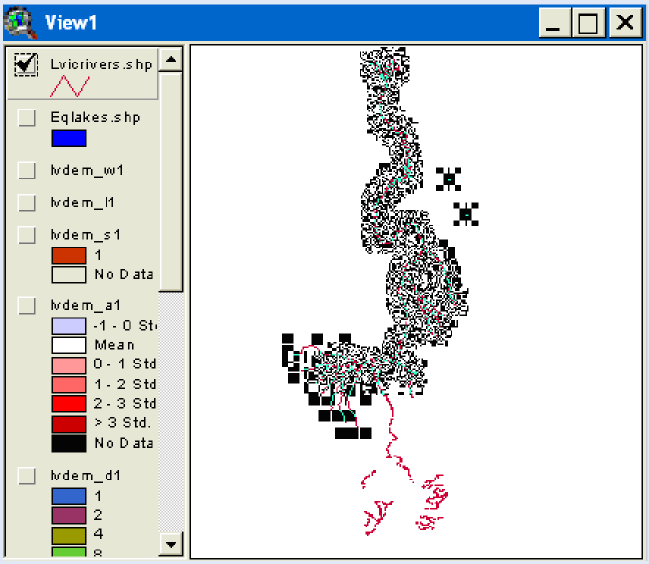
Activate this theme and zoom to full extend  .This shows the entire Nile.

Select "Start Editing" from the "Theme" menu.

Click the "Select Features" tool  and draw a box around the northern Nile. This is shown in the right hand panel. All these elements should be deleted. Click "Delete Features" from the "Edit" menu.

Continue until all river segments north of 2 degrees latitude have been removed.

Select "Stop Editing" from the "Theme" menu. Save the changes.



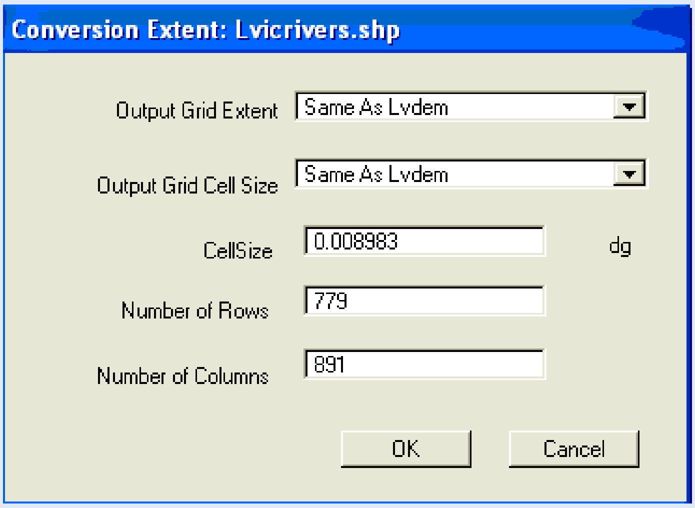
Now convert the "LvicRivers" vector layer to a gird.

Activate the "LvicRivers" layer. Select "Convert to Grid" from the "Theme" menu. Navigate to

C:\GIS_Work\Workshop\ExWshDel\Demdata.

Store the new layer as "RivGrid". Use the same settings as for the LVDEM, as shown in the right hand window. Click OK.

Use the "Dnnet-id" field, and add the new grid to the view.



Zoom in to check the accuracy of the vector to raster conversion.

Exercise: Convert the EqLakes vector layer to EqLakes grid layer, using the same procedures as above.

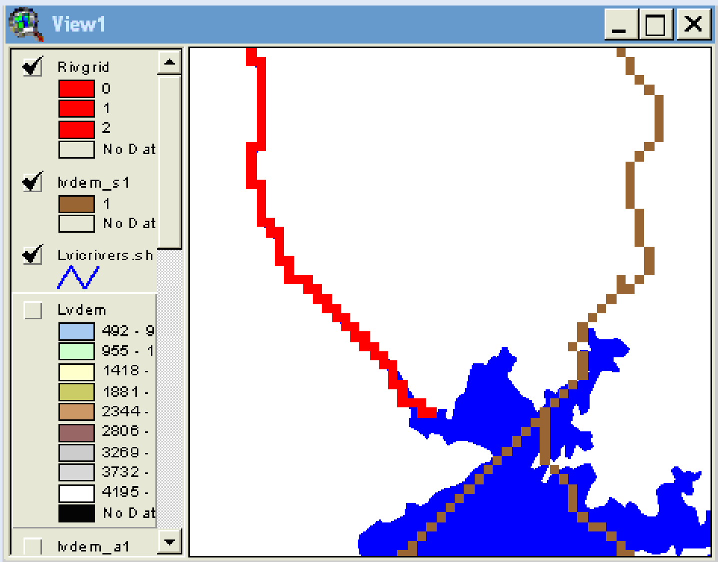
We will now use the "Reclassify" function to lower all river cells, and set all non-stream cells to 0. Generally, this 'burn-in' value is arbitrary, and one often uses –10. In this particular case, however, we will examine the northern tip of Lake Victoria to see what has caused the erroneous outlet.

Switch on the Rivergrid raster, and change the color of all its fields (except No Data) to red. Use the Legend Editor for this.

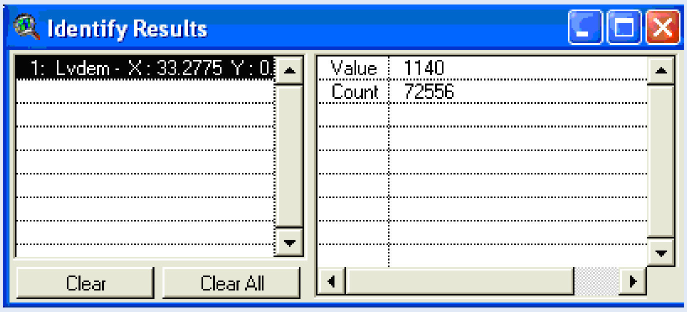
Activate the LVDEM theme.

Zoom in to the Lake Victoria outlet, as shown on the right-hand panel.

Pick the Identify Tool , and determine the elevation value for Lake Victoria.

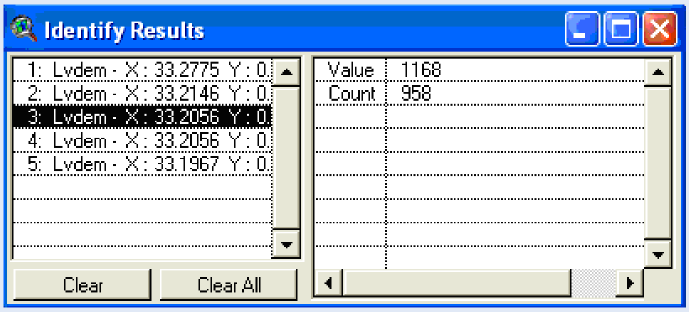


The lake has an elevation of 1140, as shown on the right. Now start checking the elevation of all red "Rivergrid" stream cells.



You will notice that one of the first cells, which is still in the Lake Victoria, has a value of 1168. It is this cell that is causing the blockage, and can be held responsible for the erroneous outlet.

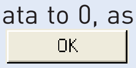
Exercise: continue following the Rivergrid cells and check if a downward slope exists all along to Lake Kyoga.



The above example shows that one should always be careful when using a DEM, especially if it has been developed for a continental or global scale. Fortunately, however, the quality and resolution of public domain DEMs is increasing rapidly.

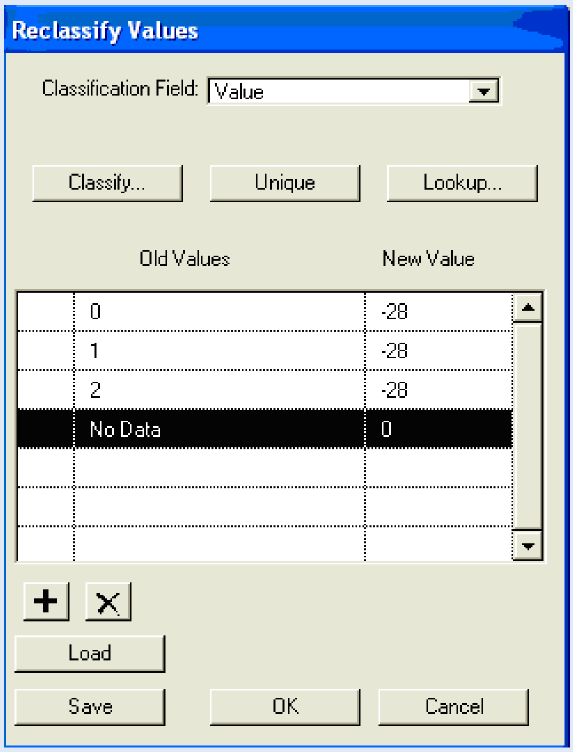
To correct for the erroneous cell, the elevation of the stream cells need to be reduced with 28 m (1168 – 1140).

Activate the "RivGrid" raster. Select "Reclassify" from the "Analysis" menu. Set the "Classification Field" to "Value".

Set all values to –28, and No Data to 0, as shown on the right hand panel. Click OK 

The new layer is automatically added to the view.

Exercise: Reclassify the EqLakes grid, using the same procedures as above.



The result is shown in the left hand panel.

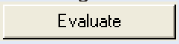
Exercise: Use Map Calculator to add the "EqLakes" to the "RivGrid" raster. Use "Convert to Grid" from the "Theme" menu to name the new layer "EqWater".

This new layer holds three values: 0 for non-stream cells, -28 for most stream cells, and –56 for stream cells near Lake Kyoga.

Check this.

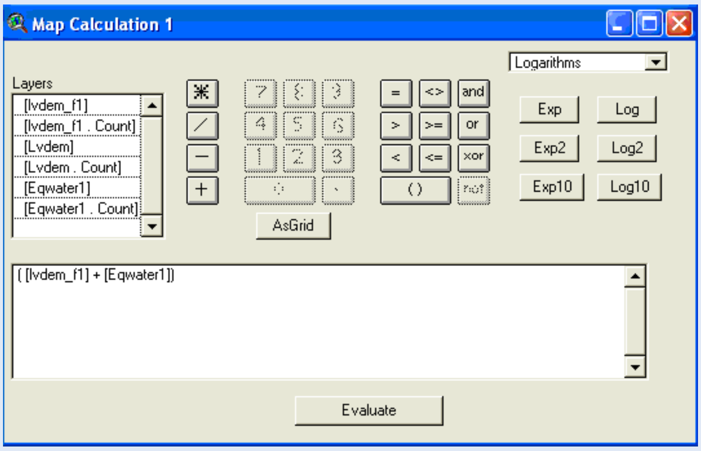
Exercise: Reclassify EqLakes to –28 for stream cells and 0 for non-stream cells. Call this layer EqLakes1.

Remove all new grid layers, except "EqLakes1" from the view. We will now add this new layer to the LVDEM, and thus burn the stream network and lake bodies into the digital elevation model.

Select "Map Calculator" from the "Analysis" menu. Build the equation as shown in the right hand window Click Evaluate 

.

Use "Convert to Grid" from the "Theme" menu to call this new grid "LVDEM_b2"

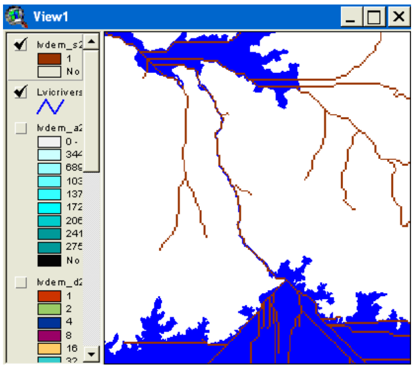


Remove all grid layers apart from "LVDEM_b2" using "Delete Theme" from the "Edit" menu. Change the legend of the "LVDEM_b2" grid to Elevation2.

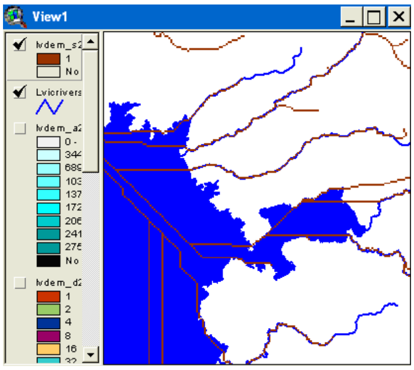
After removing all grid layers (except LVDEM_b2) check "Delineation Files..." from the "Hydro" menu. You will see that all boxes are empty.

Exercise: Redo the raster data preparation for the Watershed Delineator, this time using LVDEM_b2 as base grid. Apply the same naming convention as above, but now use number 2 (e.g. lvdem_f2 instead of lvdem_f1).

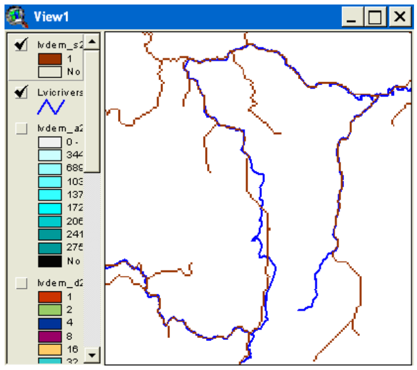
Exercise: Check the Lake Victoria outlet, the lower reach of Yala, and the middle regions of the Kagera. The results are shown below.



Lake Victoria outlet



Lower Yala reaches

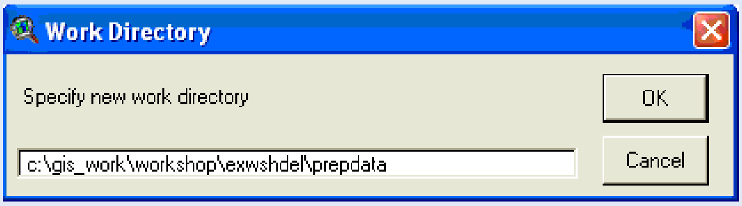


Middle Kagera region

Most of the problems in the above regions are solved. However, the drainage path for Simiyu river still shows a large discrepancy. As shown above, this may be due to one erroneous grid cell.

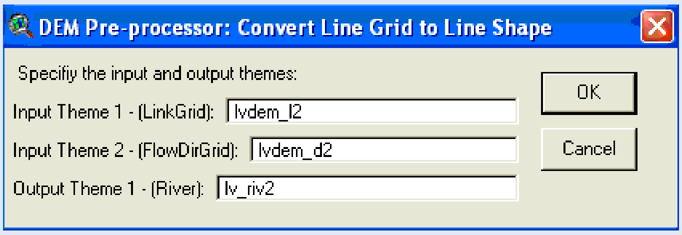
Vector Data Preparation

We continue with preparing the vector data layers. These will be stored in a designated folder called "prepdata". Use the "Set Working Directory..." function from the "File" menu to make this change, as shown on the right.



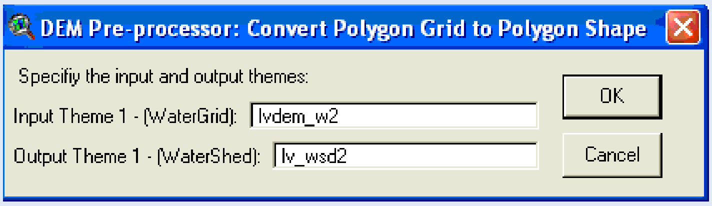
The first step is to convert the line grid to a line vector file. Select "Line GRID to Shape" from the "Hydro" menu.

Name the new shape file: "lv_riv2"



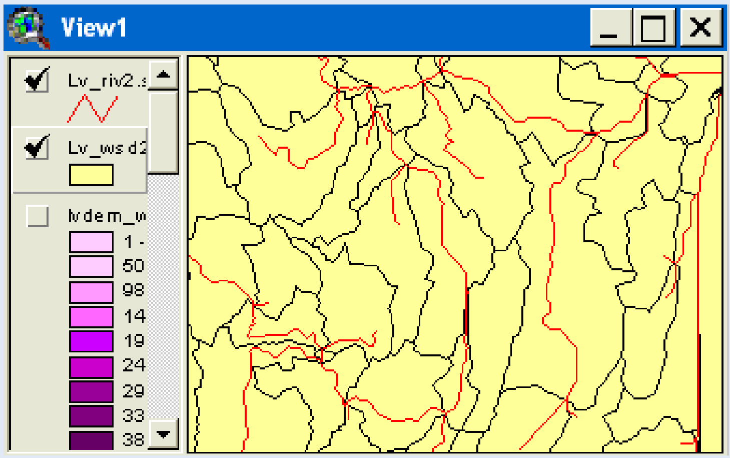
Continue with transferring the watershed grid. Select "Poly GRID to Shape" from the "Hydro" menu.

Name the new shape file: "lv_wsd2"



The two shape files are automatically added to the view. Switch on the new files. The result is presented on the left. Please note that each watershed contains one river segment only.

This vectorization process has created some single cell polygons and other 'orphan' polygons without a stream segment. These must be resolved.



This preprocessing step is performed through the function "Dissolve Streamless Polygons" from the "Hydro" menu. It identifies orphan polygons and proposes a neighboring watershed to merged it with. The user can select an alternative neighbor if he wishes. It is critical that this process is performed correctly. Although the impact of the orphan polygons is rather small on the overall drainage area, the operation of the Watershed Delineator could be unpredictable if there are multiple polygons with the same grid code.

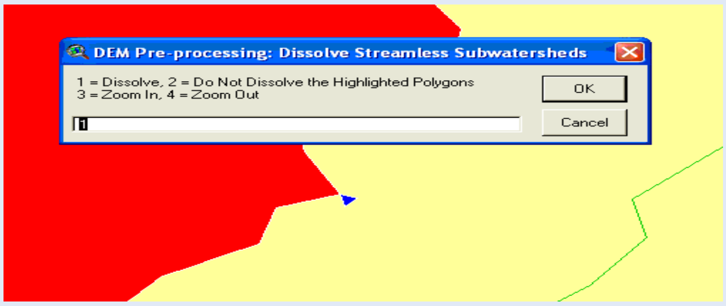
The following thumb rule was found to work fine: always agree with the proposal if the orphan polygon contains a stream segment.

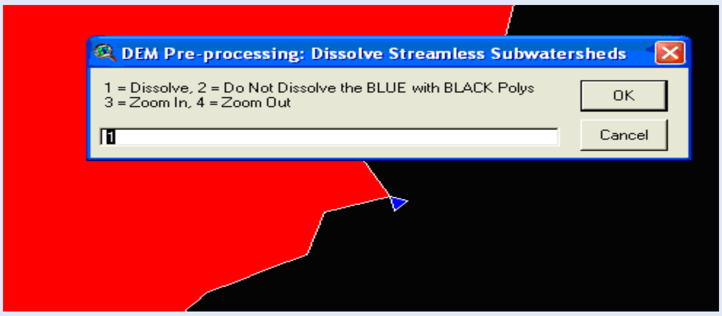
Type 1 to agree; 2 to get an alternative neighbor; 3 to Zoom In; and 4 to Zoom Out.

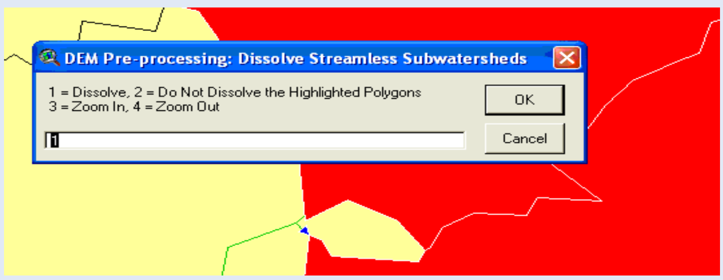
The tool uses the following color code: the orphan polygon is blue; the 'first proposal' is red; the "alternative proposal" is black.

The left-hand screen present three possible situations. The top figure proposes to merge a streamless orphan polygon to a neighboring watershed to which it only connects at one point. This is not a good choice. Type 2 to select another neighbor. This results in the middle figure, representing a much better alternative. Type 1 and click OK. The orphan polygon is now merged and has disappeared.

The bottom figure features an orphan polygon containing a stream segment. Accept this proposal, type 1, and click OK



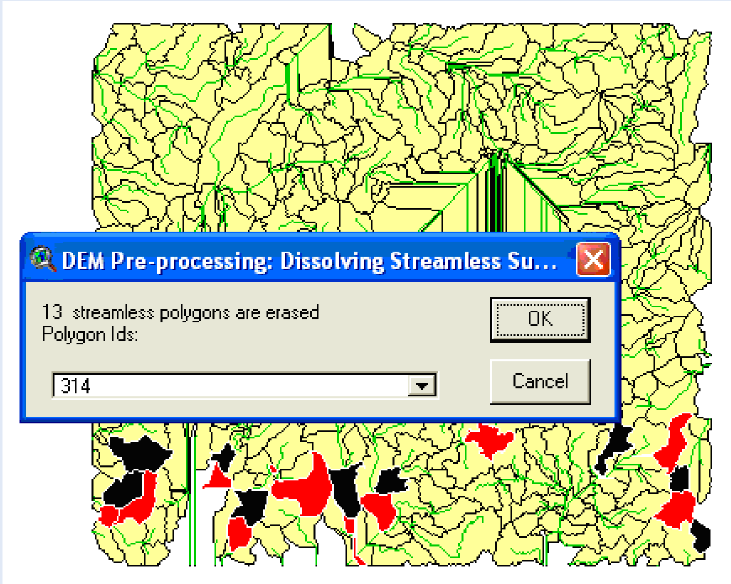




Continue this exercise until all streamless polygons have been removed. The tool does not remove colors after merging. As a result, one obtains quite a patchwork after a while, which may confuse the user. In this case, just quite the tool and restart it. This will clear all colored polygons.

Upon completion, the left-hand panel is obtained.

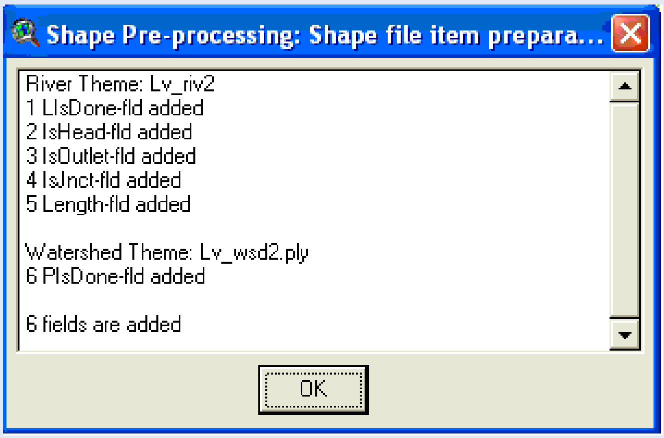
End the dissolving process by clicking Ok. This has made changes in the "lv_wsd2.shp" file.



Define Table Structure

The "Define Table Structure" function from the "Hydro" menu prepares the "rivers" and "watersheds" vector themes for further processing. It adds a number of columns to their attribute tables.

Select the appropriate file from the drop down list. Click OK. Upon completion, the right-hand box is presented. Click OK.

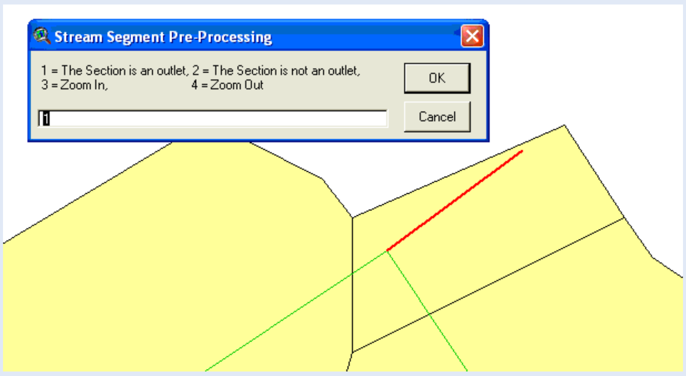


Stream Segment Processing

The "Stream Segment Processing" function from the "Hydro" menu processes the stream segment theme, and puts it into the right format for the Watershed Delineator. It will properly orient all stream segments, and assign a unique segment code.

The user is asked to identify the outlet segments. Type 1 for an outlet stream, and 2 for a non-outlet stream.

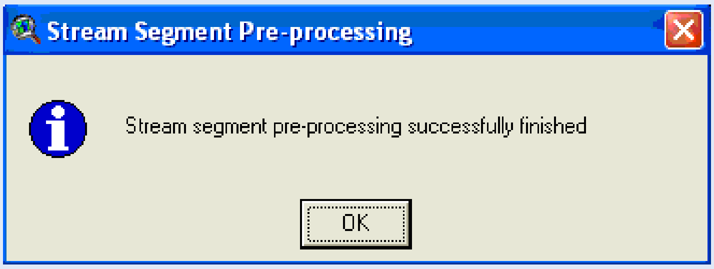
This is shown in the right-hand panel.



Continue until all segments are oriented. The program informs the user when a sub step is completed. Click OK 

to proceed. At the end of this exercise, the user will be prompted to provide a new shape name that will contain the processed river file. This name should be different from the original theme.

The right-hand message box indicates the completion of this exercise.



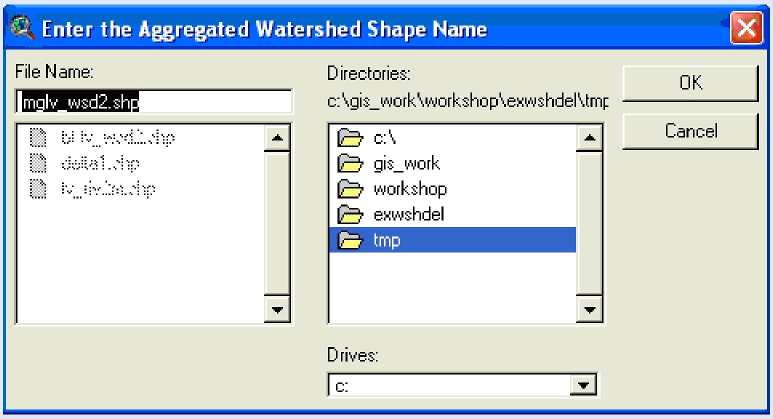
We are approaching the end of the data processing. What remains is to create aggregate sub watersheds.

Create Aggregate Sub Watersheds

This is the final data preparation step. It serves to accelerate the watershed delineation process.

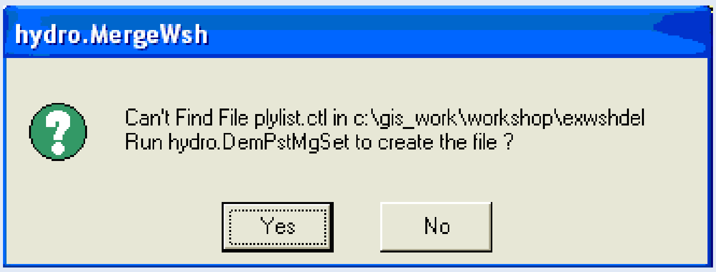
Activate the "Create Aggregate Subwatersheds" tool from the "Hydro" menu. Assign a name to the new theme.

Click OK.



The Watershed Delineator now asks to create a new file: "plylist.clt". This file determines the aggregation process. Click OK.

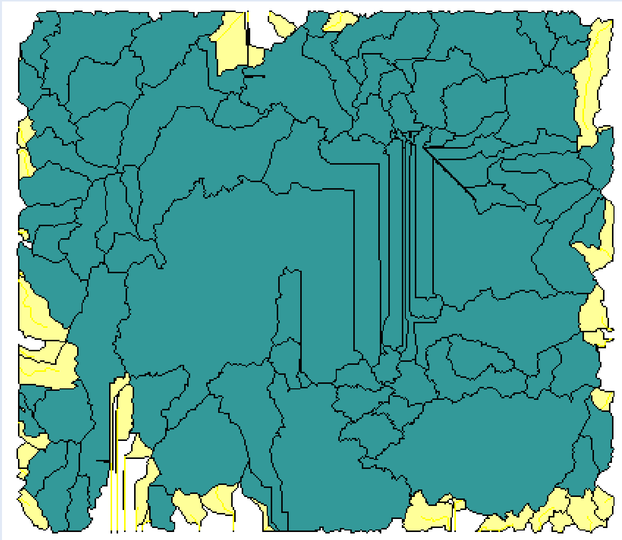
NOTE: remove this file using Windows Explorer when starting a new project. Using an old "plylist.clt" file may result Watershed Delineator to halt.



Upon completion, the right-hand window is shown. This ends the data preparation phase.

Save the project, by clicking the Save button.

The data preparation process is a lengthy affair. However, it needs to be performed only once for a particular area. Watershed delineation is now a straightforward and rapid exercise.



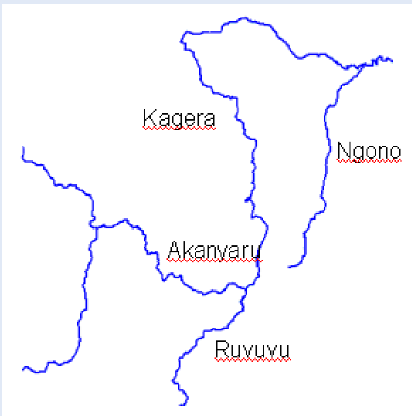
Application of the Watershed Delineator

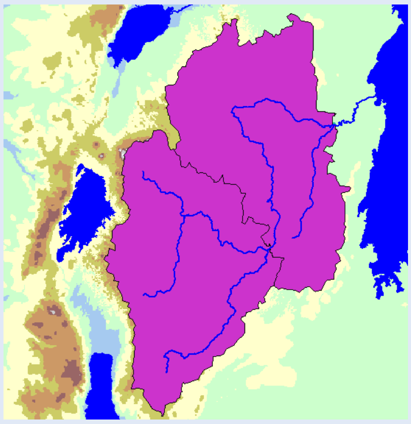
Exercise: User the "Delineate on a Point" tool to determine the watersheds for: a) Lake Victoria, b) Kagera, c) Nzoia. Snap to river section. This process creates two new shape files "Pourwsh.shp" and "Pourpnt.shp". Confirm the ID proposal.

Spend some time experimenting with the tool.

Exercise: Determine the drainage area for the section between the junctions: 1) Kagera – Ngono and 2) Ruvuvu – Akanyaru.

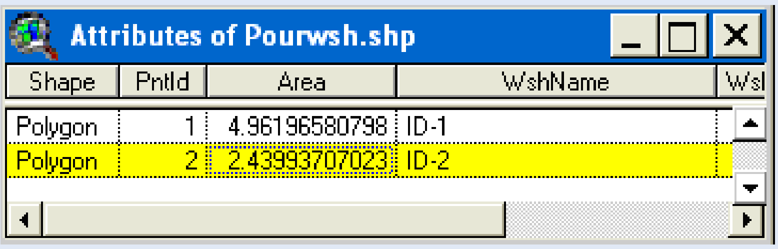
Use the "Delineate on a Point" tool to delineate the watersheds for both points.





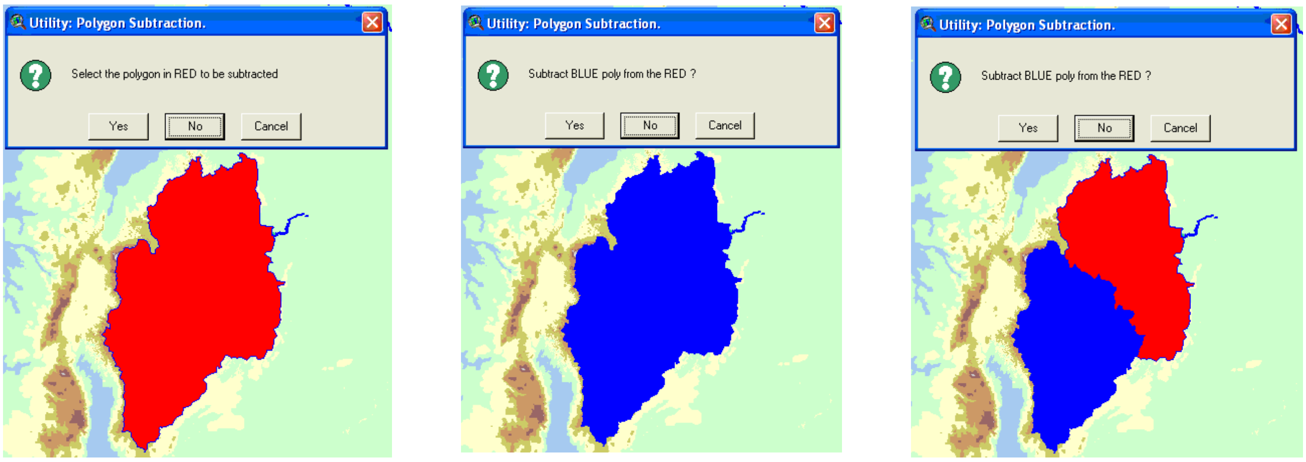
Activate the "Pourwsh.shp" and open its attribute table by clicking. Select the most upstream watershed (draining to Ruvuvu – Akanyaru confluence).

Close the attribute table, the Ruvuvu – Akanyaru watershed is now yellow.



Shape	PntId	Area	WshName	Wsl
Polygon	1	4.96196580798	ID-1	
Polygon	2	2.43993707023	ID-2	

Now use the "Polygon Subtraction" tool. Activate this tool; then click on the just delineated watersheds. Select Yes for step 1; No for step 2; and Yes for step 3.



Step 1 | Step 2 | Step 3

Give a name to the new shape file, for example: "Subwsh1.shp".

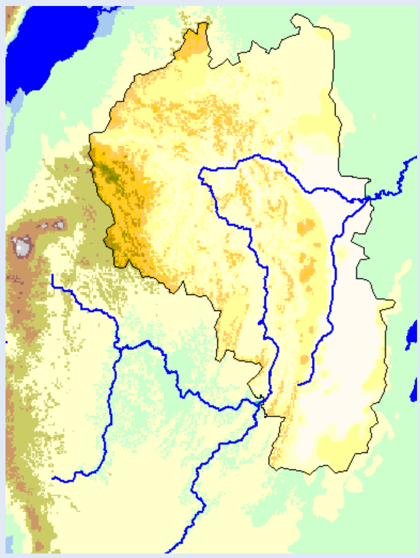
Exercise: Determine the area of the sub-watershed; use the AreaCalc script and select a proper projection.

Exercise: Determine the altitude distribution for the sub-watershed.

Step A: convert "Subwsh1.shp" to a grid using the "Convert to Grid" function from the "Theme" menu. Give an appropriate name.

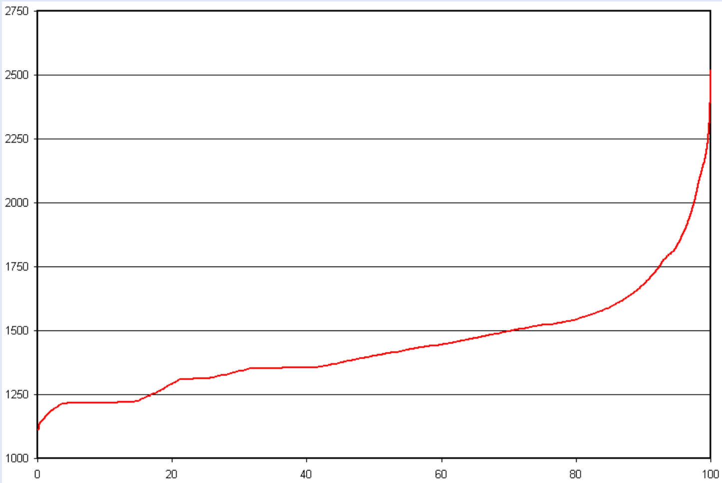
Step B: Use the "Reclassify" tool from the "Analysis" menu to set all watershed cells to 1, and non-watershed cells to 0.

Step C: Use "Map Calculator" from the "Analysis" menu to build a DEM for the sub-watershed. Multiply the new grid with the LVDEM_b2 raster. Add this to the view. The result is shown in the right-hand panel.



Activate the new grid and open its attribute table by clicking . This table contains the number of grid cells for each elevation value. Use "Export" from the "File" menu, to export this table to a dbf file.

Open this file in Excel and manipulate the data to produce the graph shown in the right-hand panel.

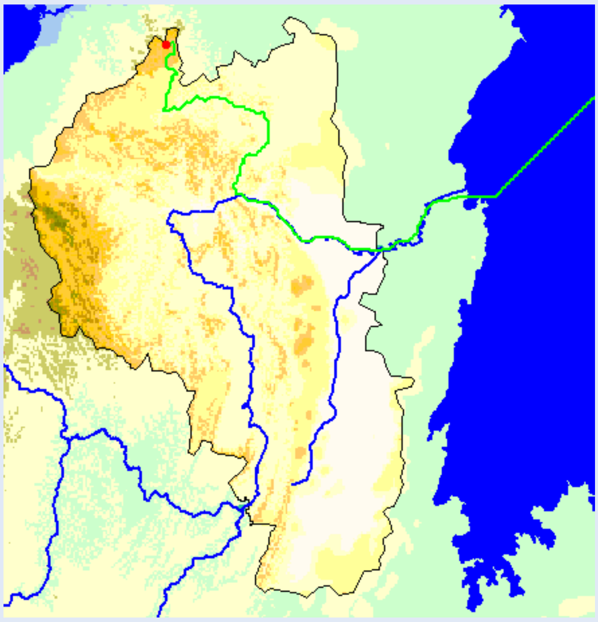


Exercise: Determine the flow path of a point at the edge (the water divide) of the sub-watershed. Use the "Trace a Flow Path" tool

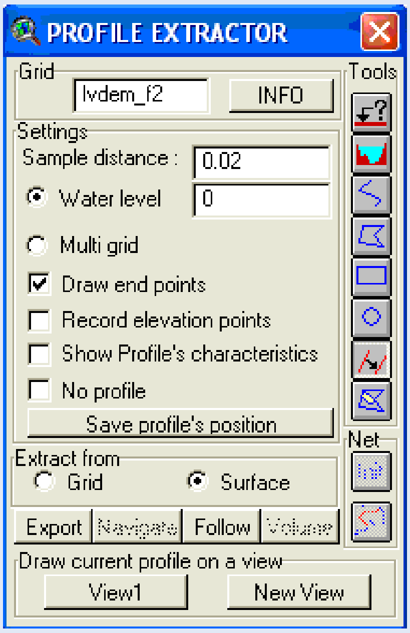
Click a point

This produces the right-hand figure.

Experiment with the flow path tool for a while.



Exercise: Determine the longitudinal profile of the flow path. Check the web for useful scripts.



Step A: Go to www.esri.com

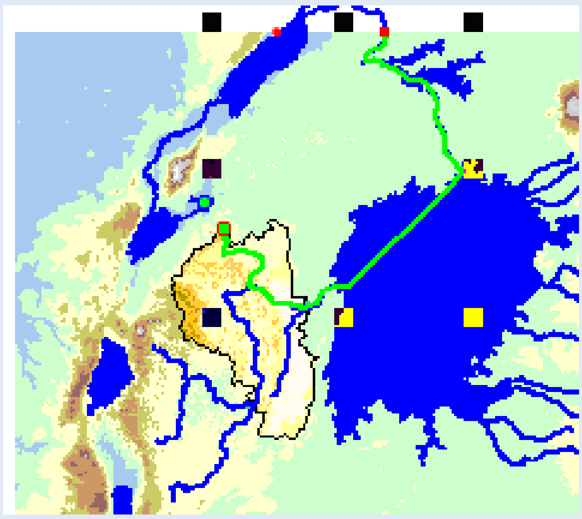
Select Support => Downloads => ArcScripts

Select ArcView.

Type "profile" in the search box. Select "Profile Extractor 6 for Spatial Analyst". Download and install this file. The extension needs to be placed in the C:\ESRI\AV_GIS30\ARCVIEW\EXT32 folder.

Activate the extension. The Profile Extractor  button is added to the interface. It activates the window on the right-hand side.

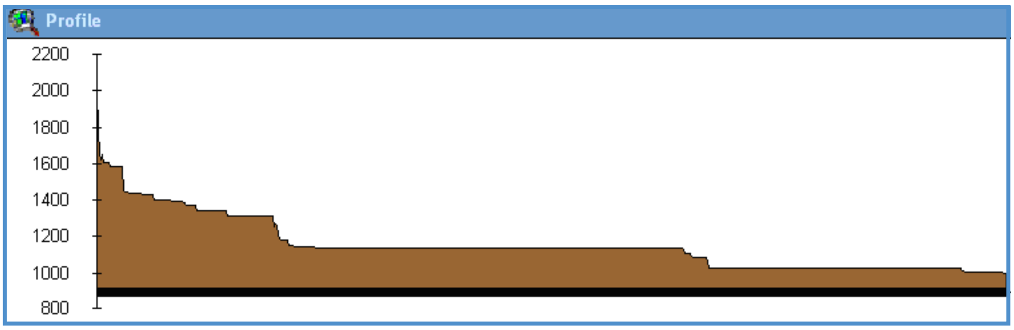
Select the "Flow Path" with the  tool, as shown in the right hand window.



Click the Profile Extractor  button.

Set grid to "lvdem_f2", and "Sample distance" to 0.02. The latter has to be larger than the cell size to accommodate for diagonal paths.

Now select  and click the flow path. This generates the below profile.



Exercise: Determine the longitudinal distribution of the flow path up to the outlet point to Lake Victoria. Use the Export function of the Profile Extractor. Prepare a graph in Excel.

Exercise: Check for a script to merge grid themes.