Determining Flow Lengths or Travel Distances in GIS

Definition (Hydrologic): The flow length is the distance from any point in the watershed to the watershed outlet. This distance is measured along the direction of flow, **not** "as the crow flies".

Definition (GIS): In GIS, the flow length of an arbitrary pixel is determined by summing the incremental distances from center-to-center of each pixel along the flow path from the selected pixel to the outlet pixel. The flow length assigned to the outlet pixel is zero.

Why are flow lengths important?

When it rains, a drop of water landing somewhere in the basin must first travel some distance before reaching the outlet. Assuming constant flow velocities (an assumption we will relax later) the pixel with the greatest flow length to the outlet represents the hydrologically most remote pixel. Its flow length divided by the flow velocity represents a representative lag time for the basin. The lag time quantifies how long before the entire basin is contributing to flow at the outlet and is a representative scale of the basin.

How do I use the GIS to determine flow lengths?

The ArcView syntax for calculating flow lengths is:

```
aGrid.FlowLength (weightGrid, upStream)
```

the ArcView help provides the following information about this statement:

> *Calculates the accumulated flow length to each cell. aGrid is a Grid of flow direction usually created with the aGrid.FlowDirection request.*
>
> *weightGrid can be a Grid or Nil, that defines the impedance to move through each cell. If weightGrid is set to Nil, then all cells will have an equal impedance.*
>
> *If upStream is TRUE, then flow length is calculated from each cell to the top of the drainage divide. If upStream is FALSE, then flow length is calculated for each cell to a sink or outlet.*

As with watershed delineation, this is again a lot to swallow. Try to read the help file syntax and make sense of the explanation. This is the only way that you will be able to learn more once this class is only. The help files, once you get used to reading them are actually extremely informative and useful.

As a practical matter, let us first use the above command to find flow lengths as they are defined above in the GIS definition. We might use the following syntax to completely analyze a flow direction grid and generate a grid of flow lengths:

```
'
'   Overhead Operations - Getting the View and Grids...
'
theView = av.FindDoc("View1")
theshed = theView.FindTheme("A Watershed").GetGrid
flowdir = theView.FindTheme("Flow Direction").GetGrid
'
'   Calculate the flow lengths within the grid in the
'   downstream direction (stored in "downgrid")
'
downgrid = flowdir.FlowLength (NIL, FALSE)
'
'   Mask out only the flow lengths within the watershed
'
downgrid = downgrid * theshed/theshed
'
'   Get flow length statistics.  The first item in the
'   length_stat list is the minimum distance, corresponding
'   to the distance at the watershed outlet.  We want to
'   subtract off this distance.
'
length_stat = downgrid.GetStatistics
length_at_outlet = length_stat.Get(0)
downgrid = downgrid - length_at_outlet.AsGrid
'
'   Finally, we want to make and add the new Flow Length
'   theme to the view.
'
theGTheme = GTheme.Make(downgrid)
theGTheme.SetName("Flow Lengths")
theView.AddTheme(theGTheme)
```

There are three ways that we might choose to look at travel times within the GIS
environment:

1. As iso-distance (contour) lines within the view.
2. As a frequency distribution.
3. As the longest flow path within the watershed.

Item 1 is directly the output of the above script. The output grid theme called "Flow Lengths" will be a visual representation of the watershed shaded accordingly. By adjusting the legend, we can precisely control the contours we wish to observe. A sample is shown below:
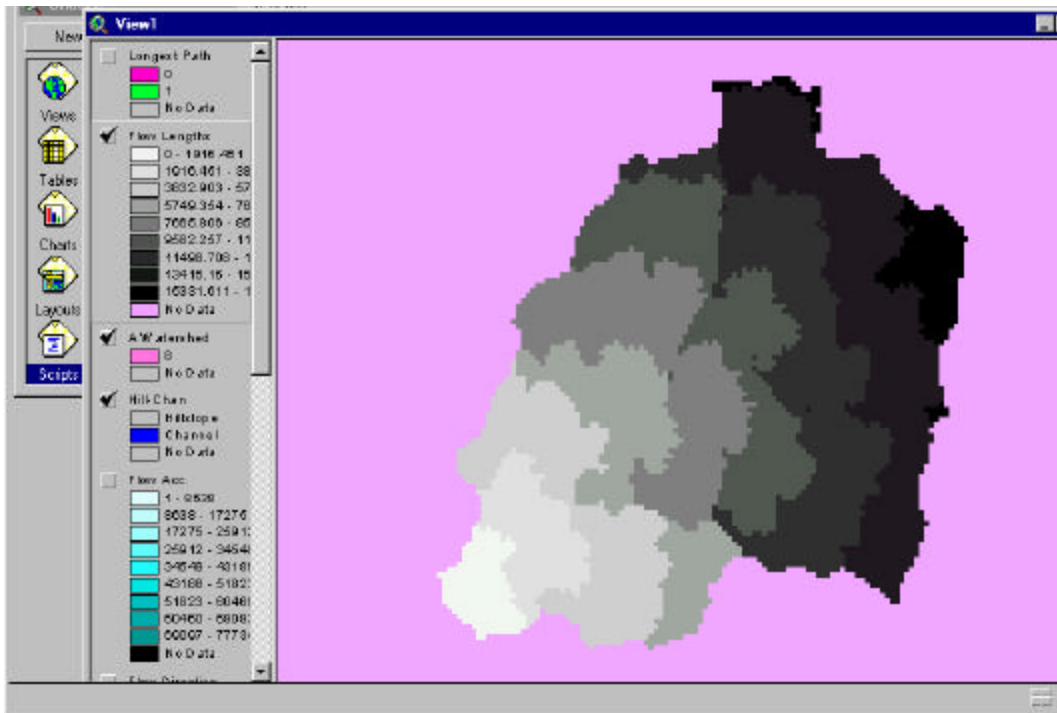
Item 2 is quickly done by clicking on the histogram tool with the flow direction theme being the active theme. A sample histogram is shown below. Those of you who have previously taken surface water hydrology will recognize the similarities between the frequency distribution idea and the concept of a unit hydrograph. The frequency distribution for the flow lengths shown in the above watershed is given below:
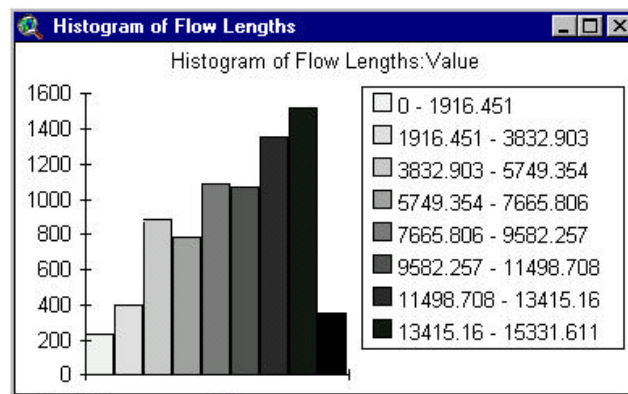
Item 3 requires some creativity to determine. You will notice that the script provided earlier uses the option "FALSE" for the "upStream" parameter. This means that flow lengths are calculated relative to the outlet (e.g. the flow length to the outlet pixel from the outlet pixel is zero). This puts the maximum flow lengths towards the extreme edges of the watershed, called the watershed divide. We can create a second grid using the opposite direction:

```
upgrid = flowdir.FlowLength (NIL, TRUE)
upgrid = upgrid * theshed/theshed
```

This grid will have many zero values all along the basin divides. A maximum value of flow length will occur at the basin outlet. This maximum value will be exactly the same as the maximum value held somewhere in the previous "downgrid" of flow lengths. Adding together the upgrid and downgrid will produce a grid of augmented flow lengths where each pixel contains the sum of the distance from itself to the outlet and to the basin divide. There will be many pixels which share the same maximum value as found in both the "upgrid" and "downgrid". These pixels lie along the longest flow path in the basin.

```
augmentedgrid = upgrid + downgrid
length_stat = augmentedgrid.GetStatistics
maxlength = length_stat.Get(1)
tolerance = 0.1 * resolution
long_path = augmentedgrid > (maxlength - tolerance).AsGrid
```

The figure below shows the output grid from the above code, the longest flow path within the basin.