Hydro Networks

Synopsis of Class 11, GIS in Water Resources, Fall 2013

Readings:

ArcGIS10.2 Desktop Help: Geometric Networks
http://resources.arcgis.com/en/help/main/10.2/index.html#/What_are_geometric_networks/002r00000001000000/

ArcGIS10.2 Desktop Help: Linear Referencing
http://resources.arcgis.com/en/help/main/10.2/index.html#/What_is_linear_referencing/003900000001000000/

Over the past four classes, you have been learning how to perform grid-based analyses to study water flow in landscapes. You have learned that water can flow from cell to cell in a digital elevation model of the land surface terrain, cells can be divided into those that depict streams and those that cover the land areas draining to streams, and a watershed can be delineated as the zone of cells whose drainage passes through a particular outlet cell. In this class, we are going to return to the vector domain to examine similar questions of the flow of water through the landscape. In doing so, there are four key principles to keep in mind:

- *Cell to cell* movement of water on digital elevation models;
- *Line to line* movement of water on geometric networks;
- *Area flows to a line,* which connects the local drainage area, or *reach catchment*, to the stream reach that flows through it;
- *Area flows to a point on a line,* which enables the delineation of watersheds from any point on the stream network.

What we are doing in making this transition is constructing in the vector domain an analogy to the cell to cell flow model in the raster domain, except that instead of water flowing from cell to cell, it flows from line to line, and instead of a cell being an elementary unit of area, the reach catchment associated with each line performs that function. In this way, both raster and vector information are used to define flow properties through the landscape, with raster information used for small areas and vector information for large ones. In the NHDPlus dataset, the continental United States has been partitioned into about three million reach catchments whose average area is 3 km^2 and whose average reach length is 2 km. Other countries, such as Australia and New Zealand, have similarly been partitioned into reach catchments, and the HydroSheds database does this for the whole earth. The automated watershed delineation tool in the ArcGIS Elevation Service also operates this way so that when you click on a point in a stream, just the local catchment gets divided into upstream and downstream parts, and then all the accumulated area upstream of the local catchment is added on by means of network capabilities.

A *geometric network* is an ArcGIS data structure that enables the connection of points and lines into a mesh that allows the tracing of movement and flow in a spatial domain. The geometric network is a general concept that can apply to roads, railways, pipes, streams and rivers and other similarly connected sets of linear features. A geometric network has three basic properties: a *geometry* model that positions the points and lines in (x,y) or (x,y,z) space, a *logical* model that defines the topology of how the points and lines are interconnected, and an *addressing* model that specifies where things are located on the lines using a *measure value m*, which measures the distance along a line from a reference location. When a set of points and lines are built into a network the points become a new type of feature class called *junctions*, and the lines become *edges*. Edges are connected to other edges only through junctions. In a case, such as in Exercise 4, where there is just a set of stream lines that are used to form a network, a set of *orphan* or *net junctions* are added at the ends of each line to enable network connectivity. A *simple edge* consists of one line and an associated set of attributes. A *complex edge* consists of two or more sequentially connected lines with a single set of attributes, which allows for the positioning of junctions on the interior of a network edge for purposes such as to denote the location of a gaging station on a stream. A network edge has an associated *flow direction* that defines the direction of flow in relation to the direction in which the points that make up the line have been digitized.

Once a geometric network has been built, it can support various network tasks, such as *trace upstream* to find all the upstream edges, *trace downstream* to find all the downstream edges, *find path* to find the shortest path between two points and *find connected* to identify all the edges and junctions that are connected to a given edge or junction. Locations on a network from which these tasks are executed are denoted by *flags*, and *barriers* can be placed to block access to particular parts of the network during trace tasks. Junctions can be designated as *sources* or *sinks* for flow entering and leaving the network. Using geometric networks to trace water flow through stream and river systems allows for tracing through *looped* flow systems, such as when a river flows around both sides of an island, and also for places where stream *divergences* occur – an upstream reach splits into two or more downstream reaches, as happens when rivers flow into estuaries.

There are many kinds of information that are associated with river and stream networks, such as points of water diversion or discharge, locations of gages and structures like reservoirs, sites for water quality or biological measurement, and lengths of streams whose geomorphic or flood properties are being defined. If a single stream network has its edges divided at every location where somebody has a point of interest, the result will be a highly fragmented network with very short stream edges. Instead, a system of *linear referencing* has been devised, where *events* are located using an addressing system in which a point location is defined by a measure value m on a particular line, rather like a street addressing system for delivering mail. In the United States, each stream reach has an associated *reach code*, and the percent distance upstream from the downstream end of the reach is used as the measure value. *Point events* can thus be geographically located on stream or river reaches in much the same way that you located stream gages at particular (x,y) points using their latitude and longitude in Exercise 2. *Line events* describe lengths along a reach that have particular properties. *Absolute* measure refers to distance along a line measured in linear units such as feet, meters, miles or kilometers. *Relative* measure refers to distance along a line measured in percent of its total length.