Introduction to GIS in Water Resources

Synopsis of Class 1, GIS in Water Resources, Fall 2011

Welcome to the Geographic Information Systems (GIS) in Water Resources class for Fall 2011. The purpose of this synopsis is to summarize the content of the first lecture in this course, an Introduction to GIS in Water Resources. This course has three instructors: David Maidment, at the University of Texas at Austin, who teaches the vector part of the course; David Tarboton, at Utah State University, who teaches the raster section of the course; and Ayse Irmak, at the University of Nebraska, Lincoln, who teaches the remote sensing part of the course. We share responsibilities for making up the homework and exams. The course is shared among the three universities via video conferencing and shared computer desktops, and the videos are made public so that others can look into the course and follow along as they wish. This is inspired by the idea of a "university without walls", in which the class learning experience is open to all.

The course is taught using the ArcGIS Geographic information system. It is not assumed that you have previous experience with ArcGIS and your capacity to use the software is developed by carrying out six fairly long computer exercises that occur at roughly two-week intervals during the first two thirds of the semester. You will also conduct a term project that deals with some aspect of the subject of personal interest to you, and present your term paper orally and in writing. All the term papers from the three universities will be publicly accessible and part of your final exam will be to write a synthesis of selected sets of these papers dealing with common themes. In this way, you will be learning not only from your teachers, but also from each other. GIS is a technology meant to empower you and others by increasing your understanding of the world around you.

The core information model of GIS is based around *themes* – layers of geospatial information, where each layer contains information of a particular kind, and all layers share a common spatial extent and coordinate system. Themes can consist of *discrete spatial features* such as points, lines or areas, called *vector* objects in GIS terminology, or *continuous surfaces* such as a raster *grids* or remote sensing *images*. Grids differ from images in that they can have any numerical value, while images have a fixed set of values classified over a range. Surfaces can also be represented by a *triangulated irregular network*, or a continuous mesh of connected triangles.

A key property of GIS, one that makes it different from other forms of information systems, is the one to one connection between each spatial feature and a record in an accompanying data table that describes its characteristics or *attributes*. A *digital map* consists of a set of layers each depicted using an appropriate symbology, such as for example, green for vegetation, blue for water, and so on. A *relational database* consists of a set of tables connected by a common attribute or *key* field that links one with another. A GIS links map features with data tables, and thus is more than a digital map or a relational database taken alone.

Perhaps the key challenge in GIS in Water Resources is to link the land and water systems. The land system with its hills, valleys, roads, and cities, lends itself to GIS representation. The water system is

more subtle – at one level it can be represented in GIS as water features, such as streams, lakes and bays – the "blue lines", or *hydrography* map layer, but at a deeper level what we seek to do is to describe the *properties* of water – its flow, surface elevation and quality, and for this we need *observational* data – time series of data from gages or collections of data from water samples, that collectively describe the character of the water itself. Water properties are dynamic in that they can change continuously in time, so the connection of geospatial and observational data has to be done carefully, recognizing that these are two fundamentally different information types.

The Consortium of Universities for the Advancement of Hydrologic Science, Inc (CUAHSI) is an organization representing 120 US universities which is supported by the National Science Foundation to advance hydrologic science in ways beyond what individual universities can achieve. CUAHSI has invented a language, *WaterML*, for conveying water observations data through the internet as *web services*. The US Geological Survey now uses WaterML to convey its time series information and a revised version called WaterML2 is being established as an international standard for conveying water observations information globally.

The Environmental Systems Research Institute (ESRI), the company that makes ArcGIS, has established ArcGIS Online, for intelligent web mapping and sharing of GIS information by communities. This system depends on web services for map information at all spatial scales from global to local. By using a *services-oriented architecture*, geospatial and observational data describing water systems and water properties can be synthesized. Standardized information models for geospatial description of surfaced and groundwater systems, Arc Hydro, and Arc Hydro Groundwater, have been developed. In this class we will learn about some of these information models and learn about the importance of information models in general for organizing and enabling the analysis that can be done with data. This science of the way information is organized underpins the ability of GIS to enable useful and empowering analyses.

Central to understanding geographic information is to understand geospatial coordinates. We are familiar with (x,y,z) coordinates in feet or meters that describe location in the *Cartesian* or *Projected coordinate system* used in science and engineering. Less familiar are *geographic coordinates* (ϕ, λ, z) that describe latitude (ϕ), longitude (λ), and elevation (z). *Latitude* has its origin at the equator, where its value is 0, and a range [-90, +90], where -90 is 90°S at the South Pole, +90 is 90°N at the North Pole. Lines of constant latitude are called *parallels* and are oriented East-West. Lines of constant *longitude* are called *meridians* and are oriented North-South. The origin of longitude is the *prime meridian* that runs through Greenwich, England, and longitude has the range [-180, +180], where negative longitudes are West of the prime meridian, including the United States, and positive longitudes are East of the prime meridian. Latitude and longitude can be measured in degrees (°), minutes (') and seconds ("), where 60 seconds equals 1 minute and 60 minutes equals 1 degree – these measures can be converted to *decimal degrees* by computing the number of minutes and seconds as fractions of a degree, and assigning a positive or negative sign to the result depending in which hemisphere the point is located. Elevation, z, in feet or meters exists in both the Geographic and Projected coordinate systems.