**Appendix 1: Watershed Science and Mapping**
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A. Background Material

Neighboring watersheds are separated by lines along ridges or drainage divides (Figure 1.1). As a result, watersheds are sometimes called "drainage basins." As water moves through a watershed, it collects and carries with it soil, plant, and animal wastes and man-made materials. The water and transported materials are delivered to an outlet or mouth. Water begins to collect and form headwaters, the origin or source of flow in a drainage network.

Headwaters provide the largest surface area for a drainage network's supply of water, as well as the materials the water may carry with it. Although often unnamed, unrecorded, and underappreciated, small headwater streams and wetlands – including those that are dry for parts of the year – are an integral part of our nation's river networks. Small wetlands and seasonal pools, even those that lack a visible outlet, are connected to stream systems by groundwater, the subsurface flow of water, and periodic surface flows.

Figure 1.1 – Watershed boundaries and drainage areas (sub basin)[1].
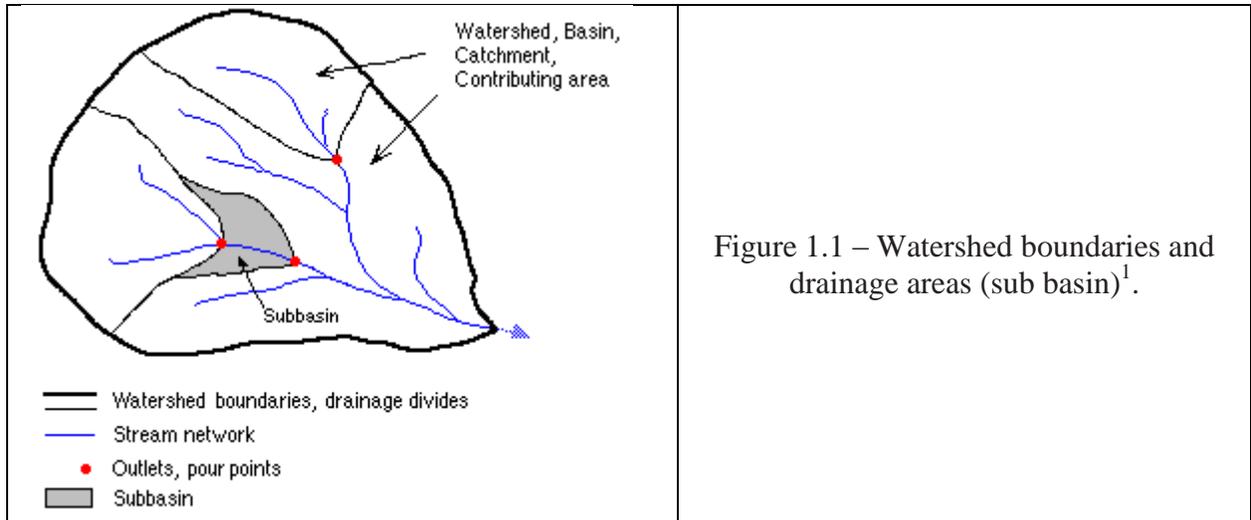
Healthy headwater streams are lined with trees and other vegetation and often have wet areas associated with them. This system of vegetation and channels provides many benefits to human communities and the natural environment. For example, it helps regulate water flow by absorbing lots of rainfall to reduce flooding, and by releasing that water between rains to keep the stream flowing. Vegetation in the riparian zone can filter rainwater on the surface and trap soil particles and other pollutants that can harm creatures in the water.

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[1] ESRI ARC GIS - How Watersheds Work,
http://resources.esri.com/help/9.3/arcgisdesktop/com/gp_toolref/spatial_analyst_tools/how_watershed_works.htm.

The cleaner the stream, the more different kinds of creatures can live there. This measure is known as biodiversity. Headwater systems also provide a steady supply of food to creatures downstream by recycling organic matter from plants and animals.

Small streams and wetlands provide a rich array of habitats that support many unique, diverse, and increasingly endangered plants and animals. Headwater systems are used by many animal species at different stages in their life history. They provide shelter, food, and protection from predators, spawning sites and nursery areas for fish and amphibians, and travel corridors between terrestrial and aquatic habitats. A number of factors are used to discuss and compare different watersheds. Important characteristics to consider are:

- Drainage area
- Length (longest flow path)
- Slope (elevation difference of flow path)
- Drainage density (sum of stream length by area)
- Shape/drainage network patterns

Stream size within a watershed is commonly defined by stream order, a way to distinguish the relative size of streams. Stream sizes range from the smallest, first-order, to the largest, twelfth-order (e.g., the Amazon River). Over 80% of the total length of Earth's rivers and streams are headwater streams (first- and second-order). As water travels from headwater streams to the mouths of mighty rivers, streams gradually increase in width and depth. The amount of water they discharge also increases.

The most commonly used stream order system is the Strahler approach (Figure 1.2). In this method, when two first-order streams come together, they form a second-order stream. When two second-order streams come together, they form a third-order stream. However, if a first-order stream joins a second-order stream, it remains a second-order stream. It is not until a second-order stream combines with another second-order stream that it becomes a third-order stream.
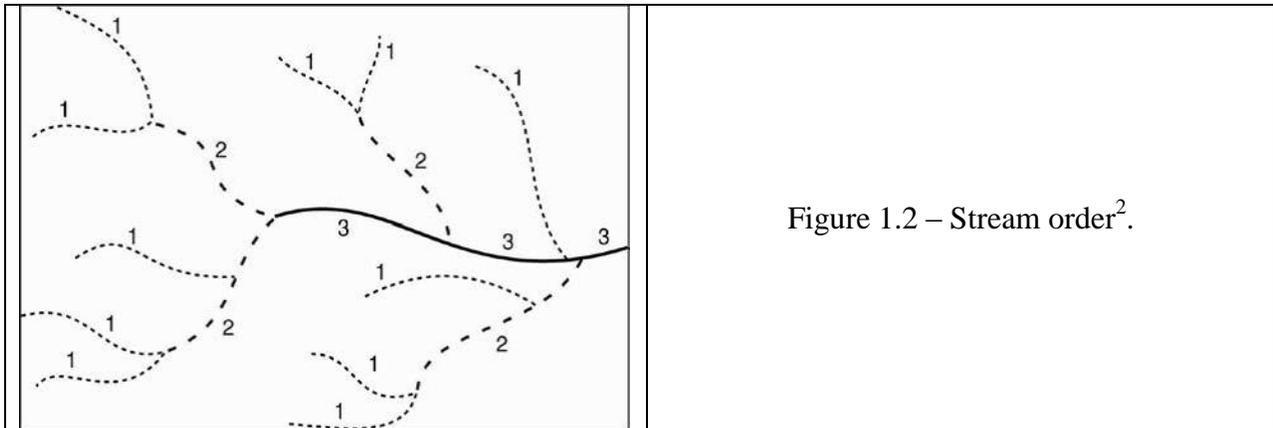

Figure 1.2 – Stream order[2].

[2] Stream and Watershed Restoration, Wiki Spaces;
https://riverrestoration.wikispaces.com/file/view/figure1_Strahler.png/322750730/figure1_Strahler.png
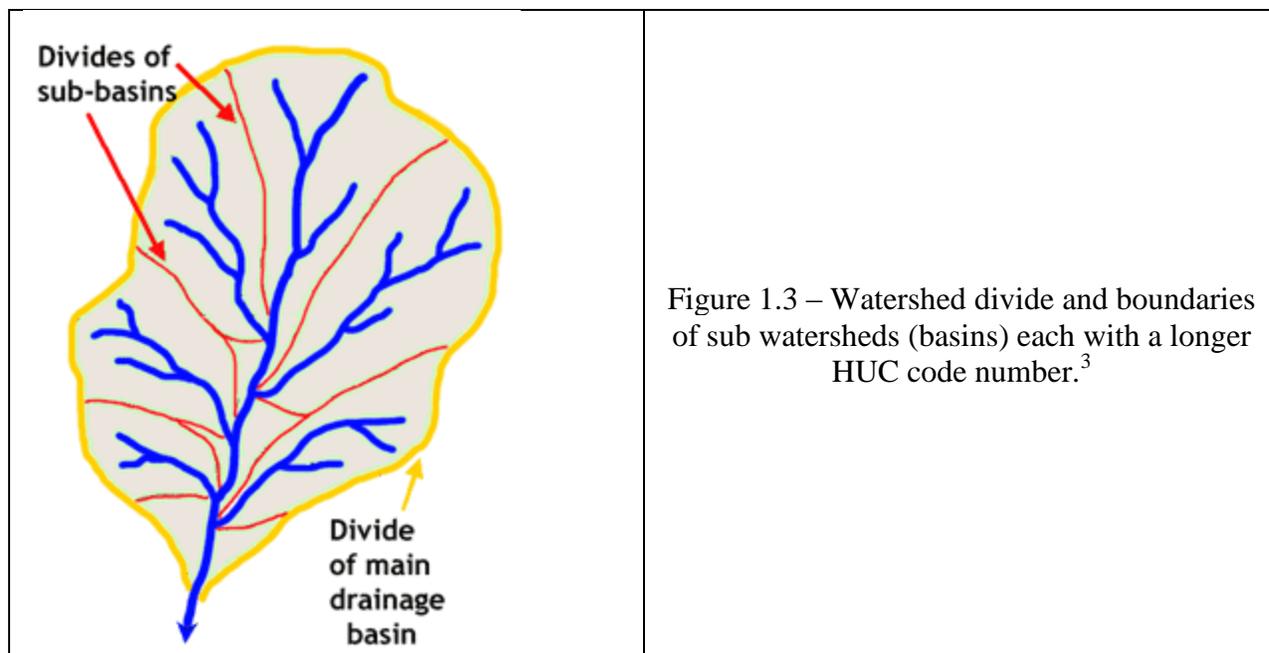
Figure 1.3 – Watershed divide and boundaries of sub watersheds (basins) each with a longer HUC code number.[3]

The U.S. Geological Survey (USGS) has developed another way to describe how smaller streams become larger rivers. USGS established Hydrological Unit Codes (HUCs) to delineate drainage basins at different scales, sometimes referred to as a "nesting" system (Figure 1.3. There are six different levels of units, which are arranged by size. The more digits are included in a HUC, the
smaller the corresponding geographic area. Thus, the fewest digits are included for regions and sub-regions, the largest units, and the most digits are included for watersheds and sub-watersheds, the smallest units. Basins and sub-basins fall in between, as follows:

- 2-digit HUC: first level (region)
- 4-digit HUC: second level (sub-region)
- 6-digit HUC: third level (basin)
- 8-digit HUC: fourth level (sub-basin)
- 10-digit HUC: fifth level (watershed)
- 12-digit HUC: sixth level (sub-watershed)

For example:

Name	HUC	Geographical Size	Area
Ohio River	05	Region	189,422 sq. mi.
Cumberland River	0513	Sub region	17,700 sq. mi.
Lower Cumberland River	051302	Counting unit	7,150 sq. mi.
Stones River	05130203	Cataloguing unit	921 sq. mi.
West Fork of Stones River	0513020302	Watershed	257 sq. mi.
Middle Fork of Stones River	051302030202	Sub watershed	67 q. mi.

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[3] National Atlas; http://www.nationalatlas.gov/articles/geology/IMAGES/contDiv_basin.gif

B. Online Tools for Watershed Mapping and Assessment

Watershed delineation is the practice of determining the drainage divide by tracing on a topographic map the dividing ridges upstream from a particular point on a stream, often at the confluence (where two streams come together) of a tributary at a higher order stream (Figure 1.4). Topography refers to how the surface of the land rises and falls.

USGS topographic quads are special maps that use contour lines to show changes of elevation, and blue lines to represent streams. These maps are useful in delineating watershed boundaries, but should not be used to determine stream status. Topographic quads vary in their coverage of small streams. Some show both intermittent (sometimes have water) and perennial (always have water) stream sections, while some show only perennial streams.
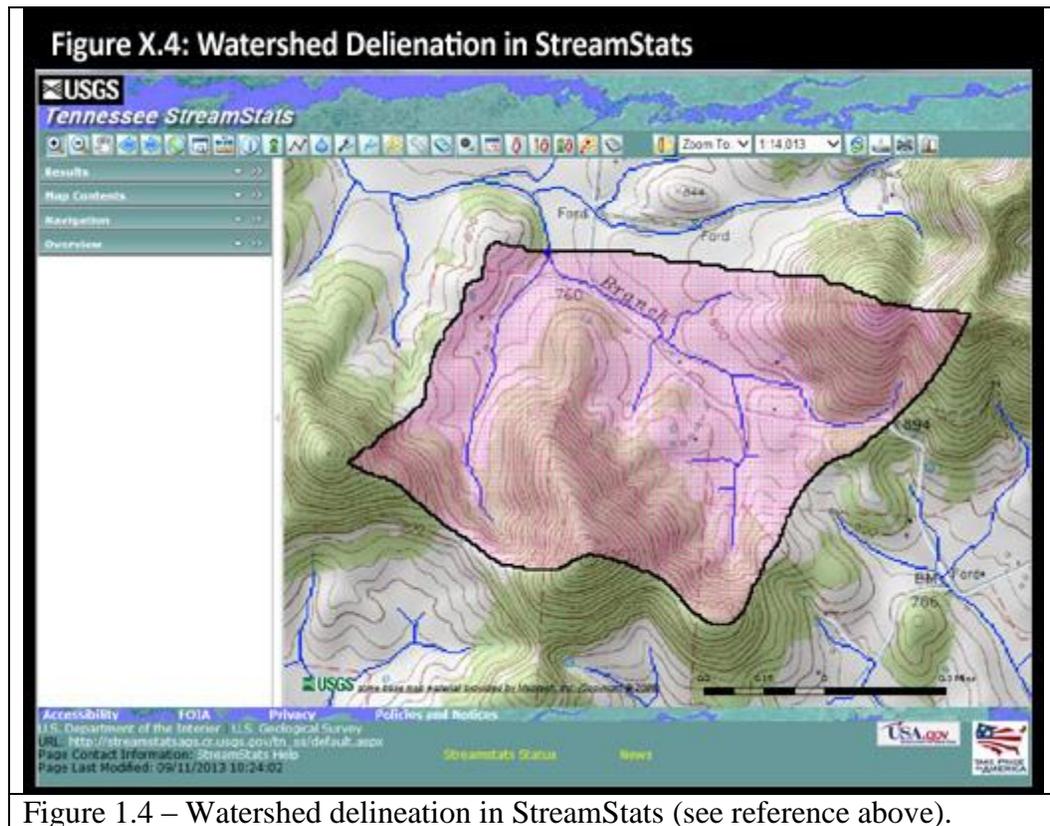

Figure 1.4 – Watershed delineation in StreamStats (see reference above).

Several useful tools exist online for mapping and evaluating streams and watershed. Among the most useful are USGS Tennessee StreamStats and NRCS Web Soil Survey.

1. USGS Tennessee StreamStats

Available online at http://water.usgs.gov/osw/streamstats/tennessee.html, or by typing "StreamStats TN" into a browser search window, this map-based application allows users to delineate watersheds based upon a point, and conduct basic calculations, such as watershed size and drainage network evaluations. (TIP: If you have problems, try using a different browser. E.g., if Firefox isn't working, try using Internet Explorer. The application can be very picky, and is frequently down for maintenance and upgrades.)

Using this application you can estimate: the 7-day, 10-year and 30-day 5-year low flows; the mean annual flow; the mean summer streamflow (June through August); and the high and low flows for a particular stream over a specific period of time. A very useful feature is "Watershed Delineation From a Point." Simply zoom in to the area you want to delineate, then click on the "Watershed Delineation From a Point" button, and click on the downstream limit of the watershed you wish to delineate. From here, you can use the tool to compute basin characteristics and flow estimates, and even export the watershed as a shapefile for use in GIS programs.

A User Guide has been developed for the Maryland StreamStats Application, which is very similar to the Tennessee StreamStats Application. This User Guide is available at: http://water.usgs.gov/osw/streamstats/UserInstructions-20120427.pdf.

2. NRCS Web Soil Survey

This is a robust tool that allows for mapping areas and identifying and classifying soils within that area. Streams may be identified by blue lines; however not all streams that meet the regulatory definition show up on these maps. The Web Soil Survey is available online at: http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

The basic steps for using the Web Soil Survey are:

1. **Use the Area of Interest tab** to define your area of interest.
2. **Click the Soil Map tab** to view or print a soil map, and detailed descriptions of the soils in your Area of Interest.
3. **Click the Soil Data Explorer tab** to access soil data for your area and determine the suitability of the soils for a particular use. The items you want saved in a report can be added to your shopping cart.
4. **Use the Shopping Cart tab** to get your custom printable report immediately, or download it later. It's called a Shopping Cart, but don't worry – it's FREE!
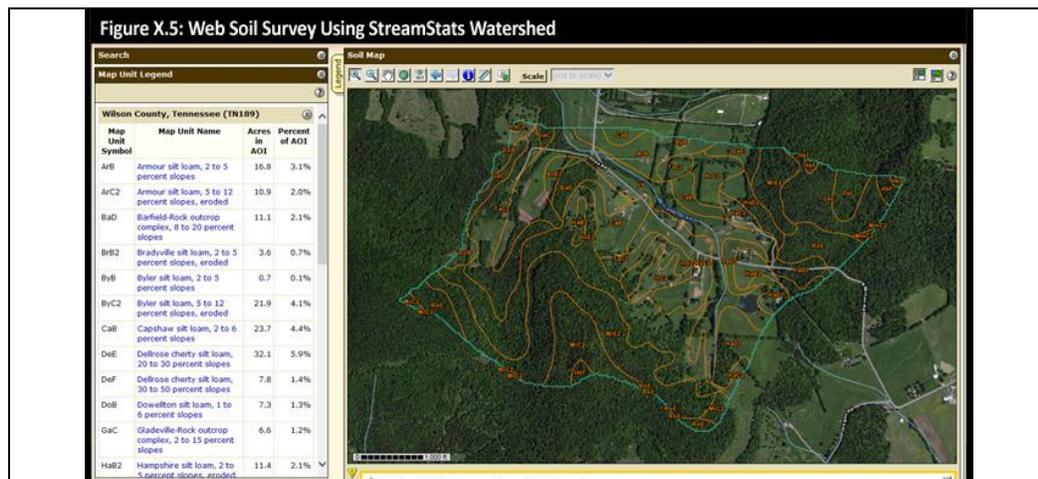

Figure 1.5 – Web Soil survey, using StreamStats Watershed (referenced above).

The Area of Interest can be defined by importing a shapefile. Using the exported shapefile from Streamstats, which was discussed earlier, is a great place to start. A Getting Started tutorial is available online at: http://websoilsurvey.sc.egov.usda.gov/App/GettingStarted.htm, and more detailed instructions are available at: http://websoilsurvey.sc.egov.usda.gov/App/Help/WSS_HomePage_HowTo_3_0.pdf.

3. Other Online Resources For Watershed Mapping and Assessment

- Community Resource Mapper**:** http://www.watershed-assistance.net/mapper/. This web site allows you to create custom watershed maps that include information about impaired waters, impervious surfaces and protected lands.

- Environmental Protection Agency's EnvironMapper for Water (Watershed Surfer)**:** http://cfpub.epa.gov/surf/locate/index.cfm. This website allows you to view and map EPA data, including information about uses assigned to local waters and impaired waters.

- Environmental Protection Agency's National Stormwater Mapper**:** http://epa.gov/nrmrl/wswrd/wq/models/swc/. This desktop application can estimate the annual amount of rainwater and frequency of runoff from a specific site anywhere in the United States (including Puerto Rico). Estimates are based on local soil conditions, land cover, and historic rainfall records.

- United States Geological Service's Science in Your Watershed: http://water.usgs.gov/wsc/map_index.html. This website helps you find scientific information organized on a watershed basis. This information, combined with observations and measurements made by watershed groups, provides a powerful foundation for characterizing, assessing, analyzing, and maintaining the status and health of a watershed.

- United States Geological Survey Water Resources Maps and Data:[4] http://water.usgs.gov/maps.html. This website provides downloadable spatial data files for exploration and analysis.

- Tennessee Department of Environment and Conservation's Watershed Management**:** http://www.tn.gov/environment/water/watersheds/index.shtml. This website includes information about Tennessee watersheds, with links to reports, assessments, water quality, and other useful information.

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[4] Site allows the user to download map data and shapefiles that can be used in a Geographic Information System (GIS), a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. It requires specialized software to graphically represent the data, perform spatial analyses, data output, and cartography. For the more technically inclined, Quantum GIS (often abbreviated QGIS) is a robust cross-platform, free and open-source desktop geographic information systems application with data viewing, editing, and analysis capabilities. More information about QGIS is available at: http://www.qgis.org/.

- The National Map and Data Viewer:* http://nationalmap.gov/viewer.html.
  The National MapViewer provides access to elevation, orthoimagery, hydrography, geographic names, boundaries, transportation, structures, land cover, U.S. topography, and historical topographical map layers for use in GIS analyses.

- U.S. Fish & Wildlife Service National Wetlands Inventory Mapper: http://www.fws.gov/wetlands/Data/Mapper.html. The Wetlands Mapper integrates digital map data with other resource information to produce timely and relevant management and decision support tools.

- Impervious Surface Analysis Tool: http://www.csc.noaa.gov/digitalcoast/tools/isat/.
  The Impervious Surface Analysis Tool (ISAT), a custom suite of easy-to-use scripts for ArcGIS, is used to calculate the percentage of impervious surface area within user-selected geographic areas. (Requires ArcGIS and Spatial Analyst.)

- I-TREE Urban Forestry Applications Suite: http://www.itreetools.org/applications.php.
  Based on years of U.S. Forest Service research and development, these innovative applications provide urban forest managers and advocates with tools to quantify ecosystem services and benefit values of community trees at multiple scales.

- BASINS VERSION 4.0: http://www.epa.gov/athens/wwqtsc/html/basins.html.
  Open source GIS that integrates environmental data, analysis tools, and modeling systems that can be used for watershed analysis and monitoring.