January 2004

LAND INFORMATION Bulletin

*from the National Consortium for Rural Geospatial InnovationS*
*Chesapeake, Wilkes University*

# GIS and Watershed Indicators

## Helping Restore Healthier Ecosystems

*The Pennsylvania GIS Consortium (PAGIS) is leading a multi-agency charge to help northeastern Pennsylvania communities tackle environmental problems in the Upper Susquehanna-Lackawanna watershed. As part of a comprehensive plan, they are employing geographic information systems (GIS) to create watershed indicators that help communities assess water quality, thereby paving the way for future ecological restoration projects.*

The Upper Susquehanna-Lackawanna (US-L) watershed in northerneastern Pennsylvania—one of 14 American Heritage Rivers in the nation—is faced with three regional environmental problems: abandoned mine lands (AML), acid mine drainage (AMD), and combined sewer overflows (CSO). This triple threat to the region's environmental and economic health has stretched local government budgets and drawn the attention of diverse state and federal agencies, as well as various community groups.

Because the US-L watershed is so vast, an environmental master plan aimed at examining the watershed "holistically" as in integrated ecosystem has evolved and is now in place. The Pennsylvania GIS Consortium (PAGIS), a non-profit organization, has worked with the GeoEnvironmental Sciences and Engineering Department at Wilkes University, the U.S. Army Corps of Engineers (Baltimore District Office), the Environmental Protection Agency (Office of Environmental Information), the U.S. Department of Agriculture (with support and funding from its rural GIS program) and local agencies and community groups to put the plan in motion.

**Figure 1.**

**photo caption here**

## Assessing watersheds

The master plan is designed to be comprehensive. Rather than evaluating one stream segment at a time, the PAGIS team developed and evaluated a series of watershed indicators to assess the relative ecological "health" of 42 individual tributary sub-watersheds as well as the river corridor of the main stem. All lie within the overall US-L watershed boundary.

The watershed indicators are assessment tools that support environmental reclamation and ecological restoration projects in the most critical locations. Restoring the watershed to a healthier environmental state is vital to the region's physical and economic health.

### Geospatial data and sources for tributary watershed indicators

- **"Smallshed" GIS delineations** (from the Pennsylvania Department of Environmental Protection)— these data were used to consolidate the stream tributaries as hydrological and ecological units on a watershed basis.
- **Tributary watershed delineations**—these data were created as part of this study.
- **Mid-resolution land characteristics** (MRLC, Thematic Mapper data)—these data are derived from satellite imagery from the early 1990s and provide information on land cover and land use (e.g., forest vs. urban areas).
- **Wetlands** (GIS coverages, from U.S. Department of Interior, National Wetland Inventory).
- **100 largest AMD discharges** (data created for this study, from U.S. Geological Survey Report).
- **CSO data** (GIS locations were obtained from EPA's Web-based GIS, EnviroMapper, and also other EPA Web pages).

This analysis is considered a first step in an evolution of watershed assessments that progressively will allow communities to address local-scale "smallsheds" within tributaries. As larger scale data are acquired and processed as part of an ongoing phase of the environmental master plan, communities can begin addressing local smallsheds.

## The appropriate scale

An Interagency Stream Restoration Working Group (15 U. S. federal agencies) developed a guide manual for stream restoration based on a hierarchical approach from smaller to larger watersheds. For example:

- local stream reaches (a 300-meter length of stream),
- local watersheds (1 to 5 square miles in area),
- tributary watersheds (10 to 400 square miles in area),
- regional landscaperiver scales (as in the US-L watershed, 2000 square miles in area),
- regional landscapes (EPA's Mid-Atlantic Region, a five-state area).

The "tributary-watershed" level (10 to 400 square miles) is being applied as a first step for watershed assessment in this phase of the environmental master plan. The sidebar at left shows the types of data and their sources for the tributary watersheds.

Overall, 2 percent of the US-L River watershed is in mining land cover (figure 2). This figure can be used as a relative point of comparison since individual tributary watersheds vary considerably, from less than 0.3 percent to nearly 14 percent. In addition, 67 percent of the US-L watershed consists of forests, the predominant land cover category. Agricultural and urban land cover classes are 23 percent and 6 percent, respectively.

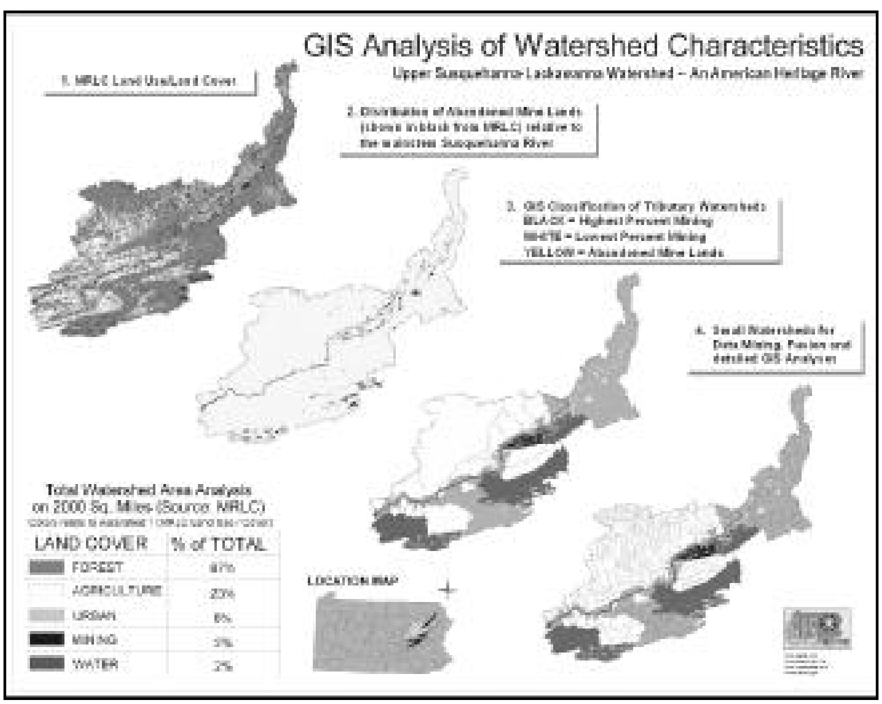


**Figure 2.**
**A graphic overview of the methods employed in this GIS analysis of tributary watershed characteristics with a particular focus on barren or mining land cover as an index to mining impacts in the region, specifically AML. A "hierarchy" of watershed ecosystems in the study area is delineated, from the whole US-L River watershed (upper left) down to the "smallsheds"as designated by the Pennsylvania Department of Environmental Protection (shown in the lower right hand corner of the figure). The figure was designed also to highlight the location and dispersion of AML as a source of non-point pollution (dark areas in the second watershed) relative to the mainstem Susquehanna River as a key receptor ecosystem.**

## Seven Watershed Indicators

The following GIS watershed indicators are summarized and evaluated in terms of their ability to discern and assess environmental conditions.

**Mining (Barren) Land Cover**

Mining impacts are the most widespread of environmental problems throughout the US-Lwatershed. Thus, percent mining land cover was used as an ecological indicator to the extent of AML, open pits, strip pits, and spoil (or culm) banks that are sources of pollution and devoid of natural vegetation in the watershed. This watershed indicator was rated "extremely high" in effectiveness to detect environmental differences between impacted vs. reference tributary watersheds. Figure 3 shows the relative ranking of mining impacts for 12 impacted tributary watersheds (i.e., those with urban areas and significant abandoned mining lands).

**Forest Land Cover**

This index was chosen because it is generally considered an important watershed parameter for regions where forest is the natural ecosystem. Forests perform a number of functions in watershed ecosystems: facilitate groundwater recharge, retain and process of pollutants and nutrients, reduce stormwater surges, and protect wildlife habitat. This index, also based on satellite imagery, was unable to detect significant environmental differences between impacted vs. reference tributaries. Thus, even some mining-impacted watersheds still retain significant remnants of their natural terrestrial ecosystem—an important asset for ecological restoration efforts by local communities.

**Wetland Land Cover**

Wetlands perform a number of functions in watershed ecosystems: recharge groundwater, retain and process pollutants and nutrients, reduce stormwater surges, and offer aquatic habitats for fish and wildlife. In this part of the analysis, the extent of wetland cover in an individual tributary watershed was developed in a GIS based on data in the National Wetland Inventory of the U.S. Fish and Wildlife Service. This index did not detect significant ecological differences in impacted vs. reference streams in the GIS analysis, again indicating remnants of natural ecological features even in tributary watersheds with mining.

**Combined Sewer Overflows**

These represent one of the major water quality issues in the US-L River watershed. At present, regional data for the whole watershed is limited to a simple count of the number of CSOs in a tributary watershed. CSOs result from the flow of wastewater mixed with urban stormwater that is diverted to streams and rivers during storm events that exceed the capacity of "older" common sewer lines, typical of cities in the northeastern U.S. In the aquatic environment, oxygen may drop to critically low levels during decomposition of organic material from mixed wastewater, impacting bottom dwelling aquatic insects and fishes. This index was rated "high" in the GIS analysis for detecting differences between tributaries with CSOs vs. those without CSOs.

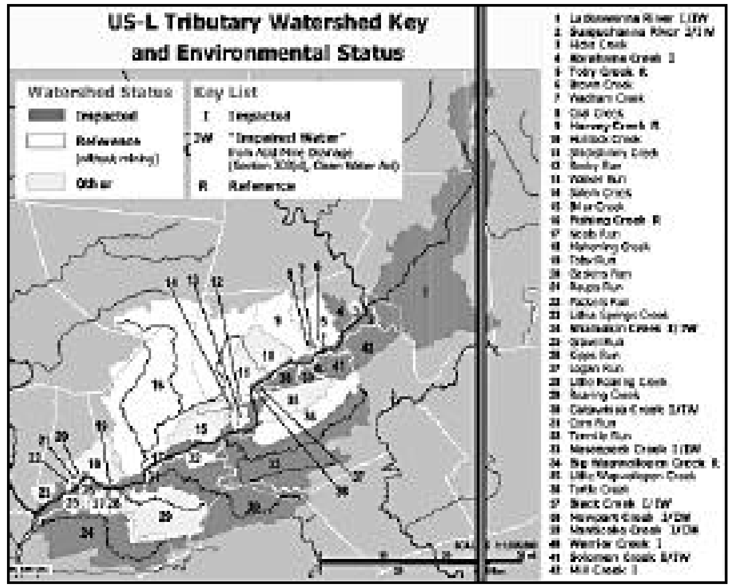


**Figure 3.**
**This map shows the status of each of the 42 tributary sub-watersheds within the Upper Susquehanna-Lackawanna watershed.**

The last three watershed indicators address aspects of acid mine drainage (AMD) from various point discharges throughout the US-L watershed. These data are from the U.S. Geological Survey report entitled, "Water Quality of the 100 Largest Mine Discharges in the Anthracite Region of Eastern Pennsylvania." For this portion of the study, a GIS was used to locate 35 of these discharge points (data from 1991) that actually occur in the watershed. The ecological, toxicological, and habitat (stream channels) impacts of AMD usually result from low pH, high iron and other dissolved metals, and high acidity.

**Hydrogen Ion Loading**

For watershed impact assessment, it is preferable to use loading rates that adjust pollutant levels, like hydrogen ion concentration (an indicator of acid conditions), relative to the volume of stream flow and for watershed area - the approach used for this analysis. This index was rated "high" for detecting environmental differences between impacted vs. reference tributary watersheds in the GIS analysis.

**Iron Loading**

Iron in high concentrations can be toxic to aquatic organisms. Also, when AMD is exposed to atmospheric oxygen in surface streams, precipitation of dissolved iron to a solid sediment material ("yellow boy") can clog rocky stream and river habitats and significantly impact aquatic populations. No other metals data are available at most of the sites even though metal toxicity is a major concern in the acidification of freshwater ecosystems. The source of data and calculations, including adjustment due to stream flow and watershed area, is the same as that described above for hydrogen ion loading. This index was rated "medium" for detecting environmental differences between impacted vs. reference tributary watersheds in the GIS analysis.

## The Upper Susquehanna-Lackawanna Master Plan

A cooperative effort among federal, state, regional, and local organizations

### Ranking of tributary watersheds

Based on abandoned mine lands (AML) from land cover data derived from satellite imagery

**Percent of watershed in mining**

**Impacted Watersheds**

| | |
|---|---|
| Newport Creek | 13.6 |
| Warrior Creek | 13.4 |
| Nanticoke Creek | 10.3 |
| Solomon Creek | 5.9 |
| Mill Creek | 5.4 |
| Shamokin Creek | 5.1 |
| Nescopeck Creek | 4.5 |
| Black Creek | 4.3 |
| Lackawanna River | 3.0 |
| Catawissa Creek | 1.9 |
| Susquehanna River | 1.8 |
| Abrahams Creek | 1.4 |

**Reference Watersheds**

(without mining)

| | |
|---|---|
| Toby Creek | 0.6 |
| Fishing Creek | 0.3 |
| Harvey Creek | 0.3 |
| Big Wapwallopen Creek | 0.0 |

**Total Number of Mine Discharges**

Like the indicators for hydrogen ion and iron, these data are taken from the 1991 water quality survey by the U.S. Geological Survey report. This indicator was used as a more general way to integrate the impacts of AMD from major point sources throughout the US-L watershed. This index was rated "high" for detecting environmental differences between impacted vs. reference tributary watersheds in the GIS analysis.

## Conclusions of GIS analysis

The percent mining land-cover class was most effective ("extremely high") in detecting statistically significant impact differences between rural watersheds without mining from the other 12 tributaries with mining. All seven indicators averaged together also were ranked "extremely high" in effectively detecting environmental conditions for rural and urban/mining streams. Individual tributaries are listed in the sidebar at left.

*This publication was produced by the National Consortium for Rural Geospatial Innovations, Chesapeake–Wilkes University. For more information contact Dale Bruns or Tom Sweet, Pennsylvania GIS Consortium, 150-180 S. River St., Box 111, Wilkes-Barre, PA 18766; email: dbruns@wilkes.edu, tsweet@odowd-itg.com; phone: (570) 408-4610.*

The Pennsylvania GIS Consortium
150-180 S. River St.
P.O. Box 111
Wilkes-Barre PA 18766