ALABAMA COOPERATIVE Extension SYSTEM

ANR-1162

ALABAMA A&M AND AUBURN UNIVERSITIES

The Alabama Watershed Demonstration Project: Water Quality and Geographic Information Systems

Introduction

This publication provides information about new approaches being used to link land use patterns and water quality. Areas discussed include the following:

- **Water quality parameters that are commonly used to evaluate stream water quality**
- **Geographic Information Systems (GIS) that can be used in the management of natural resources**
- **Water quality data incorporation into GIS to evaluate land use impacts on water quality**
- **Information about a research project that took place in South Alabama from 1996 to 1998**

This study serves to illustrate how water chemistry data and GIS can be used to examine the impact of land use on water quality, especially with respect to nonpoint source (NPS) pollution at the watershed level.

The term watershed refers to the land area that feeds a particular body of water. An extreme example of a watershed is the Mississippi River. The watershed or drainage basin of the Mississippi actually encompasses most of the middle United States and a portion of Canada. Obviously, identifying and minimizing the causes of NPS pollution within such a large area presents tremendous logistical problems. For this reason, large watersheds are divided into smaller areas, called subwatersheds, for management purposes. These subwatersheds are delineated or identified by determining the drainage area for a tributary of the larger system. It is possible to identify all of the subwatersheds of a river. The use of these smaller units to assess water quality increases the likelihood of identifying most of the sources of NPS pollution and allows easier determination of the dominant contributors to water pollution.

Solving the problems associated with NPS pollution presents serious challenges. NPS pollution does not originate from a single, easily identifiable source but rather it originates from diverse sources. An understanding of how water quality is affected by land use and the type of cover present in a given area is vitally important. Most people manage land in small units such as a field, a stand of trees, a pasture, or a home site. The activities that take place in these small areas usually have only minimal impact on local water quality. However, when the effects of management activities on each small area within a watershed are added together, the impact can be substantial. This added-together effect is referred to as cumulative. Addressing cumulative impacts is generally much more complicated than addressing the problems of a single water pollution source.

Making management decisions to avoid problems associated with cumulative impacts is extremely difficult. One of the primary reasons for this is that the people making the decisions resulting in these small impacts often do so without knowledge of other land management decisions being made in the same watershed by other people. Even if a single landowner is making all of the decisions on several adjacent "chunks" of land within a single watershed, it is often difficult to predict the effect these activities will have on overall water quality (or, for that matter, on other characteristics of the watershed). New technological tools are making it easier to evaluate these impacts and even to predict how certain activities will impact the integrity of an area.

Measurements of Stream Water Quality

Our concern about, and knowledge of, water quality has increased dramatically over the last 30 years. In that time, a number of water quality parameters (characteristics) have been found to be useful indicators of "good" or "bad" water quality. The labels "good" or "bad" are usually assigned relative to a defined use such as drinking water, swimming, or fishing. The Environmental Protection Agency (EPA) has established limits for specific water quality parameters that are used to determine how clean or dirty (degraded) a body of water is.

Some commonly measured water quality parameters include the pH (acidity/alkalinity) of the water, the amount of total dissolved solids (TDS), and the amount of total suspended solids (TSS). The total organic carbon (TOC) content of the water and the concentration of nutrients such as potassium, phosphorus, and nitrogen are also important variables. Each of these parameters can be used to evaluate the status of water quality.

Evaluating water quality in a meaningful way is a complex issue. A single sample from a specific water body can only tell you what the water quality is at that particular time. This is true because of changes that occur in water chemistry as water moves downstream, as rainfall and runoff enter the water body, as evaporation from the soil surface occurs, and as transpiration (the uptake and loss of water) by plants takes place. In order to develop an accurate understanding of how clean or dirty a particular body of water is, especially flowing streams and rivers, it is necessary to collect and analyze water samples from the same location over time.

Another important factor in evaluating water quality data is the need for measurement of the flow rate and the dimensions of a stream or river. This allows you to determine the actual volume of water in the stream, how rapidly it is moving and the discharge (the amount of water moving through the stream over time). The actual quantity (load) of nutrients, sediment, or other materials that is being carried by the stream or river each day can then be calculated. If you know the size of the watershed, you can express the load or quantity of a pollutant in the stream each day on a per acre basis.

The natural characteristics of a watershed will determine the “normal” condition of each water quality parameter. For example, watersheds with low nutrient (infertile) soils having a high percentage of sand would be expected to have stream water that is low in nutrients and low in total suspended sediments. The sources of nutrients and fine-grained sediments are limited under these conditions. Therefore, water quality is dependent, to a large extent, on what takes place within the watershed. These activities or events are what will alter the natural condition of the water. These can be natural events such as wildfires, storms, changes in vegetation over time, or man-induced events such as clearing, planting, and fertilizing.

It is important to note that not all natural waters (waters that are not affected by human activities) have what would be classified as perfect water quality. For example, some watersheds have soils that contain high quantities of salts or minerals or parent material beneath the soil that generates waters having very acidic or very alkaline pH. These natural characteristics can make the water undrinkable or unpleasant for bathing or swimming but the water is still considered normal for that particular area.

Each watershed has, among other things, topographic variation as well as a variety of soil types and land use categories. The size of watersheds varies dramatically as do the land use/land cover types occupying the landscape. The quality of water at the mouth of a stream or river can be viewed as a reflection of land use impacts within the watershed. The condition of the water leaving the watershed is determined by the land uses, the types of land over which runoff moves, the slope, parent material, biological characteristics, and size of the watershed or drainage basin. Other factors may also affect water quality.

Even though our knowledge and understanding of water quality has increased over the last 30 years we still have a lot to learn. It is for this reason that researchers continue to examine water quality and to look for new tools with which to acquire a greater understanding of water quality. These efforts will allow us to deal with existing water quality problems and to grapple with new problems that continue to emerge. Examples of some of the complicated water quality issues we face today include the increasing emphasis on intensive land management, population growth, urban sprawl, potential climate changes, increasing demand for clean water, and even the failure of septic systems.

Geographic Information Systems

Geographic Information Systems (GIS) is a computer tool now used to address new and existing water quality problems. GIS uses a computer database to store large quantities of spatial and temporal data. This allows the integration of diverse types of information into a form that makes it possible to consider different approaches to land management and environmental problems before making management decisions. Spatial data is information that describes how a specific feature is located or distributed in space. This type of information can include watershed boundaries, slope, aspect, contour, soil type, stream location, and land use/land cover. The use of GIS allows people to process and evaluate these data. Without this type of computer tool, such large amounts of data would overwhelm us.

Information stored in a GIS will come from a variety of sources. The greater the quantity and quality of the information, the more complete the GIS database will be. Sources of information include satellite images, aerial photographs, Soil Conservation Service (SCS) and Natural Resource Conservation Service (NRCS) soil maps, United States Geological Survey (USGS) topographic maps, and survey maps.

Data is entered in the GIS database and the software builds a map of the area. Actually, the computer builds what are called layers—separate maps of the same area, each of which contains different sets of information or themes. These maps are built by providing the computer with geographic coordinates identifying the location of various features (spatial data).

GIS maps can contain information on ownership boundaries and the location of man-made features such as roads, houses, and developed areas. They may also contain information on soil type, slope, land use, land cover, and the location of streams, rivers, lakes, and other water. Land use information from different points in time is entered into the database. This temporal data allows the GIS user to track changes in land use that have occurred over time (temporal changes). Information on water quality can be entered into the database, and, if the location of sample sites is known, these data can be linked to specific locations. This allows the GIS user to make connections between the type of land use and various physical properties and the quality of water within the area of interest.

The Global Positioning System (GPS) is another technological advance making it easier for land managers to develop a GIS database. GPS units allow people to determine the geographic coordinates of landscape features. For example, GPS units can be used to locate management units (pastures, fields, stands) on a map more accurately and easily than before. Today, farmers with access to a GPS unit can actually mount it on a tractor and accurately map the location and dimensions of their fields; foresters can use hand-held units to map the location of stands. GPS coordinates can also be taken at the site where water quality samples are collected. These coordinates can then be entered into the GIS database allowing these features to be positioned on the watershed map.

A GIS database is used to track actual changes taking place over time within a watershed. Aerial photographs and other spatial data generated at different points in time (some of it mapped using GPS units) are used to measure changes in land use, land cover, density of roads, houses, presence or absence of buffer zones around streams, and other items of interest. As this information is collected and evaluated, it is possible to make connections between water quality data (if available) and the changes in land use that have occurred in an area. Ideally, there will be water quality data available from several different points in time.

Advances in technology offer land managers the potential to look at the land and management activities on that land in ways that have never been readily available. GPS units are now being sold to individuals (although a good one is still expensive) and GIS software is available that can be used on personal computers. In time, the availability of these technologies should improve and the cost decrease. In addition, these technologies are becoming more user friendly all the time.

The Alabama Watershed Demonstration Project

Following is information on the Alabama Watershed Demonstration Project that illustrates application of GIS principles and technologies. The research, funded by a number of forest industry companies and federal agencies, was conducted by Drs. Graeme Lockaby, Larry Teeter, and Mark MacKenzie. Dr. Prakash Basnyat and Ms. Ashley Hamilton also participated in the study. This research examined sources of NPS pollution in small watersheds of the Alabama Coastal Plain region and related multiple land uses to nonpoint sources of pollution at the watershed level. Two other Extension publications describe additional information acquired during this study. They are ANR-1150, “The Alabama Watershed Demonstration Project: Water Quality, Nonpoint Source Pollution, and BMPs—What Landowners Know,” and ANR-1167, “The Alabama Watershed Demonstration Project: Biotic Indicators of Water Quality.”

A GIS database was developed as part of this project. Land use/land cover information was generated using satellite imagery and aerial photography and verified with spot visits to sites within the watershed. The land use/land cover information was incorporated as part of the GIS database. The watershed was found to be fairly homogenous in terms of land use. Although forest was the dominant land cover type (85 percent), the watershed also contained agricultural and urban areas. Agricultural uses included pastureland for beef and dairy cattle, row crops (cotton, corn, tobacco, wheat, and soybeans) and livestock production (poultry and pork). A variety of silvicultural practices were found to occur within the area, including extensive loblolly pine plantations, thinning and clearcutting harvesting regimes, forest regeneration practices (natural and artificial), and fertilization (agriculture and forestry related). Most of the forested area is devoted to industrial silviculture although privately owned forest land and natural stands of unmanaged Coastal Plain forests are also present.

The land use/land cover types identified in this study included pine (28.3 percent), mixed pine/hardwood (46 percent), forest regeneration (8.6 percent), clearcut, (2 percent), row crop (5 percent), pasture (9 percent), urban (0.2 percent), and water (0.4 percent). The GIS database was used to calculate the total area for each subwatershed and to determine the percentage of area within each subwatershed devoted to each of the eight land use types. In addition, the number of poultry houses, residential dwellings, and stream-road crossings was determined. The subwatersheds included in the study were found to range from 546 to 4,216 hectares in total size.

Fifteen watersheds were selected for intensive water sampling. Sites were chosen to provide a variety of land uses for evaluation. An example of the sampling design appears in Figure 1. Samples were collected upstream from where a smaller stream flowed into a larger stream. This allowed the researchers to determine the water quality associated with management of small areas and made it easier to link the land use/land cover information to water quality data. Samples were collected at the same site within each of the 15 watersheds every two weeks during the winter and early spring of 1997 and 1998. All of the streams had moving water and contained water all year (perennial streams). The majority fell within the Sepulga River Basin.

The GIS database was used to delineate the area within each subwatershed that would directly contribute water to a stream. The land use/land cover information was then placed over this contributing zone that consists of only a portion of each subwatershed. This allowed any differences in water quality between the subwatersheds to be related to actual land use/land cover differences. Basically, if you collect samples from the mouth of each stream (Figure 1) and you find that nitrate concentrations are highest at Point B, intermediate at Point A, and lowest at Point C, the next logical step is to determine what is different about the areas feeding these three streams.

This research suggests that forests act as sinks for nitrate—that is, they take up nitrate. In fact, as forested area within a contributing zone increased, downstream nitrate levels decreased. The forest regeneration and agricultural lands were identified as sources of nitrate. This is probably due to fertilization practices. The data indicate that intact streamside management zones (SMZs) are very important for maintaining water quality. The study also found that none of the water chemistry variables measured exceeded Environmental Protection Agency (EPA) allowable limits. This indicates that water quality within the study area was good during the period in which samples were collected.

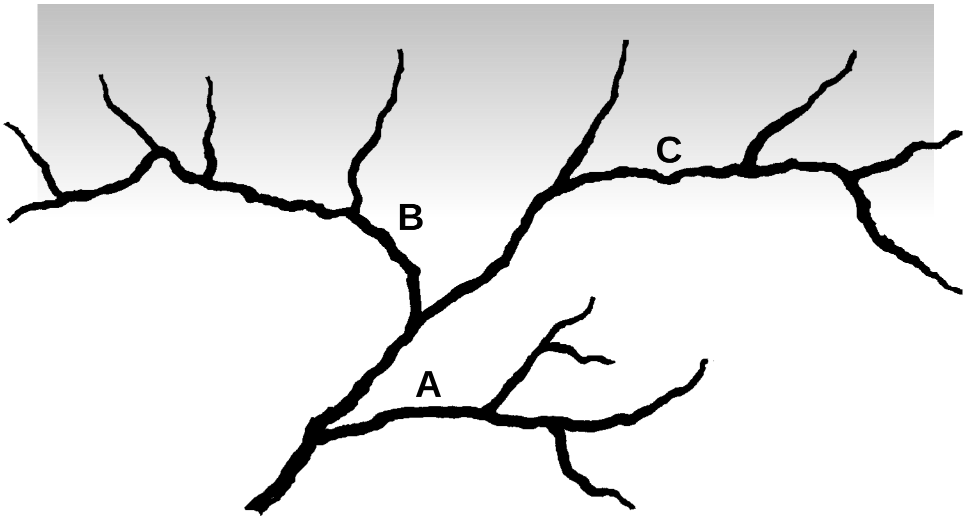

Figure 1. Watershed sampling sites

According to the researchers, maintaining water quality within the Sepulga River Basin will be dependent upon maintenance of adequate SMZs and the use of best management practices (BMPs). This is particularly true for the smaller streams within the watershed because these are the primary sources of downstream pollution. The methods of evaluating water quality and relating it to land use/land cover that were developed during this study make it possible to calculate the buffer size required to maintain target levels of water quality.

Obviously, our ability to evaluate water quality and to manage land in such a way that water quality is maintained has improved dramatically in the last three decades. As technological advances continue and the tools become easier to use, the activities described in this publication will become commonplace. Continued efforts by researchers will ensure that we have the potential to maintain a safe, reliable, and plentiful supply of water for drinking, recreation, and wildlife. Ensuring that this potential is realized will require the efforts of all land managers.

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