Applications of GIS in Watershed Management

Geographic Information Systems (GIS) is an integral component to the field of watershed science, which is increasing in interest due to its direct relationship with the health of humanity. Watersheds supply drinking water and without the proper management of these systems, threats exist to people. Watersheds are defined on the landscape depending upon which direction the surface water flows and drains and is now a multidisciplinary subject incorporating ecological and biological processes in combination with socioeconomic factors (Gupta et al., 2004). The science is comprised of individuals from varied backgrounds ranging from ecology, biology, hydrology, and engineering to manage these environments. The conservation and management of these systems has taken several different approaches including ecosystem restoration, wetland and forest conservation, and wastewater and stormwater management (Barten and Ernst, 2004). The main focus of watershed management is pollution control of waterways, particularly non-point pollution (2004). Non-point pollution is responsible for greater than sixty percent of degraded drinking supplies due to chemical runoff from agriculture and suburban and urban developments (Barten and Ernst, 2004, Bhuyan et al., 2002). Therefore, important aspects to watershed management include land use planning and the monitoring of water quality (Barten and Ernst, 2004). GIS has become a crucial tool in watershed management for modeling systems, assessing the condition of the watershed, and devising management strategies. Numerous data sources, analytical procedures, and data models have been developed and implemented and serve crucial roles in watershed management.

Many data sources are available from federal, state, and private organizations for constructing watershed models and doing spatial analyses. Since the science takes on a multidisciplinary approach with the combination of biology, ecology, economic, and social factors there are multiple datasets available at national, state, county, and local levels (Gupta et al., 2004). However, there are several base layers, which are extremely vital to watershed management (Dymond et al., 2004). These include the United States Geological Survey (USGS) digital elevation models, watershed boundaries, digital line graphs of streams and rivers, and land use (Dymond et al., 2004, Garbrecht et al., 2001). In addition to these datasets, there are many other sources of available spatial data depending upon the aspects and conditions being studied and examined within the watershed. Other datasets of extreme importance to watershed analysis and modeling include: Natural Resource Conservation Service (NRCS) soils data, USGS Hydrologic Units (HUCs), and Federal Emergency Management Agency (FEMA) floodplain data (Dymond et al., 2004, Tong and Chen, 2002). For studies incorporating socioeconomic factors the U.S. Census Bureau offers TIGER files, which include population levels, family incomes, and infrastructure information (Dymond et al., 2004). Data sources are abundant and varied and must be carefully selected when analyzing a watershed so the best representation of the system is achieved.

Many analytical procedures have been implemented in strategies devised for managing watersheds. GIS is most widely used in the data preparation of informative layers of data sources obtained from federal, state, and private organizations. These layers are placed in the same coordinate system and projection so spatial analyses can be done to assess the watershed (Lussier et al., 2001). This format is often used to show simple relationships when mathematical figures are not necessary. While
hardcopy maps can be very beneficial for assessing watersheds, data models are becoming a more popular and thorough means for managing watersheds because statistical analyses can be performed. Watershed modeling allows for assessing water quality, quantity, and the overall state of the watershed (Bhuyan et al., 2002). Numerous programs have been developed which are associated with or are compatible to GIS datasets (Ogden et al, 2001). However, this often involves entering the data in GIS, transferring the model into another program to obtain a model, and then placing the output model back into the GIS system (Verro et al., 2002). One such example is the AGNPS model which is often used to model runoff from agricultural lands (Bhuyan et al., 2002). Studies are now being done to perform direct modeling of the watershed into the GIS system for efficiency and time management purposes (2002). The future of GIS is directed towards systems which now include a spatial decision support system (Dymond et al., 2004). Under this system, GIS is performed on a web interface and is essentially done on a server, while the user accesses the program and enters data into the GIS modeling program pertaining to the watershed he or she is studying (2004).

Today, watershed management has taken a risk management approach. With so much devastation and destruction done to watersheds, the field has now taken a proactive stance to continuously monitor watersheds to prevent further pollution entering into the systems. Recent GIS studies are focusing on land use and water quality (Tong and Chen, 2002, Verro et al., 2002). With the numerous studies done on individual watersheds, similar theories and strategies can be applied to additional watersheds to create management plans for a particular watershed with the use of GIS and additional modeling programs. Since each watershed is unique and multiple factors exist which affect watersheds, the concepts of how past studies were devised and implemented can be applied to other systems. Therefore, past watershed studies serve vital roles in the development of watershed management with specific techniques, which better reflect watershed functions.

In conclusion, GIS is used extensively in the field of watershed science. Opportunities will only increase as digital data becomes a widely, more obtainable source of information which are the core components to any watershed analysis. As positional accuracy of digital data increases and more detailed data sources are created, enhanced, and refined with minimal error, watershed analyses with the use of GIS will only predict more accurate results. GIS software is continuously becoming more efficient and capable of storing larger datasets for more complex analyses and overlays. The program is also developing a more user-friendly interface with the likelihood more companies and organizations will more readily adopt the software. This will greatly aid in resource management decisions, as the initial purchasing of the software and the training of personnel will greatly outweigh the risks of not using the software. Watersheds, communities, and the environment will benefit immensely as complex ecological and socioeconomic issues are approached and alternatives and solutions are designed due to the use of GIS software in watershed management.

**Literature Cited**
(In addition to the annotated bibliography)


Annotated Bibliography


GIS was used in conjunction with remote sensing and the AGNPS model to predict the agricultural runoff and sedimentation amounts in several sub-watersheds in Kansas, which drain into a drinking water supply reservoir during different rainstorm amounts. The AGNPS model has an ARC/INFO interface so data layers from ARC comprise the model. This model is used to predict the condition of a watershed as there are variations in the environment. Such data layers used include: digital elevation models, streams, soils, and conservation practices. In addition, rainfall amounts also need to be incorporated into the model, since the agricultural runoff from different storms were being assessed. Results from the study show the importance of landcover as a GIS layer and its value in watershed modeling. From the study it was shown the AGNPS model was quite accurate for smaller watersheds with less variation in rainfall. This study shows with GIS and remote sensing, watershed models can be developed with greater accuracy.


The creation of a WebL2W, which is a web-enabled spatial decision support system for a watershed in Roanoke, Virginia is discussed within this paper. The system uses economic, hydrologic, and fish health models to create a spatial decision support system to aid in watershed management decisions. The GIS-based system (ArcView 3.2) is online and includes three core components. These components of the system are the spatial data for watershed management, the GIS, and the creation of a GIS-based interface, allowing the user to enter data and receive the results as a model with Crystal Reports or Excel spreadsheets. Through this system the user has choices for the inputs and parameters they wish to have measured and the model they wish to run. User feedback forms are online for users to comment on the quality of the results they received. This paper gives insight into the future of GIS in watershed management with internet map servers, where GIS is performed on someone else’s server. Yet, while this may be a more user-friendly atmosphere to GIS, there is also the aspect that the user needs less knowledge and understanding of the computer program. However, this is an extremely useful concept to be applied to other watersheds, despite the initial set up of the system requiring much effort.


The American Society of Civil Engineers formed a committee in 1999 to evaluate GIS modeling and the paper summarizes their findings. This paper was written to aid first
time users of GIS and it was written especially for hydrologists to help in the selection of
digital data and to describe certain GIS applications. The report gives a detailed
overview and description of available GIS data, such as general data structure, data
projection, and different data sources. For example, the paper focuses on relevant
digital data necessary for creating watershed models such as digitized stream data,
soils, precipitation, and digital elevation models. Remote sensing is discussed and the
wide variety of available data for watersheds such as land use/land cover, snow,
and surface temperature. An extremely useful topic to watershed modelers is the description of hydrographic data obtained from digital
elevation models by automated extraction with GIS software. Such data includes
channel networks, drainage divides, and surface drainage information which are core
components to watershed management. This paper is extremely beneficial as a
reference source for every individual involved in the watershed field.

Island’s watersheds on multiple scales. Human and Ecological Risk Assessement
7 (5): 1483-1491.

The uses of GIS in the Pawcatuck watershed of southern Rhode Island to display water
quality in a map format is discussed within this paper. The Pawcatuck watershed
contains sixty percent of the state’s rare plant and animal species due to the availability
of diverse wetland habitats. Within the article is the discussion of steps taken to create
GIS maps. These steps include showing a layer of natural resources at the state level.
Next, collateral data is added such as a digital elevation model, land use, and geological
information, and then the final overlay of water quality is added. The paper was written
to describe GIS with the use of overlays and the importance of visual maps to obtain
results for watershed management purposes. Therefore, the fundamentals and basic
theories of GIS are demonstrated. This is a great paper for first time users of GIS to
understand the basic role GIS has in natural resource management.

distributed watershed models. II. Modules, interfaces, and models. Journal of

This is a very beneficial paper on the uses and applications of GIS in modeling
watersheds. It is very helpful to engineers and companies wanting to incorporate GIS
software which deals with hydrology into their professions. A section on GIS
implementation and management is even discussed. Past literature on the uses of GIS
in watersheds was reviewed and serves as the basis for the report. Such aspects of GIS
which were discussed include ARC/INFO GIS, GRID, and GRASS. In addition to spatial
analyses there is also a realm of mathematical models for watersheds such as the
GIS/HEC1 Interface Module and the HEC-GeoHMS, where GIS is initially used to
prepare the data before statistical analyses are run. The paper also discusses modeling
programs not associated with GIS as built in programs or extensions, but operate as
separate systems which are compatible with GIS formats. Also included in the paper is
an overview of models developed by different agencies, which describe the models’
connections and roles to GIS and watershed hydrology. This paper serves as an
excellent reference source on GIS and modeling information and creates a foundation
for understanding and incorporating GIS into watershed management.

This article focused on the effects different types of land use have on surface water quality due to runoff at both a regional and local scale. ArcView GIS and statistical methods were used to evaluate several land use study sites and their effects on watersheds in Ohio. Specific watersheds selected in Ohio had historical data on water quality, elevation, climate, land use, and water flow so the watershed could be examined at certain periods in time. GIS was widely used in the data preparation and vast ranges of functions were employed before statistical tests were run. For example, shapefiles were created for past water quality monitoring stations by referencing these locations with an Avenue Program. In addition, a watershed modeling tool, the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) was used to predict the health of the watershed under specific conditions. In conclusion, some watersheds were found to be contaminated with high levels of nitrogen, phosphorus and Fecal coliform bacteria which were in close proximity to urban and agricultural lands. This study is a prime example of how GIS is used in conjunction with modeling programs, such as BASINS, to aid policymakers in predicting the effects land use will have on watersheds. Watersheds with historical data on land use and water quality will especially benefit from making future predictions on the health of their watershed by incorporating past relationships between these two crucial factors which comprise watershed management.


This paper focused on watershed conservation by incorporating landowners in the development of a management plan in the Higganum Creek watershed in Connecticut. Hardcopy maps using GIS layers of forest cover taken from satellite imagery and stream data were produced. Land ownership parcel data was overlaid on the two GIS layers. Landowners were contacted who owned 10 acres of more of land within the watershed and were issued a survey on their land conservation philosophies and whether they would be interested in developing a forest conservation plan for their property. The paper gives several suggestions to increase the number of landowners responding to the survey. This study shows the human dimension side to watershed management and its need to be further incorporated into watershed conservation plans. Land trust organizations would find this study extremely beneficial for their work on acquiring lands into their system. Few watershed management studies focus on the human interaction aspect to natural resource management.


The focus of this paper was on non-point source pollution in surface water from agricultural pesticides on watersheds in Italy, where the predicted environmental concentration (PEC) was measured. GIS studies in the past have included entering data into GIS, placing the data into a model in another program, and then placing the model output back into GIS. This study does the modeling of testing agricultural chemicals in
surface water directly in GIS. The modeling approach taken was one of efficiency with the least number of steps to obtain results. Several submodels, which were pesticide drift into the watershed and runoff, composed the main model. A great emphasis of the paper was on the equations devising the submodels. However, a worse case scenario approach was taken when creating the submodels, therefore the results will be based upon this. Overall, the study gave insight into the future of GIS and watershed modeling for obtaining results in a faster and more efficient manner.