# National Conference on Environmental Problem Solving with Geographic Information Systems

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# GIS Uncertainty and Policy: Where Do We Draw the Twenty-Five Inch Line?

James E. Mitchell, Kansas Geological Survey, The University of Kansas, Lawrence, KS

The growing availability of both improved hardware and software for GIS has outstripped most user's ability to identify and represent uncertainty in the available data. In practice, the proliferation and compounding of errors and uncertainty are increased as information becomes more easily handled and combined from different sources.

Errors and uncertainty are generated at various stages of GIS database development and processing. In most cases, the inherent uncertainty from source data is simply ignored and its nature eventually lost through subsequent processing. Both the location of features and their attributes can contain errors and uncertainty. By the time decision makers are presented the information, it is typically represented as correctly located and attributed. The use of weather and climate information provided by the National Climatic Data Center (NCDC) is a clear example of this scenario.

Weather station locations provided by NCDC are reported to the nearest truncated degree-minute. A minute is 1/60th of a degree of arc. In the center of the continental United States, one minute of latitude averages approximately 6,000 feet, and one minute of longitude averages approximately 4,800 feet. Thus, the station location is only known to lie within a box of approximately 1 square mile. Map representations of these data should reflect this uncertainty.

Under the Municipal Solid Waste Landfill Criteria (MSWLF), the U.S. Environmental Protection Agency has dictated that the 25-inch precipitation line be used as a regulatory boundary for the level of protection required at municipal landfill sites. How these lines are created and interpreted has important policy implications. Indeed, the cost and practicality of a given location must take this into account. If the 25-inch precipitation figure is critical, characterizing its uncertainty is also important.

This work outlines a Monte Carlo procedure to represent the uncertainty in contour lines generated from point data with known locational uncertainty. The 30-year normal precipitation data for Kansas are used as an example. The results of this study are compared to the 25-inch contour used for regulation in Kansas. The differences are significant, their implications and origin are discussed.

# Developing and Using Interpretive Hydrogeologic Maps

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The need for predicting specific hydrogeologic conditions (i.e., aquifer vulnerability to contamination), combined with the increasing availability of computerized mapping software, has led to the widespread development and use of interpretive hydrogeologic maps. Many of these maps have been developed using custom methods for specific projects. Others have been developed using published techniques. The objective of this paper is to discuss a generic method for developing interpretive hydrogeologic maps that will ensure that the method used in developing the map does not incorrectly combine the selected data layers. In addition, insight will be provided as to specific issues that should be addressed in the use of any interpretive map.

To ensure the accurate development of project-specific models/maps, several important factors must be considered. The scales of the source maps must be known, and the smallest scale must be used to constrain the final map scale. Scale-independent data (e.g., point data) must be used with regard to the resolution it contains. The accuracy and/or quality of source data must be known, particularly when factors are combined and use limitations are determined. The intended use of the final product must be one of the considerations controlling which data are used, how data are combined, and how the final product should be interpreted. The methods used to combine the data layers should be carefully selected. Different data types and intended uses have different methods that should be used to combine the data layers. The selection of the correct method both simplifies the process and ensures that the integrity of the final output will be consistent with the intended use. Interdependent factors must be identified, together with the degree of their interdependence. This will ensure that the factor combination methods use appropriate factor weights. An understanding of the hydrogeologic generalizations incorporated in the final product is necessary to ensure that the product remains consistent with the intended use. Emerging techniques of integrating ground-water flow and contaminant transport modeling with GIS-based computer mapping must be conducted with expertise from both fields, or the integrity of the output could be compromised.

There are several key issues regarding the use of interpretive maps. The collective set of source data limitations, hydrogeologic generalizations, and methods of factor combination must be considered when determining the utility that any map product will have. For example, regional hydrogeologic maps are being used for site-specific purposes in some regulatory situations. This can lead to unexpected discrepancies between what geologic sequences appear to be mapped, and what sequences are found at any given point. When properly constructed and used, interpretive hydrogeologic maps can be a useful tool for ground-water resource protection.

# "You Can't Do That With This Data" or Uses and Abuses of Tap Water Monitoring Analyses

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Over the past approximately ten years, there has been a rapid expansion of drinking water monitoring requirements under the Safe Drinking Water Act. Coupled with growing public and governmental interest in the health effects of the increasingly large number of inorganic and organic contaminants, this makes the aggregation and consolidation of this data for systemization and visualization seem highly desirable from many viewpoints. The GIS approach would seem to be a logical and powerful medium for using this data for a variety of important tasks.

At the largest scale, the problem of uniformity of water sources arises. Many water systems do not distribute water of a single chemical or physical quality, let alone from a single inlet, into the water system.

At the smallest scale, the concentrations of a variety of inorganic constituents of likely regulatory, aesthetic or health interest are not a simple function of water quality from the treatment plants. Some metals, like lead and copper, do not usually even enter the water until a consumer's house, and even within that house, the constituents display significant variability by location and over time. This largely unappreciated phenomenon renders many of the published attempts to make correlations between some apparent effects and water constituent concentrations uncertain because of a flawed sampling scheme.

Many constituents or parameters, such as pH, disinfection by-products, and chlorine residual species change throughout the distribution system because of slow chemical reactions or chemical reactions with the pipe itself.

This presentation introduces the non-specialist to important concepts in what controls the concentrations of metals and other constituents of interest in drinking water, how apparent levels of constituents are affected by the sampling protocol, and the magnitude of temporal and spatial variability present in both municipal and private water supplies. These examples show how limited generalizations may be, and how the data input into a GIS for interpretation and evaluation must be carefully analyzed and screened to determine the appropriateness for various well-intended purposes.

# Wetlands Mapping and Assessment in Coastal North Carolina: A GIS-Based Approach

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The North Carolina Coastal Management Program (CMP) is well known for its effective protection of tidal wetlands. The program, however, lacks policy and regulatory authority for non-tidal wetlands protection. A primary component of the CMP is the land use planning process where local governments are required to recognize the importance of wetlands in their land use plans. Many local governments, however, often lack the resources necessary to incorporate comprehensive wetland information into these plans. The State of North Carolina has begun to address the issues of wetland protection and management, but no information base currently exists for decision-making or policy development. The Division of Coastal Management (DCM) has, therefore, established a wetland mapping and functional assessment effort for the twenty counties which fall within the agency's jurisdiction. Data will be distributed to local planning and tax offices upon completion.

Digital overlays of 1:24,000 scale National Wetlands Inventory (NWI), detailed soil lines and satellite imagery (LANDSAT Thematic Mapper) are used to produce wetland maps in the coastal area. DCM has initiated mapping in Carteret county and has tested several classification schemes using different combinations of NWI type, soil type and land use. The resulting wetland maps have undergone both field and aerial photo verification. Where data do not currently exist, DCM is working with the North Carolina Center for Geographic Information and Analysis and other agencies to ensure their availability in the near future.

This inventory of wetland location then becomes the basis for GIS-based analysis of the ecological function of each wetland on the landscape. DCM has incorporated the results of much research as well as the professional opinions of many experts into the procedure. The procedure is based on watershed analysis and divides wetlands into hydrogeomorphic and vegetative cover wetland types. Functional parameters within the assessment include wetland type, size, soil characteristics, and landscape characteristics. Some of these landscape characteristics include watershed position, water sources, land uses and landscape pattern. Parameters are combined to assess the wetland's role in performing water quality, hydrological and habitat functions as well as the ecological risk of removing the wetland from the watershed. Functional ratings are then combined into an overall assessment of ecological significance.

Challenges have been encountered throughout this process, including choice of classification regime, choice of satellite filter (if any), methods of technology transfer, and development of AMLs. We also have confronted problems of scale and users who wish for details that push the limits of the data standards.

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Field verification by an interagency team (State and Federal) has shown reliable assessment results. In addition, overlays of US Army Corps of Engineers wetland delineation boundaries have closely approximated the DCM wetland boundaries. Such tributes to the assessment procedure have been promising, hence encouraging DCM to develop additional uses for this information. The assessment information will next be the basis of wetland restoration site selection. With minor modifications to reflect local conditions, the procedure also may be useful in other areas.

# The Watershed Assessment Project: Tools for Regional Problem Area Identification

Christine L. Adamus, St. Johns River Water Management District, Palatka, FL

The Watershed Assessment is a GIS project designed to identify surface water problems and issues in the St. Johns River Water Management District (District), Florida. It is a collection of screening tools which addresses three of the District's responsibilities: flood protection, surface water quality management, and ecosystem protection.

The District is one of five Florida water management districts. It includes all or part of 19 counties in northeast Florida and covers 12,400 square miles. Each water management district is developing a District Water Management Plan, which will provide long-range guidance for the resolution of water management issues. One of the first steps in the plan is a resource assessment. The Watershed Assessment was designed to address the type of District-wide resource assessment questions that can only be adequately answered using a GIS.

The flood protection component of the Watershed Assessment will utilize Federal Emergency Management Agency Flood Insurance Rate Maps, and existing and future land use. This component is currently in the data collection phase. The other two components have been completed.

The surface water quality component consists of:

- a water quality data analysis
- a nonpoint pollution load model, which estimates annual pollutant loads to surface waters from stormwater runoff
- an assessment of potential threats to springs' water quality

The ecosystem protection component relies on a statewide critical habitat identification, conducted by the Florida Game and Fresh Water Fish Commission. This data was revised to more appropriately address the objectives of the Water Management District. The District is using this information to identify regionally significant habitats and then evaluate what must be done to protect these areas.

With this information, planners can evaluate options for addressing problems within each of the District's major basins and recommend a plan of action.

# Riparian/Wetland Corridor Planning With GIS

Margaret A. Fast and Tina K. Rajala, Kansas Water Office, Topeka, KS

The Kansas Water Office (KWO) was awarded a grant from the Environmental Protection Agency to develop a GIS Decision Support System (DSS) that would enable the state to add to its capabilities to manage riparian/wetland corridors. The objective of the project was to make use of GIS to assess the value and vulnerability of the riparian corridor, allowing the user to evaluate a corridor segment and compare between segments, prioritizing or targeting segments for further planning activities. The Neosho River basin in Kansas was used as a pilot to demonstrate the feasibility of the concept.

A variety of databases necessary for evaluating the value and vulnerability of riparian/wetland corridors were made operational in ESRI's ARC/View software environment. The extent of the DSS project was limited to the riparian corridor along the mainstem of the Neosho River and its major tributary, the Cottonwood River. The costs associated with the development of riparian corridor segments for all perennial waters in the Neosho basin was far greater than the funding available. The Soil Conservation Service 11-digit Hydrologic Unit Code (HUC11) watersheds were utilized where possible as the basis for data base coverages.

Several important lessons were learned during the project. The importance of communication between the program professionals and the GIS technicians may be utmost. Definition of the application up front is a necessary part of facilitating this communication, as well as assuring the development of a product which is useful.

The DSS will be used by the KWO to help target sensitive areas in the Neosho basin for further planning activities. The implementation of planning objectives may involve other state agencies, local units of government, and ultimately, private landowners.

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# Small Is Beautiful: GIS and Small Native American Reservations— Approach, Problems, Pitfalls, and Advantages

Jeff Besougloff, Upper Sioux and Lower Sioux Indian Communities, Redwood Falls, MN

The Lower Sioux Indian Reservation consists of 1,754 acres in southwestern Minnesota. Despite its small size, the reservation is subject to the same federal rules and regulations as larger reservations and, to some degree, states. With a staff of one in its Office of the Environment and limited funding, the burden of complying with government mandates, managing resources, and performing planning activities across the spectrum of environmental media is an unmanageable task. The development of the Lower Sioux GIS is in response to the need for access to a wide variety of information for tribal leaders and planners in environmental media, as well as for economic development purposes. While this is the type of problem GIS is designed to alleviate, developing a system to meet small government or business needs and obtaining the systems are different projects than for a large government unit.

Development of the Lower Sioux GIS is ongoing and has resulted in the recognition of many problems unique to small government units wishing to use a GIS. Such unique problems have resulted in several innovative, and hopefully successful, solutions. The presentation is geared toward expressing the idea that the project (GIS development) can be completed and ways in which completion can occur for small governments and businesses in a world oriented toward the large-scale GIS user.

The Lower Sioux GIS system is a networked PC station through the Bureau of Indian Affairs (BIA) Geographic Service Data Center mainframes in Lakewood, CO, using Arc/Info software. Funding and training has come through several sources and joint agreements with the BIA, U.S. Environmental Protection Agency and Administration for Native Americans. It is hoped that data input will soon include use of a portable Geographic Positioning System (GPS).

# Facilitation of Water-Surface-Profile Computations by Use of a GIS

Ralph J. Haefner, K. Scott Jackson, and James M. Sherwood, Water Resources Division, U.S. Geological Survey, Columbus, OH

Water-surface profiles computed by use of a step-backwater model such as Water Surface PROfile (WSPRO) are frequently used in insurance studies, highway design, and development planning to delineate flood boundaries. Horizontal and vertical coordinate data that define cross-sectional river-channel geometry are required input for the WSPRO model. The cross-section data and other hydraulic data are manually coded into the WSPRO model, a labor-intensive procedure. For each cross section, the output from the model is used to approximate the flood boundaries and high-water elevations of floods with specific recurrence intervals (for example, 100-year or 500-year). The flood-boundary locations along a series of cross sections are connected to delineate the flood-prone areas for the selected recurrence intervals.

In order to expedite the data collection and coding tasks required for modeling, the GIS, Arc/INFO[1], was used to manipulate and process digital data supplied in AutoCAD Drawing Interchange File (DXF) format. The DXF files, which were derived from aerial photographs, included 2-foot elevation data along topographic contours with +0.5-foot resolution and the outlines of stream channels. Cross-section lines, located according to standard step-backwater criteria, were digitized across the valleys. A three-dimensional surface was generated from the 2-foot contours by use of the GIS software, and the digitized section lines were overlaid on this surface. Intersections of contour lines and the cross-section lines were calculated by GIS software and provided most of the required cross-sectional geometry data for input to the WSPRO model. Most of the data collection and coding processes were automated, resulting in a significant reduction in labor costs and human error. In addition, maps at various scales can be easily produced as needed after digitizing the flood-prone areas from the WSPRO model into the GIS.

[1]Use of trade or product names is for identification purposes only and does not constitute endorsement by the USGS.

# Data Quality Issues Affecting GIS Use for Environmental Problem Solving

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Various groups, including local, state, and federal government agencies, use a GIS to help them analyze and make decisions about environmental problems. A GIS can help decision makers use spatial information more fully than manual methods allow, but there are times when data quality issues make the use of GIS-generated outputs questionable. If environmental decisions are made based on "inaccurate" data, an erroneous decision may be made, public confidence may be eroded, or an agency may incur liability.

This presentation is designed to encourage decision makers to become more aware of data quality issues to enable them to better assess the effect of error on their intended usage of GIS data. The sources and effects of error in data acquisition, input, storage, analysis/manipulation, and output will be discussed, as well as techniques that are used to measure and report error. Data acquisition errors, such as errors in position and attribute, occur because of measurements errors; classification problems, and available data was collected at the wrong time, at the wrong scale, or for a different purpose. Data input errors frequently originate from digitizing data and can include equipment and personnel errors, and errors inherent in the source map. Data storage errors occur when data is stored at a higher level of precision than the source data. Data analysis/manipulations errors include logical inconsistency between data layers, error introduced by converting vector to raster and raster to vector data, map overlay, generalization, and other analysis functions such as slope and viewshed. Output errors occur because maps are produced that impart a false sense of accuracy and conventional symbols and colors may not be used.

# Development of Landscape Level Habitat Units Using Multi-Temporal/ Multi-Scale Remote Sensing and Ancillary Landscape Data for a Biodiversity Assessment for the Central Appalachians

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Sue Perry, U.S. Department of Interior, National Biological Survey, West Virginia Cooperative Fish and Wildlife Research Unit, West Virginia University, Morgantown, WV

Gap analysis can be defined as the search for "gaps" in the current landscape biodiversity protection system for a given region, state, country, or the entire globe. The "Gap Analysis" method uses natural vegetation and other landscape indicators of available habitat, together with indicator species, as surrogate indicators of biological diversity. Though not a substitute for detailed species by species surveys, it can provide a first-cut focus and direction for regional conservation efforts. Gap studies can provide initial data, as well as a long term usable framework into which more detailed surveys can be nested for identifying specifically needed biodiversity management areas.

The West Virginia Gap Analysis Project has been underway since 1991. The project is focusing on developing a comprehensive landscape-level biodiversity data base for the vertebrates of West Virginia. A major focus of the research is on developing habitat models for predicting species composition and potential ranges over the various landscape types of West Virginia. Gap analysis methodologies recognize that cost alone precludes state-wide, traditional intensive field inventory and monitoring. Therefore, mapping of major vegetation types and other landscape structural components is the major focus of Gap data gathering efforts. Satellite data, in conjunction with other landscape level data, such as slope/aspect, elevation, soils, hydrology, watersheds, rainfall, and temperature, are being utilized to complete vegetation structure analyses, as well as the development of integrated landscape or ecological units mapping. The project is presently focused in a 50,000 ha. pilot study in the central Appalachian highlands, because this area contains numerous species of special concern and vegetative communities, such as spruce-fir forest types, that appear to be responsive to climatic and soil chemistry changes.

# An Investigation Using GIS To Assist in Aquatic Macrophyte Management for Legend Lake, Menominee County, Wisconsin

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Stevens Point, WI

GIS' primary use in recent years has revolved around land management and issues ranging from urban to rural, range land to forest management, and mining operations to park systems. Few studies in GIS applications have been applied to the aquatic realm, namely lakes. With cooperation from the Wisconsin Department of Natural Resources and the Menominee Indian Tribe of Wisconsin, an evaluation of GIS on its ability to manage lake data was undertaken. The objectives of this subproject centered around, but were not limited to, the evaluation of GIS and its capabilities as a tool to help determine aquatic plant distributions throughout the lake. This subproject was part of a more comprehensive study that was performed on this particular lake between 1992 and 1994, where sampling was performed on the sediment, plant, and water aspects; GIS would be evaluated on its ability to link all data from the study together. The primary focus for the GIS phase of the project was to develop an efficient means to visually represent aquatic plants in map form and provide a means for spatial analyses to assist lake managers in determining plant distributions and developing effective weed management/harvesting programs. It is hoped that by using efficient sampling techniques and appropriate statistical analyses, GIS will allow for several different dimensions of visualization that will allow lake managers to keep separate the critical habitat areas of fisheries and wildlife from the areas more prone to human interaction.

# GIS-Assisted Riparian Characterization and Temperature Modeling of the Upper Grande Ronde River Basin in Northeast Oregon

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John P. Craig, Tetra Tech, Inc., Fairfax, VA

Jim Staley and Mark Flood, U.S. Army Corps of Engineers, Fort Belvoir, VA

Liz Porter, Office of Policy, Planning, and Evaluation, U.S. Environmental Protection Agency, Washington, DC

David Chen, Environmental Research Laboratory, U.S. Environmental Protection Agency, Athens, GA

Bruce McIntosh, Department of Forest Science, Oregon State University, Corvallis, OR

Widespread alteration and/or removal of riparian vegetation elevates summer water temperatures; this in turn affects the ability of many northwestern rivers to sustain a healthy coldwater ecosystem that includes annual salmon runs and resident salmonid populations. Temperature impairment occurs because of reduced shading of the stream channel and riparian zone and an increased channel width/depth ratio due to bank damage. The Upper Grande Ronde River (UGR) of northeastern Oregon is a temperature-impaired system that does not meet state water quality standards; over thirty monitoring stations have documented elevated water temperature patterns throughout the basin over the past three years, and salmonid populations are declining. Under the authority of section 303(d) of the Clean Water Act, the UGR may be the subject for development of a Total Maximum Daily Load (TMDL) for water temperature. TMDLs are developed to determine the reductions in stressor or pollutant loadings needed to bring about specific water quality improvements. In the UGR project, GIS are being used to analyze and model relationships between spatial environmental characteristics, solar radiation, shade, and elevated water temperature. Specifically, GIS is used to portray hydrologic and riparian conditions which influence water temperature, to analyze and measure riparian and other watershed characteristics, and to derive input data for a watershed simulation of temperature changes associated with various best management practices and riparian management scenarios. The watershed simulation uses the Hydrologic Simulation Program—Fortran (HSPF) which integrated the GIS information for parameters related to stream temperature through a model developed for this project, called SHADE. The GIS

and watershed modeling approach utilizes spatial data including the Digital Elevation Model (DEM) for topography, the Pacific Northwest Reach File for surface hydrography, the State Soil Geographic (STATSGO) database for soils, Oregon GAP analysis for generalized vegetative cover, and an airphoto-derived data layer representing riparian land cover in high detail. Generalized analysis of the basic GIS data layers provided a basinwide estimate of watershed characteristics affecting the temperature budget of the basin. A more detailed GIS analysis links riparian land cover characteristics and measurements to shading and temperature model components. The riparian land cover characterization process, which provided several parameters for the model, mapped a linear corridor extending outward 1,000 feet from each side of the UGR mainstem and perennial tributaries. This riparian GIS data layer contains information such as average tree height, canopy density, wetlands, land uses, and vegetation classes. GIS is also being used to derive additional model parameters from this data layer, including riparian forest offset, buffer width, and stream channel orientation, elevation, and slope.

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SESSION D-3: Wednesday, September 21, 4:00PM

# Verification of Contaminant Flow Estimation With GIS and Aerial Photography

Thomas M. Williams, Baruch Forest Science Institute, Department of Forest Resources, Clemson University, Georgetown, SC

Estimation of contaminant movement in ground water requires interpolation of data from sampling wells that represent a very small sample of aquifer volume. Spatial statistics and kriging were developed to improve confidence in estimation. Hurricane Hugo provided an opportunity to compare these estimations to actual forest mortality caused by salt water inundation associated with the tidal surge. During a period from 9-15 months after the hurricane, salt from the tidal surge moved within the shallow water table aquifer and resulted in widespread tree mortality on Hobcaw Forest in eastern Georgetown County, South Carolina. A small watershed (12.6 ha) was instrumented with 24 multi-level sampling wells. Piezometric potential and samples for salt concentration were collected for 12 months (18-30 months after the storm surge). Three-D estimations of flow directions and 2-D maps of chlorine (Cl) concentration were produced from this data. From these maps important heterogeneities were identified in the water table aquifer. Apparently, the infiltrated sea water moved to the bottom of the aquifer (5 meters) and was emerging, and killing the forest, where aquifer heterogeneity resulted in upward movements of ground water.

Georgetown County set up GIS for tax mapping in 1988 and prepared 1:4,800 orthophotographs of the entire county with true ground accuracy of < 2 meters. Color infra-red (IR) aerial photographs were taken annually after the hurricane using a Cessna 150. ERDAS GIS software and the accurate orthophoto base allowed removal of scale irregularities and distortion resulting from using the small aircraft. Scanned images, using a 3 meter pixel, were compared to kriged Cl concentration maps also using a 3 meter cell size. Grid cells with estimated Cl concentration of > 750 mg/liter also exhibited low reflectance in the IR enhanced color photos, indicating tree mortality.

In this case ground-water movement of a contaminant (NaCl) was accurately predicted by a relatively small number of sampling wells and verified by GIS and remote sensing. The criteria for success in this case were: 1) a soluble non-reactive contaminant, 2) an environmental reaction to the contaminant that could be remotely sensed, and 3) a highly accurate base that allowed correlation of the photography to the well data.

# Taking a GIS Into the 3rd and 4th Dimensions To Solve Ground-Water Remediation Problems

Dennis R. Smith, Dynamic Graphics, Inc., Bethesda, MD

Many aspects of ground-water remediation projects involve dealing with geographic data that exists in 2, 3, and 4 dimensions. For example, one component of such a project requires that the site be characterized to determine the extent of the contamination, its movement, any potential risks posed to humans or the environment, and possible remediation actions. Site characterization would normally involve studying data, such as surface features, geology, soils, surface water hydrology, hydrogeology, meteorology, land use and ecology.

Typical GIS functionality limits the user to the 2D mapping world, and this limitation can compromise a project's analysis and decisions. As an example, in resolving ground-water remediation issues, it is critical to develop an acceptable description of the contamination sources, the nature and extent of the contaminated soils and ground water, and the possible movement of the contamination. Traditional 2D mapping tools allow the scientist to develop base maps, contour maps, and cross sections from the data. Limiting the view to these 2D images forces the human mind to form an accurate 3D image of the geometric extent of these phenomena. One hydrogeologist has stated that by using a true 3D system they can analyze a site in 1/10th the time it takes using traditional 2D tools.

This paper will show how a multi-dimensional geospatial program was combined with a traditional GIS to provide valuable linkages between the data base, the GIS functions, 3D modeling and visualization, and ground-water predictive modeling and display. Application areas include site characterization, risk assessment, remedial investigations, feasibility studies, and remedial design and implementation.

Case studies will be presented of successful applications at Department of Defense locations, including a U.S. Environmental Protection Agency Superfund site, and work being done with the Department of Energy's Expedited Site Characterization Project. Descriptions of derived benefits will include: reducing the number of monitoring wells, communicating with the regulators and the public, verifying ground-water models, locating data busts, and evaluating proposed remedial actions.

# Use of a GIS To Estimate Ground-Water Availability in West Central Georgia

Bruce J. O'Connor, William H. McLemore, and Victoria P. Trent, Georgia Geologic Survey, Atlanta, GA

The five county area of west central Georgia, which includes Polk, Carroll, Haralson, Paulding, and Douglas counties, currently faces potential water shortages during drought conditions and additional water supplies will be required to accommodate future population growth. In order to supplement the water supply, the five county area is currently under consideration for a proposed regional reservoir system. As required for an environmental impact analysis being conducted by a private consulting firm, the Geologic Survey Branch of the Georgia Environmental Protection Division agreed to assess the potential ground-water supply in the area as an alternative/supplement to the proposed reservoir. The purpose of the reconnaissance-level investigation was to (1) estimate the general size of the ground-water resource that would be available to potential municipal and industrial users, as well as to (2) identify general areas that would be favorable for exploring high yielding well sites so that local governments could concentrate their well location studies in these areas. Delineation of areas favorable for exploration for high yielding wells was completed using GIS thematic overlay analysis methods. The total volume of potential ground water available in the area was estimated using "capture zone analysis" methods. Hydrogeologic, environmental, and demographic factors considered in the course of the study include slope, soils, geology, lineaments, wetlands, population density, potential sinkhole development, springs with a high discharge rate, and anthropogenic point source pollution sites. GIS overlay analysis was completed by ranking geologic units, soil units, slope units, population density units, and lineament analysis according to favorability for drilling high yielding water wells. All databases were overlaid and a total favorability score was calculated, with areas having the highest score considered most favorable for drilling high yielding wells. Potential anthropogenic pollution sites were buffered with appropriate distances to ensure safety, and the buffered areas were eliminated from further consideration for exploration. The remaining areas were categorized as least favorable, moderately favorable, or most favorable for ground-water exploration, based on the favorability score calculated in overlay analysis. Estimation of ground-water resource was made based on the total area of the areas considered most favorable for exploration, using capture zone analysis. The estimated total ground-water resource available in the 5 county area was 67.4 mgd supported by 317 wells. In addition, springs with a high rate of discharge could augment the ground-water supply by approximately 16.8 mgd.

# A Watershed-Oriented Database for Regional Cumulative Impact Assessment and Land Use Planning

Steven J. Stichter, Division of Coastal Management, State of North Carolina, Raleigh, NC

The North Carolina Division of Coastal Management (DCM) is using a GIS and GIS-produced data to support a regional assessment of relative risk of cumulative impacts of development. The goal of this effort is to locate portions of the coastal area that are at high risk of cumulative impacts of development due to existing stressors, rapid growth or a concentration of sensitive resources. The units of analysis chosen for this assessment are the small watersheds (5,000-50,000 acres) recently delineated for the State of North Carolina by the Soil Conservation Service; 348 of these watersheds fall either wholly or partially in the North Carolina coastal area. Three primary reasons drove the decision to use watersheds units: many of the natural resource concerns of the region are water dependent; watershed units facilitate connections to the state's whole-basin river planning; and the relatively small size of the watershed units allow for sufficient contrast across units.

The information gathered for this assessment ranges from terrestrial and estuarine natural resource information to demographic, housing, and economic indicators. Source data were gathered from a large number of agencies and reports; the information brought into the database came from a correspondingly wide variety of formats and reporting units. Coastal management's GIS was used to reapportion all components of the database to the watershed units.

A number of other uses of the GIS database are becoming increasingly important. These include better information for use in development permitting decisions and a greatly increased ability of DCM to serve as an information source for local land use planning. Further work must be done to make the database and methods developed for a regional assessment appropriate to local-level applications.

The purpose of this paper is to describe the programmatic context into which DCM's GIS fits, as well as database creation and data analysis for both the regulatory and land use planning programs. Primary concerns include integration of data from a variety of sources and scales and convincing planners of the usefulness of watershed units to county or municipal land use planning and water quality protection.

# Watershed Stressors and EMAP Estuarine Indicators for South Shore Rhode Island

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The U.S. Environmental Protection Agency has initiated the Environmental Monitoring and Assessment Program (EMAP), a nationwide ecological research, monitoring, and assessment program whose goal is to report on the condition of the nation's ecological resources. During the summer time period in 1990-1993, data were collected from approximately 450 sampling locations in estuarine waters of the Virginian Biogeographic Province (mouth of the Chesapeake Bay to Cape Cod). Sampling stations during this period were located in the coastal ponds and coastal area of southern Rhode Island. One of the objectives of EMAP is to explore associations between indicators of estuarine condition and stressors in the watersheds of the sampled systems. Extensive watershed information for southern Rhode Island is available in GIS format. Watershed stressors along south shore Rhode Island are compared with EMAP indicators of estuarine conditions using GIS analysis tools. The indicator values for coastal EMAP stations are associated with all of the aggregated south shore watershed stressors. The coastal pond indicator values are associated with stressors in individual watersheds for each coastal pond. For the total south shore watershed, the major land use categories are residential and forest/brush land, followed by agriculture. Closer to the coast, residential land use appears to be greater, while further from the coast, forest/brush lands are larger. Population increases dramatically with distance from the coast, but population density does not appear to be a function of distance from the coast. All of the coastal EMAP stations with data exhibit nondegraded benthic conditions, indicating no widespread problems. The individual coastal pond watersheds provide an east-west perspective, as compared to the south-north perspective with the distance from the coast. For the individual watersheds, the major land use categories are residential and forest/brush land. The population increases dramatically from west to east; population density shows an increasing trend from west to east. The only degraded benthic condition EMAP station exists in Pt. Judith Pond, which is associated with the high population density in this watershed. The degraded benthic condition appears to be due to organic enrichment.

# Design of GIS To Compare Wetland Impacts on Runoff in Upstream Basins of the Mississippi and the Volga

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The comparison of wetland hydrological functions in headwaters of the Mississippi (USA) and the Volga (Russia) could provide us with credible information as to how alternative management strategies impact runoff, peak flow, and water quality under changing climates. The macro scale "field experiment" in both areas, having close natural similarity, is already underway. Wetland conservation versus drainage is now the prevailing policy in the Upper Mississippi basin. Economic problems in Russia have prevented this policy from becoming a priority. Peat mining, reservoir construction on lowlands and drainage for farming and private gardening are common.

The project, funded by the National Science Foundation, is aimed at the development of a multi layered hierarchical base of GIS data for headwater watersheds of the Mississippi and the Volga; comparative analysis of wetland impacts on hydrology of the rivers; studies of wetland functions under climate change and variable strategies of wetland conservation; defining criteria and thresholds for wetland system stability with regard to flood risk and water quality; outlining recommendations for wetland management in the headwaters. The methodology, linking GIS with hydrological models, was already tested in the wetland study project at the Voyageurs National Park, Minnesota. The ARC/INFO GRID module was used to derive watershed variables for input to Agricultural Nonpoint Source Pollution (AGNPS), a cell-based runoff model that estimates water volume, peak flow, eroded and delivered sediment, chemical oxygen demand, and nutrient export from watersheds.

The questions addressed in the project are:

1. How does the extent and positioning of wetlands affect runoff and peak flow?
2. What are the relationships between the distribution of wetlands and other land areas, to flood risk and water quality under variable climate conditions?
3. What role do wetlands play for entrapping pollutants and sediment deposition?
4. How can criteria be developed for wetland conservation in headwaters, which will ensure environmental sustainability and multiobjective resources use?

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The methodology for comparative assessments involves hydrological models, GIS, and remote sensing. Representative watersheds in both basin areas are studied in detail, and procedures for scaling information from local to regional levels will be developed.

# GIS Techniques Applied to the Hydrogeological Characterization of a U.S. Department of Energy Facility in Northeastern Illinois

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Argonne National Laboratory (ANL) is a U. S. Department of Energy (DOE) research and development laboratory located about 25 miles southwest of Chicago, Illinois. ANL began operating in the late 1940s and today conducts a broad program of research in the basic energy and related sciences (physical, chemical, material, computer, nuclear, biomedical, and environmental). The hydrogeology of the 1,700-acre ANL site has not been studied extensively since the early 1960's.

This paper describes the data requirements, approach, and challenges in developing a workable GIS framework for the current hydrogeological characterization of the site. The use and application of black-and-white and color infrared aerial photographs, hydrogeological data, and land use information which span a 50-year period are discussed. Due to the variable quality and coverage of the available data, a practical focused approach to applying GIS techniques at a relatively small (i.e., local) scale is emphasized.

The objectives of the sitewide hydrogeological study are:

- Adequate characterization of the bedrock surface topography, glacial stratigraphy, and upper aquifer (fractured dolomite) across the site.
- Improved understanding of the occurrence and movement of ground water in the glacial till and dolomite aquifer, and the degree of hydraulic interconnection of the major hydrostratigraphic units.
- Determination of the present-day piezometric surface of the dolomite aquifer.
- Characterization of ambient ground-water quality.
- Accurate modeling of the ground-water flow system to enable the design of an effective sitewide monitoring well network.

# Geologic and Ground-Water Resource Evaluation of Will and Southern Cook Counties, Illinois, Using a GIS

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We discuss the role of the geologist in the design and implementation of GIS mapping projects in ground-water resource studies. Focusing on a specific mapping project helps to clarify the steps and thinking needed to complete the study. Geologic mapping techniques are incorporated into many projects that utilize the GIS. Although the GIS is a powerful tool, consideration must be given during project design and implementation to the abilities and limitations of the software. Project geologists must be able to interact with the GIS staff to make experience-based decisions. Familiarity with and actual use of the software is crucial in understanding the capabilities and drawbacks of computer mapping. The integrity of the data must be reviewed, limits on mapping extent must be made, and the level of detail in the mapping has to be determined so that the final product fulfills the needs of the end user, while maintaining the validity of the mapping.

As an example, a ground-water resources investigation for two northeastern Illinois counties was completed using computer mapping and GIS software. The project, initially conceived as a standard subsurface mapping project, was revised during the data collection stage to use the capabilities and features of a GIS. Approximately 10,000 records were initially critically evaluated in the creation of the basic data set used in the construction of the geologic maps. Five thousand well records were included in the preliminary database. Basic well information was entered into a PC-based spreadsheet. Selected items included well identifier, surface elevation picked from topographic maps, thickness of glacial drift, and depth to top and bottom of sand and gravel layers. An additional data set provided information on the thickness and extent of a dolomite aquifer.

Numerous data checks were then performed by staff. The geologists reviewed thicknesses and elevations of the units and resolved inconsistencies in the data. Preliminary mapping allowed for geologic review of the data so that wells with poor or highly inaccurate descriptions could be eliminated from the database. The extent of geologic units were defined and constrained based on previous mapping experience so that they could be better represented by the contouring software.

# Using GIS/GPS in the Design and Operation of Minnesota's Ground-Water Monitoring and Assessment Program (GWMAP)

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Minnesota's Ground-Water Monitoring and Assessment Program (GWMAP) is administered by the Minnesota Pollution Control Agency to evaluate baseline ground-water quality conditions regionally and statewide. The program uses a systematic sampling design to maintain uniform geographic distribution of randomly selected monitoring stations (wells) for ground-water sampling and data analysis. In 1993, GIS and Global Positioning Systems (GPS) technologies were integrated into GWMAP, automating the selection of wells and the field determination of well locations.

GWMAP consists of three components: the statewide baseline network, regional monitoring cooperatives, and a trends analysis component. In the statewide baseline network, Minnesota is divided into over 700,121 square-mile grid cells, each with a centralized, 9 square-mile sampling region. Within each target area, single-aquifer, cased and grouted wells are sampled for about 125 metals, organic compounds, and major cations and anions. We are currently finishing the second year of a five-year program to establish the statewide grid. When complete, the statewide baseline component will consist of about 1,600 wells representing Minnesota's 14 major aquifers.

In 1993, approximately 4,000 well construction records were selected for geologic and hydrologic review using a GIS overlay, from a database of 200,000 water well records maintained in the state's County Well Index (CWI). Three hundred and sixty-four wells were sampled and field located using GPS. The well selection process is semi-automated, using existing electronic coverage of Public Land Survey (PLS) data maintained in CWI, in conjunction with the digitized systematic sampling grid. The use of GIS has greatly reduced the time needed for selecting sampling stations. Coupled with the use of GPS, program costs have been reduced, allowing more resources to be applied toward sampling, while efficiency and quality of data have increased.

SESSION G-3: Thursday, September 22, 11:30AM

# The Design and Application of a GIS Data Base for the Analysis of Nonpoint Source Pollution in a Watershed

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The analysis of water quality management in watershed studies has utilized GIS technologies for over twenty years, with a variety of data base designs intended to solve and define the basic relationship between land use and water quality. Early efforts in the Lake Erie basin and other drainage systems, indicated that the analysis did not lend itself to a simple cause and effect equation, but rather required a detailed understanding of pollutant mass transport over the full range of hydrologic conditions. Even the definition of water quality was subject to the temporal and spatial variability of the natural system, which the GIS data base was designed to quantify. Through a series of related GIS applications in different drainage systems over a period of years, a body of experience has been developed in the analysis of water quality, even as our ability to create and manipulate spatial data for this purpose has dramatically increased.

A series of GIS applications in watershed analysis are briefly covered as background. The primary discussion centers on a recently completed study of the Upper Perkiomen Watershed of southeast Pennsylvania, a small (71 square miles) basin draining to a multi-purpose reservoir which has been eutrophic since its construction in 1958. The cause of this water quality degradation has changed over the past twenty years, from point source dominated, to nonpoint source (NPS) controlled, with 84% of the total annual phosphorus load presently produced by NPS. Recent research has designed a GIS to both analyze the magnitude and sources of this NPS pollution, and create a land management system to restore water quality within the drainage. The process by which this GIS data has been encoded, and the reasoning behind the inclusion of various elements, has been driven by an anticipated pollutant generation process and known Best Management Practices (BMP) control methods. The final management recommendations, however, concluded that other innovative solutions would be more effective in pollutant reduction.

# A GIS for Aquatic Resource Management and Protection for the Upper Ohio River Basin in Pennsylvania

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Douglas A. Neiman, RMC Environmental Services, Inc., Spring City, PA

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Thomas R. Proch, Pennsylvania Department of Environmental Resources, Pittsburgh, PA

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The Commonwealth of Pennsylvania (PA) successfully negotiated a $1.75 million settlement with Ashland Oil Company for injuries to aquatic natural resources resulting from the January 1988 oil spill into the lower Monongahela and Ohio Rivers. Pennsylvania Department of Environmental Resources (PADER) and the PA Fish and Boat Commission (PAFBC) contracted with the Ohio River Valley Water Sanitation Commission (ORSANCO) to provide the necessary oversight for the conduct of a recreational use study and an aquatic resource inventory and habitat classification study.

The project team, consisting of ORSANCO, PADER and PAFBC personnel agreed to use the framework of a GIS to spatially organize geo-referenced natural resource data. This paper discusses the development of a GIS basemap of a river system modified by a series of navigation dams, and outlines the ecological basis of the aquatic habitat classification system (AHC). The AHC divides individual navigation pools into component parts along longitudinal, cross-sectional and vertical axes. These components are then combined to delimit aquatic areas and habitat conditions in order to define aquatic habitat types. Once defined and understood, these habitat types can serve as the basis for the inventory of environmentally sensitive areas. This inventory would then meet regulatory requirements of the National Oil and Hazardous Substance Pollution Contingency Plan by identifying sensitive habitats, establishing priorities for their protection through an appropriate classification system, and providing a mechanism (GIS) to be used during a spill response for prompt implementation of protection measures. The completed GIS will have coverages of infrastructural, monitoring/regulatory, recreational and environmental themes.

# Examining the Influence of Watershed Characteristics on Stream Water Quality, Physical Habitat, and Biota

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John Arthur, U.S. Environmental Protection Agency, Duluth, MN

The influence of landscape-scale watershed features on water quality and biota in streams and other receiving waters is often difficult to quantify. Nonetheless, many processes that control aquatic ecosystems, as well as nonpoint source pollutants that impact water quality, are linked to relatively large spatial features of watersheds. These features include landuse patterns, surficial geology, and landscape structure. Understanding the relative influences of landuse characteristics, as opposed to geologic characteristics, is essential for developing effective remediation and assessment strategies for water resource management. Landuse is controlled by anthropogenic activities, which may be altered through management activities. In contrast, geology, and some aspects of landscape structure, are fixed, and their influences are difficult to control. A series of 62 watersheds in the midwestern United States were examined to determine the relative influences of watershed features on stream ecosystems. An extensive spatial database of watershed characteristics was constructed with a GIS. These data were used to develop predictive models of surface water quality, and to develop approaches for using biological communities (e.g., macroinvertebrates, algae) in streams as indicators of watershed condition. Several recent multivariate statistical techniques, including canonical correspondence analysis (CCA) and redundancy analysis (RDA), were employed to elucidate specific relationships among these data. Results of our studies indicate distinct linkages can be identified between landscape-scale watershed attributes and stream biota. The precision of some predictions is dependent on the spatial resolution of landscape data. Signatures from biological community data can be used to reflect watershed condition.

# Application of GIS and Modeling in Remediation of Ground-Water Contamination

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Ground-water hydrologists collect and process large amounts of data during a ground-water remediation project. The data are stored and presented in different forms such as tables, maps, charts, databases, etc. GIS, a relatively new computer-based tool, can help with the process of data manipulation and visualization. However, GIS is more than a mapping system—GIS allow users to analyze data. The analyzed data are a collection of spatial information (represented by points, lines and polygons) and their associated attributes (characteristics of the features, such as chemical characteristics), which the points, lines, and area represent. The cartographic tools of GIS then, allow the users to display, overlay, measure, merge and identify the data in support of a particular analysis. By allowing the spatial data to be displayed and analyzed, GIS provides the means necessary for effective environmental decision-making and the implementation of environmental management plans.

There are two basic map representation techniques used in a GIS: vector and raster. In a raster representation, the study area is subdivided into a mesh of grid cells. Each cell has a value, which represents a feature identifier, or a quantitative attribute value. Raster systems are suited for analysis of continuous data, such as water levels, infiltration, bedrock surface, etc. This makes a raster-based GIS an ideal choice for integration with ground-water models that use a regular grid, such as MODFLOW. One of the most popular raster GIS and image processing system that is also PC-based is IDRISI. The system provides many analytical tools that are useful in a hydrogeological study. The three most important categories of these tools are (a) database query, (b) map algebra, and (c) context operator. Because the formats of input data sets and IDRISI are different, there is a need for another program that will link GIS and MODFLOW.

MODRISI is a set of utility programs that allows an easy transfer of data files between MODFLOW, IDRISI, SURFER, Geopack, GeoEas, and spreadsheet programs. Preparation of two-dimensional arrays for the MODFLOW input files can be created easily from IDRISI image files. AutoCAD vector files, such as model boundaries, well locations, and rivers, can also be translated into a format suitable for the flow model input files. MODRISI can post-process MODFLOW output files and prepare GIS image files that can be displayed and manipulated within IDRISI. Thus, MODRISI is used as a pre- and post-processor for MODFLOW. The usefulness of the GIS for data analysis and ground-water modeling was demonstrated at the Gilson Road Superfund site.

Note: Mention of trade names does not constitute endorsement by the U.S. Environmental Protection Agency.

# Use of GIS in Modeling Ground-Water Flow in the Memphis, Tennessee, Area

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The City of Memphis, Tennessee, relies solely on ground water for its municipal and industrial water supply. Memphis Light, Gas, and Water (MLGW) Division owns and operates over 160 water wells in 10 production fields throughout Shelby County. The average MLGW production is approximately 200 million gallons per day, excluding much of the industrial demand. The city obtains its water from a thick, prolific aquifer known as the Memphis Sand. It has been generally accepted that the aquifer is separated from a surficial aquifer by a thick confining layer. In recent years, evidence of leakage from the surficial aquifer to the Memphis Sand has been found. In order to study the aquifer, the Memphis State University Ground Water Institute (GWI) is developing a hydrogeologic database of the Memphis area. The database is the basis for several ground-water flow models that have been created, as well as a part of wellhead protection programs that are currently being developed for Memphis and other municipalities in Shelby County. A geologic database was developed and is constantly being updated from borehole geophysical logs made in the area. Well locations are being field verified using a global positioning system (GPS). The use of the database has allowed the development of a three-dimensional model of the subsurface of the Memphis area. The database also contains locations of, and information on, both private and public production and monitoring wells, superfund sites, underground storage tanks, city and county zoning, landuse, and other pertinent information. Procedures for linking the database to ground-water flow and solute transport models have been developed. The data visualization capabilities and the ability to link information to geographic features makes GIS an ideal medium for the solution of ground-water problems.

An example of the use of GIS in ground-water flow modeling is the study of the Justin J. Davis Well Field. The water quality parameters of alkalinity, hardness, sulfate, and barium have significantly increased over the past 10 years at this facility. In an effort to understand why these changes are occurring, MLGW, the GWI, and the U. S. Geological Survey participated in a joint investigation of the well field. A series of 12 monitoring wells was drilled in the spring of 1992 into the surficial aquifer near the production wells. From geophysical logging and split-spoon sampling, an absence of the confining layer was found at one of the monitoring wells. All other wells penetrated various thicknesses of clay. This "window" in the confining layer suggests that the water quality changes could be due to leakage from the surficial aquifer to the Memphis Sand. Using the GIS database, a flow model of the Davis area was constructed. Also, using the surface modeling capabilities of GIS, the extent of the confining layer window was estimated and used in calculating leakage between the two aquifers. The results of these analyses also indicate that more subsurface exploration is needed to more accurately define the extent of the confining layer window.

# GIS in Statewide Ground-Water Vulnerability Evaluation to Pollution Potential

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The ground-water vulnerability of Indiana to pollution potential was evaluated using a GIS environment. Geographic Resources Analysis Support System (GRASS) and the Grid submodule in ARC/Info were used to carry out the analysis and to identify and display the areas sensitive to ground-water pollution potential. The State Soil Geographic (STATSGO) data base was employed to retrieve statewide soils information required for the analysis. The information from the STATSGO database was used within two models, DRASTIC (acronym representing the hydrogeologic settings: Depth to water table, aquifer Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone, and hydraulic Conductivity of the aquifer) and System for Early Evaluation of Pollution Potential of Agriculture Ground-Water Environments (SEEPAGE). These models employ a numerical ranking system and consider various hydrogeologic settings that affect the ground-water quality of a region. Ground-water vulnerability maps were prepared for the state of Indiana based on DRASTIC and SEEPAGE results. Continuing work comparing the existing well water quality data for determining the accuracy of the results is planned. The DRASTIC Index and SEEPAGE Index Number (SIN) maps show a great deal of potential as screening tools for policy decision making in ground-water management.

SESSION I-3: Thursday, September 22, 2:30PM

# A GIS Toolbox for Targeting Nonpoint Source Pollution in Urban Areas

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Nonpoint source pollution (e.g., agricultural, silvicultural, and urban runoff) has traditionally been defined as any source of water pollution not originating from a discernible, confined and discrete conveyance. Congress has recently addressed this issue in section 402(p) of the Clean Water Act and section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). The CZARA legislation declares the identification of priority pollutant reduction opportunities to be a logical starting point in the process of establishing an institutional framework to address nonpoint source pollutant reductions (U.S. Environmental Protection Agency (EPA), 1993).

An existing methodology for targeting critical nonpoint source pollution watersheds within an urban area is presented in the document entitled, *Urban Targeting and BMP Selection: An Information and Guidance Manual for State NPS Program Staff Engineers and Managers* (EPA, 1989). The targeting methodology is a simple, lumped parameter model whose inputs—pollutant mass load, stream size, beneficial use of waterbodies (type, status, and level), and ability to implement best management practices—are subjectively determined and weighted for each discrete watershed within the urban area under consideration.

This methodology was revised, incorporated into a distributed parameter model, and integrated with the Geographic Resources Analysis Support System (GRASS), a public domain raster based GIS. The revised targeting methodology was integrated with the GRASS GIS via a GIS toolbox of four interdependent programs, which function in series. The outcome of the final program is a raster map layer, which targets and prioritizes critical nonpoint source pollution sites within an urban area.

A spatial database of land use, soils, hydrologic soil groups, and sub-areas raster map layers of the 62 $mi^2$ Grand Calumet River watershed (Lake County, Indiana) was created to satisfy input requirements of the GIS toolbox. In addition to its role in the GIS toolbox, the database will be a valuable resource for a wide variety of future GIS applications.

# Using GIS To Create Awareness of Nonpoint Source Water Quality Impacts in an Urbanizing Watershed

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As part of the larger Narragansett Bay Estuary Project funded by the U.S. Environmental Protection Agency, the University of Massachusetts Cooperative Extension Service has contracted with the METLAND research team, housed at the University, to develop a GIS database, generate watershed wide maps, perform various analyses, and develop a modeling procedure; all with the intent to educate local officials about the impacts of development on water quality, and what local boards can do to minimize the effects of nonpoint sources of pollution.

Since the receiving waters of the Narragansett Bay are located in Rhode Island, far downstream from the watersheds in Massachusetts, upstream communities are more reluctant to enact measures to improve water resources outside of their jurisdiction. A GIS was used to create awareness of existing downstream problems, and to show upstream communities how development will ultimately impact water resources in their own backyards. This awareness was nurtured by conducting a "build-out" analysis for an entire upstream sub-watershed, the Mumford River, containing four towns and roughly 50 square miles. This build-out was coupled with a loading model, using Schueler's "Simple Method" to illustrate the potential impacts of future development, and encourage local boards to minimize future nonpoint source pollution.

GIS proved its usefulness by allowing customized maps to be developed for each town, by generating several "what if" scenarios showing the impacts of different zoning changes, facilitating long range planning for small towns without professional staff, and encouraging a regional perspective on development issues.

This project was most successful in creating a series of partnerships which will continue after the grant expires. The University was able to share data coverages with the State GIS Agency, creating new coverages not available before, specifically soils, ownership and zoning. Small towns were exposed to the potential of the new technology. Students gained from "hands-on" experience with real world problems. State Agencies were able to see their efforts understood at the local level, especially as they reorganize on a Basin approach and attempt to begin to implement a Total Mass Daily Loading (TMDL) procedure to coordinate permitted discharges and withdrawals.

As greater emphasis is placed on controlling nonpoint sources of pollution, more attention needs to be focused on local boards who control land use decisions; that is where the action is.

# Linking GIS With Watershed Models and Management Assessment Techniques

John Lovell, Richard Xue, and Mohammed Lahlou, Tetra Tech, Inc., Fairfax, VA

The integration of GIS with watershed models can play a valuable role for government agencies in decision-making for environmental protection. The GIS establishes a relation between spatial information, such as stream location and land use, to additional data, such as velocities and average depth of a stream or acreage. Watershed models can use the same information to project future water quality based on estimated changes in land use. Linking GIS with a watershed model, to produce an integrated system, is the next step in these convergent processes. For a watershed planner to make effective management decisions, it is necessary to consider dozens of projected land use plans. The most effective approach to facilitate this type of evaluation is to allow the planner to view a watershed map on the computer screen, make projected changes to the land use by 'point and click' and automatically run the model, analyze output, and evaluate model results. However, developing this capability requires a systematic approach that considers both the type of management decisions to be made, as well as fundamental engineering principles. The purpose of this paper is to discuss the processes and limitations involved in creating this link, including planning, *data limitations, modeling adaptation, incorporation of several GIS software, questions of accuracy;* as well as describing improvements, developments and recommendations.

In support of the National Pollutant Discharge Elimination System stormwater program for a local municipality, a linked system at the watershed planning level is under development. The watershed planning system for the municipality encompasses the development of a link between data coverages, watershed targeting and prioritization, modeling analyses, data post-processing, and comprehensive watershed assessment and management. The integrated planning system is also intended to facilitate the evaluation and analysis of various management measures to control stormwater runoff and pollutant loads.

# Vulnerability of Missouri Drinking Water to Chemical Contamination

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In 1991, the Missouri Department of Natural Resources began implementation of the public water system Vulnerability Assessment Program. This unique program is designed to determine if ground water and impounded surface water supplies in Missouri are threatened by chemicals being tested under the Safe Drinking Water Act. Testing waivers may be granted to a system if an examination of existing data bases for 43 agricultural and industrial chemicals indicates no contamination near the water supply. Sources for chemical contamination were entered into a GIS, along with wellhead locations and impoundment drainage basins. The state-wide analysis of the spatial relationship between water supplies and contaminate sources has resulted in considerable cost saving for Missouri.

SESSION K-1: Thursday, September 22, 3:30PM

# Determining the Extent of Agricultural Chemical Contamination in Water Resources in the Midwestern United States

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Use of agricultural chemicals, including herbicides and nitrogen fertilizer, to increase crop yields in the midwestern United States has increased dramatically over the past 30 years. Recent investigations have documented varying degrees of contamination by agricultural chemicals in surface water, ground water, and precipitation. The magnitude, spatial extent, and seasonal persistence of the contamination varies for the three water environments. Herbicide contamination is the greatest in surface water with low concentrations detected year round in most of the reservoirs and streams sampled; herbicide concentrations in some rivers during spring runoff and in some reservoirs exceeded U.S. Environmental Protection Agency drinking-water standards. Concentrations of nitrate in surface water are generally detectable year round, but are usually less than the drinking water standard (10 mg/L) in most large rivers and reservoirs. Contamination of ground water by nitrate appears to be a bigger problem. Nitrate was detected in 59 percent of 303 wells in near-surface midwestern aquifers, and nitrate concentrations exceeded 10 mg/L in about 6 percent of those wells. Herbicides or herbicide metabolites were detected in only 24 percent of the same wells, and herbicides were not detected in concentrations that exceeded drinking-water standards. Herbicide and nitrate concentrations in ground water did not vary significantly with season. Herbicides and nitrate have also been detected in precipitation. Herbicides were detected in about 25 percent of 6,000 rainwater samples collected at 81 sampling sites in the Midwest. About 1 percent of the samples had herbicide concentrations that exceeded 1 $\mu$g/L. While concentrations and mass deposition are generally small, there is indication that these agricultural chemicals are being transported long distances and deposited in relatively pristine areas.

GIS and scientific visualization systems are used to display, organize, and quantify information on sampling site locations, soils, agricultural chemical use, agricultural land use, and agricultural chemical occurrence at a level of detail suitable for regional spatial analysis. The information is being used to determine relations between ancillary information, such as chemical use or land use and chemical occurrence in the hydrosphere, and to develop models that can predict when, where, and at what level contamination by agricultural chemicals is expected.

# A GIS-Based Approach in Characterizing Chemical Compounds in Soil and Modeling of Remedial System Design

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The cost effectiveness of implementing a GIS for environmental subsurface characterization should be based on long-term remedial objectives. This paper discusses a scenario of computer aided environmental site characterization and computer model aided design for a remedial system. A project-GIS was developed for a soil remediation and "land sale" project in California. The project had a major change in scope early on and an aggressive schedule. Characterization of chemically impacted soil would have been compromised, given the above circumstances, without an ambitious undertaking of concurrently developing and implementing—early in the project—a cross-platform GIS with 3-D geostatistical and predictive modeling capabilities.

The paper demonstrates the problems solved and approaches considered. Solutions included the use of a cross-platform (i.e., DOS and UNIX) GIS to quickly and orderly incorporate spatial and chemical data sets and provide a distributed data processing and analysis environment. Given the project schedule, exclusive use of a single platform would not have been realistic because of limited data processing capacity and 3-D graphics in DOS systems and the high operating cost of UNIX workstations.

The project-GIS was the tool to assist in making short and long term decisions in regards to regulatory strategy and engineering feasibility. Use of spatial statistical and predictive models was part of a GIS-based decision-making-loop. The process supported concurrent activities in: (1) data collection field program; (2) numerical models; (3) development of cleanup goals; and (4) remedial design.

The site is environmentally complex and spatially extensive. It is impacted by numerous types of hydrocarbons, commingled with volatile compounds such as perchloroethylene and trichloroethylene. Chemical and lithologic data gathered in the past seven years populated a relational database and became the nucleus of a project-GIS which also incorporated a COMPUTER AIDED DESIGN system capable of providing both GIS and engineering support. Continuity between site characterization and subsequent remedial engineering was thus provided. Kriging of chemical and soil data produced a variety of results with the ultimate goal of generating a gridded model best able to represent field data and validate conceptualized subsurface conditions. Results affirm that high concentrations of total volatile compounds and heavy oil were mainly found in soil horizons with low permeabilities. With confidence in these spatial model results, kriged data were input to in-situ soil vapor extraction models and assisted in optimizing vent configuration and operating schedule.

SESSION K-3: Thursday, September 22, 4:30PM

# Spatial Modeling of Biocriteria and Upstream Basin Characteristics for the Black River, Ohio

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Columbus, OH

Assessment and management of surface waters has evolved from a system of primarily simple chemical criteria, to one that includes complex chemical criteria and standards for whole effluent toxicity and biological community performance (Yoder, 1991; *Water Quality Standards for the 21st Century*). Biological criteria are narrative or numerical expressions that describe the reference condition of an aquatic community inhabiting waters of a given *designated use*.

The objective of this study was to determine whether biological indices are sufficiently sensitive measures of surface water resource integrity. Using a spatial modeling methodology developed previously (White and others, 1992; *Computers and Geosciences*), we explored the relationships between two measures of biological criteria for the Black River watershed in northeastern Ohio. Values for the index of biotic integrity (IBI) and the invertebrate community index (ICI) taken from the Ohio Environmental Protection Agency (EPA) ECOS database for 1982 and 1992 were used as response variables in an ordinary least-squares (OLS) regression model. Explanatory variables in the OLS regression model represented point-source and nonpoint-source impacts in the watershed. Point-source predictor variables were extracted from the Ohio EPA Liquid Effluent Analysis and Processing System (LEAPS) database using the median and 95th percentile for such parameters as water temperature, 5-day biochemical oxygen demand (BOD), and total Kjeldahl nitrogen (TKN) measured at facility outfalls. Nonpoint-source attributes were characterized from land use/land cover classification of a March, 1991, Landsat Thematic Mapper satellite scene.

The spatial modeling methodology depends on the topologic relationships among point and areal entities to aggregate pollution sources from upstream drainage areas for landscapes having point-source and nonpoint-source water-pollution effects. The spatial model relies on an infrastructure of stream networks and drainage basin divides to define the hydrologic system. The basin divide and reach network was derived using morphometric extraction routines on digital elevation models and the U.S. EPA Reach File 3. The spatial relationships between point- and nonpoint pollution sources and measurement locations were referenced to the hydrologic infrastructure using network analysis and relational database management techniques within the GIS Arc/Info.

Implementation of this spatial model over state-wide domains would benefit the preparation of state-wide water quality summaries, like those required under Section 305(b) of the U.S. Clean Water Act (P.L. 95-217), by increasing the total numbers or lengths of "evaluated waters." Presentation of these state-wide summaries still are beset by problems of inconsistent reporting of total stream length and number of assessed waters in each state.

# GIS for Water Quality Management and Modeling in the Ohio River Basin

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The Ohio River Valley Water Sanitation Commission (ORSANCO) is an interstate water pollution control agency, established in 1948 by a Compact among eight states within the Ohio River basin and authorized by Congress. The eight signatory states to this Compact include: Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia, and West Virginia. ORSANCO works with its member states and the federal government primarily in the areas of water quality monitoring and assessment, development and administration of pollution control standards, and interstate notification and tracking of spills to the Ohio River. The Commission recently completed a three-year cooperative agreement with the U.S. Environmental Protection Agency (EPA), Drinking Water Research Division, Risk Reduction Engineering Laboratory, Cincinnati, Ohio, to develop a GIS for water quality management within the Ohio River Basin. The primary objectives of the project were to: 1) develop a spill response management system emphasizing ease and speed of use; and 2) provide a framework for the storage, manipulation and spatial analysis of geographically-referenced data pertaining to water quality management for current and future applications.

A fundamental geographic feature is the stream network, which is available at two levels of detail. EPA's Reach File (RF1) has been installed for the entire basin, while the more detailed Reach File (RF3) is available only for hydrologic units bordering the Ohio River. Other geographic data for the entire Ohio River basin include water intakes, permitted wastewater discharges, hydrologic boundaries, political boundaries, ORSANCO water quality monitoring stations, Ohio River mile points, and Toxic Release Inventory and National Priority List sites. ARC/INFO and ArcView GIS software is installed on a Data General, UNIX-based graphics workstation.

The NETWORK module within ARC/INFO has been set up to model the downstream movement of spills into any stream within the basin that is represented in the RF1. A menu-driven user interface allows for easy input of spill characteristics such as total product mass spilled, time of spill, duration of spill, stream flow regime, and an optional first-order decay rate coefficient. The pollutant is routed downstream through the RF1 stream network, and resulting travel times and pollutant concentration due to dilution and first-order decay are estimated.

A more rigorous spill model for the Ohio River only was developed using EPA's WASP4 toxic model in conjunction with stream flow data predicted by the U.S. Corps of Engineers' FLOWSED reservoir model. A menu-driven user interface allows for simple operation of the system with minimal training requirements. Time of travel and concentration estimates from the model are automatically formatted for graphical display in the ArcView GIS environment.

Additional uses of the GIS relating to watershed management will be discussed.

# Reach File 3 and the Development of GIS Water Quality Tools

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The application of GIS tools to water quality management is limited by the lack of geographically referenced data that describe the surface water environment. Ongoing efforts at the local, state, and federal level are producing a multitude of GIS data coverages describing landuse/cover and relevant water quality data files. As these data coverages become available, water quality managers will need to develop new analysis techniques to take advantage of the vast amount of geographically referenced data. A key step in the development of analytical tools for water quality management will be the development and maintenance of a coverage describing the structure and hydrology of surface waters.

Reach File 3 (RF3) is one potential source of surface water maps and topology for the development of a GIS based water quality analysis tool. This paper describes a pilot project designed to examine the suitability of RF3 as a network system for the collection, integration, and analysis of water quality data. The pilot study was developed using RF3 data for the Upper Yadkin River basin in North Carolina and Virginia U.S. Geological Survey (USGS Cataloging Unit h03040101), in conjunction with point, line, and polygon environmental feature data layers.

Using the GIS software ARC/INFO®, water quality applications were developed to select user defined reaches of the RF3 stream network and collect associated environmental data. The RF3 network allowed all stream segments above or below a given point to be selected. This allowed water quality managers and staff to quickly locate point and non-point pollution sources in a watershed to create lists and tables of known pollution sources, and calculate loads. Ongoing work involves efforts to use GIS routing capabilities to support fate and transport modeling.

This pilot project demonstrates only a few of the potential applications of RF3 to water quality. Successful implementation of this pilot project suggests that RF3 is a potentially valuable water quality analysis tool. It may also be a valuable tool to demonstrate the results of water quality analyses to managers or the public.

Because RF3 will require some processing before network algorithms can be run on a riverbasin-wide scale, it will be important to plan for the integration of RF3 into other GIS tools and data coverages. If RF3 is to be developed into a productive water quality management tool, it will be important to proceed in a way that is compatible with ongoing efforts to update RF3 and the development of new data sources.

# Nonpoint Source Pesticide Pollution of the Pequa Creek Watershed, Lancaster County, Pennsylvania: An Approach Linking Probabilistic Transport Modeling and GIS

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Allan Moose, Southampton College, Southampton, NY

The U.S. Environmental Protection Agency (EPA) has mandated that each state prepare a State Management Plan (SMP) for the management of pesticide residues in the environment of the state. One aspect of an SMP is the identification of specific soils and sites that may be vulnerable to the transport of pesticides to water resources. A system for identifying vulnerable areas by coupling probabilistic modeling, using EPA-Pesticide Root Zone Model (PRZM) with a desktop GIS (MAPINFO), has been developed. A limited test of this system was conducted where individual soil series in a watershed, shown to have transported atrazine to surface and ground water, were identified and mapped. During this project, various digital data sources, such as State Soil Geographic (STATSGO) database, U.S. Geological Survey (USGS), Digital Line Graphs (DLGs), and National Oceanographic and Atmospheric Administration climate data were evaluated for availability and ease of use. Hands-on hints and tricks for importing and using these data have been documented in this study.

From 1977 to 1979, the USGS *measured the movement of atrazine off fields of application into* water resources in the Pequa Creek basin in Lancaster County, Pennsylvania (Ward, 1987). Atrazine in surface water was measured at levels exceeding 20 ppb in storm flow and above the 3 ppb maximum contaminant level during baseflow from Big Beaver Creek, a tributary to Pequa Creek. Each soil series in the subbasin was digitized into a GIS. PRZM was used to simulate runoff, erosion, and leaching of atrazine (applied at 2.24 Kg/Ha in conventionally tilled corn) for each soil, under different slopes, for an 11 year time period from 1970 to 1980. The results for each soil series were interpreted to determine the probability distribution of atrazine in Kg/Ha for each mode of transport. These data were used by the GIS to thematically map each soil series for atrazine loss.

The results of this demonstration project suggest that the Manor silt loam, with slopes varying from 6 to 20 percent, had a high potential to transport atrazine residues to surface water. Using this type of analysis, it could be suggested that this soil series: be farmed using conservation tillage, be managed to install grass waterways or buffer strips to stop runoff, or be set aside from production in order to protect the water resources. Digital databases were available for the study area, but many technical problems were encountered in using the data. Researchers embarking on these types of modeling and GIS projects should be prepared for significant expenditures of time and finances.

# Integration of GIS With the Agricultural Nonpoint Source Pollution Model (AGNPS) To Evaluate Model Output at High Resolutions

Suzanne R. Perlitsh, College of Environmental Science and Forestry, State University of New York, Syracuse, NY

Nonpoint source pollution is the primary source of contamination for more than 80% of the impaired water bodies in New York State. Nonpoint sources from agricultural areas have been identified as major contributors of pollution to over 50% of New York State's polluted lakes and rivers. The assessment of agricultural nonpoint source pollution has been facilitated by linking data contained in a GIS with hydrologic models. One such model is the Agricultural Nonpoint Source Pollution Model (AGNPS), which simulates runoff, nutrients and sediment from agricultural watersheds. Previous AGNPS/GIS links have been limited by the AGNPS model's inability to process more than 3,200 cells. Version 4.02 of AGNPS (June, 1994) eliminates this restriction, enabling a more detailed watershed analysis.

Digital technology is advancing rapidly. Does data at higher resolutions provide better information? This paper will describe the results of an analysis of AGNPS output based on different levels of both resolution and detail in GIS data input sources. The study area is a 1.84 square mile sub-watershed of the Onondaga Lake Watershed, Otisco Valley Quadrangle, Onondaga County, New York. In this study, AGNPS input parameters have been generated using (1) digital elevation data at 10 meter resolution; (2) digital elevation data at the standard U.S. Geological Survey 30 meter resolution; (3) soils data at the soil survey level; and (4) soils data at the State Soil Geographic Database (STATSGO) level. The influence of the differences in input parameters on model output is investigated. The propagation of error, as well as the question of responsible decision making based on results of this type of GIS data analysis, will be explored.

SESSION M-2: Friday, September 23, 9:00AM

# Integration of GIS and Hydrologic Models for Nutrient Management Planning

Clyde W. Fraisse, Kenneth L. Campbell, James W. Jones, William G. Boggess, and Babak Negahban, University of Florida, Gainesville, FL

Recent evidence that agriculture in general, and animal waste in particular, may be an important factor in surface and ground-water quality degradation has induced a strong interest in nutrient management research. The principal nutrients of concern in the aquatic environment are nitrogen and phosphorus. Large amounts of those nutrients can be lost to surface and ground waters due to agricultural activities. A major source of concern in many regions is dairy operations. Dairy animal waste contains a number of constituents that can degrade surface and ground-water quality. However, land application of animal waste at acceptable rates can provide crops with an adequate level of nutrients, help reduce soil erosion and improve water holding capacity. The successful planning of an animal waste management system requires the ability to simulate the impact of waste production, storage, treatment and utilization on the water resources. It must address the overall nutrient management for the operation, including other nutrient sources such as supplemental fertilizer applications.

Linkage between GIS and hydrologic models offers an excellent way for representing the spatial features of the fields being simulated and improving the results obtained. In addition, a GIS containing a relational database is an excellent way of storing, retrieving, and formatting the various types of spatial and tabular data required to run a simulation model. The different levels of integration of hydrologic models and GIS for nutrient management planning are discussed. The approach used in Lake Okeechobee Agricultural Decision Support System (LOADSS), recently developed to evaluate the effectiveness of different phosphorus control practices in the Lake Okeechobee basin, Florida, is discussed. LOADSS consists of two primary components: 1) a regional scale GIS-based model, able to handle dairy and other forms of landuse, used to develop and manipulate regional plans aimed at reducing phosphorus loading to Lake Okeechobee, and 2) Interactive Dairy Model (IDM) used to develop farm level management plans for dairies and estimate phosphorus transport on individual dairy fields. IDM runs the Field Hydrologic and Nutrient Transport Model (FHANTM) for simulating phosphorus transport to the edge of fields, and routes phosphorus through streams and canals using an exponential decay function. Optimization algorithms are currently being added that will enable the system to select the best phosphorus control practices at the regional scale based on goals and constraints defined by the user. A second GIS-based interactive dairy model, currently under development, is also discussed. It will utilize the Ground-Water Loading Effects of Agricultural Management Systems (GLEAMS) simulation model to consider the potential leaching and runoff of both nitrogen and phosphorus. This application is designed to be generic, capable of evaluating the impacts of alternative waste management policies at the farm level for dairies of various sizes and across agroclimatic zones.

SESSION M-3: Friday, September 23, 9:30AM

# GIS Model for Land Use Suitability of Greenbelt Area

Joanna J. Becker, Environmental Planning Services, Santa Rosa, CA

This project was initiated primarily to demonstrate environmental GIS applications in urban land use planning. The purpose of the demonstration was to identify areas that would be most suitable for agricultural, rangeland or open space land uses within the greenbelt of a city with a population of approximately 50,000. The greenbelt identified by the city was largely similar to that of the watershed for which existing data was available.

To undertake the project, the data was manipulated in MacGIS, a raster-based program that was easily mastered and accessible for use. The information was then transferred via ASCII files to ArcInfo and then via DOS files to ArcView so that it could be viewed by the planning staff on the city's equipment.

Initially, six variables were used to determine land suitability for each land use category. In presenting the information, however, only the data used for determining rangeland suitability was included; and, to avoid overwhelming an audience unfamiliar with GIS, only three complete variables were demonstrated (two of which were combined into a single composite layer). In addition, the base map and the final maps for all three land uses were presented.

This project was completed within a minimal time and budget framework, and it focused primarily on demonstrating the modeling capabilities of GIS for land use planning. No attempt was made to add to the available data or to have the criteria approved by public officials, although there is interest by the city in pursuing the project further to identify areas suitable for preservation in this greenbelt.

SESSION N-1: Friday, September 23, 8:30AM

# Application of GIS for Environmental Impact Analysis in a Traffic Relief Study

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Xinhao Wang, School of Planning, University of Cincinnati, Cincinnati, OH

Environmental problems usually are results of human activities that disrupt natural processes. Solving environmental problems involves managing human activities, which has significant economic and political implications. This paper presents an application of GIS in a traffic relief study. Traffic congestion has severely impacted the environmental quality and the quality of life for residents in the project area. A project team consisting of planners, environmental specialists, historians, landscape architects, traffic engineers, and GIS professionals has been organized to solve the problem. The goal of the project is to propose alternatives to highway alignments with considerations of growth management issues, long term planning, natural and cultural resources. The impact of highway alignments on resources and economic growth has been considered from the very first step and in every major decision made for the duration of the project.

The GIS professional plays a crucial role in maintaining constant and active interactions among members of the project team, federal and state agencies, and the public. GIS has been used to develop natural and cultural resource inventory, to identify contamination sources, to evaluate environmental constraints, and to compare proposed highway alignment alternatives. The study demonstrates that a technically sound framework for applying GIS in transportation studies ensures high quality traffic design with minimum negative environmental impact. GIS provides an ideal atmosphere for professionals to analyze data, apply models, and make the best decisions. The high quality map products created with GIS enhance the quality of public presentations and reports. The authors feel that more people have realized the benefit of using GIS along with the progress of the project.

# GIS as a Tool for Predicting Urban Growth Patterns and Risks From Accidental Release of Industrial Toxins

Samuel V. Noe, Joint Center for GIS and Spatial Analysis, University of Cincinnati, Cincinnati, OH

Conventional urban planning and administrative practices do not adequately provide for the minimization of risks when industry and population are geographically incompatible. Local jurisdictions on the fringes of metropolitan areas may be particularly ill-equipped to respond and plan effectively. Supported by minimal professional staffs and unaware of specific potential risks, their elected officials may be more interested in soliciting new industrial development and the tax base it brings. Industrial zones are thus created without restrictions on facilities which may generate hazardous substances and without recognition of the possibility that underground aquifers—current or potential sources of drinking water—may underlie these zones. Facilities, which could routinely or accidentally release toxic substances into the air and ground water, are permitted without due regard for prevailing wind patterns, aquifer locations, and existing or projected urbanized areas which may be affected.

This paper describes a simple method for projecting patterns of suburban residential and industrial growth. It then shows how GIS can be used to map levels of risk from accidental releases of industrial toxins into the air and underground sources of drinking water. The model developed takes into account existing and projected patterns of residential development and toxic chemical sites in a 100 square mile study area on the northern fringe of the Cincinnati metropolitan area.

With respect to airborne releases, an existing model for predicting a unidirectional plume from a single release is enhanced by incorporation of annual climatic variations and simultaneous consideration of multiple chemicals from a single site, or from neighboring facilities.

Sources of potential releases into underground aquifers, and those resulting plumes, are examined with respect to public well sites and their corresponding water service districts. This permits mapping of relative potential risk for contaminated water supplies in existing and projected residential areas.

Use of this PC-based GIS model provides an inexpensive tool for sensitizing local officials to the consequence of past land use decisions. The model can be of even greater value in examining proposals for subsequent industrial and residential development, in formulating emergency evacuation plans, and in predicting risks from proposed industrial developments in neighboring jurisdictions.

SESSION N-3: Friday, September 23, 9:30AM

# XGRCWP, a Knowledge and GIS Based System for Selection, Evaluation, and Design of Water Quality Control Practices in Agricultural Watersheds

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Expert GIS Rural Clean Water Program (XGRCWP) integrates GIS, relational databases, simulation models, and Hyper Text Mark Language (HTML) documents to form an advisory system for the selection, siting, design, and evaluation of nonpoint source pollution control practices in agricultural watersheds. Its major features include 1) customized GIS functions to obtain spatial and attribute data and feed them to a rulebased expert system for selecting feasible control practices, 2) a user interface for examining the field-specific conditions and recommended control practices on the screen by clicking on the displayed field boundary map, 3) a direct linkage between the GIS spatial data and the relational attribute data which allows the user to examine data on the screen interactively, 4) a graphical user interface to GIS functions which enables the user to perform various routine watershed analyses, 5) linkage to HTML reference modules through Mosaic, and 6) dynamic access to other models such as agricultural nonpoint source simulation model (AGNPS). The software environment of XGRCWP is GRASS4.1 and X-Windows on SUN OS 4.3.1. Its major functions have been tested for the Sycamore Creek Watershed in Ingham County, Michigan.

SESSION O-1: Friday, September 23, 10:30AM

# EPA's Reach Indexing Project: Using GIS To Improve Water Quality Assessment

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The Waterbody System, originally developed by the U.S. Environmental Protection Agency (EPA) to support preparation of the report to Congress required under Section 305(b) of the Clean Water Act, is a potentially significant source of information on the use support status and the causes and sources of impairment of waters of the United States. There is a growing demand for geographically referenced water quality assessment data for use in interagency data integration, joint analysis of environmental problems, establishing program priorities, and planning and management of water quality on an ecosystem or watershed basis.

Since location of the waterbody assessment units is the key to analyzing their spatial relationships, EPA has placed particular emphasis on anchoring waterbodies to the River Reach File (RF3). The Reach File provides a nationwide database of hydrologically linked stream reaches and unique reach identifiers, based on the 1:100,000 U.S. Geological Survey hydrography layer.

EPA began the reach indexing project to provide an incentive for states to link their waterbodies to RF3 and to ensure increased consistency in the approaches employed in reach indexing. After a successful 1992 pilot effort in South Carolina, an expanded program began this year. Working with Virginia, a route system data model was developed and proved successful in conjunction with state use of PC Reach File (PCRF), a PC program for relating waterbodies to the reach file. Arc/Info provides an extensive set of commands and tools for development and analysis of route systems and use of dynamic segmentation. One important advantage of the route system is that it avoids the necessity of breaking arcs, an important consideration in using RF3 as the base coverage in a GIS. The use of dynamic segmentation to organize, display and analyze water quality assessment information also has the advantage of simplifying use of the existing waterbody system data. However, because of the variability in delineation of waterbodies, a number of other approaches had to be used in other states. Experience in working with these states defines a range of issues that must be addressed in developing a consistent set of locational features for geospatial analysis.

Wider use of these data is also dependent upon increased consistency in waterbody assessments within and between states. Attaining this consistency in assessment data is complicated by the choice of beneficial use as the base for assessment of water quality condition, the historical emphasis on providing flexible tools to states, and the lack of robust standards for assessment of water quality condition. Possible resolutions to the problem of building a national database from data collected by independent entities are explored.

SESSION O-2: Friday, September 23, 11:00AM

# Application of GIS Techniques to the Results of Probabilistic Modeling for Herbicide Runoff in Corn Growing Soils in Illinois, Indiana, Missouri, and Nebraska

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Patti Tillotson and Ray Layton, Du Pont Agricultural Products, Wilmington, DE

The objective of this study was to use probabilistic runoff modeling results in a GIS to identify soils which could act as potential source areas for cyanazine runoff in the Illinois River, White River, Missouri River, or Platte River basins. Sixteen counties in four states, Illinois, Indiana, Missouri, and Nebraska, were selected from the watersheds, based on corn yields, cyanazine use, and data availability. One hundred-and-six individual soil series were selected, based on corn growing potential, from these counties. The soils data, and historic as well as synthetic precipitation data, were compiled in preparation for transport modeling.

The transport model used in this study was the U.S. Environmental Protection Agency Pesticide Root Zone Model version I. To incorporate variability in soil properties, a probabilistic modeling approach was used where the soil organic content and cyanazine soil half lives were varied between known end points. The modeling scenario was that of conventionally tilled corn with one pre emergent application of cyanazine, which followed the label rate and timing. Soil specific application rates were derived from the 1994 label for cyanazine. A total of 12,960 monthly runoff values, for each of the 106 soils, were calculated by the model.

The modeling results were used to select soils to be mapped using the MAPINFO GIS. Of the 20 soils with the greatest simulated potential to transport cyanazine off the field of application, 13 occurred in Indiana and five occurred in Missouri. Application rates on these soils were generally low to moderate and none of the high application rate soils were within the top 20 soils with the greatest simulated potential for cyanazine transport in runoff. The GIS allows for the display of the soil locations, with respect to water bodies and other land uses. The GIS maps are of the same scale as that of the air photograph based soil series maps found in the county soil surveys.

The modeling and mapping resulted in the ranking of more than 100 soils with respect to the simulated potential for cyanazine to be transported off the field of application. The GIS displayed the location of soils within each target county and the results varied greatly. Some counties had distinct areas that could be problematic for potential herbicide runoff, while others showed soils widely distributed across the county. By understanding the distribution of potentially problematic soils, selection of the most effective best management practices to reduce potential runoff could be made.

SESSION 0-3: Friday, September 23, 11:30AM

# Linking Environmental Models and GIS Through Inter-Application Communication

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Many environmental modeling efforts often require the use of programs external to the GIS environment. In many instances, the GIS serves as a data warehouse and display engine, while external models use data stored within the GIS. Advances in inter-application communication now facilitate the seamless blending of multiple programs through a client-server architecture. Rather than the user starting individual programs, programs can call, execute, and pass data back and forth using software built on the inter-application communication architecture. Inter-application communication also provides other significant capabilities such as pseudo-parallel processing, in which independent segments of a model can run on separate machines operating under the same inter-application communication server. Inter-application communication also encourages the development of enterprise GIS, in which all datasets of an organizational interest can be accessed. Environmental modeling applications often use GIS-based land records information, such as land cover, water use, and infrastructure data, which is coupled to a dynamic systems model that describes change in a landscape due to functional relationships between changing parameters. In order to successfully simulate the environment in question, both software packages may need to be run simultaneously. By creating applications which use inter-application communication, multiple programs can be seamlessly linked, thereby facilitating the use of shared data and programs. This paper examines implementation strategies and benefits of inter-application communication, and the development of user-created applications that incorporate inter-application communication.

# Comparing Experiences in the British and U.S. Virgin Islands in Implementing GIS for Environmental Problem Solving

Louis Potter, Town and Country Planning Department, Government of the British Virgin Islands, British Virgin Islands

Bruce G. Potter, Island Resources Foundation, Washington, DC

The contrasting experiences of the British (BVI) and U.S. Virgin Islands (USVI) in implementing region-wide geographic systems provide lessons for GIS managers and supporters everywhere. The two island-states share a number of characteristics, including dependence on the maintenance of a high quality natural environment, to support tourism. The two governments are also very different in terms of their size, existing infrastructure, and GIS implementation. Study of the different outcomes of the two GIS implementation efforts should provide guidance to internal and external advocates for GIS implementation for environmental problem solving.

**Objectives and Brief Overview:**

Building GIS for environmental problem solving requires a major institutional commitment, especially in small governmental systems with limited financial and technical resources. This paper examines the *technical, institutional, and cultural factors* that have helped and hindered the development of GIS for the Town and Country Planning Department of the Government of the BVI, and the Government of the USVI.

Technical factors to be examined in this paper include:

- Initial system planning activities,
- Software selected,
- Hardware platform(s),
- Priorities for base map construction, other coverages, and scale considerations.

Institutional and cultural factors to be discussed include:

- Environmental problem solving in local government decision making,
- GIS leaders access to, and support from, senior government managers,
- Technical assistance sought and provided,
- Principal users,
- Typical applications.

The paper concludes with a discussion of the critical success factors seen in the comparative experience of the two systems, with suggestions for their meaning for local and regional agencies in the United States.

# Integration of EPA Mainframe Graphics and GIS in a UNIX Workstation Environment To Solve Environmental Problems

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Phillip Taylor, Tetra Tech, Inc., Fairfax, VA

Paul Evenhouse, Martin Marietta, Inc., Research Triangle Park, NC

Robert King, U.S. Environmental Protection Agency, Washington, DC

The Assessment and Watershed Protection Division (AWPD) within the Office of Wetlands, Oceans and Watersheds (OWOW) has developed water quality analysis software on the U.S. Environmental Protection Agency (EPA) mainframe computer. This software integrates national online environmental databases and produces maps, tables, and graphics which show water quality trends, discharge monitoring reports, permit limits, design flow analysis, etc. In the past, this graphical software was available only to users connected to the mainframe with IBM graphics terminals or PCs with graphics emulation software. Recently, software has been developed which can be used to: (1) access the EPA mainframe from a UNIX workstation via INTERNET, (2) execute the Water Quality Analysis System (WQAS) procedures, (3) display WQAS graphics in an X-window on the workstation, and (4) download data in a GIS format from the mainframe. At the same time, this workstation can be executing ARC/INFO and Arcview applications in other X-windows. This capability allows analysts to have the power of GIS, the mainframe databases (PCS, STORET, Reach File, Industrial Facilities Discharge File, Daily Flow File, Toxic Chemical Release Inventory), and the retrieval/analysis/display software (Environmental Data Display Manager, Mapping and Data Display Manager, Reach Pollutant Assessment, PCS-STORET Interface, UNIRAS) available to them on one desktop. Thus, the tool set available to GIS analysts for environmental problem solving has been extended. This paper will discuss how these tools and databases have been applied to several problems including: Total Maximum Daily Load (TMDL) development on the Clark Fork River (Montana); environmental risk assessment in the Brandywine River Basin (Pennsylvania, Delaware); watershed-based permitting in South Carolina; 2-D and 3-D visualization of water quality parameters in Lake Minnetonka (Minnesota); emergency response to hazardous material spills; and determination of flood boundaries from remotely sensed data (Advanced Very High Resolution Radiometer) and the EPA River Reach File.

SESSION P-2: Friday, September 23, 11:00AM

# Development of a GIS for Former Industrial Properties in the Mahoning River Corridor

Scott C. Martin and Javed Alam, Department of Civil and Environmental Engineering, and Laura Lyden, YSU Technology Development Corporation, Youngstown State University, Youngstown, OH

The decline of heavy industry in many Ohio cities has left behind vast areas of unused or underused industrial land. Developers often assume that these properties are contaminated with hazardous wastes and are reluctant to consider purchasing them because of the potential liability. In a recent study, entitled the Mahoning River Corridor Redevelopment Project, limited Phase I and Phase II Preliminary Site Assessments were conducted on twenty former industrial sites in the Mahoning River corridor. The objective of this study was to screen properties with a high redevelopment potential for evidence of obvious contamination problems. Local Chambers of Commerce receive hundreds of inquiries about such properties from prospective buyers each year. In many instances, they do not have sufficient information or manpower to adequately service these requests. Thus, an urgent need exists for a centralized database that can be used to provide detailed information on available sites both quickly and conveniently. To begin work toward this goal, a prototype GIS was developed for abandoned industrial sites in the Mahoning River corridor. Using ArcCAD software, a general base map was first developed with separate layers for political boundaries, interstate highways, state roads, secondary roads, surface waters, and project sites. Detailed site maps of selected properties were then added to the base map. These show property boundaries, buildings, access roads, and project soil sampling locations. In addition, corresponding attribute tables were developed to summarize other pertinent information, such as zoning status, ownership history, assessed property value, proximity to the 100 year flood plain, utilities, etc. The long-term goal of this project is to develop a comprehensive GIS database for all industrial properties in the Mahoning River corridor that are available for redevelopment. Efforts are currently underway to establish a service to provide this type of information to prospective developers. The availability of a comprehensive GIS will allow this service to function much more efficiently.

SESSION P-3: Friday, September 23, 11:30AM

# Polygon Development Improvement Techniques for Hazardous Waste Environmental Impact Analysis

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Recently, concern has arisen with respect to the effect of Superfund sites upon the communities surrounding them, and specifically the distribution of those impacts upon various target populations. In designing GIS applications for analyzing the potential impacts of hazardous wastes and/or waste sites upon adjacent neighborhoods, various challenges may be encountered. Questions of time, space, and scale must be addressed during GIS database design. Studies conducted by the U.S. Environmental Protection Agency and other federal agencies have indicated that certain sectors of the population may be more vulnerable to exposure to toxics than others. To date, federal departments have enlisted in several GIS-based research projects attempting to delineate "geographic hot spots" of toxic contamination. Such GIS applications at hazardous waste sites have typically employed polygons representing data from census tracts and/or municipal boundaries. However, in most cases, census tract and other bounds may not necessarily jibe with "community" and "neighborhood" boundaries. The polygons representing characteristic data for target populations may not be consistent with the actual status of those populations.

The objective of this presentation will be to demonstrate GIS methods for producing, to the greatest degree possible, socioeconomically and culturally homogenous polygons for impact analysis of specific sensitive populations and/or communities. Case study examples of community/neighborhood characterization problems encountered in developing polygons during previous field investigations involving lead contamination, Toxic Release Inventory sites, and solid/hazardous waste sites will be presented. Effective solutions and suggestions for improving polygon development will be demonstrated, including various GIS data manipulations and software applications. Also provided will be geographic and groundtruthing field methods to support and enhance the accuracy of remotely obtained information. Community and "geographic hot spot" analyses will include not only potential public health impacts, but also potential negative externalities for property and aesthetic resources.

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