Geographic Information Systems (GIS) Applications in Water Resources Research: American Water Resources Association Annual Meeting, Chicago, Illinois, November 6-10, 1994

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ABSTRACT

Four sessions of oral presentations on GIS were organized by the Technical Working Group on GIS of the American Water Resources Association (AWRA) for the 30th Annual Conference of the AWRA, November 6-10, 1994, in Chicago, Ill. This document presents the session programs, abstracts, and author information. Two of the sessions described the GIS work of the Scientific Assessment and Strategy Team on the 1993 flood in the Upper Mississippi River Basin. The third session covered generic data topics, such as data base creation, errors, spatial resolution, and processing algorithms. Various GIS applications in water quality were addressed in the fourth session.

INTRODUCTION

The 30th Annual Conference of the American Water Resources Association (AWRA) was held November 6-10, 1994, in Chicago, Ill. The AWRA Technical Working Group on GIS organized four of the conference sessions. This document contains the abstracts of the oral presentations on GIS research and applications submitted for the conference.

GIS Sessions I and II concerned the 1993 flood in the Upper Mississippi River Basin. The abstracts summarize the work of the Scientific Assessment and Strategy Team (SAST), established by the White House Interagency Floodplain Management Review Committee to use GIS technology in developing data bases and providing scientific assessments to help in making decisions about river-basin management. The abstracts from these sessions describe the many facets of the team's work in the Mississippi River Basin, especially work related to the 1993 flood.

GIS Sessions III and IV dealt with various GIS issues and applications to water resources. Presentations in one session covered generic data topics, such as data base creation, errors, spatial resolution, and processing algorithms. The fourth session described various uses of GIS applications in water quality studies.

Chapter 1 contains the programs for the four sessions on GIS. They are presented in the same order as they appear in the AWRA Annual Conference Program. Session titles and moderators are listed along with the titles and authors of the presentations. The abstracts are arranged by program sequence in chapter 2. Contact Information (addresses and telephone numbers) for the authors is listed in chapter 3. Readers wanting further information on specific research can contact the authors.

The AWRA Technical Working Group on GIS encourages the exchange of knowledge and ideas among water resources professionals and technical professionals in the field of GIS. The abstracts in this document were reviewed and selected by members of the GIS working group for presentation at the 1994 AWRA Annual Conference. They represent a cross-section of current research and applications of GIS to water resources problems, from technical data processing to long-range water resource management. Further information about the GIS working group can be obtained from C. Hallam and J. Salisbury. Information about the AWRA and the 1994 AWRA Annual Conference can be obtained from the American Water Resources Association, 950 Herndon Parkway, Herndon, VA 22070-5528 USA; telephone: (703) 904-1225.

Inclusion of abstracts of work involving GIS's should not be taken as an endorsement of their findings by the U.S. Geological Survey, the U.S. Agricultural Research Service, or the American Water Resources Association.

DESCRIPTION OF SESSIONS

Geographic Information Systems I:

The 1993 Flood in the Upper Mississippi River Basin - Part A

Session Moderator: S.K. Nanda (U.S. Army Corps of Engineers, Rock Island, IL)

Scientific Assessment of the 1993 Flood in the Upper Mississippi River Basin. Timothy D. Liebermann (U.S. Geological Survey, Carson City, NV) and John A. Kelmelis (U.S. Geological Survey, Reston, VA)

Hydrologic Modeling of West Fork Cedar River Watershed Using GEOSHED Automated Drainage Analysis. Jeff Jorgeson (U.S. Army Corps of Engineers, Vicksburg, MS), Gary E. Freeman (U.S. Army Corps of Engineers, Vicksburg, MS), Billy E. Johnson (U.S. Army Corps of Engineers, Vicksburg, MS), and Jim Nelson (Brigham Young University, Provo, UT)

Effect of Levees on the 1993 Mississippi River Flood. Gary E. Freeman (U.S. Army Corps of Engineers, Vicksburg, MS), Robert L. Barkau (Consultant to SAST, St. Louis, MO), and S.K. Nanda (U.S. Army Corps of Engineers, Rock Island, IL)

Restoring the River-Floodplain Connection to the Lower Missouri River: the Flood of 1993. David Galat (National Biological Survey, Columbia, MO), Mark Laustrup (National Biological Survey, Onalaska, WI), and John C. Dohrenwend (U.S. Geological Survey, Menlo Park, CA)

Missouri River 1993 Flood Flow Characteristics Determined from Floodplain Erosion and Deposition: Kansas City to St. Louis. John C. Dohrenwend (U.S. Geological Survey, Menlo Park, CA), Byron D. Stone (U.S. Geological Survey, Reston, VA), Milo Anderson (U.S. Environmantal Protection Agency, Chicago, IL), Lara Derasary (Urban Creeks Council, Berkley, CA), Kara A. Dohrenwend (Urban Creeks Council, Berkley, CA), Mark Laustrup (National Biological Survey, Onalaska, WI), Robert Miller (U.S. Geological Survey, Menlo Park, CA), Tom Owens (National Biological Survey, Onalaska, WI), and Cathy Tortorici (U.S. Environmental Protection Agency, Kansas City, KS)

Geographic Information Systems II:

<u>The 1993 Flood in the Upper Mississippi River Basin - Part B</u>

Session Moderator: S.K. Nanda (U.S. Army Corps of Engineers, Rock Island, IL)

Generalizing Soil Slope Data in a Geographic Information System. Norman B. Bliss (Hughes STX Corp., Sioux Falls, SD) and Maurice J. Mausbach (U.S.D.A. Soil Conservation Service, Washington, DC)

Reductions in Runoff Because of the Flood Security Act of 1985. Dennis Miller (U.S.D.A. Soil Conservation Service, Des Moines, IA)

A Summary of Average Annual Benefits from Public Law 83-566 for the Nine States within the 1993 Flood Area. Dennis Miller (U.S.D.A. Soil Conservation Service, Des Moines, IA)

Solutions for the Flooding and Other Environmental Problems in the Watershed. Gary Freeman (Waterways Experiment Station, Vicksburg, MS) and Dennis Miller (U.S.D.A. Soil Conservation Service, Des Moines, IA)

Totaling the Dollars in the 1993 Flood. David Buland (U.S.D.A. Soil Conservation Service, Huron, SD), Mark Laustrup (National Biological Survey, Onalaska, WI), and Milo Anderson (U.S. Environmental Protection Agency, Chicago, IL)

Geographic Information Systems III:

<u>GIS Applications in Data and Resolution</u>

Session Moderator: Cheryl A. Hallam (U.S. Geological Survey, Reston, VA)

A Great Lakes Data Base for Land Surface Hydrologic Process Models. Deborah H. Lee (Great Lakes Environmental Research Laboratory, Ann Arbor, MI)

Comparison of GIS-based Watershed Delineation Algorithms. M. J. Paulson (Colorado State University, Ft. Collins, CO), and Dean Tucker (U.S. National Park Service, Ft. Collins, CO)

Sources of Error in Morphometrically Defined Hydrologic Source Areas. Mark Stelford (Northern Illinois University, DeKalb, IL)

The Effect of Resolution on Hydrologic Modeling Parameters. Cheryl A. Hallam (U.S. Geological Survey, Reston, VA)

Integrating GIS and Remote Sensing Approaches with NEXRAD to Investigate How Spatial Scaling of Hydrologic Parameters Affects Distributed Hydrologic Modeling. ShengTang Ma (Earth Satellite Corp., Rockville, MD) and T.H. Lee Williams (University of Oklahoma, Norman, OK)

Geographic Information Systems IV:

<u>GIS Applications in Water Quality</u>

Session Moderator: Jayne M. Salisbury (U.S.D.A., A.R.S, National Agricultural Water Quality Laboratory, Durant, OK)

Assessment of Nitrogen Loading to Coastal Waters Using Land Use Data and GIS. Chi Ho Sham and Frank Moore (The Cadmus Group, Inc., Waltham, MA)

Regional Optimization of Nonpoint Source Load Reduction. J. Thomas Franques and Rhonda L. Townsend (King Engineering Associates, Inc., Tampa, FL)

Using GIS and Logistic Regression to Identify Relations of Land Use and Agricultural Chemical Use to Agricultural Chemical Concentrations in Rivers of the Midwestern United States. William A. Battaglin , David K. Mueller , and Donald A. Goolsby (U.S. Geological Survey, Lakewood, CO)

The annual meeting of the Technical Working Group on GIS followed this session.

ABSTRACTS

Scientific Assessment of the 1993 Flood in the Upper Mississippi River Basin

Timothy D. Liebermann and John A. Kelmelis

Record floods inundated the Upper Mississippi River Basin in mid-1993. Streamflow exceeded 100-year recurrence intervals at 45 gaging stations; rainfall totals were the largest of this century, by a substantial margin. In the wake of the flood of 1993, Federal officials are exploring questions about emergency preparedness and response, about recurrence intervals of major climatic and hydrologic events, and about existing policies that affect agriculture, insurance, ecosystems, and development in the floodplain. In November 1993, the White House established the Scientific Assessment and Strategy Team (SAST) to help investigate these issues.

The SAST develops data bases and provides scientific assessments to aid in making decisions regarding river-basin management. A large spatial data base has been assembled at the U.S. Geological Survey's EROS Data Center, using geographic information systems (GIS) technology. Climatic and streamflow records provide information on the 1993 event and also constitute a historical basis for comparison. All available information regarding levees in the Upper Mississippi has been processed into spatial and tabular data bases. Various statistical data, including crops, population, housing, and insurance and disaster payments data, have been compiled by county or census block group. A large library of digital satellite images (preflood, flood, and postflood) and of postflood aerial photographs is being examined to determine small- and large-scale processes.

A one-dimensional unsteady-flow model of the main channels, with a 6-hour time step and the capability of modeling off-channel storage and levee breaks, has been calibrated for the 1993 flood. Alternate structural scenarios--different flood amounts and several approaches to rebuilding or moving levees--will be evaluated using the calibrated model. Several small watersheds in agricultural areas outside the floodplain will be modeled to evaluate the potential effects of changing nonstructural land use practices and wetlands management.

The SAST is engaged in a landmark data-collection effort. Initial collection was completed in March 1994, with follow-on activities through September. The SAST effort should serve as a successful prototype for the creation of regional data bases and for a comprehensive, GIS-based Federal approach to planning.

Hydrologic Modeling of West Fork Cedar River Watershed Using GEOSHED Automated Drainage Analysis

Jeff Jorgeson, Gary E. Freeman, Billy E. Johnson, and Jim Nelson

The GEOSHED automated drainage analysis software was used in conjunction with GRASS software and the U.S. Army Corps of Engineers' Hydrologic Engineering Center model (HEC-1) to model runoff from the West Fork of the Cedar River Basin at Finchford, Iowa. The 3-arc-second digital elevation model was used to delineate the basin and define the geometric information for the subbasins. Thematic mapper satellite data provided land use and land cover data. Data from the STATSGO soils data base were combined with the land use and land cover data to determine the hydrologic grouping of the soils in each subbasin. These data were then used to automatically generate curve number data for use in HEC-1. Stream channel locations were digitized from 7.5' U.S. Geological Survey quadrangle sheets but are now available in digital format at a scale of 1:100,000.

Effects of Levees on the 1993 Mississippi River Flood

Gary E. Freeman, Robert L. Barkau, and S.K. Nanda

The effect that levees along the Mississippi River from Hannibal, Mo., to Cairo, Ill., had on the 1993 flood was modeled using the UNET one-dimensional dynamic flow model. The portion of the Missouri River from Hermann, Mo., to the mouth above St. Louis, Mo., was also modeled. Model scenarios included existing conditions, a condition without levees, differences in elevations that would have occurred if no levees existed for the flood, and a levee setback condition. The floodway was modeled with setback levees and with no levees, using a low Manning's *n* value to simulate cultivated vegetation, such as continued farming in the floodway, and a high Manning's *n* value to simulate the growth of natural vegetation, such as trees and shrubs on the floodway.

Restoring the River-Floodplain Connection to the Lower Missouri River: The Flood of 1993

David Galat, Mark Laustrup, and John C. Dohrenwend

Functioning large river-floodplain ecosystems require a natural hydrograph, including periodic flood pulses and low flows, natural sediment regimes, a connected river-floodplain, and native riparian and riverine plant and animal communities. Impoundment, channelization, flow regulation for navigation, and agricultural development within the floodplain of the Missouri River have severely disrupted ecological structures and processes and have separated the river from its floodplain. The flood of 1993 reconnected the river-floodplain complex for a brief interval.

In a study of historic and contemporary lower Missouri River channels and hydrology, the loss of river-floodplain habitat was measured. Levee failures and floodplain scour from the flood of 1993 produced or modified various wetland habitats, including connected and unconnected blow outs, remnant emergent wetlands, and ephemeral moist-soil areas. Spatial analysis of Landsat thematic mapper images and 1:24,000-scale aerial photographs was used to quantify distribution, morphology, and areal coverage of newly scoured floodplain wetlands. Research has been outlined to identify ecological benefits of these wetlands.

Missouri River 1993 Flood Flow Characteristics Determined From Flood-plain Erosion and Deposition, Kansas City to St. Louis

John C. Dohrenwend, Byron D. Stone, Milo Anderson, Lara Derasary, Kara A. Dohrenwend, Mark Laustrup, Robert Miller, Tom Owens, and Cathy Tortorici

Preliminary analysis of aerial photographs, Landsat thematic mapper images, and historic maps of the Missouri River flood plain reveals that more than 70 percent of local erosional and depositional features of the 1993 flood are located within the area of the "natural" (1879) river channel. Eroded holes breaching large levees (blew holes) are located mostly on the upstream sides of meanders at points of intersection between the present (structurally controlled) channel and the 1879 channel. Erosional zones of extensive scour and stripping extend as far as 1.5 km downstream from these blew holes. Holes breaching smaller off-channel levees, discontinuous channels, and elongate erosional depressions are aligned downstream from the larger holes. Thick sand deposits form arcuate belts downstream of the erosional zones. Moderately thick sand, commonly veneered with a silt and (or) mud drape, extends beyond these thick sand deposits. Thin deposits of sand, silt, and mud cover most other areas within the 1879 channel belt. Regional floodplain maps and pre- and post-flood satellite images document contrasting styles of scour and deposition along two river reaches: a broad (5-15 km wide) reach from Kansas City to Glasgow, and a narrow (3-4 km wide) reach from Glasgow to St. Louis. The broad reach is discontinuously fringed by low terraces that received only trace flood deposits. The inner floodplain consists of several levels, the lowest of which contains the majority of all flood deposits. Arcuate bands of thin sand indicate flow in large cells that followed abandoned meanders. In the narrow reach, the 1879 channel occupies as much as 80 percent of the floodplain's width. Blew holes, up to 300 m wide, occur within this old channel. Scour channels, as long as 8 km, follow its course, and sand flood deposits locally extend across its entire width.

Generalizing Soil Slope Data in a GIS

Norman B. Bliss[1] and Maurice J. Mausbach

The Scientific Assessment and Strategy Team (SAST) was formed to study the great flood of 1993 in the Upper Mississippi and Missouri River Basin. One of the objectives of the SAST was to develop a terrain classification and map of the basin. As part of this objective, the team developed a procedure to summarize slope information on soils in the basin using the Soil Conservation Service's STATSGO geographic data base. The STATSGO data base consists of the geographic distribution of soils at a scale of 1:250,000 and an accompanying attribute data base on soil properties, including slope gradients of soil components in the map unit polygons.

The S-Plus statistical package was used to cluster soil slope information for all map units in the basin. The team used S-Plus to generate statistically distinct slope-group classes. These slope-group classes were then plotted on a regional map. The slope groups are characterized by histograms showing the distribution of slope gradients within each group. The slope-group map is one of many overlays used to construct the terrain classification map of the basin

[1] Work performed under U.S. Geological Survey contract 1434-92-c-40004

Reductions in Runoff Because of the Flood Security Act of 1985

Dennis Miller

The Flood Security Act was studied to determine the effect that land treatment practices and the conversion of cropland to grassland had on runoff. Upon the installation of the Conservation Reserve Program, information was gathered describing those States primarily affected by the 1993 flood and the application of land treatment practices in those nine States. This information was analyzed on the basis of four different frequencies, the 1-year, 5-year, 25-year, and 100-year frequencies. Information presented on a county basis shows the decreased runoff caused by the application of land treatment practices and land use conversion that the Flood Security Act engendered. Information on maps shows four categories of decrease in runoff: 0-9 percent, 9-18 percent, 18-27 percent, and more than 27 percent.

A Summary of Average Annual Benefits from Public Law 83-566 for the Nine States in the 1993 Flood Area

Dennis Miller

The major purposes of Public Law 83-566 (PL 83-566) are preventing damage from erosion, floodwater, and sediment; furthering the conservation, development, utilization, and disposal of water; and furthering the conservation and proper utilization of land. Watershed projects are planned and implemented by local organizations with technical and financial assistance provided through PL 83-566. Approximately 25,049,487 acres are in completed watershed projects or projects under construction in the nine-State area. Average annual damages and benefits were gathered for the States of Iowa, Illinois, Missouri, Kansas, Nebraska, Minnesota, North Dakota, South Dakota, and Wisconsin.

The amount of protected floodplain is 2,340,591 acres. Average annual damages, without projects within the nine-State area would have been $138,442,328. Average annual damages with projects within the area were $58,500,732. Average annual benefits within the area were $78,916,767. Evaluation of these damages and benefits was based on conditions resulting from the 1993 flood. The current values were computed for input to the SAST studies.

Solutions for Flooding and Other Environmental Problems in the Upper Mississippi River Watershed

Gary Freeman and Dennis Miller

The Scientific Assessment and Strategy Team (SAST) was commissioned to study the great flood of 1993 in the Upper Mississippi River Basin. part of this team modeled three watersheds to show how runoff and peak flows are affected by land use and land management systems. The watersheds are in three distinct physiographic regions: The first is in a closed drainage (pothole) area of the Des Moines glacial lobe, the second is in a steeply sloping area of open drainage, and the third is in a gently sloping area of open drainage. Members of the team studied the effects of the potential for depressional (pothole) wetlands to store flood water, the Conservation Reserve Program (CRP) on surface runoff, conservation practices on surface water runoff, small flood prevention structures used in Public Law 83-566, and combinations of these alternatives.

Initial results show that the CRP and conservation practices reduce runoff in the flat watersheds but small detention reservoirs are more effective in reducing runoff and peak flows in the steep watershed.

Totaling the Dollars in the 1993 Flood

David Buland, Mark Laustrup, and Milo Anderson

One of the first and last tasks of the Scientific Assessment and Strategy Team (SAST) working on flood control in the Upper Mississippi River Basin was to attempt to total the amount of damages caused by the 1993 flood, the relief dollars spent on flood damages, and the property values within the flooded area. These economic data were entered into the GIS SAST data base. This effort proved much more complicated than expected.

The team used available information sources to obtain damage information and to find the total amount of Federal and non-Federal dollars spent in the recovery. They compared agriculture and nonagriculture production lost with the number of relief dollars spent, and discovered which damages were overcompensated and which damages were not covered by relief efforts. A proposal was made to place the property values from the nine States within the SAST GIS.

A Great Lakes Data Base for Land Surface Hydrologic Process Models

Deborah H. Lee

Linking Great Lakes region mesoscale atmospheric models with land surface hydrologic process models will improve estimates of climate change impacts and nonpoint source pollution caused by runoff and atmospheric deposition, and will help in water quantity forecasting and management. An important aspect of linking these models is the parameterization, determined in part by data availability, of the hydrologic processes. For such a parameterization, a data base is being constructed within the context of a geographical information system. A unique challenge to data base development has been to obtain comparable Canadian and American data. The data base contains a high-resolution digital elevation model, detailed soils data, and land cover and land use data. Other data bases have been derived from these data, such as slope, watershed delineation, and soil texture and water capacity data bases. Temporal records of hydrometeorological data (precipitation, air temperature, humidity, wind speed, cloud cover, and runoff) are linked to the spatial data by a relational data base. The incorporation of remotely sensed data from the National Operational Hydrologic Remote Sensing Center and the NOAA CoastWatch network is being explored. Sufficient data exist for developing and evaluating simple parameterizations.

Comparison of GIS-based Watershed Delineation Algorithms

M.J. Paulson and Dean Tucker

From an environmental and managerial perspective, watersheds are a critical GIS data base layer. The areal extent, perimeter, shape, and orientation of watersheds are also key parameters in hydrologic models. Historically, watersheds have been delineated manually. With the widespread use of GIS's and other software, watersheds can now be delineated automatically. The limitations of manual watershed delineation, in terms of the accuracy and reliability of the source document and the ability of the watershed-delineator to read the map, are readily understood. Automated computer watershed delineation, however, exists as somewhat of a "black box," with a host of potential pitfalls that are typically beyond the experience of GIS operators if there is no surface representation. A comparison was made of GIS-based watershed delineation algorithms found in several popular GIS packages. All of the algorithms were employed on common data sets to determine their strengths and weaknesses in relation to each other and to manual delineation. The comparison yielded recommendations for performing automated watershed delineation in different topographic circumstances.

Sources of Error in Morphometrically Defined Hydrologic Source Areas

Mark Stelford

During recent decades, field studies have cast doubt on whether Hortonian overland flow is the principal process responsible for storm hydrographs. GIS technologies and digital spatial data sets have provided hydrologists with fresh possibilities for using quantitative terrain analysis in a new generation of hydrologic response models. It is now possible to build models that take into account the geometric and spatial distribution of contributing areas. Morphometric characteristics of the landscape, such as distance from a point on the channel to the divide, land slopes and aspect, channel gradients, and basin shape, are all possible derivations from the grid samples of a digital elevation model (DEM). Investigators must be aware of the problems inherent in using DEM's in hydrologic modeling. Source data accuracy and pixel resolution vary in the data sets that are available. The grid sampling system of the DEM may miss important information about the surface in question. In recently glaciated or karst terrain, separation of real and artificial "sinks" affects automatic watershed delineation algorithms in available commercial software. Analysis of four contiguous 7.5' quadrangles in northeastern Illinois and one 7.5' quadrangle in Virginia illustrates some of the problems and provides some solutions.

The Effect of Resolution on Hydrologic Modeling Parameters

Cheryl A. Hallam

Digital elevation models (DEM) are a critical element in generating hydrologic modeling parameters. Although studies list their limitations and errors, DEM's continue to be used because they provide the data required for the automated delineation of drainage basins, stream channels, stream order, slope, aspect, flow direction, and flow accumulation over a land surface.

In this study, the U.S. Geological Survey's 1:250,000-scale DEM data base was used to generate elevation layers at a series of resolutions from 100 to 1,000 meters for a rectangular area that includes the East River Basin in Colorado. Mean elevation and slope values for each of the resolution levels were then generated and compared to assess the changes as the resolution levels were decreased. The effects of declining resolution on mean elevation and slope were analyzed using three differently defined geographic areas: the rectangular area, the East River Basin within it, and the hydrologic response units (HRU) within the basin.

For the rectangular area and the basin, the decrease in resolution was accompanied by a consistent decline in correlation between the degraded layers and the control (100-meter) data set, but minimal changes occurred in mean slope and aspect for most cell sizes. In contrast, when slope and elevation were summarized over the HRU's, the mean values were more strongly affected by declining resolution.

The findings indicate that a relationship exists between resolution declines and (1) the size of the area over which parameters are summarized, and (2) the physical characteristics used to define the area over which the values are calculated. The results suggest that data resolution is more important when using models that employ the spatially distributed parameter approach rather than those that lump the parameters over the entire basin.

Integrating GIS and Remote Sensing Approaches with NEXRAD to Investigate How Spatial Scaling of Hydrologic Parameters Affects Distributed Hydrologic Modeling

ShengTang Ma and T.H. Lee Williams

Remote sensing and GIS were integrated with NEXRAD weather radar data in a watershed modeling package, HYDROGIS, to investigate the spatial scaling of hydrologic parameters and how this affected the accuracy and spatial distribution of surface runoff measurements. The Little Washita River basin, a rural watershed in south-central Oklahoma, was modeled by using precipitation data estimates from rain gages and NEXRAD radar, and land use and land cover information methods. Storm runoff processes were simulated at various spatial resampling scales using four different aggregation methods (majority, median, average, and image resampling) to estimate the accuracy and spatial reliability of runoff measurements at each aggregating level.

Results indicate that the spatial structure of landscape significantly affects the spatial scaling, that high runoff-generating areas are important in processing surface runoff, and that the critical scale for this particular basin is about 300 m. Spatial patterns of soil and precipitation have less impact on the spatial scaling at scales of less than 1-km resolution. In addition, the method used to aggregate data or parameters is quite important--of the four methods investigated, the image resampling method was the best with respect to accuracy and spatial reliability at relatively finer scales, and the most commonly used approach, the average method, was the worst.

Assessment of Nitrogen Loading to Coastal Waters Using Land Use Data and GIS

Chi Ho Sham and Frank Moore

Concern is growing about nitrogen loading to coastal waters, because rates of primary production in coastal waters are nitrogen limited. Waquoit Bay, a shallow coastal embayment on Cape Cod, Mass., is showing symptoms of eutrophication, largely attributed to increasing nitrogen loading associated with changes of terrestrial ecosystems and land use. During the past 50 years, residential development in the Waquoit Bay drainage area has increased approximately 15-fold. In 1989, Waquoit Bay was selected as the fourth Land Margin Ecosystem Research (LMER) site by the National Science Foundation, and an interdisciplinary team of scientists was formed to assess the relationships between terrestrial ecosystem changes and coastal ecosystem dynamics. They assessed terrestrial nitrogen loading from the various land use activities in the Waquoit Bay drainage area by incorporating field studies, historical land use data, water budget analysis, ground-water modeling, and geographic information systems. This method makes it possible to quantify the total nitrogen loading in the drainage area with a high degree of certainty. Preliminary readings indicate that the total nitrogen loading in the Waquoit Bay drainage area increased two-fold during the past 20 years.

Regional Optimization of Nonpoint Source Load Reduction

J. Thomas Franques and Rhonda L. Townsend

The Tampa Bay National Estuary Program sponsored a study to develop a regional optimization model to determine pollutant load reduction strategies for Tampa Bay. The objective of the study is to determine cost-effective strategies for reducing pollutant loads from nonpoint sources to the bay.

A GIS was used to form an overlay consisting of the intersection of land use, soil type, and subbasin location for the entire watershed. A soil data base containing a depth-to-water table, infiltration rate, and slope of terrain, and a land use data base containing land use codes were also produced.

A best management practice (BMP) data base was compiled. It contained pollutant removal efficiencies, site constraints, and cost-effectiveness data for 50 BMP's considered for use in the Tampa Bay Watershed. A data base query was used to identify a set of feasible BMP's for each combination of soil and land use found in the watershed. The result is a feasibility matrix containing land use, soil type, BMP, pollutant removal efficiency, and BMP cost. The matrix was then queried with the coverage to identify a set of suitable BMP's for each area of homogeneous land use and soil type (polygon group) throughout the watershed. The set of BMP's was then evaluated for cost-effectiveness.

An optimization scheme using dynamic programming was then developed to select one BMP from the set of feasible BMP's identified. The selection process is schematized as a serial decision-making process where the stages are the polygon groups from the overlay coverage. The initial ordering is arbitrary. The decision variable is the BMP selection for the current polygon group. The input state is the capitol resource available for BMP implementation at the current polygon group. The output state is the capitol resource remaining for use in treating downstream polygon groups once the selection is made. The return (objective) is the load reduction achieved through BMP implementation. A global return function is generated for each polygon group. The global return function for the last polygon group represents the load reduction possible for each value of capitol resource availability. Once the capitol resource availability is specified, the selections are scanned in downstream order to determine the best BMP selection for each polygon group. The result is a pollutant load-reduction strategy for the Tampa Bay Watershed that shows how available resources could be allocated to achieve maximum load reduction for the region.

Using GIS and Logistic Regression to Identify Relations of Land Use and Agricultural Chemical Use to Agricultural Chemical Concentrations in Rivers of the Midwestern United States

William A. Battaglin, David K. Mueller, and Donald A. Goolsby

Logistic regression is used to identify factors having the strongest relation to agricultural chemical concentrations measured in rivers. Best-fit logistic regression techniques are developed by using water-quality data from a regional reconnaissance study (1989-90) by the U.S. Geological Survey of more than 130 rivers across the midwestern United States. These techniques are used to estimate the probability of nitrate or atrazine being within a particular concentration range. The explanatory factors for the regression models include agricultural chemical use, land use, and population density within the drainage basin, and percentile of streamflow at the time of sampling. A GIS is used to extract basin-level values of explanatory variables from existing digital data. Tools such as logistic regression models not only help identify factors that have strong relations to agricultural chemical concentrations in rivers, but may also prove helpful to water managers and suppliers who must comply with current drinking-water regulations.

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