Virginia's Waters: Current Developments

1988 Water Resources Research Forum

Briefing Papers

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Virginia Water Resources Research Center
Virginia Polytechnic Institute and State University
Blacksburg, Virginia

This publication and several of the research projects summarized in it were financed in part by the U.S. Geological Survey, Department of the Interior, as authorized by the Water Resources Research Act of 1984.

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A publication of the Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University. William R. Walker, director; Edward Born, assistant director for publications.

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Foreword

This marks the third consecutive year that a forum has been organized to facilitate the exchange of water-related information among researchers and potential users of research.

Although the Water Center had the management responsibility for the forum, the Center was ably and wisely guided by steering committee composed of the following individuals: James R. Groves, Virginia Military Institute; Allen R. Hammer, Virginia Department of Health; Janet S. Herman, University of Virginia; Bruce Nielson, Virginia Institute of Marine Science; John Powell, U.S. Geological Survey; B. Blake Ross, Virginia Tech; Ronald D. Sexton, Virginia Water Control Board; George M. Simmons, Virginia Tech; Robert B. Taylor, Virginia Department of Health; and David K. Whitehurst, Virginia Department of Game and Inland Fisheries. From the Center were Diana L. Weigmann and Elizabeth B. Crumbley. To each, I express my appreciation and thanks.

In many respects this is an unusual forum. Being held in conjunction with the North American Society's Regional Symposium on Lake and Reservoir Management, it is the first forum to be in Richmond. It also features nearly twice as many papers as last year's forum. A total of 47 papers are being presented by individuals representing 20 organizations.

We hope that the growth in popularity of the forum will not diminish its quality. If you have suggestions to improve future water research forums, I hope you will share them with me or some other member of the staff, as we are constantly on the look-out for ways to improve the effectiveness of our programs.

— William R. Walker, *Director*
Virginia Water Resources Research Center

Erosion and Sedimentation Control in Virginia

Roger T. Kilgore[1] and Jerome M. Normann

The Division of Soil and Water Conservation last summer sponsored a review of the Erosion and Sediment Control (ESC) Law. The review was performed by Smith Demer Normann, Inc. with subcontract help by GKY & Associates, Inc. and the Virginia Institute of Marine Science. The review included an assessment of the legal, staffing, technical, and enforcement provisions of the law and resulting regulatory program. This paper covers only that part of the comprehensive review performed by GKY & Associates.

The assessment included a review of technical provisions of the law, its general criteria, and specifications found in the Virginia ESC Handbook. The handbook provides the primary technical support for the program.

As part of the review, a questionnaire was sent to individuals and groups interested in or responsible for the ESC program. Part of the questionnaire addressed technical issues, and responses to technical questions were tabulated and evaluated. Differences in response patters from different groups were noted.

Finally, interviews, plan reviews, site visits, and a literature search were conducted to determine any discrepancies between the ESC program in theory and practice. Interviews included state, local government, and Soil and Water Conservation District personnel. Differences in attitude were noted in each group. Site visits and questionnaires revealed which control practices were being used and the success each was achieving.

The ESC Handbook was found to be the most comprehensive collection of information on ESC methods. However, some improvement could be achieved in documenting the most cost-effective means of achieving ESC. It was also apparent that additional work, particularly in the form of demonstration projects, would be beneficial in terms of better quantifying the effectiveness in terms of stormwater management and water quality, in addition to ESC. Specific recommendations are made for improvements to the general criteria and specifications.

[1] Presenter. GKY & Associates, Inc., 5411-E Backlick Road, Springfield, Virginia 22151.

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[1] Presenter. GKY & Associates, Inc., 5411-E Backlick Road, Springfield, Virginia 22151.

Evaluation of the Virginia Erosion and Sediment Control Program

C. Scott Crafton[1]

The Virginia Erosion and Sediment Control (ESC) Law was adopted by the General Assembly in 1973 with the intent that it would be implemented primarily by local units of government. By 1977, 171 counties, cities, and towns had adopted local ESC programs regulating the construction industry to prevent erosion and sedimentation resulting from land disturbance and protect off-site properties and waterways from degradation.

During the late 1970s and early 1980s, the program matured as the State ESC Handbook was revised, formal training programs were implemented, and the state law was improved by several amendments. However, during that same period complaints of noncompliance and enforcement problems grew at a steady rate. This fact came to a head during the 1986 session of the General Assembly in hearings regarding the addition of stop-work authority to the state law as an enforcement option.

Several legislators sensed the need for a thorough assessment of the effectiveness of local implementation of this program. They introduced language into the 1986 Appropriations Act requiring the Virginia Department of Conservation and Historic Resources (DCHR), of the Division of Soil and Water Conservation (DSWC) to conduct such an assessment and report its findings, including any impediments to effective implementation, to the 1988 General Assembly.

In November 1986 the DCHR contracted with a consulting firm to conduct this study. A literature search, mail survey, interviews, and site visits were conducted. Due to a growing sensitivity among local governments to the related issues of nonpoint source pollution and localized flooding resulting from land development, the DCHR included a study component assessing the need for a comprehensive stormwater management law and regulations in Virginia. The study was completed in late June 1987. At that time, DCHR staff began translating the findings of its study along with those of several parallel studies into a report to the General Assembly.

This paper will describe the objectives of the program evaluation, the methodologies used to conduct the study, the conclusions of significance to the program, legislative and other recommendations, and any legislative actions that may have resulted from the 1988 session of the General Assembly and the implications of such actions.

[1] Department of Conservation and Historic Resources, Division of Soil and Water Conservation, 203 Governor Street, Suite 206, Richmond, Virginia 23219.

Virginia's Agricultural Nonpoint Program: A Hands-On Approach to Water-Quality Improvement

Kenneth E. Carter and James W. Cox[1]

Over the last decade, millions of dollars and thousands of hours have been spent identifying, researching, and describing the degradation of the quality of water resources of the Commonwealth from point and nonpoint sources.

Nonpoint source pollution of the state's waters is most often the result of improper use of the land resources—uses that degrade water quality. Various scientific studies have determined the major nonpoint source (NPS) pollutants are sediment, nitrogen, and phosphorus. These pollutants differ from point-source pollutants, such as the effluent from a factory discharge pipe. They originate from every acre of cropland, grassland, and forest in Virginia. The potential for these lands to contribute nonpoint source pollutants varies inversely to the degree of management and directly to the degree of use.

As the designated nonpoint source agency, the Division of Soil and Water Conservation, Department of Conservation and Historic Resources, is responsible for implementation strategies to address efforts to solve nonpoint source based problems.

If nonpoint source pollution problems are land based, then these problems can be solved only by improved management of the land and a change of attitude by the land users. To this end, a multidirectional approach involving three major program areas was created to direct clean-up efforts. These major areas are:

- Educational Efforts
- Technical Assistance
- Financial Assistance

Educational Efforts

Efforts in the educational aspects of nonpoint source pollution have centered on both societal and individual benefits. Various methods, such as demonstrations, farm tours, brochures, and meetings, have proven successful in changing attitudes toward water quality and the acceptance of more efficient means of operation.

During 1986 and 1987 records were kept to chart the progress of this work. The Virginia Cooperative Extension Service made more than 13,500 farm visits. Individual contacts were also made by Soil and Water Conservation District personnel and SCS personnel. During this same period 28,000 farmers attended an educational meeting at which BMPs were discussed. Fourteen percent of these were farmers contacted for the first time, and 42 percent needed to use some type of BMP or conservation practice. Follow up revealed that more than 12 percent installed some type of BMP.

Technical Assistance

In order to install BMPs, resources in the form of technical expertise must be available for on-site examination, design, and implementation. To date, 28 full-time equivalent agricultural positions have been placed in local Soil and Water Conservation Districts to perform technical tasks dealing with urban and agricultural problems.

[1] Presenter. Department of Conservation and Historic Resources, Division of Soil and Water Conservation, 203 Governor Street, Suite 206, Richmond, Virginia 23219.

Financial Assistance

An aggressive program, based on cost effectiveness in pollution reduction, has been established to provide financial assistance (cost-share) to offset a portion the cost borne by the individual land user. This program has produced direct and measurable water quality improvement.

During the 1986 program year, 1,250 farmers and landowners requested financial assistance. A total of 489 completed the actual installation of one or more BMPs on their land and had their requests approved. This resulted in a reduction of soil erosion amounting to 122,772 tons on 17,335 acres of land in Virginia. This reduction in erosion means that 84,972 tons of sediment and 103,479 pounds of phosphorus were contained on the land instead of entering streams or other water courses.

Using data from actual implementation of BMPs, projections can be made concerning future efforts to address the targeting of funds, manpower, etc.

Managing Agricultural Nitrate Contamination of Groundwater in Rockingham County, Virginia

Penelope L. Diebel,[1] John M. Halstead, Randall A. Kramer, Sandra S. Batie, and Condrad D. Heatwole

Groundwater contamination from agricultural chemicals is becoming a problem in those eastern communities that combine intensive agricultural land use with sensitive groundwater systems. The authors present the results of a study of dairy farm operations in the Shenandoah Valley area. Rockingham County was selected as the study area because of its predominately agricultural economy, its vulnerability to groundwater contamination, and documented evidence of groundwater nitrate problems linked to agricultural practices. Recent studies indicate that a majority of dairy farmers in Rockingham and Augusta Counties do not have manure storage facilities. This practice leads to increased fertilizer costs to farmers and increased nitrate loadings to groundwater.

A mathematical programming model is used to evaluate the impacts of alternative pollution control policies and nitrate management practices for dairy farms in Rockingham County, Virginia. The model has two components: physical and economic. The physical component estimates the movement of nitrogen beyond the root zone, potentially into groundwater supplies. The economic decision making component compares the profitability of alternative cropping and livestock systems which reduce groundwater contamination to current practices. Thus, the model allows the evaluation of the effect of both physical restrictions on nitrate loading and economic incentives for better management of farm nutrient use. Data for the analysis was obtained from a variety of sources including a survey of dairy farmers. The survey, which was completed in the summer of 1987, yielded information on four major areas: size and type of farming operations; nutrient management and storage practices for on-farm livestock waste; drinking water problems encountered and treatment used; and general economic and environmental attitudes of county farmers.

The potential effectiveness of such policy options as cost-sharing programs for constructing manure storage facilities, field restrictions on nitrogen loading, and taxation of synthetic fertilizers are evaluated. The effectiveness of expenditures on activities such as the nutrient management program currently under way in the county, increased public education efforts and other potential policies to protect groundwater quality are also addressed using information from the attitudinal responses of the survey. The study also provides information on the economic and environmental affects of better nutrient management, and the tradeoffs between farm income and reduced nitrate loading.

[1] Presenter. Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Physiographic Analyses of the Longitudinal Distribution of Fishes in the Rappahannock River, Virginia

Eugene G. Maurakis,[1] William S. Woolcott, and Robert E. Jenkins

Analyses of the effects of elevation, gradient, and stream order on the longitudinal distribution of fishes in the Rappahannock River revealed statistically significant interrelationships between these factors. Numbers of species increased with decreasing elevations and gradients from headwater tributaries in the Blue Ridge to the mainstream at the Fall Line. Generally, species diversity increased with increasing level of stream order. Eighty-five species of fishes (62 freshwater and 23 marine) and five hybrids, identified in 365 collections, accounted for the increased diversity in populations from the mountains to the Piedmont. Replacement of species, especially marine forms, characterized the community in the tidal reach below the Fall Line. The freshwater fish fauna in the Rappahannock River is more similar to that of the York River than to any of the other three major Virginia tributaries of the Chesapeake Bay.

[1] Presenter. c/o W.S. Woolcott, Department of Biology, University of Richmond, Richmond, Virginia 23173.

Development of a Fisheries Data Base and Evaluation Protocol for Virginia's Streams

Paul L. Angermeier[1] and Richard J. Neves

A geographic information system (GIS) is being assembled for fisheries-related data from Virginia streams and rivers as a cooperative effort by the Virginia Department of Game and Inland Fisheries, the Virginia Cooperative Fish and Wildlife Research Unit, and the Department of Fisheries and Wildlife Sciences at Virginia Tech. Specific stream reaches serve as reference points in the GIS. More than 4,000 reaches have been digitized and coded with unique identification numbers according to methods established in the U. S. Environmental Protection Agency's River Reach file. The data base currently contains more than 2,000 fish collections, with each collection assigned to a particular river reach. For each reach, we have compiled 30 data elements describing its geographical and biological attributes. Important data elements include the following: stream name, county, stream order, elevation, reach, length, soil association, land use, and fish species collected. The data base is expected to provide timely, comprehensive information to resource agency personnel when fish or fishery data are needed in environmental assessments or management decisions.

In conjunction with the GIS, a protocol for assessing the relative resource value of stream reaches is also being developed. Reaches will be evaluated independently for both biological value and fishery value. Assessments will be summarized by an index, thereby providing a means for comparing resource value among reaches. Factors used to assign biological value include fish species richness, presence of rare species, habitat quality, water quality, and land use. Factors used to assign fishery value include game species composition, fishing pressure, accessibility to the public, and regional significance of the fishery. Each factor's contribution to the overall index of stream value is weighted to reflect opinions of fisheries professionals in Virginia and other states. When completed, this evaluation system will provide an objective ranking of all stream reaches in Virginia with respect to their resource value.

[1] Presenter. Virginia Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife Services, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Effects of Power Generation on Adult Striped Bass in Lake Anna, Virginia

David V. Grimes[1]

Effects of power generation on adult striped bass *(Morone saxatilis)* were studied in 1984 and 1985 as part of Virginia Power's 316(a) demonstration for its North Anna Nuclear Power Station. Habitat availability analyses showed that the coolest summer habitat available to striped bass in Lake Anna during pre-operational years (1972-1977) had temperatures ranging from 22 to 25°C. Habitat available during operational years (1978-1985) had temperatures ranging from 26 to 28°C. Age and growth data showed a decreased rate of growth for two- and three-year-old striped bass during operational years. Lengths attained by Lake Anna striped bass, from year-classes $\geq$ 1978, were below those attained by striped bass in other Virginia and southeastern U.S. reservoirs. False scale annuli and low summer condition factors indicate there is summer checking of striped bass growth occurring in Lake Anna. Biotelemetry data collected in 1984 and 1985 indicated that sustained summer rains may alleviate the effects of elevated habitat temperatures. Movement of striped bass to areas of temporarily improved habitat and good prey availability were seen after such rains. Thermal alternation of striped bass habitat in Lake Anna has not resulted in summer mortalities of striped bass.

[1] Virginia Power, 500 Dominion Boulevard, Glen Allen, Virginia 23060.

Stream Habitat Improvements in Back Creek, Bath County, Virginia

William C. Singletary, Jr.[1]

In 1986 Virginia Power completed construction of a major stream habitat improvement project at its 2100-megawatt Bath County Pumped Storage Station, the largest pumped storage facility in the world, which is co-owned with Allegheny Power System. Located in the mountainous western portion of Virginia, the Bath County Project entailed creating two separate, connected reservoirs incidental to construction of the facility. The hydro generation facility was placed in commercial service in December 1985.

The Federal Energy Regulatory Commission license provided for enhancement of sport fish habitat along a 1.5-mile warm-water stretch of Back Creek downstream of the lower reservoir. The initial plan was designed in 1977 by Drs. John J. Ney and D.L. Garling, Jr., of Virginia Tech. The plan was updated and revised in 1984. Construction took place from July through October 1985 and consisted of installing creek fronting boulders, channel constrictions, rock deflectors, small boulder dams, boulder emplacements, casting pools, wooden overhang platforms recessed in the banks, root wads, floating logs, and submerged treetops anchored to boulders in pools. In November 1985 an estimated 200-year flood inflicted substantial damage to much of the stream improvement construction. Repair and modification to the improvements was completed in June 1986.

Dr. Ney and Dr. Donald Orth of Virginia Tech have been conducting a preliminary assessment of the effectiveness of the stream improvements. In January 1988 Virginia Power biologists assumed responsibility for the remaining three years of the five-year stream assessment study required by the Federal Energy Regulatory Commission license. Due to the ongoing status of the assessment study, this presentation will concentrate on the history and physical attributes of the stream improvements.

[1] Virginia Power, 5000 Dominion Boulevard, Glen Allen, Virginia 23060.

Nutrient and Moisture Conservation for Two-Crop Rotations in the Chesapeake Bay Area as Influenced by Selected BMPs

G. Menelik, R.B. Reneau, Jr.,[1] D.C. Martens, T.W. Simpson, C. Hagedorn, and G.W. Hawkins

Nonpoint sources of pollution account for approximately 65 percent of the nitrogen (N) load that enters the Chesapeake Bay each year. It is anticipated that the loss of N from cropland can be controlled through the use of best management practices (BMPs) such as conservation tillage and increased efficiency of N utilization by the crop. This research is designed to evaluate the potential N leaching losses under both no-till and conventional-till systems for corn *(Zea mays L.)* production in two major crop rotations, i.e., continuous corn and corn-wheat *(Triticum aestivum L.)*-soybean [*Glycine max (L.) Merr.*] rotations. The continuous corn rotation is being conducted on a deep, well-drained, fine-textured Groseclose silt loam soil in the Ridge and Valley region of the state. The corn-wheat-soybean rotation is being conducted on a deep, well-drained, coarse-textured Suffolk sandy loam soil located in the Coastal Plain region of Virginia. Treatments being studied at these sites consist of a control, three rates of inorganic N fertilization at planting, one split application of inorganic N, and two types of anaerobically digested sewage sludge. Tillage management consists of no-till and conventional-till striped across treatments. The specific objectives of this paper are to evaluate the effects of tillage and N application on N conservation and distribution within the soil profile, moisture retention and distribution within the root zone, fodder and grain yield, and N uptake by the crop. No-till retained cumulatively higher moisture than conventional tillage, particularly in the upper one m of the soil profile. No-till management increased both corn grain and stover yields when compared with conventional tillage. The higher yields are attributable to the larger quantities of water available for crop use with no-till cultivation.

No-till cultivation resulted in greater N uptake by the crop and apparently higher denitrification losses. The larger quantities of N present in the Groseclose soil profile following corn harvest where conventional tillage was employed increased the potential for N leaching during periods of excess moisture as compared with no-till. Where winter wheat was grown on the Suffolk soil, deep soil samples indicated that all N not utilized by the wheat was leached from the plant root zone.

[1] Presenter. Department of Agronomy, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Pilot Study of Forested Buffer Strip Performance in the Coastal Plain

Carl Hershner[1]

A pilot study of forested buffer strip performance was conducted at a site on the York River in Virginia during the spring of 1987. Using a combination of surface runoff collection devices and shallow groundwater wells, the concentration of dissolved inorganic nutrients moving through the buffer strip was monitored. The objectives of the study were to assess methodologies for a more extensive field study and to gain a preliminary indication of forested buffer strip performance.

The pilot study provided a limited support to the hypothesis that forested buffer strips serve as a natural sink for nutrients transported from croplands by water movement. Nitrate, which was the dominant form of nitrogen entering the buffer strip, was consistently removed from water moving through the study site. Effects on other nutrient species (ammonia, nitrite and inorganic phosphate) were not consistently demonstrated.

The experience gained during the pilot study suggests a premium should be placed on investigation designs which utilize integrative performance indices. Preliminary site selection work for this study demonstrated the wide variations both within and among potential study sites. This suggests a need to develop study methodologies that produce performance assessments on broad scales of space and time in order to produce useful input for management decisions.

[1] Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia 23062.

A Study of Infiltration Trenches in Unsaturated Soil

C.Y. Kuo[1] and J.H. Kim

Interest in employing infiltration trenches to control peak storm runoff and nonpoint source pollution in urban areas has increased in recent years. The work reported here is a study of infiltration trenches in unsaturated soil. The infiltration rates and the water content distributions in soil calculated by Fok's model and a finite-difference model are compared for both the Ida silt loam and the Webster clay loam soil considering the capillary zone effect due to the groundwater table. A computer program for hydrologic routing in infiltration trenches has been developed with the infiltration rate calculation based on a three-dimensional cumulative infiltration equation. The three-dimensional cumulative equation developed in this study is recommended for the analysis and practical design of infiltration trenches, since it is easy to use and inexpensive in computation. An infiltration trench with overflow has been examined, allowing the overflow not to exceed an allowable discharge to downstream. It has been found that the surface infiltration due to overland flow does not significantly influence the infiltration rate from a trench. It has also been found that a long, narrow trench is more effective for water to infiltrate into soil than a short, wide trench for the same trench area (length x width). The hydraulic conductivity of a soil is an important factor in the design of an infiltration trench, whereas the porosity and the effective capillary potential have minor effects.

[1] Presenter. Department of Civil Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

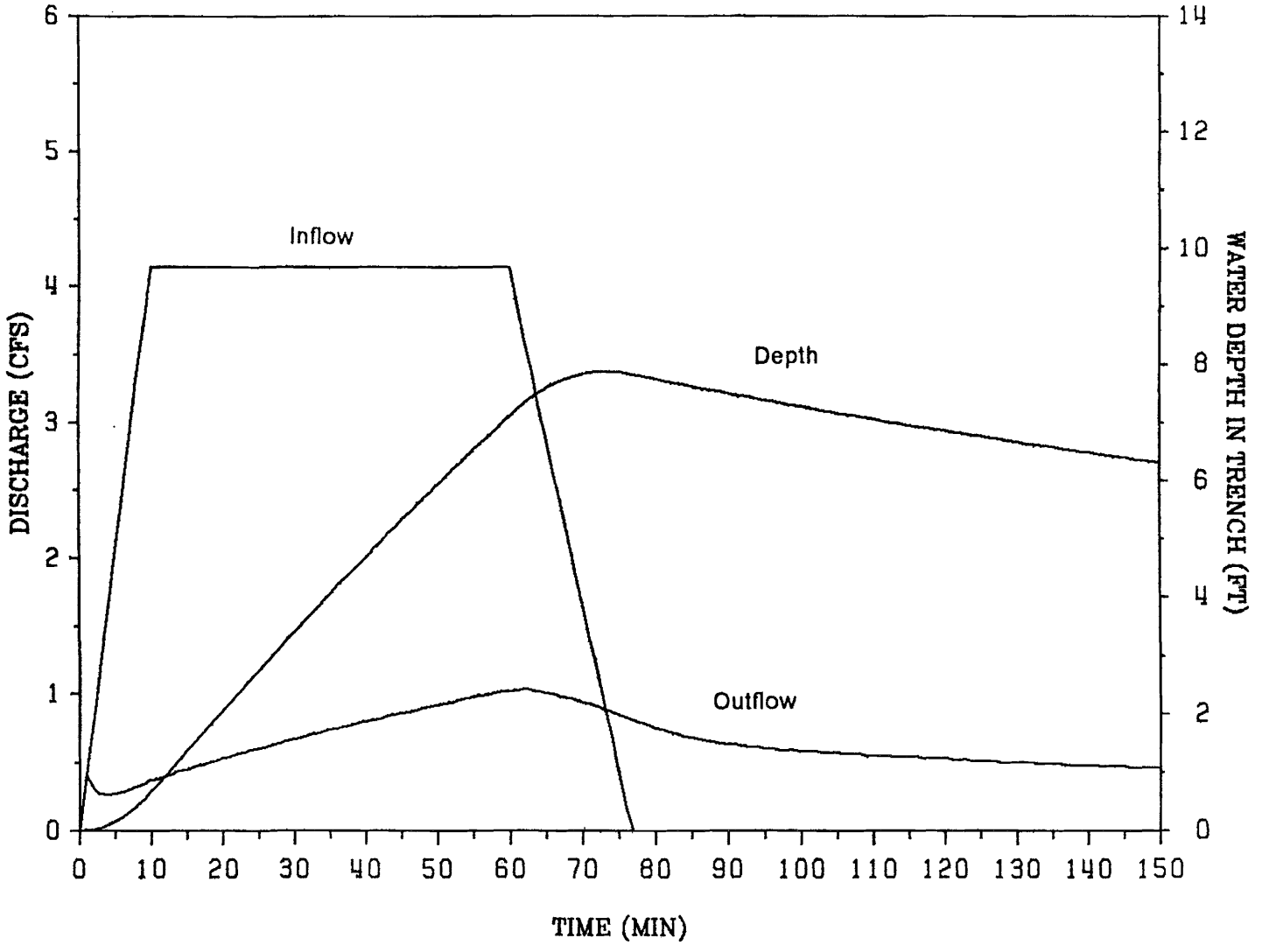


Figure 1 . Results of hydrologic routing in an infiltration trench

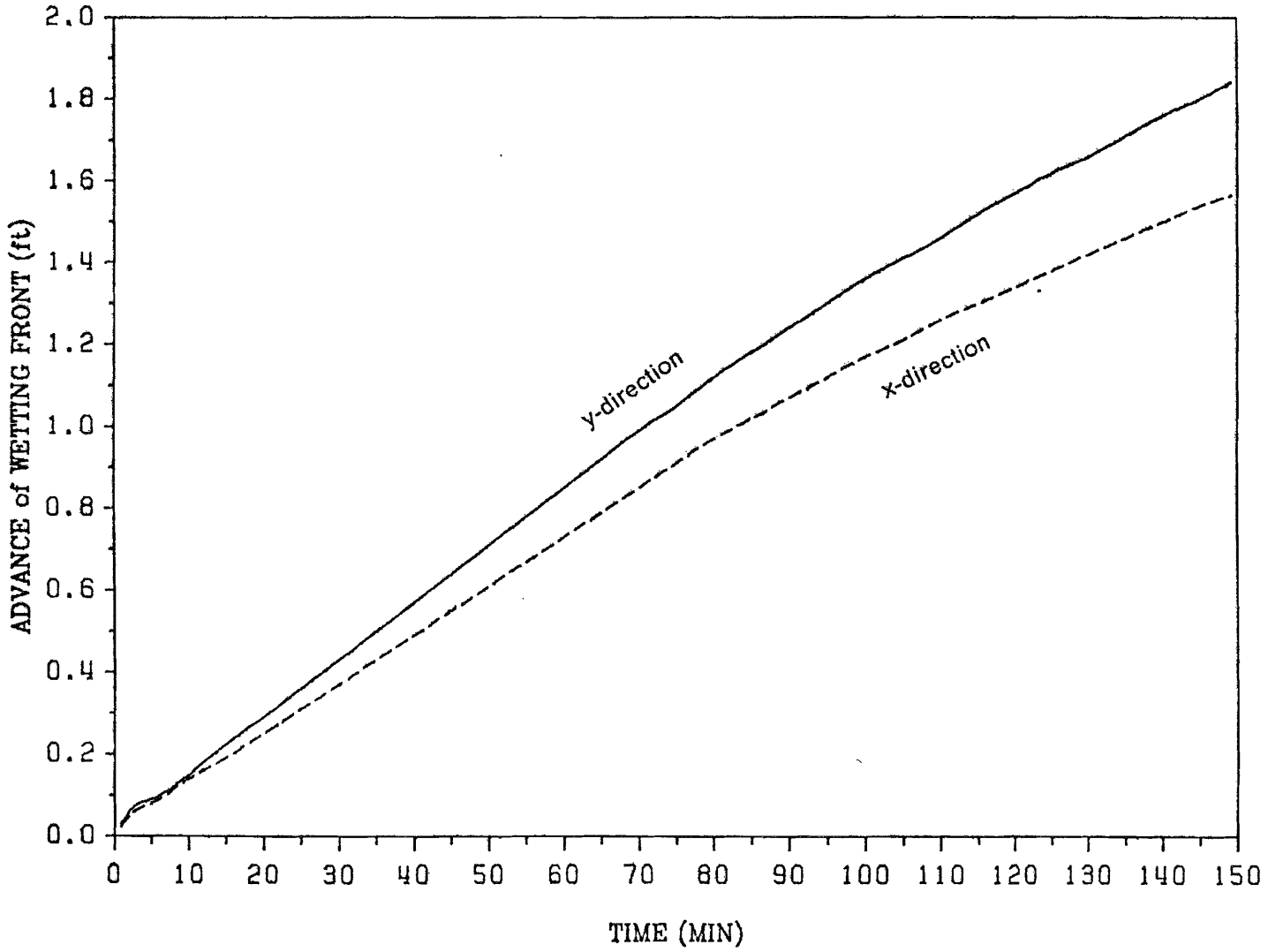


Figure 2 . Time history of the wetting front

Use of Stormwater Models to Optimize the Performance of a Regional Stormwater Detention System

John P. Hartigan[1] and Thomas S. George

The regional approach to stormwater detention has many advantages over the traditional onsite design approach, including:

- increased effectiveness
- reduction in capital and maintenance costs
- opportunities to manage existing and as projected stormwater problems
- opportunities to provide water-quality management as well as erosion and flood control protection
- increased opportunities for open space protection and recreational uses.

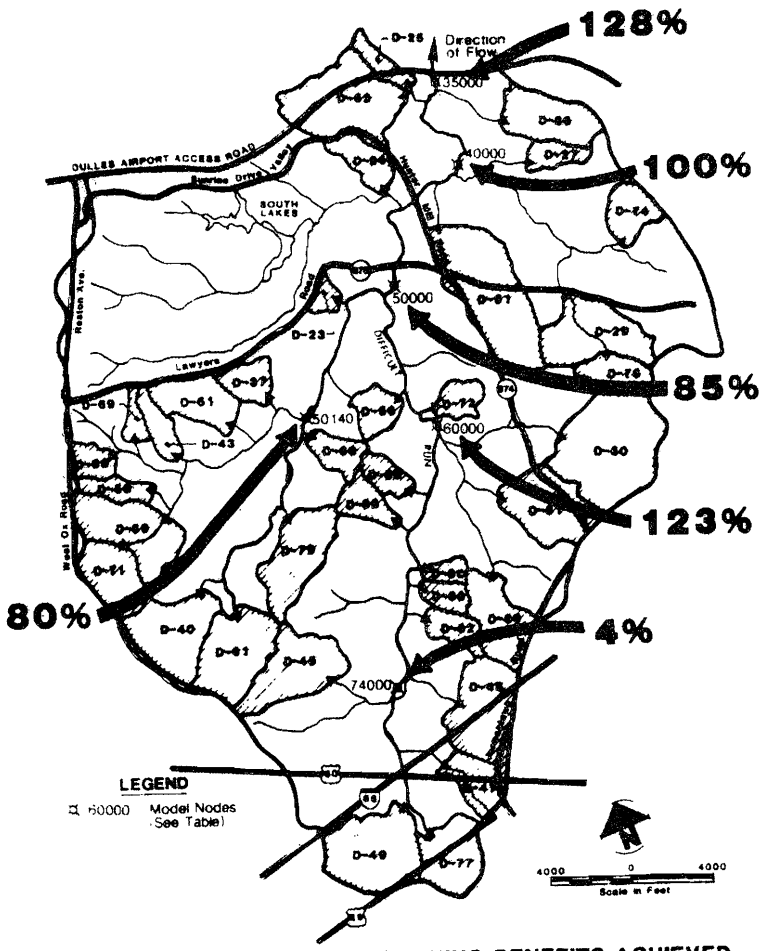
For these reasons, the Department of Public Works, Fairfax County, Virginia, is developing a regional stormwater management master plan for the county. The plan involves identifying and providing conceptual designs for up to 200 regional stormwater detention facilities to provide controls for up to 100 square miles in the rapidly urbanizing sections of the county. The regional system will provide streambank erosion control, flood control, and water quality benefits through wet and extended dry detention.

The key to a successful regional stormwater detention system is a comprehensive analysis of the topographic, land-use, and hydrologic factors within a watershed. Each of these factors governs the need for stormwater controls and defines the physical constraints for siting and designing stormwater detention facilities. The development of criteria for locating and designing regional detention basins is the first step. Topography, soils, land development, and critical environmental areas are of prime importance in locational criteria; however, property access and adjoining land use are items that must also be addressed. The design criteria focus on the particular type of detention facility to be recommended at a site and for Fairfax County facilities include wet detention and extended dry detention with 10-year flood control and/or 2-year erosion control. Once the regional detention basin sites are selected and conceptual designs are formulated, stormwater models are applied to simulate watershedwide hydrology and screen the benefits of alternate regional detention basin sites. In addition, the model is used to evaluate the watershedwide benefits of oversized detention basins which achieve lower release rates.

The result of the Fairfax County master plan is a well-tuned, regional detention system designed to control storm runoff under existing and future land-use conditions. Traditional design criteria require that postdevelopment peak discharges at a development site be reduced to predevelopment levels for a specified design storm. These performance standards result in 40 to 70 percent reductions in 2-year and 10-year peak flows for postdevelopment conditions immediately below the regional detention basin. However, applying these criteria on a regional scale in Fairfax County result in insignificant watershedwide benefits and, at some main stem locations, peak discharge *increases* of up to five percent. Travel time studies are performed with the stormwater model to identify facilities that have adverse watershedwide impacts. The model is also used to evaluate the benefits of *oversized* regional detention basins designed to achieve *lower* maximum release rates, with the objective of maximizing the use of available storage and compensating for areas not controlled by regional detention facilities. By reducing maximum release rates to 33 percent of the 2-year predevelopment peak flow, postdevelopment peak discharges (2-year and 10-year) are reduced to as much as 90 percent of the postdevelopment peak flows immediately below the detention facilities and up to 65 percent at downstream main stem locations county-

[1] Presenter. Camp Dresser & McKee, 7630 Little River Turnpike, Suite 500, Annandale, Virginia 22003.

wide. The figure below shows the increase in benefits of lower maximum release rates achieved by about 20 oversized detention basins in the upper watershed of Difficult Run (35 sq mi) in Fairfax County, VA. At location 50140 on the figure the 2-year postdevelopment peak is reduced by 30 percent with predevelopment peak flow release rates and by 54 percent with 33 percent of predevelopment flow release rates. This provides an 80 percent increase in 2-year peak-shaving benefits with the smaller detention basin release rates. Therefore, a relatively small increase in storage and capital costs produces a very significant increase in benefits.



INCREASE IN 2-YEAR PEAK-SHAVING BENEFITS ACHIEVED BY SMALLER DETENTION BASIN RELEASE RATES (33% of Predevelopment Peak Flow)

The Effect of Submersed Aquatic Weed Beds on Phytoplankton Biomass and Activity in the Freshwater Tidal Potomac River

R. Christian Jones[1]

The invasion of the freshwater tidal Potomac River by *Hydrilla* and other submersed aquatics during the 1980s has stirred controversy about the relative benefits and costs of submersed aquatic vegetation. One potential benefit suggested has been the suppression of nuisance algal blooms and this enhanced water clarity. During the summer of 1987, an interagency research team conducted a broad-spectrum research study to assess the impacts of submersed aquatic vegetation, including *Hydrilla*, on water quality and biological communities at two sites in the freshwater tidal Potomac. This paper reports on the results of phytoplankton biomass and productivity analyses conducted during that study. At each of the two study sites, three weed bed areas were identified: (1) open water control (2) *Hydrilla*, and (3) mixed species. With each area two stations were sampled. Water for analysis was carefully pumped from a depth of 0.3 m, being careful to avoid contamination from periphyton. Chlorophyll was assayed by fluorometry and productivity by C-14 uptake in the lab under an artificial light source. Preliminary results indicate that phytoplankton biomass and activity was consistently and substantially lower in the weed beds relative to the open water control. The effect was more marked at low tide than at high tide. *Hydrilla* areas had consistently less phytoplankton than mixed weed beds. Results suggest that *Hydrilla* in particular and submersed aquatic vegetation in general can have an inhibitory effect on the development of phytoplankton populations.

[1] Department of Biology, George Mason University, Fairfax, Virginia 22030.

The Relative Significance of Macrophyte and Phytoplankton Decomposition in the Consumption of Oxygen in the Lower Chesapeake Bay

Luis M. Lagera, Jr.[1] and Joseph C. Zieman, Jr.

Although phytoplankton respiration and decomposition are believed to be the principal processes that cause oxygen depletion or hypoxic conditions in the Chesapeake Bay, currently available measurements of these processes are still insufficient to test this hypothesis. Most of the available measurements relevant to this problem are dissolved oxygen measurements that do not directly provide oxygen consumption rates. The significance of other water column and benthic processes that could also consume oxygen have also not been adequately evaluated. The decomposition of macrophyte material such as *Zostera* and *Spartina* wrack in some bay areas is a benthic process that can consume oxygen. To evaluate the relative roles of water column and macrophyte decomposition in the consumption of oxygen in the lower Chesapeake Bay, we have been measuring oxygen consumption rates in surface water samples and decomposing macrophytes in the York River using BOD bottle incubations.

In the summer of 1986, standard litter bag techniques were used to obtain samples of decomposing *Zostera*, *Spartina* and *Quercus* at three sites along the lower 10-mile segment of the York River at successive stages of decomposition. At biweekly, and then monthly intervals, litter bags were collected and the remaining litter incubated for six hours in filtered seawater at ambient temperatures in the dark. Oxygen consumption was calculated from the difference in initial and final oxygen concentrations and normalized to an ash-free dry-weight basis.

Oxygen consumption rates in surface waters were estimated at each site between June and September 1987. These samples were incubated for 24 to 120 hours at 20° C. Additional oxygen consumption rates were obtained from 6 to 8 hours light- and dark-bottle incubations of water samples.

Among the macrophytes under study, *Zostera* had the highest oxygen consumption rates (0.1-5.4 mg O_2/g AFDW/h) while *Spartina* and *Quercus* exhibited lower but similar consumption rates (0.1-1.0 mg O_2/g AFDW/h). Consumption rates also significantly increased through the course of decomposition of *Zostera* while rates were relatively constant for the other macrophytes. Higher oxygen consumption rates in *Zostera* litter were expected since its low C:N ratio could afford a better substrate for microbial colonization.

On a volume basis water oxygen consumption rates were similar at all sites and through the whole sampling period, with most values between 0.01 to 0.15 mg O_2/1/h. While higher consumption rates were measured at upstream sites during most sampling times, this was not true for the entire study. Higher net production and consumption estimates for the upstream sites are thought to reflect higher seston densities. The size-fractionated water column incubations showed that at least 50 percent of the total respiration is due to organisms or particles larger than 1 μm in size.

These preliminary findings indicate that on a weight basis (AFDW), phytoplankton consumption rates are substantially higher than those of decomposing macrophyte litter. While most oxygen consumption rates for macrophyte litter were between 0.5-5 mg O_2/g AFDW/h, phytoplankton rates were between 0.5 to 15 mg O_2/g AFDW/h with most values higher than 2 mg O_2/g AFDW/h. Higher consumption estimates for phytoplankton can be attributed to the greater proportion of labile organic matter in algal cells that results in faster oxidation rates. Over time, the cumulative demand on oxygen by some amount decomposing macrophytes may be greater than that of an equal amount phytoplankton because phytoplankton material has such a short turn-over time.

[1] Presenter. Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903.

Though this information corroborates the prevailing opinion that phytoplankton respiration and decomposition impose the heaviest demand on oxygen in the water column, additional studies are still required to determine in situ consumption rates and patterns, considering the sizes and rates of production of the macrophyte litter pool and the residence time of the material.

Tracking the Fate of Phosphorus in the James River Estuary

Wu-Seng Lung[1]

Public concerns are directed at the eutrophication of the Chesapeake Bay and its tributary estuaries. The James River Basin contributes a significant amount of phosphorus to the bay. At the present time, phosphate detergents are banned in the Commonwealth as a control measure to reduce phosphorus loads to the bay. The ban is expected to provide various levels of reduction in phosphorus loads from the James River Basin, depending on the hydrologic conditions. Numerous studies of the James River Estuary addressing different issues having been reported over the years. However, several important questions still remain: how much phosphorus in the phytoplankton biomass in the estuary comes from point sources, nonpoint sources, or the upper basin? How much phosphorus in the sediments is from these sources?

A modeling analysis has been conducted to address these questions. In the analysis, a technique called numerical tagging is developed to label a single phosphorus source or a group of sources so that the contribution of the source(s) to the phytoplankton biomass could be quantified. Such a technique, similar to radioactive labelling, is needed because of the nonlinear nature of the phytoplankton growth and nutrient uptake relationship. Recent data from the James River water quality monitoring program conducted by the Richmond Regional Planning District Commission are used to support the analysis. The information generated by the numerical tagging analysis could be used to develop a sound, long-term water-quality management strategy for the James River Basin.

[1] Department of Civil Engineering, University of Virginia, Charlottesville, Virginia 22903.

Chesapeake Bay Water-Quality Conditions

Kevin Curling and Bruce Neilson[1]

Since June of 1984, the Chesapeake Bay Program has actively monitored the bay and its tributaries. In the state of Virginia, the Water Control Board, Old Dominion University, and the Virginia Institute of Marine Science share the responsibility of sampling the state's waters. VIMS samples that part of the bay located between the Maryland-Virginia border at Smith Point and Wolftrap, and stations at the mouths of Mobjack Bay, and the York, Poquoson and Back Rivers.

The water-quality monitoring is designed to produce a very well defined picture of the bay, both spatially and temporally. Of 49 stations in the bay proper, 28 are located in Virginia (20 are sampled by VIMS and eight are sampled by ODU). Cruises are conducted twice monthly, except during November, December, January and February, when only one cruise is taken. All stations are sampled within a three-day period.

The upper Chesapeake Bay in Virginia does appear to have some problems, mainly hypoxia during the summer months, that were not known to exist by many scientists and managers. The data from the monitoring program also present a bay that is much more dynamic than originally thought. Temporally, there have been both large and short-term changes. Large-scale differences between years are due to differing climatic conditions (e.g., summer droughts). The short-term changes, such as heavy rain runoff, also appear to affect the bay proper. The bay recovers from unusual conditions, such as long-term high flows, in a rather short period.

During high-flow periods, a strong pycnocline will develop in the bay, effectively eliminating any physical transport between surface and bottom water layers. The dissolved oxygen in the lower layer can be depleted rapidly. During the summer of 1987, this occurred. However, the bottom water was effectively reaerated, even while the pycnocline was developing. This reaeration event took place in a period of two weeks. After the bottom water was reaerated, the dissolved oxygen was not depleted again because the pycnocline started to dissolve. This reaeration phenomenon also occurred in 1984. During 1987, there were also very large chlorophyll blooms and nutrient spikes during the spring.

Model studies have corroborated the scientists' contentions that sediments effect the quality of the overlying waters. Preliminary efforts have been initiated to monitor sediment-water column exchanges.

[1] Presenter. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia 23062.

Geographic Information System for the Analysis of Volatile Organic Contamination in the Triassic Basin of Prince William County, Virginia

David L. Nelms[1] and Donna L. Richardson

The U.S. Geological Survey (USGS), in cooperation with Prince William County, Virginia, is investigating volatile organic carbon (VOC) contamination in the groundwater system of the Triassic basin. Contamination of the groundwater resources has been documented by comprehensive investigations conducted at an industrial area by private consultants. The contamination apparently has moved from its source, the industrial area, to a nearby county water-supply well. In addition, the Prince William Health District has documented VOC compounds in wells sampled in other areas of the Triassic basin and is concerned that areas identified for future groundwater development may also be contaminated.

A Geographic Information System (GIS), ARC INFO, is being implemented to identify sources and areas of contamination and to assess the effect of the basin's hydrology on contaminant movement. Data, considered to be pertinent to VOC contamination, were used to construct individual data layers that comprise the framework of the GIS. Groundwater Site Inventory (GWSI) well sites, State Water Use Data Systems (SWUDS) well sites, National Water Data Storage and Retrieval (WATSTORE) water-quality sites, National Uranium Resource Evaluation (NURE) water-quality sites, Triassic basin geology and lineaments, stream and road networks, and land use of 1972 were obtained from the USGS. Storage and Retrieval (STORET) well and water-quality data were obtained from the U.S. Environmental Protection Agency (EPA). Locations of wells and underground storage tank sites were provided by the Virginia Water Control Board. Locations of hazardous-waste generators were obtained from the Virginia Department of Health. The Prince William Health District provided locations and data on sites sampled for VOC and EPA priority pollutants.

GIS was utilized to manipulate these data layers to produce maps of over-burden thickness, potentiometric surface, well locations, sampling site locations, and location of sites of possible contamination in the study area. These maps and the various data layers have been used to locate VOC and soil-gas sampling sites for this study. Display of data using GIS define the characteristic composition of the contamination at each area of concern and aid in the integration of the geology, lineaments, and the potentiometric surface to determine the factors most affecting the movement of contaminated groundwater in the Triassic basin. With refinement of the GIS system and its data layers, Prince William County will have the capabilities to manipulate data layers using GIS to site landfills, municipal supply wells, and industrial complexes. Such capabilities will facilitates siting wells away from likely sources and pathways of contamination and will help locate landfills and industrial complexes in areas of least likely impact on the public health or environment.

[1] Presenter. U.S. Geological Survey, 3600 West Broad Street, Room 600, Richmond, Virginia 23230.

A Pilot GIS Study to Assist Environmental Management Decisions in the Elizabeth River Basin, Virginia

Todd W. Augenstein[1] and David R. Wolf

The U.S. Geological Survey (USGS) is currently engaged in a cooperative geographic information system (GIS) project with the U.S. Environmental Protection Agency. Input from about 15 other federal, state, and local agencies will also be included. The impetus for this cooperation has been the effort to restore the Chesapeake Bay—the country's largest estuary—to its healthy and productive past. The Elizabeth River Basin, located in and around Norfolk, Virginia, drains approximately 205 square miles of some of the most heavily industrialized and developed area in the bay watershed.

To assess the potential for contamination in the Elizabeth River Basin, data layers covering location, movement, and impact of contaminants are needed. By incorporating these spatial data layers from USGS and other federal, state, and local agencies into a centralized framework compatible with the GIS, specific analytical techniques can be carried out by local administrators, scientists, and managers in order to make more sound environmental management decisions within the basin and ultimately the bay watershed.

[1] Presenter. U.S. Geological Survey, 3600 West Broad Street, Richmond, Virginia 23230.

Status of the Hydrologic Data-Collection Networks in Virginia

Byron J. Prugh, Jr.[1]

The surface-water, groundwater, and quality-water data-collection networks in Virginia provide hydrologic data that permit assessment of the state's water resources, management of its reservoirs and hydroelectric-power production, withdrawals and discharges for its industrial needs, forecasting of its floods and droughts, documentation of its compact and legal requirements, and research and special studies by its educational and technical establishment.

The basic hydrologic data-collection networks operated by the U.S. Geological Survey (USGS) in Virginia consist of 82 continuous-record surface-water stations, 85 partial-record surface-water sites, 30 continuous-record and 34 periodic-record groundwater-level observation wells, and 11 surface-water water-quality stations in the 1988 water year.

The USGS network is complemented by 79 continuous-record surface-water streamflow gages and by 27 continuous-record and 170 periodic-record groundwater-level observation wells operated and maintained by the Virginia Water Control Board (VWCB).

The size of the networks has been progressively shrinking in recent years because of financial and personnel constraints. The surface-water network has been the most strongly affected. Since 1980, 34 continuous-record streamflow gages have been discontinued by USGS, whereas only four have been added. During the same period, 30 continuous-record streamflow gages have been discontinued by the VWCB, whereas only two have been added. Although a number of these gages were part of special projects, the failure to provide for the continued operation of at least a part of these sites does not bode well for the future. A continued decrease in the network may mean a lack of needed hydrologic data in the future.

With respect to the partial-record surface-water network, more than 20 sites have been added to the peak-flow network since 1980; however, none of the 207 low-flow sites operated from 1980-85 were continued because of a lack of funding. This lack of funding is especially unfortunate in retrospect after the severe droughts of 1986 and 1987.

One possible solution is that an increased emphasis be placed on the use of partial-record sites in Virginia to assess low flows and peak flows. In conjunction with strategically located continuous-record sites, use of partial-record sites appears to be the most cost-effective approach to delineating local trends in hydrologic variables.

The continued operation of these networks is important to help plan for increasing water needs and to monitor changing hydrologic conditions as land-use changes alter hydrologic responses of the river systems.

[1] U.S. Geological Survey, 3600 West Broad Street, Room 606, Richmond, Virginia 23230.

VirGIS: A Tool for Targeting Nonpoint Pollution Control Resources

V.O. Shanholtz, R.K. Byler, S. Mostaghimi, T.A. Dillaha, and E.R. Yagow[1]

A computerized data base has been assembled to identify agricultural areas with the greatest potential for contributing sediment and attached phosphorus to surface waters. The data base has been generated using the Map Analysis Package (MAP) and additional software developed to assist with calculations and data management not available in MAP. This system of computer programs and digitized data bases has been named the Virginia Geographic Information System (VirGIS). This system was developed by the Department of Agricultural Engineering at Virginia Tech under sponsorship of the Division of Soil and Water Conservation as part of the Chesapeake Bay Program.

By the end of the current fiscal year, more than eight million acres in the Chesapeake Bay drainage area in Virginia will be included in this system. The data base for each Soil and Water Conservation District (SWCD) consists of various data layers (soil type, elevation, stream network, etc.) whose values are encoded in one-hectare cells and are used to calculate soil erosion using the Universal Soil Loss Equation (USLE), a delivery ration, and the erodibility index (EI).

Current products from VirGIS are clear mylar overlays for USGS 7-1/2 minute topographic maps which individually display the water quality index (WQI), EI, and land use. These can be used by local Soil Conservation Services (SCS) personnel for identifying highly and nonhighly erodible land and for determining eligibility for the Conservation Reserve Program. The WQI overlay will be useful to SWCD technicians in targeting areas for active recruitment to participate in the Chesapeake Bay Program.

The future potential of the system includes distribution of the computerized data bases to each SWCD, once user friendly software is developed to allow for interactive farm planning with SCS's CAMPS program.

[1] Presenter. Department of Agricultural Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Virginia Coast Reserve Long-Term Ecological Research Program

Raymond D. Dueser[1]

The Long-Term Ecological Research (LTER) program of the National Science Foundation supports a network of 15 field sites dedicated to long-term environmental monitoring and research on ecological questions requiring long time periods for their resolution. Research groups are selected for inclusion in this network in part on the basis of research design, capacity for interdisciplinary research, and site integrity and security. The Department of Environmental Sciences, along with colleagues from Old Dominion University and the Virginia Institute of Marine Science, submitted a proposal last November to establish the Virginia Coast Reserve LTER Program. This program was funded for five years, beginning September 1, 1987.

The study area is the Virginia Coast Reserve, owned and managed by the Nature Conservancy as an area for conservation, research, and education. The LTER site extends 60 miles along the seaward margin of the Virginia Eastern Shore, from near Chincoteague Inlet southward to the mouth of Chesapeake Bay. This site encompasses 35,000 acres of barrier islands, intervening inlets, and extensive shallow bays, tidal flats, and salt marshes. It thus includes an extensive, ecologically diverse system of great natural and economic importance to the Commonwealth.

The research program is organized around questions related to (1) patterns and controls of primary production, (2) population distribution and abundance, (3) food chains, (4) organic matter accumulation, (5) nutrient cycling, and (6) disturbance frequency and effects. Both terrestrial and nearshore-marine environments are being studied, with particular emphasis on islands, bays, and marshes.

We are concerned with the effects of both short-term, stochastic events (e.g., tropical storms and hurricanes) and long-term, secular changes in the environment (e.g., sea-level rise) on the structure and function of this barrier island-lagoon complex. Given the dynamic character if this coastline over the past 5,000 years, the program also includes a strong emphasis on the historical development and evolution of the modern landscape. This research program is thus designed to provide information on the environmental history of this portion of the Virginia coastal zone, on its modern functioning, and on its probable response to future regional- or global-scale environmental changes.

[1] Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903.

Methodology to Predict Estuarine Salinity Recurrence Intervals during Drought/Flood Events

David R. Basco[1]

Time variability of the principle forcing mechanisms (freshwater inflow, tide, wind, precipitation/evaporation) induces salinity variability in estuaries. Insufficient length of records from field measurement programs prohibits the estimation of salinity recurrence intervals from available data sets.

The joint-probability method provides one way to synthetically calculate salinity distributions with specific recurrence intervals for drought/flood events. Deterministic, analytic, or numerical models for hydrodynamics and transport are combined with stochastic methods that utilize local exceedance frequency curves for each forcing function. The methodology is analogous to that currently applied for coastal storm surge elevation prediction. The paper will describe the methodology and present a simple example using analytical models.

Practical application lies in the use of 2-D and 3-D numerical models on high-speed computers. The relative magnitude of salinity change for the same recurrence interval can be quantified for upland reservoir construction, water rights reallocations, marsh enhancement, deep draft navigation channel construction and other man-made influences on estuaries. A more rational approach to estuarine productivity as related to salinity is the ultimate goal.

[1] Coastal Engineering Institute, Old Dominion University, Norfolk, Virginia 23529.

Modeling Surface- and Ground-Water Inputs to a Sensitive Wetland

G. Kenneth Young and Joseph S. Krolak[1]

The objective is to present a model that allows evaluation of specific environmental and hydrogeological monitoring issues. The compelling issue is the construction of a controversial proposed road along the high side of Huntley Meadows Park, in Fairfax County, Virginia. The road is thought to separate a wetland from its source of water. The surface and subsurface water supply to the park are monitored. Data from test borings of subsurface geology are studied, and new deep borings were made to provide data for determining both groundwater transmissibility through principal strata of interest and potential compression of strata under a new roadway constructed on fill.

The conceptual, disaggregated parameter, rainfall-runoff, daily time increment model is fit to a case study of a park. It is composed of three cells—one above the park with a high slope, one within the park with a flat slope, and one within the park consisting of the wetlands. The input is rainfall and the output is runoff. The model performs its water balance computations using a daily mass balance with the end of one day becoming the beginning of the next.

The modeling approach makes a daily water balance of the perched surface aquifer soil storage. If it rains, water is infiltrated and also runs off previous areas. The infiltration varies linearly from a maximum if the soil is dry, to zero if the soil is saturated. The available volume of soil storage is the product of porosity, soil depth, and the area of the surface that is previous. Water in storage moves down gradient by Darcy's Law and is also lost to the atmosphere by evapotranspiration. If it is a dry day, water still leaves the soil by evapotranspiration and by Darcy's Law movement. The two cells are linked by groundwater flows, base flow (interflow), and surface runoff from impervious and previous areas. The end of one day's soil moisture is the start of the next day's soil moisture. The computations go on day-by-day, for as long as daily inputs are provided. The rainfall data used to drive the model are from National Airport and are statistically representative of local rainfall falling on the park. The water balance to the central wetland is the sum of all water crossing the boundary between cell two and cell three. The model is coded in FORTRAN and runs on a personal computer.

For the soil depth, porosity, infiltration, and permeability, the response sensitivity is slight. For evapotranspiration, the sensitivity is noticeable but inelastic; the output change is much less than the put change of 20 percent. For that matter, all the above variables are inelastic. The water balance is sensitive to rainfall input. This is expected because rain drives the water balance.

[1] Presenter. GKY & Associates, Inc., 5411-E Backlick Road, Springfield, Virginia 22151.

Evaluation of a Created Wetland as an Urban Management Practice

A. Evans, Jr., T.J. Grizzard, F. Helliotis, and N.A. Goulet, Jr.[1]

The past few decades have brought an awareness of the need to control nutrient loading to surface waters—specifically, nonpoint pollution associated with stormwater runoff. Conventional stormwater detention basins located in the Washington, D.C., area have generally exhibited low phosphorus (P) removal efficiencies for stormwater runoff. Preliminary investigations suggest that artificially established freshwater marshes may be more efficient in removing stormwater-associated nitrogen (N) and P. To determine the N and P efficiency of an artificially created wetland, a field study was conducted in which an existing dry detention pond was converted into a 0.3-acre marsh. The basin of the dry pond was contoured in 0.5-foot intervals to a maximum depth of two feet, with an average depth of six inches. The marsh was planted with four wetland plant species, *Scirpus, Leersia, Saggitaria,* and *Cephalantus* at varying basin depths. Instrumentation was installed at the site to monitor meteorological conditions and storm inflow-outflow, and to automatically sample flow during storm events. Results to be presented include a description of the methodology used to convert a dry pond into a marsh, the instrumentation used to monitor the site, preliminary data regarding plant stand establishment for the first year of the study, and removal efficiencies for N and P prior to full plant-stand establishment.

[1] Presenter. Occoquan Watershed Monitoring Laboratory, 9408 Prince William Street, Manassas, Virginia 22110.

The Role of Submarine Groundwater Discharge in Transporting Nutrient Flux to Coastal Marine Environments

G.M. Simmons, Jr.,[1] K. von Schmidt-Pauli, J. Waller, and E. Lamourex

This project served as a pilot study to examine the possibility of quantifying nutrient movement into shallow marine environments in the Chesapeake Bay by submarine groundwater discharge (SGWD). The research site used for this study was off Chincoteague, Virginia, and was selected because of the site's proximity to established U.S. Geological Survey wells on the island. Seepage meters and mini-piezometers were used to quantify seepage flux and submarine manometer was used to measure hydraulic heads of SGWD at the research site. Three stations were established at the site. The first station was ~ 30 cm underwater at low tide, the second was located 10 m offshore, and the third was located 100 m offshore. Samples were collected monthly between March and May 1987.

The results showed that SGWD occurred and the highest rates, (1.6-0.6 $L/m^2/hr$) were at the shallowest depth nearest shore. The lowest rates were at the station farthest offshore (100 m) and averaged 0.8 $L/m^2/hr$. Discharge at the middle station ranged between 0.2 and 0.4 $L/m^2/hr$. Salinity of SGWD also showed the influence of fresh groundwater with values ranging between 12.1 and 20.3 ppt at the shallow station when ambient seawater ranged between 25.0 and 30.8 ppt. Hydraulic heads were maximum at low-tide periods (10.5-13.6 cm) and lowest at high-tide periods (8.0-8.8 cm).

Analyses of the SGWD showed that considerable amounts of ammonia were carried into bay waters by this mechanism. At the shallow station, concentrations ranged between 32.5 and 1687.8 $mM/m^2/hr$. The lowest values were measured at the intermediate station and ranged between 1.4 and 7.1 $mM/m^2/hr$. Values of ammonia flux by other investigators, using different techniques to quantify flux, have reported values at $uM/m^2/hr$ levels. Analyses were made for dissolved and total phosphate concentrations. Dissolved phosphate accounted for ~ 80-85 percent of total phosphate concentrations. Highest concentrations also occurred at the shallowest station and ranged between 81.8 and 1718.4 $mM/m^2/hr$. In contrast to ammonia, the lowest flux measurements of phosphate were measured at the 100 m station and ranged between 2.2 and 4.6 $mM/m^2/hr$. As with ammonia, other reported values are in the range of $uM/m^2/day$.

This study suggests that SGWD could be a very important pathway for nutrient flux in low-lying coastal habitats with little/no well defined river drainage systems. This pathway also could contribute to perturbation of SGWD carried toxic synthetic chemicals. In either case, the role of SGWD in benthic ecology may be underestimated because of its site specific nature at the sediment/water interface.

[1] Presenter. Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Dissolved Nutrient Transport in Soils of Tidal Freshwater Marshes along the Chickahominy River

R.M. Chambers,[1] J.W. Harvey, and W.E. Odum

We have completed the first year of a two-year study of subsurface transport phenomena in tidal freshwater marshes. Our objectives are to demonstrate the nature and extent of nutrient exchange processes as they pertain to water flow in marshes of different geomorphology. We are attempting to model the flow paths of soil water and dissolved inorganic nitrogen and phosphorus in low marshes (flooded completely every tidal cycle) and high marshes (less frequently flooded). Pore water samples for routine chemical analyses are retrieved with PVC suction lysimeters (sippers) that are nitrogen evacuated to maintain the anoxic character of the water (sippers nested to depths of 10, 20, 30, 40 and 50 cm into the marsh soil). To date there are 80 sippers placed in one high marsh and one low marsh on the Chickahominy River. From data collected June-August 1987, the dissolved phosphate and ammonia profiles in both of these marshes were characterized by extreme variability by depth and by position in the marsh. In the low marsh, SRP ranged from 0 to 130 micromolar, with a mean of 21.0 +1.9 s.e. (N=118). The high marsh SRP values ranged from 0 to 65 uM, mean = 25.9 + 2.8 s.e. (N=83). The ammonia concentrations (uM) in the low marsh averaged 38.4 + 3.5 s.e.; in the high marsh, 16.8 + 1.8 s.e. Along creekbanks, where drainage of water from the marsh interior occurs, SRP concentrations were positively correlated with dissolved iron concentrations (r^2 = 0.32). Chemical and hydrological evidence indicates the opportunity for subsurface drainage of pore water differs in the two marshes. The extent to which draining pore water delivers dissolved nutrients to adjacent creeks, however, is still unclear; dissolved nutrient export is not necessarily a direct function of pore water drainage.

[1] Presenter. Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903.

Hydrologic Controls on Denitrifier Activity in a Salt-Marsh Soil

K.M. Brosemer[1] and W.K. Nuttle

Wetland soil is widely regarded as a useful processor of wastewater and agricultural runoff, especially for the removal of nutrient pollutants, such as inorganic nitrogen. Microbial transformations leading to the removal of inorganic nitrogen compounds in field soils are greatly dependent on environmental conditions, especially moisture/aeration. Certain wetland soils become aerated during water table drawdown, such as occurs at tidal creek banks at low tide. We investigated whether soil denitrifier activity varied on the same spatial and temporal scales as soil aeration during low and neap tides in a salt marsh at the Virginia Coast Reserve Long-Term Ecological Research site.

We used a short-term acetylene blockage assay for denitrifier activity, measuring nitrous oxide evolved in closed incubation tubes in the field. We measured nitrous oxide by gas chromatography with electron capture detection, and soil aeration gravimetrically by water uptake into soil samples held at constant head.

Surface soils sampled along a transect normal to a tidal creek yielded high denitrifier activity within one meter of the creek bank, decreasing by a factor of 20 over the next meter, and by a factor of 160 over the next three meters. Denitrifier activity also varied with depth in the creek-bank soil, with surficial soil yielding 26 times the activity of soil taken from a depth of 12 cm, and 40 times the activity of 30 cm deep soil. Additionally, soil denitrifier activity varied over the spring/neap tidal cycle. Creek-bank soil activity at 12 cm depth increased 21 times at neap tide, when the soil was irregularly flooded.

This heterogeneity in denitrifier activity correlates well with the variation noted in soil aeration. Creek-bank surficial soils drain 10 percent of the water by volume three hours after exposure by the receding tide. Deeper soil shows somewhat less drainage, and soil sampled six meters from the creek bank shows no drainage in this time scale.

These measurements have important implications for wastewater treatment, agricultural runoff, and nutrient pollution in Virginia's waters. High levels of nutrient processing appear to occur in localized "active zones" within a wetland, and possibilities may exist for optimizing such conditions.

[1] Presenter. Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903.

Water-Quality Research on Smith Mountain Lake

Carolyn Thomas[1] and David M. Johnson[1]

Smith Mountain Lake is a 20,000-acre pump-storage hydroelectric reservoir located on the Roanoke River 30 miles downstream from the metropolitan Roanoke area. The dam was completed in 1965 and the lake reached its present level in 1969. The nearly 500 miles of shoreline is being rapidly developed, and concern has been expressed about the impact of various shoreline land uses on lake water quality. The primary objective of this study, sponsored by Ferrum College and the Virginia Environmental Endowment, was to assess the impact of each major shoreline land use on the quality of near shore water.

Results of a previous project (1985-86) to study the water quality at Smith Mountain Lake indicated that variability of most of the parameters such as total suspended solids and differences. To remedy this, the number of sample sites were increased from 16 to 30 by organizing and training lay monitors to take samples. The samples were then analyzed in our laboratory. This type of sampling has great potential for increasing surveillance of water quality. Sampling equipment, training, workshops, and quality assurance will be described.

[1] Presenters. Division of Life Science, Ferrum College, Ferrum, Virginia 24088.

Topographic Effects on the Hydrological Response of Two Catchments in Shenandoah National Park

D.M. Wolock[1]

Topographic shape is a watershed attribute thought to influence the development of saturated areas capable of producing surface runoff in upland catchments. The influence of topography has previously been incorporated in the variable source area hydrological model TOPMODEL. The topographic effect is quantified as the relative frequency distribution of the index $\ln(a/\tan B)$, where a is the upslope area per unit contour that drains past a point, and B is the local surface slope. Spatial distributions of $\ln(a/\tan B)$ were calculated for Deep Run (DR) and White Oak Run (WOR), two watersheds located in the southwestern region of Shenandoah National Park. The index was calculated on a 30 by 30 m grid interpolated from digitized 7.5 minute contour maps. The spatially aggregated relative frequency distributions of $\ln(a/\tan B)$ for the catchments were well described by a three-parameter gamma distribution fit to the first three moments of the observed distributions. The mean $\ln(a/\tan B)$ value was higher in WOR compared to DR, whereas the skew of the frequency distribution was greater in DR. The theoretical implications of these differences in the moments of the $\ln(a/\tan B)$ distributions were examined by performing a sensitivity analysis of TOPMODEL. The TOPMODEL simulations indicated that DR is more strongly dominated by subsurface stormflow that WOR, and that surface runoff is more likely to occur on WOR. The observed flow records at the outlets of the catchments suggest that after normalizing for differences in watershed area, WOR generates higher peak flows than DR. This observation is consistent with the predicted differences between the stormflow generation mechanisms of the catchments.

[1] Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903.

A Site-Specific Precipitation Model for Virginia Ecosystems

Rebecca K. Wajda[1] and R.H. Giles, Jr.

Precipitation is the key element in general models of the hydrologic cycle. It is usually the topic of interest for supplying water to the biotic system. However, a lack, or overabundance, of precipitation may adversely effect the flow of water at any, or several, of the stages of the cycle. Consequently, differences in water levels can generate changes in species and community structure and composition. The natural resource area manager is faced with the problem of having to know expected precipitation values and not having a convenient, useful method for obtaining these figures. This study reports use of computer systems to analyze, model, and present measurable precipitation information in a useful form for resource area managers. Data for 15 stations have been obtained from the Virginia Water Resources Research Center and are being analyzed through regression analysis. Upon completion of analysis, the influential variables and the Gandin optimal interpolation precipitation model will be used to construct a microcomputer-based program to estimate monthly measurable precipitation, list other major output, and produce graphic images of the study area. Programming will be done in Turbo Pascal. The completed system will allow users to enter past measured precipitation, location, and other values, and it will integrate the values into mathematical models, present graphic images of the area with expected precipitation, and list tabular results of a variety of analyses potentially useful to wildlife resource managers. Results of analysis and system construction will be available by the time of the conference.

[1] Presenter. Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Steps Toward a Comprehensive Watershed Management Plan

R. Fernando Pasquel[1] and Mohammad W. Haque

One of the tasks of Prince William County's Department of Development Administration (DDA) is the review of floodplain and stormwater management (SWM) studies prepared for industrial, commercial, and residential developments. In addition to its review functions, the DDA is starting to look at watershed management, and in particular to SWM, in a comprehensive manner. The need for this comprehensive approach stems from the significant increase in developing activity that the county has experienced in the last few years.

In order to offset the impact that development has on our streams and floodplains, the Board of Supervisors initiated a SWM Program in 1973. This program, though refined through the years, did not look at at water resources planning on a watershed basis. A new program, a comprehensive watershed management program, will include projects in SWM (quantity and quality), floodplain management, sedimentation and erosion control, groundwater management, and water resources monitoring.

The initial step towards a comprehensive watershed management program is data collection. This paper describes the development and characteristics of a SWM Data Base Management System (DBMS) using R:Base System V. This DBMS is used for the entry, retrieval, and analysis of SWM and floodplain data. The information collected in the data base is used to prepare reports, and to update and maintain the hydrologic and hydraulic models of the streams. These watershed models are being updated by DDA staff, and by consulting firms as part of drainage improvement projects and development projects.

The hydrologic and hydraulic models will be useful tools in the design of development projects, and will be used to evaluate the cumulative effects of floodplain encroachments and SWM facilities on water-surface elevations and runoff hydrographs. In addition, these models will be used to study the feasibility of regional facilities as part of a county wide retention/detention system.

In order to collect SWM information for the data base, a SWM Fact Sheet was prepared. For the different types of SWM facilities, this fact sheet provides three types of information, general facility information, design information, and administrative information. Each of these three parts of the fact sheet correspond to an input screen and a table in the data base. The data base will store information on all the SWM facilities built in the county. However, only the facilities that have a significant effect on peak discharges, volumes, and timing of the hydrographs will be incorporated in the models. The DBMS will enable users to obtain the data they require, for analysis and report preparation, in an efficient and timely manner.

[1] Presenter. Department of Development Administration, Prince William County, 1 County Complex Court, Prince William, Virginia 22191.

Application of Agricultural Nonpoint Source Pollution Computer Models to Virginia Watersheds

J.M. Flagg, S. Mostaghimi[1], and P.W. McClellan

Much of the blame for the decline of water quality has been focused on nonpoint sources of pollution. The U.S. Environmental Protection Agency (EPA) estimates that as much as 90 percent of the nitrogen resulting from nonpoint source pollution comes from agricultural runoff and cropland sediment loss. Nuisance algae blooms and eutrophic waters are often the direct result of increased nitrogen in surface- and ground-water systems. Many mathematical models have been developed to simulate nitrogen losses from agricultural lands. However, due to lack of field data, they have not been verified for a variety of watershed conditions. Before these models can be effectively used to make management decisions regarding nitrogen losses and its effect on water quality, they must be verified against field data.

The goal of this study was to investigate the suitability of two nonpoint source pollution models to Virginia's conditions. Data collected from two watersheds located in Westmoreland County and Fauquier County, Virginia, were used to evaluate ANSWERS and AGNPS abilities to adequately simulate runoff, sediment, and nitrogen losses by comparing their prediction with the observed data. One of the models is used to simulate the effects of alternative management and land-use scenarios on runoff, sediment and nitrogen losses from Virginia watersheds.

[1] Presenter. Department of Agricultural Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Seasonal and Interannual Variations in Stream-Water Chemistry in Two Catchments Impacted by Acid Deposits

P.F. Ryan[1]

The atmospheric deposition over the Eastern U.S. is significantly more acidic at present than during preindustrial times. The effects of acid deposition on a catchment scale may be assessed by examining temporal trends of the chemical composition of stream water leaving the catchment. As part of the Shenandoah Watershed Study, the chemistry of two streams, White Oak Run (WOR) and Deep Run (DR), in the southwestern part of the Shenandoah National Park, Virginia, has been monitored since 1979. The temporal variation of SO_4^{2-}, alkalinity, H^+, Cl^-, and base cations was examined. Interannual trends were obscured by pronounced seasonal variation. In DR SO_4^{2-} and Mg^{2+} had winter maxima and summer minima. These concentrations were highly correlated with stream discharge and appeared to be controlled by the flow path of water through the catchment soils. In WOR alkalinity and base cations had summer maxima and winter minima. This pattern of variation appeared to be related to stream discharge and temperature. A mechanism involving soil CO_2 concentration and hydrologic flow path was proposed. When tested within season only H^+ had a statistically significant interannual trend. H^+ was increasingly in both catchments (WOR, 0.05 ueq $l^{-1}yr^{-1}$; DR, 0.41 ueq $l^{-1}yr^{-1}$). When less stringent statistical tests were used, SO_4^{2-} (1.69 ueq $l^{-1}yr^{-1}$) and base cations (1.90 $l^{-1}yr^{-1}$) also showed a positive trend in DR. The data suggest that the DR catchment is in the process of losing its ability to retain sulfate and thus the stream has become increasingly acidic. WOR has not shown a rapid change in stream chemistry and is presumably neutralizing acid deposition through cation exchange and sulfate retention.

[1] Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903.

A Critical Evaluation of the Role of Sulfate- and Iron-Reducing Bacteria in the Mediation of Acid Mine Drainage

P. E. Bell[1] and A. L. Mills

Sulfate reduction is commonly considered to account for increased buffering capacity in sulfate-acidified freshwater systems. The Contrary Creek arm of Lake Anna in central Virginia receives acid mine drainage from several abandoned pyrite mines. Because of the large iron load in acid mine streams, bacterial iron reduction is potentially an important contributor to carbon and electron flow and may contribute to alkalinity generation or the increased buffer capacity observed in this system. When a pure culture of the sulfate reducer *Desulfovibrio vulgaris* strain SM (isolated from the sediments of Contrary Creek) is cultured in synthetic iron hydroxide medium with additions of sulfate, most of the buffering capacity is retained in the amorphous ferrous sulfide mineral phase and not in the medium filtrate. A similar phenomenon is observed with co-cultures of iron reducing bacteria. Results suggest that both iron and sulfate reduction are essential processes in the generation of permanent alkalinity in mine drainage acidified lakes.

[1] Presenter. Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903.

Sources of Sulfate in Deep Sediments of an Acidified Lake: Chemical and Isotopic Evidence

P.E. McIntire,[1] A.L. Mills, J.S. Herman, and G.M. Hornberger

Sediment sulfate concentration profiles that exhibit sulfate concentrations of up to 28 mM at depths of 20 to 60 cm have been observed in some regions of Lake Anna, Virginia, which receives large amounts of sulfate from acid mine drainage. These profiles, which have high sulfate concentrations at depth (HSD), cannot be explained by sediment diagenesis models including sedimentation, diffusion, and sulfate reduction alone. Previous experiments based on the design of a strong inference tree suggests that vertical groundwater advection of sulfate or oxygen, which induces sulfide oxidation, was not the cause of the unusual sulfate patterns. Measurements of sulfate-reducing and sulfur-oxidizing bacteria, sediment sulfide, and organic matter concentration analyses, and determiniations of the spatial and temporal variability in the occurrence of the SD profiles give circumstantial evidence that sediment sulfide oxidation did not cause HSD. Use of stable sulfur isotope ratio analyses confirmed that the HSD sulfate did not originate from the oxidation biogenic sulfides. Sulfur at depth in the HSD sediments had a stable isotope ratio ($^{34}S/^{32}S$) of +14.4 compared to a value of -12.5 for the sediment sulfides. Experiments in which cores having HSD were transplanted to the non-HSD region (and the converse) showed no changes in sulfate concentrations over the four-month incubation period. These results were interpreted to mean that upward advection of sulfate was not an important process in the sediments.

[1] Presenter. Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903.

Acid Neutralization Capacity of Eastern Brook Trout Streams in the Mountains of Virginia

James R. Webb[1]

The Virginia Trout Stream Sensitivity Study (VTSSS) was initiated to provide information about the potential effect of elevated atmospheric acid deposition on the stream habitat of the indigenous eastern brook trout (*salvelinus fontinalis*) in the mountainous region of Virginia. Low stream-water acid-neutralization capacities are known to be associated with small forested mountain watersheds underlain by shallow, base-poor soils developed on granitic or noncalcareous sedimentary bedrock types. This type of system is represented by most of the "wild" trout stream resource in Virginia. Objective assessment of the acid deposition problem relative to this sensitive ecosystem component, however, has been constrained by lack of baseline information or means to measure changing conditions over time.

Principal VTSSS project phases include: (I) a synoptic survey to determine the sensitivity of wild trout streams to acidification and (II) initiation of a long-term trend monitoring system. Preliminary results for Phase I and progress on Phase II can be reported.

VTSSS Phase I involved collection of stream-water samples from 350 individual wild trout streams during the period April 24-May 4, 1987. This sample represented approximately 80 percent of the total number of identified streams with naturally reproducing trout populations in the state. Exclusion of the nonsampled streams was primarily based on watershed disturbance criteria, access difficulty, and watershed size. A small number of streams were excluded due to the presence of carbonate bedrock which should provide infinite buffering capacity. Sample analyses include alkalinity, pH, conductivity, calcium, magnesium, potassium, sulfate, nitrate, chloride, and silica. Initial evaluation of sensitivity has been based on alkalinity—with 100 ueq alkalinity/L taken as a threshold value above which chronic stream-water acidification is unlikely to occur at current levels of acid deposition. 78 percent of the sampled streams have alkalinity values of 100 ueq/L or less, 49 percent have alkalinity values of 50 ueq/L or less, and 11 percent have alkalinity values of 0 ueq/L or less. Stream waters with alkalinity concentrations of $\leq$ 0 ueq/L had pH values from 4.7 to 6.0. Stream waters with 0-50 ueq/L had pH values of 5.3 to 6.8. Stream waters with 51-100 ueq/L had pH values of 6.3 to 7.0. These results indicated that most of the state's wild trout streams are weakly buffered against acidification.

VTSSS Phase II involved selection of 65 of the Phase I streams for quarterly sampling and analysis. Principal selection criteria included low alkalinity, minimum watershed disturbance and development, probability of long-term watershed protection, geographic distribution, and accessibility. Trend interpretation will focus on (1) changes in stream-water sulfate concentrations as an indication of changes in the magnitude of acid flux through watershed/stream systems; and (2) changes in alkalinity and base cation concentrations as an indication of the watershed/stream system response.

[1] Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903.

The Use of Spontaneous Potential in Detecting and Monitoring the Areal Extent of Contaminant Plumes

Ronald A. Erchul[1]

The object of this research was to determine if the geophysical technique of spontaneous potential (SP) could detect and monitor a contaminated waste site. SP is a geophysical method that measures naturally occurring voltage in the earth. SP effects can be due to electrochemical or electrokinetic origins. Electrokinetic effects are known as streaming potentials and are caused by the flow of fluid through a porous material (groundwater seepage through soil).

The test site was the Rose Hill lagoons located approximately four miles south of Lexington, Virginia. The Rose Hill Lagoons site consists of two unlined and uncovered lagoons within a fenced enclosure of less than one acre. The site was used for the disposal of solvents, plasticizers, and other materials resulting from industrial coating processes. The use of these lagoons began about 1972 and ended in May 1980.

Geophysical surveys of the Rose Hill site were initiated in June 1987 by installing a grid array of copper electrodes on 25-foot centers. SP measurements were collected on alternate days through July 1987. A computer generated SP contour map based on average values for the entire month of July was developed. The major anomalous areas in this map are associated with two lagoons. The strongest anomaly (-400 millivolts) is centered on the lower lagoon. (The anomaly associated with the upper lagoon appears to be spread out over the area between the entrance gate and the area where wastes were dumped into the upper lagoon.) In addition an automated data collection system was devised and used at the site for two tasks: (1) long-term monitoring of SP changes and environmental variables and (2) measuring SP changes induced by the rapid recharge of water into the lagoons by heavy rains. The SP results were also evaluated by comparison with geological observations, electrical resistivity, and seismic and penetrometer surveys of the site. The results of these geophysical and geotechnical surveys indicate the SP anomalies are associated with the major concentration of toxic materials and would require neutralization in any closure plan of this site.

[1] Department of Civil Engineering, Virginia Military Institute, Lexington, Virginia 24450.

Effect of Site Variations on Subsurface Degradation Rates

John Novak,[1] Mark Morris, and Gary Hickman

Studies have been undertaken to determine the effect of site variations on degradation of subsurface organic contaminants. Subsurface material from several sites in Virginia were collected, and microcosm degradation studies undertaken. Various organic contaminants were added to microcosms, and degradation rates determined.

Results indicate that sites may vary from those where degradation readily occurs to those where organics tend to persist. In the active sites, categorized as eutrophic, nitrage reduction dominated and the degradation rate was first order with respect to concentration. Nitrate addition stimulated degradation.

In the sites where degradation was slow, called oligotrophic sites, several unique characteristics were observed. Degradation rates were zero order in any individual microcosm but first order with respect to initial concentration. Addition of nitrage often resulted in a nitrate buildup and associated nitrite toxicity. Addition of molybdate, an inhibitor of sulface reduction, stimulated degradation, suggesting a competition between sulfate reducers and other organisms for hydrogen.

Studies currently underway are attempting to determine if the addition of nitrate or oxygen to an oligotrophic site can alter the behavior of the microbial population to promote a eutrophic response. These studies should determine the correct approach and time constraints in promoting enhanced degradation of subsurface pollutants.

[1] Presenter. Department of Civil Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

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[1] Presenter. Department of Civil Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Estimation of Acidic Inputs in Surface- and Ground-Water Discharges to the Piney River, Virginia, at the Former U.S. Titanium Site

Jeffrey A. Sitler[1] and Lyle R. Silka

The remedial investigation of the U.S. Titanium Superfund site in Piney River, Virginia, was completed on September 17, 1987. The site includes the sedimentation ponds, former copperas storage area, copperas burial pit, former leachate collection ponds, and unreachted ore stockpile. Historically, the site was the source of acidic discharges to the Piney River since operations began in the 1930s and was thought to be the cause of periodic fish kills in the river. The primary source of acidity is the dissolution of copperas, a crystalline, hydrated ferrous sulfate, which produces acidity upon the oxidation and hydrolysis of the ferrous iron.

The objectives of this remedial investigation were to characterize the nature and extent of contaminant source areas, define the pathways of contaminant migration, determine the effects on river quality, and quantify the relative contribution of acidity from each area to the total acidic discharge entering the Piney River.

Data collection was accomplished through the use of 20 onsite wells, seven surface water sampling locations, 69 soil borings, 21 infiltration tests, aquifer tests on 17 wells, analyses of 37 groundwater and more than 100 surface water samples, and the results of a surface EM geophysical survey completed by a graduate student at the University of Virginia.

Hydrologic budgets for each area of potential contamination were developed in part from soil textural data, results of soil infiltration tests, records for precipitation and temperature, topographic slope, and vegetative cover.

Based on these investigations, it is estimated that percolation rates through the source areas vary from seven inches a year in the former copperas stockpile area to 13 inches a year in the sedimentation ponds. Maximum total acidity concentrations in leachate were estimated to range from 500 mg/1 in a contaminated drainage area to 265,000 mg/1 in the copperas burial pit. It is estimated that the copperas burial pit is responsible for more than 60 percent of the acidity discharged to the Piney River. The copperas burial pit contains an estimated 16,000 cubic yards of ferrous sulfate and under current conditions will require an estimated 60 years to flush out naturally. In comparison, the estimated time of flushing of acidity absorbed to the clayey saprolite at the former copperas storage areas is on the order of 100 to 200 years, although the concentration of acidity is much less than that in the copperas burial pit. The individual percent contributions of these other areas to the acidic discharges to the river are less than 12 percent.

The findings concerning the effects on the Piney River indicate that under base-flow conditions, the contaminated groundwater that discharges to the Piney River is not sufficient to cause the river quality to exceed the regulatory limits for pH or total dissolved iron. During rainfall runoff events, pH limits can be exceeded at least in short stretches of the river due, in major part, to the erosion of acidic sediments from the sedimentation pond adjacent to the river.

[1] Presenter. Hydrosystems, Inc., P.O. Box 348, Dunn Loring, Virginia 22027.

Mass Balance of Sediment and Metals in the Elizabeth River

Maynard M. Nichols[1]

The Elizabeth River is one of the prominent "hot spots" of toxic contamination in the Chesapeake region. With increasing human and industrial activity in the river, where then do the enormous chemical loads go? Are they entrapped in the harbor, buried in the sediment, or do they "leak" into Chesapeake Bay and thus pose impacts on water quality and expose biotic resources?

This research aims to determine a first-order material balance of sediment and selected trace metals, the relative importance of different sources, and the degree of import, export and removal from the system. The sources, losses, and exchange of particulate contaminants are organized into a box model. Sediment and metals are introduced via stream runoff, urban runoff, atmosphere, industrial and wastewater discharge, and landward transport from Hampton Roads via the lower estuarine layer. Exports include losses through the upper estuarine layer and to the bottom sediments. Data come from the EPA-Chesapeake Bay Program, Virginia Water Control Board, and National Pollutant Discharge Elimination System computer files, published as well as unpublished records and reports during the period 1976-1981. Sedimentation rates are derived from dredging records between 1971-1981.

The mass balance of salt and water reveals a relatively large flow through upper and lower layers at the river mouth as a consequence of salt exchange. Despite rapid exchange, the balance for fine sediment indicates that 93 percent of the total sediment input comes from Hampton Roads via the lower layer, whereas 7 percent comes from landward sources. Of the total sediment input, 73 to 90 percent is trapped and accumulates on the channel floor, while the rest is dispersed through the upper layer. The mass balance of metals reveals that 40 to 95 percent of the total input of chromium, iron, and lead are trapped and deposited in the river sediment. In contrast, at least 56 percent of the zinc input and 68 percent of the cadmium input escape the river through the upper layer and thus pose possible impacts on bay resources.

The river system retains or mobilizes metal contaminants according to their particle reactivity. Metals with high particle reactivity are retained whereas those with low to moderate reactivity are released. The mass balance also shows that import and export through the mouth are relatively strong terms in the mass balance.

[1] Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia 23062.

The Effect of Aquifer Mineralogy and Land Use on Water Quality in the Northern Shenandoah Valley, Virginia

Richard LoCastro[1] and H.G. Goodell

Groundwater samples collected from 229 sites in Clarke and Frederick Counties of Virginia have been used to assess the influence of aquifer lithology and land use on water chemistry. Each sample was analyzed for total dissolved solids (TDS) pH, hardness, conductivity, heterotrophic bacteria, and major cations and anions. Stiff diagrams were constructed to depict the mean groundwater chemistry for four major aquifer lithologies: Cambrian and Ordovician Carbonates, Ordovician Shales, Devonian Shales and Sandstones, and Precambrian/Cambrian Metamorphics. Discriminant analysis successfully predicted the correct lithologic group for 95 percent of the water samples based on the groundwater chemistry. The same discriminant function correctly predicted group membership for 87 percent of the water analyses from the same aquifers obtained from EPA STORET data files. Groundwater samples from the carbonate aquifer were classified according to land use into two categories: agricultural and nonagricultural. Student t-tests reveal mean concentrations of K^+, NO^-_3, and $SO^2_4{}^-$ were significantly higher for samples from agricultural areas at a 95 percent level of confidence, a reflection of fertilizer and manure. The highest nitrate concentrations were observed in the carbonate aquifer where seven samples exceeded the 45 mg/L NO^-_3 drinking water standard and appear to originate from point sources. The median NO^-_3 concentration for all carbonate groundwater samples was 11.2 mg/L NO^-_3 in comparison to concentrations of 0.4, 0.8, and 1.3 mg/L for the other aquifer lithologies. Heterotrophic bacterial counts range up to 14,000 per milliliter with log normal population distribution remarkably similar regardless of lithology or land use. More than 50 percent of the samples exceeded the proposed drinking water standard of 500 colonies per milliliter.

[1] Presenter. Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903.

Structural Control of Karstic Groundwater in the Southern Appalachians, Virginia

Ernst H. Kastning[1]

Extensive exposures of Palezoic carbonate rocks occur along the entire length of the Appalachian foldbelt (Valley and Ridge physiographic province) in Virginia. Units of limestone and dolostone at or near the surface are highly karsted, exhibiting numerous dolines (sinkholes), sinking streams, caves, and springs. Most of the karstic landforms are substantially controlled by elements of the structural geologic setting, including attitude of beds, folds, faults, and joints. An understanding of the influences of structure on present-day subsurficial drainage is crucial to assessing environmental problems in the karstic regions of Virginia.

Northeasterly sets of fractures trend parallel to the axes of folds and to the strikes of major thrust faults. Perpendicular, northwesterly sets are oriented along the dip direction with respect to folded rocks or faults. These, together with conjugate sets of joints, comprise an interconnected fracture network that guides groundwater through the carbonate rock in response to prevailing hydraulic gradients. Dissolutional enlargement and augmentation of secondary porosity occur along highly conductive fractures. Groundwater flow is considerably enhanced within well-integrated and mature networks that collect surficial recharge and transmit it along tributary and master conduits to springs.

A study of karst along a transect through the foldbelt in the vicinity of the New River (Giles, Craig, Bland, Pulaski, and Montgomery counties) confirms these general relationships. Analysis of caves shows that groundwater in carbonate aquifers of the southern Appalachians moves most efficiently along strike and just below the water table in bedrock units that are relatively soluble. Consequently, flow systems are typically parallel to valley walls in this region. Alignments of dolines in Giles and Pulaski Counties provide evidence of the structural control of groundwater flow. In some cases, flow is guided by faults. This is especially evident in the origin of New River Cave in Giles County where the case is positioned along a highly transmissive fracture zone of the Saltville thrust fault and within a soluble limestone unit.

Geomorphic evolution of the region has strongly modified groundwater flow paths in selected localities. Stream capture and piracy, both on and under the surface, can rearrange routes of drainage. Incision of stream meanders can effectively guide and concentrate flow in dipping cavernous strata. These mechanisms are particularly well illustrated within the Sinking Creek drainage of Giles and Craig counties.

Analysis of the karst of the southern Appalachians provides an insight into groundwater conditions and flow patterns prevailing at the time of development of caves, dolines, and other solutional features. The influence of structure on subsurficial drainage is readily assessed upon detailed mapping of caves and tracing of groundwater from points of recharge to springs. The structural, lithologic, and topographic settings of the Appalachians result in distinguishable characteristics of the karstic landscape; however, local influences, such as structural anomalies, stream piracy, and local geomorphic processes, may modify karstic features at any one site. Careful interpretation of the karst can aid in assessing environmental groundwater problems.

[1] Department of Geology, Radford University, Radford, Virginia 24142.

Objectives of and Approaches Used in the Groundwater-Quality Assessment of the Delmarva Peninsula

Pixie A. Hamilton[1]

In April 1986, the U.S. Geological Survey began the National Water Quality Assessment (NAWQA), a program to assess the quality of the Nation's surface- and ground-water resources and to acquire and interpret information about a wide range of water-quality issues. When fully implemented, NAWQA is expected to entail surface- and ground-water studies nationwide. Prior to full implementation, several pilot projects are being conducted to evaluate feasible approaches that may be used in NAWQA studies. Three ground-water pilot projects have been started, including one project on the Delmarva Peninsula, covering eastern Maryland and Virginia and most of Delaware.

The NAWQA study on the Delmarva peninsula has two overall objectives: (1) to describe the nature and extent of water-quality problems in the study area, and (2) to develop methods and strategies for conducting regional assessments in large geographic regions similar to the Delmarva Peninsula. Specific objectives are to: (1) develop and understanding of recharge-discharge relations and groundwater-quality patterns; (2) determine the extent of contamination from man-made sources, particularly agricultural chemicals and volatile organic compounds; and (3) develop and understanding of relations between water quality and mappable features such as surficial geology, soil type, geomorphology, and land use.

One major effort in the project is to analyze existing water-quality data. Water-quality information of federal, state, and local agencies is being collected, summarized, and analyzed to provide a preliminary assessment of water quality of the Delmarva Peninsula and to identify future data needs. New analyses, including a wide range of inorganic and organic constituents, are being done for principal aquifers at sites geographically distributed around the peninsula. Local studies of patterns in groundwater flow and chemistry are being conducted in areas thought to be representative of the major hydrogeologic and land-use settings on the peninsula. Relations between water quality and mappable features are being explored using statistics and a computerized geographic information system.

[1] U.S. Geological Survey, 3600 West Broad Street, Room 606, Richmond, Virginia 23230.

The Economic Effects of Various Minimum Instream Flow Policies in Virginia

David Broomhall[1] and Darrell Bosch

Increased use of streamflows by agriculture, industry, households, and other users has caused concern about the effect of water withdrawals on downstream wildlife habitat. Various researchers have examined the effect of reduced streamflows on environmental quality. The results of these studies have led to the creation of guidelines for use by policy makers to establish minimum instream flow (MIF) requirements.

The purpose of this research was to develop and apply methods to assess the economic impact of MIF policies on irrigators who use a riparian water source. The effects of MIF policies on the amount of water available for irrigation under variable streamflow conditions were calculated. Then, the available supplies were compared to irrigation demands under variable weather conditions and the economic costs of water shortages were calculated.

The research was carried out in the Pamunkey River Basin of eastern Virginia. This basin is of particular interest because irrigation has increased rapidly there in recent years. Further, the lower reaches of the Pamunkey River include fragile coastal wetland habitats which are vulnerable to the effects of low streamflow levels.

A crop simulation model was used to calculate yields and water use under various MIF policies. Streamflow data for a 12-year period, 1973-1984, was used to predict daily supply of water. Crop yield and water use predicted by the model were combined with price and cost data to quantify the effects of reduced water supplies on farmers' net returns. Four MIF policies were evaluated: a 7Q10 policy of restricting minimum flows to the minimum seven-day average flow for the previous 10 years, a 30 percent of mean annual flow restriction, a 10 percent of mean annual flow restriction, and a 30 percent of mean monthly flow restriction.

The results show that water shortages did occur with each MIF policy in some years. However, under the 7Q10 policy there was no impact on yields or net returns. With the imposition of an MIF policy requiring that irrigation cease when streamflows drop below 10 percent of the mean annual flow, losses in net returns averaged 3 percent on the more drought-prone soils, with a maximum loss of from 18 to 22 percent, while no losses occurred on the less droughty soils. Using a 30 percent of mean flow restriction, losses in net returns occurred on all soil types and averaged 33 percent, while maximum losses ranged from 54 to 95 percent depending on soil water-holding capacity. Finally, an MIF policy of 30 percent of mean monthly flow resulted in net returns losses on all soil types averaging 19 percent, with maximum losses ranging from 54 to 94 percent.

The results show that the losses suffered by irrigators vary by the type of policy instituted but could be quite large. In selecting an MIF policy, policy makers should consider the losses imposed on irrigators by alternative standards as well as the degree of environmental protection provided by each standard. If a MIF policy is instituted, irrigators may want to consider measures such as on-farm water storage, staggered planting, and crop diversification to reduce the losses from water shortages.

[1] Presenter. Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Desalination: A Case Study in Suffolk, Virginia

Millard P. Robinson, Jr.[1] and Mark A. Thompson

In area, Suffolk is one of the ten largest cities in the nation. As the southeastern region of Virginia has prospered, Suffolk's population has risen dramatically. Regional water shortages are creating the need for additional surface- and ground-water supplies to satisfy growth. Even with an active water conservation program and the hope of Lake Gaston, additional potable water supplies will be required in southeastern Virginia. Groundwater desalination in Suffolk is one option being considered to help satisfy the city's thirst and meet water quality criteria under the Safe Drinking Water Act.

After completing a preliminary feasibility study for groundwater desalination, Suffolk hired Malcolm Pirnie, Inc. and RosTek Services, Inc. to develop a comprehensive feasibility study and start pilot testing both the reverse osmosis and electrodialysis reversal membrane processes on a deep-well water supply. Pilot studies began in November 1987 and were expected to be completed by mid-March 1988.

This paper will present the technical information developed in the feasibility study and how pilot study results compare with predicted performance criteria developed in the previous studies. We also expect to present information on the political and environmental impacts of the brine disposal issue, as an application was made to the State Water Control Board in September 1987 for an NPDES discharge permit for the concentrate.

While a proven technology in other parts of the United States, desalination of groundwater is a new concept in Virginia. It could help meet the growing demand for potable water while preserving the valuable wetlands, hardwood swamps, and tributaries of the Chesapeake Bay. Quantities and quality of groundwater available will limit the amount and cost of potable water from this resource. But, combined with other innovative water treatment concepts, membrane technology can play a significant role in meeting the future needs for a high quality potable water in many Virginia communities.

[1] Presenter. Malcolm Pirnie, Inc., P.O. Box 6129, Newport News, Virginia 23606.

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After completing a preliminary feasibility study for groundwater desalination, Suffolk hired Malcolm Pirnie, Inc. and RosTek Services, Inc. to develop a comprehensive feasibility study and start pilot testing both the reverse osmosis and electrodialysis reversal membrane processes on a deep-well water supply. Pilot studies began in November 1987 and were expected to be completed by mid-March 1988.

This paper will present the technical information developed in the feasibility study and how pilot study results compare with predicted performance criteria developed in the previous studies. We also expect to present information on the political and environmental impacts of the brine disposal issue, as an application was made to the State Water Control Board in September 1987 for an NPDES discharge permit for the concentrate.

While a proven technology in other parts of the United States, desalination of groundwater is a new concept in Virginia. It could help meet the growing demand for potable water while preserving the valuable wetlands, hardwood swamps, and tributaries of the Chesapeake Bay. Quantities and quality of groundwater available will limit the amount and cost of potable water from this resource. But, combined with other innovative water treatment concepts, membrane technology can play a significant role in meeting the future needs for a high quality potable water in many Virginia communities.

[1] Presenter. Malcolm Pirnie, Inc., P.O. Box 6129, Newport News, Virginia 23606.

A View for a Partnership in Dealing with the Commonwealth's Flood Hazard Area

James M. Wright[1]

The Tennessee Valley Authority (TVA), a wholly owned government corporation established by an act of Congress in 1933, is widely recognized as having one of the most comprehensive floodplain management assistance programs in the nation. This program was initiated nearly 35 years ago as a necessary complement to TVA's floodwater detention reservoirs to bring about the maximum degree of flood damage reduction to the Tennessee River watershed, which includes portions of seven states and comprises an area almost identical to the Commonwealth of Virginia.

TVA pioneered the "floodplain management" concept that local officials and others armed with information on flood-prone areas could and would take actions to avoid building in these areas or else take preventative measures in building to reduce the possibility of flood damages. Although the Tennessee River watershed only covers about 8 percent of the Commonwealth's land area and drains all or portions of eight of its southwestern counties, the experiences and lessons learned from working with local officials and decision makers in dealing with flood problems and flood hazards areas could be applied to the remainder of Virginia.

Several years ago TVA staff decided that this long record of floodplain management assistance to the watershed states and their flood-prone localities lent itself to both subjective and quantitative analyses. How effective have these efforts been in bringing about the maximum degree of flood damage prevention? What efforts and measures have been the most productive? An interim study based on a very comprehensive survey of about 20 watershed communities to answer these and other questions was completed about a year ago. One of the by-products of this effort was a detailed guide to evaluate a community's floodplain management program. This guide is being studied and used by others nationally.

Based on its experiences TVA believes that flood damage reduction should not be exclusively a federal responsibility or even a federal-local role, but rather a true federal-state-local partnership. This partnership entails federal assistance; state initiative, involvement, coordination, and leadership; and local responsibility, decision making, and management. Most states have not established and carried out the desired and necessary complementary roles to federal-local flood damage reduction efforts.

The author, with over 25 years' experience in managing state and federal programs of assistance in dealing with local flood problems, will share:

- The TVA experience in local floodplain management assistance over the past 35 years including lessons learned,
- The findings of a study to evaluate the effectiveness of community efforts to reduce flood losses, and
- The opportunities, challenges, and beneficial values of a true federal-state-local partnership in dealing with Virginia's flood problems.

[1] Floodplain Management Program, Tennessee Valley Authority, 200 Liberty Building, Knoxville, Tennessee 37902.

Section 205 of the Safe Drinking Water Act Amendments of 1986: An Invitation to Litigation?

George William Sherk[1]

Section 205 of the Safe Drinking Water Act Amendments of 1986, Public Law 99-339, amends the Safe Drinking Water Act by adding Section 1428: State Programs to Establish Wellhead Protection Areas. Section 1428, codified at 42 USC §300h-7, authorizes states to develop programs to "protect wellhead areas within their jurisdiction from contaminants which may have any adverse effect on the health of persons." 42 USC §300h-7(a). State wellhead protection area programs are subject to review by the Administrator of the U.S. Environmental Protection Agency. 42 USC §300h-7(c). State programs are to be implemented within two years of submission of the program to the Environmental Protection Agency for review. 42 USC §300h-7(g).

Under 42 USC §300h-7(h), federal agencies "having jurisdiction over any potential source of contaminants" as identified by a state wellhead protection area program are subject to the state program and are required to comply with all substantive and procedural requirements. This provision applies to all federal agencies unless the President exempts the potential source of contamination under the jurisdiction of a federal agency as being "in the paramount interest of the United States."

This study addresses the extent to which the Safe Drinking Water Act Amendments of 1986 subject to federal activities occurring in wellhead protection areas to state jurisdiction. The rules generally applicable to any waiver of sovereign immunity by the United States are discussed. Analogies to other federal laws having similar provisions, such as the Coastal Zone Management Act, are drawn. Finally, the possibility that the requirements of 42 USC §300h-7 will be the subject of future litigation will be examined.

Note: The opinions expressed in this study are strictly those of the author and may not represent the official position of either the Department of Justice or the United States of America.

[1] Land and Natural Resources Division, U.S. Department of Justice, Washington, DC.