Water Resources Research Institute

of The University of North Carolina

ANNUAL PROGRAM

CURRENT RESEARCH JULY 1, 1997, TO JUNE 30, 1998

The Water Resources Research Institute is a unit of The University of North Carolina system headquartered in Jordan Hall on the North Carolina State University campus.

It is one of 54 state water institutes authorized by the Water Resources Research Act of 1964 to administer and promote federal/state partnerships in research and information transfer on water-related issues.

The mission of WRRI is threefold: to identify the state's ever-changing research needs, to motivate and support research by qualified scientists, and to provide for technology transfer.

WRRI, State of North Carolina cooperate to focus research on Neuse management needs

The centerpiece of the 1997 North Carolina General Assembly's environmental legislation, the Clean Water Responsibility Act, authorizes a number of management actions aimed at improving water quality in the troubled Neuse River Estuary.

Lawmakers had to make these management decisions about the Neuse under intense pressure from opposing groups. Making political decisions that try to balance interests is the role of elected officials, and they want to make decisions that will bring about the best results with the least overall pain to their constituencies. In an effort to make the best decisions about management of water resources, lawmakers turn to scientists for assurance that what's being proposed will have the desired results. Over the last two years, North Carolina legislators sat through many long hours of scientific presentations on the problems of the Neuse. However, in the end, they had to make their decisions without any assurance that scientists know the precise linkages that produce water quality problems in the Neuse Estuary or precisely what steps will solve water quality and related problems.

Because of the complexity of the natural world, environmental management decisions will always be made amid scientific uncertainty and even scientific disagreement, and there will always be questions about whether enough information exists to make management decisions. In these circumstances, results are likely to be better if management decisions are made within a framework that imposes logic and focuses on key scientific issues, linking proposed actions to desired outcomes.

In a project sponsored by the N.C. Department of Environment, Health, and Natural Resources (DEHNR) and WRRI, scientists from four North Carolina universities and the U.S. Geological Survey have teamed up to develop such a framework to support decisionmaking for the Neuse River Basin. Dubbed "Neuse River Estuary MODMON" by the research team, the project involves three interrelated efforts:

- **Monitoring:** A massive undertaking of fish, sediments, water quality, and hydrology sampling from New Bern to the mouth of the Neuse River to provide data for water quality modeling
- **Short-term Modeling:** Calibration, improvement, and error analysis of a water quality process simulation model (CE-QUAL-W2) for the estuarine portion of the Neuse
- **Long-term Modeling:** Development of a framework for making management decisions and selection of an approach to developing a comprehensive (watershed-river-estuary) water quality model to support decisionmaking.

Each effort involves a team of scientists. Each scientist is working within his area of expertise to contribute to a common end product. All products are designed—not just to produce scientific data and understanding—but primarily to support management decisionmaking.

Monitoring

The UNC Institute of Marine Sciences at Morehead City, DEHNR, and Weyerhaeuser Corporation cooperatively operate an eight-station monitoring network that collects weekly water quality data in the Neuse Estuary. In an intense, year-long effort, scientists at the Duke and UNC-Chapel Hill marine sciences programs at Morehead City are expanding by 9 stations and enhancing this network to:

- **Obtain continuous measurements of water quality parameters at several locations.** Continuous measurement will allow better prediction of phytoplankton

continued

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WRRI ADVISORY COMMITTEE

The Advisory Committee of the Water Resources Research Institute is composed of representatives from state and federal programs, local government, industry, environmental organizations, private consultants, water and wastewater treatment plants, the university research community and others. The committee advises the Institute on the need for water-related research in North Carolina, the region, and the nation.

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INSTITUTE RESEARCH PRIORITIES

Priorities established by the WRRI Advisory Committee for the current year reflect an effort to focus research in areas of key scientific uncertainty to produce knowledge useful for management decision making:

- Development of basinwide predictive models relating point and nonpoint sources to decision-sensitive water quality responses, incorporating uncertainty analysis.
- Evaluation of urban, forest, and agricultural Best Management Practices (BMPs) for both effectiveness and cost effectiveness and development of useful predictive techniques to guide selection of BMPs for specific circumstances.
- Characterization and prediction of the transport of nutrients, pesticides, and sediment from field edge to estuary, including the actual (removal and addition) mechanisms, with emphasis on filter strips.
- Analysis of past experiences (successes and failures) in the Chowan and Albemarle-Pamlico to assess what we might learn from those experiences and studies that might be applied to coastal rivers and estuaries.
- Determination of the relationship between nutrient concentrations (or nutrient loads) and algal density (blooms) in the Neuse and other coastal rivers so that management goals can be established.
- Assessment of unintended impacts of nitrogen controls in the Neuse River (shifts in species composition).
- Determination of expected reduction in water use from various water conservation programs.
- Assessment of effectiveness of a state wetland mitigation bank as a wetland mitigation tool.
- Estimation of the nitrogen budget for the lower Neuse River - sources, sinks, residence time, and uncertainties.
- Determination of a reasonable minimum flow associated with in-stream flow structures (e.g. dams).

responses to changing water quality conditions.

- **Monitor the distribution of parameters across as well as along the river axis.** Cross-river data will support the effort to produce a three-dimensional model at the point where the river widens and becomes estuarine in nature.
- **Monitor the capacity for exchange of oxygen and nutrients between sediments and water.** Data from 40 diver-collected cores, 200 sediment grab samples, and suspended sediment sampling will be used along with data from N.C. Division of Water Quality's in-situ stirred microcosm dome monitoring to understand sediment composition and biogeochemical activity along the river bottom, to identify zones of hypoxia/anoxia, and to help model processes in the estuary.
- **Monitor flow velocities across the river and along the river downstream of New Bern.** A broad band acoustic Doppler current profiler mounted on the side of a boat will be used to collect data on estuarine longitudinal circulation (downstream at the surface and upstream at the bottom) and lateral currents. This information will help to better model how nutrients, phytoplankton, and oxygen move through the estuarine system.
- **Monitor how fish respond to changes in water quality conditions, particularly dissolved oxygen.** Bi-weekly simultaneous water quality and trawl fish sampling from the mouth of the Neuse to New Bern will produce data to discover how zones of hypoxia/anoxia affect fish distribution. Divers will also collect data to explore effects on shellfish.

During the monitoring project, researchers are making graphical summaries of the data available through a World Wide Web site: **http://www.marine.unc.edu/neuse/modmon/monitor/monitor.htm**

An Interdisciplinary Observational Program for the Neuse River Estuary, NC (50220)
Richard A. Luettich, Jr, PI
UNC-Chapel Hill Institute of Marine Sciences; **Larry B. Crowder**, Duke University Marine Laboratory (50223); **Marc J. Alperin**, **Christopher S. Martens**, and **Daniel B. Albert**, UNC-Chapel Hill Curriculum in Marine Sciences; **Hunter S. Lenihan, Jesse McNinch, Hans W. Paerl, C.H. Peterson, James L. Pinckney, John T. Wells**, UNC-CH Institute of Marine Sciences

Short-term modeling

Because of the urgent need and public demand to "do something" about water quality problems in the Neuse River Estuary, efforts to produce a model to predict water quality responses to management actions and thereby support decision making are being conducted in two phases. In the short-term modeling phase scheduled for completion by December 31, 1998, an existing model designed to simulate natural processes in rivers is being calibrated by Dr. Jerad Bales of the U.S. Geological Survey using 1991-95 data on hydrodynamic processes (flow, transport, mixing, etc.) in the Neuse Estuary, and the model is being improved with data from other locations to better represent sediment-water column interactions. While researchers will attempt to incorporate some data from the sediment studies described above into the short-term model, for the most part, data from ongoing monitoring cannot be incorporated into ongoing modeling because they cannot be analyzed and input to the model quickly enough.

Because the CE-QUAL-W2 model is being tailored for the Neuse Estuary quickly, using data known to be lacking in certain respects, scientists will put a great deal of emphasis on "uncertainty analysis," that is, determining how likely it is the model predictions are correct, where the biggest errors may occur, and what information can be provided to bring about the best error reduction.

The scientists say that in an ideal situation, uncertainty analysis of the model would take place prior to designing the monitoring program to better target data collection to reduce uncertainties. Under urgent circumstances, they say, judgment of experts on what data will best support decision making will have to suffice.

Neuse River Water Quality Modeling (50222)
James D. Bowen, UNC-Charlotte
Web site for short-term modeling: **http://www.coe.uncc.edu/~jdbowen/neem/**

Long-term Modeling

In this phase of the project, scientists will interact with resource managers to determine what kind of management approach is likely to produce the best long-term results.

Scientists and managers will identify what system responses, such as fishkills and algae blooms, they want a model to predict. They will then identify proposed management actions. Some actions already proposed are forested riparian buffers and nutrient reductions in wastewater discharge. Once management actions and desired responses are put into scientific terms, quantified, and perhaps simulated mathematically (no small feat itself), then scientists have to begin combing through models and modeling approaches to find what will best predict if management actions will produce desired responses.

For example, if managers are interested in predicting algae blooms, they must first decide how algae blooms are to be represented in a model. The current way is by modeling chlorophyll *a* concentrations. At least two approaches exist to predicting chlorophyll *a* concentrations. One is a statistical model based on observation. The other is a mechanistic model that attempts to simulate the eutrophication process. The former is more accurate but generalizes its predictions across a waterbody. The latter is less accurate but can predict chlorophyll *a* concentrations in distinct geographical areas.

To give managers the ability to predict—with known and acceptable levels of uncertainty—specific details about algae blooms, lethal and sublethal effects on fish, and other responses of interest, the scientific team will evaluate:

- widely used process simulation models
- linked process models
- a probability network model coupled with ecological network analysis
- adaptive management

The goal of the long-term modeling phase is to begin development of a comprehensive water quality model for the Neuse Basin within a decision support framework. Progress reports on the modeling components of the Neuse

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Duke scientist will develop new way of determining characteristics of fractured rock aquifers

In order to efficiently manage groundwater for water supply or to clean up contaminated groundwater, managers must be able to model the flow of groundwater in an aquifer. To construct reliable models, they must know several characteristics of the aquifer, including the crucial parameters of "storativity," which controls the rate at which water is released from each layer of the aquifer, and "transmissivity," or the rate at which water is conducted through various aquifer media.

One of the most efficient and economical ways of obtaining information about hydraulic properties of aquifers is through the flowmeter test. This test consists of running a flowmeter device in a pumped fully penetrating well and measuring flow velocities in the well at all layer junctures. Contributions to the pumping rate from each layer are calculated from these velocities, and they are used to estimate the horizontal hydraulic conductivity of each layer.

The current theory of the flowmeter test requires that the borehole be pumped at a constant pumping rate until a quasi steady state is reached before the test is performed. However, this test allows estimation of only the downhole distribution of hydraulic conductivity. It provides no information about the downhole distribution of specific storativity. Moreover, in contaminated aquifers, pumping to reach a quasi steady state may take tens of hours and increase the spread of hazardous contaminants.

The only way to measure specific storativity is through a short "transient" test, that is a test performed during initial pumping before the steady state is reached.

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USGS Section 104(g) Regional Grants

In the 1996 Water Resources Research Act reauthorization, Congress authorized $3 million each year from 1996 through 2000 for research on "water problems of interstate nature," and provided that grants made to Water Resources Research Institutes by the U.S. Geological Survey under the act must be matched on at least a two-to-one basis by non-federal funds.

Funds appropriated for these "Section 104(g)" research grants are distributed through a program of regional competition.

In 1996, four projects involving North Carolina researchers won Section 104(g) funding in this regional competition. For 1997, two N.C. projects were awarded Section 104(g) grants.

Dr. Hans Paerl and Dr. J.L. Pinckney of the UNC-Chapel Hill Institute of Marine Sciences were awarded a grant for their project to provide information on denitrification rates in the Neuse River Estuary and information to help predict the response of nitrogen-fixing algae to proposed reductions in nitrogen loading in the Neuse.

In addition, Dr. Zbigniew J. Kabala of Duke University was awarded a grant for his project to develop a theory of the transient flowmeter test and test interpretation methodology and adapt the theory for fractured rock aquifers.

Project will examine whether nitrogen-fixing algae might interfere with goals of Neuse River cleanup

The nitrogen (N)-sensitive Neuse River has been the site of periodic massive scum-forming blooms of blue-green algae (cyanobacteria), a problematic (i.e.toxic, hypoxia/anoxia inducing, food chain altering) symptom of nutrient over-enrichment. When biologically available forms of N such as nitrate and ammonium are in short supply, some cyanobacteria can use atmospheric nitrogen gas (N_2) as a nutrient source, through the process of nitrogen fixation. The bloom organisms thus far identified in the Neuse River (Microcystis and Oscillatoria) are incapable of nitrogen fixation. Blooms of these non-N_2 fixers is one of several indicators that the Neuse is experiencing excessive nitrogen loading.

Earlier research (dilution bioassays carried out in the mid-1980's) indicated that to minimize the potential for cyanobacterial and other nuisance algal blooms in the Neuse River during bloom-sensitive periods, nitrogen loading should be reduced by 30% to 40%. However, there are serious questions about the effects that such a reduction in nitrogen loading would have without an accompanying reduction in phosphorous (P) loading. Altering the N:P ratio could result in negative water quality impacts.

In systems where N has been reduced without parallel P reductions, blooms of non-N_2-fixing species have simply been replaced by blooms of N_2-fixing species. The relatively high concentrations of P favor the growth of N_2-fixing (diazotrophic) cyanobacteria. In the Neuse, inducing N-limitation through unilateral N reductions may shift the algal species composition toward diazotrophic cyanobacteria, with potentially negative water quality implications.

Scientists and managers need more information about how, and at what rates nitrogen in its various forms is cycled in the Neuse River and Estuary to determine if this scenario will occur. A key component in addressing this important question is the identification of

factors that trigger the growth and dominance of bloom-forming diazotrophic cyanobacteria.

In this project, Drs. Hans W. Paerl and James L. Pinckney of the UNC-CH Institute of Marine Sciences will investigate these fundamentally important and timely questions. Denitrification is a very important N-controlling process in which a biologically available form of N, nitrate, is converted to nitrogen gases (N_2O and N_2) that are released into the atmosphere. Environmentally, denitrification is considered a "sink" for combined nitrogen because it reduces the amount of biologically useful N compounds. This process is mediated by microbes in sediments lining the river floor. Knowing the rates of denitrification and the spatial distribution are crucial for understanding N cycling and determining N budgets, essential informational ingredients for development of nutrient-eutrophication models, including kinetic models to predict the role and importance of denitrification at reduced N loads, needed for long-term management of N-sensitive systems like the Neuse. At present, very little is known about denitrification rates in the Neuse and other North Carolina estuaries.

Drs. Paerl, Pinckney and their associates will collect sediment core samples at 5 transect sites on a monthly schedule to assess denitrification in the Neuse. These rate determinations will be used to estimate N losses through denitrification for key regions of the river and estuary experiencing various symptoms of nitrogen-driven eutrophication, including nuisance algal blooms, hypoxia, anoxia and associated adverse effects on fin- and shellfish.

Drs. Paerl and Pinckney and associates will also perform nutrient dilution bioassay experiments to determine what effects a reduction of N loading might have on algal species abundance and blooms in the Neuse. Using Neuse River water from an estuarine and a riverine site, the researchers will incubate replicate dilution treatments in ambient

Nitrogen-fixing algae *continued*

temperature and light conditions, then measure the relative biomass of algal groups in each treatment and a control. By comparing responses in the various dilutions to the control, they expect to detect community shifts. With additional analyses, they also expect to estimate N_2 fixation rates and gain insights into the mechanisms (environmental conditions, physiological state, nutrient availability) that turn on the N_2-fixing genes that control the potential for microbial N_2 fixation.

Biologically Mediated Nitrogen Dynamics in Eutrophying Estuaries: Assessing Denitrification and N_2 Fixation Responses to Proposed N Loading Reductions in the Neuse River Estuary (70166)
Hans W. Paerl and James L. Pinckney
(Contact: Hans_Paerl@unc.edu)
UNC-CH Institute of Marine Sciences
July 1, 1997, to June 30, 1998
Funded by WRRI
and the U.S. Geological Survey

NCSU researchers will examine effectiveness of system of agricultural BMPs

Nonpoint source pollution from agricultural runoff is a major water quality concern throughout North Carolina, the Southeast, and the nation. Pollutants include sediments, nutrients, and pesticides. State and federal farm-related and natural resource agencies and USDA Cooperative Extension personnel are encouraging farmers to adopt Best Management Practices (BMPs) to conserve soils and reduce nonpoint source pollution. To effectively use BMPs for water quality management, information is needed about their pollutant reduction effectiveness and costs of installing and maintaining them as well as their effects on crop yields and quality. Many studies have investigated the effectiveness of individual best management practices or compared two BMPs, such as grassed waterways, conservation tillage, grassed filter zones, or forested filter zones. However, few studies have considered the effectiveness, cost, and crop impacts of a fully integrated system of field, field edge, and adjacent woodland BMPs.

In this project Dr. Carlyle Franklin of the NCSU Department of Forestry and Dr. Gregory Jennings of the NCSU Department of Biological and Agricultural Engineering will investigate the ability of an integrated system of BMPs to handle runoff from tobacco fields in Piedmont North Carolina. Tobacco is a good crop to use for this study because heavy cultivation and heavy applications of fertilizers and pesticides are conventionally used.

On two well-instrumented 1.5-hectare agricultural watersheds at the Oxford Tobacco Research Station in Granville County, the researchers will evaluate effectiveness and costs of conservation tillage, grassed waterways/filter zones, and forested filter zones used to control runoff. The research will build on the investigators' previous studies of the hydrology, sedimentation and nitrogen cycling in the forested filter zones. It is expected to provide information on whether or not conservation tillage is cost-effective when used in combination with other BMPs, whether grassed waterways/filters are effective in reducing pollutants in major storm events, and whether management of woody vegetation in forested filter zones can enhance their nutrient removal capability. It is also expected to yield information on costs of installing and maintaining BMPs and effects of conservation tillage on tobacco yields and quality.

Effectiveness of Four Best Management Practices for Reducing Nonpoint-Source Pollution from Piedmont Tobacco Fields (70163)
E. Carlyle Franklin and Gregory D. Jennings (Greg_Jennings@ncsu.edu)
North Carolina State University
June 15, 1997, to December 31, 1998
Funded by WRRI

Project will reveal past environments of Neuse and Tar-Pamlico Estuaries

Water quality problems in the Tar-Pamlico and Neuse River estuaries are well documented and are thought to be related to both point source discharges of pollutants and nonpoint source pollution from changes in land use. However, scientific studies and monitoring that could link land-use changes and water quality changes in these systems have been conducted only in the last 30 to 40 years. These studies provide only a limited view of short term changes in the system—changes that may reflect seasonal or annual shifts and not long-term human influences. Nevertheless, a record does exist that can be used to provide managers and regulators with a much broader picture of how the systems have changed with human and climatic influences as well as the data to separate climatic from human impacts. That record lies in the accumulated sediments that underlie the estuaries and is accessible through the use of paleoecological methods. Paleoecology is the study of relationships between past organisms and the environment in which they lived. Paleoecological methods are used to reconstruct past ecosystems and to measure human influences against the naturally occurring state of those ecosystems.

In this project, Dr. Sherri R. Cooper of the Duke Wetland Center will collect and use paleoecological data to re-create the history of water quality and diatom community structure in the Tar-Pamlico and Neuse estuaries through time and to relate changes in water quality to changes in watershed land use history and other anthropogenic influences. She will take sediment cores from each estuary and examine them to discover and assess indicators of past water quality. Using radiocarbon dating, Pb-210 dating and Cs-137 dating along with pollen dating techniques, she will calculate sedimentation rates for each interval of the core and produce a time axis dating from about 1,000 years ago to the present, along which she can plot corresponding water quality and geochemical parameters. Plant and animal fossils, particularly pollens and preserved silica exoskeletons of diatoms (a form of algae), can be used to assess past eutrophication, nutrient availability, light availability, and sedimentation rates. Organic carbon in sediment layers can reveal information about past benthic oxygen demand, and sulfur compounds can tell whether oxic or anoxic conditions prevailed at the time sulfur was deposited.

The paleoecological record resulting from this work will help illuminate the debate concerning the primary factors contributing to declining water quality in estuaries and will support hindcasting models in which predictions about the effects of future environmental change on the ecology can be made.

The History of Water Quality in North Carolina Estuarine Waters as Documented in the Stratigraphic Record (70161)
Dr. Sherri Rumer Cooper
(slcooper@acpub.duke.edu)
Duke University
May 1, 1997, to June 30, 1998
Funded by WRRI

Neuse River ModMon *continued*

River project along with related papers and links are on the World Wide Web at: **http://www.marine.unc.edu/neuse/modmon/modeling/modeling.htm.**

Analysis of Ambient Monitoring Data in the Neuse River Basin (50225)
Craig A. Stow, Duke University
Contribution to Long-term Modeling Tier of the Neuse River and Estuary (50224)
Robert R. Christian, East Carolina University

Overall project coordination and development of decision analytic framework:
Neuse River Modeling and Monitoring (50219)
Kenneth H. Reckhow, WRRI & Duke Univ.
April 1, 1997, to December 31, 1998
Funded by the N.C. Department of Environment, Health, and Natural Resources

Neuse River water quality data now accessible on demonstration World Wide Web site

For decades, local, state, and federal agencies as well as universities have collected water quality data about North Carolina's streams, lakes and wells to support many short-term and long-term studies. Collecting agencies have shared their data, but there has been no comprehensive attempt to store all of these data in a single repository—until now.

Now, a common retrieval system for North Carolina water quality data is being developed as a joint effort of the Office of the Governor of North Carolina, the U.S. Geological Survey, WRRI, UNC-Chapel Hill, and the N.C. State University Computer Graphics Center. Hosted by the N.C. District of USGS, an aggregated database and World-Wide Web site is being developed to make water quality data accessible to the general public, schools, environmental consultants, and various governmental agencies.

A demonstration site with a specially designed graphical interface is now on-line, providing access to 15 basic water quality parameters for the Neuse River. The URL is: **http://wwwnc.usgs.gov/qw-cgi/qwretr.pl.** At this site, users may point and click on basin, county, and watershed maps to select specific monitoring stations and view and/or download data from those stations.

As the site is developed, additional parameters and river basins will be available through cooperation with the N.C. Division of Water Quality.

A Prototype Water Quality Data Retrieval System for the Neuse River Basin (50226))
Hugh A. Devine and Casson X. Stallings
North Carolina State University
March 1, 1997, to September 30, 1998
Funded by the North Carolina Board of Science and Technology

Project will focus on estimating costs of basinwide water quality management options

The N.C. Environmental Management Commission is poised to adopt a set of water quality management rules to be applied throughout the entire Neuse River Basin. Aimed primarily at reducing nutrient inputs to the river, the rules will tighten controls on point source dischargers and mandate use of best management practices (BMPs) to control several categories of nonpoint source pollution. While the Neuse River nutrient management plan will be the state's first set of rules to impose nonpoint source BMPs basinwide, North Carolina has embraced basinwide water quality management and developed many basin plans calling for voluntary nonpoint source BMPs.

Choosing the most efficient water quality management approach requires knowing not only the water quality impacts but also the economic impacts of options. In the case of water quality management rules, estimating the cost of complying with a rule that applies to one category of point source dischargers may be fairly straightforward, since the number of dischargers affected and the cost of employing a specific technology are likely to be known.

However, estimating the cost of implementing a range of nonpoint source BMPs throughout an entire river basin is not at all straightforward, since requirements would affect thousands of economic activities in different, site-specific ways. Calculating the likely costs of BMPs for each activity would require enormous resources and time.

Attempts have been made in other parts of the country, including the Chesapeake Bay area, to estimate the costs of basinwide nonpoint source controls, but these efforts have yielded at best crude estimates based on costs per acre applied to generalized land uses, without regard to site-specific factors that may substantially affect costs.

To fill the need for affordable techniques for estimating costs of basinwide nonpoint source control policy options, Dr. David H. Moreau of the UNC-CH Department of City and Regional Planning will develop statistical techniques to address the kinds of management options being considered by North Carolina and states with similar water quality problems.

After selecting management options to be studied, the investigator will use existing data sets (census data, building permits, computerized tax files, remote sensing aerial photographs, etc.) to define populations of lands and define appropriate sampling units for activities affected by each policy option. He will then, draw samples and make statistical inferences about the entire population.

Using case studies and available literature, he will identify relevant costs to be estimated for sampling units, then develop procedures to estimate costs with and without a given policy to establish costs that are uniquely imposed by that policy.

The final project report will include a manual of procedures with references to appropriate data sets.

Development of Methods for Estimating the Cost of Watershed Management Policies (70164)
David H. Moreau
(moreau.dcrp@mhs.unc.edu)
University of North Carolina
at Chapel Hill
July 1, 1997, to June 30, 1998
Funded by WRRI

NCSU team will develop watershed-scale model for predicting nutrient contributions in Neuse River Basin

Scientists generally agree that nuisance algal blooms and hypoxia and anoxia leading to fish kills in the Neuse River are at least partially due to excessive nitrogen loading. It has been estimated that more than 70% of the nitrogen input is from nonpoint sources, with a large portion of that coming from agricultural and forested lands. While nutrients are delivered to the estuary from watersheds throughout the river basin (and beyond in the case of atmospheric deposition), watersheds in the lower Coastal Plain may contribute a larger share because they are located closer to the estuary. If this is the case, then determining the effect of management practices to reduce nutrient losses at the outlets of lower Coastal Plain watersheds is a very important part of a basinwide management plan.

Water and nutrient management practices have been developed for reducing nutrient and sediment losses from agricultural and forested fields in the lower Coastal Plain, and reliable and fairly straightforward methods exist for estimating losses of sediments and nutrients at the edges of these fields. However, reliable and practical methods have not been developed to quantify effects of these practices on nutrient and sediment losses at the watershed scale.

Existing watershed scale models are complex and require a large number of difficult-to-determine input parameters. There may be great uncertainty in predictions made by these models because of errors associated with each input parameter and the interaction between parameters. Proper use of these complex models to predict

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CONTINUING RESEARCH

✓ ***Assessing the Impact of Septic Discharge on Water Quality on the Cape Hatteras National Seashore*** (70147) May 1, 1995, to November 30, 1997—Funded by WRRI and the National Park Service ■ Drs. David Evans and Aziz Amoozegar of North Carolina State University continue their research into whether groundwater quality on Bodie Island within the Cape Hatteras National Seashore is being degraded by septic effluent and their efforts to identify the sources and pathways of degrading constituents.

✓ ***Compliance with EPA's Information Collection Rule for North Carolina Surface Water Supplies: Bench-scale Testing of the Efficacy of Carbon Adsorption and Membrane Separation*** (70145) July 1, 1995, to September 30, 1997—Funded by WRRI and the U.S. Geological Survey ■ Dr. Francis A. DiGiano of the University of North Carolina at Chapel Hill continues a project to demonstrate the usefulness of bench-scale testing for assessing the effectiveness and cost of activated carbon adsorption and membrane separation for disinfection by-product precursor control.

✓ ***Geochemical Tracers of Groundwater Movement between the Castle Hayne and Associated Coastal Plain Aquifers*** (70148) June 1, 1996, to September 30, 1997—Funded by WRRI ■ Dr. Terri L. Woods of East Carolina University continues her investigation of the chemical and strontium isotopic characteristics of groundwater in the Castle Hayne, Yorktown and Peedee aquifers. By determining the chemical and strontium isotopic signatures of the groundwater from these associated units, she will be able to use mass balance calculations to track water movement between aquifers and possibly to estimate volumes transferred.

✓ ***Development of the Technical Basis and a Management Strategy for Reopening a Closed Shellfishing Area (70149)*** June 1, 1996, to June 30, 1998—Funded by WRRI ■ Dr. William W. Kirby-Smith of the Duke Marine Laboratory continues his project to design a plan to reopen a closed shellfish area in Carteret County that can serve as a model for reducing fecal coliform contamination and allow reopening of other closed shellfish areas in N.C. estuaries.

✓ ***Influence of Protozoan Grazing on Intrinsic Bioremediation under Anaerobic Conditions*** (70153) July 1, 1996, to December 31, 1997—Funded by WRRI and the U.S. Geological Survey ■ Dr. Robert C. Borden of North Carolina State University continues his project to determine if protozoa in soil may be controlling rates of biodegradation of petroleum contaminants by consuming the microbes that degrade hydrocarbon constituents and to model degradation rates in the field.

✓ ***Grass and Riparian Buffer Treatment of Runoff from Land Receiving Animal Waste*** (70146) July 1, 1995, to November 30, 1997—Funded by WRRI and the U.S. Geological Survey ■ Drs. J.W. Gilliam, J.R. Parsons, and R.L. Mikkelsen continue to gather data to help establish guidelines for designing effective buffers for different soil types, slopes, hydrologic, and vegetative conditions and to determine the effectiveness of buffers in removing pathogens found in animal waste.

✓ ***Characterization of Ammonia Emissions from Animal and Poultry Operations in North Carolina*** (50214) July 1, 1996 to June 30, 1999—Funded by the Division of Air Quality of the N.C. Department of Environment, Health, and Natural Resources and WRRI ■ Dr. Viney P. Aneja of North Carolina State University continues his project to begin describing all the paths of nitrogen (ammonia) volatilization, transport, transformation, and deposition at various kinds of swine and poultry operation and estimating the magnitude and frequency of loadings from these sources.

✓ ***Stable Nitrogen Tracers of Nitrogen Sources to Surface and Groundwaters near Animal Production Facilities*** (70157) August 15, 1996, to August 14, 1997—Funded by the N.C. Pork Producers; N.C. Department of Environment, Health, and Natural Resources, Division of Marine Fisheries; and WRRI ■ Dr. William J. Showers of North Carolina State University continues his project to use isotope science to measure the water quality impacts of animal waste as a source of nitrates to the Neuse River.

continued in shaded box on page 11

nutrient loading from a single watershed is expensive and time consuming even for an interdisciplinary group of research scientists. The task is beyond practical reality for policy makers and managers who need to make decisions about multiple watersheds with limited time and resources.

Water quality managers need new models that reflect the current understanding of the natural system but require input parameters that can be readily determined with a minimum of uncertainty.

To fill this need, a team of NCSU scientists will develop new watershed-scale models for predicting nutrient contribution based on their hypothesis that nitrogen loading at a watershed outlet is more affected by variations in hydrology and hydraulics than by variations in processes controlling nitrogen transformations. Rather than trying to model complex biological and biochemical nitrogen cycling processes, the scientists will lump these processes into simple empirical relationships that quantify the net change of nitrogen in the stream system. They will couple these lumped parameter models with models that simulate the variations in timing and intensity of storm events and the time required for drainage water to travel from field edge through conveyance systems to watershed outlets.

In the first year of the project, the scientists will develop two different lumped parameter models based on different approaches to representing nitrogen processing and will conduct field experiments on an existing instrumented watershed to determine the variability of the parameters used to describe the processes.

If they are successful in developing a workable lumped parameter model, the team will request a second year of funding to evaluate the models by comparing their predictions with field-measured data and with predictions of more complex process-based models. They will also evaluate the uncertainty of the

lumped parameter models due to errors in parameter estimation and errors in model assumptions.

The research team includes Drs. R. Wayne Skaggs, George M. Chescheir, Devendra M. Amatya, and Glenn P. Fernandez of the NCSU Department of Biological and Agricultural Engineering and Dr. J. Wendell Gilliam of the NCSU Department of Soil Science.

Lumped Parameter Models for Predicting Nitrogen Loading from Lower Coastal Plain Watersheds (70162)
R. W. Skaggs, G. M. Chescheir, D.M. Amatya, G. Fernandez, and J.W. Gilliam
(Wayne_Skaggs@ncsu.edu)
North Carolina State University
June 1, 1997, to June 30, 1998
Funded by WRRI

Determining characteristics of fractured rock aquifers *continued*

If numerical models can be developed that will yield estimates of both storativity and transmissivity from a transient flowmeter test, then a more economical and safer way of modeling groundwater flow and transport of contaminants in aquifers could be developed.

In this project, Dr. Zbigniew J. Kabala of the Duke University Department of Civil and Environmental Engineering will develop a theory of the transient flowmeter test and test interpretation methodology. In the first step, the theory will be developed for general layered porous media. Then it will be adapted for fractured rock aquifers such as are found in the N.C. Piedmont plateau. Dr. Kabala and his graduate student will evaluate the test in numerical experiments and in field tests at a site previously used for burial of low-level radioactive wastes where 15 unpumped monitoring wells are available.

An Improved Characterization of a Fractured-Rock Aquifer by the Transient Flowmeter Test (70165)
Zbigniew J. Kabala
(kabala@copernicus.egr.duke.edu)
Duke University
July 1, 1997, to June 30, 1998
Funded by WRRI and U.S. Geological Survey

CONTINUING RESEARCH

✓ ***Effect of Management Practices on Denitrification in Soils Fertilized with Lagoonal Swine Waste*** (70151) June 15, 1996, to August 31, 1998—Funded by WRRI and the U.S. Geological Survey ■ Dr. Stephen C. Whalen of UNC-Chapel Hill continues his project to identify field conditions under which microbes in soil most effectively convert complex forms of nitrogen into dinitrogen gas in order to determine which agricultural management practices are most likely to prevent export of nitrogen from fields treated with animal waste. In addition, he will examine the short- and long-term time trajectory for development and increase in microbial nitrogen transformations in fields treated with swine lagoon waste.

✓ ***Denitrification and Nitrification in Agricultural Soils Fertilized with Liquid Lagoonal Swine Effluent*** (50232) July 1, 1997, to June 30, 1998—Funded by the Division of Air Quality of the N.C. Department of Environment, Health, and Natural Resources ■ In a project related to the one described above, Dr. Stephen C. Whalen of UNC-Chapel Hill is examining the individual and interactive effects of environmental factors on denitrification in animal waste-amended agricultural fields and performing laboratory and field experiments to provide estimates of the annual gaseous nitrogen loss (N_2 and N_2O) to denitrification of liquid lagoonal swine effluent from spray fields. This study is part of an integrated project (See Characterization of Ammonia Emissions from Animal and Poultry Operations in North Carolina [50214]) to examine the fate of nitrogenous nutrients routinely stored in anaerobic swine waste lagoons. It will be of help to regulatory agencies in establishing BMPs and identifying needs for additional research on swine waste disposal.

✓ ***Control of Haloacetic Acid Formation in North Carolina Drinking Water*** (70155) June 15, 1996, to February 28, 1998—Funded by WRRI and the U.S. Geological Survey ■ Dr. Philip C. Singer of UNC-Chapel Hill continues exploring the possibility that elevating pH of coagulated and settled water prior to application of chlorine can control formation of haloacetic acids (a class of disinfection by-products) without significantly increasing formation of trihalomethanes (another class of disinfection by-products) or lowering the disinfection effectiveness of chlorine to unacceptable levels.

✓ ***A Decision Support System for Microbial and Disinfection By-Product Risk Analysis in North Carolina Water Supplies*** (70150) September 1, 1996, to October 31, 1997—Funded by WRRI ■ Dr. Douglas J. Crawford-Brown of UNC-Chapel Hill continues his project to develop an interactive computer-based Environmental Decision Support System that will allow water suppliers to select alternative assumptions to be used for assessing microbial vs disinfection by-product risk related to treatment options and to see how the assumptions affect the degree of confidence that can be placed in the assessment.

✓ ***Microbial Impacts of Animal Wastes on Water Resources*** (70152) June 15, 1996, to August 31, 1998—Funded by WRRI and the U.S. Geological Survey ■ Dr. Mark D. Sobsey of UNC-Chapel Hill continues his efforts to characterize and quantify the relative contributions of agricultural and commercial animal fecal wastes and human sewage effluents to levels of Cryptosporidium and Giardia in surface and ground waters in North Carolina. The purpose of the work is to provide a scientific basis for a quantitative assessment of the risk to human health and the environment from Cryptosporidium and other pathogens of agricultural animal origin in waters used for drinking water supply, recreation and shellfish raising. So far, analysis of replicate samples of cattle and swine lagoon influent and effluent has detected neither Cryptosporidium nor Giardia, and sampling of streams running through cattle and swine pastures and feedlots using BMPs has found no evidence of significant contribution of Cryptosporidium or Giardia from the animal operations.

✓ ***Protecting and Restoring Forested Stream Buffers in Existing Urban Residential Areas of Wake County*** (50216) October 1, 1996, to September 30, 1997—Funded by the Division of Forest Resources, N.C. Department of Environment, Health, and Natural Resources ■ Jeri Gray of WRRI and Rick Bailey of the Wake Soil and Water Conservation District wrap up a joint project aimed at providing information to urban landowners and local government officials in Wake County about the importance of forested riparian buffers for water quality and the importance of properly restoring riparian areas damaged by Hurricane Fran. A booklet, video, and call-in television program are products of the project.

In order to address research needs of specific groups, WRRI promotes partnership arrangements. One such partnership is the N.C. Urban Water Consortium. WRRI in cooperation with several of North Carolina's larger cities established the Urban Water Consortium to provide a program of research and development and technology transfer on water problems that urban areas share. Through this partnership, WRRI and the State of North Carolina help individual facilities and regions solve problems related to local environmental or regulatory circumstances.

The Consortium program is administered by the Institute. Participating cities support and guide the program through annual dues and enhancement funds and representation on an advisory board. Membership in the Consortium is limited to cities or special districts in North Carolina.

The program initially received support from the N.C. Department of Environment, Health, and Natural Resources and appropriations from the N.C. General Assembly. Current Consortium members are the Orange Water and Sewer Authority, Raleigh, Durham, High Point, Burlington, Winston-Salem, Charlotte, Greenville, and Greensboro.

Urban water research needs cover a broad range of topics. Problems addressed with Consortium support are described on the following pages.

Researchers shedding light on problems of algae in reservoirs

Drinking water plant managers in Piedmont North Carolina know that algae in their reservoir waters can cause problems. They know that algae can clog filters, contribute to the formation of disinfection by-products, and leave unpleasant tastes and odors in their finished water. Furthermore, algae may adversely affect drinking water quality by releasing toxins.

Because of the growing concern about algae, particularly toxic forms, and their possible effects on public health, the N.C. Urban Water Consortium has joined with the American Water Works Association Research Foundation to sponsor research that will shed light on the range of effects algae have on drinking water treatment and finished water quality. The research is being conducted by N.C. State University scientists Detlef Knappe, Sarah Liehr, JoAnn Burkholder and Howard Glasgow. It is also aimed at finding the best ways to treat raw water that contains algae, determining what can be done to control algae in reservoirs, and determining whether toxic forms of algae could threaten water supplies in the Piedmont. Work on this project began in December 1996.

To date, researchers have:

- collected information on other research through an ongoing literature review,
- worked on a method to determine algal biomass in raw, settled, and filtered water,
- begun investigating how organic matter released by algae affects the treatment process,
- begun evaluating how well conventional treatment removes algae and other particulate matter from water,

- begun a survey of treatment practices at Consortium member plants, and
- begun collecting samples and information to determine water quality and algae control practices at Consortium member reservoirs.

What the literature shows

Through the literature review, the investigators have found that when algae and blue-green algae are stressed they release large quantities of extracellular organic matter, which—depending on the kind of algae—may contain toxins or compounds that impart taste and odor to water. At least 18 genera of blue-green algae have been shown to be toxic, but toxicity varies widely. Poisoning of animals by blooms of freshwater blue-greens has been documented worldwide. While acute poisoning of humans by these organisms has not been documented, there are increasing reports of dermatitis and/or irritation from contact with freshwater blue-greens as people have more recreational contact with eutrophic waters. Some of the compounds that cause skin rashes have also shown to be tumor-producing, and chronic low-level exposure to these and other algal toxins have begun to be linked to immune system suppression.

Research into effects of algae on water treatment has linked increased turbidity levels in filtered water to elevated chlorophyll a concentrations in raw water. Indications are that in high concentrations, algae or extracellular organic matter released by algae interfere with particle destabilization in the coagulation process and, therefore, reduce filterability. Other researchers have identified elevated concentrations of dissolved iron or aluminum in filtered water as an early warning sign that the coagulation process has been adversely affected by soluble organic matter.

Studies have also shown that it is easier to remove algae from raw water when they are in their stationary growth phase, than when they are in their log growth phase.

Previous research has also revealed that algae, and more importantly the extracellular organic matter they release, can interact with chlorine to produce disinfection byproducts, some of which are suspected carcinogens. Furthermore, extracellular organic matter can serve as a substrate for the regrowth of microbial contaminants in water lines.

Studies have also shown that algae are stressed by the application of algicides to reservoirs, by chlorination prior to filtration, and by the physical process of withdrawing water from reservoirs.

Research indicates that there are problems with the most commonly used methods for controlling algae in reservoirs. Application of copper sulfate as an algicide stresses algae and induces production of extracellular organic matter, potentially including the release of toxins. Mixing (de-stratification, done to limit light and increase carbon dioxide levels) can increase inorganic carbon available for algal growth (although it could also shift species domination from blue-greens, which may be toxic, to greens). Finally, nutrient control may or may not be effective unless the ratio of nitrogen to phosphorous can also be controlled.

Developing a quick way to measure algae

If water managers have a quick and easy way to determine algal biomass in their source water, they may be able to adjust treatment methods accordingly to avoid problems. However, current quantification methods are costly and take too long to support a quick response. In this project, investigators are testing a process using a fluorometer to quantify chlorophyll a in flowing water. They are currently working on calibrating the fluorometer. They will then test it using raw water samples with concentrations of chlorophyll a determined by the standard EPA method. At the same time they will count algal cells and determine the presence of different algal species in samples in order to make comparisons between chlorophyll a levels and algal biomass.

Probing extracellular organic matter

Since extracellular organic matter (EOM) released by algae is known to affect treatment processes and the quality of finished water, the investigators are performing experiments to learn more about its role in the formation of disinfection byproducts (DBPs). They have spiked water from Falls Lake with EOM, dosed it with chlorine, and measured chlorine demand and the formation of trihalomethanes. Their initial experiments indicate that EOM greatly increases chlorine demand and the potential for DBP formation. They are now refining and repeating their experiments to produce some "hard numbers" on effects of EOM on DBP formation.

Evaluating removal of algae by conventional treatment

When high concentrations of algae are in raw water, water managers want to remove as much algal biomass as possible in the first step of the treatment process-coagulation and flocculation. In this project, investigators are trying to identify the optimum conditions for coagulation of algae. In a series of jar tests, they evaluated the effects of alum dose and pH on removal of turbidity, total organic carbon, dissolved organic carbon, and ultraviolet light absorbance in the presence and absence of algae. One important finding of these experiments was that the presence of algae did not seem to greatly affect percent removal of these commonly measured parameters even though

large numbers of free algal cells remained in the settled water. This substantiates the need for the development of a direct method for the determination of algal concentrations in drinking water treatment plants.

As this two-year study continues, the investigators will:

- continue their ongoing work,
- study the effects of oxidants on the release and/or removal of EOM, taste and odor causing compounds, and toxins,
- evaluate dissolved air flotation for removal of algae from high turbidity waters,
- validate correlations developed from bench-scale studies at pilot-scale and full-scale plants, and
- initiate experiments to evaluate the effect of nutrients in reservoirs on the production of algal toxins.

Optimization of Treatment to Mitigate Impacts of Algae and Algae Control on Finished Water Quality (50215/7)
Detlef Knappe (KNAPPE@EOS.NCSU.EDU), Sarah Liehr, and JoAnn Burkholder
North Carolina State University
December 1, 1996, to November 30, 1998
Funded by the N.C. Urban Water Consortium and the American Water Works Association Research Foundation

Project offers insight into risk assessment process and risk from Cryptosporidium in drinking water

One of the thorniest problems facing managers of public drinking water utilities is that posed by the parasite Cryptosporidium. Almost ubiquitous in surface waters, this pathogen has been implicated in numerous recent outbreaks of waterborne disease, including the well-publicized 1993 Milwaukee outbreak that sickened nearly 400,000, hospitalized 4,000 and killed 40. The parasite is difficult to kill with common disinfection practices, and can be filtered out of water to reliable zero levels only by very expensive microfiltration techniques. One of the first steps in deciding how to address the problem of Cryptosporidium is knowing what kind of risk it poses in a specific water supply.

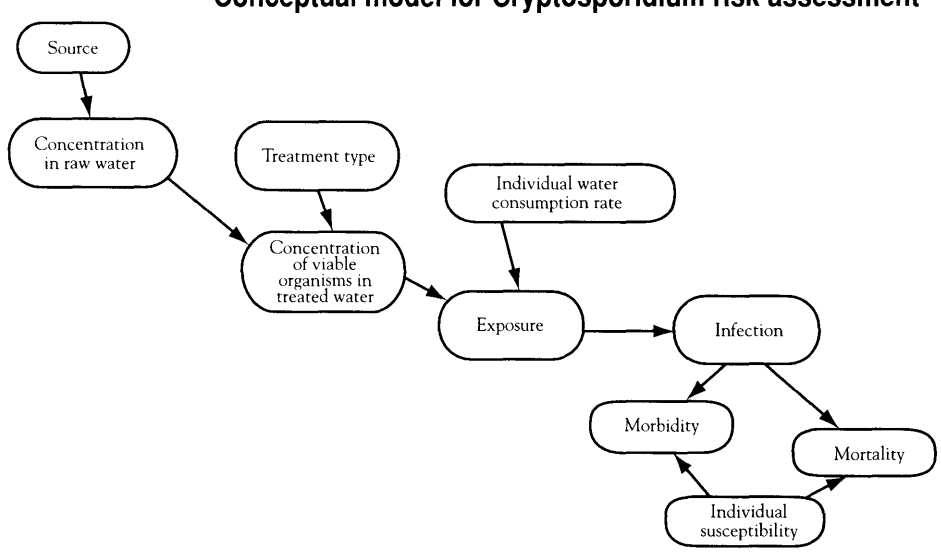
In this project, Kenneth H. Reckhow, director of WRRI, designed a conceptual model for assessing the risk that consumers of municipal drinking water in North Carolina face of infection from Cryptosporidium and the risk that immune-compromised consumers face of contracting a life-threatening illness from Cryptosporidium in drinking water. For her master's project in environmental management, Duke University graduate student Syril Director characterized uncertainties involved in Reckhow's conceptual model, then used a mathematical model representing the concept along with available "probabilistic" computer modeling programs to produce a probabilistic expression of Cryptosporidium risk for customers of several N.C. water utilities.

What is a risk assessment?

A risk assessment is a science-based estimate of the health risk a human population faces from being exposed to a particular substance. It combines information on the level of exposure to a substance with information on the toxicity of a chemical or virulence of a microbial contaminant to come up with some statement about what is likely to happened to humans who are exposed.

EXPOSURE + TOXICITY (OR VIRULENCE) = RISK

Conceptual model for Cryptosporidium risk assessment



Credibility in risk assessment

Identifying uncertainties

Because scientists never have certain knowledge about exposure or toxicity, risk may be characterized by a range of possible outcomes (e.g. "the risk could be as high as one additional case of disease X in 10,000 people or as low as no additional cases"). To come up with a reliable and creditable expression of risk, the risk assessor must identify uncertainties at each step in the risk assessment and take these uncertainties into account in the final estimates. For this project, Director examined each step in the model represented at the left and identified and modeled the uncertainties.

Uncertainty in assessing risk from Cryptosporidium in drinking water. To estimate how many Cryptosporidium oocysts (eggs) a consumer drinking water from any particular utility might consume in any day or year, it is necessary to know (1) the concentration of Cryptosporidium oocysts in the source water, (2) how much of it the treatment process removes and how much is left in finished drinking water, and (3) how much water a person typically drinks in a day.

In trying to get a reliable measurement of Cryptosporidium in source water, a risk assessor immediately comes upon a challenge: It is very difficult to detect and even more difficult to enumerate Cryptosporidium in water. They are microscopic and, even in high concentrations, are dispersed throughout large volumes of water. Further, there is no "litmus" test that will react only to them.

The first thing a technician analyzing a water sample for Cryptosopridium must do is capture all the cryptosopridium occysts from a sample of known quantity into a "supernatant." While there are standard procedures for doing this, it is not certain that these procedures actually capture every oocyst. So, to be honest about how accurate this first step of the analysis is, risk assessors may use a numerical range derived from statistical studies (of recovery rates from seeded samples), rather than a single number, to express a probable recovery rate of cryptosopridium occysts from the sample.

The next step in the analysis is to count the oocysts in the supernatant. An EPA-recognized immunofluorescence antibody test fluorescently labels the parasites so they can be seen and counted under a microscope, but the process also labels other particles. It is then necessary to microscopically distinguish the fluorescently labeled parasites from other labeled particles in the sample, and that is often nearly impossible to do. So, in this second step of measuring Cryptosporidium oocysts in source water, there is also uncertainty. Again, the risk assessor may use a range of values based on statistical studies (of accuracy in counting the parasite in seeded samples) rather than a single number to express the probable accuracy of oocyst counts.

Obviously, in the very early steps of the exposure assessment, the risk assessor already faces two serious areas of uncertainty. More will pop up at virtually every step. For instance, the exact extent to which any particular water treatment method removes or kills Cryptosporidium oocysts isn't known, and there's some uncertainty about how much tap water people actually consume in a day.

Moreover, when risk assessors reach the stage of assessing virulence of cryptosopridium, they face uncertainty about whether oocysts recovered from a specific water sample are all "viable"—that is able to cause illness, uncertainty about how many viable oocysts it takes to make any particular individual ill, and uncertainty about the seriousness of the illness in healthy and immune-compromised individuals.

To allow risk assessors to take all the many uncertainties about exposure and virulence into account, scientists have developed computer programs that generate probabilities or ranges of values for "parameters," or elements of a risk assessment model about which there is uncertainty. Using these programs along with risk assessment models, risk assessors can generate "probabilistic" expressions of risk.

Revealing assumptions. Mathematical models that are used to assess risk are by necessity simplified representations of a natural phenomenon (such as the rate of human infection by a pathogen). In simplifying phenomena enough to make calculations, modelers often make assumptions. A creditable risk assessment will always identify where assumptions were made and state what the assumptions were.

To mathematically represent the conceptual model designed by Reckhow, Director selected the "single-hit exponential" model, which had been derived from experimental data and was used to back-calculate oocyst concentrations causing the Milwaukee Cryptosporidiosis outbreak. However, she notes that the model assumes that each individual pathogenic particle ingested by a human is of equal virulence. Since scientists know very little about the infective capability of Cryptosporidium, this model could overstate the probability of infection from Cryptosporidium. Director also notes that in converting daily risk levels to annual risk levels, she assumed that there is no cumulative effect (such as development of immunity) from repeated exposures, and that if prior exposures do decrease sensitivity in a normally healthy individual, this assumption could result in overestimation of risk of illness.

Data. Even when a risk assessor scrupulously accounts for uncertainty and assumptions, insufficient data can raise questions about the reliability of a risk assessment. For this risk assessment, Director used data provided through U.S. Geological Survey monitoring of municipalities' water supply sources in the Research Triangle area. Most source waters were sampled twice, once in the fall or winter of 1994 and again between

continued

CONTINUING RESEARCH
SPONSORED BY THE N.C. URBAN WATER CONSORTIUM

✓***Assessment of Trace Element Concentrations in Municipal Wastewater Treatment Plant Discharges in North Carolina*** (50210) September 1, 1995, to June 30, 1998—Funded by the N.C. Urban Water Consortium

■ Drs. Philip C. Singer and Howard S. Wienberg of the University of North Carolina at Chapel Hill have found that strictly following recommended protocol and implementing quality assurance for wastewater effluent sample collection, handling and analysis will substantially reduce the number of instances of noncompliance with standards for mercury and cadmium. They have found that following protocol and enforcing quality assurance will reduce noncompliance for cyanide for most plants. However, they have also found that a few plants continue to show apparent high levels of cyanide in their effluents in spite of tight protocol and quality assurance. In a one-year continuation of this project, the scientists will investigate whether the current analytical methods employed for measuring cyanide are adequate and whether chlorination/dechlorination of wastewater may produce compounds that interfere with accurate measurement of cyanide in treatment plant effluent.

✓ ***Evaluation of Ponds and Wetlands for the Protection of Public Water Supplies Continuation*** (50211) January 1, 1996, to December 31, 1997—Funded by the N.C. Urban Water Consortium and the City of High Point.

■ Drs. Robert C. Borden and Sarah K. Liehr of North Carolina State University continue to examine the pollutant removal efficiency of stormwater detention ponds in the City of High Point's water supply watershed. They will use the results of their monitoring to calculate relative removal efficiencies of various stormwater control devices and to calibrate the lake water quality model MINLAKE for use in estimating season and long-term treatment efficiencies for each structure.

✓ ***Evaluation of Pesticides in Water Supply Watersheds*** (50218) April 1, 1997, to July 31, 1998—Funded by the N.C. Urban Water Consortium

■ For 16 months, Dr. Robert E. Holman of WRRI and Dr. Ross B. Leidy of NCSU collected water samples in water supply watersheds and conducted analyses for 11 pesticides: acetochlor, alachlor, aldicarb, atrazine, carbaryl, carbofuran, chlorothalonil, chlorpyrifos, methomyl, metolachlor, and 2,4-D. In more than 5,000 samples, the investigators found no traces of five of the targeted pesticides: acetochlor, alachlor, carbaryl, carbofuran, and methomyl. The only pesticide detected in raw water above the level that EPA has set for finished drinking water was atrazine. In phase II of the study, the investigators will attempt to further isolate the sources of atrazine through intensive field monitoring during the spring. Water plants will also be evaluated as to the timing and best treatment options to reduce the potential for pesticides to pass through the water treatment process.

✓***Evaluation of Wastewater Biosolids Compost for Production of Agronomic and Horticultural Crops*** (50193) January 1, 1994, to December 31, 1997—Funded by the Charlotte-Mecklenburg Utility Department

■ Dr. James E. Shelton of North Carolina State University concludes his four-year project to identify and promote appropriate uses for compost made with wastewater "biosolids" by conducting demonstration and education activities for farmers, Cooperative Extension agents, and others.

✓ ***Manual for Best Managemetn Practices for Compost Utilitization*** (50227) March 1, 1997, to March 31, 1998—Funded by the Charlotte-Mecklenburg Utility District

■ Dr. James E. Shelton continues the effort to promote agricultural and horticultural use of composed biosolids by developing and producing a manual of use guidelines to be made available to producers through the Cooperative Extension Service and trade groups.

March and April of 1995. The concentration of Cryptosporidium oocysts per 100 liters was calculated using counts of "presumed" (that is, indicated by fluorescence) or confirmed oocysts in samples. However , because of all the uncertainties involved in detecting and measuring the parasite, a "detection limit" was calculated for each sample below which reported detection of the parasite should be considered unreliable. For all the samples except one, the reported concentrations were below the detection limits, meaning that the data available for this study allowed only an assessment of risk from source waters with Cryptosporidium concentrations below "detection limits."

Results of risk assessments for N.C. water supplies

Probabilistic risk assessments for N.C. source waters sampled indicated risk equal to or above EPA's recommended maximum annual risk of infection from potable waters of 1 case of infection in each 10,000 people. Since the most urgent concern about Cryptosporidium involves risk of illness in immune-compromised individuals, this project was designed to assess the risk of disease separately from the risk of infection. This assessment indicates that if infection can be equated to morbidity in immune-compromised individuals, then risk to these people may be as high as 1 in 10 on an annual basis.

In discussing the results of her analysis, Director notes that for the N.C. water supplies studied, the model predicts a "fairly significant background rate of Cryptosporidiosis in the healthy community." She notes that this prediction is consistent with epidemiological estimates.

Director says: "Although water utility and risk managers might be uncomfortable with the concept of a persistent background rate of disease associated with the consumption of treated waters, without sterilization or the installation of microfiltration systems, this phenomenon is likely

unavoidable. For most individuals, natural immunity prevents this background incidence from becoming anything greater than a potential nuisance. However, it will be important to consider the potential for community concern in the communication of such risks to the public."

Uncertainty and Risk Analysis in Water Quality Modeling (50213)
Dr. Kenneth H. Reckhow, WRRI
August 1, 1996, to December 31, 1997
Funded by the N.C. Urban Water Consortium

STUDENT INTERN/ SCHOLARSHIP PROGRAM

WRRI coordinates three student intern projects and a scholarship program.

The N.C. Office of Waste Reduction supports seven interns who assist the staff during on-site audits and prepare reports on pollution prevention methods employed by industries. All graduating interns in this project have joined government or industry in the pollution prevention sector.

The N.C. Division of Land Resources, Land Quality Section and the N.C. Sedimentation Control Commission support one intern who works directly with the staff education specialist and two scholarships for university students in curricula related to erosion and sediment control.

The U.S. Geological Survey supports seven interns who work directly with the USGS District research staff on water resources related projects ranging from a literature review of nutrient contamination sources to maintaining a stormwater and rain gauge network.

UPCOMING WORKSHOPS AND CONFERENCES

During 1997-98, WRRI will sponsor or cosponsor the following:

September 1997

■ **9/23-24/97 Erosion and Sediment Control Design Workshop** *WRRI and the N.C. Sedimentation Control Commission and the N.C. Land Quality Section*

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TECHNOLOGY TRANSFER

WRRI disseminates information and promotes adoption of new technology and practices through publication of newsletters and technical completion reports on its projects and through sponsorship and co-sponsorship of conferences, workshops and seminars. The Institute has also established a World Wide Web page and is currently working to expand this aspect of its information and technology dissemination.

WRRI reports are distributed to libraries, and summaries of reports are published in the WRRI newsletter and distributed to interested research faculty, other state water institutes, and relevant government agencies. Single copies of publications are available to North Carolina residents at a cost of $4 per copy prepaid ($6 per copy if billed) and to nonresidents at a cost of $8 per copy prepaid ($10 per copy if billed). Send requests to WRRI, Box 7912, North Carolina State University, Raleigh, NC 27695-7912 or call (919) 515-2815. An updated listing of all WRRI publications, including technical reports, is published periodically and may be obtained by calling the Institute office.

WRRI produces three newsletters. The ***WRRI NEWS*** is published every other month and sent to nearly 3200 federal and state agencies, university personnel, multi-county planning regions, city and local officials, environmental groups, consultants, businesses and individuals. The *NEWS* regularly covers a wide range of water-related topics from current federal and state legislation and regulatory activities to new research findings and listings of water-related publications. The *WRRI NEWS* is available free of charge to residents of North Carolina. To be added to the mailing list, call or write WRRI. Email subscriptions to the *WRRI NEWS* are also available to anyone with an Internet address. To subscribe, send an email message to: listserv@ncsu.edu. In the message say: subscribe WRRI-NEWS your full name.

The ***Urban Water Consortium News*** is published annually and distributed to members of the Urban Water Consortium who use the newsletter to keep their constituencies (city councils, county commissions, etc.) informed about the activities of the consortium and about water-related issues affecting municipalities. The newsletter carries descriptions of research funded through the consortium as well as news about water-related projects undertaken independently by members, and state and federal programs and legislation.

The Institute also produces a newsletter, ***Sediments,*** published by the N.C. Sedimentation Control Commission to provide information and assistance to the regulated community and to facilitate communication among personnel of state and local erosion and sediment control programs. This newsletter is free. To be added to the mailing list contact WRRI.

WRRI's World Wide Web homepage (http://www2.ncsu.edu/ncsu/CIL/WRRI) provides on-line access to the *WRRI News*; the WRRI Annual Program; a number of technical report summaries; the Water Resources Research Seminar Series schedule; information on workshops, conferences, calls for papers, and public hearings; and other items. Over the last year, additional report summaries and a directory of Water Resources Research Expertise in North Carolina universities were put on-line. Eventually, we expect to make full-text versions of technical completion reports and "discussion papers" related to water research topics available in postscript format and to establish a water resources research forum through our web page.

1997-98 Water Resources Research Seminar Series

Monday, October 20, 1997, Room 1132, Jordan Hall, NCSU Campus. "Geochemical Tracers of Ground-Water Movement between the Castle Hayne and Associated Coastal Plain Aquifers." *Assistant Professor Terri Woods, Department of Geology, East Carolina University*

Monday, November 17, 1997, Room 1132, Jordan Hall, NCSU Campus. "Atmospheric Emissions, Transport, Transformation and Deposition of Nitrogen compounds in the Neuse River Watershed." *Professor Viney Aneja, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University*

Monday, December 1, 1997, Ground Floor Hearing Room, Archdale Building, downtown Raleigh. "Optimization of Treatment to Mitigate Impacts of Algae Control on Finished Water Quality." *Assistant Professor Detlef Knappe, Department of Civil Engineering, North Carolina State University*

Tuesday, January 20, 1998, Room 1132, Jordan Hall, NCSU Campus. "History of Water Quality in North Carolina Estuarine Waters as Documented in the Stratigraphic Record." *Assistant Professor Sherri Cooper, Nicholas School of the Environment, Duke University.*

Tuesday, February 24, 1998, Ground Floor Hearing Room, Archdale Building, downtown Raleigh. "Biologically Mediated Nitrogen Dynamics in Eutrophying Estuaries." *Professor Hans Paerl, Institute of Marine Sciences, University of North Carolina at Chapel Hill.*

Tuesday, March 30, 1998, Room 1132, Jordan Hall, NCSU Campus. "Development of Methods of Estimating the Cost of Watershed Management Policies." *Professor David Moreau, Department of City and Regional Planning, University of North Carolina at Chapel Hill.*

Monday, April 20, 1998, Ground Floor Hearing Room, Archdale Building, downtown Raleigh. "Effectiveness of Four 'Best Management Practices' for Reducing Nonpoint Source Pollution from Piedmont Tobacco Fields." *Professor Carlyle Franklin, Department of Forestry, North Carolina State University.*

Tuesday, May 19, 1998, Room 1132, Jordan Hall, NCSU Campus. "Development of the Technical Basis and a Management Strategy for Reopening a Closed Shellfishing Area." *Associate Professor William Kirby-Smith, Nicholas School of the Environment, Duke University.*

WRRI Technical Committee

The Technical Committee, composed of university faculty, reviews and makes recommendations on research proposals and in other ways lends professional expertise to the Institute's programs.

Kenneth H. Reckhow, Director, Water Resources Research Institute (Chairman)
Michael D. Aitken, Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill
James D. Bowen, Department of Engineering Technology, University of North Carolina at Charlotte
Mark M. Brinson, Department of Biology, East Carolina University
Stephen W. Broome, Department of Soil Science, North Carolina State University
Lawrence B. Cahoon, Department of Biological Sciences, University of North Carolina at Wilmington
Shoou-Yuh Chang, Department of Civil Engineering, North Carolina A&T State University
Robert R. Christian, Department of Biology, East Carolina University
B.J. Copeland, Department of Zoology, Norht Carolina State University
William L. Hinze, Department of Chemistry, Wake Forest University
Robert E. Holman, Associate Director, Water Resources Research Institute
Gregory D. Jennings, Department of Biological and Agricultural Engineering, North Carolina State University
George J. Kriz, Associate Director, Agricultural Research Service, North Carolina State University
Sarah K. Liehr, Department of Civil Engineering, North Carolina State University
Miguel A. Medina, Department of Civil Engineering, Duke University
Francisco San Juan, Department of Geosciences, Elizabeth City State University
V. Kerry Smith, Department of Economics, Duke University

UPCOMING WORKSHOPS AND CONFERENCES

continued

■ **9/25-26/97 Stormwater Quality & Watershed Management: Keeping Pace** *WRRI and the N.C. Chapter of the American Water Works Association*

October 1997

■ **10/28-29/97 Erosion and Sediment Control Design Workshop** *WRRI and the N.C. Sedimentation Control Commission and the N.C. Land Quality Section*

December 1997

■ **12/8-9/97 Nutrients in the Neuse River: Working toward Solutions** *WRRI and the N.C. Cooperative Extension Service*

January 1998

■ **1/27-28/98 Erosion and Sediment Control Local Programs Workshop** *WRRI and the N.C. Sedimentation Control Commission and the N.C. Land Quality Section*

February 1998

■ **2/10-11/98 Advanced Training: Erosion and Sediment Control Design Workshop** *WRRI and the N.C. Sedimentation Control Commission and the N.C. Land Quality Section*

March 1998

■ **3/10-11/98 Beginning Training: Erosion and Sediment Control Design Workshop** *WRRI and the N.C. Sedimentation Control Commission and the N.C. Land Quality Section*

April 1998

■ **4/1/98 Water Resources Research in North Carolina Conference** *WRRI*