Water Resources Research Institute

of The University of North Carolina

ANNUAL PROGRAM

CURRENT RESEARCH JULY 1, 1996 TO JUNE 30, 1997

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.

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Project will provide scientific basis for determining risk to public health from animal waste

Recent outbreaks of waterborne illness across the United States have made it obvious that microbiological contamination of drinking and recreational waters is still a public health concern. *Cryptosporidium parvum* and *Giardia lamblia*, protozoa that are excreted in the waste of many animals and that persist for months in water, have been responsible for many outbreaks of gastrointestinal illness. These pathogens have been found to be widespread in surface waters and have even been found in groundwaters.

Cryptosporidium and Giardia, as well as other microorganisms that can sicken or kill humans, are found in high concentrations in the wastes of hogs, cattle, poultry and other commercial animals, suggesting that wastes from animal operations could pose a significant public health threat. However, the same organisms are also found in human waste and are highly resistant to treatment that rids wastewater effluent of other pathogens. Because little is known about the fate of Cryptosporidium and Giardia in the lagoon-land application animal waste management system, there is no basis for determining whether humans or animals are more responsible for their presence in waters or how big a threat animal waste operations pose to public health. In a project selected for funding under a U.S. Geological Survey regional competitive grants program, a UNC-Chapel Hill scientist has set out to provide the information for measuring that threat.

Dr. Mark D. Sobsey of the UNC-CH Department of Environmental Sciences and Engineering intends to characterize and quantify the relative contributions of agricultural and commercial animal fecal wastes and human sewage effluents to levels of Cryptosopridium and Giardia in surface and ground waters in North Carolina.

The investigator will sample raw, treated, and stored wastes from hog, cattle, and possibly poultry operations using conventional treatment practices to establish initial concentrations of the pathogens and determine the extent of reduction by treatment. He will sample land-applied wastes and surface and

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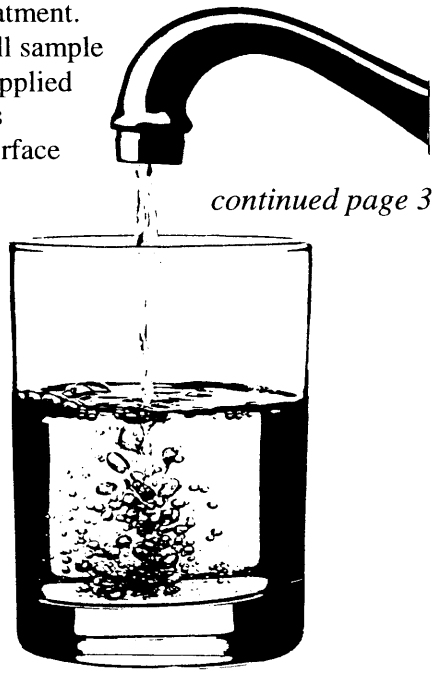

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The Advisory Committee of the Water Resources Research Institute is composed of representatives from state and federal programs, local government, industry, environmental organizations, private consultants, water and wastewater treatment plants, the 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 acute awareness of the need for better understanding of the effects of animal waste operations on water resources, the threat of microbial contamination of drinking water supplies, and natural attenuation of petroleum constituents in soils and groundwater as well as a continuing emphasis on developing information to support basinwide water quality management. Topics given highest priority by the Advisory Committee are:

❑ basinwide transport of sediment, nutrients, and fecal coliform

❑ basinwide nonpoint source management and effects from watershed modifications

❑ land use and nonpoint sources in water supply watersheds (including modeling)

❑ evaluation of nonpoint source management policies

❑ design criteria for riparian buffers

❑ risks of cryptosporidium, viruses and disinfection by-products in N.C. drinking water supplies

❑ effectiveness of agricultural best management practices

❑ water reuse and conservation

❑ risk assessment and cost of remediation

❑ wetland protection policies including mitigation methods

ground waters near sites where waste is applied to determine how well the pathogens survive under land application conditions and to determine if they move offsite into surface and groundwater. To learn more about survival rates of the parasites, he will also conduct laboratory experiments using waste samples seeded with the pathogens.

He will also sample treated wastes from demonstration constructed wetland and overland flow waste treatment systems to determine how well these proposed treatment technologies reduce pathogens.

Sobsey expects the results of his work 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.

In addition, Sobsey will work toward identifying a group of microbes and/or biochemicals whose presence in water will indicate contamination by Cryptosporidium and Giardia. Sampling for the parasites themselves is very expensive and time-consuming, but a quick, inexpensive indicator system would allow public officials to monitor drinking water sources and other waters and implement source control measures when contamination poses a risk to public health.

The scientist also expects to identify indicators that will permit differentiation between human and animal sources of fecal inputs to water sources.

Microbial Impacts of Animal Wastes on Water Resources (70152)
Dr. Mark D. Sobsey, University of North Carolina at Chapel Hill
June 15, 1996, to August 31, 1997
Funded by WRRI and the U.S. Geological Survey

UNC-CH scientist will develop system to help N.C. water suppliers assess relative health risks from disinfection by-products and microbial contamination

Statewide and nationwide, those responsible for the safety of public drinking water face a challenge of unprecedented complexity. Few if any drinking water supply sources in the United States are free from microbial contamination; therefore, disinfection and often filtration are necessary to get rid of microbes that can cause waterborne disease. At the same time, most water sources contain natural organic matter that produces several classes of compounds linked to cancer when treated with common cholorine disinfectants.

In an effort to protect consumers from potentially carcinogenic compounds in drinking water, the U.S. Environmental Protection Agency has proposed a rule that would require water systems to control levels of disinfection by-products (DBPs) in finished drinking water. The rule will affect most major water systems in North Carolina and could require changes in treatment practices, including use of alternative disinfectants that may not be as effective in controlling microbial contamination. However, EPA's proposed regulation of DBPs is controversial, because the health risk of DBPs is not as well established as the health risk from bacteria, viruses, and parasites such as Cryptosporidium and Giardia.

To produce the safest drinking water, water suppliers need to have the flexibility to select a treatment scheme for their specific source water that minimizes the total health risk by balancing the risk from microbial contamination against the risk from disinfection by-products. To do this, they need answers to the following questions:

Given my water source, if I select a specific treatment technology, what will be the level of DBP formation and what is the associated cancer risk? Are there other health risks associated with DBPs? How will the technology selected affect the risk of microbial contamination and what will be the associated health effects?

Currently, answers to those questions are uncertain. Lack of full knowledge about the quality of water sources, effects of treatment alternatives on finished water, the relationship between DBPs and cancer, the virulence of various microbial contaminants, and how microbial contaminants actually reach consumers' taps makes it impossible to answer any of the questions with certainty. Furthermore, answers to the questions will be based on assumptions about the unknowns—assumptions about which scientists, regulators, water suppliers, and consumers may disagree. Therefore, in order to make decisions about local water treatment, water suppliers also need information about the reliability (or the degree of uncertainty) of the answers they get to questions about risk and about assumptions that went into producing the answers.

To give water suppliers in North Carolina the help they need in dealing with uncertainty about water treatment methods, Douglas Crawford-Brown of the UNC-CH Department of Environmental Sciences and Engineering will direct PhD student Shannon Marquez in development of an Environmental Decision Support System (EDSS) for making risk-based decisions on drinking water treatment. The EDSS will be a fully interactive computer-based system and will incorporate data on the quality of water supplies and water treatment technologies used in North Carolina and health effects into a rigorous risk assessment methodology. Importantly, the EDSS will allow water suppliers to select alternative assumptions to be used for assessing risk related to treatment options and to see how the assumptions affect the degree of confidence that can be placed in the assessment. The system will also help WRRI and state agencies make decisions about research funding by identifying critical areas of uncertainty related to drinking water treatment.

A Decision Support System for Microbial and Disinfection By-Product Risk Analysis in North Carolina Water Supplies (70150)
Douglas J. Crawford-Brown, University of North Carolina at Chapel Hill
September 1, 1996, to August 31, 1997
Funded by WRRI

Project will help N.C. water systems out of regulatory dilemma

The U.S. Environmental Protection Agency has proposed a rule establishing maximum contaminant levels (MCLs) for two classes of disinfection by-products (DBPs) in drinking water, and the recently passed Safe Drinking Water Act reauthorization requires that EPA adhere to its schedule for finalizing this rule. Under the proposed rule, drinking water systems will have to assure that total trihalomethanes (THMs) in finished drinking water do not exceed 80 micrograms per liter (µg/l) and that total haloacetic acids (HAAs) do not exceed 60 µg/l.

Both THMs and HAAs are produced when water containing significant amounts of natural organic matter (NOM) is disinfected with chlorine, and species of both classes of DBPs have been identified as potential carcinogens. Nationwide, THMs have been found to be the predominant class of DBPs in drinking water. However, Dr. Philip Singer of the UNC-Chapel Hill Department of Environmental Sciences and Engineering found that HAA concentrations are greater in a number of Piedmont North Carolina water systems he has studied. If findings of Singer's previous studies extend to other water systems in North Carolina and the Southeast, utilities that meet the MCL for THMs will likely exceed the proposed MCL for HAAs unless they are able to adjust treatment methods.

One of the reasons for high HAA concentrations in N.C. drinking waters is the relatively low pH at which chlorination is practiced (6.0 - 6.5). In an effort to remove the organic matter that forms DBPs before chlorinating water, many utilities in North Carolina treat waters at slightly acidic pH values. Maintaining this lower pH achieves optimum coagulation of NOM, but it also encourages the formation of HAAs when the coagulated water is chlorinated at the same pH.

In his new project, Singer is looking for ways to help water utilities in North Carolina and the Southeast out of this treatment dilemma. He will explore the possibility that elevating the pH of coagulated and settled water prior to the application of chlorine can control HAA formation without significantly increasing THM formation or lowering the disinfection effectiveness of chlorine to unacceptable levels. He will also explore the usefulness of chloramination for controlling THM and HAA production.

Adding ammonia to chlorinated water produces monochloramine, which does not react with NOM to produce THMs. However, monochloramine will react with residual NOM to produce some HAAs, although to a lesser extent than free chlorine.

To evaluate pH adjustment, Singer will collect settled water samples from a number of treatment plants, chlorinate them under several pH conditions and measure the extent of HAA and THM production. He will also measure HAAs and THMs in parallel samples collected from the distribution systems of the same plants. By comparing the HAA/THM ratios of the two sets of samples, he will determine what could be expected if pH is adjusted in the plants prior to application of free chlorine.

To evaluate chloramination as an HAA control strategy, he will take samples from points before and after ammonia addition at several treatment plants using chloramination and determine the impact of chloramination on HAA and THM formation. He will also simulate chloramination in the laboratory for several water plants currently using only free chlorine and determine HAA and THM formation.

Singer expects the results of his research to provide guidelines to help water systems in North Carolina and elsewhere in the Southeast to comply with MCLs for both HAAs and THMs without compromising the effectiveness of disinfection.

Control of Haloacetic Acid Formation in North Carolina Drinking Water (70155)
Dr. Philip C. Singer
University of North Carolina
at Chapel Hill
June 15, 1996, to August 31, 1997
Funded by WRRI and the U.S. Geological Survey

Reauthorization of Water Resources Research Act of 1984

In May, Congress passed and President Clinton signed H.R. 1743, which reauthorized appropriations for state water resources research institutes through FY 2000. The law authorizes general appropriations for the 54 state institutes at the level of $5 million for 1996, $7 million for 1997 and 1998 and $9 million for 1999 and 2000. In addition, it authorizes $3 million each year from 1996 through 2000 for research on "water problems of interstate nature," and provides that in grants made under the act, non-federal funds must match federal grants on at least a two-to-one basis (was previously one-to-one).

Regional Competition

Funds appropriated for the "Section 104(g)" research grants for federal fiscal year 1996 were distributed through a program of regional competition, with teams of investigators composed of researchers from North Carolina and other states, collaborating on projects of regional interest.

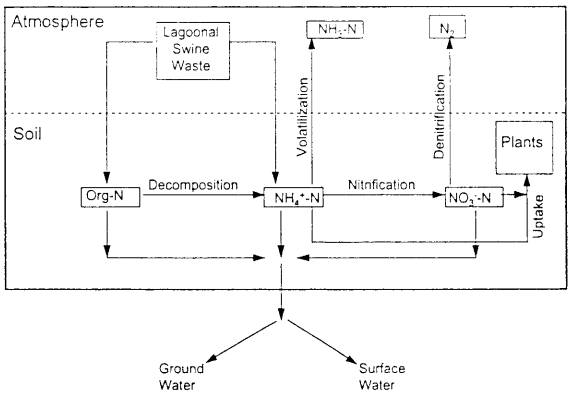
Four projects involving North Carolina researchers won Section 104(g) funding in this regional competition. Wendell Gilliam of NCSU and Michael Whalen of UNC-CH collaborated with researchers from Mississippi and Arkansas to submit a proposal for studying various aspects of the animal waste disposal problem. Mark Sobsey of UNC-CH collaborated with a Kentucky scientist on a project investigating the possible human health effects of animal waste. Philip Singer and Francis DiGiano of UNC-CH collaborated on a project aimed at helping water systems comply with requirements of the Information Collection Rule. And Michael Aitken of UNC-CH and Robert Borden and Morton Barlaz of NCSU collaborated on a proposal to study various aspects of bioremediation of soil and groundwater contaminated by hydrocarbons.

UNC-Chapel Hill scientist will look for management practices that promote conversion of nitrogen compounds in animal waste to benign nitrogen gas

As the swine industry continues to expand in North Carolina, questions have arisen about the ability of current animal waste management practices to protect surface waters from pollution by nitrogen from increasing volumes of swine waste. Because of these concerns, the State of North Carolina is funding research that could identify economically feasible alternative animal waste management technologies. Meanwhile, however, Dr. Stephen Whalen, assistant professor in the UNC-Chapel Hill Department of Environmental Sciences and Engineering, thinks that the traditional lagoon-land application system could be made more effective in preventing nitrogen pollution of streams and rivers. His current research is aimed at identifying best management practices that will promote the conversion of complex nitrogen compounds in swine waste to benign dinitrogen gas.

In 1995, some 7.5 million pigs and 9.5 million tons of pig waste were produced in North Carolina. The N.C. Agricultural Research Service has predicted that 15 million pigs will be produced here in 1996, increasing swine waste production proportionally. The most common method of disposing of swine waste involves storing it in a lagoon, where it undergoes some microbiological breakdown, then spraying the liquid lagoon effluent onto land as fertilizer for crops. Estimates are that swine lagoons and fields where waste are applied currently cover nearly 250,000 acres in the N.C. Coastal Plain, all draining eventually to coastal rivers.

Swine waste contains substantial amounts of nitrogen, a nutrient known to contribute to water quality problems in coastal rivers and estuaries. A large part of the nitrogen in swine waste may be removed during storage in lagoons, primarily by microbial breakdown of organic nitrogen compounds to ammonium (NH_4) and subsequent volatilization of ammonia (NH_3) and inert dinitrogen gas (N_2) to the atmosphere. Nitrogen that remains in lagoon effluent sprayed onto crops may be converted to several different inorganic nitrogen compounds and may volatilize as ammonia or N_2, be immobilized in the soil as ammonium, be taken up by plants as ammonium and nitrate, or leave the site in surface runoff or shallow ground water discharge, predominantely as nitrate.



Fate of nitrogen applied to agricultural crops as lagoonal swine waste

North Carolina's strategy for reducing nitrogen pollution from animal waste operations is based on maximizing the amount of nitrogen taken up by crops. Regulations require that swine lagoon effluent be applied at times and rates that meet but do not exceed plants' nutritional needs. However, since crops are inefficient at using fertilizer, assimilating at most 40 percent of the nitrogen applied in lagoon effluent, significant amounts of applied nitrogen will remain unassimilated by crops and available for export in runoff or groundwater discharge.

It is this remaining unassimilated nitrogen that is the focus of Stephen Whalen's research. Whalen believes that best management practices can be developed to promote denitrification, which breaks down unassimilated nitrate from swine waste into dinitrogen gas that will then volatilize. He thinks that such BMPs could be a critical component of systems to prevent nitrogen from animal waste operations from getting into streams and estuaries.

How extensively and how well microbes in soils can convert complex forms of nitrogen into dinitrogen gas depends on a number of factors, principally the amount of oxygen and carbon in the soil. Previous studies have suggested that the potential for denitrification is greater in clay soils than in sandy soils; for summer than for winter crops; when small volumes of effluent are applied frequently than when large volumes are applied infrequently; and when cattle graze on fields and compact soils.

To test these and other hypotheses about how management practices influence denitrification, Whalen will conduct studies at a site comprising 30 swine production operations under contract with Carroll's Foods Inc. near Warsaw in Duplin and Sampson counties. On fields that represent eight combinations of soil texture, host crop, and fertilization frequency as well as the effects of grazing, he will measure the rate at which nitrogen compounds are being mineralized to nitrate as well as microbial activity that is indicative of ongoing denitrification. He will also conduct experiments to determine the potential overall nitrification rate of the soil and the potential for denitrifing activity at representative sites during other seasonal conditions (including different fertilization schedules and fallow conditions). Analysis of observational and experimental data will allow Whalen to determine which management combinations result in the highest rates of denitrification. He will then be able to make recommendations for best management practices that will both meet the nutritional requirements of crops and promote denitrification.

Effect of Managment Practices on Denitrification in Soils Fertilized with Lagoonal Swine Waste (70151)
Dr. Stephen C. Whalen
University of North Carolina
at Chapel Hill
June 15, 1996, to August 31, 1997
Funded by WRRI and the U. S. Geological Survey

UNC-Wilmington scientists will investigate effects of animal waste on blackwater rivers

Blackwater rivers, which are extensive in coastal North Carolina, have water chemistry dominated by inputs of dissolved organic materials from surrounding wetlands. As a result, they behave differently than clearwater streams. Because of organic concentrations, light limitation and other physical factors unique to blackwater rivers, bacteria, protozoa, and algal species that utilize organic materials are abundant, and algae that depend on sun light and inorganic nitrogen are usually low in these waters.

However, during the summer of 1995, UNC-Wilmington scientist Dr. Michael Mallin documented massive blooms of photosynthetic algae in blackwater streams flooded with animal wastes from failed lagoons. During the same period, a blackwater stream designated Outstanding Resource Waters, was the site of a large fish kill caused by BOD (biological oxygen demand) loading of undetermined origin. It is possible that the BOD loading might have come from an increase in biomass of microbial species stimulated by inputs of organic nutrients.

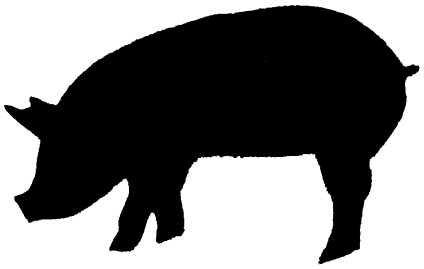
Although much research has been done in clearwater streams, little is known about the way biological communities in blackwater streams react to high inputs of organic and inorganic forms of nitrogen and phosphorus. Since the highest concentrations of nutrient-producing swine operations are in counties draining into blackwater tributaries of the Cape Fear Basin, information is needed about the potential effects of waste spills and runoff and groundwater discharge from land application sites on the biota of blackwater streams.

To provide this information, Mallin and co-investigator Lawrence Cahoon will conduct studies on the Black River and the Northeast Cape Fear River.

To determine the effect that constituents of swine waste have on photosynthetic algae, the scientists will conduct bioassay experiments. They will add ammonia, orthophosphate, and organic nitrogen and phosphorous at concentrations typical of lagoon spills and runoff to replicated river water samples and measure resulting chlorophyll *a* production. To assess the impact of swine waste on the non-photosynthetic community (bacteria, heterotrophic algae, rotifers, and protozoa), they will include ATP analysis in their bioassay experiments. ATP (adenosine triphosphate) is a compound found in all living organisms and is thus a good measure of non-photosynthetic as well as photosynthetic biomass.

The researchers expect to determine which nutrients and which forms of nutrients are most important to biological communities in blackwater streams and how seasons and background parameters affect biotic responses. Such knowledge has been important to water quality improvement efforts in clearwater systems and could be equally useful for blackwater systems.

Effect of Swine Waste Lagoon Constituents on Photosynthetic and Heterotrophic Biota of Receiving Waters (70156)
Drs. Michael A. Mallin and Lawrence B. Cahoon, University of North Carolina at Wilmington
June 1, 1996, to June 30, 1997
Funded by WRRI and the Cape Fear River Program



Isotope study is aimed at measuring increase in nitrogen loading to Neuse from animal operations

The stable isotopes of the element nitrogen have atomic weights of 14 and 15. All nitrogen compounds contain both the isotopes, but because of the different reaction rates of the heavy and light isotopes, they are incorporated into compounds in differing ratios depending on the pathways by which the compounds are produced. For instance, the process used to fix atmospheric nitrogen into commercial fertilizer has little isotopic fractionation and the resulting ammonium and nitrate are similar in isotopic composition to atmospheric nitrogen. However, as nitrogen compounds are passed up the food chain, the lighter isotopes are excreted and the heavier isotopes are retained. When nitrogen in urea (as in excreted waste) is hydrolyzed to ammonia and then converted to nitrate, more of the heavy isotope is concentrated in the resulting nitrates.

Each type of nitrogen source (wastewater discharge, crop field runoff, animal production facilities) has a narrow range of isotopic ratios that can be used to identify the process that created it. Nitrate from animal waste lagoons is the heaviest nitrogen source observed. When various sources of nitrogen compounds are mixed together in surface runoff or in a waterbody, the ratio of light to heavy nitrogen isotopes in the water can be used to gauge the relative contributions of the various sources—if the isotopic "signature" of all the sources is known and if the bio-chemical processing (such as nitrification) that goes on within the waterbody can be accounted for.

Nearly ten years ago, William J. Showers of the NCSU Marine, Earth, and Atmospheric Sciences Department. conducted a WRRI-sponsored isotope study of agricultural and wastewater sources of nitrates to the Neuse River. Showers determined the isotopic signature of wastewater from the Raleigh and Durham treatment plants (which has a higher proportion of the heavy isotope) and of drainage from two agricultural areas. During the period 1986-1988, he monitored the isotopic composition of nitrate in the Neuse River at a location just upstream from New Bern. Showers' monitoring showed that in the summer, when wastewater discharge accounts for a significant portion of the river's flow at New Bern, the isotopic composition of

continued

nitrate in the river reflected that of wastewater and that in the spring, when river flow is higher from runoff, the nitrate isotopic composition reflected that of commercial fertilizer. This and other studies have established stable isotope science as a tool for identifying sources of nitrogen.

In a new study, Showers will apply isotope science to measure the impact of a potential new source of nitrates to the Neuse—animal waste. Results of recent sampling of swine lagoons in the Neuse and Tar river basins confirm that lagoon nitrogen is significantly richer in the heavy isotope than wastewater discharge. This sampling plus the results of Showers' original study suggest that isotopic characterization of different classes of nitrogen sources to the Neuse River Basin will allow construction of mass balance equations using hydrological models and land use information to determine what proportion of nitrate loading to the Neuse comes from point sources and nonpoint sources, including animal waste, during any specific time of the year.

Information that the investigator gathered ten years ago will also provide a basis for comparing current seasonal isotopic composition of nitrates in the Neuse to those observed before animal production in the river basin exploded. This will increase the chances of assessing the water quality impacts from animal operations.

Stable Nitrogen Isotopic Tracers ($\delta^{15}N$) of Nitrogen Sources to Surface and Groundwaters near Animal Production Facilities
William J. Showers
North Carolina State University
August 15, 1996, to August 14, 1997
Funded by N.C.Pork Producers; N.C. Department of Environment, Health, and Natural Resources, Division of Marine Fisheries; and WRRI

NCSU scientist will assess contribution of animal operations to atmospheric nitrogen (ammonia) loadings

Over the last few years, it has become evident that nutrient over-enrichment of North Carolina's coastal rivers and estuaries is caused not just by wastewater discharges and nonpoint source runoff but may also be caused by atmospheric inputs—ammonia and other nitrogen compounds deposited directly into waters by rain and nitrogen compounds deposited onto dry surfaces and washed into streams by subsequent rains. The sources of atmospheric nitrogen compounds are many, but any management plan aimed at reducing nitrogen in coastal waters must include an accurate inventory of sources as well as estimates of the contribution of each source.

It has recently been suggested that an important source of atmospheric ammonia is large-scale swine and poultry operations concentrated in the N.C. Coastal Plain. While it is known that ammonia volatilizes into the atmosphere from swine waste lagoons, poultry litter storage facilities, animal houses, and fields where waste has been applied, in the United States little research has been directed at fully characterizing and quantifying nitrogen (ammonia) emissions from these animal production facilities.

In this project, Dr. Viney P. Aneja of the NCSU Department of Marine, Earth and Atmospheric Sciences will assist the N.C. Department of Environment, Health, and Natural Resources (DEHNR) and begin the process of describing all the paths of nitrogen (ammonia) volatilization, transport, transformation, and deposition at various kinds of swine and poultry operations and estimating the magnitude and frequency of loadings from these sources. He will coordinate his research with other related research funded by DEHNR.

The full project is expected to continue for three years and is aimed at

- measuring daily and seasonal fluxes of ammonia from lagoons, animal houses and waste-treated fields and developing parameters for determining atmospheric loadings based on operational characteristics and production patterns for various kinds of facilities;

- developing a Geographic Information System-based inventory of ammonia sources;

- developing a deposition map based on animal production patterns;

- and evaluating the relative importance of atmospheric deposition of ammonia to the affected watersheds in North Carolina.

Because of the urgent need for information about the contributions of animal operations to atmospheric nitrogen loadings, the investigator will devote the first year of the project to a pilot study focusing on understanding where and how emissions occur at a "typical" swine operation and testing emissions measurement technologies. Following several months of technology assessment and data collection, the investigators will hold workshops to inform other scientists and regulatory personnel about recommended methods for assessing ammonia emissions at individual animal operations.

Following the pilot study, Dr. Aneja will participate in a season of intense sampling at private cooperator swine and poultry production facilities as well as data analysis, construction of a GIS-based inventory, and development of deposition maps based on model projections.

Characterization of Ammonia Emissions from Animal and Poultry Operations in North Carolina (50214)
Dr. Viney P. Aneja
North Carolina State University
July 1, 1996, to June 30, 1999
Funded by Division of Air Quality, N.C. Department of Environment, Health, and Natural Resources and WRRI

Research continues on effectiveness of riparian buffers

The N.C. Division of Water Quality has proposed requirements for riparian buffers along streams to help filter pollutants out of runoff in the nutrient-sensitive Neuse River watershed. The USDA Natural Resources Conservation Service and the U.S. Environmental Protection Agency also promote use of riparian buffers, especially along fields where animal waste is applied. And the Blue Ribbon Study Commission on Agricultural Waste endorsed use of riparian buffers as a method of treating animal waste in runoff. However, while legislators and regulatory and technical assistance agencies seem convinced that riparian buffers are useful, no one is ready to issue guidelines to tell landowners how wide buffers should be or what vegetation they should use. The Neuse River Nutrient Management Strategy proposes establishment of a panel to decide upon appropriate buffer requirements on a site-by-site basis, and the report of the Commission on Agricultural Waste calls for a board of interagency experts to decide whether buffer standards should be uniform statewide or basinwide or should be applied on a site specific basis.

Uncertainty about buffer design stems from lack of data about their performance under a variety of conditions. While research has shown that buffers can be effective in removing pollutants, research has also shown that buffer effectiveness in removing nutrients from runoff depends upon a number of factors. Further, there is no information about how well buffers remove bacteria from animal waste runoff.

In a project begun last year, Dr. J. Wendell Gilliam of North Carolina State University is conducting research to help agencies decide how to design riparian buffers for pollutant control. Utilizing an existing, well-instrumented research facility, Gilliam is gathering 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.

Gilliam and co-investigators Drs. J.E. Parsons and R.L. Mikkelsen are in their fourth year of data collection at Piedmont and Coastal Plain experimental sites where no animal waste has been applied and in the second year of data collection from sites where poultry waste has been incorporated as crop fertilizer. They will compare the effectiveness of buffers in cleaning up runoff from the waste-treated fields with their performance in previous research. The investigators' measurements of nutrient and bacterial removal will help establish buffer effectiveness and will be used to test predictions made by models intended for designing buffers.

Grass and Riparian Buffer Treatment of Runoff from Land Receiving Animal Waste (70146)
Drs. J.W. Gilliam, J.R. Parsons, and R.L. Mikkelsen
North Carolina State University
July 1, 1995, to August 31, 1997
Funded by WRRI and the U.S. Geological Survey

NCSU scientist investigates biodegradation of benzene from leaking underground storage tanks

In 1995, the N.C. Environmental Management Commission adopted a temporary rule requiring owners or operators of leaking underground storage tanks (USTs) seeking reimbursement from the state's Underground Storage Tank Trust Fund to submit corrective action plans based on "natural processes of degradation and attenuation of contaminants" unless risk assessments show that the leaks pose a threat to human health or the environment. In the 1996 Short Session, the N.C. General Assembly adopted legislation prohibiting the Department of Environment, Health and Natural Resources from requiring remediation beyond mitigation of imminent danger at sites not shown to pose threats and directed the EMC to develop guidelines for assessing risk from leaking USTs. Use of this approach is based on the assumption that natural processes will clean up many petroleum leaks with little or no human intervention. To implement the requirements of the law, regulatory agencies need sound information on biodegradation of petroleum constituents in soils.

Numerous studies have confirmed that some constituents of petroleum—specifically toluene, ethylbenzene and xylene—are degraded by anaerobic processes once oxygen is depleted from the plume, as it inevitably is. However, there has been no conclusive demonstration that benzene, the most toxic constituent of petroleum spills, is degraded under ambient anaerobic conditions. In a recently completed study for EPA, Dr. Morton Barlaz did show degradation of all benzene, toluene, ethylbenzene and xylene in a petroleum contaminated aquifer in North Carolina. However, there was an extensive lag time (5 to 6 months) before benzene degraded, and the study did not reveal what influences the rate of benzene degradation. Knowing what influences benzene degradation and being able to predict how quickly it will degrade is critical for regulatory agencies implementing requirements of risk-based corrective action plans under North Carolina's new approach to dealing with leaking USTs.

In this project building on his previous work, Barlaz will confirm his finding of anaerobic benzene degradation and develop a better understanding of how and at what rate benzene biodegrades in the subsurface. The study will utilize replicate anaerobic microcosms using groundwater and soil from a petroleum-contaminated aquifer and radiolabeled benzene. By using three treatments and monitoring changes in benzene, total organic carbon, and production of $^{14}CO_2$, the investigator will explore the possibility that benzene is mineralized and that mineralization is influenced by the initial benzene concentration and the possibility that the observed lag time in benzene degradation

continued

Protozoan grazing to be investigated as an important control on rate of biodegradation of hydrocarbon contaminants

Microbes are present in most shallow aquifers and can degrade contaminants released from petroleum underground storage tanks. However, the major factors controlling the rate and extent of biodegradation are still poorly understood. Rates of biodegradation in laboratory experiments do not match field biodegradation rates. Therefore, it is not possible to predict the extent of contaminant migration and assess the risk associated with a particular plume.

Preliminary research by Dr. Robert Borden of the NCSU Civil Engineering Department suggests that protozoa in soil may be controlling biodegradation rates by consuming microbes that degrade hydrocarbon constituents, and that microcosms used in previous studies may have been too small to reflect the effect of protozoan population increases on bacterial populations and subsequent biodegradation rates.

In a new project, Borden will test this hypothesis using soil from a gasoline contaminated site near Rocky Point, NC. Previous studies at this site have shown that benzene, toluene, ethylbenzene, and xylenes are being anaerobically degraded with iron as the major electron acceptor. This site has already been studied extensively, and the resulting database provides a unique opportunity to compare the results of current experiments to those from earlier laboratory results.

In macrocosm experiments, Borden will add toluene and monitor changes in toluene concentration and bacterial and protozoan populations. If his hypothesis is correct, as toluene is degraded, monitoring data will show first an increase in the population of iron-reducing bacteria. Then, as a food source becomes available, the protozoan population will increase, the bacterial population will decrease, and toluene degradation will slow.

In a second set of experiments, Borden will compare toluene degradation rates and bacterial and protozoa populations in macrocosms with and without a protozoan inhibitor.

Results of these experiments should provide data to demonstrate whether the presence and activity of protozoa are a significant factor in the biodegradation rate in the Rocky Point soil. They should also allow Borden to measure degradation rates per unit mass of bacteria, which will allow development of models representing large-scale intrinsic bioremediation sites.

Influence of Protozoan Grazing on Intrinsic Bioremediation under Anaerobic Conditions (70153)
Dr. Robert C. Borden, North Carolina State University
July 1, 1996, to June 30, 1997
Funded by WRRI and the U.S. Geological Survey

Benzene biodegradation is caused by a low initial population of microbial benzene degraders.

Anaerobic Biodegradation of Benzene in Contaminated Aquifer Sediment (70154)
Dr. Morton A. Barlaz
North Carolina State University
July 1, 1996, to June 30, 1997
Funded by WRRI and the U.S. Geological Survey

UNC scientist continues study of bioremediation of manufactured gas tars

Across the United States, there are estimated to be between 1,500 and 3,000 former manufactured gas plant (MGP) sites contaminated with tars derived from coal and oil. More than 30 of these sites have been discovered in North Carolina. Pollutants of most concern include polycyclic aromatic hydrocarbons (PAH), some of which are known to be carcinogenic. Water that comes into contact with these compounds can become toxic; therefore, MGP sites pose a threat to both surface and groundwater quality.

While some PAH in contaminated soils can be degraded into harmless compounds by bacteria, high molecular weight PAH do not yield easily to bioremediation and are not entirely removed by the process. Therefore, what might be a low-cost cleanup method for MGP sites may not satisfy cleanup standards because of the carcinogenic PAH left behind.

In a project building on ongoing research, Dr. Michael Aitken of the University of North Carolina at Chapel Hill is exploring methods to enhance the biodegradation of high molecular weight PAH. It is his hypothesis that treating contaminated soil with a surfactant to loosen PAH from soil and a supplemental substrate to enhance the growth of degrading bacteria will result in biodegradation of PAH to levels that pose no threat.

To test his hypothesis, Aitken is experimenting with bench-scale, slurry-phase biological treatment of contaminated soil from a manufactured gas plant site. Slurry phase bioremediation involves the addition of excavated soil to water in a bioreactor, which is supplemented with inorganic nutrients.

Having confirmed that indigenous PAH degrading microorganisms are at work in the contaminated soil, Aitken is operating a bench-scale reactor with a 15-day residence time. He is conducting batch tests using treated soil from the reactor to test the degrading effect of a surfactant alone, the surfactant in conjunction with a supplemental growth substrate, and the growth substrate alone. Based on results from the batch tests, he will then operate the bioreactor with one or both of the supplements to test the removal of PAH over an extended time.

By monitoring PAH and surfactant biodegradation during slurry-phase treatment, Aitken intends to demonstrate a way to accomplish acceptable levels of PAH degradation and determine the amount of surfactant needed per unit of treated soil.

Slurry Phase Bioremediation of Contaminated Soil from a Former Manufactured Gas Plant Site (70144)
Dr. Michael D. Aitken, University of North Carolina at Chapel Hill
July 1, 1995, to June 30, 1997
Funded by WRRI and the U.S. Geological Survey

Project at Duke Marine Lab will develop strategy for reopening shellfish areas

In a project that holds promise for immediate results and long-term benefits, Dr. William W. Kirby-Smith of the Duke Marine Laboratory and Jim Reilly, a graduate student in Duke University's Master of Environmental Management program, are designing a plan to reopen a closed shellfish area in Carteret County. Kirby-Smith says that the project may produce a management plan that can serve as a model for reducing fecal coliform contamination and allowing the reopening of other closed shellfish areas in North Carolina's estuaries.

Public health officials use fecal coliform bacteria as an indicator of the potential presence of intestinal pathogens from fecal contamination by warm blooded animals. When fecal coliform counts are found to exceed an average of 14 colonies per 100 milliliters of water above a shellfish area, health officials declare the area closed to shellfishing. Fecal coliform bacteria enter coastal waters from many nonpoint sources—urban runoff, runoff from animal operations and agricultural fields, septic tanks, and even runoff from forestry operations and relatively undisturbed natural areas. However, according to Kirby-Smith, because fecal coliform die off before they can travel long distances, the sources responsible for contamination of a specific shellfish area are local. Therefore, he says, it should be possible to reopen specific small shellfish areas by reducing fecal coliform contributions from a relatively few local sources. He says that, just as closure of large shellfish areas has resulted incrementally as many small areas have been closed because of local contamination, the best way to reopen large shellfish areas is incrementally—small site by small site, focusing on local site-specific factors.

Following discussions with representatives of N.C. Shellfish Sanitation, the Division of Coastal Management, the Division of Marine Fisheries and the Division of Water Quality, the researchers selected a small creek located off North River in Carteret County as the target for the studies. Cowpen Creek is closed to shellfishing but has several shellfishing leases at its mouth. Adjacent areas in the North River are open to shellfishing. To understand the closure of this site, Kirby-Smith and Reilly are doing scientific detective work. They began by preparing a GIS map of the watershed and the land uses in the watershed draining to the shellfish area. To verify locations of streams and ditches on the map, they will consult with landowners and walk the shoreline. They will then use the map to locate sampling sites needed to describe the geographical distribution of fecal coliform throughout the drainage area.

When the investigators are able to analyze sampling data along with information from their map on geographical features and land use, they will be able to identify sources of fecal coliform bacteria in the watershed and determine which sources contribute most heavily to contamination of water overlying the shellfish area. They will then decide the relative importance of all the sources of fecal coliform, based, not only on loading but also on how amenable each source is to reduction. With all this information in hand, they can then describe all the options for reducing fecal coliform contamination enough to allow reopening of the shellfish site.

At this point Dr. Michael Orbach, Professor of Marine Affairs and Policy, will work with Reilly to identify the management option most likely to work, given all the political, social, economic and legal constraints related to the site. Part of developing the management plan will be identifying possible sources of technical and financial aid for landowners and local governments that may be involved in implementing land use changes called for by the plan.

The project will result not only in a plan for reopening a specific shellfish site but also in a model approach for addressing current and future shellfish closures on a case-by-case basis.

Development of the Technical Basis and a Management Strategy for Reopening a Closed Shellfishing Area (70149)
Dr. William W. Kirby-Smith
Duke University
June 1, 1996, to June 30, 1997
Funded by WRRI

East Carolina scientist will study leakage among Coastal Plain aquifers

In a previous study of the Castle Hayne aquifer, East Carolina geoscientist Dr. Terri Woods found concentrations of substances that could not be attributed to natural sources within the aquifer. The finding suggested that leakage into the Castle Hayne from underlying and overlying aquifer units may be occurring. The Castle Hayne aquifer is an important source of water to municipalities, agriculture, and aquaculture in the Central N.C. Coastal Plain. Serious water-level declines have been documented in areas of the Castle Hayne and Cretaceous aquifers of the Coastal Plain, and growth in the area is expected to increase demand for water from these sources.

Managing the use of water from the Castle Hayne requires a better understanding of the chemistry and geochemistry of associated units and the transfer of groundwater between or among them. Such information is needed to effectively locate wells, determine appropriate pumping rates and potential effects of overpumping, and assess the impact of groundwater withdrawals on surface water and vice versa.

In her current WRRI project, Woods will expand her previous investigation of the chemical and strontium isotopic characteristics of groundwater in the Castle Hayne aquifer to include the associated Yorktown and Peedee aquifers. By determining the chemical and strontium isotopic signatures of the groundwaters 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. The results of the project will provide baseline data for scientific and regulatory agencies and information to aid municipalities and others using water from the important aquifers of Coastal North Carolina.

Geochemical Tracers of Groundwater Movement between the Castle Hayne and Associated Coastal Plain Aquifers (70148)
Dr. Terri L. Woods
East Carolina University
June 1, 1996, to June 30, 1997
Funded by WRRI

Survey shows rural water and wastewater systems lag in information technology and planning

This project was carried out in 1995-96 in support of the N.C. Rural Development Center's statewide water and sanitary sewer inventory, needs assessment and GIS data set creation. To assess the status of information about water distribution and sanitary sewer collection systems in rural N. C. counties, Dr. David H. Moreau sent surveys to 486 water and 299 sewer systems in 85 N.C. counties for whom contact persons could be identified. (Highly urbanized counties were omitted.) The questionnaire included questions about the availability of system maps, base maps with which they are compatible, and readiness for GIS; inventory and value of capital assets; and planning for expansion and capital improvements. After three mailings and several rounds of follow-up phone calls, 92 percent of the water systems and 90 percent of the sewer systems responded to the questionnaire. Analysis of responses indicated that more than 87 percent of water supply systems have maps of distribution systems but that only 10% of the maps were digitized or GIS ready. The results also revealed that only 44% of the systems have capital improvement plans or statements. Eighty-four percent of the sewer systems have system maps, with 16% being digitized. Only 37% have capital improvement plans or statements. Overall, the results of the survey underscore the need for efforts being undertaken by the Rural Development Center to put all public water supply and wastewater collection and disposal systems in rural counties on the state's geographical information system.

Status of Information on Water Supply and Wastewater Systems in Rural Counties (50208)
Dr. David H. Moreau, WRRI
August 1, 1995, to July 31, 1996
Funded by the N.C. Rural Development Center

** This project was funded after the 1995-96 Annual Program was published and was therefore not included in last year's Annual Program.*

CONTINUING RESEARCH

✓ ***A New Method for Characterizing Aquatic Organic Matter*** (70142) May 1, 1995, to January 31, 1997—Funded by WRRI ■ Dr. Russell F. Christman of the University of North Carolina at Chapel Hill continues his research on a technique to permit prediction of levels of selected classes by disinfection by-products in drinking water from a knowledge of the amount of total organic carbon in a water supply that is produced within the water body and the amount that is transported into the water supply from the watershed area.

✓ ***Denitrification Dynamics of an Estuarine Headwater Creek Receiving Agricultural Runoff: The South River Estuary, NC*** (70139) January 1, 1995, to June 30, 1997—Funded by WRRI ■ Dr. Hans W. Paerl of the UNC-CH Institute of Marine Sciences continues his research into relative rates of denitrification in estuarine headwater creeks and various water best managment practices (BMPs) with the aim of helping select BMPs to optimize nitrogen removal from agricultural runoff.

✓ ***Impact of Wastewater Quality on the Long-term Acceptance Rate of Soils for On-site Wastewater Disposal Systems*** (70140) March 1, 1995, to December 31, 1996—Funded by WRRI ■ Dr. Aziz Amoozegar of North Carolina State University continues his study of which inorganic constituents of wastewater can alter the physical and chemical properties of three different North Carolina soils so as to affect the rate of wastewater movement through them. Dr. Amoozegar is scheduled to conduct a seminar on the results of this research on January 27, 1997, at the Archdale Building in downtown Raleigh.

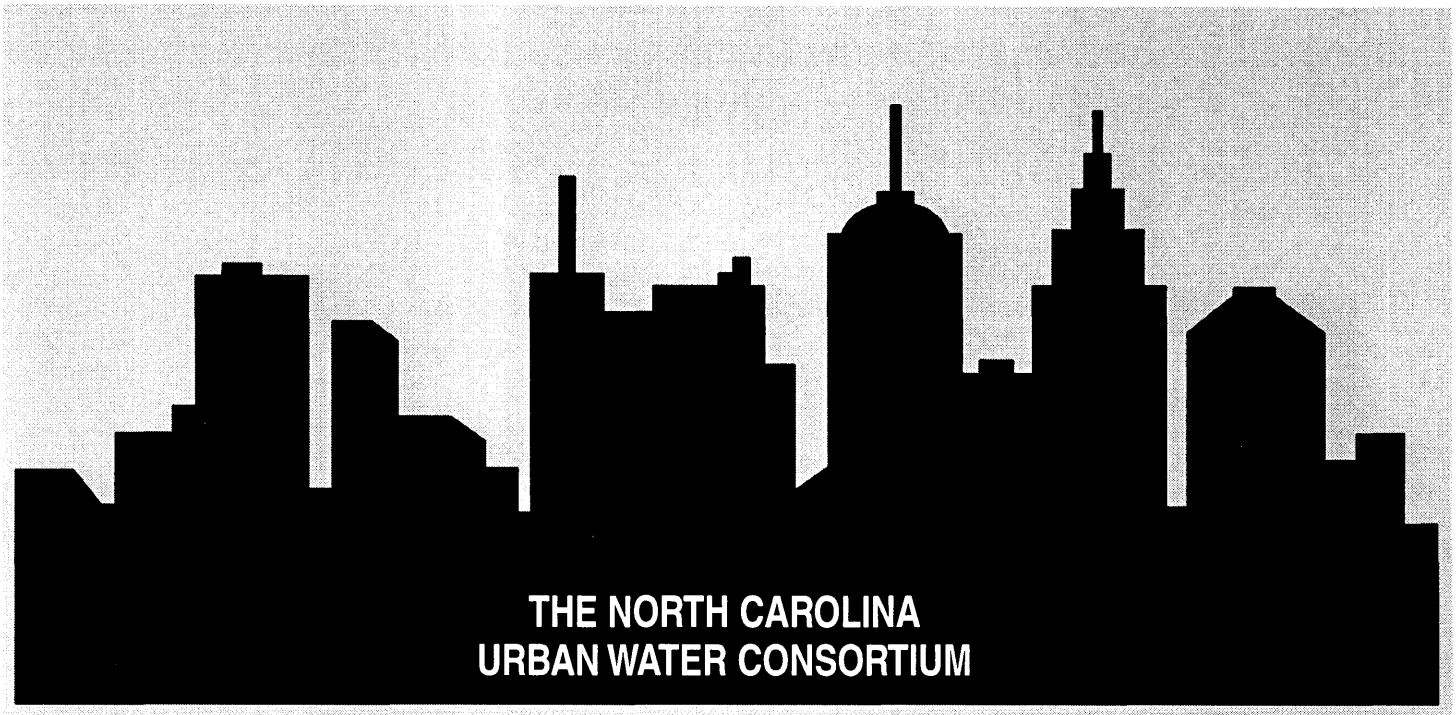
✓ ***Assessing the Impact of Septic Discharge on Water Quality on the Cape Hatteras National Seashore*** (70147) May 1, 1995 to April 30, 1997—Funded by WRRI and the National Park Service ■ Drs. David Evans and Aziz Amoozegar of North Carolina State University continue their research into whether groundwater 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. Dr. Evans is scheduled to conduct a seminar on the results of this research on October 21, 1996, at the Archdale Building in downtown Raleigh.

✓ ***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 June 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.

✓ ***In Vitro Methods for Screening and Evaluating Reproductive Impacts of Aquatic Pollutants on Fish*** (70141) June 1, 1995, to August 31, 1996—Funded by WRRI ■ Dr. Richard T. Di Giulio of Duke University continues his project using in vitro techniques to evaluate reproductive impacts to fish in the Pigeon River, NC, resulting from exposure to bleached kraft mill effluent. The goal of the project is to develop an efficient methodology for screening and monitoring the reproductive impacts of aquatic pollutants on fish in North Carolina surface waters. Dr. Di Giulio is scheduled to conduct a seminar on the results of this research on October 1, 1996, in Jordan Hall on the NCSU campus.

✓ ***Nutrient Limitation and Eutrophication Potential of the Cape Fear and New River Estuaries*** (70136) May 15, 1994 to August 31, 1996—Funded by WRRI and the U.S. Geological Survey ■ Drs. Michael A. Mallin and Lawrence B. Cahoon of the University of North Carolina at Wilmington are continuing to analyze and experiment with water samples from the Cape Fear River and the New River to determine which nutrient (phosphorous or nitrogen) and which seasonal conditions favor algal growth in the rivers.

✓ ***Development of Methods for Evaluating Wetland Hydrology*** (70137) May 15, 1994, to June 30, 1997—Funded by WRRI and the U.S. Geological Survey ■ Drs. R.Wayne Skaggs, G.M. Chescheir and D.M. Amatya of North Carolina State University continue developing and testing reference wetland simulations using the shallow water-table model DRAINMOD and the water table response model WATERCOM. Their efforts are aimed at producing simulations that can be used to identify and delineate wetlands.



THE NORTH CAROLINA URBAN WATER CONSORTIUM

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, which are matched by state 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 Cary.

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

NCSU investigators will look for ways to minimize the effects of algae on drinking water quality

The presence of algae in water supplies can greatly impact the treatment of water for drinking and other potable uses. Algae can cause turbidity and objectionable taste and odor in finished drinking water, generating consumer complaints. Additional treatment required to deal with algae can increase the use of chemicals and the volume of water required to back wash filters, increasing treatment costs. But perhaps more importantly, the presence of algae in source water can lead to higher levels of particles (which could harbor pathogens) and disinfection by-products in finished water. In addition, some algae release toxins that can affect human health. Algal blooms are typically observed in reservoirs serving as water sources for a majority of larger water utilities in North Carolina, and many of these utilities are unsure about which treatment strategies will best remedy the many problems associated with algae.

In this project Detlef Knappe and Sarah Liehr of the NCSU Civil Engineering Department and JoAnn Burkholder of the NCSU Botany Department will collaborate to produce a treatment guide for optimum algae control and effective treatment strategies to minimize the impacts of algae on the performance of treatment plants and on finished water quality. The guide will also give utilities advice on integrating treatment strategies for algae with strategies for removing disinfection by-product precursors and Cryptosporidium and Giardia cysts

continued

UNC-Chapel Hill scientists study bacterial regrowth in water distribution systems

When finished drinking water leaves treatment plants, it is largely free of microbiological contaminants because it has been treated with a disinfectant. However, studies show that bacteria can reappear in water before it reaches consumers' taps. Bacterial regrowth in distribution systems has been linked to the development of biofilms (colonies of attached growth) on pipe walls. Biofilms develop because organic material and nutrients are present in finished drinking water. Once a biofilm develops, bacteria may slough off and appear in tap water.

Most water systems add disinfectant to finished water as it leaves their plants to control the regrowth of bacteria, but there is evidence that even this disinfectant residual (usually free or combined chlorine) may not adequately dampen biofilm growth. Water suppliers with large distribution systems may also add chlorine at points throughout the system or flush pipes, particularly at "dead ends," to help control biofilm growth. However, with all the efforts to control bacterial regrowth in water systems, there is still reason to be concerned. Not all disinfectants are equally effective against bacterial regowth and some bacteria are resistant to disinfectants. Corroding pipes may use up the oxidizing (disinfecting) power of disinfectants, leaving bacteria free to grow. And, flushing may not completely remove biofilms.

Little is known about the type of microorganisms that are likely to regrow or the extent of regrowth given the environmental conditions of a specific water system. Moreover, there is little knowledge about the relationship between attached biofilms and unattached bacteria and the health risk posed by detached microorganisms.

In a project sponsored by the N.C. Urban Water Consortium, two UNC-Chapel Hill scientists are attempting to shed light on the problem of bacterial regrowth by studying the Durham and Raleigh water systems. Drs. Francis A. DiGiano and Donald E. Francisco of the UNC-CH Department of Environmental Sciences and Engineering will establish a network sampling program in cooperation with the two systems. By analyzing water from test pipes installed in existing meter boxes and backflow preventers and from dead end mains and other locations, and by analyzing biofilm taken during tappings routinely done by the utilities, they believe they can help identify the factors most important in causing regrowth. The Durham and Raleigh distribution systems are ideal for this study because they represent the two most common alternatives for disinfection—free chlorine (Durham) and combined chlorine (Raleigh). Free chlorine is said best for controlling unattached bacteria and monochloramine is supposed to be more effective in controlling attached bacteria.

This study is particularly important for small and medium sized water systems in North Carolina. While a large national study of bacterial regrowth is being conducted under American Water Works Association Research Foundation (AWWARF) funding, that study is focusing principally on very large city systems—with distribution system characteristics different from those in North Carolina, and includes few systems in the Southeast—where the combination of relatively high water temperature, high natural organic matter content, and low hardness (related to corrosivity) could significantly influence the formation of biofilms in distribution systems. The DiGiano/Francisco study will, therefore, provide a basis for testing the applicability in North Carolina of any general relationships developed from the AWWARF project. It will also provide the opportunity to test the ability of EPANET, a computer simulation model, to predict disinfectant residuals at different locations in distribution systems.

Bacterial Regrowth in Drinking Water Distribution Systems: A Comparison of Durham and Raleigh (50212)
Dr. Francis A. DiGiano and
Dr. Donald E. Francisco
University of North Carolina at Chapel Hill
July 1, 1996, to June 30, 1997
Funded by WRRI and the N.C. Urban Water Consortium

Effects of algae

and for reservoir management strategies to prevent algae problems.

The study will also evaluate the effects of nutrients in reservoirs on the production of algal toxins and evaluate the impact of algae on the cost of water treatment.

The investigators will perform a utility survey, a literature survey, bench- and pilot-scale experiments, full-scale plant measurements at participating utilities, and a water quality survey of reservoirs that serve as raw water sources for participating utilities.

Optimization of Treatment to Mitigate Impacts of Algae and Algae Control on Finished Water Quality (50215)
Detlef Knappe, 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

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

✓ ***Optimization Model for Durham Reservoir System*** (50209) July 1, 1995 to June 30, 1997-Funded by the City of Durham through the Urban Water Consortium

Dr. Donald T. Lauria of the University of North Carolina at Chapel Hill continues development of a mathematical optimization model with which the City of Durham will be able to determine optimal patterns of operation for its water supply system for given weather scenarios.

✓ ***Assessment of Trace Element Concentrations in Municipal Wastewater Treatment Plant Discharges in North Carolina*** (50210) September 1, 1995 to February 28, 1997—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 continue a project to develop and apply a protocol for analyzing trace mercury, cadmium and cyanide in the effluents of a group of wastewater treatment facilities.

✓ ***Evaluation of Wastewater Biosolids Compost for Production of Agronomic and Horticultural Crops*** (50193) January 1, 1994, to December 31, 1996—Funded by the Charlotte-Mecklenburg Utility Department through the N.C. Urban Water Consortium

Dr. James E. Shelton of North Carolina State University continues to evaluate the potential for use of compost made with wastewater "biosolids" for growing agronomic and horticultural crops. In the final phase of this project, Shelton is conducting demonstration and education activities to introduce farmers, Cooperative Extension agents and others to the usefulness of biosolids compost.

✓ ***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 Three Water Supply Watersheds*** (50189) November 1, 1992, to December 31, 1996—Funded by the N.C. Urban Water Consortium

Dr. Robert E. Holman, Associate Director of WRRI, continues to investigate the potential amount, type and source of pesticides detected in water supply watersheds for Durham, Greenville, and Orange Water and Sewer Authority.

Uncertainty analysis project is aimed at helping decision makers know when to act and when to wait for more information

Almost all decisions about controlling environmental pollution are made in the face of uncertainties deriving from incomplete knowledge. Uncertainties make it impossible to guarantee results, and public officials always face a conflict between the pressure to act on a problem and the desire to have more information to reduce the chances of making a less-than-optimal decision. However, collecting information not only delays decision making but is often costly, and if information collected is not precisely what is needed, it may do little to reduce the uncertainty facing the decision maker.

With major decisions in water quality management coming to depend more and more on models, there is a critical need to be able to identify where, in the models, the most important uncertainties reside and to estimate the probability that those uncertainties will lead to a poor decision. Identifying critical uncertainties and estimating the error that could result from them can help regulators and public officials decide when to wait for additional information and allow research to be focused on collecting information that will actually help reduce the chances of making a poor decision.

In this project, Dr. Kenneth H. Reckhow, Director of WRRI and Associate Professor in the Duke University Nicholas School of the Environment, will analyze uncertainties involved in water quality models to be used for assessing the risk posed by Cryptosporidium in drinking water and for predicting and controlling eutrophication in the lower Neuse River. In doing so, he will take advantage of recent advances in probability modeling that allow estimating the extent to which errors in one component of a complex model breed additional errors.

Such analyses have previously been done only for simple models, and this work will help point the way for integrating uncertainty analysis of complex models into environmental decision making.

In each case, the water quality model will be analyzed as part of a problem-specific decision tool. The first application, for assessing the health risks of Cryptosporidium in drinking water, will lead to an expression of the probable risk associated with various management actions in a specific water system. The analysis will be used as the basis for describing and explaining to customers of the water system management options for addressing the risk from Cryptosporidium.

A subsequent application will estimate the probability of possible responses to various nutrient management actions in the lower Neuse River.

Uncertainty and Risk Analysis in Water Quality Modeling (50213)
Dr. Kenneth H. Reckhow
Water Resources Research Institute
August 1, 1996, to July 31, 1999
Funded by the N.C. Urban Water Consortium

STUDENT INTERN PROGRAM

WRRI coordinates three student intern projects:

The N.C. Office of Waste Reduction supports four 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 supports one intern who works directly with the staff education specialist, makes presentations to schools and the regulated community, and helps develop new educational materials.

The U.S. Geological Survey supports seven interns who work directly with the USGS District research staff on water resources related projects. Current projects include the development of a nitrogen cycling database, herbicide database, groundwater flow model, landuse and biological databases, chemical loading calculations, and a database of nutrient contamination sources as well as maintenance of computer software and hardware.

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 publishes two 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, and other items. Over the next year, additional report summaries and a directory of Water Resources Research Expertise in North Carolina universities will be 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.

UPCOMING WORKSHOPS AND CONFERENCES

During 1996-97, WRRI will sponsor or co-sponsor the following:

September

■ **Coastal Water Quality Issues luncheon forum**, *WRRI and the N.C. Water Resources Association*

■ **Practical Stormwater Management Conference**, *WRRI and the N.C. Chapter of the American Public Works Association*

■ **National Symposium on Effectiveness of Erosion and Sediment Control Practices,** *WRRI, the N.C. Sedimentation Control Commission and the N.C. Land Quality Section*

December

■ **State and Federal Legislative Update luncheon forum,** *WRRI and the N.C. Water Resources Association*

January

■ **Erosion and Sediment Control Workshop for Local Programs,** *WRRI, the N.C. Sedimentation Control Commission and the N.C. Land Quality Section*

February

■ **Water Issues Related to the Global Transpark luncheon forum,** *WRRI and the N.C. Water Resources Association*

February and March

■ **2 two-day Erosion and Sediment Control Design Workshops,** *WRRI, the N.C. Sedimentation Control Commission and the N.C. Land Quality Section*

April

■ **Luncheon forum on Pesticides,** *WRRI and the N.C. Water Resources Association*

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
Morton A. Barlaz, Department of Civil Engineering, North Carolina State University
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
B.J. Copeland, Director, UNC Sea Grant College Program of The University of North Carolina
David G. Evans, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University
Robert E. Holman, Associate Director, Water Resources Research Institute
George J. Kriz, Associate Director, Agricultural Research Service, North Carolina State University
G.B. Reddy, Department of Plant Sciences & Technology, North Carolina A&T State University
Francisco San Juan, Department of Geosciences, Elizabeth City State University
V. Kerry Smith, Department of Economics, Duke University
Donald W. Stanley, Institute for Coastal and Marine Resources, East Carolina University
Philip W. Westerman, Department of Biological and Agricultural Engineering, North Carolina State University
Jy Wu, Department of Civil Engineering, University of North Carolina at Charlotte

1996-97 Water Resources Research Seminar Series

Each year a number of research faculty engaged in projects funded by WRRI present a seminar on their work. Following is the schedule of seminars scheduled for 1996-97. All seminars begin at 10:00 am.

■ Tuesday, October 1, 1996. 1132 Jordan Hall, NCSU campus. ***Methods for Evaluating Impacts of Aquatic Pollutants on Fish.*** Assoc. Professor Richard T. Di Giulio, School of the Environment, Duke University

■ Monday, October 21, 1996. Ground floor hearing room, Archdale Building, downtown Raleigh. ***Effect of Septic Discharge on Water Quality in Coastal North Carolina.*** Assist. Professor David G. Evans, Department of Marine, Earth and Atmospheric Sciences, NCSU.

■ Monday, November 25, 1996. 1132 Jordan Hall, NCSU campus. ***Toxic Dinoflagellate Probe Development.*** Assist. Professor Parke A. Rublee, Department of Biology, UNC-Greensboro.

■ Monday, January 27, 1997. Ground floor hearing room, Archdale Building, downtown Raleigh. ***On-site Water Quality of Wastewater and Acceptable Loading Rates.*** Professor Aziz Amoozegar, Department of Soil Science, NCSU.

■ Monday, February 24, 1997. 1132 Jordan Hall, NCSU campus. ***Effect of Management Practices on Soil Fertilized with Swine Waste.*** Assist. Professor Stephen C. Whalen, Department of Environmental Sciences and Engineering, UNC-Chapel Hill

■ Monday, March 24, 1997. Ground floor hearing room, Archdale Building, downtown Raleigh. ***Evaluation of Detention Ponds for Protection of Water Supply Reservoirs.*** Assoc. Professor Robert C. Borden, Department of Civil Engineering, NCSU

■ Monday, April 21, 1997. 1132 Jordan Hall, NCSU campus. ***Control of Trihalomethane Products in Drinking Water.*** Professor Philip Singer, Department of Environmental Sciences and Engineering, UNC-Chapel Hill

■ Monday, May 19, 1997. Ground floor hearing room, Archdale Building, downtown Raleigh. ***Effect of Swine Waste on Receiving Waters.*** Research Assoc. Michael Mallin, Department of Biological Sciences, UNC-Wilmington.