

# **Illinois Water Resources Center**

## **Annual Technical Report**

### **FY 2004**

## **Introduction**

The Illinois Water Resources Center (IWRC) supports outreach, education and research to promote better understanding and use of Illinois water resources. In 2004, IWRC hosted Illinois Water, a biennial conference on water issues in the state and supported research on a variety of water resource topics. In addition, IWRC continues to receive EPA funding for a regional center that provides research and other forms of technical assistance to drinking water systems in small communities. The Midwest Technology Assistance Center (MTAC) started in November 1998 and is a collaborative effort of the IWRC and nine other water resources research institutes in the Midwest and the Illinois State Water Survey. MTAC began funding four new projects in 2003. These projects include: evaluation of water treatment technology, source water protection planning, mitigation of nitrate contamination and cost-effective arsenic removal.

IWRC also assists in administering the research component of the Illinois-Indiana Sea Grant College Program in partnership with the University of Illinois, Purdue University and the National Oceanic and Atmospheric Administration (NOAA). IWRCs involvement in this program has increased the Center's opportunities for coordinating research activities with other water-related programs in the Midwest. Research topics include: water quality tracking, aquatic nuisance species mitigation, oyster disease, and aquaculture. Outreach topics include: aquatic nuisance species education and prevention.

## **Research Program**

Research priorities for IWRC include: Watershed and stream protection; integrated water management for multiple users; wetland processes; and emerging issues, including other innovative research topics that are not included in the priorities above.

IWRC funded one project that is ongoing at this time and monitored four NIWR proposals. IWRC issued a new Request for Proposals in May of 2004. The Center takes a special interest in helping young scientists establish a record of accomplishment in water resources research. The Water Resources Center encourages new scientists to submit proposals and gives their proposals extra consideration. The proposals must be of significant scientific merit (as determined by the reviewers and the Executive Committee) and have relevance to the water research priorities of Illinois to be judged worthy of funding. Virtually all projects supported by the IWRC contribute significantly to the education of students, both graduate and undergraduate, who participate in the research projects. The Student Support table lists students supported in both the internship program with the Illinois District Office of USGS, and the individual grants to faculty researchers.

# Development and Validation of a 3D Coupled Hydrologic-Biogeochemical Model for Evaluation of the Impact of Water-Table Management on Nitrate Loads from Tile-Drained Agricultural Fields

## Basic Information

<b>Title:</b>	Development and Validation of a 3D Coupled Hydrologic-Biogeochemical Model for Evaluation of the Impact of Water-Table Management on Nitrate Loads from Tile-Drained Agricultural Fields
<b>Project Number:</b>	2002IL7G
<b>Start Date:</b>	9/1/2001
<b>End Date:</b>	5/31/2006
<b>Funding Source:</b>	104G
<b>Congressional District:</b>	15th
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Nitrate Contamination, Non Point Pollution, Solute Transport
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Robert J. Hudson, Albert Joseph Valocchi

## Publication

1. Feng Yue, A.J. Valocchi, R.J. Hudson, 2004, Physically-based 3D hydrologic conjunctive modeling of water flow in tile-drained agricultural fields in Groundwater Quality 2004 Proceedings, 4th International Conference, University of Waterloo, Ontario, Canada.

## Problem and Research Objectives

One of the most promising approaches to minimizing nitrate export to rivers draining agricultural watersheds is the use of water table management, or controlled drainage. The Illinois District of the USGS has conducted a field pilot study of the benefits of controlled drainage at an active farm in east-central Illinois. Two adjacent 40-acre plots, one with tile management and the other without, have been instrumented for collecting a variety of data. Modeling is required to fully interpret the field data and to extend the results to other farm conditions.

A portion of the project involves modeling studies with Drainmod-N, a widely-applied quasi 2-dimensional model. However, because raising the water table of a farm field may increase the amount of runoff and change its subsurface interactions with the larger-scale groundwater flow field, we hypothesize that a fully 3-dimensional model is required to properly quantify the hydrologic and nitrogen budgets of the study site. Our model will simulate both surface runoff/runon and subsurface flow between the adjacent managed/conventional plots (and adjacent fields), processes which can only be represented very approximately in DRAINMOD. The improved hydrology of the model will also allow us to improve our analysis of the N budgets of the two plots, since it accounts more accurately for nitrate exchange between adjacent plots by the above hydrologic paths and will better simulate differences in denitrification in surface ponds/puddles and in the subsurface due to increases in water and solute residence times.

## Methodology

We plan to apply two different modeling approaches to analyze data being collected by USGS researchers from a paired set of agricultural fields with and without controlled subsurface drainage.

The first approach employs automatic calibration of an existing pseudo 2-dimensional groundwater/nutrient transport model (DRAINMOD and/or CERES-MAIZE) to investigate causes for the differences in nutrient export between the two fields. The second approach involves continuing development and application of a 3-dimensional model of hydrologic and solute transport.

Our emphasis is to develop a physically-based, 3-dimensional model that couples surface and subsurface flow with a biogeochemical model for nitrogen fate. The model will be calibrated and validated using the field data collected by the USGS. Our secondary objective is to apply our newly developed automatic calibration tools to DRAINMOD in order to understand the hydrology and nitrogen budgets of the controlled-drainage field study. We will attempt to quantify differences in denitrification using the model and calibrate field-specific parameters for use in the 3-dimensional model.

## Principal Findings and Significance

### *3-D Physically-Based Hydrology Model:*

CHM3D was updated with an accurate and efficient numerical framework for modeling conjunctive flows at the Ford County drainage site. This framework is now based on the fractional stepping or operator splitting technique, which separates the governing equation of each flow equation into several computational steps. As a result, CHM3D consecutively solves 2D lateral surface flow, 2D lateral subsurface flow, 1D vertical subsurface flow, 1D tile flow, 2D lateral subsurface flow, 2D lateral surface flow in each numerical timestep. Each 2D flow takes half the timestep, while each 1D flow takes one whole timestep. The coupling among different flow processes were made through the 1D vertical subsurface flow that 1) takes rainfall and surface water either as an extended computational

node when the surface becomes ponded or as an infiltrating flux at the boundary when the surface is dry; 2) and incorporates the flow to tiles as either an implicit or explicit sink with respect to the direction of this flow. Within this framework, different timesteps and numerical schemes can be applied for different fractional steps or operators depending on the scales and characteristics of each flow process. Therefore, CHM3D is not only tightly coupled but allows convenient numerical setup. Furthermore, numerically robust Alternating-Direction-Implicit method has been implemented for lateral flows, which occupies less computer CPU time to achieve good results.

***N-Cycle Modeling:***

To quantify nitrogen budgets for agricultural fields, we need to accurately estimate crop N uptake and net N mineralization in the soils in addition to hydrologic flows. In fact, crop N uptake and mineralization are both greater than N leaching in typical agricultural fields. After considering the available models, the CERES crop model coupled with the CENTURY soil organic matter (SOM) model was chosen for coupling to the hydrologic model.

A major part of our work is to develop a means of more accurately calibrating the SOM model using results from the Illinois soil N test (ISNT), which has been demonstrated to be a good indicator for N mineralization in agricultural soils. We are now in the process of modeling field studies of ISNT dynamics and agronomic rate studies to calibrate SOM model more accurately for conditions in Illinois and at the field site.

***Field-Site N Budgets:*** In order to construct a nitrogen budget of the USGS field site, we are gathering additional data that will be analyzed using the models. Our analysis of water budgets for the fields suggests that there is considerable sub-surface flow from the controlled to the free-draining site. This suggests that nitrate leaching from the controlled field may actually be greater than expected from the tile measurements alone. In addition, soil sampling was conducted before planting in 2005 and samples analyzed for ISNT, which is a measure of readily mineralizable N. We are waiting to hear from the farmer about grain yields and fertilizer rates so we can complete the nitrogen budget for the site.

# Rapid Solar Transformation of Nutrients in Natural Waters

## Basic Information

<b>Title:</b>	Rapid Solar Transformation of Nutrients in Natural Waters
<b>Project Number:</b>	2003IL22B
<b>Start Date:</b>	3/1/2003
<b>End Date:</b>	2/15/2006
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	15th
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Water Quality, Nutrients, Surface Water
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Gary R. Peyton, Gary R. Peyton

## Publication

**Problem and Research Objectives** - Solar phototransformation of nitrogen nutrients between forms such as organic nitrogen, nitrate, and ammonia can provide significant sources and sinks for the individual nutrient forms. Solar irradiation of natural organic material (NOM) can generate reactive species including free radicals, that can drive transformations such as the generation of ammonia. Recognition of these contributions may impact the setting of water quality standards and best management practices for nutrients, as well as nutrient modeling. The objectives of the project are to 1) measure the photogeneration of ammonia in several Illinois waters, 2) identify important transformation pathways, and 3) derive models for the process rates in terms of water quality parameters, which may be suitable for adaptation into water quality models.

### **Methodology**

Photoammonification rates are being measured in water samples brought to the laboratory, using simulated solar light and standard methods (phenate) for ammonia measurement, as well as other important water quality parameters. Pathways are being identified by two types of experiment: 1) model sensitizers (sources of reactive species) are irradiated in the presence of model ammonia precursors that mimic various nitrogen functional groups known to be present in NOM, in order to determine which combinations lead to ammonia production, and 2) water samples are spiked with sensitizers and (in separate experiments) model precursors, to determine which are present in the waters, and which component (sensitizer or precursor) is the limiting factor in ammonia production. Depending on the results, specific radical "probe" compounds may be used to measure radical production in the waters upon irradiation with simulated sunlight in several spectral regions. This information will be compared for various waters, and, along with the solar emission and water absorbance spectra can be used to predict ammonia photoproduction. We will also attempt to develop simple mechanistic/kinetic models of the processes for use in predictive purposes.

### **Principal Findings and Significance**

Work this year has been focused in two areas: 1) Measurement of the amount of ammonia produced photochemically from various natural waters upon irradiation with UV/visible light, and 2) determination of the reactive species and nitrogen functional groups that serve as ammonia precursors, in order to elucidate the major pathways by which ammonia is photochemically produced from natural organic material (NOM).

#### *Photochemical Ammonia Production in Natural Waters -*

Samples of several natural waters have been collected and returned to the laboratory for use in photochemical experiments. Although a variety of samples is being used, the majority of work has been focused on three local waters because of their differences and similarity, their ready availability, and interest in the variability throughout the year. For best consistency and comparability of measured values, a UV/visible lamp is used for irradiation of samples in the laboratory, and the results extrapolated to those of solar irradiation by calculation using spectra of the lamp emission, solar spectrum, and absorbance spectra of pyrex reactors, waters, and model compounds. Filtered and microfiltered (0.2  $\mu\text{m}$ ) waters were irradiated and ammonia formation monitored. Ammonia increases of 10% to 400% have been observed upon irradiation, implying that the amount of ammonia measured in some environmental samples may depend significantly on previous sunlight exposure, as transport phenomena such as nitrogen spiraling should be impacted. The initial ammonia concentration, extent of production, and evolution curve all change throughout the year, as well as with sample storage, even at 4° C after microfiltration.

The curve shape for ammonia evolution can provide information about the process. In its simplest form, ammonia production requires a photosensitizer, which upon irradiation produces a transient species that reacts with an ammonia precursor (a nitrogen-containing functional group in the NOM) to produce ammonia. If both sensitizer and precursor are present, ammonia production should begin immediately and the rate gradually slow until a plateau is reached. A plateau in ammonia production indicates that sensitizer and/or precursor has been exhausted. The rate and extent of the reaction should be dependent upon the nature and amount of sensitizer and precursor. A delay in ammonia production indicates that sensitizer and/or precursor must be

produced in a prior step before they can generate ammonia in a secondary step. Although the relationship between season and curve shape is not obvious for the 29 photoammonification experiments on local waters to date, 67% of the water samples collected during the summer (June-August, 6 samples) showed a lag phase in ammonia production, compared to only 29% in April-May (17 samples) and 17% of fall samples (Sept-Oct, 6 samples). Twenty-three of the 29 samples reached a plateau in ammonia production within 1-3 hours. Curve analysis is ongoing.

#### *Mechanisms of Ammonia Photoproduction -*

Much is known about the photoproduction of reactive species (RS), the types of compounds with which they react, and the products that are formed. In order to determine the functional groups responsible for ammonia production from NOM, RS reported or hypothesized to be produced photochemically from NOM were identified, along with the important (i.e., most plentiful) nitrogen-containing functional groups in NOM. The RS produced by these sensitizers, and model compounds (MC) representing the important nitrogen-containing functional groups were used in screening experiments to identify RS-precursor combinations that were capable of producing ammonia. RS identified included 1) free radicals such as hydroxyl, peroxy, carbonate radical, and carbon-centered radicals formed by oxidation of an organic compound by another oxidizing radical, 2) triplet states from aryl ketones such as benzophenone, 3) excited states of quinones and their corresponding semiquinone radicals, and 3) other excited species such as singlet oxygen. Carbon-centered radicals quickly react with oxygen to form peroxy radicals at the oxygen concentrations present in surface water. Peroxy radicals fall into two classes, oxidizing and reducing, but the reducing radicals quickly eliminate superoxide. Superoxide is a special case, as it can both oxidize and reduce, reducing triplet aryl ketones and quinones to ketyl radicals and semiquinones, respectively, and Fe(III) to Fe(II). Among the oxidizing radicals hydroxyl, peroxy (including superoxide), carbonate, etc., hydroxyl is the strongest, and was used for screening on the premise that if a precursor did not react with hydroxyl, it would not be oxidized by a weaker radical. Benzophenone and benzoquinone were selected to be representative of the aryl ketone and quinone classes, partly because of the wealth of data on their photoreactions. Singlet oxygen was shown by competition calculation to essentially be completely quenched by water. The above reasoning reduced the number of radicals used in the screening tests to those shown as column labels along the top of the table shown below.

Nitrogen-containing functional groups thought to be plentiful in NOM included amines, amides, and pyridine functionalities. Amino acids and amino alcohols are included in the amine category, and peptides and ureas fall into the amide category. These candidate precursor groups and their representative MCs are listed along the left-hand side of the table as row labels. In addition to RS-MC experiments to determine feasibility of the combinations, sensitizers or model precursors were added to various natural waters for irradiation, to determine which types of sensitizers and/or precursors are present in the NOM, and whether sensitizer or precursor was the limiting factor in ammonia production.

Results obtained to date are shown in the table, where + and ++ denote possible and definite ammonia production in RS-MC compound experiments or enhancement of ammonia production in RS- or MC-amended natural waters. A minus sign indicates that no effect was observed. Hydroxyl radical has been shown to generate ammonia when reacting with amines, or with the NOM in, or isolated from, surface water. A trace amount of ammonia was produced by the attack of OH radical on acetamide, but a yield of only 5% was observed based on the amount of acetamide destroyed, because of a very unreactive intermediate that is formed. In the reaction of hydroxyl radical with diethylamine on the other hand, ammonia production is almost quantitative. The benzophenone triplet excited state also produced ammonia when benzophenone was irradiated in natural waters or solutions of reconstituted Suwannee River Humic Acid (SRHA), but did not produce ammonia from acetamide in pure water. Irradiation of benzoquinone produced ammonia from SRHA but not from Salt Fork River water. These last two results are tentative, pending replication. No experiments have yet been performed using the pyridine model compound nicotinic acid.

Reactive Species or Precursor class		Oxidizing Radical	Aryl Ketone Triplet	Quinone Triplet	NOM
Representative Substance		OH radical <sup>(1)</sup> (H <sub>2</sub> O <sub>2</sub> /UV, nitrate)	benzophenone	benzoquinone	Homer L., Collins P., Salt Fork R., SRHA
Amine	diethylamine ethylamine	++ ++		++	
Amide	acetamide	++ <sup>(2)</sup>	(-)		
Pyridine	nicotinic acid				
NOM	Homer Lake	++	++		++
	Collins Pond	++	++		++
	Salt Fork R.	++		(-)	++
	Clinton Lake SRHA		++	(+)?	++

**Notes:**

1) generated by either H<sub>2</sub>O<sub>2</sub> or nitrate photolysis.

2) trace amount found – only 5% based on acetamide consumed.

# Estimating shallow recharge and discharge in northeastern Illinois using GIS and pattern recognition procedure

## Basic Information

<b>Title:</b>	Estimating shallow recharge and discharge in northeastern Illinois using GIS and pattern recognition procedure
<b>Project Number:</b>	2004IL49G
<b>Start Date:</b>	9/1/2004
<b>End Date:</b>	8/31/2006
<b>Funding Source:</b>	104G
<b>Congressional District:</b>	15
<b>Research Category:</b>	Ground-water Flow and Transport
<b>Focus Category:</b>	Groundwater, Methods, Models
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Yu-Feng Lin, Albert Joseph Valocchi

## Publication

## **Problem and Research Objectives**

The management of water resources requires quantifying the interaction between components of the hydrologic cycle, including the rates and variability of the recharge and discharge (R/D) to aquifers. These R/D rates define the relationships between the groundwater, precipitation, and surface water, and thus can restrict management options for water supply. The management of water resources in northeastern Illinois is complicated by interstate agreements, hydraulically coupled aquifer systems, natural and anthropogenic contamination, groundwater / surface water interaction, and conjunctive use of multiple resources. This research is developing a computer program implementing several methods of estimating and mapping R/D, apply the resulting software to improve the understanding of spatial variability of shallow R/D in northeastern Illinois, and thus address a research priority of national importance and of broad interest.

## **Methodology**

The first task to be addressed is the development of a Pattern Recognition Utility (PRU) to identify recharge zones within noisy spatial data and estimate R/D rates for each zone. The PRU will be a graphical user interface (GUI) tool and compatible with ArcGIS 9 that implements several advanced image processing methods and couples these to the R/D estimation codes of Stoertz and Bradbury (1989), Bradbury et al. (2000), and Lin (2002). The software will be tested on a USGS internal project (Krohelski et al., 2003) in Wisconsin to determine trends (spatial and temporal) in recharge rates and investigate dominant recharge processes occurring in select undeveloped, agricultural, and urban watersheds.

After the software is successfully tested, the approach will be used to assist in the estimation and mapping of R/D for the groundwater models that are part of a water resources assessment for northeastern Illinois (Meyer et al., 2002). Previous studies for regional R/D in this region are limited and the software will be applied to estimate the R/D to the shallow aquifers within a much short preparation time than current methods.

## **Principal Findings and Significance**

In the proposal, UCODE (Poeter and Hill, 1998) was the parameter estimation code to be used to calculate the parameter values that provide a best fit between simulated output and calibration targets measured in the field. Another potential parameter estimation code, PEST, has been under evaluation for this project since December 2004. Yu-Feng Lin attended a short course "Model Calibration and Predictive Analysis using PEST" hosted by USGS-WRD in Middleton, Wisconsin from April 4 to 7, 2005. PEST is a model-independent nonlinear parameter estimator developed by Dr. John Doherty. During this short course, Yu-Feng Lin had a special meeting with Dr. Doherty to discuss the application of PEST on this research project. The new features in PEST such as parallel processing, SVD assist and Pilot Points can provide better quality of model calibration than UCODE for this research. Further investigation is in progress and the possibility of applying PEST instead of UCODE is high.

Yu-Feng Lin also attended two ESRI ArcGIS 9 short courses: 1) Introduction to Programming ArcObjects with VBA (from November 15 to 19, 2004); and 2) Working With ArcGIS Spatial Analyst (from January 11 to 13, 2005). The programming development feature in ArcGIS 9 is

much more advanced than ArcGIS 8 (ESRI, 2001) which we proposed to use in our project proposal. The enhanced multi-language support (such as VB, C, C++ and Python) and Model Builder Platform will make the software development for this project more efficient. Therefore, ArcGIS 9 will be used for this project instead of ArcGIS 8.

All above three course trips were supported by the State of Illinois and Kane County Water Resources Department, Illinois and should be acknowledged.

### **Literature Citations/References**

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# Carbonaceous Material Fractions in Sediments and Their Effect on the Sorption and Persistence of Organic Pollutants in Small Urban Watersheds

## Basic Information

<b>Title:</b>	Carbonaceous Material Fractions in Sediments and Their Effect on the Sorption and Persistence of Organic Pollutants in Small Urban Watersheds
<b>Project Number:</b>	2004IL52G
<b>Start Date:</b>	9/1/2004
<b>End Date:</b>	10/1/2006
<b>Funding Source:</b>	104G
<b>Congressional District:</b>	15th Illinois
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Non Point Pollution, Sediments, Water Quality
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Charles J. Werth, Barbara June Mahler, Peter Chapman Van Metre

## Publication

1. Yang, Y., C. J. Werth, 2005, Carbonaceous material fractions in sediments and their effect on the sorption and persistence of organic pollutants in small urban watersheds in the 11th Annual Environmental Engineering and Science Spring Symposium, the University of Illinois, Urbana, IL, 23.

## **Problem and Research Objectives**

Particle-associated contaminants (PACs) are an important contributor to urban non-point source pollution across the Nation. PACs, which include chlorinated organic compounds, trace elements, and polycyclic aromatic hydrocarbons (PAHs), pose a threat to biota in aquatic systems and humans because many are toxic, bioaccumulative, and persistent. Since the occurrence of PACs has resulted in the impairment of thousands of streams, lakes, and reservoirs, the determination of trends (or lack of trends) in PACs is of national significance and one of the objectives of the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program, which is referred to as the Reconstructed Trends National Synthesis (RTNS) Study.

Numerous researchers have relied on the analysis of cores from streambed and lake sediments to identify trends in PACs in aquatic systems, and to reconstruct water-quality histories, based on the assumption that the chemical signatures in the cores reflect historical water quality in the influent streams (e.g. Charles and Hites, 1987; Eisenreich et al., 1989). Recently, Van Metre and Mahler (2004), as part of a USGS RTNS team, investigated the extent to which the contaminant concentrations and trends recorded in sediment cores were associated with suspended sediment in influent streams. Their research results support the use of sediment cores to infer streamwater-quality histories for many contaminants, but they also indicate that in small urban watersheds, concentrations of some PACs on suspended sediment in influent streams can greatly exceed those in bed surface sediment in the downstream reservoir, and that trends may not be preserved in cores for some PACs. These observations present a problem for effective sediment monitoring and best management practices for mitigating PAC occurrence. Although the significant loss of contaminants during transport and soon after deposition has been attributed to the solubilization of some contaminants, and the solubilization and mineralization of some solid-phase carbonaceous materials (CMs), relatively little is known about the role played by CM in the transport and fate of PACs in small urban watersheds.

The overall objective of this study is to determine how CM fractions in urban reservoir sediments affect the persistence of PACs, with a focus on hydrophobic organic compounds (HOCs). The specific objectives of this work include determining the persistence of different CM fractions in sediments during suspension, sedimentation, and burial, determining the CM fractions that control the sorption and persistence of PACs in urban reservoirs, and developing a model to predict PAC sorption to urban sediments.

## **Methodology**

This research project consists of three phases.

### *Phase I: Sampling and PAC analysis.*

Lake Como and Lake Fosdic watersheds in Fort Worth, Texas were chosen to be urban “laboratories”. Samples of lake sediments, suspended sediments and bed sediments in influent streams, soils, street dust, and parking lot dust were collected from each watershed. All samples were split; one split is being used for the analysis of PACs (trace elements, organochlorine compounds, and PAHs) and the determination of sediment deposition time at the USGS National Water Quality Lab (NWQL), and the other split is being used for CM fractionation, characterization, and sorption in our laboratory at the University of Illinois at Urbana-Champaign (UIUC).

### *Phase II: Enrichment and characterization of CM fractions.*

All samples except suspended sediment will be density separated with a sodium polytungstate (SPT) solution to obtain light particulate organic matter (LPOM), occluded particulate organic matter (OPOM), and the remaining heavy fraction (HFr)(Wander and Yang, 2000). Each fraction will be subject to a series of chemical and/or thermal treatment steps to obtain sub-samples

enriched in different CM fractions, such as total CM, humic acid, fulvic acid, kerogen plus black carbon, and black carbon.

Sediment and CM fractions will be quantified and characterized in several ways. Surface area will be determined by gas adsorption. CHN analysis, energy dispersive spectroscopy, and X-ray photoelectron spectroscopy will be used to determine the C, H, and O contents of the samples and sample surfaces. Surface functional groups will be analyzed with Fourier-transform infrared spectroscopy.

*Phase III: Measurement and prediction of sorption isotherms for PACs*

Sorption isotherms will be measured using established batch equilibrium methods (Li and Werth, 2001), with bulk sediment, soil, dust, and CM fractions of these samples, using benzo(a)pyrene (BAP) and  $\alpha$ -chlordane ( $\alpha$ -Chl) as sorbates. Radio-labeled BAP and  $\alpha$ -Chl will be used to distinguish spiked sorbate from background sorbate. All isotherms will be run at 22°C.

The sorption isotherms and the surface properties characterized in Phase II will be used to develop quantitative structure-activity relationship models to predict PAC sorption in other sediments and to identify mechanisms that control the sorption and persistence of PACs in urban reservoirs.

### **Principal Findings and Significance**

So far, we have finished the tasks in Phase I and are working on Phase II.

Cooperating with the USGS NAWQA program (RTNS team), all sampling was completed in Fort Worth, Texas, in October of 2004. Sediment cores were collected at different depth. For Lake Como, three core intervals at depths of 0-5 cm, 10-15 cm and 25-30 cm were collected. For Lake Fosdic, six samples at 5-cm intervals from the surface to a depth of 30 cm were collected. In order to determine the organic carbon (OC) profiles in the sediments, samples at 2-cm interval were also collected from both lakes, 0 – 32 cm for Lake Como and 0 – 40 cm for Lake Fosdic. Suspended sediment and bed sediment samples were collected from the corresponding influent streams of both lakes. Soil samples were collected from commercial and residential areas in each lake watershed. Dust from residential streets and sealed and unsealed commercial parking lots in each watershed were also collected.

One split of all samples is being analyzed for PAC concentration and isotope radioactivity ( $^{137}\text{Cs}$  and  $^{210}\text{Pb}$ ) by NWQL, and the other split is being treated in our laboratory. After the treatment with an excess of a 5%  $\text{H}_2\text{SO}_3$  to remove inorganic carbon, the OC and hydrogen contents of all 2-cm sediment intervals were determined with a CE 440 CHN analyzer (Exeter Analytical, Inc., MA) in the Microanalysis Laboratory at the UIUC. The OC contents of Lake Como sediments are between 3.6 – 5.6 %, without an obvious trend. However, the OC contents of Lake Fosdic sediments are greater, and there is a significant decrease in OC contents at deeper depths (6.5 – 8.5% at the depth from 0 to 25 cm; 5.0 – 6.8% at the depth from 25 to 40 cm). The different OC contents at different depths in sediments may be correlated with different CM fractions and their properties, and may influence PAC persistence. Sediment samples at 5-cm intervals are being separated into LPOM, OPOM and HF<sub>r</sub> fractions, with 1.6 g/cm<sup>3</sup> SPT solution, and pulverized to ~75  $\mu\text{m}$  particles for complete and fast reaction in subsequent chemical treatments.

Also, some samples were sent in small amounts for PAH extraction and petrographic analysis using the facilities at Tuebingen University in Germany, including the surface sediment samples (0-5 cm) from both lakes and the soil and dust samples from Lake Como.

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# Development of Water Use Benchmarks for Thermoelectric Power Generation in the United States

## Basic Information

<b>Title:</b>	Development of Water Use Benchmarks for Thermoelectric Power Generation in the United States
<b>Project Number:</b>	2004IL56G
<b>Start Date:</b>	7/1/2004
<b>End Date:</b>	12/30/2005
<b>Funding Source:</b>	104G
<b>Congressional District:</b>	Illinois 12th
<b>Research Category:</b>	Social Sciences
<b>Focus Category:</b>	Water Use, Methods, Models
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Ben A. Dziegielewski, Tom Bik

## Publication

## **A. Problem and Research Objectives**

This progress report summarizes the work that has been performed toward the completion of the “Development of Water Use Benchmarks for Thermoelectric Power Generation in the United States” (Grant No. 04HQGR0148, Letter Sub-award No. 2005-509-1-00) during the period from July 1, 2004 to April 30, 2005.

This research project aims at providing a basis for understanding water use in thermoelectric generation by developing indicators of water usage in electric power plants using different types of generation and different cooling systems. The main focus of this project is the development of average rates of water use both as withdrawals and consumptive use per unit of generated energy, as well as unit usage rates that represent the available levels of efficiency in water use (i.e., efficiency-in-use benchmarks). The following sections briefly summarize progress in specific areas of the project.

## **B. Methodology and Principle Findings and Significance**

The work on this project follows the originally submitted work tasks. The status of work on each task is given below.

### ***Task 1. Review of Past Studies of Thermoelectric Water Use***

The literature related to thermoelectric water use has been reviewed. The review included both published and unpublished sources, including information available from consultants, regulatory agencies, and water utilities. A bibliographic list of available studies has been compiled.

### ***Task 2. QA/QC Review of EIA 767 Data Set; Develop Cooling System Level database for most recent year***

The data tables in the EIA-767 data sets at the multi-scale plant level have been organized by the cooling system. The data base used in the analysis represents EIA-767 reporting years from 1996 to 2003. Currently the data set is being finalized by conducting the final phase of QA/QC.

### ***Task 3. Develop Water-use Indicators for Individual Power Plants***

A preliminary analyses of the data set have been performed using the stochastic frontier analysis approach. The estimation was done using Frontier Version 4.1. Further estimations will be conducted once the data base is finalized.

### ***Task 4. Verify Water-use Indicators through Mail Survey of Power Plants***

A draft mail survey questionnaire has been developed. It was preceded by five on-site visits of thermoelectric power plants in Illinois, Kentucky and Missouri to identify the critical operational issues in controlling water use at the plants. The draft survey is now being sent to the facility engineers at the site-visit plants for testing and to verify that the data used in determining the indicators are correct. The survey will also solicit additional information about the specific design and operational features that affect water usage rates for cooling and other purposes at each facility.

***Task 5. Develop Final Benchmarks and Benchmarking Models***

This task is yet to be completed.

***Task 6. Project Reports and Web Site***

This task is yet to be completed.

**E. Tasks for the Next Eight Months**

During the next three months, the research team aims to complete the following items:

1. Finalize master data set.
2. Re-estimate final stochastic frontier models.
3. Field the survey of power plants.
4. Prepare project completion (technical) report
5. Set up a web site and post data and publications
6. Finalize journal manuscripts

## **Information Transfer Program**

The major functions of the Illinois Water Resources Center are to oversee a research program and convey the results of research and development within the water resources field to specialists and the interested public. Information transfer is accomplished through workshops, conferences, published proceedings, a website, and maintenance of a library of Illinois Water Resources Center reports and videotapes.

In addition, the Center Director and staff serve on state advisory committees and consult with government agencies.

# Illinois Water 2004 Conference

## Basic Information

<b>Title:</b>	Illinois Water 2004 Conference
<b>Project Number:</b>	2004IL128B
<b>Start Date:</b>	11/1/2003
<b>End Date:</b>	1/1/2005
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	15th
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Education, None, None
<b>Descriptors:</b>	conference, education, outreach
<b>Principal Investigators:</b>	Lisa Merrifield, Jennifer Fackler, Stephanie Lage, Richard Warner

## Publication

1. Fackler, Jennifer, Lisa Merrifield, 2004, Water 2004 Conference Proceedings, Urbana, Illinois.
2. Fackler, Jennifer, Lisa Merrifield, 2004, Illinois Water 2004 Proceedings, Urbana, Illinois Water Resources Publication # SP 29.

Illinois Water 2004 is a statewide conference sponsored by IWRC for all citizens, groups, and students interested in water resource issues in Illinois. The conference was held at the Holiday Inn, Urbana, Illinois, on October 13 - 14. Attention was focus on science, technology, and policy developments, while also bringing major water resource organizations and interests together to explore common ground.

“Breathing New Life into the National Water Program” will be the topic for featured speaker, Roberta Savage, Executive Director/Secretary, Association of State and Interstate Water Pollution Control Administrations, and President of the Board and Chief Executive Officer, America’s Clean Water Foundation. Themed sessions covered topics including designated uses of surface water, glacial aquifers, agricultural drainage management, and water quantity. Twelve technical sessions will provide an in depth discussion of a wide variety of Illinois issues. Prior to the conference, a special discussion focused on the development of a state water monitoring council was held and during the conference a panel discussed career opportunities with students.

# Governor's Conference on the Illinois River

## Basic Information

<b>Title:</b>	Governor's Conference on the Illinois River
<b>Project Number:</b>	2004IL130B
<b>Start Date:</b>	11/1/2003
<b>End Date:</b>	11/1/2005
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	15th
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Education, None, None
<b>Descriptors:</b>	conference, education, outreach, Illinois River
<b>Principal Investigators:</b>	Lisa Merrifield

## Publication

The IWRC program specialist serves on the planning committee for the Governor's Conference on Management of the Illinois River, which was held on October 7-9, 2003. IWRC serves as a cosponsor for the conference by producing the speaker abstract book and the conference proceedings.

# Midwest Groundwater Conference

## Basic Information

<b>Title:</b>	Midwest Groundwater Conference
<b>Project Number:</b>	2004IL131B
<b>Start Date:</b>	1/1/2004
<b>End Date:</b>	11/1/2005
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	15th
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Education, None, None
<b>Descriptors:</b>	conference, groundwater, illinois
<b>Principal Investigators:</b>	Lisa Merrifield

## Publication

The IWRC program specialist serves on the planning committee for the Midwest Ground Water conference to be held in November in Urbana, Illinois. IWRC contributes conference planning knowledge, budget information and other expertise to this effort.

# IWRC Web Site

## Basic Information

<b>Title:</b>	IWRC Web Site
<b>Project Number:</b>	2004IL132B
<b>Start Date:</b>	3/1/2004
<b>End Date:</b>	2/28/2005
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	15th
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Education, None, None
<b>Descriptors:</b>	web site, outreach, education
<b>Principal Investigators:</b>	Lisa Merrifield, Jennifer Fackler

## Publication

The Illinois Water Resources Center web site ([www.environ.uiuc.edu/iwrc](http://www.environ.uiuc.edu/iwrc)) provides direct links to IWRC publications, news, and funding opportunities. Links to grant information from other Illinois and federal sources; information about issues important to Illinois waters, such as aquatic nuisance species and gulf hypoxia; and information for kids have also been developed. Information about the biennial Illinois Water conferences is maintained as part of this site. A FAQ section provides answers to questions about Illinois water issues. Over the past year, we have begun to scan all or part of our more recent publications and provide links to those documents from our web site. The response from users has been very positive. We are also in the process of updating the look of the IWRC web site. We hope to complete the transformation in the coming year.

# IWRC Newsletteer

## Basic Information

<b>Title:</b>	IWRC Newsletteer
<b>Project Number:</b>	2004IL133B
<b>Start Date:</b>	3/1/2004
<b>End Date:</b>	2/28/2005
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	15
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Education, None, None
<b>Descriptors:</b>	newsletter, outreach, education
<b>Principal Investigators:</b>	Irene Miles, Lisa Merrifield

## Publication

1. Miles, Irene, ed., 2004, Illinois Water Resources Newsletter: Fall 2004, Illinois Water Resources Center, University of Illinois at Urbana-Champaign.

The IWRC newsletter is published annually to update the over 600 subscribers about research and outreach activities IWRC is undertaking. The distribution list includes faculty on university campuses around the state, government officials, scientists, researchers and concerned citizens.

## Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	0	0	0	0	0
Masters	1	3	0	0	4
Ph.D.	0	3	0	0	3
Post-Doc.	0	0	0	0	0
Total	1	6	0	0	7

## Notable Awards and Achievements

The Illinois Water Resources center sponsored the Illinois Water 2004 conference in October 2004. Approximately 200 people attended the events and participated in the workshops. A paper and poster competition awarded prizes to one paper and one poster presenter. Evaluations of the conference were overwhelmingly positive.

## Publications from Prior Projects