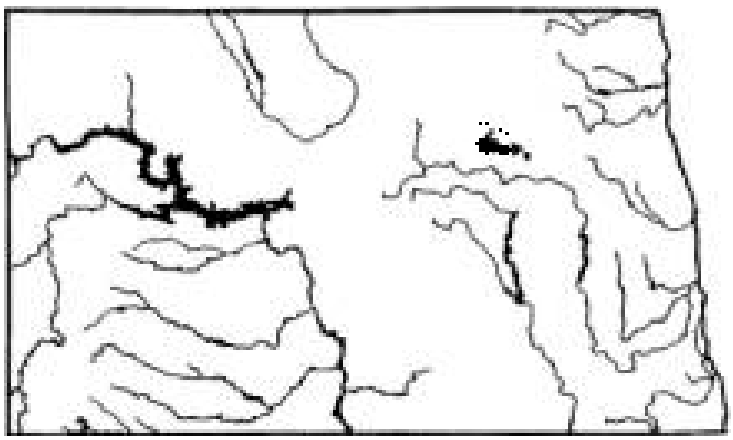

North Dakota
Water Resources Research Institute

North Dakota State University
University of North Dakota

ANNUAL REPORT

March 1, 2012 to February 28, 2013

Fiscal Year 2012 Report to the U.S. Geological Survey

June 2013

Annual Report

Fiscal Year 2012 Report to the U.S. Geological Survey

Award No. 06-HQ-GR-0104
U.S. Geological Survey

G. Padmanabhan, Director
North Dakota Water Resources Research Institute
North Dakota State University
Fargo, ND 58108-6050

June 2013

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INTRODUCTION

This report describes the activities of the North Dakota Water Resources Research Institute (NDWRRI) during the period of March 1, 2012 to February 28, 2013.

The ND WRRI is one of the 54 institutes known collectively as the National Institutes for Water Resources (NIWR). The NDWRRI was founded in 1965, by authority of Congress (Water Resources Research Acts of 1964, 1972, 1984, and 1990), and is administrated through the United States Geological Survey. Section 104 of the Water Resources Research Act requires the NDWRRI to apply its Federal allotment funds to:

1. Plan, conduct or otherwise arrange for competent research that fosters: (A) the entry of new research scientists into the water resources field, (B) training and education of future water resources scientists, engineers, and technicians; (C) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena; and (D) the dissemination of research results to water managers and public.
2. Cooperate closely with other college and universities in the state that have demonstrated the capability for research, information dissemination and graduate training, in order to develop a statewide program designed to resolve State and regional water and related land problems.
3. Cooperate closely with other institutes and other organizations in the region to increase the effectiveness of the Institute and for the purpose of promoting regional cooperation.

This year, NDWRRI once again allocated its 104(B) resources to fund Graduate Fellowship research projects. The institute also continued its efforts to enhance communications between the State and Federal agency personnel and university faculty and students. NDWRRI also worked closely with the Environmental and Conservation Sciences program of North Dakota State University (NDSU), Natural Resources Management program of NDSU, and the International Water Institute, Fargo, ND on water related research issues and collaboration.

Program Management

The Institute continued the same administrative mechanism with a director managing the institute program with the help of a State Advisory Committee. Dr. G. Padmanabhan, Professor of Civil Engineering, is the director. Linda Charlton, a NDSU employee, has been working part-time for the Institute to assist the director with Institute finances, communications and information transfer. The State Advisory Committee consists of three members representing the three principal water agencies in North Dakota: State Water Commission, State Department of Health, and the USGS North Dakota District. In addition, the Institute also seeks advice from the faculty of the two research universities of the State: North Dakota State University and University of North Dakota.

State Appropriation

The State Water Commission continued its support of 15% match to the 2012-2013 Graduate Research Fellowship program of NDWRRI under federal 104 (B) funding. This is ninth year the SWC provided support to the Fellowship program.

University Support

North Dakota State University and the University of North Dakota administrations consider the NDWRRI activities important and are supportive of its efforts.

Institute Location

The Institute continues to operate from the Administrative Building of the College of Engineering and Architecture of North Dakota State University in Fargo, North Dakota. The director may be reached at: ND Water Resources Research Institute, North Dakota State University, Civil Engineering, Dept. # 2470 Fargo, ND 58108-6050
Phone: (701) 231-7043 Fax: (701) 231-6185 E-mail: G.Padmanabhan@ndsu.edu

State Advisory Committee

The State Advisory Committee provided guidance on water resources research priorities in the State and region, and participated in the review and evaluation of research proposals and projects. The current committee members are:

Gregg Wiche, District Chief, U.S. Geological Survey, Water Resources Division, Bismarck, North Dakota

William Schuh, Water Appropriation Division, North Dakota State Water Commission, Bismarck North Dakota

Mike T. Sauer, Environmental Health Section, North Dakota Department of Health, Bismarck, North Dakota (Until November 15, 2012)

Peter Wax, Water quality Special Projects, ND Department of Health, Bismarck, North Dakota (Since November 16, 2012)

The committee members are senior officials in the three major agencies in North Dakota responsible for much of the water resources research done outside of NDSU and UND in North Dakota.

RESEARCH PROGRAM

ANNUAL BASE GRANT (104-B)

In the past several years NDWRRI has offered competitive fellowships to NDSU and UND graduate students for research on water resources topics under a Graduate Research Fellowship (GRF) program effectively using the modest amount of the 104(B) annual base grant. The program meets the requirements of Section 104 of the Water Resources Research Act of 1984.

- The fellowship program encourages entry of young university faculty and new research scientists into the water resources field;
- provides training and education to future water resource scientists and engineers;
- promotes exploration of new ideas that address water problems or expand understanding of water quantity, quality and related phenomena; and
- engages university faculty in collaborative research programs seeking supports from entities concerned with water problems.

This year also, the NDWRRI continued the GRF program and applied bulk of the federal allotment to it. The GRF program is administrated and monitored by the director. Applications are invited from the graduate students and their advisors of the two research universities of the State, NDSU and UND. A rigorous review by the State Advisory Committee and other water professionals in the state determines the awards. Active participation of the academic advisors of the students in meeting matching requirement and seeking co-funding from local, state and other sources is another positive aspect of the program. Periodical review of the progress of the students in meeting the fellowship expectations is ensured by seeking reports from the students and by encouraging them to make presentations in local, regional, and national technical seminars and conferences.

Guidelines for the 2012-2013 Graduate Research Fellowship were posted on the Institute website in September 2011, and the request for applications was announced in the faculty news publications of the two university campuses in the last week of October.

The following is the request for application that was published on the UND and NDSU campus newsletters, and distributed by e-mail lists. September 30, 2011 Issue of It's Happening at State (NDSU Publication) carried it. An announcement similar in content was also published in the University of North Dakota campus publication University Letter.

As it appeared in Sept 30, 2011 issue of IHaS:

ND Water Resources Research Institute seeks fellowship applicants

The North Dakota Water Resources Research Institute invites 2012 Graduate Research Fellowship program applications. NDSU and University of North Dakota graduate students, who conduct or plan research in water resources, can apply for fellowships of varying duration,ranging from three months to one year. Typically, fellowship awards range from $800 to $1,000 per month for master's degree students and $1,000 to $1,400 per month for doctoral students. The fellowship funds must be applied between March 1, 2012, and Feb. 28, 2013. A technical completion report co-written by the fellow and the adviser is expected of each fellowship research project. Research proposed for fellowship support should relate to water resources issues in the state or region.

Regional, state or local collaborations or co-funding will strengthen an application. Fellowships have a matching requirement of two non-federal dollars to one federal dollar. At the time of applying, applicants should have a plan of study filed and/or a thesis research topic selected. Applications need to be prepared in consultation with advisers. The applications should be co-signed by the applicants' advisers. Students and advisers who have not met the reporting requirements of their previous fellowship projects will not be considered for funding.

General criteria used for proposal evaluation include scientific merit, originality, research related to state or region, and extent of regional, state or local collaboration and/or co-funding. A panel of state water resources professionals will review the proposals. Award announcement will be made by early January, subject to the appropriation of funds for the fiscal year 2012 program by the federal government.

For more information on the program and guidelines for preparation of applications, visit www.ndsu.edu/wrri.

Applications are due by 5 p.m., Dec. 2. Submit original and four hard copies of applications to Linda Charlton, North Dakota Water Resources Research Institute, Family Life Center (FLC 320), NDSU Dept. 2030, PO Box 6050, Fargo, ND 58108-6050 and an electronic copy in Word format to g.padmanabhan@ndsu.edu.

For additional information, contact G.Padmanabhan, professor of civil engineering, at g.padmanabhan@ndsu.edu or Linda Charlton, ITS tech coordinator, at linda.charlton@ndsu.edu.

NDWRRI GRADUATE RESEARCH FELLOWSHIPS

Fellowships ranging from $2000 to $10,000 were awarded to thirteen graduate students, ten Ph.D. and three MS, conducting research in water resources topics at NDSU and UND.
Funding for the Fellowship program comes primarily from the annual base grant and an additional support of 15 per cent of the base grant comes from the North Dakota State Water Commission. Selection of student Fellows and the award amounts were based on competitive proposals prepared by the students with the guidance of their advisers. A panel of state water resource professionals reviews the proposals and selects the Fellows and award amounts are based on the quality of proposals and the priority of the proposed projects for the state and region.

2012-13 ND WRRI Fellows, their advisers, and Fellowship research projects:

Alex Stalboerger (Fellow), Biological Sciences; Marinus Otte (adviser) Tile drain water: identification of sources and quality improvement by a constructed wetland

Anusha Balangoda, Environmental and Conservation Sciences; Wei Lin Studies of Seasonal Succession of Cyanobacteria and Green algae at Heinrich-Martin Impoundment, North Dakota

Atikur Rahman, Agriculture and Biosystems Engineering; Shafiqur Rahman Vegetative Filter Strips: A Best Management Practice (BMP) for feedlot runoff poll ution control in North Dakota

Hasin Shahad Munna, Civil Engineering (UND); Howe Lim Advancing Hydrologic Simulations and Flood Frequency Analysis of Devils Lake under Climate Change Scenarios

Jun Yang, Civil Engineering; Xuefeng Chu Toward Understanding the Hydrologic Processes on Topographic Surfaces with Depressions - Development of a Physical-based Distributed Puddle-to-Puddle (P2P) Hydrologic Model

Justin Fisher, Biological Sciences; Craig Stockwell Integrating life stage habitat into landscape genetics model for the conservation of a declining amphibian species

Kate Overmoe-Kenninger, Earth Science System and Policy (UND); Xiaodong Zhang Assessment of Water Quality in Devils Lake using Satellite Imagery

Katrin Chambers, Soil Science; Francis Casey Quantifying Estrogens Bound to Soil and Manure Colloids and Assessing Their Bioavailability

Leslie Storlie, Civil Engineering; Wei Lin Investigation of Bromate Formation in Ozone Disinfection Systems through Comprehensive Sampling, Water Quality Analysis, and Model Simulation

Michael Quamme, Civil Engineering; Achintya Bezbaruah Selenium Removal from Surface and Groundwater Using Iron Nanoparticles

Tanush Wadhawan, Civil Engineering; Eakalak Khan and John McEvoy Role of agricultural drainage on transport of Cryptosporidium oocysts in North Dakota

Veselina Valkov, Civil Engineering; Wei Lin Temporal-spatial distribution (dynamics) of phytoplankton and diversity in relation to lake physical and chemical condition

Xuelian Bai, Soil Science; Francis casey Sorption, Degradation, and Mobility of 17b-Estradiol-17-Sulfate in Agricultural Soils

Tile Drain Water: Identification of Sources and Quality Improvement by Constructed Wetland

Project Number: 2011SWC
Fellow: Alex Stalboerger
Adviser: Marinus Otte and Donna Jacob
Start Date: 3/1/2012
End Date: 2/28/2013

Publication:

Alex Stalboerger, Donna Jacob, and Marinus Otte "Sulfate Removal from Agriculture Tile Drain Water by Constructed Wetlands" presentation ND Water Quality Monitoring Council meeting, Fargo, North Dakota, February 2013

Progress:

This research project took an interesting turn between 2012 and 2013. As many North Dakotans and Midwesterners know, the 2012 summer was a dry one. This made collecting water samples from a constructed wetland physically impossible for several months during the summer due to lack of running water. But this also gave us a unique opportunity to test the constructed wetland under dry conditions. Due to the short field season that resulted from the dry weather, several greenhouse experiments were started to test properties of the constructed wetland. We are looking into soil redox potentials, binding capacity of the wetland substrate related to phosphate, sulfate removal efficiency, phosphate removal efficiency, as well as LOI, and multi-element fingerprinting of the constructed wetland substrate. Many of these projects are still in progress or their data being analyzed, however from preliminary data the constructed wetland seems to be behaving as we expected and this 2013 field season has been promising with the amount of water we have received from snow melt and precipitation.

Studies of Seasonal Succession of Cyanobacteria and Green Algae at Heinrich-Martin Impoundment, ND

Project Number: 2011ND237B
Fellow: Anusha Balangoda
Adviser: Wei Lin
Start Date: 3/1/2012
End Date: 2/28/2013

Publication:

Poster- Balangoda, A. and Lin, W. Impacts of Eutrophication on Water Quality at Heinrich-Martin Dam Impoundment, North Dakota. 2nd Annual ECS Poster Session, November 2nd, 2012.

Presentation-Balangoda, A., Valkov, V., Zhao, J., Lin, W. Seasonal Variation of Water Quality and Algal Growth in the Heinrich-Martin Dam Impoundment, North Dakota. North Dakota Water Quality Monitoring Conference, February 27-29, 2012.

Progress:

The purpose of this study was to identify population variation of cyanobacteria and green algae in relation to their growth requirements. The specific objectives were: (1) To collect water samples to determine both seasonal variation of nutrient and phytoplankton biomass (as chlorophyll *a*) and impacts of artificial aeration on nutrient variation; (2) To analyze chemical, physical, and biological data to find potential factors for N limitation and what causes for P rich condition and; (3) To analyze field data to assess effectiveness of artificial aeration.

This progress report discusses the progress I have made from February 2012 to March 2013. Water quality monitoring and water sample analyses were carried out at the Heinrich Martin Dam Impoundment, (HMD) which is located in north central Lamoure County, ND on weekly schedule at six sampling sites (Site A-closer to aeration, Site B-away from aeration, sites C and D- shallow and far from aeration, Site G- closer to inlet, and Site H-located in dead area) in the summer, 2012 under the conditions of aeration. Sampling was carried out between June 20th, 2012 and October 3rd, 2012 and water samples were analyzed for NO_3-N, NH_3-N, TN, TDN, SRP, TRP, Hydrolysable P, TP, TDP, and chlorophyll *a*. In addition, DO, DO saturation, water temperature, specific conductance, turbidity, pH, were measured on site at all locations and secchi depth was measured only at sites A-D.

Aeration has effectively eliminated the thermal stratification and showed isothermal conditions in the whole impoundment. There were no anoxic conditions observed in the impoundment and DO concentration near-bottom layers increased under the conditions of aeration. DO saturation showed the impoundment was undersaturated. Portion of DO variation could be due to changes of seasonal water temperature in respect to air temperature changes and other portion may be due to DO consumption for

degradation of organic matter in sediments. DO was varied along the water column and results indicted that consumption of O_2 near-bottom layers by microbes for organic matter decomposition. DIN concentrations were relatively low due to readily consumption by algae and total organic nitrogen (TON) represented much of the TN in the whole sampling period. Excess SRP was available in the water column while algae was growing implies that supply of more SRP from lake sediments to water column by microbial degradation of organic matter in the sediments when water temperature was increasing. In contrast, when water temperature was decreasing SRP concentrations also decreased. SRP concentration was followed the seasonal variation of temperature and, approximately 60% of SRP concentration variability could be explained by water temperature. TP concentration also varied similar to SRP and when water temperature was increasing TP concentration increased and when water temperature was decreasing TP concentration decreased in the impoundment. N and P evenly distributed along the water column indicated that either vertical mixing or sediment resuspension by aeration system in the study period. The impoundment showed a N-limiting conditions and TDIN: SRP ratio was high between June and July then ratio was low from early August to early September and again increased during rest of the sampling period. So TDIN: SRP ratio was not constant through the sampling period. There were no vertical variations of chl-*a* observed; however, chl-*a* showed spatial variations. Conductivity results showed that linear increased though the sampling period indicated that there was no external run off or any dilutions in sampling period. Therefore, increased of dissolved salts through the sampling period could be from lake sediments. Steady increased of conductivity with time showed that continuous supply of dissolved salts into the water column from lake sediments.

Vegetative Filter Strips: A Best Management Practice (BMP) for Feedlot Runoff Pollution Control in North Dakota

Project Number: 2009ND183B
Fellow: Atikur Rahman
Adviser: Shafiqur Rahman
Start Date: 3/1/2012
End Date: 2/28/2013

Publications:

Rahman, A., S. Rahman, and M.S. Borhan$^{\zeta}$. 2013. Performance evaluation of three vegetative filter strip designs for controlling feedlot runoff pollution. *Journal of Civil and Environmental Engineering* 3: 124. doi:10.4172/2165-784X.1000124

Rahman, A., S. Rahman, and L. Cihacek. 2012. Effect of pH in vegetative filter strips in reducing manure borne soluble nutrients in runoff. Presented at the 2012 ASABE Annual International Meeting Sponsored by ASABE Dallas, Texas July 29 – August 1.

Rahman, A. 2013. Vegetative filter strips for controlling feedlot runoff pollution in North Dakota. Presented at the Water Quality Monitoring Council meeting and ND-WRRI Fellowship Research Presentations. February 7, 2013, North Dakota State University, Fargo, North Dakota.

Progress:

The proposed research was a continuation of an ongoing project. The ongoing research was continued during the period of February 2012 to March 2013. An ongoing laboratory experiment was also completed in the same time. A short summary of the project progress during fellowship period is given below:

Instruments were set up in three feedlot locations in the state of North Dakota, and runoff samples were collected from the rainfall events. For all collected samples, laboratory analyses were conducted to determine total suspended solids (TSS), total solids (TS), ortho-phosphorus (ortho-P), total phosphorus (TP), ammonium-nitrogen (NH4-N), nitrate-nitrogen (NO3-N), total Kejeldahl nitrogen (TKN), pH, and electrical conductivity (EC).

All the data including previous year's research of the same project were used for statistical calculation, and the results were summarized and described in a report. A manuscript was prepared and submitted for publication in a peer reviewed journal.

The last batch of an ongoing laboratory experiment was conducted in which the effect of vegetative filter strip's soil pH in reducing soluble nutrient transport was investigated. Simulated vegetative filter strips were constructed by using galvanized iron boxes and

growing tall fescue grasses on it. Runoff experiment was conducted with manured water to investigate the effect soil pH on soluble nutrient transport reduction. Laboratory analysis of the water samples collected from the runoff experiment was conducted to determine TS, TSS, ortho-P, TP, NH4-N, NO3-N, TKN, pH, and EC. The analyzed results of samples were processed for statistical calculations. The complete data analysis of results were summarized and described in a report. Partial results of the experiment were presented in an international conference.

Advancing Hydrologic Simulations and Flood Frequency Analysis of Devils Lake under Climate Change Scenarios

Project Number: 2012SWC
Fellow: Hasin Shahad Munna
Adviser: Howe Lim
Start Date: 3/1/2012
End Date: 2/28/2013

Publication:

Conference Presentations and Proceedings:

1. Munna, H.S. (2012, May). "Development of a Temperature-based Model to Simulate Evaporative Losses over Water Bodies in Cold Regions", World Environmental and Water Resources Congress, ASCE-EWRI, Albuquerque, New Mexico.
2. Lim, Y. H., Zhang, X., Kirilenko, A., Teng, W. and Munna, H. S. (2012, May). "Flood Frequency Analysis of Devils Lake under Current and Projected Future Climates Utilizing HEC Hydrologic Models, NASA Satellite Observations and Downscaled GCM Simulations", World Env. and Water Res. Congress, ASCE-EWRI, Albuquerque, New Mexico.
3. Munna, H.S. and Lim, Y. H. (2012, May). "An Efficient Method for Predicting Evaporative Losses over Water Bodies in Cold Regions using a Temperature-Based Model", Poster Paper, World Env. and Water Res. Congress, ASCE-EWRI, Albuquerque, New Mexico.
4. Munna, H.S. and Lim, Y. H. (2010, Dec). "Coupling of HEC-HMS and HEC-ResSim in Modeling the Fluctuation of Water Level in Devils Lake Using Heterogeneous Data", Poster Paper, Abstract H43F-1324 presented at 2010 Fall Meeting, American Geophysical Union, San Francisco, California.

Seminar Presentation:

1. Seminar presentation on "Water Level Quantiles of a Terminal Lake under Future Climate Change Conditions" (2012, April) at the "Terrestrial Water Cycle Seminar", NASA's Goddard Space Flight Center, Greenbelt, Maryland.

Progress:

The research focuses in calibrating a coupled rainfall-runoff model and a reservoir model for the Devils Lake using data from both ground gage stations and NASA satellite observations. The purpose is to determine the feasibility of using spatially distributed GCM data with a well calibrated hydro-climatic model to predict the probable flood severities. A temperature-based evaporation prediction model is also developed to simulate the outflow from the terminal lake. Future hydrology of the basin and lake levels of Devils Lake are simulated using the weather samples obtained from several downscaled GCM runs under varying scenarios due to anthropogenic modifications and the resulting composition of the atmosphere. 100 traces of future water levels of the Devils Lake have been generated using the predicted temperature and precipitation by the

GCMs. The synthetic traces show a downward trend in water levels for a 30 year simulation period. The annual peak series of the synthetic traces (both stage and volume) are sorted and analyzed to obtain the probabilities and return periods of extreme flood events. The Bulletin 17B recommended LP3 method along with Gaussian/Normal, Lognormal and Gamma/Pearson type 3 distributions are applied for comparison purposes. The Log-Normal probability distribution, in both cases (stage and volume) provided with better fits. Water levels of closed-basin lakes are usually characterized by high serial dependence. The lake is already in its highest peak of the recorded history (1454 ft, spring, 2011), which is set as the base condition for the simulation of future water levels. These circumstances require the probability to be calculated both in a conditional and unconditional basis. Moreover, the probability is calculated both in terms of stage and volume, and probabilities of water levels being 1456, 1458 and 1460 ft have been reported. Considering the stage of the lake, the conditional probabilities are 0.008, 0.003 and .001 percent and the unconditional probabilities are 1.12, 0.44 and 0.189 percent respectively. By converting the stages into volumes, the conditional probabilities are 0.004, 0.002 and 0.0009 percent and the unconditional probabilities are 1.5, 0.68 and 0.31 percent respectively. These lower probability values indicate a lower chance of spilling into the Sheyenne River in the near future based on GCM predictions

Toward Understanding the Hydrologic Processes on Topographic Surfaces with Depressions - Development of a Physical-based Distributed Puddle-to-Puddle (P2P) Hydrologic Model

Project Number: 2011ND239B
Fellow: Jun Yang
Adviser: Xuefeng Chu
Start Date: 3/1/2012
End Date: 2/28/2012

Publication:

Journal Publication

Yang, J. and Chu, X., 2012. Quantification of the spatio-temporal variations in hydrologic connectivity of small-scale topographic surfaces under various rainfall conditions. Journal of Hydrology, In Revision.

Conference presentations

Yang, J. and Chu, X., 2012. Modeling of Microtopography-Controlled Hydrologic Connectivity and Overland Flow Dynamics. The 2nd Annual Engineering Research Summit, April 23, 2012, Grand Forks, ND.

Yang, J. and Chu, X., 2012. Effects of Surface Microtopography on Hydrologic Connectivity. ASCE 2012 World Environmental and Water Resources Congress, May 20-24, 2012, Albuquerque, NM.

Chu, Xuefeng and J Yang. 2012. A New Surface Delineation Approach for Characterizing Threshold-Driven Watershed Processes - Introduction to the Puddle-to-puddle (P2P) Modeling System. Fifty Years of Watershed Modeling - Past, Present and Future, Engineering Conferences International, September 24-26, 2012, Boulder, CO.

Yang, J, Bogart, D., and Chu, X., 2012. Quantification of the Spatio-temporal Variability in Threshold-controlled Overland Flow Generation Processes – A Combined Experimental and Modeling Study. AGU Fall Conference, December 3-7, 2012, San Francisco, CA.

Seminars

Yang, Jun. 2012. Quantification of the spatio-temporal variations in hydrologic connectivity of small-scale topographic surfaces under various rainfall conditions. Department of Civil Engineering, North Dakota State University.

Yang, Jun. 2013. Modeling of Microtopography-dominated Overland Flow Dynamics. Department of Civil Engineering, North Dakota State University.

Progress:

Depressions on topographic surfaces play an important role in a series of hydrologic processes. However, depressions are rarely simulated in hydrologic models to explicitly account for the spatio-temporally varying, discontinuous overland flow due to their complexity. Potholes in the Prairie Pothole Region have received increasing attention because of their important roles in water retention, flood control, groundwater recharge and discharge, and water quality management. However, hydrologic functions and behaviors of these potholes are poorly understood.

The goal of this study is to develop a state-of-the-art, physically-based puddle-to-puddle (P2P) overland flow model to simulate the spatially and temporally varied hydrologic processes associated with surface depressions and their dynamic interactions. Specific objectives of the study are: (1) to develop the P2P hydrologic model; (2) to test the P2P hydrologic model by using the data from laboratory and field overland flow experiments; (3) to apply the P2P hydrologic model to a real site selected in the Prairie Pothole Region, North Dakota; and (4) to analyze hydrologic connectivity.

The progress of this study can be summarized as follows: (1) a DEM-based overland flow model has been developed, which explicitly incorporates surface depressions in a well-delineated, cascaded P2P drainage system to facilitate the simulation of puddle filling, spilling, merging, and splitting processes. Overland flow in all puddle-dominated areas is simulated by using the diffusion wave equations, and infiltration is simulated by a modified Green-Ampt model for heterogeneous soils under varying rainfall conditions; (2) the P2P model has been tested by using the data from a set of overland flow experiments for various microtopographic, soil, and rainfall conditions; (3) two connectivity indices have been proposed to quantitatively describe hydrologic connectivity influenced by surface microtopography; and (4) the threshold behavior of potholes has been analyzed for a selected area in the Cottonwood Lake area, North Dakota.

Based on the results from this study, it has been concluded that the P2P overland flow model is capable of (1) quantifying the spatio-temporal distributions and variability of overland flow, (2) characterizing the dynamic depression filling, spilling, and merging processes, (3) simulating infiltration under various topographic surfaces, and (4) revealing the threshold behaviors and hydrologic connectivity under the influence of surface microtopography. The model also can be utilized to analyze the relationships of depression storage, surface runoff, and infiltration.

Integrating Life Stage Habitat into Landscape Genetics Model for the Conservation of a Declining Amphibian Species

Project Number: 2012SWC
Fellow: Justin Fisher
Adviser: Craig Stockwell
Start Date: 3/1/2012
End Date: 2/28/2013

Publication:

Fisher, J., K. Purcell and C. Stockwell. Survey of the Genetic Diversity of Northern Leopard Frog Populations in North Dakota. Joint Annual Meeting of the Minnesota & North Dakota Chapters of The Wildlife Society, Fargo, ND, 02/2012 **Best Student Paper Award

Fisher, J., K. Purcell and C. Stockwell. Genetic Diversity of the Northern Leopard Frog Across the 100th Meridian. 9th Annual Northern Plains Biological Symposium, Fargo, ND, 04/2012

Fisher, J., K. Purcell and C. Stockwell. Genetic Diversity of the Northern Leopard Frog Across the 100th Meridian. Society for Conservation Biology – North American Congress for Conservation Biology, Oakland, CA, 07/2012

Fisher, J., K. Purcell and C. Stockwell. Landscape Influences on Effective Population Size of Northern Leopard Frog Populations in North Dakota. 50th Annual Meeting of the North Dakota Chapter of *The Wildlife Society*, Mandan, ND, 02/2013 **Best Student Paper Award

Progress:

Focus during this period was on laboratory sample processing and data analysis. Specifically, I DNA and amplified 11 microsatellite markers via PCR (polymerase chain reaction) on an additional 12 populations of L. pipiens. This work, combined with the previous data gathered, increased the sample size up to 31 populations (930 total individuals). In addition to the lab work, genetic data were analyzed and effort to build landscape genetic models using a model selection approach was begun. Results indicate that populations are structured throughout North Dakota and that isolation by distance among pair-wise population comparisons was seen. Additionally, a strong east to west trend of decreases in population genetic measures including expected heterozygosity, allelic richness, and effective population size was evident. When radial landscape attributes were extracted in a geographical information system (GIS), a model selection

approach revealed that the number of permanent wetlands (i.e., draught refugia) and percentage of grassland carry the relative model weights and are considered the top models using Akaike's Information Criterion adjusted for small sample size (AICc). These results have been presented at four different meetings resulting in two best student paper presentations.

Assessment of Water Quality in Devils Lake using Satellite Imagery

Project Number: 2011SWC

Fellow: Kate Overmoe-Kenninger (Left the project in the middle and another student, Jiexia Wu was awarded the remaining amount with a different project)
Adviser: Xiaodong Zhang

Drought Prediction using NOAH model and GRACE observation

Fellow: Jiexia Wu
Adviser: Xiaodong Zhang
Start Date: 3/1/2012
End Date: 2/28/2013

Publication:
Presentations:

Xiaodong Zhang, Jiexia Wu, Eric Castle, Drought prediction using GRACE observation and NOAH model simulation, AGU Annual Conference, San Francisco, 3-7 December, 2012

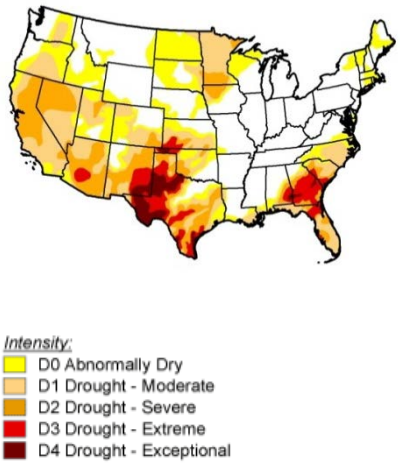
Progress:

We used NOAH Land Surface Model and Gravity Recovery and Climate Experiment (GRACE) data examining the 2010-2012 severe drought over the continental US. The NOAH model, driven by near surface meteorological "forcing" data (e.g., rainfall and downward shortwave radiation), simulates the evolution of water and energy states and fluxes in the top soil layer (2-3 m below the land surface). GRACE, measuring the Earth's gravity change, provides estimates of total terrestrial water storage (TWS). Combination of these two datasets allows estimates of monthly moisture dynamics in both top soil and groundwater layers at a spatial resolution of 1°×1° grid (latitude and longitude). During the period from 1 March 2012 to 28 February 2013, we examined the 2011-2012 severe drought over the continental US using the two datasets. The drought at surface soil layer and at groundwater level was evaluated using NOAH soil moisture and GRACE TWS, respectively, based on an agricultural drought index that is similar to the Palmer Drought Severity Index but based on soil moisture. The figure above show the drought condition in March (1st row), April (2nd) and May (3rd) of 2012 as reported by U.S. Drought Monitor and by our results of the Soil Moisture Deficit Index (SMDI) for surface soil and the Total Storage Deficit Index (TSDI) for ground water.
The distribution of SMDI matched closely the actual drought conditions reported by the U.S. Drought Monitor. Note that U.S. Drought Monitor only shows drought condition,

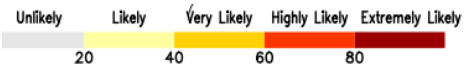
while the greenish color in our index indicates the wet conditions. What's interesting is the total storage deficit index from GRACE satellite. As indicated by TSDI, the water shortage in the deeper soil (including ground water) was much wider spread than the surface soil, extending almost entire southern part of US. The deep water deficit was also observed in Minnesota-Wisconsin region. In the northwest, both surface and deeper water are in surplus, which in the northeast, the deeper soil is wetter, but the top soil is drier in these three months. These data suggest that the drought that occurred in New Mexico-Texas region and in Minnesota may have been going on for a while, where the water in the deeper soil has already depleted.

We also developed a prognostic model for predicting droughts. The following figure shows the probability of drought predicted for March 2012 with one month lead time based on our model and its comparison with Princeton University's model. While the overall distribution of drought probability is similar between the two, the notable difference is for New Mexico and Texas.

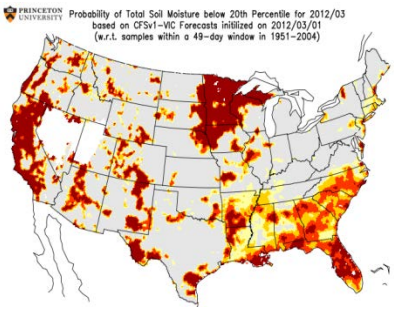
U.S. Drought Monitor Mar, 2012



Probability of drought for Mar. 2012 based on our model.



Probability of drought for Mar. 2012 based on Princeton University's model



Quantifying Estrogens Bound to Soil and Manure Colloids and Assessing Their Bioavailability

Project Number: 2011ND242B
Fellow: Katrina Chambers
Adviser: Francis Xavier McKeon Casey
Start Date: 3/1/2012
End Date: 2/28/2013

Publication:

Casey, F.X.M., S. Shrestha, X. Bai, K. Chambers and H. Hakk. 2012. Role of Conjugates in the Fate and Transport of Steroid Hormones. In Annual Meetings Abstracts [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

Progress:

The natural estrogen, 17ß-Estradiol (E2), is the most potent endocrine disrupting compound, where part per trillion concentrations can induce reproductive abnormalities in sensitive organisms. Estradiol is frequently detected in the environment at concentrations that could impact water quality. Estrogenic hormones will preferentially associate with dissolved (DOC) and colloidal (COC) organic carbon in soil and sediments, playing a significant role in the fate and transport of E2. Field studies have found significant correlations between estrogen detections and DOC and COC in soil leachate and river water. Although the association of E2 with DOC/COC can potentially facilitate its transport and persistence it is also important to identify whether the DOC/COC affects estrogen's toxicological effects. The purpose of this study is to evaluate if E2 bound to DOC/COC is of concern to organisms in the environment. The bioavailability of estradiol bound to DOC/COC will be assessed using estrogen receptor competitive assays, which will be used as analogues to measure hormone receptor binding strength

Project Objectives are:

1. Evaluate the association of radiolabeled estradiol with the both the DOC and COC fraction derived from liquid swine manure, soil and liquid swine manure applied to soil
2. Simulate rainfall events to investigate the dislodgment of radiolabeled estradiol from the COC fraction
3. Evaluate the estrogen potency of estradiol bound to the DOC/COC, DOC and COC fraction using estrogen receptor competitive assays.

Results:

- E2 Association/Dissociation with COC: The results from the ultrafiltration of the swine lagoon manure spiked with radiolabeled E2 show that E2 is associated with

COC partials and that E2 can be dislodged from the COC particles when rinsed with water. The environmental implication of these finding is that E2 can "hitch-hike" on COC partial to be distributed in the environment and be dislodged potentially as free estradiol.

- E2 Bound to COC is Characteristic of a Particulate: Reverse and normal phase Thin Layer Chromatography (TLC) has been done on the COC fraction of liquid swine manure. The result show that the radiolabelled E2 bound associated with the COC fraction does not behave like a molecule but more as a particle. Specifically, the COC fraction did not respond to chromatographic separation because the radioactivity stayed at the origin of both the normal and reverse phase TLC. This indicates that the 14C-E2 associated with the COC is acting like a particle and not like a molecule.
- E2 Bound to COC is Bioavailable: The results from the Estrogen Receptor (ER) competitive –binding assays show that there is an estrogen response induced by the E2 associated with the COC fraction. These result indicated that estradiol bound to COC still has endocrine disrupting properties and can potentially cause adverse effects to aquatic organisms. The estrogen response from the COC rinses mimics the response of the radiolabeled estradiol experiments. This indicates that estradiol can be carried by COC particles but is loosely bound and can be released into the environment as free estradiol.

Investigation of Bromate Formation in Ozone Disinfection Systems through Comprehensive Sampling, Water Quality Analysis, and Model Simulation

Project Number: 2012
Fellow: Leslie Storlie
Adviser: Wei Lin
Start Date: 3/1/2012
End Date: 2/28/2013

Publication:

1. 2012 MN AWWA Fresh Ideas Poster Competition, "An Investigation into Bromate Formation in the Ozone Disinfection Process", second place, Duluth, MN, September 20th, 2012.
2. 2012 ND WPCC Fresh Ideas Poster Competition, "An Investigation into Bromate Formation in the Ozone Disinfection Process", first place, Minot, ND, October 17th, 2012.
3. 2013 AWWA ACE National Poster Competition, "An Investigation into Bromate Formation in the Ozone Disinfection Process", pending, Denver, CO, June 10th-13th, 2013.

Progress:

Historically, the primary additive used to disinfect drinking water has been chlorine. Recently however, the use of ozone as a disinfection agent has become popular due to its reactive disinfection properties and subsequent reduction of chlorine disinfection byproducts. Due to ozone's high oxidation potential it has the ability to not only disinfect drinking water but also remove inorganic and natural organic substances making it an option for disinfection as well as taste and odor control. The Moorhead Water Treatment Plant (WTP) in Moorhead, MN uses ozone in the disinfection process to remove taste and odor compounds from the Red River of the North as well as meet primary disinfection requirements. Unfortunately, ozone has the potential of oxidizing bromide, which is found naturally in many water sources, to bromate. Bromate has been classified as a possible carcinogen by the EPA and has been given a maximum contaminant level (MCL) of 10 ppb. Knowledge on bromate formation in water treatment plants is limited as many municipalities do not have the capability to test for bromate at low concentrations. Also, most published studies were conducted using bench or pilot scale systems with pH values of 6-8. However, the Moorhead WTP is a 10 MGD facility with a pH during disinfection of 9-11 providing for a unique perspective on bromate formation. To better understand bromate formation in full-scale water treatment systems, a comprehensive study was carried out at the Moorhead WTP in 2012. Bromide concentrations in all source waters, both groundwater and surface water, were monitored determining that the groundwater sources contained more bromide than the surface water source. Water samples from different locations in the ozone chambers were collected and analyzed for bromate and other water quality characteristics. Bromate concentrations were found throughout the ozone chamber and proved to be a valid concern for the facility. Bromate formation was

found to be affected by both influent bromide concentrations and operational conditions at the treatment plant. Results indicate that bromate formation was increased by increases in pH, bromide, and ozone dose during times of high temperatures and was decreased by increases in organics. The impact of the bromate influential parameters was minimized at low temperatures. It was also observed that better operational controls need to be developed to minimize bromate formation at the Moorhead WTP. To assist the facility on developing bromate control strategies, a modeling approach was adopted to predict bromate formation at various operational conditions using temperature, pH, ozone dose, bromide, and TOC. The simplicity of the model will allow it to be implemented into the Moorhead WTP SCADA system to provide for "real-time" prediction of bromate formation and allow the treatment facility to minimize bromate formation.

Selenium Removal from Surface and Groundwater Using Iron Nanoparticles

Project Number: 2012SWC
Fellow: Michael Quamme
Adviser: Achintya Bezbaruah
Start Date: 3/1/2012
End Date: 2/28/2013

Publication:

Patents:

1. Almeelbi T., Quamme M., Bezbaruah A.N. Aqueous Phosphate Removal using Iron Cross-lined Alginate, Patent Filed, (RFT-419A), 2012.

2. Almeelbi, T., Quamme, M, Khan, E., Bezbaruah, A.N. Selenium Removal from Surface Waters: Exploratory Research with Iron Nanoparticles, Patent Filed, (RFT-419B), 2012

Conference Papers:

Quamme, M., Almeelbi, T., Bezbaruah, A.N. Selenium Removal from Surface Waters: Exploratory Research with Iron Nanoparticles, World Environmental & Water Resources congress, Albuquerque, NM, May, 2012.

Bezbaruah, A.N., Erickson, H., Dobervich, E., Laux, J., Varholdt, J., Gehlhar, A., Weber, M., Kalita, H., Almeelbi, T., Quamme, M.,Pate, M., Hossain, M.E., Grosz, A., Pergande, M. Sustainability and Nanotechnology Education in K-12: Hands-on Teaching Modules for Middle School Students and Summer Research Experience for High School Students, World Environmental & Water Resources congress, Cincinnati, OH, May, 2013.

Quamme, M., Feist, B., Bezbaruah, A.N. Entrapment of Iron Nanoparticles in Alginate Beads for Aqueous Selenium Removal, World Environmental & Water Resources congress, Cincinnati, OH, May, 2013.

Progress:

Project completed.

Bare NZVI reduced Se (10 mg/L) by 99% in ~2 h. The Ca-alginate entrapped NZVI achieved a slower yet effective removal (> 85% in 12 h). Comparison of the intitial first-order observed reaction rate constants show there is a statistically insignificant difference ($\alpha = 0.05$, $p = 0.44$). The adsorption data was found to best fit the Freundlich adsorption isotherm model with $R2 = 0.974$.

Selenium removal by NZVI in the presence of Cl-, SO42-, PO43- and As5+ was investigated, and statistically insignificant effects were observed in the presence of Cl-, SO42-, As5+ and low concentrations of PO43-, while high concentrations of PO43- had a statistically significant effect on Se removal.

Reuses of the spent (used for Se removal) NZVI particles were also explored. The Se and NZVI uptake studies by spinach (Spinacia oleracea) indicated that Se and iron (from spent NZVI) were up taken by plants.

Role of agricultural drainage on transport of Cryptosporidium oocysts in North Dakota

Project Number: 2012ND
Fellow: Tanush Wadhawan
Adviser: Eakalak Khan and John McEvoy
Start Date: 3/1/2012
End Date: 2/28/2013

Publication:

Wadhawan, T., Kasi, M., McEvoy, J., Chu, M., Khan, E. 2012. Investigating transport of Cryptosporidium under snowmelt conditions. World Environmental and Water Resources Congress. Albuquerque, New Mexico, USA.

Wadhawan, T., Kasi, M., Chu, M., Khan, E., McEvoy, J. 2012. Bench-scale rainfall and snowfall simulations to understand Cryptosporidium parvum transport in subsurface groundwater regimes. IV International Giardia and Cryptosporidium Conference, Wellington, New Zealand.

Progress:

Cryptosporidium is an infective protozoan which is one of the most important contaminants found in drinking water and is associated with a high risk of waterborne illness. The mechanism of Cryptosporidium transport in the environment remains poorly understood. Cattle and other livestock are reservoirs of human pathogenic Cryptosporidium species. Application of liquid manure to fields is a common practice in many North American farm operations. Surface runoff from agricultural fields and animal facilities contain Cryptosporidium which pose a health hazard for animals and humans. Cryptosporidium has been identifies to be prevalent in the Red River and its tributaries. The prevalence of Cryptosporidium in North Dakota and their high potency to infect humans requires us to understand transport of Cryptosporidium into surface waters during spring thaw. This information will help in risk assessment and development of control practices.

The effects of two precipitation conditions with varying intensities and durations on Cryptosporidium parvum transport were investigated. The experiments were performed in a soil box with a surface area of 172 cm2. Chloride tracer or C. parvum was applied to the surface of a saturated soil box. Rainfall intensities of 2.5 and 5 cm/h for 1 h duration were simulated using a syringe pump. Conditions were chosen to represent 1 and 10 year rainfall events for Fargo, North Dakota, USA. To simulate snowmelt, the saturated soil box was kept at -20℃ for 24 h, after which 200 g of ice (~116 mL of water) was applied. Two subsurface groundwater regimes drained the soil box using a drain tile or a small outlet. Both regimes were studied with and without the overland flow. Cryptosporidium was quantified using immunofluorescence microscopy. Our data show that none of the precipitation events could completely drain chloride or C. parvum. The numbers of C. parvum in the effluent varied from 5% to 50% of the influent. This study provides insight into the transport of Cryptosporidium under varying precipitation and subsurface flow

conditions. The results generated are useful for understanding the transport of cryptosporidium under different groundwater regimes and different precipitation conditions. This information can be used by researchers and practitioners in understanding transport of Cryptosporidium.

Temporal-spatial distribution (dynamics) of phytoplankton and diversity in relation to lake physical and chemical condition

Project Number: 2012ND244B
Fellow: Veselina Valkov
Adviser: Wei Lin
Start Date: 3/1/2012
End Date: 2/28/2013

Publication:

Veselina Valkov "Temporal-spatial distribution (dynamics) of phytoplankton and diversity in relation to lake physical and chemical condition" poster presentation at presentation at ECS Poster Session and Recruiting Fair, Fargo, North Dakota 2012

Veselina Valkov "Cyanobacteria bloom and collapse in an eutrophic lake" presentation ND Water Quality Monitoring Council meeting, Fargo, North Dakota, February 2013

Veselina Valkov "The effect of artificial aeration on phytoplankton growth in a small eutrophic lake in North Dakota" presentation at River Watch Spring Workshop, Kathryn, North Dakota, April 2013

Progress:

Artificial aeration has been used to increase dissolved oxygen concentrations in eutrophic lakes and has been adopted as a method to control algal blooms, especially those of Cyanobacteria. The aim of this study is to examine the effects of artificial desertification on Cyanobacteria growth through changing the nutrient availability.

To investigate the effect of artificial aeration on phytoplankton biomass and population structure, water samples were taken periodically in the growing seasons of 2010 and 2011 from desigated sites in an artificially-aerated eutrophic lake located in LaMore County, ND. In 2012, the sampling continued and two new sampling sites were added in very shallow parts of the lake. Changes in phytoplankton biomass were estimated by photosynthetic pigment, chlorophyll a (Chla). The relative abundance phytoplankton population was detected through species identification. In addition, field measurements of water temperature, DO, pH, conductivity and nutrient (nitrogen and phosphorus) concentrations water samples were also taken to identify how a change in nutrient concentration impact the seasonality of phytoplankton.

During 2010, 2011 and 2012, eight classes of phytoplankton were identified. Although, Cyanobacteria were expected to thrive at a low Total dissolved Inorganic nitrogen (TDIN):Soluble Reactive Phosphorus(SRP) ratio, they did not dominate in 2010. Instead, in June 2010 and 2011, diatoms out competed the other microalgae. In July 2011, however, diatoms were succeeded by the Cyanobacteria nitrogen-fixing species,

Aphanizomenon sp. and Anabaena sp. The dominant species Aphanizomenon sp. formed flattened aggregates 1-20 cm in length and diameter, and each comprised of tens to hundreds of filaments. The aeration did not reduced growth of n-fixing species. In 2012 earlier than in 2011, when aeration did not worked properly, the Aphanizomenon sp also bloom was observed, but aggregates were not detected. When the aeration was stopped on July 13, 2011 and did not worked properly in the beginning of 2012 we observed weak stratification. During that period, the nutrient rich bottom waters were separated from the surface layer and nutrient were no longer available for phytoplankton growth. However, accumulation of nutrients in the hipolimnion indicated that the sediments are the main source of nutrients for phytoplankton growth. The development of bloom was associated with low TDIN:SRP ratio and ability of Aphanizomenon to fix N2 from the atmosphere. Stopping the aeration limited both phosphorus and nitrogen availability for Aphanizomenon growth. Aggregates disintegrated in separate filaments and accumulated on the surface indicated that organism is stressed. After two weeks without aeration, TDIN and SRP availability declined, which contributed to the bloom collapse.

Sorption, Degradation, and Mobility of 17b-Estradiol-17-Sulfate in Agricultural Soils

Project Number: 2012ND243B
Fellow: Xuelian Bai
Adviser: Francis Casey
Start Date: 3/1/2012
End Date: 2/28/2013

Publication:

Bai, X., F.X.M. Casey, H. Hakk, T.M. DeSutter, P.G. Oduor, E. Khan. 2013. Dissipation and transformation of 17 -estradiol-17-sulfate in soil-water systems. Journal of Hazardous Materials. (Accepted)

Progress:

Naturally occurring estrogenic hormones are endocrine disrupting chemicals (EDCs) that can cause adverse effects to reproduction system of aquatic wildlife. Considerable amounts of animal manure-borne estrogens are found in their conjugated forms, which can hydrolyze to release free estrogens in the environment. The sulfate conjugated estrogen, 17β-estradiol-17sulfate (E2-17S), has been detected in animal manure and surface runoff near agricultural fields with manure application. In this study, the fate and persistence of radiolabelled E2-17S were investigated using batch experiments in non-sterile and sterile soils.

The radiolabelled E2-17S was synthesized in-house before conducting experiments. The experimental results showed that E2-17S dissipated more quickly in the aqueous phase of the topsoil compared to the subsoil under both non-sterile and sterile conditions, which demonstrated that soil organic carbon played a significant role. The major transformation pathway for E2-17S in the aqueous phase was hydroxylation, yielding mono- and di-hydroxy-E2-17S (OH-E2-17S and diOH-E2-17S) in soils. Free estrogens, E2 and E1, were observed at low concentrations (~1% of applied dose) on the sorbed phase, indicating that deconjugation/hydrolysis and oxidation occurred, but to a very low extent. These results also illustrated that E2-17S could undergo both biotic and abiotic transformation pathways. Nonetheless, E2-17S cannot be excluded as a precursor of free estrogens in the environment, although it may not be a major contributor of the frequently detected free estrogens in the environment. Freundlich isotherms provided highly non-linear sorption of E2-17S in all soils with moderate sorption affinities.

During the WRRI fellowship period, the experimental data were interpreted and a one-site kinetic, first-order model was applied to simulate the coupled sorption and transformation of E2-17S in the various soil-water systems. A global optimization

method was used to estimate the parameters of the non-equilibrium model. The model provided good description of the measured data for the parent and metabolite compounds in the aqueous, reversibly sorbed, and irreversibly sorbed phase. The estimated parameters were of relatively high confidence and uniqueness. All publications are in-process and in preparation. Two manuscripts were submitted to peer-reviewed journals, one of which was accepted.

Information Transfer Program Introduction

Information dissemination is done through an annual newsletter, and presentations and publications by grant and fellowship recipients. A web site also helps disseminating institute research information. The institute's website address is http://www.ndsu.edu/wrri.
Past newsletters can be accessed through the institute web site. Technical reports of Fellowship projects authored by the Fellows and advisers are also placed on the institute web site.

Information Dissemination and Communication

Project Number: 2012ND233B
Start Date: 3/1/2012
End Date: 2/28/2013
Principal Investigator: G. Padmanabhan

Activities to disseminate institute and other research under this project included:

1. Maintaining a web site
2. Publishing a newsletter
3. Publication of Fellowship and other research done through the Institute
4. Presentation of research results to state and federal water agencies
5. Sponsor or co-sponsor local or regional conferences

The website of the Institute was updated at least quarterly, and more often when a research project wished to provide updates or when a Fellow graduates. The website provides additional details on the research. The list of Institute Affiliate Faculty with their expertise was updated. Research reports published by the institute were placed on this web site as and when they became available. The institute web site is: http://www.ndsu.edu/wrri.

The Institute continued its annual newsletter, which highlighted the graduate research fellowship program, the research grants associated with it, and general summaries of ongoing research. The newsletter profiled institute research and researchers and published other newsworthy water issues in the State.

The Institute also continued its efforts to enhance communication between the State and Federal agency personnel and university faculty and students. Advisors and fellows presented their research results to State and Federal professionals in Bismarck. The Institute also encouraged its Fellows and faculty to attend seminars and conferences held in the region. Modest support for travel was provided by the institute whenever appropriate.

The Institute continued to work toward establishing the Institute as a clearinghouse for information on water resources research expertise of faculty and staff at NDSU and UND.

NDWRRI sponsored the 3rd Annual Distinguished Water Seminar

The 3rd Annual Distinguished Water Seminar was held on October 22, 2012 at NDSU campus open to faculty and students of NDSU and UND and the public. Dr. Donald Rosenberry, U.S. Geological Survey, National Research Program in Denver, Colorado conducted the seminar titled, " The importance of groundwater to lakes, wetlands, and streams: New methods, new understanding, and the societal relevance of research at the sediment-water interface." The talk was co-sponsored by the departments of Civil Engineering, Agricultural and Biological Engineering, Geosciences, the Environmental and Conservation Sciences program, and the School of Natural Resources Sciences, all of North Dakota State University. The seminar is the third of the annual Distinguished Water Seminar series by eminent water professionals on emerging issues, challenges and new research directions in water resources.

Abstract: The concept that groundwater and surface water are actually one resource, linked at the sediment-water interface of lakes, wetlands, and streams, is now widely accepted by water-resource scientists and managers alike. Recent improvements in tools and measurement resolution have led to better understanding of the physical, geochemical, and biological processes that occur at this important ecotone, but this research is not just the esoteric pursuit of scientists. These processes and linkages are directly relevant to the public, particularly when they affect property values or endangered species. Examples from out-of-control wetlands and lakes in North Dakota and Minnesota, to highly controlled lakes and rivers in Washington, California, Pennsylvania, and New Hampshire, will illustrate the dynamic nature of this interface and how the public is affected, sometimes greatly, by the linkage between groundwater and surface water.

Following the seminar, students and faculty had opportunity to interact with Dr. Rosenberry.

Dr. Xuefeng Chu of Civil Engineering department, NDSU, organized the seminar.

NATIONAL COMPETITIVE PROGRAM (104-G)

Two proposals were submitted; but were not funded:

Comprehensive Investigation of Hydroclimatic Changes in the North Central United States by Wei Lin, Peter Odour, and Karen Ryberg of Civil Engineering, Geosciences, Environmental and Conservation Sciences respectively, North Dakota State University

.

Impacts of Land-use Change on Environmental and Water Quality in the James River Basin: Predicting Economic and Physical Outcomes for Efficient Policy Making by Robert Hearne and Zhulu Lin, Agricultural Economics and Agribusiness, North Dakota State University

Institute Publications

Technical Report No: ND12-01
ECOSYSTEM SERVICES AND WETLAND CONDITION ASSESSMENT IN THE PRAIRIE POTHOLE REGION
Lindsey M. Meyers, Edward S. DeKeyser, and Jack E. Norland

Technical Report No: ND12-02
REFERENCE EVAPOTRANSPIRATION AND ACTUAL EVAPOTRANSPIRATION MEASUREMENTS IN NORTH DAKOTA
Ishara Rijal and Xinhua Jia

Technical Report No: ND12-03
FATE OF BIODEGRADABLE DISSOLVED ORGANIC NITROGEN IN FARGO WASTEWATER
Halis Simsek and Eakalak Khan

Technical Report No: ND12-04
TECHNIQUES OF ASSESSING CHANGES IN RIVER FLOODING PATTERNS IN THE UPPER MIDWEST
Kyle Hafliger and Yeo Howe Lim

Technical Report No: ND12-05
MULTI_ELEMENT FINGERPRINTING OF RIVER SEDIMENTS TO IDENTIFY DIFFUSE POLLUTION SOURCES
Dimuthu Wijeyaratne and Marinus Otte

Technical Report No: ND12-06
DEVELOPMENT OF FE-GAC ADSORBENT FOR ARSENIC REMOVAL
Qigang Chang and Wei Lin

Technical Report No: ND12-07
SOURCE TRACKING OF CRYPTOSPORIDIUM IN THE RED RIVER VALLEY
Brianna L.S. Stenger, Mark E. Clark, John M. McEvoy

Technical Report No: ND12-08
ALGINATE ENCAPSULATED NANOPARTICLE-MICROORGANISM SYSTEM FOR TRICHLOROETHYLENE REMEDIATION
Sai Sharanya Shanbhogue and Achintya N. Bezbaruah

THESES AND DISSERTATIONS

Katrin Chambers, M.S. in Soil Science, graduated in March 2013
Adviser: Francis Casey

Bioavailability of 17β -Estradiol Associated with Soil and Manure Colloidal and Dissolved Fractions.

Abstract:

Steroidal estrogens in the environment exert toxicological effects at very low concentrations. Furthermore, dissolved (DF) and colloidal fractions (CF) of soil and manure play an important role in the environmental fate and transport of steroidal estrogens. One objective of this study was to quantify the association of the natural estrogen,17β-estradiol (E2), with the DF and CF isolated from liquid swine manure (LSM), Soil, and Soil and LSM mixtures (Soil+LSM). The appropriate CF and DF size fractions of the Soil, Soil+LSM, and LSM materials were obtained by first filtering through a 0.45 µm filter, which provided the combined DF and CF (DF/CF). The DF/CF from the three media were spiked with radiolabelled 17β-estradiol (14C-E2) at two concentrations. Ultrafiltration of the DF/CF was used to isolate the CF (<0.45 µm and > 1 kDa) from the DF (<1 kDa) and 14C-E2 recoveries were measured for each size fractions. The average amounts of applied 14C-E2 recovered in the DF were 67%-72% 67%-79%, and 76%-78% for the Soil, Soil+LSM, and LSM, respectively; indicating E2 preferred to associate with the dissolved rather than the colloidal fractions of the Soil and LSM materials. Additionally, the colloidal material and its associated 14C-E2 that were retained on the 1 kDa filter were washed three times with water, and the organic carbon (OC) and 14C-E2 in each rinse were measured for all three media. These water rinses suggested that the Soil colloids held the E2 more strongly compared to the LSM; although, the total E2 on the CF was significantly lower compared to the DF. The second objective of this study was to evaluate whether the E2 associated with the DF/CF, DF, and CF of the various media could induce an estrogenic response. Estrogenicity was assessed using an E2 receptor (ER) competitor assay, which provided E2 equivalent concentration (EEQ) of DF/CF, DF and CF solutions created from the Soil, Soil+LSM, and LSM. The EEQ of these solutions were also assed for antecedent EEQ values and for EEQ values after the solutions were spiked with nonradioactive E2 (19.0 pg L-1). All media fractions examined demonstrated the ability to compete with the fluorescent ligand for the estrogen receptor binding sites but the bioavailability of E2 was reduced in the CF of the Soil and Soil+LSM medias and all fractions of the LSM media.

Chase Christenson, defended his thesis successfully, M.S. in Geology and Geological Engineering
Adviser: Scott Korom

Denitrification, the microbial reduction of nitrate (NO3-) in groundwater, has three requirements: limited oxygen, bacteria capable of mediating the reaction, and electron donors for the bacteria to use in the redox reactions. The critical factor for aquifer denitrification is the concentrations of electron donors. Without an adequate supply of electron donors, bacteria cannot reduce concentrations of either oxygen or NO3-. Artificial drainage within agricultural areas may allow contaminants to bypass, or increase conveyance through, reduced areas in which denitrification is likely to occur. This contributes to elevated NO3- yields as it is discharged directly into surface water. Depending on site geology, however, bacterial biofilms capable of NO3- reduction may cultivate within the tile drainage. This study aims to quantify and compare the potential for denitrification, as well as denitrification rates, within tile drainage and aquifer sediments at the Best Management Practices (BMP) site, within the Oakes Irrigation Test Area (OITA) near Oakes, North Dakota.

For the aquifer sediment study, sediment samples (n=43) were collected from 10 locations at the BMP site. All samples were analyzed for the following potential electron donors: organic carbon, ferrous iron, manganese, and inorganic sulfide. A subset of samples was analyzed for organic sulfur, but all were below detection limits (<0.01%). Samples were also analyzed for texture and color. For the subsurface drainage study, a nutrient tracer test was conducted within a drain tile transect at the BMP site. Sediment samples (n=6) from the gravel pack surrounding the tile drains were analyzed in the same manner as the aquifer sediments.

The major finding was that the biofilm accumulation within the gravel pack surrounding the tile drains contains adequate electron donor concentrations. However, when compared with denitrification rates occurring in the aquifer sediments, the tracer test in the drain tile produced no observable denitrification. Secondary findings indicated that electron donors are correlated with one another and electron donor concentrations are inversely correlated with grain size in the aquifer sediments.

Michael Quamme, M.S. in Environmental Engineering, graduated in May 2013
Adviser: Achintya Bezbaruah

Utilization of Nanoscale Zero-Valent Iron for the Removal of Selenium from Aqueous Environments

Abstract:

Selenium (Se) is a naturally occurring element in the environment that is a vital micronutrient but can be toxic for humans and wildlife at concentrations as low as 10 μg L-1. Of the remediation technologies available today, zero-valent iron is one of the most commonly used. Nanoscale zero-valent iron (NZVI) offers improvement over bulk iron with its increased reactivity and high surface area. It is the intent of this work to examine the efficacy of using NZVI for the remediation of Se from aqueous environments. In this study, bare NZVI particles and NZVI entrapped in calcium alginate beads were tested for the remediation of selenium (Se) in aqueous solution.

Iron nanoparticles were synthesized by the sodium borohydride reduction method and characterized using transmission electron microscopy and X-ray diffraction. Synthesized particles had an average diameter of 15.79 ± 4.38 nm and a theoretical specific surface area of 47.6 m^2 g^{-1}.

Bare NZVI reduced Se (10 mg/L) by 99% in ~2 h. The Ca-alginate entrapped NZVI achieved a slower yet effective removal (> 85% in 12 h). Comparison of the intitial first-order observed reaction rate constants show there is a statistically insignificant difference ($\alpha = 0.05$, $p = 0.44$). The adsorption data was found to best fit the Freundlich adsorption isotherm model with R2 = 0.974.

Selenium removal by NZVI in the presence of Cl-, SO42-, PO43- and As5+ was investigated, and statistically insignificant effects were observed in the presence of Cl-, SO42-, As5+ and low concentrations of PO43-, while high concentrations of PO43- had a statistically significant effect on Se removal.

Reuses of the spent (used for Se removal) NZVI particles were also explored. The Se and NZVI uptake studies by spinach (Spinacia oleracea) indicated that Se and iron (from spent NZVI) were up taken by plants.

Atikur Rahman, Ph.D. in Ag and Biosystem Engineering, graduated in March 2013
Adviser: Shafiqur Rahman

Vegetative Filter Strips: A Best Management Practice (BMP) for feedlot runoff pollution control in North Dakota

Abstract:

Runoff from animal feeding operations is a major source of surface and groundwater pollution. Vegetative filter strips (VFS) are effective ways to reduce such nonpoint source pollution. In this study, vegetative filter strips with different designs, climatic and management conditions were evaluated, which were installed at different locations of North Dakota. Runoff samples were collected from inflow (before entering VFS) and outflow (after exiting the VFS) locations using automatic samplers. Collected samples were analyzed for pH, electrical conductivity (EC), total solids (TSS), total suspended solids (TSS), total phosphorus (TP), ortho-phosphorus (ortho-P), ammonium nitrogen (NH4-N), nitrate nitrogen (NO3-N), total Kjeldahl nitrogen (TKN), total nitrogen, and potassium. Comparing results between inflow and outflow, it was observed that vegetative filter strips were effective in reducing sediment and nutrient transport. Transport reduction ranged from very low to 100%. Sediment and sediment bound nutrients were effectively removed. Soluble pollutants were not as effectively reduced as sediment bound pollutants. Comparing performance of three VFS systems with different design parameters showed that filter with longer length was more effective in reducing transport sediments and nutrients. Broad leaf cattails (Typha latifolia) which had dense leaves and stems were an important factor for effective VFS performance than mixed grasses. For some rainfall events, VFS systems were zero discharged systems when soil moisture was very low thereby pollutants discharge downstream was completely minimized.

Vegetative filter strips are not as effective in reducing transport of soluble nutrients as sediment and sediment bound nutrients as observed from many other previous studies. An attempt was made by varying the VFS soil pH in a broader range to investigate if pH would have any effect on reducing transport of soluble nutrients from manure borne runoff. Soil was treated with calcium carbonate to adjust pH at 5.5 to 6.5 (T1), 6.5 to 7.5 (T2), and 7.5 to 8.5 (T3). Soil was packed into galvanized metal boxes of dimensions 2.44×0.5×0.25 m and seeded with tall fescue (Festuca arundinacea Schreb.) to simulate vegetative filter strips. Boxes were placed in the open environment at 3% slope. Runoff experiments were conducted with manure water solution which was prepared diluting manure with tap water. Peristaltic pump was used to apply water at 1.45 L per minute and inflow and outflow samples were collected. Leachate samples were also collected. Samples were analyzed for sediments and nutrient contents. It was observed from the study that highest ortho-P transport reduction was observed in higher pH range (T3) and was 42.4% from a 2.44 m VFS. The highest NH4-N concentration reductions were 26.1% at 6.5 to 7.5 pH range. A potassium transport reduction was the highest in 7.5 to 8.5 pH range. Surface transport of nitrate nitrogen seems not affected by VFS but reductions were 100% for all pH ranges. Leaching of NO3-N at higher pH was observed, which

indicated potential of groundwater pollution from the soil with higher pH. As an amendment to increase soil pH and thereby reducing transport of soluble nutrient by using calcium carbonate showed promise.

In an attempt to establish VFS as an alternative to baseline technologies, a model is needed to develop to accurately describe the performance of VFSs. A model was developed to predict the sediment, sediment bound phosphorus, and dissolved phosphorus from the feedlot and to predict trapping efficiency of sediment, sediment bound P, and dissolved P from VFS. Two procedures were coded into FORTRAN and added into existing VFSMOD model. The model was calibrated and validated using field data. Calculated highest average prediction accuracies were -45.8%, 37.5%, and 2.59% for predicting TSS, sediment bound P, and dissolved P, respectively. Similarly, for trapping efficiency prediction, highest accuracies were 76.2%, -29.4%, and 21.4% for TSS, sediment bound P, and dissolved P, respectively. Due to limited data points and difficulties in measuring runoff volume, the model appears to be under or over predicting. In the future, model predictability may be improved by accurately measuring runoff volume and carefully selecting other input parameters.

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Fate and characteristics of dissolved organic nitrogen through wastewater treatment systems

Abstract:

Dissolved organic nitrogen (DON) represents a significant portion (25-80%) of total dissolved nitrogen in the final effluent of wastewater treatment plants (WWTPs). DON in treated wastewater, once degraded, causes oxygen depletion and/or eutrophication in receiving waters and should be reduced prior to discharge. Biodegradability, bioavailability, and photodegradability are important characteristics of wastewater derived DON and are subjects of research in this dissertation.

Four research tasks were performed. In the first task, laboratory-scale chemostat experiments were conducted to examine whether solids retention time (SRT) could be used to control DON and biodegradable DON (BDON) in treated wastewater. Nine different SRTs from 0.3 to 13 were studied. There was no correlation between effluent DON and SRTs. However, BDONs at SRTs of 0.3 to 4 days were comparable and had a decreasing trend with SRTs after that. These results indicate the benefit of high SRTs in term of producing effluent with less BDON.

The second task was a comprehensive year-round data collection to study the fate of DON and BDON through the treatment train of a trickling filter (TF) WWTP. The plant removed substantial amounts of DON (62%) and BDON (76%) mainly through the biological process. However, the discharged concentrations in the effluent were still high enough to be critical for a stringent total nitrogen discharge limit (below 5 mg-N/L).

Evolution of bioavailable DON (ABDON) along the treatment trains of activated sludge (AS) and TF WWTPs and relationship between ABDON and BDON were examined in the third task. ABDON exerted from a combination of bacteria and algae inocula was higher than algae inoculated ABDON and bacteria inoculated BDON suggesting the use of algae as a treatment organism along with bacteria to minimize effluent DON. The TF and AS WWTPs removed 88% and 64% of ABDON, respectively.

In the last task, photodegradable DON (PDON) in primary wastewater and final effluent from TF and AS WWTPs was studied. PDON and BDON fractions of DON data in the final effluent of TF and AS WWTP samples elucidate that photodegradation is as critically important as biodegradation when mineralization of effluent DON is a concern in receiving waters.

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An Investigation into Bromate Formation in Ozone Disinfection Systems

Abstract:

Ozonation is used as an alternative disinfection process to chlorination to minimize formation of disinfection byproducts. However, ozone has a potential of oxidizing bromide, a natural component of water sources, to bromate. Bromate is a possible carcinogen with a maximum contaminant level of 10 ppb. Knowledge on bromate formation in WTPs is limited. To understand bromate formation in full-scale systems, a comprehensive study was conducted at the Moorhead WTP. Bromide concentrations in source waters were monitored. Water samples from locations in the ozonation chambers were collected and analyzed for bromate and other parameters. Results showed that bromate formation was affected by bromide concentrations and operational conditions at the WTP. Water temperature, organics, pH, and ozone dose have significant impacts. Better operational controls are needed to minimize bromate formation. To assist Moorhead WTP on developing bromate control strategies, a modeling approach was adopted to predict bromate formation at various operational conditions.

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