South Dakota Water Research Institute
Annual Technical Report
FY 2003

Introduction

Research Program

During FY 2003, the South Dakota Water Resources Institute (SD WRI) used its 104B Grant Program funds to conduct research of local, state, regional, and national importance addressing many components of the hydrologic cycle. Research addressed runoff and nutrient transport; hydrologic interactions among runoff, the vadose zone, shallow groundwater and its influence on crop growth, groundwater quality characterization, and aquatic habitats and communities within them.

The subject of nutrient transport caused by runoff has been an active research area since a literature review conducted in 2000 generated statewide interest in transport of phosphorus from manure. Information is needed to support regulations to protect the water quality of lakes and streams without placing an undue burden on livestock producers. Livestock production plays a major role in agriculture, the states number one industry. Current research is exploring the upper limits of phosphorus concentration in soils before phosphorus in runoff causes major surface water quality degradation. One soil series was evaluated in 2002, three additional soils were completed in 2003, and two more soil series will be evaluated in 2004.

Research to address the vadose zone and shallow groundwater also included crop response to root zone soil water content. This research took place on highly productive soils derived from glacial till, which are common in the northern Great Plains and northern Corn Belt. Field research supported by SD WRI was used to develop and validate a water balance model of water movement within a cropped waterway with or without artificial drainage. The model was used to show that long-term average corn yields can be increased in a cropped waterway by installing artificial drainage. The data used were soil water content and movement from instantaneous profile tests. Further research will test the water balance model against standard soil water and crop models.

Groundwater research funded with the 104B program focuses on dissolved organic carbon (DOC) concentrations in the Big Sioux Aquifer. It has been discovered that wetlands, lakes, and streams that are hydrologically connected to the Big Sioux Aquifer have DOC concentrations as much as 30 times greater than the DOC concentrations of the aquifer itself. The low concentration of DOC in the aquifer may indicate that DOC can be used as a sensitive indicator of groundwater quality. However, the organic geochemistry of the Big Sioux hydrologic system must be understood before DOC can confidently be used as an indicator.

Finally, a lake habitat research project was continued in 2003. The potential invasion of exotic species such as zebra mussel and Eurasian water milfoil has spurred study of two lake habitats to document the natural populations of macroinvertebrates and aquatic plants and monitor their water quality. Further monitoring of these habitats will continue in FY04.

Lipid Geochemistry of Waters and Sediments in a Prairie Pothole Hydrologic System

Basic Information

Title:	Lipid Geochemistry of Waters and Sediments in a Prairie Pothole Hydrologic System
Project Number:	2002SD2B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	First
Research Category:	Not Applicable
Focus Category:	Groundwater, Water Quality, Hydrogeochemistry
Descriptors:	Groundwater, Big Sioux Aquifer, Dissolved Organic Carbon, Lipids, Organic Geochemistry
Principal Investigators:	James A. Rice, James A. Rice

Publication

1. Williams, M. 2003, Differences in the Chemical Composition of Dissolved Organic Carbon in Water from a Prairie Pothole Ecosystem in Eastern South Dakota, MS Thesis, Chemistry Department, South Dakota State University, Brookings, South Dakota. 111 pp.
2. Berka, M.; Rice, J. A., 2004, Absolute coagulation rate constants in aggregation of kaolinite measured by simultaneous static and dynamic light scattering, Langmuir, IN PRESS.

Problem and Research Objectives

The Big Sioux aquifer is a shallow groundwater system that supplies water to many municipalities and rural, domestic wells in eastern South Dakota. The aquifer has large storage capacity and very rapid recharge characteristics (1).

Until recently, water quality studies of the Big Sioux aquifer, and the Big Sioux Basin, have focused on the inorganic constituents of the waters. We have conducted a geochemical baseline survey of the aquifer's organic constituents that has shown that dissolved organic carbon (DOC) levels within the aquifer are low, averaging 7.7 mg DOC/L (2). However, we have found that DOC levels in wetlands, lakes and rivers that are hydrologically connected to the aquifer can be as much as 30 times higher. The relatively low levels of DOC in the system suggest that it may be a sensitive indicator of the groundwater's quality. Thus it is vital that the organic geochemistry of this system be understood and modeled.

While we are currently investigating the nature of the humic component of the DOC in the aquifer, and the flux of organic carbon between hydrologic domains (e.g., between surface water and the groundwater, or between soil water and the ground water), the effect of selective sorption of the lipid component (compounds such as fatty acids, fatty alcohols, hydrocarbons, etc.) on the chemical characteristics of the groundwater's DOC to subsurface and aquifer material as it moves from one hydrologic domain to the other, is unknown. This is particularly important since we have shown that natural sorbents such as sand, aluminum oxides and clay minerals can selectively sorb different chemical components of a water's DOC (3, 4, 5).

This proposal addresses two major priorities identified by the Water Resources Research Institute's Regional Competitive Grants Program in their solicitation. First, this study addresses the issue of ground and surface water quality. It fills a significant gap in the knowledge of the water quality of the Big Sioux aquifer by quantifying the DOC flux through the system and identifying sorptive reactions with subsurface materials that control lipid concentrations and geochemistry in the aquifer system. Second, it will investigate the relationship and connections between surface water and groundwater DOC and how the lipid components of the DOC contribute to the movement of organic carbon through each hydrologic domain. Since many organic contaminants (such as pesticides, herbicides, PCBs, or PAHs) rapidly and intimately associate with the organic coatings on mineral surfaces, knowledge of the lipid geochemistry will provide information that may be important in predicting organic contaminant fate and transport in this system. This study will provide a missing portion of the geochemical understanding of organic carbon movement that is necessary to manage this resource, protect the groundwater's quality from degradation from anthropogenic organic substances, and if one day needed, facilitate its remediation.

The comprehensive objectives of this project are to: 1) identify the solvent extractable organic compounds (ie, lipids) present in the water and sorbed to the sediments and aquifer materials using gas chromatography mass spectrometry; 2) perform sorption/desorption experiments using representative lipids (natural and model compounds) and sediment and aquifer materials (minerals isolated from cores and reference mineral specimens) to quantify the binding of lipids to mineral surfaces; 4) assess the importance of sorption to mineral surfaces as mechanism for controlling lipids in the aquifer, and; 5) identify the nature and mechanism of lipid binding to the sediment and aquifer material particle-surfaces suing solid-state NMR and small-angle x-ray and light scattering.

This report covers the final year of what was a three-year study whose goal was an understanding of the organic geochemistry of the Big Sioux Aquifer. Completing Objective 5 was the focus of this project year.

Methodology

Material

A kaolinite (KGa-2) from the Source Clay Minerals Repository was used in this study. The clay was mixed with deionized water (NANOpure, Barnstead) and the pH of the suspension was adjusted to 9.5 ± 0.1 using NaOH. The suspension was kept under a blanket of nitrogen throughout the experiment. After several intensive sonication and centrifugation steps, the < 0.2 μm size fraction was isolated and collected. The pH and the electrolyte concentration of the suspension were adjusted to pH~3 with HCl and to ~1M with NaCl respectively, and the sample was allowed to stand overnight. The coagulated clay was washed repeatedly with 1 M NaCl to sodium saturate it, washed with deionized water to remove the excess salt, and was freeze dried. Stock solutions with concentrations of 0.01-0.1 mg cm^{-3} were prepared by intensive sonication of the Na-saturated clay at pH 9.5. Time-resolved light scattering experiments were conducted with dilute kaolinite suspensions containing 2.56×10^{14} particles m^{-3} or 1.28×10^{15} particles m^{-3}. At these concentrations multiple scattering effects can be neglected.

Instrumentation

The simultaneous static and dynamic light scattering method developed for the multiangle light scattering technique was adapted to a "conventional" light scattering instrument. The experiments were performed on an ALV 5000 laser light scattering apparatus with standard pinhole optics and ALV-Goniometer System and with an ALV-5000E Multiple Tau Digital Correlator. An argon ion laser (Lexel Laser Model 95) at a wavelength of 514.5 nm was employed as the light source. The stability of the laser power is controlled by four monitoring diodes. After adjusting the scattering angle the equipment allows setting the duration time, the waiting time and the number of runs and saves the values of the scattered intensity and the autocorrelation functions after each run. Measurements were performed at another scattering angle with different samples. The experiments began with sonication, pH adjustment and with measurement of the size distribution of the stock solution. The autocorrelation functions of the dynamic light scattering experiment were performed over a 10 s interval and fitted with a non-linear least-squares fit using a first-order cumulant method.

Methods

Clay colloid samples were prepared from stock solutions and an appropriate volume of water or sodium chloride solution filtered through a 0.2 m membrane filter into 10 mm diameter light scattering cuvettes. The suspension was studied at the highest pH~9.5 where kaolinite forms a stable dispersion without dissolution before the aggregation experiment. In the aggregation experiments, 1.6-1.8 ml electrolyte solution was added to 0.4-0.2 ml of a stock solution, then poured back and sealed; this was considered to be t_0. Since the volume of the salt solution is much larger than that of the clay suspension, the mixing action induced by pouring the salt solution into the sol and pouring it back into the first cuvette leads to a sufficiently fast homogenization of the system without any mechanical mixing. The temperature during all measurements was 25.0 ^{o}C. All calculations were performed with Mathematic 5.0 (Wolfram Research).

Principal Findings and Significance

As first step in determining the effect of lipid coatings on clay colloid aggregations a mechanism of lipid removal from the waters, the clay colloid aggregation rate was determined for the < 0.2 μm size fraction of kaolinite (KGa-2) using simultaneous static and dynamic light scattering at pH 9.5. It was found that method suggested by Holthoff et al. (8) is suitable for determination of the absolute aggregation rate constant of a clay dispersion without using the particle optical factors. The determined fast aggregation rate constant is $k_{11,fast}$= (3.7±0.2)x$10^{-18}$$m^3 \cdot s^{-1}$. Stability behavior of kaolinite colloids was studied as a function of concentration of sodium chloride by simultaneous static and dynamic scattering. The critical aggregation concentration was found to be 0.085±0.005 mol·dm^{-3}. When calculating the relationship between the stability ratio and the electrolyte concentration using the DLVO theory, the best fit to the experimental data was achieved with a Hamaker constant of A=(4.7±0.2) x10^{-20} J.

References

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2. Rice, J. A. and Viste, D. A., 1994, Major Sources of Groundwater Contamination: Point and Nonpoint Contamination in a Shallow Aquifer System *IN* Groundwater Contamination, U. Zoller (ed.), Marcel Dekker, p. 21-35.

3. Vander Vorste, E.*; Rice, J. A., Selective sorption of natural organic matter by mineral surfaces II. Clay minerals, 34th Midwest Regional Mtg., Am. Chem. Soc., October 1999, Quincy, IL, abstract no. 150.

4. Williams, M.*; Rice, J. A., Selective sorption of natural organic matter by mineral surfaces I. Silica and alumina, 34th Midwest Regional Mtg., Am. Chem. Soc., October 1999, Quincy, IL, abstract no. 148.

5. Williams, M.*; Rice, J. A., Selective sorption of natural organic matter by mineral surfaces. Chemical changes after sorption on sand and alumina, Am. Chem. Soc., 219th San Francisco, CA, March 2000, abstract CHED 755.

6. Sumption, A., 2000, MS Thesis, South Dakota State University.

7. Malekani, K.; Lin, J. S.; Rice, J. A., 1997, Soil Science, 162: 333-342.

8. Holthoff, H.; Egelhaaf, S. U.; Borkovec, M.; Schurtenberger, P.; Sticher, H., 1996, Langmuir, 12, 5541-5549.

Hydrology model calibration in a glacial till system

Basic Information

Title:	Hydrology model calibration in a glacial till system
Project Number:	2002SD3B
Start Date:	3/1/2003
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	First
Research Category:	Not Applicable
Focus Category:	Agriculture, Hydrology, Non Point Pollution
Descriptors:	Agriculture, soil water movement, soil physics
Principal Investigators:	Todd P. Trooien, Hal D. Werner

Publication

1. Kathol, John. 2003. Simulated corn yield responses in drained and undrained waterways. MS Thesis. Agricultural and Biosystems Engineering Department. South Dakota State University, Brookings, South Dakota.

Problem and Research Objectives:

Soils derived from glacial till are common in the northern Corn Belt and northern Great Plains. In the Dakotas, there are nearly 19 million ha of farm land east of the Missouri River with till-derived soils. Many of these soils derived from till are among the most productive agricultural soils for crops such as corn and soybean.

The mechanism of water redistribution is poorly understood for loess-capped soils with lower layers derived from glacial till. There are three potential mechanisms for water movement to areas lower in the landscape: overland flow as runoff/runon, downward flux then lateral movement at the top of the unsaturated weathered till, and downward then lateral movement within the saturated weathered till. Subsurface water movement remains the most poorly defined. This project focused on the movement of water downward through the upper soil layers.

The results of the field research proposed in this project will be used to validate and improve water flow models currently used for assisting in the definition of yield goals. The growth and yield portions of these models generally perform adequately but the water flow submodels are not yet sufficient to simulate water flow with enough accuracy and precision to estimate the correct amount of water stress experienced by the crop.

Methodology:

The two field sites were located near the top of a hill but not at the crest, in a nearly level area. The soil surface was modified slightly so that the flooded surface was nearly level. The 2001 site was located in the NE ¼ of the SE ¼ of Section 19, R48W, T109N on a Kranzburg soil The 2002 site was in SE ¼ of the SW ¼, Section 18, R48W, T107N on a Houdek clay loam soil. The hydraulic properties at each site were measured using the instantaneous profile method, as described below.

A frame of 50 mm by 300 mm lumber was placed around the flooded area to prevent overland flow (runoff). The frame was inserted (trenched) into the soil about 100 mm to prevent near-surface lateral water movement.

Water was introduced by flooding the soil surface within the frame. An additional area surrounding the framed area was also flooded. This additional flooded area served as a buffer so that measured flow from the interior framed area was vertical. After flooding was complete, the plot area was covered with plastic to prevent evaporation from the soil surface.

During and after flooding, soil matric potentials were measured with tensiometers. The matric potentials and instrument elevations were used to calculate hydraulic gradients. Within the flooded framed area, matric potentials were measured at three depths: 450, 750, and 1050 mm below the soil surface. Matric potential measurements at each depth were replicated four times. Soil water content was measured with the neutron probe in 150 mm intervals to a depth of 1.05 m. The neutron probe measurements were replicated four times.

The plots were flooded on 24 October 2001 and 21 October 2002. Monitoring took place until 21 November 2001 and 26 November 2002. In 2002, an early freeze rendered the tensiometers useless nearly immediately after the flooding took place. In 2001, the tensiometers were operated for the entire monitoring period. In each year, the access tubes and the remainder of the equipment in the plots were removed and monitoring ceased one or two days before the first major (>20 mm) snow fall of the season.

Principal Findings and Significance:

Drainage rates from the plots were small for the relatively short monitoring periods at both sites (Figs. 1 and 2). The 2002 matric potential data are not shown because of the cold weather immediately after water application that caused immediate failure of the tensiometers. The measured water contents and matric potentials show steady but slow drainage of water from each plot after the initial flooding. The lower depths in 2002 show little change of water content but the upper layers were decreasing in water content (Fig. 2). Because the drainage rate at the site in 2001 was small and relatively constant, a single value of hydraulic conductivity was calculated at that site. That value was 2.0 mm per day. The average volumetric water content at the 1.05 m depth corresponding to that value of K was 0.330 m/m (or 33.0%).

The soils at the Kranzburg site measured in 2001 apparently increase in clay content with depth. The water content increases with depth (Fig. 1), indicating a greater clay content with a greater water holding capacity. The change of soil clay content (and stored water) with depth is very small at the Houdek (2002) site.

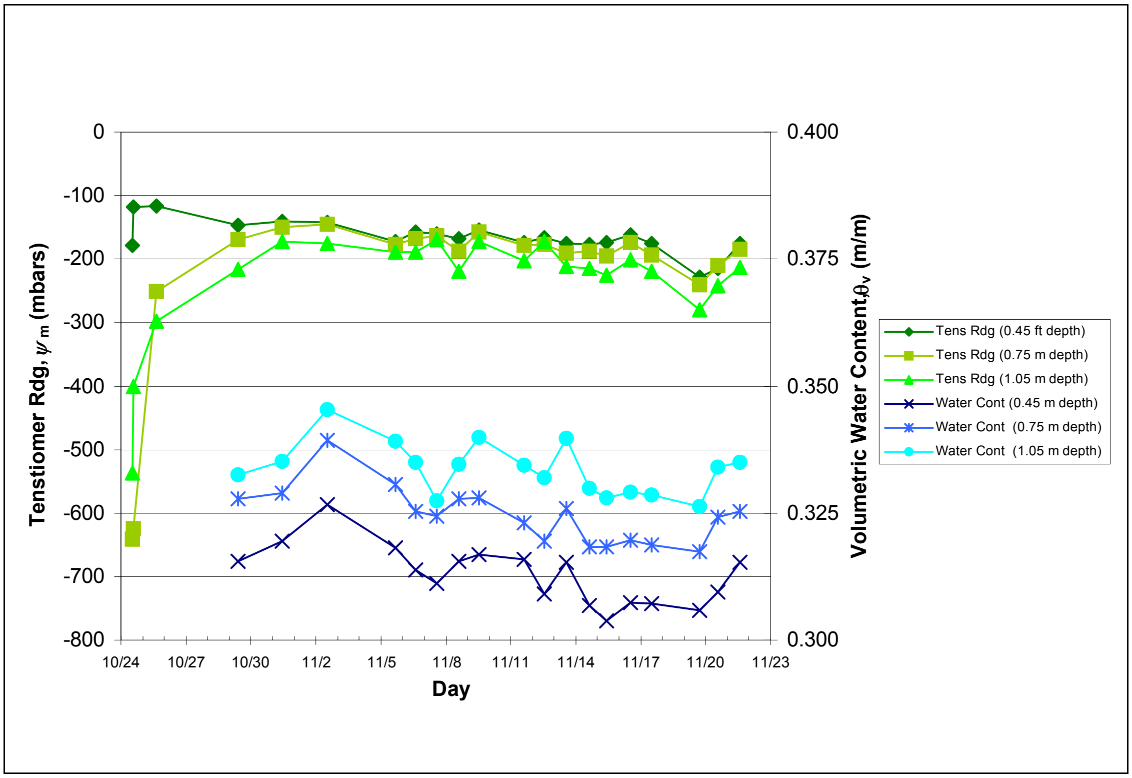

Figure 1. Matric potential and water content during the test in 2001.

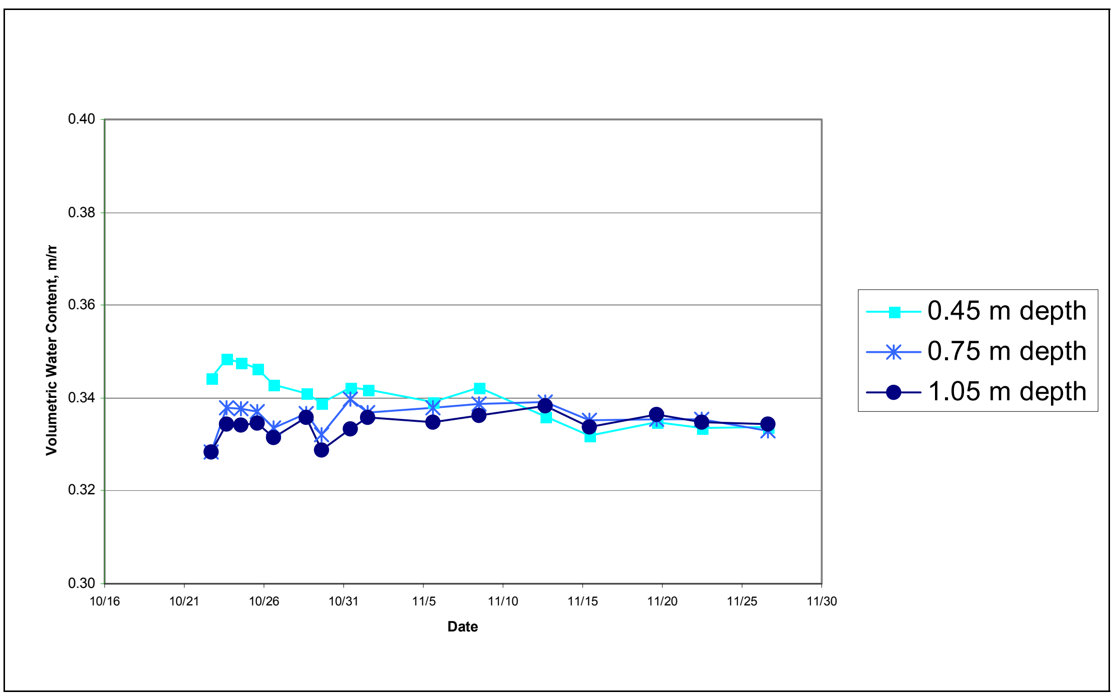

Figure 2. Water content during the test in 2002.

The vertical drainage rates at the two sites were calculated as the change of water content in the top 1.05 m of the soil profile over the entire monitoring period. The average drainage rate in 2001 was 0.48 mm per day and the average in 2002 was 0.27 mm per day. The drainage rate for various depths was also calculated using the 2002 data. The slope of the regression line (stored water regressed by date) is the drainage rate. The drainage rates varied from 0.15 mm per day (for the top 0.45 m of the soil profile) to 0.27 mm per day (0.75 and 1.05 m depths). The R^2 values for all regressions were high (between 0.66 and 0.85).

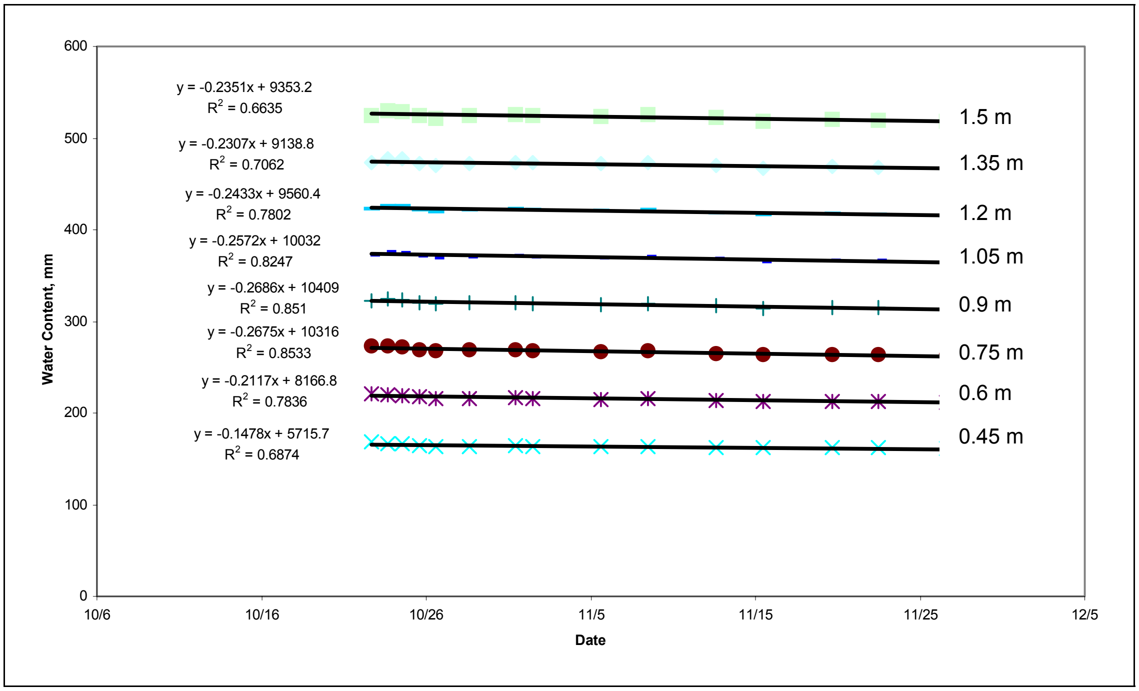

Figure 3. Drainage rate by depth at the Houdek (2002) site.

The instantaneous profile method is accurate and valuable but labor- and land-intensive. Therefore, testing of a single plot for a short time period would have value if the small data set could be extended in some manner. The instantaneous profile method was used to measure soil hydraulic properties of 36 plots during a 4-month period (Trooien and Reichman, 1990). That 4-month study took place in North Dakota at a site with till-derived soils similar to those used in this study. The single measurement of K from each site in this study can be compared to the K-water content function measured in the North Dakota study to compare the hydraulic properties of the three sites. The flooding took place during a period of nearly two months in North Dakota and resulted in water contents much greater than those measured in the current study (Fig. 3). Plotting the K value from 2001 in the current study shows that it fits reasonably well with the curve measured in the North Dakota study (Fig. 3).

The final drainage rate measured in the North Dakota study was 0.6 mm per day, which is similar to the drainage rate measured in 2001. While the drainage rate in 2001 was 0.48

mm per day, which is slightly less than the North Dakota clue of 0.6 mm per day, the water content in 2001 was also less than the water content in the ND study (Fig. 3), so you would expect to measure a lesser drainage rate.

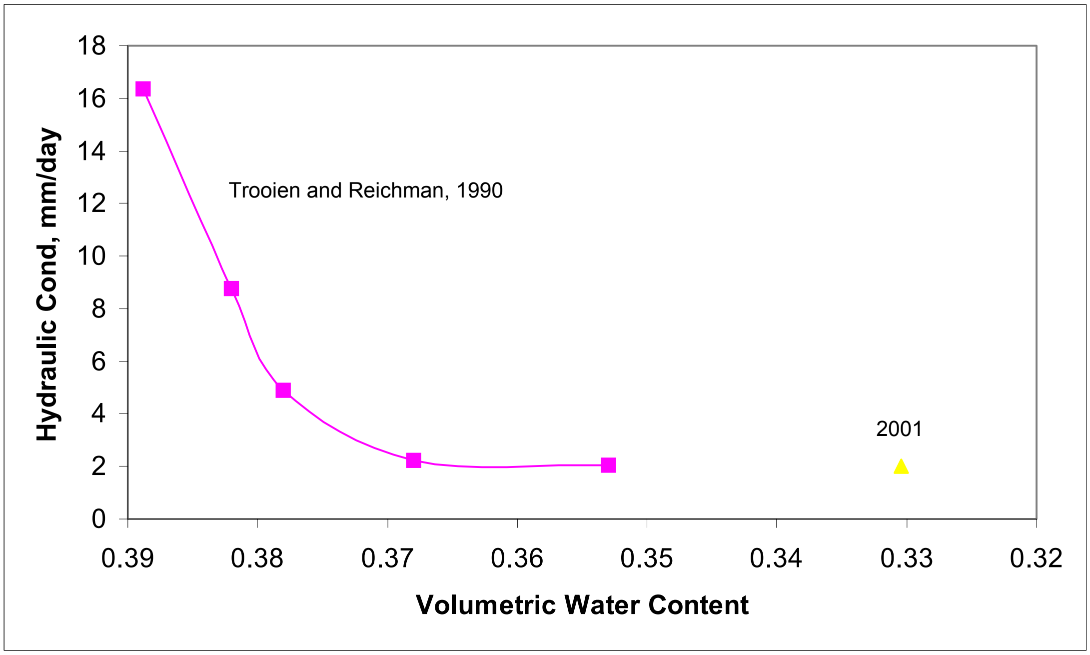

Figure 4. K(theta) function from Trooien and Reichman (1990) and from the Kranzburg (2001) site in this study.

References

Trooien, T. P. and G. A. Reichman. 1990. Hydraulic conductivity of till subsoil in North Dakota. Transactions of the ASAE 33(5):1492-1496.

Establishing a Relationship Between Soil Test P and Runoff P for a South Dakota Soil Using Simulated Rainfall

Basic Information

Title:	Establishing a Relationship Between Soil Test P and Runoff P for a South Dakota Soil Using Simulated Rainfall
Project Number:	2002SD4B
Start Date:	3/1/2003
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	First
Research Category:	Not Applicable
Focus Category:	Agriculture, Nutrients, Water Quality
Descriptors:	
Principal Investigators:	Frank V. Schindler, Ronald H. Gelderman, David R. German

Publication

1. Schindler, F.V., D. German, A. Guidry, and R. Gelderman. 2003. Assessing Soil and Runoff Phosphorus Relationships for the Moody and Kranzburg Soils. In Soil and Water Research 2003 - South Dakota State University, Plant Science Department Annual Progress Report, Pamphlet No. 9, Soil PR 03-42.
2. Schindler, F.V. 2003. Phosphorus study focuses on South Dakota agricultural soils. In South Dakota Corn Council Review, June 2003 Newsletter, p. 5. South Dakota Corn Utilization Council.
3. Schindler, F.V. 2004. Soil and Surface Runoff Phosphorus relationships of South Dakota Soil: What are the implications? Presented to the Soil Science Department, University of Wisconsin, 25 January 2004.
4. German, D.R., A. Guidry, and F.V. Schindler. 2004. Predicting phosphorus in runoff based on soil phosphorus. South Dakota State University, Agricultural Engineering Department, Soil Moisture Workshop, January 2004.

The following report discusses the results and progression of the research project titled "Establishing the relationship between soil test phosphorus and runoff phosphorus for South Dakota soils" during the funding period of March 2003 through February 2004. This project is part of an ongoing P study to evaluate the relationships that exist between surface runoff and soil P. The information gathered from this project will provide the South Dakota Dept. of Environment and Natural Resources sound scientific data in which to base their regulations of manure and fertilizer P application to agricultural land. Since this project funds 19% of our graduate student's stipend, and since she will not be done with her program until March 2005, this project was granted a no-cost extension through February 2005. The specific objectives of this project are as follows:

Objective 1: Establish correlations between STP and runoff P for South Dakota soils by conducting *in situ* rainfall simulation in the field.

Objective 2: Evaluate and P sorption saturation of South Dakota soil and its relationship to runoff P by conducting controlled, laboratory rainfall simulation.

Objective 3: Use the research results to develop educational brochures, field day demonstration events, and offer manure management education to extension educators and area animal producers

Methodology:

Field Studies: The protocol for the National Research Project for simulated rainfall-surface runoff studies was used in this study (4). Ten conventionally tilled cropland areas were identified for the Moody and Kranzburg soil series. These areas possessed similar slope and topography and were chosen based on their range in soil test phosphorus (STP) (i.e., low to high agronomic STP). The Moody sites were identified near Dell Rapids, SD, while the Kranzburg sites were located in the upper Big Sioux Watershed near Watertown, SD. Rainfall simulation was conducted on each site for three consecutive days: one at field moist conditions, and two at field capacity. Rainfall was applied at an intensity of 2.5 in hr-1. Runoff collection began after 2.5 min of continuous runoff, and was collected in toto for 30 min. Runoff was weighed to determine runoff volume, and a composite sample was taken for analysis. Surface runoff water was analyzed for Total Dissolved P (organic and inorganic P species minus sediment associated P), and Total P (total dissolved plus sediment associated P) by the South Dakota Water Resources Institute Laboratory. Composite soil samples were collected after raining and analyzed for STP and other select chemical parameters by the South Dakota Soil and Plant Testing Laboratory. The relationship between total dissolved P in surface runoff and STP was determined.

Laboratory Studies: Bulk 0-2 inch soil samples were collected from the ten field sites following field simulation. Soils were dried at low temperatures, sieved, and packed, in triplicate, into soil runoff boxes according to the National Research Project protocol. Rainfall application, runoff collection, and sample analyses for the indoor simulation were the same as described for the field studies. Representative soils samples were collected during runoff box preparation. Soil samples were crushed and passed through a 2 mm sieve. Soil P sorption saturation was determined as water extractable soil P content (mg kg^{-1}) divided by P_{MAX} (mg kg^{-1}) and multiplied by 100 (2). The P_{MAX} is the maximum amount of P that could be adsorbed by the soil and is defined as

$$P_{MAX} = (PSI + 52.9)/0.5 \quad (1)$$

where PSI is a single-point P sorption index described by (3). The PSI is calculated as

$$PSI = X(\log P_F)^{-1} \quad (2)$$

where X is P sorbed (mg kg^{-1}) = $[(P_I)(V) - (P_F)(V)]$ (kg of soil)$^{-1}$, P_I is initial P concentration in sorption solution (mg L^{-1}), V is the volume of P sorption solution (L), and P_F is the final P concentration in solution (mg L^{-1}).

Principal Findings and Significance:

Objective 1: Figures 1 and 2 show the STP and runoff P relationships developed for the Moody and Kranzburg soils, respectively, at the 0-2 and 0-6 soil depth using in-field simulated rainfall. Similar to the Vienna soil (1), a strong linear relationship existed between STP and TDP for the Moody soil. The reported R^2 values at each depth for the Moody soil indicate that STP does a very good job of estimating the P concentration in runoff. Unlike the Moody soil, however, the Kranzburg soil exhibited a curvilinear relationship (Fig. 2) indicating that a STP threshold or change point may exist. A STP threshold is the STP level where greater P release to soil solution exists per unit increase in STP. Preliminary Q/I and soil incubation studies validate a STP threshold for the Kranzburg soil at approximately 180 ppm (data not shown). This may suggest that when the Kranzburg soil reaches an Olsen-P level near 180 ppm, the rate of P released to surface runoff increases, and when compared to the Moody soil, may need to be managed differently in terms of manure P application. More definitive threshold evaluations are being conducted as part of our ongoing P management research efforts.

Based on the field runoff results, the Moody soil did not exhibit a STP threshold. However, the linearity that existed between STP and runoff P for the Moody soil suggests that continued manure or fertilizer P applications will eventually lead to deleterious surface water P enrichments. Livestock and crop producers will not be able to apply infinite amounts of manure or fertilizer P to soil without concern for water quality.

It must be noted, that the relationships developed in these studies say nothing about total or dissolved P loss from the field site, but rather give only an indication of the P concentration in runoff as a function of STP. STP alone can not predict total P loss because it is a single soil parameter and does not account for climatic, topographic or agronomic influences on P loss to sensitive water bodies. These runoff relationships, when evaluated in conjunction with climate, topography and various agronomic strategies will aid state water quality experts in determining the critical level of P in surface runoff considered problematic for water resource eutrophication. Livestock and crop producers will benefit from this information in terms of being able to develop more comprehensive nutrient management plans that safeguard South Dakota's water quality.

Objective 2: Some P-sorption saturations for the Moody and Kranzburg soils have been determined; however, we have found it is better to run larger groups of samples at one time, thereby, reducing the imprecisions that can manifest from the slight changes in experimental conditions that occur from day to day. Consequently, all remaining P-sorption capacity and P-saturation percentages will be performed following the spring and fall 2004 field simulations when a larger number of samples have been collected.

All P-sorption saturations, including the Poinsett and Barnes soils, will be completed by December 2004. All sorption saturation results will be included in the final project report.

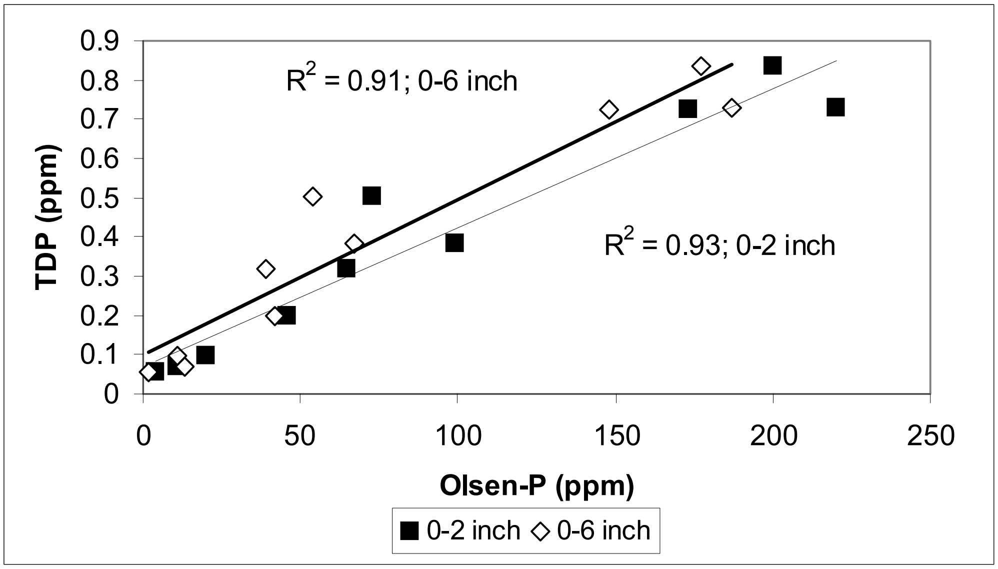

Figure 1. The relationship between total dissolved P (TDP) in field runoff and STP (Olsen-P) of the Moody soil.

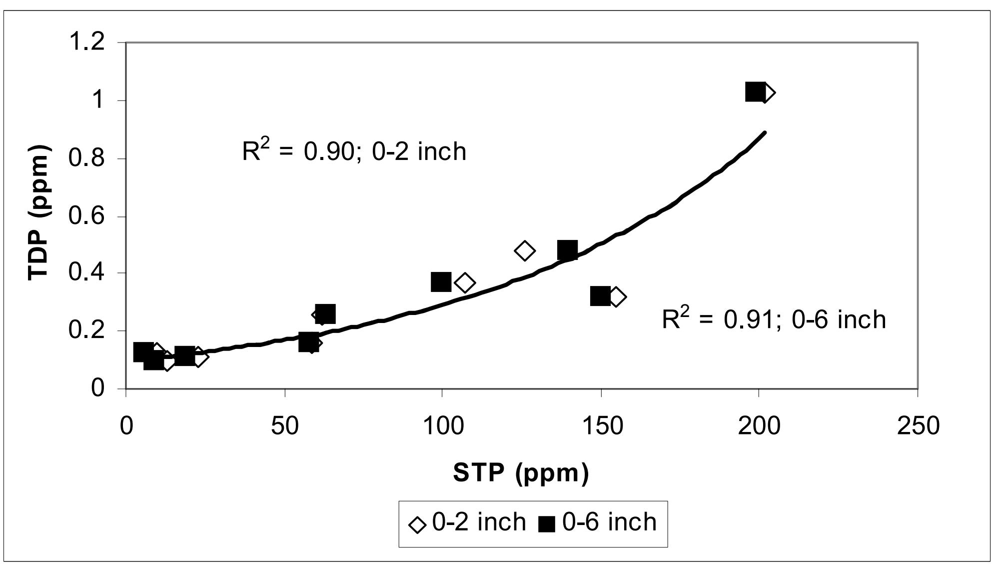

Figure 2. The relationship between total dissolved P (TDP) in field runoff and STP (Olsen-P) of the Kranzburg soil.

Objective 3: The progress and/or products of objective 3 is discussed in the "Information Transfer Program" section of PART II, below.

References:

1. Schindler, F.V., D. German, A. Guidry, and R. Gelderman. 2002. Developing soil and runoff phosphorus relationships for dominant agricultural soils in South Dakota. *In* Soil and Water Research 2002 - South Dakota State University Agricultural Experiment Station, Plant Science Department Annual Progress Report, Pamphlet No. 9, Soil PR 02-44.

2. Sharpley, A.N., T.C. Daniel, J.T. Sims, and D.H. Pote. 1996. Determining environmentally sound soil P levels. J. Soil Water Cons. 51(2):160-166.

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SERA-IEG 17 Regional Publication. Southern Cooperative Series Bulletin No. 396.

PART II:

Information Transfer Program: Mr. Jim Gerwing, South Dakota Soil Extension Specialist, presented the P runoff information generated from this project at the following meetings/workshops:

- December 2003 - 4 soil testing workshops for ag consultants and fertilizer dealers -Brookings, Parker, Pierre and Aberdeen

- Oct, Jan, and March - Manure application training workshops for people applying for state CAFO permits, Pierre (two sessions) and Huron

- Dec - Certified Crop Advisor CEU workshop in Sioux Falls

Mr. Gerwing also indicated that the issue of P runoff came up at about 20 of his regular producer meetings. Mr. Gerwing addressed the issues by citing the runoff work of this project.

A field day demonstration of rainfall simulation was also conducted at the Northeast Research Farm Summer Tour at Watertown, SD on July 2, 2003. Two demonstrations were given that day to a total of 37 area producers, extension personnel, and various other stakeholders.

One hundred P runoff brochures were created with updated information and distributed to area producers via the cooperative extension service. Copies of the brochures were given to the directors of the South Dakota Corn Utilization and the South Dakota Pork Producers Councils to distribute at their discretion. Approximately 100 P runoff handouts were created and distributed to producers, agronomists, and extension personnel during our field demonstration at the Northeast Research Farm Summer Tour at Watertown, SD on July 2, 2003.

P-runoff brochures are also made available to area producers and agronomists at the SDSU Soil and Plant Testing Laboratory.

Survey of the Macrophyte and Invertebrate Communities in Enemy Swim and Pickerel Lakes

Basic Information

Title:	Survey of the Macrophyte and Invertebrate Communities in Enemy Swim and Pickerel Lakes
Project Number:	2002SD7B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Ecology, Water Quality, Surface Water
Descriptors:	Macrophytes, Invertebrates, Water Quality, Lakes
Principal Investigators:	David R. German, David R. German

Publication

1. Schindler, F.V., D. German, A. Guidry, and R. Gelderman. 2002. Developing soil and runoff phosphorus relationships for dominant agricultural soils in South Dakota. In Soil and Water Research 2002 - South Dakota State University, Plant Science Department Annual Progress Report, Pamphlet No. 9, Soil PR 02-44.
2. Schindler, F.V., D. German, A. Guidry, and R. Gelderman. 2003. Assessing Soil and Runoff Phosphorus Relationships for the Moody and Kranzburg Soils. In Soil and Water Research 2003 - South Dakota State University, Plant Science Department Annual Progress Report, Pamphlet No. 9, Soil PR 03-42.

Introduction

The purpose of this study was to describe the macro invertebrate fauna, the aquatic macrophyte community and current trophic state of two relatively rare lake habitats in South Dakota. The potential for exotic species such as zebra mussels, eurasian water milfoil and the rusty crayfish to negatively impact the native fauna in these lakes was a concern.

Introduced exotic species could have a severe impact on native flora and fauna in these lakes. In 1986, a ship released ballast water into Lake St. Clair, Michigan and introduced the zebra mussel. This organism can kill native clams and competes with larval fish and other aquatic organisms for food. The zebra mussel has spread throughout the Great Lakes and has been found in the Mississippi and Minnesota Rivers. If this exotic species is introduced into Enemy Swim and Pickerel Lakes it is expected to have a large impact on the ecological balance.

A second exotic species, Eurasian water milfoil, has already been introduced to Lake Sharp in South Dakota. Milfoil is a fast growing aquatic weed that crowds out native plants and forms dense mats in shallow water. This plant can reproduce from a single fragment and is easily carried from lake to lake on boats and trailers. Fishermen traveling from Minnesota to fish in South Dakota waters may eventually introduce zebra mussels and/or milfoil to these habitats. South Dakota fishermen traveling to the Missouri River or out-of-state lakes are also potential carriers of exotics back to South Dakota
If invasion by exotic species does occur, data from this study would allow future managers set goals for reestablishing a more natural ecosystem and mitigate the impacts of the exotic species. Data presented in this summary report include surveys and sampling conducted in both 2002 and 2003.

Objectives

The objectives of this research were to:

1). To prepare a list of aquatic macro-invertebrates and their relative abundance for all major habitats in Enemy Swim and Pickerel Lakes.

2). To prepare a list of aquatic plants and their general distribution in both lakes.

3). To assess the current trophic state of the lakes by monitoring selected water quality parameters.

Lake Description

Enemy Swim is natural glacial lake located in northeast Day County about eight miles north of the town of Waubay, South Dakota. The lake covers approximately 2,146 acres and has a 22,310-acre watershed located mostly in Roberts County. The lake is not deep enough to form a thermally stratified system in most years (German, 1997). Most natural lakes in South Dakota are simple basins, but Enemy Swim has been described by Game, Fish and Parks Fisheries personnel as a "complex lake basin with highly variable substrate including rock, boulders, gravel, cobble, sand, etc." The varied habitat accounts for a diverse population of fish, twenty-one species have been reported in Enemy Swim Lake.

Pickerel Lake is also a natural glacial lake located in northeastern Day County about ten miles north of the town of Waubay, South Dakota. The lake covers approximately 955 acres to an average depth of 22 feet, and a maximum depth of 43 feet. The lake bottom is predominately rubble with scattered areas of sand and gravel. Silt and organic clay are found in the bays and deeper areas of the lake. Haworth (1972) reported that the north bay of the lake contains 24 feet of sediment, which has accumulated over the 12,000 years since the lake was formed. The lake is deep enough to thermally stratify during the summer months (Day Conservation District, 1991, German,1996).

Pickerel lake is the deepest natural lake in South Dakota and also has a highly variable substrate with many of the same characteristics as Enemy Swim. The main difference between the lakes is Enemy Swim has an extensive system of shallow bays whereas Pickerel lake has fewer bays and much more deep water habitat.

Enemy Swim and Pickerel Lakes are mesotrophic to lower eutrophic which represents a relatively rare habitat in South Dakota. Most natural lakes are eutrophic to hypereutrophic and many have been identified as impaired because they are not meeting their designated beneficial uses. The State of South Dakota has assigned the following beneficial uses to both Enemy Swim and Pickerel Lakes:

- Warm water permanent fish life propagation
- Limited contact recreation
- Immersion recreation; and
- Wildlife propagation and stock watering

Methodology

Objective 1: Aquatic macro-invertebrates

Shoreline habitats sampled for macro-invertebrates included rocky/rubble, sand/gravel, and muddy vegetation and were sampled at several locations. Mid-lake samples were collected in several locations to describe deeper water habitats. Samples were collected by a variety of methods including the use of Eckman dredges and a Wildco Biological Dredge. Manual collection of organisms by D-frame dip net and picking organisms from rocks, plants, and submerged wood was also conducted. Snorkeling and scuba gear was used to collect clams in deeper waters. A photographic history of many organisms collected was also kept and will be expanded in 2004. Hester Dendy samplers will be placed in several shoreline locations to gather quantitative data on macro-invertebrate populations in 2004. (EPA, 1990 and APHA, 1985).

Students participating in the “Lakes Are Cool” program collected additional macro-invertebrate samples using a variety of methods including examination of submerged wood, rocks, vegetation, detritus examined in white pans or wash buckets. Participation by the students increased the number of macro-invertebrates collected especially the more rare forms like fishfly larvae and water scorpions..

Objective 2: Aquatic macrophytes

Plants were collected by wading in shallow water and by snorkeling. All sampling locations were recorded using a portable GPS unit. Aquatic plant identifications were verified by Dr. Gary Larson at SDSU. Several specimens were pressed and added to the SDSU Herbarium collection under the direction of Dr. Gary Larson.

Objective 3: Trophic State

Trophic state was assessed by using the same water quality monitoring methods used during the Lake Protection study in 1991-1995 (German,1997). In-lake water quality samples were collected with a Van Dorn-type water sampler from three mid lake stations using a boat. A composite surface sample for the lake was formed by mixing equal amounts of water from each site. A composite near bottom sample was formed by mixing water collected near the bottom from each of the three sites in each lake. Parameters analyzed on lake samples included:

1. Total phosphorus
2. Total dissolved phosphorus
3. Organic nitrogen
4. Ammonia
5. Nitrate + nitrite
6. Suspended solids
7. pH
8. Air and water temperature
9. Dissolved oxygen
10. Secchi depth
11. Chlorophyll a (surface samples only)
12. Fecal coliform bac (surface samples only)

Water sampling was conducted at Enemy Swim Lake in mid June, July and August in 2002 and 2003. Sampling was conducted at Pickerel Lake in mid May, June, July and August and September in 2002 and 2003. Dennis Skadsen from the Day Conservation District, the Pickerel Lake Sanitary District, and the Enemy Swim Lake Sanitary District contributed to this effort

Results

Objective 1: Aquatic macro-invertebrates

The invertebrate fauna in both lakes is more diverse than was expected based on published studies of the invertebrate fauna in other South Dakota lakes.(Benson and Hudson 1975, Boehmer et. al. 1975,Donaldson 1979, Gengerke and Nickum 1972, German 1978, Hartung 1968, Hudson 1970, Schmulbach and Sandholm 1962, Smith 1971,Wolf and Goeden 1973). The presence of fishflies and stoneflies was particularly surprising because they had not been reported from this area of South Dakota prior to this study. Johnson (1997). first reported the presence of fishflies in South Dakota based on larvae collected in Lacreek refuge. The first adults reported in the state were collected during this project at both Enemy Swim and Pickerel Lakes in 2002. These specimens have been deposited in the Insect Research Collection at SDSU. Insects comprised the largest portion of the invertebrate fauna. The list of macro-invertebrates collected and identified so far at Enemy Swim and Pickerel Lakes is presented in Table 1. The list includes both adults and immature stages collected at both lakes. This list is a work in-progress. Additional taxa have been added since the last annual report. Additional work will be needed to complete the list, especially for the damselflies, beetles, dipteras, and caddisflies.

Insects

Order	Family	Genus/Species	Common Name
Ephemeroptera			
	Ephemeridae	*Hexagenia* sp.	
	Heptageniidae	*Stenonema* sp.	
	Caenidae	*Caenis* sp.	
Odonata			
	Aeshnidae		
		Anax junius	Common green darner
		Aeshna constricta	Lance-tipped darner
		Aeshna interrupta	Variable darner
	Corduliidae		
		Epitheca cynosura	Common basketail
	Limbellulidae		
		Libellula luctuosa	Widow skimmer
		Libellula Lydia	Common whitetail
		Libellula pulchella	Twelve-spotted skimmer
		Libellula quadrimaculata	Four-spotted skimmer
		Sympetrum costiferum	Saffron-winged meadowhawk
		Sympetrum internum	Cherry-faced meadowhawk
		Sympetrum rubincundulum	Ruby meadowhawk
		Sympetrum obtrusum	White-faced meadowhawk

Order	Family	Genus/Species	Common Name
Odonata (cont.)			
	Limbellulidae (cont.)	*Sympetrum corruptum*	Variegated meadowhawk
		Perithemis tenera	Eastern amberwing
		Pachydiplax longipennis	Blue dasher
		Erythemis simplicicollis	Eastern pondhawk
		Tramea lacerata	Black saddlebags
		Tramea onusta	Red saddlebags
		Leucorrhinia intacta	Dot-tailed whiteface
		Celithemis eponina	Halloween pennant
		Celithemis elisa	Calico pennant
	Coenagrionidae	Numerous species	Pond Damsels
		Enallagma antennatum	Rainbow Bluet
		Enallogma hageni	Hagen's Bluet
Trichoptera			
	Helicopsychidae	*Helico borealis*	Snail shell caddisfly
	Hydropsychidae		
	Hydroptilidae		Micro caddisfly
	Limnephilidae		Portable case makers
Megaloptera			
	Corydalidae	*Chauliodes rastricornis*	Fishfly
Hemiptera			
	Belostomatidae	*Belostoma* sp.	Small giant water bug
	Corixidae		Water boatman

Order	Family	Genus/Species	Common Name
Hemiptera (cont.)			
	Nepidae	*Nepa apiculata*	Water scorpion
	Notonectidae		Back swimmers
	Gerridae		Water strider
Coleoptera			
	Gyrinidae		Whirligig beetles
Diptera			
	Ceratopogonidae		Noseeums
	Chironomidae	Numerous species	Midges
	Culicidae		Mosquitoes
	Chaoboridae	*Chaoborus* sp.	Phantom midge

Crustacea

Order	Family	Genus	Common Name
Amphipoda			
	Gammaridae		Scuds
Decapoda			
	Cambaridae	*Orconectes virilis*	Northern crayfish
		Orconectes immunis	Calico crayfish
		Unidentified Species	

Snails

Order	Family	Genus	Common Name
Lymnophila			
	Physidae		Tadpole snails
	Lymnaeidae		Pond snails

Clams

Order	Family	Genus	Common Name
Pelecypoda			
	Unionidae	*Lampsilis*	Fat mucket
		Anodonta grandis	Giant floater

Hirudinea (leeches)

Order	Family	Genus	Common Name

Objective 2: Aquatic macrophytes

The list of macrophytes collected and identified so far at Enemy Swim and Pickerel Lakes is presented in Table 2. No new records of aquatic macrophytes for the state or for the area were recorded. There was no evidence of Eurasian water milfoil in either lake.

Table 2. Macrophytes collected at Enemy Swim and Pickerel Lakes

Common Name	Scientific Name
Water plantain	Alisma gramineum
Coontail	Ceratophyllum demersum
Needle spikesedge	Eleocharis acicularis
Spikerush	Eleocharis erythropoda
Mare's-tail	Hippuris vulgaris
Water milfoil	Myriophyllum sibiricum
Naid	Najas flexilis
pondweed	Potamogeton friesii
Variable pondweed	Potamogeton gramineus
Illinois pondweed	Potamogeton illinoensis
Floatingleaf pondweed	Potamogeton natans
Sago pondweed	Potamogeton pectinatus
Whitestem pondweed	Potamogeton praelongus
Claspingleaf pondweed	Potamogeton richardsonii
Flatstem pondweed	Potamogeton zosteriformis
Widgeon-grass	Ruppia cirrhosa
Arrowhead	Sagittaria latifolia
Hardstem bulrush	Schoenoplectus acutus
River bulrush	Schoenoplectus fluviatilis
Common bladderwort	Utricularia vulgaris
Water stargrass	Zosterella dubia

Objective 3: Trophic State

Water quality data collected for Enemy Swim Lake in 2002 and 2003 is presented in table 3. Water quality data collected for Pickerel Lake in 2002 and 2003 is presented in tables 4 and 5 respectively.

Trophic state is a way of describing how productive or enriched a lake is compared to other lakes. Lakes range from nutrient poor (oligotrophic), to moderately rich (mesotrophic), to highly enriched (eutrophic), to excessively enriched (hypereutrophic). Pickerel Lake and Enemy Swim Lake exhibited characteristics of lakes that are described as mesotrophic to early eutrophic in 2002 and 2003 (Tables 3, 4 and 5).

Table 3 . Water quality values from Enemy Swim in 2002-03.

Parameter	Unit	2002						2003					
		June 6/15/02		July 7/16/02		August 8/16/02		June 6/17/03		July 7/13/03		August 8/16/03	
Air Temperature	°C					17.0							
Transparency	ft	14.5		6.9		5.9		7.8		6.3		5.4	
		Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Water Temperature	°C	19.5	18.4	24.2	23.9	21.3	21.3	23.8	17.1	22.6	22.6	24.0	23.5
Dissolved Oxygen	mg/L	10.9	10.4	8.3	7.4	8.4	8.0	8.6	7.1	7.7	7.7	10.5	8.4
pH	--	8.90	8.92	8.74	8.63	8.52	8.86	8.85	8.78	8.72	8.58	8.76	8.66
Suspended Solids	mg/L	3.0	3.0	4.5	5.8	7.6	10.0	3.3	12.5	6.7	8.0	5.7	8.0
Total Kjeldahl N	mg/L	0.65	0.65	0.74	0.78	0.84	0.81	0.78	0.92	0.80	0.92	1.27	1.07
Organic N	mg/L	0.65	0.63	0.74	0.74	0.79	0.75	0.72	0.87	0.75	0.83	0.70	0.83
Nitrate (NO_3)	mg/L	0.044	0.060	0.020	0.000	0.074	0.074	0.024	0.024	0.010	0.011	0.042	0.042
Ammonia (NH_3)	mg/L	0.01	0.02	0.00	0.02	0.05	0.06	0.04	0.05	0.05	0.09	0.04	0.03
Total Phosphorus	mg/L	0.025	0.027	0.025	0.026	0.033	0.032	0.014	0.032	0.020	0.041	0.032	0.027
Total Dissolved P	mg/L	0.039	0.030	0.002	0.000	0.003	0.010	0.002	0.011	0.017	0.015	0.014	0.006

Table 4 Water quality values from Pickerel Lake in 2002.

Parameter	Unit	May 5/19/02		June 6/15/02		July 7/16/02		August 8/16/02		September 9/16/02	
Air Temperature	°C	10.4		17.3		22.0		17.0		25.0	
Transparency	ft	5.2		6.7		6.1		4.3		4.0	
		Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Water Temperature	°C	11.6	11.1	19.2	17.7	24.5	22.3	21.7	21.3	20.5	19.3
Dissolved Oxygen	mg/L	10.8	10.2	10.0	6.2	8.5	1.3	8.5	8.1	9.9	7.9
pH	--	9.10	9.03	8.89	8.77	8.79	8.43	7.90	8.38	9.00	8.90
Suspended Solids	mg/L	10.0	14.5	6.0	15.0	9.0	10.5	10.7	14.0	9.8	17.3
Total Kjeldahl N	mg/L	0.80	0.84	1.25	1.08	0.88	1.31	1.32	1.05	1.14	1.22
Organic N	mg/L	0.77	0.82	1.24	1.02	0.81	0.93	1.23	0.95	1.04	1.10
Nitrate (NO_3)	mg/L	0.042	0.046	0.052	0.046	0.030	0.028	0.080	0.076	0.012	0.012
Ammonia (NH_3)	mg/L	0.03	0.02	0.01	0.06	0.07	0.38	0.10	0.10	0.10	0.13
Total Phosphorus	mg/L	0.043	0.054	0.038	0.070	0.025	0.036	0.040	0.047	0.048	0.060
Total Dissolved P	mg/L	0.008	0.007	0.020	0.016	0.004	0.011	0.013	0.013	0.016	0.019

Table 5. Water quality values from Pickerel Lake in 2003.

Parameter	Unit	May 5/28/03		June 6/17/03		July 7/13/03		August 08/16/03		September 09/14/03	
Air Temperature	°C	57.0								42.0	
Transparency	ft	4.2		6.6		5.9		3.7		3.1	
		Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Water Temperature	°C	14.1	12.7	22.7	16.9	22.3	22.0	24.1	23.0	18.4	18.4
Dissolved Oxygen	mg/L	9.9	9.5	9.6	3.2	7.2	2.7	8.7	4.4	8.9	8.9
pH	--	8.58	8.56	8.74	8.33	8.56	8.33	8.66	8.40	8.65	8.64
Suspended Solids	mg/L	12.0	24.0	5.3	5.7	6.3	13.0	10.0	12.7	12.0	12.0
Total Kjeldahl N	mg/L	1.20	1.02	0.91	0.92	1.40	1.19	1.27	1.07	1.70	1.39
Organic N	mg/L	1.11	0.94	0.84	0.82	1.29	0.96	1.23	1.04	1.44	1.13
Nitrate (NO_3)	mg/L	0.025	0.025	0.025	0.024	0.012	0.012	0.043	0.042	0.042	0.044
Ammonia (NH_3)	mg/L	0.08	0.08	0.07	0.10	0.11	0.23	0.03	0.04	0.27	0.26
Total Phosphorus	mg/L	0.034	0.070	0.034	0.033	0.041	0.082	0.046	0.099	0.067	0.071
Total Dissolved P	mg/L	0.010	0.030	0.005	0.012	0.003	0.020	0.014	0.025	0.020	0.018

Transparency

The transparency of lake water is important to the aesthetic value of a lake. In most lakes, water transparency is determined by variations in suspended sediment or algal populations. It is used as an indirect indicator of algal populations in lakes without significant suspended sediment. In reservoir systems, transparency may be a function of sediment load or turbidity. Most of the time water transparencys in Pickerel and Enemy Swim Lakes are a function of algal populations. Transparency in Enemy Swim Lake ranged from 14.5 feet in June 2002 to 5.4 feet in August 2003 (Table 3). Transparency in Pickerel Lake ranged from 6.7 feet in June 2002 (Table 4) to 3.1 feet in August 2003 (Table 5). Transparencies in this range are common in mesotrophic to eutrophic lakes.

Suspended Solids

Low suspended solids concentrations are desirable in lakes for aesthetic reasons and for maintenance of a heathy fishery. Fish populations can be affected by high suspended solids in several ways. fish can be killed directly or their growth, resistance to disease and reproduction success may be reduced. Migrations can also be affected (EPA, 1976). High suspended solids concentrations result in reduced aesthetic value of a lake which can limit recreational use. The state standard for maintaining a warm water permanent fishery is 90 mg/l. This standard was not exceeded on any of the sampling dates reported for either lake (Tables 3, 4 and 5).

Phosphorus

Phosphorus is required for the growth of all forms of algae, but relatively small quantities are needed. If other nutrients are available, one pound of phosphorus can produce 500 pounds of algae (Wetzel, 1983). It is often the nutrient that limits the growth of algal populations. It is therefore also the nutrient that must be controlled in order to maintain good water quality. Total phosphorus concentrations for Enemy Swim Lake surface samples ranged from .014 mg/l on 6/17/03 to .033 mg/l on 8/16/03 (Table 3). Total phosphorus concentrations for Pickerel Lake surface samples ranged from .025 mg/l on 7/16/02 to .067 mg/l on 9/14/03 (Tables 4&5). Using phosphorus as a trophic state index, a concentration of .03 mg/l value represents the border between mesotrophic and eutrophic lakes. A concentration of .03 to .1 mg/l would be classified as eutrophic (Wetzel, 1983). Total phosphorus concentrations in this range are common in mesotrophic to eutrophic lakes.

Dissolved phosphorus is the most available form for use by algae and other plants. It is rapidly consumed by algae and seldom reaches high concentrations in surface waters unless other factors are limiting algal growth. Dissolved phosphorus enters lakes from runoff but it is also released from sediments into the water under anoxic conditions (oxygen levels near zero). In both 2002 and 2003 slightly higher concentrations of dissolved phosphorus in bottom waters compared to surface waters were observed in Pickerel Lake (Tables 4 & 5). Pickerel lake was weakly stratified and oxygen concentrations were lower in deeper waters compared to surface waters in July and July of both years (Tables 4& 5). This probably contributed to the release of phosphorus from the sediments in Pickerel Lake. In Enemy Swim Lake concentrations of oxygen and dissolved phosphorus in surface samples was essentially the same as bottom waters in 2002 and 2003 (Table 3).

Nitrogen

Nitrogen is present in lakes in several forms, both inorganic and organic. The inorganic forms (ammonia, nitrite and nitrate) are important nutrients available for plant growth. Organic nitrogen represents nitrogen incorporated into living (or once living) material and can be used to define trophic state. Wetzel, (1983) reports that mesotrophic lakes worldwide generally range from .4 to .7 mg/l and eutrophic lakes have up to 1.2 mg/l of organic N. Organic N concentrations in Pickerel Lake ranged from 0.77 mg/l on 5/19/02 (Table 4) to 1.44 mg/l on 9/14/03 (Table 5) indicating eutrophic conditions. The median concentration of organic nitrogen in Pickerel Lake from 1991 to 1995 was .62 mg/l which represents mesotrophic conditions (German, 1997). This indicates a possible increase in productivity in the lake and a move toward more eutrophic conditions based on organic nitrogen. Organic N concentrations in Enemy Swim surface samples ranged from 0.65 mg/l on 6/15/02 (Table 5) to 0.79 mg/l on 8/16/02 (Table 5). The median concentration of organic nitrogen in Enemy Swim surface samples from 1991 to 1995 was .68 mg/l which represents mesotrophic conditions (German, 1997).

Ammonia is generated as an end product of bacterial decomposition of dead plants and animals and is also a major excretory product of aquatic animals. Ammonia is directly available for plant growth and is the most easily used form of nitrogen. It can support the rapid development of algal blooms if other nutrients are present. Ammonia concentrations in Pickerel Lake surface samples ranged from 0.01 mg/l on 6/15/02 (Table 4) to 0.27 mg/l on 9/14/03 (Table 5). Ammonia concentrations in Pickerel lake surface samples ranged from below the detection limit to .15 mg/l with a median value of .01 mg/l in the period from 1991 to 1995 (German, 1997). Ammonia concentrations in Enemy Swim surface samples ranged from below the detection limit on 7/16/02 to 0.05 mg/l on 7/13/03 (Table 5).

Dissolved Oxygen

Adequate dissolved oxygen is necessary to maintain a healthy lake. Lakes with good oxygen concentrations throughout the year are more likely to have a diverse population of aquatic organisms rather than one that is dominated by a few hardy species. Low oxygen concentrations are detrimental to populations of many organisms and usually reduces diversity and stability in a lake ecosystem. .

Oxygen concentrations can also affect other chemical parameters in lakes. For example, when anoxic conditions form at the bottom of a lake, dissolved phosphorus, ammonia, and hydrogen sulfide and other undesirable substances are released from the lake sediments into the water column. These nutrients can contribute to algal growth when lakes turn over. Ammonia and hydrogen sulfide may also be toxic to aquatic organisms if they are present in sufficient concentrations.

Oxygen concentrations in Pickerel Lake and Enemy Swim Lake surface samples were consistently above the state standard of 5.0 mg/l in 2002 and 2003. This was also true of the 1991-1995 period as well (German, 1997). Weak thermal stratification and depressed oxygen concentrations were observed in Pickerel Lake in both 2002 and 2003. From 1991 to 1995 oxygen concentrations less than 5 mg/l were observed near the lake bottom on 10 of 15 sampling dates (German, 1997).

Overall the health of Pickerel Lake and Enemy Swim is good although they may be drifting to a more eutrophic condition. Collecting additional data in the next few years will help determine if this is normal year to year variation or a true trend. A large amount of construction has occurred around the shoreline in recent years especially on Pickerel Lake and land in CRP has been put back into production, which can cause more nutrients to enter the lake. Installation of the sewer system on Pickerel Lake has probably helped reduce nutrients from septic tanks but other measures to control nutrients from construction, farming and lawn care should be considered.

Youth Education

The scope of the project includes the participation of several local agencies. Dennis Skadsen of the Day Conservation District initiated an educational program called "Lakes Are Cool" to educate youth in the watershed about the importace of keeping lakes clean. The project involves teachers and students from local schools that participated in the "Lakes Are Cool" program that was held in 2002 and 2003 as part of the Enemy Swim Lake Watershed Improvement Project. This EPA funded watershed project sponsored by the Day Conservation District allowed local students to participate in the collection and identification of aquatic macro-invertebrates.

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Information Transfer Program

Information Transfer

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Congressional District:	First
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	Public outreach, youth education, agency interaction
Principal Investigators:	Van Kelley, David R. German

Publication

Public Outreach

The continued severe drought in western South Dakota the past three years has demonstrated the importance of the services offered by the Water Resources Institute's Water Quality Laboratory. The inherent quality of surface waters in western South Dakota is commonly low, leading to chronic livestock production problems. However, drought has intensified this problem for livestock producers in these semi-arid rangelands. Many dugouts and ponds degraded to the point of causing cases of livestock illness and, in some instances, livestock deaths. Although water quality problems in western South Dakota are common, some isolated cases of livestock illness and deaths due to poor surface water quality occurred in eastern South Dakota in 2001 and continued in 2002 and 2003. The SD WRI made this issue a priority in its outreach/information transfer efforts by posting information for farmers and ranchers on this subject on the Institute's web page (http://wri.sdstate.edu/drought.htm). The SDSU Agricultural Communications Department also developed a press release and special web page dealing specifically with the drought. This web page referred producers who had questions about their water quality to the SD WRI web page. Numerous requests were received by SD WRI staff for assistance with identification of potentially toxic algae from surface waters due to dry conditions. SD WRI also provided assistance to the SDSU Extension Water Quality Specialist to develop information on water with high concentrations of salts and sulfates. This data was obtained from actual samples analyzed by the SD WRI Water Quality Lab.

Public outreach takes many forms. One of the most recent at SD WRI is providing information over the Internet. A Web site for the SD WRI and Water Quality Lab has been established. The "Research Projects" section of the SD WRI Web site (http://wri.sdstate.edu) is continuing to be updated. The site allows the public to keep in touch with the activities of the Institute, gather information on specific water quality problems, learn about recent research results and links with other water resource related information available on the Web. An extensive library of information has been developed on-line and will be expanded as more information becomes available. Information regarding analytical services available at the SD WRI's Water Quality Laboratory and information that may be used to address drinking water problems has been redeveloped on-line.

The Water Resources Institute's Water Quality Laboratory provides important testing services to water users across the state. Water Resources Institute staff continues to provide interpretation of analysis and recommendations for use of water samples submitted for analysis. Information transfer to individuals with assistance to identify and solve water quality problems is an important component of the Institute's Information Transfer activities. Interpretation of analysis and recommendations for suitability of use is produced for water samples submitted for livestock suitability, irrigation, lawn and garden, household, farmstead, heat pump, rural runoff, and land application of waste. The Water Quality Lab was consolidated with the SDSU Analytical Services Laboratory in FY03 in order to provide more efficient service to the public.

SD WRI staff routinely respond to questions unrelated to laboratory analysis from the general public, other state agencies, livestock producers and County Extension Agents concerning water quality issues related to stream monitoring, surface water/ground water interactions, livestock poisoning by algae, lake protection and management, fish kills, soil-water compatibility, and irrigation drainage. WRI continues to provide soil and water compatibility recommendations for irrigation permits to the SD Division of Water Rights.

Agency Interaction

The SD WRI Information Transfer program includes interaction with local, state and federal agencies/entities in the discussion of water-related problems in South Dakota, and the development of the processes necessary to solve these problems. One example of this interaction to solve water quality problems is a program started by the Cooperative Extension Service to help livestock producers identify unsuitable water sources. The CES provides many of its Extension Educators with hand-held conductivity meters for use in the field. If samples are shown to be marginal by field testing, they are sent to the Water Quality Lab for further analysis. Often, high sulfates limit the use of waters that have elevated conductivity. A Non-Point Source (NPS) Task Force exists in South Dakota to coordinate and fund research and information projects in this high priority area. Many of the information transfer efforts of the Institute are cooperative efforts with the other state-wide and regional entities that serve on the Task Force.

In 2001 the Institute co-sponsored the "Phosphorus, Manure & Water Quality Conference". Participating agencies included the South Dakota Department of Environment and Natural Resources, NRCS, South Dakota Lakes and Streams Association, South Dakota Agricultural Experiment Station, South Dakota Cooperative Extension Service, South Dakota Department of Agriculture, South Dakota Cattlemen's Association, SDSU Plant Science Department and Soil Testing Laboratory, and the South Dakota Farm Bureau. In 2002 these groups supported research efforts need to fill gaps in our knowledge of the relationships between soil test P and runoff P. In 2003 the research was well underway with completion of soil P vs. runoff P relationships for three soils. Two additional soil series and lab work will continue in 2004. Similar coordination and information sharing continued in 2003 and 2004 as South Dakota moves toward the development of a P-index to address the issue of P buildup in the soil and its impact on water quality. A PhD student in the Atmospheric, Environmental and Water Resources Program at SDSU was hired in the fall of 2002 and is housed in the SD WRI office. This is the first time SD WRI has been able to support a PhD student in more than 20 years. The student's research project, titled "Establishing a Relationship between Soil Test Phosphorus and Runoff Phosphorus for South Dakota Soils Using Simulated Rainfall" will be the subject of the student's PhD dissertation upon completion of her degree program. This work will be important to the development of a P-index in South Dakota.

Several local and state agencies conduct cooperative research with SD WRI or contribute funding for research. Feedback to these agencies is often given in the form of pesentations at state meetings, local zoning boards, and informational meetings for non point source and research projects.

Youth Education
Water Festivals were included in the NPS Task Force's Information and Education plan in 1992 with one Water Festival held in Spearfish, South Dakota. Water Festivals have since been held in seven sites including Spearfish, Rapid City, Pierre, Huron, Vermillion, Brookings and Sioux Falls. Since their inception, Water Festivals in South Dakota have impacted approximately 68,000 fourth grade students state wide, 15,800 of which have attended our own local festival, the Big Sioux Water Festival (BSWF). SD WRI staff members will continue to support and participate in Water Festivals throughout the state in coming years. SD WRI will continue other activities to support water quality education in local schools including classroom presentations and assisting local educators with field trips. WRI staff also participated in both the first and second annual Youth Sport Fishing Day held in Aberdeen, South Dakota held in June.

Publications
Distribution of research findings to the public, policymakers and sponsors of non-point source pollution control projects is another important component of the SD WRI Information Transfer program. This is needed so that the lessons learned through research and implementation projects are not lost as the next generation of projects develop. SD WRI is committed to making this material readily available to persons within South Dakota as well as in other states. A library is maintained at SD WRI to make these materials readily available. Abstracts of research projects funded by the institute have been placed on the WRI web site along with photos and summaries showing progress on these projects will be published on the site as they become available.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	0	0	4
Masters	2	0	0	0	2
Ph.D.	1	0	0	0	1
Post-Doc.	1	0	0	0	1
Total	8	0	0	0	8

Notable Awards and Achievements

Publications from Prior Projects

None