South Dakota Water Research Institute
Annual Technical Report
FY 2002

Introduction

Research Program

During FY 2002, the South Dakota Water Resources Institute (SD WRI) used its 104 Grant Program funds to conduct research of local, state, and national significance. A project to study the effects of phosphorus in surface water due to manure application was funded. A literature review was conducted in November 2000 and has generated a great deal of interest in the state, given the fact that agriculture is the states number one industry. Information is needed about phosphorus loss in runoff as affected by land applications of livestock manure so that South Dakota can develop reasonable regulations that protect the water quality of streams and lakes without placing undue hardships on livestock producers. There is a need to understand how high concentrations of P in soil can rise before causing environmental damage. The basis regulations will be more sound if at least some of this research is conducted in South Dakota. A conference dealing with this issue was jointly hosted in August 2001. The SD WRI, in cooperation with the South Dakota Agricultural Experiment Station, the South Dakota Cooperative Extension Service, the South Dakota Cattlemens Association, and the South Dakota Pork Producers. Resesearch began on the Vienna soil series in 2002 and three additional soil series were evaluated in 2003.

Glatial till soils are common in the Northern corn belt and Northern Great Plains. These soils are the most productive agricultural soils for crops such as corn and soybeans. Research focusing on the movement of water downward through the upper soil layers was conducted during this review period. The results of the field research conducted on 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.

Research to study dissolved organic carbon (DOC) concentrations in the Big Sioux Aquifer was also conducted in FY02. The Big Sioux Aquifer is a shallow groundwater system that supplies water to many municipalities and rural, domestic wells in eastern South Dakota. DOC concentrations in wetlands, lakes and rivers hydrologically connected to the aquifer can be as much as 30 times higher. The relatively low levels of DOC in the system suggest that DOC may be a sensitive indicator of groundwater quality. Therefore, it is vital that the organic geochemistry of this sysem be understood and modeled.

A project to study the macro-invertebrates fauna and aquatic macrophyte communities in two relatively rare lake habitats in South Dakota was also begun in FY02. The potential for invasion by exotic species, such as zebra mussels and Eurasian Water Milfoil, is a concern, especially should the invasion occur prior to documenting the natural populations of these organisms.

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:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
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

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 second year of what has been proposed as a three-year study whose goal is a comprehensive understanding of the lipid geochemistry of the Big Sioux Aquifer. Completing Objective 1 was the focus of this project year.

Methodology

This site consists of self-contained, permanent/semi-permanent pothole wetland around which we have installed a field of 17 nested groundwater wells. We have recently developed a hydrologic model for this site using MODFLOW (6). The site's geology and hydrology are described in detail by Sumption (6). Dissolved organic carbon from the pothole, the groundwater and water-soluble organic carbon from the surrounding soil were fractionated using XAD-8 and XAD-4 resin columns in series. Hydrophobic and hydrophilic neutral components were isolated after desorption of the acid and base fractions from the columns.

Organic matter samples were characterized by ultrafiltration and quantitative ^{13}C solid-state DPMAS NMR and fluorescence spectroscopies.

Principal Findings and Significance

The hydrophobic and hydrophilic neutral fractions from each environment exhibit unique characteristics compared to other organic matter fractions in the system. The fluorescence and quantitative ^{13}C solid-state DPMAS NMR spectra clearly distinguish between the neutral fractions organic matter fractions. The hydrophobic and hydrophilic neutral fractions from each environment are distinct organic matter fractions. The neutral fractions are lower molecular weight materials than the other organic matter fractions. Their quantitative NMR spectra display distinct carbon type distributions that distinguish them from the other organic materials. The hydrophobic neutrals are more aliphatic than the hydrophobic neutrals. The neutral fractions fluoresce more strongly and at different wavelengths than any of the other organic matter fractions. The molecular weight data, fluorescence and quantitative ^{13}C solid-state DPMAS

NMR spectra also clearly distinguish between the neutral fractions from the groundwater, pothole surface water and water-soluble organic carbon. This indicates that even though there is a hydrologic connection between the surface and ground waters, there are mechanisms that cause the groundwater's neutral components to differentiate themselves from the surface waters (pothole and water-soluble organic carbon in the soil).

Hydraulic Calibration of the Upper Soil Layers in a Glacial Till System

Basic Information

Title:	Hydraulic Calibration of the Upper Soil Layers in a Glacial Till System
Project Number:	2002SD3B
Start Date:	1/3/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	First
Research Category:	Ground-water Flow and Transport
Focus Category:	Agriculture, Hydrology, Non Point Pollution
Descriptors:	Agriculture, Soil Water Movement, Soil Physics
Principal Investigators:	Todd P. Trooien

Publication

1. Kathol, John. 2003. Simulated corn yield responses in drained and undrained waterways. MS Thesis, Agricultural and Biosystems Engineering. 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.

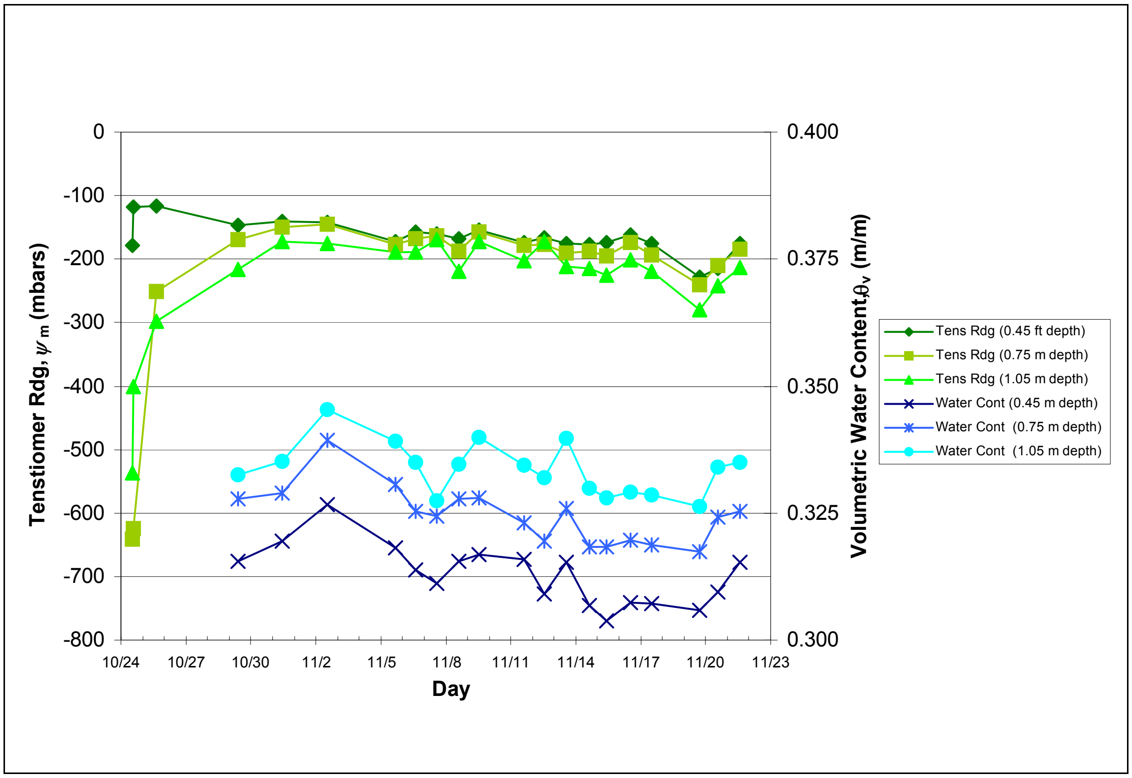

Figure 1. Matric potential and water content during the test in 2001.

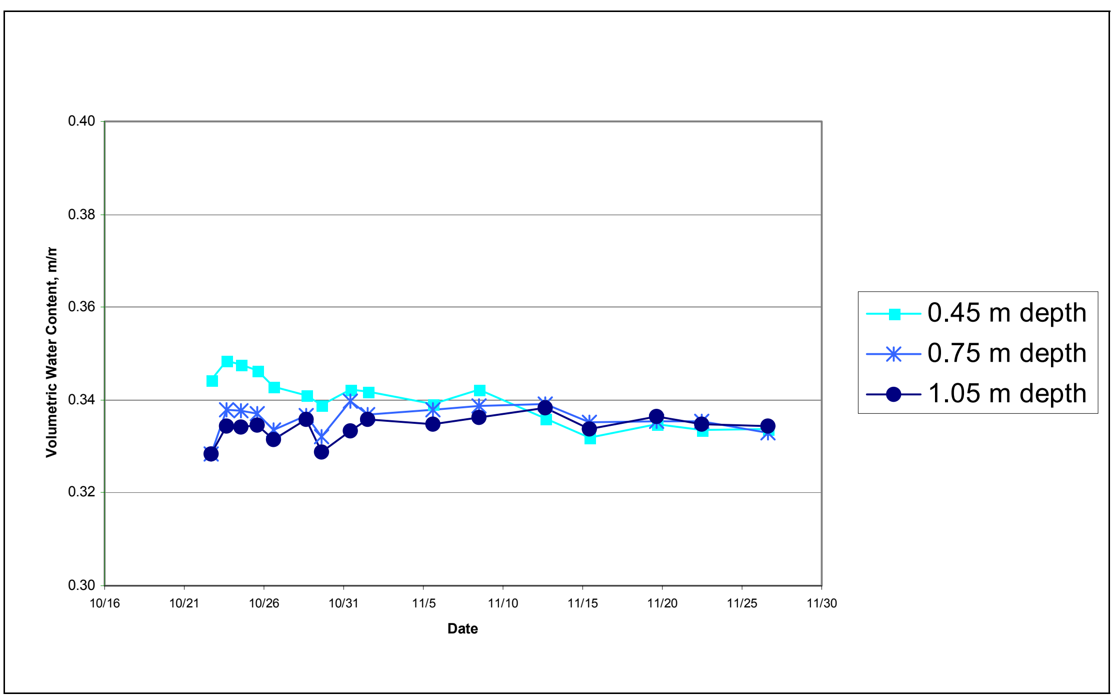

Figure 2. Water content during the test in 2002.

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).

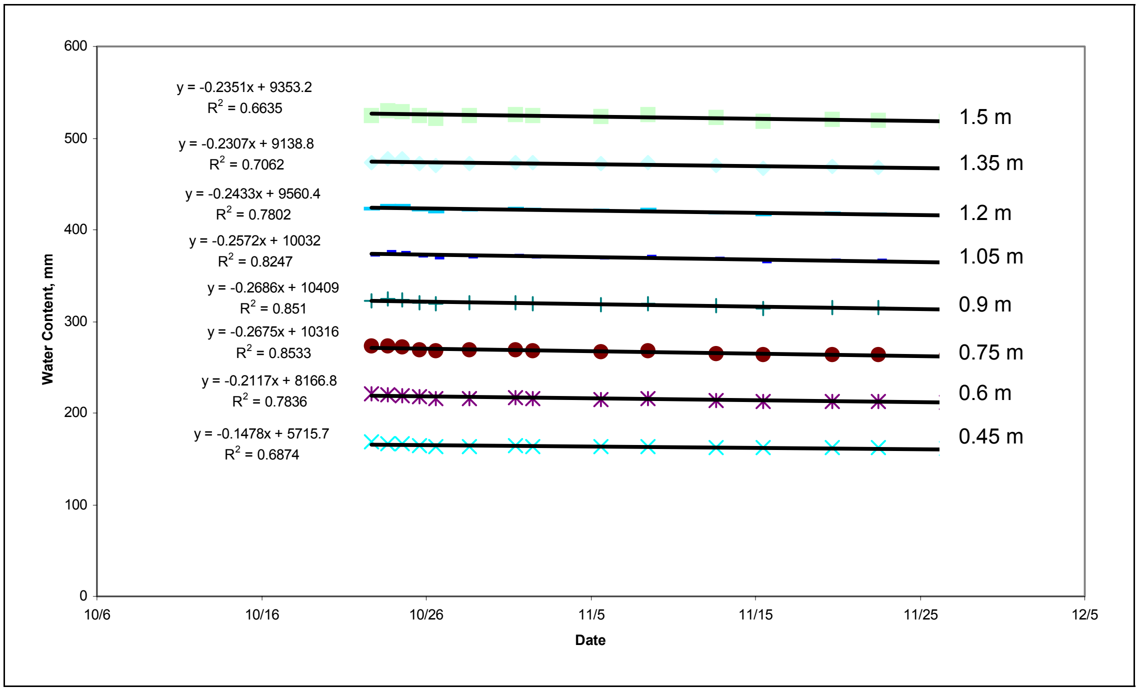

Figure 3. Drainage rate by depth at the Houdek (2002) site.

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.

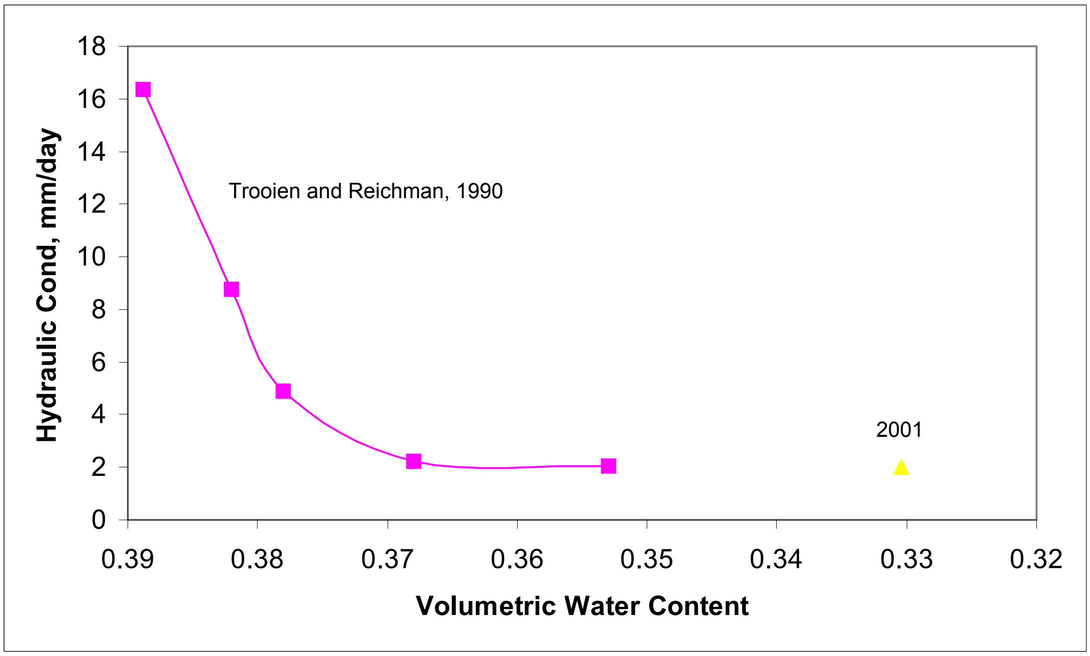

Figure 4. K(theta) function from Trooien and Reichman (1990) and from the Kranzburg (2001) site in this study.

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:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Agriculture, Nutrients, Water Quality
Descriptors:	Soil Test Phosphorus, P-Saturation, P-Runoff, Eutrophication, Livestock
Principal Investigators:	Frank V. Schindler, David J. Dixon

Publication

1. A Ph.D dissertation will be developed from research conducted on this project.

Problem and Research Objectives:

The EPA has announced a policy that would strengthen enforcement of pollution control regulations for large, concentrated feedlots. If implemented these rules will require land application of livestock wastes to be based on nitrogen and phosphorus fertilizer requirements of crops, with actual applications limited to the smaller of the two. Currently, South Dakota regulations are based upon nitrogen needs of the crop, which can result in excessive phosphorus applications (i.e. relative to the phosphorus needs of the crop).

Generally, the loss of agricultural P in runoff is not of significant economic importance to a farmer, but can lead to significant off-site economic impacts, in some cases occurring many miles from P sources. By the time these impacts are manifested, remedial strategies are often difficult and expensive to implement and they cross political and regional boundaries. It can be several years before an improvement in water quality occurs. Thus, a greater understanding of where P is coming from, how much P in soil and water is too much, and how and where we can reduce these inputs and losses must be gained through research and extension programs, in order to develop agricultural resource systems that sustain production, environmental quality, as well as farming communities(Sharpley 1997).

Several previous studies have been conducted to determine the relationship between soil test phosphorus (STP) and runoff P. These studies present substantial evidence that phosphorus concentrations in runoff increase as STP values increase. This is true for both soluble reactive P and other forms of P, including total P, although the relationship is better for soluble phosphorus. These studies are limited for several reasons, however. Most focus on dissolved phosphorus, which is an important water quality parameter, but it only represents the dissolved portion of runoff P. It does not represent the absorbed soil P that can become available for aquatic plant growth through desorption (Sharpley et al. 1996). In addition, many of the studies, especially those associated with manure application, have been conducted on pastureland, which provides little information on the effects of tillage. Even more limited is the research conducted to determine the relative importance of the factors affecting P transport on soils in the Cornbelt and the relative vulnerability of these soils to P loss (Daverede et al. 2000). There have been no studies of the relationship between STP and runoff P on South Dakota soils. The goal of this project will be to conduct studies that describe the relationship between runoff P and soil test P, on an important agricultural soil in the Brookings area.

Objective 1: Establish correlations among STP, runoff P, and P saturation for a Brookings area soil by conducting *in situ* rainfall simulation in the field.

Objective 2: Evaluate P sorption capacity of the Brookings area 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

Principal Findings and Significance:

Results:

Objective 1: Figure 1 depicts the relationship that exists between total dissolved P loss in runoff and Olsen STP at 0-2 inch soil depth for a Vienna soil as determined using in-field simulated rainfall. These data show very good linear relationship (R^2 = 0.92) between STP and runoff P for the Vienna soil. There was, however, no indication of a STP threshold, i.e., STP level where greater P loss to soil solution would exist per unit increase in STP. Such a threshold, if present, could prove very useful as an environmental indicator. When coupled with proper erosion management strategies, the STP threshold could dramatically reduce the negative environmental impacts associated with poor nutrient management. It is hypothesized that the sorption capacity of Vienna has not yet neared the point of P saturation. Research to derive a STP threshold in the Vienna and other South Dakota soils is ongoing.

Objective 2: Phosphorus sorption capacity (Pmax) can be defined as the maximum amount of P a soil can hold before reaching a saturated state. Phosphorus sorption is realized through associations with charged surfaces or as precipitation of secondary minerals like calcium phosphate. Soils adsorb or desorb P depending upon the P sorption saturation of the soil, which is defined by the following equation:

$$P\,sorption\,saturation = \frac{Extractable\,soil\,P}{P\,sorption\,capacity}(100)$$

Figure 2 shows the relationship between the degree of P sorption saturation and P sorption capacity for the Vienna soil series. This relationship was developed by equilibrating a known amount of soil with a constant P application rate of 1.5 g P per kg of soil. What the relationship shows is that at a given P application rate, soils that have a lower capacity to adsorb P (that is, lower Pmax) become P saturated more quickly, and the soils ability to hold additional P becomes reduced. Consequently, the risk of P loss to drainage and/or surface water resources is enhanced. Figure 3 verifies this assertion by showing a direct relationship between P saturation percent and TDP in runoff. As P saturation increases, P release to surface water also increases in a linear fashion.

It has been proposed by some researchers that P saturation may do a better job estimating P release to runoff than STP because it more accurately describes the effect of soil type on P release by accounting for soil properties that affect P sorption and desorption. However, we found that both the saturation percentage and Olsen STP approaches yield similar estimations of soil P release to runoff. In fact, we found the two parameters to be very highly correlated (Figure 4). This means that the 0-2 inch Olsen soil test does a very good job of estimating the P saturation of the Vienna soil. If this relationship holds true for other dominant agricultural soils of South Dakota, STP may be deemed a successful, labor saving approach to describing the P saturation status of South Dakota soil, and in estimating the degree of P release to surface runoff.

Objective 3: Approximately 1,000 total copies of several brochures, handouts, and pamphlets were produced and ready for distribution by the first manure management seminars/training sessions and field day demonstration events (March and July, 2003). Updated brochures, handouts, and pamphlets will be prepared for subsequent field day demonstration, workshops and other manure management presentations (second printing 1,000 copies, total printing 2,000 copies).

A demonstration of indoor rain simulation and a presentation of research results were held in Brookings in January 2003. The SDSU event was attended by producer groups supporting the project as well as agency personnel.

One article was prepared for the Corn Council newsletter-describing results from the field rain simulations conducted on the Vienna soil in 2002. The same information was printed on 100 brochures to be distributed at several types of meeting related to phosphorus.

Jim Gerwing, South Dakota Soil Extension Specialist, used the data from the P runoff study at nine scheduled events and referred to the data numerous times in winter meetings, workshops, an individual discussions with farmers and ag consultants.

These included: Three Manure Management Training workshops for livestock producers planning to apply for state livestock permits. The workshops were mostly attended by producers but a few agency, extension personnel and ag consultants also attended. One training session on phosphorus issues related to the use of manure for DENR, Dept of AG and other agency people. One Presentation for livestock groups and other interested individuals and organizations attending the rollout of the new CAFO rules. One Guest lecturer in the Animal Science Dept Swine Production Class, AS 126. Three Manure Management Training sessions for livestock operations with less than 1000 animal units - attended by producers and agency, and extension personnel.

Frank Schindler presented P runoff results for the Vienna soil series at four soil fertility update meetings scheduled across South Dakota (Dec. 9-12, 2002). The attendants were agronomists (crop consultants), livestock producers, some NRCS and SD DENR personnel, county extension agents, and commodity group representatives.

Preliminary Conclusions:

- **The STP and P saturation status of the Vienna soil in year one of this study were significantly related to TDP concentrations in the runoff. Further research is needed to determine whether these relationships are similar for other dominant agricultural soils of South Dakota. If so, STP may prove valuable as a universal predictor of P sorption saturation and TDP concentrations in runoff.**

Year 2 plans: The objectives for year 2 of this ongoing study are to 1) develop the correlation between runoff P and soil test P on a different Brookings area soil of South

Dakota using rainfall simulation in the field, and 2) evaluate P sorption saturation of the soil and its relationship to runoff P.

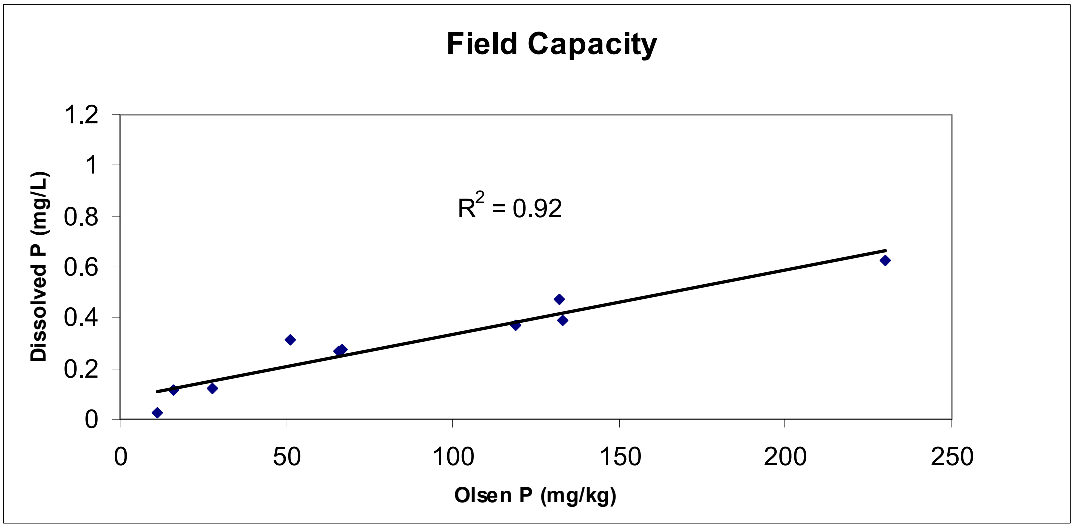

Figure 1. Total Dissolved P loss and Olsen STP at 0-2 inch soil depth and field capacity.

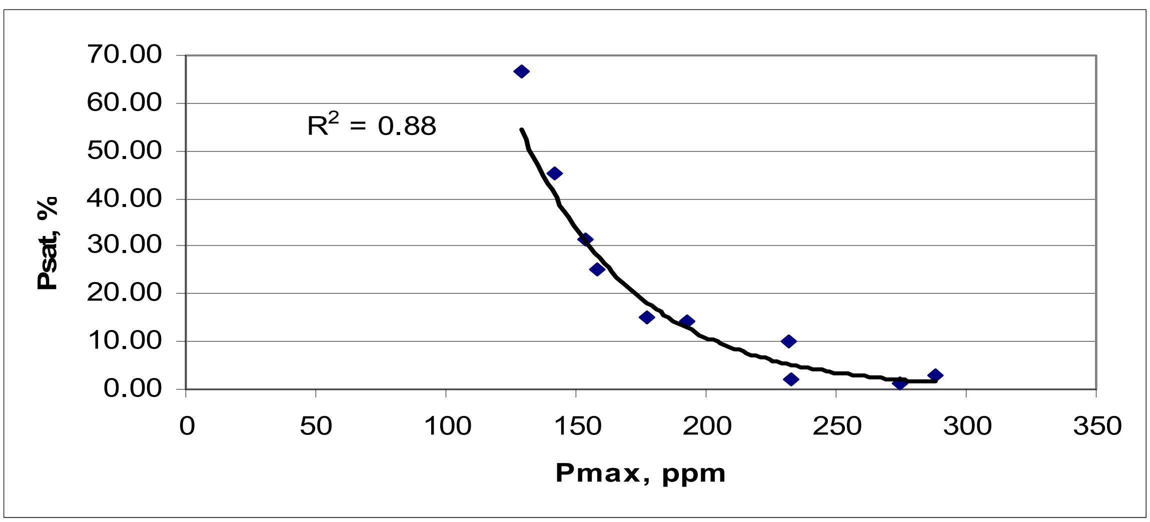

Figure 2. Relationship between P saturation percentage and P sorption of Vienna soil at the 0-2 inch depth.

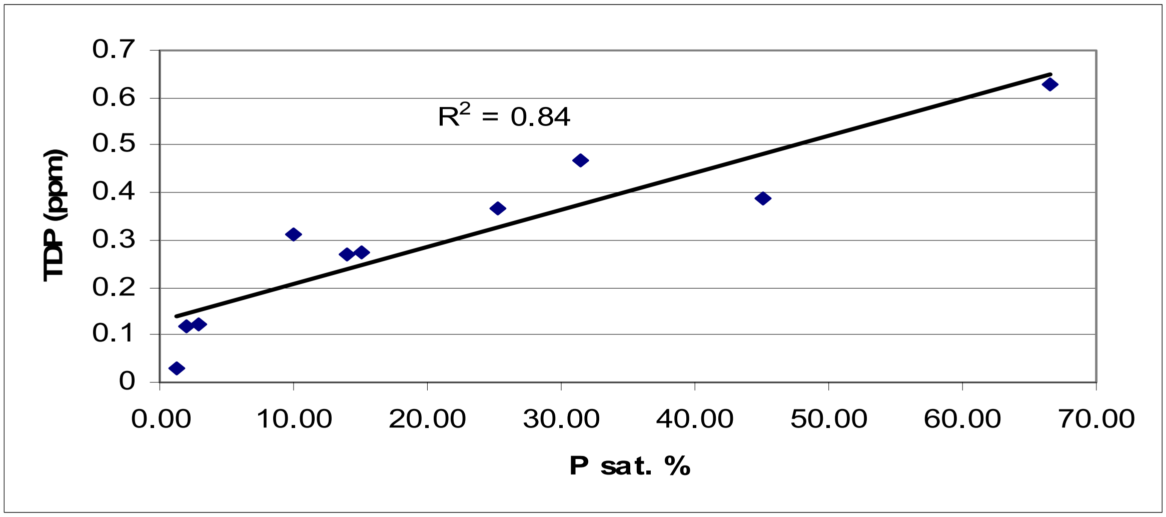

Figure 3. Relationship between P saturation percentage and total dissolved P in runoff for the Vienna soil at the 0-2 inch depth.

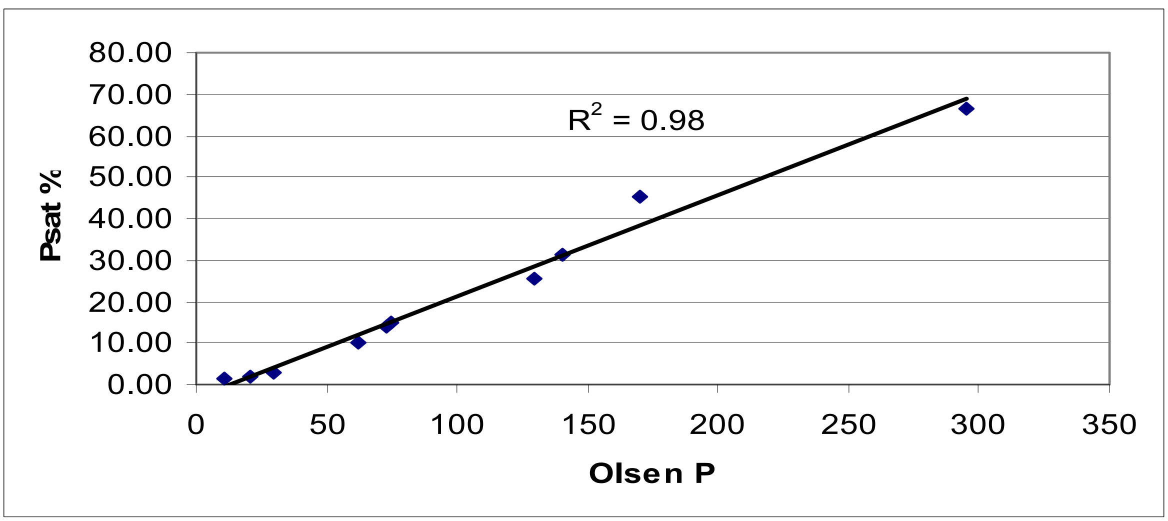

Figure 4. Relationship between Olsen soil test P and P saturation percentage for the Vienna soil at the 0-2 inch depth.

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:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Water Quality, Surface Water, Ecology
Descriptors:	Macrointertebrates, Macrophytes, Benthos
Principal Investigators:	David R. German

Publication

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 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.	
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
		Sympetrum corruptum	Variegated meadowhawk

Order	Family	Genus/Species	Common Name
Odonata (cont.)	Limbellulidae (cont.)	*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		Pond Damsels
Trichoptera			
	Helicopsychidae	*Helico borealis*	Snail shell caddisfly
	Hydropsychidae		
	Hydroptilidae		Micro caddisfly
Megaloptera			
	Corydalidae	*Chauliodes rastricornis*	Fishfly
Hemiptera			
	Belostomatidae	*Belostoma* sp.	Small giant water bug
	Corixidae		Water boatman
	Nepidae	*Nepa apiculata*	Water scorpion
	Notonectidae		Back swimmers
	Gerridae		Water strider

Order	Family	Genus/Species	Common Name
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

Basic Information

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Principal Investigators:	Van Kelley, David R. German

Publication

Public Outreach

The continued severe drought in western South Dakota the past four 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.

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 will eventually be developed on-line. 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.

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. This coordination and information sharing continued in 2003 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 presentations 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 58,000 fourth grade students state wide, 12,500 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.

Information Transfer

Basic Information

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Principal Investigators:	Van C Kelley, David R. German

Publication

USGS Summer Intern Program

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	3	0	0	0	3
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	8	0	0	0	8

Notable Awards and Achievements

Publications from Prior Projects

None