North Dakota Water Resources Research Institute Annual Technical Report FY 2002

Introduction

This report describes the activities of the North Dakota Water Resources Research Institute (ND WRRI) during the period March 2002 to February 2003.

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

1. Plan, conduct or otherwise arrange for competent research that fosters: (A) the entry of new research scientists into the water resources field, (B) training and education of future water resources scientists, engineers, and technicians; (C) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena; and (D) the dissemination of research results to water managers and the public,

2. Cooperate closely with other colleges and universities in the state that have demonstrated the capability for research, information dissemination and graduate training, in order to develop a statewide program designed to resolve State and regional water and related land problems,and

3. Cooperate closely with other institutes and other organizations in the region to increase the effectiveness of the Institute and for the purpose of promoting regional cooperation.

As noted in the National Program announcement, specific areas of emphasis are at the discretion of the individual Institute Director. The Stae Advisory Committee, water resources faculty at the two research universities of the State, and the Institute Director decided in 1998 to address this charge by directing the bulk of the Institutes resources to fund research projects coupled to Graduate Research Fellowships (GRFs). Up until then, the GRFs had only been a summer program. The upgraded GRFs program meets the requirements of Section 104 of the Water Resources Act very effectively in the following respects:

· often it is junior faculty as well as graduate students who perform competent research that fosters the entry of new research scientists into the water resources field,

· the modest 104b Federal allotment is focused on training and education of future water resources scientists, engineers, and technicians,

· graduate student thesis and dissertation topics foster the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena,

· through the Institute newsletter and website, plus student and faculty presentations and peer-reviewed publications, the dissemination of research results to water managers and the public is accomplished,

· the Institute cooperates closely with other colleges and universities in the state that have demonstrated the capability for research, information dissemination and graduate training by offering competitive fellowships at both research universities in North Dakota, and

· the Institute cooperates closely with other institutes and other organizations in the region to increase the effectiveness of the Institute and for the purpose of promoting regional cooperation by encouraging faculty to seek in-kind and cash matching support from those institutes and organizations, and its external seminar program.

Keeping in mind the modest annual allotment of $84,785 administered through the United States Geological Survey and the lack of state appropriation, the Institute continued with the Fellowship program. The website and the newsletter were continued to facilitate information dissemination and communication. The Institute also continued its efforts to enhance communication between the State and Federal agency personnel and university faculty and students. Advisors and fellows presented their research results to State and Federal professionals.

The Institute continued the same administrative mechanism with the Director, Dr. G. Padmanabhan, Professor of Civil Engineering, managing the Institute program with the help of an Advisory Committee consisting of three members representing the three principal water agencies: State Water Commission, State Health Department, and the USGS. In addition, the Institute also has a Technical Advisory Committee consisting of faculty from the two universities. Though the Institute has no state appropriated support currently, efforts were directed to seek state appropriation and other support sources. The North Dakota State University and the University of North Dakota administrations consider the Institutes activities important and are supportive of its efforts.

The Institute is currently located in the Civil Engineering department of North Dakota State University in Fargo, North Dakota. The University administration has promised a more spaceous office in anticipation of expanded activities of the Institute.

Research Program

For the last several years North Dakota Water Resources Research Institute has offered competitive Fellowships to North Dakota State University (NDSU) and University of North Dakota (UND) graduate students for research on water resources topics. This use of the modest amount of allotment from the USGS Institute base grant is perceived to meet the requirements of Section 104 of the Water Resources Research Act of 1984 effectively. The Fellowships encourage entry of new research scientists into the water resources field, training and education of future water resources scientists, engineers, preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena, and faculty to engage in research and seek collaborative support from entities concerned with water problems.

This year again the North Dakota Water Resources Research Institute continued the Graduate Research Fellowship program and applied the bulk of the Federal allotment to it. The Fellowship program meets almost every requirement of the Section 104 of the Water Resources Research Act of 1984. The

Fellowship program is administered and monitored by the Director. Applications are invited from the graduate students of the two universities of the State. A rigorous review by the advisory committee and other water professionals in the state determines the awards. Active participation of the advisors of the students in meeting matching requirements and in seeking co-funding from local, state and other sources is a positive aspect of the program. Periodical review of the progress of the students in meeting Fellowship expectations is ensured by seeking reports from the students and by encouraging them to make presentations in local and regional technical seminars and conferences.

Guidelines for the 2002-2003 Graduate Research Fellowship competition were posted on the Institute website in September, and the competition was announced in October. The following is the RFA that was published on the University of North Dakota and North Dakota State University campus newsletters, and distributed by e-mail lists:

ND WRRI Calls for Applications for Graduate Research Fellowships

The ND Water Resources Research Institute announces its 2002 Graduate Research Fellowship program. NDSU and UND Graduate students who are conducting or planning research in water resources areas may apply for fellowships varying from three summer months to a full year in duration. Stipends average $1,400 per month. The fellowship funds must be applied between March 2002 and February 2003.

Projects proposed for fellowship support should relate to water resources research issues in the state or region. Regional, state, or local collaborations or co-funding will strengthen an application.

Applications are due in the office of the director on November 16, 2001. They will be reviewed by a panel of faculty and state water resources research professionals. Announcement of awards will be made by early January.

Consult the ND WRRI website, www.nodak.edu/wrri for background on the program, and guidelines for preparation of applications. Fellowships have matching requirements. Applicants and advisors who are new to the program are urged to contact ND WRRI Director, G. Padmanabhan, at 231-7043, or G.Padmanabhan@ndsu.nodak.edu.

NDWRRI Graduate Research Fellowships

Basic Information

Title:	NDWRRI Graduate Research Fellowships
Project Number:	2002ND1B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Treatment, Wetlands, Ecology
Descriptors:	
Principal Investigators:	G. Padmanabhan, G. Padmanabhan

Publication

Graduate Research Fellowships

Seven Fellowships were selected for award in FY2002. Out of these seven, the Fellowship project 'Analysis and Reduction of Phosphorus in the Wastewater of Cargill Inc. North American Corn Milling Industry' had to be withdrawn because the awarded student left the institution. Since this happened early in the awarded period, the Fellowship was awarded to another deserving student with a different project 'Study of effectiveness of Northern Prairie Wetlands as a resource to control nutrient (Phosphorus) load to receiving water.'

The titles of the Fellowship projects awarded are given below and details are provided for each project under separate project sections.

1. Feedlot Runoff and Manure Management Modeling
2. Evaluation of Walleye to Suppress Fathead Minnow Populations in Type IV and V Wetlands
3. Physical and Environmental Factors Influencing the Periphyton Communities of the Sheyenne River, North Dakota
4. A Comparative Analysis of Fargo and Moorhead Ozonation Systems
5. Northern Forest Wetlands: Characteristics and Influences on Invertebrate and Amphibian Community Structure
6. Variables Influencing Habitat Use by Diving Waterbirds Foraging in the Prairie Pothole Region
7. Study of Effectiveness of Northern Prairie Wetlands as a Resource to Control Nutrient (Phosphorus) Load to Receiving Water

Feedlot Runoff and Manure Management Modeling

Basic Information

Title:	Feedlot Runoff and Manure Management Modeling
Project Number:	2002ND7B
Start Date:	4/1/2002
End Date:	7/31/2002
Funding Source:	104B
Congressional District:	First
Research Category:	Engineering
Focus Category:	Models, Water Quality, Hydrology
Descriptors:	Feedlot runoff, Manure management, watershed pollution
Principal Investigators:	James Lindley

Publication

1. KIZIL U., J.A. LINDLEY. 2002. Determination of Runoff Curve Number for a Bison Feedlot. 2002 ASAE/CSAE North-Central Intersectional Meeting. Parktown Hotel, Saskatoon, Saskatchewan, CANADA.September 27-28, 2002 Paper No. MBSK 02-302
2. Kizil, Unal. 2003. Ph. D., "Development of a Software Program, Feedlot Hydrology/Nutrient Management, and GIS Database for the State of North Dakota." Agricultural and Biosystems Engineering Department,College of Engineering and Architecture, North Dakota State University, Fargo, ND 58105. Major Professor: Jim Lindley

Feedlot Runoff and Manure Management Modeling

ND WRRI Graduate Research Fellowship Project
Unal Kizil, Fellow
Jim Lindley, Advisor and Principal Investigator
Agricultural & Biosystems Engineering Department
North Dakota State University
Fargo, ND 58105

Abstract

The overall goal of this research is to develop a complete feedlot runoff and manure management model to predict runoff and its concentrations generated from feedlots, and develop an online GIS database. Preservation of environmental quality makes it essential that feedlot runoff be handled and controlled appropriately to prevent water contamination. Regulations, such as Clean Water Act, provide enforceable criteria for environmental protection from contamination by livestock production. Since the animal manure is exposed to the runoff, pollution potential of the feedlots depends on the size of operation, rainfall intensity, duration and frequency. According to data obtained from G. Haberstroh of North Dakota State Department of Health, there are 106,874 animal units (1 animal unit = 500 kg of live weight) of beef cattle have been growing in North Dakota. The importance of the feedlot operations in the State, pollution potential of feedlot runoff, and regulations make it imperative to pay more attention to animal operations, especially feedlots to protect water resources. Some watershed based hydrological and water quality models have been adapted to feedlot. A manure management plan model also has been decided to use in the study. A paper describing these models has been presented in ASAE Annual Meeting. In order to validate the hydrological and water quality models, field experiments have been conducted. Runoff measurements (quantity, quality), and manure sampling have been completed.

Critical state or regional water problem being investigated

In North Dakota for regulatory purposes a feedlot is defined as "any livestock feeding, handling, or holding operation or feed yard where animals are concentrated in an area which is not normally used for pasture or growing crops and where the space per animal unit is less than 600 ft^2 (56 m^2). Concentrating cattle in feedlots has numerous advantages in terms of productivity and quality control and is a practice widely accepted in North Dakota.

In the feedlots, large concentration of animals produces concentrated areas of manure production. Runoff from cattle feedlots contains relatively high concentrations of nutrients, salts, pathogens, and BOD demand. These nutrients, which are so beneficial to crops and soils, can have detrimental effects when carried into surface or groundwater. In surface waters they may cause large growths of algae, resulting in fish kills and decreased recreational opportunities. Nutrients in groundwater contaminate wells.

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Anticipated results and benefits from the study
Considering the importance of livestock production and its potential affects on water quality in North Dakota there is a need to evaluate feedlot runoff. Anticipated benefits of the study can be summarized as follows:

a) Watershed based hydrologic and water quality models will be modified to predict feedlot runoff and its constituents.

b) Design criteria for ND feedlots will be developed as a result of the field experiments

c) The user friendly computer program will enable the producers to design runoff control structures, make manure management plans

d) Use of the computer program will reduce the overall risk of water pollution due to improper handling and management of runoff and manure.

e) North Dakota feedlots will be spatially evaluated using GIS and evaluation results will be provided online.

f) These results will demonstrate the critical watersheds in North Dakota from the viewpoint of feedlot runoff.

g) Feedlot owners will be able to evaluate their feedlots online to see if their feedlot meets the State criteria

h) Using the computer technologies, such as Internet and GIS, it will be possible and easy to reach the producers, and update information.

i) The results will provide a good base for the future studies.

Scope and objectives of the research

The overall goal of this research is to develop a complete feedlot runoff and manure management model to predict runoff and its concentrations generated from feedlots, and develop an online GIS database. The corresponding objectives to achieve the goal are to:

- define the hydrologic models for feedlots, and conduct field experiments to validate these models
- develop a user friendly computer program that will help users to predict runoff and its characteristics, design runoff management structures, and make manure management plans.
- develop an online GIS database for North Dakota feedlots that will help scientists for Nonpoint Source (NPS) evaluation, and estimate the overall pollution risk which might be generated from the feedlots.

The first objective of the study has already been completed. Some watershed based hydrological and water quality models have been adapted to feedlot. A manure management plan model also has been decided to use in the study. A paper describing these models has been presented in ASAE Annual Meeting. In order to validate the hydrological and water quality models, field experiments have been conducted. Runoff measurements (quantity, quality), and manure sampling have been completed. Flowcharts of the proposed computer program are ready. Fellowship study included the development of computer program, and validation of the results. Feedlot database that was obtained from the ND Health Department were converted to GIS format. For different rainfall events such as 10 year-24 hour, 25year-24 hour, the developed computer program was run, and results published online along with database in GIS format. An ArcView extension was used to achieve it.

Methods, procedures, and facilities

In this study, Bison Feedlots of Carrington Research Center of North Dakota State University were chosen. Carrington is 40 miles NW of Jamestown, ND and 134 miles West of Fargo, ND. Runoff from 2 lots were measured. Each 4 lots drain into a runoff storage pond. There are 2 storage ponds of size 64x16 m (1024 m^2). Size of each lot is 22x21m (462 m^2); drainage area of each runoff storage pond is 67x54 m (3618 m^2) including the pond surface area. Two flowmeters, 2 runoff samplers, and 1 water sampler (from the storage pond) were installed.

The following procedure was followed to accomplish the objectives and associated tasks of the study:

Objective 1: To define the hydrologic models for feedlots, and conduct field experiments to validate these models

a) Definition of Hydrologic Models for Feedlot Runoff: The preliminary objective of this study is to define the hydrologic models for the estimation of feedlot runoff. Although, some studies have been conducted to predict feedlot runoff, results vary widely.

b) Determination of Runoff Curve Number for Feedlots: The key factor in the estimation of runoff is curve number. To determine the curve number for North Dakota conditions runoff data were collected from 2 feedlots.

c) Prediction of Runoff Characteristics: Using nutrient and sediment transport equations it is possible to predict amount of NO_3-N lost from the first layer, organic N runoff lost, soluble P lost in runoff, sediment phase of P in runoff, and sediment yield etc. In the study, collected feedlot soil, runoff, and manure samples were sent to a commercial labs. Lab results will provided data for required variables, and feedlot runoff characteristics. Then, nutrient and sediment transport equations were calibrated for feedlots.

Objective 2: To develop a user-friendly computer program that will help users to predict runoff and its characteristics, design runoff management structures, and make manure management plans

a) Hydrology and Nutrient Transport Module: After finding the required variables for hydrology and nutrient transport model in Objective 1, Visual Basic programming language was used to develop a software program.

b) Manure Management Module: The procedure used in this module provides step-by step plan development instructions and worksheets. Entering the required information a complete manure management plan can be prepared. This module balances the plant nutrient requirements, available soil nutrients, and feedlot runoff/manure nutrients. A proper manure management prevents excessive nutrient load to the field, therefore reduces the water pollution risk.

c) Runoff Control Facilities Design Module: This module will design runoff control facilities, such as settling basin, runoff and manure holding ponds, for a given feedlot operation.

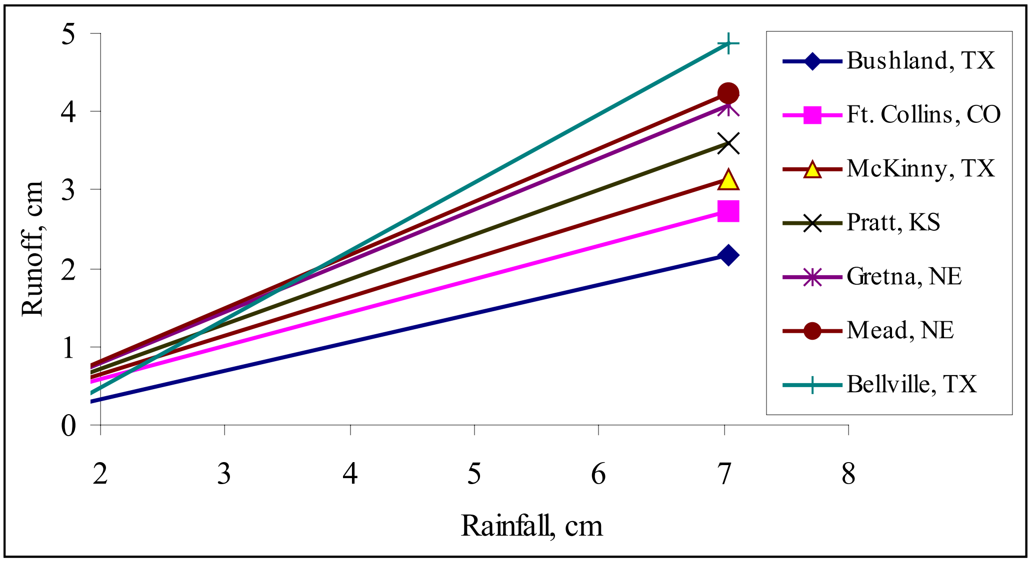
Objective 3: To develop an online GIS database for North Dakota feedlots that will help scientists for Nonpoint Source (NPS) evaluation, and estimate the overall pollution risk which might be generated from the feedlots

a) Development of On-line GIS Database: A complete feedlot database for the State of North Dakota has been obtained from Health Department. The database includes the coordinates of feedlots, number of animals, status (active or not), county, animal type, watershed etc. In ArcView GIS software a GIS-based feedlot database was developed. GIS-based database includes the mentioned information about the feedlots. Feedlots can be evaluated on-line considering the State Laws and literature.

Results
Objective 1:

Runoff generated from the feedlot and contributing areas, was calculated using SCS Curve Number method. This method is based on a number called "runoff curve number". Determination of runoff curve number is the key factor in the prediction of runoff, and nutrient transport from a feedlot. There is literature reporting the curve numbers for feedlot operations. However, this number is dependent on soil characteristics, soil cover and use, and rainfall intensity etc. Therefore, the literature values vary significantly.

The other technique has been used in the runoff prediction is developing linear relationship between rainfall and runoff. Relationships between rainfall and runoff at different locations in the USA are given in the following figure (1).



As can be seen from the figure, slopes of the linear equations are different at each location. Therefore it is essential to determine the linear relationship for the study area of interest.

The estimation of runoff quality and quantity is critical. Design of runoff containment structures, nutrient budgeting, and pollution discharge to a water body – if no containment structure available – are dependent on a good estimation of runoff depth. Therefore, developing rainfall-runoff relationship and/or determining runoff curve number for North Dakota is highly important from the view point of pollution transport from feedlot operations to the water resources of the State.

In our study we found that a curve number of 93 can be used to estimate runoff amount, and the following relationship gives the highest R^2-value of 73 between rainfall and runoff events.

$$R = 0.57P - 1.16$$

Where:

R = runoff, mm

P = rainfall, mm

Another goal of the Objective 1 was to evaluate some hydrology/nutrient transport models, such as EPIC and AGNPS. The EPIC model is a watershed-based model that can be used to predict runoff and nutrient transport along with the runoff from a particular watershed. Soil nutrient concentrations, such as N, P should be known to estimate runoff nutrient transport.

In the AGNPS model a simpler approach is used in the prediction of nutrient transport from a feedlot. Average feedlot runoff N, P, or COD concentrations should be provided to the model. Proportional to the percent manure pack on the feedlot surface, the default nutrient concentrations are changing for a particular feedlot operation. For example, if the percent manure pack is 100, it is assumed that runoff nutrient concentrations will be equal to the default values. If it is less than 100, the actual nutrient concentration of the runoff will be decreased proportional to the percent manure pack.

The purpose of our study is to see if the EPIC model approach, which is a watershed-based model, can be used to estimate nutrient transport from the feedlots. The AGNPS approach was supported with EPIC model approach. Because each model is specific to certain nutrient compounds.

The EPIC and AGNPS models were adapted to feedlot hydrology in order to predict runoff quality and quantity. Organic-N and P were predicted with high correlation coefficients of 0.89 and 0.81 respectively. Hence, the model can be used in the prediction of Org-N and P transport. Use of model will provide an opportunity to evaluate overall pollution potential of a feedlot operation if no runoff confinement systems exist.

Even though the model did not provide a good coefficient of correlation for other nutrient compounds, still the predicted results are a good representation of actual data. The runoff collected from the feedlot is not applied to field as it is generated. Stored runoff characteristics change significantly during rainy weeks, but during storage period the average pond characteristics stay stable. This implies that accurate estimation of runoff characteristics is not necessary for waste management purposes. As discussed above, average predicted and observed runoff characteristics are satisfactorily close to each other. Therefore knowing the average runoff characteristics and storage losses might be good enough to manage the feedlot runoff.

The EPIC model uses the soil nutrient characteristics as inputs and predicts the amount of nutrient transport by runoff. In this study manure samples that were collected from the feedlot surface were used as source of nutrients. The manure samples were a mixture of soil, feces, urine, water, and spilled feeding materials. During the study the animal density was high enough to provide evenly distributed and compacted manure. It is showed that manure analysis results provide data not only for manure management planning but also nutrient transport models.

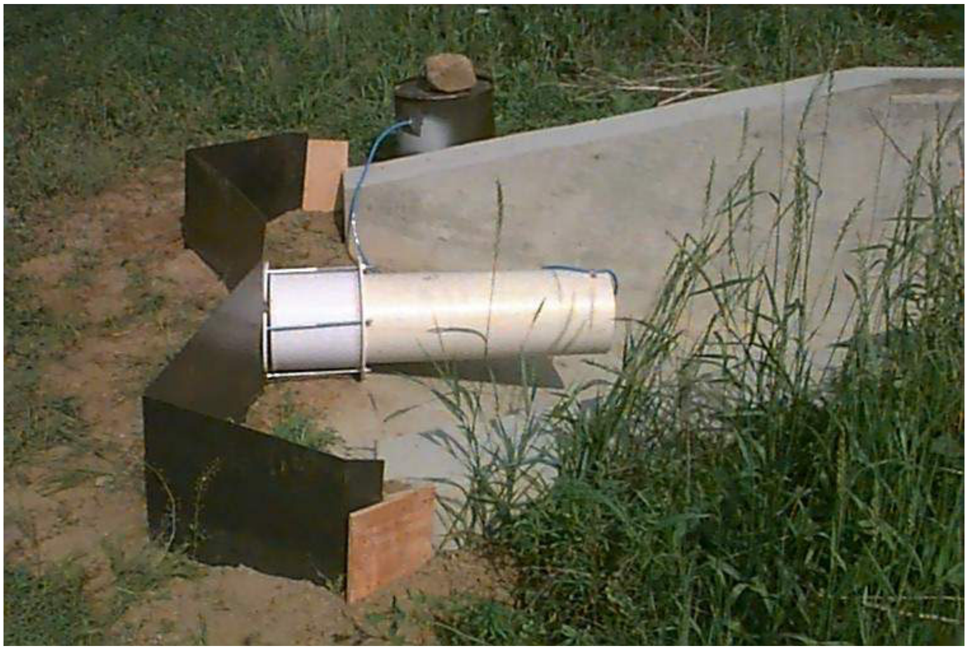
Carrington Research Center of the North Dakota State University (NDSU) University provided the feedlots, and information about the animals, operation period, etc. An automatic liquid sampler was obtained from the Civil Engineering Department of NDSU.

Objective 2:
The second objective of this study is to develop a user-friendly computer program. The program has 3 modules as follows:

1- Hydrology/nutrient module: In this module runoff quality and quantity is calculated using the models explained in the previous objective. Amount of nutrient loading to a water body (if there is no runoff containment structure, or in case of a failure of the containment structure) is estimated in this module. Also, runoff quality and quantity data is used in the second module to make a manure management budget.

2- Manure management module: Mass balance approach is used in the program to predict the nutrient fate of the manure. Manure and/or runoff application rate, required commercial fertilizer amount, and commercial value of the produced manure are some of the outputs of this module. Over application of manure and/or runoff might create water pollution due to the excess amount of nutrient build up in the soil followed by surface runoff or leaching. Therefore it is essential to apply optimum amount of manure/runoff to the field. This module can be used as a tool that provides environmentally sound waste management plans.

3- Storage or treatment system design module: The last module of the program provides a tool to design waste storage and treatment systems. To protect water resources from feedlot related pollution, manure/runoff should be controlled. Generally control means containment of the waste material and application of it to the field when the soil, and weather suitable. The design criteria were taken from the Agricultural Waste Management Field Handbook of USDA Natural Resources Conservation Service. The software was written in Visual Basic programming language.



Feedlot Runoff Measuring System

Sampling System

Evaluation of walleye to suppress fathead minnow populations in Type IV & V wetlands.

Basic Information

Title:	Evaluation of walleye to suppress fathead minnow populations in Type IV & V wetlands.
Project Number:	2002ND9B
Start Date:	5/1/2002
End Date:	12/31/2002
Funding Source:	104B
Congressional District:	At large
Research Category:	Not Applicable
Focus Category:	Wetlands, Ecology, Water Quality
Descriptors:	Aquatic Ecology, Fathead Minnow, Wetlands, Walleye
Principal Investigators:	Malcolm George Butler

Publication

Evaluation of walleye to suppress fathead minnow populations in Type IV & V wetlands

ND WRRI Graduate Research Fellowship Project
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Abstract

Changes to the landscape of the prairie pothole region over the last hundred years, primarily due to agriculture, have caused the consolidation of temporary, seasonal, semi-permanent, and permanent wetlands, creating large Type IV and V wetlands. These larger, deeper wetlands are consistently found to be in a turbid state. The increase in the depth of many prairie wetlands due to drainage and consolidation has caused a decrease in the frequency and extent of summer and winter anoxia. Historically such harsh conditions have kept fathead minnow populations in check. Fathead minnows now persist on a more permanent basis, and population densities often become very high, with repercussions throughout the food web. The high densities of fathead minnows reduce zooplankton and macroinvertebrate diversity and abundance. Reductions in zooplankton in turn directly contribute to very high abundances of algae, which are directly associated with increases in turbidity and degraded water quality. The high turbidity causes a reduction in macrophyte diversity and abundance. The overall degradation of wetlands deters waterfowl use, as many waterfowl species are dependent upon zooplankton, macroinvertebrates, and macrophytes as major food sources. The degradation of prairie pothole wetlands as a result of fathead minnow infestations is a steadily increasing problem. Innovative, effective ways to control the distribution and abundance of fathead minnow populations in wetlands throughout the Prairie Pothole Region are needed by wetland managers. The purpose of this project is to assess one possible tool that could be used by wetland mangers to improve conditions in degraded wetlands. The project also focuses on the effectiveness of wetlands as rearing sites for walleyes for subsequent stocking in lakes. Wetlands are already used for walleye rearing, but the net effects the walleyes may have on the wetlands themselves are not clear. The expected effect of adding walleyes to type V and IV wetlands with fathead minnows is that of a "trophic cascade". The bwalleyes should decrease densities of fathead minnows. The decrease in fathead minnows should allow zooplankton and invertebrate diversity and densities to increase. The increase in zooplankton, particularly Daphnia, should cause a decrease in alga standing stock, which will increase water clarity (or decrease in turbidity). The decrease in turbidity should allow macrophytes to increase in diversity and abundance. The decrease in turbidity and increases in zooplankton and macrophytes should also increase use of the wetlands by waterfowl. The survival and growth rates of the walleyes are expected to high.

REGIONAL WATER PROBLEM

Changes to the landscape of the prairie pothole region over the last hundred years, primarily due to agriculture, have caused the consolidation of temporary, seasonal, semi-permanent, and permanent wetlands, creating large Type IV and V wetlands. These larger, deeper wetlands are consistently found to be in a turbid state. The increase in the depth of many prairie wetlands due to drainage and consolidation has caused a decrease in the frequency and extent of summer and winter anoxia. Historically such harsh conditions have kept fathead minnow populations in check. Fathead minnows now persist on a more permanent basis, and population densities often become very high, with repercussions throughout the food web. The high densities of fathead minnows reduce zooplankton and macroinvertebrate diversity and abundance. Reductions in zooplankton in turn directly contribute to very high abundances of algae, which are directly associated with increases in turbidity and degraded water quality. The high turbidity causes a reduction in macrophyte diversity and abundance. The overall degradation of wetlands deters waterfowl use, as many waterfowl species are dependent upon zooplankton, macroinvertebrates, and macrophytes as major food sources. Innovative, effective ways to control the distribution and abundance of fathead minnow populations in wetlands throughout the Prairie Pothole Region are needed.

LITERATURE SUMMARY

The steady increase in land use for agriculture has resulted in consolidation of smaller shallower wetlands in the Prairie Pothole Region, creating large Type IV and V wetlands (Stewart and Kantrud 1971). The lower probability of these larger and deeper wetlands producing anoxic conditions has permitted for major increases in fathead minnow (*Pimephles promelas*) populations. Fathead minnows are a native species and are the most common fish in prairie wetlands (Peterka 1989) but their distribution is limited by the harsh conditions in prairie potholes, particularly anoxia. Fathead minnows have a very dynamic life history that under favorable conditions allows populations to grow exponentially into high densities (Held and Peterka 1974; Payer and Scalet 1978; Carlson and Berry 1990; and Duffy 1998). Due to this high reproductive potential, fathead minnows in wetlands without periodic anoxia can reach very high densities very quickly. The rapid growth and high food consumption of fathead minnows cause them to have critical influences on energy flow in wetlands. Fathead minnow diets consist predominantly of crustaceans and aquatic insects (Held and Peterka 1974). Fatheads' ability to grow so quickly and to have such a profound influence on a wetland's fauna stems from their ability to consume prey with both filter-feeding and particulate feeding methods (Hambright and Hall 1992).

The extremely high densities of fathead minnows found in the larger Type IV and V wetlands results in some negative effects on those waterbodies. Reduced abundances, biomass, and species richness in common orders of invertebrates were reported by Hanson and Riggs (1995), and Zimmer et al. (2000) documented dramatic shifts in invertebrate community composition when minnows were present. Increases in nutrient levels, phytoplankton biomass, and turbidity were seen in experimental wetlands stocked with fathead minnows (Hanson et al. 1995). Zimmer et al. (2001) found that fathead minnows directly and indirectly affect the nutrient partitioning within a wetland, with wetlands that have low macrophyte abundance and high fathead minnow densities being in a turbid state. The increase in nutrient recycling provides more nutrients available to phytoplankton, allowing them to grow and increase in density. One might expect, in response to the increase in phytoplankton, an increase in zooplankton densities, but the high feeding efficiency of fathead minnows does prohibit the increase in zooplankton, resulting in an overall increase in turbidity. Also, macrophyte communities deteriorate under the highly turbid conditions. Plant abundance and species composition decrease due to increased light attenuation (Hansel-Welch et al. in press). Nutrient recycling rates are increased in part due to the increased density and the feeding efficiency of fathead minnows and the absence of macrophytes, both of which contribute to greater turbidity (Scheffer et.al. 1993; Hanson and Butler 1994).

Previous studies evaluated ways of controlling fathead minnows but no methods have had a high success rate. In one study conducted by Zimmer (2001), rotenone was applied to ten Minnesota wetlands containing fathead minnows. Only one treatment out of the ten was successful in eradicating the fathead minnow population. In another study, commercial harvesting of fatheads was applied to two South Dakota wetlands, but had little influence on the fathead minnow populations (Duffy 1998).

The application of "biomanipulation" to control fathead minnow populations is based on the concept of a top-down effect of predation causing a "trophic cascade" (Carpenter et. al. 1985; Carpenter and Kitchell 1988). The idea is that the introduction of a top predator can alter the entire trophic structure of a system. In the case of wetlands, the top predator is a piscivore (walleye), intentionally stocked to decrease and regulate the planktivores (fathead minnows), allowing the herbivores (zooplankton) to increase and flourish. The flourishing zooplankton in turn regulate the phytoplankton by grazing. This reduction of algae also slows down nutrient recycling because nutrients are retained by the zooplankton and piscivores. The net result hoped for is a shift of the system from a turbid water state to a clear water state. The clear water state will allow the resurgence of macrophytes, which in turn contribute to suppression of algae via several mechanisms (Scheffer 1998; Moss et al. 1996). The macrophytes will also decrease turbidity by not allowing the sediment to be stirred up of the bottom by wave action created by the wind.

The use of piscivorous fish to limit fathead minnow densities and improve water quality has shown some success in previous studies. A study in a South Dakota pond showed a significant decrease in fathead minnow densities during the summer growing season due to walleye (*Stizostedion vitreum*) predation (Walker and Applegate 1976). Northern pike (*Esox lucius*) and largemouth bass (*Micropterus salmoides*) have also shown promise for suppressing fathead minnow populations (Elser et. al. 2000; Spencer and King 1984). Stocking piscivorous fish in wetlands that are already fishless can have negative effects on the wetland. Reed and Parsons (1999) reported that walleye rearing in a fishless wetland did appear to reduce densities of some invertebrate orders, and recommended that walleye rearing cease in fishless ponds.

The uncertainty surrounding the effects that stocked piscivorous fish may have on a wetland ecosystem has prevented managers from using this method to control fathead minnow populations. The rising problem of deteriorating wetlands has pushed this issue to the forefront. There is as of yet no information indicating negative effects from walleye rearing in wetland ponds already containing fathead minnows. If the current evaluation of walleye stocking proves to result in improvements in wetland water quality and other ecosystem characteristics, this technique may hold benefits for the management of both wetlands and fisheries.

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OBJECTIVES OF THE PROPOSED RESEARCH.

The degradation of prairie pothole wetlands as a result of fathead minnow infestations is a steadily increasing problem. Wetland managers need effective tools to deal with this problem. The purpose of this project is look at one possible tool that could be used by wetland mangers to improve conditions in degraded wetlands. The project also focuses on the effectiveness of wetlands as rearing sites for walleyes for subsequent stocking in lakes. Wetlands are already used for walleye rearing, but the net effects the walleyes may have on the wetlands themselves are not clear. With these two overall objectives in mind, the intent of the project is to test the following hypothesis:

- H_1: The biomass of fathead minnow populations will decrease following the introduction of walleye.
- H_2: The densities of cladocerans, amphipods, dipterans, and corixids will increase following the introduction of walleye.
- H_3: Water clarity will increase in the ponds following the introduction of the walleyes.
- H_4: The density of submerged aquatic plants will increase following the introduction of walleye.

METHODS, PROCEDURES, AND FACILITIES.

This research is part of a collaborative effort between the Minnesota Department of Natural Resources, NDSU, and SDSU. Other participants are focusing on the fisheries aspects of the study, while I am responsible for investigating responses of water quality, invertebrate communities, and plants.

Study sites and design

Eighteen semi-permanent type IV and V wetlands with established fathead minnow populations were randomly chosen for this two-year study from forty possible wetlands in the Minnesota Prairie Pothole Region. The selected ponds are distributed from the middle of Clay County south to the southern end of Big Stone County and east to Douglas and Pope Counties. The eighteen chosen wetlands were then randomly assigned to one of three treatments, with six sites in each treatment. The three treatments are: 1) walleye fry, 2) advanced-stage walleye, and 3) control (containing only fathead minnows). In the six walleye fry stocking treatments the fry were stocked in late spring and removed in the fall of 2001, this stocking and removal will be repeated for the second season of 2002. The six advanced-stage walleye treatments were stocked in the spring of 2001. Population estimates were taken this last fall (2001) and the walleyes were left in the wetlands to be carried over for the next year (2002). The treatments in the second year will be applied to the same wetlands as in the first year.

Sampling Methods

Fish communities:
Brian Herwig, a fisheries biologist from the Minnesota DNR office in Glenwood is working on biomass and relative abundance of fathead minnows. Matt Ward, a graduate student at South Dakota State University, is working on walleye diet, growth, and survival.

Aquatic Invertebrates:
Activity traps, a vertical column sampler, and an Ekman grab are being used to sample aquatic invertebrates. The sampling season begins in May and ends in September. Two sampling crews do the sampling, one crew samples the nine northern most ponds and the second crew samples the nine southern most ponds. Ten sampling sites are used per wetland; these sites were used for the entire sampling season. There are five sampling sites in the littoral zone around the wetland, and five in the open water zone.

Selection of sampling sites involves:
1. The approximate center of wetland is located.
2. Five transects at random compass bearings are selected.
    - Transects cannot be within 20^0 of each other.
    - All transects can not be within 180^0.
3. Two sample sites are located along each transect, one at the interface of the open water, and emergent vegetation and the second half way between shore and the center of the wetland.
4. Sites are marked with buoys and used for the entire sampling season.

Ten activity traps are deployed in each wetland monthly, hung from the site buoys for 24-hour periods. From the activity trap catches taxon richness and relative abundance of invertebrates are being analyzed. The analysis of invertebrate and zooplankton is being done at NDSU.

A vertical column sampler is used monthly at the five open water sites in each wetland. At each site two samples are taken. Taxon richness, relative abundance, and biomass (estimated from length-weight regressions) of zooplankton are being analyzed.

Twelve Ekman grab samples are collected once at the beginning of August in each wetland. Ten of these samples are taken at the 10 previously marked sample sites, and two samples are taken directly in the center of the wetland. Taxon richness, relative abundance, and biomass of invertebrates (from length-weight regressions) are being analyzed from the samples.

Macrophytes
Aquatic plants are sampled in late July using a plant rake. Ten sample sites are used, and at each site four samples (or rake throws) are taken. The ten sample sites are along transects one, three and five. The open and emergent sites on these transects are used, plus one in between the two

sites on those transects. One sample site is in the center of the wetland. Taxon richness and frequency of plant occurrence are being analyzed.

Water Quality Parameters:
Turbidity measurements are taken from the center of each wetland each month with a nephelometer. Water samples are also taken from the center of the wetland each month simultaneous with the other monthly sampling. These water samples are shipped to the Minnesota Department of Agriculture chemistry lab in St. Paul for analysis for total phosphorous, total nitrogen, Kjeldahl nitrogen, and chlorophyll *a*.

Facilities Used:
The Department of Biological Sciences at NDSU provides office and laboratory space, along with secretarial and clerical support. The laboratory provides microscopes, image analysis equipment, and computers. Chemicals (ethanol) are bought from the NDSU Chemistry Department. The majority of field equipment being used is from North Dakota State University, though the Minnesota DNR does provide some field equipment, for example a boat.

ANTICIPATED RESULTS AND BENEFITS FROM THE PROPOSED STUDY.

The expected effect of adding walleyes to type V and IV wetlands with fathead minnows is that of a “trophic cascade”. The walleyes should decrease densities of fathead minnows. The decrease in fathead minnows should allow zooplankton and invertebrate diversity and densities to increase. The increase in zooplankton, particularly *Daphnia*, should cause a decrease in alga standing stock, which will increase water clarity (or decrease in turbidity). The decrease in turbidity should allow macrophytes to increase in diversity and abundance. The decrease in turbidity and increases in zooplankton and macrophytes should also increase use of the wetlands by waterfowl. The survival and growth rates of the walleyes are expected to high.

The information gained by this study will be used by state and federal wetland managers in their management decisions. The information will also be used by area fisheries managers who must decide whether using wetlands as rearing ponds is an effective way of rearing walleyes for stocking, and what the environmental consequences of this practice may be.

PRIOR WORK

The first field season ended this September. Overall the work went well, with only major problem being accuracy of the nephlometers that were used. The two nephelometers will be fixed before next season plus we also add the use of a Secchi dish. We are still processing samples taken from this summer, and have just begun the September samples. Some preliminary data from May to August are presented in Figure 1. These data are preliminary and have not been thoroughly analyzed or tested for significance, yet they are encouraging.

Figure 1. Mean Catch Per Unit Effort (24hr set) of Cladocerans in All Three Treatments

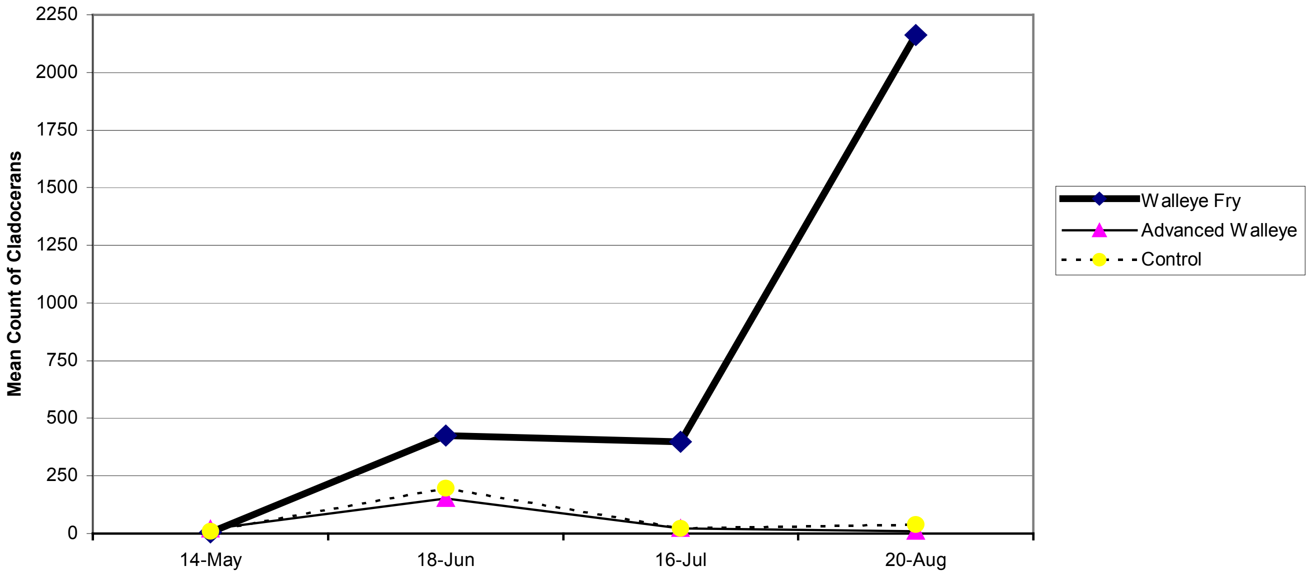


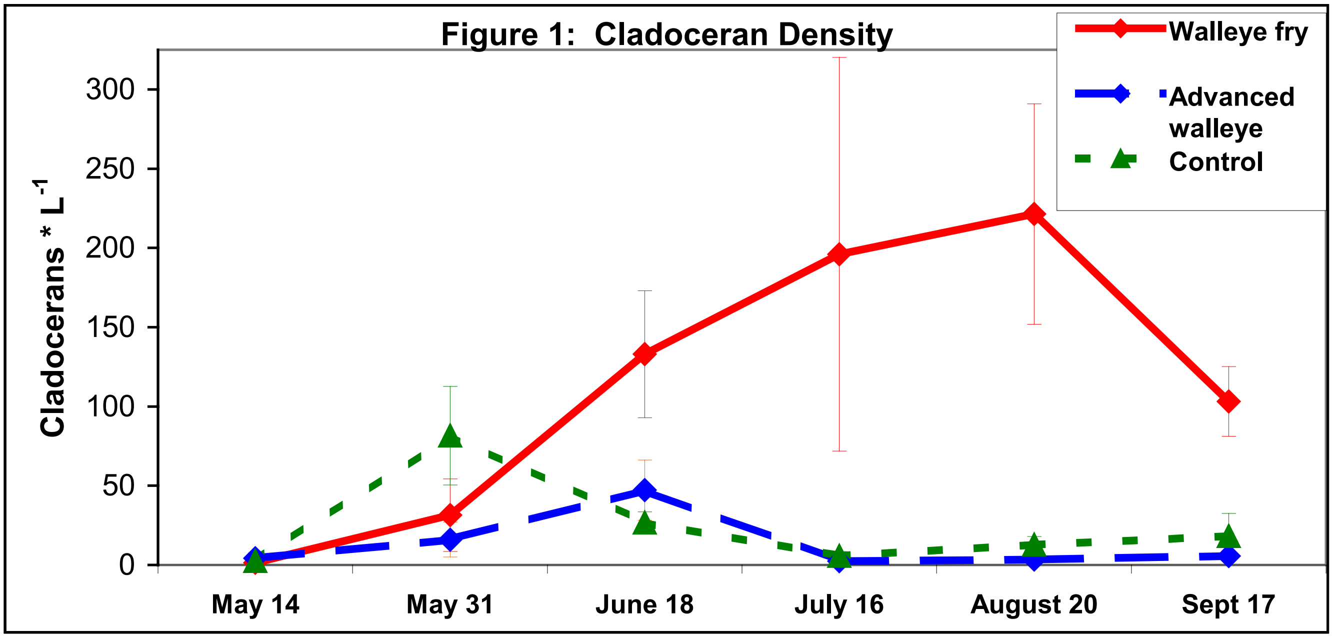
Figure 1 shows a higher densities of cladocerans in the walleye fry treatment, with an initial increase, maintainence of that increase through July, followed by a increase in August. The other treatments had a small peak in June followed by low numbers for the rest of the summer. Cladocerans are a key species in controlling alga abundances and, cladocerans are also a favorite food of fathead minnows. The trend in the fry treatments of increased cladocerans may be an indictor that the trophic cascade has occurred as hypothesized.

This upcoming winter the Ekman samples will be processed, biomass estimates will calculated using image-analysis and length–weight regressions, and the accumulated data from all the different parameters will be analyzed using SAS.

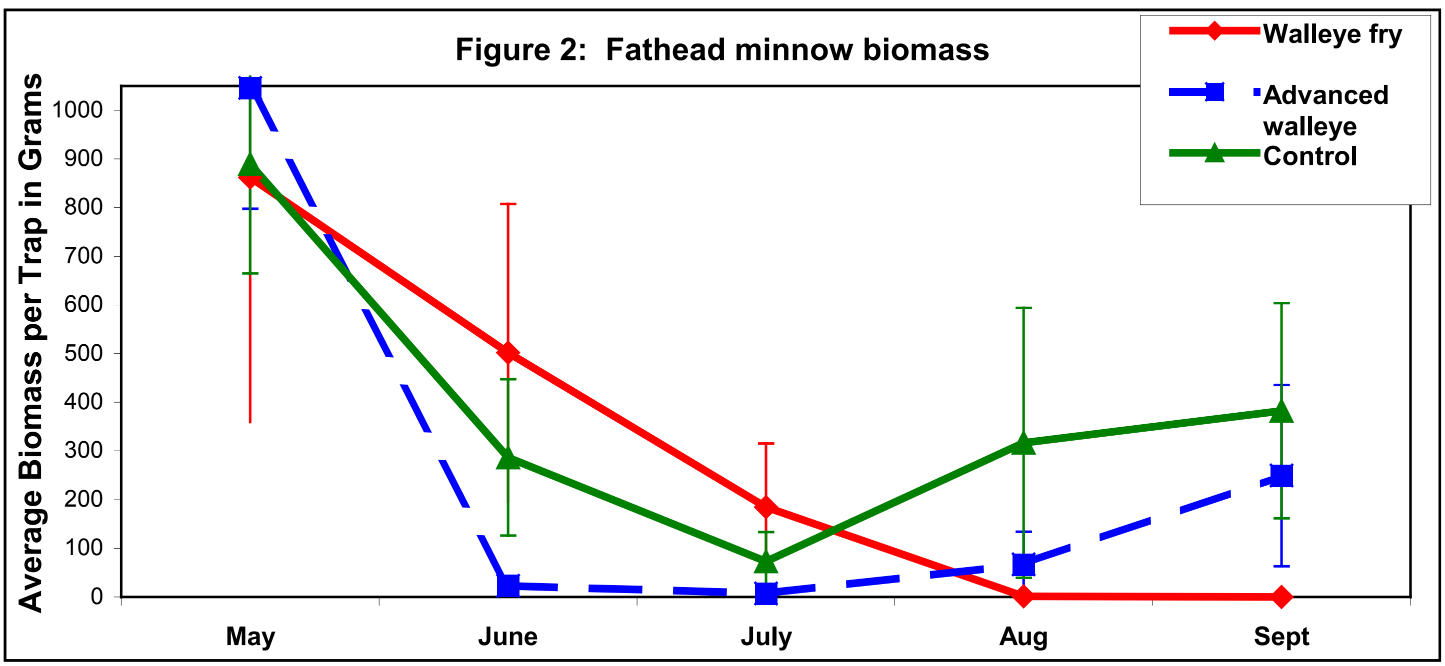
RESULTS

The greater depth of many prairie wetlands resulting from consolidation of smaller, more ephemeral wetlands has caused a decrease in the frequency and extent of summer and winter anoxia. As a result, fathead minnows now persist on a more permanent basis, often reaching high population densities, and have been found to reduce zooplankton and macroinvertebrate diversity and abundance. Reductions in zooplankton can in turn lead to increased phytoplankton, decreased water clarity, and reduced macrophyte abundance. Ultimately, these combined changes result in decreased waterfowl use. Innovative, effective ways to control the distribution and abundance of fathead minnow populations in wetlands throughout the Prairie Pothole Region are needed by wetland managers. We designed a two-year study to assess stocking of walleye fry or advanced life-stage walleye as a tool to suppress fathead minnow populations and improve water quality. All wetlands used in the study contained fathead minnow populations. Treatments consisted of 6 wetlands stocked with walleye fry, 6 wetlands stocked with adult walleyes, and 6 wetlands that were left unmanipulated (contained only fathead minnows). Response variables included measurements of the macroinvertebrate and zooplankton communities, turbidity, and multiple water quality parameters. Explanatory variables included fathead minnow biomass, macrophyte abundance, and treatments. The data analysis of the first year of data is complete. To date the majority of analyzes has followed a multivariate approach, specifically ordinations. In addition to using ordinations to analyze the data I will also be using a mixed model ANOVA in SAS to test specific hypotheses in my continuation of this study.

In the first year of the study we observed a higher density of cladocerans in the walleye fry treatment by mid June, with a 17.5-fold increase over reference wetlands by mid August (Fig. 1). Walleye fry stocking appeared to have little effect on most macroinvertebrate populations. The trend of increased zooplankton in the fry treatment, particularly the cladocerans, corroborates our observations that walleye fry were successful in suppressing fathead minnows (Fig. 2). This



released zooplankton from predation, which led to water clarity improvements in some walleye



fry treatment ponds.

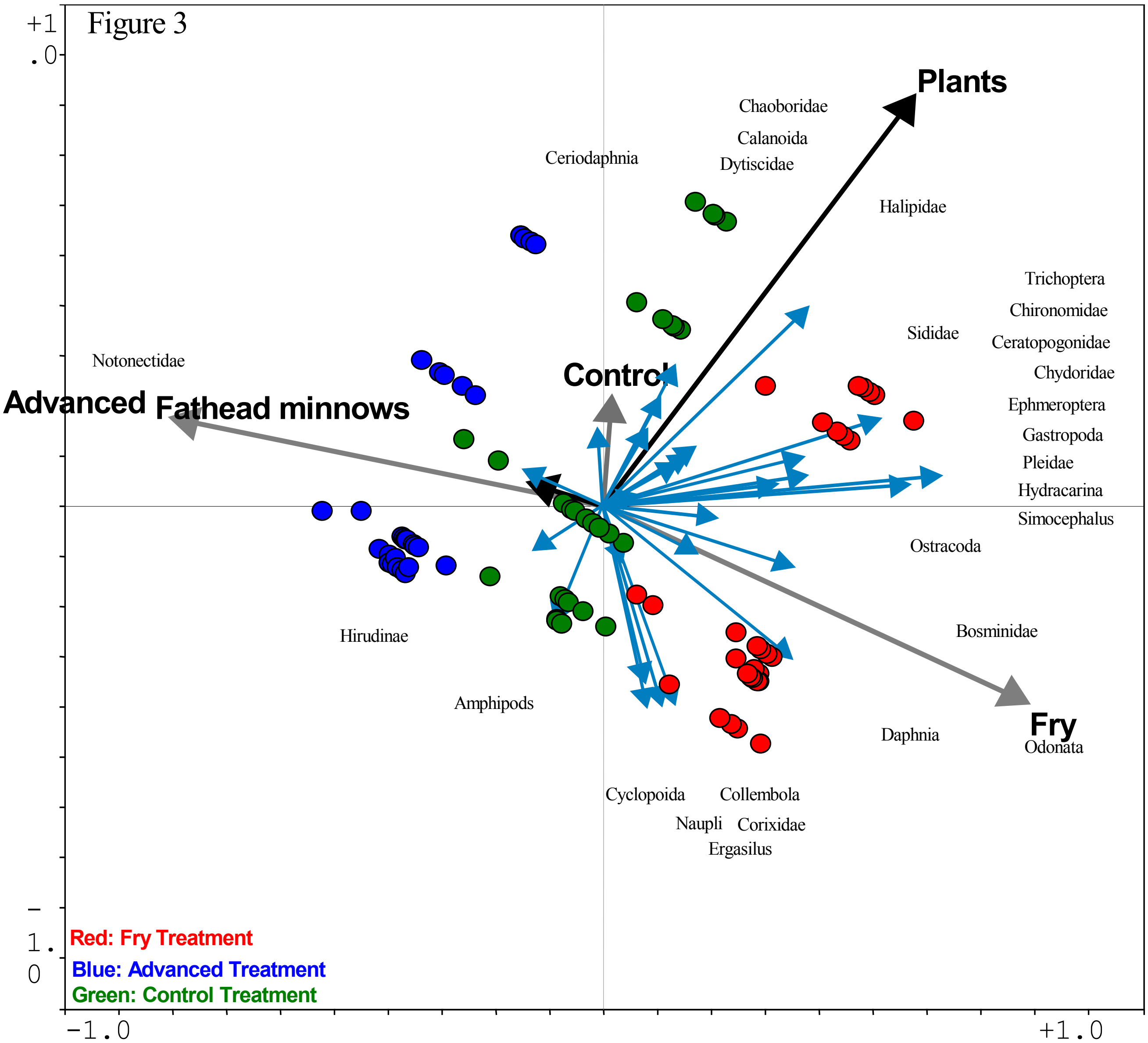


Figure 3 is an example of a partial redundancy analysis (P-RDA) ordination and how I am using this approach to evaluate my results. The explanatory variables in the RDA are the following: fathead minnows (biomass), plants (abundance), and treatments (fry, advanced, and control). The response variables are the invertebrate abundances. Three key points can be seen in the RDA. First, the majority of invertebrate taxa have a positive association with fry treatment wetlands, an over-all neutral association with control treatment wetlands, and a negative association with advanced treatment wetlands. Second, fathead minnows have a negative association with the fry treatment wetlands, a neutral association with the control treatment wetlands, and a positive association with the advanced treatment wetlands. Third, none of the treatments has a strong positive or negative association with plants.

The results from the first year of the study indicate that the biomanipulation in the fry treatment wetlands responded positively. The positive response can be seen in the decrease in fathead minnow biomass and the increase in cladoceran abundance in the fry treatment wetlands. The response in the advance treatment wetlands was negative, with decreased abundance of most invertebrate groups. The positive results in the fry treatment have potentially set the stage for those wetlands to shift from being in a turbid water state to a clear water state during the second year of the study.

Physical and environmental factors influencing the periphyton communities of the Sheyenne River, North Dakota

Basic Information

Title:	Physical and environmental factors influencing the periphyton communities of the Sheyenne River, North Dakota
Project Number:	2002ND10B
Start Date:	3/1/2002
End Date:	10/31/2002
Funding Source:	104B
Congressional District:	1
Research Category:	Not Applicable
Focus Category:	Water Quality, Ecology, None
Descriptors:	Periphyton, Diatom, Ecological Communities
Principal Investigators:	Marvin Fawley, Marvin Fawley

Publication

1. Jaskowiak, Megan Aileen. 2002. Ph.D., "Periphytic Algae in the Sheyenne River, North Dakota." Department of Biological Sciences, College of Science and Mathematics, North Dakota State University. Major Professor: Dr. Marvin W. Fawley.

Physical and environmental factors influencing the periphyton communities of the Sheyenne River, North Dakota

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Abstract
The physical factors affecting the periphyton communities of the shallow, turbid Sheyenne River (North Dakota) have been a focus of our research group for the past five years. Periphyton samples from both artificial and natural substrates at eight sites along the river were collected from 1997-1999. Major ions and other chemical parameters for these sites were determined by the North Dakota Department of Health. The algal species present in these samples have already been identified and enumerated, and some analyses have been completed. Our initial analyses (using only artificial substrate data) have indicated that certain physical factors do affect the periphyton community of this river. However, these analyses suggest that one of the most important factors affecting the periphyton communities of the Sheyenne is the presence of a reservoir, Lake Ashtabula. In this study, we plan to expand upon our analyses by critically examining the impact of Lake Ashtabula on the periphyton communities of the Sheyenne River. In addition, we will complete additional analyses of the periphyton communities found on natural substrates. Results of these analyses should enable more effective water management in the Sheyenne Basin, especially Lake Ashtabula. In addition, we plan to conclude the periphyton survey of the Sheyenne River by completing the descriptions of three potentially new species of the diatom genus Nitzschia. The complete periphyton flora of the Sheyenne River will provide an important basis for understanding the impacts of changes in the river, such as the proposed Devils Lake emergency outlet.

Description of critical regional or state water problem being investigated
This research project began as part of the environmental impact statement for the U.S. Army Corps of Engineers Devils Lake emergency outlet project. In order to moderate flooding in the closed Devils Lake Basin, an outlet to the Sheyenne River was proposed. However, components of the river biota were likely to be impacted by this diversion. The effects of the Devils Lake outlet on the Sheyenne River include increased total dissolved solids (TDS), increased flow rate, and possibly increased nutrients. In the first part of this study, periphytic algae were collected using artificial substrates at several sites along the Sheyenne River. The first goal of this study was to relate the periphyton communities to environmental factors that may be potentially affected by a Devils Lake outlet (Phillips et al. 2000). While completing this research, several additional questions arose.

One question that still needs to be answered is how the regulation of waterflow impacts the periphyton communities in this river. The Sheyenne river has been regulated since 1950, when the Baldhill Dam was built on the Sheyenne just north of Valley City to create Lake Ashtabula. Our earlier research suggested that the periphyton communities in the downstream sites are quite different from those communities found upriver of Lake Ashtabula. Research on other rivers has shown profound changes in the algal community after a dam was built (Blinn et al.1998, Baier et al.1998, Skulberg 1982). These variations in communities are due to changes in two broad environmental areas: water quality and geomorphology (Ward and Stanford 1982). An example of the first is a higher level of ammonia downstream from the dam. Erosion or changes in the shape of the river channel are an example of the second (Blinn et al. 1998). Although our earlier research has shown a difference in the periphyton communities, it is not known if these differences are statistically significant and which type of environmental change may cause the difference. The main goal of this project is to determine if Lake Ashtabula alters the algal communities of the Sheyenne River and if this shift is related to water quality or geomorphology.

A second goal of this project is the description of the periphyton of the Sheyenne River. Although over 300 taxa of periphytic algae have been identified from our samples, three of the diatoms could not be identified to species. These three diatoms are in the genus *Nitzschia*. It is likely that these diatoms are new *Nitzschia* species. These three diatoms have already been characterized by light and scanning electron microscopy. However, critical comparison with type material of closely related species still needs to be completed. Complete descriptions of these new taxa must be made to complete the descriptions of the periphyton communities of the Sheyenne River. A thorough understanding of the periphyton communities of the river will enable the assessment of the effects of future changes in the river.

Statement of results or benefits

The results of this study are expected to be significant at multiple levels. First, the impact of Lake Ashtabula on a portion of the biota of the Sheyenne River will be assessed. This assessment will provide information that can potentially be used to better manage the outflow from the reservoir. Second, there is a lack of knowledge of the algal communities of the Sheyenne River, as well as any similar river in the Red River of the North drainage. This study will provide information on the periphyton communities that will be useful for estimating the effects of other perturbations to the Sheyenne River system, as well as similar river systems in the area.

The applied aspects of this proposal will be of potential importance for the management and control of Lake Astabula. In addition, this study could provide additional information on the impact of diverting water from Devils Lake into the Sheyenne. Both the North Dakota Dept. of Health and the US Corp of Engineers have expressed interest in this study.

Nature, scope and objectives of the project, including a timeline of activities

Periphyton samples have already been collected from the Sheyenne River and Lake Ashtabula (see Section 16). Taxa have been identified and enumerated from these samples, and the North Dakota Department of Health and the U.S. Army Corps of Engineers have provided the results of water chemistry analyses from these sites. Statistical analyses (canonical correspondence analysis, etc.) these data with the specific goals of determining the impact of Lake Ashtabula on the periphyton communities of the river, and to determine if the impact of the reservoir is due to changes in water quality or geomorphology have been completed. In addition, the three potentially new *Nitzschia* taxa will be examined by scanning electron microscopy. The primary objective of this project is to complete these various analyses and prepare material for publication. Some additional sampling will also be performed to provide additional material for the characterizations of new species.

Timeline

March 2002 - October 2002. Complete all analyses and sampling for the Sheyenne River projects. Compare type material of *Nitzschia* species to the new species found in the Sheyenne River. Submit manuscripts describing 1) the new *Nitzschia* species; 2) the periphyton flora of the Sheyenne River; 3) analysis of the physical factors controlling community structure in the Sheyenne; and 4) the influence of Lake Astabula on the periphyton communities of the Sheyenne.

Methods, procedures and Facilities

Periphyton Samples

Eight sites along the Sheyenne River have been intensively sampled. Site 1 is at the Highway 30 bridge south of Maddock, ND which is located upstream of the proposed diversion inflow site for Devils Lake water. Site 2 is 3.3 miles south of Warwick, ND. Site 3 is located at the Highway 200 bridge east of Cooperstown, ND. Site 4 is the dock at the south end of Lake Ashtabula near the recreation area. The four sites downstream from Lake Ashtabula are at the 8th Ave bridge in Valley City, ND (5), at the southernmost bridge in Lisbon, ND(6), at the bridge south of Kindred, ND (7), and 0.5 miles west of Harwood, ND (8). These sites were sampled biweekly from late April through early November for the period September, 1997 through November, 1999.

Because of the clay and silt substrate that is present at the sample sites, artificial substrates were used for periphyton sampling (Aloi 1990). Acrylic substrates were suspended 0.3 m below the surface of the water (Phillips et al. 2000). These acrylic plates were placed in straight sections of the river where deep pools were not present. The periphyton was removed using a razor blade and the plate was rinsed with 25 ml of river water. An artificial substrate was not used at Lake Ashtabula. At this site, the side of the dock was scraped with a razor blade. A portion of each sample was retained for examination of live material and the remainder of the sample was preserved with Lugol's and formalin. The examination of live material determined if the diatoms present in the sample were actually alive.

Modified Taft's Syrup Medium slides were made to identify all the algae expect for the diatoms (Peterson and Stevenson 1989). Clearing methods and slide preparation were used for diatom determinations and enumeration, as described in Griffith and Perry (1995). These prepared slides were viewed at 960x magnification with oil immersion. All the algae were identified to the lowest taxonomic group possible using available keys (Prescott 1978 and 1982, Krammer and Lange-Bertalot 1986, 1988, 1991a and 1991b).

Water Chemistry

One 1 L sample and one 500 ml sample were collected from all sites except Lake Astabula for water chemistry analysis. Nitrate and phosphate levels were determined with the Cadmium reduction method (Hach Company 1984) and the Ascorbic Acid and Amino Acid Method (Clesceri et al. 1989) respectively. Major ions were analyzed by the North Dakota Department of Health. pH was determined with a pH meter. Data on water chemistry for Lake Astabula was provided by the U.S. Army Corps of Engineers. River flow data will be obtained from the United States Geological Survey webpage.

Evaluation and Statistical Analysis

The data that have already been generated from the above methods will be used to perform statistical analyses. Redundancy Analysis (RDA, reviewed in ter Braak and Verdonschot 1995) will be used to determine if the sites downstream are more statistically similar with Lake Ashtabula than with the upstream sites. Also, canonical correspondence analysis (CCA, reviewed in ter Braak and Verdonschot 1995) will be used to examine which environmental variables explain the most variance in Lake Ashtabula and the downstream sites. CANOCO (ter Braak 1990) will be used to perform both types of analyses.

Description of new *Nitzschia* taxa

Throughout the identification process, several organisms could not be identified to species. Three of these organisms belong to the diatom genus, *Nitzschia*. Before species descriptions for these organisms can be completed, it must be determined if these organisms are actually new species. The collected specimens will be compared with type species in the collection at either the Philadelphia Academy of Sciences or the California Academy of Sciences.

If these organisms are undescribed species, the new species description can be made. The first step is to take measurements on 100 specimens. These measurements include but are not limited to length of the valve, width of the valve and striae count. Second, the specimen should be examined with scanning electron microscopy. After the specimens have been extensively studied, an appropriate name will determined and a species description in Latin will be written. The steps completed in the species description will follow the nomenclature rules adopted by the International Botanical Congress (1994).

Related research

Our on-going research on the Sheyenne River includes several projects related to this proposal. In our initial project, funded by the U.S. Army Corps of Engineers, we examined both the periphyton and the phytoplankton of the Sheyenne River to estimate the potential impact of the Devils Lake emergency outlet on the algae of the River. This project resulted in a report to the Corps (Phillips et al. 2000) describing the results of our survey and a CCA of the species distribution with water chemistry. Our basic conclusion was that the algal communities of the Sheyenne River are affected by water chemistry parameters that will be altered by the diversion of Devils Lake water into the river. The relative abundance data for species of periphytic algae and environmental data were used for the assessment. This analysis was completed using canonical correspondence analysis (CCA). The environmental variables that explained the most variance in the periphyton communities were pH, orthophosphate, hardness, arsenic, sulfate and nitrite+nitrate.

This analysis included all species that were identified. An analysis was repeated after the species considered to be phytoplankton were removed. This evaluation showed different environmental variables that explained the most variance. These environmental variables were percent sodium, calcium, pH, arsenic, and sulfate. This analysis was more statistically significant. The phytoplankton species are not really part of the periphyton community and therefore, the variation seen in these species is coincidental. Therefore, the removal of these species makes the analysis more precise. These results were presented at the 2000 North American Benthological Society meeting in Keystone, CO (Jaskowiak et al. 2000), as a report to the Corps of Engineers (Phillips et al. 2000), at the Phycological Society of America Annual Meeting in Estes Park, CO. (Jaskowiak et al. 2001a), and the North American Diatom Symposium at Elly, MN (Jaskowiak et al. 2001b).

In addition, we are investigating the periphyton communities of natural substrates versus the artificial substrates used in our analysis for the Corps as well as the utility of presence/absence data for the analyses. Natural substrate communities appear to be quite different from the artificial substrate communities. These differences include several species that were not found at all on the artificial substrates. An example of these additional species is the diatom, *Navicula mutica*. However, analyses must be completed to see if these differences are statistically significant. These analyses and the analysis of the presence/absence data were completed in 2001.

Also in 2001, we initiated a new study in cooperation with the North Dakota Department of Health to investigate nutrient criteria for the Sheyenne River in order to set these criteria for North Dakota rivers and streams. This project is funded by the EPA. Our part of this study is the selection of sites representing high and low nutrient conditions, collection of periphyton and water samples, and identification and enumeration of the periphyton (both diatoms and soft algae). This project is expected to continue in 2002 with sampling from sites with intermediate nutrient loading.

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Research Findings

Aquatic systems with flowing water have very dynamic environments that produce complex periphytic algal communities. These communities are sensitive to changes in their environment. Therefore, changes in these communities can be used in water quality assessment. Historically, problems have been associated with this use of these algae. Some of these problems have been solved. In current research, these algal communities are used to monitor the quality of these systems. However, some problems still exist. These problems are that no standard sampling method has been established, identification of these organisms is difficult and requires extensive training, and the identification in existing studies may not be either consistent or correct. However, even with these difficulties, scientists have found that these communities can still be used to assess the conditions of the environment. Therefore, if the problems are overcome, then these communities would provide an accurate biological assessment of water quality.

The periphytic algae of the Sheyenne River in North Dakota were examined. This research consisted of several different studies. In the first study the distribution of the periphytic algae was examined. In the second, the distribution of the periphytic algae was correlated to changes the environmental conditions. In the third study, two species of diatoms that could not be identified to species were described as new species. Also, the differences between natural substrates and artificial substrates were compared using canonical correspondence analysis (CCA). The relative abundance data from these studies were compared to presence/absence data using multiple dimensional scaling (MDS). Last, the effects of Lake Ashtabula, a reservoir, on the down river algal populations were examined.

The objectives of the first study were to identify the periphytic algae in the Sheyenne river and to examine the distribution of the periphytic algae throughout the river. These data will be used as a baseline for further ecological studies. Altogether 132 artificial substrate samples were collected. Two hundred twenty-one periphytic algal taxa were identified and the relative abundance of each taxon was determined. Several potentially new species were detected. The distribution of periphytic algal taxa was closely examined for both seasonal and spatial patterns.

In the second study, the objective was to determine which environmental variable correlate with the distribution patterns of the periphytic algae in the Sheyenne River. Direct ordination, a type of multivariate statistics, was used. Nineteen environmental variables were used in the analysis. This analysis found that the variables that explained the most variance in the periphytic algal communities were magnesium, manganese, chloride, calcium, nitrite-nitrate, sulfate and pH ($p<0.05$).

During the examination of the periphytic algae in the Sheyenne River, 59 taxa could not be identified to species. Two of these organisms were originally identified as *Nitzschia* sp. 4 and *Nitzschia* sp. 5. The objective of the third study was to determine if these organisms are new species and to describe them. *Nitzschia* sp. 4 was compared with its possibly closest related species, *Nitzschia filiformis.* *Nitzschia* sp. 5 was compared with its possibly closest related species, *Nitzschia amphibia* and *seimrobusta.* *Nitzschia* sp. 4 and *Nitzschia* sp. 5 are differ from these described species. Therefore, *Nitzschia sheyennensis* Jaskowiak sp. nov. and *Nitzschia dakotensis* Jaskowiak sp. nov. were described from the periphytic algae of the Sheyenne River, North Dakota.

This research also included a comparison of the natural substrates and artificial substrates and a comparison of the use of presence/absence data versus relative abundance data in CCA. Natural substrate communities appear to be quite different from the artificial substrate communities. These differences include several species which were not found at all on the artificial substrates. An example of these additional species is the diatom, *Navicula mutica*. The artificial substrates appear to be a better representation of some natural substrates, e.g., rocks. Presence/absence data seem to produce the same results statistically as the relative abundance data. Further study may show that presence/absence is a viable type of species examination for water quality studies.

The effects of Lake Ashtabula on the down river algal populations are considerable. Studies have shown that sites within a river have a large year to year variation. The year to year variation within the sites in the Sheyenne River is high. However, the effects of Lake Ashtabula have a greater effect. Several species of algae that are common in the sites upriver from the reservoir are not at the sites down river. Also, species that are usually found in lakes are in the down river sites, but are not upriver from the reservoir. Close examination of the species will help determine if this effect is due to nutrient influx from the reservoir or from effects of erosion caused by the controlled flow of the river.

These studies were the first investigation of the periphytic algae in the Sheyenne River. This research found a diverse community that is in part controlled by nine environmental variables. Also, the growth of these algae is affected by year to year changes and by the influence of Lake Ashtabula. In this research, quite a few taxa could not be identified to species. Description of these new species will help to use the periphytic algae for water quality assessment. These results of this research provide the information needed to use the periphytic algae of the Sheyenne River for water quality assessment.

A Comparative Analysis of Fargo and Moorhead Ozonation Systems

Basic Information

Title:	A Comparative Analysis of Fargo and Moorhead Ozonation Systems
Project Number:	2002ND11B
Start Date:	5/1/2002
End Date:	12/31/2003
Funding Source:	104B
Congressional District:	1
Research Category:	Not Applicable
Focus Category:	Treatment, Water Supply, Surface Water
Descriptors:	Ozonation, Trihalomethane, Disinfection
Principal Investigators:	Wei Lin, Wei Lin

Publication

A Comparative Analysis of Fargo and Moorhead Ozonation Systems

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Abstract

Ozone has been increasingly used as a disinfectant in water treatment processes in the United Sates. Ozone is a strong oxidant that also can be used for taste and odor control and organic matter removal. The use of ozone for disinfection is thought to reduce the potential formation of trihalomethanes (THMs) and other harmful disinfection by products (DBPs) associated with chlorine disinfection. Also, ozone is able to achieve disinfection with less contact time and concentration than other disinfectants. However, ozone demand and reactions are highly dependent upon pH, temperature, organic concentration and other factors. Therefore, it is more difficult to control ozonation systems. Incomplete oxidation of organics under certain conditions may also produce toxic by-products. Two water treatment plants using the same source of water are investigated in this study to compare and contrast the performance their ozonation systems.The impact of operation conditions on ozone demand, odor removal efficiency, and ozonation by-product formations are investigated in the study.The information gained will be valuable for other possible ozonation applications in the aquatic environment. The type of organics and the oxidation by-products produced during the ozonation process will be identified.

STATEMENT OF THE WATER PROBLEM

Ozone has been increasingly used as a disinfectant in water treatment processes in the United Sates. Ozone is a strong oxidant that also can be used for taste and odor control and organic matter removal. The use of ozone for disinfection is thought to reduce the potential formation of trihalomethanes (THMs) and other harmful disinfection by products (DBPs) associated with chlorine disinfection. Also, ozone is able to achieve disinfection with less contact time and concentration than other disinfectants. However, ozone demand and reactions are highly dependent upon pH, temperature, organic concentration and other factors. Therefore, it is more difficult to control ozonation systems. Incomplete oxidation of organics under certain conditions may also produce toxic by-products.

Both the Fargo Water Treatment Plant, (FWTP) North Dakota and Moorhead Water Treatment Plant (MWTP), Minnesota use Red River water as their primary water source. The MWTP employs ozone for taste and odor control at a higher pH of 11 and as well as for disinfection at a lowered pH of 9.5. The FWTP uses ozone only for the purpose for disinfection at a lowered pH of 9.5. Both the plants are able to achieve its goals of disinfection and to produce high quality water with minimal THMs. One of the challenges that both FWTP and MWTP face is the high ozone demand in summer. As a result, the plants have to use its full ozone generation capacity to maintain proper ozone concentration in the ozonation chambers. This leads to the formation of ozonation by-products (OBPs) due to incomplete oxidation under different ozonation systems. These by-products have been reported to be mainly aldehydes and carboxylic acids. Although no potential health effects have been observed for the concentrations of aldehydes and carboxylic acids formed in the drinking water during ozonation, these compounds are easily biodegradable. This increase in biodegradable dissolved organic carbon (BDOC) can lead to accelerated bacterial growth and re-growth in the distribution system if it is not removed in the treatment plant. The presence of BDOC that causes these adverse effects is commonly termed as biological instability.

OBJECTIVES

This proposal is to investigate the impact of operation conditions on ozone demand, odor removal efficiency, and ozonation by-product formations. The objectives include:

- To study the factors affecting the increased ozone demand in the Fargo & Moorhead WTPs during summer season leading to increased treatment costs.
- To understand and study the different operational procedures involved in the Fargo & Moorhead WTP to optimize the results so as to suggest the better of the ozonation systems employed at the FWTP & MWTP respectively.
- Identifying OBPs formed under various operational conditions.
- Investigating operational alternatives to improve ozonation efficiency and to reduce summer ozone demand.

During the course of this project, ozonation systems performance under different conditions and the parameters affecting them will be analyzed which will lead to an improved facility operation technique derived as a corollary of the experimental studies conducted and the conclusions reached, henceforth. Also, a detailed cost analysis approach will be obtained to help justify the recommendations in the ozonation systems operations. The water chemistry involved with the ozonation process will also be studied. The information gained will be valuable for other possible ozonation applications in the aquatic environment. The type of organics and the oxidation by-products produced during the ozonation process will be identified.

METHODOLOGY

This project will include analysis of existing data and information of existing data and information, experimental studies, plant sampling, and engineering alternative evaluation and design. The project will be broken down into three tasks.

Task 1. Literature Review.

The purpose of this task is to evaluate the design and operation of the existing ozonation Systems at the Fargo Water Treatment Plant (FWTP), North Dakota and Moorhead Water treatment Plant (MWTP), Minnesota. Literature review includes Fargo and Moorhead WTPs design documents, operational data, previous study reports and environmental engineering journal articles. The literature review will focus on (1) design and operation of ozonation systems (2) mechanisms of ozone disinfection (3) sampling and sample analysis method (4) Factors affecting the ozone consumption rate variations with season (5) operational and control of ozonation systems in other water treatment plants. The theoretical and operational information obtained from literature is important for developing sampling methods, data analysis, and experimental study plans.

Task 2. Performance measurements and assessments of the ozonation systems in Fargo WTP.
The FWTP, & MWTP, use Red River water as primary water source and ozone as primary disinfectant. The raw water contains natural organic matter (NOM), which is characterized by aromaticity and biological stability. This NOM is not found to have any significant health impacts. However, ozonation of raw waters decreases the NOM by breaking the aromaticity and increased biodegradability. The ozone treatment process resembles a lightning storm. Lightning during a thunderstorm creates an electrical charge, which makes ozone that reacts with air. The operational success of the ozonation system is dependent upon the plant influent water quality as well as ozone dose, along with other factors like pH, temperature, alkalinity, etc. The ozone dose generally increases in the summer months, as the temperature of water is high, leading to higher reaction rates. This increases the ozone consumption rate, as the NOM is not completely degraded at small ozone dose. This causes increased ozone demands in summer, thus increasing the water treatment costs. Also in addition to this it leads to the formation of OBPs which a serious concern today with respect to their health impacts. In order to study the performance of the ozonation systems and the parameters affecting it, the samples will be collected in the ozonation chambers of the FWTP & MWTP locations specified below: -

- Samples of the influent water in the FWTP, ozone contact chamber and the distribution systems will be taken.
- Various Parameters like temperature, pH, alkalinity; etc. will be studied to analyze their affect on the ozonation system operation.

Task 3. Comparative Analysis of the two ozonation systems.
The data collected from the study conducted on the FWTP will be analyzed and compared with the data available through previous studies conducted on the MWTP. After the analysis it will be ascertained that which of the two WTPs possesses better ozonation systems in terms of minimal OBPs formation in the finished water. The final study report will be presented to both the FWTP & the MWTP.

EXPECTED RESULTS AND BENEFITS

During the course of this project, ozonation systems performance under different conditions and the parameters affecting them will be analyzed which will lead to an improved facility operation technique derived as a corollary of the experimental studies conducted and the conclusions reached, henceforth. Also, a detailed cost analysis approach will be obtained to help justify the recommendations in the ozonation systems operations. The water chemistry involved with the ozonation process will also be studied. The information gained will be valuable for other possible ozonation applications in the aquatic environment. The type of organics and the oxidation by-products produced during the ozonation process will be identified.

FACILITIES

This project will be completed with the additional support from both Fargo & Moorhead Water Treatment Plants and The North Dakota State University.

The Water Treatment Plants (WTPs) will provide the necessary supplies including sampling equipment, etc. North Dakota State University will provide the necessary equipment and supplies for the sample testing. The North Dakota State University will also provide lab space, sample containers, chemicals, a pH meter and GC/MS instrument.

PROPOSED RESEARCH TIMELINE

A duration of 8 months is proposed starting May 2002. During this period, an interim report will be submitted. The report will summarize the analysis of performance studies of the ozonation systems employed in the cities of Fargo &Moorhead WTPs. A final report will be submitted by December 2002.

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PRELIMNARY APPROACH

A detailed analysis of the operational data for the FWTP ozonation system and other water characteristics, as well as sampling and sample analysis from the ozonation facility are provided. Sampling locations, parameters tested and the procedures and methods used for sample analysis are also provided.

Operational Data Analysis

The FWTP provided the operational data from 01/01/01 through 06/30/02. The operational data from 08/01/02 to 01/31/03 will be collected during the plant sampling being undertaken as part of the research. The operational data consist of plant inflow rates, temperature, pH, ozone dose, ozone flow rates, off-gas concentrations, total organic carbon (TOC), and alkalinity. The data provided by the FWTP is given as daily average. The data recorded during the sampling will not be presented as average.

The water flow rates, temperature, pH in the ozone contact basin, ozone residual, off-gas conc., ozone gas flows, were recorded by the online monitoring system.

Total organic carbon (TOC) will be used as a measure of organics present in the water. The TOC analysis at the FWTP is done thrice a week, on the raw water, presedimentation effluent, and secondary softening effluent; filter influent, transfer section, and tap water. The TOC values for the period of the operational data collection were averaged, but the samples collected during the slated sampling period will not be analyzed as averages.

The ozone gas-flows into the ozone contact chamber are measured by online flow meters and are used to find the ozone dose applied to the ozone contact chamber. The total ozone dose is calculated by the following equation:

Ozone Dose (ppm) = (gaseous ozone concentration * total gas flows) / (total water flow)

FWTP Sampling and Sample Analysis

The plant sampling and sample analysis will be conducted from 08/05/02 through 01/31/03. The sampling mainly concentrates on the detailed analysis of ozone contact chamber and the factors affecting the formation and amounts of the DBPs.

Analysis of ozone contact chambers

The major goal for the detailed analysis of the ozone contact chamber was to analyze the water quality changes across the ozone contact chambers. In order to study and compare the factors and the parameters affecting the overall DBP formation at the FWTP, to those with the parameters and the operational conditions, and the altogether different ozonation system at the MWTP; a detailed analysis for the ozonation chamber was conducted.

Parameters

The operational data recorded during the sampling phase of the project was in addition to the following parameters:

- UV 254 Absorbance
- Carbonyl compound analysis

There exists a strong correlation between the UV absorbance and the total organic content present in the water (Standard Methods 5910, 1998). As the oxidation of the carbon bonds takes place during the ozonation of the water in the contact chambers, the UV 254 absorbance decreases. This is because of the fact that number of carbon double bonds decrease after the ozonation and therefore resulting in the lower UV absorbance.

The ratio of the UV absorbance to the TOC gives a parameter called the specific UV absorbance (SUVA), and is used as a measure of the partial oxidation occurring in the ozone contact chambers.

The carbonyl compound analysis was done to analyze the DBPs formed in the ozone contact chamber. The majority of the ozone DBPs formed consists mainly of low molecular weight compounds like aldehydes, carboxylic acid, and ketones.

Sample Locations

The sample location details are shown in figure 1.

- **Influent to ozone contact chamber.** The samples are taken at this location in order to determine the amounts of organic content entering the ozone contact. This sample serves as the platform for the other sample locations and the sample analysis.
- **Stage 3.** The sample is picked up at this location as this being the first point of ozone application and thus, serves as the baseline for the disinfection by-products (DBPs) formation quantification and analysis. This is where the ozone first attacks the organic content present in the water and thus the results in formation of DBPs. Therefore the sample at this point is very important as it will provide a profile of the DBP formation and the magnitudes and amounts, in which they are carried through the rest of the system.
- **Stage 4.** Samples are taken at this location as the ozone application is continued and thus makes it important to be accounted for.
- **Filter Influent.** This sampling point is very important, as here the water is free of ozone, after falling over a three feet free fall over a concrete effluent weir, and resulting in the ozone stripping. This is the immediate step after the stage 6, where the water is allowed to stand for 30 minutes, so as to allow for the ozone to decompose completely and thus it will give an estimate of the organic content still left in the water going to the filters.

Sample Analysis

Total Organic Carbon

The TOC was measured at the FWTP using a Shimadzu model 5000 instrument; a total combustion TOC analyzer equipped with an ASI 5000 A autosampler. Three successive samples were recorded and averaged giving the TOC values. The TOC unit was calibrated daily using a potassium biphthalate solution.

Alkalinity
Alkalinity was determined at the FWTP using an Auto Titrator; Mettler 5000 was used for the measurement of total alkalinity.

UV 254 Absorbance
The UV 254 absorbance was analyzed at the FWTP using a Hach 4000 spectrophotometer with quartz cells 1 cm in thickness (Standard Methods 5910 B, 1998). The lab reagent water was used as a blank for analyzing the samples.

Carbonyl Compound Analysis
Carbonyl compounds were assessed using aqueous-phase derivatization with O-(2,3,4,5, 6-pentafluorobenzyl)hydroxylamine hydrochloride (PFBHA) and capillary gas chromatograph (GC) with mass spectrometry detection (EPA method 556, 1996 and Standard Methods, 6252 B, 1998).

Sample collection for carbonyl compound analysis
The samples will be collected in 40-mL vials with PTFE-faced silicon septa screw caps. Before adding the samples to the vials, 15 mg of copper sulfate pentahydrate is added to each of the sample vial. KI acts as biocide to inhibit bacteriological decay of the method analytes (EPA method 556, 1998). Adding 5 drops of 3-mg/L KI solution to the vials containing samples quenches residual ozone (Standard Methods 6252 B, 1998).

The vials were filled to overflowing as to not allow any air bubbles in the sample vial. The vials were manually shaken for 1 minute and were kept refrigerated at 4 C till the analysis.

Procedure for carbonyl compound analysis
After collecting the samples at the FWTP, the samples were taken to the NDSU environmental engineering laboratory and allowed to equilibrate at room temperature. Twenty milliliters of the sample volume was pippeted out and discarded. The pH was adjusted to 4 by adding 200 mg KHP to each bottle containing 20 ml of sample. The surrogate standard (2,4,5 – Trifluoroacetophenone) was added in amount equal to 20 μL along with 1mL of PFBHA reagent at a concentration of 15 mg/mL. The samples were then kept into water bath at 35 C for 2 hours. After the incubation, the sample bottles were taken out and allowed to cool to room temperature for about 10 minutes. Four drops of concentrated sulfuric acid was added to each sample vial to quench the derivatization. Four milliliters of hexane containing the internal standard (1,2-dibromopropane) at a concentration of 400ug/L was added and then the samples were manually shaken for 3 minutes. The samples were then let stand for 5 minutes to allow for phase separation. The hexane layer was withdrawn from the sample bottles using a Pasteur pipette and placed into an 8-ml vial containing 3 ml of 0.02 N sulfuric acid. This is done to remove excess derivative. The samples were then shaken for 30 seconds and then allowed to stand for 5 minutes for phase separation. The hexane layer was drawn off and placed in 2 separate 2-mL vials. One μL was injected for the GC/MS analysis from one of the vials and the other was kept at 4C in the dark to serve as a backup extract.

Calibration for carbonyl compound analysis
A calibration standard was purchased from Accustandard at a concentration of 1000 ug/L in acetonitrile. The analytes included in the standard were formaldehyde, acetaldehyde, propanal, butanal, pentanal, hexanal, cyclohexanone, heptanal, octanal, benzaldehyde, nononal, decanal, glyoxal and methyl glyoxal.

Instrumentation for carbonyl compound analysis
The apparatus used for this analysis is a HP 6890 plus GC and a HP 5973 mass selective (MS) detector. The GC was equipped with a HP-5 MS column 30m long, with an inner diameter of 0.25 mm and a film thickness of 0.25 um. High-purity helium was used as carrier gas.

The data system used was a HP Kayak computer with chemstation software. This was use to control, execute and analyze all information required for the analysis.

The instrument settings are given as follows:

Injection parameters
- Inlet temperature: 250^{o}C

Gas Chromatograph Settings
- Gas flow rate: constant 1.5 mL/minute
- Temperature program: 50^{o}C for 1 minute, then rise at 4^{o}C /minute to 220^{o}C, then rise at 20^{o}C /minute to 250^{o}C , and then hold for 10 minutes.

Mass Spectrometer Settings
- Temperature: 280^{o}C

Quality Control

Carbonyl compound analysis
The internal standard and the surrogate responses for any chromatographic run should line within ±30% from the average response of the calibration curve to pass the quality control. If a run did not comply with these limits, the sample was reanalyzed. If the run still doesn't comply, new standards were prepared and checked.

As suggested in the Method 556 (EPA 1999), a midpoint calibration standard was injected, before the run and the instrument was checked for the calibration. If the calibration was not met, the instrument was re-calibrated.

FWTP OPERATIONAL DATA ANALYSIS

Fargo Water Treatment Plant data are analyzed in this chapter. The FWTP staff provided the data for the period 01/01/01 through 06/30/02. Operational data from 08/05/02 through 01/31/03 will be collected during the project progress as part of the research task.

The operational data are analyzed in order to understand the normal plant operations and to seek information and understanding about determining additional sampling necessities and parameters for a complete understanding of the ozonation process.

Ozone Contact Chamber Influent Characteristics

The characteristics of the ozone contact chamber influent were analyzed to identify the parameters influencing the ozone demand and henceforth the DBPs formation in the contact chambers. The water quality parameters monitored at the FWTP include plant inflow rates, pH, temperature, alkalinity, and TOC.

Daily plant intake from periods of 01/01/01 to 06/30/02 is shown in figure 4-1 and 4-1(a). The total flow rate coming in to the FWTP remained less than 20 MGD at all the times and was always more than 7 MGD. A peak flow of 19.24 MGD was observed in the summer of 2001. The Red River water is used as the primary source of water.

The variation of the incoming water temperature from the periods 01/01/01 through 06/30/02 is shown in figure 4-2 and 4-2(a). The temperature increased to 84 F in summer at certain times and was never below 37 F. The water temperatures stabilized in winter months (December to February), ranging from 37 to 39F.

Total Organic Carbon (TOC) variations in the ozone contact chamber influent are shown in figure 4-3. The TOC generally ranged from 4 to 6 ppm in the influent and ranged from 3.5 to 5.5 ppm in the effluent. The TOC removal trend showed large variations with the change in the season and is shown in figure 4-4. The removal was lower in winter months as compared to summer months.

Operations performed by the ozone system

Variation of ozone dose with time followed the expected trend, as gained by the understanding from the previous research (Hurley, Stuart 2000). The ozone dose is more in summer months than when compared with the winter months, which is mainly due to increased ozone demand as the water temperature is high and thus it requires more ozone to achieve same disinfection goals. The ozone dose variation is shown in figure 4-5 and 4-5(a).

The ozone dose showed variations with the temperature of the incoming water supplies. The ozone dose increased significantly in summer, with the temperatures increasing sharply and then dropped down in the winter months. The trend is shown in figure 4-6.

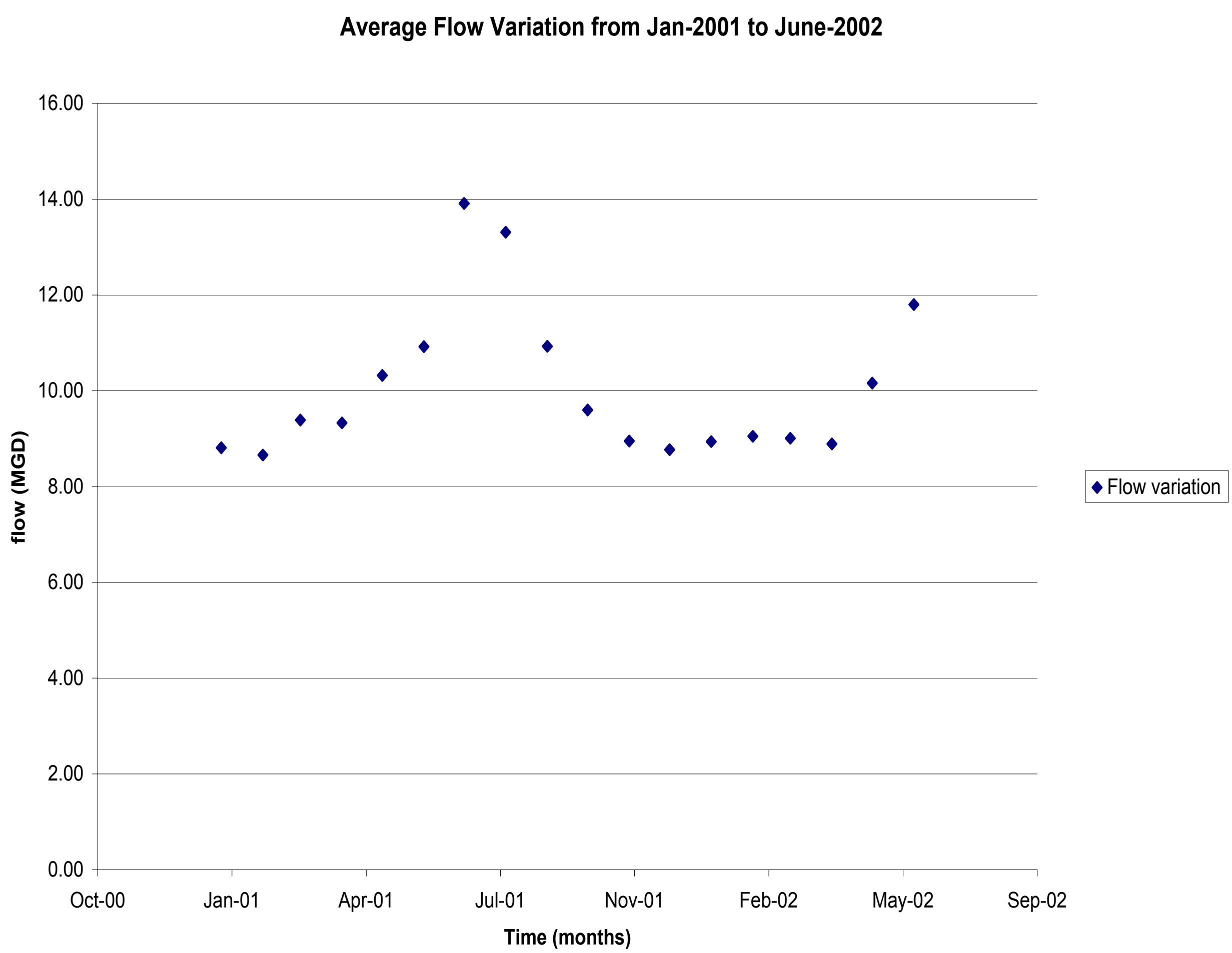
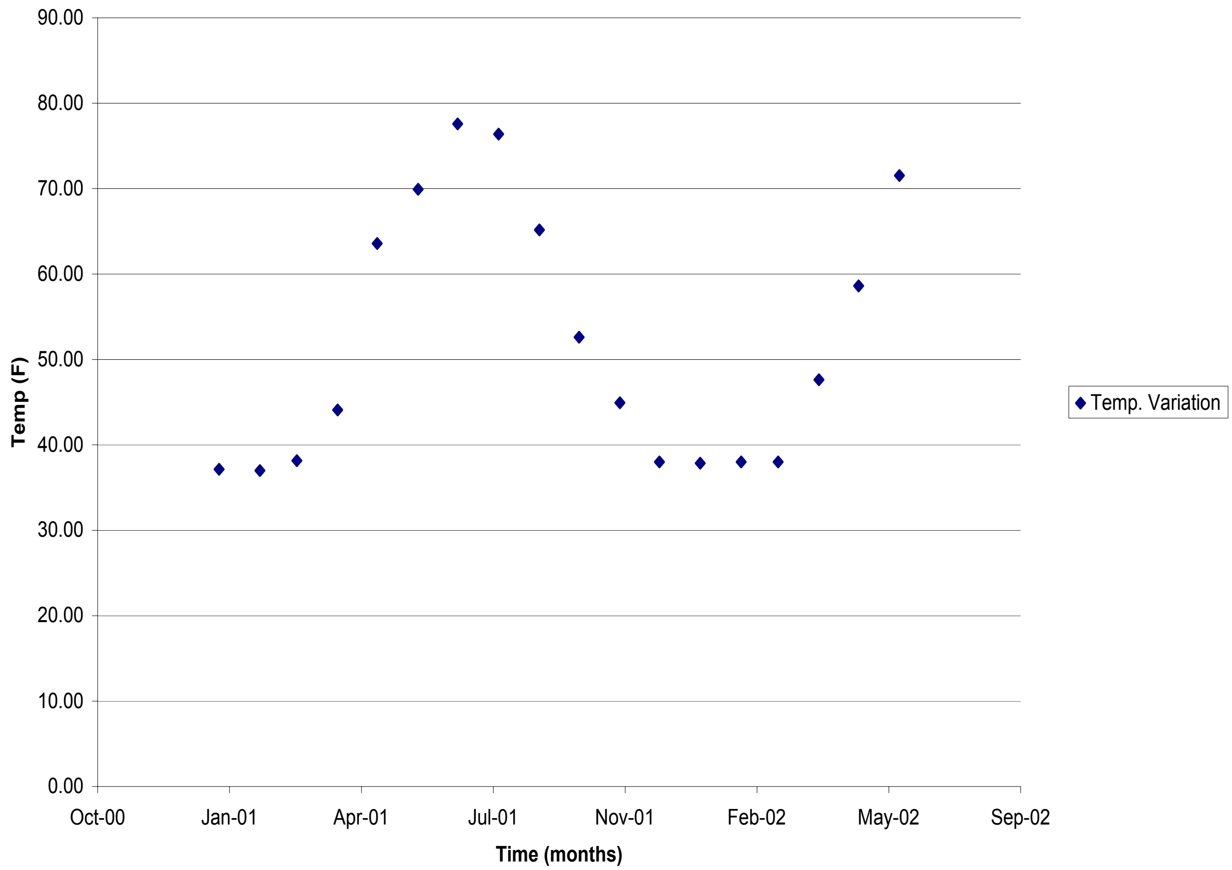

Average Flow Variation from Jan-2001 to June-2002
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
flow (MGD)
Oct-00
Jan-01
Apr-01
Jul-01
Nov-01
Feb-02
May-02
Sep-02
Time (months)
Flow variation

Figure 4-2. Temperature Variation from Jan-2001 to Jun-2002



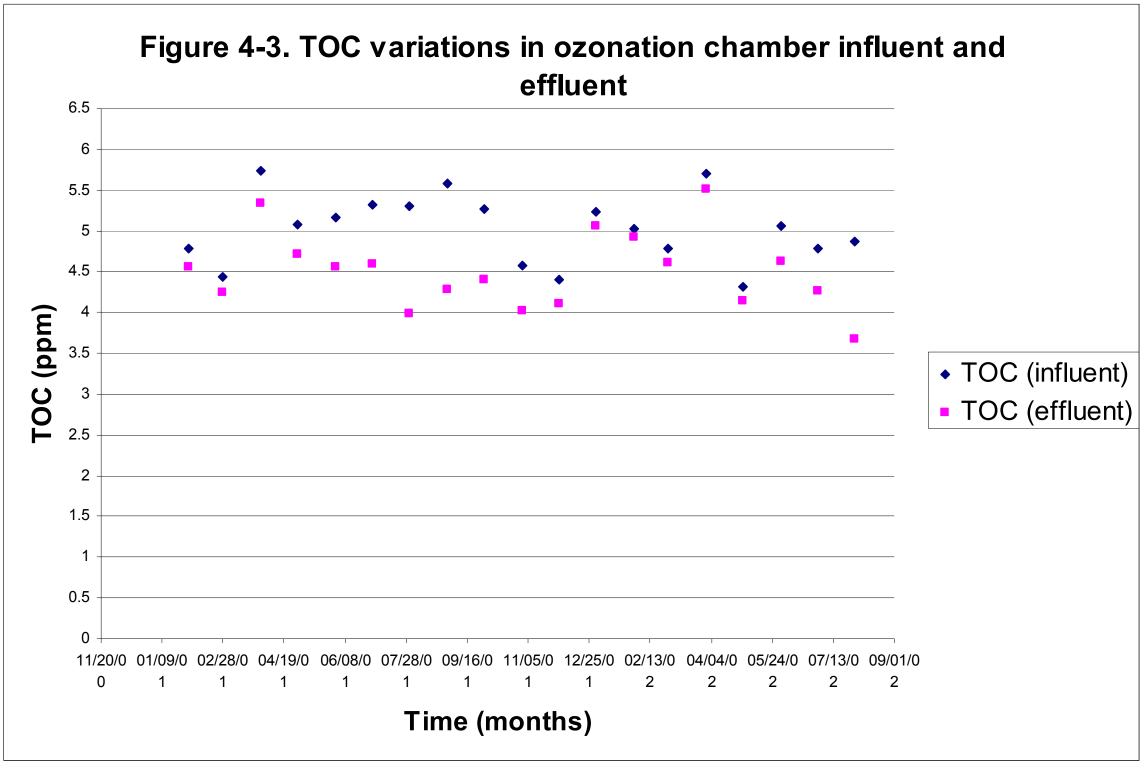
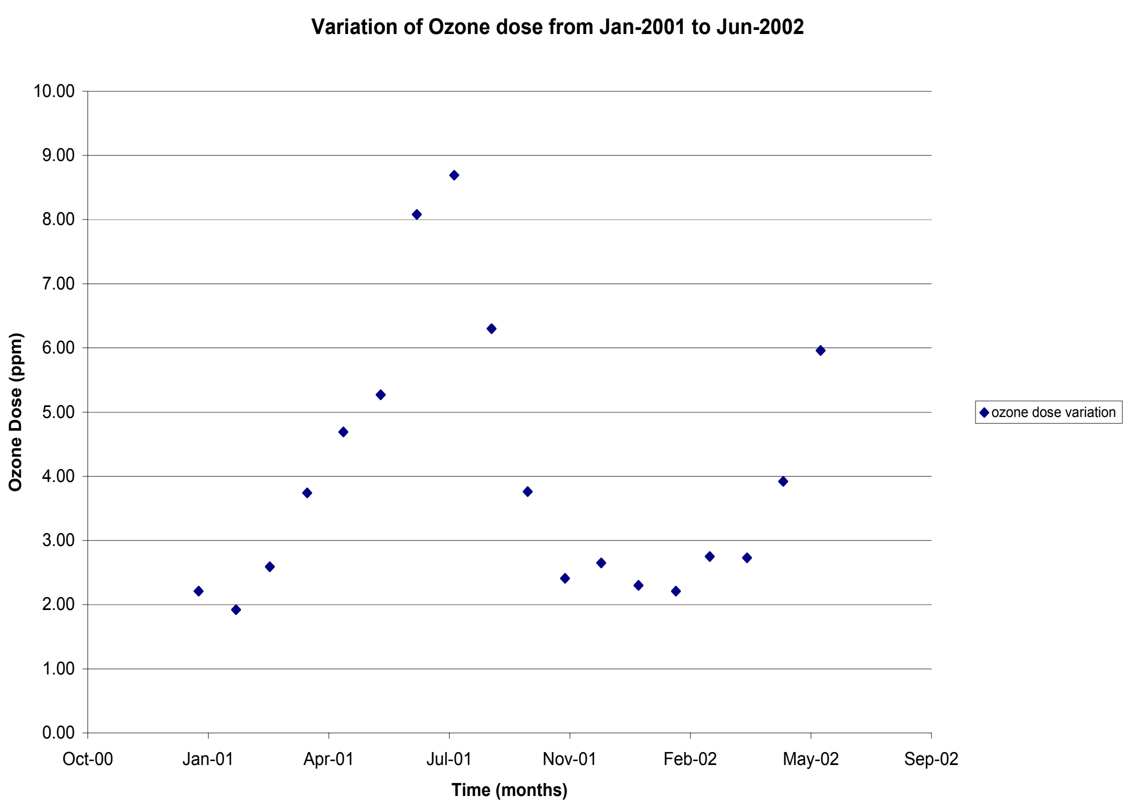
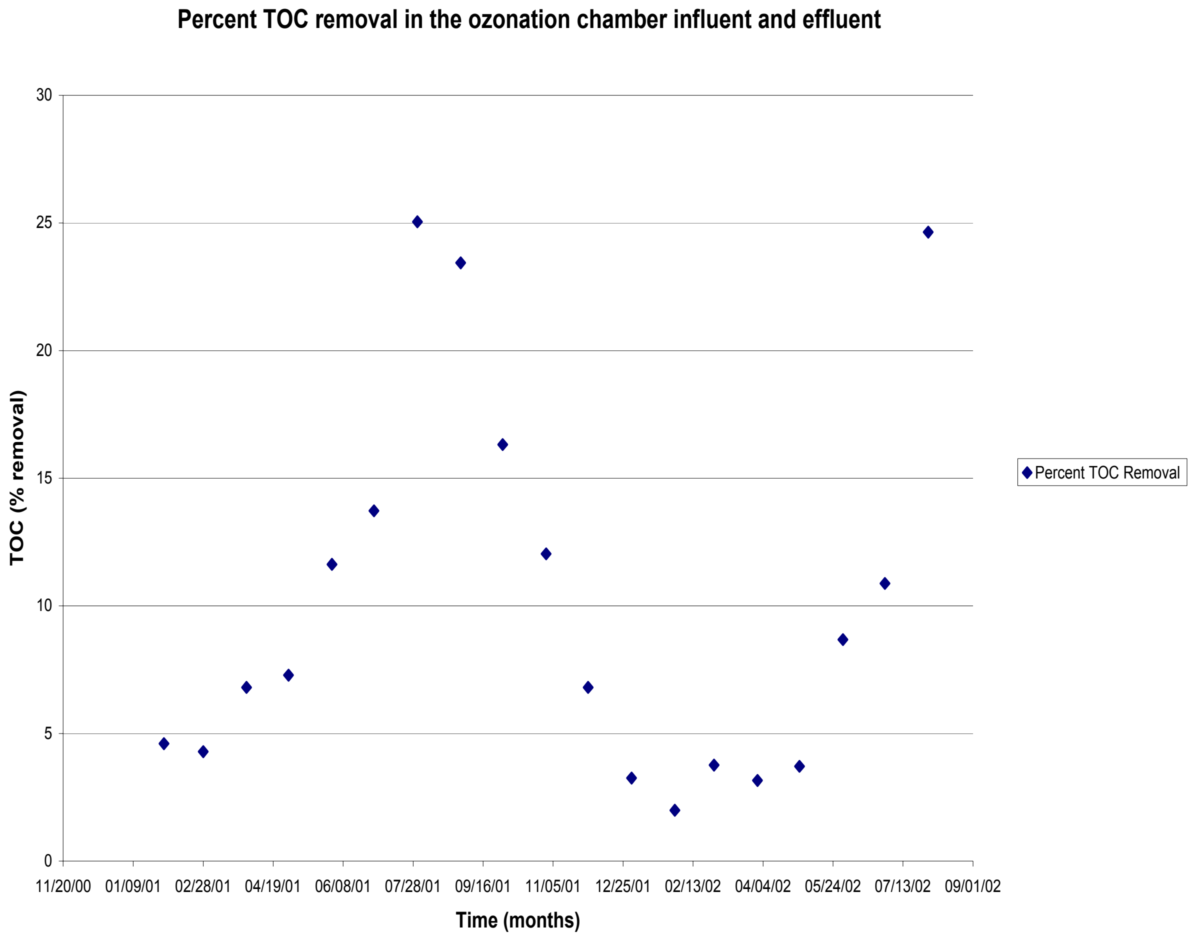
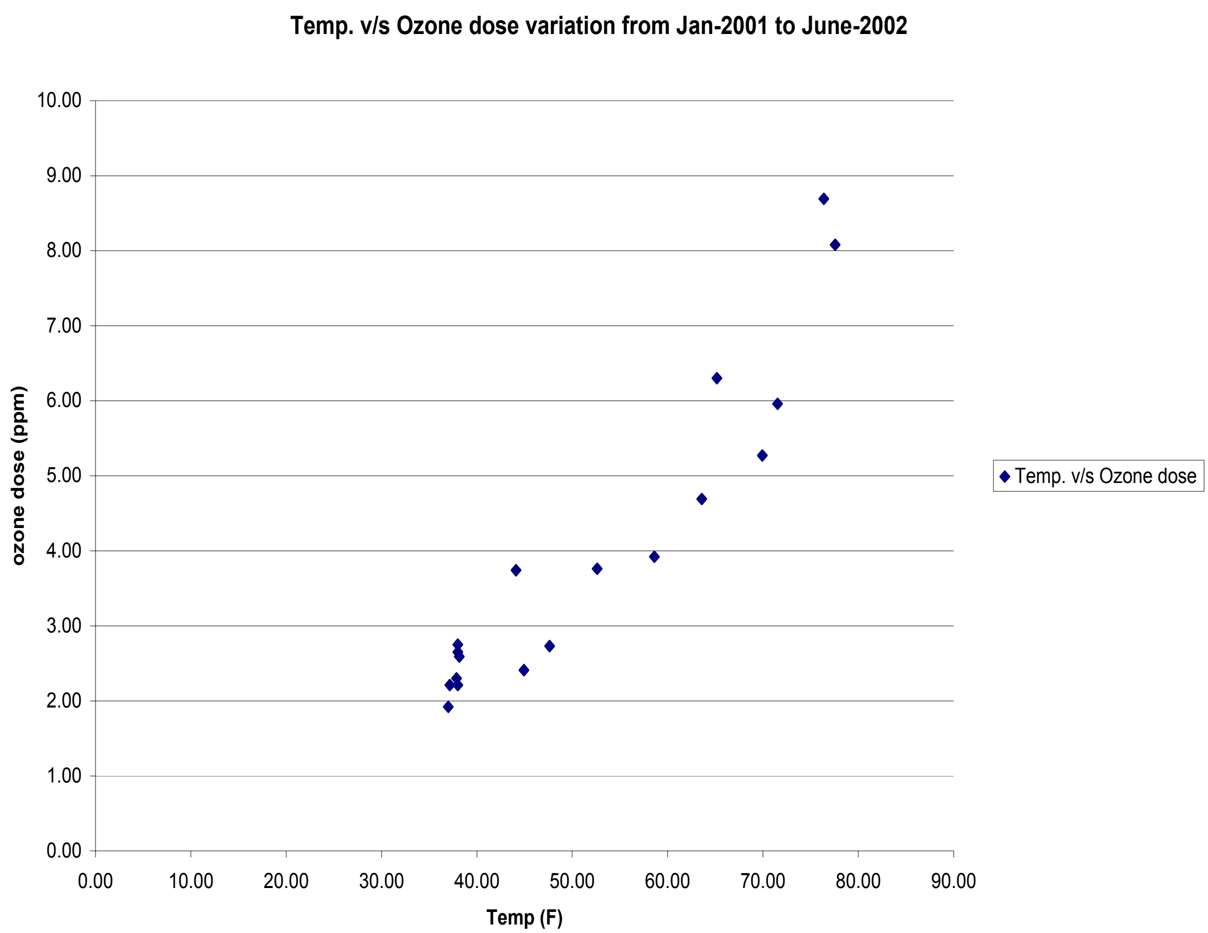


Figure 4-3. TOC variations in ozonation chamber influent and effluent
TOC (ppm)
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
11/20/00
01/09/01
02/28/01
04/19/01
06/08/01
07/28/01
09/16/01
11/05/01
12/25/01
02/13/02
04/04/02
05/24/02
07/13/02
09/01/02
Time (months)
TOC (influent)
TOC (effluent)

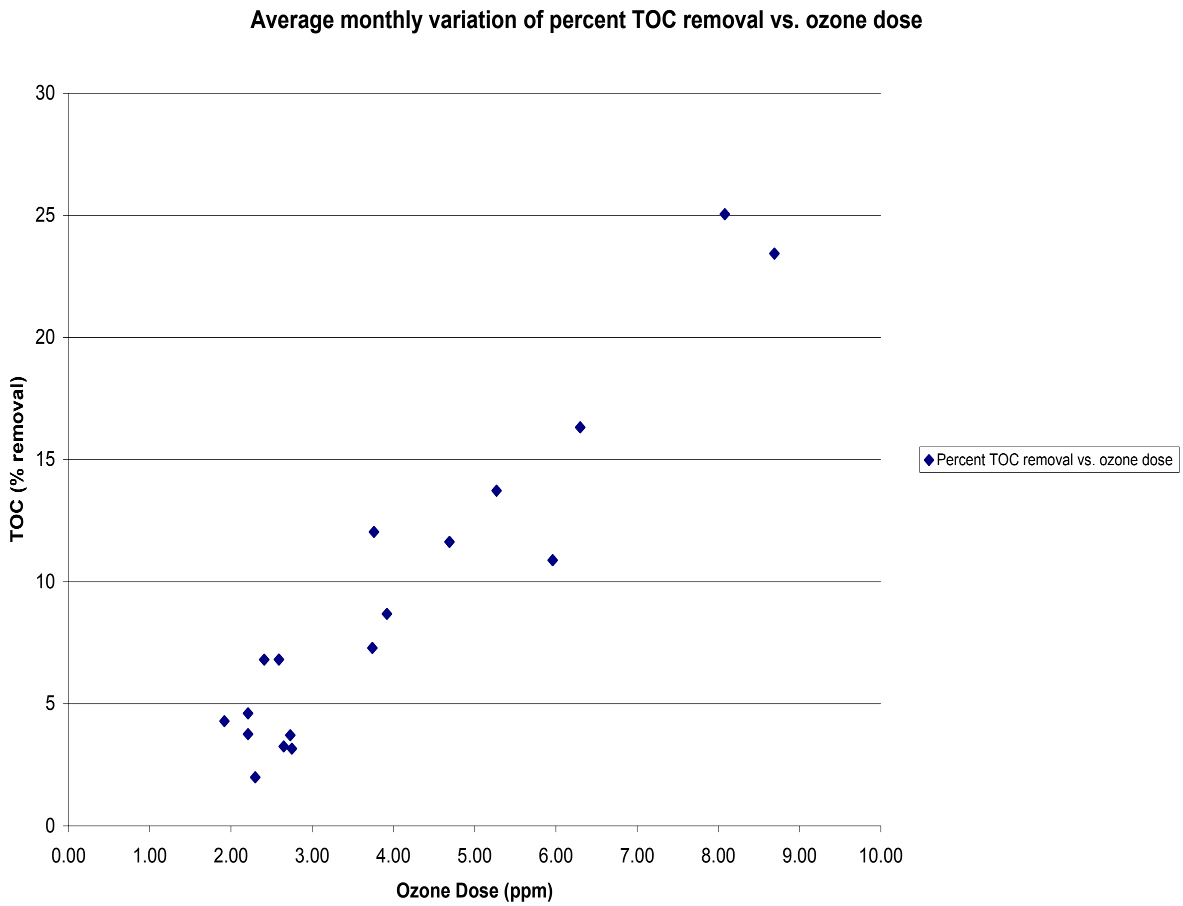

Variation of Ozone dose from Jan-2001 to Jun-2002
Ozone Dose (ppm)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Oct-00
Jan-01
Apr-01
Jul-01
Nov-01
Feb-02
May-02
Sep-02
Time (months)
ozone dose variation



Percent TOC removal in the ozonation chamber influent and effluent
30
25
20
15
10
5
0
TOC (% removal)
11/20/00
01/09/01
02/28/01
04/19/01
06/08/01
07/28/01
09/16/01
11/05/01
12/25/01
02/13/02
04/04/02
05/24/02
07/13/02
09/01/02
Time (months)
Percent TOC Removal



Temp. v/s Ozone dose variation from Jan-2001 to June-2002
ozone dose (ppm)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
Temp (F)
Temp. v/s Ozone dose



Factors affecting the Ozone System Operations

The main purpose of the operational data analysis is to understand as to the parameters studied so far affects the operational efficiency of the ozonation system. The control parameter taken here is the ozone dose. This is because the increased demand in summer and henceforth the formation of DBPs be directly proportional to the ozone dose fed into the ozone contact chambers. This will serve as the basic tool in evaluating the impact of water conditions on the ozone system.

Temperature

The temperature variation experienced by the FWTP is very large over the seasons and thus the ozone demand too, fluctuates. The ozone decomposition increases with the increase in temperature and henceforth, the ozone dose. The temperature affects the influent and effluent water quality through the ozone contact basin, as the formations of the DBPs are proportional to the ozone applied and this increases with the increased temperatures, affecting ozone system operations.

pH

The pH in ozone contact basin is very important tool in assessing the overall efficiency of the ozone operations. The ozone decomposition starts with the formation of hydroxide ions and the more the temperature, the rapid the reaction is. The FWTP keeps a constant pH in the ozone contact basin, as the purpose of the ozone usage is to provide disinfection and that is best served at a low pH.

Organic Content

The organic content present in water impacts the overall oxidation under the ozone application. The ozone required to meet the disinfection standards will increase with amount of increased organic content in the water. The parameter used to study is TOC. The influent TOC to the ozone chamber varied from 4 to 6 ppm and the effluent TOC varied from 3.5 to 5.5 ppm, over the period from 01/01/01 to 06/30/02. As the TOC concentrations increased, more ozone was applied to the water and vice versa.

Summary

The FWTP operational data analysis was important in selecting the sampling locations to undertake and meet the research goals. The analysis helped in limiting the sampling locations in and around the ozone contact chamber.

RESULTS AND DISCUSSIONS

The sampling at the FWTP was undertaken on August 5, 2002. The results are being shown and described in this chapter till September 2, 2002. The sampling parameters studied were pH, temperature, total organic carbon (TOC), UV 254 absorbance, specific UV 245 absorbance (SUVA), total alkalinity, ozone residual and off-gas concentrations, ozone dose, and total aldehydes.

The variations in the pH in the secondary softening effluent, stage 3 effluent of the ozone contact chamber, stage 4 effluent of the ozone contact chamber, and the filter influent are shown in table 5-1. The pH for the secondary softening effluent was consistent around 9.1-9.3. The average pH values for the stage 3 and 4 effluents of the ozone contact chambers were around 8.2 and 8.05 respectively, indicating that there was no considerable difference in the two stages of the ozone application. The highest pH recorded in the stage 3 and the stage 4 effluents was 8.84 and 8.63 respectively. The pH values for the filter influent were averaged around 8.21. The graphical representation of pH trends of the water entering and leaving the ozone contact basin is shown in the figure 5-1.

Table 5-1. pH values of the samples collected at the sampling locations

Date	pH - SS	pH - S3	pH - S4	pH - FI	pH - FE
8/5/2002	8.18	7.67	8.15	8.38	
8/7/2002	9.31	8.03	7.95	8.13	
8/9/2002	9.31	8.03	7.95	8.13	
8/12/2002	9.93	8.84	8.63	8.62	
8/14/2002	9.26	8.18	8.18	8.38	
8/16/2002	8.76	8.14	8.12	8.41	
8/19/2002	9.2	8.24	7.98	8.75	8.35
8/21/2002	9.1	7.98	7.78	8.53	8.32
8/23/2002	8.78	8.25	8.18	8.38	8.34
8/26/2002	8.09	8.24	7.35	7.23	8.34
8/28/2002	9.52	8.48	8.38	8.29	7.84
8/30/2002	9.09	8.31	8.24	8.17	8.39
9/2/2002	9.1	7.95	7.86	7.38	8.36

Figure 5-1. pH variations in the Secon. Soft, Stage 3, Stage 4, Filter Influent

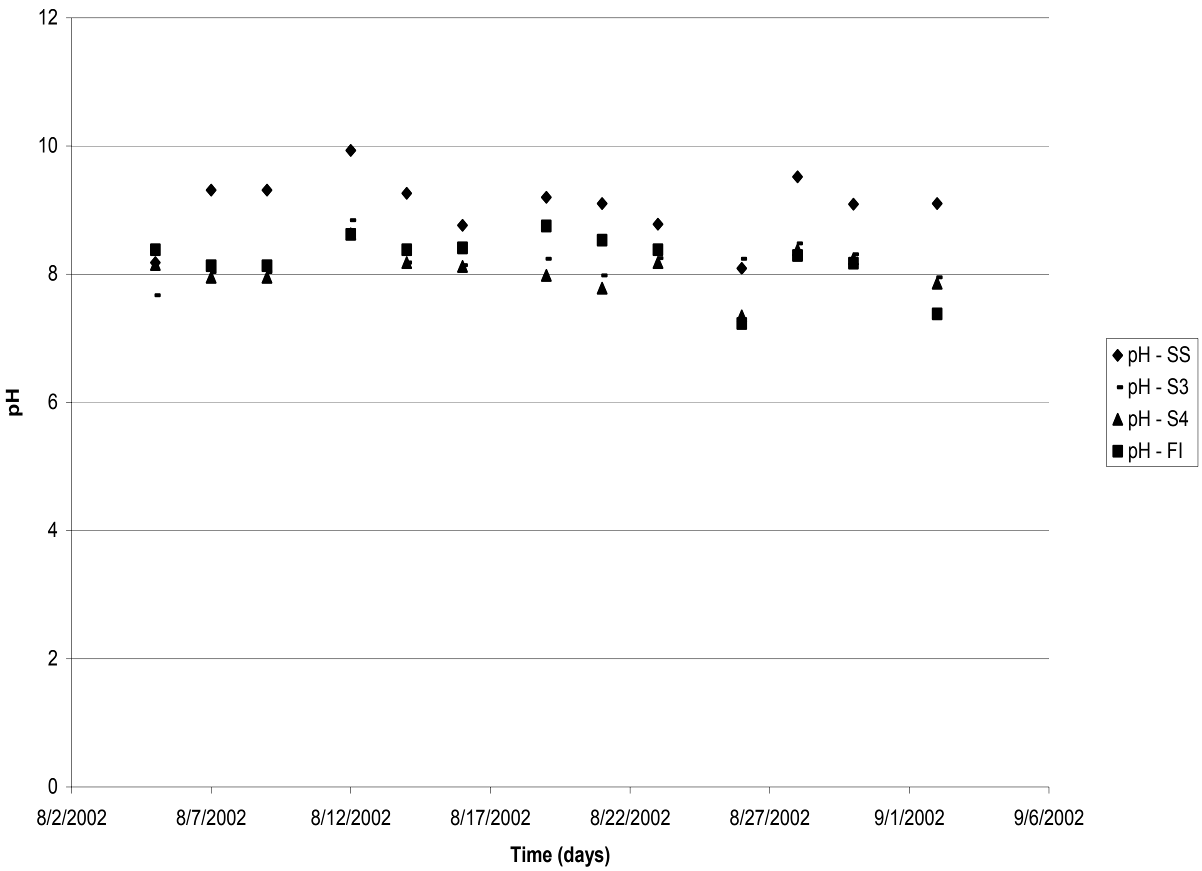
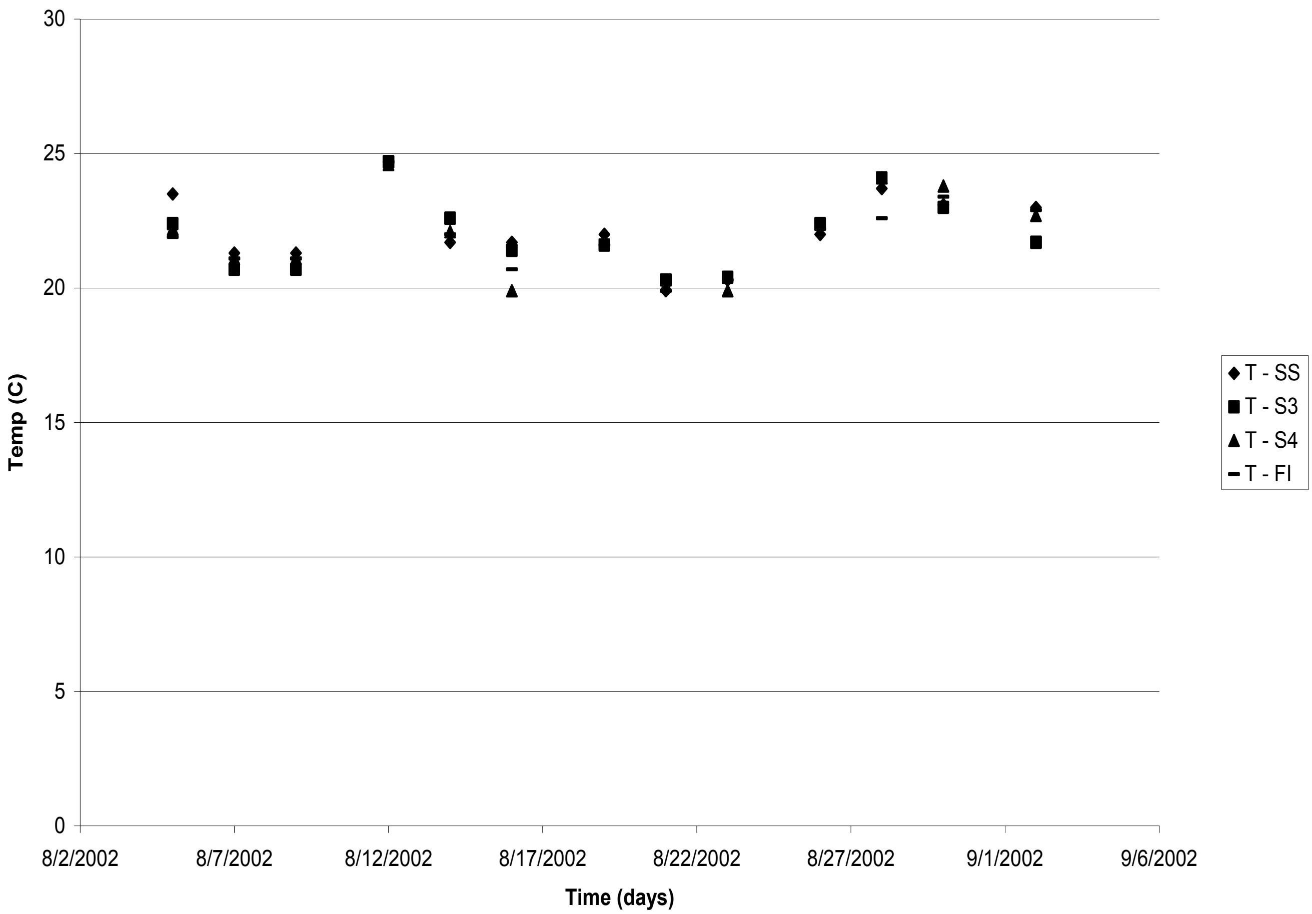


Table 5-2. Temp. values of the samples collected at the sampling locations

(All values indicated in degree celsius)

Date	T - SS	T - S3	T - S4	T - FI	T - FE
8/5/2002	23.5	22.4	22.2	21.9	
8/7/2002	21.3	20.7	21.1	21.1	
8/9/2002	21.3	20.7	21.1	21.1	
8/12/2002	24.7	24.7	24.6	24.7	
8/14/2002	21.7	22.6	22.1	22	
8/16/2002	21.7	21.4	19.9	20.7	
8/19/2002	22	21.6	21.7	21.6	21.7
8/21/2002	19.9	20.3	20.1	19.9	20.1
8/23/2002	20.3	20.4	19.9	20.3	20.1
8/26/2002	22	22.4	22.4	22.2	22.4
8/28/2002	23.7	24.1	24.1	22.6	23.8
8/30/2002	23.1	23	23.8	23.4	23.6
9/2/2002	23	21.7	22.7	22.9	21.7

Figure 5-2. Temp. varitions in Secondary Softening, Stage 3, Stage 4, Filter Influent



The temperature is a very important factor in ozone disinfection, as this decides the amounts of the ozone to be applied to the water in order to achieve the disinfection requirements. The temperature variations of the secondary softening effluent and thus the ozone contact influent and the ozone application stages, and the ozone contact effluent shown in table 5-2. The average temperature for the stage 3 and 4 of the ozone application was 22˚C and 21.97˚C respectively. The temperature for the filter influent was observed to be averaged around 21.87˚C. The results thus state that there was minimal or negligible change in the water temperature during the water treatment operations. With the winters approaching, the temperature values are expected to drop considerably. The graph depicting the temperature trends in the different sampling locations is shown in figure 5-2.

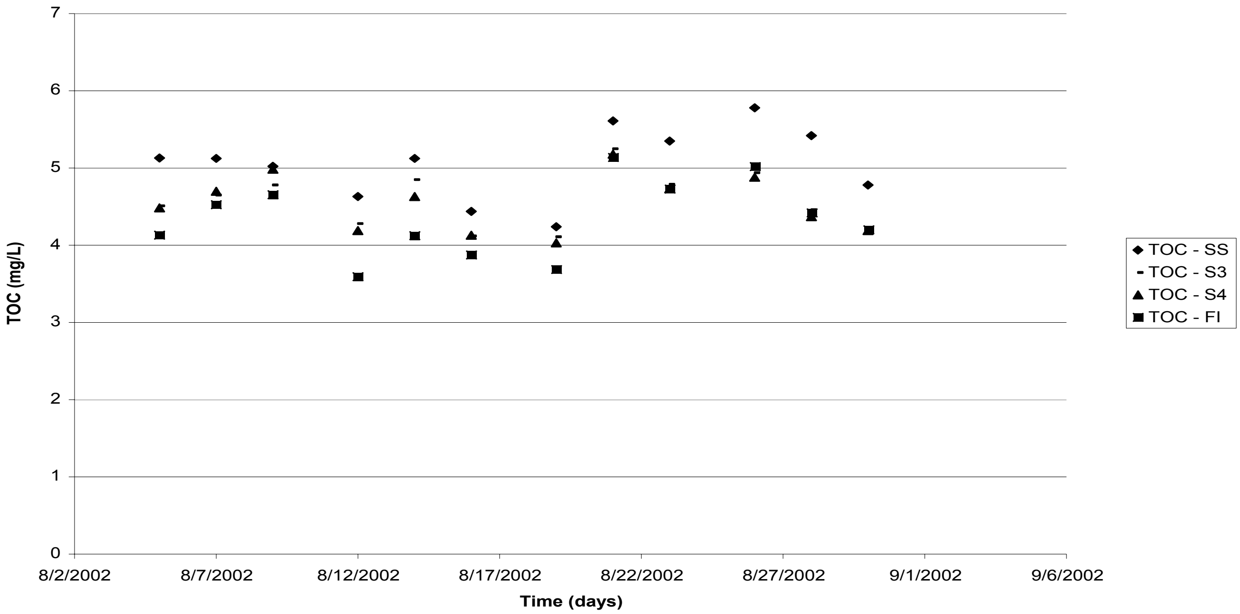
The total organic carbon (TOC) content signifies the amount of the natural organic matter present in the water. This is again a very important parameter in determining the disinfection efficiency. Higher the TOC content, more will the formation of the DBPs in the treated water. This is because of the reason that higher organic content will require more ozone application and this could result in an incomplete oxidation of the organic matter, thus resulting in the formation of DBPs. The TOC values are presented in the table 5-3. The TOC showed a declining trend with the lower water temperatures entering the plant, indicating that the ozone disinfection will be more effective in the winter season, as the water temperature, and the organic content and the pH in the ozone contact basin will be lowered. This is because lower organic content and water temperature will result in lowered ozone requirements, which will be sufficed by the lower pH at the point of application, making ozone more stable, thus allowing better disinfection. The average ozone contact influent and the effluent TOC ranged from 5.05 mg/L to 4.33 mg/L. The TOC variations for the samples taken at the different sampling locations are graphed in the figure 5-3.

Table 5-3. TOC values of the samples collected at the sampling locations

(All values indicated in mg/L)

Date	TOC - SS	TOC - S3	TOC - S4	TOC - FI	TOC - FE
8/5/2002	5.129	4.51	4.484	4.129	
8/7/2002	5.125	4.65	4.7	4.523	
8/9/2002	5.023	4.78	4.986	4.652	
8/12/2002	4.63	4.28	4.19	3.59	
8/14/2002	5.125	4.85	4.63	4.12	
8/16/2002	4.44	4.12	4.13	3.87	
8/19/2002	4.24	4.11	4.03	3.68	4.02
8/21/2002	5.61	5.25	5.18	5.13	5.13
8/23/2002	5.35	4.79	4.73	4.72	4.72
8/26/2002	5.78	4.94	4.88	5.01	5.01
8/28/2002	5.42	4.46	4.37	4.41	4.41
8/30/2002	4.78	4.21	4.19	4.19	4.19
9/2/2002					

Figure 5-3. TOC variations in Secondary Softening, Stage 3, Stage 4, Filter Influent



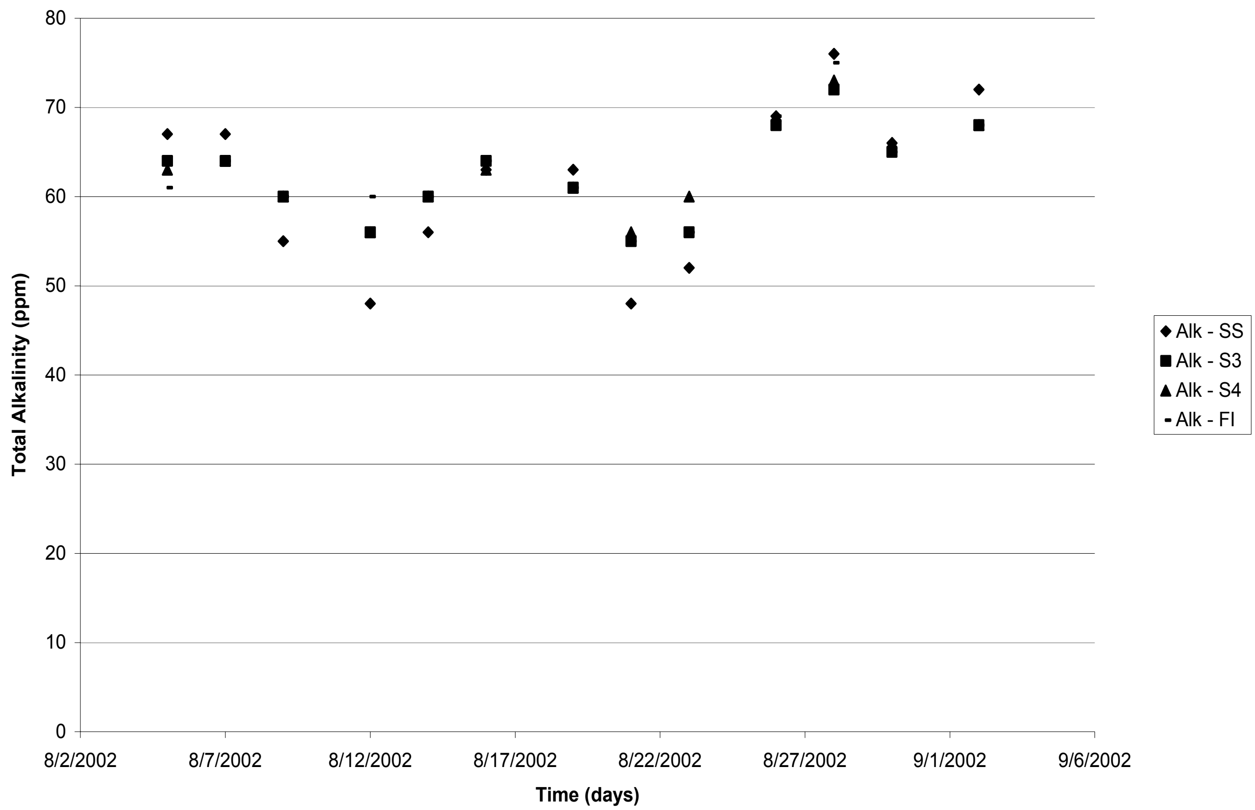
Total alkalinity was measured for the different samples and is tabulated in table 5-4. The total alkalinity showed inconsistent trend over the time period and thus it is difficult to predict the future behavioral trends. The plot showing the total alkalinity variations is graphed in figure 5-4.

Table 5-4. Total Alkalinity values of the samples collected at the sampling locations

(All values indicated in mg/L (ppm))

Date	Alk - SS	Alk - S3	Alk - S4	Alk - FI	Alk - FE
8/5/2002	67	64	63	61	
8/7/2002	67	64	64	64	
8/9/2002	55	60	60	60	
8/12/2002	48	56	56	60	
8/14/2002	56	60	60	60	
8/16/2002	63	64	63	64	
8/19/2002	63	61	61	61	61
8/21/2002	48	55	56	55	55
8/23/2002	52	56	60	56	56
8/26/2002	69	68	69	69	68
8/28/2002	76	72	73	75	73
8/30/2002	66	65	66	65	65
9/2/2002	72	68	68	68	68

Figure 5-4. Total Alkalinity variations in Secondary Softening, Stage 3, Stage 4, Filter Influent



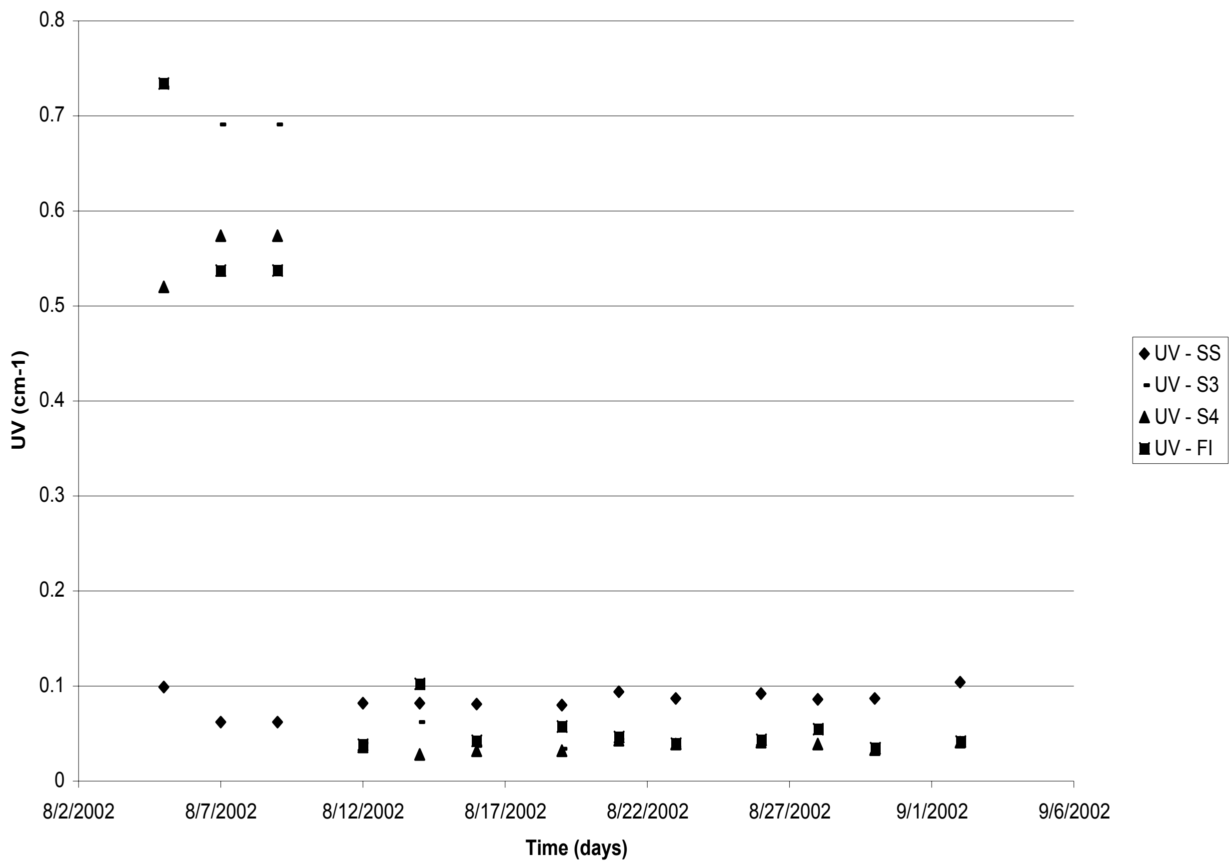
UV 254 absorbance is a measure of the incomplete oxidation of the organic content present in the water and the UV 254 values showed a declining trend across the ozonation chamber. Though the UV 254 values for the first three sampling days were unexpectedly higher, the rest of the data followed the expected trend. The values usually were smaller than 0.1 cm^{-1}. The results are shown in the table 5-5 and the values are plotted in the figure 5-5. This parameter was measured specifically to understand the incomplete oxidation trends and thus the further removal of the organic contaminants from the treated water.

Table 5-5. UV values of the samples collected at the sampling locations

(All values indicated in cm-1)

Date	UV - SS	UV - S3	UV - S4	UV - FI	UV - FE
8/5/2002	0.099	0.73	0.52	0.734	
8/7/2002	0.062	0.691	0.574	0.537	
8/9/2002	0.062	0.691	0.574	0.537	
8/12/2002	0.082	0.04	0.036	0.038	
8/14/2002	0.082	0.062	0.028	0.102	
8/16/2002	0.081	0.037	0.032	0.042	
8/19/2002	0.08	0.034	0.032	0.057	0.035
8/21/2002	0.094	0.044	0.043	0.046	0.048
8/23/2002	0.087	0.036	0.039	0.039	0.048
8/26/2002	0.092	0.042	0.041	0.043	0.045
8/28/2002	0.086	0.051	0.039	0.054	0.051
8/30/2002	0.087	0.034	0.033	0.034	0.045
9/2/2002	0.104	0.043	0.041	0.041	0.049

Figure 5-5. UV variations in Secondary Softening, Stage 3, Stage 4, Filter Influent

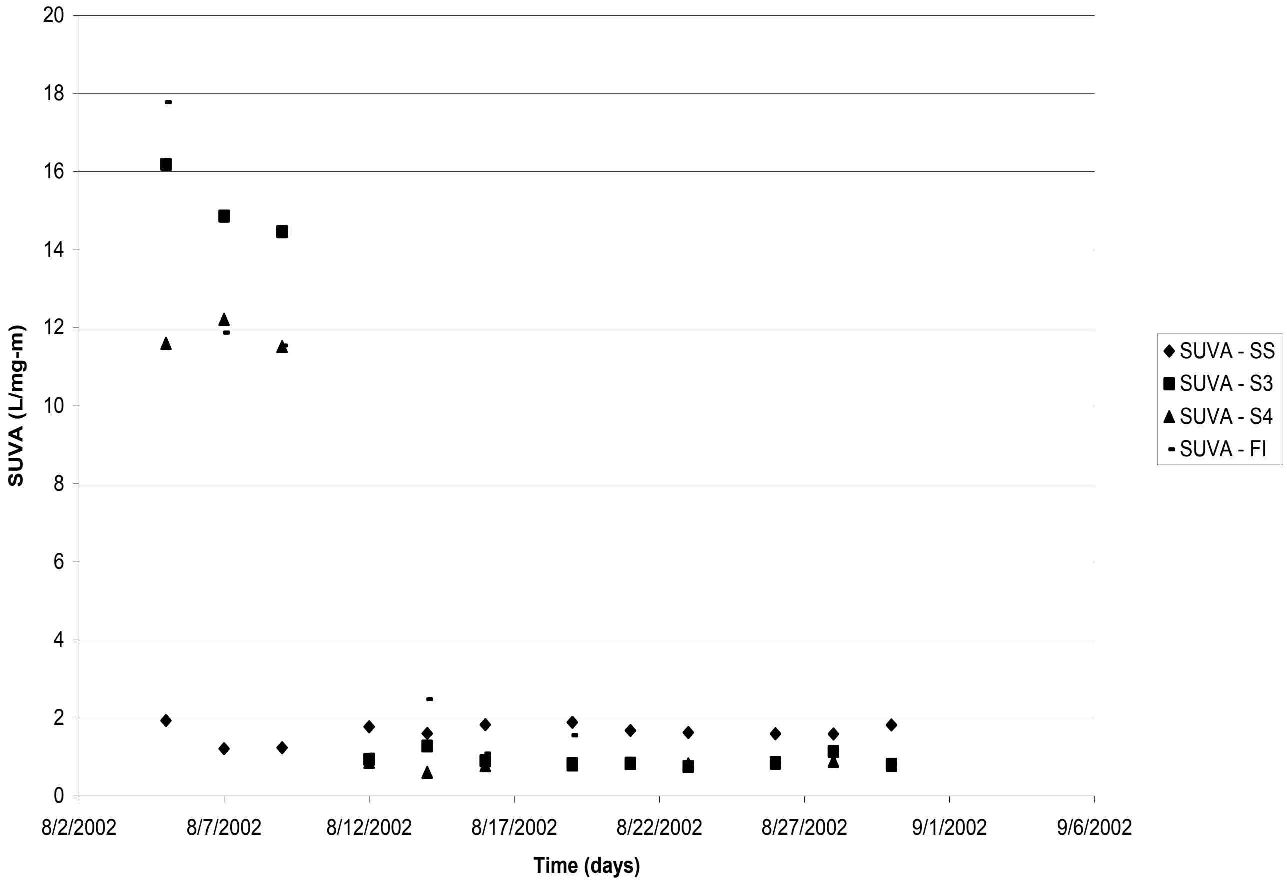


Specific UV 254 absorbance is defined as the ration of the UV 254 absorbance to the total organic carbon (TOC). This parameter is expressed in L/mg-m. The SUVA is measured in order to understand the overall oxidation process, which is being performed by the ozone, when made to react with the organic content in the water. The SUVA values decreased in magnitude across the ozone contact basin indicating complete oxidation. The SUVA values ranged from a minimum of 0.78 L/mg-m to 1.88 L/mg-m. The values are shown in table 5-6 and the variations are plotted in figure 5-6.

Table 5-6. SUVA values of the samples collected at the sampling locations (All values indicated in L/mg-m)

Date	SUVA - SS	SUVA - S3	SUVA - S4	SUVA - FI	SUVA - FE
8/5/2002	1.9302008	16.1862528	11.596789	17.776701	
8/7/2002	1.2097561	14.8602151	12.212766	11.872651	
8/9/2002	1.2343221	14.4560669	11.512234	11.543422	
8/12/2002	1.7710583	0.93457944	0.8591885	1.0584958	
8/14/2002	1.6	1.27835052	0.6047516	2.4757282	
8/16/2002	1.8243243	0.89805825	0.7748184	1.0852713	
8/19/2002	1.8867925	0.82725061	0.7940447	1.548913	0.8706468
8/21/2002	1.6755793	0.83809524	0.8301158	0.8966862	0.9356725
8/23/2002	1.6261682	0.75156576	0.8245243	0.8262712	1.0169492
8/26/2002	1.5916955	0.85020243	0.8401639	0.8582834	0.8982036
8/28/2002	1.5867159	1.14349776	0.8924485	1.2244898	1.1564626
8/30/2002	1.8200837	0.80760095	0.7875895	0.8114558	1.0739857
9/2/2002					

Figure 5-6. SUVA variations in Secondary Softening, Stage 3, Stage 4, Filter Influent



The overall results for each sampling location, with all the parameters measured at that particular location, indicated with proper units are shown in table 5-7 through 5-10. The total aldehydes quantified in the ozone contact influent and the effluent is shown in table 5-11 through 5-14.

Figure 5-6. SUVA variations in Secondary Softening, Stage 3, Stage 4, Filter Influent

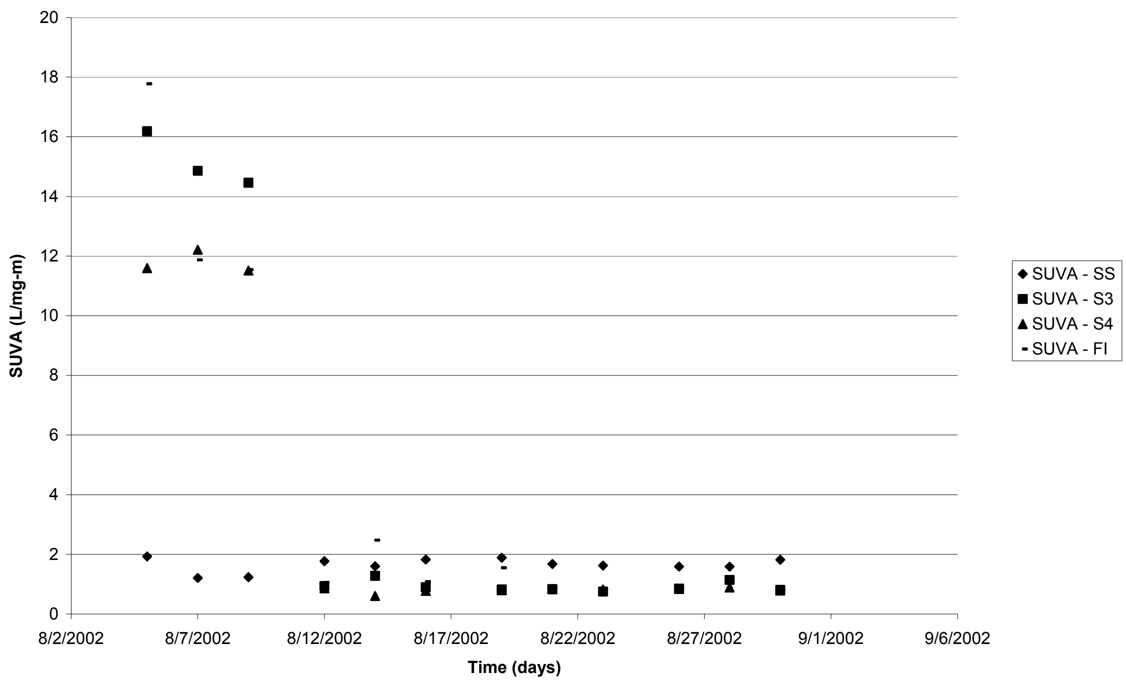


Table 5-7. Parametric Details of Secondary Softening Effluent

Date	pH	Total Alk.	Temp.	TOC	UV	SUVA	Oz.residual	Oz. gas flow	SUVA
		ppm	C	mg/L	cm-1	L/mg-cm	ppm	cfm	L/mg-m
8/5/2002	8.18	67	23.5	5.129	0.099	0.019302	0	0	1.930201
8/7/2002	9.31	67	21.3	5.125	0.062	0.012098	0	0	1.209756
8/9/2002	9.31	55	21.3	5.023	0.062	0.012343	0	0	1.234322
8/12/2002	9.93	48	24.7	4.63	0.082	0.017711	0	0	1.771058
8/14/2002	9.26	56	21.7	5.125	0.082	0.016	0	0	1.6
8/16/2002	8.76	63	21.7	4.44	0.081	0.018243	0	0	1.824324
8/19/2002	9.2	63	22	4.24	0.08	0.018868	0	0	1.886792
8/21/2002	9.1	48	19.9	5.61	0.094	0.016756	0	0	1.675579
8/23/2002	8.78	52	20.3	5.35	0.087	0.016262	0	0	1.626168
8/26/2002	8.09	69	22	5.78	0.092	0.015917	0	0	1.591696
8/28/2002	9.52	76	23.7	5.42	0.086	0.015867	0	0	1.586716
8/30/2002	9.09	66	23.1	4.78	0.087	0.018201	0	0	1.820084
9/2/2002	9.1	72	23		0.104	0	0	0	0

Table 5-8. Parametric details of Stage 3 Effluent

Date	pH	Total Alk.	Temp.	TOC	UV	SUVA	Oz.residual	Oz. gas flow	SUVA
		ppm	C	mg/L	cm-1	L/mg-cm	ppm	cfm	L/mg-m
8/5/2002	7.67	64	22.4	4.51	0.73	0.161863	0.108	23.5	16.18625
8/7/2002	8.03	64	20.7	4.65	0.691	0.148602	0.193	25.5	14.86022
8/9/2002	8.03	60	20.7	4.78	0.691	0.144561	0.193	23.7	14.45607
8/12/2002	8.84	56	24.7	4.28	0.04	0.009346	0.116	24.4	0.934579
8/14/2002	8.18	60	22.6	4.85	0.062	0.012784	0.15	21.6	1.278351
8/16/2002	8.14	64	21.4	4.12	0.037	0.008981	0.165	19.3	0.898058
8/19/2002	8.24	61	21.6	4.11	0.034	0.008273	0.133	19.8	0.827251
8/21/2002	7.98	55	20.3	5.25	0.044	0.008381	0.2	23.3	0.838095
8/23/2002	8.25	56	20.4	4.79	0.036	0.007516	0.125	22.5	0.751566
8/26/2002	8.24	68	22.4	4.94	0.042	0.008502	0.124	28.6	0.850202
8/28/2002	8.48	72	24.1	4.46	0.051	0.011435	0.16	31.7	1.143498
8/30/2002	8.31	65	23	4.21	0.034	0.008076	0.177	32.9	0.807601
9/2/2002	7.95	68	21.7		0.043	0	0.193	18.1	0

Table 5-9. Parametric variations of Stage 4 Effluent

Date	pH	Total Alk.	Temp.	TOC	UV	SUVA	Oz.residual	Oz. gas flow	SUVA
		ppm	C	mg/L	cm-1	L/mg-cm	ppm	cfm	L/mg-m
8/7/2002	7.95	64	21.1	4.7	0.574	0.122128	0.108	2.72	12.21277
8/9/2002	7.95	60	21.1	4.986	0.574	0.115122	0.108	2.78	11.51223
8/12/2002	8.63	56	24.6	4.19	0.036	0.008592	0.067	2.81	0.859189
8/14/2002	8.18	60	22.1	4.63	0.028	0.006048	0.072	2.54	0.604752
8/16/2002	8.12	63	19.9	4.13	0.032	0.007748	0.09	0.58	0.774818
8/19/2002	7.98	61	21.7	4.03	0.032	0.00794	0.073	0.293	0.794045
8/21/2002	7.78	56	20.1	5.18	0.043	0.008301	0.103	2.4	0.830116
8/23/2002	8.18	60	19.9	4.73	0.039	0.008245	0.035	2.25	0.824524
8/26/2002	7.35	69	22.4	4.88	0.041	0.008402	0.05	2.6	0.840164
8/28/2002	8.38	73	24.1	4.37	0.039	0.008924	0.05	2.96	0.892449
8/30/2002	8.24	66	23.8	4.19	0.033	0.007876	0.013	2.87	0.787589
9/2/2002	7.86	68	22.7		0.041	0	0.023	0.322	0

From the tables 5-7 through 5-10, the ozone residual variations in the stage 3 and the stage 4 of the ozone contact basin are plotted in figure 5-7 and figure 5-9 respectively. The ozone gas flows in the stage 3 and stage 4 are plotted in figure 5-8 and figure 5-10 respectively. The ozone residual and was higher in stage 3 as compared to the stage 4, mainly because of the fact that more ozone is applied in the stage 3 then in the stage 4. The amount of ozone application is directly proportional to the incoming water temperature and the organic content. The higher these values are the more ozone is required for the disinfection. The ozone residual in stage 3 was found to range between a maximum of 0.193mg/L to a minimum of 0.108 mg/L. The ozone gas flow was varying between 32.9 cubic feet per minute (cfm) to 19.3 cfm for stage 3. The ozone residual for stage 4 was varying between 0.108mg/L to 0.072 mg/L. The ozone gas flow was found to range between 2.87 cfm to 0.293 cfm.

Table 5-10. Parametric Variations of Filter Influent

Date	pH	Total Alk.	Temp.	TOC	UV	SUVA	Oz.residual	Oz. gas flow	SUVA
		ppm	C	mg/L	cm-1	L/mg-cm	ppm	cfm	L/mg-m
8/5/2002	8.38	61	21.9	4.129	0.734	0.177767	0.001	0	17.7767
8/7/2002	8.13	64	21.1	4.523	0.537	0.118727	0.001	0	11.87265
8/9/2002	8.13	60	21.1	4.652	0.537	0.115434	0.001	0	11.54342
8/12/2002	8.62	60	24.7	3.59	0.038	0.010585	0.001	0	1.058496
8/14/2002	8.38	60	22	4.12	0.102	0.024757	0.001	0	2.475728
8/16/2002	8.41	64	20.7	3.87	0.042	0.010853	0.001	0	1.085271
8/19/2002	8.75	61	21.6	3.68	0.057	0.015489	0.001	0	1.548913
8/21/2002	8.53	55	19.9	5.13	0.046	0.008967	0.001	0	0.896686
8/23/2002	8.38	56	20.3	4.72	0.039	0.008263	0.001	0	0.826271
8/26/2002	7.23	69	22.2	5.01	0.043	0.008583	0.001	0	0.858283
8/28/2002	8.29	75	22.6	4.41	0.054	0.012245	0.001	0	1.22449
8/30/2002	8.17	65	23.4	4.19	0.034	0.008115	0.001	0	0.811456
9/2/2002	7.38	68	22.9		0.041	0	0.001	0	0

Figure 5-7. Ozone residual variations in Stage 3 effluent of ozone cntact basin

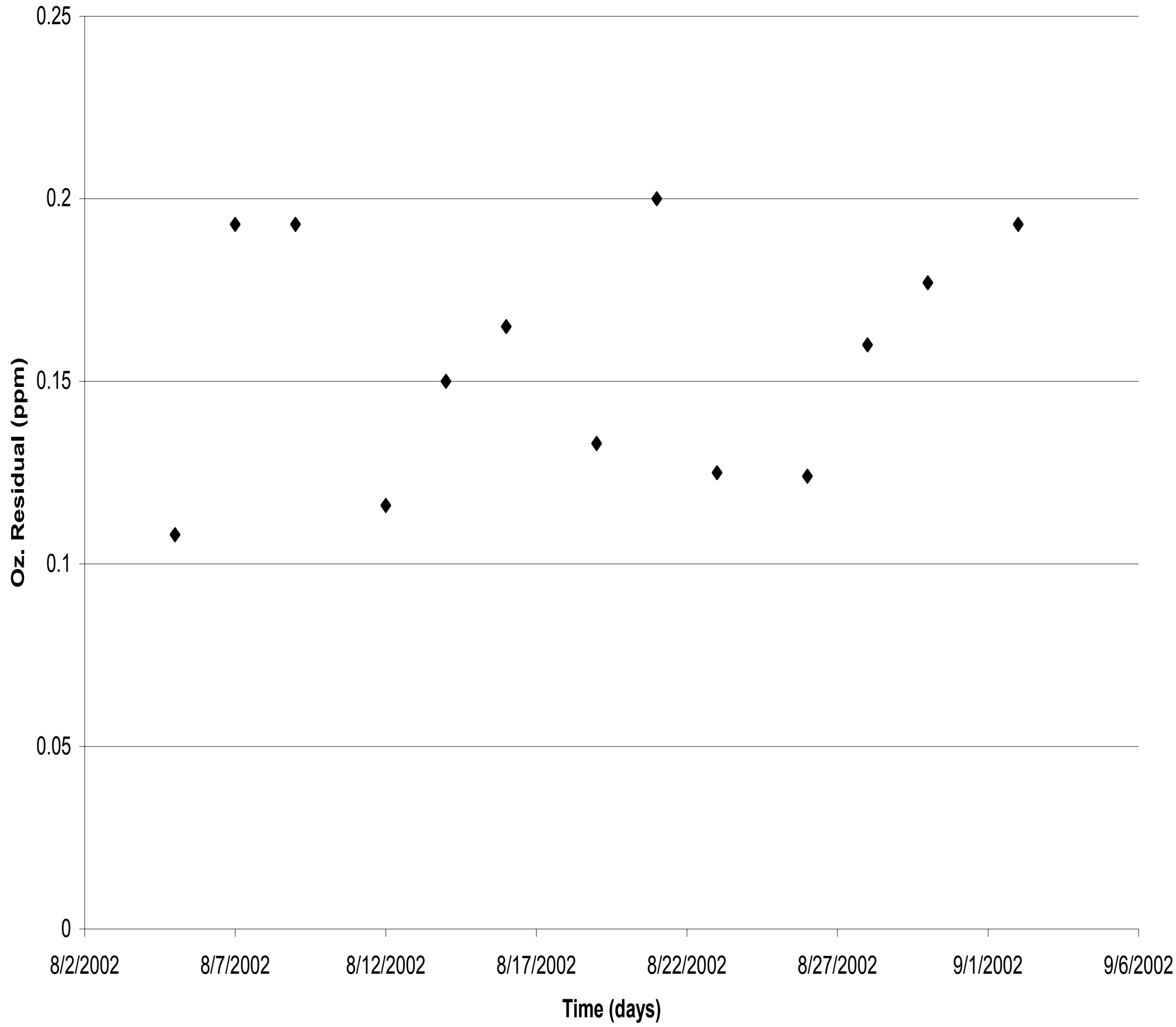


Figure 5-9. Ozone residual variation in Stage 4 effluent of the ozone contact basin

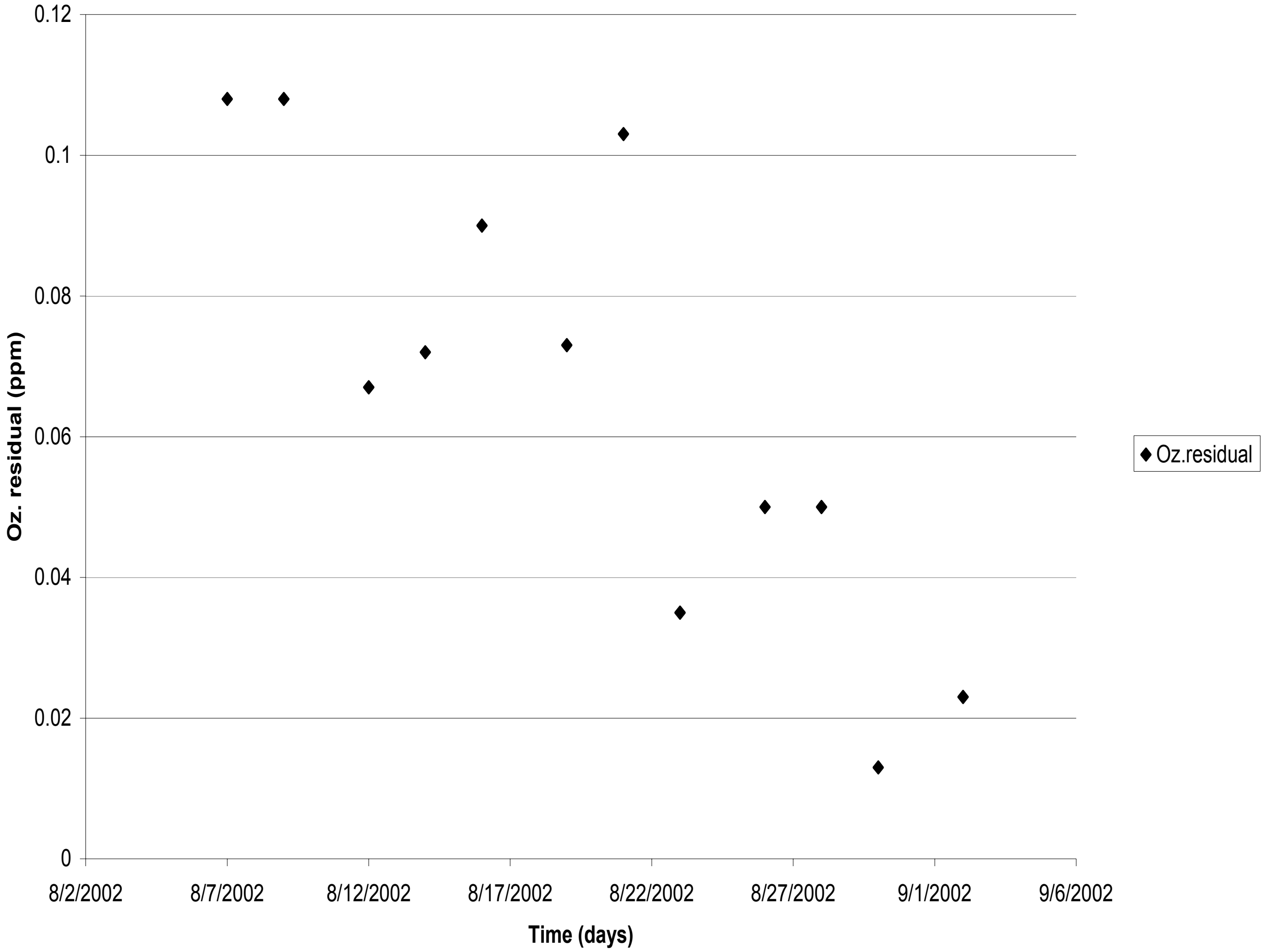


Figure 5-8. Ozone gas flow variation in Stage 3 effluent of ozone contact basin

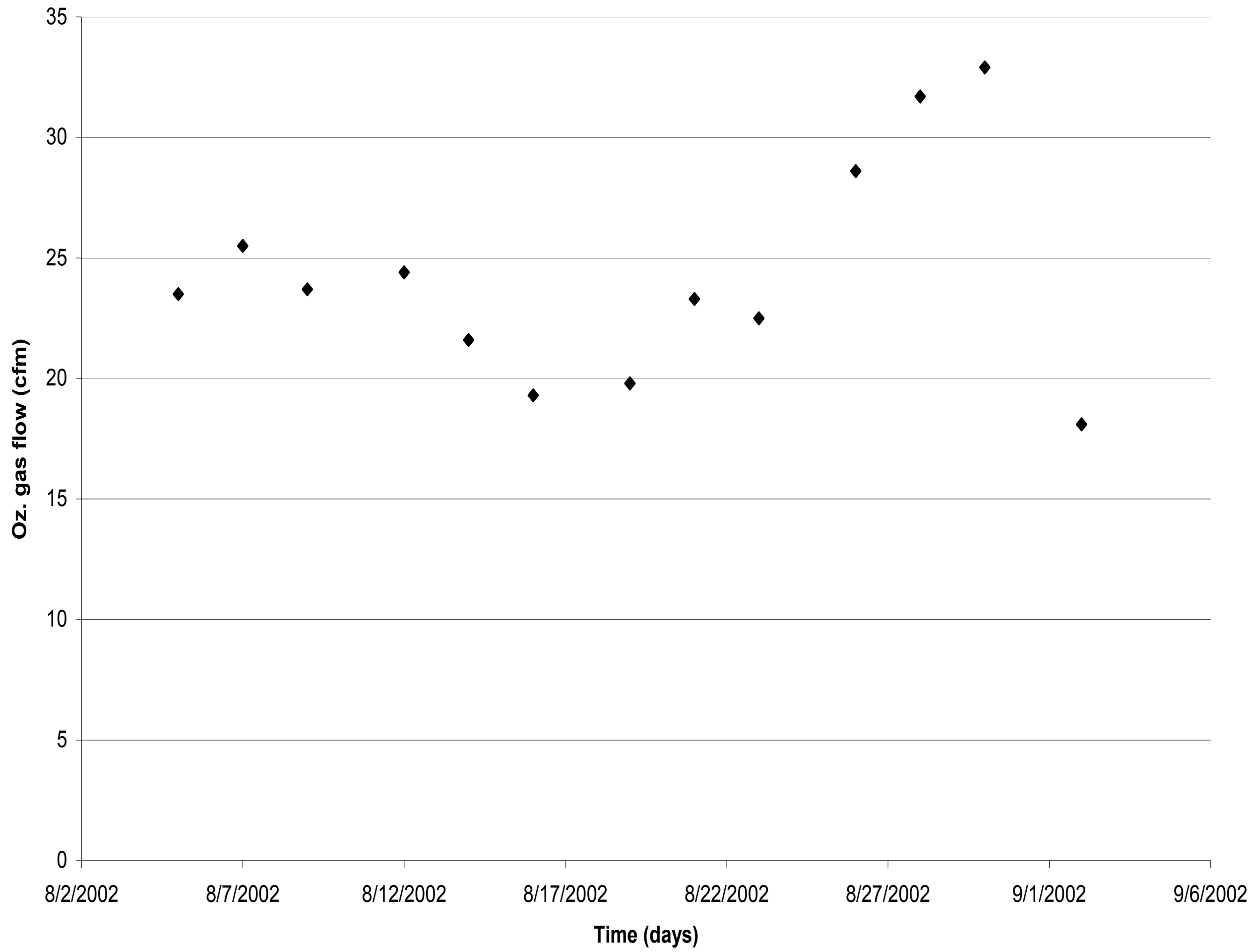
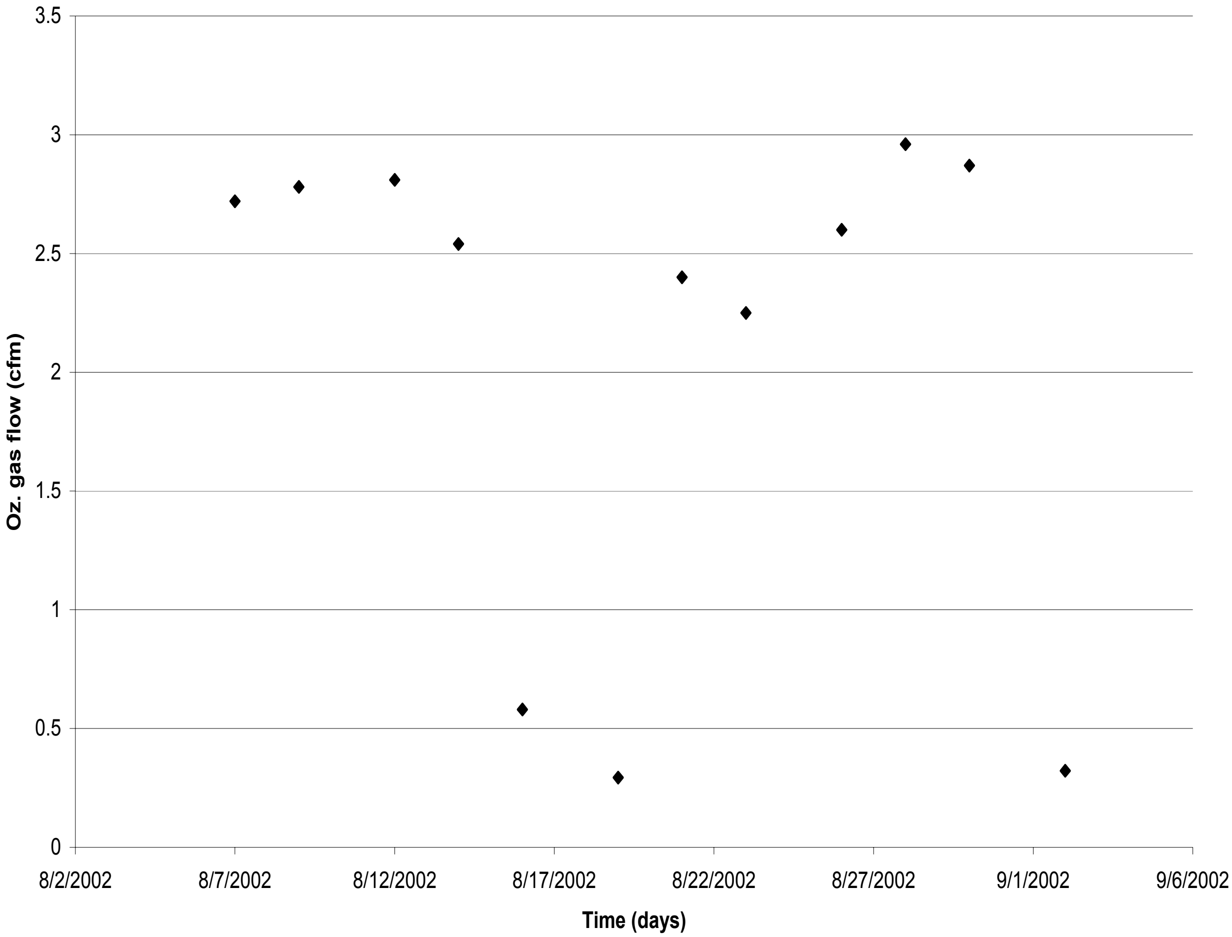
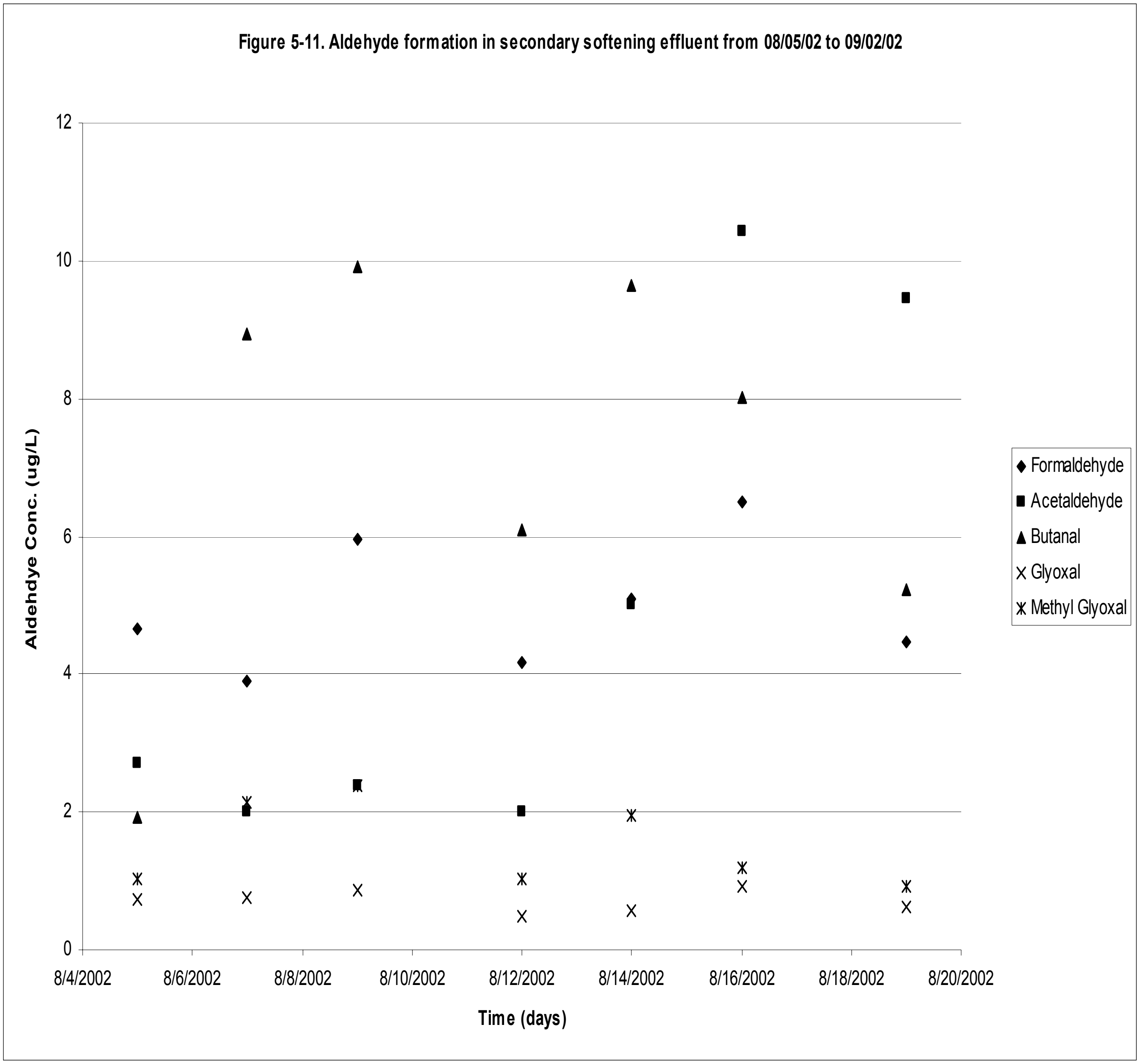


Figure 5-10. Ozone gas flow variation in Stage 4 of the ozone contact basin

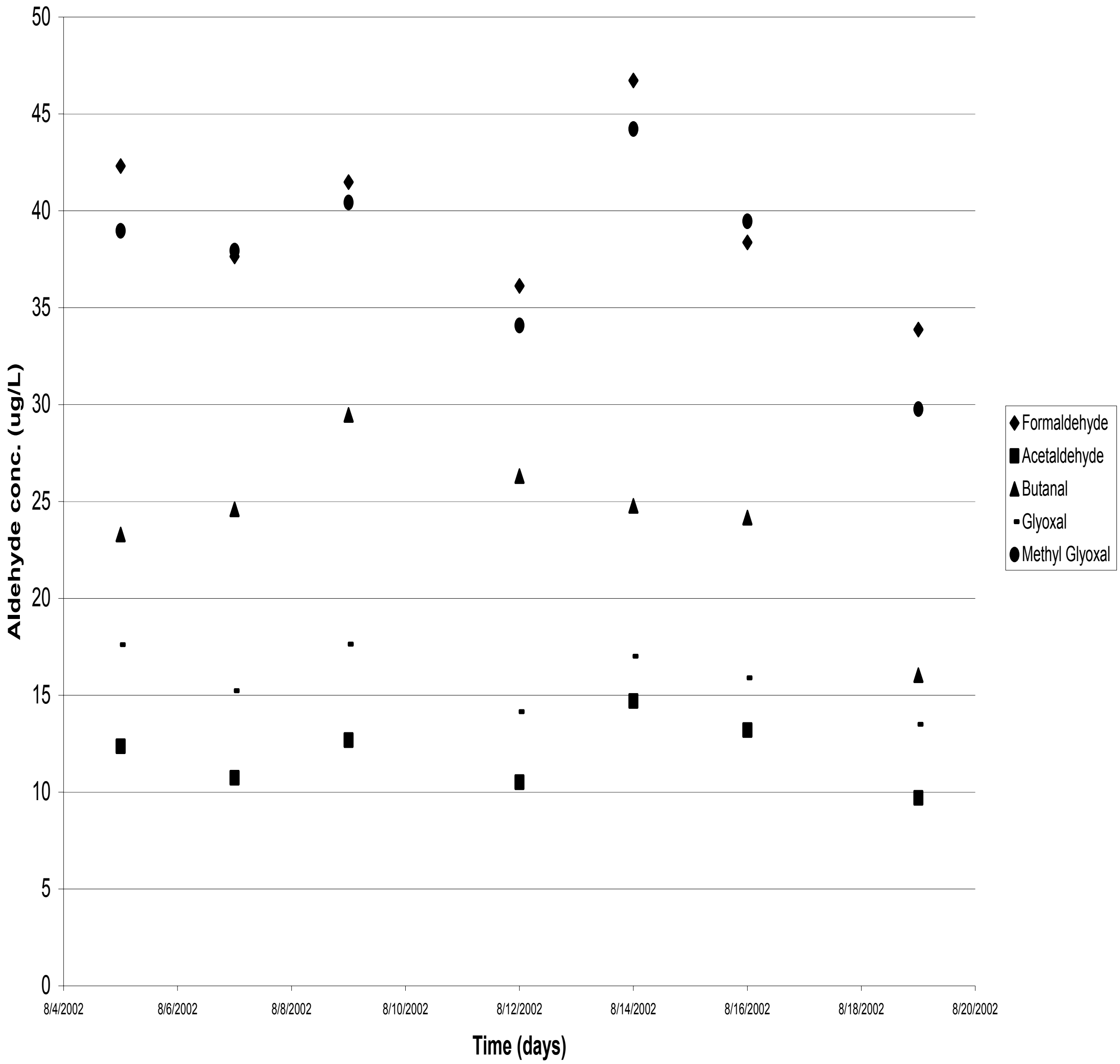


The graphical representation of the aldehydes formation at the different sampled water treatment processes is shown in figure 5-11 through 5-14. The aldehydes considered for the comparative study, were formaldehyde, acetaldehyde, butanal, glyoxal, and methyl glyoxal. This is because of the fact that the other aldehydes formation is usually very low in amounts (Hurley, Stuart 2001) and the moreover the formaldehyde is the major cause of concern, as this being a carcinogen.



The aldehydes were usually low in amounts in the water entering the ozone contact basin, and then after the ozone application, the amounts soared significantly. This was primarily due to the reason that the incomplete oxidation of the organic matter took place and thus resulted in the DBPs formation. Aldehydes were considerably reduced in amounts after the ozone was stripped out, before the treated entered the filters. The amount of aldehydes entering and leaving the ozone contact basin were low in amounts in the secondary softening effluent and the filter influent, because of the reason that in the first case, there was no ozone application and in the latter case, the ozone was stripped out, so as to make the water suitable for the biological filtration, as ozone is toxic in nature to the microorganisms. The aldehydes were largely formed in stage 3 and 4 of the ozone contact chamber, as because of the incomplete oxidation of the organic matter present in the river water, occurred on ozone application.

Fiure 5-12. Aldehyde formation variations in Stage 3 Effluent of the ozone contact basin from 08/05/02 through 09/02/02



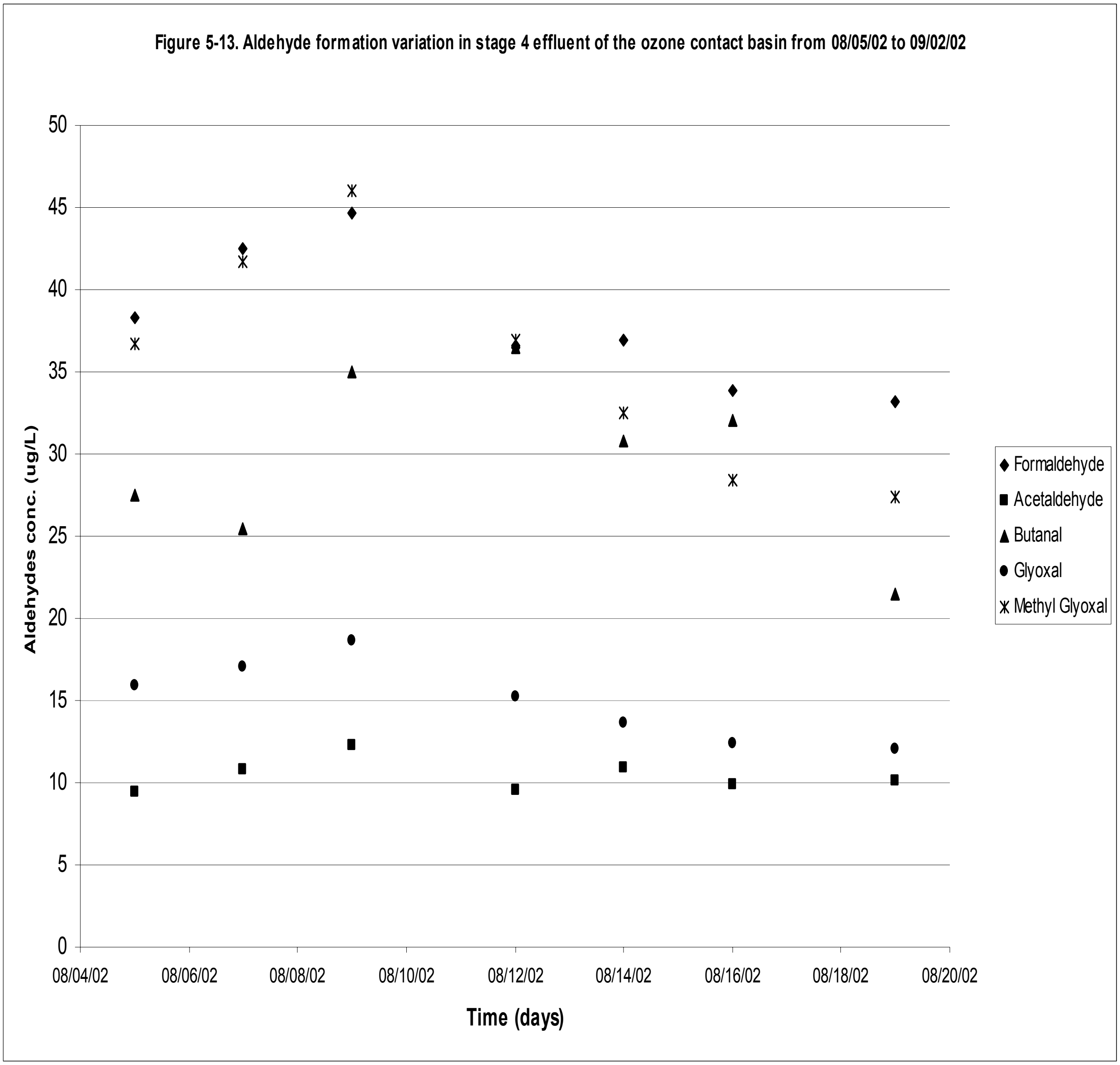
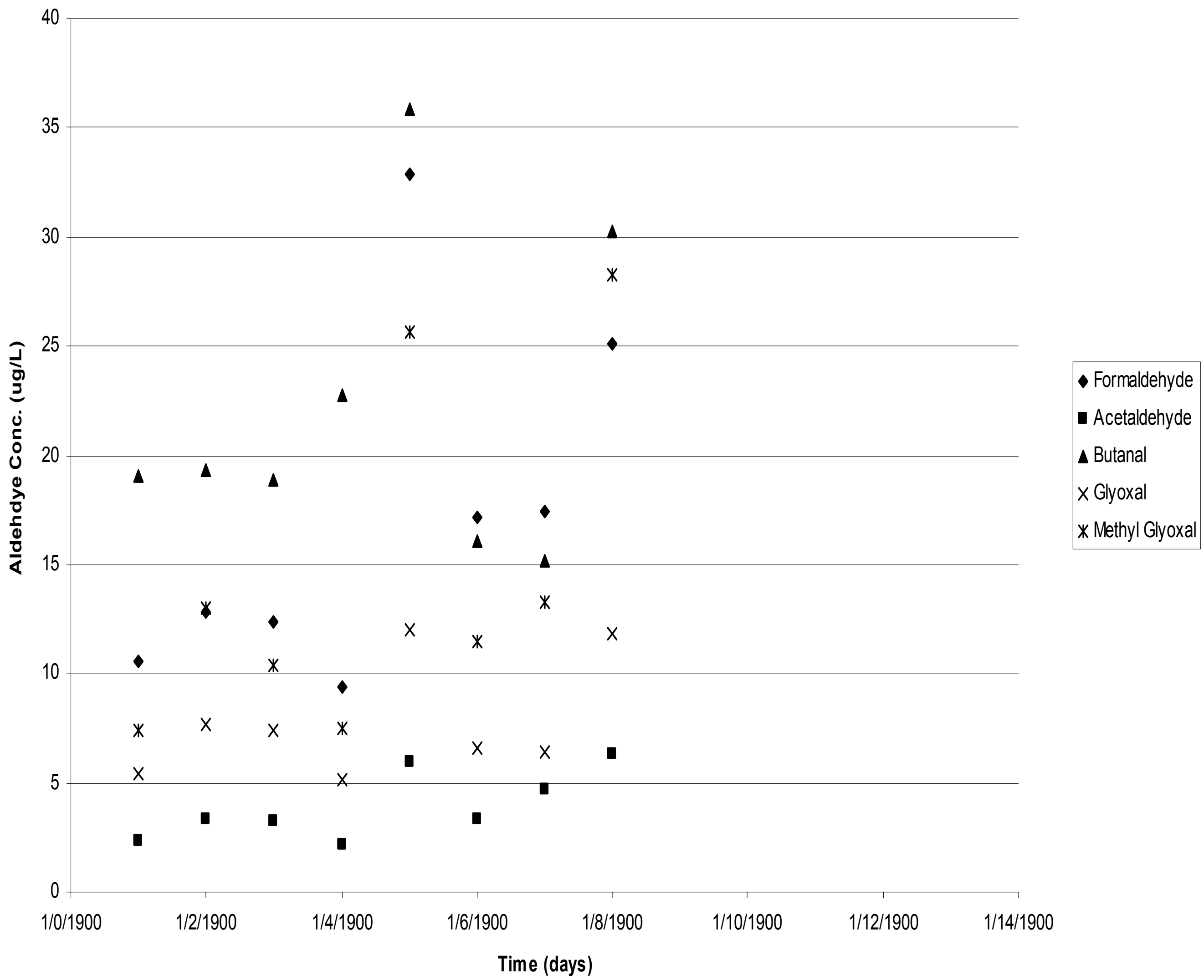


Figure 5-13. Aldehyde formation variation in stage 4 effluent of the ozone contact basin from 08/05/02 to 09/02/02
Aldehydes conc. (ug/L)
50
45
40
35
30
25
20
15
10
5
0
08/04/02
08/06/02
08/08/02
08/10/02
08/12/02
08/14/02
08/16/02
08/18/02
08/20/02
Time (days)
Formaldehyde
Acetaldehyde
Butanal
Glyoxal
Methyl Glyoxal

Figure 5-14. Aldehyde formation variation in the filter influent from 08/05/02 to 09/02/02



Northern Forest Wetlands: Characteristics and Influences on Invertebrate and Amphibian Community Structure

Basic Information

Title:	Northern Forest Wetlands: Characteristics and Influences on Invertebrate and Amphibian Community Structure
Project Number:	2002ND15B
Start Date:	5/15/2002
End Date:	12/31/2003
Funding Source:	104B
Congressional District:	1
Research Category:	Not Applicable
Focus Category:	Wetlands, Water Quality, Ecology
Descriptors:	Forest wetlands, Silviculture, Biodiversity
Principal Investigators:	Malcolm George Butler

Publication

Northern Forest Wetlands: Characteristics and Influences on Invertebrate and Amphibian Community Structure

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Abstract

Because timber harvesting, especially clear cutting, dramatically modifies vegetation and local patterns of hydrology, it is likely that biotic communities, productivity, and physical features of wetlands adjacent to harvested areas are influenced by that activity. Best Management Practices (BMPs) have been developed as guidelines for timber harvesting for protecting water quality in wetlands. Unfortunately, these general BMP guidelines were developed without the benefit of ecological data derived from these wetland types and enlightened future refinements will be impossible without empirical data. Macroinvertebrates and amphibians are very sensitive to water quality characteristics and monitoring these populations is likely to provide key insights on impacts from forest harvesting, ecological recovery of impacted areas, and usefulness of BMPs. Lack of such information limits conducive efforts of wildlife and forest managers and may compel them to rely upon paradigms from studies of prairie potholes or other systems that may not be comparable to northern forest wetlands. The goal of the proposed project is to provide relevant data and synthesis improving basic understanding and allowing development of management guidelines (such as future BMPs) conducive to maintaining wildlife habitat and biodiversity in forested landscapes.

STATEMENT OF THE WATER PROBLEM

Agriculture has transformed grasslands across most northern prairie regions of the U.S. Similarly, silvacultural activities are responsible for the most widespread landscape-scale modification of northern forest regions since arrival of European settlers. Because timber harvesting, especially clear cutting, dramatically modifies vegetation and local patterns of hydrology, it is likely that biotic communities, productivity, and physical features of wetlands adjacent to harvested areas are influenced. As an important first step, Best Management Practices (BMPs) have been developed as guidelines for timber harvesting in Minnesota (MDNR Division of Forestry 1999). BMPs are only voluntary, but do recommend general practices for protecting water quality in wetlands. Unfortunately, these general BMP guidelines were developed without the benefit of ecological data derived from these wetland types and enlightened future refinements will be impossible without empirical data. Macroinvertebrates and amphibians are very sensitive to water quality characteristics (Lannoo 1998, Brown et al. 1997, Mitsch and Gosselink 1993) and monitoring these populations is likely to provide key insights on impacts from forest harvesting, ecological recovery of impacted areas, and usefulness of BMPs. Lack of such information limits conducive efforts of wildlife and forest managers and may compel them to rely upon paradigms from studies of prairie potholes or other systems that may not be comparable to northern forest wetlands. The goal is to provide relevant data and synthesis improving basic understanding and allowing development of management guidelines (such as future BMPs) conducive to maintaining wildlife habitat and biodiversity in forested landscapes.

BACKGROUND

Northern Minnesota's landscape includes over 1.2 million hectares of forested wetlands (Trettin et al. 1997) ranging from vernal pools to permanently-flooded wetlands. Seasonally-flooded wetlands (*sensu* Stewart and Kantrud 1971) within forested regions probably support a large share of the biodiversity in these landscapes. Unfortunately, these unique wetlands have been overlooked and little is known regarding fauna, dynamics, productivity, physical characteristics, or other major features of these wetlands. To make matters worse, a large (but unknown) share of these small wetlands (< 5 ac) are essentially unaccounted for because they are unidentified in NWI data layers or by conventional aerial photography (pers. comm., Richard Buech).

Estimates indicate that Minnesota has lost approximately 45% of the 2,279,473 hectares of forest wetlands thought to have existed before arrival of European settlers (Trettin et al. 1997) and remaining areas represent a common and remarkably understudied aquatic ecosystem (Higgins and Merrit 1999); obviously, this increases ecological significance of remaining sites. On a national scale, the recent National Wetland Trends study (USFWS) indicates that for the first time the U.S. has dropped to less than 50 million acres of forested wetlands in the lower 48 states (Gary Pierce 1997). Mature forests are economically valuable to forest harvesters, and landscape modifications resulting from silvicultural activity threatens adjacent wetlands and wetland-dependent communities (Trettin et al.1997). Such threats will intensify as demand for wood, wood fiber, and paper products increase (Trettin et al.1997). In Minnesota, large, mature aspen (*Populus*) is abundant, sometimes predominant, throughout several plant communities of the Mesic Hardwood System (Almendinger and Hanson 1998) and small, seasonally-flooded wetlands are often associated with these aspen stands. Such stands are placed on a harvest rotation schedule and routinely clear cut. Special urgency exists among wildlife and forest managers concerned about fate of wetlands in these landscapes with remaining mature aspen stands (stand age 60-70 yr) because near-future demand for fiber and various wood products appears to be great.

Aspen clear cutting physically modifies landscapes; likely effects on adjacent wetlands and their associated communities are both direct and indirect and may be difficult to separate. It has been shown in other forest studies that removing trees from the landscape modifies the watertable (Roy et al. 2000). I expect that canopy removal elevates water temperatures, increasing surface evaporation rates and truncating natural wetland hydroperiods. It is widely believed that silvacultural activities increase soil compaction and enhance sediment translocation to adjacent wetlands. Timber harvesting reduces forest-floor litter and modifies structural complexity of understory vegetation adjacent to wetlands (de Maynadier and Hunter 1995). Clear-cut harvesting dramatically shifts forest age structure from a predominance of mature species to a landscape dominated by younger, often more commercially desirable trees (Mitsch and Gosselink 1993, Trettin et al. 1997). Large reductions or changes in characteristics of litter inputs to wetlands may modify energy transfer and ultimately reconfigure wetland food webs. Finally, road construction is often associated with timber harvest; new roads may constitute barriers for some amphibians, may allow nonnative plants to invade and suppress natural regeneration of wetlands that were once isolated, and are often permanent landscape features once harvesting ceases. Responses to cumulative impacts are difficult to predict, but some silvaculture activities like clear cuts are likely to have unexpected consequences for native communities and functions of northern forest wetlands (Trettin et al. 1997).

Native communities of aquatic invertebrates and amphibians integrate ecological conditions and reflect habitat quality and perhaps changes in wetlands and associated uplands. It is also likely that general wildlife values of seasonally-flooded wetlands in forested landscapes can be generally inferred from native invertebrate and amphibian communities. Aquatic organisms interact through direct and indirect trophic pathways and through a variety of non-trophic, habitat-dependent relationships (Murkin and Batt 1987, Murkin and Kadlec 1986). For example wetland invertebrates are vital food chain links supporting energy transfer through wetland food webs (Murkin and Kadlec 1986). Biotic communities, physical features, and functional characteristics of northern forest wetlands must be better understood if managers hope to predict results of wetland losses and modifications, or develop best management practices that preserve these wetland resources.

Evidence from related studies indicates that aquatic macroinvertebrates and larval amphibians will be useful indicators of at least some effects of clear cutting and perhaps altered forest-age structures adjacent to seasonally-flooded wetlands. Macroinvertebrates are important functional links in wetland food webs and certain macroinvertebrate groups such as amphipods, anostracans, conchostracans, and others require specific water conditions and hydroperiods (Wiggins et al. 1980). Also many aquatic invertebrate taxa are sensitive to sedimentation, seasonal water temperature patterns, and influx of organic matter (Thorpe and Covich 1991). Aquatic invertebrates have been widely used to assess ecological characteristics of lotic habitats (Resh and Jackson 1993) and a related approach recently has been proposed for prairie wetlands (Adamus 1996).

My study also focuses on amphibians; this is warranted due to their sensitivity at the egg and larval stages of their aquatic-obligate life cycles (Blaustein and Wake 1996) and because many amphibians are invertebrate predators, heavily dependent upon zooplankton and aquatic macroinvertebrates. Use of amphibians such as salamanders also seems justified because these organisms are terrestrial during portions of their lifecycle returning to the wetland solely to reproduce. Knutson et al (1999) report that the association between forest and amphibians is one of the most consistent landscape-scale habitat relationships reported in the literature. de Maynadier and Hunter (1995) review results of several studies indicating that salamanders are consistently reduced, at least locally, following clear cutting. Such amphibian declines appear related to reductions in forest-floor litter following timber harvest, but as Ash and Brush (1994) suggest, “we know they disappear from clear-cuts, but that is all we know”. Wisconsin and Maine has begun initiatives in ecological studies of the wetlands to aide in the refinements of future guidelines (Malcolm Hunter and Aram Calhoun, pers. comm). These studies will no doubt give managers in those regions critical information allowing them to better evaluate impacts from forestry.

OBJECTIVES

The goals for this study are two fold. First, we will characterize physical features and aquatic communities of wetland sites located within aspen-dominated landscapes. This will include summaries of hydroperiods, primary productivity, botanical characterizations, and basic “limnological characteristics ,as well as species abundance, taxon richness, and community structure of aquatic invertebrates and amphibians. A second study phase will examine relationships among physical features, biotic communities, and forest age structure (as a result of clear cutting in adjacent uplands). The study will focus on potential “treatment effects” in the following: 1) Macroinvertebrate and amphibian abundance, community richness, and for invertebrates, proportions of functional groups (scrapers, collector-gathers, shredders, etc.). 2) Hydroperiods; depth and duration of annual flooding, primary productivity and other “limnological” characteristics.

LOCATION OF PROPOSED STUDY

This study focuses on seasonally-flooded palustrine emergent sites because these wetlands are known to be important for aquatic invertebrates and amphibians and often such sites are vulnerable to effects of activities in adjacent uplands. My study sites are located within aspen-dominated landscapes of the Paul Bunyan State Forest located in the Pine-Moraines and Outwash Plains subsection of the Ecological Classification System (ECS) (Almendinger and Hanson 1998) and Buena Vista State Forest found within the Chippewa Plains subsection of the ECS.

METHODS AND MATERIALS

In each forest I have identified and begun sampling 12 palustrine seasonal wetlands within the Buena Vista State Forest. To provide some measure of inference into other landscapes, I replicated these efforts in the Paul Bunyan State Forest. Both state forests are located in different subsections of the Minnesota ECS (Almendinger and Hanson 1998). Both forests are found within the Laurentian Mixed Forest Province of north-central Minnesota. Each forest contains three clusters of four wetlands, each including one control and 3 treatment groups. Control sites are those with no adjacent forest harvesting within the past 75 years. The “effect group” (treatment) will include one site per cluster which was harvested during the winter of 2000-2001. Two “effect/ recovery” age-classes (young-age class and mid-age class) include sites adjacent to harvest events of 10-34 and 35 -59 years (respectively) before present. Age-classes were determined using a GIS-procedure that revealed “natural breaks” of aspen forest-age structure. Replicate sites within each cluster are needed to allow for anticipated high variance in response variables. Previous wetland field studies indicate that 4-5 replicate sites are likely sufficient for detecting trends in invertebrate and amphibians (Hanson and Riggs 1995, Hanson and Zimmer 1996, and Cox et al. 1998).

Invertebrate sampling will be done three times per field season with surface-associated activity traps (Hanson et al. 2000) at random locations in each wetland. Samples are placed in ETOH, transported to the laboratory, and using stereomicroscopes will be identified and enumerated. Amphibians are collected with modified minnow traps, identified, and released on site. Exploration of other amphibian collection methods such as drift fences, seining, and pitfall traps, indicated that these techniques would be less efficient in these sites. Data from recent studies indicates the use of these traps are the single best method (pers.comm. Richard Buech). Amphibians will also be sampled by Visual Estimate Surveys (VES) (Heyer et al 1994), once in early-spring and again in mid-summer.

Aquatic macroinvertebrates and amphibians will be sampled throughout the open water period, once each during April, May, June, and July. April (after ice-out). This will allow estimates of breeding adult amphibians and over-wintering macroinvertebrate populations. May, sampling should coincide with peak populations of macroinvertebrates. June, samples should reflect the recruitment of larval amphibians and early-summer populations of macroinvertebrates including predatory species. July, samples will assess remnant amphibian and macroinvertebrate populations.

Concurrent (monthly) water-quality monitoring will be done using one-liter water samples collected from the center of each wetland. Water will be tested for chlorophyll *a*, pH, dissolved oxygen, total alkalinity, total phosphorus, total nitrogen and specific conductance. Samples will be shipped to MN. Department of Agriculture's laboratory (St. Paul) for testing. Turbidity will be measured at each wetland with a portable nephelometer. Other physical data will be collected twice per field season and includes, water temperature, upland soil temperature, and concurrent monitoring of the hydroperiod. These data allow assessment of deviations from the control group and will be useful for detecting trends in the response variables.

Given the complexity of ecological data and the lack of previous experimental studies on these communities both univariate and multivariate statistical procedures will be used. Initially, I will use multivariate techniques to explore the data sets for broad trends and possible relationships among wetland parameters (pH, turbidity, etc.) and amphibian and macroinvertebrate taxa. Treatment effects will be assessed via a parametric ANOVA within PROC MIXED in GLM (SAS 1992).

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RESULTS/DISCUSSION

Community structure in seasonal wetlands may be subject more to physical features than to biotic influences. Because forest wetlands are functionally linked to the adjacent upland forest, physical modifications to the uplands may alter annual development of community structure. Timber harvesting modifies vegetation and local patterns of hydrology, including hydroperiod; thus it is likely that biotic communities and physical features of adjacent wetlands are influenced.

I characterized physical features and biotic communities of northern forest wetland sites, and assessed relationships among wetland communities and forest age structure in adjacent uplands. I sampled macroinvertebrates and recorded physical measurements in 24 seasonally flooded wetlands, within aspen-dominated landscapes, throughout the growing season (figure 1). Sampling was conducted three times per field season, initiating upon ice-out on these wetlands. Data were described using a combination of statistical techniques including multivariate Redundancy analysis (RDA), Principal Components Analysis (PCA), and mixed-model ANOVA (PROC MIXED, Littel et al. 1996).

I used partial-RDA to test for effects from physical attributes with the invertebrate community as my response variable. I used both sample period (time) and forest location , as covariables in the model. These two variables, and their associated variances, were accounted for, and removed from the model. Partial-RDA indicated that invertebrate community structure was influenced by upland forest age-structure, forest location, amount of canopy, initial water depth, hydroperiod, total alkalinity, and the presence of predatory invertebrates (Figure 2). A variance partioning exercise was conducted on the environmental variables to determine what portion of the total variance from the partial-RDA was attributable to each variable (Figure 3). Figure 3 shows sampling period and forest location was found to have the highest proportion of the variance (hence were removed from the p-RDA), with variances for canopy, hydroperiod, forest-age, initial water depth, pH, an total alkalinity were also determined.

Additionally, I assessed fixed-effects of forest-age structure and location (state forests) using a repeated measures, mixed-model (Littell et al. 1996) analysis of variance (ANOVA) on the PCA site scores. I used the invertebrate data (represented here as site scores) as the response variable; all tests were conducted at the alpha = 0.10 level. All mixed-model procedures were performed using the MIXED Procedure in SAS (SAS 1992, Littell et al. 1996). Mixed-model ANOVA showed a significant ($p< 0.05$) spatial (location) and structural (age-class) interaction among wetland sites.

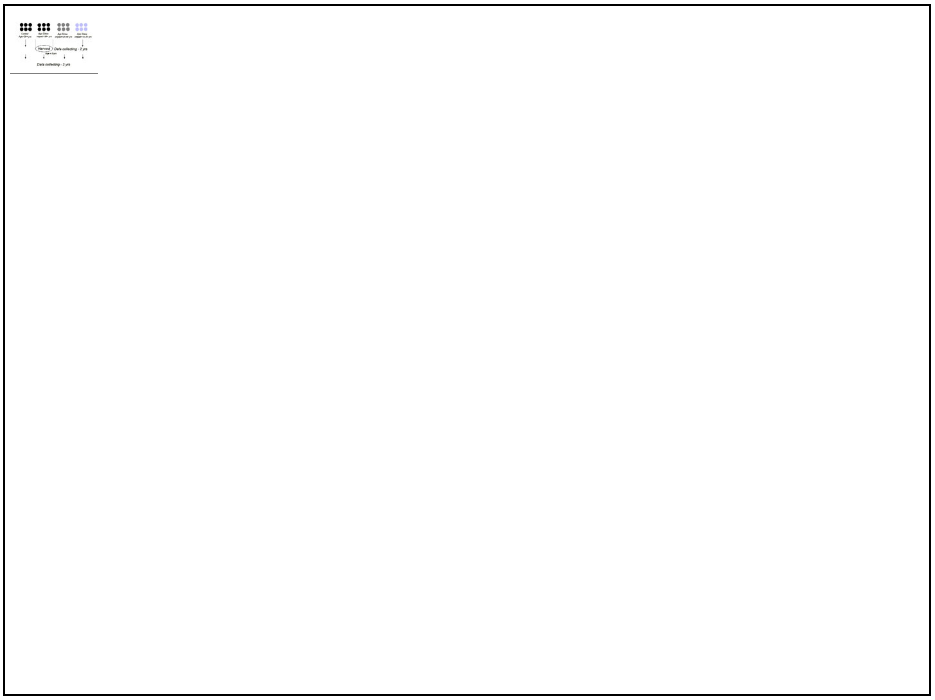

Figure 1. Study design diagram depicting the treatment groups and effect/recovery groups. Phase I includes data collected from the first two years. Phase II includes three years of data collection following clear-cut treatments to selected wetlands. Note: The four groups represent the chronology of the adjacent landscape relative to years since last forest harvest.

Time of sampling, forest-age structure, pH, specific conductance, soil temperature, and especially hydroperiod and amount of forest canopy-closure are important influences of invertebrate community structure. Thus alterations to these physical components would likely induce a subsequent changes in the invertebrate communities inhabiting wetlands adjacent to forested areas. This characterization of the macroinvertebrate communities and their analyses in light of the physical properties of my study sites completes Phase I of this study. Phase II is currently underway with data for the fourth year still being sorted and analyzed. Data from this portion of the study tends to support that clear-cutting activities increase hydroperiod in those wetlands adjacent to the clear-cut. Trends also suggest that water depth in the spring increases in association with the clear-cut areas. This result is surprising given that the past two winters in northern Minnesota experienced below average snowfall amounts. Taken together, increased depth and hydroperiod, may result in a change in the legal definition of which classification these wetlands fall under.

However, if those physical changes are indeed taking place, it may be a short term effect. Water depth and hydroperiod may return to there normal levels and periodicity as the forest regenerates.

Macroinvertebrate communities in the clear-cut wetlands (post treatment) also appear to be more heavily influenced by predatory invertebrates than those communities found in pre-treatment conditions. Biological controls of the communities are more typical in lakes and more wetlands of longer duration (Wiggin et al. 1980, Wellborn et al. 1996). Increasing hydroperiods in temporary wetlands may remove ephemeral species from specific wetlands. Ephemeral organisms, such as Anostracans, have no defense from predators. Invertebrates, especially those that are predaceous that normally invade these wetlands in the spring may become established and displace or dominate the wetlands community. Changing food-chain-base structure may also displace organisms that rely upon these wetlands as a food source.

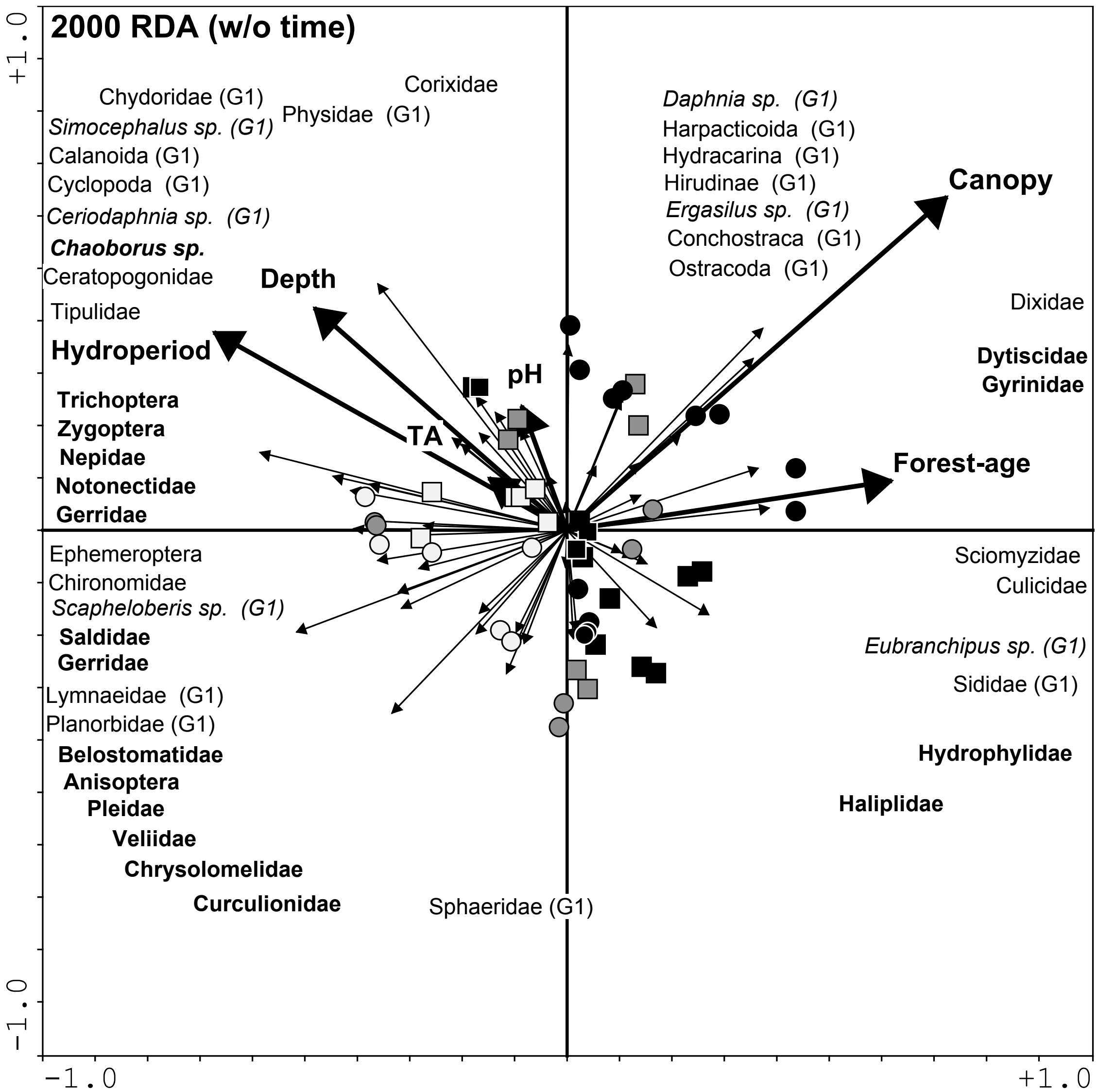

Figure 2. Partial-RDA ordination (triplot) of invertebrate communities during field season 2000 with sample period (time) and forest location treated as covariables. Partial-RDA triplot shows site locations, and species and environmental vectors. The figure shows relationships of invertebrate taxon (thin arrows) with significant environmental variables (bold arrows). Increasing length of environmental vectors indicates increasing variance accounted for and, thus, increasing influence. Circles = BVSF, Squares =PBSF, Black symbols = old-age stands, Gray = mid-age stands, and light gray = young-age stands. Predatory taxa are denoted in bold type.

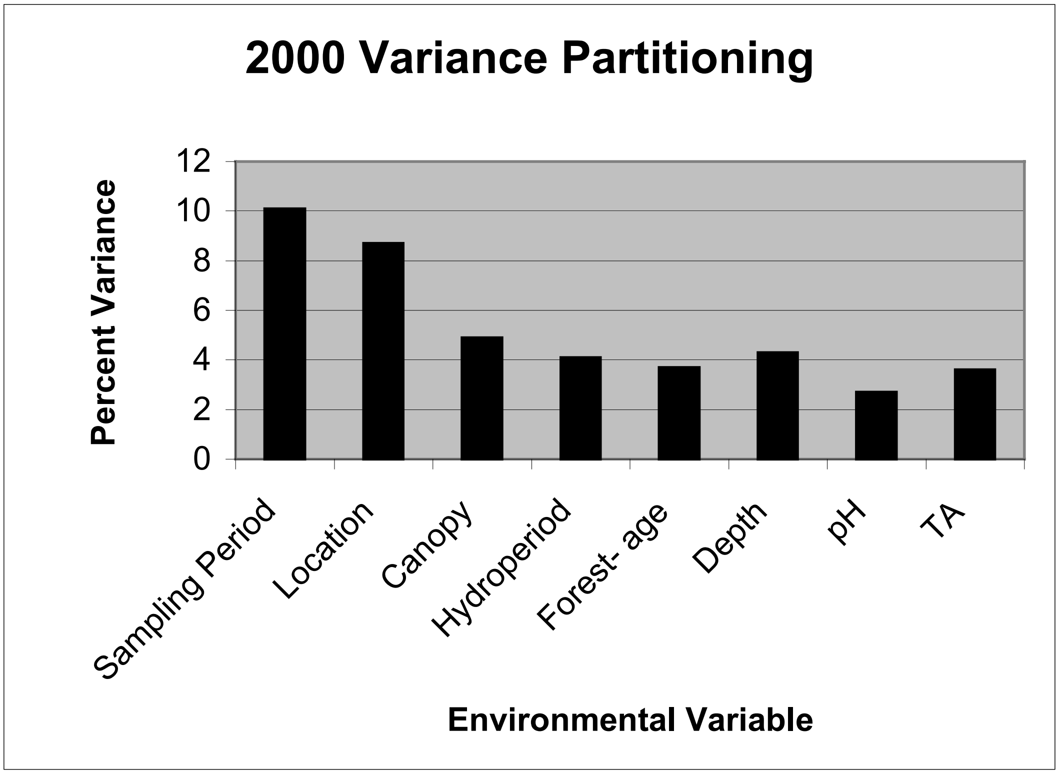

Figure 3. Results of variance partitioning following RDA of invertebrate data from field season 2000 (with sample period and forest location treated as a covariable). Variances given are reflective from total variance. Combined interaction effects between all combinations of variables were minimal at 3.9%.

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Variables Influencing Habitat Use by Diving Waterbirds Foraging in the Prairie Pothole Region

Basic Information

Title:	Variables Influencing Habitat Use by Diving Waterbirds Foraging in the Prairie Pothole Region
Project Number:	2002ND16B
Start Date:	9/1/2002
End Date:	12/31/2003
Funding Source:	104B
Congressional District:	1
Research Category:	Not Applicable
Focus Category:	Wetlands, Ecology, Water Quality
Descriptors:	Aquatic habitat, Prairie potholes, Sedimentation
Principal Investigators:	Malcolm George Butler

Publication

1. Torrence, Shannon Marie., December 2002, M.S.,"Variables Influencing Within- pothole Habitat Use by Diving Ducks Foraging in the Prairie Pothole Region," Department of Biological Sciences, College of Science and Mathematics, North Dakota State University, Fargo, North Dakota. Major Professor: Dr. Malcolm G. Butler.

Variables Influencing Habitat Use by Diving Waterbirds Foraging in the Prairie Pothole Region

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Abstract

The purpose of this study is to uncover patterns of habitat use by diving waterbirds foraging within potholes in relationship to water depth, submergent vegetation, benthic invertebrate biomass and size, and benthic compactness and particle size. The study will focus on habitat use on the scale of the individual pothole and will seek to explain observed patterns in habitat use by comparing habitat variables to morphological features of diving waterfowl species. Habitat use information can lead to a better understanding of the habitat needs of diving ducks and how to best manage aquatic habitats for these species.

Description of the Regional Water Problem

The site of the research is the prairie pothole region near Minnedosa, Manitoba, Canada, an area drastically modified for agricultural purposes. The prairie pothole region is an important breeding area for waterfowl. While destruction of nesting cover is an obvious adversity to upland nesters (i.e. all dabbling waterfowl), agriculture could also adversely affect the prairie potholes themselves, the foraging habitat of waterfowl. Breeding waterfowl species have similar nutrient requirements, however each species has specific habitat and invertebrate preferences. Inputs such as nutrient-loading and sedimentation could change the pothole habitat, the invertebrate community, and therefore the waterfowl community within these wetlands. This study will investigate the structure of the diving duck guild within potholes in relationship to habitat variables such as submergent vegetation structure, water depth, benthic particle size, and sediment compactness. Since diving ducks forage on benthic prey, sedimentation may be an important influence on the structure of the diving duck guild.

Literature Summary

The northern prairies, extending from north-central Iowa to central Alberta (Euliss et al. 1999), are important for breeding waterfowl of North America, by some estimates producing 50-80% of the continent's duck population (van der Valk 1989). While the whole of the prairie pothole region experiences a climate and hydrologic regime unique in the continent, the hydrology of the prairie pothole region itself is spatially variable, in part due to a precipitation gradient in a north-to-south and west-to-east direction (Euliss et al. 1999). Habitat heterogeneity exists within geographic sub-regions and on a much smaller scale such as a singular pothole. For example, potholes within the aspen-parkland region can vary from large, open, and permanent wetlands, to those that are small, vegetated, and intermittent. Also, the habitat structure, especially vegetation, typically changes within one pothole from the edges to the center (Stewart and Kantrud 1971).

Prairie-breeding ducks meet their nutritional needs by foraging in the potholes that characterize this region. Breeders have similar dietary needs, and forage mainly on invertebrates (Krapu and Reinecke 1992). However, prey preference varies with each species and sex (Bartonek and Hickey 1969; Siegfried 1973). Diving ducks forage within the wetland bottoms, and thus benthic structure may influence the structure of the diving duck community.

Habitat variables can influence the structure of the invertebrate community upon which waterfowl depend. For example, Topping (1971) found that larval abundance of the invertebrate *Chironomus tentans* larvae was significantly correlated with both organic carbon content and mud particle size in the 0.59-0.83 millimeter particle range. Also, invertebrates in beaver ponds tend to be distributed based on substrate type (Hodlinson 1975). In another study, chironomid densities were significantly correlated with sediment organic content as opposed to invertebrate food supply and predation (Moss and Timms 1989). Therefore, foraging ducks may use one benthic habitat over another because of the prey that habitat promotes.

Benthic conditions may also affect foraging of diving waterbirds directly by affecting accessibility to food given each species' bill behavior and morphology. To illustrate, Gerritsen and van Heezik (1985) found that three species of sandpipers prefer to forage in mud or sand as opposed to pebbles in spite of equal prey densities. They also found that sandpiper-hunting technique (tactile versus visual) varied with substrate type. By altering substrate compactness and hence, penetrability, Myers, Williams, and Pitelka (1980) found that while controlling for prey density, handling time by shorebirds varied inversely with substrate penetrability. Therefore, an environment may have an abundance of a diving duck's preferred prey but may not be conducive the bird to accessing that prey. Osnas (1998) found that diving duck communities were less evenly distributed than expected in the Minnedosa area and suggests a correlation between bill morphology and wetland characteristics is possible.

Diving ducks strain food particles with lamellae, but they also have to expunge the non-food particles associated with their invertebrate prey from their bills. Kooloos et al. (1989) has shown that dabblers have the ability to manipulate the pore size between lamellae given different food particle sizes. Other important bill morphology factors are bill volume and gape. If ducks have difficulty separating prey and detritus particles of similar sizes, detritus particle size may limit where a particular species forages. Particles large enough to enter the mouth but too small to exit through lamellar spaces may decrease the foraging ability of benthic filterers. If probers do not draw in as much non-food material as do filterers, then detritus may not as greatly affect them. Lamellar pore size may not be as plastic in divers, and Langerquist and Ankney (1988) suggest that bill size and shape may be more important in distinguishing between diving duck species.

Differences in substrate softness and texture are related to particle size and shape (e.g. sand, loam, silt, clay) and the size of the capillary pore spaces between soil particles. Substrates can range from loose sandy soils to tight clay bottoms. Loam substrates are those comprised of more or less equal amounts of sand, silt, and clay. The presence of organic matter can give sandy or clay soils the intermediate capillary qualities of loam substrates (Kramer 1983). Subsequent wet/dry cycles may also affect the compactness of wetland soils.

Agricultural practices may also affect substrate structure by increasing the rates of soil erosion and nutrient loading. As little as 0.25 centimeter of sedimentation can significantly reduce macrophyte germination in potholes (Jurik 1994, Wang 1994). Other studies also support this. In Michigan, large sediment loads significantly reduced total seed density as compared to low sediment loads (Dittmar and Neely 1999). In a study of South Dakota potholes, wetlands with cultivated catchments had higher accumulation rates of phosphorous and clay particles as compared to wetlands surrounded by grassland (Martin and Hartman 1987). Freeland, Richardson, and Foss (1999) found similar results in North Dakota wetlands. This increased sedimentation and nutrient-loading rate can be detrimental to the invertebrate community. North Dakota wetlands surrounded by agriculture were found to have reduced invertebrate complexity (Euliss and Mushet 1999). Lindemenan and Clark (1999) studied habitat use by Lesser Scaup in Saskatchewan wetlands. They found wetlands with high scores of human-induced marginal impacts had reduced amphipod and Lesser Scaup abundance. They attributed this to increased sedimentation and turbidity to negatively affects on amphipods and destruction of nesting cover.

Submergent vegetation structure is important to waterfowl as a food source (Canvasbacks eat Sago Pondweed tubers) and for its association with invertebrates. Ducks can show preference for a particular form of vegetation structure based on what invertebrates the vegetation harbors. For example, Armstrong and Nudds (1985) showed that dabbling duck species demonstrate habitat preference on the basis of vegetation structure; each species has a specific prey size preference, and each invertebrate size class is associated with a specific vegetation structure**.** Osnas (1998) found that some diving duck species such as the Canvasbacks are associated with submergent vegetation while other species such as Redheads are associated with bare sediments. Since vegetation is associated with depth, observed patterns of diving bird use by depth may be associated with changing vegetation structure within ponds.

The effects of substrate, detritus, and vegetation are not mutually exclusive. Vegetation structure is dependent benthic conditions. For example, emergent roots may not be able to penetrate harder clay soils or obtain a firm root grasp in softer substrates (Kramer 1983). Wisner (1991) found that in the presence of wave exposure, substrate softness varied inversely with organic content and the water depth of emergent vegetation. Vegetation may also stabilize benthic sediments, therefore decreasing turbidity. Also, potholes may fluctuate between macrophyte and algal dominated equilibrium states (Sandilands et al. 2000, Hargeby et al. 1994). Ultimately, these habitat variables may be controlled by subsequent wet/dry cycles.

Land-use practices can alter the physical conditions within potholes. Forty percent of the original wetlands of prairie Canada were lost due to agriculture and development (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1986), and agriculture still affects many remaining wetlands. Tillage of wetland basins has severely reduced invertebrate populations (Krapu and Reinecke 1992). This practice rids the soil of macrophytes and organic matter, reducing macroinvertebrate numbers when reflooding occurs (Swanson et al 1974). Even if a basin is not tilled, many times agricultural practices damage the wetland catchments, increasing sedimentation (Martin and Hartman 1986; Gleason and Euliss; _____ 1998).

Nudds (1992) suggests that studying waterfowl from the perspective of the ecosystem and community can give insight to management goals addressing problems currently faced by waterfowl. Thus, questions concerning associations between variables in wetland habitats and waterfowl use are of interest for several reasons. First, this research can aid in answering questions related to whether waterfowl distribution is habitat-based or structured by competition. If the structure of the diving bird community is dependent upon habitat variability as opposed to competition, then management efforts can be directed towards increasing the variability of waterfowl habitat instead of eliminating competitors. Habitat variables can also aid in constructing models that predict habitat suitability for waterfowl (Bailey 1981). For example, researching what habitat values are most important in structuring communities and how degradation affects these values can shed light on the causes of population declines such as the declining trend in the population of Lesser Scaup and may aid in reversing this trend. Species may cue in on different habitat variables when using habitats for foraging. These variables are ultimately related to a process (i.e. the need to acquire nutrients provided by a specific prey species) that this study does not directly address. However, correlations between habitat use and habitat variables can give researchers tools to infer why species use one habitat and not another.

Scope and Objectives of Proposed Research

The purpose of this study is to uncover patterns of habitat use by diving waterbirds foraging within potholes in relationship to water depth, submergent vegetation, benthic invertebrate biomass and size, and benthic compactness and particle size. The study will focus on habitat use on the scale of the individual pothole and will seek to explain observed patterns in habitat use by comparing habitat variables to morphological features of diving waterfowl species. The information collected pertaining to foraging depth will be compared to the work of Nelson (1983). Habitat use information can lead to a better understanding of the habitat needs of diving ducks and how to best manage aquatic habitats for these species.

Methods, Procedures, and Facilities

Observations

Observations of foraging diving ducks will be performed on seven study potholes. To minimize disturbance, observations are performed from blinds entered before sunrise. At every half hour for four hours all bird species on the pond are located and their activity recorded. Only duck observations of birds foraging by diving are considered for my thesis, however. To locate the ducks more precisely, a 10 X 10 meter grid structure comprised of color-coded stakes and bobbers is used. The observer uses a pothole map to record observations. These maps are also used to map out the emergent vegetation coverage.

Habitat Sampling

While setting up each pothole depth was recorded at each 10 X 10 meter point. The four corners of each 'quadrant' were averaged to get an average depth for each quadrant. A gauge was placed in each wetland so depth could be recorded for each quadrant during each observation. I sample potholes using the dive locations collected from observations during two sampling periods. The following variables are measured: depth, submergent vegetation structure, sediment compactness, and sediment particle size. Benthic invertebrates are also collected. Submerged vegetation is measured by dragging a 14-pronged garden rake one meter across the bottom two times. Sediment compactness, particle size, and invertebrate information is gathered by means of a 10 centimeter core sample. The sample is taken by placing a clear, a removable plastic insert into a core sampler. These samples can then be capped and allowed to settle. Compactness is measured in the field by using a penetrometer and in the lab by calculating bulk density. The core sample is run through a series of sieves ranging from 19 millimeters to 0.045 millimeters for particle size analysis. Particles from size 19 mm to 0.5 mm are then preserved in 70% ethanol and picked through for invertebrates. Particles from size 0.5 to 0.045 mm are frozen. Invertebrates are identified and measured for lengths under a dissecting microscope. These measurements can be used in regression equations to estimate biomass.

Statistical Analysis

Indirect and direct gradient analysis will be used to explore correlations among habitat variables, and between these environmental variables and habitat use by different waterfowl species.

Anticipated Results and Benefits of the Proposed Study

The habitats used by each species of diving duck within potholes will be characterized. This information can prove useful to managers of waterfowl production areas. Uncovering habitat use patterns in declining species such as the Lesser Scaup may help researchers understand the reason for their decline.

Summary of Results

What circumstances allow coexistence of similar species is a common but complex question in community ecology research. Sympatric species within the same guild must employ a mechanism of niche diversification in order to coexist. Niche separation may result from active competition when one species exploits or interferes with another's ability to use resources. Conversely, if species employ a resource partitioning mechanism based on differential use of habitat, the structure of a guild may depend upon spatial heterogeneity. This would reduce the influence of competition.

I studied the guild structure of foraging diving ducks on the pothole scale in southwestern Manitoba. The goals of my study were to uncover patterns of habitat use by diving ducks foraging within potholes in relationship to water depth, submergent vegetation, benthic invertebrate biomass, abundance, and size, and benthic substrate compactness and particle size and, I also sought to explain observed patterns in habitat use by comparing habitat variables to morphological features of diving waterfowl species. I found that benthic particle size and compactness decrease with depth, and submergent plants tend to grow within certain depth zones. I found that while diving ducks forage at specific depths within potholes, most divers foraged shallowly. Because most divers forage shallowly, variation in dive locations cannot be explained by habitat variables measured, nor by invertebrate biomass, abundance, or size. However, depths where divers forage within potholes can change between years. When food resources are limiting, competition may be high at shallower depths, but diving ducks most likely forage opportunistically on patchily distributed invertebrate prey.

Study of Effectiveness of Northern Prairie Wetlands as a Resource to Control Nutrient (Phosphorus) Load to Receiving Water.

Basic Information

Title:	Study of Effectiveness of Northern Prairie Wetlands as a Resource to Control Nutrient (Phosphorus) Load to Receiving Water.
Project Number:	2002ND17B
Start Date:	9/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	ND-1
Research Category:	Not Applicable
Focus Category:	Wetlands, Nutrients, Water Quality
Descriptors:	Phosphorus Transport, Wetlands, Water Quality
Principal Investigators:	Wei Lin

Publication

Study of effectiveness of Northern Prairie Wetlands as a Resource to Control Nutrient (Phosphorus) Load to Receiving Water

ND WRRI Graduate Research Fellowship Project
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Abstract

Wetlands are dominant aquatic resources in the prairie pothole region (PPR), an area that spans portions of Iowa and Minnesota, the Dakotas, and three Canadian provinces. Ranging from tiny potholes to huge lacustrine complexes, prairie wetlands are among the world's most productive ecosystems. Intense agriculture and associated drainage of wetlands, urban sprawl, and other human-induced changes over the past 100 years has had a tremendous effect on this area's natural resources. The prairie upland, almost all of the prairie wetlands, and some of the timberlands have been converted to cropland. The conversion of wetlands into agricultural lands and intense use of fertilizers has been a source of eutrification and impairment in water quality of lakes and rivers. The conversion of the depressions into wetlands has been done with a purpose of restoring the wildlife and natural habitat of the region. The results of this study will provide a better understanding of how phosphorus moves through a wetland and influences wetland characteristic. The phosphorus retention capacity and transportation through these semi-permanent wetlands can be applied to similar systems in prairie pothole region to predict the effectiveness of wetlands in controlling the phosphorus transport to the receiving streams. This information will be of interest to federal agencies such as US EPA, the Natural Resources Conservation Services, the Bureau of Reclamation, the Army Corp of Engineers, and the US Geological Survey, as well as to the State Resources Management agencies and private agencies concerned with surface water management, water quality, and wetland habitat issues.

Description of the critical state or regional water problem being investigated:

Wetlands are dominant aquatic resources in the prairie pothole region (PPR), an area that spans portions of Iowa and Minnesota, the Dakotas, and three Canadian provinces. Ranging from tiny potholes to huge lacustrine complexes, prairie wetlands are among the world's most productive ecosystems.

Intense agriculture and associated drainage of wetlands, urban sprawl, and other human-induced changes over the past 100 years has had a tremendous effect on this area's natural resources. The prairie upland, almost all of the prairie wetlands, and some of the timberlands have been converted to cropland.

The conversion of wetlands into agricultural lands and intense use of fertilizers has been a source of eutrification and impairment in water quality of lakes and rivers. The conversion of the depressions into wetlands has been done with a purpose of restoring the wildlife and natural habitat of the region.

Return of agricultural lands to natural habitats and restoration of wetlands are under way in the Buffalo River Watershed in Becker County, Minnesota. This area is reach in shallow surface water and groundwater has been drained and cultivated for nearly 40 years usually with conventional tillage. Currently, drainage ditches have been closed to restore natural water levels and to return depressions back to wetlands.

It is expected that restoration of these wetlands would reduce the nutrient loads to the receiving streams and lakes. The excess growth of hybrid cattails in these restored wetlands is suspected due to the high nutrient levels in the soil/sediment and surface water. Phosphorus, the limiting nutrients in these depressions, if studied for its movement, transformation and translocation in the wetland ecosystem would enlighten better understanding on the effectiveness of wetland in controlling nutrient loading to streams and lakes and in restoring the natural habitat and wildlife of the region.

As wetland ecosystems become degraded due to human actions, restoration efforts are becoming more pronounced. Large scale wetland restoration appears to be available management practice for controlling phosphorus (P) and other non-point source pollution to the water systems. Processes affecting fluctuations in N and P are of interest because there is conflicting evidence about the ability of wetlands to act as sinks for N and P (van der Valk *et al*., 1979). Study of Phosphorus dynamics in the system will provide a better understanding of the phosphorus transport and deposition in the wetlands. This study will help in better controlling and managing Buffalo-Red river water quality.

Anticipated results and benefits from the proposed study:

The results of this study will provide a better understanding of how phosphorus moves through a wetland and influences wetland characteristic. The phosphorus retention capacity and transportation through these semi-permanent wetlands can be applied to similar systems in prairie pothole region to predict the effectiveness of wetlands in controlling the phosphorus transport to the receiving streams. This information will be of interest to federal agencies such as US EPA, the Natural Resources Conservation Services, the Bureau of Reclamation, the Army Corp of Engineers, and the US Geological Survey, as well as to the State Resources Management agencies and private agencies concerned with surface water management, water quality, and wetland habitat issues.

Scope and Objectives of the proposed research:

Phosphorus is selected as the target nutrient for this research project. We hypothesize that transformation, movement, and concentration of phosphorus compounds in the wetlands are affected by seasonal variations of water chemistry and phosphorus solubility, sediment decomposition and subsequent release of organic phosphorus, and biological assimilation and decomposition. The objectives of this research project include:

1. Studying the seasonal water quality changes in the three wetlands;
2. Determining phosphorus forms and concentrations in wetland water, plants, sediments and soil water;
3. Performing a mass balance analysis on phosphorus and developing a mathematical model to simulate the phosphorus dynamics in the wetland systems; and
4. Sampling and data collection at the wetlands and model evaluation.

Timeline:

The project will begin in September 1, 2002 and will be continued as the student's Ph.D project till completion. The student will work on the project supported by the ND Water Resources Research Institute Fellowship through February 28, 2003. Depending on the performance of the student in the project, the Fellowship may be continued in subsequent years.

Methods, procedures, and facilities:

Hydraulic loading: Hydraulic loading and flow pattern affects the phosphorus retention capacity of the wetland. Low flow wetlands observed high P retention capacity as compared to high flow wetlands (Mitsch *et al*., 1995). This is possibly due to high hydraulic retention time in low flow condition. Adler, 1995 observed the effect of flow pattern on P removal and wetland productivity. Also observed that nutrients removal is maximal near the inlet and controls the retention capacity of the wetland.

Wetlands get hydraulic inputs from the atmosphere, surface runoff, stream flow, ground water flow, or combination of these inputs. Hydraulic loading consideration for a wetland involves careful evaluation of all inputs which primarily affects the productivity and health of a wetland.

The surface runoff reaches a particular wetland either through sheet flow (non-point source; NPS) or collected channelized flow. Discharge from the watershed contributing these flows to the wetland may be estimated using an integrated watershed approach within GIS environment. Use of either a " modeling-within" or "linked-model" approach similar to those used in non wetland studies may be possible for estimating NPS loading to wetlands (Karen *et.al*., 1995]. This use of coupled model-GIS approach has the potential to provide a general method for estimating NPS pollution potential or loading rates to wetlands and to link such information to the spatial characteristics in a watershed. Such an approach also would allow for the consideration of many more wetlands than site-specific nutrient budget studies [Karen et al. 1995]. In the studied wetlands, change/stop in agricultural practice and land use, change in ground water table through hydraulic structures may affect the NPS pollution load from the watershed which can be better addressed by this linked model simulation.

Groundwater: Lack of a subsurface component in a model constitutes a serious limitation for use in large areas of the Midwest and eastern North America where many wetlands are groundwater discharge areas (Carter 1986). There are limited wetlands where input ground water values are possible to measure as wetlands occupy a typical position with respect to ground water. So it requires an integrated use of several different methods. Shaw et al. (1990) used Darcy's equation with data from piezometers and water table wells, major ion concentrations, and environmental isotopes (deuterium and 18O), along with a simulation model to quantify P fluxes to a Canadian lake that lacked defined drainage pattern. The model will be developed including a subsurface flow component.and simulated values may be evaluated with site measured values.

Phosphorus in Wetlands: Data on total phosphorus supply to northern prairie lakes in Canada indicate that these lakes are eutrophic but the data on total phosphorus supply to wetlands and lakes within prairie of the United states are rare. Most of the data is for concentration of soluble reactive phosphorus. Barcia (1975) determined that soluble reactive phosphorus fluctuates considerably on a seasonal basis in prairie lakes and wetlands. Even with these data, it indicates that many of the wetlands in South Dakota (Petri and Larson 1973) are eutrophic. In these studies, the concentration of soluble reactive phosphorus was greater than 0.020 mg/l, considered the lowest concentration for eutrophic condition. Phosphorus data are not available in North Dakota, however a study done by

LaBaugh *et al*. 1987 indicates that the wetlands are eutrophic. Hardly any data exists for eutrophic conditions of wetlands in Minnesota. P can be an active part in the compartments such as soil sediment, overlying water column, interstitial soil water, various types of live biomass, standing dead biomass, litter and dry deposition and its content in these compartments may be studied to incorporate into the model describing the concentration/ transport of Phosphorus in a wetland system. The kinetics of P transport in these individual compartments has got an effect on the phosphorus retaining capacity of the wetland. In addition to agricultural runoff, phosphorus fixed in the sediments may be released to the water column as a result of microbial activities in the sediments (Lin and Nustad, 2000; and Nustad 2001). The impact of temperature on CO_2 solubility results in seasonal variation of water pH in wetlands. This pH variation affects the solubility of phosphorus compounds and therefore phosphorus concentrations in wetlands (Richardson and Bigler, 1986; and Freeland *et al.,* 1999). P interaction in the wetland ecosystem may be described as follows.

Sedimentation: Mitsch *et al*., (1995) has observed that most P is retained through sedimentation with some capacity for P retention by macrophytes and a lesser amount by microbial epiphyte and planktonic communities. Low water flow through velocity in the wetland enhances sedimentation of nutrients. The P in the sediments eventually gets into the water column through resuspension. Prescott (1997) has observed about 57% of P contribution to the water column comes from resuspension. Soil sorption may provide initial removal, but this partly reversible storage eventually becomes saturated

Plant uptake: Hydrogeologic setting and chemical characteristics of water in prairie wetlands result in aquatic plant communities that are very diverse. Plant communities change in response to changes in water level (van der Valk 1981). The length of time a prairie pothole contains water and the salinity of water affect the type and composition of vegetation in prairie potholes (Stewart and Kantrud 1972). The plant uptake provides short to long term retention of P depending on rate of leaching, translocation to and from storage structures. The type of plant developed in the restored wetland depends on water level fluctuations, soil organic carbon content, soil bulk density, surface water pH, alkalinity, conductivity, ca and Mg concentration (Galatowitsch *et al.,* 1996).

Litter decomposition: Changes in water level can affect N and P concentrations in wetlands due to decomposition of macrophyte vegetation (Kadlec 1986). This is explained sometimes by the soluble reactive P (SRP) in wetlands and has got a control on the P balance in the wetlands. Losses of plant material from standing dead macrophyes occur primarily due to fragmentation of the plants in winter and springs. Additional losses of plant material results from toppling of standing dead material that decomposes when submerged in the spring. This litter material is found to release N and P between May and June. This process could add N and P to the water in the wetlands during spring.

Microbial processes: Microbial action on the phosphorus transformation is an important aspect in the P cycle in the wetland. Kinetics of such transformation may be taken into consideration for study of P dynamics in wetland. Investigation of the biological processes affecting seasonal changes in conc. of nutrients in prairie wetlands and lakes are rare (van der Valk *et al.* 1979; Davis and van der Valk 1983).

Research site:

Three wetland sites have been selected based on the land use history and age of restoration carried out at the sites. These sites are located in the Hamden Slough National Wildlife Refuge in western Minnesota. One wetland group is situated at north of Bisson Lake and discharge to the lake. The two other wetland groups (straight ditch area) are situated at central part of the refuge and flows to another lake. The north of Bisson Lake site was historically range land whereas the straight ditch site was an agricultural land and the former site was restored in 1991 and the later one recently.

The task of the study will include analysis of existing data, field sampling and water quality modeling. Water quality modeling will help simulate future scenarios of nutrient (Phosphorus) transport. We need to monitor the water flow, both surface and ground water, into and out of the wetlands.

Modeling: The flow and phosphorus transport models in these types of wetland complexes will be developed. The main model may be interfaced with submodels to account for groundwater flow and quality, non-point source pollution. These models can be interfaced with GIS and digital elevation models of the topography which I have been working with. A GIS database need to be assembled.

Water quality modeling activities for this study will include

- i) evaluation of available water quality models/softwares;
- ii) formulation of mass balance and kinetic relationships for phosphorus simulation or prediction.
- iii) collection and compiling geographical, water flow and water quality data, and other pertinent data;
- iv) model development and calibration.

Flow monitoring: Both surface and subsurface flow contribute to the wetland complex under study. We need to measure or estimate the surface inflow and outflow. There is a shallow aquifer system beneath the wetland area and considerable leakage from this aquifer into the wetlands takes place. We need well piezometer monitoring system to estimate it. From May 2002 to October 2002, two measurements will be taken each month. The water monitoring data will be evaluated to determine surface water and groundwater flow rates, relationship between groundwater and surface water, and variations of water flows. The water flow and water level monitoring events will be arranged to coincide with water quality sampling to provide data for water quality modeling.

Water and Sediment sampling: Surface water and sediment samples will be carried out in the selected wetlands. Water samples will be taken at upstream and downstream of each wetland, and over some transects. Water samples will be taken twice a month from May 2002 till Oct., 2002. During each sampling event, water temperature, DO, pH, turbidity, and electrical conductivity will be monitored on site. Water samples will be preserved and taken back to NDSU for analysis of plant available phosphorus, total phosphorus, total and inorganic carbon, particle sizes, total and volatile suspended solids, and chlorophyll *a*. During the frozen season, water samples will be taken below ice level.

Two sediment samples from each wetland will be collected in May 2002. These samples will be analyzed for total phosphorus, plant available phosphorus, and calcium carbon equivalent. Since no sediment characteristic change is expected during the one-year sampling period, sediments will be sampled only once. Groundwater phosphorus concentration will be estimated through the mass balance analysis of phosphorus and model simulations.

Plant sampling: Potential biotic pools of wetland phosphorus include macrophytes, algae (phytoplankton, and metaphyton), invertebrates and vertebrates (fish and amphibians). Zimmer et al.

(in press) found wetland macrophytes to contain large quantities of phosphorus assimilated from the sediments, while other biotic pools were small. Monthly during the summer of 2001, macrophytes biomass will be quantified at two stations in each of the three wetland sites by cutting, drying, and weighing all above-sediment plant material inside 3 random, 0.25 m^2 quadrants (Filbin and Barko 1985). One station will be in the center of each wetland to sample submergent macrophytes in open water (if present); the other will be within the zone of emergent vegetation. Dried plant materials will be analyzed for phosphorus content to determine grams of phosphorus per m^2.

Research underway:

Soil (core and bag) samples are taken for determining the profile of phosphorus concentration and other compounds along transects of the wetland. The soil samples are being analyzed in Soil Science Laboratory, NDSU. The soil sampling completed at one site (wetlands north of Lake Bisson) and is underway at other two sites.

Preliminary water sampling completed and analyzed for basic water quality parameter including phosphorus. Further sampling and data acquisition will be done after the model development for Phosphorus.

The area was surveyed using GPS and level for preparing topographic map which will be used to asses the non-point source flow to these wetlands.

Literature review and evaluation of existing models are in progress. The model development for studying the phosphorus transport in these types of semi-permanent wetlands needs more attention as there are not many developed for this type of systems and is being formulated.

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Summary of Results:

Wetlands are valuable as sources, sinks, and transformers of a multitude of chemical, biological, and genetic materials (Mitsch & Gosselink, 2000). Prairie pothole marshes in North Dakota, South Dakota and eastern Minnesota are considered as one of the dominant areas of freshwater marshes in the United States. The Prairie upland, almost all of the prairie wetlands, and some of the timberlands have been converted into croplands. Wetland restoration efforts and return of the agricultural lands to natural habitats are increasing in this particular region. Phosphorus is believed to be the biggest problem in returning the reclaimed wetlands to a healthy condition. Enormous application of fertilizers has caused high phosphorus levels in soil, and water in this wetland region. These phosphorus levels can be a serious problem in causing imbalance in plant species growth and thereby a problem to water levels and also to some wildlife. This research is mainly concentrated on phosphorus transport in wetlands ecosystem.

Current status of project:

1. Key literature reviewed

Phosphorus is selected as target compound for this research project. Phosphorus compounds transportation, movement, and concentrations in wetlands are hypothesized as being affected by seasonal variations of water chemistry and phosphorus solubility, sediment decomposition and subsequent releasing of organic phosphorus, and biological assimilation and decomposition (Mitsch & Gosselink 2000).

Although phosphorus doesn't get altered directly by changes in redox potential as other nutrients do, it gets affected indirectly in soils and sediments by its association with several elements, such as iron, aluminum, zinc, and manganese (Mitsch and Gosselink 2000). Research has shown that flooding of organic soils has a great impact on P flux in water column (Reddy and Pant, 2001). Draining and subsequent reflooding of organic soils increases P flux into the water column. This may be due to mineralization of organic P, and subsequent adsorption and precipitation of mineralized P by cations including Ca and Mg. Soil conditions also (such as freely drained soils, or poorly drained soils) affect the availability of total and organic phosphorus. Studies show that organic phosphorus is less stable in poorly drained soils (Walker and Syers, 1976).

Losses and transformations of phosphorus can be better understood by P-fractionation in soils (Walker and Syers 1976). Total phosphorus can be separated into fractions: non occluded P, occluded P, organic P and acid-extractable P (apatite) (Williams et al., 1967). Redox potential and pH influence the phosphorus availability in soils (Walker and Syers 1976). The solubility of apatite decreases with the increase in pH and availability of organic phosphorus decreases with induction of anaerobic conditions.

Microbial activity also has a considerable impact on phosphorus availability in wetlands. Phosphate mineralization by microbes can be greatly affected by the water levels in wetlands (H.K.Pant and K.R.Reddy 2001).

2. Prior work

To quantify the impact of the above factors on phosphorus levels soil sampling has been done at three different locations in the study area. Testing of samples has been done for total phosphorus, available phosphorus, pH, electrical conductivity and also for some metal ions that are expected to have some influence on phosphorus availability.

3. Site Location

Three wetland/lake areas will be selected for sampling. These are located in the Hamden Slough National Wildlife Refuge in western Minnesota near the Lake Bisson. To study the phosphorus dynamics in wetlands, it is important to identify the major phosphorus sources and sinks (ex. Plant uptake).

4. Flow monitoring

Both surface and subsurface flow contribute to phosphorus transport through wetland ecosystem. We need to measure or estimate the surface inflow and outflow. There is a shallow aquifer system beneath the wetland area and considerable leakage from this aquifer into the wetlands takes place. Flow monitoring has been done using piezometer monitoring system and measurements were taken each month starting from May 2002 to October 2002. The monitoring data will be analyzed to determine surface water and groundwater flow rates, relationship between groundwater and surface water, and variations of water flows. The water flow and water level monitoring events will be arranged to coincide with water quality sampling to provide data for water quality modeling.

5. Water and sediment sampling

Phosphorus fixed in the sediments may be released to water column due to microbial activity (H.K.Pant and K.R.Reddy 2001). Changes in water level also affect the phosphorus availability in water (H.K.Pant and K.R.Reddy 2001). Surface water and sediment samples will be carried out in the three-selected wetland areas in the study area. During sampling, water temperature, DO, pH, turbidity, and electrical conductivity will be monitored in the field. Water samples will be analyzed for available phosphorus, total phosphorus, total and inorganic carbon, particle sizes and volatile suspended solids, and chlorophyll *a*. Sediment samples will be analyzed for total phosphorus, plant available phosphorus, and calcium carbon equivalent.

6. Progress to date

The analysis of existing data and field sampling will help determining the current status. Water and sediment sampling and testing will help study the phosphorus dynamics in wetlands. A water quality model will be used to analyze phosphorus inflow and outflow due to point and non-point sources.
Soil samples taken for determining the profile of phosphorus concentration and other compounds along transects of the wetland. The results from soil sample testing will be analyzed for available phosphorus and total phosphorus. Preliminary water sampling completed and analyzed for basic water quality parameter including phosphorus. The area was surveyed using GPS and level for preparing topographic map, which will be used to assess the non-point source flow to these wetlands.
Literature review of phosphorus dynamics in wetlands and review and evaluation of existing phosphorus models is under progress.

7. Funding agencies for the project

North Dakota Water Resources Research Institute
Department of Civil & Environmental Engineering

Information Transfer Program

Information transfer is done through an annual newsletter initiated in 1992, a website initiated in 1999, and presentations and publications by grant and fellowship recipients. The Institute's website address is www.ce.ndsu.nodak.edu/wrri. The newsletter is usually issued in the month of December of each year. Copies of past newsletters can be obtained by writing to the Director. Again this year, the institute continued its modest support of the Biotic Resources Seminar Series at North Dakota State University. Also it co-sponsored a regional groundwater conference. Brief descriptions of both are given below:

NDWRRI continues to help support the NDSU Biotic Resources Seminar program, which has brought 66 biologically-oriented speakers to campus since 1987. Under this multi-disciplinary program, visiting scientists are invited and hosted by faculty and graduate students from several departments in the Colleges of Agriculture and Science and Mathematics. Seminar topics range widely, with the common thread being organismal/environmental biology in the broadest sense. Of the 15 visitors hosted by this program during the past three academic years, 75% spoke on topics related to the ecology, evolution, and conservation of aquatic organisms and their habitats. Examples include the genetics and conservation of rare and endangered fish and aquatic invertebrates, human impacts on the biota of lakes, and wetland ecology. NDWRRI seed money had helped to leverage other support for this program from the NDSU Cooperative Sponsorship Committee, ND EPSCoR, and the colleges and departments of the hosts. Students, staff, and faculty from across campus attend these seminars and the associated informal gatherings. The program thus stimulates networking within campus in addition to informing NDSU researchers about studies conducted by colleagues from other institutions.

About 100 groundwater practitioners, students and faculty gathered at the 47th Annual Midwest Groundwater Conference held in Fargo, ND, on October 2nd to 4th, 2002. The NDWRRI co-sponsored the conference along with the North Dakota State Water Commission, the North Dakota Geological Survey, the Water Resources Division of the United States Geological Survey, and the Department of Geology and Geological Engineering of University of North Dakota. It is an annual conference hosted by one of the 14 member Midwest states each fall. Groundwater practitioners in private enterprise, federal, state, and local government, as well as universities from 12 different states and 2 Canadian provinces attended the conference. The conference provided an opportunity for hydrologists, geologists, engineers, planners, students and others studying the groundwater resources of their respective states to meet and exchange ideas, discuss mutual problems, and summarize results of field and laboratory studies. Thirty-eight oral and poster presentations were made in a total of one poster and six podium sessions. Participants also had the benefit of enjoying a pre-conference field trip to the Sheyenne National Grasslands.

USGS Summer Intern Program

Student Support

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

Notable Awards and Achievements

Publications from Prior Projects

1. 2000ND1B ("New Methods to Detect Chlorinated Organic Pollutants in Water") - Articles in Refereed Scientific Journals - T. L. Martin, A. F. Arruda, A. D. Campiglia, Time-resolved laser excited phosphorimetry at liquid helium temperature for the direct analysis of 2,3,7,8-tetrachlorodibenzo-para-dioxin in complex mixtures. Applied Spectroscopy (in press).