Report of Algae Tested for Toxins in Wisconsin Lakes and Streams during the Summer of 1986.

By James Vennie and Richard Wedepohl

Wisconsin Department of Natural Resources
Water Resources Management Bureau
Lake Management Program

INTRODUCTION

This study was broken into two parts. Phase I was algal sample collection and initial toxin screening. Phase II was a more detailed study of algal toxins for mutagenicity, lethal dose, and viability during storage.

Reports on both phases, along with other relavent materials are include in this document. State Lab reports are part one and part two. Part three is a algae toxins factsheet. Part four contains tables that report the data collected during the Phase I study.

A background summary and management considerations were provided by Dr. Wayne Carmichael who reviewed the information presented here.

Copies of this report can be obtained from:

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Attn.: James Vennie WR/2
P.O. Box 7921
Madison, Wisconsin

The original lab report slips were sent to Richard Wedepohl(608)267-7513 at DNR-Madison by the State Lab. They are filed in the Lake Management Files. Some of the data on all the slips were entered on to a Lotus 123 computerized Spreadsheet and is available in that form.

Lab work was done by Wyatt Repavich (608)262-1210 with assistance from Jon Standridge and Jerry Rymer. Sample collection was done by the DNR District staff their names will be found on the individual lab slips. Bob Barnum (414)497-4053 from Lake Michigan District, Water Supply, directed the sampling of the water supply systems.

BACKGROUND

By Wayne W. Carmichael, Ph.D.

Reports of toxic freshwater algae are almost exclusively due to members of the division Cyanophyta, commonly called blue-green algae or cyanobacteria. Although cyanobacteria are found in almost any environment ranging from hot springs to Antarctic soils, known toxic members are mostly planktonic (Carmichael, 1986 and in press). Economic losses due to water-based diseases of freshwater cyanobacteria toxins are the result of contact with or consumption of water containing toxin and/or toxic cells.

These toxins are all water soluble and temperature stable. They are either released by the cyanobacterial cell or loosely bound so that changes in cell permeability or age allow their release into the environment. Lethal and sublethal amounts of these toxins become available to animals during periods of heavy cell growth, termed "water blooms," especially when the water bloom accumulates on the surface, inshore, where animals are watering.

Water blooms can occur wherever proper conditions for growth, including irradiance, temperature, neutral or alkaline conditions, and nutrients are found. The increasing eutrophication of water supplies from urban and agricultural sources, which raises mineral nutrient levels, and increased the occurrence and intensity of these annual blooms. It should be noted that although there are several bloom-forming genera of cyanobacteria those that occur most often are also those that can produce toxins.

Known occurrences of toxic cyanobacteria in freshwater include Canada (four provinces), Europe (12 countries), United States (19 states), USSR (Ukraine), Australia, India, Bangladesh, South Africa, Israel, Japan, New Zealand, Argentina, and Chile. Not all blooms of a toxigenic species produce toxins, however, and it is not possible to tell by microscopic examination of the cells whether they are toxic. Environmental conditions that favor bloom formation include (1) moderate to high levels of nutrients, especially phosphorus and nitrate or ammonia; (2) water temperatures between 15 and 30 degrees C; and pH between 6 and 9 or higher.

The economic impact from toxic freshwater cyanobacteria include the costs incurred from deaths of domestic animals, allergic and gastrointestinal problems after human contact with water blooms (including loss of income from recreational areas), and increased expense for the detection and removal of taste, odor, and toxins (although no approved method yet exists for removal of toxins, activated carbon has been tried in certain areas). A full accounting of the economic problems associated with cyanobacteria toxins is given by Gorham and Carmichael (in press).

Water Management of Algal Toxins

a. Toxic freshwater cyanobacteria are present in Wisconsin in some raw surface water supplies.

b. Estimates of toxic bloom frequency range from about 25 percent in cool weather years and to 50 percent or greater in warm weather years in lakes predisposed to presence of cyanobacteria blooms.

c. Toxic blue-green algae bloom occurrence is erratic and unpredictable but are found under the same environmental conditions which favor non-toxic blooms.

d. Toxic blue-green algae (perhaps algae in general) should be included as part of a list of "agents of water-based disease" for state water management purposes.

e. Waters which are used for recreational and drinking water which favor the growth of heavy water blooms should be monitored for the presence of toxic water blooms

References

Carmichael, W.W. (1986). Algal Toxins. In: J.A. Callow (ed.) Advances in Botanical Research. V. 12. Academic Press. pp. 47-101.

Carmichael, W.W. (1988). Toxins of Freshwater Algae. In: A.T. Tu (ed.) Handbook of Natural Product Toxins. V. 3. Marine Toxins. Marcel Dekkar, Inc. pp. 121-147.

Gorham, P.R. and W.W. Carmichael. (In Press). Hazards of freshwater blue-green algae (cyanobacteria). In: C.A. Lembi and J.R. Waaland (eds.). Algae and Human Affairs. Cambridge Univ. Press.

PART 1

Summary Report of Toxic Algae Sampling in Wisconsin Lakes and Rivers during 1986

Phase One Report

Summary Report of Toxic Algae Sampling in Wisconsin Lakes and Rivers during 1986.

Wyatt Repavich, James Vennie, Richard Wedepohl, and Jon Standridge

This study was conducted by the Wisconsin Department of Natural Resources, Lake Management Program and the State Lab of Hygiene. Its objective was to confirm the findings of earlier studies of toxic algae done by Karl, 1970.

The primary questions were:

Does toxic algae exist in Wisconsin's Lakes and Rivers?

How extensive is their occurrence?

Are identifiable quantities of the algal toxins getting into the surface water supplies systems?

This study was stimulated by two incidents in Wisconsin which resulted in the deaths of dogs swimming in a lake in Polk County and cattle drinking from a pond in Green County. In the spring of 1986 a contract was established between the Department of Natural Resources (DNR) and the State Laboratory of Hygiene for the lab analysis portion of this study.

The DNR field staff was asked to collect samples of algae blooms they observed during their normal work such as supervising Aquatic Nuisance Control algae treatments.

The capability was established at the State lab to receive samples and to do an initial screening test for algal toxins. The resulting samples received by the State lab fell into four categories:

1. Samples of algae from lakes with historical algal problems.

2. Repeat samples from 7 sites (6 southern lakes and one river) collected 5 times during the summer.

3. A sampling of raw and finished water from 8 public water supply systems using surface source water collected at the same sites 3 times.

4. Incident investigation sampling related to deaths of ducks and sheep during 1986.

Sampling Methods

The DNR field staff was directed with the Appendix A memo (Bruce Baker - May 15, 1986) to collect the water containing algae in a standard 250 milliliter bacteriological bottle. This was to then be kept in a cold and dark environment and ship directly to the state lab for analysis along with the laboratory slip (Appendix B). The samples were taken generally at the water's surface along the shoreline with the field person attempting to get as much algae in the sample bottle as was possible without using an artificial means of concentrating. Variations of this method occurred in collections of the public water supply systems where one sample was collected from the raw water intake of the treatment system and another of the finished water. Some lake water samples, excluding water supply systems, were received by the lab with very few algal cells present. These were classified as "no test" samples and are reported in Table 1.

Lab Analysis methods

Samples were usually received from the field in 24-72 hours from time of collection. Upon arrival, the sample was assigned a number, mixed thoroughly, and four 2 ml subsamples were placed into 13 x 100 mm polystyrene test tubes and covered. The remaining sample in the collection bottle was then stored frozen at -20 degrees C. All pertinent information from the laboratory slip, such as the collector's name and address, the site name and exact location of collection, the date, time, and weather conditions were recorded into a log book.

One of the four test tubes was stored at 4 degrees C for subsequent microscopic identification of the algae. The other three were placed in an ethanol/dry ice bath at -70 degrees C then thawed in a warm water bath at 20-40 degrees C. This process which disrupts the cells and releases toxins was repeated for a total of three freeze/thaw cycles, then the samples were stored at -20 degrees C.

The specific algae genera present in the sample were determined by microscopic examination of wet mount slides prepared with a drop of India ink. Conventional taxonomic guides supplemented by consultations with the University of Wisconsin Botany Department were used in making the identifications. The identified algae were listed in order of dominance in the samples. Those genera most commonly observed were Anabaena, Aphanizomenon, Microcystis, Gloeotrichia, Oscillatoria, and Lyngbya (Figure 1 and 2).

Toxins were detected in the processed samples by mouse bioassay. Duplicate female albino mice (25-30 grams) were injected intraperitoneally with 0.5 cc of lysed sample (Carmichael, 1984). A third control mouse was injected with 0.5 cc of 0.9% normal saline.

Following the injection the mice were observed continuously for the first 1.5 hours, then every hour to 6.5 hours and again after 24 hours. Symptoms of toxicity including lethargy, piloerection, salivation, respiratory distress, muscle tremors, muscle fasciculation, paralysis and death were recorded. Surviving mice were dispatched with cervical dislocation and necropsies were performed on mice exhibiting symptoms.

The assay was considered positive for algal toxins if symptoms were observed, and death occurred prior to 24 hours. Hepatotoxins were differentiated from neurotoxins at necropsy. Hepatotoxins produced enlarged, darkened or mottled livers (Figure 3). Contact toxins produced numerous lesions and necrotic areas on all peritoneal organs (Figure 4). Neurotoxins showed signs of respiratory distress (convulsions, muscle tremors, muscle fasiculations and salivation) with organs appearing normal at necropsy. Occasionally a sample would produce peritonitis or massive rapid infection of the peritoneal cavity. Mice exhibiting peritonitis at necropsy were considered negative for algal toxins. Mice exhibiting peritonitis at necropsy were considered negative for algal toxins. Mice exhibiting symptoms or liver damage but surviving the 24 hours were considered marginally positive. Negative tests were indicated by absence of any symptoms and no pathology found at necropsy.

Summary of Results

The period of collection occurred from June 1986 through November 1986. A cool, windy summer resulted in fewer algae blooms to sample than expected. A total of 308 samples representing 97 lakes, 12 ponds and 5 streams were collected from 114 sites (Table 1 and Figure 5). Of these sites, 19 were positive, 6 were marginally positive, 12 were not tested and 77 were negative. The positive and marginally positive were merged and reported as toxic (Figure 6 and Table 2).

Although toxic blooms were documented in the water bodies used as water supply system sources, this screening of raw water samples indicated the presents of only a few algal cells of Anabaena, Microcystis, and Oscillatoria with no signs of toxicity in the mouse bioassay tests.

References

Carmichael, W.W. and L.D. Schwartz. 1984. Preventing livestock deaths from blue-green algae poisoning. USDA Farmers Bulletin. 2275:1-11.

Karl, G.W. 1970. Toxic algae in Wisconsin lakes. Masters Thesis, University of Wisconsin, Madison. 72 pages.

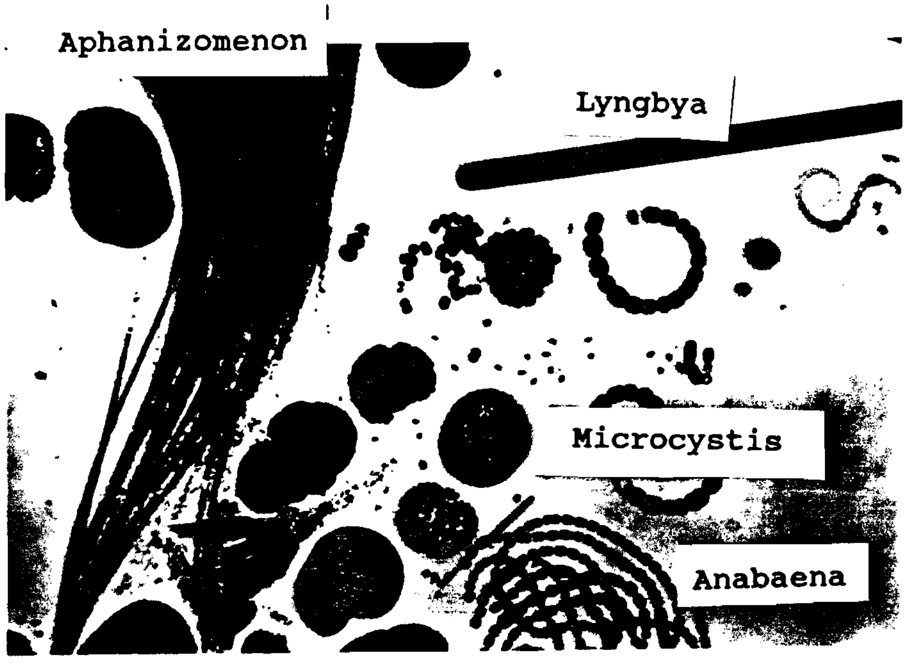

Figure 1 Commonly Observed Algae

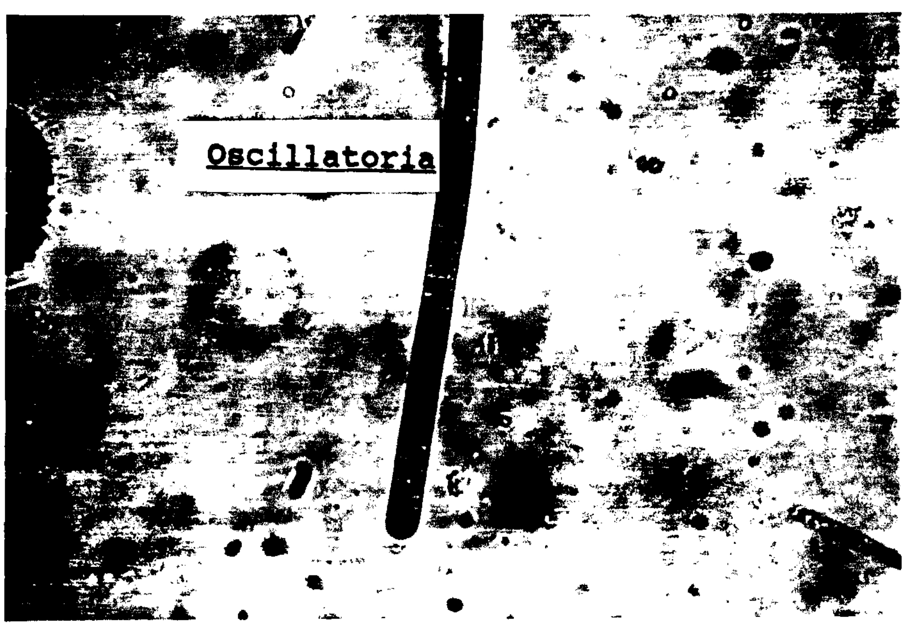

Figure 2 More common Algae

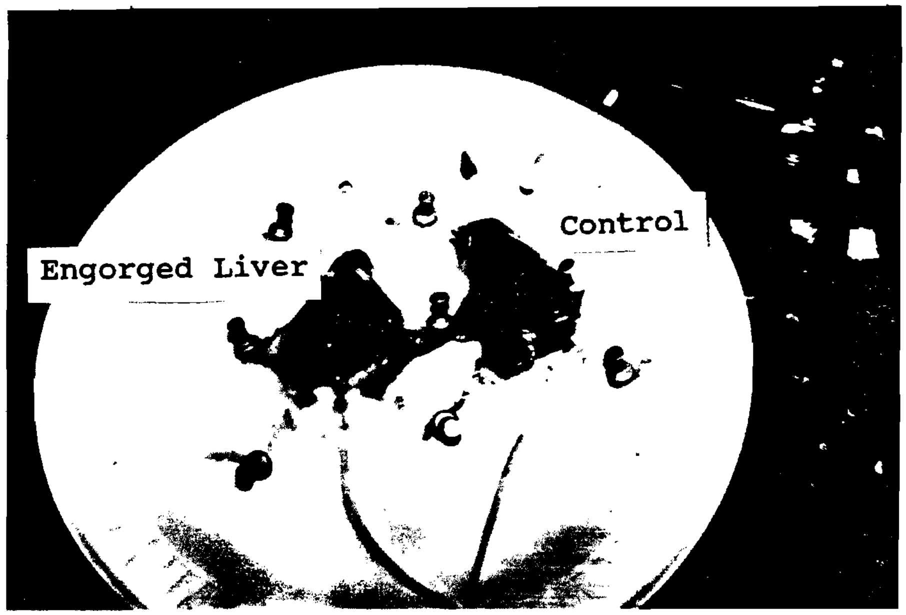

Figure 3 Hepatotoxin Effects on Mouse Liver

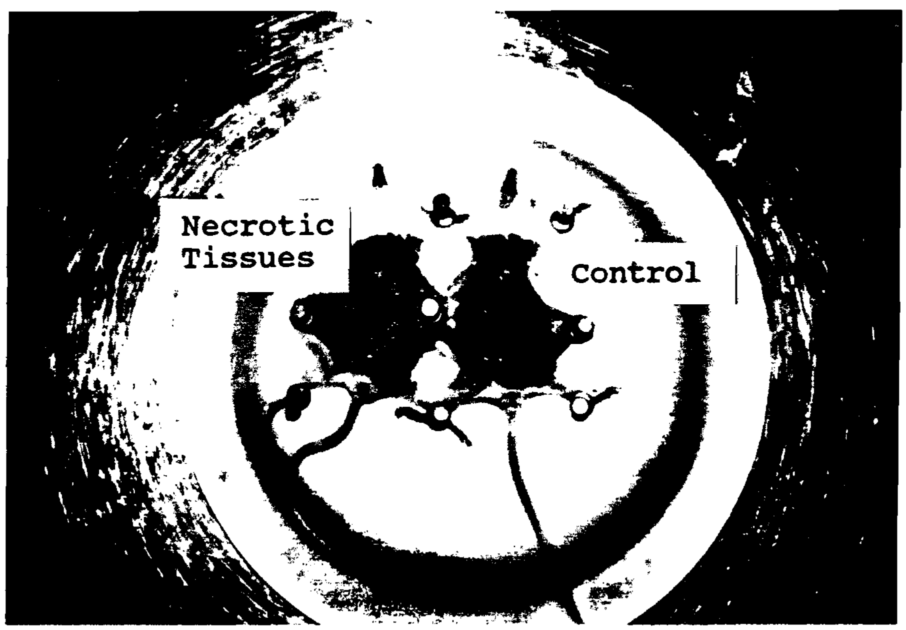

Figure 4 Contact Toxins Effects in Mice

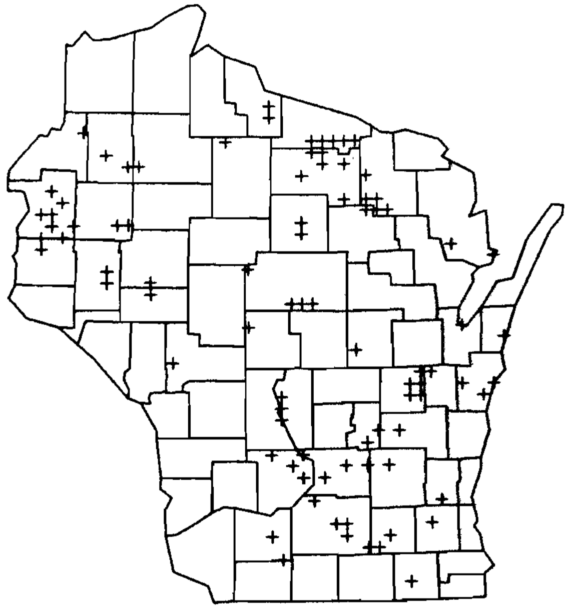

Figure 5 Lakes Sampled for Algal Toxins in 1986

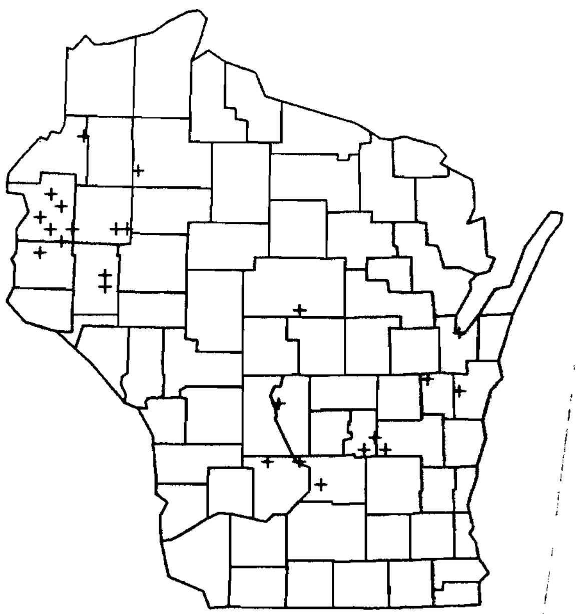

Figure 6 Lakes Where Algal Toxins were Found in 1986

Table 1 Wisconsin 1986 Algae Toxin Assay Results

Site	No Test	Negative	Marginally Positive	Positive	Total
Lakes	12	62	4	19	97
Ponds	0	10	2	0	12
Streams	0	5	0	0	5
Total	12	77	6	19	114

Table 2 Toxins Found in These Samples

TOWNSHIP	RANGE	COUNT	LAKE NAME	SAMPLE NUMBER	RESULT	ALGAE TYPES
T13N	R06E		DELTON LAKE	3	2	1 2 3
T13N	R06E	1	DELTON LAKE	5	1	1 2 3
T11N	R08E		WISCONSIN LAKE MOON LIGHT BAY	31	2	2 3 1
T11N	R08E	2	WISCONSIN LAKE MERRIMAC BOAT	32	1	2 1 3
T15N	R13E	3	LITTLE GREEN LAKE	35	1	3 4
T33N	R10W	4	TEN MILE LAKE	39	1	3 2 1
T33N	R11W	5	PRAIRIE LAKE	40	1	3
T28N	R12W	6	MENOMIN LAKE W. BEACH	43	1	3 1 2
T29N	R12W	7	TAINTER LAKE, WEST SHORE	44	1	3 1
T12N	R14E	8	BEAVER DAM LAKE HWY G	49	1	3 1
T31N	R18W	9	SQUAW LAKE NORTHEAST END	65	1	3 1
T13N	R03E	10	REDSTONE LAKE	86	2	1 3
T32N	R16W	11	MARTIN POND-FISH REARING POND	94	2	3 2 1
T34N	R18W	12	FROKNER POND-FISH REARING POND	95	2	3 1
T33N	R15W	13	MAGNOR LAKE	110	2	3 1
T19N	R21E	14	BIG LONG LAKE-BOAT LANDING	114	1	1 3 2
T20N	R17E		WINNEBAGO LAKE HIGH CLIFF	128	2	3 4
T20N	R17E		WINNEBAGO LAKE HIGH CLIFF	141	2	4
T33N	R17W		WAPOGASSET LAKE	142	2	1 3
T41N	R14W	15	STAPLES LAKE	143	1	3 1
T41N	R14W		STAPLES LAKE	144	2	3 1
T24N	R21E	16	GREEN BAY GRID 1001	156	1	3
T36N	R17W	17	BUTTERNUT BIG LAKE	157	1	3 1
T20N	R17E		WINNEBAGO LAKE HIGH CLIFF	184	2	4 1
T33N	R17W	18	WAPOGASSET LAKE	186	1	3 1 2
T35N	R16W	19	BONE LAKE	188	1	3 1
T20N	R18E	20	WINNEBAGO LAKE HIGH CLIFF	214	1	1 3 4
T26N	R06E		BIG EAU PLEINE RESERVOIR	239	2	1
T18N	R04E	21	PETENWELL LAKE CHICAGO AV.	241	1	3
T18N	R04E		PETENWELL LAKE PETENWELL PARK	244	1	3 1
T26N	R06E	22	BIG EAU PLEINE RES. CT. O NW	246	1	1 3
T38N	R09W	23	SISSABAGAMA LAKE BIG BOAT LANDING	300	2	2 1 3
T31N	R18W	24	RIVERDALE FLOWAGE-APPLE RIVER	301	1	2 1
T14N	R12E	25	MARIA LAKE SE SHORELINE	307	2	2 1

TYPES OF ALGAE CODES

1-ANABAENA
2-APHANIZOMENON
3-MICROCYSTIS
4-GLOEOTRICHIA
5-NONE
6-LYNGBYA
7-OSCILLATORIA

RESULTS CODE

1-Positive
2-Marginally Positive

Appendix A

Memo on Field Sampling Proceedure

CORRESPONDENCE/MEMORANDUM — STATE OF WISCONSIN

DATE: May 15, 1986 FILE REF: 3120

TO: Water Resources Supervisors, ATTN: Lake Management Coordinators; ANC Supervisors

FROM: Bruce Baker - WR/2 BJBak

SUBJECT: Toxic Algae Screening Survey

A screening survey to define the extent and magnitude of toxic algae blooms in Wisconsin will be conducted this summer. We will be able to test up to 500 water samples, collected from as many lakes and ponds as possible between mid-June and mid-September. Your assistance, suggestions and insights on this problem are requested.

On May 29, Dr. Wayne Carmichael from Wright State University will be in Madison to meet with Department and lab staff to discuss the problem of toxic algae. He will be presenting a seminar from 8:00 a.m. to 10:00 a.m. (Room 611B, GEF 2) and will then be meeting with the lab staff at the University to review analytical procedures. You and your associates are invited to attend.

Algal toxins have been documented as having caused the deaths of several cattle and dogs this past summer in Wisconsin. As more becomes known about the potential damage these potent toxins can cause and given that our lakes continue to become more eutrophic, we feel that it is important the problem be better understood. Three problem species of algae commonly found in Wisconsin, Anabaena, Microcystis, and Aphanizomenon, have been known to produce the exotoxins. Gloetrichia and Oscillatoria are others. Major losses to animals include cattle, sheep, hogs, birds, and fish, while minor losses have been reported for dogs, horses, small wild animals, and invertebrates. Acute oral toxicity to humans has not been documented, but there is increasing evidence that the toxins cause gastroenteritis and contact irritations to lake users. Some studies have also implicated algal toxins with long term human health problems.

The proposed collection protocol for this summer is as follows:

1. Between 100-150 samples can be collected per district as the first estimate. If possible sampling should be evened out over the time periods of June 15 to September 15 to make life easier at the lab. However, the main criteria should be to sample intense blue-green algal blooms. It has been suggested that ANC supervisors would be ideal people to collect samples, as they are travelling to, from, or are at a spray job

2. This first level survey is being set up to maximize the potential for finding problems. Therefore sampling should be done as much as possible when and where heavy blue-green algae blooms are occurring. This may mean weighting sample collection towards the later part of the summer, but we do hope you can hit some lakes earlier.

3. Samples should be collected where surface scums are the heaviest, such as at sites of wind blown accumulations or in protected bays. Samples can be collected from piers, boats, or directly from shore - whatever is most convenient. The lakes or ponds sampled are up to you. To keep this survey from adding to the workload (except for a little, tiny, bit) and becoming a separate project, please sample as is convenient, i.e. lakes where ANC treatments are being conducted or those lakes you happen to be driving past or are surveying for some other purpose, such as a beach inspection.

4. The samples should be collected in sterile 250 milliliter bacti bottles by skimming surface scums to maximize the amount of algae present in the sample. Immediately following collection samples should be iced and stored in the dark and shipped to the lab on the day of sampling.

5. If you couple sample collection to a specific incident, i.e. a fish kill, animal death, or swimming complaint, which is a good idea, and you want to be sure the lab will analyze your sample, write PRIORITY in big red letters on the lab slip. This will alert John Standridge, who will be handling this survey at the lab. On the lab slips just note sample as toxic algae in addition to providing basic locater information etc. If the lab receives more samples than budgeted, analysis will be prioritized by inspecting them for the presence of one of the major problem algae species.

I'll be notifying the departments of Health and Social Services and Agriculture of this survey so they're aware of what we'll be doing. Again, if you are responding to an incident be aware that algal toxicity problems are very ephemeral. Collecting a sample a day after or even several hours after the problem has surfaced can be too late. Since the toxins are usually concentrated in thin surface scums, a puff of wind can quickly dilute and disperse the problem, to a point where it will no longer be toxic. Remember to label the sample PRIORITY if it is very important that it be screened.

RW:cn

cc: District Directors
Jim Addis - FM/4
Steve Miller - WM/4

7007V

Appendix B

Sample Laboratory Slip

AUG 14 1986

TOXIC BLUE-GREEN ALGAE PROGRAM DATA SHEET

SITE: Big Long Lake COUNTY: Manitowoc

LOCATION: Boat Landing COLLECTOR: Rasman

DATE: 07 31 86 (MM DD YY) TIME: 10 15 (HR MIN)

114

WATER TEMP: 25 °C

pH: ______

WEATHER

1. WIND DIRECTION (CIRCLE)

   NW N NE

   W NONE E

   SW S SE

2. WIND SPEED (CHECK)

   X a. LIGHT

   __ b. BREEZY

   __ c. STRONG

3. HIGH TEMP: 82 °F

4. CLOUD COVER: 40 %

5. PREVIOUS WEATHER (DESCRIBE)

   Warm Windy

114

MOUSE ASSAY:
Positive
Negative
Negative with symptoms

CYANOBACTERIA PRESENT:
1 Anabaena
2 Aphanizomenon
1 Microcystis
0 Gloeotrichia
0 None

QUESTIONS: (608) 262-9742/2-1210

ANIMAL OR FISH KILLS (DESCRIBE)

None Observed.

OTHER OBSERVATIONS (DESCRIBE)

Extensive Bloom - Algae "stacked up" along windward (East shore) at boat landing

AUG 1 RECD

AUG 12 86

PART 2

Toxic Algae Study Report
on Mutagenicity, Lethal Dose and Sample Storage Viability

Phase Two Report

Toxic Algae Study Report
On Mutagenicity, Lethal Dose and Sample Storage Viability

Wyatt Rapavich, Jon Standridge, and William Sonzogni

Introduction

Phase one of the 1986 Toxic Algae project indicated that roughly one quarter of the waters in the State of Wisconsin contained toxic blooms at the time they were sampled. The acute effects of these toxins on animal life are well documented; however, the chronic effects are not. Therefore, both crude and purified extracts of algal toxins were tested for mutagenic activity using a battery of three *in vitro* tests -- the Ames Mutagen Test (Maron, 1983), the *Bacillus subtilis* Multigene Sporulation Test (Sacks, 1984), and a chromosomal aberration test using human lymphocytes (Cohen, 1971). Also, the viability of stored samples and the minimum lethal dose of the extracts were determined.

Methods

Algal extracts tested were both purified and crude. Purified extracts (including hepatotoxin at 0.9 mg/mL, anatoxin-a(s) at 0.02 mg/mL, and neosaxitoxin - unknown concentration) were obtained from Dr. Wayne W. Carmichael's lab at Wright State University. Eight extracts were prepared from frozen Wisconsin lake water samples proven to contain toxins by mouse bioassay. The lake water samples were thawed, mixed, and dispensed into 500 mL beakers in 50 mL aliqouts, then frozen and thawed in an ethanol/dry ice bath to disrupt the cell walls and release the toxins. Next, the sample was centrifuged to remove coarse particulate matter and the supernatant was collected and passed through a 0.45 um filter. The filtrate was then evaporated to dryness and reconstituted in 10 mL of distilled water. Again the sample was filtered through a 0.45 um filter followed by a 0.20 um filter to insure sterility. The resultant filtrate was finally placed in sterile vials and checked for the presence of viable toxins using mouse bioassay.

Ames testing was conducted on both the crude and the three pure toxins at three doses (100, 50, and 25 uL) following procedures developed by Maron (1983) using *Salmonella typhimurium* with and without the use of a liver microsome preparation (S-9). A second bacterial assay employing *Bacillus subtilis*, developed for detecting environmental mutagens (Sacks 1984), was applied to the hepatotoxin and neosaxitoxin (plus S-9 and minus S-9) and to the crude extracts (minus S-9) at three concentrations (100, 50 and 25%). The three pure algal toxins were also tested *in vitro* against human lymphocytes (Cohen 1971). Three log dilutions of toxin were tested on three human lymphocyte cell sources.

In addition to the mutagen studies, the long-term storage of toxins for future analysis was tested to determine the length of time samples may be stored and retain activity. Nine crude extracts with storage times ranging from two to six months were tested for viability using mouse assays.

Studies were also carried out to determine the minimum doses at which the toxins are lethal to mice for both purified and crude extracts. Twofold dilutions were used until a non-lethal dose was found using the mouse assay procedures.

Results

Neither bacterial assay indicated any significant mutagenic activity (Tables 1 and 2) from the toxins. *B. subtilis* did exhibit toxicity when exposed to the pure extracts at the higher doses (Table 2).

All three pure extracts, particularly hepatotoxin, were clastogenic, or capable of producing a low level of chromosome damage, in the human lymphocyte system (Table 3). No toxic effects were noted.

The viability of samples stored frozen at -20°C was variable. Neosaxitoxins were tested at 1 month was toxic, but were no longer viable when tested after six months. The hepatotoxins and contact poisons showed continued strong activity after five months of storage. Anatoxin-a(s) remained viable at six months but was not viable at ten months.

Studies were done to determine the minimum lethal dose of both crude and purified extracts. Although anatoxin-a(s) is a faster acting toxin than hepatotoxin, results in Table 4 indicate that the neurotoxin required a higher concentration (0.268 mg/kg) to kill mice, whereas hepatotoxin only required 0.080 mg/kg. Note that a(s) toxin is unstable and therefore is probably a loss of activity is expected - this indicates that the toxicity is 10 times greater than the concentration reported here (Carmichael 1987). Data on the concentration of neosaxitoxin was unavailable, therefore the final concentration of 7.14 mL/kg of the pure extract was required to kill a mouse.

The crude extract data from Table 4 demonstrates that lethal doses are related to the amount of toxin in the extract. Extracts from Beaver Dam Lake and Lake Menomin were the most potent, needing only 3.57 mL/kg of extract to kill mice. Big Long Lake, Big Eau Pleine Reservoir and Lake Delton exhibited the least amount of toxicity, requiring 14.28 mL/kg of extract. Estimates of minimum lethal doses for the Lake Menomin and Beaver Dam Lake samples for a 20 kg Springer Spaniel dog would be approximately 70 mL of lake water ingested. For a 75 kg human the lethal dose would be approximately 270 mL for the same toxin.

Conclusions

Toxic algae is a potential danger in Wisconsin. The possibility of death of livestock and other animals consuming water containing algal toxins is an ever present threat considering the relatively low doses required and the state wide prevalence of toxic blooms.

Although the Ames and B. subtilus assays do not indicate dangerous effects from chronic exposure, the lymphocyte study did suggest potential health risk related to human consumption of toxins. In relative terms, however, it should be noted that the level of chromosome damage is much lower than that produced from known clastogenic compound used as controls. Nevertheless, each of the three systems used have varying sensitivity to compounds due to different metabolic pathways and chromosome vulnerability. Therefore, the findings of the lymphocyte study should not be overlooked particularly since the effects on human cells is shown.

References

Carmichael, W.W. Personal Communications, 1987, Wright State University, Dayton, Ohio 45435

Cohen, Maimon M. and Kurt Hirschhorn, "Cytogenetic studies in animals," Chemical Mutagens, Vol. 2, Chap. 19, 1971, 515-534.

Maron, Dorothy M. and Bruce N. Ames, "Revised methods for the Salmonella mutagenicity test," Mutation Research, 113, 1983, 173-215.

Sacks, L.E. and J.T. MacGregor, "The Bacillus subtilis multigene sporulation test for detection of environmental mutagens," Chemical Mutagens, Vol. 9, Chap. 5, 1984, 165-181.

Table 1

Mutagenic Activity of Algal Toxins
in the Ames Mutagen Assay

		Ratio of Induced Revertants to Control					
		TA 98		TA 100		TA 102	
Extract	Dose (uL)	-S9	+S9	-S9	+S9	-S9	+S9
Purified Toxins							
Neosaxitoxin	100	0.02	-0.11	0.31	0.02	0.40	0.11
	50	0.48	0.22	0.07	0.19	0.13	0.13
	25	0.03	-0.14	0.11	0.10	0.60	0.23
Hepatotoxin (0.9 ug/uL)	100	0.14	0.22	0.08	0.14	0.42	0.14
	50	0.02	0.18	0.01	-0.07	0.33	0.09
	25	0.16	0.00	0.04	0.12	0.22	0.10
Anatoxin-a(s) (0.02 ug/uL)	100	0.62	0.27	0.06	0.16	0.41	0.20
	50	0.42	0.27	0.09	0.13	0.20	0.22
	25	0.02	0.09	-0.19	0.02	0.36	0.18
Crude Extracts							
L. Delton	100	0.08	0.25	0.31	-0.04	0.54	-0.10
	50	0.24	0.28	0.44	-0.07	0.27	0.06
	25	0.30	0.39	-0.07	0.04	0.15	0.11
Ten Mile L.	100	0.44	0.27	0.36	0.73	0.16	0.54
	50	0.48	-0.04	0.29	0.37	0.61	0.11
	25	0.20	0.15	0.13	0.56	0.57	0.35
L. Menomin	100	0.32	0.19	0.21	0.09	0.67	0.08
	50	0.16	0.15	0.01	0.06	0.49	0.19
	25	-0.13	0.30	-0.13	-0.01	0.23	0.02
Beaver Dam L.	100	0.07	-0.15	0.37	0.28	0.36	0.21
	50	0.22	-0.19	0.13	-0.05	0.45	0.14
	25	0.19	-0.29	0.30	-0.23	0.22	0.06
Squaw L.	100	-0.03	-0.27	0.40	-0.11	0.44	0.08
	50	0.31	0.15	0.28	0.11	0.10	-0.05
	25	0.03	-0.03	0.11	-0.15	0.04	-0.07
Big Long L.	100	0.03	0.00	0.39	-0.19	0.36	0.12
	50	-0.09	-0.29	0.29	-0.04	0.09	0.30
	25	0.03	0.13	-0.09	0.07	0.22	0.46
Staples L.	100	-0.07	-0.29	0.25	-0.01	0.14	0.02
	50	-0.03	0.04	0.30	-0.08	0.02	-0.03
	25	-0.06	0.13	0.12	-0.19	0.18	0.16

		Ratio of Induced Revertants to Control					
		TA 98		TA 100		TA 102	
Extract	Dose (uL)	-S9	+S9	-S9	+S9	-S9	+S9
Big Eau Pleine	100	0.10	-0.02	0.31	0.05	0.80	0.36
Res.	50	-0.06	-0.07	0.29	0.10	0.15	0.09
	25	0.00	0.27	0.22	-0.08	-0.15	0.52

Postives in the Ames test have a ratio value greater than 1.00 and exhibit a dose response.

Table 2

Mutagenic Activity of Algal Toxins
in the *Bacillus subtilis* Multigene Sporulation Test

Extract	Dose	S9 Mix	Number of Mutants/ 10^4 Survivors: Strain 168	Strain HCR-9	Percent Survival
Control	10 uL	-	2	6	-
	10 uL	+	2	2	-
H_2O_2	1.25 ug	-	41	58	91
Purified:					
Hepatotoxin	9.0 ug	-	1	2	74
	4.5 ug	-	3	5	125
	2.25 ug	-	1	5	126
Hepatotoxin	9.0 ug	+	2	6	68
	4.5 ug	+	3	1	85
	2.25 ug	+	0	8	85
Neosaxitoxin	100%	-	1	10	67
	50%	-	1	3	75
	25%	-	1	3	100
Neosaxitoxin	100%	+	1	3	75
	50%	+	2	1	91
	25%	+	0	5	94
Crude:					
L. Delton	100%	-	4	2	118
	50%	-	1	7	127
	25%	-	3	4	127
Ten Mile L.	100%	-	5	3	132
	50%	-	4	5	121
	25%	-	4	3	120
L. Menomin	100%	-	6	6	105
	50%	-	3	3	100
	25%	-	1	5	144
Beaver Dam L.	100%	-	4	1	124
	50%	-	3	4	139
	25%	-	4	4	135
Squaw L.	100%	-	2	5	93
	50%	-	2	2	116
	25%	-	1	5	100
Big Long L.	100%	-	0	4	101
	50%	-	3	3	113
	25%	-	2	2	95
Staples L.	100%	-	1	3	90
	50%	-	5	4	89
	25%	-	1	1	92
Big Eau Pleine	100%	-	4	4	91
Res.	50%	-	1	2	102
	25%	-	3	2	89

Positives generally exhibit a number of mutants value two times greater than the control coupled with a dose response.

Table 3

Chromosome Breakage in Human Lymphocytes Exposed In Vitro for 3 Algaltoxins*

Toxin	Concentration (ug/ml)	%Total Breaks (Range)	% Control Breaks (Range)	% Induced Breaks+ (Range)	% Mitotic Index (Range)	Control %Mitotic Index (Range)	Mitotic Index as % of control (Range)	Number of People	Number of Cells
Hepatotoxin									
	0.9 ug/ml	14-32	6	8-26	0.8-2.5	1.2-6.2	40.3-111.0	3	150
	0.9 ug/ml	12-16	6	6-10	1.0-4.6	1.2-6.2	74.2-83.3	3	150
	0.009 ug/ml++	6	4	2	1.7	2.3	47.8-87.0	1	100
Anatoxin**									
	0.08 ug/ml	12-16	4-6	8-10	1.9-2.3	2.2-2.3	82.6-104.5	2	100
	0.008 ug/ml	6-12	4-6	0-8	1.8-2.0	2.1-2.3	86.4-88.0	2	150
	0.0008 ug/ml	4-12	6	(-2)-6	1.4-2.4	1.8-2.2	77.8-109.1	2	150
Neosaxitoxin									
	0.005 ml of stock	16	4-6	10-12	1.2-1.6	1.2-2.3	52.2-133.3	2	100
	0.0005 ml of stock	12-14	6	6-8	1.2-3.5	1.2-6.2	56.4-100.0	2	100
	0.00005 ml of stock	4-11	6	(-2)-5	2.5-5.2	1.2-6.2	83.9-208.3	2	150

* 72 hour cultures with toxins added after first 24 hours.

\+ Induced breakage is total breakage from which breakage observed in parallel controls has been subtracted.

** Due to limited amount of material, could not test a higher dose.

++ This result was based only on a single treated culture.

TABLE 4

Lethal Dose of Algal Extracts

	Dose (mL)	Concentration (mL/kg mouse)	(mg/kg mouse)	Time to Death (min)
Purified				
Hepatotoxin (0.9 mg/mL)	0.5	14.2857	12.857	26
	0.1	2.8571	2.571	25
	0.05	1.4286	1.286	31
	0.025	0.7143	0.642	38
	0.0125	0.3571	0.321	<60
	0.00625	0.1786	0.161	<60
	0.003125	0.0893	0.080	<180
	0.0015625	0.0446	0.040	>180
Neosaxitoxin	0.5	14.2857	-	4
	0.25	7.1429	-	5
	0.125	3.5714	-	>210
	0.0625	1.7857	-	>210
Anatoxin - a(s) (0.02 mg/mL)	0.5	14.2857	0.286	31
	0.25	7.1429	0.143	>210
	0.125	3.5714	0.071	>210
	0.0625	1.7857	0.036	>210
Crude Extracts L. Delton	0.05	14.2857	-	26
	0.25	7.1429	-	>210
	0.125	3.5714	-	>210
	0.0625	1.7857	-	>210

	Dose (mL)	Concentration (mL/kg mouse)	(mg/kg mouse)	Time to Death (min)
Ten Mile L.	0.5	14.2857	-	40
	0.25	7.1429	-	120
	0.125	3.5714	-	>210
	0.0625	1.7857	-	>210
L. Menomin	0.5	14.2857	-	50
	0.25	7.1429	-	120
	0.125	3.5714	-	<210
	0.0625	1.7857	-	>210
Beaver Dam L.	0.5	14.2857	-	37
	0.25	7.1429	-	44
	0.125	3.5714	-	120
	0.0625	1.7857	-	>210
Squaw L.	0.5	14.2857	-	36
	0.25	7.1429	-	120
	0.125	3.5714	-	>210
	0.0625	1.7857	-	>210
Big Long L.	0.5	14.2857	-	61
	0.25	7.1429	-	>210
	0.125	3.5714	-	>210
	0.0625	1.7857	-	>210

	Dose (mL)	Concentration (mL/kg mouse)	(mg/kg mouse)	Time to Death (min)
Staples L.	0.5	14.2857	-	57
	0.25	7.1429	-	120
	0.125	3.5714	-	>210
	0.0625	1.7857	-	>210
Big Eau Pleine Res.	0.5	14.2857	-	45
	0.25	7.1429	-	>210
	0.125	3.5714	-	>210
	0.0625	1.7857	-	>210

PART 3

Fact Sheet on Algae Toxins

ALGAE THAT PRODUCE TOXINS AND THEIR POTENTIAL EFFECTS

Department of Natural Resources Lake Management Program
PUBL-WR-162 87
June 1987

Summary

Algae are fed by nutrients in lake water. Human activities add excessive amounts of nutrients to lake water which can, in turn cause more algal blooms. Algal blooms are easily recognized as thick, green slimy mats which float on the lake surface but only a few types of blue-green algae produce toxins. Limited and specific conditions are required for blue-green algae to create toxins. If ingested these blue-green algal toxins can be harmful to animals.

What are Algae?

Algae are microscopic plants that are found in all lakes as well as in the ocean. There are many different kinds of algae, and each grows under different conditions. Some algae are abundant in eutrophic (highly fertile) lakes while others are found in oligotrophic (nutrient poor) lakes. The more algae present in a lake the greener and less clear the water will appear. The amount and type of algae that are found in a lake will affect water clarity, the fishery, and the growth of other plants.

Algae as Part of the Food Chain

Algae are an important part of the natural lake food chain. These microscopic plants are eaten by microscopic animals called zooplankton. The zooplankton are eaten by fish which are then eaten by larger fish. Humans and other animals may consume these larger fish.

Different Types of Algae

Most freshwater algae can be divided into three broad categories: green, blue-green, and golden brown, based on the kind of pigments that are present in the algal cells. The algae may appear green, brown, blue, blue-green, violet, red or black.

In general, blue-green algae are the most undesirable type of algae in a lake environment. Blue-green algal blooms form thick, unsightly mats that float on the lake, especially around the lakeshore, impoundments or on small ponds.

Blue-green algae are caused by pollution entering lakes. Runoff from streets, farms and/or industries can provide the nutrients which encourage algal growth.

Algae that Produce Toxins

Blue-green algae are looked upon as the weed species of the algae family. Blue-green algae are inedible to most zooplankton (microscopic animals) and waterfowl such as ducks and geese. Some kinds of blue-green algae, under specific conditions, may be dangerous or even deadly to dogs and cattle.

Algal toxins are natural poisons that may be produced primarily by five different genera (or types) of blue-green algae. Conditions must be just right in order for the toxins or poisons to be produced. The conditions include: high levels of nutrients in the water (phosphorus and nitrogen), water temperatures between 72-80 degrees Fahrenheit, and water pH between 6-9. Toxic algal blooms usually occur on hot, dry days with very little wind in the summer and early fall.

A laboratory analysis is one way of determining whether or not a particular bloom of algae is toxic. In many cases the presence of algal toxins are recognized only after livestock or pets become ill or die after being exposed to an algal bloom.

Effects of Exposure to Algae that Produce Toxins

Toxins released into the water from dying blue-green algae may be dangerous to livestock, pets, waterfowl, and other animals. Animals drinking the water containing toxins can be affected in four ways, depending on the kind of animal, the type of poison produced by the algae, and the amount of algae consumed:

- they may damage their liver or skin;
- they may die immediately due to respiratory failure;
- they may die between one to six hours after drinking the bad water as their internal organs fail, particularly the liver.
- they may not be affected at all

How do Algae that Produce Toxins Affect Humans?

People may also be affected by algae that produce toxins, particularly from swimming in water containing the toxins, or by touching the algae itself. Symptoms include itching, reddening of the skin, eye irritation, dizziness, cramps and vomiting. Drinking minute quantities of water containing the toxins may result in gastrointestinal problems (indigestion). Generally, humans recover from the symptoms within one to two days. Long-term effects from regularly drinking contaminated water are unknown. No human deaths from drinking water containing toxins produced by algae have ever been reported in Wisconsin.

Algae that Produce Toxins in Wisconsin

Algae that produce toxins are found in lakes and ponds all over the world, including the United States, Europe, New Zealand, Australia, the USSR, Bangladesh, India, Japan, and South Africa. In Wisconsin, livestock, dogs, and waterfowl have died as a result of drinking contaminated waters.

While algal blooms are a natural part of the lake environment, we are becoming more concerned about their presence. Why? Because human activities add excessive amounts of nutrients to our lakes and streams, resulting in more frequent algal blooms with occasional toxin producing algae. To better understand how widespread and serious the algal toxin problems may be in Wisconsin, the Department of Natural Resources sampled lakes during 1986. Samples were collected at sites where blue-green algal blooms were found.

Analysis was done by the State Laboratory of Hygiene to determine if these samples were toxic. A report will soon be available which discusses these results.

Algal blooms that produce toxins are very difficult to pinpoint. Even if a blue-green algal bloom is present, toxins may not be produced. Further, scientists are coming to realize that a toxic bloom may be widespread over an entire water body, or may occur in a broken pattern where one part of the bloom may be toxic while nearby, no toxins are being produced. Wind on a lake or pond may shift the toxic or non-toxic bloom around. Even if an animal dies from drinking contaminated water, the toxins in the water may be gone only a few hours later when the water sample is taken. Therefore, it is very difficult to conduct a survey of the problems. However, the toxic algae may still be found in the animal's stomach, confirming suspicions that the water it drank may have killed it.

What Can We Do?

Limiting the amount of pollutants entering a lake is the best long-term solution to this problem. By controlling phosphorus inputs to a lake, blue-green and toxic algal blooms may be prevented. Become involved. Learn more about lakes and what you can do to help protect these valuable resources by contacting your nearest DNR office or County Extension Agent.

Although we are still in the process of learning more about algae that produce toxins, we do recognize that it is a problem on some lakes and ponds in Wisconsin. It is a potential problem that farmers, pet owners and parents should be aware of in order to prevent illness or even death. We can all play a role in helping control nuisance algal blooms by learning about and practicing ways of protecting our lake resources.

Where thick, floating blue-green algal blooms occur, farmers and others with animals should take precautions to keep animals from drinking the surface scum. Do not allow small children to drink, swim, wade, or play in the water, and never drink the water yourself where dense blue-green scums have accumulated. Prevention is the best solution to avoid loss of livestock and to avoid illness in both animals and humans.

PART 4

Tables of Data Collected.

Table 1 - Wisconsin Surface Water Supply Sampled for Algal Toxins with the Mouse Bioassay

Table 2 - Lakes Sampled for Algal Toxins in 1986

Table 3 - Intensive Sampling Conducted By Wyatt Repavich and other Southern District Staff.

Table 4 - All Samples Collected During the Survey

Table 5 - Surface Water Inventory of Lakes done 1960's to 1980's for positive toxins lakes.

Table 1 Wisconsin Surface Water Supply Sampled for Algal Toxins with Mouse Bioassay.

Analyzed by Wyatt Repavich at State Lab of Hygiene

Results
0-Negative
1-Positive
2-Marginally Positive

Algae
1-ANABAENA
2-APHANIZOMENON
3-MICROCYSTIS
4-GLOEOTRICHIA
5-NONE
6-LYNGBYA
7-OSCILLATORIA

Lake Name and Water Supply System	#	Results	Algae	Date
MICHIGAN LAKE RAW GREEN BAY CITY FROM KEWAUNEE	205	0	5	19-Aug-86
MICHIGAN LAKE RAW GREEN BAY CITY FROM KEWAUNEE	228	0	5	26-Aug-86
MICHIGAN LAKE RAW GREEN BAY CITY FROM KEWAUNEE	250	0	5	02-Sep-86
MICHIGAN LAKE FINISHED GREEN BAY	206	0	5	19-Aug-86
MICHIGAN LAKE FINISHED GREEN BAY	229	0	5	26-Aug-86
MICHIGAN LAKE FINISHED GREEN BAY	251	0	5	02-Sep-86
MICHIGAN LAKE RAW MANITOWOC INTAKE	203	0	5	19-Aug-86
MICHIGAN LAKE RAW MANITOWOC INTAKE	226	0	5	26-Aug-86
MICHIGAN LAKE RAW MANITOWOC INTAKE	248	0	5	02-Sep-86
MICHIGAN LAKE FINISHED MANITOWOC IN PLANT	204	0	5	19-Aug-86
MICHIGAN LAKE FINISHED MANITOWOC IN PLANT	227	0	5	26-Aug-86
MICHIGAN LAKE FINISHED MANITOWOC IN PLANT	249	0	5	02-Sep-86
MICHIGAN LAKE RAW MARINETTE IN PLANT	207	0	5	19-Aug-86
MICHIGAN LAKE RAW MARINETTE IN PLANT	230	0	5	26-Aug-86
MICHIGAN LAKE RAW MARINETTE IN PLANT	252	0	5	02-Sep-86
MICHIGAN LAKE FINISHED MARINETTE	208	0	5	19-Aug-86
MICHIGAN LAKE FINISHED MARINETTE IN PLANT	231	0	5	26-Aug-86
MICHIGAN LAKE FINISHED MARINETTE IN PLANT	253	0	5	02-Sep-86
SUNSET LK RAW KING WI VET HOME	199	0	5	18-Aug-86
SUNSET LK RAW KING WI VET HOME	223	0	5	25-Aug-86
SUNSET LK RAW KING WI VET HOME	270	0	3	03-Sep-86
SUNSET LK FINISHED KING WI VET HOME	200	0	5	18-Aug-86
SUNSET LK FINISHED KING WI VET HOME	224	0	5	25-Aug-86
SUNSET LK FINISHED KING WI VET HOME	271	0	5	03-Sep-86
WINNEBAGO LAKE RAW APPLETON INTAKE PUMPS	191	0	1	18-Aug-86
WINNEBAGO LAKE RAW APPLETON INTAKE PUMPS	215	0	5	25-Aug-86
WINNEBAGO LAKE RAW APPLETON INTAKE PUMPS	262	0	5	03-Sep-86
WINNEBAGO LAKE FINISHED APPLETON INTAKE PUMPS	192	0	5	18-Aug-86
WINNEBAGO LAKE FINISHED APPLETON INTAKE PUMPS	216	0	5	25-Aug-86
WINNEBAGO LAKE FINISHED APPLETON INTAKE PUMPS	263	0	5	03-Sep-86
WINNEBAGO LAKE MENASHA FILTRATION BASIN	193	0	1 3	18-Aug-86
WINNEBAGO LAKE MENASHA FILTRATION BASIN	217	0	5	25-Aug-86
WINNEBAGO LAKE MENASHA FILTRATION BASIN	266	0	3 7	03-Sep-86

WINNEBAGO LAKE MENASHA TAP WATER IN PLANT	194	0	5		18-Aug-86
WINNEBAGO LAKE MENASHA TAP WATER IN PLANT	218	0	5		25-Aug-86
WINNEBAGO LAKE MENASHA TAP WATER IN PLANT	267	0	5		03-Sep-86
WINNEBAGO LAKE NEENAH RAW WATER IN PLANT	195	0	1	3	18-Aug-86
WINNEBAGO LAKE NEENAH RAW WATER IN PLANT	219	0	5		25-Aug-86
WINNEBAGO LAKE NEENAH RAW WATER IN PLANT	264	0	5		03-Sep-86
WINNEBAGO LAKE NEENAH FINISHRD TAP WATER IN PL	196	0	5		18-Aug-86
WINNEBAGO LAKE NEENAH FINISHRD TAP WATER IN PL	220	0	5		25-Aug-86
WINNEBAGO LAKE NEENAH FINISHRD TAP WATER IN PL	265	0	5		03-Sep-86
WINNEBAGO LAKE OSHKOSH RAW WATER OUTSIDE PLANT	197	0	1		18-Aug-86
WINNEBAGO LAKE OSHKOSH RAW WATER OUTSIDE PLANT	221	0	5		25-Aug-86
WINNEBAGO LAKE OSHKOSH RAW WATER OUTSIDE PLANT	268	0	3	7	03-Sep-86
WINNEBAGO LAKE OSHKOSH FINISHRD TAP WATER IN P	198	0	5		18-Aug-86
WINNEBAGO LAKE OSHKOSH FINISHRD TAP WATER IN P	222	0	5		25-Aug-86
WINNEBAGO LAKE OSHKOSH FINISHRD TAP WATER IN P	269	0	5		03-Sep-86

Table 2 List of Wisconsin Lakes Sampled for Algae Toxins in 1986.

TOWNSHIP	RANGE	LAKE NAME
T34N	R12E	AGNES LAKE MIDDLE 1 METER
T27N	R08W	ALTOONA LAKE
T40N	R11E	ANVIL LAKE SOUTH SIDE BT LANDING
T26N	R07E	BAKER, MATT FARM
T34N	R17W	BALSAM EAST LAKE
T40N	R11E	BASS LAKE EAST SIDE R.E.PETERSON
T31N	R20E	BASS LAKE WEST END
T37N	R06E	BEARSKIN, BIG LAKE EAST @ BOAT LANDING
T18N	R16E	BEAU DES MORTES
T12N	R14E	BEAVER DAM LAKE HWY D
T26N	R05E	BIG EAU PLEINE RESERVOIR PARK NORTH BEACH
T19N	R21E	BIG LONG LAKE-BOAT LANDING
T35N	R12E	BISHOP LAKE-SE BOAT LANDING
T35N	R16W	BONE LAKE
T40N	R09E	BOOT LAKE NORTH SIDE SUNNYBROOK RESORT
T19N	R21E	BULLHEAD LAKE WEST PUB. LANDING
T36N	R17W	BUTTERNUT BIG LAKE
T40N	R12E	BUTTERNUT LAKE
T39N	R07E	CARROL LAKE OFF CTH J
T18N	R23E	CARSTENS LAKE WEST SHORE
T17N	R04E	CASTLE ROCK LAKE NW SIDE
T40N	R10E	CATFISH/EAGLE LAKE THOROUGHFARE N OF BRIDGE
T32N	R18W	CEDAR LAKE
T33N	R10W	CHETEK LAKE NEAR DAM
T6N	R03E	COX HOLLOW LAKE
T40N	R11E	CRANBERRY LAKE PUB. BOAT LANDING
T34N	R13E	CRANE LAKE - ANDERSON HOUSE
T9N	R07E	CRYSTAL LAKE
T12N	R10E	CRYSTAL LAKE
T24N	R01E	CUNNINGHAM CREEK
T34N	R13E	DEEP HOLE LAKE MIDDLE SURFACE
T2N	R16E	DELAVAN LAKE
T13N	R06E	DELTON LAKE
T11N	R06E	DEVILS LAKE
T13N	R03E	DUTCH HOLLOW LAKE PUB. BOAT LANDING
T40N	R10E	EAGLE RIVER HWY 17 BRIDGE
T9N	R19E	FIVE LAKE
T34N	R18W	FROKNER POND-FISH REARING POND POLK CO
T24N	R21E	GREEN BAY GRID 1001 1/4 MI OF BAYSHORE PK
T29N	R01E	HOLDING POND DORCHESTER POTW
T29N	R01E	HOLDING POND LYNN DAIRY
T6N	R10E	KEGONSA LAKE
T5N	R13E	KOSHKONONG LAKE
T43N	R03E	LAKE OF THE FALLS(FLAMBEAU FLOWAGE)
T40N	R07E	LITTLE ARBOR VITAE NE LDG
T19N	R16E	LITTLE BUTTE DES MORTES LAKE
T15N	R13E	LITTLE GREEN LAKE

T35N	R13E	LITTLE SAND LAKE BOAT LANDING
T40N	R08E	LITTLE ST GERMAIN LAKE EAST BAY
T37N	R10W	LONG LAKE AT THE NARROWS
T39N	R07E	MADELINE LAKE OFF CTH J
T33N	R15W	MAGNOR LAKE
T14N	R12E	MARIA LAKE SE SHORELINE
T32N	R16W	MARTIN POND-FISH REARING POND POLK CO
T28N	R12W	MENOMIN LAKE W. BEACH
T30N	R24E	MICHIGAN LAKE RAW MARINETTE IN PLANT
T7N	R09E	MONONA BAY-NORTH BEACH
T7N	R10E	MONONA LAKE
T40N	R09E	MUSKELUNGE LAKE NORTH SIDE BT LANDING
T12N	R12E	PARK LAKE ADJ TO SWIMMING AREA
T5N	R12E	PAUL BURNS POND
T35N	R10E	PELICAN LAKE EAST SIDE
T32N	R06E	PESOBIC LAKE EAST SHORE
T18N	R04E	PETENWELL LAKE ARROWHEAD LAGOON
T7N	R18E	PEWAUKEE LAKE
T34N	R13E	PICKEREL LAKE VORAS TAVERN
T37N	R12E	PINE LAKE NE SIDE
T34N	R17W	POLK CO-BELD POND-WALLEYE REARING POND
T34N	R17W	POLK CO-HELMAN'S POND-WALLEYE REARING POND
T39N	R12W	POND 10 SPOONER W/W HATCHERY
T39N	R12W	POND 7 SPOONER W/W HATCHERY
T33N	R11W	PRAIRE LAKE
T39N	R08E	RAINBOW FLOWAGE CTH E NEAR DAM ROAD
T13N	R03E	REDSTONE LAKE
T31N	R18W	RIVERDALE FLOWAGE-APPLE RIVER
T31N	R18W	RIVERDALE FLOWAGE-APPLE RIVER
T34N	R14E	ROBERTS LAKE-SE BOAT LANDING
T6N	R14E	ROCK RIVER EAST OF SUMNER
T40N	R10E	SCATTERING RICE LAKE SOUTH SHORE BT LANDING
T38N	R09W	SISSABAGAMA LAKE SW SHORE
T39N	R07E	SNAKE LAKE OFF HWY 47
T31N	R18W	SQUAW LAKE NORTHEAST END
T41N	R14W	STAPLES LAKE
T40N	R08E	STELLA LAKE BOAT LANDING
T22N	R11E	SUNSET LK RAW KING WI VET HOME
T29N	R12W	TAINTER LAKE
T40N	R11E	TAMBLING LAKE OUTFLOW RANGELINE RD
T33N	R10W	TEN MILE LAKE
T38N	R10E	THUNDER LAKE SOUTH SHORE
T21N	R06W	TRUMP LAKE
T33N	R06E	TUG LAKE NORTH SHORE SWIMMING BEACH
T12N	R05E	VIRGINIA LAKE-NORTH SHORE
T33N	R17W	WAPOGASSET LAKE
T6N	R10E	WAUBESA LAKE - BABCOCK PARK BEACH
T42N	R03E	WILSON LAKE
T7N	R09E	WINGRA LAKE
T20N	R17E	WINNEBAGO LAKE HIGH CLIFF MARINA
T11N	R08E	WISCONSIN LAKE MERRIMAC BOAT LANDING
T28N	R08W	WISSOTA LAKE
T4N	R04E	YELLOWSTONE LAKE

Table 3 - Intensive Sampling Conducted By Wyatt Repavich and other Southern District Staff.

Analyzed by Wyatt Repavich at State Lab of Hygiene

Results
0-Negative
1-Positive
2-Marginally Positive

Algae
1-ANABAENA
2-APHANIZOMENON
3-MICROCYSTIS
4-GLOEOTRICHIA
5-NONE
6-LYNGBYA
7-OSCILLATORIA

Lake Name	#	Result Alga Type	Date
KEGONSA LAKE	10	0 2 3	29-Jun-86
KEGONSA LAKE - FISH CAMP CO.	24	0 5	07-Jul-86
KEGONSA LAKE - FISH CAMP CO.	56	0 3	14-Jul-86
KEGONSA LAKE - FISH CAMP CO.	74	0 3	21-Jul-86
KEGONSA LAKE - FISH CAMP CO.	101	0 3	28-Jul-86
KEGONSA LAKE - FISH CAMP CO.	121	0 3	04-Aug-86
KEGONSA LAKE OUTLET	25	0 3 2 1	07-Jul-86
KEGONSA LAKE OUTLET	57	0 3	14-Jul-86
KEGONSA LAKE OUTLET	75	0 5	21-Jul-86
KEGONSA LAKE OUTLET	102	0 1 2	28-Jul-86
KEGONSA LAKE OUTLET	123	0 2 3	04-Aug-86
KOSHKONONG LAKE	26	0 2 1 3	07-Jul-86
KOSHKONONG LAKE	27	0 5	07-Jul-86
KOSHKONONG LAKE	58	0 1	14-Jul-86
KOSHKONONG LAKE	59	0 1	14-Jul-86
KOSHKONONG LAKE-DRIFT INN	124	0 5	04-Aug-86
KOSHKONONG LAKE-ROCK R. BOAT	77	0 1	21-Jul-86
KOSHKONONG LAKE-ROCK R. BOAT	104	0 5	28-Jul-86
KOSHKONONG LAKE-ROCK R. BOAT	125	0 3	04-Aug-86
KOSHKONONG LAKE-SHANTY INN	76	0 1	21-Jul-86
KOSHKONONG LAKE-SHANTY INN	103	0 1	28-Jul-86
MONONA BAY-TRIANGLE BOAT HOU	79	0 3 2	21-Jul-86
MONONA BAY-NORTH BEACH	80	0 3 2	21-Jul-86
MONONA LAKE	68	0 4 3	21-Jul-86
MONONA LAKE AT STORKWEATHER	190	0 4 3	16-Aug-86
MONONA LAKE EAST SHORE	225	0 3	25-Aug-86
MONONA LAKE AT STARKWEATHER	272	0 6 3	04-Sep-86
ROCK RIVER EAST OF SUMNER	28	0 2	07-Jul-86
ROCK RIVER EAST OF SUMNER	60	0 3 1	14-Jul-86
ROCK RIVER EAST OF SUMNER	78	0 5	21-Jul-86
ROCK RIVER EAST OF SUMNER	105	0 1 3	28-Jul-86
ROCK RIVER EAST OF SUMNER	126	0 3	04-Aug-86

WAUBESA LAKE - BABCOCK PARK	55	0 3	14-Jul-86
WAUBESA LAKE - BABCOCK PARK	73	0 3 2	21-Jul-86
WAUBESA LAKE - BABCOCK PARK	100	0 3	28-Jul-86
WAUBESA LAKE - BABCOCK PARK	122	0 3 4	04-Aug-86
WAUBESA LAKE - CHRISTY'S LAN	23	0 3 2	07-Jul-86
WAUBESA LAKE - GOODLAND PARK	54	0 3	14-Jul-86
WAUBESA LAKE - GOODLAND PARK	72	0 3	21-Jul-86
WAUBESA LAKE - GOODLAND PARK	99	0 3	28-Jul-86
WAUBESA LAKE - GOODLAND PARK	120	0 3	04-Aug-86
WAUBESA LAKE - LAKE FARM CO.	22	0 5	07-Jul-86
WAUBESA LAKE - LAKE FARM CO.	53	0 3	14-Jul-86
WAUBESA LAKE - LAKE FARM CO.	71	0 3	21-Jul-86
WAUBESA LAKE - LAKE FARM CO.	98	0 5	28-Jul-86
WAUBESA LAKE - LAKE FARM CO.	119	0 3	04-Aug-86
WINGRA LAKE	2	0 3	10-Jun-86
WINGRA LAKE	19	0 3	07-Jul-86
WINGRA LAKE PARK LAGOON	20	0 5	07-Jul-86
WINGRA LAKE PARK LAGOON	51	0 3 1	14-Jul-86
WINGRA LAKE PARK LAGOON	69	0 3	21-Jul-86
WINGRA LAKE PARK LAGOON	96	0 3	28-Jul-86
WINGRA LAKE PARK LAGOON	117	0 1 3	04-Aug-86
WINGRA LAKE-VILAS PARK BEACH	21	0 3	07-Jul-86
WINGRA LAKE-VILAS PARK BEACH	52	0 3	14-Jul-86
WINGRA LAKE-VILAS PARK BEACH	70	0 3 1	21-Jul-86
WINGRA LAKE-VILAS PARK BEACH	97	0 3 1	28-Jul-86
WINGRA LAKE-VILAS PARK BEACH	118	0 3 1	04-Aug-86

Table 4 Results for all samples collected and screened from Wisconsin Waters by WDNR for Algae Toxins during 1986.

Analyzed by Wyatt Repavich
at State Lab of Hygiene

Results
0-Negative
1-Positive
2-Marginally Positive

Algae
1-ANABAENA
2-APHANIZOMENON
3-MICROCYSTIS
4-GLOEOTRICHIA
5-NONE
6-LYNGBYA
7-OSCILLATORIA

#	TOWNSHIP	RANGE	LAKE NAME	RESULT	ALGAE TYPES
1	T24N	R01E	CUNNINGHAM CREEK	0	5
2	T7N	R09E	WINGRA LAKE	0	3
3	T13N	R06E	DELTON LAKE	2	1 2 3
4	T13N	R06E	DELTON LAKE	0	1 2 3
5	T13N	R06E	DELTON LAKE	1	1 2 3
6	T13N	R06E	DELTON LAKE	0	1 2 3
7	T2N	R16E	DELAVAN LAKE	0	3 1 2
8	T32N	R18W	CEDAR LAKE	0	4 3 1
9	T4N	R04E	YELLOWSTONE LAKE	0	2
10	T6N	R10E	KEGONSA LAKE	0	2 3
11	T13N	R06E	DELTON LAKE	0	1
12	T29N	R12W	TAINTER LAKE	0	3 1 2
13	T19N	R16E	LITTLE BUTTE DES MORTES LAKE	0	1
14	T29N	R12W	TAINTER LAKE	0	3
15	T28N	R08W	WISSOTA LAKE	0	2 1 3
16	T29N	R01E	HOLDING POND DORCHESTER POTW	0	3
17	T29N	R01E	HOLDING POND LYNN DAIRY	0	3
18	T9N	R19E	FIVE LAKE	0	1 3
19	T7N	R09E	WINGRA LAKE	0	3
20	T7N	R09E	WINGRA LAKE PARK LAGOON	0	5
21	T7N	R09E	WINGRA LAKE-VILAS PARK BEACH	0	3
22	T6N	R10E	WAUBESA LAKE - LAKE FARM CO. PARK	0	5
23	T6N	R10E	WAUBESA LAKE - CHRISTY'S LANDING	0	3 2
24	T6N	R10E	KEGONSA LAKE - FISH CAMP CO. PARK	0	5
25	T6n	R10e	KEGONSA LAKE OUTLET	0	3 2 1
26	T5N	R13E	KOSHKONONG LAKE	0	2 1 3
27	T5N	R13E	KOSHKONONG LAKE	0	5
28	T6N	R14E	ROCK RIVER EAST OF SUMNER	0	2
29	T9N	R19E	FIVE LAKE	0	1 3
30	T9N	R19E	FIVE LAKE	0	1 3
31	T11N	R08E	WISCONSIN LAKE MOON LIGHT BAY	2	2 3 1
32	T11N	R08E	WISCONSIN LAKE MERRIMAC BOAT LAND	1	2 1 3
33	T27N	R08W	ALTOONA LAKE	0	1 2 3
34	T28N	R08W	WISSOTA	0	2 1 3
35	T15N	R13E	LITTLE GREEN LAKE	1	3 4
36	T2N	R16E	DELAVAN LAKE-NORTHWEST CHANNEL	0	3 2 1
37	T2N	R16E	DELAVAN LAKE -SWIM BEACH WEST END	0	3 2

38	T2N	R16E	DELAVAN LAKE LAWN LODGE BEACH	0	2 3
39	T33N	R10W	TEN MILE LAKE	1	3 2 1
40	T33N	R11W	PRAIRE LAKE	1	3
41	T13N	R03E	REDSTONE LAKE	0	1 3 2
42	T34N	R17W	POLK COUNTY	0	1 2 3
43	T28N	R12W	MENOMIN LAKE W. BEACH	1	3 1 2
44	T29N	R12W	TAINTER LAKE, WEST SHORE	1	3 1
45	T33N	R11W	PRAIRE LAKE	0	3 1
46	T33N	R10W	CHETEK LAKE NEAR DAM	0	3 1 2
47	T21N	R06W	TRUMP LAKE	0	1 3 2
48	T31N	R20E	BASS LAKE WEST END	0	3 1
49	T12N	R14E	BEAVER DAM LAKE HWY G	1	3 1
50	T12N	R14E	BEAVER DAM LAKE HWY D	0	3
51	T7N	R09E	WINGRA LAKE PARK LAGOON	0	3 1
52	T7N	R09E	WINGRA LAKE-VILAS PARK BEACH	0	3
53	T6N	R10E	WAUBESA LAKE - LAKE FARM CO. PARK	0	3
54	T6N	R10E	WAUBESA LAKE - GOODLAND PARK BEACH	0	3
55	T6N	R10E	WAUBESA LAKE - BABCOCK PARK BEACH	0	3
56	T6N	R10E	KEGONSA LAKE - FISH CAMP CO. PARK	0	3
57	T6N	R10E	KEGONSA LAKE OUTLET	0	3
58	T5N	R13E	KOSHKONONG LAKE	0	1
59	T5N	R13E	KOSHKONONG LAKE	0	1
60	T6N	R14E	ROCK RIVER EAST OF SUMNER	0	3 1
61	T2N	R16E	DELAVAN LAKE LAWN LODGE BEACH	0	5
62	T2N	R16E	DELAVAN LAKE-NORTHWEST CHANNEL	0	3 2 1
63	T2N	R16E	DELAVAN LAKE -SWIM BEACH WEST END	0	3
64	T13N	R03E	REDSTONE LAKE-WEST SHORE	0	3 1
65	T31N	R18W	SQUAW LAKE NORTHEAST END	1	3 1
66	T7N	R18E	PEWAUKEE LAKE	0	3
67	T7N	R18E	PEWAUKEE LAKE	0	5
68	T7N	R10E	MONONA LAKE	0	4 3
69	T7N	R09E	WINGRA LAKE PARK LAGOON	0	3
70	T7N	R09E	WINGRA LAKE-VILAS PARK BEACH	0	3 1
71	T6N	R10E	WAUBESA LAKE - LAKE FARM CO. PARK	0	3
72	T6N	R10E	WAUBESA LAKE - GOODLAND PARK BEACH	0	3
73	T6N	R10E	WAUBESA LAKE - BABCOCK PARK BEACH	0	3 2
74	T6N	R10E	KEGONSA LAKE - FISH CAMP CO. PARK	0	3
75	T6N	R10E	KEGONSA LAKE OUTLET	0	5
76	T5N	R13E	KOSHKONONG LAKE-SHANTY INN	0	1
77	T5N	R13E	KOSHKONONG LAKE-ROCK R.	0	1
78	T6N	R14E	ROCK RIVER EAST OF SUMNER	0	5
79	T7N	R09E	MONONA BAY-TRIANGLE BOAT HOUSE	0	3 2
80	T7N	R09E	MONONA BAY-NORTH BEACH	0	3 2
81	T11N	R08E	WISCONSIN LAKE-HWY V AT GRADS	0	1 3 2
82	T6N	R03E	COX HOLLOW LAKE	0	1 3
83	T0N	R00E	FOX RIVER	0	4 3 1 2
84	T26N	R06E	BIG EAU PLEINE RESERVOR- CO. O	0	2
85	T26N	R06E	BIG EAU PLEINE RESERVOIR-CO. O	0	1
86	T13N	R03E	REDSTONE LAKE	2	1 3
87	T13N	R03E	REDSTONE LAKE	0	1 3
88	T2N	R16E	DELAVAN LAKE LAWN LODGE BEACH	0	3 2 1

89	T2N	R16E	DELAVAN LAKE-S W BEACH	0	3 2
90	T26N	R07E	BAKER, MATT FARM	0	1 3
91	T40N	R01W	BUTTERNUT LAKE	0	2
92	T18N	R16E	BEAU DES MORTES	0	3 1 4
93	T9N	R07E	CRYSTAL LAKE	0	3 2 1
94	T32N	R16W	MARTIN POND-FISH REARING POND POLK	2	3 2 1
95	T34N	R18W	FROKNER POND-FISH REARING POND	2	3 1
96	T7N	R09E	WINGRA LAKE PARK LAGOON	0	3
97	T7N	R09E	WINGRA LAKE-VILAS PARK BEACH	0	3 1
98	T6N	R10E	WAUBESA LAKE - LAKE FARM CO. PARK	0	5
99	T6N	R10E	WAUBESA LAKE - GOODLAND PARK BEACH	0	3
100	T6N	R10E	WAUBESA LAKE - BABCOCK PARK BEACH	0	3
101	T6N	R10E	KEGONSA LAKE - FISH CAMP CO. PARK	0	3
102	T6N	R10E	KEGONSA LAKE OUTLET	0	1 2
103	T5N	R13E	KOSHKONONG LAKE-SHANTY INN	0	1
104	T5N	R13E	KOSHKONONG LAKE-ROCK R.	0	5
105	T6N	R14E	ROCK RIVER EAST OF SUMNER	0	1 3
106	T2N	R16E	DELAVAN LAKE WEST BEACH # 2	0	3 1
107	T2N	R16E	DELAVAN LAKE LAWN LODGE	0	3 2 1
108	T34N	R17W	POLK CO-BELD POND-WALLEYE REARING	0	1 3 2
109	T34N	R17W	POLK CO-HELMAN'S POND-WALLEYE	0	5
110	T33N	R15W	MAGNOR LAKE	2	3 1
111	T33N	R17W	WAPOGASSET LAKE	0	1 4 3
112	T12N	R10E	CRYSTAL LAKE	0	2 3
113	T11N	R06E	DEVILS LAKE	0	5
114	T19N	R21E	BIG LONG LAKE-BOAT LANDING	1	1 3 2
115	T13N	R03E	REDSTONE LAKE-WEST SHORE	0	3 1
116	T12N	R05E	VIRGINIA LAKE-NORTH SHORE	0	3
117	T7N	R09E	WINGRA LAKE PARK LAGOON	0	1 3
118	T7N	R09E	WINGRA LAKE-VILAS PARK BEACH	0	3 1
119	T6N	R10E	WAUBESA LAKE - LAKE FARM CO. PARK	0	3
120	T6N	R10E	WAUBESA LAKE - GOODLAND PARK BEACH	0	3
122	T6N	R10E	WAUBESA LAKE - BABCOCK PARK BEACH	0	3 4
121	T6N	R10E	KEGONSA LAKE - FISH CAMP CO. PARK	0	3
123	T6N	R10E	KEGONSA LAKE OUTLET	0	2 3
124	T5N	R13E	KOSHKONONG LAKE-DRIFT INN	0	5
125	T5N	R13E	KOSHKONONG LAKE-ROCK R.	0	3
126	T6N	R14E	ROCK RIVER EAST OF SUMNER	0	3
127	T20N	R17E	WINNEBAGO LAKE HIGH CLIFF MARINA	0	3 4
128	T20N	R17E	WINNEBAGO LAKE HIGH CLIFF	2	3 4
129	T38N	R10E	THUNDER LAKE-BELOW DAM	0	1
130	T38N	R10E	THUNDER LAKE-ABOVE DAM	0	1
136	T40N	R07E	LITTLE ARBOR VITAE NE LDG	0	4 3 1
140	T37N	R06E	BEARSKIN, BIG LAKE EAST END	0	4 3 1
141	T20N	R17E	WINNEBAGO LAKE HIGH CLIFF MARINA	2	4
142	T33N	R17W	WAPOGASSET LAKE	2	1 3
143	T41N	R14W	STAPLES LAKE	1	3 1
144	T41N	R14W	STAPLES LAKE	2	3 1
145	T33N	R17W	WAPOGASSET LAKE	0	1 3 2
149	T34N	R14E	ROBERTS LAKE-SE BOAT LANDING	0	4
154	T35N	R12E	BISHOP LAKE-SE BOAT LANDING	0	1 3

156	T24N	R21E	GREEN BAY GRID 1001 1/4 MI OF BAY	1	3		
157	T36N	R17W	BUTTERNUT BIG LAKE	1	3	1	
158	T39N	R12W	POND 10 SPOONER W/W HATCHERY	0	5		
159	T39N	R12W	POND 7 SPOONER W/W HATCHERY	0	5		
160	T38N	R08E	MUSKELUNGE LAKE SW SHORE BT LANDING	0	1		
161	T12N	R05E	VIRGINIA LAKE NORTH END CHANNEL	0	3		
162	T34N	R17W	BALSAM EAST LAKE	0	1	3	
163	T34N	R17W	BALSAM LAKE	0	1	3	
164	T38N	R10E	THUNDER LAKE SOUTH SHORE	0	5		
165	T37N	R12E	PINE LAKE NE SIDE	0	1		
166	T40N	R10E	EAGLE RIVER HWY 17 BRIDGE	0	3	1	
167	T40N	R10E	CATFISH/EAGLE LAKE THOROUGHFARE	0	3	1	
168	T40N	R10E	SCATTERING RICE LAKE SOUTH SHORE	0	4		
169	T40N	R11E	TAMBLING LAKE OUTFLOW RANGELINE	0	5		
170	T40N	R11E	ANVIL LAKE SOUTH SIDE BT LANDING	0	1		
171	T40N	R11E	BASS LAKE EAST SIDE R.E.PETERSON	0	5		
172	T17N	R04E	CASTLE ROCK LAKE NW SIDE BACKWATER	0	1	4	
173	T17N	R04E	CASTLE ROCK LAKE NW SIDE	0	1	3	2
174	T16N	R04E	CASTLE ROCK LAKE SW SIDE CO. G	0	1	3	2
175	T2N	R16E	DELAVAN LAKE SOUTH CHANNEL	0	3	2	1
176	T2N	R16E	DELAVAN LAKE LAWN	0	3	2	
177	T2N	R16E	DELAVAN LAKE WEST BRANCH	0	5		
178	T2N	R16E	DELAVAN LAKE N W BEACH	0	3		
179	T12N	R12E	PARK LAKE ADJ TO SWIMMING AREA	0	1	3	
180	T12N	R12E	PARK LAKE CITY PARK ENTRANCE	0	1	3	
181	T33N	R06E	TUG LAKE NORTH SHORE SWIMMING BEACH	0	1		
182	T40N	R09E	MUSKELUNGE LAKE NORTH SIDE	0	2	1	3
183	T40N	R09E	BOOT LAKE NORTH SIDE SUNNYBROOK	0	1	3	2
184	T20N	R17E	WINNEBAGE LAKE HIGH CLIFF MARINA	2	4	1	
185	T18N	R23E	CARSTENS LAKE WEST SHORE	0	2	1	
186	T33N	R17W	WAPOGASSET LAKE	1	3	1	2
187	T33N	R17W	WAPOGASSET LAKE	0	3	1	
188	T35N	R16W	BONE LAKE	1	3	1	
189	T33N	R15W	MAGNOR LAKE	0	3	1	
190	T7N	R10E	MONONA LAKE AT STORKWEATHER CR	0	4	3	
191	T20N	R17E	WINNEBAGO LAKE RAW APPLETON INTAKE	0	1		
192	T20N	R17E	WINNEBAGO LAKE FINISHED APPLETON	0	5		
193	T20N	R17E	WINNEBAGO LAKE MENASHA FILTRATION	0	1	3	
194	T20N	R17E	WINNEBAGO LAKE MENASHA TAP WATER	0	5		
195	T19N	R17E	WINNEBAGO LAKE NEENAH RAW WATER	0	1	3	
196	T19N	R17E	WINNEBAGO LAKE NEENAH FINISHRD TAP	0	5		
197	T18N	R17E	WINNEBAGO LAKE OSHKOSH RAW WATER	0	1		
198	T18N	R17E	WINNEBAGO LAKE OSHKOSH FINISHRD TAP	0	5		
199	T22N	R11E	SUNSET LK RAW KING WI VET HOME	0	5		
200	T22N	R11E	SUNSET LK FINISHED KING WI VET HOME	0	5		
201	T32N	R06E	PESOBIC LAKE EAST SHORE	0	5		
202	T32N	R06E	PESOBIC LAKE EAST SHORE	0	5		
203	T19N	R24E	MICHIGAN LAKE RAW MANITOWOC INTAKE	0	5		
204	T19N	R24E	MICHIGAN LAKE FINISHED MANITOWOC	0	5		
205	T23N	R25E	MICHIGAN LAKE RAW GREEN BAY CITY	0	5		
206	T23N	R25E	MICHIGAN LAKE FINISHED GREEN BAY	0	5		

207	T30N	R24E	MICHIGAN LAKE RAW MARINETTE	0	5		
208	T30N	R24E	MICHIGAN LAKE FINISHED MARINETTE	0	5		
209	T2N	R16E	DELAVAN LAKE NORTH SHORE 1	0	3	1	
210	T2N	R16E	DELAVAN LAKE NORTH SHORE 2	0	3	1	
211	T2N	R16E	DELAVAN LAKE NORTH SHORE 3	0	3	2	1
212	T2N	R16E	DELAVAN LAKE CHANNEL 4	0	3	1	
213	T2N	R16E	DELAVAN LAKE SOUTH SHORE 5	0	3	2	1
214	T20N	R18E	WINNEBAGO LAKE HIGH CLIFF MARINA	1	1	3	4
215	T20N	R17E	WINNEBAGO LAKE RAW APPLETON INTAKE	0	5		
216	T20N	R17E	WINNEBAGO LAKE FINISHED APPLETON	0	5		
217	T20N	R17E	WINNEBAGO LAKE MENASHA FILTRATION	0	5		
218	T20N	R17E	WINNEBAGO LAKE MENASHA TAP WATER	0	5		
219	T19N	R17E	WINNEBAGO LAKE NEENAH RAW WATER	0	5		
220	T19N	R17E	WINNEBAGO LAKE NEENAH FINISHRD TAP	0	5		
221	T18N	R17E	WINNEBAGO LAKE OSHKOSH RAW WATER	0	5		
222	T18N	R17E	WINNEBAGO LAKE OSHKOSH FINISHRD TAP	0	5		
223	T22N	R11E	SUNSET LK RAW KING WI VET HOME	0	5		
224	T22N	R11E	SUNSET LK FINISHED KING WI VET HOME	0	5		
225	T7N	R10E	MONONA LAKE EAST SHORE	0	3		
226	T19N	R24E	MICHIGAN LAKE RAW MANITOWOC INTAKE	0	5		
227	T19N	R24E	MICHIGAN LAKE FINISHED MANITOWOC	0	5		
228	T23N	R25E	MICHIGAN LAKE RAW GREEN BAY CITY	0	5		
229	T23N	R25E	MICHIGAN LAKE FINISHED GREEN BAY	0	5		
230	T30N	R24E	MICHIGAN LAKE RAW MARINETTE	0	5		
231	T30N	R24E	MICHIGAN LAKE FINISHED MARINETTE	0	5		
232	T19N	R21E	BULLHEAD LAKE WEST PUB. LANDING	0	6	1	3
233	T38N	R09W	SISSABAGAMA LAKE SW SHORE	0	3	1	6
234	T40N	R08E	LITTLE ST. GERMAIN LAKE EAST BAY	0	3	1	
235	EXTRA	BOTTLE	NOT TESTED DUPLICATE				
236	T35N	R10E	PELICAN LAKE EAST SIDE	0	3	1	
237	T35N	R10E	PELICAN LAKE EAST SIDE	0	3		
238	T26N	R06E	BIG EAU PLEINE RESERVOIR SE BOAT	0	1		
239	T26N	R06E	BIG EAU PLEINE RESERVOIR SE BOAT	2	1		
240	T26N	R06E	BIG EAU PLEINE RESERVOIR SE BOAT	0	1		
241	T18N	R04E	PETENWELL LAKE CHICAGO AV. BOAT	1	3		
242	T18N	R04E	PETENWELL LAKE ARROWHEAD LAGOON	0	5		
243	T18N	R04E	PETENWELL LAKE MONROE PARK	0	3		
244	T18N	R04E	PETENWELL LAKE PETENWELL PARK	1	3	1	
245	T26N	R06E	BIG EAU PLEINE RES. CT. O SW SIDE	0	3		
246	T26N	R06E	BIG EAU PLEINE RES. CT. O NW SIDE	1	1	3	
247	T26N	R05E	BIG EAU PLEINE RESERVOIR PARK	0	5		
248	T19N	R24E	MICHIGAN LAKE RAW MANITOWOC INTAKE	0	5		
249	T19N	R24E	MICHIGAN LAKE FINISHED MANITOWOC	0	5		
250	T23N	R25E	MICHIGAN LAKE RAW GREEN BAY CITY	0	5		
251	T23N	R25E	MICHIGAN LAKE FINISHED GREEN BAY	0	5		
252	T30N	R24E	MICHIGAN LAKE RAW MARINETTE	0	5		
253	T30N	R24E	MICHIGAN LAKE FINISHED MARINETTE	0	5		
254	T43N	R03E	LAKE OF THE FALLS(FLAMBEAU FLOWAGE	0	1	3	
255	T42N	R03E	WILSON LAKE	0	3		
256	T40N	R01W	BUTTERNUT LAKE #1 WEST BOATLANDING	0	3	1	2
257	T40N	R01W	BUTTERNUT LAKE #2 SW SHORE SMALL	0	3	1	2

258	T2N	R16E	DELAVAN LAKE HWY 15 & 50 ASSEMBLY	0		3
259	T2N	R16E	DELAVAN LAKE SOUTH SHORE	0		3
260	T2N	R16E	DELAVAN LAKE HY 15&50 VIEWCREST	0		3
261	T2N	R16E	DELAVAN LAKE HY 15&50 HIGHLAND	0		3
262	T20N	R17E	WINNEBAGO LAKE RAW APPLETON INTAKE	0		5
263	T20N	R17E	WINNEBAGO LAKE FINISHED APPLETON	0		5
264	T19N	R17E	WINNEBAGO LAKE NEENAH RAW WATER	0		5
265	T19N	R17E	WINNEBAGO LAKE NEENAH FINISHRD TAP	0		5
266	T20N	R17E	WINNEBAGO LAKE MENASHA FILTRATION	0		3 7
267	T20N	R17E	WINNEBAGO LAKE MENASHA TAP WATER	0		5
268	T18N	R17E	WINNEBAGO LAKE OSHKOSH RAW WATER	0		3 7
269	T18N	R17E	WINNEBAGO LAKE OSHKOSH FINISHED TAP	0		5
270	T22N	R11E	SUNSET LK RAW KING WI VET HOME	0		3
271	T22N	R11E	SUNSET LK FINISHED KING WI VET HOME	0		5
272	T7N	R10E	MONONA LAKE AT STARKWEATHER CR.	0		6 3
273	T11N	R06E	DEVILS LAKE PLANKTON TOW	0		3 1
274	T5N	R12E	PAUL BURNS POND	0		1
275	T5N	R12E	PAUL BURNS POND	0		1
276	T2N	R16E	DELAVAN LAKE HIGHLAND CHANNEL	0		3
277	T2N	R16E	DELAVAN LAKE HIGHLAND BEACH	0		3
278	T2N	R16E	DELAVAN LAKE CREST CHANNEL	0		3 6
279	T2N	R16E	DELAVAN LAKE ASSEMBLY GROUNDS	0		3
280	T2N	R16E	DELAVAN LAKE SOUTH SHORE CHANNEL	0	3	1 2 6 7
281	T40N	R08E	LITTLE ST GERMAIN LAKE EAST BAY	0		1 3
282	T40N	R08E	STELLA LAKE BOAT LANDING	0		1 3
283	T39N	R07E	MADELINE LAKE OFF CTH J	0		1 3
284	T39N	R07E	SNAKE LAKE OFF HWY 47	0		5
285	T39N	R07E	CARROL LAKE OFF CTH J	0		1 3 2 7
286	T39N	R08E	RAINBOW FLOWAGE CTH E NEAR DAM	0		1 3 2
287	T35N	R12E	BISHOP LAKE - SOUTH BOAT LANDING	0		5
288	T34N	R13E	CRANE LAKE - ANDERSON HOUSE	0		3 1 2
289	T34N	R13E	PICKEREL LAKE VORAS TAVERN	0		3
290	T34N	R13E	DEEP HOLE LAKE MIDDLE SURFACE	0		5
291	T35N	R13E	LITTLE SAND LAKE BOAT LANDING	0		5
292	T28N	R08W	WISSOTA LAKE - MOON BAY	0		3 1
293	T12N	R10E	PARK LAKE	0		3 1
294	T40N	R11E	CRANBERRY LAKE PUB. BOAT LANDING	0		3 1
295	T13N	R03E	REDSTONE LAKE BOAT LANDING	0		1 2 7
296	T13N	R03E	DUTCH HOLLOW LAKE PUB. BOAT LANDING	0		6 3 1
297	T34N	R12E	AGNES LAKE MIDDLE 1 METER	0		1
298			CATTLE DEATH-ANIMAL HEALTH LAB	0		
299	T38N	R10W	LONG LAKE AT THE NARROWS	0	3	2 1 6 7
300	T38N	R09W	SISSABAGAMA LAKE BIG BOAT LANDING	2		2 1 3
301	T31N	R18W	RIVERDALE FLOWAGE-APPLE RIVER	1		2 1
302	T15N	R15E	DAVID ZECH INT. STREAM BEHIND SHED	0		DIATOMS
303	T15N	R15E	DAVID ZECH INT. STREAM BEHIND SHED	0		DIATOMS
304	T15N	R15E	DAVID ZECH INT. STREAM BEHIND SHED	0		DIATOMS
305	T15N	R15E	DAVID ZECH INT. STREAM BEHIND SHED	0		DIATOMS
306	T15N	R15E	DAVID ZECH INT. STREAM BEHIND SHED	0		DIATOMS
307	T14N	R12E	MARIA LAKE SE SHORELINE	2		2 1
308	T15N	R15E	DAVID ZECH INT. STREAM BEHIND SHED	0		DIATOMS

Table 5 Surface Water Inventory Info. on [redacted] Lakes

Lake Name	BEAVER DAM LAKE	BIG EAU PLEINE RESERVOIR	BIG LONG LAKE	BONE LAKE	BUTTERNUT LAKE	CATFISH LAKE	DELTON LAKE	EAGLE LAKE	LITTLE GREEN LAKE	MAGNOR LAKE	MARIA LAKE	MENOMIN L
County Number	14	37	36	49	3	64	57	64	24	49	24	17
Area in acres	6542	6830	120	1781	141	1012	267	572	466	224	596	1405
Lake(1)Stream(2)Impoundment(3)	3	3	1	1	1	1	3	1	1	1	1	3
Max. Depth Feet	7	46	37	43	15	30	16	34	28	15	6	34
Area Greater than 20 feet	0%	31%	20%	20%	0%	15%	0%	15%	0%	0%	0%	15%
Area Less than 3 feet	30%	7%	1%	15%	25%	5%	20%	4%	0%	25%	40%	15%
Area Sand Bottom	0%	60%	0%	75%	70%	55%	50%	30%	15%	60%	0%	70%
Area Gravel Bottom	0%	0%	5%	0%	10%	20%	0%	15%	10%	15%	0%	10%
Area Rock Bottom	7%	15%	0%	15%	0%	10%	0%	10%	10%	5%	0%	0%
Area Muck Bottom	93%	25%	95%	10%	20%	15%	50%	45%	65%	20%	99%	20%
Direct Drainage Area Sq. Miles	131	288	1	12	2	4	4	2	4	3	5	9
Area Agricultural Drainage	97%	53%	99%	35%	0%	10%	50%	5%	70%	80%	90%	90%
Area Wild & Wetland Drainage	3%	47%	0%	65%	99%	90%	50%	95%	30%	20%	10%	10%
Watershed Area Sq. Miles	139	330	2	15	2	128	80	118	4	6	5	1761
Inlet 0(None)1(Navigable)2(Not Nav)3(Several)	1	3	2	2	0	1	1	1	2	1	0	1
Outlet 0(None)1(Navigable)2(Not Nav)3(Intermittent)	1	1	2	1	0	1	1	1	2	2	0	1
Landlocked 1(Yes) 2(no)	2	2	2	2	2	2	2	2	1	2	1	2
Water Control Structure Height Feet	10	31	0	0	0	0	20	0	0	0	0	30
Alkalinity ppm	326	71	148	122	5	34	81	39	124	21	151	79
pH Standard Unit	8.5	6.7	7.8	6.8	6.8	7	7.4	7.2	8.4	6.8	7	7.6
Conductance 25 Deg. C umho/sec	719	157	262		30	64	146	87	242	153	327	166
Water Color 1(Lt.Br)2(Med.Br)3(Dk.Br)4(Clear)5(Turbid)	5	2	1		2	2	4	1	4		5	3
Secchi Disk Feet	1		5			7	2	4	9			6
Chloride mg/l	3	3	1	1	1	1	3	1	1	1	1	23
Winterkill 1(Yes)2(No)	1	2	2	2	2	2	2	2		2	1	2
Algae Public Complaints 1(Yes)2(No)	1	2	1	2	2	1	1	2		2		2
Carp 1(Yes)2(No)	1	2	1	2	2	2	2	2		2		1
Stunted PanFish 1(Yes)2(No)		2	1	2	2	2	2	2		2		2
Pollution Reached Lake 1(Yes)2(No)		1	2	2	2	2	1	2	2	2	1	1
Fluctuating Water Levels 1(Stable)2(+2 Ft&Man)3(+2 Ft&Natural)		2	2	2	1	1	2	1		2		2
Area of Adjoining Wetland(Acres)	1660	273	1	180	9	8	0	60	148	57	64	1
Percent Wetland Non-Woody	99%	0%	0%	40%	30%	60%	0%	50%	5%	99%	0%	50%
Percent Wetland Woody	1%	0%	99%	60%	70%	40%	0%	50%	95%	0%	99%	50%
Lake Volume Acre-Feet	30677	106602			1039	11818	2136		4817	2227		

Table 5 Surface Water Inventory Info. on [redacted] Lakes

Lake Name	PETENWELL LAKE	PRAIRIE LAKE	REDSTONE LAKE	RIVERDALE FLOWAGE	SISSABAGAMA LAKE	SQUAW LAKE	STAPLES LAKE	TAINTER LAKE	TENMILE LAKE	WAPOGASSET LAKE	WINNEBAGO LAKE	WISCONSIN
County Number	29	3	57	56	58	56	7	17	3	49	71	57
Area in acres	22218	1534	612	75	719	129	77	1752	376	1186	137708	3172
Lake(1)Stream(2)Impoundment(3)	3	3	3	3	1	1	1	3	3	1	1	3
Max. Depth Feet	44	16	36	20	48	32	41	37	12	32	21	24
Area Greater than 20 feet	35%	0%	24%	1%	25%	0%	40%	15%	0%	20%	15%	5%
Area Less than 3 feet	15%	5%	7%	15%	15%	30%	10%	15%	30%	12%	3%	20%
Area Sand Bottom	65%	75%	40%	70%	50%	70%	60%	65%	80%	60%	0%	80%
Area Gravel Bottom	20%	5%	0%	20%	5%	20%	20%	5%	10%	25%	0%	0%
Area Rock Bottom	0%	0%	0%	5%	20%	0%	0%	5%	0%	0%	0%	0%
Area Muck Bottom	15%	20%	60%	5%	25%	10%	20%	25%	10%	15%	0%	20%
Direct Drainage Area Sq. Miles	69	13	4	2	3	1	1	25	5	5	0	24
Area Agricultural Drainage	0%	79%	60%	95%	5%	45%	0%	85%	60%	30%	0%	90%
Area Wild & Wetland Drainage	0%	21%	40%	5%	95%	55%	99%	15%	40%	70%	0%	10%
Watershed Area Sq. Miles	5879	21	30	317	3	1	1	1677	62	59	6124	9003
Inlet 0(None)1(Navigable)2(Not Nav)3(Several)	1	1	2	1	0	0	0	1	1	1	1	1
Outlet 0(None)1(Navigable)2(Not Nav)3(Intermittent)	1	1	2	1	0	0	0	1	1	1	1	1
Landlocked 1(Yes) 2(no)	2	2	2	2	2	1	1	2	2	2	2	2
Water Control Structure Height Feet	42	0	38	23	1	0	0	52	0	3	5	38
Alkalinity ppm	30	45	101	125	34	25	47	77	44	111	135	
pH Standard Unit	8.6	6.8	8.8	8	7.9	7.6	7.4	7.4	6.8	7.2	8.6	
Conductance 25 Deg. C umho/sec	139	88	300	257	72	82	90	175	93	218	335	
Water Color 1(Lt.Br)2(Med.Br)3(Dk.Br)4(Clear)5(Turbid)	1	1	5	1	4	1	1	5	1		5	2
Secchi Disk Feet	2		2	12		7	15	9			2	
Chloride mg/l	3	3	3	3	1	1	1	23	3	1	1	3
Winterkill 1(Yes)2(No)	1	2	2	2	2	1	2	2	2	2	2	2
Algae Public Complaints 1(Yes)2(No)	2	1	1	2	2	2	2	1	1	2	1	2
Carp 1(Yes)2(No)	2	2	2	2	2	2	2	1	2	2	1	2
Stunted Panfish 1(Yes)2(No)	2	2	1	2	1	2	2	2	2	2	2	2
Pollution Reached Lake 1(Yes)2(No)	1	2	2	2	2	2	2	2	2	2	1	1
Fluctuating Water Levels 1(Stable)2(+2 Ft&Man)3(+2 Ft&Nat	2	1	2	2	1	1	1	1	1	2	1	2
Area of Adjoining Wetland(Acres)	560	3			265	4		10	27	108	620	179
Percent Wetland Non-Woody	0%	50%	0%	0%	10%	99%	0%	90%	50%	99%	10%	0%
Percent Wetland Woody	99%	50%	0%	0%	90%	0%	0%	10%	50%	0%	90%	99%
Lake Volume Acre-Feet		14035	8716	468		1626		24528	2369	20469		

Table 5 Surface Water Inventory Info. on [redacted]Lakes

Lake Name	WISCONSIN LAKE
County Number	11
Area in acres	8900
Lake(1)Stream(2)Impoundment(3)	3
Max. Depth Feet	24
Area Greater than 20 feet	10%
Area Less than 3 feet	5%
Area Sand Bottom	50%
Area Gravel Bottom	7%
Area Rock Bottom	3%
Area Muck Bottom	40%
Direct Drainage Area Sq. Miles	123
Area Agricultural Drainage	65%
Area Wild & Wetland Drainage	35%
Watershed Area Sq. Miles	8950
Inlet 0(None)1(Navigable)2(Not Nav)3(Several)	1
Outlet 0(None)1(Navigable)2(Not Nav)3(Intermittent)	1
Landlocked 1(Yes) 2(no)	2
Water Control Structure Height Feet	38
Alkalinity ppm	72
pH Standard Unit	8.7
Conductance 25 Deg. C umho/sec	227
Water Color 1(Lt.Br)2(Med.Br)3(Dk.Br)4(Clear)5(Turbid)	4
Secchi Disk Feet	3
Chloride mg/l	3
Winterkill 1(Yes)2(No)	2
Algae Public Complaints 1(Yes)2(No)	1
Carp 1(Yes)2(No)	1
Stunted PanFish 1(Yes)2(No)	2
Pollution Reached Lake 1(Yes)2(No)	1
Fluctuating Water Levels 1(Stable)2(+2 Ft&Man)3(+2 Ft&Nat	2
Area of Adjoining Wetland(Acres)	985
Percent Wetland Non-Woody	54%
Percent Wetland Woody	46%
Lake Volume Acre-Feet	53400