IOWA STATE UNIVERSITY
LIMNOLOGY LABORATORY

BLACK HAWK LAKE

DIAGNOSTIC/FEASIBILITY STUDY

IOWA DEPARTMENT OF NATURAL RESOURCES
2010

EXECUTIVE SUMMARY

Black Hawk Lake water quality is poor showing high levels of nutrients and suspended solids, low water clarity, and near-constant Cyanobacteria (aka blue-green algae) blooms. The lake receives high loads of nutrients, sediment, and bacteria from the watershed. Currently, the lake is filling with sediment that will enhance Cyanobacteria problems and shorten the useful lifetime of the lake. High nutrient concentrations primarily originate (70-90%) from activities in the upper watershed, but direct input near the lake is also detrimental. The Iowa DNR Lakes Restoration Program established a Water Quality Target (WQT) of ≥4.5 ft Secchi depth at least 50% of the time from April to September for Iowa lakes. For Black Hawk Lake, a 75% reduction in phosphorus loading from the watershed is necessary to meet this criterion. An intermediate WQT of ≥2.3 ft Secchi depth has also been considered for Black Hawk Lake. To meet this intermediate WQT, a 35% reduction in phosphorus loading from the watershed is necessary. There are several management strategies that can be used alone or in combination to meet either the intermediate or overall WQTs at varying costs. Management options include stream stabilization and riparian buffer creation, land conversion to perennial vegetation, detention ponds and CREP-style wetlands, and dredging Provost Bay to increase its nutrient and sediment retention efficiency. A table following this summary shows predicted phosphorus savings and estimated costs associated with various management options. Additional phosphorus savings could be achieved through enhanced voluntary efforts initiated by producers within the watershed. These management options include the use of cover crops, crop residue management, conservation tillage, terracing and grass waterways, and manure management. Cost-sharing through federal and state conservation, restoration, and water quality programs could reduce costs and increase the receptiveness of these management options among local producers. Ultimately, the DNR, Iowa NRCS, local officials, local producers, and other stakeholders will need to work together to develop the best combination of management options for the Black Hawk Lake and its watershed. Water quality monitoring (at least two years post-restoration) is recommended to document the effectiveness of the Black Hawk Lake restoration plan.

Phosphorus savings and estimated costs associated with various management options. P savings for stream stabilization and riparian buffers are estimated based on Dinnes (2004) for scenario A4 with P savings for A1-A3 calculated proportionally based on stream length. Estimated costs in gray boxes include land acquisition costs ($5,405 per ac). Cost estimates for dredging Provost Bay include containment site construction and land acquisition costs. Costs were rounded up to the nearest $1,000.

Scenario/Treatment		P Savings	Estimated Cost[1]
WATERSHED	**LAKE**		
A. Stream Stabilization and Riparian Buffers			
1. 1,000 ft (1/2 "unstable" banks)	None	2%	$68,000
			$85,000
2. 1,848 ft (all "unstable" banks)	None	3%	$126,000
			$156,000
3. 15,154 ft (all "unstable" plus 1/2 "moderately stable" banks)	None	24%	$1,028,000
			$1,276,000
4. 28,618 ft (all "unstable" and "moderately stable" banks)	None	45%	$1,941,000
			$2,410,000
B. Perennial Vegetation (% of watershed and surface area)			
1. 5% (658 ac)	None	7%	$205,000
			$3,760,000
2. 10% (1,316 ac)	None	12%	$410,000
			$7,520,000
3. 20% (2,631 ac)	None	23%	$819,000
			$15,039,000
4. 30% (3,947 ac)	None	35%	$1,228,000
			$22,559,000
C. Detention Ponds/CREP Wetlands (8 ponds with mean depth of 3.3 ft)			
1. 5 ac per pond	None	10%	$200,000
			$417,000
2. 10 ac per pond	None	16%	$400,000
			$833,000
3. 20 ac per pond	None	26%	$800,000
			$1,665,000
4. 30 ac per pond	None	32%	$1,200,000
			$2,498,000
D. Dredging Provost Bay (estimated costs include containment site costs)			
None	1. Dredge to 3-ft mean depth	64%	$2,500,000
None	2. Dredge to 6-ft mean depth	78%	$6,500,000

[1] The cost analysis is preliminary and for planning purposes only. More detailed cost estimates should be included as part of the engineering design of the project. Programs to assist landowners interested in conservation practices, may also qualify several of the watershed activities/projects for cost share dollars. This estimate does not consider reductions from such programs.

BLACK HAWK LAKE

DIAGONOSTIC/FEASIBILITY STUDY

Submitted by:

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INTRODUCTION

PROJECT AREA AND HISTORY OF THE WATER QUALITY CONCERNS

Black Hawk Lake is a glacially-formed shallow lake located in west-central Iowa adjacent to the small community of Lake View in Sac County (Figure 1). It lies within the boundaries of Black Hawk State Park and is adjacent to the Black Hawk Wildlife Management Area (WMA). All three areas are managed by the Iowa Department of Natural Resources (Iowa DNR). The Iowa DNR also manages the Black Hawk Waterfowl Production Area adjacent to the WMA. Camp Crescent Park, a full service campground managed by the city of Lake View, is located on the west end of Black Hawk Lake. Over half (59%) of the shoreline is in public ownership.

Water quality problems including sedimentation, summer algal blooms, poor water clarity, winter and summer fish kills have been reported for Black Hawk Lake for decades. Shallow water depth and watershed derived sediments and nutrients have been implicated as contributing to declines in lake water quality. Over the years, a wide range of management practices including aeration and dredging have been used with limited success to improve conditions at Black Hawk Lake.

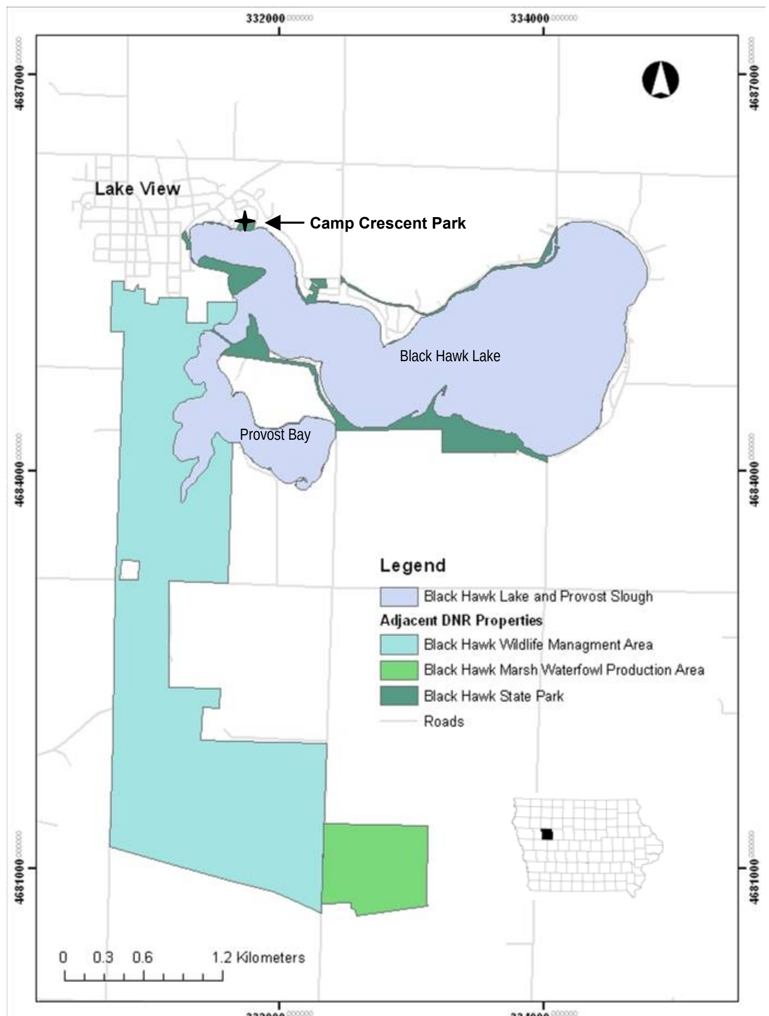


Figure 1. Location of Black Hawk Lake, Sac County, Iowa.

In 1982, a Phase I Diagnostic/Feasibility Study (DFS) was completed. This study recommended additional lake dredging and watershed management to control watershed transport of sediment and nutrients. Over a million cubic yards of sediment were removed from the lake and a wide range of soil conservation practices such as the terraces, grassed waterways, and contour farming were applied in the watershed from 1986-1994 (Iowa DNR 1996).

While some improvements were reported following the implementation of these lake and watershed restoration activities, poor water quality continue to afflict Black Hawk Lake. For example, it was listed on the Section 303(d) List of Impaired Waters in 2006. State, Federal, and City agencies are currently working with concerned citizens to address today's water quality concerns.

A POLICY FRAMEWORK: SURFACE WATER CLASSIFICATION, WATER QUALITY STANDARDS, AND IOWA WATER QUALITY TARGETS

Water Quality Standards (WQS) are used to protect and restore surface waters in agreement with the requirements of the Clean Water Act (CWA §319). WQS set goals and criteria to protect a given water body from pollutants based on its classification or *designated use*. Many factors including the physical, chemical, and biological characteristics of the water body are considered when designated uses for a water body are determined. Also taken into consideration are the use and value of the water body for public water supply and other uses such as recreational, agricultural, industrial, and navigational, as well as for protecting fish and wildlife (EPA 2009).

Under the State water quality classification system, Black Hawk Lake is designated as *Class A1*, *Class B* (LW), and *Class HH*. In short, these designations indicate the lake is used for primary and secondary recreation (e.g., swimming, boating, and fishing) and that it supports aquatic life. More detailed technical descriptions of individual classifications are provided in Box 1.

Surface Water Classification Descriptions
For Black Hawk Lake Designated Uses
Iowa Administrative Code (IAC), 567—61.3(455B)

Class "A1"
Waters in which recreational or other uses may result in prolonged and direct contact with the water, involving considerable risk of ingesting water in quantities sufficient to pose a health hazard. Such activities would include, but not be limited to, swimming, diving, water skiing, and water contact recreational canoeing.

Class "B (LW)"
Artificial and natural impoundments with hydraulic retention times and other physical and chemical characteristics suitable to maintain a balanced community normally associated with lake-like conditions.

Class "HH"
Waters in which fish are routinely harvested for human consumption or waters both designated as a drinking water supply and in which fish are routinely harvested for human consumption.

Box 1. Surface Water Classification Descriptions.

WQS are defined in Iowa Administrative Code (IAC 7/10/02) for a variety of important water quality parameters including temperature, pH, dissolved oxygen and bacteria for each designated use. General water quality criteria and specific water quality criteria applicable to Black Hawk Lake are provided in Appendix A.

Also important to restoring and/protecting surface waters in Iowa are State *Water Quality Targets*. Water Quality Targets for restoration of Iowa lakes were defined in

2006 by State Legislation (HF2782) and make the control of the delivery of phosphorus and sediment from the watershed to a lake mandatory for lake restoration projects utilizing state funding. Water quality targets (described in Box 2) address water clarity, biota, impairments, and sustainability.

The Water Quality Target of increased water clarity to 4.5 feet Secchi depth is important relative to needed reduction in phosphorus loading to reach this goal. The Water Quality Target of 2.3 feet Secchi depth is used as an intermediate goal in extremely degraded lakes.

WATER QUALITY TARGETS

(Defined in 2006 by State Legislation - HF2782)

- **Clarity:** Secchi depth must be at least 4.5 feet, 50% of the time from April to September.
- **Biota:** A diverse, balanced, and sustainable aquatic community must be maintained.
- **Impairment:** Water quality impairments must be eliminated.
- **Sustainability:** The water quality and public use benefit must be sustained for 50 years.

Box 2. Water Quality Targets (HF2782).

In aggregate, the goal of meeting water quality targets for lake restoration projects is to improve water quality to the point that excellent recreation and biological integrity are restored.

To support State of Iowa Water Quality Standards, restoration needs to consider these additional criteria:

- No agricultural or wastewater discharges causing objectionable or unsafe conditions
- Geometric mean *E. coli* < 126/100mL or single sample <235 organisms/100mL
- pH not <6.5 or >9.0
- Oxygen not <5.0 mg/L
- Temperature <32ºC (90ºF)
- Unionized ammonia generally <80 µg/L
- No substances causing odor or health risk from eating fish
- Improved fish habitat and fish communities

WHY IS THE PROJECT TAKING PLACE?

Clean lakes are compatible with economic growth and improve the quality of life for Iowans. Socio-economic, water quality, and watershed factors have been used to rank Iowa's principal public lakes for lake restoration suitability (Iowa DNR 2006). From this ranking, a priority list of 35 lakes, including Black Hawk Lake, was identified as potential lake restoration projects. As a result of this ranking, a Diagnostic Feasibility Study (DFS) was initiated as well as with the development of a Water Quality Improvement Plan for Black Hawk Lake.

WHO WAS INVOLVED IN CARRYING OUT THE PROJECT?

The Iowa DNR Lakes Restoration Program is coordinating the DFS of Black Hawk Lake. The primary focus of the Iowa DNR Lakes Restoration Program is on restoring impaired lakes for the benefit of Iowans. Because local involvement and watershed protection are essential to successful lake restoration projects, the Iowa DNR works to form partnerships with local stakeholders, private landowners and natural resource professionals. A Technical Advisory Team (TAT) including members of relevant resource agencies, as well as a local Steering Committee of interested parties and key stakeholders were assembled by the Iowa DNR to facilitate local involvement with this project.

The Iowa State University Limnology Laboratory (ISULL) was responsible for completing this DFS. The ISULL worked with the Iowa DNR and the TAT, to integrate State and local water quality goals in the restoration recommendations resulting from this work.

PROJECT PURPOSE

The purpose of this project was to provide the Iowa DNR with a DFS of Black Hawk Lake for planning a lake restoration program on the lake and its watershed. The one year project involved monitoring Black Hawk Lake and its watershed to establish a baseline for restoration potential. The goal was to identify or "diagnose" current water quality problems and to make recommendations for correcting the problems. This study approach was more intensive than is normally performed in Iowa's summer lake survey and examined the spatial structure, ecological function, and annual nutrient budget for the lake.

In the Diagnostic Study, current water quality issues and factors influencing lake water quality were identified. It included an evaluation of internal loading as a potential source of nutrients to Black Hawk Lake and was also designed to evaluate the functioning of the lake inlet (also known as *Provost Bay*). Data derived from the project were compared to past monitoring data for exploring trends within the lake. The project also determined what type of restoration activities would best mitigate watershed sediment and nutrient loading for the purpose of improving water quality before entering the lake.

In the Feasibility Study, a set of restoration alternatives addressing State Water Quality Targets and the most cost-effective alternatives for lake restoration are identified. The Iowa DNR intends to utilize the information gathered and analyzed in this study to manage the lake and allocate lake restoration funds most appropriately. The remainder of this report explains the results of the 1-year intensive study and is organized in two sections. The Diagnostic Study section includes Background Information and the results of the 2008-2009 monitoring. The information and data presented in the Diagnostic Study are integrated and recommendations made for future work in the Feasibility Study section of this report.

PROJECT TIMELINE

- July, 2008 - Initiation of fieldwork including sampling, lake mapping and GIS
- August, 2008 - Steering Committee/TAT Meeting: Introduction of ISU to groups, discuss potential goals and objectives, plan for public role-out meeting of the Diagnostic and Feasibility Study
- September, 2008 - Public Meeting: Introduce the DF Study and develop public awareness of monitoring effort. Meeting will also be attended by DNR staff to introduce the TMDL process
- December, 2008 - Steering Committee/TAT Meeting: Project update
- June, 2009 - Complete field sampling for limnological survey
- December, 2009 - Complete rough draft of diagnostic study
- February, 2010 - TAT: Review findings of the DF Study
- March, 2010 - Public Meeting: Present DF Study assessment, analysis, and restoration alternatives
- April, 2010 - Complete final draft of diagnostic study for TAT review and comment.
- October, 2010 Final Report

DIAGNOSTIC STUDY

BACKGROUND INFORMATION

LOCATION AND SURFACE HYDROLOGY

Lake Name:	Black Hawk Lake
State:	Iowa
County:	Sac
Nearest Municipality:	Lake View
Latitude, Longitude:	42.3° N, 95.0° W
USGS Major Basin Name:	North Raccoon River
USGS Hydrologic Unit Code:	07100006
Major Tributaries:	Carnarvon Creek
Receiving Water Body:	Ditch No. 57

Black Hawk Lake is a glacially-formed shallow natural lake located in Sac County, adjacent to the town of Lake View in Iowa (Figure 1). DNR maps indicate that the surface area of Black Hawk Lake is approximately 923 ac and average depth is 5.20 ft. (Figure 2). The surface area of the main basin is approximately 760 ac and average depth is 5.97 ft. The surface area of the inlet is 162 ac and average depth is 1.60 ft.

Carnarvon Creek is the primary inflow to the lake entering through the Iowa DNR Black Hawk Wildlife Management Area (WMA) located at the southwest end of the lake (Figures 1 and 3). The outlet located at the east end of the lake drains into Ditch No. 57, a tributary of Indian Creek, which flows into the North Raccoon River, at an elevation of 1221 ft MSL.

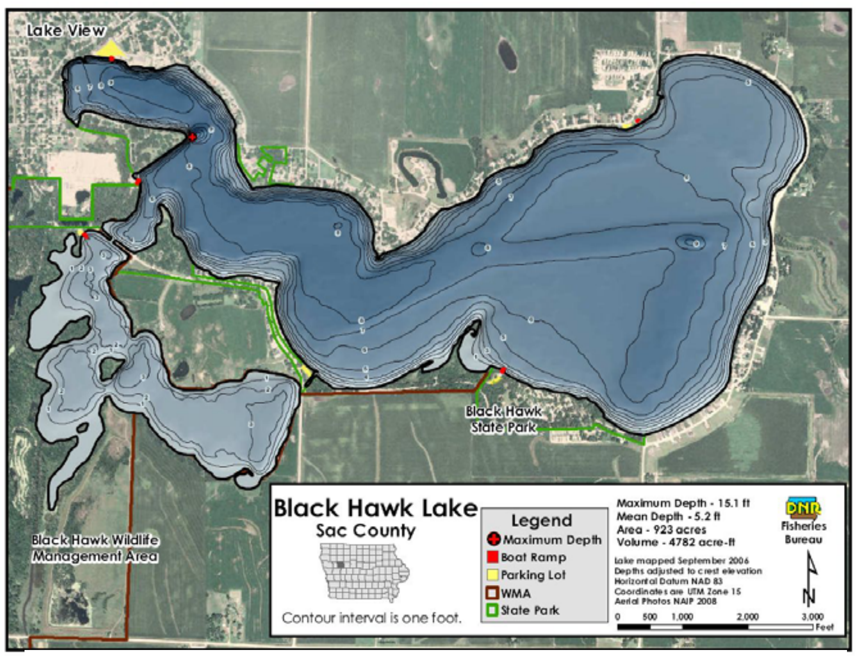


Figure 2. Black Hawk Lake including Provost Bay. Map source: Iowa DNR 2009.

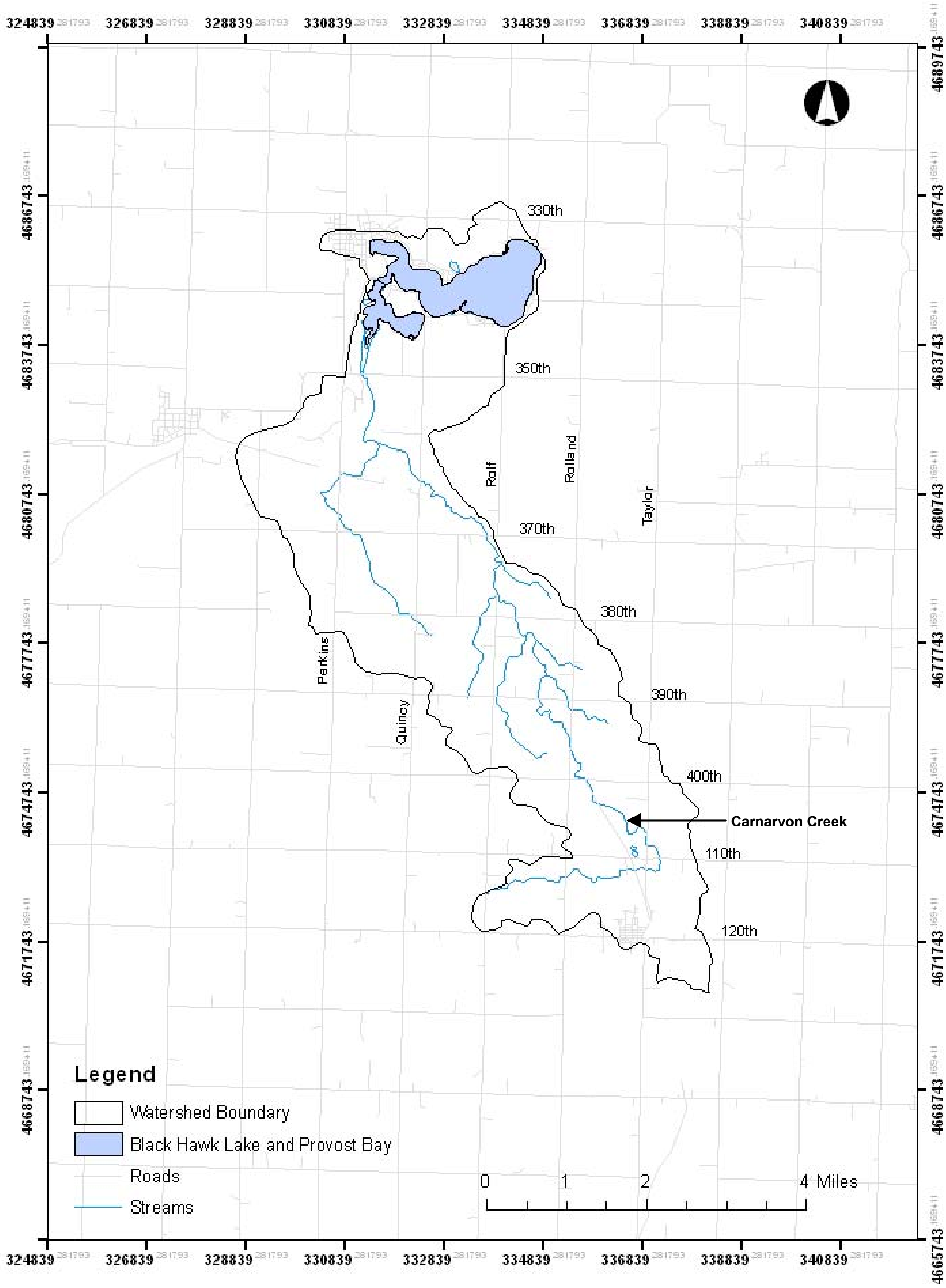


Figure 3. Black Hawk Lake Watershed originates in Carroll County near Breda, Iowa, ~12 miles south of Black Hawk Lake.

WATERSHED DESCRIPTION

A geographic information system (GIS) and data from the Iowa DNR Natural Resources Geographic Information System (NRGIS) Library, as well as other sources, were used to characterize the Black Hawk Lake watershed. The Black Hawk Lake watershed area is approximately 13,155 ac, excluding 923 ac of lake surface area. Therefore, the resulting watershed to lake area ratio is approximately 14:1. The watershed originates near the town of Breda in Carroll County 12 miles south of Black Hawk Lake (Figure 3).

Land use in the watershed is predominantly row crop agriculture (Table 1, Figure 4). Windshield surveys conducted by the Iowa DNR in 2008 confirm that the majority of the watershed is in row crop agriculture (corn-soybean rotations; Iowa DNR 2009a). Wastewater treatment ponds for Breda are situated in the upper (southern) portion of the watershed. The Iowa DNR permits wastewater discharge from these ponds during low flow conditions into Carnarvon Creek (Figure 4). The topography of the Black Hawk Lake watershed ranges from level to strongly sloping, with slopes from 0 to 25%. The majority of the area has slopes ranging from 0-9% (~71% by area; Figure 5). Soils in the watershed are derived predominantly from Wisconsin till and alluvium. The most common soil series and complexes in the watershed are Clarion (36%), Nicollet (13%), and Webster (12%). In general, these soils are relatively well drained and have moderate infiltration rate when thoroughly wet, a criteria used to evaluate runoff potential (NRCS 2009).

Table 1. Area and percentage cover for each land use/land cover type in the Black Hawk Lake watershed. Data Source: Iowa DNR NRGIS: 2002 Land Cover.

Land Cover	Total Area (acres)	% of Watershed
Corn	5001	35.5
Soybeans	4458	31.6
Un-grazed Grassland	1446	10.3
Open Water	1235	8.8
Deciduous Forest	418	3.0
Grazed Grassland	350	2.5
Wetland	221	1.6
Residential	214	1.5
Alfalfa	200	1.4
Grasslands	142	1.0
Roads	142	1.0
Coniferous Forest	89	0.6
Commercial	62	0.4
Other crops	43	0.3
Barren	39	0.3
Wet Forest	34	0.2

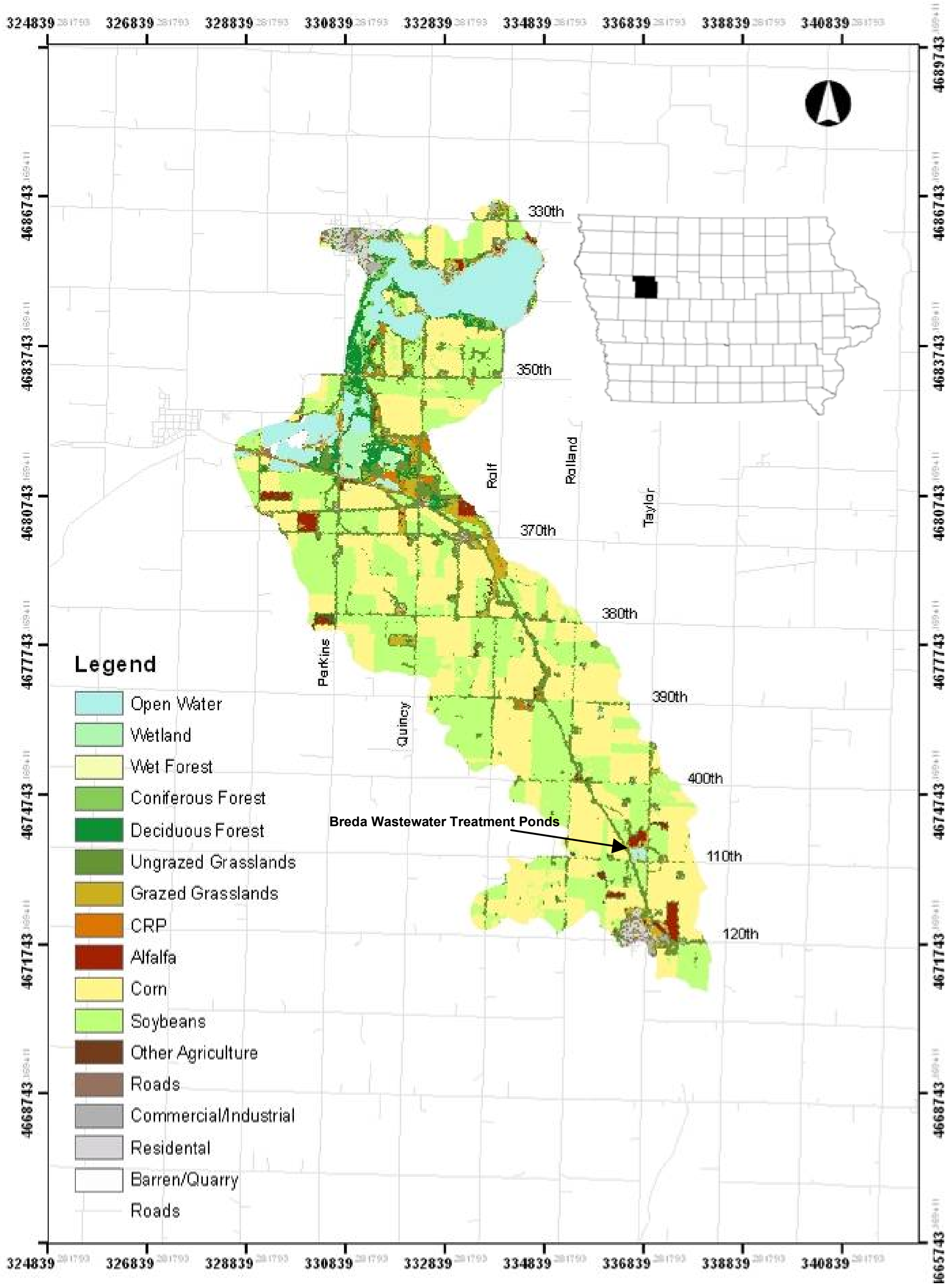


Figure 4. Black Hawk Lake Watershed: Land cover based on 2002 satellite imagery. Data Source: Iowa DNR NRGIS.

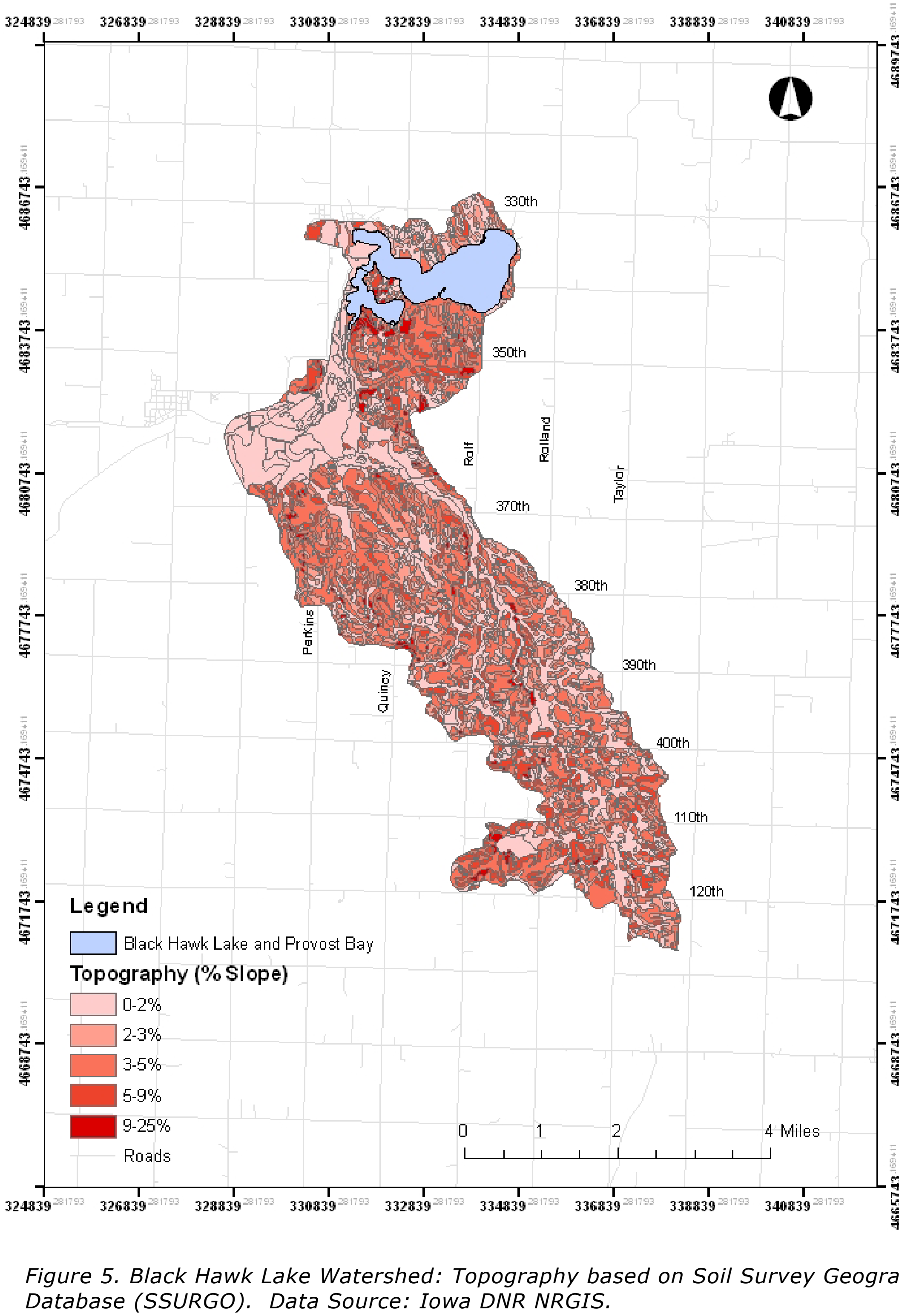


Figure 5. Black Hawk Lake Watershed: Topography based on Soil Survey Geographic Database (SSURGO). Data Source: Iowa DNR NRGIS.

DESCRIPTION OF PUBLIC ACCESS

Black Hawk Lake is within the boundaries of Black Hawk State Park (Figure 6). The park contains a swimming beach, six open picnic areas, four open shelters, one camper cabin, 128 camping sites, and four boat ramps. No fees are assessed to enter the park or to use the lake or boat ramp. The only fees charged are for specific services such as cabin or picnic shelter rental or camping spaces. The Wildlife Management Area contains approximately 3.8 miles of marked hiking and nature trails. Also adjacent to the lake is Camp Crescent Park, a full service campground managed by the city of Lake View.

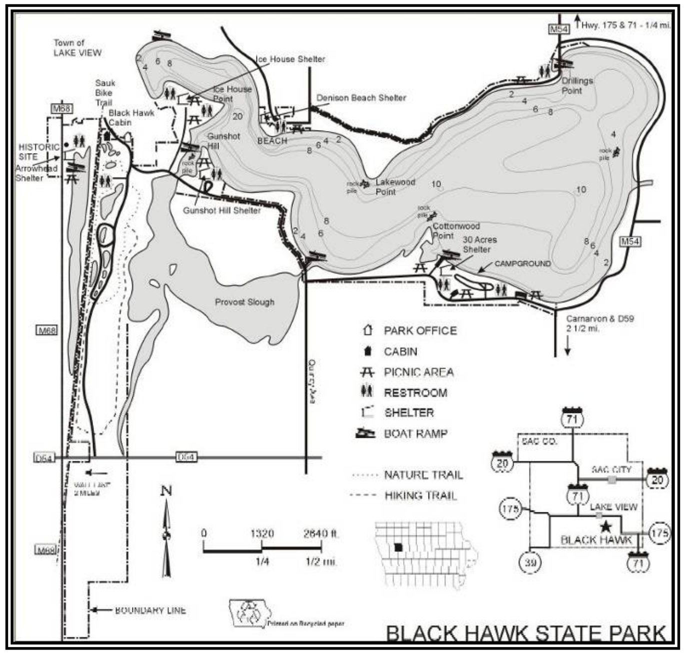


Figure 6. Black Hawk State Park. Map Source: Iowa DNR.

Bachmann (1994) indicates 59% of the lake’s shoreline is in public ownership. Iowa DNR (2009) confirmed this remains unchanged today.

Similar to many rural areas in Iowa, there is no public transportation to the lake. However, numerous state (IA 39, IA 175, and IA 7) and federal highways (US 20, US 30, and US 71) are within 50 miles of Black Hawk Lake.

DEMOGRAPHICS/POPULATION CHARACTERISTICS ASSESSMENT

According to 2008 census estimates (http://www.iowadatacenter.org/), Fort Dodge (pop. 28,515), Carroll (pop. 10,106), and Storm Lake (pop. 10,076) are the largest communities within 80 km (50 miles) of Black Hawk Lake. Nearest to the lake, Lake View (pop. 1,196) and Sac City (pop. 2,140) are the largest population centers in Sac County (pop. 10,311).

Per capita personal income in Sac County in 2007 was $34,065, which was slightly lower than the 2007 statewide per capita personal income of $34,916. Of the employed civilian population in Sac County, 21.5% are employed in education, health and social services, 14.1% in manufacturing, 13.2% in retail trade, and 12.3% in agriculture services and natural resources.

Like much of Iowa, agriculture is an important source of income in Sac County. 2007 agriculture census data from the National Agriculture Statistics Service (NASS) indicates 98% of land in Sac County is in farms (NASS 2008). Over 320,000 acres were harvested for grain (corn and soybeans) and forage, which is 88% of the total farmland or 87% of the total land in the county. In addition, the report states that in 2007 there were 474,104 hogs and pigs; 453,928 turkeys; 68,326 cattle and calves; and 3,356 sheep and lambs on farms in Sac County. In 2002, average net cash income of operations per farm was $116,993 (n=802).

HISTORY OF LAKE USE

Current statewide public-use data are not lake specific (Iowa DNR 2009c); however, rates of lake use in Iowa lakes were estimated in a four year study valuing lake water quality in the state (Otto et al. 2007). Survey respondents indicated how many day-trips and multi-day trips they made to Iowa lakes during a calendar year. Black Hawk Lake averaged 94,671 day-trips per year of the four year study, a rate of use higher than the statewide average. Although lake-specific activities were not queried in that study of lake-use, historic estimates of lake-specific use were reported in earlier lake classification studies (Bachmann et al. 1979 and 1994). From these data, Black Hawk State Park has been used extensively for camping and picnicking forms of recreation prompted by the presence of the lake. Water related activities (recreational boating, swimming, and fishing) accounted for over 50% of the use of the park 1992, up from 44% as was reported in 1979. A comparison of these two estimates show increases in fishing and boating use but declines in picnicking and camping, and swimming from 1979 to 1992 (Figure 7). Black Hawk Lake creel data from 1947-2004 indicates Black Hawk Lake fishing remains a popular activity for lake visitors (Figure 8; Iowa DNR 2009d).

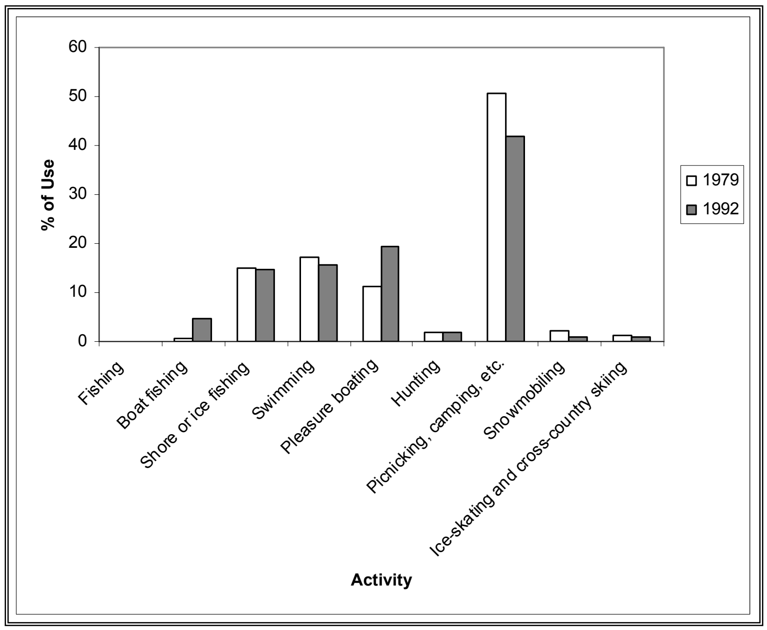


Figure 7. Comparison of recreational uses of Black Hawk Lake between 1979 and 1992 Bachmann et al 1979 and Bachmann et al 1994).

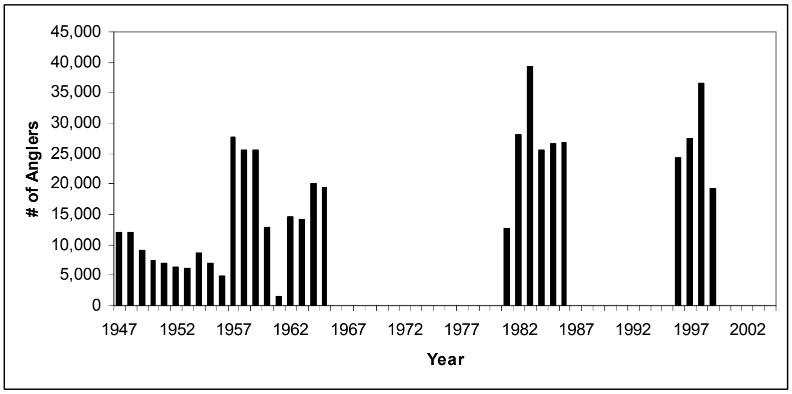


Figure 8. Number of anglers and fishing hours from creel surveys at Black Hawk Lake from 1947-2004.Data source: Iowa DNR 2009d.

Black Hawk Lake is enjoyed by large numbers of visitors annually for many types of recreation activities.

COMPARISON OF USE WITH OTHER LAKES/ECONOMIC VALUE

Visitors enjoy a variety of outdoor recreation pursuits while visiting Iowa lakes and the benefit to local economies is significant. The Center for Agricultural and Rural Development (CARD) shows that Black Hawk Lake averaged 146,043 day-use and multi-day use visitors per year and that those visitors spent $19.05 million annually on a variety of expenditures including supplies, food and lodging (Table 2).

Table 2. Spending, labor income, and job effects of visitation estimates for Black Hawk Lake (Data Source: CARD 2009).

Category	Spending	Income	Jobs
Supplies	$1,719,933	$194,675	9.5
Eating and drinking	$1,744,341	$187,075	9.3
Gas and car expenses	$663,354	$163,837	16.4
Lodging	$905,804	$321,316	21.4
Shopping and entertainment	$1,072,495	$69,439	5.1
Total	$6,105,927	$936,342	61.7

The visitation estimate for Black Hawk Lake is above the average annual visitation estimated for 17 of the 18 lakes located within 50 miles of Black Hawk Lake (Figures 9 and 10; Otto et al. 2007). Although Storm Lake consistently averaged higher numbers of single day visitors from 2002-2005, Black Hawk Lake multiple day visitor numbers reported in 2002 are considerably higher (51,372) than for Storm Lake (11,740; Figure 10).

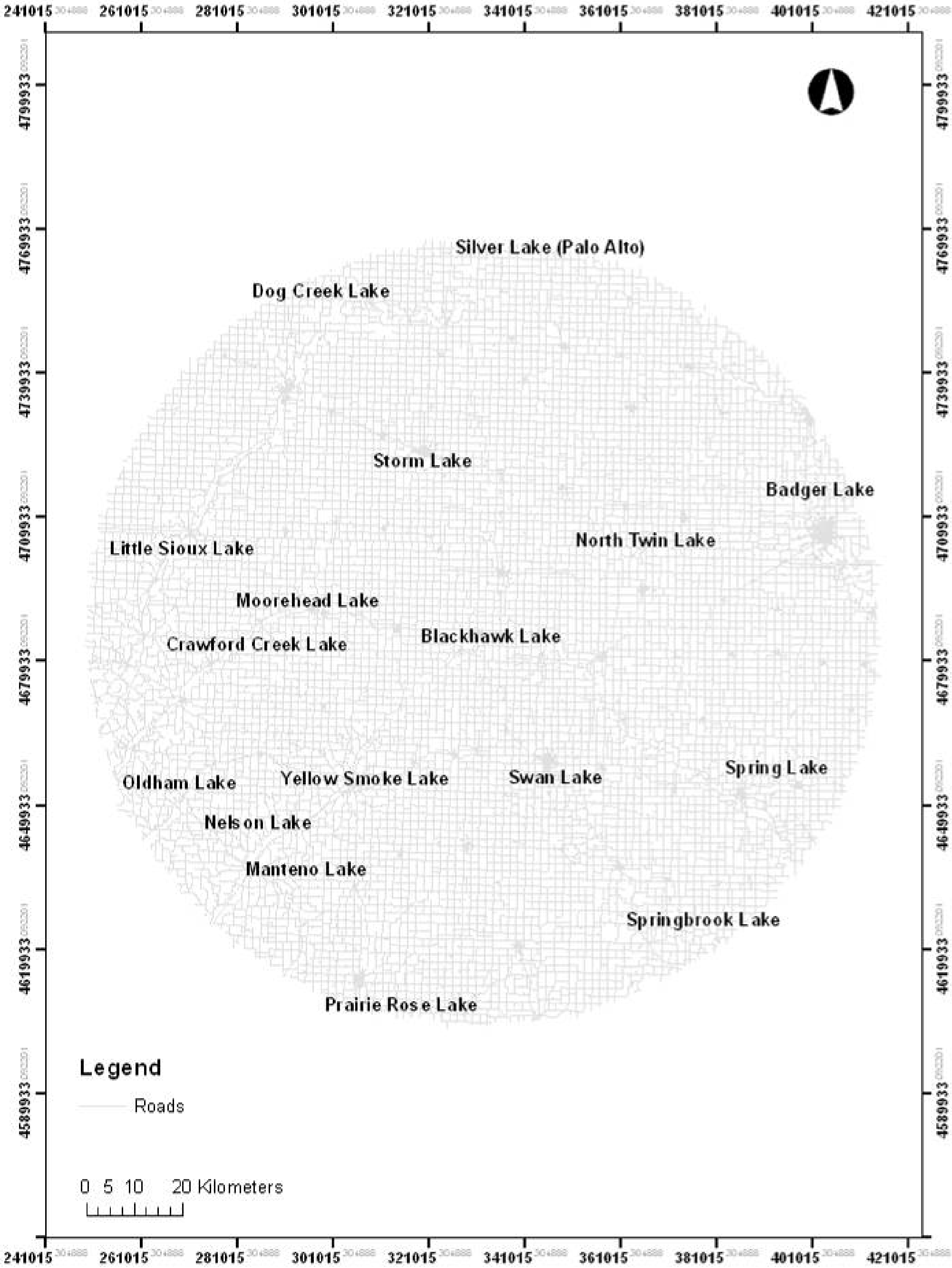


Figure 9. Lakes located within 50 miles (80 km) of Black Hawk Lake. Data source: Iowa DNR NRGIS.

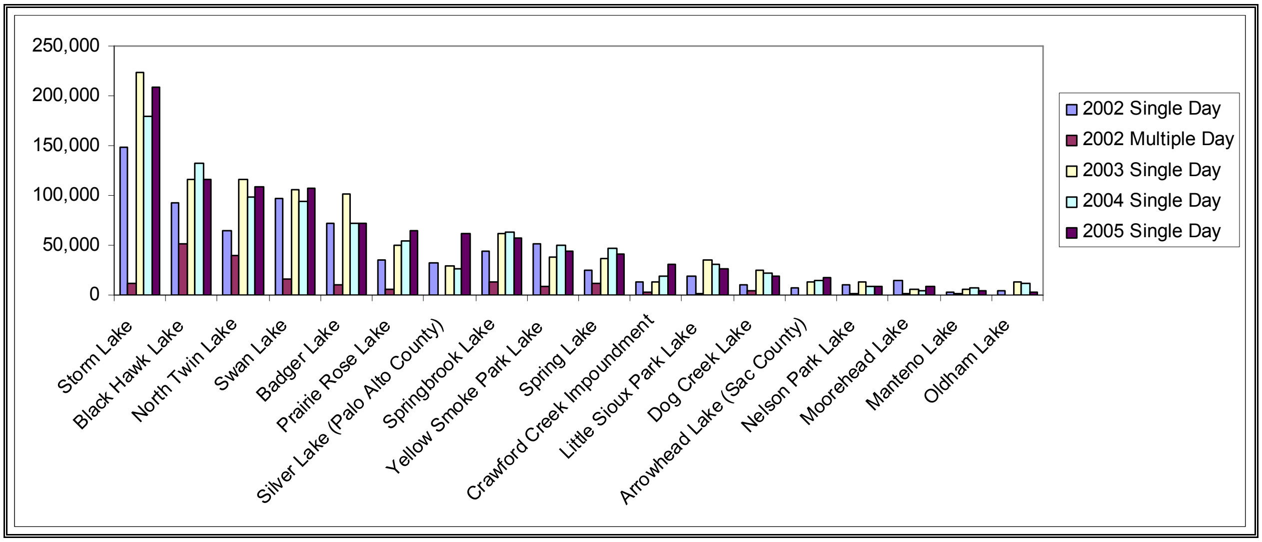


Figure 10. Visitor use estimates for single day trips (2002-2005) and multi-day trips (2002). Data source: Otto et al. 2007.

While the average annual number of visitors is slightly greater for Storm Lake, average annual estimated spending is higher at Black Hawk Lake than other nearby lakes (Table 3). When considering that these expenditures further sustain jobs and labor income to the area, the benefit to local economies is important (Table 3).

Table 3. Estimates of visitation numbers and economic benefits for Black Hawk Lake and three additional lakes within 50 miles (Data source: Otto et al. 2007).

	Average Annual Visitors	Average Annual Spending (million)	# of Jobs Supported	Regional Labor Income (million)
Black Hawk Lake	146,043	$19.05	379	$5.09
Storm Lake	167,965	$10.14	202	$2.71
Springbrook Lake	60,765	$5.96	119	$1.59
Prairie Rose Lake	47,681	$3.37	67	$0.90

HISTORICAL MANAGEMENT ACTIVITIES

Black Hawk Lake has a long history of lake management activities (Table 4). Water sampling, fish population surveys and creel surveys have been routinely conducted documenting conditions in the lake for over 50 years. Implementation of important management activities such as lake aeration and dredging as well as fish management followed many of these surveys.

Table 4. Chronology of key activities and management practices reported for Black Hawk Lake. (Data source: Iowa Lakes Information System unless otherwise indicated).*

Year	Management Practice
1916 - 1935	Dredging (973,900 yd^3*, Source: Iowa State Commission 1935)
1948 - 1951	Water sampling (temperature and Secchi depth)
1953	Creel survey
1954 - 1963	Water sampling (temperature and Secchi depth)
1964	Creel survey
1965	Creel survey; fish kill (winter); water sampling (Secchi depth);
1966	Creel survey
1968	Fish population survey
1973	Lake and watershed mapping
1974	Fish population survey
1974 - 1975	Fish kill (winter)
1977	Fish kill (winter)
1978	Aeration installed
1979	Aeration installed; fish population survey; fishery renovation
1979	Fish barrier installed between Provost Bay and the main basin of the lake
1980	Fish kill (dissolved oxygen)
1981	Aeration installed; fish population survey
1982	Aeration installed
1983	Aeration installed
1984	Commercial fishing; creel survey
1985	Aeration (winter); commercial fishing; fish habitat structures
1987	Commercial fishing; creel survey; fish population survey
1988	Commercial fishing; water sampling
1989	Aeration installed; commercial fishing
1990	Watershed activities
1991	Dredging (589,125 yd^3 from 1991 - 4/1993*, Source: Miller 2005); commercial fishing; fish habitat structures; fish population survey; fishing regulation; watershed activities
1992	Dredging (continued); aeration installed; commercial fishing; creel survey; fish habitat structures (rocks)
1993	Dredging (448,721 yd^3 from 5/1993 - 12/1995, Source: Miller 2005); commercial fishing; water sampling
1994	Dredging (continued); commercial fishing; fish habitat structures; water sampling
1995	Dredging (continued); commercial fishing; fish habitat structures; shoreline activities (rip rap)
1996	Bathymetry mapping; commercial fishing; creel survey; water sampling; watershed activities
1997	Commercial fishing, creel survey; fish stocking (flathead catfish)
1998	Commercial fishing, creel survey; watershed activities
1999	Commercial fishing, creel survey; fish kill (multiple causes); watershed activities
2000	Commercial fishing; fish population survey; fish stocking (flathead catfish)
2001	Commercial fishing; watershed activities
2002	Commercial fishing; shoreline activities (other)
2003	Water sampling (other)
2004	Watershed activities; water sampling (Secchi depth)

In 1982, a Phase I Diagnostic Feasibility Study was completed for Black Hawk Lake resulting in recommendations for lake dredging and watershed management. Over a million cubic yards of sediment were removed from the lake and a wide range of soil conservation practices were applied in the watershed from 1986-1994 (Iowa DNR 1996).

HISTORICAL LIMNOLOGICAL STUDIES

From data collected in Iowa's 1979 lake classification survey, Black Hawk Lake was classified as a eutrophic lake. The mean total phosphorus concentration was 236 μg/L (n=9), mean total Kjeldahl nitrogen was 1.30 mg/L (n=12), mean chlorophyll *a* was 148.6 μg/L (n=30), and mean Secchi disk depth was 0.2 m (n=6). Winter fish kills were reported in one year out of three and summer fish kills were estimated to be rare. Aquatic plants were absent from the lake. Shallow water depth was reported as contributing largely to the water quality problems. With 81% of the watershed in row crop production, nonpoint source pollution from soil erosion and agricultural chemicals were indicated as major issues for the lake leading to sustained algal blooms and poor water transparency. At that time, it was recommended that Black Hawk Lake be consideration for a Diagnostic Feasibility Study.

Monitoring data collected for the Diagnostic Feasibility Study from 1986-1995 documented overall reductions in total phosphorus, NO2+NO3, and chlorophyll *a* concentrations and increased Secchi disk depth during this time period. These water quality improvements were attributed to BMP implementation throughout the watershed (Iowa DNR 1996). While improvements were observed, Black Hawk Lake still maintained a eutrophic classification.

At the time of Iowa's 1994 lake classification survey, Black Hawk Lake was still classified as eutrophic. The mean total phosphorus concentration was 175 μg/L (n=9), mean total nitrogen was 3.5 mg/L (n=9), mean chlorophyll a was 133.1 μg/L (n=9), and mean Secchi depth was 0.6 m (n=3). Summer fish kills were estimated to be rare and no winter fish kills were reported since 1978. Aquatic plants were absent from the lake.

Benthic macroinvertebrates, which are important food items for fish that are often used as indicators of water quality, were studied in 2006. Downing et al. (2008) reported the sublittoral benthic macroinvertebrate community at Black Hawk Lake was found to have low biodiversity, dominated by Chironomidae (84%), a group of aquatic invertebrates that tolerate low-oxygen conditions.

Water quality monitoring at Black Hawk Lake continued as part of the Iowa Lakes Survey in 2000-2007. A summary of lake nutrient changes over time is shown in Table 5. More recent data are presented as the results section of this report.

Table 5. 2000-2007 summer averages for Black Hawk Lake. (Data Source: Iowa Lakes Information System http://limnology.eeob.iastate.edu/lakereport/)

Parameter	2007	2006	2005	2004	2003	2002	2001	2000
Secchi Disk Depth (m)	0.4	0.3	0.4	0.5	0.7	0.9	0.5	0.2
Temperature(^{o}C)	24.7	21.8	22.4	22.5	23.7	25.1	23.1	25.7
Dissolved Oxygen (mg/L)	8.6	8.9	9.1	8.2	8.9	7.9	6.8	4.5
Dissolved Oxygen Saturation (%)	103.4	99.4	103.7	94.2	105.9	95.6	78.6	55.5
Turbidity (NTU)	37.2	92.6	134.0	47.3	38.7	190.4	49.0	236.9
Chlorophyll a (µg/L)	59.8	44.5	115.4	47.4	22.8	30.4	-	79.3
Total Phosphorus as P (µg/L)	96	125	126	117	113	193	202	-
SRP as P (µg/L)	53	7	16	14	8	85	-	-
Total Nitrogen as N (mg/L)	2.77	2.15	3.21	1.74	2.64	1.92	3.15	2.39
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	1.05	0.16	1.64	0.50	1.11	0.85	1.21	0.17
Inorganic Suspended Solids (mg/L)	15	23	24	19	15	23	18	40
Volatile Suspended Solids (mg/L)	14	13	16	6	8	5	11	21
Total Suspended Solids (mg/L)	29	37	40	26	24	28	29	60
Phytoplankton Wet Mass (mg/L)	102.0	125.8	23.5	236.6	18.9	283.3	7.1	47.5
Zooplankton Dry Mass (µg/L)	184.5	280.7	292.7	295.8	440.5	281.1	222.5	181.8

FISHERIES OVERVIEW

A report on the history and overall current condition of the Black Hawk Lake fishery was provided by the Iowa DNR (Iowa DNR 2009g) and is provided in Appendix B. An overview of this report is provided below.

Black Hawk Lake has a history of providing a good sport fishery and is stocked annually with walleye and channel catfish. The fish population is composed of a large variety of species including black bullhead, channel catfish, carp, bigmouth buffalo, bluegill, black crappie, green sunfish, orange-spotted sunfish, largemouth bass, walleye, yellow perch, yellow bass, gizzard shad, white crappie, yellow bullhead, freshwater drum and flathead catfish.

Preventing winterkill and control of rough fish has been the focus of management activities for decades. Sixteen helixor aerators located in Town Bay keep the bay open over winter to prevent winterkill of fish. A fish barrier is located at the bridge between the main lake and Provost Bay to minimize rough fish access to the lake. In addition, commercial fishing is permitted in an effort to control carp in the lake.

While Black Hawk Lake is providing a good fishery for black bullhead and channel catfish today, recent declines in black crappie and walleye numbers and black crappie size are being linked to poor water quality. Without improvement, water quality will continue to inhibit a diverse fishery in the future.

TOXICITY

Metal and chemical pollutants at Black Hawk Lake were analyzed in water samples in 2001 and 2002 and in sediments in 2004 as part of the Iowa Lakes Survey. In addition, 2008 RAFT results were provided by the Iowa DNR for inclusion in the following summaries of recent toxicity screenings.

Water Pesticides and Metals

Lake water samples were collected during the 2001 Iowa Lakes Survey and analyzed for pesticides and herbicides. A subset of 36 lakes was also analyzed for organophosphate insecticides, acid herbicides, polychlorinated biphenyls, chlorohydrocarbon insecticides, and an additional 6 nitrogen containing herbicides. All pesticide and herbicide analyses were performed by the Hygienic Laboratory at the University of Iowa, following standard EPA approved methods.

In addition, during 2002 Iowa Lakes Survey, lake water samples were also analyzed for a variety of metals. All metal analyses were performed by the Hygienic Laboratory at the University of Iowa, following standard EPA approved methods. The results of the 2001 analyses are provided in Appendix C. Six nitrogen containing herbicides were detected. All other analytes were reported below quantification limits. With the exception of barium (0.14 mg/L), metal concentrations in water are reported below quantification limits.

Benthic Sediments and Metals

During 2004 Iowa Lake Survey, sediment samples were collected and analyzed for metals and pollutants including organophosphate insecticides, polychlorinated biphenyls, nitrogen containing herbicides, chlorohydrocarbon insecticides and acid herbicides. These analyses were performed by the Hygienic Laboratory at the University of Iowa following standard EPA approved methods. The list of chemicals analyzed and the results of these analyses on the original data sheets are presented in Appendix D. All pesticide concentrations were reported below quantification limits. Trace amounts (0.0089 mg/kg) of Atrazine were reported (Appendix D). A list of the metals and the concentrations in sediment samples are provided in Appendix C.

Fish Toxicity

Fish tissue samples were collected by the Iowa DNR at Black Hawk Lake once in August 2008 and analyzed for pesticides and heavy metals by the University of Iowa Hygienic Laboratory. With the exception of mercury (0.090 mg/kg in the largemouth bass and 0.031 mg/kg in the channel catfish), detectable levels of pesticides and metals were below quantification limits (Appendix E)

METHODS

CURRENT ASSESSMENT AND MONITORING APPROACH

Lake Assessment

Physical Features: Bathymetry and Sediment Deposition

Several sources of data on lake morphometry and sediment thickness were used to create maps using GIS. Sources included a set of 112 core samples taken in 1916 (Iowa State Highway Commission 1916) showing both water depth and soft sediment thickness, a bathymetric map created in 1935 to illustrate a dredging plan, a 1973 bathymetric map created by the Iowa Conservation Commission (1973), and tens of thousands of soundings collected by the Iowa DNR (ref., pers. Comm.). The "Provost Bay" was analyzed separately from the lake because survey data were only available from 1916, 1973, and 2006. These data sources were geo-referenced, adjusted to a constant elevation, and digitized by hand where necessary, and GIS software was used to calculate bottom changes over the lake's approximately 10,000 year history. Differences in depth between surveys were interpreted to represent changes in sediment thickness.

To approximate historic sediment accumulation rates, three sediment core samples were also collected and analyzed using loss on ignition (LOI) and ^{210}Pb dating methods. Percent LOI (Dean 1974) was used to analyze the sediment composition as an indication of large-scale changes in the sedimentation processes likely corresponding to European arrival and the use of intensive agricultural practices on the landscape. These cores were also analyzed using ^{210}Pb dating through alpha spectrometry (Eakins and Morrison 1978).

Water Quality Monitoring

Three sampling stations were established on Black Hawk Lake for this study (Figure 11). One primary sampling station (LS001) was located at the historic deepest sampling point in the lake. Two secondary sampling stations were located at the deep pool in the middle of the west basin (LS002) and near the east side of the lake (LS003). Lake samples at the primary monitoring station were collected at each meter of depth from the surface down to 0.5 m from the bottom. In addition to these sampling depths, a mixed zone water sample was collected using a 0-2 m integrated water column sampler. Maximum depth at the primary sampling station was 2.6 m. Mixed zone water samples were also collected using a 0-2 m integrated water column sampler at the secondary monitoring stations. Water samples collected from the three sampling locations

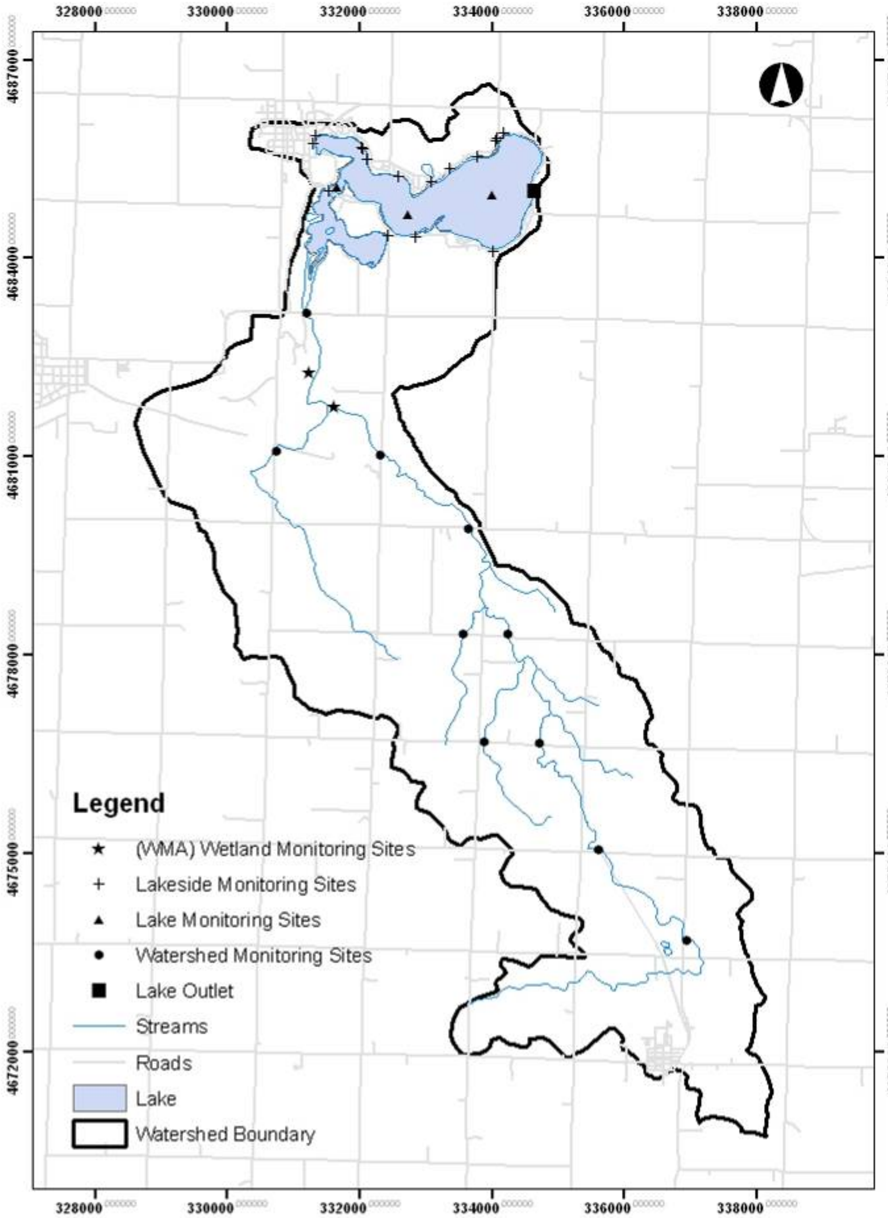


Figure 11. Black Hawk Lake and Black Hawk Lake watershed monitoring sites.

were analyzed for chemical and biological parameters important in determining water quality (Table 6). Information regarding analytical methods is available in Appendix F.

Table 6. Parameters and importance in water quality monitoring

Parameter	Importance
Total Phosphorus	The nutrient that most often leads to excess algae growth, oxygen depletion, Cyanobacteria blooms, and other water quality problems. It is used to indicate fertilizer and sewage inputs and is the nutrient that is most important to lake management models.
Soluble reactive phosphorus (PO_4)	Soluble reactive phosphorus is an analytical form of phosphorus (sometimes called "phosphate") that is soluble and is thought to be a fraction that is readily available for uptake by aquatic organisms. Lake management models rely on estimates of ratios of this to total phosphorus for determining the potential for biological removal of excess nutrients.
Nitrogen: TKN, NO_3, NH_X	Indicates fertilizer and sewage inputs; important in understanding nutrient limitation of aquatic organisms
Solids (TSS, ISS, VSS)	Total suspended solids (TSS) are the soil, silt, and biological particles suspended in the water; useful in assessing watershed contributions of silt, ecosystem productivity, and sediment re-suspension. ISS are the inorganic particles suspended in water that are usually of geological origin; useful in assessing watershed contributions of geological materials including surface and sub-surface soils. VSS are the organic particles suspended in water that are usually of biological origin; useful in assessing watershed contributions of crop natural plant residues, sewage, and organic soils, as well as ecosystem productivity, and sediment re-suspension.
Chlorophyll a	A measurement of photosynthetic pigment used to estimate phytoplankton biomass
pH and Alkalinity	pH is the inverse concentration of hydrogen ions in water. Low pH (<7) waters are acidic while high pH (>7) waters are basic. pH measurements assess acidification status, the presence of decompositional environments and high pH (>9.5) indicates extreme algae bloom environments. pH is used with alkalinity to determine carbon available to plants. Alkalinity is the buffering capacity of waters, usually derived from dissolved carbonates of calcium and magnesium. Alkalinity determines the inorganic carbon availability in water and (with pH) determines the dissolved carbon dioxide available for plant growth.
Conductivity	Indicator of the amount of ions and salts dissolved in water; used to detect decomposition, contamination by salts, and to estimate ionic strength of waters; important in detection of pollution and understanding carbon limitation by plankton.
Carbon (Dissolved Organic Carbon)	Organic matter in solution that usually results from the dissolution of plant and animal matter within lakes or in lake watersheds; DOC is useful in understanding watershed process, light penetration, and can result in highly toxic compounds after water treatment.
Turbidity	The back-scattering of light by particles suspended in the water; used to assess and establish goals of recreational use and ecosystem health.
Dissolved Oxygen	Indicates the concentration of dissolved oxygen in the water. Aquatic life (fish and fish-food organisms) can be stressed with bottom oxygen concentrations less than 5 mg/l and may die at less than 2 mg/l.
Secchi Disk Transparency	Secchi depth is used to determine water transparency. Clarity is affected by algae as well as suspended materials in the water and water color. Secchi disk depth is often used as an indicator of overall algal abundance and general lake productivity.
Plankton: Phytoplankton Zooplankton	Zooplankton and phytoplankton are a primary food source for other organisms. They respond quickly to environmental changes and species assemblages of both are useful in assessing water quality. An overabundance of phytoplankton increases turbidity, degrades recreational appeal, and can create toxins that are harmful to warm-blooded animals.
E. coli	*E coli* is a type of coliform bacteria found in the intestinal tract of warm-blooded animals. Indicates human or animal waste.
Total Coliforms	Coliform bacteria indicate the presence of all coliform group bacteria, both vegetative and fecal in origin, and are used as a tracer for human contamination.
Microcystin	Microcystis are a type of cyanobacterium common in eutrophic lakes and reservoirs. They are known to produce cyanobacterial hepatotoxins called microcystins, can be harmful to human and animal health, and can be lethal to many kinds of aquatic and terrestrial organisms.

Chemistry

Water samples were collected from all lake monitoring stations (LS001, LS002, and LS003) once each month from July 2008 through July 2009 as possible, due to ice conditions throughout the winter, and analyzed in the ISULL for the parameters listed in Table 7. Lake profile data (via a YSI sonde) were collected and Secchi disk transparency was measured as well at all three lake sampling sites.

In addition, two hourly series of samples (two extra sets of samples taken on each of two different sampling events) were collected from the primary sampling station (LS001) over days with diurnal weather developing from calm to windy conditions to evaluate nutrients loaded to the water column by wind and wave action. Internal loading amounts were approximated using estimates of inputs, outputs, and changes in storage of phosphorus within the lake.

*Table 7. Parameters analyzed in water samples collected from Black Hawk Lake (2008-2009). Analytical methods are provided in Appendix F. *Zooplankton samples were collected using a Wisconsin net tow from 0-2 m.*

Analyzed Regularly from YSI Profile Data	Analyzed Regularly at 1m intervals from surface to near bottom and (0-2m) Mixed Zone Integrated	Analyzed Regularly from (0-2m) Mixed Zone Integrated Samples
Temperature YSI	Total P	Phytoplankton Composition
Dissolved O_2 YSI	Soluble Reactive P	Zooplankton Composition*
pH YSI	Total N	Secchi Disk Transparency
Specific Conductivity YSI	$NO_2 + NO_3$	pH
Turbidity YSI	NH_4	Alkalinity
	Unionized NH_3	Microcystin
	Total Suspended Solids	*E. coli*
	Inorganic Suspended Solids	Total Coliform
	Volatile Suspended Solids	
	Dissolved Organic Carbon	
	Total Dissolved Carbon	
	Chlorophyll *a*	

Microbial and Biological Analyses

Water samples were analyzed from the mixed zone at all three lake sample locations (July – November 2008; January, March – July 2009) for presence and abundance of total coliform and *E. coli* bacteria. A total of 11 samples were collected from each of the lake sampling sites. Tributary sites were sampled 13 times and water samples collected when flow was present. Storm drains were sampled once annually following rain events and water samples collected when flow was present. In addition, bacteria data collected as part of Iowa's Beach Water Monitoring Program by the Iowa Department of Natural Resources were reviewed (Iowa DNR 2009e). The mixed zone water samples were also analyzed for microcystin concentration using commercially available immunoassay kits.

Phytoplankton and zooplankton samples were collected from the primary sampling station (LS001). Phytoplankton were collected using an integrated water column sampler. If a thermocline was present and less than 2 meters, the sample was taken from the surface to the depth of the thermocline. If no thermocline was present or was deeper than 2 meters, the water column was sampled from the surface to a depth of 2 meters. Zooplankton were collected by vertically towing a Wisconsin net (63 µm mesh size) through the same column length as was used for collecting phytoplankton.

To assess littoral zone habitat the entire parameter of the lake was visually inspected by boat for presence of aquatic macrophytes. If macrophytes were observed, the boundary of the area was delineated and plants were collected from transects located perpendicular to the shore. Plants were collected from a maximum water depth of 1.5 m to the shoreline (Chambers and Kalff 1985). Plants collected from the lake were returned to the lab for identification.

Watershed Assessment

Stream Water Quality Monitoring

A network of sampling sites was established in the watershed to calculate nutrient budgets for the lake and to localize nutrient and sediment sources within the lake's sub-watersheds (Figure 11). Water samples were taken from 11 tributary sites and at the outflow to the lake once each month from July 2008 through July 2009 as possible, due to ice conditions throughout the winter and analyzed for the parameters listed in Table 8.

Additional Water Quality Monitoring

In addition to the monthly water monitoring, two spring storm events and one fall storm event (characterized as a precipitation event yielding greater than one-inch of water in a 24-hour period in the Black Hawk Lake watershed) were also planned. Water samples were collected from 10 storm drains/tiles with direct inputs to the lake for use in determining relative storm water and materials inputs (Figure 11). These samples were also analyzed for the parameters in Table 8.

Water samples were also collected twice at two sites located in the Black Hawk WMA for the purpose of assessing wetland function (Figure 11). The sites were located above and below two wetlands/ponds located in the WMA. These samples were collected following a storm event and were analyzed for parameters in Table 8.

Finally, water samples were collected in the watershed twice for caffeine analysis, which is used as an indicator of materials of human origin. Water samples for caffeine analysis were collected at four sites, one site each up- and downstream of the Breda wastewater treatment ponds and of the town of Carnarvon. Caffeine analysis was performed by the Hygienic Laboratory at the University of Iowa, following standard EPA approved methods.

Table 8.Parameters analyzed in the field and laboratory on samples collected in the Black Hawk Lake watershed.

Analyzed Regularly at Watershed Sites	Analyzed Regularly at Watershed Sites
Field	**Lab**
Temperature YSI	Total Phosphorus
Dissolved Oxygen YSI	Soluble Reactive Phosphorus
pH YSI	Total N
Specific Conductivity YSI	$NO_2 + NO_3$
Turbidity YSI	NH_4
Discharge	Unionized NH_3
	Total Suspended Solids
	Inorganic Suspended Solids
	Volatile Suspended Solids
	pH
	Alkalinity
	E. coli
	Total Coliform

Watershed Nutrient Flux and Export Rates

The nutrient budget for Black Hawk Lake was based on continuous monitoring of stage on Carnarvon Creek and data collected on each sampling date (Table 8). Continuously recording stage (depth) sensors (Onset Hobo depth transducers) were installed in stilling wells prior to the study on Carnarvon Creek to monitor inflow. Flow rates were measured on sampling dates with a Doppler current flow meter. Daily water levels were used along with in-field discharge measurements to form discharge rating curves for estimating continuous water flux rates.

Additional water sources include direct precipitation on the lake surface and surface water flows through streams and drainage pipes. Precipitation inputs and evaporation were estimated from the Iowa meteorological Mesonet site (http://mesonet.agron.iastate.edu/). Water losses include outflow and surface evaporation. Data were combined to create hydraulic budgets for the lake over the sampling period. Nutrient export rates were measured based on continuous monitoring of water flux and sampling of measured concentrations.

Lake and Watershed Modeling

Lake Phosphorus Modeling

Geographic, bathymetric, hydrologic, and export data were integrated into a series of lake models to find which gave the best fit to observed values found in Black Hawk Lake (Kreider 2001).

Watershed Modeling

Non-point source pollution was modeled using the Soil and Water Assessment Tool (SWAT) and an ArcView interface (ArcSWAT v. 2005) as part of the Iowa DNR's Water Quality Improvement Plan TMDL study. SWAT is a continuous-time, semi-distributed, process-based model that was developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions over long periods of time (Arnold & Fohrer 2005). The model simulates a large number of physical processes, including evapotranspiration, lateral subsurface flow, return flow from groundwater, surface runoff, nutrient cycling, erosion, and sediment yield, to provide an accurate assessment of hydrologic and water quality change through time. SWAT is currently used by both the USDA and USEPA for watershed management. It outputs data on a daily time step, and these data can be aggregated to evaluate water flow and water quality over various time scales. Results of the Watershed Modeling are included in Appendix F.

RESULTS AND DISCUSSION

PHYSICAL FEATURES

Physical features of Black Hawk Lake and Provost Bay as determined in this study are summarized in Table 9. Lake water depth averaged 1.9 m (6.1 ft) and the maximum water depth was 4.6 m (15.1 ft). The water depth in Provost Bay averaged 0.62 m (2.0 ft) with a maximum depth of 0.8 m (2.6 ft).

The Iowa Lakes Information System indicates the shoreline development index (SDI), a measure of the regularity of the shoreline, is 2.0 (1 is round, 10 is extremely convoluted) at Black Hawk Lake.

Table 9. Physical features of Black Hawk Lake and Provost Bay

	Black Hawk Lake	Provost Bay
Surface area	304 ha (752 ac)	60 ha (148 ac)
Maximum depth	4.6 m (15.1 ft)	0.8 m (2.6 ft)
Mean depth	1.9 m (6.1 ft)	0.62 m (2.0 ft)
Volume	5,653,887 m^3 (4584 ac-ft)	362,084 m^3 (294 ac-ft)
Hydraulic Residence Time	0.42 yr (153 d)	0.02 yr (7 d)
Watershed area	5323 ha (13,155 ac)	-
Watershed area/Lake area ratio	18	-

LAKE BATHYMETRY AND SEDIMENT DEPOSITION

Black Hawk Lake was formed by the stranding of ice blocks in glacial materials at the end of the last glacial period. Therefore, the original volume of the lake, before sediment began to accumulate, was quite large and the lake was much deeper than it is today (Table 10). At the time of formation, the maximum depth of the lake was around 33 feet and the mean depth (the depth a hypothetical lake of Black Hawk Lake's volume would have if it were the same depth everywhere) was about 12 feet. The lake was somewhat larger back then because shore processes had not reclaimed shallow waters yet nor had subsequent dredge spoil been used to fill any lake-bed areas. As is frequently the case with other kettle lakes, the deepest place was nearer the middle of the lake than it is today (Figure 12A).

Table 10. Morphometric characteristics of Black Hawk Lake (not including Provost Bay) over its history. The year -8000 indicates 8000 BC, the approximate year of glacial withdrawal from the region.

Year	Area (m^2)	Area (ha)	Area (acres)	Mean depth (m)	Mean depth (ft)	Max depth (m)	Max depth (ft)	Volume (m^3)
- 8000	3,228,646	323	798	3.61	11.85	9.98	32.75	11,658,454
1916	3,099,722	310	766	1.11	3.65	2.13	6.98	3,451,218
1935	3,229,754	323	798	1.32	4.34	2.02	6.63	4,272,110
1973	3,070,518	307	759	1.76	5.78	3.66	12.00	5,411,906
2006	3,041,384	304	752	1.86	6.10	4.61	15.13	5,653,887

The next 10,000 years brought in sediments from the changing watershed and filled in about 2/3 of the basin's volume. By 1916, maximum lake depth had fallen to about 7 feet (Table 10) or about one-fifth of its original maximum depth. The lake was quite shallow across its entire area because sediments had filled in the deep spots and the northeast area of the lake was extremely shallow (Figure 12B). Although there was no dredging work done on the lake between 1916 and 1935, there was a very severe drought and newspaper articles of the time indicated that the level of the lake had fallen substantially, exposing much of the shallow portion of the lake. Residents were concerned that the lake might disappear entirely due to its shallow depth. Although the maximum depth of the lake did not change during this period, the water volume did, likely due to sediment compaction by drying (Table 10). The major change in the bathymetry of the lake was a deepening of the areas near shore (Figure 12C).

After 1935 there was substantial dredging performed as part of the Works Progress Administration (WPA) program. Therefore, the volume and depth of the lake were both altered significantly between 1935 and 1973. The maximum depth nearly doubled while the area declined by 16 ha (~40 acres) and the lake increased in volume by approximately 1.1 million m^3. The lake changed radically in shape as sediment that underlay the original lake, immediately post-glaciation, were removed to fill shallow lake-bed, create some artificial relief on shore, and create park land (Figure 12D). Due to dredging near the town of Lake View, IA, the deepest area was found in the extreme western part of the lake in 1973. According to reports, dredging in the 1930s proceeded day and night and could conceivable have removed a million or more m^3 of lake bottom.

Additional dredging within Black Hawk Lake occurred between the 1973 and 2006 surveys. This dredge activity is known to have removed nearly 800,000 m^3 of bottom materials. The lake increased in both maximum and mean depth during this period but the lake volume changed little. Dredge spoil was used to create new shoreline by filling some shallow areas. This is supported by the decrease in lake area (~3 ha) from 1973 to 2006 (Table 10). The dredging was performed in a nearly geometric pattern (Figure 12E), giving Black Hawk Lake a distinctive, and man-made lake morphometry. There is a nearly linear dredge-track tending east to west and a localized deep area possibly near one of the dredge mooring points.

Sediment deposition and removal in Black Hawk Lake displayed much variation throughout the lake's history but suggested substantial annual inputs of sediments. Even while the state and federal government were paying for some of the largest lake-dredging operations in Iowa history, landscape input of sediments was likely very high. Examining the aggregate image of sediment input and removal (Table 11) illustrates this history. Working backward through Black Hawk Lake's sediment history allows us to estimate the volume of sediment added to the lake annually from the watershed. For example, we know that the sediment volume in Black Hawk Lake decreased by around 200,000 m^3 over this period but DNR documented removal of >700,000 m^3. This means that around 500,000 m^3 of new sediment was added to the lake even as the state was paying to remove it. This calculation suggests that an average of around 17,000 m^3 of sediment were added to the lake from the watershed each year from 1973-2006. Because farmers have made great strides in the control of sediment losses over this century, this is likely an underestimate of the annual sediment input over the period of 1916-1973.

Table 11. Changes in main lake volume over bathymetric periods, including estimates of sediment removal and compaction. Italicized, bold values are back-calculated using sediment accumulation rates. Sediment change (m^3) was calculated as the difference in water volume between two survey years. Sediment addition over period (m^3) was calculated as the sum of sediment change and either dredge amounts or compaction loss from drying.

Year	Water volume (m^3)	Sediment change	Dredge amounts in m^3	Compaction loss from drying	Sediment addition over period (m^3)	Sediment influx from watershed/y
-8000	11,658,454					
		8,206,300			8,206,300	828
1916	3,451,218					
		-820,250		***1,137,896***	***317,646***	***16,718***
1935	4,272,110					
(1938)		-1,137,960	***1,773,253***		***635,292***	***16,718***
1973	5,411,906					
(1991-95)		-241,788	793,489		551,701	16,718
2006	5,653,887					
Total (1916-2006)		-2,199,998	2,566,742	1,137,896	1,504,639	

Assuming that this sediment addition occurred over the century (a conservative assumption) allows us to estimate both the amount of dredging done in the late 1930s and the sediment compaction that occurred during the early 1930s (Table 11). This suggests that WPA dredging in the 1930s removed nearly 1.8 million m^3 of sediment and that drying in the dust-bowl years compacted sediments by another 1.1 million m^3. At current dredging costs, watershed activities appear to be contributing sediment with an eventual annual dredging removal cost of $70,000-140,000. Sediment accumulation in Black Hawk Lake (over time, 1916-2006) is shown in Figure 13.

Provost Bay is a natural detention structure that could remove substantial amounts of nutrients and sediments before they influence the water quality of the main basin of Black Hawk Lake. The bay has not changed substantially in volume or area since the early 1900s, although alterations to water-flow patterns have changed its shape and form (Table 12; Figure 14). The Bay has been too shallow since at least 1973 to absorb significant amounts of sediments and nutrients (Table 13). The Bay is now essentially "full" and no longer able to perform a water quality improvement function for the lake (Figure 15).

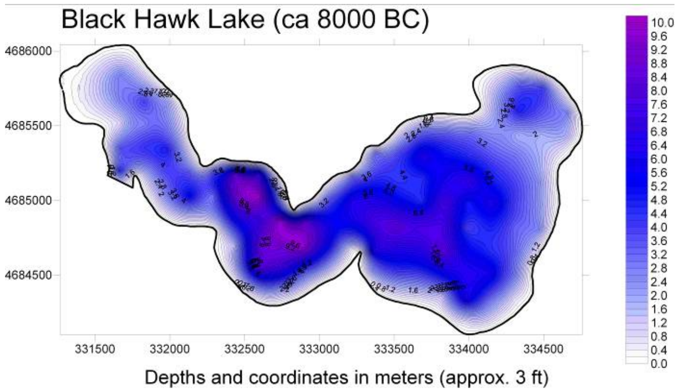
Table 12. Morphometric characteristics of Provost Bay from 1916-2009.

	Area (m^2)	Area (ha)	Area (ac)	Mean Depth (m)	Mean Depth (ft)	Volume (m^3)
1916	584,332	58	144	0.62	2.0	362,084
1973	593,561	59	147	0.63	2.1	371,319
2006	600,040	60	148	0.52	1.7	310,089

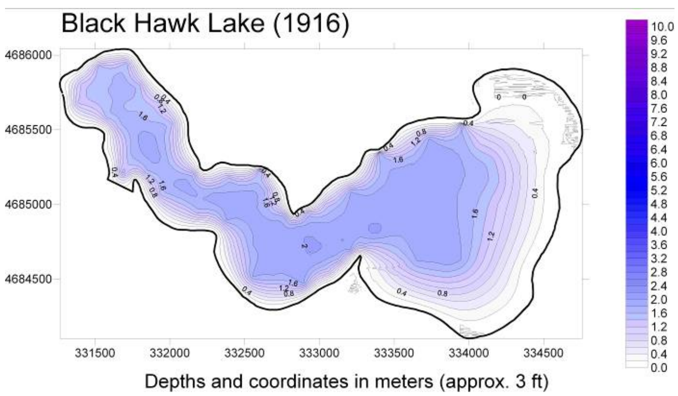
Table 13. Changes in Provost Bay sediment volume from 1916-2009.

	Areas with added volume (m^3)	Areas with decreased volume (m^3)	Net change (m^3)	Fractional change
1916-1973	56,107	84,354	-28,247	-4.8%
1973-2006	86,564	27,847	58,717	+15.8%
1916-2006	101,501	68,896	32,606	+9.0%

12A.


Black Hawk Lake (ca 8000 BC)
4686000
4685500
4685000
4684500
331500 332000 332500 333000 333500 334000 334500
Depths and coordinates in meters (approx. 3 ft)
10.0 9.6 9.2 8.8 8.4 8.0 7.6 7.2 6.8 6.4 6.0 5.6 5.2 4.8 4.4 4.0 3.6 3.2 2.8 2.4 2.0 1.6 1.2 0.8 0.4 0.0

12B.


Black Hawk Lake (1916)
4686000
4685500
4685000
4684500
331500 332000 332500 333000 333500 334000 334500
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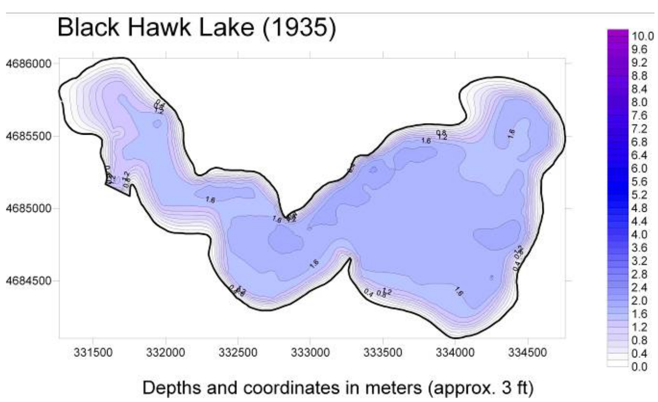
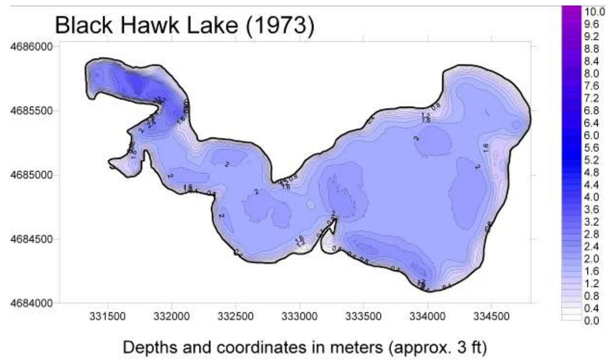
12C.


Black Hawk Lake (1935)
4686000
4685500
4685000
4684500
331500 332000 332500 333000 333500 334000 334500
Depths and coordinates in meters (approx. 3 ft)
10.0 9.6 9.2 8.8 8.4 8.0 7.6 7.2 6.8 6.4 6.0 5.6 5.2 4.8 4.4 4.0 3.6 3.2 2.8 2.4 2.0 1.6 1.2 0.8 0.4 0.0

12D.



12E.

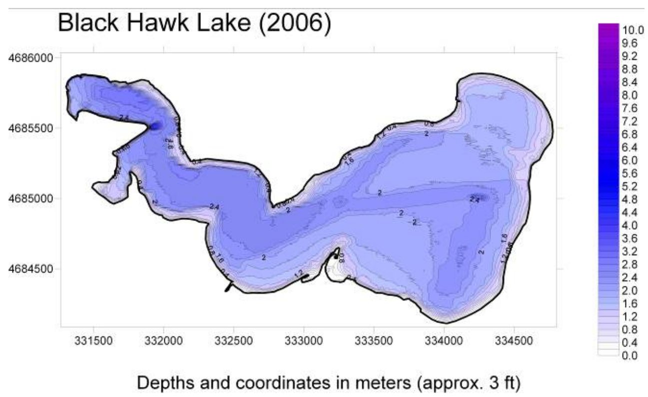


Figure 12. Estimated bathymetry of Black Hawk Lake ca 8000 BC (A), 1916 (B), 1935 (C), 1973 (D), and 2006 (E).

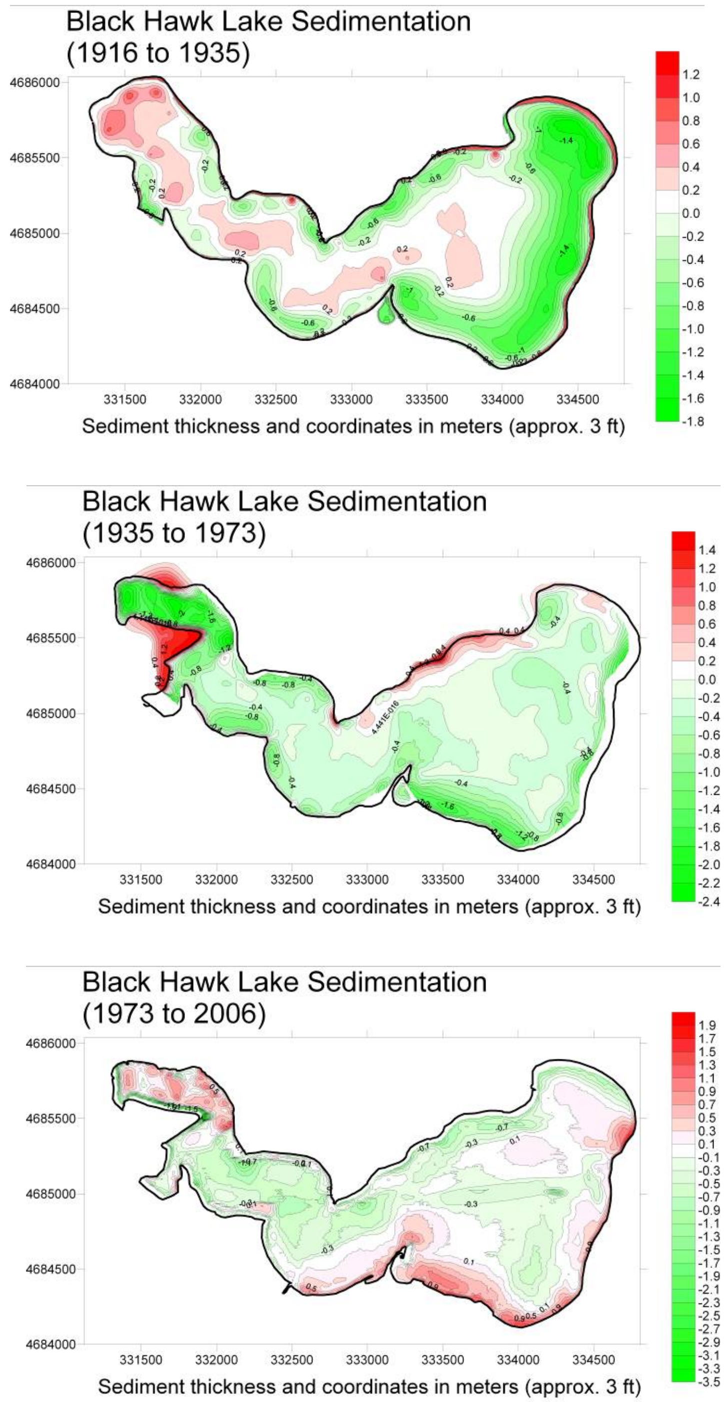


Figure 13. Comparison of sediment deposition 1916-2006. Red indicates increased sediment thickness and green indicates increased water depth.

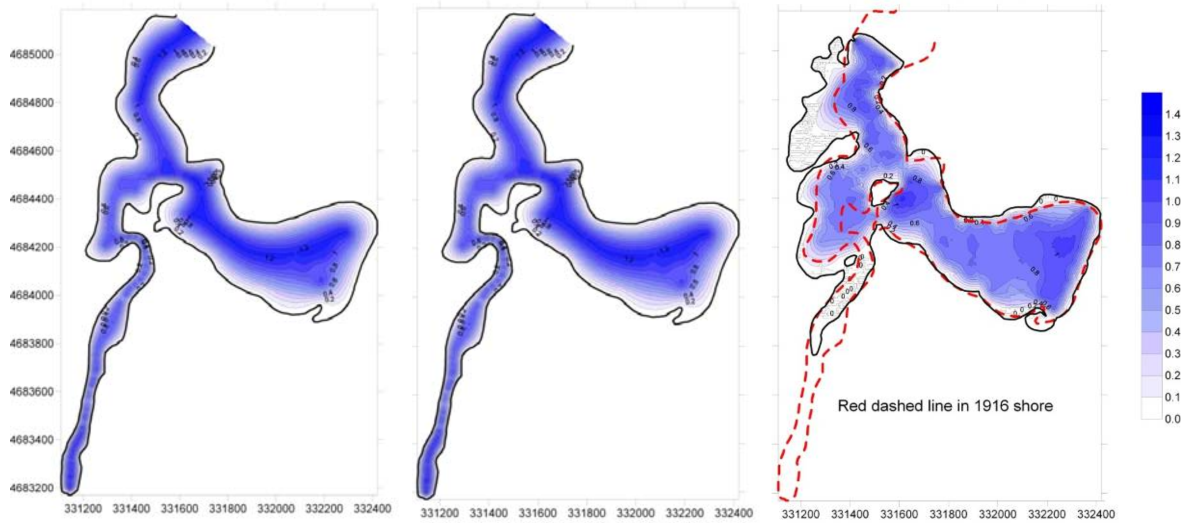


Figure 14. Changes in Provost Bay bathymetry from 1916 to 2009. Depths and coordinates are in meters (approx. 3 ft).

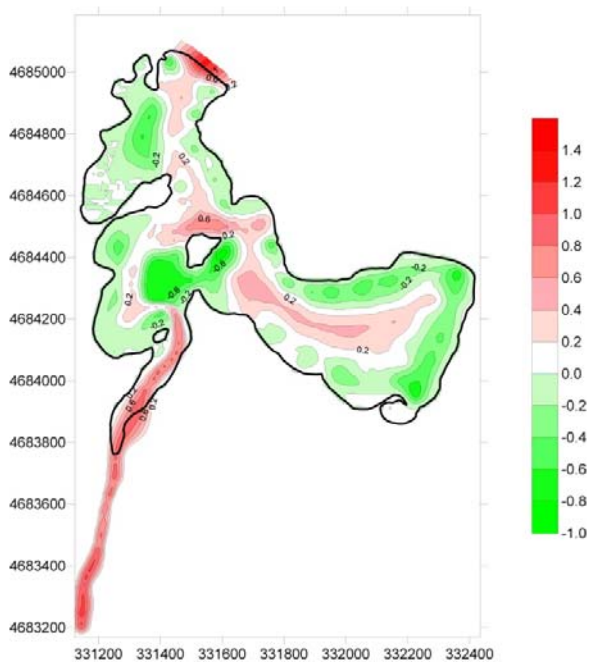


Figure 15. Sediment accumulation in Provost Bay. Sediment thickness and coordinates are in meters (approx. 3 ft). Red indicates increased sediment thickness and green indicates increased water depth.

LAKE WATER QUALITY

Physics and Chemistry

Temperature and stratification

Too shallow to develop thermal stratification during ice-free conditions, Black Hawk Lake is considered polymictic, mixing from top to bottom most of the year (Figure 16).

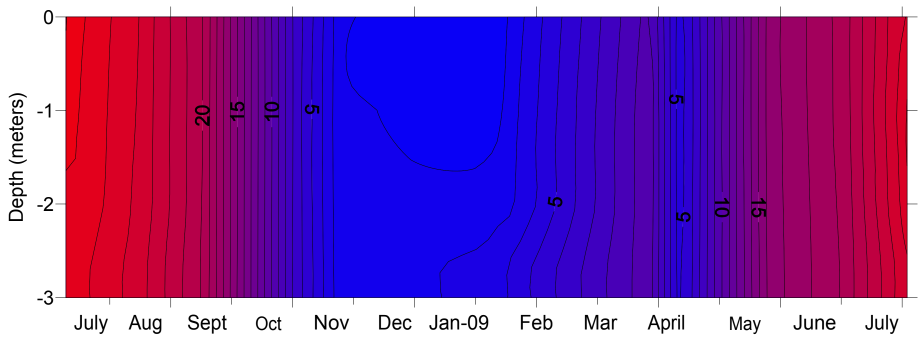


Figure 16. Temperature (°C) profile on Black Hawk Lake, July 2008 to July 2009.

Oxygen

Oxygen concentrations were adequate if not saturated (Figure 17 and 18). This is due to continuous mixing of the water column as well as high primary production that renews oxygen concentrations throughout the water column.

pH

The hydrogen ion concentration was very sensitive to periods of high primary production and high rates of decomposition. High pH was observed in late summer (August 2008) and early spring (March-April 2009), as primary production increased due to nutrient influx and increasing water temperature. Low pH measurements were observed throughout the water column in June 2009 and in deep water in January 2009, which were periods of high decomposition and sediment release of nutrients (Figure 19).

Conductivity

The electrical conductivity of the water of Black Hawk Lake was quite constant during much of the year although it increased during the winter under conditions of high decomposition and sediment release of nutrients (Figure 20).

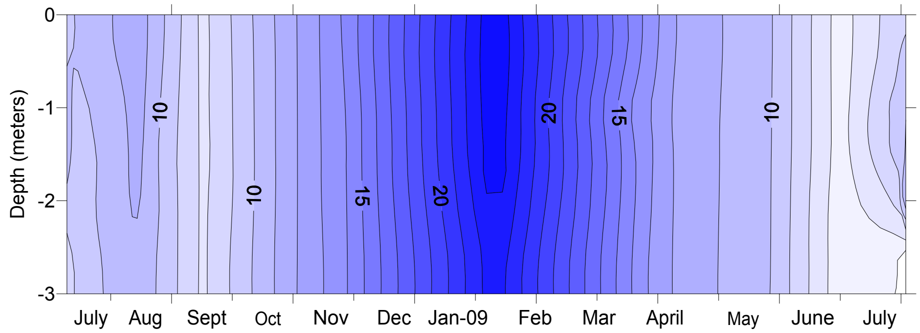


Figure 17. Dissolved oxygen (mg/L) profile on Black Hawk Lake, 2008-2009.

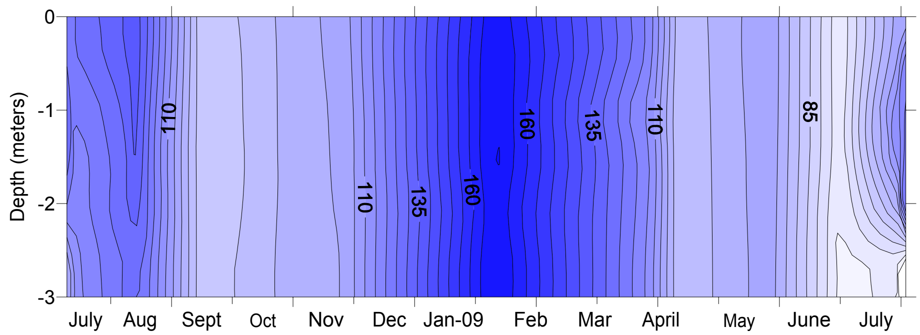


Figure 18. Dissolved oxygen (% saturation) profile on Black Hawk Lake, 2008-2009.

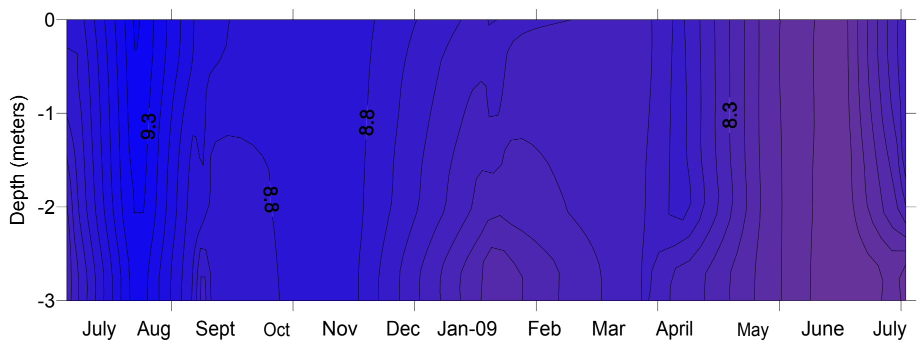


Figure 19. pH profile on Black Hawk Lake, 2008- 2009.

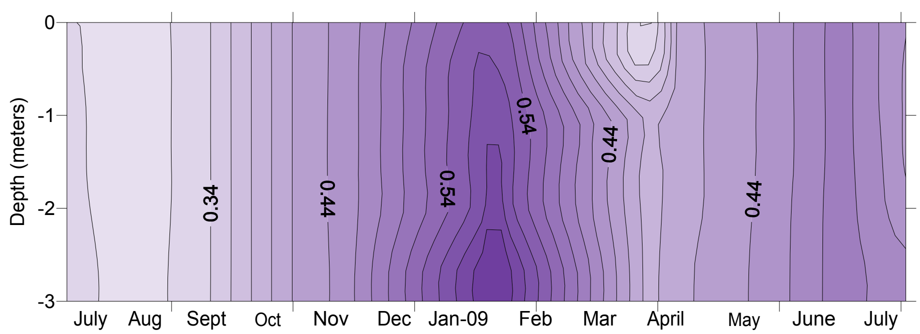


Figure 20. Conductivity profile on Black Hawk Lake, 2008-2009.

Turbidity and suspended solids

In situ turbidity showed high suspended sediment at the bottom of the lake in late June and July 2009, probably from resuspension of sediments due to turbidity currents (Figure 21). These turbidity currents over-flow, under-flow, and inter-flow the lake, depending upon the density of the material carried in the water.

High concentrations of suspended sediments were also observed throughout the water column, suggesting several important sediment inflow events throughout the year (Figures 22-24). Peaks of organic suspended solids throughout the water column during summer were likely the result of high primary production, so may represent autochthonous sediments. Inorganic sediments along the bottom of the lake in June-July indicate the effects of a large influx of sedimentary material from the watershed (Figure 21). Turbidity was higher than average turbidity reported from all Iowa lakes 2000-2007 (45 NTU).

Water clarity

Mean Secchi disk transparency of the three lake monitoring stations varied from 0.2 m (0.7 ft) to 1.4 m (4.6 ft), averaging about 0.4 m (1.3 ft) in this study (Table 14). Summer average Secchi disk measurements for this lake from 2000-2007 averaged slightly highly than this (0.5 m; 1.6 ft) (Table 5) which is lower than the 2000-2007 average of Iowa lakes in general (1.2 m; 3.9 ft).

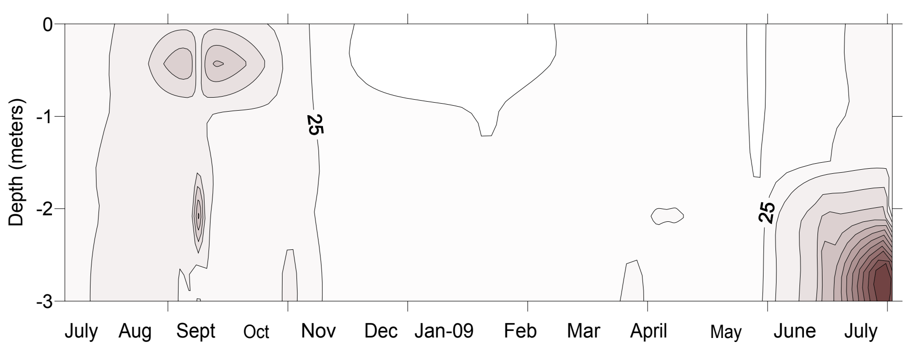


Figure 21. Turbidity (NTU) profile on Black Hawk Lake, 2008-2009.

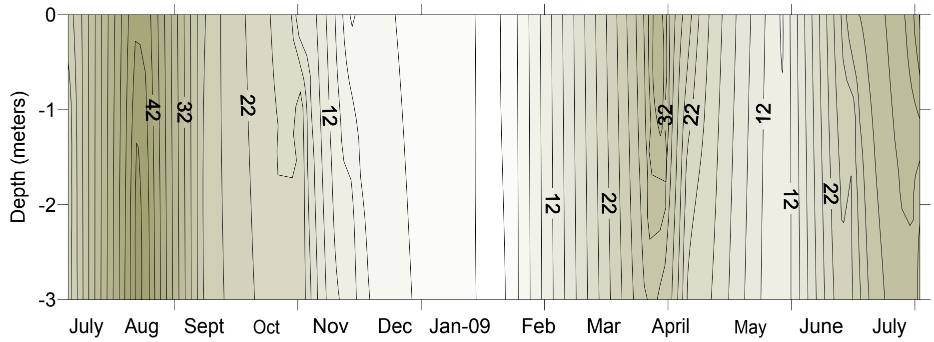


Figure 22. Total suspended solids (mg/L) profile on Black Hawk Lake, 2008-2009.

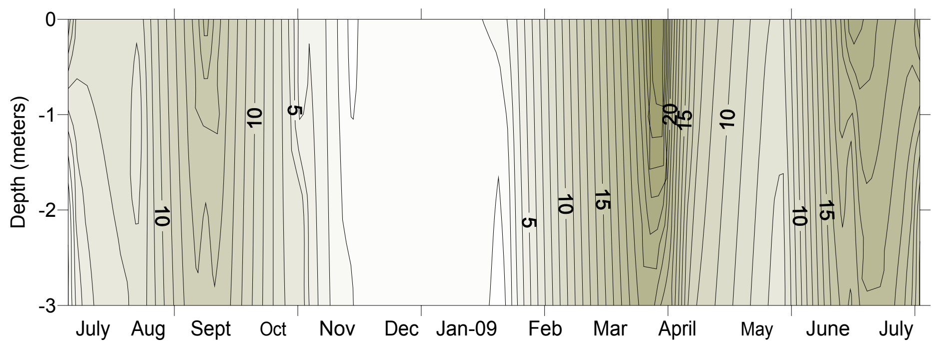


Figure 23. Inorganic suspended solids (mg/L) profile on Black Hawk Lake, 2008- 2009.

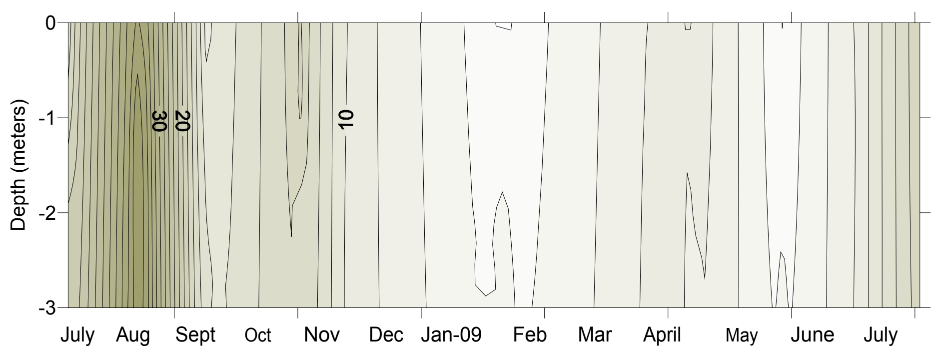


Figure 24. Volatile (organic) suspended solids (mg/L) profile on Black Hawk Lake, 2008- 2009.

Table 14. Calculated average, minimum, maximum, median values for mixed zone samples collected at three lake monitoring sites (LS001, LS002, LS003) from July 2008 to July 2009. TN:TP descriptive statistics cannot be calculated directly from those describing total nitrogen and total phosphorus.

Analyte	Average	Median	Minimum	Maximum
Secchi Depth (m)	0.43	0.40	0.20	1.40
Chlorophyll a (ug/L)	71	37	5	221
DOC(mg/L)	6.0	6.1	4.4	8.0
Alkalinity (mg/L)	188	189	129	276
Lab pH	8.6	8.6	7.9	9.4
Total Nitrogen (mg/L)	2.949	2.840	0.500	6.800
NO2+NO3 -N (mg/L)	0.927	0.700	0.100	5.040
NHx-N (ug/L)	328	166	0	2071
Unionized NH3 (ug/L)	17	12	0	53
Total Phosphorus (ug/L)	218	214	123	357
SRP as P (ug/L)	40	39	0	144
TN:TP	15	15	3	33
TSS (mg/L)	30.3	25.6	2.8	88.7
ISS (mg/L)	17.3	16.0	1.2	72.7
VSS (mg/L)	14.7	11.7	0.0	40.8

Nutrients

Mixed zone total phosphorus averaged 218 µg/L on an annual basis. Average mixed zone values ranged from 123 to 357 µg/L over the period of study with the lowest values seen in late autumn and early spring and highest values throughout the summer (Tables 14 and 15). Average TP at Black Hawk Lake was considerably higher than average TP (110 µg/L) reported for all Iowa lakes from 2000-2007. While much of the phosphorus occurred in the particulate state, average soluble reactive phosphorus (SRP) concentrations were high (40 µg/L) which was higher than the 2000-2007 summer average for Black Hawk Lake and was double the average SRP (16 µg/L) measured in Iowa lakes from 2000-2007.

Total nitrogen was abundant in the lake with high values observed periodically throughout the year much of which occurred as particles (Table 15). Ammonia concentrations were high in June, likely due to losses from surrounding fields. Nitrogen-to-phosphorus ratios (TN:TP) in Black Hawk Lake were relatively low compared to other Iowa lakes. TN:TP ranged from 3 to 33 and were typically greater than the Redfield[1] ratio (~7 by mass; Table 14). Seasonally, TN:TP

[1] The Redfield ratio indicates the "normal" ratio of nitrogen and phosphorus found in living tissue. Therefore, a Redfield ratio >7 (as mass) implies that phosphorus determines the amount of phytoplankton that grows in a lake while a Redfield ration<7 implies that nitrogen might play this role.

Table 15. Major nutrients in Black Hawk Lake. Data are averages of all three sampling stations.

Date	TP (µg/L)	SRP (µg/L)	TN (mg/L)	NHx-N (µg/L)	NH3-N (unionized, µg/L)	NO2+NO3-N (mg/L)	Total N:P
7/28/2008	223	3.5	1.63	90	23	1.39	7
8/26/2008	331	9.8	2.83	0	0	0.16	9
9/22/2008	318	79.1	2.63	0	0	0.13	8
10/30/2008	231	68.6	4.17	138	5	2.07	19
11/19/2008	151	40.8	2.50	267	17	0.94	17
1/20/2009	160	0.5	3.57	261	5	1.42	23
3/24/2009	186	0.2	3.12	157	7	1.22	17
4/6/2009	127	0.2	2.70	55	2	0.89	21
5/13/2009	173	50.1	3.13	833	31	0.96	18
6/11/2009	274	105.9	3.92	1602	50	0.55	15
7/8/2009	223	77.4	2.24	211	19	0.47	10

values approached the Redfield ratio during summer/early autumn likely related to denitrification (loss of N to the atmosphere) and large phosphorus inputs during summer (Table 15). TN:TP ratios were greater than the Redfield ratio during winter/spring (Table 15). Low TN:TP ratios may indicate conditions favoring Cyanobacteria blooms.

Profile measurements (LS001) display low total phosphorus concentrations during winter and higher concentrations during summer/autumn (Figure 25). Total nitrogen concentrations were generally high throughout the water column during this study (Figure 26). Much of the N input occurred as nitrate or nitrite (Figure 27). Ammonia concentrations became quite high from May to July and were associated with sediment decomposition, nutrient release, and high bottom temperatures (Figure 28). Nitrogen-to-phosphorus ratios (TN:TP) were typically greater than the Redfield ratio (~7 by mass) throughout the water column (Figure 29). Two periods of increased TN:TP occurred during this study: once during winter and once during early spring. High carbon was observed in deep water in September and November and throughout the water column during spring (Figure 30).

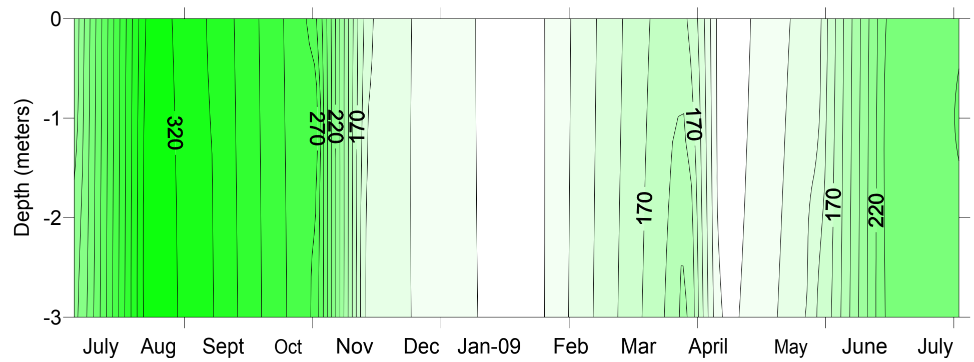


Figure 25. Total phosphorus (µg/L) profile on Black Hawk Lake, 2008-2009.

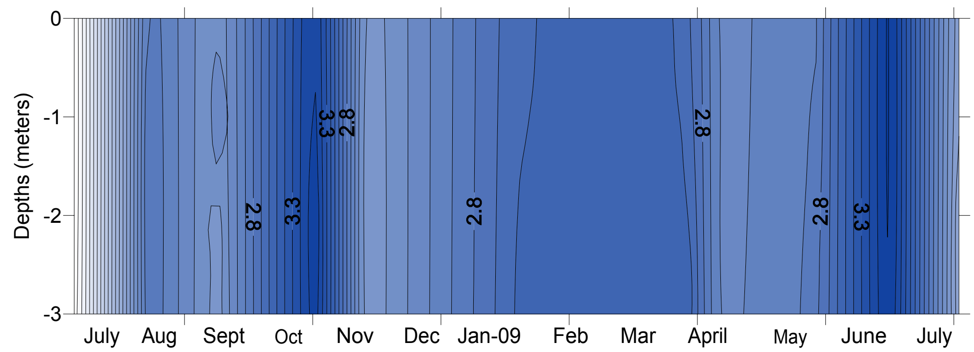


Figure 26. Total nitrogen (mg/L) profile on Black Hawk Lake, 2008-2009.

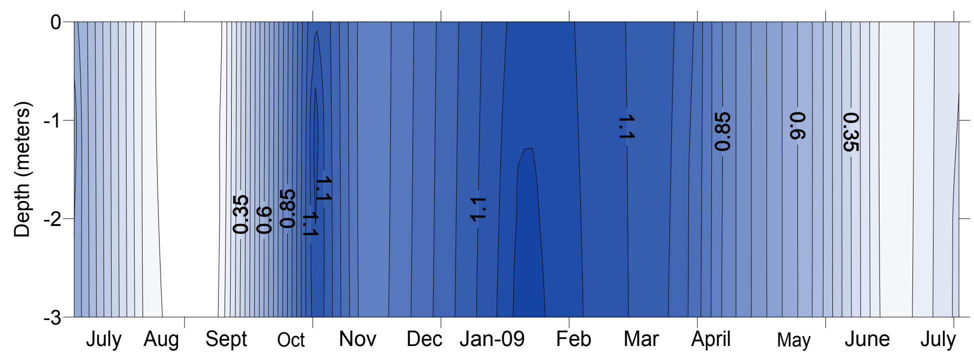


Figure 27. Nitrate and nitrite (mg/L) profile on Black Hawk Lake, 2008-2009.

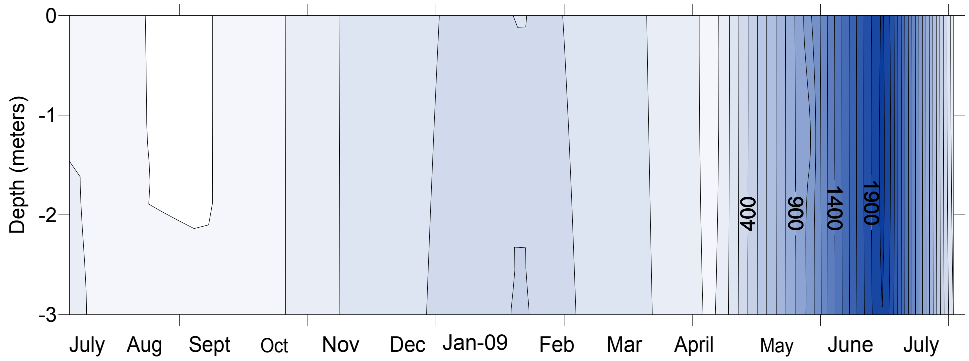


Figure 28. NHx (ammonia and ammonium) (µg/L) profile on Black Hawk Lake, 2008-2009.

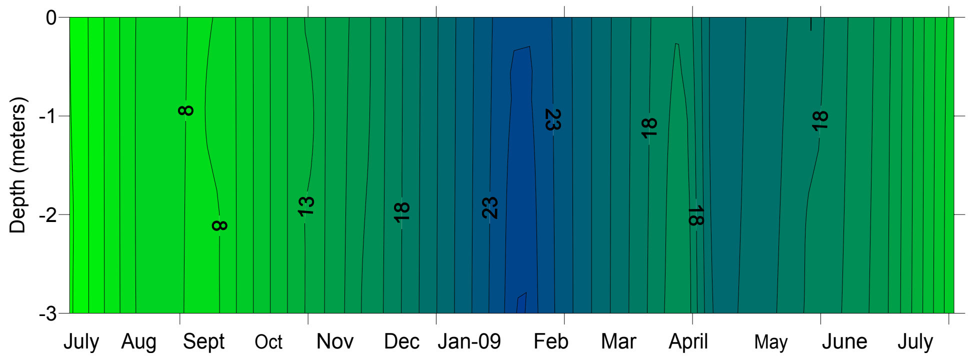


Figure 29. Ratio of total N to total P profile on Black Hawk Lake, 2008-2009.

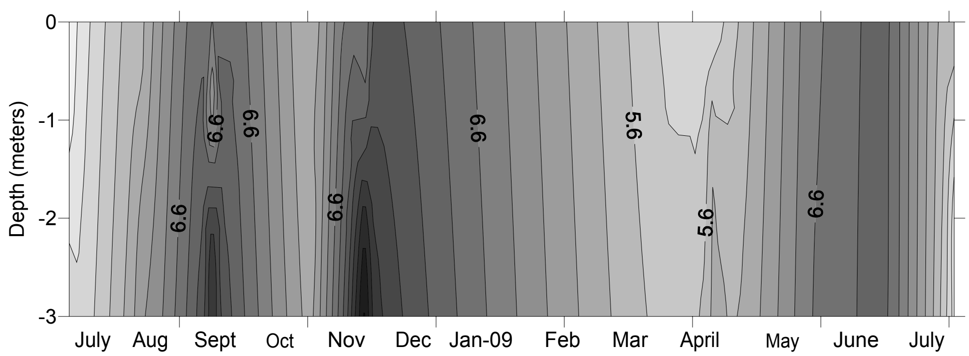


Figure 30. Carbon concentration (mg/L) profile on Black Hawk Lake, 2008-2009.

Biological and Microbial Analyses

Chlorophyll and phytoplankton

Chlorophyll averaged 71 µg/L in mixed zone samples (Table 14) compared with a summer mean of ~51 µg/L from 2000 to 2007 (Table 5). The average mixed zone values were near the 2007 average for all Iowa lakes. Chlorophyll concentrations increased throughout the summers and reached peak values in July and August (Figure 31).

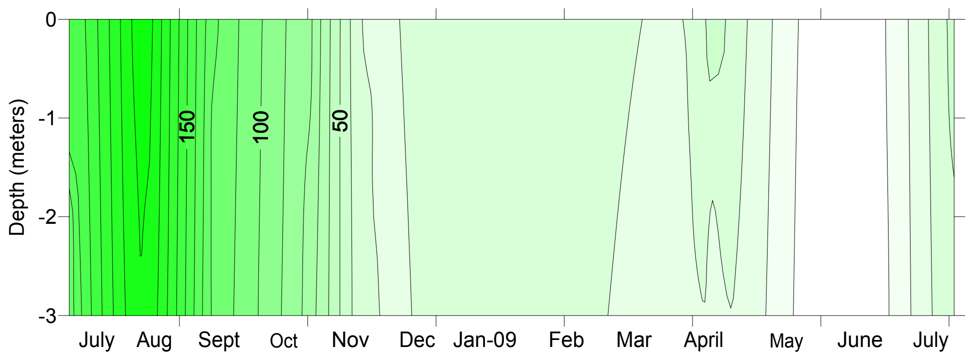


Figure 31. Chlorophyll a concentration (µg/L) profile on Black Hawk Lake, 2008-2009.

Over the year, phytoplankton biomass averaged 85 mg/L in mixed zone samples (Table 16). Summer phytoplankton concentrations at Black Hawk Lake have varied annually since 2001 (Table 5) yet averaged 81 mg/L from 2000-2007, slightly less than was observed in this annual study. The phytoplankton community developed the highest biomass over the summer months and was dominated by Cyanophyta, a phylum of bacteria more commonly referred to as blue-green algae (Figure 32). Of the blue-green algae observed, Microcystis dominated (Figure 33).

Table 16. Seasonal variation in phytoplankton biomass composition.

	Summer 2008	Fall 2008	Winter 2008-2009	Spring 2009	Summer 2009	Overall Average
Bacillariophyta (mg/L)	0.99	0.67	3.73	0.24	0.24	1.17
Chlorophyta (mg/L)	0.07	0.57	0.80	0.01	0.00	0.29
Cryptophyta (mg/L)	0.07	0.27	2.26	0.33	0.22	0.63
Cyanophyta (mg/L)	123.17	108.94	0.67	91.37	91.64	83.16
Euglenophyta (mg/L)	0.00	0.00	0.00	0.00	0.24	0.05
Total (mg/L)	124.30	110.45	7.47	91.94	92.34	85.30

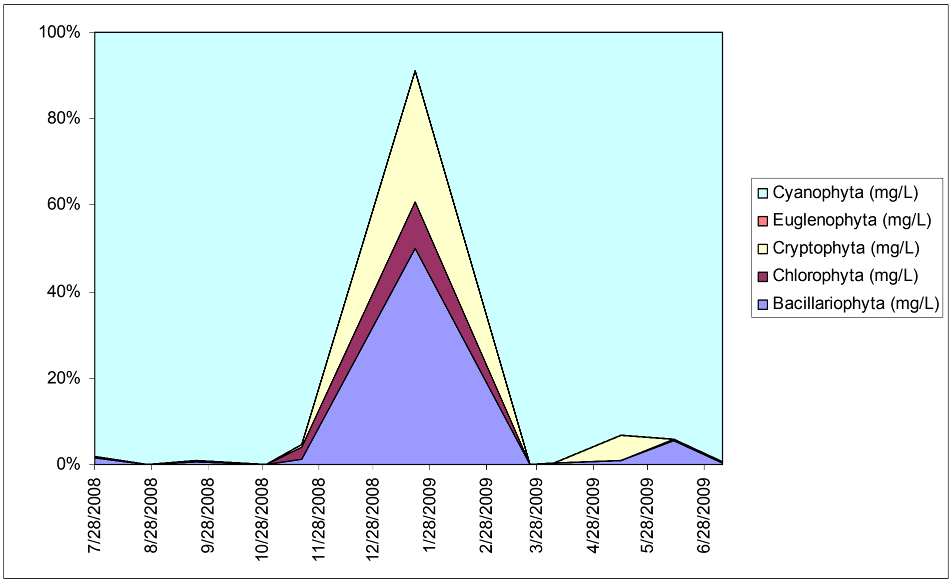


Figure 32. Percent phytoplankton composition by phylum.

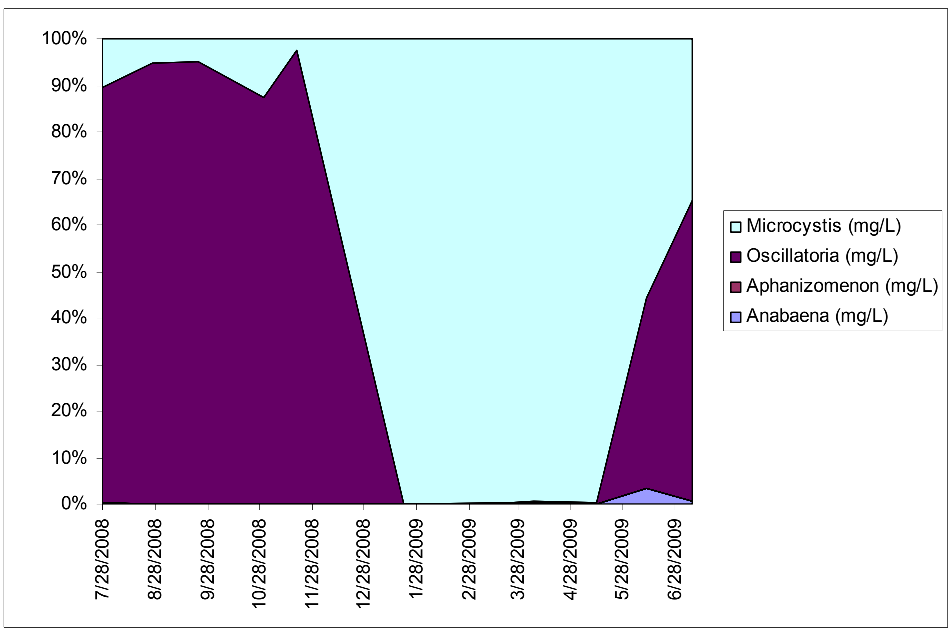


Figure 33. Percent Cyanophyta composition by genus.

Zooplankton Community Structure and Biomass.

Zooplankton in Black Hawk Lake developed highest biomass in mixed zone samples during the summer months and peaked at 2226 µg/L (Table 17). Copepoda dominated the zooplankton community from mid to late summer (2008) and over the winter months while Cladocera were dominant from April-July 2009 (Table 17, Figure 34). The zooplankton community composition varied seasonally and, only occasionally, was dominated by Cladocera, a large suspension feeder important as a food source for fish (Table 17 and Figures 35 and 36).

Table 17. Seasonal variation in zooplankton biomass composition.

	Summer 2008	Fall 2008	Winter 2008-2009	Spring 2009	Summer 2009	Overall Average
Cladocera (ug/L)	307.66	546.980	93.02	568.76	1606.44	624.57
Copepoda (ug/L)	989.96	392.99	709.20	366.32	611.99	614.09
Rotifera (ug/L)	4.76	3.34	6.91	1.45	7.70	4.83
Total (ug/L)	1302.38	943.31	809.13	936.54	2226.12	1243.50

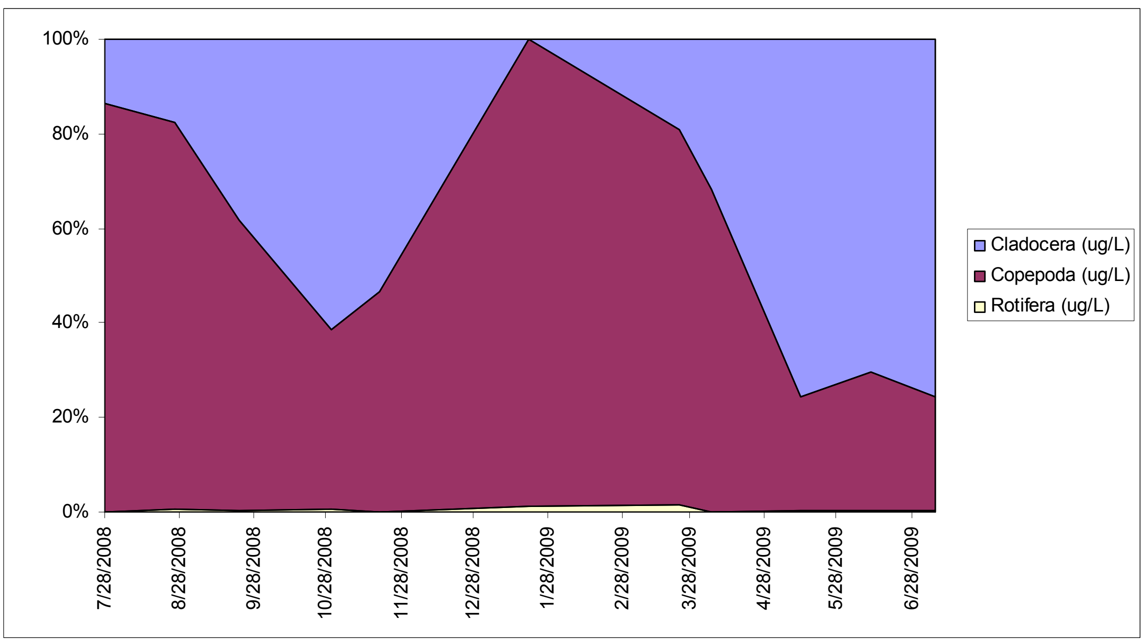


Figure 34. Percent zooplankton composition by Order (Cladocera, Copepoda, and Rotifera) in Black Hawk Lake.

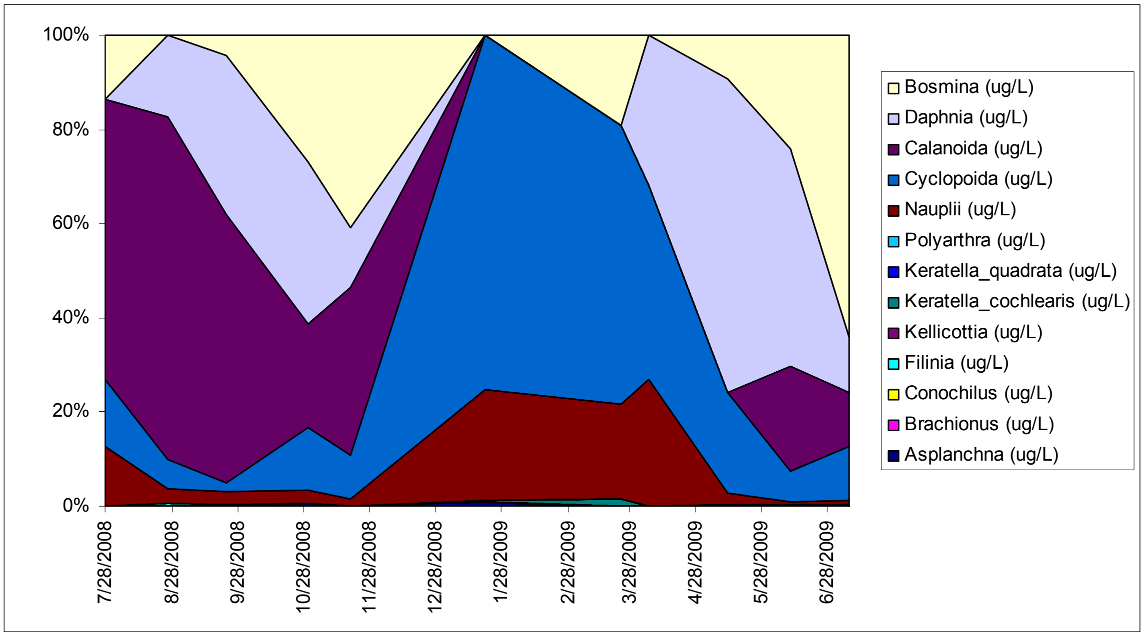


Figure 35. Percent zooplankton composition by genera in Black Hawk Lake.

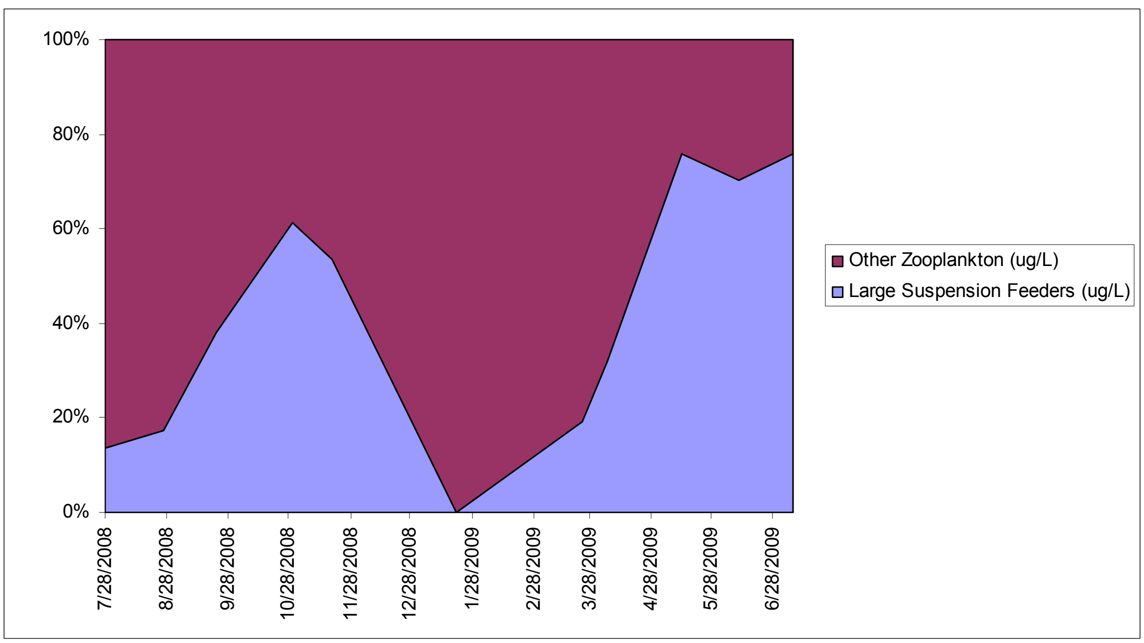


Figure 36. Percent zooplankton composition by size in Black Hawk Lake. Large suspension feeders are exclusively Cladocera (blue). Other zooplankton (red) includes all Copepoda and Rotifera.

Bacteria

The three lake sampling sites had low *E. coli* concentrations. The 2008-2009 geometric mean ranged from 3 colonies/100 mL at LS001 to 9 colonies/100 mL at LS002. Total coliform concentrations were higher with the 2008-2009 geometric mean ranging from 459 colonies/100 mL at LS003 to 1131 colonies/100 mL at LS002.

A wider range of total coliform and *E. coli* concentrations was seen in the tributary sites. The lowest total coliform and *E. coli* concentrations were observed at the outflow of the lake (site S1). Seven tributary sites (S3, S5, S6, S9, S13, S17, and S18) had total coliform concentrations greater than 2420 colonies/100 mL. Tributary site S17 had the greatest *E. coli* concentration with a 2009 geometric mean of 1733 colonies/100 mL.

All storm drain samples had total coliform concentrations greater than 2420 colonies/100 mL. The *E. coli* concentrations ranged from 53 colonies/100 mL to greater than 2420 colonies/100 mL.

Iowa DNR Beach Monitoring data (collected during the summer 2002-2009) reported the annual geometric mean of *E. coli* ranged from 33 colonies/100 mL (2002) to 69 colonies/100 mL (2009). The overall geometric mean was 51 colonies/100 mL.

Microcystin

Water samples were collected from the three lake sampling sites at Black Hawk Lake in July – November 2008 and January – July 2009. These samples were analyzed for total available microcystin concentration using commercially available immunoassay kits. A total of 11 samples were analyzed from each lake sampling site. Microcystin concentration peaked in July 2008 and July 2009 with the highest concentrations measured at LS001, which had concentrations ranging from 0.12 µg/L to 265.78 µg/L and a geometric mean of 2.17 µg/L. LS002 had concentrations ranging from 0.13 µg/L to 70.51 µg/L (geometric mean = 1.21 µg/L) and LS003 had concentrations ranging from 0.13 µg/L to 122.99 µg/L (geometric mean = 1.83 µg/L).

Macrophytes

There were no emergent or submergent aquatic macrophytes observed or collected in this survey. The absence of aquatic plants is consistent with recent Iowa DNR lake vegetation surveys (Iowa DNR 2009). A review of aerial photography suggests aquatic vegetation has been nearly absent from Black Hawk Lake from as early as the 1930's (Appendix H).

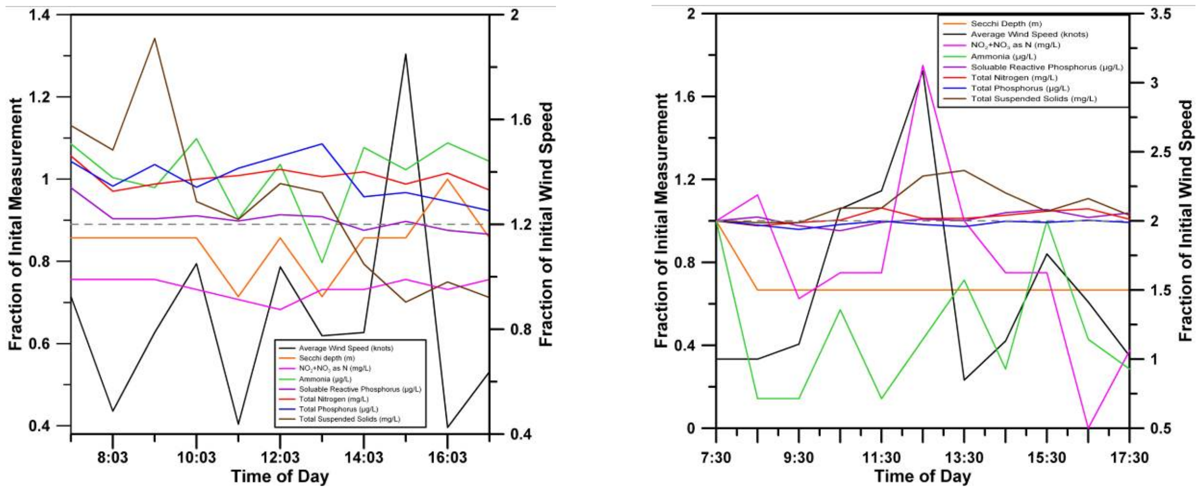


Figure 37. Diurnal plots of wind measurements (black) with sediment (brown) and nutrients concentrations (colored) and water clarity (orange) observed on Black Hawk Lake.

Diurnal Analysis and Internal Loading

Two diurnal series of samples were taken to judge whether wind mixing over the cycle from calm nights to windy days led to increased nutrients in the water column. Evidence from both of these studies indicates that the phosphorus concentration (in blue) in Black Hawk Lake changes very little over the day, due to wind-driven nutrient loading (Figure 37). This mixing influenced water clarity somewhat more than nutrients so may pose a minor recreational nuisance.

Table 18 shows internal loading estimates as measured by the amount of nutrient input or output not accounted for by surface water sources. Internal phosphorus loading (positive numbers in Table 18) was highest during spring/summer whereas total phosphorus losses (negative number in Table 18) were greatest during autumn, especially in November. During an annual cycle, internal loading resulted in a net loss of total phosphorus from the lake. Therefore, average conditions in Black Hawk Lake, and thus its overall biotic function, were not driven by annual internal loading. However, seasonal (short-term) internal loading may result in larger phytoplankton biomass than anticipated based on average lake conditions.

WATERSHED ASSESSEMENT

Tributary analysis and nutrient loads

Nutrient export rates were based on continuous monitoring of stream discharge and regular and frequent sampling of measured nutrient and sediment concentrations originating in the watershed south of Black Hawk Lake. Watershed sampling locations and subsequent sub-watersheds are displayed in Figures 38 and 39 respectively. Watershed sampling locations were sampled for nutrient and TSS concentrations monthly from July 2008 to September 2009 excluding January and February 2009 when no samples were collected (N=12). We assumed that TSS primarily resulted from sediment in this largely agricultural watershed; therefore TSS export rates approximate sediment export rates. Export rates for each sub-watershed or zone were calculated as the loading rates at the associated tributary sampling location minus loading rates at tributary sampling locations flowing into that sub-watershed (i.e. outflow – inflow). For example, the export rates from Zone 12 were calculated by subtracting loading rates at Zone 13 from loading rates at Zone 12 (Figures 38 and 39). These calculations represented nearly all of the consolidated water fluxes to the lake. Direct input from pipes and tiles to the lake (the north portion of the watershed) was estimated to be a small fraction of the nutrient and material load (see also *Additional Water Quality Monitoring Results*). Pipe and tile inputs were not included in the mass balance analysis or flux calculations because they were based only on storm event monitoring not continuous monitoring. Other inputs occurred (Table 19), but these were diffuse and also carried a small fraction of the nutrient and material load. The flux of materials from continuously monitored sub-watersheds was estimated directly (see Figures 40-42 and Table 20).

Table 18. Estimate of internal load of total phosphorus as % of total inputs to the lake. Positive values indicate internal loading while negative numbers indicate loss of phosphorus from the lake.

Time Period	Internal Loading (% of surface inputs)
07/28/08 - 08/26/08	**106%**
08/26/08 - 09/22/08	**-24%**
09/22/08 - 10/30/08	**-150%**
10/30/08 - 11/19/08	**-322%**
11/19/08 - 01/20/09	**61%**
01/20/09 - 03/24/09	**173%**
03/24/09 - 04/06/09	**-176%**
04/06/09 - 05/13/09	**83%**
05/13/09 - 06/11/09	**284%**
06/11/09 - 07/08/09	**-40%**

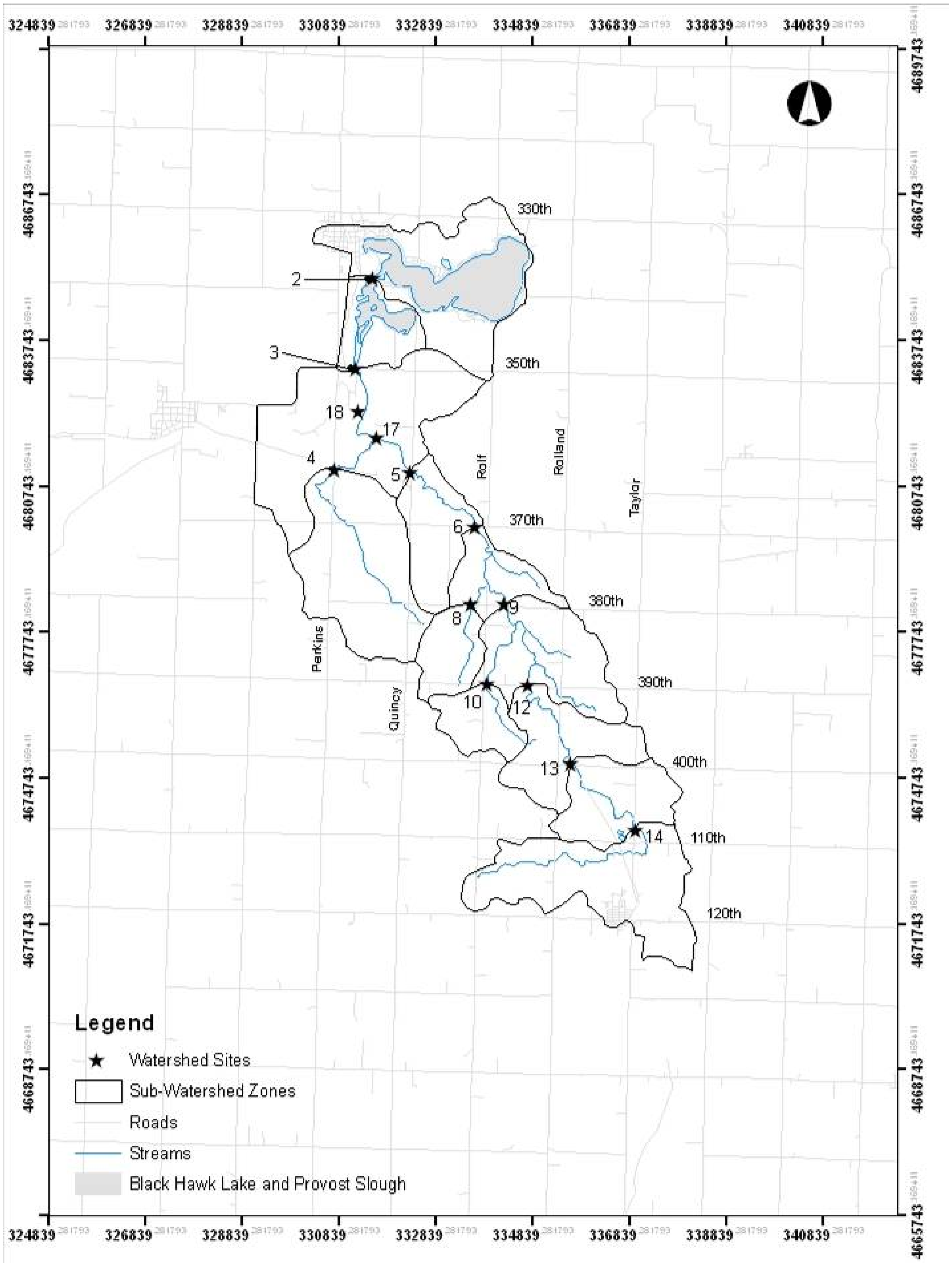


Figure 38. Black Hawk Lake Watershed: Sub-watersheds and sample locations.

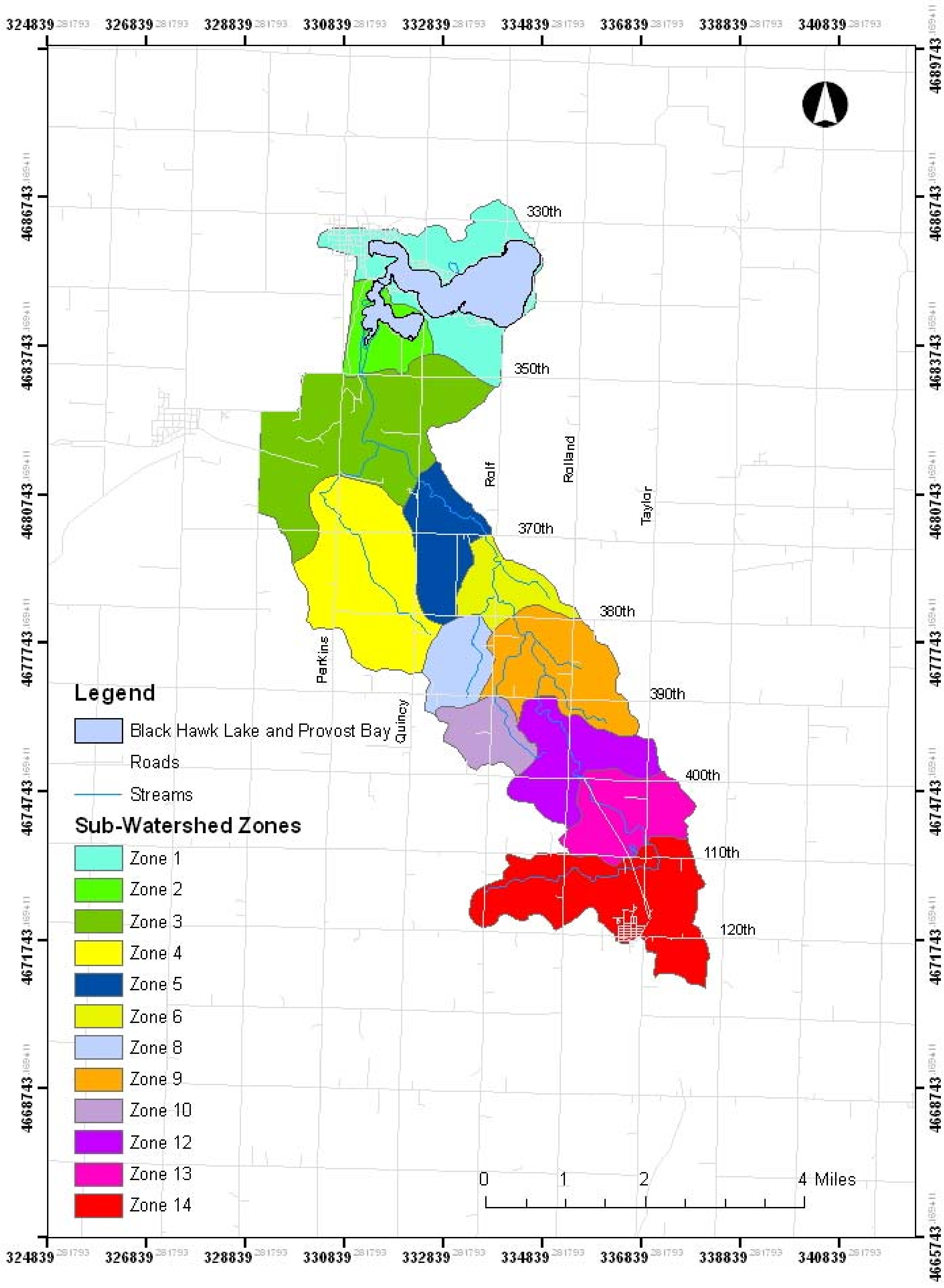


Figure 39. Black Hawk Lake Watershed: Sub-watershed "zones".

*Table 19. Mass balance analysis of measurable stream inputs and outputs. Zone export rates were calculated by subtracting inflow loading rates into the sub-watershed from outflow loading rates from the sub-watershed. *Values are in kg with lbs provided in gray boxes.*

Nutrient sources	Total TP Per Site (kg)*	Total TN Per Site (kg)*	Total TSS Per Site (kg)*	Total NO3 Per Site (kg)*	Total NH3 Per Site (kg)*
Zone 2	116	-73409	-77248	-84520	-170
(S2 – S3)	256	-161839	-170303	-186335	-375
Zone 3	-130	-102359	-965445	-110511	759
(S3 – (S4 + S5))	-287	-225663	-2128442	-243635	1673
Zone 4	137	25378	17221	25196	81
(S4)	302	55949	37966	55548	179
Zone 5	242	-8836	-102206	-9918	105
(S5 – S6)	534	-19480	-225326	-21865	231
Zone 6	178	-21534	710922	-20552	-253
(S6 – (S8 + S9))	392	-47474	1567315	-45309	-558
Zone 8	27	15773	7848	15726	8
(S8)	60	34774	17302	34670	18
Zone 9	289	61072	252455	61464	-224
(S9 – (S10 + S12))	637	134641	556568	135505	-494
Zone 10	26	10688	4929	10503	6
(S10)	57	23563	10867	23155	13
Zone 12	1221	80601	628163	80383	26
(S12 – S13)	2692	177695	1384862	177214	57
Zone 13	761	9936	192743	8206	37
(S13 – S14)	1678	21905	424926	18091	82
Zone 14	369	63636	21676	61648	805
(S14)	814	140293	47787	135911	1775
	274	8453	89995	7645	124
Unconsolidated Watershed	604	18636	198405	16854	273
	101	2118	0	877	1547
Rain & Dryfall	223	4669	0	1933	3411

Calculated P export rates from the sub-watersheds generally ranged from -0.14 to 3.11 kg ha^{-1} yr^{-1} (-0.12 to 2.77 lbs ac^{-1} yr^{-1}) indicating that some sub-watersheds (Zone 3) sequestered P while other sub-watersheds contributed much P to the overall budget (Table 20). TP export rates were greatest from the southern 1/3 of the watershed with Zones 12 and 13 contributing >50% of the TP load to Black Hawk Lake (Figure 40). The middle 1/3 of the watershed contributed only 24% of the TP load despite a larger area. The lower 1/3 of the south watershed and the north watershed accounted for 7 and 8% respectively of the P load.

*Table 20. Sub-basin watershed export rates of materials from the Black Hawk Lake watershed. Zone export rates were calculated by subtracting inflow loading rates into the sub-watershed from outflow loading rates from the sub-watershed. Export rates from any given site represent measurement made for that area or "zone" only and are not cumulative. *Values are in kg/ha/yr with lbs/ac/yr provided in gray boxes.*

	Total TP Per Site (kg/ha/yr)*	Total TN Per Site (kg/ha/yr)*	Total TSS Per Site (kg/ha/yr)*	Total NO3 Per Site (kg/ha/yr)*	Total NH3 Per Site (kg/ha/yr)*
Zone 2	0.47	-297.37	-312.92	-342.38	-0.69
(S2 – S3)	0.42	-265.27	-279.14	-305.42	-0.62
Zone 3	-0.14	-106.19	-1001.54	-114.64	0.79
(S3 – (S4 + S5))	-0.12	-94.73	-893.43	-102.27	0.70
Zone 4	0.18	33.72	22.88	33.47	0.11
(S4)	0.16	30.08	20.41	29.86	0.10
Zone 5	0.75	-27.53	-318.48	-30.91	0.33
(S5 – S6)	0.67	-24.56	-284.10	-27.57	0.29
Zone 6	0.79	-94.85	3131.41	-90.53	-1.12
(S6 – (S8 + S9))	0.70	-84.61	2793.41	-80.76	-1.00
Zone 8	0.13	74.81	37.22	74.59	0.04
(S8)	0.12	66.74	33.20	66.54	0.04
Zone 9	0.59	124.82	515.99	125.63	-0.46
(S9 – (S10 + S12))	0.53	111.35	460.29	112.07	-0.41
Zone 10	0.13	53.68	24.76	52.75	0.03
(S10)	0.12	47.89	22.09	47.06	0.03
Zone 12	3.11	205.12	1598.58	204.56	0.06
(S12 – S13)	2.77	182.98	1426.03	182.48	0.05
Zone 13	2.18	28.42	551.25	23.47	0.11
(S13 – S14)	1.94	25.35	491.75	20.94	0.10
Zone 14	0.50	86.35	29.41	83.65	1.09
(S14)	0.45	77.03	26.24	74.62	0.97
	0.55	16.93	180.21	15.31	0.25
Unconsolidated Watershed	0.49	15.10	160.76	13.66	0.22

N export rates from sub-watersheds varied considerably likely due to various agricultural practices throughout the watershed (Table 20). Almost 75% of N input to the lake originated in the southern-most watershed with Zone 12 contributing 29% of the TN load (Figure 41). Although N is often considered less important than P to lake management, the low N:P ratio in Black Hawk Lake (relative to other lakes in Iowa) suggests that N control could be used to limit algal growth under N-limited conditions. This management approach becomes more practical as N:P ratios decrease.

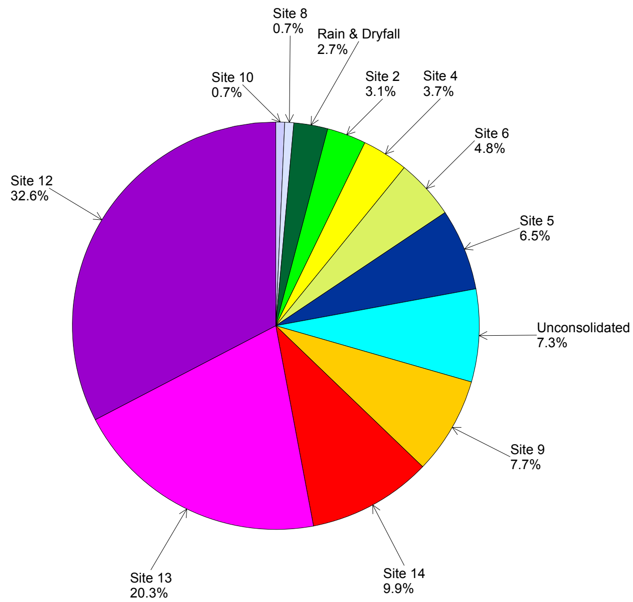


Figure 40. Phosphorus export from sub-watersheds.

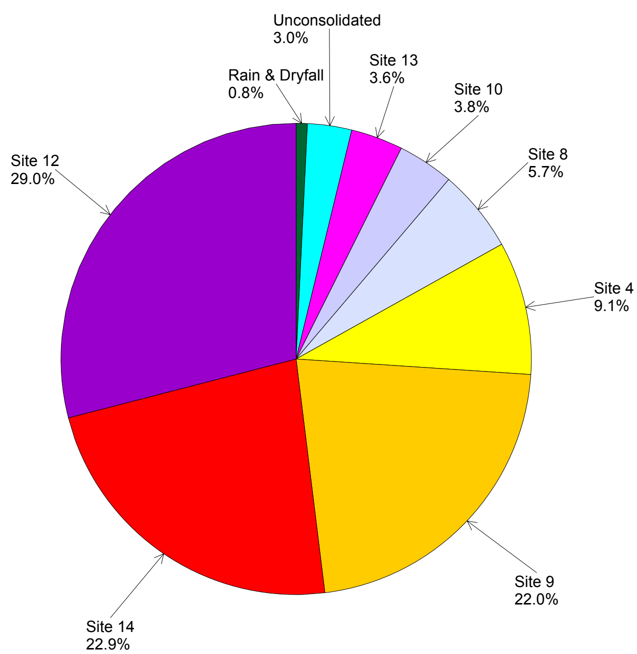


Figure 41. Nitrogen export from sub-watersheds.

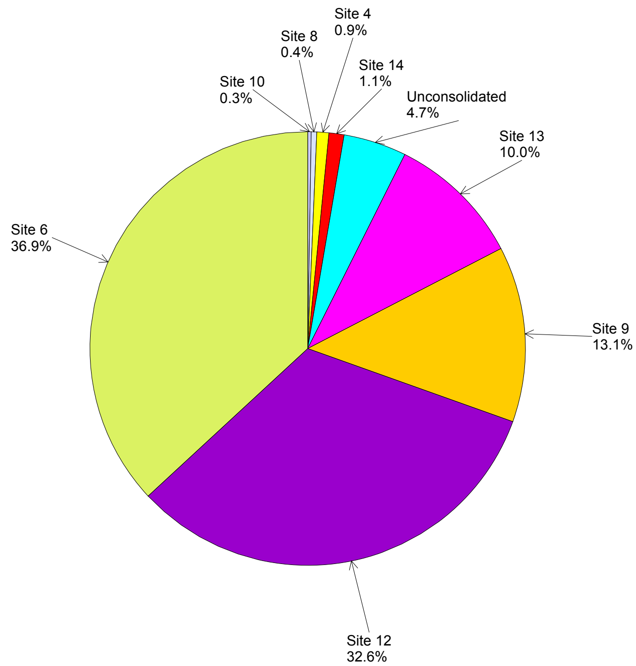


Figure 42. Sediment (TSS) export from sub-watersheds.

Suspended solids move at high rates in the southernmost 2/3 of the south watershed. The watersheds upstream from watershed sampling site 6 (i.e., Zones 6, 8-10, and 12-14) supplied 70% of the sediment load to the lake (Figure 42). Provost Bay and the wetlands located in the Iowa DNR WMA are retaining some of the watershed-derived sediments (Table 19). Loss rates of suspended solids from watersheds range from 23 to 3131 kg ha^{-1} y^{-1} (20 to 2793 lbs ac^{-1} yr^{-1};Table 20).

Additional Water Quality Monitoring Results

Additional Direct Inputs

Data collected from storm drains were averaged and included as "unconsolidated" materials in the overall nutrient budgets (Figures 40-42). It is estimated that storm drains and tiles entering the lake directly contribute ~7% of TP loads, 3% of TN loads, and 5% of TSS loads to the lake.

Wetlands

Water, nutrients, and sediments entering and exiting two DNR wetlands were monitored to gauge their relative efficiency in nutrient removal and sediment retention (Sites 5, 17, and 18 shown in Figure 38). If functioning, nutrients and sediments exiting a wetland should be less than what enters. Input-output measurements for the wetlands are shown in Table 21. "% Retention" indicates the amount of the substance that was being held or diverted by the wetland complexes.

Table 21. Wetland inputs and outputs measured for the purpose of determination function. Positive numbers indicate nutrient retention while negative numbers indicate nutrient loading.

Sampling Event 08/05/09	Site 5	Site 17	%Retention	Site 18	%Retention
TP (ug/L)	128	132	-3%	144	-9%
TN (mg/L)	15	15	4%	14	3%
TSS (mg/L)	42	23	44%	42	-81%
NO3(mg/L)	15	15	3%	14	4%
NH3 (ug/L)	19	16	16%	29	-81%
SRP as P (ug/L)	81	79	2%	79	0%
Sampling Event 09/10/09	**Site 5**	**Site 17**	**%Retention**	**Site 18**	**%Retention**
TP (ug/L)	93	91	2%	150	-66%
TN (mg/L)	10	9	9%	5	44%
TSS (mg/L)	40	32	19%	39	-23%
NO3(mg/L)	10	9	8%	4	55%
NH3 (ug/L)	36	31	14%	117	-277%
SRP as P (ug/L)	36	42	-15%	0	100%

Caffeine

Selected watershed sampling sites (S5, S6, S13, and S14) and 9 tile drains were sampled and analyzed for caffeine concentrations. Caffeine was detected at only one watershed sampling site (S13; Appendix I). Detectable caffeine concentrations indicated traces of human-derived compounds at Site 13, which is the first watershed sampling site downstream from Breda treatment lagoons.

PHOSPHORUS MODELING BLACK HAWK LAKE

Geographic, bathymetric, hydrologic, and export data were integrated into a series of lake models to find which gave the best fit to observed values found in Black Hawk Lake (Kreider 2001). The list of attempted models appears as Appendix I. We found that the Reckhow (1977) model for lakes with anoxic sediments lakes fit the observations best. The model predicted an equilibrium total P value that was about 36 µg/L lower than that observed. The next best model was the Walker (1977) general model that predicted an equilibrium P value about 45 µg/L lower than that

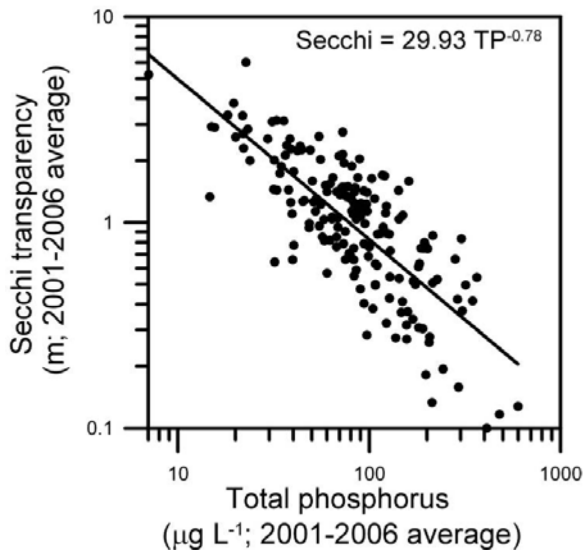


Figure 43.Secchi disk generalized phosphorus response relationship fit to Iowa data collected between 2001 and 2006. All data are annual means and represent data from >170 lakes.

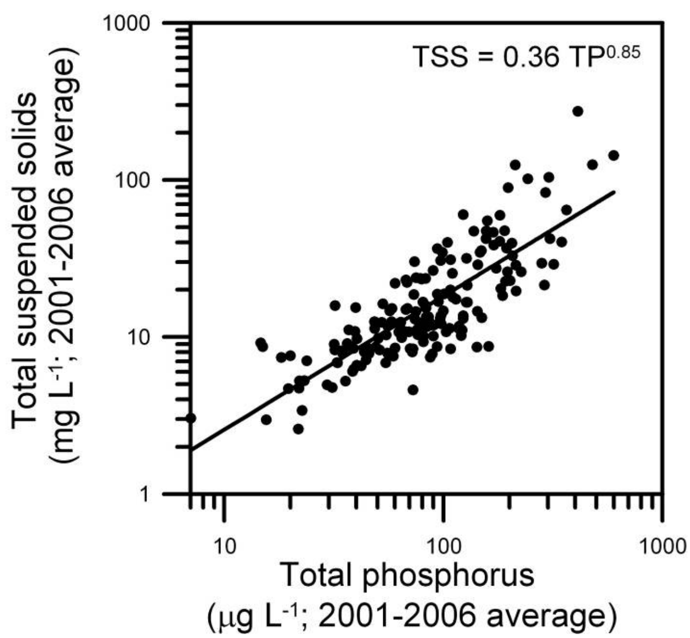


Figure 44. Total suspended solids generalized phosphorus response relationship fit to Iowa data collected between 2001 and 2006. All data are annual means and represent data from >170 lakes.

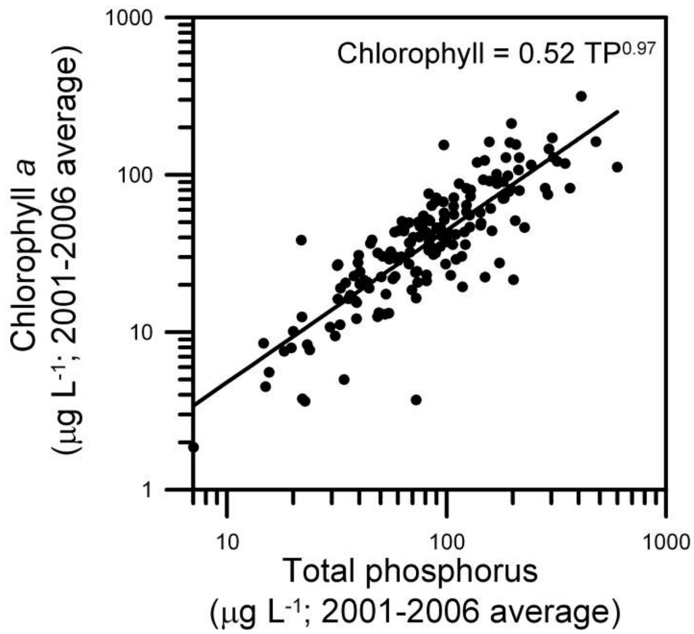


Figure 45. Chlorophyll a generalized phosphorus response relationship fit to Iowa data collected between 2001 and 2006. All data are annual means and represent data from >170 lakes.

observed. The models fit the data nicely despite uncertainty associated with the model.

In order to calibrate the predicted equilibrium total P values to expected levels of Secchi disk transparency, chlorophyll a, and total suspended solids, we fit generalized phosphorus response models from data collected on lakes across Iowa since 2001. These relationships are shown as Figures 43-45.

Figure 46 shows how total phosphorus concentrations will likely decline as more of the watershed is restored to healthy function. Significant reductions in watershed-derived phosphorus are necessary to see improvements in water quality at Black Hawk Lake. For example, almost an 80% reduction in P loading from the watershed should result in total P concentrations in the range of 40-50 µg/L. This would provide substantially improved water quality. The Secchi disk criterion of 4.5 ft (~1.5 m) could be met with a ~80% reduction in P loading (Figure 47). To achieve the intermediate water clarity goal of 2.3 ft (~0.7 m), it would be necessary to achieve a reduction in P loading by ~45%. A 45% reduction in P loading should also cut the TSS levels (Figure 48) and lead to substantially reduced chlorophyll a (Figure 49).

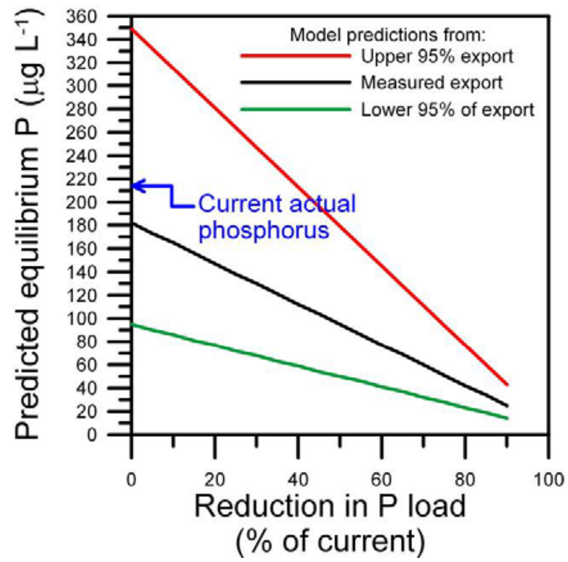


Figure 46. Modeled relationship between average equilibrium TP concentrations and the fractional reductions in the overall non-point source inputs.

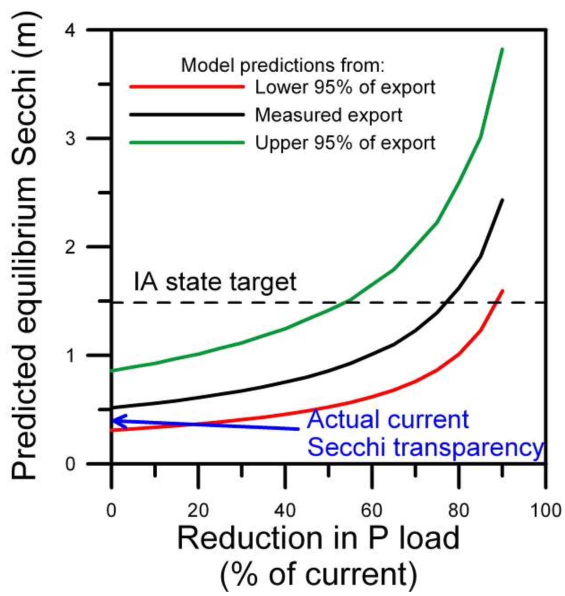


Figure 47. Modeled relationship between average equilibrium Secchi disk transparency values and the fractional reductions in the overall non-point source inputs. The relationships were obtained by combining the modeled output in Figure 46 with the relationship in Figure 43. The dashed line shows the Iowa Legislature target of 4.5 ft (~1.5 m).

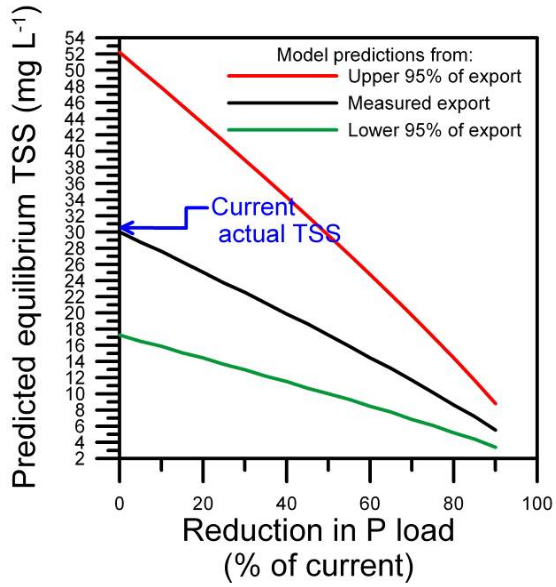


Figure 48. Modeled relationship between average equilibrium TSS concentrations and the fractional reductions in the overall non-point source inputs. The relationships were obtained by combining the modeled output in Figure 46 with the relationship in Figure 44.

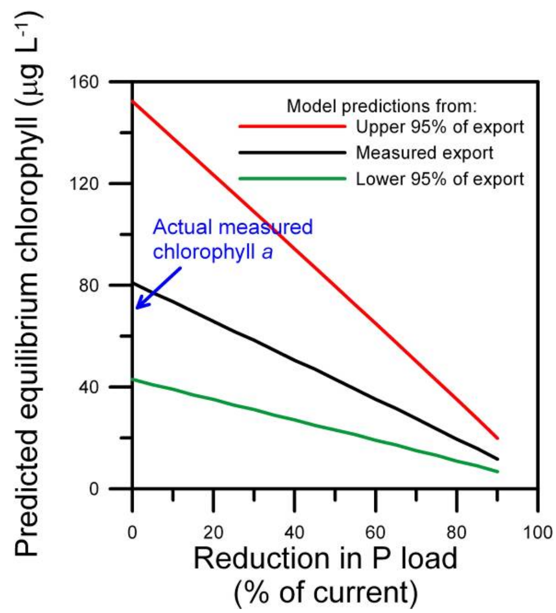


Figure 49. Modeled relationship between average equilibrium chlorophyll a values and the fractional reductions in the overall non-point source inputs. The relationships were obtained by combining the modeled output in Figure 46 with the relationship in Figure 45.

CONCLUSIONS: DIAGNOSTIC STUDY

The potential societal and economic value and the recreational potential of Black Hawk Lake are all substantial. Data in this study indicate that Black Hawk Lake water quality is poor showing high levels of nutrients and suspended solids, low water clarity, and near-constant Cyanobacteria blooms. The lake receives high loads of nutrients, sediment, and bacteria from the watershed. Currently, the lake is filling with sediment that will enhance Cyanobacteria problems and shorten the useful lifetime of the lake. High nutrient concentrations primary originate (70-90%) from activities in the upper watershed, but direct input near the lake is also detrimental. Water quality has declined over the past decades due to high nutrient inputs and filling of the wetland-slough structures resulting in poor nutrient and sediment retention upstream. Attainment of acceptable water quality goals will require a >75% reduction in nutrient and sediment loading that can be accomplished through various best management practices (BMPs; Please see Feasibility Study).

FEASIBILITY STUDY

PROBLEM STATEMENT

Black Hawk Lake has water quality problems due to sediment and phosphorus loads originating in its predominantly agricultural watershed. Runoff from the watershed contributes nutrients and turbidity to the water and may lead to higher algal populations, reduced transparency, and greater suspended solids concentrations in the near-term. Over time, accumulated sediments in the lake basin can cause a variety of water quality problems that are common to shallow lakes. Eventually, lake basins can fill to the point that they are no longer useful for open-water recreation.

Sediment and phosphorus from watershed runoff continues to impact this lake despite the collective efforts of community citizens, concerned agency officials, and scientists who have done considerable work in the Black Hawk Lake watershed. Average Secchi depth was 1.3 ft (0.4 m) at the time of sampling, and overall phosphorus levels in the lake averaged 218 µg/L. In addition, Black Hawk Lake lacks a diverse, balanced, and sustainable aquatic community. Poor water quality continues to impact popular sport fish (e.g., crappie and walleye) despite extensive fisheries management. Black Hawk Lake falls short in nearly all criteria of Iowa DNR water quality standards.

RESTORATION ALTERNATIVES

Water quality goals for Iowa lakes were defined in 2006 by State Legislation (HF2782) making it mandatory that the delivery of phosphorus and sediment from the watershed be controlled before lake restoration begins. The Iowa DNR Lakes Restoration Program has a Water Quality Target for Secchi depth to be at least 4.5 ft for 50% of the time from April to September. As an intermediate goal, when water quality is severely degraded, a target of 2.3 ft Secchi depth is used.

Water clarity at Black Hawk Lake is below the intermediate goal of 2.3 ft Secchi depth, therefore restoration alternatives considered here target primarily watershed processes contributing to water quality problems in Black Hawk Lake. Because water quality problems at Black Hawk Lake are largely watershed driven, as much as is practical, implementing watershed restoration activities prior to executing in-lake restoration activities is advised. This feasibility analysis sought a combination of watershed modifications that could yield adequate levels of phosphorus and sediment load reduction along with in-lake restoration activities designed to facilitate biological function of the system. A review of restoration alternatives and associated costs is below.

WATERSHED: SEDIMENT AND PHOSPHORUS TRANSPORT CONTROL

Decreasing the transport of eroded soil into the lake is critical to restoring Black Hawk Lake to a healthy, functioning system and to slow a return to current degraded lake conditions, post-restoration. Preventative measures in the watershed are therefore necessary to slow the input of new sediments and nutrients into the lake.

While some conservation practices addressing this issue are already being implemented, the diagnostic study indicated that significant sediment and phosphorus loading reductions using additional watershed management practices are required. Potential modifications to improve water quality downstream could include targeted stream-bank stabilization/protection, converting agricultural lands to perennial vegetation, and constructing sediment detention ponds and CREP style wetlands. Additional management strategies involving reduced tillage, cover crops, riparian buffers, grass waterways, terraces, and reduced P application would also help; their effectiveness, however, would depend on their permanence, producer enthusiasm, federal/state programs, watershed characteristics and their placement within the watershed.

Stream Protection and Stabilization

An assessment of Carnarvon Creek designed to evaluate in-stream and near-stream conditions was completed by project partners in 2009 (Appendix K). The purpose of the assessment was to target segments of the stream for Best Management Practice (BMP) implementation. The results of the assessment are available to the local Black Hawk Lake and Watershed Steering Committee and key stakeholders in the watershed for use in restoration planning.

Well placed and designed riparian buffers can be effective in capturing nutrients and sediments (Table 22; Osbourne and Kovacic 1993). Costs vary and depend greatly on the buffer strip design and complexity. For example, the total cost of installing riparian buffers consisting of only native grasses is $79/acre, whereas installation of multi-species riparian buffers with grasses, shrubs, and trees can cost up to $550/acre (Coletti 1996). When coupled with stream bank stabilization, the cost increases significantly. NRCS uses an average of $66 per linear ft for stream stabilization and $600 per acre for riparian buffer establishment (IWC 2008). It would cost $125,328 ($155,596 including land acquisition costs) to stabilize stream banks and 66-ft create riparian buffers on each side of the stream along the entire stream length (0.35 mi) identified as unstable in the RASCAL assessment (Table 23). It would cost $1.03 million

Table 22. Nutrient and sediment reductions in receiving waters associated with various best management practices (BMPs). Also, please see Dinnes (2004) and references contained within for reductions associated with BMPs in Iowa.

BMP	P (% red.)	N (% red.)	Solids (% red.)	Example References
Silt fences			50 – 90%	Lin and Hsieh 2003
Riparian forest or grass filter strips or buffers	20 – 81%	50 – 89%	80 – 81%	Daniels and Gilliam 1996; Sharpley and Rekolainen 1997; Lin and Hsieh 2003; Lowrance et al. 1997
Perennial grasses	95 – 99%		97 – 100%	Withers and Jarvis 1998
Crop residue management	12 – 25%	14 – 36%	29 – 41%	Santhi et al. 2006
Contour cropping	37%			Sharpley and Rekolainen 1997
Conservation tillage	61%			Sharpley and Rekolainen 1997
No-till agriculture	65%		95%	Sharpley et al. 1994
Grass waterways and swales	7 – 77%	14 – 24%	7 – 86%	Bracmort et al. 2006; Lin and Hsieh 2003
Terracing	60 – 68%	56 – 59%	84 – 86%	Sharpley and Rekolainen 1997; Santhi et al. 2006
Nutrient management plan	53 – 78%	77 – 93%	85 – 97%	Santhi et al. 2006
Reduce soil-test P to agronomic levels	19 – 29%			Klatt et al. 2003
Manure management	72%			Sharpley and Rekolainen 1997
Watering livestock out of streams	81%	54%	90%	Sheffield et al. 1997
Watershed-wide application of diverse BMPs	10 – 60%	2 – 39%	34 – 76%	Bishop et al. 2005; Knight and Welch 2004; Drolc and Koncan 2002; Ryding and Rast 1989

($1.28 million including land acquisition costs) to stabilize stream banks and create riparian buffers along the 2.9-mi stream length identified as having unstable or moderately stable banks.

Properly placed and designed stream riparian buffers are critical for effectively capturing nutrients and sediments from highly erodible lands. Coupled with stream bank stabilization, transport of sediments and nutrients to the lake would be greatly reduced.

Table 23. Phosphorus savings and estimated costs associated with stream stabilization and riparian buffer strips. Phosphorus savings for riparian buffers were estimated based on Dinnes (2004) for scenario A4 and calculated proportionally based on stream length for A1-A3. Estimated costs in gray boxes include land acquisition costs ($5,405 per ac).

Scenario/Treatment	Phosphorus Savings	Estimated Cost
Stream Stabilization (Estimated at $66 per linear foot)		
1. 1,000 ft (1/2 "unstable" banks)	N/A	$66,000
2. 1,848 ft (all "unstable" banks)	N/A	$121,968
3. 15,154 ft (all "unstable" plus 1/2 "moderately stable" banks	N/A	$1,000,164
4. 28,618 ft (all "unstable" and "moderately stable" banks)	N/A	$1,888,788
Riparian buffer strips (Estimated at $600 per acre)		
1. 1,000 ft (1/2 "unstable" banks)		$1,819
	2%	$18,197
2. 1,848 ft (all "unstable" banks)		$3,360
	3%	$33,628
3. 15,154 ft (all "unstable" banks plus 1/2 "moderately stable"		$27,553
banks	24%	$275,757
4. 28,618 ft (all "unstable" and "moderately stable" banks)		$52,033
	45%	$520,761
Total cost for stream stabilization and riparian buffer strips		
1. 1,000 ft (1/2 "unstable" banks)		$67,819
	2%	$84,197
2. 1,848 ft (all "unstable" banks)		$125,328
	3%	$155,596
3. 15,154 ft (all "unstable" banks plus 1/2 "moderately stable"		$1,027,717
banks	24%	$1,275,921
4. 28,618 ft (all "unstable" and "moderately stable" banks)		$1,940,821
	45%	$2,409,549

Perennial Vegetation

Increasing perennial vegetation cover in sub-watersheds contributing high nutrient and sediment loads could decrease nutrients and sediments entering Black Hawk Lake. Land conversion to perennial grass cover can reduce P and sediment loading by 95-99% and 97-100% respectively (Table 22). Management strategies involving perennial vegetation conversion provide permanent protection of aquatic ecosystems and allow direct control of watershed management activities. However, land acquisition and preparation can be costly. For example, the cost to increase perennial vegetation through land acquisition in Sac County is estimated at $5,716 per ac. This assumes land acquisition costs of $5,405 per ac (ISU 2009) and $311 per ac for site preparation (seed purchase and planting).

Management costs could be reduced through land acquisition and/or conservation programs such as the Conservation Reserve Program (CRP) and the Wetlands Reserve Program (WRP). Conservation programs aim to improve water quality through leasing cropland from producers within the watershed. Many conservation programs involve a contract, typically 10-15 years, that do not offer permanent protection to water resources. Restoration plans require management plans that address long-term lake protection (50+ years). Several conservation programs are available to producers with varying cost-share benefits. Local agency personnel (e.g. Soil and Water Conservation District, District Conservationists, Iowa DNR Private Lands Biologists) can provide current program details to interested watershed stakeholders.

The goal of the Black Hawk Lake management plan is to reduce phosphorus loading to the lake by 35-75% to achieve in-lake Secchi depths of 2.3 to 4.5 ft (Figure 47). Management plans that target the largest contributors of phosphorus and sediment are the most effective way to achieve these water quality goals. Because management costs are difficult to estimate, we based our cost estimates on previous DFS projects (Downing and Poole 2008). These models suggest achieving a 35% reduction in phosphorus would require targeting 25% (~3300 ac) of watershed land area starting with the highest contributing areas. It would require targeting 65% (~8500 ac) to achieve a 75% phosphorus reduction. Estimated costs to plant perennial vegetation in 25% of the watershed area would cost ~$1.03 million (~$18.87 million if land acquisition costs are included; Table 23). These cost estimates do no include agricultural productivity losses. Because of high associated costs, other management practices may yield more cost-effective remediation than large-scale conversion to perennial vegetation.

Table 22. Phosphorus savings and estimated costs associated with perennial vegetation conversion. P savings were based on earlier models of a similar watershed (Downing and Poole 2008). Estimated costs in gray boxes include land acquisition costs ($5,405 per ac).

Scenario/Treatment	Phosphorus Savings	Estimated Cost
Perennial Vegetation (% of watershed)		
1. 5% (658 ac)	7%	$204,561 $3,759,699
2. 10% (1,316 ac)	12%	$409,121 $7,519,398
3. 20% (2,631 ac)	23%	$818,241 $15,038,796
4. 30% (3,947 ac)	35%	$1,227,362 $22,558,194

Detention Ponds and CREP-style Wetlands

Impoundments may be useful for intercepting materials originating from upland sources and traveling via streams. Detention ponds and CREP-style wetlands would be most effective if they were located slightly downstream of those areas that act as nutrient and sediment hotpots because these streams are likely delivering a considerable proportion of the nutrient and sediment load to the lake.

Hydrologic modeling (PONDNET) was performed to estimate P reduction and costs associated with constructing detention ponds within the Black Hawk Lake watershed (Walker 1989). Eight ponds averaging 3.3 ft depth were placed in the watershed below the following watershed sampling sites: S14, S13, S12, S10, S8, S6, S5, and S4 (Figure 38). Pond surface area was varied to estimate associated P savings. The model suggested that achieving the goal of 75% P loading reduction using detention ponds alone would be difficult and costly. To achieve the intermediate goal of 35% P loading reduction, eight 40-ac ponds averaging 3.3 ft depth would need to be constructed at an estimated cost of $1.6 million (~$3.33 million including land acquisition costs; Table 25). Detention ponds could be used in combination with other management techniques to obtain both intermediate and overall water quality goals.

Table 23. Phosphorus savings and estimated costs associated with detention pond construction. Estimated costs in gray boxes include land acquisition costs ($5,405 per ac).

Scenario/Treatment	Phosphorus Savings	Estimated Cost
Detention Ponds – 8 ponds with 3.3 ft avg. depth		
1. 5 ac per pond	10%	$200,000 $416,200
2. 10 ac per pond	16%	$400,000 $832,400
3. 20 ac per pond	26%	$800,000 $1,664,800
4. 30 ac per pond	32%	$1,200,000 $2,497,200

Additional Management Strategies

A best management practice (BMP) is a practice or combination thereof that prevents or reduces nonpoint source pollution to levels compatible with water quality goals (USDA 1980). Additional management strategies, including cover crops, crop residue management, terracing and grass waterways, and manure management, could help reduce nutrients and sediments entering Black Hawk Lake. Nutrient and sediment loading reductions associated with these techniques depend on the effectiveness of these strategies (Table 22). Because these management techniques are voluntary, they require sustained enthusiasm by producers and landowners to maintain their permanence. However, these management strategies could augment restoration if combined with other primary management strategies, such as stream stabilization, riparian buffers, detention ponds, and conversion to perennial vegetation.

Cover crop introduction to row crop agriculture can help protect water quality without taking land out of production. Cover crops consist of close-growing grasses, legumes, or small grains grown primarily for seasonal protection and soil improvement (EPA, 2003). Cover crops provide several benefits to soil and water quality, including reduced erosion and sediment loss, reduced nutrient loading to receiving waters, and reduced fertilizer applications. To increase cover crop use in the watershed, Iowa State University (ISU) Extension and NRCS could increase education and outreach campaigns. Demonstrating past successes with cover crop integration would increase the probability that local producers would adopt these practices.

Crop residue management and conservative-/no-tillage farming can provide similar benefits to increased vegetative cover by increasing the amount of plant material remaining on the soil surface. Surface residue can reduce soil erosion, detachment, and sediment transport by providing cover during critical times in the cropping cycle (EPA 2003). Several commonly used methods of reduced tillage include no-till, mulch-till, and strip-till. Crop residue management, including conservative- and no-tillage, can reduce P loading to receiving waters by 12-65% (Table 22). ISU Extension and NRCS personnel can assist local producers interested in crop residue management practices.

Constructing terraces and directing runoff through grass waterways can also substantially reduce phosphorus loading to receiving waters. P loading reductions range from 60-68% and 7-77% for terracing and grass waterways BMPs respectively (Table 22). Several grass waterways are already present in the Black Hawk Lake watershed. However, many fields drain directly into streams, sometimes through localized gullies. Grass waterway construction in areas with high erosion potential could help reduce nutrient and sediment loading.

Manure management practices can help reduce nutrient loading to receiving waters. Manure management practices can reduce P loading by 72% (Table 22). Simply watering livestock away from streams can reduce P loading by 81%. These management practices would require help from the local livestock producers.

The effectiveness of the aforementioned BMPs at reducing nutrient and sediment loads into Black Hawk Lake are difficult to estimate. Their effectiveness depends on extent, placement, receptiveness of producers, maintenance and permanence, sub-watershed characteristics, and associated advisory and funding programs. Although values published in the literature are highly variable, they suggest that these techniques may be very effective at reducing nutrient and phosphorus loads to receiving waters (Table 22). Estimated costs are difficult to calculate due to numerous unknowns; therefore, we do not provide cost estimates for these management techniques. Of importance, true BMPs frequently save producers money (Ryding and Rast 1989; Sharpley and Rekolainen 1997; Withers and Jarvis 1998) and are positively cost-effective over traditional agricultural practices.

IN-LAKE ACTIVITIES

In addition to watershed activities, the diagnostic study indicated that Black Hawk Lake could also benefit from a variety of in-lake remediation activities, such as re-establishing Provost Bay as a sediment detention basin and fisheries renovation. These activities are important to restoring the biological functioning of the system.

Provost Bay as a potential sediment detention basin

Utilizing Provost Bay as a sediment detention basin is another means of minimizing the potential for watershed materials to enter the main basin of Black Hawk Lake. Models indicated that Provost Bay could reduce phosphorus inputs to the lake by 65% if average water depth were increased to 3 ft from 1.7 ft. This would require removing 381,958 yd^3 of sediment.

Hydraulic dredging, the most commonly used dredging type for lake restoration, would require a floating cutterhead dredge, a large centrifugal pump, a slurry pipe system, and a water return system. The produced slurry would be a mixture of lake water and lake sediment. Dredge spoil would have to be addressed and stakeholders would have to work together to locate and select an appropriate disposal site. Cost estimates for dredging range from $3.75 - $4.25 per yd^3 (Iowa DNR 2008a). Dredging operations to remove the aforementioned sediment volume (381, 958 yd^3) would cost ~$1.5 million using an average cost basis. Dredge spoil would require a ~84-ac containment site. Based on current land values, the containment site would cost $952,000 ($452,000 for land acquisition and $500,000 for construction). The total estimated cost for dredging and spoil containment would be $2.5 million[2].

Fisheries Renovation

Fisheries renovation and restoration would help decrease internal sediment and nutrient resuspension and restore healthy ecosystem functions including riparian and littoral vegetation. The IOWA DNR will create and execute a fisheries restoration plan that includes a fishery renovation component estimated at $350,000 and replacement of the fish barrier structure estimated at $150,000.

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[2] Local DNR Fisheries staff (personal communication on 3/4/2010) suggest dredging the east end of Black Hawk Lake as part of the management plan. The staff believes that this would reduce wind-driven mixing that resuspends lake sediments and contributes to internal nutrient loading. They recommend deepening the east end to 10 ft and Town Bay to 15 ft. The aeration system could be repaired and replaced in Town Bay after dredging. The suggested dredging operation would require removing ~1 million yd^3 of sediment at an estimated total cost of $6.5 million.

DESIGNING A RESTORATION PLAN

Based on the Iowa DNR Lakes Restoration Program Water Quality Targets, the overall goal of a restoration project would be to increase water clarity to 4.5 ft Secchi depth. To achieve this water quality target in Black Hawk Lake, a 75% reduction in phosphorus is necessary. While this could be achieved through a variety of watershed and in-lake activities, as much as is practical, watershed restoration should be established prior to in-lake restoration activities. Therefore, a potential intermediate restoration goal might be to increase water clarity to 2.3 ft which requires a 35% reduction in phosphorus. Both the intermediate and overall goals can be achieved through several management practice combinations at varying costs. The DNR, Iowa NRCS, local officials, local producers, and other stakeholders will need to work together to develop the best and most acceptable combination of approaches for Black Hawk Lake, its watershed, and community.

A matrix of watershed and in-lake restoration treatments/scenarios, phosphorus savings and cost estimates is provided for the Project Steering Committee and key stakeholders to consider when planning for the restoration of Black Hawk Lake and its watershed (Table 26). Phosphorus savings in the table are not cumulative (i.e., using scenarios A1 and C1 in combination do not produce a 12% P savings). P savings can be calculated for any treatment combination according to the following equation:

$$\text{P savings (\%)} = 1 - [(1 - X_1) \times (1 - X_2) \times (1 - X_3) \times (1 - X_j)]$$

where X_1, X_2, X_3, and X_j are P savings (as a proportion from 0-1) associated with different management techniques listed in Table 26. Calculated P savings (%) must be ≥35% or ≥75% to meet the intermediate and overall goals respectively. Estimated costs for each treatment combination can be calculated by summing the costs of each selected management technique.

The intermediate goal of 2.3 ft Secchi depth requires a 35% P savings (Figure 47). Several BMPs can be implemented to achieve this goal. For example, stream stabilization and construction of riparian buffers along all "unstable" and "moderately stable" stream banks (Scenario A4) could produce a 45% P savings at a cost of $1.95 million ($2.41 million including land acquisition costs; Table 26). Also, a combination of stream stabilization and riparian buffer construction along all "unstable" and half of "moderately stable" stream banks (Scenario A3) and construction of eight 10-ac detention ponds (Scenario C2) could produce a 36% P savings at a cost of $1.43 million ($2.11 million including land acquisition costs; Table 26). We recommend stabilizing and constructing riparian buffers along all "unstable" stream banks (Scenario A2) at a minimum in any management plan involving detention ponds or Provost Bay dredging (Table 26). Otherwise, the detention ponds and/or Provost Bay will rapidly fill with sediment and require re-dredging.

The overall goal of 4.5 ft Secchi depth requires a 75% P savings (Figure 47). Several BMPs can be implemented to achieve this goal. For example, a combination of dredging Provost Bay to 3-ft mean water depth (Scenario D1) and stabilizing all "unstable" and "moderately stable" stream banks (Scenario A4) could produce a 80% P savings at a cost of $4.45 million ($4.91 million including land acquisition costs; Table 26). Dredging Provost Bay to 3-ft mean water depth (Scenario D1), constructing eight 30-ac ponds (Scenario C4), and stabilizing and building riparian buffers along all "unstable" stream banks (Scenario A2) could produce a 76% P savings at a cost of $3.83 million ($5.16 million including land acquisition costs). These scenarios are not firm recommendations but are simply examples showing how the community and agencies can calculate P savings and costs for various management plans.

Additionally, any voluntary BMPs, such as those listed in Table 22, initiated with the help of local producers could diminish nutrient and sediment loading into receiving streams. Black Hawk Lake would experience variable phosphorus and sediment savings depending on the effective implementation of these practices and their permanence. State and local officials could encourage the use of voluntary management practices in concert with the overall watershed and in-lake management plan.

Table 24. Phosphorus savings and estimated costs associated with various BMPs. P savings for stream stabilization and riparian buffers are estimated based on Dinnes (2004) for scenario A4 with P savings for A1-A3 calculated proportionally based on stream length. Estimated costs in gray boxes include land acquisition costs ($5,405 per ac). Cost estimates for dredging Provost Bay include containment site construction and land acquisition costs. Costs were rounded up to the nearest $1,000.

Scenario/Treatment		P Savings	Estimated Cost[3]
WATERSHED	**LAKE**		
A. Stream Stabilization and Riparian Buffers			
1. 1,000 ft (1/2 "unstable" banks)	None	2%	$68,000 $85,000
2. 1,848 ft (all "unstable" banks)	None	3%	$126,000 $156,000
3. 15,154 ft (all "unstable" plus 1/2 "moderately stable" banks)	None	24%	$1,028,000 $1,276,000
4. 28,618 ft (all "unstable" and "moderately stable" banks)	None	45%	$1,941,000 $2,410,000
B. Perennial Vegetation (% of watershed and surface area)			
1. 5% (658 ac)	None	7%	$205,000 $3,760,000
2. 10% (1,316 ac)	None	12%	$410,000 $7,520,000
3. 20% (2,631 ac)	None	23%	$819,000 $15,039,000
4. 30% (3,947 ac)	None	35%	$1,228,000 $22,559,000
C. Detention Ponds/CREP Wetlands (8 ponds with mean depth of 3.3 ft)			
1. 5 ac per pond	None	10%	$200,000 $417,000
2. 10 ac per pond	None	16%	$400,000 $833,000
3. 20 ac per pond	None	26%	$800,000 $1,665,000
4. 30 ac per pond	None	32%	$1,200,000 $2,498,000
D. Dredging Provost Bay (estimated costs include containment site costs)			
None	1. Dredge to 3-ft mean depth	64%	$2,500,000
None	2. Dredge to 6-ft mean depth	78%	$6,500,000

[3] The cost analysis is preliminary and for planning purposes only. More detailed cost estimates should be included as part of the engineering design of the project. Programs to assist landowners interested in conservation practices, may also qualify several of the watershed activities/projects for cost share dollars. This estimate does not consider reductions from such programs.

POST RESTORATION MONITORING PLAN

One of the most important aspects of any restoration project is to assess and document water quality improvements. The closer that monitoring is brought to restoration areas where substantial improvements to water quality and biota are expected then the more likely water quality improvements will be documented. Therefore, the post restoration monitoring plan should include lake water monitoring as well as tributary monitoring for at least two years.

Once the dredging and soil conservation work has been completed in the watershed, a monitoring program should be established to determine conditions in the lake as well as in the tributaries. A sampling station would be established at the deepest point in the lake. For a two year period, samples would be taken monthly from September through April and biweekly from May through August at each meter of depth from the surface down to 0.5 m from the bottom. In addition to these sampling depths, a mixed zone water sample would be collected using a 0-2 m column sampler. Samples would be collected between 0800 and 1700 hours. All samples would be analyzed for total and soluble reactive phosphorus; nitrite plus nitrate nitrogen, ammonium, unionized ammonia, and total nitrogen; total suspended solids; pH; alkalinity; and carbon. Samples collected from the upper mixing zone would also be analyzed for chlorophyll a. Algal biomass in the upper mixing zone would be determined through algal genera identification, cell counts, and cell volumes, and reported in terms of biomass of each genus identified. Secchi disk transparency and suspended solids would also be determined at each sampling period. The surface area of the lake covered by macrophytes at mid-summer would be determined, and the predominant species identified and their distribution shown on a map. During the swimming season, samples would be collected twice per month at the swimming beach area for determinations of *E. coli* bacteria.

Water samples would be taken from the established tributary sites on the same days that the lake is sampled (when they are flowing) for analyses of total phosphorus, total nitrogen, total suspended solids, and carbon.

Based on current analytical fees, the estimated cost for two-years of post restoration monitoring including lake water and tributary monitoring would be $180,547.

BENEFIT OF RESTORATION

Restoration will engender major benefits both to the environment of the state of Iowa and Iowa's citizens, residents, and visitors.

- Improvements to water quality; we expect improvements that will yield conformity with Iowa's public code. For example:
    - Water quality will improve to the point that excellent recreation and biological integrity will be restored
    - No discharges in the watershed should yield objectionable or unsafe conditions
    - Geometric mean *E. coli* and fecal coliforms should be substantially reduced
    - pH should decline in mid-summer and no-longer exceed criteria during phytoplankton blooms
    - Deep waters should maintain adequate oxygen conditions
    - Temperatures should be cooler due to decreased radiative and biochemical heating
    - Unionized ammonia concentrations should always be low, promoting quality growth of fish and other fauna
    - Odor should be reduced in the lake and fish should smell fresher and be healthier
    - Total phosphorus concentrations should approach much lower values that promote ecosystem health and sustainability
    - Fish growth and habitat should be substantially improved
    - Water transparency should approach the 4.5 ft mark
- The social and economic value of the lake will be improved
    - Normally, Iowa's restored lakes show great increases in visitation; these rates are often double pre-restoration levels
    - Economic benefits to Iowa and the community are substantially enhanced. Recent research in Iowa shows that such water quality improvement increases:
        - The value of the lake to all Iowans, and
        - Enhanced local economic benefits of an improved recreational amenity.

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List of Appendices

Appendix A. Water Quality Standards

Water Quality Standards are defined in Iowa Administrative Code (IAC 7/10/02). General water quality criteria and specific water quality criteria applicable to Black Hawk Lake are summarized provided in Appendix A.

General Water Quality (IAC 61.3(2)

The following criteria are applicable to all surface waters including general use and designated use waters, at all places and at all times for the uses described in 61.3(1)“a.” of Iowa Code.

- Waters shall be free from substances attributable to point source wastewater discharges that will settle to form sludge deposits.
- Waters shall be free from floating debris, oil, grease, scum, and other floating materials attributable to wastewater discharges or agricultural practices in amounts sufficient to create a nuisance.
- Waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor or other aesthetically objectionable conditions.
- Waters shall be free from substances attributable to wastewater discharges or agricultural practices in concentrations or combinations which are acutely toxic to human, animal, or plant life.
- Waters shall be free from substances, attributable to wastewater discharges or agricultural practices, in quantities which would produce undesirable or nuisance aquatic life.
- The turbidity of the receiving water shall not be increased by more than 25 Nephelometric turbidity units by any point source discharge.
- Acceptable levels of total dissolved solids (TDS) and constituent cations and anions will be established on a site-specific basis. The implementation approach for establishing the site-specific levels may be found in the “Supporting Document for Iowa Water Quality Management Plans,” Chapter IV, July 1976, as revised on June 16, 2004.
- The *Escherichia coli* (*E. coli*) content of water which enters a sinkhole or losing stream segment, regardless of the water body’s designated use, shall not exceed a Geometric Mean value of 126 organisms/100 ml or a sample maximum value of 235 organisms/100 ml. No new wastewater discharges will be allowed on watercourses which directly or indirectly enter sinkholes or losing stream segments.

Specific Water Quality Criteria

CLASS A WATERS

Fecal coliform:	below 235 organisms/100 ml (March 15 to November 15)
pH:	6.5 to 9.0

CLASS B WATERS

pH:	6.5 to 9.0
Dissolved oxygen:	not to be lower than 5.0 mg/l at any time
Temperature:	32° C
Toxic Substances:	see IAC Ch61, p.14
Ammonia:	not more than approximately 80 ppb unionized ammonia

CLASS "HH" WATERS

Waters which are designated as Class HH shall contain no substances in concentrations which will make fish or shellfish inedible due to undesirable tastes or cause a hazard to humans after consumption. The human health criteria represent the level of protection necessary, in the case of noncarcinogens, to prevent adverse health effects in humans and, in the case of carcinogens, to prevent a level of incremental cancer risk not exceeding 1 in 100,000. Instream concentrations in excess of the human health criteria will be allowed only within the boundaries of the mixing zone.

Black Hawk Lake Fishery Summary 2009

Black Hawk Lake is a natural lake in Sac County, Iowa with a fish population composed of a large variety of species made up primarily of: black bullhead, channel catfish, carp, bigmouth buffalo, bluegill, black crappie, green sunfish, orangespotted sunfish, largemouth bass, walleye, yellow perch, yellow bass, gizzard shad, white crappie, yellow bullhead, freshwater drum and flathead catfish. There are other species that occur occasionally such as: white bass, shorthead redhorse, tadpole madtom and various species of shiners.

Black Hawk Lake was renovated in September 1979 to remove all rough fish. The lake was stocked with sport fish at that time and the most recent period of fish management was initiated. The species stocked in Black Hawk Lake in October 1979, immediately after the renovation were: bluegill, catfish and walleye. The next spring and summer the following species were added: largemouth bass, crappie, gizzard shad, northern pike, tiger muskellunge and fathead minnows. The only fish stocked since that time have been annual introductions of walleye (fry or various sizes of fingerlings) and channel catfish.

Fisheries management over the past 30 years has not varied greatly. There are sixteen helixor aerators in Town Bay that keep parts of the bay open during the winter and have prevented winterkill. A fish barrier was constructed at the bridge between the main lake and Inlet Bay to keep rough fish from having easy access to the main lake. Various biological surveys have been conducted from the renovation to the present time. A comprehensive fisheries survey was performed in 2008 using an electrofishing boat for 120 minutes in May, and fyke nets for 504 hours in September.

Black Bullhead

Black Hawk Lake has traditionally been considered a good bullhead fishing lake. Black bullhead dominated the 2008 survey with 2,202 fish averaging 8.2 inches collected. Although Black Hawk Lake has a very large bullhead population, several surveys and annual monitoring data suggests that it does not dominate the fish community to this extent. Bullheads ranged in total length from 6.0 to 10.5 inches and were in good condition (Wr = 83). There was a good number of small bullhead sampled during the 2008 survey indicating a healthy population structure. Black bullhead in recent years have been larger and in better condition than in the past. The number of anglers targeting bullheads at Black Hawk Lake and across northwest Iowa has steadily decreased over the past decade.

Channel Catfish

Channel catfish are one of the most important sport fish in Black Hawk Lake. During the most recent creel census they ranked number three for number of fish harvested. Channel catfish were the second most abundant species sampled in the 2008 survey with 199 stock-size fish averaging 18.4 inches long. Catfish sampled ranged from 11.5 to 27.0 inches and were in good condition (Wr=94). As would be expected with a species that is annually stocked, a good number (63) of channel catfish less than stock-size were also collected, almost all in fyke nets. A baited hoop net study in Black Hawk Lake in July of 2008 was extremely effective in sampling channel catfish. Fisheries personnel, using the hoop net technique, collected 6,199 channel catfish and estimated the population at 16,166 fish. This gear targets channel catfish and is being implemented as a part of our standard fisheries survey procedure. For years, 7 inch channel catfish have been stocked in Black Hawk Lake every year at a rate of 7 fish per acre. Starting in 2008 this stocking strategy was altered to 6 fish per acre stocked every other year. The change was made for several reasons which include: a shortage of channel catfish available from the hatcheries, reduced number of stocking trips due to the cost of fuel and because some research suggests that we have been stocking catfish at a higher level than is necessary to provide good fishing.

Black Crappie

Black crappie was the fifth most commonly sampled species in the 2008 fish survey, with 104 fish captured, and they were the most frequently collected species in the 2004 survey, with 427 fish taken. The average length of black crappie dropped from 8.3 inches in 2004 to 6.8 inches in 2008. This drop was mirrored in the size of the fish taken by anglers in recent years. This species has always been popular with anglers in Black Hawk Lake and have been harvested in good numbers from shore as well as docks. In the past, white crappie represented a larger percentage of the crappie in Black Hawk Lake, but in recent years they've become more scarce. In the 2004 survey 30 white crappie were captured, while in 2008 only one fish was collected.

Carp

Although reduced to extremely low levels, carp were not eliminated from Black Hawk Lake during the 1979 renovation. Carp numbers expanded quickly, but the sport fish populations and winter aeration helped keep their numbers from reaching pre-renovation levels. In the 2008 survey, carp were the third most commonly sampled species with 140 fish, while in 2004 they were fifth with 79 sampled. The average length of carp in the 2008 survey was 17.6 inches with a range of 11.0 to 30.0 inches. To help reduce the carp population in Black Hawk, a commercial fisherman has seined the lake for carp and buffalo since the mid-1980's. Despite the efforts to remove carp, they remain an important part of the fish community in Black Hawk Lake and are responsible for a portion of the water quality problems in the lake.

Walleye

Walleye was the eighth most frequently caught species in the 2008 survey with 26 fish sampled and the fourth most common in 2004 with 82 taken. The average length of walleye in the 2008 survey was 14.5 inches with a range of 10.5 to 27.0 inches. The fish were in good condition and had a Wr of 97. In 1999, after a week of extremely hot and still weather, a summerkill occurred in Black Hawk Lake that killed most of the walleye. Additional walleye were stocked in the Fall of 1999 and walleye rebounded in two years to a population with fish that were acceptable to the angler. There were two major changes in the management of walleye in Black Hawk Lake in the recent past. In 1991, a 15 inch minimum length limit was implemented and the bag limit was dropped from five to three fish. The second change was an increase in the size of walleye fingerlings stocked in our natural lakes. In the 1980's and well into the 1990's walleye fry were stocked at the rate of 3,000 per acre. Then two-inch fingerlings were stocked in June at the rate of 25 per acre, and starting in the year 2000 Black Hawk Lake was stocked with six-inch fingerlings at a rate of 28.5 fish per acre. In the last several years eight-inch fingerlings have been available in limited numbers and these fish are stocked whenever possible. These larger fish provided much more reliable year-classes in Black Hawk Lake. The walleye fishing in Black Hawk Lake has been poor the last two years; this has been mirrored in the most recent fisheries survey. The reason for this change is unknown, but may be related to the continuing poor water quality.

Yellow Bass

Yellow bass have provided good fishing in Black Hawk Lake and, although cyclic, do not reach numbers high enough to cause problems that are observed in southwest Iowa impoundments. Twenty yellow bass with an average length of 7.7 inches were sampled in the 2008 Black Hawk Lake survey. These fish ranged in length from 4.0 to 13.5 inches and were in good condition. Anglers in Black Hawk commonly harvest yellow bass when available.

Gizzard Shad

Gizzard shad provide forage for all sport fish in Black Hawk Lake and are the reason that this lake has some of the fastest growth rates in the state. Twenty stock-size (7 in and greater) gizzard shad were sampled in the 2008 fish survey. Gizzard shad ranged from 8.0 to 15.5 inches with an average length of 13.9 inches. Since gizzard shad are used for forage, fish that are smaller and more able to be utilized are more desirable. That is the current situation in Black Hawk Lake where 44 shad, less than stock-size, were sampled in 2008; they had an average length of 4.8 inches.

Summary

Black Hawk Lake is providing a good fishery for black bullhead and channel catfish. Carp are a continuing problem and are maintaining their numbers despite commercial fishing. Black crappie and walleye numbers have decreased in recent years and the average size of black crappie is smaller. The continuing poor water quality in Black Hawk Lake is most likely to blame and will continue to hamper these species in the future.

Appendix C. Summary Water and Sediment Pesticides and Metal Concentrations

Table 1. Water and sediment metal concentrations reported at Black Hawk Lake. Water and sediment samples were collected and analyzed in 2002 and 2004 respectively.

Analyte	Water Concentration (mg/l)	Sediment Concentration (mg/l)
Total Arsenic	<0.01	3.3
Total Barium	0.14	250
Total Cadmium	<0.001	<2.0
Total Chromium	<0.02	20
Total Silver	<0.01	<1.0
Total Copper	<0.01	-
Total Zinc	<0.02	54
Total Selenium	<0.01	<1.0
Total Nickel	<0.05	29
Total Lead	<0.01	20
Total Mercury	<0.0002	<1.0

Table 2. Pesticides tested for in water quality samples taken at Black Hawk Lake in 2001.

Analyte	Concentration (μg/l)	Analyte	Concentration (μg/l)
Organophosphate Insecticides:		*Polychlorinated Biphenyls:*	
Terbufos	<0.1	Aroclor 1016	<0.5
Fonofos	<0.1	Aroclor 1221	<0.5
Chlorpyrifos	<0.1	Aroclor 1232	<0.5
Ethoprop	<0.1	Aroclor 1242	<0.5
Phorate	<0.1	Aroclor 1248	<0.5
Carbofuran	<0.1	Aroclor 1254	<0.5
Malathion	<0.1	Aroclor 1260	<0.5
Dimethoate	<0.1	Chlorohydrocarbon Insecticides:	
Nitrogen Containing Herbicides:		Aldrin	<0.05
Atrazine	0.58	alpha-BHC	<0.05
Cyanazine	<0.1	beta-BHC	<0.05
Metolachlor	1.7	delta-BHC	<0.05
Alachlor	<0.1	Lindane (gamma-BHC)	<0.05
Metribuzin	0.10	DDD	<0.05
Butylate	<0.1	DDE	<0.05
Trifluralin	<0.1	DDT	<0.05
Acetochlor	0.30	Methoxychlor	<0.05
Desethyl Atrazine	0.12	Dieldrin	<0.05
Desisopropyl Atrazine	<0.1	Endosulfan I	<0.05
Simazine	<0.1	Endosulfan II	<0.05
Ametryn	<0.1	Endosulfan sulfate	<0.05
EPTC	<0.1	Endrin	<0.05
Prometon	<0.1	Endrin aldehyde	<0.05
Propachlor	<0.1	Endrin ketone	<0.05
Propazine	0.47	Heptachlor	<0.05
Dimethenamid	<0.1	Heptachlor epoxide	<0.05
Acid Herbicides:		Chlordane	<0.05
2,4-D	<0.2	Toxaphene	<0.5
Silvex	<0.2		
Picloram	<0.2		
Dicamba	<0.2		
Bentazon	<0.2		

Appendix D. UHL Water and Sediment Toxicity Data Reports

Hygienic Laboratory

The University of Iowa

Date of report: 09-27-2004

GEORGE ANTONIOU
ISU/EEOB
207 BESSEY HALL

AMES IA 50011

Sample Number	**200408565**
Date Received	07-26-2004
Project	ISU/IOWA LAKES
Date Collected	07-19-2004 10:30
Collection Site	011 blackhawk
Collection Town	
Description	sediment
Reference	SEDIMENT SAMPLES
Collector	
Phone	
Purchase Order	B55041602

Comments	*Upon receipt at the UHL sample meets standard acceptance criteria.*

Results of Analyses

Nitrogen Containing Herbicides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Atrazine	<0.01	0.01
Cyanazine	<0.01	0.01
Metolachlor	<0.01	0.01
Alachlor	<0.01	0.01
Metribuzin	<0.01	0.01
Butylate	<0.01	0.01
Trifluralin	<0.01	0.01
Acetochlor	<0.01	0.01
Desethyl Atrazine	<0.01	0.01
Desisopropyl Atrazine	<0.01	0.01

Date Analyzed: 08-28-2004 — Analyst: PB
Method: EPA 8141 — Verified: SM
Date Prepared: 07-28-2004 — Analyst: JF
Preparation Method: EPA 3550 — Verified: GJ

Organophosphate Insecticides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Terbufos	<0.01	0.01
Fonofos	<0.01	0.01
Chlorpyrifos	<0.01	0.01
Ethoprop	<0.01	0.01
Phorate	<0.01	0.01
Carbofuran	<0.01	0.01
Malathion	<0.01	0.01
Dimethoate	<0.01	0.01

Date Analyzed: 08-28-2004 — Analyst: PB
Method: EPA 8141 — Verified: SM
Date Prepared: 07-28-2004 — Analyst: JF
Preparation Method: EPA 3550 — Verified: GJ

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Acid Herbicides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
2,4-D	<0.2	0.2
Dicamba	<0.2	0.2
Silvex	<0.2	0.2
Picloram	<0.2	0.2
Bentazon	<0.2	0.2
2,4,5-T	<0.2	0.2
2,4-DB	<0.2	0.2
Acifluorfen	<0.2	0.2
Bromoxynil	<0.2	0.2
Chloramben	<0.2	0.2
Chlorthal-dimethyl	<0.2	0.2
Dichlorprop	<0.2	0.2
Dinoseb	<0.2	0.2
Pentachlorophenol	<0.2	0.2
Triclopyr	<0.2	0.2

Date Analyzed: 08-26-2004 — Analyst: JS
Method: EPA 8151 — Verified: SM
Date Prepared: 08-19-2004 — Analyst: GJ,MS,K
Preparation Method: NEIC/EPA 8150 — Verified: GJ

Polychlorinated biphenyls in Solids

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Aroclor 1016	<0.05	0.05
Aroclor 1221	<0.05	0.05
Aroclor 1232	<0.05	0.05
Aroclor 1242	<0.05	0.05
Aroclor 1248	<0.05	0.05
Aroclor 1254	<0.05	0.05
Aroclor 1260	<0.05	0.05

Date Analyzed: 08-21-2004 — Analyst: VR
Method: EPA 8082 — Verified: SM
Date Prepared: 07-28-2004 — Analyst: JF
Preparation Method: EPA 3550 — Verified: GJ

Page 2 - Continued on next page

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Chlorinated Hydrocarbon Insecticides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Aldrin	<0.01	0.01
alpha-BHC	<0.02	0.02
beta-BHC	<0.01	0.01
delta-BHC	<0.01	0.01
Lindane (gamma-BHC)	<0.01	0.01
DDD	<0.01	0.01
DDE	<0.01	0.01
DDT	<0.02	0.02
Methoxychlor	<0.01	0.01
Dieldrin	<0.01	0.01
Endosulfan I	<0.01	0.01
Endosulfan II	<0.01	0.01
Endosulfan sulfate	<0.01	0.01
Endrin	<0.01	0.01
Endrin aldehyde	<0.01	0.01
Endrin ketone	<0.01	0.01
Heptachlor	<0.01	0.01
Heptachlor epoxide	<0.01	0.01
Chlordane	<0.05	0.05
Toxaphene	<0.1	0.1

Date Analyzed: 08-21-2004 — Analyst: VR
Method: EPA 8081A — Verified: SM
Date Prepared: 07-28-2004 — Analyst: JF
Preparation Method: EPA 3550 — Verified: GJ

Description of units used within this report

mg/kg - Milligrams per Kilogram

Quant Limit - Lowest concentration reliably measured

Iowa Laboratory Certification No. 027. AIHA, NELAP, USEPA, and other credentials available upon request.

If you have any questions please call Sherri Marine at 800/421-IOWA (4692) or 319/335-4500. Thank you.

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Hygienic Laboratory

The University of Iowa

Sample Number	**200460633**
Date Received	07-26-2004
Project	ISU/IOWA LAKES
Date Collected	07-09-2004 10:30
Collection Site	011 blackhawk
Collection Town	
Description	sediment
Reference	SEDIMENT SAMPLES
Collector	ANTONOIU GEORGE
Phone	(515) 294-9908
Purchase Order	B55041602

Date of report: 08-30-2004

GEORGE ANTONIOU
ISU/EEOB
207 BESSEY HALL

AMES IA 50011

Comments	*Upon receipt at the UHL sample meets standard acceptance criteria.*

Results of Analyses

Antimony in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Antimony	<5.0	5.0

Date Analyzed: 08-11-2004 Analyst: SB
Method: EPA 6020 Verified: LF

Arsenic in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Arsenic	3.3	1.0

Date Analyzed: 08-11-2004 Analyst: SB
Method: EPA 6020 Verified: LF

Barium in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Barium	250	5.0

Date Analyzed: 08-11-2004 Analyst: SB
Method: EPA 6020 Verified: LF

Beryllium in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Beryllium	<2.0	2.0

Date Analyzed: 08-18-2004 Analyst: SB
Method: EPA 6020 Verified: TAB

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Cadmium in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Cadmium	<2.0	2.0

Date Analyzed: 08-11-2004 Analyst: SB
Method: EPA 6020 Verified: LF

Chromium in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Chromium	13	2.0

Date Analyzed: 08-11-2004 Analyst: SB
Method: EPA 6020 Verified: LF

Lead in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Lead	20	10

Date Analyzed: 08-11-2004 Analyst: SB
Method: EPA 6020 Verified: LF

Mercury in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Mercury	<1.0	1.0

Date Analyzed: 08-18-2004 Analyst: SB
Method: EPA 7471A-UHL Verified: LF

Nickel in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Nickel	29	5.0

Date Analyzed: 08-11-2004 Analyst: SB
Method: EPA 6020 Verified: LF

Selenium in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Selenium	<1.0	1.0

Date Analyzed: 08-11-2004 Analyst: SB
Method: EPA 6020 Verified: LF

Page 2 - Continued on next page

Silver in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Silver	<1.0	1.0

Date Analyzed: 08-11-2004
Method: EPA 6020
Analyst: SB
Verified: LF

Thallium in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Thallium	<1.0	1.0

Date Analyzed: 08-11-2004
Method: EPA 6020
Analyst: SB
Verified: LF

Zinc in Solid Sample

Analyte	Concentration mg/kg by dry wt	Quantitation Limit mg/kg by dry wt
Total Zinc	54	2.0

Date Analyzed: 08-11-2004
Method: EPA 6020
Analyst: SB
Verified: LF

Description of units used within this report

mg/kg by dry wt - Milligrams per Kilogram by Dry Weight

Quant Limit - Lowest concentration reliably measured

Iowa Laboratory Certification No. 027. AIHA, NELAP, USEPA, and other credentials available upon request.

If you have any questions please call Sherri Marine at 800/421-IOWA (4692) or 319/335-4500. Thank you.

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Hygienic Laboratory

ADDITIONAL RESULTS

The University of Iowa

Date of report: 12-29-2004

GEORGE ANTONIOU
ISU/EEOB
207 BESSEY HALL

AMES IA 50011

Sample Number	**200408565 Revision 1**
Date Received	07-26-2004
Project	ISU/IOWA LAKES
Date Collected	07-19-2004 10:30
Collection Site	011 blackhawk
Collection Town	
Description	sediment
Reference	SEDIMENT SAMPLES
Collector	
Phone	
Purchase Order	B55041602

Comments: *Upon receipt at the UHL sample meets standard acceptance criteria.*

Results of Analyses

Nitrogen Containing Herbicides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Atrazine	0.0089 J	0.01
Cyanazine	<0.01	0.01
Metolachlor	<0.01	0.01
Alachlor	<0.01	0.01
Metribuzin	<0.01	0.01
Butylate	<0.01	0.01
Trifluralin	<0.01	0.01
Acetochlor	<0.01	0.01
Desethyl Atrazine	<0.01	0.01
Desisopropyl Atrazine	<0.01	0.01

Comments: *J - Please note the concentration reported for this target analyte is below the laboratory's routine quantitation limit. The concentration reported should be considered estimated.*

Date Analyzed: 08-28-2004
Method: EPA 8141
Date Prepared: 07-28-2004
Preparation Method: EPA 3550

Analyst: PB
Verified: SM
Analyst: JF
Verified: GJ

Organophosphate Insecticides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Terbufos	<0.01	0.01
Fonofos	<0.01	0.01
Chlorpyrifos	<0.01	0.01
Ethoprop	<0.01	0.01
Phorate	<0.01	0.01

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Organophosphate Insecticides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Carbofuran	<0.01	0.01
Malathion	<0.01	0.01
Dimethoate	<0.01	0.01

Date Analyzed: 08-28-2004 — Analyst: PB
Method: EPA 8141 — Verified: SM
Date Prepared: 07-28-2004 — Analyst: JF
Preparation Method: EPA 3550 — Verified: GJ

Acid Herbicides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
2,4-D	<0.2	0.2
Dicamba	<0.2	0.2
Silvex	<0.2	0.2
Picloram	<0.2	0.2
Bentazon	<0.2	0.2
2,4,5-T	<0.2	0.2
2,4-DB	<0.2	0.2
Acifluorfen	<0.2	0.2
Bromoxynil	<0.2	0.2
Chloramben	<0.2	0.2
Chlorthal-dimethyl	<0.2	0.2
Dichlorprop	<0.2	0.2
Dinoseb	<0.2	0.2
Pentachlorophenol	<0.2	0.2
Triclopyr	<0.2	0.2

Date Analyzed: 08-26-2004 — Analyst: JS
Method: EPA 8151 — Verified: SM
Date Prepared: 08-19-2004 — Analyst: GJ,MS,K
Preparation Method: NEIC/EPA 8150 — Verified: GJ

Polychlorinated biphenyls in Solids

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Aroclor 1016	<0.05	0.05
Aroclor 1221	<0.05	0.05
Aroclor 1232	<0.05	0.05
Aroclor 1242	<0.05	0.05

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Polychlorinated biphenyls in Solids

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Aroclor 1248	<0.05	0.05
Aroclor 1254	<0.05	0.05
Aroclor 1260	<0.05	0.05

Date Analyzed: 08-21-2004 — Analyst: VR
Method: EPA 8082 — Verified: SM
Date Prepared: 07-28-2004 — Analyst: JF
Preparation Method: EPA 3550 — Verified: GJ

Chlorinated Hydrocarbon Insecticides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Aldrin	<0.01	0.01
alpha-BHC	<0.02	0.02
beta-BHC	<0.01	0.01
delta-BHC	<0.01	0.01
Lindane (gamma-BHC)	<0.01	0.01
DDD	<0.01	0.01
DDE	<0.01	0.01
DDT	<0.02	0.02
Methoxychlor	<0.01	0.01
Dieldrin	<0.01	0.01
Endosulfan I	<0.01	0.01
Endosulfan II	<0.01	0.01
Endosulfan sulfate	<0.01	0.01
Endrin	<0.01	0.01
Endrin aldehyde	<0.01	0.01
Endrin ketone	<0.01	0.01
Heptachlor	<0.01	0.01
Heptachlor epoxide	<0.01	0.01
Chlordane	<0.05	0.05
Toxaphene	<0.1	0.1

Date Analyzed: 08-21-2004 — Analyst: VR
Method: EPA 8081A — Verified: SM
Date Prepared: 07-28-2004 — Analyst: JF
Preparation Method: EPA 3550 — Verified: GJ

Description of units used within this report

mg/kg - Milligrams per Kilogram

Quant Limit - Lowest concentration reliably measured

Iowa Laboratory Certification No. 027. AIHA, NELAP, USEPA, NVLAP #101288-0 and other credentials available upon request.

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Hygienic Laboratory

The University of Iowa

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Appendix E. UHL Fish Toxicity Data Report

Hygienic Laboratory

The University of Iowa

Date of report: **12-22-2008**

GEORGE ANTONIOU
IOWA DEPT OF NATURAL RESOURCES
502 EAST 9TH STREET
H A WALLACE BUILDING
DES MOINES IA 50319

Sample Number	**2008039580**
Date Received	10-14-2008
Project	
Date Collected	08-13-2008
Collection Site	black hawk lake
Collection Town	
Description	fish
Reference	LARGEMOUTH BASS
Collector	MILLER LANNIE
Phone	
Purchase Order	

Comments: *Diagnostic/Feasibility*
Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

Sample Prep Chlor. Hydro. in Fish

Analyte	Concentration	Method	Analyst/ Verifier	Date Analyzed
Percent Lipids	2.98 %	EPA/AOAC	GJ,KB/SE	12-02-2008

Aroclors

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Aroclor 1248	<0.05	0.05
Aroclor 1254	<0.05	0.05
Aroclor 1260	<0.05	0.05

Date Analyzed: 12-06-2008
Method: EPA 8081
Date Prepared: 12-02-2008

Analyst: VR
Verified: SM
Analyst: GJ,KB
Verified: SE

Total Mercury in Fish Tissue

Analyte	Concentration mg/kg as rec'd.	Quantitation Limit mg/kg as rec'd.
Total Mercury	0.090	0.005

Date Analyzed: 11-19-2008
Method: EPA 7471A-UHL

Analyst: AB/SB
Verified: DS

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Page 1 - Continued on next page

Chlorinated Hydrocarbon Insecticides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Lindane (gamma-BHC)	<0.05	0.05
Dieldrin	<0.02	0.02
alpha-Chlordane	<0.02	0.02
gamma-Chlordane	<0.02	0.02
Chlordane	<0.05	0.05
Heptachlor	<0.02	0.02
Heptachlor epoxide	<0.05	0.05
Hexachlorobenzene	<0.02	0.02
DDD	<0.02	0.02
DDE	<0.02	0.02
DDT	<0.02	0.02

Date Analyzed: 12-06-2008
Method: EPA 8081
Date Prepared: 12-02-2008

Analyst: VR
Verified: SM
Analyst: GJ,KB
Verified: SE

Total Cadmium in Fish Tissue

Analyte	Concentration mg/kg as rec'd.	Quantitation Limit mg/kg as rec'd.
Total Cadmium	<0.060	0.060

Date Analyzed: 11-21-2008
Method: EPA 6020

Analyst: SB
Verified: LF

Nitrogen Containing Herbicides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Trifluralin (Treflan)	<0.1	0.1

Date Analyzed: 12-10-2008
Method: EPA 8141
Date Prepared: 12-02-2008

Analyst: PB
Verified: SM
Analyst: GJ,KB
Verified: SE

Total Lead in Fish Tissue

Analyte	Concentration mg/kg as rec'd.	Quantitation Limit mg/kg as rec'd.
Total Lead	<0.17	0.17

Date Analyzed: 11-21-2008
Method: EPA 6020

Analyst: SB
Verified: LF

Page 2 - Continued on next page

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515/725-1600 Fax: 515/725-1642

Hygienic Laboratory

The University of Iowa

Total Selenium in Fish Tissue

Analyte	Concentration mg/kg as rec'd.	Quantitation Limit mg/kg as rec'd.
Total Selenium	<0.50	0.50

Date Analyzed: 11-21-2008
Method: EPA 6020

Analyst: SB
Verified: LF

Description of units used within this report

mg/kg - Milligrams per Kilogram
% - Percent
mg/kg as rec'd. - Milligrams per Kilogram as Received
Quant Limit - Lowest concentration reliably measured

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Iowa Environmental Laboratory ID #027.

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Hygienic Laboratory

The University of Iowa

Date of report: 12-22-2008

GEORGE ANTONIOU
IOWA DEPT OF NATURAL RESOURCES
502 EAST 9TH STREET
H A WALLACE BUILDING
DES MOINES IA 50319

Sample Number	**2008039581**
Date Received	10-14-2008
Project	
Date Collected	08-13-2008
Collection Site	black hawk lake
Collection Town	
Description	fish
Reference	CHANNEL CATFISH
Collector	MILLER LANNIE
Phone	
Purchase Order	

Comments: *Diagnostic/Feasibility*
Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

Sample Prep Chlor. Hydro. in Fish

Analyte	Concentration	Method	Analyst/ Verifier	Date Analyzed
Percent Lipids	1.99 %	EPA/AOAC	GJ,KB/SE	12-04-2008

Aroclors

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Aroclor 1248	<0.05	0.05
Aroclor 1254	<0.05	0.05
Aroclor 1260	<0.05	0.05

Date Analyzed: 12-06-2008
Method: EPA 8081
Date Prepared: 12-04-2008

Analyst: VR
Verified: SM
Analyst: GJ,KB
Verified: SE

Total Mercury in Fish Tissue

Analyte	Concentration mg/kg as rec'd.	Quantitation Limit mg/kg as rec'd.
Total Mercury	0.031	0.005

Date Analyzed: 11-19-2008
Method: EPA 7471A-UHL

Analyst: SB
Verified: DS

Page 1 - Continued on next page

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Hygienic Laboratory

The University of Iowa

Chlorinated Hydrocarbon Insecticides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Lindane (gamma-BHC)	<0.02	0.02
Dieldrin	<0.02	0.02
alpha-Chlordane	<0.02	0.02
gamma-Chlordane	<0.02	0.02
Chlordane	<0.05	0.05
Heptachlor	<0.02	0.02
Heptachlor epoxide	<0.02	0.02
Hexachlorobenzene	<0.02	0.02
DDD	<0.02	0.02
DDE	<0.02	0.02
DDT	<0.02	0.02

Date Analyzed: 12-06-2008
Method: EPA 8081
Date Prepared: 12-04-2008

Analyst: VR
Verified: SM
Analyst: GJ,KB
Verified: SE

Total Cadmium in Fish Tissue

Analyte	Concentration mg/kg as rec'd.	Quantitation Limit mg/kg as rec'd.
Total Cadmium	<0.060	0.060

Date Analyzed: 11-21-2008
Method: EPA 6020

Analyst: SB
Verified: LF

Nitrogen Containing Herbicides

Analyte	Concentration mg/kg	Quantitation Limit mg/kg
Trifluralin (Treflan)	<0.1	0.1

Date Analyzed: 12-10-2008
Method: EPA 8141
Date Prepared: 12-04-2008

Analyst: PB
Verified: SM
Analyst: GJ,KB
Verified: SE

Total Lead in Fish Tissue

Analyte	Concentration mg/kg as rec'd.	Quantitation Limit mg/kg as rec'd.
Total Lead	<0.17	0.17

Date Analyzed: 11-21-2008
Method: EPA 6020

Analyst: SB
Verified: LF

Page 2 - Continued on next page

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Total Selenium in Fish Tissue

Analyte	Concentration mg/kg as rec'd.	Quantitation Limit mg/kg as rec'd.
Total Selenium	<0.50	0.50

Date Analyzed: 11-21-2008
Method: EPA 6020

Analyst: SB
Verified: LF

Description of units used within this report

mg/kg - Milligrams per Kilogram
% - Percent
mg/kg as rec'd. - Milligrams per Kilogram as Received
Quant Limit - Lowest concentration reliably measured

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1-pkg Fish See attached email for analysis
KHH Bill & Report to George Antoniou
per phone call to George. KHH 10-14-08
Rec'd Frozen

2008039580 IC
2008-10-14 12:40

Fish Tissue Sample Collection Field Sheet

Iowa Department of Natural Resources

Project: Diagnostic / Feasibility
Contaminant(s) of concern:
Collection Biologist: Lannie Miller

Location: Black Hawk Lake
Storet ID:

Collection Date Start: 08/13/08
Collection Date End: 08/13/08

Field Measurements:

Parameter	Value
Ave. Length (mm)	403.4 mm
Ave. Weight (grams)	1125.9 grams
Number of specimens	5
Species STORET ID#	31
Fish type (circle)	Bottom feeder / (predator)
Fish Species common name	Largemouth Bass
Tissue analyzed (circle)	(Fillet) / whole
Sample type (circle)	Trend / status / follow-up
County	Sac
NAD83 UTM-Northing	
NAD83 UTM-Easting	

Laboratory Analyses:

Container	Preservative	Analysis
Foil wrapped	Freezing	

Sample Comments: George Antoniou

IOWA DEPARTMENT OF NATURAL RESOURCES
WALLACE STATE OFFICE BUILDING
502 E 9TH STREET
DES MOINES, IA 50319-0034

1-pkg Fish
?KH
Recd Frozen

2008039581 IC
2008-10-14 12:40

Fish Tissue Sample Collection Field Sheet

Iowa Department of Natural Resources

Project: Diagnostic / Feasibility
Contaminant(s) of concern:
Collection Biologist: Lannie Miller

Location: Black Hawk Lake
Storet ID:

Collection Date Start: 08/13/08
Collection Date End: 08/13/08

Field Measurements:

Parameter	Value
Ave. Length (mm)	468.9 mm
Ave. Weight (grams)	849.9 grams
Number of specimens	5
Species STORET ID#	16
Fish type (circle)	(Bottom feeder) / predator
Fish Species common name	Channel Catfish
Tissue analyzed (circle)	(Fillet) / whole
Sample type (circle)	Trend / status / follow-up
County	Sac
NAD83 UTM-Northing	
NAD83 UTM-Easting	

Laboratory Analyses:

Container	Preservative	Analysis
Foil wrapped	Freezing	

Sample Comments:

George ~~Antinou~~ Antoniou
515-281-8042

IOWA DEPARTMENT OF NATURAL RESOURCES
WALLACE STATE OFFICE BUILDING
502 E 9TH STREET
DES MOINES, IA 50319-0034

George.Antoniou@dnr.iowa.gov

Appendix F: Methods

The analytical parameters measured in water samples analyzed in the ISULL and the analytical methods used are provided below. Methods for parameters measured in the field follows laboratory methods.

Laboratory Analyses

Physics and Chemistry

Soluble Reactive Phosphorus as P - Soluble reactive phosphorus samples are analyzed with an HP 8453 Spectrophotometer using the ascorbic acid method in Standard Methods (American Public Health Association, 1998). Analysis involves filtering the samples through a 0.45 µm syringe-tip filter to remove particulate matter, allowing color to develop for 10-30 minutes, creating standard curves (forced through origin) daily, running known standards and spikes with each group of samples and correcting for background turbidity using a 3-point drop correction.

Total Phosphorus - Total phosphorus samples are analyzed with an HP 8453 Spectrophotometer using the ascorbic acid method in Standard Methods (American Public Health Association, 1998). Analysis involves digesting the samples with persulfate, allowing color to develop for 10-30 minutes, creating standard curves (forced through origin) daily, running known standards and spikes with each group of samples and correcting for background turbidity using a 3-point drop correction.

Ammonia+Ammonium as N - Ammonia nitrogen samples are analyzed with an HP 8453 Spectrophotometer using the phenate method in Standard Methods (American Public Health Association, 1998). Analysis involves filtering samples through a 0.45 µm syringe-tip filter to remove particulate matter, generating standard curves (forced through origin) daily and running known standards and spikes with each group of samples.

Nitrate+Nitrite as N - Nitrate + nitrite samples are analyzed with an HP 8453 Spectrophotometer using the second derivative ultraviolet spectroscopy method (Crumpton *et al.*, 1992). Analysis involves generating standard curves daily and running known standards and spikes with each group of samples.

Total Nitrogen - Total nitrogen samples are analyzed with an HP 8453 Spectrophotometer using the second derivative ultraviolet spectroscopy method (Crumpton *et al.*, 1992). Analysis involves digesting the samples with persulfate, generating standard curves daily and running known standards and spikes with each group of samples.

Chlorophyll a - Chlorophyll *a* samples are analyzed with a TD-700 Fluorometer using the non-acidified fluorometry EPA method 445.0 (Arar & Collins, 1997). Analysis involves filtering samples through a 0.45 µm filter, extracting in 100% acetone using a probe sonicator (Jeffrey *et al.*, 1997), creating standard curves (forced through origin) annually, and running known standards with each group of samples.

Suspended Solids (Total, Volatile, & Inorganic) - Suspended solids samples are analyzed using the non-filterable residue and volatile residue EPA methods 160.2 (USEPA, 1979) and 160.4 (USEPA, 1983). Analysis involves filtering samples through a pre-rinsed and pre-weighed 0.45 µm filter, drying at 105°C, weighing to determine TSS, combusting at 550°C, and weighing to determine VSS and ISS fractions. Known standards are run with each group of samples.

Dissolved Organic Carbon - Dissolved organic carbon samples are analyzed with a Shimadzu TOC-V Analyzer using the high-temperature combustion method in Standard Methods (American Public Health Association, 1998). Analysis involves filtering samples through a 0.45 µm syringe-tip filter, creating standard curves (forced through origin) daily and running known standards with each group of samples.

Laboratory pH & Total Alkalinity as $CaCO_3$ - Laboratory pH and total alkalinity are analyzed with a Thermo Orion 950 Analytical Titrator using the titration method in Standard Methods (American Public Health Association, 1998). Analysis involves a temperature-compensated pH measurement and automated titration to pH = 4.5.

Biological and Microbial Analyses

Phytoplankton - Phytoplankton samples are concentrated, sub-sampled, and examined using a Leitz DM IL inverted microscope at 200x power (American Public Health Association, 1998). Samples are analyzed using methods similar to those described by Lund *et al*. (1958) which are a variant of the Utermöhl (1958) method. Phytoplankton are identified to genus, counted, and measured. Simple geometric model formulae are used to calculate the biovolume per liter of six divisions and the total phytoplankton community (Findenegg, 1974; Hillebrand *et al.*, 1999). The biovolume per liter is converted to wet mass per liter using a 1:1 ratio (Sournia, 1978).

Zooplankton - Zooplankton samples are concentrated, sub-sampled, and examined using a Nikon SMZ 1500 Stereoscopic Zoom Microscope and photographed using a Qimaging Retiga 2000R Digital Still Camera at 96x power (American Public Health Association, 1998). Zooplankton are identified to family, counted, and measured. Length-weight regressions are used to calculate the dry mass per liter of the Cladocera and Copepoda (Dumont, *et al.*, 1975). Rotifera dry mass per liter is determined by first calculating the biovolume per liter (Ruttner-Kolisko, 1977) then converting this measurement to dry mass per liter (Doohan, 1973 for all rotifers except Asplancha; Dumont *et al*., 1975 for Asplancha; McCauley, 1984).

E. coli Bacteria - *E. coli* bacteria samples are analyzed using an IDEXX bacteria kit according to the enzyme substrate method in Standard Methods (American Public Health Association, 1998). Analysis involves the addition of Colilert reagent, incubation for 24 hours, analysis with a long-wave UV light to count positive yellow and fluorescent wells, and data conversion to MPN. A known sample (QC 0) is run with each group of samples.

Total Coliform Bacteria - Total coliform bacteria samples are analyzed using an IDEXX bacteria kit according to the enzyme substrate method in Standard Methods (American Public Health Association, 1998). Analysis involves the addition of Colilert reagent, incubation for 24 hours, analysis to count positive yellow wells, and data conversion to MPN. A known sample (QC 0) is run with each group of samples.

Microcystin - Microcystin samples were obtained from the 0-2 meter mixed lake samples and were analyzed using a commercially-available ELISA (Enzyme-Linked ImmunoSorbent Assay) kit. Samples are concentrated into a pellet and beaten with glass beads to lyse the algal cells before analysis.

Field Measurements

Tributary

Stream Velocity and Stream Profile Measurements – Stream velocities are taken at the most constricted point in the stream, with as little vegetation or rock obstruction as possible. Profile measurements are made by transecting the stream and noting the total width with a meter marker. Table 1 describes the number of necessary depth and velocity measurements for a given total width of a stream. Depth are measured and recorded for each velocity measurement made. Stream velocities measurements are made at 60% of the depth from the water surface at that location along the stream transect. Field personnel stand downstream of the flow meter while measurements are being made, so as to not obstruct or alter stream flow (Rantz, 1982).

Table 1. Guidelines for Depth (in meters) and Velocity Measurements

Stream Width (SW) in meters	**Measurements in m/s**
SW < 0.5 m	One velocity measurement half of the width of the stream
0.5 < SW < 1.5 m	Two measurements (divide the SW by 3)
1.5 < SW < 3 m	Measurements every 0.5 m
3 m – 10 m	Measurements every 1 m
> 10 m	Five measurements (divide the SW by 5)

Total stream width and all depth and velocity measurements are recorded on the field data sheet to be used to calculate instantaneous discharge and total stream discharge.

Instantaneous Discharge - Instantaneous discharge is calculated using the midsection method for calculating discharge (Rantz, 1982). Velocity (flow) is measured at depths of 60% of the distance from the surface to the bottom (Sauer and Meyer, 1992) using a Marsh-McBirney Flo-Mate Model 2000 meter with an electromagnetic velocity sensor. The number of velocity measurements taken is determined by stream width. Streams with a width less than 0.5 meters will have one measurement taken in the center of the stream. Streams with widths between 0.5 meters and 1.5 meters will have two measurements taken at 1/3 and 2/3 distance across the stream from shore. Streams with widths between 1.5 meters and 3 meters will have measurements taken every 0.5 meters. Streams larger than 3 meters will have measurements taken every 1 meter across the channel (see Table 9).

Total Stream Discharge - Total stream discharge is estimated on all stream sites using the continuously monitored stage depth of a large stream site in the watershed. A depth transducer is used to collect the stage depth (collected from USGS depth data). The stage depth at the continuously monitored site is converted to discharges for each sub-watershed using simple stage-discharge rating curves (Gupta, 1995). Continuously monitored sub-watershed discharge is scaled to smaller sub-watersheds, assuming linearity or log-linearity of sub-basin responses (Goodrich et al., 1997). The validity of this approach is assessed by fitting the frequently observed inter-sub-watershed discharge correlations using linear and non-linear models. This is similar to the long accepted unit hydrograph approach (Maidment et al., 1996). The total discharges for each sub-watershed is summed and multiplied by 3 x 105 (5 minutes x 60 seconds x 1000 liters/m3) to yield the total discharge (in liters) over the period of the continuous hydrograph.

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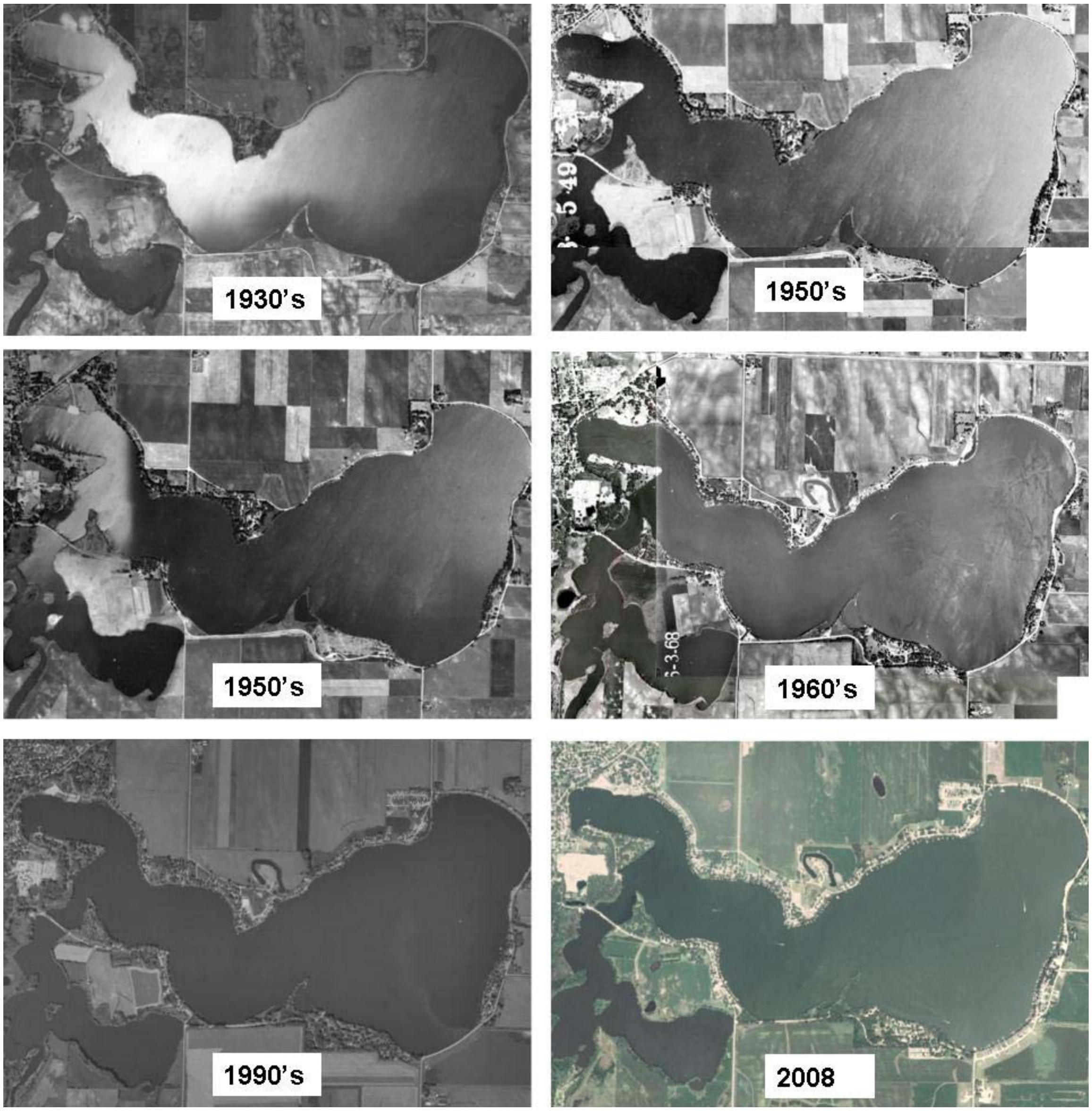
Appendix G. DNR Provided: Watershed Modeling

Appendix H. Historical Photo Review



Historical photo review (Image Source: Iowa Geographic Map Server - Iowa State University Geographic Information Systems Support & Research Facility)

Appendix I. Caffeine Analysis Results from UHL

Hygienic Laboratory

DUPLICATE COPY

The University of Iowa

Date of report: 08-18-2009

Sample Number	2009027158
Date Received	08-06-2009
Project	
Date Collected	08-05-2009 11:50
Collection Site	s05
Collection Town	Black Hawk Lake
Description	water
Reference	
Collector	KENDALL/TIEDEMAN
Phone	(515) 294-2170
Purchase Order	C00258823

AMBER ERICKSON
ISU LIMNOLOGY
253 BESSEY HALL

AMES IA 50011

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested; EXCEPT: sample temperature exceeds 6 degrees celsius. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	<40	40

Date Analyzed: 08-17-2009
Method: EPA 8270
Date Prepared: 08-10-2009

Analyst: VR
Verified: TC
Analyst: MS
Verified: KB

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Hygienic Laboratory

DUPLICATE COPY

The University of Iowa

Date of report: 08-18-2009

Sample Number	2009027159
Date Received	08-06-2009
Project	
Date Collected	08-05-2009 11:40
Collection Site	s06
Collection Town	Black Hawk Lake
Description	water
Reference	
Collector	KENDALL/TIEDEMAN
Phone	(515) 294-2170
Purchase Order	C00258823

AMBER ERICKSON
ISU LIMNOLOGY
253 BESSEY HALL

AMES IA 50011

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested;*
EXCEPT: sample temperature exceeds 6 degrees celsius.
Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	<40	40

Date Analyzed: 08-17-2009
Method: EPA 8270
Date Prepared: 08-10-2009

Analyst: VR
Verified: TC
Analyst: MS
Verified: KB

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Hygienic Laboratory

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The University of Iowa

Date of report: 08-18-2009

AMBER ERICKSON
ISU LIMNOLOGY
253 BESSEY HALL

AMES IA 50011

Sample Number	2009027160
Date Received	08-06-2009
Project	
Date Collected	08-05-2009 11:25
Collection Site	s13
Collection Town	Black Hawk Lake
Description	water
Reference	
Collector	KENDALL/TIEDEMAN
Phone	(515) 294-2170
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested;*
EXCEPT: sample temperature exceeds 6 degrees celsius.
Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	10 J	40

Comments: *J - The concentration of this compound is below the quantitation limit, but the mass spectral data meet the identification criteria indicating that the compound is present. The concentration should be considered estimated.*

Date Analyzed: 08-17-2009
Method: EPA 8270
Date Prepared: 08-10-2009

Analyst: VR
Verified: TC
Analyst: MS
Verified: KB

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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The University of Iowa

Date of report: 08-18-2009

AMBER ERICKSON
ISU LIMNOLOGY
253 BESSEY HALL

AMES IA 50011

Sample Number	2009027188
Date Received	08-06-2009
Project	
Date Collected	08-05-2009 10:30
Collection Site	s14
Collection Town	Black Hawk Lake
Description	water
Reference	
Collector	KENDALL/TIEDEMAN
Phone	(515) 294-2170
Purchase Order	C00258823

Comments

Upon arrival, sample met container and preservation requirements for the analysis requested;
EXCEPT: sample temperature exceeds 6 degrees celsius.
Please review carefully your sample results for additional analyte comments or method exceptions.
Paperwork lists collection time as 11:25; per label 10:30.

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	<40	40

Date Analyzed: 08-17-2009
Method: EPA 8270
Date Prepared: 08-10-2009

Analyst: VR
Verified: TC
Analyst: MS
Verified: KB

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Hygienic Laboratory

The University of Iowa

Date of report: 10-01-2009

AMBER ERICKSON
ISU LIMNOLOGY
253 BESSEY HALL

AMES IA 50011

Sample Number	**2009033138**
Date Received	09-10-2009
Project	
Date Collected	09-10-2009 08:20
Collection Site	black hawk s14
Collection Town	
Description	water
Reference	
Collector	TIEDEMAN MARY
Phone	(515) 294-2170
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	18 J	40

Comments: *J - The concentration of this compound is below the quantitation limit, but the mass spectral data meet the identification criteria indicating that the compound is present. The concentration should be considered estimated.*

Date Analyzed: 09-25-2009
Method: EPA 8270
Date Prepared: 09-16-2009

Analyst: ES
Verified: TC
Analyst: GJ
Verified: KB

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

The results of this report relate only to the items analyzed. This report shall not be reproduced except in full without the written approval of the laboratory.

Iowa Environmental Laboratory ID #027.

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Hygienic Laboratory

The University of Iowa

Date of report: 10-01-2009

AMBER ERICKSON
ISU LIMNOLOGY
253 BESSEY HALL

AMES IA 50011

Sample Number	**2009033139**
Date Received	09-10-2009
Project	
Date Collected	09-10-2009 08:35
Collection Site	black hawk s13
Collection Town	
Description	water
Reference	
Collector	TIEDEMAN MARY
Phone	(515) 294-2170
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	43	40

Date Analyzed: 09-25-2009
Method: EPA 8270
Date Prepared: 09-16-2009

Analyst: ES
Verified: TC
Analyst: GJ
Verified: KB

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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The University of Iowa

Date of report: 10-01-2009

AMBER ERICKSON
ISU LIMNOLOGY
253 BESSEY HALL

AMES IA 50011

Sample Number	**2009033140**
Date Received	09-10-2009
Project	
Date Collected	09-10-2009 09:35
Collection Site	black hawk s06
Collection Town	
Description	water
Reference	
Collector	TIEDEMAN MARY
Phone	(515) 294-2170
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	14 J	40

Comments: *J - The concentration of this compound is below the quantitation limit, but the mass spectral data meet the identification criteria indicating that the compound is present. The concentration should be considered estimated.*

Date Analyzed: 09-25-2009
Method: EPA 8270
Date Prepared: 09-16-2009

Analyst: ES
Verified: TC
Analyst: GJ
Verified: KB

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Date of report: 10-01-2009

AMBER ERICKSON
ISU LIMNOLOGY
253 BESSEY HALL

AMES IA 50011

Sample Number	**2009033141**
Date Received	09-10-2009
Project	
Date Collected	09-10-2009 09:50
Collection Site	black hawk s05
Collection Town	
Description	water
Reference	
Collector	TIEDEMAN MARY
Phone	(515) 294-2170
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	11 J	40

Comments: *J - The concentration of this compound is below the quantitation limit, but the mass spectral data meet the identification criteria indicating that the compound is present. The concentration should be considered estimated.*

Date Analyzed: 09-25-2009
Method: EPA 8270
Date Prepared: 09-16-2009

Analyst: ES
Verified: TC
Analyst: GJ
Verified: KB

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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The University of Iowa

Date of report: 11-16-2009

AMBER ERICKSON
ISU/EEOB
150 BESSEY HALL

AMES IA 50011

Sample Number	**2009039816**
Date Received	10-28-2009
Project	
Date Collected	10-26-2009 10:40
Collection Site	50
Collection Town	
Description	water
Reference	BLACK HAWK TILES
Collector	ERICKSON AMBER
Phone	(515) 294-7373
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	<40	40

Date Analyzed: 11-10-2009
Method: EPA 8270
Date Prepared: 11-02-2009

Analyst: ES
Verified: TC
Analyst: MS
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Iowa Environmental Laboratory ID #027.

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The University of Iowa

Date of report: 11-16-2009

AMBER ERICKSON
ISU/EEOB
150 BESSEY HALL

AMES IA 50011

Sample Number	**2009039817**
Date Received	10-28-2009
Project	
Date Collected	10-26-2009 10:50
Collection Site	51
Collection Town	
Description	water
Reference	BLACK HAWK TILES
Collector	ERICKSON AMBER
Phone	(515) 294-7373
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	<40	40

Date Analyzed: 11-10-2009
Method: EPA 8270
Date Prepared: 11-02-2009

Analyst: ES
Verified: TC
Analyst: MS
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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The University of Iowa

Date of report: 11-16-2009

AMBER ERICKSON
ISU/EEOB
150 BESSEY HALL

AMES IA 50011

Sample Number	**2009039818**
Date Received	10-28-2009
Project	
Date Collected	10-26-2009 12:00
Collection Site	52
Collection Town	
Description	water
Reference	BLACK HAWK TILES
Collector	ERICKSON AMBER
Phone	(515) 294-7373
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	<40	40

Date Analyzed: 11-10-2009
Method: EPA 8270
Date Prepared: 11-02-2009

Analyst: ES
Verified: TC
Analyst: MS
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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The University of Iowa

Date of report: 11-16-2009

AMBER ERICKSON
ISU/EEOB
150 BESSEY HALL

AMES IA 50011

Sample Number	**2009039819**
Date Received	10-28-2009
Project	
Date Collected	10-26-2009 11:47
Collection Site	53
Collection Town	
Description	water
Reference	BLACK HAWK TILES
Collector	ERICKSON AMBER
Phone	(515) 294-7373
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	<40	40

Date Analyzed: 11-10-2009
Method: EPA 8270
Date Prepared: 11-02-2009

Analyst: ES
Verified: TC
Analyst: MS
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Date of report: 11-16-2009

AMBER ERICKSON
ISU/EEOB
150 BESSEY HALL

AMES IA 50011

Sample Number	**2009039820**
Date Received	10-28-2009
Project	
Date Collected	10-26-2009 12:47
Collection Site	54
Collection Town	
Description	water
Reference	BLACK HAWK TILES
Collector	ERICKSON AMBER
Phone	(515) 294-7373
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	<40	40

Date Analyzed: 11-10-2009
Method: EPA 8270
Date Prepared: 11-02-2009

Analyst: ES
Verified: TC
Analyst: MS
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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The University of Iowa

Date of report: 11-16-2009

AMBER ERICKSON
ISU/EEOB
150 BESSEY HALL

AMES IA 50011

Sample Number	**2009039821**
Date Received	10-28-2009
Project	
Date Collected	10-26-2009 13:00
Collection Site	56
Collection Town	
Description	water
Reference	BLACK HAWK TILES
Collector	ERICKSON AMBER
Phone	(515) 294-7373
Purchase Order	C00258823

Comments: *Client requested that the sample be analyzed from the 500ml available. Upon arrival, sample met container and preservation requirements for the analysis requested;*
EXCEPT:low sample volume received.
Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	17 J	80

Comments: *J - The concentration of this compound is below the quantitation limit, but the mass spectral data meet the identification criteria indicating that the compound is present. The concentration should be considered estimated.*

Date Analyzed: 11-10-2009
Method: EPA 8270
Date Prepared: 11-02-2009

Analyst: ES
Verified: TC
Analyst: MS
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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The University of Iowa

Date of report: 11-16-2009

AMBER ERICKSON
ISU/EEOB
150 BESSEY HALL

AMES IA 50011

Sample Number	**2009039822**
Date Received	10-28-2009
Project	
Date Collected	10-26-2009 14:30
Collection Site	57
Collection Town	
Description	water
Reference	BLACK HAWK TILES
Collector	ERICKSON AMBER
Phone	(515) 294-7373
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	<40	40

Date Analyzed: 11-10-2009
Method: EPA 8270
Date Prepared: 11-02-2009

Analyst: ES
Verified: TC
Analyst: MS
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Date of report: 11-16-2009

AMBER ERICKSON
ISU/EEOB
150 BESSEY HALL

AMES IA 50011

Sample Number	**2009039823**
Date Received	10-28-2009
Project	
Date Collected	10-26-2009 15:00
Collection Site	58
Collection Town	
Description	water
Reference	BLACK HAWK TILES
Collector	ERICKSON AMBER
Phone	(515) 294-7373
Purchase Order	C00258823

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	<40	40

Date Analyzed: 11-10-2009
Method: EPA 8270
Date Prepared: 11-02-2009

Analyst: ES
Verified: TC
Analyst: MS
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

Iowa Environmental Laboratory ID #027.

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Date of report: 11-16-2009

Sample Number	**2009039824**
Date Received	10-28-2009
Project	
Date Collected	10-26-2009 15:30
Collection Site	59
Collection Town	
Description	water
Reference	BLACK HAWK TILES
Collector	ERICKSON AMBER
Phone	(515) 294-7373
Purchase Order	C00258823

AMBER ERICKSON
ISU/EEOB
150 BESSEY HALL

AMES IA 50011

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

GC/MS Extractables - Caffeine

Analyte	Concentration ng/L	Quantitation Limit ng/L
Caffeine	<40	40

Date Analyzed: 11-10-2009
Method: EPA 8270
Date Prepared: 11-02-2009

Analyst: ES
Verified: TC
Analyst: MS
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Appendix J. Phosphorus models attempted for modeling nutrient concentrations in Black Hawk Lake

Canfield, D. E., and R. W Bachmann, 1981. Prediction of total phosphorus concentrations, chlorophyll-a, and Secchi depths in natural and artificial lakes. Can. J. Fish. Aquat. Sci. 38: 414-423.

Dillon, P. J., and F. H. Rigler, 1974. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. J. Fish. Res. Board Can. 31: 1771-1778.

Kirchner, W B. and P J. Dillon, 1975. An empirical method of estimating the retention of phosphorus in lakes. Water Resources Research. 11: 182-183.

Kreider, J. 2001. Wisconsin Lake Modeling Suite (WiLMS) version 3.3.18.1. Wisconsin Department of Natural Resources, Madision, Wisconsin, USA. http://www.dnr.state.wi.us/org/water/fhp/lakes/laketool.htm

Larsen D. P. and H. T. Mercier. 1976. Phosphorus retention capacity of lakes. J. Fish.Res. Board Can. 33: 1742-1750.

Nurnberg, Gertrud K. 1984. The prediction of internal phosphorus load in lakes with anoxic hypolimnia. Limnol. Oceanogr., 29 (1) 111-124.

Organisation for Economic Cooperation and Development (OECD) 1982.

Eutrophication of waters: monitoring, assessment and control, Paris. 154p.

Organisation for economic cooperation and development (OECD), 1982. Eutrophication of waters: monitoring, assessment and control. OECD, Paris. 154pp.

Ostrofsky, M.L., 1978. Modification of phosphorus retention models for use with low areal water loading. J. Fish Res. Board Can 35: 532-536.

Reckhow, K. H., 1977. Phosphorus models for lake management. Ph.D. dissertation, Harvard University, Cambridge, Massachusetts. Catalog No. 7731778, University Microfilms International, Ann Arbor, Michigan.

Reckhow, K. H., 1979. Uncertainty applied to Vollenweider's phosphorus criterion. J. Water Poll. Cont. Fed. 51: 2123-2128.

Walker, W W, Jr., 1977. Some analytical methods applied to lake water quality problems. Ph.D. dissertation, Harvard University.

Walker, W.W. 1984. Statistical bases for mean chlorophyll a criteria. Lake Reserv. Manage. 2:57-62.

Walker, W.W. Jr., 1985. Empirical methods for predicting eutrophication in impoundments. Report No. 3. Phase II: Model refinements. USCOE waterways experiment station technical report No. E-81-9. Vicksburg, Mississippi. 300p.

Appendix K. DNR Provided: RASQAL Stream Assessment

Black Hawk Lake
In-Stream Assessment Summary

Stream Miles Assessed: **8.69**

Flow at time of survey	*Stream Miles*	*% of Total*
Normal	8.48	97.6%
High	0.00	0.0%
Low	0.00	0.0%
No Flow	0.00	0.0%
Hydrologic Varaibility		
Dry Channel	0.00	0.0%
Pond	0.00	0.0%
Pool/Glide	0.80	9.1%
Riffle	0.16	1.9%
Run	7.52	86.5%
Substrate		
Bedrock	0.00	0.0%
Boulder	0.00	0.0%
Cobble	0.00	0.0%
Gravel	0.43	5.0%
Sand	1.11	12.8%
Silt/Mud	6.92	79.6%
Clay/Hard Pan	0.00	0.0%
Sediment Coverage		
Entire Segment	0.49	5.6%
75-90% of Segment	5.14	59.1%
50-75% of Segment	1.33	15.3%
25-50% of Segment	1.54	17.7%
0-25% of Segment	0.20	2.3%
Pool Frequency		
None	4.25	48.9%
1 Pool	1.86	21.4%
2 Pools	1.51	17.4%
3 Pools	0.61	7.0%
4 Pool	0.14	1.6%
5 or More	0.11	1.3%
Riffle Frequency		
None	2.35	27.0%
1 Riffle	1.94	22.3%
2 Riffles	1.61	18.5%
3 Riffles	2.00	23.0%
4 Riffles	0.52	6.0%
5 or More	0.08	0.9%
Losing Flow		
Yes	0.00	0.0%
No	8.69	100.0%
Stream Habitat		
Poor	0.85	9.8%
Average	7.07	81.3%
Excellent	0.57	6.5%

Left Riparian Zone Width	*Stream Miles*	*% of Total*
< 10 Feet	3.31	38.1%
10-30 Feet	0.96	11.0%
30-60 Feet	1.60	18.3%
> 60 Feet	2.62	30.1%
Right Riparian Zone Width		
< 10 Feet	2.91	33.5%
10-30 Feet	1.68	19.4%
30-60 Feet	0.63	7.2%
> 60 Feet	3.09	35.5%
Left Riparian Zone Cover		
Grass	4.95	57.0%
Trees	0.82	9.4%
Pasture	1.94	22.3%
CRP-Trees	0.00	0.0%
CRP-Grass	0.78	8.9%
Residential	0.00	0.0%
Commercial	0.00	0.0%
Right Riparian Zone Cover		
Grass	5.34	61.4%
Trees	0.78	9.0%
Pasture	1.94	22.3%
CRP-Trees	0.00	0.0%
CRP-Grass	0.43	4.9%
Residential	0.00	0.0%
Commercial	0.00	0.0%
Left Adjacent Land Cover		
Row Crop	4.75	54.6%
Trees	0.63	7.2%
Grass	0.63	7.3%
Pasture	1.62	18.6%
CRP	0.79	9.1%
Residential	0.07	0.9%
Commercial	0.00	0.0%
Open Feedlot	0.00	0.0%
Farmstead	0.00	0.0%
Cliff	0.00	0.0%
Other	0.00	0.0%
Right Adjacent Land Cover		
Row Crop	4.73	54.4%
Trees	0.26	3.0%
Grass	1.04	11.9%
Pasture	1.45	16.6%
CRP	0.89	10.2%
Residential	0.00	0.0%
Commercial	0.00	0.0%
Open Feedlot	0.00	0.0%
Farmstead	0.13	1.5%
Cliff	0.00	0.0%
Other	0.00	0.0%

Black Hawk Lake

In-Stream Assessment Summary

Stream Miles Assessed:	**8.69**	
Bank Stability		
Stable	0.62	7.2%
Moderately Stable	2.30	26.5%
Moderately Unstable	5.10	58.7%
Unstable	0.32	3.7%
Artificially Stable	0.06	0.7%
Bank Height		
0 - 3'	0.02	0.2%
3 - 6'	2.71	31.2%
6 - 10'	5.46	62.8%
10 - 15'	0.22	2.5%
15' +	0.00	0.0%
Bank Erosion		
None	0.89	10.3%
Both Banks	1.66	19.0%
Alternate Banks	4.75	54.6%
Random	1.12	12.8%
Bank Material		
Rock/RipRap	0.00	0.0%
Soil/Silt	8.35	96.1%
Cobble/Gravel	0.00	0.0%
Sand	0.00	0.0%
Bank Vegetation		
None	0.10	1.1%
Overhanging Only	0.76	8.8%
Dislodged	3.21	37.0%
Partially Established	3.59	41.3%
Well Established	0.68	7.8%

Canopy Cover		
0-10%	7.39	85.0%
10-25%	0.00	0.0%
25-50%	0.15	1.7%
50-75%	0.35	4.0%
75-100%	0.61	7.0%
Right Livestock Access		
Yes	1.79	20.6%
No	6.91	79.4%
Left Livestock Access		
Yes	1.79	20.6%
No	6.91	79.4%
Channel Pattern		
Straight	2.42	27.8%
Meandering	6.07	69.8%
Braided	0.00	0.0%
Channel Condition		
Altered Channel	0.00	0.0%
Natural Channel	6.29	72.3%
Past Channel Alteration	1.63	18.8%
Recent Alteration	0.56	6.5%