Blackduck Lake (04-0069)
Beltrami County:
2008 Lake Assessment

Environmental Analysis & Outcomes Division
Water Monitoring Section
March 2009
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# Table of Contents

List of Tables ..............................................................................................................................iv
List of Figures .............................................................................................................................iv
Executive Summary ...................................................................................................................1
Introduction ................................................................................................................................2
Background ................................................................................................................................2
  Lake Morphometric and Watershed Characteristics .............................................................2
  Land Use Characteristics and Ecoregion ...............................................................................2
  Lake Mixing ...........................................................................................................................4
  Lake Level Trends ................................................................................................................5
  Precipitation ...........................................................................................................................5
  Fisheries ...................................................................................................................................7
Methods ......................................................................................................................................7
Results and Discussion ..............................................................................................................8
Trophic State Index .....................................................................................................................10
Trophic Status Trends ...............................................................................................................12
Modeling .....................................................................................................................................13
303(d) Assessment and Goal Setting ........................................................................................14
Appendix A ................................................................................................................................16
  Glossary .................................................................................................................................16
Appendix B ................................................................................................................................18
  Water Quality Data: Abbreviations and Units ......................................................................18
Appendix C ................................................................................................................................19
  References .............................................................................................................................19
Appendix D ................................................................................................................................20
  Blackduck Lake Surface Water Results ................................................................................20
List of Tables

1. Blackduck Lake ecoregional land use comparison .................................................. 3
2. Blackduck Lake summer mean water quality as compared to the typical range for NLF ecoregion reference lakes ................................................................. 8
3. MINLEAP model results for Blackduck Lake ......................................................... 14
4. Eutrophication standard by ecoregion and lake type ........................................... 15

List of Figures

1. Blackduck Lake minor watershed and land use .................................................. 3
2. Minnesota’s seven ecoregions as mapped by U.S. Environmental Protection Agency .......................................................... 4
3. Lake Stratification .................................................................................................. 5
4. Summer 2008 rainfall based on records for Blackduck, Minnesota ....................... 6
5. 2008 Minnesota Water Year Precipitation and Departure from Normal ............. 6
6. Blackduck Lake site 205 dissolved oxygen and temperature profile .................. 9
7. Blackduck Lake site 205 TP & chl-a concentrations and Secchi depth .............. 10
8. Carlson’s Trophic State Index for Blackduck Lake ............................................. 11
9. Blackduck Lake historical Secchi depths ............................................................. 12
10. Blackduck Lake historical TP, chl-a, and Secchi depths. Summer means based on MPCA and EPA NES data ................................................................. 13
Executive Summary

The Minnesota Pollution Control Agency’s (MPCA) core lake monitoring programs include Legacy Lake Monitoring, Citizen Lake Monitoring Program (CLMP), and Lake Assessment Program (LAP). In addition to these programs, the MPCA annually monitors numerous lakes to provide baseline water quality data, provide data for potential LAP and Clean Water Partnership lakes, characterize lake condition in different regions of the state, examine year-to-year variability in ecoregion-reference lakes, provide additional trophic status data for lakes exhibiting trends in Secchi transparency and to provide data for the protection, restoration, and preservation of Minnesota Surface waters through the Clean Water Legacy Act (CWLA). In the latter case, sampling is conducted to provide data on water quality conditions to achieve and maintain established standards. To make for efficient sampling, geographic clusters of lakes are selected (e.g., focus on a specific county or region) whenever possible.

The MPCA prepares lake assessments under section 303(d) Impaired Waters List of the Clean Water Act. These assessments are done to estimate the extent to which Minnesota water bodies meet the goals of the Clean Water Act. This information is shared with planners, citizens and other partners in basin planning and watershed management activities. These lakes are assessed to determine whether they meet “aquatic recreational uses”.

Blackduck Lake is a 2,686-acre lake in east-central Beltrami County within the Upper and Lower Red Lake watershed. Blackduck Lake is approximately 1 mile west of Blackduck, MN and is located in the Northern Lakes and Forests (NLF) ecoregion. The lake has a maximum depth of 8.5 meters (28 feet) and 51% of the lake is littoral. There is one public access on the northeastern shore. The total watershed for Blackduck Lake is 15,078 acres (23.5 square miles).

Blackduck Lake is an intermittently stratifying lake; a moderately deep lake that mixes during high winds in the spring, summer, and fall. Based on water quality data presented in this report, Blackduck Lake is considered to be eutrophic, having increased plant growth and nutrient levels and reduced transparency, as a result.
Introduction

This report details the analysis of monitoring on Blackduck Lake in Beltrami County during the 2008 season. Data collected in 2008 were combined with data from previous sample seasons. For data-poor lakes, monitoring establishes a baseline data. In the selection of lakes, a focus is typically placed on large lakes, typically with surface areas of 500 acres or more. Data analyzed will include all available data in STORET and data from the EPA National Eutrophication Survey (NES) conducted in 1972-1974. Further detail on concepts and terms in this report can be found in the Guide to Lake Protection and Management (http://www.pca.state.mn.us/water/lakeprotection.html).

Background

Lake Morphometric and Watershed Characteristics

Blackduck Lake is located in east central Beltrami County within the Upper and Lower Red Lake watershed. The lake is approximately one mile west of Blackduck, Minnesota. One public access is located on the northeastern shore. The lake received treated wastewater effluent from the city of Blackduck’s Class C wastewater treatment facility (WWTF) from the early 1950s to the mid 1980s. The facility utilized a trickling filter that discharged treated effluent into Colburn Creek, which subsequently drained to the lake. With a requirement to reduce phosphorus in its effluent in the early 1980s, this WWTF design was abandoned and the city of Blackduck switched to a spray irrigation facility that is still being utilized.

Blackduck Lake has a surface area of 2,686-acres, a maximum depth of 8.5 meters (28 feet) and a mean depth of 4.8 meters (15.8 feet). Approximately 51% of the lake is littoral. Percent littoral refers to that portion of the lake that is 4.6 meters (15 feet) or less in depth, which often represents the depth to which rooted plants may grow in the lake. Lakes with a high percentage of littoral area often have extensive rooted plant (macrophyte) beds. These plant beds are a natural part of the ecology of these lakes and are important to protect.

Blackduck’s watershed lies within the Upper and Lower Red Lake major watershed. The watershed has two drainage points, one of which is located on the northern shore of the lake. The contributing watershed has a total area of 15,545 acres (24.3 square miles) resulting in a watershed-to-lake area ratio of approximately 6:1. Blackduck Lake has 5 inflows and drains into the Blackduck River to the north. Watershed areas were estimated based on data from the University of Minnesota Remote and Geospatial Analysis Lab.

Blackduck Lake watershed soils are defined as medium-textured forest soils of North-Central Minnesota from the Nebish-Rockwood series. The area is undulating to hilly and the soils are light colored and well-drained. The major land uses are forestry and agriculture. (Arneman 1963). Blackduck Lake is an ice-block basin that was likely formed by glacial deposition within the till (Zumberge, 1952).

Land Use Characteristics and Ecoregion

Since land use affects water quality, it has proven helpful to divide the state into regions where land use and water resources are similar. Land use in the watershed of Blackduck Lake is fairly typical for this ecoregion with the exception of a large percentage of open grassland area. Forest is the predominant land use and falls just below the expected range for the ecoregion (Figure 1 & Table 1).
Table 1. Blackduck Lake ecoregional land use comparison

<table>
<thead>
<tr>
<th>Land Use (%)</th>
<th>Blackduck Lake</th>
<th>NLF Ecoregion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developed</td>
<td>6</td>
<td>0 - 7</td>
</tr>
<tr>
<td>Cultivated (Ag)</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Pasture &amp; Open</td>
<td>17</td>
<td>0 - 6</td>
</tr>
<tr>
<td>Forest</td>
<td>52</td>
<td>54 - 81</td>
</tr>
<tr>
<td>Water &amp; Wetland</td>
<td>24</td>
<td>14 - 31</td>
</tr>
</tbody>
</table>

Minnesota is divided into seven regions, referred to as ecoregions, as defined by soils, land surface form, natural vegetation and current land use. Data gathered from representative, minimally impacted (reference) lakes within each ecoregion serve as a basis for comparing the water quality and characteristics of other lakes. Blackduck Lake lies within the Northern Lakes and Forests (NLF) ecoregion (Figure 2). NLF ecoregion values will be used for land use comparisons (Table 1) and lake summer-mean water quality (Table 2). Additionally, the NLF ecoregion will be used for the MINLEAP model application.
Lake Mixing

Lake depth can have a significant influence on lake processes and water quality. One such process is thermal stratification (formation of distinct temperature layers), in which deep lakes (maximum depths of 9.1 – 12.1 meters (30 - 40 feet) or more) often stratify (form layers) during the summer months and are referred to as dimictic (Figure 3). These lakes fully mix or turn over twice per year; typically in spring and fall. Shallow lakes (maximum depths of 4.6 meters (15 feet) or less) in contrast, typically do not stratify and are often referred to as polymictic. Lakes with moderate depths may stratify intermittently during calm periods, but mix during heavy winds and during spring and fall. Measurement of temperature throughout the water column (surface to bottom) at selected intervals (e.g. every meter) can be used to determine whether the lake is well-mixed or stratified. It can also identify the depth of the thermocline (zone of maximum change in temperature over the depth
interval). In general, dimictic lakes have an upper, well-mixed layer (epilimnion) that is warm and has high oxygen concentrations. In contrast, the lower layer (hypolimnion) is much cooler and often has little or no oxygen. This low oxygen environment in the hypolimnion is conducive to the release of total phosphorus (TP) from the lake sediments. During stratification, dense colder hypolimnion waters are separated from the nutrient hungry algae in the epilimnion. Mixing events allow for the nutrient-rich sediments to be re-suspended and available to algae. Most of the fish in the lake are usually found in the epilimnion or near the thermocline. Blackduck Lake, based on 2008 temperature profiles, is intermittently stratified.

**Figure 3. Lake Stratification**

**Polymictic Lake**  
Shallow, no layers,  
Mixes continuously  
Spring, Summer & Fall

**Dimictic Lake**  
Deep, form layers,  
Mixes Spring/Fall

**Intermittently Stratified**  
Moderately deep  
Mixes during high winds  
Spring, Summer, & Fall

**Lake Level Trends**

The Minnesota Department of Natural Resources (DNR) Division of Waters has measured water levels on Blackduck Lake since 1954. During the period of record (1954 – 2008) the lake had varied by 4 feet, based on 169 readings. The highest and lowest recorded elevations are 1,347 feet on 6/3/2005 and 1,343 feet on 3/1/1957, respectively. The ordinary high-water mark (OHW) for Blackduck Lake is 1,346 feet.

**Precipitation**

Rain gauge records from Blackduck, Minnesota show four one-inch plus rain events during summer 2008 (Figure 4). These rain events will increase runoff into the lakes and may influence in-lake water quality and lake levels. This will be considered in the discussion of lake water quality for 2008. Precipitation records for the 2008 water year (October 2007 through September 2008) indicated average rain fall as 2 - 4 inches below normal for the Blackduck Lake area (Figure 5).
Figure 4. Summer 2008 rainfall based on records for Blackduck, Minnesota

Figure 5. 2008 Minnesota Water Year Precipitation and Departure from Normal
Prepared by State Climatology Office DNR Waters
Values are in inches
Fisheries

DNR fisheries managers utilize netting survey information to assess the well-being of fish communities and measure the efficacy of management programs. Presence, absence, abundance, physical condition of captured fishes, and community relationships among fish species within survey catch information also provide good indicators of current habitat conditions and trophic state of a lake (Schupp and Wilson, 1993). These data are stored in a long-term fisheries survey database, which has proven valuable in qualifying and quantifying changes in environmental and fisheries characteristics over time. The most recent fish assessment for Blackduck Lake was conducted in July 2006.

Blackduck Lake is intensively managed for walleye with fry stocking occurring two out of three years. Angler harvest is high, resulting in a rapid turnover of the population. Fry stocking has been a very effective means of maintaining an adequate walleye numbers. There are no plans for increasing walleye harvest regulations to improve natural reproduction for Blackduck Lake. Northern pike population was low for the 2006 assessment. This was the lowest catch rate ever recorded for Blackduck Lake.

Record amounts of black crappie and bluegill were sampled in 2006. Additionally, largemouth bass were sampled and documented for the first time. Largemouth bass were likely present before, but at levels too low to be recorded. Sunfish species are occurring in relatively low densities when compared to the dominant walleye/perch community, but provide additional biodiversity for Blackduck Lake.

The yellow perch population was above the expected size and numbers for Blackduck Lake. Yellow perch are vital to the food chain and serve a dual role as both a recreational fish for anglers and forage for predatory fish. Consistent perch reproduction provides the food base for walleye growth and survival.

Additional information on the most recent fish survey for Blackduck Lake can be found at the DNR lake finder website: http://www.dnr.state.mn.us/lakefinder/index.html. Additional information on fishery management can be found at: http://www.dnr.state.mn.us/fisheries/management/index.html

Methods

Water quality data for Blackduck Lake were collected in May, June, July, August 2008. Additional data generated for this report were collected in 2006 and 2004. Lake surface samples were collected with an integrated sampler, a polyvinyl chloride (PVC) tube 2 meters (6.6 feet) in length with an inside diameter of 3.2 centimeters (1.24 inches). Zooplankton samples were collected with a Wisconsin plankton net. Depth TP samples were collected with a Kemmerer sampler. Samples collected for this assessment were taken at Site 205, located near the eastern shore. A summary of data follows (Appendix D).

Sampling procedures were employed as described in the MPCA Lake Water Quality Sampling Standard Operating Procedures. Laboratory analysis was performed by RMB Environmental Laboratories, Inc. in Detroit Lakes, Minnesota using EPA-approved methods. Samples were analyzed for nutrients, color, solids, pH, alkalinity, conductivity, chloride (Cl) and chlorophyll-a (chl-a). Temperature and dissolved oxygen (DO) profiles and Secchi disk transparency measurements were also taken.
Table 2. Blackduck Lake summer mean water quality as compared to the typical range for NLF ecoregion reference lakes.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Blackduck</th>
<th>NLF Ecoregion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phosphorus (µg/L)</td>
<td>35</td>
<td>14 - 27</td>
</tr>
<tr>
<td>Chlorophyll-a mean (µg/L)</td>
<td>19</td>
<td>4 - 10</td>
</tr>
<tr>
<td>Chlorophyll-a max (µg/L)</td>
<td>46</td>
<td>&lt;15</td>
</tr>
<tr>
<td>Secchi Disk (feet)</td>
<td>9.2</td>
<td>8 – 15</td>
</tr>
<tr>
<td></td>
<td>2.8</td>
<td>2.4 – 4.6</td>
</tr>
<tr>
<td>Secchi Disk (meters)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen (mg/L)</td>
<td>0.9</td>
<td>&lt;0.4 – 0.75</td>
</tr>
<tr>
<td>Alkalinity (mg/L)</td>
<td>139</td>
<td>40 - 140</td>
</tr>
<tr>
<td>Color (Pt-Co Units)</td>
<td>18</td>
<td>10 - 35</td>
</tr>
<tr>
<td>pH (SU)</td>
<td>8.6</td>
<td>7.2 – 8.3</td>
</tr>
<tr>
<td>Chloride (mg/L)</td>
<td>12.7</td>
<td>0.6 – 1.2</td>
</tr>
<tr>
<td>Total Suspended Solids (mg/L)</td>
<td>5</td>
<td>&lt;1 - 2</td>
</tr>
<tr>
<td>Total Suspended Inorganic Solids (mg/L)</td>
<td>&lt;1 - 2</td>
<td></td>
</tr>
<tr>
<td>Conductivity (umhos/cm)</td>
<td>304</td>
<td>50 - 250</td>
</tr>
<tr>
<td>TN:TP ratio</td>
<td>26:1</td>
<td>25:1 - 35:1</td>
</tr>
</tbody>
</table>

Results and Discussion

Profiles were taken in May, June, July, and August at site 205. These profiles indicate that Blackduck Lake was well-mixed on all dates with the exception of July. In July slight thermal stratification was evident and DO levels drop below 5 milligrams per liter (mg/L) at approximately seven meters. The low DO in the bottom waters is the result of oxygen demand from the sediments and water column (dead algae and other organic matter), warm temperatures, and lack of re-aeration from wind mixing. This decrease is also consistent with the elevated chl-a (Figure 6). These profiles indicate that Blackduck Lake may stratify intermittently during calm periods but due to a large fetch, is generally well-mixed when there is sufficient wind. Complete mixing occurs in spring and fall when water temperatures are cool and uniform from top to bottom.

**Total Phosphorus** concentrations at site 205 averaged 35 micrograms per liter (µg/L) (Table 2). This average was above the typical range of concentrations for NLF reference lakes. TP concentrations increased over the summer and peaked in August. Since Blackduck stratifies intermittently during the summer it is possible for internal release of TP from the sediment to occur resulting in an increase of TP in the lake water (Figure 7). Watershed land use may contribute to elevated levels of TP as well. Surface water runoff from the watershed flows directly to the lake from the town of Blackduck via Colburn Creek. Runoff from impervious surfaces may carry additional nutrients to the lake; however, it should be noted that little precipitation occurred in August (Figure 4) and runoff from the watershed was limited during this portion of the summer.

**Chlorophyll-a** concentrations provide an estimate of the amount of algal production in a lake. During the summer of 2008, chl-a concentrations ranged from 5 µg/L to 46 µg/L with an average of 19 µg/L (Table 2). Concentrations greater than 20 µg/L will typically be perceived as a nuisance, while concentrations greater than 30 µg/L are perceived as a severe nuisance algal bloom (Heiskary and Walker, 1988). As such, nuisance blooms likely occurred through much of July and August (Figure 7). The summer-mean for Blackduck Lake was well above the range of values typical values for NLF lakes.
Secchi disk transparency on Blackduck Lake averaged 2.8 meters (9.2 feet) during the summer of 2008 (Table 2). The average Secchi depth fell within the typical values of the NLF ecoregion. Additionally, the change in the transparency of Blackduck Lake over the course of the summer closely mirrored the changes in nutrient availability (TP) and algal production (chl-a). The Secchi disk transparency reached a low of 1.5 meters (4.9 feet) in August (Figure 7).

Other parameters such as color and alkalinity were within the typical range for NLF ecoregion lakes; however, some parameters, such as total suspended solids (TSS) and Cl, were well above the typical range for NLF lakes. Elevated TSS is likely related to elevated algal concentrations and possibly resuspended sediment. Cl is very high relative to the typical range for NLF lakes (Table 2). A likely source of excess Cl to the lake is from deicing chemicals in stormwater runoff.

![Figure 6. Blackduck Lake Site 205 DO and temperature profiles](image-url)
Trophic State Index (TSI)

One way to evaluate the trophic status of a lake and to interpret the relationship between TP, chl-a, and Secchi disk transparency is Carlson’s Trophic State Index (Carlson 1977). TSI values are calculated as follows:

\[
\text{TP TSI (TSIP)} = 14.42 \ln (\text{TP}) + 4.15
\]

\[
\text{Chl-a TSI (TSIC)} = 9.81 \ln (\text{Chl-a}) + 30.6
\]

\[
\text{Secchi disk TSI (TSIS)} = 60 - 14.41 \ln (\text{SD})
\]

TP and chl-a are in µg/L and Secchi disk is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of ten units represents a doubling of algal biomass. Comparisons of the individual TSI measures provides a bases for assessing the relationship among TP, chl-a, and Secchi (Figure 8). In general, the TSI values are in fairly close correspondence with each other. The TSI values also correspond with observations for 2008. Based on the values presented in Table 2 and an average TSI score of 54, this lake would be characterized as eutrophic.
FIGURE 8. Carlson’s Trophic State Index for Blackduck Lake
R.E. Carlson

TSI < 30  Classical Oligotrophy: Clear water, oxygen throughout the year in the Hypolimnion, salmonid fisheries in deep lakes.

TSI  30 – 40  Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.

TSI  40 – 50  Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.

TSI  50 – 60  Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.

TSI  60 – 70  Dominance of blue-green algae, algal scum probable, extensive Macrophyte problems.

TSI  70 – 80  Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.

TSI > 80  Algal scum, summer fish kills, few macrophytes, dominance of rough fish.

Trophic Status Trends

One aspect of lake monitoring is to assess historical trends where possible based on available STORET data. A review of these data reveals a large amount of historical Secchi data for Blackduck Lake (Figure 9); however, it should be noted that the data are scattered throughout several sample locations. Based on historical Secchi data, Blackduck Lake has a long-term mean water clarity value of 2.2 meters (7.2 feet). This is below (worse than) the normal minimal depth of 2.4 meters (7.9 feet) based on NLF ecoregion reference lakes (Table 2). An improvement in transparency over time is evident in this record. In general, transparency ranged from 1.1 -1.8 meters in the late 1970s and early 1980s. Following the removal of the WWTF discharge to the lake in the mid 1980’s transparency increased to about 2.0 meters. Current ranges are typically between 2.0-2.5 meters.

A comparison between data collected before and after the removal of the WWTF effluent discharge reveals that elevated nutrient levels continue to be problematic (Figure 10). While TP in some summers (e.g. 2004 and 2008) is lower than those of the late 1970s, other summers like 2006 exhibit rather elevated concentrations and TP levels continue to be above the typical range of values for lakes within the NLF ecoregion. Additionally, chl-a levels have remained above the NLF criteria in relation to the high levels of nutrient availability; however, a Secchi comparison shows an overall improvement in water clarity. Historical data from the EPA National Eutrophication Survey (NES) conducted in 1972-1974 is included in this analysis.

Figure 9. Blackduck Lake historical Secchi depths
Modeling

Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake’s watershed to observed conditions in the lake. Alternatively, they may be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the flow or amount of water that enters the lake. To analyze the 2008 water quality of Blackduck Lake, MINLEAP (Wilson and Walker, 1989) was used.

MINLEAP, which refers to "Minnesota Lake Eutrophication Analysis Procedures", was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is intended to be used as a screening tool for estimating lake conditions with minimal input data and is described in greater detail in Wilson and Walker (1989). For the analysis of Blackduck Lake, MINLEAP was applied as a basis for comparing the observed (2008) TP, chl-a, and Secchi values with those predicted by the model based on the lake depth and size and the size of the watershed.

Blackduck Lake is located in the NLF ecoregion and the model was run using NLF ecoregion-based inputs. It should be noted that the model predicts in-lake TP from these inputs and subsequently predicts chl-a based on a regression equation of TP and Secchi based on a regression equation based on chl-a. A comparison of MINLEAP predicted vs. observed values is presented in Table 3.

The observed and MINLEAP predicted TP, chl-a, and Secchi values for Blackduck Lake are not consistent with what is expected for a lake of its size, depth, and watershed area in the NLF ecoregion. The observed TP is nearly twice the expected value and is above the 30 µg/L nutrient criteria for lakes in the NLF ecoregion for recreational use (Table 4). The watershed map, land use composition, and the flow network provide some useful insights that may help identify potential sources of excess nutrients to the lake (Figure 2). The elevated TP is likely a result of the combined effects of runoff from the watershed (in particular urban and grassland/agricultural runoff) and internal recycling. About 30-40% of the watershed lies to the east of the lake and land use in this portion is characterized by developed and open/pastured uses; both of which can be sources of excess nutrients. Elevated Cl suggests that runoff from impervious surfaces that flows directly or indirectly into the lake may be important as well. Internal recycling may also be a nutrient source with a potential for wind resuspension, sediment release as a result of high temperatures (17-21 degrees C), low DO, and bacterial decomposition at the water-sediment interface.

Figure 10. Blackduck Lake historical Chl-a, TP, and Secchi depths. Summer-means based on MPCA and EPA NES data.
Table 3. MINLEAP Model Results for Blackduck Lake

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2008 Blackduck Observed</th>
<th>Blackduck MINLEAP Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP (µg/L)</td>
<td>35</td>
<td>19</td>
</tr>
<tr>
<td>Chl-a (µg/L)</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>Secchi (m)</td>
<td>2.8</td>
<td>3</td>
</tr>
<tr>
<td>P loading rate (kg/yr)</td>
<td>-</td>
<td>891</td>
</tr>
<tr>
<td>P retention (%)</td>
<td>-</td>
<td>67</td>
</tr>
<tr>
<td>P inflow conc. (µg/L)</td>
<td>-</td>
<td>58</td>
</tr>
<tr>
<td>Water Load (m/yr)</td>
<td>-</td>
<td>1.4</td>
</tr>
<tr>
<td>Outflow volume (hm³/yr)</td>
<td>-</td>
<td>15.4</td>
</tr>
<tr>
<td>Residence time (yrs)</td>
<td>-</td>
<td>3.4</td>
</tr>
</tbody>
</table>

303(d) Assessment and Goal Setting

The federal Clean Water Act requires states to adopt water quality standards to protect waters from pollution. These standards define how much of a pollutant can be in the water and still allow it to meet designated uses, such as drinking water, fishing, and swimming. The standards are set on a wide range of pollutants, including bacteria, nutrients, turbidity and mercury. A water body is “impaired” if it fails to meet one or more water quality standards.

Under Section 303(d) Impaired Waters List of the Clean Water Act, the state is required to assess all waters of the state to determine if they meet water-quality standards. Waters that do not meet standards are added to the 303(d) Impaired Waters List and updated every even-numbered year. Once the waters are listed, an investigative study (termed a Total Maximum Daily Load - TMDL) is conducted to determine the sources and magnitude of pollution, and to set pollutant reduction goals needed to restore the waters. The MPCA is responsible for performing assessment activities, listing impaired waters, and conducting TMDL studies in Minnesota.

According to Table 4, the TP and chl-a standards for the support of aquatic recreation in lakes within the NLF ecoregion are less than 30 µg/L and 9 µg/L respectively. For chl-a levels at or below 30 µg/L, “nuisance algal blooms” (chl-a > 20 µg/L) should occur less than 10 percent of the summer and transparency should remain at or above 3 meters (9.8 feet) over 85 percent of the summer. With a summer average TP of 35 µg/L and chl-a of 19 µg/L Blackduck Lake exceeds both standards.

For Blackduck Lake, a reduction in TP will be required in order to reduce the frequency of algal blooms. Alternatively, should in-lake TP concentrations increase (or remain the same), it is likely that nuisance algal blooms will continue and transparency will be reduced. It is important to reduce as much external (watershed) phosphorus loading to the lake as possible to reduce the current concentrations; however, considering the relative shallowness and periodic mixing of the lake it is likely that internal loading of TP may continue to be a factor. This will need to be addressed in the context of an overall effort to improve water quality. Based on data that will be used in the 2010 assessment cycle, Blackduck Lake would exceed the eutrophication standards and will likely appear on the 303(d) impaired waters list.
Table 4. Eutrophication standard by ecoregion and lake type
(Heiskary and Wilson, 2005)

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>TP</th>
<th>Chl-a</th>
<th>Secchi</th>
</tr>
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Appendix A - Glossary

**Acid Rain:** Rain with a higher than normal acid range (low pH). Caused when polluted air mixes with cloud moisture; can cause lakes to be devoid of fish.

**Algal Bloom:** An unusual or excessive abundance of algae.

**Alkalinity:** Capacity of a lake to neutralize acid.

**Bioaccumulation:** Build-up of toxic substances in fish flesh. Toxic effects may be passed on to humans eating the fish.

**Biomanipulation:** Adjusting the fish species composition in a lake as a restoration technique.

**Dimictic:** Lakes which thermally stratify and mix (turnover) once in spring and fall.

**Ecoregion:** Areas of relative homogeneity. EPA ecoregions have been defined for Minnesota based on land use, soils, landform, and potential natural vegetation.

**Ecosystem:** A community of interaction among animals, plants, and microorganisms, and the physical and chemical environment in which they live.

**Epilimnion:** Most lakes form three distinct layers of water during summertime weather. The epilimnion is the upper layer and is characterized by warmer and lighter water.

**Eutrophication:** The aging process by which lakes are fertilized with nutrients. *Natural eutrophication* will very gradually change the character of a lake. *Cultural eutrophication* is the accelerated aging of a lake as a result of human activities.

**Eutrophic Lake:** A nutrient-rich lake – usually shallow, “green” and with limited oxygen in the bottom layer of water.

**Fall Turnover:** Cooling surface waters, activated by wind action, sink to mix with lower levels of water. As in spring turnover, all water is now at the same temperature.

**Hypolimnion:** The bottom layer of lake water during the summer months. The water in the hypolimnion is denser and much colder than the water in the upper two layers.

**Lake Management:** A process that involves study, assessment of problems, and decisions on how to maintain a lake as a thriving ecosystem.

**Lake Restoration:** Actions directed toward improving the quality of a lake.

**Lake Stewardship:** An attitude that recognizes the vulnerability of lakes and the need for citizens, both individually and collectively, to assume responsibility for their care.

**Limnetic Community:** The area of open water in a lake providing the habitat for phytoplankton, zooplankton and fish.

**Littoral Community:** The shallow areas around a lake’s shoreline, dominated by aquatic plants. The plants produce oxygen and provide food and shelter for animal life.

**Mesotrophic Lake:** Midway in nutrient levels between the eutrophic and oligotrophic lakes

**Meromictic:** A lake that does not mix completely
Nonpoint Source: Polluted runoff – nutrients and pollution sources not discharged from a single point: e.g. runoff from agricultural fields or feedlots.

Oligotrophic Lake: A relatively nutrient-poor lake, it is clear and deep with bottom waters high in dissolved oxygen.

pH Scale: A measure of acidity.

Photosynthesis: The process by which green plants produce oxygen from sunlight, water and carbon dioxide.

Phytoplankton: Algae – the base of the lake’s food chain, it also produces oxygen.

Point Sources: Specific sources of nutrient or polluted discharge to a lake: e.g. Stormwater outlets.

Polymictic: A lake that does not thermally stratify in the summer. Lake tends to mix periodically throughout summer via wind and wave action.

Profundal Community: The area below the limnetic zone where light does not penetrate. This area roughly corresponds to the hypolimnion layer of water and is home to organisms that break down or consume organic matter.

Respiration: Oxygen consumption

Secchi Disk: A device measuring the depth of light penetration in water.

Sedimentation: The addition of soils to lakes, a part of the natural aging process, makes lakes shallower. The process can be greatly accelerated by human activities.

Spring Turnover: After ice melts in spring, warming surface water sinks to mix with deeper water. At this time of year, all water is the same temperature.

Thermocline: During summertime, the middle layer of lake water. Lying below the epilimnion, this water rapidly loses warmth.

Watershed storage area: The percentage of a drainage area labeled lacustrine (lakes) and palustrine (wetlands) on U.S. Fish and Wildlife Service National Wetlands Inventory Data.

Zooplankton: The animal portion of the living particles in water that freely float in open water, eat bacteria, algae, detritus and sometimes other zooplankton and are in turn eaten by planktivorous fish.
Appendix B Water Quality Data: Abbreviations and Units

TP= total phosphorus in mg/l(decimal) or ug/L as whole number
TKN= total Kjeldahl nitrogen in mg/l
TNTP=TN:TP ratio
pH= pH in SU (F=field, or L=lab)
ALK= alkalinity in mg/l (lab)
TSS= total suspended solids in mg/l
TSV= total suspended volatile solids in mg/l
TSIN= total suspended inorganic solids in mg/l
TURB= turbidity in NTU (F=field)
CON= conductivity in umhos/cm (F=field, L=lab)
CL= chloride in mg/l
DO= dissolved oxygen in mg/l
TEMP= temperature in degrees centigrade
SD= Secchi disk in meters (SDF=feet)
Chl-a= chlorophyll-a in ug/l
TSI= Carlson's TSI (P=TP, S=Secchi, C=Chla)
PHEO= pheophytin in ug/l
PHYS= physical appearance rating (classes=1 to 5)
REC= recreational suitability rating (classes=1 to 5)
RTP, RN2N3...= remark code; k=less than, Q=exceeded holding time
Appendix C  References


## Blackduck Lake Surface Water Results

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