BLACKHAWK LAKE MANAGEMENT PLAN

Prepared by Agrecol Environmental Consulting

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In cooperation with

Highland Cobb Park Commission,
Iowa County Land Conservation Department and
Wisconsin Department of Natural Resources

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Summary

Lake monitoring results demonstrate that Blackhawk Lake continues to display better water quality than most impoundments in the region. More detailed studies would be needed to explain this characteristic with more certainty, but likely explanations include historically high sediment and nutrient trapping efficiencies of the inlet bays, sufficient rooted plant growths to compete with algae, removal of some highly available phosphorus from the hypolimnetic withdrawal and a relatively balanced predator-prey fish population.

Land use information and tributary monitoring results indicated that watershed sources of nutrients and sediment pose threats to the long term water quality of the lake. These sources could be reduced with implementation of improved land use practices, and may be the most important efforts to protect Blackhawk Lake.

The partial bottom discharge causes significant heat gains within the 9-right portion of the lake. As a result, thermal stratification was weakened to some degree with potential for nutrient entrainment from the hypolimnion to surface waters. The weakened thermal stratification along with the southwest wind fetch of the lake can lead to destabilization and premature lake mixing. Lake monitoring in 2006 and other years has clearly demonstrated that the 9-right basin mixes before the 9-left basin and significant algae blooms occur when that happens. In the 9-left basin, where no bottom water is released, the hypolimnion is maintained longer and sustains colder temperatures even though the basin is much shallower.

The bottom water discharge to Otter Creek removes readily available phosphorus from the system but also results in high ammonia levels and violations of dissolved oxygen criteria immediately below the lake. Water quality problems below the dam were further evidenced by growths of filamentous bacteria in the stream along with strong hydrogen sulfide odors.

An aquatic plant survey demonstrated that rooted plants provided good fish habitat throughout the littoral zone in the lake. However, the survey also documented the presence of the invasive Eurasian watermilfoil that poses a threat to both recreational uses of the lake and to fisheries habitat. A plan for managing native aquatic plants and controlling Eurasian watermilfoil has been completed.

Lake Management Recommendations

1. **Management of the outlet:** Since the existing 60% bottom to 40% surface water discharge from the lake causes premature lake mixing and algae blooms, Blackhawk Lake managers should test lake and stream responses to reducing the percent of water discharged from the bottom. Options to be tested include: 1) reducing the bottom discharge to 10% or 20% of the late season outlet flow to delay premature destratification of the lake and 2) use of a 100% top discharge.

   While a slightly reduced bottom discharge rate would continue to remove a significant amount of readily available phosphorus from the system, it would still contain high ammonia and hydrogen sulfide, causing downstream water quality problems. With use of a top discharge entirely, conditions in the 9-right basin will likely mimic those at 9-left. The 9-right basin would have a smaller epilimnetic volume and a larger hypolimnion but nutrients would not be removed as efficiently from the lake. With a 100% top draw, the quality of the receiving pond located between Plank Road and the dam would be improved and other downstream water quality problems reduced. Both scenarios would likely delay lake turnover until the fall and reduce late summer algal blooms.

2. **Watershed protection:** The Highland Cobb Park Commission and the Iowa County Land Conservation Department should work closely with landowners in the watershed to reduce sediment and nutrient runoff into the lake. With a relatively small watershed of 10,000 acres, of which about 4,000 to 5,000 acres are cropped, there is a high potential for watershed practices to be effective.

   Managing watershed nutrients, through a comprehensive nutrient management effort should be a high priority. Funds are available from the Department of Agriculture, Trade and Consumer Protection (DATCP), and should be vigorously pursued. Cost share funding for staffing may also be available either from the WDNR or DATCP.

   Expansion of the area available for the Conservation Reserve Enhancement Program (CREP) should be explored. The current CREP grasslands area comes close to the lake, but unfortunately doesn't quite make it to the lake. The value of expanding the grasslands area would be that entire fields would be eligible for this program. Discussion of this possibility with DATCP, DNR, and FSA should begin immediately given decisions will be made in the very near future.

   Purchase of easements, encouraging extensions of CRP, or purchasing of lands within the Blackhawk Lake watershed should be pursued with the state and federal governments.

3. **Stream reclassification:** The Highland Cobb Park Commission and Iowa County should work with the WDNR to reclassify Otter Creek to a warmwater stream as recommended by WDNR staff.

4. **Aquatic plant management**: The Blackhawk Recreation staff should continue to work with WDNR to prevent new aquatic exotics from entering the lake while following recommendations in the aquatic plant management plan. The recommendations include protecting native aquatic plants while controlling potentially nuisance levels of Eurasian watermilfoil.

Long Term Goals for Blackhawk Lake

Blackhawk Lake currently exhibits very good quality for an impounded lake located in the driftless area of the state. A long term goal is to maintain the lake in a meso-trophic status that will support multi-uses. Goals were established for the following:

Water Quality

- Average Clarity (Secchi disk):
  - June - greater than or equal to 20 feet
  - July - greater than or equal to 15 feet
  - August - greater than or equal to 10 feet
- Chlorophyll a (algae blooms)
  - No nuisance blue-green blooms
  - Chlorophyll less than nuisance levels (around 10 ug/l)
- Total Phosphorus
  - Maintain or reduce to a springtime average of 30 ug/l to maintain clarity and chlorophyll goals
- Trophic State – maintain trophic state indexes for Secchi, Chlorophyll, and Total Phosphorus to be indicative of mesotrophic conditions
- Thermal stratification – maintain stratification through Labor Day or beyond
- Dissolved oxygen – maintain the current epilimnetic oxygen concentrations in the lake
- Fishery
  - Maintain a healthy, balanced fish structure
  - Maintain a sufficient predator fish base (e.g. largemouth bass) to promote a larger, algae consuming, zooplankton population.
- Aquatic Plants
  - Maintain a diverse native aquatic plant community
  - Prevent introduction of new invasive species
  - Control Eurasian watermilfoil so as not to be a nuisance or to adversely affect native plants

Downstream

- Water Quality
  - Maintain downstream water quality
  - Minimize discharge of toxic concentrations of ammonia and hydrogen sulfide
  - Maintain sufficient dissolved oxygen downstream to support warm-water fishery
- Fishery
  - Maintain diverse warm water fishery
  - Provide for a put and take trout fishery

Watershed

- Increase the amount of forested or grassland watershed land cover. Focus on critical sites for reducing nutrient and sediment loading to lake
- Nutrient Loading
  - All farm acres to have implemented nutrient management plans.
  - Nutrient loading (especially phosphorus) reduced by 35% to meet lake quality goals.
- Sediment Loading
  - All farms in watershed should maintain soil loss at T or below
  - Land in CRP maintained and increased
  - Decrease loading by a minimum of 20%

Introduction

Blackhawk Lake is a 220 acre impoundment that serves as the centerpiece of the Blackhawk Lake Recreation Area. It has a maximum depth of 40 feet. Construction of the impoundment began in 1968 and was finished in 1971 as part of a PL 566 watershed protection and flood control project administered by the Soil Conservation Service (Natural Resources Conservation Service). For over three decades the impoundment has provided important lake-based recreation and tourism for Iowa County. Physical data for Blackhawk Lake follows:

- Lake type = impoundment (two earthen dams)
- Lake area = 220 acres
- Maximum depth = 40 feet
- Mean depth = 14.8 feet
- Lake volume = 3260 acre feet
- Lake flushing rate = 2.1 times per year
- Lake residence time = 0.48 year
- Watershed area = 10,000 acres

From the late 1960's to early 1970's numerous earthen dam impoundments and dry dams were constructed across the driftless area of southwest Wisconsin for flood control and recreation. A standard design feature for most of the permanent pool dams was the discharge of bottom water, including that of Blackhawk Lake (Figure 1).

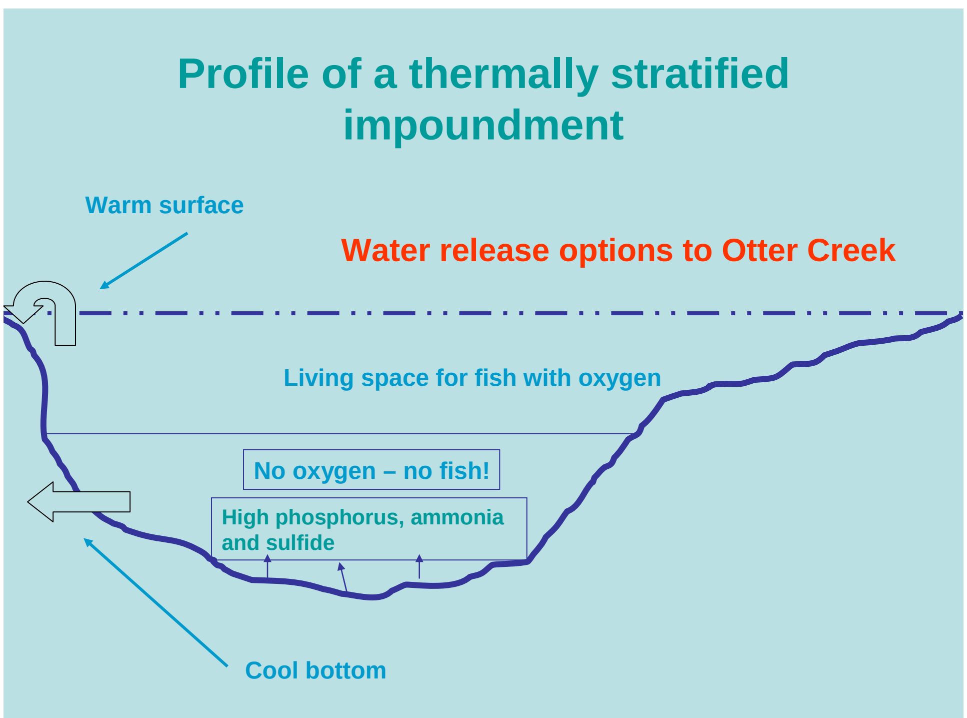

Figure 1

This feature was designed to support goals to either sustain cold water temperatures for existing trout habitat or to create trout habitat in warm water streams. For example, at Twin Valley Lake the dam was designed to create a trout fishery within a warm water stream (Iowa County Soil Conservation District 1961). The bottom water discharge from Blackhawk Lake may have been installed to mitigate some loss of trout habitat in Narveson Creek which had been stocked annually with brown trout (Piening and Threinen 1968). The fisheries in the now flooded portions of Narveson and Upper Otter creeks were dominated by warmwater species prior to construction of the dam. The main stem of Otter Creek also supported warmwater sport and forage fish populations based on electroshocking surveys conducted by the Wisconsin Conservation Department in 1962.

Over the last few decades hypolimnetic (bottom water) withdrawals have been extensively studied as a means to improve water quality in lakes by reducing internal sources of phosphorus (Nurnberg 1986, 1987). To achieve ideal reduction of internal phosphorus sources, export of phosphorus should exceed inputs from the surrounding watershed. That is certainly the case at Devil's Lake State Park where hypolimnetic withdrawal is underway to reduce historic sources of phosphorus that were stored in deep water sediment (Lathrop et al. 2005). At White Mound Lake and Twin Valley Lake, long term hypolimnetic releases of phosphorus had not exceeded inputs due to the relatively large agricultural watersheds (Marshall et al. 2006). At Lake Redstone, a proposed hypolimnetic withdrawal project was rejected since approximately 60% of the annual phosphorus load originated from sources in the watershed (Marshall et al. 2002), and reducing internal phosphorus would not sufficiently improve the lake's quality.

Another important aspect for a successful hypolimnetic release project is sustaining stable thermal stratification (Nurnberg 1987). De-stabilized thermoclines in Twin Valley Lake, White Mound Lake, and Blackhawk Lake have been found to cause nutrient transport into shallow water areas, resulting in algal blooms and poor water clarity (Marshall et al. 2006).

Hypolimnetic releases typically contain high levels of ammonia and hydrogen sulfide that can result in poor downstream receiving water quality. Wastewater treatment technologies have often been used to avoid downstream water quality problems that include low dissolved oxygen levels and nuisance bacterial growths. Long term water quality problems had been documented below Twin Valley Lake (Hilsenhoff 1971, Marshall et al. 2006) and White Mound Lake (Marshall et al. 2006), both situations where treatment of discharge water does not occur. Other studies of downstream water quality problems caused by hypolimnetic releases include Young et al. 1976, Edwards (1978) and Walburg et al. (1981).

Like most PL 566 impoundments, Blackhawk Lake was designed to release 100% of base flow inputs from the hypolimnion. However, in most southwest Wisconsin impoundments regional base flow rates have increased over the last few decades as a result of improved landscape management practices, particularly the removal of cattle from steep hillsides (Gebert and Krug 1996). As a result, the releases from the impoundments have become a blend of surface and bottom water, with discharge rates exceeding the capacities of the bottom water outlets. Typically the proportion of top to bottom water also varied seasonally as runoff conditions change.

In general, a greater proportion of bottom water is discharged during drought periods. White Mound Lake was recently modified to accommodate 100% bottom discharge during base flow. Significant water quality problems were later detected below the dam. As a result the stream was added to the USEPA 303d list of impaired waters.

Recently, the WDNR Fisheries Management staff and Iowa County Land Conservation Department had evaluated and proposed increasing the bottom flow from Blackhawk Lake. Given the problems linked to bottom water releases from Twin Valley Lake, White Mound Lake and Cox Hollow Lake, the Highland Cobb Parks Commission and WDNR Lakes Management staff proposed a study to evaluate potential impacts to both the lake and downstream water quality.

While water quality problems linked to bottom discharges had been well documented at other impoundments, Blackhawk Lake has displayed some unique characteristics. First, long term water quality has been better in Blackhawk Lake compared to most southwest Wisconsin impoundments (WDNR 1978). Second, the impoundment was created by two separate dams and these form separate deep areas and hypolimnions within the lake. None of the other impoundments contain separate hypolimnions including one without a bottom water release.

In an effort to better understand the potential impacts of a proposed increase of bottom water discharge from Blackhawk Lake, the Highland Cobb Park Commission applied for and received two Wisconsin DNR Lake Planning Grants. The Phase 1 Planning Grant was designed to establish baseline water quality, biological and recreational use data for Blackhawk Lake and on Otter Creek below the dam. The purpose of this study was to:

1) Determine potential effects of various scenarios of hypolimnetic withdrawal rates on the water quality of both Blackhawk Lake and Otter Creek below the dam; and
2) Develop specific management recommendations to support the multiple uses of Blackhawk Lake - i.e. recreational uses such as swimming, boating, aesthetics, fisheries and aquatic life, and flood control.

Phase 2 focused on estimating nutrient loading to the lake and the elements included watershed size and land use influences on lake water quality. An important component of Phase 2 was to develop hydrologic and nutrient budgets to evaluate phosphorus loading reduction strategies for Blackhawk Lake. The combined projects were designed to determine how different hypolimnetic water release scenarios will affect lake water quality and balance watershed nutrient inputs.

The data from Phase 1 and Phase 2 were combined and used to:

1) Prioritize specific lake and watershed management needs and to set long term goals for Blackhawk Lake, its watershed, and Otter Creek below the dam; and to
2) Complete a comprehensive management plan for the lake and watershed with which to amend the Lower Wisconsin Basin Plan.

Methods

Lake Sampling: Two locations (Figure 2) were established for weekly lake monitoring throughout the summer until fall turnover, the deep hole near the left dam (9-left) and deep hole near the right dam (9-right)

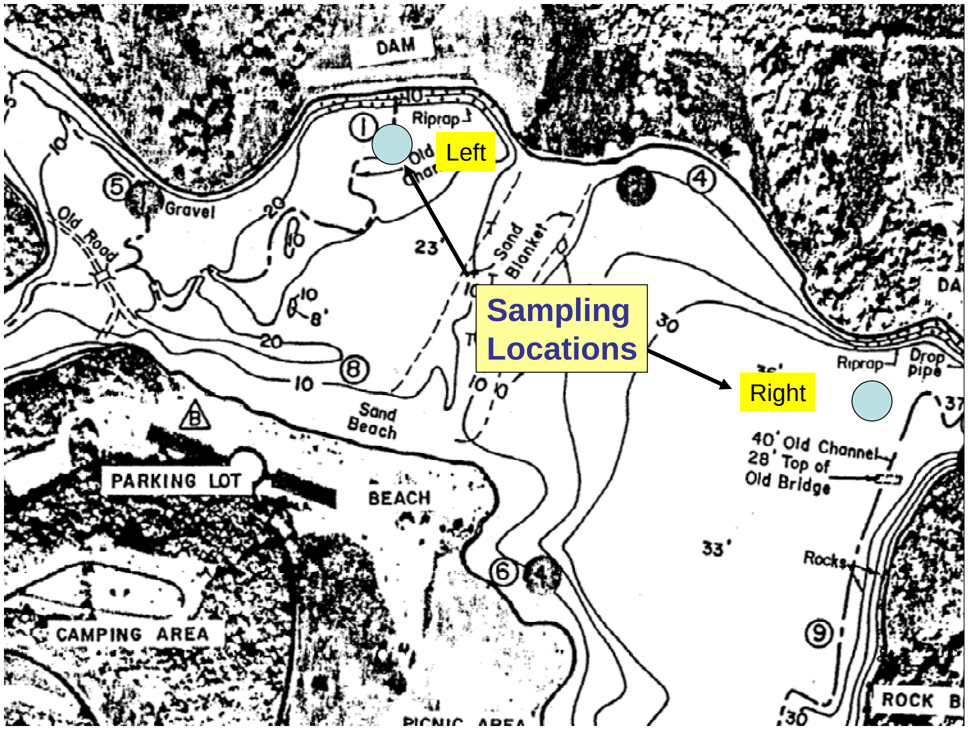

Figure 2

The Agrecol Environmental Consulting subcontractors, Lake Management Consultants Inc and Underwater Habitat Investigations LLC, and Blackhawk Lake Recreation Area staff alternated sampling so that the lake was sampled weekly at both locations. Weekly parameters included Secchi water clarity, lake level and vertical profiles of dissolved oxygen and temperature. During the weeks that the subcontractors sampled the lake, parameters also included water sampling and vertical profiles of pH and specific conductance. Surface and bottom water samples were collected with a Kemmerer water bottle and analyzed at the State Lab of Hygiene. Surface water sample analysis included chlorophyll and phosphorus and bottom samples included phosphorus and ammonia. Less frequently, mid-depth samples were also collected and analyzed for ammonia and phosphorus. Most of the water chemical samples were collected at 9-right where the hypolimnetic outlet is located. Late summer phosphorus and ammonia samples were also collected near the bottom of 9- left where withdrawal of bottom water does not occur.

Tributary and Outlet Sampling: The Agrecol Environmental Consulting subcontractors and Blackhawk Lake staff conducted biweekly and event inlet sampling on Otter Creek, Griffith Creek, Narveson Creek and Sunny Ridge Creek (Figure 3). Sampling was done to measure turbidity, flow, dissolved oxygen, temperature and water quality. Outlet flows (Appendix D Table 2) were monitored by use of stage discharge relationships.

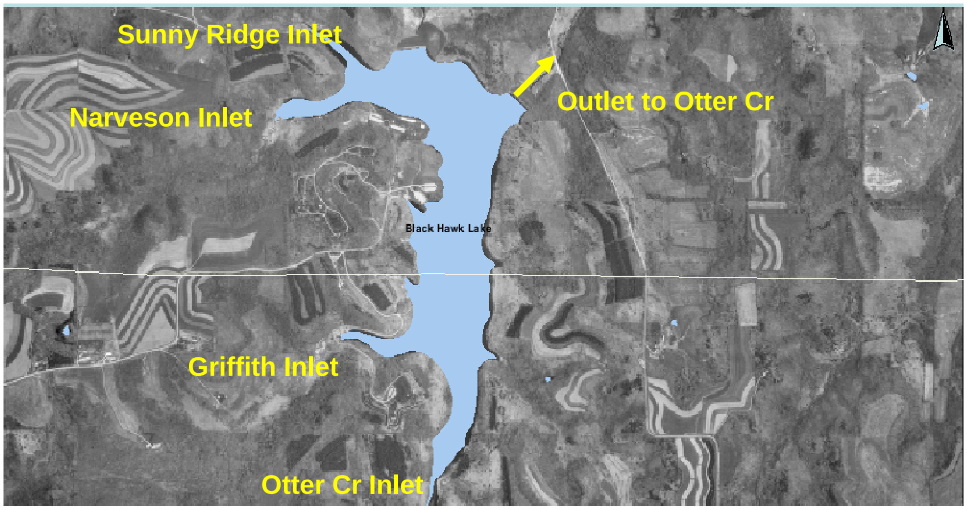

Figure 3 Watershed Sampling Site Locations

Laboratory analyses were completed by the State Lab of Hygiene. Outlet sampling began after the lake thermally stratified to monitor ammonia and phosphorus discharge trends from the hypolimnion. A YSI Model 52 dissolved oxygen meter and a YSI Model 63 pH and conductivity meter was used for all field sampling. The dissolved oxygen meter was air calibrated each sampling day. The pH meter was calibrated using two point pH 7 and 10 buffers. A General Oceanics mechanical flow meter was used to measure stream velocities or in areas of low velocity the float-area method was used for stream flow determination.

Biological Monitoring: The Agrecol Environmental Consulting subcontractors collected and analyzed macroinvertebrate samples at two tributaries and below the outlet. The invertebrates were analyzed for Family-level Biotic Index (Hilsenhoff 1988) and Family-level Ephemeroptera-Plecoptera-Tricoptera (EPT) scores. Lower Biotic Index scores indicate good water quality while greater numbers of EPT families also indicate better conditions. WDNR Fisheries Biologists collected fish community and sportfish population data within Blackhawk Lake and below the outlet in Otter Creek. The subcontractors also analyzed historic fish community macroinvertebrate data collected from Otter Creek above and below Blackhawk Lake. The coldwater Index of Biotic Integrity (Lyons et al. 1996) was used to analyze potential health of the trout streams. WDNR Lakes Management Specialists conducted an aquatic plant survey on Blackhawk Lake with the assistance of the subcontractors. WDNR Baseline protocols were used including the GPS point intercept methodology developed by WDNR ISS Scientists. Both a telescoping pole rake and rope rakes were used to collected specimens and estimate densities or rake fullness. WDNR Lakes Management Specialists also performed exotic species surveys, particularly plankton tows for zebra mussel velager larvae and surveys for toxic blue-green algae.

Land Use Inventory – Watershed Delineation: The Iowa County Land Conservation Department used GIS to quantify land uses within the watershed including cropland, woods, barnyards and grasslands. The DNR hydrology tool, using USGS regression analyses, was used to define sub-watershed boundaries and to estimate inlet flows (Figure 4). The drainage area for Sunny Ridge Inlet is approximately 1400 acres, Narveson Inlet is approximately 1500 acres, Griffith Inlet is approximately 1760 acres and Otter Creek Inlet is approximately 4900 acres.

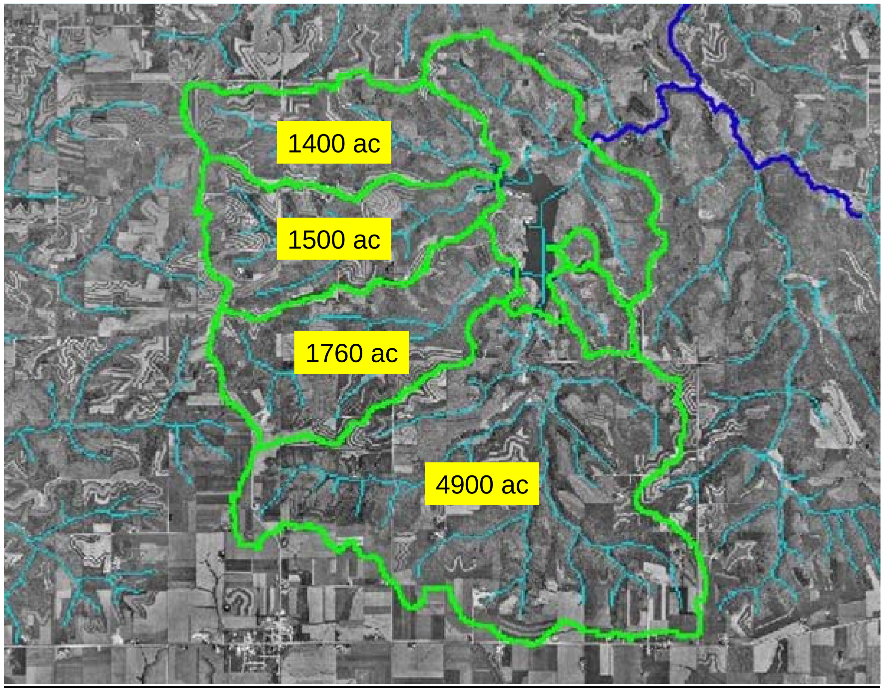

Figure 4

Data Analysis and Lake Modeling: Microsoft Excel spreadsheets were used for statistical analysis and data presentations. The Wisconsin Lake Model Suite (WILMS) was used for Trophic State Index calculations and hydrological and nutrient budget analysis.

Lake Monitoring Results

Secchi Water Clarity: Blackhawk Lake's water clarity was measured at both the left and right stations on a weekly basis by use of a Secchi disc. 2006 results are plotted in Figure 5. The Secchi disc, by being lowered into the water until it can no longer be seen, provides an indication of the amount of suspended material in the water column that limits light penetration. Higher amounts of suspended materials results in lower Secchi disc readings. Clearer water, with less algae and other suspended material, allows the Secchi disc to be seen in deeper water.

During 2006, water clarity in Blackhawk Lake ranged from a low of 4 feet on August 20th in the left basin to an exceptionally clear high of 31 feet on June 1st, also in the left basin. The summer average (June – August) Secchi depth for both the left and right basins was 10 feet. While bottom water conditions are different within the two basins, epilimnetic water is likely exchanged due to wind mixing.

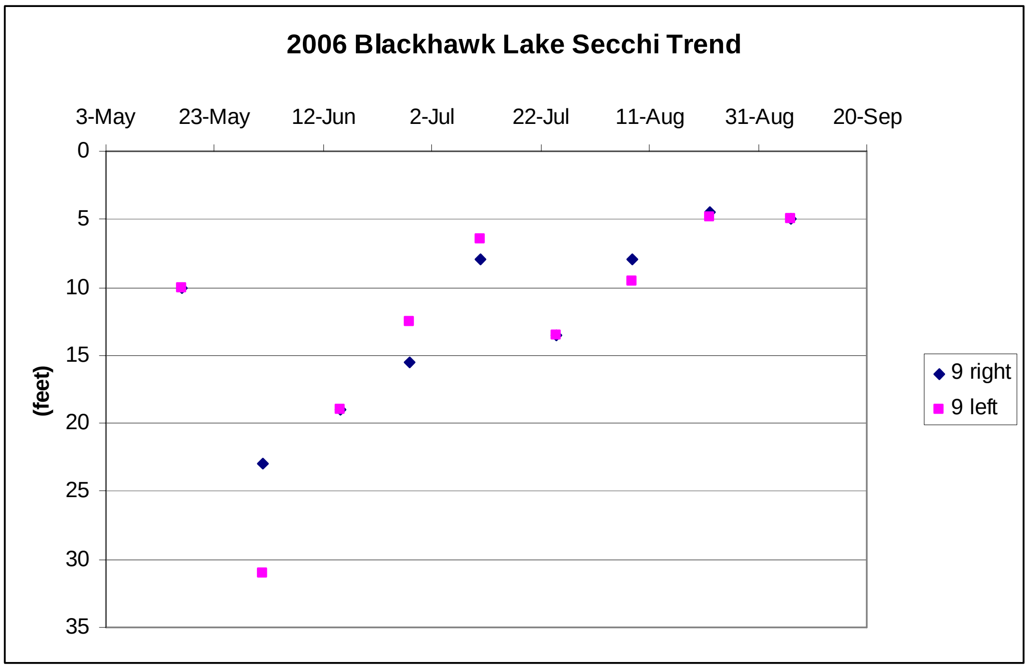

Figure 5

In 2007 similar water clarity trends (Figure 6) were observed although the summer average clarity observed in the right basin was slightly reduced from that in 2006.

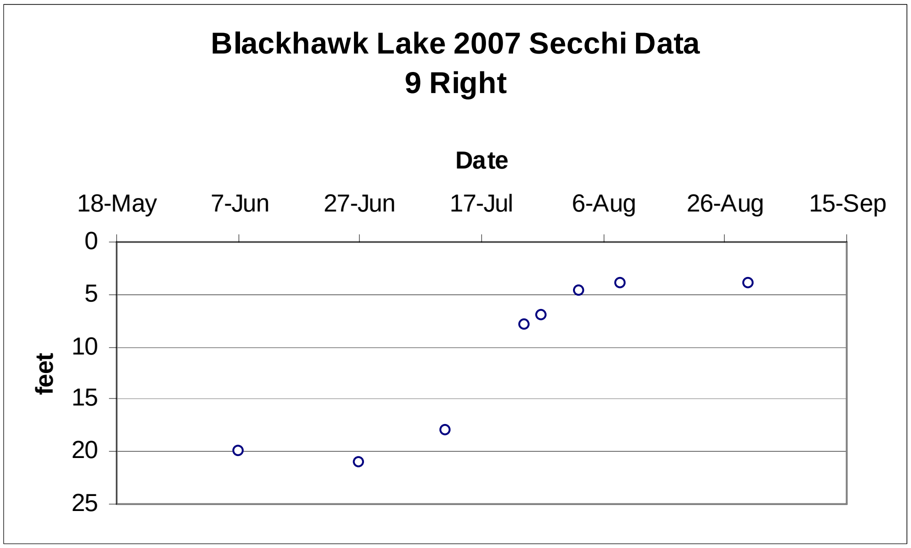

Figure 6

Compared to other lakes in the region which have a mean summer average of 3.3 feet, (Lillie and Mason 1983), the clarity of Blackhawk Lake is higher than expected. To further comparisons, the summer Secchi data is transformed to the Trophic State Index (TSI) values as shown in Figure 7. Favorable conditions are generally associated with values less than 50. While late summer TSI values in Blackhawk Lake exceeded 50, TSI values are generally higher in other area lakes including Twin Valley Lake, Cox Hollow Lake and White Mound Lake.

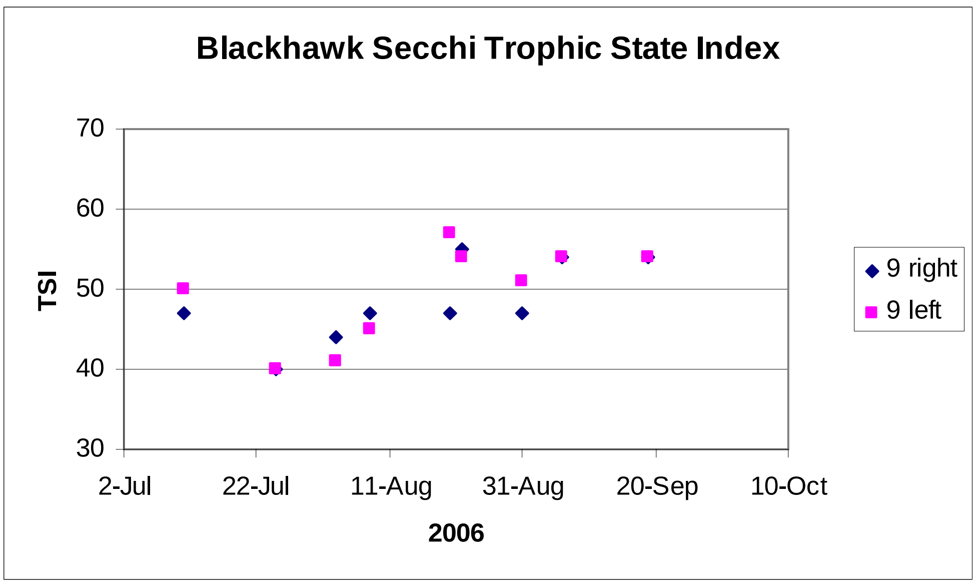

Figure 7

Total Phosphorus: In-lake water chemistries were generally collected on a two week basis between April and September of 2006. Phosphorus concentrations were obtained from the surface, mid depth, and near bottom from site 9-right, the deepest part of the lake near the primary dam outflow point (Figure 1). Phosphorus chemistry results are shown in Figure 8.

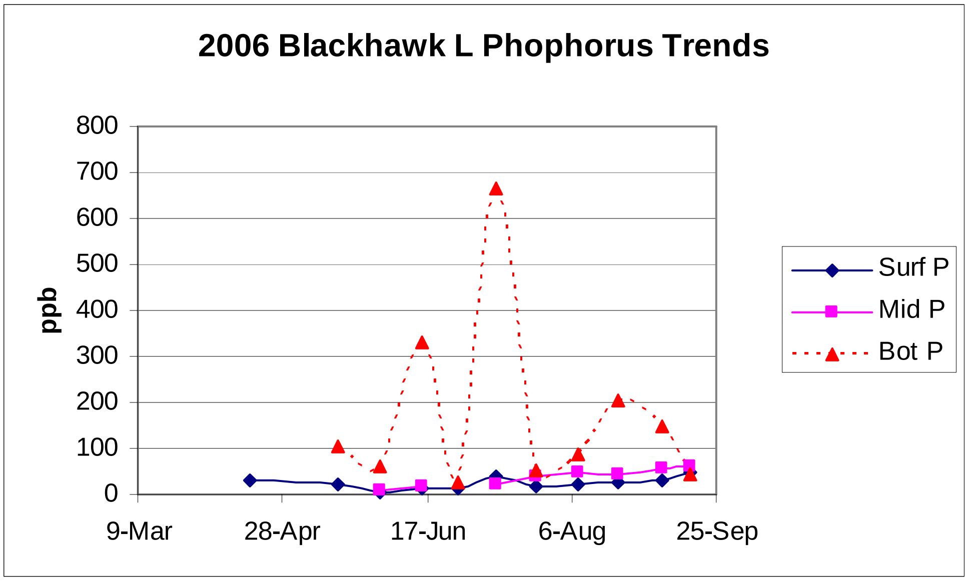

Figure 8

Like many lakes, summer algae production in Blackhawk Lake is limited by the amount of phosphorus present in the water. Generally, the higher the spring phosphorus concentration, the higher the algae production will be during the summer. Blackhawk Lake's spring mixed phosphorus concentration was found to be 32ug/l, a relatively low concentration, especially for lakes located in this part of the state.

During June, July, and August, surface phosphorus concentrations averaged 21ug/l, again a low number indicative of phosphorus being limiting to algae production. On September 16th, when the lake was mixing due to loss of stratification, the phosphorus concentration increased to 46ug/l, a result of higher phosphorus bottom waters mixing into the water column.

Bottom water phosphorus concentrations taken from near the outlet were generally higher, typical of what is found in stratified lakes following oxygen depletion. Between June and August they averaged 187ug/l but showed unusual fluctuations, varying between 26ug/l on June 28th and 667ug/l on July 11th. Such fluctuations are not typical of most lakes, although similar dynamics have been observed on lakes having bottom withdrawals like Blackhawk. At this time, it is unknown why these fluctuations are occurring, perhaps being caused by inlet density currents along with hydrodynamic variations caused by bottom withdrawal. On September 16th, the bottom water phosphorus concentration of 43ug/l was essentially the same as the top water due to the lake being destratified.

Chlorophyll a: Chlorophyll a is photosynthetic pigment found in algae and other plants. Its concentrations are used as an indicator of the amount of algae that is present in a water body. In Blackhawk Lake the chlorophyll a concentrations during the summer ranged from 1.4ug/l on June 1st to a high of 51.1ug/l on July 11th. Summer average concentration was 15.5ug/l, indicative of a moderately eutrophic lake. Chlorophyll a concentrations also were found to be consistent with surface phosphorus concentrations and water clarity measurements (higher phosphorus = higher chlorophyll = lower water clarity). Such a relationship is often not the case in impoundments on larger rivers with shorter residence time, where sediment turbidity from the watershed typically limits light penetration in agricultural areas. In this lake, watershed contributions appear to have been mitigated by the capturing of sediments and nutrients in the inlet bays. Figure 9 shows the chlorophyll and TSI transformed data trends at 9-right.

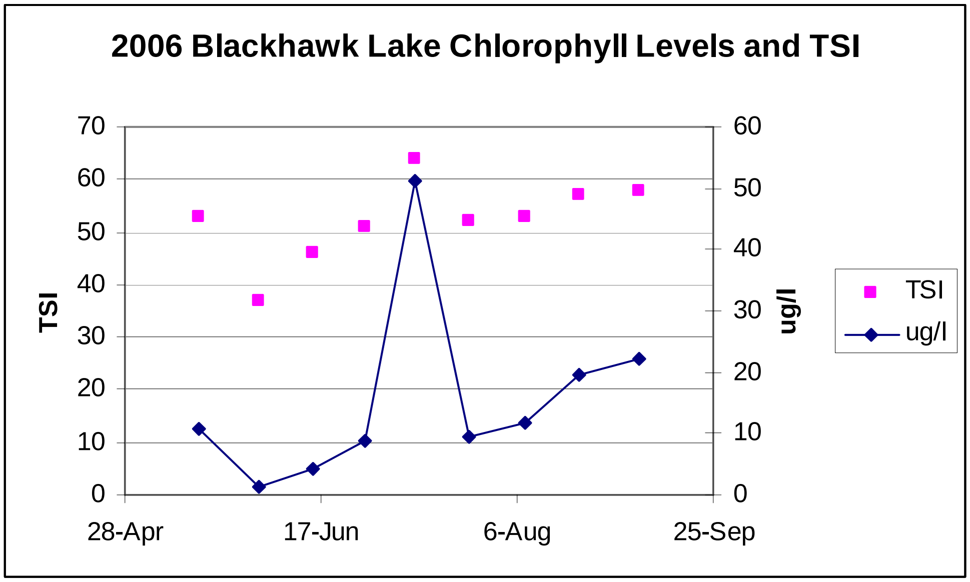

Figure 9

Dissolved oxygen and temperature profiles: Dissolved oxygen and temperature monitoring was generally conducted on a weekly basis between April and September of 2006 at both the right and left monitoring station. (See Figures 10, 11 and 12 for summer profiles at 9-left and 9-right. Complete data sets appear in the appendix)

The comprehensive temperature and oxygen data showed that both basins of Blackhawk Lake become thermally stratified during the summer months. Stratification occurs when water near the surface is warmed by the sun and forms a layer over cooler water below it. The surface water layer is called the epilimnion. The bottom water is called the hypolimnion. The area between the top and bottom water is called the metalimnion. The upper layer of the lake is generally saturated with oxygen from contact with the atmosphere and is generally well mixed by wind action where the bottom layer becomes isolated from the atmosphere. In the bottom waters decomposition processes deplete stored oxygen, and the water becomes anoxic (devoid of oxygen). In addition to loss of habitat for fish, reduction and oxidation potential changes occur which result in the sediment releasing certain chemicals to the water. Of particular importance to Blackhawk are the increases seen in the ammonia and phosphorus concentrations in the bottom water coinciding with decreased concentrations of dissolved oxygen.

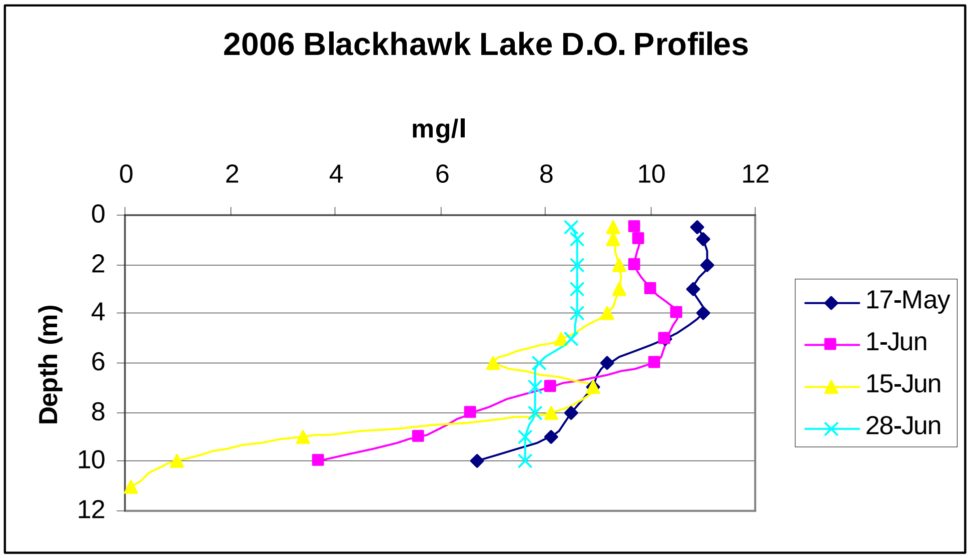

Figure 10

Both the left and right basins began to show weak stratification in early May. By June, the left basin was strongly stratified with the metalimnion forming at about 3 meters. In the right basin, temperature transition did not begin to take place until the 6 meter depth. The differences between these two basins may be a factor that 9-left is more protected from wind fetch than the right and that cold water bottom withdrawals from 9-right result in heat gain.

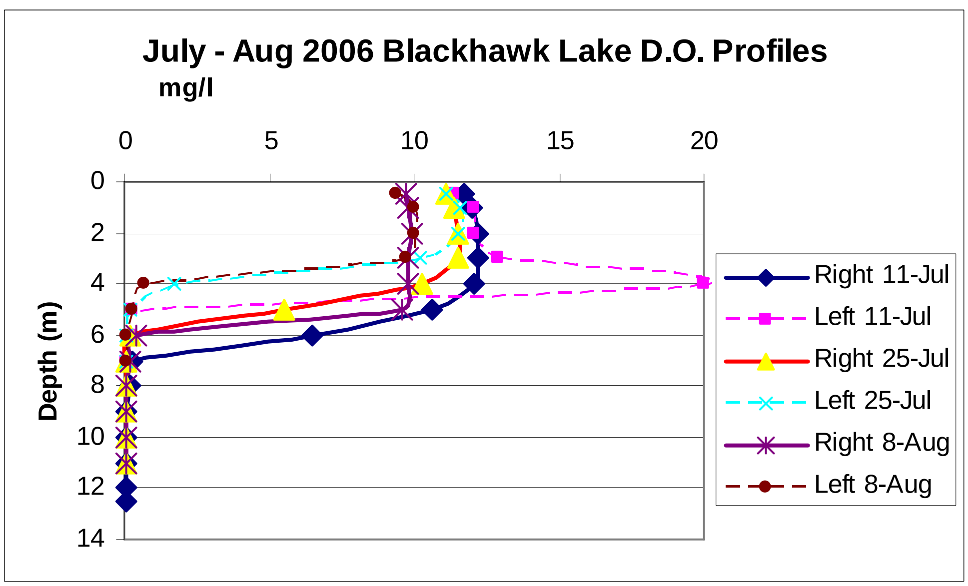

Figure 11

By mid to late July, 9-left was strongly stratified while 9-right demonstrated weaker stratification due to the factors mentioned above and lake temperature profiles shown in Figure 11.

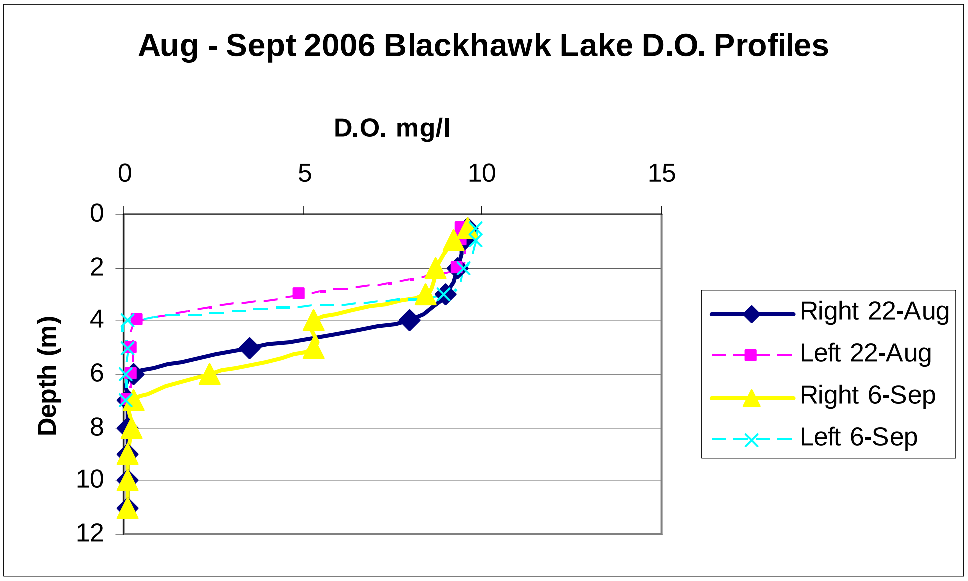

Figure 12

In early September (Figure 12), the left basin remained stratified while the right basin was only very weakly stratified with bottom temperatures being about 19 degrees C, as compared to 15 degrees C in the left.

To determine how extensive the aerial influence of the bottom withdrawal was on affecting temperatures, thermal transects were taken from the primary sampling point to points 800 feet away at depths of 5 and 6 meters. The influence of the withdrawal appeared to extend to the 800 foot point although a slight change in temperature (1.5 degrees C at 6 meter depth and only 0.2 degrees C at 5 meter depth) was observed at the furthest point.

By early July both basins showed typical oxygen profiles with oxygen being completely depleted from the bottom waters (Figure 13). Of some interest in the right basin was the presence of a metalimnetic spike in dissolved oxygen on July 11th, with waters being super saturated at the 4 meter depth, presumably a result of a bloom of the algae *Oscillatoria rubescens*.

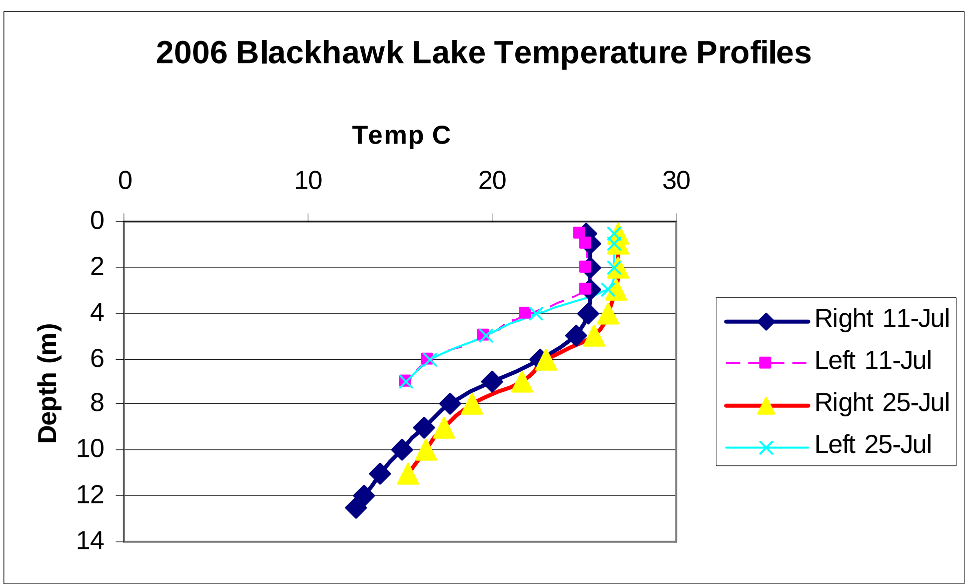

Figure 13

On September 6, 2006, the right basin began to show signs of destratification, Figure 14, while the left basin remained strongly stratified.

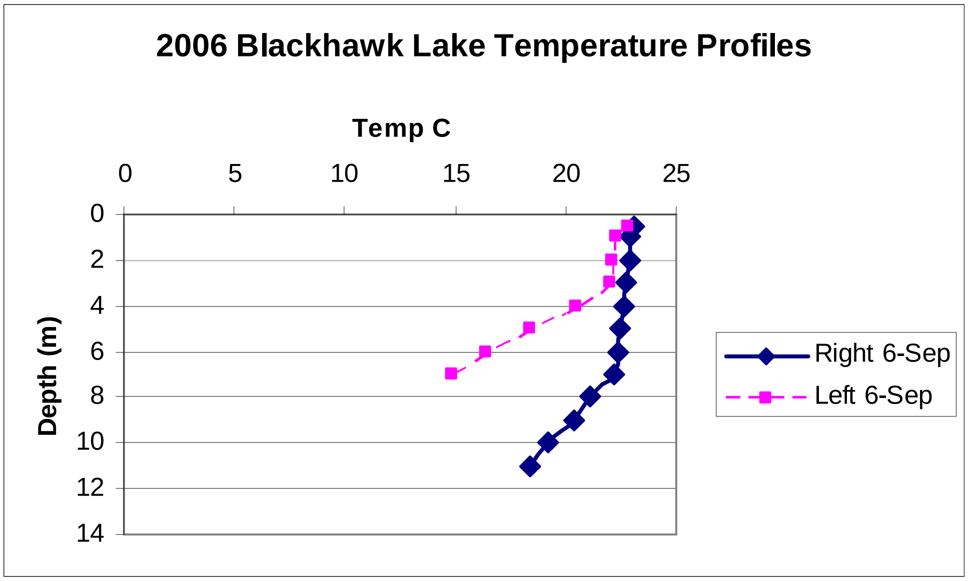

Figure 14

Data recorded in 2007 was found to be consistent with that found in 2006 (Figures 15 & 16).

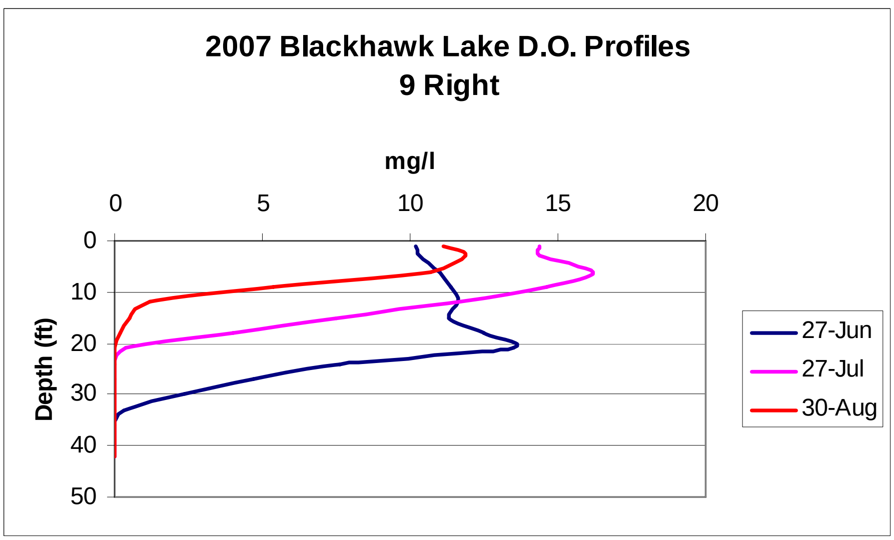

Figure 15

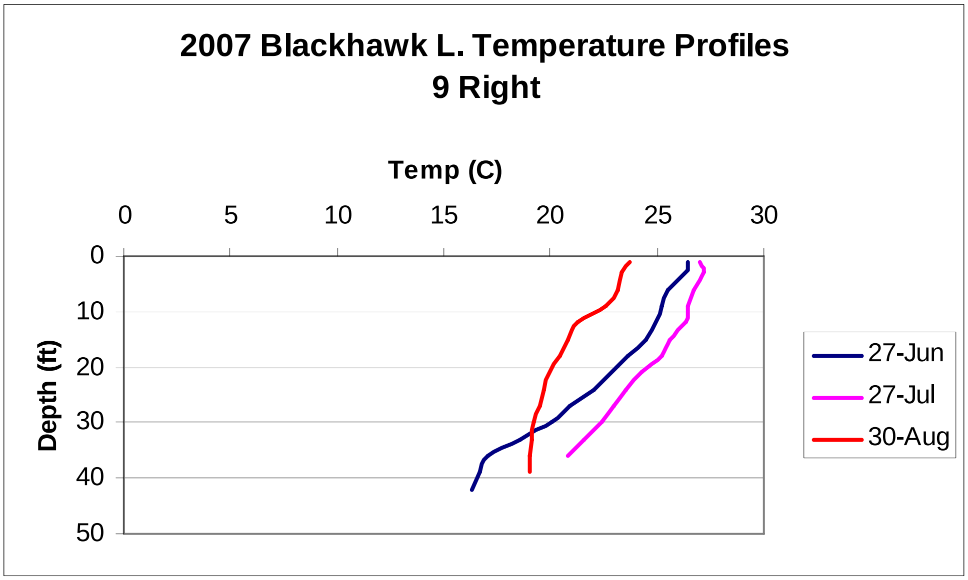

Figure 16

pH and specific conductivity profiles: Specific conductivity and pH measurements were taken concurrently with dissolved oxygen and temperature readings at two week intervals. These measurements correlated well with and confirmed the information provided by the oxygen, temperature and other data collected during the study. In the bottom waters of both basins specific conductivity increased as would be expected by the increased amount of dissolved materials present in the water, a result of the release of chemicals from anoxic conditions over the bottom sediments. In the top waters, the pH of both basins reflected increases typical of those seen due to algae production, although the right basin had slightly higher levels during the month of August. Figure 17 shows summer conductivity levels.

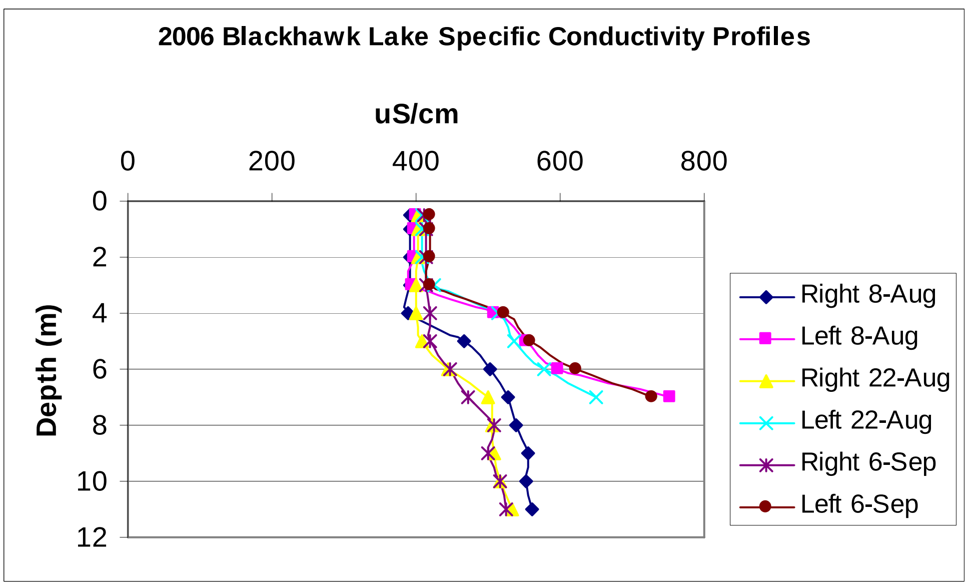

Figure 17

Ammonia: Ammonia concentrations were also sampled in the lake between June and September. As with phosphorus, samples were taken from the right station although a comparison sampling from the left station was also completed in September. Ammonia concentrations for both the mid and bottom depths for 9-right are shown in Figure 18. Ammonia nitrogen samples were collected from both the mid and near bottom depths of the lake near the point of discharge. Both phosphorus and ammonia levels increase during periods of anoxia (when no oxygen is present) as they are released from the bottom sediments. Ammonia data was primarily collected to determine what concentrations would be discharged from the bottom of the lake – a concern related to downstream water quality. Ammonia can be directly toxic to aquatic organisms and can also cause depletion of downstream oxygen levels as the ammonia utilizes oxygen when it is converted to nitrate nitrogen.

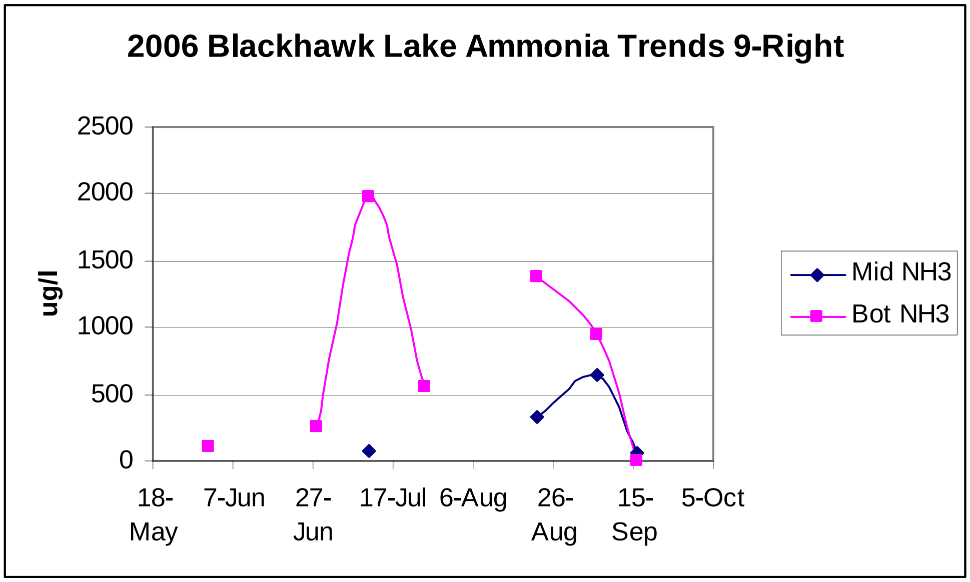

Figure 18

In the right basin, bottom ammonia concentrations averaged 865ug/l between June and September. Like phosphorus, these concentrations showed atypical fluctuation between sampling periods. An ammonia sample was also collected for comparison purposes from the bottom of the left station on September 6th and September 16th. Concentrations at the left station were significantly higher than those from the right, being 4060ug/l and 4400ug/l on September 6 and September 19, 2006 respectively, reflective of the differences caused by the bottom withdrawal of water from the right basin of the lake. The left station values show that a significant amount of ammonia was being discharged from the right station. This sampling information showed that ammonia likely increased gradually in 9-left and was sustained while in 9-right fluctuations mirrored the bottom phosphorus trends. Some of the ammonia had been discharged downstream along with phosphorus and hydrogen sulfide. Figure 19 displays late summer ammonia levels with the lower levels and the apparent decline on September 19 due to de-stratification.

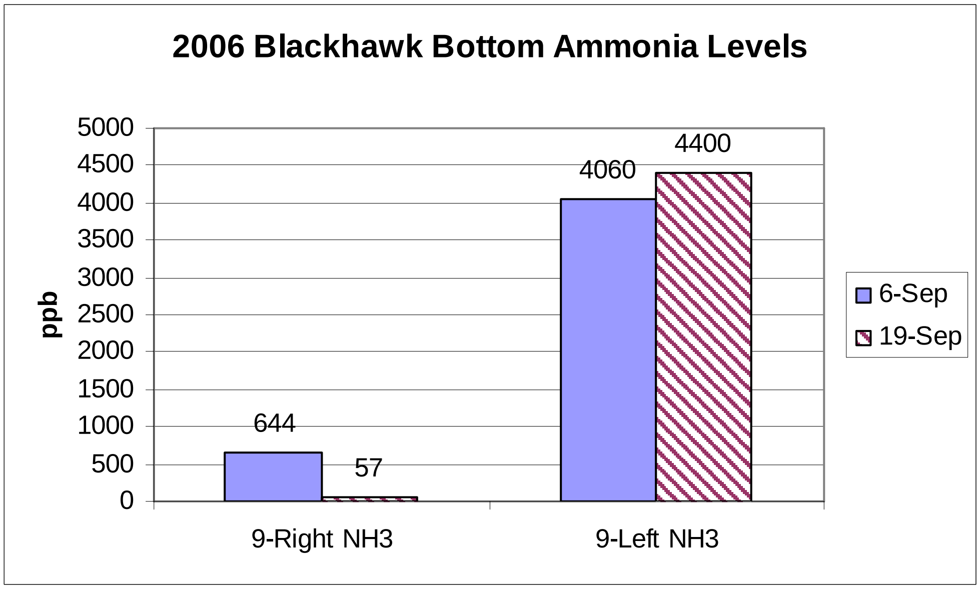

Figure 19

Aquatic plants: A total of 228 sampling points were distributed equidistantly across the lake. A total of 140 sites supported aquatic plants during the surveys performed on June 16, 17 and 22 2006. The maximum depth for aquatic plant growth was 31.4 feet and reflected the observed good water clarity in the lake. In some lakes, poor water clarity restricts rooted plant growth to very shallow water depths. Figure 20 displays the relative frequency of aquatic plants that were collected in the sampling rakes. Coontail (*Ceratophyllum demersum*) was the most frequently collected plant followed by the exotic curly-leaf pondweed (*Potamogeton crispus*) and common water weed (*Elodea Canadensis*). A total of 13 species of rooted plants, floating plants and algae were collected in the sampling rakes. Seven other species were observed near the sampling sites as well. Unfortunately, invasive Eurasian watermilfoil (Myriophyllum spicatum) was one of them, the first time it had been found in the lake. A rapid response team of volunteers, including Buck Holmes, Donna Sefton and her family and Dave Marshall, attempted to eradicate the two stands that were observed. The method for removal was using SCUBA to cut below the sediment surface and harvest the plants and fragments for disposal on shore. Unfortunately new Eurasian watermilfoil stands have been discovered in the lake. An aquatic plant management plan has been completed to guide the protection of native plants and control of Eurasian watermilfoil.

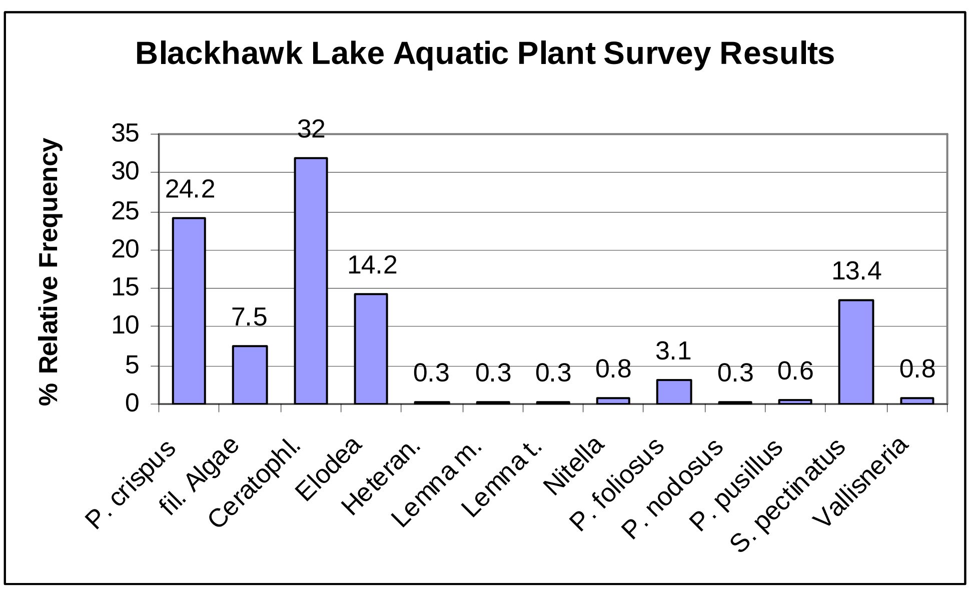

Figure 20

Lake fishery electroshocking survey: Blackhawk Lake was boomshocked on October 19 and 20, 2006 encompassing 5.28 miles of shoreline, over a sampling period of 2.77 hours. Figure 21 lists the species collected during the survey with largemouth bass being the most abundant species. In addition to largemouth bass, two other gamefish species, northern pike and walleye, were found. Figure 22 displays the percentage of gamefish species caught that had reached legal harvest size.

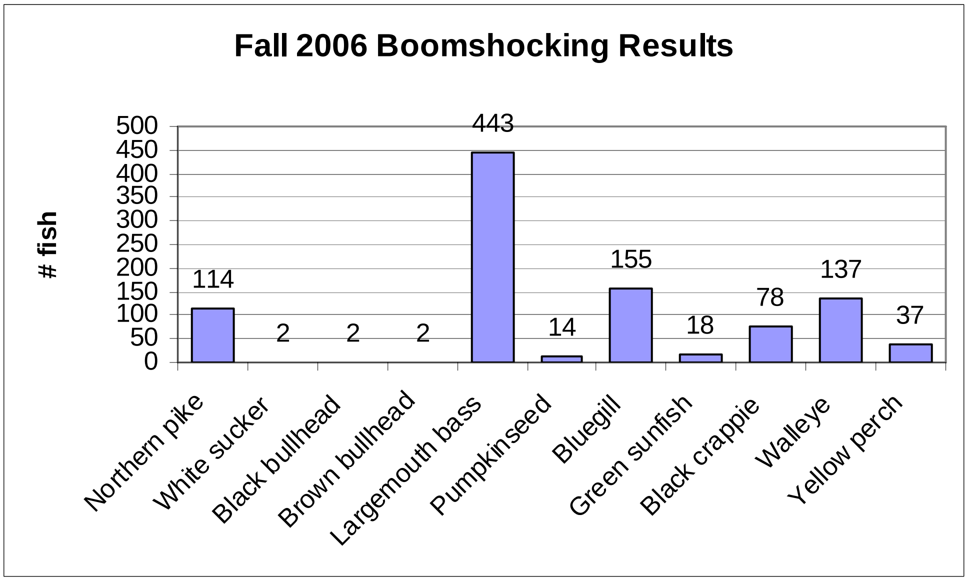

Figure 21

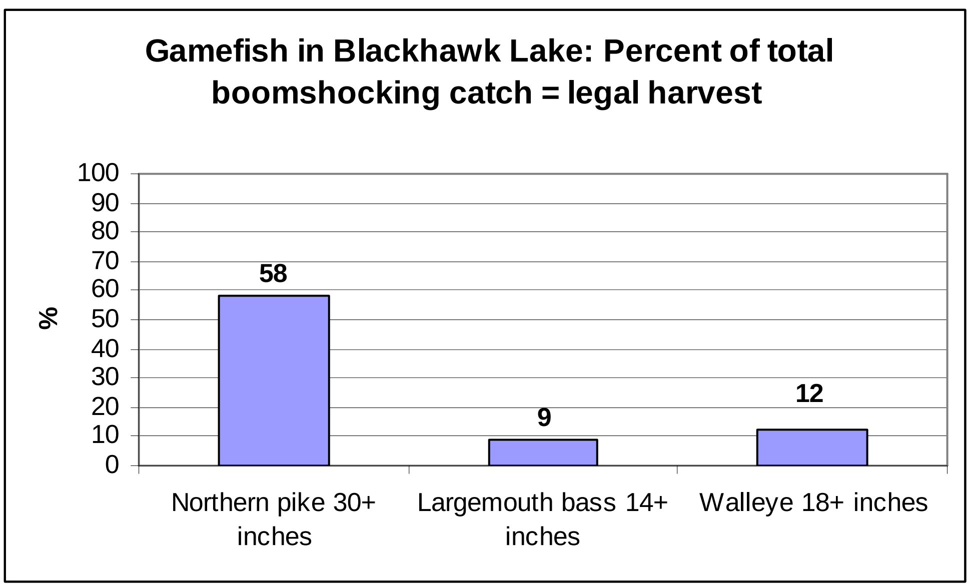

Figure 22

Stream Monitoring Results

Inlet flows: Streamflow was measured as part of this study period on the same dates as when stream samples were collected. Mean flows for the four tributary streams during the period of study were 6.1 cfs for Otter Creek inlet, 1.9 cfs for Griffith, 1.9 cfs for Narveson, and 0.5 cfs for Sunny Ridge. (See Appendix H). Unfortunately, instantaneous flow collection cannot accurately identify total tributary flow data. However, the United States Geologic Service (USGS) maintained a continuous downstream flow gauging station at Otter Creek near Clyde. The drainage area at this site is 107 square miles. As an example, flow records were compared for June 28, 2006 based upon basin area extrapolations with actual instantaneous measurements made as part of the study: Otter Creek 5.3 cfs (3.9 cfs), Griffith 1.2 cfs (1.4 cfs), Narveson 1.6 cfs (1.2 cfs) and Sunny Ridge 0.4 cfs (1.1 cfs). Estimated flow data based upon the basin comparison techniques during the period of study are shown in Appendix H. As expected, flows were highest in April, but they only decreased slowly during the summer months before increasing again in September, indicative of the very wet period experienced during the study period.

Transparency turbidity tube: This device is used in streams as an indicator of water turbidity, a measure comparable to the use of a Secchi disc in lakes. The transparency turbidity tube used in this study was 23.5 inches high and has a very small disc resembling a Secchi that fits in the bottom of a plexiglass tube. Figure 23 summarizes the 2006 stream surveys. The outlets of Blackhawk Lake and Sunny Ridge Creek had the best stream water clarities. The outlet measurements reflect capture of and net gain of sediment in the lake. Clear water conditions in Sunny Ridge Creek reflected upstream wetland filtering and higher groundwater discharge rates. The low readings observed in the other creeks reflect sediment and attached phosphorus entering and ultimately becoming more available for algae and plant growth in the lake. The total amount of phosphorus and sediment from each tributary is dependent upon watershed area and conditions along with stream flow rates. Mean flows for the four tributary streams were 6.1 cfs – Otter, 1.9 cfs – Griffith, 1.9 cfs - Narveson and 0.5 cfs Sunny Ridge.

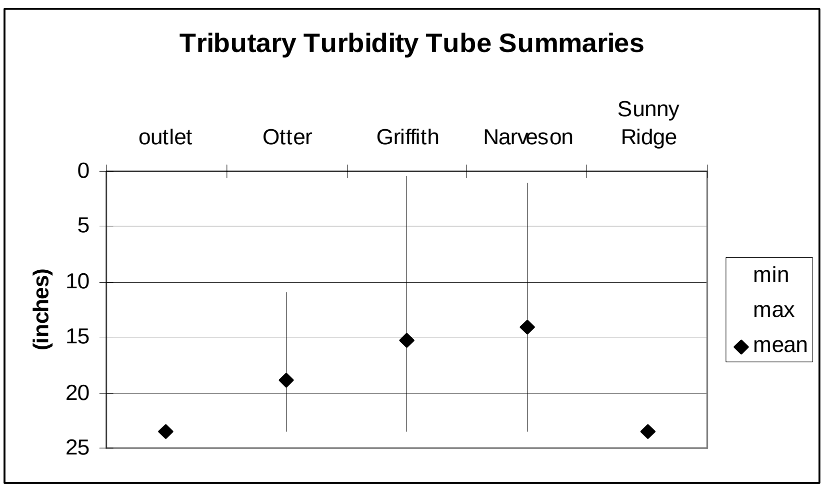

Figure 23

Sedimentation: The Natural Resources Conservation Service (NRCS) completed a sediment quantity study of the lake in 2001. The four major inlets had sediment accumulation measured by transect probing while the inlake quantity of sediment was estimated by assuming a lake wide average sediment accumulation depth of 0.5 ft. Total sediment accumulation between 1968 and 2001 was 200,000 cubic yards, an average of 6100 cubic yards/year. Results of that study are shown in Figure 24.

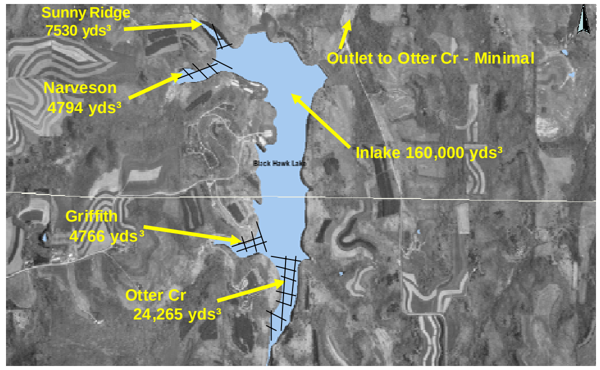

Figure 24

<u>Tributary Phosphorus</u>: Figure 25 shows relative phosphorus loading from the lakes watershed. The peak concentrations occurred during rainfall events that transport soil and attached phosphorus. Storms can also transport manure with phosphorus in the dissolved form that is immediately available for algal plant uptake. Figures 26 and 27 plots inlet phosphorus from Otter Creek and outlet phosphorus from the Blackhawk Lake dam. Opposite trends are displayed as greater phosphorus enters the lake in the spring and more phosphorus exits the lake from the anoxic bottom waters.

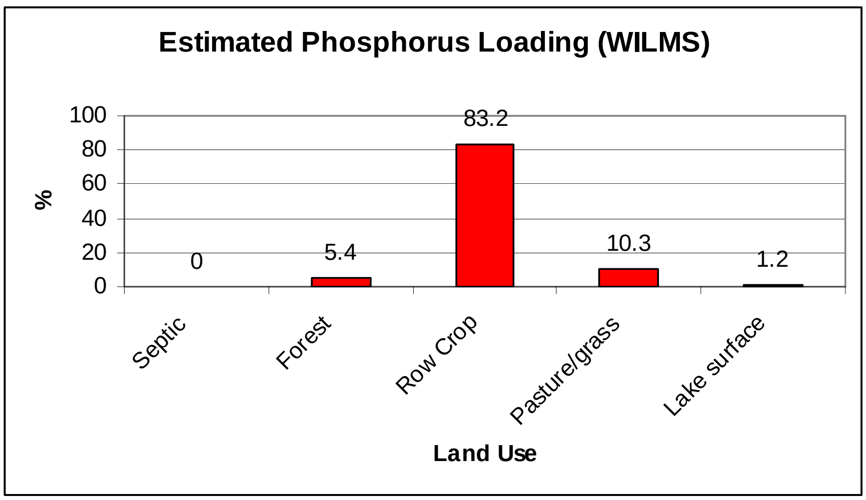

Figure 25

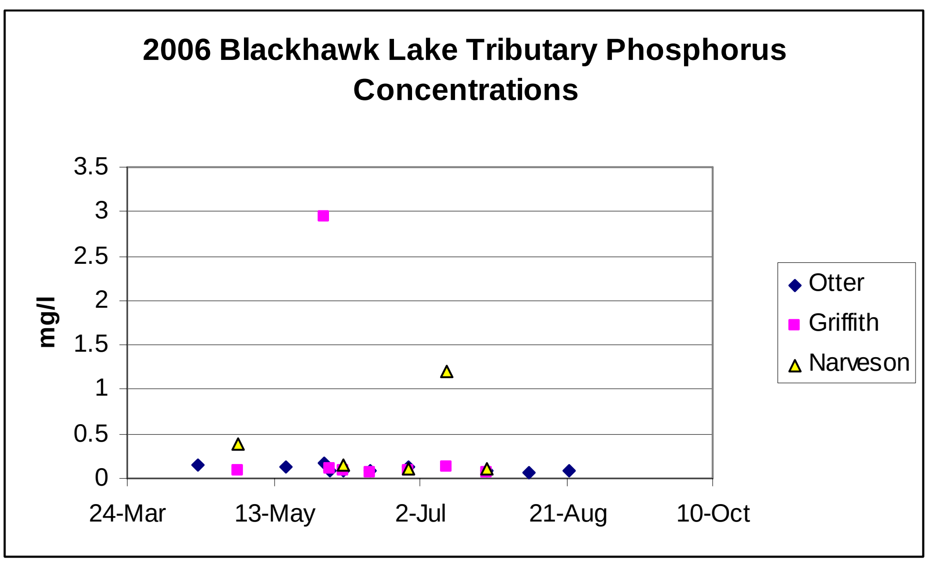

Figure 26

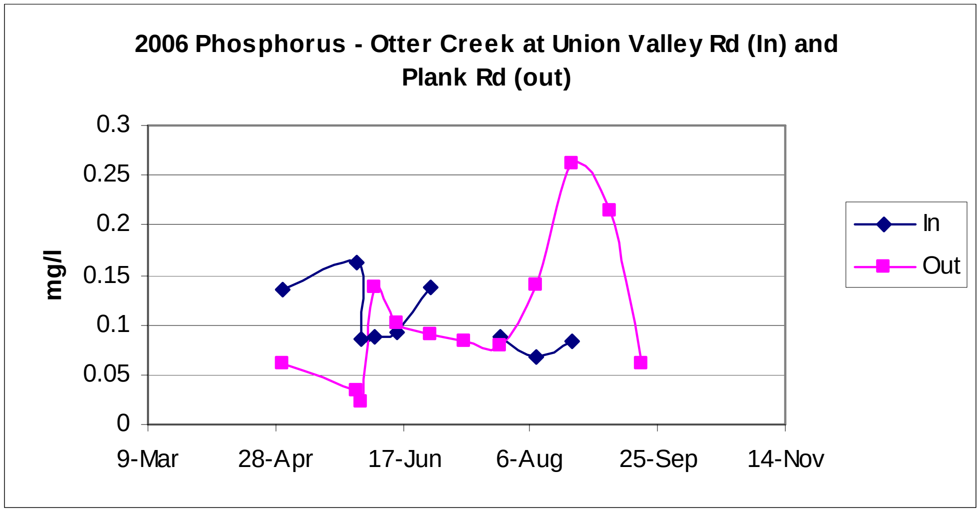

Figure 27

<u>Outlet ammonia and dissolved oxygen</u>: Ammonia is the reduced form of nitrogen and is produced by organisms as a waste matter in the bottom water of lakes with low dissolved oxygen. As the hypolimnion became anoxic in Blackhawk Lake, the release of ammonia increased. The discharge of ammonia is of concern for fish and aquatic life due to its toxicity and demand on dissolved oxygen. As the summer progressed, outlet ammonia increased (Figure 28) while dissolved oxygen levels generally decreased (Figure 29).

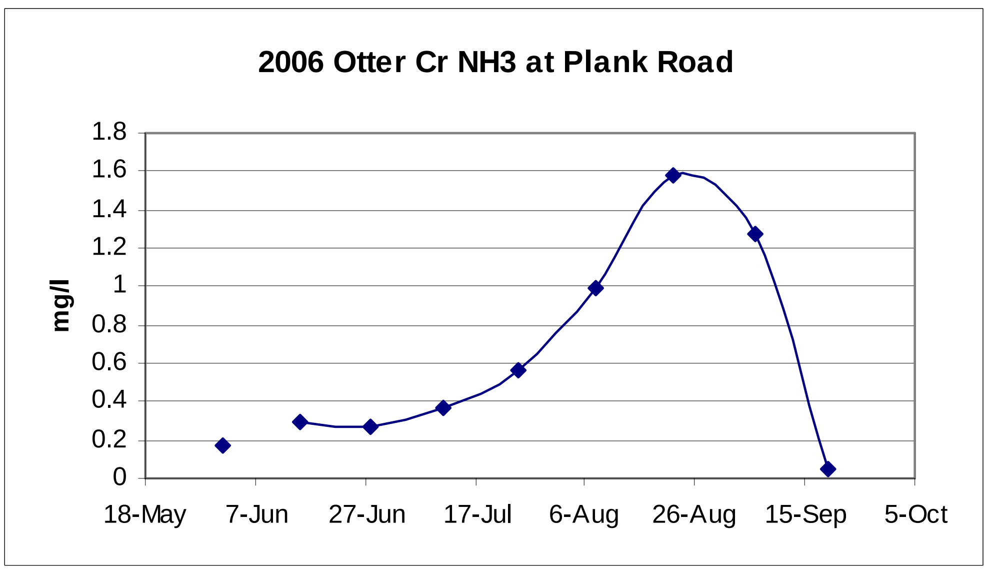

Figure 28

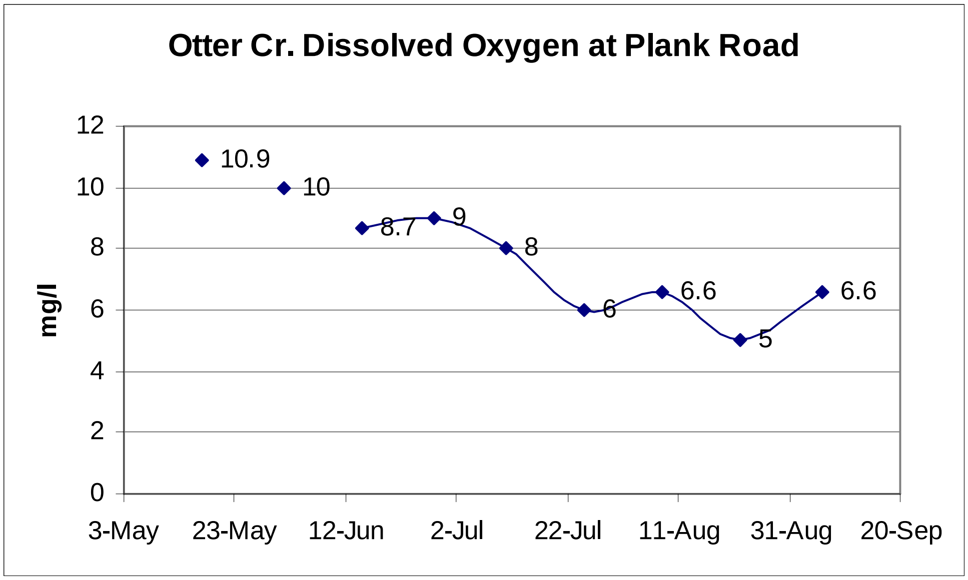

Figure 29

The water quality criterion for trout streams is 6 mg/l dissolved oxygen. Except for a concentration of 5.0 mg/l observed on August 26, 2006, this criterion was satisfied. However, the single point measurements collected during the daytime typically do not detect the lowest concentrations found in a stream. A data logger was deployed near Plank Road in July 2006. Dissolved oxygen levels fell significantly below the criterion and reflected the impacts of ammonia and other oxygen demanding material such as hydrogen sulfide on the stream (Figure 30). Previously, WDNR had deployed data loggers and found similarly low dissolved oxygen levels in 2000.

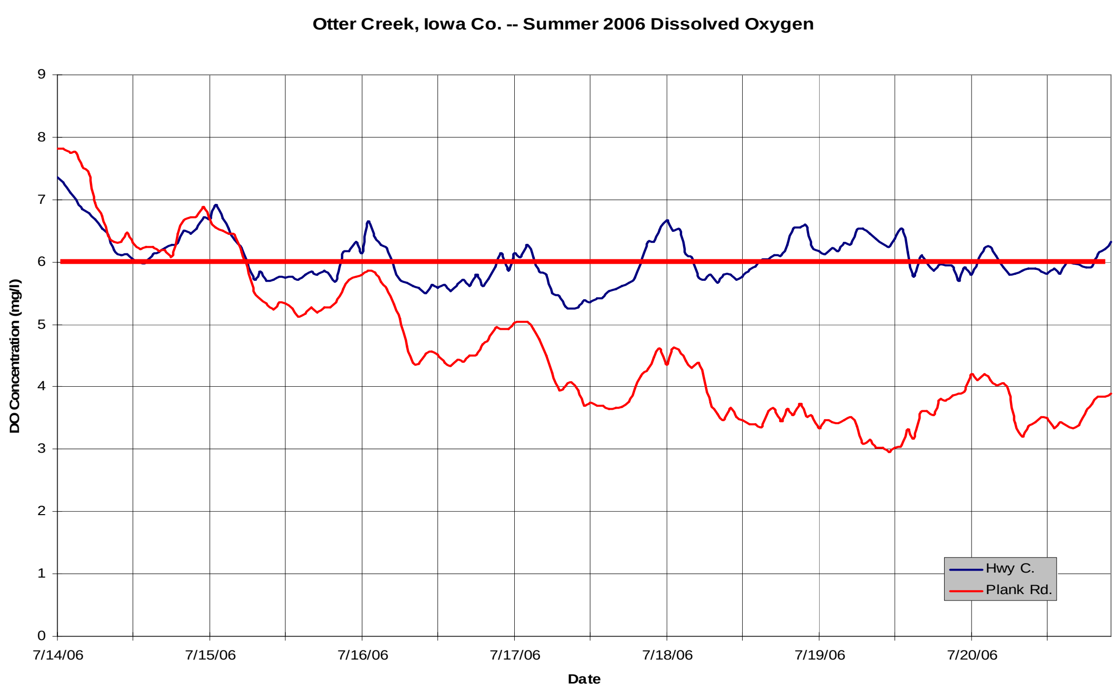

Figure 30

Stream temperature: In 2006 WDNR Fisheries staff deployed Hobo temperature data loggers on Otter Creek below the dam. At Plank Road the daily maximum mean temperature was 23 degree C (Figure 31). Further downstream at Spring Valley Road the daily maximum mean temperature had only decreased by 0.4 degrees C, indicating minimal groundwater inputs to the stream (Figure 32). WDNR staff had previously deployed these continuous monitoring temperature devices from 2002 through 2005. Figures 33 and 34 display the maximum concentrations from 2002 through 2005. High temperatures were detected in some years even when most of the mid to late summer flow discharged from the lake bottom. Quality trout streams typically have daily maximum mean temperatures lower than 22 C. While the temperature appears to be adequate in some years, the degraded water quality is another important limiting factor for trout survival.

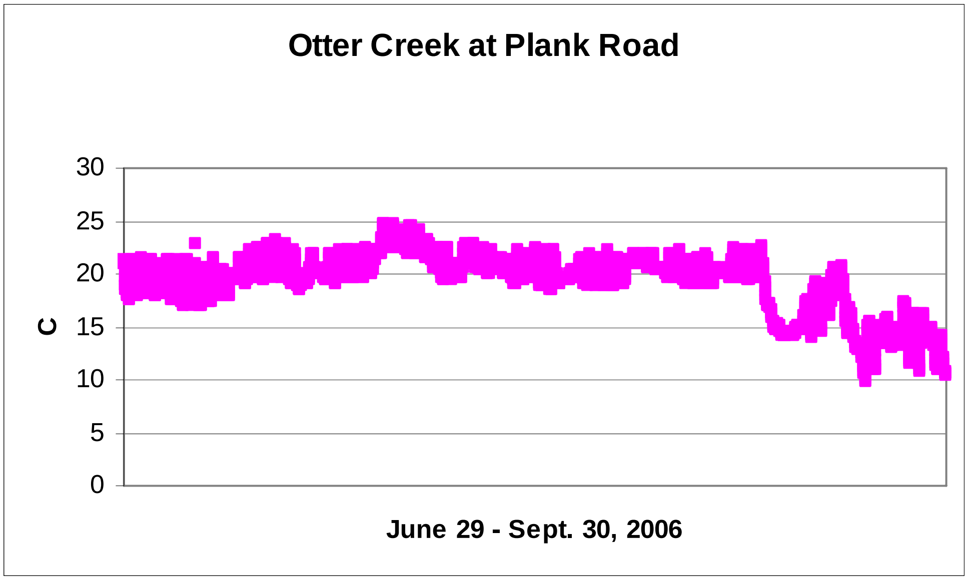

Figure 31: Daily maximum mean temp of 23 C

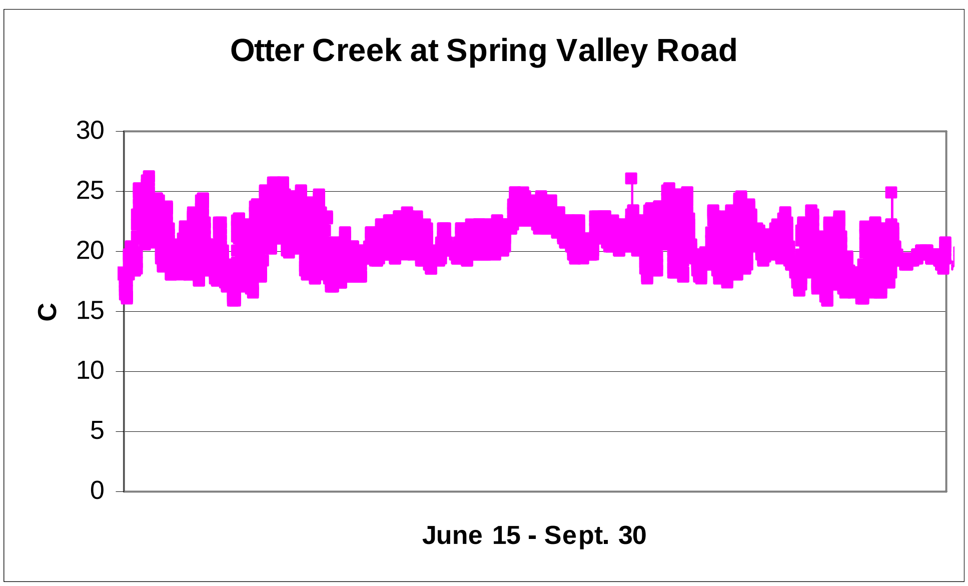

Figure 32: Daily maximum mean of 22.6 C

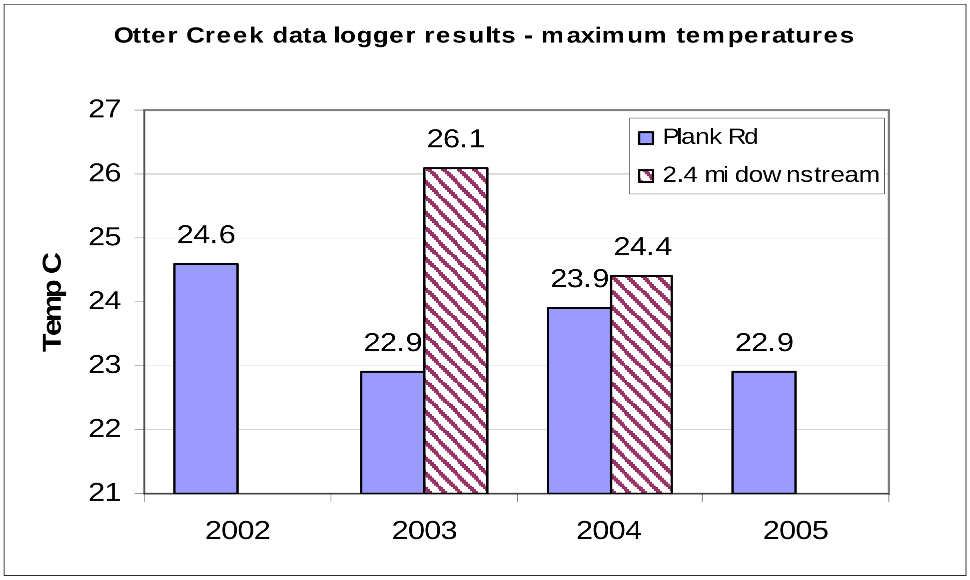

Figure 33

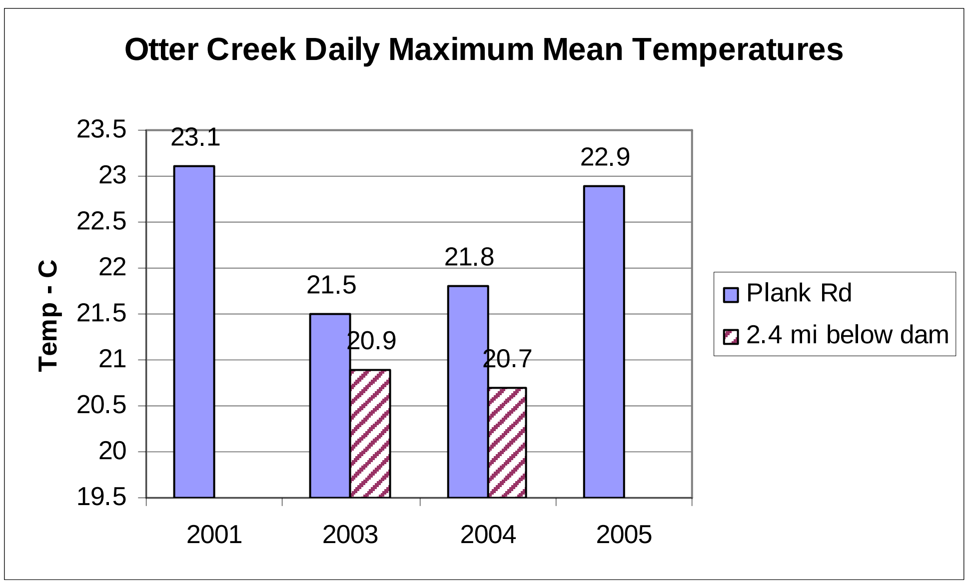

Figure 34

Stream macroinvertebrates: Aquatic insects and crustaceans (collectively called macroinvertebrates) were sampled in Otter Creek above the lake, in Griffith Creek above the lake and below the dam at Plank Road. The taxa were identified to family-level to calculate the Biotic Index (FBI), (lower numbers = better water quality) and mayfly-stonefly-caddisfly (EPTF) family numbers (higher numbers = better water quality). The best stream habitat, based on these indicators was Otter Creek above the lake followed by Griffith Creek, which appears to have affected more by runoff pollution (Figure 35). The invertebrates reflected degraded habitat below the dam and impacts of the bottom water discharge. Similar results were found in 2000 and 2001 (Figure 36).

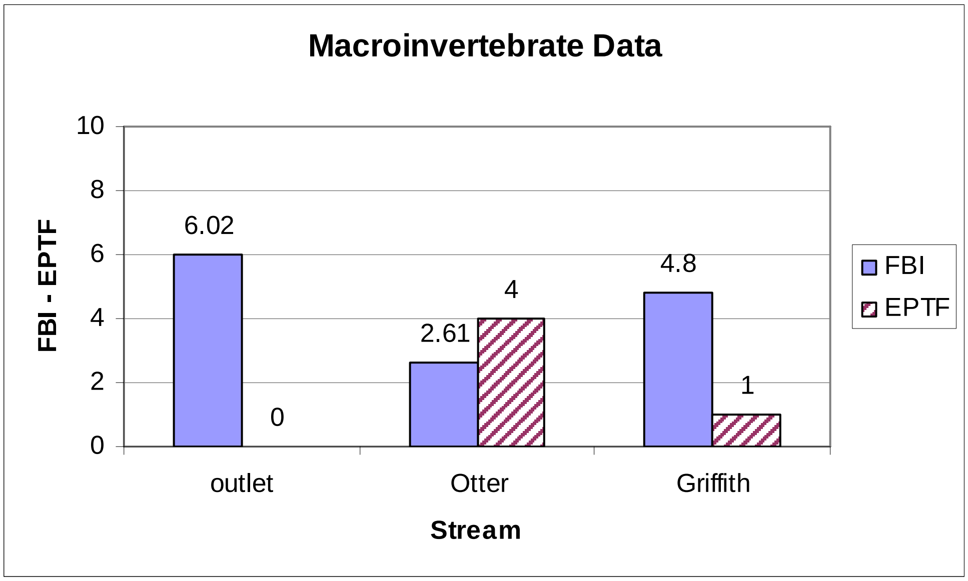

Figure 35

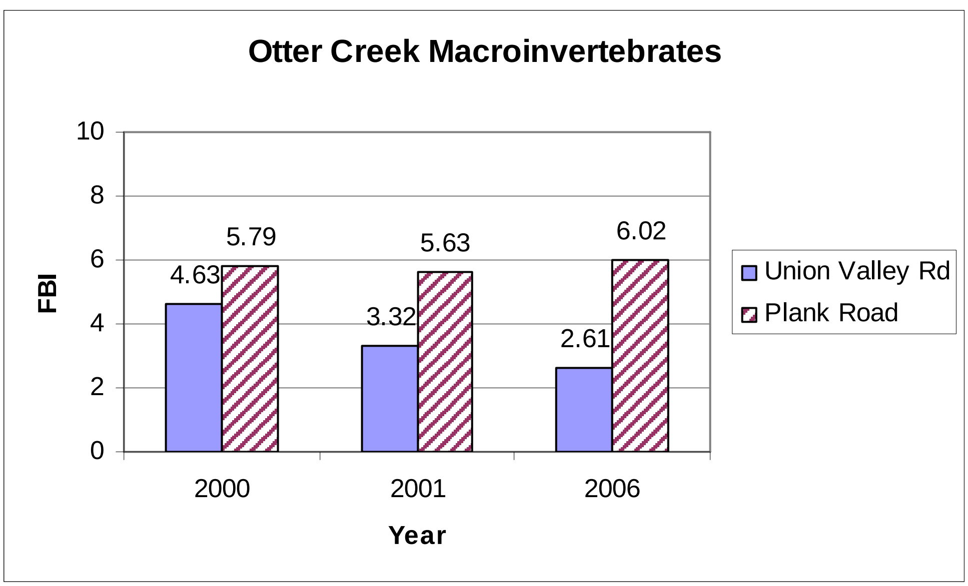

Figure 36

Stream shocking surveys: WDNR Fisheries Biologists sampled Otter Creek below the dam in 2006 with towed electro-fishing gear. The fish community data was collected to determine the coldwater Index of Biotic Integrity (IBI), a measure trout stream quality. Previous electro-fishing surveys had been completed periodically since 1962. In Figure 36, IBI scores from 2006 and in previous years demonstrated that Otter Creek had displayed poor trout management potential for decades. The best IBI score was occurred in 1962 (before Blackhawk Lake was constructed) but the "fair" value reflected the presence of several intolerant species that typically do not inhabit trout streams. Their disappearance from the stream since that time may reflect degraded water quality in the stream. Figure 36 also demonstrates the scarcity of cold water fishes in most years. Higher numbers in 2004 and 2006 reflect stocked brown, rainbow and brook trout. The complete Otter Creek fish species inventories appear in the appendix.

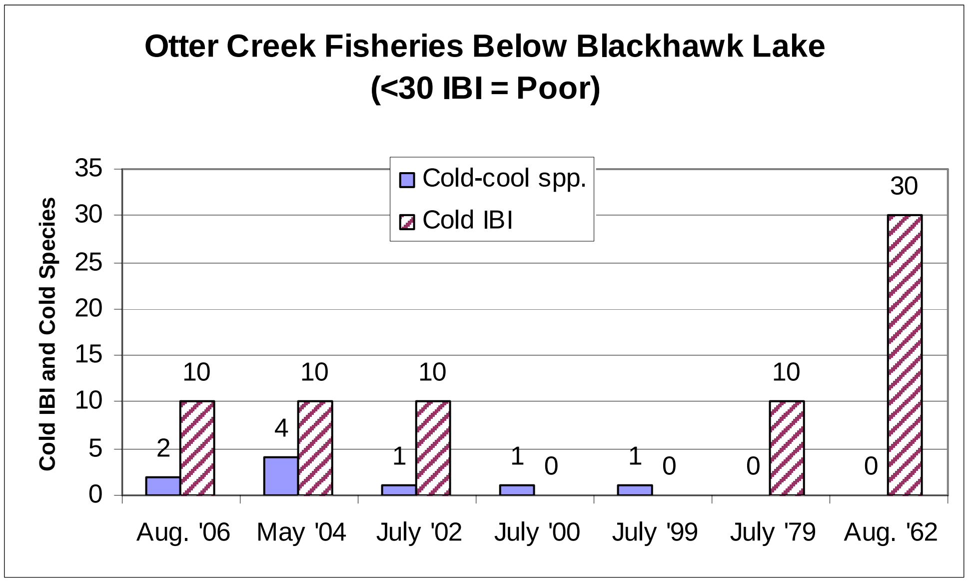

Figure 36

Toxic algae and zebra mussel veligar tows: Toxic algae samples and zebra mussel veligar tows were performed monthly in 2006. Neither toxic blue-green (Cyanobacteria) blooms nor exotic zebra mussel larvae were found in the lake.

Watershed Inventory: Iowa County staff completed a watershed land use inventory of the Blackhawk Lake watershed using GIS. The total drainage area is 10,000 acres with croplands/agriculture contributing 43% (4300 acres), grasslands contributing 24% (2400 acres) and woodlands contributing 33% (3400 acres). An animal waste or nutrient management evaluation was not completed as part of this study.

Predictive modeling: The Wisconsin Lake Model Suite (WILMS) estimated the annual lake flushing rate at 2.07 times per year giving an annual average water residence time of 0.48 years. The phosphorus loading module estimated that the most likely annual phosphorus input to the lake is 5013 Lbs/year. Figure 37 shows that agricultural land uses, encompassing roughly 50% of the watershed, contribute over 80% of the nutrient load. Since barnyards were not inventoried as part of the analysis, the total phosphorus loading may be greater. The combined grassland and woodland areas contribute less than 20% of the annual phosphorus loading.

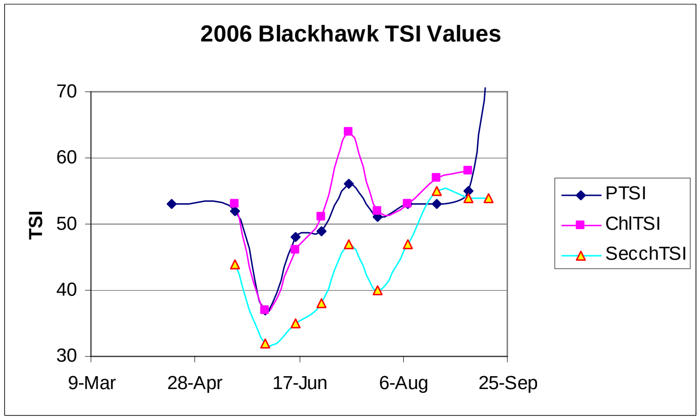
2006 Blackhawk TSI Values
TSI
70
60
50
40
30
9-Mar
28-Apr
17-Jun
6-Aug
25-Sep
PTSI
ChlTSI
SecchTSI

Figure 37

Discussion

The reasons for the favorable water clarity in Blackhawk Lake can not be completely ascertained with the available information. From a regional perspective, the Blackhawk Lake Trophic State Indices reflect better conditions than other impoundments within the Driftless Area of Wisconsin. This finding is not new. WDNR staff (1978) considered Blackhawk Lake to be the best impoundment in southwest Wisconsin based on observed water quality. Conventional wisdom suggests that the impoundment should have greater algal blooms and reduced water clarity given the large agricultural watershed to lake surface area ratio (45:1). Tributary monitoring and dominant agricultural land uses indicate significant sources of sediment and phosphorus in the watershed. Given the favorable water clarity most of the year, nutrient inputs may be deposited in the inlet bays where dense aquatic plant communities can absorb some of the nutrients. The rooted plants may also be competing with algae. Large-bodied zooplankton may be present and therefore keeping certain algal blooms in check but they were not analyzed as part of this study. The 2006 TSI data indicated that water clarity measurements were better than the chlorophyll and phosphorus data would otherwise predict (Figure 37). Zooplankton, rooted plants, certain species of algae and other ecological factors may be at work but information needed to confirm these potential interactions is not available.

While the bottom discharge from the 9-right basin is removing approximately 800 lbs/year of readily available phosphorus from the lake, significant sources of phosphorus loadings from the watershed still result in a large annual phosphorus gain to the lake.

The hypolimnetic discharge had very significant effects on both the lake and stream below the dam. Heat gain in the 9-right basin resulted in a less pronounced thermocline and increased the potential for nutrient entrainment of phosphorus into the epilimnion. Without a stable thermocline, fluctuating nutrient levels also occurred near the bottom. It was not clear if the fluctuating phosphorus in Figure 11 and ammonia in Figure 18 levels in the hypolimnion were caused by entrainment of oxygen rich epilimnetic water, fluctuating creek flows into the bottom of impoundment or both.

In August of 2002, negative effects of the hypolimnetic release were also measured. On August 7th of that year, the secchi depth was measured at 14.5 ft. The lake was stratified with a bottom temperature of 61 degrees F. Two weeks later, the lake had de-stratified following a strong southwest wind and the bottom temperature increased to 69 degrees F. The secchi depth declined to 4.8 feet. A similar event was observed in 2007 when the lake again destratified in August. Changes in bottom concentrations of both ammonia and phosphorus suggested bottom nutrients became available for algal production and resulted in the reduced water clarity. Hypolimnetic phosphorus and ammonia concentrations in early August declined from 928 ug/l and 2.24 mg/l to 235 ug/l and 0.58 mg/l respectively.

The dissolved oxygen profiles in 2006 indicated slightly greater oxygenated water volume at 9-right compared to 9-left (Figures13 & 14). Larger water volume (a thicker epilimnion) with dissolved oxygen at 9-right may have indicated effects of the bottom release or more turbulence due to wind mixing. The temperature profiles in Figures 16 and 17 demonstrated the great heat gain in 9-right and indicated why that basin of the lake de-stratifies earlier than 9-left. Earlier de-stratification can cause algal blooms from mid to late summer while a sustained pronounced thermocline will delay de-stratification, and likely algal blooms, until air temperatures drop in the fall and the lake naturally mixes.

By mid-summer, the effects of the hypolimnetic release on Otter Creek below the dam were evident. Water samples indicated high phosphorus and ammonia levels in the stream. The presence of filamentous bacteria indicated significant organic pollution that is typical of poorly treated domestic and industrial effluent. Both fish and macroinvertebrate communities reflected the polluted conditions below the dam. Low dissolved oxygen contributed to the degraded conditions along with high ammonia, hydrogen sulfide and phosphorus.

Similar conditions of weak thermal stratification in the lake and downstream water degradation were also observed with the release of hypolimnetic water at White Mound Lake and Twin Valley Lake.

Management Alternatives

Runoff pollution control: The long term health of Blackhawk Lake is ultimately linked to the surrounding watershed. While the lake has displayed better than average conditions thus far, continued nutrient loading from the watershed could ultimately tip the balance and lead to greater algal blooms and other nuisance conditions. A focused effort to better define current practices, including how soil and nutrients are currently managed could be completed, followed by an effort to implement nutrient and soil management plans for all farmers in the watershed. A number of federal and state cost share programs are available for conservation practices such as nutrient management and for the acquisition of property or purchase of protective easements. This effort could include working to expand the federal Conservation Reserve Enhancement Program to include the Blackhawk Lake area, obtaining easements on critical land areas to remove them from production, encouraging extensions of CRP, and purchase of land using local, state, or federal sources.

Removal of accumulated sediment: Historical sediment and nutrient loads captured in the inlet areas of Sunny Ridge, Narveson, Griffith, and Otter Creek, estimated to be approximately 44,000 cubic yards as of 2007, should be evaluated for future removal. Trap efficiencies of these inlet bays have been significantly reduced over the past 35 years and, unless accumulated material is removed from these areas, future nutrient and sediment loadings will become more available to aquatic plants within the lake proper.

Eurasian watermilfoil control: The discovery of Eurasian watermilfoil in the lake last summer was not encouraging. Rapid response eradication efforts may be the best option for preventing further spread of a serious threat to habitat, recreation and ecological balance in the lake.

Lake discharge options: The original installation of the bottom discharge gate was designed to create trout habitat below the lake. Given the significantly greater public use of the lake compared to the stream, coupled with numerous other healthy trout streams in the region, this same design feature could arguably be used to optimize lake conditions instead. Some experimentation may be desirable.

1. **100% surface release:** The potential benefits of surface release include discharge of algal blooms and associated phosphorus downstream. Discharging surface water containing phytoplankton has provided benefits in some impoundments. Slightly less phosphorus would be removed from the system. Dissolved oxygen profile data suggests that a 100% surface discharge would result in slightly less oxygenated epilimnetic volume, but significance from a fish habitat perspective would be minor. The 100% release would sustain thermal stratification longer and delay algal blooms, and their severity, until the lake naturally mixed in the fall but a significant amount of readily available phosphorus would not be removed from the lake. The tailrace fisheries of warm water species would be greatly improved with a surface water discharge.

2. **Maintain existing bottom/top mixed discharge:** The current system with the fixed gage height resulted in hypolimnetic discharge flows ranging from 48% to 88% of the total flow. Generally, greater bottom discharge occurs during drought periods in late summer. While water quality data suggests that removal of phosphorus from the lake has beneficial effects on lake water quality, the downstream water quality has been impaired. Premature mixing of the lake, which was caused by excessive bottom withdrawals, has resulted in late summer algae blooms, where they otherwise would not have occurred until the lake naturally mixed later in the fall.

3. **Increasing bottom discharge:** Increasing bottom discharges while reducing surface water discharge could lower lake water quality by entrainment of more phosphorus into the epilimnion by causing premature mixing. An increased bottom discharge could exacerbate existing downstream water quality problems at some times during the summer. Increased bottom discharge would likely result in the cool bottom waters being depleted sooner, resulting in more heat gain and loss of cold water discharge sooner than occurs under present operation.

4. **Reducing bottom discharge**: Increasing surface water release would likely result in greater algal export and more pronounced thermal stratification. Premature destratification of the lake, along with concurrent algal blooms, could be prevented. However, concentrations of ammonia, phosphorus and hydrogen sulfide would still be released and could cause downstream water quality degradation even at lower rates.

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Appendix A

Blackhawk Lake Planning Grant Deliverables

The goal of the lake planning grant is to establish baseline water quality, biological and recreational use data, will define watershed size, land uses and influences on lake water quality, as well as develop hydrologic and nutrient budgets and loading reduction strategies for Blackhawk Lake. The combined projects will determine how different hypolimnetic water release scenarios will affect lake water quality and balance watershed nutrient inputs.

The results from both phases of the overall study will be needed for lake and watershed modeling and management recommendations for long term lake protection. Furthermore, outlet management must avoid downstream use impairments. Otherwise, water quality standards violations could result in 303(d) designation.

The final report from Phases 1 and 2 will:
1. evaluate various scenarios for water withdrawal and recommend an optimal mix to maintain high quality recreation and fisheries in the lake, while preventing water quality degradation and supporting fisheries downstream;
2. prioritize specific lake and watershed management needs and set long term goals for Blackhawk Lake, its watershed and Otter Creek below the dam;
3. recommend stream classification for Otter Creek below the dam;
4. complete a comprehensive management plan for the lake and watershed;
5. be used to amend the Lower Wisconsin Basin Plan at the time of the next update.

The final report will be prepared in standard report format with summary, introduction, methods, results, discussion and recommendations, submitted in both electronic and paper form.

Phase One

The goal of Phase 1 is to establish baseline water quality, biological and recreational use data for Blackhawk Lake and Otter Creek below the dam to:
1. determine the potential effect of various scenarios of hypolimnetic withdrawal rates on the water quality of both Blackhawk Lake and Otter Creek below the dam;
2. develop specific management recommendations to support the multiple uses of Blackhawk Lake – i.e. recreational uses such as swimming, boating and aesthetics; fisheries and aquatic life; and flood control.

Phase 1 Project Deliverables

A report summarizing the results of the Phase 1 monitoring program will be prepared. The report will include:
1. pertinent literature reviews and review of WDNR historical data;
2. summary and interpretation of physical and chemical data for the lake and outlet;
3. summary and interpretation of biological data for the lake (fisheries, aquatic plants, invasive species and blue-green algae) and Otter Creek below the dam (fisheries);
4. 3-parameter (Secchi, total phosphorous and chlorophyll) trophic state index (TSI) trends analysis;
5. lake stratification characteristics including hypolimnetic characteristics such as volume, temporal stability and chemistry;
6. summary of recreational use surveys to help set lake protection/management goals;
7. specific recommendations for lake protection and management to support the multiple uses of Blackhawk Lake – i.e. swimming, boating, aesthetics, fishing, aquatic life and flood control.

Phase Two

The goal of Phase 2 is to develop hydrologic and nutrient budgets for Blackhawk Lake.
Watershed land uses will be mapped using GIS and aerial photography and influences on lake water quality will be modeled to develop loading reduction strategies. If further hypolimnetic withdrawal will be justified for lake water quality, understanding the relationship between watershed nutrient imports and export is just as important as understanding thermal stratification and internal loading dynamics within the lake.

Phase 2 Project Deliverables

A report will be prepared that includes:

1. results and recommendations from the Phase 1 study of the physical, chemical and biologic condition of Blackhawk Lake and Otter Creek below the dam;
2. hydrologic and nutrient budgets for Blackhawk Lake;
3. watershed land uses and estimates of loading;
4. WILMS modeling results;
5. macroinvertebrate data for tributaries and Otter Creek below the dam;
6. evaluation of the overall impacts of the watershed and outlet flow regime on the water quality of the lake as well as the downstream conditions;
7. recommendations regarding loading reductions;
8. goals and recommendations for comprehensive management of the watershed, the lake and the outlet to benefit lake water quality and recreational uses;
9. evaluation of various scenarios for water withdrawal to determine an optimal mix to maintain high quality recreation and fisheries in the lake, while preventing water quality degradation and supporting fisheries downstream;
10. specific recommendations for protection and management to support the multiple uses of Blackhawk Lake;
11. recommend stream classification for Otter Creek below the dam.

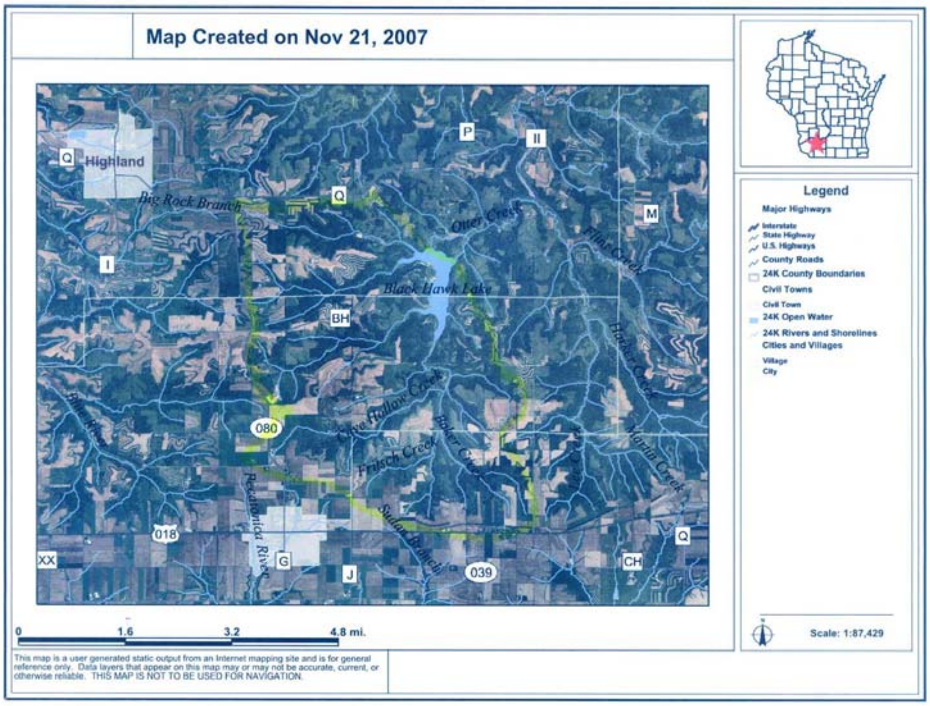
Appendix B

BLACKHAWK LAKE MONITORING PLAN, 2006

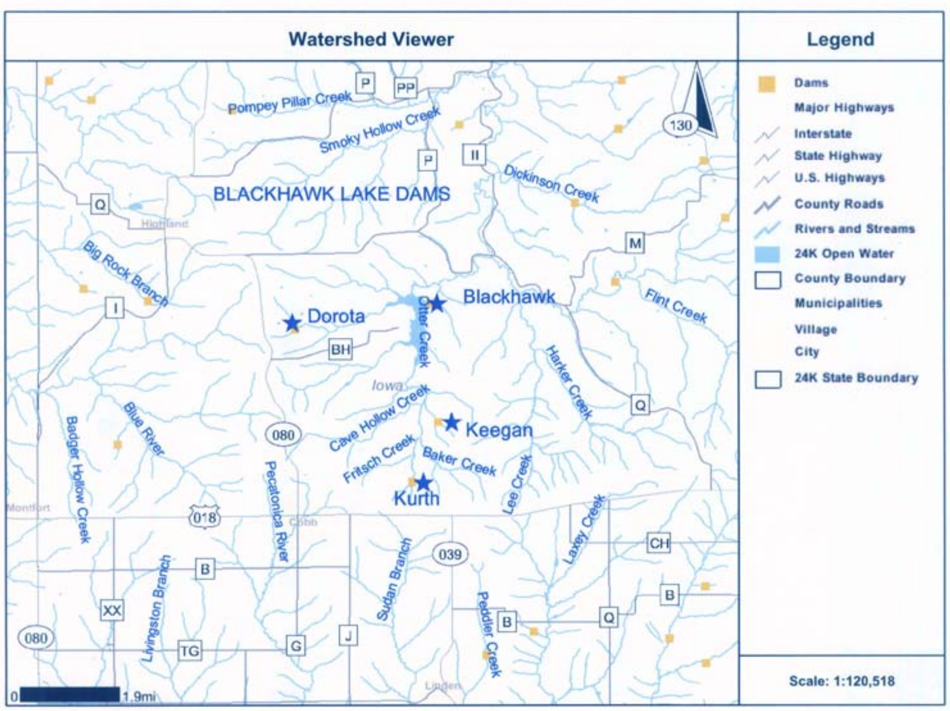
TASK	**WHO**										WEEK OF, 2006															SPR
Phase 1	Consultant	4/17	5/14	5/21	5/28	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/23	7/30	8/6	8/13	8/20	8/27	9/3	9/10	9/17	9/24	10/1	10/8	10/15	2007
IN-LAKE WQ Deep Ho	Volunteer, or																									
Secchi disk	DNR Lakes	DNR/V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	DNR	V
Temp/DO Profile		DNR/V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	DNR	V
Conductivity (field)			C		C		C		C		C		C		C		C		C		C		C		DNR	
pH (field)			C		C		C		C		C		C		C		C		C		C		C		DNR	
Total Phosphorous		DNR/V	C		C		C		C	V	C		C	V	C		C	V	C		C		C		DNR	
(Surface, Middepth, Bottom, IF stratified, otherwise surface only)																										
Chlorophyll a					C		C		C	V	C		C	V	C		C	V	C		C		C		DNR	
(surface)																										
Ammonia (Bottom)									C		C		C		C		C		C		C		C			
BOD (after DO<1)																	C		C							
In-Lake WQ - left (N) basin																										
Secchi	C or V could		V	V		V		V		V		V		V		V		V		V		V		V	DNR	
	do																									
Temp/DO profile	C or V could	DNR	V	V		V		V		V		V		V		V		V		V		V		V	DNR	
	do																									
Blue-Green Algae	DNR-LAKES							DNR			DNR			DNR			DNR			DNR						
Aquatic Plants	DNR-LAKES							DNR						DNR												
Zebra Mussels/																										
Waterfleas Tow	DNR-LAKES							DNR						DNR			DNR									
Zebra Mussel plates	DNR-LAKES																									
(hung from dock)	& VOLS																									
Chinese Mystery Snails								DNR									DNR									
IN-LAKE FISHERIES																										
Boom Shocker Survey (entire shoreline using baseline protocols)																										
* 55 degrees Fall '06																									X	
* 60 degrees spr '07																										X
Mini-Fyke net (2 set													XXX													
nights - 4 nets) July 2006																										
Phase 1	Who		5/14	5/21	5/28	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/23	7/30	8/6	8/13	8/20	8/27	9/3	9/10	9/17	9/24	10/1	10/8	10/15	2007
OUTLET WQ																										
Temp. logger																										
Gene will provide & install 8)																										
download monthly																										
well (spillway outlet)																										
just dstr Plank Road																										
upstream Flint Creek																										
downstr Flint Creek																										
Total Phosphorous at	C		C		C		C		C		C		C		C		C		C		C		C		C	
spillway outlet																										
Ammonia	C				C		C		C		C		C		C		C		C		C		C		C	
at spillway outlet																										
pH (field)	C		C		C		C		C		C		C		C		C		C		C		C		C	
DO (field)	C		C		C		C		C		C		C		C		C		C		C		C		C	
DO sag following 3	TU																									
storm events																										
1/2 hr before sunrise																										
OUTLET FISHERIES																										
Otter Creek																										
btwn Plank Rd &	DNR-FISH																									
Narvesan Creek	V																									
upstream of Flint	DNR-FISH																									
Creek	V																									
downstream of Q	DNR-FISH																									
bridge (j w/Flint)	V																									
bottom end of	DNR-FISH																									
trout water (II)	V																									
NOTE: stocked fish records made available and fish marked if need be to avoid any confusion																										
TASK	**WHO**										WEEK OF, 2006															
Tributary Sampling																										
Phase 2		3/5	3/12	3/19	3/26	4/2	4/9	4/16	4/23	4/30	5/7	5/14	5/21	5/28	SE1	SE2	SE3	SE4	SE5							
Lake Gage		V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V							
Flow										C		C		C	V	V	V	V	V							
Stage Recordings										C		C		C	V	V	V	V	V							
Turbidity Tube								DNR		DNR		C		C	V	V	V	V	V							
Total Phosphorous								DNR		DNR		C		C	V	V	V	V	V							
DATE		5/28	6/4	6/11	6/18	6/25	7/2	7/9	7/16	7/23	7/30	8/6	8/13	8/20	8/27	9/3	9/10	9/17	9/24	10/1	10/8	10/15	10/22	10/29	...	2007
Lake Gage		V	V	V		V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Flow			C		C		C		C		C		C		C		C		C		C		C		C	
Stage Recordings			C		C		C		C		C		C		C		C		C		C		C		C	
Turbidity Tube			C		C		C		C		C		C		C		C		C		C		C		C	
Total Phosphorous			C		C		C		C		C		C		C		C		C		C		C		C	
Macroinvertebrates																										
Inflow Tributary			C																							
Outlet 1 (just)			C																							
dwnstrm Plank Rd																										
Outlet 2 2-1/2 mi			C																							
dwnstrm Plank Rd																										
Recreational Use Survey			BHL																							
	C=Consultant, V= Volunteer																							12/21/2005		

Appendix C

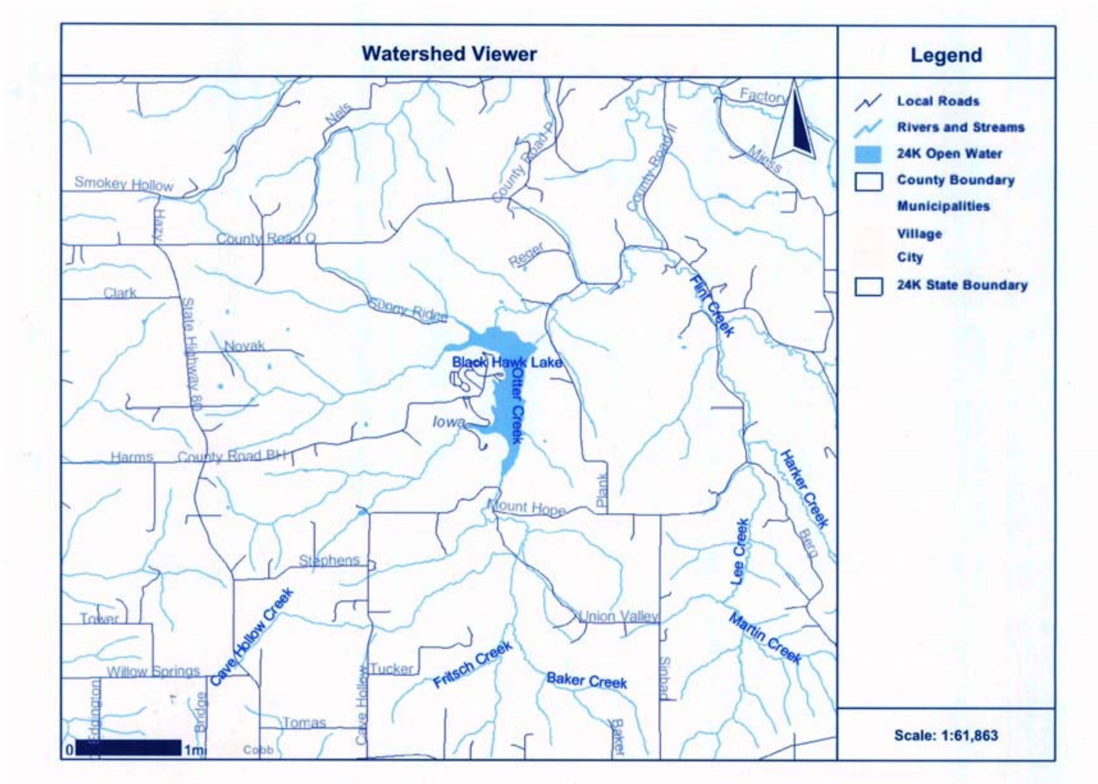
Blackhawk Lake Watershed



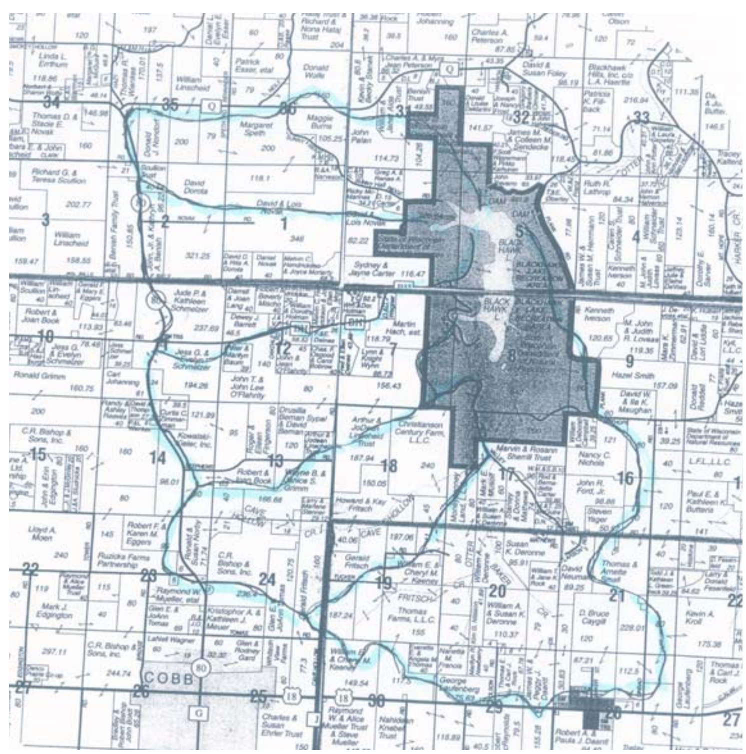
Dams in the Blackhawk Lake Watershed



Blackhawk Lake Local Stream & Road Network



Blackhawk Lake Watershed Landowners



Blackhawk Lake Watershed Active Farmers

Kevin Kroll	Laura & Mort Crowley
James Daentl	Kowalski-Kieler, Inc.
Thomas Small	Curtis Zimmerman
David Neumann	Jess Schmelzer
Carl & Tom Rock	John T O'Flahrity
George Laufenberg	John Lee O'Flahrity
Nanette Francis	Jude Schmelzer
Neal & Everette Thomas	Dave Novak*
Nancy Nichols	Sydney Carter
William Rock	William Holman
William DeRonne	Dave Dorota
Marilyn Newberry	John Benish
Steven Yager	Robert Eggers
Moneypenny Farms, LLC	Ruzicka Farms Partnership
Gerald & Tom Fritsch	Tom Wienkes
Glen Thomas	Don Nondorf
Christianson Farms LLC	John Linscheid*
Art Linscheid*	Margaret Speth
Wayne Grimm	Mike & Pat Wolfe*
CR Bishop & Sons	Maggie Burns
Ron Norby*	John Palan
Ken Iverson	William Aide
Robert Book	Greg Hall
Roger Fingerson	

*Landowners with animals

Appendix D

Blackhawk Lake Outlet
Stage-Discharge Relationships

Staff Gage Height on Riser	Bottom Discharge (cfs)	Top Discharge (cfs)
1.60	3.8	0.5
1.62	4.0	0.86
1.64	4.2	1.3
1.66	4.4	1.7
1.68	4.6	2.2
1.70	4.9	2.7
1.72	5.1	3.3
1.74	5.3	3.9
1.76	5.6	4.5
1.78	5.8	5.1
1.80	6.0	5.8
1.82	6.3	6.5
1.84	6.5	7.3

2006 Outlet Stage and Flow Data

Date	Stage – Staff Gage	Bottom Flow & %	Top Flow
April 17	1.68	4.6 cfs (68%)	2.2 cfs (32%)
May 10	1.77	5.7 cfs (54%)	4.8 cfs (46%)
May 17	1.78	5.8 cfs (53%)	5.1 cfs (47%)
May 26	1.72	5.1 cfs (61%)	3.3 cfs (39%)
June 1	1.83	6.4 cfs (48%)	6.9 cfs (52%)
June 15	1.70	4.9 cfs (64%)	2.7cfs (36%)
June 22	1.70	4.9 cfs (64%)	2.7 cfs (36%)
June 28	1.70	4.9 cfs (64%)	2.7 cfs (36%)
July 7	1.6	3.8 cfs (88%)	0.5 cfs (12%)
July 11	1.68	4.6 cfs (68%)	2.2 cfs (32%)
July 21	1.64	4.2 cfs (76%)	1.3 cfs (24%)
July 25	1.64	4.2 cfs (76%)	1.3 cfs (24%)
Aug 8	1.68	4.6 cfs (68%)	2.2 cfs (32%)
Aug 22	1.6	3.8 cfs (88%)	0.5 cfs (12%)
Aug 31	1.66	4.4 cfs (72%)	1.7 cfs (28%)
Sept 6	1.68	4.6 cfs (68%)	2.2 cfs (32%)
Sept 19	1.68	4.6 cfs (68%)	2.2 cfs (32%)

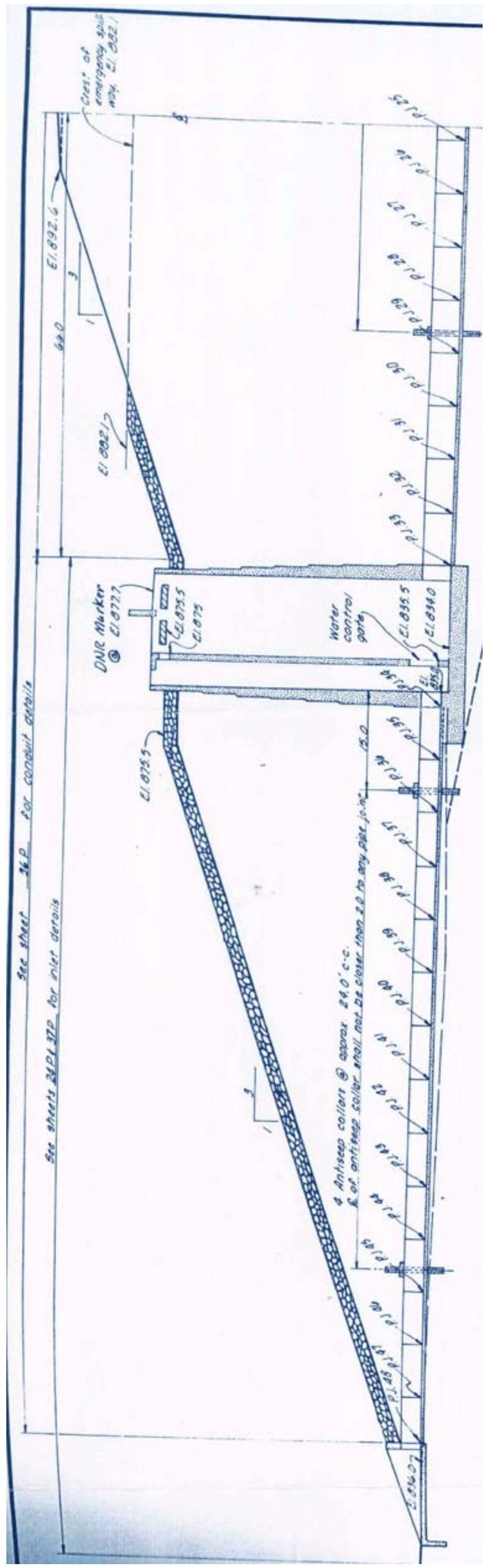
Appendix E

Otter Creek Fish Shocking Surveys

Common name	Environmental Indicator	Aug. '06	May '04	July '02	July '00	July '99	July '79	Aug. '62
Brook trout	Cold – Intol		2					
Brown trout	Cold	10	41	2	3	6		
Rainbow trout	Cold		3					
Northern pike	Warm						2	
Carp	Warm – Tolerant			1	4			
C. stoneroller	Warm	2				5		38
Hornyhead chub	Warm		99	17	10	97		33
Bigmouth shiner	Warm							13
Rosyface shiner	Intolerant							1
Common shiner	Warm		99	99	23	33		99
Suckermouth minnow	Warm							63
Southern redbelly dace	Warm		38			2		99
Bluntnose minnow	Tolerant		2			3		32
Fathead minnow	Tolerant			9				
Blacknose dace	Tolerant		1			15		1
Longnose dace	Warm					3		4
Creekchub	Tolerant	4	21					1
White sucker	Warm – Tolerant	27	99	99	99	51	99	21
Northern hogsucker	Intolerant							1
Shorthead redhorse	Warm							1
Black bullhead	Warm	1	1		3		42	
Yellow bullhead	Tolerant	15		1				
Brook stickleback	Cool	17	2					
Green sunfish	Tolerant	9		1	1		23	
Pumpkinseed sunfish	Warm						7	
Bluegill	Warm			70			44	
Black crappie	Warm			1			7	
Smallmouth bass	Warm-Intolerant						1	
Largemouth bass	Warm			6	8	2	7	
Fantail darter	Warm	12	99			57		7
Johnny darter	Warm	13	1	1		1		47
Yellow perch	Warm			2			6	
Walleye	Warm						1	
Cold-cool		**2**	**4**	**1**	**1**	**1**	**0**	**0**
Intolerant		**0**	**1**	**1**	**0**	**0**	**1**	**2**
Tolerant		**5**	**4**	**5**	**3**	**3**	**3**	**4**
Warm		**8**	**10**	**12**	**7**	**11**	**11**	**16**
Species Richness		**10**	**14**	**13**	**8**	**12**	**11**	**16**
Cold IBI		**10**	**10**	**10**	**0**	**0**	**10**	**30**

Appendix F

Blackhawk Lake Dam Cross Section



Appendix G
2006 pH Profiles

9 right

Depth	17-May	1-Jun	15-Jun	28-Jun	11-Jul	25-Jul	8-Aug	22-Aug	6-Sep
0.5	8.95	8.6	8.8	8.5	9.1	9.1	10	9.5	8.8
1	8.9	8.6	8.9	8.6	9.1	9.2	10	9.5	8.9
2	8.88	8.6	8.9	8.6	9.3	9.4	10.1	9.7	8.7
3	7.8	8.6	8.9	8.6	9.3	9.4	10	9.6	8.7
4	8.02	8.5	8.8	8.6	9.2	9.4	10	9.6	8.7
5	7.96	8.4	8.7	8.5	8.9	8.8	8.8	9.2	8.7
6	7.93	8.4	8.3	7.9	8.4	8.2	8.6	8.4	8.4
7	7.84	7.7	8.6	7.8	7.9	8.1	8.4	8.1	7.8
8	7.59	7.6	7.8	7.8	7.8	7.9	8.3	8	7.6
9	7.51	7.5	7.4	7.6	7.7	7.8	8.2	7.8	7.6
10	7.43	6.4	7.3	7.6	7.7	7.7	8.1	7.7	7.5
11			7.2		7.6	7.6	7.9	7.4	7.3
12			7.1						
12.5			6.9						
bottom	10	10	12.5	10.5	11	11	11	11	11

9 left

Depth	17-May	1-Jun	15-Jun	28-Jun	11-Jul	25-Jul	8-Aug	22-Aug	6-Sep
0.5	8.92	8.6	8.9	8	9.1	9.1	9.2	9.1	8.9
1	8.92	8.6	8.9	8.4	9.3	9.2	9.6	9.2	8.9
2	8.91	8.6	8.9	8.6	9.3	9.2	9.9	9.2	8.9
3	8.4	8.5	8.8	8.7	9.2	9.4	9.9	9.2	9
4	8.12	8.1	8.2	7.9	8.8	8.1	8.4	8.1	7.6
5	7.82	7.9	8	7.7	7.7	7.8	8.2	7.8	7.3
6	7.4	7.7	6.8	7.7	7.6	7.6	7.9	7.3	7
7	6.6	7.7	6.7	7.6	7.5	7.5	7.5	6.9	6.7
bottom	7.2	7.2	7	7	7	7	7	7	7

2006 Temperature Profiles, degrees C

9 right

Depth	17-May	1-Jun	15-Jun	28-Jun	11-Jul	25-Jul	8-Aug	22-Aug	6-Sep
0.5	14.7	23.7	22.1	23.3	25.1	26.9	26.9	25	23.1
1	14.6	23.4	22.1	23.2	25.3	26.8	26.9	24.9	22.9
2	14.6	23.3	22	23.2	25.3	26.8	26.9	24.8	22.9
3	14.5	22.6	22	23.2	25.3	26.7	26.8	24.8	22.7
4	14.2	18.9	21.4	21.8	25.2	26.3	26.8	24.7	22.6
5	13.6	17.8	20.8	20.2	24.6	25.5	25.9	24.4	22.5
6	13.3	16.1	18	17.8	22.6	22.9	24.5	24.1	22.4
7	13.1	14.9	16.8	16.6	20	21.6	22.3	22.2	22.2
8	13	14.2	15.8	15.4	17.7	18.9	20.2	21.6	21.1
9	12.8	14	14.7	14.9	16.3	17.4	19	19.7	20.4
10	11.9	13.5	14		15.1	16.4	18.2	18.4	19.2
11			13		13.9	15.4	16.8	17.3	18.4
12			12.5		13				
12.5			12.1		12.6				
bottom	10.5	10.5	12.5	10.5	12.5	11	11	11	11

9 left

Depth	17-May	1-Jun	15-Jun	28-Jun	11-Jul	25-Jul	8-Aug	22-Aug	6-Sep
0.5	14.5	24.1	22.2	23	24.8	26.6	26.6	24.6	22.8
1	14.2	23.6	22.2	23	25.1	26.6	26.6	24.5	22.3
2	14	23.4	22	22.7	25.1	26.6	26.6	24.4	22.1
3	13.7	19.3	20.7	22.3	25.1	26.3	26.4	24.1	22
4	13.2	16.4	19.2	20.1	21.9	22.4	23.7	22.2	20.5
5	12.8	14.9	17.1	17.8	19.6	19.7	20.6	19.4	18.4
6	12.3	13.7	15.4	16.4	16.5	16.6	17	17.3	16.4
7	11.8	13.4	14.6	15.4	15.3	15.3	14.1	14.2	14.9
bottom	7.2	7.2	7	7	7	7	7	7	7

2006 In Lake D.O. mg/l Profiles

9 right

Depth	17-May	1-Jun	15-Jun	28-Jun	11-Jul	25-Jul	8-Aug	22-Aug	6-Sep
0.5	10.9	9.7	9.3	8.5	11.7	11.1	9.7	9.6	9.6
1	11	9.8	9.3	8.6	12	11.4	9.8	9.5	9.2
2	11.1	9.7	9.4	8.6	12.2	11.5	9.9	9.3	8.7
3	10.8	10	9.4	8.6	12.2	11.5	9.8	9	8.4
4	11	10.5	9.2	8.6	12.1	10.3	9.8	8	5.3
5	10.3	10.3	8.3	8.5	10.6	5.5	9.6	3.5	5.3
6	9.2	10.1	7	7.9	6.5	0.2	0.4	0.3	2.4
7	8.9	8.1	8.9	7.8	0.3	0.1	0.2	0.1	0.3
8	8.5	6.6	8.1	7.8	0.2	0.1	0.1	0.1	0.2
9	8.1	5.6	3.4	7.6	0.1	0.1	0.1	0.1	0.1
10	6.7	3.7	1	7.6	0.1	0.1	0.1	0.1	0.1
11			0.1		0.1	0.08	0.1	0.1	0.1
12			0.08		0.1				
12.5			0.06		0.08				
bottom	10.5	10.5	12.5	10.5	12.5	11	11	11	11

9 left

Depth	17-May	1-Jun	15-Jun	28-Jun	11-Jul	25-Jul	8-Aug	22-Aug	6-Sep
0.5	11.4	10.4	9.7	8	11.4	11.1	9.4	9.4	9.8
1	11.1	10.2	9.8	8.4	12.1	11.6	10	9.4	9.8
2	10.9	10.1	9.8	8.6	12.1	11.5	10	9.3	9.5
3	10.9	12.5	10.7	8.7	12.9	10.2	9.7	4.9	8.9
4	10.5	7.5	5.3	7.9	20	1.7	0.7	0.4	0.1
5	9.4	5.8	4.2	7.7	0.3	0.2	0.3	0.2	0.1
6	8.6	1.8	1	7.7	0.2	0.1	0.1	0.2	0.08
7	0.4	1.4	0.2	7.6	0.1	0.1	0.1	0.1	0.08
bottom	7.2	7.2	7	7	7	7	7	7	7

2006 Measured Flows

Flow CFS

	outlet	Otter	Griffith	Narveson	Sunny Ridge
17-Apr					
1-May					
17-May	9.3	8.5		1.2	0.7
30-May		15.3	3.4		
1-Jun					
6-Jun					
15-Jun	11	4.8	1.2		
28-Jun	10.5	5.3	1.2	1.6	0.42
11-Jul	11.2	5.1	2	4.2	0.53
25-Jul	6.3	3.2	1.8	0.7	0.2
8-Aug	7.2	3.9			
22-Aug	3.9	3			
6-Sep	7.2				

2006 Stream Turbidity Tube (inches)

	Outlet	Otter	Griffith	Narveson	Sunny Slope
17-Apr		11.5			
1-May		16.5	17.25	13	23.5
17-May	23.5	23.5		23.5	23.5
30-May		13	0.5		
1-Jun					
6-Jun		23.5	18	12	23.5
15-Jun	23.5	23.5	23.5		
28-Jun	23.5	11	17	17	23.5
11-Jul	23.5	13.5	11.5	1	23.5
25-Jul	23.5	23.5	19	17.5	23.5
8-Aug	23.5	23.5			
22-Aug	23.5	23.5			
6-Sep					

2006 Stream Temp C

	Outlet	Otter	Griffith	Narveson	Sunny Slope
17-Apr					
1-May					
17-May	13.9	12.8		12.2	10.9
30-May		16.7	16.5		
1-Jun	20.2	19.3	19.5		
6-Jun					
15-Jun	17.5	13.3	13		
28-Jun	19.1	16.4	15.2	15	13
11-Jul	19.1	15.7	13.6	14.4	13.4
25-Jul	19.5	17.2	14.3	16.2	15.1
8-Aug	21.7	19			
22-Aug	20.5	16.6			
6-Sep	20.3				

2006 Stream D.O. mg/l

	Outlet	Otter	Griffith	Narveson	Sunny Slope
17-Apr					
1-May					
17-May	10.9	11.5		10.3	9.9
30-May		8	7.2		
1-Jun	10	9.9	9.5		
6-Jun					
15-Jun	8.7	9.6	10.4		
28-Jun	9	9.3	8.9	9.4	7.9
11-Jul	8	8.4	8.2	9.1	5.3
25-Jul	6	7.6	9	6.1	10
8-Aug	6.6	10.1			
22-Aug	5	9.6			
6-Sep	6.6				

Appendix H

Flow Data and Comparisons

Measured Inlet Flows CFS

	Otter	Griffith	Narveson	Sunny Ridge
17-Apr				
1-May				
17-May	8.5		1.2	0.7
30-May	15.3	3.4		
1-Jun				
6-Jun				
15-Jun	4.8	1.2		
28-Jun	5.3	1.2	1.6	0.42
11-Jul	5.1	2	4.2	0.53
25-Jul	3.2	1.8	0.7	0.2
8-Aug	3.9			
22-Aug	3			
6-Sep				

Estimated Flows - Based on Drainage Area Comparisons by Month with USGS Flow Gaging on Otter Creek

April	Otter	Griffith	Narveson	Sunny Ridge
1	3.7	1.3	1.1	1.0
2	3.7	1.3	1.1	1.0
3	7.1	2.5	2.2	2.0
4	6.1	2.2	1.9	1.7
5	5.0	1.8	1.5	1.4
6	4.6	1.6	1.4	1.3
7	6.0	2.2	1.8	1.7
8	6.0	2.2	1.8	1.7
9	5.0	1.8	1.5	1.4
10	4.6	1.6	1.4	1.3
11	4.3	1.5	1.3	1.2
12	4.2	1.5	1.3	1.2
13	4.0	1.4	1.2	1.1
14	3.9	1.4	1.2	1.1
15	3.7	1.3	1.1	1.0
16	8.4	3.0	2.6	2.3
17	20.5	7.3	6.3	5.7
18	10.4	3.7	3.2	2.9
19	8.3	3.0	2.5	2.3
20	7.1	2.5	2.2	2.0
21	6.3	2.3	1.9	1.8
22	5.8	2.1	1.8	1.6
23	5.5	2.0	1.7	1.5
24	5.1	1.8	1.6	1.4
25	4.8	1.7	1.5	1.3
26	4.6	1.6	1.4	1.3
27	4.5	1.6	1.4	1.2
28	4.2	1.5	1.3	1.2
29	4.1	1.5	1.3	1.1
30	6.3	2.2	1.9	1.7

May	Otter	Griffith	Narveson	Sunny Ridge
1	8.4	3.0	2.6	2.3
2	7.9	2.8	2.4	2.2
3	7.0	2.5	2.1	1.9
4	6.7	2.4	2.0	1.9
5	5.9	2.1	1.8	1.6
6	5.5	2.0	1.7	1.5
7	5.2	1.9	1.6	1.4
8	4.9	1.7	1.5	1.4
9	4.9	1.7	1.5	1.4
10	5.2	1.9	1.6	1.4
11	4.8	1.7	1.5	1.3
12	5.7	2.0	1.7	1.6
13	5.5	2.0	1.7	1.5
14	5.2	1.9	1.6	1.4
15	5.5	2.0	1.7	1.5
16	5.6	2.0	1.7	1.6
17	5.5	2.0	1.7	1.5
18	5.2	1.9	1.6	1.4
19	4.8	1.7	1.5	1.3
20	4.6	1.6	1.4	1.3
21	4.4	1.6	1.3	1.2
22	4.1	1.5	1.3	1.1
23	4.0	1.4	1.2	1.1
24	4.0	1.4	1.2	1.1
25	4.5	1.6	1.4	1.3
26	4.5	1.6	1.4	1.3
27	4.1	1.5	1.3	1.1
28	4.0	1.4	1.2	1.1
29	3.7	1.3	1.1	1.0
30	5.0	1.8	1.5	1.4
31	6.4	2.3	2.0	1.8

June	Otter	Griffith	Narveson	Sunny Ridge
1	4.8	1.7	1.5	1.3
2	4.3	1.5	1.3	1.2
3	4.0	1.4	1.2	1.1
4	3.7	1.3	1.1	1.0
5	3.6	1.3	1.1	1.0
6	3.7	1.3	1.1	1.0
7	3.9	1.4	1.2	1.1
8	3.5	1.3	1.1	1.0
9	3.4	1.2	1.0	0.9
10	5.0	1.8	1.5	1.4
11	4.9	1.7	1.5	1.4
12	4.2	1.5	1.3	1.2
13	3.9	1.4	1.2	1.1
14	3.7	1.3	1.1	1.0
15	3.7	1.3	1.1	1.0
16	3.6	1.3	1.1	1.0
17	3.5	1.2	1.1	1.0
18	3.8	1.4	1.2	1.1
19	3.7	1.3	1.1	1.0
20	3.5	1.2	1.1	1.0
21	3.5	1.3	1.1	1.0
22	3.5	1.2	1.1	1.0
23	3.3	1.2	1.0	0.9
24	3.3	1.2	1.0	0.9
25	3.5	1.2	1.1	1.0
26	3.8	1.4	1.2	1.1
27	4.2	1.5	1.3	1.2
28	3.7	1.3	1.1	1.0
29	3.5	1.2	1.1	1.0
30	3.3	1.2	1.0	0.9

July	Otter	Griffith	Narveson	Sunny Ridge
1	3.3	1.2	1.0	0.9
2	3.3	1.2	1.0	0.9
3	3.3	1.2	1.0	0.9
4	3.3	1.2	1.0	0.9
5	3.2	1.1	1.0	0.9
6	3.1	1.1	0.9	0.9
7	3.1	1.1	0.9	0.9
8	3.0	1.1	0.9	0.8
9	3.1	1.1	0.9	0.9
10	3.1	1.1	0.9	0.9
11	3.3	1.2	1.0	0.9
12	4.2	1.5	1.3	1.2
13	3.5	1.2	1.1	1.0
14	3.5	1.3	1.1	1.0
15	3.3	1.2	1.0	0.9
16	3.2	1.1	1.0	0.9
17	3.1	1.1	0.9	0.9
18	3.0	1.1	0.9	0.8
19	3.0	1.1	0.9	0.8
20	4.5	1.6	1.4	1.2
21	4.4	1.6	1.3	1.2
22	4.0	1.4	1.2	1.1
23	3.8	1.4	1.2	1.1
24	3.5	1.3	1.1	1.0
25	3.2	1.2	1.0	0.9
26	3.3	1.2	1.0	0.9
27	3.3	1.2	1.0	0.9
28	4.8	1.7	1.5	1.3
29	4.0	1.4	1.2	1.1
30	3.6	1.3	1.1	1.0
31	3.4	1.2	1.0	0.9

Aug	Otter	Griffith	Narveson	Sunny Ridge
1	3.2	1.1	1.0	0.9
2	3.1	1.1	0.9	0.9
3	3.0	1.1	0.9	0.8
4	2.9	1.0	0.9	0.8
5	2.8	1.0	0.9	0.8
6	3.4	1.2	1.0	0.9
7	3.8	1.4	1.2	1.1
8	3.1	1.1	0.9	0.9
9	3.0	1.1	0.9	0.8
10	3.0	1.1	0.9	0.8
11	2.9	1.0	0.9	0.8
12	2.8	1.0	0.9	0.8
13	2.7	1.0	0.8	0.8
14	2.7	1.0	0.8	0.8
15	2.7	1.0	0.8	0.7
16	2.6	0.9	0.8	0.7
17	2.6	0.9	0.8	0.7
18	2.8	1.0	0.9	0.8
19	2.8	1.0	0.9	0.8
20	2.7	1.0	0.8	0.8
21	2.7	1.0	0.8	0.7
22	2.6	0.9	0.8	0.7
23	2.6	0.9	0.8	0.7
24	3.1	1.1	0.9	0.9
25	4.5	1.6	1.4	1.2
26	3.8	1.4	1.2	1.1
27	3.3	1.2	1.0	0.9
28	3.2	1.1	1.0	0.9
29	3.2	1.1	1.0	0.9
30	3.0	1.1	0.9	0.8
31	2.9	1.0	0.9	0.8

Sept	Otter	Griffith	Narveson	Sunny Ridge
1	2.9	1.0	0.9	0.8
2	2.8	1.0	0.9	0.8
3	2.8	1.0	0.9	0.8
4	3.5	1.3	1.1	1.0
5	3.2	1.2	1.0	0.9
6	3.0	1.1	0.9	0.8
7	2.9	1.0	0.9	0.8
8	2.8	1.0	0.9	0.8
9	2.8	1.0	0.9	0.8
10	3.0	1.1	0.9	0.8
11	4.9	1.7	1.5	1.4
12	10.7	3.8	3.3	3.0
13	7.8	2.8	2.4	2.2
14	5.0	1.8	1.5	1.4
15	4.3	1.5	1.3	1.2
16	4.0	1.4	1.2	1.1
17	3.7	1.3	1.1	1.0
18	3.6	1.3	1.1	1.0
19	3.5	1.2	1.1	1.0
20	3.3	1.2	1.0	0.9
21	3.2	1.1	1.0	0.9
22	3.4	1.2	1.0	0.9
23	3.5	1.2	1.1	1.0
24	3.5	1.2	1.1	1.0
25	3.2	1.2	1.0	0.9
26	3.1	1.1	0.9	0.9
27	3.1	1.1	0.9	0.9
28	3.0	1.1	0.9	0.8
29	3.0	1.1	0.9	0.8
30	3.0	1.1	0.9	0.8