Report: Long Lake Drawdown Feasibility Study

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Long Lake Day and Night, Stillwater, MN
2005

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1. **Background**

Drawing the Long Lake water level down over the winter was identified as a method to improve water quality as well as to accomplish several other objectives identified in the 2006 Long Lake Management Plan.

The question of whether Long Lake can be drawn down to a level to achieve the following objectives has been addressed by conducting a feasibility study over the past several months.

- Consolidate loose bottom sediments
- Eliminate bottom-stirring rough fish
- Reduce nuisance submerged aquatic plants
- Stimulate growth of beneficial emergent aquatic plants
- Provide opportunity to remove sediment deltas and construct sediment trap/fore bays

The scope of the study is limited to answer the specific question: Is the drawdown of Long Lake a feasible alternative for obtaining these objectives. The report does not consider or attempt to articulate potential drawdown impacts beyond these items or permit considerations.

2. **Lake Hydrology**
   
   **a. Elevation and Volume Modeling**

   Bathymetric data for Long Lake was collected by lowering a weighted, graduated tape until it settled on the lake bed at transects across the lake. Approximately 600 depth data points were collected throughout the lake and wetland with concentration of depth data collection around the known saddle areas dividing the lake basins. The depths were surveyed using Differential GPS with the lake bed elevation being derived from the depth measurement from the surface water elevation. The GPS was calibrated to a local MNDOT benchmark (NAVD 88 datum).

   EOR survey elevation data points were combined with DNR 5 foot bathymetric data to develop a triangulated irregular network (TIN) model of the lake bottom. The ArcGIS 3D Analyst Surface Volume tool, which calculates the area and volume of a TIN surface, was used to calculate stage storage volume at elevations along with the corresponding lake bed 3 dimensional area. Figure 1 displays the resulting lake TIN model and calculated contours used for the volume analysis. Results of this analysis are displayed in Figure 1.
As Figure 1 displays, Long Lake consists of 3 main sub-basins divided at elevations of approximately 886.1 feet and 885.4 feet. Depth samples at the divides between the sub-basins were determined to aid in developing a pump sequence strategy and for individual sub-basin volume calculations.
The total controlled volume (volume below the v-notch) of Long Lake and Jackson WMA is approximately 123 million gallons and 18 million gallons respectively. Volume totals displayed in Table 1 are summed from a reference elevation of 890 feet, or about the elevation of the weir overflow structure above the v-notch on Long Lake. Elevation above the control flow out is included to account for freeboard volume as Long Lake typically maintains a water surface elevation above the v-notch on the structure.

### Table 1: Basin Area and Volume Analysis

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*Volumes displayed in Table 1 begin from a reference elevation above the control structure therefore 100% of lake area exposed represents a greater volume than the controlled volume below elevation 889.0 feet.

Figure 2 displays the elevation depth profile sampled via GIS along the lake bathymetric TIN running from the inlet at 62nd Street to the final outlet of the Jackson WMA at C.S.A.H 12. In order to avoid muck clogging of the pump equipment, the intake will need to remain between 1 and 2 feet above the lake bottom. Numerous smaller ‘pockets’ of water will remain throughout the lake once drawn down. Assuming that the profile in Figure 2 represents the majority of the lake bed, most of these pockets of water will not exceed 2 feet in depth should the lake be drawn down to the maximum extent. Figure 3 shows the approximate surface water footprint that would remain in the sub-basins and Jackson WMA following a drawdown to depth 1.5 feet.

Notice that a significant area of the central and south sub-basin will remain wet after a drawdown. It would likely require a laborious effort to remove additional water from the many pockets in this shallow area in order to allow beneficial desiccation for soil and vegetation to occur.
Figure 2: Lake Depth Profile (Alignment displayed in Figure 1)

Long Lake-Jackson WMA Bottom Profile

- Inlets controlled above 889.0 feet
- ~886.1 feet
- ~885.4 feet

Long Lake South Basin
Long Lake Central Basin
Long Lake North Basin

V-notch
Elevation @ 889.0 feet

30° RCP (2)
Elevation @ 888.8 feet

Emmons & Olivier Resources, Inc.
water | ecology | community
Figure 3: Post Drawdown Surface Water Footprint
A range of pump sizes are available to draw the lake down at rates from 1 cubic foot per second (cfs) up to 40 cfs. The District XP-SWMM model was updated with the surveyed bathymetry data for Long Lake and multiple model runs were conducted using a generic pump curve to establish the range of drawdown times available. As displayed in Figure 4, the entire volume of Long Lake can be drawn down in as little as 6 days if pumped 24 hours a day at a very high rate. The recommended average pumping rate downstream is 15 cfs for the reasons discussed in the Role of Downstream Conveyances section of this report.

b. Hydraulic Modeling and Pump Configuration Plan

A range of pump sizes are available to draw the lake down at rates from 1 cubic foot per second (cfs) up to 40 cfs. The District XP-SWMM model was updated with the surveyed bathymetry data for Long Lake and multiple model runs were conducted using a generic pump curve to establish the range of drawdown times available. As displayed in Figure 4, the entire volume of Long Lake can be drawn down in as little as 6 days if pumped 24 hours a day at a very high rate. The recommended average pumping rate downstream is 15 cfs for the reasons discussed in the Role of Downstream Conveyances section of this report.

Figure 4: Drawdown Rate Comparison

Pumping can be staged simultaneously from 2 stationary locations in Long Lake and one in Jackson WMA as displayed in Figure 5. Bathymetric mapping shows that though the majority of the volume in the southern sub-basin will be drained by pumping from the central and northern basins, only about 47% of the area may be exposed for this sub-basin of the lake. Pumping down to this level may be adequate to desiccate the fringe sediment and vegetation, however further drawdown would be required to reduce the floating aquatics that thrive in this area of the lake. As indicated by the red pump icon in Figure 5, the remaining volume in the southern basin can either be drawn down with mobile trash pumps, routing water into the central basin or possibly treated with piscicides (rotenone) to accomplish fish eradication.
Three main factors will determine the locations for the stationary pumps and are expanded upon below.

1. Lake access
2. Distance from shore to greatest depth in basin
3. Pumping pipeline alignment on lakeshore properties or floating in lake

Access to the lake will play the largest role in pump placement determination. The shaded areas in Figure 5 display parcels owned by the city of Stillwater, Washington County, or the Minnesota Department of Natural Resources. Coordination with the city on access to the lake will be crucial to effective set up of the stationary pumps as well as manipulating mobile pumps, should they be necessary. Temporary small access roads and platforms will likely be necessary to access the lakeshore from the public roadways for pump placement, refueling and maintenance.

The preliminary pumping plan includes the use of submersible pumps in the lake for the drawdown however a combination of submersible and on-shore centrifugal pumps may be needed to adequately dewater Long Lake. Pump intakes should be placed as close to the deepest sections of the lake as possible with the shortest travel distance from the shoreline as manipulating the pump equipment once in the lake is very difficult. Ultimately, pumping equipment selection would be left up to contractor preference to achieve the maximum drawdown level.

Ideally, the stationary pumps will be set up to discharge through a HDPE pipeline constructed along the shoreline. This manner of discharge is advantageous for pipe alignment, maintenance, and access during the pumping operation. Coordination with lakeshore residents will be necessary if the alignment of the pipeline will likely pass through private property. Should this not be a viable method, an in-lake floating pipeline can be constructed, however staging of this method requires adequate space for seaming the pipes together and the pipeline will be susceptible to wave and wind conditions during setup and pumping.

As Figure 2 shows, there is only two tenths of a foot in elevation change between the Long Lake v-notch elevation and the Jackson WMA outlet. It is therefore recommended that the outlet weir of Long Lake be temporarily raised in order to prevent backflow of water from Jackson WMA into Long Lake during the pumping period. Modeling results show that raising the weir overtopping to elevation 891.0 feet will adequately prevent backflow into the lake during pumping. The timing of a weir modification should be immediately prior to pumping to reduce the probability of rainfall inflow into the lake with the raised control. Consideration should be taken to assure the structure modification can easily be removed in order to relieve lake surface water elevation during the sequence of pumping.
Figure 5: Long Lake Drawdown Pump and Access Locations
c. Role of downstream conveyance on pump rates
Long Lake discharges beneath 72nd Street via twin 42 inch concrete culverts and then into an approximately 220 foot channel chocked with cattails before going into a small (less than 2 acre) open-water wetland. Water then flows through a 375 foot long flat bottom channel before entering Jackson WMA. Under normal conditions, the control structure on Jackson WMA acts to control the surface water elevation on Long Lake. The relatively shallow slope on the twin 30 inch pipes may impede discharge volumes to the channel downstream of County Road 12. The pipes are capable of conveying the flow when pumping at 40 cfs, however, as shown in Figure 6, looking downstream at Lake McKusick, the model shows that sustained pumping rates above 15 cfs may overwhelm the outlet at the south end of the lake. This condition will be further investigated should the study move to the next phase of realizing impacts from the project.

Figure 6: Lake McKusick Surface Water Elevation During Long Lake Pumping

Outlet design control elevation at 853.0. 
Model simulation start at 5-year average water surface elevation of 853.9.

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d. Upstream hydrologic connections
Upstream hydrologic connections to Long Lake were looked at to assess whether the drawdown will impact their water elevations. As Figure 2 shows, all known upstream ponds are controlled above the Long Lake control elevation and should not be impacted by drawing Long Lake down.

e. Groundwater inflow
Figure 7 displays the lake elevation record from 1996 to 2008. Observation of Long Lake elevations before and after the new control structure was installed reveal Long Lake to have maintained a surface water elevation above the control elevation with the exception of two dry periods in 2003 and 2007. It is recommended that a monitoring program be established to analyze lake water levels and inflows on a more frequent basis to determine whether surface water or groundwater is contributing to the lake maintaining water surface elevations above the control structure. Though a downward trend is observed on this chart after the control structure was installed in 2004, it is also based on the least frequent interval of data collection. This trend
could be a signature of the groundwater table lowering during this period as it is not uncommon for it to fluctuate over time. Installing rain, water level, and flow loggers to monitor Long Lake’s behavior would assist in determining whether this trend is corroborating evidence of local groundwater flow into the lake.

**Figure 7: Long Lake Elevation Record**

Discharge

Date | Elevation
--- | ---
10/28/1995 | 888.6
3/26/1996 | 888.8
8/23/1996 | 889.0
1/20/1997 | 889.2
6/19/1997 | 889.4
11/16/1997 | 889.6
4/15/1998 | 889.8
9/12/1998 | 890.0
2/9/1999 | 890.2
7/9/1999 | 890.4
12/6/1999 | 890.6
5/4/2000 | 890.8
10/1/2000 | 891.0
2/28/2001 | 891.2
7/28/2001 | 891.4
12/25/2001 | 891.6
5/24/2002 | 891.8
10/21/2002 | 892.0
3/20/2003 | 892.2
8/17/2003 | 892.4
1/14/2004 | 892.6
6/12/2004 | 892.8
11/9/2004 | 893.0
4/8/2005 | 893.2
9/5/2005 | 893.4
2/2/2006 | 893.6
7/2/2006 | 893.8
11/29/2006 | 894.0
4/28/2007 | 894.2
9/25/2007 | 894.4
2/22/2008 | 894.6

**f. Siltation**

Downstream of Long Lake is a rip rap stilling area leading into thick marsh of cattail and lily pads. This should provide sufficient energy dissipation from pumping as well as sediment settling from water being discharged. The adequacy of sediment removal will have to be determined through monitoring the turbidity of discharge. Pumping will likely disturb sediments in Long Lake that will ultimately be pumped downstream to some degree. Measures to reduce the amount of silt disturbance include rubber mats on the lake bed at the intake location and maintaining head above of the intake to prevent vortex from occurring. Further investigation into the effects of siltation due to pumping will be conducted during the impact analysis phase of this project.

Existing siltation has been documented at the some of the stormwater inlets to Long Lake. A complete or partial drawdown of the lake would allow for better access to remove the material in these areas. A dredging permit would need to be secured and proper disposal site located.

**g. Re-filling Hydrology**

The District’s XP-SWMM Model was used to run various recent precipitation records in order to determine the time it will take to re-fill Long Lake. Each of the last 3 years, a recent ‘dry’ time period (2006), a recent ‘wet’ time period (2005) and an average precipitation period (2007) were simulated assuming a complete drawdown of the lake to simulate a worst case scenario of time to
refill. The goal of the modeling was to determine the date at which the lake would return to the normal water elevation given the precipitation in the particular simulation.

As Figure 8 displays, under the precipitation scenarios of 2005-2007, the volume in Long Lake would have been re-established by the end of August of the following year. A partial drawdown would result in refill occurring earlier than displayed.

Figure 8: Long Lake Refill Analysis

h. Drawdown Cost Estimates
Cost estimates of two pumping options are displayed in Table 2. The costs are based on the estimated costs from the 2008 drawdown of Northwest and Southwest Anderson Lakes. Lake drawdown project costs are largely case specific with pump rental and fuel/energy rates remaining constant. Of the two power options, the diesel powered pump is preferred due both for cost and for versatility to be able to mobilize them during the pumping sequence. It is anticipated that residents will be concerned with pump noise and re-fueling environmental concerns. The fuel option below are for noise attenuated pumps (down to 59 DBA at 7 meters), as well as includes re-fueling spill containment skirts for pollution prevention.

Table 2: Estimated Pumping Costs

<table>
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<th>Sound</th>
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<td>Electric Operation Pump Units (no power consumption)</td>
<td>-</td>
<td>$150,000</td>
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<tr>
<td>Sound Attenuated Diesel Pump Units (no fuel consumption)</td>
<td>-</td>
<td>$112,000</td>
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3. **Soil Desiccation and Rewetting Study**

Sediment response in Long Lake to a drawdown was simulated through a Soil Desiccation and Rewetting Study. The study replicated the drying and re-wetting of lake bottom sediments. In the study, extracted lake bottom sediment samples were subjected to air desiccation, re-wetting, and a series of freeze thaw cycles to simulate likely conditions that the lake sediments would endure in a lake drawdown. Results of this study aid in predicting the level of consolidation of the lake bottom sediments as well as the affect a drawdown may have on nutrient release.

**a. Sediment Core Locations**

Sediment cores were taken from regions of Long Lake where the lake bottom would be exposed during the proposed drawdown. Sediment samples were collected using a WaterMark Universal Core Head sediment corer. Sixty centimeter core tubes were manually forced into bottom sediments until bottom resistance precluded further advancement. Core location areas are illustrated in Figure 9. Six cores were retrieved at Site 1, and two cores from each of the other nine sites, for a total of 24 sediment cores.

Anticipated sediment thickness was determined from the Washington Conservation District (WCD) Long Lake Sediment Survey in 2004. Figure 9 shows the core location sites projected upon the WCD sediment thickness map. One explanation for the large discrepancy of sediment thickness between the two studies may be the protocol used in each study. The 2004 WCD study used a 0.75 inch diameter steel pipe pushed into the sediment and measured while the 2008 EOR study used a 71 millimeter diameter sediment sampler. Though the depth results in the 2004 study show a difference between sediment densities, it is not representative of the amount of sediment that could potentially consolidate as was found from the sampling performed in 2008 and in this feasibility study.
Figure 9: Sediment Core Locations
b. Sediment Desiccation and Rewetting

Sediment cores were stored in core racks and desiccated in a laboratory setting under oxic conditions. Throughout the desiccation and rewetting procedure, sample lengths were measured and samples were weighed to determine changes in length and mass. Initial core lengths are presented in Table 3. Due to the relatively small surface area of the samples and the length of sample tube above sample surface, fans were used to shorten the length of drying time by moving air across the core cylinders. Sediments were air dried from 10/31/08 till 12/19/08. Following the air drying process, samples were subjected to a battery of freeze-thaw cycles to mimic the process sediments would go through following a fall draw down. Freeze thaw cycles occurred between 12/19/08 to 3/24/09. Freeze thaw duration ranged from daily to five day intervals. Following the freeze-thaw process, samples were re-wetted using de-ionized water. De-ionized water was poured onto the frozen cores to limit re-suspension of organic matter and the cores were subsequently thawed. De-ionized water was analyzed by Pace Labs to ensure it was devoid of soluble reactive phosphorus (SRP) prior to re-wetting. Water was then extracted from 14 cores and submitted for soluble reactive phosphorus (orthophosphate as P) analysis at Pace Laboratory. Table 3 displays the results of sample consolidation values and released SRP for each site.

Table 3: Core Desiccation and Phosphorus Values

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<th>SRP (mg/L)</th>
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<td>0.79</td>
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<td>0.20</td>
<td>0.092</td>
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*ND (Non-Detect) = <0.020 mg/L

c. Sediment Desiccation and Rewetting Results

Sediment cores showed little consolidation in the desiccation and rewetting experiment. The average consolidation was 0.22 feet (2.6 inches), with a range of 0.12 feet (1.4 inches) to 0.29 feet (3.5 inches). To the organic content of site 1B, 2B, 6B, and 8B was analyzed to determine the ratio of organic material to inorganic. The average organic content of the sediment cores was 22.7% with a range of 10 to 40%; supporting the lack of sediment consolidation. Due to finding minimal consolidation of near-shore lake bottom sediments, there would likely be negligible gain in the creation of improved macrophyte rooting substrate and nominal reduction in nutrient release through sediment suspension. Any gain of sediment consolidation achieved in the desiccation process may be negated by wave and wind action as the lake re-fills the following spring. Greater water depths are unlikely to be achieved through desiccation.
Average soluble reactive phosphorus released following the desiccation experiment was 0.19 mg/L, with values ranging from less than 0.020 mg/L to 0.74 mg/L. Fabre (1988) observed a pulse of P from sediments after refilling in a reservoir, which was attributed to elevated pH and re-suspension as a result of refill. SRP released from 1C, 1D, and 2B are relatively high in comparison.

4. Rough Fish removal and restocking plan
Carp removal has led to clearer water and healthier game fish populations in other Minnesota lakes (e.g., Hanson et al., 1990 report on Crystal Lake, MN; Lake Hanska MN, 1998). The combination of drawdown and chemical treatment is particularly effective. Chemical treatments with the piscicide Rotenone can guarantee full rough fish removal when applied to populations concentrated into smaller areas by drawdown. Late autumn or winter chemical treatments in drawn down lakes enhance winterkill, while the Rotenone oxidizes rapidly into non-toxic forms allowing re-stocking immediately the following spring. To ensure long term benefits, removal of rough fish from nearby ponds is also recommended. Public cooperation and help from local household pond companies is required to avoid re-introducing Koi from ornamental ponds.

a. Determination of fish response to drawdown
Drawing down the level of a lake over the winter is a management tool to induce winterkill. Shallow lakes do not necessarily form a layer of denser 4°C water that protects fish from the less dense but colder water above (the layer that forms ice). The shallow, cold water can then lead directly to fish mortality from freezing and can also exacerbate anoxic conditions.

When ice forms, the only addition to oxygen is winter algae. Decomposition and respiration can easily over take rates of winter photosynthesis and lead to hypoxia (low or no dissolved oxygen that kills fish). Shallower lakes are more susceptible to this effect because the overall oxygen supply is smaller but the proportion of littoral zone (and decaying plant matter) is larger. These factors make drawdown an effective tool for eliminating fish, by creating shallower conditions that increase the probability of freezing and/or hypoxia. This strategy is enhanced if there is heavy snow cover on the ice that blocks light and interferes with algal production.

Koi (Cyprinus carpio koi) and black bullhead (Ameiurus melas) are resilient to low oxygen conditions in winter that kill other fish (winter-kill). Carp in particular are surprisingly resilient to winter kill and have been known to survive in water as shallow as 0.28 m under 0.4 m of ice (Verril et al., 1995). Even in conditions that kill many rough fish, some will survive and populations rapidly rebound. On the other hand it is unlikely that non-target fish will survive drawdown and fish mortality will likely begin with non-target species before targeted rough fish are affected.

Rough fish response to drawdown alone is not predictable and does not guarantee full removal. Lake drawdown will, however, concentrate the rough fish into smaller areas, making them easier to remove with other means.

b. Current inventory from DNR records
The Minnesota Department of Natural Resources does not stock fish in Long Lake because there is no public access. DNR staff report that a combination of the high numbers of rough fish (koi and bullheads), shallow water, and cultural eutrophication make it an unlikely candidate for sustainable fisheries according to DNR records.

c. Current inventory of rough fish distribution
Koi and bullhead presence has been determined in Long Lake and the Jackson WMA from early DNR reports and recent, direct. Koi have also been anecdotally reported from a nearby pond (Brewer’s Pond and other smaller ponds). Any water body can serve as a reservoir for Koi and/or bullheads and there is a high likelihood of re-invasion of Long Lake from these ponds (see Figure 10).
d. Fish eradication methodology

Drawdown alone is unlikely to entirely eliminate rough fish from Long Lake, but it is an important step in facilitating chemical and mechanical removal. Once levels have been drawn down, chemical treatment is an extremely effective means of removing all fish. Rotenone is the recommended piscicide due to low residence time and total effectiveness (Chapman et al., 2003). Combining rotenone treatment with drawdown has been effective in removing rough fish from
similar lakes (e.g. Helsel et al., 2003) and is a common management recommendation (Wydosi et al., 1999) and is a technique to guarantee Koi removal from Long Lake.

The ideal treatment time for chemical treatment is just before ice formation. Rotenone is most often used at 20°C, primarily to ensure quick breakdown for immediate re-stocking. Treating just before ice formation would give the chemical more residence time (and more effectiveness), and does not lead to environmental concerns because even at 0°C, rotenone will break down in 3.5 days, slightly longer if there is immediate ice formation covered by snow (Gilderhaus et al., 1986).

Even under optimum pumping efficiency, up to 2 feet of water may remain in the sub-basins of Long Lake and Jackson WMA. Rotenone would need to be applied to each pocket of water left after drawdown (the amount based on the surface area of each remaining pool).

There are 11 nearby ponds that contribute to Long Lake (Figure 10). Re-establishment of carp over the distances required (50 to 1300 feet) is highly likely either by human, animal, or hydrological vector. Even rough fish elimination programs that have led to re-established sport fisheries and better water quality have been subject to re-invasion by rough fish within 10 years (Helsel et al., 2003). This makes eliminating potential sources near Long Lake very important. The ponds would not be impacted directly by the drawdown, but are small enough that rotenone application will be very effective and could be applied at the same time as the Long Lake treatment.

The cost of rotenone treatment is estimated at $229 per acre, based on actual costs of recent work on Lake Hanska, MN by the DNR and recent estimates from two contractors. The total cost estimate is based on the ideal pumping operations and the most conservative estimates for set-up and application. Costs for treating surrounding ponds are shown separately in Table 4. One method of removal of fish from the ponds is to sein net each pond to a) confirm rough fish presence and b) remove as many rough fish as possible prior to treatment. If rough fish can be confirmed absent from a pond, cost of rotenone treatment can be saved for that pond. This survey would require at least 2 field technicians working for 3 days at a cost of $6,300, which is close to the overall cost of chemical treatment (highest estimate of $6,600).

Given the cost of a fish survey rigorous enough to confirm rough fish presence, the benefit of complete eradication outweighs the few hundred dollar difference. The short residence time of rotenone makes this a safe and cost-effective option. Even with seining, the possibility of a false negative (counting a pond as fishless when it does have fish) risks the immediate possibility of re-introduction of rough fish to Long Lake, jeopardizing the costs of the whole operation.

Table 4. Cost projection for fish removal after drawdown for Long Lake

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (assume 1.5 ft depth)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotenone, Long Lake</td>
<td>$9,000</td>
</tr>
<tr>
<td>Rotenone, Jackson WMA</td>
<td>$900</td>
</tr>
<tr>
<td>Rotenone set-up and labor 1 (lakes)</td>
<td>$10,000</td>
</tr>
<tr>
<td>Rotenone, surrounding ponds</td>
<td>$6,600</td>
</tr>
<tr>
<td>Rotenone set-up and labor 2 (ponds)</td>
<td>$10,000</td>
</tr>
<tr>
<td>Mechanical removal (Long and Jackson)</td>
<td>$8,500</td>
</tr>
<tr>
<td>Spring seine netting</td>
<td>$8,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$53,000</strong></td>
</tr>
</tbody>
</table>
e. Fish re-stocking plan (and assessment of drawdown success)

Zooplankton and macroinvertebrates usually re-establish shortly after drawdown and fish removal. Desired fish re-stocking could start as soon as desired water levels are attained from spring re-fill, a procedure that has been successful in re-establishing fisheries after water levels return to normal (Helsel et al., 2003).

It is important to point out that Long Lake is shallow and eutrophic enough for frequent winter-kill, and permanent establishment of a sports fishery may be impossible. The deeper area in the northern portion of the lake would be a refuge from winter-kill if nutrient inputs were reduced, and managing the trophic system can be a key strategy to maintain water clarity. The likelihood of permanent game fish populations is increased as eutrophication issues are improved (reductions in surface run-off, reducing internal stirring from high wake by eliminating large motorboats, a healthy riparian and emergent littoral plant community, et cetera).

A stocking plan that is integrated with other lake improvements would be recommended. A stocking regime geared towards managing the top-heavy trophic levels will help maintain water clarity and stimulate macrophyte recovery. While centrarchid (pan-fish) fisheries are popular with families, stocking piscivores like northern pike (*Esox lucius*) and large mouth bass (*Micropterus salmoides*) will enhance water clarity improvements and help establish a trophic structure that maintains water clarity (French et al., 1999). Stocking too many fish or stocking only invertebrate/zooplankton predators can lead to dense periphyton that inhibits recovery of the macrophyte community and degrades water quality (Turner et al., 2005).

The stocking plan outlined in Table 5 is based on a two year cycle that ensures predators have prey to feed on. The bass fry in the first year should be able to survive on available invertebrates. Stocking a small amount of pan fish ensures a stable food source for the bass as they get larger, but high numbers are not desirable because they consume zooplankton, which can lead to an increase in undesirable algae.

In the second year, stocking is based on introducing larger predators to create a ‘top-heavy’ food web that will enhance other measures to improve water clarity. To help promote water clarity, fishing should be limited to smaller game fish but can be heavy on pan-fish.

For Long Lake, bass are recommended over walleye due to the depth profile and higher temperatures. Bass prefer warmer lakes than walleye and have a better chance of establishing in Long Lake for sustainable top-down control of algae blooms. Care should be taken not to introduce non-native minnows, leading to poor zooplankton populations and exacerbate algal blooms.

**Table 5. Post draw-down restocking plan for Long Lake, MN. * May substitute native minnow species for this trophic level if available.**

<table>
<thead>
<tr>
<th>Spring, year 1</th>
<th>Species</th>
<th>Common name</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Pomoxis nigromaculatus</em></td>
<td>Black crappie</td>
<td>500 fry per littoral acre*</td>
</tr>
<tr>
<td></td>
<td><em>Lepomis macrochirus</em></td>
<td>Bluegill</td>
<td>500 fry per littoral acre*</td>
</tr>
<tr>
<td></td>
<td><em>Micropterus dolomieu</em></td>
<td>Smallmouth bass</td>
<td>1,000 fry per littoral acre</td>
</tr>
<tr>
<td></td>
<td><em>Micropterus salmoides</em></td>
<td>Largemouth bass</td>
<td>1,000 fry per littoral acre</td>
</tr>
<tr>
<td>Spring, year 2</td>
<td>Species</td>
<td>Common name</td>
<td>Numbers</td>
</tr>
<tr>
<td></td>
<td><em>Micropterus salmoides</em></td>
<td>Largemouth bass</td>
<td>1,000 fry per littoral acre</td>
</tr>
<tr>
<td></td>
<td><em>Esox lucius</em></td>
<td>Northern pike</td>
<td>1,000 fry per littoral acre</td>
</tr>
</tbody>
</table>
Two recommendations are directed towards avoiding re-stocking the rough fish (koi and bullheads). First, it is recommended that a few simple fish surveys are conducted to assess re-stocking over the summer after drawdown and the following year, including relative survival rates over winter. This information will be necessary to determine if continued stocking is required or stocking patterns need to be altered. Second, intentional and unintentional re-stocking of koi or other carp can be avoided by public education and cooperation with landscaping contractors that install and maintain ponds. Since most companies that install ponds or water features for homeowners in Washington County also sell koi as ornamental pond fish, some effort should be spent to identify the most common contractors and solicit their cooperation for keeping koi out of Washington County lakes.

5. Analysis of plant community response
Long Lake historically has contained high levels of aquatic vegetation, including macrophyte species coontail (*Ceratophyllum demersum*) and elodea (*Elodea canadensis*). This is based on several vegetation surveys provided by the MN DNR from 1979, 1997, and a recent EOR survey in 2008 (See Figure 11). These two species of aquatic plants can be invasive, and in the case of Long Lake are considered present in nuisance levels.

The potential exists for managing aquatic plants by manipulating the lake’s water levels via drawdown. Numerous studies show that lake drawdown can cause both positive and negative impacts for controlling aquatic vegetation and that the response depends on multiple factors. That being stated, lake drawdown can bring at least short-term (1-2 years) control of some and probably most, rooted aquatic plant species if lake sediments are completely dewatered and a sufficient (1 month or more) period of extreme (freezing cold or very hot) temperatures affects the lake while drawn down (Cooke 1980). This required length of time is because rigorous conditions of exposure are needed to cause the desiccation of aquatic vegetation reproductive structures existing in the sediment (Weitkamp 2004).
Figure 11: Dominant Aquatic Vegetation Survey
a. Determination of aquatic vegetation response to drawdown
As previously stated, overwinter lake drawdown can temporarily control nuisance species of aquatic vegetation. However, the level of effectiveness in lake drawdown depends on the susceptibility of aquatic plant species to overwinter desiccation (Nichols 1975). Some aquatic species (such as pondweeds and including coontail and elodea), can be strongly resistant to this type of overwinter drawdown exposure (desiccation tolerance), and in several studies actually responded by increased growth following winter drawdown (Turner et al. 2005).

b. Determination of aquatic vegetation management
Lake phosphorus cycling is related to plant macrophyte density and decay, and therefore must also be taken into account when considering a lake drawdown. Rooted aquatic vegetation that is killed off during an overwinter drawdown would release harmful levels of available phosphorus into the lake once re-flooding has taken place, and therefore offer prime conditions for algal blooms to follow. In order to avoid this undesirable after effect, it has been found that harvesting dead aquatic plant material can result in removing significant amounts of phosphorus from the lake system (Carpenter and Adams 1978). This and numerous other studies suggest that repeated annual harvesting of aquatic plant material should be completed for a minimum of 10 to 15 years in order to sufficiently deplete sediment phosphorus. It should be noted however, that harvesting aquatic vegetative material alone can not serve to properly counteract the significant amounts of nutrient loading caused by urban runoff.

Additional studies have also looked at herbicide use in lakes, and often find this is an effect control method for short term reduction in nuisance aquatic vegetation levels (Richardson 2008, Granéli and Doris Solander 2004). Drawbacks of using herbicides to control nuisance aquatic vegetation include: high cost, possible damage to desirable species of aquatic vegetation, and the potential for the nuisance aquatic vegetation to take advantage of the disturbance and return to the lake community in large numbers (Cooke and Gorman 1980). Numerous studies have taken into account which specific herbicide compounds work most effectively at controlling which specific species of aquatic vegetation, and for the time being, coontail and elodea have been found to be most responsive to diquat and fluridone (Morris 1998).

At a minimum, the Long Lake drawdown is recommended only if the dewatering can last one month or more during the coldest month of the year. In addition, harvesting of the excess aquatic plant material would then be recommended to remove sediment phosphorus from the lake system. Repeated versions of these control measures should be strongly considered to maintain a lower level of aquatic plant biomass. Rough estimates of aquatic vegetation harvesting are $1,000 per acre, or about $100,000 for the benthic, littoral and fringe areas of Long Lake.
6. Conclusions
Conclusions from the study are divided into the individual components of analysis to address each of the objectives as described below.

a. Lake Drawdown Hydrology
   - Long Lake and Jackson WMA can feasibly be drawn down within the time frame of late fall, prior to the water bodies icing in and at a rate that would not overwhelm downstream resources.
   - Groundwater flux into and out of Long Lake remains unknown. An effort to draw the lake down and stay at a low surface water elevation could be complicated by influx of groundwater.
   - Long Lake is separated by earthen berms into 3 minor sub-basins. Multiple pumps would be necessary to effectively draw the sub-basins and Jackson WMA down. Stationary pumps will be able to draw the lake down to within 2 feet of the bottom at the intake location.
   - The footprint of water remaining in the south and central sub-basins at the 1.5 foot depth covers a large proportion of these areas, therefore requiring a significant effort, involving mobile pumps and platforms, to draw the lake water down to a level that will allow for adequate desiccation of sediments and vegetation.
   - Drawing Long Lake down by pumping would allow the opportunity to remove sediment deltas that have accumulated at the lake inlets.
   - The approximate cost of pumping Long Lake and Jackson WMA down ranges from $130,000 and $150,000 depending on the equipment used. This does not include the labor to draw the southern and central sub-basins down below the 1.5 foot depth due to the variability in level of effort required depending on the lake bottom profile and consistency once drawn down.

b. Lake Refill Hydrology
   - Modeling simulations found that Long Lake and Jackson WMA will refill to the control elevation (at 72nd Street and at TH12) within the season following a drawdown. Dates to refill range from the end of June during a wet season to the middle of August during a relatively dry season.
   - Upstream stormwater ponds will not be affected by drawing down Long Lake and Jackson WMA as they are controlled at elevations above the surface water elevation of these two water features.

c. Soil Desiccation and Rewetting Study
   - Average sediment core length was 0.84 feet; ranging from 0.60 to 1.10 feet. This is the distance a 68(ID) millimeter sediment corer could be depressed until resistance precluded further advancement. Sediment below this depth is considered consolidated and would likely not exhibit desiccation following a drawdown.
   - Average sediment consolidation was 0.22 feet; ranging from 0.12 feet to 0.29 feet. This small amount of consolidation would result in negligible gain of improved macrophyte rooting substrate and will not result in measurable water depth increases in Long Lake.
   - Average SRP released following the desiccation experiment was 0.19 mg/L; ranging from less than 0.02 mg/L to 0.74 mg/L. Release of SRP following a drawdown could result in a phosphorus spike, which is consistent with findings on other Lake drawdown studies.
o Any gain of sediment consolidation achieved in the desiccation process may be negated by wave and wind action as the lake re-fills the following spring.

d. Rough Fish Removal and Restocking Plan
  o Koi and black bullhead, both surveyed and observed in Long Lake, are resilient to low oxygen conditions in winter that kill other fish (winter-kill). Even in conditions that kill many rough fish, some will survive and populations rapidly rebound.
  o Chemical treatments with the piscicide Rotenone can guarantee full rough fish removal when applied to populations concentrated into smaller areas by a drawdown.
  o There are 11 nearby ponds that contribute to Long Lake. Re-establishment of carp over these distances is highly likely. The ponds are small enough that rotenone application would be very effective and could be applied at the same time as the Long Lake treatment.
  o Even rough fish elimination programs that have led to re-established sport fisheries and better water quality have been subject to re-invasion by rough fish within 10 years (Helsel et al., 2003).
  o The MNDNR will not sponsor a fish restocking program unless the water body has public access, adequate aeration, and a predator control plan in place. In the absence of these items the DNR is willing to provide guidance to other entities in developing such plans.
  o The approximate cost of rotenone treatment for Long Lake, Jackson WMA, and the surrounding ponds is $47,000 based on the acreage of surface to be treated and assuming a drawdown to 1.5 foot depth in Long Lake and Jackson WMA.

e. Vegetation Response to a Lake Drawdown
  o Lake drawdown can bring control of some rooted aquatic plant species if lake sediments are completely dewatered and a sufficient period of extreme (freezing cold or very hot) temperatures affects the lake while drawn down. Control of these species is has been found to be short-lived, on the order of 1 to 2 years before nuisance species regain root in the lake.
  o Aquatic vegetation such as pondweeds and including coontail and elodea, can be strongly resistant to over-winter drawdown exposure, and in several studies actually responded by increased growth following winter drawdown (Turner et al. 2005). This is consistent with the experience of the MNDNR on these species.
  o Long Lake historically has contained high levels of submerged aquatic vegetation, including macrophyte species coontail and elodea. Though these species are native to this area, they are considered present in nuisance levels. Drawdown of the lake could risk these species thriving in greater number in the following seasons.
  o Long Lake has a sufficient seedbed of emergent macrophytes that includes both desirable and nuisance species (bulrush, cattail, reed canary grass) that would likely thrive following a lake drawdown.
  o Drawdown of Long Lake would likely result in temporary control of floating leaved aquatics.
7. **Recommendations**

Given the conclusions arrived at for each component of the study, a full drawdown of Long Lake to achieve the goals set out in the Long Lake Management Plan is not recommended.

Partial drawdown of the lake to gain access to the sediment deltas at the southern end of the lake may be beneficial if this is viewed as a priority item for Long Lake. The nature of the dredged material and available disposal sites, as well as any permitting constraints will need to be assessed. The presence of groundwater flux into Long Lake should also be determined as it may negate any pumping of the lake for access and maintenance.

The northern sub-basin and Jackson WMA bathymetry are deep enough to potentially stratify and develop anoxic conditions which can augment the release of phosphorus from lake bottom sediments. A study to sample the actual phosphorus input from these areas of the Long Lake system, in combination with existing in-lake modeling, would determine the degree to which phosphorus loading from the sub-basins is disproportionate. If these areas in the system are found to contribute the majority of the internal phosphorus loading, a targeting treatment (alum, ferric chloride dosing, etc.) could be pursued.

Literature review of sediment disturbance from motor boats in shallow lakes has found that re-suspended sediments can increase biologically available phosphorus levels in the lake system. Consider a study to determine the contribution of phosphorus release from the various sources within Long Lake including recreational activities.

Continue lakeshore water quality improvements to achieve emergent vegetation improvements.
8. References


Weitkamp, D. E. 2004. Summary review: Lake Spokane drawdown effects to fish and aquatic habitat. FERC Project No. 2545, Avista Corporation