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PROJECT SUMMARY

Heims Lake is located in the City of Wyoming in Chisago County (DNR Lake ID: 13-0056-00) and eventually discharges to Comfort Lake. Heims Lake has a surface area of 91 acres, an average depth of ~4 feet, and a maximum depth of 6.2 feet.

Heims Lake has relatively good water quality, with a 3-year (2009, 2014 and 2015) growing season average phosphorus concentration of 41 µg/L, just slightly exceeding its District goal of 40 µg/L and well below the Minnesota water quality standard of 60 µg/L for shallow lakes. The aquatic plant community is diverse and established over the entire lake bed. The fish community is comprised of 5 pollutant tolerant species, commonly found in lakes that experience frequent winterkill. Heims Lake is currently in a clear water, aquatic plant dominated state. The watershed is small (three times the size of the lake surface area) with less than half of the watershed cropped or developed and very sandy soils, resulting in low watershed loads to the lake.

A water quality response model calibrated to observed in-lake phosphorus concentrations suggests that the lake is currently benefiting from a clear water, aquatic-plant dominated state, with lower observed in-lake phosphorus concentrations compared to the predicted in-lake phosphorus concentrations based on existing watershed loads. Future expected watershed changes include the development of two parcels along the south shore which will increase the septic system load to the lake, and conversion of cropland to developed land to the north of the lake which will decrease watershed runoff loads to the lake. Model scenarios indicated that improvements in lake water quality due to conversion of cropland to developed land are greater than reductions in lake water quality due to the construction of two additional septic systems. Moreover, the model scenarios indicated that the District goal of 40 µg/L can almost entirely be met through conversion of all 43 acres of cropland located north of the lake to developed land, at little to no cost to the District.

Overall, Heims Lake has very high water quality for a shallow lake in this region, and will benefit from protection of the diverse aquatic plant community established over the entire lake bed which is maintaining the clear water, aquatic plant dominated state. Improvements in Heims Lake water quality depend on future developments meeting District rule requirements, protection of the lakeshore buffer, and landowner education on proper septic system maintenance and general shoreline stewardship.
PROJECT BACKGROUND

The 2012-2021 Watershed Management Plan implementation initiative specified conducting lake water quality studies and developing management plans for lakes in the District that have not been evaluated (Figure 1). This report summarizes the results from a water quality study and management plan for Heims Lake completed in 2015. This lake is a high priority for the District because of current and expected future development pressures in the watershed (i.e., Heims Villas). This study will assist the District identify phosphorus reduction projects to meet the Heims Lake water quality goals set by the District, and ensure future development permits sufficiently protect the water quality of Heims Lake.

Figure 1. Lake Studies Schedule Map
WATER QUALITY TRENDS AND LAKE CONDITIONS

Lake and Watershed Conditions

Heims Lake is located in the City of Wyoming in Chisago County (DNR Lake ID: 13-0056-00) and eventually discharges to Comfort Lake. Heims Lake has a surface area of 91 acres, an average depth of ~4 feet, and a maximum depth of 6.2 feet. The watershed is approximately 258 acres (Figure 4), comprised of a mix of land uses: 29% cropland, 25% open water (including the lake surface), 15% forest, 13% developed, 9% wetland, and 8% pasture/grassland (Figure 5). Most of the watershed is composed of sandy, well drained soils (type A), with 25% of these soils overlain by wetlands (type A/D) and fully saturated (Figure 6). Infiltration potential in this watershed is very high and overland runoff depths were estimated to be approximately 5.9 inches based on the Sunrise SWAT model (Almendinger and Ulrich 2010). The climate for this lake was based on nearby meteorological data, with an average annual precipitation rate of 24.5 inches per year and an average annual evaporation rate of 24.5 inches per year.

The relationship between phosphorus concentration and the response factors (chlorophyll-\(\alpha\) and transparency) is often different in shallow lakes as compared to deeper lakes. In deeper lakes, algae abundance is often controlled by physical and chemical factors such as light availability, temperature, and nutrient concentrations. The biological components of the lake (such as microbes, algae, aquatic plants, zooplankton and other invertebrates, and fish) are distributed throughout the lake, along the shoreline, and on the bottom sediments. In shallow lakes, the biological components are more concentrated into less volume and exert a stronger influence on the ecological interactions within the lake. There is a more dense biological community at the bottom of shallow lakes than in deeper lakes because of the fact that oxygen is replenished in the bottom waters and light can often penetrate to the bottom. These biological components can control the relationship between phosphorus and the response factors.

The result of this impact of biological components on the ecological interactions is that shallow lakes normally exhibit one of two ecologically alternative stable states (Figure 2): the turbid water, algae-dominated state, and the clear water, aquatic plant-dominated state. The clear state is the most preferred, since algae communities are held in check by diverse and healthy zooplankton and fish communities. Fewer nutrients are released from the sediments in this state. The roots of the aquatic plants stabilize the sediments, lessening the amount of sediment stirred up by the wind. Heims Lake is currently in a clear water, aquatic plant-dominated state.

Nutrient reduction or addition in a shallow lake does not lead to linear improvement or degradation in water quality (indicated by turbidity in Figure 2). As external nutrient loads are decreased in a lake in the turbid state, slight improvements in water quality may at first occur. At some point, a further decrease in nutrient loads will cause the lake to abruptly shift from the turbid state to the clear state. Conversely, as external nutrient loads are increased in a lake in the clear water state, slight degradations in water quality may at first occur. At some point, further increase in nutrient loads will cause the lake to abruptly shift from the clear state to the turbid state. The general pattern in Figure 2 is often referred to as “hysteresis,” meaning that when forces are applied to a system, it does not return completely to its original state nor does it follow the same trajectory on the way back.
The biological response of the lake to phosphorus inputs will depend on the state that the lake is in. For example, if the lake is in the clear state, the macrophytes may be able to assimilate the phosphorus instead of algae performing that role. However, if enough stressors are present in the lake, increased phosphorus inputs may lead to a shift to the turbid state with an increase in algal density and decreased transparency. The two main categories of stressors that can shift the lake to the turbid state are:

- Disturbance to the macrophyte community, for example from wind, benthivorous (bottom feeding) fish, boat motors, water skiing, or light availability (influenced by algal density or water depth)
- A decrease in zooplankton grazer density, which allows unchecked growth of sestonic (suspended) algae. These changes in zooplankton density could be caused by an increase in predation, either directly by an increase in planktivorous fish that feed on zooplankton, or indirectly through a decrease in piscivorous fish that feed on the planktivorous fish.

This complexity in the relationships among the biological communities in shallow lakes leads to less certainty in predicting the in-lake water quality of a shallow lake based on the phosphorus load to the lake. The relationships between external phosphorus load and in-lake phosphorus concentration, chlorophyll-a concentration, and transparency are less predictable than in deeper lakes, and therefore lake response models are less accurate.

Another implication of the alternative stable states in shallow lakes is that different management approaches are used for shallow lake restoration than those used for restoration of deeper lakes.

Shallow lake restoration often focuses on restoring the macrophyte, zooplankton, and fish communities to the lake.

![Figure 2. Alternative Stable States in Shallow Lakes](image)
Figure 3. Heims Lake Bathymetry (EOR 2015)
Figure 4. Heims Lake Watershed
Figure 5. Heims Lake Watershed Land Cover (NLCD 2011)
Figure 6. Heims Lake Watershed Soils (Hydrologic Soil Groups)
Water Quality

Water quality data have been collected from Heims Lake in 2009, 2014, and 2015. Summer average phosphorus and chlorophyll-a concentrations were below the Minnesota water quality goal for shallow lakes in 2009, 2014 and 2015, and below the CLFLWD goal for Heims Lake in 2009 and 2015 (Table 1). Summer average Secchi depths were sometimes above the state and CLFLWD goals due to the lake depth being less than the clarity goal (i.e., visible to the lake bottom). Seasonal water quality trends are typical for aquatic plant dominated shallow lakes, with several small spikes in total phosphorus and chlorophyll throughout the summer, but fairly constant Secchi depth.

Table 1. Annual growing season (June – September) water quality

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Phosphorus (ug/L)</th>
<th>Chlorophyll-a (ug/L)</th>
<th>Secchi depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>SE</td>
<td>Average</td>
</tr>
<tr>
<td>2009</td>
<td>37</td>
<td>4.5</td>
<td>13</td>
</tr>
<tr>
<td>2014</td>
<td>52</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>2015</td>
<td>33</td>
<td>5.3</td>
<td>6.8</td>
</tr>
<tr>
<td>Average</td>
<td>41</td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

State Goal < 60 < 20 > 1.0
District Goal < 40 < 14 > 1.4

n/a = not available

Figure 7. Heims Lake seasonal water quality trends, 2009
Figure 8. Heims Lake seasonal water quality trends, 2014

Figure 9. Heims Lake seasonal water quality trends, 2015
Aquatic Plants

An aquatic plant survey was conducted by EOR on September 25, 2015 using a whole lake grid-point intercept survey. The lake grid coordinates were loaded into a GPS unit for ease in navigating to each grid point. At each grid point, a lake rake was cast into the water and retrieved to obtain aquatic plant specimens to identify. Lake depth at each grid point was also recorded to create a bathymetry map of the lake. A total of 24 aquatic plant species were found and no aquatic invasive species were found. Water clarity at the time of the survey was excellent and the lake bottom could be seen in areas where the vegetation was sparse.

During the aquatic plant survey, a landowner mentioned that there used to be an agricultural field that went up close to the lake. At that time, there was a lot of runoff from the agricultural field and the lake had less abundant aquatic vegetation with more turbid water than in 2015. The agricultural field has since been developed and the water started to clear up which probably helped the aquatic plants to thrive.

A floristic quality index (FQI) was calculated for Heims Lake to compare the quality of the aquatic plant community in Heims Lake to lakes with similar morphometry and location (Swink and Wilhem 1994; Rocchio 2007). A FQI uses aspects of conservation and rarity to allow for a representative calculation to be made that can be used to determine how much disturbance a given lake might have experienced (Rocchio 2007). Every aquatic plant in the state of Minnesota has been assigned a coefficient of conservatism value (C-value) ranging from 0 to 10. The C-value of all macrophytes sampled from a lake is used to determine the FQI for a given lake. Species with a C-value of 0 include species like curly-leaf pondweed because this species is non-native and indicative of a highly disturbed environment. In comparison, a species like Oakes pondweed has a C-value of 10 because this species is rare and only found in pristine settings.

The FQI score for Heims Lake based on the 2015 aquatic plant community was 26.9 (Table 2). The average FQI score for Minnesota Lakes is 23.7±8 with a median of 22.5 for lakes in the North Central Hardwood Forest ecoregion (Radomski and Perleberg, 2012). An FQI score greater than the state average suggests that Heims Lake supports a high quality aquatic plant community. Species with a C-value greater than 7 are considered to be intolerant to pollution; the presence of two species in Heims Lake with C-values greater than 7 suggests low levels of pollution are present in Heims Lake.
# Table 2. Heims Lake Aquatic Plant Community and FQI Score (EOR 2015)

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Coefficient of Conservatism (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coontail</td>
<td><em>Ceratophyllum demersum</em></td>
<td>3</td>
</tr>
<tr>
<td>Watershield</td>
<td><em>Brasenia schreberi</em></td>
<td>7</td>
</tr>
<tr>
<td>Small leaf pondweed</td>
<td><em>Potamogeton pusillus</em></td>
<td>7</td>
</tr>
<tr>
<td>Water celery</td>
<td><em>Vallisneria americana</em></td>
<td>6</td>
</tr>
<tr>
<td>Canada waterweed</td>
<td><em>Elodea canadensis</em></td>
<td>3</td>
</tr>
<tr>
<td>American white waterlily</td>
<td><em>Nymphaea odorata</em></td>
<td>6</td>
</tr>
<tr>
<td>Large-leaved pondweed</td>
<td><em>Potamogeton amplifolius</em></td>
<td>7</td>
</tr>
<tr>
<td>Robbins’ pondweed</td>
<td><em>Potamogeton robbinsii</em></td>
<td>8</td>
</tr>
<tr>
<td>Flat Stem Pondweed</td>
<td><em>Potamogeton zosteriformes</em></td>
<td>6</td>
</tr>
<tr>
<td>Small duckweed</td>
<td><em>Lemna minor</em></td>
<td>5</td>
</tr>
<tr>
<td>Water Stargrass</td>
<td><em>Heteranthera dubia</em></td>
<td>6</td>
</tr>
<tr>
<td>Common bladderwort</td>
<td><em>Utricularia macrorhiza</em></td>
<td>5</td>
</tr>
<tr>
<td>Wild calla</td>
<td><em>Calla palustris</em></td>
<td>8</td>
</tr>
<tr>
<td>Floating leaf pondweed</td>
<td><em>Potamogeton natans</em></td>
<td>5</td>
</tr>
<tr>
<td>Yellow water lily</td>
<td><em>Nuphar advena</em></td>
<td>6</td>
</tr>
<tr>
<td>Common spikerush</td>
<td><em>Eleocharis palustris</em></td>
<td>5</td>
</tr>
<tr>
<td>Broad-leaf cattail</td>
<td><em>Typha latifolia</em></td>
<td>2</td>
</tr>
<tr>
<td>Sago pondweed</td>
<td><em>Potamogeton pectinatus</em></td>
<td>3</td>
</tr>
<tr>
<td>Water smartweed</td>
<td><em>Polygonum amphibium</em></td>
<td>4</td>
</tr>
<tr>
<td>Illinois pondweed</td>
<td><em>Potamogeton Illinoensis</em></td>
<td>6</td>
</tr>
<tr>
<td>Northern water milfoil</td>
<td><em>Myriophyllum sibiricum</em></td>
<td>7</td>
</tr>
<tr>
<td>Northern blue flag</td>
<td><em>Iris versicolor</em></td>
<td>4</td>
</tr>
<tr>
<td>Hardstem bulrush</td>
<td><em>Schoenoplectus acutus var. acutus</em></td>
<td></td>
</tr>
<tr>
<td>Sessile-fruited arrowhead</td>
<td><em>Sagittaria rigida</em></td>
<td>7</td>
</tr>
<tr>
<td><strong>Average C Value</strong></td>
<td><strong>5.5</strong></td>
<td></td>
</tr>
<tr>
<td><strong>FQI Score</strong></td>
<td><strong>26.9</strong></td>
<td></td>
</tr>
</tbody>
</table>

FQI = C*√S  
C= Mean coefficient of conservatism value  
S= Number of species in sample
Figure 10. Heims Lake emergent aquatic plant distribution (EOR 2015)
Figure 11. Heims Lake floating leaf aquatic plant distribution (EOR 2015)
Figure 12. Heims Lake submergent aquatic plant distribution (EOR 2015)
Fish Community

Fish were surveyed in Heims Lake on September 26-27 and October 17 in 2015 using a combination of trap nets, seines, and backpack electrofishing consistent with current MNDNR survey techniques for small lakes by Dr. Joshua Lallaman, a biology professor with Saint Mary’s University in Winona, MN. Detailed sampling methods and results are reported in Appendix A.

A total of 5 fish species (totaling 34 individuals) were collected using both trap nets and the backpack electrofisher: bowfin, black bullhead, central mudminnow, brook stickleback, and fathead minnow. Fish biomass was dominated by bowfin and black bullhead. Both black bullhead and fathead minnow are omnivorous feeders that are capable of tolerating polluted or low quality water conditions (Drake and Pereira 2002). Bowfin and central mudminnows are both capable of gulping atmospheric air, allowing them to tolerate warm water with low oxygen concentrations (Scott and Crossman 1983). Bowfin are a top carnivore and are capable of reaching large sizes (> 30 inches), but no other carnivores or game species were present.

All fish collected were under 20 inches. Size distribution of fish suggests all fish captured were under three years of age. Given the shallow nature of the lake and high concentration of nutrients, Heims Lake is vulnerable winter or summer anoxia. The absence of any game species and the restricted size of tolerant species captured suggests Heims Lake has likely experienced recent and repeated fish kills due anoxia. The complete absence of game species suggests that no refugia exist for game species to survive significant anoxic events. Additionally, this suggests that Heims Lake lacks a significant tributary or migratory pathway for game species to naturally recolonize after winter kill events. Reports from local landowners suggest that game species were abundant in recent history (10-15 years ago), but no previous fish survey data could be found on the MNDNR website.
PHOSPHORUS SOURCES AND SCENARIOS

Phosphorus loads to Heims Lake were estimated from the following sources:

- Watershed runoff
- Feedlots
- Atmospheric deposition
- Septic systems
- Internal loading

Watershed runoff

The Sunrise River SWAT model (Almendinger and Ulrich 2010) and total phosphorus export coefficients (TPECs) were used to calculate watershed runoff volumes and TP loads to Heims Lake. Average annual overland runoff depth was estimated to be approximately 5.9 inches for the 20-year period from 1990 through 2009 based on the Sunrise SWAT model. The TPECs are the phosphorus runoff yield (i.e., loading rate) for a given land use, applicable in a given region having common surface features and a comparable climate record. The Lake St. Croix Total Phosphorus Loading Study summarized TPECs from published reports of runoff studies conducted by natural scientists and water resource managers in Minnesota, Wisconsin, and/or Upper Midwest landscapes. The Basin Team’s Implementation Committee pooled their collective knowledge of runoff behavior within in the St. Croix basin to develop a customized list of average-condition TPECs by land cover groupings (Table 3). For this watershed, the cultivated crops and developed TPECs were reduced from 0.75 kg/ha/yr to 0.4 kg/ha/yr to account for the high infiltration capacity of the watershed soils.

Under existing conditions, watershed runoff accounts for 127 acre feet of volume per year and 67 pounds of TP per year.

<table>
<thead>
<tr>
<th>NLCD 2011 Land Cover Type</th>
<th>TPEC (kg/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivated Crops</td>
<td>0.4</td>
</tr>
<tr>
<td>Developed</td>
<td>0.4</td>
</tr>
<tr>
<td>Pasture/Grasslands</td>
<td>0.25</td>
</tr>
<tr>
<td>Forest</td>
<td>0.1</td>
</tr>
<tr>
<td>Wetlands</td>
<td>0.1</td>
</tr>
<tr>
<td>Open Water</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Feedlots

There are no known feedlots in the Heims Lake watershed.

Atmospheric Deposition

Atmospheric deposition represents the phosphorus that is bound to particulates in the atmosphere and is deposited directly onto surface waters as the particulates settle out of the atmosphere. Average phosphorus atmospheric deposition loading rates were calculated for the St. Croix River.
The report determined that atmospheric deposition equaled 0.6 pounds of TP per hectare per year. This rate was applied to the lake surface area for a total of 22 pounds per year of atmospheric phosphorus deposition.

**Septic Systems**

Phosphorus loads from subsurface sewage treatment systems (SSTS) were estimated based on assumptions described in the Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (MPCA 2004) and the following assumptions: permanent residences, a failure rate of 11.4% in the St. Croix Basin, 2.68 people per residence, 1.95 lb TP production per person per year, 20% TP passing to surface waters from conforming SSTS and 43% TP passing to surface waters from failing SSTS. Based on recent aerial photography and Carriage Pass development plans, there are 10 existing septic systems within a few hundred feet of the lake shoreline that likely contribute phosphorus via subsurface flow. In addition, 2 Carriage Pass parcels near the lake shoreline remain undeveloped that could be developed in the future.

The existing 10 septic systems are estimated to contribute approximately 12 pounds of TP per year, plus an additional 2 pounds of TP per year if the two undeveloped Carriage Pass parcels are developed.

**Internal Loading**

Internal loading in lakes refers to the phosphorus load that originates in the bottom sediments or macrophytes and is released back into the water column. Internal loading can occur via:

1. **Chemical release from the sediments**: Caused by anoxic (lack of oxygen) conditions in the overlying waters or high pH (>9). If a lake’s hypolimnion (bottom area) remains anoxic for a portion of the growing season, the phosphorus released due to anoxia will be mixed throughout the water column when the lake loses its stratification at the time of fall mixing. In shallow lakes, the periods of anoxia can last for short periods of time and occur frequently.

2. **Physical disturbance of the sediments**: Caused by bottom-feeding fish behaviors (such as carp and bullhead), motorized boat activity, and wind mixing. This is more common in shallow lakes than in deeper lakes.

An average background rate of internal loading is implicit in the BATHTUB lake water quality model whose phosphorus response models are based on a natural lake development data set. Therefore internal loading rates added to the BATHTUB model during calibration represents the excess sediment release rate beyond the average background release rate accounted for by the model development lake dataset. Heims Lake is currently in a clear water state with little excess internal loading. As a result, no internal loads were needed to calibrate the model and this load source was estimated to be approximately zero.

**BATHTUB Lake Response Model**

The modeling software BATHTUB (Version 6.1) was selected to link phosphorus loads with in-lake water quality. A publicly available model, BATHTUB was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). It has been used successfully in
many lake studies in Minnesota and throughout the United States. BATHTUB is a steady-state annual or seasonal model that predicts a lake’s summer (June through September) mean surface water quality. BATHTUB’s time-scales are appropriate because watershed phosphorus loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. The heart of BATHTUB is a mass-balance phosphorus model that accounts for water and phosphorus inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and groundwater; and outputs through the lake outlet, water loss via evaporation, and phosphorus sedimentation and retention in the lake sediments.

In typical applications of BATHTUB, lake and reservoir systems are represented by a set of segments and tributaries. Segments are the basins (lakes, reservoirs, etc.) or portions of basins for which water quality parameters are being estimated, and tributaries are the defined inputs of flow and pollutant loading to a particular segment. For this study, all phosphorus sources were aggregated into a single tributary to the lake (i.e., the segment). The input required to run the BATHTUB model includes lake geometry, climate data, and water quality and flow data for runoff contributing to the lake, as previously described in this report.

BATHTUB allows a choice among several different phosphorus sedimentation models. The Canfield-Bachmann phosphorus sedimentation model (Canfield and Bachmann 1981) best represents the lake water quality response of Minnesota lakes and is commonly used for lake water quality and TMDL studies.

The Heims Lake BATHTUB model was calibrated to the 2009, 2014 and 2015 growing season average total phosphorus concentration (41 µg/L; Table 1). When the predicted in-lake total phosphorus concentration is lower than the average observed (monitored) concentration, an explicit additional load is added to calibrate the model. When the predicted in-lake total phosphorus concentration is higher than the observed (monitored) concentration, the TP sedimentation rate (or treatment capacity of the lake) is increased. For Heims Lake, the TP sedimentation rate was increased from 1 to 1.642 to calibrate the model, indicating high treatment capacity of the lake in its current clear water, aquatic plant-dominated state. Loss of aquatic plant coverage could greatly increase the amount of internal loading in Heims Lake and greatly increase the observed in-lake TP concentration.

**Phosphorus Load Scenarios**

Inputs to the calibrated BATHTUB model were modified to predict impacts of recent and expected watershed changes on in-lake phosphorus concentrations, including construction of 2 additional septic systems in the Carriage Pass residential development and conversion of a range of cropland acreage to residential or commercial development on the north side of Heims Lake. Due to the high infiltration capacity of the soils in the watershed, and the need to meet the requirements of the CLFLWD rules for all new developments (buffer and volume control for the 2-year storm event), cropland conversion to development was modeled by assuming the developed area essentially acts as a land-locked basin, infiltrating nearly all flow and loads generated by the site. Heims Lake Villas (CLFLWD Permit 15-008) is expected to convert 11.66 acres of cropland to residential development. Additional scenarios include conversion of the remaining 11.73 acres of cropland south of 257th Street on the north side of Heims Lake (23.39 acres total), and all of the cropland located north of Heims Lake (47.08 acres total).
Changes in predicted in-lake phosphorus concentration under the various cropland conversion and septic system scenarios are illustrated in Figure 13. The additional phosphorus load from two new septic systems is expected to increase the in-lake phosphorus concentration by less than 1 ppb. This increase in in-lake phosphorus concentration is easily offset by reductions in the watershed load from conversion of cropland to developed land. The planned Heims Lake Villas project is expected to reduce in-lake phosphorus concentrations by ~1 ppb, and conversion of all cropland to developed land north of Heims Lake is expected to reduce in-lake phosphorus concentrations by up to 4 ppb. This land conversion alone is nearly sufficient to meet the District in-lake phosphorus goal of 40 ppb, and at little to no cost to the District.

Figure 13. Predicted response of in-lake phosphorus concentration to changes in lake loading
MANAGEMENT PLAN

In November of 2015, field inspection of the Heims Lake drainage areas was completed. Comfort Lake – Forest Lake Watershed District permits were reviewed along with development plans obtained from the City of Wyoming. Drainage area boundaries were updated base on the best available data.

A significant portion of the watershed has recently been developed or is slated for development. Below is a list of those projects:

- **Carriage Pass.** This project was built around 2005. It includes 21 lots that range in size from 1 to 2 acres. These lots all have on-site septic systems. Only the 7 lots located directly on the lake provide surface drainage to the lake. There is a natural buffer still in place between the lots and Heims Lake. All of the roads and the remainder of the lots drain internally through grass swales to treatment basins which flow to the southeast towards the Sunrise River and eventually to Comfort Lake.

- **257th Street Improvements** (CLFLWD Permit 08-003). This project involved construction of 257th Street north of Heims Lake. Water from the street and some adjacent property is collected by storm sewer and routed to a large infiltration basin with pretreatment cells located north of 257th Street and west of Highway 61. The outlet for the basin flows to the south to Heims Lake. Based on the recent field visit it appears that this basin is functioning well and rarely discharges to Heims Lake.

- **DaVita Dialysis** (CLFLWD Permit 13-001). This project constructed a medical building west of Highway 61 and south of 257th Street. An infiltration basin was installed south of the building to provide treatment per District Rules. This project was recently completed.

- **Heims Lake Villas** (CLFLWD Permit 15-008). This project includes construction of 33 detached townhome lots. Runoff will be treated via infiltration basins per District Rules. A 75-foot buffer is also included between the development and Heims Lake.

These areas were all previously used for agricultural practices. The recent development in combination with the required BMPs and buffers will provide a significant reduction in TP load to the lake.

Three distinct areas are discussed below regarding watershed loading and lake protection (Figure 14). These areas include the area north and west of Heims Lake along 257th Street (Area 1), the residential lots on Heims Lake south and east of the Lake (Area 2), and the remainder of the drainage area south of 250th Street (Area 3).

**Area 1**

This area was essentially all agricultural prior to 2005. Since then 257th Street was installed and this area has started to develop with commercial and residential development. These projects have primarily developed under CLFLWD review and permitting. The soils are very sandy and therefore infiltration practices have been implemented. All of this area will be treated with BMPs and a protective buffer will be required along the lake per CLFLWD rules. This will result in a
significant decrease in loading to the lake. Other than making sure the required BMPs and buffers are maintained and protected, no other BMPs are recommended or needed.

**Area 2**

This area includes 10 existing residential lots and natural wooded areas along the lake. Two more lake shore lots are currently undeveloped in the Carriage Pass Development and will likely be developed in the future. A well-established buffer is in place along the entire shoreline of this area. These homes all have septic systems that will contribute some phosphorous loading to the lake. General shoreline stewardship education, including proper maintenance of the septic systems and protection of buffer areas, is recommended. An inspection of the older septic systems by a qualified professional would also be prudent.

**Area 3**

This area is located south of 250th Street. It includes large lot residential and some agricultural activity. Runoff currently all flows to a large wetland complex south in the center of the watershed. Road runoff flows through swales which are then directed to the wetland. Agricultural areas in the far southern portion of the watershed flow overland to the wetland area. The wetland area appears fairly natural with a wooded buffer. Protection of this wetland and the buffer area is important to project downstream water quality to Heims Lake.

Possible BMPs included working with the landowner(s) that farm the areas in the far southern portion of the watershed to assess the need for and, if needed, implementation of agricultural best management practices that could reduce runoff and sediment loading to the wetland. The bulk of the runoff from Field Avenue is collected in a swale that is then routed to the wetland. This is providing some treatment, but could potentially be enhanced (if needed).
Figure 14. Heims Lake management areas
REFERENCES


APPENDIX A. FISH COMMUNITY SURVEY REPORT

Fish Community Survey of Heims Lake
Chisago County, MN

October 17, 2015

Prepared for:
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Saint Mary’s University of MN
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Project Background

Heims Lake (MNDNR Public Water #13005600) is a relatively small (90 acres), shallow (<15 ft) lake located in southwest Chisago County, MN. This lake is currently considered eutrophic and the shallow nature leads to an abundance of vegetation (CLFLWD 2009). Initial monitoring in 2009 by Minnesota Pollution Control Agency (MPCA) indicates the waterbody is impaired due to high nutrient levels and poor secchi depth visibility, however, the MPCA does not have enough information to determine the suitability for swimming or fishing (MPCA 2009).

The objective of this study was to provide assessments of the fish community in Heims Lake to supplement previous chemical monitoring. Baseline data on community composition can provide information about the impacts of current water quality impairments on fish abundance, richness, and biological interactions. Future biological monitoring will be able to assess if water quality improvement strategies are having a positive effect on the fish community.

Sampling Methods

Fish were surveyed in Heims Lake with a combination of trap nets, seines, and backpack electrofishing consistent with current MNDNR survey techniques for small lakes. Five trap (fyke) nets with frames measuring 1.2 m by 1.8 m and 12.2-m leads were set in each lake for approximately 24 hours on September 26-27th, 2015. Fyke nets were spaced evenly around the southern shoreline to representatively sample fish habitat in the lake (Figure 1). Additional seine hauls were attempted on September 27th to collect smaller fish species in the near shore zone, but the high density of macrophytes made seining ineffective. To more effectively sample fish in the
nearshore zone, fish were sampled using a backpack electrofisher on October 17th. A zigzag pattern along the shoreline from 0.5-4 ft deep was completed for 20 minutes.

All captured fish were identified, enumerated, and measured for total length to the nearest mm. Individuals were also measured for weight to the nearest tenth of a gram using a portable electronic scale. All fish were released unharmed after measurement.

The potential impact of human disturbance on the biological community within each lake was estimated from an Index of Biotic Integrity (IBI). IBI’s are a unit-less, multi-metric approach that addresses species specific responses to agricultural and urban disturbances. Both species richness and species biomass data were scored using index criteria developed by Drake and Pereira (2002) for small inland lakes in Central Minnesota. In general, IBI scores are positively correlated with species richness, number of intolerant species, and increasing insectivore biomass but are negatively correlated to the number and biomass of tolerant and omnivorous species.

**Lake Results & Discussion**

**Lake Overview**

A total of 5 fish species (totaling 34 individuals) were collected using both trap nets and the backpack electrofisher: bowfin, black bullhead, central mudminnow, brook stickleback, and fathead minnow (Table 1). Fish biomass was dominated by bowfin and black bullhead (Figure 2). Both black bullhead and fathead minnow are omnivorous feeders that are capable of tolerating polluted or low quality water conditions (Drake and Pereira 2002). Bowfin and central mudminnows are both capable of gulping atmospheric air, allowing them to tolerate warm water with low oxygen concentrations (Scott and Crossman 1983). Bowfin are a top carnivore and are
capable of reaching large sizes (> 30 inches), but no other carnivores or game species were present.

All fish collected were under 500 mm (Figure 3). Size distribution of fish suggests all fish captured were under three years of age. Given the shallow nature of the lake and high concentration of nutrients, Heims Lake is vulnerable winter or summer anoxia. The absence of any game species and the restricted size of tolerant species captured suggests Heims Lake has likely experienced recent and repeated fish kills due to anoxia.

Index of Biotic Integrity

The overall IBI score for Heims Lake was 35.33 (Table 2). The metrics that had the largest difference in IBI score was the overall low species richness and large presence of tolerant and omnivorous species. IBI scores below 60 are similar to other Minnesota Lakes that have been impacted by agricultural and urban eutrophication (Drake and Valley 2005). Despite the low overall rating, the IBI score for Heims Lake was comparable to regional IBI scores and levels of impairment for neighboring lakes (Figure 4). No waterbody in the region is currently listed as exceptional, and nearly half of the surrounding water bodies are not meeting the standard set by the MNDNR.

Conclusions

Heims Lake is typical of other shallow lakes with high nutrient loads: low-to-absent game species abundance and high abundances of tolerant, omnivorous fish species due to frequent conditions of winter anoxia (Tonn and Magnuson 1982). The complete absence of game species suggests that no refugia exist for game species to survive significant anoxic...
events. Additionally, this suggests that Heims Lake lacks a significant tributary or migratory pathway for game species to naturally recolonize after winter kill events. Reports from local landowners suggest that game species were abundant in recent history (10-15 years ago), but no previous fish survey data could be found on the MNDNR website.

IBI scores for Heims Lake provides an estimate of current biological integrity and can serve as a benchmark for future lake surveys. Fish community assemblage, and resulting IBI scores, are strongly affected by impairments from cultural eutrophication that lead to fish kills of intolerant game species due to anoxia. Future improvements to nutrient impairments within the watershed could result in improved fish communities which can be monitored by changes to IBI scores.

This study represents a conservative estimate of biologic integrity and caution should be used when comparing these values to other Minnesota lakes. Drake and Pereira (2002) developed their IBI using trap nets, seines, gill nets, and electrofishing to effectively sample all species present in both near-shore and off-shore zones. Failure to effectively sample with seines or sample off-shore zones with gill-nets could have under-sampled species richness or missed relatively rare intolerant species.

Acknowledgments

Thanks to the landowners for lake access and cooperation with sampling activities. SMU environmental biology students, William Granholm, Sarah Fanning, and Crystal Gehring provided most of the assistance with fish sampling.
Literature Cited
Table 1. Total number of individual species captured, total length (TL) range, mean TL, weight range, and mean weight for fish sampled in Heims Lake.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number Captured</th>
<th>TL Range</th>
<th>Mean TL (mm)</th>
<th>Weight Range</th>
<th>Mean W (g)</th>
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<tbody>
<tr>
<td>Brook Stickleback</td>
<td>3</td>
<td>37-47</td>
<td>40.3</td>
<td>0.2-1.0</td>
<td>0.5</td>
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<tr>
<td>Fathead Minnow</td>
<td>17</td>
<td>43-67</td>
<td>55.9</td>
<td>1.0-2.6</td>
<td>1.8</td>
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<tr>
<td>Central Mudminnow</td>
<td>4</td>
<td>70-74</td>
<td>73.0</td>
<td>3.4-4.6</td>
<td>3.8</td>
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<tr>
<td>Black Bullhead</td>
<td>6</td>
<td>205-256</td>
<td>239.2</td>
<td>202</td>
<td>161.4</td>
</tr>
<tr>
<td>Bowfin</td>
<td>4</td>
<td>475-495</td>
<td>485.8</td>
<td>1060</td>
<td>1000.0</td>
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</tbody>
</table>
Table 2. Calculation of Index of Biotic Integrity (IBI) metrics for Heims Lake fish data, 2015.

<table>
<thead>
<tr>
<th>Species Richness</th>
<th>Lake Data</th>
<th>IBI Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native</td>
<td>0.4 x number native species</td>
<td>5</td>
</tr>
<tr>
<td>Intolerant</td>
<td>2.0 x number of intolerant species</td>
<td>0</td>
</tr>
<tr>
<td>Tolerant</td>
<td>10 - 3.33 x number of tolerant species</td>
<td>2</td>
</tr>
<tr>
<td>Insectivore</td>
<td>0.77 x number of insectivore species</td>
<td>2</td>
</tr>
<tr>
<td>Omnivore</td>
<td>12 -2 x number of omnivore species</td>
<td>2</td>
</tr>
<tr>
<td>Cyprinid</td>
<td>2.0 x number of cyprinid species</td>
<td>1</td>
</tr>
<tr>
<td>Small benthic</td>
<td>2.5 x number of small benthic-dwelling species</td>
<td>0</td>
</tr>
<tr>
<td>Vegetation</td>
<td>1.67 x number of vegetation-dwelling species</td>
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<tr>
<td>Nearshore</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intolerants</td>
<td>18.94 x proportion of intolerant individuals</td>
<td>0</td>
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<tr>
<td>Small benthic</td>
<td>109.89 x proportion of small benthic dwelling individuals</td>
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<tr>
<td>Vegetation</td>
<td>19.84 x proportion of vegetation-dwelling individuals</td>
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<td>Trap-net</td>
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<tr>
<td>Insectivores</td>
<td>12.35 x proportion of insectivores by biomass</td>
<td>0</td>
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<tr>
<td>Omnivores</td>
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<tr>
<td>Tolerants</td>
<td>10 - 25.64 x proportion of tolerants by biomass</td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
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</table>
Figure 1. Locations of trap net sets in Heims Lake.
Figure 2. Proportion of fish biomass (percent grams) within Heims Lake.
Figure 3. Length frequency distribution of fish catches in Heims Lake.
Figure 4. IBI status of waterbodies surrounding Heims Lake. IBI data for lakes outside the study area were obtained from Minnesota Geospatial Commons: https://gisdata.mn.gov/.