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1. Executive Summary

Over the past few years, the Rice Creek Watershed District has prioritized its efforts on Resource Management Plans in the developing portions of the District. The District's next focus is on more urbanized areas. Recently, RCWD has received numerous inquiries for assistance in cleaning up some fairly degraded urban lakes in the southwest portion of the watershed. These requests came from lake homeowners and/or associations on lakes that have been subjected to decades of concentrated urban runoff and are now showing the effects of that pollutant loading. The goal of this project is to assess the water quality of 24 lakes in the southwest portion of RCWD, particularly in relation to state standards, and to develop management action plans for each lake. The intent of the management action plans is to give the District a prioritized list of projects for further investigation. The prioritization exercise is NOT intended to make a final determination on the merits of a particular project. For most projects further feasibility assessments would be needed before the District proceeds with a particular project.

The phosphorus loads to each lake were estimated in order to develop lake response models and to determine the magnitude of the load reductions that are needed for the lakes to achieve water quality standards. The watershed loads were estimated using an urban runoff model (P8), and the internal loads were modeled using sediment data, in-lake nutrient concentrations, and basic lake morphometry to predict internal loads due to anoxic release. Lake response models were developed for each lake in order to integrate the watershed loading with the internal loading into a predictive model.

The Lake Management Action Plans (MAPs) presented here summarize lake characteristics and existing lake data, provide a diagnostic assessment of the data, summarize public input, identify water quality issues, and recommend remedial strategies on a lake-watershed basis. As such, each MAP provides a concise summary of the known issues and recommended management approaches for each lake. It is envisioned that the MAPs will be used to further define management strategies, guide development of the District's Third Generation Plan, and serve as the basis for seeking project partners and grant funding for retrofit water quality improvements.

Over 200 potential retrofit BMPs are identified in the MAPs. In order to prioritize further assessment and implementation feasibility, a simplified cost/benefit assessment was performed to assign each BMP as a Tier 1, 2 or 3 BMP (Tier 1 having the best cost-benefit ratio). Based on this prioritization, the recommended implementation strategy for 2009 includes:

- Initiation of feasibility studies on three Tier 1 BMPs
- Coordination with parks departments on six Tier 1 BMPs within community parks
- Solicitation of private party interest in potential cost share on nineteen Tier 1 BMPs
- Landowner notification of needed maintenance at three Tier 1 BMPs

2. Introduction

A. RCWD, RMPS, URBAN LAKES

Over the past few years, the Rice Creek Watershed District has prioritized its efforts on Resource Management Plans (RMPs) in the developing portions of the District. The RMP projects to date include topics such as wetland management, water quality to meet TMDL goals, and ditch repairs. Since RMPs are either approved or in the process of being written for the developing areas, RCWD's next focus is on more urbanized areas.

Recently, RCWD has received numerous inquiries for assistance in cleaning up some fairly degraded urban lakes in the southwest portion of the watershed. These requests come from lake homeowners and/or associations on lakes that have been subjected to decades of concentrated urban runoff and are now showing the effects of that pollutant loading. Some of the lakes in question include Little Johanna, Pike, Long, and Spring.

The goal of this project is to assess the water quality of 24 lakes (Figure 1, Table 1) in the southwest portion of RCWD, particularly in relation to state standards, and to develop management action plans for each lake:

Table 1. Study Lakes

Lake Name	DNR Lake ID
Hart	02-0081
Island	62-0075
Johanna	62-0078
Jones	62-0076
Josephine	62-0057
Karth	62-0072
Langton	62-0049
Little Johanna	62-0058
Little Josephine	62-0201
Locke	02-0077
Long	62-0067
Marsden	62-0059
Martha	62-0064
Moore	02-0075
Pike	62-0069
Poplar	62-0077
Round	62-0070
Rush	62-0068
Spring	02-0071
Sunfish	62-0065
Turtle	62-0061
Valentine	62-0071
Walsh	62-0214
Zimmerman	62-0053

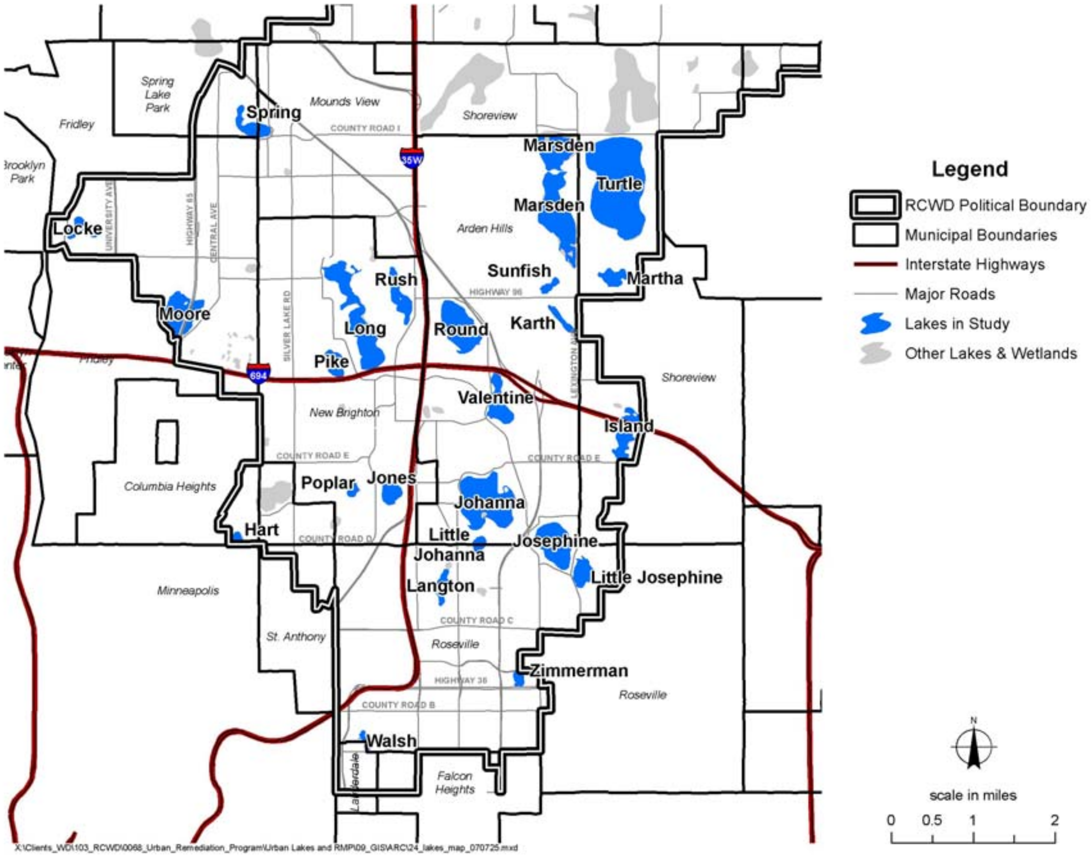

Figure 1. Location of Study Lakes

B. LAKE EUTROPHICATION STANDARDS

Water quality standards are established to protect the designated uses of the state's waters. Amendments to Minnesota's Rule 7050, approved in May 2008, include eutrophication standards for lakes (Table 2). *Eutrophication* is defined as "a process whereby water bodies receive excess nutrients that stimulate excessive plant growth" (USGS). "Excessive plant growth" often refers to algae blooms that can result in deceased water clarity (green, soupy appearance) or surface scums. Excessive algae growth can lead to a loss of native aquatic plants, decreased recreational use, unpleasant odors and appearance, and altered fish communities favoring undesirable species (rough fish). Eutrophication standards were developed for lakes in general, and for shallow lakes in particular. Standards are less stringent for shallow lakes, due to naturally higher levels of phosphorus in shallow lakes and different ecological characteristics.

According to the MPCA definition of shallow lakes, a lake is considered shallow if its maximum depth is less than 15 ft, or if the littoral zone (area where depth is less than 15 ft) covers at least 80% of the lake's surface area.

Table 2. MN Eutrophication Standards, North Central Hardwood Forests Ecoregion

Parameter	Eutrophication Standard, General	Eutrophication Standard, Shallow Lakes
Total Phosphorus (µg/l)	TP < 40	TP < 60
Chlorophyll-*a* (algae) (µg/l)	chl < 14	chl < 20
Secchi depth (clarity) (m)	SD > 1.4	SD > 1.0

C. IMPAIRED WATERS PROGRAM

Section 303(d) of the Federal Clean Water Act requires that states establish total maximum daily loads of pollutants to water bodies that do not meet water quality standards. The loading limits are to be calculated such that, if achieved, the water body would meet the applicable water quality standard. To comply with the Clean Water Act, the Minnesota Pollution Control Agency (MPCA) assesses the state's waters, lists those water bodies that are impaired (i.e. do not meet water quality standards), and conducts studies to determine the pollutant loading limits for the impaired water bodies. These studies are known as TMDL studies, or total maximum daily load studies. In Minnesota, the pollutant that is often the cause of eutrophication is phosphorus.

The MPCA sets target start and completion dates for individual TMDL studies. Studies are usually funded by either the MPCA or by local units of government. Each TMDL study describes the impairment, identifies the relevant pollutant(s), inventories the pollutant sources, calculates the capacity of the water body (i.e. the amount of pollutant the lake can process in its natural cycle), allocates the allowable loads to the different sources, and prescribes an implementation strategy to restore the water body to meet water quality standards.

Within a year of completing the TMDL study, the MPCA requires the completion of an implementation plan, which provides more specific management details than are provided in the initial TMDL study.

Several waters that are listed on the 303(d) list of impaired waters are located within the project area (Table 3).

Table 3. Impaired Lakes

Lake Name	DNR Lake ID	Year First Listed	Impairment	Target start/ completion dates
Island Lake	62-0075	2002	Nutrient/Eutrophication Biological Indicators	2010 / 2014
Jones Lake	62-0076	2008	Aquatic macroinvertebrate bioassessments	2010 / 2014
Little Lake Johanna	62-0058	2004	Nutrient/Eutrophication Biological Indicators	2010 / 2014
Long Lake	62-0067	2002	Nutrient/Eutrophication Biological Indicators	2010 / 2014
Moore Lake, East	02-0075	2002	Nutrient/Eutrophication Biological Indicators	2009 / 2013
Pike Lake	62-0069	2002	Nutrient/Eutrophication Biological Indicators	2010 / 2014
Lake Valentine	62-0071	2002	Nutrient/Eutrophication Biological Indicators	2010 / 2014

3. Phosphorus Analysis

A. NUTRIENT LOADING TO LAKES

Purpose of analysis

Phosphorus is the nutrient that, in excessive amounts, leads to eutrophication in lakes in Minnesota, and it is the nutrient that is used by the MPCA to set numeric standards for lakes. As such, phosphorus is the pollutant focused on in this report.

The phosphorus loads to each lake were estimated in order to develop lake response models and to determine the magnitude of the load reductions that are needed for the lakes to achieve water quality standards. The watershed loads and the internal loads were estimated independently.

Watershed loading

Approach

The general approach for determining the total phosphorus (TP) load entering each of the lakes in the study area was to estimate the load generated from each lake's direct watershed and to account for all additional loads coming from upstream lakes, ponds, or watersheds. Watershed TP loading was determined using a reconnaissance level P8 Urban Catchment Model. The model predicts loads generated from urban watersheds based primarily on their size and level of imperviousness. The P8 model allows the user to account for the degree to which impervious surfaces are connected throughout the watershed and, ultimately, to the receiving water body. The portion of the impervious surfaces directly connected to the receiving water body was set at 85% for each of the watersheds in the study area. The other 15% of the area is indirectly connected to the receiving water body through pervious areas such as lawns or natural areas. No attempt was made to characterize the water quality treatment being provided by small ponds or other BMPs, such as street sweeping, throughout the watersheds.

The P8 model was run using the 1995 water year (October 1994 through September 1995). This water year represents an average year for the Minneapolis-St. Paul area in terms of total precipitation and distribution of storm events. The NURP50 particle file was used in the P8 model. It represents the 50th percentile particle size distribution based on all NURP data and is recognized as the standard file for use in this type of analysis. General model parameters were established for all of the watersheds within the study area (Table 4).

Table 4. P8 Model input parameters

P8 model parameter		Setting
Pervious	Curve Number	61
	Load Factor	1
Impervious	Depression Storage	0.02 inches
	Runoff Coefficient	0.9
	Load Factor	1

Subwatersheds for the lakes were delineated from existing resources, based on best available data for the area. Data sources included:

- Ramsey County 2-foot topographic data
- USGS 10-foot topographic data (for Anoka and Hennepin County)
- 1998 RCWD Calibration Study subwatersheds
- City Local Plan subwatershed and stormsewer maps
- Institutional knowledge of the system

It was originally envisioned that these preliminary subwatersheds would be refined with the District-wide SWMM modeling effort originally scheduled for the southwest lobe of the District in 2008. Because this modeling effort was postponed, it is recommended that, when the District pursues detailed modeling of the southwest area of the District, the watersheds should be refined utilizing LIDAR and field survey data.

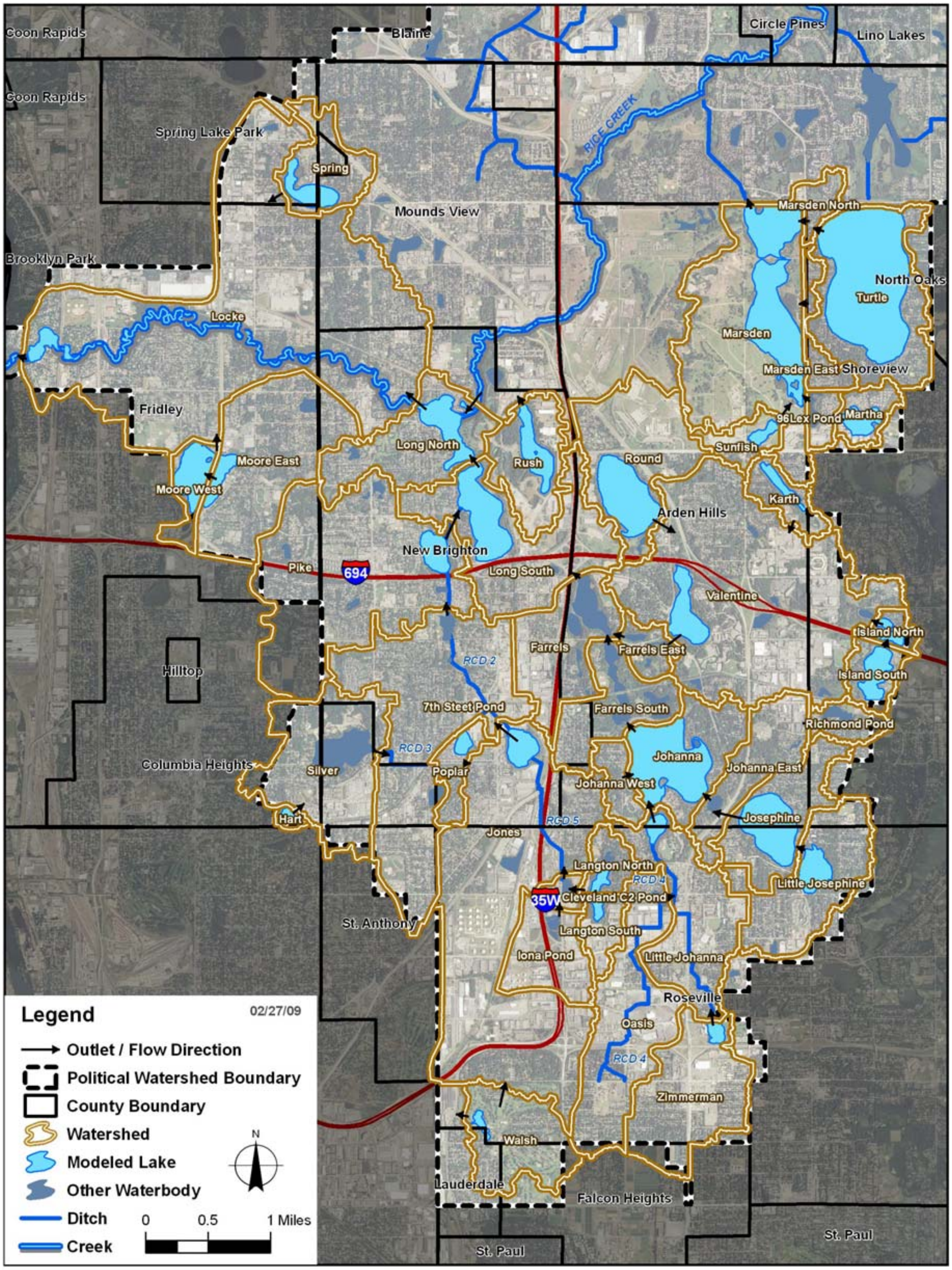

Figure 2. Subwatershed Boundaries and Drainage Direction

Impervious surface estimates for each watershed were extracted from QuickBird satellite imagery using digital image processing techniques. A supervised maximum likelihood classification using a sample priori probability was performed using 79 training samples representing urban, urban shadow, vegetation, vegetation shadow, and open water land cover types. Some urban and water features were burned into the classification manually to obtain a higher accuracy classification. Burned-in water features included modeled lake outlines as well as polygon areas representing open water MLCCS codes. Some areas classified as urban were also manually burned into the classification using polygons created by heads up digitizing. After manual edits were finished, the final classification consisted of urban (100% impervious), vegetation (0% impervious), and water (100% impervious) land cover types. Percent impervious weighted averages per subwatershed were then extracted using a zonal statistics routine.

The acreage and percent impervious for each lake's direct watershed are listed in Table 5 (see also Figure 2 for subwatershed boundaries). In some cases, additional areas drain to the lakes in the study area and these areas were modeled separately from the direct watershed area. These additional areas were separated from the direct lake watershed because they are either large, distinct areas or contain a significant water body that provides water quality treatment. The acreage and impervious percentage for these areas are also listed in Table 5.

Table 5. Watershed specific P8 Model input parameters

Direct Lake Watersheds		
Watershed Name	**Area (acres)**	**Percent Impervious**
Hart	15.9	55%
Island North	47.95	30%
Island South	91.58	32%
Johanna	207.21	22%
Jones	1699.73	50%
Josephine	279.76	27%
Karth	117.74	35%
Langton North	98.54	27%
Langton South	109.45	69%
Little Johanna	535.85	45%
Little Josephine	449.77	31%
Locke	2679.06	40%
Long North	400.62	27%
Long South	618.32	45%
Marsden	790.38	18%
Martha	76.76	43%
Moore East	701.19	36%
Moore West	47.27	40%
Pike	1228.12	38%
Poplar	108.49	43%
Round	465.07	36%
Rush	276.63	47%
Spring	302.88	35%
Sunfish	111.74	39%
Turtle	287.58	18%
Valentine	1655.41	38%
Walsh	372.2	18%
Zimmerman	531.23	46%
Additional drainage areas - no treatment		
Watershed Name	**Area (acres)**	**Percent Impervious**
Johanna East	325.45	35%
Johanna West	114.52	28%
Marsden East	116.41	26%
Marsden North	86.38	30%
Farrels	433.4	45%
Farrels East	104.59	24%
Farrels South	348.08	22%

Additional drainage areas - with treatment		
Watershed Name	**Area (acres)**	**Percent Impervious**
7th Street	1156.66	41%
96 & Lexington	71.86	47%
Cleveland & C2	53.7	63%
Iona	280.93	71%
Oasis	663.97	59%
Richmond	96.03	36%

The P8 Model was used to calculate the volume of stormwater and the total phosphorus loading from each lake's direct watershed as well as the additional areas that drain to the lakes. The model was also used to calculate the reduction in total phosphorus loading provided by the ponds located in the drainage areas with treatment shown in Table 5. Ponds in these drainage areas were modeled using configuration assumptions derived from their surface area shown in Table 6.

Table 6. Pond Configuration Assumptions

Pond	**Permanent Pool**		**Flood Pool**		**Bottom**
	Surface Area (known)	**Volume Surface Area x 2 feet deep**	**Area 110% of the permanent pool area**	**Volume Flood Pool area ½ foot deep**	**Area ~ 1/2 Permanent Pool**
	Acres	**Acre-feet**	**Acres**	**Acre-feet**	**Acres**
Oasis	6.94	13.88	7.63	3.82	3
Richmond Pond	11.59	23.18	12.75	6.37	6
Iona Pond	4.15	8.3	4.57	2.28	2
7th Street Pond	5.37	10.74	5.91	2.95	2.5
Cleveland C2 Pond	3.18	6.36	3.5	1.75	1.6
96Lex Pond	10.68	21.36	11.75	5.87	5.5

The volume of stormwater and the loading of total phosphorus to each lake were calculated as indicated in Table 7. In many cases, the direct drainage area was the only source of stormwater and TP loading. Other lakes have more complex drainage systems (see Figure 2 for subwatershed boundaries and drainage directions) and receive loading from upstream lakes, ponds, or drainage areas. The outflow volume and TP concentrations from upstream lakes were calculated using the Bathtub in-lake model as described in *Section B: Lake Response Modeling, Modeling Approach (#2)*. Volume and TP loads from upstream ponds were calculated using the P8 model as described above. .

Table 7. Source of TP Load Estimates to Lakes

Lake	TP Load Calculation Approach
Hart	Direct drainage area only
Island North	Direct drainage area only
Island South	Direct drainage area only
Johanna	Direct drainage area, Johanna West drainage area, Johanna East outflow, Little Johanna Lake outflow
Jones	Direct drainage area, Poplar Lake outflow, Cleveland C2 Pond outflow, Walsh Lake outflow
Josephine	Direct drainage area, Little Josephine Lake outflow
Karth	Direct drainage area only
Langton North	Direct drainage area only
Langton South	Direct drainage area only
Little Johanna	Direct drainage area, Oasis Lake outflow, Zimmerman Lake outflow
Little Josephine	Direct drainage area only
Locke	Direct drainage area, Rice Creek inflow (drainage area x 6 in. runoff x monitored Rice Creek TP conc of 117 µg/L)
Long North	Direct drainage area, Long Lake South outflow, Rice Creek inflow (drainage area x 6 in. runoff x monitored Rice Creek TP conc of 153 µg/L)
Long South	Direct drainage area, Pike Lake outflow, Farrels drainage area
Marsden	Direct drainage area, Marsden East drainage area, Marsden North drainage area, 96Lex Pond outflow, Turtle Lake outflow, Sunfish Lake outflow
Martha	Direct drainage area only
Moore East	Direct drainage area only
Moore West	Direct drainage area only
Pike	Direct drainage area, 7th Street Pond outflow
Poplar	Direct drainage area only
Round	Direct drainage area only
Rush	Direct drainage area only
Spring	Direct drainage area only
Sunfish	Direct drainage area only
Turtle	Direct drainage area only
Valentine	Direct drainage area, Karth Lake outflow, Round Lake outflow, North Island Lake outflow
Walsh	Direct drainage area only
Zimmerman	Direct drainage area only

Results

Results from the P8 watershed modeling are presented as part of the lake modeling discussion, *Section 2B. Lake Response Modeling*.

Internal loading

Internal loading in lakes refers to the phosphorus load that originates in the bottom sediments and is released back into the water column. The phosphorus in the sediments was originally deposited in the lake sediments through the settling of particulates (attached to sediment that entered the lake from watershed runoff, or as phosphorus incorporated into biomass) out of the water column. Internal loading can occur through various mechanisms:

- Anoxic (lack of oxygen) conditions in the overlying waters. Water at the sediment-water interface may remain anoxic for a portion of the growing season, and low oxygen concentrations result in phosphorus release from the sediments. 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. Alternatively, in shallow lakes, the periods of anoxia can last for short periods of time; wind mixing can then destabilize the temporary stratification, thus releasing the phosphorus into the water column.
- Physical disturbance by bottom-feeding fish such as carp and bullhead. This is exacerbated in shallow lakes since bottom-feeding fish inhabit a greater portion of the lake bottom than in deeper lakes.
- Physical disturbance due to wind mixing. This is more common in shallow lakes than in deeper lakes. In shallower depths, wind energy can vertically mix the lake at numerous instances throughout the growing season.
- Phosphorus release from decaying curly-leaf pondweed (*Potamogeton crispus*). This is more common in shallow lakes since shallow lakes are more likely to have nuisance levels of curly-leaf pondweed.

Internal loading due to the anoxic release in the epilimnion of each lake was estimated in this study. Internal loading due to physical disturbance and decaying curly-leaf pondweed is difficult to estimate reliably and was therefore not included in the lake phosphorus analyses. In lakes where internal loading due to these sources is believed to be substantial, the internal load estimates presented here are likely an underestimate of the actual internal load.

Approach

Internal loads due to anoxic release in the hypolimnion were calculated based on an approach developed by Nürnberg (1988, 1995) in which an anoxic factor is calculated based on in-lake TP concentrations, lake surface area, and lake mean depth, and a sediment phosphorus release rate is calculated based on sediment phosphorus concentrations.

The internal load of a lake can be estimated by the following equation:

$$\text{Internal P loading rate} = \text{AF} \times \text{RR}$$

Where AF = anoxic factor, and RR = release rate (Nürnberg 1987). These two parameters were calculated as follows.

Anoxic Factor

The anoxic factor describes the length of time (in days) that a sediment area equal to the lake's surface area is anoxic (Nürnberg 1995). The correction for lake surface area makes the anoxic factor comparable among lakes of different sizes. The anoxic factor can be calculated by knowing the spatial extent and duration of anoxia. Nürnberg (1996) estimated the anoxic factor with the following equation, developed from a data set of lakes in central Ontario and eastern North America:

$$AF_{summer} = -36.2 + 50.1 \log(TP) + 0.762z / A^{0.5},$$

where Af_{summer} = summer anoxic factor (days/yr), TP = average summer in-lake TP concentration (µg/L), z = lake mean depth (m), and A = lake surface area (km^2).

Release Rate

The release rate of phosphorus from lake sediments can be predicted by the phosphorus concentrations within the sediments (Nürnberg 1988) with the following equation:

$$RR = -0.58 + 13.72(BD\text{-}P),$$

where RR = release rate (mg/m^2-day), and BD-P = bicarbonate dithionite extractable phosphorus (mg/g dry weight). BD-P analyzes iron-bound phosphorus, and has a better predictive ability than the total phosphorus in the sediment.

Sediment collection

Lake sediment samples were collected at each lake using a WaterMark Universal Core Head sediment corer.

At the lakes that had a well-defined deep hole, two to three locations in the vicinity of the deep hole were sampled. At each location, two to three replicates were taken. All of the samples taken from these lakes were composited before preserving on ice. The deep hole samples were composited since lake sediments tend to be concentrated over time in the deepest part of the lake.

At some of the more shallow lakes that did not have a well-defined deep hole, multiple samples were taken in different locations in the lake and were not composited, but rather were analyzed individually. This was done to examine spatial variability in the sediment phosphorus concentrations, since there is not one single location within the lake where the sediments tend to concentrate. At the remaining shallow lakes, sediment was sampled in only one location. When there was more than one sample analyzed per lake, the results were averaged for purposes of estimating the internal loading in the lake.

Sediment samples were analyzed for total phosphorus, aluminum-adsorbed phosphorus, calcium-adsorbed phosphorus, iron-adsorbed phosphorus, labile phosphorus, percent organic matter, and percent solids. The iron-adsorbed phosphorus fraction (also known as BD-P, or bicarbonate dithionite extractable phosphorus) was used to predict the phosphorus release rate of the sediments.

Results

The iron-adsorbed phosphorus ranged from 17 to 1400 mg P/kg sediment (dry weight), and was positively correlated with total phosphorus ($R^2 = 0.91$, Figure 3). The highest internal loading rates (anoxic factor x release rate) were in Little Lake Johanna, Little Lake Josephine, Long Lake North, and Pike Lake (Table 9). The lowest rates were in Langton Lake, Martha Lake, Moore Lake West, Spring Lake, and Turtle Lake.

Table 8. Sediment Laboratory Results

Lake Name	TP (mg/kg dry)	P, Aluminum Adsorbed (mg/kg dry)	P, Calcium Adsorbed (mg/kg dry)	P, Iron Adsorbed (mg/kg dry)	P, Labile (mg/kg dry)	Percent Organic (%)	% Solids
Hart	770	180	280	120	<19	7.7	20
Island N	670	300	89	120	<17	13.3	20
Island S	680	370	61	120	<30	18.5	13
Johanna	950	30	180	250	<30	16.5	12
Jones	1200	390	130	420	<36	27.3	11
Josephine	1600	370	160	560	<59	32.6	6.3
Karth	750	240	150	130	<20	9.7	19
Langton N	560	360	42	86	<15	14	24
Langton S	88	33	23	17	<5.9	1	64
Little Johanna	2700	780	230	1200	<24	18	16
Little Josephine	2100	550	220	1400	<41	23.2	9.7
Locke	770	120	330	300	<13	8.7	30
Long N	2300	450	90	1300	74	32.6	7.8
Long S	2500	700	240	1300	<30	16	13
Marsden	690	180	38	310	<61	56.6	6.4
Martha	610	160	23	72	<53	63.9	7.4
Moore E	870	290	280	220	<16	10.8	24
Moore W	610	190	53	66	<37	46.5	11
Moore W	540	220	42	48	<37	53.2	10
Moore W	680	270	56	69	<35	49.7	11
Pike	2400	540	280	1200	<22	14.3	17
Poplar	790	150	290	140	<23	8.7	17
Poplar	870	170	270	150	<21	7.4	18
Poplar	640	150	210	100	<20	10.1	20
Round	850	230	81	170	<47	33.7	8.2
Rush	1500	560	75	460	<69	40.7	5.3
Spring	470	260	23	55	<110	34.2	16
Sunfish	630	260	110	130	<18	9.5	21
Turtle	1100	200	59	85	<90	28.5	4.1
Valentine	1100	140	320	360	<62	33.6	6.3
Walsh	1000	370	130	290	<29	15.0	13
Walsh	840	99	22	300	<13	9.1	28
Zimmerman	920	310	280	190	<19	11.0	20

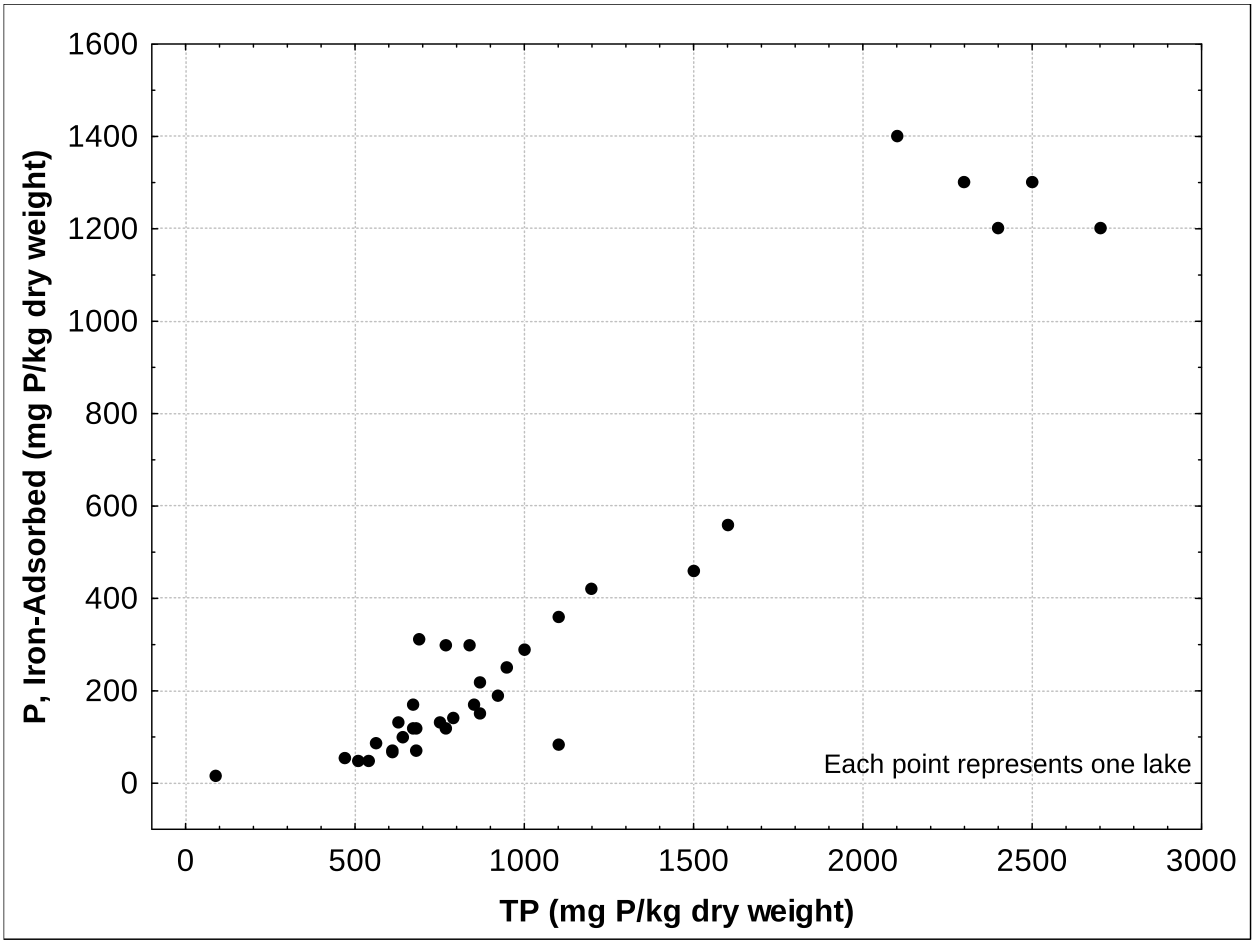

Figure 3. TP and Iron-Adsorbed Phosphorus Relationship.

Table 9. Internal Load Calculations

Lake Name	Release Rate Calculations		Anoxic Factor Calculations				AF x RR (mg/m^2-yr)	Internal load (lbs/yr)
	Iron-Adsorbed Phosphorus (mg/kg)	P Release Rate, RR (mg/m2-day)	Lake Area (ac)	Mean depth (m)	TP mean, GS (µg/L)	AF (days/ summer)		
Hart	120	1.07	8.1	0.61	168	77.9	83	6.
Island N	120	1.07	18.6	0.86	100	66.4	71	12
Island S	120	1.07	43.6	1.43	84	62.9	67	26
Johanna	250	2.85	213.5	4.92	33	44.0	125	239
Jones[1]	420	5.18	37.5	0.24	207	80.3	416	139
Josephine	560	7.10	116.4	3.22	36	45.3	322	334
Karth	130	1.20	20.5	1.50	54	54.6	66	12
Langton N	86	0.60	13.3	1.20	66	58.9	35	4
Langton S	17	-0.35	10.3	1.20	55	55.5	-19	-2[2]
Little Johanna	1,200	15.88	17.3	3.04	80	68.0	1,080	166
Little Josephine[1]	1,400	18.63	44.2	0.68	84	61.4	1,144	452
Locke[1]	300	3.54	22.4	1.20	117	70.5	249	50
Long N	1,300	17.26	73.1	1.65	145	74.4	1,284	838
Long S	1,300	17.26	118.9	3.44	54	54.4	938	995
Marsden[1]	310	3.67	271.5	0.50	61	53.6	197	477
Martha[1]	72	0.41	34.0	0.50	59	53.5	22	7
Moore E	220	2.44	29.5	1.66	44	49.9	122	32
Moore W	61	0.26	70.3	0.61	58	53.2	14	9
Pike	1,200	15.88	37.2	1.87	88	65.0	1,032	342
Poplar[1]	130	1.20	12.6	0.50	101	65.9	79	9
Round[1]	170	1.75	130.5	0.79	55	51.8	91	106
Rush[1]	460	5.73	54.7	0.50	85	61.3	351	172
Spring	55	0.17	46.4	1.50	29	39.4	7	3
Sunfish[1]	130	1.20	14.3	0.50	95	64.5	78	10
Turtle	85	0.59	447.7	3.21	21	31.9	19	75
Valentine	360	4.36	63.9	1.05	70	57.8	252	144
Walsh[1]	295	3.47	8.5	1.00	102	68.5	238	18
Zimmerman[1]	190	2.03	13.2	1.00	143	75.1	152	18

[1] In-lake phosphorus data not available and TP based on lake modeling; therefore internal loads should be considered preliminary.

[2] Low iron-adsorbed P lead to negative internal loading rate, assumed to be zero

B. LAKE RESPONSE MODELING

Purpose of modeling

Lake response models were developed for each lake in order to integrate the watershed loading with the internal loading into a predictive model. For those lakes that do not have in-lake monitoring data, the model was used to estimate the in-lake phosphorus concentrations. The model can also be used to predict the effect of phosphorus loading changes on the lakes' water quality.

Modeling approach

In-lake water quality models were developed using Bathtub (Version 6.1), an empirical model of reservoir eutrophication developed by the U.S. Army Corps of Engineers. The following steps were taken to calibrate the models. Table 10 indicates the lakes that followed the different types of calibration approaches described under step 4 below.

1) Summarize available monitoring data: The 1998-2007 averages of total phosphorus (TP), chlorophyll-*a*, and Secchi depth were used for model calibration.
2) Input watershed load: For those lakes that do not have another modeled lake in their watershed, the watershed load was determined from the P8 watershed model. For those lakes *with* another modeled lake in the watershed, the load from the direct drainage area was determined from the P8 watershed model. The load from the upstream lake and its watershed was determined by multiplying the volume of runoff draining to the lake (from the P8 model) by the observed in-lake phosphorus concentration. If there were no in-lake monitoring data, the volume was multiplied by the in-lake phosphorus concentration predicted by the Bathtub model of the upstream lake.
3) Select phosphorus sedimentation model: The phosphorus model that best predicted the in-lake TP concentration was selected. The models most frequently used were the following: Second Order, Available P; Second Order, Fixed; and Canfield & Bachmann, General.
4) Calibrate phosphorus model:
    - If the T-statistic (absolute value) was < 2.0, no changes were made to the phosphorus calibration coefficient (Approach A in Table 10). In some cases the predicted TP was quite different from the observed TP; this is acceptable for model calibration due the amount of variability in the monitoring data and the level of error in the models. However, if the observed TP was above the lake TP standard and therefore it was necessary to calculate the phosphorus load reductions needed to meet the standard, a closer match of observed and predicted values was needed:
        - If the predicted TP concentration was greater than the observed concentration, the inflow TP concentration (estimated in P8) was lowered (Approach B in Table 10).
        - If the observed TP concentration was greater than the predicted concentration, an additional internal load was added to the model (Approach C in Table 10).

- If the T-statistic (absolute value) was > 2.0, the phosphorus calibration coefficient was adjusted so that T < 2.0 (Approach D in Table 10). In one case it was still necessary to lower the inflow TP concentration in order to obtain a closer match of observed and predicted values to estimate the load reductions needed to attain the standard (Approach E in Table 10).
- If there were no in-lake monitoring data for model calibration, the phosphorus model most common in the lake set (Second Order, Fixed) was used and further adjustments were not made (Approach F in Table 10).

Table 10. Model Calibration Approaches

Approach*	Lakes
A	Island S, Johanna, Josephine, Karth, Long N, Moore W, Turtle
B	Langton, Little Johanna, Long S, Pike, Valentine
C	Island N
D	Spring
E	Moore E
F	Hart, Jones, Little Josephine, Locke, Martha, Marsden, Poplar, Round, Rush, Sunfish, Walsh, Zimmerman

*Approaches outlined in above modeling discussion

5) Incorporate internal loading: An average rate of internal loading is implicit in Bathtub since the model is based on empirical data. In the majority of the lake models, adjustments to internal loading were not necessary for model calibration. The internal loading estimate calculated from the lake sediment data was therefore not directly entered into the model, but was used to represent internal loading in the overall lake nutrient balance. In the case of Island N, an additional rate of internal loading was needed (Approach C above); this internal load was assumed to be in addition to the internal load calculated from the sediment data.
6) Calibrate chlorophyll and Secchi depth models: The chlorophyll and Secchi depth models that best predicted the observed concentrations were selected for each model. If there were no in-lake monitoring data for model calibration, the models most common in the lake set (chlorophyll: P, Linear; Secchi: vs. chl-a & turbidity) were used and further adjustments were not made.
7) Estimate watershed load reductions for lakes not currently meeting standards: After the model was calibrated to all parameters (TP, chlorophyll-*a*, and Secchi depth), the TP standard was then used as an endpoint, and the TP loads were adjusted until the model predicted that the in-lake TP standard would be reached. The model output also includes predictions of chlorophyll-*a* concentration and Secchi depth at the TP standard, in addition to predicted algal bloom frequencies, which are based on chlorophyll-*a* concentration.
8) Estimate internal load reductions for lakes not currently meeting standards: Since the internal loads were not directly incorporated into the lake response models, the internal load reductions weren't based on the lake response model but rather were based on a target phosphorus release rate, set to 7 mg/m^2-day for each lake. This rate is derived from the range of release rates in lakes of varying trophic state reported in Nürnberg (1988). The median release rate for mesotrophic lakes was approximately 5 mg/m^2-day, and the median release rate for eutrophic lakes was approximately 10 mg/m^2-day (Nürnberg 1988). The release rate goal of 7 mg/m^2-day was selected to be fall in

between the two medians. If the calculated release rate was less than 7 mg/m^2-day, then there were no recommended internal load reductions. If the rate was greater than 7 mg/m^2-day, the internal loading goal was estimated based on the difference between the calculated rate and 7 mg/m^2-day.

Results

Table 11. Lake Water Quality Data and Standard Summary

TP = total phosphorus, chl-a = chlorophyll-a (a measure of algae), Secchi = clarity or transparency

Lake	Water Quality Data Means, 1998-2007			Water Quality Standards			Meeting Standards		
	TP (µg/L)	Chl-a (µg/L)	Secchi (m)	TP (µg/L)	Chl-a (µg/L)	Secchi (m)	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
Hart*	168	75	0.4	*	*	*	N	N	N
Island N	102	25	1.3	< 60	< 20	> 1.0	N	N	N
Island S	86	34	1.1	< 60	< 20	> 1.0	N	N	Y
Johanna	31	12	2.0	< 40	< 14	> 1.4	Y	Y	Y
Jones	ND	ND	ND	< 60	< 20	> 1.0	ND	ND	ND
Josephine	36	11	2.0	< 40	< 14	> 1.4	Y	Y	Y
Karth	54	18	1.0	< 60	< 20	> 1.0	Y	Y	Y
Langton N	60	17	1.1	< 60	< 20	> 1.0	Y	Y	Y
Langton S	60	14	1.2	< 60	< 20	> 1.0	Y	Y	Y
Little Johanna	80	25	1.5	< 40	< 14	> 1.4	N	N	Y
Little Josephine	ND	ND	ND	< 60	< 20	> 1.0	ND	ND	ND
Locke*	ND	ND	ND	*	*	*	ND	ND	ND
Long N	145	57	0.6	< 40	< 14	> 1.4	N	N	N
Long S	54	25	1.4	< 40	< 14	> 1.4	N	N	Y
Marsden	ND	ND	ND	< 60	< 20	> 1.0	ND	ND	ND
Martha	ND	ND	ND	< 60	< 20	> 1.0	ND	ND	ND
Moore E	44	18	1.7	< 40	< 14	> 1.4	N	N	Y
Moore W	58	11	1.3	< 60	< 20	> 1.0	Y	Y	Y
Pike	91	53	0.8	< 60	< 20	> 1.0	N	N	N
Poplar	ND	ND	ND	< 60	< 20	> 1.0	ND	ND	ND
Round	ND	ND	ND	< 60	< 20	> 1.0	ND	ND	ND
Rush	ND	ND	ND	< 60	< 20	> 1.0	ND	ND	ND
Spring	29	2.9	2.4	< 60	< 20	> 1.0	Y	Y	Y
Sunfish	37	ND	ND	< 60	< 20	> 1.0	Y	ND	ND
Turtle	20	4.9	2.4	< 40	< 14	> 1.4	Y	Y	Y
Valentine	70	18	1.7	< 60	< 20	> 1.0	N	Y	Y
Walsh*	ND	ND	ND	*	*	*	ND	ND	ND
Zimmerman*	ND	ND	ND	*	*	*	ND	ND	ND

*No bathymetric data available. Since water quality standards are based on depths, the standards are undefined at this time.

ND = No data available

Table 12. Existing Load and Load Goal Summary

Lake	Watershed TP load (lbs/yr)	Internal load (lbs/yr)	Total load (lbs/yr)	% Watershed Load	% Internal Load	Watershed Load Goal (lbs/yr)	Internal Load Goal (lbs/yr)	Watershed Load Percent Reduction	Internal Load Percent Reduction	Total Load Percent Reduction
Hart	13	6	19	68%	32%	2	6	88%	0%	60%
Island S	47	26	73	64%	36%	47	26	0%	0%	0%
Island N	23	96	120	20%	80%	23	18	0%	82%	66%
Island	70	122	193	36%	64%	70	44	0%	64%	41%
Johanna	670	239	908	74%	26%	lake meeting WQ standards				
Jones*	1,647	139	1,786	92%	8%	396	139	76%	0%	70%
Josephine	178	334	513	35%	65%	lake meeting WQ standards				
Karth	66	12	79	85%	15%	lake meeting WQ standards				
Langton N	21	4	25	84%	16%	lake meeting WQ standards				
Langton S	46	0	46	100%	0%	lake meeting WQ standards				
Langton	68	4	72	94%	6%	lake meeting WQ standards				
Little Johanna	625	166	791	79%	21%	226	73	64%	56%	62%
Little Josephine*	228	452	679	34%	66%	122	170	46%	62%	57%
Locke*	17,364	50	17,414	100%	0%	9,053	50	48%	0%	48%
Long N	19,129	836	19,966	96%	4%	6,832	340	64%	59%	64%
Long S	476	996	1472	32%	68%	476	404	0%	59%	40%
Long	19,606	1,832	21,438	91%	9%	7,308	743	63%	59%	62%
Marsden*	509	477	986	52%	48%					
Martha*	53	7	59	89%	11%					
Moore E	173	32	205	84%	16%	121	32	30%	0%	25%
Moore W	39	9	47	82%	18%	lake meeting WQ standards				
Moore	212	41	252	84%	16%	160	41	24%	0%	21%
Pike	1,605	342	1,947	82%	18%	951	151	41%	56%	43%
Poplar*	75	10	85	88%	12%	30	10	61%	0%	53%
Round*	268	106	374	72%	28%					
Rush*	210	172	381	55%	45%	108	172	48%	0%	27%
Spring	171	3	174	98%	2%	lake meeting WQ standards				
Sunfish*	69	10	79	88%	12%	lake meeting WQ standards				
Turtle	84	75	159	53%	47%	lake meeting WQ standards				
Valentine	575	144	719	80%	20%	429	144	25%	0%	20%
Walsh*	108	18	126	86%	14%	44	18	59%	0%	51%
Zimmerman*	394	18	412	96%	4%	105	18	73%	0%	70%

*Limited or no monitoring data available, loads are based on modeling only and should be considered preliminary.

Watershed loading values are summarized from Bathtub modeling output. Values may be slightly different from P8 output due to rounding in several unit conversion steps.

4. Lake Management Action Plans

A. PURPOSE

Lake Management Action Plans (MAPs) summarize lake characteristics and existing lake data, provide a diagnostic assessment of the data, summarize public input, identify water quality issues, and recommend remedial strategies on a lake-watershed basis. As such, each MAP provides a concise summary of the known issues and recommended management approaches for each lake. It is envisioned that the MAPs will be used to further define management strategies, guide development of the District's Third Generation Plan, and serve as the basis for seeking project partners and grant funding for retrofit water quality improvements.

B. PUBLIC MEETINGS

Two public input meetings for each lake were conducted during the development of the MAPs. The first series of meetings, held in the summer of 2008, solicited input from citizens and LGU staff and officials regarding water quality concerns to further define impairments. At the second series of public meetings, held in January 2009, draft MAPs were reviewed, impairments described, and in-lake and watershed management strategies were summarized. Input received during the meetings as well as comments from LGU in response to draft MAPs were incorporated into the final MAPs.

C. MAPS

The appendix of the report presents the finalized MAPs. For each MAP one will find:

- An overview of the lake and watershed characteristics
- A summary of existing water quality data and comparison to applicable water quality standards
- A summary of public input received
- Identification of water quality issues
- Recommended management approaches for both watershed and in-lake activities
- A listing of additional data to be collected to tailor the management recommendations

Because all 24 lakes are within fully or nearly fully developed watersheds, management of land in the watershed is a critical element in addressing the identified impairments. Therefore, the identification of opportunities for retrofitting BMPs into the watershed as it re-develops or as routine maintenance occurs is a significant element of each MAP. To that end, a preliminary field reconnaissance for each watershed was conducted to identify likely regional, local, and site-specific retrofit opportunities. It should be noted that the assigned BMP classifications (regional, local or site-specific) are qualitative in nature, intended to give perspective to the relative scale of the feature and potential treatment area. Potential BMP locations identified during this field investigation are identified on Figure 1 of each MAP and detailed in the field reconnaissance supplement at the end of each MAP.

5. Long-Term Management Strategy

A. PRIORITIES

Over 200 potential retrofit BMPs are identified in the Field Reconnaissance Supplements appended to the Management Action Plans. The preliminary field reconnaissance was conducted to identify likely regional, local and site-specific retrofit opportunities that could be implemented to reduce watershed pollutant loading to downstream receiving waters. Again, it should be noted that the assigned BMP classifications (regional, local or site-specific) are qualitative in nature, intended to give perspective to the relative scale of the feature and potential treatment area.

In order to prioritize the projects, a simplified cost/benefit assessment was performed. The following criteria were used to prioritize the projects:

- Landownership – the ease of acquiring the needed permissions to utilize the land required to implement the proposed BMP.
- Studies/Planning – the amount of effort needed to assess the feasibility of a project and generate the requirements needed to implement.
- Construction Cost – the cost to construct the potential BMP.
- Pollutant Removal Potential – the amount of pollutants the proposed BMP would have the potential to remove.
- Pollutant Removal Potential relative to the Lake – the potential pollutant removal relative to the total subwatershed loading to the lake.

Qualitative rankings were based on the field investigations and institutional knowledge of the system. Projects within upstream lake subwatersheds were also considered as potential implementation projects for downstream lakes. The diminishing return of a potential project further upstream in the system was qualitatively taken into account when looking at upstream projects relative to a particular lake.

The intent of this exercise is to give the District a prioritized list of projects for further investigation. The prioritization exercise is NOT intended to make a final determination on the merits of a particular project. For most projects further feasibility assessments would be needed before the District proceeds with a particular project. Using the raw rankings as general guidance, projects were prioritized in three tiers by lake as described below:

Tier 1

Tier 1 projects consist of those projects that appear to have a very good cost benefit ratio based on the criteria described above. The projects included in Tier 1 for a particular lake are recommended as high priority for potential projects that could benefit that water body.

Tier 2

Tier 2 projects are projects that appear to have good cost benefit ratios; however, they either were projects that fell below other higher priority projects or are projects that are more suited to be implemented during road reconstruction or redevelopment projects.

Tier 3

Tier 3 projects are projects that appeared to have lower cost benefit ratios than Tier 1 or Tier 2 projects and would not be recommended as current priorities. However, these projects would still warrant investigation particularly during permit review related to redevelopment or road reconstruction projects. Also, should Tier 1 and Tier 2 projects be implemented or determined to be unfeasible, Tier 3 projects could then be assessed (as needed) to meet the water quality goals of a particular lake. Projects within upstream watersheds of other lakes were not considered as candidates for Tier 3 projects.

B. RECOMMENDED ACTIONS FOR 2009

1. For 2009 it is recommended that the District initiate feasibility studies on three of the projects included in Tier 1. These Tier 1 projects have the highest likely benefit, for a low level of additional feasibility.

    - Little Johanna 2
    - Moore 7 combined with Moore 10 & 11
    - Pike 2

2. Contact the Parks Departments and solicit interest in partnerships for the following Tier 1 projects:

    - Island 1 & 5
    - Langton 1
    - Long 17
    - Spring 2
    - Turtle 4

3. Solicit private party interest in cost shares through the Urban Stormwater Remediation Program for the following site-specific BMPs that were prioritized as Tier 1 projects.

    - Jones 22
    - Karth 5 & 7
    - Josephine 3
    - Little Josephine 9
    - Langton 3 & 6
    - Locke 19 & 24
    - Long 14
    - Marsden 2 & 3
    - Moore 12
    - Pike 11
    - Poplar 4
    - Valentine 11
    - Walsh 7
    - Zimmerman 5 & 8

4. Landowners should be notified of needed maintenance/attention at the following facilities.

   - Karth 6
   - Little Johanna 17
   - Turtle 3

The following tables include all of the projects broken down by tiers for each lake. These tables can be used a guide for future planning and implementation of CIP projects. Estimated cost ranges for Tier 1 projects were included to give a general feel for the magnitude of the projects. Further feasibility assessment and cost estimates will be needed as the District moves towards implementation of a particular project.

Lake	Tier	Project ID	Range of Probable Cost ($)	Description / Notes
Hart	No Projects Identified			
Island	Tier 1	Island 1	5-15k	(Bio)filtration basin or swale between bituminous trail and lake
		Island 2	5-30k	Multiple (in)filtration raingardens or larger retention basin
		Island 5	2-20k	Repair existing basin skimmer and excavate 2nd cell downstream of trail
	Tier 2	Island 3, 4, 6 & 7		
	Tier 3	No Tier 3 Projects Identified		
Jones	Tier 1	Jones 12	25-100k	Retrofit existing dry pond to provide (in)filtration or water quality storage
		Jones 21	25-50k	Retrofit (in)filtration or wetland treatment system at existing wooded depression
		Jones 22	2-5k	Retrofit (in)filtration raingarden into existing turf-grass swale
	Tier 2	Jones 7, 9, 10, 11, 14, 15, 16, 17 & 18, Poplar 1		
	Tier 3	Jones 1, 2, 3, 4, 5, 6, 8, 13, 19, 20, 23 & 24		
Johanna	Tier 1	Johanna 2	50-200k	Excavation of accumulated sediment and cattails from existing wetland basin
		Little Johanna 1	30-60k	Retrofit existing dry basin to provide (in)filtration storage, native vegetation
		Little Johanna 2	10-200k	Weir repair or major basin enhancement, excavate & reduce short-circuiting
	Tier 2	Johanna 1, 4, 5, & 7, Little Johanna 3, 6, 8, & 9, Little Josephine 1		
	Tier 3	Johanna 3 & 6		

Lake	Tier	Project ID	Range of Probable Cost ($)	Description / Notes
Little Johanna	Tier 1	Little Johanna 1	30-60k	Retrofit existing dry basin to provide (in)filtration storage, native vegetation
		Little Johanna 2	10-200k	Weir repair or major basin enhancement, excavate & reduce short-circuiting
	Tier 2	Little Johanna 3, 4, 6, 8, 9, 12, 13, 14, 18 & 19, Zimmerman 5		
	Tier 3	Little Johanna 5, 7, 10, 11, 15, 16, & 17		
Josephine	Tier 1	Josephine 2	15-40k	(In)filtration swale or outfall basin along lot-lines
		Josephine 3	10-40k	Retrofit existing dry basin to provide (in)filtration storage
	Tier 2	Josephine 1 & 4, Little Josephine 1, 3 & 6		
	Tier 3	No Tier 3 Projects Identified		
Little Josephine	Tier 1	Little Josephine 1	50-200k	Sediment forebay, energy dissipation and wetland treatment ponding
		Little Josephine 4	10-25k	Convert swale to filter with native vegetation, consider with LJos 5
		Little Josephine 5	10-25k	Expand existing pond, consider combined project with LJos 4
		Little Josephine 6	20-50k	Excavate sediment forebay and wetland treatment ponding
		Little Josephine 9	2-10k	Retrofit (in)filtration raingarden into existing turf-grass swale
	Tier 2	Little Josephine 3, 7 & 12		
	Tier 3	Little Josephine 2, 8, 10 & 11		
Karth	Tier 1	Karth 1	35-50k	Ponding, (in)filtration or wetland treatment at existing depression
		Karth 5	25-150k	Island (in)filtration features or porous pavement / underground filtration
		Karth 6	<1k	Vegetative amendments
		Karth 7	1-2k	Outfall/channel stabilization
	Tier 2	Karth 2, 3 & 4		
	Tier 3	No Tier 3 Projects Identified		

Lake	Tier	Project ID	Range of Probable Cost ($)	Description / Notes
Langton	Tier 1	Langton 1	15-30k	Relocate playground, incorporate filtration or water quality ponding
		Langton 3	15-40k	Remove tree, incorporate filtration or water quality ponding
		Langton 4	15-30k	Smaller alternate to Langton 3
		Langton 6	25-40k	Pavement reduction, linear filtration
	Tier 2	Langton 5		
	Tier 3	Langton 2		
Locke	Tier 1	Locke 2	20-75k	1 or 2 cell wetland treatment ponding
		Locke 14	15-50k	Reroute stormsewer outfall east, under trail, to floodplain terrace for filtration
		Locke 19	2-5k	Linear filtration along existing lot-line swale
		Locke 24	5-20k	Retrofit existing dry pond, provide (in)filtration storage, native vegetation
	Tier 2	Locke 1, 13, 16, 17, 18, 23, 25, & 27, Long 1, Pike 1		
	Tier 3	Locke 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 20, 21, 22 & 26		
Long	Tier 1	Long 1	100-500k	Reconstruct weir, consider additional upstream impoundments & excavation
		Long 14	5-25k	Excavate shallow storage areas adjacent to existing onsite catchbasins
		Long 17	10-30k	Expand and enhance existing rock storage/filter feature
		Pike 1	50-300k	Hanson Pond - Excavate sediment, expand, vegetation and carp mgmt.
		Pike 2	50-250k	Mirror Pond - sediment sealing and/or chemical treatment (add annual costs)
	Tier 2	Long 3, 4, 5 & 10, Little Johanna 2, Pike 9 & 27		
	Tier 3	Long 2, 6, 7, 8, 9, 11, 12, 13, 15 & 16		

Lake	Tier	Project ID	Range of Probable Cost ($)	Description / Notes
Marsden	Tier 1	Marsden 2	5-15k	(In)filtration raingarden for local drainage
		Marsden 3	5-15k	Retrofit dry basin to incorporate (in)filtration
	Tier 2	Marsden 4, Martha 1, 2 & 3		
	Tier 3	Marsden 1		
Martha	Tier 1	Martha 1	5-20k	Vegetative filter and/or shallow (in)filtration raingarden
	Tier 2	Martha 2 & 3		
	Tier 3	No Tier 3 Projects Identified		
Moore	Tier 1	Moore 7	10-40k	Enhance/expand existing swale, sediment forebay with downstream filtration
		Moore 10	5-10k	Convert turf to filtration raingardens
		Moore 11	10-20k	Remove bituminous flume, create linear filtration swale
		Moore 12	1-3k	Expanded storage and native vegetation amendments
	Tier 2	Moore 1, 2, 4, 5, 8 & 9		
	Tier 3	Moore 3 & 6		
Pike	Tier 1	Pike 1	50-300k	Excavate accumulated sediment, expand, vegetation and carp management
		Pike 2	50-250k	Sediment sealing and/or chemical treatment (additional annual costs)
		Pike 9	5-15k	Divert west stormsewer & 7th St runoff to filtration or water quality basin
		Pike 11	5-20k	Retrofit (in)filtration storage into dry basin
		Pike 13	20-50k	Expand or create upstream (in)filtration cell at existing basin/wetland
		Pike 27	10-25k	Ramsey County Ditch 3 outfall energy dissipation and bank stabilization
		Jones 12	25-100k	Retrofit existing dry pond to provide (in)filtration or water quality storage
	Tier 2	Pike 6, 10, 12, 14, 16, 19, 20, 21, 23, 25 & 26		
	Tier 3	Pike 3, 4, 5, 7, 8, 15, 17, 18, 22 & 24		

Lake	Tier	Project ID	Range of Probable Cost ($)	Description / Notes
Poplar	Tier 1	Poplar 1	20-100k	Need to first determine if and when the pond discharges to Poplar Lake
		Poplar 4	5-20k	Depressional storage and vegetation amendments
	Tier 2	Poplar 2 & 3		
	Tier 3	No Tier 3 Projects Identified		
Round	Tier 1	No Tier 1 Projects Identified		
	Tier 2	Round 1, 2 & 3		
	Tier 3	No Tier 3 Projects Identified		
Rush	Tier 1	Rush 2	5-20k	Wetland treatment or filtration at stormsewer outfall, assess with 3 & 4
		Rush 3	5-20k	Wetland treatment or filtration at stormsewer outfall, assess with 2 & 4
		Rush 4	5-20k	Wetland treatment or filtration at stormsewer outfall, assess with 2 & 3
	Tier 2	Rush 1		
	Tier 3	No Tier 3 Projects Identified		
Spring	Tier 1	Spring 2	5-15k	Demonstration/Education raingarden at parking lot outfall
	Tier 2	Spring 1, 3, 4, 5 & 6		
	Tier 3	No Tier 3 Projects Identified		
Sunfish	No Projects Identified			

Lake	Tier	Project ID	Range of Probable Cost ($)	Description / Notes
Turtle	Tier 1	Turtle 3	<1k	May need minor site modifications to ensure water is routed to existing BMP
		Turtle 4	5-20k	Increase treatment capacity & creatively tuck second cell to south
	Tier 2	Turtle 1 & 2		
	Tier 3	No Tier 3 Projects Identified		
Valentine	Tier 1	Valentine 2	10-20k	Small wetland treatment system or filtration basin
		Valentine 3	5-20k	(In)filtration storage & vegetation enhancement of swale upstream of culvert
		Valentine 4	20-60k	Expand & enhance swale to create shallow filtration basin, relocate parking
		Valentine 11	5-20k	Retrofit additional storage, native vegetation amendments to reduce geese
	Tier 2	Valentine 1, 6, 8, 9, 10, 13 & 14		
	Tier 3	Valentine 5, 7 & 12		
Walsh	Tier 1	Walsh 6	5-15k	Sediment excavation, pond expansion, native vegetation amendments and skimmer
		Walsh 7	3-6k	Native vegetation buffer
	Tier 2	Walsh 1, 2, 3, 4, 5 & 8		
	Tier 3	No Tier 3 Projects Identified		
Zimmerman	Tier 1	Zimmerman 5	5-10k	Retrofit dry basin, incorporate (in)filtration storage, native vegetation amendments
		Zimmerman 8	2-5k	Retrofit dry swale, incorporate (in)filtration storage, native vegetation amendments
	Tier 2	Zimmerman 1, 3 , 4 & 6		
	Tier 3	Zimmerman 2 & 7		

6. References

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Appendix – Management Actions Plans