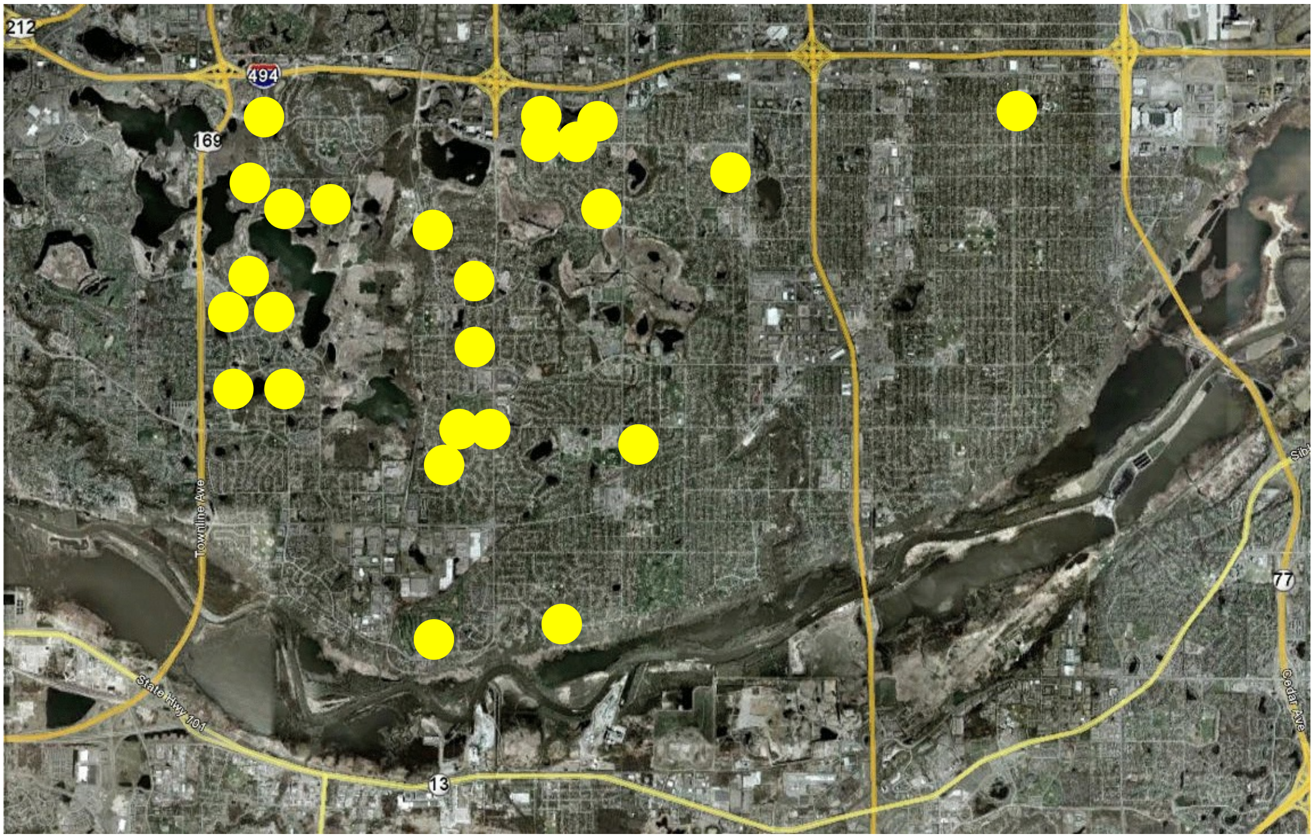

Bloomington Pond Study Area (Google Earth Map)

Water Quality, Aquatic Plants, and Fish Conditions in 26 Ponds in Bloomington, Minnesota in 2010

Ponds: River Bluff, Nesbitt, Timberglade, Berkshire, Canterbury Oaks, Hyland Courts, Round, Smith Park, Adelmann, Skriebakken, Forest Crest, Wanda Miller, Oxmore, Pauly's, Victoria, Forest Haven, Wood Cliff, Tierney's Woods, Bogen, Pickfair, Marce Woods North, Marce Woods South, South Bay, Sunrise, Xylon, and Overlook

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Water Quality, Aquatic Plants, and Fish Conditions in 26 Ponds in Bloomington, Minnesota in 2010

Summary

Stormwater ponds offer three significant benefits to the City of Bloomington: flood control, stormwater treatment, and neighborhood water resource features. The objective of this study was to evaluate 26 ponds that were representative of stormwater ponds within the City of Bloomington.

The key findings for 2010

1. All 26 ponds are functioning as intended for flood control.

2. Nearly half of the ponds were functioning for adequate stormwater treatment and meeting the goal of a pond phosphorus concentration of 150 ppb-TP or less.

3. For the other ponds in the study with high phosphorus concentrations, a combination of watershed inputs and in-lake phosphorus sources contribute to the elevated phosphorus and algae levels.

4. Fish surveys were conducted in ten ponds. Three ponds had no fish, one pond had one minnow per net, and four ponds had thousands of fathead minnows. Adelmann Pond had minnows, bullheads, and carp, which probably migrated in from a connection with Penn Lake. Wanda Miller had abundant green sunfish up to 6 inches long.

5. High densities of minnows in several ponds without plants appear to produce elevated phosphorus concentrations.

6. The City of Bloomington may have one of the largest monitored barley straw installation programs in the country. Barley straw was added to eleven ponds and all eleven showed a decrease in phosphorus compared to 2009.

7. Six of the 26 ponds had significant coverage of floating duckweed and watermeal (over 30% of the surface area). Several types of herbicides have been used over the years to control duckweed and watermeal. The plant is tough to control with herbicides. Physically removing the surface floating plants with nets has been attempted, with mixed results.

8. Four of the 26 ponds had water lilies covering more than 30% of the pond surface. Water lily coverage with vary naturally depending on water clarity and pond water levels.

9. Over half the ponds had submerged aquatic plants, but nine ponds had no submerged plants.

10. Biological manipulations that manage nutrients by way of barley straw and control fish with removal techniques should enhance submerged vegetation and appear to be a good option to lower phosphorus in ponds to meet water quality goals and to produce aesthetically pleasing pond conditions.

Key Findings for Each Pond in 2010

Summary of water quality, treatments, and observations for individual ponds.

Pond	Size (ac)	Actual TP 2010	Predicted TP Based on Runoff of 250 ppb	Treat-ment	Fish Impacts	Comments
Adelmann	6.6	162	132	None	Low to moderate	Fish may have an impact on water quality, but watershed inputs are probably a factor. Fish are probably coming in from Penn Lake.
Berkshire	0.56	415	143	Barley	Unknown	No submerged plants and a high total phosphorus (TP) even with a barley treatment. Fish may be impacting water quality. A fish survey with a fish removal option could improve water quality (WQ).
Bogen	5.0	51	118	None	Low (high minnow density but abundant plants)	WQ is better than predicted. Fathead minnows are abundant but aquatic plants are covering 80% offering a substate for food items for minnows. Bogen was partially dry in 2009 allowing plants to establish. If plants can remain, WQ should continue to be good.
Canterbury Oaks	0.84	302	142	Barley	High	WQ is worse then predicted, there is a high minnow density and no submerged plants. Barley straw is not lowering TP very much. It is suspected fish are adversely impacting WQ.
Forest Haven	7.18	35	94	None	Unknown	Combination of water lily and submerged plant growth is present. WQ is better than predicted. Fish, if present, are not a WQ factor although the pond hasn't been surveyed.
Hyland Court	1.65	79	119	None	Unknown	WQ is in good shape. Submersed plants present, although they are not abundant.
Marce Woods - N	0.85	239	164	Barley	Low (no fish observed)	WQ is still not reaching the 150 ppb goal but is dramatically improved compared to the 926 ppb-TP average in 2009. Without fish present, barley appears to be effective at reducing phosphorus in the pond.
Marce Woods - S	1.12	572	154	Sonar, Galleon	Low (no fish observed)	Highest summer average TP average of all 26 ponds. No fish were found so they were not the cause of elevated phosphorus. High TP was probably due to watershed inputs and in-pond nutrient sources. The pond was covered with nearly 100% duckweed. Herbicides had been applied but duckweed was hardly effected.
Nesbitt	1.13	163	143	Barley	Low (no fish observed)	Barley straw may have lowered TP, Nesbitt is close to the 150 ppb TP goal. No fish were found in a fish survey. Also no submerged aquatic plants were observed although there was extensive coverage with duckweed. Duckweed may be shading out submerged plant growth.
Oxmore	2.29	53	83	None	Low (high minnow density, but abundant plants)	WQ is good and better than predicted. Submerged plants are abundant and a fish survey showed an abundant fathead minnow population, but stomach content analysis showed fish feeding in the water column. Aquatic plants may be helping produce good water quality.
Pauly's	7.66	74	96	Symmetry	Unknown	WQ is good and better than predicted. Water lilies and submerged vegetation are abundant. Pond was partially dry in July of 2009, but was refilled in 2010.
Pickfair	0.69	174	188	Barley	Unknown	WQ is fair. TP was 296 ppb in 2009 and is improved this year. Barley may help reduce TP. Duckweed coverage was 100% in mid summer and 50% in August. Duckweed is probably shading out submerged plants, none were found.
River Bluff	0.69	175	123	Barley	Unknown	WQ was fair. TP was 289 ppb in 2009 and is much improved in 2010. No significant submerged plant growth was observed. Barley may be reducing TP in 2010 compared to 2009.
Round	2.49	126	94	Barley	Low (low fish density at 1 minnow/net)	WQ is improved compared to the 199 ppb-TP average in 2009. Barley straw may be reducing TP. Fish are scarce and so are submerged plants. Pond sediment analyses indicate they can support plant growth. Unknown factors are limiting submerged aquatic plants. Duckweed coverage varied from 15 to 40%.
Smith Park	7.06	46	155	None	Low	WQ is excellent and better than predicted. Abundant aquatic plants may be helping to maintain good WQ. Pond has a fishing pier and is stocked by MnDNR. Minnow population is low.
South Bay	2.33	120	101	Symmetry	Unknown	WQ is good. Submerged plants are present with an excellent fringe of emergent aquatic plants.
Sunrise - S	2.00	164	132	Barley	Unknown	WQ is fair. Good coverage of submerged plants. TP was 282 ppb in 2009 and was 164 ppb in 2010. Maybe barley straw helped reduce TP.

Pond	Size (ac)	Actual TP 2010	Predicted TP Based on Runoff of 250 ppb	Treat-ment	Fish Impacts	Comments
Skriebakken	20.08	217	115	None	Unknown	Water lilies are the trade mark of this pond, covering between 70 to 80% of the surface area. One of only two ponds out of the 26 where TP was higher in 2010 compared to 2009 (Marce Woods - S was the other). Watershed or internal loading was the likely cause. Because of the solid plant base, WQ is expected to be better in 2011.
Tierney's Woods	0.28	278	130	Barley	High	WQ slightly better than 2009, but TP is still high. Fathead minnow phosphorus loading may have overwhelmed the TP reduction from the barley straw installation. Minnow removal could improve WQ in the pond.
Timberglade	3.09	193	164	Barley	Unknown	TP is less than the 2009 concentration where it was 366 ppb. Aquatic plants are present but not abundant. Barley could lower TP even further in 2011.
Victoria	2.32	27	140	None	Unknown	Best WQ of the 26 ponds sampled. TP is much lower than predicted. Good combination of submerged and floatingleaf plants. No treatment is needed.
Wanda Miller	14	41	111	Avocet	Unknown	Good WQ. At 14 acres, second largest pond sampled. Fish survey found catchable green sunfish up to 6 inches. Abundant water lilies and submerged plants produce good WQ.
Wood Cliff	0.89	113	147	None	Unknown	TP dramatically lower in 2010 compared to the 322 ppb - TP in 2009. However, pond dried up in 2009. It refilled in 2010 and had nearly 100% coverage of submerged plants.
Xylon	0.43	218	116	Barley	Unknown	TP dramatically lower in 2010 compared to the 412 ppb - TP in 2009. There was heavy herbicide use in 2009 and barley was installed in 2010. More duckweed in 2010 than in 2009.
Overlook	5.0	70	78	None	Unknown	WQ is good with diverse and abundant submerged plant community.

Round Pond in June 2010. Water quality is improving. Barley straw installation may be a factor.

Introduction

A survey of 26 Bloomington ponds was conducted over the summer of 2010 and was sponsored by the City of Bloomington. The location of the ponds in the study is shown in Figure 1.

The objective of the survey included the following:

- Characterize water quality conditions in the selected ponds in June, July, and August.
- Evaluate how ponds were performing in regard to reducing nutrients in stormwater runoff.
- Evaluate aquatic plant and algal treatments on treated ponds.
- Suggest future management options for the Bloomington pond group.

Methods

Water Quality Monitoring and Aquatic Plant Surveys: A total of 26 ponds were selected by the City of Bloomington and were sampled by Blue Water Science in June, July, and August of 2010. Pond water samples were analyzed for total phosphorus and chlorophyll a. Secchi disc readings were also taken to measure water transparency. In addition, aquatic plant coverage was estimated and dominant plant species were noted each month.

Fish Surveys: Fish surveys using mini-trapnets were conducted on ten ponds in 2010. Two to four mini-trapnets with 2 ft x 3 ft frames and 3/16-inch mesh were used for each pond and they were set for two sampling days.

Pond Modeling: Phosphorus modeling was conducted for all 26 ponds. Watershed areas and pond areas were provided by the City. In addition, the City of Bloomington sampled stormwater runoff from June through October for flows into Round Pond. A June through August flow weighted mean was 250 ppb. This runoff value was considered to be representative for a typical watershed runoff value for the City of Bloomington for the summer of 2010. Because precipitation was above average in 2010, at 34 inches, an above average annual runoff value of 6.7 inches (17 cm) was used for pond models.

For pond phosphorus modeling, the MnLEAP model was used. Several modeling scenarios were run and included:

- Predicting pond phosphorus concentration based on an average monitored runoff value of 250 ppb-TP determined by the City of Bloomington and a runoff volume of 6.7 inches.
- Estimating phosphorus loading to a pond based on a TP runoff concentration of 250 ppb.
- Using a back-calculation to estimate phosphorus loading to a pond based on the 2010 summer phosphorus pond concentration.

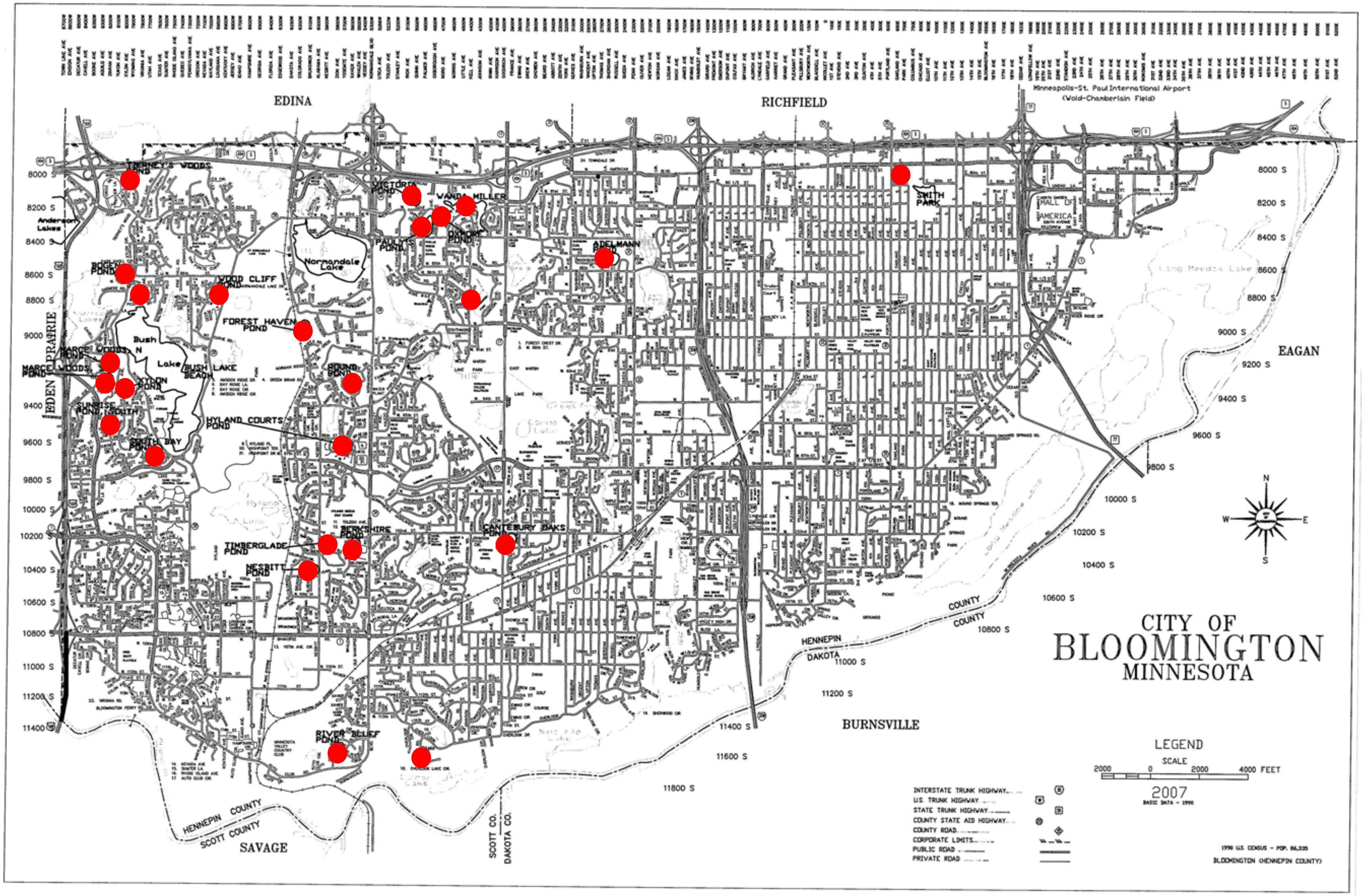


Figure 1. Locations of the 26 Bloomington ponds are shown with red dots.

Results

A total of 26 ponds were sampled in June, July, and August of 2010 and results for Secchi disc, total phosphorus, chlorophyll a, and conductivity are shown in Table 1.

Phosphorus: Pond phosphorus concentrations ranged from a low of 20 ppb (Victoria Pond in July) to a high of 971 ppb (Marce Woods S in June)(Table 1). A wide range of phosphorus concentrations were found indicating a variety of factors were influencing phosphorus levels in the ponds.

Chlorophyll: Chlorophyll a measurements are an indicator of the amount of algae in a water sample. A wide range of chlorophyll concentrations were found in the ponds over the 2010 summer ranging from a low of <1 ug/l in Forest Haven to around 200 ug/l in Skriebakken (Table 1). The high reading in July of 765 ug/l in Skriebakken was likely from a concentrated sample and not representative of conditions in the whole pond.

Secchi Disc: Secchi disc readings ranged from a low of 0.6 feet (Tierney's Woods) to a number of readings where the Secchi disc was greater than 3 feet and observed on the pond bottom (Table 1).

Conductivity: Conductivity is a measure of dissolved salts in the pond's water. It appears rainfall from June to the August sample dates generated enough runoff to dilute the ponds with water lower in conductivity then was in the ponds (Figure 2 and Table 1). Runoff in August would have a lower conductivity then runoff in April through June which would be influenced by salt from street salting over the winter. Basically, conductivity is a rough measure of stormwater runoff into the ponds.

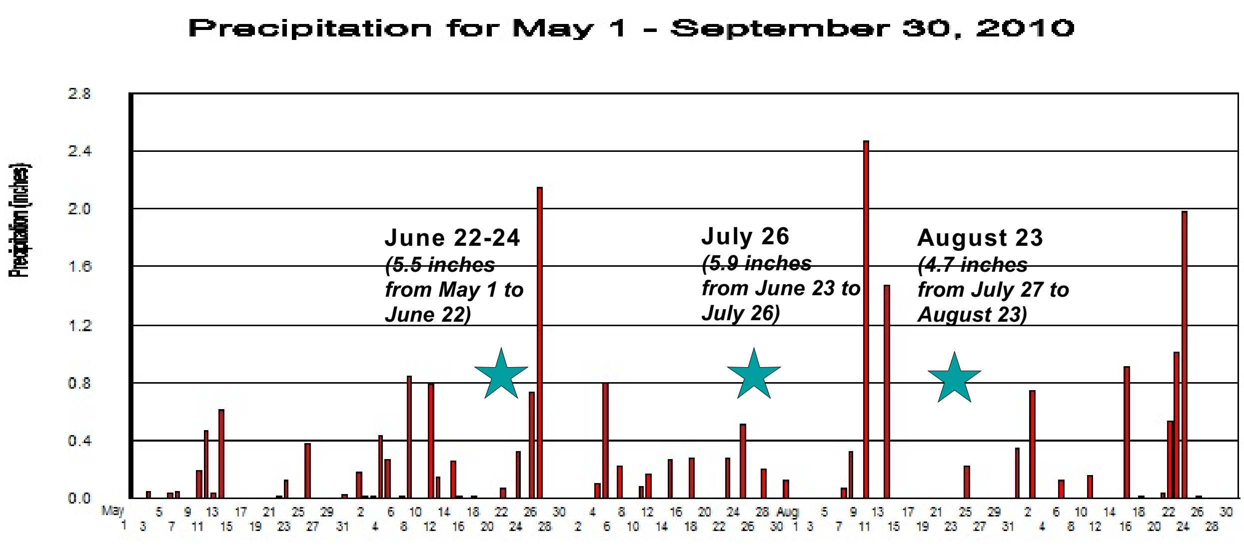


Figure 2. Daily rainfall from May 1 through September 30, 2010 recorded at the Minneapolis-St. Paul airport. Bloomington pond sample dates are shown with a star.

Table 1. Results of sampling 26 ponds for three months for total phosphorus, chlorophyll, Secchi disc, and conductivity.

Pond Name	Pond Surface Area (ac)	Avg Depth (ft)	Total Phosphorus (ppb)				Chlorophyll a (ppb)			Secchi Disc (ft)			Conductivity (umhos)		
			June 22- 24, 2010	July 26, 2010	Aug 23, 2010	Avg TP	June 22- 24, 2010	July 26, 2010	Aug 23, 2010	June 22- 24, 2010	July 26, 2010	Aug 23, 2010	June 22- 24, 2010	July 26, 2010	Aug 23, 2010
Adelmann	6.6	2.6	151	189	148	162	70	7	96.4	1.5	0.8	2.2	270	190	70
Berkshire	0.56	3	472	266	509	415	5.3	23.2	1.6	3.3 - B	2.5 - B	3.0 - B	220	160	110
Bogen	5	2.5	56	36	60	51	3.8	8	34.8	4.0 - B	3.0 - B	4.5	340	175	80
Canterbury Oaks	0.84	1.8	279	306	322	302	13	134	223	4.5	1.2	1.0	250	175	110
Forest Crest	0.45	3	138	--	--	--	6.4	--	--	2.4	--	0.7	170	165	--
Forest Haven	7.18	3.5	29	48	27	35	9.7	<1	4.9	4.8	2.0 - B	5.5	340	200	140
Hyland Court	1.65	3	91	68	77	79	12	14.1	11.6	3.3	2.0 - B	4.3	330	155	85
Marce Woods - N	0.85	1.5	258	225	234	239	70	44.1	13.2	1.8	2.0 - B	1.7	190	160	50
Marce Woods - S	1.12	2	971	459	288	572	7.6	22.3	16.4	1.5	1.9 - B	2.5	240	160	70
Nesbitt	1.13	3.5	115	258/ 192	150	163	30	26.7/ 91.6	24.6	1.8	3.5	3.8	130	75/ 90	55
Oxmore	2.29	3	24	57	78	53	2.5	16.9	66.9	5.0 - B	2.3 - B	0.7	530	700	450
Paulys	7.66	4.24	92	71	60	74	31	44.6	27.6	2.7	1.9	1.2	370	245	110
Pickfair	0.69	2.5	115	174	232	174	8.8	64.7	1.6	1.7 - B	1.5 colored	3.5	410	285	170
River Bluff	0.69	3	152	146	227	175	128	154	146	0.7	0.8	1.2	320	250	130
Round	2.49	4.49	62	212	106	126	5.0	171	11.5	5.0 B	2	1.0 - B	220	255	165
Smith Park	7.06	4 (-)	40	61	36	46	1.2	31.3	9.6	8.4	2.6	2.4	220	215	180
South Bay	2.33	2.5	89	102	168	120	22	30.5	95.8	3.2	1.5	2	240	340	220
Sunrise - S	2	1	133	121	238	164	6.9	4.8	12.1	3.0 - B	1.3 - B	3.2	140	150	100
Skriebakken	20.08	3.5	158	195	299	217	162	765	192	5.8	1.1	2	360	170	150
Tierney's Woods	0.28	3	163	320	352	278	75	38.9	176	3.0 - B	1.2	0.6	320	180	95
Timberglade	3.09	1.5	201	230	148	193	42	28.8	21.7	2.8	1.1	2.4	110	200	210
Victoria	2.32	3	32	20	29	27	3.0	2.8	4.9	4.0 - B	2.5 - B	4.3 - B	360	190	120
Wanda Miller	14	3	27	39	57	41	3.0	5	14.9	4.2 - B	3.0 - B	2.8	150	115	60
Wood Cliff	0.89	1	125	46	169	113	6.5	2.3	9.7	2.4 - B	2.0 - B	4.0 - B	220	185	95
Xylon	0.43	1.2	208	200	246	218	9.7	6.8	<1	1.5 - B	1.2 - B	1.3	80	70	--
Overlook	5	4	84	57	68	70	35	20.3	22.4	2.8	3.0 - B	1.4	270	300	170
30			--	90	100	--	--	--	--	--	--	--	--	--	--
31			--	258	--	--	--	--	--	--	--	--	--	--	--

Bush Lake (June 22, 2010): TP: 12 ppb; Chl a: 2.1 ppb

Average Pond Phosphorus, Chlorophyll Concentrations, and Secchi Disc Transparency for 2010: The June, July, August average for total phosphorus (TP), chlorophyll (Chl a), and for Secchi disc transparency is shown in Table 2 (data for individual months is shown in Table 1). Summer average total phosphorus concentrations ranged from a low of 27 ppb for Victoria to a high of 572 ppb for Marce Woods - South.

A goal for stormwater pond phosphorus concentrations is 150 ppb because a Central Hardwood Forest Ecoregion stream phosphorus value is 150 ppb. If stormwater ponds can maintain phosphorus concentrations at around 150 ppb, then the outflow from a stormwater pond will deliver an ecoregion stream phosphorus concentration to downstream waterbodies. Twelve ponds had a June-August average phosphorus concentration of 150 ppb or less (Table 2).

Table 2. Summer averages for total phosphorus (TP) and Secchi disc readings.

Pond Name	Water-shed Size (ac)	Direct Water-shed (ac)	Indirect Water-shed (ac)	Pond Surface Area (ac)	Water-shed to Pond Ratio	Average Depth (ft)	Max Depth (ft)	Actual TP (2010) (Jun, Jul, Aug Average) (ppb)	Actual Chl a (2010) (Jun, Jul, Aug Average) (ppb)	Actual Secchi Disc (2010) (Jun, Jul, Aug Average) (feet)
Adelmann	127	53	74	6.6	19	2.6	3.7	162	57.8	1.5
Berkshire	18	3	15	0.56	32	3	6.5	415	10.0	2.9+
Bogen	59	14	45	5	12	2.5	4.2	51	15.5	3.8+
Canterbury Oaks	15	6	8	0.84	18	1.8	4.5	302	123	2.2
Forest Crest	23	9	14	0.45	51	3	6.5	138*	6.4*	1.6
Forest Haven	56	27	28	7.18	7.8	3.5	7.5	35	5.2	6.2+
Hyland Court	25	5	19	1.65	15	3	5	79	12.6	3.2+
Marce Woods - N	26	4	22	0.85	31	1.5	3.5	239	42.4	1.8+
Marce Woods - S	33	7	26	1.12	30	2	6	572	15.4	2.0+
Nesbitt	42	6	36	1.13	37	3.5	5.5	163	43.2	3.0
Oxmore	10	10	0	2.29	4.4	3	6.2	53	28.8	2.7+
Paulys	96	13	83	7.66	13	4.24	6.75	74	34.4	1.9
Pickfair	85	6	79	0.69	123	2.5	5.5	174	25	2.2+
River Bluff	12	5	7	0.69	17	3	5.5	175	143	0.9
Round	26	9	17	2.49	10	4.5	5.83	126	62.5	2.7+
Smith Park	444	31	413	7.06	63	4	8 est	46	14	4.5
South Bay	16	16	0	2.33	6.7	2.5	9	120	49.4	2.2
Sunrise - S	13	9	4	2	6.5	1	2	164	7.9	2.5+
Skriebakken	319	49	270	20.08	16	3.5	8	217	373	3.0
Tierney's Woods	6	3	3	0.28	21	3	4.2	278	96.6	1.6+
Timberglade	93	49	44	3.09	30	1.5	3.5	193	30.8	2.1
Victoria	68	16	52	2.32	29	3	4.5	27	3.6	3.6+
Wanda Miller	166	50	116	14	12	3	5	41	8	3.3+
Wood Cliff	21	21	0	0.89	24	1	1.8	113	6.2	2.8+
Xylon	2	2	0	0.43	4.7	1.2	3	218	5.8	1.3+
Overlook				5		4		70	25.9	2.4+

*one month only

Pond Treatments, Aquatic Plants, Fish, and Sediments

Pond Treatments: Several treatment techniques have been used to control excessive aquatic plants and algae in a number of Bloomington Ponds. Descriptions of the chemical treatments and non-chemical treatments that have been used in the ponds are shown in Table 3.

Table 3. Description of treatment methods used for the Bloomington ponds in 2010. Other treatments used in previous years are also listed.

Aqua-Kleen	Aqua-Kleen is a herbicide and the active ingredient is 2,4-D. It is a systemic herbicide that is absorbed and moves within the plant to the site of action. It acts more slowly than a contact herbicide, but quicker than Sonar. It controls Eurasian watermilfoil and can control water lilies.
Avast:	Avast is the trade name for a fluridone herbicide. It is very similar to Sonar.
Avocet: (2010)	Avocet is a herbicide and the active ingredient is glyphosate. It is a systemic herbicide that controls emergent and floating aquatic plants including cattails and water lilies.
Barley straw:	Barley is an organic carbon amendment. Barley straw is installed contained in mesh bags. Barley is suppose to reduce phosphorus in ponds and control algae and possibly duckweed. It is a new technique and is still being evaluated.
Copper sulfate:	Copper sulfate is primarily an algaecide. Copper is toxic to algae and is usually added to a pond as a complexed copper compound to prevent a rapid precipitation of copper carbonate, which makes copper inert and no longer effective.
Cutrine plus:	Cutrine is a chelated copper algaecide. It is complexed to keep it from precipitating too rapidly. It is considered to be more effective than copper sulfate because it stays active longer.
Galleon: (2010)	Galleon is a herbicide and the active ingredient is penoxsulam. It is a non-selective systemic herbicide that requires a very long exposure period (60 days). It controls submersed, floating, and emergent plants. It's mode of action is by disrupting synthesis of amino acids.
Habitat:	Habitat is a herbicide and the active ingredient is imazapyr. It is a broad spectrum systemic herbicide used for emergent plants (such as cattails) and floatingleaf plants (such as lilies) with control in 2-4 weeks. It is not used for submersed plants. Its mode of action is by interrupting DNA synthesis and cell growth (action is similar to the herbicide Rodeo).
Hydrothol/ Aquathol: (2010)	Hydrothol and aquathol are herbicides and the active ingredient is endothall. It is a fast-acting non-selective contact herbicide used for a variety of aquatic plants including curlyleaf pondweed. Contact herbicides kill all plant cells that they contact.
RedWing: (2010)	RedWing is a herbicide and the active ingredient is diquat. It can be used for duckweed control as well as for other submersed aquatic plants. It is similar to Reward.
Reward:	Reward is a herbicide and the active ingredient is diquat. It is a fast-acting non-selective contact herbicide used for a variety of submersed aquatic plants. It's mode of action kills the vegetative part of the plant but does not kill the roots. It is suitable for spot treatments. Turbid water or dense algal blooms can interfere with its effectiveness.
Skimming:	Skimming is a process of physically removing surface growth of duckweed, watermeal, and filamentous algae using a specially designed net to round up the vegetation and remove it from the pond.
Sonar: (2010)	Sonar is a herbicide and the active ingredient is fluridone. It is a non-selective systemic herbicide that requires a very long exposure period (30-60 days). It is used for submersed plants and duckweed and watermeal. Its mode of action is by disrupting carotenoid synthesis.
Symmetry: (2010)	Symmetry is a copper-based algaecide derived from copper triethanolamine complex and copper hydroxide.
Weedtrine D:	Weedtrine is the trade name for a diquat herbicide. It is very similar to Reward.
WhiteCap:	WhiteCap is the trade name for a fluridone herbicide. It is very similar to Sonar.

Pond Treatments in 2010: A total of 17 out of 26 ponds had some type of treatment in 2010 (Table 4). Galleon and Sonar herbicides used for aquatic plant control were applied in Marce Woods-South, primarily for duckweed control. However, duckweed (DW) and watermeal (WM) are not always controlled with herbicides. Symmetry, a copper-based algaecide used to control algae, was applied in four ponds. One pond, the 14-acre Wanda Miller, had Avocet applied to control 1.5 acres of water lilies.

Barley straw was installed in 11 out of the 26 ponds. Barley straw has been shown to reduce phosphorus in ponds and thus algae is reduced as well. Barley was being tested to see if the nutrient reduction would also control duckweed in the ponds. Results from barley straw and skimming techniques to control duckweed and watermeal were mixed but all eleven ponds with barley straw had lower phosphorus concentrations in 2010 compared to 2009 with several ponds having significantly lower total phosphorus.

Table 4. Summary of pond treatments used in the Bloomington ponds in 2010.

Pond Name	Date Treated	Chemical Brand Name	Amount Applied	Area Treated (acres)
Canterbury Oaks	4/20/2010	Barley Straw	560 lbs	0.81
Hyland Court	4/27/2010	Aquathol K	5 gal	1.7
Marce Woods - N	5/13/2009	Barley Straw	480 lbs	0.69
Marce Woods - S	6/3/2010	Sonar	1 quart	1.62
Marce Woods - S	6/3/2010	Galleon	1 pint	1.62
Normandale Lake	6/29/2009	RedWing	3 quarts	0.4
Normandale Lake	7/22/2010	Symmetry	25 Gallons	12
Oxmore	7/7/2010	Symmetry	6 Gallons	2.42
Pauly's	6/4/2010	Symmetry	16 Gallons	7
Pauly's	6/19/2010	Manual Cutting	--	3.2
Pickfair	4/19/2010	Barley Straw	560 lbs	0.83
Pickfair	7/8/2010	Skimming	--	0.83
Smith Park	6/23/2010	Symmetry	1 gallon	1.84
Smith Park	6/23/2010	RedWing	1 quart	1.84
South Bay	7/7/2010	Symmetry	5 Gallons	2.87
Sunrise - S	4/22/2010	Barley Straw	800 lbs	2.62
Tierney's Woods	4/23/2010	Barley Straw	240 lbs	0.48
Timberglade	4/21/2010	Barley Straw	1,200 lbs	2.97
Wanda Miller	7/16/2010	Avocet	0.3125 Gallons	1.5
Wanda Miller	8/12/2009	Manual Cutting	--	3.2
Xylon	4/23/2010	Barley Straw	280 lbs	0.5
Round Pond	4/28/2010	Barley Straw	1760 lbs	2.5
Nesbitt Pond	4/23/2010	Barley Straw	920 lbs	1.3
Nesbitt Pond	7/26/2010	Pond Skimming	--	1.3
Berkshire Pond	4/20/2010	Barley Straw	360 lbs	0.5
River Bluff	4/30/2010	Barley Straw	480 lbs	0.7

Aquatic Plant Status of the Stormwater Ponds: Submerged aquatic plants were found in 17 ponds and duckweed and watermeal were found to have significant coverage in six ponds. No submerged plants were observed in nine ponds. Submerged plants could help to minimize duckweed coverage and could lower pond phosphorus concentrations. A variety of inhibitory factors keeps ponds from having submersed aquatic plants but all the ponds have the potential to support plants. One of the pond water quality goals is to sustain a healthy distribution of native submersed plants.

Table 5. Aquatic plant treatment methods, aquatic plant coverage, and dominant plants observed in the Bloomington ponds for 2010. Red shading indicates no submerged aquatic plants observed.

Pond Name	Pond Surface Area (ac)	Average Depth (ft)	Max Depth (ft)	Treatment Notes	% Surface Coverage			Dominant Submerged Plants		
					June 22-24, 2010	July 26, 2010	August 23, 2010	June 22-24, 2010	July 26, 2010	August 23, 2010
Adelmann	6.6	2.6	3.7		85%	15% DW	0%	sago (10%)	stringy pondweed (15%)	coontail, elodea (15%)
Berkshire	0.56	3	6.5	Barley straw	85% DW	0%	3% DW	No plants	No plants	No plants
Bogen	5	2.5	4.2		30% FA 30% DW 5%	50% - 1st basin 5% - 2nd basin	1% DW	coontail, nitella (80%)	coontail -1, stringy -3 (80% overall)	stringy pondweed
Canterbury Oaks	0.84	1.8	4.5	Barley straw	--	0%	0%	No plants	No plants	No plants
Forest Crest	0.45	3	6.5		100% DW	ND	ND	No plants	ND	ND
Forest Haven	7.18	3.5	7.5		25% WL	40% WL	70% WL	coontail (30%)	coontail, flatstem (30%)	coontail, elodea, flatstem
Hyland Court	1.65	3	5	Aquathol	2%	0%		stringy (10%)	stringy	stringy pondweed
Marce Woods - N	0.85	1.5	3.5	Barley straw	80% WM	90% DW	95% DW	No plants	No plants	No plants
Marce Woods - S	1.12	2	6	Sonar, Galleon	100% DW	100% DW, WM	50% WM	No plants	No plants	No plants
Nesbitt	1.13	3.5	5.5	Barley straw, skimming	75% DW	95% DW	100% DW	No plants	No plants	No plants
Oxmore	2.29	3	6.2	Symmetry (July 7)	2% FA	0%	0%	chara; coontail; sago (50%)	naiads-stringy (60%overall)	stringy pondweed (60%)
Pauly's	7.66	4.24	6.75	Symmetry, cutting	25% WL	35% WL	30% WL	elodea	elodea	coontail, elodea, stringy
Pickfair	0.69	2.5	5.5	Barley straw, skimming	100% WM	100% DW	50% DW	No plants	No plants	benthic algae
River Bluff	0.69	3	5.5	Barley straw	5% WM	0%	30% WM	sago	No plants	No plants
Round	2.49	4.49	5.83	Barley straw	15-20% DW, WM	40% DW	25% WM	No plants	No plants	No plants
Smith Park	7.06	4	9	Symmetry, RedWing	5% FA	5% FA	0%	coontail (30%)	coontail (20%)	coontail, elodea (30%)
South Bay	2.33	2.5	9	Symmetry	0%	0%	0%	CLP; flatstem; sago (15%)	flatstem - 1; sago - 1; stringy - 1 (15% overall)	sago, water stargrass
Sunrise - S	2	1	2	Barley straw	30% DW, WM	50% - DW 20% - WM	60% DW	nitella - 50% pond bottom	chara - 2 (90% coverage)	chara, coontail
Skriebakken	20.08	3.5	8		70% WL	DW - 3% FA - 10% WL - 80%	85% WL	coontail; elodea (50%)	coontail (50%)	coontail, stringy (50%)
Tierney's Woods	0.28	3	4.2	Barley straw	0%	0%	0%	coontail	chara (20%)	naiads, stringy (20%)
Timberglade	3.09	1.5	3.5	Barley straw	80% DW	90% DW	95% DW	coontail (10%)	arrowhead elodea; flatstem; naiads (20%)	coontail, elodea
Victoria	2.32	3	4.5		30% FA	10% FA, WL	25% WL	cabbage; coontail; elodea	elodea (40% overall)	cabbage, elodea
Wanda Miller	14	3	5	Avocet, cutting	65% WL, DW	20% - FA 50% - WL	50% WL	cabbage; coontail; floatingleaf; stringy	coontail; elodea; stringy	cabbage, coontail, milfoil (80%)
Wood Cliff	0.89	1	1.8			60% - FA 5% - DW		flatstem; sago	bulrush on shore coontail - 1; flatstem - 3; naiads - 2 (95% overall)	coontail, flatstem
Xylon	0.43	1.2	3	Barley straw	15% DW	90% DW	100% DW	No plants	No plants	No plants
Overlook	5	4			0%	5% - FA 5% - DW	5% FA	elodea; flatstem; floatingleaf; stringy	coontail; elodea; floatingleaf - 2 (5%); stringy (60% overall)	coontail, elodea, floatingleaf, sago

* CLP = curlyleaf; DW = duckweed; FA = filamentous algae; pw = pondweed; WL = white lilies; WM = watermeal

Fish Surveys Conducted in Ten Bloomington Stormwater Ponds: The results of fish surveys in ten Bloomington ponds using mini-trapnets are summarized in Table 6 and pictures of the net hauls are shown in Figure 3.

It appears high numbers of fish are correlated with elevated nutrient levels in several Bloomington ponds. Fish effects are suspected in Canterbury Oaks and Tierney's Wood Ponds where observed phosphorus is higher than predicted. Both of these ponds had little or no submerged plants. Fish stomach analysis showed food selection was mainly detritus, indicating feeding was in the sediments which in turn, could result in sediment phosphorus being translocated to the water column.

A couple of ponds were able to support minnows and still maintain good water quality. Those two ponds were Bogen and Oxmore. Both ponds had abundant submerged and emergent aquatic plant growth. Fish stomach analysis showed food selection was primarily zooplankton and invertebrates indicating feeding was in the water column. Feeding in the water column would not recycle phosphorus in the water column and not add "new" phosphorus to the pond.

Four ponds had few or no fish and these included Marce N, Marce S, Nesbitt, and Round. In these ponds, water quality is likely influenced by watershed and pond sediment factors.

Wanda Miller had abundant fish, but the community was dominated by green sunfish, which have little impact on water quality.

Adelmann Pond had bullheads, carp, and minnows. There may be some fish impacts to water quality in Adelmann Pond.

Table 6. Summary of mini-trapnet catch rates from ten stormwater ponds in Bloomington, Minnesota. Numbers represent an average of mini-trapnet lifts.

	Black Bullhead				Carp		Fathead Minnows		Green Sunfish				Total Fish/Net		Total Phos 2010 Summer Average (ug/l)	Total Phos Predicted by Modeling Using 250 ppb as Runoff (ug/l)
	0-year		*Adults*						*0-year*		*Adults*					
	#/net	*lbs/ net*	*#/net*	*lbs/ net*	*#/net*	*lbs/ net*	*#/net*	*lbs/ net*	*#/net*	*lbs/ net*	*#/net*	*lbs/ net*	*#/net*	*lbs/ net*		
Adelmann			3	0.6	1	0.6	256	0.7	11	2.1	0.3	T	270	3.4	162	132
Bogen							1,671	12.1					1,671	12.1	51	118
Canterbury Oaks							1,430	6.8					1,430	6.8	302	142
Marce Woods - N													0	0	239	164
Marce Woods - S													0	0	572	154
Nesbitt													0	0	179	143
Oxmore							1,810	7.0					1,810	7.0	53	83
Round							5.5	0.03					5.5	0.03	126	94
Tierney's Woods							1,028	4.1					1,028	4.1	278	130
Wanda Miller	0.5	T	13.5	1.5			65	0.3			38.1	4.0	117	5.8	41	111

Representative Fish Conditions in Surveyed Ponds

Adelmann (bullheads, carp, minnows, green sunfish)

Bogen (fathead minnows only species)

Canterbury Oaks (fathead minnows and green sunfish)

Oxmore (fathead minnows only species)

Tierney's Woods (fathead minnows only species)

Wanda Miller (green sunfish dominated)

Figure 3. Types of fish caught in the fish surveys of ten Bloomington Ponds. Three ponds had no fish and one pond had only a few minnows.

Round Pond Sediment Data: Although pond sediments vary from one pond to another, pond sediment samples were collected in Round Pond to get a baseline of sediment conditions in Bloomington Ponds. Three sediment samples were collected in the south end of Round Pond in three feet of water and spaced about 10 meters apart. Sediments were analyzed at the Soil Testing Laboratory at the University of Minnesota using standard soil testing methods.

The sediments were dominated by silt and sand and had less then 3% organic matter (Table 7). The phosphorus content was moderate to high. Copper, zinc, and iron were high in Sample 3 but normal in samples 1 and 2. The iron to phosphorus ratio (Fe:P) ranged from 6.1 to 10.2, indicating high potential for phosphorus release from the sediments (the arbitrary cut off is an iron to phosphorus ratio of less than 15 has the potential for phosphorus release)(Jensen et al 1992).

Results of the three pond sediment analyses indicate the pond sediments have relatively low organic matter and zinc and copper levels are low enough that rooted plants should be able to grow.

Table 7. Sediment data for three samples from Round Pond.

	Round Pond 1	Round Pond 2	Round Pond 3
Bulk Density (g/cm^3)	1.0	1.2	1.1
Organic matter (%)	2.1	1.4	2.3
Sediment pH	7.1	6.8	6.6
Bray-P (ppm)	11.0	10.0	16.0
Olsen-P (ppm)	4.0	3.0	6.0
Potassium (ppm)	36.0	38.0	47.0
Copper (ppm)	6.0	6.2	40.3
Zinc (ppm)	3.4	3.1	24.3
Iron (ppm)	66.9	82.1	163.8
Manganese (ppm)	6.8	9.5	25.4
Calcium (ppm)	596	559	649
Magnesium (ppm)	94.0	80.0	94.0
Boron (ppm)	0.3	0.3	0.5
Ammonia-Nitrogen (ppm)	9.1	4.8	5.7
Sodium (ppm)	26.0	26.0	32.0
Fe/Mn ratio	9.8	8.6	6.4
Fe/P ratio	6.1	8.2	10.2

Using Stormwater Runoff Data to Evaluate Pond Performance

Phosphorus in Runoff in 2010 and 2009: Pond total phosphorus (TP) models were run for all 26 ponds to determine if the modeled predicted pond TP was similar to the observed pond TP. When running the model, an inflow phosphorus concentration had to be selected. A summer average runoff TP concentration in 2010 of 250 ppb was used and was based on flow weighted mean runoff TP concentrations collected by the City of Bloomington from June through August, 2010 in the Round Pond watershed (Table 8). It was assumed the runoff TP concentration of 250 ppb was representative of urban runoff that flowed into Bloomington ponds in 2010 and 250 ppb-TP was used as the input for all 26 model runs. In addition, with rainfall above average, an above average runoff value of 17 cm was used. This is slightly higher than the 13 cm value used in normal years. For comparison, the TP runoff concentration in 2009 was approximately 390 ppb (Table 9) with a surface runoff value of 13 cm, which is a long term runoff average.

Table 8. Stormwater runoff samples collected from an inflow to Round Pond were analyzed for total phosphorus in 2010. Data were reported by the City of Bloomington.

Date - 2010	Total Phosphorus (ppb)	Total Phosphorus Load (pounds)	Rainfall (inches)	Period (hours)	Volume (gallons)
June 1, 2010	360	0.06	0.60	1.75	18,429
June 4, 2010	240	0.04	0.36	1.33	2,555
June 11, 2010	240	0.09	0.71	5.0	44,513
July 14, 2010	320	0.02	0.26	1.00	9,300
August 24, 2010	180	0.01	0.27	1.00	9,142
August 31, 2010	140	0.03	0.32	1.67	22,223
June-August	247 (average)	0.25 (total)	2.51 (total)	1.96 (average)	87,733 (total)
Sept 22-23	120	0.07	1.25	4.0	69,390

Table 9. Stormwater runoff samples collected from an inflow to Round Pond were analyzed for total phosphorus in 2009. Data were reported by City of Bloomington.

Date - 2009	Total Phosphorus (ppb)	Total Phosphorus Load (pounds)	Rainfall (inches)	Period (hours)	Volume (gallons)
June 16, 2009	260	0.17	0.77	5.8	57,418
June 27, 2009	470	0.11	0.40	1.5	19,795
July 9, 2009	310	0.08	0.15	1.0	8,804
July 21, 2009	460	0.16	0.67	3.0	40,540
August 7, 2009	400	0.18	1.37	5.0	52,559
August 19, 2009	430	0.38	1.88	5.0	106,912
June-August	388 (average)	1.08 (total)	5.24 (total)	3.6 (average)	286,028 (total)
October 6, 2009	420	0.14	1.40	6.0	39,993
October 21, 2009	580	0.14	0.55	6.0	29,673
October 29, 2009	550	0.26	0.60	12.25	56,396

How Are the Ponds Working?

Ponds offer at least three benefits to the City and include: flood control, stormwater treatment, and a neighborhood water resource. Based on the runoff concentration of 250 ppb, pond models were run using the watershed drainage areas (column 2) and pond areas (column 3) and average depth (column 4) and results are shown in column 6 of Table 10. These pond concentrations were than compared to actual pond TP concentrations shown in column 5 of Table 10. For most of the ponds, (14 out of 26) the actual pond TP concentrations were higher than the predicted pond TP based on a TP runoff concentration of 250 ppb. This indicates for the 14 ponds that more phosphorus was coming into the ponds than the phosphorus associated with runoff at 250 ppb-TP. The source of extra phosphorus could be from the watershed or from internal sources.

However, on the other hand, this means that 11 ponds had lower pond TP concentrations than predicted. Ponds like Bogen, Smith Park, and Victoria had lower actual summer average phosphorus concentrations than the model predictions when an estimated runoff TP concentration of 250 ppb was used. Why did these 11 ponds perform so well? Ten of the eleven ponds had submerged plants, and the one pond without plants, Pickfair, had a barley straw treatment which may have lowered the pond TP concentration.

It appears when aquatic plants are present, pond water quality is often good. This is a classic shallow lake feature. Many studies have shown that plants can sustain good water quality, but the challenge is to establish aquatic plants if they are not present. The approach is to switch a system from a turbid, algae dominated system to a clear water, plant dominated system. The key is to reduce nutrients and other factors, such as fish disruptions, that could limit plant establishment and growth.

The estimated phosphorus loading to the ponds can also be calculated. The estimated phosphorus loading to the ponds (column 7, Table 10), back calculated from the actual pond TP concentrations, is higher for 15 ponds than the estimated loading based on a TP runoff concentration of 250 ppb (Column 8).

How are the ponds working? In terms of stormwater treatment and phosphorus concentrations, some are performing better than predicted. A few have higher than predicted phosphorus concentrations indicating there is a potential for improvement. It appears, when stormwater ponds are performing to meet water quality goals, they are also an attractive neighborhood water resource.

Table 10. Summary of actual pond TP concentrations and modeling results (using the MnLEAP model) that estimate pond TP, runoff TP, and TP loading for several scenarios.

1. Pond Name	2. Water-shed Size (ac)	3. Pond Surface Area (ac)	4. Pond Average Depth (ft)	5. Actual Pond TP Conc (2010) (Jun, Jul, Aug avg) (ppb)	6. Predicted MnLEAP Pond TP Based on Typical Residential Runoff of 250 ppb	7. Estimated TP Load Based on Actual Pond TP for 2010 (kg/yr)	8. Estimated TP Load Based on Runoff TP Conc of 250 ppb in 2010	9. Estimated TP Load Needed to Meet Pond TP Goal of 150 ppb (kg/yr)	10. Estimated Runoff TP Conc Needed to Meet Pond TP Goal (ppb)	11. Reduction of TP in kg/yr Needed to Meet Pond TP Goal (kg/yr)
Adelmann	127	6.6	2.6	162	132	25	18	23	337	2
Berkshire	18	0.56	3	415	143	11	2	3	292	8
Bogen	59	5	2.5	51	118	3	3	13	406	0
Canterbury Oaks	15	0.84	1.8	302	142	6	2	2	300	4
Forest Crest	23	0.45	3	ND	158	5	3	3	254	2
Forest Haven	56	7.18	3.5	35	94	2	8	19	605	0
Hyland Court	25	1.65	3	79	119	2	3	2	150	0
Marce Woods - N	26	0.85	1.5	239	164	6	4	3	242	3
Marce Woods - S	33	1.12	2	572	154	27	4	5	265	22
Nesbitt	42	1.13	3.5	163	143	8	6	7	290	1
Oxmore	10	2.29	3	53	83	1	2	4	800	0
Paulys	96	7.66	4.24	74	96	10	14	27	515	0
Pickfair	85	0.69	2.5	174	188	11	11	9	202	2
River Bluff	12	0.69	3	175	123	3	2	2	364	1
Round	26	2.49	4.49	126	94	6	4	8	595	0
Smith Park	444	7.06	4	46	155	15	59	61	258	0
South Bay	16	2.33	2.5	120	101	3	2	5	531	0
Sunrise - S	13	2	1	164	132	3	2	2	330	1
Skriebakken	319	20.08	3.5	217	115	121	44	71	410	50
Tierney's Woods	6	0.28	3	278	130	3	1	1	335	2
Timberglade	93	3.09	1.5	193	164	16	13	12	238	4
Victoria	68	2.32	3	27	140	1	9	11	297	0
Wanda Miller	166	14	3	41	111	7	24	40	438	0
Wood Cliff	21	0.89	1	113	147	2	3	3	228	0
Xylon	2	0.43	1.2	218	116	1	0	0.4	420	0.6
Overlook		5	4	70	78	5	4	--	--	--

Notes
* One month of data
**Two months of data

Results for Ponds with Barley Straw or Herbicides or No Treatments: Eleven ponds had barley straw installed in 2010 and all eleven had lower total phosphorus (TP) concentrations in 2010 compared to 2009, with several ponds showing dramatic TP reductions (Table 11). Fish impacts in Canterbury Oaks and Tierney's Woods Pond may have contributed to the phosphorus loading in the ponds and kept the pond phosphorus concentration from decreasing more. It is suspected that Berkshire Pond may have fish impacts as well. Marce Woods - North had a significant TP decrease from 2009 and 2010, however it does not appear that barley straw was effective for controlling duckweed.

Seven ponds had herbicide or algaecide treatments in 2010. Marce Woods - South was treated for duckweed/watermeal control, but it was not very effective and it appears TP may have increased. Four ponds were treated with an algaecide (Symmetry). Water quality was already good in the ponds and the copper sulfate treatments did not increase TP. Avocet was applied in Wanda Miller for water lily control and water quality was unaffected.

Eight ponds had no treatments. Five ponds had lower TP in 2010 compared to 2009 with Wood Cliff showing the biggest improvement. Wood Cliff dried up in 2009 and reflooded in 2010 with widespread submerged plants present in 2010. The same thing occurred with Bogen Pond. Skriebakken Pond had a large TP increase in 2010 compared to 2009 and watershed inputs in 2010 were probably a factor (see Table 14). Skriebakken has abundant plants and TP is expected to be less in 2011.

Table 11. Summary of phosphorus concentrations, plants, fish, and treatments for all 26 ponds in 2010.

	Pre-Treatment TP Conc (2009)	Treatment TP Conc (2010)	Predicted TP Conc in 2010 Based on Runoff in 2010	Duckweed/ Watermeal in 2010 (% coverage)	Submerged Plants in 2010 (% coverage)	Fish TP Loading Impacts	Treatment in 2010
Barley Straw							
Berkshire	447	415	143	85 - 0	None	Unknown	Barley
Canterbury Oaks	333	302	142	0	None	Yes	Barley
Marce Woods - N	926	239	164	90	None	No	Barley
Nesbitt	219	163	143	75 - 100	None	No	Barley
Pickfair	296	174	188	100 - 50	None	Unknown	Barley
River Bluff	289	175	123	0 - 30	None	Unknown	Barley
Round	199	126	94	20 - 40	None	No	Barley
Sunrise - S	282	164	132	30 - 60	50 - 90%	Unknown	Barley
Tierney's Woods	286	278	130	0	20%	Yes	Barley
Timberglade	366	193	164	90	20%	Unknown	Barley
Xylon	412	218	116	15 - 100	None	Unknown	Barley
Herbicide							
Hyland Court	79	79	119	2	10 - 30	Unknown	Aquathol K
Marce Woods - S	495	572	154	100	None	No	Sonar, Galleon
Oxmore	50	53	83	0	50%	Possible	Symmetry
Pauly's	75	74	96	0	40%	Unknown	Symmetry
Smith Park	45	46	155	0	30	No	Symmetry, RedWing
South Bay	128	120	101	0	15%	Unknown	Symmetry
Wanda Miller	76	41	111	5	80	No	Avocet
No Treatments							
Adelmann	188	162	132	85 - 0	15	Possible	--
Bogen	228	51	118	10	80	No	--
Forest Crest	236	138*	158	--	--	--	--
Forest Haven	50	35	94	0	30	Unknown	--
Skriebakken	95	217	115	5	80	Unknown	--
Victoria	56	27	140	0	50	Unknown	--
Wood Cliff	322	113	147	5	95	Unknown	--
Overlook	--	70	78	5	60	Unknown	--

*June data only

Using the TP to Chlorophyll Ratio to Check Phosphorus Limitation: Total phosphorus (TP) and chlorophyll (chl), which is a measure of algae, were collected monthly for the 26 ponds (except Forest Crest). As a rule-of-thumb, if the TP:Chl ratio is greater than 10, then phosphorus is not causing the expected algae growth and something else is inhibiting algal growth (Carlson and Havens 2005). A total of 15 ponds had at least one month where a high ratio of over ten would indicate phosphorus was not limiting (Table 12, red shading). Five ponds had lower then expected algae growth for the whole summer (Table 12, red shading for June, July, and August). A number of factors could be limiting algal growth compared to the expectation with the high TP. For example, nitrogen could be the limiting nutrient or phosphorus could be present but unavailable for algal growth.

Table 12. Monthly values for total phosphorus, chlorophyll, and the total phosphorus to chlorophyll ratio for all 26 ponds. Red shading indicates a TP to Chl ratio greater than 10 and that something may be inhibiting algal growth.

Pond Name	Pond Surface Area (ac)	Avg Depth (ft)	Total Phosphorus (ppb)				Chlorophyll a (ppb)			Total Phosphorus to Chlorophyll Ratio)		
			June 22- 24, 2010	July 26, 2010	Aug 23, 2010	Avg TP	June 22- 24, 2010	July 26, 2010	Aug 23, 2010	June 22- 24, 2010	July 26, 2010	Aug 23, 2010
Adelmann	6.6	2.6	151	189	148	162	70	7	96.4	2.2	27	1.5
Berkshire	0.56	3	472	266	509	415	5.3	23.2	1.6	89.1	11.5	318.1
Bogen	5	2.5	56	36	60	51	3.8	8	34.8	15	4.5	1.7
Canterbury Oaks	0.84	1.8	279	306	322	302	13	134	223	21.5	2.3	1.4
Forest Crest	0.45	3	138	--	--	--	6.4	--	--	21.6	--	--
Forest Haven	7.18	3.5	29	48	27	35	9.7	<1	4.9	3	48	5.5
Hyland Court	1.65	3	91	68	77	79	12	14.1	11.6	7.6	4.8	6.6
Marce Woods-N	0.85	1.5	258	225	234	239	70	44.1	13.2	3.7	5.1	17.7
Marce Woods-S	1.12	2	971	459	288	572	7.6	22.3	16.4	127.8	20.6	17.6
Nesbitt	1.13	3.5	115	225	150	163	30	59.2	24.6	3.8	3.8	6.1
Oxmore	2.29	3	24	57	78	53	2.5	16.9	66.9	9.6	3.4	1.2
Paulys	7.66	4.24	92	71	60	74	31	44.6	27.6	3	1.6	2.2
Pickfair	0.69	2.5	115	174	232	174	8.8	64.7	1.6	13.1	2.7	145
River Bluff	0.69	3	152	146	227	175	128	154	146	1.2	0.95	1.6
Round	2.49	4.49	62	212	106	126	5.0	171	11.5	12.4	1.2	9.2
Smith Park	7.06	4 (-)	40	61	36	46	1.2	31.3	9.6	33.3	1.9	3.8
South Bay	2.33	2.5	89	102	168	120	22	30.5	95.8	4	3.3	1.8
Sunrise - S	2	1	133	121	238	164	6.9	4.8	12.1	19.3	25.2	19.7
Skriebakken	20.08	3.5	158	195	299	217	162	765	192	0.98	0.25	1.6
Tierney's Woods	0.28	3	163	320	352	278	75	38.9	176	2.2	8.2	2
Timberglade	3.09	1.5	201	230	148	193	42	28.8	21.7	4.8	8	6.8
Victoria	2.32	3	32	20	29	27	3.0	2.8	4.9	10.7	7.1	5.9
Wanda Miller	14	3	27	39	57	41	3.0	5	14.9	9.0	7.8	3.8
Wood Cliff	0.89	1	125	46	169	113	6.5	2.3	9.7	19.2	20	17.4
Xylon	0.43	1.2	208	200	246	218	9.7	6.8	<1	21.4	29.4	218
Overlook	5	4	84	57	68	70	35	20.3	22.4	2.4	2.8	3

Pond Water Quality Comparisons for 2009 and 2010 Considering Rainfall, Fish, and Treatments

Conductivity, which is a measure of dissolved salts in water, was checked in all ponds on all sample dates in 2009 and in 2010. The June conductivity readings reflect, in part, road salt that has run into the ponds. Rainfall and runoff will dilute the dissolved salts as the summer goes on and the change in conductivity is a broad indicator of how much runoff is coming into the ponds. Rainfall in 2010 was greater than in 2009 (Table 13) and conductivity was generally lower in the ponds in 2010 than in 2009 (Table 14). In both years conductivity decreased from June to August, although in a few ponds conductivity increased in July compared to June (shown with red shading in Table 14). Sometimes biological activity can increase conductivity, otherwise it might indicate the ponds did not receive enough runoff to dilute or reduce the conductivity.

Table 13. Rainfall, in inches, between pond sample dates in 2009 and 2010.

	Rainfall	
	2009	2010
May 1 to June sample date	2.49	5.05
June to July sample date	2.43 (4.92)	5.91 (10.96)
July to August sample date	7.00	4.65
Total May to August	11.92	15.61

Table 14. Results of sampling 26 ponds for three months for conductivity in 2009 and 2010.

Pond Name	Pond Surface Area (ac)	Avg Depth (ft)	Conductivity - 2009 (umhos)			Conductivity - 2010 (umhos)		
			June 18, 2009	July 27, 2009	Aug 26-27, 2009	Jun 22-24, 2010	July 26, 2010	Aug 23, 2010
Adelmann	6.6	2.6	550	405	110	270	190	70
Berkshire	0.56	3	350	340	195	220	160	110
Bogen	5	2.5	280	295	105	340	175	80
Canterbury Oaks	0.84	1.8	450	370	208	250	175	110
Forest Crest	0.45	3	--	--	150	170	165	--
Forest Haven	7.18	3.5	270	255	190	340	200	140
Hyland Court	1.65	3	260	255	109	330	155	85
Marce Woods - N	0.85	1.5	310	290	90	190	160	50
Marce Woods - S	1.12	2	490	420	130	240	160	70
Nesbitt	1.13	3.5	190	210	85	130	75/90	55
Oxmore	2.29	3	600	800	650	530	700	450
Paulys	7.66	4.24	650	dry	210	370	245	110
Pickfair	0.69	2.5	710	550	200	410	285	170
River Bluff	0.69	3	300	320	250	320	250	130
Round	2.49	4.49	310	280	230	220	255	165
Smith Park	7.06	4 (-)	430	385	120	220	215	180
South Bay	2.33	2.5	430	385	319	240	340	220
Sunrise - S	2	1	370	280	110	140	150	100
Skriebakken	20.08	3.5	350	320	250	360	170	150
Tierney's Woods	0.28	3	600	510	180	320	180	95
Timberglade	3.09	1.5	220	190	130	110	200	210
Victoria	2.32	3	550	620	140	360	190	120
Wanda Miller	14	3	450	315	100	150	115	60
Wood Cliff	0.89	1	330	ND	120	220	185	95
Xylon	0.43	1.2	ND	110	75	80	70	--
Overlook	5	4	ND	ND	ND	270	300	170

A summary of 2009 and 2010 pond total phosphorus (TP) and predicted pond TP concentrations is shown in Table 15. Since phosphorus was lower in runoff (estimated at 250 ppb) in 2010 compared to 2009 (estimated at 390 ppb), the predicted TP pond concentration is lower in 2010 compared to 2009. The actual pond TP is also generally lower and in some ponds it is drastically lower when comparing 2009 to 2010.

The greatest phosphorus decline from 2009 to 2010 was in Marce Woods - North. Barley straw may have played a role in the decline. Also a large percentage decrease in phosphorus was observed in Bogen Pond. Bogen Pond was partially dry in 2009 and reflooded in 2010.

Only two ponds, Marce Woods - South and Skriebakken, have significantly higher phosphorus in 2010 compared to 2009.

In 2010, ten ponds have actual average phosphorus concentrations lower than predicted pond phosphorus concentrations. Victoria Pond is an example of a pond that has a lower TP than predicted.

Table 15. Comparison of 2009 and 2010 data.

1. Pond Name	2. Watershed Size (ac)	3. Pond Surface Area (ac)	4. Pond Average Depth (ft)	Actual Total Phosphorus (ppb)		Predicted Total Phosphorus		Estimated Total Phosphorus Concentration in Runoff Needed to Achieve the Actual TP Conc (ppb)	
				2009	2010	2009 (based on 390 ppb in runoff)	2010 (based on 250 ppb in runoff)	2009	2010
Adelmann	127	6.6	2.6	188	162	172	132	445	367
Berkshire	18	0.56	3	447	415	188	143	1,285	1,160
Bogen	59	5	2.5	228	51	148	118	744	80
Canterbury Oaks	15	0.84	1.8	333	302	185	142	878	768
Forest Crest	23	0.45	3	236*	138*	212	158	447	445
Forest Haven	56	7.18	3.5	50	35	114	94	100	50
Hyland Court	25	1.65	3	79	79	151	119	150	155
Marce Woods - N	26	0.85	1.5	926	239	222	164	2,645	427
Marce Woods - S	33	1.12	2	495	572	205	154	1,274	1,567
Nesbitt	42	1.13	3.5	219	163	187	143	480	367
Oxmore	10	2.29	3	50	53	99	83	110	122
Pauly's	96	7.66	4.24	75**	74	125	96	180	175
Pickfair	85	0.69	2.5	296	174	265	188	446	240
River Bluff	12	0.69	3	289	175	157	123	945	455
Round	26	2.49	4.49	199	126	115	94	940	450
Smith Park	444	7.06	4	45	46	208	155	59	60
South Bay	16	2.33	2.5	128	120	124	101	410	372
Sunrise - S	13	2	1	282	164	168	132	846	378
Skriebakken	319	20.08	3.5	95	217	145	115	210	708
Tierney's Woods	6	0.28	3	286	278	167	130	835	800
Timberglade	93	3.09	1.5	366	193	222	164	750	327
Victoria	68	2.32	3	56	27	183	140	820	30
Wanda Miller	166	14	3	76	41	139	111	150	60
Wood Cliff	21	0.89	1	322**	113	231	147	598	160
Xylon	2	0.43	1.2	412**	218	143	116	2,090	762
Overlook	50 (est)	5	4	--	70	ND	ND (78)	--	170 (est)

* one month of data
** two months of data

Ranking Ponds Based on Water Quality in 2010

Water quality in Victoria Pond was a surprise. It has a relatively large watershed to pond area ratio yet had the best water quality of the ponds tested (Table 16). The black line after Round Pond divides the ponds that met the 150 ppb goal from the ponds that had a TP concentration greater than 150 ppb. Twelve ponds had TP concentrations less than 150 ppb. For the remaining 13 ponds, either watershed TP runoff concentrations are high or internal phosphorus loading is significant and contributes to the elevated pond TP concentration.

Table 16. Ranking ponds based on total phosphorus concentrations. Also shown are modeling results (using the MnLEAP model) that estimate pond TP based on runoff TP, and TP loading for several scenarios (Forest Crest was not included, it has only one month of data).

Pond Name	Pond Surface Area (ac)	Actual Pond TP Conc (2010) (Jun, Jul, Aug avg) (ppb)	Treatment in 2010	Goal for Pond TP Conc (ppb)	Reduction of TP in kg/yr Needed to Meet Pond TP Goal (kg/yr)
Victoria	2.32	27		150	0
Forest Haven	7.18	35		150	0
Wanda Miller	14	41	Avocet, cutting	150	0
Smith Park	7.06	46	Symmetry, RedWing	150	0
Bogen	5	51		150	0
Oxmore	2.29	53	Symmetry	150	0
Overlook	5	70		150	0
Pauly’s	7.66	74	Symmetry, cutting	150	0
Hyland Court	1.65	79		150	0
Wood Cliff	0.89	113		150	0
South Bay	2.33	120	Symmetry	150	0
Round	2.49	126	Barley	150	0
Adelmann	6.6	162		150	2
Nesbitt	1.13	163	Barley, skimming	150	1
Sunrise - S	2	164	Barley	150	1
Pickfair	0.69	174	Barley, skimming	150	2
River Bluff	0.69	175	Barley	150	1
Timberglade	3.09	193	Barley	150	4
Skriebakken	20.08	217		150	50
Xylon	0.43	218	Barley	150	0.6
Marce Woods - N	0.85	239	Barley	150	3
Tierney's Woods	0.28	278	Barley	150	2
Canterbury Oaks	0.84	302	Barley	150	4
Berkshire	0.56	415	Barley	150	8
Marce Woods - S	1.12	572	Sonar, Galleon	150	22

Stormwater Pond Network

Many of the stormwater ponds in the City of Bloomington are connected to other ponds. The network of the ponds sampled in this study and the water bodies they outflow to are shown on the next two pages (study ponds are shown in blue shading).

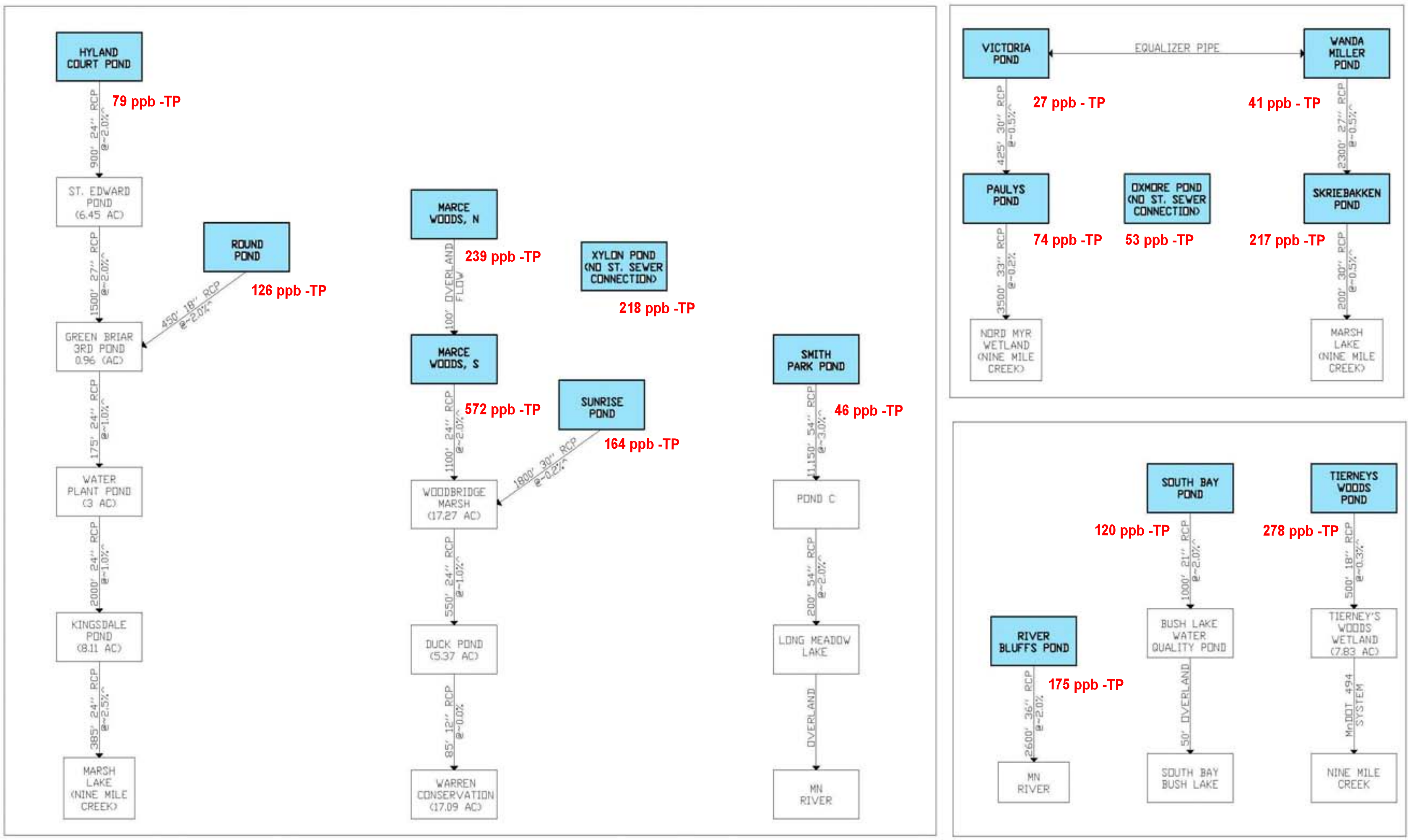
Two ponds, Xylon and Oxmore, are not connected to the stormwater sewer network.

A number of other ponds are at the head of the watershed with no inflow from other subwatersheds. These ponds have smaller watershed area to pond area ratios compared to downstream ponds. Sometimes the smaller watershed to pond ratio results in lower pond TP concentrations compared to ponds with larger ratios. That was not always the case for this study.

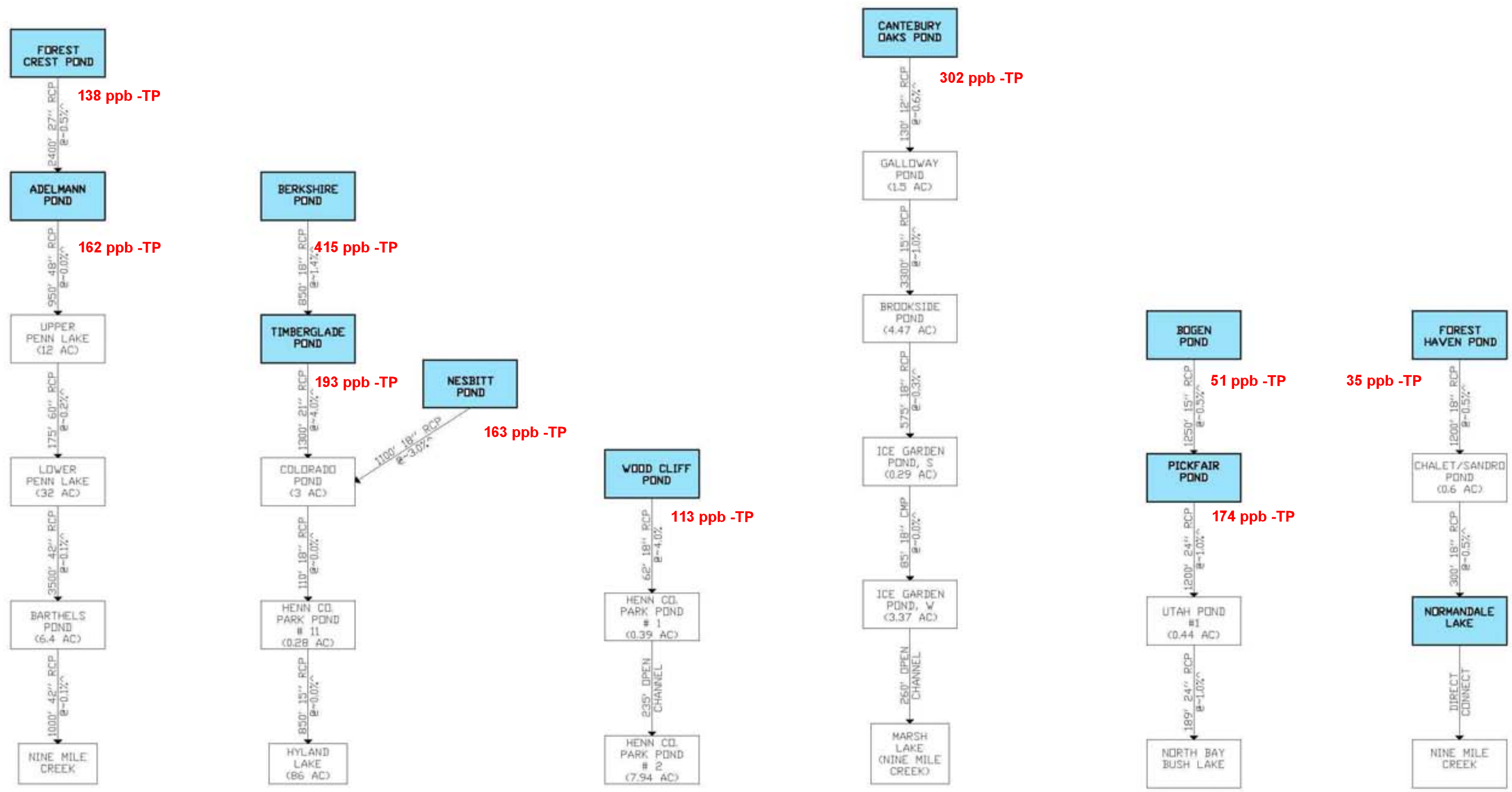
Also, recent work (McComas 2008) has found that stormwater ponds can support a variety of fish, with the most common species being fathead minnows, bullheads, goldfish, and sunfish. Other work has shown that in shallow wetland systems, minnows and other small fish can elevate phosphorus levels and eliminate submersed aquatic plants (Zimmer et al 2001). Because stormwater ponds are similar to shallow wetland systems, fish could have an impact on water quality in stormwater ponds (McComas 2008).

Also, because stormwater ponds are connected to other stormwater ponds, there may be a winter refuge somewhere in the pond network that allows fish to avoid winterkill conditions

POND NETWORK FOR CITY OF BLOOMINGTON:
POND TREATMENT PROGRAM REVIEW



POND NETWORK FOR CITY OF BLOOMINGTON: POND TREATMENT PROGRAM REVIEW



Key Findings for Each Pond in 2010

Table 17. Summary of water quality, treatments, and observations for individual ponds.

Pond	Size (ac)	Actual TP 2010	Predicted TP Based on Runoff of 250 ppb	Treat-ment	Fish Impacts	Comments
Adelmann	6.6	162	132	None	Low to moderate	Fish may have an impact on water quality, but watershed inputs are probably a factor. Fish are probably coming in from Penn Lake.
Berkshire	0.56	415	143	Barley	Unknown	No submerged plants and a high total phosphorus (TP) even with a barley treatment. Fish may be impacting water quality. A fish survey with a fish removal option could improve water quality (WQ).
Bogen	5.0	51	118	None	Low (high minnow density but abundant plants)	WQ is better than predicted. Fathead minnows are abundant but aquatic plants are covering 80% offering a substate for food items for minnows. Bogen was partially dry in 2009 allowing plants to establish. If plants can remain, WQ should continue to be good.
Canterbury Oaks	0.84	302	142	Barley	High	WQ is worse then predicted, there is a high minnow density and no submerged plants. Barley straw is not lowering TP very much. It is suspected fish are adversely impacting WQ.
Forest Haven	7.18	35	94	None	Unknown	Combination of water lily and submerged plant growth is present. WQ is better than predicted. Fish, if present, are not a WQ factor although the pond hasn't been surveyed.
Hyland Court	1.65	79	119	None	Unknown	WQ is in good shape. Submersed plants present, although they are not abundant.
Marce Woods - N	0.85	239	164	Barley	Low (no fish observed)	WQ is still not reaching the 150 ppb goal but is dramatically improved compared to the 926 ppb-TP average in 2009. Without fish present, barley appears to be effective at reducing phosphorus in the pond.
Marce Woods - S	1.12	572	154	Sonar, Galleon	Low (no fish observed)	Highest summer average TP average of all 26 ponds. No fish were found so they were not the cause of elevated phosphorus. High TP was probably due to watershed inputs and in-pond nutrient sources. The pond was covered with nearly 100% duckweed. Herbicides had been applied but duckweed was hardly effected.
Nesbitt	1.13	163	143	Barley	Low (no fish observed)	Barley straw may have lowered TP, Nesbitt is close to the 150 ppb TP goal. No fish were found in a fish survey. Also no submerged aquatic plants were observed although there was extensive coverage with duckweed. Duckweed may be shading out submerged plant growth.
Oxmore	2.29	53	83	None	Low (high minnow density, but abundant plants)	WQ is good and better than predicted. Submerged plants are abundant and a fish survey showed an abundant fathead minnow population, but stomach content analysis showed fish feeding in the water column. Aquatic plants may be helping produce good water quality.
Pauly's	7.66	74	96	Symmetry	Unknown	WQ is good and better than predicted. Water lilies and submerged vegetation are abundant. Pond was partially dry in July of 2009, but was refilled in 2010.
Pickfair	0.69	174	188	Barley	Unknown	WQ is fair. TP was 296 ppb in 2009 and is improved this year. Barley may help reduce TP. Duckweed coverage was 100% in mid summer and 50% in August. Duckweed is probably shading out submerged plants, none were found.
River Bluff	0.69	175	123	Barley	Unknown	WQ was fair. TP was 289 ppb in 2009 and is much improved in 2010. No significant submerged plant growth was observed. Barley may be reducing TP in 2010 compared to 2009.
Round	2.49	126	94	Barley	Low (low fish density at 1 minnow/net)	WQ is improved compared to the 199 ppb-TP average in 2009. Barley straw may be reducing TP. Fish are scarce and so are submerged plants. Pond sediment analyses indicate they can support plant growth. Unknown factors are limiting submerged aquatic plants. Duckweed coverage varied from 15 to 40%.
Smith Park	7.06	46	155	None	Low	WQ is excellent and better than predicted. Abundant aquatic plants may be helping to maintain good WQ. Pond has a fishing pier and is stocked by MnDNR. Minnow population is low.
South Bay	2.33	120	101	Symmetry	Unknown	WQ is good. Submerged plants are present with an excellent fringe of emergent aquatic plants.
Sunrise - S	2.00	164	132	Barley	Unknown	WQ is fair. Good coverage of submerged plants. TP was 282 ppb in 2009 and was 164 ppb in 2010. Maybe barley straw helped reduce TP.

Pond	Size (ac)	Actual TP 2010	Predicted TP Based on Runoff of 250 ppb	Treat-ment	Fish Impacts	Comments
Skriebakken	20.08	217	115	None	Unknown	Water lilies are the trade mark of this pond, covering between 70 to 80% of the surface area. One of only two ponds out of the 26 where TP was higher in 2010 compared to 2009 (Marce Woods - S was the other). Watershed or internal loading was the likely cause. Because of the solid plant base, WQ is expected to be better in 2011.
Tierney's Woods	0.28	278	130	Barley	High	WQ slightly better than 2009, but TP is still high. Fathead minnow phosphorus loading may have overwhelmed the TP reduction from the barley straw installation. Minnow removal could improve WQ in the pond.
Timberglade	3.09	193	164	Barley	Unknown	TP is less than the 2009 concentration where it was 366 ppb. Aquatic plants are present but not abundant. Barley could lower TP even further in 2011.
Victoria	2.32	27	140	None	Unknown	Best WQ of the 26 ponds sampled. TP is much lower than predicted. Good combination of submerged and floatingleaf plants. No treatment is needed.
Wanda Miller	14	41	111	Avocet	Unknown	Good WQ. At 14 acres, second largest pond sampled. Fish survey found catchable green sunfish up to 6 inches. Abundant water lilies and submerged plants produce good WQ.
Wood Cliff	0.89	113	147	None	Unknown	TP dramatically lower in 2010 compared to the 322 ppb - TP in 2009. However, pond dried up in 2009. It refilled in 2010 and had nearly 100% coverage of submerged plants.
Xylon	0.43	218	116	Barley	Unknown	TP dramatically lower in 2010 compared to the 412 ppb - TP in 2009. There was heavy herbicide use in 2009 and barley was installed in 2010. More duckweed in 2010 than in 2009.
Overlook	5.0	70	78	None	Unknown	WQ is good with diverse and abundant submerged plant community.

* Forest Crest Pond not included, one month data

Round Pond in June 2010. Water quality is improving. Barley straw installation may be a factor.

Pond Recommendations and Considerations

The goals for pond management are several-fold and include the following:

1. Maintain and/or enhance stormwater treatment function by maintaining stormwater pond TP concentrations of 150 ppb or less.

2. Maintain aesthetic values so ponds serve as a neighborhood natural resource. For the most part, limiting filamentous algae or duckweed below 30% coverage is generally aesthetically acceptable for a neighborhood pond and is a management goal.

3. Increase and/or maintain submersed aquatic plants in all ponds. A goal of 40% bottom coverage would help sustain good water quality.

It is assumed other watershed practices will be ongoing. These practices include street sweeping and ongoing information and education programs concerning residential phosphorus control projects. These projects include items such as rain gardens, rain barrels, lawn maintenance, low fertilizer use and other programs such as the City's Comprehensive Surface Water Management Plan (CSWMP) and Storm Water Pollution Prevention Program (SWPPP).

The overall pond management program discussed in this report is designed to assess the source of phosphorus to the ponds (runoff or internal), determine what is limiting submersed plant growth in some ponds, and implement projects that meet pond management goals.

To meet pond management goals, a mix of conventional and new management techniques have been proposed for individual ponds with the intention to improve pond water quality and aesthetics. A summary of the techniques is shown below and a list of possible projects is shown in Table 18.

Herbicide Options

Algaecides:

Copper-based algaecide: used to control open water algae and filamentous (floating) algae.

Herbicides:

Avast or Sonar: used to control submerged plants and for duckweed and watermeal

Galleon: used for control of a wide-variety of aquatic plants including duckweed and watermeal.

Biomanipulation Options

Barley straw: Latest research findings (McComas, unpublished) indicate adding barley straw to a pond acts as an organic carbon amendment which stimulates organic carbon-limited microbial growth. Because barley straw has a low phosphorus content, as microbes grow by decomposing the organic carbon in the barley straw they out-compete algae for phosphorus in the water column and can reduce the phosphorus concentration in the whole pond. There is strong evidence this also reduces algal growth resulting in an increase in water clarity and enhancing submerged plant growth.

Fish manipulations: Evidence is mounting that excessive numbers of fish in ponds and wetlands have impacts on water quality and aquatic plants (Zimmer et al 2001). Removing or reducing the fish in ponds could reduce internal phosphorus loading and also enhance submerged aquatic plant growth. Rotenone (a fish poison) is not the first choice for neighborhood pond fish control. Rather, netting is a better option for fathead minnow, bullhead, and carp management in these ponds with excessive fish.

A summary of recommendations for pond management actions for 2011 is shown in Table 18. For several ponds, no action is considered to see how the pond reacts. Fish removal (fathead minnows) is recommended to improve water quality in two ponds. Fish surveys will give insight to potential sources of phosphorus from bottom-feeding fish. Several herbicide applications are recommended to continue and a number of ponds are recommended to receive barley straw and/or skimming treatments.

Table 18. Pond treatments in 2009 and 2010 and recommendations for 2011. Pond ranking is based on pond TP concentrations for 2010.

Pond Name	Pond Area (ac)	Actual Pond TP Conc (2009) (Jun, Jul, Aug avg)(ppb)	Actual Pond TP Conc (2010) (Jun, Jul, Aug avg) (ppb)	Watershed to Pond Area Ratio	Aquatic Plant Status in 2010	Treatment in 2009	Treatment in 2010	Recommendations for 2011
Forest Crest	0.45	236	--	51	No sub plants, 60% DW	WhiteCap	Skim	Skim
Victoria	2.32	56	27	29	Sub plants, 4% FA	--	--	--
Forest Haven	7.18	50	35	7.8	Sub plants, 50% WL	--	--	--
Wanda Miller	14	73	41	12	Sub plants, 60% WL	Habitat	Avocet, cutting, fish survey	Manual cutting
Smith Park	7.06	45	46	63	Sub plants, 5% FA	Copper sulfate	Symmetry, RedWing	Copper sulfate
Bogen	5	228	51	12	Sub plants, 80-0% DW & WM	--	Fish survey	Fish survey
Oxmore	2.29	50	53	4.4	Sub plants	Copper sulfate	Symmetry, fish survey	Fish survey
Paulys	7.66	75	74	13	Sub plants, 30% WL	Copper sulfate, Habitat	Symmetry, cutting	Copper sulfate
Hyland Court	1.65	79	79	15	Sub plants	--	--	--
Wood Cliff	0.89	322	113	24	Dry - some plants	--	--	--
South Bay	2.33	128	120	6.7	Sub plants	Sonar	Symmetry	Symmetry
Round	2.49	199	126	10	No sub plants, 25-60% DW & WM	Barley, skimming	Barley, fish survey	Barley straw, skim
Adelmann	6.6	188	162	19	Sub plants	--	Fish survey	Fish survey
Nesbitt	1.13	219	163	37	No sub plants, 70-100% DW	Barley, Skimming	Barley, skim, fish survey	Barley straw, skim
Sunrise - S	2	282	164	6.5	Sub plants - trace 10-50% WM	Sonar	Barley	Barley
Pickfair	0.69	296	174	123	No sub plants, 100% DW	Sonar, Galleon	Barley, skim	Barley, skim
River Bluff	0.69	289	175	17	Sub plants - trace	--	Barley	Barley
Timberglade	3.09	366	193	30	Sub plants 100%-0 DW 10-95%	Sonar	Barley	--
Skriebakken	20.08	95	217	16	Sub plants, 5% FA	--	--	--
Xylon	0.43	412	218	5	No sub plants	Sonar, Galleon	Barley	--
Marce Woods - N	0.85	926	239	31	No sub plants, 100% DW	Sonar, Galleon	Fish survey, barley	Barley
Tierney's Woods	0.28	286	278	21	No sub plants	Sonar, Galleon	Barley, fish survey	Barley, fish removal
Canterbury Oaks	0.84	333	302	18	No sub plants	Sonar, Galleon	Barley, fish survey	Barley straw, fish removal
Berkshire	0.56	447	415	32	No sub plants	--	Barley	Barley, fish survey
Marce Woods - S	1.12	495	572	30	No sub plants, 100% DW	Sonar, Galleon	Fish survey, Sonar, Galleon	Barley

sub plants = submerged plants, DW = duckweed; WM = watermeal; FA = filamentous algae; WL = water lily

Pond Biomanipulation Options

Barley Straw: It appears barley straw can reduce pond TP. It doesn't matter if the source of phosphorus is from the watershed or from internal sources, the microbial growth will take the phosphorus out of the water column.

There is some evidence that barley straw can reduce filamentous algae and duckweed growth, but results in other ponds have been mixed.

Barley straw is installed in mesh bags and staked to the pond bottom to keep it in a small confined area. It is not obtrusive and bags and stakes are removed by the end of the summer (Figure 4).

Figure 4. Barley straw is anchored in a pond and removed at the end of the growing season. Barley straw is documented to reduce phosphorus in ponds.

Fish Manipulations: An evolving area in stormwater pond management is assessing the impact of the fish community on pond phosphorus concentrations. Results from work on stormwater ponds in Apple Valley show minnows and bullheads appear to influence water quality in stormwater ponds (McComas 2008)(Table 19 and Figure 5). In 2007, in several Apple Valley ponds, fish surveys were conducted and pond TP was monitored. There was a significant winterkill in the two ponds over the 2007-2008 winter. In Pond 2, fish populations decreased and TP decreased. In Pond 170, bluegills died off over the winter and were replaced with an explosion of small fish primarily minnows and young bullheads. Total phosphorus levels increased with the increase in fish in Pond 170 (Table 19).

For Bloomington ponds, a number of stormwater ponds have been surveyed to assess the fish population and the fish status was correlated with the phosphorus condition. In the future, possible fish manipulations could be considered in order to manage phosphorus concentrations in the stormwater ponds.

Table 19. Apple Valley stormwater pond phosphorus and fish conditions for 2007 and 2008.

Pond	Size (ac)	Mean Depth (ft)	2007 - TP Sept 27 (season avg) (ppb)	2008 - TP Oct 23 (season avg) (ppb)	2007 Fish #/net (pounds)	2008 Fish #/net (pounds)
2	7.2	4.5	260	97	656 (22)	76 (1.0)
170	7.3	2.5	280	448	385 (9.5)	4,237 (30)

Figure 5. Apple Valley pond fish survey results for 2007 and 2008. Fish biomass was less in 2008 than 2007 for Pond 2, but higher in Pond 170. Bluegill sunfish were found in Pond 170 in 2007 but were not found in 2008. A partial winterkill is the likely explanation.

Skimming: Skimming is the use of fine-mesh nets to remove (skim) duckweed and watermeal off of the surface of a pond (Figure 6). It is a niche area at this time and only one commercial company offers it on a routine basis. However, it is an ecologically sound approach and has long-term benefits for wildlife and water quality from the perspective that it removes excess surface growth that allows light penetration which would enhance submerged plant growth. Also removing vegetation removes a small amount of phosphorus associated with the plant material that would otherwise recycle in the pond.

Figure 6. Example of skimming duckweed and watermeal off of a pond.

Techniques Considered but Not Recommended

Ultra sound: Results are mixed for open water algae control. Duckweed and watermeal would not be impacted. Ultra sound is expensive to buy and operate and does not reduce phosphorus in ponds.

Bacterial additions: Results are mixed for algae control. Previously, bacterial products have been tried in several Bloomington ponds. Barley straw accomplishes the same thing as bacterial additions and is more cost effective.

Fountains: Sometimes physical movement of water moves duckweed to the pond edges and creates a clearing in the pond. Fountains should not cause any adverse impacts, but probability of algae control is low.

Aeration: Generally considered a method to control phosphorus release from pond sediments. However, the Bloomington ponds are shallow and usually already aerated. Aeration would not cause any adverse impacts, but algae may not be controlled.

Alum: Generally considered a sediment treatment to control the release of phosphorus from pond sediments. Could be useful in some cases for algae and duckweed control however more research is needed. Alum is available as solid pellets that can be distributed in the pond. It is more expensive than barley straw.

Iron filings incorporated into sand filters: Research is underway to assess the practicality of using sand filters impregnated with about 5% iron filings to treat stormwater pond outflows. Preliminary results by the University of Minnesota researchers are promising at the laboratory scale. This may be a stormwater management option in the future.

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APPENDIX A

Water Quality for 2009

Table A-1. Results for 2009 for sampling 25 ponds and three lakes for three months for Secchi disc, total phosphorus, and conductivity. Blue shading indicates lakes.

Pond Name	Pond Surface Area (ac)	Average Depth (ft)	Max Depth (ft)	Total Phosphorus (ppb)			Secchi Disc (ft)			Conductivity			
				June 18, 2009	July 27, 2009	August 26-27, 2009	June 18, 2009	July 27, 2009	August 26-27, 2009	June 18, 2009	July 27, 2009	August 26-27, 2009	July: Aug Ratio
1. Adelmann	6.6	2.6	3.7	257	171	137	1.5	2 - B	1.7	550	405	110	3.7
2. NW Anderson	179	4	10	375	326	ND	--	1 - B	ND	470	590	ND	--
3. Berkshire	0.56	3	6.5	473	514	353	2.5	1	3 - B	350	340	195	1.7
4. Bogen	5	2.5	4.2	233	277	175	1 - B	1 - B	0.9	280	295	105	2.8
5. Bush Lake	188	9.8	35	25	16	17	>5	>5	5.5	350	290	285	1
6. Canterbury Oaks	0.84	1.8	4.5	274	344	382	0.9	1	0.5	450	370	208	1.8
7. Forest Crest	0.45	3	6.5	--	--	236	--	--	2	--	--	150	--
8. Forest Haven	7.18	3.5	7.5	61	50	38	2.5	3 - B	5	270	255	190	1.3
9. Hyland Court	1.65	3	5	91	74	72	1.2	3 - B	2.7	260	255	109	2.3
10. Marce Woods - N	0.85	1.5	3.5	913	1710	155	0.2	0.2	1.5 - B	310	290	90	3.2
11. Marce Woods - S	1.12	2	6	528	691	267	2 - B	0.5	2.5 - B	490	420	130	3.2
12. Normandale Lake	112	4.2	10	70	95	93	3.5	2 - B	2.3	600	600	450	1.3
13. Nesbitt	1.13	3.5	5.5	306	235	116	3.9	3 - B	3.5 - B	190	210	85	2.5
14. Oxmore	2.29	3	6.2	26	47	78	--	3 - B	2.7	600	800	650	1.2
15. Paulys	7.66	4.24	6.75	96	dry	54	--	0.5 - B (est)	4.3	650	dry	210	--
16. Pickfair	0.69	2.5	5.5	451	184	254	1.8 - B	0.5	4.5	710	550	200	2.8
17. River Bluff	0.69	3	5.5	315	259	294	0.8	1	0.4	300	320	250	1.3
18. Round	2.49	4.49	5.83	211	162	223	4	3 - B	4.5	310	280	230	1.2
19. Smith Park	7.06	4 (-)	-791.5	34	50	51	5.7	5.1	3.4	430	385	120	3.2
20. South Bay	2.33	2.5	9	56	145	183	2 - B	1	1.1	430	385	319	1.2
21. Sunrise - S	2	1	2	292	312	241	1.5 - B	1 - B	1.2	370	280	110	2.6
22. Skriebakken	20.08	3.5	8	97	79	108	3 - B	2 - B	4.5	350	320	250	1.3
23. Tierney's Woods	0.28	3	4.2	253	396	208	1.5 - B	0.5	0.9	600	510	180	2.8
24. Timberglade	3.09	1.5	3.5	317	381	399	3.5 - B	1.5	2.5	220	190	130	1.5
25. Victoria	2.32	3	4.5	42	57	70	3	2 - B	2 - B	550	620	140	4.4
26. Wanda Miller	14	3	5	75	64	81	3 - B	2 - B	4.5	450	315	100	3.2
27. Wood Cliff	0.89	1	1.8	357	no sample	288	1.5 - B	NA	1 - B	330	no sample	120	--
28. Xylon	0.43	1.2	3	ND	541	284	--	0.5 - B	3	ND	110	75	1.5
28. Xylon - 2				610	ND	ND	NA			320	ND	ND	

Table A-2. Aquatic plant treatment methods, aquatic plant coverage, and dominant plants observed in the Bloomington ponds for 2009. Green shading indicates 90-100% coverage with duckweed or watermeal. Red shading indicates no submerged aquatic plants observed.

Pond Name	Pond Surface Area (ac)	Average Depth (ft)	Max Depth (ft)	Treatment Notes	% Surface Coverage			Dominant Plants		
					June 18, 2009	July 27, 2009	August 26-27, 2009	June 18, 2009	July 27, 2009	August 26-27, 2009
1. Adelmann	6.6	2.6	3.7	--	0%	3% DW	2% DW	elodea (50%), stringy pw	elodea (30%), stringy pw - common	elodea, stringy pw
2. NW Anderson	179	4	10	--	40% FA	50% FA	--	variety of submerged	unchecked	unchecked
3. Berkshire	0.56	3	6.5	--	0%	0%	0%	no plants	no plants	no plants
4. Bogen	5	2.5	4.2	--	1% FA	0%	0%	stringy pw (90%)	sago pw (80%)	no plants
5. Bush Lake	188	9.8	35	--	0%	0%	0%	chara (3), floatingleaf (2)	nearshore: chara, EWM, NWM, floatingleaf	lilies, coontail, elodea, stringy pw
6. Canterbury Oaks	0.84	1.8	4.5	Sonar, Galleon	8% DW	0%	0%	no plants	no plants	no plants (algae bloom)
7. Forest Crest	0.45	3	6.5	--	NA	NA	100% DW	NA	NA	no plants
8. Forest Haven	7.18	3.5	7.5	--	35% WL	50% WL	50% WL	coontail, curlyleaf, elodea, sago	coontail, narrowleaf pw (40%)	coontail, curlyleaf, elodea, stringy pw
9. Hyland Court	1.65	3	5	--	0%	10% FA	0%	curlyleaf (80%), stringy pw (5%)	curlyleaf pw, stringy pw (40%) (3 fountains)	curlyleaf, duckweed on shoreline, stringy pw
10. Marce Woods - N	0.85	1.5	3.5	Sonar, Galleon	100% DW	100% DW	90% DW	no plants	no plants	no plants
11. Marce Woods - S	1.12	2	6	Sonar, Galleon	100% WM 2% DW	100% WM	90% WM	no plants	no plants	no plants
12. Normandale Lake	112	4.2	10	Reward	10% DW 25% WL	60% FA 40% WL	30% DW/WM 40% WL	coontail, curlyleaf, elodea	unchecked	coontail, curlyleaf, elodea, flatstem
13. Nesbitt	1.13	3.5	5.5	Barley, Skimming	100% DW	70% DW	100% DW	no plants	no plants	no plants
14. Oxmore	2.29	3	6.2	Copper sulfate	5% FA	0%	0%	stringy pw	chara, sago pw, stringy pw 30-50%), FA on bottom in patches	stringy pw (crayfish kill)
15. Paulys	7.66	4.24	6.75	Copper sulfate, Habitat	40% WL	40% WL	25%WL	stringy pw	coontail, stringy pw	terrestrial plants
16. Pickfair	0.69	2.5	5.5	Sonar, Galleon	20% WM 60% DW	100% DW	100% DW	no plants	no plants	no plants
17. River Bluff	0.69	3	5.5	--	0%	0%	0%	sago pw (5-10%)	water stargrass (5%) aeration system	stringy pw
18. Round	2.49	4.49	5.83	Barley, skimming	60% WM	15% WM	25% (95% WM 5% DW)	no plants	no plants	no plants
19. Smith Park	7.06	4	9	Copper sulfate	19% FA	20% FA	5% FA	coontail (1%), elodea (40%) stringy pw (5%)	elodea, coontail plants out to 6 ft	coontail, elodea
20. South Bay	2.33	2.5	9	Sonar	2% DW	5% FW, DW	0%	curlyleaf (5%), sago (100%)	curlyleaf, sago (30-40%), stringy pw	arrowhead, chara, coontail, stringy pw
21. Sunrise - S	2	1	2	Sonar	5% DW	50% WM	10% WM	chara or nitella (20%)	coontail - trace	watermeal, chara
22. Skriebakken	20.08	3.5	8	--	65% WL 2% DW	65% WL DW trace	50% WL	coontail, elodea, narrowleaf pw, stringy pw	coontail (70%), flatstem	coontail, elodea, stringy pw
23. Tierney's Woods	0.28	3	4.2	Sonar, Galleon	0%	0%	0%	no plants	no plants	no plants
24. Timberglade	3.09	1.5	3.5	Sonar	10%	50% DW	95% DW	elodea (100%), flatstem pw, naiad, stringy pw	coontail (was dying back - herbicides), elodea, flatstem	no plants
25. Victoria	2.32	3	4.5	--	2% FA 5% WL	2% WL 4% FA	5% WL 4% FA	none - trace benthic algae	Cabbage (common), coontail, elodea 5 dead bullheads in small area	cabbage, coontail, elodea, floatingleaf pw, naiads
26. Wanda Miller	14	3	5	Habitat	25% WL	60% WL	60% WL	bladderwort, cabbage, coontail, stringy pw	cootail (60%), flatstem, floatingleaf	cabbage, coontail, elodea
27. Wood Cliff	0.89	1	1.8	--	0%	100% FA	20%	narrowleaf pw (50%)	60% dry, 3 inch deep	narrowleaf (50%)
28. Xylon	0.43	1.2	3	Sonar, Galleon	not checked	30% FA, DW, WM	0%	not checked	no plants (blue dye)	no plants (blue dye)

* DW = duckweed; FA = filamentous algae; pw = pondweed; WL = white lilies; WM = watermeal

Table A-3. Summer averages for total phosphorus (TP) and Secchi disc readings.

Pond Name	Water-shed Size (ac)	Direct Water-shed (ac)	Indirect Water-shed (ac)	Pond Surface Area (ac)	Water-shed to Pond Ratio	Average Depth (ft)	Max Depth (ft)	Actual TP (2009) (Jun, Jul, Aug Average) (ppb)	Actual Secchi Disc (2009) (Jun, Jul, Aug Average) (feet)
1. Adelmann	127	53	74	6.6	19	2.6	3.7	188	1.7+
2. NW Anderson	>587	587	?	179	3.3	4	10	351**	--
3. Berkshire	18	3	15	0.56	32	3	6.5	447	2.2+
4. Bogen	59	14	45	5	12	2.5	4.2	228	1.0+
5. Bush Lake	1285	778	507	188	6.8	9.8	35	19	6.0+
6. Canterbury Oaks	15	6	8	0.84	18	1.8	4.5	333	0.8
7. Forest Crest	23	9	14	0.45	51	3	6.5	236*	2+
8. Forest Haven	56	27	28	7.18	7.8	3.5	7.5	50	3.5+
9. Hyland Court	25	5	19	1.65	15	3	5	79	2.3+
10. Marce Woods - N	26	4	22	0.85	31	1.5	3.5	926	0.6+
11. Marce Woods - S	33	7	26	1.12	30	2	6	495	1.7+
12. Normandale Lake	21,556	161	21395	112	193	4.2	10	86	2.6+
13. Nesbitt	42	6	36	1.13	37	3.5	5.5	219	3.5+
14. Oxmore	10	10	0	2.29	4.4	3	6.2	50	2.9+
15. Paulys	96	13	83	7.66	13	4.24	6.75	75**	2.4+
16. Pickfair	85	6	79	0.69	123	2.5	5.5	296	2.3+
17. River Bluff	12	5	7	0.69	17	3	5.5	289	0.7
18. Round	26	9	17	2.49	10	4.5	5.83	199	3.8+
19. Smith Park	444	31	413	7.06	63	4	8 est	45	4.7
20. South Bay	16	16	0	2.33	6.7	2.5	9	128	1.4+
21. Sunrise - S	13	9	4	2	6.5	1	2	282	1.2+
22. Skriebakken	319	49	270	20.08	16	3.5	8	95	3.2+
23. Tierney's Woods	6	3	3	0.28	21	3	4.2	286	1.0+
24. Timberglade	93	49	44	3.09	30	1.5	3.5	366	2.5+
25. Victoria	68	16	52	2.32	29	3	4.5	56	2.3+
26. Wanda Miller	166	50	116	14	12	3	5	73	3.2+
27. Wood Cliff	21	21	0	0.89	24	1	1.8	322**	1.3+
28. Xylon	2	2	0	0.43	4.7	1.2	3	412**	1.8+

Notes
* One month of data
** Two months of data

Table A-4. Summary of actual pond TP concentrations and modeling results (using the MnLEAP model) that estimate pond TP, runoff TP, and TP loading for several scenarios.

1. Pond Name	2. Water-shed Size (ac)	3. Pond Surface Area (ac)	4. Pond Average Depth (ft)	5. Actual Pond TP Conc (2009) (Jun, Jul, Aug avg) (ppb)	6. Predicted MnLEAP Pond TP Based on Typical Residential Runoff of 390 ppb	7. Estimated TP Load Based on Actual Pond TP for 2009 (kg/yr)	8. Estimated TP Load Based on Runoff TP Conc of 390 ppb	9. Estimated Runoff TP Conc into Pond for 2009 (ppb)	10. Goal for Pond TP Conc (ppb)	11. Estimated TP Load Needed to Meet Pond TP Goal (kg/yr)	12. Estimated Runoff TP Conc Needed to Meet Pond TP Goal (ppb)	13. Reduction of TP in kg/yr Needed to Meet Pond TP Goal (kg/yr)
1. Adelmann	127	6.6	2.6	188	172	31	27	445	150	23	337	8
2. NW Anderson	587++	179	4	351**	--	--	--	--	--	--	--	--
3. Berkshire	18	0.56	3	447	188	12	4	1,285	150	3	292	9
4. Bogen	59	5	2.5	228	148	24	13	744	150	13	406	11
5. Bush Lake	1285	188	9.8	19	--	--	--	--	--	--	--	--
6. Canterbury Oaks	15	0.84	1.8	333	185	7	3	878	150	2	300	5
7. Forest Crest	23	0.45	3	236*	212	5	5	447	150	3	254	2
8. Forest Haven	56	7.18	3.5	50	114	4	12	100	150	19	605	ok
9. Hyland Court	25	1.65	3	79	151	2	5	150	150	2	150	0
10. Marce Woods - N	26	0.85	1.5	926	222	36	5	2,645	150	3	242	33
11. Marce Woods - S	33	1.12	2	495	205	22	7	1,274	150	5	265	17
12. Normandale Lake	21,556	112	4.2	86	--	--	--	--	--	--	--	--
13. Nesbitt	42	1.13	3.5	219	187	11	9	480	150	7	290	4
14. Oxmore	10	2.29	3	50	99	1	2	110	150	4	800	ok
15. Paulys	96	7.66	4.24	75**	125	10	21	180	150	27	515	ok
16. Pickfair	85	0.69	2.5	296	265	20	18	446	150	9	202	11
17. River Bluff	12	0.69	3	289	157	6	3	945	150	2	364	4
18. Round	26	2.49	4.49	199	115	13	6	940	150	8	595	5
19. Smith Park	444	7.06	4	45	208	15	92	59	150	61	258	ok
20. South Bay	16	2.33	2.5	128	124	4	4	410	150	5	531	ok
21. Sunrise - S	13	2	1	282	168	6	3	846	150	2	330	4
22. Skriebakken	319	20.08	3.5	95	145	38	68	210	150	71	410	ok
23. Tierney's Woods	6	0.28	3	286	167	3	1	835	150	1	335	2
24. Timberglade	93	3.09	1.5	366	222	37	19	750	150	12	238	25
25. Victoria	68	2.32	3	56	183	3	14	82	150	11	297	ok
26. Wanda Miller	166	14	3	73	139	15	36	150	150	40	438	ok
27. Wood Cliff	21	0.89	1	322**	231	7	4	598	150	3	228	4
28. Xylon	2	0.43	1.2	412**	143	2	0	2,090	150	0.4	420	0.8

Notes
* One month of data
**Two months of data

Table A-5. Listing of pond TP concentrations from the lowest (Smith Park) to the highest (Marce Woods N). The three lakes are shown at the bottom of the table.

Pond Name	Pond Area (ac)	Actual Pond TP Conc (2009) (Jun, Jul, Aug avg) (ppb)	Watershed to Pond Area Ratio	Treatment in 2009	Estimated runoff TP conc into pond (ppb)	Reduction of TP in kg/yr Needed to Meet Pond TP Goal of 150 ppb (kg/yr)	Reduction of TP in kg per watershed acre Needed to Meet Pond TP Goal of 150 ppb (kg/ac)
19. Smith Park	7.06	45	63	Copper sulfate	59	ok	--
8. Forest Haven	7.18	50	7.8	--	100	ok	--
14. Oxmore	2.29	50	4.4	Copper sulfate	110	ok	--
25. Victoria	2.32	56	29	--	82	ok	--
26. Wanda Miller	14	73	12	Habitat	150	ok	--
15. Paulys	7.66	75	13	Copper sulfate, Habitat	180	ok	--
9. Hyland Court	1.65	79	15	--	150	0	--
22. Skriebakken	20.08	95	16	--	210	ok	--
20. South Bay	2.33	128	6.7	Sonar	410	ok	--
1. Adelmann	6.6	188	19	--	445	8	0.06
18. Round*	2.49	199	10	Barley, skimming	940	5	0.19
13. Nesbitt*	1.13	219	37	Barley, Skimming	480	4	0.1
4. Bogen	5	228	12	--	744	11	0.19
7. Forest Crest	0.45	236	51	--	447	2	0.09
21. Sunrise - S	2	282	6.5	Sonar	846	4	0.31
23. Tierney's Woods	0.28	286	21	Sonar, Galleon	835	2	0.33
17. River Bluff*	0.69	289	17	--	945	4	0.33
16. Pickfair*	0.69	296	123	Sonar, Galleon	446	11	0.13
27. Wood Cliff	0.89	322	24	--	598	4	0.15
6. Canterbury Oaks	0.84	333	18	Sonar, Galleon	878	5	0.33
24. Timberglade	3.09	366	30	Sonar	750	25	0.27
28. Xylon	0.43	412	5	Sonar, Galleon	2,090	2	0.8
3. Berkshire	0.56	447	32	--	1,285	9	0.5
11. Marce Woods - S	1.12	495	30	Sonar, Galleon	1,274	17	0.52
10. Marce Woods - N	0.85	926	31	Sonar, Galleon	2,645	33	1.27

* Bioverse in 2005