Technical Pre-Proposal

Assessment and treatment of internal phosphorus loading in Northwood Lake, City of New Hope, MN

Part I: Pre-treatment study

Part II: Iron filings treatment and assessment study

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I. Proposal summary

A. Project activities

The proposed project is a two-part study to (i) investigate the internal phosphorus release in Northwood Lake in the City of New Hope (Part I), and (ii) implement an iron filings treatment in the lake and assess the post-treatment phosphorus water quality (Part II). The Part I pre-treatment study will measure the sediment phosphorus release using laboratory mesocosms of lake sediment-water columns, and measure the *in situ* water quality in the lake. If internal phosphorus release is substantial, the results will be utilized in the Part II study to chemically-inactivate the sediment phosphorus using iron filings, and then monitor the phosphorus water quality in the lake to assess the treatment effectiveness. The overall goal is to mitigate internal phosphorus loading in Northwood Lake, and eventually improve the lake water quality.

B. Relevance

The US EPA has listed ~3000 surface water impairments due to excess phosphorus and eutrophication (US EPA 2016). Phosphorus levels in lakes are influenced by the phosphorus inputs from the watershed and by internal phosphorus loading (i.e., release of phosphorus from the bottom sediments). High internal loading can cause and sustain eutrophication and harmful algal blooms that negatively impact the lake water quality. Studies have shown that internal loading should be reduced, along with external load reduction, to improve lake water quality, aid lake recovery, and meet Total Maximum Daily Load (TMDL) allocation goals (Smolders et al. 2006).

C. Project outcomes

The proposed project will assess the importance of internal phosphorus loading in Northwood Lake through a laboratory mesocosm study, and determine the effectiveness of iron filings treatment in accomplishing the goals of reducing internal phosphorus loading and improving the water quality in the lake. The project will be one of the earliest field applications of iron filings as a sediment phosphorus inactivation method in lakes. If successful, iron filings application can be a viable tool for treating lake phosphorus. Given that a large number of lakes can experience summertime anoxia and eutrophication due to high internal loading, a decrease in lake phosphorus levels will greatly benefit the lake and have important implications for TMDL implementation plans for impaired waters.

II. Background

Phosphorus is the limiting nutrient for primary production in temperate freshwaters (Schindler 1977). Phosphorus accumulated in the lake sediments can recycle back into the water column under certain environmental conditions, and this internal loading can be significant in some lakes, especially during summer. Oftentimes, internal phosphorus loading must be addressed to improve the lake water quality and satisfy TMDL goals. One of the lake treatment techniques to reduce internal loading is the chemical inactivation of sediment phosphorus, commonly using alum, iron chloride or lanthanum.

The addition of zero-valent iron metal filings to lake sediments as a measure for internal load reduction was investigated in a recent research project (Natarajan et al. 2017). Sediment cores from two eutrophic Minnesota lakes (Rush Lake in Chisago County and Ann Lake in Wright County) were subject to experimental doses of iron filings in a laboratory-scale mesocosm setup. The anoxic phosphate release from the natural (unamended) lake sediments were approximately five times the oxic phosphate release at 20 °C. The addition of > 0.05 g iron/cm^2 sediment area significantly reduced the anoxic phosphate release. Detailed analysis of the sediment phosphorus species revealed that the iron-dosed sediments contained very low mobile phosphorus in the porewater, which resulted in the decreased phosphate flux across the sediment-water interface and the very low phosphate concentrations (<0.050 mg/L) in the water overlying the sediments. The placement of an appropriate dose of iron filings is a potential sediment phosphorus inactivation tool that can be applied in lakes and stormwater ponds.

III. Proposal narrative

A. Part I: Pre-treatment study

1. Objectives

The main objective of the Part I pre-treatment study is to determine the significance of internal phosphorus loading in Northwood Lake. Using laboratory-scale mesocosms of lake sediment-

water columns, the phosphorus release rates will be measured under varying environmental conditions. Periodic field measurements of dissolved oxygen (DO), temperature, conductivity and total phosphorus will be taken to verify the environmental conditions of the lake. The water quality data and mesocosm study results will be used to assess the importance of internal loading in Northwood Lake. The Part I study will provide the information necessary for recommending an iron filings dose required to reduce sediment phosphorus release (for the Part II study).

2. Proposed site

Northwood Lake (area = 0.0607 km^2; mean depth = 0.762 m; max depth = 1.52 m), a shallow eutrophic lake located in the Northwood Park, City of New Hope, Hennepin County, MN, is the proposed site for the internal phosphorus assessment and treatment studies. The drainage area to the lake (5.42 km^2) is primarily low-density residential land. In addition to the pipe inflow from the northwest drainage area, runoff outflows from a unique treatment train system (underground vault-bioretention basins) are routed to the lake (Stantec 2014).

Figure 1. Map showing the location of Northwood Lake in the City of New Hope, Hennepin County, MN. (source: <www.maps.google.com>)

Northwood Lake was placed in the Minnesota Pollution Control Agency (MPCA)'s 303(d) Impaired Waters List in 2000 due to excess phosphorus. Conditions in the lake have been eutrophic or hypereutrophic due to the high and increasing total phosphorus (TP) concentrations that fail to meet the MPCA's water quality standard for shallow lakes (Barr 2014; BCWMC 2016). Historic water quality data indicate high average TP (> 0.196 mg/L), low Secchi depth

(0.6 m), low dissolved oxygen (< 2 mg/L below 1 m), and invasive curly leaf pondweed growth during summer (Barr 2014; BCWMC 2016). Northwood Lake has been found to stratify during some periods over summer (Barr 2014).

3. Methods and tasks

The laboratory mesocosm systems will consist of lake sediment cores placed with overlying lake water. The dissolved oxygen (DO) levels in the water columns will be manipulated to create oxic (high DO) and anoxic (low DO) conditions, and the phosphorus release from the sediments to the overlying water will be measured. The oxic and anoxic phosphorus release rates will be quantified as the linear change in phosphorus mass in the water column over the respective experimental duration. *In situ* DO, temperature and conductivity profiles will be taken at select locations in the lake during the growing season. Water samples for total phosphorus will be collected. If the lake is found to be stratified, water samples will be collected at the surface and below the stratified layer. The laboratory data and field conditions will be related to evaluate the internal loading potential in the lake.

Task 1. Sediment core collection

At least ten intact sediment cores with overlying water column will be collected through ice or from a boat. DO, temperature, and conductivity at the coring locations will be measured.

Task 2. Laboratory mesocosm studies

The sediment-water columns will be set up at 20 °C at the St. Anthony Falls Laboratory (SAFL). Bubblers will be placed above the sediment-water interface to simulate oxic conditions (by air bubbling) or anoxic conditions (by nitrogen gas bubbling) in the water column. The water column concentrations of soluble reactive phosphorus (primarily phosphate) will be monitored throughout the experimental duration, and the oxic and anoxic phosphate release rates determined.

Task 3. In situ water quality sampling

The DO, temperature and conductivity profiles will be measured in the lake water column, and water samples for total phosphorus concentrations will be taken in selected locations. Data collection will be done a few times during the growing season.

Task 4. Sediment analysis

The lake sediments will be analyzed for phosphorus and associated metal concentrations. The available (redox-sensitive and labile organic phosphorus) and unavailable (aluminum- and mineral-bound) forms of phosphorus in the pond sediments will be determined by the sequential phosphorus extraction method. Concentrations of metals (Fe, Al, Ca) in the sediments will be measured. The data will be related to the phosphorus release rates measured in the mesocosms.

The main purpose of Task 5 is to gather pre-treatment sediment quality data, so that future comparisons with iron-treated sediments can be made. The phosphorus forms in the sediments can be expected to change because of iron filings addition. The sediment data will help understand the impacts of iron dosing on the sediment phosphorus retention (or release).

Task 5: Project report

A project report, summarizing the results of the laboratory mesocosm studies and the *in situ* water quality observations, will be prepared.

The budget subtotal for Tasks 1 to 5 is $16,409.

4. Results and deliverables

The Part I pre-treatment study will determine the significance of internal loading in Northwood Lake under different environmental conditions. The phosphorus release rate data and lake water quality will help interpret the phosphorus release vis-à-vis retention by the lake sediments. A project report summarizing the results will be final deliverable for the Part I study. The iron filings dose recommended for future treatment of Northwood Lake will also be included in the report.

5. Budget and timetable

The proposed Part I study has five tasks and the budget subtotal for Tasks 1 to 5 is $16,409. The timeline listed for each task is approximate.

Table 1. Budget and timetable for the Part I pretreatment study for Northwood Lake.

Part I: Pre-treatment study				
	Tasks	**~Start by**	**~End before**	**Budget**
1	Sediment core collection	4/1/2018	5/1/2018	$ 1,106
2	Laboratory mesocosm studies	4/1/2018	8/31/2018	$ 3,279
3	*In situ* water quality sampling	5/1/2018	8/31/2018	$ 2,413
4	Sediment analysis	4/1/2018	8/31/2018	$ 6,677
5	Project report		10/31/2018	$ 2,934
			Task 1 to 5 total	**$16,409**

B. Part II: Iron filings treatment and assessment study

1. Objectives

The main objectives of the proposed Part II study are to implement iron filings treatment in Northwood Lake and monitor the phosphorus water quality in the lake to measure the treatment effectiveness. Iron filings treatment is proposed to chemically-inactivate the sediment phosphorus and reduce the internal phosphorus release in the lake. Factors affecting phosphorus release/retention will be determined based on detailed sediment analysis.

2. Proposed site

Northwood Lake (area = 0.0607 km^2; mean depth = 0.762 m; max depth = 1.52 m) in the City of New Hope (Hennepin County, MN), assessed for internal loading in the Part I pre-treatment study, is the proposed candidate for iron filings treatment.

3. Methods and tasks

The iron filings dose for reducing internal phosphorus loading in Northwood Lake will be determined based on the Part I study and Natarajan et al. (2017) study. Iron filings will be applied on the surface of lake sediments. The post-treatment water quality in the lake will be monitored by grab sampling technique over a one-year period. Sediments from the iron-treated area of the lake will be analyzed to explain the lake phosphorus levels.

Task 1. Iron filings treatment

Iron filings will be spread on the sediments in the deeper areas that are most likely to thermally-stratify and become anoxic. The assistance of the City of New Hope personnel will be needed for this task. One method is to spread iron filings over a frozen lake surface in winter so that the iron filings will eventually settle to the bottom as the ice thaws. An alternate option is to apply the iron filings using a spreader device attached to a boat during early Spring. The iron filings units (lb) and costs may change depending on Part I mesocosm study results ($2000/acre est.), and variability of iron filings costs; therefore, the costs of iron filings application is not included in the budget (please see Table 2). The purchase of the iron filings will be made by the City of New Hope, with guidance from SAFL staff. At current rates for iron filings, the estimated cost would be between $15,000 (if half the lake needs to be treated) and $30,000 (if the entire lake needs to be treated).

Task 2. Year 1 water quality sampling

Total phosphorus concentrations, and DO, temperature and conductivity profiles in the water column will be measured at various sampling frequencies during the growing season. Frequent sampling will be conducted during select periods; one possibility is to take daily *in situ*

measurements. The goal will be to follow an adaptive assessment method based on the field measurements.

Task 3. Sediment analysis

Sediment cores will be collected from the iron-treated lake area. The upper 10 cm of sediments will be subject to sequential phosphorus extraction to determine the concentrations of available (redox-sensitive and labile organic phosphorus) and unavailable (aluminum- and mineral-bound) forms of phosphorus in the sediments. The concentrations will be compared to the pre-treatment sediment data (Task 4, Part I study). Metal (Fe, Al, Ca) concentrations in the sediments will be measured.

Task 4: Project report

A project report, summarizing the effectiveness of iron filings treatment in improving the phosphorus water quality in Northwood Lake, will be prepared.

The budget subtotal for Part II, Tasks 1 to 4 is $20,847.

Add scope to Part II study

It is possible that weather conditions during the first-year monitoring could create unusual conditions in terms of phosphorus release from the sediments and phosphorus loading to the lake. Water quality monitoring in Northwood Lake may be continued for a second year, if necessary.

Task 5. Year 2 water quality sampling

Total phosphorus concentrations, and DO, temperature and conductivity profiles in the water column will be measured at various sampling frequencies during the growing season. Frequent sampling will be conducted during select periods; one possibility is to take daily *in situ* measurements. The goal will be to follow an adaptive assessment method based on the field measurements.

Task 5 will add $6,028 to the project cost. The budget subtotal for Tasks 1 through 5, including cost for Year 2 data analysis and report writing, is $26,876.

4. Results and deliverables

The Part II study will provide the effectiveness of iron filings treatment in improving phosphorus retention in the Northwood Lake. The water quality measured before and after treatment will indicate the success of the treatment method. A project report summarizing the results will be the final deliverable for the Part II study.

5. Budget and timetable

The Part II study will encompass one or two years following one year of pre-treatment study. Iron filings treatment and one-year water quality monitoring is estimated to cost $20,597 (excluding the costs of iron filings). Conducting a second-year monitoring is estimated to add $5,728 to the budget (hence, Part II study total = $26,326). As noted under Part II, Task 1, the iron filings units (lb) and costs may change depending on Part I mesocosm study results ($2000/acre est.), and variability of iron filings costs; therefore the costs for iron filings application is not included in the Task 1 budget (Table 2). The purchase of the iron filings will be made by the City of New Hope, with guidance from SAFL staff.

Table 2. Budget and timetable for the Part II iron filings treatment and assessment study for Northwood Lake.

Part II: Iron filings treatment and assessment study				
	Tasks	**~Start by**	**~End before**	**Budget**
1*	Iron filings treatment	2/1/2019	5/1/2019	$ 856
2	Year 1 *in situ* water quality sampling	5/1/2019	8/31/2019	$ 3,306
3	Sediment analysis		8/31/2019	$ 7,258
4	Data analysis and project report		10/31/2019	$ 9,428
			Tasks 1 to 4 subtotal	**$20,847**
5a-d**	Year 2 *in situ* water quality sampling	5/1/2020	8/31/2020	$ 3,305
5e-f**.	Data analysis (Year 2 data) and project report		10/31/2020	$ 2,723
			Task 5 subtotal	**$ 6,028**
			Task 1 to 5 total	**$26,876**

* iron filings costs (material+mobilization) not included
**additional scope

References

Barr (2014). *2013 Lake water quality study: Northwood Lake, North Rice Pond, and South Rice Pond*, prepared for Bassett Creek Watershed Management Commission, Barr Engineering, Minneapolis, MN.

BCWMC (2016). *Northwood Lake 2016 water quality monitoring.* The Bassett Creek Watershed Management Commission. <http://www.bassettcreekwmo.org/lakes-streams/northwood-lake> (accessed November 2017).

Natarajan, P., Gulliver, J.S., and Arnold, W.A. (2017). *Internal phosphorus load reduction with iron filings*. Final project report prepared for the U.S. EPA Section 319 Program and the Minnesota Pollution Control Agency, St. Paul, MN.

Schindler, D.W. (1977). "Evolution of phosphorus limitation in lakes: Natural mechanisms compensate for deficiencies of nitrogen and carbon in eutrophied lakes." *Science*, 195, 260-262.

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USEPA. (2016). *Specific State causes of impairment*. U.S. Environmental Protection Agency, Washington, D.C. <https://iaspub.epa.gov/waters10/attains_nation_cy.cause_detail_303d?p_cause_group_id440 =792> (accessed October 2016)

Undergraduate salary ($/hr) =	17.93
Research staff (salary+fringe) ($/hr) =	87.39
John Gulliver (salary+fringe) ($/hr) =	243.72

Part I: Pre-treatment study					
IA.	**Tasks**	**Units/hours**	**Unit cost**	**Total cost**	**Detailed task description**
1	**Sediment core collection**				
a	Staff (1 Undergraduate student + 1 Research staff)	8	$105	$843	Site work preparation, collect 10 cores, and measure in situ DO, T and conductivity
b	Materials for sediment core collection	1	$250	$250	Piston corer rental from LRC and coring supplies
c	Travel mileage	24	$0.55	$13	Mileage within MN (SAFL to Northwood Lake is 12 miles one-way; 1 trip)
			Task 1 subtotal =	**$1,106**	
2	**Laboratory mesocosm studies**				
a	Phosphorus release rate experiments at 20 °C	28	$105	$2,949	Collect and analyze water samples for phosphorus; measure DO and pH in the columns
b	Supplies for laboratory chemical analysis	1	$330	$330	Supplies for mescosm experiments, nitrogen gas tank, 0.45 micron filters, chemicals for phosphorus analysis
			Task 2 subtotal =	**$3,279**	
3	**Water quality sampling**				
a	Data collection (1 Undergraduate student)	60	$18	$1,076	In situ DO, T and conductivity profiles, and TP water sample (10 times)
b	Water sample analysis (total phosphorus)	60	$18	$1,076	TP analysis (~150 water samples; ~15 samples/sampling trip)
c	Travel mileage	480	$0.55	$262	Mileage within MN (SAFL to Northwood Lake is 12 miles one-way)
			Task 3 subtotal =	**$2,413**	
4	**Sediment analysis**				
a	Sediment extrusion and sequential phosphorus extraction	38	$105	$4,002	Extrude sediments, sediment extraction and P analysis, water content and LOI (6-10 cores; 7 samples/core)
b	Supplies for sediment analysis	1	$550	$550	Extruder rental from LRC; supplies for analysis (centrifuge tubes, chemicals, oxygen tank)
c	Metal analysis (@ RAL)	40	$40	$1,600	Metals analysis of sediments will be done at UMN's RAL (6-10 cores; 5 samples/core)
d	Data analysis (1 Research staff)	6	$87	$524	data analysis
			Task 4 subtotal =	**$6,677**	
5	**Report**				
a	Data analysis and report (1 Research staff)	28	$87	$2,447	Data analysis and report writing
b	Supervision and report (Project PI)	2	$244	$487	Data analysis and report writing
			Task 5 subtotal =	**$2,934**	
			Part I: Pre-treatment study Total =	**$16,409**	

Part IIa: Iron filings treatment and Year 1 water quality monitoring					
IIa.	**Tasks**	**Units/hours**	**Unit cost**	**Total cost**	**Detailed task description**
1	**Iron filings treatment**				
a	Iron filings (material + shipping cost)	0	$0	$0	City match of project. ~$2000/acre estimated; however iron filings quantity (lb) may change depending on Part I mesocosm study results.
b	Labor (iron filings application)	8	$105	$843	City personnel will be required.
c	Travel mileage	24	$0.55	$13	Mileage within MN (SAFL to Northwood Lake is 12 miles one-way; 1 trip)
			Task 1 subtotal =	**$856**	
2	**Year 1 water quality sampling**				
a	Data collection (1 Undergraduate student)	60	$18	$1,076	DO, conductivity and temperature profiles; water sample for TP during summer (up to 50 times)
b	Water sample analysis (total phosphorus)	60	$18	$1,076	total phosphorus analysis (~15 samples/trip)
c	Supplies for chemical analysis	1	$500	$500	sample bottles, centrifuge vials, cuvettes, chemicals for TP analysis
d	Travel mileage	1200	$0.55	$654	Mileage within MN (SAFL toNorthwood Lake 12 miles one-way; 50 trips)
			Task 2 subtotal =	**$3,306**	
3	**Sediment coring and analysis**				
a	Sediment core collection	8	$105	$843	Collect 6-10 cores from the iron-treated area
b	Materials for sediment core collection	1	$250	$250	Piston corer rental from LRC and coring supplies
c	Travel mileage	24	$0.55	$13	Mileage within MN (SAFL to Northwood Lake is 12 miles one-way; 1 trip)
d	Sediment extrusion and sequential phosphorus extraction	38	$105	$4,002	Extrude sediments, sediment extraction, P analysis, water content and LOI (6-10 cores; 7 samples/core)
e	Supplies for laboratory chemical analysis	1	$550	$550	Extruder rental; supplies for analysis (centrifuge tubes, chemicals, oxygen tank)
f	Metal analysis (@ RAL)	40	$40	$1,600	Metals analysis of sediments will be done at UMN's RAL (6-10 cores; 5 samples/core)
			Task 3 subtotal =	**$7,258**	
4	**Project supervision and project report**				
a	Data collection, analysis and final report (1 Research staff)	80	$87	$6,991	Data collection, data analysis and report writing
b	Project supervision and final report (PI)	10	$244	$2,437	Data collection, data analysis and report writing
			Task 4 subtotal =	**$9,428**	
	Part IIa study (Iron filings tretament and Year 1 monitoring) Total =			**$20,847**	

Part IIb: Year 2 water quality monitoring (added scope)					
IIb.	**Tasks**	**Units/hours**	**Unit cost**	**Total cost**	**Detailed task description**
5	**Year 2 water quality sampling**				
a	Data collection (1 Undergraduate student)	60	$18	$1,076	DO, conductivity and temperature profiles; water sample for TP during summer (up to 50 times)
b	Water sample analysis (total phosphorus)	60	$18	$1,076	total phosphorus analysis
c	Supplies for chemical analysis	1	$500	$500	
d	Travel mileage	1200	$0.55	$654	Mileage within MN (SAFL to Northwood Lake 12 miles one-way; 50 trips)
e	Data analysis and report (1 Research staff)	20	$87	$1,748	data analysis and report writing
f	Supervision and report (Project PI)	4	$244	$975	data analysis and report writing
	Part IIb (Year 2 monitoring) TOTAL =			**$6,028**	

Part IIa (Treatment and Year 1 monitoring) & IIb (Year 2 monitoring) TOTAL =	**$26,876**	