MINNEHAHA CREEK
WATERSHED DISTRICT
QUALITY OF WATER, QUALITY OF LIFE

Meeting: Board of Managers
Meeting date: 9/24/2020
Agenda Item #: 11.3
Request for Board Action

Title: Six Mile Creek-Halsted Bay Alum Projects

Resolution number: 20-075: Authorization to contract with University of Wisconsin-Stout to perform sediment core analysis
20-076: Authorization to contract with Wenck Associates to develop alum treatment specifications

Prepared by: Name: Laura Domyancich
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Reviewed by: Name/Title: Brian Beck, Research and Monitoring Program Manager

Recommended action: Approval of a contract with University of Wisconsin – Stout to perform sediment core testing of the Wassermann West pond and approval of a contract with Wenck Associates to develop alum dosing and application specifications for the Wassermann West pond and Wassermann Lake and provide limited construction oversight.

Schedule: September – October 2020: Collection and testing of sediment cores
November – December 2020: Development of application specifications and bid documents
November 2020: Community engagement
January 2021: Quote solicitation for Wassermann West and Wassermann Lake alum applications

Budget considerations: <u>Wassermann West Alum Treatment</u>
Fund names and codes: Wassermann Preserve 3-3153 (Alum Treatment); Research and Monitoring Lab Analysis 5-5001-4520 (Sediment Analysis)
Fund budgets: 3-3153: $38,603 (includes $33,942 BWSR Watershed Based Funding grant); 5-5001-4520: $120,400
Expenditures to date: 3-3153: $67,132 (2019 Alum Treatment); 5-5001: $17,478
Requested amount of funding: $5,800 for design (3-3153); $9,780 for sediment core testing (5-5001-4520)

<u>Wassermann Lake Alum Treatment</u>
Fund name: Wassermann Lake Internal Load Management 3-3156
Fund budget: $360,900 (includes $270,675 BWSR Clean Water Fund grant)
Expenditures to date: $0
Requested amount of funding: $10,000 for design

Past Board action:

Resolution 19-035:	Authorization to award contract for the Wassermann West alum treatment
Resolution 19-072	Authorization to apply for BWSR Clean Water Funds
Resolution 20-050:	Ordering of the Wassermann internal load management project
Resolution 20-051:	Approval of Wassermann internal load project agreement
Resolution 20-052:	Authorization to contract with UW-Stout to analyze Wassermann Lake sediment for alum treatment engineering design

Summary:

In May 2014, the Minnehaha Creek Watershed District (MCWD) Board of Managers formally adopted the Six Mile Creek-Halsted Bay (SMCHB) subwatershed as a geography of strategic planning and implementation focus. In March 2015, the City of Victoria (City) and MCWD executed a memorandum of understanding (MOU) which identifies the mutual value both agencies find in cooperative planning; coordination across agencies on priority water resource issues, including the restoration of Wassermann Lake; and increasing regulatory coordination to support and foster integrated water and natural resources management.

Since adoption of the 2017 Water Management Plan, MCWD has been working to implement high impact capital projects within the SMCHB subwatershed, with particular focus in the city of Victoria and Laketown Township, where current land use pressure presents a unique opportunity to implement projects concurrent with development. Under this plan, MCWD has invested substantially in both watershed and in-lake management activities in the restoration of Wassermann Lake, an impaired waterbody within the city of Victoria.

In June 2017, MCWD and the City of Victoria partnered to acquire a 33-acre parcel on the west side of Wassermann Lake now referred to as Wassermann West. In advance of that acquisition, the District and City entered into an agreement stating that the two agencies would collaborate to develop a park design that provides public access and enjoyment of the site while restoring its wetland and woodland areas and implementing water quality improvements in Wassermann Lake. With a subwatershed-wide carp management program underway, internal loading is the last remaining significant source of nutrient pollution to address in Wassermann Lake. The 2013 SMCHB Diagnostic Study estimates an annual internal release rate of 375 pounds per year, the largest nutrient source identified**.**

Wasserman West Alum Treatment
In November 2017, a contract was awarded for preliminary design for park amenity and natural resources improvements at the Wassermann West site. A component of that design scope was the development of specifications for aluminum sulfate (alum) treatment of the six-acre pond on the site. Prior analysis had identified this pond as a significant source of phosphorus into Wassermann Lake with approximately 39 pounds per year due to internal nutrient release from the pond. Wenck Associates prepared a technical memo recommending two alum treatments to occur over three years, with the first and third years having active treatment. The memo also recommends a third contingency dose sometime in the following 2-5 year window, which would be informed by effectiveness monitoring.

The first alum application to the Wassermann West pond occurred in spring 2019 resulting in a 75-pound per year decrease in phosphorus loading to Wassermann Lake. The second alum treatment is planned to occur in spring 2021. During the 2020 monitoring season, Research and Monitoring (R&M) program staff will collect sediment cores from the bed of the pond. These cores will be analyzed by the University of Wisconsin – Stout to determine the total amount of legacy phosphorus in pond sediment and the rate at which phosphorus is released from sediment into the water column. These analyses will help to identify the most cost effective alum dose and, thereby, phosphorus load reduction possible.

Because of Wenck Associates' unique qualifications and experience with alum application in the region, Wenck will develop specification documents for the alum application informed by: the sediment core lab results collected after the spring 2019 alum dose; lake bathymetry; historic and recent water quality data; initial dosing calculations; and the internal load management plan. Specifications will direct treatment locations, recommended alum application rates, application schedule, a cost-benefit analysis, and estimated project cost. Wenck will also provide limited construction oversight for the alum application, but District staff will oversee the majority of the administrative work for the project.

Wassermann Lake Alum Treatment
In January 2020, MCWD was awarded a Clean Water Fund grant from the Board of Water and Soil Resources (BWSR), positioning Wassermann Lake for an initial alum treatment in spring 2021 and a subsequent treatment in fall 2022. The total budget for this project is $355,900, including $284,720 in grant funds and $71,180 in match. MCWD's match funds

will be allocated to feasibility, pre- and post-project sediment analysis, and a portion of the treatment cost. The grant dollars will be allocated exclusively to alum application.

Sediment cores will also be collected from the bed of Wassermann Lake to inform alum dosing for the lake's first treatment. Those cores will also be analyzed by the University of Wisconsin – Stout, and Wenck will incorporate this data into project specifications for alum dosing. The specifications will also be informed by lake bathymetry, historic and recent water quality data, and buoy data. Application rates and schedule, treatment locations, estimated longevity of the treatment, a cost-benefit analysis, and total project cost will be included in Wenck's analysis. The goal of gathering this information is to meet the internal load reduction targets in the most cost-effective manner possible.

The alum treatments collectively are projected to reduce internal loading to Wassermann Lake by an estimated 90%, for a reduction of 336 pounds per year. If successful, this reduction positions Wassermann Lake to be removed from the impaired waters list.

Although the Wassermann Lake alum treatment is a separate project from the alum treatment of the Wassermann West pond and has a different funding source, due to the projects' close proximity and timing of the alum applications, staff will combine the two projects into one quote solicitation to reduce mobilization and administrative costs. Quotes for this contract will be requested in January 2021 following design and specification development by Wenck in late 2020.

Staff recommends approval of the contract with University of Wisconsin – Stout to perform sediment core testing of the Wassermann West pond and approval of a contract with Wenck Associates to develop alum dosing and application specifications for the Wassermann West pond and Wassermann Lake and to provide limited construction oversight.

Supporting documents:

Attachment 1: Wassermann West Pond Alum Design and Oversight Scope of Work
Attachment 2: Wassermann Lake Alum Design and Oversight Scope of Work
Attachment 3**:** UW-Stout Wassermann West Pond Proposal

MINNEHAHA CREEK
WATERSHED DISTRICT
QUALITY OF WATER, QUALITY OF LIFE

RESOLUTION

Resolution number: 20-075

Title: Authorization to contract with University of Wisconsin-Stout to perform sediment core analysis

WHEREAS, pursuant to Resolution 14-047 the MCWD Board of Managers has identified the Six Mile Creek-Halsted Bay (SMCHB) subwatershed as a priority area for focusing planning activities and coordination efforts with subwatershed partners;

WHEREAS, on March 26, 2015 the Board of Managers authorized MCWD to enter into a Memorandum of Understanding with the City of Victoria (the City), outlining opportunities to collaborate and integrate mutual efforts in the realms of coordinated planning of local water and land use plans, assessment of specific management issues, and coordinated regulatory review of water and land development, and specifically identified a shared interest in addressing the water quality impairment of Wassermann Lake;

WHEREAS, in January 2018 the Board of Managers adopted the MCWD Watershed Management Plan (WMP), which incorporated a comprehensive restoration strategy for the SMCHB subwatershed to achieve MCWD's goals of protecting and improving water quality, water quantity, ecological integrity, and thriving communities through land use and water integration. The WMP includes a capital improvement plan, which lists the Wassermann West External Load Reduction and Landscape Restoration as an implementation project;

WHEREAS, on November 17, 2017 the Board of Managers approved a contract with Wenck Associates for the Wassermann West Park and Natural Resource Improvements, including the development of feasibility and specifications for alum treatment;

WHEREAS, in September 2018, the Board of Managers accepted a grant award of $93,879 through the Board of Water and Soil Resources Watershed-Based Funding Pilot Program for the Wassermann West project;

WHEREAS, on March 28, 2019 the Board authorized MCWD to execute a contract with HAB Aquatic Solutions for alum treatment of the Wassermann West Pond which was implemented in April 2019;

WHEREAS, Wenck Associates recommends a follow-up treatment of alum to occur in 2021 with alum dose based on the amount of legacy phosphorus in the pond sediments;

WHEREAS, MCWD will obtain sediment core samples from Wassermann West Pond to inform the most cost effective alum dose and phosphorus load reduction, which will serve as a portion of the match funds for the BWSR Watershed Based Funding grant.

NOW, THEREFORE, BE IT RESOLVED that the Minnehaha Creek Watershed District Board of Managers authorizes the District Administrator to execute a contract with the University of Wisconsin-Stout to analyze sediments from the Wassermann West Pond for an amount not to exceed $9,780.

Resolution Number 20-075 was moved by Manager _____, seconded by Manager _____. Motion to adopt the resolution ___ ayes, ___ nays, ___abstentions. Date: 9/24/2020

_____ Date: _____
Secretary

MINNEHAHA CREEK
WATERSHED DISTRICT
QUALITY OF WATER, QUALITY OF LIFE

RESOLUTION

Resolution number: 20-076

Title: Authorization to contract with Wenck Associates to develop alum treatment specifications

WHEREAS, pursuant to Resolution 14-047 the MCWD Board of Managers has identified the Six Mile Creek-Halsted Bay (SMCHB) subwatershed as a priority area for focusing planning activities and coordination efforts with subwatershed partners;

WHEREAS, on March 26, 2015 the Board of Managers authorized MCWD to enter into a Memorandum of Understanding with the City of Victoria (the City), outlining opportunities to collaborate and integrate mutual efforts in the realms of coordinated planning of local water and land use plans, assessment of specific management issues, and coordinated regulatory review of water and land development, and specifically identified a shared interest in addressing the water quality impairment of Wassermann Lake;

WHEREAS, in January 2018, the Board of Managers adopted the MCWD Watershed Management Plan (WMP), which incorporated a comprehensive restoration strategy for the SMCHB subwatershed to achieve MCWD's goals of protecting and improving water quality, water quantity, ecological integrity, and thriving communities through land use and water integration. The WMP includes a capital improvement plan, which lists the Wassermann West External Load Reduction;

WHEREAS, in September 2018, the Board of Managers accepted a grant award of $93,879 through the Board of Water and Soil Resources Watershed-Based Funding Pilot Program for the Wassermann West project;

WHEREAS, on August 22, 2019 the Board of Managers authorized staff to submit an application to the Board of Soil and Water Resources (BWSR) Clean Water Fund grant program requesting $284,720, and requiring a 25% match of $71,180 for the implementation of the Wassermann Internal Load Management Project (the Project), BWSR notified MCWD in January 2020 that the grant was awarded in the full amount;

WHEREAS, on June 23, 2020, the Board of Managers ordered the Wassermann Internal Load Management Project in fulfillment of the MCWD Watershed Management Plan's identification of the Project as a planned capital investment to reduce internal nutrient loading, improve water clarity, and create a more abundant and diverse aquatic vegetation community with alum treatments;

WHEREAS, Wenck Associates is uniquely qualified to analyze collected water chemistry and sediment data to develop specifications for alum treatment of Wassermann Lake and the Wassermann West Pond and to provide construction oversight due to Wenck's experience in alum treatments within the region and with water quality projects within the SMCHB subwatershed.

NOW, THEREFORE, BE IT RESOLVED that the Minnehaha Creek Watershed District Board of Managers authorizes the District Administrator to execute a contract with Wenck Associates to develop alum treatment specifications for Wassermann Lake and Wassermann West Pond for an amount not to exceed $15,800.

Resolution Number 20-076 was moved by Manager _____, seconded by Manager _____. Motion to adopt the resolution ___ ayes, ___ nays, ___abstentions. Date: 9/24/2020

_____ Date: _____
Secretary

Attachment 1

WENCK ASSOCIATES

Responsive partner.
Exceptional outcomes.

September 17, 2020

Brian Beck
Research and Monitoring Program Coordinator
Minnehaha Creek Watershed District
15320 Minnetonka Blvd.
Minnetonka, MN 55345

RE: Wassermann West Pond Alum Treatment Design and Oversight Scope of Work

Dear Mr. Beck:

Thank you for the opportunity to continue to provide our services to the Minnehaha Creek Watershed District (District). As requested, Wenck Associates, Inc. (Wenck) has prepared this proposal to assist the District in developing the final design, specifications, request for quote documents, contractor selection, and oversight of the second alum application for Wassermann West Pond. This proposal only addresses requests for the second dose that is planned for 2021. Future alum doses will require an additional proposal.

Following is a scope of work for implementing the Wassermann West Pond alum treatment

Task 1. Alum Dosing and Cost Estimate Analysis

Under this task, Wenck will review the sediment core lab results collected after the first alum dose as well as the items prepared by Wenck and the District prior to the first dose, which includes: the initial sediment core results, lake bathymetry, historic and recent water quality data, the initial dosing calcs, and internal load management plan. Wenck will use this information to adjust and/or refine the alum treatment area and the chemical dosing rate for the second dose to achieve long-term reduction goals/targets. Wenck will work with District staff to prepare a plan for the second dose that includes: treatment location(s), recommended dosing rates, application schedule, updated cost/benefit analysis, estimated cost, staging area, and lessons learned from the first dose. Deliverables for this task will include a technical memo to district staff detailing the second alum dose for Wassermann West Pond. This task will be completed by November 20th, 2020

Task 2. Development of Alum Application Specifications and Bid Documents

Using the plans and specifications developed for the first alum dose, along with the analyses and memo completed under Task 1, Wenck will develop specifications and request for quote documents for the second dose for Wassermann West Pond. The specifications for the alum application will include application rates, locations, timing, equipment requirements, staging, maps for access and staging, and any other necessary information. This task will be completed by December 11th, 2020

Task 3. Contractor Selection

Wenck will assist the district with reviewing quotes and selecting the contractor(s). Wenck subtasks for this task will include helping answer any pre-quote questions, quote analysis and review with district staff, and contractor recommendation. It is understood that the request for quotes will combine both the Wassermann West Pond alum treatment and the Wassermann

Lake alum treatment as one construction project with separate quote line items for the two sites. Combining these treatments should help reduce mobilization costs.

Task 4. Application Observation

The second alum application for Wassermann West Pond will likely be conducted in the Spring of 2021 and take approximately 2 to 3 days. Wenck will be on-site during the initial set-up and early application period. For subsequent days, Wenck will be available to help the District answer questions and review water quality data to ensure progress. It is our understanding that District staff will be available to assist with application observation and monitoring. Wenck has budgeted 3 hours of staff time to be on-site during the initial set-up and early application period, and 2 hours for subsequent follow-up questions and check-ins. We will work closely with District staff and develop an on-site schedule for application observation and monitoring.

Task 5. Meetings

Wenck allotted time for one meeting (likely remote format) with district staff during the process. Additional meetings may occur if aligned with tracking and/or other monitoring events.

Budget and Timeline

Wenck will perform the work tasks described above at our most efficient discounted hourly rates that are currently used by MCWD along with direct expenses covering mileage, equipment, etc. with a total not to exceed $5,800. In the event that follow-up or out of scope items are identified or requested by the District, Wenck will work with the District to develop a scope and budget for the additional task(s) and will not proceed with identified task(s) without authorization from the District.

Task		Labor	Mileage & Equipment	Total Cost
1	Alum Dosing and Cost Estimate Analysis	$2,300	--	$2,300
2	Development of Alum Application Specifications and Bid Documents	$950	--	$950
3	Contractor Selection	$1,300	--	$1,300
4	Application Observation and Monitoring	$700	$150	$850
5	Meetings	$400	--	$400
	TOTAL	$5,650	$150	$5,800

On behalf of the 300+ employee-owners of Wenck, thank you for this opportunity to work with the Minnehaha Creek Watershed District. Should you have any questions, or need clarification, please do not hesitate to contact Jeff Strom at 763-252-6833.

Sincerely,

Wenck Associates, Inc.

Jeff Strom
Associate

Attachment 2

WENCK ASSOCIATES

Responsive partner.
Exceptional outcomes.

September 17, 2020

Brian Beck
Research and Monitoring Program Coordinator
Minnehaha Creek Watershed District
15320 Minnetonka Blvd.
Minnetonka, MN 55345

RE: Wassermann Lake Alum Treatment Design and Oversight Scope of Work

Dear Mr. Beck:

Thank you for the opportunity to continue to provide our services to the Minnehaha Creek Watershed District (District). As requested, Wenck Associates, Inc. (Wenck) has prepared this proposal to assist the District in developing the final design, specifications, request for quote documents, contractor selection, and oversight of the first alum application for Wassermann Lake. This proposal only addresses requests for the initial dose that is planned for 2021. Future alum doses will require an additional proposal.

Following is a scope of work for implementing the Wassermann Lake alum treatment

Task 1. Alum Dosing and Cost Estimate Analysis

Under this task, Wenck will review the sediment core lab results, lake bathymetry, historic and recent water quality data, and the processed buoy data that will be prepared and provided by the District. Wenck will use these analyses to define the alum treatment area and the chemical dosing rate to meet internal load reduction goals/targets. Wenck will work with District staff to design an internal load treatment plan for Wassermann Lake that includes: treatment location(s), recommended dosing rates, application schedule, estimated longevity of the proposed treatment, cost/benefit analysis, estimated cost, and potential staging area(s). Deliverables for this task will include a technical memo to district staff detailing the internal load treatment plan for Wassermann Lake. This task will be completed by November 13th, 2020.

Task 2. Development of Alum Application Specifications and Bid Documents

Wenck will develop the alum dosing specifications and request for quote documents for the initial dose for Wassermann Lake based on the internal load treatment plan developed during Task 1. The specifications for the alum application will include application rates, locations, timing, equipment requirements, staging, maps for access and staging, and any other necessary information. This task will be completed by December 11th, 2020

Task 3. Contractor Selection

Wenck will assist the district with reviewing quotes and selecting the contractor(s). Wenck subtasks will include helping answer any pre-quote questions, quote analysis and review with district staff, and contractor recommendation. It is understood that the request for quotes will combine both the Wassermann Lake alum treatment, as well as the Wassermann West Pond

alum treatment as one construction project with separate quote line items for the two sites. Combining these treatments should help reduce mobilization costs

Task 4. Application Observation

The first alum application for Wassermann will likely be conducted in the Spring of 2021 and take approximately 4 to 5 days. Wenck will be on-site during the initial set-up and early application period. For subsequent days, Wenck will be available to help the District answer questions and review water quality data to ensure progress. It is our understanding that District staff will be available to assist with application observation and monitoring. Wenck has budgeted 4 hours of staff time to be on-site during the initial set-up and early application period, and 2 hours for subsequent follow-up questions and check-ins. We will work closely with District staff and develop an on-site schedule for application observation and monitoring.

Task 5. Meetings

Wenck allotted time for 1 meetings (likely remote format) with district staff during the process. Additional meetings may occur if aligned with tracking and/or other monitoring events.

Budget and Timeline

Wenck will perform the work tasks described above at our most efficient discounted hourly rates that are currently used by MCWD along with direct expenses covering mileage, equipment, etc. with a total not to exceed $10,000. In the event that follow-up or out of scope items are identified or requested by the District, Wenck will work with the District to develop a scope and budget for the additional task(s) and will not proceed with identified task(s) without authorization from the District.

Task		Labor	Mileage & Equipment	Total Cost
1	Alum Dosing and Cost Estimate Analysis	$5,600	--	$5,600
2	Development of Alum Application Specifications and Bid Documents	$2,000	--	$2,000
3	Contractor Selection	$900	--	$900
4	Application Observation	$850	$150	$1,000
5	Meetings	$500	--	$500
	TOTAL	$9,850	$150	$10,000

On behalf of the 300+ employee-owners of Wenck, thank you for this opportunity to work with the Minnehaha Creek Watershed District. Should you have any questions, or need clarification, please do not hesitate to contact Jeff Strom at 763-252-6833.

Sincerely,

Wenck Associates, Inc.

Jeff Strom
Associate

Attachment 3

Determination of Rates of Phosphorus Release and Sediment Wassermann West Pond, Minnesota

PROPOSAL OF RESEARCH

11 September, 2020

University of Wisconsin - Stout
Sustainability Sciences Institute
Center for Limnological Research and Rehabilitation
Menomonie, Wisconsin 54751
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1.0 BACKGROUND.

Bottom sediments represent an important internal source of phosphorus (P) that can potentially subsidize high algal productivity, even when external P loading from the watershed has been reduced. For sediments containing iron (Fe) compounds, P is usually coupled with Fe dynamics and flux to the water column is regulated by oxidation-reduction (i.e., eH) and pH reactions (Mortimer 1971). A thin oxidized microzone exists in the sediment surface layer when the overlying water column is oxygenated. Under these conditions, Fe is in an oxidized state (i.e., Fe^{+3}) in the microzone as Fe~(OOH) and adsorbs P, thereby controlling its diffusion into the overlying water column. Elevated pH and production of hydroxyl ions (OH^-) during periods of intense photosynthesis can also indirectly enhance rates of P release from sediment under aerobic conditions via ligand exchange (i.e., competition for binding sites by OH^-). Under anoxic conditions at the sediment-water interface, anaerobic bacterial reduction of iron from Fe^{+3} to Fe^{+2} results in P desorption and diffusion into the water column for potential uptake by algae. Internal P loading via these recycling pathways can account for a substantial portion of the P economy of aquatic systems and hinder restoration efforts targeted at reducing algal biomass.

Fe~(OOH)~PO_4 or redox-sensitive P can be quantified via extraction with a strong reducing agent (dithionite-bicarbonate; BD; Nürnberg 1988). Additionally, biologically-labile P in the form of bacterial polyphosphates and labile organic P compounds and can be recycled to the overlying water column via mineralization and metabolic breakdown and is extracted with a basic solution (0.1 to 1.0 N NaOH; Psenner and Puckso 1988). Thus, the size of the biologically-labile P pool (i.e., redox-P and labile organic P; subject to recycling and internal P loading) in surface sediment can be quantified for evaluation and be compared to other systems to assess the potential importance as a source of P recycling in lakes.

2.0 PURPOSE.

The objectives of these investigations are to:

1. measure rates of P release from sediment under anaerobic conditions,
2. examine sediment mobile P fractions that are active in internal P loading for estimation of alum dosage,

3.0 SCOPE OF WORK.

Intact sediment cores will be collected for P flux and sediment characteristics in the deep basin of 5 lakes.

Task 1 - Laboratory-derived rates of P release from sediment under anaerobic conditions:

Triplicate intact sediment cores will be collected by MCWD personnel from a deep basin station in each lake for the determination of rates of P release from sediment under controlled laboratory conditions. All cores will be carefully drained of overlying water in the laboratory and the upper 10 cm of sediment will be transferred intact to a smaller acrylic core liner (6.5-cm dia and 20-cm ht) using a core remover tool. Surface water collected from each lake will be filtered through a glass fiber filter (Gelman A-E), with 300 mL then siphoned onto the sediment contained in the small acrylic core liner without causing sediment resuspension. They will be placed in a darkened environmental chamber and incubated at a constant temperature of ~ 20 ^{o}C to reflect summer conditions. The oxidation-reduction environment in the overlying water will be controlled by gently bubbling nitrogen (anaerobic) through an air stone placed just above the sediment surface in each system. Bubbling action will insure complete mixing of the water column but not disrupt the sediment. For each station, duplicate cores will be subjected to anaerobic conditions.

Water samples for soluble reactive P will be collected from the center of each system using an acid-washed syringe and filtered through a 0.45 µm membrane syringe filter. The water volume removed from each system during sampling will be replaced by addition of filtered lake water preadjusted to the proper oxidation-reduction condition. These volumes are accurately measured for determination of dilution effects. Soluble reactive P is measured colorimetrically using the ascorbic acid method (APHA 2005). Rates of P release from the sediment (mg/m^2 d) are calculated as the linear change in mass in the overlying water divided by time (days) and the area (m^2) of the incubation core liner. Regression analysis is used to estimate rates over the linear portion of the data.

Task 2 - Evaluation of sediment P characteristics:

The objectives of this task are to quantify sediment physical-textural characteristics and P fractions in the upper 5-cm sediment layer of each lake. Sediment sections will be analyzed for the variables listed in **Table 1**. Subsamples will be dried at 105 °C to a constant weight and burned at 500 °C for determination of moisture content, sediment density, and organic matter content (Håkanson and Jensson 2002). Phosphorus fractionation will be conducted according to Hieltjes and Lijklema (1980), Psenner and Puckso (1988), and Nürnberg (1988) for the determination of ammonium-chloride-extractable P (1 M NH_4Cl; loosely-bound P), bicarbonate-dithionite-extractable P (0.11 M BD; iron-bound P), and sodium hydroxide-extractable P (0.1 N NaOH; aluminum-bound P). A subsample of the sodium hydroxide extract will be digested with potassium persulfate to determine nonreactive sodium hydroxide-extractable P (Psenner and Puckso 1988). Labile organic P is calculated as the difference between reactive and nonreactive sodium hydroxide-extractable P.

Table 1. Textural-physical variables and biologically-labile sediment phosphorus pools.
Moisture content (%)
Sediment wet and dry bulk density (g/cm^3)
Organic matter content (%)
Loosely-bound P (mg/g)
Iron-bound P (mg/g)
Labile organic P (mg/g)
Aluminum-bound P (mg/g)

The loosely-bound (Loose-P) and iron-bound P (Fe-P) fractions are readily mobilized at the sediment-water interface under anaerobic conditions that result in desorption of P from bacterially-reduced iron compounds (i.e., Fe^{+3} to Fe^{+2}) in the sediment and diffusion into the overlying water column (Mortimer 1971, Boström 1984, Nürnberg 1988). The sum of the Loose-P and Fe-P fractions are referred to as redox-sensitive P (i.e., redox-P; the P fraction that is active in P release under anaerobic and reducing conditions). In addition, labile organic P (LOP) can be converted to soluble P via bacterial mineralization (Jensen and Andersen 1992) or hydrolysis of bacterial polyphosphates to soluble phosphate under anaerobic conditions (Gächter et al. 1988; Gächter and Meyer 1993; Hupfer et al. 1995). The sum of redox-P and LOP is collectively referred to a biologically-labile P. This fraction is generally active in recycling pathways that result in exchanges of phosphate from the sediment to the overlying water column and potential assimilation by algae.

4.0 REFERENCES.

APHA (American Public Health Association). 2005. Standard Methods for the Examination of Water and Wastewater. 21th ed. American Public Health Association, American Water Works Association, Water Environment Federation.

Boström B. 1984. Potential mobility of phosphorus in different types of lake sediments. Int. Revue. Ges. Hydrobiol. 69:457-474.

Gächter R., Meyer JS, Mares A. 1988. Contribution of bacteria to release and fixation of phosphorus in lake sediments. Limnol. Oceanogr. 33:1542-1558.

Gächter R, Meyer JS. 1993. The role of microorganisms in mobilization and fixation of phosphorus in sediments. Hydrobiologia 253:103-121.

Håkanson L, Jansson M. 2002. Principles of lake sedimentology. The Blackburn Press, Caldwell, NJ USA

Hjieltjes AH, Lijklema L. 1980. Fractionation of inorganic phosphorus in calcareous sediments. J. Environ. Qual. 8: 130-132.

Hupfer M, Gächter R., Giovanoli R. 1995. Transformation of phosphorus species in settling seston and during early sediment diagenesis. Aquat. Sci. 57:305-324.

Mortimer CH. 1971. Chemical exchanges between sediments and water in the Great Lakes – Speculations on probable regulatory mechanisms. Limnol. Oceanogr. 16:387-404.

Nürnberg GK. 1988. Prediction of phosphorus release rates from total and reductant-soluble phosphorus in anoxic lake sediments. Can. J. Fish. Aquat. Sci. 45:453-462.

5.0 COST ANALYSIS

Sediment Chemistry Price List					
Variable		Unit	Cost		
			Each	Quantity	Total
Textural and Physical Characteristics	Moisture Content-Bulk Density-organic matter	per sediment section	$30	20	$600
Sediment Phosphorus Extractions	Biologically-labile Phosphorus	per sediment section	$135	20	$2,700
Sediment Flux or Internal Loading	Incubation for rates of soluble reactive P release	per 10 cm core	$540	12	$6,480
Total					$9,780