MINNEHAHA CREEK
WATERSHED DISTRICT
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Meeting: Board of Managers
Meeting date: 1/28/2021
Agenda Item #: 11.2
Request for Board Action

Title:	Authorization to release Request for Quotes for Wassermann Lake and Wassermann West Pond Alum Treatments
Resolution number:	21-012
Prepared by:	Name: Laura Domyancich-Lee Phone: 952.641.4582 ldomyancich-lee@minnehahacreek.org
Reviewed by:	Name/Title: Michael Hayman, Project Planning Manager; Kailey Kreatz, Hydrologist
Recommended action:	Authorize staff to release a request for quotes to perform alum treatments on Wassermann Lake and the Wassermann West Pond.
Schedule:	2/1/2021: Release request for quotes 3/1/2021: Deadline to submit quotes 3/11/2021: Contract award approval by Board of Managers 5/2021: Alum applications
Budget considerations:	<u>Wassermann West Alum Treatment</u> Fund name and code: Wassermann Preserve 3-3153 (Alum treatment) Fund budget (Alum treatment): $38,603 (includes $33,942 BWSR Watershed Based Funding grant) Expenditures to date: $67,132 (2019 alum treatment) <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: $14,820 (Sediment analysis)
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 Resolution 20-075 Authorization to contract with UW-Stout to perform sediment core analysis Resolution 20-076 Authorization to contract with Wenck Associates to develop alum treatment specifications

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 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 (City) 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 374 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 which recommended 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 two-to-five year window, which would be informed by effectiveness monitoring. These alum treatments are funded by a grant from the Board of Water and Soil Resources (BWSR) Watershed Based Funding program with design and engineering costs funded through both Research and Monitoring and Project Planning program budgets.

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. During the 2020 monitoring season, Research and Monitoring program staff collected sediment cores from the bed of the pond. These cores were then 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 along with lake bathymetry information, historic and recent water quality data, initial dosing calculations, and the internal load management plan were used by Wenck Associates to identify the most cost effective alum dose and, thereby, phosphorus load reduction possible. The process by which this determination was made is described in the attached memo *Wassermann West Pond 2nd Dose Alum Treatment Recommendations* (Attachment 1).

Based on these findings, the recommended follow-up application is a lower dose, buffered alum treatment of the pond in all areas deeper than six feet. This 3-acre treatment will immobilize the remaining available phosphorus which was identified by the sediment sampling to be present in the top 10 centimeters of lake sediment. Based on communication with a local alum applicator, Wenck has estimated the cost of this treatment at $45,093 with $35,000 of that cost in mobilization fees. This estimated cost exceeds available grant funding by $6,490. Despite this funding deficit, staff recommends implementing the advised dose and treatment area based on the rigorous analysis of the sediment core and related data detailed above. If submitted quotes do exceed available grant funding for alum application, funds to compensate for the deficit will be allocated from the Project Planning budget.

Wassermann Lake Alum Treatment
In January 2020, MCWD was awarded a Clean Water Fund grant from 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 are allocated to feasibility, pre- and post-

project sediment analysis, and a portion of the treatment cost. The grant dollars are allocated exclusively to alum application.

In addition to the analyses that were performed for the Wassermann West Pond, the recommended alum dose for the lake has also been informed by continuous temperature and dissolved oxygen readings gathered by equipment placed on a monitoring buoy deployed throughout 2020. These data sets were analyzed by Wenck, and findings are reported in the attached memo, *Wassermann Lake 1st Dose Alum Treatment Recommendations* (Attachment 2). Application rates and schedule, defined treatment zones, estimated longevity of the treatment, a cost-benefit analysis, and total project cost are included in Wenck's findings.

In summary, the recommendation is to effectively split the dose into two treatments: the first in spring 2021 and a follow-up treatment in fall 2022. A cost-benefit analysis conducted by Wenck calculates the cumulative cost/pound of phosphorus removed for each depth contour. While the cumulative load reduction peaks at 310 pounds/year at the 10-foot contour, the cost per pound removed is most advantageous, while still achieving significant load reduction, by treating the lake to the 38-foot contour. Both the remediated internal load and the subsequent cost increase as the application area increases, thus the recommendation is based on balancing extending treatment area with increased cost. The proposed treatment scenario achieves an internal load reduction of 269 pounds/year. Based on this analysis, Wenck has recommended a conservative first dose with a second dose refined based on 2021 post-treatment sediment data.

The alum treatments of the pond and lake 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 State of Minnesota's Impaired Waters List.

Although the Wassermann Lake and Wassermann West pond are separate projects and have different funding sources, due to the projects' close proximity and timing of the alum applications, staff will combine the two projects into one quote solicitation to potentially reduce mobilization and administrative costs.

Staff requests authorization to release a request for quotes for the Wassermann West pond and Wassermann Lake alum treatments.

Supporting documents:
Attachment 1: Wassermann West Pond 2nd Dose Alum Treatment Recommendations
Attachment 2: Wassermann Lake 1st Dose Alum Treatment Recommendations

MINNEHAHA CREEK
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RESOLUTION

Resolution number: 21-012

Title: Authorization to Release Request for Quotes for the Wassermann Lake and Wassermann West Pond Alum Treatments

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 District 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 developed in 2016 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 and the Wassermann Lake Internal Load Management as implementation projects;

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 (BWSR) Watershed-Based Funding Pilot Program for the Wassermann West Pond alum treatment project;

WHEREAS on August 22, 2019, the Board of Managers ordered the Wassermann Lake Park Project, which includes alum treatment of the Wassermann West pond, in fulfillment of the MCWD WMP'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 in March 2020, the Board of Managers accepted a grant award of $284,720 through the BWSR Clean Water Fund grant program for the implementation of the Wassermann Internal Load Management project;

WHEREAS on June 23, 2020, the Board of Managers ordered the Wassermann Internal Load Management Project in fulfillment of the MCWD WMP'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 on September 24, 2020, the Board of Managers approved a contract with Wenck Associates 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 of the alum application;

WHEREAS on January 22, 2021, Wenck Associates provided technical memos recommending alum application and prescribing dosing and specific treatment areas of Wassermann Lake and the Wassermann West Pond to develop a request for quotes for these treatments.

NOW, THEREFORE, BE IT RESOLVED, that the Minnehaha Creek Watershed District Board of Managers hereby authorizes the release of a request for quotes for the Wassermann Lake and Wassermann West Pond Alum Treatments.

Resolution Number 21-012 was moved by Manager _____________, seconded by Manager ____________. Motion to adopt the resolution ___ ayes, ___ nays, ___abstentions. Date: January 28, 2021

____ Date: ___________________________
Secretary

Technical Memo

WENCK

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To: Minnehaha Creek Watershed District

Attn: Laura Domyancich-Lee and Kailey Cermak

From: Jeff Strom, Wenck Associates now part of Stantec
Anne Wilkinson, Wenck Associates now part of Stantec
Chris Meehan, Wenck Associates now part of Stantec

Date: January 22, 2021

Subject: Wassermann West Pond Alum Treatment 2nd Dose Recommendations (DRAFT)

Wassermann West is a seven-acre pond located upstream of Wassermann Lake in the City of Victoria. Wassermann West pond's drainage area is approximately 148 acres and contains a mix of residential, agricultural, and feedlot land use. Wassermann West Pond received the first dose of a buffered alum treatment in May 2019 (Wenck, 2018). This technical memorandum presents recommendations for the 2nd alum dose for Wassermann West Pond and includes the following components:

- Summary of the 1st alum dose completed in 2019
- Follow-up sediment core laboratory data analysis
- Recommendations for 2nd alum dose

Summary of 1st Alum Dose

The 1st alum dose for Wassermann West Pond was completed in May 2019 by HAB Aquatic Solutions (HAB). According to the Wassermann West Feasibility Study, Wenck estimated that an alum treatment of Wassermann West Pond would result in a phosphorus (P) load reduction of approximately 35 pounds per year. It was also estimated that this reduction would achieve 8% of the required watershed load reduction needed for Wassermann Lake (Wenck, 2018). The original design called for treating redox P in the top 8 cm at a rate of 517 g Al/m^2 across two half dose applications over the 3.3-acre treatment area which included all depth contours of 6 ft and deeper (Figure 1). Table 1 includes the unit quantities that were applied by HAB during the 1st dose in May 2019.

Table 1: Initial 1st dose (Wenck 2018) applied in May 2019.

Dose	Unit	Quantity
Initial Aluminum Sulfate Dose	Gal $Al_2(SO_4)_3$	7,418
Initial Sodium Aluminate Dose	Gal $NaAlO_2$	3,709

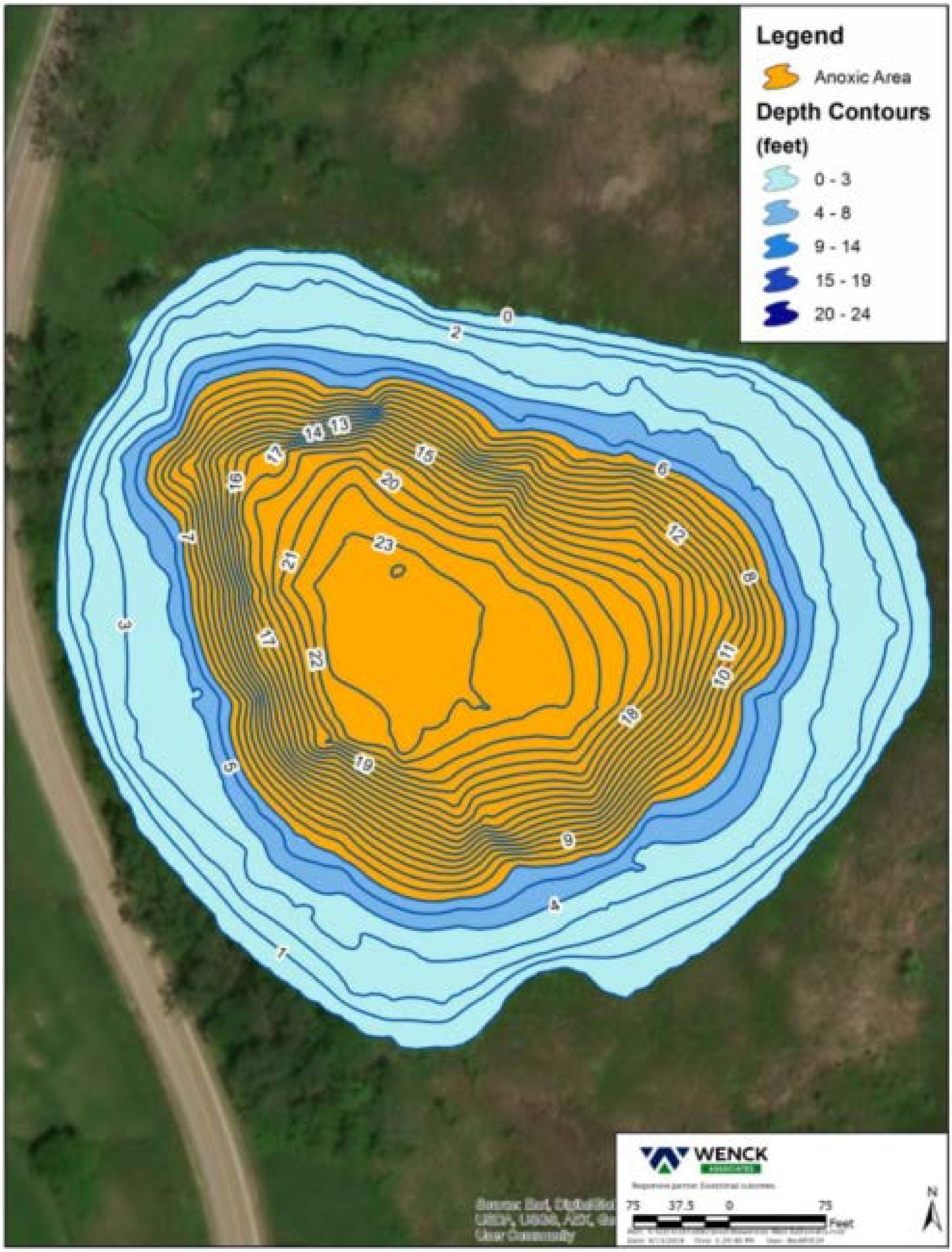

Figure 1. First dose application area

Follow-up Sediment Core Results

In September 2020, approximately 16 months after the 1st dose treatment, four follow-up sediment cores were collected by District staff within the 10-, 14-, 20-, and 22-foot depth contours (Figure 2) using a gravity sediment coring device equipped with an acrylic core liner (6.5-cm ID and 50-cm length). Cores 1-4 extend radially from the deepest location (core 1) at 22 ft to core 4 which is located within the 10-foot contour. Sediment cores from each station were transported to the University of Wisconsin - Stout Discovery Center Laboratory where they were sectioned vertically at 2-cm intervals over the upper 10-cm to evaluate variations in sediment physical-textural and chemical characteristics, including phosphorus fractionation. Phosphorus fractionation characterizes the different types of phosphorus within the sediment total phosphorus pool. In most lakes, the primary fractions that drive phosphorus release from the sediments are phosphorus bound to iron (iron-bound P) and phosphorus in the sediment porewater (loosely-bound P). Collectively, iron-bound P and loosely-bound P are referred to as redox sensitive phosphorus (redox P) as this is the form of phosphorus that is released during anoxic periods. Lakes with a high fraction of redox P have the potential to release phosphorus at a high rate. Additionally, sediment cores 1 through 4 from were analyzed in the lab for phosphorus release under anoxic conditions.

The sediment cores show a significant improvement in both Redox P in the top 6 cm and the anaerobic phosphorus release rates (Figure 3 and 4). The initial alum dose is currently achieving the 90% internal load reduction goal for all depth contours analyzed. The redox P was successfully converted to Al bound P and achieved significant reductions ranging from 62% to 81% (Figure 4). Labile P**,** the organic P fraction, increased in some of the cores following the first treatment. Alum is not as efficient in removing labile P, thus it was not included in the original alum treatment calculations and design. The best measure of alum treatment efficacy is the reduction in release rate, thus this increase although curious, is not related to the performance of the previous alum treatment.

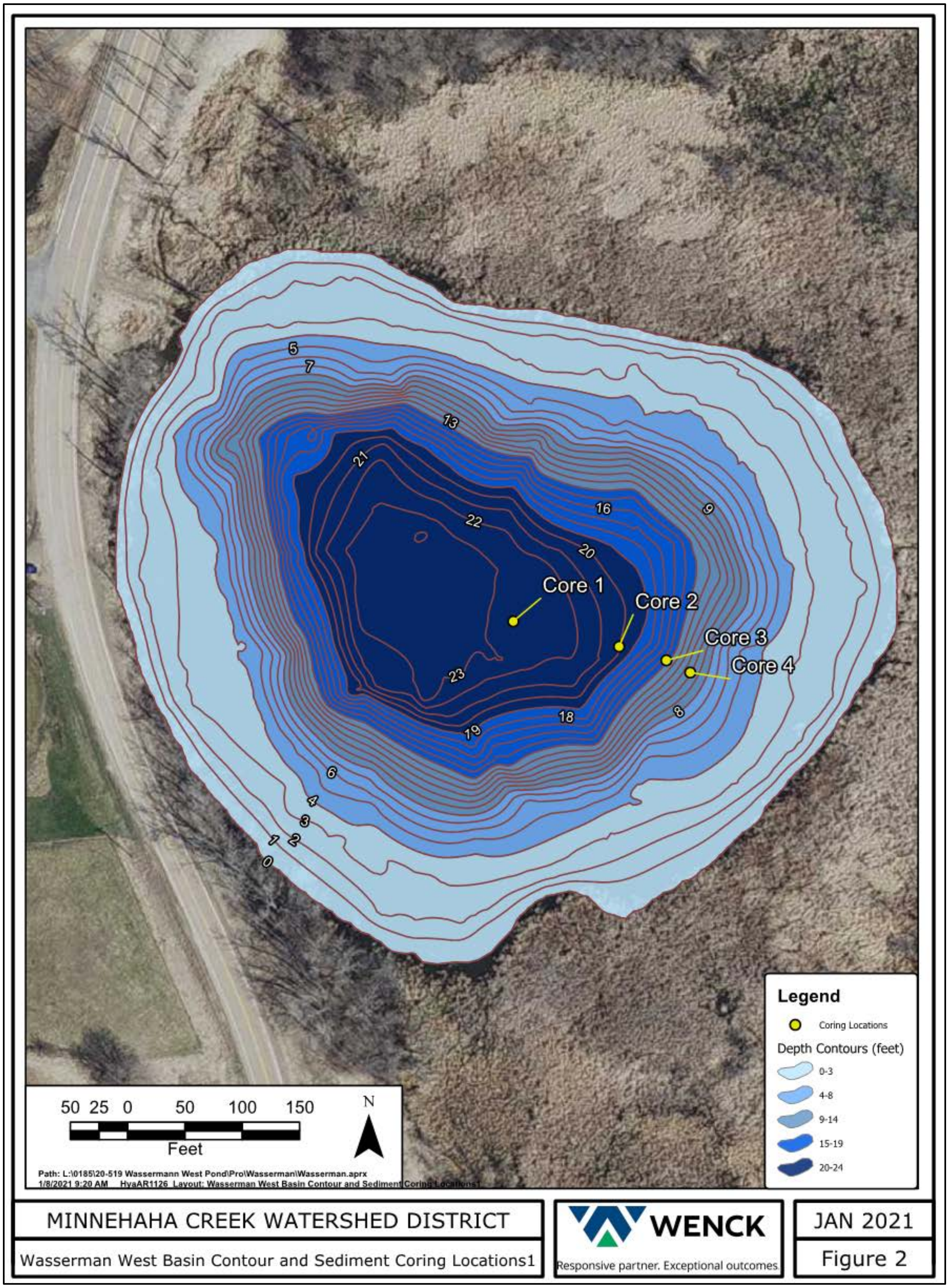

Figure 2. Post treatment sediment core locations

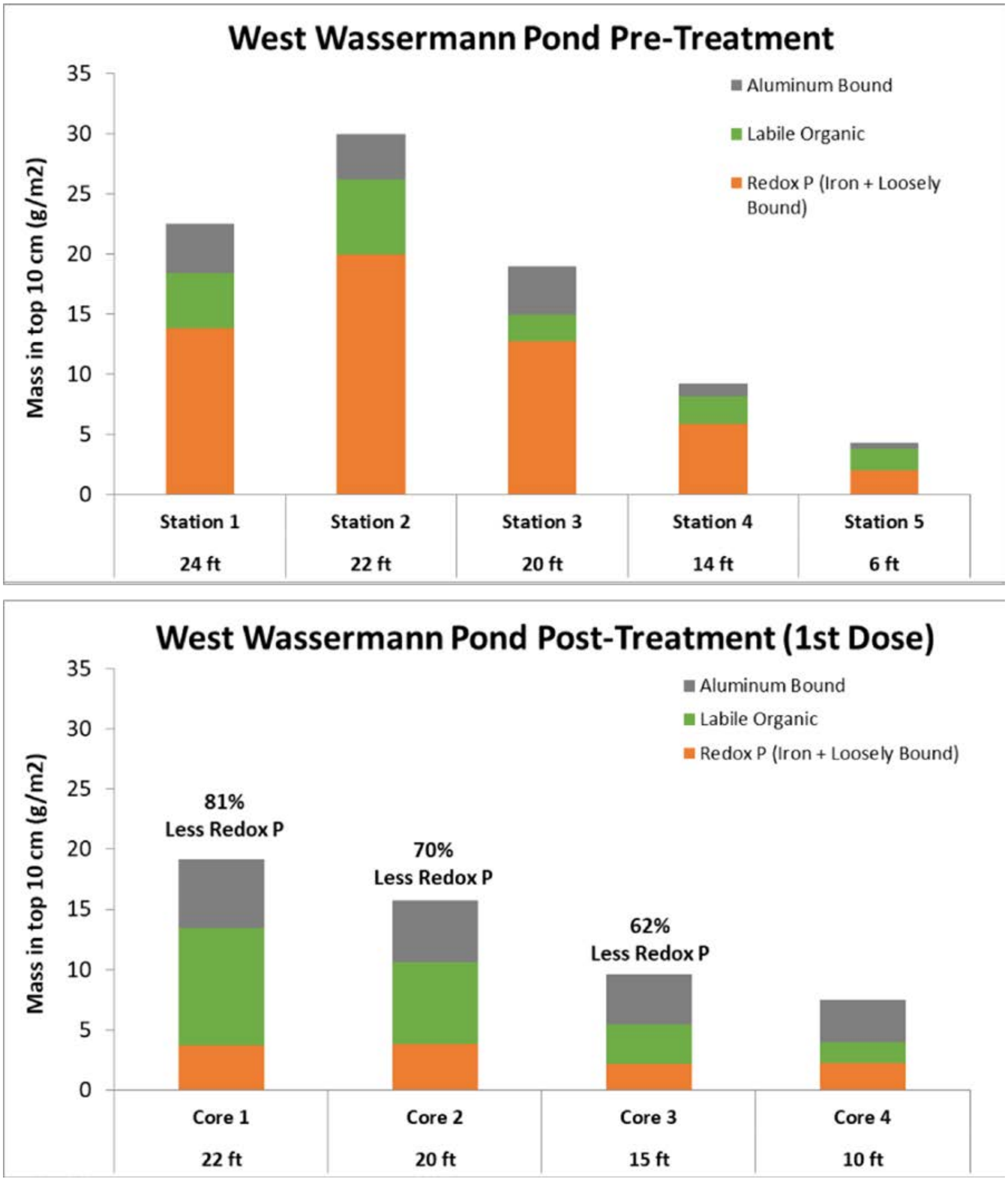

Figure 3. Comparison of pre/post treatment sediment phosphorous fraction in the top 10 cm

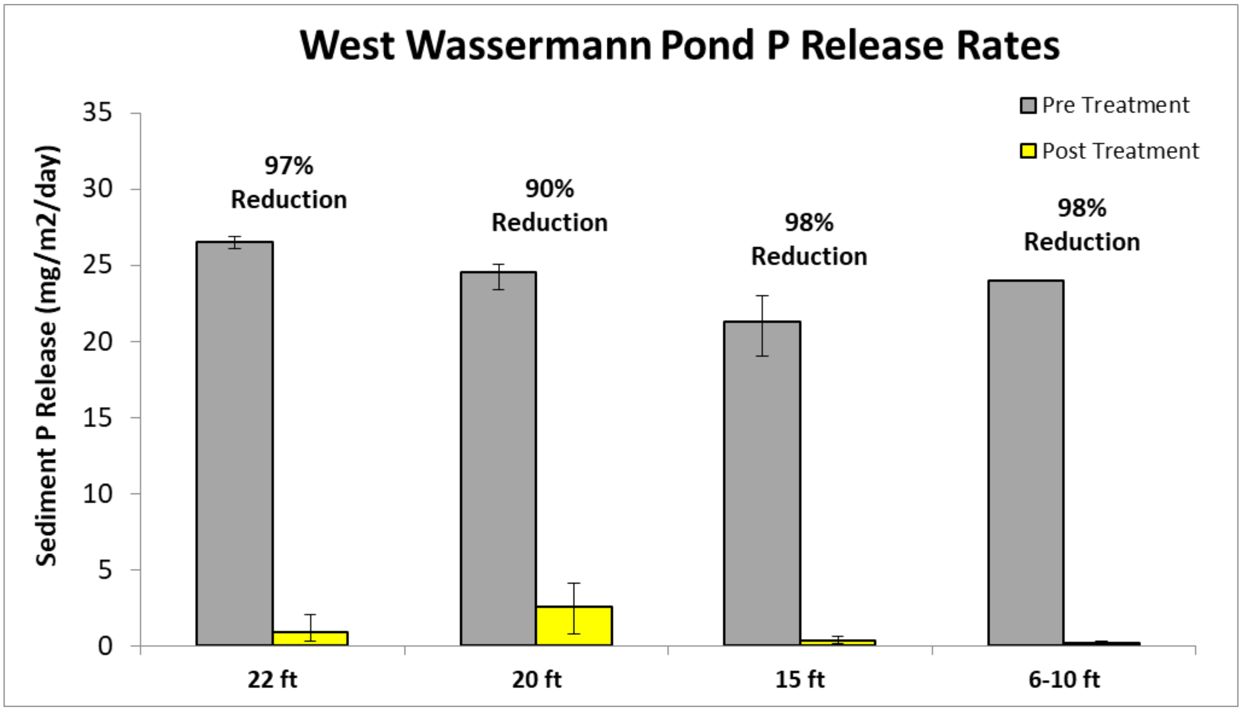

Figure 4. Comparison of pre/post treatment anaerobic release rate

Recommendations

Based on the follow-up monitoring, the first alum dose for Wassermann West Pond is currently achieving the 90% internal load reduction goal (35 lbs/yr), however, there is still available redox P observed in the sediment profiles. For the 2nd alum dose, Wenck recommends another buffered alum treatment below the 6-foot contour that targets the remaining available redox P in the upper 10 cm of the sediment. The initial alum treatment feasibility prescribed a high dose at 517 g Al/m^2 (whole dose). The first dose achieved a large reduction; thus, the recommended second dose (148 g Al/m^2) is smaller than prescribed in the feasibility study while treating the remaining redox P in the top 10 cm based on the post treatment sediment chemistry. The estimated cost for the 2nd dose is based on a quote provided by HAB Aquatic Solutions (Table 2).

The following assumptions were made for the 2nd dose costs presented in Table 2:

- Alum would be applied at a rate to deactivate 90% of the remaining redox P in the top 10 cm of the sediment
- A buffered alum treatment (i.e. two parts alum to one part sodium-aluminate) would be conducted to reduce the potential for pH reductions below 6 which can be stressful for aquatic organisms
- The mass of aluminum needed to convert redox-P to aluminum bound-P was calculated using an empirically derived relationship between redox-P concentration and the ratio needed to inactivate 90% of the elevated redox-P (Al:P90%) (James et al, 2015)
- Cost estimates were provided by HAB Aquatic Solutions, LLC which assumed:

- The alum treatments would likely take place in spring of 2021
- Wassermann West Pond (2nd dose) and Wassermann Lake 1st dose alum treatments would be done together
- COVID-19 is not significantly affecting alum and mobilization costs at this time
- Cost estimates include both mobilization and product cost

- Cost estimates for the 2nd dose were provided directly by HAB Aquatic Solutions

Table 2: Second Alum Treatment Dose and Cost Estimate

Depth (ft)	Area (acre)	Aluminum Sulfate (gal)	Sodium Aluminate (gal)	Al g/m^2	Cost*
6ft and below	3.3	3,882	1,941	148	$ 10,093
				Mobilization	$ 35,000
				Total	$ 45,093

* All costs are based on application price quoted from HAB Aquatics

References

James WF, Bischoff JM. 2015. Relationships between redox-sensitive phosphorus concentrations in sediment and the aluminum:phosphorus binding ratio. Lake and Reservoir Management 31:339-346.

Wenck, Associates, 2018. Wassermann West Pond Sediment Investigation. Transmitted to Minnehaha Creek Watershed District, April, 18, 2018.

Technical Memo

WENCK

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To: Minnehaha Creek Watershed District Association

Attn: Laura Domyancich-Lee and Kailey Cermak

From: Jeff Strom, Wenck Associates now part of Stantec
Anne Wilkinson, Wenck Associates now part of Stantec
Chris Meehan, Wenck Associates now part of Stantec

Date: January 22, 2021

Subject: Wassermann Lake 1st Dose Alum Treatment Recommendations (DRAFT)

Wassermann Lake is located within the Minnehaha Creek Watershed District (District) in Laketown Township near the City of Victoria. The lake has a surface area of approximately 170 acres and a watershed area of 2,729 acres (4.3 square miles). Its mean depth is approximately 10 feet and its maximum depth is 41 feet. Approximately 73% of the lake is littoral (i.e. having a depth of 15 feet or less).

Wassermann Lake was placed on the State of Minnesota's 303(d) list of impaired waters in 2004 and a Total Maximum Daily Load (TMDL) study for the lake was completed in 2011 (MPCA, 2011). The TMDL study determined that internal loading is potentially a significant source of phosphorus to Wassermann Lake and that significant reductions would likely be needed to meet State water quality standards. In 2013, the District completed the Six Mile Creek (SMC) Diagnostic Study (Wenck 2013). This study, which included collection of sediment cores from one location to determine phosphorus release from the lake's sediments, also concluded that internal loading is a significant source of phosphorus to Wassermann Lake. In 2019, the District updated Wassermann Lake's phosphorus model and budget using tributary and in-lake monitoring data collected by the District since completion of the TMDL and SMC Diagnostic Studies. Through this process the District determined that internal loading for Wassermann Lake will need to be reduced by approximately 337lbs/yr (90%) in order for the lake to meet State water quality standards.

Since internal loading is such a large percentage of the phosphorous budget, the District applied for and received a grant from the Minnesota Board of Water and Soil Resources (BWSR) in 2019 to conduct an aluminum sulfate (alum) treatment. The District contracted with Wenck Associates, Inc. (Wenck) to assist in conducting engineering feasibility of the treatment, and final design and cost estimates. This technical memorandum presents the results of this work which includes the following components:

- Review of temperature and dissolved oxygen (DO) data from the continuous buoy
- Sediment core laboratory data analysis
- Assessment of alum treatment design and estimated costs
- Final recommendations for the 1st alum dose (2021)
- Plans and specifications for the 1st alum dose application

Anoxia Investigation

Water column processes play an important role in lake nutrient cycling and phosphorus release from the lake sediments. Lake stratification, mixing, and absence of DO can all affect whether a lake releases phosphorus from benthic sediments. The District has collected temperature and DO profiles approximately every two weeks from April 2015 through October 2019 in Wassermann Lake. On May 20, 2020, a data buoy was deployed (Figure 1) by the District near the lake's deep hole (~41 feet) for the summer growing season to provide more frequent measurements of the lake's thermal structure, wind mixing, and/or other events that could impact the internal phosphorus load estimate. The data buoy was outfitted with sensors at various depths to continuously monitor temperature, DO, and other water quality parameters. The buoy was installed in the lake from May through late October. The buoy data was used by District staff to develop high resolution periods of anoxia and internal loading estimates for each 1-foot depth contour. As expected, the anoxic period increased with depth. The 7-foot and shallower contours never experienced anoxia (Table 1). Alternatively, the 24-foot depth contour experienced anoxia for the entire period in which the data buoy was deployed (132 days). The 14-19 foot contours experienced anoxia for approximately half of the growing season.

Figure 2. Wassermann data buoy deployment on May 20, 2020

Table 1. Depth vs number of days anoxia was observed in 2020

DEPTH (FT)	DAYS ANOXIC (DAYS)
6-7	0
8-9	15
10-13	30-50
14-19	70-100
20-23	120-130
24-38	132

Sediment Core Methods

Intact sediment cores were collected at seven locations (Figure 2) in Wassermann Lake by District staff in the fall of 2020 using a gravity sediment coring device equipped with an acrylic core liner (6.5-cm ID and 50-cm length). Cores 1-7 extend radially from the deepest location (core 1) at 35 ft to core 7 which is located within the 8-foot contour. Sediment cores from each station were transported to the University of Wisconsin - Stout Discovery Center Laboratory where they were sectioned vertically at 2-cm intervals over the upper 10-cm to evaluate variations in sediment physical-textural and chemical characteristics, including phosphorus fractionation. Phosphorus fractionation characterizes the different types of phosphorus within the sediment total phosphorus pool. In most lakes, the primary fractions that drive phosphorus release from the sediments are phosphorus bound to iron (iron-bound P) and phosphorus in the sediment porewater (loosely-bound P). Collectively, iron-bound P and loosely-bound P are referred to as redox sensitive phosphorus (redox P) as this is the form of phosphorus that is released during anoxic periods. Lakes with a high fraction of redox P have the potential to release phosphorus at a high rate. Additionally, sediment cores 2 through 7 were analyzed in the lab for phosphorus release under anoxic conditions.

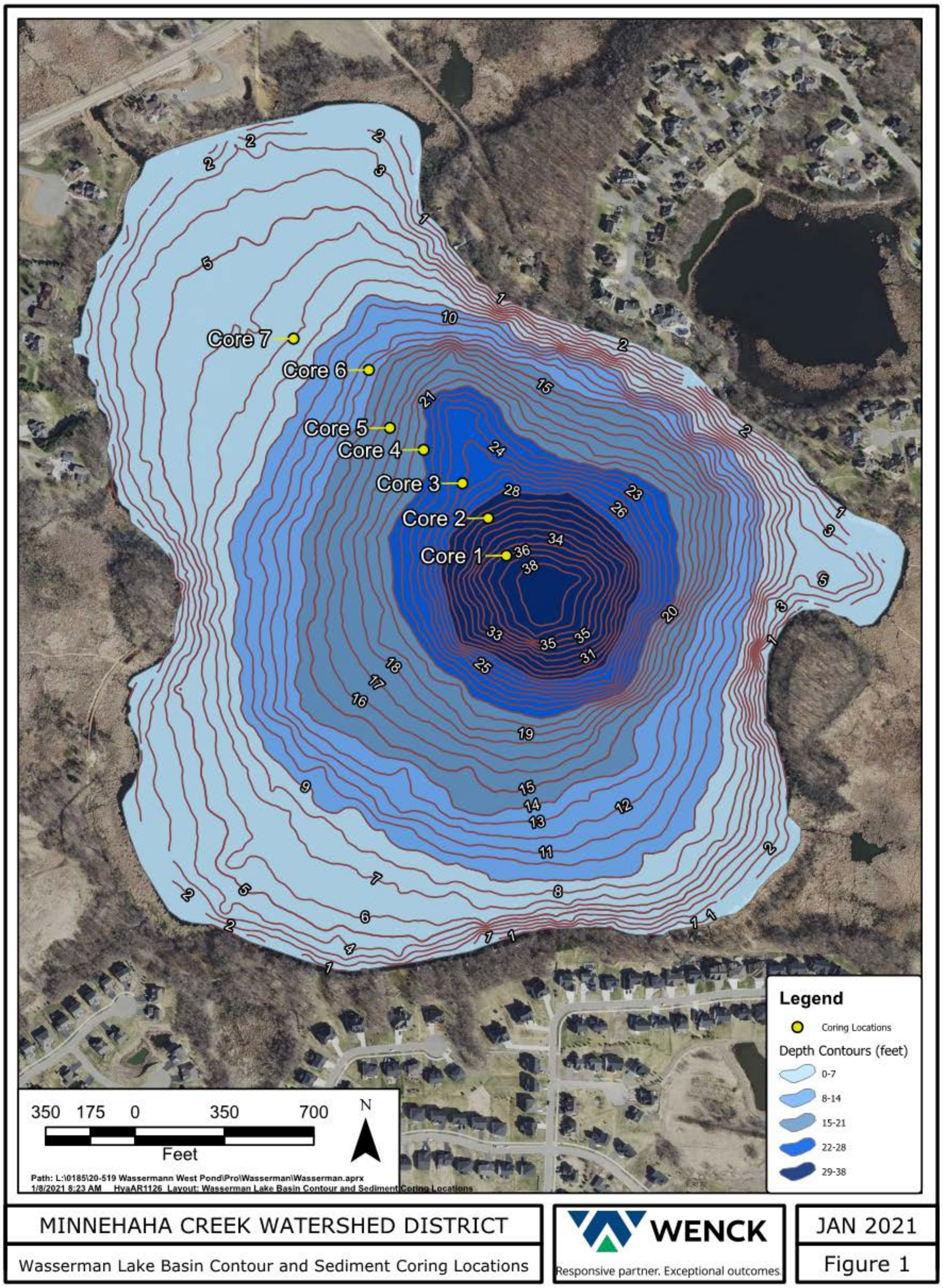

Figure 2. Lake sediment core locations.

Sediment Core Results

Laboratory analyses of the sediment phosphorus fractions indicate redox P concentrations generally increased with depth with core 1 having the highest redox P concentration and core 6 having the lowest concentration (Figure 3). The one exception to this was core 5 which had a large redox P concentration at 0-2 cm that does not fit with the rest of the profile. Nonetheless, this data point was included throughout the analyses presented in this memo to be conservative.

Redox P concentrations in the top 0-2 cm for Wassermann cores 1-6 ranged from 1.74 mg/g (core 1) to 0.49 mg/g (core 6) (Figure 3). Based on our dataset of over 100 lakes in Minnesota, the median concentration of redox P in lakes is 0.37 mg/g. Generally, we have found that lakes with redox P concentrations greater than 0.37 mg/g have higher phosphorus release rates. These data suggest that the sediments analyzed for Wassermann Lake have accumulated phosphorus that is capable of releasing phosphorus at a high rate into the water column.

Anaerobic (i.e. anoxic) phosphorus release rates for cores 2-7 ranged from 2.76 $mg/m^2/day$ (core 7) to 9.77 $mg/m^2/day$ (core 2) (Figure 4). The anaerobic release rates analyzed are within the bounds (25^{th}-75^{th} percentile) for release rates measured by Wenck in lakes throughout Minnesota.

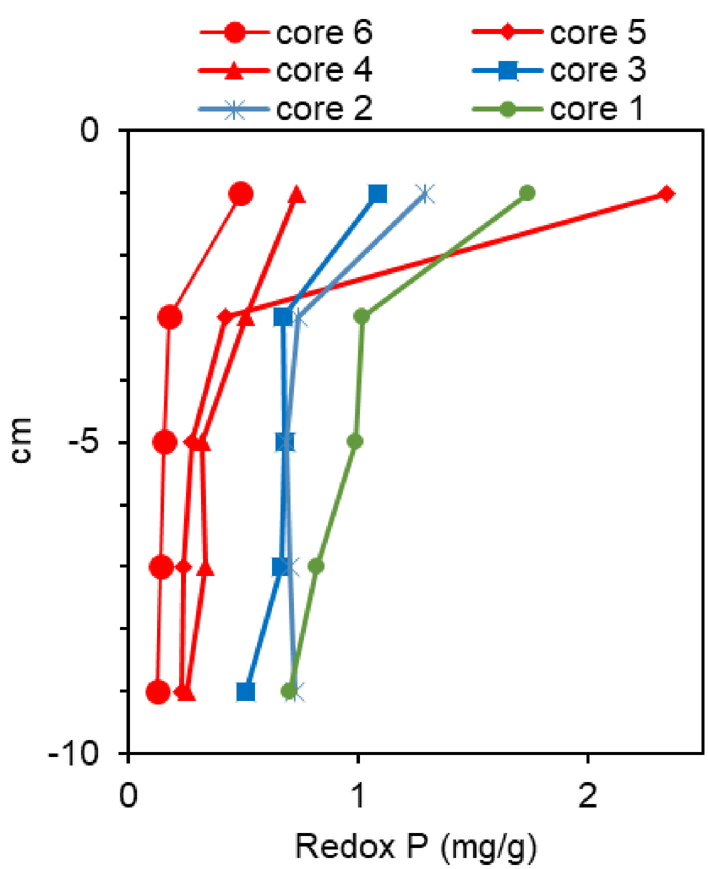

Figure 3. 2020 Sediment Redox P Profiles

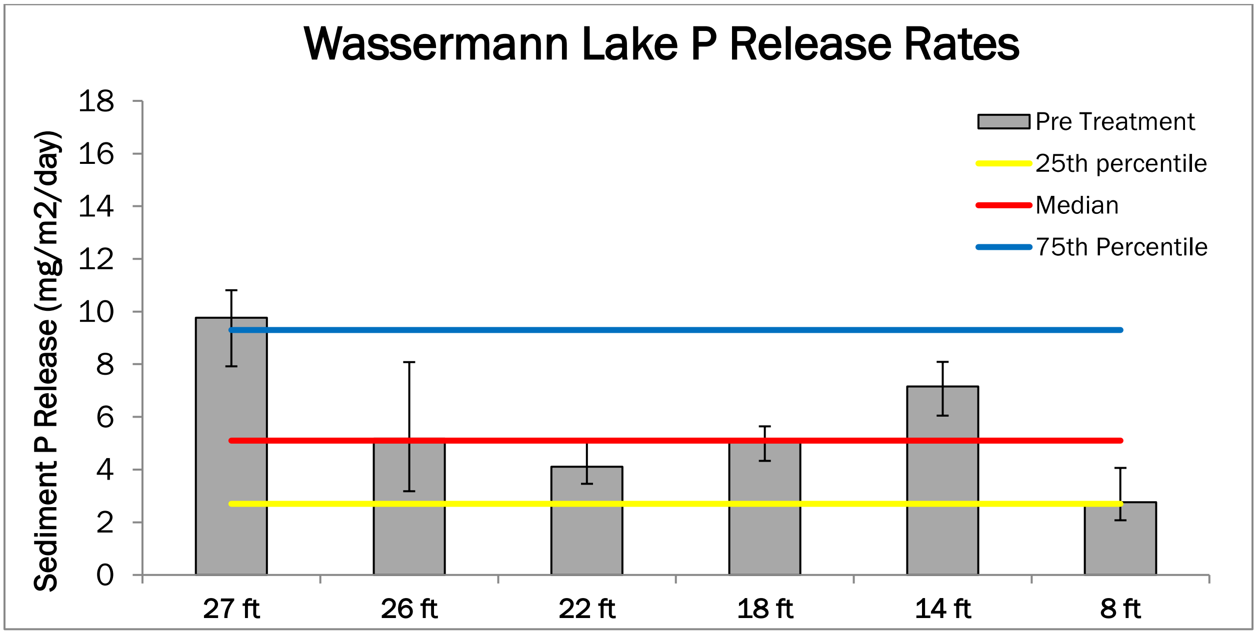

Figure 4. Comparison of Wasserman Lake lab measured anaerobic sediment phosphorus release (gray bars) to other Minnesota lakes (blue, red, and yellow lines).

Alum Treatment Design Considerations and Cost Estimates

Three factors are considered when determining whether to treat a lake with alum: 1) the rate at which phosphorus is releasing from the sediment under anaerobic conditions; 2) the depth and area of lake experiencing anoxia; and 3) redox-P concentrations in the lake's sediments. The sediment chemistry confirms anaerobic P release is elevated in Wassermann Lake (Table 2). The high resolution DO data collected by the District in 2020 indicates that the 10-38 ft depth contour experiences varying degrees of low DO (anoxic) conditions (Table 1). The sediment chemistry profiles (Figure 3) suggest all sediment cores exhibited elevated redox-P concentrations in the top 6 cm. Based on this information, as well as the results of the TMDL and SMC Diagnostic studies, it is recommended that the District pursue an alum treatment to manage internal loading in Wassermann Lake.

Aluminum sulfate (alum) is one of the most common chemicals used for sediment-phosphorus inactivation as the absorption of phosphorus to aluminum is very stable under environmental conditions and provides a long-term sink of phosphorus in the lake. Alum is applied to lakes by injection of liquid alum just below the lake water surface. The alum quickly forms a solid precipitate (floc) and settles to the bottom of the lake, which converts highly mobile sediment phosphorus (redox-P) to an immobile phosphorus fraction (aluminum bound-P). This process reduces sediment phosphorus release rates, and ultimately reduces internal phosphorus loading in lakes. The mass of aluminum needed to convert redox-P to aluminum bound-P in each treatment zone was calculated using an empirically derived relationship between redox-P concentration and the ratio needed to inactivate 90% of the elevated redox-P (Al:P90%) (James et al, 2015).

The large amounts of alum applied during one application has the potential to drive pH below 6, causing aquatic toxicity concerns. Buffered alum applications (2:1 ratio of alum +sodium aluminate) help bolster the ambient alkalinity to reduce acidification and the associated risks. Additionally, splitting alum doses into a minimum of two applications of a buffered alum solution further minimizes this risk. Splitting the treatment into two doses will increase the effectiveness and longevity of the alum application by increasing the time that fresh alum is exposed to the uppermost sediment layer containing high redox-P.

The high-resolution data from the continuous buoy and the wide coverage of the sediment cores allowed Wenck to develop a thorough cost/benefit analysis of nine different scenarios in which alum is applied at various depths ranging from the 10-foot contour to the 38-foot contour (Figure 5). The grant application submitted to the Minnesota Board of Soil and Water Resources (BWSR) stated a 337 lbs/yr reduction goal for the alum treatment which is 90% of the lakes total internal load (374 lbs/yr). This estimate is slightly higher than the internal load that was estimated using the 2020 high-resolution data and new cores. In Figure 5, the cumulative P reduction (orange line) is plotted per depth contour and peaks at 310 lb/year. The cost benefit analysis also shows the cumulative cost/lb of P removed for each depth contour (blue line). Both the remediated internal load and the subsequent cost increase as the application area increases, thus the recommendation is based on balancing extending treatment area at increased cost.

The following assumptions were made for the cost/benefit scenarios highlighted in Figure 5:

- Alum would be applied at a rate to deactivate 90% of the redox P in the top 6 cm of the sediment over the course of two applications
- The 1st alum dose would take place in the spring of 2021.
- A buffered alum treatment (i.e. two parts alum to one part sodium-aluminate) would be conducted for the 1st dose to reduce the potential for pH reductions below 6 which can be stressful or toxic for aquatic organisms
- Cost estimates were provided by HAB Aquatic Solutions, LLC which assumed:
    - The alum treatments would likely take place in spring of 2021
    - Wassermann West Pond (2nd dose) and Wassermann Lake 2021 alum treatments would be done together
    - COVID-19 is not significantly affecting alum and mobilization costs at this time
    - Cost estimates include both mobilization and alum product cost
- Cost estimates for the 1st dose (2021) were provided directly by HAB Aquatic Solutions
- Cost estimates for the 2nd half-dose used HAB's 2021 cost estimate + 15% contingency

Recommendations for 1st Half-Dose Treatment

The cumulative load reduction from the 2020 high-resolution analysis peaks at 310 lbs/yr at the 10 ft contour. However, the cost per pound removed is most advantageous, while still achieving significant load reduction, at the 14-foot contour. Treatment at the 14-foot contour would achieve an internal load reduction of 269 lbs/yr (Figure 5).

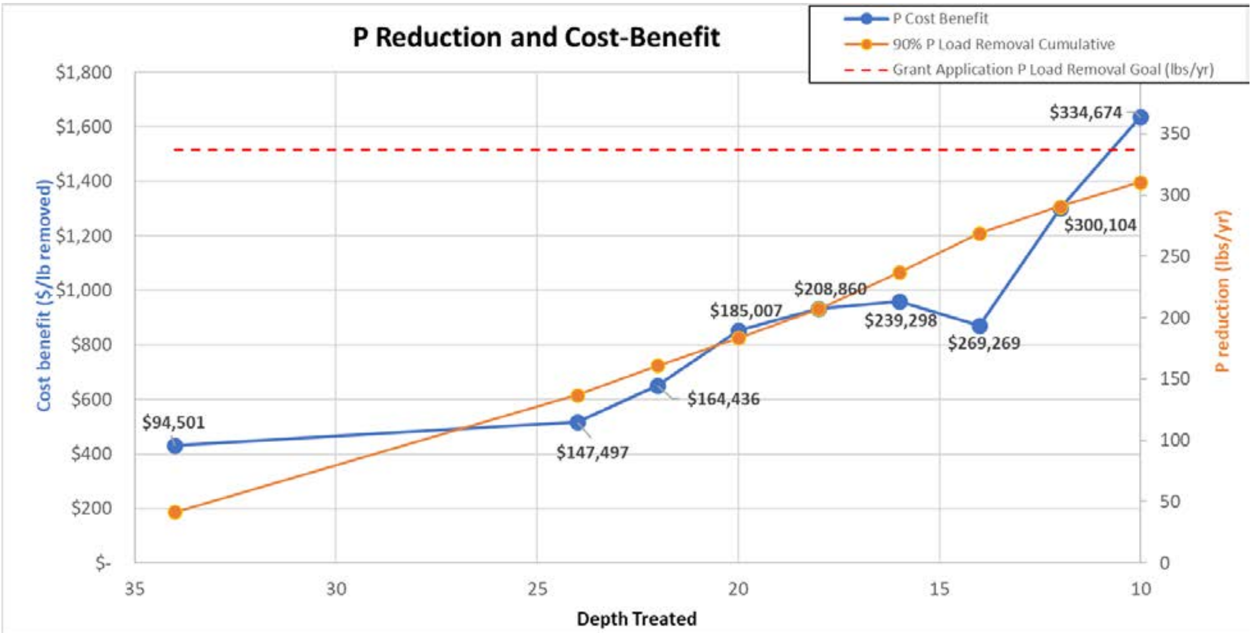

Figure 5. Alum treatment cost benefit analysis for Wassermann Lake.
Figure Notes:

- The cumulative load reduction (orange line), cost-benefit (blue line), and total estimated treatment cost (data labels along blue line) are for both doses using assumptions stated above
- The grant application load reduction goal (dotted red line) was developed based on data collected prior to 2020, while the cumulative load reduction and cost-benefit were developed using the 2020 high resolution data

Wenck recommends a buffered alum treatment that consists of two distinct areas based on differing sediment chemistry characteristics. The deeper area (24-38 feet) will receive a higher alum dose than the shallow area (14-24 feet) since more alum is required to inactivate the elevated redox-P in the deep area (Table 2 and Figure 6).

Wenck recommends the buffered alum treatment be separated into two doses with follow up sediment and water quality monitoring. We recommend that the follow-up sediment cores be collected at least one year after the 1st dose application and cores be collected at stations 2-6 and include the following parameters: moisture content-bulk density, loss-on ignition organic matter, total aluminum, aluminum bound phosphorus, and redox-sensitive phosphorus. Wenck also recommends surface and hypolimnetic water quality monitoring in years following each treatment to confirm water quality improvements in Wassermann Lake and assess if future applications will need to expand to shallower regions of the lake.

Table 2. Recommended 1st dose

DOSE	ZONE	DEPTHS (FT)	ALUMINUM SULFATE (GAL)	SODIUM ALUMINATE (GAL)	DOSE RATE (mg/M^2)
FIRST DOSE	1	14-24	13,500	6,750	59
	2	24-38	7,653	3,826.5	47
	Total	14-38	21,153	10,576.5	

Wenck developed the cost estimate for the first dose based on conversations with alum applicator HAB Aquatic Solutions and the assumptions listed above (Table 3). The first dose application is estimated to cost $131,244. The first dose is conservative based on the available 2020 dataset and cost benefit analysis. The follow up sediment monitoring will be instrumental in determining a refined second dose that will optimize load reduction and the remaining grant funding. The proposed timeline is to complete the first dose in the spring of 2021. In 2021-2022, we recommend follow up sediment core and water quality monitoring be conducted to inform the subsequent dose in fall 2022.

Table 3. Wassermann Lake 1st dose cost estimate

ZONE	DEPTHS (FT)	ALUMINUM SULFATE (GAL)	SODIUM ALUMINATE (GAL)	BUFFERED ALUM COST ($)	AREA (ACRE)	TIMELINE
1	14-24	13,500	6,750	$ 61,422.59	36.6	
2	24-38	7,653	3,826.5	$ 34,821.49	16.4	
TOTAL	14-38	21,153	10,576.5	$ 96,244.08	53	
			Mobilization	$ 35,000		
			1st Dose	$ 131,244.08		Spring 2021

* All costs are based on unit application price assumptions of $2.00/gal for $Al_2(SO_4)_3$ and $5.00/gal for $NaAlO_2$

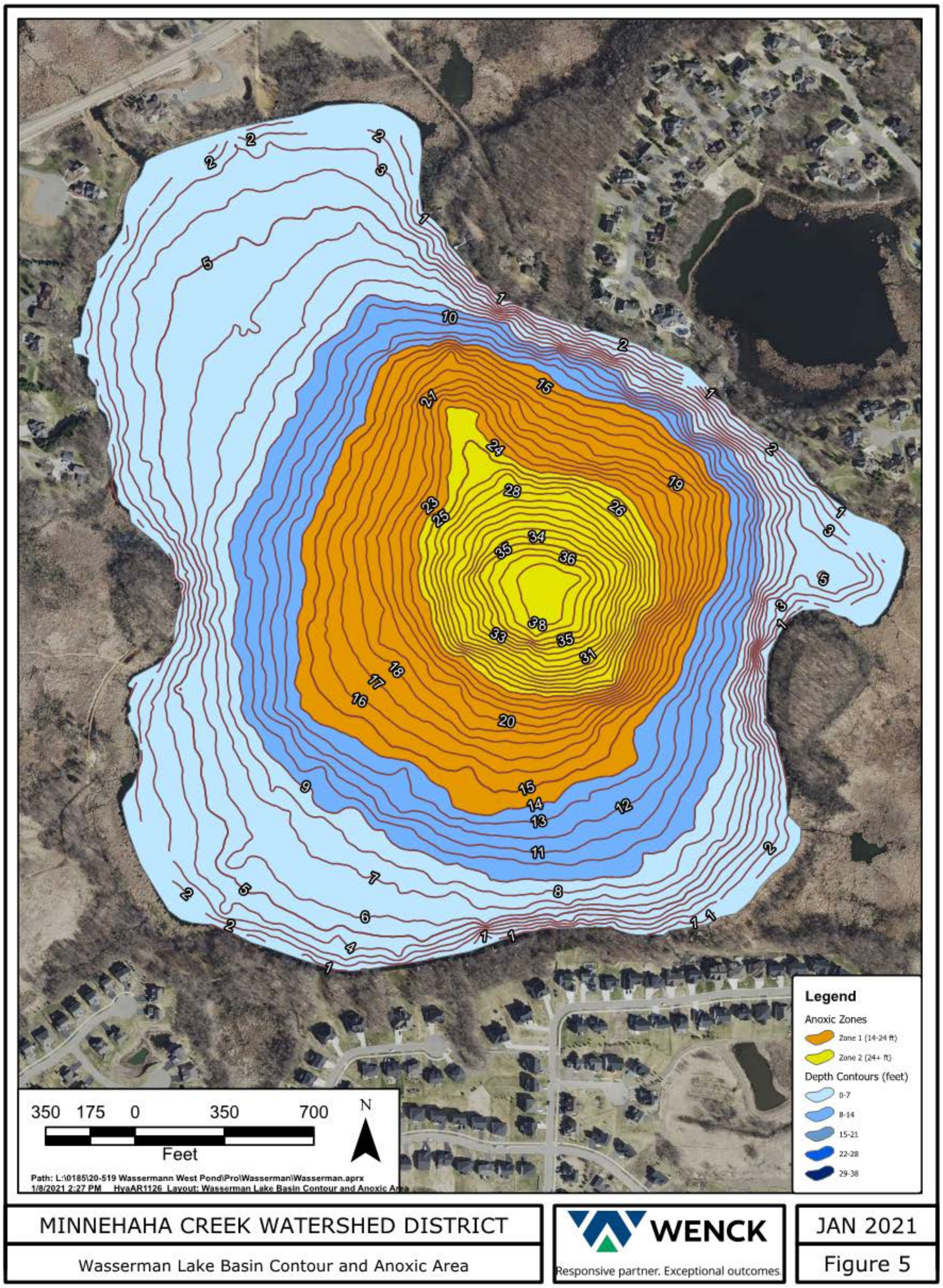

Figure 6. Wassermann Lake proposed alum treatment zones.

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