



Lake Cornelia and Lake Nancy Feasibility Study for Internal Loading Control



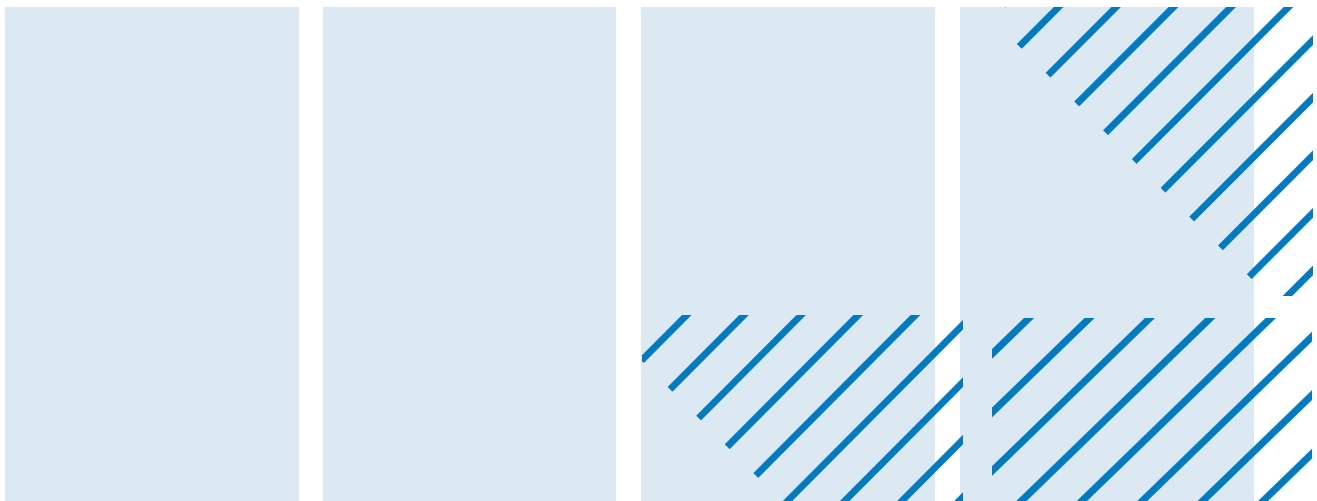
Prepared for
Nine Mile Creek Watershed District

Prepared by
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1 Executive Summary

The water quality of Lake Cornelia and Lake Nancy has historically been poor, with high phosphorus concentrations, frequent algal blooms, and turbid water conditions. High internal phosphorus loading from lake-bottom sediments and low dissolved oxygen in the summer and winter contribute to poor water quality and degraded ecology in Lake Nancy, North Lake Cornelia, and South Lake Cornelia. The type of phosphorus in the lake bottom sediments, primarily organically bound phosphorus—Org P, is especially challenging to manage as it is difficult to treat with conventional means such as aluminum treatment.

This feasibility study evaluated numerous methods to manage internal phosphorus loading in Lake Nancy, North Lake Cornelia, and South Lake Cornelia, including review of multiple sediment treatment techniques to minimize the release of phosphorus and evaluation of aeration options to increase the effectiveness of the potential sediment treatments and to support the Nine Mile Creek Watershed District's (NMCWD's) desire to maintain a native fishery.

The recommended techniques for managing internal phosphorus loading in North Lake Cornelia, South Lake Cornelia, and Lake Nancy are summarized in Table 1-1. The management recommendations were developed with consideration of effectiveness, cost, space requirements, visual impacts to public space, application techniques, and maintaining winter recreation opportunities in South Cornelia and Lake Nancy.

Table 1-1 Recommended treatment approaches, capital costs, and O & M costs

Lake	P-Binding Metal	Metal Form	Aeration System	Total Cost	Annual O&M
North Cornelia	Iron	ZVI	Diffused Air	\$189,000	\$6,500
South Cornelia	Iron	ZVI	OST + Destratification Diffused Air	\$442,000	\$11,350
Nancy	Lanthanum	Clay-bound or iron-coated solid lanthanum	None	\$90,000	0
Nancy (alternative)	Iron	ZVI	Diffused Air	\$99,000	\$5,000

Iron treatment and aeration are recommended for North Lake Cornelia and South Lake Cornelia. The goal of the iron treatments is to convert Org-P to iron-bound phosphorus (Fe-P). The aeration system is intended to keep Fe-P oxidized to prevent the release of phosphorus (internal loading). Several years after the implementation of these iron application and aeration projects, an aluminum treatment should be conducted to convert accumulated Fe-P to aluminum-bound P to permanently lock up the phosphorus in the stable aluminum-bound phosphorus compound. The timing of a follow-up aluminum treatment should be determined based on periodic sediment monitoring.

For South Lake Cornelia, the installation of an Oxygen Saturation Technology (OST) aeration system is recommended, a relatively new type of aeration system that will keep oxygen elevated to minimize or prevent fish kills without significantly impacting ice formation or thickness during the winter. To keep oxygen elevated in the summer in South Lake Cornelia, a diffused-air destratification system is also recommended for summer aeration.

For North Lake Cornelia, iron treatment in conjunction with a diffused-air aeration system is recommended. The diffused-air system is recommended for North Lake Cornelia instead of an OST system due to the lower cost and less concern about winter operation causing open water or poor ice conditions. Utilizing a diffused-air system costs less than an OST system, while still minimizing risks of winter fish kills and keeping iron in the sediments oxygenated.

For the iron treatments, application of zero valent iron (ZVI) as the iron media is recommended as a pilot. Ferric chloride and buffering chemicals are significantly more expensive than ZVI. In addition, the challenges of applying ferric chloride, a strong acidic compound, make it difficult to find interested chemical applicators. ZVI can be applied as a fine-grained solid substance on the ice during the winter using a broadcast spreader. Upon ice melting, the material will sink into the sediments.

Lanthanum treatment is recommended for Lake Nancy, with an alternative to lanthanum being diffused-air aeration and iron application. Treatment with lanthanum is considered experimental but is recommended to determine if it has the capacity to control internal loading from Org-P. Determination of the usefulness of lanthanum for control of Org-P-based internal loading in shallow lakes may help to inform appropriate treatments for other shallow lakes in the Nine Mile Creek watershed and broader lake management community. Treatment with iron and aeration can also be considered if experimentation with lanthanum is not desired. The primary challenge with iron and aeration treatment in Lake Nancy is that winter recreation on Lake Nancy prevents winter aeration. Winter aeration is expected to significantly improve the effectiveness of an iron treatment.

Because there has been significant interest in nanobubble technology, we also evaluated this aeration technology for Lake Cornelia and Lake Nancy. Because of significant cost, high space requirements, undesirable visuals for a highly-used public park space, and unknown potential ecological effects, this method is not recommended.

Phosphorus load reductions for Nancy, North Cornelia, and South Cornelia for the recommended management actions were estimated from: (1) the total phosphorus concentration reductions observed for the iron treatments at Indianhead and Arrowhead Lakes (70%), (2) estimated improvements in treatment performance with oxygen injection (OST or nanobubbles)-90% internal load reduction, and (3) binding of Fe-P by lanthanum. For Nancy, a 20 percent reduction in internal loading from lanthanum treatment is estimated given uncertainties over the capacity to control internal loading from Org-P. Using modeling results from the Cornelia UAA (Barr, 2019) and Nancy internal load study (Barr, 2022), the following phosphorus loading reductions are estimated with the prescribed treatments:

- Nancy: 2.3 pounds P per year
- North Cornelia: 111 pounds P per year
- South Cornelia: 74 pounds P per year

2 Introduction

The water quality of Lake Cornelia and Lake Nancy has historically been poor, with high phosphorus concentrations, frequent algal blooms, and turbid water conditions. As part of ongoing monitoring and assessment of Nine Mile Creek Watershed District (NMCWD) lakes, a 2019 water quality study (Barr, 2019) was conducted to assess the status of Lake Cornelia water quality and provide management recommendations. NMCWD also conducted a water quality study (Barr, 2022) for Lake Nancy and Otto in 2022 to assess the water quality status of these lakes and provide management recommendations. Because water quality in Otto met District goals, no management recommendations were provided for Lake Otto.

The 2019 water quality study for Lake Cornelia concluded that the major drivers of poor water quality in the lake were internal phosphorus loading, external loads from stormwater runoff, non-native aquatic plants (curly-leaf pondweed), and non-native fish (carp and goldfish). Management recommendations provided as part of the 2019 water quality study for Lake Cornelia were designed to address these drivers and included:

- Curly-leaf pondweed management
- Alum treatment of lake sediments
- External load treatment using a filtration-type media filter and street sweeping
- Fisheries management, including winter aeration to prevent winter fish kills

While the study recognized that implementing the recommended projects would likely not be sufficient to meet the 60 µg/L phosphorus standard for shallow lakes, the objective was to lower average summer total phosphorus concentrations, improve algal conditions in the lake, and improve water clarity. Management of the non-native (carp and goldfish) fish community was also recommended to reduce the disturbance of bottom sediments and promote a healthy and more diverse fishery.

The 2022 water quality study for Lake Nancy identified stormwater inputs and internal loading as primary sources of phosphorus to Lake Nancy, as well as an abundant goldfish population that may be hindering water quality. Because of limited opportunities to reduce stormwater inputs to Lake Nancy, recommendations from the 2022 study to reduce phosphorus, reduce chlorophyll-a, and improve water clarity were focused on internal loading control, including conducting an aluminum and iron treatment combined with winter and summer aeration, and fish management focused on goldfish removal.

This current feasibility study was initiated to provide: (1) a retrospective analysis of Lake Cornelia and Lake Nancy water quality, (2) a brief review of management actions that have been conducted and the effect of these actions on water quality, (3) revised and focused management recommendations to manage internal phosphorus loading given knowledge gained from other NMCWD lake management projects and with consideration of the current status of Lake Cornelia and Lake Nancy water quality, (4) provide conceptual treatment plan options and estimates of probable cost (Class 5: -20% + 30%) to implement recommended management actions (not including those activities currently being undertaken).

The evaluation of sediment treatment options included consideration of three phosphorus-binding elements (metals): aluminum, iron, and lanthanum. The study also included evaluation of three aeration and oxygenation approaches, including traditional diffused-air aeration, nanobubble oxygenation, and side-stream oxygenation.

3 Management History and Water Quality

3.1 Management History

The management history for Lake Cornelia, including past and ongoing projects, is provided in Table 3-1. The aluminum (alum and sodium aluminate) treatment conducted in 2020 was half the recommended dose. The half-dose was implemented out of caution, given that carp and goldfish management had not been started. The concern was that carp or goldfish may cause excessive mixing of treated sediment, leading to the burial of aluminum deep into the sediment, thereby rendering the treatment ineffective. The intention was to revisit the outcome of this treatment and assess the need for an additional treatment—this is being considered as part of this feasibility study.

Table 3-1 Record of management history for Lake Cornelia

Management Practice	Basis	Year Implemented	Lead Agency
Herbicide Treatments	Reduce the impacts of curly-leaf pondweed on producing degraded water quality and ecological conditions	2017- Ongoing	NMCWD & City of Edina
Enhanced Street Sweeping	Reduce pollutant loading from stormwater runoff	2020 – Ongoing	City of Edina
Aluminum Sediment Treatment	Reduce internal sediment phosphorus load	2020	NMCWD
Rosland Park Stormwater Filtration Vault	Reduce nutrient/pollutant loading from stormwater (following stormwater events) and remove in-lake nutrients/pollutants (during dry weather)	2022 – Ongoing (system began operating in July)	NMCWD & City of Edina
Rough Fish Removal	Reduce levels of goldfish to reduce sediment disturbance, reduce sediment phosphorus load, and promote food web balance	2023 – Ongoing	NMCWD

Some additional details on fisheries management efforts include:

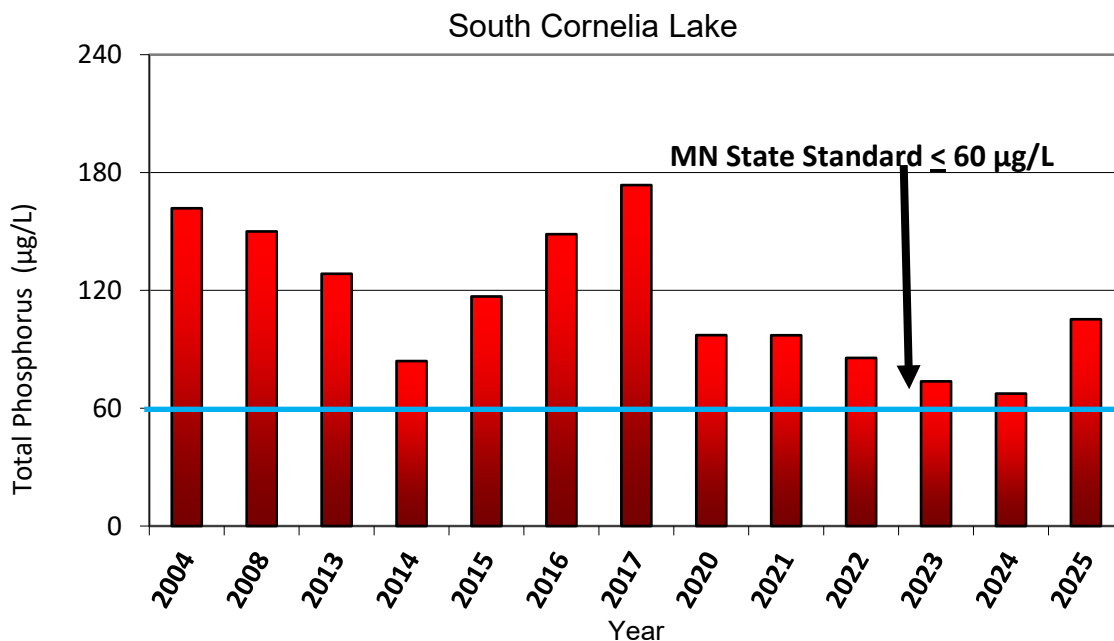
- 2018: Electrofishing and trap net surveys were conducted in North and South Lake Cornelia as well as Lake Nancy
- 2020: Goldfish study that included electrofishing and trap net surveys was completed for North and South Lake Cornelia, as well as for Lake Nancy. One baited box net trap was tested in Lake Nancy (not successful), as well as North and South Lake Cornelia, for approximately one month in each basin. Goldfish movement between basins was studied using approximately 400 PIT-tagged goldfish and radio transmitters on 10 individual goldfish.

- 2023: Electrofishing surveys before and after removal efforts were conducted in North and South Lake Cornelia. Box netting removals were conducted from June through September.
- 2024: Electrofishing surveys before and after removal efforts were conducted in North and South Lake Cornelia. Box netting removals were conducted from August through October.
- 2025: Electrofishing surveys before and after removal efforts were conducted in North and South Lake Cornelia. Box netting removals were conducted from June through October. A trap net survey was conducted in North and South Lake Cornelia in September.
- The Minnesota Department of Natural Resources has routinely conducted annual stocking of bluegill sunfish and, more recently (2024 and 2025), stocking has included gamefish such as perch, bass, and northern pike.

Fisheries survey or management work has not been conducted in Lake Nancy since 2020. No other management activities have been undertaken for Lake Nancy.

3.2 Water Quality

Total phosphorus concentrations in North Lake Cornelia since management activities commenced in 2020 do not appear to have changed notably when compared to concentrations prior to 2020 (Figure 3-1). Concentrations in South Lake Cornelia appear to have declined since 2020. Regardless, both North and South Cornelia are not meeting Minnesota eutrophication criteria for phosphorus and chlorophyll *a*, and it appears that phytoplankton have become more abundant in both North and South Cornelia since 2020 (Figure 3-2



). Application of copper sulfate to treat phytoplankton blooms was routinely conducted on North and South Lake Cornelia prior to 2020, and it is likely that the cessation of these treatments is responsible for the apparent increase in phytoplankton. Copper sulfate works by rupturing the phytoplankton cell membrane, which in turn has the effect of causing the phytoplankton to sink. This causes a near-instantaneous reduction in chlorophyll *a*, but it also reduces total phosphorus associated with the phytoplankton cellular contents as it settles into the sediments. Cessation of copper sulfate treatment

likely led to the observed increase in phytoplankton (measured as chlorophyll *a*), but this may also be masking the effectiveness of the phosphorus reduction efforts conducted since 2020. Regardless, these data indicate that further phosphorus management efforts are warranted.

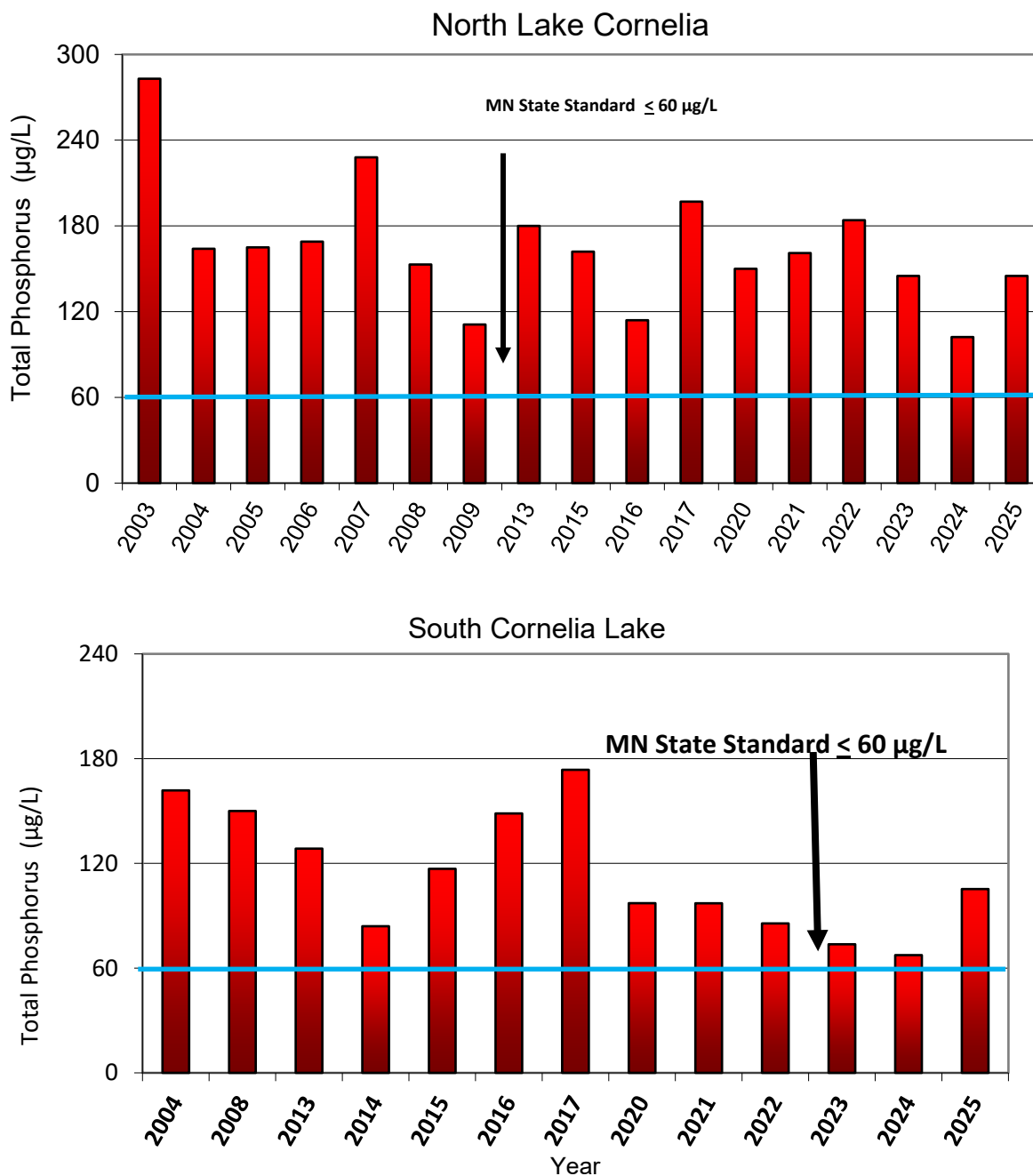


Figure 3-1 Summer average total phosphorus concentrations in North and South Lake Cornelia

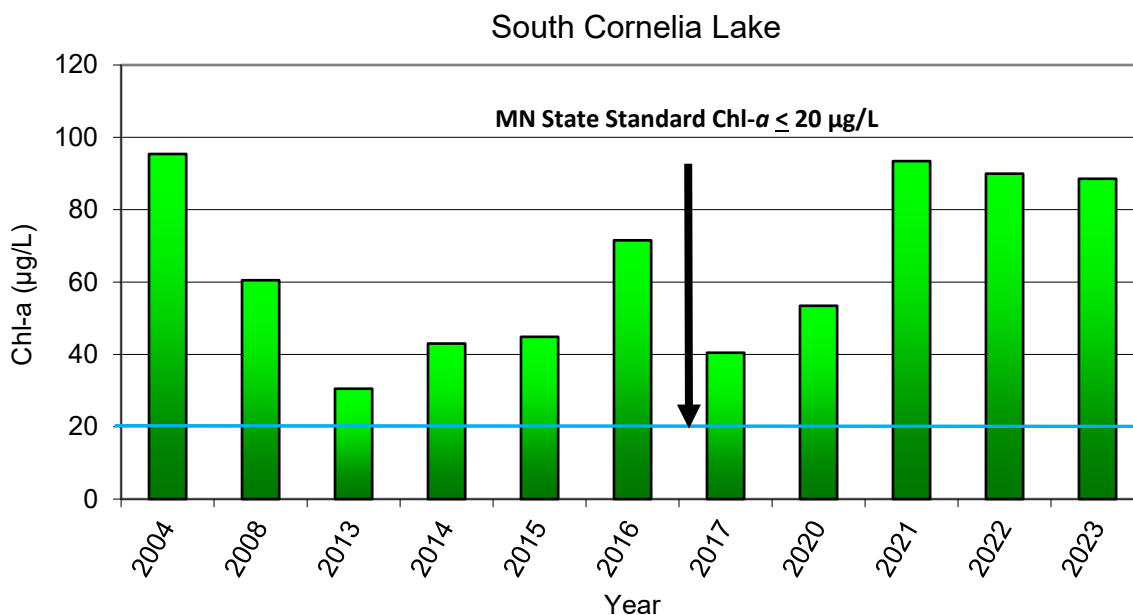
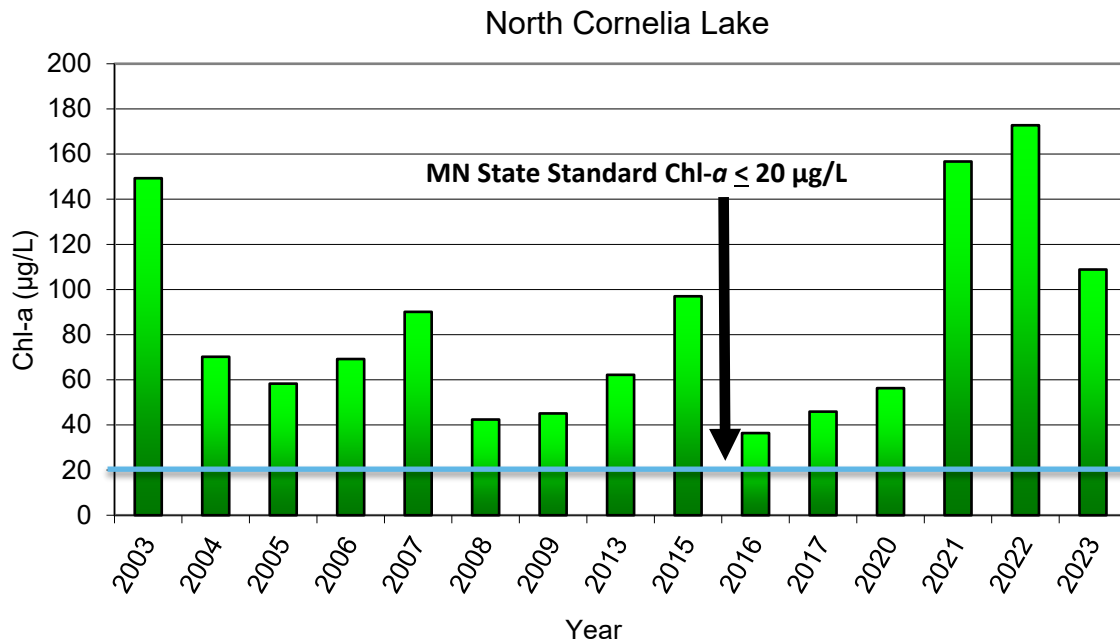


Figure 3-2 Summer average chlorophyll a concentrations in North and South Lake Cornelia

Since no meaningful management actions have been conducted in Lake Nancy, it can be assumed that the monitoring data collected in 2021 are representative of current conditions in Lake Nancy. For the April through September 2021 time period, average total phosphorus was 260 µg/L with a maximum of 390 µg/L. The pattern of change during the year is indicative of internal loading. Chlorophyll *a* concentrations during this time period averaged 95 µg/L, with a maximum of 155 µg/L.

4 Sediment Chemistry and Aluminum Treatment Outcome

In 2025, a total of 13 sediment cores were collected—five cores in North Cornelia, five cores in South Cornelia, and three cores in Lake Nancy (equally spaced across the lake). The purpose of this coring campaign was: (1) to understand the fate of the aluminum applied in 2020 (for Lake Cornelia), (2) to identify the absolute and relative concentration of phosphorus fractions in these lakes, focusing primarily on iron bound phosphorus, organically bound phosphorus, and aluminum bound phosphorus, and (3) to calculate iron, aluminum, and lanthanum-based doses for the treatment of internal loading.

4.1 Fate of Aluminum and Treatment Outcome for Lake Cornelia

Figure 4-1 shows the aluminum concentrations within the top 20 centimeters of the sediment for cores taken from North Cornelia (C1-C5) and South Cornelia (C6-C10). The results indicate that aluminum concentrations are highest in the top 0 to 4 centimeters of lake sediment, with elevated aluminum concentrations extending to 8 centimeters, compared with concentrations from deeper in the sediment (e.g., 20 centimeters). The deep sediments represent background aluminum concentrations as the aluminum from the treatment is unlikely to have mixed to this depth. The primary observation from this data is that aluminum from the 2020 alum and sodium aluminate treatment remains near the sediment-water interface and has NOT been impacted by fish activities (e.g., fish have not caused the aluminum to become buried deep into the lake sediments). Hence, the treatment is still effective and potentially actively binding phosphorus, a desirable outcome.

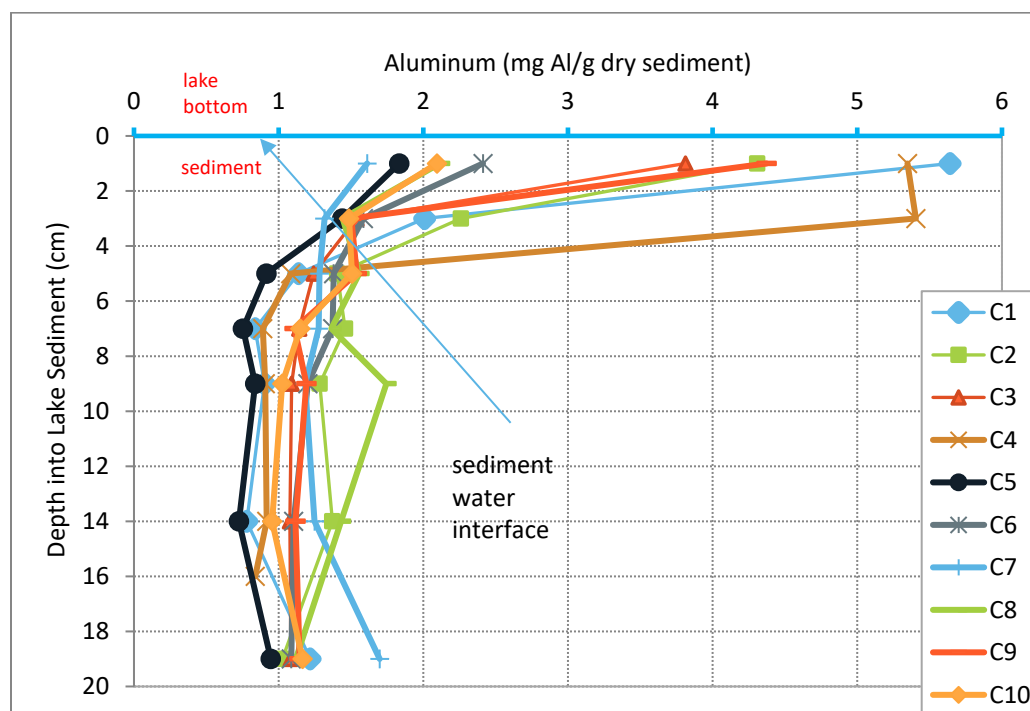


Figure 4-1 Aluminum in Lake Cornelia bottom sediments

The target of the aluminum treatment was binding of iron-bound phosphorus (Fe-P), which is a source but not the only source of internal loading, and the formation of aluminum-bound phosphorus (Al-P), which is a stable compound and is not a source of internal loading. Table 4-1 shows the concentration of Fe-P prior to treatment (2019) and after treatment (2021 and 2025). Fe-P in Lake Cornelia averaged

0.21 (mg P/g dry sediment) prior to treatment and was 0.05 in 2021 and 0.06 in 2025. The treatment reduced Fe-P by approximately 75 percent. The Fe-P concentration after treatment is below a threshold where Fe-P contributes to internal loading. However, it should be noted that there remains a significant concentration of organically bound phosphorus (Org-P) in Lake Cornelia sediments. Concentrations of Org-P were approximately 18 times greater than Fe-P in 2021 and about eight times greater in 2025. Org-P is now the primary contributor of internal loading to Lake Cornelia.

Table 4-1 Concentrations of phosphorus in Lake Cornelia sediment prior to (2019) and after (2021 and 2025) treatment

Year	Location	Average Concentration (mg P per gram dry sediment)		
		Fe-P (mg P/g dry)	Al-P (mg P/g dry)	Org-P (mg P/g dry)
2019 (before treatment)	North Cornelia	0.29	0.09	0.18
	South Cornelia	0.13	0.07	0.19
	Average	0.21	0.08	0.19
2021 (after treatment)	North Cornelia	0.05	0.11	1.04
	South Cornelia	0.04	0.06	0.77
	Average	0.05	0.09	0.91
2025 (after treatment)	North Cornelia	0.08	0.10	0.49
	South Cornelia	0.04	0.06	0.33
	Average	0.06	0.08	0.41

Based on the observed Fe-P concentrations in the sediment in 2025, a repeat treatment is not warranted at this time for the purposes of binding Fe-P. However, an additional aluminum treatment is being considered as one of the potential approaches to treat internal loading from Org-P.

4.2 Phosphorus Speciation

Figure 4-2 shows the distribution of Fe-P by depth into the lake bottom sediment in Lake Cornelia (North and South) and Lake Nancy. The concentration of Fe-P is nearly uniform from the top of the sediment layer (0 in the graph) to the bottom of the sediment layer at 20 cm. This indicates that the aluminum treatment conducted in 2020 was able to reduce Fe-P concentrations to near background. In contrast, Fe-P in Lake Nancy is elevated at the sediment-water interface (0 in the graph) and lower at depth (20 cm). This demonstrates a nice contrast between a lake that has been treated with aluminum (Cornelia—see elevated Al-P in Figure 4-3) and a lake that has not been treated with aluminum (Nancy—no elevated Al-P in the surface in Figure 4-3). Since Fe-P is elevated in Lake Nancy, this suggests that an aluminum or lanthanum treatment would be able to bind this fraction and reduce Fe-P to near background concentrations, where Fe-P would not contribute to internal loading.

While aluminum or lanthanum may be capable of binding Fe-P in Lake Nancy and reducing internal loading to some degree, the capacity of aluminum or lanthanum (discussed in more detail in Section 7) to bind Org-P, the primary driver of internal loading in both these lakes, is highly uncertain. Figure 4-4 shows that Org-P is significantly elevated in Lake Cornelia in the top 6 cm of lake bottom sediment and the top 8 cm of lake bottom sediment in Lake Nancy. Management recommendations for Lake Cornelia and Lake Nancy are largely designed to prevent the release of Org-P from lake bottom sediments.

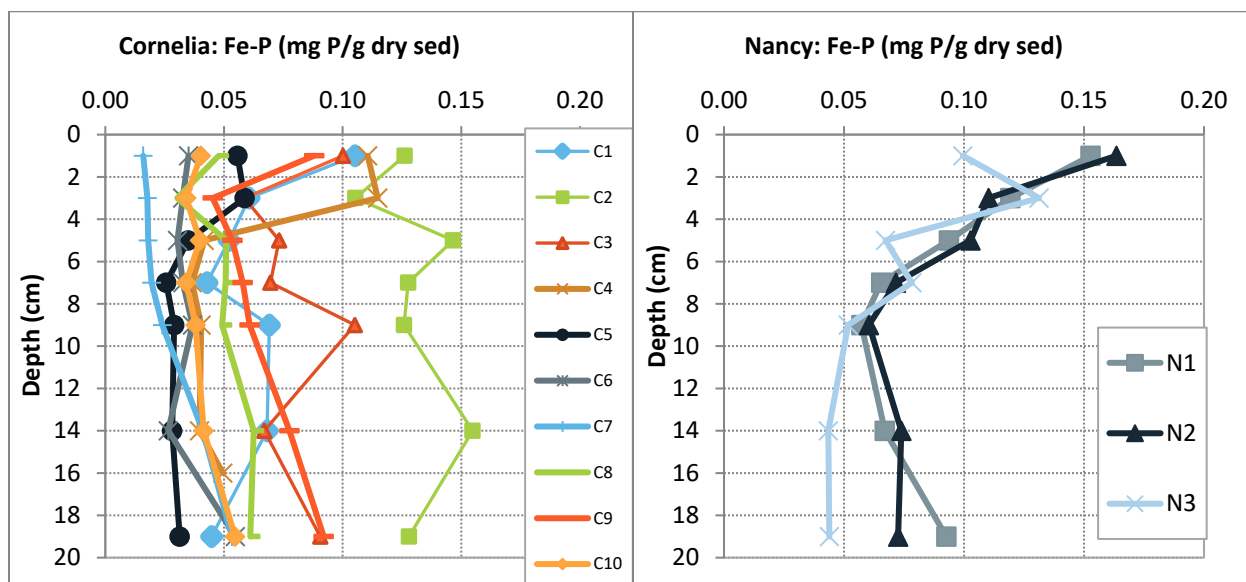


Figure 4-2 Iron-bound phosphorus in North Lake Cornelia (C1-C5), South Lake Cornelia (C6-C10), and Lake Nancy (N1-N3)

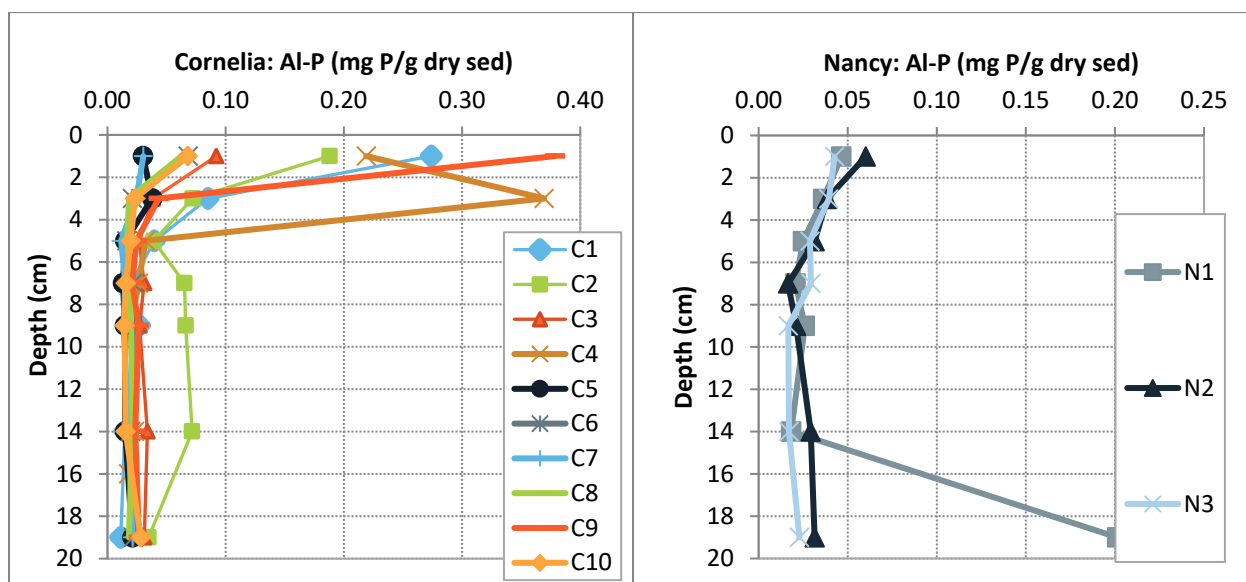


Figure 4-3 Aluminum-bound phosphorus in North Lake Cornelia (C1-C5), South Lake Cornelia (C6-C10), and Lake Nancy (N1-N3)

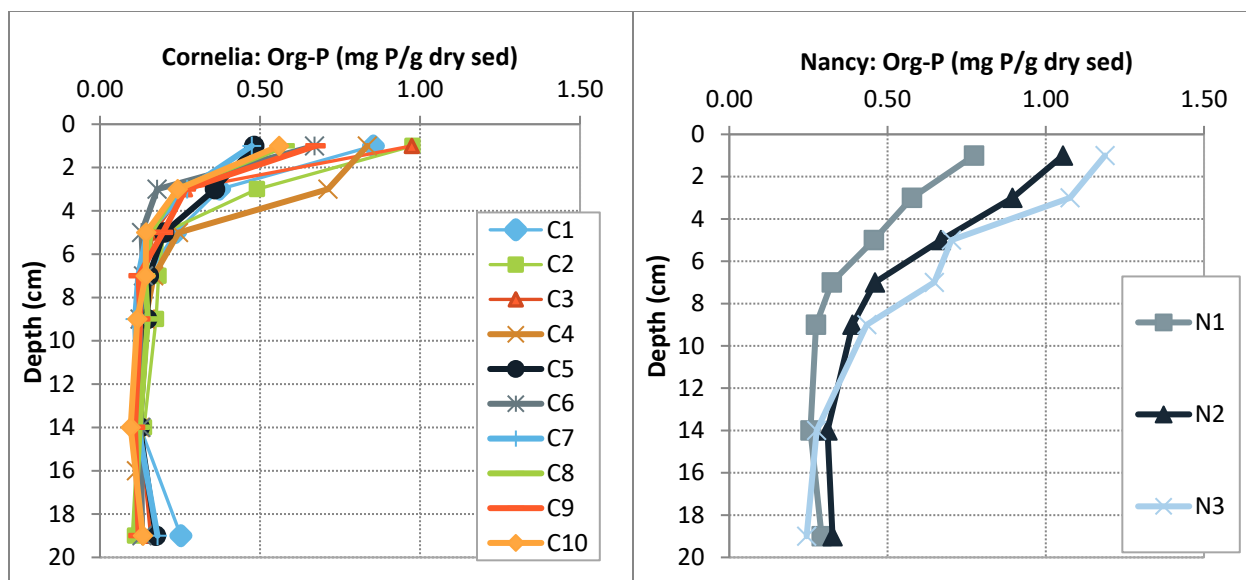


Figure 4-4 Organically bound phosphorus in North Lake Cornelia (C1-C5), South Lake Cornelia (C6-C10), and Lake Nancy (N1-N3)

5 Evaluation of Lanthanum-based Phosphorus Binding Products

Each of the phosphorus-binding elements (metals) considered as part of this feasibility study (aluminum, iron, and lanthanum) has unique chemical properties, and these properties may be beneficial depending upon the characteristics of the lake where treatment is implemented. Products that use lanthanum to bind phosphorus are being considered in this feasibility study because it is challenging to reduce internal loading when Org-P is the dominant phosphorus species in lake bottom sediment. The use of iron in concert with aeration to reduce internal loading from Org-P has been successfully applied for Arrowhead and Indianhead Lakes. Learnings from these applications are being applied to this feasibility study. For Lake Nancy, lanthanum is being considered as an option because of potential challenges with siting aeration equipment and the high Org-P concentrations in the bottom sediment. To inform the decision of whether to consider whether a lanthanum-based product may be appropriate, an extensive review of lanthanum-based treatment products was conducted, and a write-up on the findings is provided in Appendix A. A summary of this review is provided below.

Four primary factors should be considered when evaluating the use of a lanthanum-based product application for reducing internal phosphorus loading:

- Mechanism of lanthanum-phosphorus binding
- Application dose and the need for repeat treatment
- Potential for adverse effects to aquatic life
- Cost

Similar to aluminum, lanthanum binds phosphate to form a lanthanum-phosphate complex. However, since lanthanum is delivered as a clay-bound complex or as an iron-coated solid, it does not dissolve instantaneously, and hence it does not react nearly instantaneously like aluminum. According to conversations with staff from Eutrophix, a company that markets and applies a family of branded phosphorus-binding technologies, including lanthanum-based products, lanthanum-phosphorus complexes are hypothesized to develop during phosphorus release as lanthanum dissolves slowly and reacts with phosphorus in sediment porewater. If this mechanism is correct, then it is possible that lanthanum may effectively reduce internal loading from Org-P since Org-P can only be bound once it decays into phosphate. However, this mechanism of action does not appear to be documented, leading to some uncertainty about the potential effectiveness of lanthanum for Org-P treatment.

Upon review of available literature and communications with lanthanum suppliers, there is still significant uncertainty surrounding lanthanum dosing (e.g., how much lanthanum should be added to lake sediments to bind phosphorus in the sediments). Dosing recommendations of lanthanum suppliers have been based upon a ratio of one molecule of lanthanum per molecule of phosphorus in sediment (e.g., a 1:1 dosing ratio). This dosing ratio ignores: (1) spatial considerations on the need for lanthanum to come into contact with a phosphorus molecule in sediment, (2) the losses that occur when lanthanum binds organic matter and carbonate rather than phosphate, and (3) basic principles of chemical reactions such as Le Chatelier's principle (<https://www.chemguide.co.uk/physical/equilibria/lechatelier.html>).

Lanthanum advocates often suggest that lanthanum-based treatments are safer than aluminum-based treatments. This argument ignores the fact that lanthanum toxicity has been demonstrated in laboratory studies (<https://cfpub.epa.gov/ecotox>), and a comprehensive study on the ecological effects of lanthanum

in the natural environment has not been conducted. While it is possible that lanthanum may pose minimal risk to aquatic life, the lack of a comprehensive study on this subject underlies the uncertainties regarding lanthanum application.

Lanthanum is significantly more expensive per mass of metal applied when compared to aluminum and iron. Manufacturer-prescribed lanthanum doses are significantly lower compared to iron and aluminum, and hence lanthanum may appear cost-competitive on a per-lake basis. Hence, the relative cost of lanthanum compared to iron and aluminum is a function of how many repeat lanthanum treatments may be needed for lanthanum to be effective.

In conclusion, the use of lanthanum for control of internal loading from Org-P should be considered experimental, and the application of lanthanum to Lake Nancy should also be considered experimental. The benefit of a potentially successful treatment with lanthanum will be a better understanding of lanthanum as another option for controlling internal loading from Org-P in shallow lakes.

6 Dosing for Iron and Aluminum

Dosing for iron and aluminum was based upon the concentration of Org-P in lake bottom sediments collected from North and South Lake Cornelia and Lake Nancy. Doses for iron and aluminum were calculated as 20:1 ratios of metal (iron or aluminum) to Org-P ratio by mass (Table 6-1 and Table 6-2). Total dose per unit area (e.g., acre) is based upon treating the top 6 cm of lake bottom sediment.

The form of iron considered included ferric chloride or zero valent iron (ZVI) as a powder (<https://connellygpm.com/zero-valent-iron-zvi/>). If ferric chloride is used, a buffer is needed as ferric chloride is an acid (Table 6-3). The buffer considered is a calcium carbonate slurry supplied with the commercial name Calcis (<https://biosafesystems.com/product/calcis/>). Application of ZVI does not require a buffer. The prescribed buffer volume is based upon maintaining a near-neutral pH during treatment.

The aluminum treatment is a buffered application of alum and sodium aluminate with two parts alum and one part sodium aluminate by volume (Table 6-4).

Table 6-1 Prescribed iron dose for Org-P binding

Lake	Org-P	Treatment Depth (cm)	Fe: Org P Ratio	Dose
	g P / 1 cm ² m ²			Fe (g/m ²)
North Cornelia	0.45	6	20	55
South Cornelia	0.29	6	20	35
Nancy	0.49	6	20	59

Table 6-2 Prescribed mass of iron applied as zero valent iron

Lake	Treatment Area (m ²)	Dose ^[1]	Total ZVI Mass (kg)
		as ZVI (g/m ²)	
North Cornelia	69,750	57	3,979
South Cornelia	125,000	37	4,599
Nancy	14,200	62	878

[1] Iron content of ZVI: 95.7%

Table 6-3 Prescribed iron dose as liquid ferric chloride and prescribed (Calcis) buffer volume

Lake	Treatment Area (m ²)	Dose	Fe Mass (kg)	Gallons of 20% FeCl ₃	Gallons of Calcis Treatment Buffer
		Fe (g/m ²)			
North Cornelia	69,750	55	3,807	12,358	2,284
South Cornelia	125,000	35	4,401	14,284	2,641
Nancy	14,200	59	840	2,727	504
SG of 20% FeCl ₃ at 20°C	1.18				
MW of FeCl ₃	162.2				
MW Fe	55.9				
Mass (kg) of Fe in 1 L	0.081				

Table 6-4 Prescribed aluminum treatment dose as a 2-to-1 mixture of alum and sodium aluminate

Product	Treatment Ratio		Total Gallons Applied		
	Gallons Basis	Mass Basis	North Cornelia	South Cornelia	Nancy
Alum	2	0.418	14,967	17,299	3,303
Sodium Aluminate (38%)	1	0.582	7,483	24,121	1,651

7 Aeration Options Evaluation

7.1 Purpose/Role of Aeration/Oxygenation for Internal Loading

Aeration and oxygenation are evaluated in this feasibility study as a supporting management tool to address several of the root causes of poor water quality identified for North Lake Cornelia, South Lake Cornelia, and Lake Nancy. Internal phosphorus loading, periodic sediment anoxia, and unstable fish communities are key contributors to degraded conditions in these shallow lakes. Aeration and/or oxygenation are not expected to resolve internal loading on their own; rather, they are necessary to facilitate the effectiveness of other management actions when properly designed and implemented.

Aeration and oxygenation are evaluated for their potential to maintain adequate dissolved oxygen during periods of ice cover, reduce the risk of winter fish kills, and support fisheries management objectives. Prolonged winter hypoxia can hinder the survival of desirable fish species (i.e., can lead to fish kills) and destabilize fish communities, potentially favoring rough fish populations that contribute to sediment disturbance and internal phosphorus loading.

Aeration and oxygenation are also considered for their role in limiting the extent and duration of anoxic conditions at the sediment-water interface. Anoxic sediments promote phosphorus release from both iron-associated phosphorus and the decomposition of organic matter. Results of the sediment chemistry analysis indicate that organically bound phosphorus is a dominant contributor to internal loading, particularly in Lake Cornelia following the 2020 alum treatment. By reducing sediment anoxia during critical winter and late-summer periods, aeration may help limit phosphorus release to the water column.

In addition, aeration and oxygenation may support the effectiveness and longevity of sediment phosphorus inactivation treatments. Iron-based treatments require aerobic conditions to remain effective, while aluminum- and lanthanum-based treatments are less sensitive to redox conditions but may still benefit from reduced sediment anoxia. In this context, aeration is considered an enabling or complementary management action rather than a standalone solution for internal phosphorus control.

7.2 Design Considerations

Selection and sizing of aeration or oxygenation systems for North Lake Cornelia, South Lake Cornelia, and Lake Nancy is strongly influenced by lake-specific physical, operational, and use constraints. All three lakes are very shallow, with average depths of 3 to 4 feet, which limits the effectiveness of many conventional aeration approaches and increases the potential rapid oxygen loss to the atmosphere. In addition, sediment oxygen demand is high relative to lake volume in shallow lakes. Data suggests this is particularly true in South Lake Cornelia, requiring systems that can deliver oxygen efficiently and consistently during periods of peak oxygen demand.

Winter lake use represents a key design constraint, especially for South Cornelia and Lake Nancy, where ice skating and hockey activities preclude the use of open-water bubbling or plume-based aeration beneath the ice. In contrast, North Cornelia has fewer winter recreation constraints, allowing for greater flexibility in aeration approaches. Lake Nancy presents similar depth and water quality challenges as South Cornelia but with fewer fisheries considerations.

Infrastructure and siting constraints also influence feasibility. Shoreline space is limited for Lake Nancy, and any onshore equipment may require enclosures that meet local construction and aesthetic requirements. Power availability varies by site and is limited to single-phase power at Lake Nancy and

South Cornelia. While three-phase power is available at Rosland Park, a specific connection would be necessary to power an aeration or oxygenation system.

Given these constraints, no single aeration approach is expected to perform equally well across all three lakes or during all seasons. The technologies evaluated in this study have different benefits and tradeoffs among oxygen delivery, infrastructure and power requirements, operational flexibility, and compatibility with sediment phosphorus inactivation strategies.

7.3 Aeration/Oxygenation Design Criteria

Aeration and oxygenation technologies were evaluated using a set of functional design criteria intended to reflect how each system would perform under the physical and operational conditions present in each lake. The evaluation emphasizes how oxygen is delivered, how reliably it can be maintained near the sediment-water interface, and how system operation aligns with seasonal management needs.

A primary criterion is the ability to limit prolonged anoxia at the sediment-water interface. Anoxic conditions promote internal phosphorus loading through both iron reduction and organic matter decomposition. Systems that provide sustained oxygen availability near sediments were therefore viewed as more effective for supporting internal loading control objectives.

Winter operability is another key consideration. Technologies were evaluated based on their ability to function during ice cover without creating unsafe ice conditions, particularly in South Cornelia, where winter recreation limits the use of open-water aeration. Systems capable of delivering oxygen under ice with minimal surface disturbance were favored for winter operation.

Dissolved oxygen performance was evaluated in two contexts: (1) maintaining oxygen levels sufficient to support aquatic life in the bulk water column and (2) providing higher oxygen concentrations at the sediment surface to suppress phosphorus release. While site-specific targets vary, systems able to sustain oxic sediment conditions were considered better aligned with management goals.

Finally, system capacity was evaluated relative to the estimated sediment oxygen demand for each lake. Given the high sediment oxygen demand relative to lake volume, particularly in South Cornelia, system sizing and oxygen delivery rates were compared to demand estimates to assess whether each technology could meaningfully influence sediment redox conditions over time.

Based on these criteria, three general aeration and oxygenation approaches were evaluated: traditional diffused-air aeration, nanobubble oxygenation, and side-stream oxygenation. These technologies differ in oxygen delivery efficiency, operational flexibility, infrastructure requirements, and seasonal applicability, as described in the following sections. Vendors for each of these technologies were contacted to assist with preliminary sizing of each system.

7.3.1 Traditional Aeration Systems (Diffused Air)

Traditional diffused-air aeration systems introduce atmospheric air into the lake through submerged diffusers supplied by onshore compressors. Rising air bubbles to a limited degree transfer oxygen to the water, but the primary function is to induce mixing within the water column and enhance the transfer of oxygen between the atmosphere and the lake surface. These systems are commonly used in shallow lakes to increase dissolved oxygen concentrations and reduce the risk of fish kills.

For this feasibility study, commercially available traditional diffused aeration systems evaluated and sized for comparison included systems manufactured by Kasco and Hydro Logic. The Kasco system represents a conventional distributed diffuser approach, while the Hydro Logic system represents a diffused aeration design intended to increase mixing efficiency per diffuser. Together, these systems represent widely used variations of traditional diffused-air aeration technology.



Figure 7-1 **Typical aeration enclosure for diffused-air aeration**

Traditional aeration systems offer relatively low capital and operating costs and rely on well-established equipment with straightforward installation and maintenance. However, traditional diffused-air systems are often incapable of keeping up with the increased sediment demands prevalent during mid to late summer. In the summer and with warm water, oxygen solubility declines, and oxygen transfer from the atmosphere is also reduced, thereby inhibiting the maintenance of oxic conditions at the sediment-water interface.



Figure 7-2 Aeration compressors for diffused-air aeration

In addition, traditional aeration induces active mixing of the water column. In lakes with organic-rich sediments, this mixing can increase sediment disturbance and nutrient release rather than reduce internal loading. However, the area impacted by small diffusers relative to the larger surface water area may not present a great risk of resuspension. Winter operation is also constrained, as rising air plumes can weaken ice cover and conflict with winter recreation, of particular concern in South Lake Cornelia and Lake Nancy.

Overall, traditional diffused-air aeration systems are considered cost-effective and necessary options for improving bulk water column oxygenation and supporting fisheries in settings without winter use constraints. Although there are limits to the amount of oxygen that can be delivered with these systems, they have been generally effective in Arrowhead Lake, Indianhead Lake, and Lake Holiday. However, the degree of oxygen transfer provided by diffused-air systems may not be enough to limit internal loading to the extent needed to significantly reduce algal blooms. This limitation warranted the consideration of pure oxygen-based aeration alternatives. These alternatives are evaluated in subsequent sections.

7.3.2 Moleaer Nanobubbles

Nanobubble oxygenation systems deliver oxygen to water through the generation of extremely small gas bubbles, typically less than one micron in diameter. Unlike conventional aeration, nanobubbles do not rise rapidly through the water column and therefore do not create visible bubbles or induce large-scale mixing.

Due to their small size and long residence time, the manufacturers of nanobubbles equipment claim that nanobubbles are able to dissolve oxygen into the water and increase dissolved oxygen concentrations near the sediment-water interface without disrupting lake stratification or ice cover.

A primary advantage of nanobubble technology is higher oxygen transfer efficiency relative to traditional diffused-air aeration. Because oxygen is delivered without buoyant bubble plumes, nanobubble systems can operate under ice and can target oxygen delivery to sediments. These characteristics make nanobubble oxygenation conceptually well-suited for shallow lakes with high sediment oxygen demand and winter operational constraints.

For this feasibility study, nanobubble oxygenation was evaluated based on information provided by Moleaer, a commercial vendor of lake-scale nanobubble systems. Moleaer systems are typically shore-mounted, with oxygen delivered through near-shore intake and discharge piping rather than in-lake diffusers. System sizing is based on sediment oxygen demand and project-specific treatment goals rather than lake surface area or diffuser spacing. Preliminary sizing provided for North and South Lake Cornelia indicates that nanobubble systems could deliver substantially more oxygen per hour than traditional diffused aeration approaches. Given site constraints, including available power and limited open area for equipment staging/siting, nanobubble systems were not evaluated for Lake Nancy.

Despite these potential advantages of nanobubble oxygenation, several uncertainties and limitations were identified. Capital, power, and annual service costs associated with nanobubble systems are significantly higher than those of traditional diffused aeration systems. The systems require reliable power, often three-phase, or the use of phase conversion equipment where only single-phase service is available. Ongoing maintenance includes mechanical and electrical components as well as annual service contracts, contributing to higher long-term operating costs.

In addition, potential interactions between nanobubble oxygenation and organically rich sediments warrant consideration. Increasing oxygen availability may accelerate organic matter mineralization, which could temporarily increase the release of bioavailable phosphorus (and copper, which has been accumulating in the Lake Cornelia sediments) to the water column if not managed in combination with effective sediment phosphorus inactivation (e.g., iron). Regulatory considerations also apply, as nanobubble systems currently require permitting and monitoring oversight by the Minnesota Department of Natural Resources (MNDNR). There appears to be limited published research on the potential adverse effects of nanobubbles, and this consideration is particularly important since nanobubbles are composed of ozone, which is a highly reactive molecule. Some studies suggest that there are thresholds of nanobubble aeration rates that can impact aquatic plants when exceeded (Shu, 2021). Other studies have been largely focused on the effect of nanobubbles on bacteria or phytoplankton, but effects on zooplankton, aquatic insects, and fish do not appear to have been evaluated.

Nanobubble oxygenation systems also require substantial onshore and nearshore infrastructure. Systems of the size evaluated for this study are typically housed in large trailers or standard 20-foot shipping containers equipped with power distribution, pumps, compressors, and control equipment. Higher-capacity systems may require multiple containers to house separate hydraulic and gas components. Intake and discharge piping is routed from the container or trailer to the lake and may be mounted along docks, shorelines, or temporary structures extending into the lake.



Figure 7-3 Moleaer nanobubble feed pipes



Figure 7-4 Moleaer nanobubble on-shore units

As a result, nanobubble systems are visually prominent compared to traditional diffused aeration systems, which rely primarily on small on-shore enclosures and submerged equipment. Containers or trailers placed near the shoreline represent a noticeable and permanent presence that may affect aesthetics, shoreline use, and public perception, particularly in urban park settings such as Lake Cornelia. In some configurations, barge-mounted systems or dock-mounted intake and discharge structures are required, further increasing surface visibility. These siting and aesthetic considerations are important factors in assessing overall feasibility in addition to system performance and cost.

Overall, nanobubble oxygenation represents a higher-cost, higher-complexity approach that offers greater oxygen delivery efficiency and winter operability than traditional diffused-air aeration systems. While nanobubble technology may be capable of meeting sediment oxygen demand in these lakes, uncertainties related to cost, power requirements, sediment response, adverse ecological effects, and regulatory review reduce confidence relative to more established oxygen delivery methods. As such, nanobubble systems are considered a potentially effective but higher-risk option for providing aeration/oxygenation to support the effectiveness of internal loading management.

7.3.3 Oxygen Saturation Technology (side-stream oxygenation)

Oxygen Saturation Technology (OST), a type of side-stream oxygenation, supplies oxygen to the lake by directing pure oxygen to a chamber located on the lake bottom, where water and oxygen are mixed and then released along the lake bottom ([Clarity RG Services - OST](#)). Oxygen is generated using an on-site

generator that filters oxygen into a pure oxygen stream. Because oxygen is dissolved in a chamber under water, OST does not induce mixing of the water column in the summer and winter.



Figure 7-5 OST system on shore prior to deployment

A key advantage of side-stream oxygenation is its high oxygen delivery efficiency directly to the lake bottom and maintenance of oxic conditions near the sediment-water interface while preserving existing thermal structure. This approach is well-suited for shallow lakes with high sediment oxygen demand and objectives focused on preventing fish kills under the ice and maintenance of oxygen high enough to reduce internal loading during the winter months. For South Lake Cornelia, the primary goal of this system would be to prevent fish kills, while the secondary goal would be to oxidize iron in lake bottom sediments and reduce internal loading.

OST systems are well-suited for winter operation. Because no air plumes are created, oxygen can be supplied under ice without forming open water or weakening ice cover. This is particularly important for South Lake Cornelia, where winter skating and hockey activities preclude traditional bubble aeration during ice cover.

Implementation considerations include the need for onshore infrastructure such as compressors, oxygen generators, and control systems. These components typically require a small enclosure (approximately 8 feet x 6 feet) and a reliable power supply. Similar to diffused-air systems, regular maintenance of mechanical and filtration elements is needed.

Overall, OST provides a targeted and controllable method of oxygen delivery that aligns well with sediment phosphorus inactivation strategies, particularly iron-based treatments. While more complex and costly than traditional aeration, OST offers greater certainty in oxygen delivery and winter operability than diffused-air systems, with lower visibility and infrastructure demands than nanobubble systems.

7.4 Comparison and Evaluation

Aeration and oxygenation options were compared using a consistent, design-focused framework that links system configuration to expected performance and implementation needs. For each lake, systems were conceptually sized relative to estimated sediment oxygen demand to evaluate whether the approach could effectively increase dissolved oxygen conditions near the sediment-water interface. The comparison emphasizes how each system is built and operated (diffuser grids versus intake/discharge systems, degree of mixing, winter operability), along with practical implementation factors such as power needs, infrastructure footprint and visibility, maintenance requirements, and regulatory considerations. Lake-specific sizing and cost estimates are summarized in Table 7-1 through Table 7-4, and the conceptual system designs are described below.

Note that the linear diffused aeration system (e.g., destratification system) is similar to the aeration disk system except that it is a continuous aeration line that covers a stretch of lake bottom. This system has fewer feeder tubes and is less complicated than a system where each diffuser head requires a separate tube. The disk system is needed in North Cornelia since this system can keep a small area of lake surface open during the winter.

Table 7-1 Aeration and oxygenation design summary for aeration options considered

Design Criteria	Hydro Logic (aeration disk type diffused air)	Moleaer (nanobubbles)	Combined System	
			Destratification System (linear diffused-air system)	OST (oxygenation)
Setup	Onshore compressors + lake bottom diffuser grid (fewer diffusers, higher flow per diffuser)	Shore-based pumping/oxygenation; intake and discharge piping; nanobubble generation in container	Onshore compressors + lake bottom diffuser lines	Onshore oxygen generator and compressors, in-lake mixing chamber
In-Lake Components	Multiple bottom diffusers + weighted air lines	Screened intake and discharge lines (no diffuser grid)	Approximately four diffuser lines + weighted air lines	Approximately four OST systems in-lake + weighted lines for oxygen
Onshore components	Compressor cabinet(s), manifold, electrical service, enclosure/shed	20-ft container(s) or large trailer; pumps, compressors, controls; HVAC/lighting	Oxygen generator, compressor, manifold, electrical service, enclosure/shed	Oxygen generator, compressor, manifold, electrical service, enclosure/shed
Visibility	Low in-lake; small onshore presence	High shoreline presence; containerized equipment and visible piping	Low in-lake; small onshore presence	Moderate; small shed or enclosure needed
Mixing Impact	High (bubble plume mixing)	Low to moderate (oxygenation with minimal buoyant lift)	High (bubble plume mixing)	Low (oxygenation without bubble plume)
Winter Compatibility	Effective for maintenance of ice-free conditions, limited where ice recreation occurs	Compatible under ice	Not as effective at maintaining ice-free conditions. Limited where ice recreation occurs	Compatible under ice

Design Criteria	Hydro Logic (aeration disk type diffused air)	Moleaer (nanobubbles)	Combined System	
			Destratification System (linear diffused-air system)	OST (oxygenation)
Primary design basis used	Diffuser count/airflow per diffuser	Oxygen mass delivery (lb/hr) + flow (gpm)	Mixing frequency (full lake mixing per day)	Oxygen mass delivery (kg/day) + targeted circulation
Permitting	None for open water, DNR permit for winter	DNR permitting required	None for open water, DNR permit for winter	Assumed DNR permitting required
Design Tradeoffs	Lower diffuser count, but still mixing-driven	Highest oxygen delivery, but largest footprint/cost/O&M	Cannot be used to create small ice-free area on a lake	Targeted oxygen delivery with moderate footprint and O&M

Table 7-2 North Cornelia aeration system sizing by aeration option

Selected Sizing	Hydro Logic (diffused air)	Moleaer (nanobubbles)	OST+DAM
System	AirLift HF8 (x2)	L2	2 X S-8 OST units, and diffused air mixing (DAM)
Compressors	1 (1 HP) per system (x2)	integrated in containerized system	5 Hp
Total oxygen flow (lb/hr)	0.3–0.6	up to 25	2.25 lbs/hr as dissolved oxygen
Total airflow (CFM)	15 CFM per system (x2) = 30	not applicable	8 SCFM-DAM / N/A- OST
Airflow per compressor (CFM)	7.5	not applicable	NA
Number of diffusers	12	none (intake/discharge only)	1 OST units (1 middle of lake) & 2 DAM (250 ft long, 1 east, 1 west)
Airflow per diffuser (CFM)	2-2.5	not applicable	4 for the DAM, N/A for OST
Air flow per acre (CFM/ac)	1.6-2	not applicable	NA
Diameter covered per diffuser (ft)	300–400	not applicable	NA
Acre covered per diffuser (ac)	1.0–1.3	not applicable	NA
Power source	240 V (8.2 A) (x2)	3-phase 480 V	240 V (8.2 A) (x2) and 240 VAC (~32 A total)
Future expansion diffusers	4	not applicable	none
Installation cost	\$108,000	\$724,000	\$290,000
Annual electricity cost	\$2,500–\$3,000	\$10,000	\$4,300
Annual maintenance	\$3,500	\$20,000	\$7,000

Table 7-3 South Cornelia aeration system sizing by aeration option

Selected Sizing	Hydro Logic (diffused air)	OST + Diffused Air Mixing (DAM)	Moleaer (nanobubbles)
System	AirLift HF10 (x2)	2 X S-8 OST units, and diffused air mixing (DAM)	L4
Compressors	1 (1 HP) per system (x2)	5 Hp	integrated in containerized system
Total oxygen flow (lb/hr)	0.3–0.6 lbs/hr delivery	4.5 lbs/hr as dissolved oxygen	5 to 10 lbs/hr as oxygen dissolution (estimated from 50 lbs/hr delivery and 5-10% dissolution)
Total airflow (CFM)	15 CFM per system (x2) = 30	8 SCFM-DAM / N/A-OST	not applicable
Airflow per compressor (CFM)	7.5	NA	not applicable
Number of units or diffusers	16	2 OST units (1 east, 1 west location) & 2 DAM (250 ft long, 1 east, 1 west)	none (intake/discharge only)
Airflow per diffuser (CFM)	1.6-1.8	4 for the DAM, N/A for OST	not applicable
Air flow per acre (CFM/ac)	0.8-0.9	NA	not applicable
Diameter covered per diffuser (ft)	350-450	NA	not applicable
Acre covered per diffuser (ac)	1.5-2	NA	not applicable
Power source	240 V (8.2 A) (x2)	240 V (8.2 A) (x2) and 240 VAC (~32 A total)	3-phase 480 V
Future expansion diffusers	4	none	not applicable
Installation cost	\$173,000	\$359,000	\$1,118,000
Annual electricity cost	\$2,500–\$3,000	\$4,350	\$10,000
Annual maintenance	\$3,500	\$7,000	\$20,000

Table 7-4 Lake Nancy aeration system sizing by aeration option

Selected Sizing	Hydro Logic (diffused air)	Moleaer (nanobubbles)
System	AirLift HF 8	L2
Compressors	2-1HP	integrated in containerized system
Total Oxygen Flow (lbs/hour)	0.2-0.5	up to 25
Total Airflow (CFM)	15 CFM	NA
Airflow per compressor (CFM)	6.5 CFM	NA
Number of diffusers	6	none (intake/discharge only)
Airflow per diffuser (CFM)	1.3-1.5	NA
Air flow per acre (CFM)	1.8	NA
Diameter covered per diffuser (ft)	200-250	NA
Acre covered per diffuser (ac)	0.8-1	NA
Power Source	240 V (8.2 Amp)	3-phase 480 V
Future expansion diffusers	2	not applicable
Installation Cost	\$85,000	\$751,000
Annual electricity cost	\$1,200-\$1,500	\$10,000
Annual Maintenance	\$3,500	\$20,000

7.5 Integration with Sediment Phosphorus Inactivation

Aeration and oxygenation were evaluated based upon the water quality objectives and recreational limitations (e.g., winter recreation) of the study lakes. Aeration is considered a complementary action and is being considered to both enhance sediment treatment effectiveness and improve fisheries.

OST provides targeted oxygen delivery to low-oxygen bottom waters with minimal sediment disturbance and reliable winter operation. This makes it well-suited to supporting iron-based phosphorus inactivation, which requires aerobic conditions to remain effective. The primary tradeoffs are greater system complexity, onshore infrastructure, and maintenance requirements compared to traditional diffused-air aeration.

Nanobubble oxygenation can deliver large amounts of oxygen without inducing significant mixing and can operate under ice, offering potential support for iron-based treatments. However, increased oxygen availability in organic-rich sediments may accelerate mineralization and release of bioavailable phosphorus if sediment binding capacity is insufficient. Higher capital cost, power demand, highly visible shoreline infrastructure that has poor aesthetics, and regulatory oversight are additional considerations.

Traditional diffused-air aeration has the capacity to increase dissolved oxygen concentrations in the winter and summer months. This has been demonstrated by the systems installed in Lake Holiday, Indianhead Lake, and Arrowhead Lake. However, it has been observed that aeration provided by these systems does not keep up with sediment oxygen demand in the late summer. Hence, operation of these systems in the winter is recommended when feasible to oxidize the sediments during the winter in preparation for high sediment oxygen demand in the summer.

Aluminum- and lanthanum-based phosphorus inactivation are less sensitive to sediment redox conditions and do not require aeration to remain effective. In these cases, aeration primarily serves supplemental roles such as reducing oxygen stress for fish and supporting aquatic life rather than directly influencing treatment performance.

These tradeoffs highlight the need to consider aeration and sediment phosphorus inactivation together, with system selection guided by treatment type, seasonal objectives, lake use constraints, and desired levels of sediment oxygen control.

8 Engineer's Opinion of Probable Costs

8.1 Basis of Cost Estimates

This section presents the planning-level engineer's opinions of probable cost (OPC) for management options evaluated to reduce internal phosphorus loading in Lake Cornelia and Lake Nancy. The purpose of these estimates is to support comparative evaluation of treatment strategies and to inform selection and phasing of potential implementation actions. The estimates are not intended to represent final design or bid-ready construction costs.

Cost estimates were developed at a feasibility-study level using conceptual system layouts, preliminary sizing calculations, vendor budgetary information, and past construction costs for similar projects. Given the conceptual level of evaluation and uncertainties associated with treatment performance, system configuration, and operational requirements, the estimated costs are expected to have an accuracy range on the order of ± 20 to ± 30 percent (Class 5 OPC).

Costs presented herein are intended to be used on a relative basis to compare management alternatives. Management activities currently being implemented, completed, or evaluated under separate efforts are not included in the cost estimates unless explicitly noted.

8.2 Cost Evaluation Matrix and Management Scenarios

To support comparative evaluation of internal phosphorus loading management alternatives, a matrix of sediment phosphorus inactivation scenarios was developed for Lake Nancy, North Lake Cornelia, and South Lake Cornelia. The matrix reflects combinations of phosphorus binding treatments and seasonal aeration or oxygenation strategies that are feasible given lake-specific conditions and management objectives identified in this study.

Each scenario evaluated consists of a defined configuration of treatment elements grouped into the following categories:

- **Sediment Org-P binding**
 - Aluminum
 - Lanthanum-based products
 - Ferric iron-based treatments
 - Zero valent iron
- **Winter aeration or oxygenation**
 - None (due to winter ice conflicts)
 - Diffused air
 - Oxygen Saturation Technology
 - Nanobubble oxygenation
- **Summer aeration or oxygenation**
 - None (not needed for binding effectiveness)
 - Diffused air
 - Oxygen Saturation Technology

Aeration and oxygenation are evaluated as supporting or enabling measures rather than as primary phosphorus removal actions. Sediment phosphorus binding treatments are assumed to provide most of the long-term phosphorus reduction, while oxygen management influences treatment effectiveness and longevity.

Not all aeration or oxygenation approaches were considered practical for all lakes or seasons. Scenario selection reflects lake-specific constraints related to water depth, winter recreational use, available electrical service, shoreline infrastructure, and aesthetics. As a result, the matrix includes both constrained configurations representing practical implementation limits and higher-intensity configurations representing maximum feasible oxygen delivery.

Tables 8-1, 8-2, and 8-3 summarize costs for evaluated combinations of sediment treatment and aeration or oxygenation options for Lake Nancy, North Lake Cornelia, and South Lake Cornelia, respectively. For each scenario included in the matrix, capital costs and annual operation and maintenance (O&M) costs were developed using a consistent methodology. Capital cost estimates were based on conceptual system sizing, sediment chemistry-based material quantities, preliminary vendor pricing for aeration and oxygenation systems, and typical allowances for installation and supporting infrastructure. For each aeration or oxygenation system, a detailed Engineer's Opinion of Probable Cost was developed (Appendix B). Annual O&M costs include estimated electrical power consumption, routine maintenance, vendor service agreements, and periodic material reapplication where applicable. For the treatment options including ferric chloride or zero valent iron, it was assumed that summer aeration or oxygenation is required to provide oxic conditions for maximum sediment phosphorus binding efficiency.

Table 8-1 Comparative evaluation of cost for internal load inactivation approaches for Lake Nancy

Option	Description	P-Binding Element	Aeration Method		Costs			
			Winter	Summer	P-Binding Element Application	Aeration Capital Cost	Total Capital Cost	Annual O&M - Aeration
N-1	Aluminum Treatment Only	Aluminum-Alum and Sodium Aluminate	none	none	\$57,000	\$0	\$57,000	\$0
N-2	Lanthanum Treatment Only	Lanthanum-Eutrosorb or Phoslock	none	none	\$90,000 ^[1]	\$0	\$90,000	\$0
N-3	Iron + Aeration	Iron-Ferric chloride + buffer	none	Diffused Air	\$47,000	\$85,000	\$132,000	\$5,000
N-4	Iron + Aeration	Iron-ZVI	none	Diffused Air	\$14,000	\$85,000	\$99,000	\$5,000
N-5	Iron + Aeration	Iron-Ferric chloride + buffer	Nanobubbles	Nanobubbles	\$47,000	\$751,000	\$798,000	\$30,000
N-6	Iron + Aeration	Iron-ZVI	Nanobubbles	Nanobubbles	\$14,000	\$751,000	\$765,000	\$30,000

[1] Assumed 3 total treatments

Table 8-2 Comparative evaluation of cost for internal load inactivation approaches for North Lake Cornelia

Option	Description	P-Binding Element	Aeration Method		Costs			
			Winter	Summer	P-Binding Element Application	Aeration Capital Cost	Total Capital Cost	Annual O&M - Aeration
NC-1	Aluminum Treatment Only	Aluminum	None	None	\$243,000	\$0	\$243,000	\$0
NC-2	Iron and Diffused Air	Iron-ZVI	None	Diffused Air	\$81,000	\$108,000	\$189,000	\$6,500
NC-3	Iron and Aeration	Iron-ZVI	OST	Diffused Air	\$81,000	\$290,000	\$371,000	\$11,350
NC-4	Iron and Nanobubbles	Iron-ZVI	Nanobubbles	Nanobubbles	\$81,000	\$724,000	\$805,000	\$30,000

Table 8-3 Comparative evaluation of cost for internal loading inactivation approaches for South Lake Cornelia

Option	Description	P-Binding Element	Aeration Method		Costs			
			Winter	Summer	P-Binding Element Application	Aeration Capital Cost	Total Capital Cost	Annual O&M - Aeration
SC-1	Aluminum Treatment Only	Aluminum-Alum and Sodium Aluminate	None	None	\$281,000	\$0	\$281,000	\$0
SC-2	Iron + Aeration	Iron-Ferric chloride + buffer	None	Diffused Air	\$283,000	\$173,000	\$456,000	\$6,500
SC-3	Iron + Aeration	Iron (Zero Valent Iron)	None	Diffused Air	\$83,000	\$173,000	\$256,000	\$6,500
SC-4	Iron + Aeration	Iron (Zero Valent Iron)	OST	OST + Diffused Air	\$83,000	\$359,000	\$442,000	\$11,350

9 Recommendations and Discussion

High internal phosphorus loading and low dissolved oxygen in the summer and winter contribute to poor water quality and degraded ecology in Lake Nancy, North Lake Cornelia, and South Lake Cornelia. A significant challenge for these lakes includes the type of phosphorus in the lake bottom sediments, primarily organically bound phosphorus—Org P, which presents a significant challenge for managing these lakes as it is difficult to treat by conventional means (e.g., aluminum treatment). Another challenge is the limitation on the type of aeration that can be applied because of the desire to maintain safe winter recreation conditions.

This diagnostic feasibility study evaluated several methods to manage internal phosphorus loading in Lake Nancy, North Lake Cornelia, and South Lake Cornelia. The technical analysis included a review of multiple sediment treatment techniques based on past knowledge of Lake Cornelia and Lake Nancy, results of the sediment chemistry lab analysis, knowledge gained from other recent NMCWD sediment treatments, application techniques, and site considerations. The technical analysis also included evaluation of aeration options to increase the effectiveness of the potential sediment treatments and to support the NMCWD's desire to maintain a native fishery.

The recommended techniques for managing internal phosphorus loading in North Lake Cornelia, South Lake Cornelia, and Lake Nancy are summarized in Table 9-1. The management recommendations were developed with consideration of effectiveness, cost, space requirements, visual impacts to public space, and maintaining winter recreation opportunities in South Cornelia and Lake Nancy.

Table 9-1 Recommended treatment approaches, construction costs, O & M, costs per pound P removed

Lake	P-Binding Metal	Metal Form	Aeration System	Total Cost	Annual O&M
North Cornelia	Iron	ZVI	Diffused Air	\$189,000	\$6,500
South Cornelia	Iron	ZVI	OST + Destratification Diffused Air	\$442,000	\$11,350
Nancy	Lanthanum	Clay bound or iron coated solid lanthanum	None	\$90,000 ^[1]	0
Nancy (alternative)	Iron	ZVI	Diffused Air	\$99,000	\$5,000

[1] Assumes a total of three treatments.

Iron treatment and aeration are recommended for North Lake Cornelia and South Lake Cornelia. The goal of the iron treatments is to convert Org-P to iron-bound phosphorus (Fe-P). The aeration system is intended to keep Fe-P oxidized to prevent release of phosphorus (internal loading). Ultimately and several years after treatment, an aluminum treatment should be conducted to convert accumulated Fe-P to aluminum-bound P to permanently lock up the phosphorus in the stable aluminum-bound phosphorus compound. The timing of a follow-up aluminum treatment should be determined based on periodic sediment monitoring.

The recommended treatments build on the learnings from the 2024 aluminum and iron treatments and installation of diffused-air aeration systems at Indianhead Lake and Arrowhead Lake in Edina. Monitoring data indicate that the treatments combined with aeration were effective at controlling internal phosphorus loading but the aeration systems may be undersized to fully meet the sediment oxygen demand. Data suggest that winter aeration improves the effectiveness of the iron treatment.

For South Lake Cornelia, installation of an OST aeration system is recommended, a relatively new type of aeration system that will keep oxygen elevated to minimize or prevent fish kills without significantly impacting ice formation or thickness during the winter. To keep oxygen elevated in the summer in South Lake Cornelia, a diffused-air destratification system is also recommended for summer aeration.

For North Lake Cornelia, iron treatment in conjunction with a diffused-air aeration system is recommended. The diffused-air system is recommended for North Lake Cornelia instead of an OST system, as maintaining winter recreation is not a goal for this lake. Utilizing a diffused-air system provides cost savings while still minimizing risks of winter fish kills and keeping iron in the sediments oxygenated.

For the iron treatments, application of ZVI as the iron media is recommended as a pilot. Ferric chloride and buffering chemicals are significantly more expensive than ZVI. In addition, the challenges of applying ferric chloride, a strong acidic compound, make it difficult to find interested chemical applicators. ZVI can be applied as a fine-grained solid substance on the ice during the winter using a broadcast spreader. Upon ice melt, the material will sink into the sediments.

Lanthanum treatment is recommended for Lake Nancy, with an alternative to lanthanum being diffused-air aeration and iron application. Treatment with lanthanum is considered experimental but is recommended to determine if it has the capacity to control internal loading from Org-P. Determination of the usefulness of lanthanum for control of Org-P-based internal loading in shallow lakes may help to inform appropriate treatments for other shallow lakes in the Nine Mile Creek watershed and broader lake management community. For example, the use of lanthanum may have benefits for shallow lakes when the installation of aeration is not feasible. Treatment with iron and aeration can also be considered if experimentation with lanthanum is not desired. The primary challenge with iron and aeration treatment in Lake Nancy is that winter recreation on Lake Nancy prevents winter aeration. Winter aeration is expected to significantly improve the effectiveness of an iron treatment.

Because there has been significant interest in nanobubble technology, we also evaluated this aeration technology for Lake Cornelia and Lake Nancy. There are several factors that make nanobubbles undesirable for Lake Cornelia and Lake Nancy, including significant cost, high space requirements, undesirable visuals for a highly-used public park space, and unknown potential ecological effects. For these reasons, this aeration method is not recommended.

Phosphorus load reductions for Nancy, North Cornelia, and South Cornelia for the recommended management actions were estimated from: (1) the total phosphorus concentration reductions observed for the iron treatments at Indianhead and Arrowhead Lakes (70%), (2) estimated improvements in treatment performance with oxygen injection (OST or nanobubbles)-90% internal load reduction, and (3) binding of Fe-P by lanthanum. For Nancy, a 20 percent reduction in internal loading from lanthanum treatment is estimated given uncertainties over the capacity to control internal loading from Org-P. Using modeling results from the Cornelia UAA (Barr, 2019) and Nancy internal load study (Barr, 2022), the following phosphorus loading reductions are estimated with the prescribed treatments:

- Nancy: 2.3 pounds P per year

- North Cornelia: 111 pounds P per year
- South Cornelia: 74 pounds P per year

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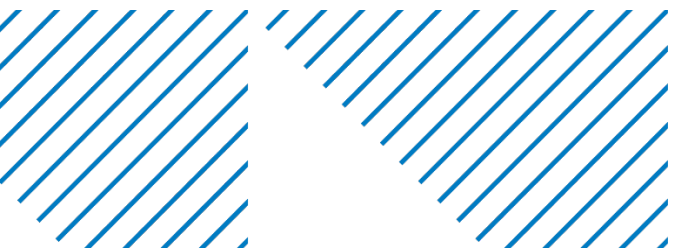
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Appendix A

Review of the Applicability of Lanthanum-based Treatments for Lake Cornelia and Lake Nancy Internal Loading Control



Technical Memorandum

To: Jordan Wein, NMCWD Water Resources Project Manager
From: Keith Pilgrim, PhD; Nathan Jahns
Subject: Review of the Applicability of Lanthanum-based Treatments for Lake Cornelia and Lake Nancy Internal Loading Control
Date: February 23, 2026
Project: Lake Cornelia and Nancy Feasibility Study
C: Janna Kieffer, Barr Engineering Co.; Erica Sniegowski, NMCWD Administrator

1 Introduction and Purpose

This memo is intended to summarize Barr's review of EutroSORB and Phoslock products and their application to water bodies for phosphorus (P) inactivation in lake bottom sediments. The purpose of this review is to understand if these lanthanum-based products would be effective for reducing internal loading in Lake Nancy and Lake Cornelia. In-lake modeling and sediment analyses have indicated that internal loading is a significant source of phosphorus to these lakes, with a predominance of the sediment phosphorus being organically-bound in both lakes. The chemistry of Lake Nancy and Lake Cornelia is also important in this evaluation. These lakes are highly productive, have high concentrations of dissolved organic carbon, and high alkalinity. Algal blooms can lead to significant daily pH fluctuations. These factors are being considered as they can impact the effectiveness of lanthanum-based treatments (Spears 2015).

The information provided in this memo is from sources and case studies where EutroSORB and Phoslock were specifically mentioned as the used product. This review was conducted at the request of Nine Mile Creek Watershed District (NMCWD) staff with a primary interest in a new EutroSORB product called EutroSORB SI. This product has not been widely used, but it is being recommended by SePRO as a potential alternative to aluminum treatment for lake sediments.

2 Product Information and Technical Specifications

Lanthanum-modified bentonite (LMB) was engineered in the mid-1990s by the Australian national science agency (CSIRO) to address the limitations of traditional nutrient precipitants. The technology was designed to strip free reactive phosphorus (FRP) from the water column and settle along with the LMB to the sediment-water interface to create a "cap" that prevents the internal loading of legacy phosphorus. This technology was first commercialized in 2000 under the trade name Phoslock, which is currently owned by Phoslock Environmental Technologies (PET) and distributed in the United States by The Orion Companies (TOC). In 2023, another LMB product, EutroSORB, was launched and marketed to offer enhanced binding efficiencies and diverse application forms, including EutroSORB G, SI, and WC. EutroSORB is a technology platform managed by EutroPHIX, a subsidiary of the SePRO Corporation. Most examples of Phoslock applications are for treatments in Europe, but some are found in North America. As EutroSORB is a recently developed product, case studies are limited. Of those that exist, information for most has been released by EutroPHIX.

Both Phoslock and EutroSORB utilize the rare-earth element lanthanum (La^{3+}) to bind phosphate (PO_4^{3-}). Lanthanum binds phosphate to form a biologically inert mineral known as Rhabdophane ($LaPO_4$). It should be noted that phosphate (PO_4^{3-}) is not available for binding when incorporated into organic matter.

Aluminum is equally incapable of binding phosphorus in organic matter. Advantages of using lanthanum to treat organic phosphorus as compared to aluminum may exist, but no literature is known to suggest that lanthanum is better suited to treat lake sediments dominated by organic phosphorus. Unlike iron-based binders, the lanthanum-phosphate bond is non-redox sensitive, meaning it can remain stable even under the anoxic (low oxygen) conditions common in the hypolimnion of eutrophic lakes (SePRO 2011, PET 2020, Broekstra and Shuler 2022). According to SePRO, this technology will reduce internal loading in ponds, lakes, and reservoirs.

One of the lanthanum-based EutroSORB products that SePRO manufactures is called EutroSORB SI. This product is iron coated lanthanum. The iron coating is insoluble in the presence of oxygen in the water column but it can be expected to dissolve under anoxic conditions in the sediment allowing lanthanum to come into contact with phosphorus in sediments. The product is applied as a liquid or as a slurry.

According to conversations with EutroPHIX representatives and SePRO documentation, dosing strategies for LMB are site-specific. They have indicated that a comprehensive assessment of water quality parameters, restoration objectives, and the characterization of phosphorus sources are used to identify doses. Dosing is calculated based on the stoichiometric requirement to bind the mobile phosphorus mass found within the water column and the upper active layers of the sediment (SePRO 2022a). The stoichiometric ratio that SePRO recommends is typically one molecule of lanthanum per molecule of phosphorus. A simple evaluation of the chemistry of lanthanum conducted by Barr using a geochemistry model demonstrates, however, that lanthanum is bound by carbonate and dissolved organic carbon and that a significant percentage of the lanthanum added to lakes can be expected to be bound by carbonate. This suggests that a one-to-one dose will not bind all the phosphorus that needs to be bound. Spatial factors such as the proximity of the lanthanum to phosphorus in sediment also need to be considered. The cost to apply either EutroSORB G or SI needs to consider that one or more follow-up applications will likely be needed if a one-to-one dose is applied in accordance with manufacturing recommendations.

3 Review of Product and Peer-Reviewed Literature

A product and peer-reviewed literature search was conducted to better understand the following: (1) the potential effectiveness and longevity of lanthanum-based products to reduce internal loading in lakes, (2) potential adverse ecological effects of lanthanum-based treatment products, and (3) dosing and cost.

The outcomes of this review are summarized in three tables provided in the Appendix. They include a summary of: (1) Table A-1: lanthanum modified bentonite product use and functionality comparison, (2) Table A-2: case studies on the application and effectiveness of EutroSORB applications, and (3) Table A-3: supplier-provided cost estimates to treat Lake Nancy and Lake Cornelia. Selected research is discussed in more detail below, in addition to calculations conducted by Barr staff to better understand dosing, chemistry, and potential ecotoxicity.

3.1 Dosing

The four lanthanum-based products considered in the review are EutroSORB G (lanthanum-modified bentonite), EutroSORB SI (iron-coated lanthanum), EutroSORB WC (proprietary mixture of binding elements, presumably including lanthanum), and Phoslock (lanthanum-modified bentonite). NMCWD staff have expressed interest in EutroSORB SI for sediment treatment of Lake Nancy and Lake Cornelia; however, we have considered all of these products since limited information on EutroSORB SI application and effectiveness is available. Table A-1 reviews the intended use and target (water column phosphorus

or free-phosphate in the sediment), composition of the products, dosing, application method, speed of action, and environmental considerations.

Notable items in Table A-1 include: (1) the intended target of these products is “free” phosphate which presumably is iron-bound phosphate or porewater phosphate in sediment and not organically-bound phosphorus, (2) the SePRO EutroSORB G product has a higher percentage of lanthanum by weight compared to Phoslock, (3) the application method varies by product and may be a solid powder or liquid (EutroSORB SI can be provided as a liquid which will likely be easier to apply), and (4) dosing varies by product and by application.

Some additional discussion of dosing is warranted. Dosing is a critical consideration as it has a significant impact on cost and expected effectiveness. EutroSORB SI is a liquid with 2 pounds of lanthanum per gallon of product (0.24 kg La/L product). According to SEPRO, 2.5 gallons can bind 1 pound of phosphorus. This is slightly higher than a 1:1 lanthanum-to-phosphorus ratio by molar weight. According to SeePRO, 50 pounds of EutroSORB G can bind 1 pound of phosphorus. This is also a 1:1 molar ratio (1 molecule of lanthanum and 1 molecule of phosphorus), and a 1:1 molar ratio appears to be consistently recommended by the lanthanum product manufacturers. It is reasonable to assume that the recommended EutroSORB SI dose would be a 1:1 molar ratio. A review of dosing for a few lanthanum-enriched bentonite applications is provided below:

- Lake Hopatcong, NJ: Aerial lanthanum dose of 2.5 g/m². 440 pounds of Phoslock per acre.
- Little Rush Lake, MN: Aerial lanthanum dose of 7.0 g/m². 625 pounds of EutroSORB G per acre.
- Moses Lake, WA: Aerial lanthanum dose of 2.7 g/m². 248 pounds of EutroSORB G per acre.
- Lake Bromont, Quebec: Aerial lanthanum dose of 17.5 g/m². 3,135 pounds of Phoslock per acre.

Doses identified above range from 2.5 to 17.5 g/m² of lake area. In contrast, the aluminum dose for the 2019 Lake Cornelia aluminum treatment ranged from 22 to 55 g/m². Adjusting for the difference in molecular weight between aluminum and lanthanum, the aluminum treatment dose for the highest Lake Cornelia dose was 16 times higher than the highest lanthanum dose on a molar basis. It remains unknown if the affinity of lanthanum for binding with phosphate can compensate for the much lower dose when compared to aluminum. It is also unknown if lanthanum will be more capable than aluminum at binding organic phosphorus and preventing internal loading from organic phosphorus. Although research by Kong (2020) indicates that lanthanum may interact with organic material encapsulating phosphorus (binding not the phosphate itself, but the polar organic compound containing phosphorus), it is currently unclear whether internal loading from organic phosphorus can be diminished by lanthanum.

3.2 Performance

Grey literature, internet-based write-ups, product case-studies, and peer reviewed literature were considered to make a determination of the potential probability of success for a lanthanum-based treatment at Lake Cornelia and Nancy. Grey literature, internet-based write-ups, and product case studies indicate that there are some successes (e.g., Lake Kitsap) and also a number of treatments that were immediately effective but effectiveness was shorter than expected (e.g., Lake Bromont). In some cases, treatments were clearly ineffective or inconclusive (e.g., Rush Lake, Grand Lake St. Marys). The study conducted by Dithmer (2016) is comprehensive and provides an objective evaluation of the outcome of 10 Phoslock treatments conducted in the United Kingdom, Germany, and the Netherlands. Sediment cores collected from treated lakes and incubated for internal phosphorus release resulted in 8 cores (lakes) having no phosphorus release and 2 cores (lakes) having high phosphorus release. This study

also clearly showed that lanthanum-bound phosphorus is formed in these treated lakes. A study conducted by Newesly (2024) showed significant phosphorus release from a Phoslock-treated lake (Lake Bromont) approximately four years after treatment. This study also showed a high rate of lanthanum flux out of sediment and the accumulation of lanthanum in porewater, with increases occurring with depth. Lake Bromont was treated with a 1:1 molar ratio of lanthanum and phosphorus. These research results contrast with manufacturer product literature that claims that lanthanum is “permanently bound.” As part of a discussion with Eutrophix staff Ryan Van Goethem on February 2, Ryan acknowledged that lanthanum does dissolve into sediment porewater and this is needed for lanthanum-phosphate binding to occur. Unlike aluminum, this mechanism may provide an opportunity for lanthanum binding of decaying organic phosphorus, but it also may provide a mechanism for lanthanum loss from lake sediments, particularly for shallow lakes. Such loss may limit longevity as lanthanum dissolves and fluxes out of lake sediment. This dissolution and fluxing mechanism for lanthanum is likely the same dissolution and fluxing mechanism for iron which is very low in Nancy and Cornelia sediments.

The phosphate binding capacity of lanthanum can be adversely affected by organic carbon and carbonate (e.g., alkalinity). Li (2020) demonstrated that the phosphate-binding capacity of lanthanum in water is affected by natural organic matter when the ratio of carbon to phosphate exceeded a threshold identified in the study. For Lake Cornelia and Nancy, phosphorus in sediments is the primary target rather than phosphorus in the water column, and, although the observed phosphorus binding inhibition was exhibited in water rather than sediment, the Lake Cornelia and Nancy sediments are high in organic carbon and hence this may affect lanthanum treatment effectiveness. The effectiveness of lanthanum treatment may also be reduced for high alkalinity lakes, as lanthanum complexes with carbonate. Dithmer (2026) concluded that Phoslock treatments may be more effective in softwater lakes. To better understand the effect of hardwater/high alkalinity on lanthanum availability, the geochemistry model Visual Minteq was used to understand lanthanum speciation in a hardwater system. For a hardwater system with alkalinity at 100 mg/L, lanthanum at 2 g/L, and pH at 6.5, the expected species distribution of lanthanum is shown below (Table 1). Nineteen percent of the lanthanum is predicted to be bound by carbonate, and 39 percent is bound by phosphate. A pH of 6.5 was used as sediments are typically acidic when anaerobic; however, a higher pH favors more lanthanum binding by carbonate, and a high pH environment is likely to occur in Lake Cornelia and Lake Nancy. This implies that dosing needs to compensate for potential losses of lanthanum binding capacity in the presence of high alkalinity and high natural organic matter.

Table 1 Expected species distribution of lanthanum in water with alkalinity of 100 mg/L as CaCO₃, recommended EutroSORB G dose for North Cornelia, pH of 6.5, and a 1:1 La to PO₄ ratio.

Percent Bound	Species
41.5	La ⁺³
0.17	LaOH ⁺²
39.0	LaH ₂ PO ₄ ⁺²
4.5	LaHCO ₃ ⁺²
0.048	La(CO ₃) ²⁻
14.7	LaCO ₃ ⁺

3.3 Cost

EutroPHIX and PET were contacted to provide product cost estimates for treating North and South Lake Cornelia and Lake Nancy. The cost estimates are summarized in Table A-4. Estimates were based upon the sediment phosphorus fractionation information provided if requested by the vendor. The EutroPHIX recommended dose was quoted as being 25 percent of the sediment dose needed to treat iron-bound phosphorus and some organically bound phosphorus. After adjusting for the difference in lanthanum content between the Phoslock and the EutroPHIX G product, the Phoslock recommended dose is approximately three times greater than the EutroPHIX dose despite EutroPHIX G containing twice the Lanthanum as Phoslock. The Phoslock recommended dose is presumably a one-time treatment, whereas EutroPHIX is recommending an initial reduced dose (25 percent of total treatment needs) with follow-up annual maintenance treatments for an unspecified number of years. Cost estimate materials from EutroPHIX are provided in Attachment A. Total product costs to treat Lake Nancy and Lake Cornelia are:

- EutroPHIX (Eutrosorb G or SI): \$171,937 for the 25 percent dose (0.25 molecules of lanthanum per 1 molecule of phosphorus)
- EutroPHIX (Eutrosorb G or SI) annual maintenance treatment: \$21,700
- Phoslock: \$346,121 for the full dose

On the basis of the mass of lanthanum delivered to sediments, the Phoslock product is approximately 50 percent cheaper.

3.4 Potential for Adverse Ecological Effects

Marketing of lanthanum-based treatment products has often emphasized that lanthanum-based treatments are better---because they are safer for aquatic life than other phosphorus inactivation products. Lanthanum is often quoted as immobile; however, it is clear from this literature review and from discussions with Eutrophix staff that lanthanum is mobile as it does dissolve, flux into porewater, and flux into the lake water column. Lanthanum also binds to constituents such as carbonate and dissolved organic carbon, thereby lowering the bioavailability of lanthanum. Based upon the literature review, it is understood that time is also a factor; in the short-term, lanthanum can be inert given the kinetics of dissolution, but over time there can be accumulation and increased concentrations in water. The aquatic life risk assessment by Limnological Solutions International (LSI, 2025) concluded that Eutrosorb SI has very low risk to aquatic life. The aquatic life toxicological data presented indicates that--for the duration of the tests conducted--the toxicity of Eutrosorb SI to aquatic life was low. The duration (time considerations) of these tests with respect to what is known about the behavior of lanthanum in the environment must be considered. Hence, in the short term, there will likely be little lanthanum dissolution and hence little exposure of aquatic life to lanthanum. Over time, dissolution will likely occur and aquatic life will be exposed to free lanthanum---this justifies the comparison of the toxicity of free lanthanum to aquatic life. The US EPA EcoTox database was queried for dissolved lanthanum toxicity to aquatic life. This query demonstrates that lanthanum can cause aquatic life mortality at low concentrations. A quick summary is provided in the bullets below (all LC50 values---the concentration where there is 50 percent mortality):

- *Hyalella azteca* - 0.018 to 1.665 mg/L
- Rainbow trout - 0.02 to 2.0 mg/L
- *Daphnia magna* - 1.61 to 2.81 mg/L

- *Daphnia carinata* - 0.043 to 2.81 mg/L

Although this is not a comprehensive risk assessment, it cannot be determined that there is no risk to aquatic life, nor can it be claimed that lanthanum-based treatments are safer than other treatments regarding aquatic life risks.

Conclusions

Based on the review of product information, case studies, peer-reviewed literature, and site-specific geochemical considerations, lanthanum-based treatments such as EutroSORB and Phoslock have the potential to reduce internal loading in Lake Nancy and Lake Cornelia; however, there are significant limitations.

- The assumption that 1 molecule of lanthanum will bind 1 molecule of phosphorus in sediments ignores factors that can interfere with binding, such as carbonate and dissolved organic carbon, as well as spatial limitations where lanthanum must make physical contact with phosphorus to form a lanthanum-phosphate bond.
- The doses being prescribed do not provide adequate phosphorus binding capacity even with the recommended annual maintenance application. Significantly more lanthanum will be needed than is being recommended EutroPHIX or PET.
- It is unknown if lanthanum will be able to effectively bind organic phosphorus in sediment. Lanthanum may be better than aluminum, given the potential for aluminum to age and lose binding capacity over time.
- The cost to conduct a lanthanum treatment for Lake Cornelia and/or Lake Nancy is significant. A more refined cost comparison will be provided in the final report.

Given these limitations, the use of EutroSORB or Phoslock for Lake Cornelia and/or Lake Nancy would need to be considered experimental.

Attachments:

Attachment A- Cost estimate materials from EutroPHIX

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[https://www.walpa.org/waterline/june-2025/novel-large-scale-phosphorus-mitigation-on-moses-lake-wa/#:~:text=Lake%20Sediment%20P%20Mitigation,the%20lake%20bottom%20\(right\)](https://www.walpa.org/waterline/june-2025/novel-large-scale-phosphorus-mitigation-on-moses-lake-wa/#:~:text=Lake%20Sediment%20P%20Mitigation,the%20lake%20bottom%20(right).). Accessed 2025 Dec 21.

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Appendix

Product Description

Table A-1 Lanthanum-modified bentonite product use and functionality comparison.

Feature	EutroSORB			Phoslock
	G	SI	WC	
Intended Use	Inactivates P in the water column before settling to the sediments, where it continues to bind free reactive P (FRP) released from the sediment ^[1] . Can be used as a recovery solution to strategically remove P from the water column or as a trophic status reset solution to remove P from water and sediment ^[2] .	Prevent P release from sediments in anoxic conditions ^[3] , ^[1] .	Inactivates excess P from surface water resources ^[4] . Can be used as a recovery solution to strategically remove P from the water column ^[2] .	Inactivates P when internal P loading from sediments outweighs external inputs ^[5] and for lentic waterbodies with excessive P or N:P ratios favoring cyanobacteria growth ^[6] .
Intended Target P Fraction	Free reactive P (FRP) in the water column and sediment ^[2] , ^[3] , ^[1] .	FRP in sediment ^[3] , ^[1] .	FRP in the water column ^[3] , ^[1] , ^[7] , ^[4] .	FRP in the water column and releasable P in the sediment ^[8] , ^[9] .
Described Composition	10% Lanthanum modified bentonite ^[2] , ^[3] .	Iron-coated lanthanum ^[1] .	Proprietary aqueous blend of phosphate-binding minerals ^[1] , ^[4] .	Lanthanum (5%) embedded in a bentonite clay matrix (~95%). A patented ion exchange process whereby lanthanum ions displace sodium ions within the clay matrix ^[8] , ^[9] .
Factors Influencing Dosing	Site-specific water quality ^[2] , lbs of P in the water column, and lbs of P in sediment, and release rate of P from sediment. High alkalinity and dissolved organic carbon may need to be considered when identifying dose.	Based on site-specific water quality ^[2] , lbs of P in the sediment, and release rate of P from sediment.	Based on site-specific water quality ^[2] and lbs of P in the water column.	Based on the quantity of phosphorus in the water column and the quantity of releasable P in the sediment ^[6] . Effective between pH 5 and 9 ^[8] , ^[9] .
Recommended Dosing Rate	50 lbs inactivates 1 lb of P ^[3] , ^[1] .	2.5 gal. per pound of P ^[3] .	16 oz. inactivates 1 lb. of P ^[1] , ^[7] .	Typically < 100 mg/L ^[8] , 100 lbs. will bind 1 lb. of FRP ^[10] .
Application Method	Applied uniformly over the surface of the water body or the area targeted; can be applied as a granule or in a slurry ^[1] .	Applied via surface spray uniformly over the surface of the water body or the area or sub-surface injections. Can be a liquid or slurry ^[1] .	Can be applied via surface spray uniformly over the surface, sub-surface injections, or poured into good mixing areas ^[1] . Does not require a slurry mix ^[7] , ^[4] .	Can be applied to the surface water in dry clay form, sprayed over the surface as a slurry, or injected at the sediment-water interface ^[6] . Granules are mixed with in-situ lake water to create a slurry ^[9] .

Feature	EutroSORB			Phoslock
	G	SI	WC	
Recommended Frequency and Timing	Not indicated.	Not indicated.	One application each month from spring through summer ^[1] . Seasonal applications suggested (spring, summer, fall) ^[7] .	Applications may occur as a single event or over several days and also may be split over a season or multiple seasons ^[8] , ^[9] .
Cost	~\$5–\$6 / lb ^[11] , ^[12] .	~\$160 / gal ^[13] .	~\$225 - \$300 / gal ^[14] , ^[15] .	~\$3-\$6 / lb ^[16] , ^[17] , ^[18] , ^[19] .
Speed of Action and Sequestration	According to manufacturer, rapid and permanent P removal ^[2] , ^[3] . Literature has shown release and dissolution in porewater ^[20] .	According to manufacturer, rapid and permanent inactivation of P ^[1] . Literature has shown release and dissolution in porewater ^[20] .	According to manufacturer, rapid and permanent inactivation of P ^[1] , ^[4] . Literature has shown release and dissolution in porewater ^[20] .	Binding is permanent, and the resulting mineral is insoluble and not bio-available ^[8] , ^[10] . Literature has shown release and dissolution in porewater ^[20] .
Environmental Considerations	Promoted as safe for fish, invertebrates, and personnel, and to not impact water quality or chemistry ^[1] . Lanthanum is acutely toxic to zooplankton at 0.049 mg/L to 2.81 mg/L according to US EPA Ecotox database.	Promoted as safe for fish, invertebrates, and personnel ^[1] . Lanthanum is acutely toxic to zooplankton at 0.049 mg/L to 2.81 mg/L according to US EPA Ecotox database.	Promoted as safe for fish, invertebrates, and personnel, does not impact water quality or chemistry and has an excellent safety profile with no environmental, health, or safety concerns ^[1] , ^[7] , ^[4] . Lanthanum is acutely toxic to zooplankton at 0.049 mg/L to 2.81 mg/L according to US EPA Ecotox database.	Negligible to very low risk to the aquatic environment ^[6] , ^[8] , ^[9] . According to literature, lanthanum accumulation observed in some aquatic life following application but with minimal acute or chronic effects ^[9] , ^[21] , ^[22] .

Footnotes:

- [1] SePRO 2025
- [2] SePRO 2022a
- [3] SePRO 2023
- [4] SePRO 2022b
- [5] Nürnberg 2017
- [6] Tetra Tech 2022
- [7] SePRO 2022c
- [8] SePRO 2011
- [9] PET 2020
- [10] Broekstra and Shuler 2022
- [11] Keystone Hatcheries 2025
- [12] Forestry Distributing 2025a
- [13] Forestry Distributing 2025b
- [14] Keystone Hatcheries 2025
- [15] SiteOne 2025
- [16] Chemical Warehouse 2025
- [17] Forestry Distributing 2025c
- [18] Jones Lake Mgmt 2025
- [19] Pond & Lake Mgmt 2025
- [20] Neweshy 2024
- [21] Waajen et al 2017
- [22] Landman et al 2007

EutroSORB Case Studies

Table A-2 Description of case studies on which EutroSORB was used.

Location	Lake Size (Acres)	P Issue	Goal	Product	Dosing	Application Schedule	Cost	Success	Source of Case Study
Big Soda Lake, CO ^[1]	~100	Increased harmful algal blooms resulting in the closure of the swim beach and limited or restricted other water activities.	Reduce algae biomass and phosphorus long-term.	EutroSORB WC	N/A	2023	N/A	P within the water column was reduced by 89.8% within the first 3-days after treatment and remained reduced after 5-months (98.2%). Substantial total phosphorus in the lower water column and within the bottom sediments.	City of Lakewood, CO public update
Kitsap Lake, WA ^[2]	246	Internal recycling of phosphorus from sediments during low oxygen events leading to annual HABs.	Mitigate legacy phosphorus	EutroSorb G	Not indicated	Twice each summer from June 2020 through 2023.	Not indicated	>40% improvement in water clarity (Secchi disc); Hypolimnetic phosphorus reduced by approx. 90%.	EutroPHIX promotional material
Lady Bird Lake, TX ^[3]	416	HABs caused by cyanobacteria which grew on the lake floor.	Inactivating phosphorus in the sediment.	EutroSorb G	Not indicated	Summer of 2021	Not indicated	77% decline in labile and iron-bound sediment phosphorus; Shift from cyanobacteria to non-toxic beneficial algae; reduction in toxin levels.	EutroPHIX promotional material
Lake Deeson, FL ^[4]	55	High levels of phosphorus and algae.	Remove 2,500 lbs of phosphorus sediments, improve water quality and remove the lake from impairment status.	EutroSORB G	Not indicated	September 2024 and March 2025	Not indicated	Lowest phosphorus, trophic index, and chlorophyll a on record; best water clarity on record.	EutroPHIX promotional material
Little Rush Lake, MN (a small basin connected to West Rush Lake) ^[5]	77 (48 treatment area)	Listed as impaired for excessive TP.	Long-term strategies to reduce phosphorus loading and improve water quality.	EutroSORB G	30,000 lbs of EutroSORB G	June 25, 2024,	Not indicated	TP in the water column showed modest short-term changes, substantial reductions in bioavailable and redox-sensitive P fractions in the sediment suggest effective inactivation of internally recycled P. Improvements in water clarity, decrease in chlorophyll-a, and stable pH.	Lake & Pond Management Corp, Freshwater Scientific Services, and EutroPHIX DRAFT EutroSORB application report

Location	Lake Size (Acres)	P Issue	Goal	Product	Dosing	Application Schedule	Cost	Success	Source of Case Study
Morrison Lake, MI ^[6]	330	Impaired for phosphorus pollution and struggles with HABs and cyanotoxins. TMDLs were established in 2006.	Restore Morrison Lake's ecological stability (clarity, native plant diversity, fisheries, etc.).	Phoslock + EutroSORB	Phoslock = 30,000 lbs in 2020, EutroSORB not indicated	Phoslock applied 6 times in summer of 2020. Phoslock + EutroSORB in 2021 and 2022.	Not indicated	80% reduction in hypolimnetic P, ~350 lbs. of phosphorus mitigated.	EutroPHIX and PLM Lake & Land Management Corp Presentation
Moses Lake, WA (Rocky Ford Arm) ^[7]	6,800 (2,083 treatment area)	Excess internal cycling of phosphorus from lake sediments and inputs from watershed sources.	Lower P levels, allowing for more years and longer summers without HAB blooms and advisories.	Sediment Inactivation (EutroSORB G) and water column/inflow mitigation (EutroSORB WC)	Sediment: 250 tons of EutroSORB G (binds up to 10,000 lbs. of P). Inflow: EutroSORB WC (binds up to 4,400 lbs. of P).	Sediment: June 2024. Inflow: Summer 2024, continued in spring 2025.	Not indicated	EutroSORB WC reduced SRP 40%; EutroSORB G reduced reduced bottom water TP >32%; Mobile surface sediment P decreased ~26%; Algae biovolume shifted to beneficial species.	EutroPHIX authored article in Washinton State Lake Protection Association newsletter
Spanaway Lake, WA ^[8]	250	Several annual episodes of cyanobacteria blooms and the associated potential for production of toxins.	Not indicated	EutroSORB G	16,000 lbs. to target 318.34 lb. of TP in surface layer above the thermocline and 20,000 lbs. to target 405 lbs. of TP in deep water areas below the thermocline.	May 2020 to strip the water column and Aug 2020 to target accumulated phosphorus in the hypolimnion.	Not indicated	Not indicated	AquaTechnex 2024 Lake Algae Management Report and Recommendations

Footnotes:

[1] Bear Creek Watershed Association 2024

[2] EutroPHIX 2024a

[3] EutroPHIX 2020

[4] EutroPHIX 2025

[5] Seltzer 2025

[6] Broekstra and Shuler 2022

[7] Van Goethem 2025

[8] AquaTechnex 2024

Phoslock Case Studies

Table A-3 Description of case studies on which Phoslock was used.

Location	Lake Size (Acres)	P Issue	Goal	Dosing	Application Schedule	Cost	Success	Source of Case Study
Lac Bromont, Quebec ^[1]	111	Decline in water quality	To significantly improve the water quality and the ecological condition of the lake by binding soluble P.	174 tons	End of October/early November 2017	Not indicated	Water samples had only just been taken; results and conclusions were pending.	PET promotional material
Grand Lake St Marys, OH ^[2]	12,850 (8 treatment area)	Suffers from extensive cyanobacterial harmful algal blooms that persist much of the year, resulting in microcystins that are often above safe contact levels.	Evaluate the effects of lanthanum clay treatments on nutrient and chlorophyll <i>a</i> dynamics and observe whether the treatments mitigated HAB biomass and toxicity within a small swimming enclosure	SeClear was applied at 3.75 mg/L and Phoslock was applied at 15 mg/L	Phoslock (granular and spread in raw form without premixing) and SeClear were applied every 3-4 weeks from May to August 2021	One dose of Phoslock+SeClear costs ~US\$5,000	Not successful beyond the day-to-week scale in a small enclosure of a larger lake.	Journal publication
Henderson Lake, Ontario ^[3]	64	Eutrophication and cyanobacteria negatively affect lake water quality.	Assess the potential use of Phoslock to reduce eutrophication.	64 tons at a rate of 0.25 kg/m ²	25–29 Apr 2016	Not indicated	TP decreased by ~12% of the pretreatment concentration in the first post treatment growing period. The average TP for 10 dates and 5 sites a few weeks later was 0.024 mg/L in the mixed surface water and 0.028 mg/L in the bottom water, indicating zero internal load.	Journal publication

Location	Lake Size (Acres)	P Issue	Goal	Dosing	Application Schedule	Cost	Success	Source of Case Study
Higgins Mill Pond, MD ^[4]	152 (small mesocosm treatment areas)	The pond is surrounded by farmland, mostly corn crops and poultry houses, yielding substantial and continuous nutrient loading from fertilizer and poultry litter applications. A confined chicken feeding operation ~0.5 km from the lake and runoff from an upstream chicken processing plant likely led to low N:P of the receiving water, resulting in recurring cyanobacterial blooms.	Mitigation of CyanoHABs using Phoslock to reduce the water column phosphorus and nutrient release from sediment.	Not Found in Source	Short-term (1 day) and long-term (28 days) experiments.	Not indicated	Diminished or reversed SRP flux from bottom sediments in short-term incubation. Hindered the P release, reduced the cyanobacterial abundance, and alleviated the bloom-driven enhancements in the pH and oxygen in long-term experiment.	Journal publication
Lake Hopatcong, NJ, ^{[5], [6]}	2,686 acres (50 acre treatment area)	HABs caused by increased water temp, stratification, and TP of 0.03 mg/L.	Prevent HABs and evaluate innovative technologies. TMDL goals of mean TP surface water ≤ 0.03 mg/L, mean chl-a of 8.1 ug/L, max chl-a of 13.6 ug/L, Secchi depth ≥ 1.0 m.	22,000 lbs or 440 lbs / acres	June 15-17, 2020	\$830k for Phoslock application and multiple other HAB prevention strategies.	Improved TDP, TP, SRP, and secchi depth two weeks post application but worsened a month after assessment results pending at time of source publication.	Lake Hopatcong Commission webpage and Princeton Hydro report

Location	Lake Size (Acres)	P Issue	Goal	Dosing	Application Schedule	Cost	Success	Source of Case Study
Laguna Niguel Lake, CA ^[7]	31	Nuisance and noxious cyanobacteria blooms; phosphorus availability is a crucial aspect.	To inactivate phosphorus as a critical component to achieve improved water quality; evaluate operational effectiveness of Phoslock. Compare pre-and post-application FRP and TP in the water column, benthic macroinvertebrate community, sediment P fractions, algal assemblage, and water quality conditions.	1:1 Molar ratio of La/P (100kg Phoslock/1kg P). Calculated on the TP measured in the water column and potentially releasable P in sediments (labile, reductant-soluble, metal oxide). A total of 51.34 MT used. Mixed into slurry.	4-day period (April 29-May 2, 2013)	Not indicated	In less than 2 weeks, significantly decreased TP (>80 %) and FRP (>95 %) in the water column and shifted potentially releasable sediment P fractions to residual forms. Cyanobacteria remained below or near detection limits and only comprised a small fraction of the algae assemblage. The benthic macroinvertebrate community was not affected.	Journal publication
Lake Lorene, WA ^{[9], [10], [11]}	15	Growing frequency of complaints from the community about the poor water quality, green color, surface algae blooms (cyanobacteria), foul odor and potential decline in waterfront property value. Hyper-eutrophic status (P pollution and potential for health impacts and death of fish and wildlife.	Mitigate hyper-eutrophic conditions by binding and inactivating the FRP in the water column and break the internal P cycling via inactivation of available P in the sediments.	9,300 lbs (first application).	June 11, 2012; follow-up dose scheduled for spring 2013.	~\$40,000 for two injections (including fees); range \$1,900–\$4,000 per acre.	One week after application, 34% decrease, 48.8 to 32.3 ug/L, in average TP and 24% decrease, 29.3 to 22.4 ug/L, reduction in FRP. One month after, TP declined to 32.3 ug/L and FRP dropping to 9.3 ug/L. 136 days after, 53% reduction in FRP, 40% reduction in TP, no blue green algae blooms in 2012, Secchi depth transparency to bottom (8 feet), No adverse impacts to aquatic organisms.	AquaTechnex, Federal Way Mirror, and KNKX Public Radio webpages

Location	Lake Size (Acres)	P Issue	Goal	Dosing	Application Schedule	Cost	Success	Source of Case Study
Lake Swan, Ontario ^[11]	14	Hyper-eutrophic terminal polymictic urban lake with little inflow; phosphorus input from Canada geese.	Intercept the internal load.	25.2 metric tons applied by barge to the lake surface by multiple passes, except for a ~1 m zone around the shoreline. Slightly higher doses were applied preferentially to the deeper areas.	April 29 to May 1, 2013	Not indicated	Average TP decreased from 0.247 to 0.099 mg/L in the first and 0.060 mg/L in the second post-treatment year. Phytoplankton biomass decreased only in the second post-treatment year when Secchi transparency increased to a growing season average of 1.4 m (range 0.7–2.7) compared to 0.5 m (0.37–0.63) before treatment.	Journal publication

Footnotes:

- [1] PET 2017
- [2] Davidson et al 2025
- [3] Nürnberg 2017
- [4] Li et al 2021
- [5] Lake Hopatcong Commission 2020
- [6] Lubnow 2021.pdf
- [7] Bishop et al 2014
- [8] AquaTechnex 2012
- [9] Federal Way Mirror 2012
- [10] KNKX Public Radio 2013
- [11] Nürnberg and LaZerte 2016

Preliminary Cost Analysis for Lake Cornelia and Lake Nancy, MN

Table A- 4 Cost estimate for a one-time application of lanthanum products to Lake Cornelia and Lake Nancy. Cost do not include annual maintenance treatments.

	Lake Cornelia (north and south)		Lake Nancy	
Parameter	EutroSORB G or SI Estimate	Phoslock Estimate	EutroSORB G or SI Estimate	Phoslock Estimate
Target Dosing Ratio	1.1:1 (La:PO ₄)	1:1	1.1:1 (La:PO ₄)	1:1
Required Product Dosing Rate	661 pounds/ac for north (high dose) 391 pounds/ac for south (high dose)	4,047 pounds/ac for north 2,553 pounds/ac for south	392 pounds/ac	2,647 pound/acre
Total Quantity of Product Needed	18,063 pounds for north 13,025 pounds for south	125,472 pounds for north 85,030 pounds for south	863 pounds	5,824 pounds
Unit Cost of Product (Bulk)	Unknown (need to get)	\$1.55/pound to \$1.60/pound	Unknown	\$1.55/pound to \$1.60/pound
Total Product Cost	\$102,500 (north) \$65,125 (south)	\$194,482 - \$200,755 for north \$131,797 - \$136,048 for south	\$4,312	\$9,027 - \$9,318



Appendix B

Cost Estimates for Considered Treatment Options



	PREPARED BY: BARR ENGINEERING CO.		SHEET:	1	OF	1
			CREATED BY:	KMP	DATE:	4/5/2026
			CHECKED BY:		DATE:	
			APPROVED BY:		DATE:	
	ENGINEER'S OPINION OF PROBABLE PROJECT COST PROJECT: Cornelia and Nancy Feasibility LOCATION: Edina, MN PROJECT #: 23271725.10 <u>OPINION OF COST - SUMMARY</u>		ISSUED:	Concept		DATE:
ISSUED:					DATE:	
ISSUED:					DATE:	
ISSUED:					DATE:	
ISSUED:					DATE:	

Engineer's Opinion of Probable Project Cost

Alum and Sodium Aluminate Treatment-Nancy

ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$6,210	\$6,210	1,2,3
2	LIQUID APPLICATION-ALUM	GAL	3,303	\$3.98	\$13,145	1,2,3,4
3	LIQUID APPLICATION-SODIUM ALUMINATE	GAL	1,651	\$9.01	\$14,879	1,2,3,4
4	SITE RESTORATION	LS	1	\$3,000.00	\$3,000	1,2,3
	CONSTRUCTION SUBTOTAL				\$37,000	1,2,3,5
	CONSTRUCTION CONTINGENCY (20%)				\$7,000.00	5
	ESTIMATED CONSTRUCTION COST				\$44,000.00	5
	PLANNING, ENGINEERING & DESIGN (30%)				\$13,200.00	7
ESTIMATED TOTAL PROJECT COST					\$57,000.00	6
ESTIMATED ACCURACY RANGE				-20%	\$46,000.00	6
				30%	\$75,000.00	6

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Includes the Cost of Application.

⁵ Estimate costs are reported to nearest thousand dollars.

⁶ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

⁶ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following construction.

	PREPARED BY: BARR ENGINEERING CO.		SHEET:	1	OF	1	
			CREATED BY:	KMP	DATE:	4/5/2026	
			CHECKED BY:		DATE:		
			APPROVED BY:		DATE:		
			ISSUED:	Concept	DATE:		
PROJECT: Cornelia and Nancy Feasibility				ISSUED:		DATE:	
LOCATION: Edina, MN				ISSUED:		DATE:	
PROJECT #: 23271725.10				ISSUED:		DATE:	
OPINION OF COST - SUMMARY				ISSUED:		DATE:	

Engineer's Opinion of Probable Project Cost

Alum and Sodium Aluminate Treatment-North Cornelia

ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$26,000	\$26,000	1,2,3
2	LIQUID APPLICATION-ALUM	GAL	14,967	\$3.98	\$59,568	1,2,3,4
3	LIQUID APPLICATION-SODIUM ALUMINATE	GAL	7,483	\$9.01	\$67,425	1,2,3,4
4	SITE RESTORATION	LS	1	\$3,000.00	\$3,000	1,2,3
	CONSTRUCTION SUBTOTAL				\$156,000	1,2,3,5
	CONSTRUCTION CONTINGENCY (20%)				\$31,000.00	5
	ESTIMATED CONSTRUCTION COST				\$187,000.00	5
	PLANNING, ENGINEERING & DESIGN (30%)				\$56,100.00	7
ESTIMATED TOTAL PROJECT COST					\$243,000.00	6
ESTIMATED ACCURACY RANGE		-20%			\$195,000.00	6
		30%			\$316,000.00	6

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Includes the Cost of Application.

⁵ Estimate costs are reported to nearest thousand dollars.

⁶ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

⁶ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following construction.

	PREPARED BY: BARR ENGINEERING CO.		SHEET:	1	OF	1
			CREATED BY:	KMP	DATE:	4/5/2026
	ENGINEER'S OPINION OF PROBABLE PROJECT COST		CHECKED BY:		DATE:	
	PROJECT: Cornelia and Nancy Feasibility		APPROVED BY:		DATE:	
LOCATION: Edina, MN		ISSUED:	Concept		DATE:	
PROJECT #: 23271725.10		ISSUED:			DATE:	
OPINION OF COST - SUMMARY		ISSUED:			DATE:	

Engineer's Opinion of Probable Project Cost

Alum and Sodium Aluminate Treatment-South Cornelia

ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$29,960	\$29,960	1,2,3
2	LIQUID APPLICATION-ALUM	GAL	17,299	\$3.98	\$68,851	1,2,3,4
3	LIQUID APPLICATION-SODIUM ALUMINATE	GAL	8,650	\$9.01	\$77,933	1,2,3,4
4	SITE RESTORATION	LS	1	\$3,000.00	\$3,000	1,2,3
	CONSTRUCTION SUBTOTAL				\$180,000	1,2,3,5
	CONSTRUCTION CONTINGENCY (20%)				\$36,000.00	5
	ESTIMATED CONSTRUCTION COST				\$216,000.00	5
	PLANNING, ENGINEERING & DESIGN (30%)				\$64,800.00	7
ESTIMATED TOTAL PROJECT COST					\$281,000.00	6
ESTIMATED ACCURACY RANGE				-20%	\$225,000.00	6
				30%	\$366,000.00	6

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Includes the Cost of Application.

⁵ Estimate costs are reported to nearest thousand dollars.

⁶ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

⁶ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following construction.

BARR	PREPARED BY: BARR ENGINEERING CO.		SHEET:	1	OF	1
			CREATED BY:	KMP	DATE:	4/3/2026
			CHECKED BY:		DATE:	
			APPROVED BY:		DATE:	
			ISSUED:	Concept	DATE:	
ENGINEER'S OPINION OF PROBABLE PROJECT COST		ISSUED:		DATE:		
PROJECT: Cornelia and Nancy Feasibility		ISSUED:		DATE:		
LOCATION: Edina, MN		ISSUED:		DATE:		
PROJECT #: 23271725.10		ISSUED:		DATE:		
OPINION OF COST - SUMMARY		ISSUED:		DATE:		
Engineer's Opinion of Probable Project Cost Ferric Chloride and Buffer Treatment-Nancy						
ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$3,670	\$3,670	1,2,3
2	MATERIAL-FERRIC CHLORIDE	GAL	2,727	\$4	\$10,963	1,2,3,4
3	MATERIAL-CALCIS	GAL	70	\$84	\$5,868	1,2,3
4	SITE RESTORATION	LS	1	\$1,500	\$1,500	1,2,3
5	APPLICATION-FERRIC CHLORIDE	GAL	2,727	\$3.00	\$8,181.59	1,2,3,4,5
6	APPLICATION-CALCINE	GAL	70	\$3.00	\$209.56	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				\$30,000	1,2,3,5
	CONSTRUCTION CONTINGENCY (20%)				\$6,000.00	5
	ESTIMATED CONSTRUCTION COST				\$36,000.00	5
	PLANNING, ENGINEERING & DESIGN (30%)				\$10,800.00	7
ESTIMATED TOTAL PROJECT COST					\$47,000.00	6
ESTIMATED ACCURACY RANGE		-20%			\$38,000.00	6
		30%			\$62,000.00	6

Notes

- ¹ Conceptual Design Work Completed (10%).
- ² Quantities Based on Design Work Completed.
- ³ Unit Prices Based on Information Available at This Time.
- ⁴ Includes the Cost of Application.
- ⁵ Estimate costs are reported to nearest thousand dollars.
- ⁶ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.
- ⁶ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

BARR	PREPARED BY: BARR ENGINEERING CO. ENGINEER'S OPINION OF PROBABLE PROJECT COST PROJECT: Cornelia and Nancy Feasibility LOCATION: Edina, MN PROJECT #: 23271725.10 OPINION OF COST - SUMMARY		SHEET:	1	OF	1
			CREATED BY:	KMP	DATE:	4/3/2026
			CHECKED BY:		DATE:	
			APPROVED BY:		DATE:	
			ISSUED:	Concept	DATE:	
		ISSUED:		DATE:		
		ISSUED:		DATE:		

Engineer's Opinion of Probable Project Cost

Ferric Chloride and Buffer Treatment-South Cornelia

ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$22,720	\$22,720	1,2,3
2	MATERIAL-FERRIC CHLORIDE	GAL	14,284	\$4	\$57,422	1,2,3,4
3	MATERIAL-CALCIS	GAL	949	\$56	\$53,144	1,2,3
4	SITE RESTORATION	LS	1	\$3,000	\$3,000	1,2,3
5	APPLICATION-FERRIC CHLORIDE	GAL	14,284	\$3.00	\$42,852.18	1,2,3,4,5
6	APPLICATION-CALCINE	GAL	949	\$3.00	\$2,847.03	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				\$182,000	1,2,3,5
	CONSTRUCTION CONTINGENCY (20%)				\$36,000.00	5
	ESTIMATED CONSTRUCTION COST				\$218,000.00	5
	PLANNING, ENGINEERING & DESIGN (30%)				\$65,400.00	7
ESTIMATED TOTAL PROJECT COST					\$283,000.00	6
ESTIMATED ACCURACY RANGE				-20%	\$227,000.00	6
				30%	\$368,000.00	6

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Includes the Cost of Application.

⁵ Estimate costs are reported to nearest thousand dollars.

⁶ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

⁶ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following construction.

	PREPARED BY: BARR ENGINEERING CO.		SHEET:	1	OF	1
			CREATED BY:	KMP	DATE:	4/5/2026
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	ENGINEER'S OPINION OF PROBABLE PROJECT COST		ISSUED:	Concept		DATE:
PROJECT: Cornelia and Nancy Feasibility		ISSUED:			DATE:	
LOCATION: Edina, MN		ISSUED:			DATE:	
PROJECT #: 23271725.10		ISSUED:			DATE:	
<u>OPINION OF COST - SUMMARY</u>						

Engineer's Opinion of Probable Project Cost						
Zero Valent Iron Application-South Cornelia						

ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$1,480	\$1,480	1,2,3
2	MATERIAL-ZERO VALENT IRON (CC1200)	LBS	878	\$0.72	\$634	1,2,3
3	APPLICATION-ZERO VALENT IRON	LS	1	\$6,000.00	\$6,000	1,2,3
4	SITE RESTORATION	LS	1	\$750.00	\$750	1,2,3
5	SHIPPING	TON	1	\$100.00	\$100.00	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				\$9,000	1,2,3,4
	CONSTRUCTION CONTINGENCY (20%)				\$2,000.00	5
	ESTIMATED CONSTRUCTION COST				\$11,000.00	5
	PLANNING, ENGINEERING & DESIGN (30%)				\$3,300.00	7
ESTIMATED TOTAL PROJECT COST					\$14,000.00	6
ESTIMATED ACCURACY RANGE		-20%			\$12,000.00	6
		30%			\$19,000.00	6

Notes

- ¹ Conceptual Design Work Completed (10%).
² Quantities Based on Design Work Completed.
³ Unit Prices Based on Information Available at This Time.
⁴ Estimate costs are reported to nearest thousand dollars.
⁵ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.
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ENGINEER'S OPINION OF PROBABLE PROJECT COST

PROJECT: Cornelia and Nancy Feasibility

LOCATION: Edina, MN

PROJECT #: 23271725.10

OPINION OF COST - SUMMARY

Engineer's Opinion of Probable Project Cost

Zero Valent Iron Application-North Cornelia

ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$8,680	\$8,680	1,2,3
2	MATERIAL-ZERO VALENT IRON (CC1200)	LBS	3,979	\$0.72	\$2,875	1,2,3
3	APPLICATION-ZERO VALENT IRON	LS	1	\$36,000	\$36,000	1,2,3
4	SITE RESTORATION	LS	1	\$4,500	\$4,500	1,2,3
5	SHIPPING	TON	2	\$100.00	\$198.93	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				\$52,000	1,2,3,4
	CONSTRUCTION CONTINGENCY (20%)				\$10,000.00	5
	ESTIMATED CONSTRUCTION COST				\$62,000.00	5
	PLANNING, ENGINEERING & DESIGN (30%)				\$18,600.00	7
ESTIMATED TOTAL PROJECT COST					\$81,000.00	6
ESTIMATED ACCURACY RANGE				-20%	\$65,000.00	6
				30%	\$106,000.00	6

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Estimate costs are reported to nearest thousand dollars.

⁵ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

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BARR ENGINEER'S OPINION OF PROBABLE PROJECT COST PROJECT: Cornelia and Nancy Feasibility LOCATION: Edina, MN PROJECT #: 23271725.10 OPINION OF COST - SUMMARY	PREPARED BY: BARR ENGINEERING CO.		SHEET:	1	OF	1
			CREATED BY:	KMP	DATE:	4/5/2026
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		ISSUED:		DATE:		

Engineer's Opinion of Probable Project Cost						
Zero Valent Iron Application-South Cornelia						

ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$8,770	\$8,770	1,2,3
2	MATERIAL-ZERO VALENT IRON (CC1200)	LBS	4,599	\$0.72	\$3,322	1,2,3
3	APPLICATION-ZERO VALENT IRON	LS	1	\$36,000	\$36,000	1,2,3
4	SITE RESTORATION	LS	1	\$4,500	\$4,500	1,2,3
5	SHIPPING	TON	2	\$100.00	\$229.93	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				\$53,000	1,2,3,4
	CONSTRUCTION CONTINGENCY (20%)				\$11,000.00	5
	ESTIMATED CONSTRUCTION COST				\$64,000.00	5
	PLANNING, ENGINEERING & DESIGN (30%)				\$19,200.00	7
ESTIMATED TOTAL PROJECT COST					\$83,000.00	6
ESTIMATED ACCURACY RANGE		-20%			\$67,000.00	6
		30%			\$108,000.00	6

Notes

- ¹ Conceptual Design Work Completed (10%).
² Quantities Based on Design Work Completed.
³ Unit Prices Based on Information Available at This Time.
⁴ Estimate costs are reported to nearest thousand dollars.
⁵ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.
⁶ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

 PREPARED BY: BARR ENGINEERING CO. ENGINEER'S OPINION OF PROBABLE PROJECT COST PROJECT: Cornelia and Nancy Feasibility LOCATION: Edina, MN PROJECT #: 23271725.10 OPINION OF COST - SUMMARY	SHEET: 1		OF 1	
	CREATED BY: KMP		DATE: 4/5/2026	
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	ISSUED:			DATE:
ISSUED:				DATE:

Engineer's Opinion of Probable Project Cost

Lanthanum Treatment- Lake Nancy

ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$3,250	\$3,250	1,2,3
2	MATERIAL-LANTHANUM BASED PRODUCT	LBS	189	\$50.15	\$9,457	1,2,3
3	APPLICTION	LS	1	\$6,000.00	\$6,000	1,2,3
4	SITE RESTORATION	LS	1	\$750.00	\$750	1,2,3
	CONSTRUCTION SUBTOTAL				\$19,000	1,2,3,4
	CONSTRUCTION CONTINGENCY (20%)				\$4,000.00	5
	ESTIMATED CONSTRUCTION COST				\$23,000.00	5
	PLANNING, ENGINEERING & DESIGN (30%)				\$6,900.00	7
ESTIMATED TOTAL PROJECT COST					\$30,000	6
ESTIMATED ACCURACY RANGE				-20%	\$24,000.00	6
				30%	\$39,000.00	6

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time. Unit expressed as pounds of lanthanum. Product can be either Eutrosorb or Phoslock. Chosen product will be based upon bid.

⁴ Estimate costs are reported to nearest thousand dollars.

⁵ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

⁶ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following construction.

 PREPARED BY: BARR ENGINEERING CO. ENGINEER'S OPINION OF PROBABLE PROJECT COST PROJECT: Cornelia and Nancy Aeration Feasibility LOCATION: Edina, MN PROJECT #: 23271725 OPINION OF COST - SUMMARY	SHEET:	1	OF	1
	CREATED BY:	MAO	DATE:	3/9/2026
	CHECKED BY:	KMP	DATE:	6/18/2026
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	ISSUED:	Concept	DATE:	
	ISSUED:		DATE:	
	ISSUED:		DATE:	

Engineer's Opinion of Probable Project Cost

Moleaer Nanobubbles L2 Nancy

2026 Lake Cornelia and Lake Nancy Feasibility Study for Internal Loading Control
Engineers Opinion of Probable Cost

LAKE NANCY- NANOBUBBLES						
ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$48,200.00	\$48,200.00	1,2,3,4,5
2	ELECTRICAL CONNECTION (3-Phase)	LS	1	\$50,000.00	\$50,000.00	1,2,3,4,5
3	3-PHASE CONVERTER	LS	1	\$30,000.00	\$30,000.00	1,2,3,4,5
5	L2 NANOBUBBLES SYSTEM	LS	1	\$400,000.00	\$400,000.00	1,2,3,4,5
8	SITE RESTORATION	LS	1	\$2,000.00	\$2,000.00	1,2,3,4,5
	SUBTOTAL				\$482,000.00	1,2,3,4,5,6
	CONSTRUCTION CONTINGENCY (20%)				\$96,000.00	1,6,7
	TOTAL CONSTRUCTION COST				\$578,000.00	1,2,3,4,5,6,7
	DESIGN, PERMITTING, CONSTRUCTION ADMIN (30%)				\$173,400.00	1,6,7,8
	ESTIMATED TOTAL PROJECT COST				\$751,000.00	1,2,3,4,5,6,7,8
				-20%	\$601,000.00	6,7,8
				30%	\$977,000.00	6,7,8

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Limited Soil Boring and Field Investigation Information Available.

⁵ Estimate assumes that projects will not be located on contaminated soil.

⁶ Estimate costs are reported to nearest thousand dollars.

⁷ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

⁸ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following construction.

 PREPARED BY: BARR ENGINEERING CO. ENGINEER'S OPINION OF PROBABLE PROJECT COST PROJECT: Cornelia and Nancy Aeration Feasibility LOCATION: Edina, MN PROJECT #: 23271725 <u>OPINION OF COST - SUMMARY</u>	SHEET:	1	OF	1
	CREATED BY:	MAO	DATE:	3/9/2026
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	ISSUED:		DATE:	
	ISSUED:		DATE:	

Engineer's Opinion of Probable Project Cost

Moleaer Nanobubbles L2 North Cornelia

2026 Lake Cornelia and Lake Nancy Feasibility Study for Internal Loading Control

Engineers Opinion of Probable Cost

NORTH CORNELIA- NANOBUBBLES						
ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION/DEMObILIZATION	LS	1	\$42,200.00	\$42,200.00	1,2,3,4,5
2	ELECTRICAL CONNECTION (3-PHASE)	LS	1	\$20,000.00	\$20,000.00	1,2,3,4,5
5	L2 NANOBUBBLES SYSTEM	LS	1	\$400,000.00	\$400,000.00	1,2,3,4,5
8	SITE RESTORATION	LS	1	\$2,000.00	\$2,000.00	1,2,3,4,5
	SUBTOTAL				\$464,000.00	1,2,3,4,5,6
	CONSTRUCTION CONTINGENCY (20%)				\$93,000.00	1,6,7
	TOTAL CONSTRUCTION COST				\$557,000.00	1,2,3,4,5,6,7
	DESIGN, PERMITTING, CONSTRUCTION ADMIN (30%)				\$167,100.00	1,6,7,8
	ESTIMATED TOTAL PROJECT COST				\$724,000.00	1,2,3,4,5,6,7,8
				-20%	\$580,000.00	6,7,8
				30%	\$942,000.00	6,7,8

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Limited Soil Boring and Field Investigation Information Available.

⁵ Estimate assumes that projects will not be located on contaminated soil.

⁶ Estimate costs are reported to nearest thousand dollars.

⁷ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

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 PREPARED BY: BARR ENGINEERING CO. ENGINEER'S OPINION OF PROBABLE PROJECT COST PROJECT: Cornelia and Nancy Aeration Feasibility LOCATION: Edina, MN PROJECT #: 23271725 OPINION OF COST - SUMMARY	SHEET:	1	OF	1
	CREATED BY:	MAO	DATE:	3/9/2026
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Engineer's Opinion of Probable Project Cost

Moleaer Nanobubbles L4 South Cornelia

2026 Lake Cornelia and Lake Nancy Feasibility Study for Internal Loading Control

Engineers Opinion of Probable Cost

SOUTH CORNELIA- NANOBUBBLES						
ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION/DEMobilIZATION	LS	1	\$65,200.00	\$65,200.00	1,2,3,4,5
2	ELECTRICAL CONNECTION (3-Phase)	LS	1	\$20,000.00	\$20,000.00	1,2,3,4,5
	3-PHASE CONVERTER	LS	1	\$30,000.00	\$30,000.00	
5	L4 NANOBUBBLES SYSTEM	LS	1	\$600,000.00	\$600,000.00	1,2,3,4,5
8	SITE RESTORATION	LS	1	\$2,000.00	\$2,000.00	1,2,3,4,5
	SUBTOTAL				\$717,000.00	1,2,3,4,5,6
	CONSTRUCTION CONTINGENCY (20%)				\$143,000.00	1,6,7
	TOTAL CONSTRUCTION COST				\$860,000.00	1,2,3,4,5,6,7
	DESIGN, PERMITTING, CONSTRUCTION ADMIN (30%)				\$258,000.00	1,6,7,8
	ESTIMATED TOTAL PROJECT COST				\$1,118,000.00	1,2,3,4,5,6,7,8
				-20%	\$895,000.00	6,7,8
				30%	\$1,454,000.00	6,7,8

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Limited Soil Boring and Field Investigation Information Available.

⁵ Estimate assumes that projects will not be located on contaminated soil.

⁶ Estimate costs are reported to nearest thousand dollars.

⁷ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

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	ISSUED:	Concept	DATE:	
	ISSUED:		DATE:	
	ISSUED:		DATE:	

Engineer's Opinion of Probable Project Cost

OST and Destratification Aeration System

2026 Lake Cornelia and Lake Nancy Feasibility Study for Internal Loading Control

Engineers Opinion of Probable Cost

NORTH CORNELIA- OXYGEN SATURATION TECHNOLOGY AND DESTRATIFICATION MIXING SYSTEM						
ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$16,900.00	\$16,900.00	1,2,3,4,5
2	ELECTRICAL CONNECTION	LS	1	\$15,000.00	\$15,000.00	1,2,3,4,5
3	CONCRETE PAD	LS	1	\$2,000.00	\$2,000.00	1,2,3,4,5
4	ENCLOSURE	LS	1	\$15,000.00	\$15,000.00	1,2,3,4,5
5	S-8 OST UNIT	EA	1	\$40,000.00	\$40,000.00	1,2,3,4,5
6	DESTRATIFICATION MIXING SYSTEM	EA	1	\$95,000.00	\$95,000.00	1,2,3,4,5
8	SITE RESTORATION	LS	1	\$2,000.00	\$2,000.00	1,2,3,4,5
	SUBTOTAL				\$186,000.00	1,2,3,4,5,6
	CONSTRUCTION CONTINGENCY (20%)				\$37,000.00	1,6,7
	CONSTRUCTION TOTAL				\$223,000.00	1,2,3,4,5,6,7
	DESIGN, PERMITTING, CONSTRUCTION ADMIN (30%)				\$66,900.00	1,6,7,8
	ESTIMATED TOTAL PROJECT COST				\$290,000.00	1,2,3,4,5,6,7,8
	-20%				\$232,000.00	6,7,8
	30%				\$377,000.00	6,7,8

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Limited Soil Boring and Field Investigation Information Available.

⁵ Estimate assumes that projects will not be located on contaminated soil.

⁶ Estimate costs are reported to nearest thousand dollars.

⁷ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

⁸ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following construction.

 PREPARED BY: BARR ENGINEERING CO. ENGINEER'S OPINION OF PROBABLE PROJECT COST PROJECT: Cornelia and Nancy Aeration Feasibility LOCATION: Edina, MN PROJECT #: 23271725 OPINION OF COST - SUMMARY	SHEET:	1	OF	1
	CREATED BY:	MAO	DATE:	3/9/2026
	CHECKED BY:	KMP	DATE:	6/18/2026
	APPROVED BY:		DATE:	
	ISSUED:	Concept	DATE:	
	ISSUED:		DATE:	
	ISSUED:		DATE:	

Engineer's Opinion of Probable Project Cost

OST and Destratification Aeration System

2026 Lake Cornelia and Lake Nancy Feasibility Study for Internal Loading Control

Engineers Opinion of Probable Cost

SOUTH CORNELIA- OXYGEN SATURATION TECHNOLOGY AND DESTRATIFICATION MIXING SYSTEM						
ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$20,900.00	\$20,900.00	1,2,3,4,5
2	ELECTRICAL CONNECTION	LS	1	\$15,000.00	\$15,000.00	1,2,3,4,5
4	CONCRETE PAD	LS	1	\$2,000.00	\$2,000.00	1,2,3,4,5
5	ENCLOSURE	LS	1	\$15,000.00	\$15,000.00	1,2,3,4,5
6	S-8 OST UNIT	EA	2	\$40,000.00	\$80,000.00	1,2,3,4,5
7	DESTRATIFICATION MIXING SYSTEM	EA	1	\$95,000.00	\$95,000.00	1,2,3,4,5
8	SITE RESTORATION	LS	1	\$2,000.00	\$2,000.00	1,2,3,4,5
	SUBTOTAL				\$230,000.00	1,2,3,4,5,6
	CONSTRUCTION CONTINGENCY (20%)				\$46,000.00	1,6,7
	TOTAL				\$276,000.00	1,2,3,4,5,6,7
	DESIGN, PERMITTING, CONSTRUCTION ADMIN (30%)				\$82,800.00	1,6,7,8
	ESTIMATED TOTAL PROJECT COST				\$359,000.00	1,2,3,4,5,6,7,8
	-20%				\$288,000.00	6,7,8
	30%				\$467,000.00	6,7,8

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Limited Soil Boring and Field Investigation Information Available.

⁵ Estimate assumes that projects will not be located on contaminated soil.

⁶ Estimate costs are reported to nearest thousand dollars.

⁷ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

⁸ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following construction.

 PREPARED BY: BARR ENGINEERING CO. ENGINEER'S OPINION OF PROBABLE PROJECT COST PROJECT: Cornelia and Nancy Aeration Feasibility LOCATION: Edina, MN PROJECT #: 23271725 OPINION OF COST - SUMMARY	SHEET:	1	OF	1
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	ISSUED:		DATE:	

Engineer's Opinion of Probable Project Cost

Traditional Aeration-Hydrologic Nancy

2026 Lake Cornelia and Lake Nancy Feasibility Study for Internal Loading Control

Engineers Opinion of Probable Cost

NANCY- HYDROLOGIC DIFFUSED AERATION						
ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$4,920.00	\$4,920.00	1,2,3,4,5
2	ELECTRICAL CONNECTION	LS	1	\$15,000.00	\$15,000.00	1,2,3,4,5
3	CONCRETE PAD	LS	1	\$1,500.00	\$1,500.00	1,2,3,4,5
4	ENCLOSURE	LS	1	\$8,500.00	\$8,500.00	1,2,3,4,5
5	AIRLIFT HF 8 CABINET WITH 2 -1 HP COMPRESSORS	EA	1	\$15,000.00	\$15,000.00	1,2,3,4,5
6	DIFFUSER	EA	12	\$300.00	\$3,600.00	1,2,3,4,5
7	SELF WEIGHTED AIR SUPPLY TUBING	LF	1,800	\$2.00	\$3,600.00	1,2,3,4,5
8	SITE RESTORATION	LS	1	\$2,000.00	\$2,000.00	1,2,3,4,5
	SUBTOTAL				\$54,000.00	1,2,3,4,5,6
	CONSTRUCTION CONTINGENCY (20%)				\$11,000.00	1,6,7
	CONSTRUCTION TOTAL				\$65,000.00	1,2,3,4,5,6,7
	DESIGN, PERMITTING, CONSTRUCTION ADMIN (30%)				\$19,500.00	1,6,7,8
	ESTIMATED TOTAL PROJECT COST				\$85,000.00	1,2,3,4,5,6,7,8
	-20%				\$68,000.00	6,7,8
	30%				\$111,000.00	6,7,8

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Limited Soil Boring and Field Investigation Information Available.

⁵ Estimate assumes that projects will not be located on contaminated soil.

⁶ Estimate costs are reported to nearest thousand dollars.

⁷ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

⁸ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following construction.

BARR PREPARED BY: BARR ENGINEERING CO. ENGINEER'S OPINION OF PROBABLE PROJECT COST PROJECT: Cornelia and Nancy Aeration Feasibility LOCATION: Edina, MN PROJECT #: 23271725 OPINION OF COST - SUMMARY	SHEET:	1	OF	1
	CREATED BY:	MAO	DATE:	3/9/2026
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	ISSUED:		DATE:	

Engineer's Opinion of Probable Project Cost

Traditional Aeration-Hydrologic North Cornelia

2026 Lake Cornelia and Lake Nancy Feasibility Study for Internal Loading Control

Engineers Opinion of Probable Cost

NORTH CORNELIA- HYDROLOGIC DIFFUSED AERATION						
ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$6,290.00	\$6,290.00	1,2,3,4,5
2	ELECTRICAL CONNECTION	LS	1	\$3,500.00	\$3,500.00	1,2,3,4,5
3	CONCRETE PAD	LS	1	\$1,500.00	\$1,500.00	1,2,3,4,5
4	ENCLOSURE	LS	1	\$9,000.00	\$9,000.00	1,2,3,4,5
5	AIRLIFT HF 8 CABINET WITH 2 -1 HP COMPRESSORS	EA	2	\$15,000.00	\$30,000.00	1,2,3,4,5
6	DIFFUSER	EA	12	\$300.00	\$3,600.00	1,2,3,4,5
7	SELF WEIGHTED AIR SUPPLY TUBING	LF	6,650	\$2.00	\$13,300.00	1,2,3,4,5
8	SITE RESTORATION	LS	1	\$2,000.00	\$2,000.00	1,2,3,4,5
	SUBTOTAL				\$69,000.00	1,2,3,4,5,6
	CONSTRUCTION CONTINGENCY (20%)				\$14,000.00	1,6,7
	TOTAL				\$83,000.00	1,2,3,4,5,6,7
	DESIGN, PERMITTING, CONSTRUCTION ADMIN (30%)				\$24,900.00	1,6,7,8
	ESTIMATED TOTAL PROJECT COST				\$108,000	1,2,3,4,5,6,7,8
	-20%				\$87,000.00	6,7,8
	30%				\$141,000.00	6,7,8

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Limited Soil Boring and Field Investigation Information Available.

⁵ Estimate assumes that projects will not be located on contaminated soil.

⁶ Estimate costs are reported to nearest thousand dollars.

⁷ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

⁸ Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following construction.

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	ISSUED:		DATE:	

Engineer's Opinion of Probable Project Cost

Traditional Aeration-Hydrologic South Cornelia

2026 Lake Cornelia and Lake Nancy Feasibility Study for Internal Loading Control

Engineers Opinion of Probable Cost

	SOUTH CORNELIA- HYDROLOGIC DIFFUSED AERATION					
ITEM NO.	ITEM DESCRIPTION	UNIT	EST. QUANTITY	UNIT COST	ITEM COST	NOTES
1	MOBILIZATION	LS	1	\$10,070.00	\$10,070.00	1,2,3,4,5
2	ELECTRICAL CONNECTION	LS	1	\$15,000.00	\$15,000.00	1,2,3,4,5
3	CONCRETE PAD	LS	1	\$9,000.00	\$9,000.00	1,2,3,4,5
4	ENCLOSURE	LS	1	\$10,500.00	\$10,500.00	1,2,3,4,5
5	AIRLIFT HF 10 CABINET WITH 2 -1 HP COMPRESSORS	EA	2	\$16,000.00	\$32,000.00	1,2,3,4,5
6	DIFFUSER	EA	24	\$300.00	\$7,200.00	1,2,3,4,5
7	SELF WEIGHTED AIR SUPPLY TUBING	LF	12,500	\$2.00	\$25,000.00	1,2,3,4,5
8	SITE RESTORATION	LS	1	\$2,000.00	\$2,000.00	1,2,3,4,5
	SUBTOTAL				\$111,000.00	1,2,3,4,5,6
	CONSTRUCTION CONTINGENCY (20%)				\$22,000.00	1,6,7
	CONSTRUCTION TOTAL				\$133,000.00	1,2,3,4,5,6,7
	DESIGN, PERMITTING, CONSTRUCTION ADMIN (30%)				\$39,900.00	1,6,7,8
	ESTIMATED TOTAL PROJECT COST				\$173,000.00	1,2,3,4,5,6,7,8
				-20%	\$139,000.00	6,7,8
				30%	\$225,000.00	6,7,8

Notes

¹ Conceptual Design Work Completed (10%).

² Quantities Based on Design Work Completed.

³ Unit Prices Based on Information Available at This Time.

⁴ Limited Soil Boring and Field Investigation Information Available.

⁵ Estimate assumes that projects will not be located on contaminated soil.

⁶ Estimate costs are reported to nearest thousand dollars.

⁷ This feasibility-level (Class 5, 0-2% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +30%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

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