Photo taken of Mirror Lake by NMCWD in May 2024

Mirror Lake Water Quality Improvement Project Feasibility Study

Prepared for
Nine Mile Creek Watershed District

Prepared by
Barr Engineering Co.

January 2025

BARR

Certification

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

Katelyn Turpin-Nagel
PE #: 59359

January 8, 2025
Date

Mirror Lake Water Quality Improvement Project Feasibility Study

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Abbreviations

AACE	Association for the Advancement of Cost Engineering
Al-P	aluminum phosphate
Barr	Barr Engineering Co.
BMPs	best management practices
Cl	chlorides
CWA	Clean Water Act
Fe-P	iron phosphate
GIS	geographic information system
ICC	Interlachen Country Club
m	meter
MnDNR	Minnesota DNR
MPCA	Minnesota Pollution Control Agency
NGVD29	National Geodetic Vertical Datum of 1929
NMCWD	Nine Mile Creek Watershed District
NPDES	National Pollutant Discharge Elimination System
OHWL	ordinary high water level
OP	orthophosphate
ROW	right-of-way
SDS	State Disposal System
TDP	total dissolved phosphorus
TKN	total Kjeldahl nitrogen
TP	total phosphorus
USACE	United States Army Corps of Engineers
µg/L	microgram per liter
VRSS	vegetated reinforced soil slope

1 Introduction and Project Background

In November 2023, the Nine Mile Creek Watershed District (NMCWD) completed the *Mirror Lake Water Quality Study* to assess lake conditions and prescribe management activities to improve water quality in Mirror Lake (Barr Engineering, 2023). The objective of this study is to further evaluate the feasibility of the management activities recommended in the Mirror Lake Water Quality Study.

1.1 Mirror Lake Overview

Mirror Lake is located in the northwestern portion of Edina, north of Highway 62, south of Interlachen Boulevard, and east of Highway 169. Mirror Lake has a water surface area of 23.5 acres, a maximum depth of approximately 13 feet, and a mean depth of 7.6 feet at a water surface elevation of 907.5 (NGVD29). Figure 1-1 shows the bathymetry of Mirror Lake. Mirror Lake is land-locked with no gravity surface outlets. Since the mid-1990s, the water level of Mirror Lake has been controlled by a pump located in the southwestern portion of the lake near Fox Meadow Park. In 2022, a new submersible pump was installed to control lake water levels. This pump is set to turn on automatically when the water surface elevation exceeds 908.5 (NGVD29) for longer than 60 minutes and pumps until the water elevation reaches 907.5 (NGVD29).

Mirror Lake generally has two tributary watershed types, as shown in Figure 1-2, where runoff is either (1) directly conveyed to the lake via surface drainage or storm sewer networks with no prior treatment (116 acres) or (2) tributary via treatment from upstream best management practices (BMPs) such as stormwater ponds, wetlands, or underground filtration practices (170 acres). The total tributary watershed area to Mirror Lake is approximately 286 acres. The watershed is largely developed, with over 63% of the watershed area consisting of single family detached residential and 13% golf course (i.e., Interlachen Country Club) (Figure 1-3).

Recent monitoring data indicate that Mirror Lake is not meeting Minnesota's eutrophication water quality standards for shallow lakes, primarily due to excess nutrients (e.g., phosphorus), which fuel algal growth and decrease water clarity (Figure 1-4). The 2023 water quality study found that phosphorus in Mirror Lake comes from several sources, including stormwater runoff from the watershed (external source) and internal sources such as nutrient-rich sediments. The summer average (June 1-Sept 30) total phosphorus concentrations between 1990 and 2021 were above the shallow lake standard of 60 µg/L, ranging from 73 to 119 µg/L. The Mirror Lake summer average chlorophyll-*a* concentrations between 1990 and 2021 were also above the shallow lake standard of 20 µg/L, ranging from 25 to 88 µg/L. The summer average Secchi disk depths between 1990 and 2021 ranged from 0.4 to 0.6 meters and were less than the minimum 1.0-meter Secchi depth standard.

The 2023 water quality study also reviewed the ecological health conditions of Mirror Lake. Historical plant surveys indicated degraded health of the macrophyte plant community with low species diversity and low growth extents (1 to 4 plant species observed between 2001 to 2021). Shoreline field review also identified notable erosion and bank failure conditions along a large percentage of the shoreline and

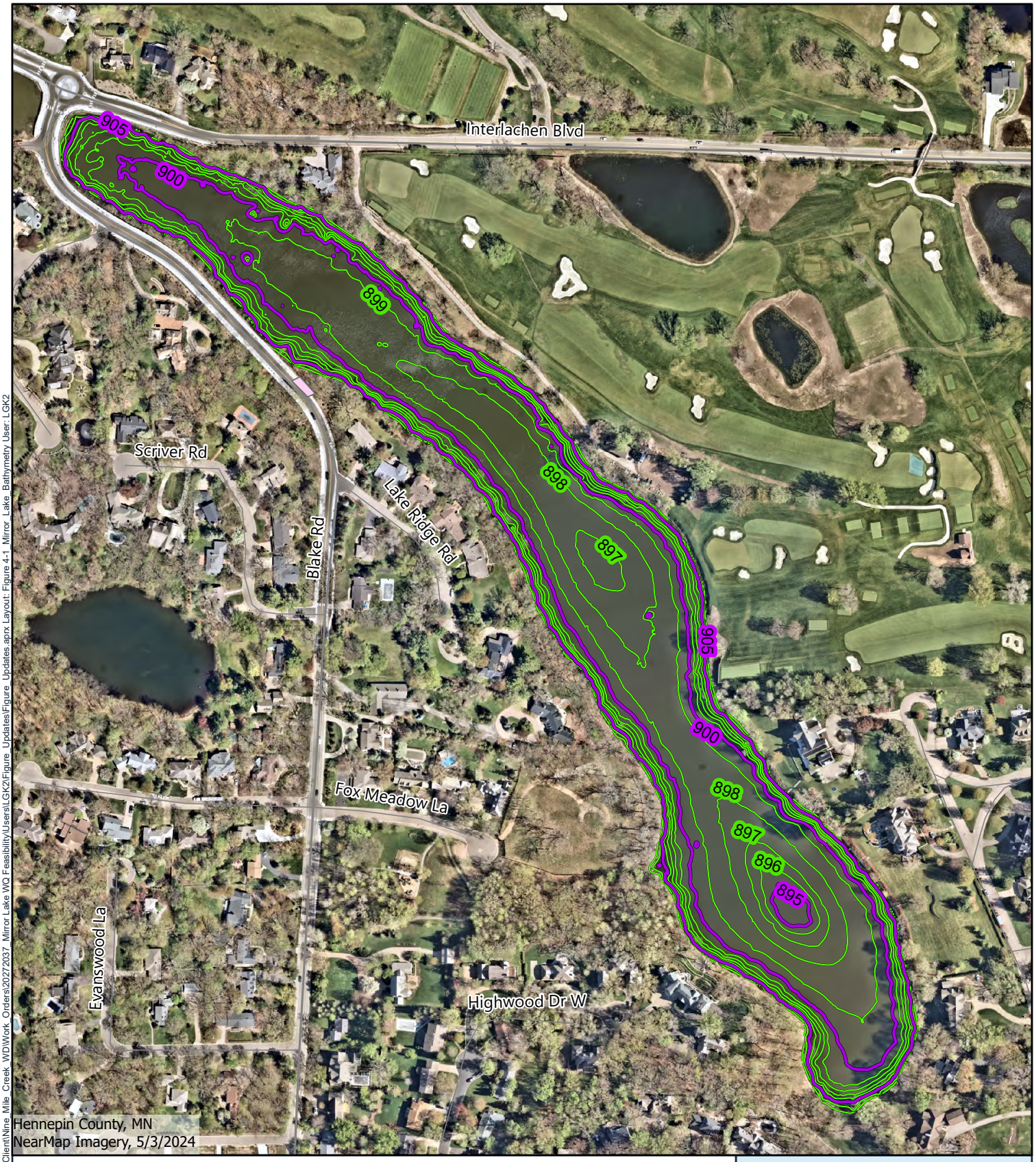
minimal planted buffers. Additionally, a fish survey completed in 2022 and anecdotal observations indicate that Mirror Lake does not have a balanced fishery (Barr Engineering, 2023).

1.2 Summary of Evaluated Management Practices

A variety of management strategies were evaluated as a part of the 2023 water quality study to address the poor water quality and degraded ecological health conditions in Mirror Lake. The evaluated management practices primarily target sources of phosphorus and nitrogen to Mirror Lake, with a focus on reducing both internal and external loading sources. A number of the recommended management strategies also work towards improving the ecological health of the lake and shoreline. Table 1-1 summarizes the management and protection strategies evaluated in the 2023 water quality study with an indication of which strategies require further evaluation as a part of this feasibility study. The management and protection strategies that were not further evaluated in this feasibility study either had enough supporting information or had existing NMCWD or City of Edina programs where project implementation could move forward without further review. Additional details on each management and protection strategy can be found in the *Mirror Lake Water Quality Study* (Barr Engineering, Mirror Lake Water Quality Study, 2023).

Table 1-1 Recommended strategies for management and protection of Mirror Lake water quality and ecological health

Management/Protection Strategy		Basis	Further assessed in Feasibility Study
Address internal bottom sediment phosphorus	Alum Sediment Treatment(s)	Reduce sediment phosphorus load	Yes, see Section 2
Address external watershed loading	Address shoreline erosion	Reduce sediment loading from shoreline erosion and protect upland habitats	Yes, see Section 3
	Enhanced street sweeping program	Reduce pollutant loading from stormwater	No, NMCWD and City coordinating
	Fertilizer management program	Reduce nitrogen sources from excess fertilizer use	No, NMCWD coordinating planning efforts
	Chloride monitoring	Continue to identify/track chloride levels from winter salt use	No, implemented through lake monitoring program
	Promote NMCWD cost-share grants to watershed residents	In a fully developed watershed, opportunities for largescale BMPs are limited	No, implemented through existing grant programs
	Fox Meadow Park Filtration Basin	Reduce pollutant loading from stormwater	No, to be reconsidered in future
Aquatic plants (macrophytes)	Curly-leaf pondweed management	Continue to monitor invasive species growth and manage as needed.	No, implemented through City monitoring and management
	Promote native aquatic plant growth	Encourage native plants to promote clear water conditions and competition with algae	No, to be considered if native plants do not re-establish following other management activities.
Fisheries	Electrofishing assessment	Determine if goldfish are degrading water quality	No, NMCWD completed study in 2024



City of Edina Bathymetry
1-foot Contours (2022)

- 1-ft Contour
- 5-ft Contour

N

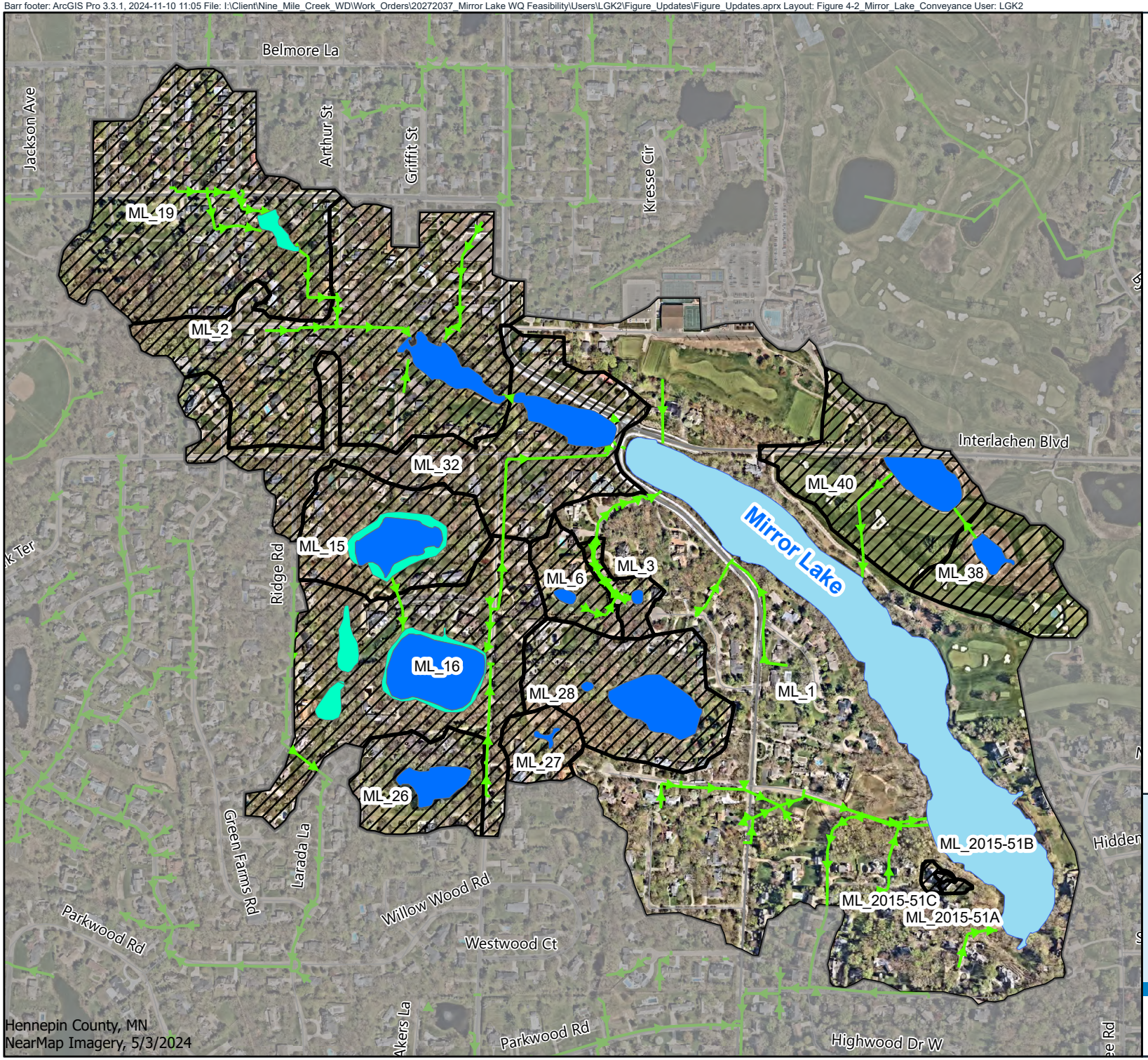
0 300
Feet

9 MILE CREEK WATERSHED DISTRICT

MIRROR LAKE BATHYMETRY

FIGURE 1-1

BARR



Storm Sewer

National Wetland Inventory (NWI) Wetlands

- Freshwater Emergent Wetland
- Freshwater Pond
- Lake

Subwatersheds

- Direct Drainage/Storm Sewer
- Treated by ponds, wetlands, BMPs

N

0 300 600

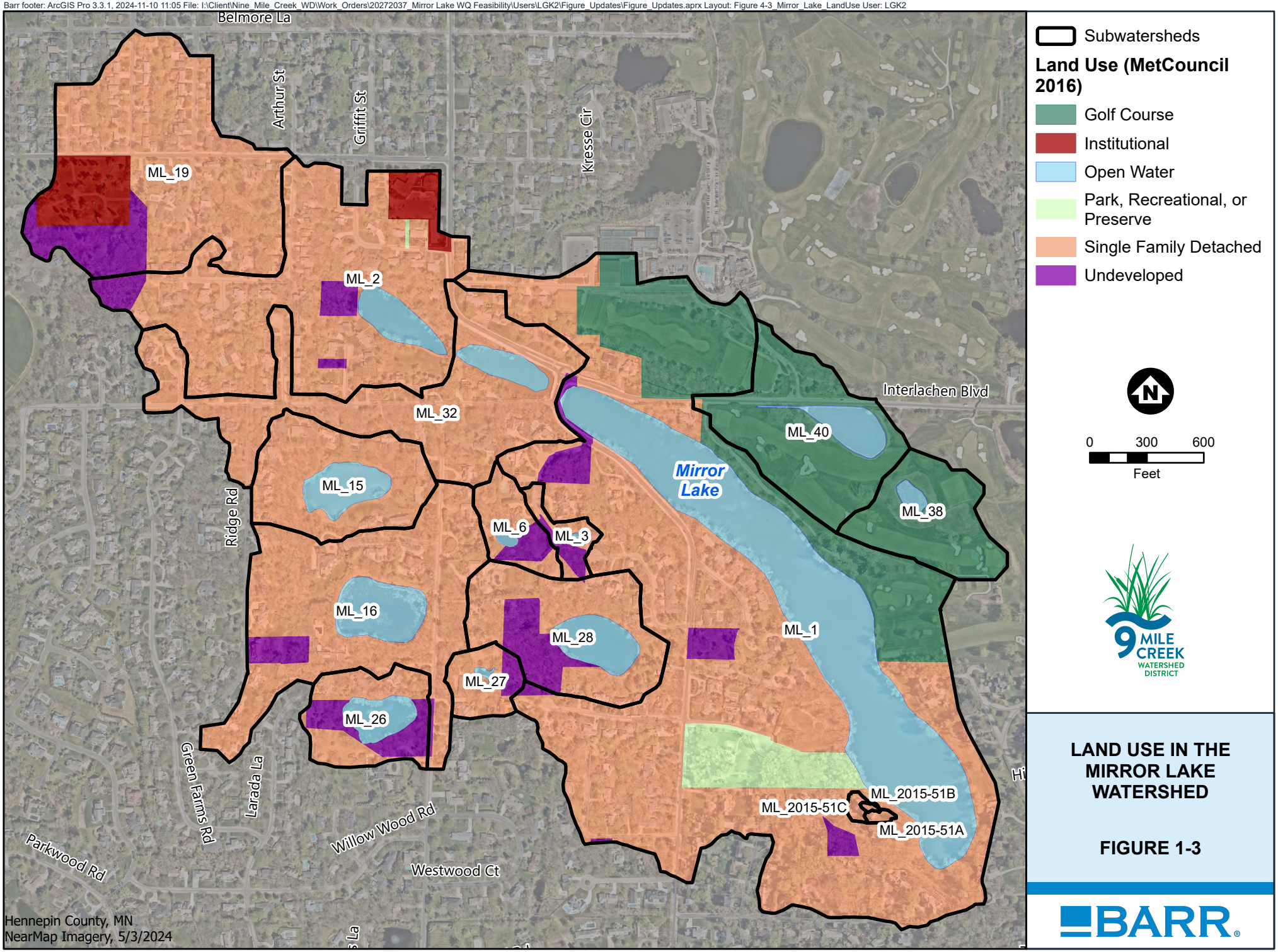
Feet

9 MILE CREEK WATERSHED DISTRICT

MIRROR LAKE SUBWATERSHEDS AND STORMWATER CONVEYANCE

FIGURE 1-2

BARR



LAND USE IN THE MIRROR LAKE WATERSHED

FIGURE 1-3

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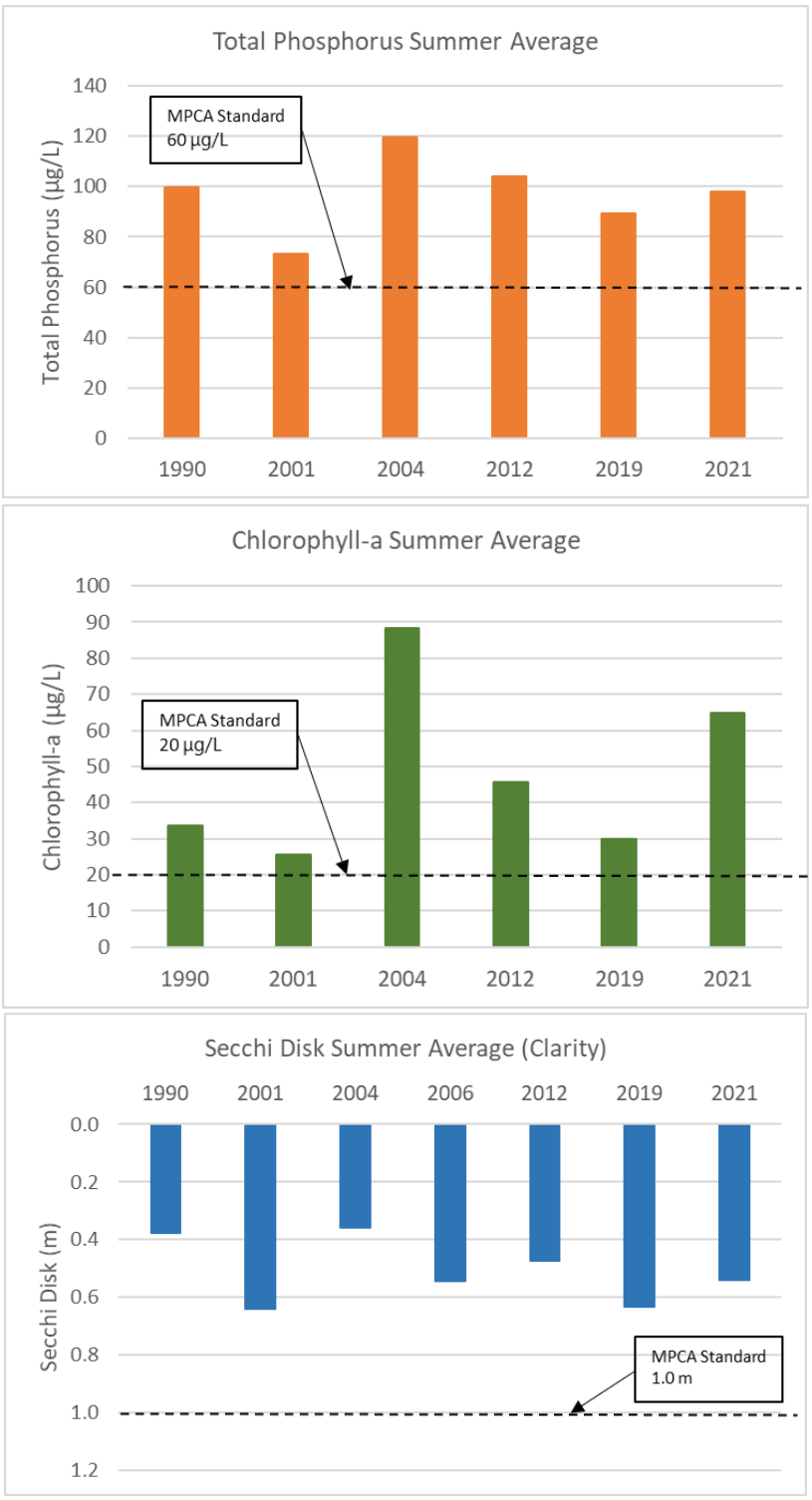


Figure 1-4 **Summer average total phosphorus and chlorophyll-*a* concentrations and Secchi disk depth measured in Mirror Lake between 1990 and 2021**

2 In-Lake Sediment Treatment

Phosphorus release from sediment is typically termed as "internal phosphorus loading". Phosphorus in lake bottom sediments is often bound to a range of different elements such as iron, manganese, aluminum, or calcium. It is the iron- and manganese-bound phosphorus (herein identified as the mobile phosphorus fraction) that releases from sediment during low oxygen conditions. Phosphorus can also be found incorporated into organic matter (organically bound phosphorus). Organically bound phosphorus also releases phosphorus from lake sediment through mineralization but typically at a slower rate than iron-bound phosphorus. The rate of release is controlled by lake water temperature and can occur under both high oxygen and low oxygen conditions.

2.1 Sediment Quality and Treatment Plan

The 2023 water quality study identified that a significant portion of the phosphorus in Mirror Lake originates from internal phosphorus loading from lake bottom sediments. Sediment cores were collected in June 2021 and used to inform the internal phosphorus loading potential of the mobile and organically bound phosphorus fractions. The average concentrations of organically bound phosphorus and mobile phosphorus in the top 4 centimeters of three cores taken from Mirror Lake were 58.1 and 11.6 µg P/cm^3 wet sediment, respectively. These observed concentrations indicate that there is potential for internal phosphorus loading of both organically bound phosphorus and mobile phosphorus; however, a more significant proportion originates from organically bound phosphorus.

The prevalence of organically bound phosphorus presents a management challenge because traditional aluminum sediment treatments (e.g., alum treatments) target the mobile phosphorus fraction and do not bind phosphorus that is incorporated into organic matter as efficiently. Over time organic phosphorus will decay and can be converted into a form that can bind with aluminum more prevalently. However, the degradation timeline of organic phosphorus may not align with the aging process of aluminum. After applying aluminum to the sediment, the aluminum will age and lose its binding capacity over time. If the aluminum aging process falls out of line with the organic phosphorus mineralization rate, it's possible for internal phosphorus loading to remain high from the organically bound phosphorus fraction in the sediment.

In lakes that have a higher predominance of organically-bound phosphorus internal loading, two adaptive sediment treatment management alternatives are typically recommended:

1. Applying multiple, partial alum treatments over multiple years to supply additional aluminum binding sites as the organic phosphorus molecules mineralize and to help offset the aging of the initial alum application.
2. Applying an iron compound such as ferric chloride along with aluminum or stand alone, to provide multiple substrate options for phosphorus binding within the sediment. The installation of an aeration system with this sediment treatment method is strongly recommended to reduce

low oxygen conditions at the sediment surface and enhance phosphorus binding efficiency with existing and applied iron in the sediment.

For Mirror Lake, the recommended approach to control internal phosphorus loading is to conduct a series of up to three adaptive aluminum sediment treatments during a ten year or more period. This sediment treatment is recommended because Mirror Lake stratifies during portions of the growing season and experiences low oxygen conditions at the sediment interface. Aluminum-bound phosphorus in the sediment is not sensitive to low oxygen conditions; however, iron-bound phosphorus will be susceptible to low oxygen conditions and release phosphorus to the water column. As such, an iron application is not recommended without the installation of aeration in Mirror Lake. During the water quality study, there was limited interest to explore aeration options for Mirror Lake due to challenging site access, the need to install electrical utilities all the way to the shoreline, and tree preservation preferences in Fox Meadow Park. As such aeration was not investigated further as a part of this feasibility study.

Figure 2-1 summarizes a suggested adaptive sediment treatment methodology using multiple, split alum sediment doses over 10+ years. It's recommended that the initial alum application have an alum dose on the higher end of the typical range, to help strip phosphorus from the water column and target the current pool of mobile- and organically-bound phosphorus in the top 6 – 8 cm of the sediment. Subsequent sediment treatments can be adapted based on success of the first treatment and the timeline for subsequent sediment treatment applications can be determined based on annual to bi-annual water quality and follow-up sediment core analysis. Alum dosing recommendations may also change slightly depending on the results of follow-up sediment core analyses and water quality monitoring data. Monitoring recommendations are summarized in Section 2.4. The adaptive treatments are recommended as follows and could be conducted in either the spring or the fall:

- **Year 1** – Apply alum and sodium aluminate simultaneously to the lake to prevent internal load from mobile-P and organic-P sources in lake bottom sediments. Apply alum and sodium aluminate at a rate to achieve 50 and 75 g-Al/m^2 to treatment zones 1 and 2, respectively, as shown in Figure 2-1.

- **Year 5** - Apply alum and sodium aluminate simultaneously to the lake to maintain internal load control in lake bottom sediments. Apply alum and sodium aluminate at a rate to achieve 50 and 50 g-Al/m^2 to treatment zones 1 and 2, respectively. Final alum dosing and the treatment timeline should be confirmed based on water quality monitoring and sediment coring.

- **Year 10** - Apply alum and sodium aluminate simultaneously to the lake to maintain internal load control in lake bottom sediments. Apply alum and sodium aluminate at a rate to achieve 25 and 25 g-Al /m^2 to treatment zones 1 and 2, respectively. Final alum dosing and the treatment timeline should be confirmed based on water quality monitoring and sediment coring.

The timing and sediment doses of the subsequent treatments may be adaptively adjusted to reduce phosphorus release rates (e.g., below 2 mg/m^2-day) based on follow-up water quality monitoring results and potential release rate experiments.

Another benefit of applying multiple, subsequent alum treatments over a 10-year (or more) time frame is this approach will provide time for native plant re-establishment. As phosphorus is stripped from the water column for each alum application, the clarity of the water should improve, and the area of native plant establishment should increase by allowing plants to grow at greater depths. Native plant re-establishment will be critical to stabilize a clearer water condition and provide an ecological sink for the uptake of in-lake nutrients.

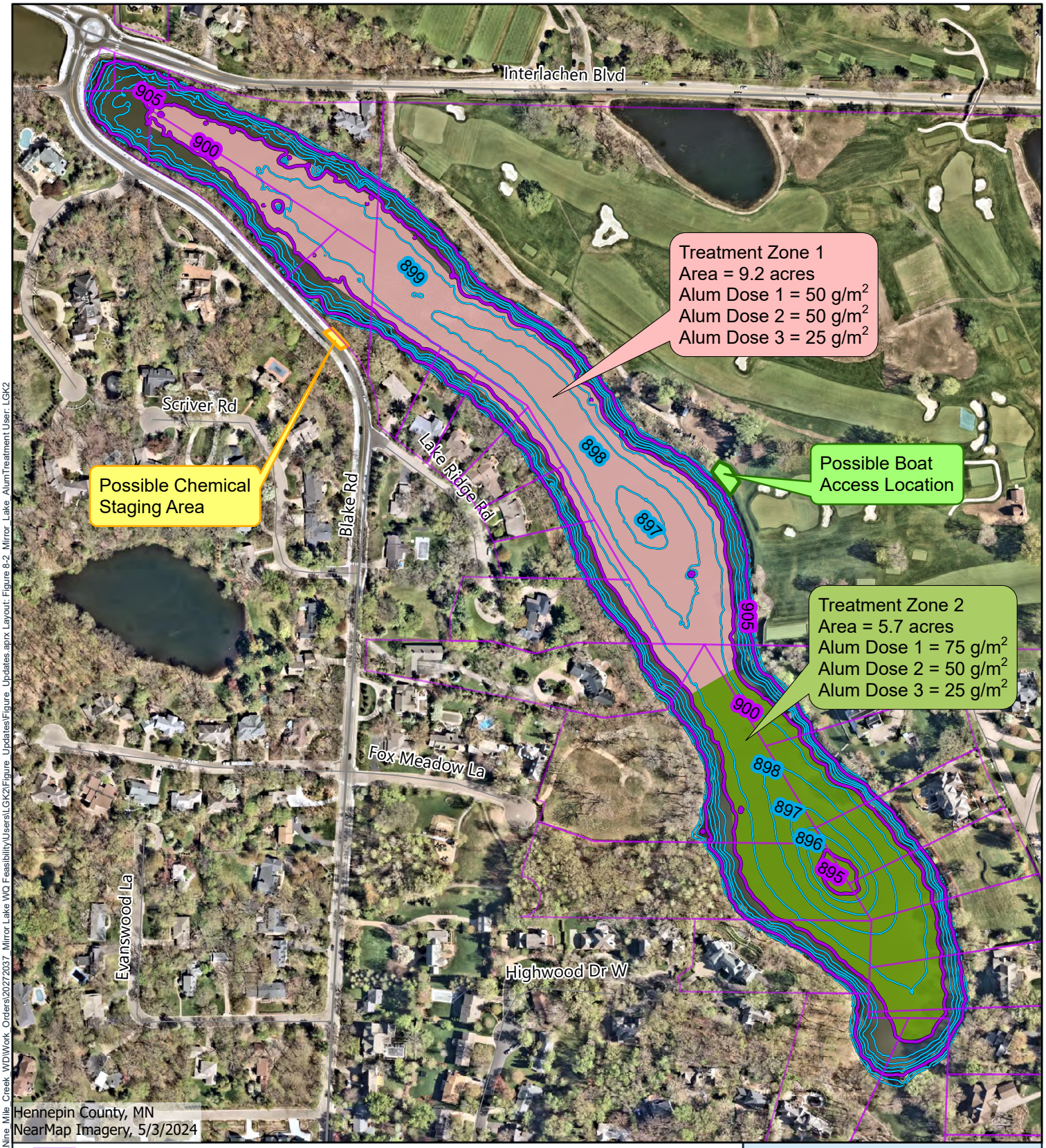
Furthermore, subsequent sediment treatments can be adapted based on review of the effectiveness of other innovative sediment treatment approaches being conducted on shallow lakes in the Nine Mile Creek watershed, such as Arrowhead and Indianhead Lakes in Edina and Wing Lake and Lake Holiday in the Minnetonka (Barr Engineering, 2023).

2.2 Access Agreements

Subcontractor access to perform a sediment treatment on Mirror Lake will likely require access agreements with private landowners. As of this study, parcels owned by the City of Edina, including right-of-way (ROW) parcels, are not conducive for boat access or chemical and equipment staging:

- Blake Road was reconstructed in 2023. The installation of sheet piles along the northwestern shoreline of Mirror Lake does not allow for boat access from city-owned parcels. Additionally, no shoulder or parking stalls are present within the city-owned parcel ROW providing minimal space for chemical tank and equipment storage and chemical loading onto the treatment vessel.
- Fox Meadow Park is located along the southwestern portion of Mirror Lake. Currently, the western side of the park is completely forested with no available vehicular access.

Given that subcontractor access via public parcels is currently not viable, developing access agreements with private landowners is recommended. Figure 2-1 provides a potential option for access and chemical storage. Recommended access and storage options via private parcels are described further below.



Property Boundary
Staging Area
Boat Access Area

Alum Treatment Zones
Zone 1
Zone 2

City of Edina Bathymetry 1-foot Contours (2022)
1-ft Contour
5-ft Contour

N

0 300
Feet

9 MILE CREEK WATERSHED DISTRICT

MIRROR LAKE ALUM TREATMENT PLAN AND ACCESS OPTIONS

FIGURE 2-1

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Access via Interlachen Country Club property:

- NMCWD and Barr staff met with Interlachen Country Club (ICC) staff in September 2024 and inquired about their willingness to allow boat access from their property. Access would include using the paved golf cart path to haul a treatment vessel to ICC's southern shoreline and launch the boat along the less steep portion of the shoreline (Figure 2-2). Boat access will likely require a small lift crane, as access with a boat trailer is likely not feasible. Mats and other protective measures would be installed to reduce damage to non-paved locations and any areas impacted would be restored to existing conditions. ICC was open to this access proposal. They also indicated that lake access would be preferred on Mondays since the golf course is typically closed for maintenance. This can be explored further during final design.

- Storing the alum chemical storage tanks on the ICC property is not recommended since truck access would be very difficult on the golf cart trails and the golf cart trails are likely not designed for such heavy vehicular loads.

Figure 2-2 Possible boat access location on the southern shoreline at Interlachen Country Club

Staging off Blake Road near 5101 Lake Ridge Road:

- For easier truck access, the alum chemical storage tanks could be stored along the ROW of Blake Road near the northern parcel owned by the property owner at 5101 Lake Ridge Road (Figure 2-3). An access agreement would be required to run hoses from the alum storage tanks across the property to the Mirror Lake shoreline. Alum would be loaded onto the treatment vessel

from these hoses. The current property owner was not contacted regarding the potential use of their property.

- Coordination with the City of Edina will also be required since the storage tanks will extend slightly beyond the bike lane into the drive lane. A flagger would likely be required during the alum application to ensure vehicular and biker safety (either hired by the contractor or coordinated with the City of Edina).

Figure 2-3 Possible chemical tank staging location off Blake Road.

In fall of 2024, a meeting was held with City of Edina staff to discuss the study findings and next steps. At this meeting, the city expressed interest in exploring the creation of a maintenance access route through the western, wooded portion of Fox Meadow Park. If constructed, this maintenance access would facilitate easier boat access for a proposed alum treatment and could be beneficial for future lake monitoring, shoreline maintenance, or other lake management activities. Additional coordination between NMCWD and City of Edina staff is needed before finalizing access options for an alum sediment treatment, which can be completed as part of final project design.

2.3 Permitting/Regulatory Considerations

2.3.1 Minnesota Pollution Control Agency (MPCA)

There is no formal permitting program for aluminum treatments (Minnesota Pollution Control Agency, n.d.), but a request must be submitted to the MPCA. Barr has historically made this request in a letter that includes a narrative describing the basis of the treatment (e.g., the need for the treatment to reduce internal loading of phosphorus into a waterbody), treatment doses, plans for monitoring and oversight during treatment, and when the application is planned.

2.3.2 City of Edina Road Closure, Sidewalk, and Traffic Detour Request

If staging for the alum treatment temporarily impacts the bike lane and one of the drive lanes along Blake Road, the City of Edina Road Closure, Sidewalk, and Traffic Detour Request form must be completed. A detour and signing plan will need to be developed and submitted to the public works department along with the request form no later than three days prior to start of work.

2.4 Post Treatment Monitoring

Table 2-1 outlines the recommended monitoring approach following the alum sediment treatments. Follow-up sediment coring and release rate experiments are shown at years 4 and 9 to assess the formation of iron-phosphate (Fe-P) and aluminum phosphate (AI-P). However, the sediment coring timeline can be adjusted based on review of the water quality monitoring data (e.g., bottom phosphorus concentrations increasing, porewater phosphorus increasing). The results of follow-up water quality monitoring and sediment coring will be used to determine the timing of subsequent aluminum treatment(s) to bind remaining or accumulated phosphorus post initial treatment.

Table 2-1 Mirror Lake post sediment treatment monitoring recommendations

Activity By Year	Activity Details
Year 1: Alum sediment treatment	Assuming application in the fall of 2025
Year 2 - 4: Annual or bi-annual lake water monitoring	Water Quality Parameters: - Surface: total phosphorus (TP), total dissolved phosphorus (TDP), orthophosphate (OP), total Kjeldahl nitrogen (TKN), chloride (Cl), Chlorophyll-*a*, Secchi Disk - Bottom: TP, TDP, OP, TKN, Cl - Profiles: Dissolved Oxygen (DO), Temperature, pH, Conductivity Consider performing porewater sampling
Year 4: Sediment analyses	Collect 2 sediment cores and analyze for phosphorus fractions, iron, and aluminum. Consider performing laboratory phosphorus release rate experiments.
Year 5: Assess the need for additional treatment and monitoring	Review water quality and sediment coring data to determine next steps
Year 5–10: Lake water monitoring	Determine monitoring schedule based on Year 5 data assessment
Year 9: Sediment analyses	Collect 2 sediment cores and analyze for phosphorus fractions, iron, and aluminum. Consider performing laboratory phosphorus release rate experiments.
Year 10: Assess the need for additional treatment and monitoring	Review water quality, porewater, and sediment coring data to determine next steps

2.5 Opinion of Cost

As part of the *Mirror Lake Water Quality Study* (Barr Engineering, Mirror Lake Water Quality Study, 2023), water quality modeling was completed to predict the effects of treating lake bottom sediments. Further design in this study did not warrant changes to the original water quality modeling completed in 2023. Water quality modeling indicates that a 70 percent reduction in internal phosphorus loading will reduce phosphorus loading to Mirror Lake by approximately 42 pounds on average during the growing season.

Planning-level opinions of probable cost were developed for alum and sodium aluminate application to lake bottom sediments. Table 2-2 summarizes the estimated application, engineering/design, and monitoring costs based on 2024 values. The opinions of cost are intended to aid in evaluating and comparing alternatives and are not an absolute value. The AACE Class 4 opinion of cost was used based on the partial project definition, use of parametric models to calculate estimated costs (i.e., making use of order-of-magnitude costs from similar projects), and uncertainty, with an acceptable range of between - 20% and +30% of the estimated project cost. A detailed opinion of probable cost for the application of alum and sodium aluminate is included in .

Consideration of cost-benefit in terms of phosphorus removal can be a useful way to evaluate project effectiveness for lakes where excess nutrients (specifically phosphorus) lead to poor water quality. The annualized cost-benefit for the Mirror Lake sediment treatments is $700 per pound of phosphorus removed, assuming the costs presented in Table 2-2, a 20-year project lifespan, and 42 pounds of annual total phosphorus removal.

The cost estimate provided in Table 2-2 assumes boat access to the lake via the Interlachen Country Club property, which would require an access agreement with Interlachen Country Club. If the City of Edina constructs a maintenance access through Fox Meadow Park, access to the lake would be somewhat simpler and contractor mobilization costs for the sediment treatments would likely be lower (an estimated $5,000 - $7,000 reduction in mobilization costs).

Table 2-2 Mirror Lake sediment treatments cost estimate

Project	Application Cost Estimate [1]	Engineering/ Design Cost Estimate [2]	Monitoring Cost Estimate [3]	Sediment Analyses Cost Estimate [4]	Total 10-year Capital Cost Estimate (-20% to +30%) [5]
Lake Sediment Treatments	$245,000	$50,000	$70,000	$30,000	$435,000 ($348,000 - $566,000)

[1] Application cost estimate assumes three alum treatments spaced by 5 years (treatment conducted at years 0, 5, and 10).
[2] Engineering/Design cost estimate assumes assistance with final sediment treatment design, contract documents, bid administration, and field observation during application.
[3] Cost estimate assumes annual water quality for years 2-5 post initial treatment and bi-annual water quality for years 6-10 post initial treatment (i.e., 7 years of monitoring post sediment treatment)
[4] Cost estimate assumes follow up sediment coring and release rate experiments to determine subsequent alum application timeline at years 4 and 9 post initial treatment.
[5] Total capital cost estimate includes 10% contingency, 7 years of monitoring post treatment, and 2 sediment analyses.

3 Shoreline Stabilization

As a part of the *Mirror Lake Water Quality Study* (Barr Engineering, 2023), Barr completed a shoreline erosion and stability general assessment of Mirror Lake in April 2023. The shoreline areas assessed, as shown in Figure 3-1 were divided into three sections: Interlachen Country Club (ICC), the northern area by Blake Road South (city-owned parcels), and the residential areas. The water quality study identified high level shoreline erosion and stability concerns and outlined overarching management practices to improve shoreline stability. As part of this feasibility study, shoreline conditions were further evaluated, and potential stabilization practices were identified on a parcel-by-parcel basis. Conceptual designs for stabilization measures were developed to help the NMCWD and property owners understand the scope and costs of potential remedial measures to stabilize the shoreline and minimize future erosion. Public communication and outreach were also conducted as part of this study in conjunction with NMCWD staff to further assess feasibility of shoreline stabilization since incorporation of shoreline stability practices would require partnerships with private property owners.

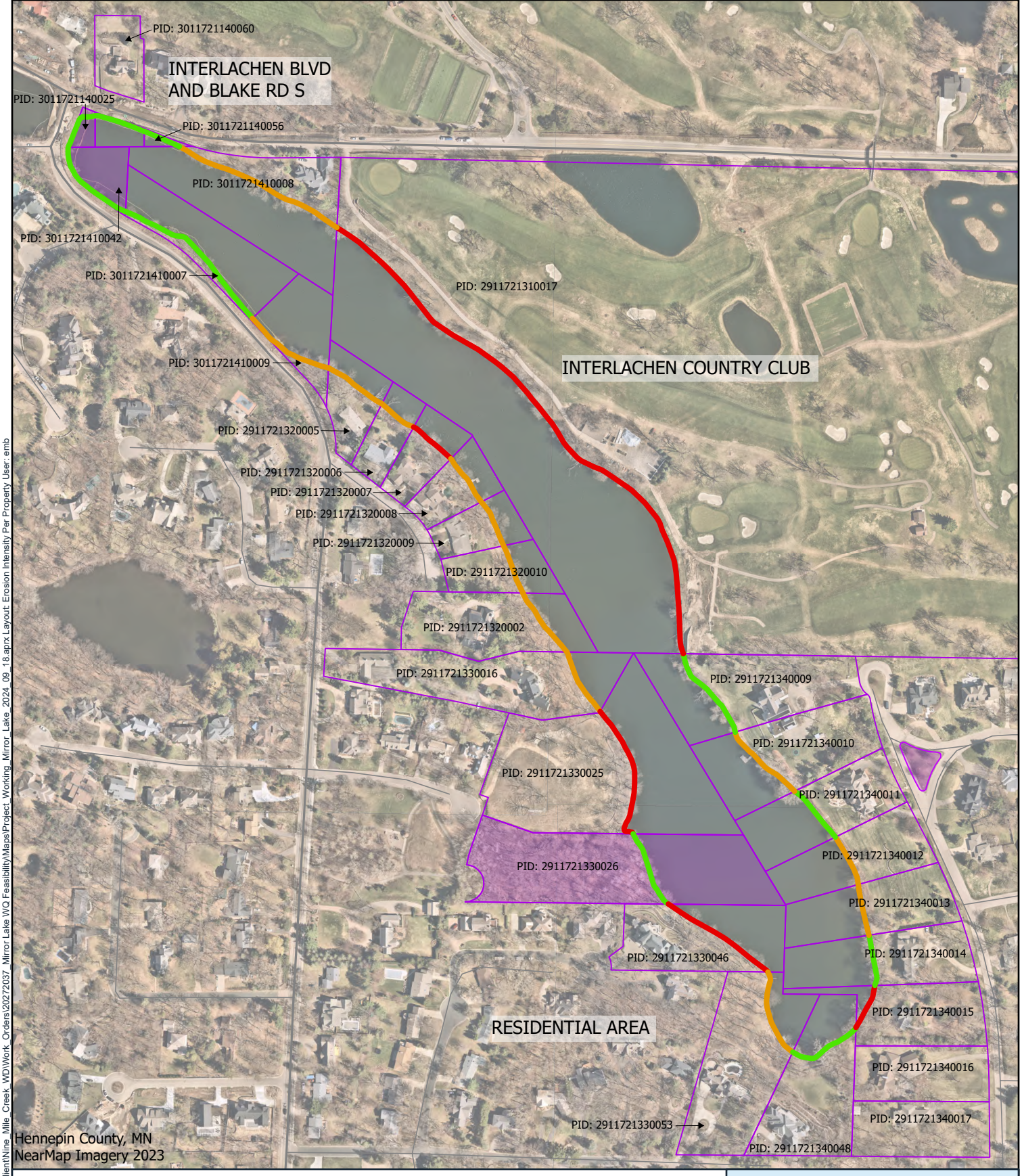
The northern area by Blake Road South was under construction as part of a street reconstruction project during the water quality study in 2023, with restoration and erosion control efforts continuing by the city of Edina in 2024. Although not included in the scope of the feasibility study, NMCWD staff did reach out to the City of Edina during the feasibility study to better understand the construction timeline and restoration plans. Besides these communications, the northern area by Blake Road South did not undergo the same assessments as the other two shoreline areas. The subsections below summarize the feasibility tasks that were completed for the ICC parcel and residential parcels.

Figure 3-1 Mirror Lake shoreline observation areas

3.1 Shoreline Erosion and Stability Assessment

The 2023 and 2024 shoreline erosion and stability assessment for Mirror Lake involved field inspections and a review of GIS NearMap imagery that could potentially indicate historical erosion patterns. During the 2023 site inspections, the entire shoreline was visually assessed from the water for signs of erosion including review of bank instability, bank undercutting, fallen trees, and density and type of vegetation ground cover. GIS analysis included a review of historical aerial imagery to examine potential shoreline changes over time. Due to variations in image angles and low resolution in the historical aerials, the analysis provided limited conclusive evidence of significant shoreline recession or erosion trends. As such, field observations resulted in the most reliable assessment of current shoreline erosion and stability conditions.

Utilizing the 2023 field observations and GIS measurements, an erosion intensity scoring system was developed as part of this feasibility study to categorize shoreline instability/erosion as being either high, medium, or low. The erosion intensity scoring system was based on evaluation criteria developed by the Wisconsin Department of Natural Resources (WiDNR, 1990). Several factors were considered, including but not limited to, bank height, bank composition, bank vegetation, average fetch, and the influence of adjacent shoreline structures. Each of these factors contributed to a composite score that helped identify areas most at risk for ongoing erosion. Figure 3-2 shows the high, medium, and low erosion intensity ratings of the Mirror Lake shoreline, by parcel. Five of the evaluated parcels received a high erosion intensity rating and thirteen parcels received a medium erosion intensity rating.



Erosion Intensity

Rank

- Low
- Medium
- High
- Property Boundary
- City-owned Parcel

0 300 600

Feet

9 MILE CREEK WATERSHED DISTRICT

MIRROR LAKE EROSION INTENSITY PER PROPERTY

FIGURE 3-2

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3.2 Residential Properties - Design and Outreach

Shoreline stabilization concept designs were developed for the residential parcels on Mirror Lake to help the NMCWD and property owners understand the scope and costs of potential remedial measures to stabilize the shoreline and minimize future erosion. The "residential parcels" include 15 privately-owned parcels and one city-owned parcel (Fox Meadow Park). The following sections provide details on development of the shoreline stabilization concept designs for the residential parcels and outreach to residential property owners.

3.2.1 Concept Designs

As part of the Mirror Lake shoreline stabilization project, several slope stabilization techniques were evaluated to address erosion and promote long-term shoreline stability and improved habitat. Using a desktop analysis of erosion intensity potential along with onsite observations, site-specific recommendations were developed based on the existing severity of erosion and the potential for continued degradation. The residential shoreline stabilization techniques include coir logs, vegetated reinforced soil slopes (VRSS) with riprap toe protection, and native plant buffers. The erosion intensity suitability, advantages, disadvantages, and relative costs of each stabilization technique are presented in Table 3-1. Detailed descriptions of the techniques, example applications, and example photos are also provided in the graphical representations shown in Figure 3-3 and Figure 3-4.

Figure 3-5 summarizes the shoreline stabilization techniques recommended for each of the properties to stabilize the shoreline, minimize or prevent erosion, and enhance ecological function. These shoreline stabilization techniques can be implemented individually, in combination, or modified in several ways depending on future design.

Increased and improved native plant buffers are recommended for all residential properties on the lake. A majority of lakeshore properties have invasive species or turf maintained up to the water's edge. Native plant buffers are an essential component of shoreline stabilization. Buffer improvements would help restore critical ecological functions by providing pollinator habitat, stabilizing soils, reducing stormwater runoff, and filtering pollutants before reaching the lake. Note that the recommended buffer width varies depending on site specific conditions.

The shoreline stabilization techniques identified for each individual property do not capture all possible stabilization techniques; however, Barr selected those that are considered most appropriate for the existing shoreline conditions on each parcel based on the best available information. Through future site investigation and design, additional techniques may be selected based on site characteristics, past project experiences, engineering judgement, and review of literature.

Table 3-1 Summary of shoreline stabilization techniques

Slope Stabilization Technique [1]	Erosion Intensity Suitability [2]	Design Advantages [3]	Design Disadvantages [3]	Relative Installation Cost [4]
Coir Log	Low - Medium	• Becomes more effective as plants establish over time • High wildlife habitat value	• Requires more land area adjacent to shore due to flatter slope profile require for maintaining slope • Lower protection against high wave energy • Vegetation establishment takes time • Human foot-traffic may damage plantings	Medium
Riprap Toe with Vegetated Reinforced Soil Slopes (VRSS)	Medium - High	• Used to establish vegetation on steep slopes (alternative to hard retaining walls) • Becomes more effective as plants establish over time • Vegetation can hide unnatural looking riprap • Hard armor on toe provides energy dissipation for ice heave and large waves	• Labor intensive install • Relatively expensive	High
Native plant buffer	Low - High	• Becomes more effective as plants establish over time • High wildlife habitat value • Reduces polluted runoff from entering lake (slows runoff and promotes infiltration) • Can be used in combination with VRSS and coir logs	• Vegetation establishment takes time • Ongoing maintenance will be required to promote native plant diversity and control invasive weed species	Low

[1] See Figure 3-3 and Figure 3-4 for additional design considerations
[2] See Section 3.1 for the completed shoreline erosion and stability assessment
[3] Adapted from the (United States Department of Agriculture, 1997)
[4] Opinion of construction costs were developed for each property and based on similar recent construction project bid prices.

KEY

Excavation Extent

Existing Slope

PLANT BUFFER

A plant buffer zone is an unmowed strip of native vegetation along the water's edge, typically 25-50 feet wide. Installing a buffer zone can restore many ecological functions critical to the health of the lake that may have been minimized previously by sod, hard structures, or mowing. Planting native grasses and flowering plants will diversify and enhance your shoreline and provide a seasonal show of color along with a deep root structure to stabilize the soil. Plant buffers can also help trap and absorb nutrients from runoff that may otherwise enter the lake.

COIR LOG

Coir logs are sturdy rolls, about 12 to 16 inches thick, made from tightly packed coconut fibers. Coir logs are often installed at the toe of the shoreline slope, as shown. Native plants can be installed behind, within, and/or in front of the coir logs. Over time, usually between 5 to 8 years, the coir logs will naturally break down. By then, the plants will have established strong root systems to keep the shoreline stable.

SHORELINE STABILIZATION TECHNIQUES FOR MILD SLOPES

9 MILE CREEK WATERSHED DISTRICT

BARR

FIGURE 3-3

Planted native buffers can assist in protecting and stabilizing the slope, as well as trapping and absorbing nutrients that may otherwise enter the lake.

Granular filter layer

KEY

- Optional Geotextile Fabric
- Excavation Extent
- VRSS Extent
- Existing Slope

VEGETATED REINFORCED SLOPE STABILIZATION (VRSS)

VRSS is a method used to secure steeper and eroding slopes, ensuring they are stable. This approach involves layering rocks, a specialized fabric, soil, and plants in a way that structurally supports the slope. The process includes installing live branches, such as dogwoods and willows, directly into the layers, as shown.



RIPRAP TOE PROTECTION

Riprap toe protection* involves using a mix of large rocks ranging in size from 2-inch to 12-inch diameter, or bigger. The riprap typically extends from above the ordinary high water level to below the lake bed to prevent erosion. To keep the rocks from sinking into the soil underneath, a layer of coarse gravel acts as a filter. Sometimes, a special fabric is also installed under the rocks for additional stability. This method is often combined with planting new, native vegetation on the upper parts of the bank to further protect and stabilize the area.



SHORELINE STABILIZATION TECHNIQUES FOR STEEPER, HIGHLY ERODED SLOPES

*Installation of riprap is allowed by the MnDNR only if there is a demonstrated need.

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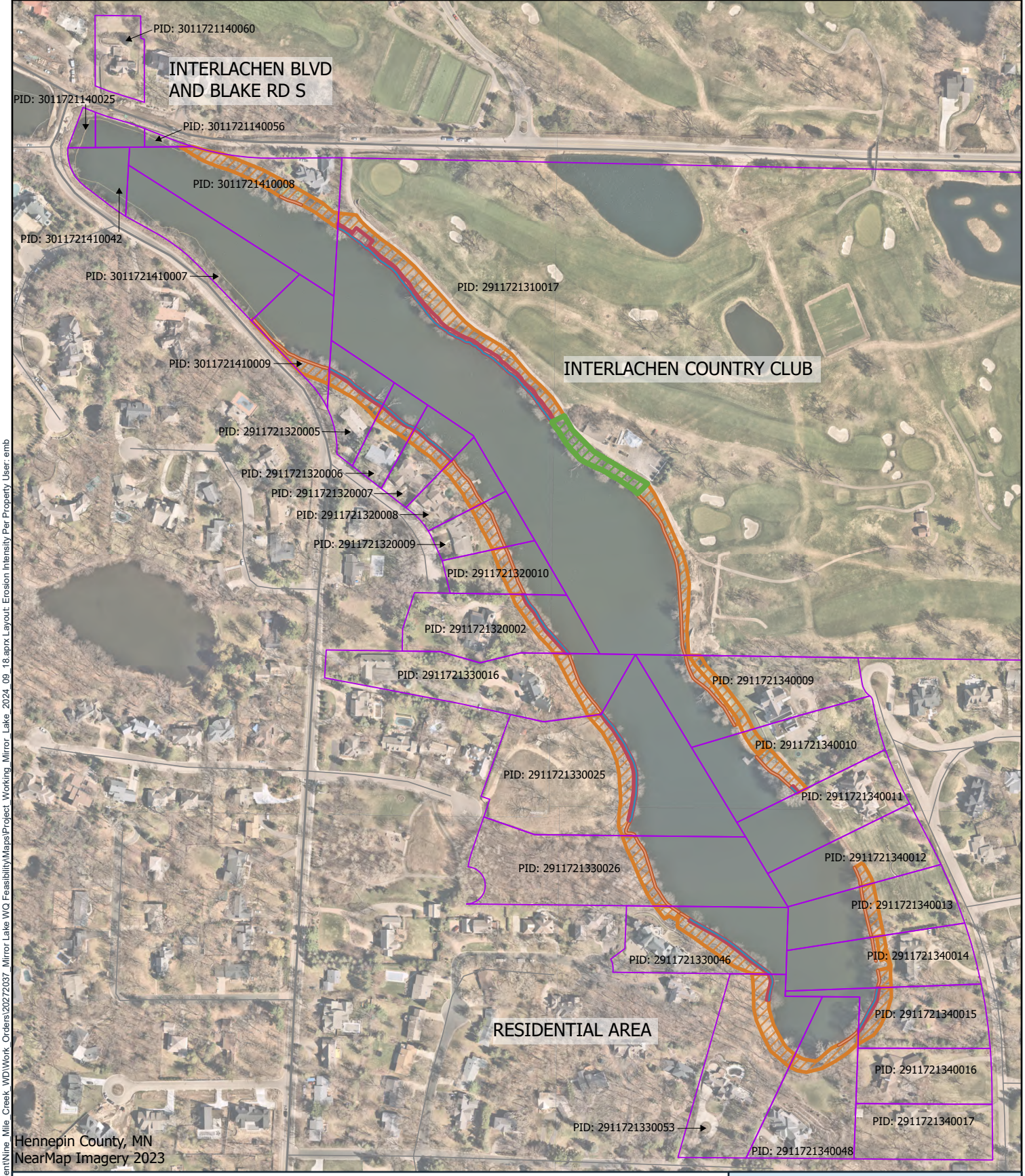
BARR

FIGURE 3-4



STABILIZATION TECHNIQUES

- Riprap Toe Protection
- Vegetated Reinforced Slope Stabilization
- Native Plant Buffer
- BioLog
- Buckthorn Removal and Restoration

Erosion control practices may require grading changes within extents shown to reduce the steepness of the shoreline.

Please Note:

This figure shows concept level stabilization recommendations. A final design may be modified based on additional analysis and/or owner preferences.

0 150 300
Feet

9 MILE CREEK WATERSHED DISTRICT

MIRROR LAKE SHORELINE STABILIZATION TECHNIQUES PER PROPERTY

FIGURE 3-5

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3.2.2 Resident Outreach

Public engagement with residents that live on Mirror Lake was an important part of assessing feasibility of the shoreline stabilization practices since implementation will require partnerships between NMCWD and lake property owners. NMCWD and Barr staff utilized a variety of strategies to contact and engage with residents who own property on Mirror Lake to identify shoreline issues, discuss opportunities for shoreline stabilization, and to solicit landowner feedback and participation interest in potential future shoreline improvement projects. Public engagement included one public meeting, mailings, and scheduled onsite meetings with individual landowners.

3.2.2.1 Public meeting and mailings

A hybrid public meeting was held at the NMCWD Discovery Point in the evening on May 13, 2024 to provide an overview of recommended water quality improvements to Mirror Lake. In late-April 2024, a postcard was mailed to Mirror Lake residents informing them of the planned community meeting. Two Mirror Lake residents attended the public meeting (one online and one in-person). At this meeting, NMCWD and Barr staff provided an overview of the feasibility study and goals for management of the lake. While the meeting provided a high-level overview of all management practices identified in the *Mirror Lake Water Quality Study* (Barr Engineering, 2023), most of the meeting focused on shoreline stabilization and gathering interest for onsite meetings with lakeshore property owners. Following the meeting, a survey was available for residents to sign up for onsite meetings. Given the low attendance at the May 13, 2024 meeting, NMCWD and Barr staff recognized that alternative engagement methods would be necessary to further assess interest of shoreline property owners to participate in potential future shoreline improvement projects.

Following the public meeting, NMCWD staff mailed additional post cards and letters to Mirror Lake shoreline owners to foster participation in onsite meetings. NMCWD staff also had success with word-of-mouth interactions from supportive lakeshore owners.

3.2.2.2 Onsite Meetings

NMCWD and Barr staff conducted onsite meetings with several interested property owners to discuss site-specific conditions, share and gather feedback on preliminary slope stabilization concepts, and to gauge interest in participating in implementation of the proposed stabilization measures.

Prior to each onsite meeting, Barr developed informational handouts for each property summarizing and graphically showing the site-specific erosion concerns and recommended stabilization techniques identified during concept design. An example handout is shown in Figure 3-6. All handouts are presented in . As demonstrated in this example handout, each handout featured:

1. A site-specific erosion rating—categorized as high, medium, or low—based on the erosion intensity analysis.
2. Representative photos illustrating the specific shoreline stability issues identified on each property along with descriptions of the erosion concerns.

3. The types and locations of the recommended shoreline stabilization techniques.

Each handout was designed to be accessible and informative, offering property owners a preliminary concept design that could be adapted based on further analysis or specific owner preferences. Besides the handout, each resident packet also included the graphical shoreline stabilization cross sections shown in Figure 3-3 and Figure 3-4.

Sharing these graphical figures with residents provided additional information on potential stabilization techniques and helped emphasize the ecological benefits of these practices, such as enhanced water quality, habitat creation, and improved shoreline stability.

In total, NMCWD and Barr completed onsite engagement meetings with 7 of the 15 residential shoreline property owners in August and September of 2024. During each meeting Barr and NMCWD staff reviewed the site-specific handouts, discussed erosion concerns identified through our field assessments, and outlined potential design alterations tailored to each property owners' requests. In addition, Barr staff walked the property with the homeowners and noted shoreline erosion issues and vegetative cover that may have changed since the initial site visit in 2023.

All 7 property owners Barr staff met with expressed interest in all, or portions of, the proposed stabilization techniques discussed. Property owners generally recognized the need to improve the water quality of the lake and were commonly interested in the proposed shoreline stabilization and buffer improvements if they served as a potential solution to the lake water quality issues. A majority of the property owners expressed interest in stabilizing their shorelines and improving habitat for pollinators. The two biggest concerns noted were:

- The visual impacts that may result from clearing vegetation - some homeowners were interested in opening up views to the lake while others were concerned with maintaining the privacy screening currently being provided by buckthorn. Site specific vegetation removal and planting design could be adjusted in future design phases to meet individual property owners' requests while also meeting NMCWD's shoreline stabilization objectives.
- The individual cost that property owners will be required to contribute as part of the improvement project. The cost apportionment between property owners and NMCWD was not defined during this stage of the study.

These concerns were noted in meeting summary reports and can be addressed in later phases of the project.

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EROSION RATING:

Low Medium **High**

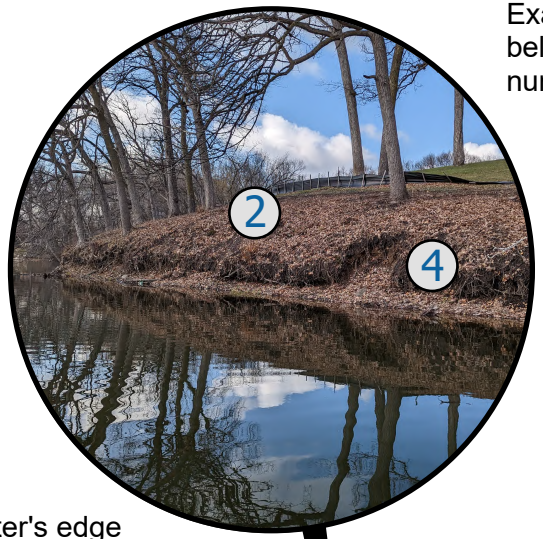
Erosion rating is based on the level of erosion concerns identified during erosion intensity analysis.

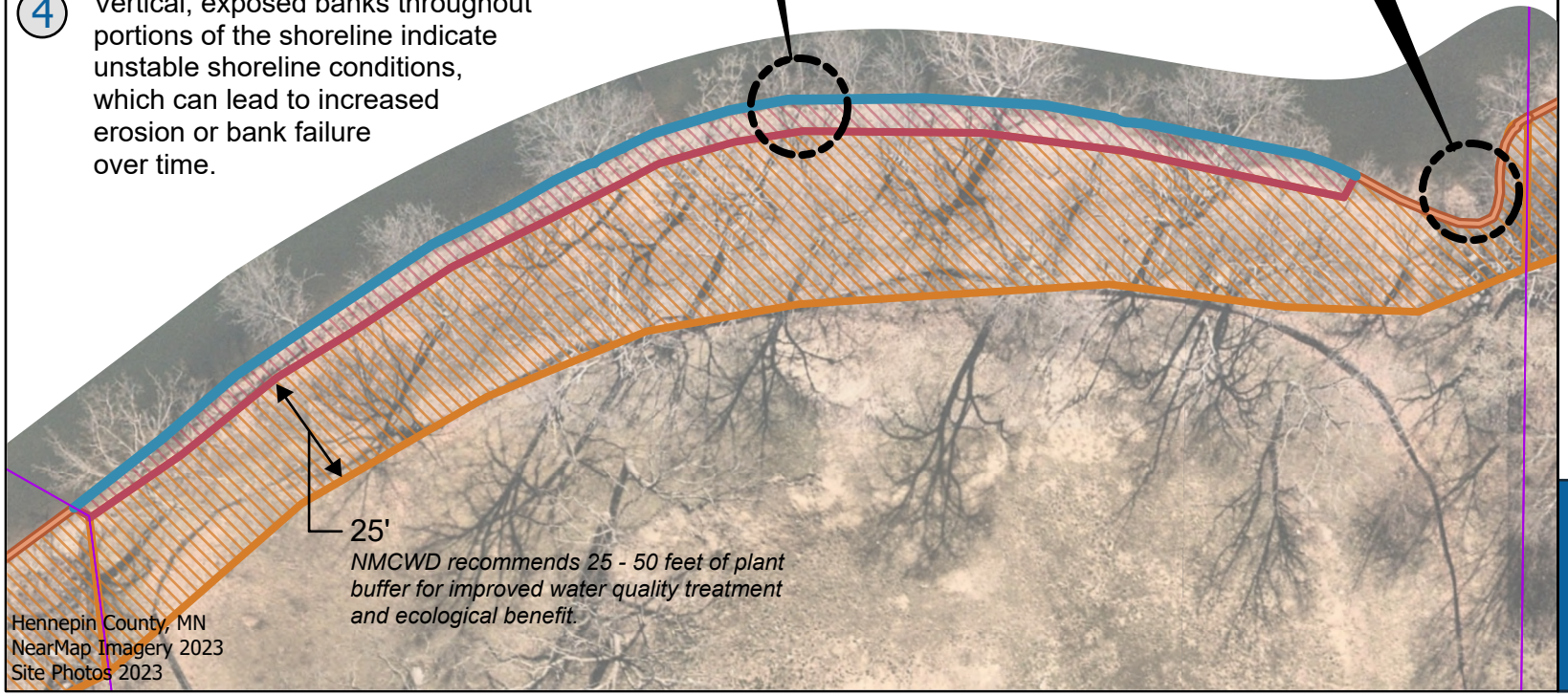
EROSION CONCERNS:

1. Lack of vegetated buffer and
2. bare soils throughout the shoreline can lead to high runoff velocities and increased soil erosion.
3. Turf extended to the lake water's edge throughout the shoreline can lead to increased erosion due to minimal protection against waves, ice, and weather.
4. Vertical, exposed banks throughout portions of the shoreline indicate unstable shoreline conditions, which can lead to increased erosion or bank failure over time.

SITE PHOTOS:

Examples of the erosion concerns are shown below with the corresponding erosion concerns numbers.





Hennepin County, MN
NearMap Imagery 2023
Site Photos 2023

LEGEND

- Property Boundary

STABILIZATION TECHNIQUES

- Riprap Toe Protection
- Vegetated Reinforced Slope Stabilization
- Native Plant Buffer

Erosion control practices may require grading changes within extents shown to reduce the steepness of the shoreline.

0 25 50
Feet

Please Note:

This figure shows concept level stabilization recommendations. A final design may be modified based on additional analysis and/or owner preferences.

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9 MILE CREEK WATERSHED DISTRICT

Example Mirror Lake Shoreline Stabilization Concept Design

6000 Fox Meadow Ln
Edina, MN 55436

FIGURE 3-6

3.3 Interlachen Country Club - Design and Outreach

Shoreline stabilization concept designs were developed for the portion of the Mirror Lake shoreline owned by Interlachen Country Club (ICC) to help the NMCWD and property owners understand the scope and costs of potential remedial measures to stabilize the shoreline and minimize future erosion. The following sections provide details on development of the shoreline stabilization concept design and coordination with ICC.

Shoreline stability and erosion concerns were identified along the ICC shoreline during field observations in spring 2023. Barr staff observed turf extending to the lake water edge over approximately 400 feet of the southern section of the ICC shoreline. In this area, near vertical banks were observed, which likely occurred due to wave action, ice movement, and lake level bounce acting on unstable banks comprised of turf grass with shallow roots. Stormwater runoff from hard surfaces such as golf cart trails and the service road may also contribute to shoreline and bank erosion. Additionally, there is an area of notable erosion and slope failure (approximately 30-foot x 40-foot) in the northernmost portion of the ICC shoreline as shown in Figure 3-7.

Figure 3-7 Area of notable erosion and slope failure along the Interlachen Country Club shoreline

3.3.1 Onsite Meeting #1

Prior to starting conceptual design, Barr and NMCWD staff met with ICC staff on June 5, 2024. The overall goals of meeting #1 were to:

1. Understand ICC's concerns with their shoreline erosion/stability and discuss historical observations.

2. Better understand infrastructure and restoration limitations/requirements to inform conceptual design efforts.
3. Discuss the following high-level slope stability and slope failure mitigation options, including advantages and disadvantages of each:
    - do-nothing
    - grading a stable slope
    - placement of riprap or rock buttresses
    - modular block retaining walls
    - vegetated reinforced vegetated soil slope (VRSS)
4. Discuss potential partnership opportunities.

Notable discussion items from the meeting with ICC staff that influenced concept design included:

1. Grading to a stable slope will not be feasible due to the location of the existing golf cart path, as well as the locations of the #11 green and #12 tee box.
2. ICC staff preferred natural vegetation stabilization approaches such as VRSS to riprap, rock, or other hardscape approaches (e.g., retaining walls). It was emphasized during the meeting that toe protection along the base of the slope would likely require riprap.
3. ICC staff discussed the recent restoration of their golf course including modernization of the grass. Staff indicated that aesthetics and compatibility of the Mirror Lake shoreline with their recent restoration efforts are important to its staff and members. As such, they are interested in native buffer plantings primarily composed of grass and sedge species in areas visible by golfers since flowering species are currently not a preferred golf course aesthetic. ICC staff was open to a more diverse native plant buffer in areas that would not be visible on the golf course (primarily the northern 1,000-foot shoreline that is not visible to golfers due to steep slopes extending down to Mirror Lake).
4. Barr and NMCWD staff discussed opportunities to convert existing turf- and invasive species-covered slopes with more robust perennial native vegetation. Barr and NMCWD discussed opportunities to replant the shoreline edge with more drought resistant and vigorous native species in addition to expanding the width of the no-mow buffer area (where feasible to maintain golf but to reduce potential runoff from irrigation, herbicides, and fertilizers).
5. The northern portion of ICC's shoreline (approximately 1,000 feet) was recently cleared of numerous canopy trees (ash and oak affected by oak wilt) and is currently vegetated with non-native smooth brome grass, Canada thistle, reed canary grass, stinging nettle, and Solomon's seal (a native woodland species that will likely not persist following removal of the canopy trees). Barr discussed the benefits of replacing these weedy species with native grass and pollinator species that could be more safely managed with fire and selective water safe herbicide. This would reduce the need for mowing on the extremely steep slopes to control weeds and trees.

3.3.2 Concept Design

A shoreline stabilization conceptual design was developed to address erosion and promote long-term shoreline stability and improved habitat along the ICC shoreline based on the desktop analysis of erosion intensity, onsite observations, and feedback received during onsite meeting #1 with ICC staff. The shoreline stabilization concept design for the ICC parcel is shown in Figure 3-8.

The recommended shoreline stabilization techniques differ along the ICC shoreline due to variations in the existing severity of erosion, the potential for continued degradation, and existing vegetation species. For example, due to the surficial slope failure observed on the northern portion of ICC's shoreline, a larger VRSS system or other repair, is recommended (providing it is supported by a geotechnical investigation, see Section 3.3.4). If left unaddressed, this could lead to further erosion and additional bank failure. A graphical cross section of the VRSS system proposed to mitigate the bank failure is shown in Figure 3-9. Other portions of the northern shoreline that exhibit vertical banks may also require techniques with a greater level of engineering, such as VRSS combined with riprap toe protection near the water's edge and planted buffers at higher elevations. For all VRSS areas, a simplified plant palette is recommended to maintain visual continuity with the golf course and ensure that the stabilization methods are effective for steeper, more eroded areas.

Along the southern shoreline where erosion is not as severe, coir logs and planted buffers are the recommended practices. A graphical cross section of the recommended techniques for the southern shoreline is shown in Figure 3-10. Currently turfgrass extends all the way to the lake water edge along the southern shoreline. By replacing this turfgrass with the native sedge grasses, the bank will be stabilized while maintaining an appearance that aligns with ICC's preferred aesthetics.

Additionally, buckthorn removal and replacement with native shrubs and grasses is recommended as a component of the shoreline restoration at ICC.

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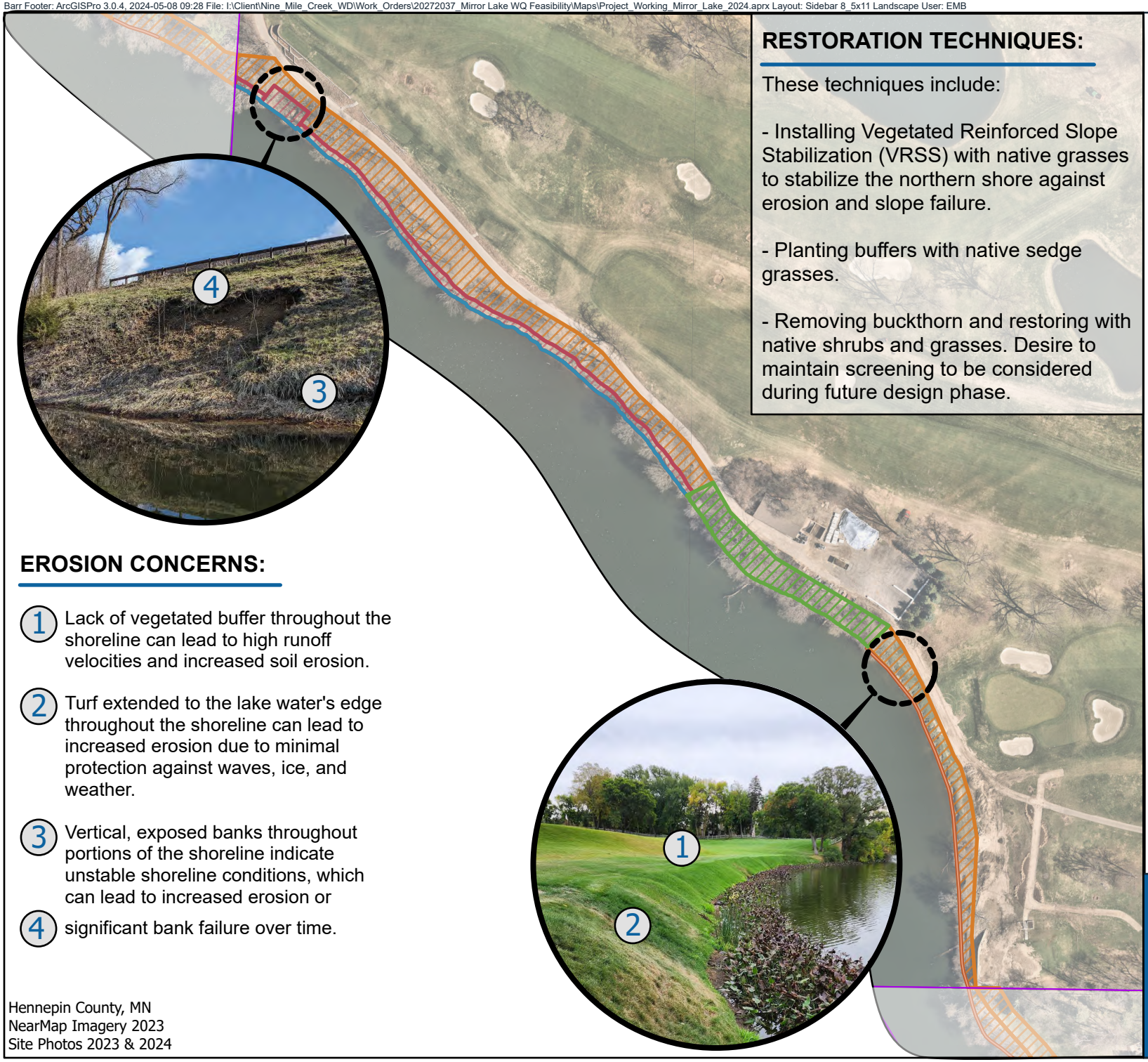


RESTORATION TECHNIQUES:

These techniques include:

- Installing Vegetated Reinforced Slope Stabilization (VRSS) with native grasses to stabilize the northern shore against erosion and slope failure.

- Planting buffers with native sedge grasses.

- Removing buckthorn and restoring with native shrubs and grasses. Desire to maintain screening to be considered during future design phase.

EROSION CONCERNS:

1. Lack of vegetated buffer throughout the shoreline can lead to high runoff velocities and increased soil erosion.
2. Turf extended to the lake water's edge throughout the shoreline can lead to increased erosion due to minimal protection against waves, ice, and weather.
3. Vertical, exposed banks throughout portions of the shoreline indicate unstable shoreline conditions, which can lead to increased erosion or
4. significant bank failure over time.

Hennepin County, MN
NearMap Imagery 2023
Site Photos 2023 & 2024

LEGEND

- Property Boundary

STABILIZATION TECHNIQUES

- Vegetated Reinforced Slope Stabilization
- Native Plant Buffer
- Buckthorn Removal and Restoration

Erosion control practices may require grading changes within extents shown to reduce the steepness of the shoreline.

N

0 100 200
Feet

Please Note:

This figure shows concept level stabilization recommendations. A final design may be modified based on additional analysis and/or owner preferences.

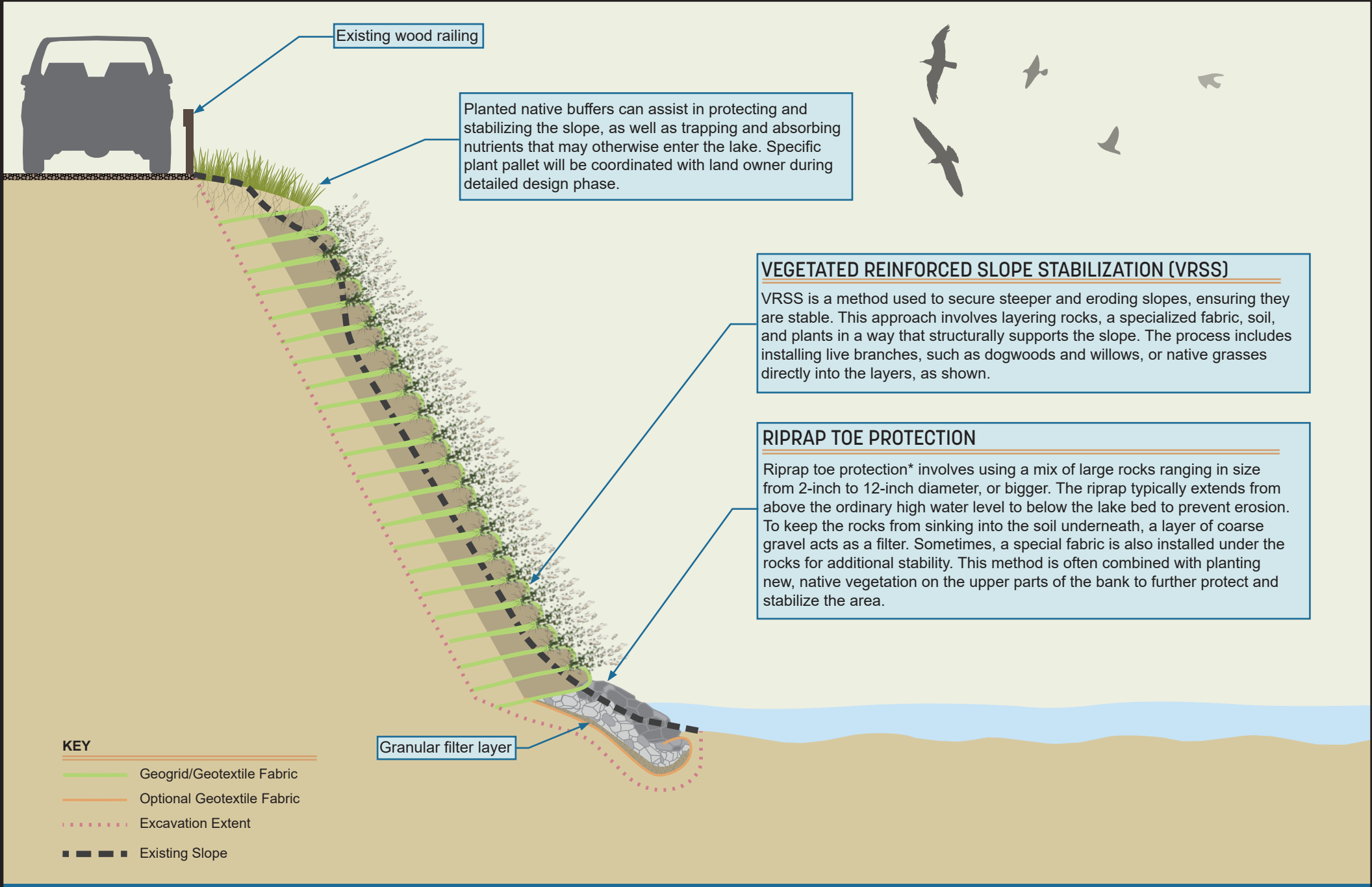
BARR

9 MILE CREEK WATERSHED DISTRICT

Mirror Lake Shoreline Stabilization Concept Design

6200 Interlachen Blvd
Edina, MN 55436

FIGURE 3-8



VEGETATED REINFORCED SLOPE STABILIZATION (VRSS)

VRSS is a method used to secure steeper and eroding slopes, ensuring they are stable. This approach involves layering rocks, a specialized fabric, soil, and plants in a way that structurally supports the slope. The process includes installing live branches, such as dogwoods and willows, or native grasses directly into the layers, as shown.

RIPRAP TOE PROTECTION

Riprap toe protection* involves using a mix of large rocks ranging in size from 2-inch to 12-inch diameter, or bigger. The riprap typically extends from above the ordinary high water level to below the lake bed to prevent erosion. To keep the rocks from sinking into the soil underneath, a layer of coarse gravel acts as a filter. Sometimes, a special fabric is also installed under the rocks for additional stability. This method is often combined with planting new, native vegetation on the upper parts of the bank to further protect and stabilize the area.

SHORELINE STABILIZATION TECHNIQUES FOR SLOPE FAILURE LOCATION

*Installation of riprap is allowed by the MnDNR only if there is a demonstrated need.

9 MILE CREEK WATERSHED DISTRICT

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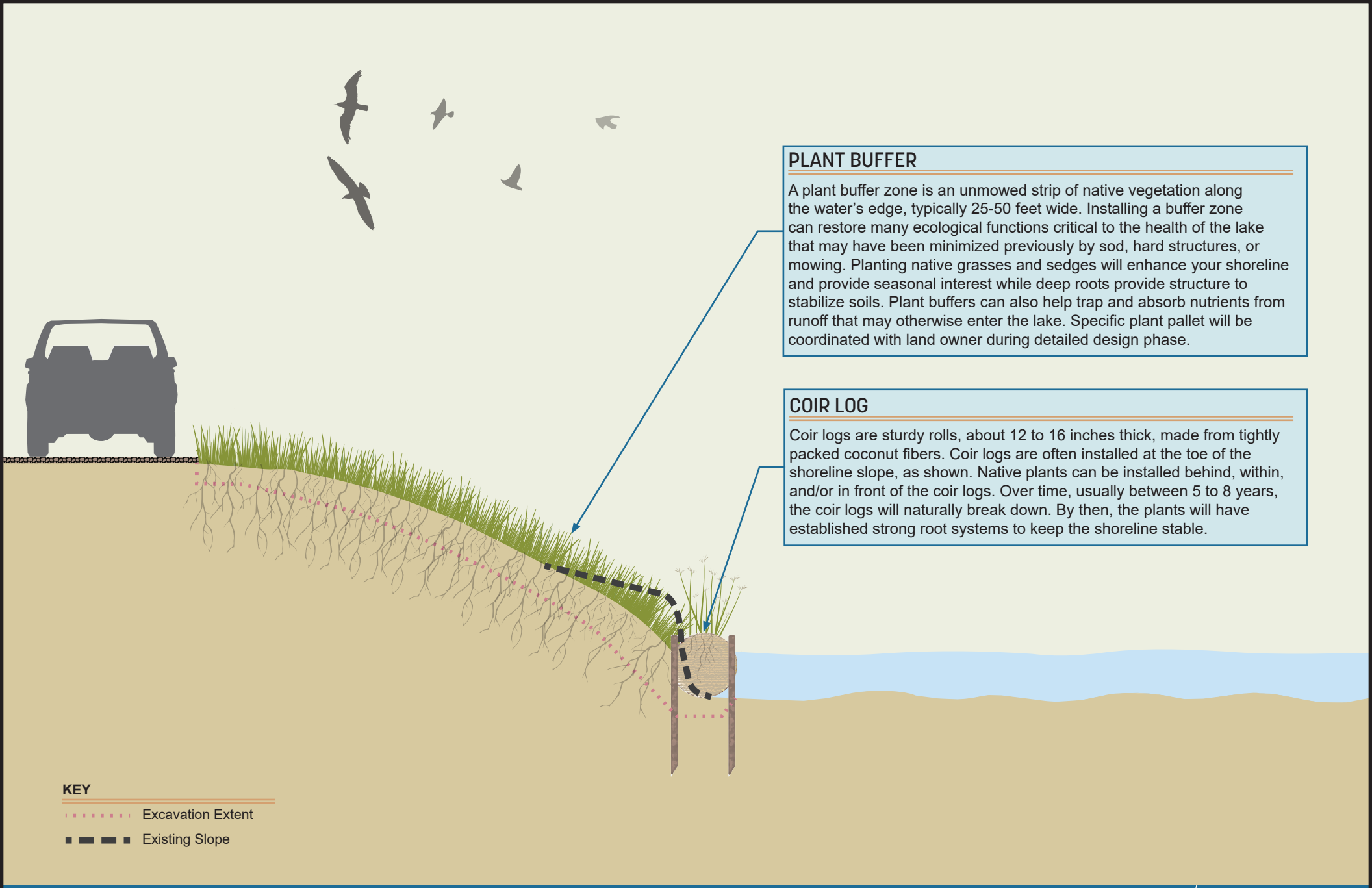
FIGURE 3-9



SHORELINE STABILIZATION TECHNIQUES FOR MILD SLOPES

9 MILE CREEK WATERSHED DISTRICT

BARR

FIGURE 3-10

3.3.3 Onsite Meeting #2

After developing the initial shoreline stabilization concept design and graphical cross sections, Barr and NMCWD staff participated in a follow-up meeting with ICC staff on September 3, 2024. The conceptual design was shared for review and discussion. Notable discussion items from meeting #2 with ICC staff included:

1. ICC staff did not object to the concept drawings. The consensus of meeting participants was that the drawings met the objectives of the meeting #1 discussion. It was noted that cost estimates had not yet been prepared for the repairs.
2. NMCWD staff informed ICC staff that implementation of the recommended shoreline stabilization measures would likely include some level of cost sharing.
3. It was emphasized that the VRSS concept at the identified notable erosion area assumes that a surficial repair is sufficient at this location, although the root cause of the failure has not yet been determined. A geotechnical investigation will be required to determine the root cause and stability of the existing slope, which could lead to other more robust slope repair recommendations.

3.3.4 Final Design Considerations

As noted above, an important consideration during final design will be to determine the root cause and type of slope failure that has occurred along the northern portion of ICC's shoreline through completion of a geotechnical investigation. Designing appropriate repairs to the slope will require defining if the slope is susceptible to deeper rotational failure as well as surficial slope failure. A surficial failure occurs when a layer of soil or rock slides down a slope, relatively parallel to the existing surface. This failure mode typically involves a relatively shallow layer of soil that is often caused by erosion, rainfall and surface drainage or activities that disturb the surface layer. A rotational failure occurs when a mass of soil or rock moves downward and outward along a curved, concave-upward failure surface. This failure mode typically involves a deeper circular shaped failure surface that may be caused by factors like the weight of the slope material, water pressure, seeps, and varying weak underlying soil layers.

A geotechnical investigation is a crucial step to understanding the subsurface conditions prior to finalizing design of a selected repair alternative. The tasks listed below are recommended as part of a geotechnical investigation for this site. A budgeting cost for the geotechnical investigation is $30,000-$40,000.

- Site reconnaissance by a geotechnical engineer to observe site conditions
- Subsurface investigation including up to 4 soil borings by a drilling contractor, followed by laboratory testing.
- Geotechnical analysis including slope stability modeling
- Reporting, including drilling summary and recommendations

The VRSS repair concept presented in this report for the steep slope failure generally assumes a surficial slope failure. The cost estimate (see Section 3.7) only includes repair of the identified notable erosion and

slope failure (approximately 70 linear feet of repair) and does not address potential adjacent unstable areas. VRSS is particularly useful for steep slopes where space is limited, and traditional methods might not be feasible. It's a flexible system that can be adapted to various site conditions and requirements. Another alternative to VRSS could be an anchored turf reinforcement mat (ATRM). An ATRM system consists of shallow earth anchors (up to 5 feet long) that secure TRM in place to establishment vegetation. The anchors provide resistance to shallow, near-surface instability, but do not address deeper global stability risks. ATRM systems have performed well on slopes as steep as 1H:1V (one foot horizontal change for every one foot of vertical change).

A geotechnical slope stability analysis may show that the existing slope does not meet typical standards of practice requirements for global stability of an engineered slope. In this case, other repair options may need to be investigated or revisited. This includes repairs that involve fully reconstructing the slope, or use of engineered features such as reinforced soil slopes (RSS). Conventional RSS are structural systems that typically utilize geosynthetic layers to stabilize steep earthen slopes with face inclinations up to approximately 70 degrees. RSS systems are constructed by placing layers of reinforcement within lifts of compacted fill. RSS systems require select granular fill and sufficient right-of-way for construction. Face treatments are typically vegetated or armored with riprap. These alternative repair techniques would likely significantly increase the cost of the slope stabilization measures. Costs for a reconstructed slope could be developed as part of a geotechnical investigation, if desired.

3.4 Maintenance of Shoreline Stabilization

Shoreline maintenance will be critical for long-term water quality and ecological benefits of installed stabilization and buffer practices. Potential maintenance activities for stabilized shorelines and approximate timelines are described below:

- Years 0-3: most intensive maintenance period, including activities such as monthly spot mowing of annual weeds, herbicide treatment of invasive herbaceous and woody resprout (fall and spring), and reseeding/replanting of bare areas. This portion of vegetation establishment is often included as part of the construction project to ensure the planted vegetation reaches maturity and meets the contractual specifications regarding establishment expectations/requirements.
- Years 3-10: maintenance activities may include monthly inspections for invasive species, monthly spot spraying of herbicide of any weed patches found, annual spot mowing of undesirable woody species and if possible, a controlled burn. This extended maintenance period is important to ensure slower growing native species can establish and additional support is provided to control some of the more persistent weed species that exist today (e.g., reed canary grass, smooth brome grass, Canada thistle, and buckthorn).
- After 10 years: with proper maintenance, the site should be fully established making weed encroachment easier to manage. Ongoing inspection and management will still be needed to prevent the most aggressive weeds and invasive tree species from outcompeting more desirable species. Twice per year invasive species should be treated by spot mowing in the summer and spot herbicide treatment as appropriate in the fall. Burning is recommended every 3-5 years after full establishment.

3.5 Private Landowner Easements and Agreements

The following are potential landowner easements, agreements, or reporting requirements that may be necessary to perform construction tasks, maintain shoreline conditions, and ensure long-term success of the implemented projects. During final design, coordination with NMCWD legal counsel will be necessary to develop easement and access agreements and reporting templates.

- Temporary easements, at a minimum, would be necessary to proceed with construction of shoreline stabilization practices and to perform short- or long-term maintenance. Permanent easements could also be considered.
- Access agreements will be necessary for temporary access during the construction and maintenance phases of the stabilization project.
- Based on preliminary discussions, it is our understanding that NMCWD is not intending to record declarations on properties for the installation of shoreline stabilization practices as would typically be required for permitted projects. If the landowner would prefer to perform long-term maintenance themselves, NMCWD would likely require annual reporting to ensure the management practice is still in place and functioning as designed.

3.6 Permitting and Regulatory Considerations

The proposed shoreline stabilization projects may require the following permits and/or agency approvals. The number of shoreline owners that participate in projects may impact the necessity of the permits that are dependent on area of disturbance. This is discussed in further detail in the subsections below.

- Compliance with the MnDNR Public Waters Work Permit
- Compliance with the Minnesota Wetland Conservation Act
- U.S. Army Corp of Engineers (USACE) Clean Water Act Section 404 and Section 401 Water Quality Certification
- Construction Stormwater General Permit from the MPCA
- Compliance with the MPCA's guidance for managing dredged material
- NMCWD Rules
- City of Edina grading permit
- Compliance with the City of Edina Tree Protection Ordinance

3.6.1 MnDNR Public Waters Work Permit

The MnDNR regulates development activities below the ordinary high-water level (OHWL) in public waters and public waters wetlands. Public waters regulated by the MnDNR are identified on published public waters inventory maps. Mirror Lake is identified as a MnDNR public water; as such, the proposed project will require a MnDNR Public Waters Work Permit for the work completed in the public water (e.g., installation of riprap toe or other shoreline stabilization practices). If shoreline stabilization implementation falls under the scope of the NMCWD's General Permit #1997-6112 and the MnDNR waives jurisdiction to NMCWD for the shoreline improvements, NMCWD's approval of the relevant work

as meeting NMCWD Rule 7.0 Shoreline and Streambank Improvements will constitute approval under the state Work in Waters rules and no separate MnDNR individual permit will be required. The consolidation of regulatory authority will need to be confirmed during final design.

3.6.2 Minnesota Wetland Conservation Act (WCA)

The Minnesota Wetland Conservation Act (WCA) was enacted to protect wetlands not protected under the MnDNR's public waters work permit program. The Minnesota WCA regulates filling and draining of all wetlands and regulates excavation within the permanently and semi permanently flooded areas of Type 3, 4, and 5 wetlands. The regulatory provisions of Minnesota's WCA are administered by local government units (LGU's), and NMCWD is the LGU responsible for administering the requirements of WCA in Edina. The need for WCA approvals or determinations will depend on whether wetlands protected under WCA (wetlands above the MnDNR's jurisdictional elevation, the OHWL, of Mirror Lake) are impacted. Wetland delineations will be required as part of final design to identify which properties, if any, have WCA-regulated wetlands above the OHWL. Any properties with WCA-regulated wetlands may require approval of activities under the WCA. Any activities that impact WCA-regulated wetlands (permanent or temporary), will require a Joint Application Form to be submitted encompassing all permanent and temporary work within the wetland(s).

3.6.3 USACE Section 404 Permit and Section 401 Certification

According to Section 404 of the Clean Water Act (CWA), the United States Army Corp of Engineers (USACE) regulates the placement of fill and certain dredging activities in jurisdictional wetlands and other waters of the United States. Jurisdictional wetlands and other waters are those that the USACE determines to have a significant nexus with navigable waters. During final design an approved jurisdictional determination request should be sent to the USACE to determine if Mirror Lake is under the jurisdiction of the USACE. If the USACE determines that Mirror Lake is under the jurisdiction of the USACE, a section 404 permit will be required.

3.6.4 Construction Stormwater General Permit

A National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) Construction Stormwater General Permit from the MPCA authorizes stormwater runoff from construction sites. A Construction Stormwater General Permit will be required if the proposed project disturbs more than one acre of soil. Disturbance of more than one acre of soil will be dependent upon the number of shoreline properties involved in a construction project at one time. If there is more than one acre of disturbance, this permit will require preparation of a stormwater pollution prevention plan explaining how stormwater would be controlled within the project area during construction.

3.6.5 Guidance for managing dredged material

Dredged material is defined as waste by Minnesota Statute 115.01, and the management and disposal of dredged material is regulated by the MPCA. It is anticipated that sediment may be dredged at small portions along the shoreline as part of proposed shoreline stabilization projects. Any excavated sediment would be removed from the project site and disposed of at an appropriate landfill or other approved site, in compliance with the MPCA's guidance for managing dredged materials.

3.6.6 NMCWD Permit Requirements

The proposed shoreline stabilization projects will require a NMCWD permit application. A NMCWD permit under the rules outlined in the paragraphs below will be required based on the anticipated project activities.

A NMCWD permit is required for any alteration or filling of land below the 100-year flood elevation of a waterbody. Since the projects will involve land and surface flow alterations below the 100-year frequency flood elevation of Mirror Lake, compliance with the requirements of NMCWD's Floodplain Management and Drainage Alterations Rule 2.0 in accordance with Rules 2.2.1 and 2.2.2 will be required. The projects will need to provide compensatory flood storage for any fill placed below the flood management elevation of Mirror Lake. Additionally, the activities must not be reasonably likely to have a significant adverse impact on any adjacent landowner(s), flood risk, basin stability, groundwater hydrology, water quality or aquatic or riparian habitats.

A permit under NMCWD's Wetland Management Rule 3.0 will be required if WCA-regulated wetlands are disturbed or downgradient from land-disturbing activities. If the permit applicant owns the land and the buffer rule imposes requirements on the project, wetland buffers may be required. If the applicant for the work does not own the land, the NMCWD wetland buffer rules may not impose implications. Even if the wetland buffer rules do not apply, the projects are expected to include establishment of native vegetation in areas adjacent to wetlands, with invasive species removed to retain natural resources and ecological value, to the extent feasible within the project limits.

NMCWD's requirements for erosion and sediment control (Rule 5.0) will apply if more than 50 cubic yards of material will be disturbed and 5,000 square feet or more of surface area will be altered, Rules 5.2.1a and b. An erosion control plan complying with the NMCWD requirements will need to be submitted.

A permit under NMCWD's Shoreline and Streambank Improvements Rule 7.0 is required for any shoreline improvements on a public water. Because the projects will involve shoreline improvements along Mirror Lake, a public waterbody, the requirements of Rule 7.0 Shoreline and Streambank Improvements will apply. To obtain a permit, it must be demonstrated that the shoreline improvements are necessary to prevent shoreline erosion or restore eroded shoreline, and the improvements will need to meet the NMCWD slope and encroachment requirements. Any riprap used for shoreline protection must meet NMCWD specifications for size, slope, horizontal encroachment, vegetative protection, and alignment. If activities conducted are pursuant to a project-specific permit from the MnDNR, no permit under Rule 7.0 Shoreline and Streambank Improvements is required.

3.6.7 City of Edina Grading Permit

The City of Edina requires Grading Permits for any project that disturbs more than 2,500 square feet of soil or land disturbance activities that exceed more than 10 cubic yards of cut or fill. Disturbance of more than 2,500 square feet of soil will be dependent upon the number of shoreline properties involved in a construction project at one time. It is anticipated the City of Edina will require a Grading Permit (meeting the requirements of Category 1 Disturbance) for the proposed shoreline stabilization projects. The permit(s) will require providing a grading plan showing the existing and proposed grades, areas of exposed soils, location and type of erosion control, existing and proposed impervious surfaces, and existing and proposed drainage.

3.6.8 City of Edina Tree Protection Ordinance

The City of Edina has established a tree protection ordinance to protect well-established and healthy trees and to account for and mitigate the loss of trees and wildlife habitat surrounding tree removal locations. A tree protection permit is required for all City of Edina projects that require grading permits. The tree protection permit must include:

- A tree protection plan indicating where Protected, Heritage, Preserved, Transplanted, and Removable trees are located, their ID #, species, diameters or heights, and protection measures.
    - Removable trees are any tree not defined as a Protected tree and defined as an invasive species by the MnDNR.
- A completed tree protection plan escrow worksheet and required escrow amount for all Protected and Heritage trees to be removed from the site.
- Proposed tree replacement plan showing all replacements for any removed Protected or Heritage Trees following the requirements of Hennepin County.

3.7 Opinion of Cost

Planning-level opinions of probable cost were developed for the shoreline stabilization practices on Mirror Lake. Table 3-2 summarizes the estimated construction, engineering/design, and maintenance costs of the proposed shoreline stabilization measures based on 2024 values. The opinions of cost are intended to aid in evaluating and comparing alternatives and are not an absolute value. The AACE Class 4 opinion of cost was used based on the partial project definition, use of parametric models to calculate estimated costs (i.e., making use of order-of-magnitude costs from similar projects), and uncertainty, with an acceptable range of between -20% and +30% of the estimated project cost. A detailed opinion of probable cost for the shoreline stabilization projects per parcel are in .

Two costs are provided for shoreline stabilization projects on residential properties to represent a range of potential residential landowner participation: (1) assuming 50% participation, and (2) assuming 100% participation. The 50% participation assumption generally corresponds to the portion of residential lakeshore owners that were interested in onsite meetings during the feasibility study. Final unit

construction costs will be variable depending on how many residential properties would participate in implementing shoreline stabilization projects.

Based on recent bid estimates received for projects similar to the Mirror Lake shoreline stabilization (e.g., sites with steep slopes and difficult access), annual maintenance costs are estimated between $20,000 - $30,000 for the first 10 years, assuming 75% or more of the residential shoreline is involved in the installation of stabilization practices. For the ICC property, annual maintenance costs are estimated between $8,500 and $11,500.

Consideration of cost-benefit in terms of phosphorus removal can be a useful way to evaluate project effectiveness for lakes where excess nutrients (specifically phosphorus) lead to poor water quality. Quantifying the benefit of shoreline stabilization techniques in terms of phosphorus reduction to the downstream waterbody is very challenging, as there are numerous processes and associated factors that influence the impacts and available literature values vary widely in range. Given the limitation in acceptable tools and significant range of uncertainty around accuracy of available estimation methods, an estimate of annual phosphorus reduction from the proposed shoreline stabilization techniques was not calculated and associated cost-benefit of implementing the shoreline stabilization techniques at Mirror Lake in terms of pounds of phosphorus removed was not quantified.

The residential cost estimates provided in Table 3-2 assume construction access would be via individual properties, which will require developing access agreements with individual property owners. Any access routes used by the contractor will need to be restored and maintained at construction completion. However, if the City of Edina decides to construct a maintenance access through Fox Meadow Park, the need for access routes at each individual property may decrease thereby reducing the access route restoration costs.

Table 3-2 Mirror Lake shoreline stabilization cost estimates

Project	Total Construction Cost Estimate [1]	Engineering/ Design Cost Estimate [2]	Total Capital Cost Estimate (-20% to +30%)	Annual Maintenance Cost Estimate [4]
Interlachen Country Club [3]	$470,000	$175,000	$645,000 ($516,000 - $839,000)	$10,000
Residential – 50% participation	$490,000	$147,000	$637,000 ($510,000 - $828,000)	$20,000
Residential – 100% participation	$800,000	$240,000	$1,040,000 ($832,000 - $1,352,000)	$30,000

[1] Construction cost estimates assume project scope as shown on conceptual plans including, but not limited to, installation of native plugs at two feet on center over the native seeding area, shrubs at twelve feet on center per lineal foot of shoreline, one tree per house, 3-year vegetation and establishment period, and necessary materials, labor and equipment associated with the project scope. Cost estimates include 10% contingency unless otherwise noted.

[2] Engineering/Design cost estimate assumes assistance with final shoreline stabilization design, permitting, wetland delineations, contract documents, bid administration, and field observation during construction.

[3] Engineering cost includes estimated cost for geotechnical investigation for ICC property.

[4] Annual maintenance cost estimates, following the initial 3-year establishment period, assume necessary work to ensure ongoing plant health including, but not limited to, mowing, pruning, mulching, irrigation, and pest control.

4 Conclusions and Recommendations

In 2023, the NMCWD completed a water quality study of Mirror Lake in Edina to assess and prescribe management activities to improve water quality and ecological health (Barr Engineering, 2023). The study recommended further consideration of potential watershed and in-lake management activities. This report summarizes a feasibility analysis and evaluation of the following management activities:

- Buffered alum and sodium aluminate sediment treatments
- Installation of shoreline stabilization practices

Other management and protection strategies that were identified during the water quality study are not evaluated in this feasibility study due to sufficient supporting information already being available or because strategy implementation will likely be through existing NMCWD or City of Edina programs. Additional details on each management and protection strategy can be found in the *Mirror Lake Water Quality Study* (Barr Engineering, Mirror Lake Water Quality Study, 2023).

4.1 Sediment Treatments

The 2023 water quality study identified that a significant portion of the phosphorus in Mirror Lake originates from internal phosphorus loading from lake bottom sediments. Analysis of sediment cores from Mirror Lake indicated there is potential for internal phosphorus loading of both organically bound phosphorus and mobile phosphorus; however, a more significant proportion originates from organically bound phosphorus. The prevalence of organically bound phosphorus presents a management challenge because traditional aluminum sediment treatments (e.g., alum treatments) target the mobile phosphorus fraction and do not bind phosphorus that is incorporated into organic matter as efficiently. Over time organic phosphorus will decay and can be converted into a form that can bind with aluminum more prevalently. However, the degradation timeline of organic phosphorus may not align with the aging process of aluminum.

The recommended approach to control internal phosphorus loading in Mirror Lake is to conduct a series of up to three adaptive alum sediment treatments during a period of ten or more years. Applying multiple, partial alum treatments over multiple years will supply additional aluminum binding sites as organic phosphorus molecules mineralize and should help offset the aging of the initial alum application. Aluminum is also not sensitive to low oxygen conditions. It is recommended that the initial alum dose be on the higher end of the typical range, to help strip phosphorus from the water column and target the current pool of mobile- and organically-bound phosphorus in the top 6 – 8 cm of the sediment. The timeline for subsequent sediment treatment applications should be determined based on annual to bi-annual monitoring and follow-up sediment core analysis.

Since the application of multiple alum treatments to control internal phosphorus loading from organically-bound phosphorus is a new sediment treatment technique for the NMCWD, more comprehensive monitoring and assessment of the Mirror Lake in-lake treatment is recommended. See Table 2-1 for post-treatment monitoring recommendations.

4.2 Shoreline Stabilization

The 2023 water quality study identified erosion and slope stability issues along much of the Mirror Lake shoreline that are likely contributing to poor water quality conditions in the lake. As part of this feasibility study, Barr further evaluated shoreline conditions and identified potential stabilization practices on a parcel-by-parcel basis. An erosion intensity scoring system was developed to characterize the shoreline instability/erosion severity as being either high, medium, or low on a parcel basis. Five of the evaluated parcels received a high erosion intensity rating and thirteen parcels received a medium erosion intensity rating.

Conceptual designs for stabilization measures were developed on a parcel-by-parcel basis to help the NMCWD and property owners understand the scope and costs of potential remedial measures to stabilize the shoreline and minimize future erosion. The shoreline assessment and development of conceptual designs for shoreline stabilization were generally focused on the privately-owned portions of the shoreline, including Interlachen Country Club (ICC) and 15 residential properties. Concept designs were also developed for the Fox Meadow Park shoreline, which is a city-owned parcel. The city-owned northern portion of the shoreline by Blake Road South was not evaluated due to an ongoing street reconstruction project.

Public outreach was also conducted in conjunction with NMCWD staff to discuss shoreline issues and opportunities for shoreline stabilization and to solicit landowner feedback and participation interest in potential future shoreline improvement projects. NMCWD and Barr completed onsite engagement meetings with 7 of the 15 residential shoreline property owners and attended two meetings with ICC staff.

The shoreline stabilization techniques recommended to stabilize the shoreline, minimize or prevent erosion, and enhance ecological function for each of the evaluated properties are shown in Figure 3-5. It's recommended that the NMCWD consider implementation of the shoreline stabilization techniques presented in this study, in partnership with landowners, with considerations to include severity of erosion, cost, potential grouping of projects (i.e., opportunities for contiguous project sites), landowner participation interest, and willingness to contribute funds, among other potential factors.

4.2.1 Residential Properties

The implementation of bioengineering-based shoreline stabilization techniques should be considered for residential properties with medium to high erosion intensity issues (see Figure 3-5 and Appendix B for site specific recommendations), including installation of coir logs and vegetated reinforced soil slopes (VRSS) with riprap toe depending on the severity of existing erosion. If project implementation is pursued, each stabilization concept will require additional engineering and landscape architecture design during final design to meet shoreline stabilization objectives to reduce erosion, address property owner design considerations and preferences, and consider budget limitations.

The installation of increased and improved native plant buffers should be considered for all the residential property owners, as well as the city-owned Fox Meadow Park parcel (see Figure 3-5 and Appendix B for

site specific recommendations). A majority of lakeshore properties have invasive species or turf maintained up to the water's edge. Native plant buffers are an essential component of shoreline stabilization. Buffer improvements would help restore critical ecological functions by providing pollinator habitat, stabilizing soils, reducing stormwater runoff, and filtering pollutants before reaching the lake. Additional recommendations for buffer installation include:

- Buffer plant species should be selected with input from property owners with maintenance and aesthetics in mind. Plant height and vigorousness should be carefully considered for long-term maintenance. Installing a diverse selection of native plants will maximize ecological benefits and promote resiliency for environmental changes over time (shade, heat, fluctuating lake levels, etc.).
- Perpetual maintenance of vegetation beyond the first three years of plant establishment will be critical for maintaining native plant diversity. Consider implementing a lake-wide management contract to ensure vegetation management efforts are completed.

4.2.2 Interlachen Country Club

Implementation of bioengineering-based shoreline stabilization techniques as well as planted buffers are recommended for the portion of the Mirror Lake shoreline owned by Interlachen Country Club (ICC). Overall, the site was rated as having high erosion intensity, with a notable erosion and slope failure area along the northern part of the shoreline and near vertical banks with demonstrated erosion issues along the remainder of the shoreline. The recommended shoreline stabilization techniques differ along the ICC shoreline due to variations in the existing severity of erosion, the potential for continued degradation, and existing vegetation species.

The slope failure observed on the northern portion of ICC's shoreline will require a large VRSS system or a more substantial repair design. If left unaddressed, the slope failure could lead to further erosion and additional bank failure. This study assumes the slope failure is surficial, which occurs when a layer of soil or rock slides down a slope, relatively parallel to the existing surface. This failure mode typically involves a relatively shallow layer of soil that is often caused by erosion, rainfall and surface drainage or activities that disturb the surface layer. However, a more detailed geotechnical investigation will be necessary as part of final design to determine the root cause and type of slope failure that has occurred (i.e., confirm if the failure was surficial or other type of failure). Results of the geotechnical investigation will be used to confirm if the large VRSS system presented in this study will be appropriate for repairing a surficial slope failure or if a more substantial repair will be necessary if the failure is more severe. Other portions of the northern shoreline that exhibit vertical banks may also require techniques with a greater level of engineering, such as VRSS combined with riprap toe protection near the water's edge and planted buffers at higher elevations.

Along the southern portion of the ICC shoreline where erosion is not as severe, coir logs and planted buffers are the recommended practices. Additionally, buckthorn removal and replacement with native shrubs and grasses is recommended as a component of the shoreline restoration.

4.3 Opinion of Cost

The planning-level opinions of cost for the Mirror Lake sediment treatments and installation of shoreline stabilization measures at the ICC and residential properties are summarized in Table 4-1. The estimated costs for the alum and sodium aluminate sediment treatment include the application and engineering/design, based on 2024 values. The estimated costs for shoreline stabilization include construction, engineering/design, and maintenance costs, based on 2024 values. The opinions of cost are intended to aid in evaluating and comparing alternatives and are not an absolute value. The AACE Class 4 opinion of cost was used based on the partial project definition, use of parametric models to calculate estimated costs (i.e., making use of order-of-magnitude costs from similar projects), and uncertainty, with an acceptable range of between -20% and +30% of the estimated project cost.

Consideration of cost-benefit in terms of phosphorus removal can be a useful way to evaluate project effectiveness for lakes where excess nutrients (specifically phosphorus) lead to poor water quality. Based on in-lake modeling conducted as part of the 2023 water quality study for Mirror Lake, and the cost estimate prepared as part of this study, the estimated cost-benefit of the proposed sediment treatments is approximately $700 per pound of annual total phosphorus reduction.

Quantifying the benefit of shoreline stabilization techniques in terms of phosphorus reduction to the downstream waterbody is very challenging, as there are numerous processes and associated factors that influence the sediment and phosphorus contributions, and available literature values vary widely in range. Given the limitation in acceptable tools and significant range of uncertainty around accuracy of available estimation methods, an estimate of annual phosphorus reduction from the proposed shoreline stabilization techniques was not calculated and associated cost-benefit of implementing the shoreline stabilization techniques at Mirror Lake in terms of pounds of phosphorus removed was not quantified. Although not quantified, stabilization of the shoreline would reduce sediment and nutrient loading to Mirror Lake from shoreline erosion, reduce nutrient loading from property runoff through filtration in planted buffers, and enhance upland habitat.

Table 4-1 Summary of planning-level costs for feasibility study projects

Project Type	Management Activity	Total Capital Cost Estimate (-20% - +30%)	Annual Operations and Maintenance Estimate	Notes
In-Lake	Lake Sediment Treatments	$435,000 ($348,000 - $566,000)	$0	Assumes 3 adaptive treatments over 10+ year period
Shoreline Stabilization	Interlachen Country Club	$645,000 ($516,000 - $838,000)	$10,000	Assumes installing VRSS to restore surficial slope failure
	Residential – 50% participation	$637,000 ($510,000 - $828,000)	$20,000	Costs adjusted assuming 50% of residential lakeshore owners are interested in implementing a shoreline stabilization project
	Residential – 100% participation	$1,040,000 ($832,000 - $1,352,000)	$30,000	Costs adjusted assuming 100% of residential lakeshore owners are interested in implementing a shoreline stabilization project

5 References

Barr Engineering. (2023). *Lake Holiday, Wing Lake, and Lake Rose Water Quality Improvement Project.* Prepared for Nine Mile Creek Watershed District.

Barr Engineering. (2023). *Mirror Lake Water Quality Study.* Prepared for Nine Mile Creek Watershed District.

Barr Engineering Co. (2022). *Lake Holiday, Wing Lake, & Lake Rose Water Quality Study.* Prepared for Nine Mile Creek Watershed District.

Minnesota Pollution Control Agency. (n.d.). *Lake Protection and Management*. Retrieved from Minnesota Pollution Control Agency: https://www.pca.state.mn.us/business-with-us/lake-protection-and-management#:~:text=MPCA%20guidelines%20for%20alum%20application,documented%20in%20soft%20water%20lakes

United States Department of Agriculture. (1997). *Slope Protection for Dams and Lakeshores.* Minnesota Technical Note 2: Natural Resources Conservation Science.

WiDNR. (1990). CHapter NR 328: Shore Erosion Control Structures in Navigable Waterways. developed information from Knutson, P.L., H.H Allen, & J.W. Webb.

Appendix A

Cost Estimates

2024 Feasibility Study for Mirror Lake

ENGINEERS OPINION OF COST

MIRROR LAKE SEDIMENT TREATMENTS				
ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	COST
Buffered Alum Sediment Treatment (Application 1)	LS	1	$ 96,000.00	$ 96,000.00
Buffered Alum Sediment Treatment (Application 2)	LS	1	$ 90,000.00	$ 90,000.00
Buffered Alum Sediment Treatment (Application 3)	LS	1	$ 59,000.00	$ 59,000.00
Engineer Data Review/Field Observation	HRS	40	$ 170.00	$ 6,800.00
Water Quality Monitoring	YR	7	$ 10,000.00	$ 70,000.00
Sediment Coring & Release Rates	EA	2	$ 15,000.00	$ 30,000.00
Project Planning/Design	HRS	250	$ 170.00	$ 42,500.00
			Subtotal =	$ 395,000.00
			Contingency (10%)	$ 39,500.00
			Total	$ 435,000.00
			-20%	$ 348,000.00
			+30%	$ 566,000.00

Assumptions

- Cost estimates assume partial alum treatments spaced by 5 years
- Cost estimate assumes annual water quality monitoring for years 2 - 5 post treatment and bi-annually for years 6-10 post treatment.
- Cost estimate assumes follow up sediment coring and laboratory release rate experiments to determine subsequent alum application timeline at years 4 and 9
- Engineering assistance with sediment treatment design, bid administration and contract documents
- Two engineering staff members to observe sediment treatments and perform pH monitoring.
- Estimated total cost is reported to the nearest thousand dollars

2024 Feasibility Study for Mirror Lake

ENGINEERS OPINION OF COST

SHORELINE STABILIZATION - RESIDENTIAL PROPERTIES					
	PROPERTY/PROPERTIES	Erosion Intensity	SHORELINE LENGTH (FEET)	UNIT COST PER SHORELINE LENGTH	COST
*	5300 Dundee Rd	Low	138	$ 72	$ 9,896
	5980 Pine Grove Rd	Low	203	$ 72	$ 14,566
	5113 Lake Ridge Rd	Medium	143	$ 107	$ 15,326
	5151 Blake Rd	Medium	185	$ 103	$ 19,071
*	5208, 5212, 5216 Dundee Rd	Low - Medium	449	$ 52	$ 23,209
	Unassigned Fox Meadow Ln	Low	215	$ 109	$ 23,466
	5105 Lake Ridge Rd	Medium	107	$ 259	$ 27,765
	6000 Pine Grove Rd	Medium	240	$ 134	$ 32,226
	5109 Lake Ridge Rd	High	132	$ 256	$ 33,798
*	6201 Interlachen Blvd	Medium	480	$ 71	$ 33,942
*	5308 Dundee Rd	High	125	$ 286	$ 35,726
*	5200, Unassigned Dundee Rd	Low - Medium	489	$ 86	$ 41,886
*	5101, Unassigned Lake Ridge Rd	Medium	425	$ 154	$ 65,638
*	5240 Highwood Dr W	High	326	$ 228	$ 74,256
	5115, 5121, 5123 Lake Ridge Rd	Medium	471	$ 168	$ 79,265
	6000 Fox Meadow Ln	High	379	$ 222	$ 83,950
				Subtotal=	$ 614,000
				Construction Mobilization (10%)	$ 61,400
				Construction 3-year Maintenance	$ 52,000
				Contingency (10%)	$ 72,700
				Construction Total	***$ 800,100***
				Engineering/Design (30%)	***$ 240,000***
				Total	***$ 1,040,000***
				-20%	$ 832,000
				+ 30%	$ 1,352,000

Assumptions

- Construction cost estimates assume project scope as shown on conceptual plans including, but not limited to, installation of native plugs at two feet on center over the native seeding area, shrubs at twelve feet on center per lineal foot of shoreline, one tree per house, 3-year vegetation and establishment period, and necessary materials, labor and equipment associated with the project scope.

- Engineering assistance with shoreline stabilization design, permitting, wetland delineations, bid administration and contract documents

- Properties shown with "*" participated in onsite meetings during the feasibility study.

2024 Feasibility Study for Mirror Lake

ENGINEERS OPINION OF COST

SHORELINE STABILIZATION - INTERLACHEN COUNTRY CLUB (ICC)				
SHORELINE AREA	Erosion Intensity	SHORELINE LENGTH (FEET)	UNIT COST PER SHORELINE LENGTH	COST
ICC Bioengineering Practices & Planted Buffers	High	1501	$ 164	$ 246,672
ICC Slope Failure		56	$ 2,077	$ 116,293
			Subtotal=	$ 363,000
			Construction Mobilization (10%)	$ 36,300
			Construction 3-year Maintenance	$ 28,000
			Contingency (10%)	$ 42,700
			Construction Total	***$ 470,000***
			Engineering/Design (30%)	***$ 141,000***
			Geotechnical Investigation	***$ 34,000***
			Total	***$ 645,000***
			-20%	$ 516,000
			+ 30%	$ 839,000

Assumptions

- Construction cost estimates assume project scope as shown on conceptual plans including, but not limited to, installation of VRSS for slope failure, installation of native plugs at two feet on center over the native seeding area, shrubs at twelve feet on center per lineal foot of shoreline, one tree per house, 3-year vegetation and establishment period, and necessary materials, labor and equipment associated with the project scope.
- Engineering assistance with shoreline stabilization design, permitting, wetland delineations, bid administration and contract documents

Appendix B

Shoreline Concept Design

Resident Handouts

Barr Footer: ArcGISPro 3.0.4, 2024-05-08 09:28 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\20272037_Mirror Lake WQ Feasibility\Maps\Project_Working_Mirror_Lake_2024.aprx Layout: Sidebar 8_5x11 Landscape User: EMB

EROSION RATING:

Low **Medium** High

Erosion rating is based on the level of erosion concerns identified during erosion intensity analysis.

EROSION CONCERNS:

1. Lack of vegetated buffer and
2. bare soils throughout portions of the shoreline can lead to high runoff velocities and increased soil erosion.
3. Vertical, exposed banks throughout portions of the shoreline indicate unstable shoreline conditions, which can lead to increased erosion or bank failure over time.

SITE PHOTOS:

Examples of the erosion concerns are shown below with the corresponding erosion concerns numbers.

Hennepin County, MN
NearMap Imagery 2023
Site Photos 2023

LEGEND

Property Boundary

0 20 40
Feet

Please Note:

This figure shows concept level stabilization recommendations. A final design may be modified based on additional analysis and/or owner preferences.

BARR

9 MILE CREEK WATERSHED DISTRICT

Mirror Lake Shoreline Stabilization Concept Design

5000 Oak Bend Ln
Edina, MN 55436

Barr Footer: ArcGISPro 3.0.4, 2024-05-08 09:28 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\20272037_Mirror Lake WQ Feasibility\Maps\Project_Working_Mirror_Lake_2024.aprx Layout: Sidebar 8_5x11 Landscape User: EMB

EROSION RATING:

Low Medium **High**

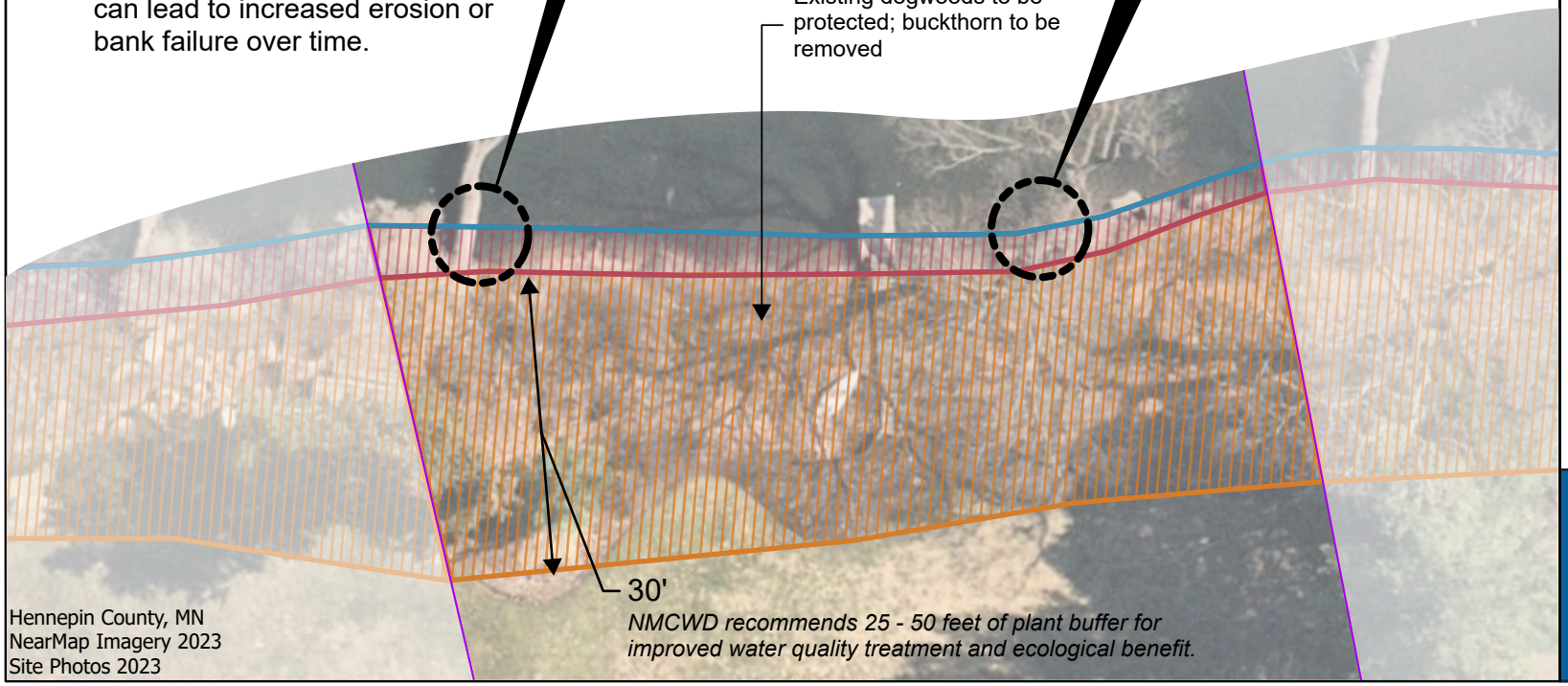
Erosion rating is based on the level of erosion concerns identified during erosion intensity analysis.

EROSION CONCERNS:

1. Lack of a dense native perennial cover on slopes located within the typical shoreline buffer area.
2. Bare soils throughout the shoreline can lead to high runoff velocities and increased soil erosion.
3. Vertical, exposed banks throughout portions of the shoreline indicate unstable shoreline conditions, which can lead to increased erosion or bank failure over time.

SITE PHOTOS:

Examples of the erosion concerns are shown below with the corresponding erosion concerns numbers.



Hennepin County, MN
NearMap Imagery 2023
Site Photos 2023

LEGEND

- Property Boundary

STABILIZATION TECHNIQUES

- Riprap Toe Protection
- Vegetated Reinforced Slope Stabilization
- Native Plant Buffer

Erosion control practices may require grading changes within extents shown to reduce the steepness of the shoreline.

0 10 20
Feet

Please Note:

This figure shows concept level stabilization recommendations. A final design may be modified based on additional analysis and/or owner preferences.

BARR

9 MILE CREEK WATERSHED DISTRICT

Mirror Lake Shoreline Stabilization Concept Design

5105 Lake Ridge Rd
Edina, MN 55436

Barr Footer: ArcGISPro 3.0.4, 2024-05-08 09:28 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\20272037_Mirror Lake WQ Feasibility\Maps\Project_Working_Mirror_Lake_2024.aprx Layout: Sidebar 8_5x11 Landscape User: EMB

EROSION RATING:

Low **Medium** High

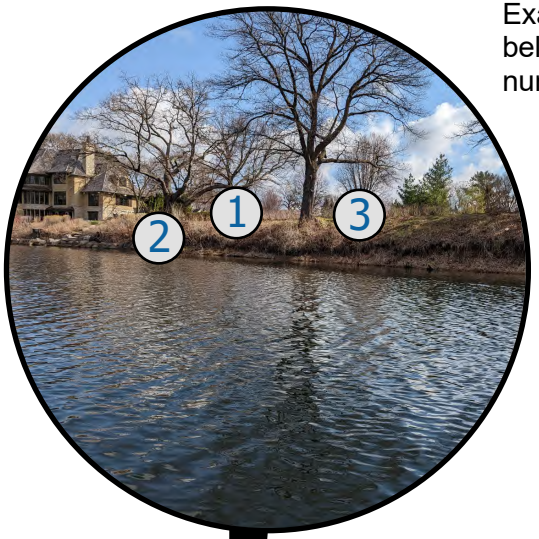
Erosion rating is based on the level of erosion concerns identified during erosion intensity analysis.

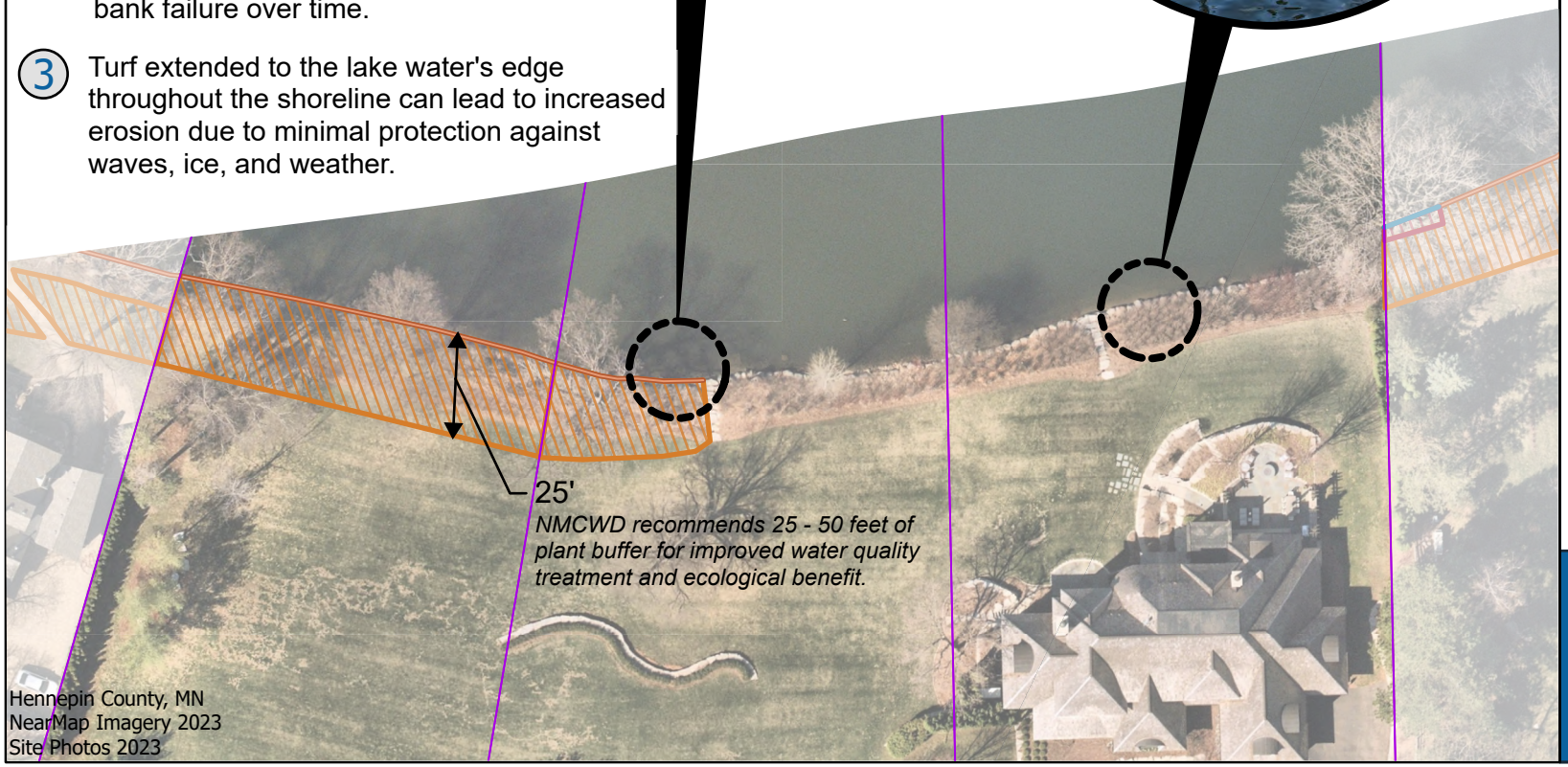
EROSION CONCERNS:

1. Lack of a dense native perennial cover on slopes located within the typical shoreline buffer area.
2. Vertical, exposed banks throughout portions of the shoreline indicate unstable shoreline conditions, which can lead to increased erosion or bank failure over time.
3. Turf extended to the lake water's edge throughout the shoreline can lead to increased erosion due to minimal protection against waves, ice, and weather.

SITE PHOTOS:

Examples of the erosion concerns are shown below with the corresponding erosion concerns numbers.





Hennepin County, MN
NearMap Imagery 2023
Site Photos 2023

LEGEND

Property Boundary

STABILIZATION TECHNIQUES

Native Plant Buffer

BioLog

Erosion control practices may require grading changes within extents shown to reduce the steepness of the shoreline.

0 25 50
Feet

Please Note:

This figure shows concept level stabilization recommendations. A final design may be modified based on additional analysis and/or owner preferences.

BARR

9 MILE CREEK WATERSHED DISTRICT

Mirror Lake
Shoreline Stabilization
Concept Design

5208 Dundee Rd
Edina, MN 55436

Barr Footer: ArcGISPro 3.0.4, 2024-05-08 09:28 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\20272037_Mirror Lake WQ Feasibility\Maps\Project_Working_Mirror_Lake_2024.aprx Layout: Sidebar 8_5x11 Landscape User: EMB

EROSION RATING:

Low Medium **High**

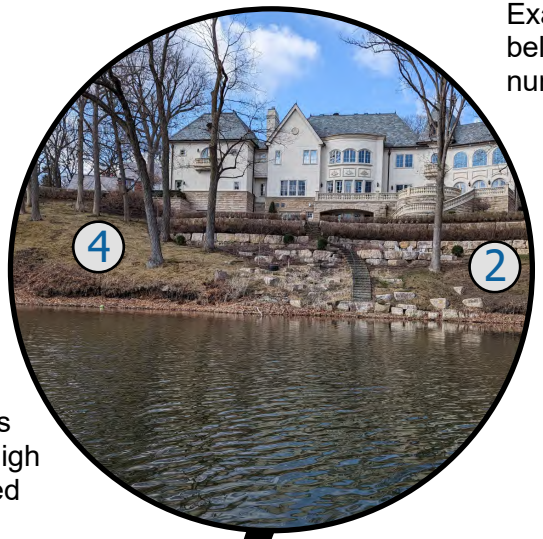
Erosion rating is based on the level of erosion concerns identified during erosion intensity analysis.

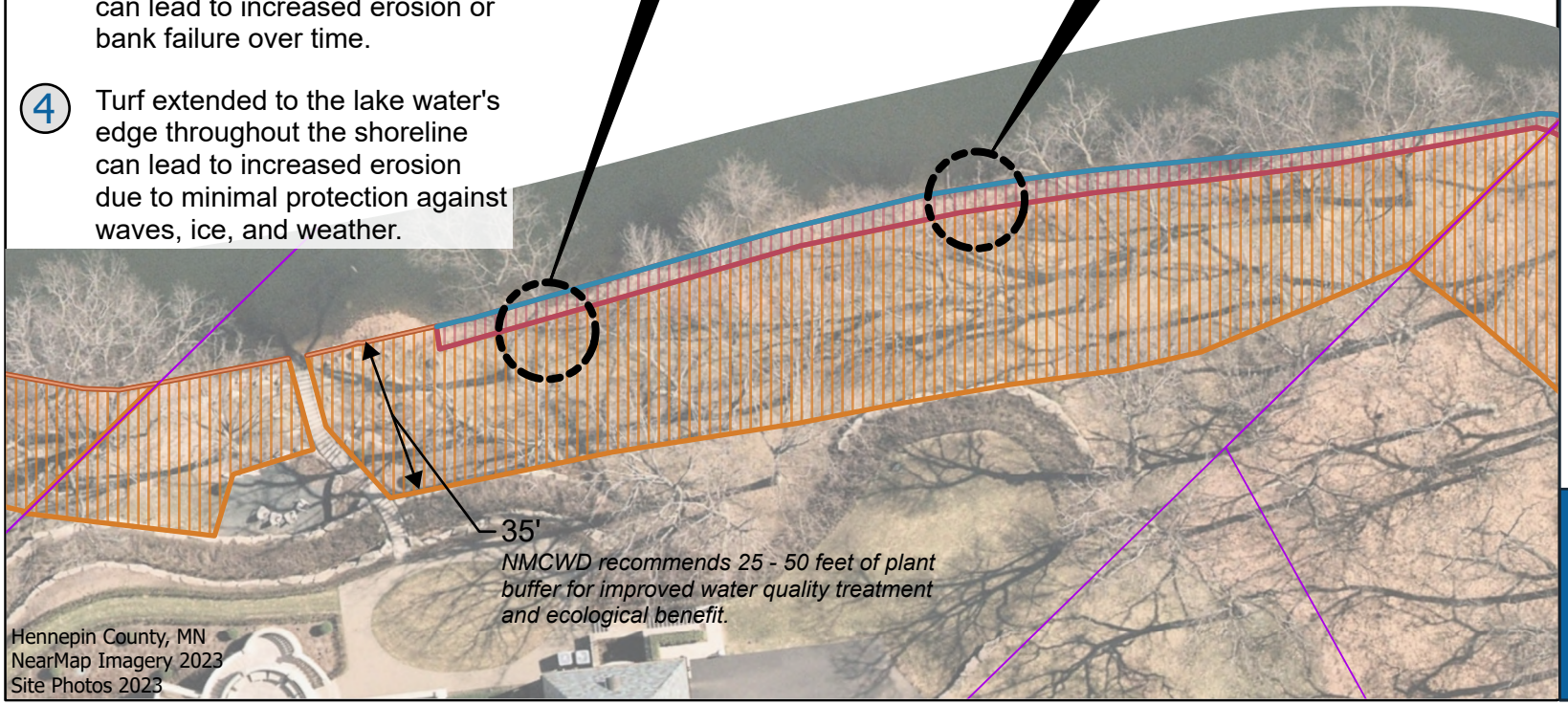
EROSION CONCERNS:

1. Lack of a dense native perennial cover on slopes located within the typical shoreline buffer area and
2. bare soils throughout portions of the shoreline can lead to high runoff velocities and increased soil erosion.
3. Vertical, exposed banks throughout portions of the shoreline indicate unstable shoreline conditions, which can lead to increased erosion or bank failure over time.
4. Turf extended to the lake water's edge throughout the shoreline can lead to increased erosion due to minimal protection against waves, ice, and weather.

SITE PHOTOS:

Examples of the erosion concerns are shown below with the corresponding erosion concerns numbers.





Hennepin County, MN
NearMap Imagery 2023
Site Photos 2023

LEGEND

- Property Boundary

STABILIZATION TECHNIQUES

- Riprap Toe Protection
- Vegetated Reinforced Slope Stabilization
- Native Plant Buffer
- BioLog

Erosion control practices may require grading changes within extents shown to reduce the steepness of the shoreline.

0 25 50
Feet

Please Note:

This figure shows concept level stabilization recommendations. A final design may be modified based on additional analysis and/or owner preferences.

BARR

9 MILE CREEK WATERSHED DISTRICT

Mirror Lake Shoreline Stabilization Concept Design

5240 Highwood Dr W
Edina, MN 55436

Barr Footer: ArcGISPro 3.0.4, 2024-05-08 09:28 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\20272037_Mirror Lake WQ Feasibility\Maps\Project_Working_Mirror_Lake_2024.aprx Layout: Sidebar 8_5x11 Landscape User: EMB

EROSION RATING:

Low **Medium** High

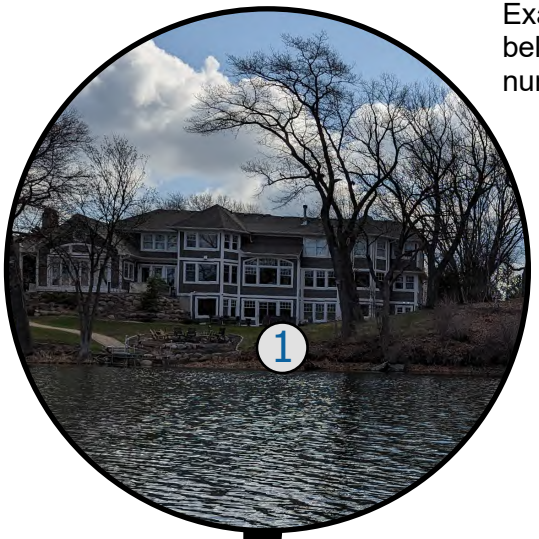
Erosion rating is based on the level of erosion concerns identified during erosion intensity analysis.

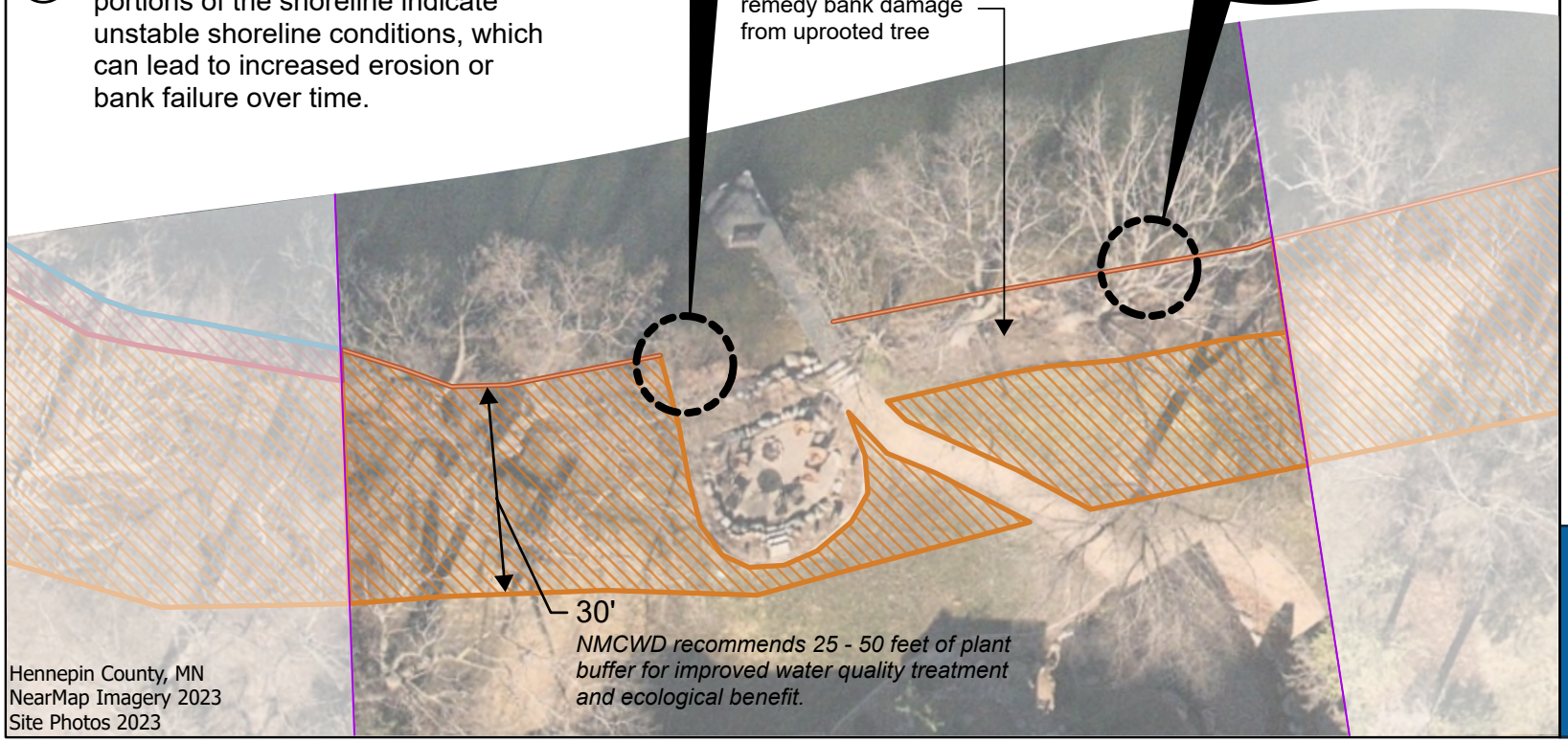
EROSION CONCERNS:

1. Lack of a dense native perennial cover on slopes located within the typical shoreline buffer area.
2. Bare soils throughout the shoreline can lead to high runoff velocities and increased soil erosion.
3. Vertical, exposed banks throughout portions of the shoreline indicate unstable shoreline conditions, which can lead to increased erosion or bank failure over time.

SITE PHOTOS:

Examples of the erosion concerns are shown below with the corresponding erosion concerns numbers.





Hennepin County, MN
NearMap Imagery 2023
Site Photos 2023

LEGEND

- Property Boundary

STABILIZATION TECHNIQUES

- Native Plant Buffer
- BioLog

Erosion control practices may require grading changes within extents shown to reduce the steepness of the shoreline.

0 15 30
Feet

Please Note:

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BARR

9 MILE CREEK WATERSHED DISTRICT

Mirror Lake
Shoreline Stabilization
Concept Design

5300 Dundee Rd
Edina, MN 55436

Barr Footer: ArcGISPro 3.0.4, 2024-05-08 09:28 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\20272037_Mirror Lake WQ Feasibility\Maps\Project_Working_Mirror_Lake_2024.aprx Layout: Sidebar 8_5x11 Landscape User: EMB

EROSION RATING:

Low Medium **High**

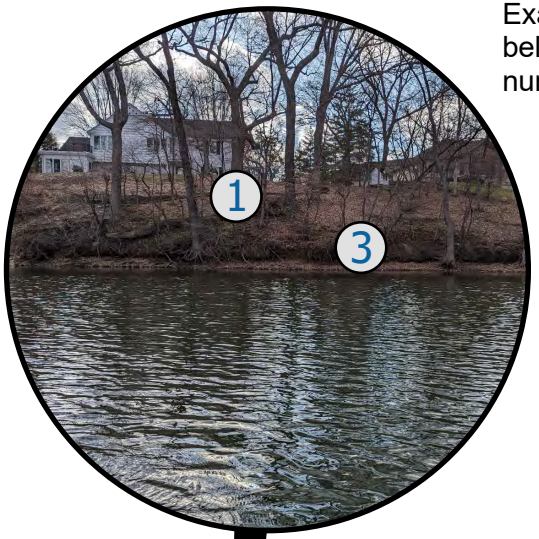
Erosion rating is based on the level of erosion concerns identified during erosion intensity analysis.

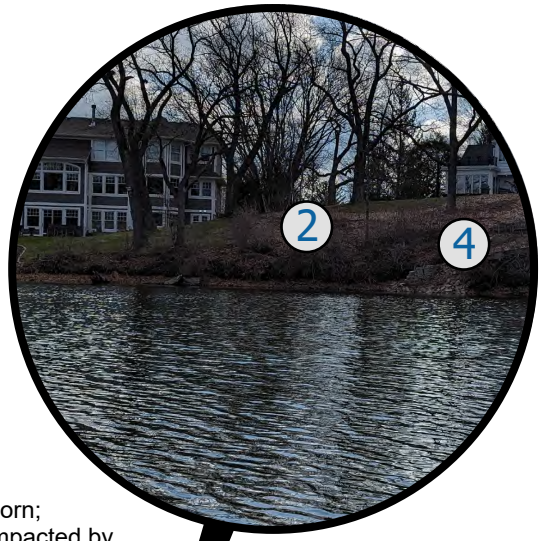
EROSION CONCERNS:

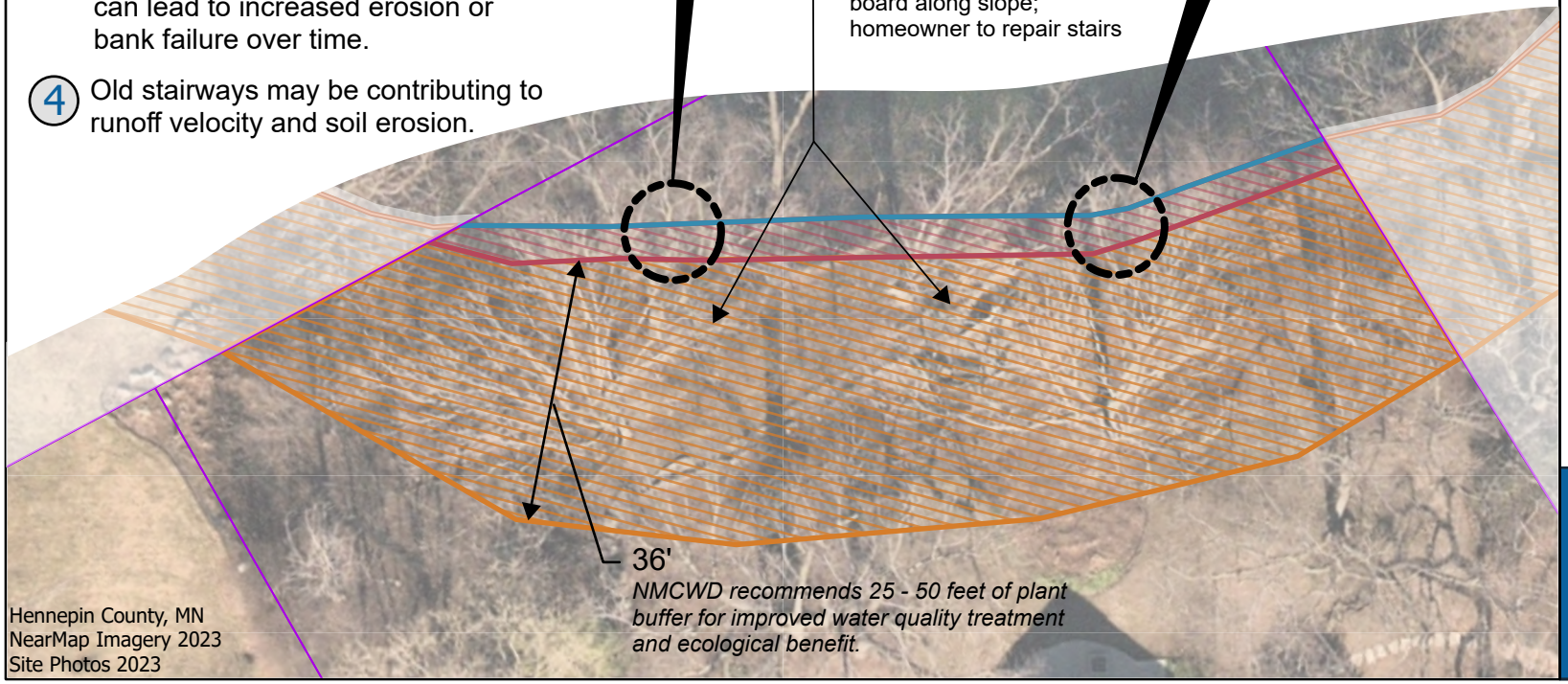
1. Lack of a dense native perennial cover on slopes located within the typical shoreline buffer area.
2. Bare soils throughout the shoreline can lead to high runoff velocities and increased soil erosion.
3. Vertical, exposed banks throughout portions of the shoreline indicate unstable shoreline conditions, which can lead to increased erosion or bank failure over time.
4. Old stairways may be contributing to runoff velocity and soil erosion.

SITE PHOTOS:

Examples of the erosion concerns are shown below with the corresponding erosion concerns numbers.







Hennepin County, MN
NearMap Imagery 2023
Site Photos 2023

LEGEND

- Property Boundary

STABILIZATION TECHNIQUES

- Riprap Toe Protection
- Vegetated Reinforced Slope Stabilization
- Native Plant Buffer

Erosion control practices may require grading changes within extents shown to reduce the steepness of the shoreline.

N

0 15 30
Feet

Please Note:

This figure shows concept level stabilization recommendations. A final design may be modified based on additional analysis and/or owner preferences.

BARR

9 MILE CREEK WATERSHED DISTRICT

Mirror Lake Shoreline Stabilization Concept Design

5308 Dundee Rd
Edina, MN 55436

Barr Footer: ArcGISPro 3.0.4, 2024-05-08 09:28 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\20272037_Mirror Lake WQ Feasibility\Maps\Project_Working_Mirror_Lake_2024.aprx Layout: Sidebar 8_5x11 Landscape User: EMB

EROSION RATING:

Low Medium **High**

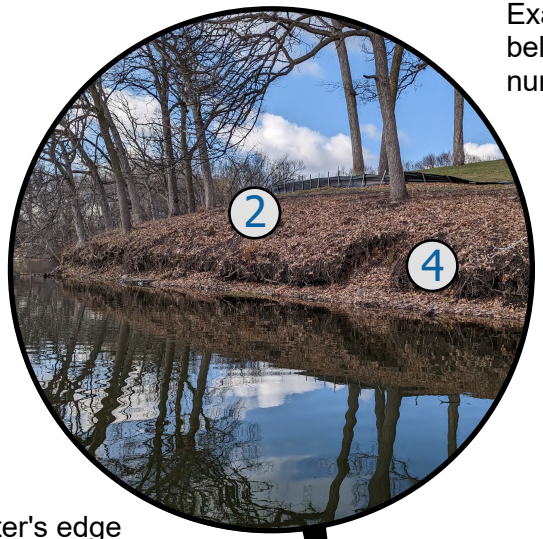
Erosion rating is based on the level of erosion concerns identified during erosion intensity analysis.

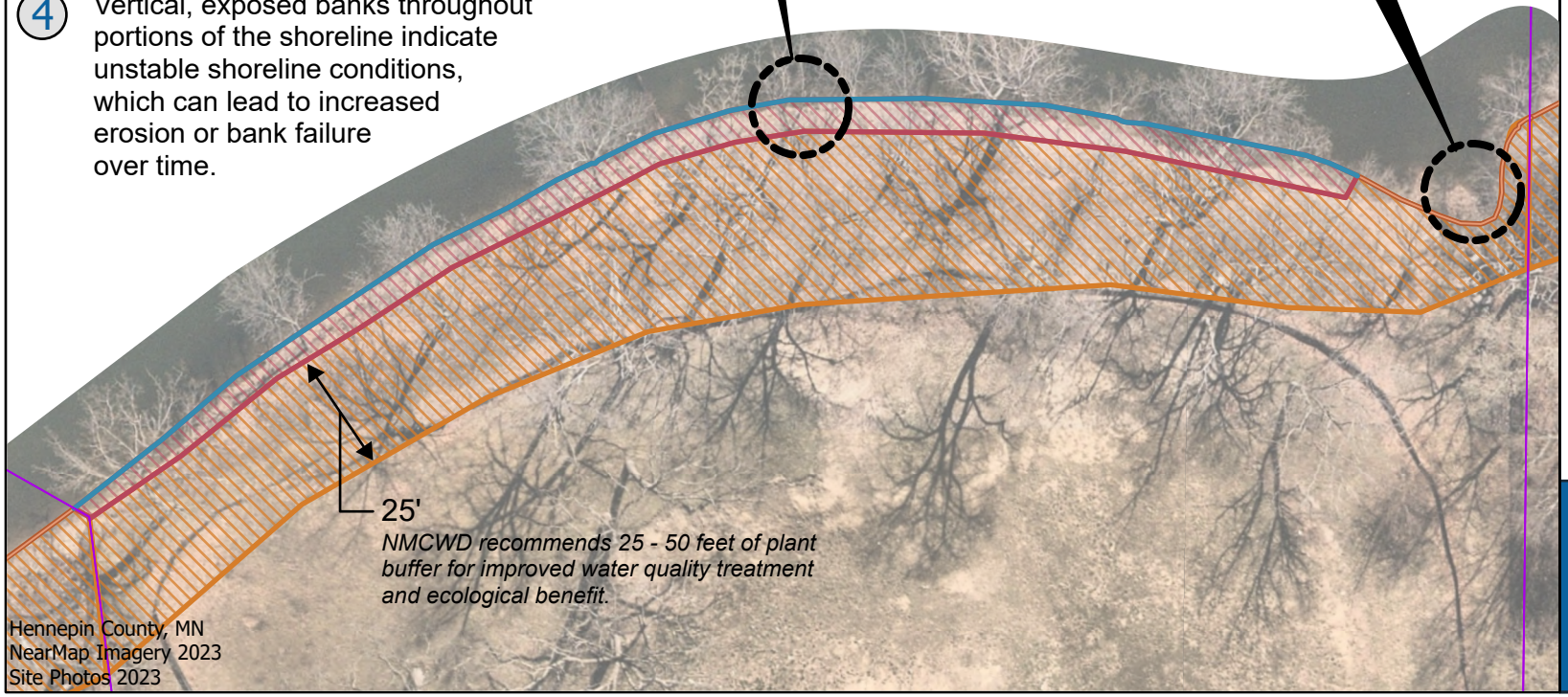
EROSION CONCERNS:

1. Lack of vegetated buffer and
2. bare soils throughout the shoreline can lead to high runoff velocities and increased soil erosion.
3. Turf extended to the lake water's edge throughout the shoreline can lead to increased erosion due to minimal protection against waves, ice, and weather.
4. Vertical, exposed banks throughout portions of the shoreline indicate unstable shoreline conditions, which can lead to increased erosion or bank failure over time.

SITE PHOTOS:

Examples of the erosion concerns are shown below with the corresponding erosion concerns numbers.





Hennepin County, MN
NearMap Imagery 2023
Site Photos 2023

LEGEND

- Property Boundary

STABILIZATION TECHNIQUES

- Riprap Toe Protection
- Vegetated Reinforced Slope Stabilization
- Native Plant Buffer

Erosion control practices may require grading changes within extents shown to reduce the steepness of the shoreline.

N

0 25 50
Feet

Please Note:

This figure shows concept level stabilization recommendations. A final design may be modified based on additional analysis and/or owner preferences.

BARR

9 MILE CREEK WATERSHED DISTRICT

Mirror Lake Shoreline Stabilization Concept Design

6000 Fox Meadow Ln
Edina, MN 55436

Barr Footer: ArcGISPro 3.0.4, 2024-05-08 09:28 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\20272037_Mirror Lake WQ Feasibility\Maps\Project_Working_Mirror_Lake_2024.aprx Layout: Sidebar 8_5x11 Landscape User: EMB

EROSION RATING:

Low **Medium** High

Erosion rating is based on the level of erosion concerns identified during erosion intensity analysis.

EROSION CONCERNS:

1. Lack of a dense native perennial cover on slopes located within the typical shoreline buffer area.
2. Vertical, exposed banks throughout portions of the shoreline indicate unstable shoreline conditions, which can lead to increased erosion or bank failure over time.
3. Old stairway may be contributing to runoff velocity and soil erosion.
4. Select tree removal may limit future erosion by reducing probability of trees falling out of the bank.

SITE PHOTOS:

Examples of the erosion concerns are shown below with the corresponding erosion concerns numbers.

Hennepin County, MN
NearMap Imagery 2023
Site Photos 2023

LEGEND

- Property Boundary

STABILIZATION TECHNIQUES

- Native Plant Buffer
- BioLog

Erosion control practices may require grading changes within extents shown to reduce the steepness of the shoreline.

0 25 50
Feet

Nearmap aerial imagery and site photos spring 2023

Please Note:

This figure shows concept level stabilization recommendations. A final design may be modified based on additional analysis and/or owner preferences.

BARR

9 MILE CREEK WATERSHED DISTRICT

Mirror Lake Shoreline Stabilization Concept Design

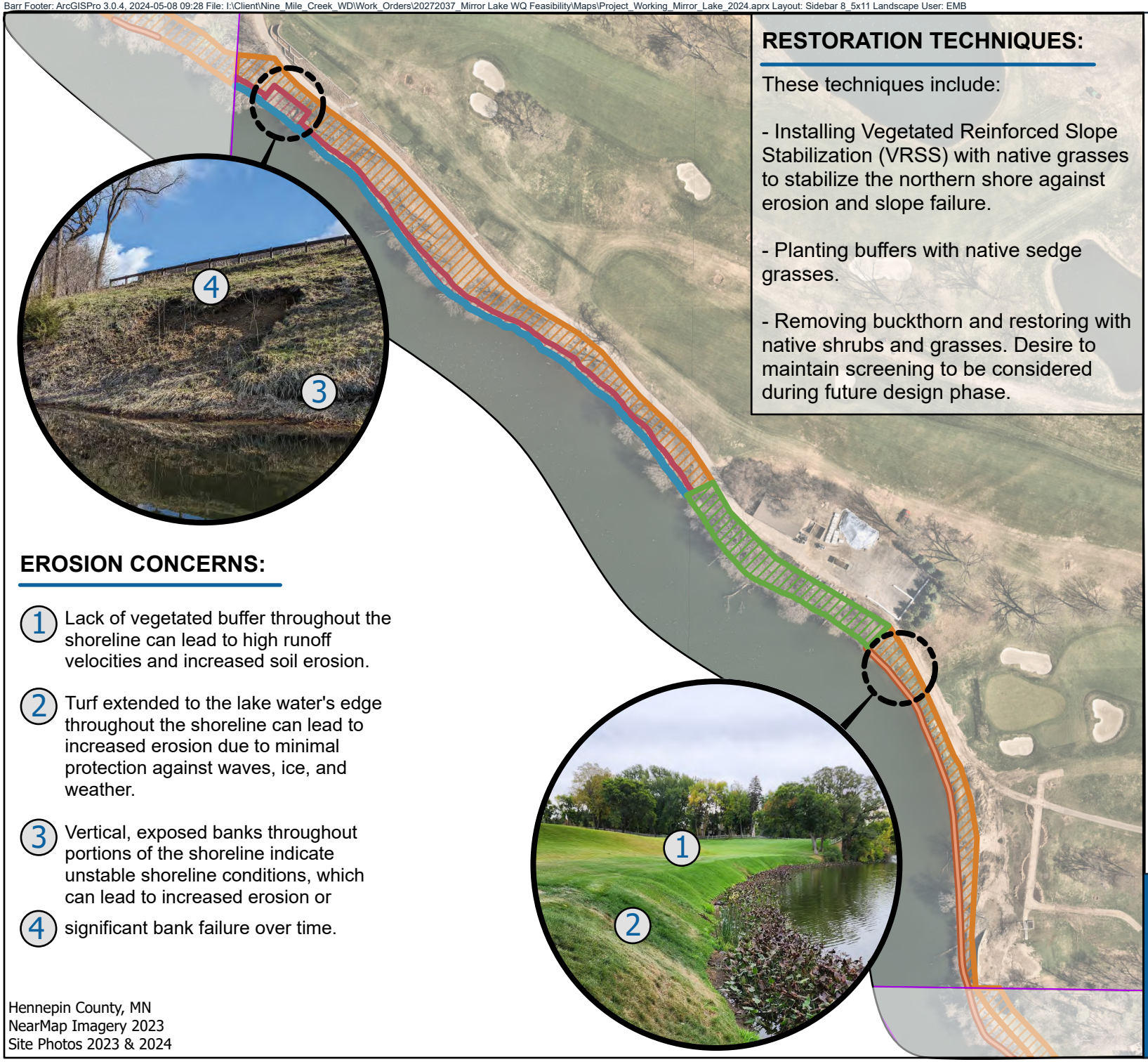
6201 Interlachen Blvd
Edina, MN 55436

Appendix C

Shoreline Concept Design

Interlachen Country Club Handouts

Barr Footer: ArcGISPro 3.0.4, 2024-05-08 09:28 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\20272037_Mirror Lake WQ Feasibility\Maps\Project_Working_Mirror_Lake_2024.aprx Layout: Sidebar 8_5x11 Landscape User: EMB



RESTORATION TECHNIQUES:

These techniques include:

- Installing Vegetated Reinforced Slope Stabilization (VRSS) with native grasses to stabilize the northern shore against erosion and slope failure.

- Planting buffers with native sedge grasses.

- Removing buckthorn and restoring with native shrubs and grasses. Desire to maintain screening to be considered during future design phase.

EROSION CONCERNS:

1. Lack of vegetated buffer throughout the shoreline can lead to high runoff velocities and increased soil erosion.
2. Turf extended to the lake water's edge throughout the shoreline can lead to increased erosion due to minimal protection against waves, ice, and weather.
3. Vertical, exposed banks throughout portions of the shoreline indicate unstable shoreline conditions, which can lead to increased erosion or
4. significant bank failure over time.

Hennepin County, MN
NearMap Imagery 2023
Site Photos 2023 & 2024

LEGEND

Property Boundary

STABILIZATION TECHNIQUES

Vegetated Reinforced Slope Stabilization

Native Plant Buffer

Buckthorn Removal and Restoration

Erosion control practices may require grading changes within extents shown to reduce the steepness of the shoreline.

N

0 100 200
Feet

Please Note:

This figure shows concept level stabilization recommendations. A final design may be modified based on additional analysis and/or owner preferences.

BARR

9 MILE CREEK WATERSHED DISTRICT

Mirror Lake Shoreline Stabilization Concept Design

6200 Interlachen Blvd
Edina, MN 55436