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Technical Memorandum

To: Bassett Creek Watershed Management Commission (BCWMC) and City of Plymouth
From: Barr Engineering Co.
Subject: Item 5A – Study of Chloride extraction/dilution for Parkers Lake (PL-7)
Date: November 9, 2023
Project: 23270051.57

5A. Study of Chloride extraction/dilution for Parkers Lake (PL-7)

Recommendations:

1. We recommend that the Commission use the results of this study to consider the feasibility of implementing ion exchange treatment at a small scale, such as at a stormwater pond upstream of a chloride-impaired or threatened lake (e.g., at a pond upstream of Crane Lake). A small pilot project could also include comparing the ion exchange treatment option with the cost and practicality of enhanced source control in the tributary watershed.

2. In addition to the recent changes to the City's Parkers Lake monitoring program, we recommend that the Commission and the City of Plymouth add a winter (January or February) lake water quality sampling event to the current protocols to establish an annual chloride mass balance baseline and to better measure future watershed source reductions of applied chloride.

Executive Summary

Parkers Lake, in the City of Plymouth, is impaired due to high chloride concentrations. Stormwater monitoring data shows that most chloride enters the lake from industrial and commercial areas to the northeast of the lake. Prior to this study, there was some belief that lake water only left the lake when water levels were high, leaving salty water to continuously accumulate in the bottom of the lake. This study revealed that the lake and chloride-laden water flushes about once every 1.4 years (consistent with the lake water residence time). Regardless of flushing, the lake currently does not meet State water quality standards for chloride. Hence, chloride reduction measures are needed.

The Commission approved a scope of work for the Chloride Extraction/Dilution from Parkers Lake Study (this study) from the Commission Engineer at their September 15, 2022, meeting. The goal of the study was to determine viable options for sufficiently removing chloride from Parkers Lake to meet the MPCA water quality standard. The study analyzed two primary alternatives to reduce chloride in Parkers Lake: 1) pumping lake bottom water directly to the sanitary sewer, and 2) pumping lake bottom water, treating it, and returning treated water to the lake.

Alternative 1: Despite numerous discussions with Metropolitan (Met) Council regulators and submittal of pre-permit documentation, the Met Council ultimately declined a request to permit the proposed discharge of chloride-laden lake water into the sanitary sewer. The Met Council noted that their Metro wastewater treatment plant is not designed to treat chloride and their internal policy precludes them from accepting discharges that they cannot treat and would simply pass pollution downstream.

Alternative 2: Two different treatment systems were evaluated for this alternative – a small scale reverse osmosis system (RO) and an ion exchange system (IX). Both systems would pump water from the bottom of the lake, treat it, and return the treated water back to the lake. This memo presents detailed data on both systems including permitting considerations, pre-treatment needs to remove total suspended solids (TSS) in the water before it goes through either RO or IX, equipment needs, maintenance needs, capital costs, and annual operation costs. The table below summarizes the outcomes of the evaluations. Recommendations for next steps are shown at the top of this memo and explained more fully in Section 4.2.

	Reverse Osmosis	Ion Exchange
Advantages	• Has high quality permeate stream • Has high removal efficiency of chlorides	• No other effluents to be managed if regenerated off-site.
Disadvantages	• Requires pretreatment for TSS and organic matter removal • Has high capital cost • Requires proper management of the reject or concentrate	• Requires pretreatment for TSS and organic matter removal. • High sulfate may compete with ion exchange sites and shorten the run time between regeneration. • On-site regeneration would require storage of caustic regenerant at the site and disposal of high pH spent regenerant.
Capital Cost	$825,000	$540,000 (equipment rental)
Annual Operation and Maintenance	$97,300	$126,200
Annualize Cost per Pound Chloride Removed	$11.04	$11.84

1 Introduction and Background

This memo presents results of a study on the efficacy of extracting or diluting chloride in Parkers Lake in the City of Plymouth. The Commission approved the scope for this study in September 2022.

Parkers Lake is impaired for chloride, which builds up at the bottom of the lake. During dry conditions, there are no outflows from the lake. In high-water conditions, water flows from the lake to the stormwater system, a lift station and eventually discharges into Medicine Lake. Land uses south of the lake are primarily residential, northwest of the lake is primarily park and multifamily, and northeast of the lake are industrial/ commercial. In-lake chloride monitoring, which has been ongoing since 2006, confirms that it is common for the lake to exceed chloride standards. Stormwater flowing into the lake is monitored by the

City of Plymouth and Three Rivers Park District (TRPD). This monitoring shows the area northeast of the lake contributes the highest amount of chloride to the lake.

The Commission approved a feasibility study for the BCWMC CIP Parkers Lake Drainage Improvement Project (PL-7) in May 2020, which included an alternative to add the Parkers Lake Chloride Reduction Project to the project (https://www.bassettcreekwmo.org/index.php?cID=521). In 2021 and 2022 the City of Plymouth partnered with the Hennepin County Chloride Initiative, cities, Met Council staff and watersheds to convene a technical cohort to investigate chloride reduction projects and education strategies. Data was pooled and analyzed for similarities to better target best management practices (BMPs), risks and opportunities for Parkers Lake. Three primary recommended BMPs resulted from the technical cohort's work: 1) develop a grant program that targets chloride reduction through private applicators and private property, 2) construct a pilot program for an on-site collection system to capture chloride effluent for disposal or reuse, and 3) perform in-lake chloride removal through dilution or effluent removal.

At the July 21, 2022, Commission meeting, the City of Plymouth reviewed the specifics of each BMP option including pros and cons, general cost, general level of effort, and presumed efficacy. Commissioners discussed the options and their previous engagement with Met Council staff regarding whether they would allow the discharge of chloride-laden stormwater to the sanitary sewer. It was noted that the discussion with Met Council may need to be revisited for some of the options. During that Commission meeting, it was noted that discharge to the sanitary sewer bypasses other resources like Medicine Lake, which is on the cusp of being impaired for chlorides. It was also noted that the Mississippi River is still far from exceeding chloride standards and occasional discharges to the river through the sanitary sewer are unlikely to impair the river; thus, this strategy could be a cost-effective removal tool to protect the environmental health of a lake. However, the Met Council does not treat for chlorides at the wastewater treatment plants so the pollutant load would be conveyed to the downstream river systems. The City of Plymouth proposed that they bring back to the Commission a scope of work for the Commission Engineer to perform an initial study of Parkers Lake to determine how practical in-lake removal could be. The Commission approved a scope of work for the Chloride Extraction/Dilution from Parkers Lake Study from the Commission Engineer at their September 15, 2022, meeting. The goal of the study was to determine viable options for sufficiently removing chloride from Parkers Lake to meet the MPCA water quality standard.

This study included many activities:

- sample coordination and testing with City of Plymouth and TRPD
- review and discussion of targeted sample analysis with MET COUNCIL
- review of permitting requirements for water withdrawal from the lake and discharge of raw and/or treated water (including treatment residuals)
- estimating costs and amount of chloride removal for each removal method
- evaluating the possibility of delisting Parkers Lake and/or estimated time to revert to current state without additional source control measures.

Permitting requirements were also documented as this project would likely require a Special Discharge Permit from MET COUNCIL for discharge of the high-chloride lake water and/or treatment residuals. In addition, the project may require a Minnesota Department of Natural Resources (MnDNR) Public Waters or Appropriation permits for lake water withdrawal and conditions on the return flow of treated water.

The study analyzed two primary alternatives to reduce chloride in Parkers Lake: 1) pumping lake bottom water directly to the sanitary sewer, and 2) pumping lake bottom water, treating it, and returning treated water to the lake.

This memorandum summarizes the water quality parameters of Parkers Lake, describes potential water treatment technologies for chloride removal, and provides preliminary treatment design concepts, cost estimates and chloride load reduction estimates for each viable water treatment technology.

1.1 Parkers Lake and Lake Watershed

Table 1-1 shows information on Parkers Lake and its watershed used for mass balance modeling and evaluating treatment objectives. The lake volume, surface area and average depth were calculated from lake bathymetric data. Parkers Lake is dimictic, which means that it typically mixes twice per year, and the thermocline depth can vary between 15 feet and 20 feet during summer stratification. (The thermocline delineates the top of the lake from the bottom of the lake. During summer stratification, these layers rarely mix due to differences in water density.) The volume of Parkers Lake below the thermocline is approximately 40 million gallons, or between 10 and 20 percent of the overall lake volume. Historical lake level monitoring indicated that the observed water surface elevations have exceeded the normal level of the lake two thirds of the time. As a result, lake outflow (and flushing) is common during all, but the driest years.

Table 1-1 Parkers Lake Information [1]

Parameter	Value
Watershed Area	1,065 acres
Lake Size	97 acres
Average Depth	12 ft
Maximum Depth	37 ft
Volume	379 million gallons
Ordinary High Water Level (OHWL)	935.9 ft
Normal Water Level (NWL)	934 ft
Downstream Receiving Waterbody	Medicine Lake

Figure 1-1 shows the Parkers Lake watershed, including the stormwater monitoring locations. Based on the mass balance modeling developed for this study, it is estimated that approximately two thirds (66%) of the total chloride load to Parkers Lake is coming from the Site 2a subwatershed to the northeast (industrial/commercial land use). The Site PL2 subwatershed from the northwest (parkland and multifamily residential land use) contributes approximately 16 percent of the total chloride load, while the Site PL1 from the subwatershed to the south (residential land use) and the unmonitored (direct) drainage areas each contribute 9 percent. Based on the estimated total watershed chloride load and typical mass of chloride in Parkers Lake, it is expected that the full lake mass of chloride is typically flushed out by the incoming load every 1.4 years.

1.2 Water Quality and Comparison with State Chloride Standard

Parkers Lake is included on the Minnesota Pollution Control Agency's (MPCA) Impaired Waters List for exceeding the chronic chloride standard of 230 milligrams per liter (mg/L) [(2)]. Chloride enters the lake primarily during winter and spring snow melt from the use of deicing salt. Because higher chloride concentrations result in higher water density, the chloride accumulates in the lowest part of the lake, resulting in higher chloride concentrations in the lake bottom (hypolimnion). When the lake mixes during the spring and fall, the high chloride concentrations in the hypolimnion can mix throughout the lake and cause the chloride concentration to exceed the MPCA standard.

Because of the higher concentrations, chloride removal can be accomplished most effectively by treating water from the hypolimnion.

Figure 1-2 shows that the chloride concentration generally increases as the sample depth increases. Very few of the surface and mid-depth samples exceeded the chloride standard, while the bottom-water chloride sample concentrations typically exceed the 230 mg/L chloride standard.

For delisting purposes, the MPCA evaluates exceedances of standards for toxic pollutants (including chloride) over consecutive three-year periods. Two or more exceedances of the chronic standard (230 mg/L), or one exceedance of the maximum standard (860 mg/L for chloride), in three years is considered an impairment.

The chloride concentrations from all samples (analyzed throughout the water column) met the chloride standard in 2007, 2016 and 2022. Our review of the lake and watershed monitoring and modeling data and climate records indicates that all three years benefitted from higher lake levels and flushing, along with early spring (mid-March) snowmelt, followed by higher-than-normal rainfall runoff through the end of April.

Parkers Lake appears to stratify during most years. During drier years, the stratification may be more pronounced, but that was not evaluated in detail for this memorandum. For purposes of treatment design, we assumed that the water to be removed or treated would be collected from the lake bottom (36-foot depth), but it could be collected at a shallower depth if intake installation costs warrant.

Figure 1-1 Parkers Lake Watershed and Stormwater Monitoring Sites

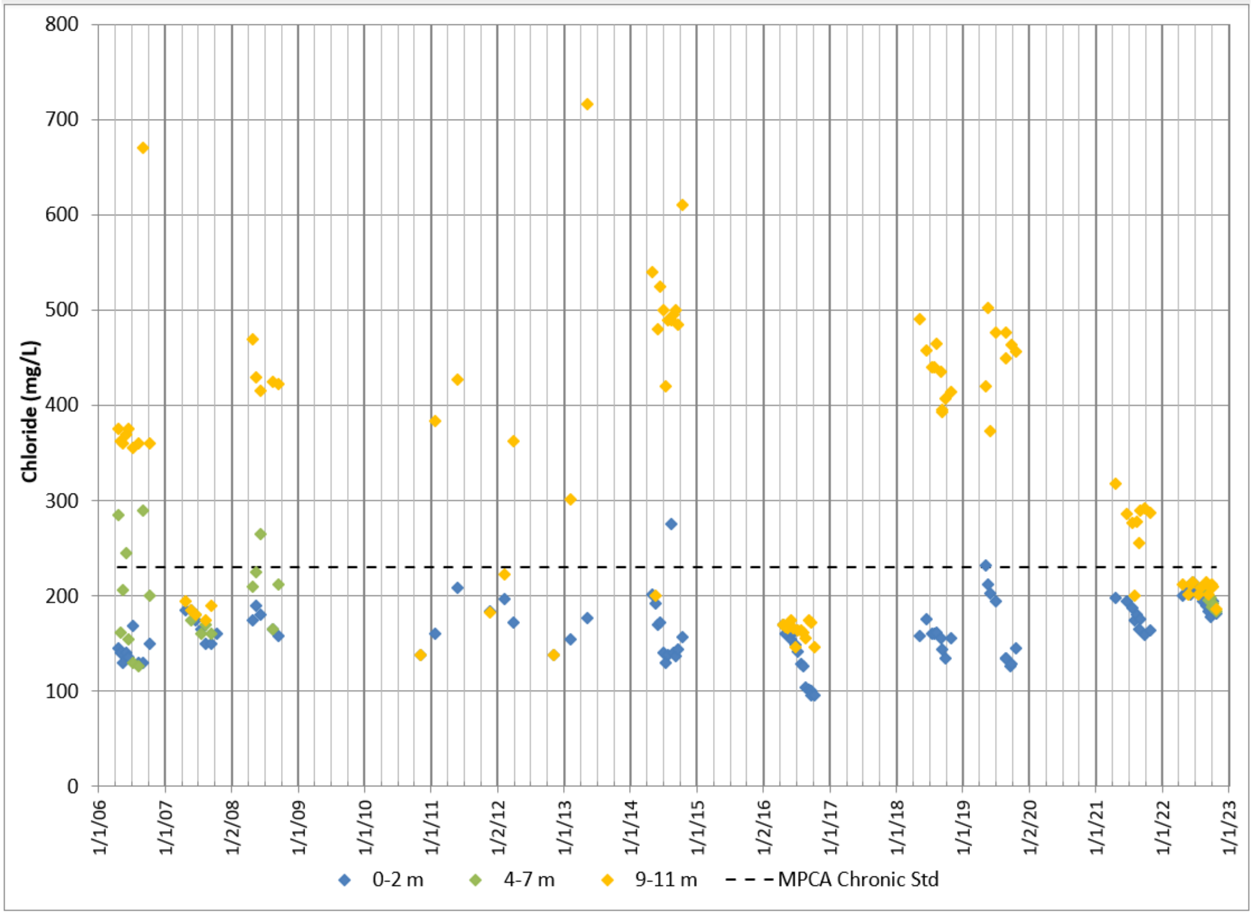

Figure 1-2 Summary of 2006 through 2021 MPCA Chloride Data

2 Alternative 1—Pumping Lake Bottom Water to Sanitary Sewer

Barr hosted several phone calls, sent email communications, and held a meeting with Met Council staff to discuss the possibility of obtaining a Special Discharge permit that would allow for pumping of the Parkers Lake bottom water to the sanitary sewer during times where hypolimnetic chloride concentrations exceeded the State standard. Met Council considered a pre-permit submission that provided more background about the proposed discharge, including pumping rates/timing, water quality and basis for the request. After considering the pre-permit submission, Met Council indicated that they would not permit the proposed discharge, primarily because their Metro wastewater treatment plant is not designed to treat chloride and their internal policy precludes them from accepting discharges that they cannot treat and would simply pass pollution downstream. Their decision is in keeping with their decision for a similar request to discharge pond water with high chloride levels from the Ridgedale stormwater pond(s).

3 Alternative 2—Pumping Lake Bottom Water, Treating, and Returning to Lake

3.1 Study Objectives

The study objectives included:

- Evaluating chloride removal technologies to achieve a reliable chloride concentration <230 mg/L in the lake.
- Comparing pretreatment technologies to protect the chloride removal treatment process from total suspended solids (TSS) in the influent water.
- Describing the process flow of potential water treatment options including source water, treated water and residual discharges.
- Providing cost estimates of the water treatment options for chloride removal.

3.2 Design Basis

The chloride treatment system will need to meet the design basis requirements shown in Table 3-1. The design flow is selected based on the capacity of small reverse osmosis (RO) treatment systems. The duration of operation is selected based on operation during warmer weather only. The goal is to treat a significant volume of water within the hypolimnion as this is the only layer of the lake that experiences exceedances of the chloride standard.

Table 3-1 Design Basis

Parameter	Value	Comments
Flow	20 gpm	Selected to minimize size of chloride removal technology
Daily Operation	24 hrs/day	Assumes automated operation; permits for continual operation may also be needed from Planning Department
Annual Operation	Up to 32 weeks per year (to treat up to 5 million gallons) during the spring-fall period	Allow sufficient time for residuals drying
TSS at Inlet	10 mg/L	Used to determine backwash frequency, or frequency of filtration media change-out
Prefiltration Requirement	5 microns for RO 10 microns for ion exchange	
Residuals disposal	Dry to less than 60% solids – RO Replaceable media vessels – ion exchange Media replacement once per week – cartridge or bag filters Backwash – discharge to infiltration basin or pond	Disposal of any residual to the Met Council sewer is deemed unacceptable.

3.3 Evaluation of Chloride Removal Technologies

The sections below evaluate a treatment technology to separate chloride from water and return the treated water to the lake. Pretreatment will be required to protect the chloride removal technologies from periodically high TSS in the lake.

3.3.1 Pretreatment Technologies

It is assumed that Parkers Lake total suspended solids (TSS) concentrations are high enough (>1 mg/L) that the lake water will require prefiltration/pretreatment for TSS prior to using a chloride-reducing technology. Sand filtration, cartridge filtration, bag filtration, and ultrafiltration (UF) are all potential pretreatment technologies. The following bullets (and Table 3-2) provide an overview of these options, comparing the advantages and disadvantages of each pretreatment option.

Sand filters

- Remove contaminants from water by allowing contaminated water to percolate through a sand-based filter media.
- Require backwashing when the sand filter reaches its solids holding capacity.
- Filter more than 99% of TSS larger than 1 micron.

Cartridge and bag filters

- Uses replaceable cloth or paper media as the filtering agent.
- Filter bags or cartridges must be replaced when the solids holding capacity is reached.
- Can be sized to remove particles as small as 0.2 microns.
- For this application, we assumed a 2-stage system to produce the desired filtration without requiring unacceptably frequent filter changeouts.

Microfiltration/Ultrafiltration (MF/UF)

- Use hollow-fiber membranes to remove solids based on their sizes relative to the membrane pores.
- UF membranes filter more than 99% of TSS mass greater than 0.01 micron.
- MF membranes filter more than 99% of TSS mass greater than 0.1 micron
- The resulting water (permeate) quality is consistent.
- UF requires continuous, usually automated, maintenance cleaning and backwashing to considerably extend the life of the membranes.

Table 3-2 Comparison of pretreatment technologies

	Advantages	Disadvantages
Sand filters	• Efficient removal of suspended particles • Easy to operate and low maintenance requirements • Long service life	• Backwash water may require treatment. • Will generate 400 to 500 gpd of backwash for every 10 gpm of capacity
Cartridge filters	• Removal of smaller particles than sand filters • Lower pressure requirements and energy costs • Backwash is not required • Suitable for smaller treatment systems	• Not practical for larger flows or large systems • Cartridges need to be replaced periodically • Replace 1 to 2 20-inch cartridges per day.
Bag filters	• Lower cost compared to cartridge filters • Suitable for smaller treatment systems	• Not practical for larger flows or large systems • Bags need to be replaced periodically
MF/UF	• Best removal of suspended solids	• Frequent backwash required • Will generate 700 to 800 gpd of backwash for every 10 gpm of capacity • Chemical backwash required • Will generate 25 to 35 gpd of chemical backwash for every 10 gpm of capacity required • Higher operational costs due to energy and chemical requirements • Higher capital cost

3.3.2 Pretreatment Recommendation

Because the Met Council is already concerned about reject RO water going to the sanitary sewer, we recommend using cartridge or bag filters because there is no liquid waste stream to deal with. If the solid waste is deemed excessive, or if the filters clog excessively, sand filtration can be considered.

A sand filter will generate a backwash flow that can likely be returned to the lake with the treated water. The backwash would include solids removed from the treated water to protect the downstream treatment process but would not include the chlorides. If the lake has periods of high solids, this may be the preferred filtration method. If the backwash is not allowed to be returned to the lake, it could be discharged to a small infiltration basin or pond.

Because the MF/UF system will generate a backwash stream that may be difficult to dispose of, we did not consider this option further.

3.3.3 Chloride Treatment Technologies

Reverse osmosis and ion exchange are the two treatment technologies we considered for chloride removal. Below is a summary of each technology. Table 3-3 compares their advantages and disadvantages.

3.3.3.1 Reverse Osmosis

Reverse osmosis (RO) uses spiral-wound membranes to remove more than 95% of monovalent and divalent ions. A pump pressurizes the feed water and pushes it against the RO membrane resulting in two streams, the permeate (the water after it flows through the membrane) and the reject (concentrate).

- The permeate:
  - Is approximately 80% of the feed flow.
  - Has approximately 5% of the chlorides and other ions present in the feed flow.
- The reject or concentrate stream:
  - Is approximately 20% of the feed flow.
  - Has approximately 5 times the concentration of the ions removed from the feed flow.
  - Requires further treatment (evaporation) to reduce its volume for proper disposal (incineration or landfilling), or discharge to Met Council sewer (if permitted).
- RO systems have high capital costs due to cost of membranes, pressurized vessels, high-pressure pump, and manufactured skids.
- RO membranes require chemical addition to the feed such as antiscalants and biocides to avoid membrane fouling and reduced performance.
- Since chloride removal from Parkers Lake would be an annual event during spring, summer, and fall, the RO membranes would need to be properly cleaned and flushed, then stored with water and possibly a preserving chemical to ensure optimum performance for yearly treatment events. As an alternative, the membrane elements could be replaced on an annual basis.

3.3.3.2 Ion Exchange (IX)

Ion exchange (IX) treatment consists of resin selective to specific ion(s) loaded in pressurized vessels. In this case, chloride is exchanged with another anion, usually hydroxide (OH^-) upon contact with the resin inside the vessel.

- IX vessels require backwashing when the flow drops or differential pressure across the vessel increases, but this is not expected to be a frequent requirement unless run times are very long.
- No chemical is added prior to the IX treatment.
- The effluent has similar water quality as the influent but with low concentrations of the target ions and any other ions that the resin has a high affinity for. For this application, the resin will likely remove sulfate and phosphate preferentially. The phosphate removal will be beneficial and will not significantly reduce the resin's capacity for chloride. Depending on the sulfate concentration in the lake, the resin's chloride reduction capacity may be somewhat lower. Future monitoring of sulfate is recommended, but it was already assumed that we wouldn't get 100% chloride treatment in the vessel, and thus, do not expect sulfate concentration to change capital (or greatly increase O&M) costs.
- After all exchange sites are filled, the resin requires replacement or regeneration. Because on-site regeneration will generate a waste that is difficult to dispose of, on-site regeneration was not considered further.

- Because chloride removal from Parkers Lake will be a yearly event during spring, summer, and fall, the IX vessels would need to be properly cleaned and flushed, then stored with water and possibly a preserving chemical to ensure optimum performance for yearly treatment events and to avoid damage to the resin.

Table 3-3 Advantages and disadvantages of chloride removal technologies

	Advantages	Disadvantages
Reverse Osmosis	• Has high quality permeate stream • Has high removal efficiency of chlorides	• Requires pretreatment for TSS and organic matter removal • Has high capital cost • Requires proper management of the reject or concentrate
Ion Exchange	• No other effluents to be managed if regenerated off-site.	• Requires pretreatment for TSS and organic matter removal. • High sulfate may compete with ion exchange sites and shorten the run time between regeneration. • On-site regeneration would require storage of caustic regenerant at the site and disposal of high pH spent regenerant.

3.3.3.3 Chloride Treatment Recommendation

Because RO and IX both offer advantages for treatment, and because they will have different capital and operational costs, both are considered in the following sections.

3.4 Preliminary concept design

This section describes preliminary concept design of both RO and IX treatment systems.

3.4.1 Assumptions

We made the following assumptions for designing the process flow diagram, sizing equipment, and providing cost estimates.

- The treatment system and any necessary structures will be placed on City, County or TRPD property.
- The treatment system will be operated by City of Plymouth staff.
- The system will be operated at 20 gpm average flow to treat up to 5,000,000 gallons in 180 days during April to October every year.
- The water will be pumped from the lake bottom (36-foot depth).
- The treatment system will typically operate when the lake is at its normal water level of 934.0 ft NAVD 88.
- All equipment will be housed in a secure treatment building with access for maintenance activities. The treatment building will be located at 5 feet above the lake's OHWL of 935.9 ft NAVD 88.

3.4.2 Common requirements

The following systems are required for both options, which can be run by a typical operator with maintenance performed by the supplier:

- Inlet screen – ¼" wedge-wire tee-screen installed at the intake.
    - Designed to meet fish entrainment requirements.
    - Lowered into place from a small work barge with a precast concrete ballast to set approximately 1 foot off the bottom of the lake.
    - Set at approximately 36 feet of depth.
- Inlet pipe – 3-inch ductile iron pipe.
    - 1000 feet length lowered into place from a work barge to lay on the bottom of the lake between the inlet screen and lake exit.
    - Dewatering adjacent groundwater required to install the pipe 3 feet below the NWL and maintain at least 3 feet of cover as it leaves the lake.
- Pump station – Self-priming centrifugal pumps.
    - Will lift water from the hypolimnion and pump through the prefilter at a rate of up to 20 gpm.
    - Capable of pumping flush water from the treated water tank to the inlet screen at a rate of 30 gpm.
- Prefilter – multi-stage bag filter.
    - 50-micron x 10 micron, or 50-micron x 5 micron depending on the chloride treatment process.
    - Sized to require bag replacement no more frequently than once per week.
- Treated water tank – staging tank for water used for flushing the inlet screen
    - 600-gallon cross-linked polyethylene tank
- Return pipe – 2-inch ductile iron pipe in joint trench below ice level.
    - Will return treated water to the epilimnion.
- Process piping and valves – will allow flushing of the inlet pipe and screen with treated water.

3.4.3 Option 1 – Ion Exchange treatment

The first option considers IX for chloride removal. Figure 3-1 shows the process flow diagram for this treatment option. Option 1 includes the following:

- Ion exchange
    - Chloride selective resin in a three-vessel rental skid.
    - 20 gpm capacity.
    - Sufficient resin volume to require change-out no more than once per week
    - The rental option assigns responsibility for resin changeout, regeneration, and storage between treatment events to the equipment supplier.

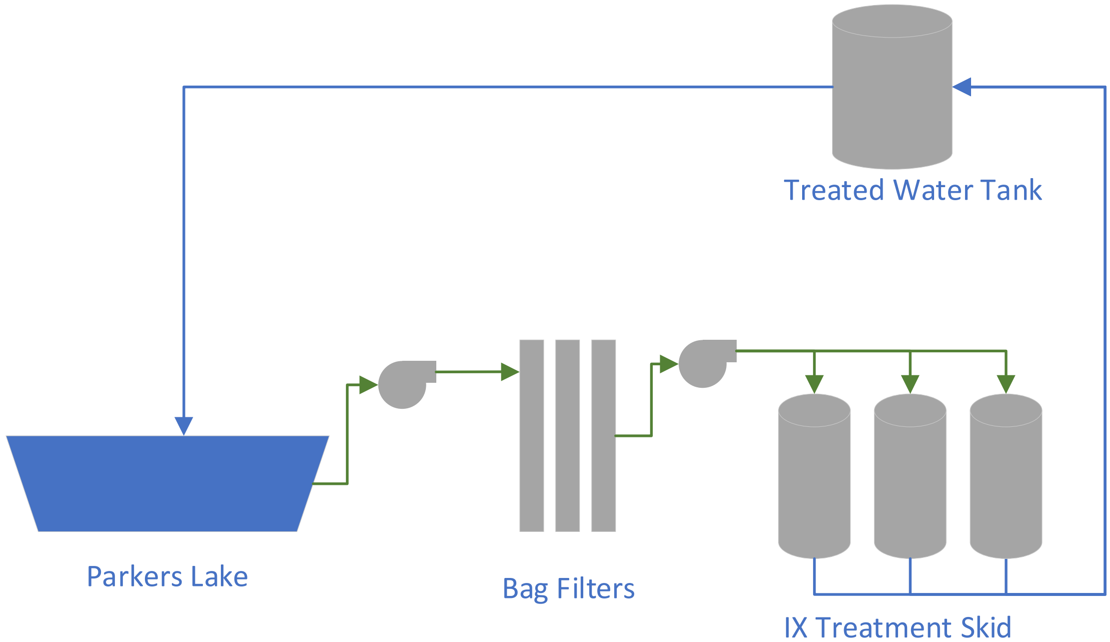

Figure 3-1 Ion Exchange Process Flow Diagram

3.4.4 Option 2 – Reverse Osmosis Treatment

The second option considers RO for chloride removal. Figure 3-2 shows the process flow diagram for this treatment option.

Option 2 includes the following systems:

- Reverse osmosis
  - 20 gpm capacity
  - 2-stage RO skid with pumps, valves, pressure vessels, membrane elements, instrumentation, and control panel.
  - Replaceable membrane elements

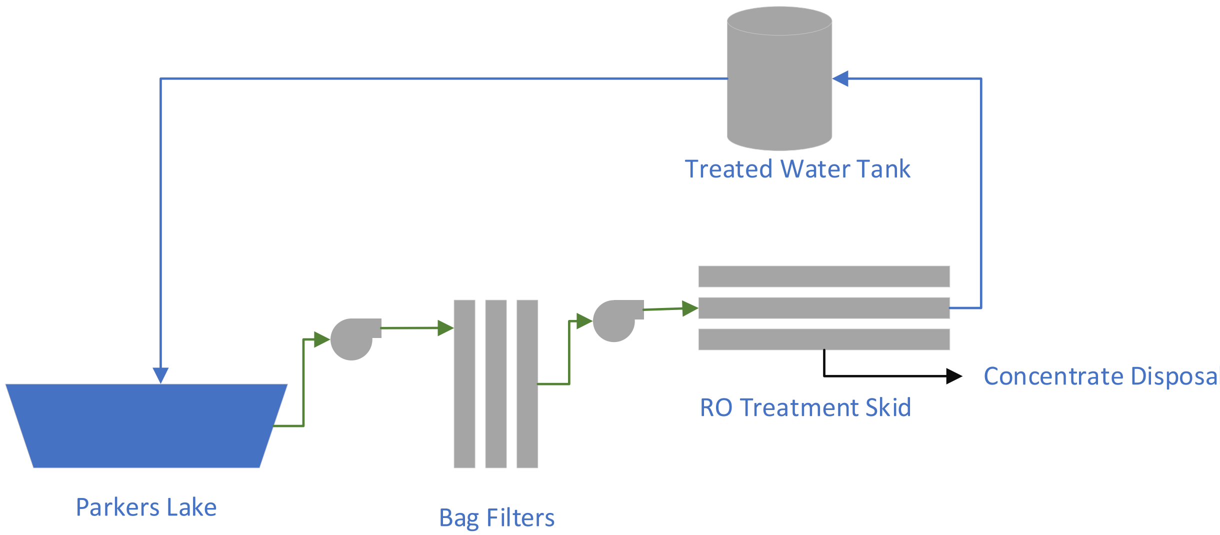

Figure 3-2 Reverse Osmosis Process Flow Diagram

It may be possible to dispose of concentrate in the sanitary sewer system. This is typically where reverse osmosis concentrate from industrial wastewater or municipal water treatment processes is discharged. However, the Met Council provided a preliminary opinion that this would not be allowed.

Landfill disposal is feasible if the wastewater is dried sufficiently to pass a paint filter test. This would likely require drying the concentrate to approximately 60% total solids. At a treatment rate of 20 gpm, the RO system will generate almost 6,000 gallons of concentrate per day. This would need to be reduced to about 80 gpd of concentrate solids through evaporation. This cannot be accomplished with non-mechanical drying systems and would be cost prohibitive with a mechanical evaporator crystallizer due to the high capital cost of equipment and energy input for evaporating water. For this evaluation, concentrate disposal is not considered beyond sewer discharge. If the Met Council refuses to accept the concentrate discharge, the RO option may not be viable.

3.5 Class 4 cost estimate

Barr prepared Class 4 cost estimates, as defined by the American Association of Cost Engineers International (AACI International), for each option as summarized in Table 3-4.

Table 3-4 Summary of capital cost estimates

	Option 1 IX vessel Rental	Option 2 RO
Mobilization	$35,000	$53,000
Site Grading and Access	$10,000	$10,000
Inlet Screen	$15,000	$15,000
Inlet and Return Pipe	$240,000	$240,000
Inlet Pump	$15,000	$15,000
Prefilter	$27,000	$27,000
Chloride Removal Treatment	$0	$111,000
Treated Water Tank	$3,000	$3,000
Residuals Pipe	$0	$10,000
Treatment Building	$25,000	$60,000
Electrical and Controls	$14,000	$44,000
Contingencies	$58,000	$88,000
Construction Cost	**$442,000**	**$676,000**
Engineering, Legal, Administrative	$98,000	$149,000
Total Project Cost	**$540,000**	**$825,000**
Accuracy Range (-20%)	$440,000	$660,000
Accuracy Range (+30%)	$710,000	$1,070,000

Mobilization includes contractor overhead costs for performance bonds, regulatory requirements, insurance, submittals, and moving equipment to and from the site. It is estimated to be approximately 10% of the total construction cost.

Site Grading and Access Roads includes construction silt fence and other construction stormwater management requirements as well as mass grading and pavement construction.

Inlet Screen includes a ¼" wedge-wire tee-screen sized to meet fish entrainment requirements installed from a construction barge.

Inlet, Outlet, and Residuals Pipe includes pipes and valves required to move water from the inlet through treatment and to the discharge. Because locations have not been evaluated, costs are allowances that account for installation below the water level and added length required for inlet pipe.

Inlet Pump includes a single self-priming centrifugal pump sized to pump water from the lake through the prefilter.

Prefilter includes bag filtration housing and media and installation.

Chloride Removal includes capital equipment and installation required for each option. Because the ion exchange option will include rental vessels, the cost of those tanks is included in O&M costs. The capital cost for that system does include appropriate piping, valves, instrumentation, and tank pads.

Treated Water Tank includes treated water storage for backwash, flushing, and discharge to the lake.

Treatment Building includes sheltered space for process equipment and pumps. The treatment building is assumed to be a concrete block construction.

Electrical and Controls is a placeholder based on 20% of equipment and building costs that includes motor control, heating and ventilation, and wiring and lighting.

Contingencies are estimated at 15% of direct costs. This is a place holder for work that is required but is not identified in a specific line item. As the design progresses, the contingencies will decrease.

Engineering, legal, and administrative costs are estimated at 22% of construction costs.

Table 3-5 Summary of annual operation and maintenance costs

	Option 1 IX Rental	Option 2 RO
Operation	$48,600	$44,400
Maintenance	$10,800	$15,300
Material	$30,000	$30,000
Chemical		$1,000
Energy	$800	$1,600
Fees	$36,000	$5,000
Total	**$126,200**	**$97,300**

Operation costs include operational labor, laboratory labor and testing fees, reporting, and administrative costs. Systems with more unit processes tend to have higher costs in this category. The main assumption that influences this line item is labor costs, which are assumed to be $100/hr for operators and $150/hrs for administration.

Maintenance costs include labor for maintaining, adjusting, and repairing mechanical equipment. Systems with more pumps and other motor-driven equipment tend to have higher costs in this category.

Material costs include lubricating fluids, gaskets, seals, replacement parts, and disposal of residuals. Systems with more pumps and other motor-driven equipment tend to have higher costs in this category. Residual disposal fees for the RO system are assumed to be equal to a typical residential monthly sewer bill.

Chemical costs include antiscalants and cleaning chemicals.

Energy costs include the power costs for operating motor-driven equipment. Power costs are assumed to be $0.12/kW-hr.

Fees includes rental costs and assumes current sewer use fees and we assume a time value of money based on BCWMC policy. The Met Council levies industrial charges for flow, BOD, and TSS.

3.6 Treatment Option Summary

Removal of chloride from the Parkers Lake hypolimnion could be achieved with reverse osmosis (RO) treatment or ion exchange (IX). RO will have higher capital costs and lower operation and maintenance (O&M) costs, while IX will have lower capital costs and higher O&M costs. Based on the initial cost estimates, the payback period for RO treatment would be more than 30 years. Assumptions that could change the payback period include:

- Extending treatment longer through the summer months would increase the IX rental costs and decrease the payback period.
- Drying and landfill disposal of RO residuals would increase disposal costs and increase the payback period.

To further develop the chloride treatment design option(s), we recommend these next steps:

- Conduct comprehensive water quality testing on the water to be treated to inform potential treatment interferences, chemical use and other O&M costs associated with the pretreatment and/or treatment options. Samples should be collected from the same depth that the treatment system will pump and treat. This data will:
  - Determine raw water quality parameters that may impact RO treatment and chemical requirements.
  - Model water quality data of both RO reject, and RO permeate.
  - Determine concentrations of all ions that may potentially interfere with chloride ion exchange.
  - Verify assumptions on seasonal TSS concentrations.
- Discuss the location and operation of the treatment system with City of Plymouth and Hennepin County, as a specific location was not selected. The preferred location will be:
  - Close to the lake edge.
  - At an elevation close to the OHWL.
  - Acceptable to the landowners.
  - Accessible from existing access drives.
- Review RO concentrate discharges with the Met Council.

4 Overall Project Cost Considerations, Conclusions and Recommendations

4.1 Analysis of Annualized Cost Per Pound of Chloride Removal

We used the following assumptions to develop the economic analysis:

- The system will be operated at up to 20 gpm flow to treat up to 5 million gallons within a 32-week period during the Spring-Fall period each year that preliminary monitoring indicates that chloride exceedances are expected.
- Options are compared as equivalent uniform annual costs (EUAC) estimated for a 30-year life cycle.

- Capital costs are converted to an annual cost using an interest rate of 3% with discrete compounding.
- O&M costs will be incurred once per year at the end of the year.
- Salvage values (applicable for intake piping and building) are not considered.
- Equipment service life is 20 years. With regular maintenance this could be extended to 30 years without extra wear and tear or corrosion on parts.

Table 4-1 summarizes the annualized cost estimates and cost per pound of chloride removed for both treatment options considered. Option 2 includes Met Council fees in the O&M costs, while the rental fees are the primary drivers of increased O&M costs for Option 1. We expect that both options will result in long-term average chloride removals of approximately 13,120 pounds per year, which would reduce the average amount of chloride in the hypolimnion of Parkers Lake by 16%. We expect that this estimated load reduction would correspond to a long-term chloride concentration of 280 mg/L in the hypolimnion, while the long-term average chloride concentrations in the surface and middle sampling points of Parkers Lake would be maintained at approximately 165 mg/L, well below the 230 mg/L State Water Quality Standard.

Table 4-1 Summary of capital and O&M cost estimates and cost-effectiveness

	Option 1 IX vessel Rental	Option 2 RO
Total Capital Cost (from above)	$540,000	$825,000
Annual O&M Cost (from above)	$126,200	$97,300
Year 20 Replacement Costs	$56,000	$197,000
30-year EUAC Including Replacement Costs	**$155,300**	**$144,900**
30-year EUAC Without Replacement Costs	$153,700	$139,400
Annualized Cost per Pound of Chloride Removed	**$11.84**	**$11.04**

4.2 Discussion and Overall Recommendations

Parkers Lake regularly discharges water during all but the driest years; therefore, we expect that the full in-lake mass of chloride is typically flushed out by the incoming load every 1.4 years. Per State water quality standards, a lake is considered impaired if two or more measurements exceed the chronic criterion (230 mg/L) within a 3-year period or if one measurement exceeds the maximum criterion (860 mg/L). Because of this, it will be difficult for either of the treatment options to produce early season chloride concentrations that meet the 230 mg/L standard in a typical year, without additional source load reductions (about 20%) or an order of magnitude increase in treatment capacity (and corresponding cost increases).

It is likely that a combination of watershed source control to reduce chloride loading and the treatment Option 1 (ion exchange) will meet MPCA's lake chloride standard. However, because of the large scale of the Parkers Lake project and the additional costs and permitting requirements (Parkers Lake is a MnDNR public water), we do not recommend moving ahead with the Parkers Lake project at this time. Rather, we recommend that the Commission consider design refinements and the feasibility of implementing ion exchange treatment at a smaller scale, such as at a stormwater pond upstream of a chloride-impaired or threatened lake (e.g., at a pond upstream of Crane Lake). A smaller, pilot project could also include comparing the ion exchange treatment option with the cost and practicality of enhanced source control in the tributary watershed. If the ion exchange treatment option is successful at this smaller scale, then the Commission can consider implementing this type of treatment at a larger scale/larger waterbody.

In addition to the recent changes to the City's Parkers Lake monitoring program, we further recommend that the Commission and the City of Plymouth add a winter (January or February) lake water quality sampling event to the current protocols to establish an annual chloride mass balance baseline and to better measure future watershed source reductions of applied chloride.

5 References

1. **Bassett Creek Watershed Management Commission.** Parkers Lake. *Bassett Creek WMO.* [Online] Bassett Creek WMO, 2023. [Cited: August 25, 2023.] https://www.bassettcreekwmo.org/lakes-streams/parkers-lake.

2. **Minnesota Pollution Control Agency.** Minnesota's impaired waters list. *Minnesota Pollution Control Agency.* [Online] MPCA, 2023. [Cited: August 25, 2023.] https://www.pca.state.mn.us/air-water-land-climate/minnesotas-impaired-waters-list. wq-iw1-73.