Water Softening Treatment Plant Study City of Grand Ledge

Project No. 200548
August 20, 2020

Review Draft

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Prepared For:
City of Grand Ledge
Eaton County, Michigan

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List of Tables

List of Figures

Figures Following Text

List of Acronyms

ACH air change per hour
ADD average daily demand
AHU air handling units
CFM cubic foot per minute
CIP clean in place
CMU concrete masonry unit
DX direct expansion
DWRF Drinking Water Revolving Fund
EGLE Michigan Department of Environment, Great Lakes, and Energy
fc foot candle
FRP fiber reinforced plastic
gpm gallons per minute
HMO hydrous manganese oxide
HPF horizontal pressure filter
i/o input/output
IX ion exchange
LBWL Lansing Board of Water & Light
MCL maximum contaminant level
MDD maximum daily demand
MG million gallon
mgd million gallons per day
mg/L milligrams per liter
NEC National Electric Code
NPDES National Pollutant Discharge Elimination System
O&M operation and maintenance
(pCi/L) picocuries per liter
PLC programmable logic controller
PSI pounds per square inch
RD Rural Development
RO reverse osmosis
SCADA supervisory control and data acquisition
SDWA Safe Drinking Water Act
SESC Soil Erosion and Sedimentation Control
sf square foot
TDS total dissolved solids
TSP twisted shielded pair
USDA United States Department of Agriculture
USEPA U.S. Environmental Protection Agency
VFD variable frequency drive
VPN virtual private network
WTP water treatment plant
WWTP wastewater treatment plant

1.0 Executive Summary

The City of Grand Ledge (City) retained Fishbeck to evaluate options for the replacement of the City's existing iron removal treatment system. Fishbeck is evaluating three options as part of this process: the installation of a new iron removal system, the installation of a new softening system, and receiving water from the adjacent Lansing Board of Water & Light (LBWL) system. This report evaluates the second option, the installation of a new softening treatment system to replace the existing iron removal system.

The City's existing iron removal plant utilizes an AERALATER® Type II-Q Packaged Iron and Manganese Removal System by General Filter (Aeralater) for iron removal. The Aeralater is at the end of its useful life, and has significant signs of deterioration. The repair of the Aeralater system was investigated as part of a prior study completed by Fishbeck, which determined that repair of the Aeralater would be costly and would give a low return on investment. The City opted to move forward assuming that the Aeralater unit would need to be replaced, rather than attempt to repair it.

An updated Basis of Design was developed for the water treatment plant to determine the required capacity of a new facility. To establish the Basis of Design, the last ten years of water demand data for the City system and recent raw water quality data were analyzed. Trends in the water demands were evaluated and used to project the estimated water demands 20 years into the future. A 2040 projected average daily demand of 0.91 million gallons per day (mgd) and a 2040 projected maximum day demand of 1.74 mgd were estimated. Ultimately, for the purposes of this study, a plant capacity of 4.0 mgd was selected by the City. This higher capacity would provide room for growth in the City water system and a treatment capacity safety factor in case of an emergency. The raw water quality analysis indicated that iron and radium removal would likely be needed. The existing treatment process removed iron, but not radium. However, radium levels in the raw water have been close to the United States Environmental Protection Agency (USEPA) maximum contaminant levels (MCL) in the past. Due to the observed values of radium, the Michigan Department of Environment, Great Lakes, and Energy (EGLE) has indicated to the City that any changes to the treatment process should include provisions for radium removal. These provisions were included in the conceptual design of the new treatment process alternatives.

In addition to the removal of iron and radium, this report evaluates the softening of the raw water. The raw water has a significant amount of hardness, about 460 milligrams per liter (mg/L) as calcium carbonate. A target hardness value after softening would be about 120 mg/L as calcium carbonate. Many Grand Ledge water customers have home softeners to reduce the high hardness in the City's water. A softer water would reduce the amount of soap needed when washing clothes and dishes. Soft water can also reduce lime scale buildup in pipes and appliances in homes.

Three treatment process alternatives for a new water softening treatment system for the City were evaluated. The three alternatives evaluated were reverse osmosis (RO) softening, ion exchange (IX) softening, and lime softening. A target hardness of 120 mg/L as calcium carbonate was used to assess each alternative. The feasibility of each treatment process alternative was evaluated and cost estimates for constructing and running the treatment processes were created. This evaluation was conceptual in nature. Further refinement of the required treatment process, construction cost estimates, and schedule for completion would be completed as part of the preliminary design process, if the City chooses to move forward with one of these options.

For each alternative, a conceptual design, process schematic, and conceptual plant layout were completed. Each alternative includes a new water treatment plant building on the existing treatment plant property, located south of the existing plant and garage. The building would be constructed with split-face block walls and a sloped, standing-seam metal roof. It would include a new laboratory, a unisex bathroom, janitor's closet, process area for the treatment equipment, a control room, an electrical room, a mechanical (HVAC) room, and chemical feed and storage rooms.

For the RO softening alternative, RO membranes, which remove virtually all dissolved solids including hardness components, can be used to soften the raw water. Some hardness in the water is desirable to provide a stable and non-corrosive water. To achieve that, the process normally includes bypassing a stream of filtered, unsoftened water, referred to as the blend stream, that is blended with the RO treated water to achieve the target hardness level. RO membranes have the added benefit of removing currently-regulated contaminants such as metals, organics, pesticides, and pathogens (including viruses), and have been shown to be effective in removing many of the emerging contaminants of concern, as well as unregulated emerging contaminants regulated by USEPA and EGLE. The RO membranes would remove radium from the water as well, precluding the need for adding hydrous manganese oxide (HMO) to the pressure filters. It should be noted that regulated contaminants, including radium, would not be removed in the blend stream; however, with the removal of all radium in water passing through the RO membranes, the blended water would have radium concentrations far below regulatory limits.

Additional raw water and iron removal capacity would be needed because the RO softening system requires up to 25% of the inlet flow for membrane cleaning and operation. RO membranes are susceptible to fouling, which can interrupt treatment production. The RO process produces a significant waste stream that is high in total dissolved solids (TDS). This waste stream could not be handled by the City's existing wastewater treatment plant (WWTP), and the plant would require improvements to handle the additional flow from a RO water plant. Another option would be discharging concentrate to the Grand River. A permit from EGLE would be required for the discharge to the Grand River and a cascade aerator could be required at the point of discharge.

For the IX softening alternative, IX pressure vessels would be provided with an ion exchange resin to remove hardness by adsorption. During this process, sodium (and alternatively potassium) ions are exchanged for the calcium and magnesium hardness ions, reducing the hardness to almost 0 mg/L. Some hardness in the water is desirable to provide a stable and non-corrosive water; to achieve this, the process normally includes bypassing a stream of filtered water that is blended with the ion exchange treated water to achieve the target hardness level. The ion exchange resin would need to be regenerated periodically using a regenerate solution (typically sodium chloride brine solution) to replenish the exchange sites.

Ion exchange would be the most cost-effective softening option. However, it does have some disadvantages. The sodium-based ion-exchange process would result in an increase in the treated water sodium concentration. The sodium concentration of the blended water is estimated to be in the range of 80 to 120 mg/L, assuming the process removes all the calcium and magnesium from the treated water, which is well above the USEPA recommended sodium concentration limit of 30 to 60 mg/L. Many City customers that currently have in-home ion exchange water softeners would have similar concerns with elevated sodium in their drinking water.

The waste stream produced by the ion exchange system would be difficult to manage. The TDS concentration of the ion exchange waste stream is quite high, estimated at about 26,000 mg/L. This TDS concentration makes discharge to the Grand River infeasible. While the flow is relatively low, it is unknown if the City's WWTP could handle the concentrated waste stream, which also includes high chloride and calcium concentrations from the ion exchange system, without significant improvements to the WWTP.

For the lime softening alternative, lime would be added to raise the pH of the water, precipitating the calcium carbonate and magnesium out of the water. Lime softening is a proven technology that many Michigan water supplies use to soften groundwater in Michigan. Lime softening removes calcium and magnesium hardness, along with iron and manganese, by a process of chemical precipitation. In addition, lime softening is also effective in removing radium. A lime softening plant also produces a fairly stable finished water for the purposes of corrosion control.

The lime softening alternative evaluated includes a traditional treatment process, using solids contact clarifiers as a vessel for chemical precipitation, flocculation, and settling.

Traditional lime softening has some disadvantages. It utilizes a fairly large footprint in comparison to other options. It requires a significant amount of chemical usage; the delivery and feeding of lime can be messy to work with and labor intensive. Lime softening has a fairly high capital and operational cost due to its large footprint and significant chemical usage. Lime softening produces a large amount of sludge, which in this case, must be mechanically dewatered and hauled away for land application. Lime softening is typically used for larger scale treatment plants, and is the technology that LBWL uses.

The use of pellet reactors for softening, which precipitates calcium carbonate onto a sand media in a vertical reactor, was also considered. However, pellet softening can only remove carbonate hardness. The Grand Ledge raw water has a significant amount of non-carbonate hardness. Therefore, pellet softening could not meet the hardness target, and was considered an infeasible softening alternative and eliminated from further evaluation.

The conceptual design, layout, and sitework for each of the softening treatment alternatives were evaluated. Capital and operation and maintenance (O&M) cost estimates were estimated for each alternative. The construction cost opinion includes the cost of a new treatment plant, the site work, and associated work at the existing wells and elevated tanks. Estimated costs for engineering, a corrosion control study, and pilot testing, if needed, are included in the Engineering & Studies column. The annual O&M costs include the electrical, chemical, and labor costs. Costs are summarized in Table 1.

Table 1 - Softening Alternatives Cost Comparison

Softening Alternative	Construction Cost Opinion	Engineering & Studies	Total Project Costs	Annual O&M Costs
RO Softening	$30,265,000	$3,305,000	$33,570,000	$509,000
IX Softening	$19,882,000	$2,295,000	$22,184,000	$508,000
Lime Softening	$26,807,000	$3,130,000	$29,937,000	$637,000

As noted previously, there is uncertainty for both the RO and IX softening options with the handling of the treatment residuals. Discharge of the RO concentrate to the Grand River was assumed for that alternative. The brine waste stream from an IX softening plant was assumed to be discharged to the sanitary sewer. However, further evaluation would be necessary to verify if the City WWTP could handle the brine waste stream. Further investigation into the handling of these treatment residuals is recommended if the City wishes to move forward with either RO or IX softening.

Cost estimates presented are based on July 2020 cost indices and the project components as presented herein. Actual project costs may differ based on the final scope of the project design components, the bidding climate at the time the project is bid, material pricing fluctuations, and other factors.

2.0 Introduction

The City retained Fishbeck to evaluate various alternatives for replacement of the City's existing iron filtration system. The three general approaches for replacement include: installing a new iron removal system, installing a new water softening treatment system, and connecting to and receiving softened water from the LBWL. This report addresses the second approach listed: building a new City-owned water softening plant.

The City owns and operates a municipal water system that supplies water to the City of Grand Ledge and portions of Oneida Township. The City water system consists of four groundwater supply wells, an iron removal treatment plant, two elevated tanks, and a ground storage tank and pump station. The iron removal plant is supplied by three of the groundwater supply wells (Well Nos. 6, 7, and 8).The fourth well (Well No. 2) can only pump directly to the water system. The iron removal plant utilizes an Aeralater to remove iron from the water.

The City's Aeralater system, installed in 1988, is approaching the end of its useful life and showing significant signs of deterioration. Significant repair to the Aeralater system would be required for continued long-term use. Fishbeck completed a small study in 2019 to determine if the Aeralater could be repaired. The repair was estimated to be costly and disruptive to the existing treatment system. In addition, it was unknown how long the unit would remain operational if repaired, due to its age and condition. Replacement of the Aeralater system was recommended.

This evaluation considers three treatment process alternatives for a new water softening treatment system for the City, including reverse osmosis (RO) softening, ion exchange (IX) softening, and lime softening. The feasibility and cost estimates for each of the treatment process alternatives were evaluated. This evaluation is conceptual in nature. Further refinement of the design of the treatment process, construction and engineering cost estimates, and schedule for completion would be completed as part of the preliminary design process, if the City chooses to move forward with one of these softening treatment alternatives.

3.0 Existing System

The City's existing water supply and treatment system consists of four groundwater supply wells and an iron removal plant.

3.1 Existing Well System and Capacity

The existing well system consists of four groundwater wells. Three of the wells supply raw water to the iron removal plant, and the fourth well pumps directly to the City's distribution system. Table 2 below shows the capacities of the existing groundwater supply wells.

Table 2 - Existing Well Capacities

Well Number	Well Capacity (gpm)	Well Capacity (mgd)
Well No. 2*	400	0.58
Well No. 6	1,100	1.58
Well No. 7	500	0.72
Well No. 8	400	0.58
Total Capacity	2,400	3.46
Firm Capacity	1,300	1.88

* Well No. 2 pumps directly to the distribution system.

The total capacity of the existing raw water system is 2,400 gallons per minute (gpm). The firm capacity of the raw water supply system is 1,300 gpm with Well No. 6 (the largest well) out of service.

However, the raw water capacity of the existing iron removal plant is different than that of the system. Well No. 2 pumps directly to the distribution system and cannot provide raw water directly to the iron removal plant without the significant expense of running a raw water main from the well to the plant, a distance of nearly one and a half miles. Raw water can only be supplied to the treatment plant by Well Nos. 6, 7, and 8. Thus, the total raw water capacity supplied to the iron removal plant is 2,000 gpm (2.88 mgd) and the firm raw water capacity supplied to the iron removal plant is 900 gpm (1.30 mgd).

3.2 Existing Iron Removal Plant

The existing iron removal plant uses an Aeralater system with a design treatment capacity of 2.3 mgd, which combines aeration, detention, and filtration in a single treatment unit to remove iron from the raw water. Raw water is pumped from the wells to the top of the unit and flows by gravity through a distribution tray. The iron in the water is oxidized by air drawn upward through the top of the unit using an induced draft blower. A detention tank sits just below the aeration portion of the unit, which promotes flocculation and provides enough detention time for the iron to precipitate. The water then passes through the dual-media (sand and anthracite) filters at the bottom of the unit, which filter the iron precipitate out of the water. The filtered water exits through a common outlet connection, is chlorinated for disinfection, and flows to the clearwell. High service pumps convey water from the clearwell to the distribution system.

3.3 Raw Water Quality

The raw water quality of Well Nos. 6, 7, and 8 was assessed for a number of parameters to identify any other potential raw water quality issues to address with a new treatment plant. Table 3 shows the raw water quality parameters measured for each well.

Table 3 - Raw Water Quality Parameters for Existing Wells

Raw Water Quality Parameters	Well No. 6	Well No. 7*	Well No. 8*	Units
Ammonia as N	0.2	0.2	0.2	*mg/L*
Arsenic	0.006	0.004	0.012	*mg/L*
Calcium	120	140	104	*mg/L*
Chloride	38	146	9	*mg/L*
Fluoride	0.33	0.29	0.5	*mg/L*
Hardness as $CaCO_3$	460	527	425	*mg/L*
Iron	0.94	3.02	0.8	*mg/L*
Magnesium	39	43	40.1	*mg/L*
Manganese	-	0.19	0.13	*mg/L*
Nitrate as N	0	0	0.3	*mg/L*
Nitrite as N	0	0	0	*mg/L*
pH	7.21	7.04	7.5	*mg/L*
Potassium	2.2	3.2	1.6	*mg/L*
Silica as SiO_2	15	14	19.3	*mg/L*
Sodium	21	69	8.9	*mg/L*
Specific Conductance	895	1313	670	*umhos*
Sulfate	105	127	76	*mg/L*
Total Alkalinity as $CaCO_3$	350	360	340	*mg/L*
Total Organic Carbon	1.63	1.47	9.0	*mg/L*
Zinc	-	0.02	0	*mg/L*

mg/L – milligrams per liter
* - The higher value of two sets of testing data was chosen for Wells 7 and 8

As Table 3 shows, the raw water from Well No. 7 has significantly higher iron and hardness than the other wells. In addition, Well No. 7 is high in chlorides and specific conductance. The iron levels in all three wells are above the USEPA recommended Secondary MCL of 0.3 mg/L. The manganese values measured in Well Nos. 7 and 8 are also above the recommended Secondary MCL of 0.05 mg/L. The hardness of the raw water is fairly high, exceeding 400 mg/L for all three wells and exceeding 500 mg/L for Well No. 7. For comparison, a typical target hardness range for a softened water supply is between 100 to 140 mg/L.

Radium is not shown in Table 3, but is known to be a potential issue in the City's raw water. Values as high as 3.1 picocuries per liter (pCi/L) of combined radium 226/228 have been observed (the limit is 5 pCi/L). The gross alpha radium has reached values of 12 pCi/L (the limit is 15 pCi/L). Provisions for radium removal in the treatment process have been included as part of the conceptual design.

3.4 Water Demands

Water demands for the City system were assessed as part of the study to establish the needed capacity for the water treatment plant.

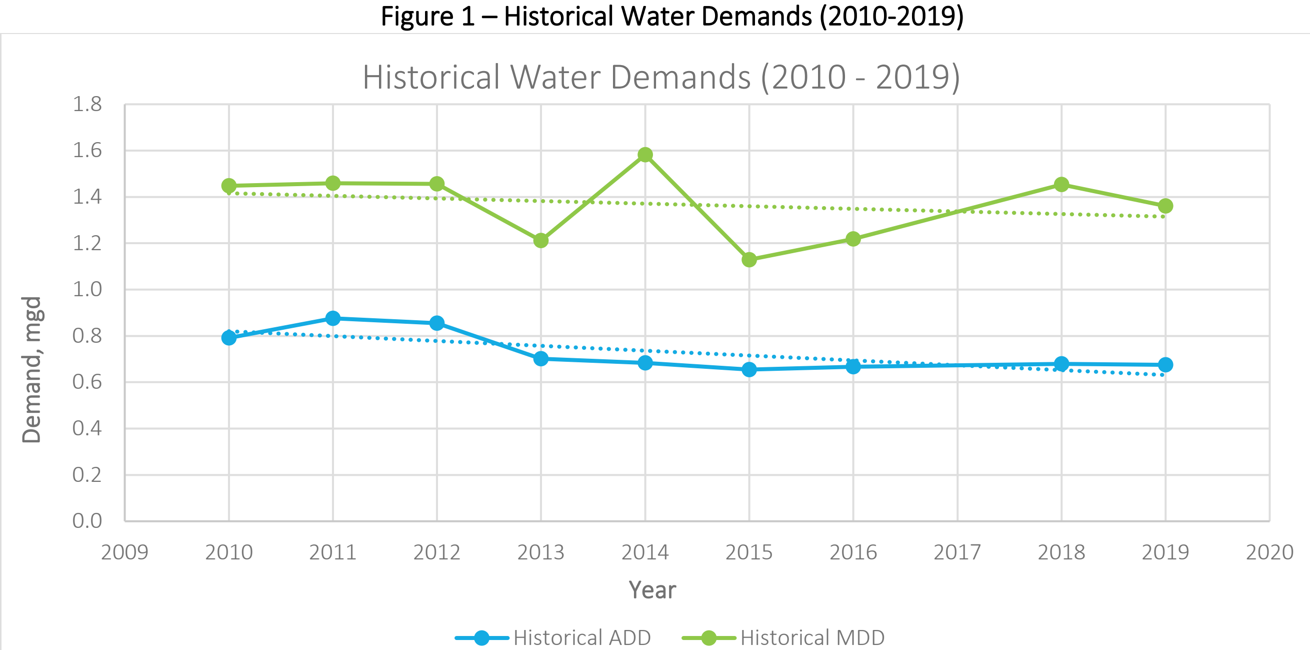
3.4.1 Historical Demands

The City provided data on historical water use for the years 2010 through 2019. For the purposes of this analysis, the water pumped from the plant to the system was assumed to be equivalent to the water demand of the customers in the system. In Table 4 below, a number of metrics are used to describe water demands in the City water system. The average day demand (ADD) is the average daily water pumped to the system. The maximum day demand (MDD) is the maximum amount of water pumped to the system in a single day, annually. The MDD:ADD peaking factor of the system is the ratio between maximum and average day demand for each year. The ADD, MDD, and MDD:ADD peaking factors were calculated for the years 2010 through 2019; the results, as well as the ADD and MDD trend lines, are shown in Table 4 and Figure 1. The ADD and MDD have trended downwards from 2010 to 2019.

Table 4 – Historical Water Demands (2010 – 2019)

Year	Average Day Demands, mgd	Maximum Day Demands, mgd	MDD:ADD Peaking Factor
2010	0.79	1.45	1.83
2011	0.88	1.46	1.67
2012	0.86	1.46	1.70
2013	0.70	1.21	1.73
2014	0.68	1.58	2.31
2015	0.65	1.13	1.72
2016	0.67	1.22	1.83
2017	0.65	1.42	2.20
2018	0.68	1.45	2.14
2019	0.67	1.36	2.02
Average	0.72	1.37	1.91

Figure 1 – Historical Water Demands (2010-2019)



3.4.2 Water Demand Projections

The starting point for the ADD and MDD projections was estimated to project future water demands. The starting point for the ADD was estimated by finding the standard deviation of the historical data and adding 1.65 times the standard deviation to the historical average of the ADD. Statistically, this value is predicted to be greater than 95% of the probable future values of the ADD based on the dataset. To find the starting point for the MDD, the average MDD:ADD peaking factor of the dataset was multiplied by the determined starting point of the ADD. Table 5 shows the historical water demands and the associated statistical metrics used.

Table 5 – Historical Demands and Statistical Metrics Used (2010-2019)

Year	Average Day Demands (mgd)	Maximum Day Demands (mgd) (maximum on MORs)	MDD:ADD Peaking Factors
2010	0.79	1.45	1.83
2011	0.88	1.46	1.67
2012	0.86	1.46	1.70
2013	0.70	1.21	1.73
2014	0.68	1.58	2.31
2015	0.65	1.13	1.72
2016	0.67	1.22	1.83
2017	0.65	1.42	2.20
2018	0.68	1.45	2.14
2019	0.67	1.36	2.02
Average	0.72	1.37	1.91
Maximum	0.88	1.58	2.31
Minimum	0.65	1.13	1.67
Standard Deviation	0.09		
Avg + 1.65 * StDev	0.86		

The starting point for the ADD projections is 0.86 mgd. The starting point for the MDD projections is 1.64 mgd, which is the starting point of the ADD, 0.86 mgd, multiplied by the average MDD:ADD Peaking Factor, 1.91.

The ADD and MDD water demands for the City system, starting at the points described above, were projected out for the next 20 years. Both the ADD and MDD showed a downward trend over the dataset; however, the City has experienced some growth in recent years. Based on this information, an annual demand growth of 0.25% was assumed for the demand projections. Figure 2 shows the historical dataset and the demand projections for both the ADD and MDD; Table 6 shows the current, 5-year, and 20-year projected demands.

Figure 2 – Projected Demands for City Water System

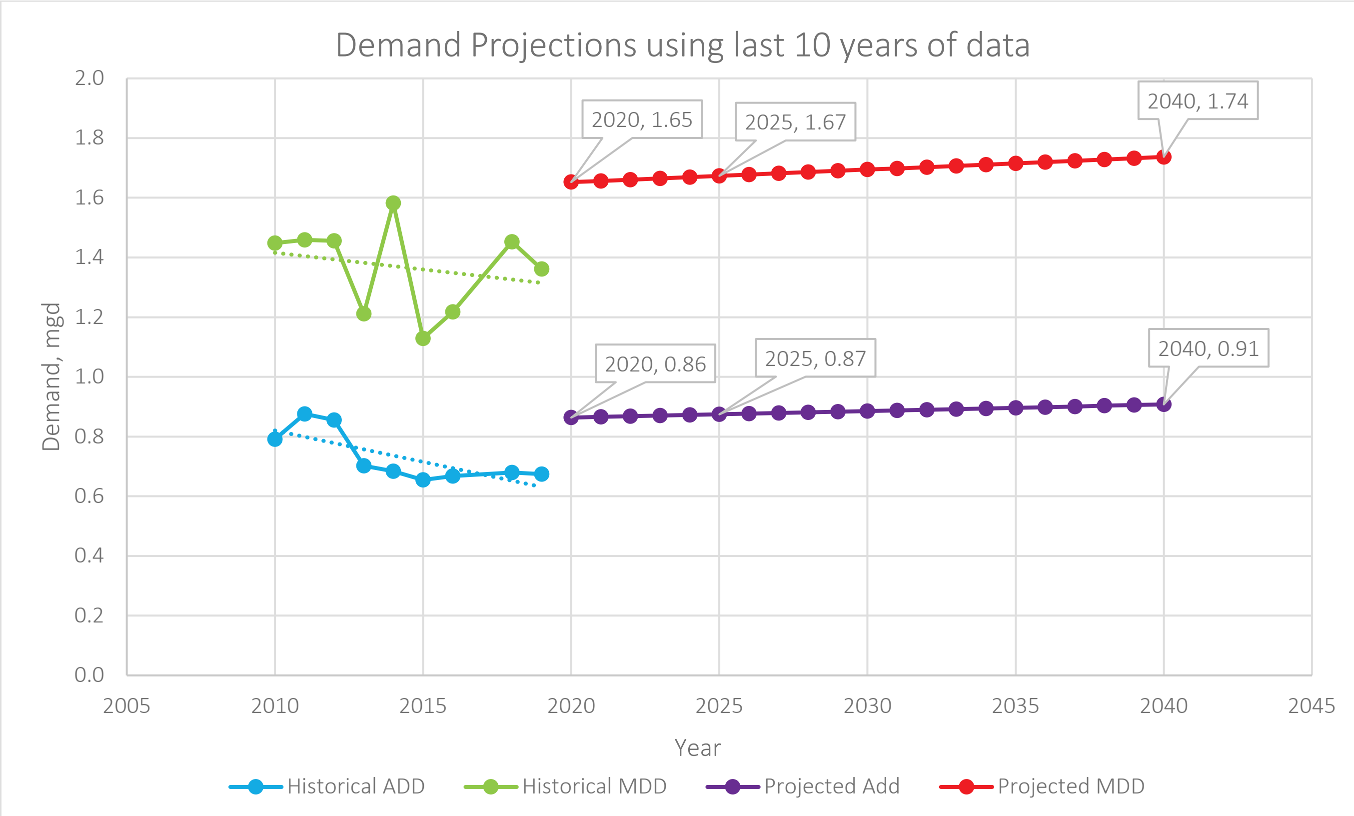


Table 6 – Projected Demands for City Water System

Year	Average Day Demands (mgd)	Maximum Day Demands (mgd)
2020	0.86	1.65
2025	0.87	1.67
2040	0.91	1.74

3.4.3 Design Plant Capacity

The design treatment capacity of the plant to be used as the basis of the study was determined through the demand projections, equipment sizing and needs, and discussion with City staff. The chosen capacity was used to evaluate the treatment plant alternatives and to develop equipment sizing and associated costs. A design capacity of 4.0 mgd was chosen by the City as the treatment plant capacity to evaluate. Sizing of the plant considered future demand projections and some allotment for growth.

4.0 Design Considerations Common to all Alternatives

Three treatment process alternatives were evaluated for a new water softening treatment system for the City.

4.1 Conceptual Basis of Design Information

The following design information and assumptions were used to evaluate treatment and construction alternatives considered in this report.

- The new treatment plant to be rated for a firm capacity of 4.0 mgd.
- The plant processes would be designed to reduce hardness, iron and manganese, and radium present in the raw water to meet recommended drinking water standards.
- The target hardness is 120 mg/L.
- The design should allow the City's current treatment plant to operate until the new plant is online.
- Chlorine gas is the preferred option for disinfection.
- Some means to control the flow of the backwash waste to the sanitary sewer should be considered. To accomplish this, the construction of a backwash equalization basin would be needed. The basin would be sized to allow all of the filters to be backwashed in the same day.
- The complexity of a softening treatment plant would require the City to hire additional staff. The cost of additional labor has been accounted for in the O&M costs for each alternative.
- Each softening alternative being evaluated has the added benefit of providing radium removal.
- It is understood that additional raw water capacity would be required to match the new treatment plant capacity. Costs presented to not include costs for additional raw water supply.
- Each softening alternative assumes a new 1.0 MG finished water ground storage tank and high service pump station.

4.2 Siting of New Treatment Plant

Each of the treatment plant options would be sited south of the existing treatment plant and garage. The access road would be extended and wrap around the plant to allow for adequate access for chemical delivery. Existing raw and finished water mains would be utilized as much as possible. Second raw water and finished water mains would be added for redundancy and operational flexibility of the new plant. A new backwash equalization tank would be constructed onsite north of the new plant. Backwash and filter-to-waste from filtration would flow by gravity to the tank and then to the sanitary sewer through a control valve located in a vault to the west of the new equalization tank.

4.3 Building Description

Each of the options would have a similar proposed building construction, which is described conceptually in this section. The details of the construction would be refined as part of the preliminary design process.

4.3.1 Project Architectural Description

Exterior masonry walls would be cavity construction consisting of an interior load bearing concrete masonry unit (CMU) wythe and an exterior split-face decorative block veneer. The decorative block would be produced with integral color and water repellant admixtures for low maintenance. Rigid insulation would be installed in the cavity to meet energy code requirements. Interior masonry walls would be painted hollow core CMU.

Roofing would be prefinished, standing-seam metal roof panels applied over sheathing, metal roof deck, and cold-formed steel roof trusses. Gypsum board would be applied to the underside of the roof trusses. Batt insulation with sheet vapor retarder would be installed between the trusses to meet energy code requirements.

Exterior doors and frames would be painted, hollow-metal construction. The doors would be insulated and galvanized. Interior doors and frames would be painted, hollow-metal construction. Doors at chemical storage rooms would be fire-rated fiber reinforced plastic (FRP) construction for chemical resistance with panic hardware. Door hardware would be keyed to match the Owner's existing system.

Interior ceilings in process, chemical storage, and mechanical equipment spaces would be painted gypsum board. Suspended acoustical ceilings would be provided in administrative spaces, corridors, and restrooms.

Floors would be sealed concrete in the process, chemical storage, and mechanical equipment spaces. Vinyl composition tile flooring would be provided in administrative spaces, corridors, and restrooms with a resilient base applied to the perimeter walls.

The assumptions described above are based on the typical construction of similar facilities and are used to establish project costs. These details can be adjusted during design.

4.3.2 Project Structural Description

The overall building structure concept is generally metal roof decking over cold-formed steel trusses bearing on concrete masonry walls. Cold-formed steel trusses may often be spaced four feet on center, rather than two feet, as is common with wood trusses, but a sub-framing system should then be considered for ceiling support. The masonry walls would be reinforced with vertical bar reinforcing at a regular spacing, wire reinforcing in joints, and added reinforcing around openings. The mezzanine structure would be precast concrete plank with a cast-in-place concrete topping bearing on concrete masonry walls.

Building slab-on-grade would be concrete on compacted granular soil, with welded wire reinforcing. A pipe trench would be constructed of reinforced concrete with reinforcing amounts and water stopped joints intended to minimize cracking and leakage. The grating over the trench is presumed to be heavy duty galvanized steel, capable of carrying a heavy wheel load. Supplementary steel members supporting the grating and other steel necessary in the building would be galvanized structural steel shapes. Slabs in chemical storage rooms would be constructed of reinforced concrete and designed to be fluid containing.

Pending a geotechnical investigation, foundations are presumed to be shallow strip and spread footings constructed of reinforced concrete.

The backwash equalization tank concept consists of reinforced concrete bottom slab with trench/sump, walls, and top slab designed and reinforced to minimize cracking. Interior beams and columns would likely be required. At least two aluminum access hatches would be located at the ground surface for access into the tank and maintenance. Tank joints would be water stopped. The top slab would slope for drainage and be covered with sheet waterproofing wrapped onto the tank walls two feet down around the perimeter.

4.4 Process Systems

The proposed process systems that are common to all of the alternatives are described conceptually in this section. The details of these systems would be refined as part of the preliminary design process.

4.4.1 High Service Pump Station and Finished Water Storage

A high service pump station would be constructed in the new treatment plant. Four high service pumps with room for a fifth would be installed with a capacity of 1.3 mgd each. The high service pumps would pump from a 1.0 MG above-ground prestressed concrete storage tank just north of the new treatment plant into the distribution system. The high service pumps would be outfitted with variable frequency drives (VFDs) to allow greater control of the flow and pressure from the new plant.

4.4.2 Chemical Storage and Feed Systems

4.4.2.1 Chlorine Gas

The chlorine gas system would include two separate rooms: a chlorine gas storage room and a chlorine gas feed room. The storage room would hold eight – 150 pound (lb) cylinders. Vacuum regulators would be fitted to three of the cylinders, which would sit on scales that measure how much of the chlorine gas has been utilized. The cylinders would be kept in place by chain restraints bolted to the wall.

Gas piping from the cylinders would be run to two chlorinators installed in an adjacent room to control the feed rate of chlorine gas through an injector/eductor into a carrier water line fed by the plant service water. The chlorine gas feed rate would be metered based on the flow rate from the filters.

A chlorine gas scrubber or chlorine gas containment may be required by EGLE to protect the surrounding residential areas in the event of a gas leak. Gas leak detectors would be provided to alarm to supervisory control and data acquisition (SCADA) in the event of a gas leak and activate any scrubber or containment system that is installed. The cost to install and house a chlorine gas scrubber was included in the conceptual estimate.

4.4.2.2 Phosphate

A blended phosphate, of which the majority is orthophosphate, would be fed to the finished water for protection of the piping system service leads and residential plumbing against corrosion of piping systems. The blended phosphate would be received and stored in 55-gallon drums. Chemical metering pumps would be used to feed the phosphate to the finished water lines. The weight of liquid in the drum in use would be continuously measured using a chemical scale.

4.4.2.3 Fluoride

Liquid fluoride would be fed into the distribution system to enhance dental protection for the City's customers. Hydrofluosilicic acid (23%) would be received and stored in 55-gallon drums. Chemical metering pumps would be used to feed the fluoride to the finished water lines. The weight of liquid in the drum in use would be continuously measured using a chemical scale.

4.5 Mechanical Systems

Ventilation and makeup air for the new treatment facility would be provided by air handling units (AHU). Return air from the areas would be continuously recirculated via the AHUs. Outside air would be supplemented as required to ventilate the space per code requirements and to provide makeup air that is being exhausted from the chemical rooms and laboratory. Chemical rooms would be provided additional heat by corrosion resistant natural gas unit heaters. Direct expansion (DX) portable dehumidifiers would provide dehumidification for the process area. The chemical rooms would be exhausted by an individual roof-mounted exhaust fan with CPVC or 316 stainless steel ductwork. A transfer grille would be installed on the common wall with the process area for each chemical room to allow air to flow from the process area when the exhaust fan causes a negative pressure. The chemical rooms would be continuously exhausted at a minimum of 1 cubic foot per minute (CFM) per square foot (sf) floor area or 1 air change per hour (ACH), whichever is greater. The rooms would also be exhausted at 6 ACH when occupied, as sensed by activation of the respective room's light switch. The chlorine storage/chlorine feed rooms would be exhausted at 60 ACH outdoor air when occupied, as activated by a switch on the outside of the room near the door and the chlorine detector. A mini-split DX system would provide cooling for the laboratory.

A complete plumbing system would be provided in accordance with the 2015 Michigan Plumbing Code and applicable ordinances. Systems would include sanitary waste and vent, domestic hot and cold water with recirculating hot water return, and natural gas. Domestic hot water would be provided by a water heater. Chemical rooms would have emergency shower/eyewash combination units as required by code. The building chemical rooms would have a complete wet pipe fire protection system.

4.6 Electrical Systems

A new 480Y/277-volt, 3-phase (secondary) electrical service would be obtained from the local utility company for the new treatment plant. It is assumed that a 300-KVA pad-mounted transformer would be provided. The exact loading calculations would be developed during design. A diesel generator would be provided to supply standby power in case of a utility power outage. The generator would be sized so that the treatment plant can meet average day demands. Provisions (i.e., generator docking station) would be included for connecting a portable generator and load bank so the generator can be serviced and maintained with minimal interruptions in accordance with the requirements of Article 700.3 of the National Electrical Code (NEC). The generator would be located outside in a weather-protected, sound-attenuated enclosure. A sub-base fuel storage tank sized to allow the generator to operate at full load for a minimum of 24 hours would be provided with the generator.

Power would be distributed via a main service-entrance rated circuit breaker, automatic transfer switch, motor control centers, power distribution panelboards, 208Y/120-volt step-down transformers, and lighting panelboards. Motor starters and VFDs would be provided as required for controlling motor loads. Electrical services to existing facilities on the same site as the plant would remain and be reused.

A new diesel generator and automatic transfer switch would be provided at Well 6. The generator would be located outside in a weather-protected sound-attenuated enclosure with a sub-base fuel storage tank sized to allow the generator to operate at full load for a minimum of 24 hours. Existing pumps, motors, and VFDs would remain and be reused at Well Nos. 6 and 7. The existing 125KW generator and transfer switch would remain and be reused at Well 7. A new VFD and motor would be provided at Well 8.

Rigid metal conduit would be utilized above grade in locations that are not corrosive areas; PVC-coated rigid metal conduit would be utilized in corrosive areas. Below grade conduit would be Schedule 40 PVC where it is not concrete encased. Duct banks outside buildings would utilize Type EB (Schedule 20 PVC) conduit and be concrete encased. Minimum conduit size would be ¾-inch. Wiring would be specified to be Type THHN/THWN-2. Minimum conductor sizes would be #12 for power wiring, #14 for control wiring, and #16 twisted shielded pair (TSP) for analog signal wiring. Electrical work would be specified to be in accordance with the NEC and locally adopted codes.

LED lighting would be provided throughout the plant to deliver an average of 30 foot-candles (fc) of illumination. Higher lighting levels (i.e., 50 fc average) would be provided in the control room, laboratory, chemical feed rooms, and offices. Emergency lighting can be provided via fixtures with integral battery back-up or by circuiting fixtures to a separate emergency power distribution system powered via the generator. Exact details would be determined during design. Lights would be controlled via local switches and occupancy sensors. Wall-mounted exterior LED lighting would be provided above personnel doors for egress purposes. Pole-mounted LED lights would be provided to illuminate the access drive and parking areas. Exterior lighting would be controlled via a lighting contactor and photocell.

Chemical feed rooms would be considered High Hazard (H-3 or H-4) occupancies depending on chemical characteristics and quantities (volumes). A fire alarm system would be provided throughout the plant and include initiating devices (e.g., smoke detectors, manual pull stations, and tamper and flow switches) and indicating appliances (e.g., audio/visual alarms) as required by NFPA 72 (Fire Alarm Code). Access control, security, network, and camera system requirements would be determined during design.

4.7 Control System

Treatment equipment, chemical feed systems, and instrumentation and controls would be monitored and controlled by a programmable logic controller (PLC) based control system. Control panels with distributed PLCs and input/output (I/O) racks would be strategically located throughout the plant. Level, flow, pressure, temperature, and analytical instruments would be wired to local control panels. Each control panel would include an uninterruptible power supply to allow equipment to ride through momentary power interruptions. A network of computer servers and client workstations would interface with the PLCs and be programmed to provide operator interface visualization, alarming, reporting, trending, data collection, storage, and archiving features. Industrial workstations with touchscreen capabilities can be provided in certain control panels as necessary. Control system equipment would be connected together on an Ethernet network. Category 6 (copper) cabling would be used for network connections shorter than 300 feet. Multi-mode fiber optic cabling would be used for longer runs and between buildings. Remote access to the control system can be provided via an Internet connection and virtual private network (VPN). Managed Ethernet switches would be utilized to provide network security. Access via cell phones, tablets, and hand-held devices can also be incorporated.

PLCs and remote communications with well houses and other sites (e.g., elevated tanks, etc.) would be upgraded as part of constructing the new plant. A new control panel with local PLC, I/O rack, touchscreen operator interface, and cellular and/or radio modem would be provided at each site. Existing instruments and motor controls would be reused at each well house. Modems may include both cellular and radio (licensed or spread spectrum) communications to back up each other for increased reliability. New antennas would be provided as required. Radio path testing to confirm antenna specifications and mounting heights can be performed during design or construction.

5.0 Reverse Osmosis Treatment Alternative

RO membranes have been used for municipal water treatment for many years. Their predominant use originated with the desalinization of brackish and sea waters. RO membranes, which remove virtually all dissolved solids including hardness components, can also be used to soften water. Some hardness in the water is desirable to provide a stable and non-corrosive water. To achieve that, the process normally includes bypassing a stream of filtered, unsoftened water that is blended with the reverse osmosis treated water to achieve the target hardness level. RO Membranes have the added benefit of removing currently regulated contaminants such as metals, organics, pesticides, and pathogens (including viruses), and have been shown to be effective in removing many of the emerging contaminants of concern, as well as unregulated emerging contaminants regulated by USEPA and EGLE. The RO membranes would remove radium from the water as well, precluding the need for adding HMO to the horizontal pressure filters (HPF). It should be noted that regulated contaminants, including radium, would not be removed in the blend stream; however, with the removal of all radium in water passing through the RO membranes, the blended water would have radium concentrations far below regulatory limits.

5.1 General Process Flow Description

Raw water would be pumped from Well Nos. 6, 7, and 8 through HPFs for iron removal. The water would then pass through cartridge filters to an above-ground RO break tank ahead of the RO skids constructed just outside of the building. RO skid feed pumps would pull from the RO break tank and feed the RO skids at high pressure to force the water through the semi-permeable membranes. The treated water would pass to an above-ground finished water storage tank. High service pumps would pump water from the finished water storage tank to the distribution system.

Figure 1 shows a process schematic of the RO system. Figure 2 shows a conceptual floor plan of a RO softening plant for the City.

5.2 Process Systems

The proposed process systems for the RO softening alternative are described in this section. The details of these systems would be refined as part of the preliminary design process.

5.2.1 Modification of Existing Well Pumps

The addition of the HPFs would cause additional headloss through the new RO softening treatment plant as compared to the existing iron removal plant. Well Nos. 6 and 7 are equipped with VFDs and sufficient pumping capacity to pump to the existing plant or the distribution system. Both pumps have sufficient hydraulic capacity to supply the RO softening plant. Well No. 8 is currently designed to only pump to the existing treatment plant. It would require additional pump capacity, which can be achieved by pulling the pumps for these wells and installing additional bowls, which would increase the amount of head the pump can provide. It is anticipated that the motor for Well No. 8 would need to be upsized to meet the new pump design requirements. It is recommended that it is outfitted with a VFD for greater control of the flow coming from the well. A generator would be provided at Well No. 6 for redundancy in case of a power outage. In addition, the controls at each well house and elevated tank would be modified to integrate with the new plant controls.

5.2.2 *Iron Removal and Filtration*

Three HPF vessels would be required for this alternative. They would be configured in an end-piped configuration with each vessel having two independent filter cells for the removal of iron from the raw water. Space would be provided in the plant for an additional filter in the future, if required. Each filter cell would have a capacity of roughly 1.13 mgd, providing the plant with a firm iron removal capacity of 5.6. The additional capacity of the iron removal system is needed to supply the RO membranes, which would generate considerable concentrate (reject) flow. The HPFs would contain a dual-media bed of sand and anthracite to filter out the oxidized iron from the raw water. Flow through the HPFs would be controlled via electrically-actuated valves.

The HPFs would need to be periodically backwashed to remove accumulated solids from the filter media. The backwash process would consist of an initial combined air and water backwash process to agitate the filter media and dislodge residual solids for waste discharge, and a second backwash at a higher rate of flow with water only to re-stratify the filter media. The backwashed filter cell would then run filter-to-waste to allow any remaining debris and turbidity stirred up by the backwash process to pass from the filter, before it provides water to the system.

Air for the backwash process would be provided by two blowers. The backwash water would be provided from the pressurized filtered water passing through the other cells and controlled via an electrically-actuated valve. An alternative backwash source that could be utilized in case of a failure of the regular backwash supply would be gravity flow from the finished water storage tank. The backwash wastewater and the filter-to-waste water would flow by gravity into a sump (with an air gap). The combined wastewater would then flow by gravity to a newly constructed, below-grade, cast-in-place concrete equalization basin north of the treatment plant. The combined wastewater would then discharge by gravity to the City’s existing sanitary sewer system, controlled via an electrically-actuated valve in a vault between the equalization basin and the sanitary sewer.

5.2.3 *Reverse Osmosis System*

The RO system consists of cartridge filters, RO skids, and a clean-in-place system.

5.2.3.1 <u>Cartridge Filters</u>

Three off-skid cartridge filters would be provided between the HPFs and the RO break tank. Two of the filters would be online with a third as a standby. The cartridge filters are used to remove any particulates before they reach the membranes. Membranes are susceptible to fouling from particulate or suspended solids in the water stream. The cartridge filters would cause some headloss, which would be overcome by the well pumps. The well pumps would pump directly through both the HPFs and the cartridge filters to reach the RO break tank. The cartridge filters would be housed in horizontal vessels for ease of operation and maintenance.

5.2.3.2 <u>Reverse Osmosis Skids</u>

Water would be provided to the RO skids using four RO feed pumps, one for each skid, which would pump water from the RO break tank to the associated skid. The pumps would provide the high pressure needed to force water through the semi-permeable RO membranes.

The RO membrane process includes three basic flow streams: the feed, the permeate (or purified water), and the concentrate (or waste stream). The membrane elements are housed within pressure vessels, which are secured to factory-assembled skids. The pressure vessels are arranged in stages, where the concentrate from the first stage becomes the feed for the subsequent stage. The permeate from each stage is blended together to create the resultant product stream. The concentrate from each of the stages forms the waste stream.

Permeate exiting the membrane equipment would have essentially zero hardness, low alkalinity, and could be corrosive. To control the corrosivity of the water, the permeate would be blended with water bypassed around the skids to provide a finished water at the target hardness level. Flow through the bypass line would be controlled by a flow meter and control valve near the feed into the RO permeate line. A pressure sustaining valve would be installed on the feed line into the RO break tank to ensure the bypass line had sufficient pressure to meet the blended water target.

5.2.3.3 Clean-in-Place System

The membrane elements would require chemical cleaning on a routine basis, typically every six months. A clean in place (CIP) system consisting of two chemical tanks and a CIP pump would deliver cleaning solution to each membrane unit by permanent piping that terminates near each unit. CIP flows can range as high as 1,500 gpm at 60 pounds per square inch (psi) and may require neutralization prior to disposal. A variety of acid and alkaline cleaners must be stored onsite for use in the CIP process. A third tank to hold permeate flush would also be near the CIP system. A permeate flush pump would be provided near this tank.

5.2.4 Degasifiers

Membrane softening would remove dissolved bicarbonate alkalinity, resulting in permeate with a depressed pH. As a result, pH adjustment would be needed. Adjustment of the pH after the RO skids would be accomplished using degasifiers (air stripping to remove dissolved carbon dioxide) with a sodium hydroxide feed system as a backup. Three forced draft aerator degasifiers would be installed with room for a fourth. Each degasifier would have a capacity of 2.0 mgd. Water would pass through the degasifiers to the finished water storage tank. High service pumps would pump from the storage tank to the distribution system.

5.2.5 Residuals Handling

The concentrate from the RO skids would be high in TDS and presents disposal challenges. Based on the total hardness of the raw water, the expected concentrate waste stream TDS concentration would have an estimated concentration of 2,700 mg/L. Alternatives for concentrate disposal include surface water discharge, sanitary sewer, and deep well injection. The concentrate stream would be a sizable volume, typically ranging from 20 to 30% of the inlet flow, or as much as 0.8 to 1.2 mgd during a maximum day demand for the proposed RO plant.

There are three methods to dispose of RO concentrate flow: discharge to sanitary sewer, discharge to a waterway, and deep well injection. A cursory look at the existing City WWTP capacity indicated that it could not hydraulically handle the RO concentrate flow on top of what it already treats. Deep well injection is expensive and difficult to permit, install, and operate. Discharge of the RO concentrate to the Grand River is likely the best alternative. A cost for a lift station and 1.25 miles of 12-inch force main was included in the RO option using an estimated route through the City and some conceptual costs. Note that the route of this main would need to be evaluated as part of the preliminary design of this option, if the City decides to go with RO softening. The feasibility of this option would depend on a fairly extensive review with EGLE on whether the City can discharge to the Grand River with the RO concentrate. A cascade aerator may be required by EGLE at the point of discharge into the Grand River. The cascade aerator would likely be a maintenance issue as there would be significant scaling from the concentrate, and the aerator would be remote from the plant.

It is assumed that the neutralized CIP discharge can be sent to the existing City WWTP through the sanitary sewer system. Note that the CIP process is only completed once every month for each skid and is a low volume.

5.2.6 Chemical Storage and Feed Systems

This section describes additional chemical feed systems for RO softening not discussed in Section 4.4.3.

5.2.6.1 Sodium Bisulfite System

Sodium bisulfite would be added to the feed water of the RO system to remove chlorine remaining from the pretreatment step. The RO membranes are not tolerant of chlorine (or other oxidants), requiring the chlorine to be removed before water is fed through the membranes.

The sodium bisulfite solution would be delivered in 275-gallon chemical totes. The solution would be transferred from the tote to an adjacent day tank using a transfer pump. Two metering pumps (one on standby) would be installed to meter chemical to the filtered water that feeds the RO system.

5.2.6.2 Anti-scalant System

Anti-scalant would be added to the RO system’s feed water to ensure that the minerals in the water remain in solution and to prevent scaling on the RO membranes.

The anti-scalant solution would be delivered in 275-gallon chemical totes. The solution would be transferred from the tote to an adjacent day tank using a transfer pump. Two metering pumps (one on standby) would be installed to meter chemical to the filtered water that feeds the RO system.

5.2.6.3 Sodium Hydroxide System

Sodium hydroxide would be added to the blended water for pH adjustment, as the permeate from the RO system is anticipated to have a depressed pH value. This system would act as a backup to the degasifiers if they were ever taken out of service.

The sodium hydroxide solution would be delivered in 275-gallon chemical totes. The solution would be transferred from the totes to an adjacent day tank using a transfer pump. Two metering pumps (one on standby) would be installed to meter chemical to the blended water before it leaves the plant.

5.3 General Discussion on RO Softening

Reverse osmosis softening would provide a finished water that meets the target hardness and could remove existing and emerging contaminants from the water, acting as a barrier for any issues with the source water. It should be noted that contaminants would not be removed from the blend stream, which is bypassed around the RO skids. A RO softening plant would be expensive to construct and operate. In comparison to the flows for a treatment plant providing only iron filtration, additional raw water and iron removal capacity would be needed, because the RO softening system would generate up to 25% of the inlet flow as waste concentrate stream. RO membranes are susceptible to fouling, which can interrupt treatment production.

In addition to the issues described above, the waste stream produced by the RO system would be difficult to manage. The TDS concentration of the RO waste stream is quite high, estimated at about 2,700 mg/L. It is possible that EGLE would allow discharge of the RO waste stream to the Grand River. However, this would require the construction of a lift station and nearly 1.25 miles of 12-inch force main to convey the RO concentrate flow to the river. The RO waste stream can also cause maintenance issues, as it has a tendency to scale, which could turn into a major maintenance issue given the length of the main to the Grand River. Management of the RO concentrate would warrant further investigation if the City decides to move forward with RO softening.

Table 7 describes the advantages and disadvantages of a RO softening system.

Table 7 – RO Softening Advantages and Disadvantages

Advantages	Disadvantages
• Barrier for removal of a range of contaminants for water that passes through RO membranes. • Operation can be automated requiring minimal additional labor. • RO membranes can remove currently regulated contaminants, including radium, and have been shown to be effective in removing unregulated emerging contaminants that pass through the RO membranes.	• Membranes are sensitive to fouling. • Produces a high-volume waste stream that has elevated TDS. • Additional well capacity required because of 20 to 25% rejection rate. • High operational costs, specifically power consumption. • Additional staffing will be needed

6.0 Ion Exchange Treatment Alternative

Ion exchange (IX) softening is a process that removes hardness by adsorption onto an ion exchange resin. During this process, sodium (and alternatively potassium) ions are exchanged for the calcium and magnesium hardness ions, reducing the hardness to almost 0 mg/L. Some hardness in the water is desirable to provide a stable and non-corrosive water. To achieve this, the process normally includes bypassing a stream of filtered water that is blended with the ion exchange treated water to achieve the target hardness level. The ion exchange resin must be regenerated periodically using a regenerate solution (typically sodium chloride brine solution) to replenish the exchange sites. The IX reactors would remove radium from the water as well, precluding the need for adding HMO to the HPF. It should be noted that regulated contaminants, including radium, would not be removed in the blend stream; however, with the removal of all radium in water passing through the IX reactors, the blended water would have radium concentrations far below regulatory limits.

6.1 General Process Flow Description

Raw water would be pumped from Well Nos. 6, 7, and 8 through the horizontal pressure filters for iron removal and through the ion exchange reactors for softening directly to an above-ground storage tank north of the plant. High service pumps would pump water from the finished water storage tank to the distribution system.

Figure 3 shows a process schematic of the IX system. Figure 4 shows a conceptual floor plan of an IX softening plant for the City.

6.2 Process Systems

The proposed process systems for the IX softening alternative are described in this section. The details of these systems would be refined as part of the preliminary design process.

6.2.1 Modification of Existing Well Pumps

The addition of the HPFs and the IX reactors would cause additional headloss through the new IX softening treatment plant, as compared to the existing iron removal plant. Well Nos. 6 and 7 are equipped with VFDs and sufficient pumping capacity to allow them to pump to the existing plant or the distribution system. Both pumps have sufficient hydraulic capacity to supply the IX softening plant. Well No. 8 is currently designed to only pump to the existing treatment plant. It would require additional pump capacity. This can be achieved by pulling the pumps for these wells and installing additional bowls, which would increase the amount of head the pump can provide. It is anticipated that the motor for Well No. 8 would need to be upsized to meet the new pump design requirements and it is recommended that it is outfitted with a VFD for greater control of the flow coming from the well. A generator would be provided at Well No. 6 for redundancy in case of a power outage. In addition, the controls at each well house and elevated tank would be modified to integrate with the new plant controls.

6.2.2 Iron Removal and Filtration

Three HPF vessels would be required for this alternative. They would be configured in an end-piped configuration with each vessel having two independent filter cells for the removal of iron from the raw water. Space would be provided in the plant for an additional filter in the future, if required. Each filter cell would have a capacity of roughly 0.8 mgd, providing the plant with a firm iron removal capacity of 4.0 mgd. The filters would contain a dual-media bed of sand and anthracite to filter out the oxidized iron from the raw water. Flow through the filters would be controlled via electrically actuated valves.

The HPFs would need to be periodically backwashed to remove accumulated solids from the filter media. The backwash process would consist of an initial combined air and water backwash process to agitate the filter media and dislodge residual solids for waste discharge, and a second backwash at a higher rate of flow with water only to re-stratify the filter media. The backwashed filter cell would then run filter-to-waste to allow any remaining debris and turbidity stirred up by the backwash process to pass from the filter, before it provides water to the system.

Air for the backwash process would be provided by two blowers. The backwash water would be provided from the pressurized filtered water passing through the other cells and controlled via an electrically actuated valve. An alternative backwash source that could be utilized in case of a failure of the regular backwash supply would be gravity flow from the finished water storage tank. The backwash wastewater and the filter-to-waste water would flow by gravity into a sump (with an air gap). The combined wastewater would then flow by gravity to a newly constructed, below-grade, cast-in-place concrete equalization basin north of the treatment plant. The combined wastewater would then discharge by gravity to the City's existing sanitary sewer system, controlled via an electrically-actuated valve in a vault between the equalization basin and the sanitary sewer.

6.2.3 Ion Exchange System

The IX reactors are pressure vessels filled with an ion exchange resin. As water passes through the reactors, sodium ions are exchanged for the calcium and magnesium hardness ions, reducing the hardness. The IX resin is often also effective in reducing radium. Five 12-foot-diameter IX reactors with a capacity of 1.0 mgd each would be installed, providing a firm capacity of 4.0 mgd.

The ion exchange resin must be periodically regenerated using a sodium chloride brine solution to replenish the exchange sites. To achieve this regeneration, brine tanks and brine pumps would be provided along with the IX reactors. The brine would be pumped through the IX reactors to regenerate the IX resin. When the regeneration is completed, the spent brine is wasted.

In addition, the IX reactors must be periodically backwashed to remove any solids trapped in the resin bed. Filtered water from the HPFs would be used to backwash the IX reactors.

6.2.4 Residuals Handling

IX softening results in the generation of a brine waste stream, having a relatively low volume with a high concentration of TDS consisting primarily of sodium, calcium and magnesium chlorides. Typical methods to dispose of the brine flow include discharge to the sanitary sewer, discharge to a waterway, and deep well injection. Discharge of the IX concentrate to the Grand River is not likely to be approved by EGLE given the very high TDS concentrations in the brine waste stream. Deep well injection is expensive and difficult to permit, install, and operate. The only likely option for disposal of the brine is discharge to the sanitary sewer and conveyance to the City WWTP. The feasibility of this option would depend on whether the City's WWTP would be able to handle the brine waste stream. Further analysis on the ability of the City's WWTP to accept the concentrated waste stream is recommended if the City opts to further advance this alternative.

6.2.5 *Chemical Feed Systems*

Beyond the salt and brine systems needed for this process, no additional chemicals are needed besides those chemicals previously described in Section 4.4.3.

6.3 General Discussion on IX Softening

Ion exchange is potentially the most cost-effective softening alternative. However, it does have some disadvantages. The sodium-based ion-exchange process would result in an increase in the treated water sodium concentration. There is no MCL for sodium; therefore, elevated sodium concentrations do not pose a compliance issue. However, in 2003, the USEPA issued a Drinking Water Advisory that sodium in drinking water is recommended not to exceed 30 to 60 mg/L. It also recommended a maximum sodium concentration of 20 mg/L for at risk people, such as those with high blood pressure and heart disease. Based on the total hardness concentration of the raw water, we would expect the sodium concentration of the blended water to be in the range of 80 to 120 mg/L.

Table 8 describes the advantages and disadvantages of an IX softening system.

Table 8 – Ion Exchange Advantages and Disadvantages

Advantages	Disadvantages
• Facility would be easily expandable. • Simplest of the softening processes evaluated. • Process produces least amount of wastewater and residual solids. • Operation can be automated requiring minimal additional labor. • IX resin for softening would provide radium removal.	• Addition of sodium to finished water. • Cost of large quantity of salt used. • Produces a waste stream with high concentrations of TDS. • Disposal of brine wastewater to WWTP may be undesirable and could require upgrades at WWTP.

7.0 Lime Softening Treatment Alternative

Lime softening removes calcium and magnesium hardness, along with iron and manganese, by a process of chemical precipitation. In addition, lime softening is also effective in removing radium. Lime softening is a proven technology that many Michigan water supplies use to soften groundwater in Michigan. The lime softening process would remove radium from the water as well, precluding the need for adding HMO to the HPF.

Lime softening can be achieved with a more conventional process as is described in this section. Another method that was investigated was the use of pellet reactors to soften water. However, pellet softening only removes calcium hardness, not magnesium hardness. Analysis of the City's raw water quality data indicated that without removal of magnesium hardness, the target hardness value of 120 mg/L could not be achieved. Thus, pellet softening was not considered further in this report.

7.1 General Process Flow Description

Raw water would be pumped from Well Nos. 6, 7, and 8 to two aerators at an elevation that would allow for gravity flow through the treatment process. Water would flow by gravity from the aerators/head tanks to two solids contact clarifier softening reactors. Lime, sodium hydroxide, and ferric chloride would be added to each solids contact clarifier where precipitation and clarification would occur. Clarified water would flow to two recarbonation tanks where liquid carbon dioxide would be added to the water, reducing the pH to a stable level and ending the chemical precipitation process. From the recarbonation tanks, the water would pass to a set of four gravity filters where any remaining precipitated solids would be filtered out. The filtered water would flow by gravity to a 1.0 MG above-ground finished water storage tank. High service pumps would convey water from the finished water storage tank to the distribution system.

Figure 5 shows a process schematic of the lime softening system. Figure 6 shows a conceptual floor plan of a lime softening plant for the City.

7.2 Process Systems

The proposed process systems for the lime softening alternative are described in this section. The details of these systems would be refined as part of the preliminary design process.

7.2.1 Modification of Existing Well Pumps

The lime softening alternative would have similar hydraulics to the existing iron removal plant. None of the existing wells would need to be upgraded to serve the new plant. A generator would still be provided at Well No. 6 to provide redundancy in case of a power outage. In addition, the controls at each well house and elevated tank would be modified to integrate with the new plant controls.

7.2.2 Aeration System

Raw water would be pumped to tall cylindrical head tanks that would have an aerator mounted above them. The water would cascade over several aerator trays, which would remove dissolved gases from solution. Removing dissolved carbon dioxide would increase the pH and reduce the required lime dosage, and thus, would lower softening sludge production. Aeration would also strip hydrogen sulfide and radon, if present.

Two head tanks with aerators would be installed with the lime softening plant. Each aerator would have a capacity of 2.0 mgd, allowing either to provide average day demands for the plant if one is out of service.

7.2.3 Solids Contact Clarifiers

The aerated water would then flow by gravity from the head tanks and into the two solids contact clarifiers where the chemical precipitation softening reactions would occur. Solids contact clarifiers are available in various design configurations; some have mechanical mixers and sludge collectors, and some have hydraulic mixing and sludge fluidization. Conical clarifiers with hydraulic mixing/fluidization were assumed for this study, since they are relatively easy to operate and maintain. Each steel clarifier would be approximately 40 feet in diameter at the top, and 30 feet high. Lime slurry and sodium hydroxide in proper proportions would be added to raise the pH so that calcium carbonate and magnesium hydroxide would precipitate. Iron and arsenic would also precipitate. The chemical precipitation process would also provide radium removal. Ferric chloride would be added as a flocculent/settling aid to prevent excessive solids carryover from the tanks. The ferric chloride would also help maintain a distinct sludge blanket interface.

Two solids contact clarifiers would be installed with the lime softening plant. Each clarifier would have a capacity of 2.0 mgd, allowing the plant to meet average day demands with one of the clarifiers out of service.

7.2.4 Recarbonation Tanks

The clarified and softened water at a high pH would flow from the clarifiers to the recarbonation tank. There, carbon dioxide would be diffused into the tank to lower the pH and stabilize the water. This would stop the chemical precipitation process for the water. A sulfuric acid storage and feed system would be installed to act as a backup to the carbon dioxide.

Two recarbonation tanks would be installed with the lime softening plant. Each tank would have a capacity of 2.0 mgd, allowing either to provide average day demands for the plant if one is out of service .

7.2.5 Gravity Filtration

Following recarbonation, the water would be filtered by gravity through dual media sand and anthracite filters. Four filters would be provided with a design filtration rate of 3 gpm per square foot. Each filter would have a capacity of 1.04 mgd during normal operation. If one filter is out of service, the loading would be increased on the other three filters temporarily, allowing the plant to continue to operate at full capacity. From the filters, the treated water would flow to an above-ground finished water storage tank for equalization and pumping to the distribution system.

The filters would need to be periodically backwashed to remove accumulated solids from the filter media. The backwash process for the filters would consist of an initial combined air and water backwash process to agitate the filter media and dislodge residual solids for waste discharge, and a second backwash at a higher rate of flow with only water to re-stratify the filter media. The backwashed filter would then run in a filter-to-waste mode for a short time to allow any remaining debris and turbidity stirred up by the backwash process to pass from the filter to waste, before the filter is placed back online.

The air for the backwash process would be provided by two blowers. The backwash water for the filters would be provided by a backwash pump drawing from the finished water storage tank. The backwash wastewater and the filter-to-waste water would flow by gravity into a sump (with an air gap). The combined wastewater would then flow by gravity to a below-grade, cast-in-place concrete equalization basin to be located north of the treatment plant. The combined wastewater would discharge by gravity to the City's existing sanitary sewer system, controlled via an electrically-actuated valve in a vault between the equalization basin and the sanitary sewer.

7.2.6 Residuals Handling/Mechanical Dewatering

The solids contact clarifiers would produce a significant amount of waste lime sludge as part of the treatment process. Lime sludge lagoons were considered to dewater and store the sludge. However, the land needed for the lagoons was significant and no land near the proposed plant site appears to be available. Thus, mechanical dewatering was considered to be necessary.

Waste lime sludge would be periodically discharged from the solids contact clarifiers to sludge holding and thickening tanks. The dewatering system would consist of two filter press feed pumps, and two plate and frame presses. The press feed pumps would draw the sludge from the holding/thickening tanks and provide the high pressures needed to supply the plate and frame presses. The plate and frame presses would dewater the sludge, with the dewatered solids being conveyed to a dumpster. The filtrate would discharge to the backwash equalization tank. Alternatively, the filtrate could be returned to the head of the plant. The dewatered solids would be hauled away and land applied as a soil supplement for farmland, or disposed of in a landfill.

7.2.7 Chemical Storage and Feed Systems

This section describes additional chemical feed systems for lime softening not discussed in Section 4.4.3.

7.2.7.1 Lime System

Bulk pebble lime would be stored in two steel lime silos. The lime would pass by gravity from the silos to two lime slakers, which would make a lime slurry suitable for conveyance into the clarifier influent lines. The lime slakers would be sized to provide the needed capacity with one of the slakers out of service. Three pumps would convey the lime slurry to the solids contact clarifiers.

7.2.7.2 Sodium Hydroxide System

Sodium hydroxide solution would be delivered by bulk tanker truck and stored in two 5,000-gallon FRP bulk storage tanks. The solution would be transferred from the bulk storage tanks to an adjacent day tank using a transfer pump. Four metering pumps (one on standby) would be installed to meter chemical to the clarifier influent lines.

An alternative to the use of sodium hydroxide would be to add more lime and also add soda ash. Soda ash would be stored and fed in a similar manner to the lime. This option may be less expensive on a chemical cost basis, but would require another dry feed system to operate. This could be investigated as a part of preliminary design if the lime softening alternative was to be pursued.

7.2.7.3 Ferric Chloride System

Ferric chloride would be added to the clarifier influent lines as a flocculant/settling aid, and to help maintain a distinct sludge blanket interface in the solids handling clarifiers.

The ferric chloride solution would be delivered by bulk tanker truck and stored in two new 5,000-gallon FRP bulk storage tanks that would be installed in the room. The solution would be transferred from the bulk storage tanks to an adjacent day tank using a transfer pump. Four metering pumps (one on standby) would be installed to meter chemical to the clarifier influent lines.

7.2.7.4 Carbon Dioxide System

Liquid carbon dioxide would be delivered by bulk tanker truck and stored in a tank just outside of the plant. The carbon dioxide would be diffused as gas into the recarbonation tanks.

7.2.7.5 Sulfuric Acid System

The sulfuric acid system would act as a backup to the carbon dioxide used in the recarbonation tanks. Sulfuric acid (93%) would be received and stored in 55-gallon drums. Chemical metering pumps would be used to feed the sulfuric acid to the recarbonation tanks. The weight of liquid in the drum in use would be continuously measured using a chemical scale.

7.3 General Discussion on Lime Softening

Lime softening would provide a finished water that meets the target hardness and would provide radium removal. A lime softening plant can also produce a stable finished water for the purposes of corrosion control. It is a proven softening process. The equipment used in a lime softening plant has low power requirements.

However, lime softening has some disadvantages. It has a large footprint in comparison to other options. It requires a significant amount of chemical usage and the delivery and feeding of lime can be messy and labor intensive. Lime softening has a relatively high capital and operational cost. Lime softening also produces a large amount of sludge, which must be mechanically dewatered and hauled away for land application.

Table 9 describes the advantages and disadvantages of a lime softening system.

Table 9 – Lime Softening Advantages and Disadvantages

Advantages	Disadvantages
• Lower power requirements for softening reactors and longer equipment life. • Easier to establish water stability with respect to corrosion control. • Relatively straight forward treatment process. • Provides radium removal.	• High chemical dosages/usage required to meet target hardness goal. • Produces large amount of residuals. • Dealing with lime chemical, dust, and sludge can be messy and labor intensive. • High capital and operational costs. • More labor intensive than other alternatives.

8.0 Storage Analysis

Storage capacity for the City distribution system was evaluated to determine if adequate storage was provided at the 20-year projected demand, assuming the full capacity of the treatment plant is utilized. Two different storage calculation methods were used in accordance with two differing methods of storage analysis. The larger value calculated from the two equations is used.

The first calculation used was as follows:

(Equalization Storage) + (Higher of Fire Storage or Emergency Storage) = Recommended Storage

The second calculation used was as follows:

(Fire Storage) + (Emergency Storage) = Recommended Storage

For equalization storage, which is intended to provide operational flexibility to meet varying demands, a value of 25% of the MDD is generally accepted. The maximum fire flow requirement for a major industrial user in the system is 3,500 gpm for 3 hours. Emergency storage, which considers major power outages, main breaks, or similar, considers the need for ADD storage for an extended duration. A 12-hour emergency was considered in this evaluation.

8.1 20-Year Projected Demand Storage Analysis

The projected 2040 MDD for the City is approximately 1.74 mgd. Therefore, for equalization storage, 25% of 1.74 mgd equals 0.44 MG. For fire flow, 3,500 gpm for 3 hours is equivalent to a volume of 0.63 MG. For emergency storage, a 12-hour emergency with ADD equals 0.46 MG. Since the fire storage requirement exceeds the emergency storage requirement, the fire storage requirement was used in the first calculation:

0.44 MG + 0.63 MG = 1.07 MG of storage recommended

For the second calculation:

0.63 MG + 0.46 MG = 1.09 MG of storage recommended

The greater value of the two calculations is used for a recommended storage of 1.09 MG in the City distribution system.

The existing City distribution system has two elevated storage tanks and a ground storage tank at the Industrial Park Pump Station. The elevated storage tanks have volumes of 0.5 MG and 0.1 MG, respectively. The ground storage tank at the Industrial Park Pump Station has a usable volume of 0.39 MG; the remainder of the volume for the ground storage tank is reserved for the National Guard Armory. In addition to the existing storage, a 1.0 MG above ground finished water storage tank would be constructed with the new softening plant. Assuming up to half of the volume of the finished water storage tank is usable storage, the total usable storage in the system totals 1.49 MG. There is enough usable storage to meet the recommended storage volume of 1.09 MG.

It should be noted that the 0.1 MG elevated tank is over 100 years old and will likely be taken out of service within the next 20 years. The proposed alternatives would still meet recommended storage with this tank removed from service.

8.2 Full Build-out Storage Analysis

The full build-out MDD to match the sizing of the City's new treatment plant is 4.00 mgd. Therefore, for equalization storage, 25% of 4.00 mgd equals 1.00 MG. For fire flow, 3,500 gpm for 3 hours is equivalent to a volume of 0.63 MG. For emergency storage, a 12-hour emergency with ADD equals 1.00 MG. Since the emergency storage requirement exceeds the fire storage requirement, the emergency storage requirement was used in the first calculation:

1.00 MG + 1.00 MG = 2.00 MG of storage recommended

For the second calculation:

0.63 MG + 1.00 MG = 1.63 MG of storage recommended

The greater value of the two calculations is used for a recommended storage of 2.00 MG in the City distribution system.

As demands approach the full capacity of the new treatment plant, an additional 0.5 MG of storage is recommended to be added to the system assuming the water storage volume at that time is the same as the existing water storage.

9.0 Pilot Testing

Pilot testing studies evaluate the designed water treatment processes, equipment, and chemical feed results for a limited time at a limited scale to verify the treatment efficacy and to determine potential design considerations for full-scale implementation. A pilot study can be completed over a relatively short of a few weeks. Typically, a manufacturer would have a small pilot plant that utilizes the design of a larger plant. The pilot plant is used to treat a small flow from the existing untreated raw water. The efficacy of the treatment can be determined using the water produced from the pilot plant. A pilot study can save significant cost for the final design by accurately establishing the rate at which the raw water can be treated, as well as the amount and type of chemicals needed for proper treatment.

Pilot testing is recommended for the RO and IX softening options. This is necessary to identify any issues with fouling of the RO membranes and the efficacy of the pretreatment system ahead of the RO membranes. For the IX reactors, the study would ensure that the selected resin is providing good removal of both hardness and radium. In addition, the pilot study can confirm the treatment efficiency of the processes and the chemicals being fed, identifying any potential issues and helping to solidify the design. The pilot plant study can also identify any unforeseen water quality issues in the finished water.

A cost for the pilot study is included in the estimate for the RO and IX softening alternatives.

Pilot testing is not required for lime softening.

10.0 Corrosion Control Study

Each softening alternative would introduce new treatment processes and chemicals to the City's water treatment system. It is likely that EGLE would require an updated corrosion control study to ensure the finished water in the City distribution system remains stable with the changes in treatment.

There are several approaches to completing a corrosion control study. It is our understanding that EGLE prefers a style of study that uses a combination of multiple corrosion control study techniques.

The solubility of the scaling on the inside of lead pipes could be tested by exhuming some lead pipe samples and analyzing the layers of the scale on the inside of the pipe. A model of the solubility of the interior of the pipe would be created based from this information. Different lead compounds have differing solubility (some are more stable than others) and knowing which compound is dominant can inform corrosion control treatment decisions. The solubility model created from this analysis can then be used to predict the most effective means of corrosion control treatment to prevent the leaching of lead and copper into the water.

Finished water samples with and without phosphate addition could be obtained. These samples would be put in jars with lead coupons for about two months to determine how much of the lead would leach from the coupon into the water. It is also likely that some samples from households throughout the City system would be gathered to assess the lead present at customer taps.

11.0 Cost Analysis

Capital costs for each treatment process alternative for the construction of a new softening treatment plant, associated work on the treatment plant site, and associated work at remote sites were estimated. In addition, the O&M costs associated with operation of the new treatment plant were estimated.

11.1 Capital Costs for Reverse Osmosis Treatment Alternative

11.1.1 Capital Cost Estimate for the Treatment Plant

The estimated costs for an RO softening treatment plant are presented in Table 10. The RO treatment plant costs are summarized by these categories: the construction of the building, the purchase and installation of major process equipment, process piping and valving through the plant, the chemical storage and feed equipment, the mechanical or HVAC, equipment and conveyance, the electrical systems for the plant including an allowance for a new electrical service from the utility, and the control systems and programming for the plant. Also included in the capital cost estimates are cost adding factors for the general conditions, overhead and profit for the contractor, and a conceptual design contingency.

Table 10 – RO Softening Treatment Plant Costs

Component	Estimated Cost
Building Construction	$4,900,000
Process Equipment	$6,345,000
Process Piping and Valving	$973,000
Chemical Storage and Feed Equipment	$550,000
Mechanical Equipment (HVAC)	$506,000
Plant Electrical	$1,721,000
Plant Control System	$1,434,000
Subtotal	**$16,429,000**
General Conditions, OHP (15%)	$2,465,000
Treatment Plant Subtotal	**$18,894,000**
Conceptual Design Contingency (20%)	$3,779,000
Construction Cost Opinion	**$22,673,000**

11.1.2 Capital Cost Estimate for Sitework

The estimated costs for the sitework at the plant site are presented in Table 11. Sitework costs are summarized by these categories: the installation of site utilities including new raw and finished water mains and backwash drain piping; general sitework including constructing the asphalt access roads, site concrete, landscaping and other general sitework items; the construction of a new backwash equalization basin; a control valve vault to control the flow of backwash to the City sanitary sewer system; the construction of an above-ground reverse osmosis break tank; the construction of an above-ground finished water storage tank; and an RO concentrate lift station and force main that discharges into the Grand River. Also included in the capital cost estimates are cost adding factors for the general conditions, overhead and profit for the contractor; and a conceptual design contingency.

Table 11 – RO Softening Sitework Costs

Component	Estimated Cost
Site Utilities	$1,112,000
General Sitework	$308,000
Backwash Equalization Basin	$550,000
Backwash Control Valve Vault	$100,000
RO Break Tank	$300,000
Finished Water Storage Tank	$1,000,000
RO Concentrate Lift Station and Force Main	$1,655,000
Subtotal	**$5,025,000**
General Conditions, OHP (15%)	$754,000
Sitework Subtotal	**$5,779,000**
Conceptual Design Contingency (20%)	$1,156,000
Construction Cost Opinion	**$6,935,000**

11.1.3 Capital Cost Estimate for Work at Remote Sites

The estimated costs for work at the City's remote sites associated with the construction of the reverse osmosis softening plant are presented in Table 12. The work at the remote site costs are summarized by these categories: the outfitting of the raw water supply wells to pump through the HPFs to the RO break tank, the installation of a generator and automatic transfer switch at Well No. 6, and controls upgrades at the remote well sites and elevated tanks. Also included in the capital cost estimates are cost adding factors for the general conditions, overhead and profit for the contractor, and a conceptual design contingency.

Table 12 – RO Softening Work at Remote Sites Costs

Component	Estimated Cost
Increase Well 8 Capacity	$115,000
Well 6 Generator and Automatic Transfer Switch	$80,000
Controls Upgrades at Remote Sites	$280,000
Subtotal	**$475,000**
General Conditions, OHP (15%)	$72,000
Work at Remote Sites Subtotal	**$547,000**
Conceptual Design Contingency (20%)	$110,000
Construction Cost Opinion	**$657,000**

11.1.4 Summary of Capital Costs

A summary table of the capital costs is shown in Table 13. Cost estimates for a pilot study for the new treatment plant, a corrosion control study, and estimated engineering costs are included in the capital costs. The pilot study would be used to assess the performance of the iron removal pretreatment with the RO skids, evaluate the performance of the RO membranes and assess the efficacy of the chemical treatment. Costs to run raw water to the pilot plant are included in the pilot plant cost estimate. A corrosion control study is required by EGLE to confirm that the finished water from the new treatment plant would be stable, preventing lead and other heavy metals from leaching from the water mains to the water in the distribution system.

Table 13 - Summary of RO Softening Project Costs

Cost Category	Estimated Costs
Treatment Plant	$22,673,000
Sitework	$6,935,000
Work at Remote Sites	$657,000
Total Construction Cost Opinion	**$30,265,000**
Pilot Study	$75,000
Corrosion Control Study	$180,000
Engineering	$3,000,000
Administrative, Legal, Bonding	$50,000
Total Project Cost	**$33,570,000**

11.2 Capital Costs for Ion Exchange Treatment Alternative

11.2.1 Capital Cost Estimate for the Treatment Plant

The estimated costs for the ion exchange softening treatment plant are presented in Table 14. The IX Treatment Plant costs are summarized by these categories: the construction of the building, the purchase and installation of major process equipment, process piping and valving through the plant, the chemical storage and feed equipment, the mechanical or HVAC, equipment and conveyance, the electrical systems for the plant including an allowance for a new electrical service from the utility, and the control systems and programming for the plant. Also included in the capital cost estimates are cost adding factors for the general conditions, overhead and profit for the contractor, and a conceptual design contingency.

Table 14 – IX Softening Treatment Plant Costs

Component	Estimated Cost
Building Construction	$3,455,000
Process Equipment	$3,429,000
Process Piping and Valving	$950,000
Chemical Storage and Feed Equipment	$257,000
Mechanical Equipment (HVAC)	$438,000
Plant Electrical	$1,212,000
Plant Control System	$1,010,000
Subtotal	**$10,751,000**
General Conditions, OHP (15%)	$1,613,000
Treatment Plant Subtotal	**$12,364,000**
Conceptual Design Contingency (20%)	$2,473,000
Construction Cost Opinion	**$14,837,000**

11.2.2 Capital Cost Estimate for Sitework

The estimated costs for the sitework at the plant site are presented in Table 15. Sitework costs are summarized by these categories: the installation of site utilities including new raw and finished water mains and backwash drain piping, general sitework including constructing the asphalt access roads, site concrete, landscaping and other general sitework items, the construction of a new backwash equalization basin, a control valve vault to control the flow of backwash to the City sanitary sewer system, a IX brine waste line to the City sanitary sewer system and the construction of an above-ground finished water storage tank. Also included in the capital cost estimates are cost adding factors for the general conditions, overhead and profit for the contractor, and a conceptual design contingency.

Table 15 – IX Softening Sitework Costs

Component	Estimated Cost
Site Utilities	$1,226,000
General Sitework	$308,000
Backwash Equalization Basin	$550,000
Backwash Control Valve Vault	$100,000
Finished Water Storage Tank	$1,000,000
Subtotal	**$3,184,000**
General Conditions, OHP (15%)	$478,000
Sitework Subtotal	**$3,662,000**
Conceptual Design Contingency (20%)	$733,000
Construction Cost Opinion	**$4,395,000**

11.2.3 Capital Cost Estimate for Work at Remote Sites

The estimated costs for work at the City's remote sites associated with the construction of the reverse osmosis softening plant are presented in Table 16. The work at the remote site costs are summarized by these categories: the outfitting of the raw water supply wells to pump through the HPFs and the IX reactors to the finished water storage tank, the installation of a generator and automatic transfer switch at Well No. 6, and controls upgrades at the remote well sites and elevated tanks. Also included in the capital cost estimates are cost adding factors for the general conditions, overhead and profit for the contractor, and a conceptual design contingency.

Table 16 – IX Softening Work at Remote Sites Costs

Component	Estimated Cost
Increase Well 8 Capacity	$115,000
Well 6 Generator and Automatic Transfer Switch	$80,000
Controls Upgrades at Remote Sites	$280,000
Subtotal	**$475,000**
General Conditions, OHP (15%)	$72,000
Work at Remote Sites Subtotal	**$547,000**
Conceptual Design Contingency (20%)	$110,000
Construction Cost Opinion	**$657,000**

11.2.4 Summary of Capital Costs

A summary table of the capital costs is shown in Table 17. Cost estimates for a corrosion control study and an estimated design engineering fee are included in the capital costs. The pilot study would be used to assess the performance of the iron removal pretreatment with the IX reactors, evaluate the performance of the IX resin and assess the efficacy of the chemical treatment. Costs to run raw water to the pilot plant are included in the pilot plant cost estimate A corrosion control study is required by EGLE to confirm that the finished water from the new treatment plant would be stable, preventing lead and other heavy metals from leaching from the water mains to the water in the distribution system.

Table 17 - Summary of IX Softening Project Costs

Cost Category	Estimated Costs
Treatment Plant	$14,837,000
Sitework	$4,395,000
Work at Remote Sites	$657,000
Total Construction Cost Opinion	**$19,889,000**
Pilot Study	$75,000
Corrosion Control Study	$180,000
Engineering	$1,990,000
Administrative, Legal, Bonding	$50,000
Total Project Cost	**$22,184,000**

11.3 Capital Costs for Lime Softening Treatment Alternative

11.3.1 Capital Cost Estimate for the Treatment Plant

The estimated costs for the lime softening treatment plant are presented in Table 18. The lime softening treatment plant costs are summarized by these categories: the construction of the building, the purchase and installation of major process equipment, process piping and valving through the plant, the chemical storage and feed equipment, mechanical dewatering of the sludge, the mechanical or HVAC, equipment and conveyance, the electrical systems for the plant including an allowance for a new electrical service from the utility, and the control systems and programming for the plant. Also included in the capital cost estimates are cost adding factors for the general conditions, overhead and profit for the contractor, and a conceptual design contingency.

Table 18 – Lime Softening Treatment Plant Costs

Component	Estimated Cost
Building Construction	$4,165,000
Process Equipment	$6,360,000
Process Piping and Valving	$932,000
Chemical Storage and Feed Equipment	$766,000
Mechanical Equipment (HVAC)	$486,000
Plant Electrical	$1,707,000
Plant Control System	$1,422,000
Subtotal	**$15,838,000**
General Conditions, OHP (15%)	$2,376,000
Treatment Plant Subtotal	**$18,214,000**
Conceptual Design Contingency (20%)	$3,643,000
Construction Cost Opinion	**$21,857,000**

11.3.2 Capital Cost Estimate for Sitework

The estimated costs for the sitework at the plant site are presented in Table 19. Sitework costs are summarized by these categories: the installation of site utilities including new raw and finished water mains and backwash drain piping, general sitework including constructing the asphalt access roads, site concrete, landscaping and other general sitework items, the construction of a new backwash equalization basin, a control valve vault to control the flow of backwash to the City sanitary sewer system, and the construction of an above-ground finished water storage tank. Also included in the capital cost estimates are cost adding factors for the general conditions, overhead and profit for the contractor, and a conceptual design contingency.

Table 19 – Lime Softening Sitework Costs

Component	Estimated Cost
Site Utilities	$1,152,000
General Sitework	$308,000
Backwash Equalization Basin	$550,000
Backwash Control Valve Vault	$100,000
Finished Water Storage Tank	$1,000,000
Subtotal	**$3,110,000**
General Conditions, OHP (15%)	$467,000
Sitework Subtotal	**$3,577,000**
Conceptual Design Contingency (20%)	$716,000
Construction Cost Opinion	**$4,293,000**

11.3.3 Capital Cost Estimate for Work at Remote Sites

The estimated costs for work at the City's remote sites associated with the construction of the reverse osmosis softening plant are presented in Table 20. The work at the remote site costs are summarized by these categories: the installation of a generator and automatic transfer switch at Well No. 6 and controls upgrades at the remote well sites and elevated tanks. Also included in the capital cost estimates are cost adding factors for the general conditions, overhead and profit for the contractor, and a conceptual design contingency.

Table 20 – Lime Softening Work at Remote Sites Costs

Component	Estimated Cost
Well 6 Generator and Automatic Transfer Switch	$80,000
Controls Upgrades at Remote Sites	$280,000
Subtotal	**$360,000**
General Conditions, OHP (15%)	$54,000
Work at Remote Sites Subtotal	**$414,000**
Conceptual Design Contingency (20%)	$83,000
Construction Cost Opinion	**$497,000**

11.3.4 Summary of Capital Costs

A summary table of the capital costs is shown in Table 21. Cost estimates for a corrosion control study and an estimated design engineering fee are included in the capital costs. A corrosion control study is required by EGLE to confirm that the finished water from the new treatment plant would be stable, preventing lead and other heavy metals from leaching from the water mains to the water in the distribution system.

Table 21 - Summary of Lime Softening Project Costs

Cost Category	Estimated Costs
Treatment Plant	$21,857,000
Sitework	$4,293,000
Work at Remote Sites	$497,000
Total Construction Cost Opinion	**$26,647,000**
Corrosion Control Study	$180,000
Engineering	$2,900,000
Administrative, Legal, Bonding	$50,000
Total Project Cost	**$29,777,000**

11.4 O&M Costs for Treatment Alternatives

The City water system would have O&M costs to operate each softening treatment process alternative, both the treatment plant and remote sites. The O&M costs for each treatment alternative would include electrical costs to run the existing well pumps as modified to pump water to the treatment plant, as well as additional electrical costs to run equipment in the treatment plant. The O&M costs are based on production at average day demands. The cost of electrical power was assumed to be $0.10/Kilowatt-hour. The costs also include the cost of acquisition of chemicals based on estimated usage for the treatment of the water in the new plant. O&M costs for the handling of treatment residuals would also be included.

11.4.1 O&M Costs for Reverse Osmosis Softening Alternative

The O&M costs for a RO softening treatment plant were evaluated. The electrical costs for operating the well pumps and the new equipment in the plant were included in the O&M costs. The costs to purchase new chemicals as they are used in the treatment process were evaluated including costs for chlorine gas, hydrofluorosilic acid, blended phosphate, sodium bisulfite, anti-scalant, sodium hydroxide, CIP acid, and CIP base. It is estimated that the membranes in the RO skids would need to be replaced in 15 to 20 years. This number was converted to an annual cost to provide a comparison of the annual O&M costs between the softening treatment alternatives. Four additional full-time operators were estimated to run the new RO softening treatment plant. An annual cost of $75,000 was assumed for each full-time operator. A RO plant is fairly complex in comparison to the existing City iron removal plant and would need significantly more oversight and control. All the O&M costs were assessed at the current average water demands.

Table 22 shows the estimated annual O&M costs for the proposed RO softening treatment plant.

Table 22 - O&M Costs for the RO Softening

O&M Cost Items	Annual Cost
Electrical Costs	$96,000
Chemical Costs	$63,000
Membrane Replacement	$50,000
Additional Staffing	$300,000
Annual O&M Costs	**$509,000**

11.4.2 O&M Costs for Ion Exchange Softening Alternative

The O&M costs for an IX softening treatment plant were evaluated. The electrical costs for operating the well pumps and the new equipment in the plant were included in the O&M costs. The costs to purchase new chemicals as they are used in the treatment process were evaluated including costs for chlorine gas, hydrofluorosilic acid, blended phosphate, and salt to produce brine for resin regeneration. It is estimated that the resins in the IX reactors would need to be replaced in 15-20 years. This number was converted to an annual cost to provide a comparison of the annual O&M costs between the softening treatment alternatives. Three additional full-time operators were estimated to run the new IX softening treatment plant. An annual cost of $75,000 was assumed for each full-time operator. An IX plant is complex in comparison to the existing City Iron Removal plant, but would not need as much oversight and control as the other softening alternatives. All the O&M costs were assessed at the current average water demands. Table 23 shows the estimated annual O&M costs for the proposed IX softening treatment plant.

Table 23 - O&M Costs for the IX Softening

O&M Cost Items	Annual Cost
Electrical Costs	$50,000
Chemical Costs	$213,000
Resin Replacement	$20,000
Additional Staffing	$225,000
Annual O&M Costs	**$508,000**

11.4.3 O&M Costs for Lime Softening Alternative

The O&M costs for a lime softening treatment plant were evaluated. The electrical costs for operating the well pumps and the new equipment in the plant were included in the O&M costs. The costs to purchase new chemicals as they are used in the treatment process were evaluated including costs for chlorine gas, hydrofluorosilic acid, blended phosphate, lime, sodium hydroxide, carbon dioxide, and ferric chloride. The lime softening plant would produce a significant amount of lime sludge, which would need to be hauled away and land applied to farmland after dewatering (note that if the sludge could not be land applied it would have to be land filled and the cost of disposing of the sludge would increase). An estimated four additional full-time operators were assumed to run the new lime softening treatment plant. An annual cost of $75,000 was assumed for each full-time operator. A lime plant is fairly complex in comparison to the existing City Iron Removal plant and would need significantly more oversight and control. All the O&M costs were assessed at the current average water demands. Table 24 shows the estimated annual O&M costs for the proposed lime softening treatment plant.

Table 24 - O&M Costs for the Lime Softening

O&M Cost Items	Annual Cost
Electrical Costs	$74,000
Chemical Costs	$209,000
Residuals Handling	$54,000
Additional Staffing	$300,000
Annual O&M Costs	**$637,000**

11.5 20-Year Present Worth Analysis

A 20-year present worth analysis will be completed in conjunction with the separate studies evaluating water softening treatment, iron removal, and water supply from the LBWL. The capital and O&M costs presented here will be used for that analysis along with an estimation of salvage costs.

12.0 Permitting Requirements

A preliminary review of the permits needed for the selected alternative was performed. An Act 399 Permit for the construction of a new water treatment plant would need to be obtained by the City from EGLE.

A soil erosion and sedimentation control (SESC) permit would need to be obtained by the contractor from the local enforcement agency. Similarly, the contractor would need to acquire a building permit from the authority having jurisdiction.

A national pollutant discharge elimination system (NPDES) permit would need to be obtained to discharge the RO concentrate to the Grand River. It is unknown at this time if this permit would be granted by EGLE. A cascade aerator at the point of discharge to the Grand River may be needed to ensure there is sufficient dissolved oxygen in the RO concentrate discharge.

At this conceptual stage, there were no other permits identified. If additional permits are needed, they would be identified during preliminary design.

13.0 Funding Sources

There are a number of funding sources available to finance the project. These sources would be generally described in this section. It should be noted that some of the funding sources have limited funds or specific requirements that may impact availability and/or timing of the funding.

13.1 Drinking Water Revolving Fund

The Drinking Water Revolving Fund (DWRF) provides reduced interest rate loan financing to qualified water suppliers to finance construction of public water systems. In addition to the loan provided by EGLE, suppliers also have the option to pay for part of their project with cash and other resources. Funding is provided at the federal level and administered by EGLE.

The rates on the loans for Fiscal Year 2021 are 1.875% for a 20-year loan and 2.125% for a 30-year loan. Communities that qualify as disadvantaged are eligible for a 40-year loan at 1.875%. Some project components may be eligible for principal forgiveness. The amount of loan dollars and principal forgiveness available each year is subject to the federal allocation.

The loan is handled as a municipal bond issued by the applicant community. The bond must have an investment-grade rating and is subject to all applicable state and federal requirements associated with municipal finance/debt activity. A bond attorney must be involved; communities typically retain a financial adviser to assist them through the financing process.

Eligible projects may include new wells, new water treatment plants, storage facilities, upgrades or expansions to existing facilities, transmission lines, pumping facilities, and other related waterworks system improvements. Part 54 of Act 451 permits suppliers serving less than 10,000 persons to receive reimbursement of project planning costs upon delivery of an approvable project plan to EGLE. Legislation has been passed to provide a funding mechanism for this reimbursement. Projects must comply with Davis-Bacon wage rate requirements and American Iron and Steel provisions.

All projects are reviewed and scored based upon a priority point system. All scoring factors point to the need for the project to comply with federal drinking water requirements. The scoring system is designed to address the most serious risks to human health and ensure compliance with the requirements of the federal Safe Drinking Water Act (SDWA). Affordability is addressed by the award of additional points. Eligible projects are prioritized in the order of highest score with their costs and all projects that fall within the federal allocation for loans can proceed with the loan.

The following is the timeline for the program:

- Intent to Apply Form Due: April 1.
- Project Plan Submittal: July 1 (extended from May 1 due to COVID-19).
- Projects are reviewed and placed on the priority list: October 1.

13.2 Water & Waste Disposal Loan & Grant Program – Rural Development

The United States Department of Agriculture (USDA) Rural Development (RD) program provides funding for clean and reliable drinking water systems, sanitary sewage disposal, sanitary solid waste disposal, and stormwater drainage to households and business in eligible rural areas.

Funds are generally distributed as long-term, low-interest loans. If funds are available, a grant may be combined with a loan for eligible activities. The program provides low-interest loans, usually, over a 40-year period to assist communities of 10,000 people or less to finance drinking water treatment projects.

Fixed interest rates are assigned based on the need for the project and the median household income of the area to be served. These needs are updated quarterly and include poverty line, intermediate, and market rates. The rate is only locked in once the full application is completed and reviewed and the letter of conditions are issued.

Projects are not required to comply to Davis Bacon wage rate requirements (unless leveraging sources require it). American Iron and Steel provisions are required. Projects are required to openly bid all materials and equipment. For example, piping specifications must include plastic pipe and ferrous pipe, or two different types of plastic pipe. Sole sourcing preferred suppliers for equipment may be allowed with written request for less than normal competition if the owner can demonstrate that they have standardized on a particular supplier to facilitate spare parts inventory and/or maintenance activities.

The loan amount applied for is the amount given for the loan. If the project comes in lower than expected, the excess funds can be used to fund additional activities, as long as they are identified in the original Preliminary Engineering Report and Environmental Report. Extra funds cannot be used to pay off debt or to pay salaries. There are no penalties for early repayment of the loan.

Applications for funding are accepted year-round.

13.3 Issuance of a Bond

The issuing of a bond to pay for the selected alternative is a common method of funding a water project. The market rates for a bond are likely to be higher than the loan rates obtained through a DWRF or RD loan. However, the City would not have any of the funding program restrictions in terms of product or material selections.

14.0 Summary

The City's existing Aeralater system has been in service for over 32 years and needs to be replaced. Three softening treatment alternatives were investigated for the replacement of the existing system. Those alternatives included reverse osmosis softening, ion exchange softening, and lime softening. The design of the treatment plant was based on a capacity of 4.0 mgd, which will allow for significant growth and provide a significant safety factor for the City.

The conceptual design, layout, and sitework for each of the softening treatment alternatives were evaluated. Capital and O&M cost estimates were created for each alternative. The cost of a new treatment plant including associated work at the wells and elevated tanks, the cost of operating the treatment plant, the engineering design fee, and associated studies to aid in the efficient and effective design of a new plant were included in the cost estimates of each alternative. Those costs are shown in Table 25.

Table 25 - Softening Alternatives Cost Comparison

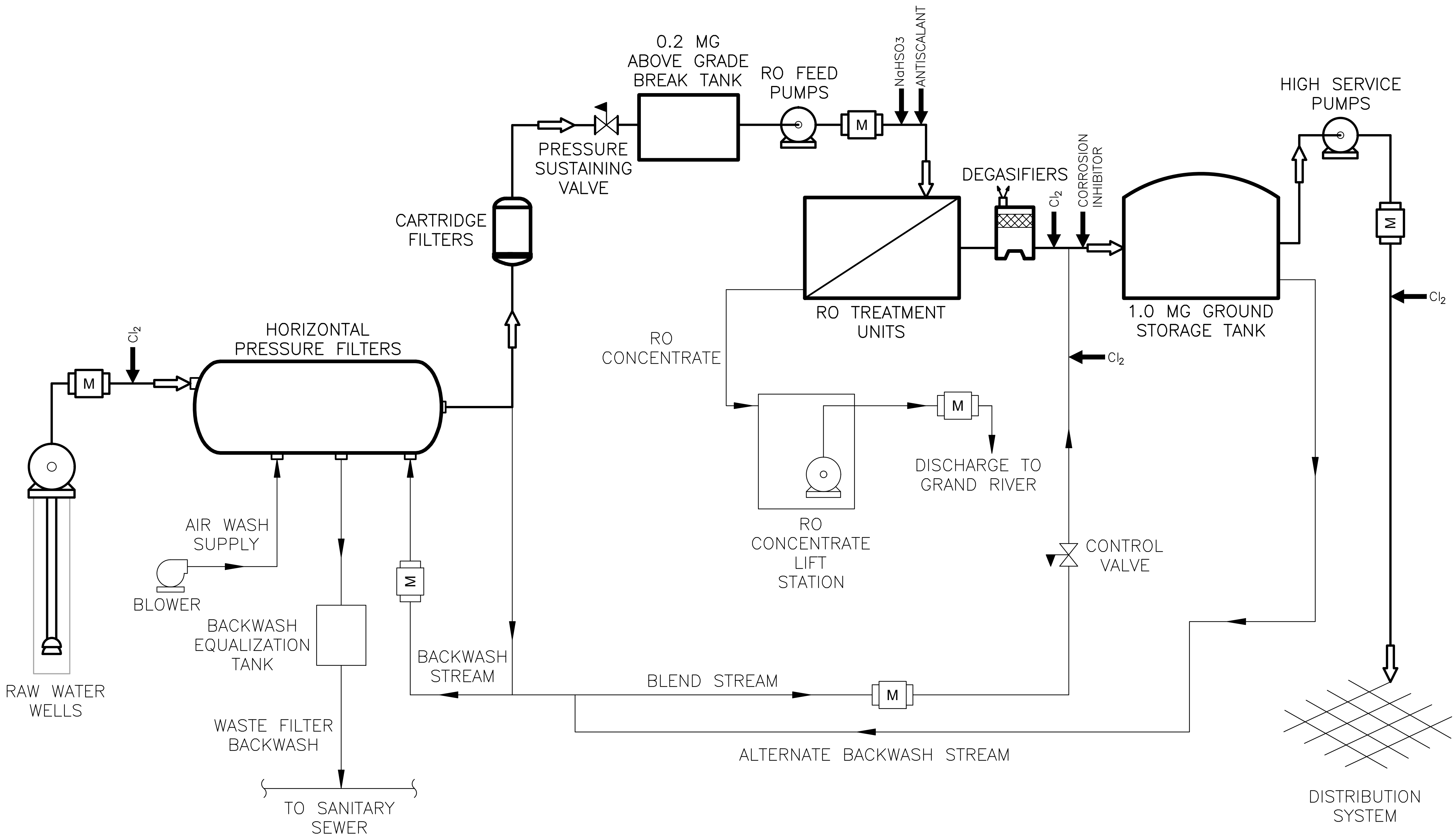
Softening Alternative	Construction Cost Opinion	Engineering & Studies	Total Project Cost	Annual O&M Costs
RO Softening	$30,265,000	$3,305,000	$33,570,000	$509,000
IX Softening	$19,889,000	$2,220,000	$22,184,000	$508,000
Lime Softening	$26,647,000	$3,130,000	$29,777,000	$637,000

It should be noted that there is uncertainty for both the RO and IX softening options for the handling of the treatment residuals. A lift station and force main from the plant to the Grand River for discharge of the RO concentrate was assumed to be part of the project. The brine waste stream from an IX softening plant was assumed to be discharged to the sanitary sewer. The City WWTP could require expansion or improvements to handle the brine waste stream. If the City would like to move forward with either the RO or IX softening option, further investigation into the handling of these treatment processes' residuals would be needed.

Cost estimates presented are based on July 2020 cost indices and the project components as presented herein. Actual project costs may differ based on the final scope of the project design components, the bidding climate at the time the project is bid, material pricing fluctuations, and other factors.

A present worth analysis will be completed to be used as a comparative cost for other options to replace the City's current water supply.

Figures



REVERSE OSMOSIS SOFTENING SCHEMATIC

NO SCALE

fishbeck
Engineers | Architects | Scientists | Constructors

Hard copy is intended to be 11"x17" when plotted. Scale(s) indicated and graphic quality may not be accurate for any other size.

City of Grand Ledge
Eaton County, Michigan

Water Softening Treatment Plant Study

PROJECT NO.
200548

FIGURE NO.
1

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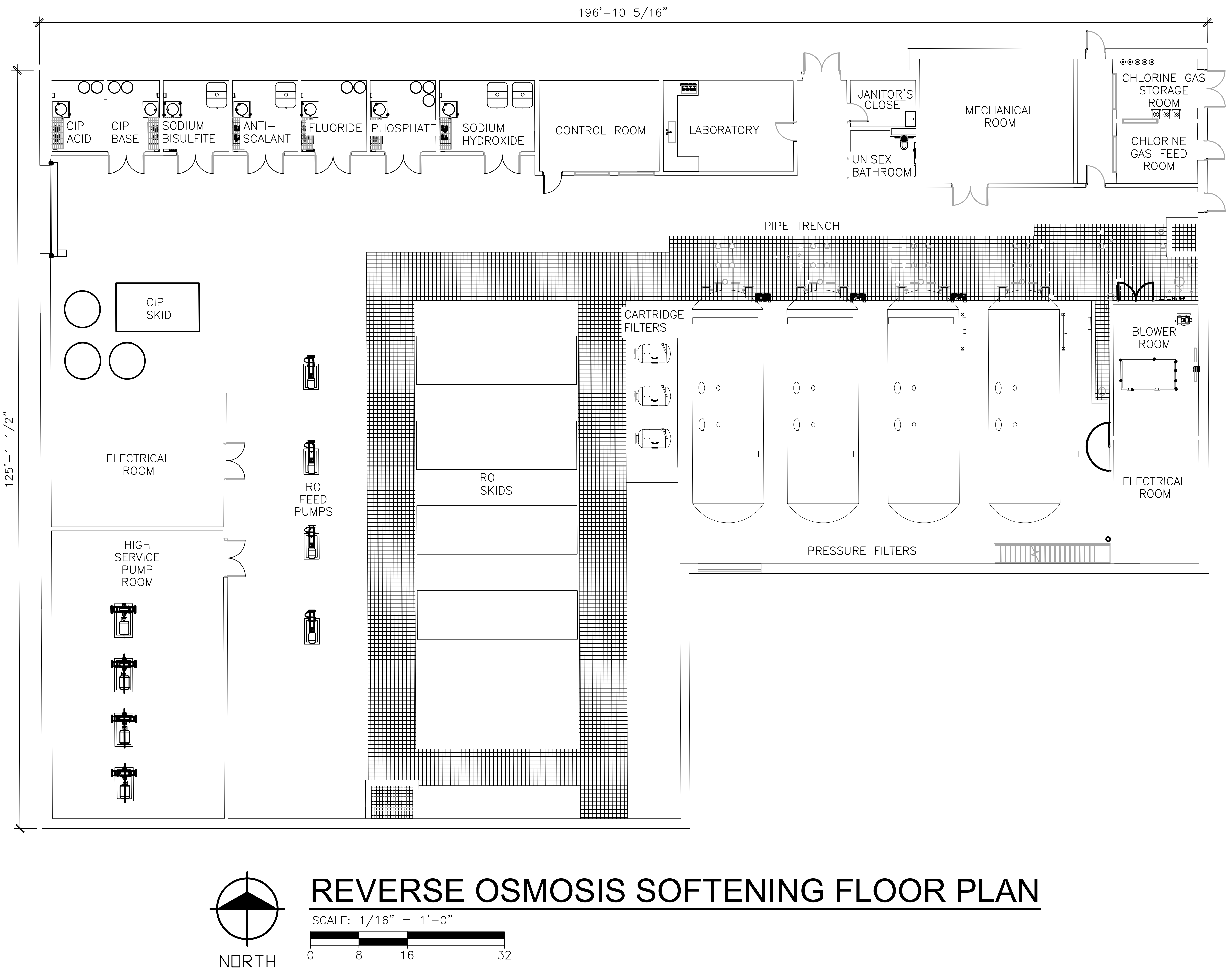

REVERSE OSMOSIS SOFTENING FLOOR PLAN

SCALE: 1/16" = 1'-0"

0 8 16 32

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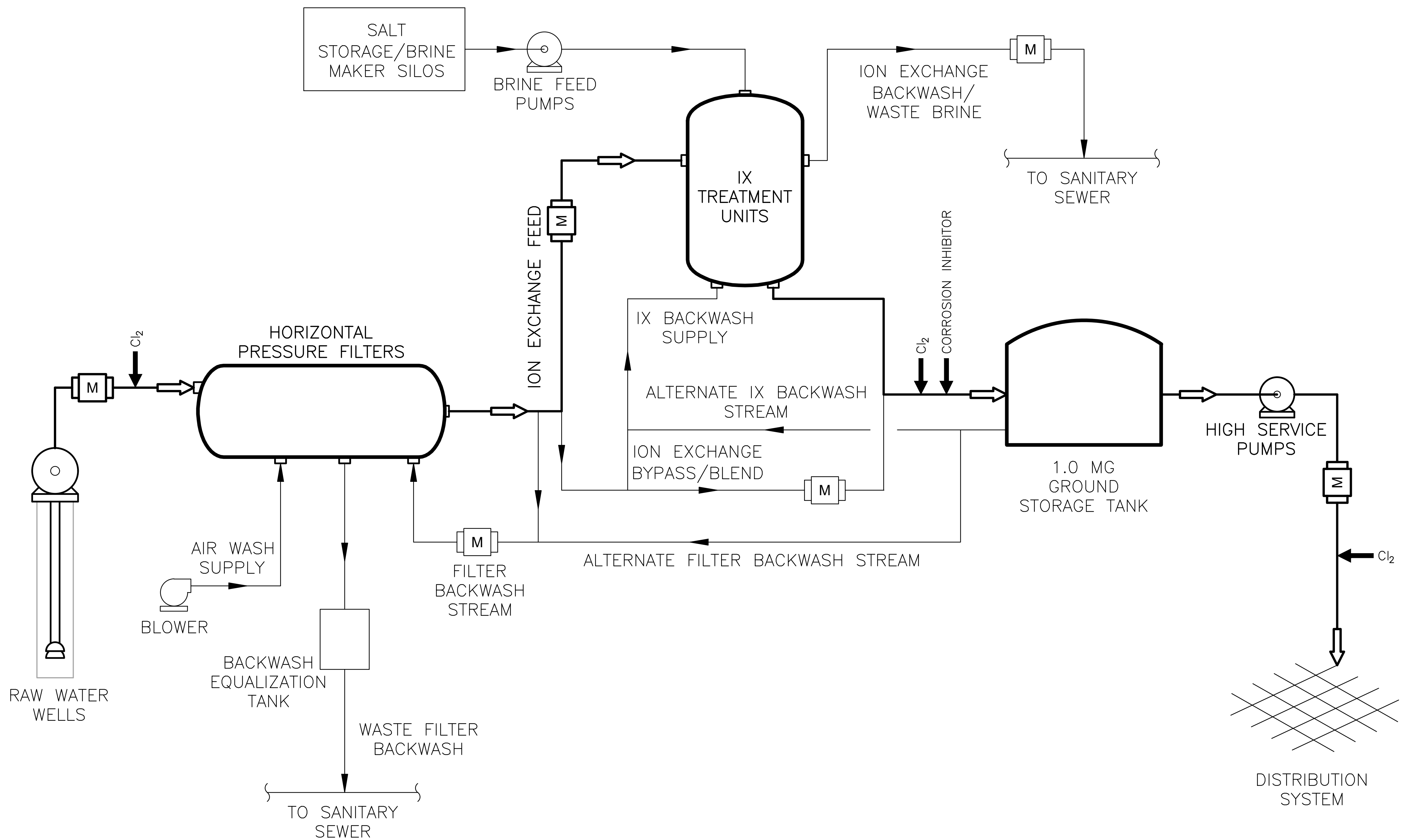
City of Grand Ledge
Eaton County, Michigan

Water Softening Treatment Plant Study

PROJECT NO.
200548

FIGURE NO.
2

PLOT INFO: C:\USERS\CGM\DESKTOP\RO_FLOORPLAN-CGM.DWG LAYOUT: RO_FLOORPLAN DATE: 8/20/2020 TIME: 3:52:51 PM USER: CMCCORKLE



ION EXCHANGE SOFTENING SCHEMATIC

NO SCALE

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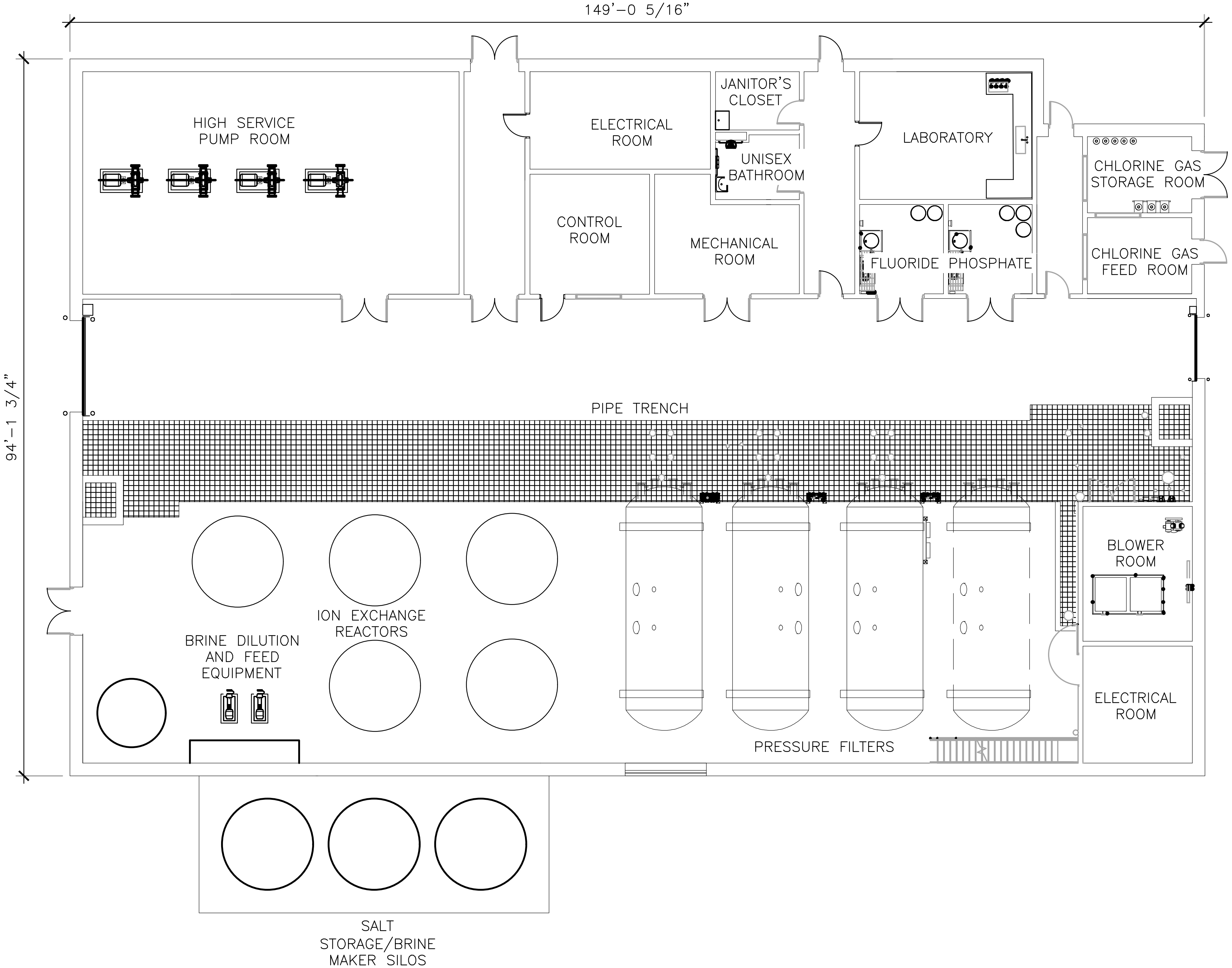
City of Grand Ledge
Eaton County, Michigan

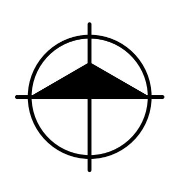
Water Softening Treatment Plant Study

PROJECT NO.
200548

FIGURE NO.
3

PLOT INFO: Z:\2020\200548\CAD\PRECD\FLOW SCHEMATICS.DWG LAYOUT: IXSCHEMATIC DATE: 8/20/2020 TIME: 12:22:27 PM USER: CMCCORKLE





ION EXCHANGE SOFTENING FLOOR PLAN

SCALE: 1/16" = 1'-0"

0 8 16 32

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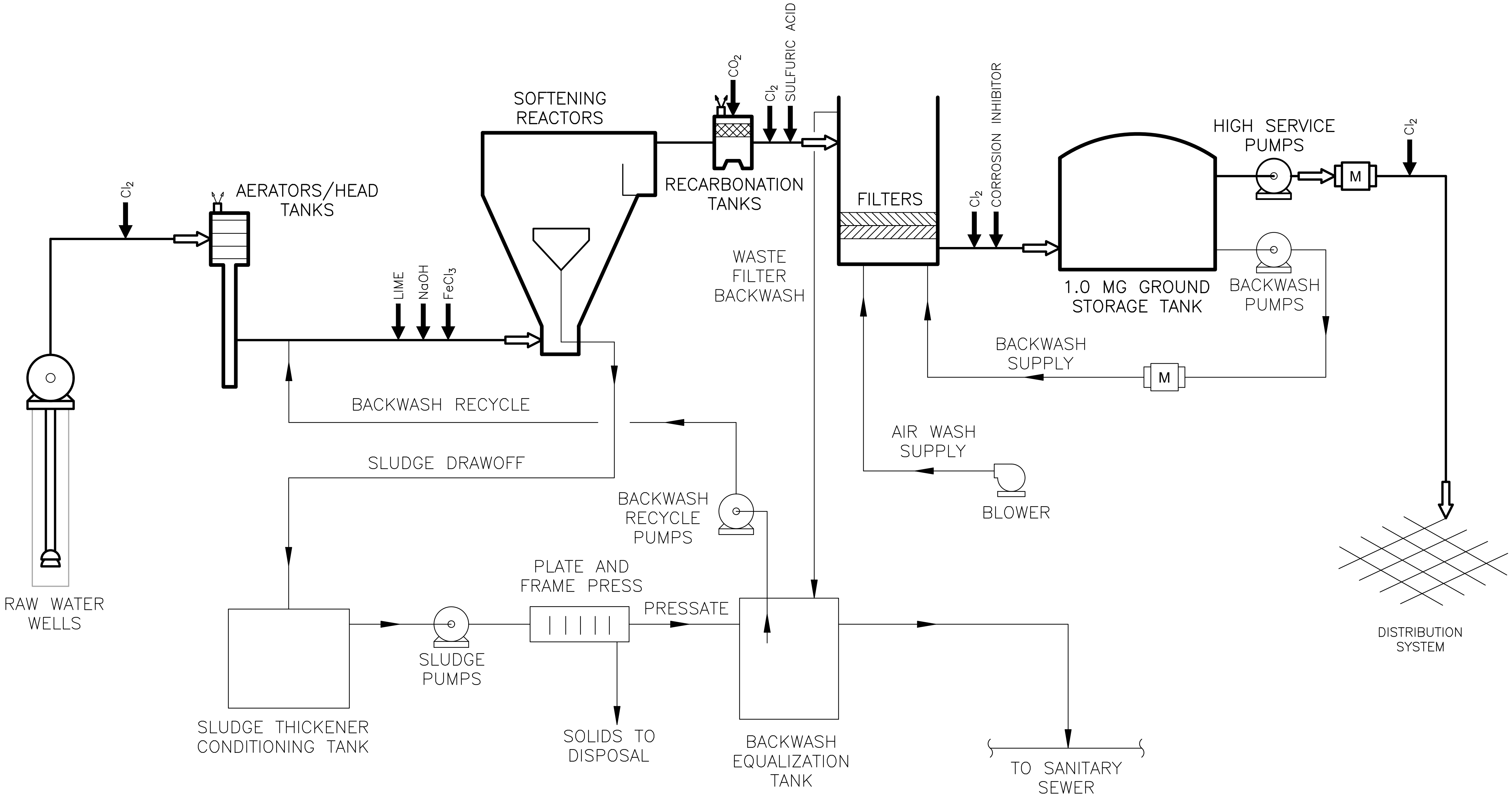
City of Grand Ledge
Eaton County, Michigan

Water Softening Treatment Plant Study

PROJECT NO.
200548

FIGURE NO.
4

PLOT INFO: C:\USERS\CGM\DESKTOP\IX_FLOORPLAN_CGM.DWG LAYOUT: IXFLOORPLAN DATE: 8/20/2020 TIME: 2:53:11 PM USER: CMCCORKLE



LIME SOFTENING SCHEMATIC

NO SCALE

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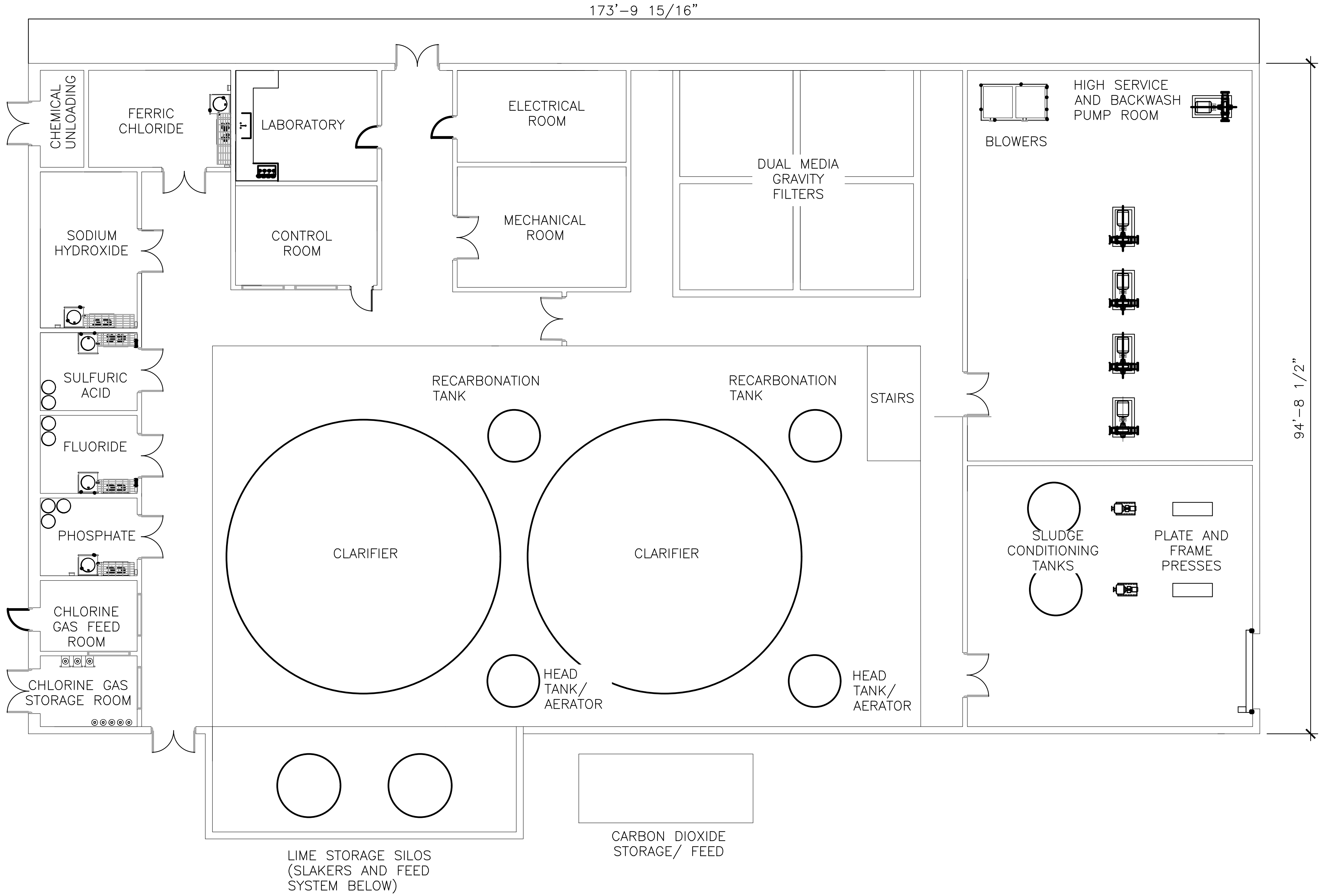
City of Grand Ledge
Eaton County, Michigan

Water Softening Treatment Plant Study

PROJECT NO.
200548

FIGURE NO.
5

PLOT INFO: Z:\2020\200548\CAD\PRECD\FLOW SCHEMATICS.DWG LAYOUT: LIMESCHEMATIC DATE: 8/20/2020 TIME: 12:22:39 PM USER: CMCCORKLE



LIME SOFTENING FLOOR PLAN

SCALE: 1/16" = 1'-0"

0 8 16 32

NORTH

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City of Grand Ledge

Eaton County, Michigan

Water Softening Treatment Plant Study

PROJECT NO.

200548

FIGURE NO.

6

PLOT INFO: C:\USERS\CGM\DESKTOP\LIME_FLOORPLAN_CGM.DWG LAYOUT: LIME FLOOR PLAN DATE: 8/20/2020 TIME: 2:51:10 PM USER: CMCCORKLE