WTP4 Pre-Feasibility Study

Northeast Well Field Expansion Planning

Prepared for
City of Blaine, MN

April 8, 2016

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Certifications

I hereby certify that these specifications were prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

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1.0 Introduction

The City of Blaine's (City) population is projected to continue to grow and in order to meet water supply needs, new wells and treatment are needed. Blaine's potable water is currently supplied by wells drawing from the quaternary, Jordan, and Tunnel City-Wonewoc aquifers. Water from these wells is treated to mainly remove iron and manganese, provide disinfection, and prepare the water for distribution. Recently proposed development in the northeast part of the City will require potable water system expansion in and around the existing water tower site near 125th Avenue NE and Lexington Avenue N in Blaine, which has been planned for some time. This area will need new water supply wells, raw water main, and eventually a new water treatment plant. New Wells No. 18-21 are included in the City's existing DNR appropriations permit which expires in March 2017. To meet the desired schedule, and to fit in with ongoing development in an around the existing water tower site, wells and water main need to be bid and constructed yet this year. For that to happen in an orderly way, a conceptual layout of major infrastructure elements to be located at the water tower site is needed and will be provided in this report.

Barr has been working with the City and the DNR to site the new wells and conduct pumping tests to verify that groundwater pumping at the well sites will not adversely impact surface waters. New Well 18 was drilled in 2015 to test the availability of water in the quaternary aquifer in the Northeast Well Field. Test pumping and modeling of Well 18 revealed that there is a sustainable supply of water in the quaternary aquifer that can be appropriated without adverse impacts to surface water features of value.

This report is one component of ongoing planning for infrastructure needs in the Northeast Well Field area, and will specifically discuss the fourth water treatment plant (WTP4). The well field and WTP4 are planned to provide up to an additional 6,000 gallons per minute (gpm) of potable water. As the City plans for WTP4, City staff has expressed interest in evaluating process options to potentially improve the efficiency of operations at the plant relative to the existing water treatment plants. The process options considered include:

- Gravity vs. pressure filtration
- Filter media options
- Backwash procedure and equipment options
- Chemical oxidation options (for manganese oxidation)
- Disinfectant options
- Backwash recovery
- Clear well options

This pre-feasibility report provides an overview of process options, their pros and cons, and their estimated capital costs. Using some basic assumptions regarding approach to plant design, this report also presents a preliminary layout for a 6,000-gpm gravity filter plant and presents site layout options for use in budgeting, planning, and coordinating site infrastructure. This will allow planned well and water main design and construction to occur in a planned and orderly manner.

2.0 Water Quality and Treatment Needs

In May 2015, Well 18 was subject to an aquifer test that was completed as part of the Northeast Well Field Evaluation. The Northeast Well Field Study is evaluating what, if any, impact pumping from the planned future supply wells might have on local surface water features and to better ensure that the City will be able to obtain approximately 6,000 gpm from the well field. During the aquifer test, a water sample was collected from Well 18 and analyzed by Pace Analytical. A summary of select water quality data from that sampling event is presented in Table 2-1. A wide range of volatile organic compounds was also analyzed and none were found to be present at concentrations above the analytical method reporting limit (i.e., "non-detect").

Of the parameters analyzed, only manganese exceeds one of the national drinking standards—in this case, a secondary drinking water standard. At the concentrations present in Well 18, the manganese may cause black staining for end users and have an unfavorable, metallic taste. For this reason, the primary treatments recommended for the proposed WTP4 are manganese removal via chemical oxidation and media filtration, and chemical addition for disinfection and fluoridation, as required by the Minnesota Department of Health. Section 3.0 discusses process options for these treatment processes.

While not detected at a concentration above the national drinking water standard, the presence of cyanide in the well sample is not typical for Minnesota groundwater. Additional sampling and analysis of the well is recommended to determine if the presence of cyanide is confirmed and to assess if further investigations are warranted.

The five wells planned and sited in this new Northeast Well Field are intended to supply water from both the quaternary and the Tunnel City-Wonewoc (TCW) aquifers, which is similar to the raw water at the City's other three water treatment plants. Staff has indicated that quaternary aquifers tend to have higher manganese, approximately 0.3-0.5 mg/L, and the TCW aquifer wells tend to have higher iron, approximately 0.4-0.5 mg/L. The water quality analysis from Well 18 is similar to the water quality of other wells in the City of Blaine and, therefore, for this phase of work, we have assumed that raw water quality to WTP4 will be similar to the iron and manganese levels in the raw water at the other treatment plants. Additional water sampling and analysis and piloting should be performed after the completion of the future well construction to verify the raw water quality of the supply water to the treatment plant.

Table 2-1 Well 18 Sampling and Analysis Results

Parameter	Units	Value	National Primary and Secondary Drinking Water Standards
General Chemistry			
Alkalinity, bicarbonate	mg/L as $CaCO_3$	226	
Ammonia	mg/L as N	0.25	
Carbon, total organic	mg/L	2.8	
Hardness, total	mg/L as $CaCO_3$	197	
pH	SU	8.0	6.5 to 8.5
Solids, total	mg/L	<10	
Solids, total dissolved	mg/L	236	500
Turbidity	NTU	0.1	
Metals			
Arsenic	µg/L	<0.5	10
Barium	µg/L	66.0	2,000
Beryllium	µg/L	<0.2	4
Cadmium	µg/L	<0.2	5
Calcium	mg/L	53.4	
Chromium	µg/L	<10.0	100
Copper	µg/L	<10.0	1,000-1,300
Iron	µg/L	<50.0	300
Lead	µg/L	<0.5	15
Magnesium	mg/L	15.4	
Manganese	**µg/L**	**372**	**50**
Mercury	µg/L	<0.2	2
Potassium	mg/L	2.3	
Selenium	µg/L	<1.0	50
Sodium	mg/L	20.1	
Thallium	µg/L	<0.2	2
Zinc	µg/L	<20.0	5,000
Anions			
Bromide	mg/L	<0.2	
Chloride	mg/L	<1.0	250
Cyanide	µg/L	32.1	200
Fluoride	mg/L	<0.1	2-4
Nitrate	mg/L as N	<0.2	10
Nitrite	mg/L as N	<0.2	
Sulfate	mg/L	2.2	250
Microbial			
Coliforms, total	--	Absent	0
E. coli	--	Absent	0

2.1 Distribution System Considerations

A detailed comparison of the finished water qualities from the City's other water treatment plants and the raw water for WTP4 was outside the scope of this prefeasibility study. However, it is recommended that differences in finished water qualities and their potential impacts on the distribution system be reviewed during the detailed feasibility stage of project development. Even small differences in, or changes to, the finished water qualities' pH, hardness, alkalinity, residual oxidants (e.g., disinfectants, dissolved oxygen, etc.) and oxidation-reduction potential (ORP) can potentially impact distribution system water quality in terms of both aesthetic concerns and corrosion potential. The purpose of a review of the finished water chemistries would be to proactively identify potential distribution system issues so they can be addressed in detailed design, if necessary.

3.0 Process Options

The following sections describe the criteria used for selecting the treatment process for WTP4. The general process flow schematic with each unit process is shown below:

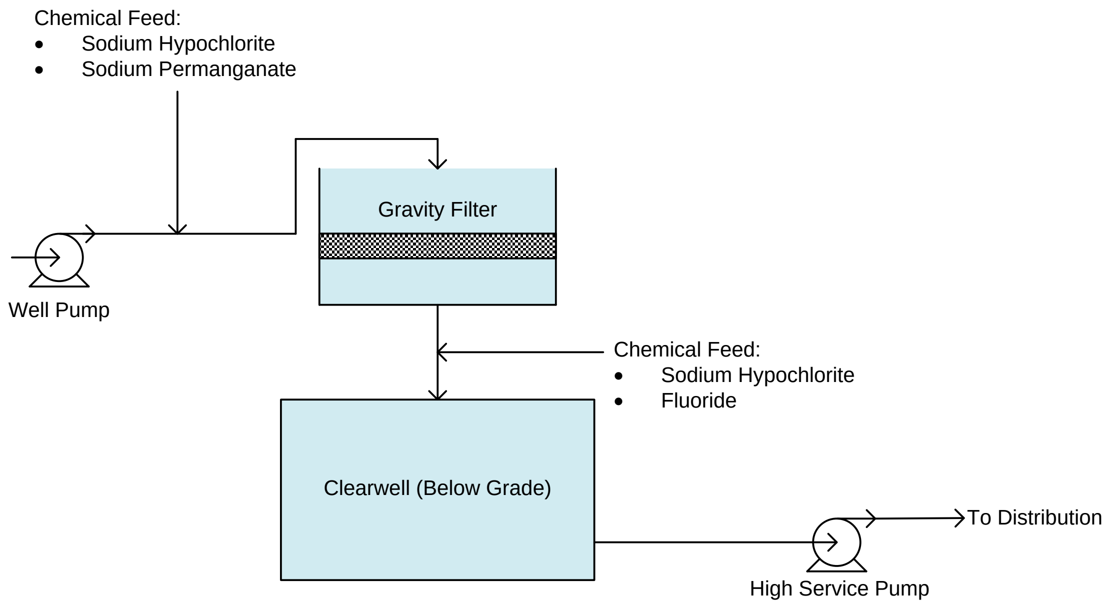


Figure 3-1 Process Flow Schematic

3.1 Gravity vs. Pressure Filters

Gravity and pressure filters are two proven effective technologies used by municipalities for iron and manganese removal. Gravity filters use differences in elevation to provide the pressure needed to transfer water through the filter media bed, whereas pressure filters use pumping to transfer the water through a media bed.

Gravity filters require a larger building footprint compared to pressure filters with non-traditional media like the existing Blaine WTPs, as the media has different loading rates. Building height must accommodate the elevation change needed to transfer the water using gravity filtration. Gravity filters require extensive structural concrete and installation of filter internals including underdrain piping, troughs, and media supports. This increases installation cost compared to pressure filters.

Gravity filters are open and can be viewed while operating and backwashing, which is beneficial for troubleshooting. Pressure filters are enclosed and cannot be viewed while operating, making troubleshooting more challenging. Pressure filter vessels also usually require confined-space entry protocols for internal vessel inspection and maintenance.

Both filters use similar techniques for backwashing by using clean water run in reverse through the filter to wash the media. Many also use air scour to enhance the effectiveness of the backwash cycle and to minimize the amount of backwash water needed. Gravity filters can alternatively use wash water with a surface wash. Backwashing options are further discussed in Section 3.3.

Both filters use similar media which are further discussed in Section 3.2.

After touring several local plants, interviewing operations staff from those facilities, and reviewing the engineering and economic considerations, City staff have elected to proceed with gravity filtration for WTP4.

3.2 Media

There are many different media types and configurations that have been used for iron and manganese removal and that have been proven to produce the desired finished water quality. This section discusses three media options for WTP4. Ultimately, the media types should be piloted in order to select the best option. The three media options discussed in this section are silica sand mono media, greensand/anthracite dual media, and pyrolusite.

3.2.1 Silica Sand Mono Media

Silica sand is the most commonly used filter media and has shown to provide good removal of iron and manganese when used in combination with an oxidation process. A mono media filter would typically consist of 30 inches of sand with an effective size of 0.45 mm to 0.55 mm. This media configuration has been used in many applications and has been well documented and proven to work. When compared to dual-media configurations, discussed in the next section, mono media configurations will have shorter filter run times. This is due to the filtering mechanics happening in the single media. As the media is restratified during backwash, the finer sand particles migrate to the top of the filter. The finer particles remove the bulk of the impurities in the top few inches of the media bed and require backwashing before the full capacity of the bed depth can be utilized. This phenomenon led (historically) to the use of dual-media filters.

3.2.2 Greensand/Anthracite Dual Media

Dual-media filters consist of a bottom layer of fine sand and a top layer of coarse anthracite coal. The coarse top layer allows for deeper penetration of the filtered impurities, thereby utilizing more of the full bed depth for filtering capacity. This results in longer filter run times and greater efficiencies. In the case of iron and manganese removal, it is typical to use greensand media in place of the sand. Greensand is a granular media with a manganese dioxide coating that acts as a catalyst in the oxidation/reduction reaction of iron and manganese. Greensand typically has superior iron/manganese removal capability than silica sand.

3.2.3 Pyrolusite

A third media option that City staff has expressed interest in is pyrolusite. Pyrolusite is a naturally occurring manganese dioxide media capable of oxidizing iron and manganese without the use of oxidants for recharge. Pyrolusite is a coarse granular material with a high specific gravity and is capable of higher filter loading rates up to 15 gpm/ft^2 (AWWA, 2015). Proper operation of pyrolusite media requires adequate backwashing. The higher specific gravity of pyrolusite requires higher backwash rates than silica sand and air scour. Typical rates are on the order of 25 – 30 gpm/ft^2 to achieve a 30% bed expansion. Some pyrolusite manufacturers recommend daily backwashing to maintain effective iron/manganese removal. City staff is currently in the process of obtaining quotes for changing out the existing filter media in WTP-1, 2, and 3 with pyrolusite. Depending on the observed performance of the pyrolusite, the City may choose to install pyrolusite in WTP4.

3.2.4 Summary

A summary of the three types of media is below.

Table 3-1 Typical Filter Media Characteristics
(10 State Standards, 2012; Inversand, 2016; AWWA, 2015)

	Silica Sand Mono Media	Greensand/Anthracite Dual Media	Pyrolusite
Effective size	0.45-0.55 mm	0.3-0.35 mm/0.6-0.8 mm	0.3-0.8 mm
Specific gravity	2.6	2.4-2.6/1.3-1.8	4
Filter loading rate	2-4 gpm/ft^2	Up to 12 gpm/ft^2 (pilot testing recommended at rates >6 gpm/ft^2)	Up to 15 gpm/ft^2
Backwash rate	10-15 gpm/ft^2	Minimum 12 gpm/ft^2 at 55°F	No air scour: 25-30 gpm/ft^2 With air scour: 5 gpm/ft^2 (with 3 scfm/ft^2 air) and 20 gpm/ft^2 (no air)
Media depth	30 inches	15 to 18 inches anthracite 15 to 24 inches greensand	36-48 inches

Table 3-2 Media Pros/Cons

	Pros	Cons
Silica sand mono media	• Widely used, proven performance • Low backwash rate required	• Clogging in top few inches results in more frequent backwashing • Lower filter loading rate results in larger footprint
Greensand/anthracite dual media	• Widely used, proven performance • Greater depth penetration of filtered material results in greater bed capacity • Greensand more efficient means of removing Fe/Mn • Lower backwash rate required	• Media requires recharging with permanganate • Lower filter loading rate results in larger footprint
Pyrolusite	• Little to no chemical needed to remove Fe/Mn • Higher filter loading rate results in smaller footprint	• Air scour required due to high specific gravity • High backwash rate required • Little information available on performance

For the purpose of this study, we have assumed use of dual media consisting of greensand and anthracite in the filters. This media was used to develop the filter sizing for the preliminary plant layout and the cost estimate.

3.3 Backwashing

Filter performance is primarily driven by two factors: media type and backwashing procedure. The media type is fixed, once it is selected, and will not change unless a new media is installed. The backwash procedure can be designed to be flexible, allowing for adjustment to optimize filter performance. Effective backwash is a very important part of overall filter performance. Backwashing can be accomplished with three different methods:

- Water wash only
- Water wash with surface wash
- Water wash with air scour

The water wash only method is rarely used in new designs or filter retrofits. The water wash only method typically uses a much higher volume of water to achieve the same cleaning result as the water/surface wash or water/air wash. The water/surface wash has been widely used for many years and provides an additional means of filter cleaning that reduces the amount of wash water needed. The surface wash mechanism is mounted above the filter media and usually penetrates a few inches into the media which works well with mono media applications, but not very well with dual-media applications. For these reasons, it is assumed that water wash with air scour will be utilized in WTP4 for filter backwashing.

There are three methods most widely used for providing backwash water:

- Flow bled from the high-service discharge pipe
- Self-backwashing filters
- Direct pumping from a sump or clear well

3.3.1 Flow from Finished Water (Distribution System)

Backwash water can be bled from the high-service discharge pipe to supply wash water. This method requires no additional pumps, but results in significant energy loss due to the pressure reduction needed to control the flow to prevent media loss. This application would consist of a pressure-reducing valve or orifice plate and an optional flow-control valve. The pressure-reducing valve or orifice plate would reduce the pressure to an acceptable level, while the flow-control valve could be used to vary the backwash rate to allow for flexibility. This option can be more difficult to optimize because the backwash flow is linked to the distribution system. When a backwash is initiated, a demand is placed on the distribution system that may result in pressure drops or the inefficient filling of the towers. These factors must be considered during design in order to minimize impacts to the distribution system and provide adequate backwash control.

3.3.2 Self-Backwashing Filters

A second option for providing backwash water is to use the effluent water from filters in service to provide the wash water for the filter in backwash. In this configuration, all of the filters discharge into a common wet well. A control weir keeps the water level at a constant level that is high enough to provide enough driving head. There also must be enough operating filters online to provide adequate flow. Self-backwashing filters require no additional piping or pumps but would require a flow-control valve and additional concrete for the wet well. Hydraulics are limited by the number of filters in service and the height of the weir. Flow can be varied by adjusting the height of the wet well that serves as the backwash supply.

3.3.3 Direct Pumping from a Sump or Clear Well

Direct pumping from a sump or clear well provides the most flexibility in the backwash procedure. Direct pumping consists of a pump, valves, and piping to draw water from a sump or clear well and send it to the filters. The pump is sized to provide the necessary flow and head for the maximum backwash rate and either a variable frequency drive (VFD) or flow-control valve is used to vary the backwash loading rate. Varying backwash loading rates can be used to provide a low and high rate wash period which works well with air scour and dual-media applications. Backwash loading rates can also be optimized through observation and recordkeeping, which assists operations staff in making sure effective backwashing occurs over a range of conditions.

Backwash redundancy is something that should be considered during design. It is common to find applications where both a direct pump method and flow bled from the high service line are implemented. The direct pump serves as the primary backwash method, while the high-service bleed serves as a back-up.

3.3.4 Backwash Summary

A summary of the backwash alternatives is shown below:

Table 3-3 Backwash Summary

	Flow from HS discharge pipe	Self-backwashing filters	Direct pumping from sump or CW
Equipment needed	Pressure-reducing valve or orifice plate, valves, piping, flow-control valve	Flow-control valves, clear well level control gates, and additional concrete	Pump, valves, piping, VFD or flow-control valve
Flow variation to optimize	Yes	Yes	Yes

Table 3-4 Backwash Pros/Cons

	Pros	Cons
Flow from high-service pumping discharge pipe	• No additional pumps required • Flow can be varied to optimize backwash • Adequate amounts of water available	• Significant energy losses due to pressure reduction required • Challenging control of backwash flow
Self-backwashing filters	• No additional pumping	• Must be enough operating filters online to provide adequate flow
Direct pumping from sump or clear well	• Provides the most flexibility • Easy backwash optimization due to stand-alone system • Adequate amounts of water available if clear well sized and operated correctly	• Requires additional pump and electrical • Requires additional building space

For the purpose of this study, we will assume that finished water flow from the distribution system will be used to backwash the water. This choice is reflected in the preliminary plant layout and the cost estimate.

3.4 High-Service Pumping

High-service pumping can either deliver treated water from the filter or from a clear well. City staff have indicated that they would utilize high-service pumping in order to minimize the water supply well pump and motor size and head requirements.

3.5 Clear Well

City staff have indicated they would like to utilize a clear well instead of pumping directly from treatment to the distribution system. The clear well provides a buffer between the treatment plant and the City's distribution system. High-service pumps will deliver water from the clear well to the water supply piping. There are two main types of clear wells used for finished water with high-service pumping:

- Below the WTP
- Below grade, adjacent to the WTP

Building footprint is reduced when it is below ground, but becomes less accessible compared to being adjacent to the facility. A clear well below ground could have greater construction costs associated with potential excavation issues. For pre-feasibility design and costs, a clear well below grade adjacent to the WTP is assumed and discussed further in Sections 4.0 and 5.0.

3.6 Sodium vs. Potassium Permanganate

In addition to chlorine, there are two other primary oxidants used for iron and manganese treatment:

- Potassium permanganate ($KMnO_4$)
- Sodium permanganate ($NaMnO_4$)

Potassium permanganate (2-4% solution) and sodium permanganate (20% solution) are two chemicals typically used to oxidize and precipitate manganese in water prior to filtration. Both forms of permanganate are also used to regenerate the manganese oxide coating on the greensand media.

Potassium permanganate is delivered as a dry powder requiring mixing and is less expensive than sodium permanganate; however, potassium permanganate requires more preparation and safety considerations. Potassium permanganate is delivered as a solid powder and must be dissolved with water in a mixing tank prior to being added to the untreated water. Preparing the potassium permanganate requires additional cleanup precautions and safety procedures for staff. Sodium permanganate is delivered as a liquid to a bulk storage tank and ready for use without additional preparation. Both chemicals can be transferred from the bulk tank to the filter feed water using peristaltic or diaphragm pumps. However, based on operator experience at other facilities, potassium permanganate can clog diaphragm pumps; therefore, peristaltic pumps are recommended. When using sodium permanganate, special piping solvent welds and Viton seals are needed for pipe fittings and pumps. It is also recommended that peristaltic pumps be used for sodium permanganate.

City staff has stated preference for using sodium permanganate and, as such, this chemical was used to develop the preliminary construction cost estimate.

3.7 Disinfection Options

Chlorine is the most widely used chemical for disinfection of drinking water. Chlorine will be added both to the pre-filter for oxidation and to the finished water to maintain a chlorine residual. There are three methods commonly used to provide the chlorine:

- Gaseous chlorine
- Bulk sodium hypochlorite
- Onsite sodium hypochlorite generation

3.7.1 Gaseous Chlorine

The City of Blaine currently uses gaseous chlorine, so it is a familiar system. A gaseous chlorine disinfection system is generally comprised of bulk gaseous chlorine cylinder delivery and storage, a chemical feed and injection system, chlorine dose and residual monitoring devices, a chlorine gas scrubber, and leak detection/alarm systems. Chlorine is typically transported by truck as 100 percent (%) free available chlorine (FAC) liquefied compressed gas in either 150-lb. or 1-ton steel cylinders.

Chlorine gas storage and use requires many safety precautions be incorporated into the design and operation of the system. This includes specific equipment segregation, ventilation, gas monitoring and alarm, egress, gas leak scrubber, and temperature control requirements to prevent leaks and to mitigate the impact of any leaks that may occur. Typically, scrubber systems are used to control chlorine gas emissions. As was noted on the recent plant tour, the City of Maple Grove uses an alternative to a scrubber. If such an option is of interest to the City of Blaine, further evaluation of alternatives to a scrubber would need to be conducted during the feasibility study or detailed design. Alternatives would likely require special approval. Chlorine gas requires training and safety procedures, as well as an emergency management plan.

3.7.2 Bulk Sodium Hypochlorite

Bulk sodium hypochlorite (NaOCl) involves delivery of liquid NaOCl, typically 12.5% (trade percentage, 12.5 g available Cl_2 per 100 mL of solution), into a bulk storage tank. Peristaltic or diaphragm pumps are used to dose NaOCl at desired disinfectant injection points. Sodium hypochlorite degrades over time during storage. As such, strength of the bulk solution must be measured routinely and dose adjustments made as necessary.

Miscellaneous tank level sensors, vents, gauges, secondary containment, and piping and appurtenances are required in a bulk NaOCl system. Bulk NaOCl is a simple system that is easy to operate and requires little training. Bulk solutions are considered hazardous material and require care when handling and triggers a requirement for an emergency management plan.

3.7.3 Onsite Sodium Hypochlorite Generation

Onsite sodium hypochlorite generation (OSHG) involves the generation of hypochlorite through the use of a brine solution and electricity. Equipment for an OSHG system generally includes a tank to hold the brine solution, water softener, electrical rectifier, electrolytic cells, hypochlorite storage tanks, hydrogen dilution blower, and feed pumps. Salt (similar to that used for a home water-softening system), is delivered to the site and stored in the brine tank. Softened water is added to the tank to create the brine. An electrical rectifier converts AC power into DC power where it then energizes the electrolytic cells. The brine solution flows through the electrolytic cells and the electricity converts the sodium and chloride ions into sodium hypochlorite and hydrogen gas. The hydrogen gas is vented outside of the building, while the hypochlorite is stored in tanks. The solution produced is a 0.8% solution, which is below the threshold of 1% for hazardous materials. This low concentration relieves the City of needing an emergency management plan, onsite scrubber, chemical deliveries, and other onsite chemical handling safety measures. After further discussions with the City, OSHG was chosen to be part of the base plant design and layout.

3.7.4 Summary of Disinfection Options

Table 3-5 Disinfection Summary

	Gaseous Chlorine	Bulk Sodium Hypochlorite	Onsite Sodium Hypochlorite Generation
Facility/Equipment	• Bulk chlorine storage • Gas injection system • Chlorine monitoring devices • Scrubber or nitrogen shutoff	• Bulk hypochlorite storage • Feed pumps • Levels, vents, gauges • Tank berm	• Water softener • Salt storage and brine tank • Electrical rectifier, electrolytic cells • Hypochlorite storage tank • Blower • Feed pumps
Hazardous Material Emergency Management Plan	Yes	Yes	No
Chemical Weight Percent	100% (as Cl_2)	12.5% (by weight as Cl_2)	0.8% (by weight as Cl_2)

Table 3-6 Disinfection Pros/Cons

	Pros	Cons
Gaseous Chlorine	• Pure chlorine, typically cheaper delivery cost • No chemical degradation • Simple system to operate	• Requires safety training • Requires emergency management plan
Bulk Sodium Hypochlorite	• Relatively easy delivery • Low capital cost • Simple system to operate	• Bulk hypochlorite degrades over time • Requires safety training • Requires emergency management plan
Onsite Sodium Hypochlorite Generation	• Does not require emergency management plan • Does not require handling hazardous materials • Chemical feed system is simple to operate	• Higher initial capital cost • Generation system has more complex components that require maintenance • Larger feed pumps required

3.8 Backwash Recovery

Backwash recovery is a practice to reclaim and reprocess the water used during backwash to maximize overall water treatment efficiency. Two options were considered:

- Settling tanks
- Lamella clarifier system

3.8.1 Backwash Water Settling Tanks

Backwash water settling tanks simply store the water for a period of time, allowing the solids in the backwash water to settle to the bottom. The clear water is decanted and sent back to the treatment process. The sludge is periodically removed from the bottom and conveyed to the sewer.

3.8.2 Lamella Clarifier System

A Lamella clarifier uses inclined plates to settle the solids where they slide down by gravity to a sludge collection hopper. Prior to entering the clarifier, the water enters a mix tank where polymer is added to form large particles and increase settling. The combination of polymer addition and the inclined plates decrease the settling time, thus decreasing the footprint compared to settling tanks.

The clean water flows through orifices and exits at the top of the clarifier and back to the treatment process. The sludge is periodically drained to the sewer or a sludge holding tank. Bench testing is recommended to determine the optimum polymer to use with the backwash water quality. The Lamella process also requires field refinements to determine optimum run times and sludge discharge timing.

Lamella systems work best with continuous backwash flow which are typical for large WTPs that have multiple filters and backwashes with minimal downtime between each cell.

After further discussions with the City, the Lamella system was chosen to be part of the base plant design and layout.

3.8.3 Summary of Back Recovery Options

Table 3-7 Backwash Recovery Summary

	Settling Tanks	Lamella Clarifier System
Equipment	• Backwash water storage tank • Sludge wasting drains • Decant piping	• Lamella clarifier • Polymer addition mix tank • Polymer addition system • Sludge wasting equipment

Table 3-8 Backwash Recovery Pros/Cons

	Pros	Cons
Backwash Water Settling Tanks	• Simple design • Easy to operate • Lower initial capital cost • Low maintenance • No additional mixing and chemical addition	• Longer solids settling time • Less backwash recovery • Requires larger building footprint
Lamella Clarifier System	• Shorter solids settling time • Smaller building footprint • Increase in backwash recovery • Once optimized, it has effective solids removal	• Higher initial capital cost • Requires additional chemical and mixing costs • Requires continuous supply of chemical delivery and preparation • Initially requires troubleshooting and process optimization • Operates better with continuous backwash flows

4.0 Preliminary Design Basis

The following sections describe a basis of preliminary design for WTP4 which will be used to determine an estimated building footprint. This footprint will be used to determine site layout and placement of piping. The sizing is based on several assumptions of selected options that were discussed in Section 3.0. Assumptions that were made are listed below.

- Gravity filtration
- Greensand/anthracite media
- Pumped backwash
- Backwash settling tanks

4.1 Filter Type and Size

Filter sizing was completed assuming gravity filters with conventional greensand/anthracite media. This sizing resulted in the largest footprint which ensures adequate space on the site for any option the City chooses. Sizing criteria used was obtained from Recommended Standards for Water Works, 2012 (10 State Standards), as well as various water treatment textbooks. The sizing criteria are as follows:

- 2-4 gpm/ft^2 filter loading rate, typically 3 gpm/ft^2 for iron/manganese removal (10 State Standards, 2012)
- Minimum depth of filter box 8.5 feet (10 State Standards, 2012)
- Minimum depth of water over media 3 feet (10 State Standards, 2012); typical design of 6 feet (Beverly, 2012)

The design flow for the filters is 6,000 gpm. At a design loading rate of 3 gpm/ft^2, the required filter area is 2,000 ft^2. Assuming four filter cells, the required filter area per filter is 500 ft^2. Filter dimensions of 25 feet by 20 feet would provide the necessary 500 ft^2 per filter. The number of filters and filter cells will be determined in detailed design.

The total depth of the filter must provide the necessary driving head to push the water through the filters by gravity. The total driving head is measured as the distance from the operating water level in the filter to the filter effluent pipe elevation. Total driving head can also be calculated as the clean bed headloss through the filters plus the operational headloss. The measured total driving head must be greater than the calculated total driving head for the filter hydraulics to work properly. The calculated total driving head was determined as follows:

- Clean bed headloss through the filter media and piping (headloss values are typical per FTDH. Actual values will be determined during piloting and design using media characteristics)
  - Anthracite headloss: 12 inches
  - Greensand headloss: 24 inches
  - Filter flow-control valve: 12 inches
  - Filter piping: 6 inches
  - Total headloss through media and piping: 4.5 feet

- Assumed operational headloss (typical operational headloss is 8-10 feet. Greater values result in media compaction, while lesser values result in shorter filter run times)
    - Operational headloss: 8 feet
- Total driving head required: 4.5 + 8 = 12.5 feet

The actual total driving head can be determined by summing the physical dimensions of the filter components. The following shows the determination of the actual total driving head.

- Spacing from bottom of underdrain to filter effluent pipe: 4 feet
- Underdrain thickness: 9 inches
- Greensand thickness: 18 inches
- Anthracite thickness: 12 inches
- Water depth above media: 6 feet
- Total driving head is the sum of the above depths: 13.25 feet

Assuming a 2-foot freeboard above the filter operating water level, the total filter box depth will be 15.25 feet.

4.2 Clear Well Size

Clear well volume is typically sized in conjunction with the distribution system storage requirements. Sizing is based off of peak demands and minimum fire flow needs. In the case of Blaine, the City has existing distribution system storage that meets the requirements of demand and fire flow. The second method for determining clear well sizing is based on disinfection requirements. Typical contact time for disinfection is 30 minutes, which has been assumed in this report for planning purposes. Other factors such as pH, temperature, and the presence of other reactive constituents must ultimately be considered when determining the design contact time. The effective contact time is a function of the time it takes for 90% of the water to pass through the unit. This time is designated as the t_{10} time. United States Environmental Protection Agency (EPA) established criteria for determining the t_{10} time by use of baffling factors (Baruth, 2005). It was assumed that average baffling conditions could be achieved by designing intra-basin baffles and an outlet weir. Using the baffling factor for average baffling of 0.5 and a desired effective contact time (t_{10}) of 30 minutes, the hydraulic detention time can be determined by dividing t_{10} by the baffling factor. This equates to a detention time of 60 minutes. At the peak flow of 6,000 gpm, the required clear well volume is 360,000 gallons.

4.3 Pump Size

Discussions with City staff have led to a decision to utilize high-service pumping to feed the distribution system whether gravity or pressure filters are constructed. High-service pumping would reduce the horsepower requirement for the well pumps, which would result in improved well pump operation and maintenance. High-service pumps will be sized to provide flowrates that meet the demand and pressure of the distribution system.

It was assumed for this report that backwash would be supplied by a pump. Approximate sizing for a backwash pump was determined by considering the flow and head required to result in a 50% media bed expansion. It is recommended by 10 State Standards to size a backwash pump for 15 gpm/ft^2. Each filter measures 500 ft^2 in filter area, which results in a required design backwash flow of 7,500 gpm. Headloss in the backwash system would need to be evaluated during design, but for the purpose of this report, an assumed total headloss of 30 to 40 feet was used to determine a horsepower range. The flow and assumed headloss results in a break horsepower range of 56 to 75 hp. Assuming a pump and motor efficiency of 80%, the motor horsepower range would be 70 to 100 hp. The pumping requirements could be less, depending on the type of backwashing that is selected, and will be determined in the detailed design.

4.4 Media

The media was assumed to be conventional dual media consisting of greensand and anthracite. This assumption provides a conservative estimate of the building footprint. Media depths and characteristics are based on recommendations from 10 State Standards and are as follows:

- Total media depth greater than 24 inches and no more than 30 inches. Typical media depth is 30 inches.
- Minimum of 12 inches of media with an effective size no greater than 0.45 mm to 0.55 mm.

Based on these standards, media depths of 18 inches of greensand and 12 inches of anthracite are assumed for design.

The physical properties of the media would follow the recommendations set forth in 10 State Standards. The media properties are presented below.

- Anthracite media
  - Effective size: 0.8 mm to 1.2 mm
  - Uniformity coefficient: less than 1.7
  - Specific gravity: greater than 1.4
- Greensand media (based on manufacturer information; Inversand, 2016)
  - Effective size: 0.3 mm to 0.35 mm
  - Uniformity coefficient: less than 1.6
  - Specific gravity: greater than 2.4

4.5 Plant Layout

The plant layout must also take into account the following space requirements:

- Access to equipment
- Control room, lab, restroom
- Fluoride system room
- Disinfection system room

    - Assumed to be onsite sodium hypochlorite generation
- Sodium permanganate storage and feed system
- One gravity filter with four cells
- Exterior clear well below grade
- Lamella clarifier system with sludge storage
- High-service pump room
- Electrical/mechanical Room

The current layout proposes a building footprint of approximately 20,000 ft^2 (205 feet x 96 feet). The preliminary plant layout is provided as Figure 4-1 and is included with this report.

4.6 Site Layout

WTP4 is assumed to be on the City-owned water tower parcel, and will be between existing Well No. 18 and future Well No. 19. The WTP will be accessible from Lexington Avenue N. Wells No. 18-22 will deliver raw water to the plant, and the plant will use high-service pumping from the clear well to deliver water to the distribution system and the adjacent elevated tower.

Specific site plans were not included in this pre-feasibility study, but the general footprint of future WTP4 is shown on Figure 4-2, along with the future wells and raw water mains for infrastructure planning purposes.

5.0 Capital Planning

A cost estimate was created to provide a budgetary amount for the design and construction of WTP4. The cost estimates for the pre-feasibility design are considered a Class 5 estimate, as described by the Association for the Advancement of Cost Engineering International (AACE), Cost Estimate Classification System with an expected accuracy range of -20% to -50% (low) and +30% to +100% (high) (AACE, 2005). A more detailed analysis of the equipment and design will need to be completed to update the cost estimate and refine the accuracy.

A combination of the following resources was used for the project cost estimate:

- Cost Estimating Manual for Water Treatment Facilities (McGivney, et al., 2008)
- Estimates from similar projects
- Engineering judgment
- Discussions with water treatment equipment vendors

5.1 Base Plant Cost

The base plant cost includes the following items:

- Gravity filter structure
- Dual-filter media
- Filter backwash pump
- Water wash with air scour
- Lamella clarifier system (backwash recovery)
- Backwash recovery sludge storage tank
- Clear water storage, below grade, outside of the building (clear well)
- High-service pumping
- Disinfection chemical feed (onsite sodium hypochlorite generation)
    - Water softener
    - Brine storage tank
    - Brine metering pumps
    - Hypochlorite generator
    - Sodium hypochlorite storage tanks
    - Sodium hypochlorite meeting feed pumps
    - Hydrogen exhaust fan
- Fluoride chemical feed
- Admin, lab, maintenance
- Sodium permanganate chemical feed
- Miscellaneous piping and valves
- Backup generator
- Building construction
- Sitework

The total estimated project cost for the base plant is $21.9 million. The detailed estimate is summarized in Table 5-1.

Table 5-1 Base Plant Pre-Feasibility Cost Estimate

	Process Item	Quantity	Cost Per Item	Total Cost
1	Gravity Filter Structure[1]	1	$2,434,000	$2,434,000
2	Dual-Filter Media[2]	1	$114,000	$114,000
3	Filter Backwash Pump[3]	1	$272,000	$272,000
4	Wash Water with Air Scour	1	$367,000	$367,000
5	Backwash Recovery Sludge Storage Tank[4]	1	$87,000	$87,000
6	Clear Water Storage (Clearwell)[5]	1	$492,000	$492,000
7	High-Service Pumping	1	$358,000	$358,000
8	Admin, Lab, Maintenance	1	$238,000	$238,000
9	Onsite Hypochlorite Generation[7]	1	$421,000	$421,000
10	Fluoride Chemical Feed	1	$19,000	$19,000
11	Sodium Permanganate Chemical Feed[6]	1	$19,000	$19,000
12	Lamella Clarifier Backwash Recovery System[7]	1	$174,000	$174,000
13	Backup Generator	1	$250,000	$250,000
14	Misc. Piping and Valves (50% of equipment cost)	1	$2,495,000	$2,495,000
15	Building Construction	19,700	$250	$4,930,000
	Subtotal Process Item Costs			**$13,100,000**
	Yard Piping 10%			$1,400,000
	Site Work Landscaping 5%			$700,000
	Site Electrical & Controls 20%			$2,700,000
	Total Construction Cost			**$17,900,000**
	Engineering, Legal & Administrative 22%			$4,000,000
	Total Project Cost			**$21,900,000**

1 Four cells, one filter unit
2 Base plant assumes dual media
3 Each filter cell uses same backwash pump
4 One tank for sludge storage
5 Below ground clear well
6 Estimate from similar project
7 Based on vendor budgetary quotes

6.0 Summary and Conclusions

This pre-feasibility report presents a preliminary design basis and cost estimate for a gravity filtration plant with a 6,000-gpm capacity. A budget of $21.9M and a footprint as shown on Figure 4-1 can be used for preliminary budgeting and infrastructure planning. The construction cost per volume (excluding engineering, legal, and administrative costs) is estimated to be approximately $3k/gpm. This is consistent with inflation-adjusted costs of similarly sized gravity filtration plants built recently in the metro area, which ranged from $2.4k/gpm to $3.0k/gpm. Recently, construction costs have been increasing with higher bids from contractors and should be considered when planning the budget. Another item which may impact the construction cost is the type of soil at the site. If soil borings show poor soils at the site, construction costs may increase if soil corrections or other design modifications are necessary to address the site conditions.

The following are key design decisions that will affect the design and cost of the plant:

1. Filter and media type, and filtration rate
2. Disinfection system type
3. Oxidant chemical feed approach
4. Backwash recovery
5. Clear well design
6. Administrative facilities

When the future water supply wells are completed, further water quality analysis and pilot testing is recommended to determine the media performance and design criteria, and then to select the most cost-effective media option for WTP4. This data should be incorporated into a feasibility study that will guide plant design.

A draft schedule for WTP4 planning, design, and construction is included in Appendix A for reference.

7.0 Next steps

The following steps are recommended to continue planning for WTP4. These items are ordered in sequence of completion.

1. Complete water quality analysis from the new wells, including confirmatory testing for cyanide at Well 18.

2. Complete a pilot study of the proposed filtration system once new wells are online.
    a. We would recommend piloting dual media with anthracite and greensand and up to two other different media types.
    b. Evaluate backwash rates for each media type.
    c. Evaluate chemical feed requirements.

3. Complete a full feasibility study for WTP4.
    a. Include piloting data.
    b. Confirm prior decisions made for gravity filters with dual-media, high-service pumping, onsite chlorine generation, and the use of Lamella clarifiers for backwash.

4. Authorize and complete the design and construction of Water Treatment Plant No. 4.

8.0 References

AACE International, 2005. Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries, 2005, p. 1 – 9.

American Water Works Association, 2015. Iron and Manganese Removal Handbook, 2nd ed.

Baruth, E., 2005. Water Treatment Plant Design, 4th ed.

Beverly, R., 2012. Filter Design and Troubleshooting Handbook.

Edzwald, J., 2011. Water Quality and Treatment: A Handbook on Drinking Water, 6th ed.

Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, 2012. Recommended Standards for Water Works ("10 States Standards").

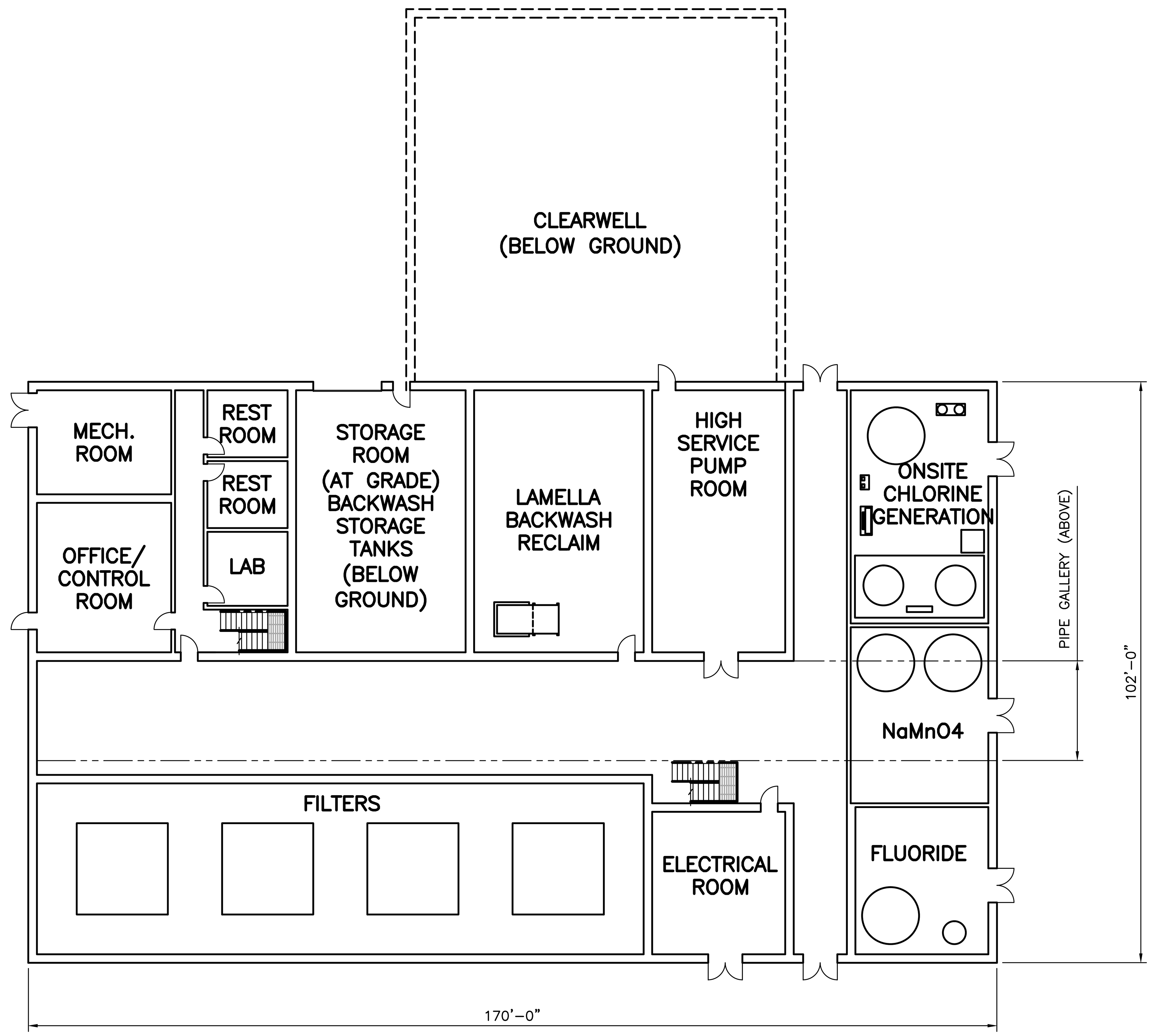
Inversand Company, 2016. Greensand Plus Technical Data. Accessed from http://www.inversand.com/our-product/technical-data/greensandplus-100/ on February 1, 2016

McGivney, W. and S. Kawamura, 2008. Cost Estimating Manual for Water Treatment Facilities.

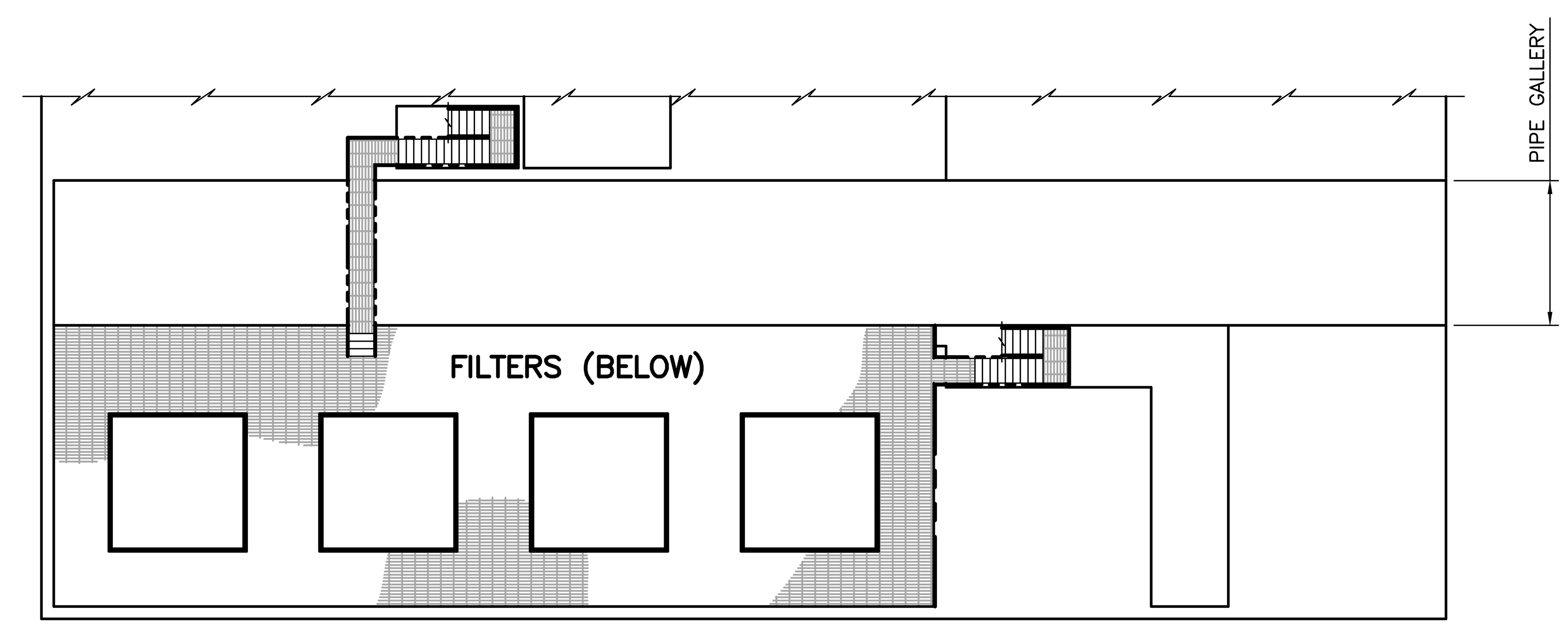
RSMeans, 2015. Heavy Construction Cost Data, 29th ed., 2015.

SEH, 2015. Pilot Study Report, Pilot Study for Filter Media Evaluation.

Figures



1 PLAN: GALLERY OPERATIONS LEVEL
1/8"=1'-0"



2 PLAN: FILTER OPERATIONS LEVEL
1/8"=1'-0"

PRELIMINARY DRAFT

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION

RELEASED TO/FOR: CLIENT / BID / CONSTRUCTION — A B C 0 1 2 3 — DATE RELEASED

BARR
Corporate Headquarters: Minneapolis, Minnesota Ph: 1-800-632-2277
Project Office: BARR ENGINEERING CO. 4300 MARKETPOINTE DRIVE Suite 200 MINNEAPOLIS, MN 55435 Ph: 1-800-632-2277 Fax: (952) 832-2601 www.barr.com

Scale	AS SHOWN
Date	1/19/16
Drawn	MRP2/DAK
Checked	
Designed	
Approved	

FIGURE 4-1
PRELIMINARY PLANT LAYOUT

BARR PROJECT No.
CLIENT PROJECT No.
DWG. No.
REV. No.

CADD USER: Dean Kemmer FILE: M:\ADEPTWORK\DAK\2302103700_PRELIMINARY LAYOUT.DWG PLOT SCALE: 1:1 PLOT DATE: 3/3/2016 1:39 PM
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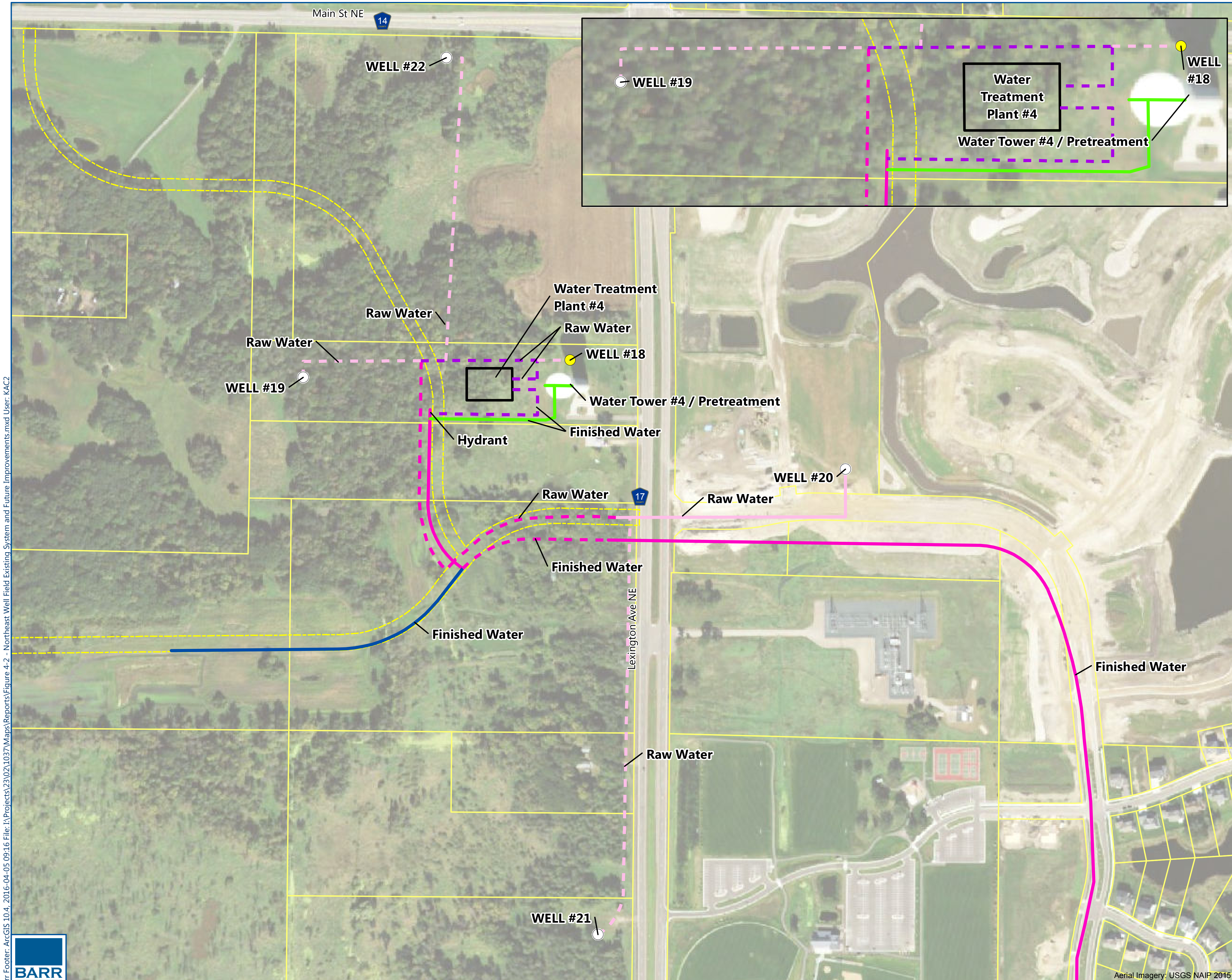


- Existing Well
- Future Well
- 12" (Existing)
- 12" (Future)
- 16" (Existing)
- 20" (Existing)
- 24" (Existing)
- 24" (Future)
- 30" (Future)
- Future Road
- Parcel Boundary

DRAFT

N

0 350 700

Feet

NORTHEAST WELL FIELD EXISTING SYSTEM AND FUTURE IMPROVEMENTS
City of Blaine, MN

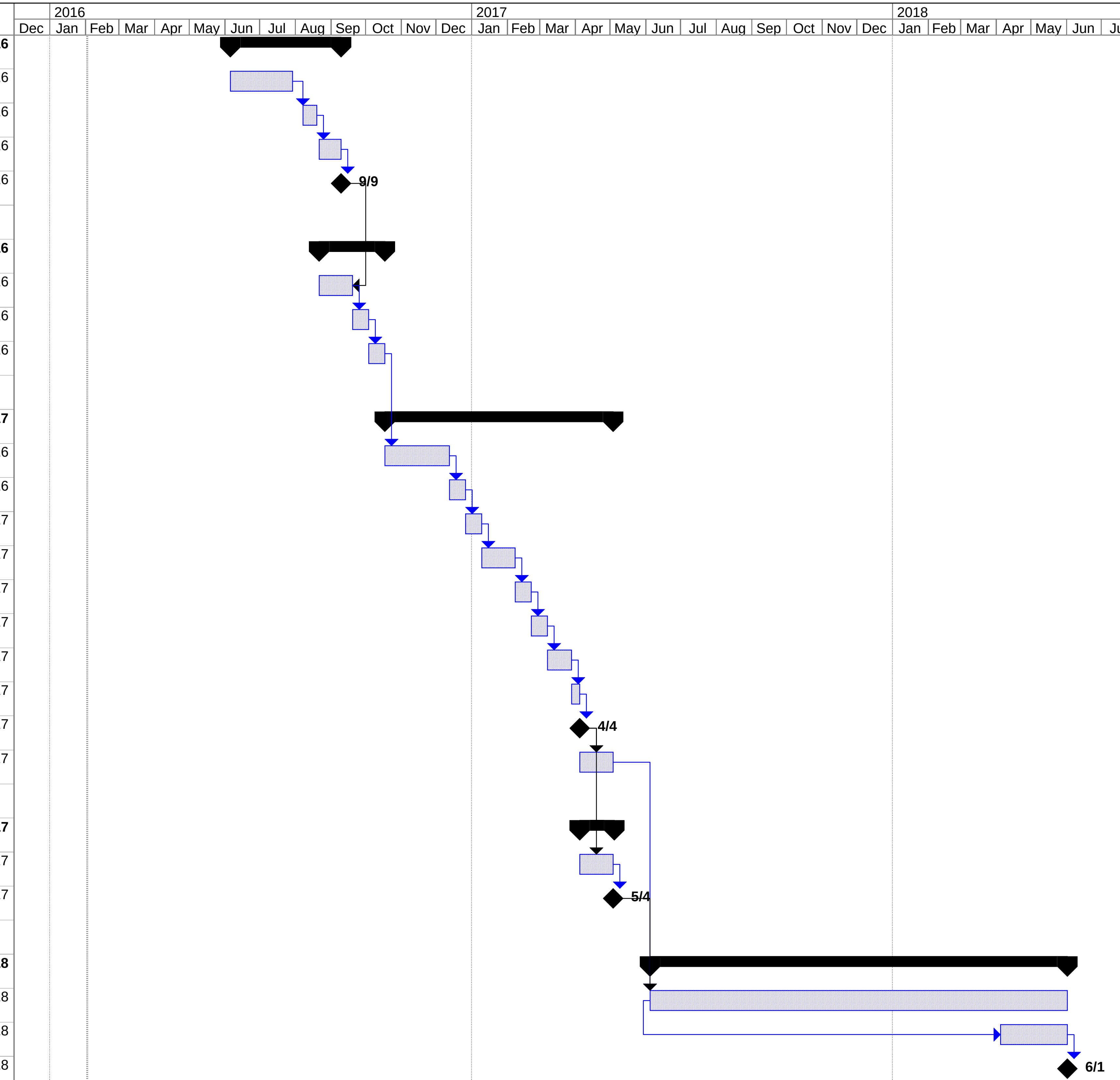
FIGURE 4-2

Appendix A

Preliminary Project Schedule

Appendix A
Preliminary Project Schedule
WTP4 Design and Construction

ID	Indicators	Task Name	Duration	Start	Finish
1		**Feasability and Pilot Study**	**70 days**	**Mon 6/6/16**	**Fri 9/9/16**
2		Feasability Study	40 days	Mon 6/6/16	Fri 7/29/16
3		Pilot	10 days	Mon 8/8/16	Fri 8/19/16
4		Data Analysis and Reporting	15 days	Mon 8/22/16	Fri 9/9/16
5		Estimated decision date on media	0 days	Fri 9/9/16	Fri 9/9/16
6					
7		**Preliminary Design**	**41 days**	**Mon 8/22/16**	**Mon 10/17/16**
8		Preliminary Design	21 days	Mon 8/22/16	Mon 9/19/16
9		30% Internal Review	10 days	Tue 9/20/16	Mon 10/3/16
10		30% Client Review	10 days	Tue 10/4/16	Mon 10/17/16
11					
12		**Final Design**	**142 days**	**Tue 10/18/16**	**Wed 5/3/17**
13		60% Design	40 days	Tue 10/18/16	Mon 12/12/16
14		60% Internal Review	10 days	Tue 12/13/16	Mon 12/26/16
15		60% Client Review	10 days	Tue 12/27/16	Mon 1/9/17
16		90% Design	21 days	Tue 1/10/17	Tue 2/7/17
17		90% Internal Review	10 days	Wed 2/8/17	Tue 2/21/17
18		90% Client Review	10 days	Wed 2/22/17	Tue 3/7/17
19		100% Design	15 days	Wed 3/8/17	Tue 3/28/17
20		100% Design Review	5 days	Wed 3/29/17	Tue 4/4/17
21		Final Plans and Specification Issued for Bidding and Permitting	0 days	Tue 4/4/17	Tue 4/4/17
22		MDH Review	21 days	Wed 4/5/17	Wed 5/3/17
23					
24		**Bidding**	**22 days**	**Wed 4/5/17**	**Thu 5/4/17**
25		Advertise	21 days	Wed 4/5/17	Wed 5/3/17
26		Bid Opening	1 day	Thu 5/4/17	Thu 5/4/17
27					
28		**Construction**	**260 days**	**Mon 6/5/17**	**Fri 6/1/18**
29		Construction	260 days	Mon 6/5/17	Fri 6/1/18
30		Startup	42 days	Thu 4/5/18	Fri 6/1/18
31		Commissioning	0 days	Fri 6/1/18	Fri 6/1/18



Project: Appendix A - Preliminary Proje
Date: Tue 2/2/16

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			