FINAL

CONDITION ASSESSMENT REPORT

Well Field, McBaine Water Treatment Plant, and West Ash Booster Pump Station

B&V PROJECT NO. 188264

STATE OF MISSOURI
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Columbia Missouri Water and Light

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

1.0 Introduction

The McBaine Water Treatment Plant (WTP) is a rated 32 Million Gallons per Day (MGD) ground water softening plant consisting of aeration, 2-stage precipitative softening, filtration, and disinfection facilities, which treats raw groundwater supplied by 15 vertical wells located in the Missouri River alluvium. The WTP is owned and operated by Columbia Water and Light (CW&L). The WTP was originally constructed in 1970 and has seen a number of upgrades and expansions throughout its service life. These improvements have allowed the facility to increase in capacity from 16 million gallons per day (MGD) to its current rated capacity of 32 MGD, while continuing to provide quality water to its customers. However, replacement and upgrades to existing equipment and structures are necessary, especially for a facility in operation for more than 45 years, to continue to produce quality water. Over time, deterioration of assets affects performance, operator flexibility, and reliability, which limit the overall capacity of the facility. This report assesses the condition of the existing equipment to determine which components need to be replaced to meet current critical demands and water quality, identifies potential improvements that will enhance performance and reliability, and addresses future capacity increases.

Based on the findings from the condition assessment summarized in Chapters 5 and 6, alternatives were developed to replace deteriorated equipment and enhance performance and operation. Various alternatives were also developed in Chapters 8 and 9 that expand the capacity of the plant that incorporated costs and other factors related to the overall condition and operation of the plant. Chapter 10 summarizes the overall costs and provides and preliminary schedule to implement the recommended improvements.

Summarized in Chapter 11 is information collected during the condition assessment on individual equipment assets that can be utilized for future asset management system.

The condition assessment also includes the Well Field and West Ash Booster Station.

2.0 Plant Description

Raw water is conveyed from the well field to the plant through a network of piping, and upon entering the plant, flows through a single 36-inch diameter flow meter prior to being divided between four 8 MGD induced-draft aerators, which initiate oxidation of iron and remove carbon dioxide and hydrogen sulfide. The aerated water discharges to a common wet well, from which it flows via concrete flumes to four 8 MGD primary/secondary softening basin trains. The two original basin trains are equipped with upflow solids contact clarifier (SCC) equipment in the primary basins, and with flocculating clarifier equipment in the secondary basins. The remaining two basin trains constructed during the first and second plant expansion basin trains have SCC equipment in both the primary and secondary basins. Lime is added at each of the primary basins to reduce the hardness of the raw water to approximately 150 mg/L as $CaCO_3$. Chlorine is added between the primary and secondary basins to maintain 2 to 3 mg/L free chlorine residual in the water within the secondary basins and the downstream filters to achieve compliance with the virus inactivation CT requirements of the Ground Water Rule and to provide the desired chlorine residual in the finished water leaving the plant. Provisions for reducing the softened water pH through addition of carbon dioxide are not currently available.

Settled water from basin trains 1 and 2 and from basin trains 3 and 4 flows by gravity to two effluent drop boxes, where fluoride is added prior to discharge to a common filter influent pipe. Eight multimedia (anthracite / sand / garnet) filters remove suspended solids and turbidity from the settled water. Each filter is equipped with a hydraulic surface wash system to enhance removal of solids from the upper portion of the bed during backwashing. Effluent turbidity from individual filters is continuously monitored. The filters are backwashed by gravity flow from an elevated wash water storage tank. There is no finished water clearwell or storage facility at the existing plant site. Water from individual filters discharges to a common 24-inch diameter effluent pipe header, from which it is conveyed to the distribution system via 8 vertical turbine high service pumps through two 36-inch diameter transmission mains. As there are no rate control valves in use for individual filters, the filters operate in declining rate mode, with cleaner filters operating at higher throughput rates than filters with higher levels of solids deposition. Additional chlorine (if required) can be fed to each of the finished water transmission lines, along with ammonia (seasonally) to convert the free chlorine residual to the combined (chloramine) form to halt further formation of regulated chlorine-based disinfection byproducts.

Settled solids from the primary and secondary basins discharge to four onsite holding/dewatering lagoons. Filter backwash discharges to a reclaim basin. Provisions for return of lagoon decant flows to the backwash reclaim basin are in place, in addition to provisions for surface discharge under an NPDES permit. Flow from the backwash reclaim basin is conveyed to the common aerator discharge wet well.

Based on plant operating data for 2008 through March 2015, the well field conveys an average flow of 12.4 MGD to the plant. The reported average flow delivered to the distribution system is 12.6 MGD. In-plant water losses are minimized through recycling of filter backwash and lagoon decant flows to the plant headworks, downstream of the aerators. Table 2-1 below summarizes reported daily raw and finished water flows. While identification of potential reasons for higher reported treated water flows than raw water flows is outside of the scope of this evaluation, these differences are likely due to inherent differences in the accuracy of flow metering equipment, potentially compounded by summing of finished water flow data from the two separate plant discharge pipelines.

Table 2-1 Plant Flow Data (January 2008 – June 2015)

PARAMETER	AVERAGE	RANGE
Plant Influent Flow, MGD	12.41	6.14 – 24.10
Treated Water Pumped, MGD	12.59	6.66 – 23.60

3.0 Condition Assessment Approach

Condition assessment teams comprised of Black & Veatch and CW&L staff reviewed the treatment plant equipment and plant operations. The electrical and instrumentation assessment was completed on May 1, 2015. The structural assessment was completed on May 12, 2015. The chemical feed, mechanical process, and HVAC inspection occurred on May 19th and again on June 11th. The process review was completed on May 27, 2015. The assessments consisted of a visual inspection of key process equipment and interviews with CW&L staff regarding the equipment. As part of the inspection, Black & Veatch prepared rating forms that assigned numerical values to probability-of-failure and consequence-of-failure criteria of certain components. The methodology used to establish these values and results from the ratings are included in Section 6.

4.0 Water Quality and Chemical Feed Rates

Table 4-1 summarizes raw and finished water quality characteristics for the McBaine Water Treatment Plant. The information presented in Table 4-1 is based on monthly average data provided by the plant staff for January 2008 through mid-2011. While the information presented in Table 4-1 is based on monthly average values, and therefore does not reflect short-term variations in concentrations, plant operators indicate that both raw and finished water quality parameters typically do not exhibit significant variations, and that overall water quality has not changed appreciably since the period for which data was provided.

Table 4-1 - Water Quality Data (January 2008 - June 2011)

PARAMETER / SAMPLE LOCATION	AVERAGE	RANGE
Turbidity, NTU		
Raw Water	1.26	0.24 – 5.65
Primary Basin Discharge	8.5	2.3 – 26.6
Plant Discharge	0.48	0.22 – 1.48
pH, units		
Raw Water	7.18	7.08 – 7.36
Aerated Water	7.51	7.36 – 7.76
Primary Basin Discharge	8.96	8.61 – 9.38
Plant Discharge	8.57	8.17 – 8.93
Total Alkalinity, mg/L as $CaCO_3$		
Raw Water	300	280 - 319
Aerated Water	291	265 - 313
Primary Basin Discharge	127	106 - 140
Plant Discharge	121	97 – 137
P Alkalinity, mg/L as $CaCO_3$		
Raw Water	0	-
Aerated Water	0	-
Primary Basin Discharge	22	5 - 31
Plant Discharge	14	6 – 22
Total Hardness, mg/L as $CaCO_3$		
Raw Water	325	306 - 348
Aerated Water	315	293 - 337
Primary Basin Discharge	151	144 - 160
Plant Discharge	154	143 – 163
Calcium Hardness, mg/L as $CaCO_3$		
Raw Water	236	216 - 256
Aerated Water	230	209 - 253
Primary Basin Discharge	82	73 - 94
Plant Discharge	85	74 – 94
Magnesium Hardness, mg/L as $CaCO_3$		
Raw Water	88	80 - 95
Aerated Water	85	76 - 101
Primary Basin Discharge	69	59 - 77
Plant Discharge	68	60 – 79
Iron, mg/L		
Raw Water	6.00	5.01 – 7.62
Aerated Water	5.77	5.14 – 6.57
Primary Basin Discharge	1.07	0.74 – 4.66
Plant Discharge	0.08	0.01 – 1.10
Carbon Dioxide (calculated), mg/L as CO_2		
Raw Water	50	30 - 59
Aerated Water	24	11 – 38
Free Chlorine Residual, mg/L		
Plant Discharge	2.05	1.50 – 2.65
Total Chlorine Residual, mg/L		
Plant Discharge	1.71	1.60 – 2.01

Table 4-2 summarizes daily lime, fluoride, and chlorine feed dosages for January 2008 through June 2015. Feed dosages were determined based on the indicated total pounds of chemical fed per day and the corresponding daily total raw water flow treated. Information on raw water flows is also included in Table 4-2.

Table 4-2 Chemical Feed Rates and Plant Flow Data (January 2008 – June 2015)

PARAMETER	AVERAGE	RANGE
Lime Dose, mg/L as CaO	183	102 – 300
Chlorine Dose, mg/L	7.32	4.47 – 11.82
Fluoride Dose, mg/L as F*	0.63	0.18 – 1.73
Plant Influent Flow, MGD	12.41	6.14 – 24.10
Treated Water Pumped, MGD	12.59	6.66 – 23.60
*Assumes average 25.5% H_2SiF_6 acid concentration		

The raw water exhibits high concentrations of hardness and alkalinity, and precipitative softening with lime addition is therefore practiced to produce an aesthetically acceptable treated water supply. Maintenance of a pH of approximately 9.0 in the softening basins promotes precipitation which reduces total hardness to approximately 150 mg/L as $CaCO_3$ while maintaining the pH of the finished water within the targeted range. No provisions for adjustment of finished water pH through addition of carbon dioxide are currently in place. Lime consumption, as discussed in section 5 of this report, slightly exceeds theoretical requirements. While the source water contains significant concentrations of iron, the treatment process reduces iron concentrations to well below the secondary (non-enforceable) standard of 0.3 mg/L and the typically recommended level of less than 0.1 mg/L.

While there currently are no specific requirements for the turbidity of the finished water for plants treating ground water sources not subject to direct surface water influence, the turbidity of the filtered water for the period evaluated routinely exceeded the current allowable level of 0.3 NTU, for a minimum of 90% of monthly samples, for plants treating surface water supplies.

A corrosion prevention additive is not currently applied to the finished water leaving the plant, and the ability to inhibit corrosive degradation of distribution system piping and appurtenances through deposition and maintenance of protective calcium carbonate coatings is not routinely monitored. Calculation of typical indices which provide an indication of the finished water's ability to deposit (or dissolve) protective calcium carbonate coatings, using average water quality conditions summarized in Table 4-1 and assumed average water temperature of 15°C and total dissolved solids concentration of 350 mg/L, revealed the following:

- Langelier Saturation Index (LSI): 0.72 (Values >0 indicates water will deposit $CaCO_3$)
- Calcium Carbonate Precipitation Potential (CCPP): 7.9 mg/L (4 – 10 mg/L desirable)

This suggests that the finished water is oversaturated with calcium carbonate, and should therefore be capable of maintaining protective calcium carbonate coatings within the distribution system. It is emphasized, however, that the actual extent of these coatings and verification of their presence within the distribution system served by the McBaine Water Treatment Plant is outside the scope of this evaluation.

5.0 Existing Conditions

This section describes the conditions of the existing treatment components that were observed on the site investigations and review of historical operating data and documents. Included within this section are preliminary conclusions and recommendations. These recommendations are focused on replacement of deteriorated equipment and do not address capacity increase. These recommendations, along with enhancements and expansion alternatives, will be further defined in later sections to determine the feasibility of implementing the recommendations and whether they fit within the long term expansion plan for the plant. Therefore, these recommendations will not necessarily be included in future plant maintenance and upgrades.

5.1 WELL FIELD

McBaine Water Treatment Plant is fed by 15 vertical wells located in the alluvial aquifer in the McBaine Bottoms. CW&L has incrementally added wells since the 1970s to meet growth in water demands. The most recent wells to be constructed were Wells #13 and #14 in 2000 and Well #15 in 2007. The CW&L is currently planning to add three wells (#16, #17, and #18) in Fall 2016 to increase overall well field capacity. Figure 5-1 shows the locations of the existing wells and proposed wells #16, #17, and #18.

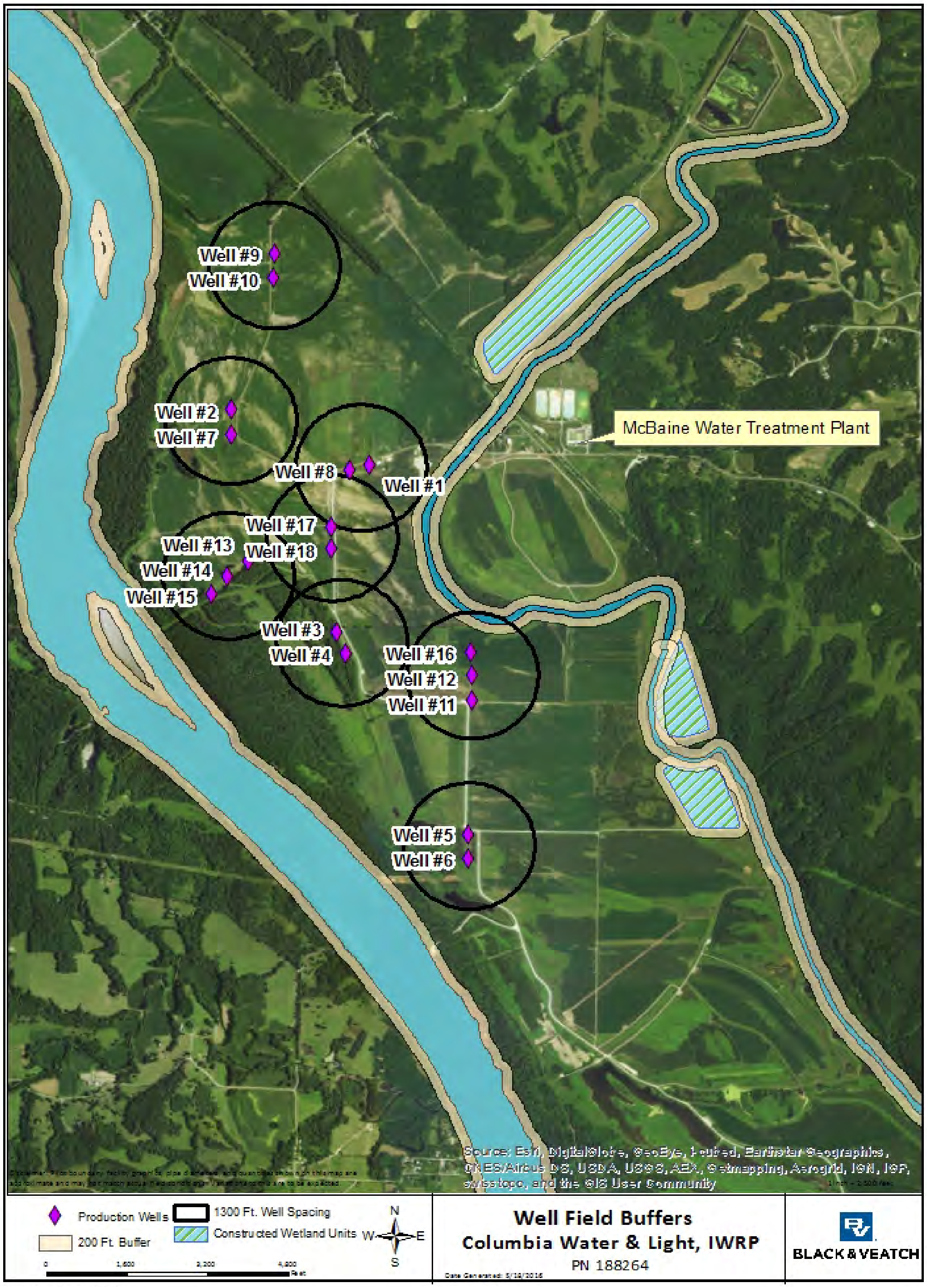


Figure 5-1 Well Field

5.1.1 Well Field Characteristics

Generally, the wells have similar components and characteristics. Most of the wells are terminated approximately 110 ft below grade and consist of a 26 inch diameter screen extending 35 ft. The well casing extends about four feet above the 100-yr flood elevation with the equipment located on an elevated platform. All wells are equipped with vertical turbine pumps, an air release valve, a bubbler draw down level meter, a flow meter, a pressure gauge, a check valve, and an isolation valve. A small drain line is routed from the discharge pipe in the buried manhole back to the well to allow the exposed vertical pipe to drain the pipe when the well is not in use to prevent freezing. All the elevated platforms are similar, and consist of a checkered plate floor, steel circular sides to 42 inches above the platform, and a removable circular fiberglass reinforced plastic (FRP) top. Platform sizes vary between wells, with the older wells having smaller platform areas.

Table 5-1 below summarizes well characteristics.

Table 5-1 Well Characteristics

WELL NO.	YEAR DRILLED	PLATFORM ELEVATION	SCREEN DIAMETER	SCREEN LENGTH	DESIGN HEAD (FT)	MOTOR SIZE (HP)	MOTOR TYPE[1]
1	1972	589.42	18	30	80	40	CTL
2	1972	588.71		35	150	75	VFD
3	1972	588		35	80	40	CTL
4	1972	584.44	26	35	80	60	CTL
5	1972	584.43		35	150	75	VFD
6	1972	583.91	26	35	200	75	CTL
7	1978	588.52		35	-	75	RVSS
8	1984	590.65		35	80	50	CTL
9	1990	588.03	26	35	50	60	RVSS
10	1990	589.59		35	105	75	RVSS
11	1990	590.32	26	35	150	75	VFD
12	1998	590.52	30	35	-	40	RVSS
13	2000	592.86	30	35	150	75	VFD
14	2000	591.75	30	35	150	75	VFD
15	2007	592.05	30	35	-	75	RVSS

1. Motor types are either variable frequency drives (VFD), reduced voltage solid state starters (RVSS), or contactor line starters (CTL).
2. 100 yr Flood elevation is 584.0

5.1.2 Well Field Operation

Although there is some attempt to balance pump and motor usage, the current operation primarily consists of the operators selecting a combination of wells to achieve a desired flow rate. Runtime on wells is recorded but not monitored, and no pattern or method is employed in the rotation of pumping units. This results in uneven usage of wells. With the addition of the VFDs to some of the existing wells, more combinations should be utilized along with a more consistent rotation of wells to even out usage between the wells.

5.1.3 Specific Capacity

Specific capacity, which is a well's pumping rate in gallons per minute divided by the drawdown in feet, is typically used to indicate the efficiency and capacity of a well. A greater specific capacity means that the well is more efficient and productive. The specific capacity is a major indicator of a well's remaining useful life by evaluating the percent reduction in specific capacity over time between cleanings, and how the well responds to cleanings. However, lower specific capacities do not necessary mean the well needs to be replaced as higher draw down on the wells are acceptable provided the water level remains above the top of the screen and pump impellers, although it does require larger pumps to overcome the additional head lift required to pull from lower water levels. However, in severe drought conditions with a lower water table, lower specific capacity may limit the capacity of the wells. To keep the water level from dropping below the top of the screen during drought conditions, the pump capacity would have to be reduced to limit drawdown on the well. Additional hydro-geologic investigations are required to determine the impact on overall well field capacity at severe drought conditions with low specific capacity wells, but initial review of the historical draw downs and current ground water levels shows that most of the wells have water levels significantly above the top of the screen.

The table below summarizes the specific capacity of the wells after their most recent treatment. Where data was available, it also summarizes the percent gain after treatment of each well. This information is useful to track historical performance and can help predict future rehabilitation or replacement of the wells. Conclusions from this data and condition assessment are summarized at the end of this section.

Table 5-2 Specific Capacities

WELL NO.	INSTALLED SPECIFIC CAPACITY	DATE OF LAST TREATMENT	S.C BEFORE LAST TREATMENT	S.C AFTER TREATMENT	% GAIN FROM TREATMENT
1	280	2015	101	235	132%
2	290	2015	41	62	51%
3	280	2015	89	102	15%
4	280	2015	57	79	39%
5	290	2015	45	50	12%
6	280	2014	-	54	-
7	290	2015	46	80	74%
8	235	2015	43	54	26%
9	206	2014	-	118	-
10	292	2015	88	115	31%
11	334	2015	105	111	6%
12	335	2014	-	112	-
13	262	2014	-	99	-
14	262	2014	-	117	-
15	364	2014	-	239	-

5.1.4 Well Field Capacity

The Missouri River alluvial aquifer near McBaine is highly productive and has the ability to yield a significant quantity of water for the City of Columbia for the foreseeable future. In 2012, Black & Veatch completed the McBaine Well Field Study which evaluated the capacity of the aquifer along with the capacity of the existing 15 wells. The evaluation considered the impact of interference when multiple wells were in operation. This evaluation indicated that the total well field capacity is approximately 28 MGD with all 15 wells in operation based on interference.

To further confirm the current well capacity, a well field pumping test was conducted with all 15 wells in operation on September 15, 2015. The test showed that the well field had a total capacity of 28.5 MGD with all wells in operation. However, under this condition, Aerators 3 and 4 were overflowing at the plant. When the flow was restricted to Aerators 3 and 4 to force equal flow to Aerators 1 and 2 to prevent overflowing, the overall well capacity was reduced to about 26.9 MGD. Note, that the wells only operated less than an hour under this condition so the long term impact of interference may not have been observed.

The following table summarizes the individual well capacity observed during the pumping test and estimate total dynamic head for each well.

Table 5-3 Flow Rates during Pumping Test

WELL NO.	FLOW RATE (MGD)	TOTAL HEAD (FT)
1	1.19	84.8
2	2.79	120.4
3	1.31	101.1
4	1.76	94.9
5	2.48	139.2
6	1.24	124.9
7	1.29	102.5
8	No reading	97.2
9	1.73	99.6
10	2.89	113.1
11	2.88	111.7
12	1.79	114.2
13	1.79	121.5
14	3.33	114.4
15	2.44	111.2

Information from the performance test was used to create a simplistic hydraulic model to estimate the total dynamic head in the system at various flow rates. Figure 5-2 illustrates a system head curve for several of the wells within the system.

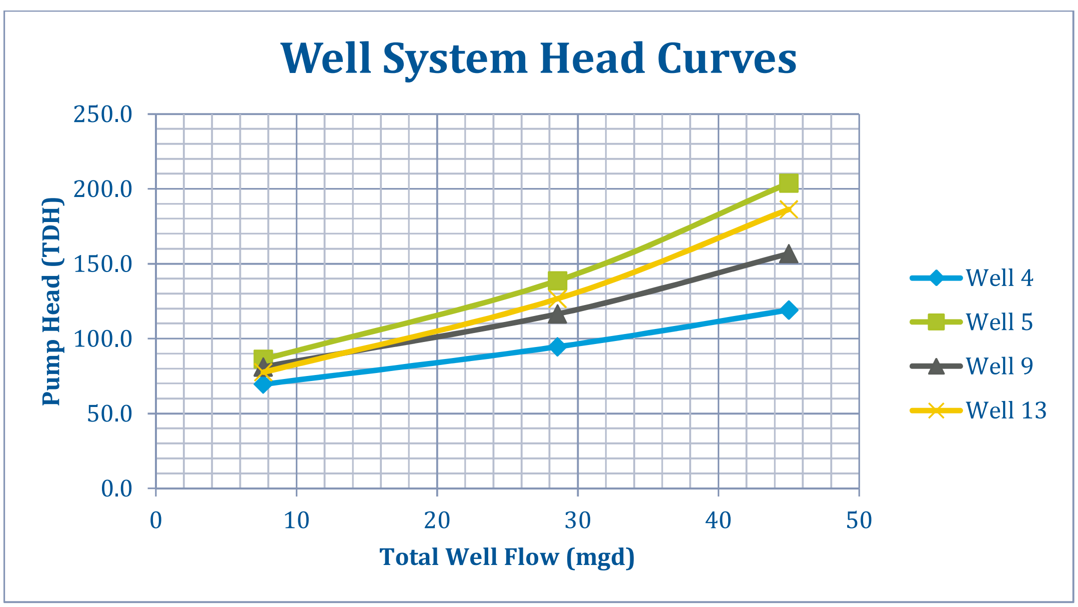


Figure 5-2 Well System Head Curves

The differences in pump head between the wells can be attributed to the location of the well within the system, specific capacity, and pumping rate of the well. Based on this information, it is recommended that all future wells be rated at about 150 ft to overcome the system head for 32 MGD. If flows are increased above 32 MGD, an additional raw water transmission main to the plant should be installed to keep the overall hydraulic head below 150 ft.

To provide redundancy and increase reliability, three wells are scheduled to be drilled by summer 2016 that will provide an additional 6 MGD of installed well capacity. Table 5-4 summarizes the total well field capacity based on interference and piping losses for both existing and future conditions with the three new wells.

Table 5-4 Well Field Capacities

CONDITION	CURRENT (MGD)	AFTER WELLS 16,17 &18 (MGD)
Total Installed Capacity, considering pipe losses	26.9	32.9
Firm Installed Capacity (Well 14 off-line)	23.6	29.6

1. The three future wells were estimated at 2 MGD each.
2. Well 14 was selected as off-line for firm capacity as it had the highest pumping rate during the flow test. (During the test the VFD was operating at 100% speed)

Based on this information, even with the three additional wells, the current firm capacity of the well station is below the rated capacity of the plant. Replacement of the single stage, lower head pumps at the wells will increase the firm capacity of the well field to meet plant capacity. The raw water capacity will also increase if modifications are made to Aerators 1 and 2 to lower the inlet elevation. The modifications to the aerators will increase capacity by about 1.6 MGD.

5.1.5 Well Field Condition

The well houses are weathered, mildly corroded, and in need of cleaning and coating. Existing single stage pumps are being phased out and replaced with newer, higher pressure pumps. CW&L has been following a well treatment schedule to maintain existing well capacity.

All of the well houses are extremely small with limited space for installing electrical components. Access to the platform is through a floor hatch which is no longer permitted by MDNR on new installations.

Adding electrical equipment of any significant size may cause non-compliance in meeting the requirements for space and clearance regarding electrical equipment stated in the National Electric Code. Significant corrosion is present on the electrical components in some of the wells. Corrosion of the electrical components can cause overheating of components and/or conductors to the point they become damaged and fail.

CW&L currently implements a well field maintenance program with a well driller to test the performance of the individual wells and determine which wells should be rehabilitated including which pumps are in need of re-build or replacement.

Well Communication

According to CW&L staff, radio well communication drops out frequently leaving CW&L blind as to the pump operation. Existing faulty radio communication equipment is slated for replacement in the near future.

Well Motors and Motor Starters

All well motors are rated 460V and are vertical type. Power ratings for the well motors range between 40 and 75 horsepower. Some well motors are original to their respective well's construction around 1970. Wells which were added later with the plant expansion projects have newer motors correlating to the time of their construction. CW&L did not indicate they have encountered any substantial problems with the well motors themselves. The well motors' nominal size and common construction and arrangement mean spare motors can be kept in CW&L's inventory and/or the motors can be repaired or re-wound by any motor repair shop in short order.

Currently, the motor starters at the wells are a mixture of contactor line starters, reduced voltage solid-state starters (RVSS) and variable frequency drives (VFD). The RVSS and VFD units have been installed by the CW&L staff as part of their own maintenance activities. The VFD observed at Well #14 was a recently installed unit manufactured by Dura Pulse.

At the time of the inspection, three wells had these VFDs installed. Only one unit, Well #14, had a runtime showing only 538 hours on its elapsed time meter. CW&L staff indicated they plan to replace more of the well motor controllers with a similar set-up. Black & Veatch has no experience with Dura Pulse VFD units and cannot comment on the expected reliability or durability of the units. Furthermore, the VFD enclosures were noted as ventilated only and did not appear to have any means for surge suppression. VFD units are very sensitive to high ambient temperatures (in excess of 100 degrees F) and electrical surges like the type caused by nearby lightning strikes. Hot summer weather and electrical storm activity has the potential to impact well pumping reliability for VFD controlled units where constant speed units either with contactor or RVSS based starters would be less affected.

With a plan by the CW&L to eventually have all wells with VFD capability, the issue of harmonics must be considered in the design. Specifically, harmonic levels on the utility power distribution system are a concern. With the whole of the well field being converted to VFD units, all of which are on a common distribution network, excessive harmonic levels have the potential to cause capacity and heating issues with the existing infrastructure if not adequately mitigated.

The main benefit of the Dura Pulse VFD is the small footprint and inexpensive cost (about $3,500 for 75 HP drive), which allows for replacement of the electrical equipment on the existing platforms (a typical 75 HP drive is 18"x24"x84"). If the installed drives continue to operate effectively and reliable, plus with the addition of proper ventilation and confirmation of no harmonic impact on the electrical distribution system, then CW&L should continue with the plant to install these VFDs on the existing wells.

Well Instrumentation and Control

Well instrumentation includes a bubbler level transmitter (OTT Hydromet CBS) and a flow meter. The bubbler level transmitter is a packaged unit that includes a compressor and pressure transmitter that is used to measure the well level. A digital display is required since the level transmitter is not an indicating type. Altogether, the bubbler packaged units and the digital displays that were observed appear to be in good condition.

At most of the wells a V-cone flow element (McCrometer V2 System) with a differential pressure sensing flow transmitter is used to monitor the flow pumped out of each well. The only exception is at Well No. 15, which has a magnetic flow meter. One disadvantage with the use of the V-cone flow element and differential pressure sensing flow transmitter is the possibility of the static sensing lines freezing or plugging. At the wells that were inspected, the static sensing lines were wrapped in insulation with heat tracing, so this should prevent the lines from freezing as long as power is not lost during low temperatures. The use of magnetic flow meters would eliminate the possibility of plugging and freezing. Therefore, less maintenance would be required with the use of magnetic flow meters. A digital display is also required at each of the wells that are equipped with the V-cone flow element and differential pressure sensing flow transmitter. All of the flow meters inspected appeared to be working well.

Raw Water Flow Measurement

An ABB differential pressure sensing flow transmitter is used with an orifice plate to measure the plant influent flow. The signal from this transmitter is sent to the plant's Main PLC remote I/O panel. The transmitter is a blind instrument, so without the PLC, the operator cannot view the flow. If there is an issue with the orifice plate, it will be very difficult to replace the orifice plate, but there are few things that can go wrong with an orifice plate. The differential pressure instrument is a standard instrument and can be easily replaced if it fails.

5.1.6 Well Field Existing Conditions Summary

The wells are critical components of the water system operation. Therefore, the electrical systems and motor operation at each well must be thought of as critical infrastructure and protected and built with as much redundancy and robustness as possible. The following recommendations and potential improvements should be considered for all the wells:

- Additional wells are needed to allow the well field to meet the rated plant capacity of 32 MGD. It appears the addition of Wells 16, 17, and 18 will get the wellfield capacity very near 32 MGD. However, operation of all of the wells would be required to meet this capacity.
- With 18 total wells, many which are 45 years old, well condition will vary, and some wells will always be in need of repair. Therefore, additional redundancy in the well field (more than one spare well) is critical to be able to deliver peak flow.
- To determine replacement, specific capacities of each well should be re-calculated every 2-3 years. When the total decrease in specific capacity reaches 33 percent, the well would be scheduled for rehabilitation. If the specific capacity drops by more than 33 percent within four years after rehabilitation, and/or pumping capacity reduced by more than 20 percent, and/or the drawdown level is at or below the top of screen or impeller, the well would be scheduled for replacement.
- Run wells updated with VFDs replaced by CW&L to the maximum extent possible to determine operating reliability and longevity prior to replacement of additional units. Particular attention should be paid to operations interrupted due to excessive temperature or component failure due to surges. Log any issues encountered for consideration in the next phase of the study and preliminary design.

- Replace electrical components which are in poor physical condition immediately. Components which exhibit thermal or corrosion damage shall be replaced with new equipment at the earliest opportunity to maintain reliable operation.
- Expand space in well houses if possible to allow for better thermal management and to allow any installed electrical equipment to meet the NEC requirements for clearances and space about electrical equipment.
- Existing wells #5 and #6 are the closest to the constructed Wetland Units 1-4 located in the Eagle Bluff area. Because of the elevated concentrations of chloride found by the USGS in the groundwater beneath the Eagle Bluffs area and near the constructed wetland units, and uncertainties about any potential future effect of the effluent on the quality of CW&L's well water supply, it is recommended that new wells not be installed any closer to these wetland areas than the existing wells. Because of these uncertainties, and to reduce concerns about future migration of treated effluent, the new wells should be installed toward the west and north if possible.
- With a plan by CW&L to eventually have all wells with VFD capability, the issue of harmonics must be considered in the design. Specifically, harmonic levels on the utility power distribution system are a concern. With the whole of the well field being converted to VFD units, all of which are on a common distribution network, excessive harmonic levels have the potential to cause capacity and heating issues with the existing infrastructure if not adequately mitigated. A design which addresses harmonics levels is recommended.
- Enclose well houses at pipe penetrations to minimize the potential for freezing of instrument lines.
- Electric power monitors should be installed at each new well. The current and voltage of the power feed should be monitored by the individual RTU at each well. Other electric power data that should be considered for monitoring includes watt-hours, frequency, and power factor.
- Develop a long term implementation schedule for well replacement. Replacement wells could be installed adjacent to existing wells. New wells and platforms should be designed to current MDNR guidelines.

Specific recommendations for each well are included in Appendix A. The proposed improvement alternatives are discussed in Section 8.1.

5.2 AERATORS

McBaine WTP is equipped with four induced draft aerators to remove carbon dioxide and hydrogen sulfide, and to oxidize soluble iron and manganese. Each aerator has a rated capacity of 8 MGD. Aerators No. 1 and No. 2 were replaced in 1995, separate from the first expansion in 1994. The third aerator was installed during the 1994 expansion and the fourth aerator was installed during the second expansion in 2006.

5.2.1 Aerator Performance

Aerators No. 1 and No. 2

Differences in influent piping configuration between the original two aerators and the aerators installed during the first and second plant expansions result in hydraulic imbalances and inability to distribute flow equally between all in-service units. This reduces aerator performance efficiencies, as a majority of the total flow treated is handled by only two of the four existing units. Internal packing in all aerators has been removed due to fouling problems attributed to excessive deposition of iron precipitates. Fouling of the packing was observed within several weeks after initial installation. While some removal of carbon dioxide (CO_2) is achieved as the water cascades downward through the unequipped aerator shells as indicated by the observed increase in pH between the aerator influent and discharge, it would be expected that performance is less efficient than typically achieved by aerators equipped with well-designed internal baffling and flow distribution.

Aeration is typically provided to reduce CO_2 levels prior to softening of ground water supplies in order to reduce both required lime dosages and the amount of solids generated. Performance of the existing aerators with regard to CO_2 removal was therefore evaluated to identify potential additional operating costs associated with higher lime dose consumption and solids disposal requirements. CO_2 concentrations at the aerator discharge were calculated using monthly average values for pH and alkalinity for samples collected from the aerator discharge flumes for January 2008 through June 2011, for 2012 and 2013, and during the first four months of 2015. Results of this review are summarized in Table 5-5.

Table 5-5 Carbon Dioxide Concentrations in Aerated Water, mg/l

PERIOD	AVERAGE	RANGE
January 2008 – June 2011 (42 months)	21.6	11.2 – 30.6
January 2012 – December 2013 (24 months)	28.0	21.4 – 37.9
January – April 2015 (4 months)	22.3	20.8 – 23.6
Total Evaluation Period (70 months)	23.8	11.2 – 37.9

Based on the raw and aerated water CO_2 historical values, the existing aerators are achieving approximately 50 percent removal of CO_2 without internal media. This is based on an average plant flow of about 12 MGD. As flow increases, it would be expected that the removal efficiency will drop slightly.

To confirm historical values and estimate the CO_2 removal at various flow rates, site testing was conducted on the aerators on September 15, 2015. Data was collected before and after the aerators at different flow rates. Figure 5-3 below plots the results of the aerator performance at different flow rates.

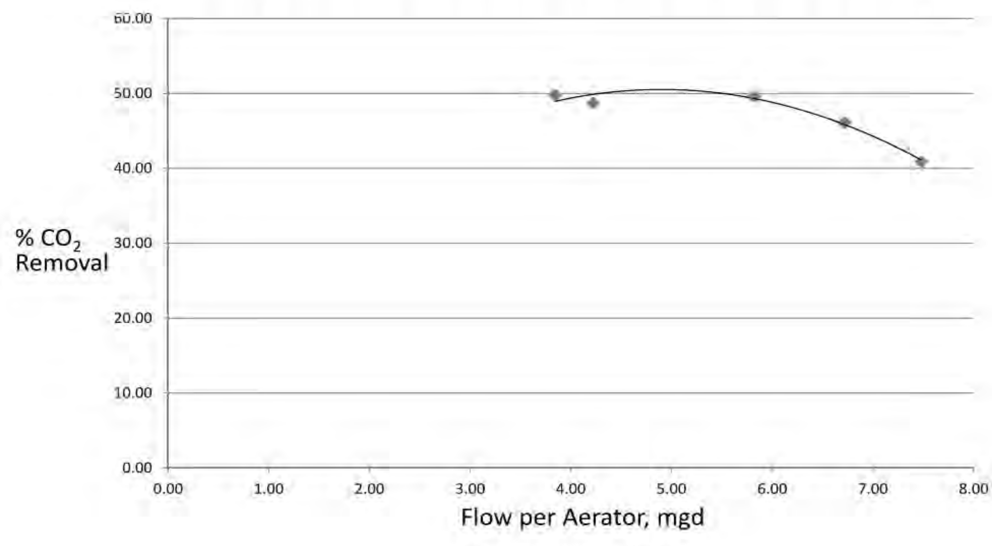


Figure 5-3 CO2 Removal vs Aerator Flow During High Rate Testing

Based on the results from the testing, at an average flow rate of 4 MGD per aerator the removal efficiency is around 50 percent. If the flow is increased to 8 MGD the removal efficiency drops to about 40 percent.

Based on the data collected, modifications to the aerators have the potential to reduce lime usage and solids disposal costs. Currently, most of the flow goes through only two aerators, resulting in higher flow rates per aerator. If the flow can be spread evenly between the aerators the maximum flow rate per aerator would be decreased, thus increasing the removal efficiency.

Table 5-6 summarizes the potential operating costs savings if improved CO_2 removal efficiencies are achieved by the aerators at various removal efficiencies.

Table 5-6 Lime and Disposal Costs vs Aerator Performance

PARAMETER	VALUE AT INDICATED CONDITION			
	CURRENT CONDITION	60% CO_2 REMOVAL	70% CO_2 REMOVAL	80% CO_2 REMOVAL
CO_2 at Aerator Discharge, mg/L	24	20	15	10
Required Lime Dose, mg/L	34.1	28.4	21.3	14.2
$CaCO_3$ Solids Produced, mg/L	55.0	45.4	34.1	22.7
Lime Cost, $/year	119,000	99,200	74,400	49,600
Solids Disposal Cost, $/year	64,800	54,000	40,500	27,000
Total Annual Cost, $/year	183,800	153,200	114,900	76,600
Net Annual Savings, $/year	-	30,600	68,900	107,200

Assumptions:

1. Average raw water CO_2 concentration = 50 mg/l
2. Current average CO_2 concentration in aerated water = 24 mg/l (52% removal)
3. Lime cost = $185 per ton of quicklime (90% purity)
4. Solids disposal cost = $63 per ton of dry solids
5. Lime consumption = 1.275 lbs of 100% CaO per lb of CO2 removed
6. CaCO3 production = 2.27 lbs per lb of CO_2 removed by lime
7. Annual average raw water treated = 12.4 MGD.

As shown in Table 5-6, significant annual operating cost savings could be achieved through improved CO_2 removals. A 10 percent increase in removal efficiency results in an annual net savings of about $30,600.

CW&L currently works with an outside contractor to remove settled solids from the lagoons, and to haul the solids to off-site disposal sites. CW&L indicates that they believe the current contracted cost of $63 per ton of dry solids is likely to increase (possibly by a significant amount) when the contract is renewed or a new contractor is selected. Therefore, the annual costs savings shown in Table 5-6 may not accurately reflect potential future conditions, should contract solids disposal costs increase. The table also doesn't reflect future increases in water demands. For example, should the unit disposal cost increase from the current $63 per ton to $94.5 per ton (a 50% increase), and average plant flows increase to 15 MGD, the annual cost savings associated with aerator improvements to yield a 70% CO_2 reduction would increase to approximately $97,980 (a 42 percent increase).

Increasing the removal efficiency with the existing aerators may be difficult. The existing induced-draft aerators are relatively short (12 ft height); therefore, significant improvements in CO_2 removal beyond what is currently achieved through simple cascading of flow downward may be difficult unless higher density media is installed. As previously experienced at the plant, higher density media in this type of application may result in excessive deposition of iron precipitates, resulting in the need for frequent cleaning to avoid plugging of the internals.

The more common internal media configuration currently used in many induced-draft and forced-draft aerators is shown in the photo below.

PVC Aerator Media Configuration

This type of media configuration eliminates much of the iron precipitate fouling problems associated with older slat-type aerators. However, required aerator heights to achieve 70 to 80 percent CO_2 removal with this type of media are typically 18 to 20 feet. Raising the aerators to this height will increase required well discharge pressures and lower the overall well field capacity unless larger pumps are installed.

In lieu of taller aerators, the existing aerators could be modified with new PVC internals. Discussions with WesTech Engineering Inc. with regard to potential modifications to the existing aerators to improve CO_2 removals revealed the following:

- Projected equipment cost to retrofit the four existing units with PVC internals similar to those illustrated in the photo above is approximately $260,000. This cost does not include installation.
- While this type of media minimizes the potential for fouling of the aerator with iron precipitates, removal and cleaning of the PVC tubes would still be necessary on an annual basis to maintain removal efficiencies.
- WesTech calculations suggest that the existing units are achieving approximately 50 percent removal of CO_2 without internal media. This agrees with average CO_2 removals based on

plant collected data. However, WesTech aerator model projections also suggest that significant improvements in CO_2 removal efficiencies would likely not be achieved through retrofitting of the units with new PVC internals.

- Aerator height would need to be increased from the current 12 feet to approximately 20 feet in order to reliably achieve 70 to 80 percent removal of CO_2 using current aerator internal designs.

5.2.2 Aerator Condition

No significant issues were observed or noted with the blowers, vessels, or piping other than the hydraulic imbalance. Since the internals have been removed minimal maintenance is required on the units.

The four blowers associated with each aerator provide an air-to-water ratio of approximately 3.5 scfm/gpm, which meets current MDNR guidelines. However, if one blower is off-line, this value is reduced to 2.6 scfm/gpm. If the existing aerators are to remain in service, blower capacities should be increased from 4,950 scfm to 6,550 scfm to provide a firm blower capacity capable of achieving an air-to-water ratio of 3.5 scfm/gpm. This upgrade should occur when the existing blowers are unusable and in need of replacement.

A visual inspection of the structural conditions at the aerators revealed concrete platform cracking and two locations of concrete spalling. The cracking observed was all narrow hairline width cracks with exception of cracking originating at the spall at the north reentrant corner. Photos of this crack and spalling are shown below. The other location of spalling occurs at the underside of the expansion joint on the north side walkway. These items are not a threat to the integrity of the structure at this time.

Re-entrant corner with spall and crack.

Spalling at construction joint.

5.2.3 Aerators Existing Conditions Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- The configuration of the aerators results in the inability to effectively aerate the water at higher flows, as more flow passes through aerators 3 and 4 than through aerators 1 and 2.

This higher flow rate through units 3 and 4 results in lower CO_2 removal efficiencies, thus requiring more lime at higher flows. Therefore, the current configuration does not effectively treat the plant rated capacity of 32 MGD.

- As significant improvements in performance through retrofitting of the existing units with new PVC internal flow distribution trays cannot be guaranteed, and as this modification would result in the need for annual cleaning of aerator internal components, these modifications are not considered to be cost-effective and are therefore not recommended.
- Modifications to influent piping and internal flow distribution equipment for two of the existing aerators to permit simultaneous operation of all units at equal throughput rates would improve overall performance, and increase capacity.
- The expansion joint appears to have been repaired in the past however the repair did not utilize proper detailing for concrete surface repair. A properly detailed and executed repair will solve the spalling issues.
- When replacing blowers, capacity per blower should be increased from the current 4,950 scfm to 6,550 scfm to comply with MDNR requirements for air-to-water ratios. Several of the blowers are currently not working and should be replaced.

New, taller aerators equipped with PVC internals would provide substantial annual cost savings in lime usage and solids removal. The annual savings could be near $100,000 per year if 80 percent CO_2 reduction were achieved. This option requires all new aerators, and may not be feasible unless well supply system pumping head is increased to accommodate the additional static head imparted by increased aerator height. This approach should be evaluated further as part of the long term alternatives to determine if it would be feasible based on the current well field configuration and future flow rates.

The proposed improvement alternatives are discussed in Sections 8.2 and 8.3.

5.3 PRIMARY BASINS

Primary Basins No. 1 and No. 2, installed in 1970, are Walker HC Clariflow upflow clarifiers. Primary Basin No. 3, installed in 1997, is IDI Solids Contact Clarifier, Acceletor Type IS. Primary Basin No. 4, installed in 2007, is US Filter GF Solids Contact Clarifier Contraflow C.

Flow enters the basins from a common aerator effluent chamber through individual concrete flumes. Each primary basin influent flume contains a Parshall flume which was intended to measure flow. However, these are not effective in measuring flow because the downstream water level is too high, so flow split is hydraulically controlled by the effluent weirs on the primary clarifiers. This results in inaccurate flow split between the basins.

5.3.1 Primary Basin Performance

Mixing/Lime Usage

The primary function of the mixing equipment within the reaction zone of a solids contact clarifier is to (a) promote contact between the lime and the incoming raw water, and (b) promote agglomeration of softening precipitates into larger particles which will settle rapidly. When this is accomplished, both required lime dosages and the turbidity of the resulting settled water at that basin discharge are minimized. It was noted during the plant inspection that the mixing equipment within Primary Basins 1 and 2 has been removed, as plant staff have observed that the basins exhibited little or no differences in performance regardless of draft tube drive unit operation. Poor internal solids recirculation capability is commonly reported for older Walker Process solids contact clarifiers, and can be attributed to significant undersizing of the impeller drives and to draft tube inlet elevations which are well above the floor of the clarifiers. As there are currently no provisions for mixing/solids recirculation within Primary Basins 1 and 2, overall basin performance would be expected to be inferior to that of Primary Basins 3 and 4, which have conventional turbine-type mixing/recirculation equipment. Results of a comparison of primary basin operating parameters for two 2-week periods during 2015 are summarized in Table 5-7. These periods were selected such that the performance of the older Walker Process solids contact clarifiers with no internal mixing/recirculation can be compared directly to that of the newer clarifiers with provisions for internal solids recirculation.

Table 5-7 Primary Basin Operating Data (Daily Average Values)

PARAMETER / LOCATION	APRIL 2015 (12 DAYS)		JUNE 2015 (14 DAYS)	
	AVERAGE	RANGE	AVERAGE	RANGE
pH, units				
Primary Basin 1	-	-	9.06	8.85 – 9.28
Primary Basin 2	9.15	8.88 – 9.33	-	-
Primary Basin 4	8.67	8.44 – 8.86	8.74	8.34 – 8.98
Total Hardness, mg/L $CaCO_3$				
Primary Basin 1	-	-	164	144 - 175
Primary Basin 2	164	152 - 179	-	-
Primary Basin 4	170	158 – 182	164	149 – 175
P Alkalinity, mg/L $CaCO_3$				
Primary Basin 1	-	-	20.4	15.3 – 26.0
Primary Basin 2	27.9	21.3 – 38.0	-	-
Primary Basin 4	9.7	2.0 – 17.3	11.7	4.0 – 18.0
Turbidity, NTU				
Primary Basin 1	-	-	8.5	5.8 – 10.8
Primary Basin 2	7.4	4.9 – 9.3	-	-
Primary Basin 4	6.4	4.4 – 8.1	13.1	11.0 – 16.0

As shown in Table 5-7, for the periods reviewed, Primary Basins 1 and 2 operated at higher pH (and at higher hydroxide alkalinity concentrations, as indicated by higher P alkalinity concentrations) than Primary Basin 4, while achieving essentially equivalent hardness removals. This suggests that for a given level of hardness reduction, required lime dosages are notably higher for Primary Basins 1 and 2 than for Primary Basin 4. In addition to higher lime dose requirements, absence of mixing/solids recirculation capability in Primary Basins 1 and 2 may also result in higher levels of unreacted lime in the settled solids removed from the basins and/or in the amount of solids carried over the secondary softening basins.

A comparison of theoretical vs. actual lime consumption was prepared using the monthly average raw and finished water quality and lime feed data summarized in Tables 4-1 and 4-2. As information on typical lime purity is not available, a quicklime purity of 90% CaO was assumed when comparing theoretical and actual lime feed requirements. Results of this comparison are summarized in Table 5-8.

Table 5-8 Theoretical vs Actual Lime Dosages (Jan 2008 - June 2011)

PARAMETER	AVERAGE	RANGE
Calculated Lime Dose, mg/L as 100% CaO	138	119 – 160
Actual Lime Dose, mg/L as 100% CaO	160	134 – 186
Lime Overfeed, %	16	0 – 35

While it is recognized that comparison of actual lime feed requirements with theoretical (calculated) requirements is at best an inexact process due to difficulties in accurately tracking lime feed rates, exceeding theoretical requirements by an average of 16 percent over an extended evaluation period suggests that potential exists for reducing lime dosages through improvements in mixing and solids recirculation capabilities for the primary softening basins.

Settled Water Turbidity

The 2010 "Compliance and Operation Inspection Report" prepared by MDNR expressed concerns with regard to carryover of turbidity from the secondary clarifiers to the filters and resulting filter solids loadings and impacts on filter performance. A previous study (Carollo, December 2012) also noted that settled turbidities frequently exceeded 10 NTU, and were "higher than the 1-2 NTU anticipated for SCC's operating with similar loading rates".

A summary of daily average settled water turbidity values at the primary and secondary basin discharge for two months during mid-2015 is presented in Table 5-9.

Table 5-9 Settled Water Turbidities (May/June 2015)

SAMPLE LOCATION	AVERAGE	RANGE
Basin Train 1		
Primary Basin Discharge	8.6	5.8 – 14.3
Secondary Basin Discharge	4.5	1.0 – 13.2
Basin Train 3		
Primary Basin Discharge	8.5	5.2 – 13.4
Secondary Basin Discharge	4.4	1.3 – 9.2
Basin Train 4		
Primary Basin Discharge	12.2	2.8 – 17.3
Secondary Basin Discharge	5.9	2.8 – 9.8

Review of the information presented in Table 5-9 indicates the following:

- Average settled turbidities at the secondary basin discharge were considerably less than 10 NTU (average settled turbidity during the period evaluated was 4.9 NTU).

- The secondary basins do provide some additional reduction of turbidity beyond that provided within the primary basins. Average turbidity at the secondary basin discharge was approximately 50 percent less than at the primary basin discharge during the period evaluated.

The McBaine plant is currently operated to achieve selective reduction in calcium hardness concentrations by maintaining pH conditions which result in removal of calcium as calcium carbonate ($CaCO_3$) precipitate, with little or no removal of magnesium hardness. While some minor removal of magnesium hardness occurs at pH conditions which are optimal for removal of calcium hardness, significant removals of magnesium hardness are not achieved unless the pH within the softening process is maintained at 10.6 – 10.8 or higher. In general, systems which do not operate at pH levels that result in significant removal of magnesium hardness generally report higher settled turbidities than do utilities that are operated to remove magnesium hardness, as they do not benefit from magnesium hydroxide's ability to function as an effective coagulant and to facilitate maintenance of low turbidities in the settled water.

While the turbidity of the settled water at the secondary basin discharge may be higher at times than desirable to ensure consistently low filtered water turbidities, settled turbidities in the 8 to 12 NTU range, with periodic excursions of 30 to 50 NTU, are not unusual for plants practicing selective calcium hardness removal (no magnesium hardness removal) and with no provisions for addition of a coagulant to enhance solids agglomeration and settling. Pure $CaCO_3$ precipitates from solution as very fine and discrete/dispersed particles, which are difficult to flocculate and settle. While difficulties in achieving good flocculation and settling of $CaCO_3$ particles generated in precipitative softening applications have been well-documented, $CaCO_3$ is readily removed by granular media filtration, particularly in the presence of filter aid polymers applied at low doses and/or when coagulant is applied within the softening process. This characteristic of $CaCO_3$ particles explains why utilities practicing precipitative softening can consistently maintain compliance with filter effluent turbidity requirements even when filter influent turbidities are as high as 40 – 50 NTU. However, it is also emphasized that the particles must be properly conditioned for filtration under these high settled water turbidity conditions, either through addition of a filter aid polymer, or through addition of a coagulant within the softening basins. Addition of a cationic polymer within the softening basins, or as a filter aid at low doses (0.05 to 0.10 mg/L) is the most common approach to ensuring that particles which carry over from the softening basins are properly conditioned to ensure effective removal during filtration.

5.3.2 Primary Basin Operation

MDNR's 2010 "Compliance and Operation Inspection Report" makes reference to lack of a "sludge blanket", and recommends that the basins be operated "in a manner so that a sludge blanket develops to aid in settling turbidity out of the water". It is not clear from the comment if the reviewer is making reference to a sludge blanket near the floor of the basins (with the surface of the blanket slightly above the elevation of the reaction zone skirt bottom), or to an apparent lack of solids within the center reaction zones of the clarifiers. However, it is emphasized that the existing solids contact clarifiers are of the internal slurry recirculation configuration, and are not designed to be operated as sludge blanket units, where all of the water exiting the center mixing/reaction zone is forced to flow through a preformed "blanket" of softening precipitates in order to function properly. Attempts to operate the clarifiers to maintain a blanket of previously formed precipitates would result in excessive torque on the solids collection rakes and probable shutdown of the rakes due to the excessive torque conditions.

The previous Carollo study indicates that plant operators report difficulties in maintaining acceptable levels of solids within the reaction zones of the primary basins without exceeding the torque ratings of the solids collection rakes. Reported torque rates for the existing primary basins, and corresponding unit loadings, are summarized in Table 5-10.

Table 5-10 Torque Ratings for Primary Basins

PARAMETER	PRIMARY BASINS 1 & 2	PRIMARY BASIN 3	PRIMARY BASIN 4
Design Torque, ft-lbs*	100,000	45,000	32,000
Unit Loading, lbs/ft	62.5	28.1	20.0
*Per "McBaine Water Treatment Plant Expansion Preliminary Design Report" (Carollo, Dec. 2012)			

Current Black & Veatch design practice includes use of unit loading rates for softening basins of 24 to 40 lbs/ft, depending on the anticipated composition of the settled solids. (For example, a unit loading rate of 40 lbs/ft would be appropriate for the rake mechanism within a solids contact clarifier practicing selective calcium hardness removal, and producing a relative heavy calcium carbonate precipitate). Design unit loading for primary basins 1 and 2 exceed the typical maximum 40 lbs/ft value by a significant margin, but design unit loadings for primary basins 3 and 4 are significantly lower than 40 lb/ft. Therefore, development of conditions which would result in exceedances of torque ratings for basins 3 and 4, particularly when the density of the settled solids is considered, would not be unexpected. Lack of ability to suspend and recirculate solids in primary basins 1 and 2 also likely contributes to development of high rake arm torque conditions due to excessive compaction of the calcium carbonate precipitate formed within those basins.

Any future replacement of primary basin equipment should include evaluation and specification of design rake torque loadings which are appropriate for current softening practices and the characteristics of the precipitate(s) formed.

5.3.3 Potential for Expansion

The potential for increasing primary softening basin design throughput rates was evaluated by comparing current design parameters with Missouri DNR requirements, as outlined in "Minimum Design Standards for Missouri Community Water Systems" (December 2013). A summary of current MDNR design criteria for solids contact clarifiers and current McBaine primary basin design parameters is presented in Table 5-11.

Table 5-11 Missouri DNR Design Criteria for SCCs vs. McBaine WTP Primary Basins

PARAMETER	MDNR CRITERIA	CURRENT VALUE FOR INDICATED BASIN TRAINS		
		1 & 2	3	4
Mixing Zone Detention time, minutes	≥ 30	26	16	22
Settling Zone Detention Time, hours	1.5 – 2.0[1,2]	2.03	2.20	2.11
Surface Loading Rate, gpm/sq ft	≤ 1.0[3,4]	1.02	1.07	0.96
Weir Loading Rate, gpm/ft	≤ 10	6.7	6.1	6.0
Recirculation Rate, x basin design flow	3 - 6	0	x 13.3	x 6
Scraper Design Torque, ft-lbs	-	100,000	45,000	32,000

[1]For softening units treating only ground water
[2]Lower values may be "considered" if supported by pilot and/or full-scale demonstration
[3]For units used for softening
[4]Higher values may be "considered" if satisfactory supporting data is provided

It is apparent from review of information presented in Table 5-11 that primary basin capacity cannot be expanded without exceeding multiple MDNR design criteria, unless sufficient justification can be provided to and accepted by the Department. Black & Veatch has substantial experience with design and operation of solids contact basins with surface loading rates that are higher than and mixing zone and settling zone detention times that are less than current MDNR design requirements. We typically design primary softening basins treating surface water supplies at loading rates of 1.25 gpm/sq ft, and have used rates of 1.50 to 1.75 gpm/sq ft for basins treating ground water supplies. For example, a recent 30 MGD primary solids contact clarifier design approved by the Kansas Department of Environmental Health for precipitative softening of water from a collector well located along the Missouri River was designed based on the following criteria:

- Detention time in mixing zone = 10 minutes
- Detention time in settling zone = 1.39 hours
- Surface loading rate = 1.75 gpm/sq ft
- Weir loading rate = 11 gpm/ft

This clarifier has been in service for more than 5 years, is routinely operated at or near full rated treatment capacity, and has consistently produced high-quality settled water which complies with all applicable regulatory requirements and with the utility's internal softening goals.

WesTech Engineering Inc. was consulted to assist in determining how the capacity of the existing primary basins could be expanded while minimizing exceedances of MDNR design criteria and maintaining design parameters which could be supported based on Black & Veatch softening basin design and operation experience. This evaluation assumes complete replacement of equipment in all four primary basins with identical equipment to achieve the desired design criteria. Results of this evaluation are summarized in Table 5-12.

Table 5-12 Primary Basin Design Parameters at Expanded Flow Capacities

PARAMETER	10.75 MGD CAPACITY[1]	11.25 MGD CAPACITY[2]	MDNR CRITERIA
Mixing Zone Detention time, minutes	20	15	≥ 30
Settling Zone Detention Time, hours	1.57	1.57	1.5 – 2.0
Surface Loading Rate, gpm/sq ft	1.30	1.32	≤ 1.0
Reaction Zone Diameter, feet[3]	29.4	25.2	-

[1]Total primary basin capacity = 43 MGD
[2]Total primary basin capacity = 45 MGD
[3]As measured four feet below water surface

Based on the information presented in the table above, it appears to be feasible to expand current primary basin total production capacity to 43 – 45 MGD through replacement of existing equipment that doesn't comply with all current MDNR criteria, but which would have a high probability of MDNR approval, based on experience elsewhere in treating similar source water. This would allow CW&L to retain the current two-stage treatment approach (which would also likely improve potential for MDNR approval of primary basin detention times and loading rates which deviate from current criteria) while delaying construction of additional basins. Including provisions for adding a coagulant within the primary or secondary basins to enhance solids removal capabilities could be a condition of approval of reduced reaction zone detention times and higher clarifier surface loading rates.

5.3.4 Primary Basins Condition

All primary settling basins were inspected from the exterior space by walking the perimeter and center walkway normally accessible spaces. In addition, Primary Settling Basin No. 1 was out of service at the time of inspection. Primary Settling Basin No. 1 was entered and inspected from the interior of the tank.

Primary Basins No. 1 and No. 2 basin equipment are original from 1970. Most of the equipment has deteriorated, and the mixing equipment has been removed. The control panels were observed to have broken components. Panels and conduits were in generally deteriorated condition. The drive equipment and rake arm were functioning. However, they trip out at higher solids loadings. Motors for the basin equipment appeared to be serviceable and could be refurbished as appropriate for the application.

Weirs and launders in primary basin no. 2 are not evenly installed, resulting in uneven flow across the basin. Sediment was present in the troughs, which restricts flow and has the potential to release slugs of sediment into the downstream secondary basins.

CW&L has replaced many of the sludge valves with pinch valves. The pinch valves appeared to be working as intended and no issues were identified by CW&L staff other than access restrictions in the sludge valve pit for Basin 3.

Notable structural items for Primary Settling Basin No. 1 include cracking of concrete walls and surrounding concrete top slabs, popouts in the top slab walkways, and surface corrosion of cover plates and support angles, as well as localized coating failures on the walls. Photos of these notable items are shown below.

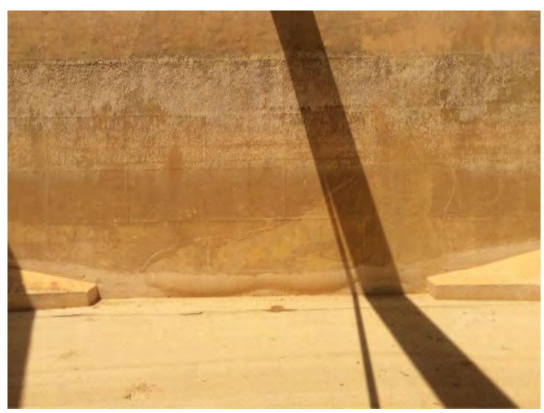
Crack in Top of North Wall in Primary Basin No. 1.

Crack Comparator Measurement at Top of Wall.

Cracking and Popouts in Top Slab of Tunnel near Primary Basin No. 1.

Crack Comparator Measurement at Top Slab of Tunnel near Primary Settling Basin No. 1.

Surface Corrosion of Cover Plate and Support Embedments.



Coating failure on North Wall of Primary Settling Basin No. 1.

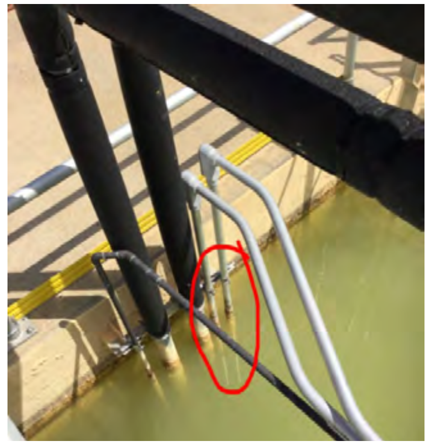
Crack widths at the top of wall are on the order of 0.03 inches at the time of measurement. Cracks of this width generally will not self-heal and will require repair. These cracks should be repaired via epoxy injection in order to prevent future deterioration of the wall surrounding the crack and to increase watertightness of the structure. The popouts are due to expansion of chert material present in the coarse aggregate in the concrete. This is superficial damage that can be prevented by sealing the concrete surface from moisture. This improvement is not required at this time. The surface corrosion of the cover plates and support angles is currently superficial in nature. In order to prevent significant corrosion, these items should be thoroughly cleaned, prepared, and coated.

The concrete coating failures inside the tank are likely due to moisture migration during the life of the coating or local defects in the surface preparation during the coating installation. These areas will eventually rupture the coating and increase potential of the tank to leak more than current leakage rates. These local failures should be repaired during upcoming upgrades. Repair would include local removal of the coating and reinstallation of a new coating with proper surface detailing and transition with the existing coating.

Primary Basin No. 3 equipment and control panel appeared to be in good condition with the exception of some weathered pilot devices on the face of the control panels. Installation includes a separate control panel for sludge collector and mixer. Mixer control panel includes a small VFD which was observed to be operational. Motors for the basin equipment appeared to be serviceable. The basin equipment is painted carbon steel.

Primary Basin No. 4 equipment appeared to be in good condition with the exception of some deterioration in the paint on the collector and mixer motors. The basin equipment is stainless steel. Motors for the basin equipment appeared to be serviceable. Two electrical installation items were observed regarding electrical conduits which are recommended for correction. Electric conduits routed to the collector motor are routed along the floor of the surrounding platform. This presents a tripping hazard to personnel and is subject to physical damage. It is recommended this conduit be revised to be routed underneath the platform to eliminate these hazards. Additionally, it was observed that there are electrical conduits which route under the waterline within Primary Basin No. 4. Corrosion was observed at the water line interface of this conduit. The loss of structural integrity of this conduit will act as a drain with water being funneled to the electrical equipment at the terminus of these conduits. It is recommended an alternative route be determined and implemented for these circuits and the existing conduits be removed.

Primary Basin No. 4 - Conduit posing a tripping hazard and subject to damage.



Primary Basin No. 4 - Conduit routed below the water line.

5.3.5 Primary Basin Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- The basin hydraulic and loading rates meet the 32 MGD peak plant capacity. However, at higher flows the water depth in the influent Parshall flumes will be too high and will not provide accurate flow measurement.
- Primary Basin No. 1 and No. 2 mixing equipment has been removed from service, resulting in inefficient lime use and reduced performance. The equipment is outdated and it is difficult to obtain replacement parts. It is recommended that Primary Basin No. 1 and Primary Basin No. 2 equipment be replaced.
- To increase capacity of the existing plant while maintaining two stage softening capability, equipment in all four basins would need to be replaced.
- The concrete is in satisfactory condition with no major issues.
- Hydraulics to the basins will need to be improved if higher flow rates are to be processed through the existing basins.
- To avoid short circuiting within the basin and improve flow distribution, weirs should be leveled in all primary basins.

The proposed improvement alternatives are discussed in Section 8.4.

5.4 SECONDARY BASINS

The existing secondary basins currently function primarily as chlorine contact units to achieve compliance with disinfection CT requirements for inactivation of viruses, in addition to providing some additional removal of turbidity/solids not removed within the primary basins. No chemical is added within the secondary basins to provide for additional softening or to promote additional flocculation and settling of solids is currently practiced. Addition of provisions for feeding a coagulant (ferric sulfate or cationic polymer) at the secondary basin inlets would improve ability to reduce the turbidity of the settled water applied to the filters. However, as discussed in the following Filtration section, unless a need to reduce filter influent turbidities is identified (for example, should a new raw water source be added which is determined to be subject to direct surface water influence), provisions for coagulant addition within the secondary basins to reduce filter influent turbidities, and/or other modifications to improve performance are not needed at this time.

5.4.1 Secondary Basin Condition

The secondary settling basins were inspected from the exterior space by walking the perimeter and center walkway normally accessible spaces. In addition, Secondary Settling Basin No. 2 was out of service at the time of inspection. Secondary Settling Basin No. 2 was entered and inspected from the interior of the tank.

Secondary basins No. 1 and No. 2 equipment were observed to have broken components. Control panels and conduits were in generally deteriorated condition. Equipment is original from 1970. Motors for the basin equipment appeared to be weathered but serviceable and could be refurbished as appropriate for the application. The rake arms typically do not operate as plant staff has seen little or no benefit with the arms if they are rotating.

Notable items from the Secondary Settling Basin No. 2 include damaged ladders, missing fall protection closure gates at four of the six tank entry ladders, one location of a tripping hazard due to conduit crossing the walking surface at the tank ladder entry, cracking of concrete walls and base slabs, spalling under the west walkway guardrail posts, as well as localized coating failures on the walls.

The damaged ladder includes bent rungs and rails as well as missing anchorage points. This is due to wear and tear over the life of the tank. We recommend the ladder be removed and replaced with a new ladder. Additionally the openings in the guardrail at the ladder entry present a safety hazard. We recommend closer gates be installed as soon as possible at the four tank entry ladders and the tripping hazard be mitigated by locally rerouting the conduit out of the walking surface or installing a walking surface transition cover over the conduit.

The crack widths at the top of wall and base slab are on the order of 0.025 inches. Cracks of this width generally will not self-heal and will require repair. We recommend the cracks be repaired via epoxy injection in order to prevent future deterioration of the wall surrounding the crack and to increase watertightness of the structure.

The concrete spalling is likely due to moisture at the base of the guardrail posts combined with freeze thaw cycling in winter months. These locations of spalling will need to be repaired as continued damage may lead to unsecure guardrail supports. Repair for these items can be done by removing the full thickness of surrounding concrete and installing repair mortar tight to the existing base with a slight slope away from the post.

The coating failures are likely due to moisture migration during the life of the coating or local defects in the surface preparation during the coating installation. These areas will eventually rupture the coating and increase potential of the tank to leak more than current leakage rates. As a preventative measure we recommend these local failures be repaired. Repair would include local removal of the coating and reinstallation of a new coating with proper surface detailing and transition with the existing coating.

Bent and Damaged Ladder at Secondary Settling Basin No. 2.

Crack in West Wall of Secondary Settling Basin No. 2.

Crack in Southwest corner of West Wall in Secondary Settling Basin No. 2.

Crack in Base Slab of Secondary Settling Basin No. 2.

Crack Comparator Measurement of Base slab Crack.

Concrete Spalling at Underside of Walkway on West Side of Secondary Settling Basin No. 2.

Coating Delamination with Fluid Build Up in Secondary Settling Basin No. 2.

Missing Fall Protection Gate at Ladder (Typical 4 locations) and Conduit Tripping Hazard at Ladder Entry.

Secondary Basin No. 3 equipment appeared to be in good condition with the exception of some weathered pilot devices on the face of the control panels. Installation includes a separate control panel for sludge collector and mixer. Mixer control panel includes a small VFD which was observed to be operational. Motors for the basin equipment appeared to be weathered but serviceable.

Basin No. 4 equipment and overall installation appeared to be in good condition. Motors for the basin equipment appeared to be serviceable. Electric conduits routed to the collector motor are routed along the floor of the surrounding platform, similar to Primary Basin No. 4. This presents a tripping hazard to personnel and is subject to physical damage. It is recommended this conduit be revised to be routed underneath the platform to eliminate these hazards. Additionally, it was observed that there are electrical conduits which route under the waterline within Secondary Basin No. 4, similar to Primary Basin No. 4. Corrosion was observed at the water line interface of this conduit. The loss of structural integrity of this conduit will act as a drain with water being funneled to the electrical equipment at the terminus of these conduits. It is recommended an alternative route be determined and implemented for these circuits. Also, a number of circuits appear to have been disconnected and abandoned to equipment no longer present. It is recommended these circuits and raceways be completely removed.

Secondary Basin No. 4 – Abandoned Conduits

Hach CL17 chlorine analyzers are used to monitor the chlorine levels at the secondary settling basin effluent, one for basin trains 1 and 2, and one for basin trains 3 and 4. These analyzers appear to be relatively new and be in good working condition. No changes to these analyzers are required. A Hach pH analyzer is used to measure the pH of the secondary settling basin effluent water. The pH analyzer uses a SC100 analyzer, which is being phased out by the manufacturer, therefore, this analyzer should be replaced with the Hach SC200 when it fails.

5.4.2 Secondary Basin Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- Flow restrictions in the filter influent piping from Basin 3 and Basin 4 restrict the overall plant capacity. The restriction is primarily caused by the 30 inch piping between filter 6 and the 42 inch tee from the basin flume. When Basins 3 and 4 are in operation with Filters 1-4, the maximum capacity of the two basin trains is about 15 MGD before weirs are overtopped in the secondary basin. Replacing the v-notch weirs in the secondary basin with submerged orifices would eliminate short-circuiting at higher flows.
- Secondary Basins No. 1 and No. 2 have electrical equipment that has deteriorated and should be replaced. The clarifier mechanical equipment is beyond the typical lifespan for this type of equipment, and is difficult to find replacement parts. However, replacement of the basin equipment with newer settling equipment provides little process value unless the plant is converted to single stage softening.
- Incorporate miscellaneous structural and electrical repairs as described in this section.
- The pH analyzer uses a SC100 analyzer, which is being phased out by the manufacturer, therefore, this analyzer should be replaced with the Hach SC200 when it fails.

5.5 FILTERS

Filtration is achieved by eight dual media gravity filters that follow the secondary basins. Four of the filters were installed in 1970 as part of the original construction. Two additional filters were added in both the 1994 and the 2006 expansions. Each filter consists of two bays sharing a common inlet, outlet, and waste gullet. Each filter is equipped with a surface wash system.

5.5.1 Filter Performance

The current filter operating mode (declining rate-of-flow as filters accumulate solids, with cleaner filters operating at higher hydraulic loading rates and treating a greater percentage of total plant production) results in significant spikes in filter effluent turbidities as additional high service pumps cycle on and flows through the filters increase. The configuration of the high service pumps does not allow for the filters to operate in a more consistent effluent rate-of-flow control because the filter effluent valves cannot modulate to control flow through filters without causing cavitation on the high service pumps.

Filter Effluent Turbidity

The turbidity of the filtered water is higher than would typically be expected from a dual-media or mixed-media filter treating properly conditioned lime softened water. As shown in Table 5-13, during the most recent two full months of plant operation, filtered water turbidity was less than 0.5 NTU for only 46 percent of samples analyzed, and turbidity exceeded 1.0 NTU for almost 20 percent of all samples. In addition, review of this data indicates that turbidity spikes occur frequently, and often result in increases in turbidity from initial values of 0.3 – 0.5 NTU to 3 to 6 NTU. While turbidity following these spikes typically drops back to average conditions within 2 to 4 hours of when the spike initially occurs, it is also not unusual for turbidity to remain well above average conditions for 6 to 12 hours (or more) after the initial spike occurs. There are currently no regulatory requirements governing the turbidity of the combined filter effluent or for individual filters for plants treating ground water sources, and therefore these high turbidity incidents do not present regulatory compliance concerns. However, this performance is definitely indicative of conditions under which floc particles carried over from the clarifiers are not properly conditioned to promote good filtration performance. Removal of $CaCO_3$ particles by granular media filters is typically very effective if the particles are properly conditioned such that they can be readily removed by the filters. However, if not properly conditioned through addition of coagulant and/or a filter aid, these particles typically do not adhere well to the filter media, and are easily detached during changes in flow through the filters, resulting in elevated effluent turbidity.

Table 5-13 Filter Effluent Turbidity (May – June 2015)

PARAMETER	MAY 2015	JUNE 2015	TWO MONTHS
Average Turbidity, NTU	0.94	0.74	0.85
Turbidity Range, NTU	0.11 – 8.80	0.05 – 7.02	0.05 – 8.80
% of Samples ≤ 0.3 NTU	17.9	22.5	20.2
% of Samples ≤ 0.5 NTU	42.6	50.1	46.3
% of Samples ≥ 1.0 NTU	24.6	15.6	19.3
Based on combined filter effluent samples collected at 2-hour intervals			

One readily-implementable approach to reducing filtered water turbidity would be to add provisions for applying a filter aid polymer to the settled water. Many plants which practice precipitative softening have achieved significant improvements in filter performance through addition of cationic polymer at low dosages (0.1 – 0.2 mg/L) at the filter influent. It is critical that cationic polymer, rather than anionic polymer, is used for filter aid, as anionic exhibits a tendency to essentially "glue" filter media together if too much is applied, or if carryover of residual polymer (if fed upstream at the primary or secondary basins) occurs. Nonionic polymers are generally ineffective in softening applications unless fed at fairly high dosages, and tend to exhibit the same media fouling issues as anionic polymers.

Filter Media

Current filter media configuration is reported to be as follows:

- 21 inches of anthracite (effective size: 0.90 – 1.00 mm)
- 7 inches of fine sand (effective size: 0.45 – 0.55 mm)
- 2 inches of garnet (effective size: 0.25 – 0.35 mm)

MNDR design requirements for conventional rapid-rate gravity filters state that media depth should not be less than 24 inches nor more than 30 inches, and that a minimum of 12 inches of media having an effective size no greater than 0.45 mm to 0.55 mm be provided. Based on current media configuration, the existing filters would not comply with MDNR requirements, as the combined depth of the fine sand and garnet layers (9 inches) is less than the required minimum 12 inches. In addition, per current MDNR requirements, when anthracite is used as a "cap" over smaller sand media, "shall have effective size of 0.6 mm – 0.8 mm". While the current anthracite media does not comply with this requirement, use of anthracite with an effective size of 0.9 mm to 1.1 mm in dual-media or mixed-media filters is common practice within the water industry. Therefore, an increase in the total depth of the sand and garnet layers to at least 12 inches should be considered during any future media replacement program in order to facilitate MDNR approval; however, reductions in the effective size of the anthracite would not be recommended.

5.5.2 Filter Capacity

Based on the current filter area of 676 sq ft per filter, the hydraulic loading rate with one of the eight total filters out of service is 4.7 gpm/sq ft at the current 32 MGD rated plant capacity. MDNR requirements for rapid rate gravity filters state that design loading rate "shall be a maximum of two gallons per minute per square foot of the filter surface area", with the largest filter out of service, and with a qualifier that higher rates "may be considered" based on site-specific conditions, designer justification, and other factors. It is considered unlikely that MDNR would approve further increases in hydraulic loading rates for the existing filters unless significant improvements in rate-of-flow control, filter monitoring (rate-of-flow and head loss indication), and pretreatment to reduce filter influent turbidities were to be implemented. Pilot-scale or full-scale testing could be conducted to demonstrate ability to operate at higher rates; Black & Veatch has been successful in getting regulatory agencies to accept loading rates as high as 6 gpm/sq ft for dual-media filters treating lime-softened water. However, even at an approved loading rate of 6 gpm/sq ft, maximum capacity for the existing filters would be limited to approximately 41 MGD.

5.5.3 Filter Condition

Filter Valves

All motorized valve actuators on Filters 5, 6, 7 & 8 have recently been replaced with newer Limitorque actuator models. Some of the motorized valve actuators on Filters 1, 2, 3 & 4 have been replaced with Limitorque actuators while others have been repaired or replaced in kind with the existing original filter actuator types. CW&L reported problems with position encoders which were causing most of the valve actuators to be repaired or replaced on a case by case basis. High service pump discharge valves are 125 VDC units. None of the motorized valve actuators were observed to have an NEC required local disconnecting means installed. It is recommended that safety switch disconnects be added to all valve actuator installations.

The isolation valves installed in the common influent filter header that were installed as part of the first expansion do not provide an effective seal when trying to isolate filters or basins. These valves are installed in locations which are difficult to access, but will be critical during construction of plant improvements to allow portions of the plant to be offline for rehabilitation. CW&L has also indicated they have observed flow restrictions on the filter influent suction header from Secondary Basin Nos. 3 & 4. The filter influent piping is symmetric between basin trains 1 & 2 and 3 & 4. However, there are 30 inch isolation valves on each side of the 42 inch influent tee from Basins 3 & 4 that are not present on Basins 1 & 2. Therefore, the flow restriction may be caused by these valves, especially if one of these valves is partially closed. Repair or replacement of these valves should be incorporated prior to any major rehabilitation work with the basins or filters.

Filter Controls

Ultrasonic level transmitters are used to measure each filter's level. Some of the filters still have Milltronics Hydroranger 200 ultrasonic level transmitters. As these units have failed (filters 1 & 6), less expensive Omega ultrasonic level transmitters were installed. These new level transmitters do not have local display and are not as configurable as the original units. These ultrasonic level transmitters will definitely measure the filter level just as well as the more expensive models, but since this unit has no readout, the operators will not be able to monitor the filter level when the filter PLC goes down.

To monitor the filter effluent flow, each filter has a venturi tube with a differential pressure sensing flow transmitter installed in the effluent piping of the filter. According to CW&L, the flow transmitters used for filters 5-8 have been providing false readings, but in general, this type of flow meter is a time-proven and accepted approach. The venturi tube itself contains no parts that require maintenance. The only component that will need maintenance is the static sensing lines and the differential pressure sensing flow transmitters (various manufacturers are installed). These components are relatively inexpensive and can be easily replaced when they fail. Therefore, the venturi flow elements and differential pressure sensing flow transmitters appear to be in good working conditions and meet the needs of the plant.

Each filter is also provided with a filter head pressure transmitter. A differential pressure transmitter (various manufacturers are installed) is used to measure the filter head. These instruments are standard instruments and can be easily replaced when they fail. These filter loss of head meters are relatively ineffective as the configuration of the high service pumps makes the head difference between all the filters the same under all conditions. No change is recommended for these instruments.

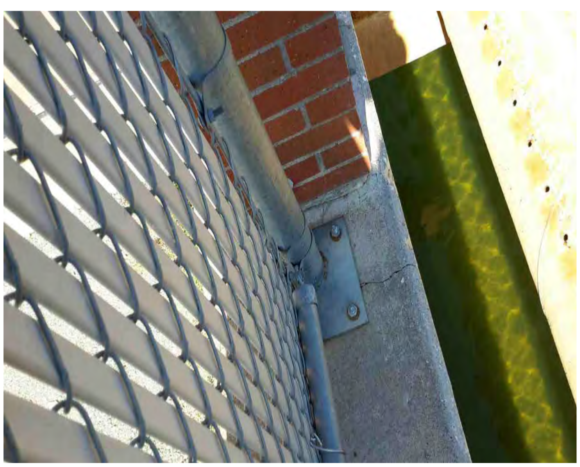
Each filter has a Hach SC100 (analyzer) and 1720E (sensor) to measure the filter effluent turbidity. These instruments appear to be in good working condition. According to Hach, the SC100 analyzers will soon be phased out. The replacement for this analyzer is the SC200. Hach still supports the SC100 units, but as these units fail, Hach suggests that they be replaced with the SC200 analyzers.

A Foxboro pressure sensing level transmitter is used to monitor the backwash tank level and seems to be in good condition. The transmitter has an LCD display, but it is configured to display the pressure instead of the level. Black & Veatch would suggest that the transmitter be reconfigured, so that it displays the backwash tank level.

The flow from the backwash tank is measured, monitored, and controlled by the plant control system. A Foxboro differential pressure sensing flow transmitter is used to measure the differential pressure through an orifice plate to determine the flow. Similar to the backwash tank level signal, the flow signal is also connected to a remote I/O panel and monitored by the plant's Main PLC. This flow instrument also appears to be in good working condition. In order to make it easier for the operators, Black & Veatch would also suggest that the transmitter be reconfigured to display flow instead of differential pressure.

The filter building was inspected from the outside at grade level and by a thorough walk through in the interior operating level and basement level. All observations were done from normally accessible space.

Exterior notable items are one location of cracking near a guardrail post at the northeast corner of the building, missing splash blocks, poor site drainage at the down spouts, and one location of concrete spalling at the southwest corner of building at the top of the concrete footing supporting the face brick. All of these items are minor in nature at this time. As a preventative repair step, iti is recommend to repair the concrete surface and inject the exposed crack. The missing splash blocks and drainage issues can be resolved by adding fill to drain runoff away from the building and placing splash blocks under all down spouts.



Crack at Base of Guardrail Post.

Roof drainage from down spouts drains towards foundation walls.

Spall at base of face brick.

Interior notable items include;

- Minor cracks observed in the CMU block walls
- Hairline cracking in the operating floor slab
- Openings in the fall protection guardrailing at the filter tanks
- Leaking cracks in the foundation/basin walls.

These items are shown in the following photos. The cracks in the CMU block walls are relatively tight and occur only in a few select locations. This type of cracking is typical for structures of this age, and is most likely due to seasonal and long term moisture variation in the block construction. No repair is recommended for the CMU at this time. The hairline cracking in the operating slab is also minor and typical for concrete structures. These cracks have likely been present since the original construction and will open and close based on seasonal temperature change. No repair is recommended at this time. The cracks in the foundation/basin walls that are actively leaking will require repair. These cracks are most likely due to shrinkage of the concrete during the original construction and seasonal temperature change. Injecting these cracks with a hydrophilic polyurethane foam during the winter or early spring when the cracks will be in their widest state is recommended. The leaking expansion joint should be repaired as well. The repair of the leaking expansion joint will require a combination of concrete surface repair and waterproofing the joint. If the tank on the opposite side of the expansion joint will be taken out of service this can be accomplished with a tank interior applied joint seal. The guardrail openings should be closed off with lockable safety gates. These can be installed on the existing guardrail.

Crack with efflorescence on filter wall. Surface damp to the touch. Typical two locations.

Leaking expansion joint in Filter building Basement.

Top of leaking expansion joint. With spalling and cracks.

Base of north side expansion joint with water pooling and flowing to floor drain.

Crack with efflourescence on filter wall. No moisture on surface.

Opening in Guardrail. Recommend this be closed with new safety gate.

5.5.4 Filters Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- The current filter loading rate of 4.7gpm/sq ft is within an acceptable loading rate for this type of filter. Therefore, the filters are able to meet the plant rated capacity of 32 MGD. However, because the filters operate in declining rate mode and there is no flow control, when newly washed filters come online, they typically exceed this loading rate, causing the potential for higher turbidity excursions. Converting to rate of flow filters would require a clearwell downstream.
- Proceed with replacement of existing actuators on Filters 1-4 with new actuators matching the actuators installed on Filters 5-8. Consider purchasing all the actuators under one contract for discount versus purchasing and installing one at a time. Installation will still need to be staged to minimize plant unit shutdowns.
- It is recommended that safety switch disconnects be added to all valve actuator installations.
- Replace the Keystone 30 inch valves that were installed as part of the 1994 expansion that are inoperable. Consider moving the location of the valve located between Filters 6 influent and the 42 inch tee from Basin 3 and 4 to the other side of Filter 6 influent, so it is between Filters 5 and 6, to reduce headloss through the valve. These valves will need to operate during any major plant modifications.
- Increase the total depth of sand and garnet layers to at least 12 inches to meet MDNR requirements as filters are rehabilitated.
- Considering feeding a cationic polymer as a filter aid ahead of the filters to improve turbidity removal and overall filter performance. The addition of the filter aid is not required unless more stringent turbidity goals are required, but will improve performance.
- Incorporate miscellaneous structural repairs.

The proposed filter improvement alternatives are discussed in Section 8.6.

5.6 DISINFECTION

MDNR has adopted a policy under which plants treating ground water sources not subject to direct surface water influence must continuously maintain disinfection conditions which will ensure a minimum of 4-log inactivation of viruses. These disinfection conditions are based on the amount of chlorine contact time and residual chlorine, which establishes a “CT” value for the amount of virus inactivation achieved.

Primary disinfection at the McBaine plant is accomplished through maintenance of a free chlorine residual across the secondary softening basins at concentrations which ensure compliance with disinfection CT requirements. Use of a conservative baffle factor (T_{10} to DT ratio) at the maximum design flow of 8 MGD, regardless of actual basin throughput rate, is required by MDNR in the assessment of disinfection CT compliance. While free chlorine contact time is also provided across the filters, MDNR does not allow credit for this due to difficulties in accurately determining available chlorine contact times across individual filters operating at different flow rates. Addition of ammonia at the filter discharge results in the formation of a combined chlorine (chloramine) residual, which is relatively ineffective with regard to inactivation of viruses. Free chlorine residuals at the secondary basin discharge, based on daily measurements at 2-hour intervals, are summarized in Table 5-14 for May through June 2015.

Table 5-14 Free Chlorine Residuals at Secondary Basin Discharge (May – June 2015)

SAMPLE LOCATION	FREE CHLORINE RESIDUAL, MG/L	
	AVERAGE	RANGE
Combined Trains 1 & 2 Discharge	2.17	0.65 -4.15
Combined Trains 3 & 4 Discharge	2.55	0.94 – 3.89

Water temperatures within the secondary basins typically range from approximately 12 to 15 degrees C. At these temperatures, required CT values for 4-log inactivation of viruses with free chlorine are approximately 5 mg-min/L at 12C and 4 mg-min/L at 15C. Based on a secondary basin total volume of 758,000 gallons, and a baffle factor of 0.1 and full 8 MGD design flow per train, T_{10} detention time provided within the secondary basins is 13.6 minutes. Therefore, required free chlorine concentrations across the secondary basins would be only 0.3 to 0.4 mg/L to maintain conditions which would ensure 4-log inactivation of viruses. As shown in Table 5-14, chlorine residuals maintained across the secondary basins typically exceed minimum required levels by a significant margin. This suggests that unless the source water classification changes such that compliance with CT requirements for disinfection of ground water subject to direct surface water influence is required, existing chlorine contact times and chlorine residuals within the secondary basins are more than adequate to comply with regulatory requirements.

Should potential future changes in source water require maintenance of disinfection conditions which would provide for inactivation of both *Giardia* and viruses, additional chlorine contact time would be needed. Preliminary review suggests that adequate contact time would likely exist within the secondary basins to comply with required disinfection CT criteria for ground water subject to direct surface water influence if (1) a higher baffle factor could be utilized, and (2) CT calculations were to utilize actual basin throughput rates, rather than an assumed maximum 8 MGD rate per basin train. Tracer testing could be conducted at the McBaine plant across the secondary basins to demonstrate that use of higher baffle factors would be appropriate. Tracer studies conducted across secondary softening basins (both conventional flocculating clarifiers and solids contact clarifiers) at other treatment facilities suggest that while baffle factors greater than 0.1 are typically achieved, they may not be substantially higher. For example, testing conducted by Black & Veatch across a flocculating clarifier at another two-stage softening plant over a range of throughput rates showed baffle factors ranging from approximately 0.25 when operating at approximately 50 percent of design flow capacity to 0.19 at full basin design capacity.

Tracer testing across each of the secondary basins at flow rates approaching or exceeding full design flow conditions has been conducted by plant staff. Test results based on reported T_{10} detention times were as follows:

- Basin Train 1: 8.2 MGD test flow rate; T_{10}/DT (baffle factor) = 0.22
- Basin Train 2: 8.0 MGD test flow rate; T_{10}/DT (baffle factor) = 0.25

- Basin Train 3: 8.35 MGD test flow rate; T_{10}/DT (baffle factor) = 0.20
- Basin Train 4: 7.85 MGD test flow rate; T_{10}/DT (baffle factor) = 0.27

Review of testing results provided suggest that the tests were conducted in accordance with procedures recommended by USEPA in their Surface Water Treatment Rule "Guidance Manual", and that the results obtained agree well with those derived from testing of secondary basins in precipitative softening applications by Black & Veatch and others. However, as the testing was not conducted under the direction of nor witnessed by an Engineer, MDNR reportedly will not consider accepting these results and allowing use of the higher baffle factors. Additional discussions with MDNR could be conducted to request that they consider these results following review and comment by Black & Veatch, and/or to identify specific procedures which should be followed during any repeat testing to ensure MDNR acceptance of the results.

Assuming that a higher secondary basin baffle factor of 0.2 would be approved by MDNR, required free chlorine residual concentrations for compliance with disinfection requirements for ground water under direct surface influence as a function of both total plant flow and water temperature are summarized in Table 5-15.

Table 5-15 Required Free Chlorine Residuals for CT Compliance Across Secondary Basins

PLANT FLOW, MGD	MINIMUM REQUIRED FREE CHLORINE RESIDUAL AT INDICATED TEMPERATURE, MG/L			
	5° C	10° C	15° C	20° C
45	3.4	2.4	1.5	1.1
40	3.0	2.1	1.3	1.0
35	2.5	1.8	1.1	0.8
30	2.1	1.5	0.9	0.7

Assumptions:
All basin trains in service
T_{10}/DT (baffle factor) for all basins = 0.2
0.5-log Giardia inactivation

Development of a plant-specific spreadsheet program which would facilitate more accurate tracking of actual disinfection CT conditions within the secondary basins would assist operators in maintaining required chlorine residuals. Should future source water conditions change such that maintaining higher CT values required for disinfection of ground water under direct surface influence is required, improved CT calculation procedures will almost certainly be required, particularly if incorporation of available CT values for the filters is needed to comply with disinfection regulatory requirements.

5.7 HIGH SERVICE PUMPING

High service pumping consists of eight vertical turbine pumps that deliver water to the distribution system through two finish water transmission mains. All the pumps pull from a common 24 inch suction header. Pumps 1-4 were installed in 1970. Pumps 5 and 6 were installed as part of the 1994 expansion and pumps 7 and 8 were installed in 2007.

5.7.1 Pump Station Capacity

Each high service pump is rated at 4,200 gpm at 204 ft of head and is equipped with a 300 hp motor. Based on the rated capacity, the high service pumps have a firm capacity of 42.3 MGD and peak capacity of 48.4 MGD. An evaluation of plant SCADA data reveals that the discharge pressure is typically higher than 204 ft when multiple pumps are in operation. Available SCADA data from June 2015 was plotted in Figure 5-3 to develop a system head curve for the pump station. Because several of the pumps are on VFDs, it is difficult to determine how many pumps were in operation for the recorded data points. However, based on the information available and interpolation of system head pressures at higher flows, the high service pump station appears to have a firm capacity of between 26-30 MGD with seven pumps in operation. However, during the June 2015 pumping operations only one of the two finished water transmission mains were in operation. It is recommended to return the second finish water transmission main to service to reduce the discharge pressure of the pump station to increase the overall capacity, and to reduce energy consumption from the pumps. Once both transmission mains are in service, an additional hydraulic pumping review should be completed to confirm capacity.

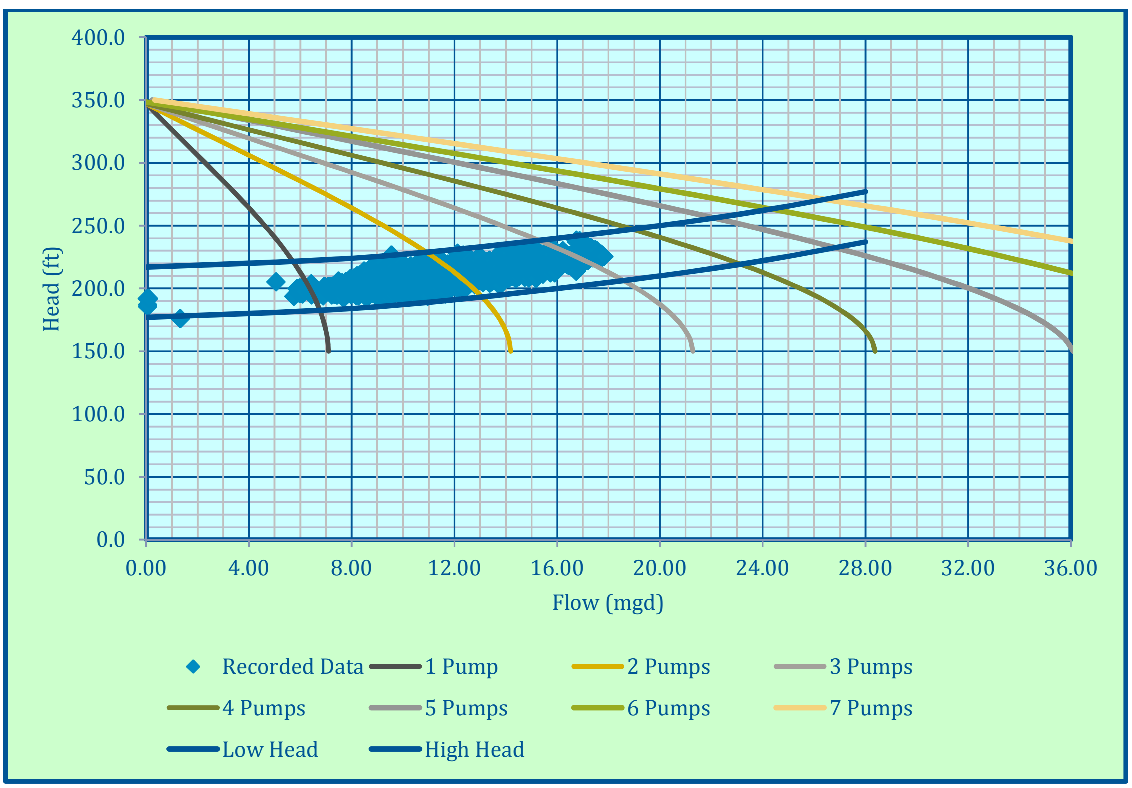


Figure 5-4 McBaine WTP High Service Pump Station - System Head Curves

5.7.2 Pump Station Condition

Although the pumps are all at various ages, CW&L has re-built the pumps over time so they are generally in good condition. No significant issues were identified onsite or by the plant staff when observing the pumps.

The pumps installed as part of the original plant are nearing 45 years old. Typically, after a re-build you can expect 10-15 additional years of operation for these types of pumps. However, this can be highly variable on a case-by-case basis. If repairs on pumps become more costly, or more regular (less than 10 yrs), then pump replacement is recommended.

Pump Motors and Motor Starter

The eight High Service Pump motors are of various ages and configurations. All motors were operational when observed, although CW&L staff reported there are some units which pose more challenging operational restrictions than others, particularly HSP-3 which includes an eddy current drive which is difficult to maintain. CW&L has started to replace or re-wind the original 2,300V motors to have a 460V rating whenever a motor problem requires major maintenance or repair. In addition to changing to 460V, CW&L staff is also installing 480V VFD units on these units to gain variable speed capability. Table 5-16 below indicates the general details of each high service pump motor and starter as well as any general installation details.

Table 5-16 High Service Pump Motors

HIGH SERVICE PUMP	YEAR INSTALLED1	HORSE-POWER	VOLTAGE	STARTER TYPE	INSTALLATION NOTES
1	1971	300	2300	Contactor	Original motor likely previously rewound.
2	2014	300	460	VFD	Original 2300V motor replaced with new NEMA premium efficient 460V motor. Installation includes dry-type 2300V-480Y/277V transformer and Toshiba VFD adjacent to the pump motor.
3	1971	300	2300	Contactor	Includes original eddy current drive which CW&L reports is difficult to maintain and limits serviceability of this pump.
4	1971	300	2300	Contactor	Original motor likely previously rewound.
5	1995	300	2300	Contactor	Includes vibration and temperature protection.
6	1995	300	2300	Contactor	Includes vibration and temperature protection.
7	2013	300	460	VFD	Original 2300V motor rewound by Illinois Electric Co. to operate as a 460 V motor. Installation includes dry-type 2300V-480Y/277V transformer and Toshiba VFD adjacent to the pump motor. Includes vibration and temperature protection.
8	2006	300	2300	Contactor	Includes vibration and temperature protection.

1. Year of installation indicated is approximate.

Instrumentation

The speed of the high service pumps that are equipped with VFDs is controlled to maintain a level setpoint within the common filter influent header from the east or west basins. The level in this header is measured by an OTT CBS bubbler unit. Using hand actuated valves, the operator can select which bubbler tube (east or west basin) to use for the level measurement. The level signal from the bubbler unit is sent to a single loop controller that controls the speed of the high service pumps. Per CW&L staff, the redundant level controller has failed and has never been replaced. Since this level controller is critical for the automated control of the high service pumps, it is recommended that the failed level controller be replaced.

A pressure switch is installed on the suction piping of each high service pump. These switches are hardwired interlocked with the pumps to stop the pumps when a low suction pressure exists. These pressure switches appear to be in good working condition.

An ABB differential pressure sensing flow transmitter is used with an orifice plate to measure both finished water transmission mains. The signal from this transmitter is sent to the plant's Main PLC remote I/O panel. The transmitter is a blind instrument, so without the PLC, the operator cannot view the flow. If there is an issue with the orifice plate, it will be very difficult to replace the orifice plate, but there are few things that can go wrong with an orifice plate. The differential pressure instrument is a standard instrument and can be easily replaced if it fails.

5.7.3 High Service Pumps Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- The pump station has a firm capacity of 42.3 MGD and peak capacity of 48.4 MGD based on the rated design point. However, review of plant SCADA data reveals that the discharge pressure was higher than the rated point, resulting in a firm capacity of between 26-30 MGD. System pressures and tank levels within the system were not evaluated as part of this assessment to determine if the system could operate at lower pressures to increase capacity at maximum flow rate. However, some additional headloss is caused by only one of the two finished water transmission mains being in use. It is recommended that the second transmission main return to service to reduce pump station pressures, to increase capacity and improve energy efficiency. Utilizing both transmission mains and accounting for lower pressure within the system at peak conditions, it appears the pump station is able to provide a firm capacity of 32 MGD.
- In general, the existing motors appeared serviceable with all motors being able to maintain operation with proper maintenance and with the potential for re-winding to refurbish a motor core as needed.
- Make repairs and/or maintenance improvements in coordination with planned improvements to the larger electrical system. It is suggested that additional pump motors not be rewound or replaced with a configuration different from its respective original installation until a master plan for electrical improvements is in place.
- High Service Pumps 1, 3 and 4 are the oldest units with the least amount of modern protection features. These units should be the first to be addressed in any systematic upgrades to the high service pumps.

- High Service Pump 3 should have its eddy current drive removed at the earliest opportunity. The controls are obsolete, service support is difficult to obtain and the equipment is beyond its expected service life.
- Install redundant level loop controller for master filter level control.

The proposed improvement alternatives are discussed in Sections 8.7 and 8.8.

5.8 CHEMICAL FEED SYSTEMS

5.8.1 Lime Feed System

Lime is fed to raise the pH and soften the water to 140 to 160 mg/l $CaCO_3$. The lime feed system consists of two storage silos used to store dry quicklime. An RDP lime feed system was installed at the plant in 2007. The RDP lime feed system consists of a dry lime feeder at the outlet of each storage silo, feeding into a dedicated tank-type lime slaker beneath. Slaked lime slurry is drained by gravity from each slaking tank to a dedicated lime slurry aging tank on a lower level. Lime slurry is recirculated by recirculation pumps, from the aging tank, in a loop back to the slurry aging tanks. Lime slurry is metered from the recirculation loop remotely at the application points by flow meters and controls valves at the softening basins. All lime slurry piping is stainless steel and in good condition.

The existing lime feed system is in good condition. The silo outlet was repaired with gray tape which indicates a minor repair of the flexible connections may be necessary. The lime equipment did not have nameplates with equipment capacities for review.

While slurry concentrations maintained by the existing RDP Tekkem batch-type lime slakers are not routinely monitored, operating staff report that maintenance of a lime slurry concentration of approximately 10 percent is targeted. Each of the two existing slakers have a reported capacity of 4,000 lbs per hour of 100% $Ca(OH)_2$ at a slurry solids concentration of 20 percent, which is equivalent to approximately 3,030 lbs per hour of 100 percent quicklime (as CaO). However, the current vibrating screen grit handling system limits the maximum slurry concentration that can be reliably be maintained to less than 20 percent. Conversations with RDP with regard to other similar Tekkem installations indicate that a maximum slurry concentration of 12 percent is recommended when the vibrating screen grit handling system is used to ensure reliable service. When higher slurry concentrations are required, RDP recommends retrofitting of the system with a newer grit system design.

At 12 percent slurry concentration, capacity of each of the existing slakers is 2,400 lbs/hour of 100% $Ca(OH)_2$. Adequacy of existing lime feed capacity was evaluated based on the following assumptions:

- Quicklime purity = 90% CaO
- Average applied lime dosage = 180 mg/L (1,500 lbs/MG) of 90% CaO
  - Calcium hydrate equivalent dose = 1,782 lbs/MG of 100% $Ca(OH)_2$

Based on these assumptions, maximum plant flow that could be treated with (1) no modifications to the existing slakers and grit handling system, (2) operation at maximum 12 percent slurry concentration, (3) operation under average lime dose conditions, and (4) only one of the two existing slakers in service, is 32.3 MGD, which is equal to the current rated plant production capacity. While both existing slakers could be operated simultaneously to maintain the finished water total hardness goal when required, lime dosages exceed average conditions and no system backup/standby capability would then exist.

RDP has provided a conceptual design for modifications to retrofit the existing slaker system with their Suspended Bed Slurry Scrubber system to improve ability to remove fine grit from the existing slurry loop. Installation of this system would increase the capacity of the existing lime feed system.

The Lime Building was inspected from the outside by walking the perimeter of the building at grade level and on the inside by walking the interior ground floor and platform spaces. The only notable item for the building is missing joint filler and sealant in the concrete block wall at the Southeast corner of the building. Filling this gap with backer rod and caulking is recommended in order to ensure the proper sealing of the structure and to prevent any potential moisture and air transport issues.

Missing Joint Filler at Top of Wall

5.8.1.1 Lime Feed System Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- The capacity of the existing system is able to treat the peak plant flow of 32 MGD at average lime feed rates with one unit out of service.
- A new grit removal system will increase capacity and improve performance.
- Fill gap in joint filler with backer rod and caulk.

The proposed improvement alternatives for the lime feed system are discussed in Section 8.9.

5.8.2 Chlorine Feed System

The existing gaseous chlorine system is a vacuum withdrawal type system using one-ton containers. The one-ton containers are located in the Chlorine Storage Room where an overhead monorail exists for moving containers to the scales. However, the monorail does not extend outdoors for truck unloading. Ton containers are delivered by truck and rolled off the truck onto the dock through a double door into the Chlorine Storage Room. Containers are stored directly on the floor in lieu of trunnions. The Chlorine Storage Room is only accessible from outdoors.

The plant operates with four ton containers online, withdrawing chlorine gas, with an additional four in standby connected through a mechanical-type automatic switchover device. Each container online and in standby is on a dedicated scale to monitor the remaining chlorine in each container. The automatic switchover allows a switch from empty to full ton containers for continuous disinfection. Each container online (and in standby) is equipped with both a Capital Controls container-mounted vacuum regulator and a Halogen emergency shutoff valve actuator. Vacuum regulators are vented into the Chlorine Storage Room. The storage room has one chlorine gas detector with an alarm light outside the room, but the room does not have an emergency scrubber to mitigate a chlorine gas leak. Access to the Chlorine Feed Room is from the interior of the building. There is no chlorine gas detector in the Chlorine Feed Room.

Three chlorine feeders located in the Chlorine Feed Room control chlorine feed rates to each application point which consists of four pre filter application points to Secondary Basins No. 1 through 4 and two post filter application points. The maximum capacity of all three feeders combined is 2,000 ppd. One feeder is equipped with a controller for electronic flow pacing control while the remaining feeders are only capable of manual control. Chlorine feeders meter the gas to water-operated eductors which generate a chlorine solution from a single water supply. The chlorine solution is then split with valves and rotameters to feed solution to multiple application points from a single feeder.

At the time of the condition assessment, two feeders (and two eductors) were operating simultaneously. Gas discharge from each feeder was combined in a discharge piping header and then split to two eductors. The flow from each eductor was then split to multiple application points. This method of chemical feed controls only the rate of chlorine solution and offers little or no control over the gas chlorine flow. Consequently, operators do not have control over where the chlorine is actually applied, but only control the total amount of chlorine being applied.

Ten State standards requires backflow prevention between pre and post filter application points specifically for water operated chlorine feed system. The plant does not employ dedicated water sources for eductors to prevent backflow of unfiltered water to post filter application points.

There are five BW Technologies Gas Point chlorine gas detectors installed in various locations throughout the Chemical Building and the tunnel between the Chemical Building and Filter Building. All five gas detectors are connected to a gas detector panel that displays the gas levels of each sensor. This panel is located on an exterior wall of the Chemical Building. Per the manufacturer, they have not supported the Gas Point gas detection system for about five years, so replacement parts for this system will be difficult to find. Black & Veatch highly recommends that this gas detection system be replaced with a new gas detection system.

5.8.2.1 Chlorine Feed System Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- The existing chlorine feed system is able to meet the peak plant flow of 32 MGD.
- CW&L should evaluate what is the best long term disinfectant for the plant by comparing economic and non-economic criteria for continued use of chlorine gas with addition of a chlorine gas scrubber and other enhancements, bulk hypochlorite, and onsite generation of sodium hypochlorite.

- Even if chlorine gas is not selected as the long term disinfectant, chlorine gas feed control should be incorporated in the interim. This includes using the chlorine residual analyzers on the secondary basin trains to control the chlorine gas feed rate based on residual control mode. One analyzer should be installed on each train at the secondary basin effluent. The operator will input a desired residual and the chlorine feed rate will be adjusted to maintain the setpoint. The best method for control would be to have an individual chlorine feeder dedicated to each feed point. In lieu of dedicated feeders, flow control valves and flow meters could be utilized to measure and control chlorine solution to each feed point.
- If chlorine is selected as the long term disinfectant, the following improvements are recommended:
  - Chlorine feed room access to the interior of the building should be eliminated to prevent chlorine gas from escaping into occupied areas of the plant. Access should only be from the exterior.
  - Chlorine ton containers should be stored on floor-mounted trunnions to prevent containers from inadvertently moving.
  - The existing monorail should be extended outdoors for truck unloading to eliminate rolling of the containers.
  - Separate water systems, isolated by a backflow preventer, should be provided for pre and post filter application points.
  - An emergency chlorine gas scrubber should be installed to remove chlorine gas from the storage room interior in the event of a chlorine gas leak. It is also advisable to have at least two chlorine gas detectors in the Chlorine Storage Room and one in the Chlorine Feed Room.

The proposed improvement alternatives for the chlorine feed system are discussed in Section 8.10.

5.8.3 Fluoride Feed System

Fluoride is delivered, stored and fed as 24% hydrofluosilicic acid. The fluoride feed system consists of an outdoor bulk storage tank (constructed of HDPE), an indoor 60-gallon HDPE day tank, and three tube-type peristaltic metering pumps. Existing metering pumps are Wallace & Teirnan ChemTube PPS pumps with a nameplate maximum capacity of 5 gph at 120 psi. The nameplate indicates the pumps were supplied in 2011. Fluoride metering pumps are not flow paced, but manually controlled by operators. At the time of the condition assessment, one pump was running at approximately 20.6% of capacity.

Fluoride solution is transferred from the bulk tank to the day tank by gravity via single contained underground PVC pipe into the operations building lower level. The operator manually opens a valve at the day tank and then the day tank fills until the valve is manually closed. There was no automatic shut off of the day tank fill piping when the day tank reaches maximum level. The day tank rest on a floor scale to remotely monitor tank contents.

The fluoride area in the lower level was not isolated from other rooms in the building. Secondary containment was provided around the pumps and day tank. However, within the containment area there was a floor drain. It was unclear where the drain terminated.

Indoor fluoride piping was in fair condition with some leaks evident in the system. Outdoor feed piping from the storage tank to the day tank is small-diameter, single contained piping that is vulnerable to breakage and UV light degradation.

The outdoor storage tank is located inside an unlined, uncovered, concrete secondary containment basin with walls approximately 4 feet high. There was no personnel access to the basin by ladder or stairs nor was there a means to remove rainwater or spilled liquids. The tank does not have an overflow nozzle, drain nozzle, or site liquid level gauge. Plant operations staff indicate that the tank is more than 10 years old.

A pressure sensing level transmitter is used to monitor the fluoride bulk storage tank level. This instrument appears to be in good working condition, but it is a blind transmitter. To allow the operator the ability to accurately know the fluoride level in the tank without the plant control system, Black & Veatch would recommend a digital display be added or to replace the pressure sensing level transmitter with one that has a digital display.

5.8.3.1 Fluoride Feed System Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- The feed system has sufficient capacity for 32 MGD.
- The fluoride day tank fill system is highly susceptible to leaks or mishaps that could result in a day tank overflow into the building lower level. The piping from the storage tank should be upgraded to double-contained piping for a more robust piping system that protects the primary pipe from damage. While gravity fill is not recommended, the day tank fill pipe should be fitted with an electric valve to automatically shutoff flow when the day tank reaches a maximum liquid level.
- The fluoride feed system has only manual controls. The chemical feed rate is manually set by the operator. Automatic controls could be added to adjust the feed rate based on flow to maintain a desired dose. Leak detection, and pump fault alarms could also be incorporated into the operations for better operator control.
- The fluoride day tank and metering pump area should be divided off from other areas of the building and provided with a dedicated ventilation system. Fluoride vapors are highly corrosive to metals and electronics even those not associated with the fluoride feed system. Isolation of the fluoride area interior space will ensure longevity of other equipment in the building.
- The fluoride storage tank is likely near replacement. A new tank should be provided with adequate capacity to accept a full truckload of fluoride plus an additional 25%. This volume equates to approximately 5,500 gallons. The new tank should incorporate a flush bottom drain, overflow nozzle, pump suction, site level gauge, vent, and top and side manways. If possible, the tank and containment area should be covered with a canopy to protect piping from UV exposure and prevent accumulation of rainwater
- The storage tank containment area should be fitted with stairs or a ladder to allow for personnel access to the interior. Additionally, the storage tank containment area should be

fitted with a sump or other means to accumulate and remove rainwater and spilled liquids in the containment area for proper disposal.

- The storage tank containment area (and day tank and metering pump area) should be lined with a corrosion protection liner to prevent acid spills form damaging the concrete. The drain should be plugged. The plug should be configured to be removable to allow the drain to be utilized during washdown.

The proposed improvement alternatives are discussed in Section 8.11.

5.8.4 Ammonia Feed System

Liquid ammonium sulfate (LAS) is delivered, stored and fed as 40% LAS solution. The LAS system consists of an insulated outdoor bulk storage tank (constructed of HDPE), two indoor 125-gallon HDPE day tanks, and four tube-type peristaltic metering pumps. The outdoor storage tank is insulated for freeze protection. Existing metering pumps are Wallace & Teirnan ChemTube PPS pumps with a nameplate maximum capacity of 5 gph at 120 psi. The nameplate indicates the pumps were supplied in 2011. LAS metering pumps are flow paced with chlorine residual to maintain a chloramine residual.

The ammonia system is the primary reason why the redundant finish water transmission main is not in use as the current pumps do not have sufficient turndown to meet the lower feed ranges if the flow is split between two pipes. New tubes or replacement of the pumps are recommended to allow both mains to be in service.

LAS flow is transferred from the bulk tank to the day tank by gravity via single contained underground PVC pipe into the operations building lower level. The day tank fill process is automatic from plant SCADA with an electrically actuated valve above the day tank. The day tanks rest on a floor scale to remotely monitor tank contents.

The LAS area in the lower level was not provided with secondary containment around the pumps and day tank.

Indoor LAS piping was in poor condition with numerous leaks evident in the system. Outdoor feed piping from the storage tank to the day tank was small-diameter, single contained piping that is vulnerable to breakage.

The outdoor storage tank is inside an unlined concrete, uncovered, secondary containment basin with walls approximately 4 feet high. There is no personnel access to the basin by ladder or stairs nor is there a means to remove rainwater or spilled liquids. The tank does not have a site liquid level gauge. Plant operations staff indicated that the tank is more than 10 years old.

Two chemical day tanks are used to store the liquid ammonium sulfate. Each tank has a load cell that is connected to a dual channel display/transmitter. The load cells and dual channel display/transmitter appear to be working well.

5.8.4.1 Ammonia Feed System Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- The feed system has sufficient capacity for 32 MGD.
- The pump heads or tubes should be resized, or new pumps provided, to allow both finished water lines to be utilized. If new pumps are provided, only three are required, one to serve each transmission main and a common backup.
- The LAS day tank and metering pump area should be provided with secondary containment to prevent uncontained spills of LAS into the lower level.
- The piping from the storage tank should be upgraded to double-contained piping for a more robust piping system that protects the primary pipe from damage.
- LAS day tank fill procedures should be modified to manually-initiated fill with automatic shutoff when the day tank reaches a maximum liquid level. High level alarms should be added in the event of the shutoff valve not properly closing.
- The LAS storage tank is likely near replacement. A new tank should be provided with adequate capacity to accept a full truckload of ammonia plus an additional 25%. This volume equates to approximately 5500 gallons. The new tank should incorporate a flush bottom drain, overflow nozzle, day tank suction piping, site level gauge, vent, and top and side manways. If possible, the tank and containment area should be covered with a canopy to protect piping from UV exposure and prevent accumulation of rainwater
- The storage tank containment area should be fitted with stairs or a ladder to personnel access to the interior. Additionally, the storage tank containment area should be fitted with a sump or other means to accumulate and remove rainwater and spilled liquids in the containment area for proper disposal.

The proposed improvement alternatives are discussed in Section 8.12.

5.9 WASH WATER TOWER

The wash water tower was constructed in 1970 as part of the original plant. It provides sufficient capacity for backwashing of the filters by gravity flow. The plant also has a backwash pump for backup.

The wash water tank tower foundation was inspected from the outside by walking the perimeter of the foundation at grade level and by viewing the interior from the entry platform. All observations were done from normally accessible space. No interior inspections were completed.

Exterior notable items are twelve locations of scaling of the concrete foundation wall and minor staining of the interior concrete. Example scaling and staining conditions are shown in the following photos. The scaling of the exterior concrete foundation is due to rain water runoff eroding the surface cement paste from the concrete and leaving the aggregate more exposed. This deterioration is minor in nature at this time. At the owner's option, a coating can be applied to the exterior exposed surfaces. A cementitious waterproofing similar to Thoroseal can be applied to prevent further deterioration. The staining of the interior concrete is most likely due to condensation water from the tower surfaces accumulating on the base slab. The condensation water is likely depositing surface corrosion product from the piping, valves, and tower. The surface corrosion in the interior is very minor and considered superficial at this time.

Scaling Due to Erosion of Cement Paste at Base of Wash Water Tower.

Staining on Interior Surfaces of Tower Foundation Concrete Walls and Base Slab.

A Foxboro pressure sensing level transmitter is used to monitor the backwash tank level and seems to be in good condition. The transmitter has an LCD display, but it is configured to display the pressure instead of the level. Black & Veatch suggests that the transmitter be reconfigured, so that it displays the backwash tank level.

The flow from the backwash tank is also measured, monitored, and controlled by the plant control system. A Foxboro differential pressure sensing flow transmitter is used to measure the differential pressure across an orifice plate to determine the flow. Similar to the backwash tank level signal, the flow signal is also connected to a remote I/O panel and monitored by the plant's Main PLC. This flow instrument also appears to be in good working condition. In order to make it easier for the operators, it is recommend to reconfigure to display flow instead of differential pressure.

5.9.1 Wash Water Tank Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

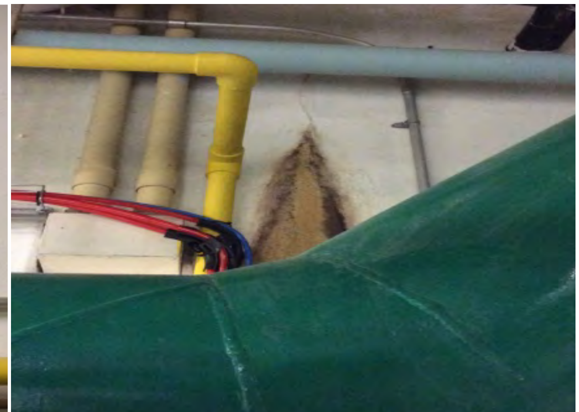
- The wash water tank provides sufficient capacity for washing the filters. A backwash pump is available if the tank has to be off-line for cleaning and painting.
- An interior inspection was not conducted as part of this evaluation. The inside should be inspected to determine condition and if re-coating is required.
- Minor exterior repairs should be addressed.

5.10 TUNNELS AND CHEMICAL BUILDING BASEMENT

The chemical building basement and tunnels between the primary and secondary clarifiers were inspected from the interior spaces. All observations were done from normally accessible space.

Notable structural items for the tunnels include various cracks in the tunnel walls. Example cracks are shown in the following photos. These cracks are due to temperature and shrinkage effects. We recommend injecting the leaking cracks in the walls with hydrophilic polyurethane foam. Ideally these should be repaired during winter or early spring months during the period where the cracks are widest.

Crack in Tunnel wall.



Crack with Active Leak at Basin Corner in Chemical Building Basement.

Piping and valves located within the tunnel and basement appeared to be good condition except for the plant service water isolation valves. Many of these are inoperable and need to be replaced. Replacement will need to be sequenced to allow the plant to remain in operation.

5.11 WEST ASH BOOSTER PUMP STATION

Transmission mains from the Water Treatment Plant extend to the West Ash Booster Pump Station and reservoir. The Pump Station consists of five vertical turbine pumps. All the pumps were installed as part of the original construction in 1970. There is space within the building for one additional pump.

The pumps draw suction out of onsite underground reservoirs through two 30 inch suction headers. The booster station provides pressure to the distribution system and is controlled off the water level in the Walnut Tank. Each pump has a manual isolation valve on the suction line, and a motor operated discharge isolation valve with battery backup. A check valve and flow meter is located on each discharge pipe.

5.11.1 Pump Station Capacity

Pumps 2, 3, 4, and 5 are all rated 2,800 gpm at 241 ft. Pump 1 is rated t 3,800 gpm at 193 ft. Pump 2 is connected to a gas driven engine generator for backup. Table 5-17 summarizes the pump criteria.

Table 5-17 Pump Criteria

	PUMP 1	PUMP 2	PUMP 3	PUMP 4	PUMP 5
Rated Flow, gpm	3,800	2,800	2,800	2,800	2,800
Rated Head, ft	193	241	241	241	241
Rated Speed, rpm	1,770	1,780	1,785	1,770	1,767
No. of Stages	2	3	3	3	3
Manufacturer	Layne	Layne	Layne	Layne	Layne
Serial No.	100375	64517	64519	64520	64518
Motor hp	250	250	250	225	250

Available SCADA data from June 2015 was plotted in Figure 5-4 to develop a system head curve for the pump station. Based on the information available and head conditions observed, the pump station has a firm capacity of between 17 and 19 MGD. If all five pumps are in operation, the pump station capacity is increased to about 22-24 MGD.

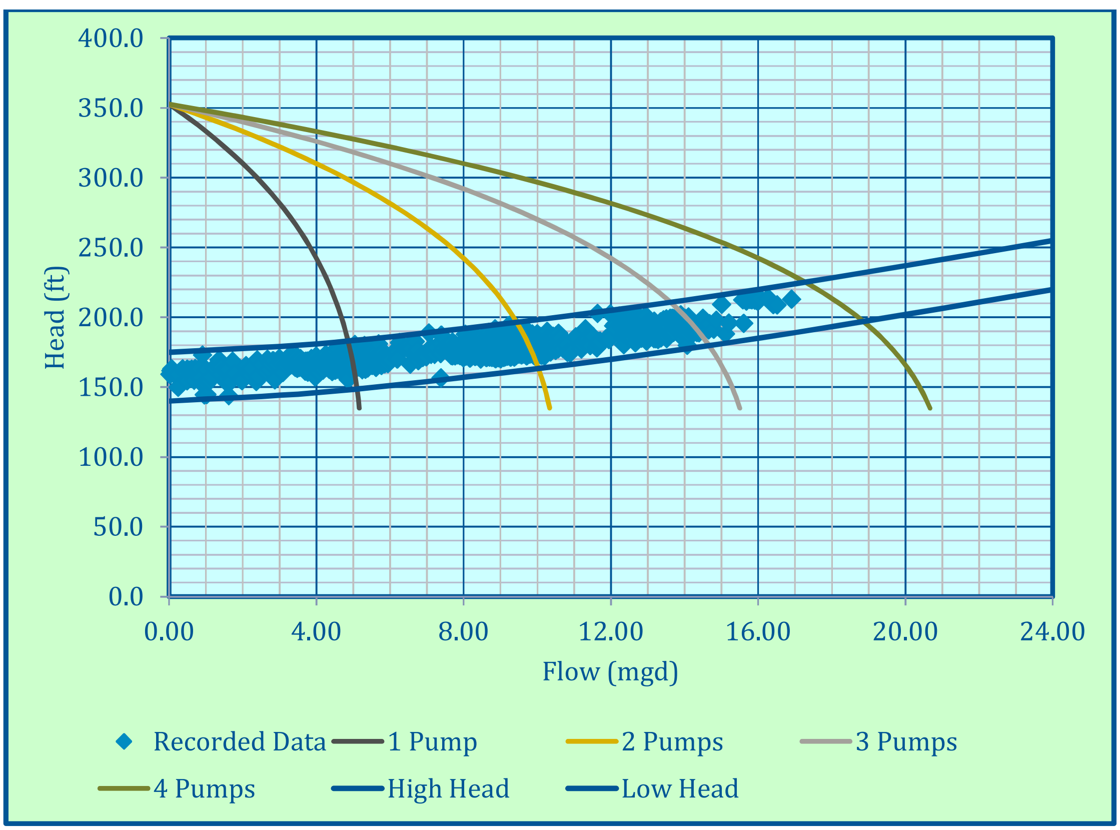


Figure 5-5 West Ash Booster Pump Station Head Curves

5.11.2 Pump Station Condition

No significant issues were observed with the conditions of the pumps. Pumps 2, 3 and 4 are the original pumps from 1972. Pump 1 has nameplate date of 1983. No information was available on Pump 5. Recently, pumps 2 and 3 were rebuilt with new gear boxes and motors.

The pump discharge isolation valve actuators are from the original construction. The Limotorque actuators are controlled through connections to the individual pump motors. If power is lost to the pump station, the valves close utilizing a battery bank. Generally, the actuators have performed as intended. However, the pump station has flooded in the past when the valves have not properly closed. The controls are antiquated and enclosures difficult to access and maintain.

Pump Motors and Motor Starter

The five West Ash Booster Pump motors are of various ages and configurations. All motors were operational when observed, except for pump 3 which was disassembled due to a recent failure of the original eddy current drive equipment which could not be repaired. CW&L staff had replacement electrical equipment for pump 3 ready nearby consisting of a new 460V rated motor, 2300-480Y/277V dry-type stepdown transformer and 480V VFD unit similar to the arrangement of the high service pump motors at the Water Treatment Plant. CW&L staff reported that they plan to replace or re-wind the original 2,300V motors to have a 460V rating, as appropriate, whenever a motor problem requires major maintenance or repair. For the units which are changing to 460V, CW&L is also installing 480V VFD units on these units to gain variable speed capability. Table 5-18 below indicates the general details of each West Ash Booster pump motor and starter as well as any general installation details.

Table 5-18 West Ash Booster Pump Motors

BOOSTER PUMP	YEAR INSTALLED[1]	HORSE-POWER	VOLTAGE	STARTER TYPE	INSTALLATION NOTES
1	1995	250	2300	Contactor	Original motor likely previously rewound.
2	1971	250	2300	Contactor	Original 2300V motor rewound at least once in the past by Illinois Electric Co. Installation includes a mechanical clutch to an existing natural gas engine as a back-up prime mover.
3*	2015*	300	460*	VFD*	*No electrical installation was present at the time of observation in April 2015. New motor, transformer and VFD components were present on the operating floor awaiting installation. It is assumed that CW&L will complete the installation of the replacement equipment before the end of the calendar year.
4	1971	225	2300	Contactor	Original motor likely previously rewound. Includes original eddy current drive which CW&L reports is difficult to maintain and limits serviceability of this pump.
5	1971	250	2300	Contactor	Original motor likely previously rewound. Includes vibration and temperature protection.
1. Year of installation indicated is approximate.					

Instrumentation

A Hach APA 6000 ammonia/monochloramine analyzer is used to measure the ammonia concentration at the pump station. A new generation of these analyzers (model 5500sc) has been released by Hach. Since the existing analyzer will still be supported by Hach and appears to be in good working condition, there is no need to replace the analyzer at this time. We recommend that the analyzer not be installed in the same room as the plant control system hardware as it currently is to avoid water damage to the plant control hardware.

A Hach CL17 chlorine residual analyzer is also used at the West Ash Booster Pump Station. This analyzer appears to be relatively new and in good working condition. Similar to the ammonia/monochloramine analyzer, Black & Veatch would also recommend that this analyzer be moved away from the plant control system hardware.

Differential pressure sensing flow transmitters are used with an orifice plate to measure the booster pump station effluent flows. The transmitter is a blind instrument, so without the PLC, the operator cannot view the flow. It will be very difficult to replace the orifice plate, but there are few things that can go wrong with an orifice plate. The differential pressure instrument is a standard instrument and can be easily replaced if it fails. Currently, only one of these flow meters is working, so the differential pressure units that have failed should to be replaced.

Suction pressure at the booster station is also monitored. A pressure transmitter is installed in an old chart recorder enclosure. This instrument is a blind unit, so the operator cannot view the suction pressure at the instrument. This instrument is currently working, but we would recommend that the existing transmitter be replaced with an industrial rated, indicating transmitter. The old chart recorder and pressure transmitter can be demolished, and the new pressure transmitter installed in its place.

Ultrasonic level transmitters are used to monitor the reservior levels at the booster pump station. CW&L reports that these instruments have failed in the winter when condensation freezes on the sensor face. To prevent this from happening again, Black & Veatch would recommend that the ultrasonic level transmitter and transducer be replaced with a unit that has a special transducer that is equipped with a heater. Each booster pump is equipped with Mercoid pressure switches for pump protection. These pressure switches are hardwired in the pump control logic. The pressure switches appear to be older, but they are operational. These pressure switches could be replaced easily as needed.

5.11.3 West Ash Booster Station Existing Condition Summary

The following summaries the findings and preliminary recommendations from the condition assessment;

- Based on the current operating conditions, the existing pump station has a firm capacity of between 17 and 19 MGD. If one additional identical pump is added, the firm pump station capacity is increased to 22-24 MGD.
- In general, the existing motors appeared serviceable with all motors being able to maintain operation with proper maintenance and with the potential for re-winding to refurbish a motor core as needed. The notable exception is Booster Pump 4 and its eddy current drive. The eddy current drive unit controls are obsolete and repair parts and/or availability are questionable. CW&L has already experienced a catastrophic failure on the identical Booster

Pump 3 and has chosen not to repair but completely replace the previous motor and eddy current drive unit.

- Make repairs and/or maintenance improvements in coordination with planned improvements to the larger electrical system. It is suggested that additional pump motors not be rewound or replaced with a configuration different from its respective original installation until a master plan for electrical improvements is in place.
- Booster Pump 2 with its mechanically connected natural gas engine is currently the only source of standby power for pumping at the station. The gas engine is located in the same vicinity as the pumps and is original equipment to the pump station. An electrical solution which allows standby power from a stand-by source to be directed to any of the pumps is recommended.
- Booster Pumps 2, 4 and 5 are the oldest remaining units. These units should be the first to be addressed in any systematic upgrades.
- Booster Pump 4 should have its eddy current drive removed at the earliest opportunity. The controls are obsolete, service support is difficult to obtain and the equipment is beyond its expected service life.
- Repair effluent flow meter and move analyzers away from control cabinets.
- Replace discharge isolation valve actuators.

The proposed improvement alternatives are discussed in Section 8.18.

5.12 ELECTRICAL POWER DISTRIBUTION

5.12.1 Well Field

All of the well installations are powered from an underground, three-phase, 13.8 kV distribution feeder network which is owned, operated and maintained by the Light Department of CW&L. At an area adjacent to each well or group of wells, the 13.8 kV power circuit is brought above ground on a service pole and routed to pole mounted step-down transformers. Poles and transformers for the wells are also owned, operated and maintained by the Light Department of CW&L. The supply voltage is reduced to 480 V and routed to a service meter. The 480 V, three-phase service is split into feeders on the pole for the respective wells served and then individual service feeders are routed underground to each respective well in their own conduits. Refer to the following photo as an example of one of these service platforms serving Wells 13, 14 and 15.

Wells 13, 14 and 15 Service Platform

The 480 V service feeders are routed to the electrical equipment on the well head elevated platforms. The 480 V power supply terminates at either a separately mounted main disconnect switch or a main disconnect which is part of the respective well's motor controller panel. From this main 480 V feed, power is routed to the motor controller unit as described in the Well Field section of this report as well as to a small step-down transformer located within or adjacent to the well motor control panel to derive 120 V single-phase power for lighting and receptacle, ventilation and control equipment for the respective well. Standby power is available at all wells in the case of utility power outage from engine-generators located at the Water Treatment Plant as described in the next section.

Since the electrical power distribution system is owned, operated and maintained by the Light Department of CW&L, the Water Department is not directly responsible for this equipment. No deficiencies were noted by Black & Veatch or CW&L staff regarding this power distribution system; however, is it recommended that the Water staff monitor the condition and operation of the power supply equipment and alert the Light Department to any issues which need correction. It is also recommended that particular attention be paid to issues of lightning/surge arresting equipment, proper overcurrent protection devices, service disconnects, proper grounding systems and adherence to NEC code requirements for spaces about electrical equipment when any systematic upgrade to the wells are considered. Deficiencies in some of these areas were suspected during field investigation.

5.12.2 Water Treatment Plant

5.12.2.1 Utility Service and Outdoor Substation

Utility electrical power for the Water Treatment Plant is derived from an overhead, three-phase, 13.8 kV distribution feeder loop network which is owned, operated and maintained by the Light Department of CW&L. Two service poles located near the plant entrance gate bring two 13.8 kV service feeders underground onto the plant site and terminate at a pair of adjacently located pad mounted medium-voltage sectionalizing switches. These switches have the capability to switch each feeder connection to the plant's main transformers described below so that they are powered from one or both 13.8 kV loop circuits or connected to either of two onsite engine-generator standby sources in the case of problems or outage on the utility distribution system. The diesel engine-generators are outdoor self-contained units located adjacent to the electrical substation and are capable of providing standby power for the entire plant and also for back-feeding the 13.8 kV utility line network to provide standby power to the well field. Generators are connected to transformers which step-up their native voltage to 13.8 kV for utilization on the 13.8 kV utility network. A third underground utility line originating from a different source and from a different direction was reported by CW&L staff to exist and is connected to one of the sectionalizing switches. This third utility line has the potential to be a further redundant source of utility power for the plant; however, CW&L staff reported that this line is currently not serviceable due to damage to the line causing ground faults.

Feeders from each of the sectionalizing switches are then routed to two substation style oil-filled transformers which step-down the voltage from 13.8 kV to 2.4 kV for utilization at the Water Treatment Plant. The transformers are not original to the plant construction. They are estimated by CW&L staff to have been replaced circa 1990. The transformers appeared to be weathered but serviceable. The transformers are critical electrical equipment with each transformer supporting about half of the plant's capacity. The CW&L staff reported that the City Light Department does not and will not maintain spare transformers in their inventory with a 2.4 kV service voltage in the future due to their general rarity in the utility's system. Therefore, the transformer equipment is near the end of its service life and is obsolete. The City Water Department will have to make special arrangements to maintain and/or replace this transformer if it were to become necessary. A long lead time for this type of repair or replacement would be expected.

The 2.4 kV service feeders from each transformer route underground and terminate at two medium-voltage motor control center line-ups in the Filter Building. One feeder is original to the plant construction and terminates in the original 2.4 kV service load center installed during the plant's initial construction. The second feeder terminates at a 2.4 kV service load center installed in the Filter Building Expansion which was added under an expansion project around 1995. This second feeder also has a sub-feeder from the transformer secondary connection to an adjacent step-down transformer located in the outdoor substation which derives 480 V power for the Maintenance Building. The 13.8 kV sectionalizing switches, the two main 2.4 kV step-down transformers and the Maintenance Building step-down transformer and the generator step-up transformers are all located in a fenced outdoor substation on the east side of the plant.

The electrical service power distribution system consisting of the two service poles, 13.8 kV feeder cables and conduits, two 13.8 kV sectionalizing switches, two engine-generators with step-up transformers, two plant main service step-down transformers (2.4 kV) and the Maintenance Building step-down transformer (480V) is owned, operated and maintained by the Light Department of CW&L. The Water Department is not directly responsible for this equipment. No deficiencies were noted by Black & Veatch or CW&L staff regarding this power distribution system other than the faulted redundant utility feeder and the limited availability of replacement power transformers with a voltage of 2.4 kV. It is recommended that the Water staff monitor the condition and operation of the power supply equipment and alert the Light Department to any issues which need correction. As part of the next stage of the condition assessment and preliminary design, a desired solution to the issue of the 2.4 kV service issue will have to be determined and coordinated with the Light Department.

5.12.2.2 Electrical Load Centers (2.4kV)

The 2.4 kV electrical distribution load centers consist of two distinct installations located in the Filter Building. The first is the original portion of the electrical system installed with the initial plant construction around 1971. The second is the portion of the electrical system installed as part of the expansion of the Filter Building around 1995.

The original portion of the Filter Building includes a 2.4 kV motor control center as its main service load center. The load center is a service entrance for one of the utility feeders and includes a utility power meter at its main disconnect. The load center contains contactor starters for High Service Pumps 1 through 4 as well as eddy current clutch controls for two high service pump units. One of the eddy current units is no longer installed as it has been replaced by a new motor and VFD as described in the High Service Pumps Section. Fused switches for feeders to Power Centers 1 and 2 from which 480V power is derived for the original Filter Building and Operations/Chemical Feed Areas, respectively, as well as a tie connection to the newer Filter Building Expansion 2.4 kV load center are also included. The motor control lineup is over 40 years old and is a custom fabricated motor control and switchgear line-up created by Central Electric Co. The load center consists of mainly Westinghouse components. Both Central Electric Co. and Westinghouse are no longer in business. While the overall visual condition of this load center is good, the equipment is at the end of its useful life with many components no longer being produced.

The expansion portion of the Filter Building includes a 2.4 kV motor control center as its main service load center. The load center is a service entrance for one of the utility feeders and includes a utility power meter at its main disconnect. The load center contains contactor starters for High Service Pumps 5 through 8 as well as fused switches for feeders to Power Center 3 and Motor Control Center 4 from which 480 V power is derived for the Chemical Building expansion and the Filter Building expansion, respectively, as well as a tie connection to the original Filter Building 2.4 kV load center. The motor control lineup is approximately 20 years old and is a standard motor control product (Limitamp model) manufactured by General Electric. The overall visual condition of this load center is good and the components contained within the equipment should be available for the foreseeable future.

5.12.2.2.1 Electrical Load Centers (2.4kV) Existing Condition Summary

The following summaries the findings and preliminary recommendations from the condition assessment;

- The 2.4 kV load centers are critical equipment to the plant operation. All power for the plant process loads originate from one of two load centers for which approximately half of the load is shared between each unit. One load center is over 40 years old and is obsolete and at the end of its expected life. The other load center is still serviceable, but with the issue of the Light Department not supporting services at 2.4 kV as described in the preceding section, the newer 2.4 kV load center may not have significant usefulness as an existing asset with any pending change to the service voltage. The following recommendations and potential improvements should be considered:
- Make repairs and/or maintenance improvements in coordination with planned improvements to the larger electrical system.

- In general, 2.4 kV load centers should be replaced with new load centers at a different voltage and 2.4 kV should no longer be utilized on the plant site. 480 V services and service load centers are feasible with the existing plant infrastructure.
- Any capital improvements should be staged to start with the original Filter Building 2.4 kV load center as it is the oldest and most in need of immediate replacement.

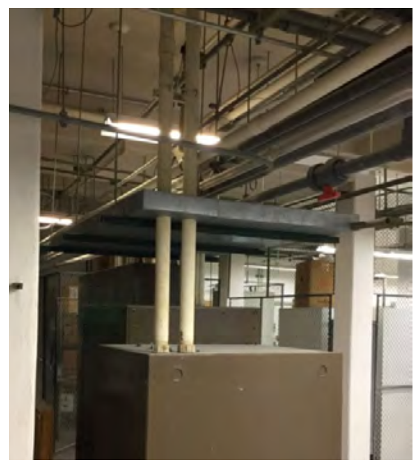
5.12.2.3 480 V Electrical Load Centers

All 480 V power, with the exception of the Maintenance Building and MCC-4 in the Filter Building Expansion, originates from one of three indoor secondary unit substations on the plant site called Power Centers. In each case, a power center is comprised of a medium-voltage switch or air-terminal connection, an integral dry-type transformer(s) and a close coupled 480 V distribution panelboard. The power center equipment is critical to the plant's operation as failure of any of these power centers will result in partial or total shutdown of the plant.

Power Center 1 is located on the operating floor of the original Filter Building and supplies power to Filters 1 through 4 as well as the original Filter Building mechanical loads. Power Center 1 is over 40 years old and is a custom fabricated substation consisting of a 2.4 kV air terminal connection (disconnect switch located at adjacent 2.4 kV motor control line-up), a 300 kVA 480 V step-down transformer, a 37.5 kVA 120/240 V dry-type transformer, a 5 kVA 120/240 V dry-type transformer and an integral 480 V distribution panelboard. Refer to the following photo. The load center consists of mainly Westinghouse components. Westinghouse is no longer in business. CW&L staff reported this unit started smoking in the recent past; however, the unit did not fail and has continued in operation. The CW&L staff is sufficiently concerned that replacement equipment has been procured and was observed sitting nearby. Replacement is not planned until a catastrophic failure is realized due to the fact that the unit cannot be replaced without shutting down the majority of the plant. Power Center 1 is at the end of its useful life and is not considered reliable.

Power Center 1

Power Center 2 is located in the basement of the Operations Building and supplies power to the original Chemical Feed and Lime Handling loads as well as Settling Basins 1 and 2 and the Aerators. Power Center 2 is over 40 years old and is a custom fabricated substation consisting of a 2.4 kV disconnect switch, a 500 kVA 480V step-down transformer, 50 kVA, 37.5 kVA and 7.5 kVA 120/240V dry-type transformers, an integral 480 V distribution panelboard and a close coupled motor control center (MCC-2). Refer to the following photo. The load center consists of mainly Westinghouse components. Westinghouse is no longer in business. When the unit was observed, excessive vibration and noise caused by ferroresonance in one of the transformer units was noted. Additionally, the unit has a number of water or chemical pipes running directly over the electrical equipment. This does not meet the requirements of the NEC which require the area 6-feet above all electrical distribution equipment to be free of any non-electrical installations. Furthermore, there is evidence that leaking pipes may have caused issues previously as a large drip tray has been fabricated and installed. Refer to the following photo. Power Center 2 installation is not well suited for critical electrical equipment. Since it is the same age as Power Center 1, it is at the end of its useful life and is not considered reliable.



Power Center 2

Power Center 3 is also located in the basement of the Operations Building and supplies power to the expanded Chemical Feed loads as well as the Operations Building ground floor. Power Center 3 is approximately 20 years old and is a standard substation product consisting of a 2.4 kV disconnect switch, a 500 kVA 480 V step-down transformer and a close-coupled 480 V distribution panelboard. The load center is manufactured by General Electric. The overall visual condition of this load center is good and the components contained within the equipment should be available for the foreseeable future.

Motor Control Center 4 is the final source of 480V power on the plant site and is located in the Filter Building Expansion and supplies power to Filters 5 through 8 as well as the Filter Building expansion mechanical loads and Lime Feed Expansion. Motor Control Center 4 is approximately 20 years old and is a standard motor control center with a 750 kVA 480 V step-down transformer source close-coupled to its main breaker section. The motor control center and transformer are manufactured by General Electric. The overall visual condition of this load center is good and the components contained within the equipment should be available for the foreseeable future.

5.12.2.3.1 480V Load Centers Existing Condition Summary

The following summaries the findings and preliminary recommendations from the condition assessment;

- The 480 V load centers are critical equipment to the plant operation. All 480 V power for the plant process and building loads originate from one of four load centers. No load center has any backup source of power or redundancy, meaning an outage on any of the four load centers will result in partial or total shutdown of the plant. Power Center 1 and 2 are over 40 years old and are obsolete and at the end of their expected lives. Power Center 3 and MCC-4 are still serviceable and could remain in service with modifications as needed to revise or eliminate their respective 2.4 kV power sources in coordination with the changes recommended in the previous section. The following recommendations and potential improvements should be considered:
- Make repairs and/or maintenance improvements in coordination with planned improvements to the larger electrical system.
- Power Centers 1 & 2 should be replaced with new load centers due to their age and condition.
- Power Center 2 replacement load center should be located in a different location from the current location since the current location does not meet the requirements of the NEC.
- Power Center 3 and MCC-4 should be modified to eliminate their 2.4 kV power sources and utilize a new 480V sub-feed from a new 480 V power source. All downstream circuits would remain and be unaffected.

5.12.2.4 Panelboards and Small Transformers

Electrical panelboards and small dry-type transformers are located throughout the plant site and are of different ages, configurations and voltages. Panelboards are utilized to supply feeders to smaller process and building mechanical loads. Table 5-19 below indicates the general details of each existing panelboard as well as any general installation details.

Table 5-19 Panelboards and Small Transformers

TAG NO.	YEAR INSTALLED[1]	BUS AMP RATING	VOLTAGE RATING	MOUNTING TYPE	INSTALLATION NOTES
H1	1971	100	120/240	Surface	Located in the Operations Building basement. Source transformer located in Power Center 2.
H2	1971	100	120/240	Flush	Located in the north wall of the Filter Building. Source transformer located in Power Center 1.
L1	1971	225	120/240	Flush	Located in the east wall of the Operations Building, Control Room/Office area. Source transformer located in Power Center 2.
L2	1971	225	120/240	Surface	Located in the Operations Building basement. Source transformer located in Power Center 2.
L3	1971	225	120/240	Flush	Located in the north wall of the Filter Building. Source transformer located in Power Center 1
LP1	1995	225	120/240	Flush	Located in the Operations Building hallway. Source transformer (T4) located in basement adjacent to Power Center 3.
LRP1	1995	225	120/240	Flush	Located in the Operations Building hallway. Source transformer (T5) located in basement adjacent to Power Center 3.
LRP2	1995	225	120/240	Surface	Located in the Operations Building basement. Source transformer (T3) located adjacent.
PP2	1995	225	480	Surface	Located in the Operations Building basement. Source is adjacent Power Center 3.
LP10	1995	225	120/240	Surface	Located in Filter Building expansion Electrical Room. Source transformer (T10) is adjacent.
PP10	1995	225	480	Surface	Located in Filter Building expansion Electrical Room. Source is adjacent MCC-4.
LP11	2005	225	120/208	Surface	Located in Filter Building expansion Electrical Room. Source transformer (T11) is adjacent.
PP11	2005	225	480	Surface	Located in Filter Building expansion Electrical Room. Source is adjacent MCC-4.
LP-L1	2005	125	120/208	Surface	Located in Lime Feed expansion Electrical Room. Source transformer (T-L1) is adjacent.
PP-L1	2005	600	480	Surface	Located in Lime Feed expansion Electrical Room. Source is MCC-4 in Filter Building.
PPDC	1971	400	125 (VDC)	Flush	Located in the north wall of the Filter Building. Source battery rack located adjacent.

1. Year of installation indicated is approximate.

5.12.2.4.1 Panelboards and Small Transformers Existing Condition Summary

The following summaries the findings and preliminary recommendations from the condition assessment;

- The panelboard equipment are not critical equipment to the plant operation, however the oldest panelboards at the plant are nearing the end of their expected life span. 480 V and 125 VDC power panels are the most important as they support the larger and critical valve actuator loads, respectively. Only the panelboards installed circa 2005 include surge protection equipment which may protect the panel and associated loads from any surge events encountered. The following recommendations and potential improvements should be considered:
- Investigate older panelboards as part of other pending electrical improvements.
- Replace panelboards for which parts are no longer available and include features such as main breakers and surge protection devices in each panel.

5.12.3 West Ash Booster Pump Station

5.12.3.1 Utility Service and Outdoor Substation

Utility electrical power for the West Ash Booster Pump Station is derived from two overhead, three-phase, 13.8 kV distribution feeder circuits which are owned, operated and maintained by the Light Department of CW&L. Two service poles located on the southeast corner of the site and on the west side (across Bernadette Dr.) of the site bring two 13.8 kV service feeders underground onto the pump station site and terminate at a pair of adjacently located substation style oil-filled transformers which step-down the voltage from 13.8 kV to 2.4 kV for utilization at the pump station. The transformers appeared to be weathered but serviceable. The transformers are critical electrical equipment with each transformer providing 100% of the pump station capacity. The CW&L staff reported that the City Light Department does not and will not maintain spare transformers in their inventory with a 2.4 kV service voltage due to their general rarity in the utility's system. Therefore, the transformer equipment is near the end of its service life and is obsolete. The City Water Department will have to make special arrangements to maintain and/or replace this transformer if it were to become necessary. A long lead time for this type of repair would be expected.

From the transformers, 2.4 kV feeders are connected to an adjacent pad-mounted automatic transfer switch. CW&L staff reported that the automatic switch controls of this switch were not working and needed repair, however manual switching of the device was still possible if required. CW&L also reported the Bernadette Dr. service drop was the preferred utility circuit while the southeast service drop was used as a standby source. There is no on-site electrical generation present at the West Ash Booster Pump Station. A single 2.4 kV service feeder from the automatic transfer switch routes underground and terminates at a medium-voltage motor control center line-up in the Pump Station on the operating level. The feeder is original to the station construction and terminates in the original gear installed from the plant's initial construction. The two main 2.4 kV step-down transformers and the automatic transfer switch are all located in a fenced outdoor substation on the north side of the pump station site.

The electrical power distribution system consisting of the two service poles, 13.8 kV feeder cables and conduits, two service step-down transformers (2.4 kV) and the pad-mounted automatic transfer switch is owned, operated and maintained by the Light Department of CW&L. The Water

Department is not directly responsible for this equipment. No deficiencies were noted by Black & Veatch or CW&L staff regarding this power distribution system other than the non-functional automatic source switching feature of the transfer switch and the unavailability of replacement power transformers with a voltage of 2.4 kV. It is recommended that the Water staff monitor the condition and operation of the power supply equipment and alert the Light Department to any issues which need correction. As part of the next stage of the condition assessment and preliminary design, a desired solution to the issue of the 2.4kV service issue will have to be determined and coordinated with the Light Department.

5.12.3.2 2.4 kV Electrical Load Center

The 2.4 kV electrical installation consists of a single 2.4 kV motor control switchgear line-up located on the operating level. The original portion of the electrical load center was installed with the initial pump station construction around 1971. The line-up was modified and expanded as planned future pumps were added at later dates. The load center is a service entrance for the utility feeder and includes a utility power meter at its main disconnect. The load center contains contactor starters for Booster Pumps 1 through 5 as well as eddy current clutch controls for two booster pump units. One of the eddy current units is no longer installed and has been demolished and will be replaced by a new motor and VFD as described in the West Ash Booster Pumps section. A fused switch provides power to a dry-type stepdown transformer from which 480V power is derived for the pump station. The motor control lineup is over 40 years old and is a custom fabricated motor control and switchgear line-up created by Central Electric Co. The load center consists of mainly Westinghouse components. Both Central Electric Co. and Westinghouse are no longer in business. While the overall visual condition of this load center is good, the equipment is at the end of its useful life with many components no longer being produced.

5.12.3.2.1 2.4 kW Electrical Load Center Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- The 2.4 kV load center is critical equipment to the booster pump station operation. All power for the pump station originates from a single bus load center and has no electrical redundancy for the electric motors. The load center is over 40 years old and is obsolete and at the end of its expected life. Additionally, with the Light Department not supporting services at 2.4 kV as described in the preceding section, the 2.4 kV load center may not have significant usefulness as an existing asset with any pending change to the service voltage. The following recommendations and potential improvements should be considered:
- Make repairs and/or maintenance improvements in coordination with planned improvements to the larger electrical system.
- 2.4 kV load centers should be replaced with new load centers at a different voltage and 2.4 kV should no longer be utilized at the pump station.
- Replacement load centers for the pumps should be split into 2 units to eliminate single points of failure which have the potential to disable the entire pump station.
- Consider on-site generation on order to distribute reliable standby power to the entire booster pump station.

- Convert unused office and/or chlorine feed rooms into air-conditioned Electrical Rooms. This is especially true for any VFD equipment which may be a desired addition for new booster pump starters.

5.12.3.3 480 V Electrical Load Centers, Panelboards and Transformers

All 480 V power for the pump station originates from a single dry-type 112.5 kVA transformer located on the lower level of the pump station. The transformer steps the voltage down from2.4 kV to 480 V and is then sent to a motor control center located on the motor operating floor above. A 480 V power feeder is then routed down to the lower level again and terminates at a dry-type 50 kVA lighting transformer. This lighting transformer steps the voltage down from 480 V to 120/240 V and is then sent back to the motor control center located on the motor operating floor above. CW&L reported that a broken pipe in the pump room (basement level) of the booster pump station has previously resulted in flooding of the entire station substructure including the level on which these transformers are located. 480V power is critical to keeping the pump station operational as the auxiliary loads it powers are required for continuous pump operation.

The pump station motor control center is located on the operating floor of the pump station and supplies power to pump station building mechanical loads, DC battery systems and 120/240V loads. The MCC is over 40 years old and is a custom fabricated line-up consisting of motor starters, lighting contactors and two integral 120/240 V distribution panelboards. The load center consists of mainly Westinghouse components. Westinghouse is no longer in business. The MCC is at the end of its useful life.

The motor control center also provides power to a 125 VDC panelboard via battery changer and battery bank. The 125 VDC power is used to operate valves and close pump outlet valves in the case of station power loss. 125 VDC Panelboard as well as motorized valve actuators appeared to be original equipment from the stations initial construction. Valve operator controls are obsolete and the installation was observed to include unnecessary conduit seal offs which would make any modifications to the existing equipment and wiring very difficult without complete disruption of the existing electrical installation.

5.12.3.3.1 480V Electrical Load Center Existing Condition Summary

The following summaries the findings and preliminary recommendations from the condition assessment;

- The 480 V motor control center and pump outlet valve actuators are critical to reliable operation of the pump station. All 480 V and 120/240 V power for the pump station originate from two transformers located on a lower level of the pump station which can be flooded. No backup source of power or redundancy exists for this lower voltage equipment, meaning an outage on any once piece of equipment will result in partial or total shutdown of the pump station. The pump station MCC is over 40 years old and is obsolete and at the end of its expected life. Booster pump outlet valve motor actuators are also obsolete and in need of replacement. The following recommendations and potential improvements should be considered:

- Transformers which provide power for the pump station should be relocate to the operating floor level to avoid flooding concerns for electrical distribution equipment.

- Replace load centers for the existing MCC with 2 load center units to eliminate single points of failure which have the potential to disable the entire pump station.

- Replace the pump outlet valve motor operators with modern, submersible rated actuator units. DC operation can be avoided with systematic electrical system upgrades with on-site generation capability described in the preceding section.

The proposed electrical system improvement alternatives are discussed in Section 8.16.

5.13 PLANT CONTROLS

The current configuration of the plant control system includes local PLCs and remote I/O panels in different process areas throughout the plant. These PLCs and remote I/O panels communicate with the plant's Main PLC using Genius communication modules. The plant's Main PLC is a GE 90-70 PLC with Genius I/O blocks, Genius bus controller modules, and Genius communication coprocessor modules. The communication coprocessor modules are used for serial communication with the SCADA server and remote well sites via spread spectrum radios. There are two Genius bus controller modules that communicate with two Genius buses that connect many of the plant's process area PLCs and remote I/O panels.

Genius Bus #1 is used to communicate with the Control Room Remote I/O Panel (LCP220-10), Fluoride Remote I/O Panels #1 and #2, Ammonia Remote I/O Panels #1, #2, and #3, Reclaim Pump Remote I/O Panel, each of the Sludge Flush Valves Remote I/O Panels (LCP250 and LCP260), and the Lime Feed System PLCs (LCP220-11A, LCP220-11B, & LCP220-11C). All of the remote I/O panels connected to Genius Bus #1 use a Genius Bus Controller module with VersaMax I/O modules to communicate over the Genius bus. The final device on this Genius bus is the Lime Slurry System PLC, which has a Genius Bus Controller module. According to CW&L, there is an addressing issue that has caused this communication link to fail. This PLC also communicates with the Lime Slaker #1 and #2 PLCs over an Ethernet communication link. All three of the lime feed system PLCs are GE Fanuc 90-30 PLCs that were supplied by the lime feed equipment supplier.

Genius Bus #2 communicates with the PLCs and remote I/O panel in the Filter Building. The filter control consoles (LCP220-01 thru LCP220-08) and the Common Function Remote I/O Panel (LCP220-09) are all connected on this bus. Each of the eight filter control consoles is equipped with a GE Fanuc Series 90-30 PLC and a GE DisplayPAC-OP Operator Interface Terminal (OIT). For communication on the Genius bus, each filter PLC is equipped with a Genius Bus Controller module. The filter PLC CPU is also connected to the filter OIT using a serial communication protocol (SNP – Series Ninety Protocol), which supports a master/slave mode of operation. In addition to the PLC controls, all of the filter consoles are equipped with local manual control devices on the console door, so if the PLC were to fail, the filter operation can be controlled using these local hand switches.

The Common Function Remote I/O Panel uses a Genius Bus Controller module with VersaMax I/O modules. As described above, this remote I/O panel communicates with the plant's Main PLC over Genius Bus #2. It is used to monitor and control equipment that is common to the filters such as the backwash tank level transmitter, wash water flow control valve, backwash flow meter, chlorine analyzers, and filter to waste flow meter.

The plant's Main PLC also communicates with the remote wells over a serial communication link. Each well has a GE VersaMax Micro Controller PLC and XStream-PKG spread spectrum radio for remote monitoring and control from the main plant. Overall, it appears that the existing local control panels are in good working condition, but according to WTP staff, they occasionally lose communication with some of the wells. Recalibration of the radios and radio antennas could improve the signal strength at some of these wells and allow for more reliable communication with the plant.

In addition to the wells, there are other remote locations that are connected to the SCADA system. At the West Ash Pump Station, a GE 90-70 PLC is used to monitor and control the pump station. This PLC is also used in monitoring the Walnut Tower. The West Ash Pump Station PLC has one communication coprocessor module for communicating (serial) with the downtown servers. A copper to fiber converter is then used to connect the PLC to the SCADA servers at the downtown office. Another communication coprocessor module is used to communicate with the Walnut Tower. The data collected from the tower is then sent to the SCADA servers through the other coprocessor module.

The data that the plant's Main PLC collects from the plant and remote sites is sent to SCADA servers located in a downtown office. Through the use of one of the Main PLC's communication coprocessor modules, it sends data to and receives data from the SCADA servers using serial communication. A multiplexor device (GE JungleMUX Sonet Multiplexor) is used to connect the plant's Main PLC and all of the SCADA computers located in the plant's control room to the remote SCADA servers over a fiber optic cable between the two locations. The SCADA computers at the plant communicate through the multiplexor using Ethernet communication. The multiplexor directs network traffic between all of these devices giving each device a turn to communicate with the remote SCADA servers. Using QEI (now known as CG Automation) SCADA software, the SCADA servers compile all of the water system data and make it available for monitoring on the SCADA computers at the plant control room. When the multiplexor connects a SCADA computer to the SCADA servers, that SCADA computer will receive the data collected by the plant's Main PLC and other remote PLCs and send control commands back to the SCADA servers. These control commands will then be sent to the appropriate PLC the next time that the multiplexor connects it to the SCADA server.

As mentioned above, the SCADA computers at the plant run QEI SCADA software. This software allows the operators to view plant data and issue control commands. The existing SCADA screens appear to mostly consist of many data tables that display the plant process data with little graphical representation of the plant process. The SCADA software used for this application uses pixel based graphics, and when compared to today's SCADA software, it is not as easy to develop new screens or modify the existing screens. In addition, the plant personnel stated that this SCADA software has limited alarming features.

5.13.1.1.1 Plant Controls Existing Condition Summary

The following summaries the findings and preliminary recommendations from the condition assessment;

- According to the PLC manufacturer, the GE 90-70 PLC hardware and the Genius I/O hardware are considered obsolete. GE no longer supports this PLC hardware, and replacement modules will be extremely hard to find and expensive to purchase. Since the plant's Main PLC and the West Ash Pump Station PLCs are critical devices at each of their locations, these PLCs need to be replaced as soon as possible. A planned approach to the replacement of these PLCs can be developed as opposed to reacting when one of them fails and replacement parts cannot be found.
- Recommend replacement of the existing SCADA hardware and software. Since the SCADA software that is currently used is for both the water plant and the power division, new

SCADA servers dedicated to only the water plant and the remote sites associated with the water division will be used. In addition, Black & Veatch would recommend that these servers be installed at the plant, so that the plant's SCADA system is not completely dependent on the communication link to the down town location. If the ability to monitor and control the plant from the down town location, an operator work station could be installed at this location and connected to the servers at the plant.

- The filter PLCs are GE Fanuc 90-30 PLCs. These PLCs are considered a mature product by GE. These PLCs are still supported by GE for the next several years (5-6 years), but when this time expires, they will be considered obsolete like the 90-70 PLCs. Therefore, Black & Veatch recommends that these PLCs be replaced in the future.
- Upgrade the communication and controls at the wells. To make this communication link more dependable and gain faster data exchange, Ethernet radios could be installed at each remote site and at the plant.

The proposed plant control system improvement alternatives are discussed in Section 8.15.

5.14 MECHANICAL HVAC AND PLUMBING

5.14.1 Water Treatment Plant

5.14.1.1 Operations Building

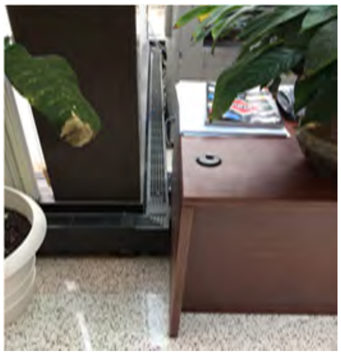
The original operations building was built in 1970 and designated as the 'Chemical Building'. A major remodel, as part of the plant expansion in 1993, removed the boiler/heating water system and the heat pump cooling system and replaced them with a water source heat pump system for heating and cooling. The system uses potable water as a heat source and heat sink in a once- through arrangement. Parallel backflow preventers protect the potable water system. Condenser water return discharges into the aerated raw water channel.



Heating and cooling are decoupled from ventilation. Seven zone heat pumps provide heating and cooling to the ground floor level and are located above the suspended ceiling. Three zone heat pump units serve the lower level. An air handling unit (AHU) located on the lower level, equipped with an electric heating coil, a water pre-cooling coil and a direct expansion refrigerant (DX) cooling coil, conditions outside air for ventilation and delivers it to the ground floor laboratory and lobby corridor. Electric duct heaters provide zone temperature control on the air delivered to the lab. A water-cooled condensing unit rejects heat from the DX AHU cooling coil to the water loop described above.

A utility type fan mounted on the roof provides air exhaust for the main laboratory and the water lab across the hall, and a separate fan provides exhaust for the storage room. Ductwork for the lab fan has been modified by staff. Power roof ventilators provide exhaust for restrooms and the mechanical room.


Electric baseboard heaters provide heating to the building lobby. A recessed electric wall heater provides heating to the building entry vestibule.




One of the zone heat pump units has been replaced by plant staff, and another zone heat pump has been removed and replaced with a traditional split system air handler, with an air cooled condensing unit located on the roof, as part of the control room remodeling undertaken by the staff.


The chlorine storage and feed rooms are served by separate ventilation systems which were replaced in the 2007 expansion. The systems consist of wall inlet louvers and dampers with ductwork and power roof ventilators for exhaust. Heating is provided by electric unit heaters.



The lower level pipe galleries are served by electric unit heaters. Portable dehumidification units were added by staff.

An emergency eyewash fixture is installed on the sink in the laboratory and an emergency shower is located in the ceiling.


An emergency shower and eyewash fixture is located on the lower level near the fluoride system.


Floor drains in the lower level of the Operations building are original.

The water-cooled heat pump system type installed in the 1993 expansion is considered very energy efficient in the industry. However, this equipment is over 20 years old which is the expected service life. Staff was unavailable for comment on frequency of repair; however, the fact that the heat pump serving the conference room has already failed and has been replaced, and the heat pump serving the lower level locker and restroom is inoperative, indicates that failure of other equipment is likely in the near future. Controls on the ventilation air handler were missing and had apparently failed and their function was manually bypassed.

HVAC equipment installed in the 2007 expansion is in fair condition and should have at least another seven to ten years of service life. Some vibration issues were noted on the chlorine room exhaust fan, which should be addressable with maintenance.

The emergency shower and eyewash fixture in the lower level is in poor condition. Floor drains on the lower level are in poor condition. Staff reports that the floor drain piping was inspected by camera and found to be generally rusted out.

5.14.1.1.1 Operations Building Mechanical Existing Condition Summary

The following summaries the findings and preliminary recommendations from the condition assessment;

- The ventilation, heating and cooling systems for the Operations Building need replacement in the near future. Below are descriptions of possible options.
  - Replace the systems in kind. This can be done over time as components fail, or in a complete package. The water source heat pump system currently in place is considered highly energy efficient. This approach would involve the least amount of design work. Staff indicated dissatisfaction with the heating performance of the heat pumps. This could be addressed with addition of electric heating capacity in the zone units and adjustment of temperature setpoint for air supply.
  - Replace the systems with a variable refrigerant flow (VRF) system with water source heat pump. This type of system is also considered highly energy efficient and involves an arrangement similar to the current system of above ceiling heat pumps providing heating and cooling to the respective zone, the units connected by a refrigerant piping loop to a water source heat pump in the mechanical room. A dedicated outdoor air unit would provide ventilation air similar to the current arrangement. Electric supplemental heating should be provided.
  - Replace the systems with packaged rooftop air cooled refrigerant systems with heat pump or electric heat. This type of system would be the simplest to operate but would be the least energy efficient. Packaged rooftop heating and air conditioning units would deliver conditioned air through ductwork to the various areas of the building. Ventilation would also be provided through the units. Zone boxes with reheat coils would be provided for zone temperature control. New penetrations would be required in the roof deck and structural analysis would be required. Supplemental electric heat would be recommended in the lobby, vestibule and restrooms.
  - Replace the systems with split system air cooled refrigerant systems. Air handlers with direct expansion cooling coils and heat pump or electric heating coils would deliver conditioned air and ventilation air through ductwork to the various areas of the building. Condensing units or heat pumps would be located on the roof or at grade and connected by refrigerant piping to the air handlers. Zone boxes with reheat coils would be provided for zone temperature control. Supplemental electric heat would be recommended in the lobby, vestibule and restrooms.
- Plumbing system recommendations include:
  - Replacement of the emergency shower and eyewash fixtures, and addition of water supply tempering for the fixtures, which did not appear to be in place.
  - Floor drains and piping need to be replaced.

5.14.1.2 Filter Building

The original filter building was designed by Black & Veatch in 1970. The building has been expanded in 1993 and another addition in 2007. The building is heated and ventilated. The original heating system consisted of hot water unit heaters which were supplied through the pipe tunnel by the boiler in the Operations Building. When the boiler was removed in the 1993 expansion, the original lower level gallery unit heaters in the filter building were removed but not replaced, and the piping and supports were abandoned in place. Electric unit heaters were installed on the grade level and in the new expansion lower level and pipe tunnels.

The original ventilation concept has been carried through the additions. Fresh air enters the ground level through wall louvers with motor operated dampers and is exhausted through ceiling grilles to power roof ventilators.

A heat pump unit connected to the Operations Building system serves the 1993 pipe gallery and tunnel. A dehumidification unit was part of the original design for the lower level pipe gallery; modifications appear to have been made by the staff over the years, however only a fan box appears to be functional at present. Portable ductless dehumidification units have been installed by the staff in recent years and appear to be functioning.

5.14.1.2.1 Filter Building Mechanical Existing Condition Summary

The following summarizies the findings and preliminary recommendations from the condition assessment;

- Original HVAC equipment has been maintained but is in poor condition. Staff has added insulated covers over intake louvers and dampers.
- Equipment installed in the 1993 expansion is nearing the end of its expected life. One of the power roof ventilators has been replaced.
- Equipment installed in the 2007 expansion is in good condition and should have seven to ten years of remaining service life.
- Recommendations include:
    - Replacement of electric unit heaters, power roof ventilators and ventilation intake dampers and operators on the systems over 20 years old.
    - Demolition of the original dehumidification unit and heat pump unit in the pipe gallery and replacement with a dehumidification unit with a cooling coil that will condition outside ventilation air for the pipe gallery as well as provide dehumidification.
    - Demolition of abandoned heating water piping and supports.

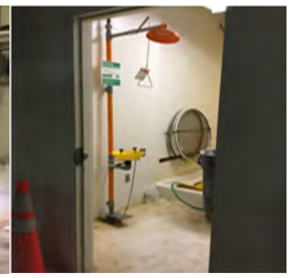
5.14.1.3 Lime Building

The Lime Building was added as part of a plant expansion in 2007. The lower level connects to the pipe gallery of the Operations Building.

The building is heated and ventilated. Ventilation equipment consists of wall louvers with gravity dampers for intake and power roof ventilators with gravity dampers for exhaust. Heating equipment consists of wall hung electric unit heaters.



Emergency shower and eyewash fixtures are located in the main room and the filter cleaning room.

5.14.1.3.1 Lime Building Mechanical Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- The equipment is in good condition and should have seven to ten years of remaining service life. The intake dampers open by air pressure and the blades do not open fully. Staff have propped the blades in the Lime Room fully open to increase airflow.
- Water from the emergency showers drains across the floor to floor drains. The floor drains are plugged with powdered lime, which is an ongoing maintenance concern.
- Recommendations include:
  - HVAC recommendations include adding electric damper operators to the ventilation intake dampers. This will allow some additional natural ventilation from prevailing wind to occur in the summer, while cutting down on cold outside air infiltration and heating requirements in the winter.
  - Plumbing system recommendations include addition of a water heater and mixing valve for water supply tempering for the emergency shower and eyewash fixtures, which is usually a plumbing code requirement and did not appear to be in place.

5.14.2 West Ash Booster Pump Station

The pump station was completed in 1971. The building mechanical equipment includes heating, ventilation and air conditioning systems. The building heating system consists of a natural gas fired boiler system which includes a circulating pump, makeup water system, natural gas regulator, induced draft flue vent fan, and controls. Combustion air is provided through a roof hood with a manual damper in the connecting duct to a room ceiling grille. The heating water is distributed to floor-mounted, fan-equipped cabinet heaters and suspended overhead unit heaters.




The ventilation system consists of wall louvers with motorized dampers for intake and power roof ventilators for exhaust. Ductwork connects the lower levels of the pump station to an exhaust fan on the roof. Inlet air is transferred down the stairway from the louvers in the pump room. Portable circulation fans have been added by staff.



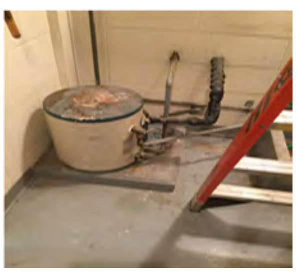


The air conditioning system serves the control room and restroom and consists of an air handling unit suspended overhead in the janitor's room and distribution ductwork. The original unit rejected heat to the pump room; it has been replaced with a traditional DX split system unit with a condensing unit located on the roof. The roof has two levels; the condensing unit is on the lower roof.


Staff has installed portable ductless dehumidification units on the lower levels of the pump station. One was operational and the other was not.

Sump pumps on the lowest level are more recent replacements. An additional pump was added by staff after a flooding incident.

A water heater located in the janitor's closet provides hot water for the restroom and janitor's sink.



5.14.2.1.1 West Ash Booster Pump Station Mechanical Existing Condition Summary

The following summarizes the findings and preliminary recommendations from the condition assessment;

- The heating and ventilation equipment has been maintained and some has been replaced. Much appears to be original and is well past its expected service life. The boiler and heating water system were shut down for the season and operation could not be verified. The boiler circulation pump appears to be a more recent replacement. Power roof ventilators serving the pump room are more recent replacements. The majority of the damper actuators on air inlet dampers were disconnected, presumably due to failure. Some of the unit heater thermostats were missing.
- The lowest level had a significant humidity and condensation issue although the dehumidifier was running. The cold water in the adjacent reservoir and in the large diameter piping was cooling the pipe and room surfaces such that the pipes were covered

with condensation and the floor was entirely wet. The exhaust fan serving the space was not being used, although it did energize when turned on.

- Heating Systems. Staff reported that the pump motors provide sufficient heat that the building needs very little heating under normal operating conditions, and there is a desire to remove the boiler with its associated maintenance.
- Due to the age of the heating equipment, replacement will need to take place in the near future. Below are descriptions of replacement options.
    - The natural gas supply currently serving the boiler could be used for a forced air furnace to supply heating through ductwork to the office area and smaller rooms. Gas fired unit heaters could be installed to provide backup heating in the pump room in the event the pump motors are off. Electric unit heaters could replace the hydronic heat on the lower levels. Heat from the pump room will not reach the lower levels as heat rises.
    - The heating water cabinet heaters could be replaced with electric cabinet heaters, and the heating water unit heaters could be replaced with electric unit heaters. This would likely result in higher utility costs than option 1.
- Ventilation Systems. The ventilation equipment that has not already been replaced should be replaced in kind.
- Air conditioning systems. The air conditioning equipment has been replaced in recent years and should have seven to ten years remaining service life. The refrigerant lines for the replacement unit were routed through the roof hood serving the demolished unit and the throat of the hood blocked with plywood. In the event that the roof is replaced, this arrangement should be improved.

The proposed improvement alternatives are discussed in Section 8.17.

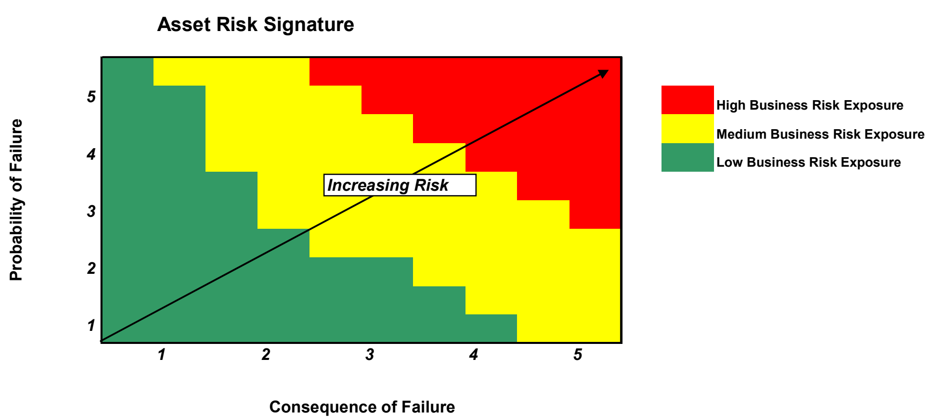
6.0 Asset Risk Rankings

This section summarizes the asset risk scores that were developed as part of the condition assessment for each functional unit. For some of the functional units, such as basins and electrical equipment, the scores were further broken down by sub-functions of similar age or condition.

The asset risk signatures for all the individual assets associated with the functional unit were considered when determining the ratings and risk signatures of the functional unit. These asset risk rankings will be used to identify improvements that are needed to continue to operate the plant for the long term, as well as prioritizing the improvements to determine the most critical items to address first. Further development of these alternatives and a final implementation plan will be discussed in later sections.

6.1 ASSET RISK METHODOLOGY

Field observations and input from CW&L staff were used to develop a methodology for rating the condition of assets. The rating scores for assets were used to compute asset risk scores or signatures based on the numerical product of the numerical rating for Probability of Failure (POF) multiplied by the Consequence of Failure (COF) rating, as depicted in the Asset Risk Signature chart below. The asset risk scores were then adjusted to account for maintenance priority and remaining life factors. The asset risk score or signature is used to prioritize improvements that will be recommended in later sections.



Prior to the field assessments, the Black & Veatch team (Team) developed assessment criteria to support the rating of assets and obtained available equipment information by reviewing plant records. The assessment criteria are provided in Tables 6-1 and 6-2 in the following section.

6.1.1 Assessment of Probability of Failure (POF)

The facilities at the WTP were evaluated for their Probability of Failure using the POF criteria in Table 6-1.

Table 6-1 Probability of Failure Criteria

RANKING	DESCRIPTION
CONDITION	
1	New or very good condition, 0% requiring replacement
2	Minor defects only, 5% requiring replacement
3	Corrective maintenance , 10-20% requiring replacement
4	Significant deterioration, 20-40% requiring replacement
5	Unserviceable, 50 – 100% requiring replacement
RELIABILITY	
1	Exceptional reliability, > 10 yrs
2	Random breakdown, > 5 yrs
3	Occasional breakdown, > 2 yrs
4	Periodic breakdown, < 1 yr
5	Frequent breakdown, < 3 mo
CAPACITY	
1	Exceeds desired capacity
2	Meets desired capacity
3	Fails to meet desired capacity at peak operation
4	Fails to meet desired capacity at normal operation
5	Significantly fails to meet desired capacity
FUNCTIONALITY	
1	Exceeds functional requirements
2	Meets all functional requirements
3	Fails some functional requirements
4	Fails significant functional requirements
5	Fails all functional requirements

The Probability of Failure scores were assigned using the following guidelines:

- Condition – Brand new or essentially new equipment was given a rating of 1. Old equipment that runs acceptably with only typical corrective maintenance required was rated a 3. Equipment requiring significant maintenance was rated a 4 or 5.
- Reliability – Equipment only requiring scheduled preventative maintenance was rated a 2. If more than scheduled maintenance is required, the rating was a 3. If the equipment is not usable, then it was rated a 5.
- Capacity – Equipment whose capacity matched the capacity required to perform its function was rated a 2. If the equipment had excess capacity it was rated a 1 and equipment was rated a 4 if it was slightly under its required capacity.

- Functionality – Equipment that performed its function adequately was rated a 2. If equipment failed to achieve its function, it was rated a 3, 4, or 5.

6.1.2 Assessment of Consequence of Failure (COF)

The facilities at the WTP were evaluated for their Consequences of Failure using the COF criteria presented in Table 6-2. The COF rating scores were combined with the POF rating scores to develop risk rankings for the facilities.

Table 6-2: Consequence of Failure Criteria

RANKING	DESCRIPTION
HEALTH AND SAFETY	
1	Does not result in injury or illness
2	
3	Minor/Reportable Injury or Illness ($2,000 - $20,000).
4	Potential for Serious Injury
5	Serious Injury or Loss of Life
DIFFICULTY OF REPAIR	
1	< 1 day
2	Between 1 day and 1 week
3	Between 1 week and 1 month
4	Between 1 and 3 Months
5	> 3 months
REDUNDANCY	
1	>100% redundant assets in-place as part of process
2	80-100% redundancy in-place
3	51 -80% redundancy in-place
4	25%- 50% or less redundancy in-place
5	Asset serves primary function with no back-up

Consequences of Failure scores were assigned using the following guidelines:

- Health & Safety – Equipment was evaluated on the potential for harm to humans in the event of failure with the equipment. The more serious the harm, the higher the rating. Equipment was only evaluated on its specific function within the plant. Although failure with one piece of equipment could have consequences with associated equipment and have impacts throughout the plant, the rating provided was only for the specific piece of equipment being evaluated.
- Difficulty of Repair – Equipment was rated a "2" if spare parts were readily available, service could be performed by local technicians, the service work was not labor intensive, the equipment was easy to access, or no shutdowns or temporary operations were required. If any of these conditions became less favorable, the rating of the equipment was higher.

- Redundancy – The redundancy percentage was determined by considering the number of pieces of equipment needed to meet maximum day demands as compared to the number of units available. For example, four primary basins are required to meet peak flow of 32 MGD. If one basin is out of service, the remaining redundancy in place is 75%. This would be scored a 3.

6.1.3 Maintenance Priority Factor

Some assets are more critical to operation and safety at the plant. For instance, if the chlorine feed system fails it must be fixed immediately to return the plant to operation, and to address potential safety concerns. This would be considered a high priority asset and be given the highest score of 5. However, HVAC equipment is not as critical to overall operation and would be given a low score of 1.

The WTP does not have a database for O&M costs or maintenance records for individual equipment and processes. For future condition assessments and to track maintenance costs for individual items, Black & Veatch recommends developing a computerized database to maintain these records. These programs can be used to establish and maintain key asset management practices and improve reliability, performance, and economic optimization of the treatment plant assets. Further discussion on asset management systems will be discussed in later sections.

6.1.4 Age and Expected Life Factor

Black & Veatch engineers estimated the age and expected life for various plant assets based on an understanding of the plant's development phases, input from CW&L staff, nameplate data, and review of related design documents.

One area of concern with older assets in particular is that the installation year may not accurately reflect major overhauls or refurbishments. For example, a new motor might have an expected life of 30 years while a rebuild at the end of the 30 years might add an additional 15 years to its life. These assets are refurbished to a condition between "good as new" and "bad as old" (i.e. as bad as it was before breakdown if the maintenance is reactive). There are relatively few assets, mostly major equipment, that are maintained in this way.

Table 6-3 indicates a "characteristic life" for each asset type. The characteristic life estimates the number of service years until a majority of assets of that type will no longer meet their service demands. These estimates are derived from engineering experience. Many assets can extend beyond these years and continue to function with proper maintenance and rehabilitation.

Table 6-3 Estimated Equipment Life

DESCRIPTION	EFFECTIVE LIFE
SCADA Equipment, PLC and I&C Equipment	10
Chemical Feed Pumps	10
Analyzers	10
HVAC Equipment	15
Chemical storage tanks	15
Filter Equipment, Media	15
Chlorine Feeders	15
Flow Meters	20
Variable Frequency Drives	20
Lime Equipment	20
Pumps, smaller than 75HP	25
Valve Actuators, electric	25
Air Compressor and Blowers	25
Basin Residuals Collection Drive, Clarifier Drive	25
Electrical Equipment	25
Pumps: larger than 75hp	35
Valves	30
Aerator	30
Wells	35
Concrete Structures	100

Based on this table, and estimated age of the assets, a remaining life factor was assigned to each asset. Table 6-4 summarizes the remaining life factor for various conditions.

Table 6-4 Remaining Life Factor

FACTOR	REMAINING LIFE
1	Greater than 10 years remaining
2	Between 5-10 years remaining
3	Life remaining between 0-5years
4	Life exceeded between 0-10 years
5	Life exceeded by more than 10 years

6.1.5 Development of Asset Risk Signatures

As described above, individual POF and COF ratings were determined through the assessment activities for each item considered. Following the assessment of equipment, the risk rankings were determined according to the following methodology.

Step 1: Develop Composite Probability of Failure (POF) Rating

Composite POF ratings were determined for each asset by considering its POF score for each of the possible four failure categories. The composite POF rating indicates the likelihood of the asset failing to meet any one of the four failure criteria described in Table 6-1. For example, an asset may score very low in all but one of the four POF rating categories, and score a rating of 5 in just one category (such as the condition-based failure) causing the maximum value of 5 to be assigned for the composite POF rating, indicating that a high score in any one failure category may cause the asset to fail.

Step 2: Develop Composite Consequence of Failure (COF) Rating

Because consequences-of-failure of an asset are cumulative, COF ratings are added together to create a composite rating. However, to normalize the summation of the COF ratings back to a range of 1-5 for use in the asset risk signature chart presented below, the sum of the individual scores for the three COF categories for each asset is divided by three to determine the composite COF score.

Step 3: Develop Asset Risk Signatures

The Asset Risk Signature is the product of the composite POF score multiplied by the composite COF score. This score is then adjusted by multiplying by both the maintenance factor and remaining life factor. To normalize these factors both are divided by 3.

6.2 FUNCTIONAL UNIT RATING SUMMARY

The condition assessment ratings for the process equipment and facilities, electrical equipment, and instrumentation equipment are summarized in Tables 6-5 and 6-6. Individual assets were grouped as part of this summary into unit process arrangement. A complete list of asset information will be included in an appendix in the final report.

Table 6-5 Functional Unit Risk Signature for Process Equipment

PROCESS/PUMPING	CONDITION	RELIABILITY	CAPACITY	FUNCTIONALITY	HEALTH/SAFETY	REDUNDANCY	REPAIR	MAINT. PRIORITY	LIFE FACTOR	ASSET SCORE
Primary Basin 1 and 2	5	4	2	4	2	3	3	3	5	**22.2**
Chlorine Feed System	3	3	2	4	5	3	4	5	2	**17.8**
Aerators 1 and 2	3	2	5	4	2	3	3	4	2	**11.9**
WTP Original HVAC Equipment	4	3	3	3	2	3	2	2	5	**10.4**
Ammonia Feed System	4	4	3	4	4	1	3	4	2	**9.5**
Well Field	4	4	3	3	2	2	3	3	V	**9.3**
High Service Pumps (Pumps Only)	2	3	2	3	2	2	3	4	V	**9.3**
West Ash Pumps (Pumps Only)	2	3	2	2	2	2	3	4	V	**9.3**
Filters	2	2	2	3	2	2	3	4	V	**9.3**
Primary Basin 3	2	2	3	3	2	3	3	3	3	**8.0**
Lime Feed System	1	2	3	2	3	3	3	4	2	**8.0**
Fluoride Feed System	4	3	2	2	4	1	3	3	2	**7.1**
Aerators 3 and 4	3	2	2	4	2	3	3	3	2	**7.1**
Secondary Basin 3	2	2	2	3	1	3	3	3	3	**7.0**
Wash Water Tank	2	1	2	2	2	1	4	3	4	**6.2**
WTP 1994 Version HVAC	3	3	3	3	2	2	3	2	4	**6.2**
WTP 2007 Version HVAC	2	2	2	3	2	2	3	2	4	**6.2**
Secondary Basins 1 and 2	4	3	2	2	1	3	3	1	5	**5.2**
Raw Water Transmission Main	1	1	2	2	2	5	1	5	1	**3.0**
Primary Basin 4	1	2	3	3	2	3	3	3	1	**2.7**
Reclaim basin	2	1	2	2	2	5	4	3	1	**2.4**
Secondary Basin 4	2	2	3	2	1	3	3	1	1	**0.8**

1. "V" indicates variable age. For these assets, and average age factor of 3 was applied.

Table 6-6 Functional Unit Risk Signature for Electrical and Instrumentation.

ELECTRICAL/INSTRUMENTATION	CONDITION	RELIABILITY	CAPACITY	FUNCTIONALITY	HEALTH/SAFETY	REDUNDANCY	REPAIR	MAINT. PRIORITY	LIFE FACTOR[1]	ASSET SCORE
Medium Voltage Distribution (2400V)	4	4	2	3	4	3	5	4	5	**35.6**
West Ash Medium Voltage Distribution	4	4	2	3	4	3	5	4	5	**35.6**
WTP Original Low Voltage Panels	4	4	2	3	3	4	4	3	5	**24.4**
WTP Utility Service and Substation	3	3	2	3	3	3	4	4	5	**22.2**
Plant Control System	4	3	3	4	4	5	3	4	3	**21.3**
WTP 1994 Version Low Voltage Panels	3	3	2	3	4	4	4	3	3	**12.0**
Well Field Distribution	2	2	2	2	2	2	3	3	V	**4.7**
WTP 2007 Version Low Voltage Panels	2	2	2	2	3	4	4	3	1	**2.4**

1. "V" indicates variable age. For these assets, and average age factor of 3 was applied.

A total of thirty unit process assets are included in Tables 6-5 and 6-6. The Risk Signatures and condition assessments were used to develop a prioritized list of improvements that are included in later sections.

Table 6-7 lists high and medium priority improvements that should be investigated in Phase 2 of this study. These recommendations, along with other alternatives to address reliability, process improvements, and expansion are further developed in the next sections.

Table 6-7: Recommendations for Further Evaluation in Phase 2

PRIORITY LEVEL	RECOMMENDATION FOR FURTHER EVALUATION
High Priority	1. Replacement of the equipment in primary basins 1 and 2. 1. Feed rate controls and safety improvements to the chlorine feed system. 2. Replacement of the 2400V electrical equipment and motors at both WTP and West Ash Pump Station. 3. Safety improvements to the ammonia and fluoride feed systems. 4. New plant control system. 5. Modifications to the aerators to distribute flow evenly. 6. Replacement of original low voltage electrical equipment at WTP. 7. Rehabilitation of the well field to increase firm capacity.
Medium Priority	2. Improvements to the lime feed grit removal system. 3. Redundant raw water transmission main and influent flow meter. 4. Modifications to the filters to improve turbidity removal and pump control. 5. Hydraulic modifications to the basins to promote even flow distribution. 6. Increasing the torque rating on primary basins 3 and 4. 7. Replacement of old HVAC equipment at WTP and West Ash.

7.0 Development of Alternatives

In general, the treatment plant appears to be operating satisfactorily and is able to meet regulatory requirements. The plant has rarely operated near capacity, so only limited operational data under peak operating flow conditions is available. However, as the demands increase within the service area, the plant will continually become more stressed. Based on the review of water quality, plant daily operation logs, and results of the condition assessments, there are a number of improvements that should be considered for the plant to maintain a reliable water supply and meet future regulatory and demand requirements.

The following sections describe alternatives to address a full range of improvements, ranging from replacement only of deteriorated equipment to requirements for expanding plant production capacity to up to 60 MGD. These categories can be summarized as follows:

- Replacement. All Items included within this category are the minimum recommended improvements to continue to operate the plant in its current state. These are alternatives to be completed within the next 5 years and specifically address deficiencies identified as part of the condition assessment. These improvements are generally replacement of equipment only and do not significantly improve performance, increase reliably, and/or increase capacity of the facility.
- Enhancements. Items included within this category improve performance and reliability of the facility; however, they do not significantly increase capacity of existing facility.
- Expansion to 45 MGD. Alternatives included within this category are specific to increasing the plant capacity to 45 MGD by the following:
  - Alternative 1: Re-rating the primary basins to 45 MGD while maintaining existing basin configuration.
  - Alternative 2: Construction of a new basin train north of the existing treatment plant
  - Alternative 3: Modify Secondary Basin No. 4 into a primary basin and eliminate the current "two stage" softening flow scheme. This alternative includes a clearwell, contact basin, and new high service pumping station.

  Expanding the plant capacity to 45 MGD aligns with estimated year 2033 future water production projections included in the "Long Range Water System Study" (Jacobs, January 2015).
- Expansion to 60 MGD. Alternatives included within this category are specific to increasing the plant capacity to 60 MGD by the following:
  - Alternative 1: Combining the re-rating the primary basins to 45 MGD while also construction one 15 MGD basin train.
  - Alternative 2: Construction of two new basin trains north of the existing treatment plant
  - Alternative 3: Modifying the current plant to single stage softening.

  Expanding the plant capacity to 60 MGD aligns with the ultimate buildout capacity identified in the "McBaine Water Treatment Plant Expansion Preliminary Design Report" (Carollo, Dec. 2012).

The 45 MGD expansion alternatives will consider both continued groundwater raw water supply and also groundwater under the influence (GWUDI) raw water supply. All alternatives for 60 MGD will assume the water supply will be classified as GWUDI.

Chapter 8 includes the replacement/enhancement alternatives. Chapter 9 includes the expansion alternatives. Following the development of these alternatives are recommendations and overall phasing plan.

Evaluation of alternative lime disposal methods were not included as part of this assessment.

7.1 CAPITAL COSTS CRITERIA

Estimates of capital costs were developed from unit and lump sum prices for the various components for each facility. Pricing was based primarily on material quotes from various vendors and manufacturers, past experience, 2015 building cost data, and information from similar projects recently constructed in the region. Additional amounts for general requirements (permitting, contingencies) and engineering, legal, and administrative costs were combined to obtain a total estimated project cost for the alternative.

Quantities for structures, building, process components, pipeline lengths, and basin sizes were developed based on preliminary process sizing of the treatment components, preliminary site layout, and similar facilities. Contingencies are defined as unknown or unforeseen costs. The level of detail available at the planning/conceptual phase of the project does not provide sufficient definition to fully capture all the costs associated with the project. Generally, for this type of project a Class 4 estimate is used, which is defined as follows:

- Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, confirmation of economic and/or technical feasibility, and preliminary budget approval. Typically, engineering is from 1% to 15% complete. Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.

However, each alternative has different levels of details and unknowns. Therefore, the contingency used in each alternative varied based on the level of unknowns. The primary purpose of the costing included in each alternative in this study is to provide an order of magnitude and budgetary price for each item, and to help select which alternative is best for the plant.

Life cycle costs are also included in some of the alternative evaluations. The following table summarizes the life cycle cost factors used in the evaluation.

Table 7-1 Life Cycle Cost Factors

LIFE CYCLE COST FACTORS		
ITEM	**UNIT**	**VALUE**
Financial Evaluation Items		
Effective annual interest rate	%	4%
Effective Discount/Escalation Rate	%	2%
O&M Costs		
Electricity	kW-hr	$0.08
General Maintenance	% Equip	2%
12.5% Bulk Hypochlorite	gallon	$0.90
Chlorine Gas	lb	$0.22
Salt (NaCl)	lb	$0.09

8.0 Replacement/Enhancement Alternatives

Alternatives for each unit process were evaluated to address deficiencies and improve performance are included in this section. A description, layout drawings (if applicable), and construction costs were developed for each alternative. A comparison of advantages and disadvantages for each alternative is provided, along with a recommendation of the preferred alternative. The replacement/enhancement improvements are prioritized in a later section along with a proposed implementation schedule which factors in long term expansion in selection of alternatives.

8.1 WELL FIELD ALTERNATIVES

The existing wells will continue to exhibit diminished capacity and require frequent repairs unless improvements continue to be made. The well platforms need to be expanded if new, larger and more robust electrical equipment is installed. The following well field alternatives were evaluated to address rehabilitation of the wells and enhancements:

Alternative WF1: Rehabilitation of existing structures and equipment

Alternative WF2: Replace existing platforms with new elevated platforms

Alternative WF3: Abandonment of existing wells and installation of collector wells

8.1.1 Alternative WF1: Rehabilitation of Existing Structures and Equipment

This alternative addresses deficiencies with the existing wells, and replacement of low performing wells. Generally, this is a continuation of the work currently being conducted in the well field involving replacement of older, single stage pumps, new electrical equipment, and well treatment. This alternative also includes repairs to the existing well houses, which includes:

- Cleaning and painting of the well houses
- Sealing of the pipe penetrations to prevent freezing of instruments
- Installation of Ethernet radios for communication
- Other miscellaneous repairs to the well structures.

Currently, Wells 2, 5, 11, 13, and 14 are being retrofitted with 75 hp motors and Durapulse VFDs. The Durapulse drives are inexpensive and have a small footprint which allows them to be installed inside the existing well enclosures. Proposed new wells 16, 17, and 18 will also be equipped with Durapulse VFDs.

Because of the limited experience with these types of drives, this alternative includes no additional VFDs beyond the eight planned to be installed on existing wells until the wells have operated for a significant number of hours over at least two summers. Also, as discussed previously, these VFDs do not have all the features typically seen at treatment facilities, including surge protection and harmonic filtering. Therefore, prior to installing additional VFDs in existing well houses, a harmonics evaluation should be conducted to identify potential implications to the power distribution system.

After installation of Wells 16, 17, and 18 almost half of the wells installed will have VFDs. This should provide sufficient flexibility in the well field for the plant operators to set a desired influent flow rate and adjust the flow with the VFDs. Also, it allows more wells to operate at one time at a lower individual flow rate, which decreases the velocity through the screens, and thereby potentially extending the timeframe between cleanings.

Rehabilitation of the platforms, well treatment, and pump replacement would be sequenced over time within the well field. Many of the wells are near 50 years old. Complete replacement of the older existing wells should be included in a long term implementation schedule. Many of the replacement wells can be drilled adjacent to the existing well, provided spacing of at least 25 ft is provided from the old well. Therefore, additional land is not required and pipeline extensions would be minimal.

To determine replacement, specific capacities of each well should be re-calculated every 2-3 years. When the total decrease in specific capacity reaches 33 percent from last rehabilitation, the well would be scheduled for rehabilitation. If the specific capacity drops by more than 33 percent within four years after rehabilitation, and/or pumping capacity reduced by more than 20 percent, and/or the drawdown level is at or below the top of screen or impeller, the well would be scheduled for replacement.

Note, lower specific capacities do not necessarily mean the well will need to be replaced as higher draw down on the wells are acceptable provided the water level remains above the screens and pump impellers. However, larger pumps will be required to overcome the additional head. As evident from the performance test results, the discharge pressure will be significantly increased at higher flow rates. Therefore, all pumps and motors not rated near 130-150 ft of head will have significant flow reductions when the plant is operating at higher flows unless a new transmission main is installed.

Electric power monitors would be installed at each new well. The current and voltage of the power feed would be monitored by the individual PLC at each well. Other electric power data that should be considered for monitoring includes watt-hours, frequency, and power factor.

Key benefits for this alternative include:

- Relatively low cost to extend life of existing well field.
- Continued maintenance and rehabilitation restores capacity of existing wells, delaying the additional costs of more wells.

Disadvantages with this alternative include:

- Space within the existing well houses is limited without proper clearances for electrical equipment.

8.1.2 Alternative WF2: Replacement of Existing Well Platforms

This alternative includes the same well treatment and pump replacement included in alternative WF1. However, instead of refurbishing the existing well enclosures, newer, larger platforms will be installed on existing wells. Located on the well platform will be a fiberglass reinforced plastic (FRP) building with approximate dimensions of 11 ft x 11 ft. The FRP building will come equipped with a door, lights, access hatch, louver and a fan. The louver and fan will be designed for the loads present in the building. The new enclosure will provide sufficient space to allow for a more robust VFD to be installed, meeting all current electrical code space requirements.

Aluminum stairs or ladder with landing will be provided outside the exterior door. The landing will be designed to support the electrical equipment panel weights to facilitate removal.

No major equipment will be supported off the FRP enclosure to allow the entire building to be removed if necessary. However, with the access hatch and stair platform normal maintenance and cleaning will not require removal of the FRP building. This allows the equipment to remain inside the building and protected from the environment when well treatment is being performed. The well house will be insulated to improve energy efficiency.

The platform would be supported directly off the well column.

Key benefits of this alternative include:

- Improves safety by eliminating floor hatch and providing the necessary electrical clearances inside the enclosures.
- More energy efficient structure, including the ability to add air conditioning to meet cooling requirements for the VFDs.
- Allows for sufficient space to install more robust VFDs if performance of the Durapulse drives proves not to be cost-effective.
- Allows for continued maintenance and rehabilitation of existing wells, delaying the additional costs of more wells.

Because of the additional costs, new well platforms would only be provided for wells that appear to have remaining life over 10 years. Wells near the end of their effective service life are not included with this alternative.

8.1.3 Alternative WF3: Collector Wells

An alternative to rehabilitation or replacement of the existing vertical wells is to construct a horizontal collector well.

Figure 8.-1 below illustrates a typical horizontal collector well.

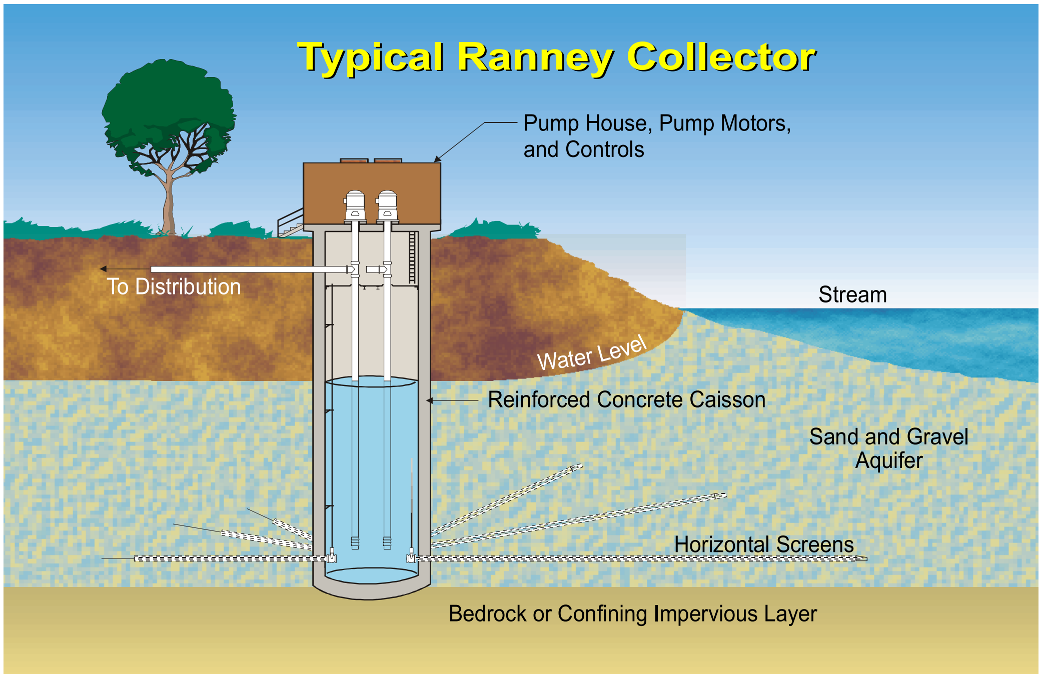


Figure 8-1 Typical Collector Well

A collector well would be constructed by sinking a cast in place concrete caisson (approximately 20 feet in diameter) from the ground surface, through the alluvium, until it reaches bedrock or a confining impervious layer below the aquifer. The bottom of the caisson would be sealed and the interior dewatered. Well screens would then be installed horizontally from the interior of the caisson into the most desirable portion of the aquifer. The screens would usually be near the bottom of the aquifer where the larger aggregate would be located and where there is the greatest thickness of saturated aquifer above the screens. Vertical diffusion vane pumps would be installed in a pumping station constructed above the caisson to convey groundwater from the horizontal collector well. The initial capital costs for a horizontal collector well are higher as compared to vertical wells. However, operation and maintenance costs are generally lower since there would be only one pumping facility to maintain. Three or four pumps, installed in a single horizontal collector well pumping station, could potentially convey up to 15-20 million gallons per day in your aquifer, however more investigation is required to determine the aquifer capacity.

Typically, the screens are directed toward surface water to allow the surface water to more rapidly recharge the aquifer; however, this most likely cause regulators to classify the groundwater supply as being under the direct influence of surface water. This affects the plant as it will have to meet turbidity goals and most likely add contact basins within the process. However, there are some facilities in Missouri that do have groundwater only collector wells, but these would be lower capacity collector wells. Additional analysis and review of water quality would be required to determine the source water classification.

Another concern with collector wells is that unlike multiple vertical wells, they present a single point for contamination. If the collector well would become contaminated the entire plant water supply would be unusable. Therefore, this alternative initially includes one new collector well, sized for 15-20 MGD, while keeping 8 to 9 of the existing vertical wells in operation. As existing vertical wells become damaged or costly to repair, they will no longer be maintained and will be abandoned.

Eventually, as the newer wells reach their end of life there would be at least one more collector well to match the existing 32 MGD treatment capacity, with an additional one or two collector wells to meet future capacity requirements.

The location of the collector well would be near the Missouri River. A new 36 to 42 inch pipeline would be routed from the collector well to the existing piping to connect to the raw water supply.

8.1.4 Cost Comparison

The table below summarizes estimated project costs for the well field alternatives described above. These estimated costs include approximately 50 ft of additional piping for each new replacement vertical well since it is anticipated they will be located near existing wells, and 8,500 ft of 42 inch piping to connect the new collector well to the existing piping located away from existing wells. The costs do include installation, general requirements, engineering, and contingencies.

Table 8-1 Well Replacement Cost Comparison

ALTERNATIVE	PROJECT COSTS
Well Treatments (per well)	$20,000
Well Rehabilitation	$98,000
Well Rehabilitation- New pump, motor, electrical	$65,000
Power Monitor (per well)	$4,000
New Elevated FRP Building and Stairs (per well)	$131,000
New Vertical Well (per well)	$570,000
Collector Well (no pipeline)	$6,113,000
Collector Well (each, including 8,500 ft of pipeline)	$9,534,000

1. Well rehabilitation includes new pump, motor, electrical panels, power monitor, and well house repairs. It does not include well treatments.
2. New radios are being installed under another contract. Therefore, the cost for radios are not included in alternatives above.

8.1.5 Conclusions and Recommendations

The existing well field has high producing wells and has been a reliable source of supply for the plant. Therefore, the continued use of vertical wells for water supply is recommended to meet the current plant capacity. Although there is less O&M with collector wells, the cost of one collector well is substantially more than the cost of replacement vertical wells that it is not cost effective to switch supplies at this time. This does not include the additional treatment costs for changing the source water to GWUDI if a collector well is installed.

However, as the plant capacity expands beyond 32 MGD further evaluation between collector wells and vertical wells should be conducted to determine the best long term approach, with the most deciding factor being the classification of source water and impact on overall plant operation. However, even if collector wells are selected to meet future capacities, a combination of collector and vertical wells should be implemented to provide source water redundancy to the plant. Therefore, in the interim, rehabilitation and replacement of wells should continue.

As noted, the well field capacity is highly variable so continued monitoring of the wells is required to confirm when wells should be treated or replaced. However, based on the age of the wells, overall capacity of the well field, and results from recent treatments and specific capacity evaluations, it is recommended that over the next 6-8 years, at least six wells should be budgeted for replacement.

Generally, it is recommended that two wells be replaced every two to three years, with the original wells being first on the list of replacement. If newer pumps and motors have been installed in any of these wells they can be relocated to the new adjacent replacement well. Replacement of the wells will reduce annual maintenance costs and increase the firm capacity of the well field by replacement of the lower capacity wells. New wells should be located along existing pipelines, and/or to the northwest away from the Eagle Bluffs Conservation Area.

The actual number of wells to be replaced, and timeframe for replacement, should still be made on a case by case basis using the historical performance of the well, maintenance costs, and criteria summarized in Chapter 5 of this report.

In addition to the phased implementation plan described in the table below, each well should be equipped with power monitors and new radios meeting FCC regulation.

Since the well houses were built prior to the current requirements the existing well houses do not necessarily have to be modified to meet current electrical clearances and access requirements. However, replacement of the existing well houses with new FRP buildings and stairs should be considered for improving safety at the wells. When deciding whether to modify the well house, the overall lifespan of the well should factor into the decision. The original wells, installed in 1972, are still in operation. Therefore, for Wells 9-15, all installed after 1990, it can be reasonably expected that their remaining life will be another 15-20 years.

The following table summarizes the overall project costs for the well field recommendations and implementation time. All costs in 2015 dollars.

Table 8-2 Well Alternatives Project Costs

ALTERNATIVE	PROJECT COSTS	RECOMMENDED TIME FRAME
Well Treatments (yrs 0-6)	$100,000 (annually)	5 wells per year for yrs 0-6
Well Treatments (yrs 6+)	$80,000 (annually)	4 wells per year for yrs 6+
Well Replacement (Well 2 and 8)	$1,140,000	2-4 yrs[1]
Well Replacement (Well 4 and 7)	$1,140,000	4-7 yrs[1]
Well Replacement (Well 1 and 3)	$1,140,000	7-10 yrs[1]
Power Monitors (15 total)	$60,000	1 yr
Well Rehabilitation-new equipment (6 total)	$390,000	1-3 years
New FRP Well House (6 total)	$786,000	Within 4 yrs

1. The dates and wells indicated for replacement should be used for budgetary purposes only. Additional monitoring should occur prior to scheduling for replacement as these wells may be able to remain productive for some time.
2. The summary includes replacement of the pump and motor in well 1, 3, 6, 12, 13, and 14. Wells that are scheduled to be replaced within 4-6 years were not included in the pump replacement.

The total project costs over the next eight years, not including well treatments, is $4,656,000 if the recommended well field improvements are implemented. These improvements do not significantly increase capacity, but provide for a more reliable water supply.

8.2 RAW WATER LINE ALTERNATIVES

The raw water line that enters the basement beneath the aerators presents a potential single point of failure which would completely shut down the plant. The 36 inch pipe as it enters the building is approximately 13 ft below grade and adjacent to existing structures. Therefore, if a break did occur in this pipe it would take a significant amount of time to excavate and replace, potentially several days. A break during peak demands could potentially cause significant supply concerns within the system.

In addition, there is no redundancy built into the raw water flow meter. This flowmeter is critical to plant operation as it is used to determine chemical application rates and to record the raw water flow. Any repair work required to remove the internal components of the flow meter would require the entire plant to be shut down. The following are three alternatives to address reliability in the raw water line:

Alternative RW1: Add redundant Aerator Influent line with flow meter.

Alternative RW2: Add redundant raw water line from Highway K to Aerators.

Alternative RW3: Add isolation valves in raw water line between wells 13, 14, and 15.

8.2.1 Alternative RW1: Redundant Raw Water Flow Meter

This alternative includes a new raw water flow flowmeter installed in a new aerator influent line that would connect to the 48 inch raw water line north of the existing aerators and enter the basement beneath Aerator No. 4. The new line would connect to the existing influent header between Aerators 3 and 4. The existing 36 inch x 24 inch reducer and 24 inch valve would have to be relocated near Aerator No. 4 influent to allow for tee to be installed in the aerator header pipe. The existing valve between Aerators 2 and 3 would be closed to allow for installation of the tee without a full plant shutdown.

It appears the existing septic tank and associated pump would need to be relocated to facilitate installation of the new pipe. Therefore, costs for relocation of the septic tank are included in this alternative.

The existing flow meter is 36 inches. It is recommended that the new influent line and flow meter also be 36 inches. However, because the new aerator influent will serve primarily as redundancy, it can be reduced to 24 inches if necessary to fit within the existing site. A 24 inch influent line and flow meter would provide sufficient capacity for average day flow rates.

Key benefits of this alternative include:

- Allows for maintenance and replacement of the existing raw water flow meter without taking the entire plant off-line.
- By having two influent lines, head loss in the influent pipeline is reduced under normal conditions, eliminating the 36 inch pipe restriction and increasing the raw water capacity.

Disadvantages of this alternative include:

- Requires relocation of the septic tank.
- Does not eliminate the single point of failure in the raw water line, as a section of 48 inch piping that does not have redundancy or means to repair without shutting the entire plant down would still exist.

8.2.2 Alternative RW2: Redundant Raw Water Lines

This alternative includes the new influent flowmeter described in Alternative RW1, but extends a new raw water line to the west to intercept the 24 inch northwest raw water line. Extending the pipe to connect to the 24 inch northwest raw water line provides a complete looped raw water system and redundancy to the plant.

Key benefits of this alternative include:

- Eliminates the single point of failure in the raw water line.
- Increases capacity of the raw water piping.

8.2.3 Alternative RW3: Isolation Valves in Well Field Raw Water Piping

This alternative includes the addition of mainline isolation valves between Wells 13, 14, and 15 to allow for isolation of seven wells at one time while still being able to send water to the plant. These isolation valves would help facilitate pipe repairs and cleaning.

Key benefits of this alternative include:

- Allows for multiple wells and raw water piping to be offline at one time while the system is still able to deliver flow from seven wells.

8.2.4 Cost Comparison

Project costs for the raw water line alternatives are summarized in the table below.

Table 8-3 Raw Water Alternatives Costs

ALTERNATIVE	PROJECT COST
RW1: Redundant Raw Water Flow meter	$233,000
RW2: Redundant Raw Water Line	$379,000
RW3: Isolation Valves in Well Field	$84,000

8.2.5 Conclusions and Recommendations

The raw water line presents a single point of failure that could potentially shut down plant operation for several days if a major break occurred. In addition, there currently is no means to maintain the existing raw water flow meter without completely shutting down the entire plant.

Implementing RW2 is recommended to provide full redundancy into the plant for the raw water supply. The configuration of RW2 may be changed if the plant capacity is increased as the redundant line could be routed to new aerators or process trains.

The isolation valves in the well field, Alternative RW3, is recommended to improve flexibility for maintenance in the well field.

The total project cost for rehabilitation/enhancements of the raw water pipeline is $463,000.

8.3 AERATOR ALTERNATIVES

Several alternatives were developed to address deficiencies with the aerators and improve performance. These alternatives include:

- Alternative AR1: Retrofit existing four aerators with new PVC internals.
- Alternative AR2: Modify Aerators 3 and 4 to hydraulically balance all four aerators.
- Alternative AR3: Modify Aerators 1 and 2 to hydraulically balance all four aerators.
- Alternative AR4: Replace existing aerators with taller units to increase CO_2 removal efficiency to approximately 80%.

8.3.1 Alternative AR1: Retrofit Existing Aerators with New PVC Internals

This alternative includes increasing aerator CO_2 removal efficiency by retrofitting the existing aerators with new PVC internals. The original aerator internals were removed due to the high rate of iron precipitate buildup, which resulted in the need for frequent maintenance. Typically, aerators are designed with readily-removable internals to reduce maintenance; the existing aerators were not designed with this critical feature. Due to the design of the existing aerators, removal, cleaning, and replacement of the internals was a laborious task.

The new internals would be 2 inch diameter PVC tubes on 6 inch vertical centers, supported by stainless steel screen wire. Because of the short height of the aerators, relatively dense aerator media packing would be required to improve performance. Based on discussion with Westech, retrofitting the existing aerators with new PVC internals would only improve the CO_2 removal by about 5 percent above their current removal rate, and any cost savings resulting in less lime usage would be offset by the additional maintenance required to clean the internals.

8.3.2 Alternative AR2: Balance Hydraulics – Modify Aerators 3 and 4

Aerators 1 and 2 receive raw water from an influent pipe entering from the top of the aerator. Aerators 3 and 4 receive raw water from an influent pipe entering the side of the aerator. The centerline elevations of the two aerator influent systems are not the same, which creates a hydraulic imbalance. Based on the results of the performance test, Aerators 3 and 4 begin to overflow when they are loaded at 15 MGD, with very little flow going to aerators 1 and 2. Therefore, under normal conditions the flow through Aerators 3 and 4 is significantly higher than Aerators 1 and 2 unless the plant staff throttles back flow between the aerators. Throttling increases the head to the aerators.

This alternative includes modifying the influent piping to Aerators 3 and 4 to match the hydraulic grade line of Aerators 1 and 2. The 24 inch influent pipe would be extended up approximately 5 ft to match the hydraulic grade line in Aerators 1 and 2. The piping would loop down and connect to the existing 18 inch header pipe. This alternative requires no modifications in the aerator internals or piping connections.

This alternative would increase the required head by about 5 ft, essentially serving the same purpose as throttling the valves currently do, which reduces the well capacity and increases pumping costs. Based on the results of the performance test, the well field capacity will be reduced by about 2 MGD (from 28.5 to 26.9 MGD) with 15 wells in service to meet the hydraulic conditions for this alternative.

However, the additional pumping costs may be offset by an increase in CO2 removal efficiencies of approximately 10 to 15 percent, which reduces overall lime usage. The estimated gain in removal efficiency was determined based on the results of the performance test and historical plant data. A summary of the estimated cost savings is included in the life cycle analysis at the end of this section.

8.3.3 Alternative AR3: Balance Hydraulics – Modify Aerators 1 and 2

To balance the hydraulics between all of the aerators without increasing head conditions and reducing well field capacity, the influent piping to Aerators 1 and 2 would be lowered to match the influent piping elevation of Aerators 3 and 4.

Currently, Aerator 1 and 2 influent lines enter the top of the aerators. The 24-inch influent lines would be cut above the aerator base and a 24 inch by 18 inch reducing tee installed to split the influent flow to two 18 inch headers. Four 18 inch by 12 inch reducing tees would be installed with four butterfly valves to split the influent flow through four penetrations through the side of Aerators 1 and 2. Four new 12 inch diffuser headers and 6 inch diffusers with VariFlo nozzles would be provided for each aerator. The existing top penetrations would be removed and new vents would be installed.

This alternative would also improve efficiencies of approximately 10 to 15 percent.

8.3.4 Alternative AR4: Replace Existing Aerators with Taller Units

This alternative includes complete replacement of the existing aerator with four new 20-ft tall units to increase CO_2 removal efficiency by about 30 percent above their current operation.

Taller aerators would increase the required head by about 10 ft, which reduces the well capacity and increases pumping costs. Based on the performance test results, the overall well field capacity would be reduced by about 5 MGD under the current well conditions, resulting in maximum capacity of about 23.5 MGD. However, installing new, higher horsepower motors on the wells rated at higher head would be able to overcome the higher head, and the additional pumping and capital costs may be offset by the increased removal efficiency of the aerators.

The new aerators would be located at the same location as the existing aerators.

8.3.5 Cost Comparison

The table below summarizes the estimated capital cost, relative yearly O&M savings, and relative present worth for each alternative. The yearly O&M incorporates the annual lime savings minus the additional pumping costs. For Alternative AR1, it was estimated that any lime reduction savings would be offset by additional cleaning costs, therefore no net change in overall O&M costs.

Table 8-4 Aerator Alternatives Cost

ALTERNATIVE	PROJECT COST	RELATIVE YEARLY O&M	RELATIVE 20-YR PRESENT WORTH
AR1: Retrofit With New PVC Internals	$459,000	($17,654)	$459,000
AR2: Modify Aerators 3 and 4	$109,000	($25,134)	($302,000)
AR3: Modify Aerators 1 and 2	$252,000	($35,308)	($325,000)
AR4: Replace with Taller Aerators	$2,879,000	($94,965)	$1,326,000

Assumptions:
1. Removal Efficiency improvement of 10% at average conditions for AR2 and AR3, and 5% for AR1.
2. Removal efficiency improvement of 30% at average conditions for AR4.
3. Lime costs of $185 per ton of quicklime (90% purity)
4. Solids disposal costs = $63 per ton of dry solids

8.3.6 Conclusions and Recommendations

Alternative AR3, modifying Aerators 1 and 2, is recommended for the aerators. Although this alternative has more capital cost that alternative AR2, it does not reduce plant capacity and requires no additional pumping costs. Taller aerators do reduce annual operational costs. However, the capital costs to install the new aerators are not offset by the reduction in annual operating costs.

The total project cost for rehabilitation/enhancements of the aerators is $252,000.

8.4 BASIN ALTERNATIVES

The following primary and secondary basin improvements were evaluated:

Alternative B1: Replace Primary Basin No. 1 and 2 equipment.

Alternative B2: Modify Primary Basins No. 3 and 4 Drive Units.

Alternative B3: Replace Secondary Basin No. 1 and 2 equipment.

Alternative B4: Flow distribution improvements.

Alternative B5: Increase Filter Influent Header Piping.

Alternative B6: Replace Parshall Flumes with Velocity Flow Meters.

8.4.1 Alternative B1: Replace Primary Basins No. 1 and 2 Equipment

The Walker equipment in Primary Basins No. 1 and 2 have been installed for 45 years and are at the end of its useful life. The existing Walker mixing equipment in the center of the basin has been removed, most likely due to poor impeller drive performance. Without proper mixing equipment, lime use efficiency decreases, and poor floc particle formation results in higher solids carryover. In addition, weirs and launders are not installed evenly, resulting in uneven flow across the basins.

Alternative B1 includes replacement of Primary Basins No. 1 and 2 equipment, launders, weirs, and controls. New equipment would incorporate mixing equipment with higher mixing rates to increase reaction efficiency. The equipment would be designed with provisions for adding coagulant within the primary basins to enhance solids removal capabilities and reduce required reaction zone detention times.

Key benefits for this alternative include:

- Reduce current lime dosage rates while decreasing settled water turbidity
- Reduce solids carryover into Secondary Basins
- Increase equipment reliability and serviceability
- Potentially increase basin capacity
- Enhance flow distribution within the basin with the replacement of launders and weirs

8.4.2 Alternative B2: Modify Primary Basins No. 3 and 4 Drive Units

This alternative includes replacing the drive units in primary basins 3 and 4 to increase the torque rating.

The drive units in Primary Basins No. 3 and 4 drive the rakes at the bottom of the basin to collect solids that has settled out. The existing drive units for Primary Basins No. 3 and 4 are rated at 45,000 ft-lbs and 32,000 ft-lbs, which equates to 28.1 lbs/ft and 20.0 lbs/ft unit loading, respectively. Black & Veatch typical design standard for the type of operation currently practiced at McBaine is 40 lb/ft unit loading rating.

It has been noted that the drive units trip out when a higher solids concentration is maintained in the center cone. High solids concentration within the center reaction well is essential to reducing high primary basin effluent turbidity. Current concentrations range from 0.5% to 1%; normal solids concentrations for this type of equipment should be around 10%.

Key benefits for this alternative include:

- Reduce frequency of drive units tripping out due to higher than normal solids loading rate
- Reduce buildup and compaction of solids at the bottom of the basin
- Lower effluent turbidity by increasing the solids concentration within the center cone; higher torque is needed to dispose of settled solids

8.4.3 Alternative B3: Replace Secondary Basin No. 1 and 2 Equipment

This alternative includes replacement of basin equipment in Secondary Basins No. 1 and 2. As with the Primary Basins, Secondary Basins No. 1 and 2 equipment is original to the plant construction and nearing the end of its useful life. Several components were broken and control panels were generally deteriorated. Secondary basins in operation result in very little turbidity removal. If single stage softening is employed, Secondary Basins No. 1 and 2 equipment would be replaced with flocculating clarifier equipment.

Key benefits for this alternative include:

- Replace deteriorated equipment.

8.4.4 Alternative B4: Flow Distribution Improvements

Existing v-notch weirs would be leveled to create proper flow distribution across the whole basin. Leveling all weirs would help avoid short circuiting within the basin and reduce solids carry over from the Primary Basins to the Secondary Basins. This alternative also includes replacement of the v-notch weirs in Secondary Basin No. 3 with submerged orifice collection pipes, similar to Secondary Basins No. 1 and 2. This type of effluent collection system maintains a more even distribution of flow, because the collecting pipe is rigidly connected to the basin wall in short spans and the orifice elevation is not as critical. Existing v-notch weirs spans are much longer and result in the center portion deflecting and allowing the height of water over the weir in that section to increase, thus increasing the flow rate in that one area of the basin. The existing effluent discharge flume penetrations would be sealed and a new penetration would be cored to allow a new collection header to be installed.

Key benefits for this alternative include:

- Eliminate basin short circuiting

8.4.5 Alternative B5: Eliminate Bottleneck in Filter Influent Piping

Secondary Basin effluent flows from the launders into a discharge flume between the two basins. From the discharge flume, the settled water flows into a 42-inch filter influent header, which immediately splits to two 30-inch filter influent headers. One 30 inch pipe feeds either Filters 1&2, or Filters 7&8. The other 30 inch pipe feeds the remaining filters. As observed during the performance test, when basin trains 3 and 4 are operating near 15 MGD and flow is sent to Filters 1-4, an additional 1 ft of headloss occurs between the secondary basins and filters than when Filters 7 or 8 are being used. This additional headloss causes the weirs in Secondary Basin to become submerged.

This alternative includes increasing the pipe size from 30 inches to 42 inches in the Filter influent piping between the 42 inch tee from Basins 3&4 to the 42 inch tee from Basins 1&2.

Construction and sequencing of this alternative would be challenging. The general sequence to complete this work is as follows:

- Install new 42 inch isolation valve between Filter 6 and 42 inch tee from Basins 3&4. During this work only Filters 1 and 2 would be operational.
- Install new 42 inch isolation valve between Filter 3 and 42 inch tee from Basins 1&2. During this work only Filters 7 and 8 would be operational.

- Once the new 42 inch isolation valves are installed, replacement of the 30 inch piping between Basins 1&2 and 3&4 would occur. While this work was being completed only Filters 1&2 and 7&8 would be available.

Installation of the new piping will significantly restrict space available to access valves on the elevated platform.

8.4.6 Alternative B6: Replace Parshall Flumes with Velocity Flow Meters

Parshall Flumes are located in the influent channel to each basin train to measure flow. Historically, these flumes have not provided accurate flow measurements and currently are disabled. This alternative replaces the Parshall Flumes with velocity flow meters located in the straight channels downstream of the Parshall Flume. For velocity flow meters to work effectively, straight section of channel is required, which is available here. Reviewing the channel layout with manufacturers confirms an expected accuracy of 1-2 percent. It should be noted that as evident during the performance testing, wave action was occurring in the channels when the basins were initially put into operation. Therefore, during this initial period the flow meters will be inaccurate. The existing Parshall Flumes will be removed, which will improve basin hydraulics.

Key benefits for this alternative include:

- Provides means to measure flow to each basin for chemical feed.

8.4.7 Cost Comparison

The table below summarizes the capital costs for each alternative.

Table 8-5 Basin Alternatives Cost

ALTERNATIVE	CAPITAL COST
B1: Replace Primary Basin 1 and 2 Equipment	$1,709,000
B1A: Stainless Steel Components	$1,854,000
B2: Modify Primary Basin 3 and 4 Drive Units	$219,000
B3: Replace Secondary Basin No. 1 and 2 Equipment	$1,081,000
B3A: Stainless Steel Components	$1,331,000
B4: Basin Flow Distribution Improvements	$173,000
B5: Increase Filter Influent Header Piping	$929,000
B5A: Replace 2-30 inch Filter Influent Valves Only	$131,000
B6: Replace Parshall Flumes with Velocity Flow Meters	$211,000

8.4.8 Conclusions and Recommendations

Primary basin 1 and 2 equipment is critical to plant operation and performance and should be replaced as one of the highest priorities. The new equipment may need to be configured for higher loading rates if the expansion alternative that includes re-rating the basins is selected. Therefore, prior to replacing the equipment, a decision on the long term approach for plant expansion is needed to properly design the equipment.

Many of the other improvements listed above are also dependent on the long term plan for the plant. Recommendations for the other alternatives are summarized below:

- B2: Replacement of primary basin 3 equipment is required if the basin capacity is re-rated to higher capacity, and also may be required to convert to stainless steel if single stage softening is used. (note a waiver may be allowed to avoid this). Primary Basin 4 is already stainless steel, however the influent is bottom fed to the unit. Based on the conceptual layout for single stage softening this basin would have to be fed by a pipe supported from a walkway, therefore modifications to the center column and tube will be required. Therefore, in the interim no modifications are recommended for Primary Basin 3 and 4 until part of an overall expansion project.

- B3: The secondary basin collection equipment should also remain and only be replaced if part of an overall expansion alternative.

- B4: Replacement of the effluent v-notch weirs to submerged orifices on secondary basin no. 3 should be included to improve flow.

- B5: Although there are some flow limitations with the current piping arrangement, filter influent piping modifications are not recommended unless the filters are re-rated to higher capacity, or part of an overall expansion. Improvements to the secondary basin effluent weirs, as described in B4, will help relieve the flow constraints.

- B5A. Replacement of the isolation valves in the filter influent header should be part of an overall plant expansion, to be completed prior to isolating basins/filters for work.

- B6: Replacement of the Parshall Flumes with velocity flow meters are recommended to reduce headloss and allow for flow pacing of chemicals to each basin.

Therefore, in summary, alternatives B1, B4, and B6 are recommended with the replacement/enhancement alternatives.

The total project cost for rehabilitation/enhancements of the basins is $2,093,000.

8.5 RESIDUALS

Residuals alternatives include:

<u>Alternative R1:</u> Redundant residuals line from sludge vaults to lagoon piping

<u>Alternative R2:</u> Additional Lagoon Discharge Points

8.5.1 Alternative R1: Redundant Residuals Line from Sludge Vaults to Lagoon Piping

This alternative includes a redundant 12 inch residuals line from the sludge vault to the lagoon piping network, but does not include additional discharge points at each lagoon or a second connection to the reclaim basin discharge pumps. This will allow one line to be taken offline for cleaning, and will also allow basins to send residuals to the lagoon while other basins are being drained for cleaning.

The new sludge line will intercept the 12 inch sludge line from Basins 1 and 2 in the vault pit located in the basement of the Operations Building. A new 12 inch line would be routed through the sludge cleanout vault and to the lagoons. Both pipelines will be interconnected to allow for flexibility in discharging of residuals.

8.5.2 Alternative R2: Additional Lagoon Discharge Points

This alternative includes a redundant residuals line at the lagoons, with additional discharge points, and the connection to the reclaim basin discharge pumps. This alternative also includes a redundant line from the sludge pits located in the basement of the Operations Building.

8.5.3 Cost Comparison

The table below summarizes the capital costs for each alternative.

Table 8-6 Residuals Alternatives Cost

ALTERNATIVE	CAPITAL COST
R1: Redundant Line from Sludge Vault to Lagoon Piping	$158,000
R2: Additional Lagoon Discharge Points	$608,000

8.5.4 Conclusions and Recommendations

Installation of a redundant sludge line from the sludge vault to the lagoons would improve operation and flexibility, allowing basins to be drained at the same time blowdowns are occurring, and providing a spare line if plugging occurs. This line would be even more critical if existing basin capacity is expanded. Therefore, this redundant line is recommended. However, before installation of the line the proposed expansion concept should be confirmed as the piping may interfere with future basins or aerators.

Adding discharge points in the lagoon would also help distribute the solids in the lagoons. However, the plant has operated for many years without these additional points and has not experienced lagoon storage issues. The residual process may also change in the future, potentially pumping to the river or installation of a dewatering system. Therefore, adding more discharge points at this time should be deferred for now.

The total project cost for rehabilitation/enhancements of the residual line is $158,000.

Note, none of these alternatives address future residuals handling and disposal.

8.6 FILTER ALTERNATIVES

The physical condition of the filters and equipment are generally in good shape. However, filter performance, specifically in regards to turbidity removal, is not as effective as most dual-media plants treating properly conditioned lime softened water. As discussed previously, provided the plant continues to be a ground water source supply plant, no significant improvements to the filters are required. However, if the plant source water is reclassified as GWUDI, which is highly likely at some point in the future as the supply increases, modifications to the filtering process will be required. In addition, as the current filters are rated at 4.7 gpm/sq ft, any increase in rated capacity that may be approved by MDNR would likely be contingent upon implementation of significant improvements in rate of flow control, filter monitoring (head loss), and pretreatment to reduce filter effluent turbidities.

The following filter alternatives address specific items identified in the condition assessment, and include considerations to meet future performance requirements.

Alternative F1:	Replace valve actuators on Filters 1 -4
Alternative F2:	Miscellaneous structural repairs to filter building
Alternative F3:	Addition of cationic polymer to improve filter performance
Alternative F4:	Increase media depth in filters to meet MDNR requirements
Alternative F5:	Addition of air scour to reduce backwash
Alternative F6:	New clearwell downstream of filters

8.6.1 Alternative F1: Replace Valve Actuators on Filters 1-4

In lieu of replacing one actuator at a time under maintenance budget, this alternative includes replacement of all the valve actuators on Filters 1, 2, 3, and 4 under one project. The actuators that would be replaced for each filter include the following:

- 24 inch filter influent
- 30 inch filter drain
- 18 inch filter effluent
- 24 inch filter backwash
- 10 inch filter to waste

A total of twenty valves are included in this alternative. The replacement of the actuators would still have to be staged to minimize filter outages. However, if the work is completed under one package there could be significant savings in both the cost of the valves and installation due to economics of scale. The new actuators on Filters 5-8 are Limitorque L120 multi-turn actuators. These actuators have a strong history of performance in this type of application. There is a strong preference to have uniformity in all the filter actuators to allow for similar control between filters. Therefore, identical Limitorque actuators are recommended for Filters 1-4. Discussions with the actuator manufacturer are recommended on a wholesale discount if multiple actuators are purchased at one time. It is reasonable to estimate a 25-35 percent discount if multiple actuators are purchased at one time.

Key benefits of this alternative include:

- Improved flow control for filters.
- Potential for cost savings if all actuators are replaced as a package.

8.6.2 Alternative F2: Miscellaneous Structural Repairs

This alternative addresses the structural deficiencies identified as part of the condition assessment. These items include:

- Repair cracking near guardrail at the Northeast corner of the building.
- Replace missing splash blocks and poor site drainage at downspouts.
- Repair concrete spalling at Southwest corner of building.
- Routing Filter building drains located on north side away from basins.

8.6.3 Alternative F3: Addition of cationic filter aid polymer to improve filter performance

This alternative includes implementation of a filter aid polymer feed system in the settled water drop boxes prior to the flow entering the filters to improve filter performance. Many plants which practice precipitative softening have achieved significant improvements in filter performance through addition of cationic polymer at low dosages (0.1 – 0.2 mg/L) at the filter influent. It is critical that cationic polymers, and not anionic polymers are used for filter aid, as anionic will essentially "glue" filter media together if too much is applied, or if carryover of polymer residual from the basins occur. Nonionic polymers are generally ineffective in softening applications, but if enough of it is added as a filter aid it will work to some extent, but can also exhibit the same media fouling issues as anionic polymer.

The chemical feed system would consist of totes, a day tank, and feed blenders to feed the solution to the channels. One feeder would be dedicated to each channel with a common spare. It is preferred to have shorter piping runs for the feed lines. Therefore, the feed system could be located on the pump station operating floor (old electrical equipment will be removed). If totes are used, access to a loading dock will be required.

Key benefits of this alternative include:

- Improves performance of the filters.
- Potentially allows for higher filter loading rates.
- Relatively low cost.

Disadvantages of this alternative include:

- Another chemical to be handled.
- Excessive dosing will potentially cause filter issues. Therefore, dose pacing and accurate flow measuring would be incorporated.

As discussed, the addition of filter aid is not required unless reductions in filter effluent turbidity are needed to comply with more restrictive filter performance requirements associated with treatment of ground water subject to direct surface water influence.

8.6.4 Alternative F4: Increase media depth in filters to meet MDNR requirements

Based on current media configuration, the existing filters would not comply with MDNR requirements, as the combined depth of the fine sand and garnet layers (9 inches) is less than the required minimum 12 inches. This alternative includes replacement of the media to meet the MDNR requirements.

All the media, except Filter 1, was replaced as part of the 2005 expansion. Sand can last indefinitely if it doesn't become excessively encrusted with calcium carbonate, and if it does, it can typically be acidified in place to remove the encrustation. Anthracite is usually good for at least 10 years, but many treatment plants have anthracite that has lasted 18-20 years prior to replacement. However, as the anthracite's sharp edges get removed due to repeated backwashing, filtration efficiency starts to suffer. Therefore, the anthracite should be replaced within the next five years. When the anthracite is replaced, the sand depth should be modified to meet MDNR requirements.

8.6.5 Alternative F5: Addition of air scour

An air scour system, such as the Roberts Water Technology Inc Aries equipment, could be installed in each filter basin. Filters 7 and 8 have already been configured to accept an air scour system. This type of system would release air directly into the media through an air grid embedded at the base of the filter media, and directly above the support gravel. The modules could be installed without removing the media or underdrain. A new blower would supply air at a rate of 2.5 scfm/sf of filter area. Based on operating experience with filters in similar applications, the addition of the air scour system would reduce the wash water volume necessary for effective cleaning by 25 to 50 percent.

Key benefits of this alternative include:

- Reduces the amount of backwash water required for cleaning the filters.
- Potentially increases filter run times by providing more thorough cleaning.

Disadvantages of this alternative include:

- Costly to implement.
- Because the backwash water is reclaimed and sent back to the head of the plant, reducing the overall volume of backwash water does not have as significant impact on this facilities versus other facilities that dispose all backwash water.

8.6.6 Alternative F6: New clearwell downstream of filters

Installation of a finished water clearwell downstream of the filters would potentially provide significant process enhancement as it would enable conversion of the filters to switch from declining rate mode to constant rate- of- flow mode. Essentially, the filter flow rates would then be controlled by each individual filter rate of flow valve, and not by the pumps. To switch modes, the clearwell operating water level will have to be below the bottom of filter. Therefore, the clearwell will be buried and deeper than the existing filter building. In addition, the high service pumps would have to be reconfigured or replaced as the suction elevation will be lowered on the pumps.

The initial configuration consists of two clearwells, one located near the southeast corner of the filter building, and the other near the southwest corner. The common filter effluent piping will extend out the east side of the filter building and feed the southeast clearwell. The southwest clearwell will be fed from a similar piping arrangement out of the west side of the filter building. An interconnect would also be provided between both clearwells.

It is anticipated that the existing 24 inch filter effluent piping will have to be increased to 36 inches from Filter 3 to southeast clearwell, and likewise from Filter 6 to the southwest clearwell. The clearwell operating water surface elevation would be approximately 4 ft below the bottom the filters. Based on a total water depth of 10 ft the bottom elevation of clearwell will be about elevation 457.0, approximately 7 ft below the existing filter pipe gallery floor. This results in a total clearwell depth of approximately 27 ft to match the filter building floor elevation. The size of the clearwell will be dependent on its function. If the clearwell is strictly used as a wetwell for the pumps, it can be relatively small (100,000 gallons). However, if the clearwell will be used to achieve disinfection contact time for compliance with CT requirements for ground water subject to direct surface water influence, it will need to be larger. For this alternative, it is assumed that the clearwell will serve strictly as a wetwell for the pumps. Each wetwell would have a total volume of about 100,000 gallons.

New vertical turbine high service pumps would sit on top of each clearwell and supply the system through the existing finished water transmission mains. Each clearwell will essentially be designed for 16 MGD as it will be difficult to get flow from one clearwell from the filters furthest away. Therefore, a redundant pump would be located at each clearwell. For the basis of this project, eight high service pumps were included (4 per clearwell). However, if selected, the number of pumps could be reduced if larger pumps are provided. At least two pumps at each station would be equipped with VFDs.

A building will sit on top of the clearwell for the pumps and electrical equipment. The backwash pumps and filter wash pumps will remain at their current location.

Key benefits for this alternative include:

- The addition of a clearwell to convert to rate of flow filter mode may be required to meet future turbidity limits, especially if other process improvement such as new basin equipment and filter aid do not reduce turbidity.
- Simplify pumping operations.

Disadvantages of with this alternative include:

- Very costly to implement and construct.
- The clearwell will be deep and located in a floodplain near the existing levee.

<u>Alternative Concepts</u>

Several alternative configurations were considered, including modifying each filter effluent location to the south side of the filter building, or eliminating one filter and using it as equalization downstream of the filters. Relocating the filter effluent to the south would require modifications to each filter box underdrains as the effluent drop box is currently on the north side. Also, a new building or vault would be required along the full length of the filters to access the valves and flowmeters. Therefore, this was determined not to be feasible.

Using one filter for equalization would reduce the capacity of the filters, requiring additional filter capacity to be added. Plus, because the filter used for equalization would have the water surface elevation above the filter underdrain elevation, air binding may occur in the filters. However, it would potentially allow the filters to operate more evenly as the pumps would draw flow from the equalization “filter”, which would fluctuate with demand, and the flow through the other filters would be more constant. This approach would be unconventional, and would reduce capacity, so it was eliminated from consideration.

However, this concept could be tested by plant staff at some point with their current filters. During the next media replacement, all the media could be removed from one filter, and with no media, the effluent valve could be opened to allow water to backfill into the filter. The filter would have to operate as finished water, so approval by MDNR would be require as it would have an open top.

8.6.7 Cost Estimates

The table below summarizes the project costs for each filter alternative.

Table 8-7 Filter Alternatives Cost

ALTERNATIVE	CAPITAL COST
F1: Replace Valve Actuators on Filters 1-4	$89,000
F2: Miscellaneous Structural Repairs	$15,000
F3: Filter Aid Polymer	$164,000
F4: Increase Media Depth (includes all media replacement)	$536,000
F5: Addition of Air Scour	$813,000
F6: New Clearwell and Pump Station (two clearwells/PS)	$9,935,000

8.6.8 Conclusions and Recommendations

Many of the filter improvements listed above are also dependent on the long term plan for the plant. Recommendations for the each specific alternative is described below:

- F1: Existing actuators on filters 1-4 do not operate effectively, resulting in potential turbidity spikes in filter operation, difficulty in isolating filters, and not having all the functionality that the current actuators models have in being able to communicate with the plant control system. Therefore, this alternative is recommended to be implemented and should be one of the higher priority items.

- F2: Miscellaneous structural repairs should be addressed, but no major issues were observed so this item is not as high priority as others identified in this report.

- F3: Filter aid polymer would improve the performance of the filters. However, since the plant currently does not have turbidity limits, it is not necessary to install. With any planned modifications to the existing plant to increase flow, or if the source water is re-classified to GWUDI, installation of a filter aid polymer system is recommended. The system could be installed prior to either the plant expansion or reclassification to observe the improved performance of the filters, which may provide sufficient information to potentially re-rate the filters to higher loading rates if performance significantly improves. Therefore, at a minimum, a trial system should be implemented to determine effectiveness before a full scale system is installed.

- F4: Increasing media depth is recommended to improve performance, but does not need to be implemented until the next media replacement.

- F5: Since the plant recycles wash water and there are currently no turbidity limits, the installation of an air scour system is not necessary at this time. As part of future plant expansions, specifically if the filters are re-rated to higher capacity, the addition of air scour would be needed at that time.

- F6: The addition of a clearwell and pumping station would improve filter performance. However, currently the plant is meeting all filtering requirements and the cost to implement this alternative is high. Therefore, this alternative should only occur if the source water is reclassified to GWUDI, if the filter loading rates are increased, and/or disinfection credit is required across the filters. There may be a possibility that adding filter aid polymer would allow the filters to meet turbidity requirements for GWUDI without the need of the clearwell. However, operational data would be required to confirm. Therefore, the additional of a clearwell and new pumping station should not occur unless related to major plant revisions.

Therefore, alternatives F1, F2, and F3 are recommended with the replacement/enhancement alternatives. **The total project cost for rehabilitation/enhancements of the filters is $268,000.**

Alternative F4, filter media, does not need to be implemented until the next media replacement so the costs for this are not included in the total above. Alternative F3, filter aid polymer, is not critical at this time but is recommended at least on a trial basis within the next few years to determine effectiveness. The cost for F3 is included in the total above.

8.7 HIGH SERVICE PUMP ALTERNATIVES

Several high service pump alternatives were developed to increase reliability of the existing pumps, improve safety, replace outdated equipment, and address future capacity. It is anticipated that with any alternatives that include re-rating the existing filters, a downstream clearwell will be required which would result in the existing high service pumps becoming obsolete. Therefore, any new high service pumps would be configured with the new filter complex. If new filters are constructed for either filter alternative F8 or F9 and no downstream clearwell is required, then the pump station would have a similar configuration to the existing filters.

The following are the alternatives that were evaluated:

Alternative HS1: Repair/replacement of existing pumps and motors

Alternative HS2: Replace all 2400V motors and electrical gear

Alternative HS3: Reconfigure existing pump suction piping

8.7.1 Alternative HS1: Repair/Replacement of Existing Pumps and Motors

This alternative continues the existing approach by the CW&L staff to re-build or replace existing pumps and re-wind or replace existing motors as needed to continue existing pumping operation. Unless wear or issues arise sooner, pumps should be evaluated every 15-20 years and motors every 10-15 years. Pumps 1, 2, and 3 have been in service for 45 years.

This alternative also includes replacement of Pump 3 eddy current drive with a new 480V VFD motor and individual step-down transformer as the other remaining pumps would remain on 2400V power.

Installation of a redundant level instrument on the master filter level controller is also included in this alternative.

8.7.2 Alternative HS2: Replace all 2400V Pumping Equipment

This alternative includes replacement of all the existing 2400V motors with new 480V motors. At a minimum, two additional pumps would be equipped with VFDs for a total of four with VFDs. However, this alternative includes all eight pumps to be equipped with VFDs. Two of existing VFDs would be re-used.

In lieu of individual transformers for each pump, two large transformers (one duty, one backup) and an electrical distribution panel will be provided for the high service pumps. The new electrical equipment will be located in the existing filter electrical room. The transformers would be located outdoors and convert the existing 2400V power supply to 480V. The plant would remain on 2400V at the power locations.

8.7.3 Alternative HS3: Reconfigure existing Pump Suction Piping

This alternative includes reconfiguring the existing pump suction piping by increasing the size to balance suction flows to the pumps, and potentially lowering the impeller elevations to allow the filter rate of flow valves to control filter flow, versus the pumps. There are several approaches which were considered, which include:

- Option 1: Increase size of common filter effluent from 24 inches to 36 inches.
- Option 2: Replacing the existing pump inlet piping with a can. The can would sit on the floor which would enable the pump impellers to be lowered, thus lowering the minimum suction elevation by several feet and potentially allowing the filter rate of flow valves to control flow. In addition, the can would be large enough to provide some flow equalization between the pumps.
- Option 3: Re-purposing the 30 inch filter drain piping located beneath the floor to the pump suction header. To accomplish this, a new drain line would be located overhead, but below the wash water inlet elevation, to collect all the wash water flow. It would intercept each filter drain line. Existing floor drains would have to be routed in a new trench and pumped up to the drain line. The 24 inch existing filter effluent header would connect into the vertical 30 inch filter drain piping to supply filtered water to the 30 inch drain piping located beneath the floor. At each pump location, the floor would be broken out and the pump would be connected to the header pipe. This arrangement lowers the pump impeller by an additional 4 ft compared to the first option.

Option 1, increase size of influent header, would provide more volume in the suction side of the pump to help equalize flows between the filters. However, it will not impact the required minimum submergence on the impellers, thus not allowing the filters to operate in rate-of-flow mode. Installation of a larger pipe will change the flange location off the tee for each individual pump suction line, which would require the pump location to shift. The cost associated with installing the new header, plus relocating each individual pump, does not make this option feasible.

Option 2, replacing the pump inlet piping with a can is not feasible after discussion with pump manufacturers. The minimum discharge the inlet tee can be above the bottom of the can is 60 inches. The current distance from the inlet to the floor is 25 inches. Because each filter effluent pipe is located above the common 24 inch effluent header it is not feasible to modify the piping to get the required 60 inches without major pipe modifications. Therefore, this option is not feasible.

Option 3, re-purposing the 30 inch filter drain piping located beneath the floor, would also require extensive modifications and is not considered feasible.

8.7.4 Cost Estimates

The table below summarizes the project costs for each high service pump alternative. Note for HS2, the cost for replacing the 2,400V equipment is for only upgrading the high service pumps to 480V, dropping the voltage from 2,400V to 480V.

Table 8-8 High Service Pump Alternatives Cost

ALTERNATIVE	PROJECT COST
HS1: Repair/Replacement of Pump/Motor (each)	$120,000
HS2: Replace 2,400V Pumping Equipment	$1,512,000
HS3: Modify Suction Piping	Not Feasible

8.7.5 Conclusions and Recommendations

CW&L should proceed with replacing the eddy current drive on Pump 3. Replacement of the pumps/motors of the other pumps should continue to occur similar to the current maintenance schedule.

Alternative HS2, replace only 2,400V pumping equipment, eliminates the major 2,400V load at the plant. However, it would require dedicated 2400V-480V transformers that would eventually be abandoned with the entire plant eliminates the 2400V equipment, and does not set up the overall plant for future expansion if the pump station is relocated or additional pumps are required. Therefore, the replacement of the 2,400V pumping equipment should occur as part of an overall electrical project to replace the 2400V equipment. Therefore, all costs for pump improvements are included in the electrical alternatives.

8.8 FINISHED WATER TRANSMISSION MAIN

The following two alternatives were evaluated for the finished water transmission main.

Alternative FW1: Replace 36 inch flow meter in west transmission main.

Alternative FW2: Install flushing connections on transmission mains.

8.8.1 Alternative FW1: Replace Flow meter in West Transmission Main

The flow meter in the west finished water transmission main is not operable. This flow meter would be replaced to allow both finished water lines to be utilized. Having both lines in service keeps the water fresh and reduces the energy consumption on the high service pumps, and also allows ammonia to be flow paced using the meter.

8.8.2 Alternative FW2: Install Flushing Connections on Transmission Mains

When one of the finished water transmission mains is unused for an extended period, there is no easy means to flush the water prior to entering the system, unless the water is back fed into the basins through the surge relief. Therefore, flushing hydrants would be added on both lines to allow the water to be drained prior to entering the system.

8.8.3 Cost Summary

The table below summarizes the capital costs for each alternative.

Table 8-9 Finish Water Transmission Main Alternatives Cost

ALTERNATIVE	CAPITAL COST
FW1: Replace Flowmeter in West Transmission Main	$ 35,000
FW2: Install Flushing Connections on Transmission Mains	$ 20,000

8.8.4 Conclusions and Recommendations

Alternative FW1, replace flowmeter in west transmission main, is recommended. Alternative FW2, install flushing connection on transmission main, is also recommended; however this could be installed as part of one of the expansion projects.

The total project cost for rehabilitation/enhancements of the finished water line is $55,000.

8.9 LIME FEED SYSTEM

The following alternative was evaluated for the lime feed system:

Alternative L1: Install grit separator

8.9.1 Alternative L1: Install Grit Separator

This alternative consists of replacement of the vibrating screen grit handling system with a suspended bed slurry scrubber system to improve the ability to remove fine grit from the existing slurry loop. This installation would increase the capacity of each slaker from about 2,400 lbs/hr to 3,030 lb/hr of 100 percent quicklime (as CaO). Work associated with this alternative includes:

- Removal of existing vibrating screens.
- Re-routing of existing loop piping to the scrubbers.
- Remove and install new slurry aging tank covers.
- Modify the existing dosing assemblies to restrict grit from being dosed with the slurry, thereby returning grit to the scrubbers.
- Installation of the new scrubbers.

8.9.2 Cost Summary

The table below provides the capital cost for this alternative.

Table 8-10 Lime Feed System Improvement Cost

ALTERNATIVE	CAPITAL COST
L1: Add New Grit Separator	$418,000

8.9.3 Conclusions and Recommendations

The additional of the grit separator improves operation and increases capacity of the system to allow it to meet plant flow rates of up to 45 MGD. Therefore, it is required as part of any expansion project. Modifying the grit system prior to expansion would provide little benefit for the cost, therefore not recommended if the plant maintains capacity of 32 MGD.

The total project cost for rehabilitation/enhancements of the lime feed improvements is $0.

8.10 CHLORINE FEED SYSTEM

The following alternatives were evaluated for the chlorine feed system:

Alternative CL1: Automate chlorine gas feed system.

Alternative CL2: Modify chlorine gas system.

Alternative CL3: Convert to 12.5% bulk hypochlorite.

Alternative CL4: Convert to onsite generation of 0.8% sodium hypochlorite.

All chlorine feed alternatives were evaluated based on the following design criteria:

- Flows
  - Design average flow of 15 MGD
  - Peak design flow of 32 MGD
- Chlorine Dose
  - Design average dose of 7.5 mg/l
  - Peak design dose of 11 mg/l
- Chlorine Feed Rates
  - Design average feed rate of 938 pounds per day
  - Design peak feed rate of 2,935 pounds per day
- Chemical costs
  - Salt – $0.09 per pound
  - Chlorine gas - $0.22 per pound
  - Sodium Hypochlorite - $0.90 per gallon

8.10.1 Alternative CL1: Automate Chlorine Gas Feed System

The existing chlorine gas feed system consists of chlorine feeders that are adjusted manually and the resulting chlorine solution being split between the feed points by adjusting the solution flow rates. This alternative includes use of chlorine residual analyzers at each secondary basin outlet to control the chlorine gas feed rate based on residual remaining in the system. If the basin influent flow meters are replaced, a flow based feed mode would also be used. All feed rate controls will be from the plant control system.

The operator will input a desired residual and the chlorine feed rate will be adjusted to maintain the setpoint. One additional feeder would be required to allow for dose pacing of the chlorine gas to all four basins at one time. If one feeder is out of service, or if the finished water chlorine feed point is in use, the plant would have to adjust rates manually, similar to the current operation. There would be significant lag time between when the chlorine rate is adjusted and when it gets to the analyzer. This lag time will have to be incorporated into the control scheme to prevent continuous adjustment of chlorine rates.

Refer to Figure 8-2 below for schematic of the proposed modifications to the chlorine feed system.

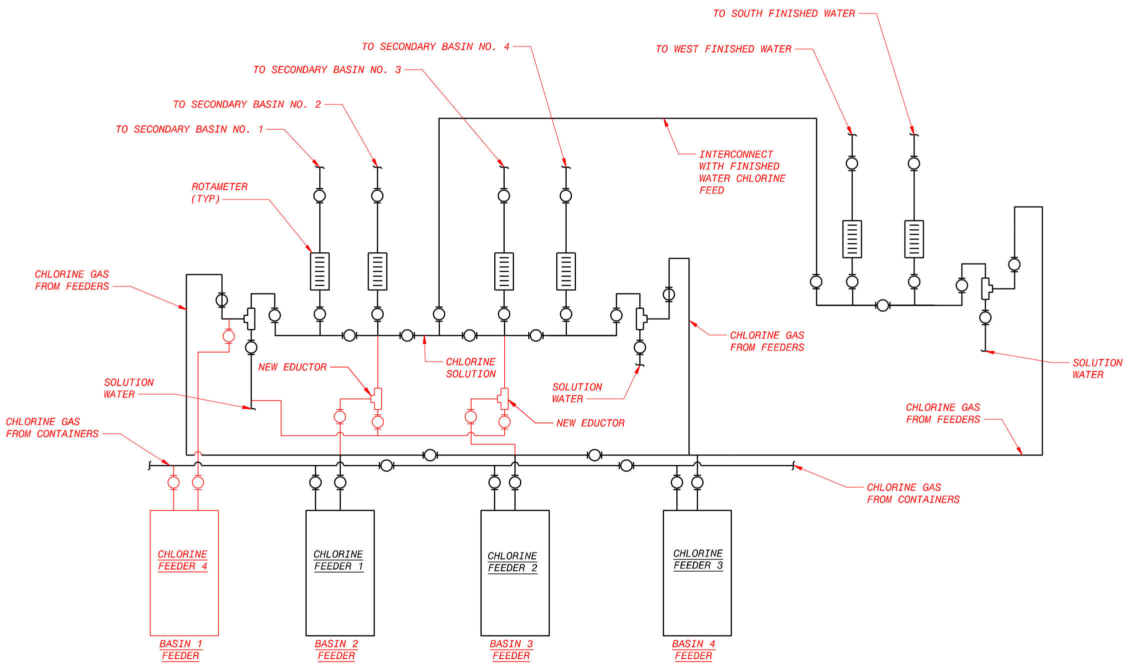


Figure 8-2 Chlorine Gas Feed System Modifications

8.10.2 Alternative CL2: Modifications to Chlorine Gas System

This alternative includes modifications to the chlorine gas system to improve safety and operation of the system. Improvements with this alternative include:

- Addition of three new feeders, providing a total of six feeders, one dedicated to each feed point.
- Chlorine feed room access to the interior of the building would be eliminated to prevent chlorine gas from escaping into occupied areas of the plant. Access will only be from the exterior.
- Chlorine ton containers would be stored on floor-mounted trunnions to prevent containers from inadvertently moving.
- The existing monorail would be extended outdoors for truck unloading to eliminate rolling of the containers.
- Separate water system, isolated by a backflow preventer, would be used for pre and post filter application points.
- An emergency chlorine gas scrubber would be installed to remove chlorine gas from the storage room interior in the event of a leak. The chlorine scrubber would be located north of the drive near the old lime silo. A wet or dry type scrubber would be used.

Refer to Figure 8-3 for schematic of the proposed modifications to the chlorine feed system.

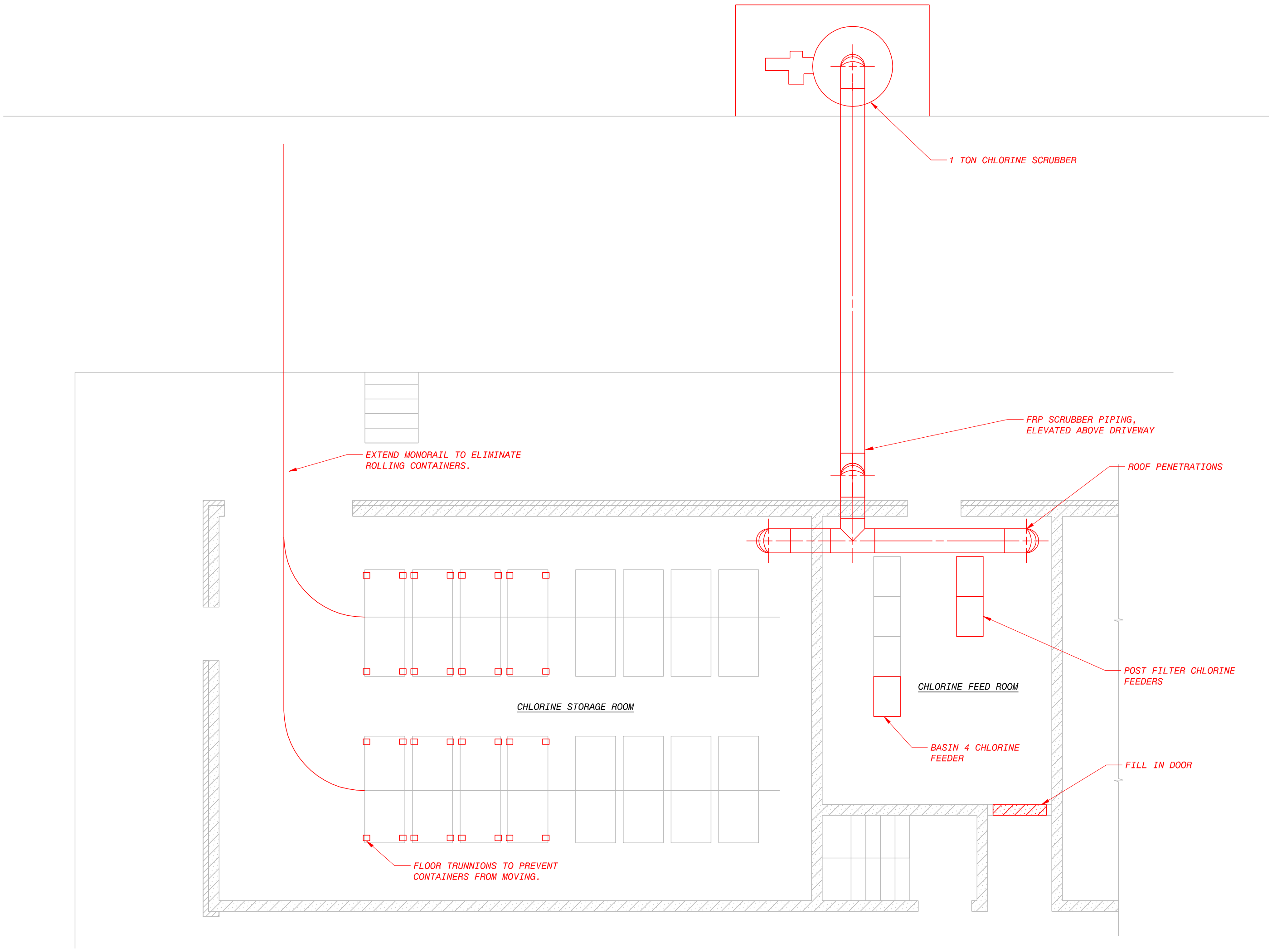


Figure 8-3 Addition of Scrubber

8.10.3 Alternative CL3: Convert to 12.5% bulk sodium hypochlorite

This alternative includes abandonment of the existing chlorine gas feed system and installation of a new sodium hypochlorite feed system that would use 12.5% bulk hypochlorite solution as the disinfectant.

Major components for the sodium hypochlorite feed system include bulk storage tanks, diaphragm or peristaltic metering pumps, transfer pumps, day tank, piping, valves, instrumentation and controls, electrical, and HVAC equipment. Storage tanks are typically constructed of fiberglass reinforced plastic (FRP).

The bulk storage tanks would be sized for 30 days of supply at average flow, average dose. Based on a design average flow of 15 MGD and average dose of 7.5 mg/l, the required bulk hypochlorite storage is 27,600 gallons. It is anticipated that storage tanks would be located in outdoor containment near the old lime silos as there is not sufficient space in the existing Chlorine Storage Room. The day tanks and metering pumps would be located in existing Chlorine Storage Room.

A special consideration associated with bulk sodium hypochlorite storage and use involves the degradation or decay of the chemical over time, which results in aged solutions that are weaker and less effective. The degradation of sodium hypochlorite may also present safety issues and regulatory issues in the future. Certain factors speed up the degradation of sodium hypochlorite, including metallic impurities, exposure to sunlight, pH outside the desired range, increased temperature, and higher original concentration. Each of these factors contributes to the degradation of sodium hypochlorite in different ways. To minimize degregation, a canopy will be located over the storage tanks to limit sunlight exposure to the tanks.

A 12.5 percent concentration of hypochlorite freezes at -3°F. Therefore, outdoor storage facilities require heat tracing of exposed piping and tanks. Consideration for installing the tanks and metering pumps inside a new building should be given during detailed design if this alternative is selected.

Located inside the existing chlorine storage room will be two day tanks and seven metering pumps. One pump will be dedicated to each basin train and finished water transmission main, plus a common spare. On smaller systems, one day tank is typically sufficient. However, this presents a single point of failure in the chlorine feed system. Therefore, two day tanks are recommended for this system. Typically, one would be dedicated for pre-filter chlorine applications points, and the other for post-filter application points. However, piping will be provided to allow either day tank to supply any of the feed pumps.

The size of the day tanks should be based on the higher of the maximum flow/average dose or average flow/maximum dose for a 24 hour period. Based on this criteria, the total day tank volume would be about 1,400 gallons.

Although not as stringent as the requirements for indoor chlorine gas facilities, liquid sodium hypochlorite at 12.5 trade percent is classified as a corrosive health hazard under the IBC. In addition to the secondary containment provisions required for liquid health hazards, appropriate automatic sprinkler systems and ventilation powered by standby or emergency power may be required for an indoor sodium hypochlorite storage and feed facility if the volume is about 500 gallons. However, review from the local fire protection district would ultimately decide whether fire suppression would be required.

The secondary degradation byproduct of sodium hypochlorite is dissolved oxygen. The release of dissolved oxygen may cause air binding of pumps and dangerous over-pressurization of piping systems. These issues must be addressed by specific feed system design measures. Plastic diaphragm valves or vented ball valves are recommended for shutoff valves in 12.5 trade percent sodium hypochlorite service. Metering pump suction piping should be sloped up towards the storage tank (allowing gas bubbles to flow back to the tank when the sodium hypochlorite velocity is low) and a vent should be provided in the suction piping.

The choice of metering pumps can help eliminate air binding of pumps. Peristaltic pumps reduce the risk of oxygen accumulation in the metering pump head and the impacts of air-binding that would paralyze the pump.

<u>Operational and Safety Issues:</u> Operationally, bulk sodium hypochlorite feed systems are similar to other liquid chemical feed systems. However, due to degradation issues, active management of storage times in order to maximize efficiency is required. Piping systems and valves must be designed to prevent over-pressurization.

Due to the high pH of 12.5 trade percent sodium hypochlorite solution and the sodium content, scaling can occur at sodium hypochlorite injection points. Frequent cleaning and preventive maintenance can be effective to keep injection nozzles functioning properly. Concentrated sodium hypochlorite solution is also aggressive towards threaded connections and poor quality solvent welded joints. Sodium chloride salt crystals tend to plate out in small openings, causing expansion, continued leakage, and maintenance issues.

The high pH will also impact the finished water pH. Based on similar types of facilities, switching from chlorine gas to bulk hypochlorite will increase the finished water pH by about 0.3 units.

Use of bulk sodium hypochlorite would eliminate the need for preparation and maintenance of an Risk Management Plan.. Bulk sodium hypochlorite is a corrosive liquid that operators must handle with care. However; the use of bulk sodium hypochlorite would increase plant personnel and public safety, and would reduce security risks at the plant, as compared to the continued use of chlorine gas.

<u>Construction Staging</u>

The existing chlorine gas system will have to remain operational while the new bulk hypochlorite system is installed in the Chlorine Storage Room. The work will have to be phased to make this occur. The following sequence is anticipated for construction:

- Construction of the outdoor containment area, bulk storage and transfer pumps, and canopy would be completed.
- All piping outside of the Chlorine Storage Room would be completed except final terminations at feed points to allow chlorine gas system to remain operational.
- Four of the seven metering pumps would be piped on skids, tested, and ready for installation.
- With two basin trains out of service, the spare containers on the south side of the room would be removed and one day tank and the four metering pumps would be installed. Final connections for the tanks and pumps would occur over 2-3 days while the chlorine gas system remained operational.
- Once the pumps are operational, the feed system would switch over to the hypochlorite with the four pumps feeding all the dedicated feed points for the two basin trains and finished water line.
- The gas system would be fully demolished and the remaining day tank, metering pumps, and containment curb constructed.

Note that this requires work inside the chlorine room while gas is in use.

Refer to Figure 8-4 for proposed layout of the bulk hypochlorite feed system.

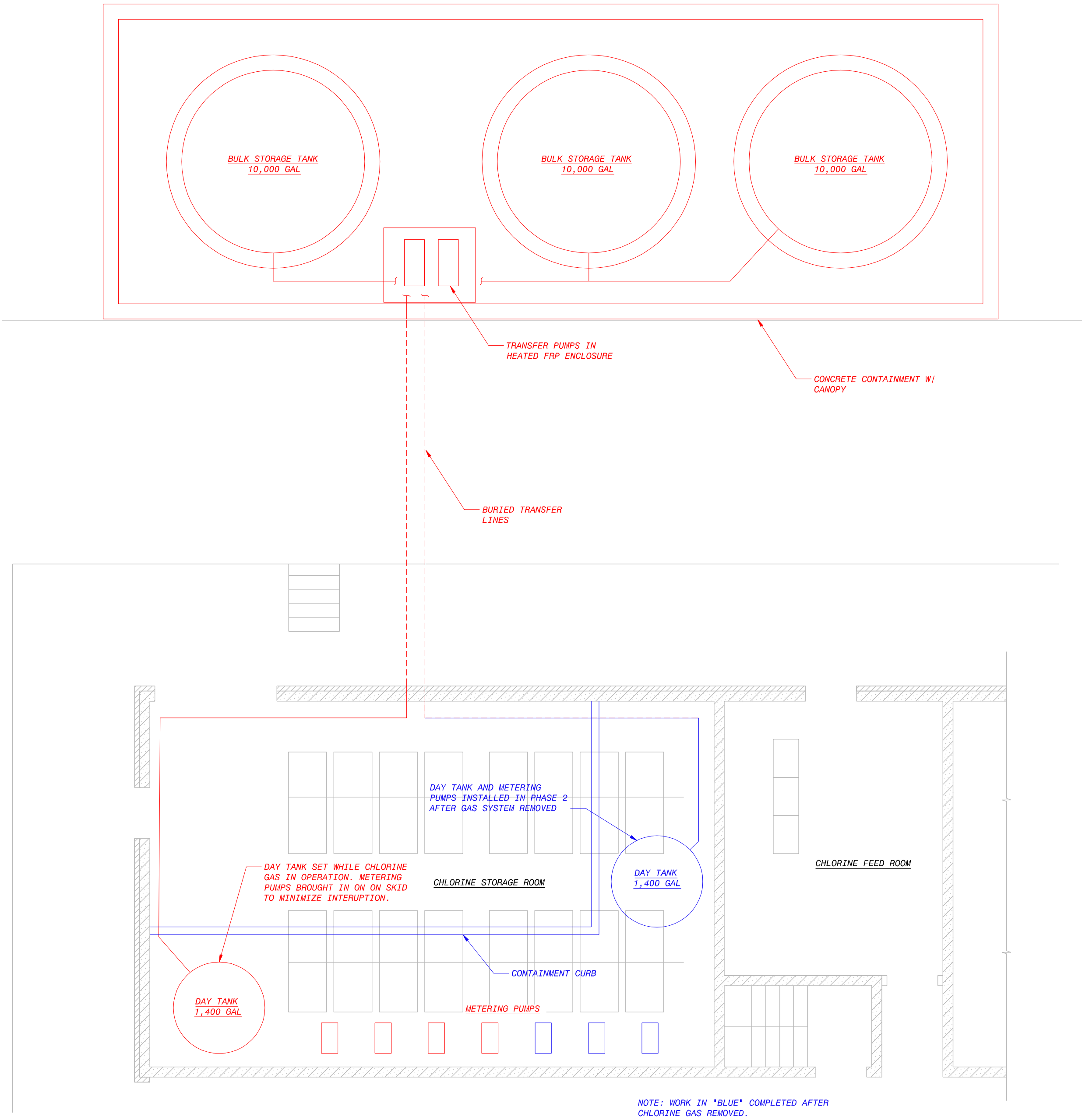


Figure 8-4 Bulk Hypochlorite Feed System

8.10.4 Alternative CL4: Convert to Onsite Generation of 0.8% Sodium Hypochlorite

This alternative includes abandonment of the existing chlorine gas feed system and installation of onsite generation of sodium hypochlorite. Major components of an onsite generation system include:

- Generation equipment including rectifiers
- Brine storage tank
- Brine pumps

- Water Softeners
- Metering Pumps
- Bulk Storage tanks
- Air Blowers

It is anticipated that the generation equipment, blowers, water softeners, metering pumps, brine pumps and control panels will be located in the existing chlorine storage room. The bulk storage tanks for the dilute sodium hypochlorite solution and the bulk salt storage/brine tank will be installed outdoors under a canopy near the abandoned silos. Heat tracing will be used to prevent freezing of the chemical and exposed piping. The dilute solution will freeze at the same temperature as water, 32°F. A hydrogen release standpipe will also be located in the containment area.

Byproducts of the sodium hypochlorite generation process include hydrogen gas and waste brine from the water softening equipment regeneration process. Blowers will be provided to induce positive ventilation to dilute the hydrogen gas concentration as it is vented from the hydrogen release standpipe and bulk storage tanks. Flow switches are provided on the blower system to ensure airflow prior to system operation. Ventilation system failure will cause an automatic shutdown of the generation system to prevent a dangerous build up of highly explosive hydrogen gas.

Waste brine is only produced during the water softener regeneration cycles. Two dual tank water softener systems will be used such that one tank may be in service while the other is in the regeneration or standby mode. These units will be sized for a maximum of one regeneration cycle requirement per day, which would produce an approximate 5 gpm waste stream for 30 minutes approximately every 5 hours, for a total of approximately 750 gallons per day. The waste cannot be sent to the septic system as the brine will corrode the septic tank. Therefore, if the plant is not connected to the sewer system, the waste brine will be sent to a brine waste storage tank. This tank will be periodically pumped out by the CW&L sludge truck and be disposed at a wastewater facility.

MDNR does not have specific standard for storage requirements when using onsite generation of sodium hypochlorite. The following are two sizing and storage approaches:

<u>Option 1:</u>

This approach includes providing three units each, sized for 33 percent of the maximum feed demand, which results in each unit rated at 1,000 ppd. This arrangement provides over 100 percent backup at average day demand conditions and 67 percent capacity at maximum demand conditions with one unit out of service. The 0.8 percent concentration of hypochlorite storage tanks will be sized to provide adequate storage for three days of storage at 33 percent of the maximum dose/maximum feed rate, to offset any lost capacity if one generator is out of service. Based on this concept, total tank storage of 45,000 gallons would be required. Three 15,000 gallon storage tanks, 14 ft diameter, along with two brine tanks would be required for this alternative. Each brine tank would be sized for 15 days of maximum flow/ average dose resulting in each being sized for 50 tons of storage.

As part of the system, a dilution panel would be provided that takes 12.5 percent bulk hypochlorite and dilutes to 0.8 percent. This allows for a backup feed system in the event of a long term system outage. It is anticipated that a delivery of 12.5 percent hypochlorite can be made to the plant within 3 days.

No day tanks or transfer pumps are required for this system.

This concept matches another installation in Missouri that was approved by MDNR.

Option 2:

This approach includes providing two units each sized for maximum flow at average dose, which results in each unit rated at 2,000 ppd. This arrangement provides 33 percent additional capacity with both systems in operation at maximum flow, maximum dose. The 0.8 percent concentration of hypochlorite storage tanks will be sized for 1,000 ppd for three days to offset the lost capacity if one unit is offline at peak flow, peak demand. If the peak flow, peak demand lasts longer than 3 days, then bulk hypochlorite would be provided and diluted for backup. This results in a total storage volume of 45,000 gallons.

Construction Staging

The existing chlorine gas system will have to remain operational while the new system is installed in the Chlorine Storage Room. The work will be phased to make this occur. The anticipated sequence of construction is similar as for the bulk hypochlorite alternative, except that after the metering pump installation, the system will have to be fed by diluted bulk hypochlorite until the onsite generators are installed and operational. It is expected that use of bulk hypochlorite would be required for several weeks.

Refer to Figure 8.5 for proposed layout of the onsite generated sodium hypochlorite feed system.

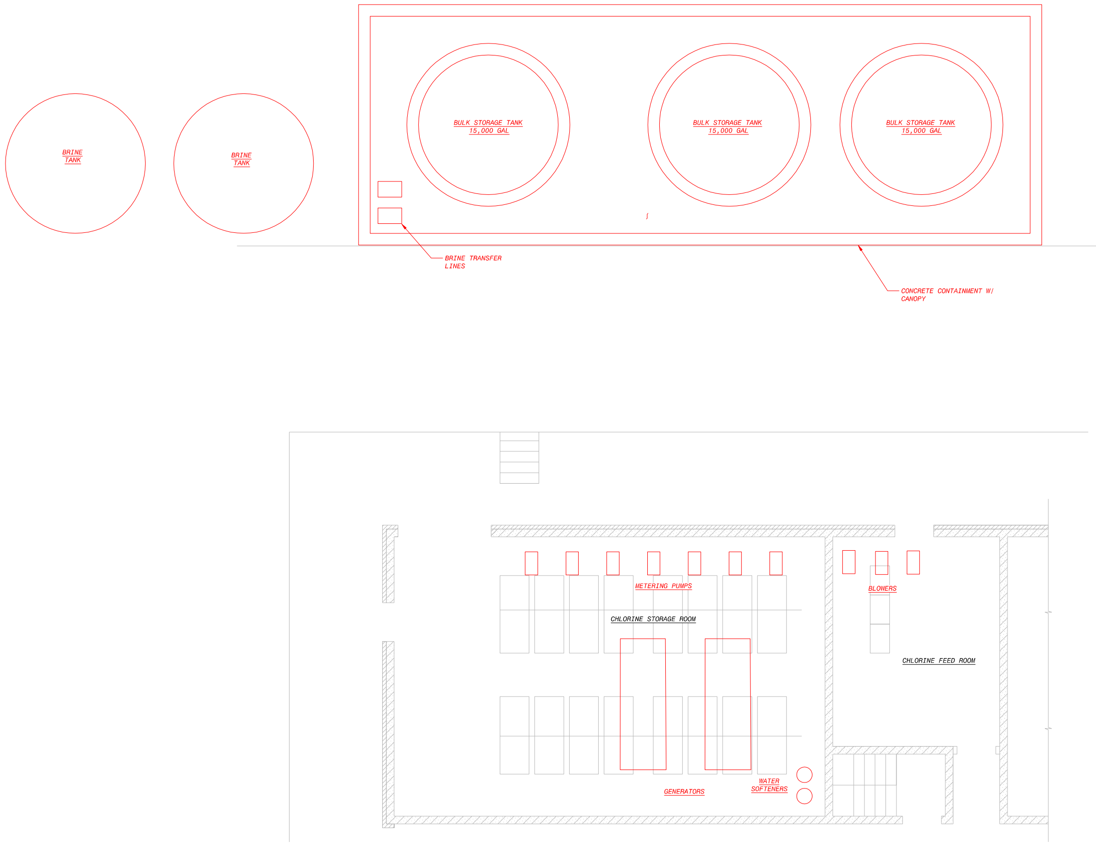


Figure 8-5 Onsite Generation of Hypochlorite

8.10.5 Cost Summary

The table below presents capital costs, estimated annual operation and equipment replacement costs, and effective present worth costs based on 25 year life cycle for the chlorine alternatives described above.

Table 8-11 Chlorine Feed System Alternatives Cost

ALTERNATIVE	CAPITAL COST	ANNUAL O&M COST	25-YR PRESENT WORTH
CL1: Automate Chlorine Feed System	$163,000	$81,687	$1,758,000
CL2: Chlorine Gas System Modifications	$810,000	$81,687	$2,405,000
CL3: Conversion to Bulk Hypochlorite	$1,065,000	$300,021	$6,922,000
CL4: Conversion to Onsite Hypochlorite	$3,386,000	$193,486	$7,164,000

8.10.6 Conclusions and Recommendations

The chlorine alternatives described were evaluated based on their safety and environmental concerns, and a variety of other factors including capital and operating costs, ease of operation, and staff familiarity. The evaluation and selection process was performed as follows:

Comparison of Alternatives

The table below presents a general summary of the advantages and disadvantages of the different disinfection systems.

Table 8-12 Summary of Advantages and Disadvantages

SYSTEM	ADVANTAGES	DISADVANTAGES
Chlorine Gas	• Low operational cost. • Low transportation cost. • Plant staff familiarity. • No degradation or waste product issues. • Simple and efficient disinfection. **Cost to produce one lb of 100% chlorine:** **$0.24 (includes all O&M)**	• Regulated oxidizing physical hazard and a corrosive and toxic health hazard. • Highest safety risk to staff and environment. • Emergency treatment system required. • Risk Management Plan and Process Safety Management Plan required. • Self contained breathing apparatus (SCBA) must be worn by appropriate staff during container change out. • Low public perception.
Bulk Sodium Hypochlorite	• Low initial / capital cost. • Perceived to be safer than chlorine gas. **Cost to produce one lb of 100% chlorine:** **$0.93 (includes all O&M)**	• Product degradation. • Generates chlorate and oxygen gas as degradation byproducts. • High operational cost. • High transportation cost. • Must operationally balance minimizing storage times and having product available for use. • Regulated corrosive health hazard. • High risk to the community due to the transportation of a corrosive chemical to the WTP • Impacts finished water pH
	• No toxic chemicals are stored, handled, or produced. • No toxic chemicals are transported to the WTP. • Lowest safety risk to staff, public, and environment. • Low operational cost. • Product degradation minimized. • Low price volatility. **Cost to produce one lb of 100% chlorine:** **$0.56 (includes all O&M)**	• High initial / capital cost. • Generates hydrogen gas as a byproduct. • Regeneration of the water softener generates a small brine waste stream. • Unless storage is provided, short product storage time requires quick operator response to equipment problems in order to ensure continuous disinfection of finished water.

Economic and Non-Economic Criteria

The criteria and weighting factor for the economic and non-economic comparisons are shown in Table 8-13.

Table 8-13 Economic and Non-Economic Evaluation Criteria

NON-ECONOMIC EVALUATION CRITERIA	
Criteria	**Weighting Factor**
Capital Cost	15
Present Worth Cost	15
Chemical Stability	5
Chemical Delivery	5
Operational Simplicity	10
Plant Safety	20
Community Safety	20
Regulatory	5
Reliability	5
Summary	**100**

After establishing the weighting factor, each alternative was considered with regard to the criteria, and a score was assigned to each alternative on scale of 1 to 10, with 10 indicating the best performing technology in the respective criteria category. Based on the importance factors of the criteria and the individual criteria scores for each alternative, a total score was calculated. The higher the total score, the better that the alternative met the criteria. Table 8-14 summarizes the results.

Table 8-14 Non-Economic Evaluation Results

CATEGORY	WEIGHT	CL1 (GAS)	CL2 (SCRUB)	CL3 (HYPO)	CL4 (OSG)
Capital Cost	15	10	7	5	1.
Present Worth Cost	15	10	8	3	3
TOTAL COST	**30**	**20**	**15**	**8**	**4**
Chemical Stability	5	10	10	6	8
Chemical Delivery	5	8	8	5	10
Operational Simplicity	10	10	10	9	7
Plant Safety	20	1	3	9	10
Community Safety	20	1	3	10	10
Regulatory	5	2	5	9	10
Reliability	5	10	10	9	7
TOTAL NON-ECOM	**70**	**25**	**34**	**59**	**61**
TOTAL COMPOSITE	**100**	**55**	**57**	**71**	**67**

Ranking of Alternatives

The results from the economic and non-economic evaluations were used to establish overall rankings for the alternatives.

If cost were the only factor to consider, then the recommended approach would be to upgrade the chlorine gas system with scrubber and automatic controls. However, this approach does not address the safety and security concerns related to possible chlorine gas leaks while the cylinders are in transit to the site and possible operator injuries resulting from handling the dangerous chemical.

If costs were not considered, then CL4 onsite generation, best meets the non-monetary criteria established for the study. But the CW&L must provide quality water to their customers in a cost effective manner, therefore costs must be considered.

Based on the total composite score, converting to bulk hypochlorite is the recommended alternative at this time. The lower initial capital cost will allow more funds to be spent on other critical plant improvements, and the overall payback period for onsite generation is about the length of time the equipment would need to be replaced. One variable that does remain is the bulk hypochlorite price. The current bulk hypochlorite pricing is lower than a few years ago (about $0.30/gal lower), so if the price does increase, it would make onsite generation more favorable in the future, especially as flows increase. The benefit of the bulk hypochlorite system is that a majority of the tanks could be re-used for onsite generation, so it is easily convertible in the future if conditions change.

The total project cost for rehabilitation/enhancements of the chlorine feed improvements is $1,065,000.

8.11 FLUORIDE FEED SYSTEM

The following alternatives were evaluated for the fluoride feed system:

Alternative FL1: Rehabilitate existing feed system

Alternative FL2: Feed System enhancements

8.11.1 Alternative FL1: Rehabilitate existing feed system

This alternative improves the condition of the existing fluoride feed system. The following improvements are included with this alternative:

- Piping from the storage tank would be upgraded to double-contained piping.
- The day tank fill pipe would be fitted with an electric valve to automatically shutoff flow when the day tank reaches a maximum liquid level.
- A new bulk tank would be provided with adequate capacity to accept a full truckload of fluoride plus an additional 25%. This volume equates to approximately 5,500 gallons. The new tank would incorporate a flush bottom drain, overflow nozzle, pump suction, site level gauge, vent, and top and side access manways. The existing tank should be replaced within the next 5 years.
- The storage tank containment area would be fitted with stairs or a ladder for access.

- The storage tank containment area (and day tank and metering pump area) would be lined with a corrosion protection liner to prevent acid spills from damaging the concrete. The drain would also be plugged. The plug would be configured to be removable to allow the drain to be utilized during washdown.

8.11.2 Alternative FL2: Feed System Enhancements

Included with this alternative are modifications that would improve performance, safety, and reliability of the system. These include:

- The fluoride day tank and metering pump area would be segregated from other areas of the building and provided with a dedicated ventilation system.
- Automatic controls for the fluoride feed system. Leak detection, and pump fault alarms would be incorporated into the operations for better operator control.
- The tank and containment area would be covered with a canopy to protect piping from UV exposure and prevent accumulation of rainwater
- The storage tank containment area would be fitted with a sump or other means to accumulate and remove rainwater and spilled liquids in the containment area for proper disposal.
- Improvements included in alternative FL1.

8.11.3 Cost Summary

The table below summarizes the capital costs for each alternative.

Table 8-15 Fluoride Feed System Alternatives Cost

ALTERNATIVE	CAPITAL COST
FL1: Rehabilitate Existing Feed System	$70,000
FL2: Feed System Enhancements	$244,000

8.11.4 Conclusions and Recommendations

Both alternatives improve the safety and condition of the fluoride feed system. Alternative FL1, rehabilitate existing feed system, should be implemented as a priority item to prevent potential leaks from causing damage and presenting safety concerns. Alternative FL2 should also be implemented at some point to isolate the fluoride feed system from equipment and other chemicals.

The total project cost for rehabilitation/enhancements of the fluoride feed improvements is $314,000.

8.12 AMMONIA FEED SYSTEM

The following alternatives were evaluated for the ammonia feed system:

Alternative AM1: Rehabilitate existing feed system

8.12.1 Alternative AM1: Rehabilitate existing feed system

This alternative improves the condition of the existing ammonia feed system. The following improvements are included with this alternative:

- The pump heads or tubes would be resized, or new pumps provided, to allow for feeding ammonia to both finished water lines. If new pumps are provided, only three are required, one to serve each transmission main and a common backup.
- The LAS day tank and metering pump area would be provided with secondary containment to prevent uncontained spills of LAS into the lower level.
- The piping from the storage tank would be upgraded to double-contained piping for a more robust piping system that protects the primary pipe from damage.
- LAS day tank fill procedures would be modified to manually-initiated fill with automatic shutoff when the day tank reaches a maximum liquid level. High level alarms would be added in the event of the shutoff valve not properly closing.
- A new bulk tank should be provided with adequate capacity to accept a full truckload of ammonia plus an additional 25%. This volume equates to approximately 5,500 gallons. The new tank would incorporate a flush bottom drain, overflow nozzle, pump suction, site level gauge, vent, and top and side access manways. If possible, the tank and containment area should be covered with a canopy to protect piping from UV exposure and prevent accumulation of rainwater. The existing tank should be replaced within the next 5 years.
- The storage tank containment area should be fitted with stairs or a ladder to personnel access to the interior. Additionally, the storage tank containment area should be fitted with a sump or other means to accumulate and remove rainwater and spilled liquids in the containment area for proper disposal.

8.12.2 Cost Summary

The table below provides the capital cost for this alternative.

Table 8-16 Ammonia Feed System Alternatives Cost

ALTERNATIVE	CAPITAL COST
AM1: Rehabilitate Existing Feed System	$83,000

8.12.3 Conclusions and Recommendations

This alternative is recommended to allow both transmission mains to be utilized and improve safety and operation of the ammonia system.

The total project cost for rehabilitation/enhancements of the ammonia feed improvements is $83,000.

8.13 PLANT SERVICE WATER

The following alternative addresses modifications to the plant service water:

Alternative PW1: Rehabilitate plant service water

8.13.1 Alternative PW1: Rehabilitate Plant Service Water

This alternative includes replacement of the isolation valves installed on the plant service water piping from either original construction or the 1994 expansion. Currently, many of these valves are inoperable and thus do not allow sections of the piping to be isolated for repair. Work on this alternative will need to be sequenced and would require potential temporary connections, to facilitate replacement of the valves while keeping the treatment plant in operation. This alternative assumes 10 valves are in need of replacement.

This alternative also includes replacement of two backflow preventers that serve the chemical feed systems.

8.13.2 Cost Summary

The table below provides the capital cost for this alternative.

Table 8-17 Plant Service Water Alternatives Cost

ALTERNATIVE	CAPITAL COST
PW1: Rehabilitate Plant Service Water	$55,000

8.13.3 Conclusions and Recommendations

This alternative is recommended prior to any major plant work to allow for the plant to isolate portions of the plant for extended periods for modifications.

The total project cost for rehabilitation/enhancements of the ammonia feed improvements is $55,000.

8.14 SEWER SYSTEM

The following alternative addresses modifications to the sewer system:

Alternative SS1: Route sewer to Wastewater Treatment Plant

8.14.1 Alternative SS1: Route Sewer to Wastewater Treatment Plant

This alternative includes replacement of the existing septic field with a lift station and 3 inch forcemain routed to the City's WWTP. The forcemain would be routed to the west across the creek and then along the treatment lagoons to the head of the plant. The route consists of 16,800 ft of pipeline and five creek crossings.

8.14.2 Cost Summary

The table below provides the capital cost for this alternative.

Table 8-18 Plant Service Water Alternatives Cost

ALTERNATIVE	CAPITAL COST
SS1: Route Sewer to Wastewater Treatment Plant	$702,000

8.14.3 Conclusions and Recommendations

This alternative provides a permanent sanitary solution for the plant, and it would be able to accommodate additional flows as the plant expands capacity. However, this is an initial costly investment and should be weighed against other improvements, cost to rehabilitate/expand existing system, and overall capital budget. This should be considered a low priority improvement.

The total project cost for rehabilitation/enhancements of the sanitary system is $702,000.

8.15 PLANT CONTROL SYSTEM UPGRADES

The improvements to the plant control system can be completed as one major plant control upgrade project or a phased approach to limit the down time and spread the costs for this upgrade. If a phased approached is selected, the first phases of the plant control system upgrade should address the most critical items, and the later phases would upgrade the plant control system hardware/software that is not as critical.

Based on this, the following two alternatives were developed.

Alternative PC1: Control upgrades as a phased approach

Alternative PC2: Control upgrades as one project

8.15.1 Alternative PC1: Control Upgrades as a Phased Approach

Things to consider when defining the phases for upgrading the plant control system are:

- Hardware Availability
- Time Required For Upgrade
- Plant Operation During Upgrade

Based on these major items, the following phased approach for the upgrade of the plant control system has been developed:

Phase 1: Replace the majority of the outdated PLCs and modify communications for Ethernet capabilities.

Phase 2: Rehabilitate existing SCADA system by replacing hardware and software.

Phase 3: Future replacement of Filter PLCs and OITs.

Phase 4: Upgrade existing wellfield communications and controls to Ethernet based system.

The following describes the work as broken down per phase. Refer to Figures PC1 for schematic showing the proposed improvements.

Phase 1: PLC Replacement and Communications Modifications

According to the PLC manufacturer, the GE 90-70 PLC hardware and the Genius I/O hardware are considered obsolete. GE no longer supports this PLC hardware, and replacement modules will be extremely hard to find and expensive to purchase. Since the plant's Main PLC and the West Ash Pump Station PLCs are critical devices at each of their locations, these PLCs need to be replaced as soon as possible. A planned approach to the replacement of these PLCs can be developed as opposed to reacting when one of them fails and replacement parts cannot be found.

The first step in this planned approach of replacing these PLCs is to determine what PLC manufacturer to use. After speaking with a local GE representative, the conversion of the 90-70 PLC program may not be an easy conversion. Some additional programming will be required. The conversion of the 90-30 PLC and VersaMax Micro PLC programs would be easier. In addition, most new plant control systems utilize an Ethernet network for communication between the PLCs and SCADA computers, which Black & Veatch would recommend. Therefore, all of the PLC programming used for communication will need to be revised. If the phased approach of replacing the plant control system is used, it will be easier to transition to the newer PLCs if the same PLC manufacturer is used. A different manufacturer could be used, but additional hardware, software, and/or programming will be required to allow communication between two different PLC manufacturers during the transition between PLC upgrades. If CW&L plans to use system integrators to program the PLCs, another thing to consider is the programming abilities of these local system integrators. In general, most system integrators are capable of programming PLCs from the major PLC manufacturer's, such as Allen-Bradley (Rockwell Automation) or GE. Based on these considerations, Black & Veatch would recommend that CW&L continue to use GE PLC hardware and replace the GE 90-70 PLCs with GE RX3i PLCs.

The current location of the Main PLC panel is in the basement of the Admin./Chem. Building. As suggested by CW&L, Black & Veatch recommends that the new Chemical Building PLC be installed on the main level of the building near the current location of the server hardware to reduce the risk of damage due to flooding and place the panel in a more stable environment. After installing the new PLC panel, the I/O currently wired to the Main PLC and the remote I/O panels located within this building (currently communicating on Genius Bus #1) can be transitioned to the new Chemical Building PLC. The program logic that resides in the Main PLC will need to be re-programmed within this new PLC. All of the programming associated with the data exchange between remote I/O and plant PLCs will need to be completely revised. Since the Lime Feed System PLCs are already communicating with one another over an Ethernet network, these PLCs could be connected to the new Plant Control System using Ethernet communication. In order to establish the Ethernet network, an Ethernet switch will be required for the new Plant Control System. Due to the distance between the proposed location of the Ethernet switch (rack mounted near the Chemical Building PLC Panel) and the lime feed system, Black & Veatch would recommend that a fiber optic cable be routed between these locations. The new Ethernet switch will need to have both copper and fiber ports to make the necessary connections to the remote PLCs. At the lime feed system, Black & Veatch recommends replacing the existing Ethernet switch with a new one that is equipped with both copper and fiber ports.

For the filter PLCs and remote I/O that were connected to the Genius Bus #2, the configuration and programming of the new Chemical Building PLC will depend on when the system upgrades are made to the Filter Building. If the plant control system modifications for the Filter Building are done at a later date, the Common Function Remote I/O will still need to be monitored and controlled by the Chemical Building PLC. The Genius Bus Controller module used by the Common Function Remote I/O will need to be replaced with a Profinet communication module. At the Chemical Building PLC, a Profinet communication module will also be required to connect the remote I/O to this PLC. Since the existing Filter PLCs are equipped with an Ethernet port, these PLCs could be configured to communicate with the Chemical Building PLC using Ethernet communication. A small industrial rated Ethernet switch should be installed within each filter panel, and a larger Ethernet switch will be required in the Filter Building to allow this type of communication. If the system upgrades to the Filter Building are made at the same time, the new Filter PLCs and Filter Building PLC (which replaces the Common Function Remote I/O) can be installed and connected to the Plant Control System using the fiber optic cable ring that is proposed for the Ethernet communication.

For remote communication with the wells, new Ethernet radios would be installed at each well. A new Ethernet radio would also be installed at the plant that would be connected to the Plant Control System through an Ethernet switch.

This phase also needs to include the replacement of the West Ash Booster Pump Station PLC. Black & Veatch would also recommend that a GE RX3i PLC be installed at this location. Ethernet communication will be used to communicate with the plant. Depending on the control hardware that is used at the Walnut Tower either Profinet or Ethernet communication can be used to communicate with this remote site.

The communication between the Main PLC, the West Ash Booster Pump Station PLC, and the SCADA servers would also be changed to an Ethernet communication link. Some programming and network hardware changes will be required to change the communication link from serial communication to Ethernet.

<u>Phase 2: SCADA Rehabilitation</u>

In phase 2, Black & Veatch would recommend replacing the existing SCADA hardware and software. Since the SCADA software that is currently used is for both the water plant and the power division, new SCADA servers dedicated to only the water plant and the remote sites associated with the water division will be used. In addition, Black & Veatch would recommend that these servers be installed at the plant, so that the plant's SCADA system is not completely dependent on the communication link to the down town location. If the ability to monitor and control the plant from the down town location, an operator work station could be installed at this location and connected to the servers at the plant.

The server at the plant and the server at West Ash Pump Station should be setup in a redundant server configuration to run the new SCADA system with all of the plant data being saved on both servers. In addition, these servers would be configured to automatically switch over to the backup server when the primary server fails. A thin client with two monitors, keyboard, and mouse shall be installed within the plant's control room and used as an operator workstation. Black & Veatch would also recommend another thin client with a touch screen monitor be installed within the Filter Building to allow the operator to view all of the HMI screens from this building also. An Ethernet network will be used to transfer data between all of these new servers and operator workstations, so Ethernet switches, CAT cable, and possibly fiber optic cable will also be required to connect all of these computers. With the use of local servers and an all Ethernet communication network, all of the operator workstations can receive and send data to the process equipment faster than the current SCADA system. It also possible to have a tablet loaded with the HMI screens that would allow the operator to view these screens anywhere within the plant. If this is something that CW&L desires, WIFI antennas would be required throughout the plant to provide the necessary coverage to allow the operator to connect to the plant control system.

The latest version of a SCADA software package will be installed on these servers and thin clients. Similar to the selection of a PLC manufacturer, Black & Veatch would also recommend that one of the major SCADA software suppliers (Wonderware, iFix, etc.) be used, so that CW&L will have several system integrators to choose from when bidding this work. With the use of this software, new windows based graphics will be used to develop an application specifically designed for the water plant. The new software will be more user friendly for both the integrator and operator. New screens can be configured that graphically represent the different process at the plant. Alarming and reporting features can also be developed to meet CW&L's needs.

Phase 3: Filter PLC and OIT Replacement

As mentioned above in the description of the existing system, the filters PLCs are GE Fanuc 90-30 PLCs. These PLCs are considered a mature product by GE. These PLCs are still supported by GE for the next several years (5-6 years), but when this time expires, they will be considered obsolete like the 90-70 PLCs. Therefore, Black & Veatch recommends that these PLCs be replaced in the future. There are two options to upgrade these PLCs. If CW&L wishes to reuse the existing filter PLC panels, the existing PLCs could be replaced with Rx3i PLCs. The existing PLC programs that control the filter operation should be easily converted to the newer PLCs, but some reprogramming will be required for the communication with the Common Function Remote I/O Panel. When these PLCs are replaced, the Genius bus that is used to communicate between the filter PLCs and the remote I/O in the Common Function Remote I/O Panel will no longer be used.

Another option is to replace the whole filter control panel. If this option is selected, Black & Veatch recommends installing a new filter control panel that monitors and controls a pair of filters to reduce the amount of panels needed. Since the existing PLCs only controlled one filter, a direct conversion of the PLC program will not be allowed, but the existing PLC programs can still be used as a basis for programming the new PLC.

For either filter PLC upgrade option, Black & Veatch also recommends that the Common Function Remote I/O be converted to the Filter Building PLC. This PLC will monitor and control the common equipment associated with the filters. By converting this remote I/O to a PLC, this equipment will be controlled and monitored by a local PLC within the Filter Building. During a filter back wash cycle, the associated filter PLC will directly communicate with the Filter Building PLC and request the operation of the required equipment.

If the option to re-use the existing filter panels is selected, the existing operator interface terminals (OITs) should also be replaced. The existing OITs communicate with the filter PLCs over a serial communication link. The new OITs should communicate with the new PLCs over an Ethernet connection with the new filter PLCs. As described in Phase 1, a small industrial rated Ethernet switch should be installed within each filter control panel, so by connecting the new OIT to this Ethernet switch, it can communicate with its associated filter PLC.

Phase 4: Well field Communication Upgrade

To make the communication link between the Plant Control System and the well field more dependable and gain faster data exchange, Ethernet radios will be installed at each well site and at the plant in a future project. Black & Veatch would also recommend that the existing VersaMax micro PLCs that are not equipped with an Ethernet port be upgraded in order to take full advantage of the Ethernet communication. Due to the small amount of I/O that each well PLC monitors and controls, small brick style PLCs are more than enough for this application as long as they are equipped with an Ethernet port.

In addition to the PLC and radio upgrades, another feature that could be added to the wells is the installation of a security camera system to monitor the well site. This camera system would also communicate over the Ethernet radios. One camera manufacturer installs a DVR at each remote site that records high quality video. The camera system can be configured to send a low quality video or picture file of the remote site over a configurable frequency (for example a video or picture file can be sent every five minutes) to the plant. This method would conserve radio bandwidth and not overload the radio communications. If a security issue or event occurs, plant personnel can access high definition video from the DVR at the well site to see more than what was sent to the plant.

8.15.2 Alternative PC2: Control Upgrades as One Project

This alternative includes the same major components and work described in Alternative PC1, but with all the work completed under one large control upgrade project. Work would still be staged under the project to keep the plant in operation during the upgrades, but one contractor and system integrator would perform all the work.

8.15.3 Cost Summary

The table below summarizes the capital costs for each alternative.

Table 8-19 Plant Control System Upgrades Cost

ALTERNATIVE	CAPITAL COST
PC1: Control Upgrades as Phased Approach	$1,887,600
PC2: Control Upgrades as One Project	$1,716,000

Note, for PC1, this is the cost for the entire project. Portions of the work would be completed at different times so each individual project would be less, but the overall project slightly more due to economy of scale and the costs to develop separate documents to accommodate the phased approach.

8.15.4 Conclusions and Recommendations

A control upgrade is critical for the plant to continue to monitor performance and maintain water quality. In addition, since the Light Department is discontinuing support of the existing SCADA system replacement is necessary. The proposed system will be an "industry" standard system that would improve support capabilities and be configured to operate a water plant. Conducting the upgrade over time will make it more difficult for the plant to operate in the interim. Also, it is critical that a new control system is in place before any expansion to integrate the new system into the existing plant, and to provide better control and monitoring of the existing system as the flow rates increase. Therefore, Alternative PC2, control upgrades as one project, is recommended as a priority improvement. Refer to Figure 8.6 for illustration.

The total project cost for rehabilitation/enhancements of the control upgrades is $1,716,000.

8.16 ELECTRICAL ALTERNATIVES

The existing electrical distribution systems for the Columbia Water Treatment Plant and the West Ash Booster Pump Station are shown in Figure E1.1 which also shows the recommended demolition of various pieces of electrical equipment which comprise the existing electrical system. These recommendations stem from the data gathered and analyzed as part of the condition assessment report. The main factors driving the scope of the recommended demolition are the age and obsolescence of the existing equipment and the limited support for electrical systems operating at 2,400 Volts. Since the service transformers at both facilities are 2,400 volt units, both facilities are impacted. CW&L staff reported during the condition assessment that the Light Department, which owns and maintains the service transformers, will no longer inventory replacements for the 2,400 Volt transformers. As such, the service transformers are obsolete and need to be replaced with an alternative arrangement at both facilities. Furthermore, since the 2,400 Volt switchgear at the plant and booster pump station are original equipment and are the oldest electrical distribution equipment, these 2,400 Volt switchgear units are obsolete, beyond their useful life, and are recommended for replacement. The remainder of the demolition shown involves removal of other major electrical equipment which is beyond its useful life or does not align with any of the proposed alternatives for upgrades of the respective electrical distribution systems at either facility.

Based on the condition assessment analysis and the resulting determination of the recommended demolition of electrical equipment, two alternatives have been developed to outline potential electrical distribution upgrades for the WTP and West Ash Booster Pump Station facilities. In the case of both alternatives, the following design goals are applicable:

- Eliminate 2,400 service voltage
- Provide sufficient redundancy to eliminate significant single points of failure
- Provide isolation and flexibility for plant maintenance operations
- Provide sufficient capacity to allow for facility expansion
- Retain on-site standby power capability for essential loads (WTP)
- Add on-site standby power for essential loads (Pump Station)

The following electrical improvements were evaluated:

Alternative E1: Replace electrical distribution equipment with all 480V equipment.

Alternative E2: Install 13.8 kV switchgear and step down to 480V distribution equipment.

8.16.1 Alternative E1: Single Voltage System

Figure E1.2 shows the electrical distribution upgrade details of Alternative E1. Alternative E1 includes the following design features:

- 480V Service Transformers (Light Department equipment)
- 480V Distribution Switchgear (WTP & Pump Station)
- 480V Pump Motors and Drives (WTP & Pump Station)
- New engine-generator (Pump Station)
- Retention of 1994 and 2008 expansion project 480V load center equipment (Plant)

Benefits of Alternative 1 include an electrical distribution system which is entirely at 480 Volts and no large transformers to own or maintain by the Water Department. Limitations of Alternative E1 include limited capacity for expansion due to limitations of 480 V systems, single major busses which cannot be isolated to prevent single failure disabling portions of the plant and large cable runs between buildings and on site.

Therefore, there is real no advantage to this alternative and it would make expansion more costly so this alternative was removed from consideration.

8.16.2 Alternative E2: Flexible Electrical Distribution

Figure E2 shows the electrical distribution upgrade details of Alternative E2. Alternative E2 includes the following design features:

- No Service Transformers [Service at 13.8kV]
- 13.8 kV Distribution Switchgear (WTP)
- 480V Distribution Switchgear (Pump Station)
- 480V Pump Motors and Drives (WTP & Pump Station)
- New engine-generator (Pump Station)
- All new major 480V Load Centers (WTP)

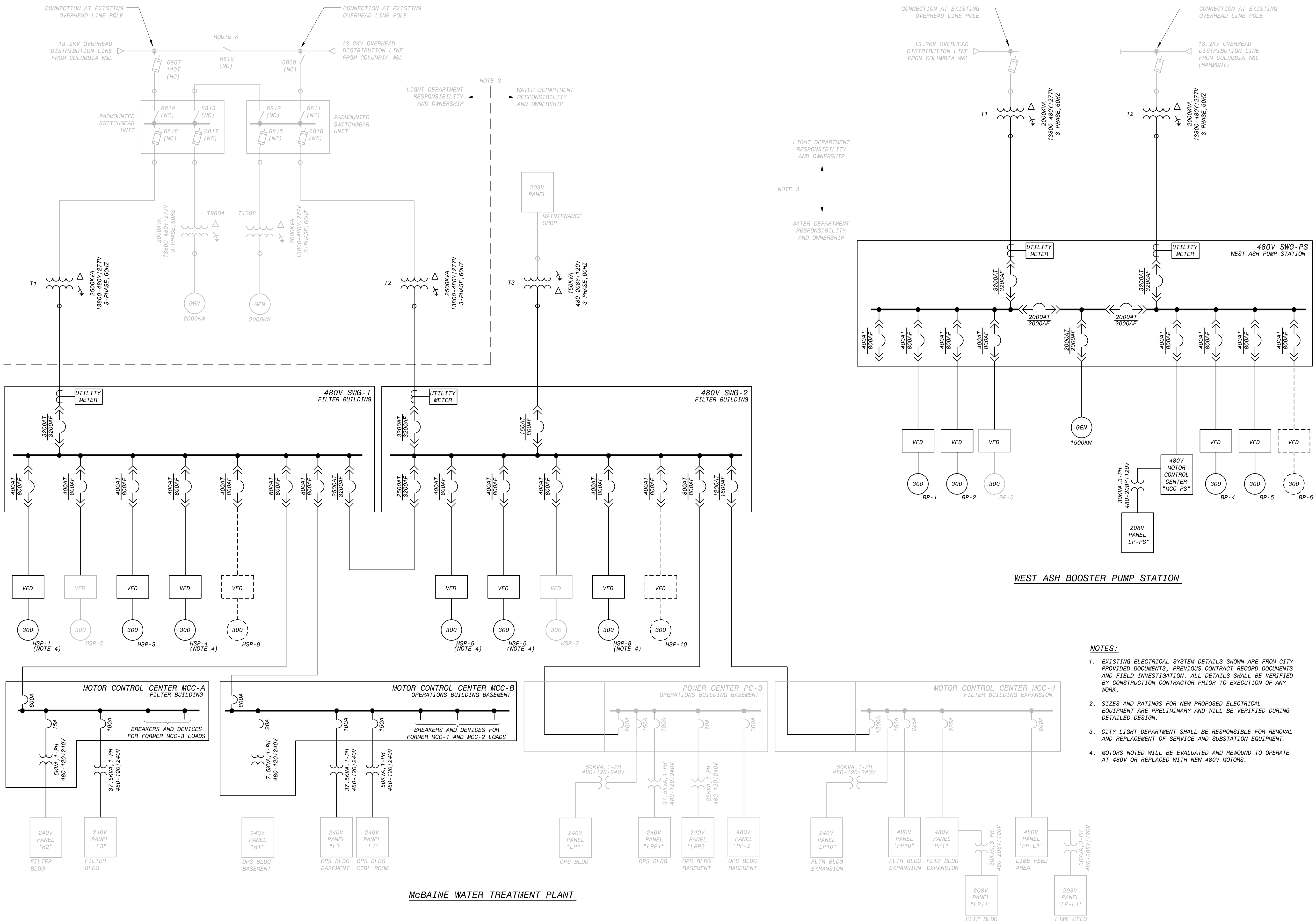
Benefits of Alternative E2 include an electrical distribution system which has no inherent limitations on expansion due to system capacity, maximum flexibility for maintenance and redundancy (no single points of failure), secondary 480V load centers dedicated to their respective area of location and smallest outdoor distribution cable runs. Limitations of Alternative E2 include ownership by the Water Department of several large transformers and responsibility for medium-voltage switchgear operation.

8.16.3 Cost Summary

The table below summarizes the capital costs for each alternative.

Table 8-20 Electrical Alternatives Cost

ALTERNATIVE	CAPITAL COST
E1: Replace Electrical Distribution Equipment	Not Recommended
E2: Install 13.8 kV Switchgear/replace all 2400V Equipment	$3,190,000



NOTES:

1. EXISTING ELECTRICAL SYSTEM DETAILS SHOWN ARE FROM CITY PROVIDED DOCUMENTS, PREVIOUS CONTRACT RECORD DOCUMENTS AND FIELD INVESTIGATION. ALL DETAILS SHALL BE VERIFIED BY CONSTRUCTION CONTRACTOR PRIOR TO EXECUTION OF ANY WORK.
2. SIZES AND RATINGS FOR NEW PROPOSED ELECTRICAL EQUIPMENT ARE PRELIMINARY AND WILL BE VERIFIED DURING DETAILED DESIGN.
3. CITY LIGHT DEPARTMENT SHALL BE RESPONSIBLE FOR REMOVAL AND REPLACEMENT OF SERVICE AND SUBSTATION EQUIPMENT.
4. MOTORS NOTED WILL BE EVALUATED AND REWOUND TO OPERATE AT 480V OR REPLACED WITH NEW 480V MOTORS.

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CITY OF COLUMBIA, MISSOURI
WATER AND LIGHT DEPARTMENT
MCBAINE WTP AND WELL FIELD CONDITION ASSESSMENT

ELECTRICAL
POWER DISTRIBUTION FUNCTIONAL DIAGRAM - ALTERNATIVE 1

DESIGNED: AJT
DETAILED: AJT
CHECKED:
APPROVED:
DATE:

0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO. 188264

FIG E1.2
SHEET
OF

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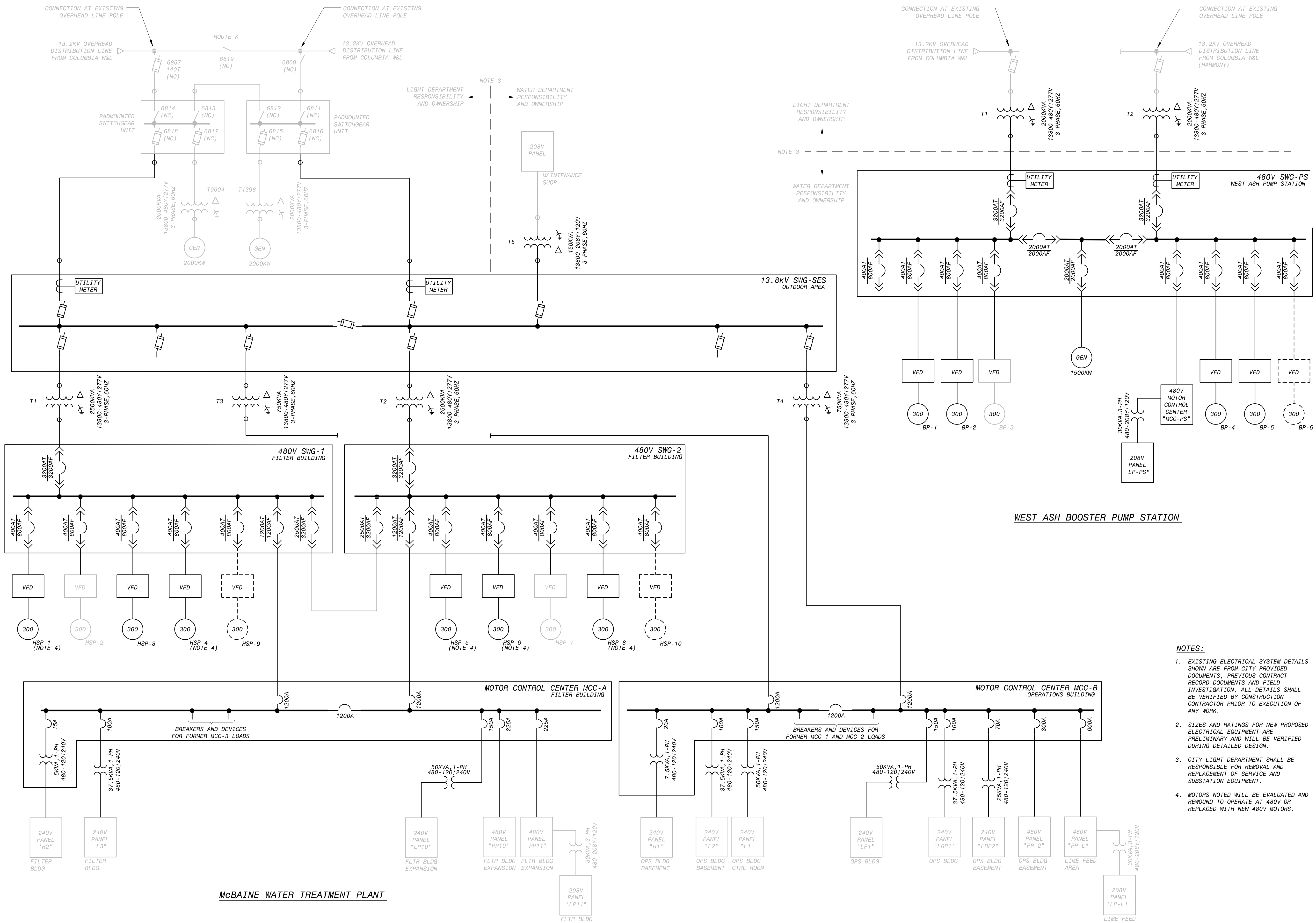

NOTES:

1. EXISTING ELECTRICAL SYSTEM DETAILS SHOWN ARE FROM CITY PROVIDED DOCUMENTS, PREVIOUS CONTRACT RECORD DOCUMENTS AND FIELD INVESTIGATION. ALL DETAILS SHALL BE VERIFIED BY CONSTRUCTION CONTRACTOR PRIOR TO EXECUTION OF ANY WORK.
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4. MOTORS NOTED WILL BE EVALUATED AND REWOUND TO OPERATE AT 480V OR REPLACED WITH NEW 480V MOTORS.

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CITY OF COLUMBIA, MISSOURI
WATER AND LIGHT DEPARTMENT
MCBAINE WTP AND WELL FIELD CONDITION ASSESSMENT

ELECTRICAL
POWER DISTRIBUTION FUNCTIONAL DIAGRAM - ALTERNATIVE 2

DESIGNED: AJT
DETAILED: AJT
CHECKED:
APPROVED:
DATE:

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE

PROJECT NO. 188264

FIG E2
SHEET
OF

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8.16.4 Conclusions and Recommendations

The electrical distribution and high voltage equipment is a critical component of the plant. The current 2400V equipment is outdated and difficult to find replacement parts for, is unreliable, and does not have all the safety features of newer electrical equipment. Therefore, alternative E2, replace all 2400V equipment is recommended.

The total project cost for rehabilitation/enhancements of the electrical upgrade is $3,190,000.

8.17 WTP HVAC AND PLUMBING IMPROVEMENTS

Alternative M1: Treatment Plant HVAC and Plumbing Improvements

Alternative M2: West Ash Pump Station Improvements

8.17.1 Alternative M1: Treatment Plant HVAC and Plumbing Improvements

Improvements to the HVAC and plumbing systems at the water treatment plant include the following at each facility:

Operations Building

The ventilation, heating and cooling systems for the Operations Building need replacement in the near future. This alternative includes replacing the systems in kind. This can be done over time as components fail, or in a complete package. The water source heat pump system currently in place is considered highly energy efficient. Staff indicated dissatisfaction with the heating performance of the heat pumps. This could be addressed with addition of electric heating capacity in the zone units and adjustment of temperature setpoint for air supply.

The additional improvement options as discussed in Section 5.14.1 will need to be evaluated in the future to determine the best long-term option.

Plumbing system improvements include:

- Replacement of the emergency shower and eyewash fixtures, and addition of water supply tempering for the fixtures, which did not appear to be in place.
- Floor drains and piping need to be replaced.

Lime Building

- HVAC recommendations include adding electric damper operators to the ventilation intake dampers. This will allow some additional natural ventilation from prevailing wind to occur in the summer, while cutting down on cold outside air infiltration and heating requirements in the winter.
- Plumbing system recommendations include addition of a water heater and mixing valve for water supply tempering for the emergency shower and eyewash fixtures, which is usually a plumbing code requirement and did not appear to be in place.

Filter Building

- Replacement of electric unit heaters, power roof ventilators and ventilation intake dampers and operators on the systems over 20 years old.

- Demolition of the original dehumidification unit and heat pump unit in the pipe gallery and replacement with a dehumidification unit with a cooling coil that will condition outside ventilation air for the pipe gallery as well as provide dehumidification.
- Demolition of abandoned heating water piping and supports.

8.17.2 Alternative M2: West Ash Pump Station HVAC and Plumbing Improvements

Improvements to the HVAC and plumbing systems at the West Ash Pump Station Include:

1. The boiler should be replaced with a gas forced air furnace to supply heating through the ductwork to the office area and smaller rooms.
2. Gas fired unit heaters should be installed to provide backup heating in the pump room in the event the pump motors are off. Electric unit heaters should replace the hydronic heat on the lower levels as heat from the pump room will not reach the lower levels as heat rises.

8.17.3 Cost Summary

The table below summarizes the capital costs for each alternative.

Table 8-21 HVAC And Plumbing Improvements Alternatives Cost

ALTERNATIVE	CAPITAL COST
M1: Treatment Plant HVAC Improvements	$299,000
M2: West Ash Pump Station HVAC Improvements	$88,000

8.17.4 Conclusions and Recommendations

Both alternatives are recommended to replace deteriorated equipment and improve efficiency.

The total project cost for rehabilitation/enhancements of the HVAC improvements is $387,000.

8.18 WEST ASH PUMP STATION

The following alternative addresses improvements to the West Ash Pump Station:

Alternative WA1: Roof replacement

Alternative WA2: Replace all 2,400V electrical gear

Alternative WA3: Replace flow meter and discharge valve actuators

8.18.1 Alternative WA1: Replace Roof

This alternative includes removal of the existing roof and replacement with a new thermoplastic (TPO) roofing material.

8.18.2 Alternative WA2: Replace all 2,400V electrical gear

This alternative includes replacement of all the 2400V electrical equipment at West Ash. Demolishing of existing equipment includes two 1,500KVA transformers, enclosed automatic transfer switch, 2400V MCC, 2400V Motors, and MCC-2.

An electrical schematic showing the proposed new work is included on Figure E 1.2 included in the WTP electrical section. The new work generally consists of two new transformers, a new 480V switchgear, four new VFDs and motors, and a new 480V MCC to serve the other loads in the building. The VFDs would be located in the existing Chlorine Storage Room to allow for conditioned space.

The new switchgear would be configured for connection to a future generator that would provide backup power to the pump station in the event of a sustained power outage. A 1,500kw generator is anticipated to provide sufficient pumping to maintain normal operation. The generator is not included in this alternative.

8.18.3 Alternative WA3: Replace discharge valve actuators

This alternative includes replacement of the discharge valves and actuators on the pumps. The existing actuators are original battery backup and are in need of replacement. Since the valves need to be able to close in the event of a power outage, it is recommended that new butterfly valves be installed on each discharge that utilizes a pneumatic actuator. An air compressor, dryer, and receiver would be provided with the pneumatic system. The receiver would be sized large enough to supply enough air to close all the valves in the event of a power outage.

8.18.4 Cost Summary

The table below summarizes the capital costs for each alternative.

Table 8-22 West Ash Alternatives

ALTERNATIVE	CAPITAL COST
WA1: Replace roof	$46,000
WA2: Replace 2,400V electrical equipment	$2,055,000
WA3: Replace discharge valves and actuators	$172,000

8.18.5 Conclusions and Recommendations

The West Ash Pump Station is a critical component of the system. The alternatives described above replace outdated equipment to improve reliability of the pump station. All three alternatives are recommended.

The total project cost for rehabilitation/enhancements of the West Ash Pump Station improvements is $2,273,000.

9.0 Expansion Alternatives

Alternatives were developed to address future capacity requirements. Since the ultimate capacity of the plant is uncertain at this stage two alternatives were developed for future plant capacity, including 45 and 60 MGD. The alternatives described in this section illustrate the general components in sufficient detail to develop conceptual costing and feasibility.

Refinement of the recommended plan as based upon a target capacity should occur in order to optimize the layout and better define costs and layout requirements. Included in Section 10 is the implementation schedule which combines the recommended expansion alternative with the replacement/enhancement alternatives discussed in Section 8 to provide an overall plan for capital improvements to the treatment facility.

The alternatives developed were based on maintaining all treatment within the existing site. The alternatives range from modifying the existing treatment trains to constructing new treatment trains north of the existing plant. One of the alternatives includes converting the plant to full single stage softening to match the proposed plan in the preliminary design report. As noted in the report, the costs for addressing the condition of existing facilities were not included in the overall cost for the previously recommended plan. The alternative described herein for converting to single stage softening includes these additional costs, and was developed using the same approach as the other alternatives to provide an "apple to apple" comparison.

The following alternatives were established as options for expanding the capacity of the existing plant to either 45 or 60 MGD. The associated impact if the groundwater is reclassified as GWUDI. The alternatives evaluated include:

Alternative EXP 45-1: Re-rate existing basins to 45 MGD

Alternative EXP 45-2: Construct new 15 MGD process train

Alternative EXP 45-3: Convert to partial single stage softening

Alternative EXP 60-1: Re-rate existing basins and construct new 15 MGD process train

Alternative EXP 60-2: Construct two 15 MGD process trains

Alternative EXP 60-3: Convert all existing basins to single stage softening

Alternative GWUDI-1: Impact on Alternative EXP 60-1 if source water is reclassified as GWUDI

Alternative GWUDI-2: Impact on Alternative EXP 60-2 if source water is reclassified as GWUDI

9.1.1 Alternative EXP 45-1: Re-rate existing basins to 45 MGD

As discussed in Section 5, there is excess capacity available in the existing basin complex if a higher loading rate is used for the primary basins. The higher loading rate would exceed MDNR standards, however would be well below the loading rates successfully used at numerous other facilities around the region. The key to achieving higher basin loading rates is upgrading the existing basin equipment to improve performance followed by demonstration testing to receive approval by MDNR. This approach will require replacement of all the primary basin equipment which has reached the end of its useful life. The new equipment should be configured with reaction zones sized for the higher loading rates and should be discussed with MDNR prior to implementation.

Other modifications to the plant would be required to increase plant capacity to 45 MGD. The following summarizes the improvements required to expand the plant to 45 MGD if the basin capacity is increased to 45 MGD.

Well Field

The existing well field will have a firm capacity of just over 29 MGD after installation of Wells 16, 17, and 18. Based on an average well capacity of 1,600 gpm, seven additional vertical wells would need to be constructed within the existing well field to increase the total firm raw water supply to 45 MGD. This would result in a total of 25 vertical wells in order to produce 45 MGD.

Additional investigations will be required to locate the wells in order to avoid interference with the existing wells, avoid potential contamination, verify capacity, and avoid classification of the new wells as groundwater under the influence of surface water (GWUDI). However, based on the production of the existing wells and historical information available on the aquifer, it appears feasible to maintain a large wellfeld in the aquifer without the source water being classified as GWUDI. Therefore, it is assumed that the source water will remain classified as groundwater only for this alternative. Alternatives GWUDI-1 and GWUDI-2 describe the modifications to the plant if the source water is reclassified.

The benefit of installing vertical wells is that the capacity can be increased over time to match the system demands. The disadvantage of the installing vertical wells for expansion is the maintenance required to continually clean and maintain 25 wells. Based on the initial cost evaluations, it will be less expensive to construct vertical wells versus collector wells. However, the maintenance costs will be significantly more. The deciding factors should be whether there is enough land available to site 25 wells and if the plant can maintain its current classification. If these two factors can be met, vertical wells should be installed to meet the capacity. If either of these conditions changes, a collector well should be considered.

Raw Water Conveyance

The plant is currently fed by a 24 inch and 48 inch raw water line. Although this project did not include extensive investigation of the capacity of the raw water piping, based on the results from the performance test and analysis of pipe velocities at 45 MGD, an additional raw water line is recommended as the capacity approaches 45 MGD. If the ultimate capacity of the plant will be 45 MGD, then a 36 inch raw water line is sufficient. If the ultimate plant capacity will be 60 MGD, then a new 42 inch raw water line extending to near Well 17 is recommended. Since the locations of the new wells are unknown, this alternative assumes 8,500 ft of 36 inch piping with one creek crossing for costing purposes.

The new raw water line should be constructed when system pressures cause the existing well pumps to exceed a total dynamic head of 150 ft at full capacity, which is anticipated to occur after another 2-3 additional wells are added to the system.

Aerators

Two new aerators rated at 8 MGD and equal size of the existing aerators would be installed north of the existing aerators. Effluent from the aerators would be routed into the existing aerator effluent chamber. The aerators would be installed at the same hydraulic grade line as the existing aerators to allow flow to be split evenly between the aerators. A separate flow meter and control valve would be installed for the two new aerators, providing redundancy in the raw water line and influent flow meter.

This alternative would require coring an opening in the existing aerator influent box causing a plant shutdown. It would also require relocating the septic tank to facilitate installation of the raw water line.

Basins

The equipment in all four primary basins would be replaced with equipment meeting the requirements for higher loading rates and provide symmetric flow and process characteristics. To help relieve the bottleneck in basin trains 3 and 4, the weirs on Secondary Basin No. 3 would be replaced with submerged orifices. Based on past hydraulic studies and data collected from the performance test, each basin train is capable of conveying up to 12 MGD if the restrictions in the Parshall Flumes are eliminated. Therefore, this alternative includes removal of the Parshall Flumes and installation of new influent velocity flow meters.

Filters

It may be possible to re-rate the existing filters to 6 gpm per square foot to increase the firm filtering capacity up to 40 MGD without building additional filters. This would require significant modifications to the filter influent piping and filter profile, addition of filter aid polymer, air scour, and conversion to rate of flow control which would require a downstream clearwell. Even with these changes, performance data will need to be approved by MDNR for this higher loading rate.

Based on the historical filter performance and accounting for the difficulty of operating the eight existing filters at this higher rate, this alternative includes keeping the existing filters rated at their current flow and adding three new filters to meet the 45 MGD capacity. The three new filters allow the plant to maximize the full 45 MGD of treatment capacity, as opposed to only 40 MGD with re-rating the filters. Furthermore, the three new filters could be constructed with fewer interruptions to plant operation.

The new filters would be located south of the existing Filters 1-4. Alternative filter technologies, such as deep bed filtration, could be considered during detailed design. However, for the purposes of these evaluations and to simplify operation by keeping all filters identical, the new filters would be dual media gravity matching the same profile and characteristics as the existing filters.

Since the new filters will not be hydraulically symmetric to the existing filters, a new clearwell would be constructed beneath the new filters to allow the new filters to operate in rate of flow mode to improve filter performance. The clearwell would be constructed to be expandable in the future if flows from the existing filters are routed to the clearwell to eliminate the current declining rate filter mode. However for this alternative, the existing filters would remain as declining rate with the effluent piped directly to the high service pumps. If groundwater is reclassified to GWUDI in the future, all flow could be routed to the clearwell to provide additional disinfection.

A new pipe from the Secondary Basin No. 1&2 outlet box would be routed directly to the new filter influent header. The pipe would be supported off the side of Secondary Basin No. 1 south wall and routed below the basin effluent orifice pipe. The filter influent header inside the building would also be routed out of the building to the east to provide two connection points to the filter influent. There will be some operational restrictions in filter operation caused by the influent piping. If basin trains 1&2 are out of service, it will be difficult to get flow to the new filters with the long filter influent piping, which would be worse than what currently exists when Filters 1-4 are only in operation with basins 3 and 4. However, if half of the basins are out of service, then the plant can operate with the 8 existing filters and the need to use the new filters would be minimal.

The filters would utilize the existing wash water tower, with a new backup wash water pump installed above the clearwell. A new filter drain would be routed to existing reclaim basin.

It is recommended with this alternative that a filter aid polymer system would be incorporated to improve filter performance.

High Service Pumping

Three new vertical turbine high service pumps would be located above the clearwell at the new filter building. The pumps would draw suction from the clearwell with the discharge from the pumps connected into the south finished water transmission main. A valve would be installed in the south main to allow the flow from the new filters to be diverted to the west transmission main if the south main is out of service. A dedicated flow meter would be required for the discharge piping with an additional chlorine and ammonia feed point. The new pumps would be VFD driven and would operate to maintain a set water level in the clearwell.

Chlorine Feed System

To meet the average chlorine feed dose at 45 MGD, a feed rate of 2,815 pounds per day of chlorine is required. The configuration of the chlorine cylinders, four connected together, limits the capacity to about 2,000 ppd due to the number of chlorine containers connected in parallel and the feeder sizes. Adding more cylinders to the manifold and increasing the feeder size would allow the system to feed the required maximum chlorine feed rate, however, there would not be sufficient storage space in the existing room for 30 days of storage.

The chlorine evaluation in Section 8 recommended conversion to bulk hypochlorite. Considering the capacity restrictions discussed above, this alternative includes conversion to bulk hypochlorite.

Lime Feed System

The existing lime feed system is able to meet the average lime dose of 180 mg/l at 32 MGD with one slaker out of service. By replacing the current vibrating screen grit handling system with a suspended bed slurry scrubber, the lime feed system capacity would be increased to 41 MGD at average dose, with one unit out of service. The maximum lime feed rate at 45 MGD can be met with both slakers in operation. Therefore, the costs for improvement or expansion of the lime feed system are not included in this alternative.

Fluoride and Ammonia Systems

Although the fluoride and ammonia bulk storage and day tank capacities are sufficient for the higher flows, the condition of the tanks and equipment are deteriorated and are in need of replacement. Therefore, although replacement with the initial expansion is not essential, these systems should be replaced with new tanks and metering pumps. One additional ammonia feed pump will be required to feed the discharge out of the new filter building.

Electrical

The electrical improvements, which include installation of a plant switchgear and conversion from 2,400V to 480V as recommended in Section 8, should be implemented prior to or as part of this expansion. The new electrical loads associated with this alternative are primarily the three new high service pumps and the seven additional well pumps. These loads would be served by the new switchgear.

The existing washwater tank, residual basins, and reclaim basin would be used for the expansion.

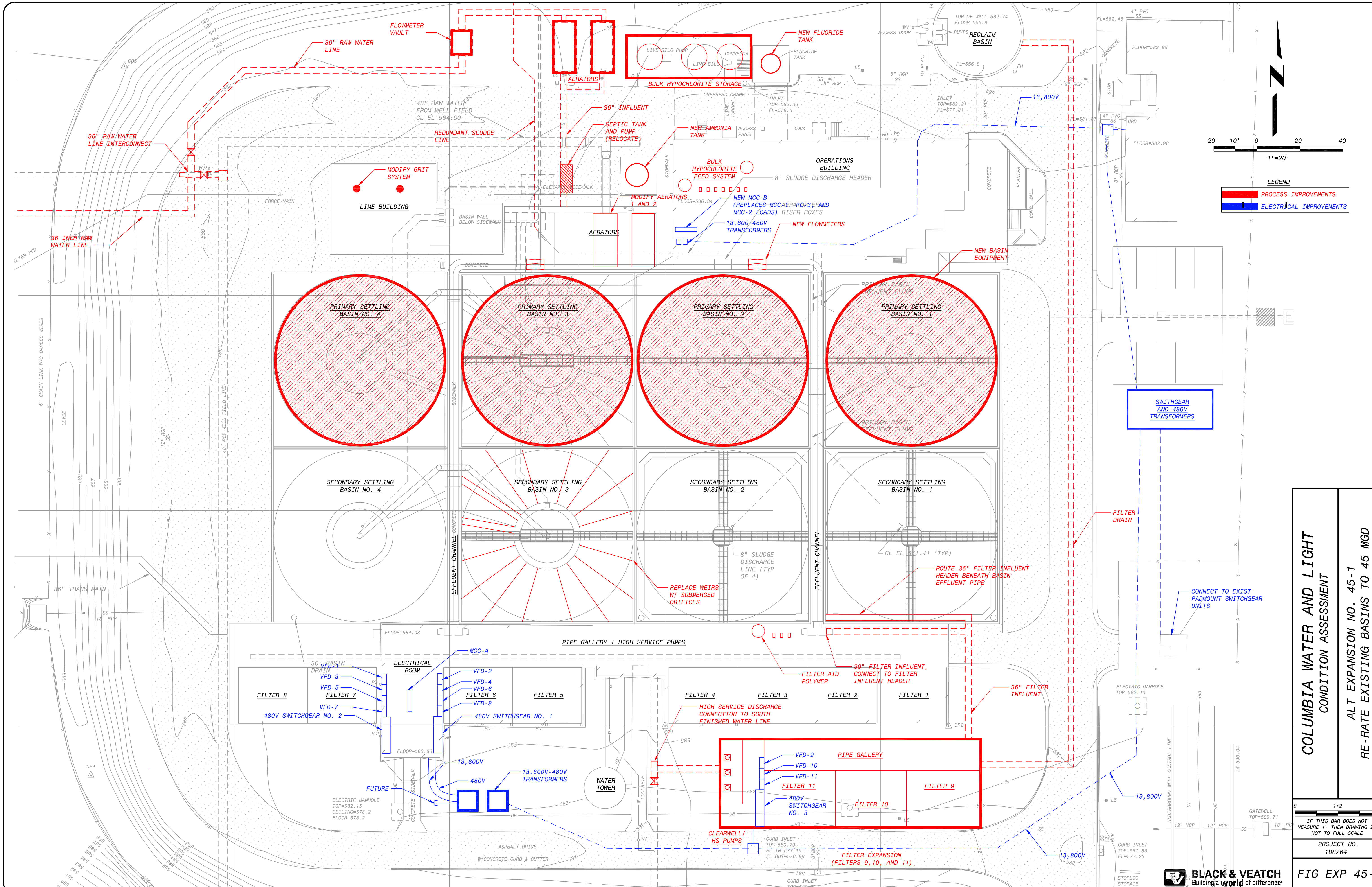
Refer to Figure EXP 45-1 for a layout of this alternative.

9.1.2 Alternative EXP 45-2. Construct new 15 MGD process train

In lieu of expanding the capacity of the existing plant within the footprint of the existing basin trains, a new process train would be constructed north of the existing plant. The basin and filter complex of the new train would be sized for approximately 15 MGD, resulting in a total rated plant capacity of 47 MGD. By constructing the new basin capacity at 15 MGD it provides a reliable treatment capacity of 38 MGD if one basin is out of service. There would be added benefit by increasing the size of the basin to about 15 MGD, allowing the new train to meet average day conditions. This simplifies the operation of the existing plant and results in higher quality water as the existing plant can operate at lower production rates the majority of the time. In addition, once the new basin train is in service the other rehabilitation/enhancement projects required at the existing plant can be implemented with less interruption in plant capacity by concurrently taking multiple treatment trains out of service. The final decision on the size of the new process train should factor in long term growth, plant flexibility, and future water quality requirements.

The new process train would consist of:

- Two induced draft aerators, each sized for 7.5 MGD
- One aerator effluent box to accept reclaim water
- One circular solids contact unit with diameter of approximately 115 ft.
- One recarbonation basin sized for 20 minutes of contact time.
- Four filters, each sized for 5.0 MGD to allow full train capacity to be met with one filter out of service. Filter construction would be similar to existing filters, except the filters would operate in rate-of-flow control mode to allow steady flows across the filters to improve filter performance.
- A post-filter baffled clearwell sized for to provide wetwell volume for pump operation (approx. 250,000 gallons) and filter backwash. The clearwell would be configured to be expandable in the future if source water was reclassified as GWUDI and disinfection CT was required in clearwell.



FLOWMETER VAULT
36" RAW WATER LINE
AERATORS
BULK HYPOCHLORITE STORAGE
NEW FLUORIDE TANK
FLUORIDE TANK
RECLAIM BASIN
48" RAW WATER FROM WELL FIELD CL EL 564.00
36" INFLUENT
SEPTIC TANK AND PUMP (RELOCATE)
NEW AMMONIA TANK
REDUNDANT SLUDGE LINE
36" RAW WATER LINE INTERCONNECT
MODIFY GRIT SYSTEM
LIME BUILDING
BULK HYPOCHLORITE FEED SYSTEM
OPERATIONS BUILDING
8" SLUDGE DISCHARGE HEADER
MODIFY AERATORS 1 AND 2
NEW MCC-B (REPLACES MCC-1, PC-3, AND MCC-2 LOADS)
13,800/480V TRANSFORMERS
NEW FLOWMETERS
36 INCH RAW WATER LINE
13,800V
NEW BASIN EQUIPMENT
PRIMARY SETTLING BASIN NO. 4
PRIMARY SETTLING BASIN NO. 3
PRIMARY SETTLING BASIN NO. 2
PRIMARY SETTLING BASIN NO. 1
PRIMARY BASIN INFLUENT FLUME
PRIMARY BASIN EFFLUENT FLUME
SWITCHGEAR AND 480V TRANSFORMERS
SECONDARY SETTLING BASIN NO. 4
SECONDARY SETTLING BASIN NO. 3
SECONDARY SETTLING BASIN NO. 2
SECONDARY SETTLING BASIN NO. 1
EFFLUENT CHANNEL
8" SLUDGE DISCHARGE LINE (TYP OF 4)
REPLACE WEIRS W/ SUBMERGED ORIFICES
ROUTE 36" FILTER INFLUENT HEADER BENEATH BASIN EFFLUENT PIPE
FILTER DRAIN
CONNECT TO EXIST PADMOUNT SWITCHGEAR UNITS
36" TRANS MAIN
PIPE GALLERY / HIGH SERVICE PUMPS
MCC-A
ELECTRICAL ROOM
VFD-1
VFD-2
VFD-3
VFD-4
VFD-5
VFD-6
VFD-7
VFD-8
FILTER 8
FILTER 7
FILTER 6
FILTER 5
FILTER 4
FILTER 3
FILTER 2
FILTER 1
480V SWITCHGEAR NO. 2
480V SWITCHGEAR NO. 1
FILTER AID POLYMER
36" FILTER INFLUENT, CONNECT TO FILTER INFLUENT HEADER
36" FILTER INFLUENT
HIGH SERVICE DISCHARGE CONNECTION TO SOUTH FINISHED WATER LINE
13,800V
480V
13,800V-480V TRANSFORMERS
FUTURE
WATER TOWER
PIPE GALLERY
VFD-9
VFD-10
VFD-11
FILTER 11
FILTER 10
FILTER 9
480V SWITCHGEAR NO. 3
CLEARWELL / HS PUMPS
FILTER EXPANSION (FILTERS 9, 10, AND 11)
LEGEND
PROCESS IMPROVEMENTS
ELECTRICAL IMPROVEMENTS
1"=20'
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CONDITION ASSESSMENT
ALT EXPANSION NO. 45-1
RE-RATE EXISTING BASINS TO 45 MGD
FIG EXP 45-1

- Three high service pumps would be located above the clearwell and pump finished water to the south high service line. The high service pumping would be expanded in conjunction with any clearwell expansion.
- A new backwash tank, or dedicated backwash pumps, would be constructed to serve the new filters.

As indicated, this alternative includes recarbonation between the solids contact unit and filters, whereas the existing plant has an identically sized secondary basin after each primary basin. The recarbonation basin would essentially serve the same purpose by providing a buffer between the softening process and filters. The existing secondary basins, where the equipment is no longer in use, could provide adequate detention to reduce pH if necessary in the future. Therefore, the basis of this alternative include a recarbonation basin. The potential benefits of incorporating a secondary basin to maintain consistency between all process trains should be considered as part of any preliminary design.

This alternative also includes replacement of existing primary basin 1 and 2 equipment with new equipment to allow the existing plant to operate effectively. Improvements to the well field, raw water line, chemical feed systems, and electrical are similar to improvements identified in Alternative EXP 45-1 with the exception of the aerator influent pipe into the existing aeration box is not required for this alternative.

Refer to Figure EXP 45-2 for layout.

9.1.3 Alternative EXP 45-3. Convert to Partial Single Stage Softening

This alternative implements the first phase of conversion of the entire plant to a single stage softening process. The first secondary basin to be converted to single stage softening would be Secondary Basin No. 1. The total basin capacity would be 40 MGD if only one basin is modified. However, this alternative also includes re-rating the four existing primary basins from 32 mgd to 37 MGD to achieve the full 45 MGD.

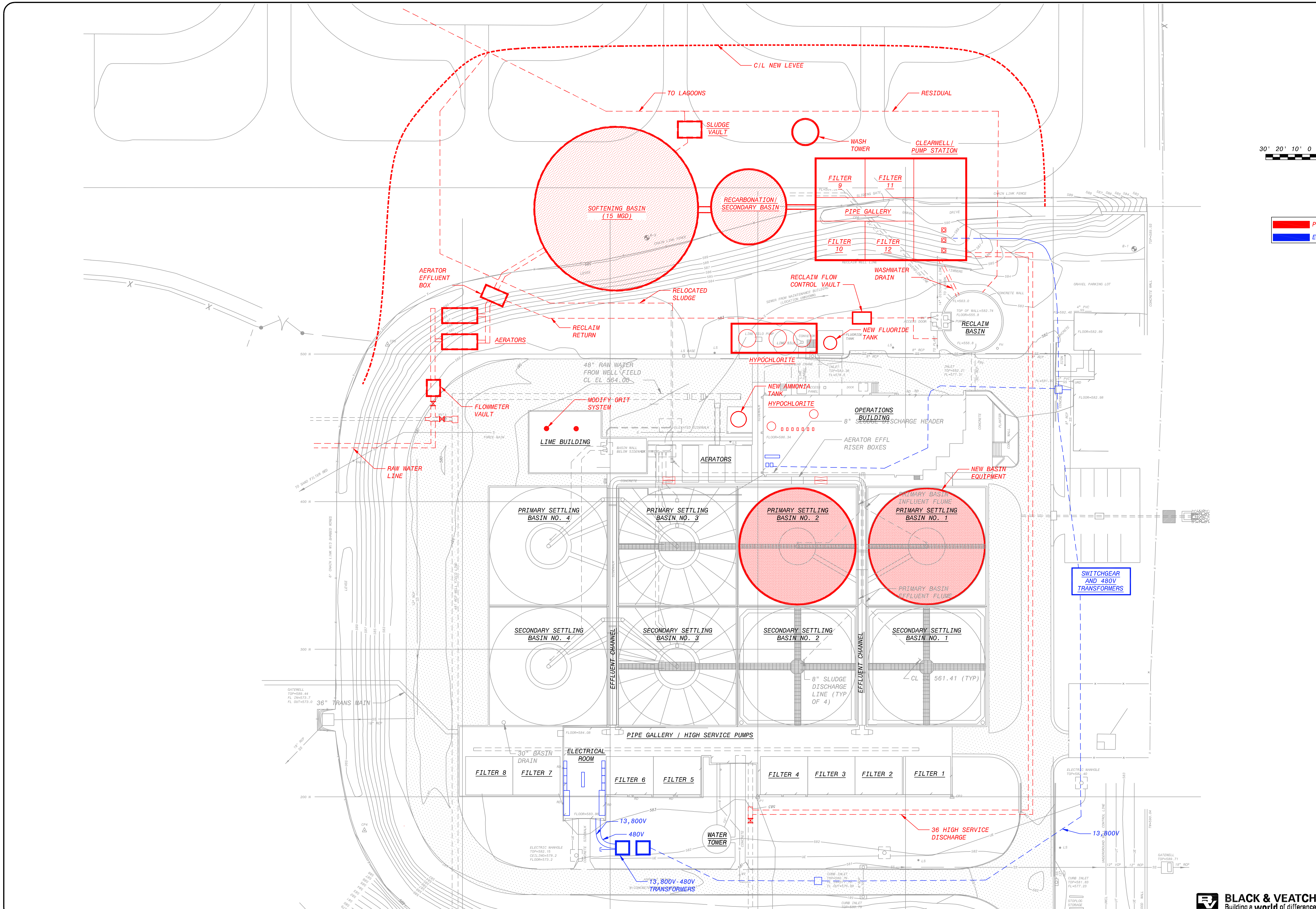
The following summarizes the requirements for this alternative.

<u>Aerators</u>

To align with the Phase 2 expansion to 60 MGD, two new aerators, an aerator effluent box, and an influent flow meter vault would be located west of the existing basins. Flow from the two new aerators would be conveyed to existing Primary Basins No. 3 and No. 4. Modifications to both basins would be required to allow piping to enter the center column from a side entry, as opposed to the current configuration which enters the basins beneath the center column. The influent piping would be supported from a new walkway or support structure. The levee would be expanded to the west to accommodate space for the new aerators, effluent box, and flow meter vault. The existing aerators would supply Primary Basins No. 1 and No. 2, as well as the new Primary Basin No. 5 (formally Secondary Basin No. 1).

<u>Basins</u>

New basin equipment would be required in all the existing primary basins and new Primary Basin No. 5. Primary Basins No. 3 and No. 4 are not sized correctly for higher loading rates, do not meet the torque ratings, and neither have side entry influent configuration.



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COLUMBIA WATER AND LIGHT
CONDITION ASSESSMENT

ALTERNATIVE EXP 45-2
NEW 15 MGD BASIN TRAIN

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FIG EXP-45-2

Flow would be piped directly from the existing aerator effluent box to Primary Basin No. 5. Existing basin train No. 1 would then operate as single stage softening and Basin Trains No. 2, 3, and 4 would continue to operate in their current configuration.

A dedicated flow meter and control valve would be installed in the influent piping to new Primary Basin No. 5. Since the basins would no longer be hydraulically balanced, the control valve would have to modulate to match the flow with the other basins in service. The new basin influent pipe would be sized large enough to eventually also supply flow to Primary Basin No. 6 (Formally Secondary Basin No. 2). The influent piping would be cored through the aerator effluent box, center wall between existing Primary and Secondary Basin No. 1, and the effluent channel between existing Secondary Basin No. 1 and No. 2. Coring through the aerator effluent box will require a plant shutdown.

The effluent from existing Primary Basin No. 1 and existing Secondary Basin No. 2 (now Primary Basin 5) would be diverted to the east into a separate effluent pipe that would connect to the main filter influent header. A recarbonation basin would be located in the parking area east of the basins where water from all primary basins would be blended and CO_2 would be added in the future to control pH prior to connecting to the existing filter influent header. For this alternative the CO_2 feed system is not included in the cost estimate.

Filters

The piping from the recarbonation basin would continue to a new filter building with three new filters constructed south of existing Filters 1-4. The new filter building, clearwell, and pump station would be similar to Alternative EXP 45-1, with the exception that in lieu of high service pumps above the clearwell, there would be transfer pumps to convey the flow to a new disinfection contact basin. The three transfer pumps would be lower head, approximately 30-40 ft, and rated at 7.5 mgd each. A new filter drain would be piped from the filter complex back to the reclaim basin.

It is unclear if MDNR would allow the existing filters to operate in their current configuration with no downstream clearwell if the plant is converted to single stage softening. It would be costly to implement a second clearwell and transfer pump station for the existing filters. Therefore, this alternative assumes that the existing filters will continue to operate in their current configuration with the high service pumps remaining. However, it would require that flow from only trains 2, 3 and 4 which still have two stage softening, be sent to the existing filters to meet disinfection requirement and flow from the single stage basins only be sent to the new filters.

Contact Basin/High Service Pumping

A new contact basin would be required since the secondary basins can no longer be utilized for disinfection. The transfer pumps in the new filter building would convey flow to the new contact basin. The contact basin would be sized for half of the future flow, approximately 30 mgd, which results in about 650,000 gallons of contact time. New high service pumps would be located above the contact basin to convey treated flow to the system. The new pumps would initially be sized for 15 mgd to match the flow from the new filters, but expandable to 30 MGD. This concept is currently based on a below grade contact basin. However, an above grade contact basin, potentially constructed out of the floodplain, could be utilized with an at grade high service pump station.

In summary, the basin operation would consist of the four existing aerators serving Primary Basins No. 1 and No. 2, as well as existing Secondary Basin No. 1 (now Primary Basin 5). The two new aerators would supply Primary Basins No. 3 and No. 4. New filters located south of Filters 1-4 would have transfer pumps to convey the filtered flow to a new contact basin and high service pumping. It may be required that flow from Primary basin No. 1 and No. 5 be routed to the new filters.

Improvements to the well field, raw water line, chemical feed systems, and electrical are similar to what is included in Alternative EXP 45-1.

Refer to work shown as Phase 1 on Figure EXP 60-3.

9.1.4 Alternative EXP 60-1: Re-rate existing basins and construct new 15 MGD process train

This alternative essentially combines Alternative EXP 45-1 and EXP 45-2 to increase the plant capacity to 60 MGD. In addition to the modifications described in those alternatives, a new lime feed building, additional hypochlorite storage, and connections to both finished water transmission mains would be required for this alternative.

This alternative assumes the raw water supply remains classified as groundwater. Therefore, the raw water supply would consist of an additional 7 wells, bringing the total number of wells to 32. However, if there is not sufficient capacity in the wellfield nor the desire to have 32 vertical wells, a collector well could be constructed with a dedicated raw water pipeline routed directly to the 15 MGD basin train which would be designed for GWUDI. Flow from the collector well would not be sent to the existing plant, only sent to the new process train. Therefore, the existing plant could remain classified as groundwater only treatment and not require extensive modifications.

Refer to Figure EXP 60-1.

9.1.5 Alternative EXP 60-2: Construct two 15 MGD process trains

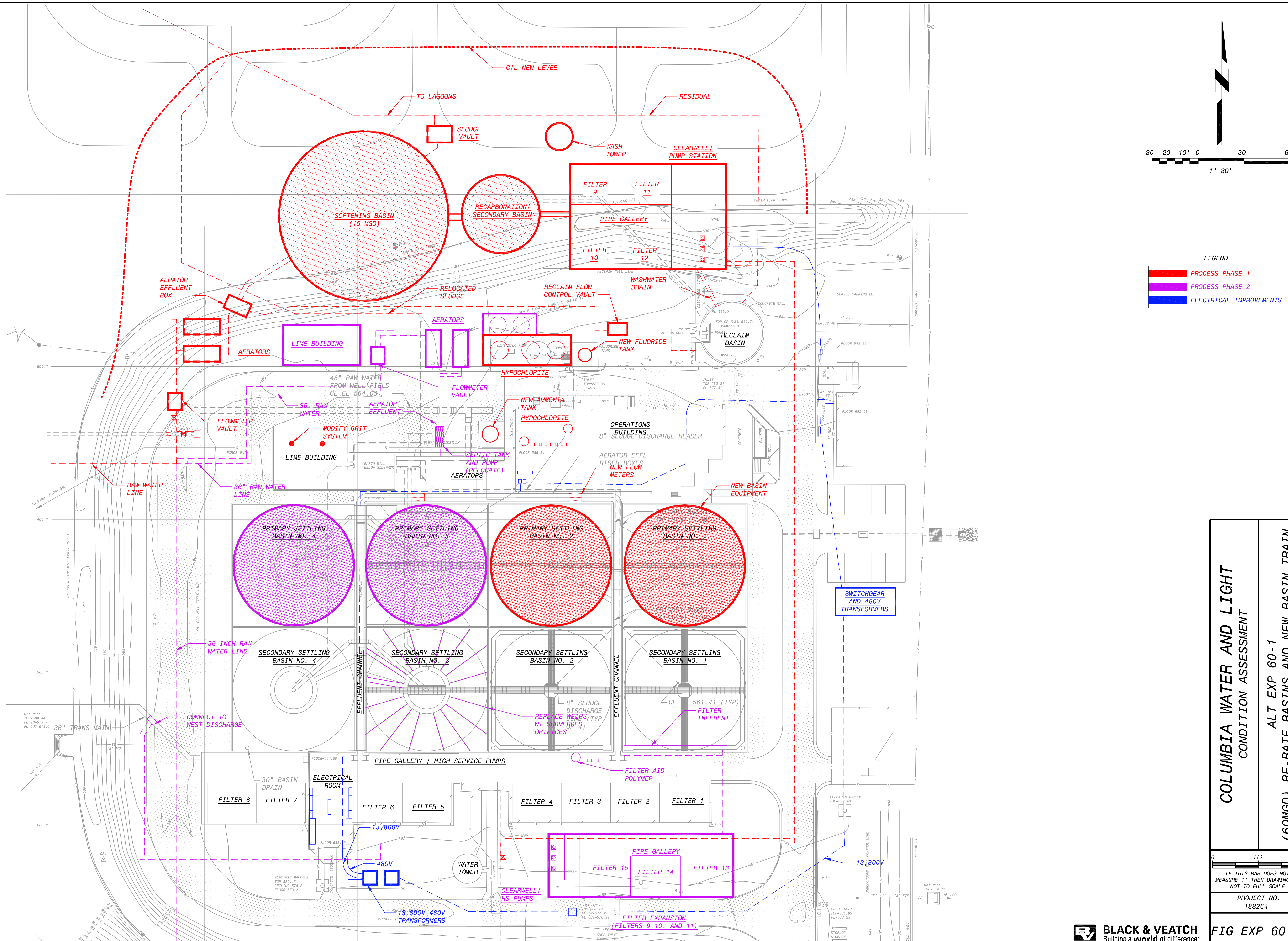
This alternative includes constructing two new 15 MGD basin trains north of the existing plant and keeping the existing plant at its current 32 MGD capacity. Essentially, it is constructing a second identical basin train and filter complex to Alternative EXP 45-2. This alternative has the least overall impact on the existing treatment plant.

Refer to Figure EXP 60-2.

9.1.6 Alternative EXP 60-3: Convert to Full Single Stage Softening

This alternative includes converting all the secondary basins to single stage treatment. Lime would be fed to each basin and effluent from each basin piped directly to the filter influent headers through recarbonation chambers. The major components include the items described in EXP 45-3 with the additional improvements:

- Addition of two aerators and routing new influent lines to Secondary Basins No. 3 and No. 4
- Replacement of existing Secondary Basins No. 2, 3 and 4 with solids contact softening equipment
- Basin Train No. 4 effluent piping to a new recarbonation chamber, with effluent connected to filter influent header
- Modifications to the existing basins effluent channels for recarbonation.



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CONDITION ASSESSMENT

ALT EXP 60-1
(60MGD) RE-RATE BASINS AND NEW BASIN TRAIN

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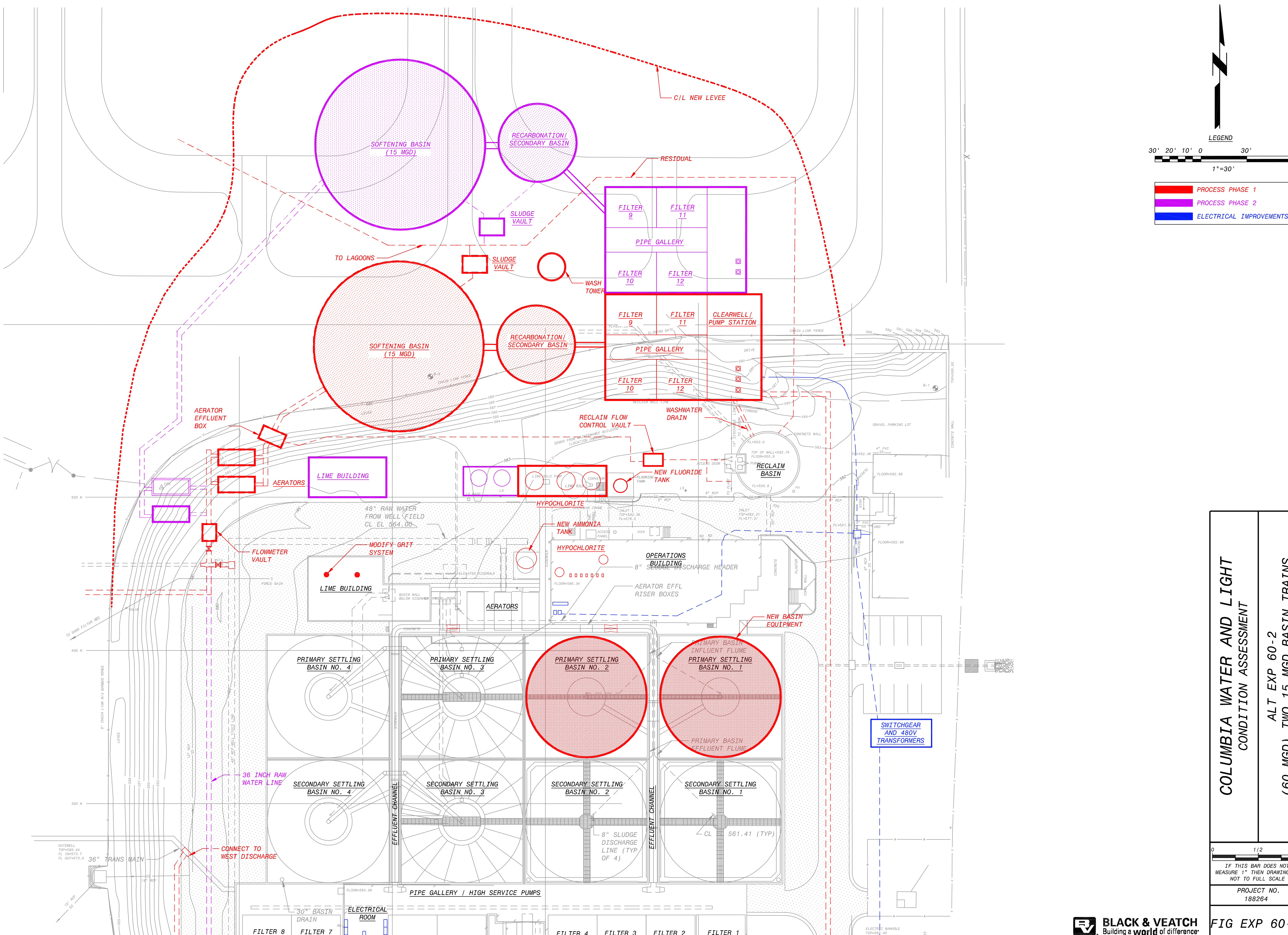
FIG EXP 60-1



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CONDITION ASSESSMENT

ALT EXP 60-2
(60 MGD) TWO 15 MGD BASIN TRAINS

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FIG EXP 60-2

- Three new filters west of existing filter complex with a clearwell and transfer pumps to convey to expanded contact basin.
- New high service pumps to convey all the flow from the contact basins to the distribution system.
- Improvements to raw water supply, raw water piping, chemical feed, and electrical similar to Alternative EXP 60-2.

This alternative would include extensive work within the existing basin footprint, making construction sequencing challenging and costly. This alternative would be the most difficult to implement while maintaining operation of the plant.

This alternative would be configured for GWUDI so no additional modifications beyond what is described here would be required if the source water is reclassified.

Refer to Figure EXP 60-3, Phase 2, for summary of the work associated with this alternative.

9.1.7 Alternative GWUDI-1: Impact on Alternative EXP 60-1 if Source Water is Reclassified as GWUDI

This alternative identifies the modifications to the plant if the source water is reclassified as ground water under the influence (GWUDI). This alternative includes the modifications to the existing plant identified in Alternative EXP-60-1, plus modifications to the existing filters to reconfigure from declining rate mode to rate of flow mode. The modifications include installation of a new clearwell and relocation of the high service pumps to allow all the flow from the filters to first enter the clearwell before pumping. The clearwell installed as part of the Alternative EXP 60-1 would be used for half of the flow, with the remaining flow going to the second new clearwell.

Under this alternative, the clearwells are not required for disinfection contact time as disinfection can be achieved in the secondary basins, but only to improve filter performance by allowing for flow control across each filter. Therefore, if filter performance can be improved through other enhancements, the addition of the clearwell and associated work in this alternative may not be required.

Refer to Figure GWUDI-1 for layout.

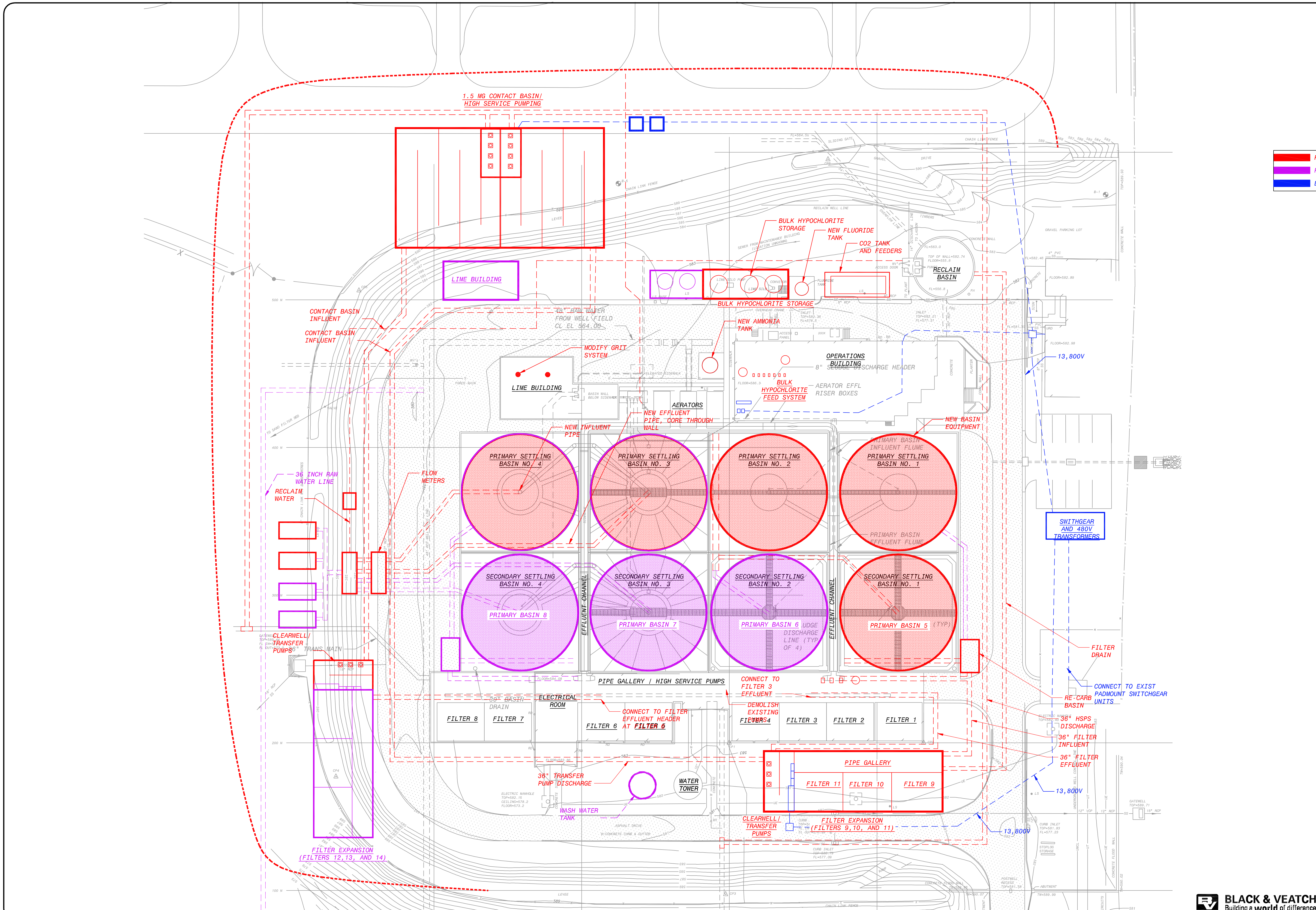
9.1.8 Alternative GWUDI-2: Impact on Alternative EXP 60-2 if Source Water is Reclassified as GWUDI.

If the plant expansion includes two 15 MGD process trains with the entire plant being classified as GWUDI, then modifications to the existing plant would be required in addition to the plant expansion. The primary modifications would include demolition of the existing high service pumps, installation of two clearwells, and new high service pumps downstream of the existing filters to allow the filters to operate in ‘rate of flow” control. As discussed in EXP 60-2, this concept is highly unlikely as the flow classified as GWUDI could be diverted only to the new process trains.

Refer to Figure GWUDI-2.

9.1.9 Cost Summary

The table below summarizes the project costs for each of the alternatives described above.



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ALT EXP 60-3
(60 MGD) SINGLE STAGE SOFTENING

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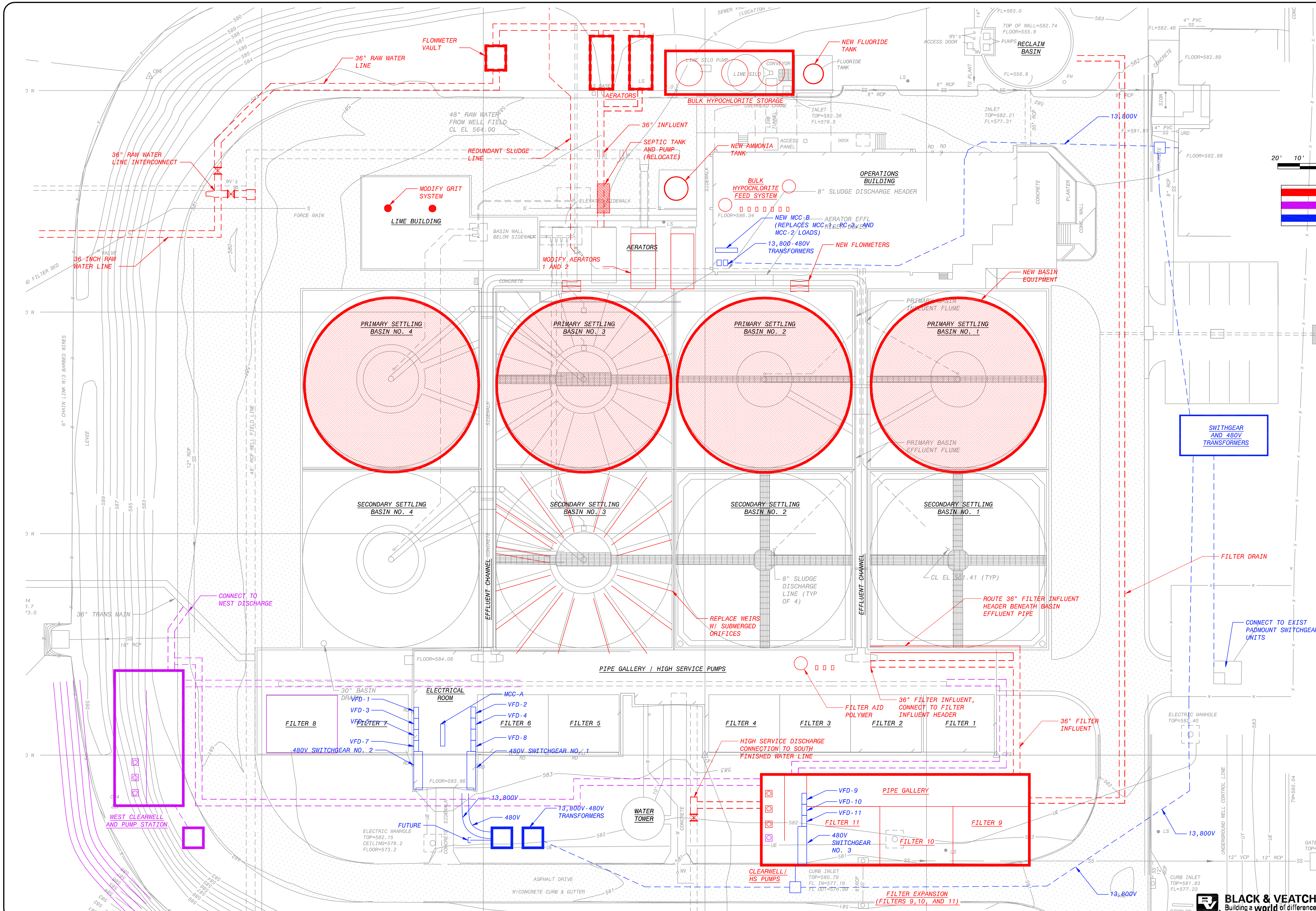
FIG EXP 60-3



COLUMBIA WATER AND LIGHT
CONDITION ASSESSMENT

ALT GWUDI-1
GWUDI IMPACT ON RE-RATING BASINS

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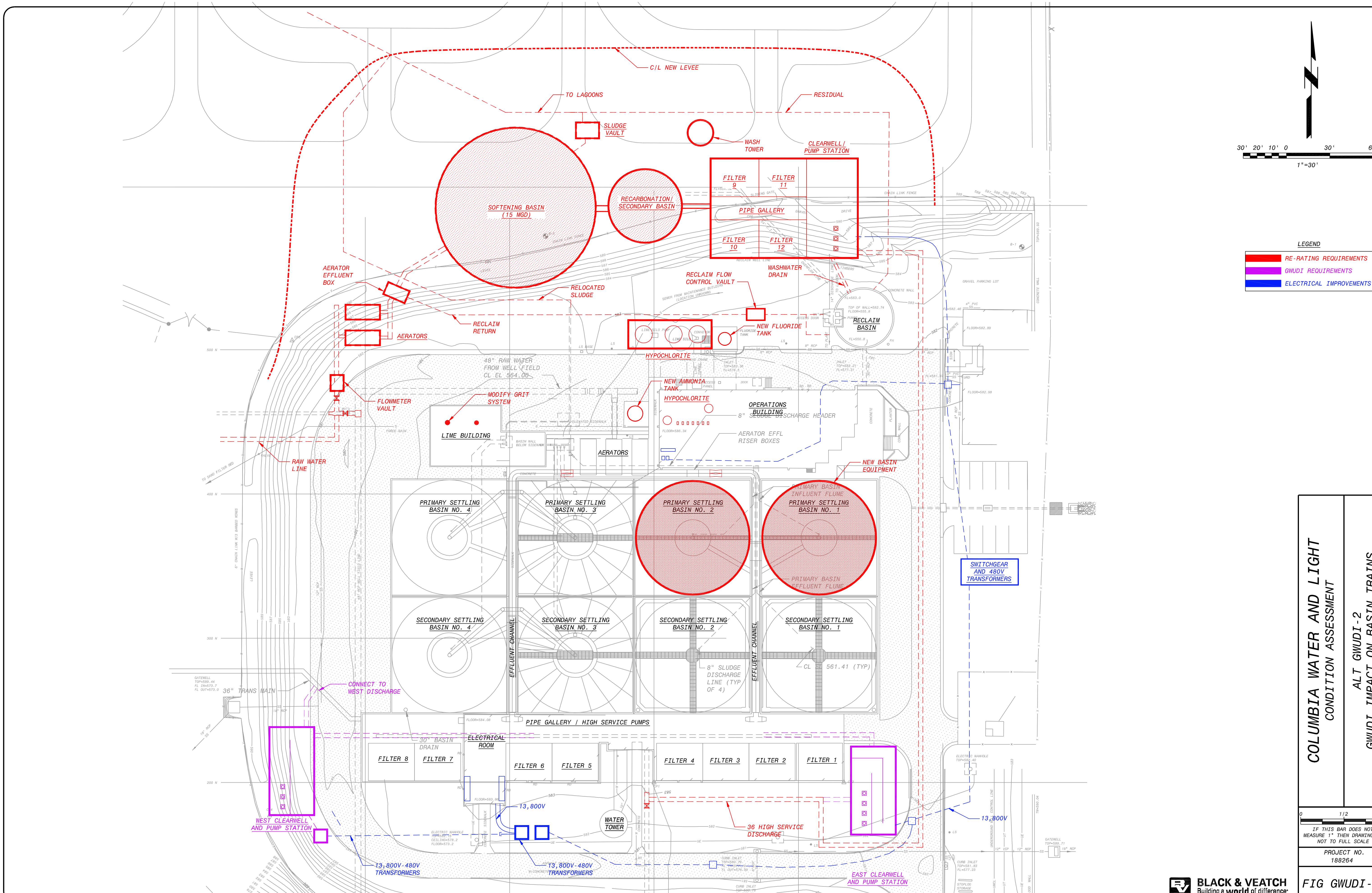
FIG GWUDI-1



COLUMBIA WATER AND LIGHT
CONDITION ASSESSMENT

ALT GWUDI-2
GWUDI IMPACT ON BASIN TRAINS

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FIG GWUDI-2

Table 9-1 Costs for Expansion Alternatives (in $1,000s of Dollars)

ALTERNATIVE	EXP 45-1	EXP 45-2	EXP 45-3	EXP 60-1	EXP 60-2	EXP 60-3	GWUDI-1	GWUDI-2
	RR Basins	New Basins	Single Stage	RR+ Basins	2 Basins	Single Stage	60 RR+ Basin	60 All Basins
Water Supply								
Wells	$3,640	$3,640	$3,640	$7,280	$7,280	$7,280	$7,280	$7,280
Raw Water Piping	$2,720	$2,720	$2,720	$3,312	$3,312	$3,312	$3,312	$3,312
Water Supply Construction Total	**$6,360**	**$6,360**	**$6,360**	**$10,592**	**$10,592**	**$10,592**	**$10,592**	**$10,592**
Treatment Plant Expansion								
General Requirements	$3,065	$3,285	$3,826	$6,080	$6,220	$7,423	$6,518	$6,840
Site Structures/Site Piping	$1,421	$3,016	$5,418	$4,224	$4,110	$8,493	$4,371	$4,883
Aerators	$951	$951	$988	$1,680	$1,759	$1,759	$1,825	$1,759
Basins	$2,925	$4,486	$2,283	$5,852	$7,530	$5,164	$5,852	$7,530
Filters	$8,191	$7,138	$8,191	$17,318	$16,499	$18,957	$17,318	$17,318
Clearwells(Transfer Pumping)	$1,621	$1,351	$2,946	$2,759	$2,508	$5,614	$3,851	$4,034
Contact Basins	$0	$0	$2,099	$0	$0	$3,801	$0	$0
High Service Pumping	$2,273	$2,273	$2,273	$4,545	$4,418	$4,418	$7,276	$7,276
Chemical Feed Systems	$1,768	$1,868	$2,318	$5,862	$6,674	$6,706	$5,912	$6,674
Electrical and Instrumentation	$5,138	$5,403	$5,379	$7,967	$8,110	$8,723	$8,186	$8,329
Treatment Plant Subtotal	**$27,353**	**$29,771**	**$35,721**	**$56,287**	**$57,828**	**$71,058**	**$61,109**	**$64,643**
Construction Total	**$33,713**	**$36,131**	**$42,081**	**$66,879**	**$68,420**	**$81,650**	**$71,701**	**$75,235**
Engineering/Administration	$5,057	$5,420	$6,312	$10,032	$10,263	$12,248	$10,755	$11,285
PROJECT TOTAL	**$38,770**	**$41,551**	**$48,393**	**$76,911**	**$78,683**	**$93,898**	**$82,456**	**$86,520**

9.1.10 Conclusions and Recommendations

Selection of the recommended plan for future expansion of the plant is based on a number of factors, including:

- Capital Costs
- Operational Costs
- Constructability
- Regulatory
- Operational

Every utility weighs these factors differently when selecting a long term path forward for their system. Therefore, a discussion is warranted between CW&L staff before a specific alternative can be selected. However, based on this evaluation and analysis of the alternatives, the following are findings and recommendations related to each of these factors:

<u>Capital Costs:</u>

- The least costly alternative for 45 MGD involves re-rating the existing plant. To achieve the 45 MGD capacity the overall cost of this alternative is approximately $2.8M less than next lowest, which is constructing a new process train.
- The least costly alternative for 60 MGD also involves re-rating the existing plant plus the 15 MGD process train.
- The cost for implementing partial single stage softening is approximately $9.6M more than re-rating the existing plant. The primary reasons this alternative is substantially more costly is the significant site piping requirements, reconfiguration of the basins for the future 60 MGD flow, and construction of a new contact basin. If the ultimate capacity would be capped at 45 MGD, there would be some means to reduce the overall costs. However, it would still cost more than the other alternatives.
- The overall cost difference between re-rating the existing basins versus constructing new process trains, for either the 45 or 60 MGD capacity, is less than 10 percent of the overall project costs.
- If the entire plant is reclassified as GWUDI, single stage softening is still the highest cost alternative.

<u>Operational Costs:</u>

- Alternatives EXP 45-3 and EXP 60-3, single stage softening, both require additional transfer pumping, resulting in more electrical usage compared to the other alternatives.
- Chemical usage between the alternatives would generally be the same.
- Alternative EXP 45-1 requires the least amount of equipment. Therefore, it would be anticipated to have the lower overall maintenance costs.

<u>Constructability</u>

- A new process train would be the easiest to construct as it would have minimal impact on existing operation, and no major construction work would be required near the existing plant.

- The other alternatives would require multiple partial plant shutdowns where the plant won't have access to several unit processes for a significant period, along with several full plant shutdowns to make critical tie-ins. The full plant shutdowns would have to be coordinated in low demands with strict timeframes for returning the plant to service. These shutdowns add to the costs of the project.
- Given the age and condition of the existing plant, relying on major unit processes of the existing plant results in additional risk to the City and your customers.
- Routing the site piping for the single stage alternatives would be challenging as there is limited space on the site and the potential for conflicts with buried utilities is extremely high. Routing the influent piping within the basins will also be challenging, especially finding unobstructed locations to core through existing walls. Modifications of this magnitude cannot be fully assessed until final design, but potentially can be very costly.

Regulatory

- Both re-rating of the existing basins and conversion to single stage softening will require special coordination with MDNR to receive approval Whereas, constructing the new process train would generally meet all MDNR guidelines and be less likely to have any issues during permitting.
- Basin performance data will most likely be required for re-rating the basins. Therefore, the new basin equipment would have to be installed first and operated for an extended period to illustrate performance at the higher rates before approval is received.
- MDNR may be reluctant to allow conversion to single stage softening unless improvements can be made in the plant process on filtered water turbidities.
- If the new raw water supply is reclassified as GWUDI, this flow could be directed to the new process train in EXP 45-2 and treated while the existing plant remained as a groundwater only plant.

Operational

- The new process train would give the plant flexibility with essentially two plants. This would make future shutdowns for maintenance much easier, and because the new process train would have some excess capacity, would result in the existing plant not operating near its hydraulic capacity which would improve treatment performance.
- Both re-rating the existing plant and single stage softening would make plant operation more challenging. For both alternatives, filter influent flows would have to be controlled to the new filters while still allowing the existing filters to operate in declining rate. The entire plant hydraulic profile would be near capacity more often with little ability for the entire system to float between flow scheme changes. Feeding lime to 8 primary basins at one time would be challenging from an operational standpoint. The plant would also have to operate a transfer pump station and assure the necessary contact time is achieved for the single stage alternatives.

Based on this evaluation and the factors described above, the recommended expansion alternative for 45 MGD is Alternative EXP 45-2, construction of a new process train. This alternative has costs higher than re-rating of the existing plant, but has significant other advantages as described above.

The major disadvantages with this alternative are that it requires utilization of some of the lagoon area, modifications to the levee, and has a higher upfront capital costs to construct the new process train. However, included with this alternative are improvements to some components of the existing plant, including aerators, primary basins 1&2, electrical, instrumentation, and chemical feed systems. Many of these items could be implemented in phases prior to the expansion provided they are configured for the proposed expansion, or the new process train could be constructed first and improvements to the existing plant completed afterwards over a longer period.

Table 9-2 separates the new process train costs from rehabilitation/enhancement costs for Alternative EXP 45-2.

Table 9-2 Alternative EXP 45-1 Cost Breakdown

COMPONENTS	PROJECT COSTS
New 15 MGD Process Train	$23,062,000
Wells/Plant Modifications for expansion	$19,019,000
Construction Total	**$42,081,000**
Engineering/Administration	$6,312,000
PROJECT TOTAL	**$48,393,000**

There would be some components of the plant rehabilitation/enhancements that should be completed with the new process train such as instrumentation, main electrical distribution, and some chemical feed improvements. These costs have been included in the cost above for the new process train. Costs that are not included in the process train are well field expansion, replacement of existing basin equipment, modifications to existing filters and high service pumps, and other capacity related improvements to the existing plant. Therefore, without completing the full rehabilitation/enhancement components identified with this alternative the plant capacity would not significantly increase, but would provide for a more reliable facility.

The decision regarding expansion from 45 MGD to 60 MGD does not necessarily have to be made at this time. Either constructing another basin train or re-rating the existing plant are both viable alternatives, with the deciding factor being the source water characteristics. If the existing plant can treat up to 45 MGD while still remaining classified as a groundwater, then Alternative EXP 60-1 is recommended. However, if it is believed that at some point in the future the source water will be classified as GWUDI, constructing the second process train would then be recommended to allow all the source water to go to the new process trains.

Single stage softening is an acceptable treatment approach for lime softening and is common for many plant upgrades or expansions. However, in Columbia's case, the cost, physical constraints, and operational constraints required to convert the existing plant to single stage are not cost effective as compared to the other alternatives.

Refer to Section 10 for an implementation schedule for the replacement/enhancement alternatives and expansion. The implementation schedule assumes that EXP 60-1, combination of new process train and re-rating the filters, is the long term expansion alternative.

10.0 Summary and Implementation Schedule

Alternatives and recommendations for rehabilitation, enhancements, and expansion of the McBaine Water Treatment Plant and West Ash Booster Pumping Station were summarized in Sections 8 and 9 of the report. These costs do not incorporate any changes to lime disposal.

Table 10-1 provides an implementation schedule for the recommended rehabilitation improvements identified in Section 8.

Table 10-1 Rehabilitation Implementation Schedule

ALTERNATIVE	1-4 YRS	4-7 YRS	7-10 YRS
WF1: Well Replacement (6 total)	$1,140,000	$1,140,000	$1,140,000
WF1: Well Rehabilitation	$150,000	$150,000	$150,000
B1: Replace Primary Basin 1 and 2 Equipment	$1,709,000		
F1: Replace Valve Actuators on Filters 1-4	$89,000		
F2: Miscellaneous Structural Repairs	$15,000		
HS1: Repair/Replacement of Pump/Motor		$120,000	
FW1: Replace Finished Water Flow Meter	$55,000		
FL1: Rehabilitate Fluoride Feed System	$70,000		
AM1: Rehabilitate Ammonia Feed System	$83,000		
PW1: Rehabilitate Plant Service Water	$55,000		
PC2: Control Upgrades as One Project	$1,716,000		
E2: Replace all 2,400V Equipment		$3,190,000	
M1: Treatment Plant HVAC Improvements			$299,000
M2: West Ash Pump Station HVAC Improvements		$88,000	
WA1: Replace West Ash Roof		$46,000	
WA2: Replace West Ash 2,400V Equipment	$2,055,000		
WA3: Replace West Ash Discharge Valves	$172,000		
SUBTOTAL	**$7,309,000**	**$4,614,000**	**$1,589,000**
REHABILITATION TOTAL	**$13,512,000**		

Table 10-2 provides an implementation schedule for the recommended enhancement improvements identified in Section 8.

Table 10-2 Enhanced Implementation Schedule

ALTERNATIVE	1-4 YRS	4-7 YRS	7-10 YRS
WF2: New Well Houses (6 total)		$393,000	$393,000
RW2: Redundant Raw Water Line at Plant		$463,000	
RW3: Isolation Valves in Well Field	$84,000		
AR3: Modify Aerators 1 and 2	$252,000		
B4: Basin Flow Distribution Improvements	$173,000		
B6: Replace Parshall Flumes with Velocity Flow Meters	$211,000		
R1: Redundant Pipeline to Lagoon			$158,000
F3: Filter Aid Polymer		$164,000	
FW2: Install Finished Water Flush Connection	$20,000		
CL3: Conversion to Bulk Hypochlorite	$1,065,000		
SS1: Route Sewer to wastewater plant			$702,000
FL2: Fluoride Feed System Enhancements		$244,000	
SUBTOTAL	**$1,805,000**	**$1,264,000**	**$1,253,000**
ENHANCEMENT TOTAL	**$4,322,000**		

Table 10-3 provides an overall implementation schedule for the recommendations in the report. The implementation schedule includes rehabilitation, enhancements, and expansion. The schedule is geared towards addressing the most critical items first, as well as attempting to spread the overall costs out evenly between the time periods. Table 10-3 includes the process train being constructed as part of the expansion, after improvements to the plant have been completed.

Table 10-3 Overall Implementation Schedule

ALTERNATIVE	1-4 YRS	4-7 YRS	45 MGD	7-10 YRS	60 MGD
Rehabilitation	$7,309,000	$4,614,000		$1,589,000	
Enhancements	$1,805,000	$1,264,000		$1,253,000	
Well Field Expansion			$6,360,000		$3,640,000
WTP Expansion			$23,062,000		$27,787,000
Total	**$9,114,000**	**$5,878,000**	**$29,422,000**	**$2,842,000**	**$31,427,000**

CW&L can choose to do portions of the rehabilitation and enhancement recommendations piecemeal over time to spread out the cost of projects. However, ideally they would be combined with the plant expansion to improve constructability and improve the overall cost efficiency of the program. The exact timing and need of the plant expansion cannot be fully assessed until other ongoing studies are complete.

Table 10-4 summarizes the total costs for each category.

Table 10-4 Total Costs

ALTERNATIVE	COSTS
Rehabilitation	$13,512,000
Enhancements	$4,322,000
Expansion – 45 MGD	$29,422,000
Expansion – 60 MGD	$31,427,000
Total	**$78,683,000**

As the CW&L develops an overall capital improvement plan there are some overlaps between the rehabilitation/enhancement recommendations and expansion recommendations. Also, some of the improvements associated with the expansion of the plant could be completed prior to major expansion to improve current operation and simplify the expansion project. Or, as indicated above, the new process train could be constructed first and then rehabilitation/enhancements could be staged over a longer period. As long term needs of the system are further defined, this schedule should be modified to reflect the timing of capacity and availability of funding to implement the improvements.

Without implementing the rehabilitation and enhancement items the plants reliable capacity is about 24 MGD.

11.0 Asset Information Inputs

CW&L currently does not use any software or database system to manage asset data and work orders. Asset data collected as part of the condition assessment will be used to populate a future asset management system. This information will be useful to track future work and expenses at the facility, and to develop a more accurate maintenance budget for maintaining the system.

The information collected on each asset during the assessment was used to estimate asset criticality and estimated remaining life. Each asset was assigned a rating based on the condition of the equipment, incorporating both likelihood and consequence of failure to suggest the correct maintenance strategy for a given asset. A proposed set of strategies are summarized in the table below.

Table 11-1 Proposed Strategy Summary

EXAMPLE STRATEGY	DESCRIPTION
Critical R&R	Indicates an asset is likely to fail and that its failure would have significant negative consequences. These assets should be given attention as soon as possible and likely scheduled for major rehabilitation or replacement. Issues should generally be addressed before assets reach this point leaving few or no assets in this category.
Priority R&R	Assets are less urgent than critical R&R but otherwise similar. These assets should likely be scheduled for repair or replacement within the current budget cycle.
Opportunistic R&R	Assets are in or are likely to be in poor condition but the consequence of their failure is low. They should be given attention as resources are available.
Monitoring	Assets are those of moderate to high consequence of failure that are expected to remain in good condition for the near future. As the deteriorate, they will move up to the priority and/or critical R&R strategies
Priority Monitoring	Same as “monitoring” but for higher-risk assets expected to move into an R&R strategy in the near future.
Run to Fail	Assets are those with low consequence of failure that can be run until they are in poor condition and move up to the opportunistic R&R category.

The condition assessment identified 565 assets. These assets generally represent equipment and systems such as pumps, electrical equipment, instrumentation, chemical systems, valves, and HVAC equipment. It does not include items such as building structures, basins, reservoirs, and underground infrastructure. The table below summarizes the strategy ratings for each of these assets.

Table 11-2 Maintenance Strategy Groups

GROUP	STRATEGY	COUNT	% OF ASSETS	EQUIPMENT VALUE (2015 $)
A	Critical R&R	30	5%	$2,222,000
B	Priority R&R	95	17%	$2,630,500
C	Opportunistic R&R	85	15%	$2,008,000
D	Monitoring	215	38%	$7,669,000
E	Priority Monitoring	79	14%	$1,475,500
F	Run to Fail	61	11%	$3,843,000
	TOTAL	**565**	**100%**	**$19,848,000**

It is important to note the cost figures shown are preliminary estimates for current equipment cost only and do not include design and installation costs. Rather than a budgetary estimate, the costs shown are intended to provide a sense of how asset value is distributed across the various maintenance strategies and how capital replacement needs may change over time.

The expected life remaining was based on the information provided in Table 6-3. The following table provides a summary of the estimated life remaining of the existing assets.

Table 11-3 Expected Asset Life Remaining Summary

GROUP	REMAINING LIFE	COUNT	% OF ASSETS
A	Life Exceeded by > 10 Years	121	21%
B	Life Exceeded by 5-10 Years	80	14%
C	Life Exceeded by < 5 Years	43	8%
D	Life Remaining Between 0-10 Years	171	30%
E	Life Remaining > 10 Years	150	27%
	TOTAL	**565**	**100%**

There are currently no industry standards for establishing a maintenance budget. Assuming an average life expectancy of 20 years, then 5% of the assets would theoretically be replaced every year. Using this method, the annual maintenance budget would be approximately 5% of the total equipment value, or $992,400.

Key recommendations for maintaining and improving this information include formally incorporating information collection and updating into maintenance routines and the implementation of an asset tagging and mobile data system to make this information collection more efficient and accurate. Asset criticality ratings are more static than their likelihood of failure counterparts, but they should also be periodically reviewed and updated as plant operations and service requirements change. Finally, the collection of additional work order information will allow maintenance costs to be utilized in asset decision making.

Asset management requires systems and processes, but also requires the right organizational culture. Therefore, early in the process of implementing these recommendations, the concept and benefits of risk-based asset management should be explained to all staff and select staff should understand and be given the opportunity to comment on how the asset strategies are developed and assigned. Additional training will be required to ensure that field staff apply a standardized process for asset condition evaluation. Following this training, managers should begin to use the management system to help prioritize preventative and reactive maintenance and also to identify assets which require additional risk reduction measures.

Carefully executed, this risk-based approach to asset management can reduce costs and boost staff morale while improving performance and reliability. These benefits are realized by using asset information to allocate resources where they will have the greatest benefit and to extract the maximum safe utility from each asset.