

West Street Water Treatment Plant
Georgetown, MA

Water Treatment Plant Process Improvements Draft Report

Town of Georgetown Water Department

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Tighe&Bond
Engineers | Environmental Specialists

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Executive Summary

The Georgetown Water Department (PWS ID 3015000) hired Tighe & Bond in July 2019 to complete an evaluation of their West Street Water Treatment Plant. This treatment plant removes iron and manganese from the Water Department's three existing ground water sources, namely the Marshall Well (03G), Commissioners Well (04G), and Duffy's Landing Well (05G). The treatment plant is unable to operate at full capacity due to elevated levels of iron in the raw water. After blending of the three sources, the average iron concentration has more than doubled (5 to 6 mg/L) from the original design. As a result, the treatment plant experiences short filter run times and requires significantly more operator attention than originally planned. Based on our initial evaluation of the treatment plant facilities and operations, we are providing the following summary of our observations and recommendations.

Issues associated with backwash of the filter system

The backwash operation has historically been a source of concern for the Water Department's operational staff. It appears the implementation of new valve actuators has made a significant impact in reducing the hydraulic shear of the filter media during a backwash. Any additional valve speed modifications may only provide a small improvement on the hydraulic shear on the filter media. The main issue at this point is the increased loading rate on the filters during a backwash event.

We recommend developing a plan to separate the filter system from the water distribution system during backwashing. AECOM included in their 2013 Comprehensive Water System Evaluation Report a recommendation to design and construct a clearwell/backwash water supply tank at the WTP site that would achieve this goal. This recommendation is identified as Long Term Goal - L1 in their report. It is our opinion that the addition of a clearwell is needed to improve the backwashing process at the treatment plant and minimize the disruptions that occur in the distribution system.

Full automation of the backwash system can be completed by implementing upgrades to the controls. This would be ideal, however further evaluation is needed to determine the long-term benefit of this upgrade. The existing controls provide "Semi-Automatic" backwashing of the filter system. The Water Department should continue to have an operator on-site during a backwash so that any failures or disruptions can be addressed quickly to minimize any impacts to the filter system and distribution system.

Issues associated with filter system runtimes

Based on our initial evaluation, it is our opinion that there are no operational or minor equipment modifications that would significantly improve the existing filtration system and associated filter media performance. We were unable to determine the actual makeup of the filter media bed due to the many additions of media that have been made over the years. It is important that a full characterization of the media bed be completed.

In May 2015 Blueleaf Inc, performed a pilot study at the treatment plant on the blended sources of the Duffy and Marshall Wells. Two pilot-scale pressure filters were operated as a representation of the existing full-scale filtration system. This pilot test showed that even with a full media replacement of 10 inches of anthracite above 20 inches of GreensandPlus™, filter run times to breakthrough were still less than 24 hours at the design loading rate of 2.5 gpm/sf and less than 48 hours at the current operational loading rate of 1.25 gpm/sf.

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Although the pilot data suggests that the media in the existing filter system is causing the filter performance to suffer slightly, replacing the media is unlikely to provide a significant increase in filtration system operation. It is possible that additional filter surface area could reduce the frequency of backwashing, however the additional backwash water volume that would be required for the additional filters would offset the reduction in backwash frequency. Reduction in raw water iron concentration by implementing pre-treatment is the preferred method to extend the current filter runtimes beyond 48 hours at the existing operational filter loading rates.

Historical chemical feed system modifications

Post Filter pH Adjustment

Overall the post-filter pH adjustment system appears to be working as intended. Based on the review of the historical lead and copper sampling and finished water data, it does not appear that an additional corrosion control inhibitor chemical is needed at this time to comply with lead and copper action levels.

Issues associated with relocation of the pre-filtration chlorine feed vault

It is likely the relocation of the chlorine injection upstream of the WTP was effective in oxidizing iron prior to filtration. During periods of shutdown, it appears that much of the iron was precipitating in the raw water main upstream of the filter system which allowed iron to accumulate in the pipe. During startup of the treatment plant, the deposits of iron floc mobilized and eventually were transported to the filter system. When this material reached the anthracite layer of the filters, it effectively plugged the anthracite cap and caused reduced run times and turbidity spikes.

Our review of the Blueleaf Pilot Study Report data suggests that the pretreatment conditions currently utilized at the treatment plant are appropriate. The existing pre-treatment oxidation system converted 99.5% of the total iron to a precipitate prior to filtration. Blueleaf states in their report "[…] pretreatment conditions at Georgetown are appropriate. Modifying the pre-oxidation dose, type, detention time, or pH is unlikely to dramatically improve media performance." Based on this conclusion, we do not believe any additional changes to the location of the chlorine injection are needed to provide additional detention time prior to filtration. We concur with the assessment made in Blueleaf's report that changes in the pre-oxidation chemical feed scheme will not have an appreciable impact on the existing filter media performance.

Water storage tank concerns

When designed and installed properly, the Gridbee systems should provide adequate mixing of the storage tank water volume. Mixing alone will not improve water age unless the water volume within the storage tank is turned over periodically. It is our understanding that a small operational band is used to control the water level in the tanks as the operators have difficulty filling the tanks during the summer while they are trying to keep up with high demands. MassDEP recommends that water storage tanks be operated so that the stored volume is completely turned over every 3 to 5 days. Further information is needed including historical water level data in order for Tighe & Bond to provide a thorough review and recommendation on the operation of the water storage tanks.

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Treatment Plant Upgrade Recommendations

Tighe & Bond recommends the Georgetown Water Department consider conducting a pilot study to determine the applicability of adding biological filtration as a pre-treatment method for reducing the raw water iron concentrations prior to the existing greensand filtration process at the water treatment plant. We expect that this pilot study will confirm that biological iron treatment is capable of reducing the iron concentrations to below the SMCL (0.3 mg/l). The addition of a clearwell is also recommended to provide a separation from the filter system and the distribution system during backwash. This clearwell will store pre-treated unchlorinated water that would be used to backwash both the biological filters and the greensand filters which should minimize the potential of a disruption occurring within the distribution system during backwash events. The existing greensand filters should be rehabilitated along with a full replacement of the filter media as part of any planned upgrade to the treatment plant. These recommended upgrades should provide a significant improvement to the water quality and improve the operational efficiency of the treatment plant.

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Section 1 Background

The Georgetown Water Department services approximately 8,200 residents and is located in Essex County, Massachusetts. The main source of water into the distribution system comes from the West Street Water Treatment Plant (WTP). The WTP is designed to remove iron and manganese and provide chemical treatment from the Georgetown Water Department's (GWD) three ground water sources: Marshall Well, Duffy's Landing Well, and Commissioners Well. The existing WTP was constructed in 2000 and was designed with a treatment capacity of 2.5 million gallons per day (MGD). At the time the plant went on-line, the raw water iron concentration was 2.5 mg/L. In 2016, the Water Department's maximum day demand was approximately 1.6 MGD. However, the average raw water iron concentration after blending the three well sources has more than doubled (5-6 mg/L). As a result, the treatment plant experiences short filter run times and requires significantly more operator attention than originally expected.

1.1 West Street WTP Raw Water Sources

The GWD utilizes three groundwater wells for its water supply: Marshall Well, Duffy's Landing Well, and Commissioner's Well. The Marshall Well and Duffy's Landing Well are both located off West Street behind the WTP and the Commissioner's Well is located on Baily Lane. The wells are gravel packed, draw water from the Park River, and are 40 to 60 feet deep. Table 1-1 provides physical properties of the wells.



FIGURE 1-1 Photo of Marshall Well (one of the three GWD water sources)

Table 1-1: Physical Properties of the GWD Wells

Supply Facility	Year Constructed	Well Depth (feet)	Well Yield	
			Safe Yield (GPM)	Typical Pumping Rate (GPM)*
Marshall Well	1964	56.65	1,000	200 GPM
Duffy's Landing Well	1996	64.5	1,050	415 GPM
Commissioner's Well	1970	38	585	300 GPM
		Total	2,635 GPM (3.79 MGD)	915 GPM (1.32 MGD)

*Pumping rates-based average of 2019 data through June 30

The well water is blended then chemically treated and filtered to remove iron and manganese. At low concentrations, iron and manganese in drinking water result in aesthetic issues and are therefore regulated under secondary drinking water standards. Secondary standards do not include enforceable limits and apply to contaminants that have no immediate adverse health effects but cause a nuisance or aesthetic problem to the consumer. The symptoms of increased iron and manganese levels may include hard, rusty or cloudy water, stains on household fixtures, or metallic tastes.

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At high concentrations, manganese may pose a health risk. The Environmental Protection Agency's (EPA's) Drinking Water Health Advisory for Manganese and the Massachusetts DEP's Office of Research and Standards Guideline recommend a manganese exposure limit of 0.3 mg/L for the general population lifetime exposure and 1.0 mg/L for the general population 10-day exposure. Table 1-2 shows the average iron and manganese levels have remained constant from 2016-2019.

Table 1-2: Blended WTP Influent Raw Groundwater Quality (Averages)

Parameter	Units	Blended Raw Groundwater Quality				SMCL*
		2016	2017	2018	2019	
Iron	mg/L	5.22	4.79	5.28	5.05	*0.3*
Manganese	mg/L	1.38	1.32	1.31	1.06	*0.05*
pH	S.U.	6.50	6.48	6.46	6.43	

*SMCL = Secondary Maximum Contaminant Level

Over the past few years, the WTP has experienced and elevated influent raw water quality of 5 mg/L iron and 1.25 mg/L manganese. These raw water concentrations represent a significant increase from the water quality at the time of the WTP Construction.

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Section 2
Comprehensive Water System Evaluation Report (2013)

Other consultants have prepared several reports and technical memorandum in the last decade. The report titled "Comprehensive Water System Evaluation Report" was submitted to the Georgetown Water Department in November 2013. This report provided a summary of all the work done by previous consultants to date. Tighe & Bond has reviewed AECOM's report to re-evaluate the GWD's needs and planning recommendations by expanding upon the 2013 report. A list of the report's recommendations is provided below:

Short Term:

- Distribution System Water Age Reduction
    - S1 – Eliminate the elevated tank and use the concrete tanks to control the well pumps and vary their water level by six to ten feet.
    - S2 – Add electric mixers to the concrete tanks.
    - S3 – Regular maintenance flushing in the eastern section of town.
- Water Chemistry Modifications
    - S4 - Re-utilize the post filter pH adjustment chemical application point and use a liquid caustic chemical instead of lime. Renovate the existing lime feed room for caustic feed.
    - S5 – Relocate the pre-chlorine feed point in a new vault further upstream of the filters to provide additional detention time.
- Other Recommendations
    - S6 – Perform uni-directional flushing and/or ice pigging, in selected sections of water main followed by super-chlorination of water mains.
    - S7 – Reduce the speed of the valve actuators on the filter control valves.

Medium Term:

- M1 – Apply a corrosion inhibitor / sequestrant chemical after the filters.
- M2 – Install automatic flushing hydrants.
- M3 – Use Chloramines as a distribution system disinfectant.
- M4 – Demolish the older concrete storage tank and construct a new storage tank on the east side of town or at the location of the demolished older concrete tank.

Long Term:

- L1 – Design and construction of a clearwell/backwash water supply tank at the WTP
- L2 – Pilot test two clarification technologies for use in a new water treatment plant.

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- L3 – Design and construction of a new WTP that utilizes clarification, filtration and a clearwell to more effectively treat raw water.

Our review of these recommendations, discussions with the Georgetown Water Department at the Water Commissioners meeting August 5, 2019, and site visit to the WTP on August 28, 2019 has given us the following basis of understanding:

The Short-term Recommendations listed in the Report are complete, however S5 - *Relocate the pre-chlorine feed point in a new vault further upstream of the filters to provide additional detention time* was decommissioned due to undesirable results (see Section 2.1). Other Short-term Recommendations have been beneficial to the operation of the WTP such *as:*

- *S4 - Re-utilize the post filter pH adjustment chemical application point and use a liquid caustic chemical instead of lime. Renovate the existing lime feed room for caustic feed;* and
- *S7 - Reduce the speed of the valve actuators on the filter control valves*.

2.1 Previously Recommended Water Treatment System Improvements Assessment

S4 - Re-utilize the post filter pH adjustment chemical application point and use a liquid caustic chemical instead of lime:

The original lime feed room has been updated with potassium hydroxide feed systems. The new KOH feed systems have been designed to raise the pH of the filtered water prior to distribution from 6.8/7.0 s.u. to approximately 7.5 s.u.

The new Potassium Hydroxide (KOH 45%) storage and feed room consists of two 500-gallon polyethylene bulk storage tanks. Each storage tank is equipped with a tank mounted Lutz drum pump which transfers chemical to the 55-gallon polyethylene finished water KOH day tank. The day tank is equipped with a level transmitter and acts as the chemical feed tank for two finished water metering pumps. The two metering pumps are LMI Series C911-460SI metering pumps capable of providing 2.5 gph at 150 psi. These feed systems are operational and are working as intended.

S5 – Relocate the pre-chlorine feed point in a new vault further upstream of the filters to provide additional detention time:

It is our understanding that this improvement was implemented. However, after a period of time, chlorine injection at this new upstream location was terminated due to the negative impacts to treatment. It is likely the relocation of the chlorine system, upstream of the WTP, was effective in oxidizing iron prior to filtration. However, due to periods of shutdown, much of the iron was precipitating in the raw water main upstream of the filter system, which allowed iron to accumulate in the pipe. During startup of the WTP, the deposits of iron floc would be mobilized and eventually were transported to the filter system. When this slug reached the anthracite layer of the filters, it effectively plugged the anthracite cap leading to reduced run times and turbidity spikes. Due to these reasons, chlorine injection was reverted back to its original location within the WTP. However, it

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appears that iron is still being effectively oxidized at the WTP prior to filtration with the existing injection scheme.

Tighe & Bond reviewed the Pilot Study Report completed by Blueleaf Inc., dated May 2015. The Pilot Study results describe the existing chemical treatment approach, injection at the WTP, as adequate for precipitation of iron and maintaining media charge on the existing filtration media. During the pilot study, the pilot filtration system used influent water that was chemically pretreated by the WTP with sodium hypochlorite and potassium permanganate for pre-oxidation and continuous regeneration of the media, and with potassium hydroxide for pH control.

Results of the pilot test indicated that GreensandPlus™ and anthracite media could reduce the influent iron and manganese concentrations to below the respective Secondary Maximum Contaminant Levels (SMCLs).

This data suggests that the pretreatment conditions currently utilized at the WTP are appropriate for treating the raw water from the Marshall and Duffy's Landing wells. However, the Commissioner's well was not in use during the pilot study. Influent raw water total iron and manganese concentrations were approximately 5 mg/L and 0.8 mg/L respectively. The existing full-scale pre-treatment oxidation system converted 99.5% of the total iron to a precipitate prior to filtration. Blueleaf states in their report "[…] pretreatment conditions at Georgetown are appropriate. Modifying the pre-oxidation dose, type, detention time, or pH is unlikely to dramatically improve media performance."

Based on this conclusion, we do not believe any additional changes to the location of the chlorine injection are needed to provide additional detention time prior to filtration. We concur with the assessment made in Blueleaf's report that changes in the pre-oxidation chemical feed scheme will not have an appreciable impact on the existing media's performance.

S7 - Reduce the speed of the valve actuators on the filter control valves have been beneficial to the operation of the WTP:

Tighe & Bond reviewed the current setup and operation of the existing filtration system. Previous reports discuss that high concentrations of iron in the filtered effluent are likely caused by hydraulic shear forces in the filters during backwash events. This is thought to be primarily caused by a spike in filter surface loading rate when one filter cell is taken off line due to backwashing, representing an approximate 16% increase in filter surface loading rates in each of the filters still producing water. In addition, Tonka Water noted that the operation of the backwash effluent valve also caused a rapid pressure surge in the filters between the refill and re-stratification steps. These hydraulic shocks to filters near their terminal filtration capacities, (i.e. filters with high concentrations of precipitated iron within the media beds), will cause a sudden release of iron into the filtered water effluent.

During our visit to the site, we observed the backwash of Filter #1. It was noted that the filter backwash effluent control valve has been recently upgraded with an AUMA electric actuator. The valve had been set to be open at 26% during most operational processes, closing only during the Simul-Wash step. During the observed backwash, the filter pressure dropped steadily from 100 psi to 80 psi. Little to no spike in turbidity was observed (on trending screens) during the transition to the high rate backwash step. An

initial spike in turbidity was seen, following a time delay for the sample return, once the first cell high rate backwash was initiated. The turbidity spike was minor for the first cell and gradually decreased as each cell was cleaned/backwashed. This indicates that the additional surface loading is most problematic when cleaning the first cell (when the system is at its "dirtiest") and dissipates to near zero as the subsequent filters are backwashed and then brought back online.

It is possible that additional flow control through each vessel, or reduced speed of the well VFDs during a backwash, could reduce the turbidity spike. However, these solutions are complex and require additional instrumentation and controls. It is unlikely to be worth the additional cost for only a marginal reduction in turbidity. In addition, it is unlikely that a reduction in flow through the WTP during a backwash would be possible during the summer months, which is when this modification would be most beneficial. A reduction in WTP output during the summer months would make it more difficult to maintain water levels in the system tanks.

It appears the implementation of the new valve actuators has made a significant impact in reducing the hydraulic shear of the filter media during a backwash. Any additional valve speed modifications may only have a small impact on the hydraulic shear on the filter media. The main issue at this point is the increased loading rate on the remaining filters in service during a backwash.

Medium-Term Water System Improvements (M1 – M4):

It is our opinion that none of the outstanding previously recommended Medium-Term water system improvements will have a significant effect on the filtration system performance.

Long-Term Water System Improvements (L1 – L3):

None of the previously recommended Long-Term improvements have been completed. Tighe & Bond will provide an evaluation of the previously recommended Long-Term water system improvements in later sections following our discussion of the existing West Street Treatment Plant.

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Section 3
Facility & Process Evaluation

On August 28, 2019, Tighe & Bond conducted an on-site evaluation of the West Street WTP to review existing conditions and treatment plant capacity. During the evaluation, Tighe & Bond staff evaluated unit processes, valves, tanks and other pieces of equipment to determine their condition and possible repair/replacement needs. The assessment was based largely on the visual evaluation of existing equipment, however, where possible, we also confirmed the operability of mechanical systems such as pumps and blowers. The following systems/unit operations within the WTP were assessed:

- Chemical feed and storage systems
- Iron and manganese filtration system
    - Equipment and Operation
    - Backwash Supply and Control
- Backwash reuse and residuals management systems
- Water Treatment Plant building systems
- SCADA and Instrumentation
- Water Treatment Plant site
- Water Distribution system

The evaluation findings and recommended improvements are summarized in the following subsections.

3.1 Chemical feed and storage systems

3.1.1 Overview

The WTP uses chemicals to increase the pH and oxidize iron and manganese from the groundwater. In addition, chemicals are used for 4-log virus inactivation compliance, residual disinfection and corrosion control. The following are the chemicals used, the purpose of each as well as a description of current equipment:

Potassium hydroxide [KOH] – Potassium Hydroxide [KOH] (Caustic) is used to raise the raw water pH from 6 s.u. to 6.8 – 7.0 s.u. on average.

Before reaching the plant, the water from all three wells is treated with caustic to raise the pH levels. From 2016-2019, the average of caustic use has remained similar. Average caustic usage data at the raw water wells are shown below in Table 3-1.

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Table 3-1: Potassium Hydroxide Usage Data

Well	Daily KOH Usage (gpd)	KOH Feed Rate (gph)	KOH Dose (mg/L)
Duffy's Landing	6.50	0.5	15
Marshall	11.3	0.9	36
Commissioner's	16.5	1.3	55

No plans were provided by the GWD depicting the caustic storage and feed systems at the existing well buildings. In addition, no data was provided by the GWD for chemical usage of caustic at the WTP, however the information gathered on the WTP caustic system within this section was developed during our site visit.

The Tonka literature recommends maintaining a pH of 6.8 – 7.0 s.u. ahead of filtration when using continuous regeneration of greensand with permanganate and when removal of iron is a primary objective. Additional adjustment of filtered water pH prior to entering the distribution system is done using the caustic as well. The pH is increased again before leaving the WTP to aid in reducing the corrosivity of the water and reduce lead and copper precipitation in the distribution system. The finished water pH is typically maintained at 7.4 – 7.5 s.u.

The WTP caustic storage and feed system consists of two 500-gallon polyethylene bulk storage tanks. Each storage tank is equipped with a tank mounted Lutz drum pump which transfers chemical to the 55-gallon polyethylene finished water caustic day tank. The day tank is equipped with a level transmitter and acts as the chemical feed tank for two finished water metering pumps. The two metering pumps are LMI Series C911-460SI metering pumps capable of providing 2.5 gph at 150 psi.

Sodium hypochlorite [NaOCl] – Sodium Hypochlorite [NaOCl] (Chlorine) is used as a pre-filtration oxidant to drive dissolved iron into a particulate state. After pH adjustment, chlorine is used for oxidizing iron and manganese (partially). Typically, a filter effluent chlorine residual of 0.5 – 1 mg/L is recommended to maintain charge on the greensand media. Chlorine is also used for 4-log compliance by maintaining a chlorine residual into the distribution system post-filtration. Average chlorine usage data is shown below in Table 3-2.

Table 3-2: Sodium Hypochlorite Usage Data

Chemical Name	Chemical Usage (gpd)	Feed Rate (gph)	Dose (mg/L)
Sodium Hypochlorite, 12.5% (NaOCl) - Oxidation	29.60	2.30	5.19
Sodium Hypochlorite, 12.5% (NaOCl) - Disinfection	6.71	0.52	1.35
Average Chlorine Residual = 1.6 mg/L			

The WTP chlorine system consists of one 1,300-gallon bulk storage tank equipped with two top mounted transfer drum pumps. Chemical is transferred from the bulk storage tank using one of two Lutz tank mounted transfer pumps. One pump is dedicated to pumping chlorine into the raw water chemical day tank. The second pump is dedicated to pumping chlorine into the finished water chemical day tank. The raw water day tank is

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approximately 95-gallons and is equipped with a Hi-Techno Pump model IX-C060TCN-TF-U rated for 15.8 gph at 145 psi. The finished water day tank is 45 gallons and is equipped with an Iwaki Metering Pump Model EHE31E1-VE rated for 5.5 gph at 150 psi.

Potassium Permanganate [$KMnO_4$] – Potassium Permanganate [$KMnO_4$] (Permanganate) is used following the addition of chlorine to provide a continuous manganese dioxide coating on the greensand media and to facilitate oxidation of manganese. The charged coating is what drives manganese removal through adsorption and oxidation to a precipitant through the filtration media's surface charge. Average permanganate usage data is shown below in Table 3-3.

Table 3-3: Potassium Permanganate Usage Data

Chemical Name	Chemical Usage (gpd)	Feed Rate (gph)	Dose (mg/L)
Potassium Permanganate Solution (KMnO4)	37.91	2.94	1.85
Target Solution Strength = 4%			

The permanganate system consists of two 350-gallon chemical mix tanks. Each mix tank is sized to create a permanganate solution by adding dry permanganate granules to water. The permanganate is kept in solution by using the tank mounted Lesson mixer. Chemical is fed directly from the mix tanks to the raw water injection by using one of two Prominent Sigma metering pumps model SICAHM12090PVT0570D120 rated for 28.6 gph at 145 psi.

3.1.2 Evaluation

The chemical feed systems at the WTP were evaluated during our site visit. None of the chemical feed systems at the well sites were evaluated as part of this site visit.

Potassium Hydroxide [KOH] (Caustic)

Only the caustic system within the WTP was evaluated during our site visit. This system is used to increase the pH of the water before leaving the WTP. However, no issues were reported by the operator regarding the existing caustic feed systems at the wells.

The WTP finished water caustic system appeared to be in adequate condition and no issues were raised by the operators on size or operations of the existing caustic feed and storage systems.

Lead & Copper:

Tighe & Bond reviewed data from the Water Department's previous three years of Lead and Copper sampling as part of this evaluation.

In 2016, two sampling sites located at 291 North Street and 373 North Street had lead level results above the Action Level of 0.015 mg/L. In 2016, none of the sampling sites had copper sampling results above the Action Level of 1.3 mg/L. The 90th percentile sample for lead was reported as 0.013 mg/L which was below the action level of 0.015

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mg/L. The 90th percentile sample for copper was reported as 0.3 mg/L which was below the action level of 1.3 mg/L

In 2017, none of the sampling sites had lead sampling results above the Action Level of 0.015 mg/L. In 2017 none of the sampling sites had copper sampling results above the Action Level of 1.3 mg/L. The 90th percentile sample for lead was reported as 0.005 mg/L which was below the action level. The 90th percentile sample for copper was reported as 0.59 mg/L which was below the action level.

In 2018, none of the sampling sites had lead sampling results above the Action Level of 0.015 mg/L. In 2018 one of the sample sites (35 Tenney Street) had a copper concentration above the Action Level of 1.3 mg/L. The MassDEP form reporting the 90th percentile sample results was not included in the data provided to Tighe & Bond. However, we calculated the 2018 90th percentile sample for lead as 0.007 mg/L which was below the action level. Similarly, the 90th percentile sample for copper was calculated as 0.92 mg/L which was below the action level of 1.3 mg/L

Chloride to Sulfate Mass Ratio:

Chloride, Sulfate and Alkalinity play a significant role in determining the corrosive effects of a water source. Public water supplies with a high number of lead service lines may require extra treatment to reduce the corrosive effects of their water sources. Although the GWD has not reported high levels of lead or copper within the past three years, the chloride to sulfate mass ratio (CSMR) is an important parameter to understand the corrosivity of the water in the distribution system.

Tighe & Bond reviewed one sample from November 2018 with regard to the corrosivity of the finished water.

Table 3-4: Finished Water Quality Data

Contaminant	Result
pH (s.u.)	7.1
Alkalinity (mg-$CaCO_3$/L)	95
Chloride (mg/L)	43.3
Sulfate (mg/L)	28

Based on the water quality data provided, we have estimated the CSMR of the finished water to be approximately 1.55. Levels of CSMR exceeding about 0.6 have been associated with accelerated lead solder corrosion. However, the finished water alkalinity concentration is well above the recommended 50 mg/L, as $CaCO_3$, which should reduce concerns of elevated chloride concentrations.

Sodium Hypochlorite [NaOCl] (Chlorine):

Both chlorine storage and feed systems are adequate for the current WTP operations. The raw water day tank can store 36 hours of hypochlorite at design flow and a dose of 5.2 mg/L. The raw water chlorine pump operates at 15% of its maximum feed rate; at design flow the pump would operate closer to 30% of the maximum feed rate. The filtered water

chlorine day tank can store 72 hours of chlorine at design flow, at an oxidant dose of 1.4 mg/L while maintaining a free chlorine residual of 1.6 mg/L.

The chlorine bulk storage tank is sized adequately for the current WTP operations. However, at design flow, the bulk storage tank would only provide approximately three weeks of chemical storage. Oxidant demand can be variable depending on the water quality of the source. Typically, the WTP is operated with permanganate as a co-oxidant with chlorine. The extra storage and feed capacity in the day tanks and chemical metering pumps allow the WTP to increase capacity if raw water quality decreases or while the permanganate system is offline.

Potassium Permanganate [$KMnO_4$] (Permanganate):

The permanganate storage and feed systems are adequate for the current WTP operations. The mix tanks can store one week of permanganate solution at design flow and a dosage of 1.9 mg/L. The mixing tanks are sized to produce a 1.8% solution with one full tank per 5 gallons of permanganate granules. The typical permanganate solution strength of 4% would require 160 gallons. The permanganate metering pump currently operates at 54% of its maximum feed rate. At design flow, the pump would operate closer to its maximum feed rate.



FIGURE 3-1 Photo depicting potassium permanganate tank

3.1.3 Recommendations

Potassium Hydroxide [KOH] (Caustic):

Overall the caustic feed system appears to be in satisfactory condition. Based on the review of the historical lead and copper sampling and finished water data, it does not appear that an additional corrosion control inhibitor chemical is needed at this time to comply with lead and copper action levels. The finished water CSMR is concerning, however the finished water pH and alkalinity are sufficient to reduce problems associated with chloride corrosion of lead and/or copper services. It is unlikely that any additional treatment systems to improve iron and manganese filtration at the WTP would have a significant impact on the corrosivity of the finished water.

Sodium Hypochlorite [NaOCl] (Chlorine):

Overall the chlorine feed system appears to be in satisfactory condition. No changes to the existing system are recommended at this time. However, changes to the treatment system to improve iron and manganese filtration at the WTP may require modifications to the chlorine system.

Potassium Permanganate [$KMnO_4$] (Permanganate):

Overall the permanganate system appears to be in fair condition, however, the permanganate system could use additional cleanup at the storage and feed area.

It is common for chemical solution mixing areas to become messy when chemical solutions are created from dry chemical. The current permanganate mix system requires operators

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to lift 5-gallon containers of chemical to the top of the solution tanks and pour the granular material into the tank. Inherently this process can involve spilling of dry chemical, which can disperse powder in the immediate area, and is ultimately labor intensive.

We recommended the GWD install a permanganate educator system for chemical solution makeup. An educator system is a simple and reliable way to hydrate dry chemical. The system uses make-up water flow through a venturi educator to create a suction force for entraining chemical powder. The system is controlled by a panel and is equipped with a programmable batch controller and flow sensor to properly meter the correct amount of make-up water for the desired permanganate solution strength. The educator system allows for reduced O&M of the permanganate solution and enhances the reproducibility of chemical solution strength. Systems of this type are generally limited to sites with batch water available at pressures of 80 psi or greater. If system pressure is lower or is significantly variable; an in-line booster pump can be installed in the educator line to provide the necessary flow through the venturi.

Changes to the treatment system to improve iron and manganese filtration at the WTP may require additional modifications to the permanganate system, however this system appears adequate for current WTP operations.

3.2 Filtration System - Equipment and Operations

3.2.1 Overview

The WTP filtration system consists of two 10-foot diameter, 38-foot long horizontal pressure filters manufactured by Tonka Equipment Company. Each vessel is made up of four isolated cells. Each cell achieves iron and manganese removal by utilizing a dual media system consisting of 10-inches of anthracite coal media above 20-inches of greensand media, as originally designed. Each cell is designed with 88.75 square feet of filtration media surface area resulting in a 355 square foot media surface area per filter and a total filtration media area of 710 square feet. This media area corresponds to a filtration rate of 2.46 gpm per square foot at the plant design flow rate of 1,750 gpm. The filtration system is typically operated at 800 gpm, continuously, corresponding to a filter loading rate of approximately 1.13 gpm per square foot.



FIGURE 3-2 Photo depicting one Tonka horizontal pressure filter

Each filter cell is equipped with the Tonka Equipment Companies proprietary Simul-Wash™ Backwash System and a 3/8-inch underdrain plate with Tonka's ABS diffuser Nozzles installed 12-inches on center. The location and design of the Tonka ABS diffuser nozzles assure uniformity of flow and help prevent clogging during backwash.

Each filter cell operation is controlled by Bray Pneumatical Piston actuated butterfly valves. Each filter cell has five dedicated pneumatic butterfly control valves that set the filter mode (production, backwash, and rinse). Each filter train shares three pneumatic controls and two rate set butterfly valves for isolation, operation, and the various backwash steps.

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3.2.2 Evaluation

During our visit, we observed several areas on the filtration system where steel was beginning to corrode, and paint was peeling. Most notably this was occurring on the filter face piping, tank hatches, and on the underside of the filtration system.

During our visit we did not observe any internal portions of the filter system. Tighe & Bond reviewed the Tonka Water field reports and media core analyses that were completed in March 2015 and March 2017.

Our review of the reports found many uncertainties regarding the current media makeup of the filters. Tonka noted in their April 2015 media analysis that the manganese greensand was in satisfactory condition. However, the data presented in this lab analysis indicated the media fractionation of anthracite to greensand had shifted from the original design specification. The filter cells Tonka tested had too much anthracite and not enough greensand. Similarly, in the 2017 lab report, Tonka noted that the anthracite sample was drastically undersized and out of specification for uniformity. The report suggests the sample may have contained a large number of fine particles. We believe this may be from the consistent media replacements in which operators have slowly replaced the existing ferro-greensand media with GreensandPlus™ in addition to replacing anthracite lost during the backwashes. We do not know the extent of the media replaced over the last decade as we have not received purchase orders or logs of the number of media bags used in a given year or any indication of the number of bags used per filter or per filter cell.

The 2017 media analysis report by Tonka recommends continued use of the media if performance or run length does not suffer. However, data suggests that even with the current raw water concentrations of iron and manganese increasing over the past decade, the filter system should still be performing better than current operations.

In May 2015, Blueleaf Inc. performed a pilot study on the blended source of Duffy and Marshall Wells at the WTP. The purpose of the study was to investigate possible causes for poor effluent water quality from the WTP. Pilot filtration trials were performed at a filter surface loading rate (FSLR) of 1.25 gpm/sf to mimic the current operation of the existing filtration system and at 2.5 gpm/sf to mimic the original design. Four pilot-scale pressure filters were operated; all containing GreensandPlus™ and anthracite. A total of 12 filter trials were completed with four different depths of GreensandPlus™ and anthracite

Table 3-5: Blueleaf Inc., 2015 Pilot Filters

Date (2015)	Filter A	Filter B	Filter C	Filter D
5/14 – 5/16 5/16 – 5/18	16” GSP + 14” Anthracite		20” GSP + 10” Anthracite	
5/22 – 5/24	22” GSP + 8” Anthracite		24” GSP + 6” Anthracite	
FSLR	Design (2.5 gpm/sf)	Current (1.25gpm/sf)	Design (2.5 gpm/sf)	Current (1.25gpm/sf)

Filters C & D operated between the dates of May 14 thru May 18 and best represent the existing full-scale filtration system. This pilot test showed that even with a full media replacement of 10-inches of anthracite above 20-inches of GreensandPlus™, run times to breakthrough were still less than 24 hours at the design loading rate of 2.5 gpm/sf and

less than 48 hours at the current operational loading rate of 1.25 gpm/sf. However, the pilot data suggests that the media in the existing full-scale system is causing the filter performance to suffer slightly.

The pilot data showed that 10-inches of anthracite cap above 20-inches of GreensandPlus™ should have filtration runtimes of greater than one day at 1.25 gpm/sf. However, the filter system approaches breakthrough of the media after only 24 hours of operation. We believe this may be due to the yearly media replacements by the operations staff. The existing filter media is no longer 1/3rd anthracite and 2/3rd catalytic media; there is now less catalytic media (Greensand/GreensandPlus™) and more anthracite in the filters. These media replacements have also caused a buildup in fine particles in the media bed that may be reducing expected performance. The exact media makeup and depth in every filter cell are unknown. The inconsistency between cells may be reducing the performance of the filter system.

3.2.3 Recommendations

Tighe & Bond has not received any additional media lab reports from GWD which indicate a full investigation into the media makeup and depth of every filter cell at the WTP. We recommend the GWD perform a full filter media investigation to determine what media makeup is currently in each filter cell and the corresponding depth and media fractionation so that future media replacements can be properly coordinated, and so that the media can be returned to its original design specification intent of 10-inches of anthracite above 2-inches of GreensandPlus™. If the data indicates the media is mostly anthracite, as stated in the 2015 Tonka lab analysis, a full media replacement is recommended.

Future media replacements should be coordinated with any additional proposed treatment upgrades. If GreensandPlus™ is to remain as the main treatment system at the WTP, the media replacement should consist of 10 inches of anthracite coal media over 20 inches of GreensandPlus™. Modifications to the treatment system are suggested in the following sections, and may change the recommended media fractionation. In addition, an allowance should be carried during the media replacement for both an internal evaluation of the filter tank and the cost to repair the filter tank internally if needed.

Due to the extensive corrosion of the filters and process piping, we recommend sand blasting and recoating the exterior of all the process piping and metal tanks. Tank internal paintings should be done during a filter media replacement. However, replacement of the media and painting of the tanks would require a temporary treatment system or a new pre-treatment system that remove enough iron to allow for manganese treatment using one filter train for the duration of the upgrade.

There are no operational or minor equipment modification recommendations that would dramatically improve the existing filtration system and associated filter media performance. Reduction in raw water iron concentration by way of pre-treatment may be the only way to extend the current filter runtimes beyond 48 hours at the current operational filter loading rates.

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3.3 Filtration System - Backwash Supply and Control

3.3.1 Overview

The existing West Street WTP filter system is typically backwashed once or twice per day depending on the season and the corresponding water usage in Town. Backwash is required when the filter media reaches the point of saturation. This is indicated when the loss of head gauge shows excessive headloss, or if breakthrough of yellow water or excessive turbidity is detected in the effluent water. Operators have determined that if differential pressure exceeds 3 – 3.5 psi, breakthrough of iron and manganese will occur. Operators typically backwash at or before 3 psi during the winter to avoid breakthrough when water system demand is low and there is water available for backwash. Due to the system being directly connected to the distribution system, the operators are often forced to operate the filters above 3 psi, past breakthrough, in the summer months in order to keep up with system demand and maintain a full storage tank level. Backwash of greensand and GreensandPlus™ dual media systems often require large volumes of water. However, in the proprietary Tonka Simul-Wash™ system, the typical volume is slightly minimized. The filter system backwash procedure is as follows:

1. Draindown – 3 minutes
2. Simul-Wash™ – 12 minutes at 5 gpm/sf
3. Refill – 3 minutes
4. Air Purge – 3 minutes at 266 SCFM/sf
5. High Rate BW – 6 minutes at 10 gpm/sf
6. Rinse – 2 minutes at ~1 gpm/sf

The procedure for Simul-Wash™ backwashing of the filter cells consists of a simul-wash and backwash while the other filter cells are maintaining normal operation (in-service). The well pumps are locked on and one cell is drained down, simul-washed, refilled, and high-rate backwashed using water from the remaining seven cells. The backwashed cell is then rinsed (filter to waste) prior to being returned to service and backwashing the next cell. Water for backwashing is provided from the wells, filtered through the existing cells in-service and from the distribution system if raw water flow is less than 900 gpm. Air is provided by a 2HP Spencer blower located in the garage below the WTP main floor.

3.3.2 Evaluation

During our visit, we observed the operation and backwashing of the filter system. To our knowledge the filtration system operated normally under a semi-automatic backwash cycle (automatic backwashing while the operator is present on-site).

The operators monitor backwash flow by measuring the difference between the raw water into the filter system minus the finished water flow out to the distribution system. None of this flow is metered directly and flow is strictly governed by rate set valves and hydraulic conditions; there are no modulating valves. Typically, the wells provide approximately 800 - 900 gpm, which is satisfactory for the high rate backwash (re-stratification). It is unknown whether additional system water is back flowing through the filter causing the re-stratification rate to exceed the 10 gpm/sf threshold stated in the O&M Manual. Issues related to media loss as stated in the Section 3.2 may have a direct relation to the lack of metered, controlled backwash flow rate.

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During our visit, we observed a backwash of Filter #1. It was noted that the filter backwash effluent control valve was recently upgraded with an AUMA electric actuator. The valve had been set to be open at 26% during most operational processes (closing only during the simul-wash step). Hydraulic conditions are typically changed by closing the 26% open Auma actuated butterfly valve during Simul-wash and opening a corresponding, smaller, butterfly valve to restrict the flow through the filter during this step.

During the observed backwash, the filter pressure dropped steadily from 100 psi to 80 psi. Little to no spike in turbidity was observed (on trending screens) during the transition to the high rate backwash step. An initial spike in turbidity was seen, following a time delay for the sample return, once the first cell high rate backwash was initiated. The turbidity spike was minor for the first cell and gradually decreased as each cell was cleaned/backwashed. This indicates that the additional surface loading is most problematic when cleaning the first cell (when the system is at its "dirtiest") and dissipates to near zero as the subsequent filters are backwashed and then brought back online.

3.3.3 Recommendations

The backwash operation has historically been a source of concern for the GWD. We recommend developing a plan to disconnect the filter system from the water distribution system for backwashing. We concur with AECOM's 2013 recommendation L1 - Design and construction of a clearwell/backwash water supply tank at the WTP site would achieve this goal. With a separate clearwell to supply backwash water, a more consistent forward flow into the system can be achieved. In addition, backwash pumps will allow for better flow control of the water supplied to the backwash during each step.

Full automation of the backwash system is currently possible; however, it is not recommended to be used when the operators are not present at WTP. Although the control panel is designed to automatically operate the filter system under a backwash, the reliability of the pneumatic valves is critical. An operator that is present during a backwash allows for failures to be caught quickly to minimize damage and impacts to the distribution system. Due to the filters direct connection to the distribution system, valve failure could potentially cause excessive flow reversal from the system, which could cause a significant drop in system pressure, dirty water complaints and excessive wasting of finished water.

3.4 Backwash Reuse & Residuals Management Systems

3.4.1 Overview

Backwash residuals are collected in one of two floor troughs on the south side of each filter. The troughs contain approximately 50 gallons and are separated into two compartments by a V-notch weir plate. The two troughs are connected by a 12-inch DI pipe below the Filter Room slab. The pipe runs West to East connecting Filter #2 backwash trough to Filter #1's backwash trough, then conveys the backwash residuals to the yard east of the WTP to the Backwash Reuse Storage Tank.

The Backwash Reuse Storage Tank is a 25-foot tall glass fused to steel tank with an assumed nominal capacity of 180,000 gallons and a 35-foot diameter. The original tank was fitted with a floating decanter which consists of a weir attached to mooring rods. This weir pulls clarifier backwash residuals supernatant and returns the supernatant to the front of the WTP. The backwash residuals management system also consists of a small

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reuse pump and waste station. This building houses the recycle pumps that are connected to the floating decanter inside the residuals tank.

Recycled supernatant is pumped from the Reuse Pump and Waste Station through a 3-inch DI pipe approximately 120 feet where the pipe is tapped into the 10-inch DI raw water main and returned to the head of the WTP.

The lagoons are approximately 32-feet wide by 70-feet long with a total depth of approximately 5.5 feet. The lagoon is lined by a geotextile to prevent leaching of backwash water directly to the ground. The bottom of the lagoon consists of 6-inches of screened gravel bed on each side of the geotextile liner. The underdrain is positioned above a layer of gravel, and beneath 8 inches of 3/8-inch stone. A filter fabric is placed over the underdrain stone bed and covered with a 12-inch deep sand bed. The intent of this sand bed is to catch settled iron and manganese residual solids from the backwash waste. Periodically, this sand requires excavation and replacement with fresh virgin sand. There is approximately 4 feet of water above the sand bed resulting in an approximate working volume of 67,000 gallons per lagoon.

The underdrain system consists of 4-inch perforated PVC laterals spaced 10-feet on center connected by a central 4-inch perforated PVC header. Each of the lagoon's main headers lead to an outlet structure at their north ends. There is also a 4-inch DI supernatant withdrawal pipe connected to a 3-inch suction hose. The hose connects to a floating dock strainer intended to gravity feed the backwash supernatant from the lagoon to the outlet structure.



FIGURE 3-3 Photo depicting one of two lagoons

These outlet structures are constructed with a 48-inch outlet weir to allow overflow of the backwash lagoons to the outlet structure. Each of the 4-inch pipes at the outlet structures are terminated in the structure by a 4-inch sluice gate which controls the flow from the lagoon into the outlet structure. Flow from the open sluice gates or flow over the outlet weir collect in the outlet structure and are conveyed by gravity through a 12-inch SDR 35 PVC pipe to a common manhole at the north end of the lagoons. This manhole collects water from both backwash lagoon outlet structures and then conveys the water through a final 12-inch SDR35 PVC outfall to the north of the lagoons. The outfall is approximately 60 feet in length and leads to a 120-foot 8-foot-wide discharge swale which extends to the Parker River. The discharge swale has five check dams at 15 feet on center along its length.

3.4.2 Evaluation

It is our understanding that the backwash recycle system is mostly dismantled. The floating weir and recycle pump stations have been mostly decommissioned and used for spare parts. The existing system operates without any recycling of backwash supernatant. At the time of our visit, we were unable to view the inside of the Backwash Reuse Tank.

The residuals lagoons appeared to be in adequate condition, but they were overgrown with vegetation and dried material. The lagoon decanter system also appeared to be dismantled. The operators indicate regular cleaning of the lagoons. During this cleaning

process, it is evident some of the filter media is being washed out through the backwash process.

Due to the frequent backwashing of the filter system, the existing lagoons may not be adequate for the amount of backwash waste produced daily. It appears the filter system backwash schedule may be overwhelming the existing residuals management system's design intent. Without the Backwash Reuse system, backwash of both filters occurs daily, and the backwash residuals management system sees flows of approximately 90,000 gallons per day. MassDEP recommends lagoons be "designed with a volume 10 times the total quantity of wash water discharged any 24-hour period" [MassDEP Drinking Water Policies and Guidelines Chapter 5]. Therefore, the current storage volume of 134,000 gallons is significantly undersized based on the MassDEP Guidelines. Without planned reuse, the backwash lagoons should contain approximately 900,000 gallons. This would require 30,000 square feet of lagoon area or 0.7 acres, without any modifications to the existing depth.

It is our assumption the design intent was to backwash once every 48 hours to allow the daily backwash loading to be approximately 45,000 gallons. Furthermore, the Backwash Reuse System would have to recycle approximately 70% of the backwash waste to allow for proper loading to the lagoons.

Additionally, no issues associated with the backwash outfall to Parker River have been reported to Tighe & Bond. We did not evaluate the backwash flows in relation with any outfall permit requirements.

3.4.3 Recommendations

Due to the difficulty of operating the filter system with the current raw water quality, we do not recommend the GWD repair and reintroduce the backwash recycle system at this time. It is possible that recycling of backwash supernatant may increase the raw water iron and manganese and cause additional difficulty with filter operations and shorten runtimes. Currently, the source water wells are running below capacity. Therefore, there are no issues related to water supply which may require recycling to reduce the amount of water lost to backwashing.

The backwash residuals management system and lagoons are significantly undersized. However, we do not recommend additional lagoon storage area at this time. We recommend treatment system modifications to reduce the frequency and/or quantity of backwashes and to install a treatment system capable of handling the additional iron and manganese loading that would allow the backwash reuse system to be returned to service. With these modifications in place, it may be possible to keep the existing lagoon system without expansion.

The backwash reuse system would require a new floating decanter, new pumps and pump house, new instrumentation and may also require additional equalization storage to ensure the lagoons are not overloaded on a daily basis.

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3.5 Water Treatment Plant Building Systems

3.5.1 Overview

The West Street WTP is a masonry block building approximately 100-ft by 40-ft with a gable roof protected by asphalt shingles. The WTP is two stories tall with the main floor being used for control room, chemical storage, and general water treatment process area. The basement is a two-port garage. The building has a large overhead door on the south end of the WTP in front of the filter system. Above the laboratory is an equipment storage area accessible by a ladder.

The HVAC system is comprised of Natural Gas Unit heaters and two dehumidifiers suspended from the ceiling. Due to poor ventilation in the filter room, operators have installed two small exhaust fans into the face of the overhead door.

The WTP has a 120/240V, 125-amp electrical service with a 1KVA distribution transformer. The WTP has a 100kW generator adjacent to the lower garage area. Lighting in the process room was designed with two 40-foot tracks of seven fluorescent lights. Fluorescent lights we also designed to be suspended from the ceiling north of the filters in the process area. Additionally, five fluorescent lights are mounted on each of the east and west exterior walls to illuminate the filter face piping. The laboratory and chemical feed areas are also equipped with fluorescent lights.

3.5.2 Evaluation

The condition of the building structure is adequate. The building finishes are in need of re-painting. Walls, floors, doors and piping are all exhibiting coating delamination in certain areas. The filter room overhead door is aging and has been modified to include two small fans for room exhaust. The original roof is approaching it's expected beneficial life, soffits and the wood trim are beginning to rot. The soffit light covers are also missing.

The existing lighting system has been modified significantly. It appears the original track lights above the filter area have been replaced or were never installed. The operators have strung temporary incandescent shop lights along the 40-foot track. The existing lighting is, most likely, approaching the end of its useful life. The generator outside the WTP building is overgrown with vegetation.

In addition, the existing HVAC systems may be approaching the end of their useful lives.

3.5.3 Recommendations

The WTP should be renovated to include new coating systems on the walls doors, floors, and piping. HVAC and plumbing systems should be re-evaluated to confirm the remaining useful lives. Existing equipment such as the natural gas heaters, louvers, ventilation system, water heater, eyewash and building sanitary plumbing should be re-evaluated and replaced, as needed as part of future WTP renovations.

All existing incandescent or fluorescent lighting should be replaced with new, low-energy consumption LEDs. Following upgrades to the WTPs ventilation system, the existing overhead door should be replaced. Additionally, the WTP roof, soffits and trim should be replaced.

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3.6 SCADA and Instrumentation

3.6.1 Overview

The existing WTP operates on a 5-year old VT SCADA system. The WTP communicates with the wells via radio. The WTP PC system was updated in 2018 to bring the WTP up to date on software. However, no upgrade in PLC hardware has been done to date.

The filter control and process control systems use Allen Bradley PC controllers, type SLC 5/03. The programs are stored in RAM memory and are backed up with a battery that serves as an uninterrupted power source (UPS). The UPS has an intended useful life of 5 years. In addition, there currently is no electrically erasable programmable read-only memory (EEPROM) chip installed to store a backup of the program.

The filter control panel is protected by a 5-amp fused disconnect on the lower right terminal strip. The controller and modem connection have their own separate disconnects. The CPU is also internally fused. The switches and indicators on the front of the panel are NEMA-rated Allen Bradley 800E series. All factory-installed wiring connects to the left side of the terminal strips and all field-installed wiring comes off to the right. Internal wiring is 18 or 14-gauge MTW or THHN rated 600 VAC and 105 degrees centigrade. The control enclosure requires no ventilation and the panel UIL listed serial number is AT-903165.

The filter control panel operator interface terminal is an Allen Bradley Panelview™ 550 graphical operator interface providing control and monitoring functions of the filtration system.

3.6.2 Evaluation

VT SCADA is an acceptable modern controls system software that should be adequate for use at the West Street WTP and throughout the distribution system. The existing filter and process control panels are running on aging SLC 5/03 CPU. These PLCs are older Allen Bradley units which are no longer manufactured. The current set-up is also running out of space for additions/modifications in the plant. The filter and process control panels are adequate for current operations at the WTP but may be approaching the end of their useful life.

3.6.3 Recommendations

The GWD should consider upgrading the process and filter control panels as part of a larger upgrades project as these panels are nearing the end of their useful life. Additional rehabilitation to the control panels is needed in the short term. Replacement of the existing UPSs is probably due in the near future. Additionally, a more comprehensive program could be included to allow for chemical dose fractioning per well in addition to being flow paced. This would allow for better use of chemicals and allow operators to adjust well VFDs, as needed, and have a corresponding turndown/up of the chemical metering dose in relation to specific well raw water quality.

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3.7 Water Treatment Plant Site

3.7.1 Overview

The site is located at 75 West Street. The WTP site is approximately 5.4 acres. This parcel abuts several other parcels owned by the Town of Georgetown on which several of the source wells are drilled. The WTP also abuts the Parker River and municipally owned soccer fields.



FIGURE 3-4 Photo depicting Parker River

The major WTP site features include the WTP, well buildings, Reuse Storage tank, backwash lagoons and access road.

3.7.2 Evaluation

During our site visit we walked through 75 West Street and down most of the access road to the well houses. We observed minor cracking and spalling in the concrete stairs and upper loading dock. As noted above, the lagoons appeared to be overgrown with vegetation and dried residuals, in addition there was minor damage to the lagoon fence. Overall the WTP site has been maintained and is in adequate condition.

3.7.3 Recommendations

Minor concrete repairs and paving may be needed in the future. Cleanup of the site around the lagoons is recommended.

3.8 Distribution System

3.8.1 Overview

The West Street WTP pumps filtered water into the water distribution system, which consists of 66 miles of watermain. Storage in the distribution system is provided by a 0.6 MG concrete water storage tank located off Baldpate Road and a new 0.75 MG elevated water storage tank on Long Hill. The water distribution system services approximately 8,200 residents and experiences a 1.3 MGD peak season demand as reported in previous reports.

To assist with mixing in each system storage tank, Gridbee active mixing systems have been installed. Additionally, the GWD has experienced occasional issues related to TTHMs in the summer.

3.8.2 Evaluation

When designed properly, the Gridbee systems keep the tank water well mixed. However, mixing does not improve water age unless the water storage tank is turned over periodically. Typically, the more turnover the better, however system pressures and water supply need to be considered in setting the low tank level.

The operators indicated they use a small operational band in the tanks because they have trouble filling the tank during the summer and are trying to keep up with demands. The GWD wells are operated frequently, allowing for only a small band of turn over within the water storage tanks. Operators have elected to run the WTP at a lower capacity to extend run times to only require one backwash per day. This creates a strain on the WTP's ability

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to maintain full tanks and minimum distribution system pressures, as backwashes may require system water for high rate re-stratification step.

3.8.3 Recommendations

The GWD tank operations should be in-line with the guidelines provided by MassDEP and the USEPA. Special considerations should be given to tank operations during periods of high demand. Water storage and pressure in the system are critical to the continuing operation and backwash of the filtration system. Reducing the storage tank volume too low to facilitate tank turn over should only be done following complete backwash of the filtration system. Tanks should be refilled immediately following draining to allow for sufficient water supply for backwash and to meet system demand simultaneously.

MassDEP recommends WSTs be designed to facilitate turnover of water in the finished water storage. Excessive water age is an important factor related to water quality deterioration. A 3-5-day complete water turnover is recommended as a starting point, and each finished water storage facility should be evaluated individually and given its own turnover goal.

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Section 4
Water Treatment Plant Upgrades Recommendations

Based on our review of the existing plant data and our onsite evaluations, Tighe & Bond has developed a list of recommendations for GWD to address the current operational issues at the West Street WTP. This section will expand upon the 2013 AECOM long term recommendations as well as present additional recommendations from our Work.

4.1 Comprehensive Water System Evaluation Report (2013) Long-Term Recommendations Evaluation

As discussed in Section 2, the report titled "Comprehensive Water System Evaluation Report" was submitted to the GWD in November 2013. Tighe & Bond has reviewed AECOM's report to re-evaluate the GWD's needs and planning recommendations by expanding upon the 2013 report. In the previous section we've addressed the short- and medium-term recommendations. In this section, Tighe & Bond will review the proposed Long-Term Improvements listed in the 2013 report. These recommendations were made in 2013 and were made on the assumptions based upon the performance of the shorter-term improvements discussed above. The 2013 Long-term improvements were as follows:

Long Term:

- L1 – Design and construction of a clearwell/backwash water supply tank at the WTP site. (2013 Estimated Cost: $2.0 - $2.8 million; ENR Adjusted Current Estimated Cost: $2.3 – $3.3 million)
    - The addition of a clearwell/backwash water supply tank WTP would have multiple benefits. It would serve as a dedicated source for backwash water, eliminating the potential for lower quality water to enter the system during backwash cycles. It would also provide more chlorine contact time. If this tank is constructed, it should be located at an elevation that would allow it to be utilized if a new WTP is constructed.
- L2 – Pilot test two clarification technologies for use in a new water treatment plant (2013 Estimated Cost: $140,000 -$170,000)
    - Pilot testing would be necessary if the decision was made to build a new WTP. This decision should not be made until the above improvements have been enacted and evaluated.
- L3 – Design and construction of a new WTP that utilizes clarification, filtration and a clearwell to more effectively treat raw water (2013 Estimated Cost: $8 - $10 million; ENR Adjusted Current Estimated Cost: $9.4 – $11.7 million)
    - Design and construction of a new WTP is only recommended after all above improvements have been considered, implemented and evaluated.

L1 – Design and construction of a clearwell/backwash water supply tank at the WTP site.

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Based on our review of the WTP, it is in our opinion that *L1 – Design and construction of a clearwell/backwash water supply tank at the WTP site* is a necessary modification to improve the operations of the WTP. However, based on our review, we do not believe an on-site clearwell will significantly change the quality of water to the distribution system or change the run time of the filtration system. Future modifications to the WTP should include provisions for an on-site backwash supply tank but should be coordinated with other major treatment improvements so that the tank can be properly integrated into the proposed upgrade.

L2 – Pilot test two clarification technologies for use in a new water treatment plant

Based on our review of the WTP, we believe *L2 – Pilot test two clarification technologies for use in a new water treatment plant* is a possible avenue for the GWD to pursue, however, additional treatment recommendations may be more prudent. Alternative recommendations have been provided in Section 4.2.

L3 – Design and construction of a new WTP that utilizes clarification, filtration and a clearwell to more effectively treat raw water

Based on our review of the WTP, we believe *L3 – Design and construction of a new WTP that utilizes clarification, filtration and a clearwell to more effectively treat raw water* is a possible avenue for the GWD to pursue, however, additional treatment recommendations may be more prudent. Alternative recommendations have been provided in Section 4.2.

4.2 West Street WTP Treatment Upgrade Alternatives

This section provides alternate treatment recommendations for improving the filtration system performance and extending the typical filtration system run-times between backwashes.

4.2.1 GreensandPlus™ Media Replacement

As discussed in Section 3.2, it is important for GWD to understand the media makeup within the existing filtration system. Any upgrade seeking to maintain existing Greensand filter system infrastructure would also require a media replacement. The existing media makeup is currently unknown. Future media replacements should be done to replace all existing media with the correct ratio of anthracite above GreensandPlus™. Depending on the proposed upgrades, if a pre-treatment step is recommended, it may not be necessary to include an anthracite cap above the GreensandPlus™.

4.2.2 Additional GreensandPlus™ Filters

Additional GreensandPlus™ filtration area would provide for less volume per filter which corresponds to a decrease in overall filter surface loading rate. Theoretically this change would extend the filter run times, assuming a full media replacement of the existing filtration system with GreensandPlus™.

The Technical Data Sheet published by Inversand, the manufacturer of GreesandPlus™, states that GreensandPlus'™ capacity is between 700 and 1200 grains of oxidized iron and manganese per square foot of bed area. For the purposes of this calculation, we will assume 1,000 grains of oxidized iron and manganese per square foot of bed area. As stated in Section 1, the blended raw water iron and manganese concentrations for the West Street WTP raw water is approximately 5 mg/L and 1 mg/L, respectively. Therefore,

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based on the assumed contaminant loading, we can assume a total oxidant demand of 7 mg/L, approximately 0.4 grains per gallon. Oxidant demand is calculated by the following: Oxidant Demand = (1 x [Fe-mg/L] + 2 x [Mn-mg/L]).

Assuming a media capacity of 1,000 grains per square foot, we derive a theoretical treatment capacity of 2,500 grains per gallon. To effectively remove iron and manganese at the average flow (915 gpm), with the above raw water concentrations, the filtration system would need to be 1,054 square feet to allow for a 48-hour run time between backwashes. 1,054 square feet of filter surface area corresponds to a 50% increase in existing filter surface area, with one additional 10-ft diameter horizontal filter. For the maximum flow rate of 2.5 MGD, or 1,750 gpm, the corresponding filter surface area would be 2,000 square feet, or a 180% increase in the existing filter surface area, approximately four additional 10-ft diameter horizontal filters.

This basic desktop analysis is in line with the conclusions provided by Blueleaf Inc., following their 2015 Pilot Study. As discussed in Section 3.2.2, Blueleaf found that the existing full-scale filters are likely under-sized for the iron and manganese concentrations currently in the raw water.

Although it is possible to reduce the frequency of backwashing by increasing the filter surface area, the additional volume of water required to backwash larger filters would likely negate any reduction in backwash volume from longer run times. Currently, the filtration system produces approximately 90,000 gallons per day of backwash water; backwashing two 10-foot filters daily. Backwashing three 10-foot filters once every 48 hours would require 135,000 gallons of backwash water supply but could be equalized over two days to produce approximately 67,000 gallons per day of backwash wastewater to the lagoons. Unfortunately, most of the concerns regarding the frequency of backwashing are in relation to supply of backwash water and not disposal. Although there would be a benefit in metering the disposal of the backwash waste over two days, the supply of 135,000 gallons following the 48 hour run times would be prohibitive to the GWD making this treatment alternative unlikely to be feasible or cost-effective.

4.2.3 Biological Iron and Manganese Filtration

Microorganisms that oxidize iron and manganese are naturally-occurring and can be found in groundwater sources throughout the world. These bacteria are ubiquitous and have evolved over millions of years to survive on the chemical energy found to be dissolved iron and manganese in groundwater.

In biological filtration systems, iron- and manganese-oxidizing bacteria (IOB and MOB) that are naturally present in the groundwater form a biofilm inside pressure filtration tanks on the surface of filter sand media. These bacteria generate energy through the aerobic oxidation of Fe^{2+} to $Fe(OH)_3$ or Mn^{2+} to MnO_2. Biological iron and manganese oxidation are typically accomplished in two stages in series because IOB and MOB have different preferential ranges of pH and oxidation-reduction potential (ORP). Optimal pH, ORP and dissolved oxygen (DO) are required for the correct operation of the biological process. This can be achieved through controlled injection of process air (depending on the raw water pH) to increase the ORP and achieve specific target DO ranges.

The metal precipitates formed by biological oxidation are denser and more crystalline than those formed through chemical oxidation; therefore, biological filters foul less rapidly and produce denser backwash sludge. Due to this more crystalline precipitate structure,

biological filtration may offer longer filter run times between backwashing because the buildup of head loss through the filter system is slower than the traditional pressure filtration medias, like the Greensand filtration currently used at the West Street WTP. Extended filter run times improve system efficiency by processing more water between backwashing. In addition, each backwash event produces less backwash water as it is not necessary to use as high of a backwash flow rate as the Greensand filters. When these two factors are combined, the biological filtration can often use/produce 80% less backwash water than traditional chemically enhanced adsorptive pressure filtration, such as the Greensand Filtration.

GWD offers a unique possibility for integrating biological filtration into an existing filtration system, opposed to abandoning existing capital to construct a new conventional treatment WTP. Typically iron and manganese biological filtration is designed for two-stage filtration, i.e. IOB filter raw water iron and MOB filter raw water manganese in separate pressure vessels. However, it is possible to use biological iron filters up-front of the existing process to reduce the raw water iron to near or below the SMCL prior to filtration by GreensandPlus™.

We've re-evaluated the calculations in Section 4.2.2 assuming pre-treatment of iron by a biological iron filter. For the purpose of this calculation, we will assume 1,000 grains of oxidized iron and manganese per square foot of GreensandPlus™ bed area. Assuming the existing filters are only loaded with 1 mg/L of manganese, we can assume a total oxidant demand of 2 mg/L, approximately 0.12 grains per gallon. Assuming a media capacity of 1,000 grains per square foot, we derive a theoretical treatment capacity of 8,300 grains per gallon. This translates to an expected runtime, at average flow (915 gpm), of 100 hours. Similarly, at design flow, 2.5 MGD, we could expect filter run times of approximately 48 hours.

Treatment raw water iron concentrations of 5 mg/L may allow for a filter loading rate of approximately 6 gpm/sf or greater. At this loading rate, a biological iron filtration system would require approximately 292 square feet at 2.5 MGD. This required surface area translates to approximately four 10-foot diameter vertical pressure filters or one 10-foot diameter horizontal pressure filter, similar to those operating at the existing WTP. Filter loading rates can be variable from site-to-site depending on water quality. Investigations into the in-situ biological treatment of the raw water are necessary to understand the maximum filter loading rates and runtimes. Tighe & Bond has been involved in the construction of all three biological iron filtration systems in New England. These filtration systems have all been designed at 6 gpm/sf and above, some have even operated at above 10 gpm/sf.

Unlike abiotic filtration systems, such as GreensandPlus™ filtration systems, biological iron filtration consists of living organisms which are highly sensitive to disinfection chemicals. Therefore, the current backwash scheme of using finished-chlorinated water flow from the distribution system would be detrimental to the biological iron filters. A new backwash storage tank would be required between the biological iron filters and the pre-oxidation chemical injection for the GreensandPlus™ filtration. This backwash storage tank would serve a similar purpose to the tank described under the previously recommended *L1 – Design and construction of a clearwell/backwash water supply tank at the WTP site*, however this tank could not be used for additional chlorine contact time.

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4.3 Recommended Treatment Upgrades

Tighe & Bond recommends the GWD conduct a pilot study to determine the potential for biological iron pre-treatment. If biological iron treatment is capable of removing iron to below the SMCL, it is possible to couple these treatment processes and allow for re-use of existing WTP infrastructure.

We believe these recommendations should be investigated prior to investing in a conventional clarification and filtration treatment process. We believe the existing WTP contains capital assets worth preserving and that construction of a completely new treatment process would represent a last resort for the GWD. It is our belief that a new building, adjacent to the existing WTP could provide for a raw water iron pre-treatment step prior to the existing Greensand filtration system.

4.3.1 Biological Treatment Upgrades

Biological iron pre-treatment would involve construction of a new WTP Building adjacent to the existing WTP, a new filtration system, extensive piping modifications, a new intermediate backwash supply clearwell and miscellaneous piping, HVAC and electrical systems. The biological iron pre-treatment system may also allow the GWD to restore the Backwash Reuse system, however, extensive testing should be done to confirm the amount of chlorine residual leached from the GreensandPlus™ filters into the backwash waste.

4.3.2 Existing WTP Upgrades

Installation of a biological iron pre-treatment system would involve improving and maintaining many of the assets currently housed in the West Street WTP. The recommended existing WTP modifications include: installation of a potassium permanganate educator system, a full media replacement (media to be determined) for the existing filtration system, rehabilitation of the existing backwash reuse system as well as miscellaneous building, site, SCADA and Instrumentation improvements as listed in Section 3.

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WTP CONCEPT SITE

LEGEND

- Gate Valve
- Water Main

LOCUS MAP



N

0 50 100

Feet

1:1,200

NOTES

1. Based on MassGIS Color Orthophotography (2013-2014)

WTP Modification
Concept Site Plan
7S West Street
Georgetown, Massachusetts

November 2019

Tighe&Bond
Engineers | Environmental Specialists

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