FINAL
Results of the
Flint Surface Water Treatment Plant Evaluation

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Prepared By
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For
Eastern Research Group, Inc. (ERG)
and
U.S. Environmental Protection Agency
Office of Civil Enforcement

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1 INTRODUCTION

Sleeping Giant Environmental Consultants, LLP (SGEC) was contracted to travel to Flint, Michigan, to assess the capacity of the Flint surface water treatment plant (FSWTP) to treat raw surface water from Lake Huron. The Lake Huron water will be supplied to the FSWTP by the Karegnondi Water Authority (KWA) and must be treated to meet the requirements of the Safe Drinking Water Act (SDWA) and National Primary Drinking Water Regulations (NPDWRs). Of primary concern is the plant's ability to achieve and maintain compliance with the surface water treatment rules while producing noncorrosive finished water.

Additionally, SGEC was asked to inspect two booster chlorination facilities, located at separate distribution storage and pumping stations, and report on their ability to ensure maintenance of an adequate free chlorine residual throughout the distribution system. This issue will be briefly discussed in the design section.

2 FSWTP EVALUATION PROTOCOL

When evaluating the FSWTP's capacity, SGEC focused on the relationships between four key areas critical to the success of surface water treatment plants. Those areas are:

- Design
- Operation
- Maintenance
- Administration

SGEC assessed each of these four areas in terms of its impact on the performance of the plant and its ability to provide safe and reliable drinking water. The objective was to produce a prioritized list of factors that might be hindering or preventing the plant from achieving compliance. Finally, SGEC was to provide recommendations intended to help Flint managers, operators, and maintenance personnel achieve long-term compliance.

3 FACILITY INFORMATION

The FSWTP is a conventional filtration facility that includes three-stage tapered flocculation, sedimentation using lamella plates, and dual media (granular activated carbon [GAC] over sand) filtration followed by disinfection using free chlorine, with contact time provided by a 3.0 million gallon (MG) clearwell. The FSWTP also has a system to inject ozone, if needed, for disinfection or oxidation. Fluoride can be injected for control of dental caries and orthophosphate for corrosion control. Softening facilities are available, but were not evaluated as it was predetermined that softening will not be needed when treating KWA water. The plant has two flumes that will be used for bypassing the softening clarifiers. Therefore, maintenance of the softening facilities will not be necessary. There has been discussion of making trial runs using Flint River as a source while wasting treated water back to the river. SGEC has assumed that, for purposes of trial runs, softening would not be employed.

Filter backwash is accomplished with a combination of air scour and water wash. The water for backwash is provided from the distribution system using distribution pressure. Spent filter backwash water and water that is filtered-to-waste can be recycled back to the head of the plant or discharged to the sanitary sewer.

4 DESIGN

4.1 Major Unit Process Evaluation

The purpose of the major unit process evaluation is to determine if the plant's major treatment processes (flocculation, sedimentation, filtration, and disinfection) have the appropriate size and configuration to treat the expected peak instantaneous flow while producing water that meets regulatory requirements. SGEC assumes that the peak instantaneous flow will be the flow rate necessary to produce the City of Flint's maximum daily demand. This will be the maximum flow rate to which the unit processes are subjected and the hydraulic condition under which the treatment processes are likely to be the most vulnerable to the passage of microorganisms and pathogens. If the treatment processes are adequate at the peak instantaneous flow, the plant should be capable of providing the necessary effective barriers at lower flow rates. Per the FSWTP operators and managers, the plant is hydraulically incapable of handling more than 24 million gallons per day (MGD). Fortunately, 24 MGD is estimated to exceed the City of Flint's maximum daily demand.

The major unit process evaluation does not include a detailed assessment of the condition of the facility's existing mechanical equipment and controls or the operational practices. SGEC assumes the mechanical equipment and controls can be repaired or replaced, minor improvements can be made, and process control procedures implemented to enable compliance over a shorter term and with expenditures that would be expected to be less than replacing unit processes. Performance limitations caused by mechanical equipment or operational practices, when identified by SGEC, are addressed as issues that may limit the plant's performance and are presented with recommendations for addressing them later in this report.

It is important to note that, when the plant is first put back in service, the City will continue to be served with treated water from Detroit. Water treated by the FSWTP will be dechlorinated and wasted back to the river. Currently, the plant's wastewater handling facilities are not adequate for simultaneously wasting filtered water and spent filter backwash water. Facilities for this purpose must be in place before plant startup. This work will take planning, engineering design, and will likely require review and permitting by the Michigan Department of Environmental Quality (MDEQ).

4.1.1 <u>Performance Potential Graph</u>

The major unit process evaluation was based on the FSWTP treating KWA raw water and the limited information provided to SGEC regarding the KWA raw water quality. Each of the major unit processes (flocculation, sedimentation, filtration, and disinfection) was assessed by comparing its rated treatment capability against the peak instantaneous flow the plant is capable of producing. The processes were evaluated individually and the ratings assume that all units are operating simultaneously (i.e., none are out of service). The capacities determined in this assessment may differ from those approved by the MDEQ, as some regulatory agencies rate facilities based on one or more units being out of service for maintenance. Results of the evaluation are shown as a Performance Potential Graph (Figure 1) in which the major unit processes are indicated by the labels on the left side of the graph (y-axis) and the capacity of each in MGD by the length of the bar (x-axis). The expected peak instantaneous flow is represented by the red dashed vertical line at 24 MGD.

Thus, the horizontal bars of the graph represent the projected capability of each unit process to produce finished water that meets regulatory requirements. The unit process capabilities were estimated based on each unit's physical size and configuration, SGEC's experience with similar processes, generally accepted industry and regulatory design standards, and, to a limited extent, the plant's past performance using a more challenging raw water source (the Flint River).

KWA raw water quality data were requested, but not made available to SGEC. However, it is reportedly lower in turbidity (1-5 nephelometric turbidity units [NTU]), significantly more stable, and lower in total organic carbon (TOC) than the Flint River source. Capacities of major unit processes are, to a large extent, determined by the quality of the raw water to be treated. Therefore, if the KWA water ultimately has high turbidity spikes and/or significant levels of total organic carbon, the FSWTP's capabilities would need to be reevaluated.

The shortest bar (sedimentation) likely represents the major unit process that potentially most limits the plant's compliance capability. However, sedimentation is unlikely to be a limiting factor unless the turbidity and/or TOC of the KWA water are much greater than expected.

As shown by the graph (and the criteria and assumptions listed below), the plant is judged to have the capacity to meet regulatory requirements. The criteria and assumptions used to assess each major unit process are outlined in the notes below the performance potential graph and described in more detail in the following text.

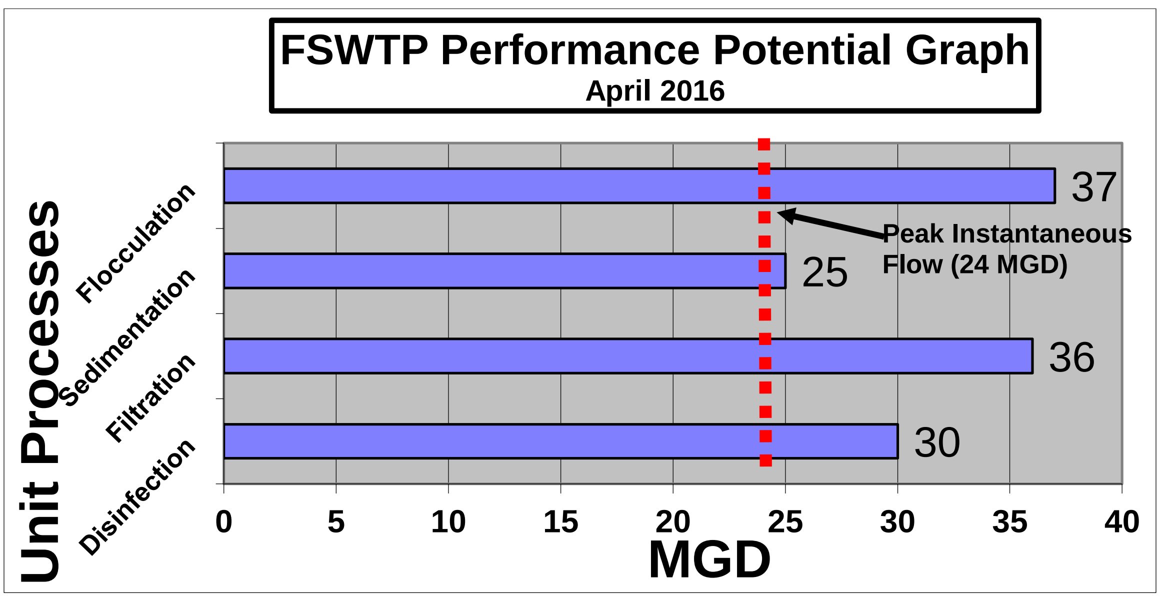

Figure 1 – FSWTP Performance Potential Graph

Assumptions:

1. *Flocculation*
   - *Rating based on ≥ 30 minutes of hydraulic detention time through three stages with variable speed mixers and temperatures as low as 0.5 °C*
2. *Sedimentation*
   - *Rating established at 4 gallons per minute per square foot (gpm/ft^2) of the projected horizontal area of the plates*
   - *Raw water with turbidity < 10 NTU and low TOC*

3. *Filtration*
   - *Rated at 3 gpm/ft² (if media were to be changed out to typical sand/anthracite dual media, SGEC would rate the filters at 4 gpm/ft²)*
4. *Disinfection*
   - *≥ 1.5 milligrams per liter (mg/L) free chlorine at the end of the contact time*
   - *pH ≤ 7.5*
   - *Water temperature ≥ 0.5 °C*
   - *Post filtration chlorination in 3 MG clearwell*
     - *Water level at low alarm (11 feet [ft])*
     - *Baffling factor of 0.28 (per MDEQ sanitary survey)*

4.1.2 Flocculation

Flocculation is accomplished in three stages; turbine mixers are used in each stage. The intensity of the mixing in each stage can be adjusted to control the type of floc formed and sent to the sedimentation basins. Assuming the need for 30 minutes of hydraulic detention time, the flocculators should be capable of operating satisfactorily at 37 MGD, or more than 150 percent of the peak instantaneous flow.

4.1.3 Sedimentation

The first removal barrier in the treatment plant is accomplished by sedimentation. The FSWTP's sedimentation is provided by three parallel basins. When treating Flint River water using ferric chloride at sufficient concentrations for enhanced coagulation, there were problems with sediment removal from the basins. Operators reported this problem was primarily a result of the inability to fully open sludge wasting valves. A larger air compressor has subsequently been installed, which operators confirmed solved the problem. Based on the limited information provided on the KWA water, raw water turbidities are expected to be lower and, because of the expected low TOC concentrations, enhanced coagulation should not be needed. Therefore, significantly less sludge will be produced and the sedimentation basins can be rated higher than they would be if the plan were to continue use of the Flint River.

Each basin contains four 71 ft long by 5 ft wide plate settler units, providing a total projected horizontal area of 4,260 square feet (ft²). At SGEC's rating of 4.0 gpm/ft², the sedimentation basins should be able to treat up to 25 MGD. The sedimentation basins will not limit the FSWTP's performance when treating KWA water.

4.1.4 Filtration

Filtration is the plant's final physical barrier to accomplish particle removal. Typical anthracite over sand dual media filters, with proper pre-treatment, should be capable of achieving compliance at surface loading rates of 4.0 gpm/ft² and sometimes as high as 6.0 gpm/ft². However, the original dual anthracite and sand media have been changed out and the filters now have 18 inches of GAC over 12 inches of sand. The GAC was installed to reduce disinfection byproduct precursors and its capacity is probably exhausted. The KWA water is expected to have very low levels of disinfection byproduct precursors, so reducing their level via GAC is not expected to be necessary. However, GAC can remove turbidity even when its adsorptive capacity has been exhausted.

SGEC was provided with some information on the GAC that indicates an effective size of 0.55-0.75 millimeters (mm) and a uniformity coefficient of 1.9. The original anthracite reportedly had an effective size of 1.0-1.2 mm and a uniformity coefficient of ≤ 1.6. Thus, the GAC is comprised of smaller particles with a wider range of sizes. This could result in fines at the filter surface causing shorter filter runs. However, the operators did not report any problems with short filter runs and, in fact, indicated that filter runs ranged from 24 to 50 hours. Ultimately, SGEC conservatively rated the filters at 3.0 gpm/ft^2 resulting in a filtration capacity of 36 MGD. It should be noted that the filters could meet the peak instantaneous flow of 24 MGD when operating at 2.0 gpm/ft^2 and, with change-out to sand and anthracite (typical of dual media filters), surface loading rates of 4.0 gpm/ft^2 and higher could be achieved. The filters are not expected to limit the FSWTP's performance.

The filters are backwashed with a combination of water and air scour, which is the standard of the industry for effective media cleaning and minimizing wasted water. The backwash water is provided through a single connection to the distribution system. The distribution pressure is reduced by a control valve and the backwash water flow rate is controlled by rate control valves at the filter. It was noted during the initial tour of the plant that there is no backflow protection on the backwash water feed line. This is a low risk cross-connection between the distribution system and unchlorinated filtered water.

4.1.5 Disinfection

Disinfection provides the final barrier against pathogens by inactivating microbial contaminants that escape the removal processes provided by sedimentation and filtration. The disinfection process was assessed based on the USEPA Surface Water Treatment Rule requirements for 3-log removal and/or inactivation of *Giardia* cysts, and 4-log removal and/or inactivation of viruses. The regulatory agency determines how much credit is to be granted for removal of cysts and viruses by sedimentation and filtration. The remainder of the requirements must then be met by disinfection. Adequacy of disinfection is determined by multiplying the disinfectant concentration (C) in mg/L by the time (T) in minutes that the water is in contact with the disinfectant. The product of this calculation is called "CT" and is measured in milligram▪minutes per liter (mg▪min/L). The level of CT required for inactivation of cysts and viruses is determined by the water temperature, pH, contact time in minutes, and the free chlorine residual at the end of the contact time.

The *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991 edition, points out that well-operated conventional treatment plants can be expected to achieve at least 2.5-log removal of *Giardia* cysts. Therefore, SGEC assumes that the FSWTP will receive credit for 2.5-log removal of *Giardia lamblia* cysts[2] and 2.0-log for viruses; the remaining 0.5-log for *Giardia lamblia* and 2.0-log for viruses must be achieved through inactivation by meeting specified CT requirements. When free chlorine is used as the disinfectant, the controlling factor is the requirement for inactivation of 0.5-log *Giardia* cysts because they are more difficult to inactivate than are viruses. Therefore, the FSWTP's disinfection capability is based on the CT requirements for inactivation of 0.5-log *Giardia lamblia* cysts.

For purposes of the FSWTP evaluation, near worst-case conditions were used to evaluate the FSWTP's disinfection capacity. First, it was assumed that the water pH would be no greater than 7.5. Second, the temperature was assumed to be 0.5 °C. Third, the free chlorine residual was assumed to be at least 1.5 mg/L after contact time in the 3.0 MG clearwell. Fourth, the water level in the clearwell was assumed to be at the low water alarm level of 11 ft. Finally, a baffling factor of 0.28 was used, based on a disinfectant tracer study discussed in a 2013 sanitary survey report. Under these

[2] Information on the log removal credit provided by MDEQ was not provided.

conditions, a CT of 46 mg▪min/L is needed to inactivate 0.5-log *Giardia lamblia.* Using these assumptions, the plant's disinfection capacity was determined to be 30 MGD using only post-filtration chlorination and giving no credit for use of ozone. Therefore, the FSWTP will not be limited by its disinfection capacity.

4.1.6 Ozone for Oxidation or Disinfection

The FSWTP has the capability to inject ozone into the raw water before any of the other treatment processes. Ozone can serve as a disinfectant and/or as an oxidant. It will not be needed to meet the surface water treatment rules' disinfection requirements, but it may prove to be helpful for taste and odor control or as an aid to the coagulation processes. Operators report that there have been operational problems with the ozone injection facilities, but that those problems have largely been solved by contracting with the manufacturer for ongoing technical assistance and maintenance.

4.1.7 Major Unit Process Evaluation Summary

As shown in Figure 1, SGEC's assessment is that the FSWTP's major unit processes will not limit the FSWTP from effectively treating the KWA water. The plant was originally constructed more than 50 years ago, but was originally well designed and has benefitted from recent upgrades.

4.2 Filter Evaluation

SGEC typically assesses the condition and placement of the media in filters to identify factors limiting performance of the filtration process. The presence of mudballs, surface cracking, depressions, mounds, or displaced media may often be attributed to excessive use of coagulant chemicals, inadequate backwashing, or more serious problems related to the underdrain system. The assessment typically includes a physical inspection of the filter bed and backwash practices. The FSWTP's filters are currently out of service so backwashing could not be observed. However, the operators drained several of the filters and SGEC probed, cored, excavated, and examined the condition and stratification of the sand and GAC. In the first five filters examined, the sand and GAC were found to be almost completely mixed from top to bottom. This was cause for concern as the sand and GAC should be re-stratified after each backwash. Another filter was found in which the sand and anthracite were properly stratified. It was eventually determined that, after the plant was shut down, many of the filters had air and sub-fluidization backwash water introduced, causing the mixing of sand and GAC.

In the filters known to have been in use, the surface of the GAC appeared to be reasonably level. This is significant because, more often than not, if a filter has serious underdrain problems, there are indications that can be seen by observing the filter's surface. The free board (distance between the top of the backwash water troughs and the surface of the GAC) was a little over 60 inches. Several of the filters were probed and the depth of the mixed GAC and sand averaged slightly less than 29 inches. In the stratified filter, the depth of GAC ranged from 14 to 17 inches and the sand depth ranged from 9 to 10 inches (plant specifications reportedly called for 18 inches of GAC over 12 inches of sand).

The media in the filters showed no signs of floc accumulation, compaction, cracking, or mud balls. The surface of the stratified filter did have evidence of fines; however, the effective size of the GAC is reportedly 0.55-0.75 mm, so this does not seem unusual. As noted above, the smaller media size may lead to shorter filter runs.

Because the plant is not in operation, SGEC was not able to observe the backwashing procedures. The typical backwash procedure was reported to be as follows:

1. The effluent valve is closed, waste valve opened, and the water level drops to the level of the backwash water troughs.
2. Air and water backwash is started, with the water flow rate increased from zero to 2,000 gpm (2.9 gpm/ft^2) over 90 seconds.
3. The water flow is increased from 2,000 gpm to 6,300 gpm (9 gpm/ft^2) over the next 60 seconds.
4. Simultaneous air/water backwash occurs for 480 seconds.
5. Air is turned off and the water flow is ramped from 6,300 gpm to 9,800 gpm (14 gpm/ft^2) over 120 seconds.
6. Water backwash at 9,800 gpm occurs for 150 seconds to flush the dislodged material and stratify the sand and GAC.
7. The flow rate is ramped down to zero over 180 seconds.
8. The filter is started slowly and filter-to-waste occurs until the effluent is acceptable before being placed back in service.

The FSWTP's backwash procedure is not typical of filters using air scour and could result in use of excess backwash water and media loss. However, the backwash troughs are fitted with tube settler devices that are designed to limit the loss of GAC when simultaneous air scour/water backwash occurs during overflow of spent filter backwash water. SGEC has no experience with the backwash trough tube settler devices, but they appear to be effective as very little GAC has been lost.

4.3 Corrosion Control

The FSWTP has the equipment necessary for injecting orthophosphate and is currently boosting the phosphate levels in the treated water the plant receives. The orthophosphate injection facilities, when moved to the appropriate site, will be capable of providing the treatment necessary for KWA water.

It is likely that the finished water pH may have to be increased to ensure that the orthophosphate is effective for corrosion control. Therefore, storage and pumping facilities will have to be provided to introduce the appropriate chemical(s). These facilities will need to include redundancy, safety provisions, storage, and secondary containment.

4.4 Distribution Storage and Booster Chlorination

SGEC was asked to inspect booster chlorination installations at two distribution storage and pumping facilities. These booster chlorination stations have been put online in an effort to obtain free chlorine residuals throughout problem areas in the distribution system. SGEC's understanding is that water from the distribution system is injected with chlorine during the night when the two large reservoirs are being filled from the distribution system. During the day, pumps take suction from the reservoirs and boost the distribution system's pressure and chlorine residual. This is not an ideal arrangement. A more typical arrangement would be for chlorine to be injected in a water main serving an isolated portion of the distribution system that, due to water age and/or residual losses in storage, experiences low residuals. In such a situation, the injection of chlorine can be adjusted based on actual in-pipe residuals and flows, and the downstream residual more accurately controlled.

In the current Flint booster chlorination arrangement, there seems to be little control over where the inflow to the tank is coming from or where the outflow is going. Therefore, control over distribution residuals is unreliable and, aside from strategic flushing, there is no certainty that the chlorinated water is directed to the areas where it is needed most. Over the short term, this kind of booster chlorination coupled with strategic flushing should be reasonably effective and helpful in providing chlorinated water throughout the distribution system. Over the long term, the hydraulics of the distribution system should be assessed and, assuming booster chlorination is necessary, improvements made to target the areas of low free chlorine residual. Additionally, the volume of the two distribution storage reservoirs may be greater than what is needed or desirable for the current population. Since chlorine residuals are lost in storage and disinfection byproducts are produced, the system's storage needs should be evaluated.

5 OPERATION

The assessment of the operation of the FSWTP was based primarily on interviews with staff from all disciplines (i.e., operations, maintenance, laboratory, and management) since the plant was not operating at the time of the evaluation. Data from when the plant was operating and treating Flint River water were also reviewed and show that the plant is capable of meeting the turbidity standards of the US EPA Surface Water Treatment Rules, even when using the Flint River as a raw water source. This supports SGEC's conclusions regarding the adequacy of the FSWTP's major unit processes for treatment of KWA water, as discussed above.

The fact that the plant was not operational during the evaluation limited SGEC's ability to determine the capability of the plant and the operators to respond to unexpected events, such as equipment failure or rapid changes in raw water quality.

Several employees from the FSWTP operation and maintenance staff were interviewed, and they provided consistent information in those interviews. Conclusions drawn by SGEC based on the information they provided are as follows:

- Aside from compliance with the regulatory requirements, management has not established and communicated measureable goals and objectives for finished water quality.
- The operational staff has the ability and expertise to conduct tests of various water quality parameters. When the FSWTP was operating, the operational staff measured coagulant dose, pH, temperature, chlorine residuals, etc., but often without an understanding of the purpose. Further, the goals of the testing were often moving targets, with no explanation of the reasons for the day-to-day changes.
- As one would expect with a staff that has limited experience with surface water treatment, there is an apparent lack of understanding of water treatment concepts and how those concepts can apply to controlling treatment processes in ways that ensure high quality finished water. The lack of experience, expertise, and confidence was not problematic when the FSWTP was "tested" periodically with the treated water wasted back to the river. It became a substantial issue when the decision was made to use the Flint River as the City's raw water source and operate the FSWTP full-time. The staff was unprepared and ill-equipped to make this major transition.

- There are few, if any, written standard operating procedures available for staff to follow in order to ensure consistent and appropriate operation of the FSWTP.
- Lack of communication between staff and management, as well as among operations/maintenance personnel, is a significant problem.
- There is a lack of process control equipment available for use by the operators. Such equipment is necessary to make the rapid decisions required when reacting to changing raw water conditions (e.g., raw water turbidimeter, online streaming current monitors, bench top streaming current meter, zeta meter). Essentially, the only equipment available for making coagulation control adjustments is a jar test apparatus. Few, if any, operators know how to use the jar test apparatus properly, calibrate it to the plant's processes, interpret the results, or scale them up to full plant scale.
- Some equipment and instrumentation, including the supervisory control and data acquisition system (SCADA), are in need of repair, upgrade, or replacement. (See maintenance section, below.)

6 MAINTENANCE

The plant is old, but its major components are in good condition due to significant upgrades over the past several years. Equipment needed for operation of the system when using treated Detroit water has generally been well maintained, while other facilities and equipment used only when treating raw surface water have been neglected.

During interviews of the plant operations and maintenance staff, several conclusions could be drawn.

- There is no asset management system available.
  - There is no inventory of the equipment.
  - There is no inventory of the operational status of the equipment or condition.
  - There is no understanding and/or documentation of the remaining useful life of the equipment.
  - There is no estimate of the value of the equipment or the costs of replacement.
- Staffing is inadequate for water treatment plant maintenance needs, and additional staff are also required for maintenance of facilities that are not essential for water quality.
- There is no preventive maintenance program. The maintenance is done primarily on a "crisis" basis.
- The SCADA system is incomplete and portions of the existing system do not work properly. There has been little explanation/communication as to when and how these problems will be corrected. The operators feel they have little input into the priorities for repair of, or the design of, the SCADA system.
- There is no inventory of critical spare parts, and purchasing policy has limited the acquisition of an appropriate inventory of parts.
- There is no formal work order program to prioritize, track, and evaluate the effectiveness of maintenance tasks.

- In the view of the plant staff, the purchasing policy is cumbersome, lengthy, and with little feedback/communication regarding time delays.

7 ADMINISTRATION

A final component of the FSWTP evaluation is assessment of the impact on the plant of the FSWTP's administration. This is critical because without proper support from management, compliance is difficult. Support often involves the adoption of appropriate goals for finished water quality, followed by financial and administrative support, and tracking of progress to ensure that goals are being met.

Once again, evaluation of the management of the FSWTP is difficult because most of the current managers are new in their positions and have little first-hand knowledge of past management practices. SGEC was able to interview Flint's new city administrator, chief financial officer/budget director, and utilities supervisor. Those interviews indicated that management is more than willing to take all steps necessary to ensure support for the FSWTP and its staff. The interviews also made it clear that support is likely to be limited by available finances.[3] Thus, the best efforts of staff and management may not be good enough in the absence of adequate funds to cover essential staff, staff training, equipment, chemicals, monitoring, and plant upgrades.

In view of the unusual situation regarding management, SGEC had to draw conclusions based largely on in-plant interviews with FSWTP personnel. The most significant items of concern raised during the interviews were:

- Insufficient funding to meet plant needs resulting in:
  - Rejection of expenditure requests with no feedback from City Hall.
  - Extended lag times between requests for expenditures and their approval (for requests large enough to require City Council approval).
- Lack of communication both up and down the organization. Staff members felt that they received very little information from management, and believed that management had little interest in receiving input from staff.
- Management has not established clearly defined and measurable goals and objectives for the quality of treated water or water in the distribution system.

8 RECOMMENDATIONS

SGEC's main focus was to assess the capacity of the FSWTP to treat raw KWA water to meet the requirements of the SDWA and NPDWRs. Of primary concern was the plant's ability to achieve and maintain compliance with the surface water treatment rules while producing finished water that would not cause violations of the Lead and Copper Rule. SGEC was also to inspect two booster chlorination facilities and report on their ability to ensure maintenance of free chlorine residuals throughout localized areas of the distribution system.

SGEC's evaluations were complicated by the plant being out of service, a lack of information on the quality of the expected raw water to be treated, lack of financial

[3] Budget summary information was requested, but not provided.

information, the inability to interview the person who was responsible for process control decisions when the plant was in operation, and a lack of information on the distribution system. Given these limitations, various issues that have potential impacts on compliance have been identified. Those issues are presented in this section, followed by SGEC's recommendations for addressing them. The issues and recommendations are organized in the same manner as the body of the report. That is:

- Design (including distribution storage, pumping, and booster chlorination)
- Operations
- Maintenance
- Administration

The issues and recommendations are classified on two levels of priority. Priority 1 items are those that SGEC considers must be addressed to ensure that compliance is achieved. Priority 2 items are those SGEC considers important, but not necessarily essential to achieve compliance. Further, SGEC assumes that the City of Flint will identify and contract with engineering firms with the expertise needed to address the complex issues facing the system.

8.1 Design Issues and Recommendations

Priority 1 – Injection of Chemicals
Issue: Plant operators need maximum flexibility for introduction of chemicals that may prove to be essential for producing high quality drinking water that meets surface water treatment rules' requirements and that will not cause violations of the Lead and Copper Rule. The plant is well designed and pumping facilities, piping, and injection points are in place to perform the activities recommended below. A few new injection points may need to be tapped and existing facilities will need to be tested to ensure the injection points function appropriately.

Recommendation: The City's consulting engineering firm should determine the plant's capabilities to introduce chemicals appropriate for treating surface water and control of corrosion.

Provisions should be made to inject at least three chemicals ahead of the rapid mix units (chlorine, coagulant, coagulant aid), one after rapid mix (flocculant aid), two at the effluent from the sedimentation basins (chlorine, filter aid), two post-filter pre-contact basin (chlorine, plus an optional chemical) and three at high service pumping (chlorine, corrosion control chemical, pH adjustment chemical). All feed pumps and all delivery piping should be extensively tested before plant startup.

Priority 1 – Instrumentation
Issue: Operators do not have, but need, instrumentation that will enable them to quickly react to changes in raw water quality. Instrumentation should include online streaming current meters (SCM) and a bench top SCM or a zeta meter.

Recommendation: Each treatment train must be equipped with an online SCM, and a spare SCM should be on site to provide appropriate redundancy. The ongoing SCADA improvements should enable the operators, at their discretion, to allow automatic adjustment of coagulant or coagulant aid based on SCM readings. Purchase of a bench top streaming current meter and/or a zeta meter should be considered.

Online turbidimeters should be provided for raw water and the effluent for each sedimentation basin.

Priority 1 – Filter Media
Issue: The original filter media have recently been changed out, but SGEC was not able to determine the precise specifications of the sand or GAC that were installed. The specifications are important for determining if the new media are appropriate for treatment of KWA water, for estimating appropriate filtration rates and filter run times, and for determining appropriate backwash techniques.

Recommendation: Engineers with extensive knowledge of high rate granular dual media filters are needed to obtain representative samples of the sand and GAC for sieve analysis and testing for calcium carbonate buildup. This information should be used to determine if the media are suitable for the intended purposes (assuming adsorption of organic compounds will not be necessary).

Priority 1 – pH Adjustment
Issue: The plant needs to be able to raise the pH after disinfection contact time has occurred in the 3.0 MG clearwell. This is expected to be necessary to ensure maintenance of the distribution pH in a range appropriate for corrosion control using orthophosphate.

Recommendation: The City's consulting engineering firm should determine the most desirable and cost effective method of pH control. Provisions for pH control should be designed, constructed, and tested before plant startup. The design must meet MDEQ standards and include provisions for safety, redundancy, climate control (if necessary), storage, and secondary containment.

Priority 1 – Disposal and Handling of Spent Filter Backwash Water
Issue: As the plant now exists, water can be produced, dechlorinated, and wasted, or a filter can be backwashed, with spent filter backwash water being directed to recycle facilities or the sanitary sewer. However, producing finished water and backwashing a filter cannot be done simultaneously without discharging to the river and potentially violating the Clean Water Act. During plant trials and startup with either Flint River or KWA water, the plant will have to be able to produce water at the same time a filter is being backwashed. Facilities will need to be provided to accommodate these needs, but it is likely that the facilities can be temporary and above grade.

Recommendation: The City's consultant should evaluate the existing wastewater piping and pumping facilities to determine what improvements and modifications are needed to accommodate normal plant operations. The needed improvements should be designed, submitted for review and approval by the MDEQ, and constructed.

Priority 2 – Disinfection
Issue: Gas chlorination reduces the pH of water and may expose operators and the surrounding area to safety and health risks associated with spills and leaks.

Recommendation: The City's consultant should do an analysis to determine the optimal chlorination method, considering safety, ongoing and capital costs, and impacts on corrosion control. Consideration should include gas chlorine, purchase and injection of sodium hypochlorite solution in bulk, and onsite generation of sodium hypochlorite solution or mixed oxidants.

Before plant startup, provisions for the selected technology should be designed, submitted to MDEQ for review and permitting, and constructed. The facilities should meet all requirements of the current edition of *Recommended Standards for Water Works* and the MDEQ design standards.

Finished water chlorination facilities should be physically separated from pre-filtration injection points to avoid cross-connections. The existing gas chlorination facilities should be closely inspected to make sure there are no cross-connections. SGEC's inspection during a walk-through of the plant raised concerns about such a cross-connection.

Priority 2 – Intake Improvements
Issue: The Flint River Intake likely needs to have minor repairs and/or improvements completed if it is going to be used as a source of water for startup training and/or as a long-term backup source. SGEC considers it a logical candidate for both purposes.

Recommendation: The City's consulting engineer should evaluate the intake to determine necessary improvements. The evaluation should address operator safety, repair of the intake, improved access to the bar screens, and site security.

Priority 2 – Low Service Pumping
Issue: Efficient low service pumping is essential if the Flint River is to be used as a source of water for startup training and/or as a long-term back-up source.

Recommendation: The City's consulting engineer should evaluate the condition and adequacy of low service pumping. Variable frequency drives should be considered for better flow control.

Priority 2 – Ozone System
Issue: Operation of the ozone system has reportedly been plagued with problems. SGEC was informed that many of the problems were caused by inappropriate programming by a contract maintenance provider and that those problems have been, to a large extent, solved by a new contract with the equipment manufacturer. Nevertheless, this is an issue that should be looked into prior to startup of the treatment plant.

Recommendation: The City's consulting engineer should evaluate the condition of the ozonation facilities. Repairs and/or replacements should be made as necessary.

Priority 2 – Potential Cross-connection
Issue: The filters are backwashed by water from the distribution system. There is no backflow prevention assembly on the backwash water line. This creates a potential cross-connection between the filtered, but undisinfected, water and the distribution system.

Recommendation: MDEQ should be contacted to determine how best to eliminate the cross-connection and protect the distribution system.

Distribution storage, booster pumping, and booster chlorination

Priority 1 – Booster Chlorination and Distribution Pressure
Issue: Booster chlorination has been implemented at two distribution storage and pumping facilities. The storage reservoirs are filled during the night when demand is low.

Chlorine is injected into the fill line during this time. During the day, booster pumps send the chlorinated water into the distribution system to boost pressures and increase chorine residual. Automated flushing valves are used to flush aged water and improve chlorine residuals throughout the distribution system. This has been fairly effective in improving chlorine residuals where none previously existed. However, it is not the ideal method for booster chlorination.

Recommendation: When the hydraulic analysis of the distribution system is completed, alternatives for more direct targeting of areas lacking chlorine residual should be investigated by the City's consulting engineers. Such alternatives could include:

- Manipulation of distribution valves to increase turnover and reduce water age in problem areas.
- Determination of how much distribution storage is actually needed and, if appropriate, installation of divider walls in the large reservoirs to reduce storage and residence times.
- Installation of mixing devices in the distribution storage reservoirs.
- Installation of small, strategically located booster chlorination and pumping facilities appropriate for long-term operation.
- Determination if, and to what extent, booster pumping is necessary. If it is necessary, determine if there are more effective and efficient methods than those now in place.
    - Smaller and/or variable frequency drive pumping facilities may have the potential to provide adequate pressure to problem areas while reducing energy costs, water use, and main breaks.

Priority 2 – Booster Chlorination Facilities
Issue: Are the calcium hypochlorination facilities appropriate for use in the distribution system?

Recommendation: In SGEC's experience, calcium hypochlorite pellet disinfection systems are more typically used in dry, hot areas where humidity does not impact the calcium hypochlorite pellets and where high summertime temperatures cause significant off-gassing of chlorine from liquid sodium hypochlorite. Assuming they are closely monitored by SCADA and daily visits, the two installations are likely to be adequate for the short-term emergency chlorination now being practiced. If they prove to be unreliable or take too much operator time, liquid sodium hypochlorite should be considered.

If it is determined that booster chlorination will be needed over the long term, the City's consulting engineers should evaluate where, how, and with what facilities chlorination should be accomplished. Those facilities should be designed, reviewed and permitted by MDEQ, and then installed.

8.2 Operation Issues and Recommendations

Priority 1 – Operator Qualifications
Issue: Operators are deficient in experience and expertise regarding the concepts of coagulation control and surface water treatment when using a conventional high rate granular media filtration plant.

Recommendation: Management should ensure that operators have comprehensive training in surface water treatment and the application of surface water treatment concepts for successful operation of the FSWTP. Training should include:

- Regulations regarding surface water treatment.
- Coagulation theory and control.
- Filtration concepts.
- Filter maintenance and operation.
    - Filtration concepts.
    - The filter cycle.
    - Management of filter flow rates.
    - Backwashing procedures when using air scour (backwash management and optimization).
    - Filter monitoring and use of data.
- Use of "special studies" to assess alternatives.

There are several sources of training available, including, but not limited to: MDEQ, Michigan-American Water Works Association (MI-AWWA), Michigan State University, and Lansing Community College.

Priority 1 – Acquisition of Appropriate Expertise
Issue: The FSWTP staff has gaps in expertise and in numbers. Experienced operators well versed in surface water treatment need to be recruited and hired. Reportedly, additional staff will be hired, but the new personnel will be operator trainees with little or no experience. Operating a granular media surface water treatment plant is complex and challenging; mistakes can have a huge impact on public health.

Recommendation: The City needs to evaluate how to obtain, train, and retain experienced water treatment operators. It may be difficult to find new employees that have the combination of training and experience necessary to ensure protection of public health. If such employees cannot be hired, the City should look into obtaining expertise on a contractual basis for the short term, and possibly for the long term. Qualified and experienced personnel need to be available and, preferably on site at all times if the plant is to operate around the clock.

Priority 1 – Standard Operating Procedures
Issue: There are few written standard operating procedures (SOPs) at the FSWTP. SOPs are necessary to ensure consistent and efficient operation and maintenance.

Recommendation: Before plant startup, operators should be required to work in teams with experienced personnel, in-house or third party, to develop SOPs including:

- Process monitoring (applicable processes) – establishment of goals and objectives, measurement of goals and objectives, establishment of procedures for modifying goals and objectives, development of a process monitoring plan inclusive of raw water to predict water quality changes, etc.
- Management of corrosion control processes, including monitoring of appropriate parameters, making adjustments based on monitoring, and maintenance of equipment.
- Coagulation control.

  - Jar testing, use of streaming current meters, desk top analyzers, and application of results to plant operations.
  - Charting of coagulant use to develop a historic data base.
  - Evaluating alternative chemicals.
- Control of flocculators.
- Control of the sedimentation process.
  - Equalization of flow.
  - Sludge removal.
- Control of the filtration process.
  - Surface loading rate control.
  - Management of filters to avoid flow surges and turbidity spikes.
  - Filter backwashing procedures.
  - Development and use of filter turbidity profiles.
  - Management of spent filter backwash water recycle.
- Disinfection.
  - Managing time water is in contact with disinfectant at different concentrations (CT).
  - Calculating and reporting disinfectant concentration (C).
- Calibration of chemical feed pumps.
- Calibration of other instruments (flow measuring devices, level indicators, etc.).
- Online instrumentation maintenance and calibration, including data verification procedures.
- Making chemical feed rate adjustments using SCADA with followup verification.
- Laboratory procedures (collection of samples, analysis of samples, certification requirements for the analysis).
- Data management (SCADA security, records retention, report preparation, trend analysis, report generation).
- Safety procedures (use personal protective equipment, confined space entry and location, chemical handling, spill cleanup).
- Emergency response procedures.

The number and range of useful SOPs are very large and will continue to expand. A procedure for reviewing, maintaining, and updating SOPs should be created.

Priority 1 – SCADA
Issue: The SCADA system is being expanded and modified. Some functions of the existing SCADA system, months after development, are still inoperable. No explanation for these failures, nor any indication of when repairs will be made, have been provided to the operators. Further, operators feel they have little input or control over development.

Recommendation: The existing SCADA system should be made fully functional prior to development of new modules. A point-by-point check of all SCADA functions needs to be completed. Operators should be involved in planning the design to ensure that the final product meets their needs. The SCADA system needs to be evaluated so all critical equipment and parameters are properly monitored and alarmed to provide all necessary safeguards. The SCADA system needs to have its security levels established and data access controlled.

Priority 2 – Professional Development

Issue: Operations and maintenance staff have not had adequate opportunities to network with other professionals or to take advantage of useful publications.

Recommendation: The City needs to encourage and fund staff participation in professional organizations such as the state section of the AWWA and the Water Research Foundation (WRF). Networking with other professionals will have a positive influence on staff. AWWA, WRF, and similar organizations produce many materials (e.g., cross-connection control safety, coagulation control, filter operation and maintenance) essential for operation and maintenance of the treatment plant, distribution system, and storage facilities. The development of an area-wide cooperative of systems treating Lake Huron water could provide a forum for exchanging and sharing knowledge and resources.

Priority 2 – Dam Operation
Issue: The operators are required to manage the operation of the dams. The management of the dams requires the most effort during climatic events, when changes in raw water quality are most likely. During these times, the operators should be focused on the water treatment process.

Recommendation: The operation and maintenance of the dams should be transferred to another department that does not have the public health responsibilities of operating the water treatment plant.

8.3 Maintenance Issues and Recommendations

Priority 1 – Asset Management
Issue: There is no asset management system available.

Recommendation: An asset management system should be developed that addresses, but is not limited to:

- An inventory of assets, including condition, operational status, useful life, value for replacement, incorporation into the capital improvement plan, etc.
- Spare parts inventory and assessment of the need for parts.

Priority 1 – Staff Number
Issue: Having only two maintenance staff available for the FSWTP is inadequate to meet the maintenance needs.

Recommendation: Additional staff must be hired and trained. Some of those hired should include personnel experienced in large scale mechanical facilities, have technical aptitudes, and can come on board with limited additional training.

Priority 1 – Preventive and Corrective Maintenance
Issue: There is no formal preventive and corrective maintenance program. Maintenance priorities appear to be established by crisis.

Recommendation: A computer-based preventive and corrective maintenance program should be developed and put in place. The program should prioritize and track work orders and evaluate the effectiveness of maintenance activities. There was reference to a working program being used at the wastewater treatment plant, but the evaluation team did not confirm that.

8.4 Administration Issues and Recommendations

Priority 1 – Goals and Objectives
Issue: The city's management has not formally adopted measurable and achievable goals and objectives for treated water and water throughout the distribution system.

Recommendation: The city council needs to formally adopt water quality goals for the water treatment plant and distribution system. The goals and objectives need to be clearly communicated to staff and adequate resources and follow up need to be provided.

Priority 1 – Funding
Issue: Funding appears to be inadequate to provide the staffing, equipment, monitoring, training, and other necessities for ensuring safe drinking water.

Recommendation: Funding must be sought and obtained. Without adequate funding, proper operation of the FSWTP would be very problematic and compliance questionable. The City needs to develop one-year, five-year, and twenty-year financial plans.

Priority 1 – Purchasing Procedures
Issue: Delays in receiving approval for purchase of essential equipment create serious inefficiencies in plant operations, management, and planning. For example, development of a new SCADA system is reportedly stalled due to lack of approval for a change order. While there may be good reasons for the delay, those reasons have not been communicated to staff and this leads to unnecessary frustration and discontent.

Recommendation: The City needs to develop a purchasing process that allows for rapid approval of equipment necessary for the efficient operation of the water treatment, storage, and distribution system. When funds are not available, or other unavoidable problems prevent quick turn-arounds, the reasons for delays should be communicated to FSWTP personnel to avoid unnecessary frustration and inefficiencies in workload planning (see recommendations regarding communication).

Priority 1 – Communication
Issue: A common theme of the interviews was lack of communication between staff and management, as well as among operations and maintenance staff. Further, communication between staff members is poor, which may be causing a lack of teamwork.

Recommendation: Management needs to develop lines of communication and methods of communication. Staff members should be kept informed of progress toward established goals and objectives and staff input should be sought when appropriate. Mid- and lower-level managers and supervisors should receive training in personnel management and supervision.

Priority 2 – Management's Familiarity with Plant Needs
Issue: In the past, it appears as if City management was not fully aware of the problems and needs of the FSWTP.

Recommendation: City managers (administrators and council members) need to become better educated regarding the operation, condition, and needs of the water treatment, distribution, and storage facilities. A better understanding of these facilities will enable managers to prioritize needs and make better decisions.

Priority 2 – Personnel Management
Issue: There appears to be a lack of personnel management, resulting in inadequate allocation of manpower and excessive overtime.

Recommendation: Management needs to evaluate the status of the existing and future staff and allocate those resources in a balanced manner directly related to where manpower is most needed. The operator shifts seem to be very awkward and alternative shifts should be evaluated.

An employee evaluation program should be implemented, with established evaluation criteria and definitive goals and objectives for each employee. If the provisional employee policy is retained, the requirement to meet the qualifications of the job description within a specified time needs to be enforced. The use of overtime, though not popular, needs to be controlled.