Results of the
Comprehensive Performance Evaluation of
Purdue Water Treatment Plant
Eastsound Water Users Association

286 Enchanted Forest Road
Eastsound, WA 98245

September 11-13, 2017

Prepared by:
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For

The Washington Department of Health

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Date of Site Visit:

September 11-13, 2017

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ABBEVIATIONS AND ACRONYMS

CFE	combined filter effluent
CPE	Comprehensive Performance Evaluation
CTA	Comprehensive Technical Assistance
CT	residual disinfectant concentration (mg/L) x time (minutes)
EWUA	Eastsound Water Users Association
EPA	United States Environmental Protection Agency
gpm/ft^2	gallons per minute per square foot
gpm	gallons per minute
hp	horsepower
IFE	individual filter effluent
MGD	million gallons per day
mg/L	milligrams per liter
mg▪min/L	milligram▪minutes per liter
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity units
PBT	performance based training
PWTP	Purdue Water Treatment Plant
PWS	public water system
SCADA	supervisory control and data acquisition
SCM	streaming current monitor
SOP	standard operating procedure
SLR	surface loading rate
SOR	surface overflow rate
SWTR	Surface Water Treatment Rule
TA	technical assistance
THDT	theoretical hydraulic detention time
TOC	total organic carbon
TOP	Treatment Optimization Program
WA DOH	Washington Department of Health
WTP	water treatment plant

INTRODUCTION

Both federal and state performance standards for filtered water turbidity have become more rigorous over the past several years in an ongoing effort to provide higher levels of public health protection against pathogens. Improved particle removal, measured as filtered water turbidity in nephelometric turbidity units (NTU), is particularly important to protect against pathogens that are resistant to disinfectants such as the cysts of *Giardia* and *Cryptosporidium*. This is true because turbidity serves as a surrogate for measuring the removal of pathogenic organisms. Achieving these performance standards can be difficult for many surface water treatment plants unless they implement new and improved procedures to ensure high quality filtered water. Consequently, the Washington Department of Health (WA DOH) is providing proactive technical assistance to enable Washington's surface water treatment plants to produce water significantly better than required by state and federal rules.

One of the WA DOH efforts is to provide Comprehensive Performance Evaluations (CPE) to identify factors that may limit plant performance. CPEs were developed by the United States Environmental Protection Agency (EPA) and have been adopted as a technical assistance tool by the WA DOH. The purpose of the CPE is to assist surface water treatment plants in their efforts to "optimize" plant performance and in so doing, exceed federal and state turbidity standards. Specifically, regarding turbidity, the goal of WA DOH is for surface water treatment plants to produce filtered water with a turbidity of less than 0.10 NTU from each individual filter's effluent (IFE) as opposed to the regulatory requirement of less than 0.30 NTU in the combined filter effluent (CFE). Research has shown that reducing the turbidity of filtered surface water to less than 0.10 NTU eliminates nearly 100 percent of disinfection resistant cysts that can cause waterborne diseases. Optimizing surface water treatment plant performance makes good sense in terms of public health protection.

The CPE of the Eastsound Water Users Association's (EWUA) Purdue Water Treatment Plant (PWTP) was conducted as a part of WA DOH's technical assistance program. It was conducted for technical assistance purposes and not in response to any known or anticipated compliance problems. Additionally, the CPE evaluated the plant's performance against the WA DOH optimization goals as outlined in Figure 2 and which are more stringent and protective of public health than existing regulatory requirements.

EVALUATION PROTOCOL

The CPE is the first part of a program developed by the EPA and called the Composite Correction Program (CCP). The CCP consists of two components. The first component is the CPE, which is an evaluation of the existing treatment plant. It consists of a systematic, comprehensive procedure to identify the unique combination of factors that limit performance of the treatment plant. The second component is Comprehensive Technical Assistance (CTA), which is a facilitated procedure to address performance limiting factors identified in the CPE and improve performance of the plant.

The CPE focuses on the fundamental relationships between four key areas critical to the success of surface water treatment plants. Those areas are:

- Plant design
- Plant operation

- Plant maintenance
- Plant administration

During the CPE, each of these four areas is assessed in terms of its impact on the performance of the plant and its ability to provide safe and reliable drinking water. The objective of the CPE is to produce a prioritized list of factors preventing the plant from achieving optimized performance. This list is then provided to, and discussed with, the plant staff and administrators at the close of the CPE. Once performance limiting factors are identified, the plant staff can often take steps to address each without further assistance from the WA DOH or consultants. In the case of factors that are difficult to address, Sleeping Giant Environmental Consultants, LLP (SGEC) may recommend technical assistance facilitated by the WA DOH or a third party. Each CPE report from SGEC briefly discusses whether technical assistance is advisable for the surface water treatment plant.

The CCP was originally developed to ensure surface water treatment plants' compliance with the requirements of the Surface Water Treatment Rule. However, over the past 25 years, it has gained prominence as a mechanism that can be used to improve the performance of surface water treatment plants, resulting in production of treated water of significantly higher quality, and thus safer, than required by state and federal rules. Improving surface water treatment plant performance to improve the physical removal of particles and inactivation of pathogens is now an important and effective strategy to protect against pathogenic microorganisms.

WA DOH Treatment Optimization Program (TOP) Goals

Outbreaks of waterborne diseases during the 1970s, 1980s and 1990s caused concern among public health professionals and water purveyors. The concerns were triggered by outbreaks caused by pathogenic organisms shown to be resistant to disinfection by chlorination. These diseases were primarily giardiasis and cryptosporidiosis. Cysts that caused these two diseases are commonly found in untreated, or inadequately treated, surface waters.

While EPA was developing its CCP protocol during the 1990s, various research projects were underway at universities across the nation to determine how effective granular media filtration could be at removing cysts of *Giardia* and *Cryptosporidium*. The parallel efforts of EPA developing the CCP and university researchers investigating turbidity measurement as a surrogate for cyst removal led to significant and promising conclusions:

- EPA's work with surface water treatment plants across the nation showed that granular media filtration is capable of consistently achieving filtered water turbidity levels less than 0.10 NTU.
- In the majority of surface water treatment plants, filtered water turbidity levels of less than 0.10 NTU can be consistently achieved <u>without major capital improvements to the plant</u>. Often, changes made to improve water quality also improve treatment efficiency and reduce energy and chemical costs.
- Researchers' findings in their work with *Giardia* and *Cryptosporidium* cysts showed that, at filtered water turbidity levels less than 0.10 NTU, cyst removal can approach 100 percent.

Figure 1 was developed using the results of one such study and shows the relationship between filter effluent turbidity measurements and *Giardia* cyst removal efficiency. At effluent turbidity levels of 0.3 NTU (i.e., the regulatory requirement for combined filter effluent turbidity) more than 95 percent of the cysts were removed. However, since cysts often occur in high concentrations (i.e., millions), 95 percent removal could potentially leave the filtered water with significant numbers of viable pathogens. As noted above, this is of concern because cysts are resistant to normal disinfection processes. The promising and more relevant portion of the graph shows that the cyst removal curve approaches 100 percent when turbidity measurements are less than 0.10 NTU.[1] These results indicate that higher levels of public health protection are achievable.

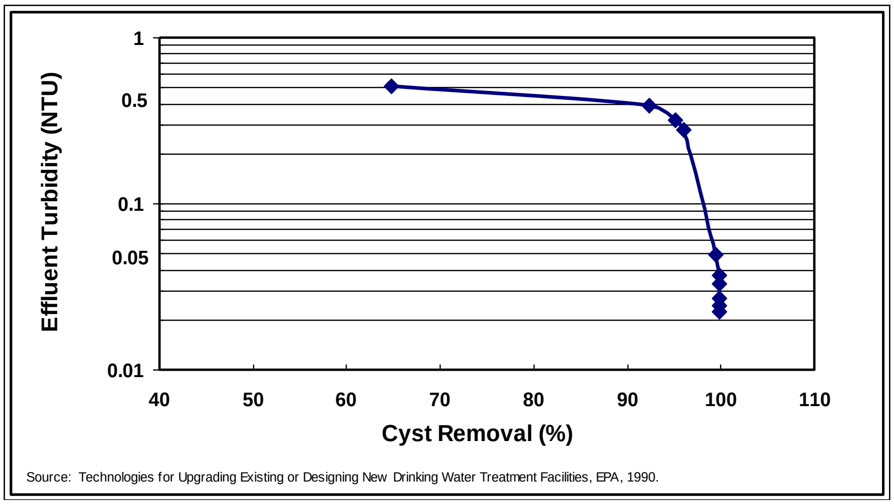

Figure 1 – Percent Cyst Removal vs. Filtered Water Turbidity

Because better public health protection is achievable and affordable, the WA DOH has adopted the optimization criteria listed in Figure 2. Therefore, CPEs conducted for the WA DOH utilize these goals as benchmarks against which a water plant's performance is assessed. The plant's performance is measured to determine what corrections, if any, will be necessary to become optimized. These performance goals are in four general categories:

- Minimum data monitoring requirements
- Individual sedimentation basin turbidity performance goals (for plants with sedimentation basins)
- Individual filter turbidity performance goals
- Disinfection performance goals

Figure 2 provides detailed criteria for each goal established by WA DOH's Treatment Optimization Program. The goals have been adopted by many of Washington's surface water treatment plants to provide a level of public health protection higher than that provided by simply meeting the state and federal regulatory requirements. Achieving the optimization goals ensures that each treatment process in the surface water treatment plant is operating with an efficacy that provides a very high level of public health protection. Typically, treatment plants have one or two removal treatment processes (sedimentation and filtration) and one treatment process that inactivates pathogens (disinfection).

[1]Other research using cysts of both *Giardia* and *Cryptosporidium* have recorded similar relationships between individual filter effluent turbidity measurements and cyst removal efficacy.

Figure 2 – Treatment Optimization Program Goals

FACILITY INFORMATION

Overview

The Purdue Water Treatment Plant (PWTP) is owned and operated by the Eastsound Water Users Association (EWUA). It is located on Orcas Island, southeast of the community of Eastsound at an elevation of roughly 975 feet. The PWTP went online in 1983. Its water source is Purdue Lake and the intake is located roughly 50 yards southeast of the dam. Purdue Lake covers an area of about 11 acres and holds up to 36 million gallons of water. The Purdue Lake watershed reportedly consists of 350 acres, of which 100 belongs to the Eastsound Water Users Association. The remaining 250 acres of watershed are located within the Moran State Park. The lake is filled by runoff but is also thought to receive water from spring sources located beneath the water surface. The spring water contains elevated levels of manganese, which presents problems in terms of water treatment.

During extended periods of drought, the quantity of water can be reduced to levels of concern. Additionally, the Eastsound Water Users Association is concerned about water quality changes that may be occurring due to climate changes and the constant influx of ground water with high concentrations of manganese. Consideration is being given to planning and implementing a water quality study designed to develop predictive trends in Purdue Lake's water quality and quantity. The PWTP is 34 years old and destined for replacement. Therefore, it is wise to consider water quality changes when planning for that replacement.

Raw water can be provided to the PWTP by gravity from an intake located near the bottom of the lake near the dam. Alternatively, raw water can be pumped from a floating intake that was installed in 2012 to take advantage of seasonal changes in water quality through the water column. Raw water turbidity is normally low but manganese concentrations can vary seasonally and there is some concern that climate change may lead to future problems with algae and/or disinfection byproduct precursors.

The water system serves a population of roughly 2,000 residents. Water use increases significantly during summer months due to visiting tourists.

As shown in the schematic in Figure 3, the PWTP is a pre-engineered package plant with all the major treatment components of a conventional surface water treatment plant (i.e., coagulation, flocculation, sedimentation, filtration and disinfection). However, the flocculation and sedimentation processes are downsized, making the plant only appropriate for treating high quality raw water (in terms of both turbidity and organics). These abbreviated processes are not capable of handling water with high turbidity for more than short periods of time nor are they amenable for use in the enhanced coagulation processes for removal of disinfection byproduct precursors.

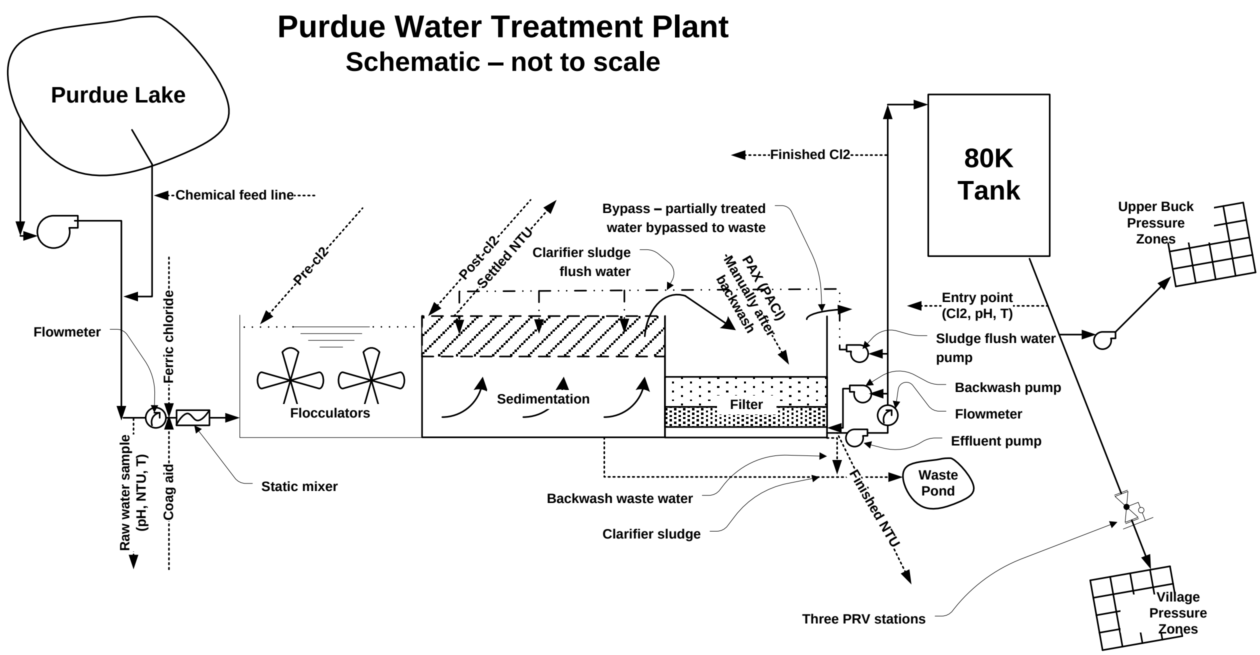

Figure 3 – Schematic of PWTP

Source Water and Intake
As noted above, the source water for the PWTP is Purdue Lake, which is served by a protective watershed and ground water springs. There is a permanent intake located in a vault at the bottom of the lake near the dam. In 2012, a second floating intake was installed to take water from near the lake's surface during times when the manganese concentration is less at that level. Water from the permanent intake flows to the plant by gravity while water from the floating intake is pumped to the plant with a 3-horsepower (hp) pump.

Coagulation
The raw water flows into the treatment plant via a 4-inch diameter pipe. Coagulant and coagulant aid are injected into a tee and each branch of the tee is fitted with a static mixer. After the static mixers, the two pipes discharge the water into the first flocculation chamber at two points to minimize short circuiting through the basin. There is no way of determining the percentage of flow that is directed to each influent line of the tee or to ensure that the injected coagulants are appropriately distributed to the two flows. While this seems to be a design problem, it does not appear to have any discernable negative impacts on the treatment processes.

Flocculation
At noted above, raw water with coagulants enters the first flocculation basin through two separate influent lines designed to minimize short-circuiting through the basin. The first basin is mixed with a constant speed paddle wheel to begin formation of floc particles. The theoretical hydraulic detention time (THDT) in this basin is nine minutes.

The effluent from flocculation basin one passes into a second identically-sized basin equipped with a paddle wheel mixer with an adjustable turning speed. As raw water quality conditions change, the operators adjust the paddle wheel's rotational speed to produce the desired floc particles. When the plant is operated at the design flow rate of 175 gallons per minute (gpm), the THDT is 18 minutes.

Sedimentation
Water from the second flocculation basin enters the sedimentation basin through a single pipe located just above the sludge collection zone. The pipe has perforations on each side designed to introduce the water and floc in a manner that encourages plug flow in the sedimentation basin. The floc is removed from the water in an upflow process utilizing settling tubes inclined at 60 degrees from the horizontal. The clarified water exits the tubes and is collected by slotted collection pipes for transfer to the filter. The slots in the collection pipes are distributed in a manner to minimize short-circuiting through the tube settlers. At a surface overflow rate (SOR) of 2.4 gallons per minute per square foot (gpm/ft^2) the basin can produce 175 gpm.

The settled material migrates down the inclined tubes to the bottom of the settling tank. From this sludge collection zone, sludge is automatically purged twice each hour and drained to the spent filter backwash water pond. When the filter is backwashed, additional sludge is removed by manually injecting finished water, using the surface water pump and injection lines installed by the operators. The injection lines are submerged below the water surface but backflow protection is provided.

Filtration
Water from the sedimentation basin flows to the mixed-media filter, which has 18 inches of 1.0-1.2-millimeter (mm) anthracite over nine inches of 0.45-0.55-mm silica sand over

three inches of 0.25-0.35-mm garnet sand. These filter media are supported by graded gravels. The filters are operated at up to five gpm/ft^2 and, at this rate, can produce 175 gpm. The filtered water is pumped to an 80,000-gallon above ground clearwell from which if flows by gravity to the distribution systems.

Backwashing of the filter is accomplished by air scour followed by water wash. The air scour facilities were installed in 2009 when the filter's media were replaced. The spent filter backwash water flows by gravity to a small backwash water pond, which overflows to the creek.

Disinfection
The PWTP utilizes a dilute solution of sodium hypochlorite for disinfection and oxidation of dissolved manganese. The first chlorine injection point is at the head of the treatment plant (into the first flocculation basin). The dose at this point is adjusted to ensure oxidation of the dissolved manganese. The second injection point is into the stream of clarified water flowing to the filter. This dose is adjusted to ensure disinfection requirements are met and to maintain a suitable chlorine residual throughout the distribution system.

Contact time for meeting CT (residual disinfectant concentration (mg/L) x time (minutes)) requirements is provided by prechlorination with time through the flocculators and sedimentation basin (stage one) and primary chlorination of the sedimentation basin effluent with contact time through the filter, pipe line to the 80,000-gallon clearwell, plus roughly 1,600 feet of 6-inch diameter transmission main (stage 2) prior to what may be determined by WA DOH to be the first customer. For calculation compliance, the operators do not consider the CT provided by prechlorination or contact time through the filter or finished water line to the clearwell.

Filter-to-Waste Water, Spent Filter Backwash Water and Sludge
The filter is almost exclusively backwashed based on head loss. Backwashing is accomplished manually and, after backwash, a coagulant is manually introduced on top of the filter to reduce the amplitude and duration of after-backwash turbidity spikes. Following backwash, the filtered water is wasted until the effluent turbidity is less than 0.10 NTU. The wasted water flows by gravity to the small spent filter backwash water pond. On an as-needed basis, the pond is cleaned and the sludge is stored on an EWUA site.

Auxiliary Power
The treatment facilities, including raw water and finished water pumping, can be powered by an on-site generator. The generator is regularly exercised but must be put in service manually.

PLANT DESIGN

Major Unit Process Evaluation
The purpose of the major unit process evaluation is to determine if each step in the treatment process (flocculation, sedimentation, filtration, and disinfection) is of adequate size to treat the current peak instantaneous flow while producing water that meets water quality optimization goals as described in Figure 2. The major unit process evaluation assesses the adequacy of existing facilities in terms of basin size and configuration and their ability to achieve optimization goals when treating the raw source water. The

assumption is that if the basins are not of adequate size, then optimization goals often cannot be met without major construction. Because the effectiveness of each step in the treatment process is dependent on the adequacy of prior steps, if any one of the major unit processes is undersized, the plant may not be capable of meeting optimization goals.

The major unit process evaluation does not include an assessment of the condition of existing mechanical equipment or the operational practices applied to the facility. The evaluators assume mechanical equipment can be repaired or replaced, minor improvements can be made, and process control requirements implemented to meet optimization goals. Performance limitations caused by mechanical equipment or operational practices are also addressed as factors limiting performance and are presented later in this report.

Peak Instantaneous Flow

Since the plant's treatment processes must provide an effective barrier continuously, a peak instantaneous operating flow is determined. As noted previously, the peak flow represents the maximum flow rate to which the unit processes are subjected. It is the hydraulic condition under which the treatment processes are likely to be the most vulnerable to the passage of contaminants. If the treatment processes are adequate at the peak instantaneous flow, then it is assumed they can provide effective barriers at lower flow rates. The peak instantaneous operating flow of the PWTP was established at 175 gpm or 0.25 million gallons per day (MGD) because this is the maximum flow rate at which the plant is operated.

Performance Potential Graph

The results of the major unit process evaluation for the plant are shown as a Performance Potential Graph in Figure 4. The adequacy of each major unit process was assessed by comparing its treatment capability to the peak instantaneous flow rate through the plant (the red vertical line at 0.25 MGD).

Criteria and assumptions used to assess each major unit process are described in the notes below the performance potential graph. The flow rates at which the processes were assessed are shown on the bottom of the graph (x-axis). The lengths of the horizontal bars on the graph represent the projected water production capability of each unit process while meeting optimization goals. These capabilities were projected based on each unit's physical size and configuration, the CPE team's experience with similar processes, industry guidelines, raw water quality, the plant's past performance, and generally accepted design standards. The shortest bar represents the unit process that is most limiting to the plant's ability to achieve optimized performance.

Flocculation

Flocculation/sedimentation is the first physical particle removal barrier in a surface water treatment process. The PWTP's flocculation is accomplished in a two-stage process with tapered mixing. The THDT of the flocculation basins is 18 minutes. Based on past performance, the quality of the raw water and generally accepted design standards for high quality surface water sources, SGEC assigned a capacity of 0.25 MGD to the flocculation process. Flocculation is not a performance limiting factor.

Sedimentation

After flocculation, sedimentation is accomplished using tube settlers in the sedimentation basin. At an SOR of 2.4 gpm/ft^2, SGEC has determined the sedimentation basin to be capable of meeting optimization goals. Thus, sedimentation is not a performance limiting factor.

Filtration

Filtration is the PWTP's second and final physical barrier that accomplishes particle removal. Dual- or mixed-media filters, with proper pretreatment, can achieve optimization at surface loading rates (SLR) as high as 6.0 gpm/ft^2. However, due to the downsized (as compared to true conventional plants) flocculation and sedimentation basins, SGEC has rated the PWTP's filter at an SLR of 5 gpm/ft^2, primarily based on past performance. It should be noted that, at times, the turbidity of the clarified water going on the filter is higher than that of the raw water. Under these conditions, the plant is not effectively utilizing sedimentation as a physical barrier. However, when there is

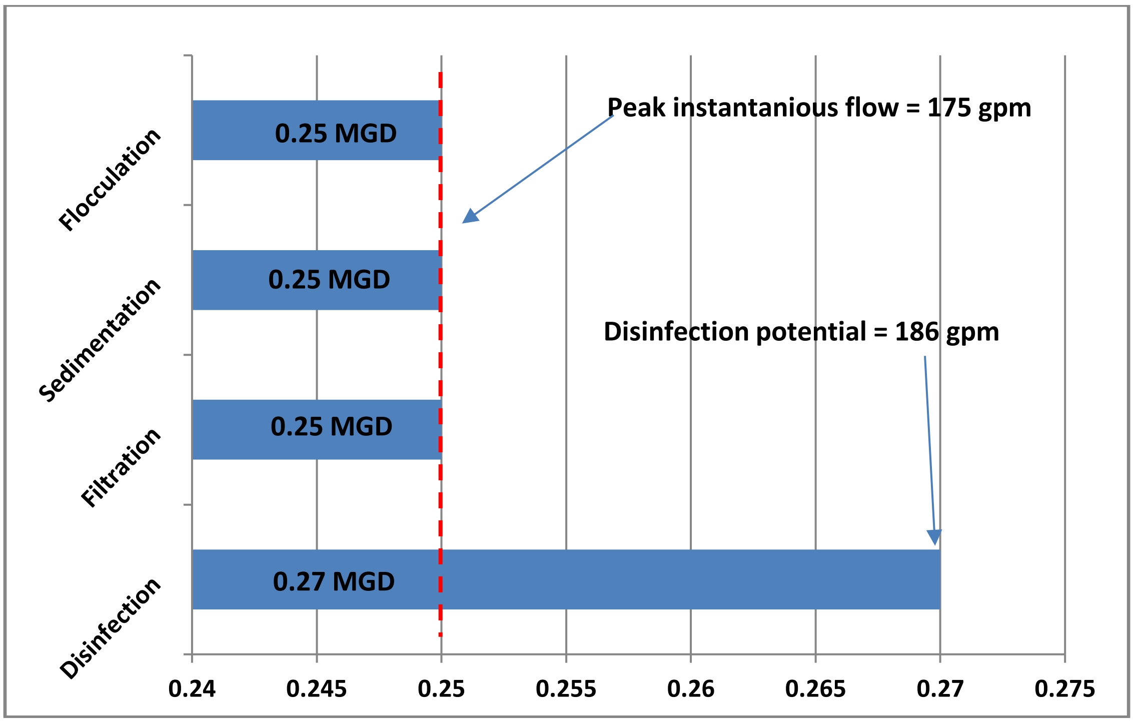

Figure 4 – PWTP Performance Potential Graph

Assumptions used for performance potential evaluation:

1. *Flocculation rated at 18 minutes theoretical hydraulic detention time*
2. *Sedimentation rated at a surface overflow rate of 2.4 gpm/ft^2*
3. *Filters rated at 5.0 gpm/ft^2 surface loading rate*
4. *Disinfection*
   - *Temperature ≥0.5 ºC*
   - *pH ≤ 7.0*
   - *Chlorine residual ≥ 1.6 mg/L*
   - *Water level at 16 feet*
   - *1.0-log Giardia lamblia and 2.0-log virus activation required by WA DOH*
   - *Baffling factor of 0.1 in clearwell and 1,600 feet of 6-inch diameter pipe before the first customer.*

little turbidity (few particles) in the raw water, it is often difficult to produce a settleable floc. In the final analysis, SGEC believes the filter will not limit the plant's performance even when little removal is accomplished in the sedimentation basin. Therefore, the filter is not likely to limit the plant's performance.

Disinfection

Disinfection provides the final barrier in the multiple barrier concept of surface water treatment by inactivating microbial contaminants that escape the removal processes provided by coagulation, flocculation, sedimentation and filtration. The disinfection process for the PWTP was assessed based on the Surface Water Treatment Rule's (SWTR) requirements for 3-log removal/inactivation of *Giardia lamblia* cysts and 4-log removal/inactivation of viruses. The *Giardia* removal and/or inactivation is the more stringent criterion when free chlorine is used as a primary disinfectant. In the case of the PWTP, the WA DOH credits the plant for removal of 2.0-log *Giardia lamblia* cysts and 1.0 log virus removal. Therefore, 1.0-log *Giardia* and 3.0-log virus inactivation must be achieved through disinfection. Compliance is achieved by meeting specified disinfection requirements as measured by the disinfectant concentration in milligrams per liter (mg/L) multiplied by the time in minutes that the disinfectant is in contact with the water. The product of this calculation is termed "CT" and is measured in milligram▪minutes per liter (mg▪min/L). For determining the disinfection capacity of the PWTP, SGEC selected near-worst case water quality parameters in terms of pH and temperature. Free chlorine is less effective as a disinfecting agent as the temperature goes down and more effective as the pH goes down. Therefore, SGEC selected the lowest water temperature of 0.5 degrees centigrade along with a pH of 7.0, which is higher than that normally occurring throughout the disinfection process. A free chlorine residual of at least 1.6 mg/L was selected, which appears to be roughly the residual needed to maintain the desired chlorine residuals in the distribution system. Finally, it was assumed there was a water level at or above 16 feet in the clearwell, a baffling factor of 0.1 in the clearwell, and 1,600 feet of 6-inch diameter transmission main available for contact time prior to the first customer. No credit was considered for prechlorination or contact time through the filter.

Using these criteria and assumptions, the PWTP's disinfection capacity was determined to be 186 gpm (0.27 MGD), which is significantly higher than the peak instantaneous flow of 0.25 MGD. Obviously, with warmer water temperatures, lower pHs and/or lower peak hour flow rates, the chlorine residual can be reduced while compliance is still achieved.

Major Unit Process Evaluation Summary

As shown by the Performance Potential Graph (Figure 4) and the above discussion, the major unit processes will not limit the PWTP's performance in terms of achieving the WA DOH optimization goals.

PLANT OPERATION

Performance Assessment

A component of the CPE is the assessment of the WTP's ability to meet the relevant optimized performance goals outlined in Figure 2. Optimized performance goals, for purposes of this CPE, represent performance that exceeds the current regulatory requirements and requires a facility that treats a source water of variable quality to consistently remove an appropriate level of turbidity in the settling process while producing high quality filtered water (i.e., less than 0.10 NTU). More specifically, the evaluation team believes that "true optimization" of the filtration process is achieved when the filter can always produce filtered water with turbidity of ≤ 0.10 NTU.

Multiple treatment processes (i.e., coagulation, flocculation, sedimentation, filtration, and disinfection) are provided in series to remove and inactivate microbial pathogens. Each of the available processes represents a barrier to prevent the passage and survival of these microbial pathogens through the plant. By providing multiple barriers, the potential of pathogens passing through the entire plant and surviving to cause waterborne disease is minimized.

Based on records submitted to the WA DOH by the PWTP, an assessment of the past 32 months (January 1, 2015 – August 31, 2017) performance at the PWTP was conducted to identify whether specific treatment unit processes were performing in a manner that achieved optimization.

Performance Assessment Turbidity Profiles

Figure 5 is a graphical representation of the daily raw, settled, and maximum combined filter effluent (CFE) water turbidities for 2017 through August. The raw water turbidity

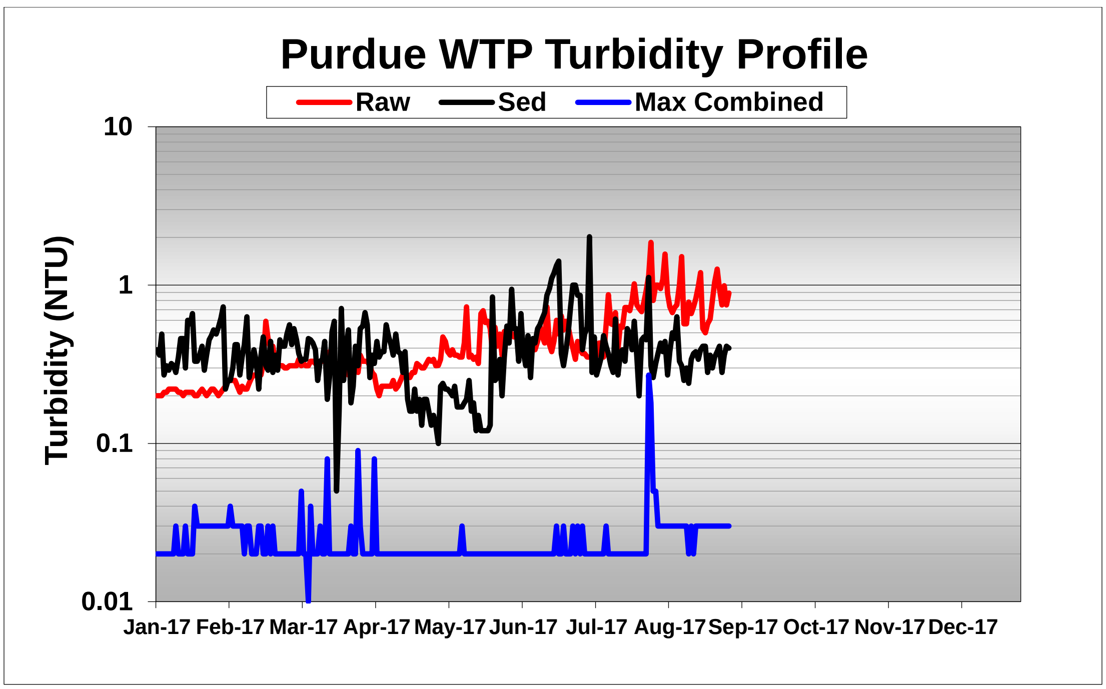

Figure 5 – Performance Trends (January 1, 2017 – August 31, 2017)

values for the period are represented by the red line of the figure. Raw water turbidity averaged 0.4 NTU with a maximum of 1.9 NTU. Settled water turbidity, shown with the black line, averaged 0.4 NTU and had a maximum of 2.0 NTU. The graph shows that the settled water turbidities are higher than the raw water turbidities. This is due to low turbidities (high quality) of the raw water and the plant producing turbidity through the flocculators to provide effective treatment.

Table 1 Raw, Settled and CFE Turbidity Data (January 1, 2017 to August 31, 2017)			
	Raw (NTU)	**Settled (NTU)**	**CFE (NTU)**
Average	0. 4	0.4	0.03
Maximum	1.9	2.0	0.27
Minimum	0.2	0.1	0.9
95%	1.0	0.9	0.03
Settled < 1 NTU	97.1%		
CFE< 0.10 NTU	99.2%		

The data shown in Figure 5 for the "combined filter effluent" (blue line) represent the maximum daily turbidity values as recorded by the CFE online continuous monitoring turbidimeter. These values averaged 0.03 NTU with a maximum measurement of 0.27 NTU. Ninety-five percent of the readings were less than 0.03 NTU and over 99 percent were less than 0.10 NTU. The data for the calendar years 2015 and 2016 showed a CFE average turbidity of 0.05 and 0.06 NTU respectively. The 95-percentile for 2015 and 2016 was 0.09 NTU.

The graph (Figure 5) and summary information in Table 1 show that, during 2017, the CFE that was entering the clearwell exceeded 0.10 NTU only one time. This occurred in July 2017 and was reportedly due to a chemical feed problem.

Performance Assessment Summary
In summary, the performance assessment data and information gathered during the CPE indicate that the plant is optimized and very well managed, maintained and operated.

PLANT MAINTENANCE

The PWTP has been in service for 34 years and is still producing water that meets and exceeds the WA DOH optimization goals. This fact alone says something about the EWUA and operators in terms of maintenance. However, in SGEC's opinion, this is an area where there is room for improvement. The PWTP has no structured maintenance program. All plants benefit from having a structured maintenance program that includes preventative, predictive, and corrective maintenance activities. Having proper maintenance reduces unscheduled down time and typically makes life less stressful for the operators.

There are no indications that maintenance, at this time, will limit the performance of the PWTP

PLANT ADMINISTRATION

A final component of the CPE is the assessment of the PWTP's administration in terms of its impact on the plant. This is necessary because without proper support from administration/management, optimization is seldom achieved. Support often involves the adoption of appropriate goals for finished water quality followed by financial and other support necessary to ensure the goals are met.

The EWUA is governed by a general manager who answers to a seven-member board of directors. Budget documents provided by the general manager show that the EWUA is financially sound. The PWTP is adequately staffed with competent operators, and the general manager has everyone working as a team to provide high levels of service and continuing improvement. Capital improvements are typically funded from a reserve account as opposed to debt. Management is continually working and planning to make operations more efficient. For example, a new metering system has been installed that provides the EWUA and its customers real time information on water use and leaks. This system conserves water and energy and, primarily due to water conservation, is expected to pay for itself in less than four years.

An organizational chart is shown in Figure 6 below.

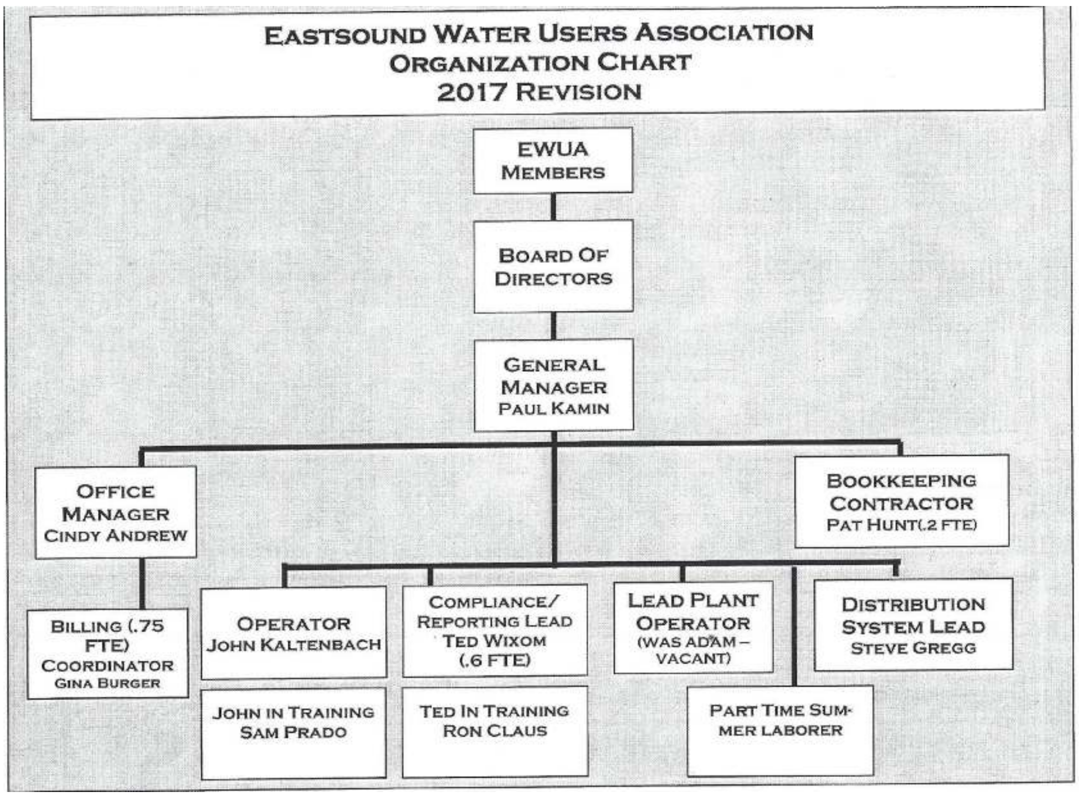

Figure 6 – Organizational Chart (provided by EWUA)

In conclusion, the PWTP is well managed. Performance measures, including the WA DOH TOP goals, have been adopted, strived for and consistently achieved. In discussing the PWTP budget with management and staff, SGEC believes that the PWTP is generally well funded, with management given appropriate discretion in terms of purchasing needed supplies and equipment. Further, maintaining an experienced and competent staff has not been an issue.

SPECIAL STUDIES

During the CPE, special studies are typically conducted to assess the plant's performance and process control. The following is a summary of one of the special studies.

Filter Assessment
Assessment of the condition and placement of the filter media can be an important step in identification of 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 evaluation includes a physical inspection of the filter bed and backwash practices. The typical process includes the following steps:

1. First, the filter is completely drained. As the filter drains, the surface of the water is observed to see if vortexes are formed that could indicate short-circuiting through the media and underdrains. As the water level reaches the filter surface, mounding or depressions, if present, will be easily observable.

2. After the water is out of the media, the filter is entered for inspection, coring, excavation and sampling of the media at various depths to determine how much material is removed at each depth.

3. After the work on the filter has been completed, the media are replaced in the excavations, all tools are removed and the filter is filled slowly from the bottom to force air from the underdrains and media.

4. After the filter is filled and allowed to stand for a short time to allow air to escape, it is backwashed with the plant’s normal backwashing procedure. During the backwashing process, the evaluators look for signs of underdrain disruption (i.e., boils in the wash water and/or uneven distribution of air). After the spent filter backwash water begins to overflow to waste, samples are collected every minute until overflow ceases.

5. When the backwash water flow has reached its highest rate, the expansion of the filter media is measured at several locations.

6. After the backwash is completed, the filter is again drained.

7. After the filter is completely drained, it is again entered and samples of media are collected throughout the depth of the filter to determine the extent of cleaning achieved by the backwash procedure.

8. After all tools are removed from the filter, it is again filled slowly from the bottom and allowed to rest while air is purged from the media.

9. Finally, the filter is backwashed a second time.

10. After the second backwash, the filter is slowly restarted and filtered-to-waste until the effluent turbidity is appropriate for putting the filter back in service.

For assessment of the PWTP filter, steps 6-9 were omitted because the concentration of manganese in the water makes it very difficult to wash samples of media for determination of filter loading and after-backwash media cleanliness. Therefore, after the filter was entered and examined, it was refilled from the bottom, backwashed, filtered-to-waste and returned to service.

At the time of the assessment, the filter was at the end of a filter run as determined by head loss. The filter was observed during the draining process, and as the water reached the level of the anthracite, it was clear that the surface of the filter was level with no indications of underdrain disruptions or inadequate cleaning (e.g., there were no mounds, cracks, separation of media from the filter walls or craters).

The filter was entered and the backwash water trough was found to be suitably level from side to side and lengthwise. The distance from the top of the filter wall to the anthracite surface (free board) was found to be 41 inches. The distance from the backwash water weirs to the anthracite surface was 36 inches.

The bed of the filter was probed at multiple locations, and the depth of media was determined to vary from 30-34 inches. Much of the variation is likely because the top layer of support media can often be penetrated by the probe.

The media were cored at several locations and excavations were made at two sites, one of which was used to check the condition of the pipe that carries air to the air scour lines. The construction specifications that were provided to SGEC indicated the filters were to have 18 inches of 1.0-1.2-mm anthracite over nine inches of 0.45-0.55-mm silica sand over three inches of 0.25-0.35-mm garnet sand. The excavations showed it was about 17 inches from the anthracite surface to the top of the anthracite/sand interface zone. The interface appeared to range from 3-4 inches in depth, and the depth of the silica sand/garnet sand zone was about nine inches. The manganese staining made it difficult to determine exactly where each of the media types ended and began. The media appeared to be clean, angular and in good condition. There was no compaction, mounding, craters or mudballs. The surface of the anthracite did not exhibit an excess of fines that would cause short filter runs.

A set of core samples were removed at three locations across the filter. The samples were derived from depths of 0-2 inches, 2-6 inches, 6-12 inches and in 6-inch increments throughout the remaining depth of the filter. The samples were collected to be used with a washing technique designed to determine how much floc is being captured and retained at each level of the filter media. As noted above, the washing technique was not used because of the manganese staining.

After the work was completed on the filter, the tools were removed and the filter was refilled from the bottom. It was allowed to rest for a few minutes to let air escape from the media and underdrains and then was backwashed. The typical backwash procedure is as follows:

1. The filter is drained to a level just above the anthracite.
2. Air scour, without water wash, is initiated and operated for two and one-half minutes.
3. Air is turned off and the backwash water pump is started.
4. The operator begins to slowly open the backwash water valve. The backwash valve is typically opened over 20-30 seconds to avoid surges through the underdrains and media.
5. Water backwash, without air scour, continues at full flow for five and one-half minutes.
6. The backwash water pump is turned off.

7. Slow rate backwash continues for roughly two minutes by allowing water from the clearwell to flow by gravity (backwards) through the filter.
8. The backwash valve is then slowly closed.
9. The filter “rests” for three minutes while the operator applies a diluted mixture of polyaluminum chloride to the water on top of the filter.
10. The effluent pump is started and the filter-to-waste valve opened.
11. The water is filtered-to-waste until the turbidity is reliably less than 0.10 NTU.
12. The filter is put back into service.

The above steps roughly outline the standard operating procedure for backwashing. It should be noted, however, that backwashing is conducted manually and there is evidence that operators adjust the procedure to some extent based on head loss before backwash and other criteria. Prior to the backwash, the filter had been in service for two days and had a head loss measured at 33 inches. After the backwash, the head loss on the clean filter returned to 79 inches, the head loss that the filter had when it was placed into service.[2]

During the backwash that was conducted for the filter assessment, the filter and water surfaces were observed for signs of boiling or uneven distribution of air, which could be indicative of underdrain problems. No problems were observed. Also, the extent of media expansion was measured at several locations across the filter during the time when the backwash pump was operating at its highest flow rate. The expansion was measured at about 2-4 inches or 7-14 percent. Typically, media expansions of 20-35 percent are recommended during the fluidized step of backwash. However, the media appeared to be suitably re-stratified and cleaned and SGEC did not identify the lack of expansion as a problem.

During the backwash, samples of the spent filter backwash water were collected at one-minute intervals after the overflow to the troughs began. The turbidity of each sample was then measured, and the results are shown graphically in Figure 7. As a rule of thumb, backwashing procedures are likely to be adequate and a filter considered optimally clean when the spent backwash water turbidity is in the range of 10-15 NTU (Kawamura, 2000). If the backwash water has a significantly higher turbidity at termination, then the length of backwash may not be adequate to remove material dislodged from the media, or the backwash rate may be inadequate to remove the dislodged material. In either case, the filter could be left vulnerable to turbidity breakthrough. On the other hand, if the spent filter backwash water turbidity is less than 10-15 NTU, the procedure may be wasting backwash water and/or over-cleaning the media. Over-cleaning sometimes causes an increased after-backwash turbidity in terms of amplitude and duration. Figure 7 shows that the PWTP filter was backwashed with overflow occurring for five minutes. The turbidity of the spent filter backwash water was about 10 NTU after 5 minutes of overflow. At this point, backwash ceased.

[2] Headloss at PWTP is measured using a clear tube connected to the plenum (base) of the filter with the water level in the tube measured in inches. This tube is connected to the filter wall and is taller than the maximum water level in the filter. When the filter is clean, the water level in the tube is typically 79 inches. As the filter is used, the water level in the tube decreases representing the pressure loss through the dirty filter. The filters are backwashed, typically, when the water level in the tube is approximately 36-39 inches. The loss in water level, using this scenario, represents a filter headloss of 3.3-3.6 feet (79 inches – 36-39 inches).

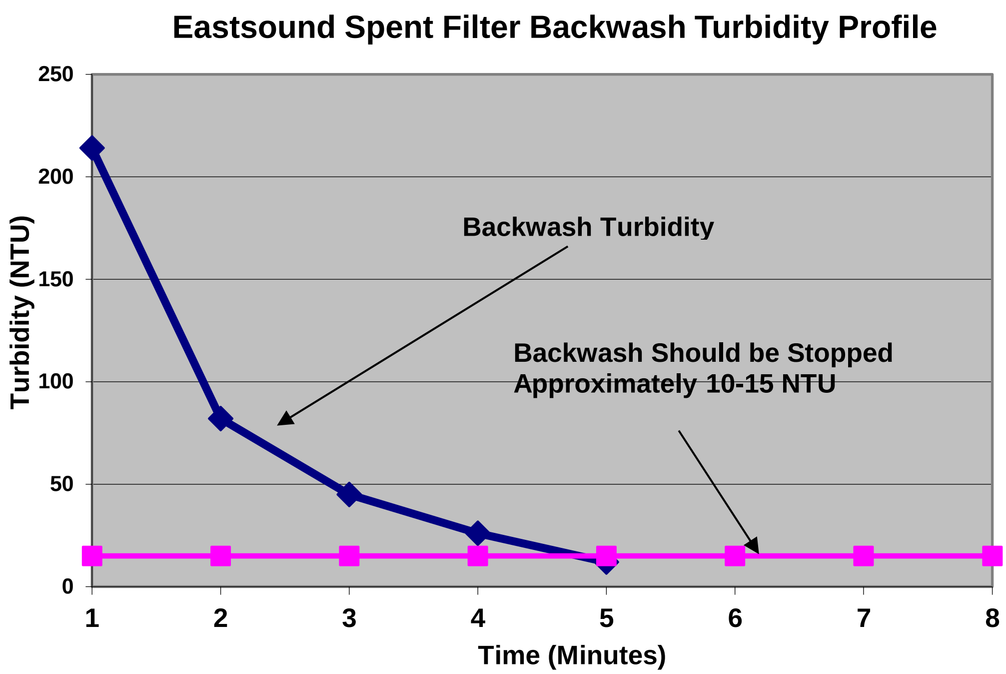

Figure 7 – Spent Filter Backwash Water Turbidity Profile

These results seem to indicate that the full flow water backwash is conducted for about the correct amount of time.

Information gained through the filter assessment (condition of the filter surface, cleanliness of the media, absence of mudballs, media expansion and the turbidity profile of spent filter backwash water) taken together indicate that the filter is likely being appropriately cleaned during backwash. As noted above, the presence of manganese in the raw water causes staining of the media grains and adds color to the spent filter backwash water. This makes it more difficult to accurately assess the condition of media. It is safe to say, however, that if there were significant problems with the backwash procedure they would have caused easily discernable problems over the years of operation since the media were installed in 2009. The procedure is not conducted in a manner that follows the generally accepted “best” methodology for cleaning granular media filters with air scour. While no problems have been noted by SGEC, it may be that special studies could show that changes could lead to more efficient cleaning while utilizing less water and energy. The only way to know for sure is to conduct carefully planned special studies to develop objective and measurable data.

PERFORMANCE LIMITING FACTORS

The areas of plant design, plant operation, plant maintenance, and plant administration were evaluated to identify factors that limit performance. These evaluations were based on information obtained from the plant tour, interviews, performance and design assessments, special studies, and the judgment of the evaluation team. Each of 50 common performance limiting factors was addressed as a potential issue at the plant. Factors identified as limiting performance were then classified as A, B, or C according to the following guidelines:

A - Those having a major effect on performance on a long-term, repetitive basis.
B - Those having a moderate effect on performance on a routine basis, or major effect on a periodic basis.
C - Those having only a minor effect on performance.

Considering the 50 common performance limiting factors, SGEC concluded that no factors were limiting the PWTP's performance. In short, the PWTP is meeting the WA DOH optimization goals and has been doing so for some time. However, like all facilities, the PWTP has room for improvement. SGEC offers no specific recommendations but, rather, the following thoughts, all of which were discussed with operators and the general manager during the CPE. Most of these are, to some extent, components of ongoing planning efforts by EWUA and not original ideas advanced by SGEC.

Thoughts Regarding Pursuit of Continued Improvement

- Special Studies**:** EWUA has participated in WA DOH's performance based training (PBT) and is familiar with the methodology for conducting special studies. Further, the staff is unusually talented and technically competent, and management appears to be amenable to devoting man hours to efforts for improved efficiency resulting in public health protection while conserving water and energy. Two obvious areas for special studies include:
    - Backwashing procedures
        - As noted above, it may be possible (no guarantees) to make the backwashing process more efficient.
    - Alternative coagulants, coagulant aids, flocculant aids, filter aids
        - The coagulants currently used are doing an excellent job. However, that is not to say there are others that, alone or in combination, could be as effective at less cost – or more effective.
- Consider measurement of CT parameters at first customer
    - Currently, EWUA shows compliance with CT requirements by making very conservative assumptions intended to cover areas where there is no measurable data. Installation of appropriate instrumentation just ahead of the first customer (to be determined by WA DOH) would allow operators to know exactly what CT is available and make adjustments in flow rates and chlorine residuals in a manner to optimize operations.
- SOPs
    - The EWUA has SOPs but they do not appear to be universally adhered to and are not updated or consistent between various versions of the same SOP.
    - There may be other areas of operations that could benefit from development of SOPs.
- SCADA
    - Auto shutdown(s)
        - The PWTP does not automatically shut down if there is a chlorine feed or residual failure. There may be other automatic shutdown provisions that could be developed to protect public health.
    - As more capacity is developed in the SCADA system, more automation could be provided and more useful data collected.
- This aging plant, as well as all plants, needs a good maintenance program. EWUA needs to develop a maintenance program for the infrastructure, mechanical

equipment, and instrumentation. Some of the elements of the program should be:
  - Preventative maintenance – scheduled and planned actions to prevent equipment breakdown or failure. This could include greasing, oil changes, filter changes, reagent change-out in instruments, tubing change-out in pumps, painting, etc.
  - Predictive maintenance – scheduled maintenance to minimize disruptions and maintain data integrity. This could include equipment inspection (corrosion evaluation), instrument calibration, pump calibration, etc.
  - Corrective maintenance – repairs as needed to bring back to operating condition.
- Water quality studies
  - Many surface water sources are being impacted by changing climate conditions that appear to be causing algae blooms and increasing organic content in raw waters. Additionally, the lake is fed water from ground water sources that are likely adding manganese to lake sediments.
    - EWUA is considering development of a lake water monitoring program to evaluate water quality trends. Such trends will enable EWUA to anticipate and manage future water quality issues.
- Start planning for WTP replacement
  - EWUA has 34-year-old plant that is likely to be near the point where a complete rehabilitation will be needed or replacement may be called for.
  - Using information provided by the planned water quality studies, EWUA can explore all future options, including rehabilitation of the existing plant, while considering potential water quality changes. Other replacement technologies that could be investigated include:
    - Conventional plant
    - Plant with contact adsorption clarifiers
    - Slow sand filter
    - Membrane plant
    - Use of granular activated carbon contactors with any of the above

PROJECTED IMPACT OF COMPREHENSIVE TECHNICAL ASSISTANCE

The last step of the CPE process is to assess the potential for improved performance through formal technical assistance such as Comprehensive Technical Assistance (CTA) or Performance Based Training (PBT). CTA is site-specific assistance targeted at the system’s specific needs, whereas PBT brings together operators from multiple surface water systems with related issues and provides group training geared toward making operational changes that enhance and optimize performance. PBTs and CTAs are formal programs that can address the factors identified as limiting the plant’s performance during the CPE. CTA and PBT are typically initiated when performance problems are identified.

The evaluation team understands that PWTP has participated in PBT and additional PBT is clearly not essential.

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